EG&G
ENERGY MEASUREMENTS GROUP

EGG 1183-2455
S-746-R

UCRL--15419-1

DE86 011494

CLIMAX SPENT-FUEL DOSIMETRY

PROGRESS REPORT
SEPTEMBER 1981 - SEPTEMBER 1982

MASTER

by

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AUGUST 1982

This report is unclassified: ______________
Classification Officer

Work performed for the Lawrence Livermore National Laboratory
under SANL 909-034

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SUMMARY

Data from the second exchange of dosimeters from the Climax Spent Fuel Test Facility were evaluated for gamma-ray and neutron exposures. The data followed the previous trend of significant disagreement between the various exposures derived from measurements of different absorption peaks.

The effects of temperature during irradiation were investigated and shown to be the major, if not the only, cause of the differences observed and commented on in the previous data collected last year. New data concerning irradiation temperature can be used to eliminate from consideration any neutron-caused effects, of at least a gross magnitude, at the Climax facility. Corrected data taking into account the effects of temperature during irradiation are provided for last year's data as well as for the current year. The gamma-ray data show an overall decline in integrated dose, as expected from decay considerations. The neutron data are less consistent, with some apparent spectral shifts with time.

The 247-nm and 374-nm absorption peaks in LiF chips can provide dosimetry coverage from 10^4 to 10^8 rads-LiF. Calibration data at 25-30°C have verified that the dosimetry system is essentially temperature-independent over this range. The neutron fluence at the facility is small but measurable, and produces little effect on the gamma-ray dosimeters.

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1. INTRODUCTION

Work accomplished in FY82 is covered in this progress report. During this time one set of dosimeters was recovered from Climax test facility and evaluated for gamma and neutron exposures. Another set was emplaced. The resulting data from the gamma dosimeters followed the trend discussed in last year's report,[1] i.e., there was significant disagreement between the various exposures derived from measurements of different absorption peaks.

Verification of the previously found disagreement prompted a preliminary experiment to test the effect of elevated temperature during irradiation. Significant effects were found contrary to expectations based on published data.[2] These preliminary data showed that the 443-nm peak was much more severely affected than either the 247-nm or 374-nm peaks. If overlap could be achieved, these latter two peaks appeared to be the best choice for dosimeters at elevated temperatures.

The calibration data from FY81 stopped at A.U. 2.5* due to limitations of the spectrophotometer used (and small size of the LiF chips). Adequate overlap between the 247-nm and 374-nm peaks could only be obtained if the upper density limit were extended to A.U. 5 and the lower to A.U. 0.01. Fortunately, the existing spectrophotometer, a Beckman 5270, had been constantly improved and A.U. 0.01 was readily achievable; unfortunately, A.U. 5 was still out of reach. By chance the 247-nm absorption peak is near the 253.7-nm emission line of a low-pressure mercury arc source. There also is an emission line at 296.5 nm, near the minimum between the absorption peaks at 247 nm and at 315 nm. Armed with this information, we constructed a simple hand-operated spectrophotometer out of a low-pressure mercury arc lamp and the monochrometer from the 1L500 photometer (used last year for ratio measurements). This apparatus was designed to have the highest photon throughput possible, and appears to yield acceptable data at least to A.U. 4.5. Several cross checks were made at lower absorbances with the 5270 spectrophotometer and good agreement was found.

The finding of temperature effects during irradiation implied that some part of the FY81 data needed correction. Furthermore, a new calibration curve was necessary. Both these tasks were accomplished, and are presented in the report.

