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CALCULATIONS OF FLOW OSCILLATIONS DURING REFLOOD USING RELAP4/MOD6

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Flow oscillations between the downcomer and the electrically heated core during reflood have been observed in reflood experimental facilities such as Semiscale[1] and FLECHT-SET (Westinghouse)[2,3]. The purpose of this study was to investigate the primary mechanism responsible for the initiation and continuation of the oscillations during reflood using the RELAP4/MOD6 code. The present study, which produced significant results concerning the accuracy of RELAP in predicting the dynamic features of density-wave and pressure drop oscillations, was conducted on the German three-loop PRIMAR KREISLAUF (PKL) Reflood Experimental System.

RELAP4/MOD6 is an analytical computer code which can be used for best estimate analysis of PWR or BWR reactor system blowdown and reflood response to a postulated LOCA. In a recent reflood simulation study of Semiscale reflood experiments, RELAP demonstrated that it can predict the frequency of the flow oscillation within 10% of the experimentally measured value[4]. In a frictionless U-tube oscillation study, RELAP predicted the oscillation frequency within 1% of that obtained from the analytical solution.

The PKL facility is a three-loop simulation of a West German pressurized water reactor, fabricated in a reduced scale that maintains prototype volume-to-power ratio. It was designed specifically for system experiments simulating the reflood phase of hypothesized LOCA accidents. The full length electrically-heated 340-rod core is divided into hot, average, and cool channels and has

an overall power capacity of 1.45 MW and a peak power of 1.5 kW/m. Test K5A was a 200% cold-leg break experiment with an initial system pressure of 0.42 MPa. The emergency core coolant was injected into the intact-loop cold legs and into the upper annulus. The coolant was at 100 K subcooling. The average injection rate for the first 35 seconds was about 15.5 kg/s. Thereafter, the rate was suddenly reduced to between 10.5 and 6.8 kg/s. The initial cladding temperature at the 2-meter evaluation was 833 K.

To model the PKL facility for Test K5A, standard RELAP4/MOD6 modeling procedures and guidelines for input parametric values were employed. The RELAP4 PKL model consists of 37 control volumes, 40 nodes, and 50 heat conductors as shown in Figure 1. Calculation of system behavior was initiated with the experimental system filled with saturated steam and representative rods in each of the three electrically isolated core sections at prescribed surface temperatures. ECC injection was initiated in this environment at time equals zero seconds.

The RELAP4/MOD6 calculation of flow oscillations in the PKL K5A reflood test compared well with the experimental data. Most significantly, both predicted and measured oscillations exhibited transient characteristics of density-wave and pressure drop oscillations[5,6]. The dynamic features of density-wave oscillations in the PKL reflood test system are very similar to those observed in the Semiscale, FLECHT-SET reflood experiments. The density-wave oscillation period calculated by RELAP4/MOD6 code is about 2.9 seconds, which is about 14% less than the experimental value of 3.3 seconds, as shown in Figure 2. The calculated maximum pressure-drop oscillation period is 7.1 seconds which is also 14% less than the experimental value of 8.3 seconds. Figure 2 also shows that the RELAP prediction of the

onset of pressure-drop oscillation is about 50 seconds earlier when compared with the test data. It is the first time that the observed density-wave and pressure-drop oscillations in reflood experimental systems were so closely predicted by RELAP4/MOD6 code. The average core mixture level rising rate calculated by RELAP matches the test data well. The predicted heater rod surface temperature and quench time at the hot spot is about 5 to 15% higher than the test data.

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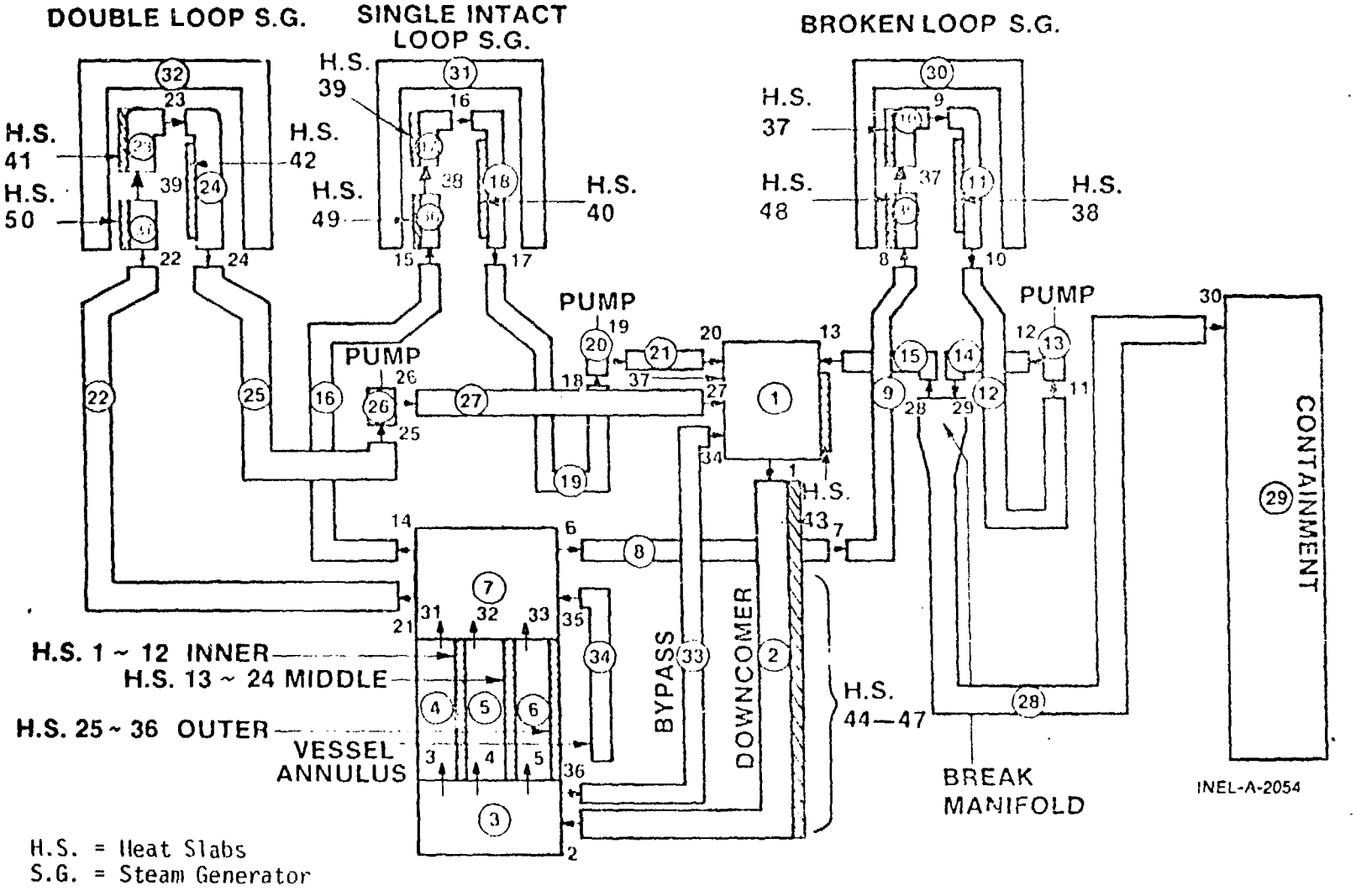

