INTERIM REPORT

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INTERIM REPORT

## I. Steam Explosions

The single droplet experiments continued this month. Fifteen successful experiments have been conducted using iron oxide as the fuel (0.3 gm @ 2000 K) dropped into water (3.5 kg @ 300 K). The purpose of these initial tests was to demonstrate reproducibility for a given set of initial conditions. During this experimental series, both spontaneous and artifically triggered explosions occurred. The prime variable that was changed causing these two triggering modes was the molten fuel drop height in air; when the drop height was small (<10 mm) spontaneous explosions occurred, and when it was large (>20 mm) spontaneous explosions were suppressed long enough to artificially induce the interaction with a bridgewire. Entrained air in the vapor film may be the reason for these effects. Debris collection and data reduction are underway for these tests, as well as analysis to understand the results.

The second in-vessel FITS experiment, FITS2A, was performed in April. The purpose of this experiment was again to determine the pressure and temperature responses of the interaction vessel to a violent explosion. The initial conditions were similar to test FITS1A except that the melt-mass was increased from 2 to 3 kg. This was done to insure that a spontaneous explosion would occur, based on empirical evidence from EXO-FITS tests. A violent spontaneous explosion did result; however, it occurred early in the mixing process before all the melt had entered the water. The data are now being reduced and further analysis will be conducted. Due to budget constraints, the next FITS experiment is scheduled for sometime in May. In the interim, EXO-FITS experiments will be conducted to understand the early trigger.

Analysis this month has continued on modelling the explosion propagation and the fluid-structural interactions in the full-scale reactor vessel.

The 1-D transient propagation model has successfully predicted the explosion detonation velocity in the EXO-FITS tests (~ 300-500 m/s). This velocity is found to depend upon the vapor and fuel volume fraction in the fuel-coolant mixture and the initial trigger pressure. The predicted peak shock pressures are about 100 MPa. Data from EXO-FITS tests have not verified this value although in every test the peak pressures were greater than 20 MPa.

In order to assess more realistic effects of the steam explosion in the vessel, two calculations are being prepared:

(1) A March/Corral computer run to obtain estimates of the geometry of the core and vessel at the time of fuel-coolant contact.

(2) A structural calculation of the early and late time expansion of the explosion to assess the mitigating effects of lower plenum failure and slug breakup due to upper internal structures.

During April, several presentations were made describing the various aspects of the steam explosion program. Three papers were presented at the Thermal Reactor Safety Conference in the Class 9 Accident session by L. S. Nelson, R. L. Woodfin and M. L. Corradini. The papers were well received. Later in the week D. E. Mitchell and M. L. Corradini gave presentations at the U.S.-F.R.G. Information Exchange Meeting concerning the FITS experiments and the analysis employed in the Zion-Indian Point Study.

In addition, final preparations are underway to submit the experimental details of the single drop experiments to the CSNI as part of the Joint interpretative exercise. A copy of the letter from Mr. M. Stevens of the CSNI is enclosed as attachment 1.

## II. Core-Concrete Interactions

### CORCON Development

CORCON cleanup and simplification activities continued during April. They included the removal of more redundant variables, revamping of the common blocks, and finding and eliminating occasional bugs.

The melt/gas-phase chemical equilibrium solution algorithm was determined to be the main weakness in the code at present. The problem is not so much that the solution technique is seriously inaccurate, but rather that the inaccuracies are random. Consequently, small changes in input variables, such as one would make in a parametric or sensitivity study, lead to random variations in the calculated equilibria. It is impossible to separate these variations from those attributed solely to the changes in the input parameters. An investigation was undertaken to explore the possibility of using an alternate solution technique. It was concluded that none of the alternative methods found was likely to be better than the present one - each has its own problems which differ from, but are not necessarily smaller than, those in the present technique. This being the case, an effort was initiated to try and reduce or eliminate the problems in the existing solution algorithm.

The experimental conditions for the two Code Comparison tests were obtained from D. A. Powers and used to set up an input deck for CORCON. Initial calculations for the purpose of predicting

the experimental variations, as part of the code comparison - test analysis task will subsequently be made usirg CORCON-MOD 0.

An assessment was made of a fission product decay heat generation model suitable for use in CORCON. Several levels of sophistication are possible in describing this phenomenon. The initial model will be kept fairly simple and designed for ease of modification and improvement. It will contain a simple aerosol generation model to allow depletion of the decay heat sources in the melt.