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*Absorbance Units (A.U.) = $-\log_{10} T_i$ where T_i is the internal transmittance

2. GAMMA-RAY CALIBRATION AT ELEVATED TEMPERATURES

The gamma-ray data reported last year did not agree internally; that is, the exposures determined from the 443-nm and the 374-nm peaks were different. The most likely explanation (of those not explored) was the effect of elevated temperature during exposure. Existing data[2] implied little, if any, effect on the 443-nm peak, and hence the presumption was that the 374-nm peak had a significant temperature sensitivity. This was further reinforced by the reasonable agreement found between the 443-nm and 247-nm data at 0.51 m and 0.66 m radii in CEH3. Resolution of this problem, involving a new set of calibration curves obtained at an elevated temperature, was left for this year. The set of preliminary data obtained from this year's dosimetry revealed a similar disagreement, and an exploratory number of points were subsequently obtained at a 70°C temperature using a convenient ^{60}Co source at our facility. These new data showed a significant temperature effect for the 443-nm peak and zero to small effects on the other two peaks. Clearly, a new calibration was needed.

The original calibration data were obtained by use of a ^{60}Co array at Sandia National Laboratory. At the time we expected to obtain exposures in Climax up to 5×10^8 rads-LiF, and the Sandia facility was the only suitable source. Actual field exposures, however, did not exceed 4×10^7 rads-LiF, and could thus be simulated on sources at our facility with lower cost to the project. These sources provided rates of 1700 or 1.2×10^5 rads per hour.

A simple temperature-controlled exposure holder for 10 LiF chips was constructed, and calibration curves were obtained from 10^4 to 2×10^7 rads-LiF. These curves, shown in Figure 1 superimposed on the previous 25°-30°C curves from the Sandia irradiations, have some interesting features. First we see that the 443-nm peak shows a large shift between the two temperatures. This most likely means intermediate curves for intermediate temperatures, an undesirable complication.

Second, we notice essentially no temperature effect on the 374-nm peak. The slope at low exposures is different, but it is thought that improvements to the Beckman 5270 spectrophotometer which enabled these points to be taken have resulted in a more accurate curve shape in this region.

The last feature of interest involves the 247-nm data. The preliminary exploration mentioned above led us to expect that the 443-nm peak, when calibrated at low temperatures, would not be useful as a dosimetric tool at high temperatures. Continuous coverage of the exposures expected could only be obtained if the 247-nm curve were extended upward in exposure and the 374-nm curve extended downward to meet or overlap with it. As noted, the spectrophotometer had been continually improved, and eventually reasonable data were obtained at A.U. 0.01 or $\sim 10^6$ rads/LiF for the 374-nm peak. Unfortunately, not enough photons were available to go beyond ~A.U. 2.5 for the 247-nm peak; this left a gap between the upper range of the 247-nm curve and the lower range

