Department of Energy
Washington, D.C. 20545

Docket No. 50-537
HQ:S:83:219

MAR 04 1983

Dr. J. Nelson Grace, Director
CRBR Program Office
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Grace:

THERMAL MARGIN BEYOND THE DESIGN BASE (TMDBD)

Enclosed are the CRBRP Project's responses to questions raised in recent discussions regarding our TMBDB design and analysis. For your convenience, we have labelled the responses with designators (e.g. "A1") which we understand was originally established by your Brookhaven National Laboratory consultants.

Overall, the Project considers several of the overly conservative assumptions made by the NRC Staff's consultants with regard to treatment of sodium aerosols to result in an extreme departure from best-estimate analyses, and are inappropriate for assessments of beyond design basis accommodation features. While the Project believes it is feasible to design to accommodate these extremely conservative conditions, we expect to demonstrate in the OL review that conditions are within the Case 1 evaluation shown in the enclosure.

On a related matter, while the Project has not reached a final decision regarding the specific composition of limestone concrete to be used for the reactor cavity floor, we have discussed this with the staff and understand that either calcitic or dolomitic limestone concrete would be acceptable from a TMBDB perspective, based on available experimental data.

If you have any questions, please call Wayne Pasko (FTS 626-6096) of the Project Office's Public Safety Division.

Sincerely,

John R. Longenecker
Acting Director, Office of
Breeder Demonstration Projects
Office of Nuclear Energy

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A1 - NRC consultants have recently completed thermal analyses of the CRBR containment for the TMBDB scenario taking into consideration the potential insulating effect of sodium aerosol deposits on the containment wall and dome. The project had earlier performed analyses of such an effect and discussed them with the staff at the April 16, 1982, TMBDB meeting. The two analyses were performed with significantly different assumed thermal properties of the plated aerosol (see Table A1-1) and, as a result, the analyses predict significantly different containment conditions (see Table A1-2, cases 1 and 2; the Base Case, with no aerosol insulation effect, is shown for comparison). The project has reassessed its earlier calculation and concludes that it still represents a best estimate bound suitable for beyond design basis analyses. Further, the project concludes that even conservative assumptions enveloping all potential uncertainties would be significantly less severe than the staff consultant's calculations.

The project has been reviewing the bases for the differences in the two estimates of the conductance of the aerosol layer. This review indicates that the primary difference between the two analyses is in the amount of aerosol predicted to be plated on the wall and dome. The walls and ceiling are emphasized because this is the heat transfer path to the annulus cooling system; aerosol deposits on the floor and other horizontal surfaces have only minor impact on calculated containment temperatures, except that once deposited there they are not available to insulate the wall or dome. The form of the deposits on the wall and dome, particularly the porosity and the resulting conductivity, is also important in determining the effectiveness of the aerosol as an insulator. Finally, other approximations in the evaluation, particularly the timing of the deposits, contribute to an unrealistically severe estimate by the staff's consultant of the thermal effect of the deposits.

The amount of aerosol assumed to be plated on the walls and ceiling in the NRC staff consultant's calculation (3.9 g/cm^2 in Table A1-1) was obtained by adding 50% more to the value orginally calculated by the staff's consultant at Battelle Columbus. It is our understanding that the parameters selected for use in the model for thermophoresis, as the driving force which encourages aerosol to deposit on walls, led to the high mass per unit area in the calculation. To assess the reasonableness of the staff consultant's calculation, the project compared the resulting values against the latest available empirical evidence. The selected standard for comparison is the ratio of material deposited on the walls and ceilings ("vertical" surface in the analysis) to the material deposited on the floor and other horizontal surfaces. Comparing deposited mass per unit area, (mass loading) to allow for different geometries, the Battelle calculation of 2.66 g/cm^2 involves a mass loading ratio of 7 to 1 in favor of deposition on horizontal surfaces. In all of the experiments performed at HEDL to date, comparable measured values have always been in excess of 100 to 1. In fact, in the

most recent experiment (AB-5) which included thermophoretic conditions prototypic to CRBR TMBDB, the measured value was 180 to 1 (reference Al-1).

