CONF-880506--15

MAY 1 ...

PRD COMPONENTS OF A HOMOGENEOUS U10Zr-FUELED 900 MWt LMR*

by

D. Meneghetti and D. A. Kucera
Argonne National Laboratory
Argonne, Illinois 60439-4820, USA

CONF-880506--15

DE88 010039

Submitted for Presentation at the ANS
Topical Meeting on Safety of
Next Generation Power Reactors
May 1-5, 1988
Seattle, Washington

*Work supported by the U. S. Department of Energy, Civilian Reactor Development, under Contract W-31-109-Eng-38.

PRD COMPONENTS OF A HOMOGENEOUS U10Zr-FUELED 900 MWt LMR*

D. Meneghetti and D. A. Kucera
Argonne National Laboratory
Argonne, Illinois 60439-4820, U.S.A.

ABSTRACT

The linear and Doppler feedback components of the regional contributions of the power-reactivity-decrement (PRD) for a representative 900 MWt homogeneous U10Zr-fueled sodium-cooled reactor are calculated. The PRD is the reactivity required to bring the reactor from zero-power hot-critical condition to a given power level. These components are further separated into power dependent and power-to-flow dependent parts. The values are compared with corresponding quantities calculated for the Experimental Breeder Reactor II (EBR-II). The implications of these comparisons upon inherent safety characteristics of metal-fueled sodium-cooled reactors are discussed. The effects of fuel axial restraint on feedback, resulting from possible fuel-clad interactions due to burnup are also calculated. The possible enhancement of desirable feedbacks by use of appropriately designed subassembly-duct bowing feedback characteristics is estimated.

*Work supported by the U. S. Department of Energy, Civilian Reactor Development, under Contract W-31-109-Eng-38.

PRD COMPONENTS OF A HOMOGENEOUS U10Zr-FUELED 900 MWt LMR*

D. Meneghetti and D. A. Kucera
Argonne National Laboratory
Argonne, Illinois 60439-4820, U.S.A.

SUMMARY

Interest in inherent safety characteristics of metal-fueled sodium-cooled fast reactors resulting from the recent Inherent Safety Demonstration Test [1] at the Experimental Breeder Reactor II (EBR-II) has prompted the need for a detailed analysis of the feedback components of a larger system for comparisons with corresponding EBR-II values. Linear components of the power-reactivity-decrements (PRDs) of EBR-II loading configurations are obtained[2] using the EBRPOCO code[3] which calculates detailed axially delineated contributions of the components for every subassembly of a loading configuration. The PRD is the reactivity required to bring the reactor from zero-power hot-critical condition to a given power level. The EBRPOCO code, which is designed specifically for EBR-II analyses, has been modified sufficiently to enable it to be used for an analogous calculation of a representative homogeneous type 900 MWt metal-fueled reactor.

The description of the homogeneous 900 MWt reactor of this study is similar, but not identical, to that of a preliminary reference core design[4] for a 943 MWt metal core. Some modifications were made to the reactor design to enable usage of the modified EBRPOCO code. In addition because some design aspects required for the detailed calculations of the feedbacks were not available it was necessary to assume some needed design parameters. The metal

*Work supported by the U. S. Department of Energy, Civilian Reactor Development, under Contract W-31-109-Eng-38.

fuel is U10Zr of 75% smear density. The fuel of 36 in. (91.4 cm) length is contained in 0.280 in. (0.711 cm) outer diameter cladding having radial thickness 0.018 in. (0.0457 cm). There are 271 fuel elements per subassembly having subassembly flat-to-flat outer dimension 5.99 in. (15.2 cm). Subassembly rows 1 to 5 and 6 to 7 constitute the two differing enrichment core zones except for twelve boron carbide control rod locations in row 5. The row 8 blanket subassemblies are assumed to contain U10Zr elements of depleted uranium. The row 9 reflector subassemblies are assumed to contain steel rods. The shield subassemblies in outer rows 10 and 11 contain boron carbide. The inlet sodium coolant temperature is 675°F (357°C) and the primary flow is about 86,000 gpm (5.42 m^3 s^{-1}).

Regional distributions of calculated linear and Doppler components of the PRD at 900 MWt, assuming fresh fuel with no fuel-to-clad interaction, are listed in Table I. The components are coolant density (density reduction of sodium coolant due to coolant temperature), coolant displacement (displacement of sodium coolant by radial thermal expansions of claddings, structural rods, subassembly ducts, and steel of lower and upper axial reflector regions), steel density (density reductions of these steel components due to axial expansions by temperatures), bond sodium (resultant of bond sodium displacement by differential thermal expansions of fuel and cladding and of density reduction of bond sodium due to temperature), fuel and blanket axial expansions, and Doppler (in fuel and blanket). The rod bank suspension component is due to the downward thermal expansion of the control rods and of the portion of the overhead suspensions immersed in outlet-temperature coolant.

