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TWO-DIMENSIONAL MODELING OF SODIUM BOILING IN A SIMULATED LMFBR LOSS-OF-FLOW TEST*

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SUMMARY

Loss-of-flow (LOF) accidents are of major importance in liquid-metal fast breeder reactor (LMFBR) safety. Tests have been performed to simulate the simultaneous failure of all primary pumps and reactor shutdown systems in a 37-pin electrically heated test bundle installed in the KNS sodium boiling loop at the Institute of Reactor Development, Karlsruhe[1]. The tests simulated LOF conditions of the German prototype LMFBR, the SNR 300. The main objectives of these tests were to characterize the transient boiling development to cladding dryout and to provide data for validation of sodium boiling codes. One particular LOF test, designated L22, at full power was selected as a benchmark exercise for comparison of several codes at the Eleventh Meeting of the Liquid Metal Boiling Working Group (LMBWG) held in Grenoble, France, in October 1984. In this paper, the results of the calculations performed at Oak Ridge National Laboratory (ORNL) with the two-dimensional (2-D) boiling code THORAX[2,3,4] are presented.

The THORAX code is a thermal-hydraulic boiling code that assumes an equilibrium mixture, two-phase flow with slip. A simplified 2-D geometry is assumed; it consists of two interacting flow channels, one for the interior and one for the edge region, to represent the flow in the hexagonal bundle. This code was developed at ORNL and has been used for analysis of boiling data in 19- and 61-pin bundles. The THORAX code has been successfully used in the analysis of boiling transients under forced and free-flow conditions up to the onset of dryout[2,5]. The essential 2-D nature of the boiling behavior has been modeled in analyses of these transients.

The KfK-KNS 37-pin bundle Test L22 was at full power: 19.38 kW/pin for a inlet temperature of 380°C and an initial inlet velocity of 3.38 m/s. The test bundle was divided into 64 axial nodes, each 25.0 mm in length. The heated length was 900 mm long with a chopped-cosine power profile and a peak-to-average ratio of 1.29. The flow decay was simulated in the THORAX code by modeling the test section pressure drop decay from 125.0 kPa to the static head pressure of 21.3 kPa. The absolute outlet pressure was set at 107.0 kPa for a saturation temperature of 900°C. The THORAX calculation was performed with a time step of 50 ms. The two-phase region and the mass flux field predicted by THORAX are shown in Figs. 1 and 2 at times of 7.5 s and 9.25 s, respectively. The horizontal axes are scaled proportional to the flow area in these plots, and the mass flux vectors are located radially in the centers of the interior and edge channels. Boiling initiation is predicted to occur centrally in the bundle near the end of the heated section at 6.1 s. At 7.5 s (Fig. 1), this two-phase region develops rapidly. It causes a large flow diversion to the outer regions of the bundle, and the Ledinegg instability causes a sharp reduction in the inlet flow. The onset of dryout is calculated at 9.25 s in the central channel, 125 mm upstream of the end of the heated section. At this time, the two-phase region is very extensive being 950 mm long at the central region of the bundle. In the experiment, the power was cut off at 9.45 s by the heater-protection system because of dryout detection. The THORAX calculation agrees well with the experimental results from the benchmark exercise.

In conclusion, the transient development of the two-phase region is predicted for the 37-pin simulated SNR 300 full-power LOF test from the time of boiling inception to the onset of cladding dryout. The predicted time of the onset of

dryout is in close comparison to the experimental observations. This indicates strongly that the THORAX code models the correct 2-D effects that determine the timing of the boiling phenomena.

