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QUARTERLY PROGRESS REPORT

TO THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

July 1 - September 30, 1968

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ORNL-TM-2730

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July 1 - September 30, 1968

NOVEMBER 1969

OAK RIDGE NATIONAL LABORATORY

Oak Ridge, Tennessee

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QUARTERLY PROGRESS REPORT

TO THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Title of Project:

Mutagenic Effectiveness of Known Doses of Gamma Irradiation in Combination with Zero Gravity on Neurospora

For the Period:

July 1 - September 30, 1968

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CONTENTS

I. Introduction. 1

II. Development of Passive Dosimetry System

A. Correction Factors for EG&G Calcium Fluoride Dosimeters. 5

B. Correction Factors for EG&G Lithium Fluoride Dosimeters. 11

C. Correction Factors for ConRad Lithium Fluoride Teflon-Disk Dosimeters. . . . 13

D. Corrections for Over-Response to Scattered Low-Energy Radiation. . . . 21

E. Care and Handling of Dosimeters. 24

III. Summary of Results Obtained with Calibrated Dosimeters. 26

I. INTRODUCTION

The quarterly reports ORNL-TM-1734, ORNL-TM-1959, ORNL-TM-2189, ORNL-TM-2190, ORNL-TM-2235, ORNL-TM-2310, ORNL-TM-2544, and ORNL-TM-2566 provide background information for the data in the present report. ORNL-TM-1734 describes the results of early experiments in the laboratory designed to estimate dose-response curves for the induction of mutations in the ad-3 region and for nuclear inactivation of heterokaryotic conidia, and the results of experiments to assess the possible effects of anoxia during irradiation. The development of the Neurospora housings and modules for use in the Biosatellite experimentation is described, and the results of biological assays with conidia used in the qualification and acceptance tests of the hardware at the General Electric Company facility are also presented in that report. ORNL-TM-1959 describes tests, launch simulations, and gantry exercises at Cape Kennedy in preparation for the Biosatellite I flight, as well as plans and personnel deployment procedures for the Biosatellite I flight. ORNL-TM-2189 describes some of the activities at the time of preparation for the Biosatellite I flight and presents data and an analysis of data derived from conidia irradiated in the ground-control portion of that experiment. Some of the input and output sheets for the electronic data-processing system are also included and described in that report. ORNL-TM-2190 is concerned strictly with

dosimetry and describes the ConRad passive dosimetry system upon which we had been relying and some of the sources of variation and problems associated with the use of this system. ORNL-TM-2235 describes briefly the two gantry exercises immediately preceding the Biosatellite II flight. It also contains a description of ORNL personnel activities during the preparation of material for the Biosatellite II flight and during the flight itself. The experimental plan and the selection of conida from both the flight and ground-control portions for the assays for nuclear inactivation and forward mutation are also described.

In ORNL-TM-2310 the preliminary data from the Biosatellite II experiment are presented, along with the genetic analysis and tentative conclusions. Included in that report are data input sheets, or IBM machine print-outs reproducing the input data, and data print-outs indicating the steps in the regression analyses used to estimate and compare the dose-response curves for various genetic effects measured in the flight and ground-control samples. In ORNL-TM-2544 are described the computer programs for conidial survival and overall forward mutation induction in the ad-3 region, as well as the programs for estimating the individual induction curves for the various classes of ad-3 mutations. ORNL-TM-2566 includes a comparison of overall ad-3 mutation induction curves from preflight, flight, simultaneous control, and post-flight control experiments. Also included are the comparisons of flight data pertaining to the induction of different classes of ad-3 mutations

with similar data from the pre-flight and simultaneous ground-control experiments.

During the first half of the year 1968, the major activities were the three post-flight ground-control exercises at the Ames Research Center. The first, termed the Post-Flight ARC Dosimetry Test, was a dosimetric analysis of the flight and ground-control capsules used in the Biosatellite II experiment. The second, termed phase B, involved the irradiation and assay of biological samples in the flight and ground-control capsules, but there was no attempt to use centrifugation and vibration to simulate these parameters of flight. In the third exercise, termed phase C, one set of biological materials was subjected to irradiation as well as to centrifugation and vibration profiles in the flight capsule while a second set was being subjected to irradiation in the ground control capsule without centrifugation and vibration. The development and use of passive dosimetry systems are described in the present report. Also described are the results of dosimetric analyses in the three post-flight tests and in those pre-flight tests for which calibrated dosimeters were used. Dosimetry from the Biosatellite II flight is described in a previous report (ORNL-TM-2310).

II. DEVELOPMENT OF PASSIVE DOSIMETRY SYSTEM

A dosimetry system distributed by Controls for Radiation, Cambridge, Mass., (ConRad) involving lithium fluoride (LiF) teflon-disk dosimeters having a thickness of 0.13 mm and a diameter of 13 mm was initially chosen for use in the Neurospora assemblies for the reasons listed in a previous report (ORNL-TM-2190). However, with continued use, these dosimeters were shown to be highly unreliable unless precalibrated. To supplement the ConRad system, dosimeters provided by Edgerton, Germeshausen, & Grier, Santa Barbara, Cal. (EG&G), were most recently adopted. The EG&G system includes a thermoluminescent dosimetry (TLD) read-out machine, model TL3, and rod-shaped dosimeters composed of lithium fluoride TLD powder or calcium fluoride TLD powder enclosed in tiny glass cylinders. It was thought that the use of both CaF_2 and LiF TLD powder dosimeter capsules from EG&G, as well as the ConRad LiF teflon disks, would not only provide a better estimate of the gamma radiation exposure at each filter position but also provide additional information, i.e., a rough estimate of the amount of scattered ionizing radiation below about 100 mev.

As tests began with the simultaneous use of the three types of dosimeters, it became obvious that for best results one could not apply the machine reading of thermoluminescence to a simple calibration table, but rather that a series of correction factors should be determined and used to convert the machine readings to exposures in Roentgens. The correction factors, determined with the assistance of Arthur C. Lucas of

of EG&G, will be discussed in the following sections.

A. Correction Factors for EG&G Calcium Fluoride Dosimeters

1. Calibration Factors for Individual Dosimeters. The calibration of the TLD read-out machine is such that the readings are not in Roentgens. The EG&G Company exposes each dosimeter to a known low dose of ^{137}Cs gamma radiation and then obtains a thermoluminescence reading from the machine. The gamma radiation dose in rads is divided by the TLD reading to provide a correction factor for each dosimeter. For the CaF_2 dosimeters used in the Biosatellite experiments, the calibration factors provided by EG&G for individual dosimeters range from about 5 to 8.

2. Correction for Loss of Thermoluminescence Due to Exposure of Dosimeters to Light. At Oak Ridge National Laboratory, seven sets of 24 dosimeters each (eight ConRad LiF teflon-disk dosimeters, eight EG&G calcium fluoride dosimeters, and eight EG&G lithium fluoride dosimeters per set) were irradiated with an X-ray exposure of 800 Roentgens (G.E. Maxitron Two Fifty, 250 Kvp, 30 ma, 3 mm aluminum extrinsic filtration). Immediately after irradiation, half of each set was placed in the dark and half was left in the customary storage shelf in laboratory light. A complete set of 24 dosimeters was subjected to TLD determination at each of several time intervals after irradiation. The results (Table 1) indicate that the LiF dosimeters were not affected by storage in the light but that the CaF_2 dosimeters definitely exhibited a diminished thermoluminescence after storage in the light. These data are summarized in Fig. 1, where the loss of thermoluminescence is indicated to be as much as 45% of the original. The correction factors for various periods of storage in the light are derived and presented in Table 2 and Fig. 2. Needless to say, the standard procedure adopted is to store and handle all CaF_2 dosimeters in the dark between irradiation and TLD determinations, thus eliminating the need for this kind of correction.

Table 1. Response of dosimeters in roentgens after exposure to light for varying periods of time following irradiation (Each point is an average of four readings)

No. Days after Irradiation	EG&G CaF_2 (dark)	EG&G CaF_2 (light)	EG&G LiF (dark)	EG&G LiF (light)	ConRad LiF (dark)	ConRad LiF (light)
1	877	772	958	847	900	900
4	891	583	850	894	900	925
7	878	555	935	1006	850	860
12	887	524	874	906	860	875
14	881	484	994	877	860	875
46	918	405	1024	1021	875	825
Average	888	Not valid	939	925	874	876

Table 2. Decrease in TLD readings from EG&G CaF_2 dosimeters due to light exposure for various time intervals following x-ray exposure and required correction factor

No. Days after Irradiation	Average TLD Reading (dark)	Overall Average (dark)	Average TLD Reading (light)	Percentage (light ÷ dark)	Correction Factor
1	877	888	772	86.9	1.15
4	891	888	583	65.6	1.52
7	878	888	555	62.5	1.60
12	887	888	524	59.0	1.69
14	881	888	484	54.5	1.83
46	918	888	505	56.8	1.76

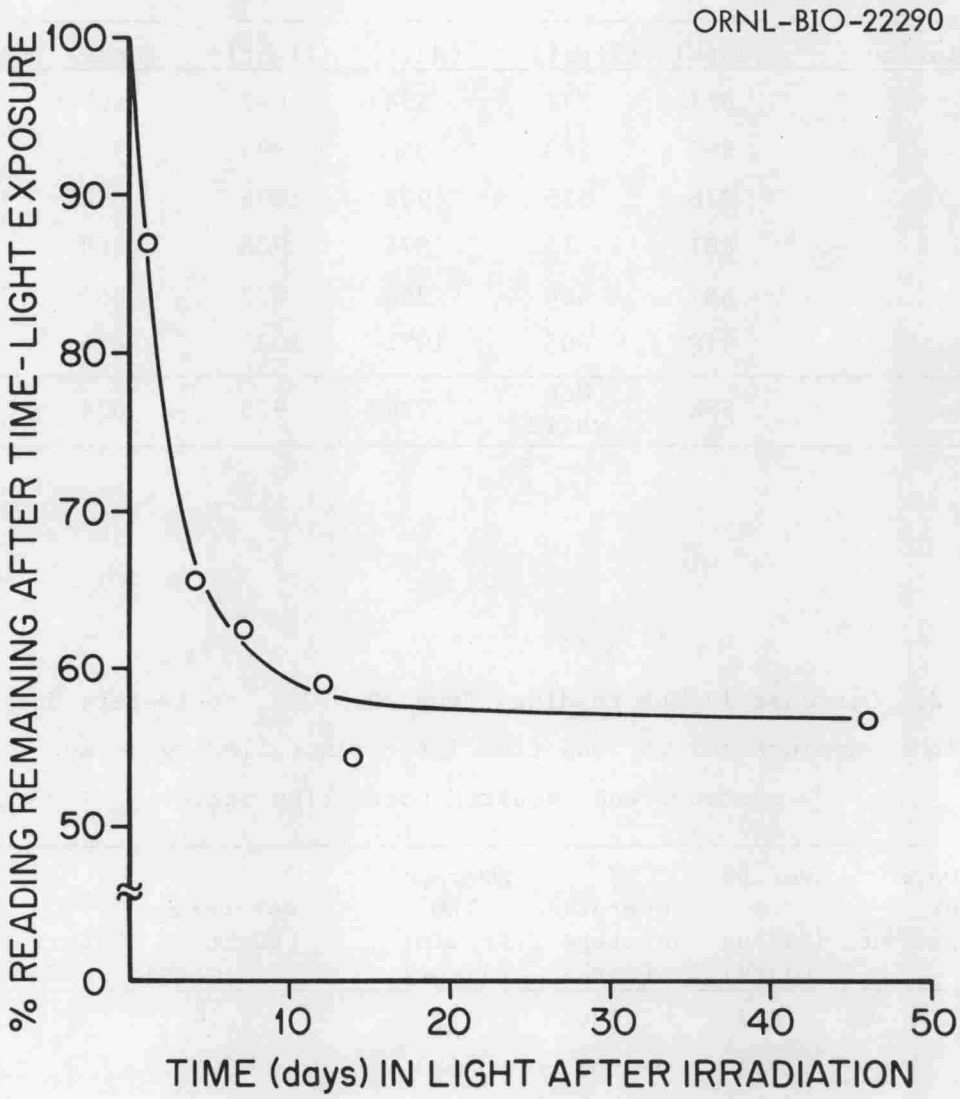

Fig. 1. Percentage of Original Reading Which Remains in CaF_2 Dosimeter After Exposure to Light, Following Irradiation.

ORNL-BIO-22291

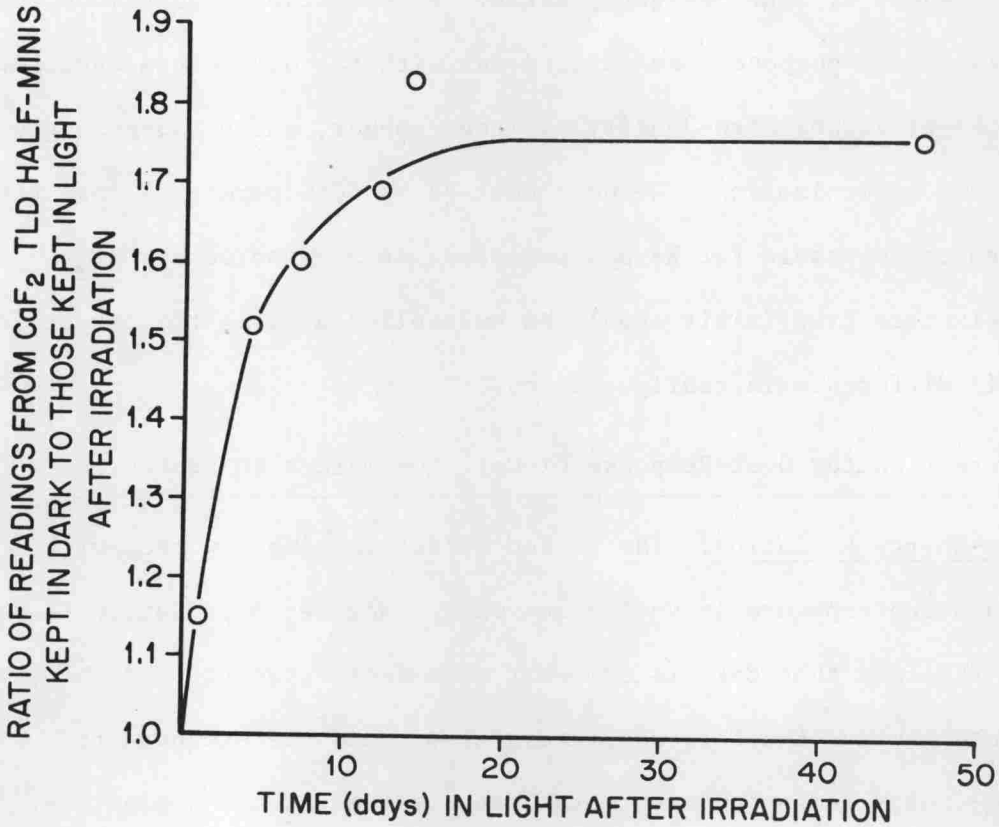

Fig. 2. Time-Light Fade Correction-Factor Curve for CaF_2 Dosimeters.

