RADIOLOGICAL OPTIMIZATION IN A REACTOR DISMANTLING PROGRAMME

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ABSTRACT

The dismantling project of the Belgian nuclear testing reactor BR3, which constitutes the object of a CEC research contract, requires the implementation of the ALARA principle on certain important operations. The major operations of the first phase consist of the decontamination of the primary circuit and the cutting of the thermal shield which are now practically terminated. The radiological optimization study is being carried out in collaboration with CEPN (Centre d'Etude de l'Evaluation de la Protection dans le domaine nucléaire, Fontenay-aux-Roses, France).

A general working sheme was developed, consisting of

- the elaboration of an evaluation methodology for the prediction of doses ;
- the identification and comparison of standard and alternative procedures ;
- the follow-up of the doses during the operation(s) and the feed-back to the predictions.

Aiming at the dose predictions, the operations fore-mentioned were subdivided into unitary or elementary tasks, each of them being characterized by its localization, dose rate, work volume or exposure time and an exposure coefficient.

Concerning the decontamination of the primary circuit, certain measures for dose reduction were identified and their influence on the dose predictions evaluated. As a result of the application of these measures and of the experience from the feed-back of early dose measurements, a reduction of 30 % in dose predictions was calculated. The collective doses observed during the execution of the operations differed from the predicted values by less than 20 %.

As far as the cutting of the thermal shield is concerned a special problem will be formed by the generation of secondary wastes (aerosol, scrap...).

INTRODUCTION

The BR3 reactor is a Pressurized Water Reactor with a capacity of 11 MWe and had been operated from 1962 to 1987. Actually the SCK/CEN is dismantling or decontaminating certain parts of the reactor. The Commission of the European Communities selected BR3 as a pilot dismantling project for the 1989-93 R&D programme on the decommissioning of nuclear installations. The phases of dismantling/decontamination envisaged or completed until now, include :

- the decontamination of the primary circuit
- the cutting and elimination of the thermal shield (phase 1)
- the segmentation of the lower and upper core support assemblies and of the reactor vessel collar (phase 2)

The total contamination distributed on the inner surface of the primary circuit was estimated at 7 to 11 TBq before decontamination. The main contributors were Co-60 (≈ 80 %), Cr-51 (10 %), Mn-54 (5 %) and Co-58 (4 %). Specific β γ activities were comprised between 200 and 1000 kBq/cm^2. Concerning the reactor vessel (Fig. 1) the neutron-induced activitity of the lower and upper core support plates and the thermal shield is very high. For the thermal shield it amounted to 32-87 MBq Co-60/g and 1.0-3.6 MBq Mn-54/g at mid 1989. The activation of the reactor collar is very low due to its great distance from the reactor core.

ORGANIZING RADIOLOGICAL OPTIMIZATION (ALARA)

In recent years the SCK/CEN has done much effort in the field of radiological optimization (ALARA). The effective dose constraint at the SCK installations has been set at 20 $mSv.y^{-1}$ following international trends of reducing professional dose limits. Evaluations are being made of the feasibility to lower dose constraints still to 10 $mSv.y^{-1}$.
A project has been set up, including formation of staff members of SCK in ALARA procedures and radiological optimization studies in specific fields. Objects of such studies have been selected in the field of nuclear site restoration and in the field of the dismantling operations at BR3. However not the dismantling as a whole will be envisaged ; only specific parts of it will constitute the objects of the optimization.

Until now radiological optimization has been mainly involved in some large stereotype projects in the field of maintenance at nuclear power stations such as the replacement of steam generators. A dismantling project shows special features while all operations are only executed once. The CEPN (Centre d'étude sur l'évaluation de la protection dans le domaine nucléaire) has been contracted to execute the formation task and to support the radiological optimization of some specific dismantling operations.

DECONTAMINATION OF THE PRIMARY CIRCUIT

In the framework of the decontamination of the primary circuit of BR3 the tasks executed in collaboration with CEPN concerned :

- the choice of the decontamination process from a radiological optimization point of view

- the application of an evaluation methodology for the prediction and analysis of doses
- the organization of follow-up of job-related doses during the operations
- the feed-back from observations to predictions and the drawing of lessons from the experience.

