Letters to the Editor

Comments on "An Assessment of Steam-Explosion-Induced Containment Failure. Parts I-IV"

The October 1988 issue of *Nuclear Science and Engineering* published a series of unusually lengthy letters[1] discussing several articles on steam explosions.[2] These letters are concerned with whether a finite probability can be assigned to the alpha-mode failure in the light of the uncertainties in modeling, particularly premixing.

Given the complexity of steam explosions, the uncertain initial conditions of how and when the melt and water come in contact, and the apparent polarized position of the research community, I doubt that an acceptable approach in predicting the probability of the alpha-mode failure will emerge in the near future.

I agree with Berman that the premise that large energy releases can occur only during the initial melt penetration requires proof. In fact, recent examination of industrial boilers that were damaged from steam explosions[3] show that such a proof may not be forthcoming. First, the explosions occurred from 10 to several hours after the initial contact between the smelt and water. Second, the conversion of the available thermal energy to the energy that deformed the surrounding structures can be represented by 0.1%. When this factor is applied to the 150 GJ of thermal energy stored in a molten core of a nuclear reactor, the resultant damage energy of 150 MJ is in the ballpark of the energy required to fail the vessel head.

The above two points lead to the conclusions that (a) little will be gained by investing additional efforts in predicting the probability of the alpha-mode failure, and (b) the energetics from potential steam explosions in nuclear facilities may be sufficiently high and should not be ignored.

Recent experimental results[4,5] clearly demonstrate that fundamental knowledge of droplet fragmentation and energy propagation at the interface of stratified layers is still lacking. Obtaining this knowledge through simple, well-planned experiments, with the ultimate objective of accident mitigation in mind, is a viable alternative to probabilistic predictions and seemingly endless "refinements" of the premixing model.

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2. T. G. THEOFANOUS et al., *Nucl. Sci. Eng.*, **97**, 259 (1987); M. A. ABOLFADL and T. G. THEOFANOUS, *Nucl. Sci. Eng.*, **97**, 282 (1987); W. H. AMARASOORIYA and T. G. THEOFANOUS, *Nucl. Sci. Eng.*, **97**, 296 (1987); and G. E. LUCAS et al., *Nucl. Sci. Eng.*, **97**, 316 (1987).

3. T. M. GRACE and R. R. ROBINSON, "Energetics of Smelt/Water Explosions," NUREG/CR-4745, U.S. Nuclear Regulatory Commission (Oct. 1986).

4. R. ANDERSON et al., "Experimental and Analytical Study of Vapor Explosions in Stratified Geometries," *Proc. Natl. Heat Transfer Conf.*, Houston, Texas, July 24-27, 1988, p. 236, American Nuclear Society (1988).

5. D. L. FROST, *Phys. Fluids*, **31** (Sep. 1988).

Response to "Comments on 'An Assessment of Steam-Explosion-Induced Containment Failure. Parts I-IV'"

Hopenfeld's letter[1] uses smelt reboiler explosions to claim that

1. delayed explosions can occur
2. the conversion of thermal energy in such explosions can be taken as 0.1%
3. for a whole-core explosion, the above yields 150 MJ of damage energy, which "is in the ball park of the energy required to fail the vessel head"
4. the probability of alpha-mode failure cannot be estimated.

If we accept claim 2, for a whole-core explosion, we would, indeed, estimate 150 MJ of mechanical energy release. Even if all such energy was focused toward the vessel head, it would be impossible to produce failure. We have estimated a minimum energy to detach the head of ~600 MJ (see Part IV of our papers[2] under discussion). There is an additional 150 MJ required to make it rise to the 40-m elevation to cause containment failure. We can categorically state that the probability of alpha failure (and indeed even vessel failure) for such an explosion would be *ZERO*! Thus, his claims 3 and 4 do not follow.

Unfortunately, we cannot use this approach to show that alpha failure is impossible, because the basic premises for 150-MJ mechanical energy release, i.e., his claim 2, are questionable because of the following: