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An International Intercomparison of Environmental Dosimeters Under Field and Laboratory Conditions

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OAK RIDGE NATIONAL LABORATORY
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APRIL 1975

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ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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ABSTRACT

Based on the results of a pilot study at ORNL in 1973, a more comprehensive international intercomparison of integrating dosimeters for the assessment of external penetrating environmental radiation fields was carried out. Forty-one laboratories from eleven countries participated in this study. A total of 56 sets of six detectors each were mailed to and from Houston, Texas, where they were exposed for three months (July to September 1974) as follows: two in an unprotected space out-of-doors 1 m above ground; two in an air-conditioned shielded area with a known, low exposure rate; and two with the second group, but with an additional exposure to 30 mR. Evaluation of the dosimeters provides information on the calibration precision, the accuracy of field measurement, and transit exposure. Some of the results are:

1. Although the TLD data (53 sets) were widely scattered, all but ten sets were in reasonable agreement with regard to the laboratory (28 $\pm$ 5 mR) and field (16 $\pm$ 4 mR) exposures;
2. No significant differences in the accuracy and stability of the various TL phosphors used (23 LiF:Mg,Ti; 12 $CaSO_4$:Dy,Tm;

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*Operated by Union Carbide Corporation for the Energy Research and Development Administration.

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10 CaF_2:Dy; 8 CaF_2:Mn) were found, with the exception of CaF_2:Dy, which exhibited larger than the average standard deviations;

3. Film and TSEE dosimeters (as used by three participants) did not provide data under field conditions; and
4. Transit exposures varied between zero and 55 mR, but no close correlation between distance and transit exposure was found (the 18 overseas participants reported values between 4 and 32 mR).

Future intercomparisons of this type are planned by the authors.

INTRODUCTION

One of the prime purposes of time integrated measurements of external environmental radiation is the estimation of potential population exposures, particularly in areas with abnormal radiation levels and in the environs of nuclear facilities. With the increasing concern about the possible effects of very low radiation levels, this subject attracts more attention, and a multitude of reports have been published recently or presented at meetings (i.e., Lowder 1974, and Hart 1974). The first step of an environmental monitoring program is usually the measurement of local exposure levels utilizing a network of stations which are situated outdoors, about 1 m above ground.

The time averaged environmental gamma radiation level varies substantially from one location to another, mostly due to differences in the concentration of naturally radioactive elements in the upper layers of the soil. The cosmic radiation exposure which is usually

responsible for a significant portion of the total exposure, varies as a function of altitude and latitude but is more uniform and easier to assess (the currently accepted average sea-level value in the U.S. is 3.7 $\pm$ 0.2 μR/h, Lowder 1974). The total environmental exposure rate also varies with time. Differences of 25% and more have been observed from one month to the next in some locations as a function of the soil-water balance and other factors (Burke 1975).

A variety of devices is available for environmental radiation monitoring. Real-time instruments for environmental exposure measurements based on scintillation or gas ionization (see, for example, Lowder 1974) represent an excellent method not only for integral measurements, but also for recording short-term exposure rate fluctuations. Unfortunately, such devices are rather large, expensive and require frequent servicing. As a result, small and inexpensive integrating detectors have come into wide usage for such purposes. However, the performance of these devices under frequently adverse environmental conditions is often questioned.

It should be apparent that photographic film, although it is still occasionally used in environmental monitoring, is not sufficiently stable. Radiophotoluminescent glass dosimeters can only be considered for very long monitoring periods (more than several years) due to their excellent stability, but relatively poor sensitivity (König et al. 1974). Most widely used are TLD phosphors of various composition, shape, and encapsulation mode. Although several other phosphors have been found to be considerably more sensitive and exhibit at least comparable

stability, LiF:Mg,Ti (mostly as Harshaw TLD-100 or 700) is currently the most widely employed material for environmental monitoring, probably because of its widespread use in personnel monitoring.

Obviously, much can be learned from the vast accumulated experiences with personnel dosimeters (for a recent review, see Becker 1973), but important differences have to be considered.

1. High stability is even more important in environmental monitoring because of the more prolonged possible exposure to extremes in temperature and humidity;
2. While the lower useful exposure limit in personnel dosimetry is approximately 10-50 mR, exposures as low as one mR should be measurable with good precision in environmental studies;
3. The overall accuracy of an environmental dosimeter should be at least 5-10%, in particular when they are used to demonstrate compliance with regulations limiting emissions from nuclear facilities, as compared to about $\pm$ 30% tolerances for personnel dosimeters.
4. The photon energy dependence is of less concern because only a small and relatively constant percentage of the typical external environmental exposure is due to photons with an energy of less than 100 keV (according to calculations by Beck 1972, about 6%); cutting off the sensitivity of a detector such as $CaSO_4$ or CaF_2 with a metal filter at 80-100 keV will, therefore, not compromise the results.

Intercomparisons on the regional, national, or international scale of the performance of dosimetry systems for specific purposes such as routine personnel monitoring, criticality accidents, and biomedical neutron and gamma radiation have been carried out frequently in recent years by groups of individual scientists or international organizations such as Euratom and IAEA. They greatly helped to improve the state of art in these fields (for a recent compilation, see IAEA 1973). Although the dosimetric systems involved are frequently the same, again the specific requirements for environmental systems clearly are different. To our knowledge, no large-scale intercomparisons of environmental dosimeters have yet been carried out.

