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THE EFFECT ON CROSS SECTIONS FOR QUAD CITIES BY INTRODUCING CONTROL ROD HISTORY IN THE ASSEMBLY PROGRAM LEWARD

Erik Nonbøl

Abstract

This paper shows the effect on the 2-group neutron cross sections for the BWR reactor Quad Cities by introducing control rod "history" in the assembly program LEWARD. Control rod "history" is a concept which accounts for the movement of control rods during operation.

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CONTENTS

1. INTRODUCTION

At the Nordic Reactor Physics Conference in Helsinki in 1987 the programme complex LEWARD/NOTAM was presented (1), as well as a calculation on Quad Cities for verification of the program complex.

Because of some deviations between calculations and experiments a number of items were pointed out as being responsible for the disagreements.

Among these the lack of taking control rod history into account was believed to be the most serious one.

This paper shows the effect on the 2-group cross sections for Quad Cities by introducing control rod history in the assembly program LEWARD.

2. TREATMENT OF "CONTROL ROD HISTORY" in LEWARD

Previously, the 2-group cross sections in LEWARD were calculated as function of the following parameters:

1) Fuel type
2) Burnup
3) Accumulated void ("void history")
4) Actual void
5) Control rods

For each fuel type a burnup history at a specific accumulated void content was calculated both with and without control rods. At each burnup step a calculation was done at increased actual void.

Thus if a node had been with control for a long period since start-up and then suddenly the control rod was withdrawn, the cross sections would be calculated as had the node been without control since start-up.

The burnup distribution within the node is, of course dependent on the time in which the control rod has been in and so are the cross sections.

An exact simulation of the control rod history is very computer time consuming. It would require assembly burnup calculations concurrently for each node during the 3D-overall core calculation.

The method chosen for simulating the "control rod history" is based on the following assumption:

1) The cross sections depend on the accumulated burnup time in which the control rod has been inserted but not on the detailed time variation of the control rod movements.

Thus, if a node has been without control since start-up and then a control rod is inserted in a specific burnup time and then withdrawn, the cross sections are calculated as if the control rod had been inserted from start-up in the specific burnup time followed by the corresponding burnup time without control.

In other words the accumulated burnup time with control rod present is pushed to the beginning of life of the fuel.

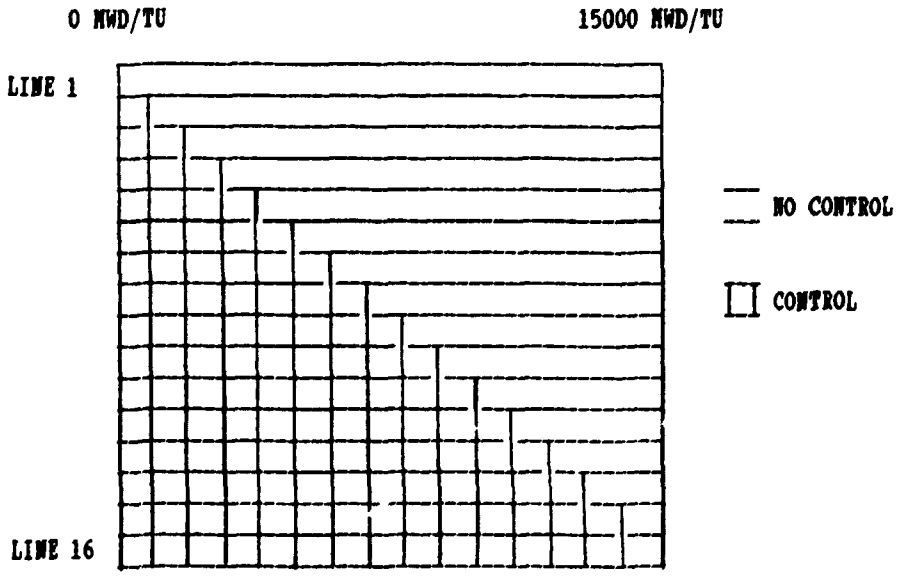
3. PROCEDURE FOR CALCULATING 2-GROUP CROSS SECTIONS FOR QUAD CITIES

The calculation of 2-group cross sections for Quad Cities to a burnup of 15.000 MWd/tU has been made with the following parameters:

Fuel types	: 0 Gd, 2 Gd, 3Gd
Accumulated voids %	: 0, 30, 50, 70
Actual voids%	: 10, 40, 60, 80
Burnup steps	: 15, 20, 20

where 0 Gd means fuel assembly without gadolinium rods and 2 Gd means assembly with 2 gadolinium rods. Fuel without Gd burns in steps of 1000 MWd/tU while fuel with Gd burns in steps of 500 MWd/tU until 5000 MWd/tU and then in steps of 1000 MWd/tU. In Fig. 1. is shown a Quad Cities fuel assembly with 3 gadolinium pins.

The calculation can be illustrated in the following way for 0 Gd fuel:



When one line in the scheme is completed, the calculation of the next line starts from the "no control" point of the just completed line, so the total calculation scheme is triangular.

In the previous version of LEWARD without control rod history, only the first line and the last line in the scheme were calculated.

4. COMPUTER TIME CONSUMPTION

The total number of burnup steps including initial steps for the triangular scheme becomes:

$$\frac{(N+1)(N+2)}{2}$$

where N is number of burnup steps.

In the old version the corresponding number was N+1.

BU-step	New LEWARD	Old LEWARD
0 Gd	136	16
2 Gd	231	21
3 Gd	231	21
total	598	58
CPU-hour	200	19

The computer time consumption for the new version of LEWARD has thus been increased by a factor of 10 in the actual case.

