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LAC-TR-112

LACBWR CYCLE 7 FUEL PERFORMANCE

AND

FINALIZED REFUELING PLAN FOR CYCLE 8

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WP-3

1.0 SUMMARY

LACBWR Fuel Cycle 7 ended on April 9, 1982, after approximately 15 months of operation. The incremental core exposure during the cycle was 5953 MWD/MTU and the EOC core average exposure was 12,481 MWD/MTU. The cycle was limited by depletion of excess reactivity resulting from fuel burnup.

During the majority of Cycle 7 the off-gas activity and primary coolant gross β/γ, α, I-131, and Dose Equivalent I-131 activities were low and relatively steady at values below those recorded in Cycle 6 . The relatively small but significant increases in gross β/γ and iodine activities near the end of the cycle resulted from the failure of the one fuel rod in fuel assembly 1-08. (See Figure 2).

During the refueling outage each fuel assembly was removed from the core and examined. One assembly of fuel Type I had a single broken fuel rod and during the handling in the FESW approximately 5" of fuel rod fell out of the assembly. (See Section 2.2.2). All other fuel assemblies were free of defects. Table I gives a historical summary of LACBWR fuel performance for all seven cycles.

The LACBWR core configuration for Cycle 8 consists of 24 fresh Type III assemblies, 38 exposed Type III assemblies from EOC 7, and 10 exposed Type III assemblies which were discharged at EOC 6. No Type I or Type II Allis-Chalmers fuel assemblies will be in the reactor core during Cycle 8. All fuel assemblies are in Zircalloy shrouds.

The core average exposure at BOC-8 is 6,813 MWD/MTU. The expected length of Cycle 8 under full power condition is 4,831 MWD/MTU or 200 full power days. With coast-down to 85% of rated power the expected cycle length is 251 full power days or 358 days at 70% plant factor.

2.0 CYCLE 7 ANALYSES

2.1 CYCLE HISTORY

Cycle 7 began on January 11, 1981 and ended on April 9, 1982, for a total of 453 days. During this period the energy produced was equivalent to 283.9 full power days. The exposure distribution in the fuel at EOC-7 is shown in Figure 1. The core average exposure at EOC was 12,481 MWD/MTU and the cycle length was 5,953 MWD/MTU.

The cycle was terminated when the fuel assembly in core position C-8 reached the Technical Specification exposure limit of 17,200 MWD/MTU. However, the reactor power level near the end of the cycle was limited by depletion of excess reactivity resulting from fuel burnup. At the end of the cycle, the power level was 78% with the center control rod partially inserted. All other rods were fully withdrawn.

Figure 2 shows a power histogram for Cycle 7 along with off-gas activity and primary coolant gross β/γ, α, I-131 and Dose Equivalent I-131 activities. The radioactivity in the coolant and off-gas of a reactor is a sensitive indicator of fuel clad integrity. As can be seen from the plots in Figure 2, all of these parameters exhibited relatively constant, low values in the LACBWR during the majority of Cycle 7 indicating very little if any fuel clad degradation. The spikes in ^{131}I acitivity in the reactor coolant after the scram on October 18, 1981 probably indicate the initial failure of the defective fuel rod in fuel assembly 1-08 (see Section 2.2.2 below) and the increase in off-gas activity and coolant iodine activity during February and March of 1982 are indicative of further degradation of that fuel rod. The infrequent spikes in α acitivity in the reactor coolant were due to fuel material still in the system from previous fuel failures being resuspended in the coolant by reactor shutdown transients and the restarting of coolant pumps, etc.

2.2 FUEL INSPECTION

Each fuel assembly was removed from the reactor and examined in the spent fuel storage pool with an underwater TV camera and by direct visual observation. All assemblies except 1-08 were then examined for fission gas release by dry sipping. (See Section 2.2.3).

The inspection by TV camera revealed that one Type I fuel assembly, 1-08, had a broken fuel rod.

2.2.1 GENERAL APPEARANCE

With the exception of Assembly 1-08, the general appearance of the fuel was very good. No deformation of fuel rods or other assembly components were observed and no clad defects were evident. As in previous cycles, all the fuel assemblies exhibited some crud deposition but the extent of the crud build-up was less than that observed during previous refuelings. The present crud is lighter colored and more reddish in contrast to the darker colored crud observed in the past. Very little sloughing or flaking of the crud on the fuel rod surfaces were observed. The fuel assembly nozzles and lower fuel rod support grids were quite clean with no significant crud build-up.

2.2.2 FAILED ASSEMBLY 1-08

When fuel assembly 1-08 was removed from core position A-5 on April 20 it was observed that the second fuel rod from the NW corner in the outer row on the west side of the assembly (Reference Figure 1) was broken just above the lower intermediate spacer band. Several cracks in the clad were observed in a segment of this rod approximately 5.5 inches long. Essentially all of the clad appeared to still be present in the fuel assembly and probably no more than 10 g of uranium was missing from the assembly. The rest of the fuel assembly appeared to be in good condition with no defects or abnormalities noted.

During subsequent handling for additional examination and photography on May 18, a piece of the fuel rod approximately 5 inches long was dislodged from the assembly and fell to the bottom of the storage well.

This fuel rod failure appeared very similar to those observed in the past in LACBWR Type I and Type II fuel. The clad failure is probably due to oxygen assisted stress-corrosion cracking of the stainless steel induced by the stresses of pellet clad interaction.

The following history of this fuel assembly is of interest although no specific cause for the failure of the fuel rod has been discovered in the records. Assembly 1-08 was placed in the LACBWR core on July 11, 1967 during the initial reactor loading. On August 8, 1967 while being moved in the core as part of the Low Power Test Program, the lower intermediate spacer band was damaged when it hung up on the top of the fuel shroud and the assembly was returned to new fuel storage. In 1976 the fuel assembly was sent to the EXXON fuel fabrication facility to be repaired. The fuel rods were removed and then the bundle was reassembled with new intermediate spacer bands. During this work two fuel rods (not including the one that failed) were found to be slightly bowed and were straightened to meet specifications. A total of 31 fuel rods, including the two that were straightened, were radiographed to check on pellet integrity. Two of the rods, neither of which were the rod that failed, were found to contain a small but acceptable pellet chip. After being reassembled and having passed all QC checks the repaired assembly was returned to LACBWR on May 26, 1977. Assembly 1-08 was loaded into core position B-5 on May 7, 1979 for Fuel Cycle-6 operation and was moved to core position A-5 for Cycle-7 operation.

