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In 1990 he joined the Nuclear Directorate of UNESA (association of the Spanish electric utilities) in the radioctive waste management area, during three years. Since then he has been involved in the NPP's Operations Committe as responsible for activities on lifetime management, maintenance and equipment qualification/dedication, acting as technical secretary of several working groups.

ASPECTS OF LIFETIME MANAGEMENT IN SPANISH NUCLEAR POWER PLANTS

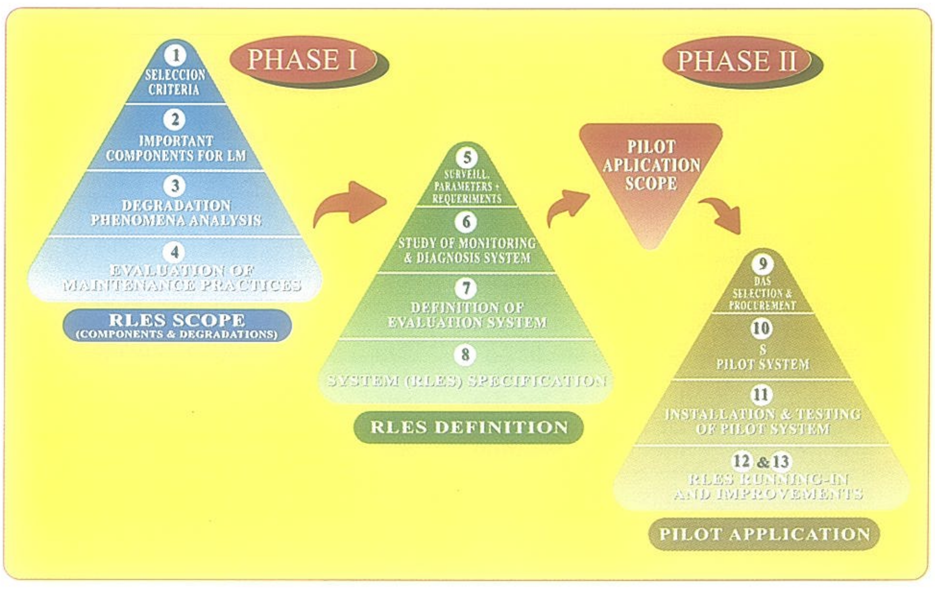
L. FRANCIA

INTRODUCTION

Traditionally, the aim of the operating and maintenance criteria adopted at nuclear power plants has been to ensure that these plants operate in accordance with the conditions for which they were designed, until the end of their scheduled lifetime, in other words to have their service lifetime coincide with their design lifetime.
Currently, and for reasons of economic and financial efficiency, conservation of the environment and the physical scarcity of new sites (site demand), the aforementioned criteria have given way to the criterion of improving the plant equipment, components and operating procedures, with a view to extending the technical lifetime of these installations under safe conditions beyond the period of time for which they were originally designed.
The strategic interest of the Spanish Electricity Sector in the development of Lifetime Extension and Management Plans for its installations, and the importance of the associated decisions making up these plans, require and demand permanent efforts aimed at providing tools and capabilities for increasingly accurate plant analysis, evaluation of conditions (remaining lifetime) and surveillance.
Although conditioned by aspects such as the following:

- licences, administrative permits and their renewal;

F I - *General RLES Project approach*



- the conditioning factors of economics and competitiveness in relation to other energy sources;
- growth in electricity demand;
- the generation of wastes, decommissioning policies and sites,

the option of Lifetime Extension is clearly present in the strategy of the sector and in the energy policy of the country (National Energy Plan - PEN).

An essential step to be taken prior to exercising the option of extending plant lifetime is the implementation of technologically well supported Lifetime Management Programmes which, in addition to serving as an essential platform enabling this option to be kept open, would also provide other, highly significant indirect benefits. Among those benefits worthy of special mention are optimization of the operation of the installations and a reduction in operating and maintenance (O&M) costs .

