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ANALYSIS OF A PWR DOWNCOMER AND LOWER PLENUM UNDER ASYMMETRIC LOOP FLOW CONDITIONS

by

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ANALYSIS OF A PWR DOWNCOMER AND LOPER PLENUM UNDER ASYMMETRIC LOOP FLOW CONDITIONS

Certain postulated transient conditions in a PWR may cause the flow rate and the temperature of the coolant entering the core from one of the cold leg loops to differ significantly from those in the other loops. Some examples of such transients are:

- a stuck-open relief valve on the steam generator,
- a steam line break in which one of the steam lines ruptures,
- the loss of feedwater to one steam generator, and
- the overfeeding of one steam generator.

Many transients with asymmetric reactor inlet water temperatures have been analyzed with the assumption that the coolant is at a uniform "mixed" temperature at the core inlet. The downcomer and the lower plenum were thought to create sufficient fluid turbulence to completely mix all cold leg flows before entering the core. Some preliminary thermal mix testing at Oconee 1 in 1979 indicated that total mixing did not occur in the lower plenum. These results opened new speculation as to the validity, i.e., conservatism, of certain transient analyses such as mentioned above.

When the flow rate and/or temperature of the loops are not balanced, the resulting thermal mixing at the core inlet will become nonuniform, and the assumption of perfect mixing is not only unwarranted, but may lead to an erroneous prediction of radial power distribution. Realistic prediction of thermal mixing in the downcomer and lower plenum is thus important in providing realistic predictions of power tilts and recriticality potential in the asymmetric cooling transients and hypothetical accidents. Knowledge about thermal mixing also is important in predicting the departure from nucleate boiling (DNB). The objective of this paper is to describe the results of the three-dimensional steady-state calculations for the analysis of thermal mixing in a PWR. The specific case chosen for the present study is one of the tests conducted in the Oconee-1 PWR described in Reference 1. those tests were conducted to determine the extent of downcomer and lower plenum mixing in response to various temperature differences or flow imbalances between the two coolant loops. These tests were performed specifically to obtain coolant temperature profiles at the core inlet, core outlet, and various axial locations in the core under imposed offset loop conditions.

The calculations were performed using the COMMIX-1A computer code (2). Some preliminary results were presented previously without comparison with test data (3). COMMIX-1A (2) is a modified advanced version of COMMIX-1 (4). It is a general-purpose single-phase steady-state/transient three-dimensional thermal hydraulics computer program. COMMIX-1A has a wide range of applicabilities (5). Although it was developed for LMFBR component/multicomponent applications using sodium properties, the computer code has been modified under EPRI sponsorhip to include water properties for pressurized water reactor applications. The water properties used for these computations are based on the Brookhaven National Laboratory package which uses the formulations of Jordan (6). These properties account for full compressibility, and are not limited to a thermally expandable fluid.

The test chosen for the analysis is test No. 3 of Reference 1; test number 3 has 40% full core power level, a +16.96°F (+9.42°C) temperature mismatch or bias between the A and B cold leg loops, for all four coolant pumps operating. This test was chosen for several reasons. First, it is wholly typical of the results obtained for the 22 runs performed; second, the temperature imbalance was the largest of all runs.

Figure 1 shows velocity vector plot in a meridional plane joining the

A2 and B1 pumps. The flow rate imbalance between the two cold legs was 2.5%. Figure 2 shows a corresponding isotherm plot which clearly shows an imperfect thermal mixing in the lower plenum. Figure 3 shows comparison between the code predicted temperatures and the plant data. Considering the complexity of the lower plenum geometry due to the internal structures, the agreement is good.

The major result was that detailed modeling of the 52 asymmetrically located instrument guide tubes together with the structures in the lower plenum yielded generally good agreement with the data. It is shown that highly complex three-dimensional flow patterns are created in the lower plenum. Because of a lack of computational tools in the past, the analysis of such complex thermal mixing processes in an operating PWR has only now been possible. Most of the thermal mixing trends at the entrance to the core and midplane deducted from the 29 thermocouple reading were correctly computed by COMMIX-1A.

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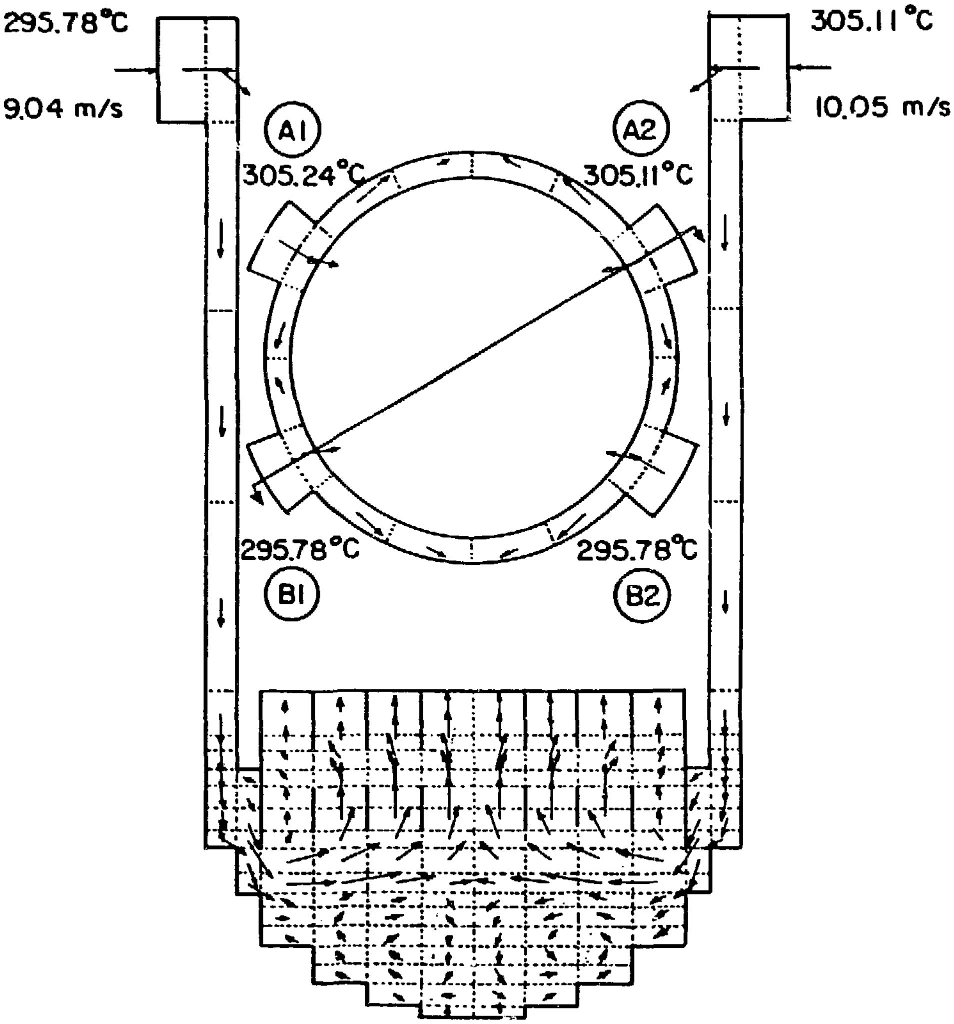

Fig. 1 Velocity Vector Plot in Aximuthal Planes J=2,10 for Asymetric Case with 2.5% Fow Imbalance

