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Ten years of transient monitoring experience in French PWR units

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1 INTRODUCTION

The high quality design of a nuclear steam supply system generally relies on sophisticated analysis which allows to verify that various criteria are met, each of them guaranteeing the avoidance of a particular type of damage. To perform these analyses, the designer must make assumptions as to the way the plant will be operated and needs input data which may not be very well ascertained beforehand.

A good example of this is the list of operational transients which has to be postulated to perform the fatique analysis of primary circuit components. According to the French regulation, this list may be proposed by the designer but it must be agreed on by the future user. And, of course, the plant operator is required to make sure that, during operation, actual transients are identical to (or, at least, enveloped by) the design ones or, in other words, to verify that, during operation, components are never put in a more severe situation than what they were designed for.

It is for this reason that, since the startup of Fessenheim I nearly ten years ago, a procedure making it possible to continuously check the validity of design analyses (in particular, fatigue resistance analyses) has been applied in all French PWR power plants.

In this paper, after recalling how the procedure works, we propose to discuss the major lessons drawn from these ten years of experience, emphasizing, outside of mere compliance with statutory regulations, EDF's interest in making available a "history" of the loads on nuclear steam supply systems.

In particular, at a time when both the United States and France are starting to make in-depth studies on the factors and aging conditions of equipment with a view to prolonging the life of PWR plants, it seems to be of great importance to be able to estimate the fatigue condition in power plants.

From the balance we have thus far, though the present monitoring transient procedure for the overall nuclear steam supply system appears to be sufficient, it nevertheless becomes evident that additional benefits can be drawn from one-line fatigue monitoring devices which are presently being developed, these benefits applying to certain areas that are particularly sensitive. We are therefore going to discuss the benefits that can be drawn from adding or partially substituting the present method.

2 TRANSIENT MONITORING AND BOOKKEEPING PROCEDURE

The procedure itself has already been discussed in several publications (1), (2), (3), where the reader can find a more detailed description.

2.1 Design transient list

To perform mandatory fatigue analysis of class I components, a list of operational transients had to be postulated. This list includes a functional description of each transient and the corresponding variations of the main physical parameters: primary and secondary pressure, cold leg, hot leg and pressurizer temperatures, flowrates, etc. The expected number of occurrences during the lifetime of the plant is also specified. This list was established on the basis of previous experience and anticipated operating practice but it must be noted how difficult it is to make reliable assumptions about how a plant will be run within the next 40 years! Besides "operating policy" aspects, possible in-service modifications of components or control systems may induce significant changes to transient features. The above remarks support the idea that, within its lifetime, a plant could be subjected to more severe or more numerous transients than it was designed for so that the design fatigue analysis would be meaningless. Transient monitoring and bookkeeping procedure was adopted to verify that it is not the case by continuously comparing actual and design transients.

2.2 Transient detection and comparison

The first step of the procedure consists in detecting the transients. This is done by monitoring the main physical parameters (mainly pressure and temperature) using regular plant instrumentation. Small fluctuations were eliminated from the procedure by determining parameter thresholds below which the structure is shown to undergo no fatigue damage. These thresholds were estimated by performing thermoelastic analysis of the most sensitive and significant regions of the primary circuit. These studies and various functional considereations led to the presently adopted threshold values:

primary pressure:	1 MPa
secondary pressure:	0.5 MPa
primary loop temperature:	5° C
pressurizer temperature:	6° C
charging-line temperature:	20°C

As it can be seen, specific thresholds were estimated for parts where specific transients occur.

Each time a threshold is overpassed, the transient must be identified with one of the design list; actual and predicted parameter variations must be compared with respect to amplitude and slope and all these informations are kept on file. The procedure allows the operator to know, at any time, how many transients of each kind have already been encountered and how many are left. The detailed procedure includes instructions to deal with specific cases: rapid sequence of transients, transient within an other one, etc.

The background and reasons which led to the method definition have been discussed in (1).

3 RESULTS OF TEN YEAR TRANSIENT MONITORING AND BOOKKEEPING EXPERIENCE

The results that can be seen from application of the procedure are collected twice a year and entered into a comparative analysis comparing the various plants within a single standard plant type.

The first conclusion that can be drawn is that the transients taken into account at design stage match reasonably well with operating condtitions.

Figure 1 shows, for example, the comparison between the temperature variation in the primary loop during cold shutdown of the nuclear steam supply system at Blayais 4, and the variation theoretically designed for such a transient. It can be noted that actual cooling is significantly lower than the design condition.