2.2.3 DRY SIPPING RESULTS

With the exception of 1-08, all fuel assemblies were examined for fission gas release by dry sipping. No significant variations were observed in the Xe-133 activity measurements, whereas during previous refueling's, dry sipping identified defective assemblies as those whose activities were from one to several orders of magnitude above the rest. Therefore, it was concluded that there were no leakers among the 71 assemblies which were dry sipped.

2.2.4 COMPARISON WITH PREVIOUS CYCLES

The fuel condition at the end of Cycle 7 was similar to that at EOC-6, with the exception of assembly 1-08. With only one failed rod, Cycle 7 performance bettered that of Cycles 1 through 5 and equalled that of Cycle 6.

The historical performance of the LACBWR fuel from Cycle 1 through Cycle 7 is presented in Table I. As seen from this table, Cycle 7 was of average length at 5,953 MWD/MTU. The end-of-cycle average exposure, maximum assembly average exposure, and average exposure of assemblies discharged were higher than some other cycles but still below design values.

The cycle operating conditions were approximately average for the LACBWR with 45 startups (~ 28 to heating power only), 13 scrams while at power, and 4 normal shutdowns from power. Four startups were from cold conditions. The end-of-cycle off-gas and primary system activities for each cycle are also listed in Table I. It is evident that at the EOC-7, all of these indicators of fuel condition are considerably lower than at the end of most previous cycles and are approximately the same as at the EOC-6.

To date, no fuel rod failures have been detected in the Type III (EXXON) fuel. This operational experience indicates that the Type III fuel is less prone to failure and will give much better and longer service than the Type I or Type II fuel.

3.0 FINALIZED LACBWR RELOAD PLAN FOR CYCLE 8

3.1 CORE CONFIGURATION FOR CYCLE 8

Two Type I fuel assemblies with an average exposure of 11,014 MWD/MTU and thirty-two Type III assemblies with an average exposure of 16,402 MWD/MTU were discharged at the end of Cycle 7. The average exposure of the 34 assemblies was 16,085 MWD/MTU. The assemblies discharged along with their core location during Cycle 7 and their exposure are listed in Table II.

The core configuration for Cycle 8 consists of 24 fresh Type III fuel assemblies, 38 exposed Type III assemblies from EOC-7, and 10 exposed Type III assemblies which were discharged from EOC-6. The fresh assemblies are arranged in a somewhat circular pattern, as shown in Figure 3. The core average exposure at BOC-8 is 6,813 MWD/MTU. All fuel shrouds will be Zircalloy.

3.2 EXPECTED LENGTH OF FUEL CYCLE 8

The detailed studies of the burnup of Cycle 8 with the Trilux code show that the expected cycle length under full power conditions is 4,831 MWD/MTU which is equivalent to 200 full power days. With coast-down to 85% of rated power after the control rods are fully withdrawn the expected cycle length is 251 full power days or 358 days at 70% plant factor. The highest exposure assembly will be on the periphery of the core and will be about 18,940 MWD/MTU when the core average is 12,890 MWD/MTU.

The lead exposure for the non-peripheral assemblies will be approximately 16,300 MWD/MTU, well below the present Technical Specification limit of 16,800 MWD/MTU.

The expected fuel exposure distribution near the end of Cycle 8 is shown on Figure 4.

3.3 COMPARISON OF ACTUAL RELOAD FOR CYCLE 8 TO PROPOSED RELOAD

The actual reload configuration for Fuel Cycle 8 shown in Figure 3 is nearly the same as the proposed reload shown in Figure 3 of LAC-TR-104.* The only differences are:

(1) The actual BOC core average fuel exposure is 6,813 MWD/MTU vs. 6,514 MWD/MTU in the proposed reload.

(2) The two Type I fuel assemblies 1-8 and 1-24 in core positions A-5 and A-6 of the proposed reload have been replaced by Type III assemblies 3-27 ad 3-6.

Check calculations have been performed which show that the minor increase in core average exposure (4.6%) and the substitution of two different exposed assemblies in peripheral positions will <u>not</u> have a significant effect on operating characteristics or reactor physics parameters. For example, the calculated minimum cold shutdown margin with 28 control rods inserted and one rod stuck out is 5.6%$\Delta k/k$ for the actual reload vs. 5.4%$\Delta k/k$ for the proposed reload.

The maximum worth for an ejected control rod was found to be 2.45%$\Delta k/k$ for the actual reload vs. 2.48%$\Delta k/k$ for the proposed reload, and, based on the rod withdrawal transient, the minimum allowable steady-state Minimum Critical Power Ratio was found to be 1.56 for the actual reload vs. 1.57 for the proposed reload.

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*"Refueling Plan for Cycle 8 of LACBWR," LAC-TR-104, November, 1981.

