Regulatory damage monitoring of the liquid metal reactor SUPERPHENIX

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ABSTRACT

At site, regulatory fatigue monitoring of liquid metal reactor SUPERPHENIX is presented. With no special code for this reactor type on hand, the existing pressure vessel regulatory guide has been utilised. A method has been implemented at site. Its characteristics are :
- A total of 36 sensitive structures monitored.
- An automatic surveillance of significant events on the basis of established stress criteria.
- The recognition of events and their assimilation to design conditions.

INTRODUCTION

The French law passed in 1974 imposes on the operators of pressure vessel equipment special tasks supervision of those components. It obliges them to insure that operating transients are neither more severe nor more numerous than those anticipated during design. The plant operator have to hold records of operating transients, available at any time. This law is valid for all French Pressurized water reactor (PWRs). A method was developed to take into account any significant variation of the parameters governing the mechanical behavior of PWRs, where one main parameter (internal pressure) affects, in similar ways, most of the reactor components (see ref. 1)

The liquid metal reactor prototype SUPERPHENIX, although not being a pressure vessel is subject to this regulation.
Due to complex behavior of the main components of a liquid metal reactor, a specific methodology and procedures have been put in place to conform with demands of this regulation. This method, which is actually partially computerized, allows to supervise the damage of some sensitive structures of the reactor.

The damage monitoring of these structures already form the object of several anterior publications (2) (3) and (4). These articles were in general centered around two topics : the detection of significant events and their recognition. These two topics will be resumed and updated with feed-back and improvement actions.

EVENTS DETECTION

It is the first step of sensitive structure monitoring on liquid metal reactor SUPERPHENIX.

Method

The result of a structure's monitoring, for example the external shell of the Above Core Structure in the free level zone is presented as shown in figure 1, when a reactor trip and a start up transient occur on the reactor.
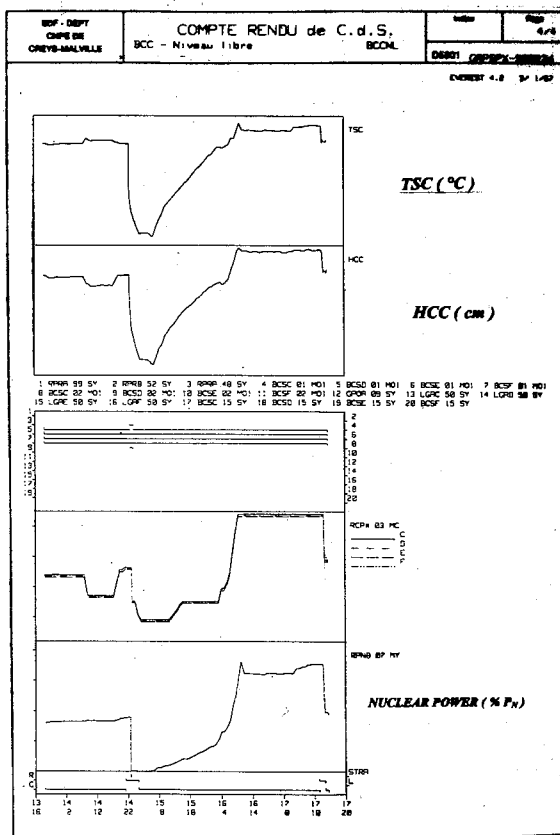

fig. 1. ACS event restitution

This result is not the restoration of a well known reactor state but the result of a detection based on the continuous stress assessment from parameters monitoring (for instand, for the external shell of the Above Core Structure in the free level zone, parameters are the hot plenum temperature, TSC, and the free level position, HCC, see fig.1).
Figure 1 shows that a criterion has been exceeded and was the occasion for a recording of parameters inducing stresses.

This criterion is, in agreement with the French Safety Authorities, the following :

An event is significant (and therefore, according to regulation, has to be analyzed and accounted) when it has induced in the monitored structure a significant stress range.

This definition is very important because it governs all the methodology of supervision. This methodology consists in calculating on-line a stress range increase induced by a variation of parameters governing the behavior of the monitored structure.
For each monitored structure, parameters and physical phenomena are very different. For example, the effect of a Steam Generator dry-out is not the same near the external shell of the Above Core Structure as near the steam generator water inlet sleeve. Therefore, the monitoring is individualized, structure by structure, or equipment by equipment.
This monitoring is independant of the states of the reactor. It detects and restores all the periods during which the considered structure has been submitted to a significant stress variation.