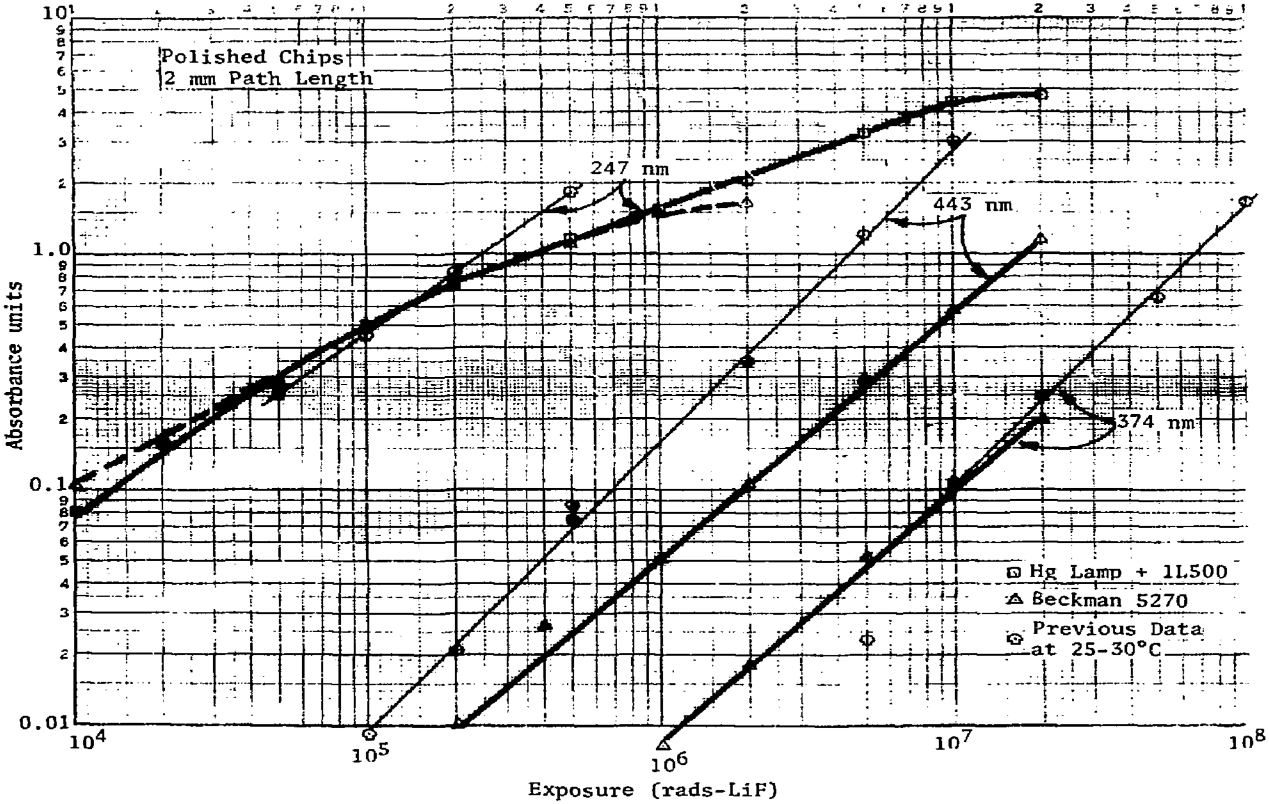

Figure 1. LiF calibrations at 60°C

of the 374-nm curves. Worse yet, these tails of the curves were not as reliable as the main body of data, and the effective gap was wider than at first sight.

The solution worked out for this impasse was found by the observation that the 253.7-nm line from a low-pressure mercury arc lamp, a very intense line, was near the 247-nm absorption peak in LiF. The FWHM for the 247-nm peak is about 40 nm, and thus the 253.7-nm emission line at 7 nm above the peak centroid wavelength is close enough to the peak position that it could be used for accurate absorption measurements. By chance, a second mercury line at 296.5 nm is near a minimum between the 247-nm and 315-nm peaks. We could thus measure absorption peak height from the transmitted intensities measured for these two mercury lines. In the simple spectrometer we constructed, care was taken to obtain the highest photon throughput. Initial measurements with various ND filters suggested we could measure up to A.U. 5. This extrapolated to $\sim 5 \times 10^6$ rads-LiF, and gave a confortable overlap with the 374-nm data.

As seen from Figure 1 we were only able to reach A.U. 4 to 4.5 reliably. The slope is quite different from the previous data, however, and overlap to $\sim 1 \times 10^7$ rads-LiF is possible. The 5270 data, taken from the same set of 10 chips, illustrate that the special spectrometer does yield A.U. values rather than arbitrary numbers and, further, that the low photon flux available in the 5270 causes a saturation-like effect at about A.U. 1.5.

In summary we find the following:

1. The 443-nm calibration curve exhibits significant effects correlated with temperature during irradiation.
2. These effects probably vary with temperature, and hence a multiplicity of curves would be needed to cover the Climax situation.
3. The 374-nm calibration curve shows little effect of temperature during irradiation. It has been measured between 10^6 and 2×10^7 rads-LiF at 60°C. Previous data extend up to 10^8 rads-LiF at ~30°C.
4. The 247-nm calibration curve shows some effect of temperature during irradiation. It has been measured from 10^4 to 2×10^7 rads-LiF, is useful only up to $\sim 1 \times 10^7$ rads-LiF. The previous data from ~30°C show only slight deviations up to $\sim 2 \times 10^5$ rads-LiF.
5. The combination of the 247-nm peak with the low-pressure mercury arc spectrometer source and the 374-nm peak using a standard spectrophotometer provide continuous dosimetric coverage from less than 10^4 to 10^8 rads-LiF.

