Attachment for Response 2.9 ii

LANDAUER®

Title:	Environmental Dosimeter Type Testing		
Document Number:			
Revision Number:	1	Revision Date:	June 11, 2007
Revision Details:	Update for New InLight EX Environmental Dosimeter with 0.1 mrem LLD		
Topic of Study:	Modified InLight Dosimeter for Environmental Use		
Preparer:	*Ryan Ford*	Reviewed By:	*Mark Salasky,* *Cliff Yahnke, Ph.D.*
Reviewer Comments:			
File Name:	Environmental Dosimeter.doc	Data File Name:	Environmental InLight.xls
Data File Type:	Microsoft Excel	Program Version:	2000

☐ See Attached Document	
Introduction	The adoption of the InLight dosimeter for placement outdoors as an environmental dosimeter requires type testing in conformance with ANSI N545 – 1975 and HPS Draft Standard N13.29.
Methods	Obtain type-testing data acquired for the InLight dosimeter and present it with respect to the requirements of each environmental standard. Where existing data is not valid, perform new tests to demonstrate conformance.
Results	Results are shown below, and are organized by criteria. In some cases the results were held to standards listed in IEC 61066.
Conclusions	The InLight environmental dosimeter meets or exceeds the requirements of these standards. A summary of the tests and results is presented in Table 1.
Recommendations	
Further Study	
References	1. ANSI N545 – 1975. Performance, Testing and Procedural Specifications for Thermoluminescence Dosimetry (Environmental Applications). 2. HPS N13.29 Draft. Environmental Dosimetry Performance, Criteria for Testing. November 9, 1995. 3. NRC Regulatory Guide 4.13. Performance, Testing and Procedural Specifications for Thermoluminescence Dosimetry (Environmental Applications). 4. IEC 61066. Thermoluninescence Dosimetry Systems for Personal and Environmental Monitoring. 1991.
Keywords	

Table 1: Executive Summary and Table of Contents

Criteria	Page	Pass	Fail
Energy Dependence	5	☒	☐
Directional Dependence	7	☒	☐
LLD Calculation	9	☐	☐
Light Penetration	10	☒	☐
Linearity	12	☒	☐
Reproducibility	14	☒	☐
Uniformity	15	☒	☐
Length of Field Cycle	17	☒	☐
Moisture Dependence	19	☒	☐
Self-Irradiation	20	☒	☐
Neutron Sensitivity	21	☒	☐
N13.29 Requirements	23	☒	☐
Field Testing	24		
Dosimeter Designation	29		

<table>
<tr><td>Criteria: Energy Dependence</td><td>ANSI N545, 4.3.4, N13.29, Section 4.1. The N545 standard requires energy dependence testing at 'several energies' between 30 keV and 3 MeV. The dosimeter has been tested at Sr-90, Cs-137, H40 and H100.</td></tr>
<tr><td>Energy Dependence:
Methods</td><td>The energy dependence test was performed by exposing five dosimeters to each energy level at 0° and calculating the average and standard deviation of the response. Exposed doses were calculated using the measured air kerma rate multiplied by the factors shown in HPS N13.29. Exposures were performed without a PMMA phantom.</td></tr>
<tr><td>Energy Dependence:
Results</td><td>
<table>
<tr><th>Energy</th><th>Hp(0.07) Avg Bias ± Stdev</th><th>Hp(10) Avg Bias ± Stdev</th></tr>
<tr><td>662 keV</td><td>0.001 ± 0.04</td><td>0.001 ± 0.04</td></tr>
<tr><td>88 keV (H100)</td><td>0.05 ± 0.07</td><td>-0.02 ± 0.06</td></tr>
<tr><td>33 keV (H40)</td><td>-0.16 ± 0.05</td><td>-0.10 ± 0.05</td></tr>
<tr><td>Sr-90</td><td>-0.05 ± 0.13</td><td></td></tr>
</table>
The biases meet the requirement of ANSI N545 to be within 20%.</td></tr>
</table>

