CONF-840614--1

DE84 004017

CONF-840614--1

# In-Pile Loss-of-Flow TREAT Test L05 with Prototype Fast Reactor Fuel*

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In assessing the safety of liquid metal fast breeder reactors, various extremely-low-probability hypothetical core-disruptive accidents, with postulated events that might challenge containment and lead to release of radioactive material, are considered.

Test L05, conducted in Argonne National Laboratory's Transient Reactor Test Facility (TREAT) with UK Prototype Fast Reactor (PFR) fuel, simulated one such accident. L05 was an in-pile, transient-undercooling-driven overpower (TUCOP) test within the PFR/TREAT collaborative program between the USDOE and the UKAEA.

Seven grid-spaced full length, bottom-plenum fuel pins containing annular pellets of mixed oxide were tested to destruction in a Mark-IIIC integral loop with a flowing sodium environment. The UK manufactured fuel was preirradiated in the PFR to an axial peak burn-up of 4.2 a/o.

In a large plant TUCOP scenario, the decreasing sodium flow following a pump run-down causes the lead subassemblies to undergo sodium coolant voiding which in turn causes power to begin to rise throughout the reactor. As further intermediate subassemblies boil and void, the power rise is accelerated into a burst. Accident energy and progression is then strongly dependent on competing reactivity feedbacks from sodium voiding and fuel dispersion in these intermediate channels. The lead subassemblies were



*Work performed under the auspices of the U.S. Department of Energy.

simulated in PFR/TREAT test L04[1], and the intermediate subassemblies are simulated in test L05.

The overpower portion of the test transient is characterized by a power rise on a 450 ms period through one e-folding followed by a more rapid rise on a 150 ms period to a peak power of about 20 times nominal. This burst, nearly 1500 J/g at the axial peak power location in the fuel, simulates the above scenario. A five-second power flattop at nominal power, with about one third of nominal coolant flow, thermally conditioned the test fuel prior to the burst portion of the transient and produced a near-to-boiling coolant condition.

Coolant flow rates and pressures were measured at the inlet and outlet to the test section. Pressure in the gas plenum region above the sodium was monitored by a third pressure transducer. System temperatures were measured by thermocouples located throughout the test loop; seven were in-sodium, twelve were attached to the outside of the flowtube (three at each of four elevations along the active length of the test fuel) and two were above the sodium in the gas plenum.

Figure 1 is a composite graph of selected test results. While indications of some boiling exist at the onset of the burst, large flow disruptions and indications of fuel failure began well within the faster-period portion of the burst. Prior to fuel disruption, measured temperature rises along the outside of the flowtube wall as well as in the coolant above the fuel were well predicted by thermal-hydraulic analyses using the US computer codes COBRA and FPIN/BOIL and the UK codes SABRE and NASLIP. In addition, at the test section inlet and outlet, the time of appearance of large flow disruptions resulting from coolant boiling was predicted by the FPIN/BOIL code.

