

# Generation of dose databases for an operator training application in nuclear facilities

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## Abstract

Operators in nuclear facilities can receive high doses during some operations. An operator training application for simulating those operations will be very useful for reducing doses received by workers as well as minimising operation time. On this subject, a Virtual Reality application was developed jointly by IBERINCO and the Nuclear Engineering Department of the Polytechnic University of Valencia to simulate refuelling operations in Nuclear Power Plants with the goal of operator training. An application of this type requires to know doses, both instantaneous and accumulated, at all times during operator training. Therefore, it is necessary to elaborate a database containing dose rates at every point in the plant. This database shall be based on Radiological Protection Surveillance data measured in the plant during previous operations. In this paper, the procedures developed to automatically obtain the desired dose database from selected input data for the operator training application are presented and analysed.

## 1. Introduction

One of the most critical operations in Nuclear Power Plants from the radiological protection point of view is refuelling as operators can receive high doses during this operation. A training program simulating refuelling operations will be a useful tool for both reducing doses received by workers (ALARA principle) and minimising operation time.

In this sense, a Virtual Reality application has been developed [1, 2] within the framework of the CIPRES Project (Cálculos Interactivos de Protección Radiológica en un Entorno de Simulación, i.e. Interactive Calculations of Radiological Protection in a Simulation Environment), an R&D project sponsored by IBERINCO and developed jointly by IBERINCO and the Nuclear Engineering Department of the Polytechnic University of Valencia.

The Virtual Reality application requires the possibility of displaying doses, both instantaneous and accumulated, at all times during operator training. Real time calculation of these doses will require a huge computational power. Therefore, it is necessary to set up previously a database containing dose rates at every point in the refuelling plant that could be received by operators. This database is based on Radiological Protection Surveillance data measured throughout the plant during refuelling [3, 4, 5]. A computational application has been developed to manage data and make up the final database. A set of routines has been implemented in order to generate the dose database tables required.

## 2. Calculation Method

In order to allow the movement of operators throughout the whole plant in the training program, dose calculations should be made for the entire plant rather than for fixed operator positions. Thus, a wide set of points covering the entire refuelling plant, distributed in a square mesh, has been considered for dose calculations. Dose rates have been estimated from measured values for this mesh of points.

Two main assumptions have been assumed:

- Time variable has been discretized, dividing the refuelling operation into stages. Calculations have been performed for each stage considered in the refuelling, assuming that dose rates do not vary during the whole stage.
- Only two different positions in height have been considered: that of the refuelling plant and the reactor pool floor. Therefore, two different x, y, z lattices have been considered for each stage, with a constant value of z for each lattice.

The calculation of the dose rate is carried out by means of linear interpolation applying the computer program MATLAB. 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 MATLAB program allows a graphic representation of results, which is very useful for their correct interpretation and to give appropriate feedback, if any, for input data. Figure 1 shows the dose rate maps obtained with Matlab at the end of the removal of the vessel head.

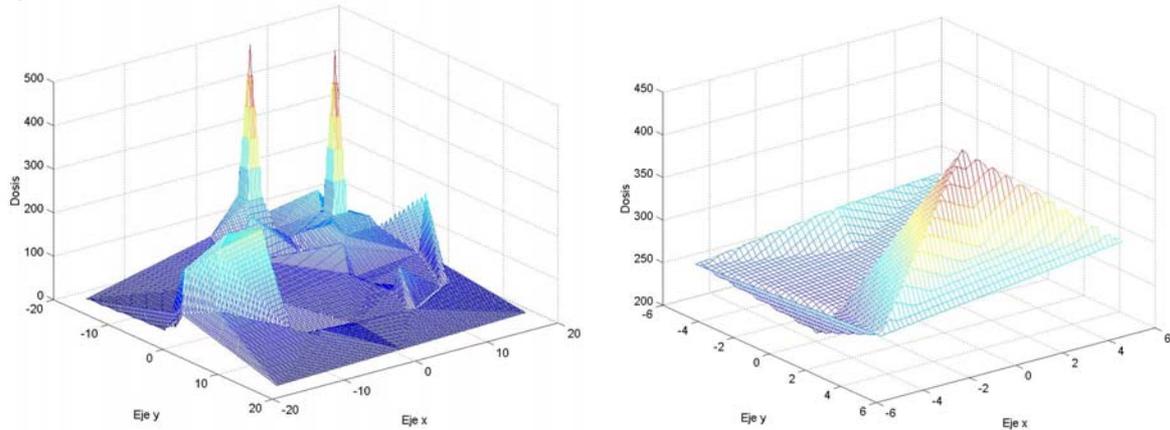


Fig. 1. Dose maps at the end of the removal of the vessel head. Left, refuelling plant level. Right, reactor pool level.