<table>
<tr><td>Criteria: Directional Dependence</td><td>ANSI N545, 4.3.5, N13.29, Section 4.3. Directional/Angular Dependence</td></tr>
<tr><td>Directional Dependence:
Methods</td><td>The directional dependence test was performed by exposing three badges to each configuration and calculating the average bias and standard deviation.</td></tr>
<tr><td>Directional Dependence:
Results</td><td>
<table>
<tr><th>Photon Energy</th><th>Orientation</th><th>Hp(0.07) Average Bias ± Stdev</th><th>Hp(10) Average Bias ± Stdev</th></tr>
<tr><td>662 keV</td><td>Horizontal -60°</td><td>0.03 ± 0.04</td><td>0.03 ± 0.04</td></tr>
<tr><td></td><td>Horizontal 60°</td><td>0.04 ± 0.02</td><td>0.04 ± 0.02</td></tr>
<tr><td>88 keV (H100)</td><td>Horizontal -60°</td><td>0.10 ± 0.04</td><td>0.02 ± 0.04</td></tr>
<tr><td></td><td>Horizontal 60°</td><td>0.18 ± 0.04</td><td>0.10 ± 0.04</td></tr>
<tr><td>33 keV (H40)</td><td>Horizontal -60°</td><td>-0.06 ± 0.03</td><td>0.02 ± 0.03</td></tr>
<tr><td></td><td>Horizontal 60°</td><td>-0.19 ± 0.01</td><td>-0.13 ± 0.01</td></tr>
</table>

These data show that the average bias for the shallow dose is –19% at 33 keV and 60°, and better at each of the other configurations.

The data for vertical angles is expected to be within the results for horizontal exposures because the badge is longer along its horizontal axis. This assumption will be validated at a later date.</td></tr>
</table>

Criteria: LLD Calculation	N13.29, Section 4.2. Lower Limit of Detection (LLD)
LLD Calculation: Methods	As part of the development of this new dosimeter, Landauer will perform a thorough evaluation of its LLD. The test plan will be as follows: 1) Twenty badges will be annealed. 2) Ten will be exposed to 500 mrem Cs-137 and 10 will remain unexposed. 3) All dosimeters will be read with a set of 9 freshly annealed calibrates, with three blanks, three irradiated to 500 mrem Cs-137 and three irradiated to 1000 mrem Cs-137. The LLD will be calculated using the InLight EX dose algorithm and the HPS N13.32 – 1995 method for calculating LLD.
	When development is complete, it is expected that the LLD will be less than 0.1 mrem.

<table>
<tr><td>Criteria: Light Penetration</td><td>ANSI N545, 4.3.6. Light Penetration, Light Tightness</td></tr>
<tr><td>UV Light:
Methods</td><td>
Four groups of eight dosimeters were annealed and prepared for testing. The standard dosimeter case, which contains a rubber gasket as an additional light sealant, was used for the test groups, but not the control dosimeters stored in foil pouches. All four groups received 1000 mrem of exposure to Cs-137. Group 1 was exposed to 57 W/m^2 of UV light for 7 days, where 77% of the total intensity was UV. The temperature of this environment was less than 40°C. Group 2 was placed in a foil pouch in an adjacent location of approximately the same temperature.

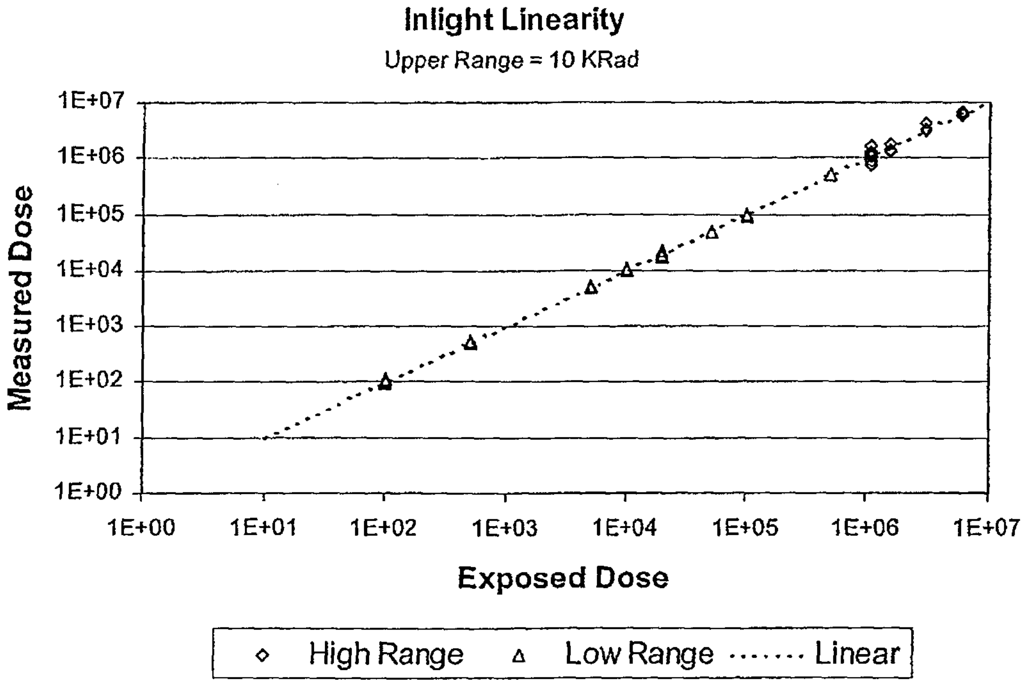
Group 3 was placed under fluorescent annealing lamps having an intensity of 21 W/m^2 ($<$0.1% UV). The temperature of this environment was also less than 40°C. Group 4 was placed in a foil pouch adjacent to group 3.