TABLE I
FUEL PERFORMANCE IN THE LACBWR

CONDITION	CYCLE 1 11 JULY 67- 19 AUG. 72	CYCLE 1A 14 OCT. 72- 30 MAR. 73	CYCLE 2 25 JUNE 73- 3 NOV. 73	CYCLE 3 21 DEC. 73- 9 MAY 75	CYCLE 4 11 AUG. 75- 11 MAY 77	CYCLE 5 9 MAR. 78- 25 MAR. 79	CYCLE 6 25 MAY 79- 9 NOV. 80	CYCLE 7 11 JAN. 81- 9 APR. 82
CORE AVG. EXPOSURE (MWD/MTU)	0 - 9,968	8,667 - 11,107	6,251 - 7,953	3,928 - 11,269	5,906 - 12,833	5,763 - 9,729	4,203 - 11,542	6,528 - 12,481
CYCLE LENGTH (MWD/MTU)	9,968	2,440	1,702	7,341	6,927	3,966	7,339	5,953
MAX. BOC ASSEMBLY AVG. EXP.	0	12,810	15,300	15,660	11,580	12,589	13,065	13,247
MAX. EOC ASSEMBLY AVG. EXP.	12,810	15,770	16,740	21,532	19,642	14,889	16,688	17,196
# OF ASSY. DISCH.	8	26	25	25	32	28	24	34
AVG. EXPOSURE OF DISCH.	11,490	14,360	11,591	15,530	16,459	13,966	14,872	16,085
# OF ASSY. DISCH. WITH $\bar{E}$ >15,000	0	10	3	9	27	0	12	32
# OF ASSY. DEFECTIVE	8 PROBABLE	20	23	10	26	17	1 PROBABLE	1
# OF ASSY. WITH VISIBLE DEFECTS	1	15	11	4	6	7	0	1
MAX. # OF VISIBLY DEFECTIVE RODS PER ASSEMBLY	1	9	8	6	9	4	0	1
TOTAL # OF VISIBLY DEFECTIVE ROD	3	42	36	18	19	12	0	1
ESTIMATED TOTAL # OF DEFECTIVE ROD	NA	47	48	24	40	22	1	1
NO. OF ASSY. WITH SIGNIFICANT FUEL DISPLACED DURING OPERATION	0	0	0	0	3	0	0	0
AVG. EXPOSURE OF DEFECTIVE ASSY.	11,490	13,986	11,190	16,691	16,774	13,880	16,688	11,006
EXP. RANGE OF DEFECTIVE ASSY'S	11,034 - 12,136	12,264 - 15,205	2,200 - 15,300	13,528 - 21,532	12,042 - 19,642	11,925 - 14,889	NA	NA
MAX. EXPOSURE OF GOOD ASSY.	12,810	15,770	16,740	18,982	17,361	14,713	16,656	17,196
SCRAMS WHILE AT POWER	NA	4	7	14	9	12	14	13
COLD SHUTDOWNS	NA	2	2	5	5	5	6	3
TOTAL # OF STARTUPS/TO HEATING RANGE ONLY			2[illegible]/8	53/27	32/11	23/7	50/29	45/28
FUEL TYPES (# OF ASSY/TYPE)	72/I	72/I	48/I, 24/II	24/I, 48/II	72/II	40/II, 32/III	2/I,12/II,58/III	2/I, 72/III

WP-3

TABLE I - (Continued)
FUEL PERFORMANCE IN THE LACBWR

CONDITION	CYCLE 1 11 JULY 67- 19 AUG. 72	CYCLE 1A 14 OCT. 72- 30 MAR. 73	CYCLE 2 25 JUNE 73- 3 NOV. 73	CYCLE 3 21 DEC. 73- 9 MAY 75	CYCLE 4 11 AUG. 75- 11 MAY 77	CYCLE 5 9 MAR. 78- 25 MAR. 79	CYCLE 6 25 MAY 79- 9 NOV. 80	CYCLE 7 11 JAN. 81- 9 APR. 82
STARTUPS FROM COLD SHUTDOWN			3	6	6	6	7	4
ROD MOVEMENT RESTRICTIONS	Rod Interchange Allowed at Full Power	Rod Interchange Allowed at Full Power	No Rod Interchanges Allowed	No Rod Interchanges Allowed	No Rod Interchanges Allowed	No Rod Interchanges Allowed	No Rod Interchanges Allowed	No Rod Interchanges Allowed
POWER ESCALATION RESTRICTIONS	None	Above 10% Power 1%/Min. With 10 Min. Hold After Each 5% Increase.	Above 10% Power 1%/Min. with 10 Min. Hold After Each 5% Increase. Also, 5%/Day Above 57% Power On First Escalation of Fuel Cycle.	Above 10% Power 10%/Hr. After July 1974, Reduced to 1%/Hr. Above 60% Power. Also, On Initial Escalation of Cycle, 10%/Day From 40% to 60% and 5%/Day Above 60% Power.	Above 10% Power 10%/Hr. Also, On Initial Escalation of Cycle 10%/Day From 40% to 60% and 5%/Day Above 60% Power.	5%/Hr. Up to 50% Power. 1%/Hr. Above 50% Power. All Cold Startups 10%/Day From 30% to 50% Power and 5%/Day Above 50% Power. Above 25% Power, No Control Rod Withdrawn More Than 4"/Hr.	15%/Hr Up to 50% Power. 1%/Hr. Above 50% Power. All Cold Startups 10%/Day from 30% to 50% Power and 5%/Day Above 50% Power. Above 25% Power, No Control Rod Withdrawn More Than 4"/Hr.	5/%Hr Up to 50% Power. 1%/hr above 50% Power. All cold startups - 5%/hr up to 40% Power. 10%/day from 40% to 60% Power. 5%/day above 60% power. Above 25% Power, no control rod withdrawn more than 4"/hr.
<u>END OF CYCLE CONDITIONS:</u>								
POWER	97%	98%	82%	85%	56%	49%	76%	78%
OFF-GAS ACTIVITY AFTER 150 FT^3 HOLDUP TANK (Ci/DAY)	Approx. 320	Approx. 900	Approx. 720 (Approx. 860)*	Approx. 450 (Approx. 519)*	Approx. 1,000 (Approx. 1,750)*	Approx. 290 (Approx. 500)*	Approx. 280 (Approx. 361)*	Approx. 320 (Approx. 402)*
PRIMARY SYSTEM GROSS β/γ ACTIVITY (μCi/g)	Approx. 1.0	Approx. 4.0	Approx. 2.1 (Approx. 2.5)*	Approx. 2.0 (Approx. 2.3)*	Approx. 13.0 (Approx. 22.8)	Approx. 3.1 (Approx. 6.2)*	Approx. .8 (Approx. 1.0)*	1.1 (Approx. 1.4)*
PRIMARY SYSTEM I-131 ACITIVITY (μCI/g)		Approx. 69.9E-3	Approx. 47.9E-3 (Approx. 57.2E-3)	Approx. 14.7E-3 (Approx. 16.9E-3)*	Approx. 37.4E-3 (Approx. 65.4E-3)	Approx. 9.3E-3 (Approx.18.6E-3)*	Approx. 2.1E-3 (Approx. 2.7E-3)*	1.9E-3 (Approx. 2.4E-3)*
PRIMARY SYSTEM DOSE EQUIVALENT I-131 ACTIVITY (μCi/g)						Approx. 3.9E-2 (Approx. 7.8E-2)	Approx. 1.5E-2 (Approx. 1.9E-2)*	1.7E-2 (Approx. 2.1E-2)*
PRIMARY SYSTEM α ACTIVITY (μCi/g)	Approx. 0.35E-6	Approx. 3.5E-6	Approx. 1.2E-6	Approx. 3.5E-6	Approx. 66.1E-6	Approx. .85E-6)	Approx. .08E-6	Approx.0.10E-6 (Approx.0.13E-6*

