PDR

BNL-NUREG-30722

Paper Submitted to the 1982 Annual Meeting of the
American Nuclear Society, Los Angeles, California,
June 6 - June 11, 1982

RECEIVED
FEB 8 1982
US NUCLEAR REGULATORY COMMISSION
DOCUMENT MANAGEMENT BR
TIDC

Effects of Subcooling and Rod Drop Speed on the BWR Rod Drop Accident

D. Cokinos, J. Carew, and A. Aronson

BROOKHAVEN NATIONAL LABORATORY
Department of Nuclear Energy
Upton, New York 11973

January 1982

NRC Research and/or Technical Assistance Report

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

8202160042 820131
PDR RES
PDR

The techniques and models used in the analysis of the control rod drop accident (CRDA) in a BWR have ranged from approximate conservative methods with a simple feedback model[1] to detailed representations of the thermal-hydraulic and neutronic mechanisms[2]. In a recent paper Cheng and Diamond[3] presented a detailed evaluation of the CRDA and the effects of varying a number of important accident parameters. Their calculations performed with the BNL-TWIGL[4] core dynamics code, have shown that the effect of inlet subcooling and rod drop speed play an important role in determining the severity of the rod drop accident. The purpose of the work summarized in this paper has been to determine in detail the dependence of the rod drop accident parameters on the (a) inlet subcooling and (b) rod drop speed.

Knowledge of the effects of increased inlet subcooling is of interest since, during the approach to a hot standby condition from cold critical, a BWR core may be highly subcooled. On the other hand, an increase in the speed of the dropped rod will result in a faster transient and lead to higher peak power and peak fuel enthalpy. A quantitive evaluation of these effects is necessary in establishing the severity of the CRDA.

Using the Cheng and Diamond BWR-4 model at hot zero power (HZP) conditions a set of BNL-TWIGL CRDA calculations has been carried out for inlet subcoolings ranging from saturation to 100°F for the case of a 5 ft/sec rod speed. In all cases moderator feedback was included and the dropped rod was taken to be the center rod with a static rod worth of $\sim 2\%\ \Delta k/k$. The core power response to this $\sim 2\ \Delta k/k$ rod worth at HZP is a large rapid power excursion at 0.5 sec. which, in this case, is immediately terminated by Doppler and/or void feedback. In Fig. 1 the transient behavior of the reactivity components at saturation and at 50°F inlet subcooling are presented.

The void, and to a lesser degree the Doppler reactivity can be seen to increase rapidly at ~0.5 sec. in order to reverse the rising power in the saturated case. However, in the 50°F subcooled case, the power rise is reversed almost entirely by the much stronger Doppler reactivity with the void reactivity being almost inconsequential in the mitigation of the accident due to the subcooled state of the core.