In 1972 and 73, evidence was accumulating that the results of various laboratories undertaking measurements with different detectors at the same location did not always agree within the assumed accuracy limits of the detectors. In a pilot intercomparison study at ORNL (Dickson, et al. 1975), for example, the detectors of five groups from three countries were exposed simultaneously to about 10 mR of artificially increased background radiation. As can be seen in Table 1, the findings varied substantially. Therefore, during a USAEC Workshop on environmental radiation in New York early in 1974, an ad hoc committee consisting of the authors of this report was formed to carry out a more comprehensive and systematic intercomparison. Time and location (July through September in Houston, Texas) were chosen because

TABLE 1

RESULTS OF 1973 OAK RIDGE NATIONAL LABORATORY ENVIRONMENTAL DOSIMETER INTERCOMPARISON

INSTITUTION NUMBER	DETECTOR	REPORTED EXPOSURE-RATE (μR/h)
1.	CaF_2:Dy*	31.3
	LiF:Mg,Ti†	34.5
2.	CaF_2:Dy*	36.7
	LiF:Mg,Ti†	33.0
3.	CaF_2:Dy*	25.5
	CaF_2:Mn*	27.5
4.	BeO (TSEE)	20.5
	$CaSO_4$:Dy‡	40.3
	$CaSO_4$:Dy†	59.0
5.	Photographic Film	139
	LiF-Teflon†	171
	$Li_2B_4O_7$:Mn,Si†	157

*with photon energy compensation filter

†without photon energy compensation filter

‡with photon energy compensation filter of insufficient thickness

1. The hot and humid climate of southeast Texas approximates one extreme of the variety of conditions in which such dosimeters should perform well;
2. The site, a future location for a nuclear power reactor station, offered physical security and continuously recorded meteorological data;
3. The Health Physics Society Annual Meeting in Houston, July 1974 afforded participants an opportunity to visit the intercomparison site; and
4. One of the committee members (T.F.G.) is based in Houston.

A list of potential participants known by the committee members to be actively engaged in environmental dosimetry was compiled and an intercomparison protocol was devised and mailed to the individuals on the list in spring 1974. Twenty-six U. S. and 25 international invitations were issued. Twenty-nine U. S. and 12 international groups participated, representing Canada and West Germany (two groups each) as well as Brazil, Denmark, India, Israel, Italy, the Netherlands, Switzerland and Taiwan (one group each). Some of the groups submitted more than one type of dosimeter. A total of 56 dosimetry systems were intercompared. Additionally, three sets of dosimeters arrived too late for inclusion into the study and were returned. Virtually all types of dosimeters in use were represented in the intercomparison. The study was free of charge to the participants.

PROCEDURES

The primary objectives of the intercomparison were to assess the state of the art of integrating environmental dosimetry by examining

the dispersion of the results of participants; to compare the response of various types of dosimeters; and to provide dosimetry groups with an opportunity to compare their results with those of their peers. The intercomparison involved field exposed, laboratory exposed, and control dosimeters and was designed in such a way that the differences between the field and control, and the laboratory and control dosimeters should be independent of exposures in transit and thus truly intercomparable. Good performance of the laboratory dosimeter and poor performance of the field dosimeter would indicate proper calibration, but inadequate stability under environmental conditions, while poor but comparable performance of both laboratory and control dosimeters indicates systematic problems, for example with the calibration.

Each participant was requested to airmail a set of six dosimeters of each type that he wished to intercompare: two "field" dosimeters, two "laboratory" dosimeters, and two "control" dosimeters. Upon receipt, the dosimeters were transferred to a low-background shielded area (Adams and Gasparini 1970) located on the Rice University campus, in which the measured exposure-rate amounted to 1.5 $\pm$ 0.2 μR/h. On July 2, 1974, 47 sets of field dosimeters were separated from the control and laboratory dosimeters and deployed at the field site in close physical proximity. On July 9, seven sets which had not arrived by July 1st were separated and similarly deployed. Dosimeters received after July 9, 1974 were not included in the study. The temperatures at the field test site varied between 11.5°C and 35.4°C, with an average of 23.6°C during the test. The average relative humidity was 81% and ranged to 100%, and there was 258 mm of rainfall during

18 days and an average of 60% of possible sunshine. A portable, battery operated recording ion chamber was also deployed on the site on July 9. The ion chamber was serviced biweekly and the magnetic tape analyzed by the ERDA Health and Safety Laboratory, New York. The estimated radiation exposure during the experiment amounted to 16.3 $\pm$ 0.8 mR, with hourly fluctuations observed between 7.0 µR/h and 12.9 µR/h.

Some of the dosimeters received for the intercomparison did not appear to be packaged or identified in a manner that would withstand three months in the selected environment. Therefore, all the field dosimeters were additionally packaged in heat sealable polyethylene bags (0.05 mm foil thickness). Except for this additional foil, the dosimeters were unprotected from the environment. On August 17, 1974, the laboratory dosimeters were separated from the control dosimeters and simultaneously exposed to 30 $\pm$ 1.5 mR from a 10 mg ^{226}Ra source encapsulated in 0.5 mm of a Pt/Ir alloy. After the irradiation, which took 180 minutes, the laboratory dosimeters were immediately reunited with the control dosimeters in the shield.

On September 30th, 1974 the field dosimeters were recovered, reunited with the laboratory and control dosimeters and returned (in case of overseas participants by airmail) to the participants together with a response form. Response forms, received for all but two of the dosimeter sets submitted for the study, were evaluated by the authors in January 1975.