* Values in parentheses are estimated for 98% reactor power.

TABLE II

LACBWR Fuel Assemblies Discharged at End of Cycle 7.

Fuel Assembly No.	Core Position	Exposure, MWD/MTU
1-24	A-6	11,021
1-08*	A-5	11,006
3-28	C-8	17,196
3-5	H-3	17,166
3-31	B-7	17,128
3-2	K-4	17,067
3-30	B-4	17,053
3-3	K-7	16,988
3-20	D-9	16,948
3-13	G-2	16,940
3-17	D-2	16,863
3-16	G-9	16,855
3-25	C-3	16,853
3-8	H-8	16,820
3-53	G-7	16,653
3-40	D-4	16,625
3-54	E-8	16,624
3-39	F-3	16,603
3-52	G-4	16,536
3-41	D-7	16,512
3-51	E-3	16,370
3-42	F-8	16,357
3-57	C-6	16,130
3-36	H-5	16,086
3-22	B-9	15,993
3-11	K-2	15,985
3-21	B-2	15,919
3-12	K-9	15,915
3-56	C-5	15,889
3-37	H-6	15,845
3-49	F-6	15,263
3-44	E-5	15,258
3-48	F-5	15,216
3-45	E-6	15,211

Average exposure of discharged assemblies is 16,085 MWD/MTU.

*Assembly 1-08 had a failed fuel rod.

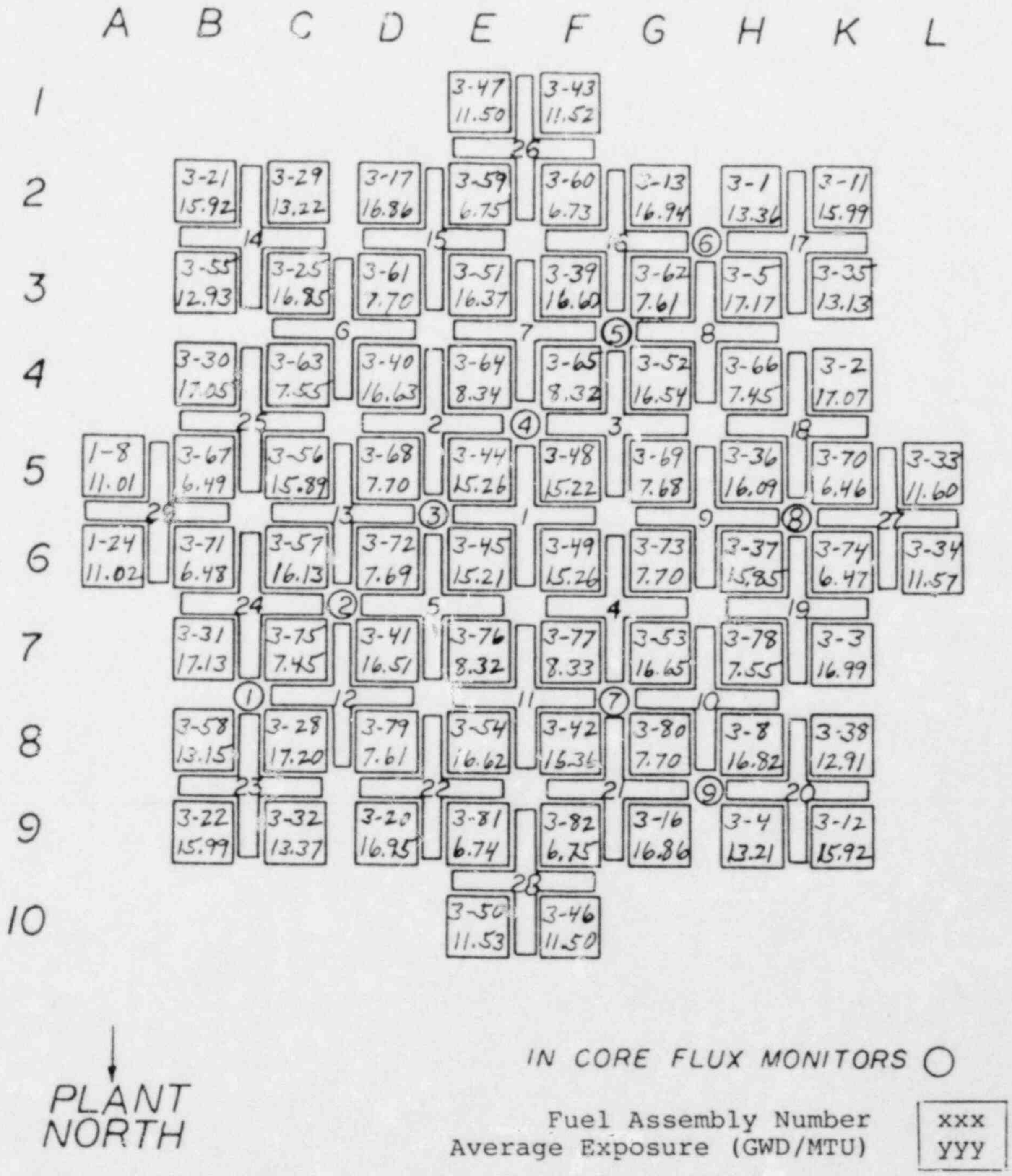

FIGURE 1 - LACBWR Core Configuration and Fuel Assembly Exposure at End-of-Cycle 7, April 9, 1982. EOC Core Average Exposure 12,481 MWD/MTU.

