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EFFICACY OF VARIOUS SYRINGE SHIELDS FOR ^{99m}Tc

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Abstract—Use of a syringe shield to minimize the radiation dose to nuclear medicine technologists from ^{99m}Tc during kit preparation and patient injection is considered an integral part of an ALARA program. This paper discusses various parameters which should be taken into account in the design of a shield, and evaluates the efficacy of one in-house fabricated and two commercially available shields.

HISTORY

THE EXCEPTIONAL growth of nuclear medicine over the past decade coupled with an increasing concern over occupational radiation exposure has resulted in the need to seek out and eliminate various sources of occupational radiation exposure (NRC79a). In a nuclear medicine clinic one of the first targets is the unshielded syringe used to inject a radioactive compound into a patient (NRC79b). Various groups have attempted to determine radiation dose to the fingers and reduce that dose through the use of syringe shields (Ba76; He73; Ho74; Hu71; Mc69; Ne69).

PARAMETERS FOR DESIGN

As with any radiation shielding design, the relative geometry of the source and regions of interest is critical and must be well defined before initiating shield design. Two of these parameters, volume injected and injection technique, were studied at three large medical institutions.

Injected volume data for the three institutions are presented at Fig. 1. (The lower volume at institution A is due to the practice of mixing kits with the lowest volume of pertechnetate recommended by the kit manufacturer, while institutions *B* and *C* use the largest volume recommended.) With its smaller average injected volume, at *A* almost all injections are done with 1 cc capacity tuberculin syringes, while at *B* and *C*, 3 cc capacity syringes are used. In both cases, the syringes are plastic disposables.

The second design parameter studied was injection technique. Of the twelve technologists observed at the three institutions, seven held the syringe as shown at Fig. 2. Two held the front of the barrel during venipuncture and then walked the fingers to the rear of the barrel for injection, flushing and removal. The three remaining held the front of the barrel during the entire procedure, using their second hand to manipulate the piston. The need for this general handling technique, which yields the control and surface-needle angle necessary for successful venipuncture, is the origin of much of the dissatisfaction among technologists with many commercially available shields. For any given shielding material, dose reduction improves as the thickness is increased. However, the increase in thickness forces an increase in the venipuncture angle, which reduces the probability of a successful injection. It may also be noted that balance is critical in a design which will allow the technologist to successfully enter a vein with the 0.7-mm outer diameter 22 gauge needle typically used.

Other more easily defined parameters of course include linear attenuation coefficient

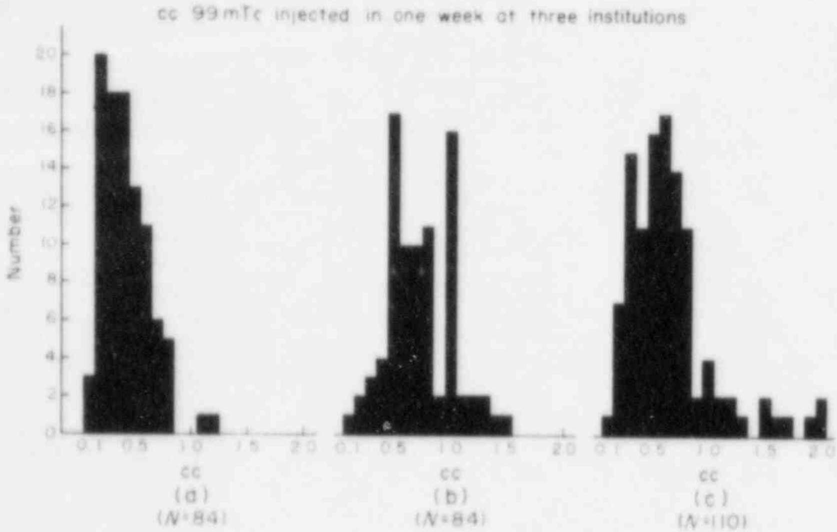

FIG. 1. Frequency distribution of volumes of ^{99m}Tc-labelled pharmaceuticals which were injected over a 1-week period at three general medical and surgical hospitals.

