PWR life evaluation project at EDF

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1 INTRODUCTION

1.1 We mainly rely on PWR : A glance at two diagrams representing the share of PWR units in EDF generation facilities (fig.1) and in the national power supply (fig.2) is enough to understand fully the utmost importance of maintenance, service life evaluation, and future replacement problems of these homogeneous and still young units.

1.2 What is new about our situation ? : In our past of thermal generation, these questions did not arouse such a stringent incentive. The technical progress was so fast throughout the "glorious thirty years", and the fuel market was jeopardized to such an extent by the end of this golden age that we frequently had to decommission the plants before their technical death, because of economical obsolescence (fig.3).

1.3 Long life chances of PWR units : We may expect that our recent PWR units will benefit in the future of a much more favourable situation, due to many conditions both economical and technical :

a) increased stability in the size of the units and in their thermal performances

b) low fuel cost, with a limited part of natural ressources, therefore unsensitive to such overthrows as are experienced by the oil price

c) lack of other generation system which could compete severely with PWR, and bring them to economical obsolescence in the next decades

d) stability of the basic safety rules applied to construction and operation in the past decade, in such a way that the in service experience (for example, TMI) could be applied to existing recent plants without prohibitive expenses

e) good native tendency of PWR to offer a long service life, due both to low thermal fatigue because of the moderate operating temperatures and to the high quality of

design due to the modern mechanical rules and methods applied to the main NSSS components design.

All these convergent reasons lead E.D.F. management to undertake a broad program of work, in view of gaining a better evaluation an a better use of this long life potential. This program was named "Projet durée de vie".

2. GUIDELINES OF THE PROJECT

2.1 Define and limit the scope : first, we tried to lay down the problem correctly. In fact, there cannot be any absolute physical limit to the service life of a PWR plant, since all major equipments could be replaced if necessary, with the only exceptions of the civil work and - perhaps - of the RPV. Therefore the matter is - basically - an economical optimization problem.

To simplify it extremely, we have to deal with opposite effects of first, the weight of construction expense in the unit of production cost, which is reduced by an increase of service life, and second the maintenance cost, which we may expect to grow finally to a prohibitive level, when some "critical components" require heavy repair or replacement costs (fig.4). Working in this direction, we may neglect all maintenance works and costs that can be normally included, on basis of experience, in a normal, well fitted maintenance program, which is worked out in conjunction with the project, but separately - with a preliminary conclusion that the life extension project has to be handled as far as possible by the people in charge of maintenance program.

Of course, the emphasis must be put on the safety aspects of the problem, which will always benefit of a top priority in the studies. But, in this respect, we have not to deal which the same administrative restrictions that our american colleages : a priori, our operation permit covers the design life of 40 years and, thanks to the youth of our plants, we don't have their problems of licence extension in a near future.

2.2. Critical components : Starting from the above mentioned principle , we laid down, according to the engineering judgment of the most experienced people in our staff, the list of "critical" or"sensitive" equipments : These components for which we could not reasonably provide provisions for heavy repairs or replacement in the current maintenance programs and budgets.

This list included :

- The major primary system components of the NSSS
- The containment, major structures, as well as ancilliary

- The instruments and main control equipments
- The electric cables
- The turbogenerator set

For each of these critical components, we should work basically in two phases :

First, we should gather and summarize all available useful data pertaining to life evaluation or extension : design and fabrication data, available R a D and special test results, in service experience, all elements brought either by domestic or international experience as fas as it is applicable.

Then, starting from these "statements", we should define and perform all complementary studies and work useful to ensure a better knowledge and control of the aging processes, improve the surveillance and maintenance programs, determine the costs and plannings of the anticipated big repairs and replacements.

2.3 Objectives : The final purpose of the program is, of course, to supply the management with the best elements for them to face, in the future, the difficult decisions of replacement or life extension, and to develop, as soon as necessary , improvements in operation and maintenance programs.