The Lifetime Management Programmes require the performance of multidisciplinary development projects and tasks. These programmes combine medium-term planning and continuous, on-going evaluation.

The current situation and age of Spain's nuclear power plants make it possible to address these programmes for the different plants in a gradual fashion. The current status of Lifetime Management activities at the Spanish NPP's may be summarized as follows:

• In addition to the habitual tasks of maintenance, component repair and/or replacement, the NPP's have programmes for the surveillance and mitigation of the more severe degradations, established to different degrees.

• Certain plants have Lifetime Management programmes of varying scope. With some exceptions, these programmes are not global in nature, but are limited to isolated tasks of documentary identification and compilation for the future analysis, surveillance and mitigation of severe ageing phenomena, this being more a part of the area of maintenance than of lifetime prediction and the adoption of the anticipatory measures associated with Lifetime Management Programmes.

• The recent regulatory proposal regarding Periodic Safety Reviews includes, within its scope, evaluation of the condition of safety systems and equipment and of the measures adopted for control of their ageing, along with the evolution and extrapolation in time of such measures.

Compliance with these requirements underlines the need for the establishment of Lifetime Management Programmes facilitating tracking of system and equipment conditions and validating the conservation measures adopted, this notwithstanding the Lifetime Extension strategy adopted by the NPP's and justified with respect to regulatory requirements.

• The need for the NPP's to have technological tools supporting present and future Lifetime Management initiatives has given rise to the "Nuclear Power Plant Remaining Lifetime Evaluation System" Project (RLES). This project, managed by Unidad Eléctrica, S.A. (UNESA) within the framework of the Electrotechnical Technology Research and Development Programme (PIE), is being undertaken by the Electricity Sector, and its first phase was completed at the beginning of 1995.

The RLES Project constitutes a fundamental point of reference which has made it possible to define common techniques and methodologies for gradual performance of the Lifetime Management Programmes by the different plants. This provides the Electricity Sector with a basic, powerful tool facilitating decision making and supporting the different NPP's Lifetime Management Programmes.

The objective pursued being to promote the technical and economic interest of Lifetime Management Programmes and facilitate the start-up and use of such programmes by all the NPP's, mention should be made of the fact that although the methodologies and technologies are in general common to all the plants, each must establish a Lifetime Management Programme suited to its operational strategy, age and technical characteristics and regulatory obligations, and provide support for it through customized prediction and tracking mechanisms.

In this respect it should be pointed out that the RLES tool is modular in design, this allowing it to be adapted in its scope and specific characteristics to the possible needs of each plant.

LIFETIME MANAGEMENT AND THE NATIONAL ENERGY POLICY

The National Energy Plan currently in force, for the period 1991-2000, contemplates plant lifetime extension as an alternative within Spanish energy policy with a view to ensuring adequate coverage of electricity demand in the near future.

In order to achieve the priority objective of maintaining the country's nuclear power plants in conditions guaranteeing the high levels of reliability and safety achieved to date, there is a need for continued NPP maintenance and lifetime extension activities, support services and management of human resources.

As regards the first of these aspects, it is necessary to continue the efforts made by the NPP owner companies in investments aimed at maintaining the plants in optimum conditions of safety and availability and at the implementation of whatever service lifetime extension programmes might be considered appropriate from the technical and economic point of view.

In relation to R&D in the nuclear field, the priority issue of *Nuclear Power Plant Materials and Operation* is considered to be a fundamental support as regards the operational availability of the plants and the extension of their service lifetime. The objectives of this issue are as follows:

- progressive enhancement of inspection and preventive maintenance techniques;
- the adoption of procedures for extension of plant lifetime;
- the selection of new materials;
- permanent updating of operations personnel training methods, and
- prevention of material degradation.