DISCUSSION OF RESULTS

A summary of all the results is given in Table 2. All data have been rounded off to one decimal. The participants were requested to estimate the actual field and laboratory exposures from the exposures measured with the "field", "laboratory", and "control" dosimeters. The field exposure is defined as the total exposure measured with the "field" dosimeters minus the exposure measured with the "control" dosimeters after the subtraction of the exposure received in the storage shield from the latter (for the time the "field" dosimeters were separated from the "control" dosimeters). The laboratory exposure is defined as the total exposure measured with the "laboratory" dosimeters minus the total exposure measured with the "control" dosimeters. Each participant's estimates are shown in Table 2. They were recalculated by the authors and where the estimates differ the recalculated number is given in parenthesis. In almost every case, the differences occurred because of computational errors. It should be pointed out, however, that had these measurements been made as part of an environmental monitoring program, e.g., for the purpose of determining exposures related to nuclear facilities, any error, computational or otherwise, would in fact be an error. Because of this, all analyses were performed using both the reported and the recalculated exposure estimates. Since the errors were random, the overall conclusions do not differ significantly. To give a true representation of TLD capability, all analyses presented in this paper are based on the recalculated estimates.

TABLE 2

INTERCOMPARISON OF ENVIRONMENTAL DOSIMETERS UNDER FIELD AND LABORATORY CONDITIONS
SUMMARY OF RESULTS

SERIAL NUMBER	FIELD			LABORATORY			TRANSIT		DISPERSION† (%)	CALIB. SOURCE	DE-TECTOR** TYPE	READER** TYPE
	EXPOSURE (mR)	ACCURACY (%)	CORREC-TIONS†	EXPOSURE (mR)	ACCURACY (%)	CORREC-TIONS†	EXPOSURE (mR)	CORREC-TIONS†				
2	15(18.7)	6.7	N	32	9.4	N	10.3	N	6.1	^{60}Co	g	aa
12	16	12.5	N	29	10.3	N	4.7	N	6.0	^{137}Cs	g	aa
13	14	*	*	19	*	*	14.3	*	6.1	^{137}Cs	g	aa
18	14.8(17.3)	10.1	N	38.2(37.9)	21.5	N	5.2	N	*	^{238}U	g	aa
37	15	20.0	N	30	26.7	N	8.6	N	4.0	^{137}Cs	g	aa
43	15(14.1)	13.3	N	25	12.0	N	4.0	N	*	^{137}Cs	g	aa
47	14.4	14.6	N	24.5	13.5	N	0.0	N	4.2	^{226}Ra	g	aa
50A	15.4	54.9	A	27	40.7	A	15.8	A	57.6	^{60}Co	g	aa
3A	18.1	22.1	N	29.8(26.6)	13.4	N	7.1	N	4.6	^{137}Cs	g	cc
3C	19.6	20.4	N	26.9	14.9	N	5.1	N	15.7	^{137}Cs	g	cc
9	13.8	17.4	N	27.4	17.9	N	3.7	N	13.1	^{137}Cs	g	cc
35	15.4	11.0	N	27.0	8.7	N	13.1	N	1.8	^{226}Ra	g	cc
46	9.1‡	5.6	A	31.2	26.6	A	-1.1	A	45.2	^{137}Cs, ^{241}Am	g	cc
52	16.5	21.1	*	27.8	21.2	*	32.3	*	3.2	^{226}Ra	g	cc
39	18.1	+46.4, -22.1	N	30.4	+29.9, - 15.5	N	8.6	N	5.4	^{137}Cs	g	kk
10	15.1	+10.0, -5.0	A	29.0	3.7	N	2.7	N	0.9	^{137}Cs	g	ll
11	13.6(13.4)	-8.8	N	26.4	5.7	A	6.1	A	1.9	^{226}Ra	g	ll
24	23	*	*	27.5	*	*	12.8	*	*	^{226}Ra	g	ll
27	14.8	24.3	N	32.6	8.9	N	1.0	N	17.9	^{60}Co, ^{137}Cs	g	ll
42A	14.8	5.7	N	28.5	4.6	N	10.4	N	2.8	^{226}Ra	g	ll
53	8.7(11.9)	37.5	N	29	10.3	N	26.0	N	1.7	^{60}Co	g	ll
1	14.6(13.3)	10.9	A	23.8	10.6	A	2.8	A	3.6	^{226}Ra	b	aa
50B	39.3	32.0	A	99.1	27.2	A	10.1	A	21.1	^{60}Co	b	aa
3B	14	10.7	A,B'	23.2	6.5	A,B'	6.7	A,B'	1.1	^{137}Cs	b	cc
6	27(28.2)	24.1	A	47	24.5	A	9.8	A	6.4	^{60}Co, X-Rays	b	cc
40	17.5	3.2	A,B,C	43.3(40.0)	27.3	A,B,C	5.2	A,B,C	2.9	^{60}Co	b	cc
45	NR	NR	NR	28.0	6.1	A	3.8	A	8.9	^{137}Cs, ^{241}Am	b	cc

TABLE 2 cont.

