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EFFECT OF PRESSURE AND FLOW ON THE BWR ROD DROP ACCIDENT*

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Effect of Pressure and Flow on the BWR Rod Drop Accident

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The rod drop accident (RDA) is a design basis accident for boiling water reactors (BWRs). Thermal-hydraulic feedback and reactor scram play an important role in containing the accident should it occur. In the past, while the instantaneous Doppler feedback and reactor scram were taken into account in the analysis of the accident, the important moderator feedback due to steam voids and moderator (coolant) temperature has been traditionally neglected because this approach is conservative. The conservatism has been quantified by a recent study[1,2]. While the study did take into account the moderator feedback, it considered reactor core behavior under the assumption of constant pressure and flow. A recent reactivity initiated accident (RIA) test[3] conducted at the Idaho National Engineering Laboratory indicated that both the pressure and flow may change significantly during such an accident. Both of these variables will affect void formation, hence the moderator feedback. The point at issue in the present study is then whether the assumption of constant pressure and flow can overestimate the effect of the moderator feedback and hence cause an underprediction of the consequence of the accident.

We have made such an assessment using the plant transient code RELAP-3B[4] in conjunction with the core dynamics code BNL-TWIGL[5]. The method of analysis consists of an iteration in which the BNL-TWIGL power history drives the RELAP-3B calculation and the resultant time-dependent pressure and inlet flow are, in turn, used in the BNL-TWIGL core calculation. The iteration is continued until the power history converges.

The plant transient (RELAP-3B) model mocks up all the major components of the pressure vessel including the core. There are 10 nodes in the core to represent the average channel and another 10 nodes for the hot channel. The detailed representation of the core is essential to observe the local pressure and flow behavior in the accident.

The core dynamics (BNL-TWIGL) model mocks up the core in (R,Z) geometry with a fine-mesh grid for both the neutronics and thermal-hydraulics. However, the pressure is considered constant in space in this model.

Our objective was to see how large a change in moderator feedback would be observed if the pressure pulse was taken into account. Hence, the assumption of spatially constant pressure was circumvented by using a conservative approach: the hot spot (rather than the core average) pressure response from RELAP-3B was used as the reference pressure in BNL-TWIGL. In addition, the case chosen to be calculated was for a high worth rod in which the effect of moderator feedback was the largest of any considered in the original study.[2] This was also expected to maximize the effect of varying pressure.

The reactor was initially at hot zero power conditions with no inlet subcooling. The rod dropped at 1.5 m/s and was worth 2.1% $\Delta k/k$. The resulting inlet flow and hot spot pressure are shown in Figure 1. It is important

