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Safety Reports Series

No. 15

IMPLEMENTATION AND REVIEW OF A NUCLEAR POWER PLANT AGEING MANAGEMENT PROGRAMME

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IMPLEMENTATION AND REVIEW
OF A NUCLEAR POWER PLANT
AGEING MANAGEMENT PROGRAMME

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FOREWORD

Ageing in nuclear power plants must be managed effectively to ensure that design functions remain available throughout the service life of the plant. From the safety perspective, this means controlling, within acceptable limits, ageing degradation of the systems, structures and components (SSCs) important to safety so that there remain adequate safety margins, i.e. the required integrity and functional capability of both passive and active SSCs in excess of their normal operating requirements.

The IAEA has issued two reports that provide methodological guidance on the technical aspects of ageing management. One, in the Technical Reports Series (No. 338) is entitled ‘Methodology for the Management of Ageing of Nuclear Power Plant Components Important to Safety’, and the other is a Safety Practices publication (No. 50-P-3) with the title ‘Data Collection and Record Keeping for the Management of Nuclear Power Plant Ageing’. In contrast, this Safety Report deals with the organizational/managerial aspects of ageing management.

Plant operations, inspection and maintenance supported by trending and assessment of condition and functional indicators are the primary means of managing ageing in nuclear power plants. Experience shows that the effectiveness of ageing management can be substantially improved by co-ordinating these and other relevant programmes and activities under an umbrella type programme utilizing a systematic ageing management process. Such ageing management programmes (AMPs) are now required by an increasing number of safety authorities and are being implemented by many utilities, often as a part of nuclear power plant life or life-cycle management programmes that involve the integration of ageing management and economic planning. This publication provides information on good practices relating to the implementation and review of an AMP.

The guidance in this report is intended primarily for nuclear power plant and utility management, which has the direct responsibility for implementing plant programmes that manage ageing degradation, and for safety authorities responsible for verifying that ageing in these plants is being effectively managed. It is envisaged that the information provided will assist them in reviewing and improving existing AMPs or in implementing new AMPs, taking into account national requirements. The report will also be of interest to technical support and R&D organizations.

The work of all contributors in the drafting and review of this publication is greatly appreciated. In particular, the IAEA would like to acknowledge the contributions of T. Andreeff of Canada, J.P. Hutin of France, J. Stejskal of Switzerland, and D.R. Hostetler and J.P. Vora of the United States of America. The officer responsible for this report was J. Pachner of the Division of Nuclear Installation Safety.

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CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

As a nuclear power plant ages, its reliability and the safety margins provided by the design tend to decrease and its operations and maintenance costs are likely to increase unless an awareness of the need to manage age related degradation is imparted to and acted upon by the plant's operations and maintenance personnel. The ageing[1] of nuclear power plant systems, structures and components (SSCs) important to safety must be effectively managed[2] to ensure that the required safety functions are available throughout the service life of the plant, including its extended life. Naturally, the ageing of other SSCs must also be properly managed to provide for reliable and economic plant operation.

Many organizations, including the IAEA, are devoting substantial efforts to dealing with the technical aspects of managing nuclear power plant ageing. The results of these efforts have been widely publicized and have contributed to the timely detection and mitigation of the age related degradation of plant SSCs. In contrast to the many published reports and papers which deal with the technical aspects of ageing management, little has been published on its organizational/managerial aspects.

The IAEA Nuclear Safety Standards (NUSS) Code on the Safety of Nuclear Power Plants: Operation [1] and the associated Safety Guide on the management of nuclear power plants [2] require that appropriate documented management programmes be established in order to achieve the objectives and carry out the responsibilities of the operating organization with respect to the safe operation of such plants. A Safety Guide on the periodic safety review of operational nuclear power plants [3] provides guidance on a systematic assessment of the effectiveness of these programmes and on overall plant safety.

To effectively manage the ageing of SSCs important to safety, plant owners/operators need to have in place programmes that provide for the timely detection and mitigation of ageing degradation in order to ensure that the required safety margins (i.e. the integrity and functional capability) of the SSCs are

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[1] In this report, the term 'ageing' is used to mean the process by which the physical characteristics of a system, structure or component change with time or use. This process may involve a single or combination of several ageing mechanisms. All materials in a nuclear power plant experience ageing degradation to a greater or lesser extent, which may lead to the functional degradation of plant SSCs.

[2] Throughout this report, effective ageing management means the engineering and operations and maintenance actions to control, within acceptable limits, the ageing degradation of SSCs.

maintained. Safety authorities are responsible for verifying that ageing is being efficiently managed and that effective programmes are in place for continued safe plant operation.

Existing programmes relating to the management of nuclear power plant ageing include maintenance, in-service inspection and surveillance, as well as operations, technical support and external programmes such as R&D. Experience shows that effective ageing management of SSCs can best be accomplished by co-ordinating these programmes under a systematic ‘umbrella’ type ageing management programme (AMP). This Safety Report supplements the NUSS Code on Operation and associated Safety Guides by providing information on effective practices relating to the implementation and review of such an AMP.

Systematic AMPs are being implemented by an increasing number of utilities, often as part of nuclear power plant life or life-cycle management[3] programmes which involve the integration of ageing management and economic planning. It is recognized that economic considerations are an important aspect of decisions on the type and timing of ageing management actions and continued plant operation. However, since this report is written from the safety perspective, it deals only with ageing management, which is a subset of life management.

1.2. OBJECTIVE

The objective of this report is to provide guidance on: the co-ordination of relevant existing operations, maintenance, engineering and R&D programmes under a proactive, umbrella type AMP utilizing a systematic ageing management process aimed at maintaining plant safety and reliability; and ongoing and periodic reviews of the effectiveness of such a programme.

1.3. SCOPE

This report deals with the organizational and managerial aspects of nuclear power plant ageing management, including assessments of the effectiveness of a nuclear plant’s AMP. The technical aspects of ageing management for specific SSCs and economic considerations are not addressed.

[3] ‘Life management’ is defined as the integration of ageing management and economic planning to: (1) optimize the operation, maintenance, and service life of SSCs; (2) maintain an acceptable level of performance and safety; and (3) maximize return on investment over the service life of the plant.

1.4. STRUCTURE

The rationale for a nuclear power plant AMP is presented in Section 2. Section 3 sets out the objective and describes the concept and scope of this programme, while Section 4 provides guidance on the organization, responsibilities and implementation of an AMP. Guidance on carrying out a review of the AMP is covered in Section 5. The appendices elaborate certain elements of the AMP.

2. RATIONALE FOR AN AMP

As noted above, effective ageing management of SSCs can best be accomplished under a systematic, umbrella type programme that co-ordinates existing activities relevant to managing ageing. The reasons for instituting such an AMP, the need to use a systematic ageing management process, the need to manage the ageing of all SSCs, and the need to co-ordinate relevant programmes and activities are discussed in Section 2.

2.1. THE NEED TO USE A SYSTEMATIC AGEING MANAGEMENT PROCESS

Effective ageing management requires an SSC specific application of a systematic ageing management process. This generally applicable process is illustrated in Fig. 1 (page 13), which is an adaptation of Deming's 'PLAN–DO–CHECK–ACT' cycle to the ageing management of an SSC.

A comprehensive understanding of an SSC, its ageing degradation and the effects of this degradation on the SSC's ability to perform its design functions is the basis and a prerequisite for a systematic ageing management process. This understanding is derived from a knowledge of the design basis (including applicable codes and regulatory requirements); the design and fabrication (including the material properties and specified service conditions); the operation and maintenance history (including commissioning and surveillance); inspection results; and generic operating experience and research results.

Deming's 'PLAN' activity in the ageing management process is aimed at maximizing the effectiveness of ageing management through the co-ordination of all programmes and activities that relate to managing the ageing of an SSC. It includes the identification and documentation of applicable regulatory requirements and safety criteria, relevant programmes and activities and their respective roles in the ageing management process, as well as a description of the mechanisms used for programme co-ordination and continuous improvement. The 'DO' activity of the ageing management process is aimed at minimizing expected SSC degradation through the operation/use of the SSC in accordance with operating procedures and limits. The goal of the 'CHECK' activity in the ageing management process is the timely detection and characterization of any degradation through SSC inspection and monitoring and the assessment of observed degradation to determine the type and timing of any corrective actions. The 'ACT' activity in the process is aimed at the timely mitigation/correction of SSC degradation through appropriate maintenance, including SSC repair and replacement.

