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Integrated Fuel-Coolant Interaction Code : Assessment of
Stand-Alone Version 6.0 *

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In the event of a severe reactor accident leading to core melt, it is possible that molten fuel materials will come into contact with water, producing a molten fuel-coolant interaction (FCI). A computational tool, the Integrated Fuel-Coolant Integration code, version 6.0 (IFCI 6.0), has been developed and demonstrated, in a stand-alone format, as capable of assessing explosive and nonexplosive Fuel-Coolant Interactions. The IFCI code is expected to fulfill the need to have one code that would handle mixing of hot particles with coolant, particle size variations, space or volumetric influences (size and scaling) and detonation triggers.

IFCI is a best-estimate code that attempts to model all phases (mixing, triggering, propagation, and expansion) of FCIs in as mechanistic a manner as possible.¹ IFCI is a two-dimensional, cylindrical finite difference solution of the Navier-Stokes equations, for vapor liquid and melt, including models for, momentum advection, surface tracking, Weber breakup, bulk boiling and subcooled surface boiling, and triggering. Modules and references associated with reactor cores, detailed structural information, and extraneous codes linkages have been removed in order to create a stand-alone tool to study all phases of FCI progression. Code size was reduced from 93138 to 35445 lines, and compile time reduced by 20%. The basic features of IFCI and the assessment using FITS, FARO, and IET experimental cases are presented.

A generic FITS-Type Pouring mode experiment was simulated to ensure continuity between

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this and previous versions of IFCI. Results of that numerical experiment have been previously issued as a report.¹ The results of this case are not discussed in the context of FCI phenomenology, but only as a comparison to the previously executed version of the code. Results of a 0.5 s IFCI 6.0 simulation, executed on a Cray-YMP, match exactly with those of Young. However, results from IFCI 6.0 when executed on the SUN Sparc2 workstation are noticeably different despite the use of double precision on the workstation. The cause has not been determined, and is the subject of further study. The SUN results demonstrate considerably larger (> 50%) spatial variation (from cell to cell) in pressure and temperature. Melt volume fractions differ slightly, and pressures differ by as much as 10% between the two cases. The pressures do not diverge, however, as the simulation progresses. Any difference in compilation and executable may produce slightly different timesteps and results. Unfortunately, FCI progression is highly sensitive to perturbations in the fuel/coolant interaction zone.

Several simulations of the FARO Quench Test, performed at JRC-Ispra, were run, not only to demonstrate IFCI's capabilities for quenching of molten fuel, but also to provide insight into how user input affects the results of this experimental simulation. Results, especially the progression of the melt through the coolant, were sensitive to axial and radial nodalization. However, global values, such as maximum liquid temperature, and steam pressure are consistent to within 10-20% during the course of the simulation. The maximum simulated pressures at the upper plenum location are within 10% of each other, but 20% higher than corresponding instrumented experiment location. Liquid temperatures, compared at 35 cm above the vessel floor, overpredict the measured liquid temperature rise of 17°C, with the maximum being 25°C, 33% more than experiment.

Two experiments (IET-8 A&B)² were performed in the Surtsey facility at Sandia National Laboratories, both resulting in energetic FCIs. IFCI 6.0 qualitatively captures all FCI phases,

water ejection and has been used, posttest, to track pressure response to within an order of magnitude. The maximum pressure detected by a transducer near the cavity wall is about 3.5 MPa, and has been simulated to within a few percent in one IFCI 6.0 posttest analysis.

The stand-alone version of IFCI is shown to reproduce results of previous code versions, and to provide acceptable simulations for FCI-steam explosions of reactor materials using entirely mechanistic models, except for triggering. However, the operational assessment has demonstrated some convergence difficulties, sensitivity to nodalization, and machine dependency.

References

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