ENERGY RESEARCH, INC.

P.O. Box 2034
Rockville, Maryland 20847
(301) 881-0866 / FAX 881-0867

July 25, 1994

Dr. A. Behbahani
U. S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Accident Evaluation Branch
Division of System Research
Mail Stop TWF-K8
Washington, D. C. 20555-0001

Subject: Ex-vessel calculations for the CE System 80+ using GT3F computer code. Contract No. NRC 92-04-045, Task Order 4.

Dear Dr. Behbahani:

Attached please find the supplemental report entitled "Analysis of Ex-Vessel Steam Explosions for the Combustion Engineering System 80+ Using the *GT3F™* Computer Code" dated July 1994, and the responses by the authors to my comments on the original report (memorandum from H. Esmaili to M. Khatib-Rahbar dated June 13, 1994).

The authors have made a serious effort to respond to all my concerns/comments regarding the original calculations and I am generally satisfied with their responses. The residual concerns, such as the melt breakup and travel time in the water pool before bottom contact and experimental validation can only be resolved as the *GT3F™* experimental validation basis increases.

In the supplemental report, the authors have performed two additional calculations involving failure of a single instrument tube penetration in the central region of the cavity, and near the corbel support with a subcooled water pool consistent with the initial and boundary conditions established in ERI/NRC 94-201. In their original report (June 1994), the water pool was saturated.

In the following paragraphs, I will briefly describe the results of these simulations, provide comparison with the TEXAS and IFCI calculations where appropriate, and draw some conclusions.

Central Instrument Tube Failure

The transient pressure profiles and the pressure impulses in the explosion zone and along the corbel support are provided in Figures II.6 through II.9 of the supplemental report. The effect of the triggering strength (10% and 20% fuel fragmentation in the trigger cell) indicate that increasing the triggering strength results in a substantial increase in the peak explosion pressure (from approximately 50 bars to about 90 bars). The maximum explosion pressure in the TEXAS and IFCI calculations were found to be approximately 95 bars and 250 bars, respectively. The peak explosion pressure with a stronger trigger (90 bars) is comparable to the TEXAS simulation (95 bars).

The peak pressure impulse in the explosion zone is approximately 16 kPa-s using *GT3F™* compared to 42 kPa-s and 39 kPa-s from the TEXAS and IFCI calculations, respectively. The results of *GT3F™* further indicate that the maximum pressure impulse on the corbel support is 7.5 kPa-s compared to 15 kPa-s from the IFCI calculation.

Based on these calculations and considering the different modelling approaches in the current computer codes and the parametric nature of the present fragmentation models, the variations in the expected impulse loads on the corbel support are clearly anticipated. However, the conclusion that can be drawn at this point is that for a single instrument tube penetration failure in the central region of the cavity, the damage potential and failure likelihood of the corbel support are deemed to be low which is consistent with our original conclusion in ERI/NRC 94-201.

Outer Instrument Tube Failure

The outer instrument tube failure involved two *GT3F™* propagation simulations, namely, a computational domain diameter of 30 cm and saturated water pool (original report), and a computational domain diameter of 300 cm and subcooled water pool (supplemental report). In the latter, due to proximity of the failure location to the corbel support, the pressure profiles were provided for the explosion zone at a distance of 15 cm from the center of the explosion zone that corresponded to the location of the corbel support. It should be mentioned that the presence of the corbel support was not explicitly modelled in the latter approach. The peak pressure impulse in the original report was found to be approximately 120 kPa-s compared to 13 kPa-s in the supplemental report. In addition, for the latter case, the peak pressure impulse was approximately 16 kPa-s in the explosion zone which was only slightly higher that the pressure impulse 15 cm away from the explosion zone. I agree with the authors that a rigorous simulation in this case would require a 3-D simulation. However, their current simulations can provide a reasonable assessment of the failure likelihood. The insights from these calculations are that the pressure impulse on the corbel support would be similar to the impulse in the explosion zone, and the effect of confinement or proximity of the explosion zone to the solid boundary tends to increase the pressure impulse. In conclusion, the failure likelihood of the

corbel support is expected to be relatively high should an explosion occur near this region. This is consistent with our original conclusion in ERI/NRC 94-201.

Multiple Instrument Tube Failures

For this case, the results of calculations provided in the original report were not realistic. The fuel concentration was predicted to be low and the explosion pressures were also low. The authors have suggested that this case requires a 3-D simulation. The 3-D simulation recommended by the authors involves only 1/4 of the cavity geometry. Clearly, a 3-D simulation is always more realistic than a 2-D simulation.

However, it appears that for the failure of multiple instrument tube failures, the explosion energy and the pressure impulses on the corbel support would be high and the failure likelihood of the cavity boundary would also be relatively high. This conclusion is based on the results of the TEXAS calculation that predicts higher peak explosion pressures as a result of larger amount of fuel involved in the explosion and insights from the 2-D calculations using both IFCI and *GT3F™* with single instrument tube failures in the central region of the cavity and near the corbel support. It is evident that as the number of penetrations increases, the explosion zone cross-sectional area also increases and this region would involve some penetration that are closer to the corbel support. Therefore, the peak pressure on the corbel support would not be substantially less than the explosion zone. These factors tend to increase the pressure impulse on the corbel support leading to its potential failure.

Final Remarks

It is important to note that the underlying phenomena associated with the steam explosion issue are still not well understood and the current hypotheses remain technically controversial. The current state-of-the-art computer codes provide different modelling approaches, and most importantly the parametric fuel fragmentation models are based on a limited number of experiments. Therefore, given the current state of knowledge and the various modelling approaches, it is clear that predictions within a factor of 2 or 3 are certainly anticipated. This is especially true when code predictions are attempted for large scale reactor applications.

Please feel free to call me if you have any questions and/or comments.

Sincerely,

H. Esmaili

Hossein Esmaili

Enclosures: (1) Supplemental Report
(2) Responses by the Authors to the Review of the Original Report

cc: M. Khatib-Rahbar, ERI
F. Eltawila, NRC
S. Abdel-Khalik, Georgia Tech
S. M. Ghiassian, Georgia Tech
ERI/NRC-045 file