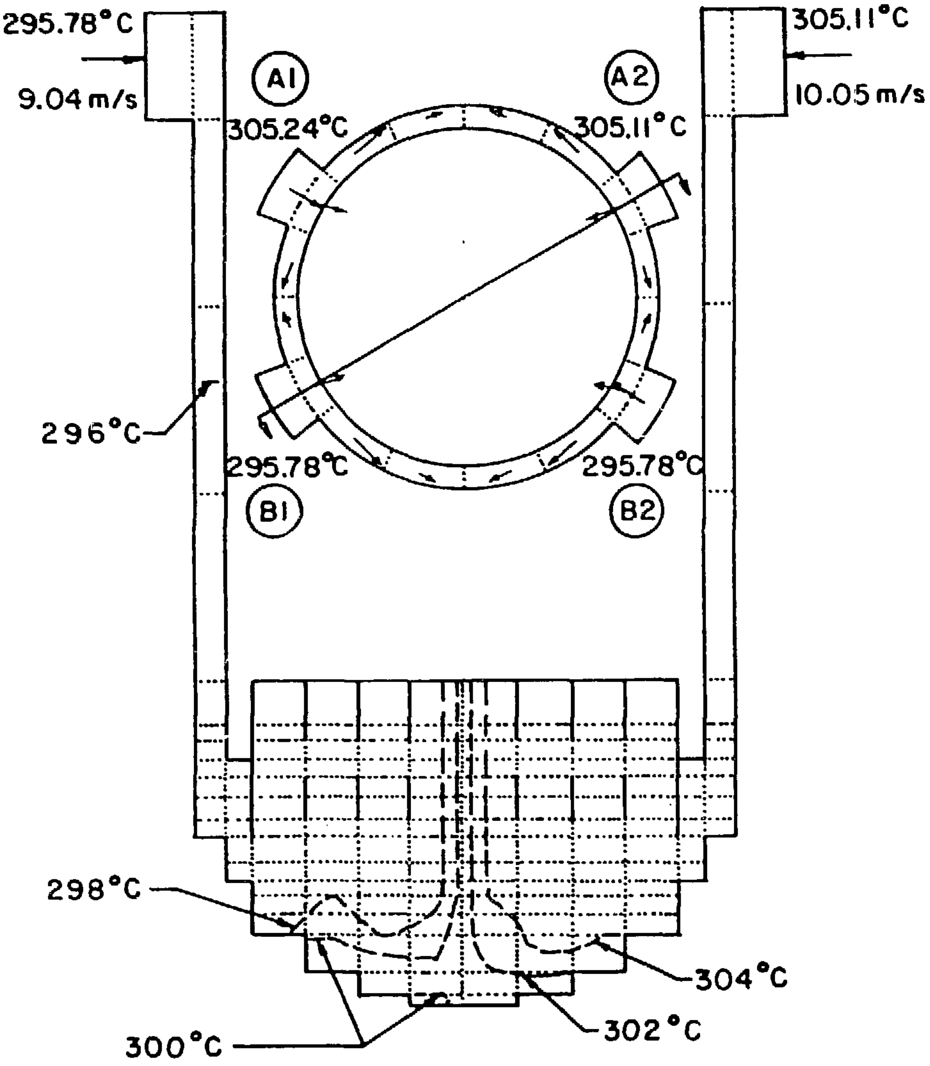

Fig. 2 Isotherm Plot in Aximuthal Planes J=2,10 for Asymmetric Case with 2.5% Flow Imbalance

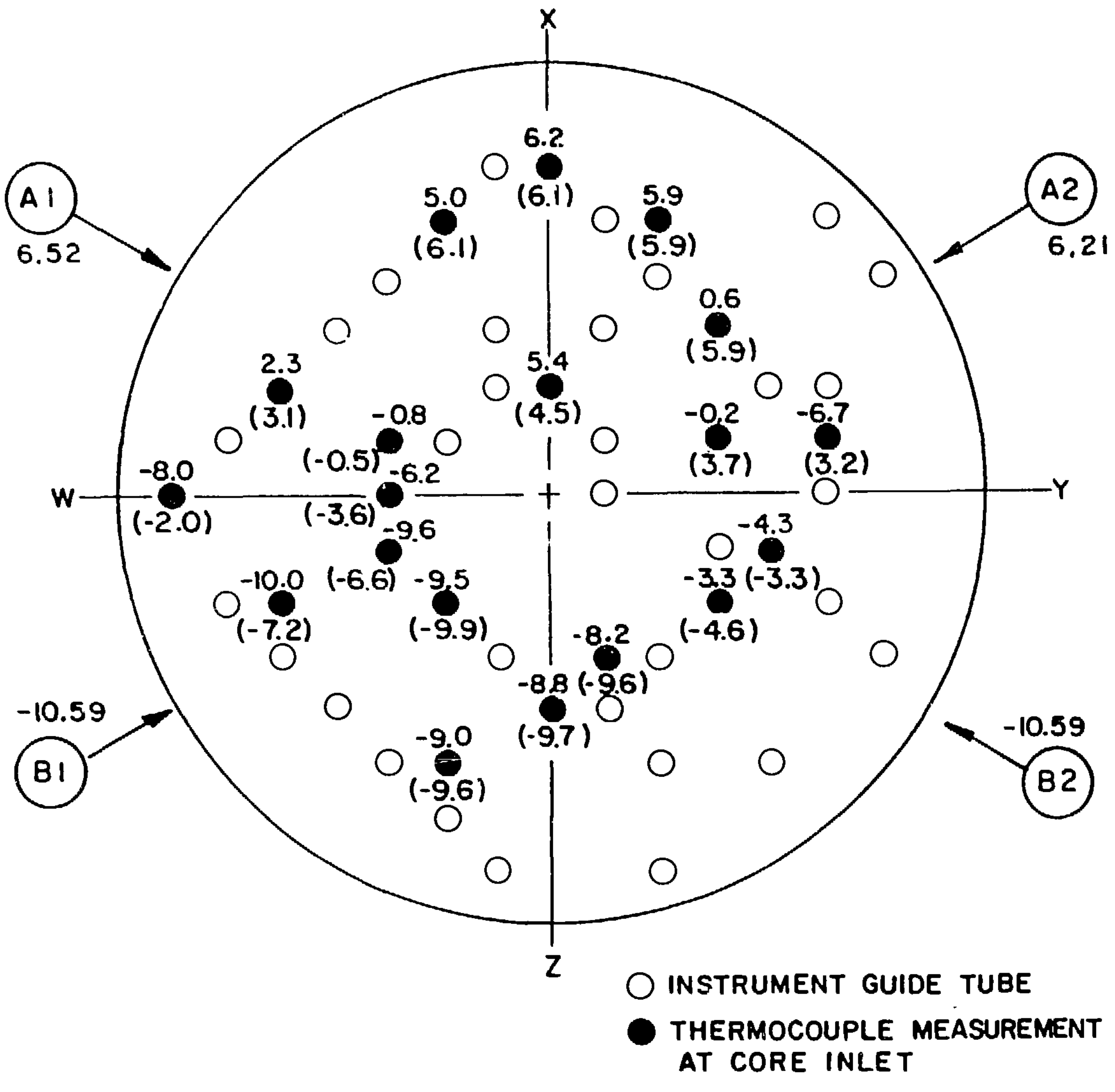

Fig. 3 Comparison of COMMIX-1A Calculations with Thermocouple Data for Asymmetric Case with 2.5% Flow Imbalance. All Values are in °F Departure from 575°F. Open numbers: Plant Data Numbers in Parentheses: COMMIX-1A Calculations