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THE EFFECT OF VISIBLE LIGHT ON HARSHAW MODEL 8801 THERMOLUMINESCENT DOSIMETERS

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ABSTRACT

It has been known for some time that illumination of lithium fluoride (LiF) thermoluminescent dosimeters, particularly with ultraviolet wavelengths, causes these dosimeters to emit thermoluminescence (TL), similar to that caused by exposure to radiation. However the effect of incandescent light on dosimeters is not well documented. In this study the growth, saturation and spectral dependence of this luminescence is studied for open dosimeter cards illuminated with room incandescent light, and for dosimeters inside their holders exposed to bright sunlight. The results confirm that illumination with room light does give rise to luminescence in unirradiated dosimeters. Light in the ultraviolet is an order of magnitude more efficient in producing this TL than is longer wave length (red) visible light. The illumination-induced TL saturates at intensities that correspond to TL produced by exposure of about 70 mR of ^{137}Cs; thus illumination clearly can give rise to false radiation exposure reports. Moreover it was found that the dosimeter holder allows enough sunlight to enter so that exposure of dosimeters to bright sunlight will activate some of the chips of the dosimeter cards in a fashion identical to that of room light. The glow curves produced by light are broader than those produced by gamma irradiation and a series of experiments have confirmed that the light induced TL comes from the Teflon sheets holding the LiF dosimeters, rather than the LiF chips themselves.

1. INTRODUCTION

One of the major sources of uncertainty in measurements of low radiation doses with LiF thermoluminescent dosimeters (TLDs) is the presence of background thermoluminescence (TL) in an annealed dosimeter (i.e., TL not due to previously absorbed ionizing radiation). It is known that ultraviolet light illumination can give rise to such background TL bands in TLDs[1-3] or, conversely, can cause fading of radiation-produced bands[3]. We have recently observed that the magnitude of this background as well as the shape of TL glow curves can be changed significantly by illumination of the bare dosimeter cards with visible light. This phenomenon was discovered while reviewing glow curves of dosimeters exposed to TLD processing room lights even though these lights were expressly designed not to emit any ultraviolet radiation.

Another problem that has been appearing repeatedly in routine personnel monitoring may also be in part related to light illumination of dosimeters. This problem consists of unexplained and probably false high readings, usually together with anomalous glow curve shapes. Such readings most often appear in the #3 chips (thin LiF for sensitivity to low energy beta and X rays) of returned field dosimeters. These chips are covered with silvered mylar; however the silvering is not heavy enough to make the film completely opaque to light and it is not known whether enough light can enter a dosimeter to give rise to the occasionally observed anomalies.

The present study is aimed at obtaining a better assessment of the effect of visible light on the TLD system[4] in use at the Martin Marietta Energy Systems installations, with the expectation that such knowledge will allow us to better judge whether any modifications of procedure would increase the accuracy or reliability of our personnel dosimetry program.

2. EXPERIMENTS

In most of the experiments described below TLD cards[4] containing 4 LiF chips were used. There are two 0.015" thick (chips #1 and 2) and one 0.0036" thick (chip #3) TLD 700* chips and one 0.015" thick TLD 600* chip (chip #4). Each chip is held between two Teflon sheets. The history of the dosimeter cards was not known in detail, but all of them had been irradiated to 500 mR (5 x 10^{-3} Gy) of ^{137}Cs gamma radiation for the development of element correction coefficients and then had had multiple further irradiations to low doses (~ 5-20 mR) during their field use as personnel dosimeters. They were annealed at 300 °C after every irradiation, as part of the normal "read" cycles described below. Throughout this work we report the integrated TL outputs in pseudounits of mR, to allow easy comparison of the illumination effects with TL due to ionizing radiation, measured with the same equipment. During all the measurements reported below the samples received no significant ionizing radiation; only in samples stored for extended times for the purpose of measuring the stability of light induced TL was there any significant contribution of background radiation (~ 1 mR/week).

