CHAPTER 5

PRESENT CORE (CORE NO. 5) CALCULATIONS

5.1 Prediction of Excess Reactivity

Core No. 5 is the current core. It began operation in March 1985. To construct this core from Core No. 4, the nine partially-burned elements with 20 wt.% U that have been inserted in Core No's 2 and 4 were moved from the C-ring to the D-ring. Five fresh elements with 20 wt % U were also inserted in the D-ring to fill the fuel rod positions in this ring. In addition, a number of standard elements with 8.5 wt % U were shuffled. The four control rods in the D-ring with fuel followers containing 8.5 wt % U were not changed. A complete loading list can be found in Appendix D.

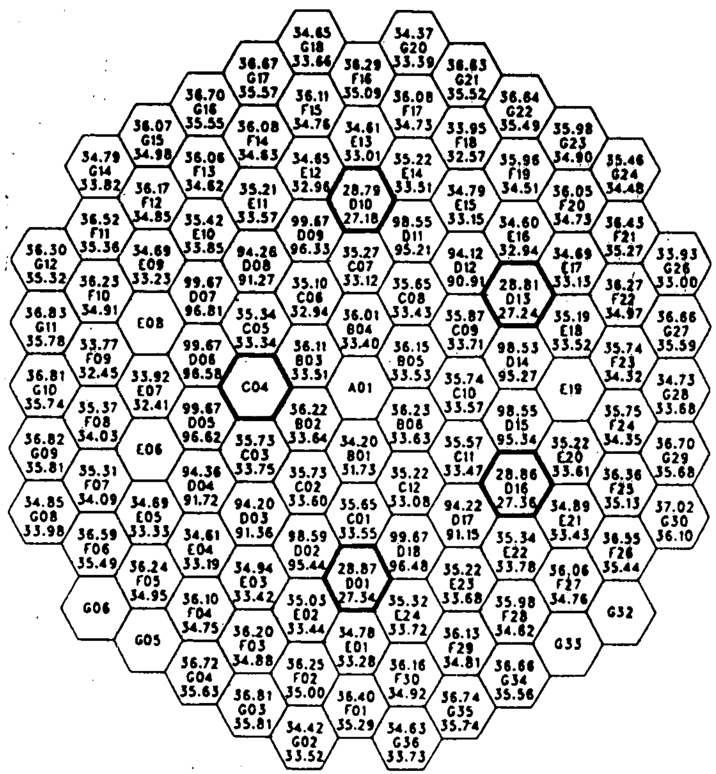
Figure 5.1 shows the loading diagram for Core No.5. The D-ring divides the core into an inner zone and an outer zone. This artifice of an inner zone containing only elements with 8.5 wt % U and an outer zone containing a mixture of elements with 8.5 wt % U and 20 wt % U will be retained throughout this study. The basic strategy is to shuffle 8.5 wt % elements between the outer zone and the inner zone and to add new fresh 20 wt % elements to the E- and F- rings of the outer zone

A burnup calculation for Core No. 5 (see fig. 5.2) indicated that this core could be operated for about 151 MWd with an EOC excess reactivity of 1.9 % $\delta k/k$. This EOC excess reactivity is approximately the same as that for Core No.4. The cold-to-hot reactivity

