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Simulation Experiments on the Radial Pool Growth in Gas-releasing Melting System*

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Following an HCDA, molten core-debris can contact the concrete foundation of the reactor building resulting in a molten UO_2/concrete interaction and considerable gas release.[1,2] The released gas can pressurize the containment building potentially leading to radiological releases. Furthermore, directional growth of the molten core-debris pool can reduce the reactor building structural integrity. To implement design changes that insure structural integrity, an understanding of the thermal-hydraulic and mass-transfer processes associated with such a growth is most desirable. Owing to the complex nature of the combined heat, mass, and hydrodynamic processes associated with the two-dimensional problem of gas release and melting, the downward[3] and radial penetration problems have been investigated separately. The present experimental study addresses the question of sideward penetration of the molten core debris into a gas-releasing, meltable, miscible solid.

In this study the molten core debris and concrete were simulated by aqueous solutions of potassium iodide of various densities and polyethylene glycol 1500 (a water soluble wax) laced with $NaHCO_3$, respectively. $NaHCO_3$ (sodium biocarbonate) was mixed at ratios of 5% and 10% by weight in the wax. The potassium iodide solution was made 1<u>N</u> acidic for reaction with the $NaHCO_3$ to release CO_2 gas. The test sample was cylindrical with diameter and height of 7.6 and 15.3 cm, respectively. The top of the test sample was insulated to

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eliminate melting along the top surface. The initial temperature of the solution was 65°C, 25°C above the melting point of the solid, which was kept constant throughout each run. The experiment was initiated by submerging the test sample in the preheated solution. Each quasi-steady experiment lasted for about 1 minute, and a total of 12,000 cc of solution was used in each run. This eliminated viscosity and density variations throughout each run. A time lag of 4 s was observed between the submerging and the initial gas release time.

The gas release and melting phenomena were observed to be a combined process. Gas release along the full length of the sample occurred at a uniform rate. The released gas along the vertical surface moved up in a periodic roll pattern. Along the exposed bottom surface the small gas bubbles conglomerated into a larger bubble. After overcoming surface tension and the drag force, this unstable bubble was released to the top of the liquid pool. This process occurred periodically. When the liquid pool density was lighter than the melt, only the melt formed along the bottom surface flowed to the bottom of the tank. The large gas bubbles that were observed when $\rho^* > 1$ (ρ^* is the ratio of pool density to the melt density) were no longer present.

In a non-gas-releasing melting system,[4] when $\rho^* > 1$ the melt flow was directed upward with a curvature appearing near the bottom of the solid sample. A similar effect but in reverse occurred when $\rho^* < 1$. In either case the melt layer flow controlled the melting heat transfer and the melting rate in a non-gas-releasing melting system.. At $\rho^* \approx 1$, the formed melt was more or less stagnant; the convection currents within the liquid pool controlled the melting rate. In a gas-releasing melting system on the other hand, there existed two separate flows adjacent to the solid wall: (1) flow of the melt layer and (2) a foamy gas flow which was always directed upward owing to its very small density, compared to its surrounding liquid. When $\rho^* > 1$, the melt film and the gas layer had an upward parallel-flow arrangement, with gas flow enhancing the flow of the melt film. For a fixed gas-release capability of the solid, increase in the melting rate is very small as ρ^* increases above 1.05 (see Fig. 1). Larger gas-release capability of the solid, although contributing to a higher melting rate, portrays a similar melting rate increase. For large ρ^* the liquid pool density has almost no effect on the melt rate. This leads to the postulation that gas release rate controls the melting rate.

When $\rho^* < 1$, the gas layer flows upward, whereas the melt film flows downward. At the interface of these two counterflow currents, Helmholtz instability sets in. Such instability results in entrainment of melt into the gas film and vice versa, thus increasing the melt removal rate, and hence the melting rate, (see Fig. 1). The melting rate versus ρ^* for a non-gas-releasing melting system is also given on Fig. 1 which lies above the 5% gas-releasing data for density ratios in the range of $\rho^* > 1.05$. This could be attributed to the partial insulating effect of the gas film.

