^{7}LiF AND CaF_2:Mn EXPERIMENTAL DATA FOR EVALUATING TLD ENERGY RESPONSE THEORY

by

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1.0. INTRODUCTION

During the past decade, thermoluminescent dosimeters (TLDs) have received international attention for the measurement of gamma energy deposition, in various regions of low power critical assemblies. This interest was largely generated by the successful demonstration of the method by scientists within Argonne National Laboratory's Applied Physics Division[1,2,3]. Specific measurements for which this method has been employed include (1) characterizations of fast reactor assemblies[1,4-6], (2) energy deposition in shielding materials[7,8], (3) gamma heating measurements in fast breeder reactor blankets[9], and (4) energy deposition in reactor control rods[10,11].

1.1 History of Method Development and Evaluation

The particular advantage of using TLDs for gamma heating measurements, is the small size of the dosimeters. When placed within a gamma irradiated medium, the TLDs do not appreciably perturb the gamma field. This non-perturbation characteristic is desirable when a good estimate of the surrounding medium's radiation dose is required. Nevertheless, despite their small size, TLDs exhibit a linear response as a function of gamma dose over a wide range of radiation exposures[12]. However, it should be mentioned that this linear response characteristic holds only when the radiation makeup remains unchanged.

The theory used to relate absorption of gamma radiation in a medium, to that of the resulting ionization produced in a TLD, was forwarded by T.E. Burlin[13,14]. Based upon this theory, various computational methods were developed to determine this relationship[15,16]. One such method is incorporated into the TERC/III computer code, which was developed by scientists at Argonne National Laboratory.

Once the computational methods were developed, raw TLD data were acquired for their evaluation[17,18]. This was accomplished by gamma irradiation of encased ^7LiF TLDs. The encasements included sleeves of B_4C, Teflon, iron, copper, lead, stainless steel, tantalum, and aluminum. The studied gamma energies ranged from 0.662 to 1.333 MeV. With comparison of the experimental results to the computational methods, good correlation was found to exist.

1.2 Scope of Experimentation

In order to further evaluate the various computational methods, a broader data base needed to be generated. As a result of this need, response data were obtained by irradiating encased ^7LiF and CaF_2:Mn TLDs. Encasements included sleeves made of lead, tantalum, tin, zirconium, copper, stainless steel, iron, aluminum and natural LiF. Gamma energies ranged from 0.122 to 1.333 MeV. The experimentally determined energy response results, and comparisons between these results and TERC/III calculations, are presented.

To compliment the energy response study, the results of a sleeve thickness investigation are also reported. For this study, ^7LiF and CaF_2:Mn response data were obtained using a variety of sleeve thicknesses. The investigated gamma energies and sleeve materials were the same as those used for the TLD energy response study.

2.0 EXPERIMENTAL EQUIPMENT AND MATERIALS

Equipment and materials, which were available for the performance of the experimental phase of these investigations, are described in this chapter. Except for the TLD encasing materials, which were on loan from Argonne National Laboratory, all items were purchased with available research funds.

2.1 TLD Response Measurement Equipment

During execution of the TLD energy response study, individual dosimeter responses were measured using a Harshaw 2000 TLD Reader. A photograph of the equipment is shown in Fig. 2.1. This particular analyzer consisted of two major components, a 2000-A Thermoluminescence (TL) Detector and a 2000-B Automatic Integrating Picoammeter. A CO_2 gas metering system was connected to the 2000-A unit for the purpose of purging the TLD heating chamber of residual air. In the course of normal operation, the TL detector utilized a photomultiplier tube (PMT) to measure the individual TL emissions released during prescribed TLD heating cycles. During measurement of these heat induced emissions, the PMT currents were simultaneously integrated by the 2000-B unit. These integrations produced LED readings of total charge, which were relative measures of total TLD response. This was the desired quantity used to relate the instrument output to the gamma-ray induced excitation within the dosimeters.