TRR-1/M1 CORE No.5

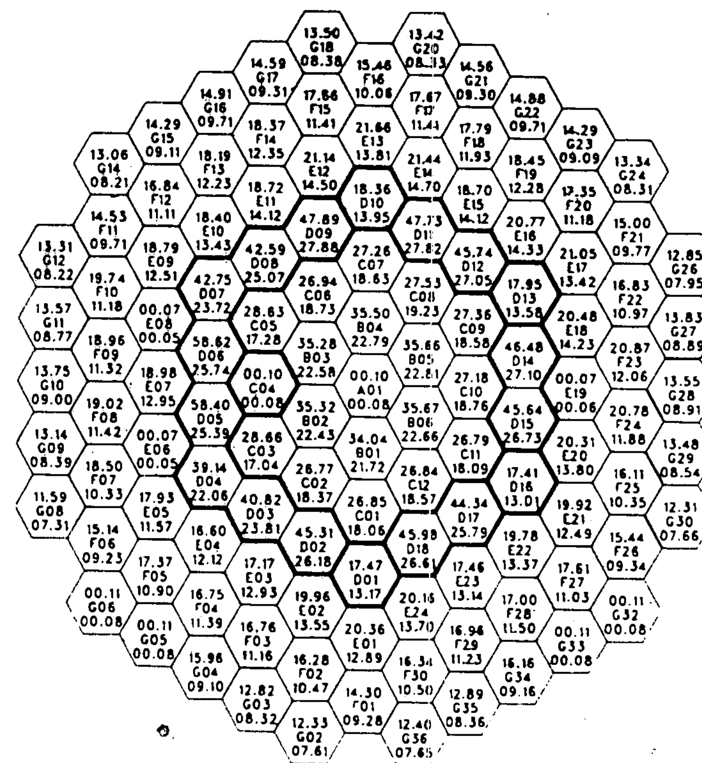
^{235}U Loadings, g

BOC (Top) and EOC (Bottom)



BOC Power Densities, W/cm^3

Peak (Top) and Average (Bottom)



Total ^{235}U Content at BOC	:	4831.28 g
Total ^{235}U Content at EOC	:	4644.92 g
Average ^{235}U Burnup	:	1.2354 g/MWd
No. of 8.5 wt. %U elements	:	98
No. of 20 wt. %U elements	:	14

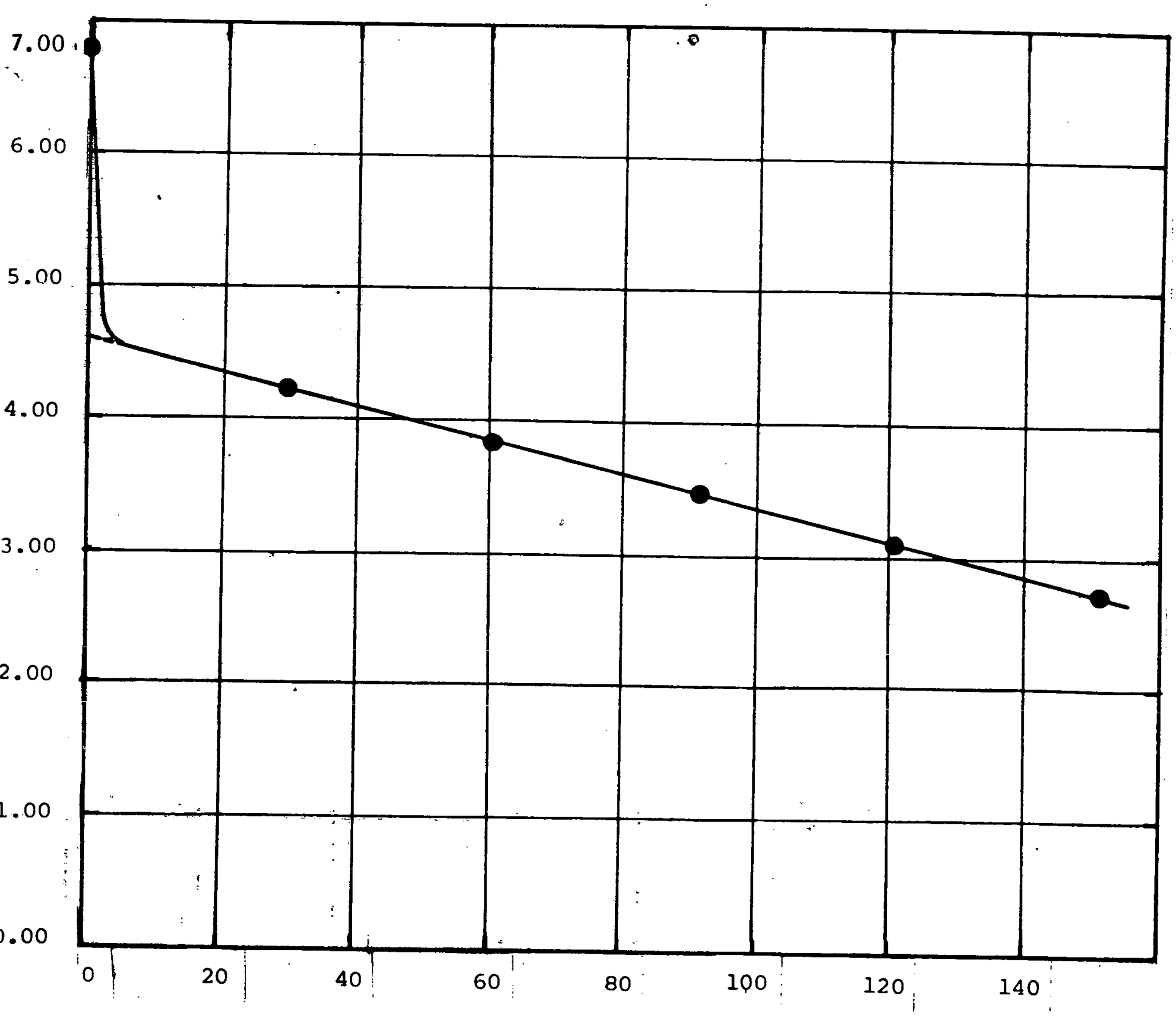
Peak Power Density	:	58.62 W/cm^3 in D6
Average Power Density in Fuelled Regions	:	14.15 W/cm^3

