EVALUACION, MODIFICACIONES Y EXTENSION DE VIDA DE LAS CENTRALES NUCLEARES. EL PUNTO DE VISTA DE LA INGENIERIA

NPP EVALUATION, BACKFITTING AND LIFE EXTENSION. AN ENGINEERING VIEWPOINT

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INTRODUCTION

During the decade of the '80s, the Owners of the two oldest operating plants in Spain designed and built during the '60s -namely, José Cabrera NPP, a Westinghouse PWR, and Santa María de Garoña NPP, a GE BWR- undertook the following important programs:

1. *A far-reaching Systematic Evaluation Program (SEP) for the José Cabrera NPP consisting in the systematic safety review of the plant design, followed by the necessary hardware modifications, to upgrade it and make it comply with current safety criteria, and a Plant Upgrading Program for the Garoña Nuclear Station focusing on specific topics affecting GE BWR Mark-I type plants of the same vintage*

2. *A Remaining Life Management Program to ensure that the units, after extensive backfittings and high capital investment, would complete their design life, leaving open the option for plant life extension. These two units are today considered by the Spanish nuclear industry as the pilot plants for Plant Life Extension (PLEX) programs for PWRs and BWRs in our country*

The purpose of this paper is to summarize the principal lessons learned from EMPRESARIOS AGRUPADOS' participation as an architect-engineering organization in the engineering, design and implementation of these Programs. They are practical examples of positive experience which could be considered as a reference when carrying out similar programs for other plants.

PLANT SYSTEMATIC EVALUATION AND BACKFITTING

Because of the larger scope -affecting structures, systems and components the entire plant- and due to the systematic review methodology applied, the examples of positive experience summarized in this first part of the presentation will only *refer to the SEP for the José Cabrera PWR-type plant. A similar set of recommendations could also be extracted from the Garoña BWR-type plant upgrading effort.*

In summary, the SEP performed for the José Cabrera PWR-type plant addressed the following three aspects to bring the plant to an acceptable safety level in accordance with today's licensing positions:

1. *An evaluation of the as-built plant design against current licensing criteria for essentially the same number of safety topics as those required by the NRC to be addressed in similar SEPs for old plants in the USA*

2. *An evaluation of plant modifications necessary to implement the Three Mile Island (TMI) Short-Term Lessons Learned requirements which, at the time, was requested of all plants in Spain by the Nuclear Safety Council*

3. *An evaluation of the impact of implementing specific plant modifications identified by the Owner, based on his operational experience, to facilitate plant operation and maintenance*

The plant SEP was performed by a well-integrated team composed of the Owner, Westinghouse as the original plant supplier, and Empresarios Agrupados as the architect-engineer. They all worked in full cooperation in this important project which was structured into three well-differentiated phases: (I) Evaluation (1979-1981), (II) Design (1981-1982), and (III) Implementation of Physical Modifications (1983-1985).

Review Methodology

The review procedure consisted in comparing the as-built design of the plant with current licensing criteria in a number of safety "topics" which were essentially the same in quantity (137) and in content as those required by the US NRC to be addressed in similar SEPs for old American plants. Examples of evaluation topics were: Containment pressure and heat removal capability; Environmental qualification; Redundancy and Physical Separation, etc.

For each safety topic, the corresponding plant design was reviewed to determine whether it complied with current licensing requirements and an individual evaluation dossier or report was prepared which included: (1) a Definition of the topic to ensure that all participants had a common understanding; (2) a Safety Objective of the review, (3) identification of Current Licensing Criteria with a list *of codes, standards and regulations applicable to the review, (4) a Document List, including all the drawings, calculations and information on the original plant design on which the review was based, (5) a discussion on the Evaluation, and (6) the Review Findings which described the results of the evaluation and indicated whether or not it was judged that the plant design complied with current licensing criteria and the disposition on the actions to be taken in case of noncompliance.*

In brief, backfitting recommended in case of noncompliance fell into one or more of the following categories: (1) perform a more refined, thorough engineering analysis because compliance could still be achieved through further evaluation work; (2) draw up a new operating, maintenance or surveillance procedure, or introduce changes to existing ones, including changes to the Plant Technical Specifications, and (3) implement physical backfittings consisting of modifications or additions to structures, systems and components in the plant.

