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Mr. M.W. Jankowski
Accident Source Term Program Office
United States Nuclear Regulatory Commission
WASHINGTON, D.C. 20555
U.S.A.

Dear Mike:

Thank you very much for the hospitality and good weather I enjoyed in Washington. I found the meeting very informative and stimulating. I have collected some thoughts and suggestions which I would request you forward to the groups at Batelle and Sandia.

The work on the BMI-2104 study represents a significant advance on the estimation of the source term. The approach of detailed modelling of the behaviour of fission products from the beginning of an accident appears to be a tractable proposition although a demanding one. The Batelle groups have done an impressive job in carrying out their calculations.

I have some minor comments on the editing of the reports which may be impossible to implement at this late date. The authors frequently assume the reader to be as familiar as they are with the definitions of control volumes and accident timing with the result that many graphs are difficult to interpret. Perhaps more informative figure captions will help. The organization of the reports into sections corresponding to thermal hydraulics, transport through the primary heat transport system and transport through containment has the unfortunate result that data for each accident sequence are scattered throughout the report and it is difficult to follow a single accident sequence. Organization based on accident sequence would perhaps have been more relevant and easier to follow.

There are many approximate models included in the computer codes used for this study. The significance of the bottom line fission product release values rests in the confidence one has in the accuracy of the models and the input parameters for those models. The document assembled by T. Kress (ORNL/TM-8842) provides a good summary of the key models incorporated in the Batelle study and should be clearly referenced as a comparison document to be read along with BMI-2104. In addition, the Batelle study will be more historically valuable if there is an appendix available listing the values of key parameters used (as identified possibly by the Sandia study) and the reasoning behind each choice.

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Due to the large number of approximate physical models employed in BMI-2104, a sensitivity (or uncertainty) study such as that performed by the Sandia group is extremely valuable. From the discussion at the meeting, it was apparent that the Batelle workers have also explored some variables and this information should be included in the reports. Without a document on the Sandia project available, I cannot comment on the completeness and validity of the Sandia study, but the overall approach of backward progression through important parameters to explore the most probable phase-space of the calculations appears intelligent and efficient.

The most striking result of the Sandia study, which I observed, was a drastic change in the airborne concentrations of CsI and CsOH in containment as a function of time compared to the Batelle results. The difference could be traced directly to an explicit treatment of CsI and CsOH as individual aerosol components having a difference history than generalized corium aerosols. This leads to my most basic criticism of both the Batelle and Sandia studies. As a chemist I am apprehensive about seeing a line on a graph labelled as a specific chemical (such as CsI). As the Sandia work shows, explicit consideration of a single species can change predictions of its behaviour. However, with the limited exception of CORSOR, none of the computer codes considers the chemistry of Te, CsI or CsOH.

Starting in the fuel there is some question as to whether release rates measured on UO_2 + fission product simulants or old irradiated fuel are valid. Experiments such as those ongoing at PBF (which show lower than expected release rates) are required to correctly model the behaviour of the real I and Cs inventories in fuel under operating conditions. In addition, core melting occurs early enough in some accident sequences (e.g. AB) that it may be necessary to consider the release from fuel of the parent Te and Xe isotopes to fully model the time dependence of CsI and CsOH. Coupled with this may be a requirement to consider the radioactive decay and release history of individual Cs, I and Te isotopes to get accurate airborne activities as a function of time.

Within TRAP-MELT there is no provision for reaction of CsI, CsOH or Te with any of the primary system materials. There is also no provision for the hygroscopic nature of the cesium salts which will affect re-evaporation rates and aerosol behaviour in the primary system.

Within containment it appears likely that the hygroscopic nature of CsI and CsOH will lead to formation of aerosols with slope factors nearer to 1 than assumed by the Sandia study, even in steam atmospheres below the saturation limit. This will certainly affect the airborne Cs and I concentrations. There is also no consideration of the chemical effects of a hydrogen burn on the aerosol chemistry. In such a combustion event, CsI may reasonably be expected to react to form CsOH and HI. The latter will not condense on dry aerosols but will dissolve in wet aerosols and hence the airborne iodine concentrations may depend strongly on the accident sequence and timing. In addition, adsorbed Te may react to form gaseous H_2Te available for subsequent release.

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As Carl Johnson suggested, I believe that the chemistry of the core-concrete interaction may be more complex than has been assumed to date, but I am not sure whether this will appreciably affect the airborne activity and I suggest that this be explored by the Sandia group.

In general, I feel that there is scope within all of the codes of the Batelle suite to include more explicit and exact descriptions of chemical behaviour. In particular for Cs, I and Te, this will improve our ability to anticipate the real behaviour of these species under accident conditions. The Sandia work demonstrates that improving the physics and phenomenological accuracy of the computer codes leads to lower predicted values for the source term, a desirable result. Increasing the physical and chemical sophistication of the codes will give us more confidence in our ability to accurately predict the behaviour of single chemical species such as CsI and CsOH as well.

