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HANFORD MULTIPURPOSE TL DOSIMETER FIELD TESTS AND EVALUATION*

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DISCLAIMER

HANFORD MULTIPURPOSE TL DOSIMETER FIELD TESTS AND EVALUATION

A new multipurpose thermoluminescent dosimeter (TLD) has been developed for Hanford to replace the currently used beta-gamma film dosimeter for personnel monitoring of radiation exposure. Implementation of this new system began in January, 1972. Before implementation, field tests were conducted to compare the multipurpose TLD with film dosimeters and exposure rate instruments that are currently used to assist in the evaluation of dose to personnel. It must be pointed out that in this type of study, it is very difficult to identify the type and quantity of radiation to any degree of accuracy so that most of the results can be used only for comparison purposes. A description of the multipurpose TLD and the lab tests that were performed in its evaluation are described in another report.[1] An exploded view of the dosimeter is shown in Figure 1.

These field tests were conducted in two main parts. One set of tests consisted of placing two multipurpose dosimeters, two beta-gamma film dosimeters and two NTA neutron film dosimeters on two-gallon polyethylene jugs filled with water. These jugs were placed in normal work locations in Hanford facilities and remained in position until a significant exposure had been accumulated on the dosimeters. Exposure rates were measured with typical exposure rate instruments at the beginning of the

exposure and were postulated to be constant during the time the jugs were in position.

The second portion of the field test consisted of selecting employees to wear the new TL dosimeters in addition to their assigned beta-gamma and NTA neutron film dosimeters. Selection of participating employees from the Atlantic Richfield Hanford Company (ARHCO) was made on the basis of work location, job classification, and the anticipated exposure during the test period. The work locations selected were Purex, B Plant, Z Plant, the Tank Farms, and the 222-S Analytical Laboratory. Selected participants each had a recent history of above average monthly radiation exposure. Process operators, radiation monitors, laboratory workers, and maintenance craftsmen, in approximately equal numbers on each shift, participated in the tests. Field tests were also conducted with Douglas United Nuclear (DUN) employees. Selection of DUN employees was made on a similar basis as used for ARHCO but involved a smaller group of employees. Stephens self-reading pocket dosimeters (pencils) were also worn by the DUN employees.

The NTA and beta-gamma film dosimeters were processed and interpreted using normal procedures. The multipurpose dosimeters were read out on a modified TLD reader and the results were interpreted using the following four equations:

$$\text{Penetrating dose} = \frac{R_1}{k_1} \tag{1}$$

$$\text{Derma dose} = \text{penetrating dose} + \frac{R_1 - k_2 R_2}{k_3} \tag{2}$$

$$\text{Thermal nuetron dose} = \frac{R_3 - R_4}{k_4} \quad (3)$$

$$\text{Fast neutron dose} = \frac{R_4 - k_5 R_5 - k_6(R_3 - R_4)}{k_7} \quad (4)$$

where R_1, R_2, R_3, R_4 and R_5 are the net integrated counts from the phototube due to the thermoluminescence of each TLD block, respectively. The calibration constants k_1---k_7 are all determined by exposure to known calibration sources.

The calibration sources used for the multipurpose dosimeters were radium, strontium, plutonium fluoride and thermal neutrons from the Hanford sigma pile. The calibration sources used to interpret the film dosimeters were radium, uranium beta, 16-keV X-ray, plutonium fluoride, and thermal neutrons from the Hanford sigma pile.

The most meaningful results were from the tests which use the set of six dosimeters (2 TLD, 2 beta-gamma film and 2 NTA film) symmetrically attached to a jug filled with water. These jugs were placed in the 105-KE, 105-N, Purex, B Plant, 234-5, 325, 327, 3745 and 3745-B Buildings for various periods of time to accumulate exposure. CP and snoopy readings were made at each of the 49 jug locations. The dosimeters were all interpreted and the results are tabulated in Table I, page 9. There are no surprises from the comparisons.

Due to the thinner effective filter in the TLD badges (0.025" aluminum vs 0.020" tantalum), the penetrating dose interpretations tend to be higher than for the film dosimeters. In general, the derma doses are about the same for those doses that

can reasonably be interpreted from film. There are some discrepancies at high exposures where the film is difficult to read. The fast neutron interpretations for the multipurpose dosimeters were more consistent than for NTA film. The multipurpose dosimeter gave a positive indication of neutron exposure in all areas where neutrons were known to exist. This was not the case with NTA film.

Another striking comparison is the precision of the two TLD readings for a given location compared to the two film readings. Paired film dosimeter readings which show significant differences are both given in the Table, whereas the two TLD dosimeters, in all cases, agreed with each other within 10 percent.