Figures 2 and 3 show a comparison between the number of transients reckoned five years after C.O.D. and the number normally anticipated at design stage (apart from load variations) for one of the oldest units in Program No. 1 contract. Figures 4 and 5 give the same results for load variations. It can be seen that the number of transient occurrences over five years is significantly lower than expected. These two conclusions (i.e., less severe transients and lower number of occurrences) are perfectly valid for transients in the overall nuclear steam supply system. Nevertheless, differences must be made, emphasizing two points:

1. The margins that can be determined from Figures 2 to 5 regarding the number of occurrences reflect an overall conservatve appreciation in design assumption which, in order to be calculated in terms of fatigue damage reduction, require that a distinction be made between such and such a type of transient. Heterogeneity then becomes obvious. For example, while the number of occurrences of such a transient as "nuclear steam supply system cooling down" quite corresponds to what had been postulated, a transient such as "loss of off-site power" is very infrequent . Each are of different importance, in terms of fatigue damage, depending on materials.

2. Along with monitoring the overall transients in the nuclear steam supply system, a follow-up was made on particular transients in certain systems (such as chemical and volume control system or residual heat removal system). Therefrom, it appeared that the frequency of occurrence of certain transients was higher than anticipated, or that transients of a more severe nature than foreseen had occurred. As an example, Figure 6 gives the number of transients computed on Bugey 2 charging line. It becomes apparent that among the three transients nos. 36, 37 and 38, transient no. 37 - six years after C.O.D. - had already reached nine-tenths of the quota designed for its entire lifetime (forty years).

This type of problem (transient occurring too often, or transient that has more severe pressure and temperature variations than anticipated) has in fact mainly been reported on chemical and volume control system charging lines.

It gave rise to two types of corrective actions. The first action, which is convenient for the plant operator, consists in revising the design calculations on the basis of hypotheses for more realistic loads (i.e., more severe) such as highlighted by the TMB procedure.

Of course, when these calculations involve equipment that was already under heavy stress from the start, it is not always possible, and makes it very difficult to achieve resistance analysis.

The second corrective action consists in changing the operating conditions (operating procedures or control systems) in order to reduce loads. In the case in point, both methods have been applied to the charging line, where the following were performed at the same time: the manufacturer redefined the list of transients, and modifications were carried out on the pressurizer level and chemical and volume charge line and discharge line control systems in order to reduce frequency and magnitude of certain thermal shocks (such as great increases in charging flowrate during emergency shutdown).

4 ADVANTAGE OF THE TMB FOR EDF

For many reasons, it is a significant asset to be able to track the history of the loads undergone by PWR nuclear steam supply systems and thus gather a realistic assessment of component fatigue. We shall try to exemplify this consideration with concrete cases.

At the design phase of a new type of plant, TMB feedback experience gained from previous plants makes it possible to adopt more realistic design hypotheses and, taking into account what we said above, ones that are generally less extreme. Currently, the definition of the list of 1,500 MW plant conditions integrates the experience acquired with 900 MW and 1,300 MW plants (for example, in defining transients during testing periods, before startup). Following the lessons drawn from the TMB procedure, the improvements in control loops that were implemented on the 900 MW PWR series were incorporated in new class series from the design phase.

Many benefits are thus offered to the plant operator:

- Using actual transients rather than design transients is of advantage in analyzing the fatigue of possible defects detected during in-service inspection. This approach was used at CHOOZ A to demonstrate the acceptability of the defects found in the socket-welding on the chemical and volume control system charging line.
- Another possibility would be to adapt in-service inspection frequency to transient bookkeeping results. Indeed, in all in-service inspection programs, the interval between two visits is given in terms of number of years. But, in fact, there are locations where the main damage to be feared is fatigue due to pressure and thermal transients. So that it would be more logical to express the frequency of inspections in terms of number of cycles. Transient monitoring and bookkeeping allow this kind of approach, which is presently applied when redefining the in-service inspection doctrine for class I auxiliary systems.
- In a similar light, the TMB procedure makes it possible to consider certain items of equipment as "consumable". Thus, rather than designing for the pressurizer, SEBIM pressure relief valve bellows which have forty years life, it seems preferable to allow that these components be changed every hundred operations, such operations being bookkept.

These considerations can be applied to the overall NSSS in the context of plant life extension studies (4). If, after forty years' time, only a part of the design transients have actually occurred, or if the actual transients were less severe, it will be possible to demonstrate that the nuclear steam supply system can be operated for a longer period of time, at least with respect to fatigue damage (corrosion or erosion should be looked at with a proper approach).