Fig.5.1 Core No.5 ^{235}U loadings and power dansities

Fig 5.2 TRR-1/M1 CORE No.5

Calculated Reactivity Rundown Data

Energy Release, MWd	k_{eff}	Excess React., $\%\delta k/k$	($)
0.0	1.05125	4.875	6.964
30.17	1.03065	2.973	4.247
60.34	1.02766	2.691	3.844
90.51	1.02481	2.421	3.459
120.68	1.02202	2.154	3.077
150.85	1.01944	1.907	2.724



swing is about 1.68 % $\delta k/k$ (see section 4.4) and the reactivity worth of the lazy susan from the up position to the down position is about 0.25 % δ k/k.

5.2 Peak Power characteristic

Figure 5.1 also shows the 3D peak and the 3D average power densities in each fuel cell of Core No. 5 at BOC. The peak power density (58.62 W/cm^3) occurs in the fresh element with 20 wt % U located in position D6 at the interface between D6 and the transient rod position C4 and at the 10 th. plane (see fig 3.2).

The calculations in this study were run with the transient rod fully-withdrawn. Since the transient rod follower contains air, cell C4 contains about 40.248 vol.% water and 16 vol.% aluminum. The neutron spectrum is softer at the interface between positions D6 and C4 because neutrons arriving at this interface from various sources must travel through more water than neutrons arriving at the other interfaces. Since the fuel element in position D6 contains fresh fuel with 20 wt % U, the power peak occurs at this location in these calculations.

Three test calculations were run to provide some verification of this conclusion. In the first test calculation, the material compositions in positions C4 and C10 were interchanged with the result that a peak power density of 56.99 W/cm^3 now occurred in position D14. The other two test calculations were run with the transient rod follower materials in position C4, by varying the water fractions of 30 vol.% and 50 vol.% instead of the nominal 40.248 vol.%. The peak power densities in position D6 were 56.04 W/cm^3 with 30 vol.% water in position C4, 58.62

Table 5.1 Power densities in Core 5 (watts/cm^3)

	40.248 % V H_2O in C4	40.248 % V H_2O in C_4 (C4 $\rightleftarrows$ C10)**	30.00 % V H_2O in C4	50.00 % V H_2O in C4
C4	.104	27.347	.083	.124
D6	58.621*	44.996 Peak at D14 56.988)	56.042*	61.432*

* Peak Power densities.