As an overall comparison of the two systems (TLD vs film), the various doses determined by the dosimeters in each building are totaled and shown for easy comparison. The TLD interpretations were simply summed. Where discrepancies appeared in the pairs of films for penetrating and derma dose, that reading most consistent with the corresponding CP integrated dose and TLD result was used. All of the penetrating dose comparisons were good except for B Plant. After studying the densitometer readings for those films, it was concluded that the film was too black to permit an X-ray interpretation which should have been significant. Therefore, the assignment of 35 percent of this X-ray dose to penetrating dose (which is the customary procedure) could not be done. Therefore, the penetrating dose interpretation for film was low.

All of the derma dose comparisons were good except at the 325 Building where the TLD indicated 50 percent more than the

film. The largest contributor to this discrepancy was the badges at 604 BG location where the TLD indicated twice as much derma as the film. If the dose interpretation obtained from the TLD's is compared to the integrated CP dose, the agreement is reasonable for both these work locations.

Special attention should be given the special laboratory exposures at the bottom of Table I. These exposures were made to known sources where the doses could be measured and/or calculated. In all cases, the TLD indicated more reasonable interpretations than film dosimeters.

An identical but less extensive study was conducted at a later time and the neutron results are shown in Table II. In addition to the film, TLD and field instruments, a tissue equivalent proportional counter (TEPC) was used to measure neutrons. Again, there are some wide variations between the film and TLD measurement of fast neutron dose. Whenever the field instruments indicated the presence of neutrons, the TLD responded positively. On top of the KE Reactor, adjacent to #23 vertical safety rod, the TEPC and TLD system were exposed in a very nonuniform neutron field with the TLD placed in the center. The difference in TEPC and TLD dosimeter results was expected, but the film missed most of the neutron dose. Other exposures show a wide variation in film results for fast neutron dose. Both film and TLD do a satisfactory job measuring thermal neutrons, although the film results are more scattered.

Average quality factors ($\overline{QF}$) for fast neutrons were obtained for 13 different field and laboratory exposures of the TEPC. The

average of the $\overline{QF}$ for these exposures is 10.1. For widely varying geometry, the range in $\overline{QF}$ is from 8.5 for a bare ^{252}Cf to 12.0 for a heavily shielded storage vault containing plutonium fuels. These measurements indicate that 10 is very good $\overline{QF}$ for fast neutron dose interpretation in Hanford facilities. A $\overline{QF}$ of 3 is used for all thermal neutron dose interpretations. These $\overline{QF}$ values have been utilized in interpretaion of dose equivalent for the multipurpose dosimeter.

The second portion of the field tests consisted of comparing dose interpretation from the multipurpose dosimeter with results obtained from the film dosimeter normally worn by the employee. A summary by work location of November, 1970 and January, 1971 data is given in Table 3, page 14. A complete list of the data summarized in this Table is given in Appendix A. Although everyone in a given building or classification group does not get exactly the same type or amount of exposure, their combined exposures can be discussed with some meaning. Overall, the results for each month are consistent. The penetrating dose interpretations show the differences in filters between the two systems which tend to indicate more dose to the TLD in the presence of intermediate energy photons and intermediate and high energy beta particles (conditions prevalent at Purex, 222-S, T and B Plants and with radiation monitors). The penetrating dose interpretation at 234-5 Building was influenced by the large X-ray component of the exposure. The filter system of the film dosimeter tends to over-estimate the penetrating portion of the X-ray contribution of the exposure.

The TLD derma and penetrating dose interpretations are low compared to film for the 234-5 Building. The film dosimeter has been observed to over-respond compared to TLD and pencils in similar circumstances. The high TLD derma interpretation for Purex, Tank Farms, and B Plant is most likely due to the high penetrating interpretation from beta and X-ray exposures. The film interprets more of this type of exposure as non-penetrating than does TLD. The sums for film are still less than for TLD.

The TL and film derma interpretation for T plant, radiation monitors and Shop's personnel are comparable even though the penetrating dose for each may not be. The total exposures were interpreted in different ways in the two badge systems but both gave similar results. The high derma interpretation at 222-S Building by film can be reconciled by considering two conditions. First, the TLD is calibrated to ^{90}Sr, which is prevalent in the building, and the film is calibrated to uranium-beta. Therefore, the film over-responds to Sr-β by about 40 percent. Secondly, the film interprets soft X-rays (8 keV) as equal mrads of beta exposure while the TLD interprets only 14 percent of that exposure. Both of these conditions prevail in the 222-S Building.