3. CORRECTIONS TO FY81 DATA

Last year's Climax Spent Fuel Dosimetry report (EG&G 1183-2432)[1] contained gamma dosimetry data (Table 5, page 12) based on calibrations done at 25 to 30°C. Data presented in Section 2 of this present report show that some of the reported data are in error by significant amounts, others are only slightly different, and the 374-nm data are unaffected by use of a 60°C calibration curve. This higher temperature calibration curve is thought to be more nearly representative of the actual Climax conditions.

The raw data from FY81 have been examined, and new exposures were determined using the 60°C calibration curves presented in Figure 1. Since these calibration data were obtained with relatively short exposure times compared to the Climax Test duration, the fade corrections discussed in the previous report have been applied to the newly determined exposures. The results of these changes are given in Table 1. This set of data represents the best estimates at the present time for the gamma-ray exposures encountered in Climax.

Note that the 443-nm data have been eliminated, since the calibration curves necessary for their interpretation were not measured. The 547-nm data also do not have proper calibration curves. The remaining two data sets do cover the complete experimental range, however, and have the benefit in most cases of two calibration curves, one at 60°C and the old one at 25-30°C.

The 247-nm data were estimated by using the A.U. measured last year for each dosimeter together with the new 60°C calibration curve of Figure 1. This procedure was necessary since the dosimeters had been baked out for reuse. Thus, the dosimeters themselves were not read in the Hg-lamp spectrometer described this year, and hence the validity of these data depends upon: 1) the present spectrometer providing A.U. data rather than relative numbers, and 2) that the previous readings actually were correct A.U. values. It appears from Figure 1 that the Hg-lamp spectrometer does yield data similar to the Beckman 5270 and hence provides proper A.U. values. There is, however, a significant slope difference between the previous data (labeled 25-30°C on Figure 1) and the current calibration curve. A similar, though less pronounced, slope difference is seen in the 443-nm data in Figure 1, and it is expected that the irradiation environment temperature is responsible for these effects. If this is the case and since we have shown that the present Hg-lamp spectrometer does indeed yield A.U. data, the values reported in Table 1 for last year's exposure should be closer to the actual values than the previous data.

An error found in the original data reported for the pre-exposed chip at 0 meters in hole CEH4 has been corrected in Table 1 (and also in Appendix A).

The extension of the 374-nm calibration curve to lower A.U. values showed that the 5×10^6 rad point at 0.023 A.U. was in error. Elimination of this point allowed a better fit to the upper four points on the 25-30°C calibration curve extending from 1×10^7 to 1×10^8 rads. This curve in Figure 1 was used to reinterpret the FY81 data in conjunction with the 60°C 247-nm curve.

Table 1. Gamma dosimeter data* -- exposure period: April 1980 to 12 January 1981

Hole Number, Dosimeter Location	Vertical Distance From Midplane (m)	Exposure (rads/LiF)	
		247 nm Peak	374 nm Peak
CEH1 (wall)	+1.22		2.9×10^7
	0		3.2×10^7
	-1.22		2.9×10^7
CEH3 (wall)	+1.83		1.4×10^7
	+1.22		3.2×10^7
	+0.61		3.4×10^7
	0		3.6×10^7
	-0.61		3.6×10^7
	-1.22		3.8×10^7
	-1.83		1.7×10^7
CEH3 (0.51 m)	+1.22	$1.6 \pm 0.3 \times 10^6$	1.3×10^6
	0	$1.1 \pm 1.9 \times 10^6$	--
	-1.22	$1.0 \pm 1.7 \times 10^6$	1.2×10^6
CEH3 (0.66 m)	+1.22	$9.9 \pm 0.3 \times 10^4$	
	0	$1.2 \pm 0.3 \times 10^5$	
	-1.22	$1.4 \pm 0.2 \times 10^5$	
CEH4 (heater) (wall)	+1.22		6.4×10^6
	0		5.3×10^7
	-1.22		>3 A.U.
CEH7 (wall)	+1.22		3.0×10^7
	0		3.0×10^7
	-1.22		3.7×10^7
CEH11 (wall)	+1.22		2.8×10^7
	0		3.0×10^7
	-1.22		2.7×10^7