3. Correction for Difference Between EG&G and Biosatellite Irradiation Configuration. In the Biosatellite, the dosimeters and biological samples were enclosed in assemblies of approximately tissue-equivalent density. Also, in the ORNL X-ray procedure for calibration purposes, it was customary to irradiate the dosimeters free in air, supported on a sheet of light-weight plastic. At EG&G the irradiations for calibration purposes are carried out with the dosimeters enclosed in a pad of rather high-density silicone rubber, which causes a greater amount of ionization. We were advised by EG&G personnel that the apparent exposure for X-rays and gamma rays measured by CaF_2 dosimeters free in air should be multiplied by 1.14 to correct for this difference in configurations.

4. Correction for Over-Response of CaF_2 Dosimeters to Scattered Low-Energy Radiation. The method of determining how much of the radiation exposure is due to low-energy scattered radiation is based on the fact that CaF_2 is somewhat more dense than LiF and that, consequently, the CaF_2 dosimeters absorb and over-respond to low-energy radiation much more strongly than do LiF dosimeters. It is considered desirable to have the capability of checking the portion of the total radiation exposure which is in the form of low-energy radiation. However, different corrections must be applied to CaF_2 and LiF dosimeters to subtract out that portion of the reading which is due to over-response to low-energy radiation and to obtain an estimate of exposure. In the EG&G calibration exposures with ^{137}Cs gamma radiation, the correction is negligible. For X-rays

and ^{85}Sr gamma radiation in the Biosatellite configuration, the corrections are derived and discussed in Section D.

5. Conversion from Rads to Roentgens. EG&G uses the rad as the unit of radiation quantity, whereas the Biosatellite experimenters adopted the Roentgen. The dose in rads is divided by 0.96 to convert to Roentgens (International Commission on Radiological Units, Report 10b, 1962).

B. Correction Factors for EG&G Lithium Fluoride Dosimeters

1. Calibration Factors for Individual Dosimeters. LiF dosimeter readings must be multiplied by individual factors (as described in Section II, A, 1, this report) ranging from 20 to 26 for our batch of dosimeters.

2. Nonlinearity Correction Factors. CaF_2 dosimeter TLD readings are proportional to total exposure of ionizing radiation over a wide range. Because this is not true of LiF TLD readings, it is necessary to determine experimentally the degree of nonlinearity (nonproportionality) of LiF dosimeter response with increasing dose and to obtain a dose-dependent correction factor to be applied to LiF readings. For this purpose, sets of eight EG&G LiF dosimeters were exposed to 10, 100, 200, 400, 800, 1600, 3200, 4500, or 7200 Roentgens of X-rays (Maxitron Two Fifty, 250 Kvp, 30 ma, 3 mm aluminum extrinsic filtration). The TLD readings from these were multiplied by individual correction factors and the readings for each group were averaged. The reading for the 10 R set was then equated to 1.0, and at each other dose level that reading was computed as a proportion of the reading at 10R, as shown in Table 3.

Table 3. Ratio between response of EG&G LiF dosimeters at various total exposures and 10 R exposure (All exposures on ORNL X-ray)

Exposure (roentgens)	Response R	Ratio Between Varying Levels and 10 R
10	1.426	1.000
100	1.455	1.020
200	1.430	1.003
400	1.475	1.034
800	1.546	1.084
1600	1.523	1.068
3200	1.862	1.306
4500	2.056	1.442
7200	2.255	1.581

Figure 3 shows the nonlinearity curve for X-rays, and Fig. 4 shows a corresponding curve for ^{85}Sr gamma radiation developed and provided by EG&G. It has been customary to use the exposure estimated by the irradiation of CaF_2 dosimeter(s) at the same time to indicate what nonlinearity correction factor to apply to a particular LiF dosimeter reading.

3. Correction for Difference between EG&G and Biosatellite Irradiation Configuration. The reason for this correction is described in Section II, A, 3, (this report); if irradiated free in air, EG&G LiF dosimeter readings are multiplied by 1.02.

4. Correction for Over-Response of LiF Dosimeters to Scattered Low-Energy Radiation. This correction is derived and presented in Section D and discussed in Section II, A, 4, (this report).

5. Conversion from Rads to Roentgens. As mentioned in Section II, A, 5 (this report), divide dose in rads by 0.96 to convert to Roentgens.

C. Correction Factors for ConRad Lithium Fluoride Teflon-Disk Dosimeters.

1. Calibration Factors for Individual Dosimeters. ORNL-TM-2190 presents the evidence that, contrary to the claims of the manufacturer, each ConRad dosimeter must be assigned an individual correction factor. This procedure (described previously in ORNL-TM-2190) consists, in brief, of assigning an arbitrary serial number to each dosimeter, irradiating large groups of dosimeters with the same X-ray exposure (preferably simultaneously on a revolving platform not close to the source), subjecting each dosimeter to a thermoluminescence reading always using the same planchet with dosimeter exposed to the light

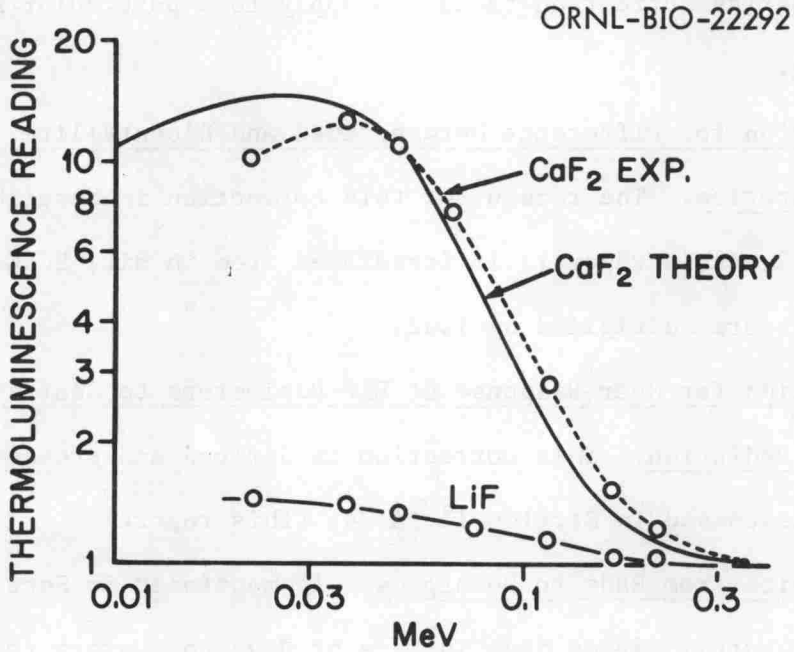

Fig. 3. Energy Dependence of Mini TLD with Respect to Air

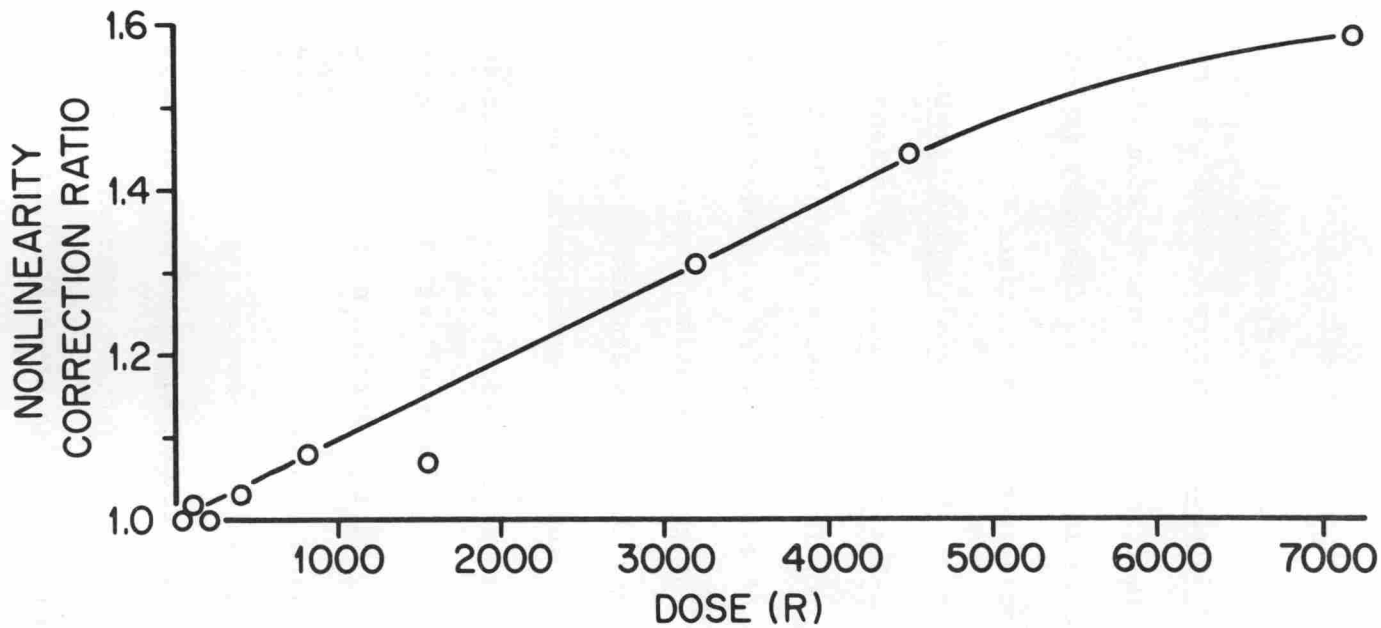

Fig. 4. X-Ray Nonlinearity Correction Curve for LiF Dosimeters.

detector through a 7/16" hole in the upper screening), obtaining the average of a given day's readings, and dividing any individual reading by the average to obtain the individual correction factor.

2. Nonlinearity Correction Factors. These are the same as those for EG&G LiF dosimeters (Figs. 3 and 4 and Section II, B, 2, this report). The exposure estimated by CaF_2 dosimetry is used to indicate what value to choose from the appropriate figure.

3. Correction for Over-Response of ConRad Lithium Fluoride Dosimeters to Scattered Low-Energy Radiation. The rationale for this correction is the same as for the EG&G dosimeters. In Tables 4 and 5 are shown the results of experiments for obtaining the correction factors for X-rays and ^{85}Sr gamma radiation, respectively. TLD readings from groups of eight dosimeters exposed to a range of X-ray or from single dosimeters exposed to ^{85}Sr gamma radiation in the Biosatellite are corrected by their individual calibration factors and then corrected for nonlinearity. The resulting figures are divided into the actual exposures to give a proportion of the corrected reading which is due to the radiation exposure, i.e., an exposure estimate now corrected for over-response to low-energy radiation. It is obvious from Tables 4 and 5 that the correction for X-rays and that for ^{85}Sr gamma radiation is constant over the exposure range examined. The readings from dosimeters exposed to X-rays are multiplied by 0.777 to correct for over-response to low-energy radiation. For ^{85}Sr gamma radiation in the Biosatellite Neurospora assembly, the correction factor is 0.988.

Table 4. An estimate of the percentage of the initial reading of EG&G LiF dosimeters which is not due to over-response to low-energy radiation in X-ray exposures

Nominal Dose (approximate)	Average Reading (roentgens)	Non-linearity Factor	Partially* Corrected Reading	Fully* Corrected Reading	Percentage not Due to Over-Response
100	146	1.00	146	113	77.4
200	286	1.01	283	223	78.8
400	590	1.03	573	448	78.2
800	1186	1.08	1098	884	80.5
1600	2436	1.15	2118	1611	76.1
3200	5959	1.31	4549	3493	76.8
4500	9253	1.44	6426	4937	76.8
7200	16234	1.58	10331	7900	76.5
				Average	77.7

*Partial correction includes application of individual calibration factors, nonlinearity factors, multiplication by 1.02 (see Section II, A, 3), and division by 0.96 (see Section II, A, 5). Full correction involves correction for over-response to low-energy radiation as well.

Table 5. Estimates of the percentage of the TLD reading from EG&G LiF dosimeters which is not due to over-response to low-energy radiation from a ^{85}Sr gamma source

Partially Corrected TLD Readings*	Fully Corrected TLD Readings*	Percentage not Due to Over-Response to Low-Energy Radiations
3486	3443	98.8%
2404	2372	98.7%
1586	1555	98.0%
2834	2796	98.7%
1886	1860	98.6%
1648	1639	99.5%
1083	1067	98.5%
937	928	99.0%
1375	1363	99.1%
991	977	98.7%
639	632	98.9%
533	527	98.9%
463	457	98.7%
290	287	99.0%
	Average	98.8%

*Partial correction includes multiplication by calibration factor for individual dosimeters, division by nonlinearity factor, multiplication by 1.02 (see Section II, A, 3), and division by 0.96 (see Section II, A, 5), but excludes a correction for over-response to low-energy radiation. The latter correction is included in the fully corrected data (second column).

