ISTC Project No. K-1265

Experimental study of the processes at the corium melt retention in the reactor pressure vessel

Summary of Technical Report

on the work performed from May 01, 2006 to April 30, 2010

Authorized for unrestricted publication

Affiliated State Enterprise "Institute of Atomic Energy" of the Republican State-Owned Enterprise "National Nuclear Center" of the Republic of Kazakhstan

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Title of the Project: Experimental study of the processes at the corium melt retention in the reactor pressure vessel (INVECOR)

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Objectives / scope of work and technical approach / expected results

Overall Project objective - to improve the safety assessment of LWR corium in-vessel retention (IVR) under severe accident conditions

Specific objective of the project is the experimental simulation of the thermal and physicochemical processes at the retention of the prototype molten corium pool on the water-cooled lower head of the reactor pressure vessel.

The Project tasks involved the modernization and adjustment of the test facility that are accompanied with the project, calculation and experimental activities. The key task of the project is the performance of three large-scale integral experiments on simulation of falling 60 kg prototype core material melt of the light-water-moderated reactor (LWR) on the reactor vessel model and subsequent modeling of decay heat in the corium on its retention in the reactor pressure vessel during 1…2 hours.

The experiments were carried out in the “Lava-B” test facility and involved the induction melting of the initial loading of the LWR core components and the discharge of the produced melt into the reactor vessel model. The decay heat was simulated with the device of 5 coaxial plasmatrons immersed into the corium melt.

The main results of the project are the large-scale tests data on structures of the melt pool on the lower head reactor vessel and corrosion of the reactor vessel steel depending on the prototype corium compound and distribution of heat loading on the vessel. The obtained data may be used in the development of the models describing behavior of the melt at the in-vessel accident phase, variation of the appropriate computer codes on justification of the in-vessel retention concept (IVR) foe the existing and new-developed reactors

Obtained results

In the result of the test facility modernization the volume of the electric melting furnace crucible was enlarged and accuracy of temperature control of the heated corium components was enhanced. The total power of the plasmatrons device for the decay heat modeling was doubled as compared with the former system, that enabled to bring the specific capacity of the volumetric heat generation in the corium to 8…10 W/cm^3. The lifetime of the graphite plasmatrons nozzles was extended up to 2,5 hours. The technique for applying protective coating on the experimental facility graphite elements contacting with the corium melt during the experiments was developed. The experimental section with thermal insulation on the external water-cooled surface, enabling to increase temperature in the corium/steel contact area up to 850…1300 °C under condition of the experimental facility limitations on its internal volume and capacity of the equipment used, was designed.

All activities on the equipment updating were accompanied with appropriate calculations. Working capacity of the concepts and the advanced elements and units were confirmed in the course of the supporting experiments conducted in the small-scale and large-scale test facilities.

There were performed 4 large-scale experiments. During the tests 60 kg prototype corium melt C-30 was drained into the experimental section where the decay heat simulator was located during 1…2 hours. In the second integral test, the stainless steel in the form of cladding of the internal surface of the reactor vessel model was added to the oxide corium melt. In the third integral test, a steel sheet was thrown down on the oxide corium surface (after its drain into the vessel model) to simulate “focus-effect”. The fourth integral test was a repetition of the first test on corium composition, but the vessel model insulation was enhanced to increase temperature in the corium/steel interaction area. In the first and second tests, about 10 kg oxide corium fragments were preliminary located in the vessel model before the main melt mass drain.

The temperature of the corium/steel interaction area in the performed tests was 850…1400 °C at specific power of the volumetric energy release 8…10 W/cm^3 in the corium. The duration of the corium retention process simulation in the vessel was from 1 to 2 hours.

After the experimental sections disassembling it was discovered that in all tests a layer of the fragmented corium with thickness 2…3 cm was formed on the surface of the solid corium ingot. Thereby, the layer thickness depends on melt temperature on its draining into the vessel model and on temperature of the experimental section in the course of the in-vessel corium retention simulation. The layer formation causes analysis enables to assume that that is the result of corium melt jet spraying on its falling on the lower head reactor vessel and prompt solidification of drops at its contact with relatively cold wall of the vessel model.

The study of the corium in the solid ingot and in its fragments over the solid layer demonstrated the identity of the phase composition that confirms indirectly the version on the fragmented layer formation.

Keywords:
Light-water-moderated reactor; severe accident; reactor core; corium; reactor pressure vessel; decay heat; coaxial plasmatrons; large-scale experiments; in-vessel retention (IVR); melt jet; fragmentation; corium ingot; physical and chemical interaction; solid solution; external cooling.