The closed loop of the generic ageing management process indicates the need for continuous improvement of an SSC specific AMP based on the current understanding of SSC ageing and on the results of self-assessments and peer reviews. Such a programme is a mixture of SSC specific ageing management actions designed to minimize, detect and mitigate ageing degradation before SSC safety margins are compromised. This mixture reflects the level of understanding of SSC ageing, the available technology, the regulatory/licensing requirements and plant life management considerations and objectives. The timely feedback of experience is essential in order to provide for ongoing improvement in the understanding of SSC ageing and in the effectiveness of the AMP.

2.2. THE NEED TO MANAGE THE AGEING OF SHORT AND LONG LIVED SSCs

There are thousands of plant SSCs that may affect the safety and life of the plant, and which are subject to ageing degradation. Their rates of degradation and their lifetimes vary considerably. From the ageing management perspective, it is useful to consider them in two broad categories.

Short and long lived active SSCs usually require some form of maintenance intervention many times before the end of their service life. The usual maintenance strategy is to identify failure modes from operating experience and to devise appropriate preventive maintenance tasks to prevent these failure modes. Such maintenance tasks typically monitor the condition, test functionality, replace consumables, piece parts and components, and generally ensure that an SSC remains functional. In most cases, the age related degradation of active and short lived SSCs is adequately addressed by existing maintenance and equipment qualification programmes, where these programmes are in place and are effective.

For most passive SSCs, such as pressure boundary components, cables and structures, neither corrective nor preventive maintenance is planned over the life of the plant. Long lived passive SSCs are designed for fabrication with materials and by techniques that permit them to reach the end of plant life with an adequate safety margin still remaining. However, because of a lack of operating experience over their 30–40 year design lives, unforeseen ageing phenomena and error induced ageing, caused by shortcomings in design or manufacturing, or by operating errors, may occur. This may cause premature degradation and failure of long lived passive SSCs. Inspection, surveillance and monitoring of these SSCs and the service conditions to which they are exposed are therefore needed to verify that ageing degradation is controlled effectively. In addition, for systematic ageing management of long lived passive SSCs, there is a need for feedback of results from the research and analysis of operating experience.

2.3. THE NEED TO CO-ORDINATE RELEVANT EXISTING PROGRAMMES

Existing programmes that contribute to managing the ageing of plant SSCs include the following:

— *Preventive maintenance programmes*. The primary means of managing ageing in nuclear power plants.
— *In-service inspection, surveillance, testing and monitoring programmes.* Generate data on condition and functional indicators[4] of SSCs and on plant service conditions that are needed for monitoring ageing mechanisms, for detecting degradation, for deciding the type and timing of maintenance and of other ageing management actions, and for verifying that the degradation is being adequately controlled.
— *Data collection and records management programme(s).* Provide information for screening plant SSCs and for ageing management evaluations. Ideally, a records management system provides integrated, 'one stop' access to all information on plant SSCs. It should include a master equipment list which identifies all nuclear power plant components and their classifications by system and design basis documentation of the functional requirements, performance parameters, SSC boundaries, general design requirements, design margins and system interfaces.
— *Equipment qualification programmes.* Provide assurance that equipment important to safety (covered by such programmes) will perform designated

[4] A condition indicator is a characteristic of an SSC that can be observed, measured and trended to infer or directly indicate the current and future ability of an SSC to function within acceptance criteria. A functional indicator provides a direct indication of the current functional capability of an SSC.

safety functions when required throughout the installed life of the equipment. Preserving equipment qualification in operational nuclear power plants is addressed in detail in Ref. [4]. The ageing degradation of such equipment is, in many Member States, taken into account by establishing a so-called 'qualified life', which is the maximum period that a component may be kept in normal service with a reasonable assurance that it would perform as required under design basis accident conditions.

— *Component specific programmes.* Deal with the functionality of major SSCs or classes of SSCs, such as the steam generator, reactor pressure vessel, or motor operated valves.
— *Chemistry programmes.* Aim at reducing corrosion through managing system chemistry.
— *Operating procedures.* Designed to control, within acceptable limits, service conditions (e.g. pressure–temperature cycles) that contribute to the age related degradation of SSCs.
— *Feedback of operating experience, analysis of significant events and research programmes.* Provide additional insights and understanding of the ageing processes affecting plant SSCs.
— *Spare parts programmes.* Ensure the availability of spare parts and maintain their condition (i.e. prevent their degradation) while in storage.
— *Techniques of reliability centred maintenance and probabilistic safety analysis.* Used to establish an effective preventive maintenance programme at a new nuclear power plant or to enhance the maintenance programme at an operational plant.

By means of such programmes, utilities already have a significant head start in implementing a systematic AMP. However, there are common organizational problems, which are outlined below.

First, problems arise because the responsibility for the programmes described above is typically distributed among several nuclear power plant organizations, including operations, maintenance, technical support and engineering. This division of responsibilities requires co-ordinating mechanisms which are frequently inadequate to support a thorough evaluation of the material condition of specific components. For example, the precursors of degradation identified in one programme might not be used to direct the detection of ageing effects through another programme or be correlated with indications observed in other programmes. As a result, the detection of an unanticipated ageing phenomenon may be significantly delayed. For example, excessive corrosion could be anticipated from chemical excursions identified in the review of system chemistry; accelerated ageing and premature failure caused by a design fault could be predicted from the feedback of external operating experience; or indications from non-destructive examination found during in-service inspection could be explained by unusual events detected through on-line transient monitoring.

Another problem is that existing programmes have been developed in response to a variety of needs. The objectives of these programmes, which relate to both economics and safety, are not always consistent. In some cases, the components included in a programme are limited by the scope required by the regulatory authority. In other cases, the programmes have been developed around the objective of assuring maximum plant availability and production reliability. As a result, gaps may exist between existing programmes relevant to managing nuclear power plant ageing.

In summary, owing to different objectives and possible gaps in the scope of existing programmes, and a lack of a co-ordinating mechanism, utilities may not have the necessary assurance that their nuclear power plants will be adequately safe and reliable to the end of their service life. These problems may be overcome by co-ordinating existing programmes within a comprehensive and proactive AMP, and the required material condition of the nuclear power plant may thus be effectively maintained.

3. DESCRIPTION OF AN AMP

3.1. OBJECTIVE OF AN AMP

The objective of an AMP is to provide for the timely detection and mitigation of significant ageing effects in nuclear power plant systems, structures and components important to plant safety and reliability so as to ensure their integrity and functional capability and to contribute to continued safe and reliable plant operation.

3.2. CONCEPT OF AN AMP

The main characteristics of an AMP are comprehensiveness and a proactive and systematic approach. The programme should enhance and co-ordinate, but not replace, existing programmes and activities that address plant ageing. AMP evaluations may also identify opportunities to reduce existing testing, surveillance and maintenance activities. In this way, the AMP can provide for the management of plant ageing that is both more effective and efficient.

The systematic screening of SSCs ensures that the programme has a practical scope and an appropriate focus. While it is expected that the age related degradation affecting most relatively short lived plant components such as gaskets, lubricants and some instrumentation and control (I&C) equipment is already addressed by existing programmes, this should be confirmed. However, many long lived, passive components such as piping and structures with poor accessibility, vessels or valve bodies have frequently been overlooked. Thus, the AMP also provides for the systematic ageing management of long lived passive components and structures that are not routinely inspected, maintained or replaced.

Appropriate corporate recognition, management support and resources for the AMP are needed to provide a good basis for ensuring that technical evaluations conducted under the programme are thorough and of high quality and that the recommendations are acted upon.

The best time to start an AMP is when the plant begins operation. For a major plant SSC, it is better to prevent or control degradation than to correct degradation that has already occurred. Experience shows clearly the benefits of proactive ageing management in comparison with a reactive approach. As a result of a proactive approach, reactor pressure vessel radiation embrittlement is, in general, predictable and under control. In contrast, a reactive approach to steam generator corrosion has resulted in increased operations and maintenance costs, culminating in extensive and expensive replacement programmes.

