# MEMORANDUM

**Date:** November 23, 1999

**To:** G.B. Wallis, Chairman, Thermal-Hydraulic Subcommittee, ACRS

**From:** N. Zuber, ACRS Consultant N. Zuber 11/27/99

**Subject:** **ACRS Thermal-Hydraulic Subcommittee Meeting: "Resolution of Generic Letter 96-06, Waterhammer Issues" Rockville, MD**

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This memorandum provides my assessment, comments and recommendations concerning the information presented by the industry at the above meeting, and documented in EPRI's Interim Report TR-113594 V1 and V2, July, 1999, which addresses the safety issues raised in the Generic Letter 96-06, dated September 30, 1996.

## 1. The Research Program

To respond to the concerns raised in the Generic Letter 96-06, the industry initiated and conducted analytical and experimental investigations in two facilities over a period of one year. In addition, it assembled an Expert Panel consisting of Prof. P. Griffith, MIT, Dr. F. Moody and Prof. B. Wiley, University of Michigan, to provide independent program oversight and guidance.

The industry's positive attitude in response to NRC's concerns should be commended. Furthermore, the industry should be encouraged to involve nationally recognized experts whenever it is asked to address and resolve generic safety issues.

## 2. The Report TR-113594

This report is perhaps the most "user *un*friendly" document with which I have been confronted in a long time!

It is nearly impossible to find information pertinent to experiments and/or analyses without being forced to search through the entire 453-page report.

The Executive Summary (one and one-half pages long) is too brief, superficial and general. It provides information more appropriate to an abstract of a technical paper than to an Executive Summary of a 453-page report.

For its own benefit, the industry should be requested to make the results of its research effort more accessible and effective. To this end I recommend the inclusion of an Executive Summary that:

- Briefly describes the experiments (geometry, parameters, etc.) and analyses (models, assumptions, etc.)
- Summarizes briefly, but quantitatively, the findings
- Lists and justifies the conclusions
- Lists and justifies the recommendations, together with the limitations

and, most importantly,

- Provides a detailed and informative "road map" for the report.

## 3. The Experiments

Section 4 of the report presents a good state-of-the-art summary of waterhammer occurrence due to condensation (CIWH) and to column closure (CCWH.) It notes and discusses the effects of pipe geometry (length and diameter,) pipe orientation, void formation, flow regime transition, liquid subcooling, interface area, condensation rates, velocities of steam and of the liquid while it drains or refills a hydraulic network.

However, to my great surprise and disappointment, this information was not used to demonstrate quantitatively that the test matrices for the various experiments generated adequate data to deal with the various issues. A quantitative demonstration and confirmation could have been made by relating (via scaling and/or models) test conditions to those anticipated in a NPP.

As a matter of fact, I was unable to find in all of this lengthy and poorly organized report, a section which would demonstrate and confirm that scaling was used to establish test matrices for the various experiments. Consequently, the question of the experimental data's adequacy to address and resolve NPP safety issues is left unanswered.

This a most serious deficiency, inasmuch as the test data are to be used to validate methods which "provide realistic and justified bases for assuring plant safety and minimizing unnecessary modifications to the plants" (quoted from page V. of the report.)

The seriousness of this deficiency may be best illustrated by considering the two examples discussed below:

- Figure 8-5B on page 8-11 of the report shows CIWH test results obtained with horizontal pipes 2" and 4" in diameter. It can be seen that the scatter of the data increases with increasing diameter. Thus, for the 2" pipe, the data range from 20 psig to 60 psig (that is, by a factor of three,) whereas for the 4" pipe, the range is from 20 psig to 180 psig (a factor of nine.)

  Inasmuch as in a NPP, a CIWH can occur in pipes up to 16" in diameter, two questions must be raised. The first is concerned with whether or not the scatter continues to increase in pipes larger than 4". The second deals with the peak pressure that can be expected in a 16" diameter pipe. The report provides no answers to these questions. Indeed, it neither notes nor discusses the effect of pipe diameter on the scatter of the data.

- The second example is provided by Table 6-7 on page 6-12, which deals with a most important Request for Additional Information (RAI) made by NRR and the response provided by the industry.

  The request was for a "detailed description of the 'worst case' scenarios for waterhammer and two-phase flow" and for a confirmation "that the analyses included a complete failure modes and effects analysis (FMEA.)"

  The response of the industry (see page 6-12) was to provide a guidance for defining the "worst case" scenarios and for the FMEA, which sates on page 3-5 that:

  "Effects to be considered should include at least the following:

  - void flow rate/regime
  - voiding thermodynamics
  - FCU thermodynamics
  - refill flow rate."

This qualitative statement provides absolutely no new information – that is, information that was not available in 1996 when the Generic Letter 96-06 was issued. It definitely cannot resolve the safety issues raised in that letter.

Consequently, a quantitative definition and evaluation of the "worst case" scenarios and a complete analysis still need to be made.

In view of the foregoing, I conclude that there is no quantitative evidence that the test matrices generated adequate and/or sufficient data to validate methods which "provide realistic and justified bases for assuring plant safety."

To benefit form the research effort carried out to-date, the industry should be requested to:

1) Provide quantitative evidence that the test data are sufficient to resolve the safety issues raised in the Generic Letter 96-06. Such a quantitative demonstration and/or confirmation can be achieved through scaling;

2) Define quantitatively the conditions and/or limitations beyond which the test data cannot be used. This, again, can be accomplished through scaling and modeling;

and

3) Define quantitatively the conditions resulting in a "worst case" scenario and demonstrate that test matrices included these conditions.

## 4. The Analytical Models

Two modeling approaches were used in the analysis; one based on the method of characteristics (MOC) and the other, on a rigid body model (RBM.) Both models use the experimental data (discussed above) for four purposes (see pages E-9, E-13 and sections 1.4.2, 1.4.3 and 2.3.2 in Appendix E,) that is, to:

1) Justify the assumptions made in the analyses;

2) Provide the "appropriate inputs" for air concentration and the condensation heat transfer coefficient, as "these two variables have a significant influence on the pulse shape, duration and magnitude." (from page E-13 in Appendix E;)

3) Guide and perform sensitivity evaluations;

and

4) Benchmark and validate both codes (MOC and RBM.)

This heavy reliance on experimental data clearly demonstrates and confirms the pivotal role of the tests in determining whether or not the proposed methodology can "provide realistic and justified bases for assuring plant safety."

It is precisely for this reason that I emphasized so strongly in the preceding section the need for demonstrating quantitatively that test conditions (and therefore the data) are applicable to a NPP and include those which result in a "worst case" scenario.

Inasmuch as such a demonstration has not been presented by the industry, either in the report or during the meeting, there is **no** evidence that the MOC and RBM models provide "justified bases for assuring plant safety."

## 5. Conclusions

I am in complete agreement with and fully supportive of the two objectives stated by the industry – that is, to

> *"provide realistic and justified bases for assuring plant safety and minimizing unnecessary modifications to the plants."*

However, if the industry is to minimize the unnecessary modifications, then it should and must provide a methodology that meets the first objective. For reasons discussed in sections 3. and 4. above, such a methodology has not been provided, either during the meeting or in the report.

The necessary and sufficient requirements for a methodology that assures plant safety are stated in the three requests noted in section 3.

I trust that the industry will continue to exhibit the positive attitude to which I referred in section 1., so that both objectives can be realized.