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MAINTENANCE RELATED TO LIFE MANAGEMENT: SURVEY AND CONTROL OF EQUIPMENT AGEING

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Abstract

The aim of this paper is to review relevant objectives and aspects of the Maintenance Evaluation and Improvement Programmes for Nuclear Power Plant Life Management.

Recent experience shows that current maintenance practice often fails to directly address long-term degradation that affects singular plant components and equipment populations. Instead, delayed attention to the consequences makes good Life Management unfeasible. This has brought about the need for specific Maintenance Evaluation and Improvement Programmes to adjust to the basic objective of Life Management which is to protect against, mitigate and/or monitor ageing that affects the safe, profitable life of the facility.

The paper analyses the methodologies used, incidents during their application and the main conclusions reached from the implementation of these programmes in Spanish nuclear power plants. Special attention is paid to recommended solutions for improving the efficiency of the utility's contributions, its leadership in task development and integration, and its interfaces with organisations specialised in providing services that support Life Management Programmes.

The coexistence of these and other similar maintenance programmes make it necessary to integrate tasks to optimise effort and tools. The paper analyses the guidelines to be considered when integrating these Programmes with other maintenance optimisation programmes (economy and feasibility, RCM) and with tasks derived from the application of Maintenance Rule regulatory requirements.

Lastly, the paper reports on the state of these Maintenance Evaluation and Improvement Programmes, their development, what prospects they have, and the Industry's initiative and actions concerning the matter.

1. INTRODUCTION

Around the world, power station owners are increasingly concerned to optimise Plant Life Management. In response, they are setting up Life Management programmes, of more or less ambitious scope and depth.

Strategic, economic and security concerns and the close link between life extension work and the improved maintenance practices that are so important today, will increase and globalise these programmes for monitoring and conservation or mitigation of ageing.

These programmes are all based on knowledge of the precise condition of all components and populations with the greatest effect on the economics and safety of the plant, and trends in changes in their condition.

The technical support for these programmes is:

- Methodologies and knowledge required to identify degradation mechanisms as a function of the characteristics of the components or populations, and service conditions
- Techniques for determining condition and trends over time
- Analysis of the efficiency of maintenance practices based on the above knowledge, techniques and methodologies
- Improvement of maintenance practices for adequate mitigation and monitoring of ageing
- Techniques and tools for collecting and ordering data about ageing and for condition assessment

The following sections describe the structure and content of these programmes, with special emphasis on engineering tasks that support them.

2. BASIC OBJECTIVES AND STRUCTURE OF REMANENT LIFE MANAGEMENT PROGRAMMES (RLMP)

2.1 OBJECTIVES OF AN RLMP

The basic objectives of an RLMP translate into information about the condition of the installation and forecasting of its possible change over time. This knowledge enables the selection of adequate measures for monitoring, conservation, mitigation, repair, replacement or modification of the installation and the process, compatible with the owner company's strategy and a cost-benefit ratio favourable for the installation.

An RLMP is a continuously repeating cycle of evaluating condition and taking corrective and/or monitoring measures.

The frequency of evaluation of condition varies with each plant, component or population. It can range from continuous monitoring of components used in very harsh conditions, those that may present unpredictable change and/or those with more weight in management, through to re-evaluation over extended periods for components and populations in which degradation is slower or better understood.

2.2 STRUCTURE OF AN RLMP

On the basis of the objectives described, RLMPs are structured as shown in Figure 1. The activities that support these programmes are:

- Selection of important components and populations, according to economic and safety indicators, and the establishment of priorities for the RLMP on the basis of a rigorous and formal application of the methodologies based on weighted criteria

- Analysis, during the initial evaluation, of the characteristics of the components and their service conditions to identify potential ageing. These are complemented with study of history of incidents during operation and maintenance, and with the definition and execution, where appropriate, of additional tests and/or inspections. Periodic re-evaluations are fed back to the same sources, where they are added to the data from monitoring of ageing trends

- Evaluation and optimisation of maintenance and monitoring practices, to mitigate or survey the effects of ageing

- Analysis, selection and implementation of remanent life management measures, decided on the basis of the tasks described above. These measures are assigned to the following different areas:

    - Repair, replacement and modification in component populations especially affected

    - Modifications to operating procedures to reduce harshness where appropriate

    - Modifications to maintenance practices, to make them more effective for mitigating the effects of ageing

    - Implementation of additional monitoring necessary to obtain a more accurate picture of change in degradation mechanisms of most severe ageing effects or where uncertainty of evaluation is greatest

3. DESCRIPTION OF ENGINEERING TASKS FOR RLMP

All stages of the activities involved in an RLMP require heavy support from specialised engineers. The prediction of potential ageing and evaluation of the degree to which this affects the different components, and especially, the monitoring of change in their condition and/or prediction of the change, as well as the definition of corrective or monitoring measures, require massive specialised engineering support in these fields.

There follows a brief description of the main tasks and methodologies required for an RLMP.