The reading/anneal cycle was the same as that used for routine personnel dosimetry, a linear temperature rise from 50°C to 300°C at a rate of 25°C/s, with a holding period at 300°C of 3.3 s. The TL of the four chips was read simultaneously as a function of time (temperature) with an automatic dosimeter reading system.[4] Room light illumination was performed with the dosimeter cards resting 12" away from a yellow tinted incandescent tube light.[5] Monochromatic illumination was performed with a 100-watt tungsten lamp and a series of interference filters and lenses. The monochromatic light was focused so that only only one chip rather than the whole card would be illuminated; even with the focusing 16 h of illumination was required to obtain observable changes. The intensity of light of the various wave lengths at the sample position was determined with a Si photo-diode, S 1337-66BQ.

*Harshaw Chemical Co.

3. RESULTS

3.1 EFFECT OF ROOM LIGHTING

A dosimeter that has been annealed and kept in the dark will normally produce very slight residual signal during the reheating for another Tl acquisition run. This residual signal which includes the effect of noise in the photomultiplier corresponds to approximately 2 mR for the thick chips (numbers 1, 2, and 4), and to 10 mR for the thin chip (#3). These values correspond to the detectability of the system. Upon illumination with visible light the subsequent signal during heating increases above this detectability limit. Fig. 1 depicts the integrated intensity of the TL for thin and thick chips as a function of illumination time. It is clear that the light induced luminescence is significant, particularly for the thin chip. The light induced TL begins to saturate after approximately 10 hours at values of ~ 60 mR (thin chip) and ~ 15 mR (thick chips). Although not shown in Fig. 1, illumination for much longer times (150 hours) causes the light induced TL to increase only a slight amount, to 70 mR and 17 mR respectively.

The shape of the TL glow curve is rather broad and peaks at a lower temperature than that produced by ionizing radiation. This fact can be seen clearly in Fig. 2 where typical glow curves for illuminated and irradiated samples are depicted.

The fading behavior of the light induced TL is shown in Fig. 3. About half of the stored luminescence disappears upon storage in the dark for ~ 3-5 days. It is not possible to determine a more accurate value of the "half life" because the dosimeters vary in their TL output near their detectability limit.

3.2 SPECTRAL DEPENDENCE

The spectral dependence of the light induced TL is shown in Fig. 4. In that figure the sensitivity

$$S = (D-D_o)/It,$$

where D is the integrated TL output (mR), Do is the residual signal for an annealed chip, I is the light intensity in watts, and t is the illumination time plotted as the ordinate. The wave length of the

