Validation of Numerical Simulations of Activation by Neutron Flux

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Keywords: decommissioning, characterization, waste management, numerical simulations.

ABSTRACT

The knowledge of the radionuclide content of radioactive waste is of utmost importance for safety and waste management reasons.

Numerical simulations are used at EDF-CIDEN to anticipate the dismantling and the radioactive waste management.

The activation scheme by neutron flux developed at EDF-CIDEN comprises four steps :

- Step 1 : Computing of a 3 dimensional multigroupe neutron flux map. The mapping of the neutron flux is obtained on the basis of a neutron propagation calculation. The codes used are MCNP reference [1] or TRIPOLI reference [2]. Both solve the transport equation called the Boltzmann equation. The input data covers the microscopic cross-sections, the 3 dimensional geometry, the chemical compositions with no impurities and the computed neutron sources resulting in the neutrons emitted by the fuel assemblies. The neutron flux map is calculated at the nominal power rating conditions, and each flux is homogenized in a limited number of energy groups.

- Step 2 : Calculation of the activities. The activities are calculated for each component or sub-component of interest. The code used is DARWIN-PEPIN (developed by the French CEA). It solves a system of Bateman equations. The input data covers the 3-dimensional neutron flux map calculated in step one, the microscopic cross sections, the radioactive decay series associated with the radioactive half lives, the chemical compositions with impurities, and the history of irradiation resulting in the daily power production. The output data is the radioactive inventory of each component or sub-component of interest limited to a list of 143 radionuclides.

- Step 3 : Waste classification. According to the radioactive inventory of each component or sub-component, and the waste classification criteria, a waste classification can be made. Basically the criteria are based on the levels of specific activity and radiotoxicity of 143 radionuclides.

  The distinction between the "Long Life" and the "Short Life" waste is based on a list of specific activity limits for 40 radionuclides. If none of these limits are crossed, a weighted specific activity level is used to separate "Very Low Activity" and "Short Life" waste. The weighted specific activity value is obtained by taking into account the levels of specific

activity balanced with the levels of radio-toxicity of 143 radionuclides.

- Step 4 : Validation of the numeric simulations. Comparisons between the calculated radioactive inventories and the results of radio-chemical analyses can be made. For this, we need samples, results of radio-chemical analyses of these samples, and results of calculations linked to the analyses.

  The comparisons are based on Calculation Measurement ratios (C/M). A value greater than 1 corresponds to an overestimated calculation, and a value less than 1 corresponds to an underestimated calculation. Depending of the C/M results, the input data may be redefined to make a new simulation.

  These comparisons are made with regards to the activation of "standard" chemical elements (meaning radionuclides being perfectly modeled with no uncertainty about the chemical concentrations). The results, linked with "standard" chemical elements, can be used to validate the calculation scheme, including the neutron propagation, the neutron activation and all the other associated simplified assumptions (geometry, history of irradiation, etc). For steel, activation of "Fe" is retained, and for stainless steel, activation of "Fe" and "Ni" are retained.

Overall, the feedback from Chooz A (300MWe Pressurized Water Reactor) shows that numerical simulations produce a slight overestimation of "Fe-55" and "Ni-63". The results linked with minor chemical elements or impurities allowed us to validate the use of the average measured compositions.

REFERENCES

[1] Nuclear Energy Agency - Computer Program Services - CCC-0701 MCNP4C2

[2] Nuclear Energy Agency - Computer Program Services - NEA-1716 TRIPOLI-4 VERS. 8.1

[3] Nuclear Energy Agency - Computer Program Services - NEA-1339 PEPIN