

## **DECOMMISSIONING OF CREYS-MALVILLE NUCLEAR POWER PLANT: RADIOLOGICAL CHARACTERIZATION**

S. Tontini  
AREVA / FRAMATOME-ANP  
10, rue Juliette Récamier  
69456 Lyon cedex 06 – France  
Email : [sebastien.tontini@framatome-anp.com](mailto:sebastien.tontini@framatome-anp.com)

B. R. Poncet  
Electricité de France (EDF) – CIDEN  
35-37, rue Louis Guérin, BP 1212  
69611 Villeurbanne cedex France  
Email: [bernard-r.poncet@edf.fr](mailto:bernard-r.poncet@edf.fr)

### **ABSTRACT**

Creys-Malville French fast reactor was shut down a few years ago and it has now to be dismantled with the first EDF NPP.

An essential stage in the decommissioning of the Creys-Malville NPP, and of any other nuclear decommissioning project, is the radiological characterization of the installation.

Good knowledge of the initial radiological state of the reactor block is essential in order to ensure that the radiological risk is managed during the dismantling operations, and to provide the data necessary for subsequent waste management.

Therefore, radiological characterization has to provide the best possible information on:

- the total and the specific activity of the radio-elements present in the installation and the evolution of this activity in relation to the decay time;
- distribution of the part due to activation and the part due to the contamination of the structures and components;
- mapping of the dose equivalent rates in the reactor block and their evolution in time, under the specific influence of the different sources.

To meet these objectives, the radiological inventory of the installation applies various methods, especially theoretical ones, using radiation protection calculation codes.

The purpose of this paper is to describe the methods of radiological characterization in readiness for dismantling work and to organize the management of the waste produced by Creys-Malville reactor block dismantling operations.

## **INTRODUCTION**

The evaluation of NPP structure and component activity has to take account of the methods used to declare the waste in relation to the different management channels.

Therefore, it should take into account the two following components:

- contamination ;
- activation.

## **ACTIVATION**

### **Primary System**

The flows of neutrons generated in the core during operation of the NPP, leads to activating nuclear reactions in the structures subjected to neutron irradiation.

The activity induced by the activation of the reactor block internal structures and components is essential data for defining the orientation of waste to the various storage channels and to ensure the radiological risk is controlled. The same problem occurs for each shut down NPP as described in [1] and [2].

As part of the studies performed for decommissioning the Creys-Malville Super-Phenix NPP, the activity calculations for the structures and primary system components break down into three stages:

- calculation of the intensity of the sources in the fuel and fertile media at 320 JEPN and of the neutron flux inside the core ;
- calculation of the flux propagated outside the core based on the previously calculated neutron sources. The geometry used is cylindrical, two-dimensional of type R-Z, extending from the center of the core to the concrete reactor block, from the center of the core to the vessel head plug, and from the center of the core to the under-vessel concrete ;
- determination of the spot concentrations of activity in the primary system structures and components based on the fluxes obtained (per space interval and energy group), characteristics of activation reactions (microscopic thermal cross-section, resonance integral, fast macroscopic cross-section, energy threshold and so on), and the chemical composition of the materials.

Calculations of the neutron flux in the core and propagation beyond the core takes place using the ERANOS code, which is dedicated to the study of fast breeder reactors.

Activity calculations were carried out by taking account the past history of plant operation from its divergence to its shutdown on 24 December 1996, that is to say a total period of operation equivalent to 320 JEPN.

The activation calculations have shown that the highest activities are located in the lower axial zone below the core. The side and upper zones are protected better due to the presence of lateral and upper neutronic protections. Moreover, high cobalt content stellite coatings are encountered in the lower axial zone on the following components :

- assembly supports;
- truck/truck support contact surfaces.

The main source of gamma radiation during the first 20 years is Co60, the origin of which is the neutronic irradiation of natural cobalt, exclusively made up of Co59 present in alloys and steels, by the capture of one neutron:  $\text{Co59}(n, \gamma)\text{Co60}$ . Co60 is  $\beta^-$  radioactive, with a radioactive half-life of 5.27 years, emitting two  $\gamma$  photons with 1.33 MeV and 1.17 MeV energy on each disintegration.