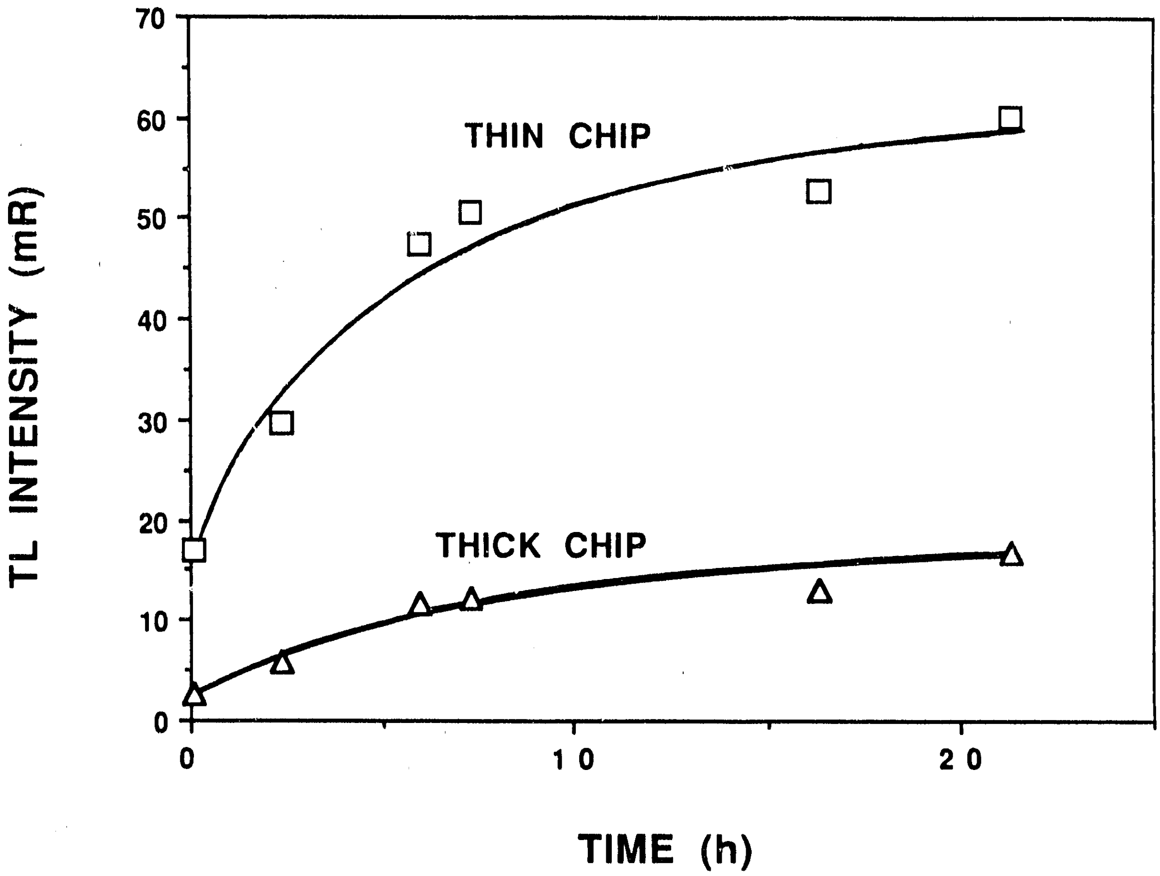

Fig. 1. Increase of thermoluminescent response of Harshaw LiF dosimeter cards due to illumination with yellow tinted incandescent light. The response is given in pseuo-units of mR to allow comparison of the light response to the dosimeter's normal radiation response.

