

BNL-NUREG--32108

DE83 002825

BNL-NUREG-32108

Conf-830304-3

Paper Submitted to the Mathematics and Computation Division

Topical Meeting of the American Nuclear Society

Salt Lake City

March 28-31, 1983

Two-Dimensional Dynamic Analysis of a BWR Rod-Drop Accident

D. Cokinos and J. Carew

BROOKHAVEN NATIONAL LABORATORY
Department of Nuclear Energy
September 1982

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

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER

JHP
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

The work summarized in this paper is part of BNL's on-going effort to study a wide variety of core and reactor safety problems. To meet this goal BNL uses large computer codes capable of simulating normal and abnormal reactor behavior. This paper presents and discusses recent results on the behavior and dynamic response of a BWR core during a control rod drop accident (CRDA). The work focuses on two important aspects of the BWR CRDA: inlet subcooling and speed of the dropped rod. These parameters play a major role on the severity of the CRDA.

The techniques and models used in the study of rapid reactivity insertion in a BWR have ranged from approximate conservative methods with simple feedback models¹ to detailed representations of coupled neutronic thermal-hydraulic mechanisms.² An up-to-date overview of computer codes which model core behavior under steady state and accident or operational transient conditions has been recently presented by Diamond³. A detailed evaluation of the CRDA has been recently presented by Cheng and Diamond⁴. Their calculations have shown that the effect of inlet subcooling and rod drop speed may 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 manner in which the rod drop accident parameters are affected by the inlet subcooling and 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 quantitative evaluation of these effects is necessary in establishing the severity of the CRDA.

The BNL-TWIGL⁵ code used in our analysis solves the time dependent neutron diffusion equation in two dimensions (R-Z geometry) with two energy groups and six delayed neutron precursor groups simultaneously with time-dependent thermal-hydraulic equations. The transient discussed here is initiated by simulating control rod movement for a given inlet temperature.

A set of BNL-TWIGL calculations has been carried out for inlet subcoolings in the range from saturation to 100°F using a BWR-4 model at hot zero power (HWP) conditions. Moderator feedback was included in all cases. The rod was "dropped" in the center of the core where its static worth was $\sim 2\%$ $\Delta k/k$. The rod drop speed was 5 ft/sec.

A reactivity insertion of this magnitude at HZP produces a large power excursion. Based on the thermal-hydraulic model in BNL-TWIGL, the core thermal power rises rapidly to a peak value of ~ 16 GW for the saturated case and to ~ 72 GW for the case with an inlet subcooling of 80°F , as shown in Figure 1. The rise in the power is reversed at ~ 0.5 sec. by the combined effects of the void and Doppler feedback. Figure 2 shows the transient behavior of the reactivity components at saturation and at an inlet subcooling of 80°F . 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 80°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. 3. 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.

BNL-TWIGL calculations were also performed with an increased rod drop speed of 15 ft/sec at saturation and at an inlet subcooling of 20°F . For both the saturated and the 20°F subcooled cases the increase in the rod drop speed from 5 ft/sec to 15 ft/sec resulted in an increase of $\sim 140\%$ in power. The peak fuel enthalpy increased by $\sim 30\%$ and $\sim 22\%$, respectively, for the two cases.

In conclusion, BNL-TWIGL has enabled us to determine the dependence of the CRDA peak power and fuel enthalpy on the core inlet subcooling and rod drop speed. The results show that the peak power and fuel enthalpy increase rapidly with inlet subcooling up to a subcooling of $\sim 20^\circ\text{F}$ and become relatively insensitive at higher subcoolings. Furthermore, as the rod drop speed is increased, the calculations show that the peak fuel enthalpy increases by $\lesssim 30\%$. It must be pointed out that in all cases studied the peak fuel enthalpy was found to be well below the 280 cal/gm 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), 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. D.J. Diamond, "Light Water Reactor Coupled Neutronic and Thermal-Hydraulic Codes" NUREG/CP-0034, 2, 736 Proceedings of the Topical Meeting on Advances in Reactor Physics and Core Thermal Hydraulics, Kiamesha Lake, NY, September 22-24, 1982.
4. H.S. Cheng and D.J. Diamond, "Analyzing the Rod Drop Accident in a Boiling Water Reactor" Nucl. Technol. 56, 40 (1982).
5. D.J. Diamond, "BNL-TWIGL, A Program for Calculating Rapid LWR Core Transients" BNL-NUREG-21925, Brookhaven National Laboratory (1976).