The most important task is to decide which are the most suitable points for dose rate measurements, in order to optimize the generation of the dose database. This implies a thoroughly revision of all procedures involved in the refuelling operations. Data available from Radiological Protection Surveillance records are usually scarce and its distribution in the plant is not the most appropriate. Interpolation methods demand the most external points in the plant being well defined in order to carry out the interpolation calculations towards the interior of the refuelling plant. Therefore, new points have been proposed for compulsory measurements at outer nodes of the mesh. Moreover, a square mesh including the entire refuelling plant is required by interpolation routines. However, the plant is circular, and consequently some virtual points are introduced such as corners of the square mesh outside the plant, where measurements are obviously not possible. These points require dose data, which have to be calculated introducing some hypothesis and implementing some routines in Matlab. The application runs in a sequential way such as it is represented in the scheme of figure 2. First, all routines implemented in Matlab are executed. A table containing dose rates calculated in each node of the designed lattice for the refuelling plant is obtained for each stage. Data generated by Matlab are later treated in Excel by means of a set of macros and when the run is finished, new dose tables are generated and incorporated to the database within the CIPRES application [4, 5, 6].

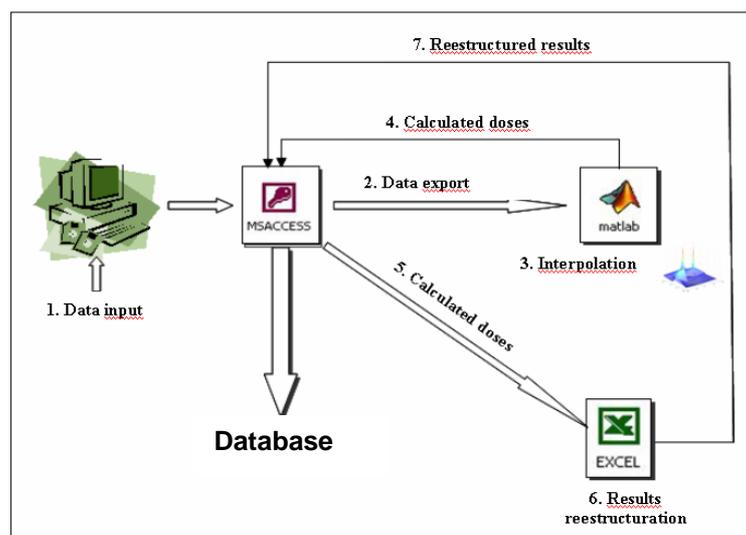


Fig. 2. Outline of the sequence followed for the generation of the dosimetric databases

### 3. Development of the application

The calculation of the dose rate has not only been optimized for the database required by the Virtual Reality application, but rather the execution of these calculations has also been automated. So the dosimetric database can be completed with data belonging to other refuellings, whenever it was necessary.

With this purpose, an Access application has been developed [7, 8], managing the whole process of creating databases. The power provided by queries, macros and visual basic modules makes an easy programming, and the calculation process will be more automatic, minimising user intervention. The application has been fully implemented under a Windows environment. The main window of the application is represented in figure 3.

