Comparison of L04, L05, and L07: Three Irradiated 7-Pin Bundle TUCOP Tests*

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Four transient-undercooling-driven overpower (TUCOP) tests on seven-pin bundles have been performed in the PFR/TREAT program. All were on full-length, bottom-plenum UK-design fuel. Three of them (tests L04, L05, and L07) tested sibling fuel elements having had the same preirradiation in PFR; one (L06) tested fresh fuel. The three tests on preirradiated fuel were designed to determine the differences in the motions of reactor-core materials that would result from the variation in power-to-flow mismatch conditions across the core of a commercial-size reactor during a hypothetical TUCOP accident. By initiating the overpower bursts at different fuel-coolant thermal-hydraulic states, the three tests yielded distinct differences in fuel and coolant response, providing a wide range of behavior useful in verifying accident models and codes. Test L04 failed fuel into mostly-voided coolant channels with cladding weak or molten, L05 into partly-voided channels with intact but weak cladding, and L07 into channels just beginning to void with cladding still strong.

The power burst used in tests L04 and L05 had a period of ~0.18 s and reached a peak power of about 20 times nominal. The burst employed in L07 was faster and reached a peak power about 80% higher than in L04 and L05 to allow

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investigation of the special case of possible fuel accumulation near the failure site in fast-burst TUCOPs. However, the total energy deposition in the LO7 burst was only about 7% higher than in the LO4 and LO5 bursts so that conditions for fuel response would be related to, although distinct from, those observed in LO4 and LO5.

Conditions at the onset of the power burst varied among the tests, from sodium boiling driven flow reversal and extensively voided channels in LO4, to incipient boiling in LO5, and relatively cool cladding and coolant in LO7. Figure 1 (top and center sections) compares the measured power and inlet flow rates in the tests. Similar, gradual monotonic expulsion of sodium through the inlet began early in the power burst in LO4 and LO5, apparently driven by the increasing vigor of bulk boiling in the coolant channels. In contrast, sodium expulsion in LO7 had a sudden onset and was substantially more vigorous, suggestive of a local molten-fuel/coolant interaction (MFCI) in a liquid-filled channel. Peak reverse flow rate at the inlet in LO7 was about twice that in LO5, and the peak outlet flow rate in LO7 was about six times that in LO5. Measured pressures at the inlet and outlet of the coolant channels correlate with the channel condition at cladding breach and with the magnitude of the observed flow perturbations: no significant pressure events occurred in LO4 or LO5 in which fuel entered voided or partially-voided channels whereas in LO7 sharp pressure spikes typical of MFCIs occurred coincident with the rapid coolant acceleration.

Of greatest interest is the nature of the fuel motion: is it monotonically dispersive or temporarily compactive? The single parameter best describing the net effect of the time-dependent fuel distribution is its reactivity worth. The curves in Figure 1 (bottom section) show the variation
in worth during the three tests as determined from the fuel motion measured by the TREAT fast-neutron hodoscope and scaled through an axial worth function appropriate for a large reactor core. (Corrections to account for such effects as flux tilting and fuel self-shielding changes have not been applied to the worth curves; thus, at present, the curves are more useful in revealing trends and relative behavior among the tests than they are in indicating absolute worth magnitudes.) In L04 and L05, axial expansion of the fuel column accounts for the initial loss of worth (about 5%) after the bursts began. Subsequent losses occurred as the cladding breached and ex-pin fuel motion occurred, with perhaps some early spalling of solid fuel. Upward fuel dispersal was similar in the two tests, but greater downward dispersal in L04 resulted in a larger reduction in worth. Test L07 also showed an initial worth reduction, but smaller than in L04 and L05. At cladding failure, a rise in worth occurred as fuel momentarily accumulated just above the fuel-column midplane, but subsequent upward fuel dispersal reduced the worth to the same minimum that occurred in L05.

Tests L04, L05, and L07 covered the spectrum of conditions expected in a power-producing LMFBR undergoing a hypothetical unprotected loss-of-flow accident. They all lead to final configurations having substantially-reduced fuel worth, with implication for benign consequence of this hypothetical accident.
REFERENCES


3) T. H. Bauer, et al., "PFR/TREAT Test L04 and L06: Irradiated Versus Fresh LMFBR Fuel Under TUCOP Accident Conditions", these proceedings.


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