A parametric range of 25 to 50 years was chosen as a basis for the studies. The lower limit corresponds to the minimum time anticipated in the economical calculations for the return of the investment costs. The upper limit was chosen more arbitrarily, as beeing already very far for plants whose maximum time in service is no more than 10 years.

The enquiry is mainly focused on the standardized 900 MW serie units.

3 MAIN TASKS AND SHEDULE

Beyond its preparation and organization phase, achieved by the member of its steering comitee, the project is divided into 8 tasks (fig.5).

task 1 (under way) - gathering and synthesis of available data, for the critical components
task 2 (under way) - expected effects of operation modes, load and frequency follow up, fuel cycle improvments,...
task 3 (under way) - impact of service life of existing plants on the recent evolution in safety requirements and rules

task 4 economical prospective : identitying - for the earliest period anticipated for the replacement of the 900MW units - the economical data pertaining to the alternative plants. This task is actually developed apart from the project

task 5 defining and organizing the complementary work program, which can be felt as necessary from the conclusions of tasks 1 to 3

task 6 development of this complementary program

task 7 setting up elaborated aid to decision tools for plant life extension or replacement

task 8 synthesis and conclusion reports

4 ORGANIZATION

Tasks 1 to 4, 7 and 8 are basically handled by EDF teams. The complementary program (tasks 5-6) will need a wider participation of other organizations constructors, laboratories.

The first task of "assessments" from existing data and to day conclusions drawing will be accomplished by the end of 1987.

The complementary work program could last 2 more years, maybe longer : In fact, this task is broadly shared with the common maintenance improvement program permanently developed by EDF technical services.

5 SOME PRELIMINARY CONCLUSIONS

Currently, only very preliminary conclusions can be drawn, since most of the project work is in progress. However, some main elements may be already perceived and discussed.

5.1 Reactor pressure vessels : The reactor pressure vessel may appear as the most limiting component, because of the embrittlement effect of neutron flux on the wall in the core region. EDF 900 MW vessels have been designed and are surveyed in service according to rules very similar to US NRC regulation, but with somewhat more stringent limitation in cooper content - 0,10 % max., with actual values between 0,06 and 0,08 %, except for the welds in the oldest ones, which can reach 0,11 - 0,12 %. The results of the surveillance program are still limited, since the maximum fluence on withdrawn specimens do not exceed 1,5 10 EE 19 nvt|cm2, equivalent to 12 years of normal operation. Nevertheless, these results are all below the "safe" prediction of the newest formulae (Guthrie, Houssin) and their extrapolation to 40 years lead to a probable upper limit of RTNDT of about 50°C for all parts of any 900 MW vessels - fig.7 - with exception of some oldest welds which are expected to exceed this value by about 30°C.

These results, compared with the US NRC "screening criteria", and backed up by extensive studies of tolerable postulated defects, lead firmly to the conclusion that the irradiation embrittlement of RPV will in no respect contribute to the life limitation of these plants, even if a life prolongation over the design life of 40 years was aimed.

5.2 Mechanical behaviour of NSSS main components. The project is - to a large extent - an exercise in prediction : how the equiments will age, what will be the signs or "indicators" of aging, what to say of the likely service life under safe and reliable conditions, under what provisuibs of examination an repairs... ?

The evaluation of time dependant mechanical damages - wear, and fatigue can rely only on two types of data :

a) analytical appraisal, from the design studies, more or less combined with extensive qualification tests,

b) full time in service experience. For this relatively new and very huge machines, it is obvious that our in service data don't give us sufficient information : Our experience rarely exceeds 10 to 15 years, which is not so much for a 50 years forecast.

We see immediately a strong difference between the main NSSS compoments and the others.The RPV, for exemple, did benefit by a very extensive appraisal with sophisticated design methods like those of ASME III, subsection NB, in such a way that you are pretty sure that it will not suffer excessive fatigue damage within 40 years, if not much more, under the only provision of a careful transient monitoring ensuring you that the actual transients don't exceed the design provision. At the opposite, for equipment designed with more a conventional method, as it would be also for fossil fired boiler parts, the design data don't teach you much on the likely mechanical life, and let you dependent mainly of in service experience.