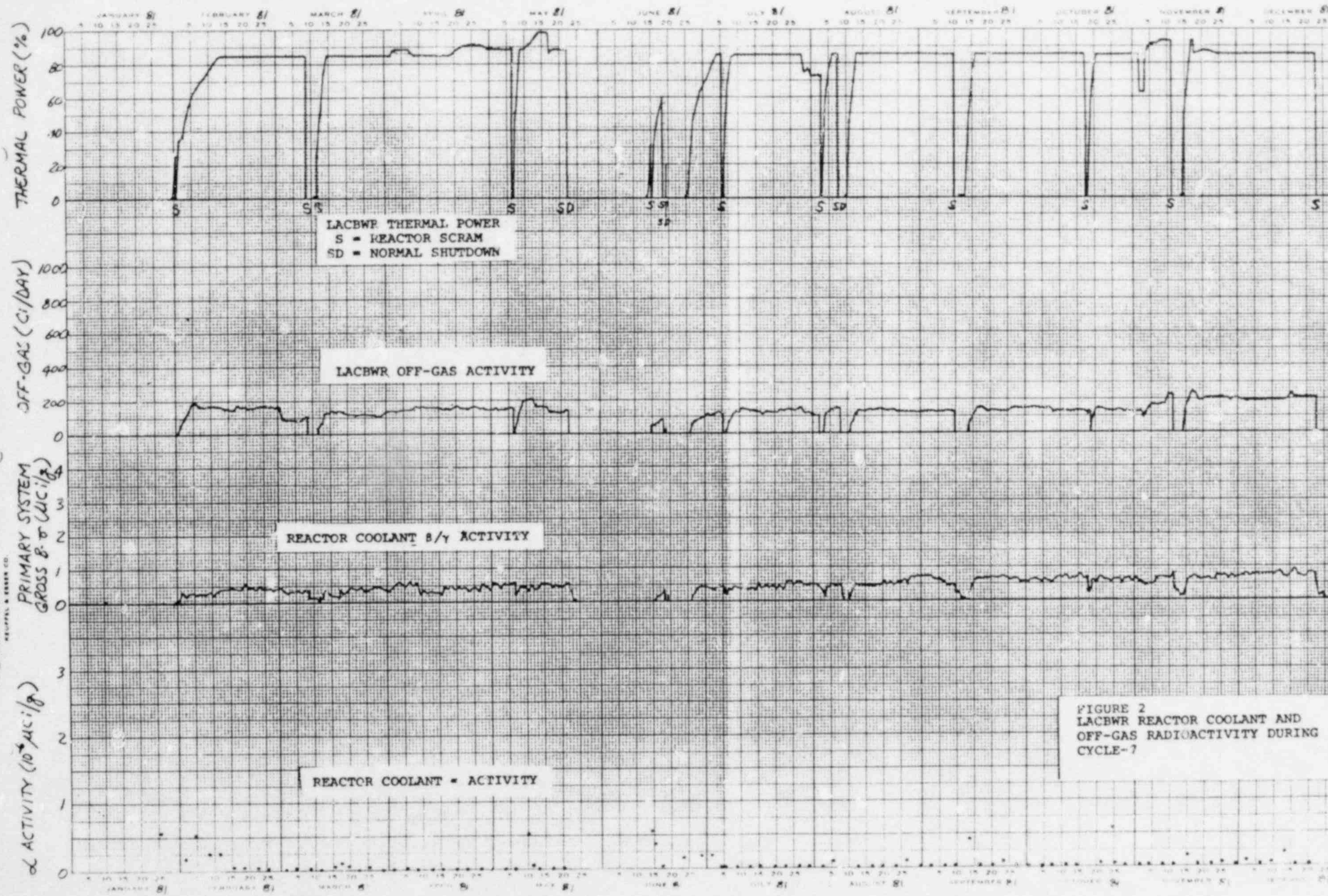

FIGURE 2
LACBWR REACTOR COOLANT AND OFF-GAS RADIOACTIVITY DURING CYCLE-7

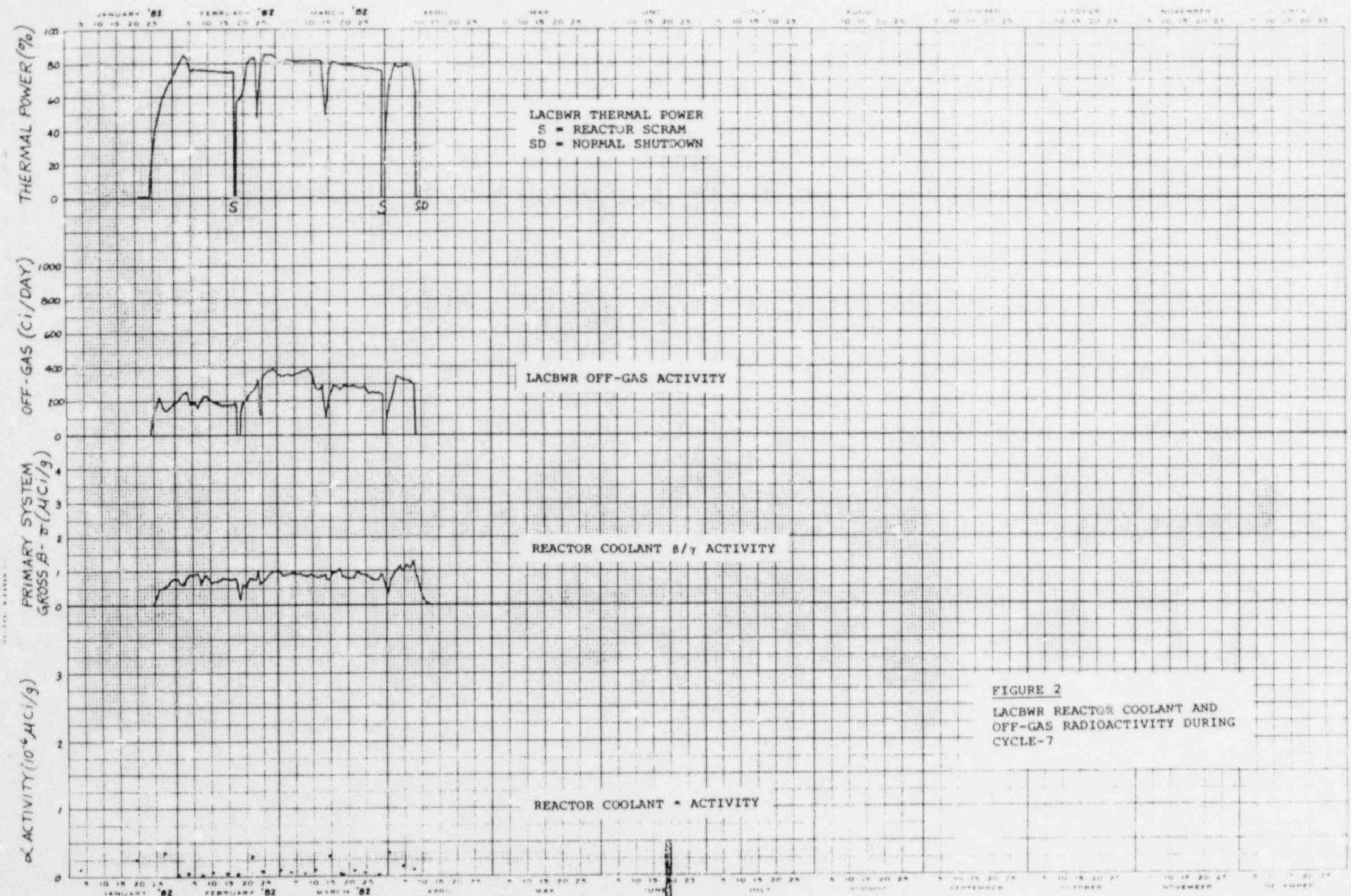

FIGURE 2