After 7 days of exposure, all dosimeters were read with a set of 9 freshly annealed calibrates, with three blanks, three irradiated to 500 mrem and three irradiated to 1000 mrem. A paired t-test was run for groups 1 and 2, and for groups 3 and 4.
</td></tr>
<tr><td>UV Light:
Results</td><td>
The readings for groups 1 – 4 are shown in the following table. Each group had an average of 1109 to 1138 mrem. The t-tests for both the UV and visible tests showed that exposure to UV or visible light did not have an effect on the response of the dosimeters.
<table>
<tr><td>Group</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td></td><td colspan="4">DDE</td></tr>
<tr><td></td><td>1148</td><td>1133</td><td>1037</td><td>1124</td></tr>
<tr><td></td><td>1120</td><td>1156</td><td>1099</td><td>1119</td></tr>
<tr><td></td><td>1135</td><td>1181</td><td>1123</td><td>1122</td></tr>
<tr><td></td><td>1122</td><td>1127</td><td>1145</td><td>1054</td></tr>
<tr><td></td><td>1147</td><td>1122</td><td>1076</td><td>1119</td></tr>
<tr><td></td><td>1130</td><td>1110</td><td>1114</td><td>1129</td></tr>
<tr><td></td><td>1203</td><td>1125</td><td>1120</td><td>1078</td></tr>
<tr><td></td><td>1096</td><td>1103</td><td>1158</td><td>1159</td></tr>
<tr><td>Average</td><td>1138</td><td>1132</td><td>1109</td><td>1113</td></tr>
<tr><td>Stdev</td><td>31.2</td><td>25.3</td><td>38.6</td><td>32.4</td></tr>
</table>
</td></tr>
<tr><td>UV Light:
Conclusions</td><td>Exposure to UV or visible light does not significantly affect the response of the dosimeter. In all cases the response difference meets the maximum variance of 10% as specified in IEC 61066.</td></tr>
</table>

UV Light: Discussion	This test was performed using a Landauer holder with a rubber gasket to seal the slide-entrance and release clip openings. The InLight environmental dosimeter uses the same gasket, however, it is adhered directly to the dosimeter case on both sides. As such, these results apply to either dosimeter design. The InLight dosimeter is received in a laboratory under normal ambient lighting. Supporting data shows that the dosimeter is light-tight without the use of the gaskets, and for this reason use of the gasket in the Landauer case has been discontinued. The extreme outdoor lighting conditions expected during normal use of the environmental badge warrant the use of the gasket as a precaution against loss of signal. The dosimeter will still be prepared and staged for analysis under normal ambient lighting conditions.

Criteria: Linearity	Linearity of dosimeter from 50 mrem to 6,000 rad.
Linearity: Methods	The InLight readers at Landauer are periodically calibrated and tested for linearity. Historical data were queried from the database. The data shown in Figure 1 represents data from various manual and automatic readers, including one high-range reader (1000 rad to 10 KRad) with a maximum exposed dose of 6,000 rad.
Linearity: Results	The slope of the low range data is 1.029 (50 mrem to 1000 rem), and the slope of the high range data is 1.03 (10.5 rad to 10 Krad). The r-squared values for both readers were 0.998 and 0.969, respectively, showing a linear response within these ranges.

Figure 1: Linearity of the InLight Dosimeter



Criteria: Reproducibility	ANSI N545, 4.3.2, Reg. Guide 4.13, C.5
Reproducibility: Methods	Ten InLight dosimeters were annealed, exposed to 1000 mrem Cs-137, then read. The cycle was repeated ten times. Statistics were calculated for the ten consecutive readings as well as for the ten readings from each cycle. One InLight dosimeter was exposed to 1000 mrem and read ten times, and statistics were calculated. The CV of the reproducibility shall be less than 3%.
Reproducibility: Results	The data are shown in the Table 2. The 'average' CV statistic is 2.5% for ten dosimeters read once, while the 'average' CV statistic is 1.8% for one dosimeter read ten times. The CV statistic for one dosimeter read ten times is 1.2%. Each result is less than the specified value of 3%.