That must be emphasized : we users, as well as our industrial partners, could be tempted to claim against the huge costs of class 1 components studies. But we realize after a short reflexion that these studies were fully justified, not only by the safety requirements from which they proceeded in fact, but also by the firm basis they supply to any prospective reflexion.

As for the results of the first review of the class 1 design data and comparison with the actual operation condition, we can see only some limited potential concerns: auxiliary piping and nozzles, like pressurizer surge line or feed and bleed line, subject to more severe thermal transients, stratifications, or some questionable construction details like thermal sleeves attachements in oldest units. Outside these few points, which will need further

work, the situation of the main components relatively to fatigue or other mechanical damage is very sound, and could accomodate large life extensions over the 40 years design life. This was not the case for conventional high temperature units, creep exhausted by 30 to 40 years.

5.3 Materials behaviour. Although we don't anticipate any fatal issues of plant life because of corrosions or aging of materials, there is no doubt that such degradation could turn to severe concerns on maintenance costs. We cannot in this brief review give an extensive list of such problems, but we may at least indicate two important points :

The first is related to steam generators tubes. Its is well known that these thin structures are subjet to many types of corrosion, by caustic agents, chloride and even in pure water when the chromium content is not high enough. Adequate and severe precautions in the secondary water chemistry can prevent most of these corrosions, but cannot fight against the "Coriou" corrosion in pure water, accelerated by the high levels of residual stress which are found in the roll-expansion zone, or in the shortest radius bends.

Since these corrosion crackings may require - in spite of the remedies brought - the plugging of a progressively increasing number of tubes, we could have to replace steam generators. On the newest in service units, the optimization of the thermal treatment of the tubes should bring very definite improvements, and still better ones on the units under construction, fitted with 690 alloy.

But anyhow, so various and complex are the possible modes of S.G. tubes failures, not only by corrosion, but also by mechanical wear, that it is very difficult to reach a firm assessment that S.G. may live 40 years or more.

A sowewhat comparable problem might be faced with some duplex austenitic-ferritic structures of casted pieces of main primary piping, subject to thermal aging when the rate of ferrite - or "chromium equivalent"Cr + Mo + Si - is too high. This thermal aging may reduce the thoughness of the piece to such an extent that the size of acceptable flaws would become unreasonably small - leading to such important requirements of in service inspection flaw dectection sensibility that the best choice would be to change the pieces - Currently, these phenomena are not still fully evaluated.

What we can say - at least - for these types of concerns, is that they have not much to deal with the life of the plants, so far they would need convenient solutions well before our target of 25- 50 years of life. And we may reasonably expect that the developed improvements will ensure that the same concern should not happen two times in a plant life !

Among other time dependant processes, we can also mention the long term behaviour of electric cable insultation, which must be evaluated : replacing important parts of these cables would be extremely costly, in time and delay more than in direct cost.

5.4 Other mechanical main components : Due to the operating temperature, the turbine is naturally protected against creep, which is a long time concern to the fossil fired units - However, the mode of degradation of turbines rotors parts - shafts, disks, blades, are so complex, with mixtures of fatigue and corrosions, and so difficult is the exact knowledge of the stresses involved, that a correct prediction of the maintenance costs is uncertain - the same observation can be made for the alternator.

For such items also, the problem is rather related to maintenance costs, rather than to service life : the failures may happen as well after few years, so that a life limit of 30 or 40 years does not show any particular meaning. Anyhow, we can state that the design data of these big machines do not supply us with "life indicators" comparable to the numerous elements on which we rely for class 1 NSSS components : we can only "wait and see".

5.5 Final conclusion. In the present state of our enquiry, we have anticipated some concerns on the main equipments of our PWR plants, which could lead in the future to maintenance costs and lacks of availability in excess of the common provisions actually considered. It will be an important goal of the project to adjust as far as possible our forecasts, and still more to develop preventive remedies to smooth the curves (fig.8) and avoid any crisis. Indeed, we should be largely helped in this task by the standardization of our units.