The project is convinced that these recent data prove the staff consultant's original mass loading calculation to be excessively conservative. This viewpoint has been discussed with the staff and consultant. The Battelle consultant has at least partially concurred and has recalibrated his thermophoretic model parameters based on the newly available AB-5 data. The recalibrated model, including the project's latest value for actual horizontal surface in containment, yields 0.38 g/cm^2 as the total wall and ceiling deposit, a value which the Battelle consultant estimates may still be high by a factor of two. The project considers the final adjusted value, 0.19 g/cm^2, to be a conservative upper bound (the resulting ratio of horizontal to vertical deposits per unit area is approximately 80 to 1). The project's best estimate bound in Table Al-1 is still only half as much or 0.10 g/cm^2, implying a ratio of 160 to 1. This value is quite close to the 180 to 1 mass loading ratio measured in the AB-5 test.

The form of the aerosol deposits, including porosity and conductivity, must also be determined, before the thermal impact of the mass loading can be calculated. The staff consultant at Brookhaven who performed the thermal analyses assumed a porosity of 60%, but judged the value nonconservative. The staff's Battelle consultant has observed that an earlier study at Battelle (BMI-NUREG-1977) supports this value. That study was a Millikan cell analysis of individual sodium oxide agglomerates at various humidities which yielded an average porosity of 60%. The project has again tried to base its own evaluation on the available experimental evidence. Porosities in excess of 95% (very light "fluff") have been observed in settled deposits on horizontal surfaces in experiments at HEDL. The characteristics of wall deposits have not been measured and reported at HEDL, however, since thick wall deposits (> 1/8 inch) have never been observed in sodium aerosol tests; therefore, wall deposition has not been considered to be a significant sodium aerosol effect either by the experimeters or by analysts, for whom the experiments are being performed. There is thus some uncertainty with respect to a quantitative upper bound for wall porosity though qualitatively the project is convinced that direct application of horizontal data would not be justifiable. The project's judgement is that 60% porosity is a reasonable best estimate value but given the lack of direct measurements approximately 90% was used for the Case 1 analysis. In conjunction with this porosity value, the project has concluded that the conductivity value of 0.05 BTU/hr.-ft-^{o}F suggested by the staff's consultant is an appropriate one.

Given mass loading and porosity, one can determine average deposit depth. Given the depth and the conductivity, one can determine the overall conductance which is the principal input to

thermal evaluation of the aerosol impact. Combinations of parameters producing the same overall conductance will yield the same answer in the thermal calculation. Thus the project's Case 1 analysis would also apply approximately for alternate parameters such as 0.20 g/cm^2 and 75% porosity or 0.39 g/cm^2 and 60% porosity, though the determination becomes somewhat more complex if the dependence of conductivity on porosity is factored in.

While mass loading and deposit form are the principal considerations, the project has also identified other related approximations in the analysis. The most significant ones are:

- The NRC thermal analysis conservatively assumed that all of the aerosol was plated on the containment walls and ceiling instantly at the start of the TMBDB scenario even though most of the aerosols are not formed for many hours. Since this assumption is not realistic, the project has made modifications to the thermal analysis code to obtain a realistic, time-dependent aerosol deposition rate and repeated the analysis with all other parameters unchanged (see Table A1-2, Case 3). This evaluation indicates that even for these extreme assumed aerosol plateout conditions, there are not significant increases in containment temperatures (37°F) and pressures (1 psig) prior to containment venting and purging and that the containment conditions after venting are significantly less severe than without the time dependence (compare Case 2 in Table A1-2).

- The horizontal surface area utilized for the aerosol analysis only includes the floor area. If all the horizontal surface areas in containment are included (as is done for experimental data reduction), the settling area increases by a factor of approximately 2 and the settled mass becomes greater than that predicted (and, hence, the vertical mass loading is reduced accordingly). The increased horizontal surface was considered in the latest Battelle mass loading calculation, but not in the one used for the thermal analyses (Cases 2 and 3).