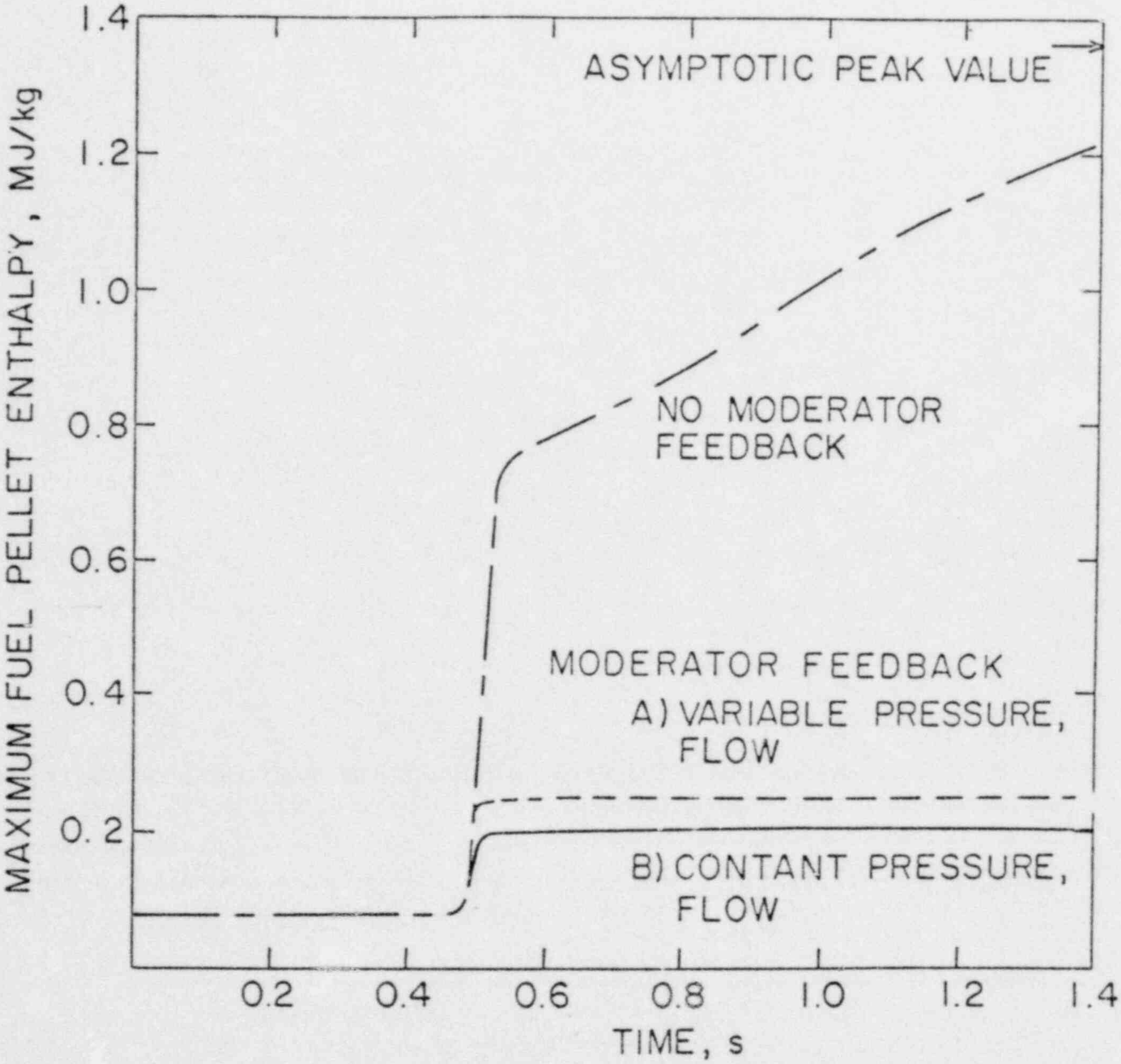

Figure 2. Maximum Fuel Enthalpy with Different Assumptions

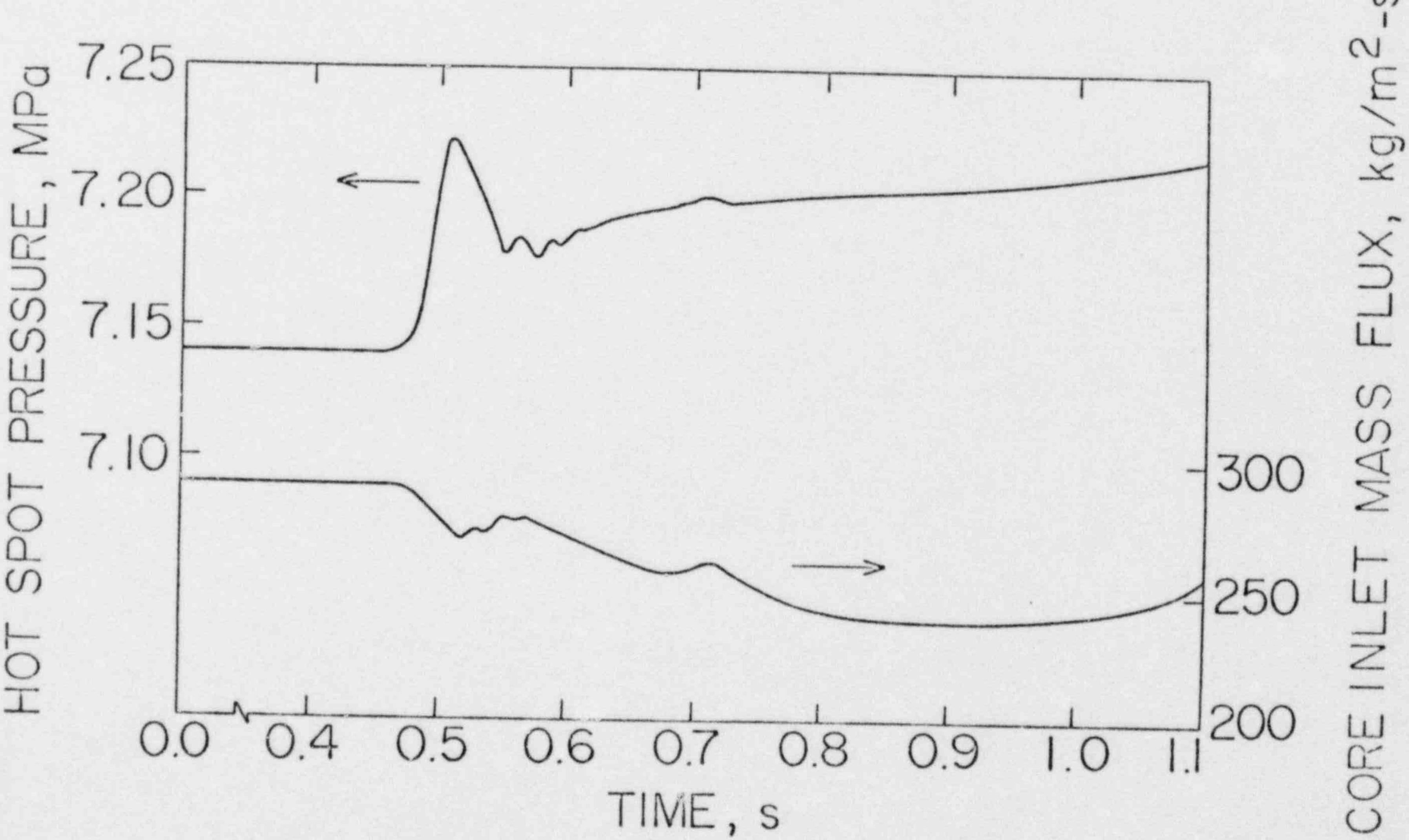

Figure 1. Core Inlet Mass Flux and Hot Spot Pressure

to note that the inlet flow tends to decrease when the pressure increases. This is inherent in a BWR and was also observed in the recent RIA test.[3] While the increasing pressure tends to inhibit void generation, the decreasing flow tends to encourage void formation. The net effect will depend on the relative magnitude of these two factors.

The resulting maximum fuel enthalpy (radially averaged across the pellet) is shown in Figure 2 along with the results obtained assuming that pressure and flow do not vary in time with and without moderator feedback. Taking into account moderator feedback but assuming constant pressure and flow reduced the peak fuel enthalpy during the transient from 1.36 MJ/kg (330 cal/g) to 0.21 MJ/kg (50 cal/g). The corresponding reduction in peak core power was from 80 GW to 16 GW. When the effect of changing pressure and flow is taken into account, as described above, the peak fuel enthalpy becomes 0.26 MJ/kg (62 cal/g) and the peak power 27 GW.

In summary we have calculated the presssure rise and inlet flow variation during a rod drop accident. The results show that the effect of these parameters tends to increase the calculated peak fuel enthalpy. Nevertheless, it is clear that the moderator feedback still has a strong inherent mitigating effect on the transient, and the effect of pressure and flow on the RDA is, in this sense, of second order.

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