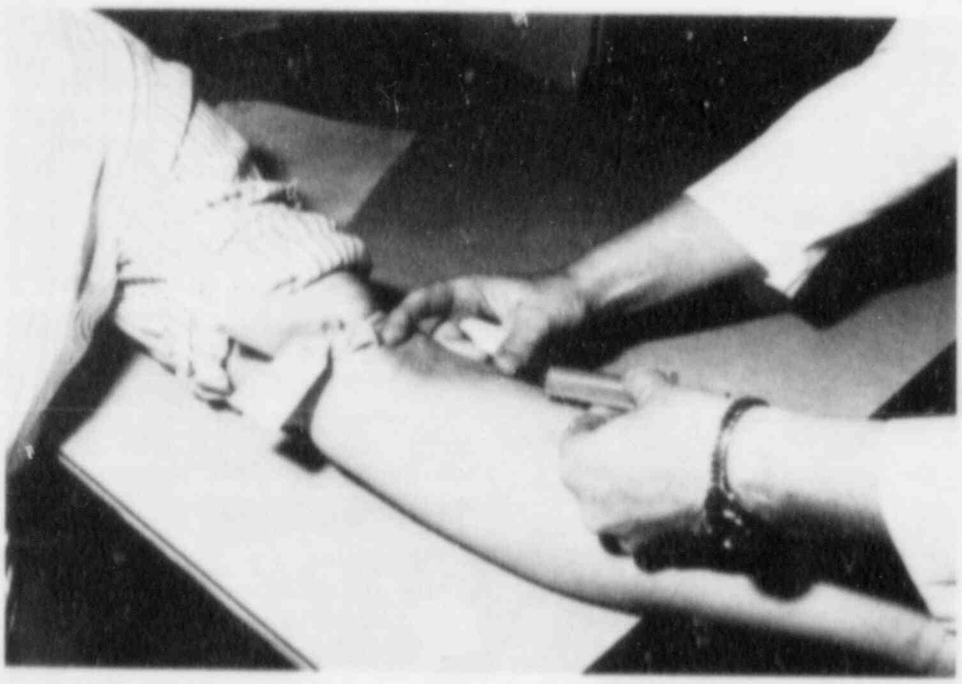

FIG. 2. Common geometry of a patient, technologist, and syringe during venipuncture and injection of imaging agents

of the shielding material, its metallurgic properties, and availability.

EXPERIMENTAL RESULTS

Using the jig shown at Fig. 3, the finger exposure expressed as mR/mCi-min was measured for both 0.5 and 1.0 cc volumes of pertechnetate in a 3 cc syringe unshielded, with a leaded glass shield, with a tungsten/aluminum shield (both commercially available), and with a 1/16-in. lead shield which was fabricated in-house. Sketches of the shields are superimposed on Fig. 6. Exposures were measured with 1 × 1 × 6 mm Harshaw TLD-100 LiF rods (Ha77) using a modification of the Ehrlich heating technique (Eh74). In each case a pertechnetate-loaded and calibrated syringe was placed on the jig for several hours; the cumulated mCi-minutes was calculated. Directional sensitivity and energy dependence were assumed to present negligible error (Mo77). Before each run, each individual rod was calibrated in the jig at Fig. 4. Γ_Δ of 0.72 R-cm²/mCi-hr and half-life of 6.03 hr (Ba76), and negligible syringe wall attenuation were assumed. Time delays between end of exposure and readout were controlled to minimize errors due to fading of the TL signal. Data for 0.5 and 1.0 cc ^{99m}Tc pertechnetate in 3 cc plastic syringes appear at Tables 1 and 2 respectively. Coefficients of variation (S.D. ÷ mean, indicated as $s \div \mu$) are also listed. Five separate runs for each combination of shield and volume were made.

For the unshielded syringe, the data fall as expected, i.e. decreasing rapidly with distance from the source. The tungsten/aluminum data may be perplexing at first blush. In this shield, the front portion is fabricated of tungsten, which provides excellent shielding for the index finger. However, the thin rear aluminum sleeve provides only a factor of 2 shielding for the mid finger, and negligible shielding for the ring finger. Both the leaded glass and lead shields provide shielding for the index and mid finger; unfortunately, the ring finger is almost in direct view of the dose, and is definitely within the

