1. There is no basis for using the "estimated" conversions from smelt reboilers to the nuclear reactor situation. Both peak pressure (and energy release) and damage potential depend strongly on system materials and constraints, respectively.
2. Stratified explosions are considerably less energetic than those that can occur during the transit of the molten corium to the lower plenum. We have reported (Part II of our paper under discussion) mixing calculations involving 5 t of melt, which could yield up to 1500 MJ of mechanical energy if exploded.

In conclusion, Hopenfeld's letter indicates that he comprehends the energy-conversion/structural aspects of our work (Parts III and IV), and his last sentence ("obtaining this knowledge through well-planned experiments . . . is a viable alternative to . . . endless refinements of the premixing model") demonstrates that he missed altogether the essence of our probabilistic approach (Part I) and the role of modeling the premixing process in it (Part II)—experiments are an integral part of the approach, and multifield modeling of premixing is an essential aid to making such experimentation meaningful. Furthermore, premixing modeling has just begun (ours are still the only published results) and its state is a far cry from that of a "seemingly endless refinement."

T.G. Theofanous

University of California, Santa Barbara
Department of Chemical and Nuclear Engineering
Center for Risk Studies and Safety
Santa Barbara, California 93106

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Comments on Fuel-Coolant Premixing Modeling

Theofanous et al.'s four-part study of the probability of steam-explosion-induced containment failure[1] has stimulated considerable discussion and criticism among various workers in the United States.[2] Most of the controversy has been caused by the premixing work (Ref. 1, Part II) and, in particular, the claim by Theofanous et al. that "the issues of transient and two-dimensional effects on fuel-coolant mixing in the lower plenum of a pressurized water reactor (PWR) are addressed and resolved."

It is clear from the comments made by Berman, Marshall, Corradini, and Theofanous, which appeared in Letters to the Editor in *Nuclear Science and Engineering* in October 1988 (Ref. 2), that this claim must not be taken literally. It is also clear that this issue can only be fully resolved when there is sufficient detailed experimental data to validate a dynamic mixing model, which includes a transient melt jet breakup model, and when the various empirical mixing criteria are replaced by validated detonation/expansion models. The purpose of the present letter is to bring to the notice of the participants in this debate the considerable amount of work in the United Kingdom on premixing that has been performed over the last 5 years. This has culminated in the development of a transient multiphase mixing model,[3] which would have appeared as part of Corradini's Table I (Ref. 2, p. 173) as shown below:

Model	Advantages	Disadvantages
CHYMES (Fletcher and Thyagaraja)	Two-dimensional Dynamic liquid breakup Unequal velocities compared with Brookhaven National Laboratory and Argonne National Laboratory experiments	Equal temperatures for coolant liquid and vapor

Furthermore, Theofanous et al.'s calculations are not "the only ones available to this day for large pours in the lower plenum of a pressurized water reactor (PWR) at low pressures," and the situation with regard to independent numerical calculations is not as bad as he thinks, i.e., there was no need for him to produce an independent numerical model for himself to compare with his homogeneous flow model. One already existed and has been used successfully to model experiments[3-5] and to guide experimenters on the effect of important variables.[6]

We now return to the issue of alternative large-scale mixing simulations. Figure 1 shows the geometry and boundary conditions used in large-scale mixing simulations performed using CHYMES (Ref. 7). Figure 2 shows the mass of melt where the void fraction α is <70% as a function of time for three different calculations:

1. the standard model as described in Refs. 3 and 7
2. a simulation where there is no slip between the water and steam, i.e., homogeneous flow
3. a simulation where the water volume fraction dependence of the vapor production rate has been changed from being proportional to α_w to $\alpha_w^{2/3}$, as used by Theofanous et al.[1]

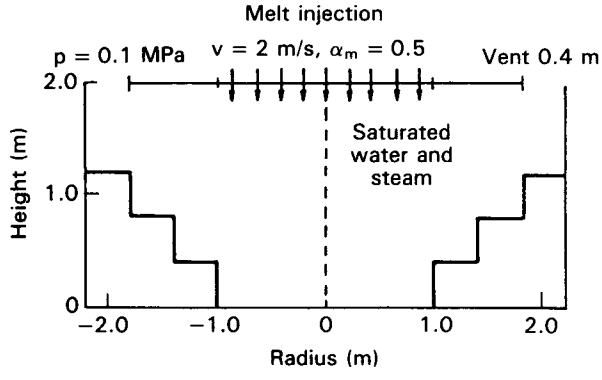

Fig. 1. Geometry and boundary conditions used in the large-scale mixing simulations.