*NOTES:
1. Data without errors indicated have errors of 3-4% at 2σ. Other indicated errors are at 2σ.
2. Data have been corrected for temperature-induced fade.
3. >3 A.U. means density exceeded measuring range of spectrophotometer.
4. CEH4 had pre-irradiated chips with exposures of 8.5×10^6, 5.6×10^7, and 2.9×10^8 given.
5. See Appendix A for raw data.

4. FIELD DATA, CLIMAX TEST

This section presents the gamma-ray and neutron dosimetry data obtained during the 284-day exposure from January 1981 to October 1981. Details of the dosimetry apparatus and analysis methods are contained in the preceding report, EG&G 1183-2432.[1]

4.1 DOSIMETRY LOCATIONS

The dosimetry locations were identical to those noted in the previous report except that all locations had the same 284-day exposure time.

4.2 GAMMA-RAY DOSIMETRY DATA

The gamma-ray data derived from the ^{7}LiF chips are given in Table 2. All exposures are based upon the current 60°C calibration curves (Figure 1). The 247-nm data were taken with the special spectrometer described in Section 2. The 374-nm data were derived from measurements made with a Beckman 5270 spectrophotometer, the same instrument used for the previous year's data. Improvements to this instrument have resulted in an extension of its calibration curve to lower exposures, and a general reduction of noise.

The tabulated errors and those in the Table 2 footnote refer to the precision of individual determinations. The overall accuracy, traceable to the NBS through our 3-terminal ionization chamber data, is no better than ±4%. Thus, the best of the data are approximately ±6%. Even though the present 60°C calibration curve seems to have solved the previous uncertainties, it should be remembered that there may still be some uncorrected temperature effects in these data.

4.3 NEUTRON ACTIVATION FOIL DATA

Table 3 contains the basic activation foil data obtained from the SAMPO Ge(Li) detector fitting code. Corrections have been made for lack of saturation due to the short exposure time, decay during counting, and resonance self-absorption for the cobalt and silver foils. The large errors noted for many of the data points reflect the low counting rates observed. The Table 3 data were used as input to an iterative unfold code, CRYSTAL BALL, which produces a neutron spectrum that could have caused the set of activities found. At least three different activation foils are required for proper operation of this code; hence, only spectra for the wall locations were obtained.

Table 4 presents the results of the spectral unfolding process. As noted in last year's progress report, more detail is available if needed.

Table 2. Gamma dosimeter data* — exposure period: 12 January 1981 to 23 October 1981

Hole Number, Dosimeter Location	Vertical Distance From Midplane (m)	Exposure (rads/LiF)	
		247 nm Peak	374 nm Peak
CEH1 (wall)	+1.22		2.8×10^7
	0		2.9×10^7
	-1.22		2.9×10^7
CEH5 (wall)	+1.22		2.8×10^7
	+0.61		2.9×10^7
	0		3.1×10^7
	-0.61		3.2×10^7
	-1.22		3.1×10^7
	-1.83		1.6×10^7
	-2.44		--
CEH3 (0.51 m)	+1.22	$1.5 \pm 0.2 \times 10^6$	1.2×10^6
	0	$1.4 \pm 0.2 \times 10^6$	--
	-1.22	$1.4 \pm 0.2 \times 10^6$	--
CEH3 (0.66 m)	+1.22	$9.1 \pm 1.8 \times 10^4$	
	0	$9.0 \pm 0.2 \times 10^4$	
	-1.22	$7.5 \pm 1.4 \times 10^4$	
CEH4 (heater) (wall)	+1.22		2.3×10^6
	0		2.0×10^7
	-1.22		>3 A.U.
CEH7 (wall)	+1.22		2.9×10^7
	0		2.7×10^7
	-1.22		3.0×10^7
CEH11 (wall)	+1.22		2.7×10^7
	0		2.8×10^7
	-1.22		2.8×10^7