Extent of Modifications and Problematic Safety Topics

The SEP resulted in significant physical modifications to the plant, including the redesign of exisiting mechanical, electrical and I&C systems and extensive modifications in piping, HVAC ducts and electric cable tray layout; replacement of old components; addition of new equipment; construction of new buildings, etc, the details of which go beyond the intention of this paper. It should be mentioned, however, that the cost of the SEP - including engineering, equipment and construction - was higher than the original investment by the utility to build the complete plant in the '60s.

The safety review topics that originated the more extensive and/or significant modifications were those involving emergency core cooling system improvement, compliance with single failure criteria, safeguard redundancy, physical and electrical separation, auxiliary safety system upgrading, control room habitability, fire protection, maintaining environmental conditions, seismic upgrading, equipment environmental qualification, availability of emergency power supply and improvement of radioactive waste treatment systems.

The Action Plan

This is the top-level document in the program which should be drawn up to present the organized results of the systematic safety review. The Action Plan should summarize the full evaluation dossier or report on each review topic. It *should define the evaluation criteria that have been applied and specify the necessary engineering analysis and changes to structures, systems and components to reach the required safety level. It is recommended that the Action Plan be submitted to the licensing authorities to obtain, if possible, acceptance in principle to the proposed actions.*

The Design Concept Document

This document expounds the Action Plan and presents a preliminary design of all proposed changes to plant structures, systems and components in an intregrated, coordinated and comprehensive manner. The Design Concept Document should:

- *Provide a reference design guide common to all participants in the upgrading program*
- *Include the design criteria, design basis and applicable codes and standards for each of the proposed modifications*
- *Provide justification of the adequacy of the proposed modifications to meet established safety requirements*
- *Provide preliminary design solutions for the proposed modifications, including system flow diagrams and descriptions, logic and/or analog control diagrams, one-line diagrams, equipment lists and data sheets, physical layout drawings, etc*

The Design Concept Document should be submitted by the Owner to the licensing authorities with the purpose of obtaining approval of the proposed preliminary design solutions before proceeding with the detail design, hardware procurement and change implementation at the plant.

Integration

Rather than provide solutions for individual topics, an effort should be made to perform an integrated safety assessment and design the required modifications, so that balanced and integrated decisions can be made on applying current safety criteria to the old plant. Factors that should be considered before deciding on a plant modification include (a) the safety significance of the change, (b) radiation exposure to workers, (c) impact of the change implementation and (d) implementation schedule.

Application of Codes, Standards and Regulations

Systematic safety evaluation, design, procurement of equipment and construction of required changes were performed applying codes, standards and regulatory requirements in effect in Spain and in the United States -as the country of origin of the original plant supplier (Westinghouse)- at the time the program was implemented.

Only regulations of "significant importance" were considered, defined as those whose absence could result in a significant increase in the likelihood of major degradation of two or more of the three barriers in the defense-in-depth concept. In practical terms, this meant the application of all top-level nuclear laws in Spain and compliance with US 10CFR20, 50 and 100.

US NRC Regulatory Guides were applied to new structures, systems and components added to the plant. For those that were modified or not affected by changes, the application of Regulatory Guide positions was interpreted on a case-by-case basis.

New equipment was procured and qualified to current codes and standards. Existing safety-related equipment was not replaced if engineering evaluation and judgement -based on its design and fabrication features, aging condition and operating and maintenance records- showed a high probability of it performing adequately under postulated design events and operating and environmental conditions.

Deviations from Current Licensing Criteria

To comply with new criteria, deviations have to be admitted when it can be shown that replacing or upgrading safety-related structures, systems and components would result in mere marginal improvements, create long delays in the program, or would not be economically justified. In accepting deviations, a favourable review of related plant operating records should always be a factor and criteria such as the following can be applied:

- *The deviation does not significantly increase the probability and consequences of an accident and therefore the safety level is maintained in essence*

- *Nonsafety-related systems can be used for safety functions*

- *Augmented monitoring and surveillance*

- *System reliability can be improved by selected modifications*
- *System reliability can be improved by administrative changes or modification of procedures*

Design-Basis Development

To perform safety evaluations and to implement plant modifications, utilities should avail of a complete, adequate set of design documents defining the design of their plants. Safety evaluations and plant modifications have to be based on a clear understanding of the design bases and available design margins for the as-built plant. This need, coupled on occasions with efforts to improve the configuration management of the plant, has led utilities in Spain to implement Design-Basis Document (DBD) development programs and Design- Document Reconstitution (DDR) programs. This is of particular importance for those plants built in the late '60s and early '70s, when project documentation requirements and practices were not as extensive as in more modern units, and is equally recommendable whenever SEPs or case-by-case plant upgrades are performed.