MOTIVATIONS FOR LIFETIME MANAGEMENT PROGRAMMES

Different feasibility studies and pilot projects have demonstrated that extending the service lifetime of nuclear power plants beyond their design lifetime (40 years) is technically feasible. The studies and reference projects undertaken to date conclude that there are no technical impedimenta to service lifetime being extended, and even up to 50 or 60 years. Nevertheless, technical feasibility will depend on the specific situation of each plant, its design, operating history, the conservation of its critical components, etc, among other things.

Furthermore, the application of a Lifetime Management Programme providing surveillance of the ageing of major components is:

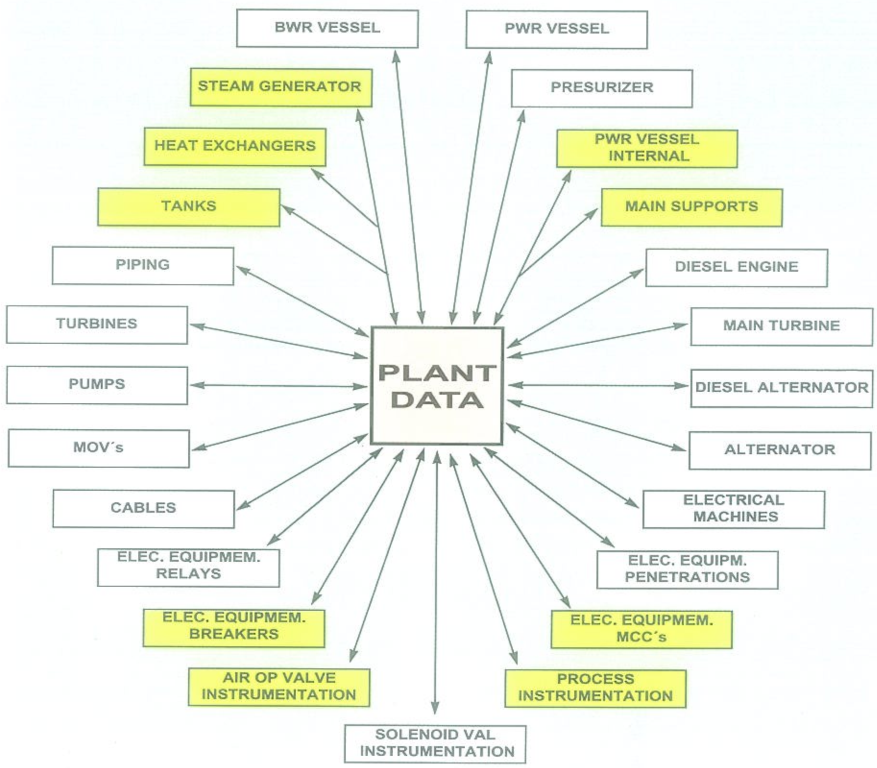
- economically compatible with the objective of immediate profitability;
- totally necessary for advantage to be taken of the economic benefit which operating the plant will imply after 25 years of operation; and
- convenient in order to improve the long-term reliability of the plants.

As regards the short-term benefits (immediate profitability), one of the conclusions from the analysis of the investments required for implementation of a Lifetime Management Programme is that these are compatible with the generation of competitive kilowatt-hours, since such programmes offer immediate improvements. These include a reduction in the unavailability factor and an increase in overall plant output, both of which lead to higher production figures.

The two greatest attractions of a Lifetime Management Programme are,

however, undoubtedly the following:
- The generation of cheap kilowatt-hours, especially after 25 years of operation (plant depreciation period).
- An increase in plant reliability and safety.