- The derivation of parameters for the analysis considered that only sodium oxide was present, and that all sodium hydroxide would be formed by the water release from the floor and would remain at the floor. Experimental programs, like the analysis, have not included airborne sodium hydroxide. In a CRBR TMBDB event approximately 1/2 of the water vapor formed is formed by the hydrogen burning in the RCB atmosphere. This water vapor would react with the sodium oxide in the atmosphere and convert it to sodium hydroxide. The presence of this sodium hydroxide is significant since

the sodium hydroxide would melt at the temperatures of interest (the melting point of sodium hydroxide is approximately 600°F) and this would decrease the thickness (and the porosity) of the plated wall aerosol layer. The Project calculates that 25% of the plated wall mass loading will be sodium hydroxide.

- The driving force for thermophoresis is the temperature gradient across the laminar boundary layer at the RCB wall, and this temperature gradient is proportional to the heat flux at the RCB wall. If an aerosol layer does build-up on the wall, it will further reduce the heat flux (at least temporarily while the atmosphere temperatures increase) which in turn will reduce the thermophoretic effect. In addition, the calculations performed by the NRC consultant utilized project supplied temperature gradients which are 15% above actual calculations for the Base Case scenario. The Project estimates that these factors would decrease the plated mass loading through boildry in Case 2 (Table A1-2) by approximately 25%, assuming all other parameters and assumptions were not changed. The estimate is based on comparing calculated heat fluxes between Case 3 and the Base Case values used by the staff consultant.

- The thermal analysis assumed that all the plated aerosol remained on the wall and ceiling. This assumption is conservative for two reasons. First, the better the insulating properties of the plated aerosol (i.e., the higher the porosity), the lower the strength of the deposits will be, such that the deposits may fall off the wall under their own weight. Secondly, approximately two-thirds of the surface area for plating is on the containment dome and the aerosol must cling to an inverted surface. In reality, it would not be expected that all the plated aerosol would remain on the wall/ceiling if such large quantities ever could plate-out. (The NRC analysis assumes approximately 800,000 lb. of aerosol clinging to the wall and dome.) In the sodium aerosol tests, no build-up of plated aerosol has ever been observed which is comparable to the NRC predicted value.

<u>Summary and Conclusions</u>

The Project's review of the NRC consultant's analysis has indicated several areas where overly-conservative assumptions were made. For example, correcting just one assumption so that the amount of aerosol plate-out in the calculation is deposited in a realistic time-dependent fashion, the TMBDB analysis is virtually unchanged for the first 50 hours of the scenario and a decrease in the vent times is not required. The project concludes that these calculation do demonstrate the importance of

determining appropriate aerosol parameters and assumptions, but that the staff consultant's initial calculation itself is neither a best estimate nor even a suitably conservative upper bound.

Based on all of the above, the project believes that the CRBRP analysis (Case 1, Table A1-2) represents at minimum an appropriate best estimate and more likely an upper bound on the effect of sodium aerosol deposition on TMBDB thermal conditions. While the available experimental data support this project position, the data base at present permits some residual uncertainty. The project will pursue these uncertainties to ensure appropriately conservative design conditions for TMBDB features in the operating license application.

In the interim, to bound the potential impact of uncertainties on the CRBR TMBDB design approach, the project has run an additional analysis (Case 4 in Table A1-2) including time dependence and a relatively small (50%) increase in the conductance of insulating aerosol layer used in the NRC consultant's calculation. The project considers this thermal conductance value (a factor of seven below the value the project deems appropriate) to be excessively conservatively and inappropriate as a licensing basis for TMBDB features. Nevertheless, the project has determined the feasibility of meeting established TMBDB criteria with reasonable modifications to present feature designs for Case 4 conditions. Specifically, the polar crane was analyzed for 1400°F (predicted Case 4 maximum crane temperature is only 1225°F) to verify acceptable strains on the containment shell. Cleanup system operation at 1500°F was demonstrated in HEDL tests (reference A1-2); Case 4 conditions would require redesign for the quench tank sizing and interconnecting piping. Hydrogen sample line filtering is feasible with fallbacks contemplated in the ongoing test program. Finally, instrumentation for in-containment temperature and pressure measurement is available for the higher Case 4 temperatures.