An AMP requires appropriate data which are retained for the life of the plant. These data also provide the basis for a plant life management programme and will aid in justifying continued operation of the plant to the regulatory authority. Implementation of an AMP will identify data collection and record keeping requirements to support ageing management evaluations. Where plant wide databases are already in place, formats for AMP related data collection, trending and records should be compatible with those databases. If such databases do not exist, then suitable ones should be established as part of the AMP. Appendix I and Ref. [5] provide additional guidance on this subject.

3.3. SCOPE OF AN AMP

An AMP deals with two types of changes in plant SSCs which occur with time and use and which may have an impact on plant safety and reliability. These are physical or material degradation of SSCs and obsolescence of SSCs owing to evolving technology and standards. In addition, to be effective an AMP should deal with the human aspects of ageing management relating to the awareness, motivation and relevant competencies of plant personnel. These three elements of AMP scope — material ageing, technological obsolescence and human aspects — are discussed in turn in this section.

3.3.1. Managing of material ageing

Managing material ageing involves screening SSCs, performing ageing evaluations for the selected SSCs, implementing appropriate ageing management actions, and maintaining a 'living', SSC focused AMP. The discussion of methodology in this section is very abbreviated. A full description can be found in Ref. [6].

Screening components. A nuclear power plant consists of a large number and variety of SSCs. To determine what are effective and practical ageing management measures, it is neither practical nor necessary to evaluate the ageing degradation of all of these SSCs. Establishing the extent of the programme is done through component screening.

The selection of important SSCs focuses resources on the subset of SSCs that can have a significant impact on the continued safe and reliable operation of the nuclear power plant. Both active and passive components are considered. Many of the components that would be identified as important are relatively short lived or are consumables (e.g. gaskets, lubricants and some I&C equipment) and are already covered by existing effective replacement/maintenance programmes. These components should not require further ageing evaluations if the ageing mechanisms affecting them are already well understood and effective ongoing ageing management actions are in place. On the other hand, the AMP will provide for the systematic ageing management of many long lived, passive components which are not routinely inspected or maintained (e.g. inaccessible pipes, structures, vessels or valve bodies).

Performing ageing evaluations. Evaluations of the selected SSCs systematically assess age related degradation mechanisms and their effects on the ability of important SSCs to perform their design functions, and identify or develop effective ageing management actions to detect and mitigate those effects before the integrity and functional capability of the SSCs are compromised. In other words, the intent of these ageing evaluations is to provide for control, within acceptable limits, of the potential ageing degradation effects. Service conditions, ageing mechanisms and their effects that have been experienced or are anticipated are considered, significant ageing mechanisms and condition or functional indicators that can be used to monitor and evaluate ageing effects are identified, and practical and effective ageing management actions are recommended (this includes an economic evaluation of available ageing management actions in order to assess their viability.)

Ageing evaluations will likely find that existing programmes and activities at nuclear power plants are already addressing many of these aspects of ageing management. Nonetheless, there are likely to be a number of recommendations which can enhance or supplement existing programmes and activities. This requires a review of the recommendations with those responsible for implementation, and agreement on which recommendations will be acted upon.

Recommendations may include changes in hardware, operations or maintenance. Additionally, gaps in the basic knowledge and understanding of ageing phenomena may indicate that additional R&D is required to support the development of ageing detection and mitigation measures.

Implementing ageing management actions. The ageing management evaluations provide recommendations. Responsibility for implementing these recommendations typically lies with the plant organizations responsible for inspection, maintenance, engineering and operations. These organizations first need to review the recommendations and decide on their cost effectiveness and long term safety and reliability benefits. Each recommendation should therefore have an appropriate disposition provided: either it will be carried out and a budget and schedule will be prepared, or it will not be carried out and a rationale for deletion from the programme will be provided. The combined budgets and schedules for the recommendations that are accepted become the implementation plan for a given ageing evaluation. Such an implementation plan needs to be monitored. Appropriate reporting mechanisms and performance indicators should thus be part of the implementation plan.

Maintaining a living programme. During the service life of a nuclear power plant, there is a need to provide for continuous improvement of the AMP. It is prudent to periodically update ageing evaluations, re-evaluate the effectiveness of SSC specific ageing management actions in the light of current knowledge and adjust the AMP, as appropriate.

Current relevant knowledge consists of information on plant operation, surveillance and maintenance histories, and external information on the results of post-service examinations, R&D and operating experience. New degradation mechanisms or unexpected degradation locations may be inferred from an incident occurring in just one plant in the world. Nuclear power plant operating organizations should therefore strengthen their relationships to facilitate the exchange of relevant information. Plant owners groups are an excellent forum for exchanging such information.

Provisions to detect, evaluate and mitigate the effects of unanticipated ageing mechanisms should be an integral part of the living AMP. Since it is not always obvious that a particular event is a sign of the onset of an ageing problem, it is recommended that the AMP processes allow the analysis to be performed in two steps:

- — A preliminary analysis to recommend the immediate actions necessary to maintain plant safety and availability and to collect relevant information for follow-up work, as appropriate.
- — A detailed analysis to investigate the root causes of the event, the potential consequences, and whether it indicates a new ageing problem.

The detailed analysis often requires specific technical expertise or further studies, testing, or investigation. It may be performed by an ageing management team or specialized contractors under the supervision of the AMP unit, as described in Section 4.2.2. The inclusion of plant personnel in such studies is important because of the need to use actual operating history. Examples of unanticipated ageing phenomena that would be addressed by an AMP are given in Appendix II. Information on AMP self-assessment and peer reviews whose objective is ongoing programme improvement is given in Section 5.

3.3.2. Managing technological obsolescence

For some equipment, technological obsolescence rather than material ageing may be the primary concern. This might be the case where nuclear power plant programmes are adequate to deal with the material ageing of equipment, but the lack of spare parts makes it difficult to maintain the required functional capability. The technological aspects of ageing management involve ensuring the continued availability of qualified spare parts or providing for the timely replacement of obsolete equipment, such as I&C equipment.

The rate at which radiation, heat, wear and parts availability affect I&C systems leads to an economic in-service life expectation of between 10 and 15 years. Over the life of a typical nuclear plant it is probable that the plant owner must plan to replace the I&C systems at least once and it is possible that this might need to be done a second time for a plant with a long service life.

Suppliers of equipment such as instrumentation and microswitches may periodically change their specifications. Suppliers may elect to stop making safety qualified equipment or change designs as a result of new technologies or changing industrial standards. Thus, qualified replacement parts may no longer be available for essential plant equipment. At some point, parts unavailability may dictate design changes to support the installation of new equipment. It is therefore essential that any changes in suppliers or equipment specifications be conveyed to the responsible procurement engineer to ensure that there is a continued adequate supply of qualified spare parts. Many nuclear power plants are currently facing these concerns and should already have programmes in place to address them.

The existing procurement processes should be periodically reviewed to assess the continued availability of qualified spare parts. It is essential that concerns about the availability of spare parts are identified in a timely manner so that the procurement processes can be adjusted promptly. Alternatives such as equipment replacement to take advantage of new technologies should also be evaluated. For computer based equipment, for example, the assessment may find that the equipment has an adequate life remaining, but the manufacturer has plans to stop supporting the equipment.

Repeated instances can be cited where product lifetimes of computer based equipment have dropped from around ten years to below two years, which places a burden on the utilities to carry a sufficient holding of spares when the expected service life is 10–15 years.

3.3.3. Human aspects of ageing management

The ultimate success or failure of the AMP depends upon the degree of understanding, acceptance and support of the staff of the nuclear power plant. While ageing management actions are recommended by the AMP organization, implementation of these recommendations is the responsibility of the relevant nuclear power plant organizations. Early warning of emerging ageing phenomena and feedback concerning ageing management actions already in place are also provided by these organizations.

The human aspects of ageing management involve creating a sense of ownership and support for the AMP on the part of all relevant nuclear power plant personnel. Attention to the human aspects of ageing management will ensure the competence of these personnel to carry out assigned responsibilities and sensitivity to indications of possible ageing phenomena. This will help to ensure that every significant repair/refurbishment/replacement decision, every change in operating or maintenance procedures and every design change is evaluated in the light of the AMP objective.