With respect to the economic advantage of plant operation following depreciation, the interest of this issue might be summarized by pointing out that the cost of electricity generation by nuclear means, taking into account the new investments required for the implementation of a Lifetime Management Plan, will be highly competitive in comparison to other energy sources (coal, gas), assuming these last plants to be depreciated also.
In relation to long-term plant reliability, it should be pointed out that Lifetime Management Programmes include surveillance of the ageing and degradation mechanisms affecting important safety-related components. Logically, therefore, the number of cases of malfunction and unavailability of such components should decrease, and plant reliability and safety should increase for the same reason.
From all viewpoints, therefore, extending the service lifetime of nuclear power plants will be a good decision, since under these conditions they will have little impact on system tariffs and may continue to provide an important part of electricity production under conditions of quality and safety. In other words, a cost/benefit analysis of this type of initiatives would provide clearly positive results.
By nature, Lifetime Management Plans attempt to gain insight into the long-term condition of the major plant equipment, identifying and planning activities relating to the inspection, documentation, evaluation and repair or replacement of these components. Quite obviously, the sooner an integrated, systematic programme of this type is implemented, the easier it will be to solve the problems of ageing of critical components and plan the necessary investments with sufficient time.



F II - *Modular diagram of RLES and modules considered*

ASSOCIATED TECHNOLOGICAL CHALLENGE

The lifetime extension programmes carried out in recent years have concluded that a limited number of components may present uncertainties in this area. In this respect, the new Lifetime Management Programmes concentrate on specific surveillance and inspection activities aimed at certain structures, systems and components, along with application of an adequate plant maintenance plan.
In keeping with the above, the Lifetime Management Programme should include basic aspects such as the following:

a) The evaluation of maintenance practices as regards their efficiency in relation to remaining lifetime management. In this context it should be taken into account that analysis of the cause of failures and long-term ageing phenomena are not always considered in current maintenance practices.

b) The surveillance of the condition of structures, systems and components. In this respect it is necessary to install monitoring systems and develop applied prediction techniques.

c) The establishment of a systematic approach for the analysis of the causes of system, component and structure failures.

Given the capabilities currently available or under development, there are areas which imply a technological challenge for the optimum implementation of plant lifetime management. The following may be singled out for special mention:

• In-depth study of certain degradation mechanisms, and in particular the evolution with time of representative parameters, with a view to increasing the accuracy of condition diagnosis and assessment. This effort would be supported basically by laboratory work oriented towards the characterization of defects, the variation of such defects during accelerated tests or the selection of materials providing better behaviour.

• Incorporation in condition diagnosis of new testing and inspection techniques improving knowledge of degradations and defects.

• The development and refinement of remaining lifetime prediction tools. This refinement would be based on better knowledge of the evolution of degradation variables and on the adaptation and integration of suitable techniques for the acquisition and processing of data relating to these variables.

• Enhancement or development of new computer codes and analytical methodologies (engineering and analysis) for in-depth, accurate investigation of data, parameters and values allowing conditions to be assessed better and more reliably.

• Selection and study of the behaviour of new materials or the regeneration of existing materials.

• Development of new designs and manufacturing techniques aimed at preventing or reducing ageing, to the extent possible.

• Development of lifetime management programmes facilitating and optimizing decision making in relation to the investments required (equipment replacement, refurbishments, new systems, operating changes, etc.), with consideration given to the profitability of the plant throughout its design lifetime and possible lifetime extension.

These programmes should consider questions relating to economic parameters (investments, interests, return, etc.), associated costs (for new investments and improvements) and risks and uncertainties, among other factors, linking these aspects to the technical information obtained from the condition evaluation programmes. In this respect, decisions regarding the refurbishment and replacement of a given component or system may be taken at the optimum moment, taking into account the depletion of service lifetime, recovery of the initial investment and delays in new investments.

NPP LIFETIME MANAGEMENT SYSTEM

As cuestioned before, the implementation in Spanish nuclear power plants of global ageing surveillance and control programmes providing support for the optimization of plant lifetime management is done through the RLES Project. The development tasks for this project were presented by UNESA during a meeting of experts promoted by the IAEA and held in Tokyo in November 1994, and also more recently during the international PLIM+PLEX'95 conference held in Nice (France) in November 1995.

The RLES Project is being performed with Spanish engineering firms and support from research centres, the Sta. Mª de Garoña (BWR, 460 MWe) and Vandellós II (PWR, 1004 MWe) NPP's acting as reference plants for its development.

The fundamental objectives of the Project have been as follows:

• Selection of major components for NPP Lifetime Management.