Table 2: Reproducibility Results

Slide	DDE 9/5/2003	DDE 9/8/2003	DDE 9/9/2003	DDE 9/10/2003	DDE 9/11/2003	DDE 9/12/2003	DDE 9/15/2003	DDE 9/16/2003	DDE 9/18/2003	DDE 9/19/2003	Avg	Std	CV
1025	1035	1054	1033	1036	1059	1063	1013	1034	1069	1051	1045	17	1.7%
1036	995	1002	975	1015	1055	1008	983	1017	990	1014	1005	22	2.2%
1076	998	1063	1023	1018	1058	1028	1030	1037	1051	1033	1034	20	1.9%
1268	1047	1032	1036	1053	1065	1063	1076	1085	1071	1089	1062	20	1.8%
1299	1028	1036	1025	1057	1050	1037	1037	1070	1056	1068	1046	16	1.5%
1308	1009	1001	1029	1033	1067	1036	1040	1079	1072	1048	1041	26	2.5%
1762	990	1012	995	1008	1012	990	1025	1003	1031	1022	1009	14	1.4%
1805	1020	1056	1042	1051	1038	1028	1032	1039	1070	1055	1043	15	1.4%
1814	1006	988	981	993	1004	980	993	1031	1002	1016	999	16	1.6%
1870	988	987	983	999	1033	1025	988	1035	994	1013	1005	20	2.0%
Avg	1012	1023	1012	1026	1044	1026	1022	1043	1041	1041	Avg CV		1.8%
Std	20	29	26	23	22	27	28	27	34	26			
CV	2.0%	2.8%	2.5%	2.2%	2.1%	2.7%	2.8%	2.6%	3.2%	2.5%	2.5%		

Reading No.	Measured Dose (mrem)
1	1005
2	1001
3	1001
4	997
5	988
6	988
7	989
8	975
9	973
10	972
Avg	989
Std	12
CV	1.2%

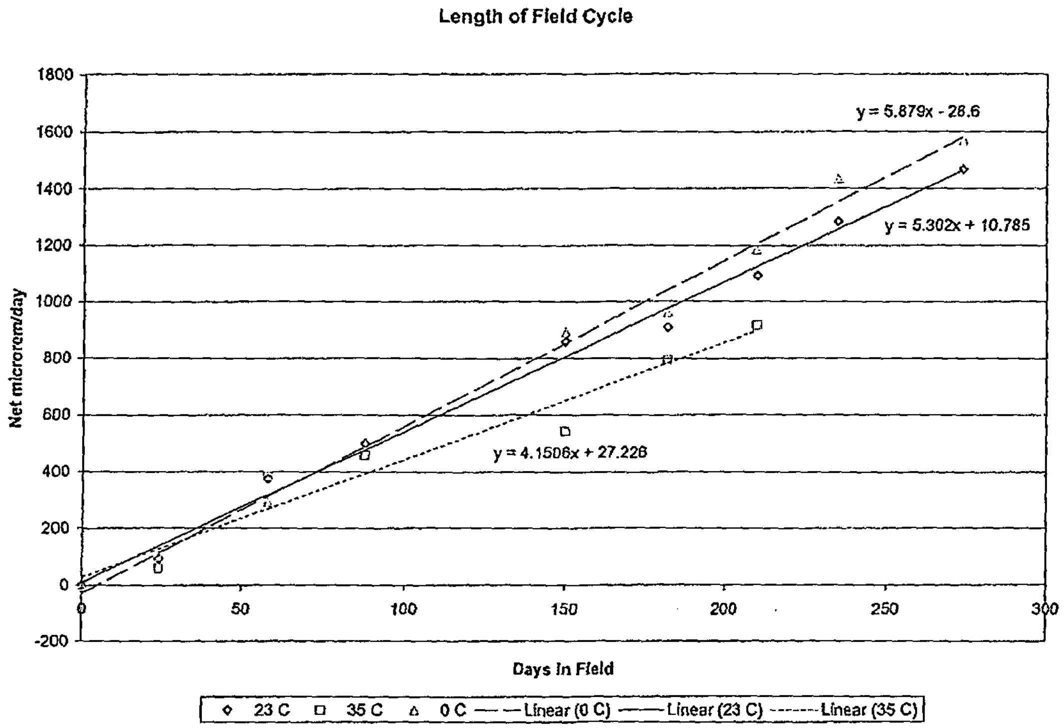
Criteria: Uniformity	ANSI N545, 4.3.1, Reg Guide 4.13, C.4.
Uniformity: Methods	Forty-five dosimeters were annealed and placed in a 23°C dark environment with a background rate equal to 5.3 µrem/h (Note that the actual background rate was approximately half the background rate specified in the standard: 10 µR/h). Summary statistics for 4 field cycles ranging from 0 to 274 days were calculated. The relative standard deviation (CV) should be less than 7.5%.
Uniformity: Results	The results shown in Table 3 have a CV of less than 7.5%, which meets the requirement for acceptable performance.

