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BEHAVIOR OF FOUR PWR RODS SUBJECTED TO A SIMULATED LOSS-OF-COOLANT ACCIDENT IN THE POWER BURST FACILITY

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SUMMARY

Cladding deformation characteristics resulting from the first nuclear blowdown tests (LOC-11) conducted in the Power Burst Facility (PBF) are emphasized in this paper. The Loss-of-Coolant Accident (LOCA) Test Series[1] is being conducted in the PBF reactor at the U.S. Department of Energy's Idaho National Engineering Laboratory (INEL) near Idaho Falls, Idaho, for the U.S. Nuclear Regulatory Commission. The objective of the LOC-11 tests was to obtain data on the thermal, mechanical, and materials behavior of pressurized and unpressurized fuel rods when exposed to a blowdown similar to that expected in a pressurized water reactor (PWR) during a hypothesized double-ended cold-leg break.

The test hardware consisted of four separately shrouded fresh fuel rods of PWR 15 x 15 design. Initial plenum pressures ranged from atmospheric to 4.8 MPa (representative of end-of-life).

During LOC-11C, the four fuel rods were subjected to 6.5 hours of nuclear operation at approximately 67 kW/m average rod power to cause decay heat build-up. Just before the start of blowdown, cladding surface temperatures were about 620 K and fuel centerline temperatures were in the 2500 to 2600 K range.

During the 30-second blowdown transient, CHF occurred 2 seconds after initiation. Fuel centerline temperature dropped continuously, while cladding surface temperatures increased. Maximum cladding temperatures of 1030 to 1050 K occurred 15 seconds into the transient.

Posttest destructive examination revealed cladding microstructures and oxide thicknesses consistent with the measured cladding temperatures. The cladding surface thermocouples did not appreciably affect cladding temperature distribution (fin cooling effect) in the vicinity of the thermocouples. This absence of the fin cooling effect is in distinct contrast to Power-Cooling-Mismatch type transients.[2]

Fuel restructuring, consisting of limited equiaxed grain growth, occurred near the center of the pellets. This growth was attributed solely to high power operation prior to blowdown. The transient caused no anomalous fuel pellet behavior.

Cladding deformation occurred on all four rods during the transient. No bowing was observed after the test. However, the diameter changes illustrated in Figure 1 occurred. The atmospheric pressure rods showed a diameter reduction of 0.1 mm, and the pressurized rods a diameter increase of 0.2 to 0.3 mm.

The cladding temperatures and magnitude of deformation afforded an opportunity to study the incipience of cladding deformation in both pressurized and unpressurized rods. Time-temperature and time-stress histories were evaluated to determine the chronology of cladding deformation. Cladding microstructural and microhardness surveys were performed to correlate cladding structure and hardness to cladding temperature in the areas where the cladding diameter departed from nominal. These analyses showed that cladding diameter increases began about 14 to 15 seconds into the transient, and that the cladding in the region where the diameter started to increase was partially recrystallized and therefore softer than the as-received material. The probable temperature range was 870 to 920 K.[3]

Cladding collapse probably began much earlier in the transient (3 to 4 seconds after initiation) when coolant pressure was still high and cladding temperature low. The cladding at the boundary of the collapse zone had not undergone recrystallization, and had not softened. The probable temperature for the initiation of collapse was less than 850 K, which is lower than the 920 K previously identified.[4] Collapse also occurred over a much greater axial distance than did the diameter increase on the pressurized rods.

In summary, posttest evaluation of the Test LOC-11 fuel rods revealed no major fuel rod damage. Low cladding temperatures and the small amounts of deformation enabled a detailed study of the early phases of cladding deformation. On the basis of these limited data, the beginning of ballooning coincides with a partial recrystallization and softening, whereas collapse does not. Collapse probably occurs almost immediately after the start of blowdown. Ballooning began after temperatures were at their maximum values.

