Sandia National Laboratories
Albuquerque, New Mexico 87185

RECEIVED
JUN 26 1981
U.S. NUCLEAR REGULATORY COMMISSION

June 10, 1981

Mr. Richard R. Sherry
U. S. Nuclear Regulatory Commission
Division of Reactor Safety Research
Fuel Behavior Research
Washington, DC 20555

Dear Rick:

Enclosed are the status reports for the months of March and April for the core melt program.

Sincerely,

Marshall

M. Berman, Supervisor
Reactor Safety Studies
Division 4441

MB:4441:pr

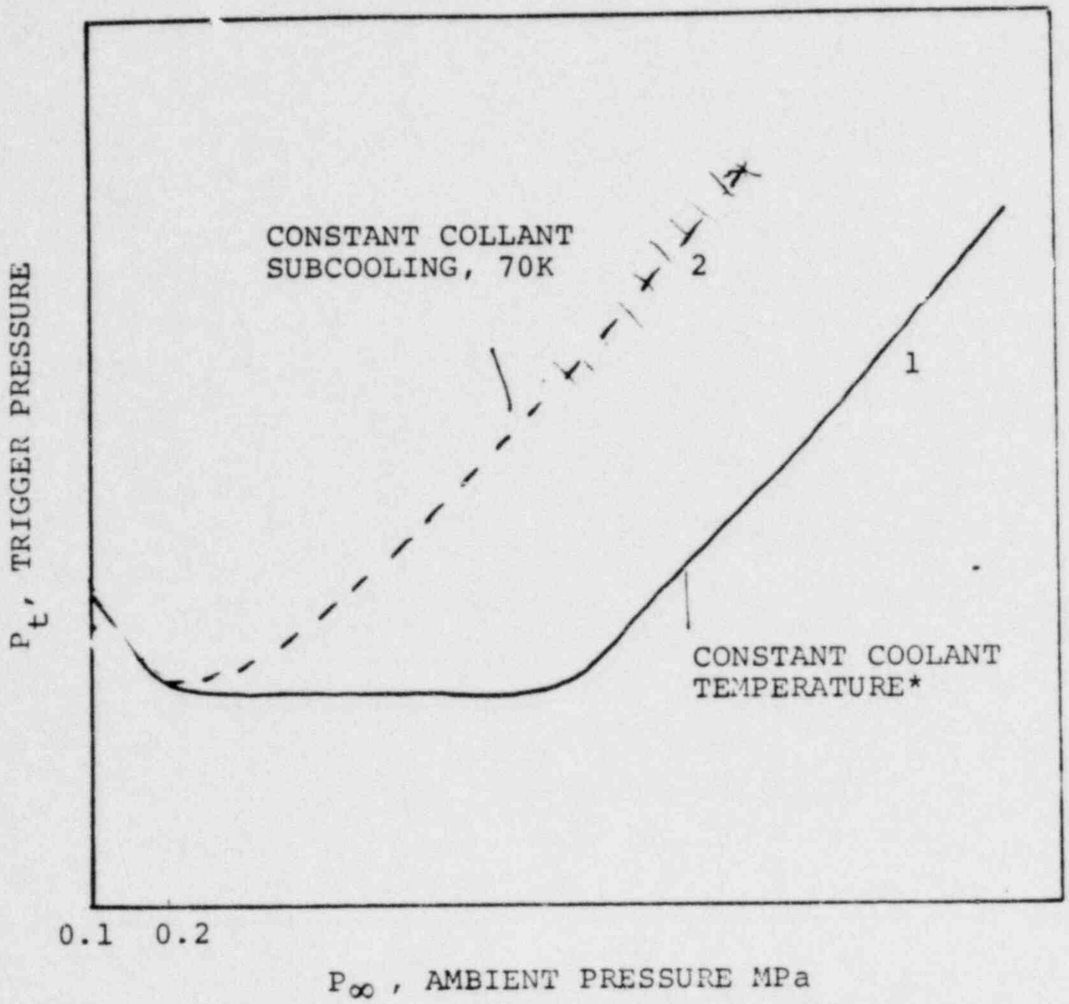
Enclosure

## I. Steam Explosions

During March and April of 1981, we completed a fifth single droplet test series in which the ambient pressure, $P_\infty$, was varied at a given coolant subcooling. The results of the experiments indicated that explosivity slightly increased and then decreased with increasing $P_\infty$. At $P_\infty$ = 0.1 MPa, the explosion was triggered by a bridgewire pressure pulse, $P_t$, of about 0.3 - 0.4 MPa. At $P_\infty$ = 0.2 MPA, the required trigger pressure decreased to about 0.2 MPa. As we increased the ambient pressure further, the required trigger pressure increased. At 0.5 MPa the required trigger was about 0.8 MPa.

This behavior is qualitatively similar to the previous test series for which the coolant temperature was held constant and $P_\infty$ increased (see Figure). It is obvious from the figure that the decrease in explosivity (increasing $P_t$) that results from increasing $P_\infty$, is partially offset by increasing subcooling. These two compensating effects produced the rather wide region of constant explosivity evident in curve (1). The vertical separation between the curves, $\Delta P_t$, is a measure of the increase in explosivity due to subcooling alone. The initial decrease in explosivity at $P_\infty = 0.2$ MPa is still unexplained. In the next two months, we plan to do experiments to investigate the effect of melt oxygen content on the explosion suppression using $FeO_x$ fuel droplets.

