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POOL BOILUP ANALYSIS USING THE TRANSIT-HYDRO CODE WITH IMPROVED VAPOR/LIQUID DRAG MODELS*

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by

Roald A. Wigeland and Dale L. Graff**

Argonne National Laboratory
Reactor Analysis and Safety Division
9700 South Cass Avenue
Argonne, Illinois 60439

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** AT&T Bell Laboratories, Naperville, IL 60566

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Pool Boilup Analysis Using the TRANSIT-HYDRO Code with Improved Vapor/Liquid Drag Models

by

Roald A. Wigeland and Dale L. Graff

The TRANSIT-HYDRO computer code[1] is being developed to provide a tool for assessing the consequences of transition phase events in a hypothetical core disruptive accident in an LMFBR. The TRANSIT-HYDRO code incorporates detailed geometric modeling on a subassembly-by-subassembly basis and detailed modeling of reactor material behavior and thermal and hydrodynamic phenomena. The purpose of this summary is to demonstrate the validity of the improved vapor/liquid momentum exchange models in the TRANSIT-HYDRO code for a prototypic experiment and describe some implications for transition phase scenarios.

The TRANSIT-HYDRO computer code uses separate momentum conservation equations for the liquid and vapor fields. These equations are connected by an interphase momentum exchange, or "drag", term. The vapor/liquid momentum exchange models were developed from basic physical principles, an analysis of the range of anticipated accident conditions, and previously developed models. A detailed discusion of the basic principles can be found in Clift, Grace and Weber[2], and in Wallis[3]. The models developed by Ishii and Zuber[4] were particularly useful as they were well supported by experimental data.

The interphase drag modeling is a function of void fraction, flow regime, particle (bubble or drop) size and particle shape. Four flow regimes are used: bubbly flow, churn-turbulent flow, drop/annular flow, and a special case of slug flow. The flow regime is selected based on the local void fraction and the void fraction distribution. The transition from bubbly flow to churn-turbulent flow occurs at a void fraction in the range of 0.35 to 0.55. A similar transition from churn-turbulent flow to drop/annular flow occurs in the void fraction range 0.60 to 0.80. The lower values are generally selected for deeper pools, as determined from experimental data.

Different correlations for determining the drag are used in each of these flow regimes, and the correlation selected is also dependent on the particle size. Multi-particle effects are generally accounted for by using the mixture viscosity concept and other relations as advanced by Ishii and Zuber[4], although in modified forms suitable for use in the TRANSIT-HYDRO code. Due to the general nature of the models, they are not limited to a particular set of materials, and should be applicable to both simulant and real reactor materials.

Recently several scenarios have been suggested for LMFBR transition phase events. One of the possibilities is for forming subassembly-size or multiple-subassembly pools of material as the fuel and steel melt following initial fuel pin disruption and dispersion. Subsequent events are characterized by material vaporization and relocation with relatively low accelerations. In particular, the mechanism of pool boilup in the transition phase has been suggested as a means of keeping the molten material in a subcritical configuration and avoiding recriticalities, even at decay heat levels.

In order to determine the suitability of the models for such pool boilup situations, the TRANSIT-HYDRO code was used to simulate the gas injection experiments performed by Orth, et al.[5] These experiments were selected because the pool behavior is determined only by the momentum transfer between the two phases. In these experiments, a controlled amount of gas was injected over a large volume into a column of water. The top of the experiment was open to the atmosphere, so that no pressurization occurred. The results of the experiment included measurements of the average pool void fraction and average bubble size as a function of gas injection rate (or superficial velocity which is the gas injection rate divided by the flow area). This type of experiment is easily modeled by the TRANSIT-HYDRO code, with the gas injection rate converted into a suitable mass source term. The calculations were performed starting from a completely separated liquid pool and vapor region. The results of the calculation and the comparison to experimental data is shown in Figure 1. The good agreement between calculation and experiment gives confidence that the interphase drag models can adequately simulate such experimental data, and that they could be used for transition phase calculations, especially for pool boilup behavior.

A more prototypic situation has been modeled using TRANSIT-HYDRO starting with an initially dispersed pool in one subassembly, with the void fraction distribution identical to that for the intact fuel pins. The material was melted in place, and then allowed to move while power was held constant at about 4% of full power (a typical value at approximately 10 seconds after decay heat levels have been attained). In order to provide the greatest chance for pool boilup and dispersal, the subassembly was completely open at the top, so that liquid and vapor could freely escape. There was also no heat transfer to the subassembly walls so that all of the heat generated would go towards vaporization. As a scoping calculation this is not unrealistic in view of the low thermal conductivity fuel crusts that would form between the subassembly wall and the molten fuel/steel mixture.