In view of the above findings, it could be surmised that when concrete walls of the reactor cavity are attacked by molten UO_2, the density difference between the molten UO_2 and concrete is not as important a factor on melting rate as is the gas-release rate from concrete. In fact the greater the gas content in concrete, the greater is the radial penetration rate.

References:

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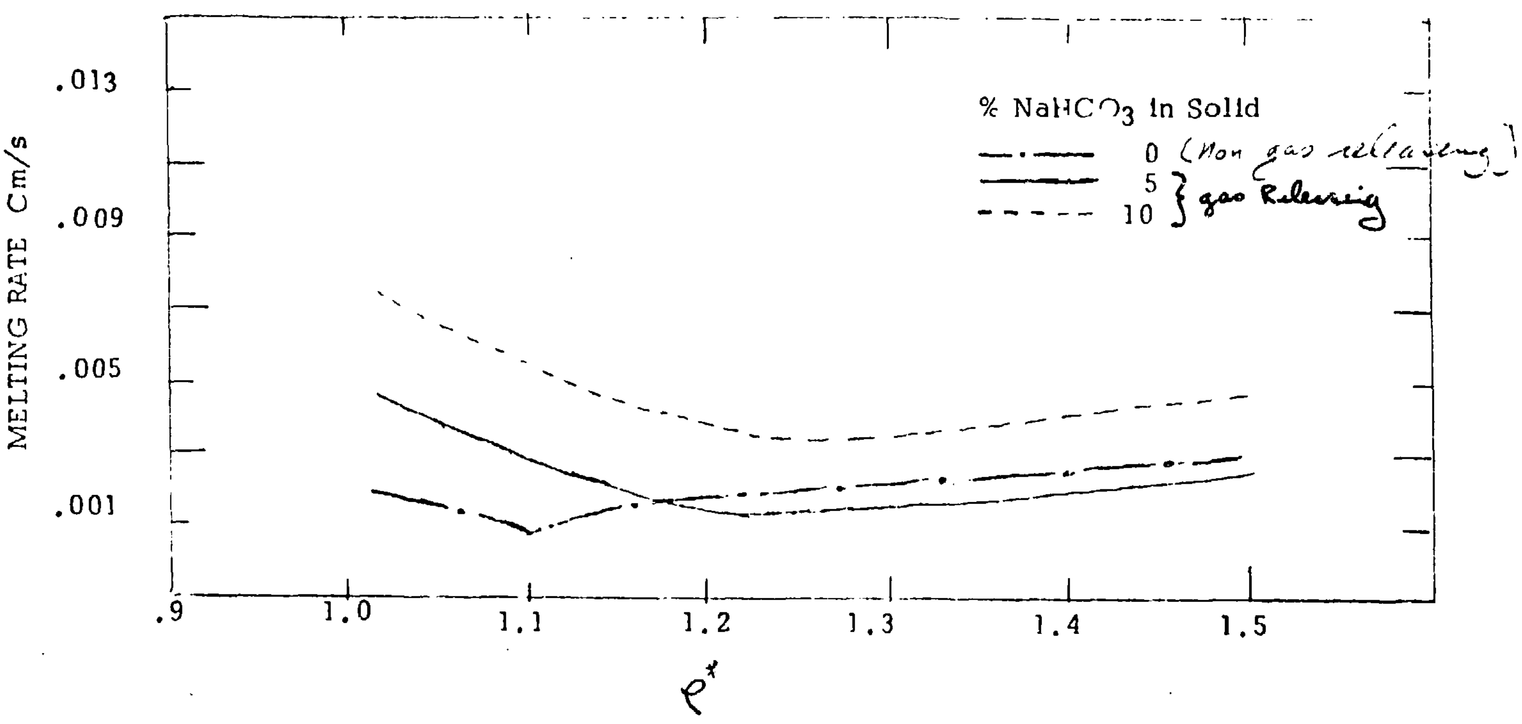

Fig 1. Sideward Melting Rate as a Function of the Density Ratio, ρ^*.