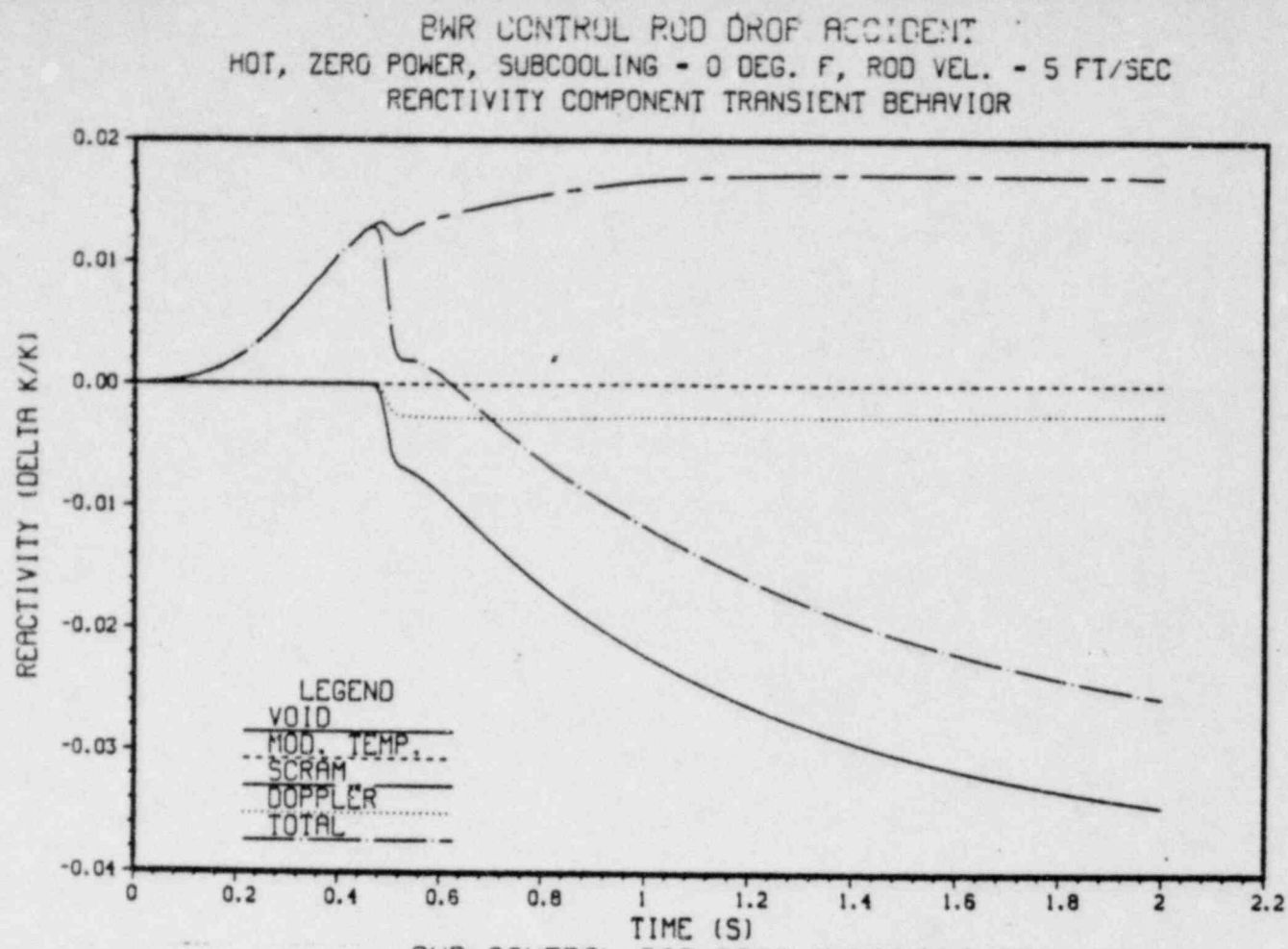
The variation of the peak fuel enthalpy and power as a function of subcooling is given in Fig. 2. The rapid rise in both these parameters, in the range between saturation and an inlet subcooling of 20°F is due to the decrease in the void feedback with the Doppler feedback becoming the dominant mechanism for limiting the power excursion as subcooling increases. It is important to note that in all cases the CRDA peak fuel enthalpy is well below the 280 cal/gm criterion.

In order to evaluate the effect of the rod drop speed on the CRDA peak fuel enthalpy and power BNL-TWIGL calculations were also performed with an increased rod drop speed of 15 ft/sec at saturation and an inlet subcooling of 20°F. It should be noted that a rod drop speed of 15 ft/sec is more than four times the average measured speed and represents an extreme case. Increasing the rod drop speed from 5 ft/sec to 15 ft/sec resulted in an ~140% increase in power for both the saturated and the 20°F subcooled cases. The corresponding increase in peak fuel enthalpy is ~30% and ~22%, respectively, for the two cases.

In summary, the dependence of the CRDA peak power and fuel enthalpy on the core inlet subcooling and rod drop speed have been determined. Both the peak power and fuel enthalpy are found to increase rapidly as a function of subcooling up to a subcooling of $\sim$20°F and are relatively insensitive at higher subcoolings. The peak fuel enthalpy increased by $\gtrsim$30% as the rod speed was increased from 5 ft/sec to 15 ft. sec. In all cases the peak fuel enthalpy was well below the 280 cal/gm fuel criterion.