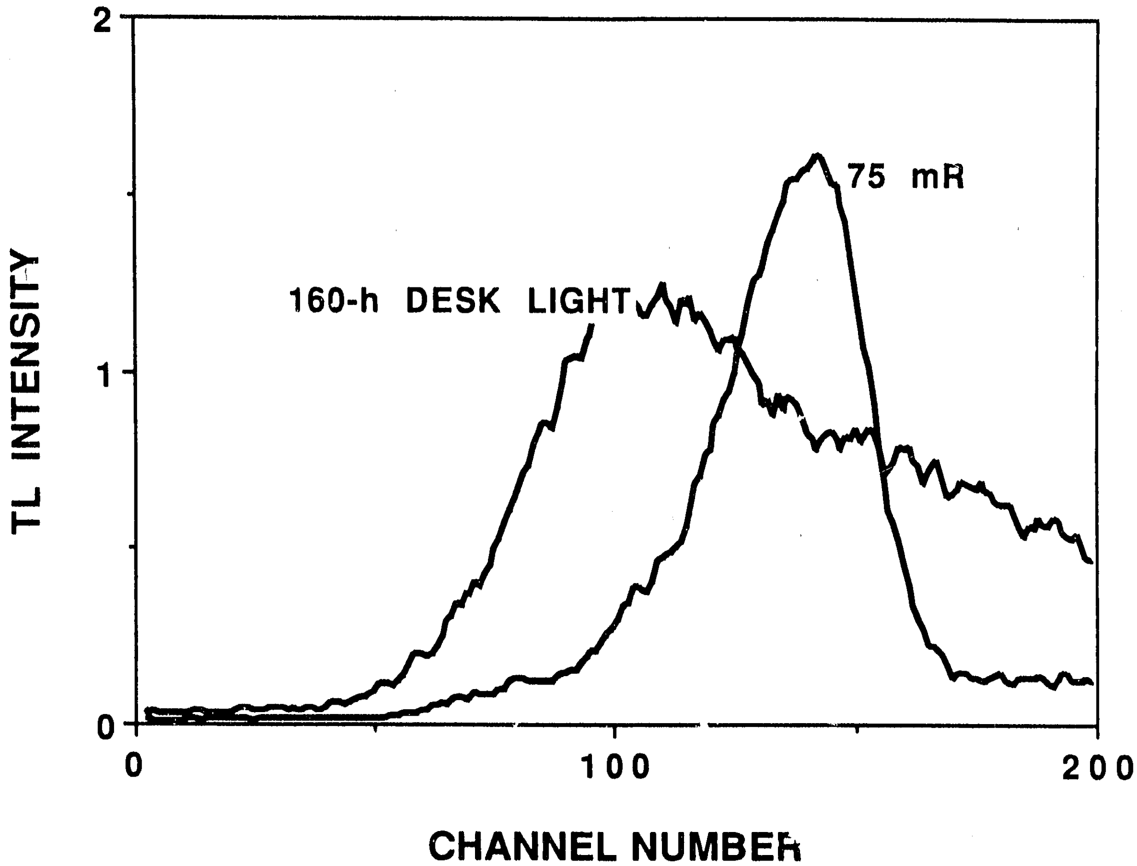

Fig. 2. Comparison of glow curves produced by light and by radiation. The ordinate scale is in arbitrary units.