BWR CONTROL ROD DROP ACCIDENT
HOT, ZERO POWER, SUBCOOLING = 0; 80 °F, ROD VEL. = 5 FT/SEC
CORE THERMAL POWER TRANSIENT BEHAVIOR

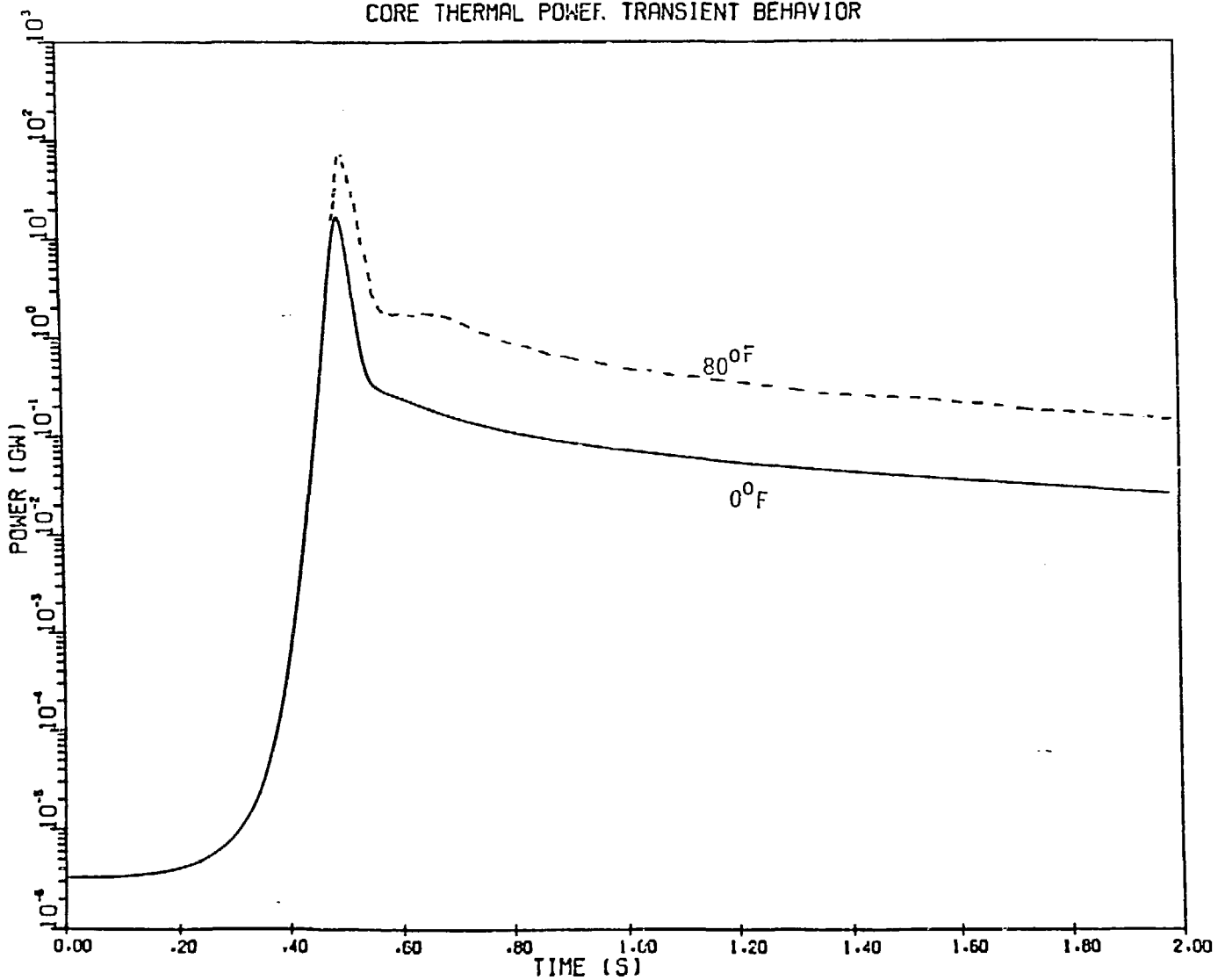