In this stage, the optimization know-how being limited and the procedure of decontamination being nearly determined, based upon the experience of the 1975 decontamination, the identification and comparison of standard and alternative procedures for optimization purposes has not been worked out.

Concerning the choice of the decontamination process, technical requirements already reduced potential processes to LOMI (Low State Transition Metal-ion reagents) and CORD (Chemical Oxidizing Reducing Decontamination). From the point of view of radiation protection and efficiency the two processes were very similar. Nevertheless CORD was designed as the better one since it yielded lower waste volumes. During this evaluation it was also pointed out that irrespective of the decontamination process the potential for workers'exposure is more important during the preparatory phase, when checking the installation and verifying valves, pumps ... (several years after the last outage !), than during the decontamination itself.

The methodology for the prediction and analysis of doses was based upon the principle of dividing the operations into elementary tasks, each of which being characterized by the geographical zone, the dose rate and the volume of work (man.h). The persons required for each elementary task were to be characterized by their speciality (expertise), working conditions and exposure coefficient (the ratio between his individual exposure dose rate and the representative value for the zone). For the calculation and analysis of dose values in this way, the computing programme DOSI ANA of CEPN was applied.

The decontamination of the primary circuit has been divided into approximately 100 elementary tasks, 90 of them being preparatory operations. A first prediction of the total collective dose amounted to 0.199 man Sv, 0.195 man Sv being due to the preparatory phase. From the analysis of the predicted dose some important conclusions could be drawn. Considering an annual individual dose limit of 20 mSv and the different types of expertise required, a total number of 14 technicians were to be provided for, 9 persons of which could reach the annual dose limit within a period of 3 to 4 months. The individual reference level of 2 mSv $month^{-1}$ was foreseen to be exceeded or attained for a number of 20 elementary tasks.

During execution of the tasks the following-up of doses was carried out applying job-related dosimetry. In that time the dosimeters used were stylo-type ones ; it was recommended that more precise, electronic devices should be applied manageable with processor and PC. With one third of the

elementary tasks executed, the comparison between predicted and measured doses showed an O/P ratio of 0.85. However differences between predictions and observations were considerably higher for some elementary tasks.
At that time it was decided to undertake some dose reduction measures such as the use of biological shielding (lead, wool) on the reactor cover, the filling of some components of the circuits with water and the reduction of the number of bolts to be applied on the reactor cover, which lowered dose predictions with 25 %. Especially the last measure was very effective in this respect.
From the following-up of the job-related doses so far it was also learnt that for rather immobile positions on the operating deck, dose rates had been underestimated and for rather mobile tasks on the pool-bottom the influence of near-by sources overestimated. The correction of these erroneous assumptions yielded another net decrease in predicted doses of 5 %.
A new prediction of doses was then made and a collective dose of 0.142 man Sv was calculated.
The predicted and observed doses are graphically depicted on Fig. 2. As may be noticed the difference between the second prediction and the observations is very small (observed dose: 0.140 man Sv). Decontamination factors between 2 and 16 at various reference points on the primary circuit have been obtained.

CUTTING OF THE THERMAL SHIELD

The cutting of the thermal shield of the reactor has been executed with three techniques in order to gain experience for further segmentation operations. These operations are : electro erosion (in-situ) ; mechanical sawing (in-situ) ; plasma torch (in separate chamber).
Some characteristics of these techniques with respect to the cutting of the thermal shield are indicated in the following table.

	time for cutting 1 m	width of the cut	waste produced for cutting 1 m
electro erosion	29 h	7 mm	4.2 kg
mechanical sawing	2.5 h	4 mm	2.4 kg
plasma torch	3.3 min	11 mm	6.5 kg

Also for these operations a real optimization study could not be started, because of the requirements for technical experimentations which reduced the number of options that could be taken into account considerably, and because of the late introduction of optimization considerations in the planning. It was then decided that experiences from phase 1 and phase 2 operations be used to develop and improve equipment and procedures needed for optimization purposes.
One of the items which had to be improved concerned the

follow-up of job-related doses. Therefore an electronic computerized dosimetric system (GAMMA COM) was put into service. With this system, indications about residence times at different ambiant levels of radiation can be obtained.