Overall, the project concludes that potential sodium aerosol insulating effects will never be important prior to venting (first tens of hours into an event). While it is feasible for TMBDB accommodation features to be designed for upper bound aerosol impacts based on conservative interpretations of currently available data and uncertainties, the project considers so extreme a departure from best-estimate to be entirely inappropriate for sound engineering of beyond design basis accommodation features. The project expects to demonstrate in its operating license application that conditions are well within the Case 1 evaluation throughout a TMBDB scenario.

Reference

A1-1 HEDL-SA-2854
"Aerosol Behavior Code Validation and Evaluation (ABCOVE) Program - Preliminary Results of Tests AB-5"
R. K. Hilliard 12/15/82

Table A1-1

Assumed Aerosol Parameter Wall and Ceiling Surfaces	Project	NRC
Mass Loading Density (g/cm^2)	0.10	3.9
Total Mass Deposited (lbs)	20,875	798,000
Porosity	90%	60%
Thickness (inches)	*0.167	1.80
Thermal Conductivity (Btu/hr-ft-°F)	*0.05	0.05
Thermal Conductance $\frac{K}{X}$ (Btu/hr-ft^2-°F)	3.6	0.33

*These values have been revised based on the current data review; the mass loading and, most importantly, the overall thermal conductance are not changed from the 4/16/82 values.

Table A1-2

Summary of CACECO Analysis

Case	Thickness/ Inches	Conductance, Btu/hr-ft^2-^oF	Time Factor	Conditions at Venting (36 Hours) H(%)	P(psig)	T(^oF)	Conditions After Venting T_{max}(^oF)	T_{ave}(^oF)	H_{max}(%)
Base Case	-	-	-	4.5	13.1	620	917	750	4.0
1	0.167	3.6	No	4.3	16.0	696	1215	900	4.0
2*	1.8	0.33	No	4.5	25.8	976	2188	1850	5.2
3	1.8	0.33	Yes	4.0	14.1	657	1770	1350	4.0
4	-	0.50	Yes	4.0	13.4	632	1550	1180	4.0

* This analysis was performed by an NRC staff consultant.

A2 - We do not agree that the error in treating sodium aerosols is on the "non-conservative side." What is neglected here is a possible time lag in transfer of heat to the aerosol mass when the RCB atmosphere temperature is increasing and from the aerosol when the temperature is decreasing. Thus there is a slight non-conservatism when the temperature is increasing and a slight conservatism when it is decreasing. In the base case TMBDB the atmosphere it oscillating up and down throughout the sodium boiling period so the net effect will be to average out the error.

A3 - The head leakage estimates are based upon the results of the Structural Margins Beyond the Design Base (CRBRP-3, Vol. 1). SMBDB is currently the subject of a separate, intensive review by the NRC which will resolve the issue of the primary system response to an HCDA. If this review results in a change of the head leakage, this change will be factored into the TMBDB analysis.

A4 - The heat transfer calculation done by the CACECO code determines both the heat load and the average thermal response of the structures. The TRUMP calculation was a parallel thermal analysis used to determine detailed thermal responses thereby yielding a 2D thermal profile of the structures as opposed to the 1D reponses calculated by CACECO. Care was taken to ensure that the same amount of energy was input to both models. The TRUMP results were checked against the CACECO results to verify that the cases were parallel.

Both CACECO and TRUMP models accounted for the change in thermal effects caused by the initiation of the annulus cooling system. CACECO accomplished this by adding a heat sink which simulated the effects of annulus cooling. TRUMP did this by a gas flow in the annulus. In both cases the heat transfer coefficients were changed to reflect the transition from no annulus cooling to annulus cooling at 36 hours.

