

CT-1571

# Los Alamos

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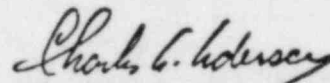
Dr. Max Carbon  
United States Nuclear Regulatory Commission  
Advisory Committee on Reactor Safeguards  
Washington, DC 20555

Dear Dr. Carbon:

I have gone over the documents submitted to me and my notes from the ACRS meeting of March 10 and 11, which dealt with the Clinch River Breeder Reactor CP Review and TMBDB in particular, and have put together the enclosed report that summarizes my review of the TMBDB issue. I have confined my review to those areas that I have expertise or particular experience in--mainly thermomechanics, engineering design, and finite element analysis. I will be prepared to summarize my review at the April 14 meeting.

If you have any questions, please call me at FTS-843-5150.

Sincerely yours,



Charles A. Anderson, Group Leader  
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REVIEW OF THE TMBDB ISSUE  
CLINCH RIVER BREEDER REACTOR CP REVIEW

Charles A. Anderson  
Los Alamos National Laboratory  
March 30, 1983

## I. OVERALL REVIEW

I was generally impressed with the quality of the presentations that were given by the applicant and the NRC. Most questions seemed to me to be answered directly, and the majority of those that weren't should be the subject of some further research. That is not to say that such research should hold up the decision on the CP. The engineering that has gone into designing against a TMBDB scenario is considerable and now well documented; what remains is to clear up certain unanswered questions (or questions that appear to have several answers) that have importance to TMBDB.

## II. ELEVATED TEMPERATURE DESIGN

The presentation here wasn't part of the TMBDB presentation, but it does have relevance to TMBDB. As everyone realizes the CRBR nuclear system is characterized by high temperature and low pressure. Thus, high temperature creep and creep rupture of metals is an important design constraint. Dr. Zudans raised the question of whether the now considerable high temperature data base for LMFBR materials extends to TMBDB temperatures or does it cover only temperatures associated with design basis accidents. Or posed another way, "Is there sufficient margin as far as high temperature creep and creep rupture are concerned to cover TMBDB events, or has the margin been eaten up by design basis transients during the plant lifetime?"

This appears to be an important question for TMBDB and could be answered by carrying out some finite element creep calculations on a representation plant component (such as, primary piping or a pipeway cell liner) using design basis transients and seeing if the ultimate strain limit can accommodate a TMBDB temperature transient on the component.

## III. CONTAINMENT VESSEL AND CONFINEMENT BUILDING

The containment vessel ultimate pressure capability is about a factor of two greater than postulated TMBDB pressure loadings both before and after sodium boil-dry, which is a sufficient factor of safety for a beyond design basis accident. Hence, considering that the other defensive measures preclude a hydrogen detonation, I believe that the containment vessel is capable of handling the TMBDB loadings.

The confinement building was also analyzed for thermal stresses and concrete cracking that developed during the course of a TMBDB because of the operation of the Annulus Cooling System. Critical stressed regions were identified and these regions were further reinforced, according to the applicant. Details are not given; however, the applicant claims that concrete cracking was accounted for in the finite element analysis by changing material properties (presumably wherever the maximum principal stress exceeded the concrete tensile strength) and iterating the residual stresses to zero. It now appears from some recent research at Northwestern<sup>1</sup> that such a procedure is strongly affected by the mesh size used to represent the problem. On the other hand what the applicant has done is likely to be conservative. Analysis of other concrete structures was performed in like fashion.

I recommend that the applicant or NRC look at the problem of how to properly account for concrete cracking in the various containment structures required during TMBDB.

#### IV. BASE MAT RESPONSE

The basemat TMBDB scenario involves attack and dissolution of the liner by the molten sodium-core debris mixture, then attack and decomposition of the concrete substrate up until the point of sodium boil-dry, and then attack of concrete by the core debris. Because of the irreversibility of pouring the foundation and basemat for this plant and because it provides one of the main defense mechanisms against TMBDB, I believe that the base mat penetration problem is a key issue in granting the CP for the Clinch River Nuclear Plant. The following aspects of my review of the problem concerned me.

1. The many experiments that have been conducted on sodium-concrete interactions do not yet appear to provide a very sound data base for modeling the attack on the basemat. It is claimed that there is little dependence on temperature (apparently Arrhenius's laws are not at work) and on scale (apparently scaling laws don't apply). The chemistry of the reactions appears to be unknown since no equilibrium constants or reaction rates have been quoted as a function of temperature. Understandably the phenomenon is clouded with the accumulation of the reaction products at the sodium-concrete interface, turbulence, etc. How seriously has modeling of the sodium-concrete interaction phenomenon been attempted? It seems that if we can calculate the thermal-neutronic-structural behavior of the

reactor core during an HCDA (for which there is little experimental data) then we should be able to do the same for a relatively simpler physical system for which some data exists. I recommend that a re-evaluation of the existing data be undertaken, and that additional experiments be carried out to explain differences. In the meantime the NRC staff must base its decisions on bounding reaction rates.

2. For the problem of core debris-concrete interaction, it also seems to me that further modeling is needed. The calculation of thermal stresses, concrete creep, and concrete cracking in the base slab is possible with the current generation of finite element codes. These calculations would answer questions of basemat interactions with the confinement building and whether cracking develops on the bottom of the basemat for a hot spot proceeding down from the top of the basemat. If cracking were to occur on the bottom of the basemat, is it not possible for ground water to penetrate the basemat and interact with the core debris and/or sodium? These questions should be addressed.

#### V. CELL LINERS

The NRC has requested that the applicant provide additional analysis for cell liner strains during TMBDB and to include details of stress concentrations near penetrations, etc. This may be followed by an experimental program to corroborate the analyses, depending on the strain level indicated by the analyses. Presumably these efforts will be accomplished in time for implementation of design fixes, if found necessary.

These additional efforts should allay any concerns for the integrity of the cell liners during a TMBDB.

#### VI. CORE CATCHER FOR RISK REDUCTION

I reviewed the SAI report by B. Atefi and R. Liner on risk reduction feasibility studies including addition of a core catcher to the existing design of the CRBRP cavity. The claim is that comparable risk reduction could be achieved with a more reliable shutdown heat removal system.

Even so, considering the problems with sodium-concrete reaction rates and depth of concrete penetration by the core debris after boil-dry, it seems to me that a further examination of the core catcher options should be undertaken.

However, it is very important that the behavior of the core catcher when attacked by the sodium-fuel debris mixture be better understood than our understanding of sodium-concrete interaction.

## VII. INSTRUMENTATION

The instrumentation proposed for TMBDB consists of nuclear (radiation), chemical (hydrogen concentration,) and thermal (temperature and pressure). There appears to be no mechanical instrumentation for TMBDB such as motion or strain measurement (for example, of the containment vessel). I realize this could be an expensive undertaking, but for a first-of-a-kind reactor perhaps should be considered.

I remember doing technical assistance work for the Fort St. Vrain HTGR where we used accelerometer (required I presume for seismic monitoring) measurements to estimate forces developed in the core of the reactor from an unanticipated temperature (and neutronic) fluctuation. The point being that an instrument used for measuring motion was used to help to explain a thermal anomaly.

## REFERENCE

1. Z. P. Bazant, "Mechanics of Fracture and Progressive Cracking in Concrete Structures," Report No. 83-2/428M, February 1983.