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EFFECT OF THERMAL-HYDRAULIC FEEDBACK ON THE BWR ROD DROP ACCIDENT*

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* Work performed under the auspices of the U. S. Nuclear Regulatory Commission.

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An important design-basis accident for boiling water reactors (BWR's) is the rod drop accident (RDA). This accident is defined[1] to be a rapid reactor transient caused by an accidental drop (out of the core) of the highest-worth control rod at various conditions ranging from cold start-up to about 10% of rated power. For most BWR designs the highest worth rod is normally situated at the center of the core. Despite the fact that the chance of a RDA is extremely unlikely, the consequence of the RDA is of concern because of the potential for damage to fuel rods.

Historically, the unavailability of a realistic multi-dimensional reactor dynamic code has necessitated the use of approximate models such as point kinetics or the adiabatic approximation together with a simple feedback model. The simple feedback model usually takes into account Doppler feedback and reactor scram but neglects moderator feedback due to void and moderator temperature under the assumption that this approach is conservative.

Neglecting moderator feedback during the RDA is a poor assumption because energy is deposited in the fuel over a 3 to 4 second time period and hence there is time for heat to be conducted to the coolant. This may tend to ameliorate the accident considerably. Evaluation of the thermal-hydraulic feedback effect on the RDA in a BWR has been scarce in the literature. The object of this paper is to demonstrate the beneficial effect of thermal-hydraulic feedback in the RDA.

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The analysis was done with BNL-TWIGL[2], a two-energy group, two-dimensional (R, Z) reactor dynamics code taking into account all thermal-hydraulic feedback and control rod movement. Six delayed neutron precursor groups are considered. Thermal-hydraulic effects are calculated with a one-dimensional two-phase flow model in conjunction with a one-dimensional heat conduction model in parallel channels.

The case studied was a center rod drop accident in a BWR/4 at 10% power at beginning-of-life conditions. The control rod distribution was an in-sequence rod pattern to be expected in normal operation at 10% power. The resultant center rod worth was 0.8% $\Delta k/k$ and the average axial power shape was bottom-peaked with a peaking factor of 1.45. The rod velocity was 1.524 m/s (5 ft/s) and the scram velocity was 0.914 m/s (3 ft/s). Reactor scram was initiated by a 120% overpower trip with a scram delay time of 0.2 s.

The accident was calculated up to four seconds with and without moderator feedback. The case without moderator feedback was run with both void and moderator temperature held fixed at their initial steady-state values.

The results of the calculations are presented in Figure 1 for the transient power behavior and in Figure 2 for the peak fuel enthalpy. The dramatic effect of moderator feedback during the accident is clearly seen. Reactor scram was never initiated throughout the accident when moderator feedback was included since the reactor power never reached 120% of rated. In both cases the reactor power reached its peak at the time (2.4s) the rod moved fully out of the core. In the case without moderator feedback during the transient, reactor scram did occur and helped terminate the accident. The peak fuel enthalpy reached 73 cal/gm for the case without moderator feedback; whereas, it was only 42 cal/gm if the moderator feedback was included during the accident.

In conclusion, moderator feedback during the rod drop accident has a great mitigating effect on the consequence of the RDA and should be taken into account in the analysis of the RDA in BWR's.

REFERENCES

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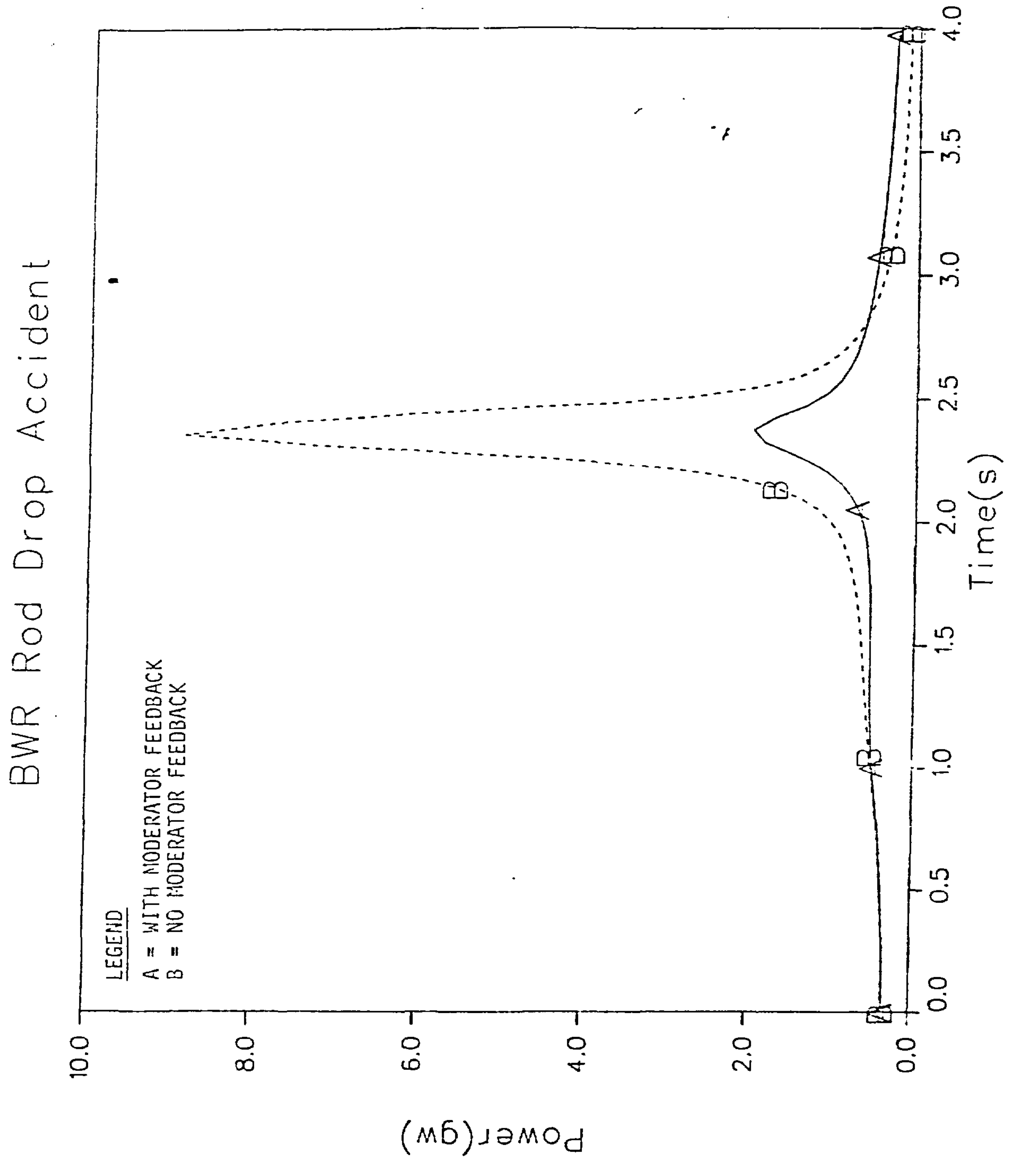

Figure 1 Transient behavior of reactor power