A9 - At the rated make-up flow (150gpm), approximately 90,000 lb. of sodium could be pumped into the RCB over a period of approximately 1 hour (compared to 1,100,000 spilled initially). Adding this sodium to the RC would improve containment conditions at the time of venting and purging, since the additional mass of sodium would also increase the length of time to sodium boiling and, therefore, decrease the total amount of aerosols generated and energy transferred to the RCB at the time of venting. The effect of additional sodium drained into the RC is shown for cases 3 and 4 in Table F.4-1 of CRBRP-3, Vol. 2. These cases assumed that 37,100 gallons were drained into the RC from the PSOV (Note: This amount of sodium is larger than the 16,000 gallons that can be in the Make-up Tank for 3 loop operation.). As can be seen, this additional sodium increases the time to hydrogen ignition and improves slightly the containment conditions at 24 hours.

B1 - The Project has proposed a "Reasonable Upper Bound" (RUB) case of 7"/hr for 20 minutes followed by 1"/hr thereafter. This case bounds the rates and amount of reaction of all sodium-concrete tests performed to date. It is not reasonable to extend the 7"/hr from 20 minutes to 1 hour since there have been no tests to date which have shown rates of 7"/hr extending beyond 20 minutes.

B2 - The Project plans no more sodium-concrete interaction tests with dolomitic limestone concrete. The tests on dolomitic-concrete characterization (water release, heat of reaction, etc.) are almost completed and the results will be made available to the NRC. If it is decided that the dolomite data base is not sufficient to support the Project position on sodium-concrete reactions, calcitic limestone will be used in the RC floor and pipeway cells.

B3 - Differential Scanning Calorimeter (DSC) methods were used to supplement the DTA results. However, the small sample size and temperature limit (500°C) of the DSC equipment limited the usefulness of that method. DTA equipment was available that was capable of handling the desired samples and temperatures. DTA methods can also give quantitative data from which heats of reaction may be calculated from integration of temperature curves, as was done for the sodium-concrete work. The method provided results which give reasonable agreement when compared with the known heats of reaction for the expected chemical reactions.

Additionally, as noted in Item B4, this "sodium-concrete reaction" energy does not include the energy of CO_2 and water reacting with sodium, and these latter two reactions provide for more energy input to the sodium pool than the "sodium-concrete reaction" [Note: there is some concern that a portion of the CO_2 reaction is also counted in the sodium-concrete reaction, but this is obviously conservative.] Therefore, this issue does not appear to be a significant issue with respect to the overall TMBDB scenario.

C1 - The reviewer's theory that hydrogen burning explains the absence of hydrogen in the Series E experiments overlooks the fact that, in the same experimental series with otherwise identical test conditions, when the mole fraction of H_2O exceeded that of O_2 there was an abrupt appearance of hydrogen.

C2 - A major source of water vapor in the RCB is the burning of hydrogen. This water vapor and that from Cell 105 are in intimate contact with the finely divided sodium oxide aerosol being produced by burning sodium vapor in the atmosphere, so it is appropriate to assume they would react first as modeled in CACECO. CACECO does not calculate that any water is held up by absorption on sodium hydroxide.

C3 - This question was asked during the 1978 independent design review of TMBDB and resolved as part of the 1979 Key Systems Review:

"Oils, paints, insulation materials and flammable coolants were evaluated in terms of the maximum energy release assuming complete oxidation (sodium would be gettered by oxygen thereby precluding a sodium/hydrocarbon reaction). The calculated energy release in containment above grade was found to be less than 3% of the total chemical reaction energy during the scenario. The 3% value is conservative since complete oxidation of the addressed materials would not occur (i.e., the insulation and cable materials would smolder and char, also the oil considered is well protected from the ignition source in contaiment)."

"Conservative first order calculations below grade indicate that gas temperatures would rise by approximately 50°F assuming instantaneous complete oxidation."

"The fiberglass media filter materials present in containment would not be expected to contribute as an energy source to the scenario (via chemical reactions). This is because glass fiber materials are non-reactive in the presence of NaOH, and as a consequence other material interaction with the filter media would not be expected. Furthermore, these materials are scheduled to be removed prior to reactor startup."

D1 - The Project modeling of hydrogen flammability is based upon tests performed by the Project on hydrogen flammability in the presence of sodium. The LWR hydrogen information is not applicable to this case since this information does not address the effect of the sodium. There is no disagreement that the 6% hydrogen concentration criteria for purging and venting is conservative, particularly with sodium present.