Both operators and maintenance staff need to be encouraged to promptly report anomalies that could indicate the onset of degradation so that they can be investigated and any corrective actions can be taken at the earliest opportunity. Similarly, error induced degradation (as a result of installation, operation or maintenance errors) should be identified and appropriate measures sought to reduce their frequency. These may include improved training or quality assurance.

Feedback from field staff may, however, be hindered by data management systems which make it difficult to accurately record and store results, or which may not prompt operating and maintenance staff to provide the right kind of data. Examples are transient operating data and maintenance work reports. As utilities upgrade their data systems they should consider the collection of such data by their staff. Impressing the importance of uniform data collection for subsequent analysis will have a greater effect if the staff interface with the data storage system is well designed.

A multidisciplinary approach to ageing management requires the frequent use of working parties and teams. Training in team skills (e.g. problem solving) and selecting capable team facilitators will help ensure that the teams are effective.

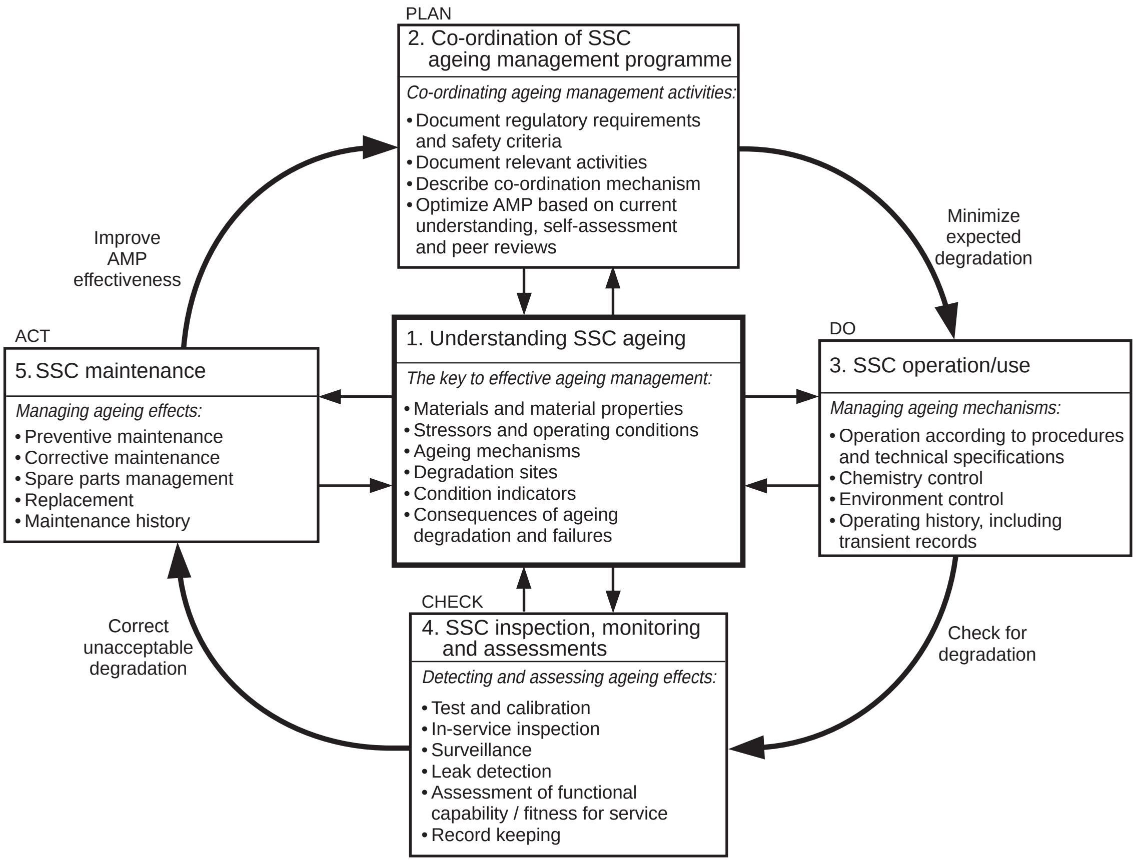

FIG. 1. A systematic ageing management process (AMP: ageing management programme, SSC: system, structure or component).

The human aspects of ageing management can best be addressed by making the relevant nuclear power plant organizations key members of ageing management teams (as discussed in Section 3.3.3) and by including AMP objectives, activities and the roles of different nuclear plant organizations, as shown in Fig. 1, in training programmes. All relevant plant personnel should be led to feel that ageing management is an integral part of their job and should be made to understand their role in the ageing management process (Fig.1). Management support and promotion of the programme will help accomplish this. Additional insights in this regard are provided in Ref. [7].

4. THE AMP MODEL AND ITS IMPLEMENTATION

The comprehensive nature of an AMP requires the involvement and support of many organizations in a utility and may be regarded as an intrusion by some. As a result, successful implementation of such a programme requires careful preparation to ensure that it is understood and accepted by all involved. This in turn will require strong support from utility management.

Implementing the AMP is a complex undertaking that should begin with a pilot programme in order to establish the organizational interfaces and AMP processes, demonstrate the value of the AMP and create support for further work.

This section describes the organizational and managerial aspects that need to be addressed when implementing the AMP described in Section 3. The AMP model described is based on the experience of several utilities (e.g. Electricité de France (EDF), Swiss utilities and Baltimore Gas and Electric in the USA) but may, of course, be modified to suit particular circumstances. For example, the co-ordinating role played by an AMP unit can be assigned to a maintenance of quality assurance organization, and a small nuclear utility would likely make use of relevant expert groups organized by an owners group rather than creating its own ageing management teams to perform evaluations. The descriptions and names used are functional since organizational names are utility specific.

4.1. ORGANIZATIONAL MODEL FOR IMPLEMENTING A SYSTEMATIC AGEING MANAGEMENT PROCESS

The implementation of a systematic ageing management process requires an organization that builds on and systematically co-ordinates all relevant existing plant and external programmes and activities. The organizational model for an AMP is

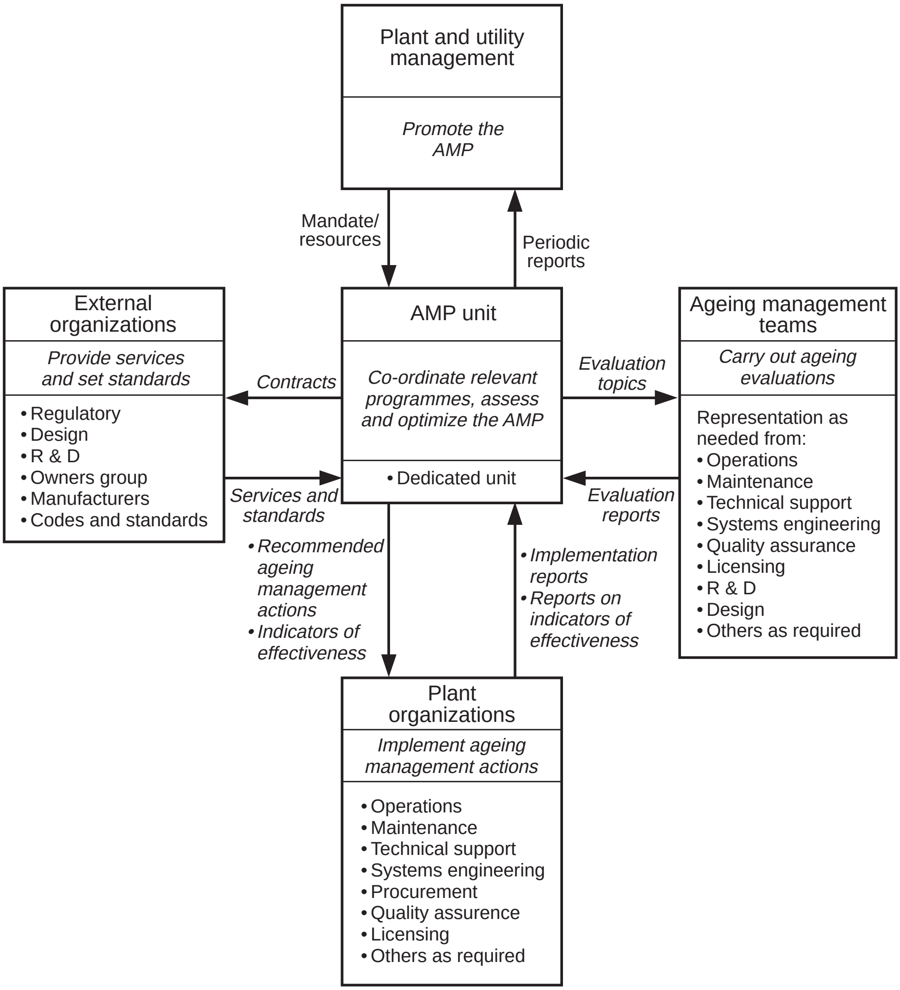

FIG. 2. Organization of an AMP: participating organizations, functions and their interfaces.

