UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAY 2 2 1981

MEMORANDUM FOR: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Robert B. Minogue, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER 121, CORCON-MOD1
AN IMPROVED COMPUTER MODEL FOR THE INTERACTION BEHAVIOR OF MOLTEN CORE MATERIALS WITH CONCRETE

Introduction

This memorandum transmits the results of completed research on the interaction of molten core materials with reactor cavity concrete. Specifically, this letter describes the advanced melt/concrete interactions code - CORCON-MOD1.

The primary objective of the molten fuel interactions program, which was initiated in 1975 at Sandia Laboratories, is to investigate the physical phenomena associated with interactions of a molten core with the containment concrete basemat following reactor vessel melt-through during postulated core melt accidents. Specific objectives are to determine the rate of penetration of the melt through the concrete and to characterize the rate of production of steam and noncondensible gases generated during the interaction. These phenomena are important to the assessment of core melt accident risks since they impact directly on the timing and mode of containment failure. Melt penetration rates through the concrete determine the timing of containment failure via basemat melt-through. The steam and noncondensible gases produced during the interaction are significant contributors to containment overpressure failures and to containment failure modes resulting from the combustion of flammable gases (H_2, CO, hydrocarbons).

The CORCON code embodies the state-of-technology of our understanding of melt/concrete interactions. The CORCON code improves upon a preliminary computer model INTER[1,2] developed previously at Sandia and has similar capabilities to the WECHSL[3] code being developed at the KfK Laboratory in the Federal Republic of Germany. The CORCON code provides the Nuclear Regulatory Commission (NRC) with the best available tool for evaluating the melt/concrete interaction phase of postulated core melt accidents.

The code can be used in the following applications:

(1) Severe accident risk and consequence studies,

(2) Evaluation of plant specific severe accident risks (e.g. Zion/ Indian Point Study),

(3) Evaluation of the performance of ESFs and proposed mitigation features during severe accidents, and

(4) Development of rules for Degraded Core Cooling, Minimum Engineered Safeguards, etc.

This research program is being conducted by Sandia National Laboratories (Dr. M. Berman, Program Manager) under the direction of the Severe Accident Assessment Branch, Office of Nuclear Regulatory Research (RES). Enclosure 1 is a draft user's manual for the CORCON-MOD1 code. The code has been set up and is operational on the Brookhaven National Laboratory (BNL) computer system and can be remotely accessed from NRC headquarters. Enclosure 2 contains the necessary information for accessing the code.

Code Description

The CORCON code describes the physical phenomena associated with the interaction of a molten core with the reactor cavity concrete basemat under postulated core meltdown accident conditions. The major physical systems which the CORCON code models are the concrete, the molten pool, and the gas atmosphere and surroundings directly above the pool. Analytical models are provided for the important physical and chemical interaction phenomena including: melt/concrete heat transfer, concrete decomposition and ablation, growth of the cavity, heat transfer within the pool and from the pool surface to the atmosphere and surroundings, gas evolution from the decomposing concrete and melt/gas chemical reactions, and decay heat generation within the melt. The code can be applied to the analysis of both reactor accident phenomena and prototypic interaction experiments.

An indepth discussion of the physical models in the CORCON-MOD1 code is contained in Enclosure 1. The following section briefly describes the principal code features.

The code allows the molten pool to exist as layers of immiscible phases. Currently, the code treats up to three layers; a heavy oxide layer, a metallic layer, and a light oxide (slag) layer. The coding structure will allow for up to a total of six layers including a coolant layer above the melt (not currently modeled in CORCON-MOD1). Relative layer densities determine their vertical orientation (i.e. layers can flip during a problem calculation).

Time-dependent concrete ablation and growth of the molten pool cavity is modeled by a routine developed by ACUREX/Aerotherm Corporation under contract to Sandia[4]. The ablation and cavity shape change models assume steady-state, one-dimensional concrete ablation coupled to a two-dimensional axisymetric shape change procedure. The shape change procedure employed in the CORCON code is based on a method that was first developed for modeling the shape change of ablating reentry vehicle nosetips.

The thermal dehydration and decomposition of the concrete produces copious quantities of gases (principally water vapor and carbon dioxide). The large amounts of gas released by the decomposing concrete exert a controlling effect on many physical processes governing the interaction behavior. For example, heat transfer between the molten pool and the concrete, and between layers within the pool, is modeled by applicable gas film models and natural and gas-driven convection models respectively.

The concrete decomposition gases are assumed either to escape from the melt cavity region along the gas film between the melt and the concrete, or to enter the melt and to rise as bubbles through the melt. In passing through the various molten layers the gases are assumed to come into thermal equilibrium with each layer. In the metallic layer the steam and CO_2 are reduced by the metallic elements present to the combustible species H_2 and CO. These rise through the remainder of the pool and are released to the atmosphere.

Heat is transported away from the melt at the upper surface of the melt by both convection and radiation to surrounding structures. The current radiation model in CORCON-MOD1 assumes uniform temperature gray body radiation with a shape factor for two infinite parallel plates.

Energy sources (and sinks) within the molten pool itself include the heats of chemical reactions and radionuclide decay heat.

The CORCON-MOD1 code is written in FORTRAN-IV and requires approximately 105 K of core to run on the CDC 7600.