The CPU-time are based on a VAX 8700 computer which is a 6 MIPS machine to compare with a SUN 4/100 which is a 7 MIPS machine.

5. RESULTS

Fig. 2 shows k-infinity for a Quad Cities assembly without gadolinium rods. Parameter is the burnup which has taken place with control rod inserted. On top of the figure the results are shown with control rod out and below with control rod in.

For control rod out the curve with burnup parameter 0 corresponds to the old version of LEWARD, while for control rod in the dotted line corresponds to the old version of LEWARD.

The effect of taking control rod history into account for this assembly without gadolinium is seen to be most pronounced at high burnup.

For assemblies with gadolinium rods the opposite is the case, that is, the effect of the control rod history on k-infinity is biggest at low burnup and less pronounced at high burnup. This is clearly seen in Fig. 3 for a Quad Cities assembly with 3 gadolinium rods.

Fig. 4 shows the thermal diffusion coefficient D2 as function of burnup for an assembly with 3 Gd rods and Fig. 5 the corresponding thermal absorption cross section SS22. Again the dotted curve for control rod in and the curve with burnup parameter 0 for control rod out corresponds to the old version of LEWARD.

Fig. 6 shows the thermal fission cross section as function of burnup for an assembly with gadolinium. The effect of the control rod history is demonstrated very clearly. For the case with control rod in the thermal flux is pushed towards the detector corner of the assembly. Since the high enriched fuel rods are concentrated around this corner the thermal fission cross section is increased compared with the case with control rod out.

Fig. 7 shows the effect of control rod history on the thermal cross section of xenon XE2.

Finally Figs. 8-9 show the instrument factors as function of burnup. Fig. 8 is TIP1, the reaction rate in a fission chamber and Fig. 9 TIP2, the reaction rate in a gamma thermometer. The effect of taking control rod history into account is quite clear as well as the increased readings for the assembly with control rod in.

6. CONCLUSION

It has been shown that the new LEWARD version with control rod history modelling has produced changes in cross sections and instrument factors which are large enough to expect considerable changes in the over-all 3D-simulation.

We look forward to presenting the verification calculation on Quad Cities as soon as we have succeeded in transferring the program COSIMA from our old B7800 computer to the new VAX8700 computer.

REFERENCES

(1) HØJERUP, C.F. (1987). LEWARD, An LWR Assembly Programme. Status of Reactor Calculations in the Nordic Countries. (Helsinki).

(2) NONBØL, E. (1987). Calculations on Quad Cities as a Verification of the LEWARD/NOTAM Code System. Status of Reactor Calculations in the Nordic Countries. (Helsinki).

FIG. 1.

QUAD CITIES FUEL ASSEMBLY WITH 3 GD PINS

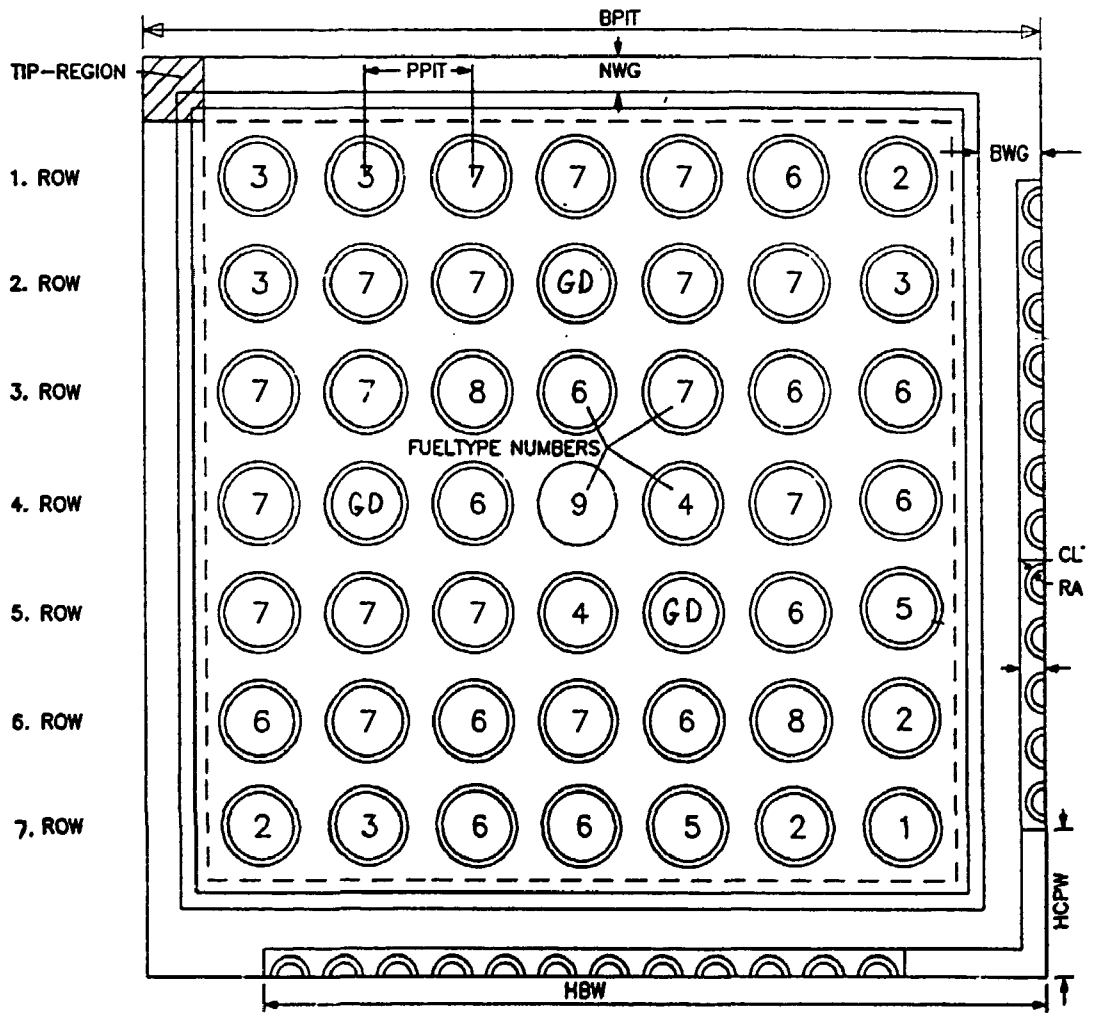


FIGURE 2.