*NOTES:
1. Data without errors indicated have errors of 3-4% at 2σ. Other indicated errors are at 2σ.
2. Data have been corrected for temperature-induced fade.
3. >3 A.U. means density exceeded measuring range of spectrophotometer.
4. CEH4 had pre-irradiated chips with exposures of 5.0×10^6, 2.0×10^7, and 5.0×10^8 given.
5. Exposure duration was 284 days.
6. See Appendix B for raw data.

Table 3. Activation foil data

Hole Number, Dosimeter Location	Vertical Distance From Midplane (m)	Saturated dps Per Nucleus			
		^{60}Co	^{110m}Ag	^{54}Mn	^{58}Co
CEH1 (wall)	0	1.696 E-19 ±0.102	9.701 E-20 ±0.182	1.763 E-22 ±0.182	2.914 E-22 ±0.116
CEH3 (wall)	+1.22	1.743 E-19 ±0.180	7.677 E-20 ±0.195	1.216 E-22 ±0.210	1.621 E-22 ±0.182
	+0.61	2.318 E-19 ±0.168	1.077 E-19 ±0.167	1.367 E-22 ±0.214	2.192 E-22 ±0.171
	0	2.474 E-19 ±0.152	1.021 E-19 ±0.173	1.804 E-22 ±0.174	2.409 E-22 ±0.156
	-0.61	1.722 E-19 ±0.070	9.544 E-20 ±0.243	1.793 E-22 ±0.277	2.608 E-22 ±0.221
	-1.22	1.671 E-19 ±0.197	7.082 E-20 ±0.230	1.254 E-22 ±0.225	1.888 E-22 ±0.197
	-1.83	2.408 E-19 ±0.154	8.424 E-20 ±0.222	--	--
	-2.44	--	--	--	--
CEH3 (0.51 m)	0	3.085 E-19 ±0.161	1.302 E-19 ±0.410	--	--
CEH5 (0.66 m)	0	1.654 E-19 ±0.062	6.882 E-20 ±0.121	--	--

*NOTES:

1. ± figures are fractional errors at 2σ, i.e., 0.102 is 10.2%. These have been derived from fitting errors and multiple counts.
2. ^{60}Co and ^{110m}Ag have been corrected for self absorption of 0.2 and 0.072, respectively.
3. No activity was detectable for foils at hole CEH4. No data were taken for holes CEH7 and 11. Lack of other entries in the table means foil activity was too low to be quantifiable.

Table 4. Results of CRYSTAL BALL unfold code*

Hole Number, Dosimeter Location	Vertical Distance From Midplane (m)	Neutron Exposure Rate		E_{ave} (MeV)	n/cm^2-s	
		rads/s	REM/s		<0.55 eV	>0.55 eV
CEH1 (wall)	0	2.11 E-5	1.46 E-4	0.335	3600	16300
CEH3 (wall)	+1.22	1.26 E-5	7.55 E-5	0.232	4500	10100
	+0.61	1.78 E-5	1.14 E-4	0.255	4300	15300
	0	1.79 E-5	1.09 E-4	0.245	6300	14000
	-0.61	1.75 E-5	1.12 E-4	0.289	4000	14400
	-1.22	1.37 E-5	8.77 E-5	0.274	4300	10300

*NOTE: Errors on unfolded data are probably no better than ±30%.