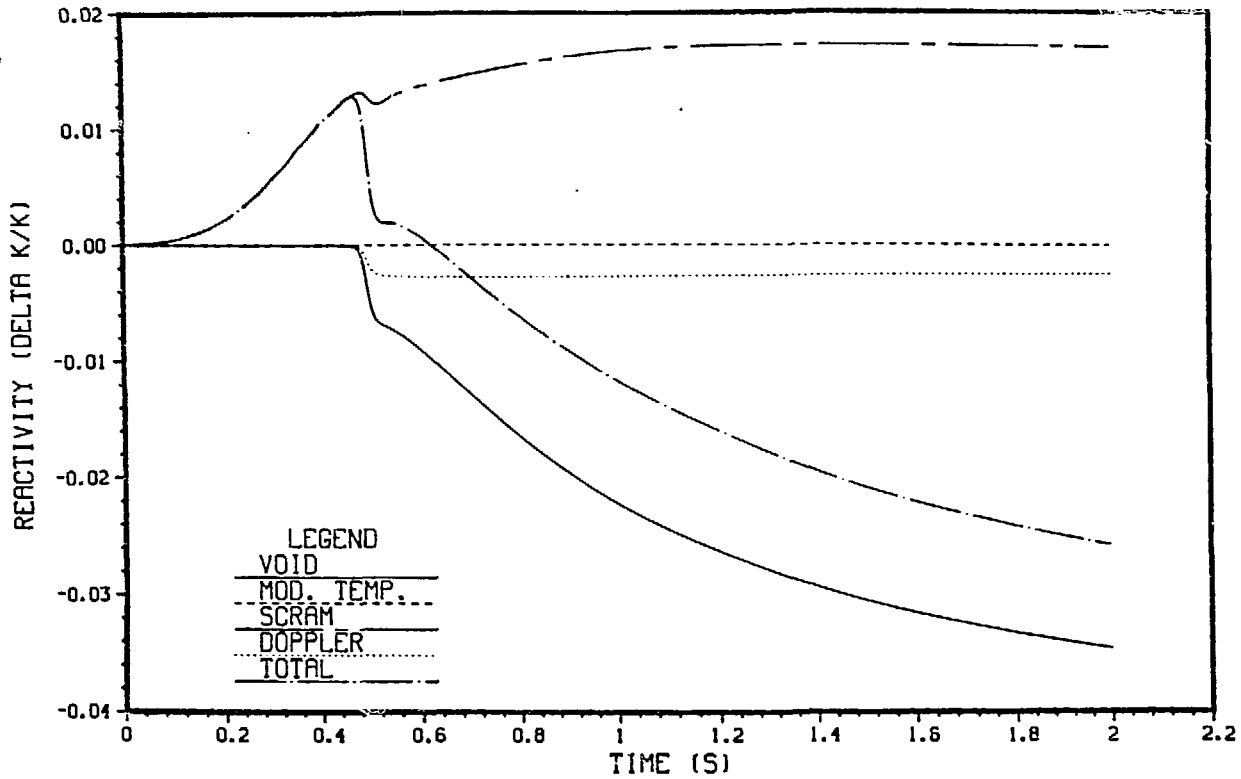


Figure 1
Core Thermal Power Transient Behavior at Saturation and at Inlet
Subcooling of 80 °F