There is a concern that carbon monoxide is not considered in the post-boil dry period of the TMBDB analysis. The Project does consider carbon-monoxide in the post-boil dry period (see Item 20 on page 3-25 of CRBRP-3, Vol. 2). Additionally, a presentation was made to the NRC on August 17, 1982 in which the generation of CO and hydrogen in the post-boil dry period was addressed and the amount venting and purging required to control these combustible gases was discussed.

D2 - We agree that only trace amounts of NaH exist in the sodium pool at the time of incipient pool boiling (9-10 hours in the base case scenario). As presented in the April 1982 NRC technical exchange meeting this trace amount, when multiplied by the 1.2×10^6 lbs. of sodium at 10 hours would "tie up" enough hydrogen, if released, to increase the calculated 4.4% hydrogen in containment (CACECO calculation with NaH) to 5.2% if that amount were not tied up in NaH. This difference of 0.8% is all that is tied up, and it does not amount to a large enough quantity to significantly change any TMBDB conclusions.

D3 - The Project currently has underway, and has reported to the C on, an experimental program to qualify the operation of the filte for the containment air sampling l'.es. This item should, therefore, not be an issue.

E2 - The only error in CACECO we are aware of was in the energy modeling, which was identified by BNL in 1979, and corrected by HEDL at that time. This is discussed in HEDL-TME 79-2, "Analytical Validation of CACECO," dated August 1979.

E3 - We agree that the minimal gain in accuracy may well be over-balanced by the increase in cost. No action is planned on this item.

E4 - The case where the RCB floor was sub-divided to account for the slower water release from the RCB floor is the TMBDB Base Case. In naming the resulting heat structures, one was called the "RCB floor" and the other was called the "HAA wall" which may have confused the reviewer, but they both are in fact the RCB floor. Their area split was contrived so as to give the correct water release to the RCB from the floor for the first 24 hours of the scenario, such that it is not true that all the RCB floor water went to the drain and was forever removed from the calculation. This time period of 24 hours was chosen originally because of the NRC imposed 24 hour no-vent criterion and the analysis is realistic for this time period.

The Base Case was known to be non-conservative in this regard beyond 24 hours and work is underway at W-WM to assess the impact based on new WATRE results recently obtained from HEDL. It appears from the BNL analysis that it is a small effect, i.e., a two hour decrease in vent time from the base case 36 hours. We expect to further confirm this when our results are available.

E7 - The purge system does not contain a check valve; rather, narrow range pressure interlocks will be provided which will close the purge line isolation valves whenever the containment pressure exceeds the atmospheric pressure (see page 2-25 of CRBRP-3, Vol. 2). Additionally, the hold-up time in the purge system will be approximately 5-10 seconds at full purge flow (8,000 scfm), such that small amounts of backflow will not cause an unfiltered release. It should be noted that only atmospheric air will pass through the purge line isolation valves.

G2 - This issue has been resolved with the NRC as part of their containment review (see letter HQ:S:82-156, J. R. Longenecker to P. S. Check, "Agreements and Commitments from the December 21, 1982 Meeting on SER Open Items," dated December 29, 1982.)

G3 - (The reviewers refer to page A-19; this should be page 4-9, since this is the page where the reference to sodium carbonate is made.). The statement regarding the difficulty of filtering sodium carbonate does not indicate a lack of confidence in the scrubbing system, but, rather, reflects a technical concern based upon the limited solubility of sodium carbonate in water. This issue is discussed in more detail in Appendix E.7 of CRBRP-3, Vol. 2 and an up-date of this section was recently provided to the NRC (see letter HQ:S:82:140, J. R. Longenecker to P. S. Check, "Submittal of Information on TMBDB," dated December 7, 1982.) Basically, this update states that the TMBDB Air Cleaning Tests demonstrated that the sodium carbonate removal efficiency is comparable to those for other aerosol products (99% or greater) when sufficient quantities of water are used. This issue should, therefore, be resolved.