Both types of dosimeters indicated the presence of neutrons in the 234-5 Building only. The slow neutron interpretations were comparable, but the TLD indicated fast neutron exposures on a greater number of dosimeters than did film. This was expected because of the higher sensitivity of the TLD 600's when compared to NTA film.

The DUN field studies were also concluded in January, 1971. The results for November, December and January are included in

Table IV. The Tld, film, and pencil results were quite consistent. A few very obvious exceptions can readily be attributed to negligence in carrying out wearing directions by the individuals assigned TLD dosimeters. The data shown in Appendix A have been marked with an asterisk when we were able to determine that negligence in wearing instructions was the main reason for discrepancy in the data from the two badge systems.

The overall results from the multipurpose dosimeter have indicated that it works well in the wide variety of exposure situations encountered in Hanford facilities. The calibrations and methods of evaluation described provide acceptable dose interpretations for routine personnel monitoring for exposures to beta particles, X-rays, gamma rays, slow, and fast neutrons, either singularly or in combinations. The TLD dose interpretations are not as complex as those for film nor does the TLD have the limitations exhibited by the film dosimeter system. The multipurpose dosimeter has met or surpassed all of the design criteria. The implementation of the system will be a decided improvement in the field of personnel dosimetry at Hanford.

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TABLE I

SPECIAL FIELD STUDIES

(Two-gallon polyethylene jug filled with water was used as phantom)

Work Location	Pen mrad		Derma mrad		N_s mrem		N_f mrem		Exposure Duration (hr)	CP^2 (mr)	Snoopy (mrem)
	TLD	Film[1]	TLD	Film[1]	TLD	Film	TLD	Film			
PUREX											
Q-3	120	100	120	100	9	20	180	180	121	120	160
H-2	230	160	230	(290) 200	--	30 0	--	--	120	240	--
Q-Cell	40	(30) 0	40	(30) 0	--	--	--	--	120	120	--
RAC	2350	(2500) 1300	2350	(2500) 1300	--	0 40	--	fog	49	1470	--
F 15	180	60	400	700	--	--	--	--	49	539 196	--
B-5	230	(250) 120	230	(250) 120	--	0 30	--	--	1	300	--
L-10	160	160	160	170	--	0	--	--	120	240	--
RI-20	260	220	260	220	30	40	790	90	120	120	720
	3570	3480	3790	4260	39	57	970	270		3640/ 2806	880
B-Plant											
51	890	60	3760	820 (5060)	--	--	--	--	23	4600/ 690	--
IAW	450	150	1170	1650	--	6	--	--	22	1540/ 550	--
14-1	530	(310) 600	530	(310) 1250	--	12	--	--	3.67	590/ 260	--
14-Cell	90	70	90	(180) 100	--	--	--	--	22.5	180	--
West Stor	2300	1630	2300	1630	6	9	--	fog	3.67	2940/ 1840	--
26-Cell	300	0 (30)	1750	4000 (1720)	--	6	--	--	4	4000/ 1400	--
	4560	2250	9510	10550	6	33				13850/ 4920	

TABLE I (Cont'd)

Work Location	Pen mrad TLD	Pen mrad Film[1]	Derma mrad TLD	Derma mrad Film[1]	N_s mrem TLD	N_s mrem Film	N_f mrem TLD	N_f mrem Film	Exposure Duration (hr)	CP^2 (mr)	Snoopy (mrem)
Z Plant, 234-5											
228-17DC	150	260 (170)	210	310	--	9	200	--	72.4	150	200
192-194	140	140	210	140	138	0 45	1360	1660	72.7	150	950
228-H611	80	100	80	120	18	12	650	320	2.34	60	330
228-958	450	530	450	530	135	30	730	350	72.5	510	360
228-H618BS	100	130 (270)	100	140 (330)	6	0 9	170	--	72.5	510	360
194	60	80	60	20 90	9	6	390	210	2.75	90	550
221-Center	1470	1270	1470	1270	18	6 0	940	fog	73	1460	660
221-N	1640	1360	1640	1360	24	0 18	1060	fog	73	2480	1310
	4090	3920	4220	4060	348	135	5500	2540		5410	11200
105-KE (Reactor Operating)											
γ mon	1600	(2000) 1350	1600	(2000) 1350	6	--	--	--	44	1890/ 1670	<50
X-1,2A	340	340 (190)	340	340 (190)	72	24	980	0	42.75	260	430
Face-8510W	210	320 (200)	210	320 (200)	12	9	300	--	164	164	80
X-1,2D	450	410	500	410	30	15	--	--	42.75	300	70
γ mon,3L	490	450	490	450	--	6	--	--	164	490	<20
Face-0174	370	480	370	480	9	15	330	0	164	330	80
KER	4620	4500	4620	4500	3		--	--	43.5	5870	--
Top #21	1020	1160	1020	1160	219	42	5100	130	43.5	1020	1700
	9100	9390	9150	9390	351	111	6710	130		10324/ 10104	2430

