DEVELOPMENT OF A DOSE DATABASE IN THE REFUELLING SCENARIO OF A NUCLEAR POWER PLANT FOR A VIRTUAL REALITY APPLICATION

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1. INTRODUCTION.

Operators in Nuclear Power Plants can receive high doses during refuelling operation. A training program simulating refuelling operations will be useful to reduce doses received by workers as well as to minimise operation time.

With this goal in mind a Virtual Reality application is developed in the frame of CIPRES Project (**C**álculos **I**nteractivos de **P**rotección **R**adiológica en un **E**ntorno de **S**imulación - Interactive Calculations of Radiological Protection in a Simulation Environment), a R&D project sponsored by IBERINCO and developed jointly by IBERINCO and the Nuclear Engineering Department of the Polytechnic University of Valencia [1].

The Virtual Reality application requires the possibility of displaying doses, both instantaneous and accumulated, at all times during the operator training. Therefore, it is necessary to elaborate a database containing dose rates at every point of the refuelling plant. This database is elaborated from Radiological Protection Surveillance data measured throughout the plant during refuelling operation [2, 3].

To estimate doses throughout the refuelling plant some interpolation routines have been used. Different assumptions have been adopted in order to perform the interpolation and obtain consistent data.

In this paper, procedures developed to elaborate the dose database for the Virtual Reality application are presented and analysed.

2. ANALYSIS OF THE REFUELLING.

Prior to dose calculations, operations carried out and operator activities during refuelling should be analysed [4]. As a result of this analysis, the refuelling operation is divided into 50 stages: 26 for the vessel opening; 3 for the fuel movement and 21 for the vessel closing. This division facilitates dose calculations as it permits the discretization of the time variable, and it is also useful for the design of the Virtual Reality application.

Operations with special relevance in the refuelling process have been taken into account for the selection of stages. Special interest has been focused on the operations with greater radiological impact.

Every stage has been further divided in procedures that correspond to individual actions, necessary to accomplish successfully the corresponding stage. Finally, operators are assigned to those procedures in fixed points throughout the refuelling plant. However, restricted movements of the operators throughout the whole plant should be considered in the refuelling simulation. Thus, dose calculations should be made for the entire plant rather than for fixed positions of operators. That is, a wide set of points covering the entire refuelling plant will be considered for dose calculations.

Furthermore, this method facilitates the application of a general calculation model. On the other hand, both instantaneous and accumulated doses received by operators should be known at any moment during the training. Therefore, doses must be estimated for each stage of the refuelling.

3. CALCULATION METHOD.

Data used for the elaboration of database tables are based on the Plant Radiological Report. A set of ALARA records is taken from the Radiological Surveillance Recording. These records contain the dose rate measurements periodically made during refuelling operations at different points all over the refuelling plant.

Dose rate should be estimated from these measured values for a set of points covering the whole refuelling plant, distributed in a square mesh with 200 mm pitch. Only two different positions in height are considered: that of the refuelling plant and the reactor pool floor. It has been supposed that both auxiliary and refuelling platforms are sited at the level of the refuelling plant. Therefore, an x, y, z lattice is considered, with only two values for z, x and y being the coordinates of the lattice nodes covering the plant.

Time variable has been discretized, so that calculations have been performed for each stage considered in the refuelling, supposing that dose rates do not vary during the whole stage.

The calculation of the dose rate is carried out by means of linear interpolation applying the computer program MATLAB [5]. A 3-D routine has been used corresponding the three dimensions to coordinates x, y of each node, the third dimension being the calculated value of the dose rate.

The linear method has been chosen for interpolation despite the sudden variations shown in results (calculated doses). The cubic method, presenting softer variations, has the inconvenience of a higher uncertainty in results, with higher maximum values and lower minimum values that even fall down below zero.

4. ANALYSIS OF THE INPUT DATA.

In order to adapt dose rate values contained in ALARA records to each refuelling stage a detailed analysis of the radiological surveillance data is necessary before preparing the input deck for MATLAB.

In many situations it is reasonable to think that dose values measured at a point can still exist some time after the measurement is made, so that they can be extended. Therefore, in each stage one can use not only data from Radiological Surveillance records corresponding to this stage, but also those records from previous stages. For instance, when vessel head or internals are settled on the plant, it can be expected that measured doses remain during some time. In fact, it can be applied to many points where changes in dose are not expected. With this hypothesis, the number of input data is increased and the interpolation improved.