5 IMPROVEMENTS AND NEW DEVELOPMENTS

The actions taken in this field are in accordance with two basic concerns:

1. The first is an attempt at easing the operator's workload, while refining the TMB procedure.
2. The second stems from the acknowledged intrinsic limitations of procedure and from the need to resort either to an alternative method or at least to a complementary one for more precisely monitoring cerain sensitive areas.

Concerning the first point, which was comprehensively discussed in (3), it should only be pointed out that the the TMB procedure was drawn up in a restrictive and "instructive" manner in order to make it easy to use. On the other hand, operators sometimes have difficulty in classifying transients, and all the more so as the list of design conditions only includes a limited number of transients. Furthermore, these are assumed transients, a grouping of actual transients of the same type. Another difficulty derives from the fact that monitoring relied on standard detection systems not particularly adapted to monitoring highly stressed areas and sometimes altogether missing.

It is for this reason that a present effort is being made to computerize power plants - particularly the most recent ones. At the same time, procedure is further developed with a view to incorporating functional concepts to complement information provided by sensors.

Still the procedure has limitations:

- For the areas monitored, the method used - which is based on pressure and temperature changes, not taking into consideration stresses - does not make it possible to draw all the benefits possible from monitoring.

It can be of particular value to precisely define the level of fatigue damage reached, particularly when the aim is to prolong the lifetime.

- Some areas or phenomena are not perceived. The surge line of the pressurizer, for example, does not have any detectors that could monitor the shocks it has to withstand (6). Likewise, the stratification phenomena cannot be analyzed.

For all these reasons, EDF has been developing for a number of years now on-line fatigue monitoring devices which are used to make a real-time estimate of the stresses on certain sensitive points and the associated fatigue damage. Such devices (5) can be installed on microcomputers. A prototype has been in operation since the end of 1985 on Bugey 2 charging line; it proves to be more efficient than TMB (Figure 7 shows that the transients estimated by these devices are of less severe nature than those counted by the TMB procedure).

In a second stage, a device of the same type should be installed at the end of 1987 on a pilot unit; this device will monitor specific transients in the pressurizer surge line, an area which is highly stressed by load regulation and load following (6).

6 CONCLUSIONS

The continuous verification of design hypotheses has important consequences. If what is actually observed is more severe than what has been postulated at the beginning, the design analysis must be performed again, or the operating conditions must be modified. In the opposite case, which is the general case, significant savings can be made (particularly in the sense of a reduction of some regulatory requirements).

To carry this still further, with the aim of prolonging the lifetime of power stations, it should be of interest to add to the present overall procedure a more precise, on-line monitoring of certain areas.

REFERENCES

(1) R. Noel & J.P. Mercier. Bookkeeping the operating transient in EDF PWR plants. SMIRT-6 Conference, Paris, 1981.

(2) J.P. Hutin. Reactor pressure vessel integrity and inservice inspection. SMIRT-7 Conference, 1983.

(3) G. Cordier & J.P. Hutin. Suivi en exploitation des transitoires subis par les chaudières REP - Comparaison aux situations définies à la conception (Monitoring during operation of transients undergone by pressurized water reactors (PWRs) - Comparison to conditions defined on design). Journées d'études AFIAP, Paris, October 1986.

(4) R. Noel. Durée de vie des centrales (Lifetime of power plants), Journées d'études AFIAP, Paris, October 1986.

(5) G. Bimont. Comparison between real and design thermal transients in the charging line nozzle of a PWR. SMIRT-6 Conference, Paris, 1981.

(6) J.P. Thomas. Quelques exemples de l'interêt d'enregistrer les conditions de fonctionnement des appareils des chaudières nucléaires (Some examples of the advantage of recording operating conditions for nuclear steam supply system devices). Journées d'études AFIAP, Paris, October 1986.