shown in Fig. 2. There are six distinct functions within an AMP, each of which corresponds in this model to an organizational unit:

(a)	Promote the AMP	*Plant and utility management*
(b)	Co-ordinate relevant programmes	*AMP unit*
(c)	Carry out ageing evaluations	*Ageing management teams*
(d)	Provide services and set standards	*External organizations*

(e) Implement ageing management actions	*Plant organizations*
(f) Assess and optimize the effectiveness of the AMP	*AMP unit*

Figure 2 also shows the principal participants and the main information flows between organizations. An indication of the resources needed is given below.

The plant and utility management sets out the objectives of the AMP and assigns the necessary resources. Some time needs to be devoted to an oversight role to ensure that the programme is meeting its objectives.

As can be seen from the figure, the key role in the AMP is played by an *AMP unit*, which is responsible for the co-ordination of relevant programmes and activities within the AMP and for ongoing assessment and optimization. This unit interfaces with the other four organizational units. The AMP unit is viewed as a full time unit with its own resources. Optionally, it may accomplish its co-ordinating role through part-time committees. Staff have a good technical and operations background, as well as planning and co-ordination skills. This unit is typically quite small unless it carries out its own ageing evaluations. The size of the AMP unit and its place within a utility or nuclear power plant organization depends on specific requirements and circumstances. The unit may be placed within an existing organization, e.g. a maintenance or quality assurance organization, or be set up as an independent unit. It is essential that the AMP unit is the facilitator of the systematic ageing management process and is seen by other participating organizations as such and not as an obstacle.

Ageing management teams are created for specific technical evaluations using the appropriate experts. The participants will be different depending on the evaluations and may work part-time on the team. Although the teams are created for a specific task, they may continue to meet periodically after their evaluation is completed in order to review new developments and update their recommendations. With a mature programme, typically three or four teams may be active at any time. EDF and a group of Swiss nuclear utilities have reported good experience with such teams.

External organizations typically fall into two categories. There are fee for service organizations providing services in the areas of engineering, design, manufacturing and research. A second category consists of organizations responsible for regulatory oversight or for standards. In both cases the preferred interface is through the AMP unit.

Plant organizations, such as those dealing with maintenance, engineering, operations, training, information management and safety, are responsible for implementing the actions recommended by the ageing management teams. They also supply experts to these teams.

Not shown in the figure are other relevant bodies doing work in the field of ageing management such as owners groups, utilities and international organizations such as the IAEA. The AMP unit also liases with these bodies.

4.2. RESPONSIBILITIES OF AMP PARTICIPANTS

Consistent with the AMP organizational model described earlier and in Fig. 2, the responsibilities of the organizations participating in the AMP process are summarized in Fig. 3 and discussed in detail in the following sections.

4.2.1. Responsibilities of plant and utility management

Plant and utility management is responsible for defining AMP objectives, creating an AMP unit, defining its responsibilities and providing the required resources. Because the AMP unit has a co-ordinating role, it is important that this role is understood and accepted by the rest of the utility organization. As mentioned earlier, the AMP unit should be seen as a facilitator of the systematic ageing management process. Management needs to champion a systematic AMP and ensure that it receives support and co-operation. It may choose to accomplish this by appointing a Management Steering Committee that meets periodically with the manager of the AMP unit. Such a committee could have representatives from operations, engineering, research and design and thus would be able to assist the AMP manager in resolving any organizational problems. Management also needs to monitor the effectiveness of the AMP, approve major actions recommended by ageing management teams and resolve potential problems.

4.2.2. Responsibilities and activities of the AMP unit

The AMP unit manages the ageing evaluations which form the foundation of the AMP and co-ordinates the implementation of the resulting recommendations. AMP unit personnel take the lead for these long range evaluations and thereby ensure the continuity and consistency of AMP activities.

Before starting any evaluations, the AMP unit needs to develop programme procedures and a methodology. Included in this methodology are screening procedures, although the AMP unit may assign the task of the actual screening to an ageing management team (screening is done in the early stages of the AMP and identifies which SSCs or degradation mechanisms require ageing evaluations).

AMP unit personnel usually do not possess all of the expertise required to conduct technical assessments since actions to mitigate the effects of ageing may result in changes to operating procedures, surveillance or monitoring activities, replacement strategy, inspection programmes or design. This is especially true if the AMP unit is small. The AMP unit, therefore, organizes and directs interdisciplinary teams to develop and prioritize ageing management alternatives and to identify the most cost effective approach, consistent with safety and reliability requirements.

This publication has been superseded by SSG-48.

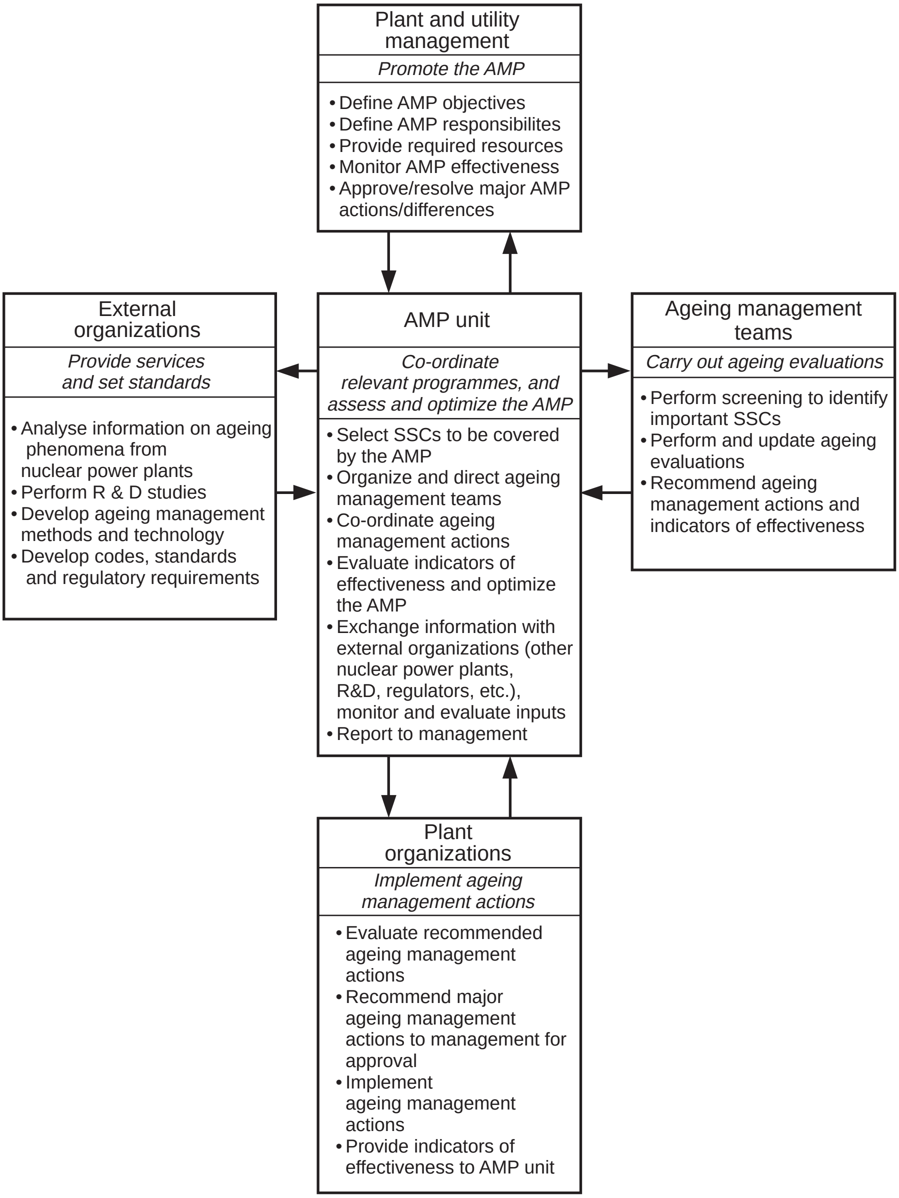

FIG. 3. Responsibilities of AMP participants.