** C4 and C10 were switched.

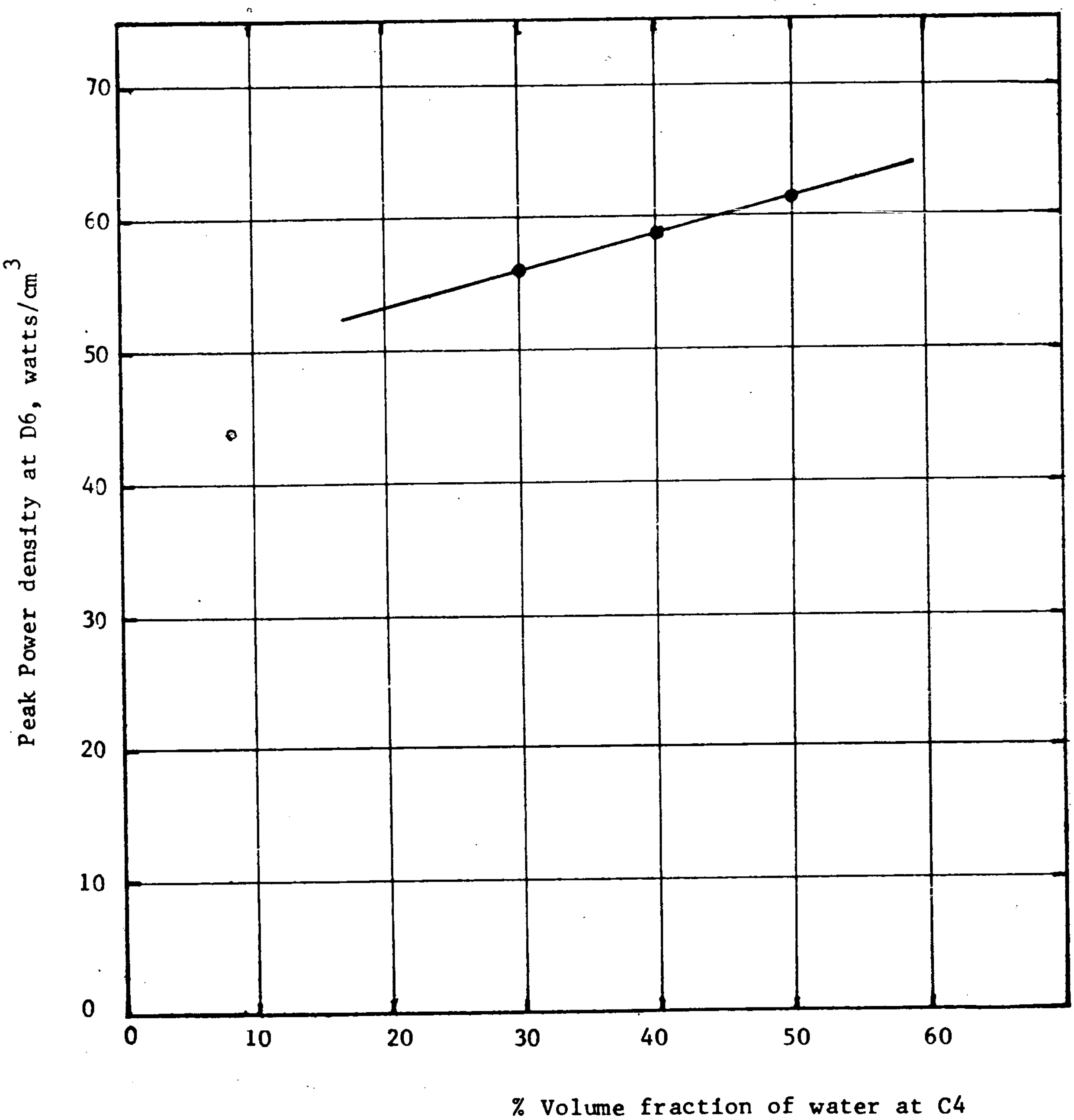


Fig. 5.3 Power density at D6 VS volume fraction of water at C4 (Transient Rod)

W/cm^3 with 40.248 vol.% water in position C4, and 61.43 W/cm^3 with 50 vol.% water in position C4. The results of this study are tabulated in table 5.1 and Fig 5.3.

One of the important safety limits with TRIGA fuel is the peak operating temperature of the fuel. In general, the peak temperature does not occur at the same location as the peak power due to heat conduction in the fuel meat. Heat transfer calculations were not performed as part of this study. However, all of the peak power densities that were calculated are close to or lower than that for position D6 in Core No. 5.

The OAEP is considering operation of the TRR-1/M1 for periods longer than 7 hours per day in order to meet the demand for radioisotopes productions more efficiently. One of the consequences of longer continuous operation is that the xenon concentration in the core will buildup closer to its equilibrium value and remove reactivity that would otherwise be available for burnup. Table 5.2 contains calculated values on the reactivity worth of the xenon buildup as a function of operating time in Core No.5.

5.3 Xenon Defects

The normal operation of the TRR-1/M1, is about 6-7 hours a day, 5 days a week. In such operational manner, the Xenon poison in the core can not buildup to the equilibrium value due to relatively short operation time. Usually, the Xenon buildup at the equilibrium value after 60 hours of operation. However, it is necessary to study the reactivity loss caused by Xenon poison buildup in the core. Thus, the calculation for the 4 days continueous operation in core No. 5 was performed at the Beginning of Cycle (BOC) in order to estimate the maximum reactivity can be obtained after compensating Xenon.