BWR CONTROL ROD DROP ACCIDENT
HOT, ZERO POWER, SUBCOOLING - 0 DEG. F, ROD VEL. - 5 FT/SEC
REACTIVITY COMPONENT TRANSIENT BEHAVIOR



BWR CONTROL ROD DROP ACCIDENT
HOT, ZERO POWER, SUBCOOLING - 80 DEG. F, ROD VEL. - 5 FT/SEC
REACTIVITY COMPONENT TRANSIENT BEHAVIOR

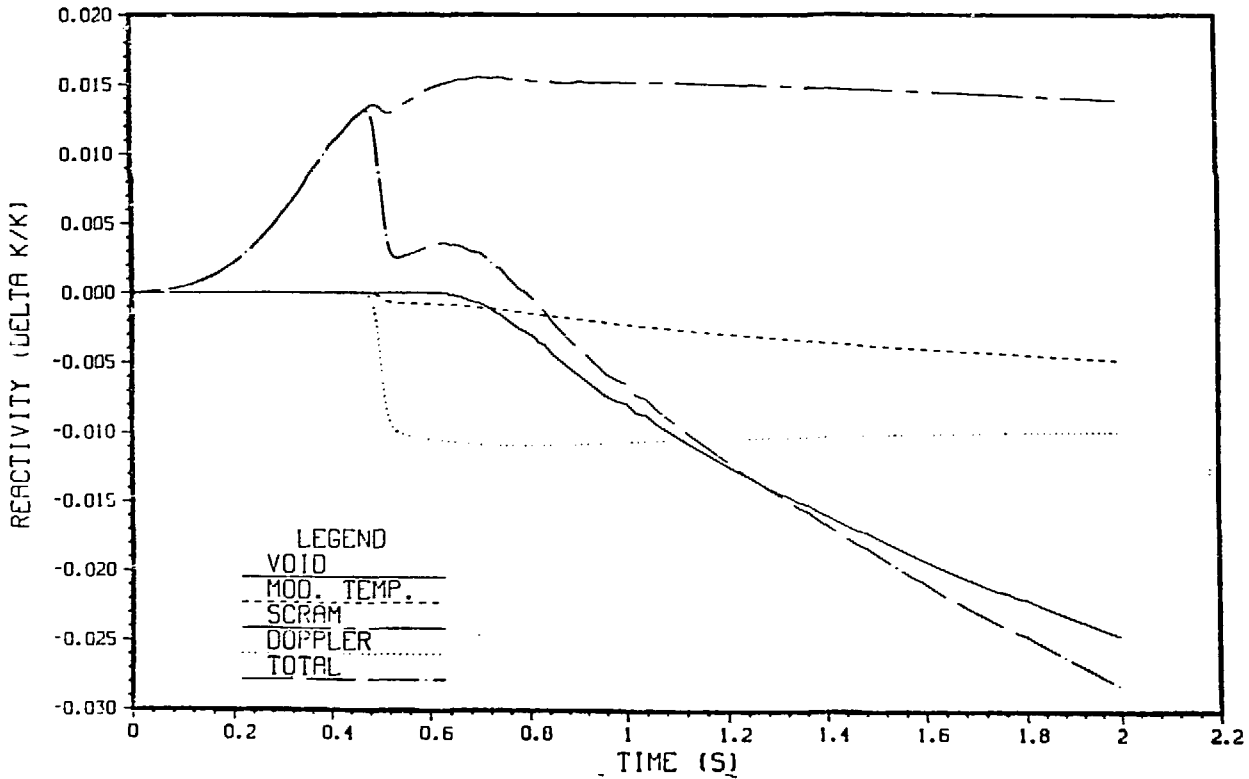


FIGURE 2

Transient Behavior of the CRDA Reactivity Components at Saturation and at an Inlet Subcooling of 80 °F.