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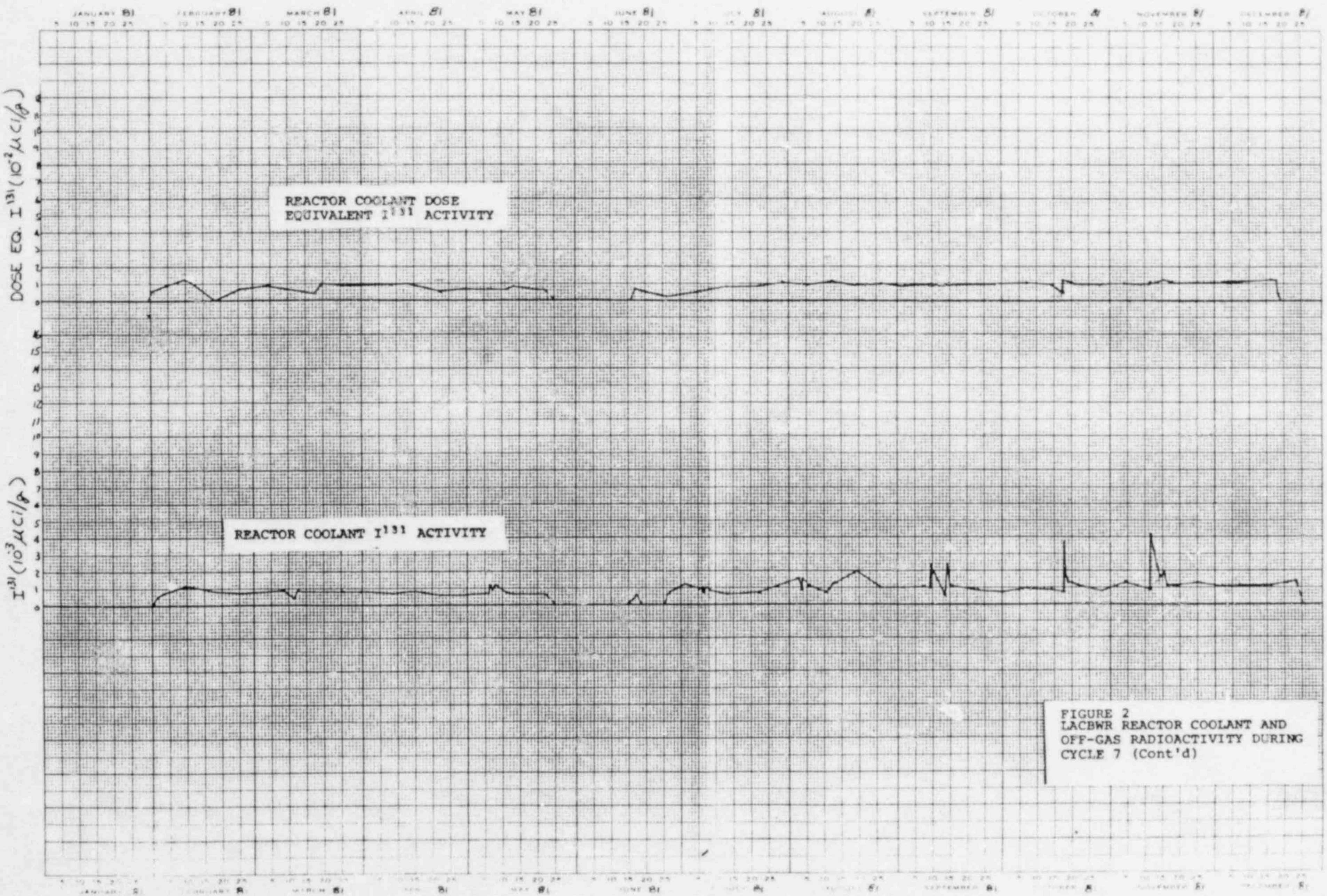

FIGURE 2
LACBWR REACTOR COOLANT AND OFF-GAS RADIOACTIVITY DURING CYCLE 7 (Cont'd)