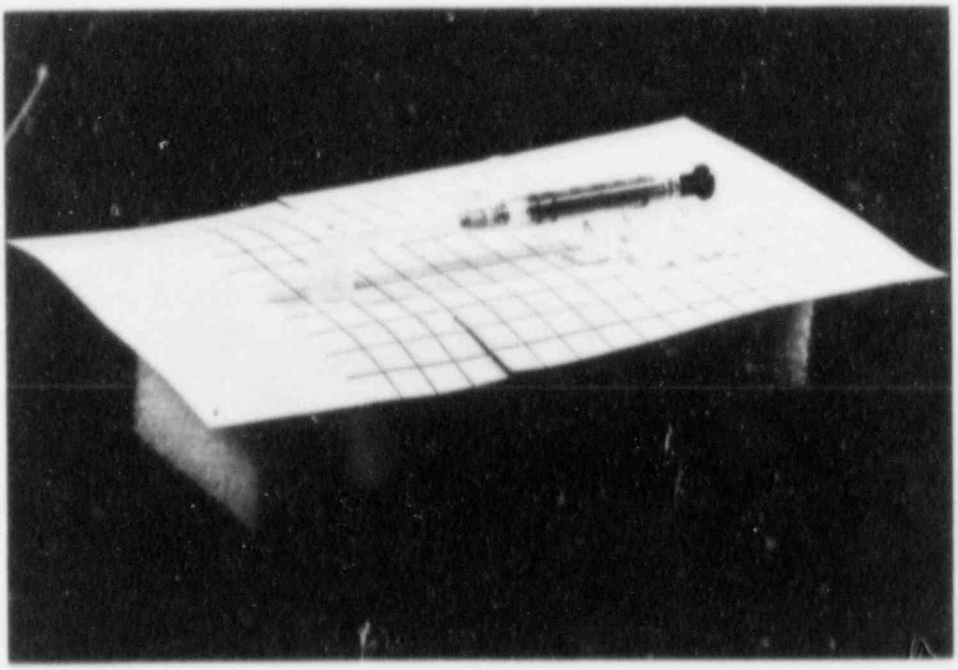

FIG. 3. Jig used to measure finger exposure. 1 × 1 × 6 mm LiF TLD-100 rods were laid atop water-filled plastic test tubes at points indicated.

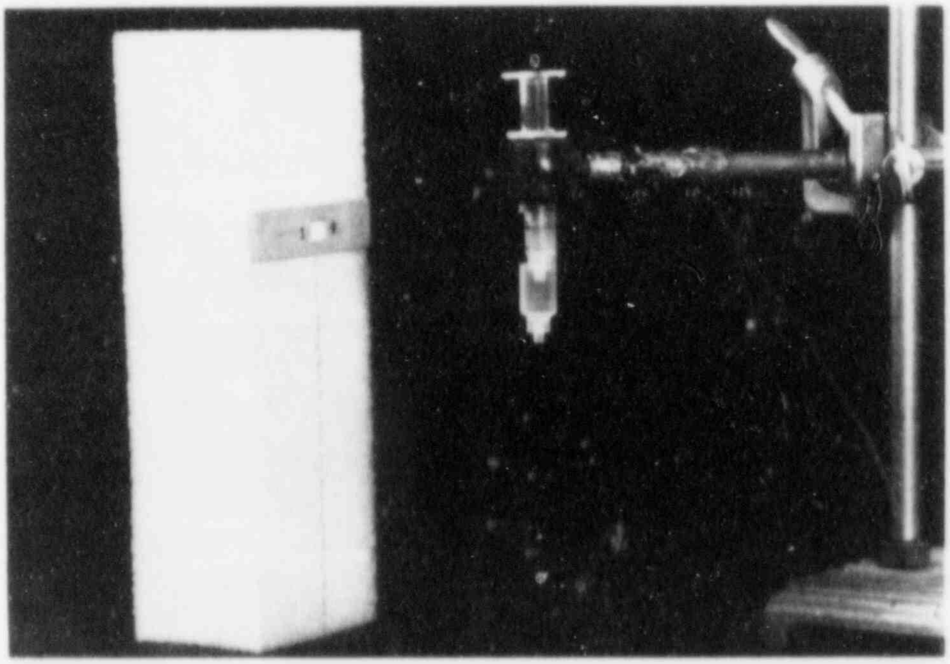

FIG. 4. TLD calibration jig. Rods are in wood cutout, 0.5 cm^3 pertechnetate is 10.0 cm distant in small syringe at right.