5. DISCUSSION

The effects of temperature during irradiation have been investigated and have been shown to be the major, if not the only, cause of the differences observed and commented upon in the data collected last year. The 443-nm peak exhibited the largest temperature effect and has been dropped from further consideration. The 547-nm peak, useful primarily for exposures in excess of those encountered in Climax, has also been dropped. The remaining two peaks, 247 nm and 374 nm, were retained for the current experiment and their 60°C calibration curves given in Figure 1 illustrate the lack of a temperature effect for the 374-nm peak and the relatively small effect on the 247-nm peak.

It is believed that these new data concerning irradiation temperature can be used to eliminate from consideration any neutron-caused effects, at least of a gross magnitude, at Climax.

The gamma-ray data show an overall decline in integrated dose, as would be expected from decay considerations. There are a few exceptions in the data for the 0.51-m distance in hole CEH3, probably due to measurement errors. The neutron data are less consistent with some apparent spectral shifts with time.

The chips in the heater hole, CEH4, were given exposures before emplacement, as noted in Table 2. The general agreement found in the post-exposure measurements is encouraging.

In conclusion the 247-nm and 374-nm peaks can provide dosimetry coverage from 10^4 to 2×10^7 rads-LiF at 60°C. Parts of this range, 10^4 to 2×10^5 rads for the 247-nm peak and 10^6 to 10^7 rads for the 374-nm peak, have been shown to be free of environmental temperature effects at 25-30°C compared to 60°C during irradiation. The slope and position of the 374-nm curve from 10^7 to 10^8 rads for a 25-30°C irradiation environment suggest that it may be applicable at 60°C as well. The neutron fluence rate at Climax is small but measurable, and produces little effect upon the gamma-ray dosimeters. Changes in the ^{60}Co and ^{110m}Ag activities may be a guide to water infiltration, since their cross sections imply a sensitivity to lower energy neutrons that may result from moderating effects of the water.

REFERENCES

1. Quam, W. and T. DeVore, "Climax Spent Fuel Dosimetry — Progress Report, FY 1980-1981," EG&G Report Number EGG 1183-2432, Santa Barbara Operations Report Number S-720-R (October 1981).

2. McLaughlin, W.L., et al., "Electron and Gamma-Ray Dosimetry Using Radiation Induced Color Centers in LiF," Second International Meeting on Radiation Processing, Miami, Florida (October 1978).

APPENDIX A: TABULATION OF RAW DATA TAKEN JANUARY 1981 USING BECKMAN 5270 SPECTROPHOTOMETER

These data were used together with the calibration curves of Figure 1 to derive the Fade-Corrected Data given here and in Table 1.

Hole Number, Dosimeter Location	Vertical Distance From Midplane (m)	Maximum Temperature (°C)	247 nm			374 nm			443 nm	
			A.U.	Fractional Fade	Fade-Corrected Data	A.U.	Fractional Fade	Fade-Corrected Data	A.U.	Fractional Fade
CEH1 (wall)	+1.22	65				0.380	1.00	2.9(7)	1.89	0.96
	0	72				0.435	0.99	3.2(7)	2.08	0.94
	-1.22	61				0.392	1.00	2.9(7)	1.53	0.97
CEH3 (wall)	+1.85	71				0.161	1.00	1.4(7)	0.83	0.94
	+1.22	71				0.434	1.00	3.2(7)	2.17	0.94
	+0.61	78				0.444	0.97	3.4(7)	2.33	0.91
	0	78				0.491	0.97	3.6(7)	2.59	0.91
	-0.61	78				0.483	0.97	3.6(7)	2.71	0.91
	-1.22	60				0.540	1.00	3.8(7)	>3	0.98
	-1.83	60				0.201	1.00	1.7(7)	1.03	0.98
CEH3 (0.51 m)	+1.22	65	1.424	0.74	1.6(6)	0.011	1.00	1.3(6)	0.068	0.97
	0	69	1.210	0.73	1.1(6)	<0.01	1.00	--	0.055	0.95
	-1.22	63	1.223	0.75	1.0(6)	0.01	1.00	1.2(6)	0.055	0.98
CEH3 (0.66 m)	+1.22	61	0.373	0.76	9.9(4)				0.005	0.98
	0	65	0.416	0.74	1.2(5)				0.005	0.97
	-1.22	60	0.457	0.76	1.4(5)				0.007	0.99
CEH4 (heater) (wall)	+1.22	76				0.062	0.98	6.4(6)	1.96	0.92
	0	82				0.738	0.96	5.3(7)	>3	0.89
	-1.22	59				>3	1.00	--	>3	0.98
CEH7 (wall)	+1.22	67				0.400	1.00	3.0(7)	2.01	0.96
	0	73				0.408	0.99	3.0(7)	2.05	0.93
	-1.22	59				0.515	1.00	3.7(7)	2.85	0.98
CEH11 (wall)	+1.22	68				0.377	1.00	2.8(7)	1.84	0.95
	0	78				0.395	0.97	3.0(7)	1.93	0.91
	-1.22	67				0.354	1.00	2.7(7)	1.80	0.96

