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STEAM GENERATOR TUBE RUPTURE EFFECTS ON A LOCA

MASTER

Jeffrey L. LaChance
(EG&G Idaho, Inc.)

A problem currently experienced in commercial operating pressurized water reactors (PWR) in the United States is the degradation of steam generator tubes. Safety questions have arisen concerning the effect of these degraded tubes rupturing during a postulated loss-of-coolant accident (LOCA). Scaled experiments of this type accident in the Semi-scale Mod-1 system (Test Series 28)[1] indicate that a potential exists for elevated peak cladding temperatures above those obtained for a LOCA without tube ruptures. To determine the effect of a small number of tube ruptures on the behavior of a large PWR during a postulated LOCA, a series of computer simulations was performed under the sponsorship of the Nuclear Regulatory Commission - Division of Operating Reactors (NRC-DOR).

The primary concern of the study was to determine whether a small number (10 or less) of steam generator tubes rupturing at the beginning of core reflood during a 200% cold leg break would result in high cladding surface temperatures. Additional reflood analyses were performed to determine the system behavior when from 10 to 60 tubes rupture at the beginning of core reflood. The FLOOD4 code[2] was selected as being the most applicable code for use in this study after an extensive analysis of the capabilities of existing codes to perform simulations of a LOCA with concurrent steam generator tube ruptures. The version of FLOOD4 used in this study is stored under EG&G Idaho, Inc. Configuration Control No. H00404IB.

The secondary-to-primary flow from ruptured steam generator tubes is modeled in FLOOD4 by a fill junction which requires both the magnitude and quality of the ruptured tube flow as input. The quality of the secondary-to-primary flow could not be easily determined and was

expected to significantly affect the system behavior. Thus two sets of FLOOD4 calculations simulating various numbers of tube ruptures at the inlet plenum of the intact loop steam generators were performed. The first set (nominal calculations) used the Semiscale Mod-1 Series 28 experimental data to estimate the amounts of secondary water vaporized in the primary. This set of calculations was expected to yield the best estimate of actual PWR behavior. The second set of calculations assumed all of the secondary liquid was vaporized in the steam generator (X_{SG} = 1.0) and thus was expected to result in an upper bound on the possible peak cladding temperatures. Additional calculations were performed for 10 tubes rupturing at the outlet plenum of the intact loop steam generator and for various numbers of tube ruptures at the inlet plenum of the broken loop steam generator. These calculations used the nominal values of secondary-to-primary flow quality calculated from the Semiscale Mod-1 Series 28 experiments.

The peak cladding temperatures during reflood predicted in the FLOOD4 calculations are shown in the accompanying figure. The trend in the peak cladding temperatures is very similar to the trend observed in the Semiscale Mod-1 Series 28 experiments. The results of the study indicate that the rupturing of 10 or less steam generator tubes in any of the steam generators during a 200% cold leg break will not result in a significant increase in the peak cladding temperature. However, because of the vaporization of the steam generator secondary water in the primary side of the steam generator, a significant increase in the core pressure occurs which retards the reflooding process.

The secondary-to-primary flow associated with approximately 20 tubes rupturing in the inlet plenums of the three intact loop steam generators was found to be sufficient to stagnate the core flow and result in peak cladding temperatures above 1477 K. The core flow was also stagnated for approximately 23 tubes rupturing in the broken loop steam generator. Due to the fact that the tube ruptures occur in a single steam generator in the broken loop, the secondary water was depleted early in the