Table 1. Finger exposure from 0.5 cc ^{99m}Tc *in* 3 cc *plastic syringe*

	Unshielded			Tungsten/aluminum			Leaded glass			1/16 in. lead		
	index	mid	ring	index	mid	ring	index	mid	ring	index	mid	ring
mRem/mCi-min	0.84	0.29	0.14	0.0074	0.12	0.11	0.0040	0.0028	0.0064	0.0030	0.0018	0.0066
s/μ	5.7%	1.9%	2.3%	14.0%	19.4%	21.1%	21.0%	52.7%	20.9%	30.4%	80.2%	19.4%

Table 2. Finger exposure from 1.0 cc ^{99m}Tc *in* 3 cc *plastic syringe*

	Unshielded			Tungsten/Aluminum			Leaded glass			1/16 in. lead		
	index	mid	ring	index	mid	ring	index	mid	ring	index	mid	ring
mRem/mCi-min	1.3	0.37	0.16	0.0066	0.20	0.14	0.0061	0.0015	0.0097	0.0028	0.0014	0.0082
s/μ	8.9%	10.4%	4.9%	21.1%	9.6%	13.1%	41.7%	70.9%	59.1%	13.2%	39.1%	33.8%

cone of primary and scattered radiation emanating from the rear of the syringe barrel (see Fig. 5).

The small coefficients of variation for the unshielded syringe data suggested that the relatively poor reproducibility of the various shield data, with coefficients of variation ranging from 9.6 to 80.2%, may have been due to the inability to exactly reproduce the relative geometry of the syringe, shield and TLDs from run to run. To assess this possibility, autoradiographs of shielded syringes with 1.0 cc pertechnetate were taken. The autoradiographs are shown at Fig. 5, and the axial optical density of the autoradiographs with the syringe and shield superimposed

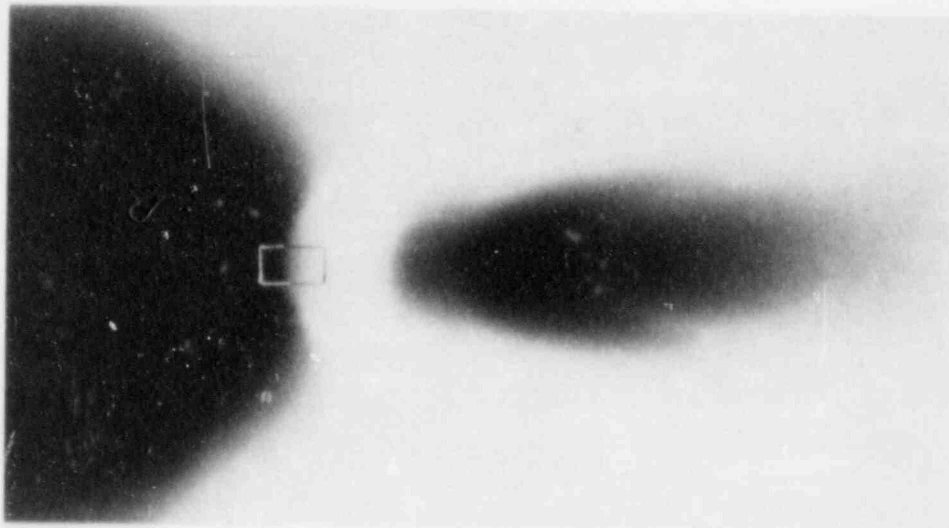

FIG. 5(a).

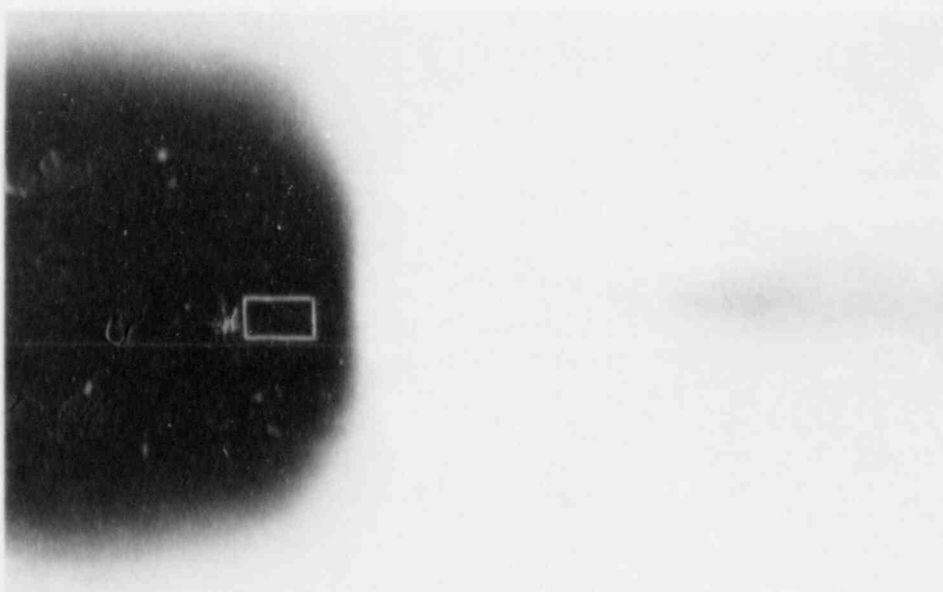

FIG. 5(b).

