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MEASUREMENTS AND ANALYSIS OF STEAM GENERATION RATE FROM QUENCHING OF SUPERHEATED DEBRIS BEDS*

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Light water reactor degraded core accident sequences have been postulated which lead to deposition of superheated debris beds in the reactor cavity [1]. The debris beds are assumed to be cooled by an overlying pool of cooling water. The quenching of the debris is predicted to pressurize the containment building as a result of the steam generated during the quench process. Mechanistic models of debris bed quenching are required to predict the containment pressurization response to the steam and to the gases released from the concrete.

Previous investigations [2, 3] of debris bed quenching with top flooding were conducted with beds of 3 mm spheres. Cho [2] concluded that while the pattern of water penetration into the beds is complex and spatially non-uniform, the overall rate of bed cooling is controlled by flooding near the top of the bed. Ginsberg [3], in agreement with Cho, showed that the quench process proceeds in two stages: initial penetration and final refill. Steam generation measurements showed that the heat transfer rate was constant throughout the entire process. The particle quench times suggested that the bed heat transfer rate was independent of initial bed temperature. A transient bed quench model "TRANSBED", the basis of which is a countercurrent flooding model, was proposed to characterize the entire quench process [3].

The objective of this paper is to present recent experimental data for the rate of steam generation resulting from cooling of superheated packed beds of

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spheres by a saturated overlying pool of water. The effects of bed temperature and of sphere diameter are discussed.

The experimental apparatus is shown schematically in Fig. 1. Steel spheres were preheated in a container positioned in the furnace. While in the oven, the particles rested on a sliding shutter. The test vessel shown in Fig. 1 is a Schedule 10 stainless steel pipe, 1.219 m long, 108.2 mm inside diameter, with a 3.05 mm wall thickness. The test section is instrumented with thermocouples which penetrate through the wall into the test container. Thermocouples are also mounted on the outer wall of the pipe. A turbine flow meter was used to monitor the flow of steam during the particle quench process. An experimental run was initiated after establishment of the desired sphere, water and test wall temperatures. At that time the shutter was retracted and the particles were dropped into the dry test vessel, where they formed a packed bed. After a short wait period, the water was released from a holding vessel onto the particle bed, thus initiating the quench process. Data acquisition continued until termination of boiling activity within the test vessel.

Figure 2 presents steam generation rate data traces obtained from the quench of beds of 3.18 mm and 6.35 mm diameter stainless steel spheres with water at the saturation temperature and at atmospheric pressure. The initial sphere temperature was 810K in both cases. Shown on the traces are the times t_d, obtained from the thermocouple data [4], that the initial penetration of water reached the bottom of the bed. The straight lines shown with the curves represent the steam generation rate equivalent to the heat flux computed using the Lipinski [5] countercurrent-limited flooding model. The 3.18 mm and 6.35 mm data indicate that the steam flowrate is reasonably constant throughout the entire quench period, except for the period of initial water/particle contact and the final approximately 30 seconds of the quench. For both particle diameters, the data suggest that approximately 40% of the initial bed stored energy was removed during the initial water penetration period.

The results substantiate the previous observations that the initial penetration of water leaves pockets of unquenched spheres [2] and that the steam generation rate is constant during both the initial penetration and final refill stages of the quench process [3]. Additional data with sphere temperatures between 533K and 977K indicate that the steam generation rate is independent of initial sphere temperature. This observation lends support to the conclusion that the quench process is limited by the rate of water supply to the dry regions of the bed. The reasonably good agreement with the Lipinski model, moreover, supports the contention that the steam generation from the debris bed quench process is limited by two-phase countercurrent flooding limitations for the particle bed sphere diameters of this experiment.