Five EXO-FITS tests were conducted during this time period. All five used approximately 5 kg of Corium-A+R thermite as the fuel. Only one test, MDC-2, resulted in a violent steam explosion. The estimated conversion ratio of this spontaneous explosion was about 2%. The reason for the lack of the explosion in the other tests is not completely understood, although we feel it is probably caused by variations of initial melt temperature and composition. We plan to attempt one more EXO-FITS test in May at a high initial fuel temperature. Then the FITS-B test series will begin.



*Consequently, subcooling increases with increasing ambient pressure.

The analyses performed these last two months have focused on the FITS-G tests. A simple model was written to describe the FITS-1G test. The model represents the test as a closed system consisting of four material volumes which transfer mass and energy between them; fuel, coolant liquid, atmosphere, and a cold steel wall. It neglects the production of hydrogen and its combustion. The model includes a correlation for condensation heat transfer which we developed from first principles. The major unknown in the model is the fraction of the melt (and the associated particle sizes) which mixes with the coolant and forms a debris bed on top of the remaining solidifying melt. We have successfully matched the early pressure and temperature data of FITS-1G when we used the experimentally observed debris mass and an assumed particle diameter of 10 mm.

## II. Core-Concrete Interactions

During March and April, copies of the CORCON-MOD1 draft report and of the code itself were transmitted to a number of outside requestors. We have received no reports of difficulties with the code.

At the request of T. Pratt, BNL, and J. Meyer, NRR, we performed a number of CORCON calculations and hand calculations for use in the Zion/Indian Point (ZIP) Study being prepared by NRR. Specificallly, we addressed four major questions for the TMLB' accident scenario:

(i) What is the expected penetration rate for a core-concrete interaction without water present in the reactor cavity (in the time period of a few hours to a few days after SCRAM)?

(ii) What is the expected rate of gas generation from such core-concrete interactions?

(iii) What is the expected upward heat flux that would be radiated to containment walls and could generate additional gases?

