Summary submitted for presentation at the 1983 Annual Meeting of the American Nuclear Society in San Francisco, California, October 30 - November 4, 1983.

CONF-831047--37

DE83 014685

RESULTS OF THE GAP-4 EXPERIMENT ON MOLTEN-FUEL DRAINAGE THROUGH INTERSUBASSEMBLY GAP GEOMETRY

by

B. W. Spencer, D. Vetter, R. Wesel, and J. J. Sienicki

Reactor Analysis and Safety Division

Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

RESULTS OF THE GAP-4 EXPERIMENT ON MOLTEN FUEL DRAINAGE THROUGH INTERSUBASSEMBLY GAP GEOMETRY*

by

B. W. Spencer, D. Vetter, R. Wesel, and J. J. Sienicki

Argonne National Laboratory

Argonne, Illinois 60439

One of the key issues in assessment of the meltout phase of a hypothetical core disruptive accident in the LMFBR system involves the timing and paths for dispersal of molten fuel from the disrupted core. The earliest available paths are through the axial blankets in the fuel assemblies. An extensive test program was previously carried out examining molten fuel penetration behavior axially through this pin bundle structure.[1] Although these tests have generally shown that the available injected fuel mass can be relocated into the axial blanket region, the injected fuel typically came to rest and solidified within the pin structure, creating plugs. Given the formation of such plugs, further analysis of the meltout phase indicates that the core power generation results in additional fuel melting in the initially intact subassembies as well as mild internal pressurization. The restraining hexcan walls will heat up, and it is estimated that they will reach melting in a time scale of ~2-4 s, far sooner than the axial plugs are expected to melt out. The significance of this result is that additional paths for fuel escape from the core are expected to become available as the hexcan walls lose their structural integrity, namely: i) the gaps between the hexcans leading to the below-core volume via drainage, ii) the intersubassembly gaps as a path for pressure-driven expulsion into the radial blanket and shield assembly region, iii) blowdown and/or drainage through the relatively wide-open control rod (CR) assemblies, and iv) paths opened by removal of structure such as upper

* Work performed under the auspices of the United States Department of Energy.

hexcan stubs. Some or all of these removal paths are expected to become available during the hexcan meltout stage prior to the disrupted region achieving core-wide coherency.

A program of experiments is underway at Argonne National Laboratory to investigate molten fuel penetration through these postulated escape paths. The purpose of the GAP-4 test was to examine the penetration distances of molten fuel flowing through the flat, narrow channels representing the inter-subassembly gap geometry. In the experiment design, the gap geometry was selected to be two-dimensional on the basis that the gap volume in a reactor design would be interconnected and continuous. Hence, outside the peak temperature and fluence regions where the gaps may be constrained, fuel entering into the gaps will generally be able to spread laterally as it flows downward. This was accommodated in the experiment by injecting the molten fuel across one "flat" width, 6.3 cm, and allowing the fuel to spread across ~3 flats width, 20.3 cm. The gap thickness of 4.3 mm was determined on the basis of the thicknesses of the mating load pads in the CRBR design. The overall length of the gap path in the experiment design, 1.0 m, is the distance from the core midplane downward to the top of the shield zone where the SA-to-SA gap reduces to the clearance dimension. The tests were performed dry (i.e., without the presence of sodium liquid or sodium film on the channel surface) since the gaps in the active fuel region would void prior to hexduct meltout.

The molten fuel used in these tests was a mixture of UO_2 (81%) and molybdenum (19%) which was generated by an exothermic thermite reaction at a temperature of ~3470 K. Although the SA blowdown process in the reactor may result in carryout of liquid fuel in a dispersed flow regime, the process was conservatively modeled such that the gas/vapor could disengage from the fuel and escape axially while the molten fuel was ejected laterally into the inter-subassembly gap. The fuel removal process is then envisioned as a simple downward gravity draining. Hence, the experiments were performed under nominally gravity drain conditions, although in reality this may be an overly pessimistic assumption.

In the GAP-4 test, the structure temperature was initially 1170 K, and the initial injection pressure was ~0.15 MPa (7 psid); 2.38 kg of molten reaction products entered the gap test section. The leading edge penetration distance was found to be 0.35 m. The material showed a gradually widening flow pattern. Fingers of molten material were observed to have drained down along the walls beyond the nominal leading edge location.

The posttest examinations showed the presence of stable, insulating fuel crusts on the steel walls; there was only localized melting and ablation of the walls. Although these observations are consistent with the stable-crust, conduction-limited model of heat transfer controlling the fuel freezing process[2], application of this model to the test conditions results in calculated penetration distances in excess of 1 m, considerably longer than found in the experiments. Factors contributing to shorter penetration depths have been examined analytically, namely, i) lack of superheat in the thermite reactants, ii) radiation heat loss from the leading edge, and iii) the cooling effect of blowby gas. It was found that none of these individual effects could satisfactorily explain the measured penetration behavior although combinations of effects cannot be precluded.

The results of the GAP-4 test have demonstrated the ability of molten reactor materials, represented by the UO_2-Mo mixture, to drain under gravity through the narrow 2-D channel geometry representative of the intersubassembly gaps in the reactor system. The test results indicate that a predominately UO_2 fuel mixture with ~330°C "superheat" has the ability to drain ~0.35 m through the channel in which the initial wall temperature is nominally equal to the sodium saturation temperature, 1170 K. (This distance is about two-thirds the distance between the bottom of the active fuel and the top of the shield in the CRBR design). Hence, while the measured penetration length is significantly shorter than predictions based upon the conduction-freezing model applied to test conditions, the penetration distance may be significant in terms of fuel removal from the core region. This is particularly true in view of the fact that a very conservative approach was adopted in performing these tests -- namely, gravity drainage rather than pressure driven mode of dispersal.

References

1. B. W. Spencer, et al, "Reactor-material Fuel-freezing Experiments Using Small-bundle, CRBR-type Pins", ANL-80-22 (1980).

2. M. Epstein, et al, "Transient Freezing of a Flowing Ceramic Fuel in a Steel Channel," Nucl. Sci. Eng., 61, (1976).