DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE FOR OPERATIONAL HEALTH (AFMC)
BROOKS CITY-BASE TEXAS

9 Aug 06

MEMORANDUM FOR AFRL/MLS-OL
4750 STAFF DRIVE BLDG 2330 RM 112
TINKER AFB OK 73145-3317

FROM: AFIOH/SDR
2350 Gillingham Drive
Brooks City-Base TX 78235-5103

SUBJECT: Consult Letter, IOH-SD-BR-CL-2006-0067, Electronic Personal Dosimeter Response to Pulse X-Ray Units Used for Nondestructive Inspection

1. Introduction: Michael Paulk, Chief, USAF Nondestructive Inspection (NDI) Office, requested the Air Force Institute for Operational Health, Radiation Surveillance Division (AFIOH/SDR) evaluate the response of Thermo Electron Corporation's Electronic Personal Dosimeter EPD Mk2 to the new NDI digital pulse x-ray radiation systems. A policy letter from HQ USAF/SGO, dated 6 July 2006, subject: "Policy for Electronic Personnel Dosimeters (EPDs) for Non-Destructive Inspection (NDI)" endorsed EPD technology "as a replacement to current Digital and Personnel Alarming Dosimeters for NDI operations." The letter also recommends that AFIOH/SDR "be consulted on specific devices that will best support NDI objectives." This evaluation supports our commitment to identify the most suitable dosimeters for various NDI applications. Based on our evaluation we recommend you use a x-ray pocket dosimeter comparable to the Dosimeter Corporation 862L when using digital pulse x-ray radiation systems.

2. Background: On 26 July 2006, 1Lt Joshua Hubbell conducted a series of tests at the 33MXS NDI Lab, Eglin AFB, FL. 1Lt Hubbell used the Fox Ray II Portable X-Ray Inspection System equipped with a Golden Engineering XR200 x-ray source. According to the operator's manual, the XR200 produces 60 nanosecond x-ray pulses up to an energy of 150 kVp at a dose rate comparable to a 1.0 mA constant potential machine.

IAW TO 33B-1-1, sections 6.3.10.2 and 6.3.10.2.1, "personal alarming dosimeters shall be set to give alarm signals at preset dose rates" and "doses (from electronic personnel dosimeters) shall be recorded in the dosimetry log at the end of each operation." The Mk2 EPD is the USAF standard for electronic dosimetry for routine use of radioactive materials and for NDI X-ray systems. As such, its use was recommended for all NDI operations. Additional information provided by NDI staff indicated that tests performed

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by the US Army showed the Mk2 EPD significantly under responded to the new digital pulse NDI X-ray systems.

3. Findings: Measurements indicated that the EPD Mk2 is not capable of accurately measuring x-ray radiation from these new short-pulsed systems. Tests conducted on 26 July 06 showed the Mk2 EPD grossly under responded by as much as 99% when placed in a pulsed x-ray environment as compared to Panasonic UD802 thermoluminescent dosimeters (TLDs). This under response is attributed to short pulse duration (60 nanoseconds) and the EPD's inability to accurately quantify a pulse of less than 600 nanoseconds.

Per the policy letter from HQ USAF/SGO, EPDs "provide a number of significant advantages that afford more accurate and reliable radiation protection to NDI technicians and operators." Given the unique characteristics of the Fox Ray II Portable X-Ray Inspection System or a similar system, however, AFIOH/SDR recommends AF NDI personnel wear a x-ray pocket dosimeter comparable to the Dosimeter Corporation 862L when using these pulse x-ray systems.

4. If you have any questions, please contact 1Lt Joshua Hubbell at DSN 240-5574 or send an email to Joshua.Hubbell@brooks.af.mil.

