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EDF EXPERIENCE WITH "HOT SPOT" MANAGEMENT

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ABSTRACT

During the past few years, "hot spots" due to the presence of particles of metal activated during their migration through the reactor core, have been detected at several French pressurized water reactor (PWR) units. These "hot spots," which generate very high dose rates (from about 10 Gy/h to 200 Gy/h) are a significant factor in increasing occupational exposures during outages. Of particular concern are the difficult cases which prolong outage duration and increase the volume of radiological waste.

Confronted with this situation, Electricité de France (EDF) has set up a national research group, as part of its ALARA program, to establish procedures and techniques to avoid, detect, and eliminate of hot spots. In particular, specific processes have been developed to eliminate those hot spots which are most costly in terms of occupational exposure due to the need for reactor maintenance.

This paper sets out the general approach adopted at EDF so far to cope with the problem of hot spots, illustrated by experience at Blayais 3 and 4.

INTRODUCTION

Hot spots are very small individual particles which generate high local dose rates. Almost all hot spots in France consist of activated erosion or corrosion products. Seven units are currently affected by this in France:

- Tricastin 1, 1984 - 3rd cycle - 900 MW unit
- Blayais 3, 1984 - 1st cycle- 900 MW unit
- Saint-Laurent B2, 1988 - 5th cycle - 900 MW unit
- Dampierre 3, 1989 - 7th cycle - 900 MW unit
- Cattenom 1, 1989 - 2nd cycle - 1300 MW unit
- Blayais 4, 1990 - 6th cycle - 900 MW unit
- Chinon B2, 1993 - 8th cycle - 900 MW unit

Hot spots have very significant consequences: they affect exposure, increase costs, and lengthen the unavailability of units:

- significant increase in the collective dose for the outage the first year it appears: 50% increase in the collective dose at Tricastin 1, Cattenom 1, and Dampierre 3,

- risks of internal exposure,

- increase in the length of unit outages owing to the need for longer system flushing operations and more delicate maintenance operations,

- increase in maintenance costs, and
- increase in the volume of waste produced.

In order to gain a better understanding of the phenomena involved and to implement the appropriate campaigns, EDF has adopted a dualistic approach to the problem:

- creation of a national group and compilation of good practices from experience feedback ("hot spots" file),
- creation of local groups to apply the strategy to take account of the specific requirements of each site.

The general approach adopted for managing hot spots covers both technical and organisational matters:

- technical, in terms of effective detection and location and using an analysis method to determine the root cause of the problem so that it can be eliminated more easily.
- organisational in terms of making the main players aware of the problem so that effective protective measures can be taken and good practices promoted.

The section below shows how this approach was applied at Blayais Power Plant.

IDENTIFICATION OF THE ROOT CAUSES OF HOT SPOTS: EXPERIENCE AT BLAYAIS 3 AND 4

Blayais 3 and 4 were first linked up to the French national grid in 1983. They are among the small number of French units which, initially loaded with FRAGEMA type fuel, were loaded with ANF assemblies from 1985 onwards in the case of Blayais 3 and from 1986 in the case of Blayais 4. Both units now contain 100% ANF fuel. Since 1984, in the case of Blayais 3, and since 1990, in the case of Blayais 4, Blayais nuclear power plant has been confronted with the problem of hot spots which play a considerable part in increasing exposure during unit outages. In order to remedy these problems, the plant management has, since 1992, adopted an ALARA policy to identify the causes of this high level of exposure and eliminate them, in particular by a policy of dose rate reduction and hot spot elimination.

Detecting and Locating Hot Spots

The analysis of how the hot spots in Blayais 3 and 4 have developed can be summed up as follows:
The first occurrences of cobalt-60 hot spots in Blayais 3 were detected as early as the first unit outage in 1984. They were followed during the fourth unit outage (1988) by large-scale clad spalling, and then in the seventh outage (1991) by the appearance of silver-110 following wear to the clusters and finally by further occurrences of cobalt-60 hot spots in the 1992 outage.

The situation is less complex in the case of Blayais 4. Cobalt-60 hot spots appeared during the sixth and ninth unit outages (1990 and 1993 respectively).

Hot spots are generally propagated in a similar manner in all units. The areas most prone to hot spots are the fuel ponds, reactor coolant system, drainage systems (Reactor Cavity and spent fuel pit cooling and treatment system), systems connected to the drainage systems (blowdown, venting and nuclear drain systems, residual heat removal systems and chemical and volume control systems) and certain systems connected to the reactor coolant system.