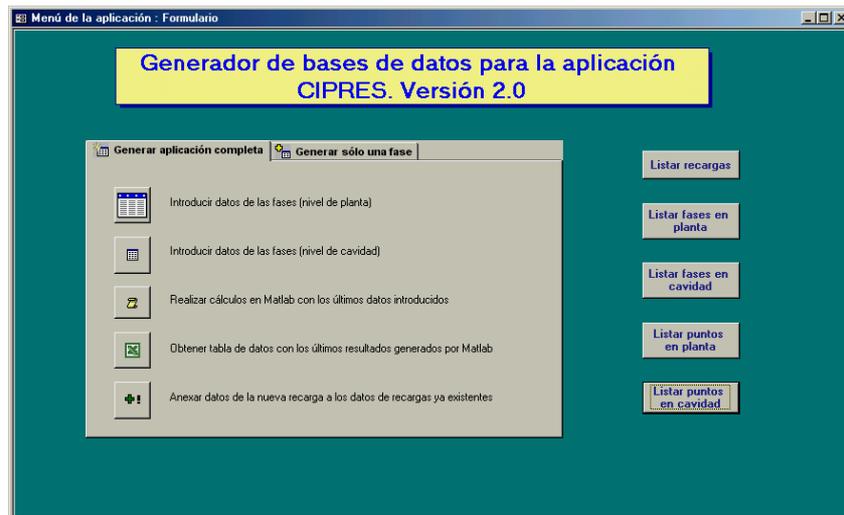


Fig. 3. Main menu of the CIPRES application

Data input is easier when appropriated forms are used. Users can also be safely guided through the entire database creation process by presenting adequate dialog boxes. The user introduces through forms (see figure 4) dose rate values measured in the previously established points. The process should be repeated for every stage.

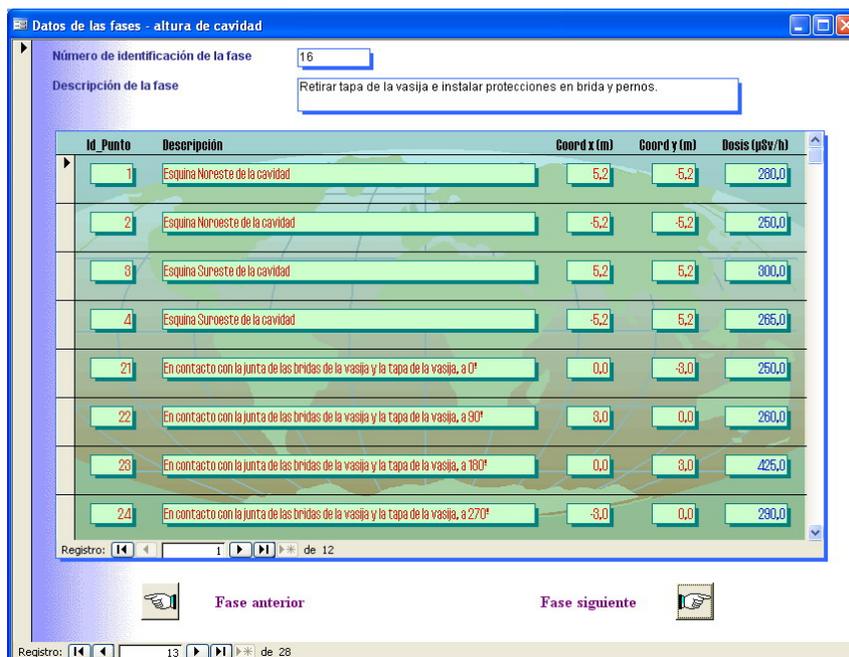


Fig. 4. Input data form at pool level

In order to guide the user to handle the application, several information screens are presented along the calculation process. They are the following:

- Map points, with the situation of measure points on the refuelling plant
- List of refuelling tables already included in the database
- List of refuelling stages
- List of measure points

After the introduction of input data, the process becomes practically automatic, with some interventions of the user to accept the allocation of tables.

## 5. Conclusions

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

Dose rate calculations have been optimized with an improved planning of the Radiological Surveillance in order to obtain more accurate dose rate values for some points of interest. For this purpose new points of measurement were included, especially at outer nodes of the mesh covering the refuelling plant.

An application has been developed to set up a dose rate database from input data given by Radiological Surveillance service. Its main skills are:

- Friendly environment.
- The calculation speed is increased, reducing the time required for the elaboration of future databases.
- Easy handling, which makes possible their use for everybody with minimum office computer system knowledge.
- Tool of great power and flexibility
- It allows varying the localization of the measure points. Especially interesting condition for the case of hot spots.

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. Furthermore, it would be a useful pattern for the development of a similar application for the training of workers participating in especially dangerous operations.

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