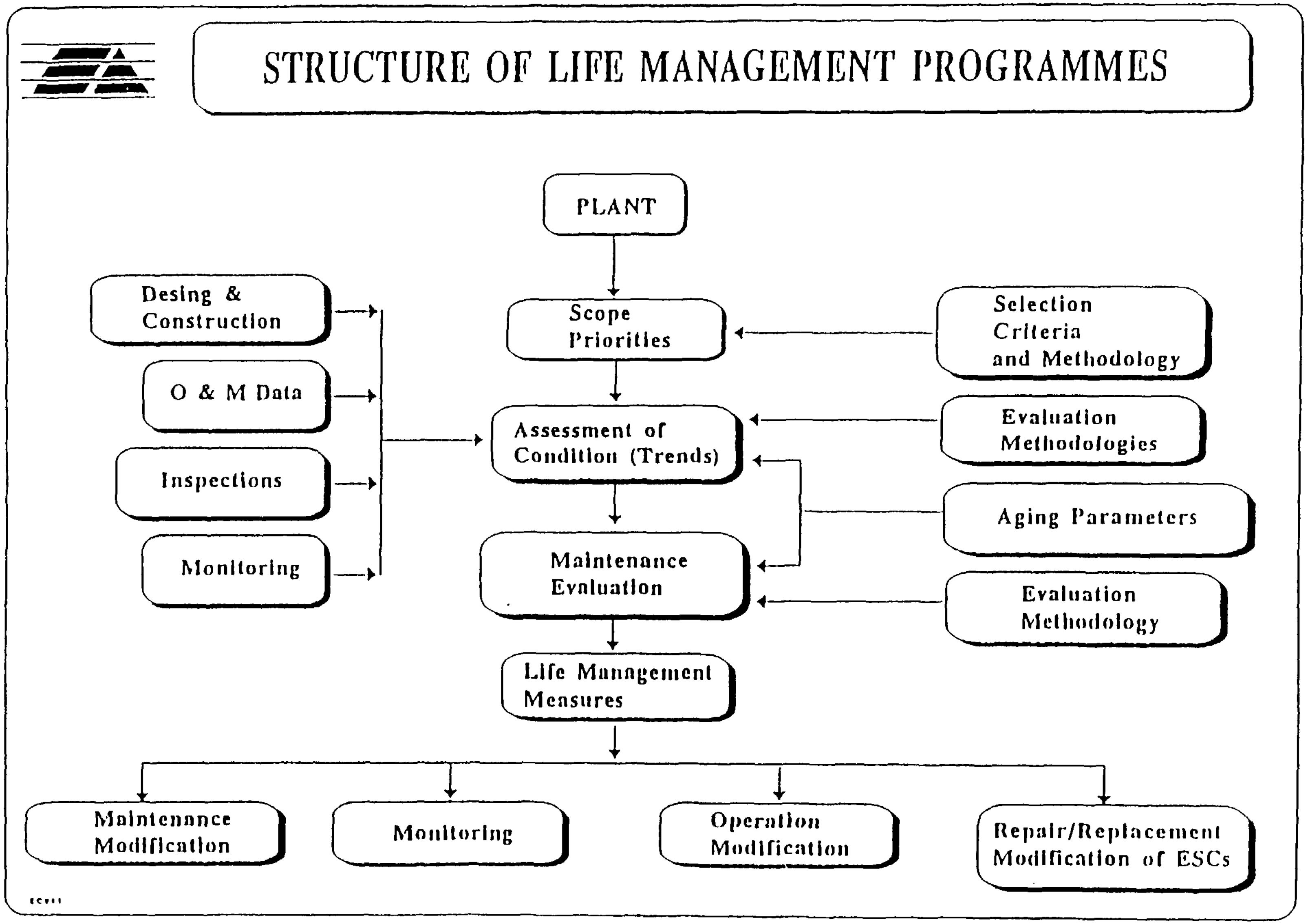
STRUCTURE OF LIFE MANAGEMENT PROGRAMMES
PLANT
Desing & Construction
O & M Data
Inspections
Monitoring
Scope Priorities
Assessment of Condition (Trends)
Maintenance Evaluation
Life Management Measures
Selection Criteria and Methodology
Evaluation Methodologies
Aging Parameters
Evaluation Methodology
Maintenance Modification
Monitoring
Operation Modification
Repair/Replacement Modification of ESCs

Figure 1

3.1 SELECTION AND PRIORITISATION OF COMPONENTS WITHIN THE RLMP STRATEGY

The first requirement for adequate plant life management is to avoid dispersion and waste of the RLMP resources. These resources are always limited, and should not cover the whole population, indiscriminately. Prioritisation is necessary and needs to be slightly adjusted periodically, to adapt to the margin of uncertainty of all predictions. This prioritisation uses a weighted criteria methodology.

The strategy of each plant affects the methodology through adjustments in the plant-unique weighting of each of the criteria.

The filter criteria for the selection of components are grouped in three types:

- Safety criteria
- Availability criteria
- Replacement and cost criteria

Compliance with any of the criteria above means that the component is important for remanent life management. The criteria of the Weighting Methodology, are grouped to apply them in a more homogenous way.

Each of the criteria are assigned their own waiting factor. The plant should participate with the engineering panel in the definition of some of the factors as far as these factors are a reflection of its operating strategy.

The conclusion of this process is a prioritised list of components, which is used as the subject of the RLMP.

3.2 IDENTIFICATION OF DEGRADATION AND EVALUATION OF CONDITION

This task consists of clearly differentiated stages. The RLMP begins with an initial condition evaluation, which serves as the basis for establishing the main corrective and monitoring actions, and for preparing the first cost/benefit analyses for Life Management. The RLMP continues to progress with periodic re-evaluation of condition to confirm the corrective measures are the right ones and to adopt new measures, if necessary, as a result of the monitoring established.