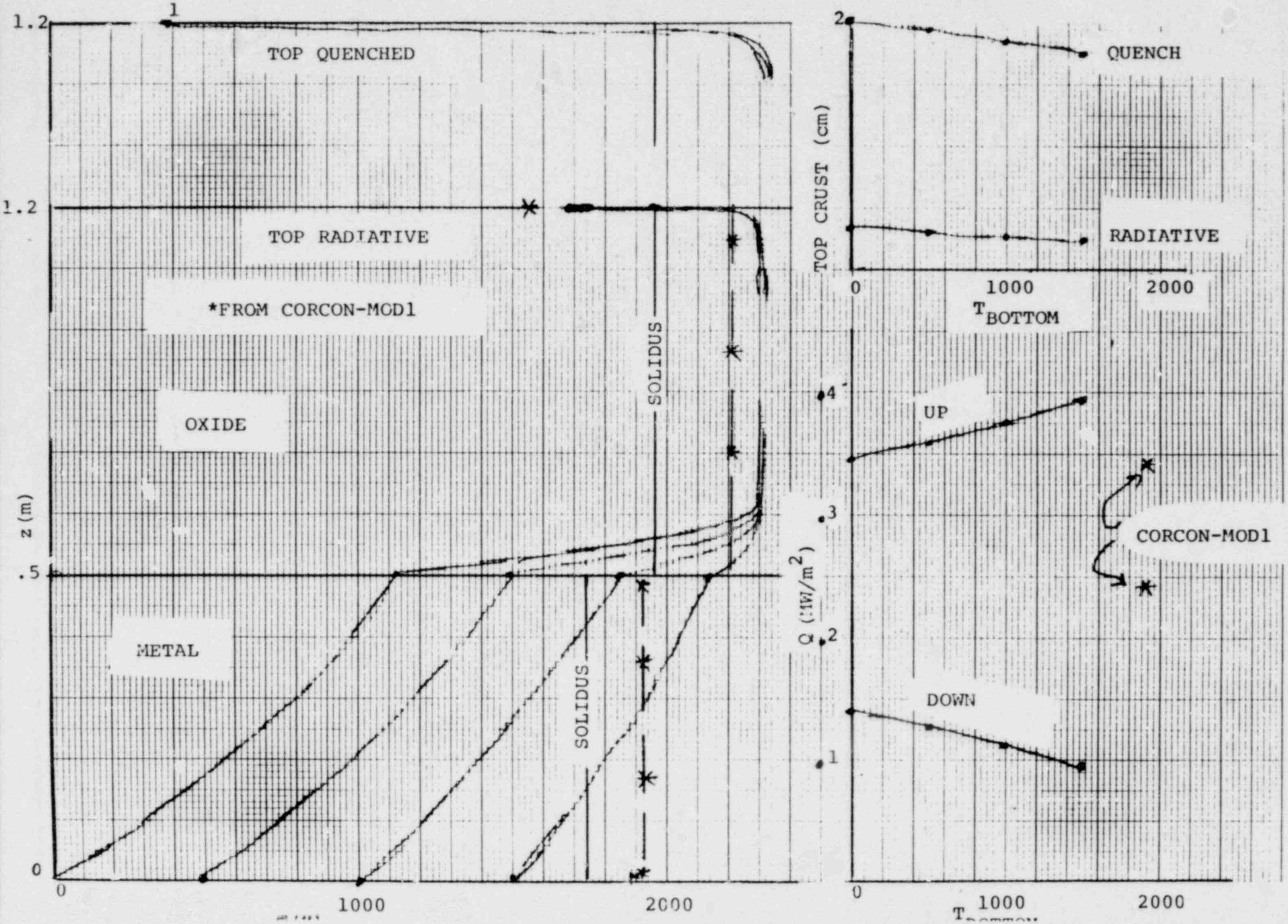
(iv) What is the expected difference in containment response if the reactor cavity contains some inventory of water?

Copies of the results were sent to T. Pratt, to J. Meyer, and to you.

In our attempts to model the long-term interaction, we have formulated a model for one-dimensional heat transfer in layered pools without gas stirring. The model assumes laminar or turbulent natural convection in liquid regions with unstable temperature gradients, and conduction elsewhere. It is described in detail in the January-March Quarterly (to be published), where we demonstrate good agreement with the correlations of Kulacki and co-workers for the cases considered by them. We have applied the method to the CORCON LWR Sample Problem, using CORCON-calculated conditions at 2 hours (equivalent to 4 hours after SCRAM).