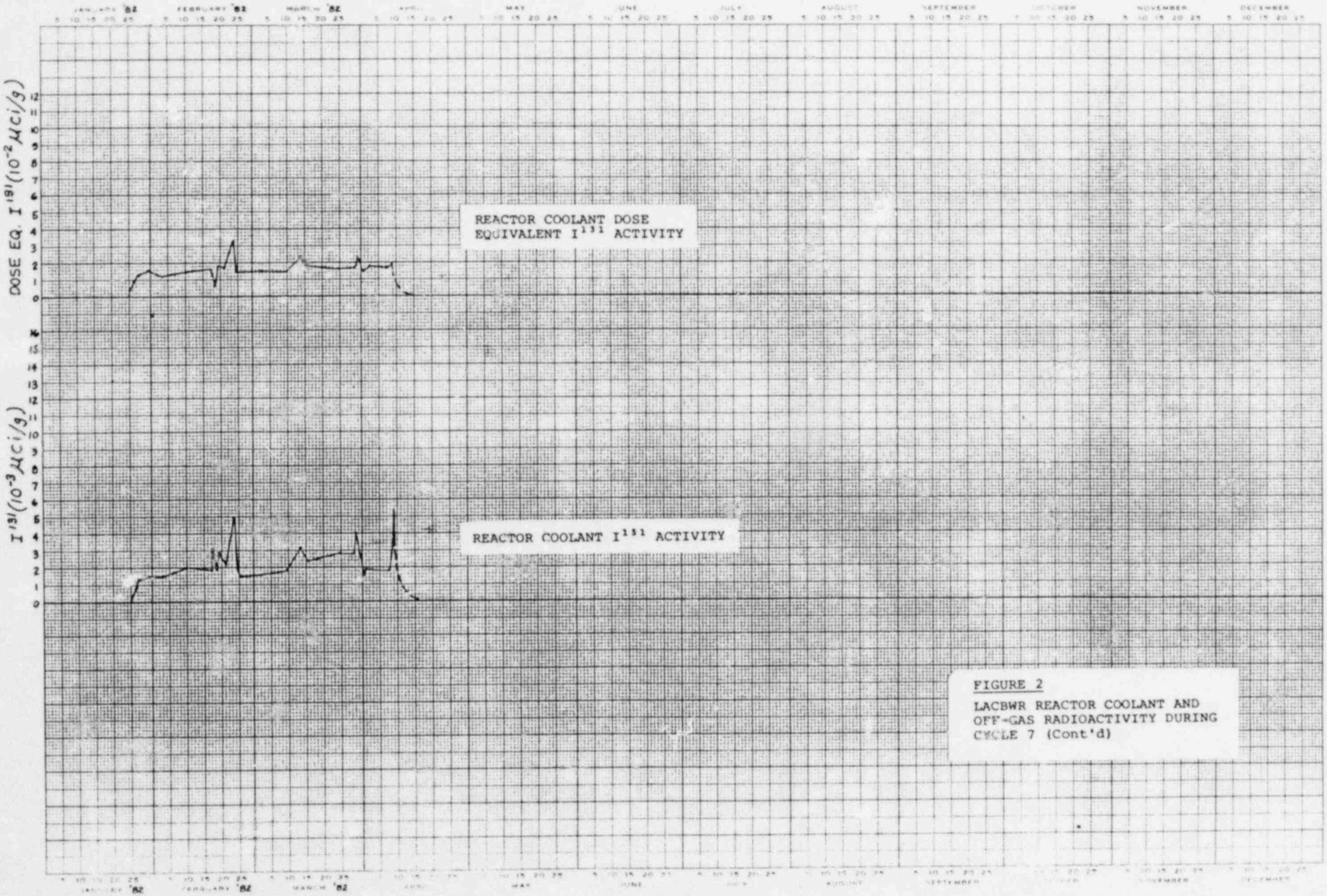

FIGURE 2

LACBWR REACTOR COOLANT AND OFF-GAS RADIOACTIVITY DURING CYCLE 7 (Cont'd)