Appendix A provides additional information regarding the ageing processes affecting main components and component groups in nuclear power plants.

The initial evaluation begins with a determination of potential degradation mechanisms and of the level of harshness of these on the selected components. This requires a study of the characteristics of the components relative to their design, materials, manufacture, process and service conditions.

This analysis is complemented by a rigorous study of the history of the operation and maintenance, and the results of diagnosis and monitoring, to detect incidents that might have affected the condition of the plant, or for evidence of degradations. Uncertainty about the severity of some of these ageing effects may require extra inspections or tests, to provide more precise data.

Condition evaluation requires collection and ordering of the documentation and records of manufacturer, operation and maintenance that contain information needed for the analysis. This collection requires application of procedures that establish the data and records, with the periodicity of their acquisition clearly identified for successive re-evaluations, and the screening requirements for easier collection and analysis. In this area, the Events Log is of special interest. It organises the selected records of Plant Events that have a significant effect on component life and that are being used, both for the initial evaluation and for periodic re-evaluations.

The periodicity of successive re-evaluations varies for each plant, component and population, depending on age, management strategy and the severity of the ageing. The purpose of re-evaluation is to confirm or modify the corrective action taken on the basis of monitoring of the ageing. The benefit of an RLMP is based on the precision of the determination of the condition and especially its trend, to make possible the calculation of residual life required to support any management decisions.

For this purpose, a programme is established for monitoring parameters that represent the progress of ageing. This together with the results of the inspections, testing and maintenance work at the plant constitute the raw material of the residual life analysis.

The need for this monitoring and the prediction tools described, have led to development work, which in the case of Spain, are referenced to the Project for Development of a Remanent Life System for Nuclear Power Plants[1] (SEVR) that arose from a life extension management initiative by UNESA and owners' groups. The project has completed functional specification and architecture of the system, and is ready to begin developing the Pilot application.

Chapter 4 describes in more detail, the engineering tasks involved in the installation and use of specific monitoring and global systems as described above.

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[1] *Proyecto de Desarrollo de un Sistema de Gestión de Vida Remanente de Centrales Nucleares*

3.3 MAINTENANCE PRACTICES EVALUATION TO OPTIMISE RLMPs

In addition to the improvements in operation and service conditions, a substantial part of the causes and effects of ageing mechanisms have to be mitigated by maintenance work. The nature of these long-term ageing mechanisms has meant that, in certain cases, current maintenance practices do not prevent them. This requires these practices to be evaluated and modified where necessary to improve their efficiency in conservation and the mitigation of degradation.

Appendix B describes the methodology for maintenance evaluation and provides details regarding the lessons learned during its application in the two pilot plants.

The engineering activities followed in the evaluation process are:

1) DEFINITION OF SCOPE OF EVALUATION OF MAINTENANCE

The tasks described above produce the component-degradation mechanism pairs that it is considered necessary to evaluate.

2) PRODUCTION OF COMPONENT DEGRADATION SHEETS (CDS)

A component degradation sheet (CDS) is completed for each component selected.

The data to be filled out on the CDSs are: component description; functions; design parameters; operating experience; degradation mechanisms; and the part of the component affected by ageing.

3) PREPARATION OF MAINTENANCE PRACTICES DATA SHEETS

For each of the programmes, practices and procedures that affect each component/degradation mechanism pair, a data sheet is prepared, showing the following information about the practice: limitations on performing it, time when corrective action is taken, the data necessary, action to be taken to mitigate, detect and monitor the degradation and finally comments and experience resulting from the practice application.

The purpose of this task is to take and inventory of all practices current at the Plant and to discover details of the application, to exploit them and improve their efficiency for life extension.

4) EVALUATION

Each Component Data Sheet is attached to all the Maintenance Practice Data Sheets that affect the component. With the information from both sources, the Maintenance Evaluation Checklist is completed.

The evaluation shows the possible deficiencies in control of ageing of the maintenance of each component. When necessary, improvements to maintenance are proposed, documenting the details of the improvements using the tool developed for that purpose, the Maintenance Evaluation Proposed Improvement.

3.4 ANALYSIS, SELECTION AND APPLICATION OF MEASURES FOR IMPROVEMENT OF LIFE MANAGEMENT

The tasks described above provide information about ageing and trends, and the degree of uncertainty in their evaluation, and also a determination of the efficiency of maintenance practices and their shortcomings. On the basis of this, it is possible to decide on the life extension measures to be applied. These measures fall into the following categories:

- Repairs, replacements or modifications and most efficient programming, of the components most severely effected and/or for which the improvement in availability or performance justifies the investment. It is important to remember that Remanent Life is only considered as such if it is safe (reliable) and economically viable

- Modifications to operating procedures and/or in service conditions to make them less harsh

- Improvements to Maintenance Practices, to achieve full efficiency, for safe and economically viable life extension

- Implementation of additional monitoring with some of the following criteria:

  - Improve precision of condition evaluation and trends, for those component/degradation mechanism pairs for which forecasting is more uncertain

  - Allow for continuous condition monitoring, or at least to reduce the effort required for collection and analysis of the information required during re-evaluation

  This improves the flexibility and solvency of life management decisions

  The type of monitoring and the parameter to represent ageing should be selected with realistic criteria of accessibility and efficiency

4. REMANENT LIFE EVALUATION SYSTEMS. ENGINEERING TASKS FOR ADAPTATION AND USE

As described in Section 3, the need for an increasingly precise and up to date understanding of the condition of the components and the evaluation of their state over time for good Life Management, has created a need for tools and methodologies. This situation has led to development of specialised systems for monitoring of certain types of ageing (fatigue, erosion-corrosion, stress corrosion cracking, vibration, degradation of electrical insulation, electrical machines, etc.) and more ambitious general systems, such as the SEVR developed in Spain by UNESA and that concerns the acquisition, storage and processing of data for significant parameters and evaluates the conditions and trends in conditions over time of the main single components and component populations.