Figure 1 shows the values for the maximum specific activity of the main components and structures of the reactor block ten years after plant shutdown (apart from the contamination source term).

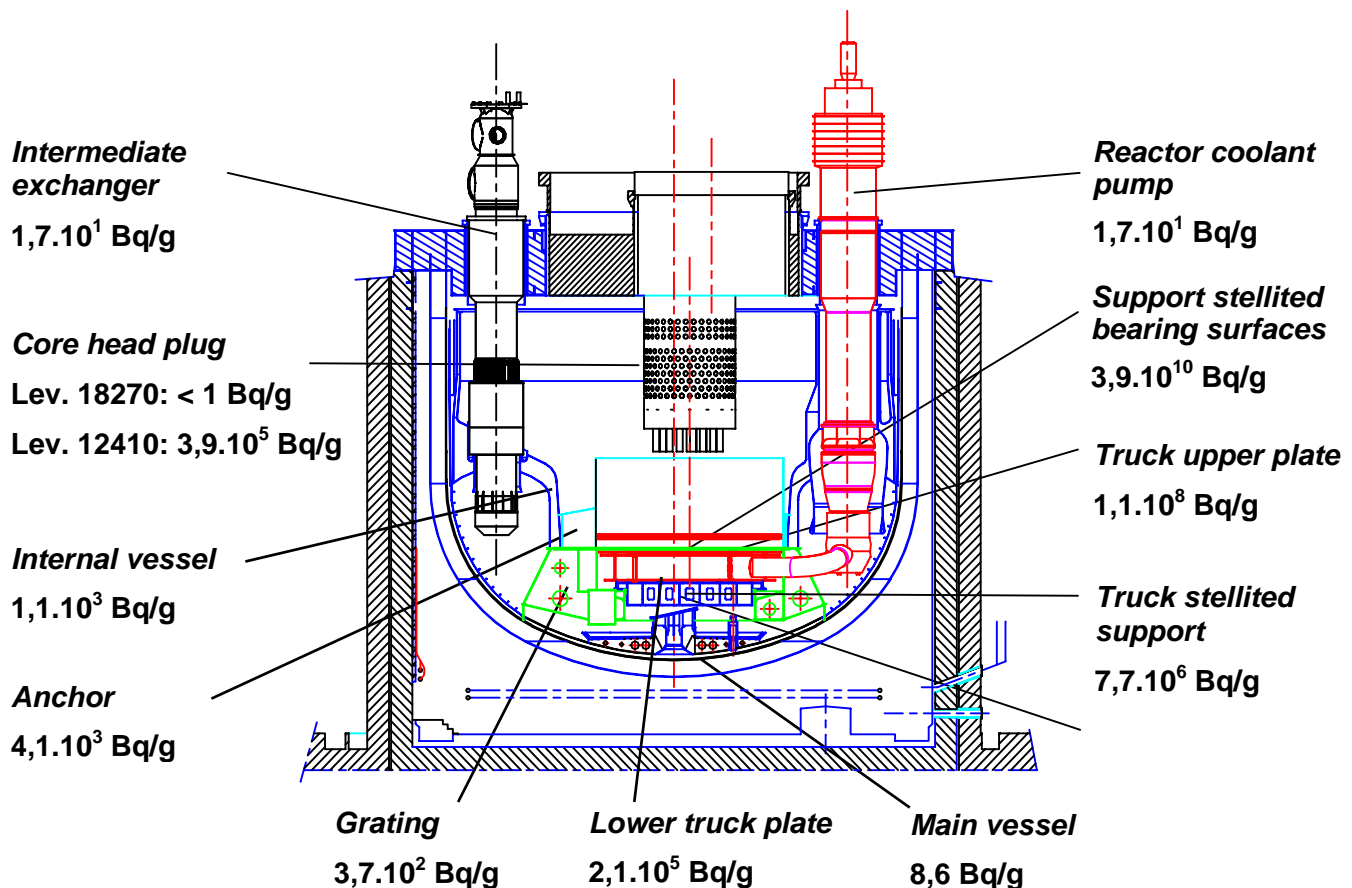


Fig. 1. Maximum activity concentration in Bq/g 10 years after shutdown.