However in the optimization process for the cutting operations not only external dose rates are important. Other radiological factors such as exposure through other pathways and the generation of waste are very important. During the cutting operations important quantities of solid and liquid waste are generated. These include not only the cutted segments but also secondary waste such as aerosols, ions dissolved in the water, scrap, dross, etc... The finer forms of waste can give rise to internal contamination of the operators if not adequately filtered.
The whole package of secondary waste (including filters and resins used for purifying air and water) pose a problem of collection, transport and disposal. The way of solving this problem may also be subjected to an optimization study. Potentials for exposure due to accidental releases have also to be taken into account.

The follow-up of the cutting operations revealed some elementary potentials for dose reduction :

- the unnecessarily high number of personnel present at the working place during certain operations
- the additional number of manipulations which were necessary because of the unavailability of the transport container for the waste in due time
- the obstruction of the working place with equipment and waste offering potentials for accidents and increasing working times

CONCLUSIONS

- For all phases of the dismantling operations at BR3 executed so far, the radiological optimization considerations have been introduced too late. In order to be able to conduct the optimization in an efficient way it must be taken into account from the very beginning.
- Although an efficient optimization has not been possible some interesting experience was gained and important conclusions were derived from the dose prediction and analyses for some operations (e.g. with respect to the number of operators-technicians being necessary .
- The necessity or desirability of the presence of an ALARA coordinator at the site was experienced.
- Radiological factors other than external doses are also to be allowed for in the optimization process (internal contamination, quantities of waste, potentials for exposure).

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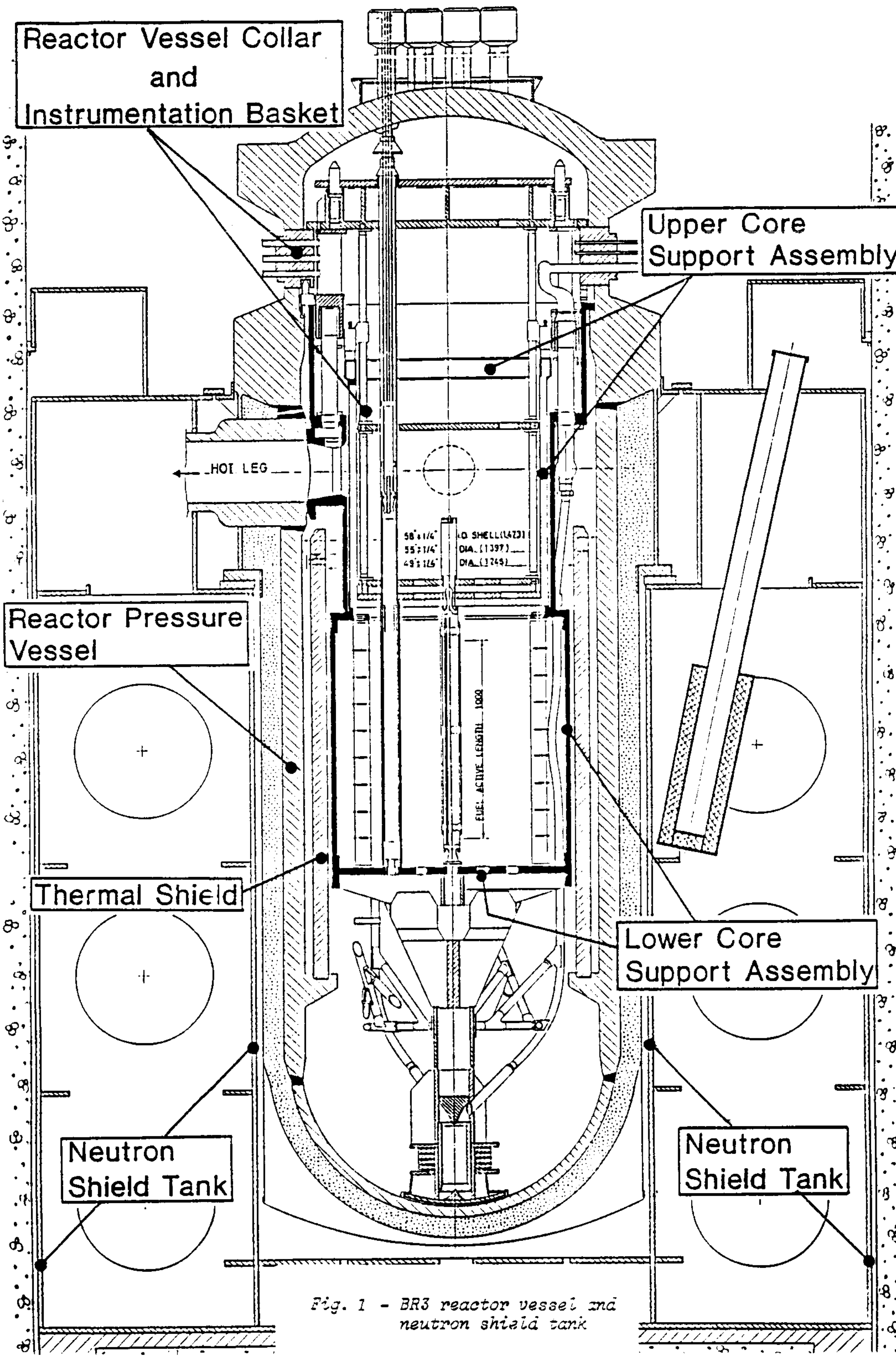