The results of the calculation showed that there was considerable vaporization of steel, even at these low power levels. The vaporization rate was sufficient to carry the molten fuel/steel mixture upward and out of the calculation region. Therefore, it appears possible for the pool to boil up under the most favorable conditions, even at decay heat levels. The consequences of using more realistic boundary conditions can now be investigated, to see if boilup is possible when heat transfer to the wall and restricted flow from the subassembly is included.

In summary, the improved fuel/liquid momentum exchange models in the TRANSIT-HYDRO code have made it possible to accurately model two-phase pool boilup situations. Initial calculations on more prototypic situations also showed that it was possible to disperse a molten fuel/steel pool at decay heat levels under favorable conditions.

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R. Wigeland

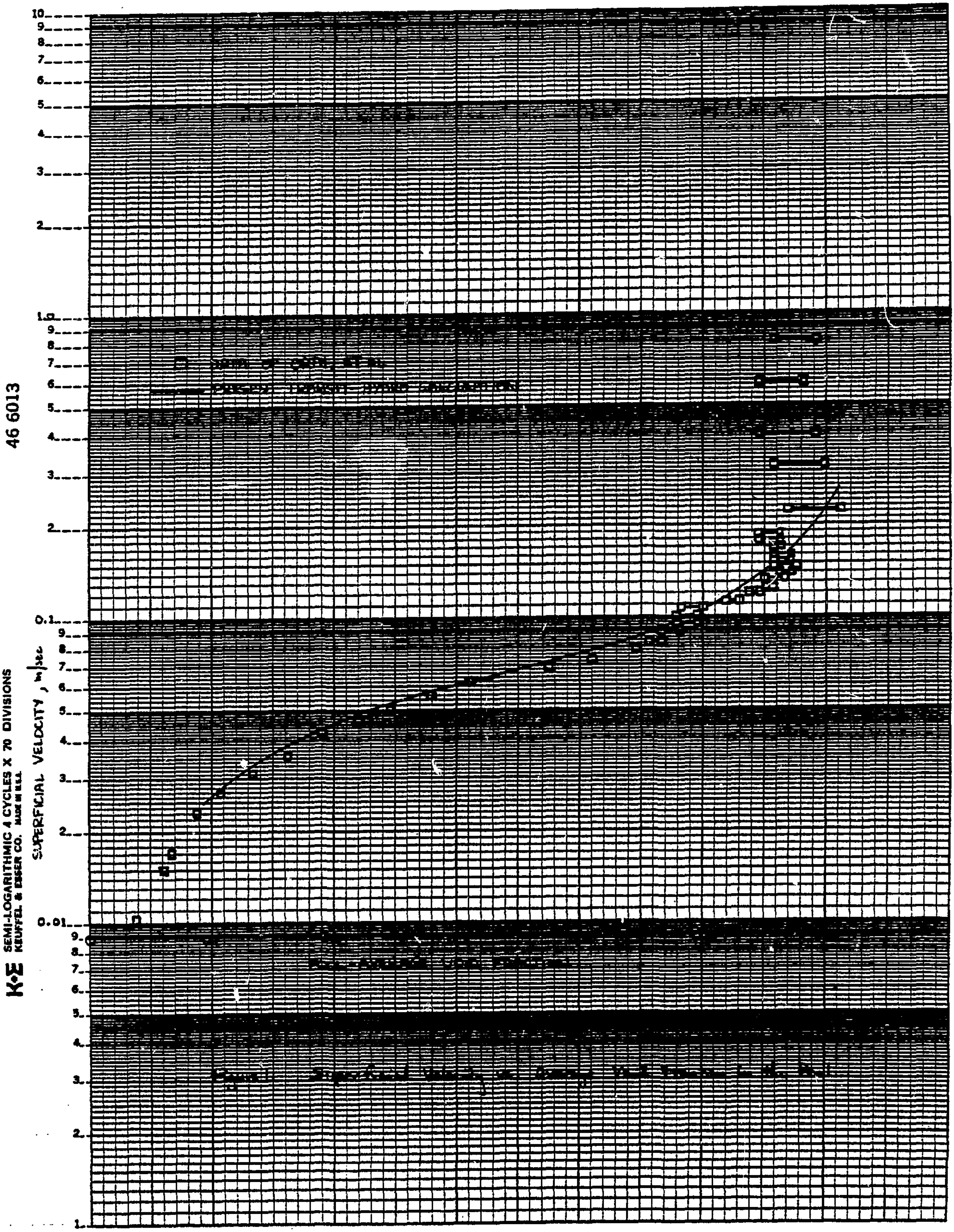

Figure 1 [illegible]