In view of the large number of events that occurred during the life of the installation that could have consequences for the final radiological state (power modifications, operating incidents, etc.), the complexity of the calculations and the lack of details as to the source data such as the contents of impure elements in the materials, the uncertainty as to the results of activity is often considerable and difficult to quantify. It is impossible to have exact knowledge of the radiological condition through calculations alone. Consequently, these results have to be crosschecked as far as possible with readings obtained in the reactor block or on extracted components such as dose rates, samples, etc.

### **Secondary System**

Taking into account their physical separation and the protections implemented in the primary system, the secondary systems are not subjected to the neutron flux and are not activated.

### **CONTAMINATION**

The activity in the nuclear zones results mainly from contamination (the neutron fluxes were too low in normal operating conditions to activate the structures).

This is caused by deposits of radioelements present in the cooling liquid (primary and secondary sodium). Calculation of this component relies therefore on the creation of a list of radioelements that are or could be present in significant quantities in the sodium.

### **Primary System**

In the absence of a failed fuel element, the radionuclides present in the reactor coolant sodium may be derived from:

- the sodium itself;
- the impurities present in the supplied sodium;
- fuel dust resulting from the production of pins on the outside of the sheaths;
- metal elements from the structures and components.

When these elements, which are subjected to neutron flux, present in the reactor block are activated, radioisotopes are created.

The evaluation of the concentrations is based on the exact knowledge of the flux outside the core and the coefficients of dissolution/abrasion of metals in the sodium, as well as the consequences for their physicochemical behavior. Certain radionuclides have physical and chemical behavior which favors depositing or adsorption on the walls.

These assumptions are taken into account in order to obtain a coherent estimate of the sodium/wall distribution using all the information available.

The approach adopted for the evaluation of the radioactivity of the sodium impurities and the elements coming from the dissolution of structure materials is as follows:

- search for the sodium impurities that may be activated starting from the results of the analyses on the delivered sodium;
- search for the elements of the materials of the structures placed in sodium solution which may be activated;
- classification into families according to the probability of being rendered radioactive and according to the cross section and the concentration;
- irradiation of the radionuclides during 320 EFPD by taking account of the past history of plant operation, and by taking the flux at the center of the core in order to calculate the activation of the primary sodium impurities.

The estimate of the activity of the fission products and the heavy radionuclides emitting alpha, beta and gamma radiation takes place by considering an oxide pollution on the fuel and fertile pins on completion of their fabrication (a few heavy metal  $\mu\text{g}$  per pin).

The last stage consisted in comparing the activities of the radionuclides measured in the TASTENA (sodium samples) with the calculated activities and, by applying selection criteria, retaining the value which may be considered a "reference" value in order to draw up the final list.

### **Special Case of Tritium**

Tritium is also present in the sodium reactor coolant in significant quantities, the sources of tritium are:

- ternary fission in the fuel;
- nuclear reactions on the control rod boron;
- activation of the boron and lithium impurities present in the delivered sodium, the fuel and the materials and structures;
- reactions of the fuel pins with the pressurization helium.

The two first methods of formation are the most common. However, differences of concentrations allow the tritium to migrate in the opposite direction to hydrogen through the metal walls. This makes the theoretical evaluation of the radioactivity of this isotope difficult to assess. The value associated with tritium then results from measurements.

In view of the time that has passed since the shutdown of the Creys-Malville reactor, and the evacuation of waste resulting from its dismantling, reactions with products having a period of less than 50 days were excluded from the search for possible activation reactions apart from the Ar37 referred to in the ANDRA specifications relating to the Aube surface disposal.