I congratulate all those involved in these two studies for their fine work. I hope that some of my suggestions, if they cannot be incorporated in current studies, will be included in future work on the source term.

Sincerely,

David Wren

DJW/pam

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February 5, 1984
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Peer Review Report

To: Accident Source Term Program, RES, USNRC
Attention: M.W.Jankowski and M. Silberberg
Subject: Comments and Suggestions Related to the Peer Review Meeting of January 26-27, 1984 on Severe Accident Source Term Reassessment

Comments and suggestions are submitted as follows:

A. Regarding the final version of the BMI-2104 volumes:

1. A clear and complete discussion should be given (in Volume V) of the differences in input, assumptions and calculational modeling of the original SURRY report (Volume I). Perhaps a summary of this could be given in tabular form.

2. It appears desirable to have the BMI-2104 volumes complete enough so they stand alone but it may be desirable to have a separate volume to make it possible to present a rather complete description and discussion of the codes used---with detail given at least to the extent given ORNL/TM-8842.

3. The drafts of Volumes IV, V and VI of BMI-2104 lack a presentation of adequate information of the reactor coolant system. The equivalent (if not actual) geometrical dimensions of the control volumes, as used for MERGE and TRAP-MELT calculations of the various accidents should be given. This was done in Volume I (see Table 6.2 and pages 6-1 and 6-2 of BMI-2104, Volume I, July 1983 - Draft report) but should be done more completely to answer questions about the equivalence of the various dimensions given (in Table 6.2) and, for example, is the wall surface for deposition equal to the heat transfer area and how much of the surface is horizontal.

B. Regarding matters related to the chemistry of the fission product source term:

I. Give the temperature, the mass flow rate and H_2/H_2O molecular ratio of the gas emitted from the reactor core in a given accident sequence as a function of time. This would provide quantitative data on the chemical environment in which I, Cs and Te would sorb

and desorb on or chemically react with metal surfaces and aerosols in the RCS. This would be very useful for continued analysis of and research on chemical phenomenon pertinent to TRAP-MELT type calculations.

2. Give results of calculations of the aerosol emitted by the core including (1) composition (2) mass flow rate and (3) particle size as a function of time. Perhaps a tabulation similar to VANESA output tables of the BMI-2104 volumes could be given. This would be useful so that the chemical reactivity of the aerosol can be appraised. The aerosol may turn out to be a very effective chemisorber (getter) for Te and result in transport of Te by the aerosol.

3. Such a tabulation should perhaps also be given of the aerosol entering the containment. This data for aerosol entering the containment would be available similar to that provided by VANESA.

4. Add boric acid as a constituent of the emitted gas and also the water in the lower core and plenum. This would make it possible to estimate the likely effect boric acid will have on the deposition and release chemistry of fission products Cs and I. Cesium inthe form of CsOH vapor or deposits may well be transformed to cesium metaborate ($CsBO_2$), which appears to be a very stable compound of lower vapor pressure than CsOH or CsI. Cesium then tends to be strongly retained on metal surfaces or aerosols if boric acid is present in sufficient quantity. Furthermore, iodine will tend to be converted to a volatile form (HI) which will be carried to the containment with H_2+H_2O gas in a LOCA (AB or S_2D). HI will of course tend to be absorbed by liquid H_2O if it encounters any. The ner conversion reaction is:

$$H_3BO_3 + CsI = CsBO_2 + H_2O + HI$$

Comments added February 21, 1984

5. The amount of boron in the RPV is an accident will depend in part on the amount of boron as "chemical shim" in the coolant in the case of PWR. Taking no credit for this (an accident may occur at a time when the boron is at a low concentration in the coolant), there will be a large amount of boron contributed by boronated water from the accumulators in the case of a LOCA (AB or S_2D) of a PWR. In the particular case of the SURRY PWR it is estimated the accumulator water will contribute about 195 Kg of boron (2500 ppm B is assumed to be in the water). Only 10.5 Kg B is required to tie up the cesium as the metaborate, $CsBO_2$.

C. Uncertainty in the Estimate of the Source Term.

As indicated above TRAP-MELT calculations include two source term uncertainties due to neglected phenomena:

1. The possibly strong chemisorption of tellurium by the aerosol. In the extreme this could lead to almost all of fission product tellurium being associated with aerosol and this would be released to the containment to a greater extent than now calculated.

2. The affect of boric acid on cesium retention and iodine release in LOCA accident sequences.

It is planned to review the chemical thermodynamics and discuss the implications of these neglected phenomena in detail in the writer's forthcomeing report on the NRC/IDCOR Technical Exchange Meeting of February 7-8, 1984.