GRQ

CT-1244

TO: Gary Quittschreiber

FROM: I. Catton

SUBJECT: USA/FRG Fuel Melt Research Program Review and Information Exchange Meeting, 11-12 April, 1980

The USA research sponsored by NRC-RSR was presented and no new information surfaced. In that it has been presented before and my comments have previously been expressed, I will not reiterate. The work done in support of the Rogovin report was discussed by Dr. R. Denning of BCL and will appear in Vol. II of the Rogovin report. The conclusions of Dr. Denning's presentation are worth noting:

1. Can't predict severity of fuel damage based on MARCH type analysis,

2. Uncertainties in boundary conditions are too great, and

3. There are a number of modelling uncertainties.

Apparently there are a number of versions of codes such as ORIGIN and as a result different people obtain different answers. RELAP was noted to have done better in a TMI-2 calculation than TRAC. Actually results seem to have converged reasonably well considering the complexity of the problem. Dr. Benjamin noted that containment model uncertainties are significant and may dominate vented filter design.

Dr. Barnacik, GRS, described the Beta Facility. Its purpose is to study concrete penetration by a core melt. In that the FRG containment design tries to keep the reactor cavity dry, no tests will be run with water. Three regimes of melt-concrete attack have been established:

1. $1900 < T_p < 2400°C$
   $0 < t < 7$ hrs
   Vigorous attack by a well stirred pool of molten core debris. Vessel failure is assumed to yield a molten mixture at 2400°C.

2. Mixture Melt Temperature $< T_p < 1900°C$
   $7 < t < 8$ hrs
   A more quiescent melting attack where concrete thermal properties add possible pool segregation are important. They have some concern about layer to layer heat transfer.

3. $T_p \sim$ Mixture Melt Temperature
   8 hrs $< t$
   Freezing and re-melting will be occurring. This regime is the least understood of the three

The first tests will be the following:

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$T_p = 2000°C$

Power = 8.4 MW Induction Heater at 1000 H_3 with at least 38% efficient coupling

300 < Mass of Melt < 600 Kg Iron
t = 300 min continuous

Results from this series of tests will be available in mid 1983. An acoustic method developed by SANDIA will be used to follow the decomposing concrete surface. The concrete crucible will be 40 cm in diameter (5 Taylor wavelengths) and 2 meters deep. This does not address the question of penetration when the cross-sectional area is very large and the gases resulting from decomposition can spread the melt into a thin layer.

Dr. Hoseman presented an overview of the FRG work on soil penetration (Dr. Peeks could not attend the meeting). They have chosen a soil that is a mix of Al_2O_3, $CaCO_3$ and silica sand (SiO_2). A series of experiments is planned starting with 4 kg of steel, inductively heated at 6.34 kw/hr on both wet and dry sand. They will also study the soil mix, wet and dry, with both steel and a corium mix. Tests run so far show lots of crusts and bubbles with wet sand having less penetration. A typical sand penetration experiment shows a layering-corium melt, crust, dry steam filled sand, heated wet sand and an unaffected zone. The dry zone is acting like a heat pipe with condensation taking place in the wet zone and aporation at the dry zone-wet zone interface.

The FRG engineers believe steam explosions are a very complicated function of at least temperature, thermal properties, geometry and mass ratio. A number of their ideas are:

a) The efficiency of the interaction is less than ten percent based on ideal shock tube tests as other geometries will be less. The SANDIA small scale tests showing 15% and higher are too idealistic.

b) Estimate work 50 to 60 ms after triggering to be 50 to 60% of the 10% available.

c) An increase of system pressure could suppress the explosion but good rapid mixing will override the pressure suppression effect (this is in contrast to Henry's hypothesis).

d) Theories are hard to validate and there are many reservations about models.

e) Extrapolation of results from less than 1 Kg to 1000 Kg yields conservative results because small experiments are more ideal for an efficient rapid interaction.

f) FRG will rely on the SANDIA large scale tests to confirm the conservatism resulting from extrapolation.

g) Rather than attempt to develop theories, it is believed to be better to use engineering judgment and get on with the job.

h) An estimate must be made of the maximum expected mass that might interact so that an estimate of the maximum loads on the RPV can be made.

i) Factors of importance are, contact mode, coherence of the reaction, mixing velocity, how reaction is triggered, superheat of melt, and volume ratios. One must focus on the pre-fragmentation phase and contact modes.

j) Preliminary estimates are that there will be 40 tons of melt and that 5 tons will interact.

Projects associated with containment hydrogen are as follows

1. Containment thermal hydraulics, Dr. Mayinger at TUH

2. Containment code including H_2 dispersing, Dr. Jahn at GRS Munich

3. Experimental studies of H_2 dispersion, Dr. Kanzlieter at Battele Frankfort

Presently the Germans do not believe that H_2 detonation is a problem. Rather, the combination of H_2 from a zirc-steam reaction plus a steel-steam reaction will almost always cause a containment overpressurization at some time due to a rapid burn. Their present modeling assumes the H_2 is uniformly mixed.

Experiments are underway to understand how a core melts. It is a complicated process due to the formation of eutectics that are dependent on the chemistry of Zr, U, O_2 and H_2O and heat up rate. When the heat up rate is less than 0.5°C/SCC the ZrO and UO_2 melts and if greater, the Zr clad melts first. The melt seems to run down between the pins and refreeze. This forms a plug that moves downward. Below the plus is clear. The steel and steam were noted to form a messy foamy material. The slump and refreeze will be a prime factor in determining the rate of delivery of molten material to the lower head. There is a chance that the melting and refreezing will go on until the core has melted down to the core support structure and allow a large amount of molten material to rapidly enter the lower head. It was noted by SANDIA that the resulting steam explosion might damage the steam generator tubing. The UO_2-ZrO mixture is less dense than molten steel. Penetration of the lower head will therefore most likely fail in the manner described by Mayinger-- failure at or near the upper surface of the molten UO_2-ZrO pool

The attack of the concrete during the early stages results in a great deal of gas being generated. This makes the early period modeling very important. The molten steel will be below the UO_2-ZrO and will probably quickly freeze. The question then becomes how fast does a steel plug heated from above penetrate concrete. It is not clear that the answer to this question will come from any of the research programs as they are now structured.

The German containment has no coolers and is dry until the molten core penetrates the shield wall and allows the sump water to leak in. The lack of coolers makes life difficult yet the Germans will not consider vented containment.

A series of codes for class IX accidents have been put together in a single package called KESS. It is composed of

MELSIM:- a sophisticated core melt code

KAUHZ: a simple single pin slumping model

LUECKE: a detailed evaporation model for heat removed from core fragments

RAUHZ: heat up of melt in dry part of RPV

KAVERN: concrete penetration code

COCO: containment codes

There are additional codes that complete the KESS code system. A workshop for its use will be scheduled for late summer at KfK.