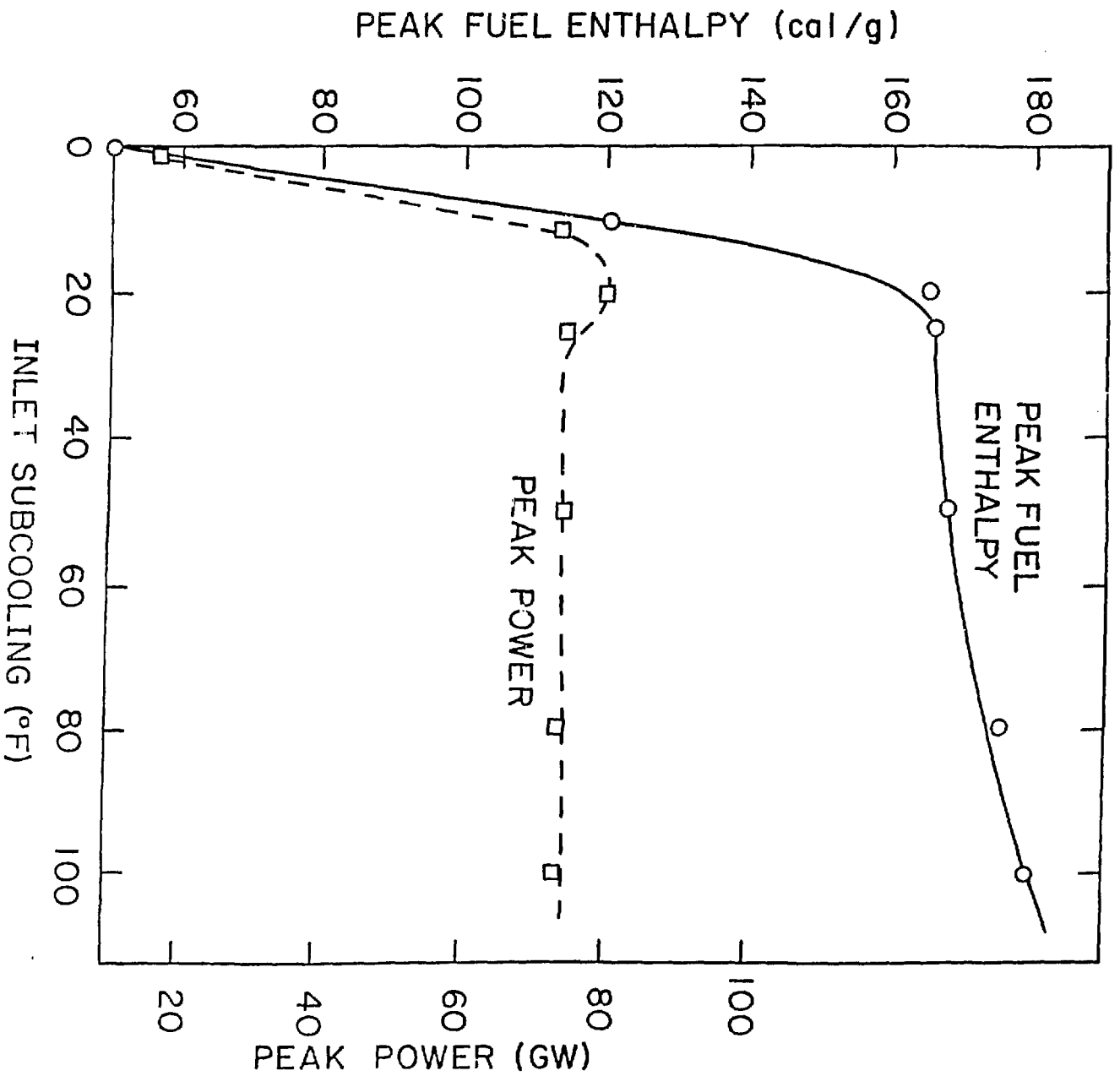


FIGURE 3
 Peak Fuel Enthalpy and Peak Power as a
 Function of Inlet Subcooling