4. Calibration Curve for Converting Corrected TLD Readings to Roentgens.

In Table 6, the TLD readings of dosimeters subjected to known radiation exposures in open planchets and in the older closed planchets are corrected for individual calibration factors, as well as for nonlinearity, and for over-response to low-energy radiation.

Table 6. Correction of x-ray calibration-curve readings for nonlinearity and over-response to scattered radiation so that the final figure is proportional to thermoluminescence due to primary plus corrected secondary radiation

	ConRad Readings with Open Planchet			ConRad Readings with Screened Planchet		
X-Ray Exposure (Roentgens)	Reading with Partial Correction[1]	Non-linearity factor	Corrected Reading[2]	ConRad Closed Reading[1]	Non-linearity factor	Corrected Reading[2]
114	26	1.00	20.2	15	1.00	11.7
220	54	1.01	41.5	31	1.01	23.8
452	110	1.03	82.9	67	1.03	50.5
885	231	1.08	166.1	135	1.08	97.1
1639	511	1.15	345.2	287	1.15	193.9
3427	1136	1.31	673.7	659	1.31	390.8
4650	1761	1.44	950.2	1061	1.44	572.5
7350	3147	1.58	1547.6	1788	1.58	879.3

[1] With correction factors for individual dosimeters from precalibration experiment.

[2] Correction involves dividing by dose-dependent nonlinearity factor and multiplying by 0.777 (per Table 4).

The resulting corrected readings are plotted (Fig. 5) against the actual X-ray exposure in Roentgens to provide a graph that one may enter with a TLD reading (first corrected for individual calibration factor and for dose-dependent nonlinearity and for over-response to low-energy radiation) and obtain the ionizing radiation exposure in Roentgens. This graph reads in Roentgens, so no conversion from rads to Roentgens is needed.

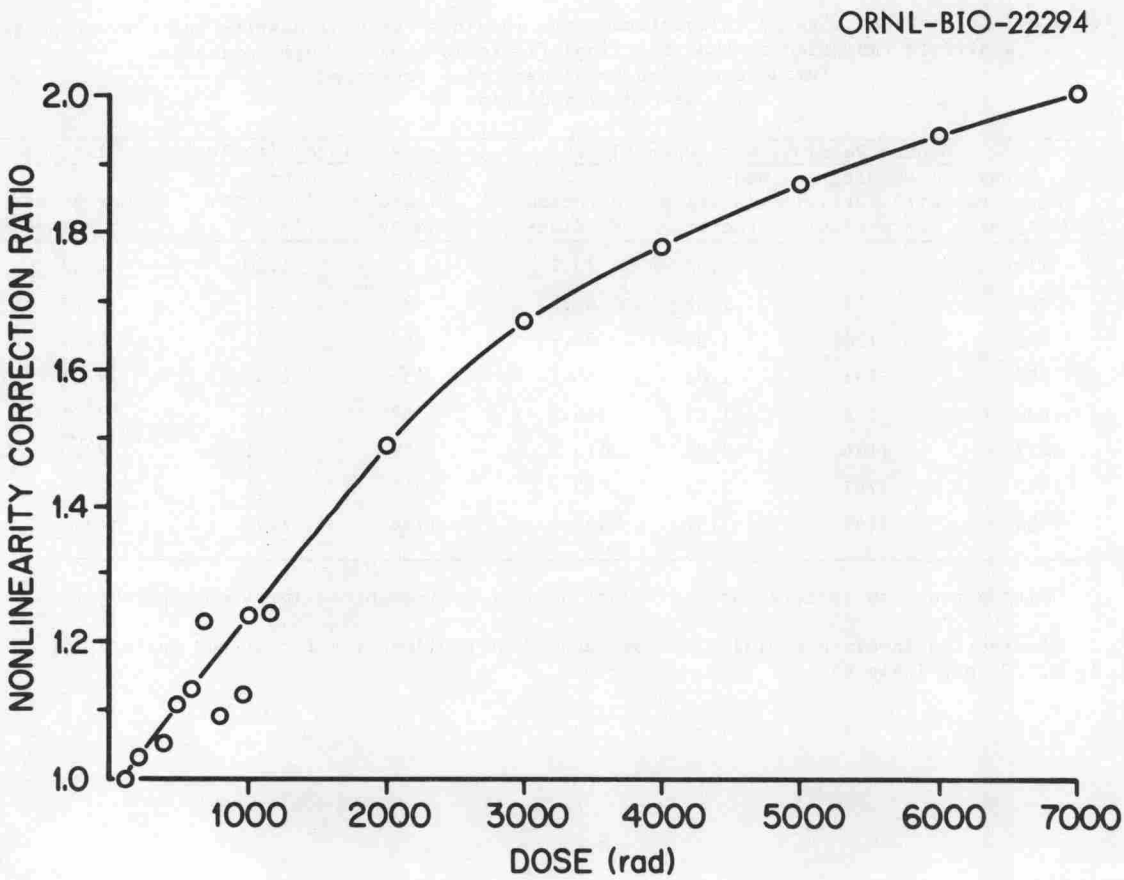

Fig. 5. ^{85}Sr Nonlinearity Correction Curve for LiF Dosimeters

D. Corrections for Over-Response to Scattered Low-Energy Radiation. Figure 6, representing experimentally determined estimates of the sensitivity of EG&G CaF_2 and LiF dosimeters to gamma radiation of different energies, was provided by EG&G. Above about 0.2 MeV the difference between CaF_2 and LiF responses approaches zero, whereas at lower energies the difference may be as high as 11.0.

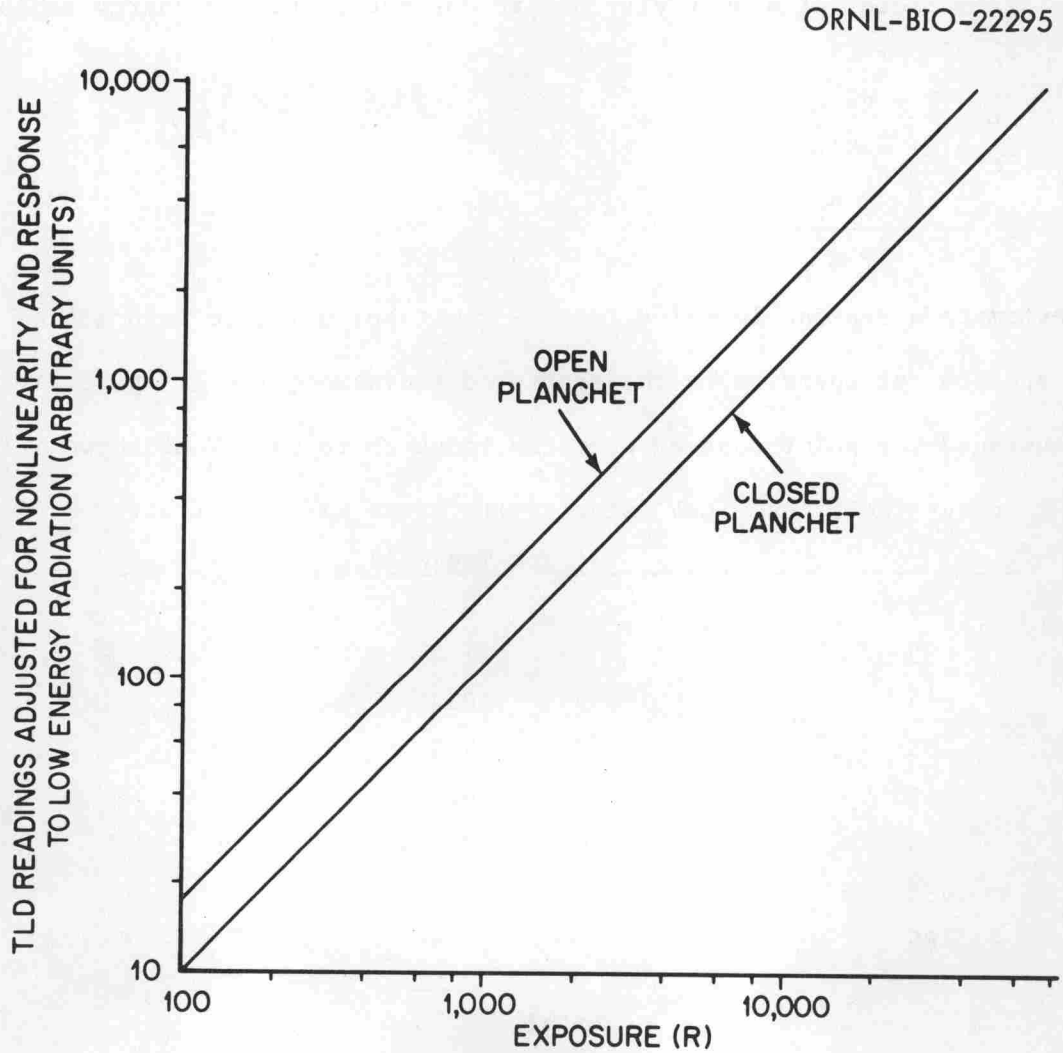

Fig. 6. ORNL Standard Calibration Curve for ConRad LiF.

Amount of thermoluminescence due to primary plus corrected secondary radiation.

The procedure for estimating the amount of scattered radiation from the dosimeter readings was provided by EG&G and is derived as follows:

R_C = response of CaF_2 dosimeter

R_L = response of LiF dosimeter

P = primary radiation dose in rads

S = scattered radiation dose in rads (below about 100 kev)

P + S = the radiation dose in rads

f = factor of sensitivity of CaF_2 dosimeters to low-energy radiation

g = factor of sensitivity of LiF dosimeters to low-energy radiation

$$R_C = P + fS$$

$$R_L = P + gS$$

$$R_C - R_L = S(f - g)$$

$$S = \frac{R_C - R_L}{f - g}$$

To estimate a reasonable value for f - g without definite information about the spectrum of energies in the scattered radiation, the LiF sensitivity is averaged for points spaced over the range 25 to 95 KeV as shown below:

Energy (KeV)	CaF_2 sensitivity minus LiF sensitivity (from Table 6)
25	9.4
35	11.0
45	10.4
55	9.3
65	6.7
75	5.2
85	3.9
95	2.8
Total	58.7
Average	7.4

The value of g, averaged for this same range, is about 1.3.

To convert the responses of LiF and CaF_2 dosimeters to radiation exposure, the following procedure (which we have referred to as Method I) may be used:

$$R_L = P + gS$$

$$P = R_L - gS$$

$$P + S = R_L - gS + S$$

$$P + S = R_L - S(g - 1)$$

$$P + S = R_L - (1.3 - 1)\frac{R_C - R_L}{f - g}$$

$$P + S = R_L - \frac{0.3}{7.4}(R_C - R_L)$$

$$P + S = R_L - 0.041\ (R_C - R_L)$$

A procedure (termed Method II) derived from the above circumvents the relative unreliability of individual LiF dosimeter readings. A large number of sets of data from (1) a previous identical experiment involving CaF_2 and LiF dosimeters irradiated simultaneously or from (2) the same experiment is used to average out the LiF variability. Ratios between paired CaF_2 and LiF readings are computed and averaged, and the mean ratio is used in correcting the CaF_2 readings as follows:

$F = R_c/R_L$, i.e., F is defined as the mean ratio of CaF_2 response to LiF response from a previous identical experiment.

$$R_L = R_C/F$$

$$P + S = R_L - 0.041(R_C - R_L)$$

$$P + S = \frac{R_C}{F} - 0.041(R_C - \frac{R_C}{F}$$

$$P + S = R_C\ (\frac{1}{F} - \frac{0.041\ (F-1)}{F})$$

$$P + S = \frac{R_C}{F}(1 - 0.041\ F + 0.041)$$

$$P + S = \frac{R_C}{F}(1.041 - 0.041\ F)$$

From the dosimetry exercise at Cape Kennedy in August, 1967, average values of $R_C/R_L(=F)$ were obtained for each of the Neurospora assemblies with ^{85}Sr gamma radiation. These data and the resulting formula for correcting the CaF_2 readings for over-response to scattered low-energy radiation have been used in some subsequent experiments and are as follows:

"6000 R" Neurospora assembly	$F = 1.42$	$P + S = 0.692\ R_C$
"2500 R" Neurospora assembly	$F = 1.46$	$P + S = 0.672\ R_C$
"1000 R" Neurospora assembly	$F = 1.29$	$P + S = 0.766\ R_C$
"500 R" Neurospora assembly	$F = 1.34$	$P + S = 0.736\ R_C$

E. Care and Handling of Dosimeters. The following procedures were selected from the manufacturers' manuals and/or were shown by extensive experience to be essential for good dosimetric estimates.

1. EG&G Calcium Fluoride Dosimeters.

   a. Keep dosimeters clean; handle only with forceps.

   b. Keep dosimeters in the dark after irradiation, e.g., with a photographer's change bag.

   c. Be certain that dosimeters are completely dry before they are read out.

   d. De-dose according to manual (350°C for two hours at doses used).

   e. Before inserting dosimeters into sterile Neurospora assemblies, sterilize by heating at 80°C for 24 hours.

2. EG&G Lithium Fluoride Dosimeters.

   a. Keep dosimeters clean; handle only with forceps.

   b. Be certain that dosimeters are completely dry before they are read out.

   c. After making TLD reading, leave dosimeter in position in machine for an additional 30 seconds.

   d. De-dose according to manual (400°C for one hour at doses used).

   e. Sterilize by heating 24 hours at 80°C. All dosimeters in a series must receive identical heat treatments whether sterilization is needed or not.