H1 - The comments on the formation of a coolable bed reflect a misunderstanding of the RV failure modes and the design of the RC. The best estimate RV failure mode for the Base Case is a creep rupture failure of the RV at the bottom head of the RV and a subsequent creep rupture failure of the GV. For this failure mode, the core debris will exit the vessel, followed immediately by the sodium in the vessel. For

purposes of analysis, all the debris is assumed to exit the vessel at this time, since this will maximize the energy input to the sodium pool. The comment on the effect of the vessel head falling before the upper vessel structures is confusing. Failure of the upper vessel structures and upper vessel head will not affect the local distribution of the debris. If the head were to fall, any material would escape to the RCB, not to the guard vessel. However, core debris would not be expected to escape from the RV through the head.

H2 - The distribution of core debris within the RV prior to the RV failure is not significant with respect to ex-vessel debris bed coolability. The analysis assumes that all the core debris is at the bottom of the vessel and that a non-coolable bed forms in the bottom of the RV, which is the cause of the RV failure.

Even if the "in-vessel" bed stratifies by melting of the high power assemblies, the ex-vessel bed would not be expected to stratify, due to the mixing inherent following RV failure and subsequent sodium spill into the cavity.

I3 - Burning 1000 pounds of sodium in air will not result in an RCB pressure of 6.6 psig. Conservative calculations using spray code analyses have indicated a maximum pressure of approximately 2 psig. In addition, the cell liners have been designed for external pressures of 5 psig. The liner anchorage is capable of resisting significant tensile loads, equal to the strength of the studs in tension. It is expected that the actual capability for external pressure at the outset of the accident is much higher since both the liner and the supporting concrete are at low temperature.

I4 - The reactor cavity liner was represented by models of restrained strips or panels and not by a model of an infinite unconstrained cylinder. The actual boundary conditions imposed by the physical constraints of the system were prescribed in the analysis and no superposition was used. The models and methods of analysis are described in Section 3.2.2.5.1.1.1 of CRBRP-3.

It appears that the reviewer is not refering to the Reactor Cavity liner, but to the Reactor Cavity concrete wall. In this case a model of an infinite cylinder and superposition were used. Subsequently extensive analysis of the Reactor Cavity concrete wall has been performed (not incorporated in CRBRP-3) using detailed finite element models that include the actual physical constraints of the system with no superposition. The results of these analyses support the conclusions in CRBRP-3.

J1 - We are not attempting to calculate "the complicated heat transfer processes, phase changes, and chemical reactions" during the post-boildry phase with the TRUMP code. We chose, rather, to bound the problem of the melting attack into the basemat by forcing 90% of the available heat downward and assuming the lowest eutectic melting temperature, without attempting to calculate how that much heat could

be forced downward. Since this reduces the problem to heat transfer (i.e. where does the heat end up when 90% is forced downward?), TRUMP, a heat transfer code, was used.

J2 - We agree that our model of molten pool attack bounds the problem of post-boildry basemat penetration.

J3 - The molten steel is not considered in the thermal modeling since its thermal resistance is insignificant. However, it is considered as a source for the post-boil dry generation of hydrogen and carbon monoxide (see the response to D1).

While the density driven inversion of the molten steel and oxide layers may be significant with respect to a realistic evaluation of the melt front, the TMBDB analysis was performed parametrically by varying the downward heat transfer form 10% to 90%. The density driven inversion phenomena would be of interest only if it could cause the downward heat transfer to exceed 90%.

K1 - The Project program for demonstrating survivability of the TMBDB instrumentation has been presented to the NRC. With respect to the concerns expressed regarding the accuracy, time response, and time of qualification of the pressure and temperature sensors, the requirements specified by the Project are consistent with the purpose of these sensors, which is to monitor the state of the RCB to aid the operator in a determination of protective action. This supports the overall philosophy of TMBDB to provide an extra measure of protection to the public health and safety, i.e, there is no requirements for a "diagnostic" capability for "Beyond the Design Base" events. [Note: This diagnostic capability does exist with margin for DBE's as described in the Accident Monitoring Program.] Any additional increase in response time and accuracy is not feasible or necessary for the hydrogen monitoring system.