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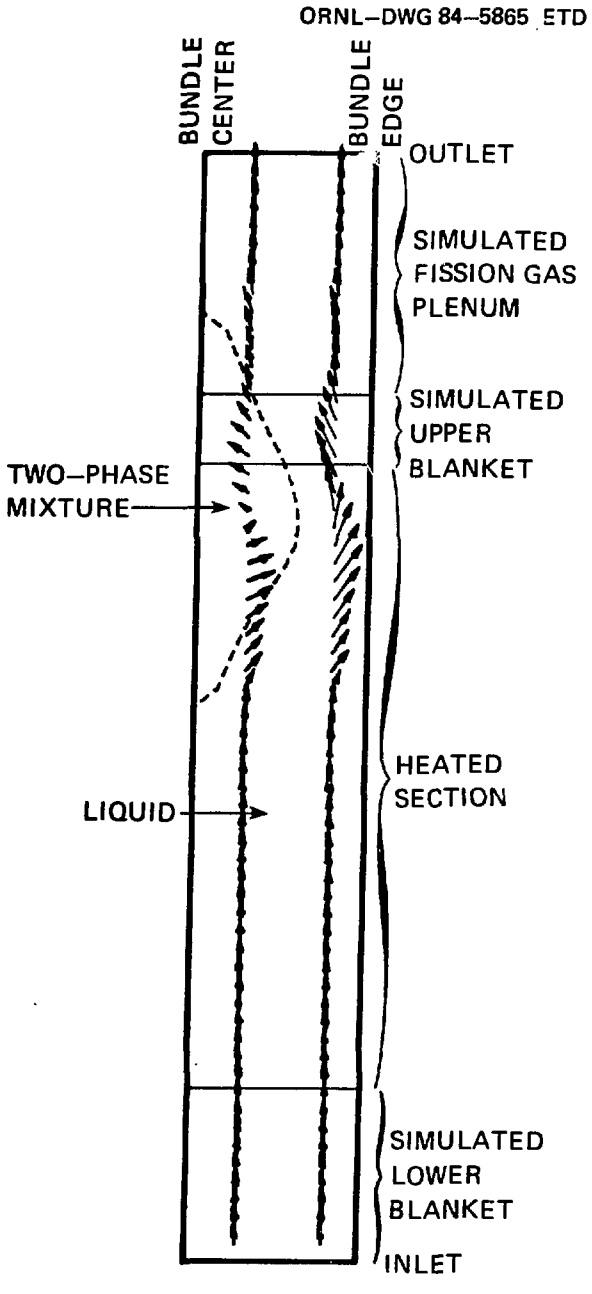
FIGURE CAPTIONS

Fig. 1. THORAX calculated mass flux field at 7.5 s into KfK-KNS 37-pin LOF Test L22.

Fig. 2. THORAX calculated mass flux field at 9.25 s into KfK-KNS 37-pin LOF Test L22.



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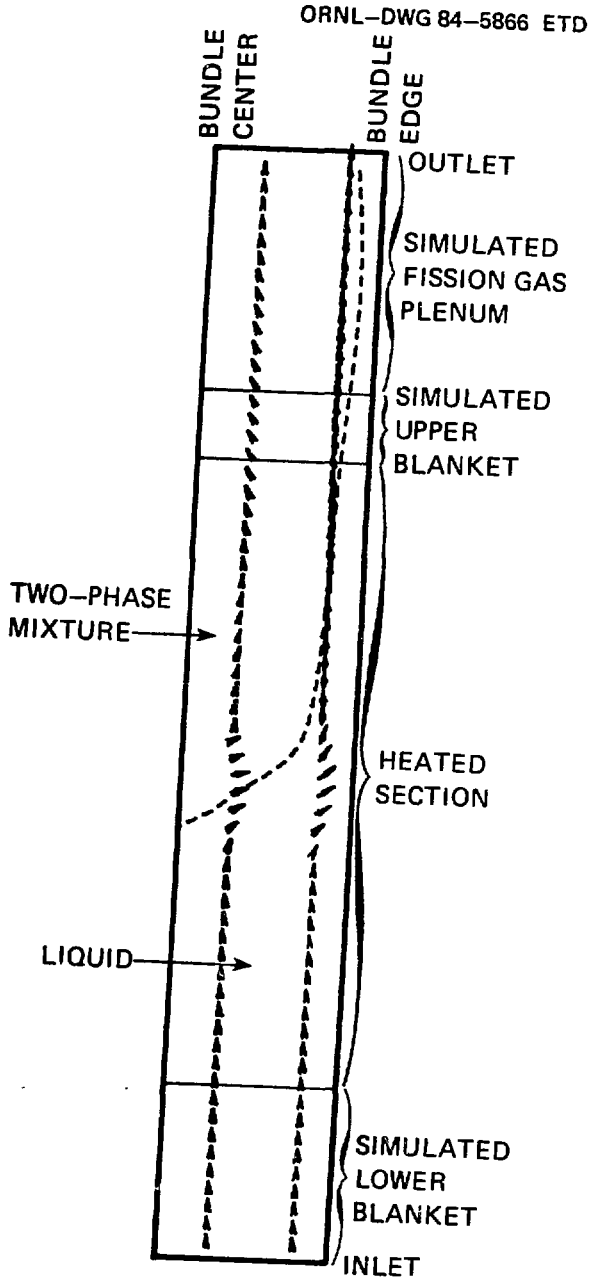

Fig. 2. THORAX calculated mass flux field at 9.25 s into KfK-KNS 37-pin LOF Test L22