Analysis of the Root Cause of Hot Spots

The national working group recommended the following four-stage procedure for discovering the initial metallurgical composition of the hot spots and determine their cause:

1) Analysis of hot spot composition:

   - gamma spectrometry associated with measuring the dose rate upon contact with the hot spot,
   - analysis of dimensions,
   - chemical analysis in the laboratory once the hot spot has been isolated (if it can be isolated).

2) Estimation of the active life and radioactive half-life after activation.

3) Determination of the initial metallurgical composition of the hot spots (using previous results or by consulting a table of ratios of activation products).

4) Search for past events and comparison with analysis results.

At Blayais Power Plant, radiochemical analyses were carried out with the unit in various states: in operation and in outage.

With the unit in operation, peaks appear for the activities of corrosion products in the reactor coolant system, and vary with operating conditions during load following. Gamma spectrometry carried out in recent years has shown a high amplitude in the cobalt-58 peaks (in the region of 100 MBq/m^3) with a cobalt-58: cobalt-60 ratio of less than 5:1.

One other matter worth noting is the simultaneity of the peaks for cobalt, niobium-95, and zirconium-95, which are the main components of the cladding.

It would seem that with the unit in operation, the contamination, which only weakly adheres to the fuel cladding, tends to come away in the coolant flow, taking with it fragments of the cladding.

Several sorts of analyses were carried out with the unit shut down.

Mention must first be made of the contamination measurements taken in the reactor coolant system by means of g spectrometry on the U-tubes, the hot and cold legs and the primary and secondary sides of the steam generators. These measurements indicated a considerable amount of activity deposited in Blayais 4 in the form of cobalt-60, compared with the average for the population of plants; cobalt contamination is presumed to occur between cycles 1 and 7, in view of the evolution curve. Measurements on Blayais 3 indicate a normal quantity of activity deposited in the form of cobalt-60.

Furthermore, specific g spectrometry measurements were carried out during the 93 outage on hot spots consisting of cobalt-60 only (nuclear sampling system, residual heat removal system and reactor cavity and spent fuel pit cooling and treatment system). These analyses showed that contamination propagated through the systems after fuel handling operations during unloading. This meant that contamination in the systems adjoining the reactor coolant system would then probably be spread by movements of water. As a matter of fact, it was found that radioisotopes such as cobalt-60, zirconium-95, niobium-95, and chromium-51 were only found at the bottom of the fuel pond after unloading operations, showing that contamination is caused by flux. Again, it would seem that the corrosion products fixed to the fuel come loose during handling operations, carrying with them fragments of cladding, explaining why hot spots of zirconium-95 and niobium -95 have been observed.

This clearly shows that fuel is a vector in contamination by flux.

Finally, samples were scraped from the cladding of three fuel pins in the reactor building and analysed. In addition to the major components of the cladding (zirconium-95 and niobium-95), no representative quantities could be found of other radioisotopes. It would seem that deposits of chromium and cobalt oxide all come loose during handling operations.

We can therefore conclude that in the lack of other sources of contamination, the situation should improve with time, if reactor building ponds are carefully cleaned. This was observed in Blayais 3, where no more chromium-51 can be found and where there are no new hot spots, just old hot spots carried by the movements of water.

Movements of water are therefore the contamination vector in the absence of flux.

The root causes of contamination are doubtless linked to the degradation of stellite parts which make up certain items of equipment in the reactor coolant system and associated systems:

- wear of the mating surface of certain valves (charging pumps discharge),
- degradation of the mating surface of the self-aligning bearings and anti-rotation pins of reactor coolant pump bearings,
- metal pick-up at the radial keys of reactor vessel bottom internals.

The results of these analyses show that one possible scenario for the cause of contamination at Units 3 and 4 could be:

1. **Stellite contamination,**
2. **Migration of contamination from fuel cladding,**
3. **Loosening of deposits during handling operations (even during operation),**
4. **Spread of contamination by movements of water.**

APPROACH ADOPTED AT THE BLAYAIS SITE TO REDUCE EXPOSURE

System Flushing

System flushing by shift teams and decontamination by the General Service Departments under the co-ordination of the Industrial Safety and Radiological Protection Section are unarguably the major factors in reducing dose rates.

The drains of the nuclear island vent and drain system are flushed at the start of the outage. Further clear improvements in results can be made, where this is possible, by fitting out the low points to optimise venting and by using mobile filtration equipment.

