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TWO PHASE NONEQUILIBRIUM HEAT TRANSFER IN THE TRAC-PD2 CODE

by

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ABSTRACT

The Transient Reactor Analysis Code (TRAC) is being developed by the Los Alamos Scientific Laboratory for the Division of Reactor Safety Research, United States Nuclear Regulatory Commission. TRAC is a best-estimate, multidimensional, nonequilibrium computer code intended for the analysis of loss-of-coolant accidents (LOCA's) in light water reactors. TRAC-PD2 is the third, detailed, pressurized water reactor version of the code.

The TRAC code is modular both by components and by function. That is vessels, pipes, pumps, etc. can be coupled together in any manner in order to simulate a reactor or a particular experimental facility. Individual physical phenomena are also coded in separate subroutines.

This paper discusses the wall to fluid heat transfer coefficient correlations, the interfacial heat transfer models, and presents results for several experimental facilities.

Wall/Fluid Heat Transfer. The TRAC wall to fluid heat transfer coefficient correlations are coded in a separate package, called HTCOR, which is used by all components, under all flow conditions.

This heat transfer package contains correlations for seven heat transfer regimes:

1) convection to single phase liquid,
2) nucleate boiling,
3) transition boiling,
4) film boiling,

5) convection to single phase vapor,
6) convection to a two-phase mixture, and
7) condensation.

In addition to the above correlations, critical heat flux (CHF) and minimum stable film boiling (T_{min}) correlations are used to describe the boiling curve. The Dittus-Boelter equation or natural convection equations are used for the calculation of single phase heat transfer coefficients, while the Chen correlation is used for the nucleate boiling and condensation regimes. The Bromley and Dougall-Rohsenow equations are used for film boiling, and quadratic interpolation is used for the transition boiling regime. Since TRAC is a nonequilibrium code, heat transfer coefficients are needed for each phase. This paper describes the calculation of the wall to fluid heat transfer coefficients for each phase, based upon the basic correlations previously described. The methods used to smooth the boiling curve between regimes are also described.

Interfacial Heat Transfer. In the TRAC code the separate interfacial heat transfers to the vapor and liquid are specified. The interface is assumed to be at the fluid saturation temperature and

$$q_{i\ell} = h_{i\ell} A_i (T_L - T_{sat})$$

$$q_{iv} = h_{iv} A_i (T_V - T_{sat})$$

A simplified thermal energy jump condition specifies the vapor generation rate

$$\Gamma = \frac{q_{iV} + q_{iL}}{h_{fg}}$$

Four separate flow regimes are considered for the purpose of calculating interfacial heat transfer coefficients for boiling: bubbly, bubbly-slug, churn turbulent, and annular-mist regimes. A separate single separated regime is assumed during condensation. The flow regime map is discussed as are the individual correlations for each regime.

TRAC Comparisons with Data. TRAC-PD2 has been applied to a number of experimental facilities in order to assess the coded models. Results are presented in this paper for a number of cases, showing the effect of the heat transfer models. Comparisons are made between both TRAC-P1A, TRAC-PD2, and the data. Results are presented for the Bennett steady-state tube experiments, showing the effect of the Biasi and Bowring CHF correlations (Bowring is not included in TRAC-PD2). LOFT results show the influence of the homogeneous nucleation and Iloeje T_{min} correlations and the CISE heated tube experiment shows additional comparisons of TRAC-P1A and TRAC-PD2 results.