Film Badge Dosimetry Versus Luminescence Dosimetry

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Studies comparing film and luminescence dosimetry are reviewed. The accumulated evidence indicates a clear superiority of luminescence dosimetry over film dosimetry.

The field of personnel radiation monitoring is presently in a state of radical change. It appears that the unreliability of the film badge is now firmly established, bringing into question the value of much of the massive amount of personnel dosimetry data accumulated in the past three decades.

This article examines the evidence "against" the film badge and reviews the comparative studies "for" solid-state dosimeters in an effort to gain a fuller appreciation of the devastating appraisal of the film badge recently made by Becker *(1)*: "... film has to be placed in a category of accuracy close to the 'erythema dose' . . . which was en vogue 50 years ago."

The Case "against" the Film Badge

Just over 10 years ago, Gorson, et al *(2)* engaged in a study to determine the degree of confidence that one might reasonably be expected to have in measurements reported by commercial film badge dosimetry services. An intercomparison study involving 12 commercial film badge services was carried out. Only photon radiations (x-rays, gamma rays, and mixtures of these radiations) were considered, with exposures being confined to between 16 and 8,200 mR. Several disturbing observations were made. For example, one company with a superior performance record was able to keep only one-fifth of its measurements within its advertised precision of 10%; another company reported exposures of 10 and 6,000 mR for two badges that had received identical 130-mR exposures. Such findings led Gorson, et al to conclude that the precision that one can reasonably expect of commercial film badge dosimetry services is from 50% below the true value to 200% above it.

At about the same time that Gorson, et al were pursuing their evaluation, Menker and Dauer *(3)* evaluated the accuracy and precision of the measurements of 15 commercial film badge suppliers. The companies were informed only of the type of radiation to which each badge had been exposed and were further advised that no mixing of radiation types had occurred. The data returned by the companies showed large dispersions. Readings of badges exposed to ^{226}Ra photons ranged from 72% below the true value to 50% above it. The corresponding ranges for ^{60}Co gamma rays and 250 kvcp x-rays were −86%/+52% and −62%/+119%, respectively. Most appalling, however, were the results for 80 kvp x-rays: −68%/+2,635%. Menker and Dauer concluded that although the companies claim a precision of within 10−20% of the true value, their performance seldom warrants claiming anything less than 50%.

These studies contributed to stimulating the existing effort to devise personnel dosimeters with improved accuracy and precision. From this general effort there arose several comparative studies involving film badge dosimeters and luminescent dosimeters. Let us now consider how these studies further underlined the inadequacy of film dosimetry.

The Case "for" Luminescent Dosimeters

In an early comparative study of thermoluminescent and film dosimeters, Suntharalingam and Cameron *(4)* presented evidence to show that the precision obtainable with thermoluminescent dosimeters surpassed that commonly obtained with film dosimeters.

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At about the same time, Becker wrote an article *(5)* in which he summarized the disadvantages of film dosimeters relative to thermoluminescent dosimeters (TLDs) and radiophotoluminescent dosimeters (RPLDs). His concern for the existing status of film-dominated personnel dosimetry was expressed as follows: "Nobody should be satisfied with a personnel dosimeter whose reading may be right within ±20 or 50%, but may, with unpredictable probability, also be wrong by a factor of more than 5 – 50 in both directions."

Becker also discusses the several specific features that make TLDs and RPLDs superior to film dosimeters: (A) TLDs and RPLDs are capable of greater precision; (B) certain thermoluminescent materials exhibit greater photon sensitivity; (C) TLDs and RPLDs possess responses having a relatively minor energy dependence; (D) the dynamic range of TLDs is greater than eight decades; (E) it is possible to construct TLDs and RPLDs that possess a relatively minor directional dependence; (F) TLDs and RPLDs exhibit little fading; (G) the manufacturing of consistent TLDs and RPLDs is possible; (H) TLDs and RPLDs are simple to read out; and (I) TLDs and RPLDs are reusable.

Of course, the fact that we have two clearly superior solid-state dosimeters brings us to a comparison of the two. For medical applications, the lithium fluoride TLD seems the best choice because its response is quite "flat" over a wide energy range. However, in situations requiring long-term exposure and intermediate readout capability, the RPLD is the one of choice because its information content is not destroyed during readout (as is the case for TLDs).

The 1968 paper by Attix, et al *(6)* contains results of two comparative studies involving TLDs and film dosimeters. Thermoluminescent, quartz-fiber, and film dosimeters were compared as gamma ray dosimeters in the first study. Ionization dosimeters and TLDs compared favorably with film differing substantially and systematically. In the second study, film dosimeters and glass-encapsulated TLDs were again compared as gamma ray dosimeters. This time the exposed dosimeters were placed in an air-conditioned room for a month before being read. At readout, the TLD measurements were corrected for trap-decay fading. The film readings showed clearly, however, that such corrections were not sensible for film, the latent-image fading of film being simply too erratic.

Hall and Wright *(7)* carried out a similar comparative study. They compared lithium fluoride TLDs with film at the Savannah River Laboratory plutonium facility. During a 6-month period, 66 employees wore both TLDs and film dosimeters to measure skin exposure. At readout, the TLD measurements were on the average about 50% below the film measurements.

In a followup experiment, Hall and Wright gave TLDs and film dosimeters known x-ray exposures. The disagreement in the measured exposures was pronounced. The TLDs were within about 20% of the true exposures, while the film exposures were always in error by at least a factor of two.

Recently, Crosby *(8)* made a hospital-based comparative study of TLDs and film dosimeters. In his study ten individuals from three hospitals wore TLDs and film dosimeters side-by-side for 1 year (these individuals worked in diagnostic radiology, nuclear medicine, and radiotherapy). The badges were changed every month. At the end of the year, 15 of the 120 film badge readings exceeded the corresponding TLD measurements by at least a factor of 10 (with all 15 cases being workers in diagnostic radiology).

The Future of Personnel Dosimetry

It seems clear that the end of film-dominated personnel dosimetry is past due. In looking at the worldwide status of personnel dosimetry in 1971, Attix *(9)* noted that several large laboratories were already depending exclusively on luminescence dosimetry. For example, Lawrence Radiation Laboratory had begun to monitor 7,100 workers exclusively with TLDs and Knolls Atomic Power Laboratory was about to do the same for its 4,000 employees.

Why hasn't the change-over proceeded more quickly? At least three reasons come to mind. First, many believe that only the film badge represents a legal record. Cusimano and Cipperley *(10)* point out, however, that the AEC regarded a solid-state dosimeter reading recorded in the regular course of business equally admissible as evidence as a processed dosimetry film. Second, there seems to be a general lack of knowledge of the evidence pointing to the inadequacy of film as a personnel dosimeter. This article may help to alleviate that situation. Third, film dosimeters are inexpensive; however, the growing use of solid-state dosimeters will most certainly lead to the disappearance of that advantage.

Collateral Reading

The physics of TLDs and RPLDs is presented elsewhere in a tutorial article by this author *(11)*. Applications of TLDs in the radiologic sciences are given in a paper by Raeside and Anderson *(12)*.

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