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In-Pile TREAT Test L04: Simulating a Lead Sub-assembly in an
Unprotected LMFBR Loss-of-Coolant Accident*

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Test L04 in the PFR/TREAT series is the first multi-pin, in-pile simulation of a LMFBR transient undercooling/overpower (TUCOP) accident using full length prototypic fuel irradiated in a fast reactor. L04 is a gridded 7-pin bundle test performed in the ANL Mk-III integral loop in a flowing sodium environment and uses prototypic, bottom plenum, UK reactor fuel, pre-irradiated in the PFR to an axial peak burn-up of 4.2 a/o.

The objective of L04 was the study, by simulation, of coolant voiding and fuel motion during the initiating phase of a hypothetical TUCOP accident in a large LMFBR. Test L04 is intended to study the behavior of a centrally located, "lead" subassembly with the highest power-to-flow ratio.

In the TUCOP scenario a relatively slow power rise is initiated by reactivity feedback from coolant voiding in lead subassemblies. This is accelerated into an overpower burst by the subsequent voiding of a large preportion of the inner region of the reactor core. Accordingly, the power burst in test L04 was planned to occur after a well-developed coolant void exists in the test fuel core region.

The choice of a power burst for L04 was guided by considerations of whole-core reactor accident calculations as well as safety limitations of TREAT. An initial portion of the power burst was characterized by a 450 ms period through one e-folding, followed by a more rapid (~150 ms period) power rise to a peak of >20 times nominal. A burst of this nature, depositing

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~1000 J/g at the axial peak power location in the fuel, simulates power increases in the above scenario.

A unique feature of L04 was the initiation of the power burst ~0.5 s after receipt of a low inlet flow signal from the experiment. Thus L04 simulated the coolant voiding/reactivity feedback that exists in large LMFBR's and assured that fuel failed into flow channels significantly voided of sodium coolant.

Pretest planning for L04, in particular the coolant boiling and voiding analysis used the FPIN/BOIL code. FPIN/BOIL is a single pin, single channel fuel mechanics and thermal hydraulic code that adds a single bubble coolant voiding model to the existing FPIN-1 code system. The onset of inlet flow reversal in the test was well predicted.

Figure 1.0 is a schematic of the integral flowing sodium loop utilized for the test and also identifies the principal sensors and their locations.

Figure 2.0 is a composite graph of the test results. At 4.5 s the flattop portion of the transient was achieved and simultaneously the programmed flow coastdown was initiated. Approximately 190 ms later at 6.4 s perturbation at the outlet flowmeter, FM-3, was evident. At 7.65 s local boiling is evident from all flowmeter signals as exemplified by FM-1 (lower bend), FM-2 (inlet), FM-3 (outlet) and FM-4 (pump leg) flowmeters. At 8.5 s flowtube wall thermocouples at the fuel axial position $X/L = 0.83$ and the top of the fuel (represented by TC-9 and TC-13, respectively) reach a sodium boiling plateau and the loop plenum pressure, PT-3, (originally set at 0.085 MPa) indicated 0.1 MPa absolute. Shortly thereafter, thermocouple, TC-15 in sodium above the fuel pin, also reaches the temperature plateau. The burst initiation generator (BIG) detected incipient flow reversal, (<10% of the original flowrate), at 8.7 s, and after a 0.5 s delay to assure extensive

voiding, the reactor control rod program initiated the burst position of the transient at 9.2 s. Pin failures may be evident 150 ms later i.e., at 9.35 s when the outlet flowmeter signal indicated an expulsion flowrate ~4 times the original setting. At 9.6 s vigorous reverse inlet flow indicated significant voiding. The second period of the burst commenced at 9.75 s. At 10.02 s peak power is attained, and significant radial and axial fuel motion were indicated by the failures of all thermocouples surrounding the fuel. No large pressure spikes ($>>0.5$ MPA) were evident by PT-1 (inlet) and PT-2 (outlet) pressure transducers. Subsequently, 20 to 30 ms after peak power, total flow blockage occurred. Up to the time of extensive fuel disruption, intact geometry thermal hydraulic calculations with FPIN/BOIL are in good agreement with the measured temperatures of both the wall and the in-flow outlet thermocouples.

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Figure 1.0. Loop Schematic and Primary Sensor Locations.

Figure 2.0. L04 TUCOP Sequence of Events.