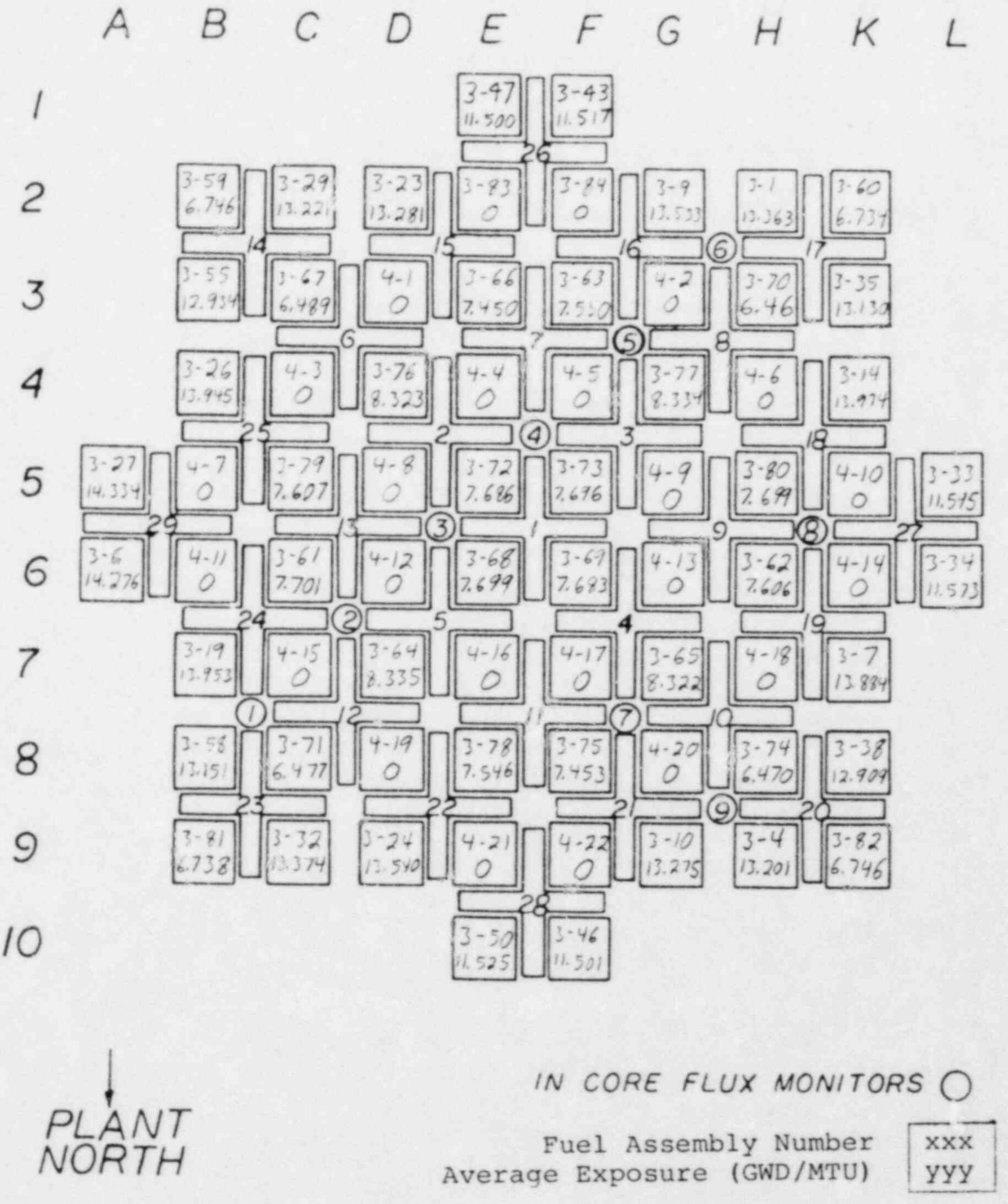

FIGURE 3 - LACBWR Reload Configuration for Cycle 8. The BOC Core Average Exposure is 6,813 MWD/MTU.

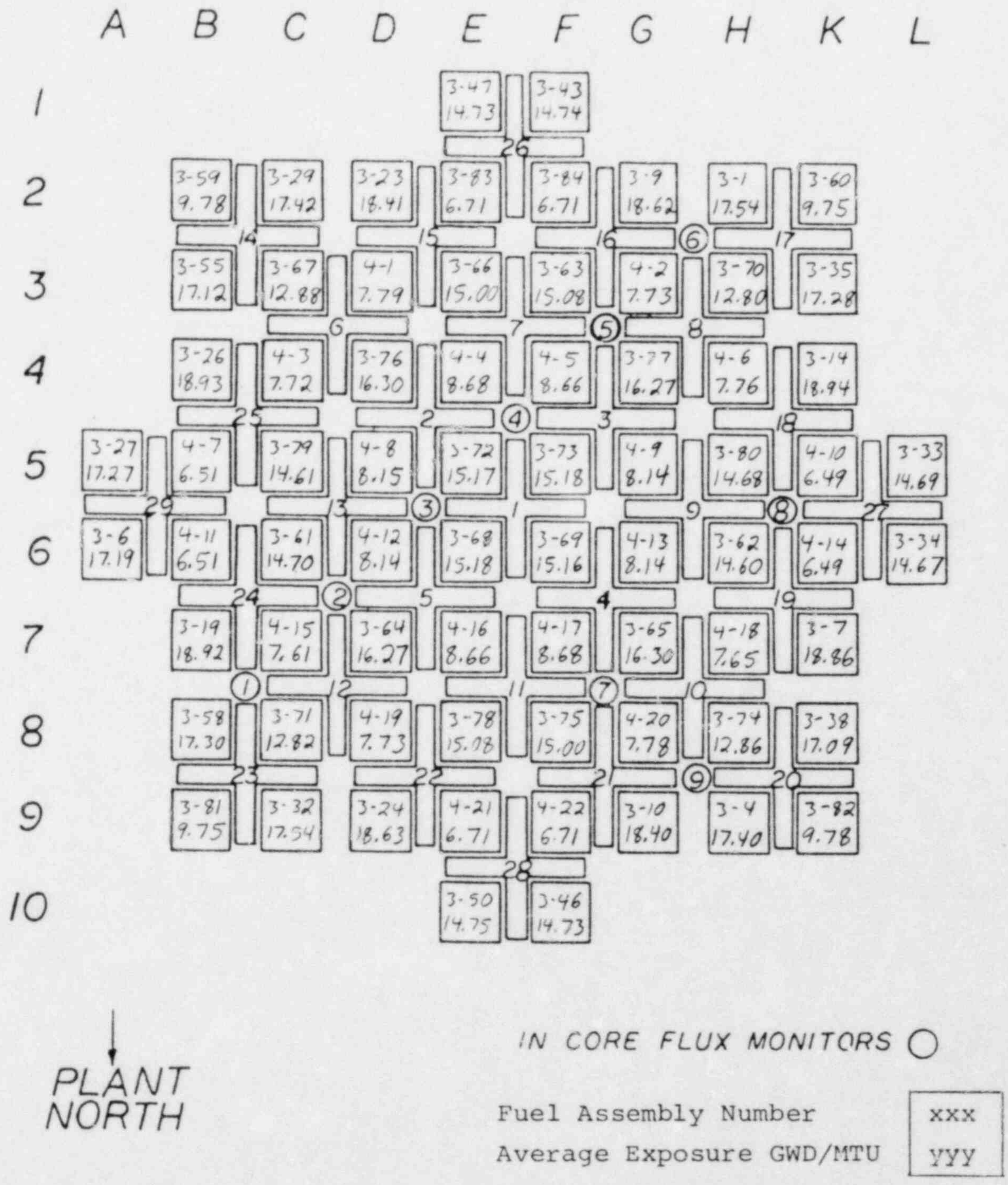

FIGURE 4 - EXPECTED FUEL EXPOSURE DISTRIBUTION NEAR END OF CYCLE 8. CORE AVERAGE EXPOSURE SHOWN IS 12,890 MWD/MTU.