SERIAL NUMBER	FIELD EXPOSURE (mR)	FIELD ACCURACY (%)	FIELD CORRECTIONS†	LABORATORY EXPOSURE (mR)	LABORATORY ACCURACY (%)	LABORATORY CORRECTIONS†	TRANSIT EXPOSURE (mR)	TRANSIT CORRECTIONS†	DISPERSION† (%)	CALIB. SOURCE	DETECTOR** TYPE	READER** TYPE
49	16.2	10.7	N	29.3	7.2	N	10.1	N	7.9	^{60}Co	b	dd
22	12	3.2	N	28	3.2	N	1.0	N	15.3	^{137}Cs	b	ee
5	15.9	12.6	A	25.5	11.8	A	4.0	A	3.6	^{226}Ra, ^{60}Co	b	hh
16	12.1	19.8	B',D	27.9	10.0	B',D	10.4	B',D	4.9	^{60}Co	c	bb
21	11	3.2	D	29	3.2	D	9.8	D	13.3	^{137}Cs	c	bb
28	10.7(13.9)	10.0	D	15.8(26.2)	10.0	D	8.9	D	8.7	^{226}Ra	c	bb
48	14.8	6.6	A	29	3.8	A	11.4	A	1.9	^{60}Co	c	ff
15	21	9.5	N	34.2(28.3)	4.4	N	8.6	N	4.4	^{137}Cs	c	kk
19	14.6	6.1	A,C,D	29.5	2.5	A,C,D	2.2	A,C,D	9.0	^{226}Ra	c	kk
20	15.0	13.3	A,B,D	27.9	10.8	A,B,D	0.9	A,B,D	15.9	^{137}Cs	c	kk
38	18.7(15.1)	10.7	A,D	30.5	5.6	A,D	8.9	A,D	1.3	^{137}Cs	c	kk
25	25.5	4.7	N	20.9	5.7	N	7.5	N	29.7	^{226}Ra	d	ll
31	13.3	7.0	B'	35.7	2.0	B'	54.6	B'	1.0	^{60}Co	e	cc
4A	18.3	4.9	A,D	29.4(26.2)	6.5	A,D	8.4	A,D	*	^{60}Co	e	gg
17	17.9	13.3	N	29.3(29.4)	20.5	N	11.3	N	10.2	^{238}U	e	hh
23	12.4(12.9)	9.7	N	25.5(25.7)	10.2	N	3.8	N	8.2	^{137}Cs	e	ii
32	17.9	7.3	A'	32.1	5.0	A'	6.7	A'	3.3	^{137}Cs	e	ii
33	18.1	7.2	A	32.6	4.9	A	6.5	A	2.7	^{137}Cs	e	ii
34	16.0	7.5	N	29.2	5.1	N	5.8	N	2.8	^{137}Cs	e	ii
26	14.4	6.3	N	22.2	5.4	N	7.5	N	10.0	^{226}Ra	e	ll
42B	19.2	3.1	N	29.8	1.1	N	6.1	N	0.9	^{226}Ra	e	ll
4B	19.0	*	A,D	27.1	*	A,D	8.6	A,D	*	^{60}Co	f	gg
44	13.5	7.8	D	28.3	4.4	D	4.6	D	1.8	^{137}Cs	f	jj
36	12.3(12.6)	*	N	27.3	*	N	4.7	N	16.9	^{60}Co	g,e	ll
14	14.5	8.3	A	25.7(25.9)	5.0	A	1.6	A	3.0	^{226}Ra	g,b	aa
41	33	30.3	A	27(23.5)	22.2	A	18.3	A	21.1	^{226}Ra	a	ee
30	NR	NR	NR	34	26.5	N	36.8	N	*	^{60}Co	h	mm
51	NR	NR	NR	30.5	108.2	*	18.5	*	43.6	^{226}Ra	i	nn
54	NR	NR	NR	30	33.3	N	0.0	N	0.0	^{60}Co	j	nn
Laboratory Exposure Ionization Chamber	16.3	5.0		30	10.0					^{226}Ra ^{226}Ra		

†see text for explanation
*insufficient information provided by the participant
**see code given in Table 4
‡total exposure measured with field dosimeters
( )numbers in parenthesis were calculated by the authors and indicate a computational error in the numbers as reported by the participant
NR NO RESPONSE

The transit exposure as given in Table 2 was calculated by subtracting from the total exposure measured with the "control" dosimeters that portion received while the "control" dosimeters were in the storage shield. Corrections made by the participants for fading, energy dependence, directional dependence and self-irradiation are indicated in the Table by A, B, C, and D, respectively. Primed indicators imply that the participant reported a physical correction (e.g., an energy compensating shield) as opposed to a mathematical correction. It is likely that in some cases physical corrections were employed, particularly for energy dependence, and were not reported as such by the participants.

The accuracies given in the Table are those reported by the participants. The authors did not suggest how to estimate the accuracy of the results, and it is not known how the errors were estimated. There seems to be a tendency to overestimate the accuracy of the detectors. In one instance, the same participant estimated the accuracies of the three different systems which he used in such a way that there was no overlap between the ranges of his three differing results. The dispersion, or measure of precision, was determined by calculating the difference between the two measurements reported in each category divided by the average of the two, multiplying by 100, and averaging these values over the three categories, "laboratory", "field", and "control". Overall, the precision is not as good for the "control" dosimeters, 12.9%, as for the "field" or "laboratory" dosimeters, 7.3 and 8.3% respectively.

The calibration source used by each participant is also given in Table 2, with ^{137}Cs (23), ^{60}Co (17), and ^{226}Ra (16) being the most common. The Table also indicates the detector and reader types used by the participants. The code for each type and the numbers of each type are given in Table 3.

An attempt was made to classify the participants according to the type of institution which they represent (universities, government agencies, national laboratories, power companies, etc.), but no conclusions could be drawn with regard to their relative performance in the test. As can be seen from Table 4, there is also no significant difference in the relative performance of LiF:Mg,Ti; $CaSO_4$:Dy,Tm; and CaF_2:Mn, but CaF_2:Dy exhibits a larger standard deviation than the others, probably due to the difficulties associated with its pronounced low-temperature glow peak.

