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| ISTC Project No. 2936 |
| Modelling of Reactor Core Behaviour under Severe Accident Conditions. Melt formation, relocation and evolution of molten pool |
| Summary of Technical Report |
| on the work performed from August 1, 2004 to July 31, 2007 |
| Authorized for unrestricted publication |
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# Objectives / scope of work and technical approach / expected results

Processes of reactor core degradation represent the most significant factor of severe accident development since they provide the initial conditions for ex-vessel phenomena and determine the fission product and hydrogen source term. The investigation of in-vessel melt behaviour is of paramount importance with respect to reactor materials oxidation kinetics, possible reflooding of the core and reactor pressure vessel failure analysis.

The general objective of the proposed project is to perform the detailed analysis of the available and new experimental data, to update, improve and verify the developed models and to prepare them for benchmarking of simplified models and for implementation in the existing system codes. Thus the proposed project will contribute to the reactor core degradation modelling.

# Obtained results

* The model for dissolution of ZrO2 and UO2 by molten Zircaloy, U-Zr-O melt oxidation and release from the cladding breach were developed on the base of the new crucible tests data from FZK collaborators. On the base of newly developed models, new numerical modules were developed and implemented in the SVECHA code with tight coupling of these modules with other SVECHA modules describing heat exchange, cladding oxidation and thermo-mechanical deformation. The model for dissolution of ZrO2 and UO2 by molten Zircaloy and U-Zr-O melt oxidation was extended to non-equilibrium conditions and validated against FZK crucible tests data. The modified SVECHA code was applied to interpretation of corium melt behaviour in the in-pile tests Phebus FP, in cooperation with collaborators from JRC, IRSN and CEA.

# The physical model and numerical module on melt relocation in the form of drops and rivulets were developed and implemented in the SVECHA code. The new numerical module was implemented in the code as a subroutine of the massive blockage (slug) relocation model.

* The physical model and numerical module on melt relocation in the form of massive blockage (slug) were developed. The new numerical module was implemented in the SVECHA code. Tight coupling of this module with other SVECHA modules describing candling, heat exchange, cladding oxidation, thermo-mechanical deformation was organised.
* Analysis of the new ITU tests on irradiated and MOX fuel dissolution by molten Zr and U-Zr-O melting points determination was carried out. On the base of the tests analysis, correction of the fuel dissolution model for irradiated and MOX fuel was implemented. The ternary U-Zr-O phase diagram which is a part of the melt physico-chemical interactions model is improved using the new tests data on U-Zr-O melting points determination.
* The developed SVECHA/MELT code includes the new models developed in the Project and describes a complicated process of molten corium relocation under severe accident conditions at NPP. The code SVECHA/MELT was validated against integral bundle tests CORA-WWER (FZK).
* The new modules for melt relocation and physico-chemical interactions are prepared for implementation in the system codes such as ICARE/CATHARE, MELCOR, or ASTEC.

#### The previously developed three-dimensional CONV code for simulation of three-dimensional flows in the Boussinesq approximation on Cartesian grids with a local refinement near domain with singularities of flows was supplemented model for calculation of flows with a variable density without Boussinesq approximation.

#### Model for numerical simulation of melt flows simultaneously with heat transfer in the reactor case and crust formation at high Rayleigh numbers was developed and implemented in code. For the modeling of turbulence implemented algebraic turbulent models and direct numerical simulation were used. A computing technique of modeling of turbulence was validated on results of problems with lid-driven flows and flow in tube. In all cases the good coincidence of numerical results to the reference data is marked.

#### On the basis of the modified CONV version the simulation of molten-salt tests obtained on RASPLAV facility was carried out. The obtained results demonstrate, that the developed approach predicts correctly the absolute values of crust thickness.

#### On the base of the carried out numerical researches and adaptation of previously developed software, more perfect version of a code permitting of calculation of three-dimensional flows with variable properties, appropriate to real corium properties or prototypes was obtained.

#### Matrix of validation for developed models was created, including as results of the theoretical analysis and experimental data (BALI, COPO and SIMECO) for convection of a heat-generating fluid.

#### The preliminary numerical simulation of circular heat used in experimental facility LIVE was carried out by means of CONV code which was validated and adapted to conditions of project.

# Keywords: core degradation, melt formation, melt relocation, melt oxidation, molten pool