3. ConRad Lithium Fluoride Teflon-Disk Dosimeters.

   a. Keep dosimeters clean; handle only with forceps.

   b. Be certain that dosimeters are completely dry before they are read out.

   c. Use the same planchet for all readings in a series.

   d. Leave dosimeters in the reader for 45 seconds after they are read out.

   e. Let planchet cool a total of 2 minutes between readings.

   f. Anneal for 24 hours at 80°C to de-dose and/or sterilize.

III. SUMMARY OF RESULTS OBTAINED WITH CALIBRATED DOSIMETERS

Calibrated dosimeters were used on only two pre-flight tests, i.e., the Biosatellite B 301 Gantry Exercise and the Pre-Flight Dosimetry Test at Cape Kennedy. One vehicle was used in each of these tests, but there were three replicates of the dosimetry test.

Table 7 shows, for the 301 Gantry Exercise, the individual dosimetric readings after all correction factors have been applied and the exposure estimates have been expressed in Roentgens. Figure 7 shows the same data plotted with the regression line. Data from the Pre-Flight Dosimetry Test at Cape Kennedy are shown in Table 8. Figure 8 shows the data from the first exposure plotted with the regression line for all three runs combined. Exposures 2 and 3 are shown in Figs. 9 and 10 with the same line drawn in.

The Post-Flight ARC Dosimetry Test employed the two vehicles used in the Biosatellite Experiment and consisted of three runs. The corrected data from that experiment are shown in Table 9. The flight vehicle data are plotted by replicates in Figs. 11, 12, and 13. The line drawn on each is the combined regression analysis of all data obtained from the flight vehicle. The data from the ground-control vehicle are plotted in the same manner in Figs. 14, 15, and 16. The regression line is from the analysis of all ground data combined.

The Biosatellite Post-Flight Ground-Control Experiment Phase B data are shown in Table 10 with plots shown in Figs. 17 and 18. The combined regression line is drawn in.

Table 7. Estimates of the radiation exposures (in Roentgens) received by individual dosimeters in the 301 gantry exercise

Module and Filter Position	Distance from Source (cm)	EG&G LiF	EG&G CaF_2	ConRad LiF	Module and Filter Position	Distance from Source (cm)	EG&G LiF	EG&G CaF_2	ConRad LiF
6000 R 1	6.12	-	2518	4600	1000 R 1	15.10	994	-	925
R 2	6.43	4078	3297	3900	R 2	15.41	948	643	875
R 3	6.74	3901	3036	3650	R 3	15.72	934	697	825
R 4	7.05	3956	2905	3400	R 4	16.03	853	751	800
R 5	7.36	3349	2806	3100	R 5	16.34	692	749	760
R 6	7.67	2325	2510	2900	R 6	16.65	779	648	650
R 7	7.98	3049	2366	2750	R 7	16.96	697	677	725
R 8	8.29	2472	2566	2550	R 8	17.27	771	639	710
R 9	8.60	2260	2031	2300	R 9	17.58	753	-	660
R 10	8.91	2249	1899	2050	R 10	17.89	648	610	650
2500 R 1	9.67	2137	1294	1950	500 R 1	20.94	561	250	450
R 2	9.98	1727	1775	1850	R 2	21.25	559	235	475
R 3	10.29	2040	1679	1800	R 3	21.56	483	-	430
R 4	10.60	1793	1561	1650	R 4	21.87	408	363	410
R 5	10.91	1473	1536	1550	R 5	22.18	469	399	425
R 6	11.22	1546	1475	1450	R 6	22.49	453	385	400
R 7	11.53	1218	1508	1450	R 7	22.80	410	348	390
R 8	11.84	1366	1495	1300	R 8	23.11	451	393	380
R 9	12.15	1425	1318	1275	R 9	23.42	400	537	360
R 10	12.46	1080	1261	1175	R 10	23.73	365	316	360

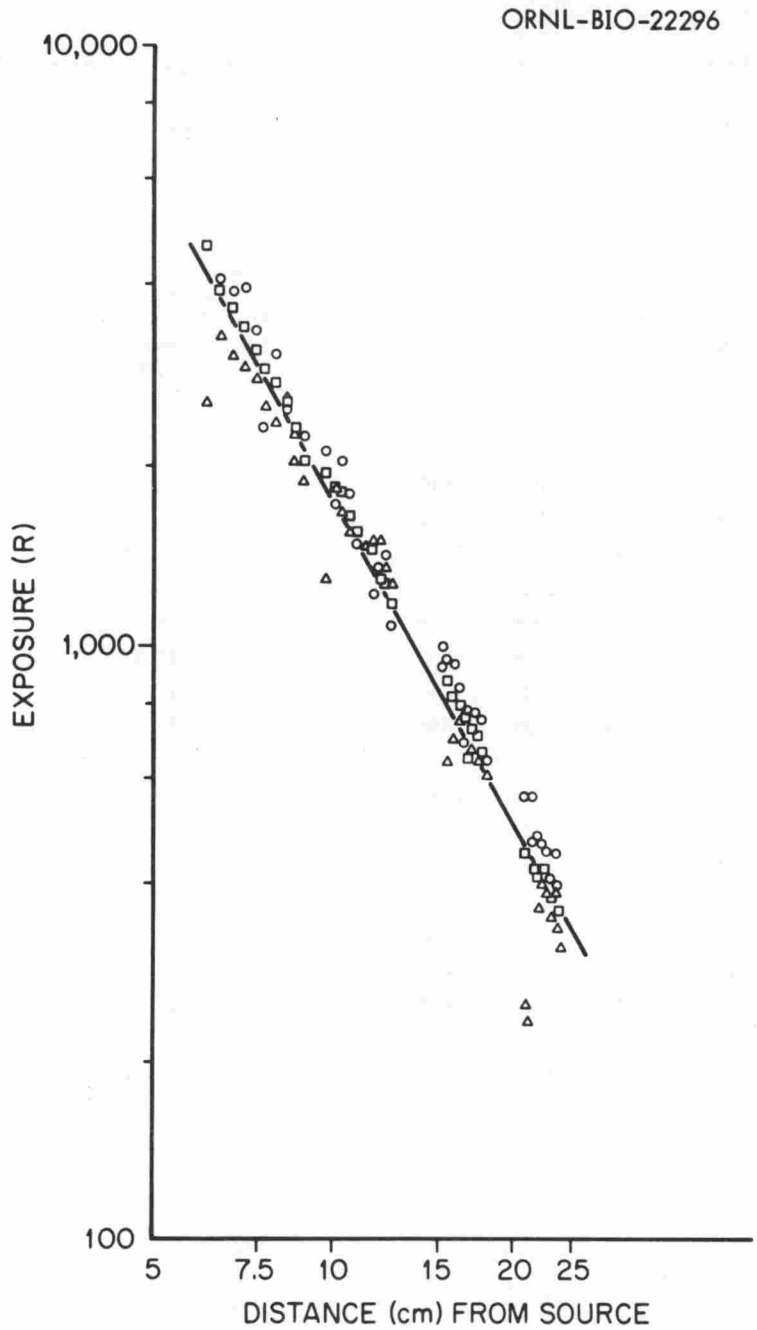

Fig. 7. Radiation Exposure for 301 Gantry Exercise

Logarithm of gamma radiation exposure to each dosimeter in the 301 Gantry Exercise plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

Table 8. Estimates of the radiation exposures (in Roentgens) received by individual dosimeters in the pre-flight dosimetry test at Cape Kennedy

Module and Filter Position	Distance from Source (cm)	EG&G LiF			EG&G CaF_2			ConRad LiF		
		Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
6000 R 1	6.12	972	795	899	966	955	930	1125	1000	1050
2	6.43	880	830	831	887	865	858	1010	900	950
3	6.74	820	788	794	800	793	786	900	875	900
4	7.05	759	686	748	735	735	757	875	825	860
5	7.36	665	648	650	684	655	678	760	710	725
6	7.67	619	574	623	618	591	593	720	660	725
7	7.98	610	557	584	568	526	620	675	625	675
8	8.29	524	530	510	513	518	512	640	610	600
9	8.60	503	476	498	434	494	209	580	560	580
10	8.91	464	434	467	477	466	487	550	495	530
2500 R 1	9.67	448	400	427	407	395	420	510	475	470
2	9.98	429	382	381	367	364	387	495	470	450
3	10.29	367	355	385	360	362	377	460	435	425
4	10.60	341	330	336	351	346	374	430	400	400
5	10.91	358	328	322	318	318	350	390	380	380
6	11.22	323	300	288	311	309	323	390	330	350
7	11.53	311	281	281	305	274	283	350	340	340
8	11.84	291	284	257	286	265	272	350	325	320
9	12.15	259	239	246	262	258	259	340	320	310
10	12.46	262	253	247	258	249	252	325	300	290
1000 R 1	15.10	166	152	153	135	147	145	195	195	175
2	15.41	162	141	132	133	139	140	185	175	185
3	15.72	149	137	133	121	123	129	170	185	180
4	16.03	133	138	137	121	114	134	170	165	165
5	16.34	134	131	131	117	116	121	150	165	160
6	16.65	136	128	116	102	113	121	150	155	155
7	16.96	120	129	120	104	117	113	145	155	145
8	17.27	123	159	114	106	104	107	145	145	145
9	17.58	113	114	102	102	101	107	130	140	140
10	17.89	114	145	106	99	90	99	130	140	123
500 R 1	20.94	81	74	73	76	76	78			
2	21.25	77	75	74	71	71	77			
3	21.56	72	72	71	74	73	73			
4	21.87	77	76	71	70	70	74			
5	22.18	76	59	66	66	66	74			
6	22.49	87	72	65	67	66	68			
7	22.80	73	59	59	64	64	65			
8	23.11	62	65	49	61	62	65			
9	23.42	62	58	60	62	59	64			
10	23.23	62	54	49	56	54	59			

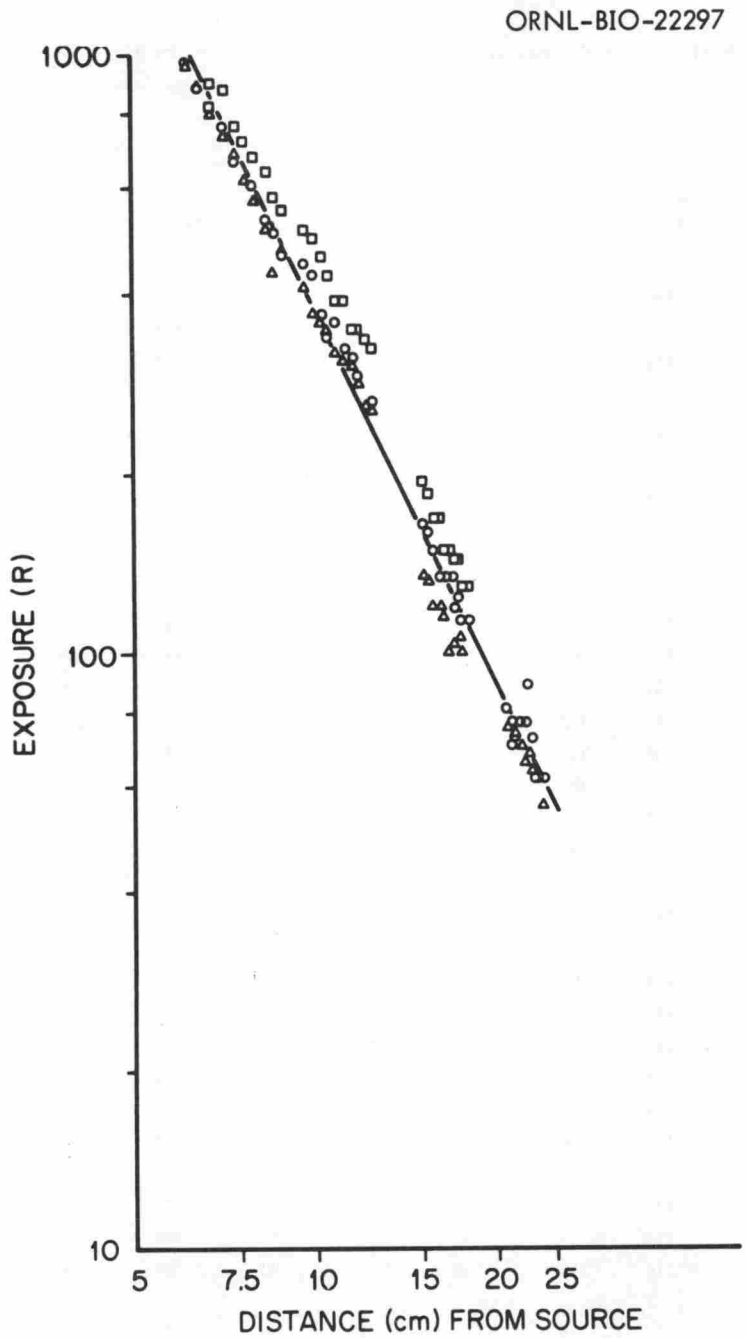

Fig. 8. Radiation Exposure for Pre-Flight Cape Kennedy Dosimetry Test (Run 1)

Logarithm of gamma radiation exposure to each dosimeter in the Pre-Flight Cape Kennedy Dosimetry Test (Run 1) plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line from all three runs combined. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