Table 3: Uniformity Results at 23°C

Date	4/28/2003	6/25/2003	7/25/2003	1/27/2004
Days in Field	0	58	88	274
Dosimeter 1 (mrem)	9	20	20	41
Dosimeter 2 (mrem)	8	17	20	47
Dosimeter 3 (mrem)	7	18	19	42
Dosimeter 4 (mrem)	8	19	21	40
Dosimeter 5 (mrem)	8	17	20	46
Average (mrem)	8	18	20	43
Stdev (mrem)	0.58	1.30	0.71	3.11
CV	7%	7%	4%	7%

Criteria: Length of Field Cycle	ANSI N545, 4.3.3. This test is intended to demonstrate that background dose accumulated on the test dosimeters does not fade.
Length of Field Cycle: Methods	Five dosimeters were read monthly at three temperatures: 0°C, 23°, and 35°C. Five dosimeters were read at the beginning of the test to establish a baseline control dose. Each month, the net dose was calculated, and plotted in the figure shown below, for a period of approximately nine months. The ratio of the response obtained for the field cycle to twice that obtained for half the field cycle was calculated. The ratio must not be less than 0.90.
Length of Field Cycle: Results	As illustrated in Figure 2, the slope of the line 'net dose vs. days in field' was calculated as 5.3 μrem/hr at 23°C (rsquared = 0.99), 4.15 μrem/hr at 35°C, and 5.88 μrem/hr at 0°C. The ratio described above is 1.0 for any given field cycle up to 274 days. The ratio is greater than 0.9, showing that background dose is not fading.

Figure 2: Background Dose vs. Length of Field Cycle



Criteria: Moisture Dependence	ANSI N545, 4.3.7. The purpose of this test is to show the effect of moisture on dosimeter readings.
Moisture Dependence: Methods/Results	Testing has been performed at approximately 98% relative humidity and temperatures up to 122°F on the standard InLight dosimeter. There was no significant difference between dosimeters stored in a dry environment compared to the dosimeters stored at high temperature and humidity. While the aluminum oxide material is exposed to moisture in the standard holder, the InLight Environmental dosimeter is encapsulated in a completely waterproof PVC pouch. This model can therefore resist complete submersion in water for extended periods of time without a significant effect on the dosimeter readings. Tests are underway to measure the permeability of the PVC plastic to moisture by measuring the weight gain of desiccant sealed within the waterproof pouch.

Criteria: Self-Irradiation	ANSI N545, 4.3.8. Self-irradiation is defined as the accumulation of signal in the absence of an external radiation field.
Self-Irradiation: Methods	Ten dosimeters were annealed and assembled into standard InLight holders for a 33 day self-irradiation period. All dosimeters were read with a set of 9 freshly annealed calibrates, with three blanks, three irradiated to 500 mrem and three irradiated to 1000 mrem. The expected background rate is 6 mrem/month.
Self-Irradiation: Results	The dose results obtained from reading the twenty badges are shown in Table 4. The two means of 9.3 (read after 33 days) and 4.9 (read immediately) provide a net dose of 4.4 mrem. This value is less than the expected background accumulation rate of 6 mrem, showing a self-irradiation value of zero.
Self-Irradiation: Conclusions	The value for self-irradiation is zero. This result meets the maximum rate of self-irradiation of 10 mrem/month specified in IEC 61066.