To complete the sleeve-thickness study, individual TLD responses were measured with two analyzers, namely the Harshaw 2000, and a photon

THIS BOOK CONTAINS NUMEROUS PAGES WITH PICTURES THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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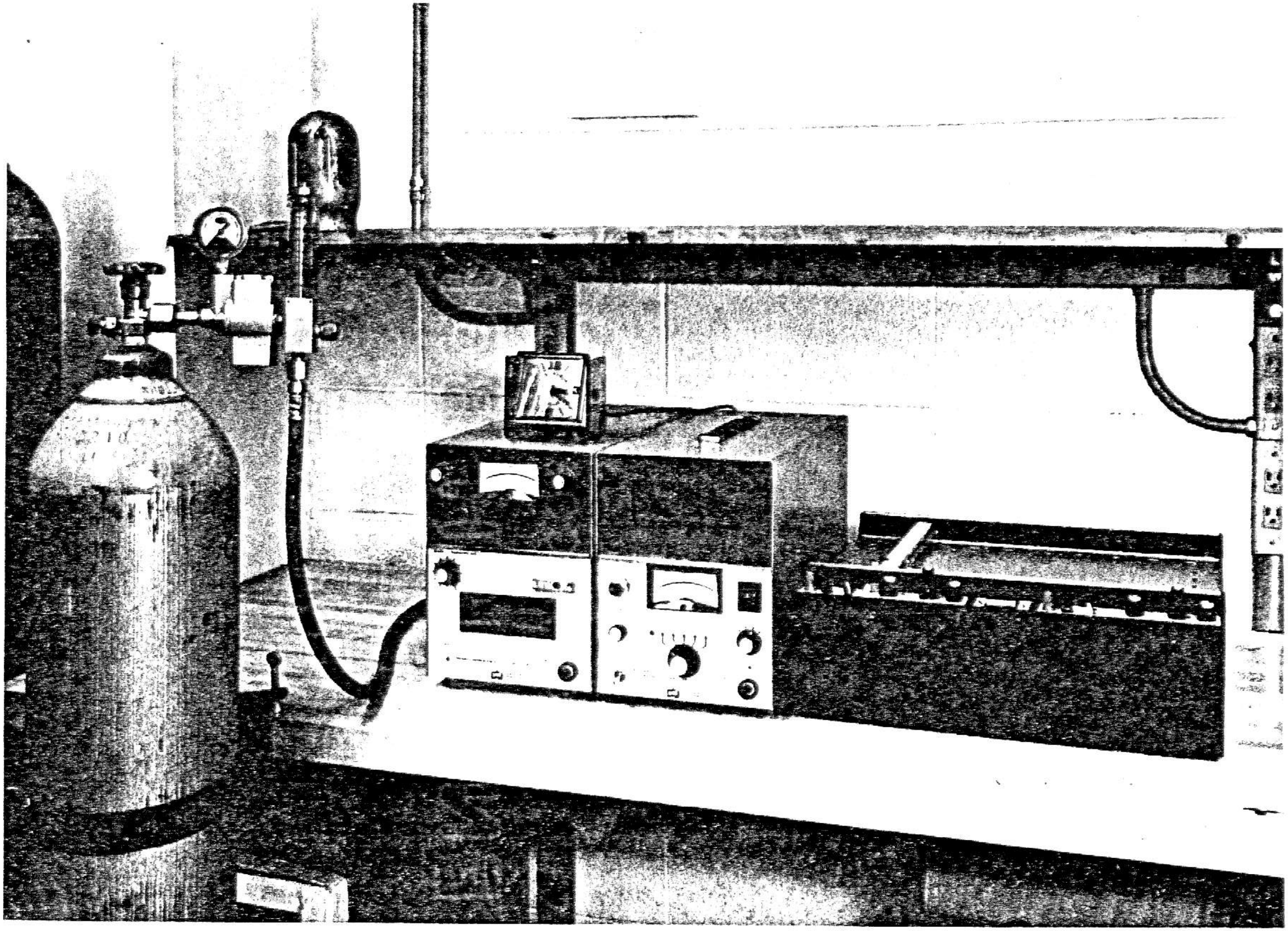

