Panasonic

Statement concerning the Panasonic **UD-802A** Dosimeter and the Panasonic **UD-700** Readers

1. Design Concept.

The choice of the heating method in a TLD Reader will almost completely characterize the complete system in terms of measurement and reliability. Furthermore, as personal monitoring services are under pressure to quickly and reliably process many dosimeters each day, handling and loading of dosimeters with minimum precaution is paramount.

In order to release the stored energy in a TL-detector, it is necessary to subject the detector to special conditions not found during its wear-term. In conventional TLD, this necessitates applying a controlled temperature rise up to around 400ºC.
The heat source should be located outside the field of view of the photomultiplier to avoid thermal noise. The applied heat should be isolated from the reader components to avoid mechanical disruption and, in the case of multi-element dosimeters, from TL-elements adjacent to the heated element to avoid induced fading.

The TL-materials should be constructed to allow for handling without risk of contamination by dirt, sweat, grease and other factors capable of generating false signals when heated.

Filtering materials, especially metals, have a large impact on angular response and should be minimised and where possible, incorporated into the dosimeter rather than the holder for (a) reduction in measurement uncertainty and (b) automation in packaging.

Materials with low effective atomic numbers will ensure a flat energy response over all occupational energies and reliable calibration at dose equivalent quantities. Combining these materials with other materials in a four-element dosimeters will give a discriminating dosimeter, providing information on energy.

One of the original heating systems used a contact or hot-planchette system. The requirement was for the TLDs be clean and to have full surface contact with the planchette.

In 1968, a stream of hot nitrogen gas was proposed for heating TLDs. This was adopted by manufacturers as the gas better fits the various shapes of the TL-detector and is a non-contact system. It remained for manufacturing designs to try to eliminate spread of the gas throughout the reader although it is agreed that a steady flow of nitrogen through the reader on a 24 hour basis may be necessary to eliminate air impurities.

The evolution of the non-contact heating system was realized in the form of optical heating. The requirement here was for elimination of the gas supply and its potential heat spread into other areas of the Reader.
The idea of an optical heating system is in itself not a new one but required the development of a TL-detector with infrared absorber.

Panasonic has developed an optical heating method which can heat the Panasonic thin-element TLD to 360ºC within 2 seconds by IR radiation from a tungsten lamp. Digital heat-profiles are generated and controlled by direct heat-flux measurement. An important feature of this method is that an extremely localized area can be exclusively heated very quickly without heating the surrounding parts. For this reason, the dosimeter materials need not be heat resistant and the reader is freed from extraneous heat which often causes mechanical or electronic malfunctions.

2. Optical Heating System

Construction

Figure 1 shows a cross-sectional diagram of the TL-element and optical heating system.
The TL-element is composed of a single layer of phosphor granules, approximately 90µm each and covering an area 3mm in diameter, bonded onto a polyimide substrate file and enclosed in a transparent Teflon cover of depth $22mg/cm^2$. A thin layer of carbon of depth $11mg/cm^2$ on the opposite side of the film acts as an infra-red absorber. Up to four of these elements are mounted onto a solid polycarbonate plate of dimensions 12x48x1.8mm.

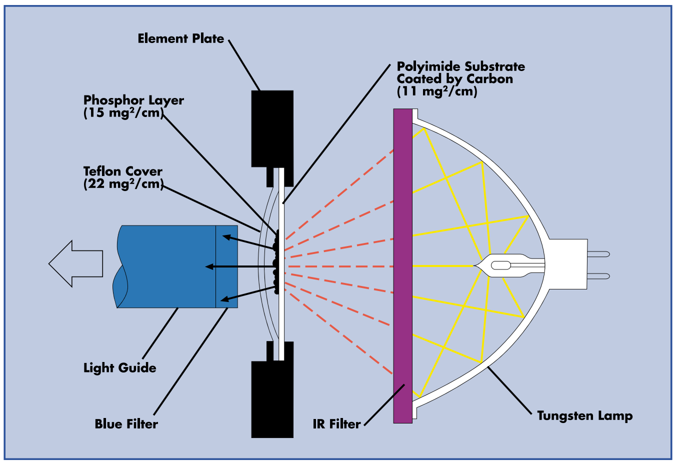

Figure 1 – Structure of Optical Heating System and Dosimeter Element

Pulsed light from the lamp is focused onto the TL- element. Typically, three pulses of duration 0.1sec to 0.4sec will induce three TL-peaks. The first is a very small and rapidly decaying low-energy peak. The second is a dominant and stable peak at about 210ºC. The third is the product of the release of the deep energy traps, effectively annealing the element for re-issue.