Table 4: Self-Irradiation Results

	Dosimeter #	1	2	3	4	5	6	7	8	9	10	Average	Stdev
Read after 33 days	Dose (mrem)	12	9	6	7	9	12	8	8	9	13	9.3	2.3
Read Immediately	Dose (mrem)	5	6	5	7	5	4	5	2	5	5	4.9	1.3

Criteria: Neutron Sensitivity	N13.29, Section 4.4. Sensitivity to fast and/or thermalized AmBe neutrons (via proton recoil and alpha particle).
Neutron Sensitivity: Methods	Six aluminum oxide detectors were exposed to 5000 mrem AmBe fast neutrons (Test 1). Half were exposed without the top layer of polyester substrate (Test 2). The top half of the six dosimeters was covered with a proton recoil radiator used with the Landauer N1 dosimeter. Three more dosimeters were exposed with a boron radiator covering the top half of the dosimeter (Test 3). All nine of the dosimeters were covered with black poly paper used in the Luxel dosimeter and heat-sealed to ensure a light-tight seal. For a fourth group (Test 4), one dosimeter having the boron radiator was exposed to the initial 5000 mrem AmBe fast neutrons, followed by 3600 mrem thermalized AmBe neutrons.
Neutron Sensitivity: Results/Conclusions	The approximate photon dose for the control half of the dosimeters was 181 mrem (3.6%)* for AmBe fast neutrons, and 1485 mrem (41.3%) for AmBe thermalized neutrons. This dose is attributable to the 60 keV photon associated with Americium-241. The percentage is higher for thermalized neutrons because of the lack of lead shielding on this source. The test side of the dosimeters yielded an additional 32 mrem for Test 1, 42 mrem for Test 2, -16 mrem for Test 3, and 51 mrem for Test 4. In all 4 cases, the percentage of measured neutron dose to delivered neutron dose is less than 1%. As such, this dosimeter is considered neutron insensitive. *3.6% is a consistent gamma/neutron ratio for this source

N13.29 Draft Standard Compliance

Criteria:	Statement:
3.1.1: Information supplied to the testing laboratory.	Dosimeters, algorithms and procedures used during testing are consistent with those used by that processor during routine operation.
3.1.2: Performance Testing	Accident, routine and energy response testing is documented within this testing report. Field-testing conditions have been simulated at various temperature and humidity conditions with results suggesting that the dosimeter would perform successfully under actual prolonged field exposures of up to one year.
3.1.3: Number of Test Dosimeters	Quantities of the InLight Environmental dosimeter are available to meet the quantities necessary for testing and filling routine customer orders.
3.1.4: Test Schedule	Landauer is able to meet the scheduling requirements for performance testing.
3.1.5: Dissemination of Test Results	Landauer is capable of reporting results within the required 30-day period for laboratory and field-testing.
4.1 – 4.4: Other Testing Documentation	Results for energy response, angular dependence, LLD, and neutron sensitivity are provided in other sections of this document.
N13.29, Table 3: Conversion Factors	Landauer maintains NIST traceable ionization chambers for measuring the photon air-kerma rate for the radiation sources described in this standard.

Field Testing

Field Testing	The purpose of this test is to document performance of the Inlight Environmental dosimeter during field deployment testing.
Methods	A total of 20 dosimeters were deployed in groups of four to five locations on the Landauer property. Five dosimeters were kept inside as controls. The dosimeters were deployed for three months to simulate a quarterly cycle. At the end of three months, the dosimeters were retrieved, decapped, and read with three QC's exposed to 50 mrem and three freshly annealed blanks. The converted values were run through version 1.00 of the environmental Inlight algorithm. The dates of deployment were March 16, 2004 to June 15, 2004, and included temperatures ranging from sub-zero to above 90°F, as well as rain, wind and snow.
Results	After one month the dosimeters were inspected for leaks, and one dosimeter was found to have a cut in the vinyl pouch. The cut allowed moisture to reach the dosimeter, however, there was no damage. A separate study to try to create cuts in the vinyl through temperature cycling was initiated. This test did not result in additional cuts, so the cause of the cut is still unknown. The ambient and directional doses are shown in Table 1, along with the photon energy. These data show a background accumulation of 0.19 mrem/day to 0.23 mrem/day for the five outdoor groups, while the indoor controls had a background accumulation of 0.25 mrem/day. To determine if fade is the cause of this difference, the next cycle of dosimeters deployed in the field includes several exposed to 500 mrem, with a similar control group indoors. The second possible cause of the higher indoor rate is the storage location in proximity to a concrete/stone block wall, which may have a slightly higher natural radiation exposure rate. Finally, the small sample size may be the cause of the difference. The photon energy arrived upon by the algorithm is divided approximately 50 – 50 between PH and P. The controlling ratio for this decision is OW/Cu, where the ratio has to be less than 1.1 to be chosen as P. At low doses, the percentages are amplified, causing what would be expected as P to be chosen as PH. The difference in dose calculation between the two energies is small (6% ambient, 14% directional), so the selection of energy is considered to be acceptable. The QC dosimeters read a control subtracted average of 54 mrem, while the freshly annealed blanks read between 3 and 4 mrem. The minimum reportable dose for Inlight dosimeters will be 0.1 mrem. The rate of background accumulation for the outdoor controls is consistent with control doses on Luxel dosimeters, and as such is an appropriate dosimeter for environmental monitoring. Finally, this test revealed the inadequacy of the rubber adhesive gaskets. All of the indoor samples were found with gaskets that had separated from the dosimeter. The outdoor samples did not have this separation, probably as a result of high temperatures improving the adhesive bond. The next revision will include an improved cover for the holes in the case.