The application and use of this type of system requires a substantial amount of engineering, which translates into tasks such as those described below:

- Definition of the scope of application suited to management of the plant and its configuration and characteristics. This task includes, as described above, prior evaluation of significant ageing and the components affected, and analysis of the effectiveness of maintenance practices to mitigate them

- Analysis of information generated by operation and maintenance, that may be used by the Remanent Life Evaluation System and communication lines, acquisition modes and interfaces

- Analysis of available signals that are useful to the Remanent Life Evaluation System, data lines and process and pre-processing requirements

- Analysis of specialised monitoring and diagnosis systems, available at the Plant and communications lines and interfaces with the Remanent Life Evaluation System

- Definition, location and characteristics of new monitoring sensors, signal pre-processing and data acquisition processing

- Adaptation of Remanent Life Evaluation System to specification of each plant (communications, acquisition, storage and processing of data, algorithms for evaluation of conditions and trends, incorporating coefficients and factors specific to each component, definition of admissible limits for ageing-significant parameters, etc.)

The nature of these engineering tasks makes it essential that the system be adapted and installed by persons or organisations that are experts in ageing of installations and monitoring and diagnosis tools.

Appendix A

AGEING OF MAIN COMPONENTS IN NUCLEAR POWER PLANTS

A1 INTRODUCTION

The tasks of surveillance, evaluation and control of ageing, and the research efforts of the majority of countries have provided several valuable lessons to be taken into account in Plant Life Management Programmes.

Plant Life Management Programmes carried out by Electric Utility Owners in practically all countries —and pressure from regulatory bodies to monitor the ageing of NPPs and its resulting potential impact on their safety— have resulted in a profound knowledge of critical degradations and represented an economic and technical effort from which future power plants should benefit.

This paper examines serious degradations that affect main, single components and component populations.

A1.1 Ageing of Main Components in NPPs

NPP systems, components and structures undergo degradations of different types even before they are installed. Some of the degradations affecting main components or groups of components in varying degrees are listed below:

- Fatigue
- Stress Corrosion Cracking (SCC)
- Corrosion
  - General corrosion
  - Local corrosion
  - Microbiologically influenced corrosion (MSC)
- Erosion and Erosion/Corrosion (E/C)
- Creep
- Wear
- Stress relaxation
- Embrittlement
  - Thermal
  - Strain age
  - Neutron
- Fouling
- Cracking/spalling
- Electronic drift
- Vibration of electronics
- Electrical component design factors
- Thermal/irradiation ageing of nonmetallic materials

Obviously the effects of these vary from component to component, depending on the variables of design, materials, manufacture, process, fluid chemistry, environment, stresses associated with operating modes, maintenance, etc.

A few of the more severe degradations affecting some of the most significant components or structures are listed below.

Main Degradations in Materials Used in the Reactor Coolant System and Related Systems

- Wrought Austenitic Stainless Steels

  Main Problems: Sensitisation and cold work from forming and bending make the material susceptible to IGSCC and IASCC

  Solutions: Use materials resistant to sensitisation (low-carbon types such as 304L, 316L, 304NG, 316NG and modified 347). Materials in the solution heat-treated condition (≈ 2000°F) and grinding and cold work control

  Ensure average ferrite content in the welding materials in the range of 5 to 13 FN (Ferrite Number)

  For welded designs of internals, crevices, fillet welds and dissimilar metal welds should be avoided

  Prevent corrosive environments by limiting halogens to < 5 ppm and O_2 < 10 ppb

  Reduce neutron fluence for vessel and internals ($<10^{20}$ MeVn/cm^2)

- Martensitic Stainless Steels

  Main Problems: These materials are used chiefly in pumps and valve components and are susceptible to SCC

  Solutions: Control the heat treatment (normalised and tempered) to limit hardness

- Ni, Cr, Fe Alloys

  Main Problems: These materials, used in specific applications due to their strength and low thermal expansion characteristics, present SCC (Alloy 600 and Alloy X-750 because of improper heat treatment) at temperatures greater than 600°F

  Solutions: Reduce the neutron fluence ($<10^{20}$ MeVn/cm^2) to avoid IASCC

Use Alloy 690, but only for specific components (till proven by experience)

Carry out special treatment (1300°F, 12-20 hours) to improve resistance to SCC

Restrict the use of Alloy X-750 with tough material specification

- Austenitic Stainless Steel Castings

Main Problems: Embrittlement after long periods of exposure to high temperature (>600°F), due to the transformation of delta ferrite to a sigma phase. Molybdenum contributes to degradation

Solutions: Solution heat treatment (>2000°F), use of centrifugal casts, ferrite control ($5 > FN < 14$) and molybdenum control