The large contributions are the rod bank, fuel axial expansion, and Doppler. For EBR-II the large contributions are instead the coolant density, structural expansions including coolant displacement, rod bank, and axial fuel expansion[2].

The value of the rod bank component can vary depending upon the number of rods used, the differential worth of the rod bank at the bank position, and the lengths of overhead suspensions immersed in outlet coolant. The effective value of the fuel axial expansion component can be considerably decreased if sizeable amount of the fuel is adhered to the cladding because of burnup. Effects of adherence upon feedback are estimated.

PRD effects of subassembly-duct bowings (which include also the effects of diametral expansions of ducts) with power might add a nonlinear positive or negative component to the total linear values. For EBR-II the sign of the component is interpreted as largely dependent upon the extent of initial looseness or tightness, respectively, of the ducts at the contact locations at zero power[5]. A value of about +15 Ih has been deduced for EBR-II run 93A; in contrast, a value of about -25 Ih has been deduced for EBR-II run 85A[2]. Tight interaction of ducts could result in a negative component because the duct diametral expansions with power then tend to simulate radial expansion effects similar to a steel continuum. This could increase the linear PRD by about -25 Ih to -30 Ih depending upon the axial position of the duct contacts and the specifics of design of the core restraint. If available this would represent an additional large negative contribution to the PRD.

Results of separate analyses of the power dependent and of the power-to-flow dependent components of the PRD are also presented. The implications of the results of these separations upon the inherent safety characteristics of the reactor compared with correspondingly separated EBR-II values[6] are discussed.

REFERENCES

1. H. P. Planchon, J. I. Sackett, G. H. Golden, and R. H. Sevy, "Implications of the EBR-II Inherent Safety Demonstration Test," Nuclear Engineering and Design 101 (1987) p. 75.
2. D. Meneghetti and D. A. Kucera, "Comparisons of PRD Components for Various EBR-II Configurations," Proc. Topl. Mtg. Reactor Physics and Safety, NUREG/CP-0080, Vol. 1, Saratoga Springs (1986) p. 130.
3. D. Meneghetti and D. A. Kucera, "EBRPOCO-A Program to Calculate Detailed Contributions of Power Reactivity Components of EBR-II," Proc. Int. Topl. Mtg. Advances in Mathematical Methods for the Solution of Nuclear Engineering Problems, Vol. 2, Munich (1981) p. 225.
4. Y. Orechwa and H. Khalil, "Physics Implications of Oxide and Metal Fuel on the Design of Small LMFBR Cores," Topl. Mtg. on Reactor Physics and Shielding, Vol. I, ISBN: 089448-113-4, Chicago (1984) p. 323.
5. D. Meneghetti and D. A. Kucera, "Nonlinear PRD Components of EBR-II Compared with Bowing Calculations," to be presented at ANS Meeting, Los Angeles, November 1987.
6. D. Meneghetti and D. A. Kucera, "Delineations of Power and Power-to-Flow Feedback Components of EBR-II," Trans. Amer. Nucl. Soc., Vol. 53 (1986) p. 459.

TABLE I. Linear PRD Components (Ih)[a] of a 900 MWt Homogeneous U10Zr-Fueled Reactor

Region	Coolant Density	Coolant Displ.	Steel Density	Bond Sodium	Fuel Axial Exp.	Doppler	Sums
Core	-9.0	-2.0	+0.7	-2.8	-32.5	-26.2	-71.8
Above core	-7.3	-1.4	-1.0	0	0	0	-9.7
Below core	-0.1	-0.1	-0.1	0	0	0	-0.3
Rad. blkt.	+0.1	-0.3	-0.2	-0.6	0.0	-1.5	-2.5
Rad. refl.	-0.1	0.0	-0.1	0	0	0	-0.2
Rad. shld.	0.0	0.0	0.0	0	0	0	0.0
Sums	-16.4	-3.8	-0.7	-3.4	-32.5	-27.7	-84.5

Rod bank suspension[b] = -26.4 (includes fuel upward lift by lower reflector expansion)

Linear component (includes nonlinear Doppler component)
= -84.5 - 26.4 = -111. Ih

Linear power coeff. = $\frac{-111.}{900.}$ = -0.123 Ih/MWt

a. 444 Ih per %$\Delta k/k$ and $\beta_{eff} \cong 0.0070$.

b. 114 in. (290 cm) from top of core to top of rod suspensions affected by outlet temperature; 12 rods at 9 in. (22.9 cm) B_4C insertions.