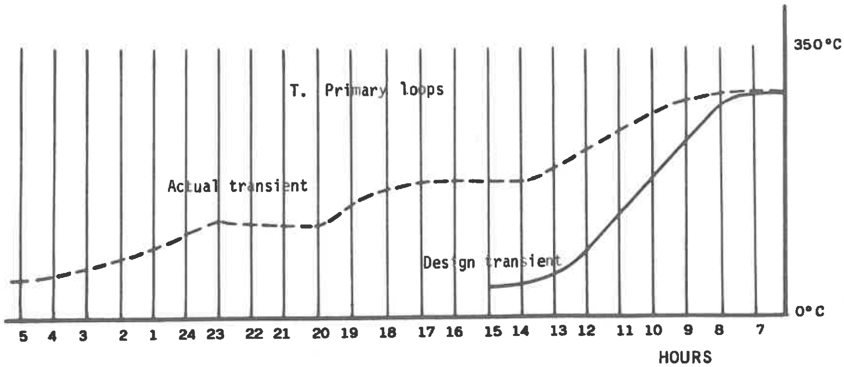


FIG. 1 COMPARISON BETWEEN DESIGN AND ACTUAL TEMPERATURE VARIATION DURING A REACTOR COOL-DOWN AT BLAYAIS 4

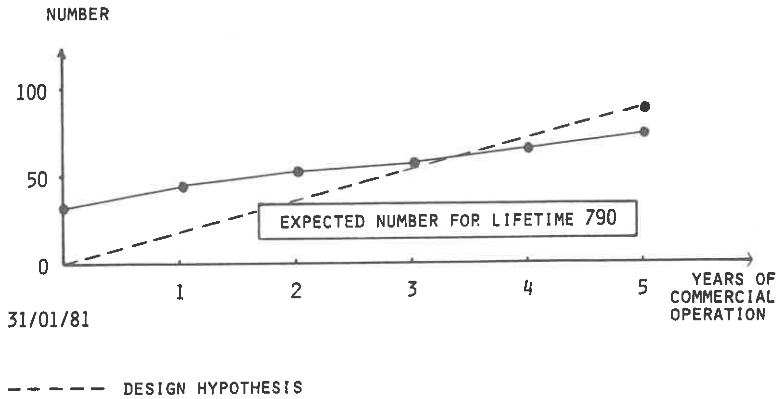


FIG. 2 : COMPARISON BETWEEN ACTUAL NUMBER OF OCCURRENCES OF NORMAL OPERATING TRANSIENTS (EXCLUDING LOAD CHANGES) AND DESIGN PREDICTION AT TRICASTIN 1

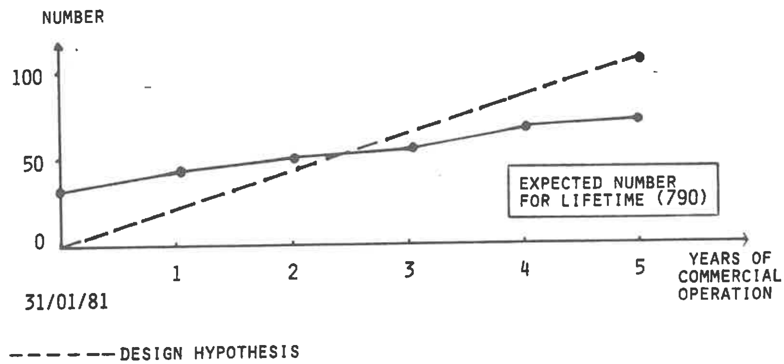


FIG. 3 : SAME COMPARISON AS FIG. 2 FOR ABNORMAL OPERATING TRANSIENTS

FIG. 4 : SAME COMPARISON AS FIG. 2 FOR LARGE LOAD CHANGES (85 % NP)