A graphical presentation of the distribution of the results of all dosimeters exposed to 30 mR in the laboratory is given in Fig. 1. 59% of the detectors fall within $\pm$ 10%, 80% within $\pm$ 20%, and 89% within $\pm$ 30% of the expected value. In Fig. 2 representing the field measurements, the two sets of photographic films and one TSEE set are not included because these detectors did not provide any data. The average of the readings of the TLDs (16.2 mR) agrees within 0.9% with the ionization chamber reading. Of all the TLDs, 34% fell within $\pm$ 10% of the average, 74% within $\pm$ 20%, and 85% within 30%. The standard deviation of all the field exposures ($\pm$ 26%) was significantly higher than that of the laboratory exposures ($\pm$ 16%), probably

TABLE 3

DETECTOR AND READER TYPES USED BY PARTICIPANTS

CATEGORY	DESIGNATION	NUMBER IN STUDY	CODE FOR TABLE 2
Detectors			
TLD	BeO	1	a
	CaF_2:Dy	10	b
	CaF_2:Mn	8	c
	CaF_2, natural	1	d
	$CaSO_4$:Dy	10	e
	$CaSO_4$:Tm	2	f
	LiF: Mg, Ti	23	g
TSEE	BeO	1	h
FILM	AgfaGevaert	1	i
	Kodak Type 2	1	j
Readers			
TLD	Eberline TLR-5	11	aa
	EG&G TL-2A, 2B, 3A, 3B	4	bb
	Harshaw 2000	12	cc
	Harshaw 4000	1	dd
	Harshaw 2271	1	ee
	Harshaw CP-1112/PD	1	ff
	Teledyne 7100	2	gg
	Teledyne 7300	2	hh
	Teledyne 8300	4	ii
	Teledyne UD-505A	1	jj
	Victoreen 2600	5	kk
	Non-commercial	10	ll
TSEE	Non-commercial	1	mm
FILM	Densitometer	2	nn

TABLE 4

INTERCOMPARISON RESULTS ACCORDING TO TLD TYPE

CATEGORY	FIELD			LABORATORY		
	NUMBER	AVERAGE EXPOSURE (mR)	STANDARD DEVIATION (%)	NUMBER	AVERAGE EXPOSURE (mR)	STANDARD DEVIATION (%)
TLD TYPE						
LiF	21	15.6	18.6	21	28.3	12.9
CaF_2:Dy	7*†	16.7	32.3	8*	30.6	27.6
CaF_2:Mn	8	14.7	20.1	8	28.5	4.5
CaF_2natural	1	25.5	------	1	20.9	------
$CaSO_4$:Dy	9	16.4	14.4	9	29.2	13.9
$CaSO_4$:Tm	2	16.3	------	2	27.7	3.1
BeO	1	33.0	------	1	23.5	------
LiF:$CaSO_4$:Dy	1	12.6	------	1	27.3	------
LiF:CaF_2:Dy	1	14.5	------	1	25.9	------
TOTAL (all types)	51*†	16.3	25.7	52*	28.5	15.9
ESTIMATED EXPOSURE‡		16.3	5		30.0	5

*excluding serial number 50B
†excluding serial number 45
‡field estimate based upon ion chamber data; lab estimate based upon activity of source, exposure time and exposure distance.

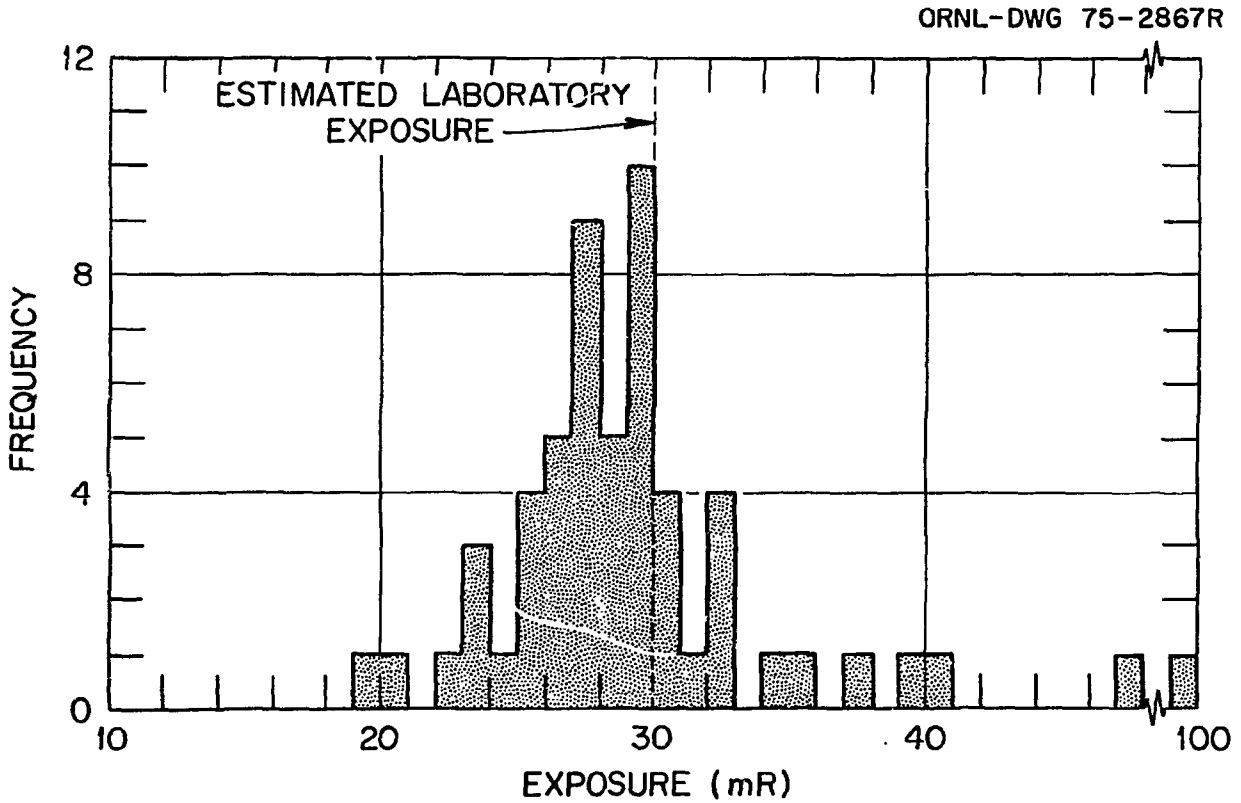
ORNL-DWG 75-2867R
ESTIMATED LABORATORY EXPOSURE
FREQUENCY
12
8
4
0
10
20
30
40
100
EXPOSURE (mR)