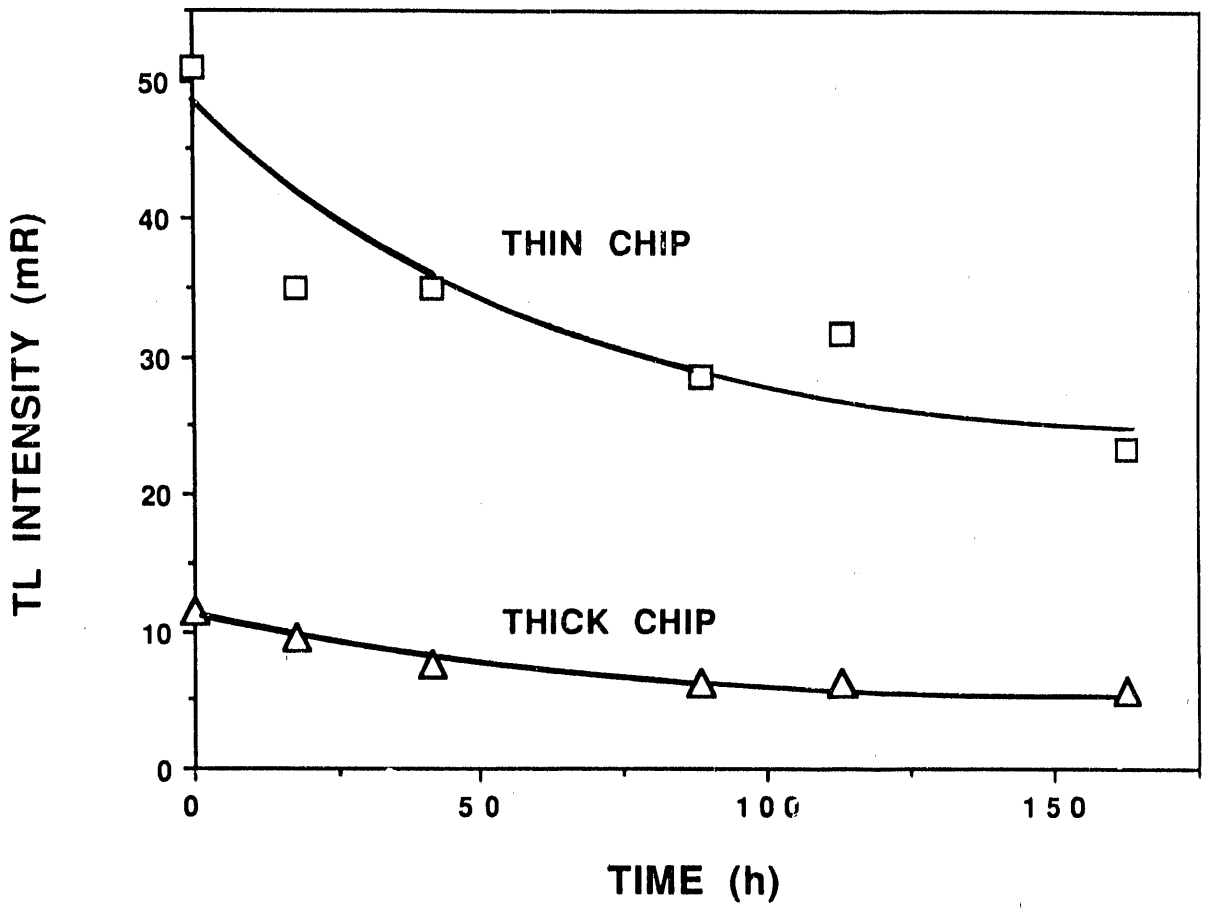

Fig. 3. Fading of light induced thermoluminescence in Harshaw LiF dosimeter cards. The ordinate scale is in pseudo-units of mR as in Fig. 1; the abcissa is storage time in darkness after an initial illumination with incandescent light.