- Carbon and Low Allow Steel

Main Problems: Corrosion, erosion/corrosion, pitting and crevice corrosion, and environmentally-assisted fatigue

Solutions: Use austenitic stainless steel cladding for PWR vessels, BWR vessels with hydrogen water chemistry and piping in contact with the reactor coolant

For BWR vessels without H_2 chemistry and the remaining components, establish corrosion allowances on the basis of experience in the industry and a plant life of 60 years. Limit the sulphur content to obtain a high resistance to environmentally-assisted fatigue crack growth

The use of 1% Cr alloys or, wherever possible, piping designed for low fluid velocities (< 5 ft/sec) will reduce the erosion-corrosion rates

Single Components. Specific Problems

- Reactor Pressure Vessel. Fast Neutron Embrittlement

Experience shows that changes occur in the ductility properties of the RPV material due to the effect of fast neutron exposure. Decreased notch-ductility is a function of neutron dose, irradiation temperature and content of copper, phosphorous, vanadium and nickel in the welding materials used for joining the ferritic base materials of the RPV. The parameter used to express ductility reduction is the reference nil ductility transition temperature (RT_{NDT}) and is used to define pressure and temperature transients and limits during heatup, cooldown and pressure tests.

The design and manufacture of new RPVs should diminish the effect of embrittlement in zones directly surrounding the active core which are exposed to the highest neutron radiation.

To reduce this degradation, penetrations and nozzles should be avoided in the beltline region and, in general, it is advisable to decrease the number of welds in these zones, use base and welding materials with a low content of copper, phosphorous, vanadium and nickel, and reduce the levels of neutron flux affecting the shell.

The current reactor vessel material surveillance programme based on test data should be maintained for the new RPV even though the RT_{NDT} shift predicted on the above basis is conservative.

Fatigue Failures in LWR Components

Field failures have identified several sites susceptible to damage from fatigue which were not considered vulnerable to fatigue in the original design.

Failures of components on which fatigue analyses were performed have resulted from stressors which were not accounted for in the design analysis. These stressors include low- and high-cycle fatigue due to thermal stratification, high-cycle thermal fatigue from thermal stripping and thermal mixing, mechanical fatigue from flow-induced vibrations and low-cycle environmentally-assisted fatigue (Tables 1 and 2 show examples of fatigue failure areas in LWR components).

Table 1 Areas of Fatigue Failures in BWR Plants

Location	Mechanical Stress[2]		Thermal Stress	
	High-Cycle	Low-Cycle	High-Cycle	Low-Cycle
Reactor vessel				
Feedwater nozzle			x	x
CRDRL nozzle			x	x
Reactor internals				
Feedwater sparger	x			
Jet pump	x			
Steam dryer	x			
Recirculation system				
Pump internal welds	x			
Thermowell	x			
Small piping				
Branch connections	x			
Instrumentation lines	x			
Control rod drive system				
Insert/withdraw lines	x			

2 Not including pressure stress

Table 2 Areas of Fatigue Failures in PWR Plants				
Location	**Mechanical Stress**[3]		**Thermal Stress**	
	High-Cycle	**Low-Cycle**	**High-Cycle**	**Low-Cycle**
Steam generator				
Feedwater nozzle area			x	x
Girth weld area				x
Tubes	x[4]			
Pressuriser				
Lower head				x
Diaphragm welds (B&W)				x
Reactor internals				
Flux thimble tubes	x			
Bolts	x			
Holddown ring	x			
Core barrel	x			
In-core instruments	x			
CRDM penetrations in RPV head			x	x
Reactor coolant pump				
Shaft	x			
Piping				
Thermal sleeves	x			
ECCS and RHR piping			x	x
Feedwater piping			x	x
Surge line			x	x
Small piping				
Branch connections	x			
Instrumentation lines	x			

Steam Generators

The main degradations affecting these components are:

- IGSCC affecting the inner surface (PWSCC) of U-bends and roll-transition zones, and the outer surface of hot-leg tubes in the tube-to-tube sheet crevice zone
- Pitting in cold-leg tubes where scale contains copper deposits
- Wastage on the outer surface of the tubing above the tube sheet
- Denting affecting the tubes in the tube-support zones

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3 Not including pressure stress

4 Environmentally-assisted fatigue caused stress concentrations for crack initiation in once-through steam generators, and anti-vibration bar problems caused failures in recirculation steam generators

- Fretting due to flow-induced vibrations which affect contact points between the tube and the antivibration bar

The solutions for limiting stressors are put into practice by one or several of the following lines of action:

- Use of heat-treated Alloy 690 for tubing material to provide more resistance to SCC in an alkaline environment

- Use of tube support plates manufactured from chromium ferritic stainless steel and new designs with broached holes which direct the flow along the tubes reducing dryout in the crevices

- Inclusion of blowdown arrangement and support plate geometry to improve flow distribution above the tubesheet, and to minimise potential local concentrations of impurities (in the tube-to-tubesheet intersection zones)

- Tube expansion procedures which eliminate the tube-to-tubesheet crevice

- Strict control of water chemistry on the secondary side and use of titanium condenser tube material

Emergency Diesel-Generators

The analysis of EDG failures shows that more than 50% of them may be attributed to ageing.

Some of these ageing mechanisms are:

- Vibration
- Thermal and mechanical shocks and excessive operating loads
- Corrosion
- I&C set points drift
- Chemical attack from fuel and lube oils
- Environmental conditions and fouling
- Microbiologically influenced corrosion

The solution to such ageing lies in implementing certain improvements in the equipment, and a degradation detection and mitigation programme right from commencement of operation.