SCOTT M. NICHELSON, Lt Col, USAF, BSC, CHP, CIH
Chief, Radiation Surveillance Division

Attachments:
1. TLD vs. EPD Summary for Exposures Conducted 26 July 2006
2. Individual TLD and EPD Results for Each Exposure

Attachment 1

TLD VS EPD SUMMARY FOR EXPOSURES CONDUCTED 26 JULY 2006

		TLD Average Results (mrem) (9 TLDs)*		EPD Average Results (mrem) (9 EPDs)**	
# of Pulses	Distance (feet)	Shallow Dose	Deep Dose	Hp07 (Shallow Dose)	Hp10 (Deep Dose)
1	1	0	0	0.003	0.002
1	2	0	0	0.003	0.003
1	3	0	0	0.002	0.002
25	1	45.9	38.2	0.051	0.038
25	2	14.4	13.1	0.064	0.041
25	3	0	0	0.027	0.033
50	1	91.2	73.7	0.051	0.074
50	2	27.2	24.3	0.052	0.077
50	3	2.6	1.1	0.042	0.054
99	1	162.0	127.0	0.079	0.137
99	2	51.4	45.4	0.235	0.140
99	3	24.9	23.6	0.153	0.176
198	1	253.0	199.7	0.154	0.215
198	2	92.9	78.9	0.233	0.246
198	3	60.1	55.3	0.708	0.413

* Minimum Detectable Dose for the TLD is 10 mrem
** Minimum Displayable Dose for the EPD is 0.001 mrem

Attachment 2

Individual TLD and EPD Results for Each Exposure

Table 1: TLD Results for Exposure of 1 Pulse at 1 Foot*

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0400203	0	0	0
0400666	0	0	0
0401145	0	0	0
0401219	0	0	0
0401279	0	0	0
0407088	0	0	0
0407091	0	0	0
0407093	0	0	0
0407486	0	0	0
Average	0	0	0
St Dev	0	0	0
Dose/Pulse	0.00	0.00	0.00

* Minimum Detectable Dose for the TLD is 10 mrem

Table 2: EPD Results for Exposure of 1 Pulse at 1 Foot**

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0081918	0.002	0.002
0103208	0	0.003
0103341	0.002	0.002
0103644	0.002	0.002
0103651	0.017	0.002
0104525	0.002	0.002
0104712	0	0.002
0104779	0	0.002
0104831	0	0.002
Average	0.003	0.002
St Dev	0.005	0.000
Dose/Pulse	0.00	0.00

** Minimum Displayable Dose for the EPD is 0.001 mrem

Table 3: TLD Results for Exposure of 1 Pulse at 2 Feet*

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0106571	0	0	0
0203740	0	0	0
0400099	0	0	0
0400400	0	0	0
0401068	0	0	0
0401165	0	0	0
0401210	0	0	0
0401223	0	0	0
0401292	0	0	0
Average	0	0	0
St Dev	0	0	0
Dose/Pulse	0.00	0.00	0.00

* Minimum Detectable Dose for the TLD is 10 mrem

Table 4: EPD Results for Exposure of 1 Pulse at 2 Feet

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103708	0.005	0.003
0103894	0.003	0.003
0105613	0.002	0.003
0105900	0.002	0.003
0106069	0.002	0.003
0106098	0.002	0.002
0106162	0.005	0.005
0106175	0.002	0.002
0106234	0.003	0.003
Average	0.003	0.003
St Dev	0.001	0.001
Dose/Pulse	0.00	0.00

Table 5: TLD Results for Exposure of 1 Pulse at 3 Feet*

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0103333	0	0	0
0104021	0	0	0
0203653	0	0	0
0203729	0	0	0
0400101	0	0	0
0400500	0	0	0
0400600	0	0	0
0401230	0	0	0
0401442	0	0	0
Average	0	0	0
St Dev	0	0	0
Dose/Pulse	0.00	0.00	0.00