The combination of the rapidity and localization of the applied heat together with its subsequent absorption means that the element can be exclusively heated without effect to the surrounding parts.

Figure 2 shows the three peaks with the main peak highlighted in yellow from approximately 1 to 2sec into the reading process. Superimposed here are the lamp voltage and current waveforms. It was found that heating rates can be changed by manipulating the lamp voltage from 4 to 14v with the areas of the glowcurves remaining constant. Shown here is a 5volt pulse, considered to be optimum for response stability as a function of repeatability.

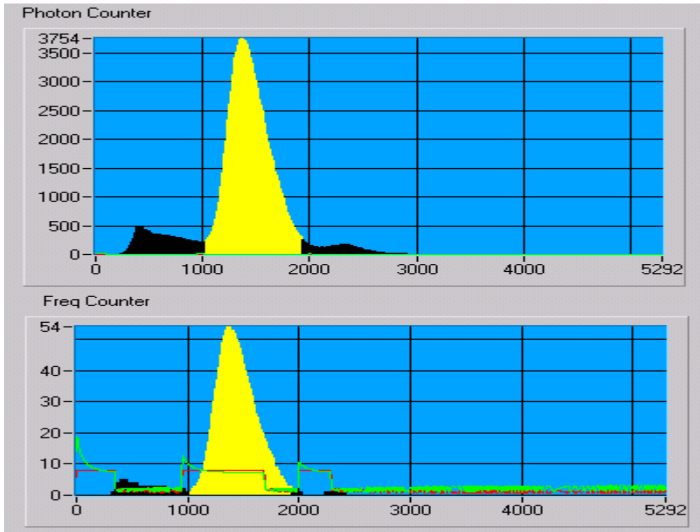

Figure 2 – Glow Curves of Lithium Borate:Cu as a function of applied lamp pulse.

As the lamp is effectively a radiation source emitting short bursts of high energy, a heat flux sensor was chosen as a means of measuring the heat transfer to the TL-element. This typically consists of a thermopile for registering actual heat flux surrounded by a resistance temperature sensor for temperature compensation. Heat flux is the rate of energy transfer per unit area. Whereas temperature is dependant upon the material present, heat flux measures the energy crossing a boundary and is therefore not restricted by the thermal mass of the system

Figure 3 shows first the heating profile superimposed over the glowcurve and then the temperature file as a function of temperature over time. The 3 glowcurve peaks are reached at about 120°C, 220°C and 350°C.