Improvements could include the incorporation of prelubrication and preheating of the diesel.

The degradation detection and mitigation programme should include:

- Plant Maintenance oriented to preventive maintenance based on trending of significant parameters, rather than overhauls on a strictly periodic basis
- Testing procedures which exclude harmful practices. The test programme should include prelubrication, slow loading, longer run times, and post-test gradual load reduction and cooldown
- Vibration monitoring/signature analysis
- Lube-oil analysis and ferrography to detect metal wear
- Specific governor maintenance based on the manufacturer's recommendations
- MIC control programme

Instrumentation and Control Equipment

The following are degradation mechanisms that affect I&C subcomponents:

- Corrosion (diaphragms, bellows, bourdon tubes, electronics, switches, linkages) (Note: corrosion also includes IGSCC, MIC)
- Thermal ageing (solenoid valve operators, high temperatures in the process and in the environment)
- Fatigue (diaphragms, bourdon tubes, bellows, linkages)
- Wear (elastomer seats, linkage mechanisms, switches)
- Electronic drift (circuits)
- Vibration (design and installation practices)
- Radiation (nonmetallics, O-rings, seals, insulation)
- Setpoint drift (mechanical/electrical interaction)

The significance of any of these degradation mechanisms to the safety functions is limited by the programmes used to detect and mitigate such degradation. Plants should therefore establish programmes of such frequency and attributes as to ensure early, adequate identification and mitigation of any ageing parts and their replacement (by plugging technology).

Typical attributes of these programmes include calibration, functional testing, visual and thermographic inspections, and operator logs and checklists.

Electrical Equipment

The potentially significant ageing degradation mechanisms for these components are:

- Corrosion of buses, transformers, contacts, operating mechanisms, electronics, relays, switches, cables, motor bearings, connectors, batteries, battery chargers and panel components

- Fatigue (including vibration) in connectors, contacts, operating mechanisms, relays, circuit breakers, cables, motor bearings, battery grids and case, chargers and inverters

- Wear of contacts, operating mechanisms, relays, circuit breakers and motor bearings

- Electronic drift in electronic components and devices, relays, inverters, chargers and panels

- Design factors in contacts, arc chutes, operating mechanisms and circuit breakers

- Fouling of motor winding insulation and bus insulators

- Loss of mechanical and electrical properties (e.g., insulation resistance power factor or loss factor) in cable jackets and insulation due to radiation and thermal effects and dependent upon the materials used in the cable

It may generally be said that degradation associated with electrical equipment can be detected and mitigated by means of adequate plant maintenance and testing activities based on vendor recommendations and plant/industry operating experience. Special attention should, however, be paid to cables since their replacement is complicated and requires extensive outage time.

A2 MAINTENANCE FOR AGEING MANAGEMENT

An Effective Maintenance Programme is the cornerstone of the Ageing Management Programmes which they are designed to support.

A programme or combination of programmes meeting the following criteria is considered to be effective for detecting and mitigating ageing, and for monitoring performance throughout plant life:

1. The programme and implementation procedures ensure that component functions are properly addressed, considering the effects of age-related degradation and performance criteria

2. The programme and implementation procedures are kept up to date with expected significant changes and/or tendencies in ageing processes

3. The programme establishes specific acceptance criteria to determine the need for corrective actions

4. The programme provides for adequate monitoring of process and physical parameters used in performance evaluations

These Maintenance and Ageing Control Programmes are based on the timely definition or identification of any significant ageing, its evolution, causes, location and representative parameters and its permanent comparison with maintenance practices, monitoring, testing, inspection, housekeeping, etc. Assessments are carried out on such specific attributes of these practices as adequacy, frequency, action levels, acceptance criteria, corrective measures, documentation requirements, etc.

Appendix B

MAINTENANCE RELATED TO LIFE MANAGEMENT

B1 MAINTENANCE ENGINEERING OF LIFE MANAGEMENT PROGRAMMES

B1.1 Introduction

An adequate plant Life Management requires the establishment of maintenance aimed at identification, monitoring and control of the ageing processes that affect plants. The characteristics of single equipment items and component populations in NPPs and the severity and peculiarity of their service conditions have produced specific forms of degradation which are not always covered by current Maintenance practices which tackle, solely and belatedly, the consequences of these ageing processes.

This has led to the need to assess maintenance practices and adapt them to the basic objective of Life Management which is conservation, mitigation and/or monitoring of ageing processes that affects plant safety and profitability.

New regulatory requirements, regarding monitoring of ageing processes and ensuring efficient maintenance as a safety guarantee (Maintenance Rule), have reinforced the need for Maintenance Evaluation to optimise resources and tools.

Maintenance Evaluation and Optimisation activities aimed at efficient Life Management and their integration into those associated with the aforementioned regulatory requirements are essential for plant operation safety and profitability.

The following is a summary of the methodologies and contents of NPP maintenance evaluation and improvement based on their application to Garoña and Vandellós II NPPs as part of the UNESA Project for the development of a NPP Residual Life Evaluation System.

B1.2 Objectives of Maintenance Evaluation and Improvement Programmes for Life Management

Maintenance evaluation and improvement aimed at optimising Life Management is integrated in terms of scope, priorities and cost/profit balances into Life Management Programmes.