DBDs contain an organized collection of plant design-basis information and reference to supporting design documentation in which the rationale or the whys of the design bases can be found. Depending on this specific need, the design document background and status of each plant, the method used by utilities to develop DBDs necessarily differs. However, some common aspects they have in which we have participated are outlined below.

DBDs are generally organized into four different levels or groups: (1) System-oriented DBDs, preparing a DBD for each system; (2) Structure-oriented DBDs, producing a DBD for each main building or structure (eg, reactor building, containment, essential water intake structure, etc); (3) Component-oriented DBDs, developing a DBD for each major component or group of similar components (eg, RHR heat exchanger, piping, supports, valves, pumps, tanks, etc); and (4) Topical-oriented DBDs, whereby a DBD is prepared for each main design topic such as equipment seismic qualification, control room habitability, high-energy line break, etc.

DBD development programs are best begun by designing a pilot program with a representative system, structure, component and design topic. This will help to define the main attributes of DBDs and serve as a prototype for drawing up the remaining documents. DBD content and format should be user-friendly and are normally organized as a combination of a compilation of self-contained information and a directory with cross-references to other supporting design documents.

DBDs should provide a single point of entry to find both licence criteria and engineering design bases for systems, structures, components and design topics.

Design Document Reconstitution

Developing DBDs requires the availability of a complete and adeuqate set of plant design documents. This includes (1) design input documents, (2) design calculations and analyses, and (3) design output documents (eg, specifications and drawings) specifying and reflecting the design of structures, systems and components. For this reason, a DBD development program needs to be supported by the parallel implementation of a Design-Document Reconstitution (DDR) program.

The scope of the DDR program will be determined through the following steps:

1. *Identifying which attributes or controlling design parameters in the DBDs require to be supported by design documentation*

2. *Retrieving this design documentation from the utility, NSSS vendor and architect-engineer files*

3. *Identifying the missing documentation*

4. *Defining which documents need to be regenerated because they are missing or are incomplete or inaccurate*

5. *Establishing priorities to regenerate design documents, concentrating first on those documents that are necessary for engineering support to plant operation and operator quick response to plant events, or that are required to demonstrate the adequacy of numerical values in the plant technical specifications. Examples of these types of documents are P&IDs, system descriptions, instrument lists, control diagrams, instrument set-point lists, one-line electrical diagrams, relay coordination studies, etc*

6. *Finally, it should be understood that, once reconstituted, DBDs and design documents shall be subject to independent design verification followed by validation against the existing plant configuration. Thereafter, throughout the life of the plant, changes to these documents resulting from plant modifications should be controlled within the framework of the necessary configuration management system*

Configuration Management

In the process of controlling modifications resulting from new regulatory requirements, correction of operating problems, plant improvements and modernization by the utility, an essential task is to make sure that approved changes: (1) comply with the design bases of the affected structure, system or component, and (2) are correctly incorporated in the plant documents, which shall at all times be consistent with one another and reflect the "as-built", physical reality of the plant.

An effective practice to resolve this problem is to implement a Configuration Management (CM) Program as an integrated process to ensure that at all times: (1) Plant hardware items and documents conform to the design bases, and (2) Plant documentation accurately reflects the physical and functional characteristics of the plant. A Configuration Management Program should feature the following essential elements:

- *An Identification System for Configuration Items, consisting of procedures to identify plant hardware and documents subject to configuration control. Plant configuration documents include those controlled documents used to support plant design, operation, maintenance, testing, procurement and training*

- *Design-Bases Documentation for such hardware items and documents under configuration control, with verification that design bases have been adequately translated into plant documentation*

- *A Change Control System, ensuring through written procedures that proposed changes to the plant are properly initiated, submitted, reviewed by all organizations affected, designed, evaluated, approved, implemented, verified and recorded. An essential part of change control is verification that the modification complies with the design-basis documentation, has been properly incorporated into the plant documentation and adequately implemented in the physical plant*