TABLE I (cont'd)

Work Location	Pen mrad TLD	Pen mrad Film	Derma mrad TLD	Derma mrad Film	N_s mrem TLD	N_s mrem Film	N_f mrem TLD	N_f mrem Film	Exposure Duration (hr)	CP^2 (mr)	Snoopy (mrem)
105-N (Reactor not operating)											
Top-NW	300	280	300	280	--	9	--	--	23.25	350	--
Face	560	480	560	480	--	12	--	--	22.5	1580/ 1350	--
Top Ball	800	670	800	670	--	15	--	--	.67	400	--
51'V-11,12R	90	80	90	80 (120)	--	--	--	--	145.25	290	--
V-11 #6	1110	1130	1110	1130	3	12	10	--	23.5	1760	--
Ball RE	1300	1160	1335	1160	--	15	--	--	2.0	1500	--
V-12,R,Pipe	7410	(7000) 10000	7410	(7000) 10000	--	--	--	--	23.34	700	
308 Decon	1480	1230	1480	1230	--	15	--	00	144	1300/ 1000	--
	13050	12030	13440	12070	3	78				7880/ 7350	0
325-B											
32	950	850	950	850	3	12	--	--	14	1010	--
200	300	250	300	250	--	12 0	--	--	44	660	--
	1250	1100	1250	1100	3	24				1760	
325											
604 GB	1330	1550	3170	1660	--	27	0	fog	19.5	2730/ 2340	--
603 HG	1060	560	2080	1390	00	9	--	00	19.5	2370/ 880	--
	2850	2640	5710	3690	0	36				5100/ 3220	

TABLE I (Cont'd)

Work Location	Pen mrad TLD	Pen mrad Film[1]	Derma mrad TLD	Derma mrad Film[1]	N_s mrem TLD	N_s mrem Film	N_f mrem TLD	N_f mrem Film	Exposure Duration (hr)	CP[2] (mr)	Snoopy (mrem)
327											
Basin	80	0 (50)	100	40 (90)	--	--	--	--	43	410	--
B Cell	1010	820	1080	830	--	9	--	--	18.5	1850	--
	1090	870	1180	920		9				2260	
Special											
Ra γ	310	260	310	260	--	6	--	--		300	(Radicon)
PuF_4	100	60	100	60	6	--	620	460	112		590 (calib)
^{90}Sr	100		315	690	--	--	--	--	64	275	(VCP)
^{252}Cf	180	135	180	135	12	6	1470	4500	65		2070 (calib)

[1]Results in parentheses were used in totals.

[2]First reading is CP window open, second reading window closed.

TABLE II

SPECIAL STUDIES (mrem)

(Two-gallon polyethylene jug filled with water was used as phantom)

	Thermal Neutrons		Fast Neutrons			
Location	Film	TLD	Snoopy	TEPC	Film	TLD
105-KE						
X-1	54	57	60	270	0	530
Top #23	150	141	1400	1700	470	4100
Mon	27	< 3	0	0	0	60
Front Face	33	7	50	900	0	250
308 Bldg.						
Rm 208	81	84	2000	2700	270/260	3700
Corr #7	180	390	4200	14100	1270	11100
Vent Rm.	0	3	30	30	0	0
Rm C	75	18	700	730	70	870
234-5 Bldg.						
17 DC	27	6	340		0	100
HC-11	75	12	280		0	180
9B Top Stairs	21	11	410		100	440
9B Under Stairs	0	18	280		60	450
Rm 221	21	18	410	790	170	460
Rm 192	45	66	510	620	950	490
Rm 192-C	0	6	150	230	310	240
Rm 193	36	36	380	500	770	600
2731-Z	0	< 3	200		60	50

TABLE III

ARHCO FIELD STUDIES - NOVEMBER 1970

	mrad Pen		mrad Derma		mrem Neutron S		mrem Neutron F	
	TLD	Film	TLD	Film	TLD	Film	TLD	Film
234-5	4030	4600	4550	5520	132	129	2850	240
Purex	910	120	1370	1140				
222-S	930	850	1710	3160				
Shops	540	580	540	610				
Tank Farm	3690	2210	3890	2590				
T Plant	30	0	50	70				
B Plant	800	350	1190	1000				
Rad. Mon.	760	520	930	860				
TOTAL	11690	9230	14230	14950	132	129	2850	240