In other words, both the scope of the maintenance practice evaluation process and the objectives of this evaluation are focused on determining, for component populations important to Life Management, the efficiency of prevailing maintenance practices to prevent, mitigate and/or monitor ageing and correct its consequences, by providing resources for safe and profitable plant management.

The purpose of these programmes is to question existing practices regarding their efficiency in ensuring adequate reliability and immediate availability. The experience of Spanish NPPs in this respect confirms that these practices are efficient and there are optimisation programmes under way to reduce activities and their concentration on components with greater responsibility.

The evolution of degradation mechanisms is in most cases slow and easily detectable through normal inspection and monitoring. Lack of knowledge about these ageing processes and their evolution precludes the adoption of mitigation and/or monitoring measures and that is why it is necessary to assess these practices in order to adapt them to the objectives of the Life Management Programme.

The main objective of Maintenance Evaluation for Life Management, therefore, is to detect additional tasks or changes in the frequency or scope of some existing ones aimed at identifying and mitigating long-term degradations and their evolution, which are the vital variables to be considered in Management decisions. The basic contents of this main objective are summarised below.

- Identification of all degradation mechanisms that affect components or structures and cause failures or malfunctions. Knowing the cause allows adoption of more efficient, short- and long-term maintenance and/or operation measures saving labour and the cost of corrective actions or replacements

- Following up ageing processes using the parameters defined in the Maintenance Evaluation is a fundamental contribution to predictive Maintenance activities, with their attendant advantages

- The updated information on plant condition generated by Maintenance for Life Management, and more important still, trends in the development of this condition are essential for any operation strategy

- Maintenance improvement for life management constitutes the basis for compliance with regulatory requirements on the control of ageing and its impact on nuclear safety. It also contributes to keeping open the option of license renewal, even beyond design life

- The basic objective of maintenance evaluation and improvement for life management is to maintain safety in the facility throughout its life. This concurs with the philosophy of the Maintenance Rule (10 CFR 50.65), so that the improvement of maintenance practices must translate in the medium and long term in the upkeep of the good performance levels required by the Maintenance Rule

- This makes maximum use of the set of specific programmes established in the power plants while avoiding unnecessary or duplicated work through the knowledge of the internal causes of degradation. Hence the importance of integrating these programmes with maintenance optimisation ones based on statistical reliability levels

B2 METHODOLOGIES OF THE MAINTENANCE EVALUATION AND IMPROVEMENT PROGRAMMES FOR LIFE MANAGEMENT

These programmes have been applied in Spain at the nuclear power plants of Garoña and Vandellós II, in the framework of a project of the Spanish electric power sector aimed at developing a life evaluation system.

The evaluation methodology covers the activities indicated in Figure B1 and briefly described below:

a. Determination of the population covered by the evaluation, following selection criteria established in accordance with the life management strategy of each plant. The application of weighted criteria and of the Delphi methodology also allow the establishment of management priorities

b. Identification of the significant degradations to be evaluated. Said identification came as a result of the studies of degradations that could significantly affect, directly or indirectly, the population selected. In any event, this process was carried out through the condition evaluation tasks performed in the corresponding life management programme. From these sources is obtained the information contained in the Component Degradation Sheets, which provide the basic data regarding materials, design, construction, configuration, operation conditions, design and fabrication codes, degradation factors, affected subcomponents, operating history and relevant incidents. The Degradation Data Sheet must contain complete information on each component/degradation for the efficiency analysis of maintenance practices with respect to ageing control. The proper preparation of these data sheets was based on the participation of experts in the evaluation of ageing processes; they integrate all the information required to make them self-sufficient in the evaluation

c. Inventory of current maintenance practices in the power plant. The practices to be evaluated cover all testing and inspection tasks required in the technical specifications, the inspections imposed by applicable codes and standards, as well as preventive and predictive maintenance activities with their surveys. They also include all the tasks covered in the specific programmes (motor-operated valves, erosion/corrosion, SCC, electrical engines, calibrations, environmental qualification, leaks, vibrations, etc.) of each power plant

   An inventory of activities is established for each maintenance practice, and laid out in the corresponding Maintenance Instructions Sheet, indicating the subject, scope, acceptance criteria, collected data, frequency, as well as the events and incidents of interest that are related to the practice