Code Application and Limitations

The CORCON-MOD1 code represents the state-of-technology of our understanding of the melt/concrete interaction phenomena. However, the following limitations should be understood and accounted for by users of the code.

The CORCON-MOD1 code is currently applicable <u>only</u> to the high temperature phase of the interaction phenomena when the melt is sufficiently hot that it is entirely liquid and is eroding the concrete at a rapid rate. This limitation is critical. Recent calculations[5] indicate that during some core melt accident sequences the melt may begin to freeze prior to complete penetration of the basemat. Since the solidification temperature of the molten core materials is above the melting temperature of most concretes, penetration of the concrete by the hot solid core debris will continue. CORCON-MOD1 does not model this latter phase of the interaction and should not be applied to this phase.

The CORCON-MOD1 code cannot be applied to the interaction of molten core debris with most core retention materials. This restriction results from the many code models that assume copious gas flow through the molten pool. Experimental evidence indicates that most candidate core retention materials (e. g. magnesium oxide, high alumina cement, firebrick, etc.) produce much less gas than concrete during interaction with molten core materials.

The current version of the CORCON code does not include models for an overlying liquid coolant layer.

The thermo-chemical model for gas phase reactions (oxidation, hydrogenation, etc.) in the atmosphere directly above the melt has not been incorporated into the current code version.

The heat transfer models from the pool surface to the atmosphere are approximate (e.g. constant convection heat transfer co-efficient, incorrect form factor for radiation heat transfer).

The mass and energy additions to the pool caused by melting and ablation of materials above the pool which may fall into the pool are not modeled.

Oxidation of the metallic phase of the melt by gases which escape from the cavity through the gas film between the melt and the concrete is not modeled. These and other limitations and uncertainties are discussed in more detail in Enclosure 1.

Recommendations

(1) NRC staff and NRC consultants use the CORCON-MOD1 code for future analysis of the interaction of molten core debris with concrete and that the use of the INTER code be discontinued.

Future and Related Research

Current plans are to issue an improved version of the CORCON code (MOD2) near the middle of calendar year 1982. In this version of the code every effort will be made to include at least rudimentary models for concrete attack by hot solidified debris. Efforts to model the initial refreezing and resolidification phase of the interaction will be delayed until 1982. The code development effort in these areas is chiefly limited by the lack of an experimental basis for the models. Additionally, in MOD2 of the code we plan to add or improve models which will eliminate or relax some of the more important limitations identified in the preceding section.

Planned sensitivity studies with the code will aid in identifying which models require immediate improvement and which model improvements can be delayed.

Melt/concrete experimental programs are planned both at Sandia (Large Melt Facility) and at the German KfK Laboratory (Beta Facility) to provide data needed for code development and to aid in validating the code.

Efforts are currently underway to evaluate the best method for interfacing the CORCON-MOD1 code with the large meltdown accident systems codes (e.g. CONTAIN, MARCH).

For further information on the CORCON-MOD1 code, on its use, or on future CORCON code development plans, please contact Richard Sherry of my staff (427-4329).

Robert B Minogue

Robert B. Minogue, Director
Office of Nuclear Regulatory Research

Enclosures:

(1) Draft Sandia NUREG Report, "CORCON-MOD1: An Improved Model for Molten-Core/Concrete Interactions,: SAND 80-2415, by J. Muir, R. Cole, M. Corradini, and M. Ellis

(2) Information for CORCON-MOD1 use on the BNL computer system.

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References

(1) Murfin, W. B., "A Preliminary Model for Core-Concrete Interactions," SAND 77-0370, Sandia Laboratories, October 1977

(2) Research Information Letter No. 28, "Melt/concrete Interactions," Memorandum from S. Levine, RES to E. G. Case, NRR, and R. B. Minogue, SD, May 9, 1978

(3) Memorandum from J. F. Muir, Sandia National Laboratories, to Distribution, "Acquisition of German Fuel Melt/Structural Materials Interaction Computer Codes," June 19, 1980.

(4) Kwong, K. C., Beck, R. A. S., and Derbidge, T. C., "CORCON Program Assistance", ACUREX Final Report FR-79-10/AS, ACUREX Corporation/ Aerotherm Aerospace Systems Division, Mt. View, Calif., July 1979

(5) Murfin, W. B., "Report of the Zion/Indian Point Study: Volume 1," NUREG/CR-1410, August 1980

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Enclosure 2

Information for Running the CORCON-MOD1 Code on the BNL Computer

The CORCON-MOD1 code has been set up and is operational on the BNL CDC 7600/6600 system.

The code is set up on a disc file under the filename "SHERRYCORCONMOD1", ID = ZZRNRC.

The file contains three partitions: the first partition is in CDC UPDATE format, the second is a relocatable binary file, and the third is an absolute binary file.

Input data for a sample problem is "currently" set up on an INTERCOM file "CORCONDATA", ID = SHERRY.

For information on how to set up a CORCON run on the BNL computer refer to the NRC's "Computer User's Guide" available from the NRC Office of Administration, Division of Automatic Data Processing Support.

ENCLOSURE 1

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NUREG/CR-2142
SAND80-2415
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CORCON-MOD1: AN IMPROVED MODEL FOR MOLTEN-CORE/CONCRETE INTERACTIONS

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