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ENHANCED DESIGN, OPERATION AND MAINTENANCE PRACTICES FOR A LONGER PLANT SERVICE LIFE

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ABSTRACT

Plant service life problems have been under detailed investigation in France and the experience acquired by our company over the past 25 years in the design, construction and maintenance of Pressurized Water Reactors has contributed to develop skills, equipment and capabilities available for efficient plant aging management and component service life extension.

The service life of a nuclear power plant is deeply dependant of the provisions made during the design stage, directly linked to good operating conditions and adequate maintenance practices.

This paper presents the importance of these three steps (design, operation and maintenance) for plant service life concern.

PROVISIONS MUST BE MADE DURING THE DESIGN STAGE

For the design of new plants FRAMATOME proposes to implement an integrated strategy to reach a long life duration target.

This integrated strategy is summarized in the attached scheme :

- During a first step a list of critical items is prepared on the base of both experience of utility and Framatome. Then a review of the estimated loads and duties is performed (load due to transients, damage due to corrosion, etc...), their acceptability for these critical items is evaluated and design provisions for life duration are made consistent with the expected life duration. This work takes into consideration some aspects such as reliability analysis and In Service Inspection program as well as preventive and predictive maintenance strategy.

- During the design of the plant a detailed analysis of the transients and the loads (not only mechanical or thermal but also including chemistry and aging) will allow to confirm the list of critical items as well as defining the provisions to be taken during the manufacturing of equipment and the construction of the plant.

  In parallel the reliability analysis and In Service Inspection programs and predictive maintenance program are drafted and correlated with this life duration task. Benefit is also taken from the French experience and R & D studies for service life of the French units.

- During the manufacturing and construction phase, FRAMATOME will complete the assurance of the life duration, that is a checking that all provisions required are taken and documented. So the life assurance appears at this stage as a part of the Quality Assurance. The manufacturing and construction events and the as-built real characteristics of the equipment are also taken into acount to reassess and assure the life duration. A life Duration Report is prepared presenting all design manufacturing and construction aspects important for life duration.

  A lesson of the experience is that all information which may have an impact on the assessment of life duration must be carrefully recorded and filled, so this must be done during all phases of a new project.

- During the plant operation, the utility will have the responsability to execute the planned monitoring, In Service Inspection, maintenance, to log and count the effective transients during operation, to analyse the events which could have impacts on life duration, to reassess this life duration periodically, and to record every information possibly related to this question and, in case it is needed to apply for licence extension.

Life extension from 40 to 60 years for instance can be obtained by defining extra provisions or performing specific studies during the design stage. Some examples of such a provisions are as follow :

. Lower copper limit for the deposit weld material of the welds adjacent to the core shell for the reactor pressure vessel.

. Thermal ageing test program for cast product.

. Adjonction of thermal sleeves and optimization of the shape of the surge line.

. Steam Generator service life can be improved by :

  - Addition of one set of anti-vibrations bars.
  - Implementation of an anti-stratification device inside the main feedwater nozzle thermal sleeve.
  - Change of primary seprator material.

. Special care is taken with the reactor internals (additional mechanical analyses).

. Stress report calculations for a 60 years design life for all primary circuit equipment (RPV, reactor coolant piping, steam generators, casing of primary pumps, pressurizer, pressure housing of CRDM).

. Environmental qualification of electrical cable should be conducted with a 60 years service life.

SMOOTH OPERATING CONDITIONS

Experience with operations of French nuclear power plants has shown that two of the most significant causes of adverse plant transients are reactor trips and spurious safety injection. An analysis of data showed that about two third of the unscheduled plant outages resulted from actuation of protective devices, often due to shortcoming in plant control and protective systems. Bringing the NSSS from hot to cold shut-down, or reverse, is a relatively infrequent operation but involves keeping tight control of several key parameters as well as avoiding equipment fatigue (particularly of the pressurizer surge line with its two nozzles, the bottom part of the pressurizer and the charging line).

In France, considerable effort has been made to improve control and protection system. This has contributed to a significant decrease in unwarranted reactor trips and safety injections.

Furthemore to facilitate and simplify operation, Framatome developped a system to automatically control plant cooldown and heatup. Initially intended for the N4 series of advanced PWR units, this system reduces the risks associated with infrequently performed manual operations while at the same time minimizing the equipment fatigue.