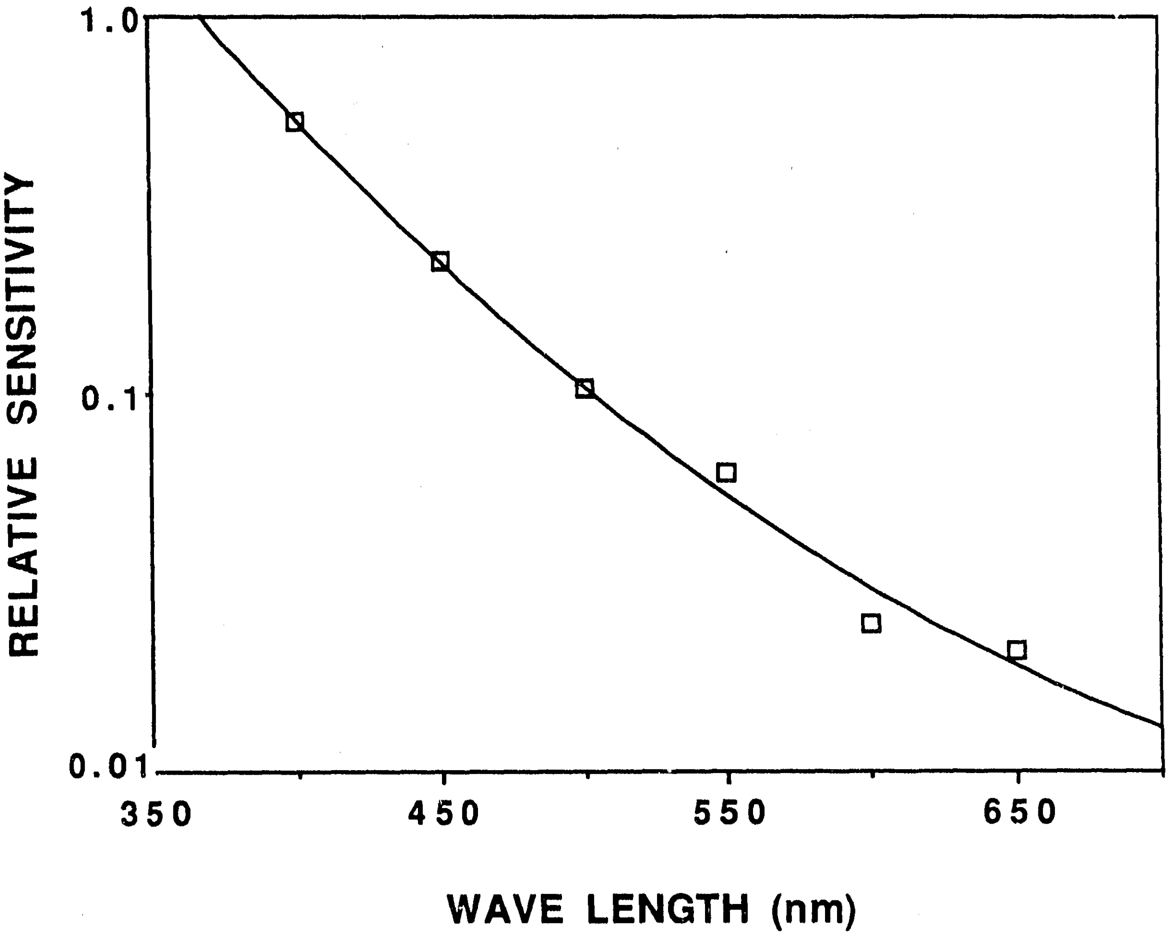

Fig. 4. Spectral sensitivity of LiF dosimeter cards. Units for the ordinate scale are mR thermoluminescence response for dosimeter chip #3 divided by light energy falling on the chip in joules.

light is plotted as the abcissa. It is clear from the figure that ultraviolet light is an order of magnitude more efficient in producing the TL under discussion, but that even red light can produce a significant effect. There is no evidence of any sharp structure in the spectral dependence of the illumination sensitivity.

3.3 EFFECT OF SUNLIGHT ON DOSIMETERS INSIDE THEIR HOLDERS

The above described results show clearly that visible light produces a TL response in LiF dosimeter cards. Moreover, we know that the dosimeter fronts used at Martin Marietta Energy Systems are not completely light tight; the silvered mylar foil that covers chip #3 is not totally opaque and a small amount of additional light enters at the slot used to insert identifying labels. The average TL measured on 2 sets of 5 encapsulated dosimeters, exposed, respectively, 4 h and 6 1/2 h to bright sunlight is compared in Table 1 with identical dosimeters kept in the dark. Clearly chip #3 exhibits TL comparable to the saturation level determined with room light; chips #1 and #4 also show significant increases in TL. Chips #1 and #4 are located, when encapsulated, near the "T" slot through which the label passes and through which light can enter the dosimeter.

Table 1. Response of encapsulated dosimeter cards to sunlight

Treatment	Dosimeter chip number			
	i	ii	iii	iv
No light	1.87	2.47	13.8	1.68
4 h sunlight	6.95	4.39	49.0	6.94
6.5 h sunlight	7.50	3.70	53.3	6.28
6.5 h sunlight and 7 d in dark	4.93	3.30	39.7	5.50

Fig. 5 depicts a typical glow curve from chip #3 of one of the sunlight illuminated dosimeter cards. The curve is compared with one produced by gamma irradiation. The difference in curve shape supports the proposition that sunlight illumination of encapsulated dosimeters has a similar effect as does visible room light illumination.

3.4 ORIGIN OF LIGHT INDUCED THERMOLUMINESCENCE

As indicated in Section 3.1, the light induced TL, when expressed in mR equivalent units, is greater by a factor of three in the thin #3 chips than in the thick chips. If this TL were due to electrons trapped throughout the bulk of the LiF chip (similar to the effect of ionizing radiation) then the thin and thick chips would yield a more comparable mR equivalent TL output. On the other hand, the surface to volume ratio is greater for the thin chips, so that Tl stemming from surfaces would be greater from the thin chip. Also the LiF chips in the dosimeter cards are covered with Teflon sheets; the relative amount of Teflon is also greater for the thin chips. Mason[6] has postulated that light induced TL comes from LiF surfaces; Hoots & Landrum[1] mention that plastic can contribute to the TL. Also Horowitz[7] and Spanne[8] refer to earlier work[9] that indicates that adhesive covered Teflon tape gives rise to TL glow peaks with maxima at approximately 120°C. In order to determine whether the light induced TL we observe stems from the chip surface or the Teflon sheets that hold the chips in the dosimeter cards, we removed the LiF chips from a number of dosimeter cards and illuminated and measured the induced TL of these cards. In Table 2 we show the average TL response of three cards without LiF, after a three day illumination with visible (yellow) light and after three days in the dark. These data are compared with the response of normal dosimeter cards. Clearly the TL response of the cards without LiF is greater than that of dosimeters that contain LiF chips. The fact that the response of the LiF-free cards is greater rather than equal to that of normal cards can be explained by that fact that the LiF chips shield a portion of the Teflon sheets from the light.

