CONF-791103--19

BEHAVIOR OF A NINE-ROD PWR BUNDLE UNDER POWER-COOLING-MISMATCH CONDITIONS

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An experiment to characterize the behavior of a nine-rod pressurized water reactor (PWR) fuel bundle operating during power-cooling-mismatch (PCM) conditions has been conducted in the Power Burst Facility (PBF) at the Idaho National Engineering Laboratory (INEL). The experiment, designated Test PCM-5, is part of a series of PCM experiments designed to evaluate light water reactor (LWR) fuel rod response under postulated accident conditions[1]. Previous PCM experiments were single-rod or four-rod tests where each rod was contained within an individual coolant flow shroud. Test PCM-5 was the first nine-rod bundle experiment in the PCM test series. The primary objectives of the experiment were:

(1) to evaluate the potential for rod-to-rod interactions by allowing the test bundle to operate in film boiling for a period of time, and

(2) to assess the applicability of the previously obtained single-rod PCM data to bundle geometries.

The nine PWR-type fuel rods were arranged in a square 3 X 3 lattice with a pitch indicative of a commercial 15 X 15 PWR fuel bundle. In this configuration, the central fuel rod environment is considered representive of a power reactor rod during a postulated PCM event. The zircaloy clad rods had an active fuel length of 0.914 m and provided a bundle average peak power of approximately 57 kW/m. To obtain a relatively flat rod-to-rod power profile, the nominal fuel enrichments were 93, 35 and 20% for the center, side, and corner rods, respectively. The coolant conditions were 590 K inlet temperature, 15.5 MPa system pressure, and 1090 kg/s·m^2 mass flux through the test bundle. Figure 1 is a schematic representation of the Test PCM-5 test train assembly showing the relative positions of the test fuel bundle and related instrumentation.

PCM conditions were initiated by slowly increasing the PBF driver core power in a stepwise manner while maintaining constant pressure and coolant flow rate. During the power increase, a corner fuel rod in the test bundle experienced film boiling operation, followed by film boiling on other rods. The test bundle was allowed to continue high-temperature operation for about 10 minutes, during which time seven of the nine fuel rods experienced film boiling for various times. Figure 2 illustrates the film boiling history for the test.

During the film boiling period, a corner and a non-adjacent side fuel rod failed. The corner rod failed while operating at high temperature as a result of the severe cladding oxidation and embrittlement incurred during about 8.5 minutes of sustained film boiling. The side rod failed as a result of rewetting-induced thermal shock on an embrittled cladding following a film boiling period of approximately 300 seconds.

The power and coolant conditions at the onset of film boiling for Test PCM-5 are compared with previous PCM tests in Figure 3. As shown, the conditions leading to film boiling for the central fuel rod in the Test PCM-5 compare favorably with those determined from previous PCM tests in which the fuel rods were enclosed in individual coolant flow shrouds. Individual coolant flow shrouds eliminate the potential for direct rod-to-rod interactions.

From the results of nine-rod bundle Test PCM-5, it has been concluded that:

(1) There was no evidence of direct rod-to-rod interactions; specifically, film boiling and fuel rod failure propagation did not occur.

(2) The central fuel rod of the test bundle behaved independently of the peripheral rods and similar to the behavior of a fuel rod with its own coolant flow shroud. The previously established DNB data base for individually shrouded fuel rods is considered applicable for assessing the DNB response of an interior rod within a bundle.

REFERENCE

1. "Nuclear Regulatory Commission, Reactor Safety Research Program: A Description of Current and Planned Reactor Safety Research Sponsored by the Nuclear Regulatory Commission's Division of Reactor Safety Research," NRC Report NUREG-75/058, NTIS, 1975.

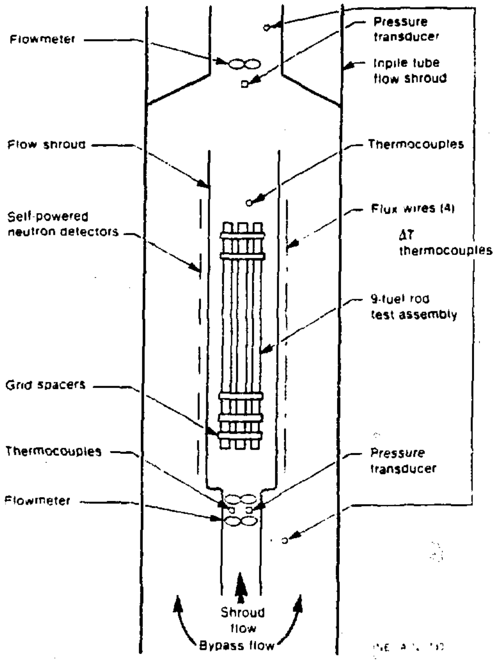
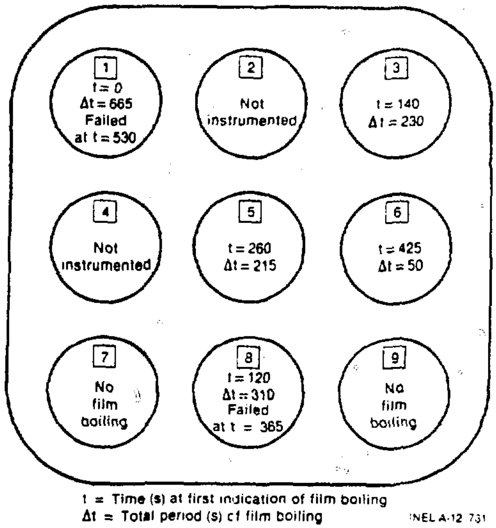


Fig. 1 Schematic representation of the Test PCM-5 test train assembly showing the relative positions of the fuel rods and train instrumentation.

Fig. 2 Film boiling history for Test PCM-5.



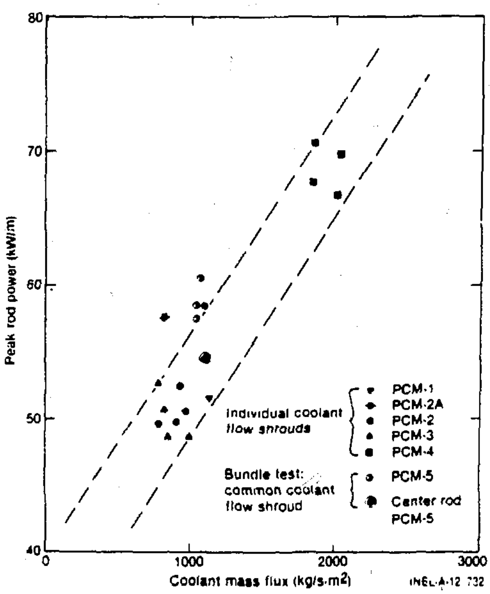


Fig. 3 Comparison of the conditions at the first indication of film boiling for the PCM test series.