Fig.5.4, obtained from table 5.2, shows that the equilibrium Xenon occurs during 2-3 days of operation (approximately) and the maximum reactivity of Xenon = $ 2.36

Table 5.2 Core No.5 four-days operational data for Xe-Study

MWd	k_{eff}	% $\delta k/k$	$
0.0	1.05125	4.875	6.96
0.2	1.04260	4.086	5.84
0.4	1.03839	3.697	5.28
0.6	1.03620	3.494	4.99
0.8	1.03503	3.384	4.83
1.0	1.03429	3.315	4.74
2.0	1.03352	3.243	4.63
4.0	1.03329	3.222	4.60

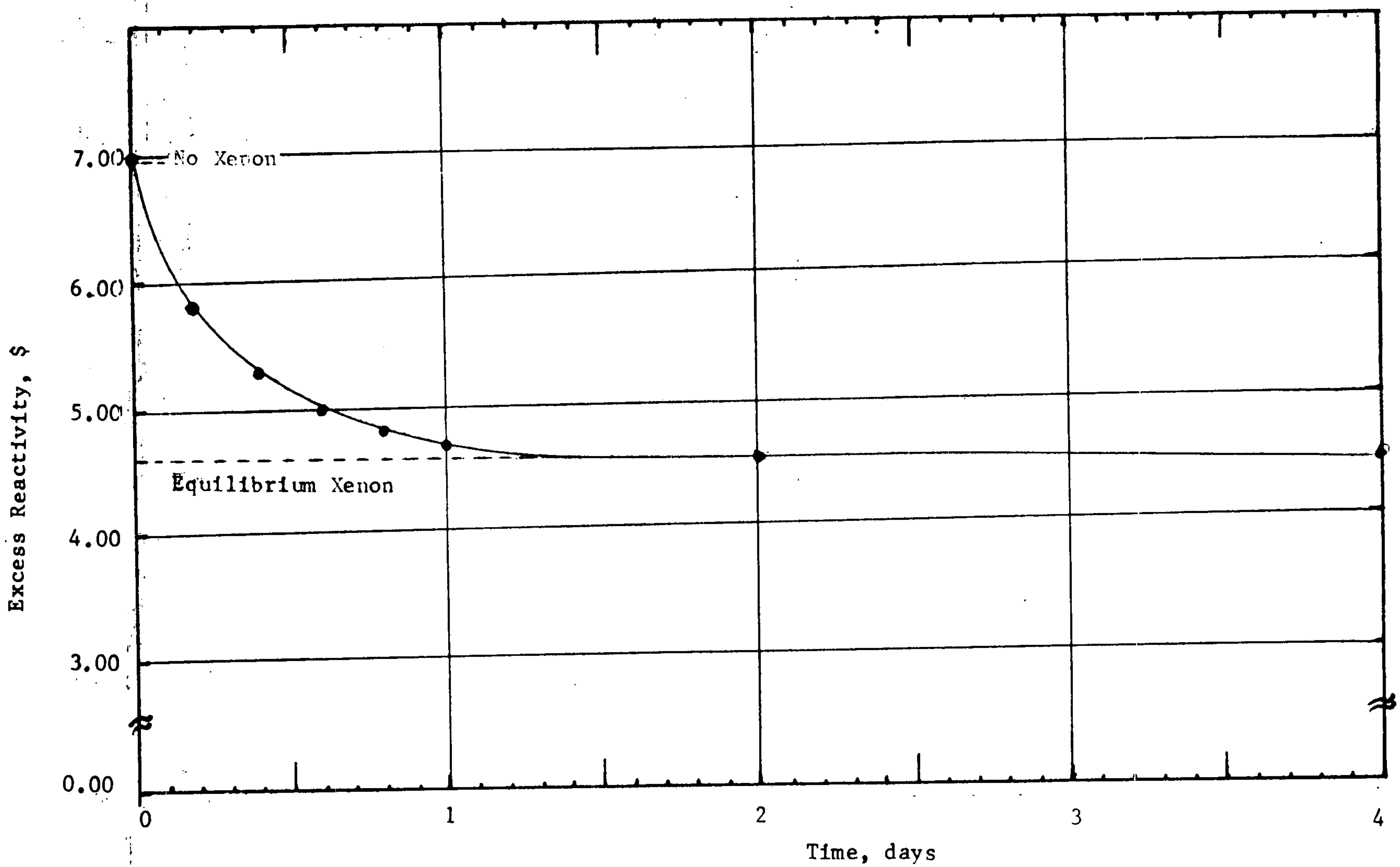


Fig. 5.4 Xenon buildup in four days operation in Core No.5