A paper entitled "Modelling of Molten Fuel/Concrete Interactions," by J. F. Muir and A. S. Benjamin, was presented at the ANS/ENS Topical Meeting on Thermal Reactor Safety held in Knoxville, Tennessee, on April 7-11, 1980. A review of the current status of CORCON and a discussion of the results of an initial sample problem calculation (the ZIP conditions), including comparisons with INTER and WECHSL predictions for the same conditions, were presented at the USA/FRG Fuel Melt Research Program Review and Information Exchange Meeting also held at Knoxville on April 11 and 12.

### Experimental Program

In anticipation of the need to describe crust formation and growth on oxidic melts when modelling the long-term behavior of melt/concrete interactions, the viscosity of two-phase siliceous melts was examined. The precipitation of solids in these melts will cause the viscosity of the resulting slurry to differ from that of the single phase melt. In general, such slurries are thixotropic, i.e., the viscosity is a non-linear function of shear rate. Furthermore, at zero shear rate, the slurry viscosity is also a non-linear function of the particulate volume fraction. Correlations were obtained from the literature for the viscosity of slurries which model both of these effects. They show that slurry viscosity increases with particulate volume fraction and with decreasing shear rate.

## III. Separate Effects Tests for TRAP Code Development

Experiments to measure the vapor pressure of CsOH in moist and dry $N_2$ are continuing. Also continuing are experiments studying the possible conditions for desorption of Te from nickel and stainless steel. No desorption was found at temperatures at or below 700C.

Fabrication of the Fission Product Reaction Facility is proceeding. The difficulties in fabrication of a nickel crucible for the interim laser cell have been resolved.

Attachment 1 2pp

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24th March 1980

TO THE PARTICIPANTS IN THE

CSNI Joint Interpretation Exercise on Selected Fuel-Coolant Interaction (FCI) Experiments

Eleven research centres have responded positively to my telex (EN/S/1107) of 10th January, and have indicated that they wish to participate in the exercise. Attachment 1 lists the contact persons at the different laboratories. Mr Harry Teague, whose efforts were vital to setting up the exercise, has recently been promoted to new responsibilities at SRD. In consequence, he will be unable to take an active part in the exercise itself, but will be following its progress with great interest.

To maintain speedy communication between participants with a minimum of confusion, I should like to suggest that the following procedures be adopted.

Sandia and Winfrith expect to have their data sets ready in two or three weeks, and will send them as soon as possible directly to the twelve addresses given in Attachment 1.

If you want any clarification of the data, or supplementary information, please write directly to Sandia or Winfrith (as the case may be) and send a copy of your request to me. Sandia/Winfrith should reply directly to the questioner, and either send copies to the remaining ten addresses in attachment 1, or send a copy to me.

.../2

cc: Mr Teague, SRD
Mr Gilby, SRD
Mr Wright, UCLRC
Delegations

(I would then send copies of both the inquiry and response to the other participants for their information and possible use in their analysis.)

Attachment 2 contains the responses to the request in my telex for suggestions as to what key physical effects and values the interpretations should attempt to predict and explain, qualitatively or preferably quantitatively (such as relative importance of different physical processes, order of magnitude of important quantities, etc.).

Also attached for your information is the addendum to document SEN/SIN(78)41, which summarizes the opinion of the CSNI Expert Group on the Science of FCIs about the status of theoretical understanding and experimental results available about FCIs as of late 1978. (As you may recall, recommendation 7 in that document eventually led to this interpretive exercise).

We hope that it can be run with a need for only one meeting in the autumn, a Workshop to review the interpretations and arrive at conclusions regarding the state the art of theoretical understanding of FCIs, what uncertainties remain to be reduced by further research, as well as recommendations on what further action, if any, CSNI should consider taking. It would probably be desirable to convene a meeting of the Group of Experts on the Science of FCIs in conjunction with the Workshop, to discuss the latest experimental results and theoretical ideas from the different laboratories. I shall write to you in late June to find out your feelings regarding the timing and location of the Workshop. By that time you should have had a chance to estimate the time you wish and are able to devote to the interpretive exercise.

Please do not hesitate to contact me to help smooth out any communication problems that may arise.

