June 16, 2004

Professor Michael Z. Podowski
Professor of Nuclear Engineering Physics
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Dear Professor Podowski:

Thank you for your letter of May 21, 2004. Dr. Carl Paperiello has asked me to respond for him. You asked for comments on your thoughts regarding NRC research on code development and also enclosed an example showing an issue with the wall drag partitioning scheme of the RELAP5 code. I will first address your comments with respect to the NRC code development program and then follow up with a discussion of wall drag in our system codes.

Your first comment concerns the development activities associated with the NRC thermal-hydraulic system analysis codes. As you state, much of the recent development activity associated with our code consolidation project (the TRACE code) has been in the areas of numerical model improvements, new computer platforms and an improved user interface. In addition, a large effort has been expended to modernize the code architecture (to minimize maintenance costs and facilitate future development efforts), to develop an External Component Interface (to facilitate coupling to other codes), and to incorporate both models for boiling water reactors (to recover the TRAC-B capability) and the capability to process RELAP5 input models. This code consolidation and modernization phase has now been completed. The focus of our current efforts is on assessment (both for separate effects and integral effects tests), identification of code deficiencies (both in robustness and simulation accuracy), and prioritization and amelioration of deficiencies. Consequently, we are already in the process of doing what you suggest, namely revisiting the physical models in the code and upgrading them where necessary.

Your second comment touches upon NRC sponsored research on the development of an advanced multi-dimensional computational fluid dynamics (CFD) model for multiphase flow. Specifically, you point to the potential for coupling the CFD model with the system code and for using multiphase CFD as a way of investigating and perhaps developing improved constitutive models for the system code. The NRC is developing an in-house CFD analysis capability which previously had been restricted to single-phase flow. Future plans call for extending this capability to multiphase CFD, but the resources are not yet available to

realize this. Also, coupling of a multiphase CFD code with the system analysis code (TRACE) is considered premature. We agree with your suggestion for using multiphase CFD as a "numerical wind tunnel" to aid in the development of physical models for the system code and will consider this approach as code model deficiencies are uncovered and prioritized.

Turning now to your example of the issue with the RELAP5 wall drag partitioning scheme, the concept of induced shear is not a new one and appears in the volume averaged two-fluid equations derived by Professor Ishii in 1975. However, as you point out, this term has not been explicitly modeled in the two-fluid momentum equations in the NRC system thermal-hydraulics codes. Also, as you correctly surmise in your attachment, the effects of neglecting this term have not been evident in system calculations due to the relative unimportance of two-phase wall drag. For most components, the drag force is dominated by form losses and, where wall drag is significant, the flow is primarily single-phase. Nevertheless, neglecting this term can result in calculated behavior that does not match physical intuition, for example, the existence of an appreciable relative velocity in fully developed horizontal dispersed bubbly flow. Consequently, your suggestion will be taken into account when upgrading the wall drag model in the TRACE code.

In your attachment, see equation 28, it is stated that in RELAP5 the total two-phase flow pressure drop is only due to the effect of gravity. This statement follows from the assumption made in equations 26 and 27 that the interfacial force can be replaced by the buoyancy force. In actual numerical calculations, the interfacial friction force is not assumed to be equal to the buoyancy term but rather is calculated as a function of the relative velocity. Consequently, the two-phase pressure drop is not incorrectly calculated to be solely dependent upon the effect of gravity. Instead, the two-phase frictional pressure gradient is calculated correctly, within the limitations of the constitutive model, but the effective interfacial force is larger than that necessary to compensate for buoyancy. In your example, this would cause the computed void fraction to increase from 10% to about 11%. A difference that would not be noticeable in most calculations.

However, there is a real problem with the wall drag modeling in RELAP5 and, to a lesser degree, in the TRACE code. This problem was noted in doing calculations for condenser tubes involving co-current down flow in the annular flow regime. For this case, the induced shear should be zero as the flow is separated. However, the wall drag partitioning scheme used in RELAP5 places the majority of the wall drag on the vapor phase instead of on the liquid film. The result is a calculated liquid film thickness an order of magnitude too small. This problem will soon be remedied in the TRACE code and, as this involves modifying the wall drag formulation, provides an opportunity to consider the implementation of an induced shear term as well.

Thanks again for your comments regarding NRC research on code development. We agree that "the weakest link determines the quality of the chain" and that for thermal-hydraulic system

codes the weakest link is often the physical models. Consequently, we are now focusing our efforts on code assessment and model improvement. We look forward to future cooperation in multiphase CFD research and eventually performing multiphase CFD calculations in-house and to the coupling of the NPHASE code with TRACE. Should your research efforts uncover any other potential model deficiencies in our codes please forward these to us.

Sincerely,

/RA/
Farouk Eltawila, Director
Division of Systems Analysis and Regulatory Effectiveness
Office of Nuclear Regulatory Research

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