ARHCO FIELD STUDIES - JANUARY 1971

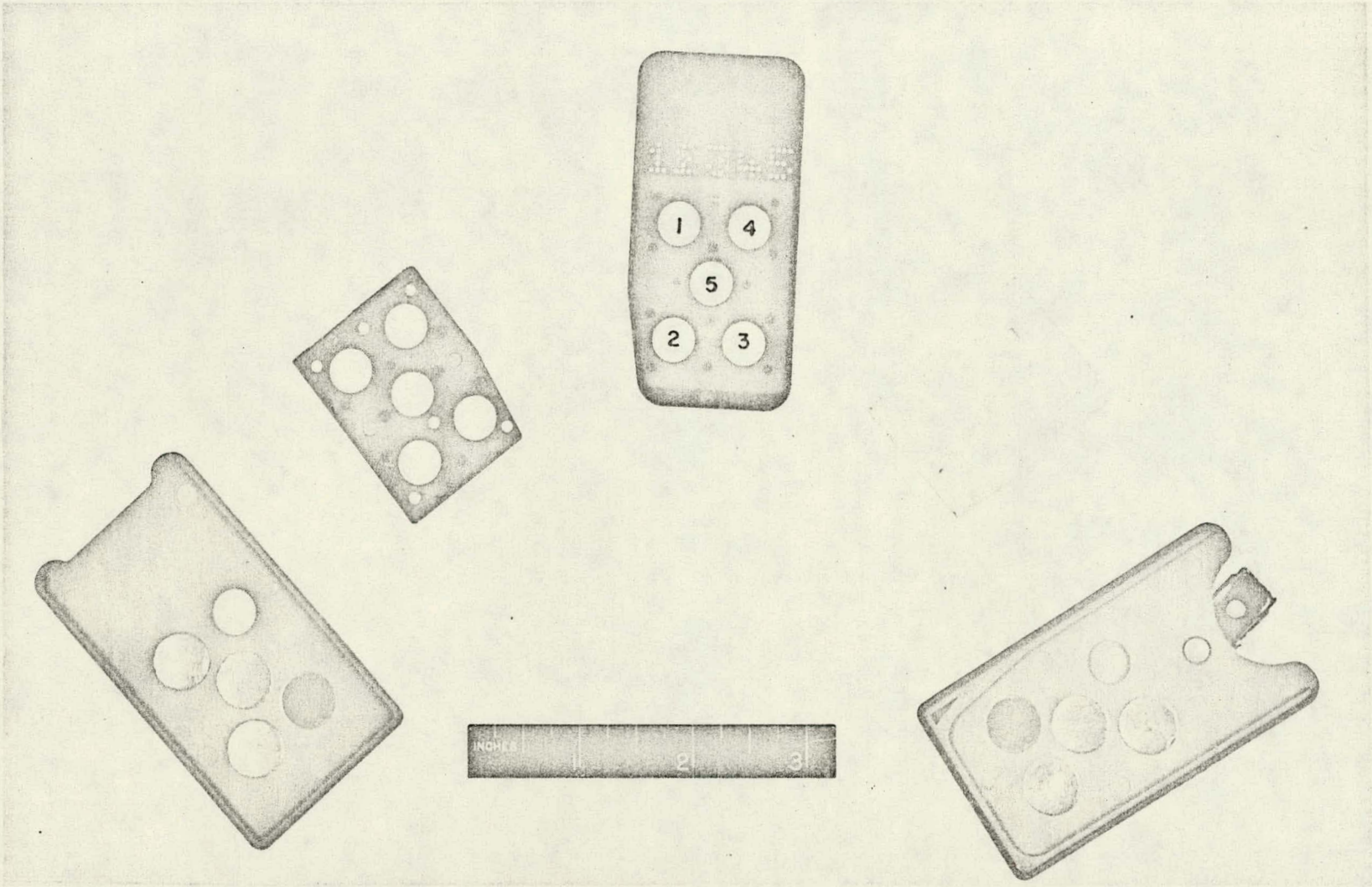
234-5	4250	4450	5070	5950	177	450	1360	480
Purex	1580	480	2510	1710				
222-S	1150	740	2160	3060				
Shops	680	550	720	750				
Tank Farm	4790	3330	5190	4030				
T Plant	120	0	120	190				
B Plant	1520	580	2070	1290				
Rad. Mon.	580	390	780	810				
TOTAL	14670	10520	18620	17790	177	450	1360	480