References

1. R.C. Stirn, et.al., "Rod Drop Accident Analysis for Large Boiling Water Reactors," NEDO-10527, General Electric Co., (1972), also Supplement 1 (1972) and Supplement 2 (1973).
2. H.S. Cheng and D.J. Diamond, "Thermal Hydraulic Effects on Center Rod Drop Accidents in a Boiling Water Reactor," BNL-NUREG-27544, Brookhaven National Laboratory, 1980.
3. H.S. Cheng and D.J. Diamond, "Analyzing the Rod Drop Accident in a Boiling Water Reactor" Nucl. Technol. 56, 40 (1982).
4. D.J. Diamond, "BNL-TWIGL, A Program for Calculating Rapid LWR Core Transients" BNL-NUREG-21925, Brookhaven National Laboratroy (1976).



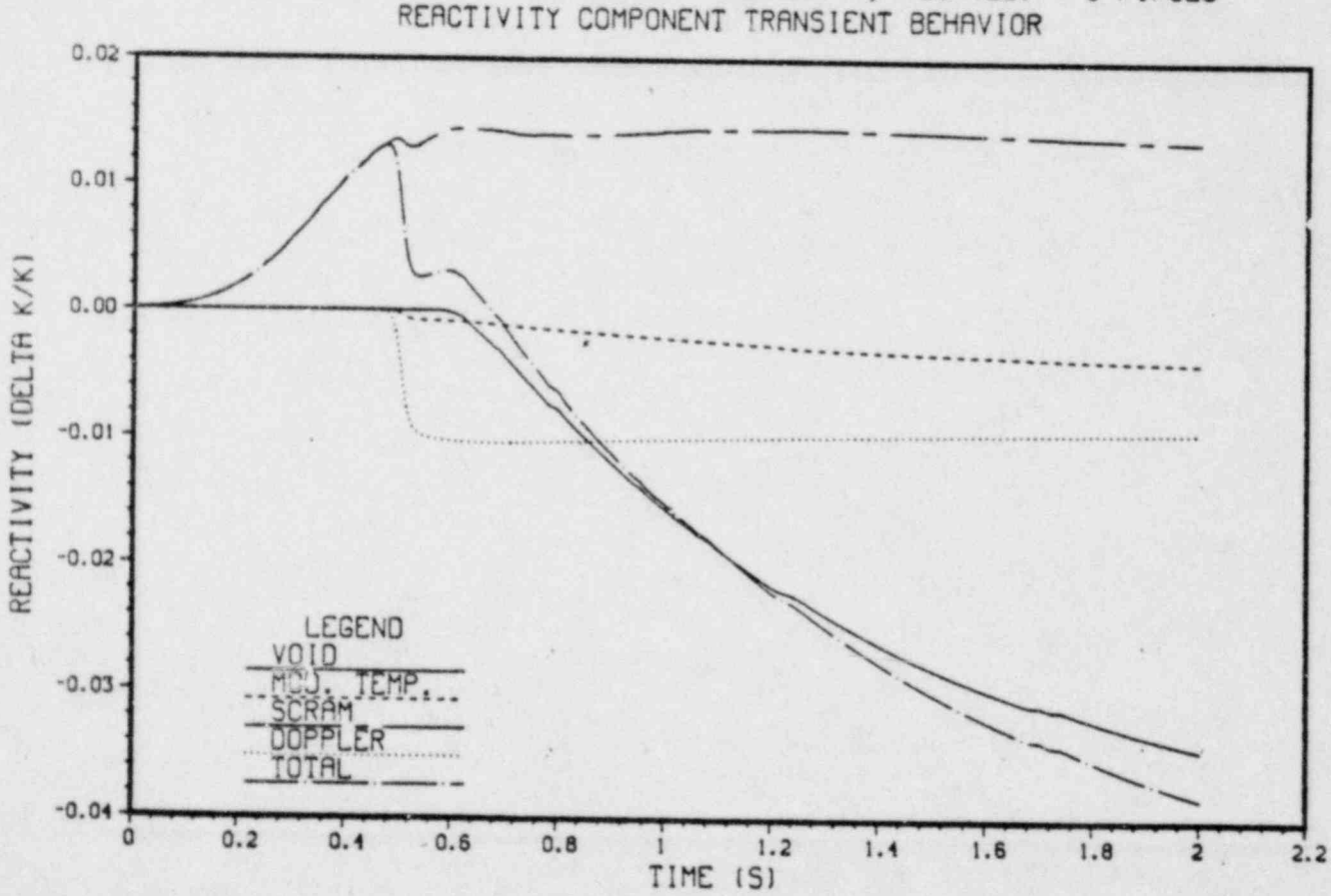


Fig. 1 Transient Behavior of the CRDA Reactivity Components at Saturation and at an Inlet Subcooling of 50°F