A major problem in obtaining correct input data (dose rates) for interpolation is the lack of data, mainly on the walls and external zones of the refuelling plant. Thus, some hypotheses are established in order to assign dose rate values to those points of interest where measurements were not performed. Some auxiliary dose estimation may be necessary as well as other calculations to confirm the adopted hypotheses. Both hypotheses: extension of dose values and assignment of dose rate for points of interest, have been shown very effective to enhance interpolation results with actual doses. Really, it becomes essential to have appropriate values of dose rates in outer nodes of the mesh.

Finally, a special attention should be given to areas with extremely high values of dose rate, the so called hot spots. The most relevant ones are the waste drums and the filtering equipment of the reactor pool water.

Hot spots are not usually accessible to operators and are surrounded by a shielding barrier, e.g. lead slabs, that reduces doses to values close to background. Therefore, dose rate values measured at hot spots should not be included in the input data deck, even being actual values, since they do not contribute properly to calculations for two reasons. First, the operator will not usually be permitted to stand in these sites. Second, the interpolation will produce high dose rate values around hot spots and they can be overestimated due to shielding.

Thus, measured exact values have been introduced for hot spots, but area dose rate values have been assigned to the next points, representing the true situation caused by shielding.

5. RESULTS.

When the MATLAB program is run to perform interpolation, for each stage a table containing dose rates calculated in each node of the designed lattice for the refuelling plant is obtained. The MATLAB program also allows the obtaining of a graphic representation of results, which is very useful to adequately interpret them and to give an appropriate feedback, if any, for input data.

The dose rate map obtained for the stage 15 “Removal of the vessel head” can be seen in figure 1. The situations at the beginning and at the end of this stage are represented in figures 2 and 3 respectively.

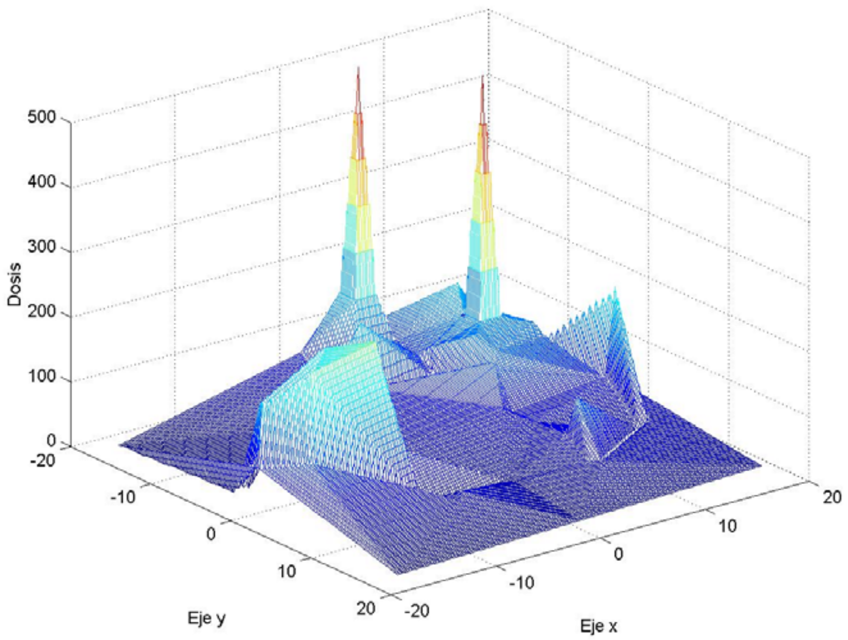

Fig 1. Dose map during the “Removal of the vessel head” stage.

One can see at the back of the graphics in figure 1, two dose rate peaks corresponding to the mentioned hot points: filtering equipment for the reactor pool water and waste drums. Also shown in the graphics is the higher dose rate produced by the drywell head deposited on the refuelling plant during a previous stage. Finally, the dose rate due to the vessel head when it is deposited onto the plant can be also seen at the right back of the graphics.