Yours sincerely,

Michael Stephens

Michael Stephens
Nuclear Safety Division

**Attachment 1**

**Contact Persons for the**

**CSNI Joint Interpretation Exercise on Selected Fuel-Coolant Interaction (FCI) Experiments**

| | |
|---|---|
| France | M. Georges Berthoud<br>Laboratoire de Thermohydraulique des Métaux Liquides<br>Service des Transferts Thermiques<br>Département de Transfert et Conversion d'Energie<br>Commissariat à l'Energie Atomique<br>Centre d'Etudes Nucléaires de Grenoble<br>B.P. No. 85X - Centre de Tri<br>F-38041 Grenoble Cedex<br><br>Tel: (76) 97.41.11 Poste 3416<br>Tlx: 320323 ENERG A |
| Federal Republic of Germany | Dipl. Ing. Manfred Bürger<br>Institut für Kernenergetik und Energiesysteme<br>Universität Stuttgart<br>Pfaffenwaldring 31<br>Postfach 801140<br>D-7000 Stuttgart 80 (Vaihingen)<br><br>Tel: (0711) 7841 or 7842368<br>Tlx: 07255445 UNIV D |
| | Dr Ing Leonardo Caldarola<br>Institut für Reaktorentwicklung<br>Kernforschungszentrum Karlsruhe GmbH<br>Postfach 3640<br>D-7500 Karlsruhe 1<br><br>Tel: (07247) 823974<br>Tlx: 7826484 KFK D |
| Italy | Ing. Giovanni Scarano<br>Il Direttore<br>Laboratorio Studi Dinamica e Sicurezza del Nocciolo<br>Divisione Ricerca e Sviluppo<br>Dipartimento Reattori Veloci<br>Comitato Nazionale per l'Energia Nucleare<br>Centro di Studi Nucleari della Casaccia<br>S.P. Anguillarese km 1+300<br>C.P. No. 2400<br>I-00100 Roma<br><br>Tel: 4698<br>Tlx: 613296 CNEN CASACCIA |

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Attachment 2

Following are participants' responses to the question: what key features of the experiments should the interpretations attempt to include?

- "We think that the interpretations should attempt to clarify the conditions under which incoherent interactions will decay or escalate and coherent interactions will propagate. The mechanisms on which the escalation and propagation process are based should be identified and as much as possible quantified, using the theory of thermal detonation. An essential point herein should be to analyse the dominant fragmentation modes. Furthermore, the importance of the spontaneous nucleation criterion should be discussed for the different stages (coarse mixing, escalation and propagation). Important parameters from our view are: Materials, mass ratio, drop size, void fraction, temperatures, pressure ratio, pressure rise time, energy release, pressure development, interaction zone length, fragmentation degree and time, propagation velocity, fluid and drop velocities behind the front, for incoherent interactions: delay time between trigger and expansion, and for coarse mixing: quality of mixing".

  Dipl. Ing. M Bürger, IKE, University of Stuttgart

- "I suggest that participants be asked:

  1. To consider quantitatively the energetics of proposed fragmentation mechanisms, and the resulting interfacial areas.

  2. To determine, from the calculated degree of fragmentation, the expected heat transfer and vapour generation rates, and hence to predict quantitatively the observed pressure signals.

  3. To show clearly, for the large scale metal/water Thermir expt., where, and at what rate, the postulated fragmentation process occurs in relation to the observed propagating shock front".

  Dr S J Board, CEGB Berkeley Nuclear Laboratories

- "In connection with what interpretations should be attempted for the Winfrith experiments, we suggest the following:

1. Calculate the initial conditions just before the interaction (e.g. vapour fractions, interface temperatures) which are not available as direct experimental data.

2. Calculate propagation velocities and peak pressure.

3. Discuss how the necessary degree of fragmentation can be obtained, bearing in mind the nature of the recovered debris.

4. Estimate heat transfer rates during the experiment.

5. Compare energy release with that estimated from experimental data.

In the case of the Sandia experiments the analysis should cover the same points except for propagation velocity".

Mr R B Tattersall, AEE Winfrith

- "I believe the interpretations should aim to identify and quantify the mechanism(s) of the propagation step".

Prof. T Theofanous, Purdue University

- "Having had the advantage of seeing the other participants comments, and after discussion with Mr Teague, I would like to note the following:

1. Interest seems to be mainly devoted to propagation and fragmentation. The initiation phase is also important and should also be considered.

2. There is little mention of the spontaneous nucleation theory: I hope one of its proponents will attempt an interpretation.

3. We must beware that we get interpretations, not explanations. I get the impression from some of the comments that it is the latter they will attempt. We already know there is sufficient energy available, that models with many parameters can explain what happened, etc. What we need is more than this: Not a plea that a particular process is feasible but that there are features that mean that the process must be the mechanism.

I feel that the exercise will be worthwhile if we can concentrate the minds of the participants on what we can learn about the mechanisms that occurred in the experiments rather than showing that certain mechanisms are feasible."

Mr G J Vaughan, SRD Culcheth