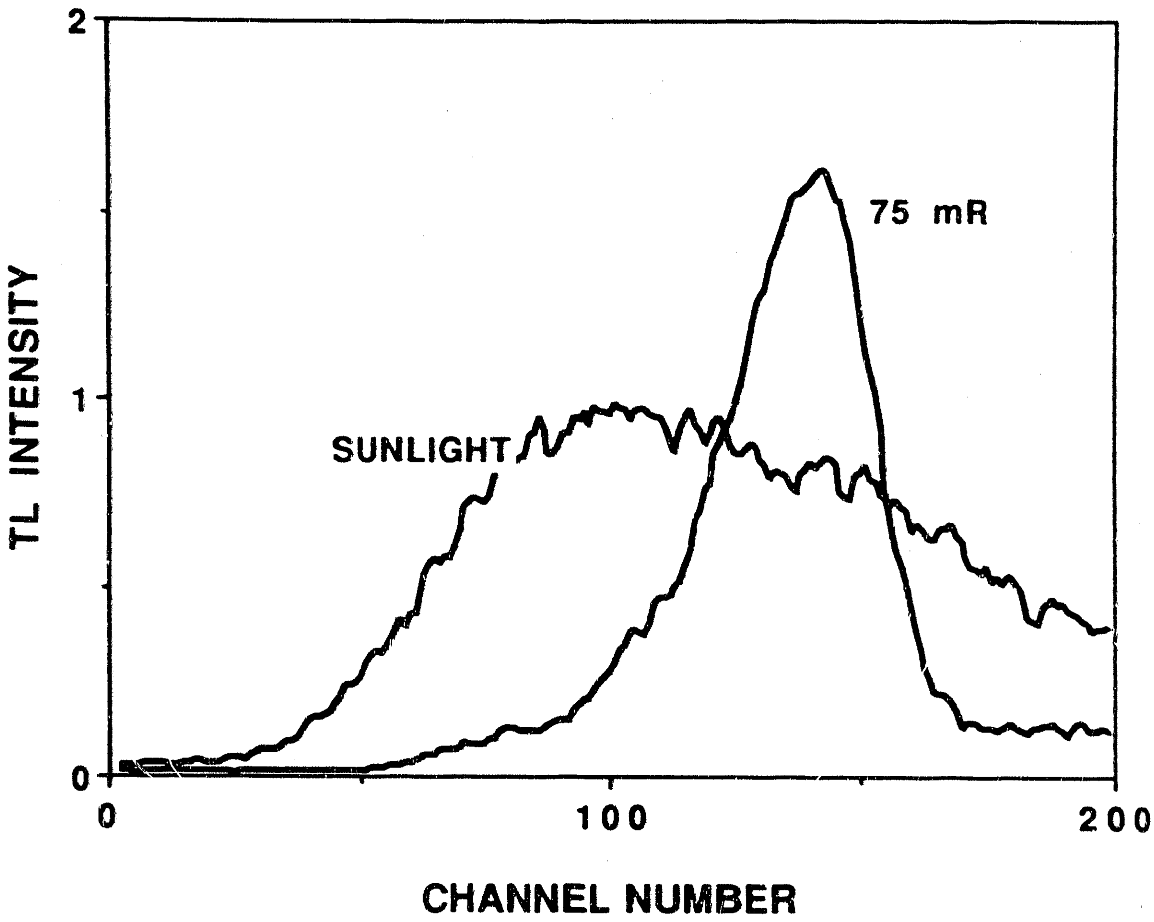

Fig. 5. Comparison of glow curve produced by sunlight falling on an encapsulated dosimeter card with a glow curve produced by gamma rays. The ordinate scale is in arbitrary units.