KINF AS FUNCTION OF BURNUP, WITH AND WITHOUT CONTROL

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN

FUEL ASSEMBLY: QUAD CITIES,NO GD PINS, 50% VOID

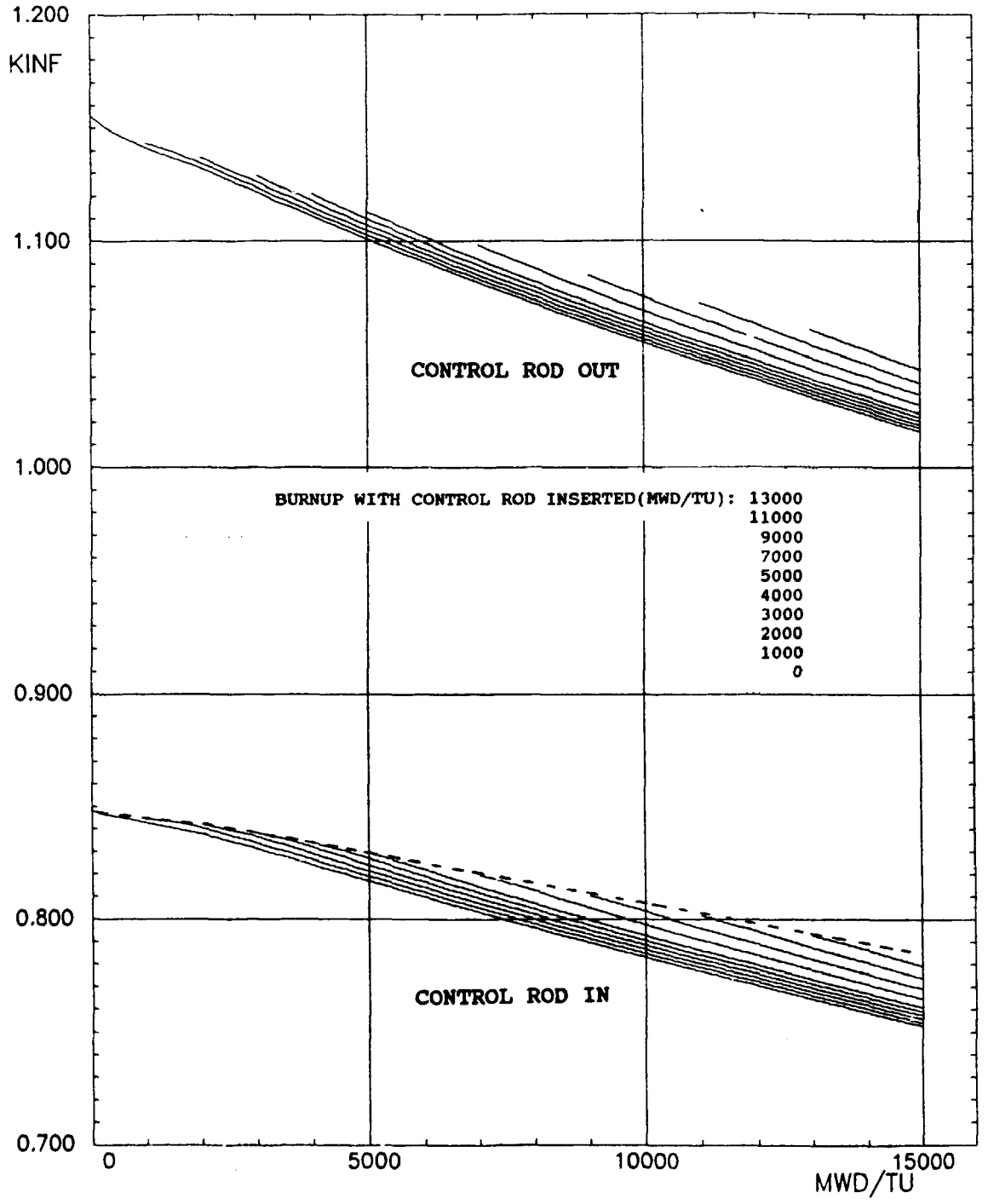


FIGURE 3.