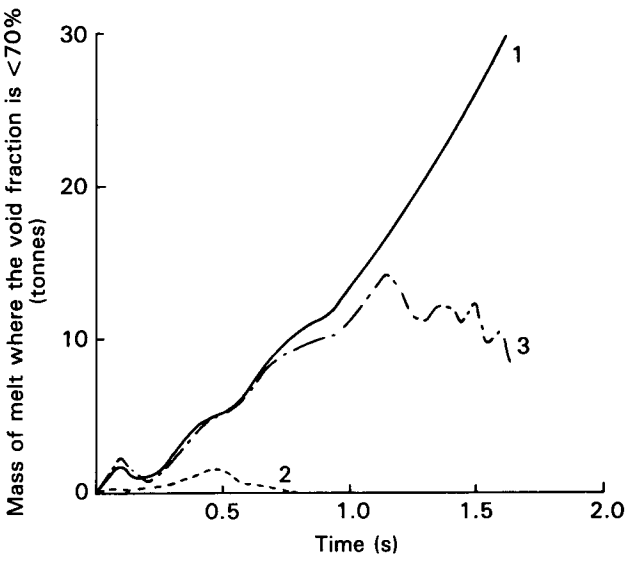

Fig. 2. Mass of melt where the void fraction is <0.7 as a function of time. Case 1 is for a standard version of CHYMES, case 2 for homogeneous flow, and case 3 for a modified vapor production term.

In all cases a fixed melt particle size of 20 mm was used. The following are evident from these calculations:

1. The homogeneous flow assumption ensures that there is little water present where there is melt, because as steam is produced and expelled it is forced to take the water out with it by design.
2. Making a modest change to the vapor generation term can have a very big effect on the predicted mass of melt in the premixture as defined by Theofanous et al.[1]; i.e., the predicted mass of melt in the "mixture" rises monotonically for a period of 1.5 s in case 1 and peaks at a value of ~15 tonnes in case 3. Thus, until we know more precisely what constitutes an explosive mixture, results of the type presented in Fig. 2 should only be used to examine the effect of varying parameters and initial conditions, etc., and should not be used as literal predictions of the "mass mixed." A detonation model is currently being developed for this purpose.[8]

To summarize, we have shown that there is also a U.K. model of premixing that has been used to perform reactor-scale simulations. However, it suffers from the same limitation as all the U.S. work: It is not yet a fully validated tool, and it can only be one if modelers and experimentalists work closely in a scientific manner. In this spirit, it should be feasible to develop validated models of all stages of the steam explosion process.

D. F. Fletcher
A. Thyagaraja

Culham Laboratory
General Physics and Theory Division
Abingdon
Oxon, OX14 3DB, United Kingdom

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Response to "Comments on Fuel-Coolant Premixing Modeling"

There are two points being made by Fletcher and Thyagaraja.[1] The first challenges our statement that the only calculations available for large pours in reactor geometries and low pressures are ours. The other presents some results of their own and points out that very large premixtures can be obtained using their modeling approach and assumptions. We consider each point in turn.

On the question of the availability of reactor simulations other than ours, they claim that such have existed, but no evidence is provided to support this claim. Fletcher and Thyagaraja's Ref. 3 through 6 contain *no* such calculations. In fact, the *first and only, to this day*, calculation besides our own is the one presented in this letter by Fletcher and Thyagaraja. It may be interesting to the reader to know how this calculation came about.

I first learned of Fletcher and Thyagaraja's efforts in this area at a January 1987 meeting of a group of specialists on steam explosions at the Committee on Safety of Nuclear Installations (Organization for Economic Cooperation and Development) in Paris. In June 1987 I suggested to S. Board that it may be worthwhile to carry out a comparative exercise with Fletcher using our respective premixing models. Board supported the idea and talked to Fletcher, who accepted also, I thought, with enthusiasm. He agreed quickly with my specification for this exercise, which, in fact, is what is shown in Fig. 1 of Ref. 1. We both completed the exercise soon after that and were preparing to publish the results, except that Fletcher kept inventing reasons for postponement. We had agreed that we would *not* use these results until they were published together. In August 1988, Fletcher indicated to us that he was no longer interested in this