• Identification of the most significant ageing and degradation phenomena.

• Determination of the causes of such ageing phenomena and analysis of the conservation or mitigation methods associated with the operating and/or maintenance practices applied by the plants or proving to be the best suited.

• Identification of the most efficient and accessible parameters for the surveillance and assessment of ageing.

• Definition of a computer application facilitating management of information relating to surveillance parameters, by developing a modular acquisition and analysis system for data relating to such parameters.

The initial scope of the project has included practically all the systems, structures and components of the two reference plants, from the major components (reactor vessel, internals, steam generators, pressurizer, primary piping, containment, Diesel generators, turbine-generator set, etc.), some of which have been covered by other projects, to other items of equipment and families of components making a significant contribution to the safe and profitable operation of the plant (piping, valves, pumps, heat exchangers, electrical equipment, I&C equipment, civil works, etc.).

In keeping with its objectives, the RLES Project is structured in two phases (Fig. I), the first of which was completed at the beginning of 1995. This initial phase is aimed at defining the system with regard to its scope (components and degradation phenomena to be evaluated by the system) and computer application (functional and architectural specification), the objective of the second phase being development of a reduced-scope pilot application demonstrating the functionality and capacity of the system.

The aim of the definition of scopes that constituted the first phase was to identify which light water reactor (LWR) plant components and degradation phenomena were to be monitored by the RLES. With a view to selecting these components and phenomena, the definition of scopes was grouped into three activities.

The first action, based on a general selection methodology (Activity 1), consisted of drawing up lists of components of importance for Lifetime Management (Activity 2) for each plant model (BWR and PWR), based on the reference plants. The second step was to identify the degradation mechanisms affecting these components and to assess their potential and impact (Activity 3).

Activity 3, developed on the basis of assessment studies and dossiers, also included study of the analysis, control and mitigation methods for the identified degradation phenomena, this being an essential task for definition of the RLES in the second part of Phase 1. The components and degradation phenomena having been identified, it was necessary to avoid redundancy between RLES actions and the habitual maintenance activities of the plants with respect to control of ageing. Activity 4, Maintenance Practice Evaluation, was defined with this aim in mind.

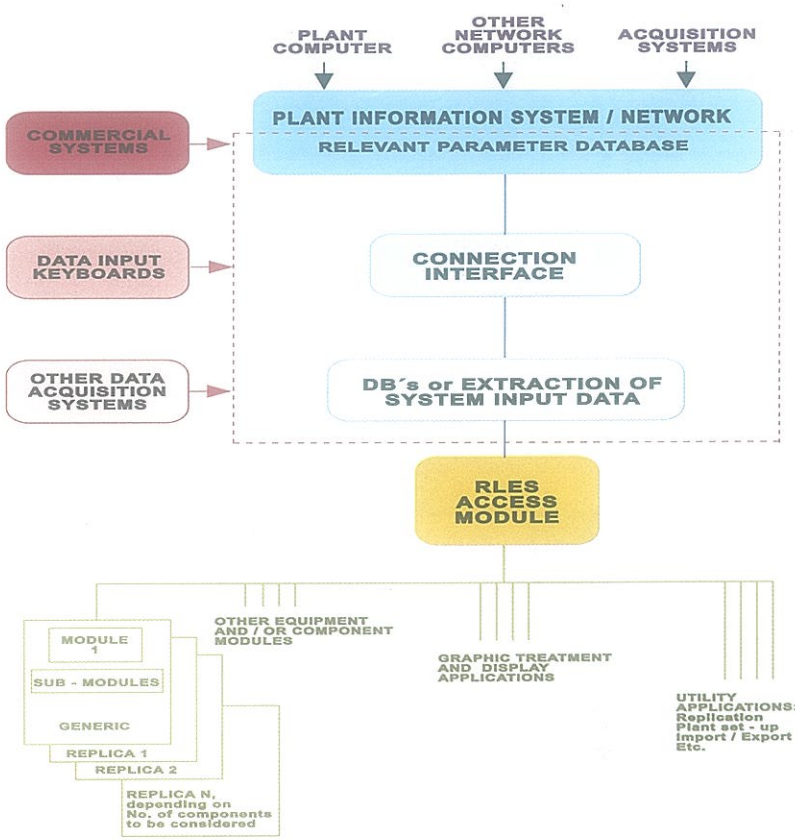
The final result of the scope definition process was a list of pairs of components and significant degradation phenomena (C/DP) for BWR and PWR plants, whose evolution would be tracked by the RLES, either individually or as a supplement to maintenance activities.