KINF AS FUNCTION OF BURNUP, WITH AND WITHOUT CONTROL

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN

FUEL ASSEMBLY: QUAD CITIES, 3 GD PINS, 50% VOID

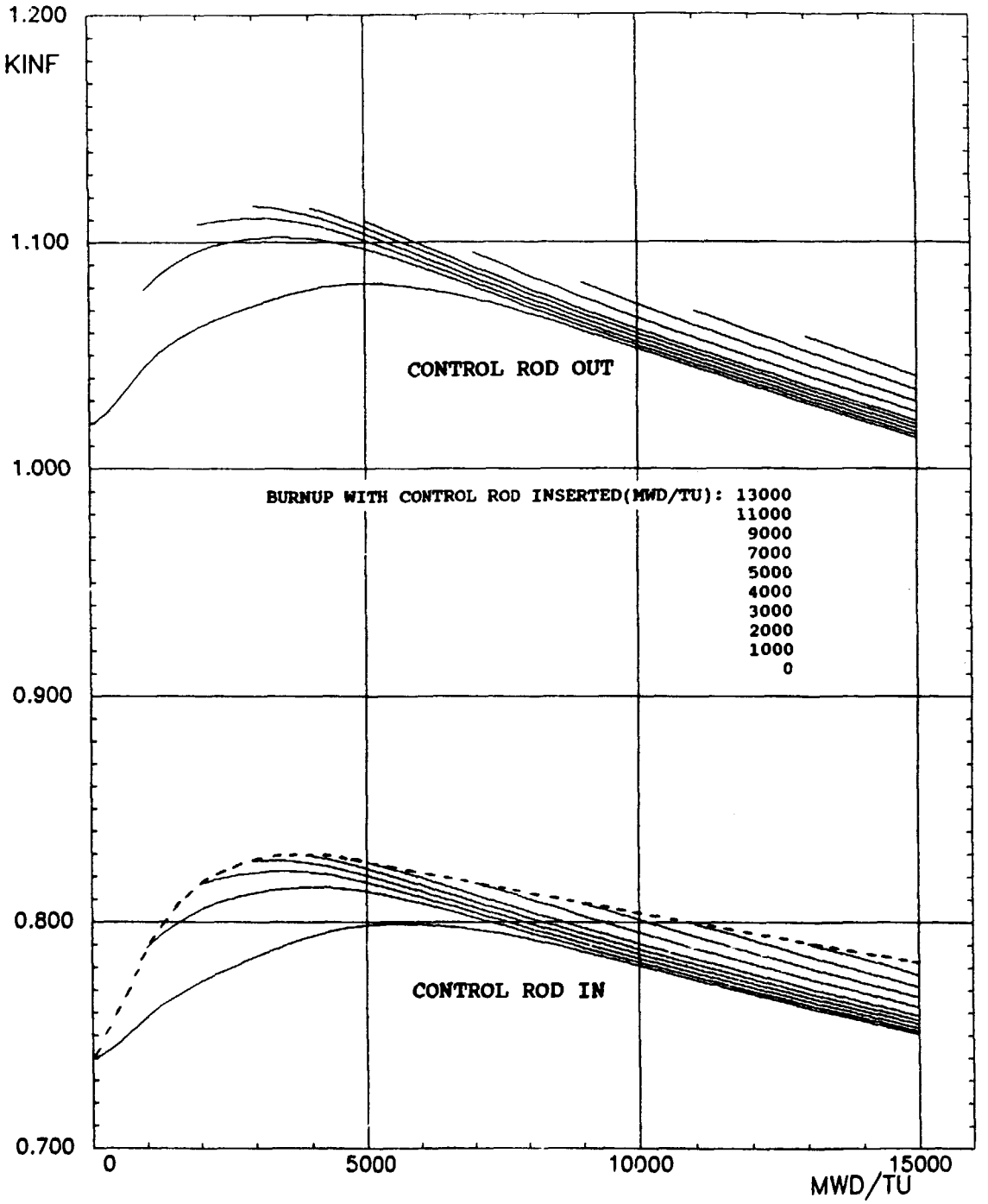


FIGURE 4.

D2 AS FUNCTION OF BURNUP, WITH AND WITHOUT CONTROL

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN
FUEL ASSEMBLY: QUAD CITIES, 3 GD PINS, 50% VOID