Figure 1

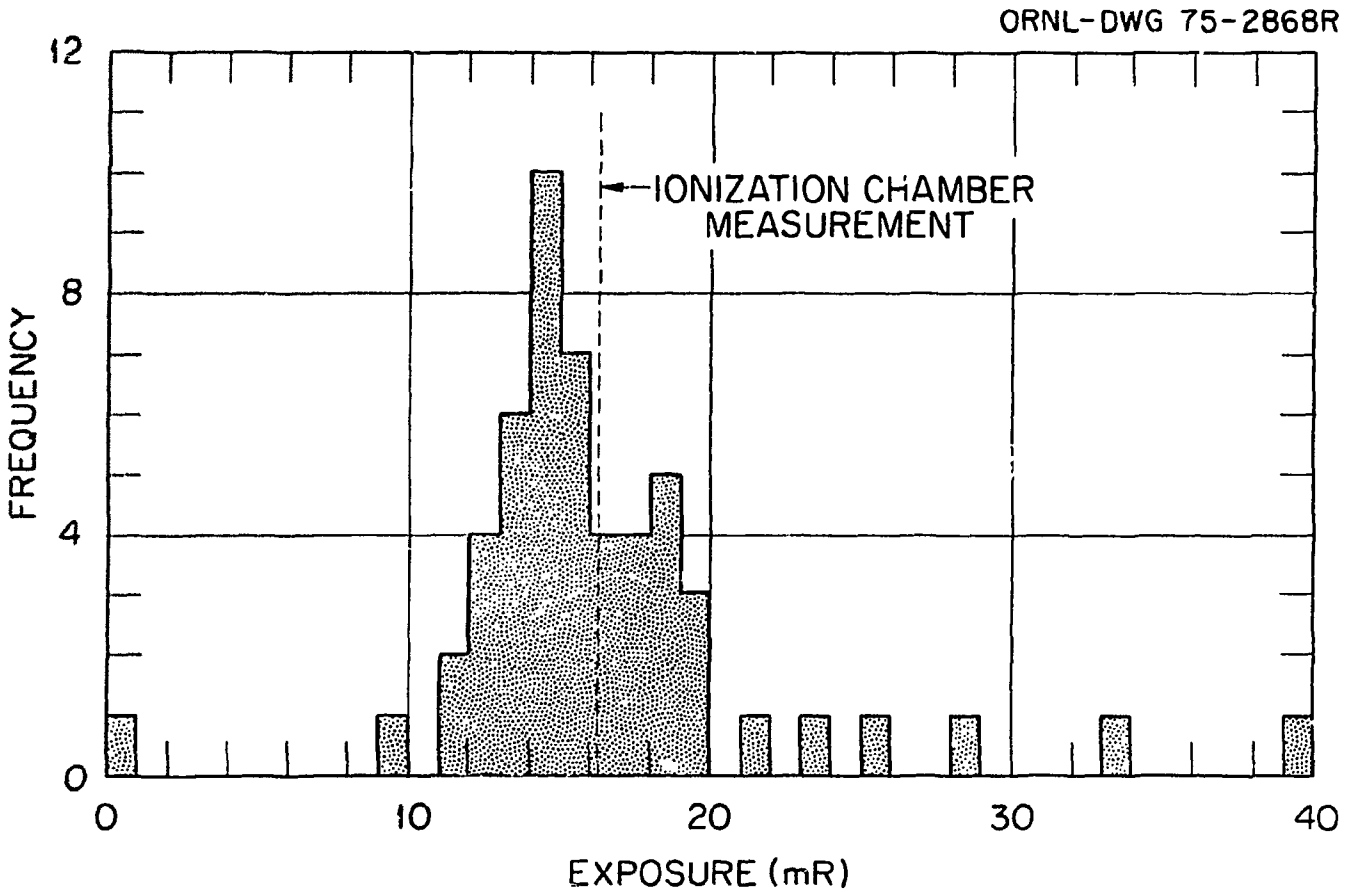
ORNL-DWG 75-2868R
12
8
4
0
FREQUENCY
IONIZATION CHAMBER
MEASUREMENT
0
10
20
30
40
EXPOSURE (mR)

Figure 2

because of the harsher climatic conditions and lower exposure levels involved.

It can be seen in Fig. 3 that the correlation between transit exposure and round trip distance is very poor. Obviously, in many cases only a fraction of the transit exposure can be attributed to the increased cosmic radiation exposure in high-flying aircraft (assuming travel by the shortest route). At least in the cases of some unusually high values, the detectors have apparently received additional radiation from some other source. Transport or storage together with radioisotope shipments is a possible source of this additional exposure.

The exposures received while flying the estimated round trip distances at 55° geomagnetic latitude during solar minimum at a speed of 885 km/h and at three different altitudes are indicated by the solid lines in Fig. 3. These estimates are based on the cosmic ray data of O'Brien (1975). Even if the typical total transit time amounted to two weeks during which the detectors were exposed to an additional 20 μR/h, the estimated exposures in Fig. 3 would only be increased by 7 mR, and still be insufficient to account for many of the exposures measured. It is obvious from the results that estimates of transit exposures may be highly inaccurate and that where transit exposures must be accounted for they should be measured directly.