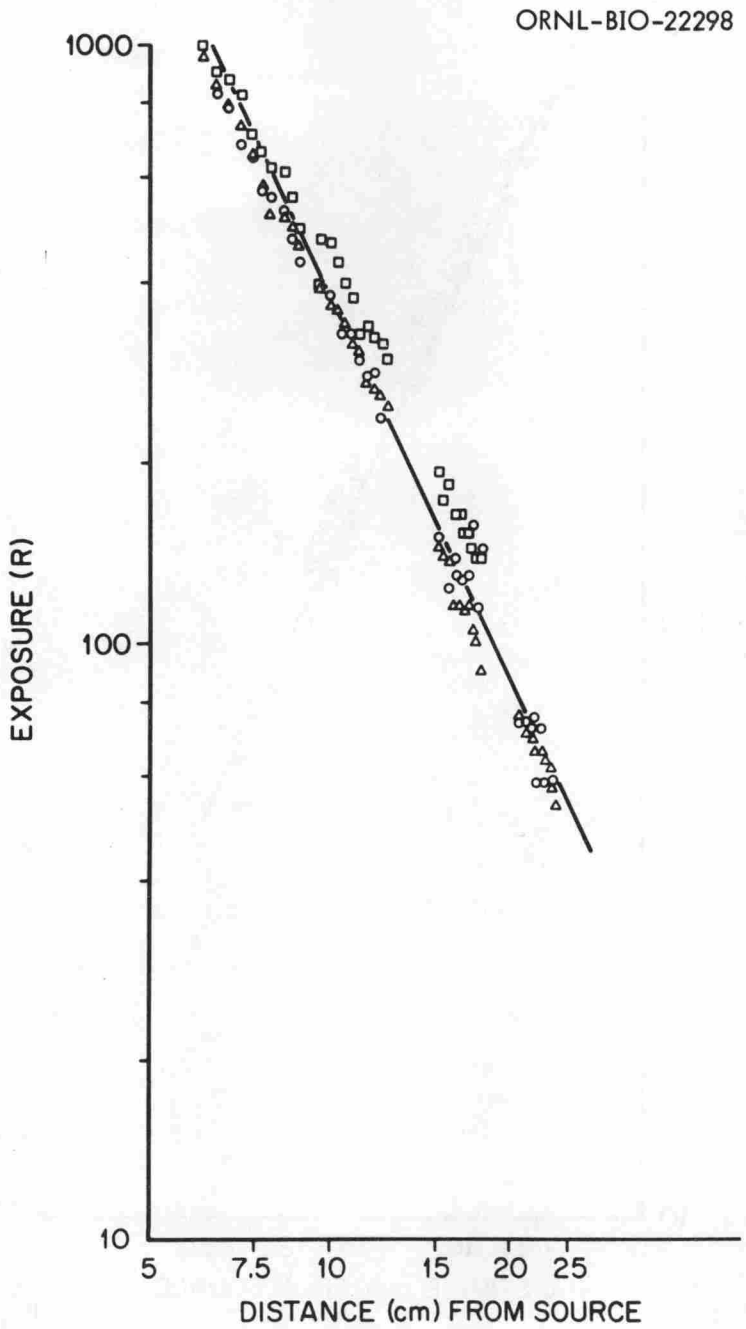

Fig. 9. Radiation Exposure for Pre-Flight Cape Kennedy Dosimetry Test (Run 2)

Logarithm of gamma radiation exposure to each dosimeter in the Pre-Flight Cape Kennedy Dosimetry Test (Run 2) plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with regression line from all three runs combined. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

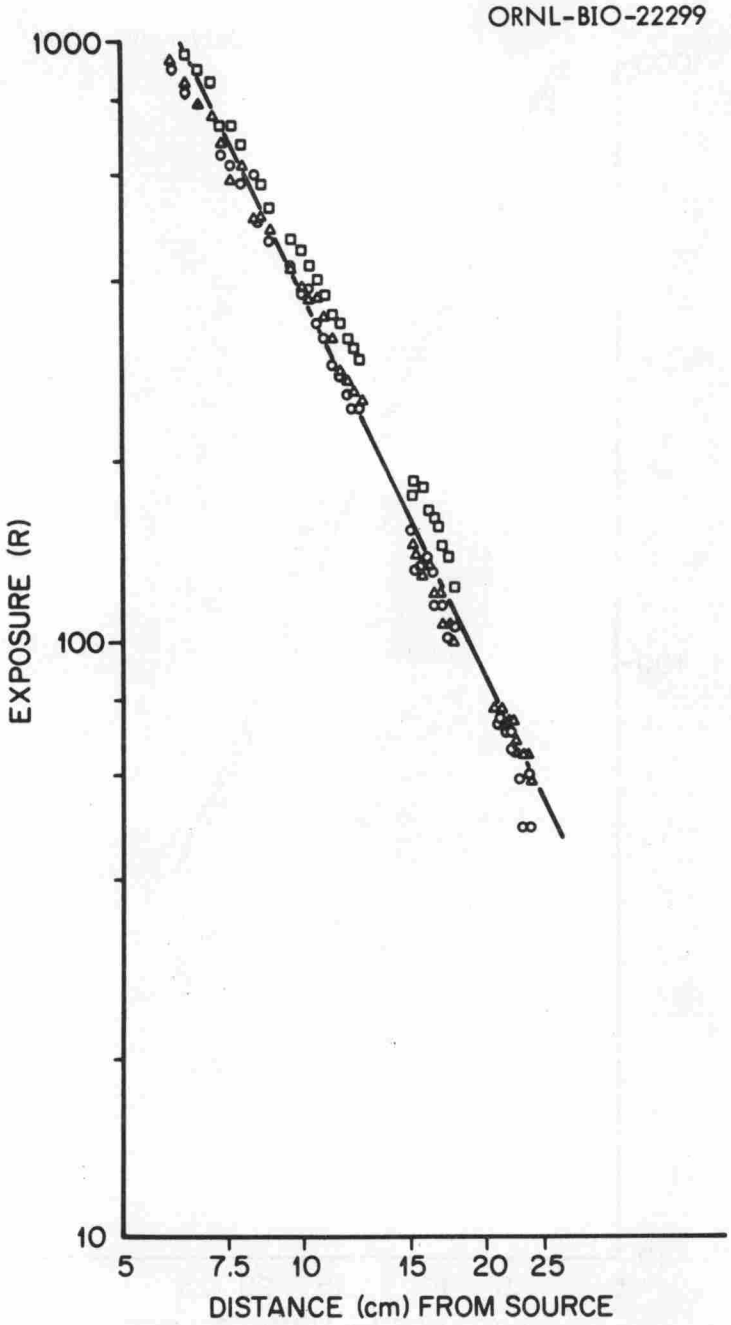

Fig. 10. Radiation Exposure for Pre-Flight Cape Kennedy Dosimetry Test (Run 3).

Logarithm of gamma radiation exposure to each dosimeter in the Pre-Flight Cape Kennedy Dosimetry Test (Run 3) plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line from all three runs combined. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

Table 9. Estimates of the radiation exposures (in Roentgens) received by individual dosimeters in each of three replicates in the post-flight ARC dosimetry test.

Module and Filter Position	Distance from Source (cm)	EG&G LiF Run 1		EG&G LiF Run 2		EG&G LiF Run 3	
		Flight	Ground	Flight	Ground	Flight	Ground
6000 R 1	6.12	909	889	830	853	909	853
2	6.43	869	830	770	790	790	751
3	6.74	837	731	758	640	790	731
4	7.05	731	711	691	640	652	672
5	7.36	711	672	608	600	612	593
6	7.67	616	569	529	553	537	612
7	7.98	584	593	553	403	490	553
8	8.29	553	482	514	533	494	514
9	8.60	549	470	514	442	514	458
10	8.91	482	427	442	458	442	427
		EG&G CaF_2 Run 1		EG&G CaF_2 Run 2		EG&G CaF_2 Run 3	
1	6.12	1040	950	960	860	950	860
2	6.43	950	900	850	730	925	750
3	6.74	850	850	-	700	740	690
4	7.05	820	800	700	610	700	640
5	7.36	725	725	660	625	625	580
6	7.67	660	625	600	510	590	520
7	7.98	610	540	550	460	-	500
8	8.29	550	550	-	470	470	440
9	8.60	405	490	450	410	460	425
10	8.91	465	460	400	380	430	390
		ConRad LiF Run 1		ConRad LiF Run 2		ConRad LiF Run 3	
1	6.12	1000	960	850	925	850	900
2	6.43	880	880	725	850	800	825
3	6.74	780	810	640	775	725	730
4	7.05	725	725	620	710	650	675
5	7.36	675	680	540	580	580	610
6	7.67	630	650	510	600	510	570
7	7.98	580	570	450	510	505	530
8	8.29	520	545	460	480	500	470
9	8.60	480	490	410	460	420	445
10	8.91	445	475	365	420	380	395
		EG&G LiF Run 1		EG&G LiF Run 2		EG&G LiF Run 3	
2500 R 1	9.67	466	411	367	427	387	383
2	9.98	427	395	383	411	352	427
3	10.29	403	379	391	348	363	352
4	10.60	363	356	371	300	308	379
5	10.91	336	348	356	217	320	332
6	11.22	357	308	332	316	308	300
7	11.53	312	284	304	296	320	300
8	11.84	312	269	269	257	249	257
9	12.15	308	253	245	257	253	237
10	12.46	273	341	269	257	249	237
		EG&G CaF_2 Run 1		EG&G CaF_2 Run 2		EG&G CaF_2 Run 3	
1	9.67	460	410	400	345	385	380
2	9.98	420	400	385	335	370	340
3	10.29	380	390	370	-	-	325
4	10.60	350	360	360	-	-	320
5	10.91	330	325	-	-	-	-
6	11.22	330	-	350	-	350	270
7	11.53	-	-	340	-	340	-
8	11.84	-	-	305	285	295	280
9	12.15	-	-	300	265	285	300
10	12.46	210	310	320	260	255	275
		ConRad LiF Run 1		ConRad LiF Run 2		ConRad LiF Run 3	
1	9.67	425	450	365	410	370	390
2	9.98	410	420	355	390	345	360
3	10.29	390	390	335	355	320	340
4	10.60	355	375	320	320	285	325
5	10.91	325	350	290	310	275	295
6	11.22	300	330	285	300	255	290
7	11.53	280	310	265	280	250	280
8	11.84	265	290	245	270	230	250
9	12.15	245	290	250	260	220	245
10	12.46	240	260	230	235	215	220

Table 9 (continued)

Module and Filter Position	Distance from Source (cm)	EG&G LiF Run 1		EG&G LiF Run 2		EG&G LiF Run 3	
		Flight	Ground	Flight	Ground	Flight	Ground
1000 R 1	15.10	218	187	200	162	167	182
2	15.41	182	187	200	159	142	150
3	15.72	182	156	118	158	166	151
4	16.03	182	187	91	164	169	149
5	16.34	182	155	118	164	142	150
6	16.65	157	155	91	163	146	182
7	16.96	151	155	120	130	141	-
8	17.27	150	-	-	132	137	129
9	17.58	149	-	96	132	113	132
10	17.89	120	-	96	127	114	131
		EG&G CaF_2 Run 1		EG&G CaF_2 Run 2		EG&G CaF_2 Run 3	
1	15.10	205	190	180	170	210	195
2	15.41	192	185	163	170	158	170
3	15.72	188	180	158	165	171	161
4	16.03	195	172	157	158	138	160
5	16.34	-	170	150	146	145	155
6	16.65	160	153	132	158	145	145
7	16.96	158	148	140	142	145	143
8	17.27	142	142	125	147	130	135
9	17.58	138	141	116	121	135	125
10	17.89	142	133	118	121	135	118
		ConRad LiF Run 1		ConRad LiF Run 2		ConRad LiF Run 3	
1	15.10	160	175	160	175	150	165
2	15.41	138	165	152	175	150	150
3	15.72	128	153	152	152	138	142
4	16.03	120	149	150	158	138	138
5	16.34	132	149	150	150	132	126
6	16.65	128	142	143	150	120	138
7	16.96	152	132	138	138	126	122
8	17.27	132	128	143	132	110	116
9	17.58	143	120	128	128	110	116
10	17.89	132	120	115	115	105	110
		EG&G LiF Run 1		EG&G LiF Run 2		EG&G LiF Run 3	
500 R 1	20.94	105	110	97	110	110	103
2	21.25	132	110	98	79	79	102
3	21.56	105	108	68	79	80	102
4	21.87	103	105	98	80	80	101
5	22.18	103	70	68	80	80	73
6	22.49	73	75	98	79	79	74
7	22.80	103	75	68	80	79	74
8	23.11	73	75	68	79	79	73
9	23.42	73	75	67	80	49	73
10	23.73	73	75	68	77	80	74
		EG&G CaF_2 Run 1		EG&G CaF_2 Run 2		EG&G CaF_2 Run 3	
1	20.94	105	104	105	90	100	92
2	21.25	100	104	92	90	93	95
3	21.56	102	95	92	86	93	86
4	21.87	93	95	91	80	88	87
5	22.18	93	89	84	86	83	86
6	22.49	86	89	-	83	83	86
7	22.80	85	90	70	77	81	75
8	23.11	85	89	72	77	82	73
9	23.42	80	82	72	78	76	73
10	23.73	80	76	71	66	70	67
		ConRad LiF Run 1		ConRad LiF Run 2		ConRad LiF Run 3	
1	20.94						
2	21.25						
3	21.56						
4	21.87						

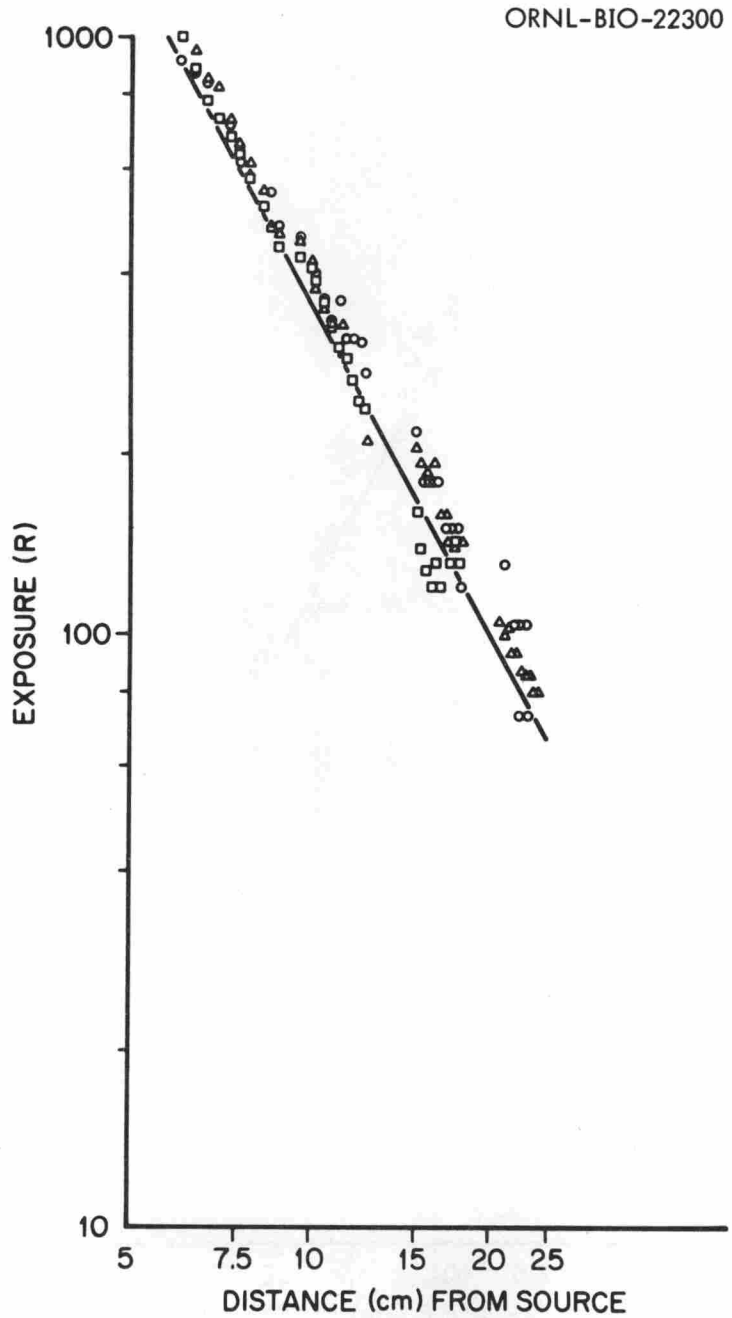

Fig. 11. Radiation Exposure for Post-Flight ARC Dosimetry Test (Run 1 -- with Flight Vehicle).