Table 1:

Info	Ambient	Directional	Energy	Days	mrem/day	Average mrem/day
50 mrem QC	56	56	P	<1		
50 mrem QC	59	59	P	<1		
50 mrem QC	58	58	P	<1		
Area 1	24	24	P	91	0.25	
Area 1	22	20	PH	91	0.22	
Area 1	22	21	PH	91	0.23	0.23
Area 2	22	20	PH	91	0.22	
Area 2	19	18	PH	91	0.19	
Area 2	22	21	PH	91	0.23	
Area 2	21	19	PH	91	0.21	0.21
Area 3	17	16	PH	91	0.18	
Area 3	16	15	PH	91	0.16	
Area 3	17	16	PH	91	0.17	
Area 3	23	23	P	91	0.24	0.19
Area 4	19	19	P	91	0.20	
Area 4	22	22	P	91	0.22	
Area 4	24	24	P	91	0.24	
Area 4	24	24	P	91	0.24	0.23
Area 5	21	21	P	91	0.21	
Area 5	19	19	P	91	0.19	
Area 5	20	20	P	91	0.21	
Area 5	22	21	PH	91	0.23	0.21
Control	23	23	P	91	0.23	
Control	24	24	P	91	0.24	
Control	26	26	P	91	0.26	
Control	27	27	P	91	0.27	
Control	25	25	P	91	0.25	0.25
FA Control	3	3	P	<1		
FA Control	4	4	P	<1		
FA Control	4	4	P	<1		

Dosimeter Designation: InLight Environmental Dosimeter

A. Technical Description:

The InLight Environmental Dosimeter is designed for monitoring environmental radiation exposure. The badge consists of a waterproof plastic envelope, which is sealed closed to hold a dosimeter and label, Figure 1. The front of the dosimeter is shown on the left.

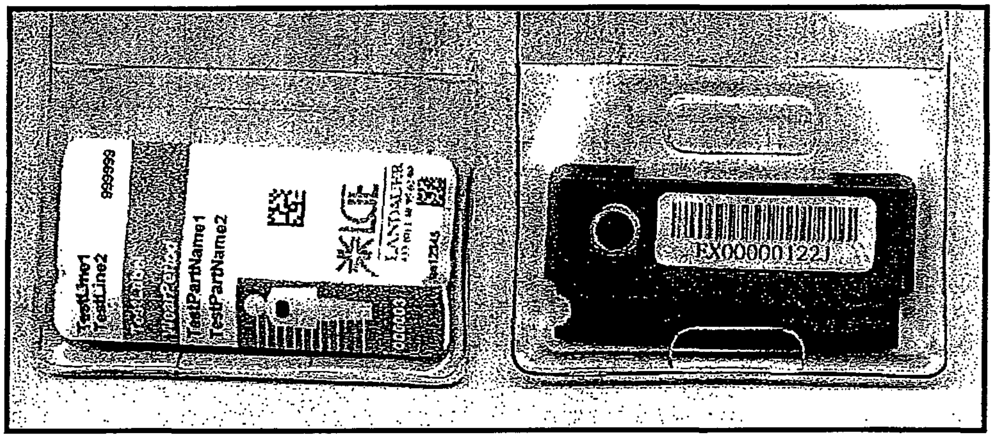


Figure 1: InLight Environmental Dosimeter

The dosimeter consists of a case that contains metal and plastic filters and a plastic slide containing that contains detector elements, Figure 2. The detector element is a layer of Al_2O_3 sandwiched between two layers of polyester for a total thickness of 0.3 mm. Optically Stimulated Luminescence (OSL) is the method of analysis applied to the detector. This figure shows a standard InLight case. The environmental dosimeter contains the open window, plastic and copper filters only.