A number of steady-state calculations were performed. In one group, the upper boundary condition was taken as radiative, and

Figure 1. TEMPERATURE PROFILES, etc., at SCRAM + 4 HOURS



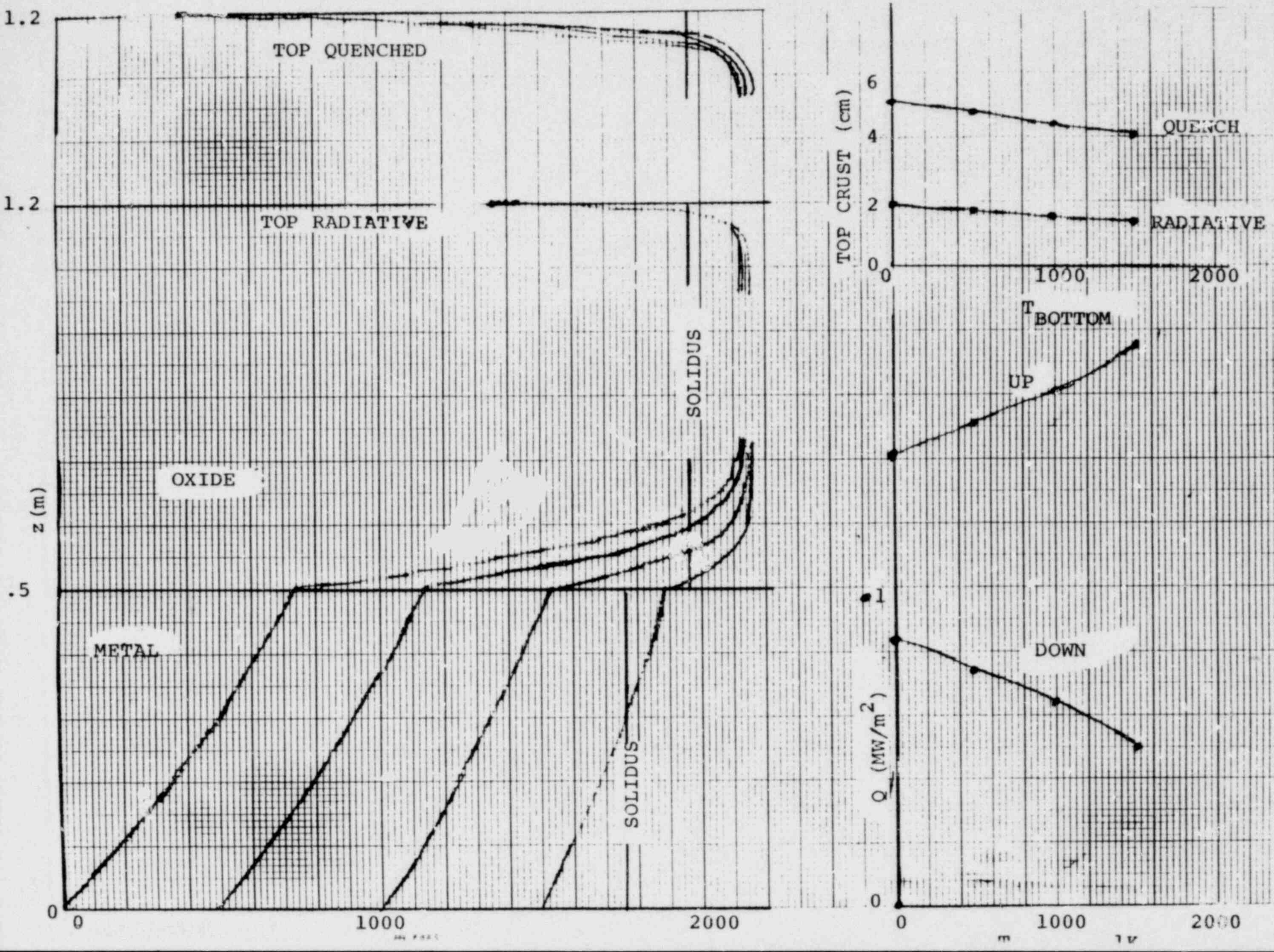
the lower boundary temperature varied parametrically. In a second group, the parametric variation was repeated but with the top boundary assumed quenched to 373 K (as though an overlaying water layer existed). The temperature profiles as a function of pool depth are shown in Figure 1 for bottom temperatures of 0, 500, 1000, and 1500 K (the bottom of the "pool" is taken to be z = 0, i.e., the concrete-metal interface, even if the metal has solidified). Although the temperatures in the metal layer are strong function of the lower temperature boundary conditions, the temperatures near the top surface and throughout most of the oxide layer are almost independent of bottom boundary temperature. The top boundary condition, radiative or quenched, has almost no effect except on the top crust thickness. The quenched conditions produce a crust more than 5 times thicker than the radiative condition, as shown in the upper right graph in Figure 1.