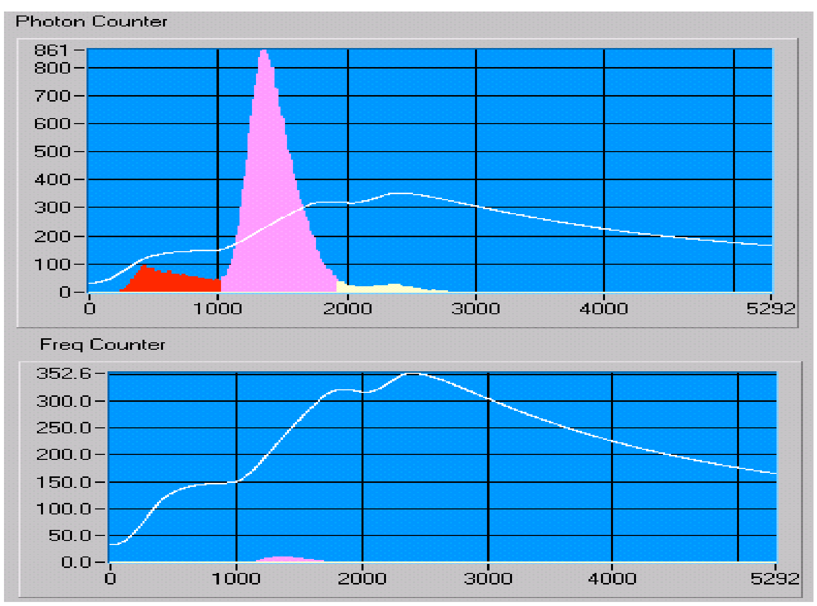

Figure 3– Heating profile as a function of time and temperature

3. TL Materials.

Figure 4 shows the response of several commercially-available TL materials as a function of absorbed dose in material/ tissue. It can be seen that the over-response at low energies increases as a function of effective atomic number Z, e.g. Li-floride=8.4, Al-oxide=11.3, Ca-Sulphate=15.3 compared with tissue=7.4 etc.

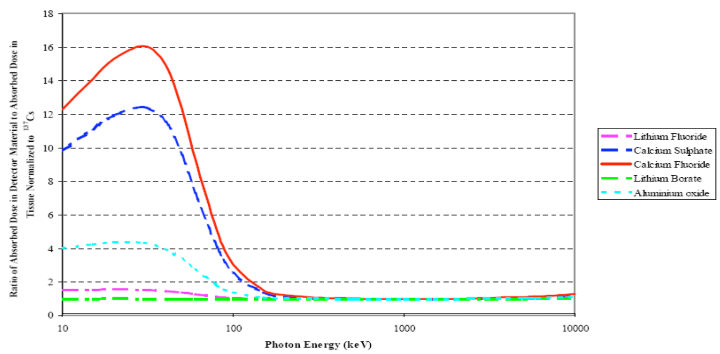

Figure 4 – Energy Response of Phosphors

Figure 5 shows how the response of these TL-materials compare with several common detectors. The over-response at energies<100keV can be seen for non-tissue-equivalent materials.

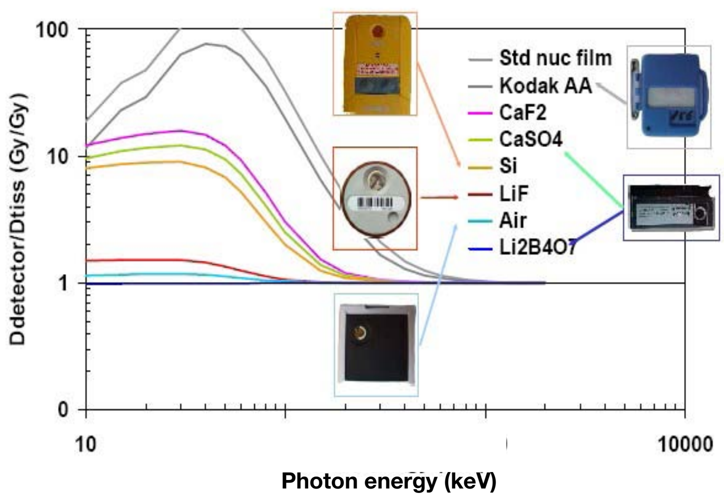

Figure 5 – Absorption of common detectors relative to soft tissue

Scientists at the Panasonic Central Research Laboratories in Osaka have developed an efficient $^{n}Li_2$ $^{n}B_4O_7$: Cu preparation exhibiting maximum TL efficiency where the atomic ratio of B/Li = 2 using a sintering method.
This ratio also resulted in virtually zero absorption of moisture (Figure 7). $^{n}Li_2$ $^{n}B_4O_7$: Cu is 7.3 – very similar to tissue ~ 7.4.
Response of the phosphor at < 100keV is a function of effective atomic Number Zeff .
The TL signal is optimum for photomultiplier tubes at 365nm wavelength. (Figure 6). A preparation of $CaSO_4$: Tm was also researched and developed. The over-response of $CaSO_4$: Tm (Zeff ~ 15.3) is used to advantage as shown in Section 4.