* Minimum Detectable Dose for the TLD is 10 mrem

Table 6: EPD Results for Exposure of 1 Pulse at 3 Feet**

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103707	0.003	0.003
0103866	0	0.003
0103874	0.002	0.002
0104943	0.003	0.003
0106061	0.003	0.003
0106074	0	0.002
0106075	0.002	0.002
0106184	0.002	0.002
0106221	0.002	0.002
Average	0.002	0.002
St Dev	0.001	0.001
Dose/Pulse	0.00	0.00

** Minimum Displayable Dose for the EPD is 0.001 mrem

Table 7: TLD Results for Exposure of 25 Pulses at 1 Foot

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0202523	47	45	39
0204916	45	43	38
0400209	56	46	35
0400210	36	36	33
0400212	43	42	38
0400213	44	43	41
0400953	44	42	37
0401070	46	44	40
0401258	52	49	43
Average	45.9	43.3	38.2
St Dev	5.6	3.5	3.0
Dose/Pulse	1.84	1.73	1.53

Table 8: EPD Results for Exposure of 25 Pulses at 1 Foot

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0081905	0.216	0.036
0082029	0.039	0.042
0082087	0.031	0.039
0103134	0.033	0.039
0103298	0.025	0.036
0103389	0.033	0.041
0103667	0.03	0.041
0104504	0.031	0.036
0104762	0.025	0.034
Average	0.051	0.038
St Dev	0.062	0.003
Dose/Pulse	0.00	0.00

Table 9: TLD Results for Exposure of 25 Pulses at 2 Feet

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0101497	15	14	12
0201427	15	15	14
0202353	14	14	12
0203413	17	16	15
0203430	13	13	11
0203440	13	13	13
0203445	18	17	15
0203954	11	11	12
0203961	14	14	14
Average	14.4	14.1	13.1
St Dev	2.1	1.8	1.5
Dose/Pulse	0.58	0.56	0.52

Table 10: EPD Results for Exposure of 25 Pulses at 2 Feet

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103869	0.334	0.041
0103906	0.036	0.036
0103922	0.023	0.039
0103977	0.038	0.042
0104942	0.02	0.041
0106144	0.036	0.039
0106161	0.016	0.042
0106200	0.039	0.044
0106218	0.03	0.042
Average	0.064	0.041
St Dev	0.102	0.002
Dose/Pulse	0.00	0.00

Table 11: TLD Results for Exposure of 25 Pulses at 3 Feet*

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0101494	0	0	0
0203305	0	0	0
0203419	0	0	0
0203433	0	0	0
0203434	0	0	0
0203435	0	0	0
0203956	0	0	0
0203991	0	0	0
0204338	0	0	0
Average	0.0	0.0	0.0
St Dev	0.0	0.0	0.0
Dose/Pulse	0.00	0.00	0.00

* Minimum Detectable Dose for the TLD is 10 mrem

Table 12: EPD Results for Exposure of 25 Pulses at 3 Feet

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103718	0.028	0.033
0103888	0.008	0.03
0103892	0.034	0.033
0104940	0.028	0.036
0105982	0.009	0.033
0105983	0.031	0.034
0106064	0.039	0.034
0106095	0.028	0.033
0106100	0.036	0.03
Average	0.027	0.033
St Dev	0.011	0.002
Dose/Pulse	0.00	0.00

Table 13: TLD Results for Exposure of 50 Pulses at 1 Foot

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0101788	73	73	68
0108240	94	79	63
0203978	83	81	73
0204519	72	71	66
0400005	103	95	81
0400060	114	106	91
0400061	103	83	63
0400063	103	97	85
0401146	76	76	73
Average	91.2	84.6	73.7
St Dev	15.6	12.0	10.0
Dose/Pulse	1.82	1.69	1.47

Table 14: EPD Results for Exposure of 50 Pulses at 1 Foot

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0076656	0.05	0.077
0081904	0.05	0.08
0103391	0.066	0.07
0103646	0.056	0.07
0103665	0.033	0.072
0103685	0.053	0.073
1048101	0.061	0.067
0104803	0.058	0.078
0104827	0.03	0.078
Average	0.051	0.074
St Dev	0.012	0.005
Dose/Pulse	0.00	0.00