MAINTENANCE ASSESSMENT — REMANENT LIFE MANAGEMENT

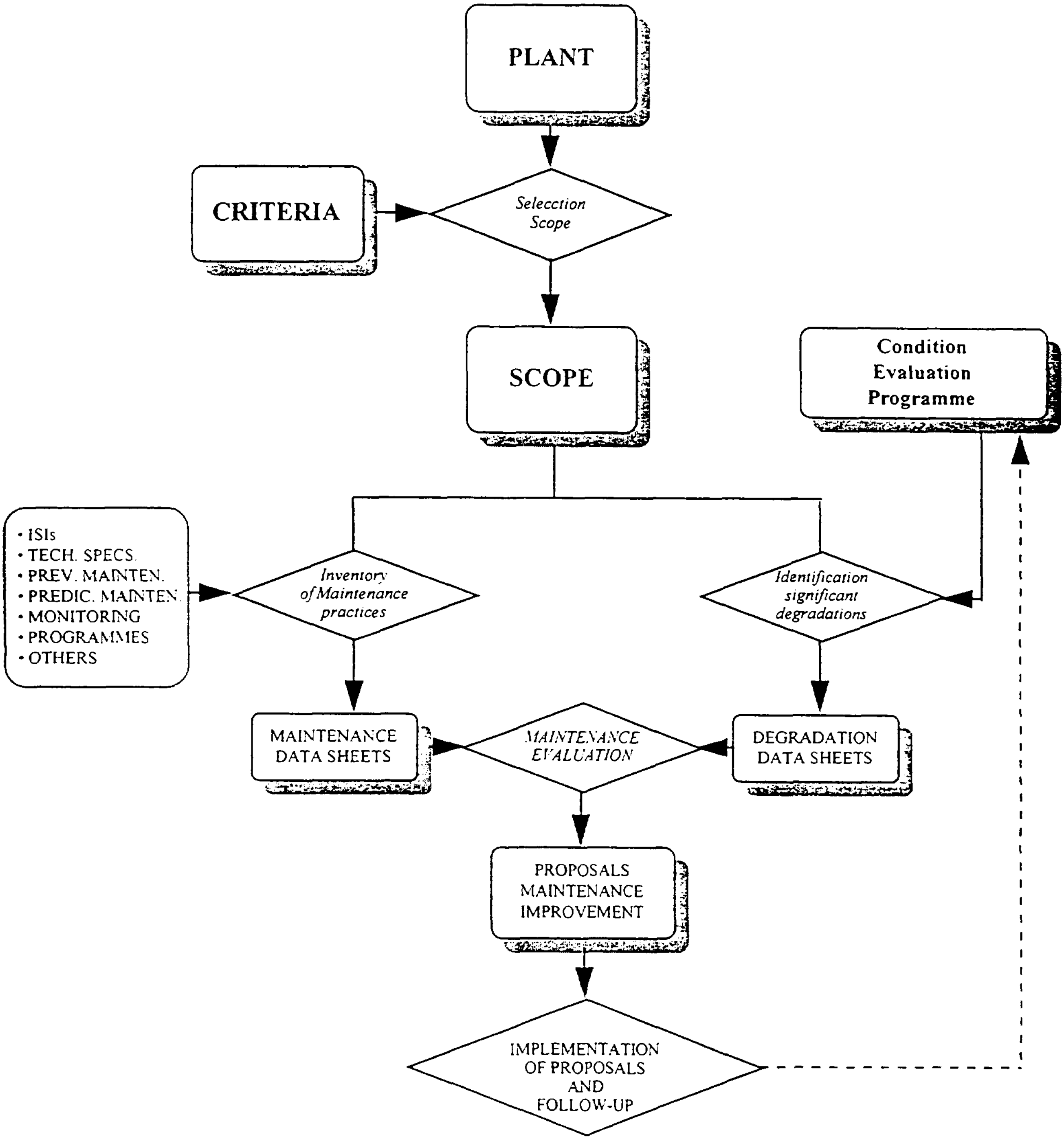

Figure B1

The participation in the inventory activities of personnel specialised in the different components and their degradation mechanisms led to orienting the consultations on site to gather information regarding each practice in a selective and efficient way, allowing the reduction of time required for the process and the improvement of inventory quality for the purpose of the evaluation

d. Evaluation. The methodology was complemented with relevant evaluation guides to determine in detail the weaknesses of each maintenance practice in some of the following areas:

- Appropriate scope and depth to detect the degradation
- Suitability of the frequencies and acceptance criteria
- Information generated sufficient for evaluation purposes
- Formal procedures and data

Experience Obtained

The performance of the aforementioned engineering tasks and their results have provided useful experience, whose main conclusions are laid out below:

- The availability of proven methodologies and the contribution of personnel with experience in the tasks described make it possible to improve the efficiency of current maintenance practices in order to optimise plant life management

- The cost of implementing the recommendations arising from the evaluation process is of little significance, and is always compensated by the benefits resulting from the safe and profitable management of the facilities

- There are obvious benefits in integrating these programmes with the maintenance rule implementation programmes or in their complementarity with other programmes such as maintenance optimisation

Here are some of the advantages of such an integration:

- The implementation of maintenance improvements to optimise life management should translate into improved performance of the maintenance rules in the medium and long term

- The condition monitoring imposed in the framework of life management is the valid performance parameter that can be used in the Maintenance Rule for structures, cables, active components in standby and passive components

- The justification of inherently reliable structures and components within the Maintenance Rule is supported by the follow-up on the condition of life management programmes

- The information generated in life management programmes regarding operation records, population statistics, trends in condition evolution, etc., are basic materials often shared with the Maintenance Rule. Hence the convenience of integrating the different information systems (databases, information supports and sources, and tools)

- These maintenance improvement programmes for life management go hand in hand with the optimisation programmes, as they are complementary in their objectives (short-term v medium- and long-term), in their scopes (mainly oriented to integrity in the one, and to operability in the other), in the identification of critical points (through evaluation of condition in the first, through statistics in the other), and in surveys (condition v performance)

  For these reasons, these programmes, far from being mutually exclusive, require on the contrary to be fully integrated

Just as the early implementation of a Life Management Programme is recommendable to reap the most benefits possible, so is maintenance evaluation to such an end, in order to ensure early knowledge of degradations and performance of conservation, mitigation and/or monitoring actions as soon as possible, which should contribute decisively to better life management.