CONCLUSIONS

Although the overall results of this intercomparison were reasonably good, it is evident that some participants must improve their procedures and/or calibration techniques substantially before they will

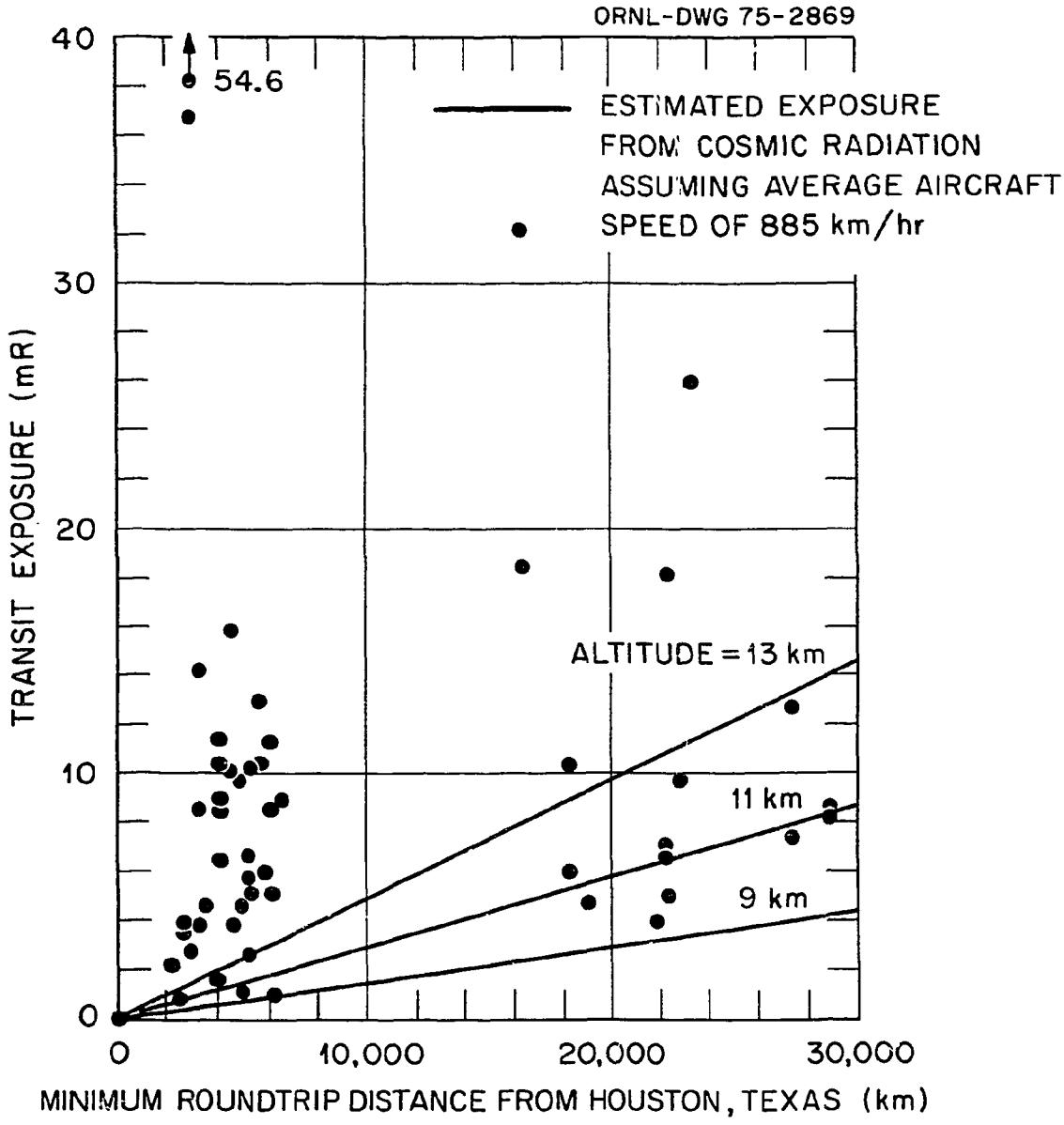
ORNL-DWG 75-2869
40
30
20
10
0
54.6
ESTIMATED EXPOSURE
FROM COSMIC RADIATION
ASSUMING AVERAGE AIRCRAFT
SPEED OF 885 km/hr
ALTITUDE = 13 km
11 km
9 km
TRANSIT EXPOSURE (mR)
0
10,000
20,000
30,000
MINIMUM ROUNDTRIP DISTANCE FROM HOUSTON, TEXAS (km)

Figure 3

be able to produce sufficiently reliable results (a few participants over- or underestimated both laboratory and field exposures by as much as 15 to 20 mR). One can also speculate that the relatively good performance of some participants is not "typical", but representative of their very best efforts (participants were encouraged to do so), which they would not devote to more routine situations. It is, for example, well-established in personnel monitoring that the poor performance of some film badge services is not so much due to the inherent limitations of the film, but to poor evaluation of the detectors. Obviously, no simple assumptions should be made with regard to transit exposures whenever environmental dosimeters are being mailed. We consider this one of the more important results of this study.

Further intercomparisons of this type are anticipated and interested readers are encouraged to contact one of the authors for details. It can be hoped that this experiment and possible future intercomparisons will have a beneficial effect on the state-of-the-art in this field.