Prior to unloading, the pond drain line is flushed through a filter at the bottom of the pond, depending on the dose rates in the lines. This is a delicate operation; should the filter leak, contamination would spread into the reactor cavity and spent fuel pit cooling and treatment system and the nuclear island vent and drain system.

Still depending on the dose rates, the high-pressure safety injection system, U-tubes and medium-pressure safety injection systems are flushed. One of the sensitive issues is that of flushing the pressuriser surge leg; the pressuriser spray is used to perform this task at the dissimilar-metal weld when draining the reactor coolant system to bring the residual heat removal system to mid-loop operation. Flushing is indirect, and therefore of limited effectiveness.

After unloading, following large-scale contamination of a nuclear island vent and drain system header in the containment annulus (200 mSv/h) for collecting the drains from the U-tubes and safety injection system accumulator tanks, flushing was carried out but proved to be of limited effectiveness since much of the contamination had already become fixed.

Finally, the residual heat removal system was flushed, thereby reducing the ambient dose rate around the heat exchangers by a factor of ten.

Decontamination

As shown above, the bottom of the reactor building pond must be decontaminated after unloading, so as not to spread contamination in the systems.

Other decontamination operations can be carried out. In particular:

- decontamination of the steam generator water boxes using a high-pressure water lance at the beginning of the outage; the exposure cost of this operation is high, and so should only be carried out if the steam generators are highly contaminated or as part of a large-scale maintenance program,

- decontamination of the sump at the bottom of the reactor building with its associated tank; the exposure cost of this operation outweighs the few advantages it might have. A water filtration/circulation system is used for the decontamination, and should be replaced by a mechanical process,

- ultrasonic decontamination of pipework valves; this process gives good results.

Scheduling Maintenance Operations

A considerable reduction in exposure can be achieved by the constant concern during the outage of ensuring that the systems are not dewatered.

In the case of the secondary side steam generators, a schedule is drawn up and distributed to all the relevant persons in charge of maintenance operations to ensure that the operations are carried out with the steam generators full. This good practice will be developed during future outages.

Coordination of Lead Shielding Work

The use of shields can bring about significant dose savings, but care must be taken to ensure that their installation does not entail additional dosimetric costs. Lead shielding work is therefore coordinated during the unit outage in the light of:

- the work planned,
- the various system flushing operations,
- the water levels.

Such co-ordination allows the amount of lead used to be quantified, the points where lead shielding work is systematically carried out to be located, and suggestions for improvement to be made. At the end of the outage, an end-of-job meeting is held with the contractor managers to analyse results and suggest improvements.

Training and Motivating Workers

Doses can be reduced by making the players aware of how they can modify their behaviour on the worksite. When contractors start working at the site they are made aware of the specific radiological protection problems at the unit, and the maintenance workers are taught simple actions for reducing their exposure. A dossier is drawn up for this, containing the following major elements :

- reason for the maintenance work,
- unit background,
- action undertaken by EDF (search for a root cause and a remedy),
- what is expected of the workers,
- actions which will promote experience feedback.

Exposure targets are set and maintenance work is planned in the light of dose rates as early as the joint plant/contractor manager preparation meetings. During the maintenance work, regular meetings are held with the work managers to solve the problems in real time.

An excellent example of this co-ordination involves the services. The services consists of four sections: scaffolding, heat lagging, pond decontamination and cleaning assistance/various decontamination operations. Analysis of the average dose for this area indicated a reduction of almost 35% between 1992 and 1993 through the policy of making the players aware of the problems and as a result of work by the Industrial Safety and Radiological Protection Section in preparing, monitoring and organising experience feedback for worksites.

CONCLUSION

Considerable progress was made with regard to reducing collective exposure during unit outages in 1993. Brainstorming organised by the power plant management, and carried out in close collaboration with the site Operations, Maintenance, Chemistry, General Services and Radiological Protection Departments, reduced the collective dose for Blayais 3 by 20 % and for Blayais 4 by 40 %. Nothing is ever completely certain in this area, and efforts have still to be made.

The program of actions at Blayais Power Plant is centered around two main areas:

- Identification of root causes: it is planned to inspect the radial keys of reactor vessel bottom flushing, and to replace sections of pipe to which contamination has become fixed, and to develop a tool for decontaminating and inspecting the dissimilar-metal weld in the pressuriser surge leg.

Generally speaking, radiological protection is beginning to be recognised in the field as one of the technical components of the problems encountered. This approach should be promoted by adopting a global approach to problems, combining the various specialisms, professions and hence preoccupations, without being detrimental to the quality of interactions between the plants and head office. This would make the most of experience feedback.

Author Biography

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