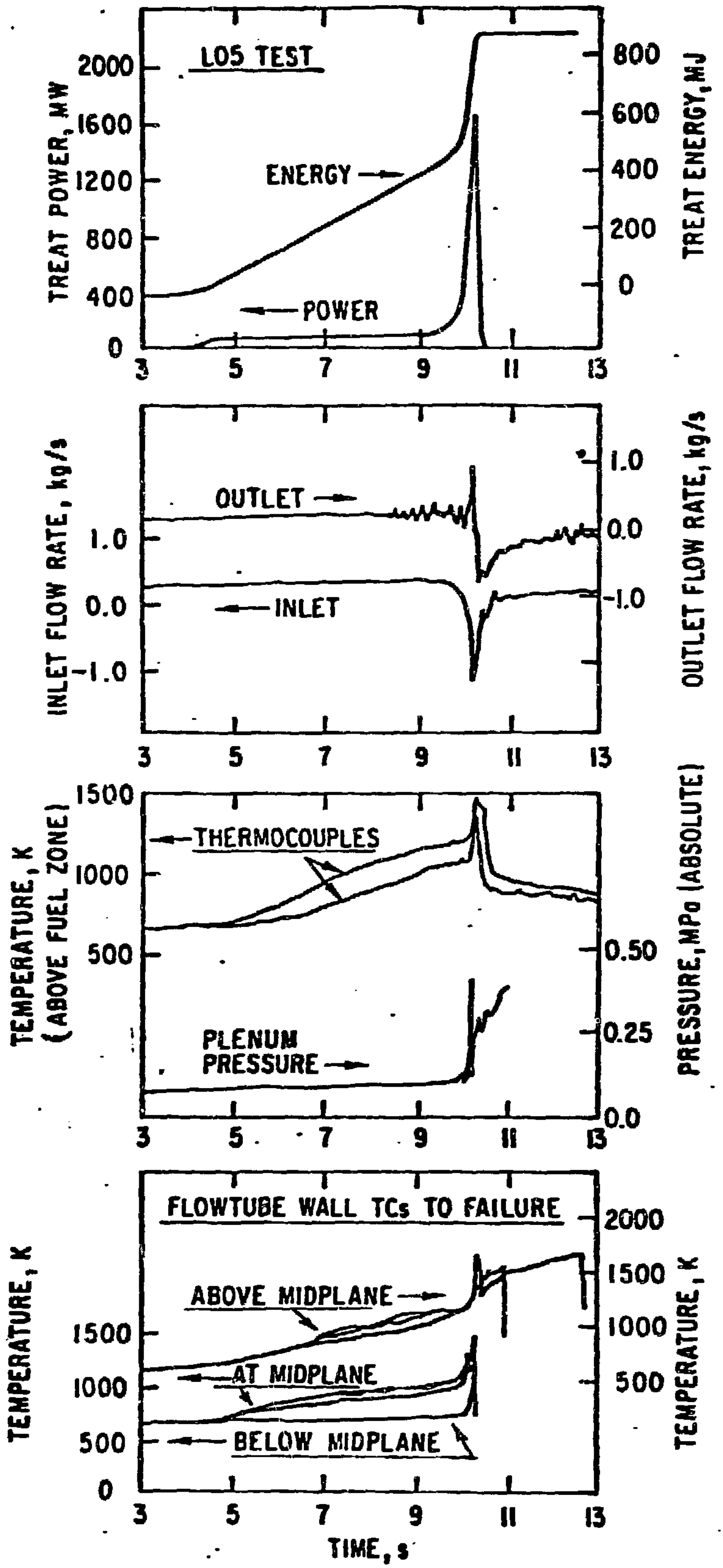
Assessing the time of fuel failure was more difficult because extensive coolant boiling decouples the test fuel from pressure and flow sensors located above and below the fuel. However, strong indications exist that molten fuel and fission gas had been released from the fuel shortly before peak power. These indications include a very rapid expulsion of sodium both upward and downward coincident with a pressure spike in the pressure transducer in the loop's gas plenum. The expulsion is corroborated by an abrupt temperature rise in the thermocouples above the fuel zone and by the slightly later failure of flowtube wall thermocouples presumably from melt-through after contact with molten fuel debris.

Based upon the observed times of failure of the flowtube thermocouples, it is deduced that molten fuel was initially released at a point somewhere between 50 and 80 percent of the active height above the bottom of the fuel. Calculations corroborate that, at the time of the inferred fuel release, a significant quantity of the fuel was molten and peak cladding temperatures were rapidly approaching melting. Both experimental results and calculations indicate that molten fuel was initially released into the voided portion of a coolant channel. Total sodium flow blockage was observed at the end of the transient.

It is useful to compare the results of intermediate subassembly simulation test L05 to those of the lead subassembly simulation test L04[1] in which the power burst was initiated after the coolant channel was significantly voided. The same power transient was applied to both tests L04 and L05. Unlike in L04, fuel melting in L05 preceded cladding failure and cladding melting. In both cases however, initial fuel release was into a voided coolant channel. Fuel element failure appears to have occurred further above the fuel midplane in L05 than in L04 and posttest radiographs indicate more fuel disruption in L04 than in L05.

Reference


1. J. P. Tylka, T. H. Bauer, A. E. Wright, A. L. Davies, R. Herbert, W. J. Woods, "In-Pile TREAT Test L04: Simulating a Lead Subassembly in an Unprotected LMFBR Loss of Flow Accident", Trans. Am. Nucl. Soc., 45, 408 (1983).



LOS TEST
TREAT POWER, MW
TREAT ENERGY, MJ
ENERGY
POWER
OUTLET
INLET
INLET FLOW RATE, kg/s
OUTLET FLOW RATE, kg/s
THERMOCOUPLES
TEMPERATURE, K (ABOVE FUEL ZONE)
PLENUM PRESSURE
PRESSURE, MPa (ABSOLUTE)
FLOWTUBE WALL TCs TO FAILURE
ABOVE MIDPLANE
AT MIDPLANE
BELOW MIDPLANE
TEMPERATURE, K
TIME, s

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