REFERENCES

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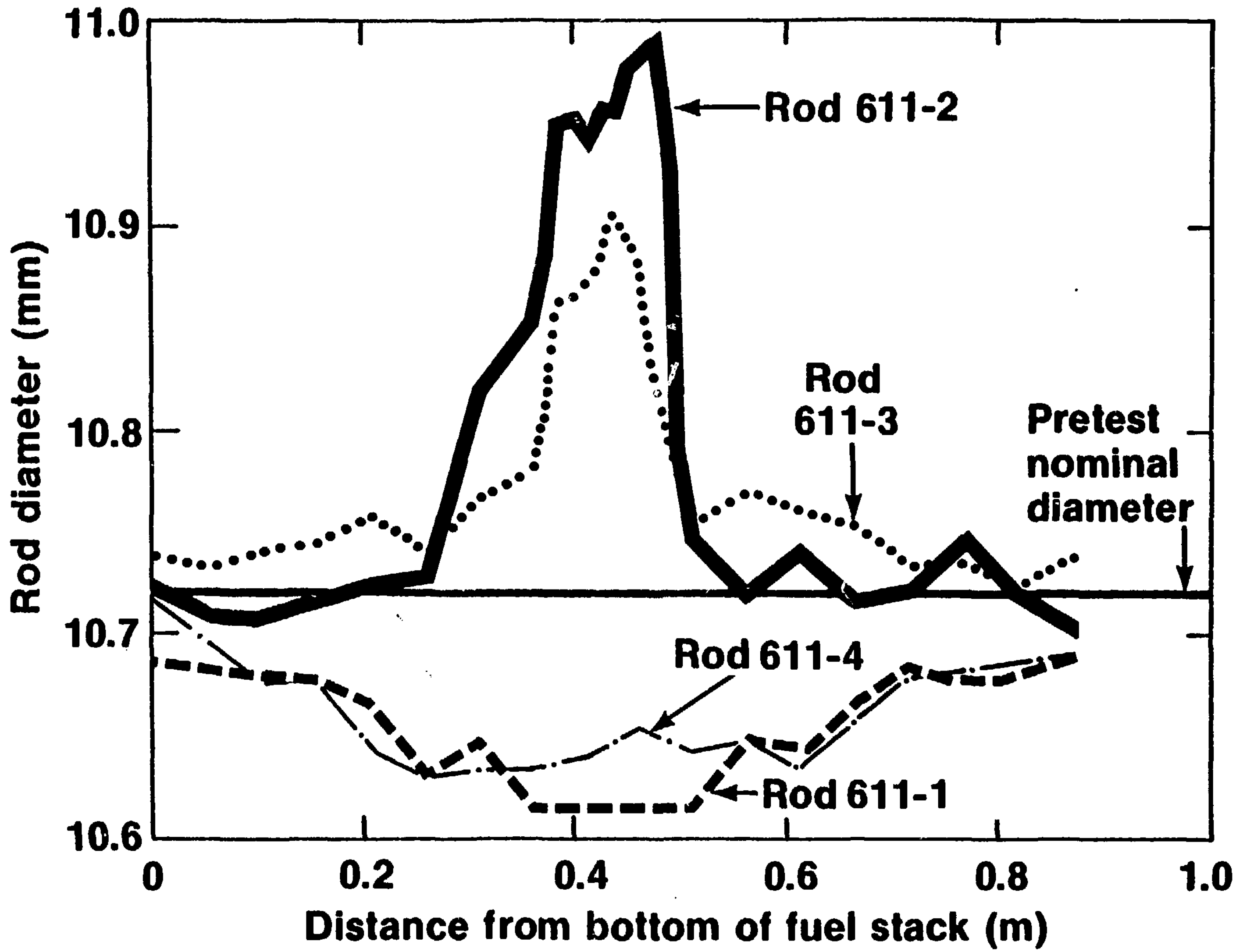
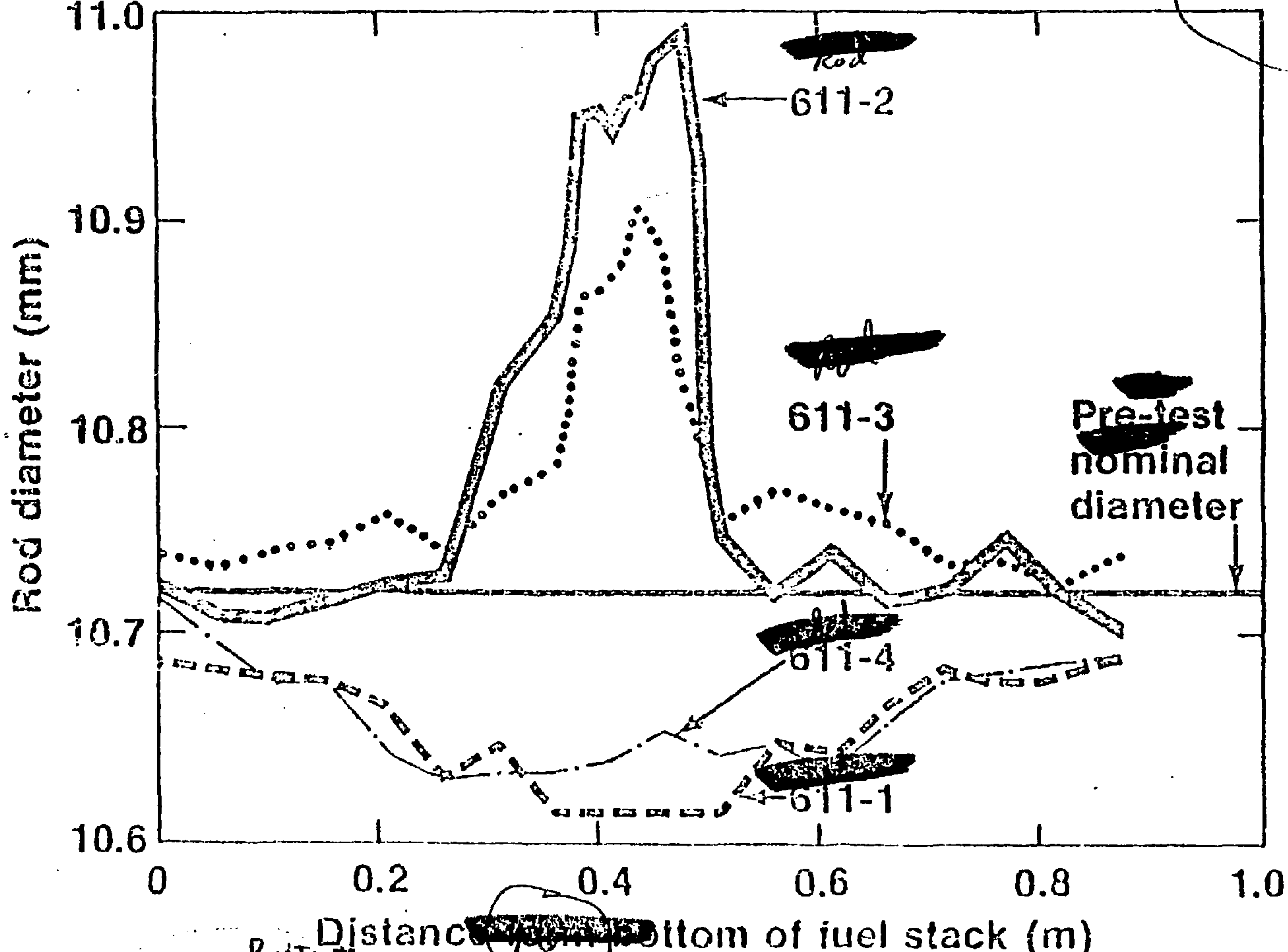


11.0
10.9
10.8
10.7
10.6
Rod diameter (mm)
0
0.2
0.4
0.6
0.8
1.0
Distance from bottom of fuel stack (m)
Rod 611-2
Rod 611-3
Pretest nominal diameter
Rod 611-4
Rod 611-1

INEL-S-8923

LOC-11 Fuel Rod Diameter Versus Length



PostTest LOC-11 Fuel Rod Diameter , Length

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