Table 2. Response of Teflon film to light

Treatment of dosimeter card	Dosimeter chip position i	ii	iii	iv
Annealed	4.64	4.02	20.9	4.50
Annealed and 3 d in dark	4.30	4.01	19.9	3.61
Annealed and illuminated 3 d with yellow light	26.6	26.5	117.4	27.1
Normal dosimeter card for comparison				
Card with LiF chip 3 d illuminated	17 (thick chip)		70 (thin chip)	

4. DISCUSSION AND CONCLUSIONS

The experiments described above have shown that exposure of Harshaw 8801 TLD cards to room light can produce a TL response. This response corresponds to signals from exposure of ~ 70 mR of ^{137}Cs gamma radiation on chip #3 and ~ 17 mR on the thicker chips. Since the lower limit of reporting radiation exposure is 10 mrem for chip 1 (deep dose-equivalent) and 30 mrem for chip 3 (shallow dose-equivalent), the light induced TL can give rise to false positives if some precautions are not taken. The simplest precaution is to limit the light exposure of dosimeter cards after they have been removed from their holders. Fig. 1 indicates that 12" away from a yellow incandescent light ~ 1 h of illumination produces about 1/10 of the saturation TL. Thus if yellow tinted incandescent light is used in the processing room and exposure of the dosimeter cards to light is limited to a few minutes, the illumination effects should be negligible. Nevertheless procedures should be modified to indicate that whenever dosimeter cards are left unattended, they should be covered.

Blue to ultraviolet light is more efficient than yellow light in producing the TL under discussion. Bright sunlight on encapsulated dosimeters can cause a problem. To eliminate this effect requires heavier silvering or darkening of the mylar film and redesign of the dosimeter front to eliminate or at least decrease the light transmission of the label insertion slot.

Since the light induced luminescence stems primarily from the Teflon sheets holding the LiF chips, development of a less light sensitive plastic or other encapsulation material may eliminate the problem under discussion.

A recent study was made of the light sensitivity of LiF-Teflon thin-sheet beta dosimeters.[10] The author(s) found, as we did, significant thermoluminescence after exposure to light. Although they report a more complex spectral response than we found, it is probable that much of the effect they have observed is due to the Teflon binder used in these dosimeters.

The data presented above are for unirradiated dosimeter cards. Supporting our findings is a very recent study by Bradley[11] of the combined effect of radiation and fluorescent light illumination on similar dosimeters. The author found that illumination of unirradiated dosimeters produced, respectively, ~ 20 and ~ 70 mR equivalent TL in thick and thin unirradiated chips. This result is in agreement with our findings. Moreover Bradley[11] found that for combined irradiation and illumination the effect of illumination lessened as the irradiation increased; at doses >~ 500 mR (0.5 Gy) subsequent illumination actually tended to produce fading, in agreement with previous studies.[3]

There has been some discussion in the literature [12,13] of the phenomenon of photo-transferred thermoluminescence (PTTL), in which heavily irradiated and annealed samples can be reread after illumination with ultraviolet. For some materials, LiF:Mg, Ti among them, the first readout anneal does not remove all radiation induced trapped charges. Deeply trapped charges are not removed by a 300°C anneal and can be redistributed by light so that a subsequent readout anneal will produce thermoluminescence, of the order of a few percent of the original readout. It should be pointed out that the samples used for the present experiments had not been heavily irradiated. The largest dose was that due to the original calibration (500 mR), after which multiple anneals occurred. We estimate from the PTTL studies in the literature[12,13] that previous irradiation up to 1 R followed by anneals would produce PTTL no greater than 3 mR and therefore would not be the source of the effects we attribute to illumination.

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