Table 15: TLD Results for Exposure of 50 Pulses at 2 Feet

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0105691	17	18	18
0106072	31	30	28
0107800	32	31	28
0205632	21	22	22
0206811	28	26	22
0400013	29	27	23
0400102	26	27	26
0400103	25	24	22
0400104	36	34	30
Average	27.2	26.6	24.3
St Dev	5.8	4.9	3.9
Dose/Pulse	0.54	0.53	0.49

Table 16: EPD Results for Exposure of 50 Pulses at 2 Feet**

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103608	0.069	0.081
0103698	0.034	0.08
0103929	0.064	0.075
0104107	0.078	0.08
0104118	0.039	0.075
0104228	0.052	0.078
0104248	0	0.072
0104929	0.072	0.077
0106202	0.058	0.075
Average	0.052	0.077
St Dev	0.024	0.003
Dose/Pulse	0.00	0.00

** Minimum Displayable Dose for the EPD is 0.001 mrem

Table 17: TLD Results for Exposure of 50 Pulses at 3 Feet*

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0104582	12	11	0
0108285	11	11	10
0109048	0	0	0
0200476	0	0	0
0202624	0	0	0
0205403	0	0	0
0400030	0	0	0
0400139	0	0	0
0400663	0	0	0
Average	2.6	2.4	1.1
St Dev	5.1	4.9	3.3
Dose/Pulse	0.05	0.05	0.02

* Minimum Detectable Dose for the TLD is 10 mrem

Table 18: EPD Results for Exposure of 50 Pulses at 3 Feet

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103704	0.009	0.052
0106041	0.048	0.055
0106170	0.045	0.053
0106173	0.061	0.053
0106180	0.038	0.048
0106182	0.023	0.055
0106196	0.053	0.052
0106209	0.047	0.055
0106220	0.052	0.059
Average	0.042	0.054
St Dev	0.016	0.003
Dose/Pulse	0.00	0.00

Table 19: TLD Results for Exposure of 99 Pulses at 1 Foot

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0107686	124	125	122
0108570	169	144	115
0202604	133	132	125
0204471	182	150	115
0400003	192	175	144
0400140	170	145	118
0400146	185	173	148
0400685	173	162	139
0400911	130	127	117
Average	162.0	148.1	127.0
St Dev	25.9	18.7	13.1
Dose/Pulse	1.64	1.50	1.28

Table 20: EPD Results for Exposure of 99 Pulses at 1 Foot**

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103097	0	0.136
0103654	0.067	0.142
0104503	0	0.127
0104722	0.144	0.139
0104761	0.102	0.141
0104764	0	0.134
0104789	0.1	0.142
0104798	0.133	0.138
0104825	0.161	0.136
Average	0.079	0.137
St Dev	0.065	0.005
Dose/Pulse	0.00	0.00

** Minimum Displayable Dose for the EPD is 0.001 mrem

Table 21: TLD Results for Exposure of 99 Pulses at 2 Feet

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0100658	44	45	43
0101076	44	44	43
0104398	51	48	42
0107195	45	44	41
0205678	69	65	57
0400679	53	50	45
0407076	46	47	45
0407293	60	57	51
0407460	51	48	42
Average	51.4	49.8	45.4
St Dev	8.4	7.0	5.2
Dose/Pulse	0.52	0.50	0.46

Table 22: EPD Results for Exposure of 99 Pulses at 2 Feet**

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103703	0.169	0.15
0103913	0.097	0.145
0103923	0.116	0.142
0103926	0.086	0.147
0104044	1.156	0.13
0104182	0.217	0.141
0106066	0.131	0.141
0106088	0	0.136
0106097	0.144	0.13
Average	0.235	0.140
St Dev	0.350	0.007
Dose/Pulse	0.00	0.00