- *A Document Control System with procedures for document identification, storage, access and retrieval. A document database, containing document identification, organization responsible, quality classification, release authority, distribution, changes in process or approved, etc, is a tool normally used as part of the system*

PLANT REMAINING LIFE MANAGEMENT & LIFE EXTENSION PROGRAMS

The capacity of nuclear generation in Spain will be reduced by some 6000 MW by the year 2015 if units currently in operation are decommissioned at the end of their 40-year design life. The obligation to maximize the benefit from capital assets, the high cost of new plants, the difficulties in finding new sites and, above all, the government's decision to postpone the construction of new nuclear units until the year 2000 have reinforced the interest of Spanish utilities in ensuring the safe and economic use of remaining plant life and, in due course, in obtaining licensing renewal from the regulatory authorities to extend plant life beyond that originally expected.

Preserving the remaining life of the plant and keeping the option open for life extension should be a concern common to all nuclear utilities. However, this may be of particular importance to those oldest units that are required by the regulatory authorities to implement systematic evaluation programs resulting in extensive backfitting with high capital investment. For this type of plant undertaking a SEP, the following should be considered:

- *If the decision to extend the life of the plant beyond its design life has already been taken at the time a SEP is started, both the PLEX program, focussing on life extension, and the SEP, oriented towards safety-upgrading, should be combined and integrated, and both programs developed and licensed simultaneously*

- *If the decision to extend plant life beyond the original design life has not yet been taken, it is in any event advisable to complement the SEP with a set of short-term tasks aimed at optimizing, controlling and managing the remaining life and aging of the plant and, at the same time, keep the life extension option open*

This latter approach, formally organized into a Plant Remaining Life Management Program, is currently being taken by nuclear utilities in Spain, not only for two plants of the oldest vintage for which extensive backfitting has been carried out -namely, José Cabrera and Garoña NPPs, designed and built in the '60s- but also for more modern plants commissioned in the '80s for which Plant Owners are leaving the PLEX decision until the future. These two old plants have been chosen by the PWR and BWR Owners' Group in Spain as pilot plants for life extension programs.

Remaining Life Management Programs, as implemented in Spain today, focus on the following principal objectives:

- *Identifying components and structures critical to plant remaining life completion and/or life extension*

- *Defining and understanding the aging or degradation mechanisms and their indicators*

- *Understanding the risk significance of aging processes, identifying those aspects of primary concern*

In meeting these Program objectives, an important role is played by condition monitoring, record-keeping, trending, predictive and preventive maintenance, inspection and diagnosis oriented toward keeping a close track on the evaluation of critical components and taking the necessary measures to preserve them from aging.

Remaining Life Management Programs are specific for each plant, although they all have some tasks in common. The following is a generic description of some representative near-term activities extracted from the Programs in which Empresarios Agrupados, in close partnership with the American company Multiple Dynamic Corporation (MDC), is currently participating in Spain:

1. *Identification of Critical Components; developing and applying criteria and methodology to identify components critical to design life completion or extension, establishing priorities for work to be done*

2. *Plant Records - Identification and Collection; consists in identifying and compiling original design, fabrication and testing records, as well as operating and maintenance records, to be retrieved from the past and/or to be registered in the future. In particular, it is essential that key operating records be identified and maintained to reconstruct the operating history of the plant for future analyses and remaining-life assessments*

3. *Acquisition of Material Extracted for Future NDE and Destructive Testing. PLEX analyses and evaluations will have to be supported in the future by NDE and destructive testing of sample material and components extracted from the plant. This requires the establishment of a plan and procedures for the identification, acquisition, storage and preservation of such samples. They include steel, concrete, piping, cabling and small components (such as relays, switches, instruments, solenoids, etc), as they become available through the repair and replacement of plant materials and components*

4. *Base-Line Survey of Safety-Related Concrete Structures; consists in*

conducting a systematic survey to record abnormalities, identifying trouble spots, deciding on "quick-fixes", crack-mapping, and determining acceptance criteria for visual inspection and necessary inspection documentation