Fig. 2.1. Photograph of the Harshaw Model 2000 TLD analyzer and CO_2 gas purge system.

detection system which was developed within the Nuclear Engineering Department at Kansas State University. A detailed discussion of the photon analyzer's operating characteristics is presented in Ref. 19. Basically, the photon detecting system differs from the Harshaw analyzer in only two respects. First, the total number of photons detected by the PMT (rather than the PMT current) is integrated and second, N_2 (rather than CO_2) gas is used for purging of the TLD heating chamber. In a manner similar to the integrated charge result for the Harshaw 2000, the integrated number of photon counts is the quantity used to relate instrument output to the radiation induced excitation within the TLDs.

An X-Y recorder was employed in concurrence with both analyzers during data acquisition. It was used to generate glow curves (PMT response rate versus time) and temperature profiles whenever permanent records were required. Normally, only the integrated responses were recorded.

2.2 Annealing Equipment

Two ovens (see Fig. 2.2) and a draft-free drawer were available for annealing of TLDs prior to radiation exposures. The first oven, a Thermolyne Type 10500 furnace with solid state temperature control, and an operating range of 30-1200°C, was used for TLD annealing at 400°C. A Thelco Model 16 Precision Oven, with an operating range of 0-200°C, was employed for TLD annealing at 100°C.

Pyrex petri dishes were used as TLD receptacles during the pre-annealing procedure. Pyrex glass was chosen because its surface is