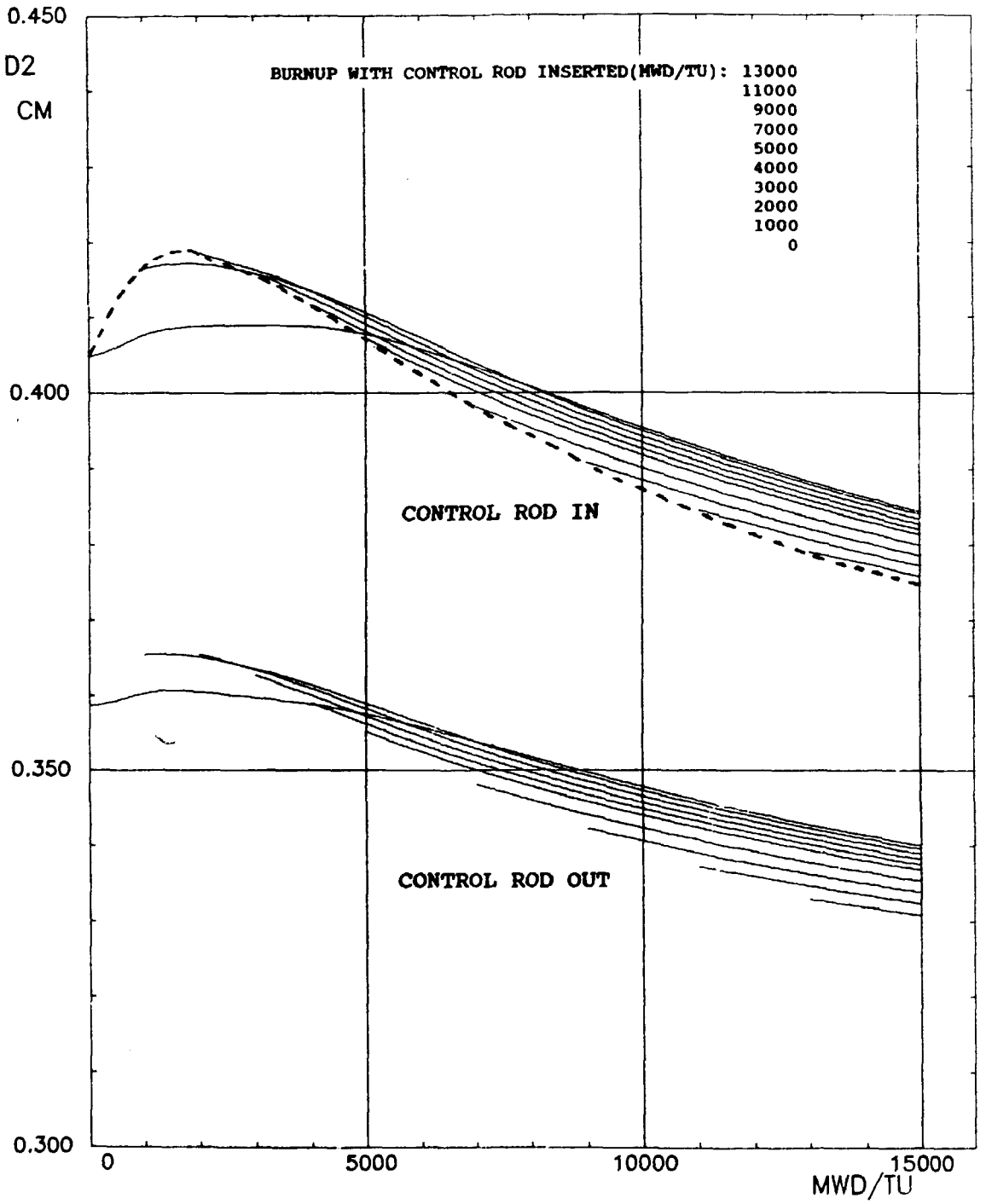


FIGURE 5.

SS22 AS FUNCTION OF BURNUP, WITH AND WITHOUT CONTROL

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN
FUEL ASSEMBLY: QUAD CITIES, 3 GD PINS, 50% VOID

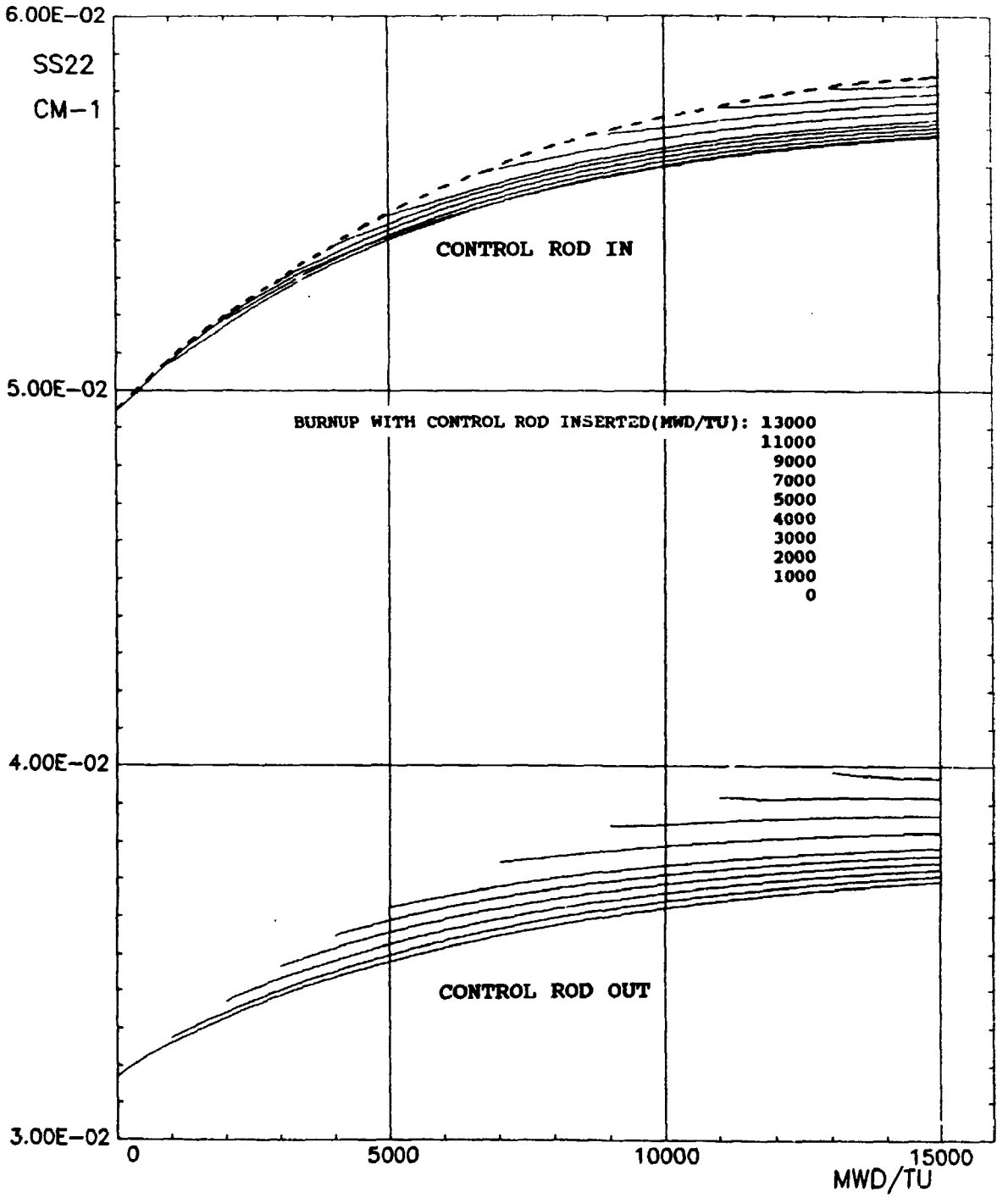


FIGURE 6.