TABLE IV

DUN FIELD STUDIES

Month	Pen (mrads)			Derma (mrads)	
	TLD	Film	Pencil	TLD	Film
Nov.	1990	1390	1235	1990	1440
Dec.	6410	7500	6305	6560	7500
Jan.	210	950	995	250	950

AN EXPLODED VIEW OF THE HANFORD MULTIPURPOSE DOSIMETER CARD



APPENDIX A

ARHCO - NOVEMBER FIELD TESTS RESULTS

Badge #	Work Location	Pen(mrads)		mrads Derma		mrem Fast Neutrons		mrem Slow Neutrons	
		TLD	Film	TLD	Film	TLD	Film	TLD	Film
1	a	70	70	70	100	---	---	---	---
2	a	170	730	170	750	180	0	6	20
3	b	0	0	0	0	---	---	---	---
4	c	330	230	690	1090				
5	d	90	60	90	60				
6	d	0	130	0	150				
7	d	230	210	230	220				
8	a	30	80	60	90	0	110	0	0
9	e	170	130	170	130				
10	b	30	0	30	0				
11	c	140	40	310	550				
12	c	80	40	80	60				
13	c	60	30	120	250				
14	e	80	60	80	60				
15	e	60	50	60	50				
16	e	140	110	140	110				
17	c	460	320	460	320				
18	c	0	0	0	0				
19	a	120	190	190	240			3	
20	a	150	220	250	280				
21	a	80	110	110	140	140	0	3	0
22	a	80	140	90	170				
23	a	180	250	180	290	410	0	15	0
24	e	160	140	160	140				
25	a	210	240	240	280	260	0	12	40

APPENDIX A (Cont'd)

Badge #	Work Location	Pen(mrads)		mrads Derma		mrem Fast Neutrons		mrem Slow Neutrons	
		TLD	Film	TLD	Film	TLD	Film	TLD	Film
26	b	40	0	40	0				
27	f	30	0	50	70				
28	a	290	240	350	280	0	0	3	0
29	c	100	0	100	80				
30	e	100	50	100	50				
31	e	210	130	210	130				
32	a	450	290	470	340	130	0	15	40
33	a	130	90	140	120	120	0	3	0
34	a	160	140	160	160	80	0	3	0
35	g	30	20	30	20				
36	a	70	120	70	140	100	0	3	0
37	b	0	0	20	40				
38	a	110	140	110	160	90	0	6	0
39	a	140	110	140	130	390	0	15	0
40	a	120	150	120	190				
41	e	220	180	220	180				
42	a	30	50	40	60	90	0	3	0
43	a	160	230	210	280	270	130	9	30
44	b	0	0	0	0				
45	a	150	180	150	210	160	0	3	0
46	c	60	30	110	240				
47	a	80	60	120	90	40	0	3	0
48	b	70	50	70	50				
49	c	90	50	90	190				
50	a	40	50	50	60	0	0	3	0
51	a	80	130	80	150				
52	c	80	400	130	530				
53	a	200	240	230	290	130	0	3	0
54	c	90	30	180	250				
55	a	80	0	100	70	40	0	9	0

APPENDIX A (Cont'd)

Badge #	Work Location	Pen(mrads)		mrads Derma		mrem Fast Neutrons		mrem Slow Neutrons	
		TLD	Film	TLD	Film	TLD	Film	TLD	Film
56	a	20	0	20	0	160	0	9	0
57	g	0	0	30	0				
58	g	0	0	0	0				
59	e	260	70	260	70				
60	e	60	30	60	30				
61	b	0	0	0	50				
62	b	20	0	30	40				
63	b	0	0	0	0				
64	e	110	60	110	60				
65	b	60	0	170	270				
66	b	30	0	30	20				
67	b	0	0	0	0				
68	g	0	90	0	180				
69	g	40	30	60	90				
70	g	30	0	60	120				
71	b	0	0	20	0				
72	b	70	30	70	50	60	0	3	0
73	e	220	160	220	160				
74	b	70	30	110	30				
75	g	0	0	0	0				
76	b	0	0	0	20				
77	g	0	0	0	20				
78	g	290	220	380	310				
79	b	60	0	90	30				
80	e	100	70	100	190				
81	g	0	0	0	50				
82	b	0	0		0				
83	g	0	0		0				
84	b	20	0	80	0				
85	g	170	110	170	160				

APPENDIX A (Cont'd)