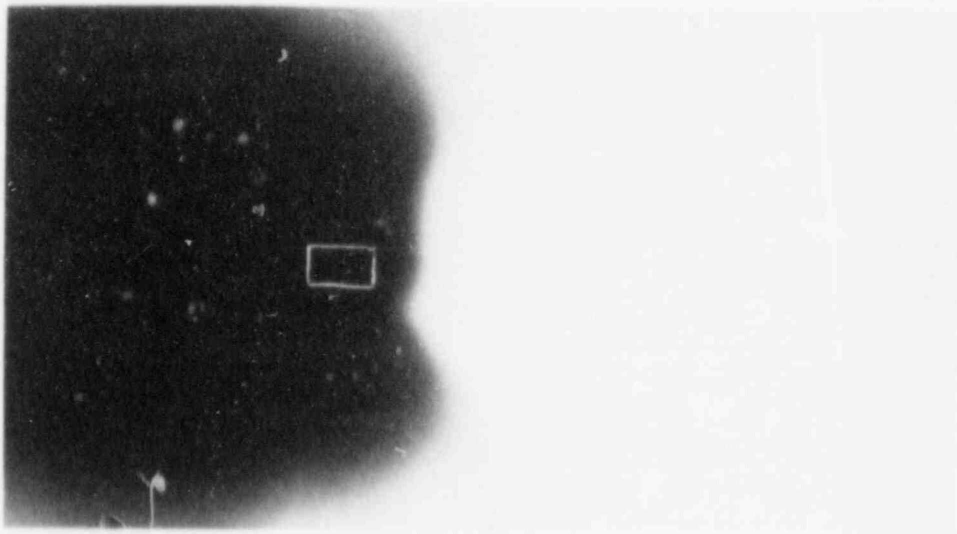

FIG. 5(c).

FIG. 5. Autoradiographs of shielded syringes with 1.0 cc pertechnetate. A tungsten/aluminum; B leaded glass; C 1/16 in. lead. Location of 1 cc volume in each syringe is highlighted.

appear at Fig. 6. (All autoradiographs were taken with GAF SR-2 film in Kodak X-omatic regular cassettes. It may also be noted that an unshielded syringe yields a slightly elliptical but otherwise unremarkable autoradiograph.)

Realizing that absorbed radiation dose in tissue is critically dependent on spectrum at low energies, spectra were taken by laying each syringe and shield on an uncollimated $11\frac{1}{2} \times \frac{1}{2}$ in. 37 PMT Anger camera. The spectra, reproduced at Fig. 7, appeared to be isotropic. Equipment suitable for further investigation of this parameter is not available at this institution.

DISCUSSION

While all syringe shields reduced the index finger exposure at least 20-fold, the efficacy of the various shields in reducing the exposure to the middle and ring fingers varied from 0 to 250-fold. It is assumed that thumb exposure is equal to middle finger exposure. It appears that, of the three shields examined, the maximum overall reduction is provided by the lead sleeve type shield, with or without glass. (We prefer the shield without glass because the glass can break if dropped, and the glue used to hold the glass in place is compromised by the chemicals in both commercially available decontamination solutions used at this institution. They are also less expensive.) From technologist interviews, it is noted in passing that the NRC syringe shield exemption for pediatrics (NRC79a) should be explicitly expanded to include all patients with recessed veins. Given that, finger exposure commitment from injections might still be significantly reduced with the implementation of a syringe shield program.