Logarithm of gamma radiation exposure to each dosimeter in the Post-Flight ARC Dosimetry Test (Run 1 -- with the flight vehicle) plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line from the three flight vehicle runs combined. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

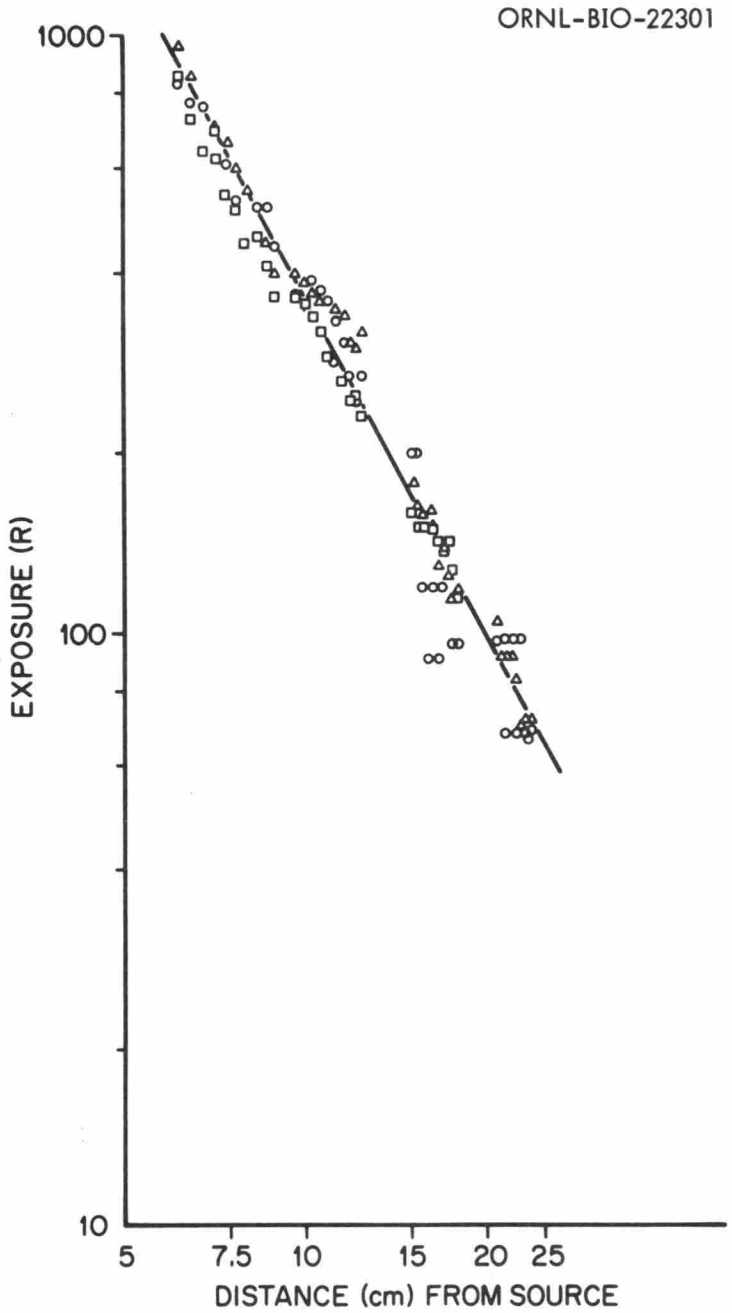

Fig. 12. Radiation Exposure for Post-Flight ARC Dosimetry Test (Run 2 -- with Flight Vehicle).

Logarithm of gamma radiation exposure to each dosimeter in the Post-Flight ARC Dosimetry Test (Run 2 -- with the flight vehicle) plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line from the three flight vehicle runs combined. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

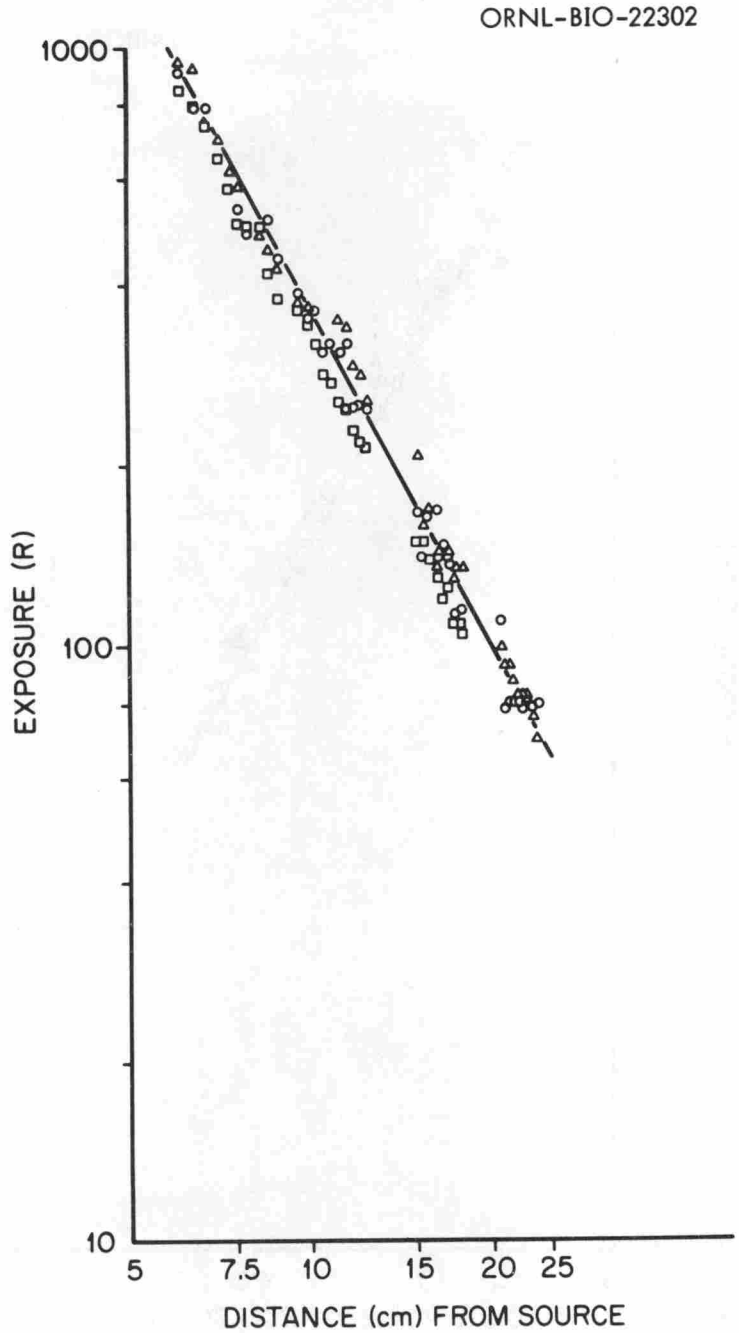

Fig. 13. Radiation Exposure for Post-Flight ARC Dosimetry Test (Run 3--with Flight Vehicle).

Logarithm of gamma radiation exposure to each dosimeter in the Post-Flight ARC Dosimetry Test (Run 3--with the flight vehicle) plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line from the three flight vehicle runs combined. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

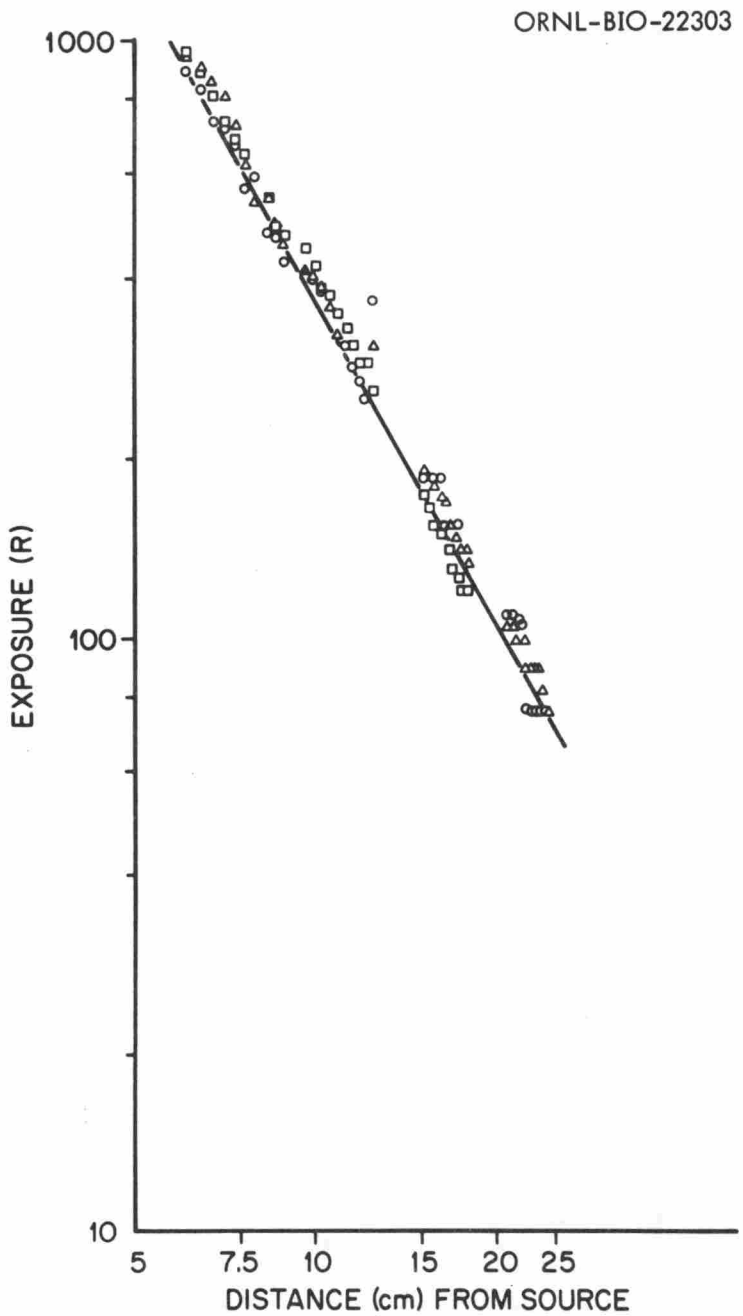

Fig. 14. Radiation Exposure for Post-Flight ARC Dosimetry Test (Run 1--with Ground-Control Vehicle).