In agreement with the French Safety Authorities, the significant stress range was set as the stress range which would produce, in the cyclic fatigue analysis of the structure, a fatigue damage equal to 10^{-6}, i.e. the stress range $\Delta\sigma$ corresponding to a number of allowable cycles of 10^6 on the design fatigue curve, at the maximum temperature occurring in the structure life-time.

In order to calculate a stress range from a parameter variation, variations have been classified into two categories :

 Fast variations : a fast variation will induce a stress peak due to the thermal inertia of each structure and this has to be taken in account.
A threshold value is determined for each parameter. For a multi-parameter structure, this threshold concept is extended via an « admissible domain » in the space of the parameters variation : the crossing of the border of this domain is equivalent to a threshold overshoot.
A variation is fast when a large paramater variation occurs in a time interval less than « ts », named the oblivion time of the structure for this parameter. The oblivion time is the time interval after which the stress level due to a step-wise variation of a parameter has reached its asymptotic value within 10% of the stress range induced by the variation of the parameter.

 Slow variations : during a slow variation of its governing parameters, the structure is assumed to be subjected to a stress level which depends only on the value of the parameters at the time considered.
The stress tensor at any instant is pre-tabulated from the values of the parameters, and the stress variation between two instants may be calculated.
No oblivion time may be specified. For practical application the search interval will however be limited to the duration of the longest transient expected to occur on the structure (20 hours in Superphénix)

Thermal and thermomechanical finite element calculations were performed to establish connection between stresses and parameters for the two types of variation and for every supervised structure.

Structures monitored by this method are the following :

 * 2 zones of the main reactor vessel : the connecting course and the triple point which receives the core support structures,

* 2 zones of the <u>Above Core Structure</u> : the free level area and the upper brace/shell junction,

* 3 zones of the <u>Intermediate Heat Exchanger</u> : the tube bundle region, the outlet nozzle, and the « Y junction » between the outlet sodium shell and the support structure of the IHX .

* 1 zone of the <u>Steam Generator</u> : the water inlet sleeve.
More, a special creep monitoring is performed for the steam outlet sleeve.
Considering the 8 intermediate heat exchangers and the 4 steam generators, a total of 36 structures is thus monitored. See fig. 2.
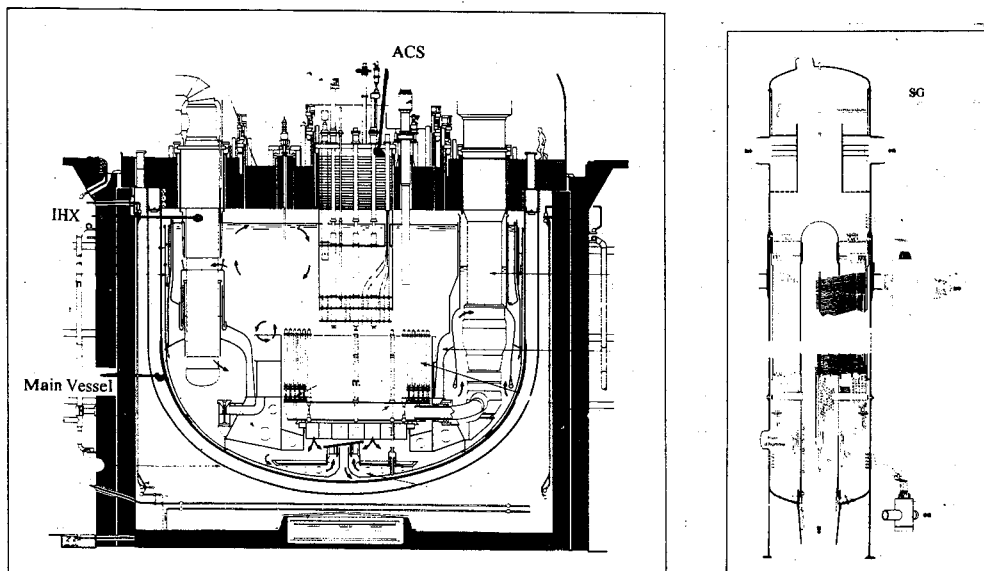

Fig. 2.Monitored structures

Means

This detection step is performed at the power plant site by a software program operating on a HP workstation. See fig.3.