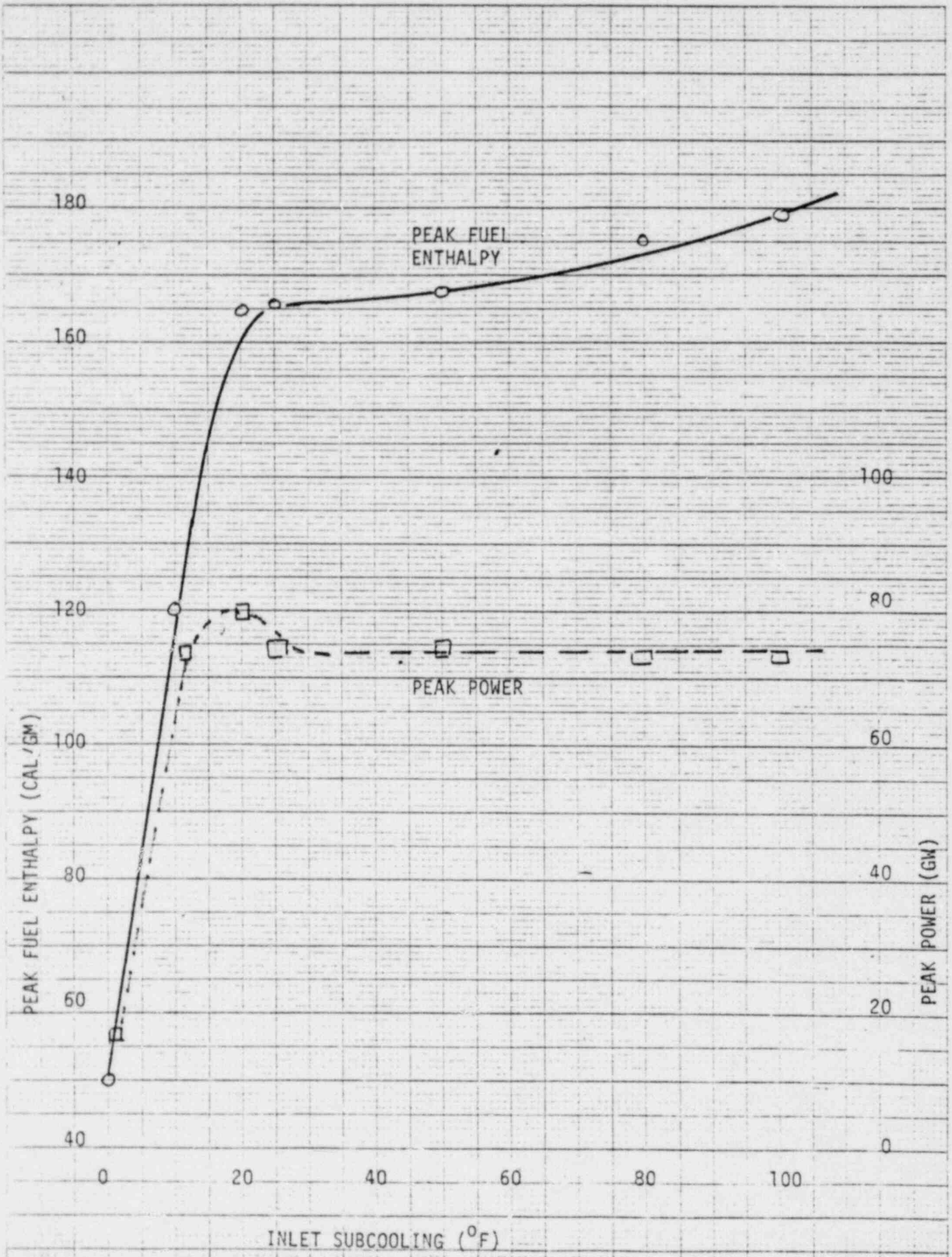


Figure 2 - Peak Fuel Enthalpy and Peak Power As A Function of Inlet Subcooling