Logarithm of gamma radiation exposure to each dosimeter in the Post-Flight ARC Dosimetry Test (Run 1--with the ground-control vehicle) plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line from the three ground-control vehicle runs combined. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

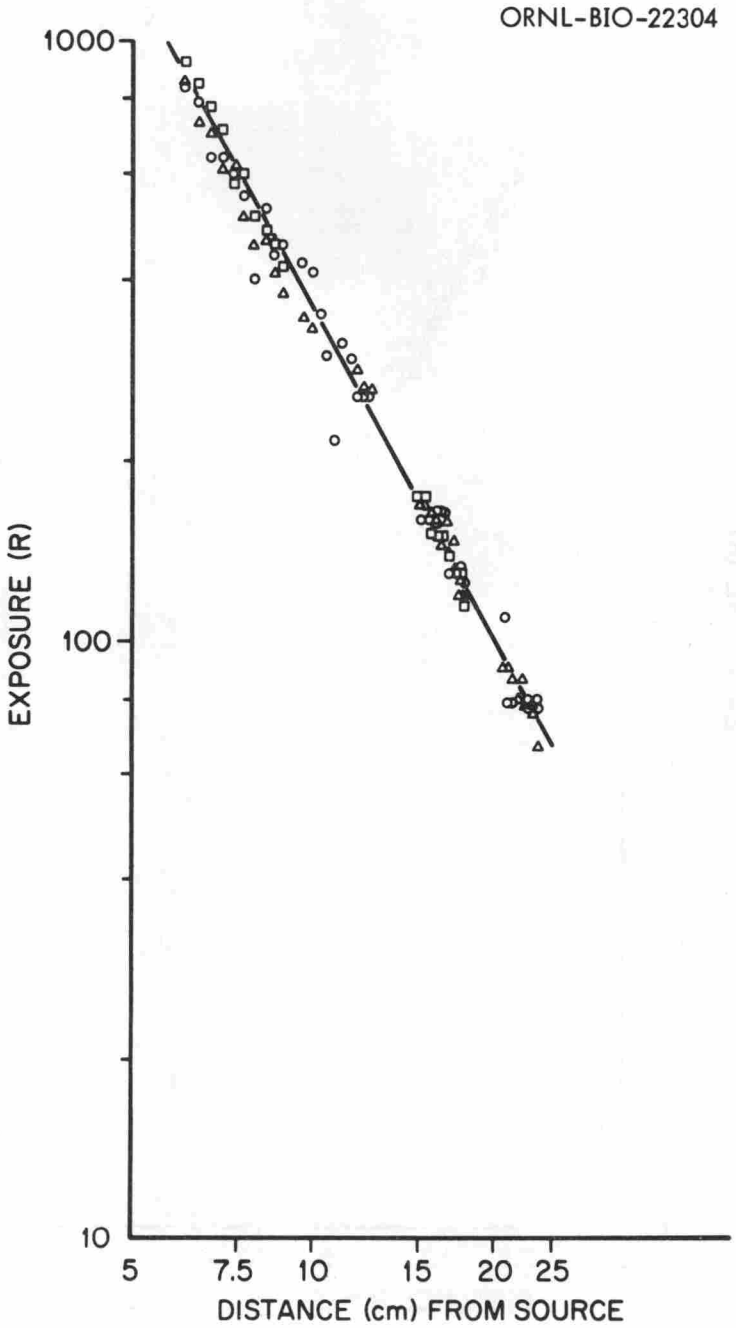

Fig. 15. Radiation Exposure for Post-Flight ARC Dosimetry Test (Run 2--with Ground-Control Vehicle).

Logarithm of gamma radiation exposure to each dosimeter in the Post-Flight ARC Dosimetry Test (Run 2--with the ground-control vehicle) plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line from the three ground-control vehicle runs combined. (O = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

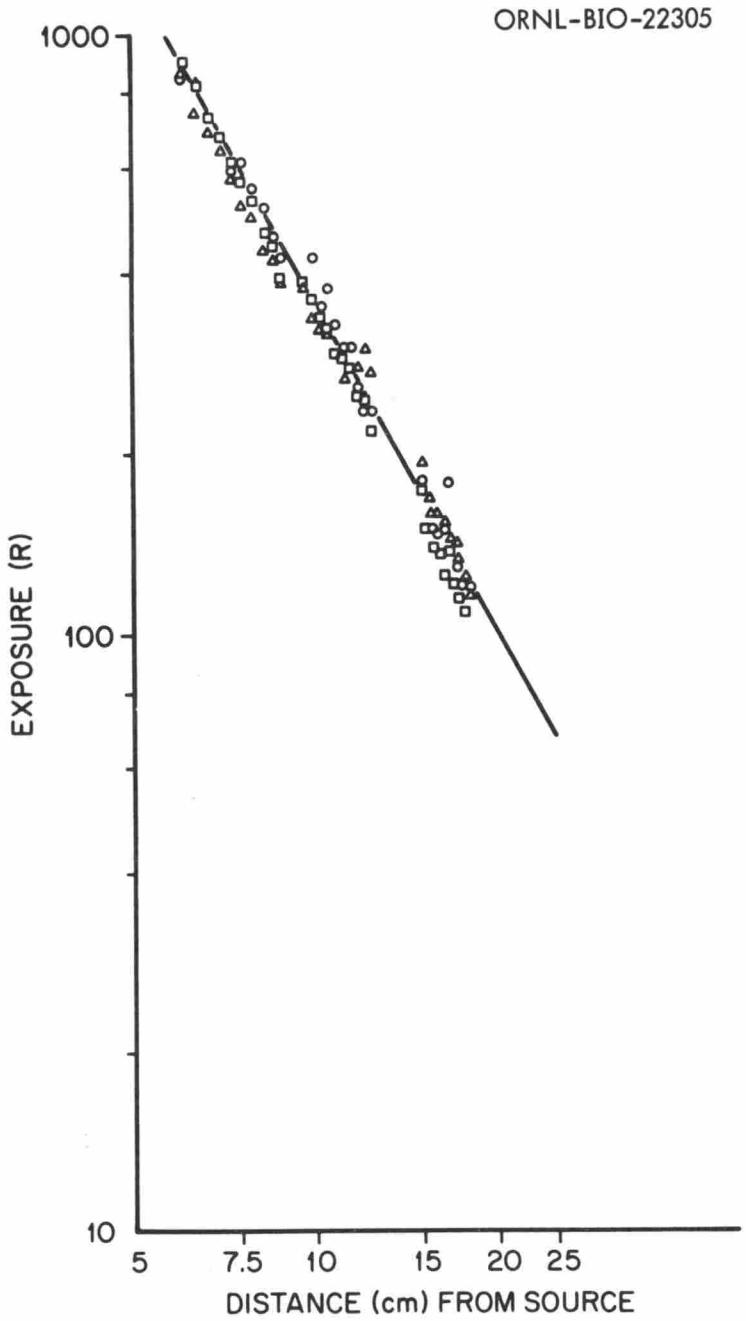

Fig. 16. Radiation Exposure for Post-Flight ARC Dosimetry Test (Run 3--with Ground-Control Vehicle).

Logarithm of gamma radiation exposure to each dosimeter in the Post-Flight ARC Dosimetry Test (Run 3--with the ground-control vehicle) plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line from the three ground-control vehicle runs combined. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

Table 10. Estimates of the radiation exposures (in Roentgens) received by individual dosimeters in the post-flight phase B ground-control experiment.

Module and Filter Position	Distance from Source (cm)	EG&G LiF		EG&G CaF_2		ConRad LiF	
		Flight	Ground	Flight	Ground	Flight	Ground
6000 R 1	6.12	2953	3342	2696	2593	3175	3500
2	6.43	2323	2454	2442	2307	2900	3250
3	6.74	2715	2458	2379	2503	2750	2900
4	7.05	1261	2451	1967	-	2500	2500
5	7.36	2171	2028	-	2111	2275	2250
6	7.67	1353	2060	-	1719	2150	2225
7	7.98	1776	1707	1624	1779	1850	1910
8	8.29	1458	1588	1332	1659	1750	1725
9	8.60	1647	1478	1348	1387	1700	1700
10	8.91	1435	1370	1396	1463	1560	1475
2500 R 1	9.67	-	1247	986	1131	1610	1675
2	9.98	1482	1308	-	1239	1400	1450
3	10.29	1193	1356	-	1183	1325	1350
4	10.60	906	1211	899	1114	1210	1225
5	10.91	846	940	-	877	1180	1160
6	11.22	948	912	835	1009	1120	1075
7	11.53	926	961	732	960	1025	1010
8	11.84	909	860	642	778	960	920
9	12.15	958	783	616	888	950	875
10	12.46	-	827	591	798	810	850
1000 R 1	15.10	533	603	-	513	625	540
2	15.41	582	664	540	542	600	510
3	15.72	460	457	555	499	580	495
4	16.03	539	543	502	593	570	495
5	16.34	437	427	504	501	510	465
6	16.65	497	515	496	472	500	440
7	16.76	494	513	446	470	475	425
8	17.27	434	397	479	440	440	395
9	17.58	464	452	451	416	440	385
10	17.89	399	366	331	406	410	365
500 R 1	20.94	341	304	322	291	310	310
2	21.25	351	261	313	282	295	275
3	21.56	288	294	299	275	290	270
4	21.87	323	238	315	269	275	255
5	22.18	348	273	317	255	205	250
6	22.49	266	211	287	249	255	240
7	22.80	262	267	264	240	250	230
8	23.11	302	250	274	232	235	215
9	23.42	200	226	262	226	230	210
10	23.73	215	233	242	216	225	215

ORNL-BIO-22306

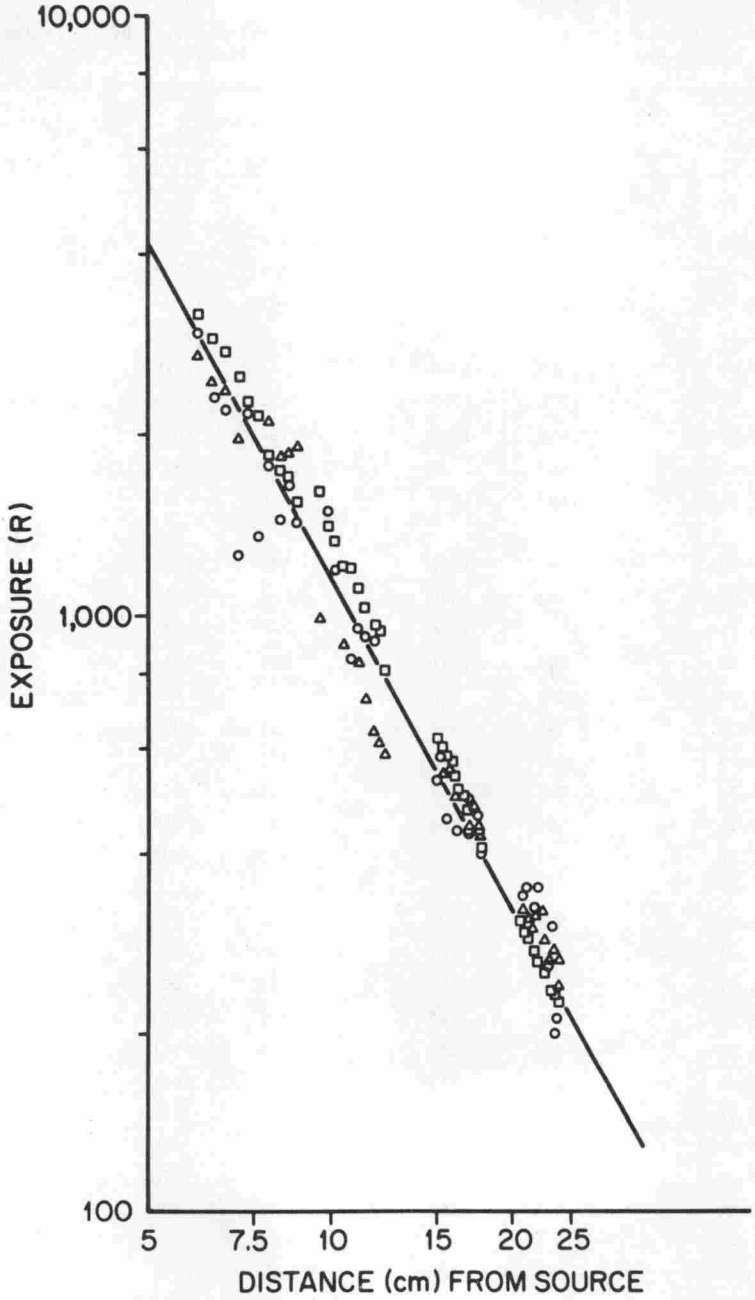

Fig. 17. Radiation Exposure for Post-Flight Phase B Ground-Control Experiment (Flight Vehicle vs Distance).

Logarithm of gamma radiation exposure to each dosimeter in the Post-Flight Phase B ground-control experiment with the flight vehicle plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line. (O = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

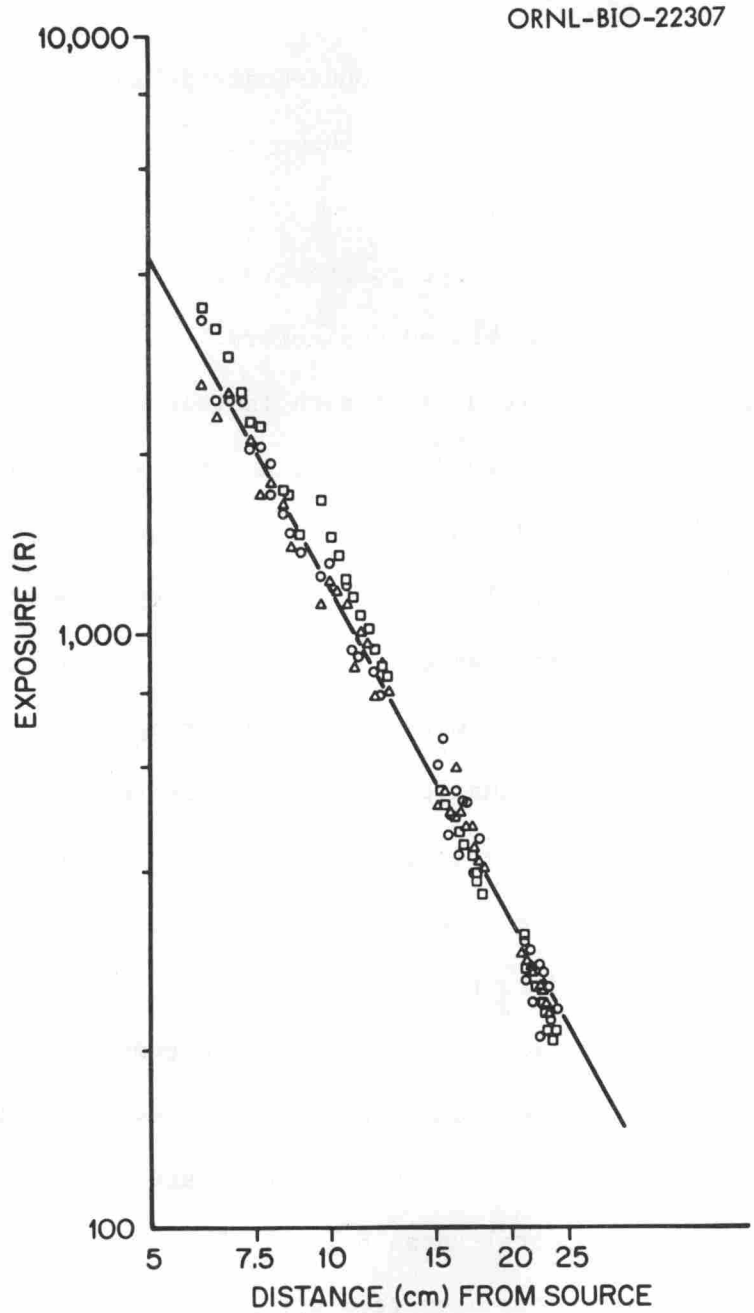

Fig. 18. Radiation Exposure for Post-Flight Phase B Ground-Control Experiment (Ground Control vs Distance)

Logarithm of gamma radiation exposure to each dosimeter in the Post-Flight Phase B Ground-Control Experiment with the ground control plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad dosimeters.)