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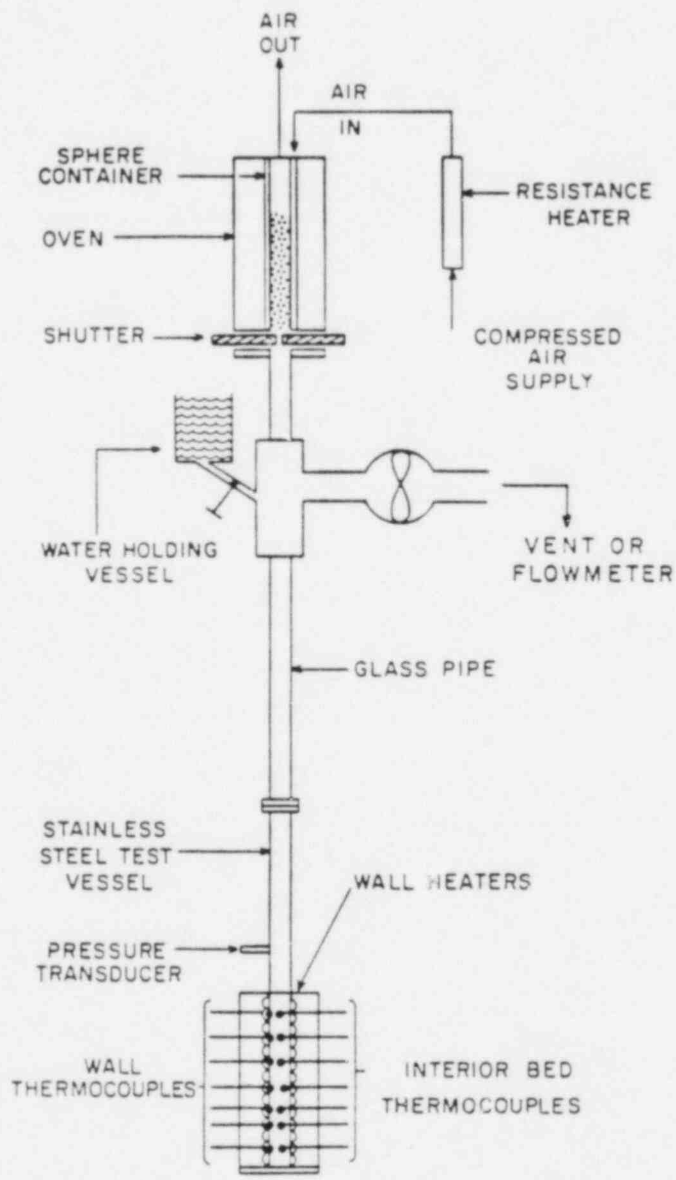