The components and degradation mechanisms and corresponding evaluation methods having been identified, definition of the RLES required as an initial step that the surveillance and monitoring parameters associated with the evaluation methods, and corresponding acquisition requirements, be accurately defined (Activity 5). Parallel to this activity an analysis was made of the technology currently available in relation to component diagnosis and surveillance systems and the feasibility of incorporating them into the RLES, thus avoiding the duplication of developments already finished or under way (Activity 6).

Once these activities had been completed, it was possible to go on to define the RLES computer application. It was decided that this should be a modular system, with each module corresponding to a standard component in accordance with the established scope (Fig. II), and it was designed in this way. The first step in defining the computer application was to translate the technical surveillance and monitoring requirements defined in Activity 5 into user requirements (documentation to be used by the programmers) and to establish generic hardware and software requirements for the system (Fig. III). On the basis of the above the RLES functional specification and architecture were developed, defining all complete or reduced system applications.

Phase 2 of the Project will consist of detailed development and implementation of a reduced scope RLES application at a demonstration plant. A fundamental stage in development of this prototype is definition of its scope since, although limited, it should serve to verify all the areas of RLES performance. Thus, the scope of the pilot application will centre on components and degradation mechanisms of special significance for the demonstration plant and on combinations of data acquisition configurations allowing the capabilities of the System to be demonstrated.

Once the scope has been established, the following stages will be, on the one hand, analysis of the data acquisition systems available at the demonstration plant and/or definition of new acquisitions and, on the other, detailed programming of the modules to be included in the pilot application. On completion of these activities the system will be installed and the corresponding test programme will be run. Given the characteristics of ageing management, it is necessary to establish a running-in period allowing the performance of the RLES to be evaluated and possible improvements to be defined.



F III - *Conceptual diagram of RLES*

INTERFACES BETWEEN LIFETIME MANAGEMENT AND THE REGULATORY FRAMEWORK

The concept of lifetime management runs parallel to plant operation and to the process of ageing, as a result of which it must be introduced via a systematic approach.

Although regulatory aspects may vary from one country to the next and formal definition of the lifetime established for a plant depends, among other things, on licensing processes (in certain countries nuclear power plants are granted licenses for a given operating period, while in others the validity of the license is unlimited, with safety revisions being applied at certain previously determined intervals), the milestone of lifetime extension should not be considered a "decisive moment" for a nuclear power plant but rather as the "continuation" of an adequate, solid process of operation and maintenance which began the very first day it entered into service.

In Spain, nuclear power plants operate with Operating Licences or Permits which are granted for start-up and periodically renewed (every two years). Throughout the period of validity of the permit the regulatory body (Nuclear Safety Council - CSN) continuously tracks modifications to the applicable nuclear standards, design modifications implemented, in-house and industry operating experience, etc., and the corresponding Probabilistic Safety Analyses (PSA's) carrying out by all plants in accordance with the "Integrated Programme for PSA Performance and Use in Spain", defined by the CSN.

In this context, the concept of *Lifetime Extension* is closely linked to that of *Lifetime Management*, inasmuch as attempts are made to gain insight at all times into the status of the plant and its components and their remaining lifetime, with operation and maintenance being managed in accordance with the results derived from these programmes.