ACKNOWLEDGMENTS

The authors would like to express their sincere appreciation for the substantial efforts devoted by the participants (Table 5) to this study. We want to thank H. M. Prichard, University of Texas, School of Public Health, for his valuable assistance. We are also grateful for the provision of the storage location by Rice University and the field site and meteorological data by Houston Lighting and Power.

TABLE 5
INTERCOMPARISON PARTICIPANTS

NAME	AFFILIATION	LOCATION
V. Balasubrahmanyam	Radiation Protection Bureau Department of National Health and Welfare	Ottawa, Canada
Burton M. Ball	Vermont Yankee Nuclear Power Corporation	Vernon, VT, U.S.A.
Stephen T. Bard	NUS Corporation	Rockville, MD, U.S.A.
Klaus Becker	Oak Ridge National Laboratory Health Physics Division	Oak Ridge, TN, U.S.A.
Merlyn R. Boss	Dow Chemical	Golden, CO, U.S.A.
Lars Bøtter-Jensen	Danish Atomic Energy Commission	Roskilde, Denmark
Gail de P. Burke	USAEC Health & Safety Laboratory	New York, NY, U.S.A.
Donald D. Busick	Stanford Linear Accelerator Center	Stanford, CA, U.S.A.
Peter T. Crinigan	Consolidated Edison	Buchanan, NY, U.S.A.
John P. Cusimano	USAEC Dosimetry Branch, HSL	Idaho Falls, ID, U.S.A.
Jack Dauch	Teledyne Isotopes	Westwood, NJ, U.S.A.
Sudernaique F. Deus	Instituto de Energia Atômica Cidade Universitária	São Paulo, Brazil
Kenneth J. Eger	General Electric Company	Morris, IL, U.S.A.
Stewart A. Farber	Yankee Atomic Electric Company	Westborough, MA, U.S.A.
Richard C. Fix	Interex Corporation	Natick, MA, U.S.A.
Richard Gammage	Oak Ridge National Laboratory	Oak Ridge, TN, U.S.A.
Thomas F. Gesell	University of Texas School of Public Health	Houston, TX, U.S.A.
R. F. Grossman	National Environmental Research Center, E.P.A.	Las Vegas, NV, U.S.A.
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Roscoe M. Hall	Savannah River Plant	Aiken, SC, U.S.A.
T. G. Hobbs	National Bureau of Standards	Washington, D.C., U.S.A.
Andrew P. Hull	Brookhaven National Laboratory	Upton, NY, U.S.A.
J. G. Johnston	Victoreen Instrument Division of VLN	Cleveland, OH, U.S.A.
Alun R. Jones	Health Physics Branch CRNL	Ontario, Canada
H. W. Julius	Radiological Service Unit TNO	Arnhem, The Netherlands
John L. Lobdell	Tennessee Valley Authority	Muscle Shoals, AL, U.S.A.
Arthur C. Lucas	Harshaw Chemical Company	Solon, OH, U.S.A.
C. E. Morse	Maine Yankee Atomic Power Company	Wiscasset, MA, U.S.A.
E. K. A. Piesch	Karlsruhe Nuclear Research Center	Leopoldshafen, Germany
E. A. Sanchez	Eberline Instrument Corporation	Santa Fe, NM, U.S.A.
G. Scarpa	Laboratorio Dosimetria, C.N.E.N. Casaccia	Rome, Italy
T. Schlesinger	Soreq Nuclear Research Center	Yavne, Israel
Richard C. M. Sha	Radiation Management Corporation	Philadelphia, PA, U.S.A.
S. D. Soman	Bhabha Atomic Research Centre	Bombay, India
Betsy K. Tanner	Emory University	Atlanta, GA, U.S.A.
Milt Trautman	Eberline Instrument Corporation	West Chicago, IL, U.S.A.
J. W. N. Tuyn	CERN	Geneva, Switzerland
F. Wachsmann	Institut für Strahlenschutz	Neuherberg, Germany
Stanley J. Waligora, Jr.	Eberline Instrument Corporation	West Columbia, SC, U.S.A.
Pao-Shan Weng	National Tsing Hua University	Hsinchu, Taiwan
Sam T. Windham	U.S. Environmental Protection Agency	Montgomery, AL, U.S.A.

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FIGURE CAPTIONS

Fig. 1. Frequency distribution of the exposures measured with all detectors in the laboratory tests.

Fig. 2. Frequency distribution of the exposures measured with the thermoluminescence dosimeters in the tests (excluding films and TSEE).

Fig. 3. Transit exposures of detectors mailed to and from testing area.

QUESTIONNAIRE

Dear Participant in the 1974 Intercomparison:

Thank you very much for your cooperation in this study. This report represents the summary of the results. Because we believe that these data are of sufficient general interest and in order to invite wider participation in possible future intercomparisons, we also intend to present them (as we agreed, also without identifying the participants with their results) at the Annual Meeting of the Health Physics Society in Buffalo, July 14-17, 1975, and to submit a slightly modified version for publication in the Health Physics Journal. If you have any serious objections against our analysis of your results which we should, in your opinion, consider in the published version, please contact any of us immediately. If we do not hear from you within three weeks after receipt of the report, we will assume that you agree with our presentation. In any event, would you kindly fill out and return this questionnaire to Gail Burke.

1. Comments on this report, or suggested data corrections:

2. Are you interested in future intercomparisons of this type, and if so, would you suggest any changes in the procedures (duration, etc.)?

3. When, and under what climatic conditions should we organize another intercomparison (in the committee's opinion, the choice is either winter 1975/76 in the New York area, or summer 1976 in the Oak Ridge area)?

4. Can you provide names and addresses of additional potential participants not listed in Table 6 to be invited for future tests?

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