In addition to the intrinsic sodium activity, the main elements contributing to the activity of primary sodium on 1st January 2001 are:

- tritium;
- corrosion products: Fe55, Ni59, Ni63, Co57, Co60, Mn54, Zn65...;
- fission products: Cs137, Tc99, Nb93m, Mo93, Ba133, Ru106...;

- emitting  $\beta\gamma$  heavy nuclei Pu241;
- emitting  $\alpha$  heavy nuclei Pu238, Pu239, Pu240, Am241...

### **Secondary Sodium**

A similar methodology is employed for the secondary sodium.

The activity of the radio-elements present in the secondary sodium was determined by considering the radiation, during 320 EFPD, of the sodium and metal element impurities resulting from the solubilization of structure materials under the maximum flux observed at the intermediate exchangers.

Following the calculations, it appears that the activity of the secondary sodium is primarily due to the tritium produced in the reactor coolant circuit and which migrates by diffusion through the metal walls of the intermediate exchangers. This radioactivity was estimated from the tritium measurements made on the TASTENA's samples.

### **DOSE RATES GENERATED BY THE ACTIVATION OF STRUCTURES AND PRIMARY COMPONENTS**

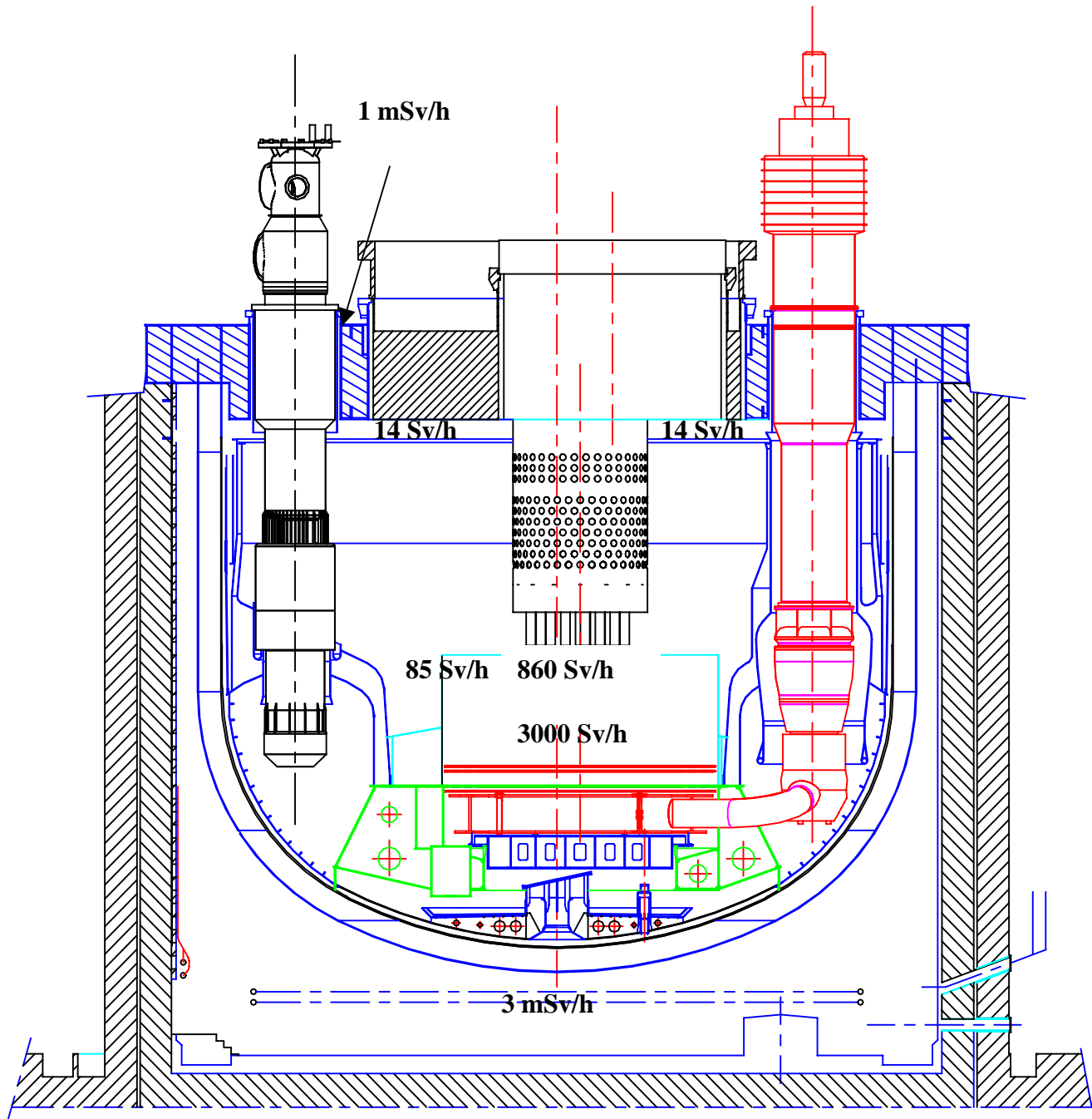
In order to ensure that the radiological risk is controlled during the removal and treatment operations and to meet the requirements for waste management (channels, conditioning, etc.), the dose rates around the components, in the reactor block, on the slab, in the reactor cavity and in certain specific zones of the core support structures involved in the retention tank resorption operations, are evaluated.