However, the bases of the system are very sound, as are also the most potentially troublesome components which are doubtless the main contaiment structures and the RPV. These main items will certainly not contribute to life limitation of the plants within the 40 years design life and probably much more.

Then we may expect from these units a long and safe service life.

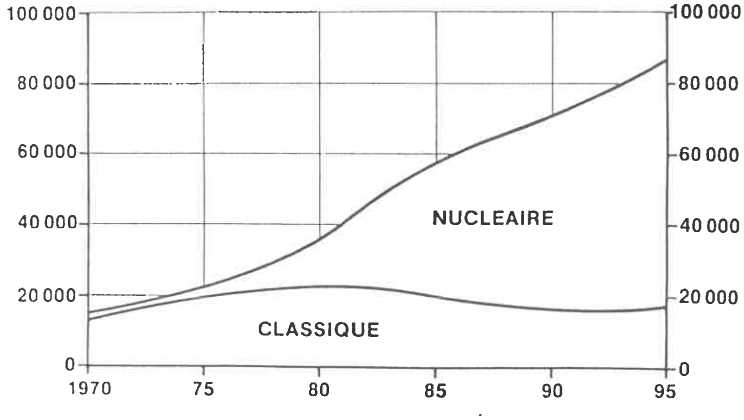

Figure 1. Puissance thermique installée EDF (MWe).

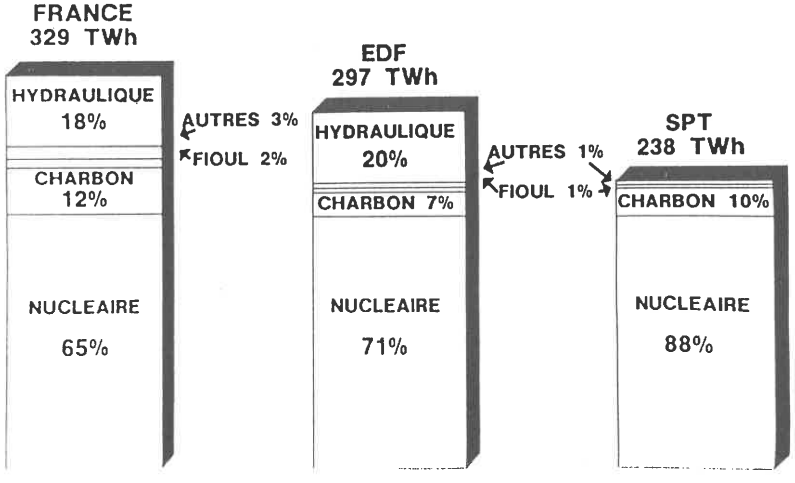

Figure 2. Principaux résultats 1985.

EPOQUE DES MISES EN SERVICE	1930-1940	1960-1970
PUISSANCES UNITAIRES (MW)	20 - 50	250 - 600
CONSOMMATIONS (MJ/kWh)	16 - 15	11 - 9,5
EFFECTIFS (agents/MW)	5 - 3	0,3 - 0,2

Figure 3. Evolution de la productivité (thermique à flamme).

