NUMERICAL SIMULATION OF THE RD-14M TEST T9308

M. An*, W. Thompson* and M. Wright**

ABSTRACT

In 1990, the AECB opened the Action Item 90G02 to track the progress of the Canadian nuclear utilities in addressing concerns related to core cooling in the absence of forced flow. The main concern is that, under thermosyphoning conditions in the unbroken loop following a LOCA, flow may stop in individual channels. This may lead to high sheath temperatures, possibly jeopardising the integrity of the unbroken loop pressure boundary and an escalation of the initial event consequences. This type of flow behaviour occurred in a few thermosyphoning experiments performed with the RD-14M facility [1] at relatively high system inventory. The percentage of inventory in the loop at this time was comparable to that in the reactor unbroken loop following a LOCA.

Over the intervening years, many simulations of the RD-14M experiments in which thermosyphoning flow breaks down have been performed. Recently, simulations of one test, T9308 [2] have shown that individual heated section behaviour is best matched with various two-phase conditions at each feeder connection to the outlet header. However, the header conditions in these CATHENA simulations were treated as uniform (single node boundary condition) and trial and error was used to determine the transient void conditions. A more fundamentally based assessment of the header fluid conditions is therefore required in order to predict the reactor situation confidently.

The purpose of this work is to simulate the transient 3-D behaviour of the water-steam mixture within the outlet header #5 of the RD-14M loop during Test T9308. The header geometry is shown in Figure 1, in which five outlet feeders from heated sections 10 to 14 are connected to the header. Also attached to the header are one boiler pipe rising to boiler #1, and one dead-ended pipe to a pressure relief valve. This pressure relief valve is not representative of a CANDU, but is required for over-pressure protection of the RD-14M test-rig. The dead-ended pipe has been modified to save computer resources while conserving the volume and height of the original pipe, and it may be important during the transient process for refilling the header due to its contained volume and height relative to the header.

* Atlantic Nuclear Services Ltd., New Brunswick
** NB Power, New Brunswick

The general-purpose Computational Fluid Dynamics (CFD) code, PHOENICS [3] has been employed for the simulations. The Eulerian-Eulerian technique, which treats the two phases as 'interpenetrating continua', is used to solve for the variables-of-interest for each phase. These variables include pressure, three velocity components, volume fraction, enthalpy and turbulent parameters. It is assumed that both phases share the same pressure

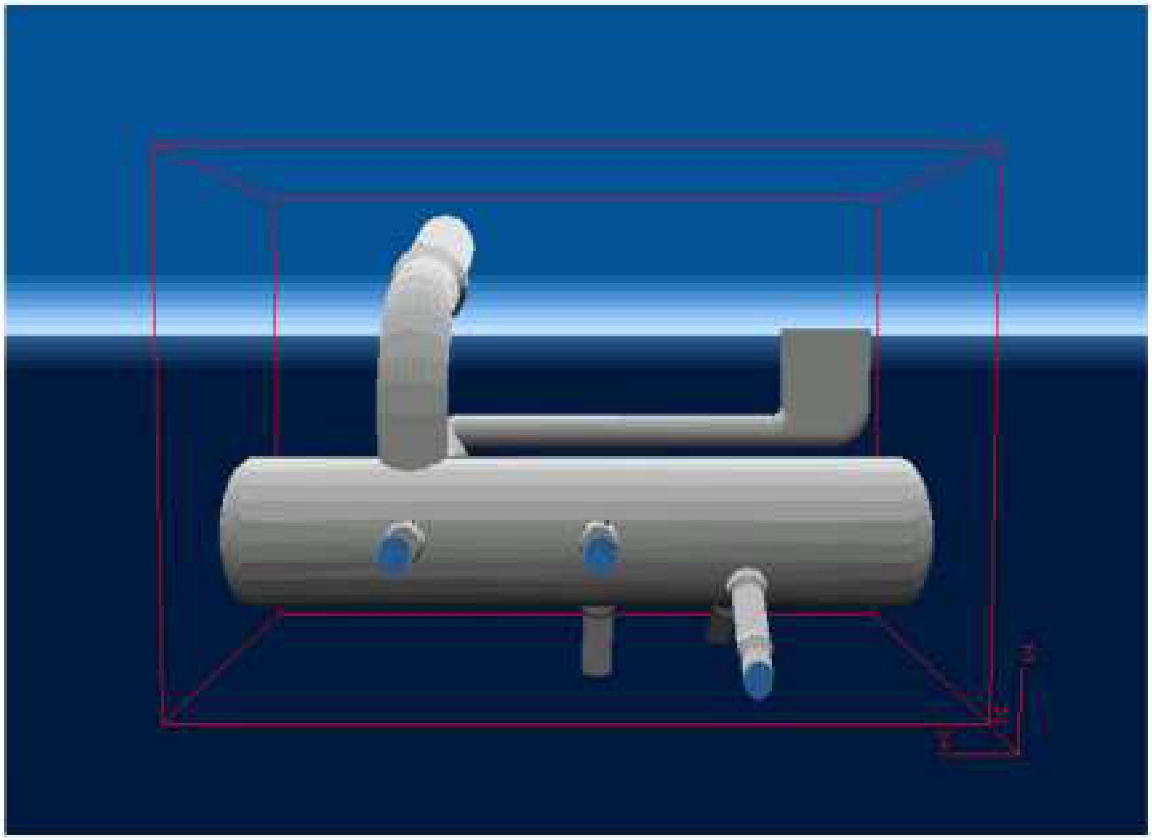

Figure 1

that is solved based on the liquid phase. Buoyancy force is applied on the second phase, i.e. the steam phase.

The effective viscosity hypothesis is adopted, where the turbulence effect on the mean flow is interpreted as a turbulent viscosity in addition to the laminar viscosity of the fluid. Phase diffusion terms, representing the turbulent fluxes associated with the correlation between fluctuating velocity and volume fraction, are also considered.

The Inter-Phase Slip Algorithm (IPSA) built in PHOENICS is adopted, where the links between the phases – interphase mass, momentum and heat transfer – have been all introduced via relevant interphase sources in the governing equations for the concerned variables, during preliminary test simulations with a simplified geometry. However, due to convergence difficulties with the above actual complicated geometry and time restraint for this work, only the interphase momentum transfer is eventually considered. This simplification in physical mechanism is assumed acceptable since the sole cause for the interphase mass and heat transfers in this case is the variation of pressure, which has no significant change within the whole domain and over the time period selected for transient simulations.

Reference

1. McGee, G.R., et al., RD-14M Facility Description, COG Report, COG-88-42, 1989.
2. Ross, W.E. and Ballyk, J.D., Assessment of CATHENA for Thermosyphoning Applications: Test T9308 Heated Section Simulations, AECL Report, TTR-642, July 1998.
3. CHAM, PHOENICS Computational Fluid Dynamics Software, ver. 3.2, Concentration, Heat & Momentum Limited, London, UK.