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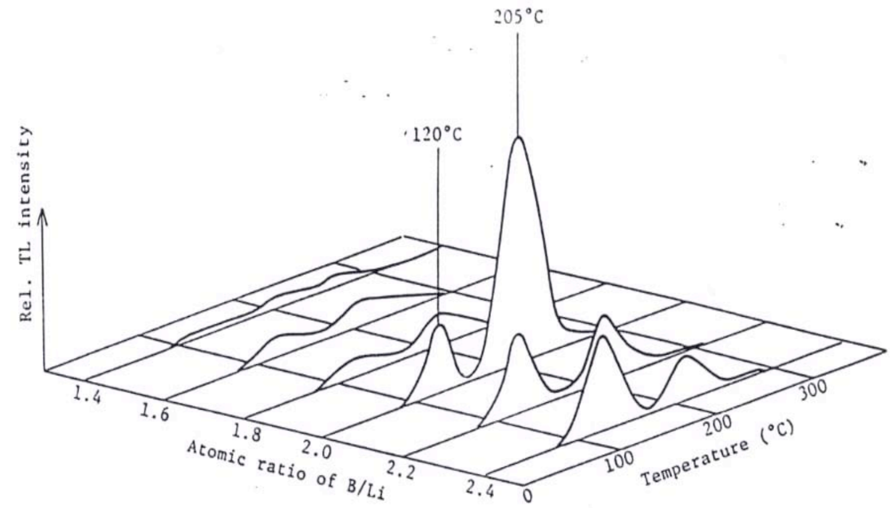

Figure 6 - Glowcurves of 0.03wt% Cu-activated lithium borate at various B/Li atomic ratios

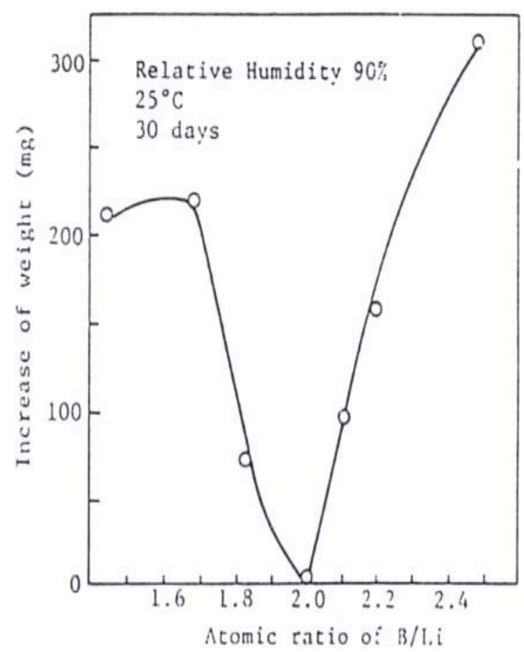

Figure 7 - Change of phosphor weight due to moisture absorption in Cu-activated lithium borate phosphors with various B/Li atomic ratios.

4. Discrimination and Algorithm

Dosimeters with 2 or less elements are known as non-discriminating dosimeters. This means that (a) no information about energy is available and (b) non-tissue-equivalent phosphors cannot accurately report unknown irradiations <100keV.

The flat response of $Li_2B_4O_7$:Cu means that, in its simplest form, the dosimeter/reader can be calibrated at a single-point irradiation in dose-equivalent units. The addition of $CaSO_4$:Tm under a combination of plastic and lead allows the dosimeter to be exploited for energy and angular information.

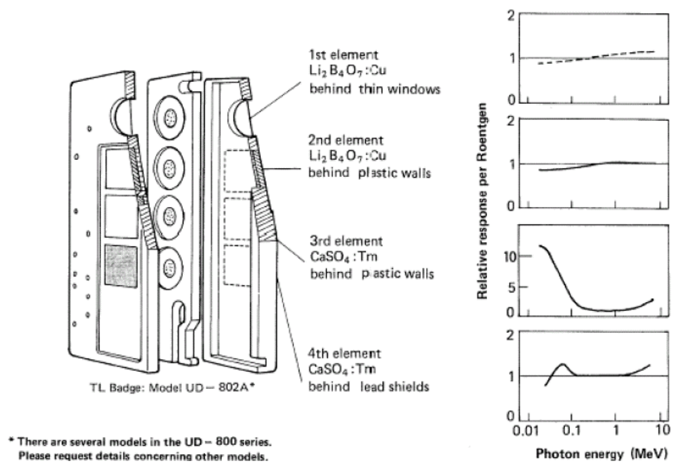

Figure 8 – Dosimeter Construction..

Panasonic and users have developed dose algorithms based on the dose response of the four elements E1, E2, E3 and E4 in various holders.