The basic data are a subset of the data used for reactor operation (about one hundred sensors or sensing switches). These data are stored on magnetic tapes (data are presently registered every ten seconds, 60 000 measuring points a week, one tape a week).

Then, the tapes are treated by the software. Sensors data are changed into parameters data governing the behavior of each structure using transfer functions. Periods without significant event are eliminated, which allows to divide, on average, by a factor 15 the measuring points number and therefore the time of processing and the size of the data storage. Structures are processed one by one.

At the end of the processing, data and results are stored on an optomagnetic-disc (a disc every 6 months). A structure of database then allows the publishing of events detected by the

software, or to refer to a list (detected events, treated period, underdata...). Published information is what is necessary for the event recognition.

The currently database contains data and results since the month of December 1986, that is ten years of data acquisition on a same storage type.
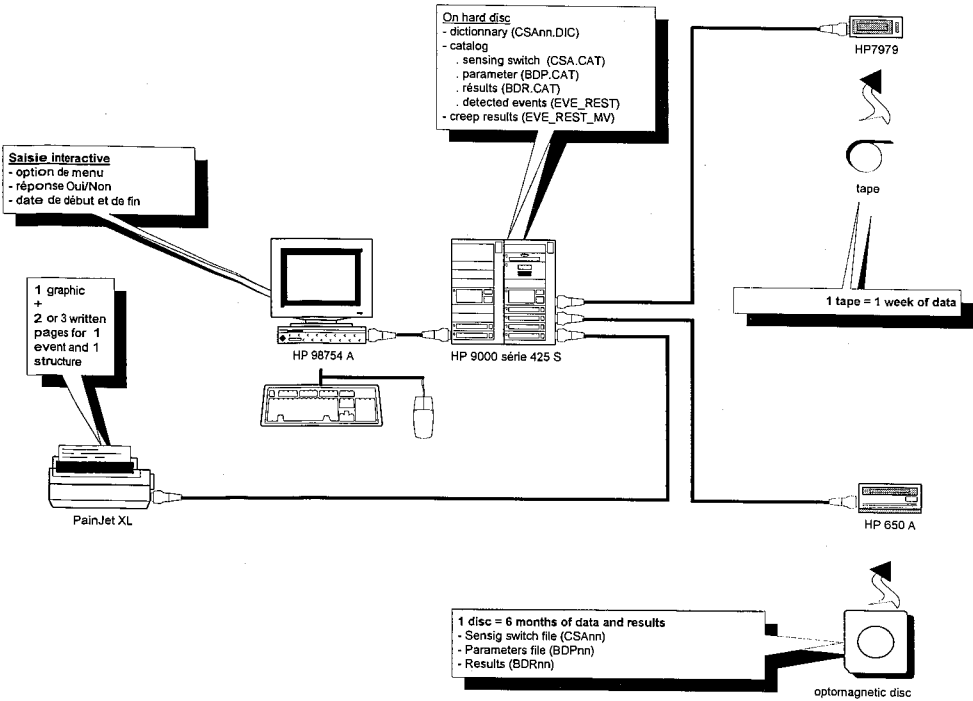
On hard disc
- dictionnary (CSAnn.DIC)
- catalog
  . sensing switch (CSA.CAT)
  . parameter (BDP.CAT)
  . résults (BDR.CAT)
  . detected events (EVE_REST)
- creep results (EVE_REST_MV)

HP7979

tape

Saisie interactive
- option de menu
- réponse Oui/Non
- date de début et de fin

1 graphic
+
2 or 3 written pages for 1 event and 1 structure

HP 98754 A

HP 9000 série 425 S

1 tape = 1 week of data

PainJet XL

HP 650 A

1 disc = 6 months of data and results
- Sensig switch file (CSAnn)
- Parameters file (BDPnn)
- Results (BDRnn)

optomagnetic disc

Fig. 3. Hardware

RECOGNITION AND ACCOUNTING OF DETECTED EVENTS

It is the second step of sensitive structure monitoring on liquid metal reactor SUPERPHENIX.

Method

So as to conform with the regulation, it is necessary to compare events detected to expected conditions.

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For a given equipment, it has been anticipated a list of normal and upset conditions with a number of occurrences for each condition. In the stress report, fatigue damage assessment was performed with detailed calculations of a limited number of conditions, named design conditions (design conditions depend on monitored structure).