The teams submit their recommended actions and indicators of effectiveness to the AMP unit and the unit in turn provides these to plant organizations for implementation. If the organization disagrees with the recommendations, the unit attempts to resolve the disagreement and, in those cases where resolution is not possible, refers the case to the plant or utility management, as appropriate. This should be rare if the plant organizations are represented on the teams preparing the recommendations.

The AMP unit also provides the liaison between the teams, other organizations supporting ageing management, quality assurance and other sources of ageing management information, such as utilities, owners groups, regulators, R&D organizations, manufacturers, and national and international sources of information. In cases where the teams cannot make definitive recommendations because of gaps in knowledge or the need for additional codes and standards, the AMP unit co-ordinates resolution with the appropriate R&D laboratory, manufacturer, code committee or other external organization.

Independent of the needs of the AMP teams, the AMP unit maintains contact with external organizations involved in ageing management programmes. This includes contacts with other nuclear power plants and laboratories, either directly or through owners groups, to monitor plant operating experience and R&D results concerning age related degradation encountered at other nuclear power plants in their country and around the world. The AMP unit interprets the applicability of this information to its own plant(s).

AMP unit personnel should monitor the implementation of ageing management actions and evaluate the indicators selected to monitor the effectiveness of the AMP. These self-assessment activities provide the basis for periodic reports to management and for ongoing optimization and improvement of the AMP.

4.2.3. Responsibilities of the ageing management teams

Interdisciplinary ageing management teams are established under the direction of the AMP unit to: perform technical evaluations, such as screening SSCs using a methodology developed by the AMP unit; determine the effectiveness of existing plant programmes to manage the ageing of specific SSCs; identify appropriate ageing management actions and indicators of effectiveness, taking into account costs; identify R&D requirements; and investigate unanticipated ageing phenomena. The results of these investigations may include recommendations for the following kinds of ageing management actions: modification of operations and maintenance procedures and operating conditions; replacement of degraded or obsolete components; changes to monitoring or maintenance programmes; improvements to data collection, record keeping and data trending practices; and requirements for R&D.

The expertise required for these evaluations should be drawn on a matrix organizational basis from operations, maintenance, engineering, design, research and economics, as appropriate. Participation on the AMP teams by plant personnel develops their sense of ownership in the recommended ageing management actions and reduces the possibility of disagreement when the recommendations are issued to nuclear power plant organizations for review and implementation. To ensure uniformity of evaluations, these teams should be chaired or co-chaired by AMP unit personnel.

While a 'matrixed' ageing management team is the preferred method of producing ageing assessments, other options are possible. These include the use of staff attached to the AMP unit, external consultants, and assessments by expert groups of major SSCs, such as a reactor pressure vessel or steam generator, that already exist at a utility or are sponsored by an owners group. Regardless of the alternative chosen, the team should follow the standard methodology developed by the AMP unit and should work closely with the plant organizations. The range of possible evaluations and the makeup of the team are illustrated by some examples:

— *Screening SSCs.* An ageing management team performing a screening to identify important SSCs would require participants from organizational units that are responsible for equipment lists, safety classification, plant reliability and economics and are knowledgeable regarding the design functions performed by the SSCs being screened.
— *Ageing evaluations.* An ageing management team responsible for ageing evaluations of important SSCs (e.g. the reactor pressure vessel, steam generators, cables and I&C equipment) would require participants from organizational units that are responsible for systems engineering, research, design requirements, materials, the operating environment, operating history, inspections and maintenance to ensure that potential age related degradation mechanisms are addressed and that appropriate ageing management actions are identified.
— *Unanticipated ageing phenomena.* Interdisciplinary ageing management teams are also responsible for detailed analyses of unanticipated ageing phenomena. The identification and evaluation of unanticipated ageing phenomena usually requires inputs from operational history, inspections, testing, engineering and R&D. The teams must integrate these inputs to characterize the ageing phenomena and to identify appropriate ageing management actions (see Appendix II for examples of such investigations).

4.2.4. Responsibilities of external organizations

It is anticipated that the need to call upon external organizations will be identified by the ageing management teams, which may identify issues that require further evaluation before ageing management actions can be identified. Some issues may require additional research either at a suitable laboratory or, for members, through a plant owners group or a research institute such as the Electric Power Research Institute in the USA.

Other issues may require design changes by equipment manufacturers, or new codes and standards from the responsible code committees or the regulatory authority. The AMP unit will co-ordinate interaction with these external organizations.

4.2.5. Responsibilities of plant organizations

The operations and maintenance and technical support organizations of a nuclear power plant have the primary responsibility for implementing ageing management actions. The responsible organization should evaluate actions recommended by ageing management teams and implement those that are practical and cost effective. It should also collect data (indicators) for monitoring the ageing of SSCs and for the evaluation of AMP effectiveness.

It is expected that representatives from relevant plant organizations will serve as members of the teams that perform evaluations and develop the appropriate recommendations. As members of the teams, plant personnel would thus be familiar with the recommendations and the indicators of effectiveness. Nevertheless, the responsible plant organization should formally evaluate the recommendations, perform cost–benefit analyses and implement those that are practical and cost effective. More expensive actions may require approval by utility management. The responsible plant organization should report to the AMP unit on the implementation of recommended ageing management actions, and a justification should be provided when the recommendation is not accepted. In addition, agreed upon operating data that form the indicators of AMP successes (or failures) should be reported for use in the AMP self-assessment process.

4.3. IMPLEMENTATION OF AN AMP

The comprehensive nature of an AMP requires the participation and support of many nuclear power plant organizations. As a result, successful implementation of the AMP will require careful preparation to ensure that it is understood and accepted by all relevant organizations of the plant.

As a starting point, utility management should define the AMP's objectives, policies and responsibilities and inform all levels of the utility organization that their support is essential to programme success.

Utility management should establish an AMP unit to manage the programme and provide the necessary staffing, resources and support to ensure that the AMP unit can perform its functions. An experienced manager with a suitable nuclear power plant engineering, operations and maintenance background should oversee and co-ordinate the AMP and supervise the activities of the AMP unit. The unit’s staff should not have other production related responsibilities at the plant or within the utility. However, the unit may be placed within an existing nuclear power plant organization such as the maintenance organization. Should the staff have other responsibilities and have to choose between solving an immediate problem affecting plant operations or addressing a longer term ageing issue, the longer term issue would inevitably be deferred.

An AMP is inherently a long term programme. As a result, the AMP unit should be insulated as much as possible from short term budget fluctuations that would compromise the continuity of the ageing evaluations and ageing management actions under the AMP.

The level to which the AMP unit reports, the degree of autonomy given, and the resources allocated to the programme should emphasize the importance that utility management gives to managing ageing.

The AMP unit does not necessarily need to be located ‘on-site’, although this is probably the preferred location as it is closer to the source of the ongoing input data and ageing management activities. Some utilities with more than one station may prefer to establish a central AMP unit to cover all stations, since this will help to ensure consistent programmes at each station. In this situation, the AMP unit should have designated representatives at each station who report directly to the central AMP unit. At EDF, the AMP unit is at the corporate level, with counterpart engineers in each plant.