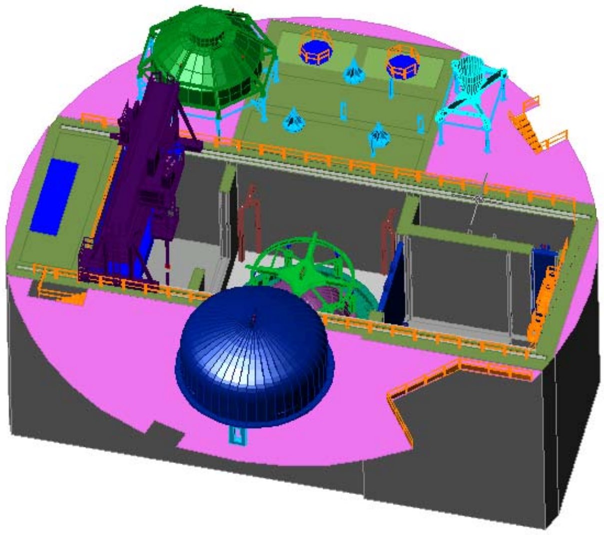

Fig 2. Plant situation at the beginning of the “Removal of the vessel head” stage.

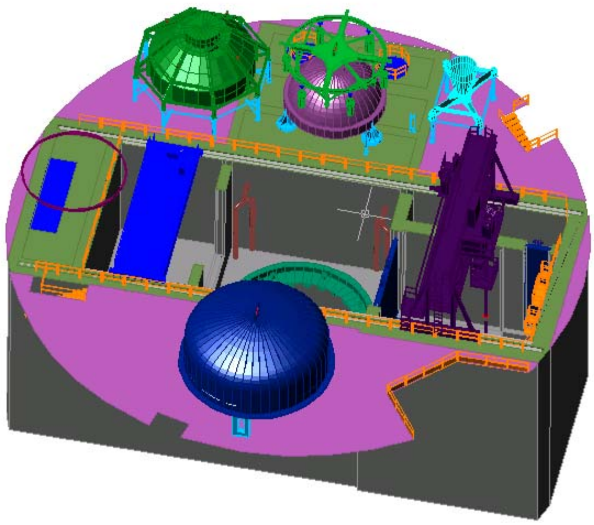

Fig 3. Plant situation at the end of the “Removal of the vessel head” stage.

Results obtained with MATLAB are exported into a spreadsheet where they are appropriately elaborated and finally exported into an ACCESS database [6] that will be incorporated into the CIPRES application [1].

A view of the refuelling plant as presented by CIPRES Virtual Reality application during the mentioned stage can be seen in figure 4. Users of the application can change and/or move operators in the Virtual Reality environment [7].

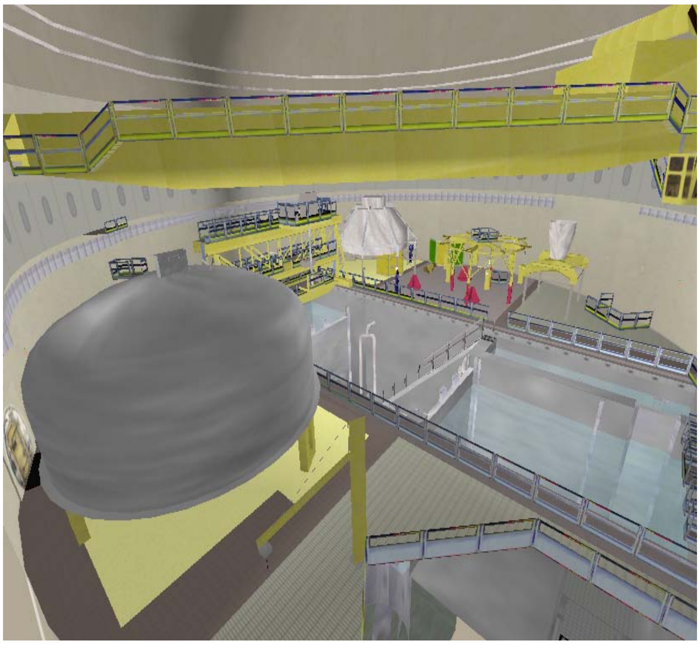

Fig 4. Virtual Reality view of the refuelling plant during the "Removal of the vessel head" stage.

Operators during their training using the CIPRES Virtual Reality application can see a screen such as that presented in figure 5. Once more we are presenting the stage when the vessel head is removed. In this case, the procedure when the strongback is fixed on the vessel head.