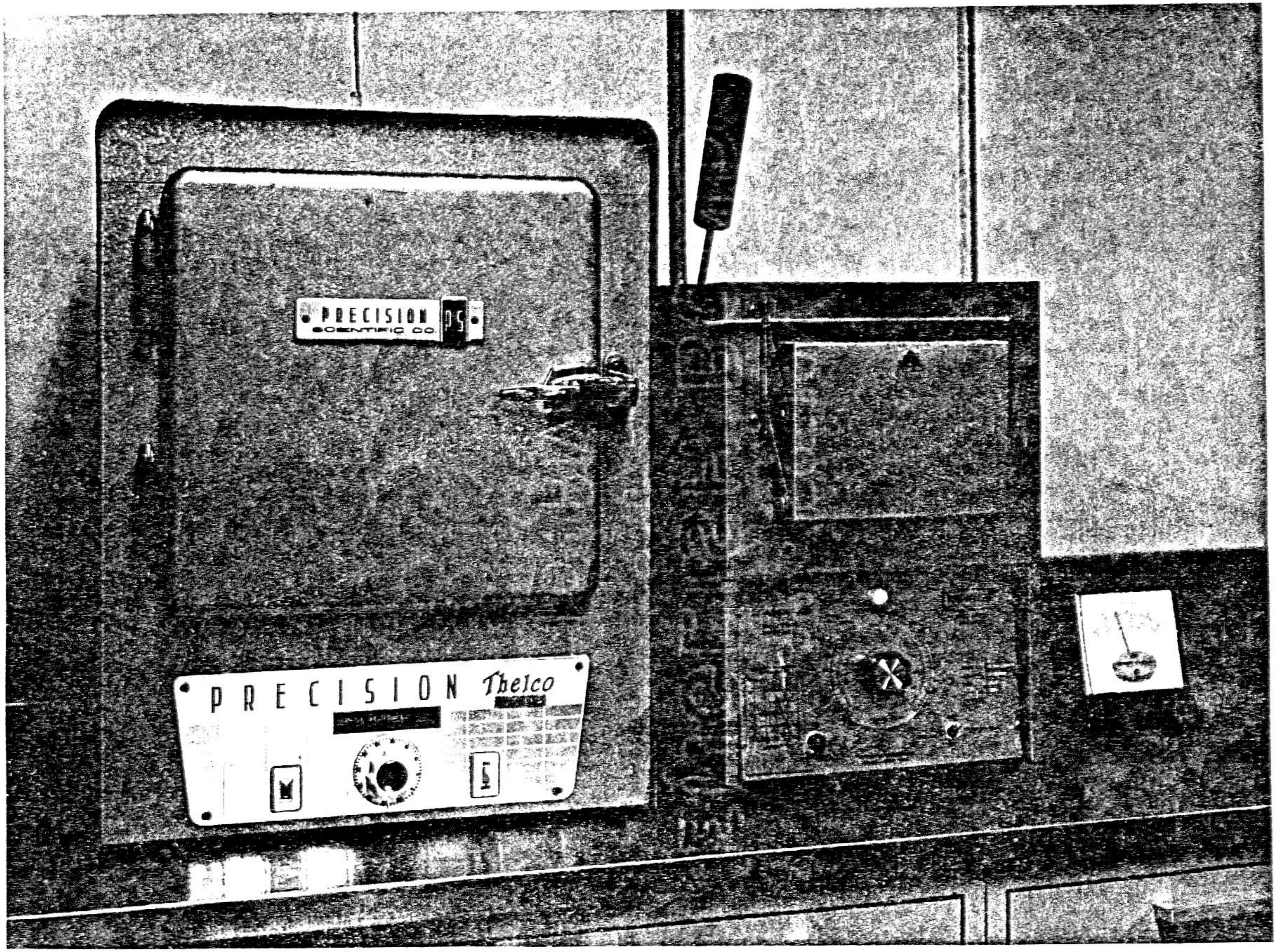

Fig. 2.2. Photograph of the TLD annealing ovens.

resistant to oxidation at high temperatures. If a material not resistant to this formation was chosen, the surfaces of the TLDs could have been contaminated. This occurrence would have had a detrimental affect on the precision of the dosimeters.

A draft free drawer, located directly below the ovens, was used for cooling the TLD ladened petri dishes. Situated at the bottom of the drawer was a sheet of asbestos upon which the receptacles were placed. The asbestos pad was used to avoid any appreciable drawer-bottom conduction cooling of the dishes. Prevention of this phenomenon allowed for slower and more reproducible TLD cooling rates. Rapid cooling tends to increase the size of the undesirable low temperature TLD response peaks[12].

2.3 Handling Equipment

TLDs were handled using a special plastic tipped tweezers. The tweezers was used to avoid abrasion or crushing of the delicate dosimeters. If incurred, both of these phenomena could have affected a TLD's response characteristics.

In order to maintain the individuality of each TLD, the dosimeters were stored in numbered coin envelopes. The envelopes were chosen because of their amenability to storage and cataloging.

2.4 Thermoluminescent Dosimeters

One thousand new TLDs of two varieties were purchased for the energy response study. The first type consisted of Harshaw TL-700 (^{7}LiF) 1x1x6 mm rods enriched to 99.993 percent ^{7}Li. The second consisted of

Harshaw TL-400 (CaF_2:Mn) rods of the same size. A closeup photograph of the two varieties is shown in Fig. 2.3.

2.5 Encasement Materials

The set of encasement materials (sleeves) employed for the TLD energy response study consisted of ten encasements each of the materials lead, tantalum, tin, zirconium, copper, iron, stainless steel, aluminum, and natural LiF. All sleeves were cylindrical in shape and approximately one-half inch in length. For each encasement, the radial wall mass thickness was nominally 0.7 g/cm^2. The number of sleeves available and their associated physical parameters are presented in Table 2.1.

For the sleeve thickness investigation, the encasements consisted of the same variety of materials discussed above (see Table 2.2). As may be observed, there were a number of different radial wall thicknesses for each encasement material. Also, indicated for each wall thickness is a wall-curvature correction ratio with the associated corrected wall thickness. These corrected thicknesses were calculated to compensate for wall curvature since the encased dosimeters were irradiated using essentially a monodirectional gamma flux. This correction is discussed in much greater detail in Section 5.3. All the sleeves employed during both investigations are shown in Fig. 2.4.

2.6 Gamma Ray Sources

Six sources, purchased from Isotope Products Laboratory, were used for the energy response and sleeve thickness investigations. A com-