SF2 AS FUNCTION OF BURNUP, WITH AND WITHOUT CONTROL

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN
FUEL ASSEMBLY: QUAD CITIES, 3 GD PINS, 50% VOID

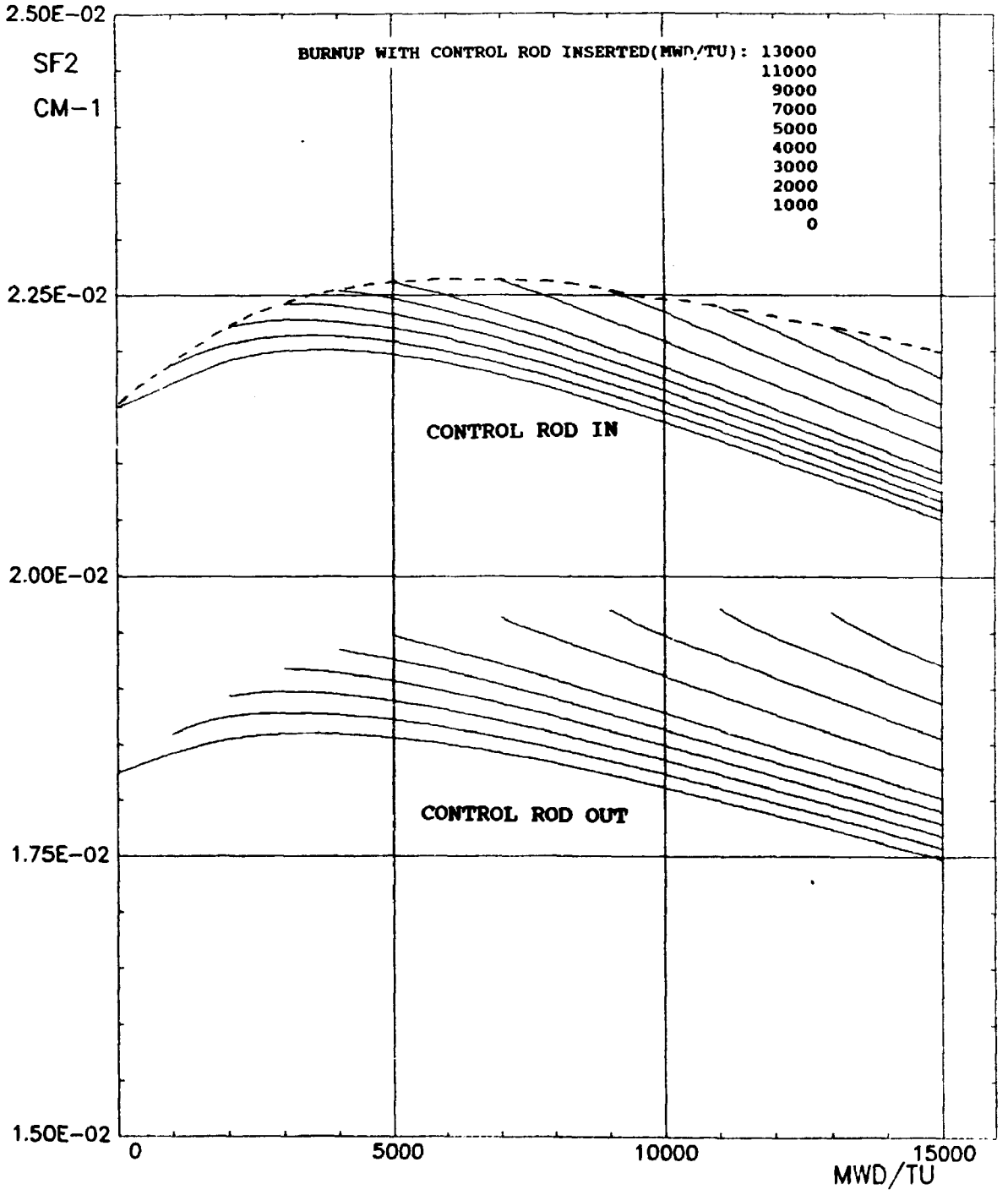


FIGURE 7.

XE2 AS FUNCTION OF BURNUP WITHOUT CONTROL ROD

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN
FUEL ASSEMBLY: QUAD CITIES, 3 GD PINS, 50% VOID