Badge #	Work Location	Pen(mrads)		Mrads Derma		mrem Fast Neutrons		mrem Slow Neutrons	
		TLD	Film	TLD	Film	TLD	Film	TLD	Film
86	e	20	0	40	20				
87	g	40	0	90	110				
88	g	50	0	100	120				
89	g	390	300	390	310				
90	b	40	0	60	0				
91	b	100	0	150	0				
92	e	260	100	380	100				
93	g	70	0	230	0				
94	e	260	150	260	150				
95	e	270	130	270	130				
96	g	30	0	40	30				
97	b	60	20	80	80				
98	b	70	0	70	90				
99	b	20	0	20	0				
100	b	30	0	30	0				
101	e	110	60	110	60				
102	g	0	0	0	0				
103	b	0	0	0	190				
104	b	70	0	100	60				
105	e	70	70	80	160				
106	g	30	0	30	30				
107	b	0	0	20	20				
108	g	0	0	0	0				
109	b	0	0	0	30				
110	g	0	0	0	20				
111	g	40	0	40	20				
112	g	130	0	170	50				
113	g	40	0	70	40				
114	e	280	230	280	310				

APPENDIX A (Cont'd)

Badge #	Work Location	Pen(mrads) TLD	Pen(mrads) Film	mrads Derma TLD	mrads Derma Film	mrem Fast Neutrons TLD	mrem Fast Neutrons Film	mrem Slow Neutrons TLD	mrem Slow Neutrons Film
115	b	0	0	0	0				
116	b	0	0	10	0				
117	e	190	---	190	---				
118	e	70	60	70	60				
119	g	80	0	90	90				
120	e	400	300	430	300				
121	b	40	0	40	50				
122	g	0	0	0	0				
123	e	20	50	20	120				
124	b	50	20	90	60				
125	g	130	100	150	100				
MONTHLY TOTAL		11690	9230	14230	14950	2850	240	132	129

Work Locations:
a - Z Plant
b - Purex
c - 222-S
d - Shops
e - Tank Farms
f - 221-T
g - 221-B

ARHCO FIELD STUDIES - JANUARY 1971

Badge ARHCO-A	Work Location	Penetrating TLD	Penetrating Film	Derma TLD	Derma Film	mrem Neutron-F TLD	mrem Neutron-F Film	mrem Neutron-S TLD	mrem Neutron-S Film
1	a	80	130	120	160				330
2	a	210	780	240	800			6	30
3	b			70					
4	c	190	110	510	920				
5	d	130	90	150	230				
6	d	40	40	60	80				
7	d	240	170	240	180				
8	a	120	150	130	190			3	40
9	e	340	310	380	310				
10	b	40		40					
11	c	120	50	310	570				
12	c	250	240	300	240				
13	c	70	30	170	200				
14	e	240	190	240	190				
15	e	170	150	170	200				
16	e	280	170	280	170				
17	c	130	50	130	50				
18	c	50		70	60				
19	a	110	70	150	120			3	
20	a	80	120	90	220			3	
21	a	100	110	160	150			3	
22	a	70	60	80	90				
23	a	270	280	320	370	200		9	30
24	e	180	130	200	230				
25	a	210	250	250	330	200		12	40
26	b	40		40					
27	f	120		120	190				
28	a	70	50	80	70				20
29	c	100	30	100	30				
30	e	140	140	190	140				

(Cont'd)

Badge ARHCO-A	Work Location	Penetrating		Derma		mrem Neutron-F		mrem Neutron-S	
		TLD	Film	TLD	Film	TLD	Film	TLD	Film
31	e	200	150	200	150				
32	a	280	310	320	390				
33	a	80	100	110	140		100	6	30
34	a	160	130	160	180	140		3	
35	g	130	60	150	150				
36	a	140	170	140	240	230		6	
37	b	0	20	80	60				
38	a	160	170	180	230	160		6	30
39	a	390	320	400	400		110	36	20
40	a	170	190	250	250				30
41	e	270	250	270	260				
42	a	120	100	120	140			6	20
43	a	230	270	350	360	180	110	9	50
44	b	40		40					
45	a	150	130	150	180			6	30
46	c	120	40	210	290				
47	a	110	70	150	130			3	30
48	b	70	50	70	140				
49	c	80	60	150	320				
50	a	70	30	110	60	140			
51	a	120	80	210	120				
52	c	140	100	220	180				
53	a	190	100	190	140	110			
54	c	80	80	190	310				
55	a	180	130	210	180			15	
56	a	80		80	60		160	18	20
57	g	20		50					
58	g	40		80					
59	e	360	160	360	160				
60	e	580	330	580	340				

(Cont'd)