Auxiliary feedwater system actuations are minimized and the amplitude and number of thermal shocks to the pressurizer are reduced. The system improves stability of the pressurizer pressure and level and lowers the thermohydraulic stress on certain high usage factor areas.

Plant Life Management necessitates the fatigue monitoring of the most critical equiment areas in order to appreciate as precisely as possible either the limit of life or, if the component is replaceable, the optimal time of replacement. A lower rate of damage can be obtained (and evaluated by a monitoring system) by adaptation of operating mode in order to minimize the frequency and range of thermal transients. On line monitoring of critical components plays an important role in the process of identifying and understanding potentially adverse conditions. It also enables assessment of damage initiation and evolution.

Transient logging can be carried out manually (following detailed procedure based on functional analyses and mechanical calculations) or automatically on-line using a computer based system such as the FRAMATOME Operating transient Monitoring System (OTMS).

This system uses the physical parameters which are relative to the fatigue critical areas. Then the system analyses these data and performs structural calculations to provide fatigue assessments.

These assessments are of two kinds :

. the usage factor in critical areas gives an accurate but local information on the fatigue status of involved areas,

. the operating transients records are compared to design transients which provide a general fatigue status of the systems and equipment.

The data thus collected provides a complete and detailed description of the in-service operation of the plant systems. This information can be stored for later analysis or be used for real time calculation of different types of damage and for evaluating the operation transient impact on system and equipment service life. The concept of real time monitoring also enables periodic updating of inspection and maintenance procedures thereby optimizing equipment replacement schedules.

The French utility EDF will begin installation of such an automatic monitoring method on all domestic NPPs in 1994. This system will allow Framatome to follow the consequences of the operating mode on the fatigue ageing of the most critical items for life duration, and thus to adapt and to optimize the operating mode in order to minimize fatigue damage of these items.
In addition the OTMS system will allow to define the most appropriate periods for equipment repair or replacement.

ADEQUATE MAINTENANCE PRACTICES

Extending plant service life can be achieved by improving component reliability, preventing equipment degradation, implementing component and systems modifications, providing in-service controls and surveillance and ensuring the necessary repairs and replacement meanwhile demonstrating the safety requirements compliance. In other words the plant service life of a nuclear power plant is directly linked to good maintenance practices.

In France, besides the close cooperation between the French utility EDF and FRAMATOME, for the EDF plant life project, a very important maintenance activity is performed to ensure a proper operation of the nuclear units. These French nuclear plants under operation are based on two standardized designs 900 MWe (34 units) and 1300 MWe (20 units). Information from earlier plants in each series has been used to upgrade and backfit the units leading to improvements in safety, availability and potential plant life.

EDF has implemented a policy of upgrading and backfitting of its 900 MWe units to bring each to the same level of technology as the last in the series, Chinon B4. This plant itself benefitted from operational feedback with upgrades integrated during construction. The EDF policy has been implemented by using the ten-years major inspection and test outage required by the French authorities to perform upgrades and backfits. In addition these outages provide important information for plant aging assessment.

It is important for plant life management that good routine and preventive maintenance practices are implemented to ensure components do not degrade prematurely. Routine maintenance of moving parts in particular pumps and valves is of the utmost importance as a preventive measure.

Some operations can be performed on the main components, such as chemical cleaning of the secondary side of the steam generators or cleaning of the in-core instrumentation thimble guide tubes.

These type of operations usually require a significant amount of analysis, process qualification, development of special maintenance facilities and personnel training prior to implementation.

A good example is corrective maintenance to reactor coolant system components. In the steam generator, maintenance is effective principally on the tube sheets and tube bundles. Actions include nickel electroplating, tube sleeving, tube removal, shot-peening and antivibration bar replacement. Reactor vessel maintenance is principally addressed to closure flange seal grooves, closure stud holes, seized studs reactor internals guide tube pins and in-core instrumentation.

In addition to these repairs, corrective maintenance is being continiously developed, leading to new methods and tools such as upflow conversion and steam generator replacement.

Some heavy maintenance or repairs have been necessary in recent years (changes/repairs of reactor vessel heads, steam generators replacement) and the life duration program appears of utmost importance since the economical impacts are extremely high.

CONCLUSION

The life of a specific Nuclear Power Plant terminates when the authorization to operate it is withdrawn, and/or when the operation of the Plant turns to be no more economically competitive. These two circumstances are often mixed, as the licensing may remain theoretically possible by making very costly modifications, repairs, demonstrations, but not sound economically. There are recent examples of plants where this just happened.