While large, multi-unit utilities generally have the resources and expertise to support the required range of ageing management teams, this may not be the case for smaller utilities or utilities with only a single nuclear unit. In such cases, the preferred approach would be co-operative funding of ageing management teams by several utilities. The most logical working arrangement would be to co-ordinate such efforts through the owners group. This approach has been successfully demonstrated by a group of Swiss nuclear utilities (GSKL).

The combined experience of the AMP unit should touch on as many aspects of nuclear power plant design, operations, maintenance and licensing as possible. The size of the AMP unit will depend upon the number of plants being supported and the utility’s attitude to the use of consultants as against performing work in-house.

Management should authorize training to ensure that all relevant nuclear power plant personnel understand the ageing management process, the likely benefits in terms of the plant’s safe, reliable and economic operation, and the purpose of any new or revised programmes associated with the AMP.

Implementation of an AMP should start with a pilot project dealing with a limited number of representative SSCs in order to establish, refine and adapt the AMP processes and interfaces at the nuclear power plant. Pilot SSCs should be chosen for the purpose of demonstrating AMP processes and assessing the availability of data, rather than on the basis of their importance for plant safety or reliability. Establishing interfaces between plant organizations responsible for implementing ageing management actions and other participants in the AMP is especially important for the success of the programme. Steam generator tubing or auxiliary piping of the primary circuit are good examples for commencing AMP implementation. Once the processes have been demonstrated, implementing procedures written and a working relationship established, the AMP can be extended to cover the remaining important SSCs.

AMP benefits will be maximized if the programme is implemented at the beginning of operations at a nuclear power plant. This will ensure that plant personnel develop a sensitivity to ageing management early on which will support the early identification of opportunities for improved plant performance and long term safe and reliable operation.

5. REVIEW OF AN AMP

This section provides guidance for reviews of the effectiveness of a nuclear power plant AMP. There are three complementary types of AMP reviews, as shown in Table I. These differ in the independence of the review team, the degree of

TABLE I. REVIEW OF AN AMP

Review type	Carried out by	Objective	Frequency
Self-assessment	AMP unit	Optimize the AMP	Annual
Peer review of relevant programmes	Peer review team as part of an overall plant audit	To determine whether existing relevant programmes meet generally accepted practices and to identify areas for improvement	Two years
Comprehensive programme review	Nuclear power plant owner/operator as part of a comprehensive safety review	To determine whether ageing is being effectively managed, the required integrity and functional capability of SSCs are being maintained, and an adequate AMP is in place for future plant operation	Ten years

formality and rigour of the assessment process and the interval between reviews. They provide, at one end of the spectrum, short term managerial operational and quality control and, at the other end, a comprehensive review of AMP effectiveness in ensuring the material fitness of the plant for future operation. The following text provides guidance and details on the three types of reviews listed above.

5.1. SELF-ASSESSMENT OF AMP EFFECTIVENESS

The objective of self-assessment is to provide for ongoing programme optimization. Such ongoing assessment of the effectiveness of an AMP is carried out, usually on an annual basis, by the AMP unit through the monitoring of ageing management actions and evaluation of both SSC specific indicators of effectiveness and programme level performance indicators.

These reviews should make use of relevant results collected through other existing self-assessment/feedback loops, for example for maintenance, operations or chemistry programmes. The AMP self-assessment should allow those in charge of the programme to take timely actions to improve AMP activities and organizational interfaces when necessary and thus facilitate a continuous improvement process.

Examples of SSC specific types of indicators of effectiveness include:

- Service conditions,
- Test data,
- Failure data,
- Condition indicator/degradation data,
- Maintenance history data.

Examples of programme level performance indicators are:

- Forced outage rate owing to equipment failures,
- Comparison of preventive and corrective maintenance efforts,
- Chemistry control index,
- Inspection programme compliance.

5.2. PEER REVIEW OF RELEVANT PROGRAMMES

The objective of a peer review of relevant existing programmes is to determine whether these programmes meet generally accepted standards and practices and to identify areas for improvement. The review therefore includes all of the programmes important to ageing management, as listed in Section 2.2, and is usually carried out as part of an overall plant audit.

Such audits require considerable expertise in audit techniques and credibility of the auditors. For this reason, they are carried out by permanent audit organizations such as the Institute of Nuclear Power Operations (INPO). In addition, the IAEA conducts peer reviews (for example, Operational Safety Review Team audits) and some large utilities have established an in-house programme evaluation capability (for example, EDF, Nuclear Electric and Ontario Hydro). In such cases, the peer review organization is independent of the nuclear power plant operating organization and reports to senior utility management.

Programme audits are typically conducted by a 15–20 person team over a period of two to three weeks. The team consists of experts in technical support, operations, maintenance, chemistry, planning, training and administration. Prior to the audit the team examines documentation on plant performance, including event reports and performance data, looking for particular areas of concern. The audit itself is conducted through a series of direct observations intended to identify both programme strengths and weaknesses. The problems are formally reported to utility management, along with the corrective actions agreed to by the plant. Subsequent evaluations will determine the effectiveness of these actions in improving performance.

5.3. COMPREHENSIVE PROGRAMME REVIEW

The objective of a comprehensive programme review is to determine whether ageing in a nuclear power plant is being managed effectively so that the required integrity and functional capability of SSCs are maintained, and whether an adequate AMP is in place for future plant operation.

In a comprehensive programme review the following aspects of the management of ageing should be examined:

(1) General attributes of the AMP (e.g. programmatic aspects, such as policy, resources, procedures and records);
(2) Scope of the AMP (e.g. screening methodology and SSCs covered by the AMP);
(3) Quality of programmes for ageing management of specific SSCs (e.g. the degree of understanding of SSC ageing and the effectiveness of established detection and mitigation programmes);
(4) Results achieved (e.g. the actual physical condition of SSCs, equipment qualification status and relevant plant safety indicators).

To help in making judgements on AMP effectiveness, agreed indicators of effectiveness should be used for each of these four aspects. A list of possible indicators is given in Appendix III.

The requirement for a comprehensive AMP review may be established by the national regulatory authority. Such a review would normally be conducted within the framework of a periodic safety review of an operational nuclear power plant (ten year typical period) [3] or a major licence renewal review (e.g. as in the USA). It is the responsibility of the plant owner/operator to conduct and document the review and the responsibility of the regulator to evaluate the results of the review. The scope of the review, the procedure and the indicators of effectiveness should be agreed in advance with the regulator.

Review procedure. The description below follows the general procedure for a periodic safety review [3] and is adaptable to national requirements. It consists of three major steps: an assessment of the current ageing management status, an interim safety review and an in depth safety review.

The review should take into account the results of: all existing programmes and activities which are relevant to the AMP at the nuclear power plant (Section 2.2); AMP self-assessments (Section 5.1); peer reviews of relevant programmes (Section 5.2).

Assessment of the current status of ageing management. In this step, information on the AMP is reviewed and compared with the agreed upon indicators. A list of deviations from current requirements is documented in a report. All significant programme strengths (i.e. where requirements are exceeded) and deficiencies (i.e. where requirements are not achieved) should be clearly identified. If there are no deficiencies, further steps of the review are not necessary.

Interim safety review. In this step, each deficiency identified in step 1 is subjected to an immediate review to determine its safety significance and the appropriate corrective action(s). The review uses existing information and expert judgement rather than detailed analysis and is documented in a report. In cases where the safety significance is high, immediate remedial action(s) should be implemented. The regulator is responsible for assessing the adequacy of the remedial actions and interim measures relating to deficiencies of medium safety significance.

In-depth safety review. In this step the safety significance of individual deficiencies and the adequacy of corrective actions from the interim review are verified. If the in-depth analysis shows that the actions resulting from the interim review are inadequate, the feasibility of other permanent corrective actions is assessed. The acceptability of continued plant operation is then assessed, with account taken of all remaining deficiencies.

When it is not practical to implement the corrective actions within the time-scale of the review, an implementation schedule should be agreed between the plant owner/operator and the regulator. There should be appropriate follow-up to ensure compliance with the schedule.

Appendix I

DATA COLLECTION AND RECORD KEEPING

Data collection and record keeping are ongoing activities at all nuclear power plants. However, an AMP may require that the scope, level of detail and/or frequency of data collection be modified in response to specific ageing concerns. A specific ageing management team (see Section 4.2.3) should therefore be set up to assist plant personnel in understanding the importance of data collection and the format for collection. Two examples of data collection needs are given below.