Badge ARHCO-A	Work Location	Penetrating TLD	Penetrating Film	Derma TLD	Derma Film	Neutron-F TLD	Neutron-F Film	Neutron-S TLD	Neutron-S Film,
61	b	50		50	30				
62	b	40		140	290				
63	b	80	30	80	30				
64	e	120	90	120	90				
65	b	140	90	220	220				
66	b	70		70					
67	b	60		60	240				
68	g	120	60	150	150				
69	g	50		110	160				
70	g	130	70	130	100				
71	b	50		70					
72	b	120	100	120	140			3	
73	e	150	120	200	120				
74	b	80	20	80	20				
75	g			20					
76	b	Not Used							
77	g	70		70	80				
78	g	90	50	110	70				
79	b	100	90	150	150				
80	e	90	70	90	310				
81	g	70		70	50				
82	b	50		50					
83	g	120	70	120	70				
84	b	40		40					
85	g	160	120	160	120				
86	e	50		50					
87	g	50		90	130				
88	g	80	60	240	410				
89	g	280	210	300	230				
90	b	30		60	40				

(Cont'd)

Badge ARHCO-A	Work Location	Penetrating TLD	Penetrating Film	Derma TLD	Derma Film	mrem Neutron-F TLD	mrem Neutron-F Film	mrem Neutron-S TLD	mrem Neutron-S Film
91	b	40		40					
92	e	470	150	470	150				
93	g	0		10					
94	e	80	60	110	110				
95	e	120	120	120	120				
96	g	70	30	70	110				
97	b	100		140	40				
98	b	90	30	120	30				
99	b	40		90					
100	b	0		70					
101	e	270	140	270	140				
102	g	40		60					
103	b	20		20					
104	b	80	30	150	120				
105	e	190	210	290	310				
106	g	70	40	130	80				
107	b	20	30	40	30				
108	g	30		60					
109	b	0		120					
110	g	30		70					
111	g	110		110					
112	g	40		70					
113	g	40		40					
114	e	220	250	240	310				
115	b	30		30					
116	b	50		50					
117	e	140	80	170	80				
118	e	30	20	70	110				
119	g	120	80	150	80				
120	e	120	90	120	90				

(Cont'd)

Badge ARHCO-A	Work Location	Penetrating TLD	Penetrating Film	Derma TLD	Derma Film	mrem Neutron-F TLD	mrem Neutron-F Film	mrem Neutron-S TLD	mrem Neutron-S Film
121	b	80	40	120	110				
122	g	30		80	30				
123	e	250	200	270	200				
124	b	0	40	20	110				
125	g	160	130	240	130				
MONTHLY TOTAL		14670	10520	18620	17790	1360	480	177	450

APPENDIX A (Cont'd)

DUN FIELD STUDIES - NOVEMBER 1970

	mrads						
	Pen			Derma		Neutrons TLD	
Badge#	TLD	Film	Pencil	TLD	Film	Slow	Fast
1	70	-	-	70	--	-	-
2	20	-	5	20	-	-	-
3	70	60	55	70	60	-	-
4	110	90	105	110	90	-	-
5	290	280	145	290	280	-	-
6	60	100	55	60	100	-	-
7	90	-	25	90	-	-	-
8	40	0	10	40	-	-	-
9	20	0	0	20	50	-	-
10	60	80	45	60	80	-	-
11	340	-	-	340	-	-	-
12	-	-	125	-	-	-	-
13	450	410	310	450	410	-	-
14	30	90	85	30	90	-	-
15	130	100	110	130	100	-	-
16	210	180	160	210	180	-	-

APPENDIX A (Cont'd)

DUN FIELD STUDIES - DECEMBER 1970

	Pen (mrads)			(mrads) Derma		mrem Neutron-s	mrem Neutron-f
Badge#	TLD	Film	Pencil	TLD	Film	TLD	TLD
251	290	280	280	290	280		
252	*210	1090	880	210	1090		
253	*180	310	280	180	310		
254(Laundry)	640	280	265	670	280		
255	* 60	150	135	60	150		
256	* 40	270	250	160	270		
257	840	780	855	840	780	3	
259	230	270	240	230	270		
261	1020	980	1010	1020	980		
262	290	340	345	290	340	3	
266	380	380	295	380	380		
267	110	170	130	110	170		
269	340	410	370	340	410	3	
270	990	970	980	990	970	3	
271	550	540	640	550	540		
274	240	280	260	240	280		

DUN FIELD STUDIES - JANUARY 1971

251-A	40	80	95	40	80		
252-A	* 0	160	165	0	160		
259-A	* 20	220	290	20	220		
59-A	140	210	155	140	210		
270-A	* 10	140	150	30	140		
271-A	* 0	140	140	20	140		

*Doubtful as to consistancy of wearing.

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