The dose equivalent rates at different points of the reactor block will be used to optimize the decommissioning strategy and the dismantling operations to be defined: remote operations, contact interventions, definition of the biological protections and so on.

The calculations carried out are performed for several advanced states of the plant decommissioning operations.

Based on the  $\gamma$  radiation spectra determined from the isotope activities for the selected cooling times, the dose equivalent rates are mapped using the MERCURY 5 computer code. This software covers three-dimensional geometries and integrates the straight line spot attenuation nuclei for gamma radiation (biological dose, heating, etc.) using a Monte Carlo technique in the multi-group approximation.

As an example, Figure 2 shows the dose equivalent values obtained at various points of the Super-Phenix reactor block generated by the activation of the structures and the primary system components at 1<sup>st</sup> January 2010 in the drained vessel configuration.



**Fig. 2. Dose equivalent rate in reactor block Vessel drained on 1<sup>st</sup> January 2010.**

The dose equivalent rates in the reactor cavity and the reactor block are essentially due to the structures located in the lower axial zone below the core (truck and/or truck support). These structures, which include the stellite coatings with high cobalt content (assembly supports, truck/truck support bearing surface), contribute to more than 99% of the total dose equivalent rate.

## **CONCLUSION**

Decommissioning operations will generate waste requiring a general approach to site management and preparations for their evacuation towards the various suitable channels.

In order to attain this goal, the first step is the complete radiological appraisal of the installation. In this context, a quantitative and qualitative evaluation of the primary and secondary systems was carried out.

The information thus obtained will then enable :

- analysis of the destination of the various wastes and effluents generated by the decommissioning of the radioactive and/or contaminated systems having been in contact with the primary or secondary sodium and/or its aerosols ;
- definition of the elements needed to establish the principles of treatment, management and the destination of this waste from the places of production up to the stacking areas for evacuation ;
- the definition of the elements needed to establish the statutory documents for their evacuation from the site.

## **REFERENCES**

[1] Bernard PONCET, WM'03 Conference, 2003 TUCSON, Arizona  
« CHARACTERIZATION OF GRAPHITE SLEEVES FROM BUGEY 1 EDF PLANT FOR PERMANENT DISPOSAL – MESUREMENT AND CALCULATION OF SCALING FACTORS FOR DIFFICULT-TO-MEASURE NUCLIDES »

[2] Bernard PONCET, WM'05 Conference, 2005 TUCSON, Arizona « CHLORINE EVALUATION OF GRAPHITE FROM NUCLEAR POWER PLANTS »