Fig. 1 The PKL three-loop RELAP4/MOD6 nodalization.

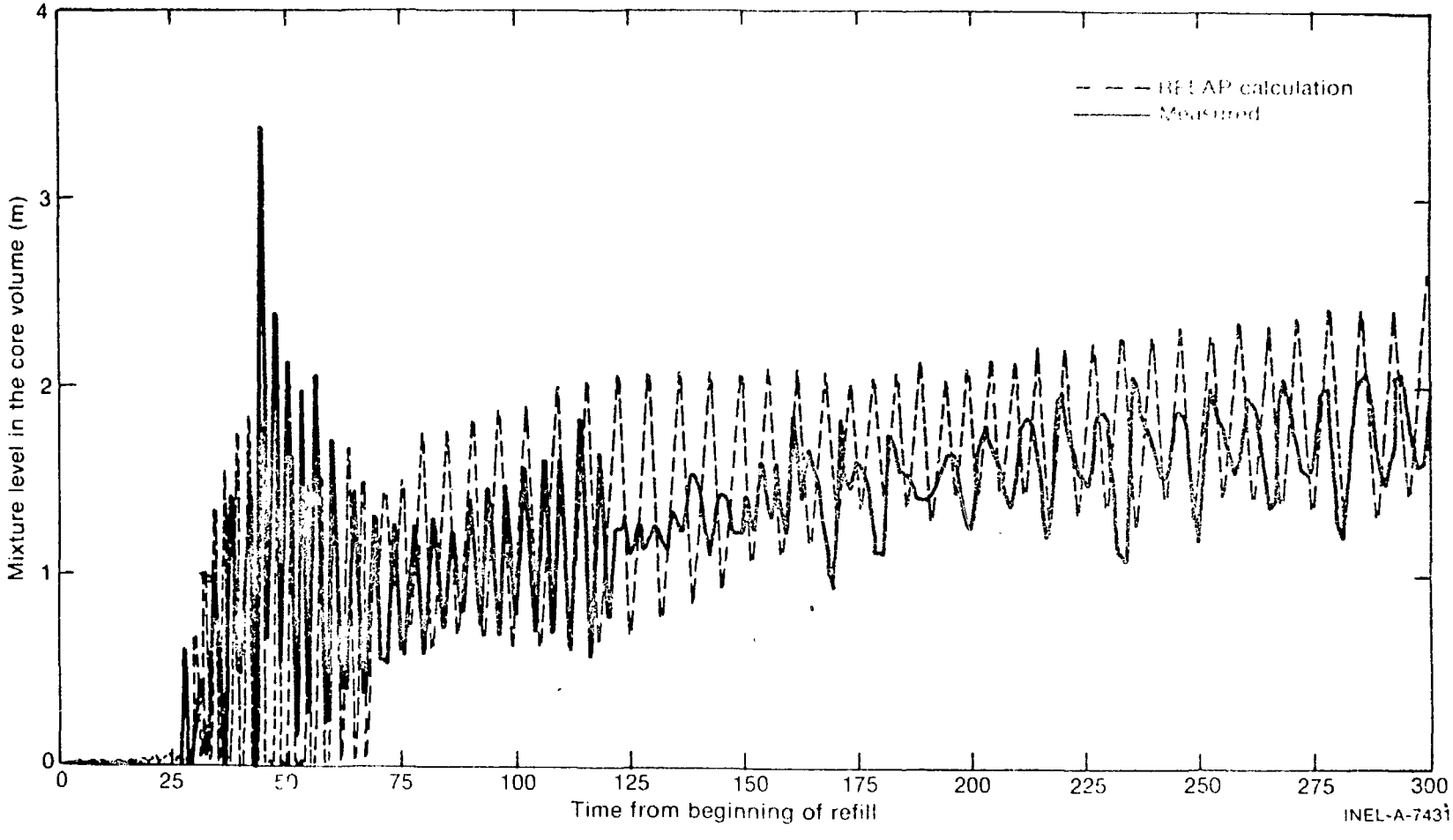

Fig. 2 Comparison of calculated and measured flow oscillations in the core volume for PKL Reflood Test K5A.