So the life duration challenge is to assure now that no technical modification, repair, maintenance, nor important engineering work either, will be necessary in the far future, the cost of which would make the continuation of the operation of the Plant uneconomical.

Plant life concern must be kept into consideration as soon as possible in the design phase (for new plants) or from the very beginning of unit operation (for existing plants). This necessary anticipation will allow a proper management of this issue, leading to benefit thanks to better availability and longer service lives of critical equipment.

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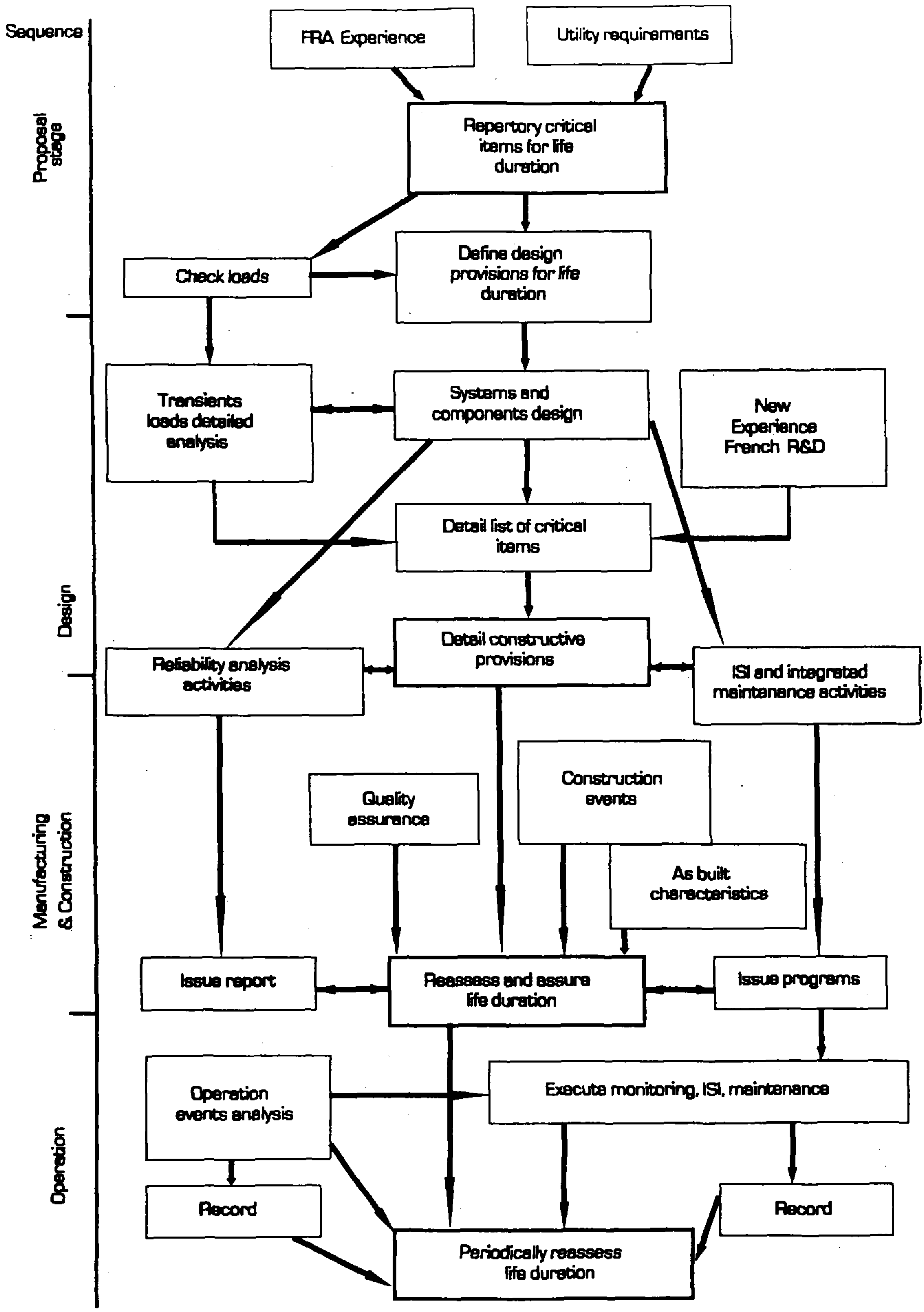

I.S.I : In Service Inspection

STRATEGY FOR A LONG LIFE