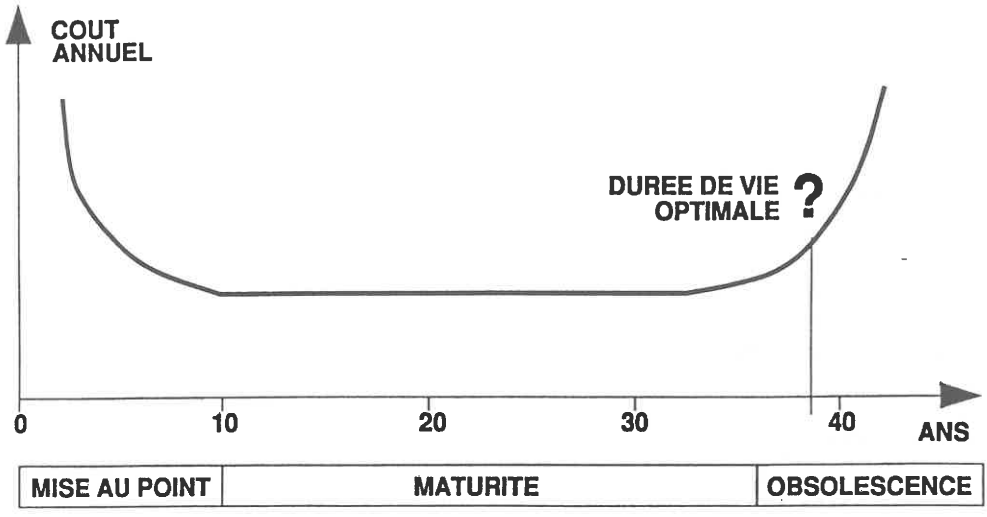

Figure 4. Evolution du coût de la maintenance.

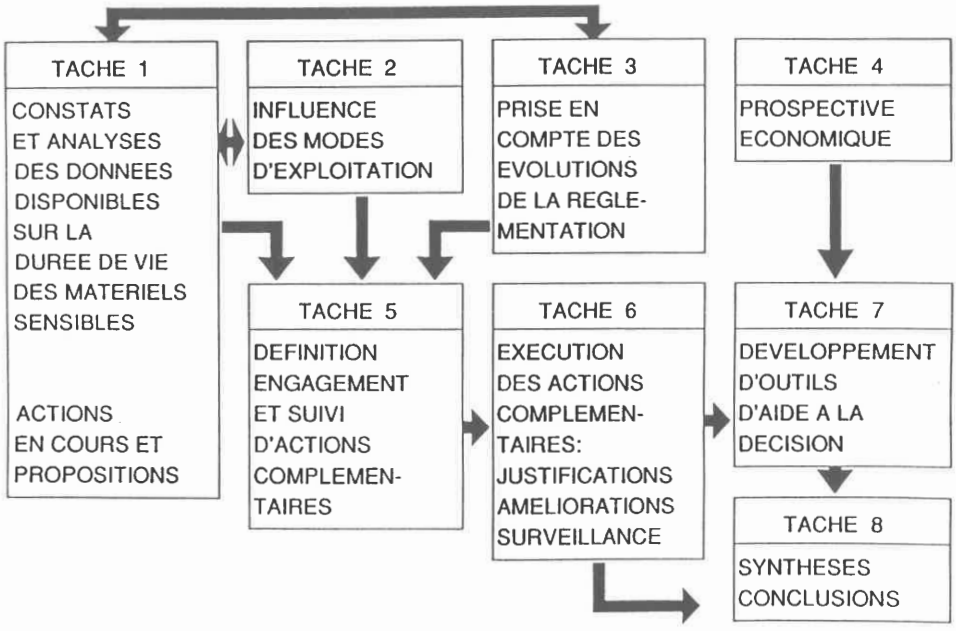

Figure 5. Projet durée de vie: organigramme.

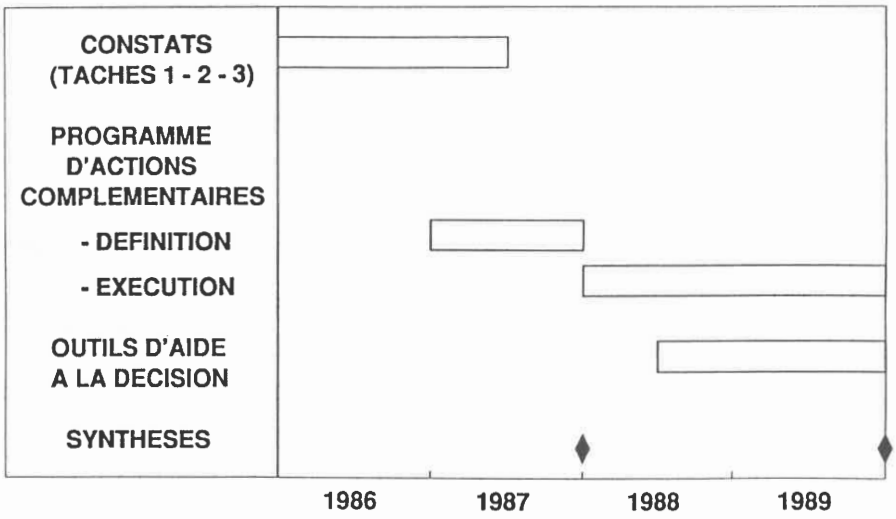

Figure 6. Projet durée de vie: planning.