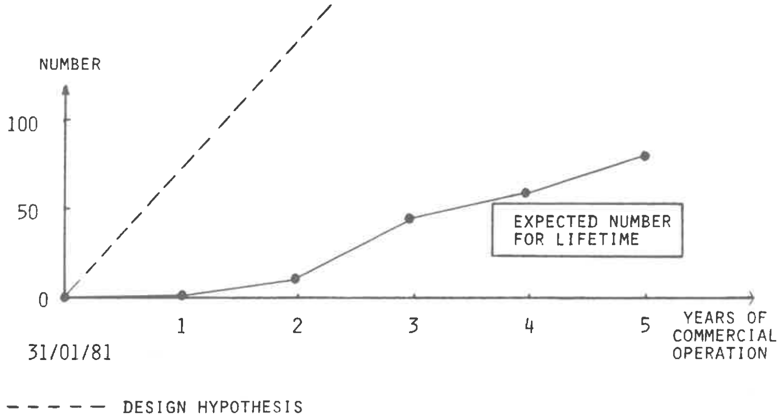
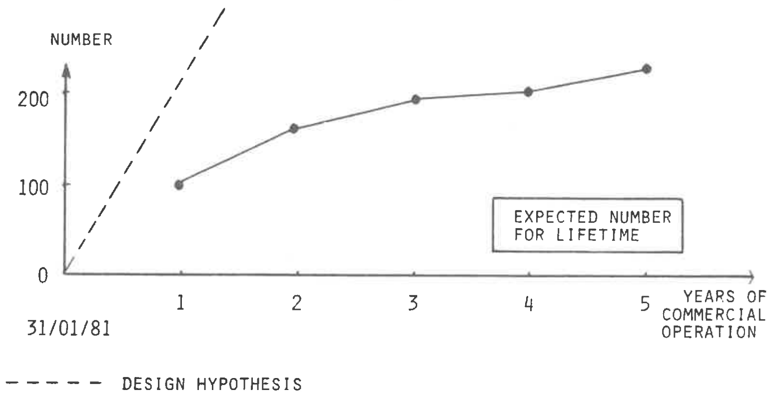
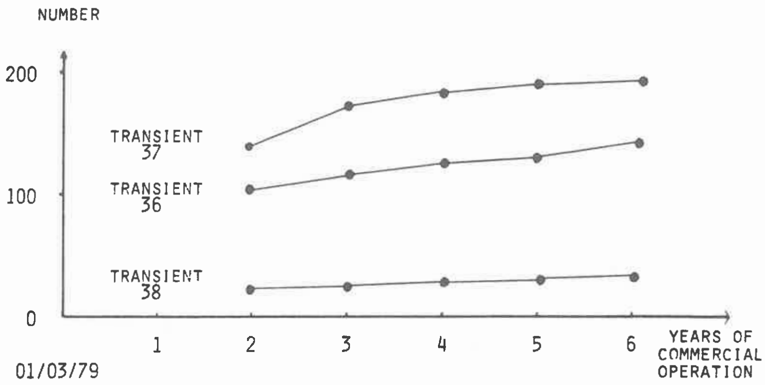


FIG. 5 : SAME COMPARISON AS FIG. 4 FOR SMALLER LOAD CHANGES (50 % NP)





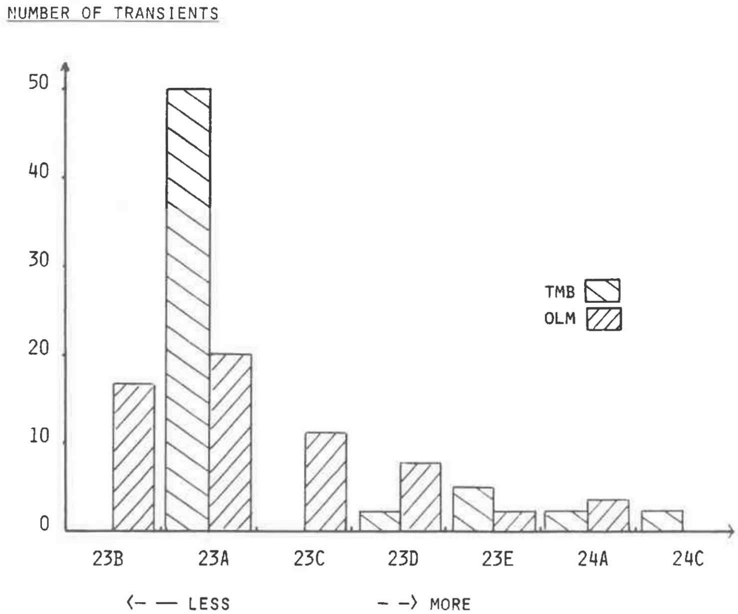
TRANSIENT N°	DESIGN NUMBER OF OCCURRENCES FOR LIFETIME	DESIGN USAGE FACTOR
36	2000	0,045
37	220	0,023
38	200	0,75
AUTRES	48000	0,02
	TOTAL :	0,838

EVALUATION OF ACTUAL USAGE FACTOR FOR 6 YEARS OF COMMERCIAL OPERATION

$$137 \times \frac{0,045}{2000} + \frac{188}{220} \times 0,023 + \frac{29}{200} \times 0,75 = \underline{0,13}$$

EXTRAPOLATION TO 40 YEARS (LIFETIME) : <u>0,54</u>

FIG.6 NUMBERS OF ACTUAL TRANSIENTS ON BUGEY 2 CHARGING LINE NOZZLE



DESIGN TRANSIENTS CLASSIFIED ON A SEVERITY CRITERION

FIG.7 COMPARISON BETWEEN IDENTIFICATION OF 60 ACTUAL TRANSIENTS ON THE CHARGING LINE NOZZLE AT BUGEY 2 BY TRANSIENT MONITORING PROCEDURE AND ON LINE FATIGUE MONITORING.