INTERIM REPORT

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I. Steam Explosions

The small scale experiments are continuing. The second single droplet test series using iron-oxide droplets in water was completed. The purpose of this series was to determine the threshold trigger pressure necessary to initiate an explosion for a given set of initial conditions; i.e. water at 20°C and iron-oxide drop ($FeO_{1.3}$) at 2000°C with a diameter of ∿3 mm dropped from a height of 15-20 mm. Results indicated that a trigger pressure in the range of 0.3-0.5 MPa is needed to initiate an explosion. At pressures less than 0.3 MPa the droplet film boiling behavior changes with undulations being induced, but no explosion. Between 0.3-0.5 MPa, these induced undulations become more intense and an explosion occurs a few milliseconds after trigger firing. As the trigger pressure increases further, the delay decreases and the explosion becomes more energetic until at P_{trig} ∿1.5-2.0 MPa, the explosion is prompt and resembles the results of the published experiments 11-1-1 and 11-2-1. Another accomplishment this month has been the construction and testing of the high ambient pressure chamber for single droplets tests. The chamber is designed for pressures in the range of 1 MPa and check out and testing will begin in July. Finally debris analysis is continuing. The explosions consistently produce debris with mean particle diameters of 100 μm or less.

The third FITS experiment (FITS3A) was conducted on June 25, 1980. This experiment used a 5.5 kg melt mass of Fe-$A_{\ /3}$ dropped into 226 kg of water at 23°C. A spontaneous propagating explosion was observed in this experiment very similar to the exo-FITS tests. Fragments generated during the explosion penetrated one of the pressure relief diaphragms and caused early venting of the chamber. Data from eight pressure transducers, one thermocouple and two melt velocity sensors are now being reduced. Fuel debris generated by the explosion was extremely fine, and sieve analysis is now being performed.

This month analysis efforts have been addressing three areas:

(1) Obtaining consistent meltdown calculations for the Zion nuclear station using the MARCH code.

(2) Modelling the FITS experiments and the full scale reactor using the 1-D transient mechanistic explosion model and a 2-D empirical explosion model.

(3) Analyzing the small scale experiments.

The meltdown calculations performed using the MARCH code at Sandia for the Zion reactor do not agree completely with those published in the ZIP study. The input conditions are identical yet the meltdown timing differs. We do not understand the discrepancy at this time. Also it was hoped that the MARCH calculations could give some insight into the vessel geometry at the time of fuel-coolant

contact for an in-vessel steam explosion. The code predicts rapid radial meltout compared to axial penetration, which would tend to support the view of fuel-coolant contact via core barrel failure. However, because we do not yet know the details of the models it is not clear if this result is physically reasonable.

Analysis of the FITS experiments using the 1-D transient model is continuing. Also an empirical explosion model was incorporated into the hydrodynamics code CSQ to perform a two-dimensional calculation of the explosion in FITS. These same models are being used to assess the early time explosion behavior in the full scale reactor and the late time expansion. In trying to interpret the SIMMER results as published in the ZIP study (NUREG/CR-1411) we found that the steam explosion work potential estimate (~3400 MJ) is essentially equivalent to the work derived from a Hicks-Menzies calculation (i.e. maximum theoretical limit ~5000 MJ). This estimate is based upon the assumption of a fuel-to-coolant mass ratio of ~16 and a liquid slug composed of fuel. We feel that this work potential is very conservative for three reasons.

(1) The mass ratio assumed in the calculation may be too fuel-rich and it neglects any entrainment based on experiments and our analysis and it neglects any entrainment of water which would reduce the work potential.

(2) The large numerical mesh cells used in the calculation may artificially enhance the fuel-steam heat transfer during the expansion resulting in a high estimate of work potential. Also, the fuel-coolant heat transfer rate model has not been shown to be applicable to LWR materials.

(3) Prototypic experiments at Sandia using Corium A+R have demonstrated that the explosion conversion ratio ($\leq$ 0.1%) may be much lower than that for iron-alumina (~1-2%). Los Alamos assumed ~8.5% for the ZIP study.

Work is continuing in these areas.

II. Core-Concrete Interactions

CORCON development activities continued in several areas. As discussed last month, the Newton-Raphson interation in subroutine ENRCON (to determine each new layer temperature, knowing layer mass and enthalpy) can fail if the layer is near the freezing point of one of its constituents because the heat of fusion makes h(T) discontinuous. A simple bisection backup was coded, tested, and incorporated into CORCON during June.

Additional modifications incorporated into CORCON this month include the revised melt/gas-phase chemical equilibrium solution technique described last month, and several other miscellaneous modelling corrections and changes (including modifications to the plotting routines). The resulting improved form of the initial version, CORCON-MOD0$^+$, is now operational. A new permanent file and backup

tape of this version were created during June.