5. *Base-Line Wall Thickness Survey of Pressurized Components; consists in specifying and taking a first set of wall-thickness measurements for pressure-retaining components subject to critical conditions of internal and/or external erosion, corrosion and wear. The activity includes specifying the components (eg, tanks, piping, heat exchangers, etc) and the location, frequency and distribution of wall-thickness measurements to be taken as a reference for future trending analyses*

6. *Environmental Conditions Monitoring Program. This program will identify non-metallic, critical components sensitive to the environmental conditions. Pressure, temperature, relative humidity and radiation level will be monitored and recorded in areas where these components are located, as frequently as necessary to obtain an envelope of actual environmental conditons versus time. These plots will then service to justify extension of life extension in the future*

7. *Expansion and Formalization of Fatigue Cycle Monitoring Program. Fatigue is a key mechanism affecting the service life of a component. To calculate fatigue, that is to determine "used-up" versus "remaining" life, it is necessary to reconstruct the history of the component. This program will identify critical components requiring fatigue-cycle counting and specify the counting procedures*

8. *Aging Preservation or Mitigation of more Exposed Components and Structures. Those few plant components and structures that may be the cause of special concern due to their advanced aging are identified under this program and assigned preferential preservation or mitigation provisions, without waiting for a more in-depth, lengthy evaluation of critical plant components*

9. *Plant Lay-Up Program; consists in specifying and implementing simple lay-up techniques developed to protect those fluid systems and components that are subject to highly agressive corrosion conditions when thay are inactive. System and component degradation is often accelerated during periods of plant shutdown, such as refuelling or extended maintenance outages. Equipment preservation techniques during these inactive periods help to prolong their service life, prevent crud accumulation and improve plant performance*

10. Plant Maintenance Evaluation and Improvement Program; reviewing the various maintenance programs existing in the plant (ie, predictive, preventive and corrective programs; in-service inspection, leak detection, instrument calibration, equipment qualification and spare parts programs; inspection, monitoring and diagnosis programs, etc) and assessing them from the point of view of effectively controlling degradation and aging of critical components

On the basis of Remaining Life Management Programs drawn up by Empresarios Agrupados and MDC for José Cabrera and Garoña NPPs, both plants began to perform a series of tasks to optimize the remaining life of their facilities. The following is a brief outline of the most important near-term activities being performed in these programs for each plant. It should be noted that a Life Extension Feasibility Study and a list of critical components had already been prepared and were available for both plants as a result of previous work.

At the José Cabrera PWR Plant, tasks which have begun or which will shortly begin are:

- *Logging of historic plant events prior to preparing the Plant Event Book*
- *Preparation of a program to identify, collect, organize and file documents needed to evaluate plant condition*
- *Analysis of design documents, data and operational transient records related to the reactor pressure vessel and internals*
- *Preparation of inspection procedures to evaluate the condition of the reactor pressure vessel and internals*
- *Establishment of an environmental conditions monitoring program to produce a database to support the evaluation of non-metallic components*
- *Inspection of the paintwork on critical structures to define the condition prior to preparing an improved maintenance program*
- *Inspection of the containment steel liner to establish a baseline for future line thickness trending and surveillance of corrosion and other physical damages*
- *Inspection of electric cables prior to defining inspection methods and programs for future surveillance*

At the Garoña BWR Plant, the most important near-term activities being performed *as part of the Remaining Life Management Program are:*

- *Identification, collection, organization and filing of design documents and plant records not included in a prior documentary conciliation phase*

- *Preparation of a Plant Event Book*

- *Development and implementation of methods for monitoring and mitigating erosion-corrosion in major piping systems and components*

- *Reactor pressure vessel fatigue evaluation*

- *Implementation of a Material Sample Collection Program for assessing the condition of the plant*

- *Research studies on thermal embrittlement of stainless steel castings in the reactor recirculation loops*

- *Vibration monitoring of emergency diesel-generators to establish a baseline for future trending and diagnosis*

- *Implementation of an Experimental Lay-Up Program during extended plant outages in a reduced number of fluid systems, prior to extending it to other systems*

- *Preparation of a Maintenance Worthiness Evaluation Program, which consists in making an inventory of existing plant maintenance programs followed by an evaluation of their worthiness to prevent the degradation of critical components, introducing the necessary improvement to current maintenance practices to this effect*

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