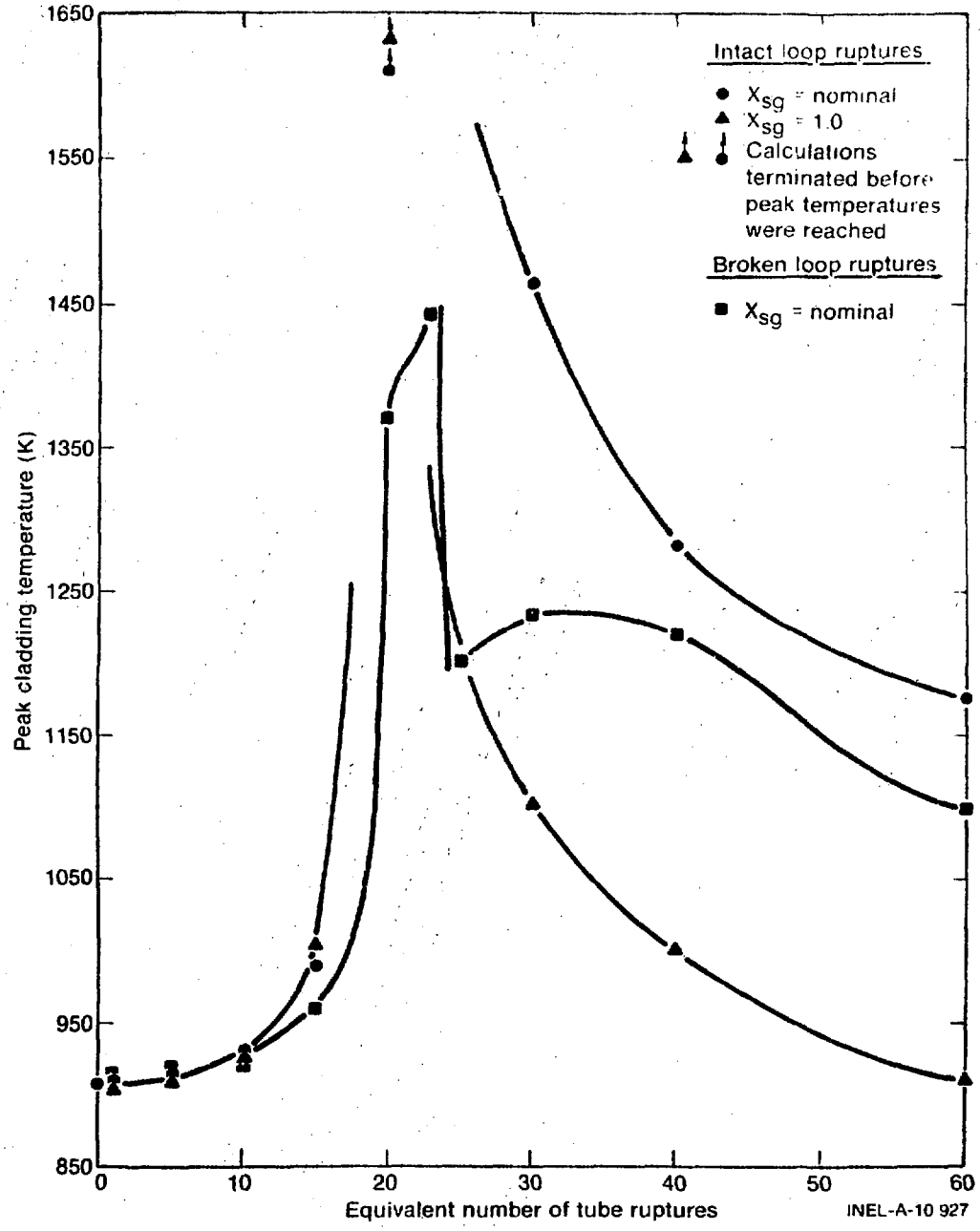

Fig. 1 Peak cladding temperatures during reflood as a function of the number of tubes ruptured in the steam generators.

transient. This depletion allowed the core to be reflooded relatively early compared to the time required when 20 tube ruptures were simulated in the intact loop steam generators and thus the peak cladding temperature obtained was below 1477 K.

For more than 25 tubes ruptured at the beginning of reflood, substantial core heat transfer occurred from negative core steam flow and fallback of liquid from the upper plenum. As a result, the peak cladding temperatures were below 1477 K and generally decreased as the number of tubes ruptured increased.

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1. James M. Cozzuol, et al, "Investigations of the Influence of Simulated Steam Generator Tube Ruptures During Loss-of-Coolant Experiments in the Semiscale Mod-1 System", TREE-NUREG-1213 (May 1978).

2. Robert L. Benedetti, et al, "Potential Influence of Three-Dimensional Effects on PWR LOCA Behavior", TREE-NUREG-1031 (February 1977).