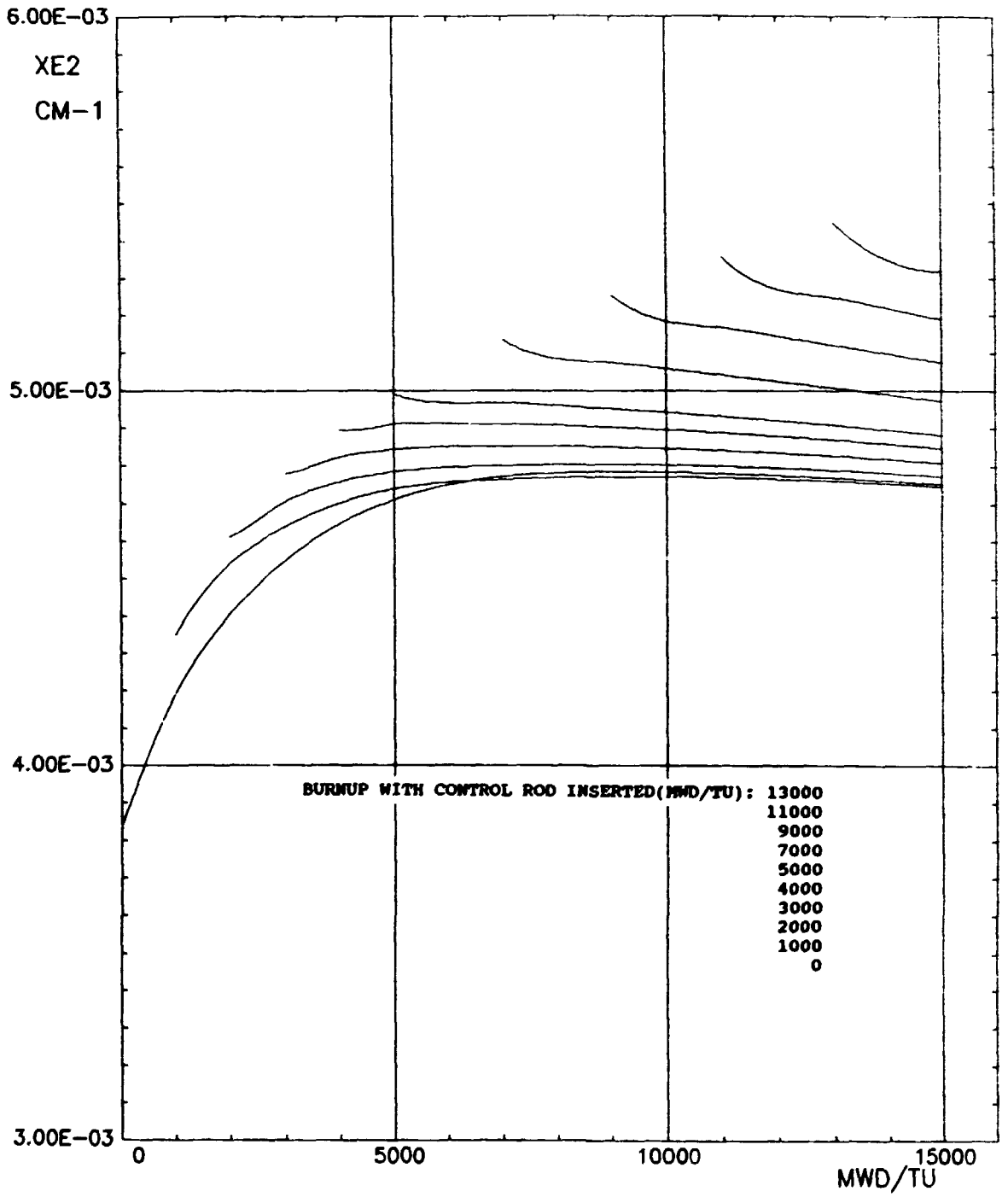


FIGURE 8.

TIP1 AS FUNCTION OF BURNUP, WITH AND WITHOUT CONTROL

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN
FUEL ASSEMBLY: QUAD CITIES, 3 GD PINS, 50% VOID

