Revaporisation of fission product deposits in the primary circuit and its impact on accident source term

Abstract:
Chemical revaporisation or physical resuspension of fission product deposits from the primary circuit is now recognised to be a major source term in the late phase of severe fuel degradation in a severe nuclear accident. These results come from tests carried out under different experimental projects in the European Commission (EC) Framework Programmes. These include the revaporisation tests carried out at the Transuranium Institute (ITU), Karlsruhe under the Fourth Framework Programme, the Phébus FP post-test analysis programme that examined FPT1, FPT3 and FPT4 deposits in separate-effect tests as well as EXSI-PC tests carried out at VTT, Espoo. The first tests at ITU and VTT concentrated on the behaviour of caesium as a very important fission product; this has helped detailed interpretation of the integral Phébus FP tests and has clarified some puzzling observations. Testing with Phébus FPT1 and FPT4 deposits at ITU demonstrated that revaporisation is a likely, rather than a possible, phenomenon with a severely degrading bundle. They have also shown that any changes in temperature (substrate or gas), flow rate or atmosphere composition or pressure can lead to the volatilisation or removal of the deposited caesium. Cs was particularly easy to follow given the high activity levels of Cs in the deposit. However further analysis of the deposits shows that other fission products are also subject to revaporisation. In the most recent FPT3 test, the chemical analysis of the filters has enabled examination of other fission products and demonstrated that these can be equally active in such conditions. Further separate effect tests in the EXSI-PC facility at VTT, Espoo have also given further insight as to the chemical reactions that major fission products (e.g. Cs, I) undergo under steam flows. One important result is the significant fraction of iodine that was released and transported in gaseous form at rather low circuit temperatures. In support of the experimental data, ‘ab initio’ theoretical approaches are being used at IRSN to demonstrate the interaction mechanisms of iodine and caesium vapours with typical primary circuit substrates under severe accident conditions. These approaches are expected to help interpret the Phébus FP experiments and VERCORS fission product tests as well as the CEA’s on-going ISTP-VERDON tests under mixed air and steam conditions. The combination of the three different research approaches will enable a much improved understanding of major chemical interactions in the primary circuit and so permit a more accurate simulation of a severe accident in primary circuits of water-cooled reactors with the ASTEC integral code, using improved thermodynamic data in the SOPHEAROS module. This, in turn will help to reduce the uncertainties in the anticipated source term to the environment.

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