This process may be split up into several steps.

The first step consists, if necessary, in cutting up the event. Indeed, a detected event is often the sum of several normal or upset conditions (for example, load change and shutdown) .
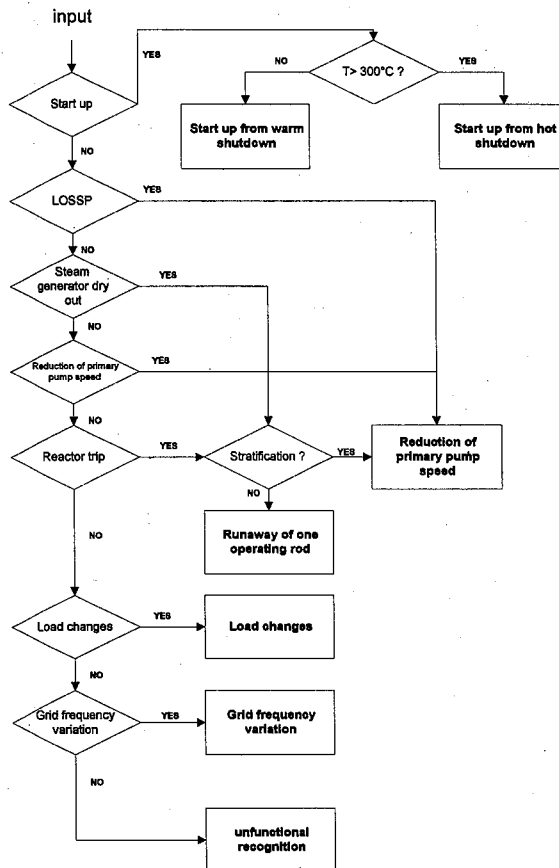

fig. 4. Logical diagram

The second step recognizes the detected event among one of the list of normal and upset conditions and compare it to the corresponding design condition.
This recognition can be functional. The operator examines various indicators (sensing switch or sensor like pump speed, nuclear power...) which characterize the behavior of the reactor

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during the event. From this information, a logical diagram is entered (see figure 4). Then, the operator checks that the detected event is less damaging than the corresponding design condition.

If the functional recognition has not been possible, a set of coefficients is provided and a calculation is performed with the relevant formula. The value of the « severity criteria » thus obtained is compared to the design condition values.

Should the values of the parameter variations exceed the design condition values, the detected event would be sent to the design team for detailed analysis.

The third step is the detected event accounting. Periodic records are issued to summarize the total number of occurrences of each condition encountered on a structure. The comparison between the allowable number of occurrences and the effective number of occurrences accounted is a measure of the fatigue damage of the structure.

Means

Recognition and comparison are not yet computerized. A manual of procedures is used by the plant operator. For each detected event, a file is created, with a complete diagram, a summary of the shift log and an event notice.

The notice is stored on a microcomputer P.C., software ensures the management of allowable occurrences for each structure and publishes boards to send to French Safety Authorities.

All actions are submitted to the Quality System of the plant operator. Plant operating personnel in charge of events accounting are trained and working authorized. Each step of accounting is checked.

Feed-back

The most important feedback of these last years concerns more the usual practice of this method by plant operating personnel than the method itself.

The most important points are the following :

* The method is efficient and operational.
* The more the plant operating personnel knows reactor operation, the easier the work is done.
* To estimate fatigue damage of each structure, one by one, and therefore, to recognize normal or upset conditions from time intervals which contain significant stress range is a difficult task :
- It involves a lot of work due to the management of 32 structures. For example, a reactor trip transient involves recognition and management of 32 events.
- The intellectual process, to go from stress to the operating transient is not an easy task, and in any case more difficult than in the reverse order (operating transient → stress, i.e. the usual process).

Therefore, we are now thinking to optimize events recognition and management. It involves the global understanding of the reactor state, fast analysis and global allocation possibility.

With regard to data processing, improvement can be :
- an automatic recognition of events.
- complete automatic process, from tape processing to the publishing of boards for the Safety Authorities.

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CONCLUSION

This paper has presented the regulatory damage monitoring of the liquid metal reactor SUPERPHENIX .

36 sensitive structures are monitored.
Strict tools and methods have been developed. Plant operating personnel has been trained and authorized.

The feed-back becomes important, actions of optimization are under way.

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