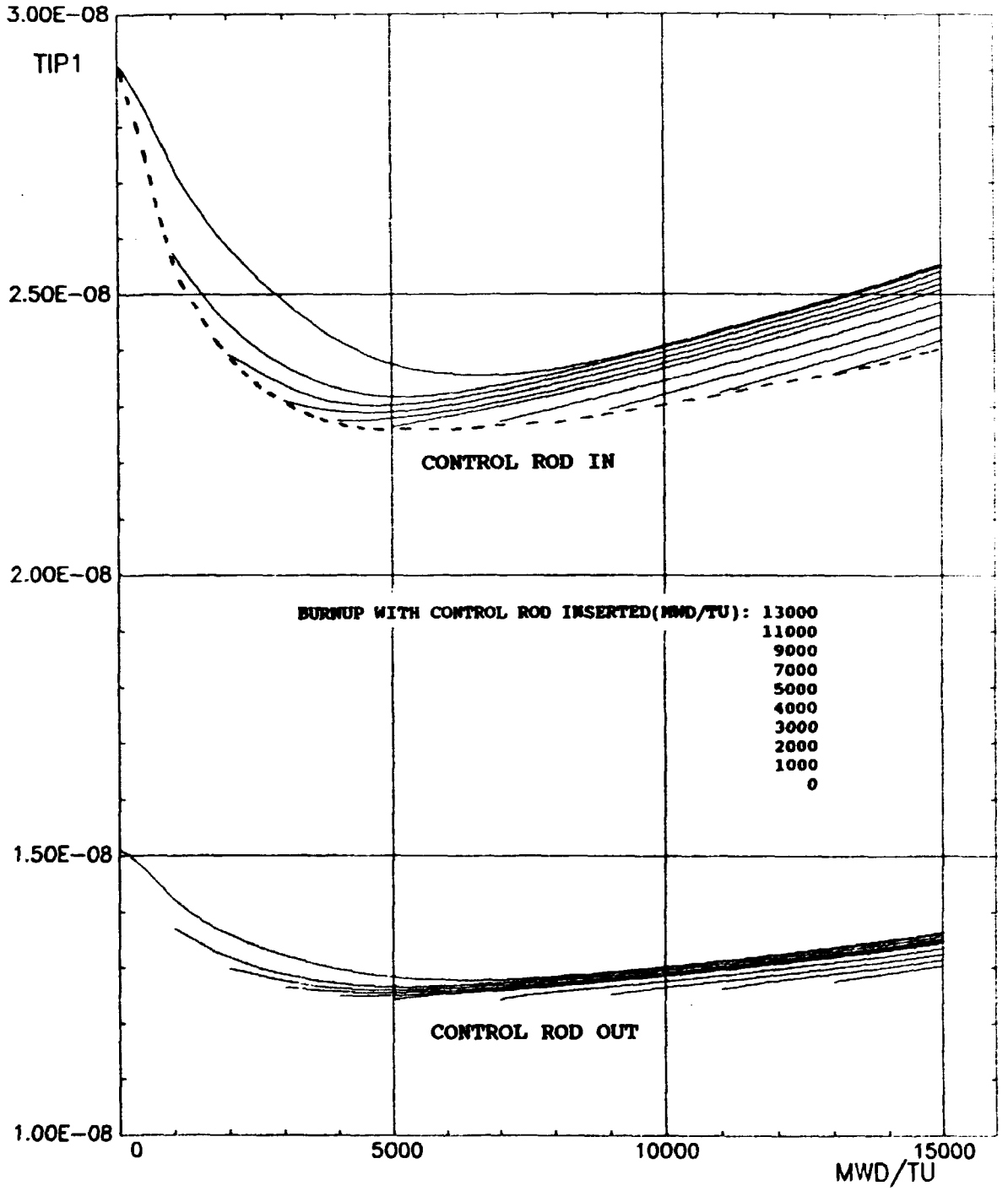
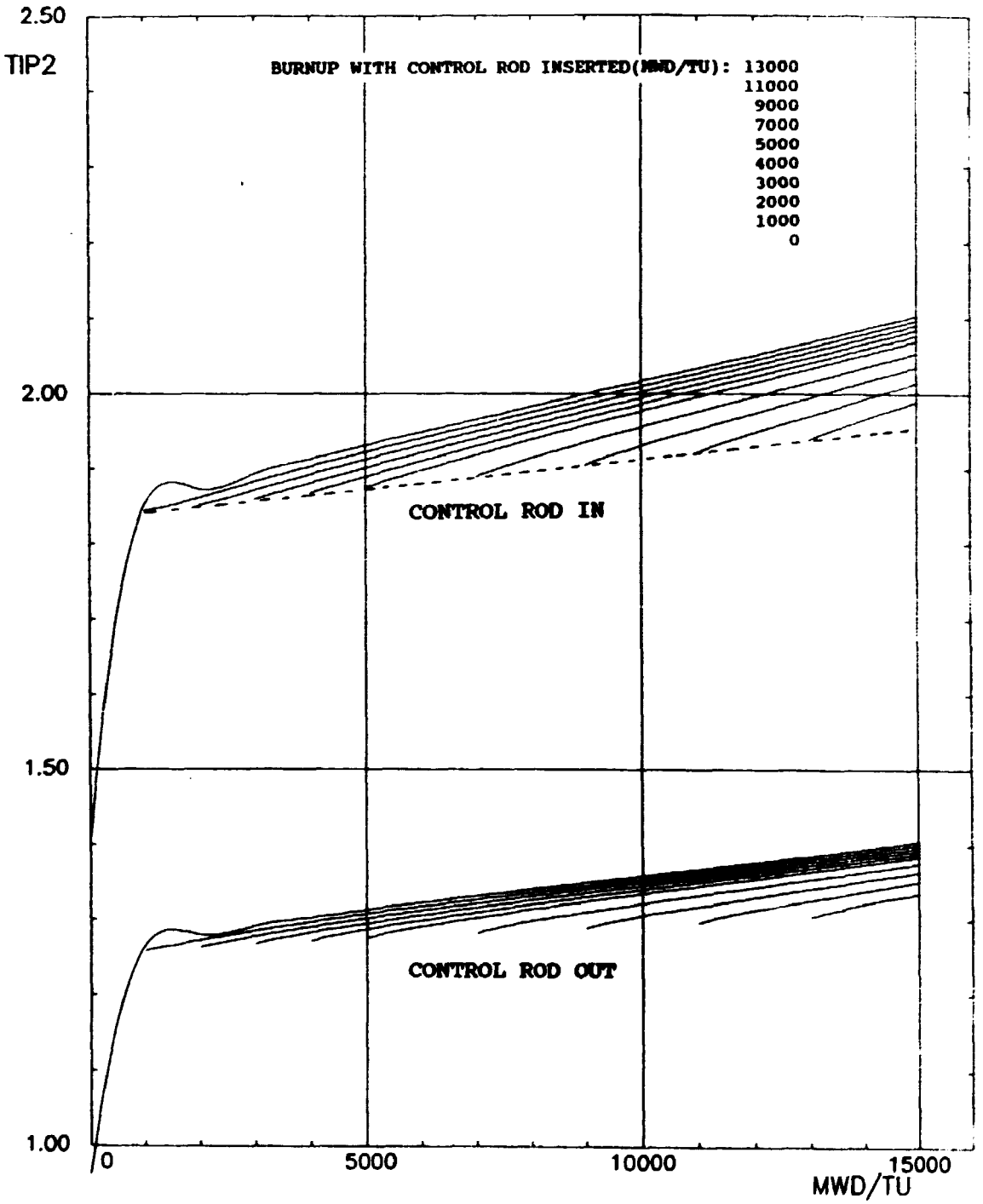


FIGURE 9.

TIP2 AS FUNCTION OF BURNUP, WITH AND WITHOUT CONTRCL

PARAMETER IS THE BURNUP, WHICH HAS TAKEN PLACE WITH THE CONTROL ROD IN
FUEL ASSEMBLY: QUAD CITIES, NO GD PINS, 50% VOID



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