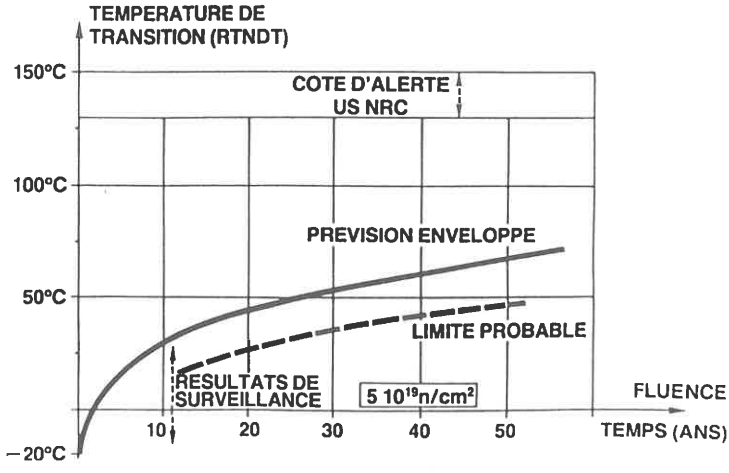

Figure 7. Résistance à l'irradiation (cuves 900 MW CP 1&2).

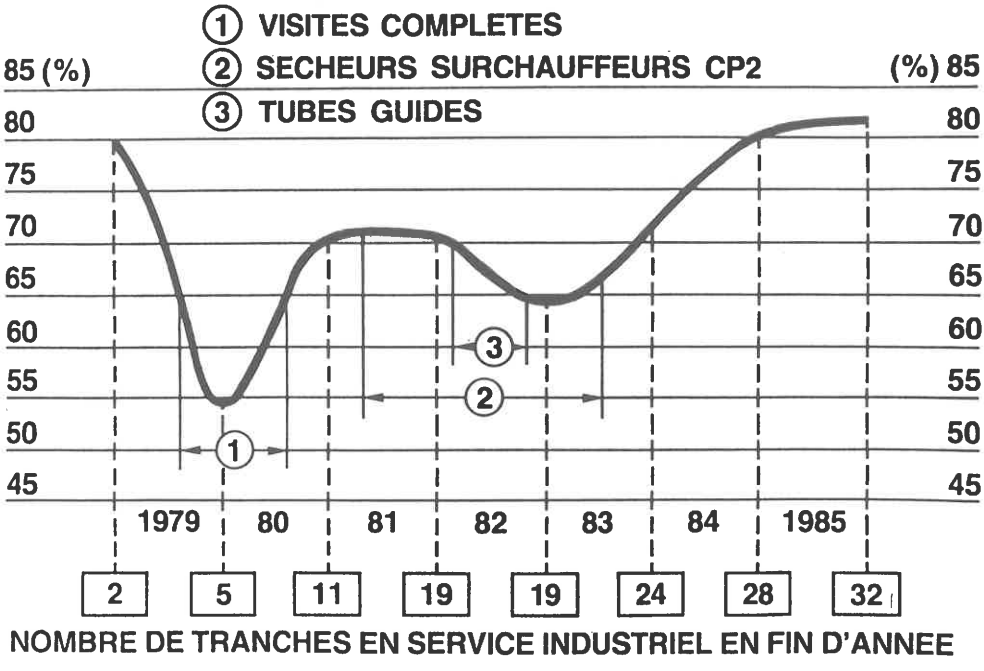

Figure 8. Evolution de la disponibilité
(parc nucléaire REP 900 MW).