For expediency, heat transfer coefficients describing the heat fluxes within pool layers (from interior to periphery) were specified as constants in CORCON-MOD0 (bulk-to-layer interface constants input and bulk-to-gas film constants hardwired). To relax this restriction and provide more realistic modelling of the pool heat transfer, expressions for the heat transfer coefficients recommended by F. G. Blottner have been coded, incorporated into CORCON, and given limited testing. These relations describe the enhanced heat transfer caused by bubble injection and agitation within the melt over that due to natural convection in the limit as the injected gas flow approaches zero. While some changes in temperatures and heat fluxes occurred, no large changes from previous results have been observed.

Toward the end of the month, work was begun on activating the coolant layer option in CORCON. Because the basic bookkeeping and much of the actual coding already exist, major efforts will be evaluation and incorporation into the code of (1) material properties and (2) heat transfer coefficients for the coolant. The former was approximately 1/3 completed during the month, the latter will be addressed in July.

The code comparison test analysis effort continued during June. The initial test conditions supplied by Dana Powers were somewhat in error and minor corrections are being made on a continuing basis. Therefore, although CORCON-MOD0+ has completed the calculation of the test behavior the final predictions will not be completed until all the errors in initial conditions have been corrected and experimental uncertainties identified. At present, CORCON predicts that for test CC-1, the melt cools to approximately 1850K by the end of the test with a downward erosion of $\sim$7 cm. INTER calculations for the same conditions predict final temperatures of 1700K with downward erosion being about 2 cm.

Work continued on the development of a decay heat generation model for inclusion in CORCON. The SANDIA-ORIGEN code was used to obtain decay power and mass concentrations of the energetic elements for a 20 day period following shutdown. The core condition was conservatively assumed to be that which would yield the maximum expected decay heat generation. The energetic elements have been divided into four groups according to their chemical nature. An aerosol generation model will be included to describe the temporal mass depletion of these groups from the melt.

A Sandia memo providing brief descriptions of the 15 German computer codes obtained by Mr. Vernon Badham, UCLA, in May, was written and distributed. A magnetic tape containing the source, update, and data files for these codes (35 files) has been written, validated on the CDC7600 and mailed along with supporting documentation to UCLA. Requests for the German codes are being referred to Dr. I. Catton, UCLA.

III. Separate Effects Tests for TRAP Code Development

The purpose of the separate effects tests is to identify the vapor species existing in steam environments which contain fission product elements and measure the required physical properties.

Transpiration experiments at New Mexico Tech: These experiments were to measure the vapor pressure of CsOH. The quality and quantity of experiments have not been satisfactory to data. Consequently, the contract has been cancelled and work will be performed in-house. In July, transpiration experiments will be started at Sandia using the CsI transpiration apparatus.

Transpiration experiments at Sandia: Scoping experiments have been run to determine at what temperature tellurium is evolved from stainless steel and nickel surface. Tellurium reacts with these metals above 400°C to give a surface telluride layer. Previously it was noted that temperatures ~850°C were required in order that the metal telluride layer dissociate to give tellurium vapor (equation A).

$$MTe \rightarrow M + 1/2\ Te_2 \qquad \text{(Eqn. A)}$$

These temperatures were also needed when water vapor was present in the gas stream, thus metathetical reactions that would produce H_2Te vapor (Eqn. B) do not seem to occur.

$$MTe + H_2O \rightarrow MO + H_2Te \qquad \text{(Eqn. B)}$$

In current experiments H_2 was added to the gas stream; its only observed effect was to lower the temperature at which tellurium was evolved from the telluride compounds (catalytic action?). However only elemental tellurium was evolved. No H_2Te was detected. This is puzzling in a chemical thermodynamics sense. The expected equation is

$$MTe + H_2 \rightarrow H_2Te + M \qquad \text{(Eqn. C)}$$

Based on the dissociation products only Equation A occurs but H_2 should have no effect if that is so. A possible explanation is that tellurium is present not as a metal telluride compound but as a mixed-oxide-telluride, MO_xTe_y, in which case the reaction might be (in unbalanced equation):

$$H_2 + MO_xTe_y \rightarrow M + H_2O + Te$$

These effects will be investigated further. In addition, quantitative data on the rate of tellurium evolution is to be obtained using a microbalance system. The effects of gas flow rate and gas composition are to be studied.

Interim laser system: Assembly of the interim laser cell is complete. During July, the laser alignment and monochromator response will be checked with preliminary experiments with CsI started soon thereafter.

Fission Product Reaction Facility: Remaining commercial orders have been placed for late July delivery. Components for the steam system have been moved into the spectrometer laboratory where initial check out of the system and the spectrometer equipment has begun. During July, check out and assembly of the system will continue.