The continuous process of safety assessment practised in Spain will be complemented in the future by the performance of Periodic Safety Reviews (PSR's). The recent extensions to the Operating Permits granted to the Spanish plants increase the period of validity to 4 or 5 years, and include the condition that a PSR be performed. The CSN has published a draft Safety Guide (GS-1.10) establishing the basic objectives, criteria and scope for PSR performance. For their part, the nuclear power plants, in contact with the CSN and within the framework of UNESA, are preparing a document developing this guide and establishing in detail the scope and contents of the PSR which each plant must submit to the CSN one year prior to the end of the period of extended validity of its Operating Permit. Generally speaking, the PSR's will be carried out every 10 years, the first being set in the extended Operating Permit requiring its performance.

The scope of the PSR's will take into account the following aspects:

- Operating experience.
- Experience in relation to radiological impact.
- Changes in the standards/rules.
- Equipment behaviour.
- Design modifications.
- Probabilistic Safety Analysis (PSA).
- Safety assessment and improvement programmes.

The item relating to "Analysis of Equipment Behaviour" is basically the one most closely linked to lifetime management programmes. The scope of this item will make it possible to check the suitability of the measures established for tracking of plant safety-related equipment status, with a view to avoiding, detecting and correcting its deterioration during service lifetime. In this respect, the following measures are foreseen:

a) Analysis of the results of the applicable Maintenance Rule programmes (10CFR50.65) or equivalent programme, required to the Spanish plants by the CSN.
b) Review of the results obtained from application of the In-Service Inspection Programme, including analysis of relevant findings and their possible relationship with the actual operating conditions to which the components have been subjected, according to the operating experience of the plants, and proposals regarding the corrective actions to be implemented in successive inspections.
c) Review of the results of the surveillance requirements or demands established in the Technical Specifications (Tech Specs).
d) Review of the status of equipment qualification and of application of the corresponding qualification maintenance programmes, with special attention paid to the processes of managing qualified or dedicated spares/items.
e) Identification of the processes of

Continued on page 45

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deterioration or ageing of equipment detected in previous programmes and of the corrective measures taken or scheduled.

This last point includes express reference to the plant programmes relating to Lifetime Management. In this context, the contents of the PSR will consider the following:

- Identification of the number of transients occurred and quantification and trending of these transients in order to verify that plant behaviour stays within the design forecasts and that the extrapolation to the lifetime foreseen for the installation is acceptable.
- Identification of the processes of deterioration or ageing detected by the previous programmes and of whatever mitigating measures have been applied.
- The following will be included in those cases in which a formal Lifetime Management plan has been established on the basis of the years of plant operation or for other reasons:
  - Lifetime Management Plan implementation status.
  - Most significant activities performed within the Lifetime Management Plan.
  - Future activities scheduled within the Lifetime Management Plan.
- In those cases in which preliminary activities allowing for the implementation of a Lifetime Management Plan have been scheduled on the basis of the years of plant operation or for other reasons, information will be provided on (1) evaluation of the annual reports required by the Operating Permits, and/or (2) development of the aforementioned preliminary activities and their future scheduling.

CONCLUSIONS

In practically all countries, there has been a stepping up in recent years of NPP Lifetime Extension and Management programmes and associated activities relating to the surveillance, evaluation and control of equipment ageing and, where applicable, equipment updating and replacement. The technology to be applied requires important capital investments, as well as considerable investments in Technological Research and Development. These programmes provide invaluable lessons for the NPP owner companies, inasmuch as they are vital for knowledge to be gained into the status of the installations and the possibility of extending their lifetime and also contribute to improving the use of existing investments. In this respect, and taking into account regulatory requirements such as Periodic Safety Reviews or the implementation of the Maintenance Rule, advantage may be taken of Lifetime Management programmes for the following:

- keeping an adequate level of safety in plant operation;
- increased plant efficiency and availability and of performance indicators in general; and
- optimization of O&M costs, this leading in the long term to the continued competitiveness of the kWh produced,

aspects which it will be possible to appreciate in the future as concepts of lifetime management are implemented.