The Biosatellite Post-Flight Ground-Control Experiment Phase C data are shown in Table 11 with plots shown in Figs. 19 and 20. The combined regression line is drawn in.

Table 12 shows a summary of exposures to certain filters in all those experiments that utilize calibrated dosimeters.

Regression analyses were done on each individual set of data from all experiments with calibrated dosimetry, and the slopes of all the curves are shown in Table 13. An examination of the slopes of the curves reveals some discrepancies. Theoretically, the slopes should be very nearly the same. There are however, some exceptions. The Biosatellite Pre-Flight Ground-Control (Dosimetry) Test has steeper slopes than the other experiments. One explanation of this may be that the EG&G data were compiled and corrected by a representative of that company, and it is possible that not all of the same correction factors were applied to these data as were applied to the other data.

For the most part there is good agreement between flight and ground-control vehicles, and between runs. The two EG&G systems are usually in good agreement, but the EG&G and ConRad results are somewhat different in the Post-Flight Ground-Control Phase B Test. The most likely explanation is that the ConRad dosimeters have received enough cumulative irradiation to alter their sensitivity slightly.

Table 11. Estimates of the radiation exposures (in Roentgens) received by individual dosimeters in the post-flight phase C ground-control experiment.

Module and Filter Position	Distance from Source (cm)	EG&G LiF		EG&G CaF_2		ConRad LiF	
		Flight	Ground	Flight	Ground	Flight	Ground
6000 R 1	6.12	2786	3167	2997	3121	3650	3550
2	6.43	2330	2903	2703	2804	3625	3350
3	6.74	2768	2892	2506	2352	3050	3100
4	7.05	2074	2459	2261	2200	2750	2700
5	7.36	1800	2069	1993	2053	2600	2600
6	7.67	1585	1849	1881	1927	2230	2400
7	7.98	1918	1918	1793	1775	2300	2200
8	8.29	1626	1777	1619	1567	2025	1925
9	8.60	1421	1355	1568	1667	1675	1725
10	8.91	1432	1518	1408	1473	1725	1850
2500 R 1	9.67	1454	1380	1514	1483	-	1400
2	9.98	1578	1137	1403	1422	-	1200
3	10.29	1578	1190	1342	1338	-	1150
4	10.60	1107	1057	1227	1239	-	1050
5	10.91	-	1201	1249	1245	-	1025
6	11.22	1241	1262	1085	1138	-	975
7	11.53	1238	1178	1027	1090	-	925
8	11.84	979	1123	997	979	-	875
9	12.15	974	1135	888	920	-	800
10	12.46	925	945	837	880	-	750
1000 R 1	15.10	718	658	751	728	620	540
2	15.41	704	682	752	699	560	540
3	15.72	604	835	689	706	560	520
4	16.03	642	749	650	699	520	505
5	16.34	546	638	630	666	505	485
6	16.65	577	593	635	-	485	470
7	16.96	561	745	576	569	470	390
8	17.27	602	612	545	559	445	375
9	17.58	514	647	550	528	425	360
10	17.89	438	430	499	487	430	345
500 R 1	20.94	361	415	333	362	270	295
2	21.25	315	339	329	350	270	290
3	21.56	299	320	306	325	250	270
4	21.87	296	318	312	332	235	260
5	22.18	253	299	-	302	240	270
6	22.49	278	277	-	302	220	240
7	22.80	276	322	-	290	220	245
8	23.11	256	277	-	275	205	235
9	23.42	252	275	-	271	210	235
10	23.73	279	280	-	278	205	230

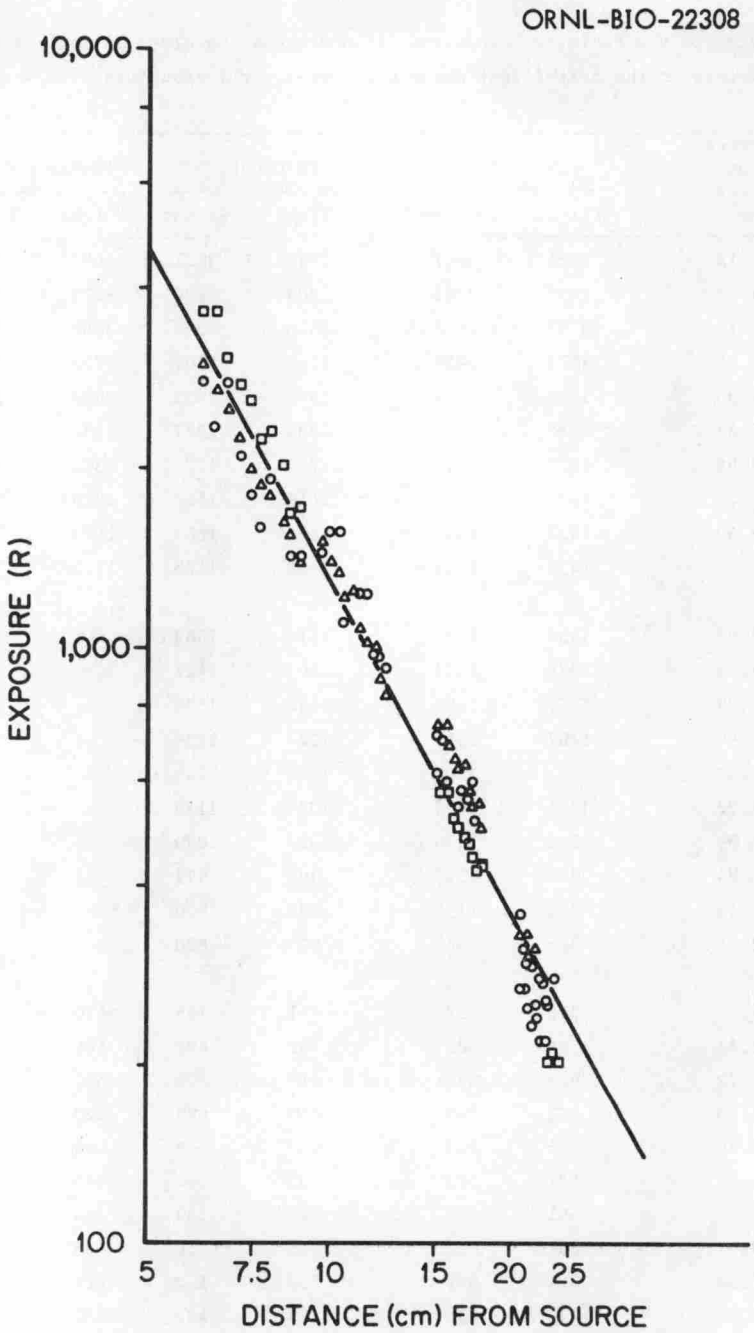

Fig. 19. Radiation Exposure for Post-Flight Phase C Ground-Control Experiment (Flight Vehicle vs Distance).

Logarithm of gamma radiation exposure to each dosimeter in the Post-Flight Phase C Ground-Control Experiment with the flight vehicle plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

ORNL-BIO-22309

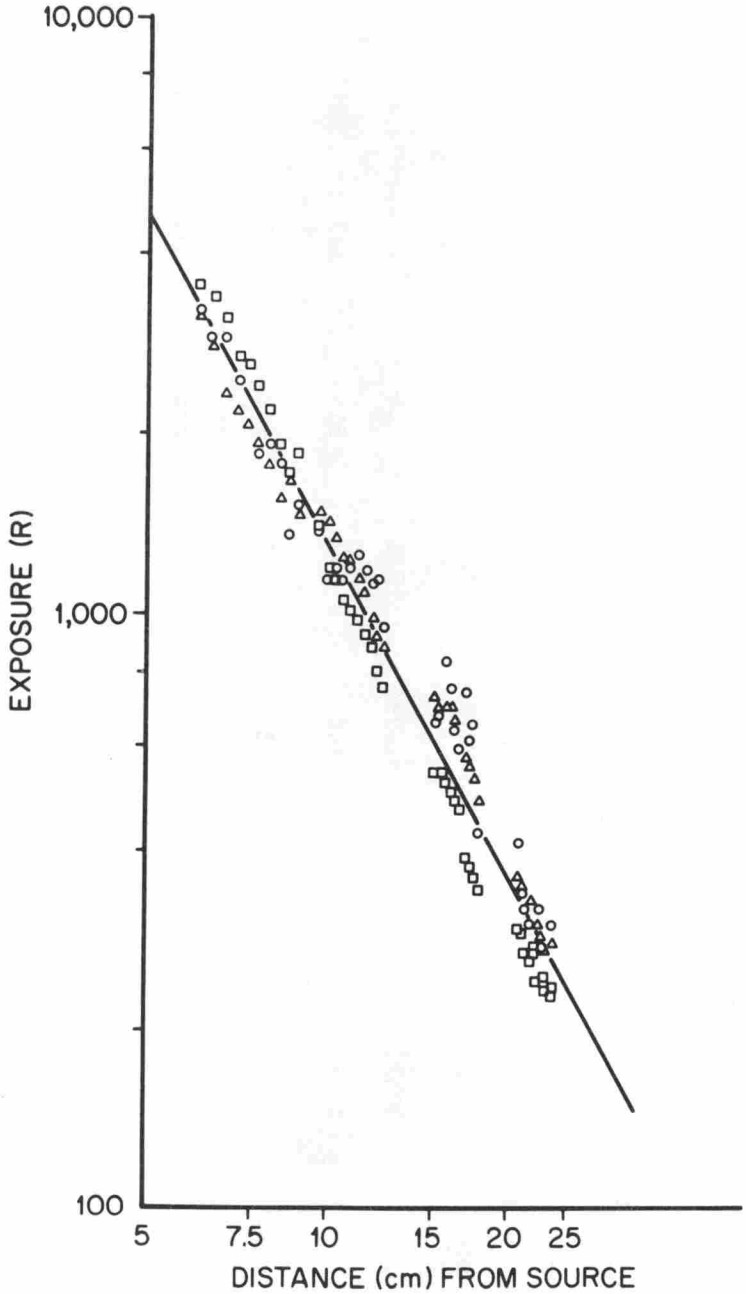

Fig. 20. Radiation Exposure for Post-Flight Phase C Ground-Control Experiment (Ground Control vs. Distance).

Logarithm of gamma radiation exposure to each dosimeter in the Post-Flight Phase C Ground-Control Experiment with the ground control plotted against logarithm of distance (cm) separating each dosimeter from the radiation source, with the regression line. (0 = EG&G LiF dosimeters; △ = EG&G CaF_2 dosimeters; □ = ConRad LiF dosimeters.)

Table 12. Summary of exposures to selected filters from all experiments in which calibrated dosimeters were employed

Package	"6000 R"		"2500 R"		"1000 R"		"500 R"	
Filter Position (cm from source)	1 (6.12)	5 (7.36)	1 (9.67)	5 (10.91)	1 (15.10)	5 (16.34)	1 (20.94)	5 (22.18)
Test								
Pre-Flight Dosimetry	1073	728	410	318	161	136	81	72
301 Gantry	4228	3037	1861	1499	836	726	465	420
Biosatellite II	3136	2235	1353	1084	597	516	327	295
Cape Kennedy Dosimetry Test	895	388	639	312	172	149	95	85
Post-Flight Phase B	2955	1266	2100	1013	555	479	303	272
Post-Flight Phase C	3235	1392	2302	1115	612	529	335	301

Table 13. Regression coefficients for gamma radiation exposure plotted against distance separating dosimeter from radiation source for each of the exercises in which calibrated dosimeters were employed

Experiment	EG&G LiF	EG&G CaF_2	ConRad LiF	All Systems Combined
Biosatellite B 301 Gantry	-1.760	-1.817	-1.829	-1.794
Biosatellite B Pre-Flight Ground control				
Run 1	-2.046	-2.130	-2.005	
Run 2	-2.048	-2.120	-1.871	
Run 3	-2.137	-2.094	-1.962	
All runs combined				-2.101
Biosatellite B Post-Flight Ground Control Phase A				
Run 1 Flight	-1.823	-1.853	-1.944	
Ground	-1.801	-1.827	-1.948	
Run 2 Flight	-1.944	-1.896	-1.701	
Ground	-1.776	-1.753	-1.764	
Run 3 Flight	-1.874	-1.844	-1.877	
Ground	-1.813	-1.766	-1.925	
All flight data combined				-1.841
All ground data combined				-1.800
Biosatellite B Post-Flight Ground Control Phase B				
Flight	-1.696	-1.653	-1.953	
Ground	-1.894	-1.839	-2.069	
All phase B data combined				-1.794
Biosatellite B Post-Flight Ground Control Phase C				
Flight	-1.741	-1.647	-2.137	
Ground	-1.708	-1.713	-2.069	
All phase C data combined				-1.843
Biosatellite B Flight and Simultaneous Ground Control (ORNL-TM-2310)				
Flight	-1.808	-1.865	-1.830	
Ground	-1.830	-1.840	-1.849	
All flight and ground control data combined				-1.837

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