The algorithm uses the element response ratios E1/E2, E2/E3, E3/E4, E1/E4 and (E2-E4)/(E1-E4), allowing the users to calculate Hp(0.07), Hp(10), Hp(3) and also to identify particles and energies as a result of the algorithm.

Alternatively, the user can generate their own dose response algorithm particular to their own dosimeter/holder combination. Because the UD-802A has built-in filters, simple plastic holders can be sourced and algorithms simply built.

Step 1 – The dosimeter/holder combination is irradiated with ^{137}Cs to calibrate the TLD Reader to match the deep dose equivalent for Element 2 and for Element 3.

Step 2 – The dosimeter/holder combination is irradiated and read for several lower energies (figure 9)

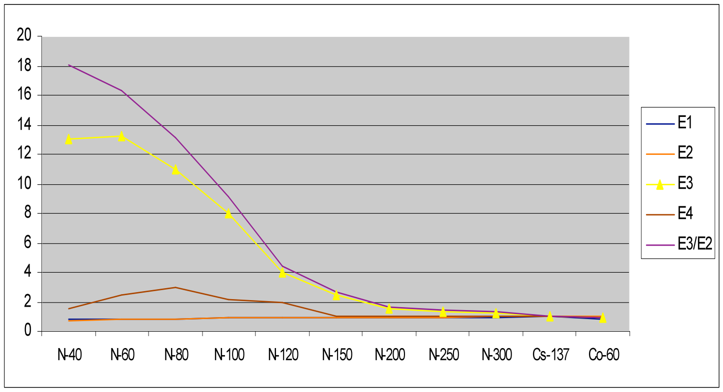

Figure 9 – Chart of element responses as a function of radiation energy.

Step 3 – Calculate and plot the ratio of Element 3/Element 4 as a function of Element 2 (Figure 10)

Step 4 – Add trendline and curve fit to a minimum of two orders.

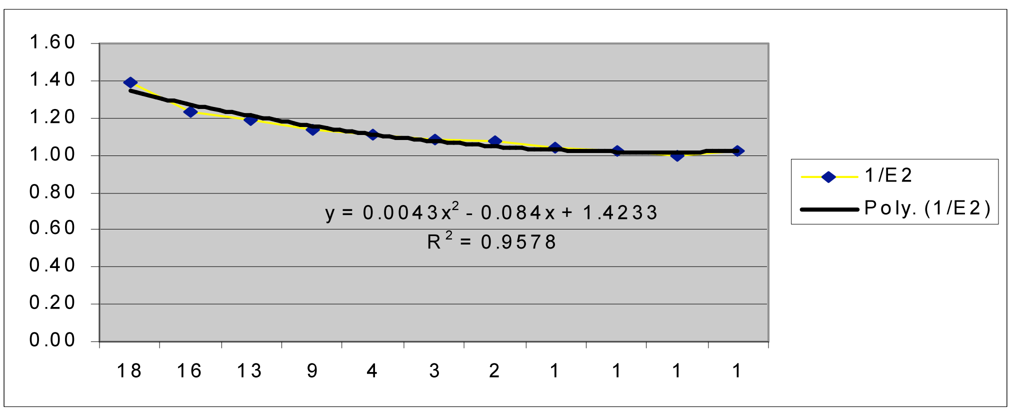

Figure 10 – Curve fit of 1/E2 as a function of Element ratios .

Finally, for any four-element dosimeter readout, the true deep-dose response can be calculated as a function of E2 * $(0.0043x^2 - 0.084x + 1.4233)$ (example only).

The energy approximation can also be obtained from the same E3/E2 ratio.

5. Dosimeter Construction.

To eliminate human errors in handling at the dosimetry laboratory and wearing, Panasonic designed an element card that is permanently encapsulated. This has the following advantages:

a) The dosimeter is extremely robust inside and outside it's wearing holder and can be mailed/handled securely.
b) The dosimeters built-in filters eliminate most shielding variations experienced in the other forms using holders with metal shields.
c) The dosimeter lends itself to automatic packing/wrapping or any form of simple plastic holder.

Finally, the dosimeter has a unilateral construction - front and back (Figure 11).