APPENDIX B: TABULATION OF RAW DATA TAKEN DECEMBER 1981 AND JULY 1982 USING Hg-LAMP SPECTROMETER FOR THE 247-nm PEAK AND IMPROVED BECKMAN 5270 FOR THE 374-nm PEAK

These data together with the calibration curves of Figure 1 were used to derive the exposures tabulated below and in Table 2.

Hole Number, Dosimeter Location	Vertical Distance From Midplane (m)	Maximum Temperature (°C)	247 nm			374 nm			443 nm	
			A.U.	Fractional Fade	Fade-Corrected Data	A.U.	Fractional Fade	Fade-Corrected Data	A.U.	Fractional Fade
CEH1 (wall)	+1.22	65				0.33	1.00	2.8(7)	1.48	0.96
	0	72				0.35	0.99	2.9(7)	1.58	0.94
	-1.22	61				0.35	1.00	2.9(7)	1.58	0.97
CEH3 (wall)	+1.22	71				0.33	1.00	2.8(7)	1.54	0.94
	+0.61	71				0.34	1.00	2.9(7)	1.28	0.94
	0	78				0.37	0.97	3.0(7)	1.63	0.91
	-0.61	78				0.39	0.97	3.2(7)	1.44	0.91
	-1.22	78				0.38	0.97	3.1(7)	1.46	0.91
	-1.83	60				0.153	1.00	1.6(7)	0.79	0.98
	-2.44	60	0.39	0.76	1.1(5)	<0.01	1.00	--	--	0.98
CEH3 (0.51 m)	+1.22	65	1.38	0.74	1.5(6)	~0.01	1.00	1.2(6)	0.078	0.97
	0	68	1.29	0.73	1.4(6)	<0.01	1.00	--	0.056	0.95
	-1.22	62	1.36	0.75	1.4(6)	<0.01	1.00	--	0.068	0.98
CEH3 (0.66 m)	+1.22	60	0.36	0.76	9.1(4)				0.005	0.98
	0	64	0.35	0.75	9.0(4)				0.005	0.97
	-1.22	60	0.31	0.76	7.8(4)				0.005	0.99
CEH4 (heater) (wall)	+1.22	76				0.021	1.00	2.3(6)	1.12	0.92
	0	82				0.23	0.96	2.0(7)	1.88	0.89
	-1.22	59				>3	0.98	--	>3	0.98
CEH7 (wall)	+1.22	67				0.34	1.00	2.9(7)	1.82	0.96
	0	73				0.31	0.99	2.7(7)	1.11	0.93
	-1.22	59				0.36	1.00	3.0(7)	1.28	0.98
CEH11 (wall)	+1.22	68				0.31	1.00	2.7(7)	1.16	0.95
	0	78				0.33	0.97	2.8(7)	1.27	0.91
	-1.22	67				0.33	1.00	2.8(7)	1.55	0.96

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