FIGURE 1 - Schematic Diagram of Particle Bed Quench Apparatus

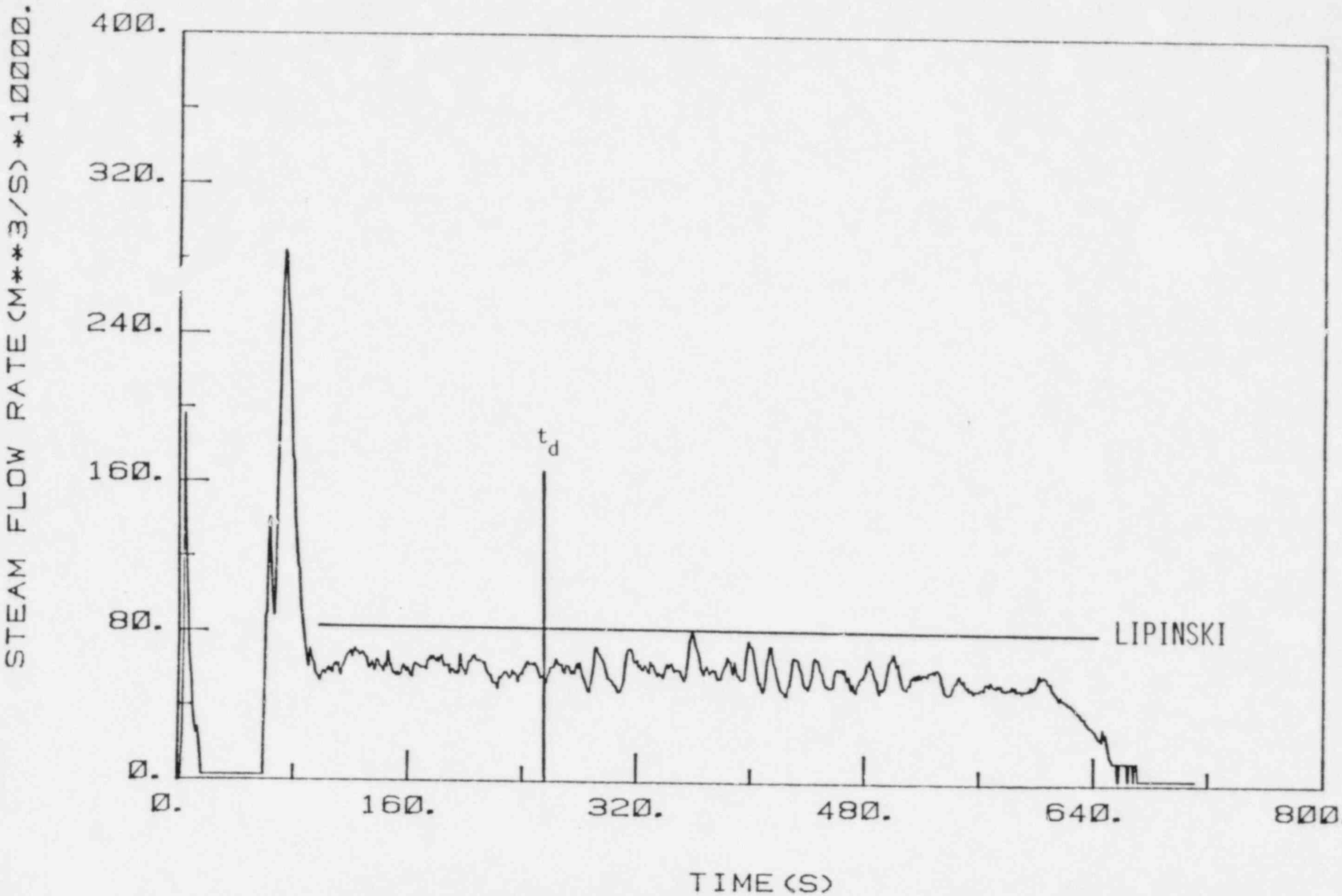

FIGURE 2(a) - Steam Flowrate Trace with Lipinski Prediction for 3.18 mm Sphere Bed, Porosity = 0.40

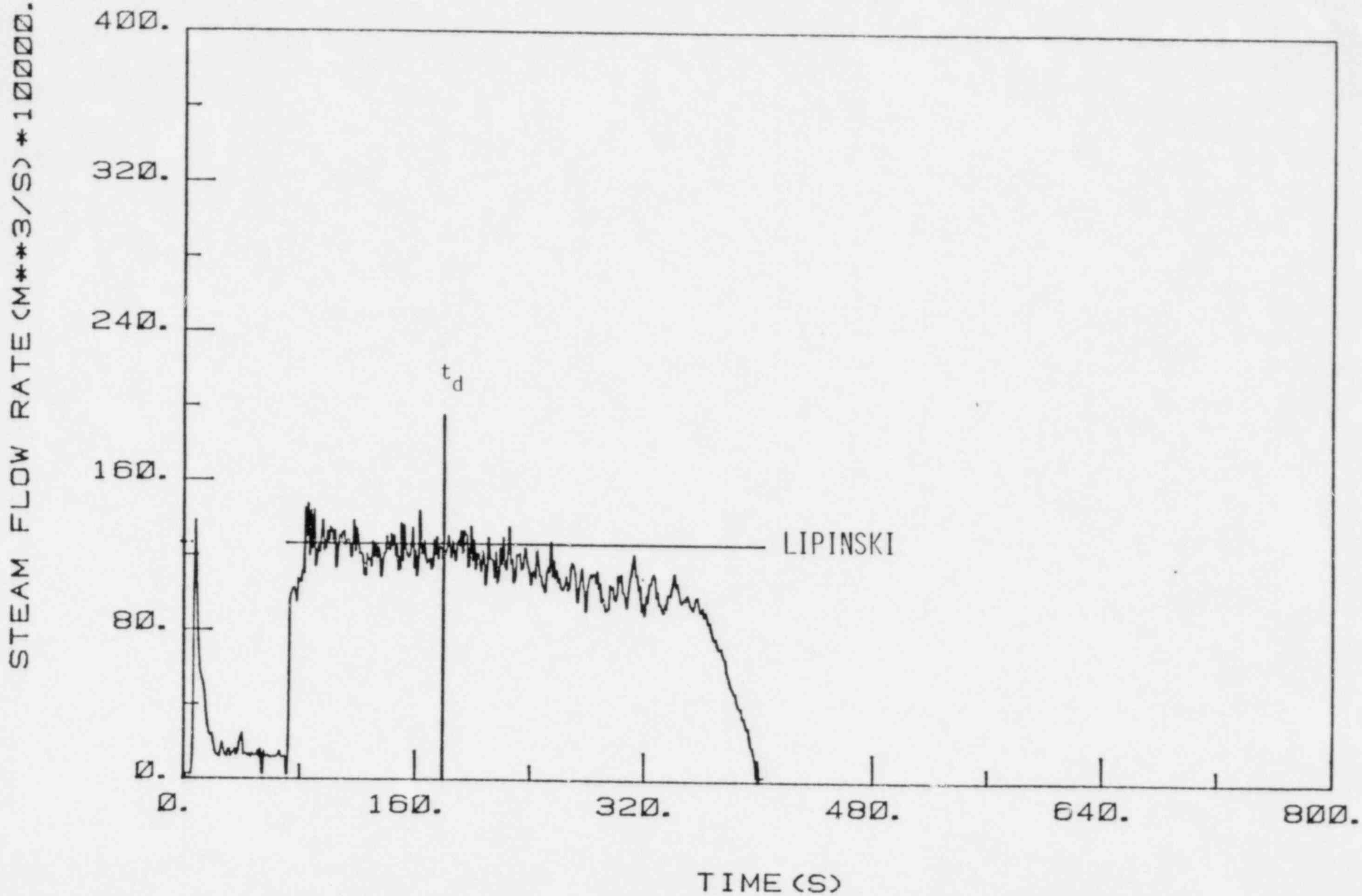

FIGURE 2(b) - Steam Flowrate Trace with Lipinski Prediction for 6.35 mm Sphere Bed, Porosity = 0.40