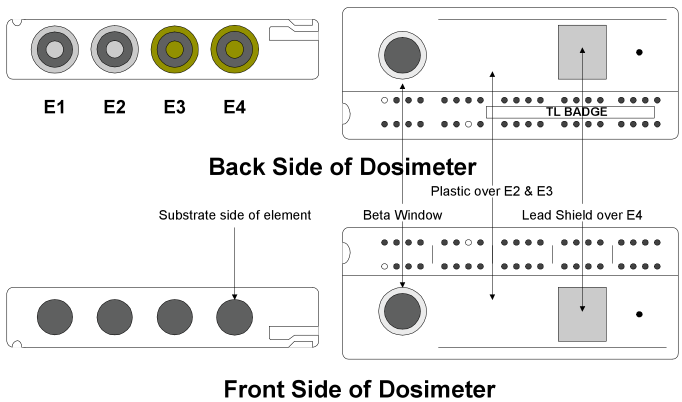

Figure 11 – Dosimeter construction

It should be noted that Element 1 ($Li_2B_4O_7$:Cu) is attenuated by only 14 mg/cm^2 plastic whilst the actual phosphor layer itself of ~90µm, rendering it almost ideal for superficial dose measurement.

6. General Characteristics

Response stability:
Under normal operating conditions, the UD-802A dosimeter shows a very stable dose response for more than 1,000 cycles of exposure readings – ideal for correction factor application.

Reproducibility: $Li_2B_4O_7$:Cu ± 5%
$CaSO_4$:Tm ± 2.5%

Fading: <5%/year (corrected)

Angular dependence: The UD-802A will have some dependency on the construction of the holder, but for the standard Panasonic holder UD-874ATM at 0 – 60° irradiation to the following energies:
75keV Element 2 : 1.0 to 1.10. Element 4 : 1.0 to 1.20
^{60}Co Element 2 : 1.0 to 1.05 . Element 4 : 1.0 to 1.10
The high over-response at 60° to 75keV on Element 4 is a function of some secondary-electron activity of the Pb-filter and it used to advantage in algorithms to detect angular irregularities.

Detectable Dose: 0.01mSv with 95% confidence

Dose Confirmation: Four glowcurves per dosimeter – each glowcurve counts digitally sampled at 22msec intervals.

7.Readers

The optical heating system described in Section 1 has been installed in a variety of readers such as:

UD-716AGL Desktop reader
UD-7900M Automatic reader

The most advanced TLD reader for large scale processing is the UD-7900M.

Figure 12 – UD-7900M Automatic TLD Reader.

Additionally, an automatic irradiator UD-794D based on the UD-7900M mechanics and utilizing a 74GBq source is available with a 500 dosimeter loading.
A custom designed shield and shutter reduces the background radiation to levels generally acceptable to an office environment use.
The user can program one irradiation across all dosimeters or store profiles for a different irradiation for every dosimeter.

8. Manufacturing

The dosimeters are irradiated with a ^{137}Cs source and the responses are calculated by comparing the irradiated value and read value from a TLD Reader standardized with reserved calibration TLDs. The dosimeters are ranked according to the response of each element (Q, R and S-codes) and then selected according to the standard deviation of each individual element compared to the mean response for that same element (Q and R-codes) in order to unify their sensitivities. Only T-codes are not ranked but selected according to the response.

All Dosimeters have sequential seven-digit ID Codes specified by the user when ordered.

Panasonic dosimeters are delivered and stored in magazines holding 50 dosimeters at a time. The magazine slots are keyed for correct dosimeter insertion. The magazines are inserted into the TLD readers for processing.

Figure 13 –Dosimeter Magazines

9. References

[1] Yamamoto et al., Construction of a Composite Thin-Element TLD using an Optical Heating Method. Health Phys. Vol. 43, No. 3, pp 383-390. (1982)
[2] Barnes, A., Heat Flux Sensors. Sensors Online (1999)
[3] UD-7900M Operation Manual v1.9 (2002)
[4] Bartlett D. Harmonisation and Dosimetric Quality Assurance (Eurodos 2005).
[5] Yamamoto et al., A New Phosphor for TLD. Health Physics Vol.44, No.4 (1983)
[6] Plato P. Users Manual for Panasonic TLD Reader