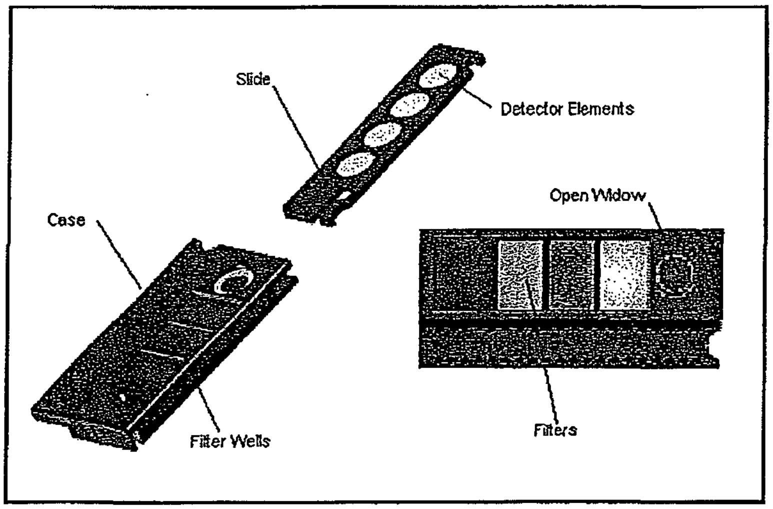


Figure 2: InLight Dosimeter

B. Holder Description:

Size: Rectangular design 6.3cm X 4.5 cm X 0.6 cm thick
Constructed of PVC plastic, RF sealed and waterproof. Formulated to meet -10°F impact testing.

C. Dosimeter:

Size: Rectangular design 5cm X 2.4cm X 0.6cm thick
Constructed of polystyrene plastic. Two flexible black gaskets are applied to the case to prevent light entry under extreme outdoor conditions. These gaskets are removed prior to analysis.

FRONT

				Thickness (mg/cm^2)			
Dosimeter Element	**Density (g/cm^3)**	**Thickness (mm)**	**Thickness (10^{-3} in)**	**Open Window**	**Plastic**	**Copper**	**Copper**
Waterproof PVC Cover	1.406	0.3	12	42.2	42.2	42.2	42.2
2 mil Polyester Beta Window	1.26	0.05	2	6.3	0.0	0.0	0.0
Label (polypropylene)	0.9	0.05	2	4.5	4.5	4.5	4.5
Label (flexo film varnish)	0.93	0.03	1	2.8	2.8	2.8	2.8
Plastic Filter Polyester	1.26	0.7	28	0.0	88.2	0.0	0.0
Copper	8.96	0.4	16	0.0	0.0	358.4	358.4
Polyester Substrate	1.26	0.1	4	12.6	12.6	12.6	12.6
			Total	68.4	150.3	420.5	420.5

BACK

				Thickness (mg/cm^2)			
Dosimeter Element	**Density (g/cm^3)**	**Thickness (mm)**	**Thickness (10^{-3} in)**	**Open Window**	**Plastic**	**Copper**	**Copper**
Waterproof PVC Cover	1.406	0.3	12	42.2	42.2	42.2	42.2
External Strap Holder	1.406	0.25	9	35.2	35.2	35.2	35.2
2 mil Polyester Beta Window	1.26	0.05	2	6.3	0.0	0.0	0.0
Plastic Filter Polyester	1.26	0.7	28	0.0	88.2	0.0	0.0
Copper	8.96	0.4	16	0.0	0.0	358.4	358.4
Polyester Substrate	1.26	0.1	4	12.6	12.6	12.6	12.6
			Total	96.2	178.1	448.3	448.3

D. Identification:

The back of the dosimeter contains a label printed with the wearer name, series code, account name and/or wear date. Each dosimeter packet has an identification number.

E. Analysis Equipment:

Analysis equipment includes Landauer manual and automatic InLight (OSL) readers consisting of a LED stimulation array, photon-counting system, and associated fixtures.

F. Detection Capabilities:

a. Photons (X and gamma rays) with energies above 15 keV nominally: 0.1 mrem to 1000 rem.
b. Beta particles with energies greater than approximately 500 keV average energy: 20 mrem to 1000 rem.
c. Meets or exceeds requirements of ANSI N545 – 1977, NRC Regulatory Guide 4.13, and HPS N13.29 Draft Standard for environmental dosimetry.