Maintenance and testing personnel should understand that data collection after active component testing (e.g. valve closure time) is important. Even though results comply with technical specification criteria, they may be useful for trend analysis and ageing management. Such data will be correctly collected only as the result of interfaces between the AMP and the personnel in charge of data collection.

Routine information such as test results or monitoring data which is not directly related to an incident, failure, or degradation, can, nevertheless, provide insights into the material condition of the nuclear power plant. These data are generally collected by production personnel and evaluated by engineering personnel. Clear and detailed instructions should be provided so that the data can be processed accurately and according to a common format. If, for example, all primary system pressure and temperature transients are identified right at the beginning and characterized for severity, the fatigue status and remaining fatigue lifetime of reactor coolant system components can be assessed under the AMP.

For the primary system pressure boundary components of a PWR, design rules require a fatigue assessment based on a list of transients which are supposed to represent the entire life of the plant. Of course, this assessment is meaningful only if during operation plant staff verify that all actual transients are not more severe or more numerous than assumed in the design analysis. When it is done properly, transient monitoring and documentation give, at any time, a clear view of where each component stands with respect to its fatigue margins.

The ‘fatigue management’ programme should be co-ordinated by the AMP unit. Transient detection, which is performed by the production staff, is one of many steps which must be performed for the programme to be effective. The other steps include threshold evaluation, detection procedure establishment, result analysis, comparison with design assumptions, understanding of abnormal transients, optimization of operating practices to reduce fatigue loading, optimization of the in-service inspection schedule, and evaluation and surveillance of critical points. The AMP facilitates appropriate interaction between the maintenance, operation, engineering, structural and material science and plant systems and personnel involved in the fatigue management programme. Such a programme should start on the very first day of nuclear power plant operation.

Appendix II

EXAMPLES OF UNANTICIPATED AGEING PHENOMENA ADDRESSED BY AGEING MANAGEMENT TEAMS

Cast austenitic steel thermal ageing. Under certain conditions, cast austenitic steel may undergo thermal ageing which could result in a loss of ductility and an increased risk of the propagation of pre-existing defects. For many plants, this possible mode of degradation was not taken into account in the original design and construction, although it may affect components of safety related systems. R&D results indicated the relevant parameters to estimate component sensitivity, but, in most cases, none of the existing operations and maintenance activities or programmes was appropriate to detect, monitor or evaluate the actual occurrence of this ageing phenomenon.

The AMP identified the issue, collected and analysed data and proposed a strategy to utility management. An ageing management team co-ordinated the activities of the relevant utility departments and external specialists in order to investigate all aspects of the problem and recommend ageing management actions: estimating the sensitivity of actual plant components (including on-site sampling); initiating laboratory investigations; looking for monitoring techniques; discussing the problem with vendors; assessing structural integrity and safety issues; studying replacement feasibility and parts availability; investigating maintenance and/or operation countermeasures; and making predictions about the ageing evolution. Only the ageing management team was able to facilitate the interaction of specialists from so many fields.

In the case of a significant incident occurring in one plant owing to an unanticipated ageing mechanism, other plants which did not anticipate that ageing mechanism might be forced into a long outage to evaluate their status and take appropriate measures.

Stress corrosion cracking of high nickel alloys. Before it had a widespread effect on steam generator tubes, the potential for this ageing mechanism was known by only a few researchers. Even after the steam generator effects were well known, it took several years before AMP staff in some utilities realized that extensive investigation of other high nickel alloy components should be initiated. This led to the discovery of cracking in pressurizer instrumentation nozzles and core vessel head penetrations.

Erosion–corrosion. This phenomenon, which was recognized throughout the nuclear industry as a known form of ageing degradation, occurred at a nuclear power plant in an unanticipated location and caused a feedwater pipe rupture. Utilities then collaborated to identify the root causes of this degradation and develop a monitoring and mitigation programme that effectively controls its effects. Examples of ageing management actions include inspections, water chemistry control and design changes to use erosion–corrosion resistant material.

Appendix III

INDICATORS OF AMP EFFECTIVENESS

The following indicators are given as results oriented criteria and typically describe activities that contribute to the effective management of nuclear power plant ageing. Before starting a comprehensive AMP review, the indicators of effectiveness to be used in the review should be agreed between the regulatory body and the licensee responsible for conducting the review. They should be updated and further elaborated in accordance with current knowledge, standards and practices, and checked for consistency with the relevant national and international codes and standards.

III.1. GENERAL ATTRIBUTES OF AN AMP

(1) A systematic AMP that is clearly defined and documented. This documentation includes:

- — Overall policy that defines the scope, objectives, activities and general responsibilities for all relevant organizational units, programmes and activities correlated with the systematic ageing management process;
- — Methods and procedures for the conduct of activities aimed at understanding, effective monitoring and mitigation of ageing;
- — Performance indicators by which the effectiveness of the AMP can be measured.

(2) Staffing and resources that are sufficient to accomplish AMP objectives.

(3) Personnel who clearly understand their authority, responsibilities, accountabilities and interfaces with other organizational units.

(4) Personnel who are knowledgeable of ageing phenomena and their potential impact on plant safety and reliability.

(5) Personnel trained and qualified to perform assigned job functions.

(6) Records on SSCs important to safety that provide relevant, accurate, sufficiently comprehensive and readily retrievable information to support ageing management activities.

(7) Spare parts of required quality that are available when needed and suitably stored, taking account of the shelf life.

(8) Replacement of obsolete equipment on a timely basis.

(9) AMP self-assessment that provides for periodic evaluation of the effectiveness of the AMP, and for the results to be used to make programme improvements.

III.2. SCOPE OF THE AMP

(10) Methodology and criteria used for identifying SSCs covered by the AMP that are clearly documented and acceptable.
(11) A list of SSCs covered by the AMP that is available and acceptable, as well as a procedure that controls any changes to the list.

III.3. QUALITY OF PROGRAMMES FOR THE AGEING MANAGEMENT OF SPECIFIC SSCs

The following attributes are applicable to each SSC covered by an AMP.

(12) Potential ageing degradation that may affect the design functions of an SSC that has been identified, evaluated and documented.
(13) An effective programme exists for the timely detection and mitigation of ageing processes and/or ageing degradation effects. A typical programme includes, but is not necessarily limited to, observing operational limits, inspection, surveillance, condition indicator evaluation and trending, maintenance and record keeping.
(14) Acceptance criteria[5] have been established to determine the need, the type and timing of corrective action(s). These criteria are typically given by or derived from sources such as technical specifications, industry codes and standards, regulatory requirements, operating experience and vendor criteria.

III.4. RESULTS ACHIEVED

(15) The actual physical condition of SSCs covered by an AMP is satisfactory in terms of the required safety margins (i.e. the integrity and functional capability of passive and active SSCs):

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[5] An acceptance criterion is a specified limit of a functional or condition indicator that is used to assess the ability of an SSC to perform its design function(s).

— SSC condition and/or functional indicators, provided by in-service inspection, surveillance, testing or condition monitoring and their trends conform to acceptance criteria.
— Ambient environment parameters (e.g. temperature, humidity, radiation fields) and their trends are within specified limits.
— System parameters (e.g. pH, conductivity, activity, temperature and pressure), their transients and trends are within acceptance limits.

(16) The qualification of SSCs covered by the equipment qualification (EQ) programme has been satisfactorily established and preserved (the effectiveness of the EQ programme should be reviewed if it is credited in the AMP):

— The list of equipment covered by the EQ programme and a procedure that controls any changes to the list are available.
— Qualification reports and other supporting documents (e.g. EQ specifications and a qualification plan) are available.
— Verification is provided that the installed equipment is qualified according to specification.
— Procedures are provided and mechanisms are in place to preserve qualification during the equipment's installed life.
— Effect of equipment failures on EQ is analysed and appropriate corrective actions are taken.
— Records of all qualification measures are kept in a form suitable for auditing.

(17) Relevant plant safety indicators, such as maintenance preventable failures or safety system unavailability, have been satisfactory.

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