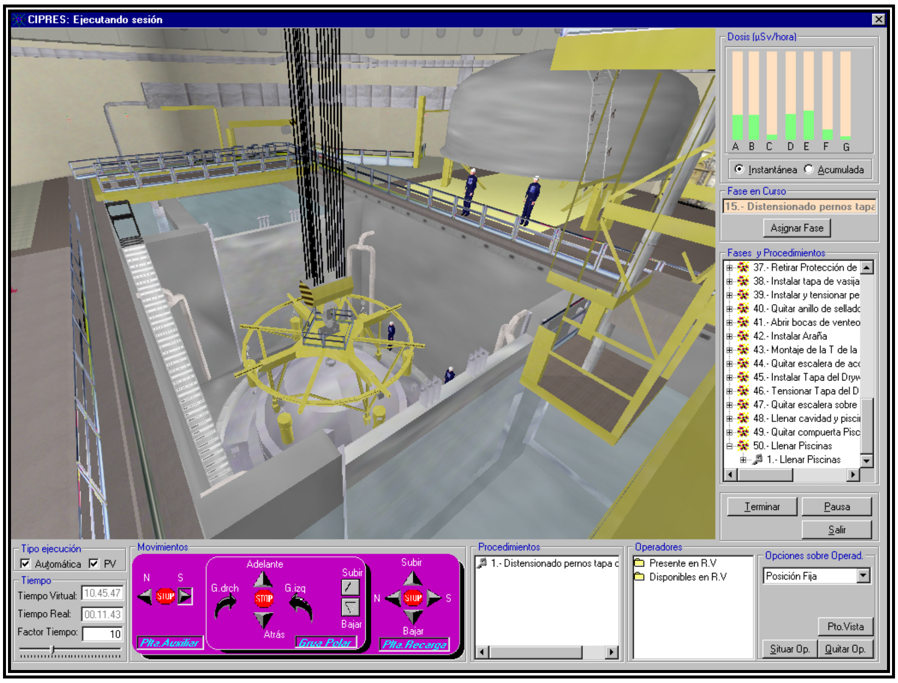

Fig 5. CIPRES application screen.

Finally, a coloured map showing dose received at each stage can be obtained from CIPRES. For the repeatedly used stage 15 one can see in figure 6 the instantaneous dose all over the refuelling plant. User can switch from instantaneous to accumulated dose just pressing a button.

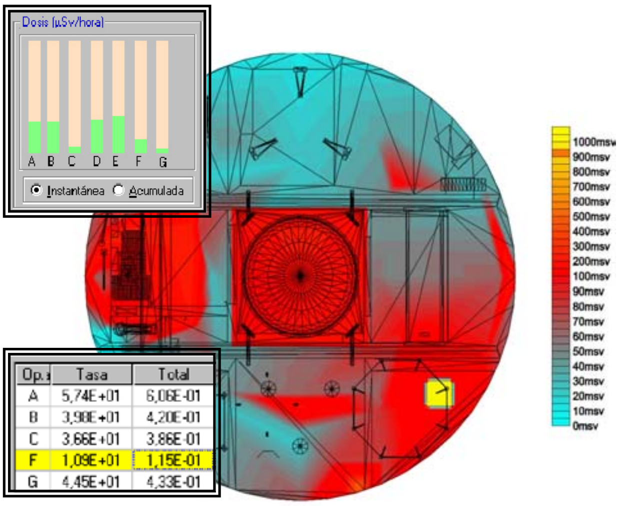

Fig 6. View of the dose map generated by CIPRES for the "Removal of the vessel head" stage.

6. CONCLUSIONS.

A database containing the dose rate values potentially received by an operator during refuelling operations in a Nuclear Power Plant has been satisfactorily elaborated, starting from data provided by the Plant Radiological Report.

Refuelling procedures are classified into stages and an exhaustive analysis of each stage has been performed in order to overcome those difficulties due to diversity of data and its irregular location through the refuelling plant. Some hypotheses have been introduced in order to extend the validity of some dose rate measurements and to assign dose rate to points of interest that allow one to obtain results in good agreement with measurements.

Dose rate calculations can be optimized with an enhanced planning of the Radiological Surveillance in order to obtain more accurate dose rate values for some points of interest.

The analysis of hot spots allowed us to isolate them, considering the actual dose rate received by operators. This analysis can be completed with various shielding calculations.

The obtained dose rate tables have been successfully included in the CIPRES Virtual Reality application. During the operator training using this application both instantaneous and accumulated dose can be viewed on screen.

The CIPRES application is a powerful tool for the training and education of operators, first of all for the implied dose savings, which consequently produce a time saving and, obviously, an economic saving too.

Furthermore, the philosophy of the application, in particular dose calculation, can be applied to other operations performed in nuclear or radioactive installations, both industrial and medical.

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