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Title of Summary Nuclear Fuel Rod Response During LOFT Tests L2-2 and L2-3

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NUCLEAR FUEL ROD RESPONSE DURING LOFT TESTS L2-2 and L2-3

by

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Comparisons of the measured fuel rod peak cladding temperatures for the first two nuclear loss-of-coolant experiments (LOCE), LOCEs L2-2 and L2-3, are presented. These LOCEs were performed in the Loss-of-Fluid Test (LOFT) facility at the Idaho National Engineering Laboratory. The LOCEs provided a basis for evaluating the effect of initial power on the maximum cladding temperatures during a large break (200%, guillotine) LOCE and identified important core thermal-hydraulic responses that influence the peak cladding temperatures.

The LOFT facility is providing data on the integral response of nuclear reactor systems to postulated loss-of-coolant accidents. The LOFT reactor has been scaled to model large pressurized water reactors (PWR). The LOFT core contains 1300 fuel rods pressurized to 0.10 MPa helium which are 1.676 m in length and have nominal commercial PWR fuel radial dimensions. LOCEs L2-2 and L2-3 were 200% cold leg break LOCEs and were conducted with a maximum linear heat generation rate of 26.2 and 39 kW/m, respectively. Nearly 200 thermocouples monitored fuel response.

Figure 1 presents typical fuel rod cladding thermocouple data at peak power locations from LOCEs L2-2 and L2-3. The differences in cladding temperature response can be attributed to the difference in steady state power and associated fuel rod stored energy and slight differences in the initial thermal-hydraulic conditions. The increased stored energy was the main factor resulting in the difference in

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peak cladding temperature, 780 K versus 920 K. The difference in cladding temperature response following the 5-to-8-s cladding quench was due to a larger initial fuel stored energy in LOCE L2-3 which was sufficient to sustain the temperature rise until the emergency core coolant reflooded the core. The energy remaining in the fuel in LOCE L2-2 following the early quench was not sufficient to sustain a cladding temperature rise.

Comparison of the measured thermal-hydraulic data from the LOCEs show the cladding temperatures to be influenced by two major hydraulic phenomena which were nearly identical for each experiment. The first is related to the reestablishment of core flow after initial core flow stagnation. For both LOCEs, within milliseconds after the break, core flow stagnation occurred which eventually resulted in a boiling crisis and increased cladding temperatures from 1.0 to 1.5 s. At approximately 2.5 s, positive core flow was reestablished in both experiments which limited further cladding temperature increase. The limited cladding temperature increase at 2.5 s can be seen in Figure 1 for both experiments. The second important hydraulic effect is due to increased, lower quality flow through the reactor vessel between 6 to 8 s that resulted in cladding temperature quench. This is a result of flow redistribution through the reactor vessel when the inlet broken leg experienced saturated choking. This increased core flow resulted in a bottom-to-top quench of the cladding temperatures. The peak cladding temperatures during LOCE L2-3 generally took longer to quench, indicating that the cladding rewet characteristics are a function of temperature.

No fuel rod failure occurred in either LOCE. Comparison of measured cladding temperature and pressure loadings indicate the cladding to be within elastic limits. Based on zircaloy material property data, pressurized fuel rods would not have experienced ballooning in either experiment.

Analysis of results from LOCEs L2-2 and L2-3 led to the following conclusions:

(1) Cladding thermal response is strongly coupled to core thermal hydraulics. The core thermal hydraulics were very similar during LOCEs L2-2 and L2-3, resulting in similar fuel rod response. The differences in cladding temperatures are due to differences in fuel rod power.

(2) Resumption of a small positive core flow is sufficient to further limit post-departure from nucleate boiling cladding temperature rise.

(3) Elevated cladding temperatures can be cooled and quenched during the blowdown phase of a LOCE.

(4) The cladding temperatures and pressure loadings are not sufficiently severe to result in plastic deformation (collapse). For pressurized PWR fuel experiencing the LOCE L2-3 experimental conditions, cladding ballooning would not be expected.

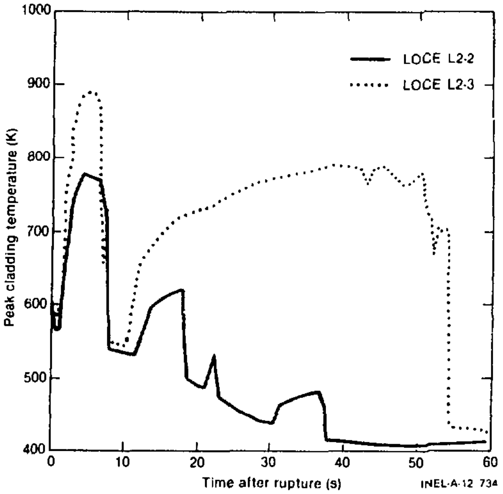

Fig. 1 Typical fuel rod peak cladding temperatures from LOCEs L2-2 and L2-3.