The lower right graph in the figure shows the heat fluxes in the upward and downward directions as function of the lower boundary temperature. For all cases, much more heat is transported upwards than downwards; the difference increased with increasing lower boundary temperature. These curves also illustrate the rather weak dependence of heat flux on lower boundary temperature. CORCON-MOD1 predictions for this calculation (using bubble-driven heat transfer coefficients) are shown by asterisks. CORCON predicted lower heat fluxes in the upward direction, and higher downward fluxes. Temperatures in the metal layer were above the solidus, as expected, since CORCON cannot treat crust development. Oxide layer temperatures were only slightly below the predictions of the simple model, although the surface was cooler than for the radiative boundary condition. CORCON-MOD1 has no provision for a coolant layer, and no comparisons were made against the quenched boundary condition of the simple model.

The calculations were repeated for the lower heat generation appropriate for 7 days after SCRAM, Figure 2, and results are attached. These results suggest that while it may be possible to freeze the metallic phase of the melt fairly early, the bulk of the oxide phase may remain molten for weeks. Also, very little effect may be had by increased top cooling, beyond a modest increase in crust thickness (assuming no coolable debris bed is formed).

In CORCON-MOD1, the VISRHO package is used to calculate the viscosities of siliceous oxidic mixtures, using the methods of Bottinga and Weill. This involves some aliasing of species not in the original data base as well as extrapolation in both temperature and silica content. We became aware that this sometimes produces unreasonably high viscosity values (in one case, ~ 10 poise for a dominantly $UO_2$ - $ZrO_2$ melt at 2800 K). The high viscosity leads to reduced heat tranfer and exaggerated level swell. There seems to be no easy solution. The Bottinga-Weill correlation was originally used because little else was available, and that situation is unchanged. One possibility which we are investigating,

Figure 2. TEMPERATURE PROFILES, etc., at SCRAM + 7 DAYS



is to modify a method of H. R. Shaw's. This method was developed from the same data used by Bottinga and Weill, and is considered to be less accurate within that data base. However, the extrapolated properties of the method are more well behaved.

In mid-March, Jim Muir left the CORCON program. Jim shaped much of the development of the project, and his contributions will be missed in the future.

Copy to:
NRC Public Document Room (2)
R. A. Bari, BNL
B. S. Burson, NRC, RES
I. Catton, U of C.
Dae Cho, ANL
M. Cunningham, NRC, RES
R. T. Curtis,NRC, RES
R. Denning, BCL
R. DiSalvo, NRC, RES
W. V. Johnston, NRC, RES
C. N. Kelber, NRC, RES
J. Long, NRC, NRR
A. Marchese, NRC, NRR
J. Meyer, NRC, NR
W. Milstead, NRC, NRR
J. Murphy, NRC, RES
J. Norberg, NREC, OSD
W. Pasedag, NRC, NRR
G. Quittschreiber, NRC, ACRS
J. Read, NRC, NRR
M. Silberberg, NRC, RES
T. Speis, NRC, NRR
D. Swanson
T. Walker, NRC, RES
R. Wright, NRC, RES
2514 - D. E. Mitchell
4400 - A. W. Snyder
4422 - D. A. Powers
4440 - G. R. Otey
4441 - R. K. Cole
4441 - N. A. Evans
4441 - D. P. Kelly
4441 - M. L. Corradini
4442 - W. A. VonRiesemann
4755 - J. F. Muir
5836 - L. S. Nelson
3151 - W. L. Garner
4441 - M. Berman