Fig. 1 - BR3 reactor vessel and neutron shield tank

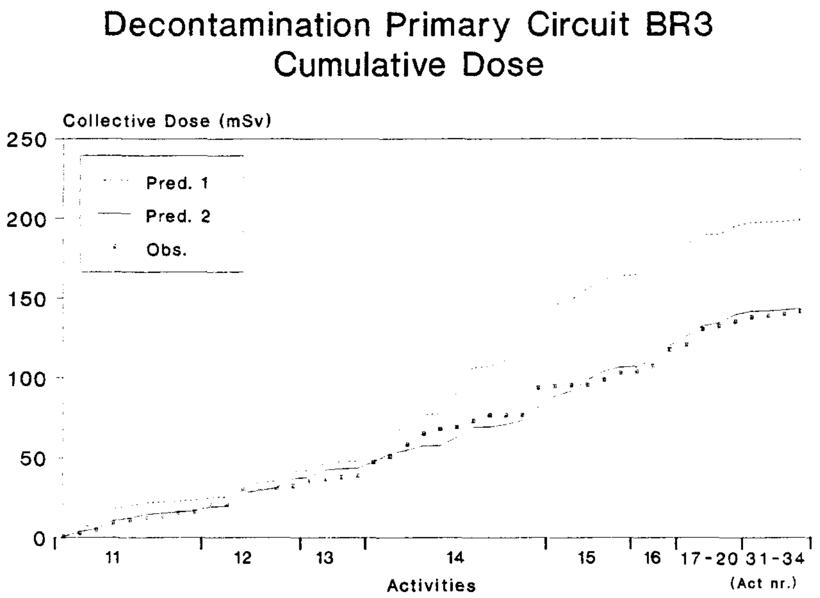

Fig. 2. Comparison of observed and predicted collective dose equivalents.

LEGEND : ACTIVITIES

11 Preparation of the working place
12 Replacement of seals
13 Closing of the reactor vessel
14 Placing and thightening of the bolts
15 Checking of the circuits
16 Modifications of the circuits
17 Filling and venting of the circuits.
18+19 Measuring dose rates
20 Hot run test
31-34 Execution of the decontamination