The 13-month use of the in-house fabricated syringe shield (1/16 in. sheet lead, rolled and dipped in a plastic grip compound to eliminate lead skin contamination) has not reduced the extremities exposures at this institution as indicated by commercially processed TLD rings. This is of no significance, however, because the cumulated departmental exposure is a function of patient load and technologist rotation, complicated by ring use habits (worn on the index, mid, or ring

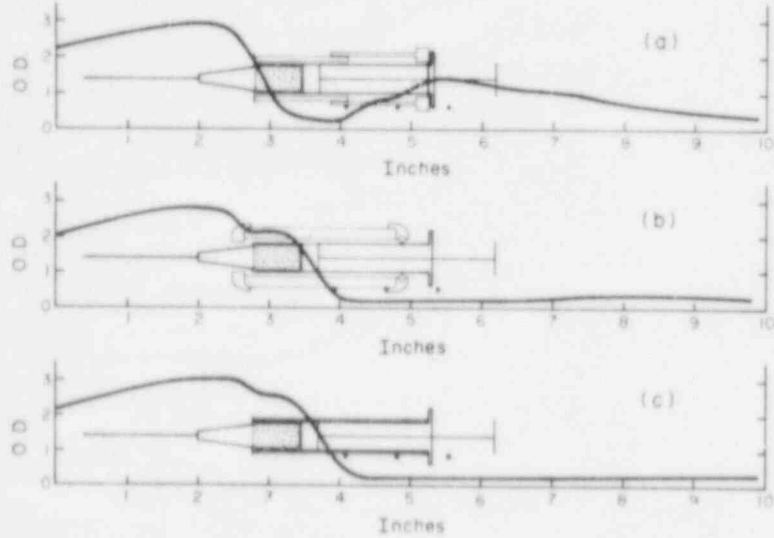

FIG. 6. Optical density scan of the autoradiographs at Fig. 5. A tungsten/aluminum; B leaded glass; C 1/16 in. lead. Film planes are at respective x-axes, black dots indicate location of TLDs with respect to syringe shields.

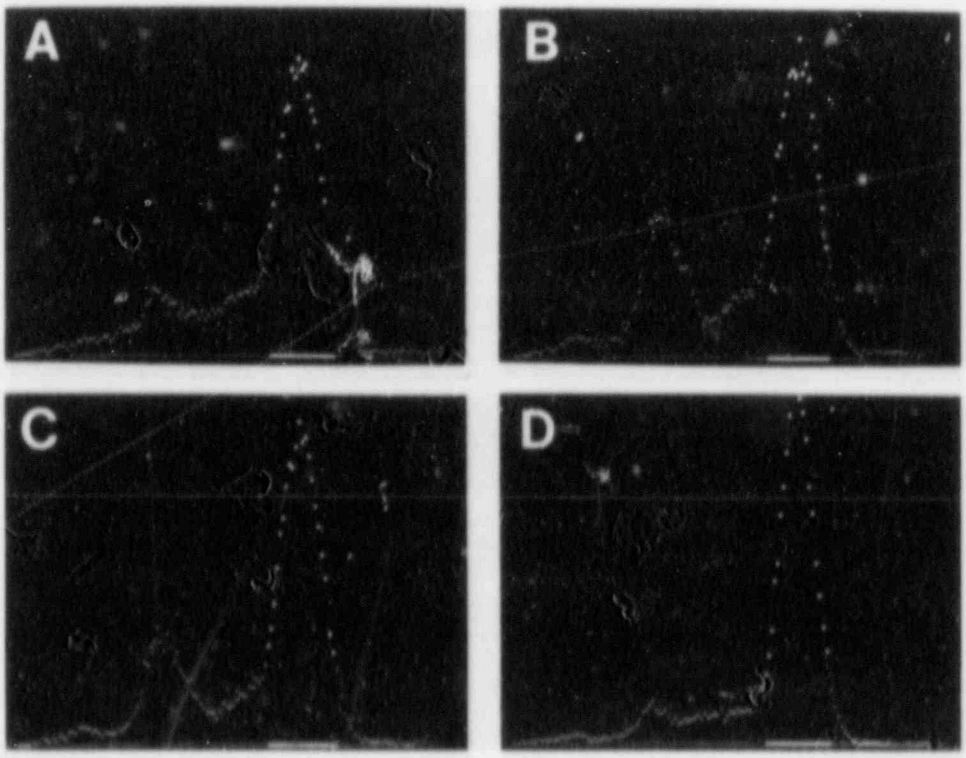

FIG. 7. Spectra emanating from the various shielded syringes. A tungsten/aluminum; B leaded glass; C 1/16 in. lead; D unshielded.

finger and facing the palm or the surface of the hand) and technology student rotations. It may also be noted that the flux gradient, most dramatically exhibited by the autoradiographs, renders the TLD ring exposure monitor no more than an order of magnitude indicator.

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