CONF-850420--2

The Effect of Primary Pump Coastdown on Unprotected Loss-of-Flow Transients in EBR-II*

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DE85 002148

to be presented
at the
Second Specialist's Meeting on
Decay Heat Removal and Natural Convection
in LMFBRs
Long Island, New York
April 17-19, 1985

*Work supported by the U.S. Department of Energy under contract W-31-109-Eng-38. This abstract will not be published, it will be used for paper selection only.

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A loss-of-flow (LOF) accident of considerable interest in current LMFBR safety study is a total loss of pumping power coupled with a failure of the reactor shutdown system (RSS). Confirming predictions of this type of unprotected transient is the primary purpose of the Shutdown Heat Removal Tests (SHRT) presently scheduled for June 1985 in the Experimental Breeder Reactor II (EBR-II). The tests are also intended to validate predictions of the maximum operating power at which the reactor can safely sustain a total loss of power (station blackout) and a failure of RSS. An extensive series of tests was successfully completed in June of 1984 which investigated the reactor shutdown cooling capability following protected LOF events and the inherent reactivity feedback characteristics in EBR-II in preparation for making predictions of the upcoming unprotected tests. This paper discusses details of the unprotected LOF transient analysis, the validation of the EBR-II reactivity feedback modeling, and the significance of primary pump coastdown characteristics on peak reactor temperature.

The analytical studies were performed with the aid of the NATDEMO system code[1] which provides a neutronic-thermal-hydraulic simulation of the primary, intermediate, and steam heat transport systems of the EBR-II plant. Additional detailed studies were done with a coupled thermal-hydraulic code (HOTCHAN) to determine peak temperatures in the hottest channels as well as to predict the behavior of a special subassembly (XX09) instrumented with thermo-

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couples and two flowmeters. NATDEMO has been extensively validated with measured data from numerous EBR-II tests and plant transients. Pretest predictions utilizing both HOTCHAN and NATDEMO were also well confirmed by results of the SHRT series just completed.

Certain features of the EBR-II will first be discussed which are very important in assessing the impact of unprotected LOF transients on core temperatures. It should be noted that a total loss of station power causes both primary and secondary flow systems to coast down simultaneously. Backup power (diesel supplied) is available, however, to supply an auxiliary pump in the primary loop and to the main pump in the secondary loop. In addition, emergency power remains available to operate the main plant systems such as the steam pressure control system. In the present study, the mitigating influence of the above backups was disregarded with the result that both the primary and secondary systems experience early transition into natural convection. Another important feature of the EBR-II is that it contains only uranium metallic fuel in the driver and depleted natural uranium in the outer blanket. An intermediate radial zone consists of a stainless steel reflector which enhances the power generation in the driver zone and decreases the breeding of plutonium in the blanket zone compared with no radial reflector present at all. The EBR-II core characteristics cause rapid thermal response of the drivers during an LOF event. Since the EBR-II is a form of pool-type LMFBR, the dynamic response of the primary-tank sodium is very slow due to large inventory of sodium in the tank; this is in strong contrast to the rapid response of the driver fuel.

The reactivity feedbacks are all negative with the exception of the subassembly bowing component which can vary from positive to negative, depending upon the reactor configuration and flow distribution in the reactor. The "linear" (or non-bowing) reactivity components are regarded as constant effects and are essentially linear with steady-state changes in power. The Doppler effect, also negative, is very small although the fuel temperature (expansion) effect is significant and operates on the same time scale. The remaining effects are proportional to local power/ flow ratio and thus are related essentially to sodium temperatures in the driver, reflector and blanket zones as well as the lower and upper regions of the axial reflectors.

The feedback model also takes account of the radial grid spacing of subassem-subassemblies which is affected by temperature changes at the reactor inlet plena. The recent feedback validation tests indicated that a positive bowing component was present but that most of the linear feedback in NATDEMO could be left unchanged. The magnitude as well as the dynamic response characteristic of bowing have uncertainties in EBR-II. Based on the recent test data, the driving force for bowing was weighted predominately by the driver with the remainder being driven by the reflector zone. Since a similar core loading will be installed for the unprotected LOF test series, the nominal feedback model (with an adjusted positive bowing component) was used in the present study.

The rate of primary flow coastdown can be varied by a factor of about seven in EBR-II, depending somewhat on the initial flowrates; the corresponding pump stopping times range from 10 to over 70 s. Such a variation is possible because the primary pumps are powered by variable speed motor-generator (M-G) sets coupled with the fact that power can be interrupted at individual breakers in each M-G set. This range of coastdown behavior is a result of the effective rotating inertia and will be exploited in the upcoming test series to confirm the predictions. Six unprotected LOF tests were designed to investigate the impact on reactor temperatures as a function of the primary flow coastdown rate, the secondary flow and the auxiliary pump flow. The tests planned are currently limited by fuel eutectic temperatures between the element and cladding which are 1319 and 1301°F for the driver and blanket subassemblies, respectively. In order to meet the required temperature limit, the initial power and flow will be 16.7 and 20% of their rated values, re-respectively, and the primary tank temperature will be reduced to 640°F from the nominal 700°F for all the tests. In addition to the predictions of the test cases, a total station blackout event from 100% power and flow condition is also analyzed.

The results show that primary flow coastdown rate and the operation of the auxiliary pump have dramatic effects on the reactor temperatures. The impact of secondary flow is less and depends somewhat on the test condition. When the auxiliary pump is in operation, the effect of secondary flow on the reactor temperature becomes even less significant during an LOF event.

Reference

1. D. Mohr and E. E. Feldman, "A Dynamic Simulation of EBR-II Plant During Natural Convection with the NATDEMO Code," Decay Heat Removal and Natural Convection in Fast Breeder Reactor, Hemisphere Publication Corp. (1981) pp. 207-223.