** Minimum Displayable Dose for the EPD is 0.001 mrem

Table 23: TLD Results for Exposure of 99 Pulses at 3 Feet

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0101967	32	31	29
0110228	28	28	28
0201202	38	35	31
0202827	12	12	12
0205480	33	33	31
0400661	11	11	12
0400670	13	13	13
0401487	31	31	30
0401509	26	26	26
Average	24.9	24.4	23.6
St Dev	10.2	9.7	8.6
Dose/Pulse	0.25	0.25	0.24

Table 24: EPD Results for Exposure of 99 Pulses at 3 Feet

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103624	0.163	0.222
0103972	0.067	0.08
0104146	0.273	0.209
0010488	0.17	0.231
0104944	0.202	0.222
0106062	0.239	0.223
0106116	0.072	0.086
0106206	0.061	0.091
0106208	0.133	0.22
Average	0.153	0.176
St Dev	0.077	0.068
Dose/Pulse	0.00	0.00

Table 25: TLD Results for Exposure of 198 Pulses at 1 Foot

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0401568	276	246	206
0401569	321	298	253
0401570	183	161	134
0401571	228	203	170
0401572	206	191	161
0401573	246	239	218
0401574	297	272	227
0401576	258	235	194
0401577	262	255	234
Average	253.0	233.3	199.7
St Dev	43.3	42.3	38.5
Dose/Pulse	1.28	1.18	1.01

Table 26: EPD Results for Exposure of 198 Pulses at 1 Foot

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103492	0.111	0.147
0103911	0.145	0.194
0104472	0.325	0.231
0104499	0.098	0.275
0104526	0.169	0.208
0104548	0.248	0.244
0104763	0.123	0.164
0104806	0.167	0.248
0104892	0.003	0.223
Average	0.154	0.215
St Dev	0.092	0.041
Dose/Pulse	0.00	0.00

Table 27: TLD Results for Exposure of 198 Pulses at 2 Feet

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0104841	107	104	96
0205285	80	80	76
0401578	97	93	84
0401579	106	89	71
0401580	111	98	83
0401581	87	87	83
0401582	83	72	58
0401583	75	76	73
0401584	90	90	86
Average	92.9	87.7	78.9
St Dev	13.0	10.3	10.9
Dose/Pulse	0.47	0.44	0.40

Table 28: EPD Results for Exposure of 198 Pulses at 2 Feet

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103710	0.13	0.252
0103727	0.217	0.206
0103899	0.228	0.275
0104185	0.178	0.217
0106011	0.261	0.277
0106084	0.253	0.248
0106128	0.245	0.259
0106189	0.372	0.256
0106213	0.214	0.228
Average	0.233	0.246
St Dev	0.066	0.025
Dose/Pulse	0.00	0.00

Table 29: TLD Results for Exposure of 198 Pulses at 3 Feet

Serial #	Shallow Dose (mrem)	Eye Dose (mrem)	Deep Dose (mrem)
0106959	67	64	58
0107990	66	63	56
0201140	52	53	51
0202577	65	64	61
0204578	58	58	54
0205063	60	59	54
0205114	54	53	49
0205235	62	61	58
0205825	57	58	57
Average	60.1	59.2	55.3
St Dev	5.3	4.2	3.7
Dose/Pulse	0.30	0.30	0.28

Table 30: EPD Results for Exposure of 198 Pulses at 3 Feet

Serial #	Hp07 (Shallow Dose) (mrem)	Hp10 (Deep Dose) (mrem)
0103920	0.448	0.411
0104110	0.363	0.397
0104152	0.345	0.389
0104329	0.384	0.416
0104914	0.292	0.448
0105888	3.431	0.433
0106195	0.361	0.406
0106212	0.306	0.397
0106214	0.444	0.423
Average	0.708	0.413
St Dev	1.022	0.019
Dose/Pulse	0.00	0.00