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NEW DEVELOPMENTS IN ULTRASONIC IMAGING OF THE CHEST
AND OTHER BODY ORGANS

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The accurate measurement of transuranic elements deposited in the lung is a complex task. One of the problems is measuring uranium-L x-rays associated with plutonium passing through the chest of an accidentally exposed subject.

These x-rays average 17 keV in energy and are heavily absorbed in tissue; the half-value layer is about 6 mm. This results in a sensitivity curve (amount of plutonium present versus chest-wall thickness) with an extremely steep slope (Fig. 1).

Using two 120-mm-diam Phoswich detectors placed directly over the chest touching the body surface, we have calculated that every millimeter error made in determining chest-wall thickness results in a 10% error in the final assessment of the plutonium lung burden. Because the normal human chest-wall thickness varies from about 1 to 4.5 cm, it is important that an accurate determination be made for every person counted for plutonium or for other heavy elements with similar emissions.

At LLL [1] we have designed and developed an ultrasonic B-scanning system (brightness modulated time-base) for defining the structure within the body. This scanner is similar to those used in medical diagnostic ultrasound systems. It makes continuous transverse and longitudinal scans approximately 30 mm apart over an area covered by the radiation detectors. Each scan is displayed on a storage scope, a hard copy is made, and the data are digitized and recorded on magnetic tape. The tape is read into a computer that displays each scan in up to 64 colors, each related to an assigned echo intensity.

Because the maximum pulse-echo intensity occurs at the interface producing the greatest difference in acoustical impedance, a maximum intensity is obtained at the air-tissue interface. We determine this interface for each scan by using the computer to fit a curve through selected points representing the maximum returning

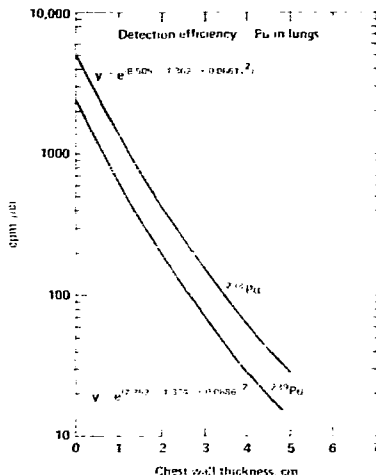


Fig. 1. Plutonium calibration curve for LLL twin Phoswich detectors.

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echo intensity. Computer programs have been written to determine the distance between the lung and chest-wall interface and the outer surface of the chest wall at several points on each scan. These points are exponentially averaged to obtain an average chest-wall thickness that is used, with other information, to derive a calibration factor for plutonium in the subject. It is also combined with the counting data to obtain the plutonium lung burden.

Since photon transmission characteristics differ in fat and soft tissue, assessing the fat content is important and can provide a correction factor for counter sensitivity when viewing various organs. For example, the fat content in the human chest wall varies, according to one study, [2] from 10 to 34%, the mean value being 22%. For 17-keV x-rays passing through the 2.5-cm-thick chest wall of an average person, this represents a 25% correction to the photon transmission curve that can easily be calculated from simple ultrasonic measurements of fat layers. Total correction for extremes in body build could exceed 50%, and is obviously an important factor in plutonium lung counting. We have made measurements of this type recently to characterize subjects undergoing lung counts.

We have used ultrasonic techniques to determine the precise location and shape of liver and kidneys as well as other body organs for detector placement and to determine tissue thickness and fat content.

Although ultrasonic measurement is extremely useful to the Whole Body Counting specialist and enables him to adjust calibration factors appropriately for different subjects, the data are not always well defined at the lung boundary, especially from deeply returning echos in subjects of more than average body build. A program has been developed to display ultrasonic data in three-dimensional form using color graphics, as described earlier. Multiple scans are displayed together to produce a topographical map of structures within the body. By using this technique, a much better characterization of the organ is achieved, and by using neighboring elements in the surface, missing sonic data needed to fully define a structure under study can be interpolated.

The main advantage of the B-scanning and three-dimensional systems are that a cross-sectional view of the area scanned can be obtained immediately and all of the anatomical boundaries of interest displayed. More careful measurements can then be made to characterize a particular region, once initial landmarks have been established internally. The system has an accuracy of ± 2 mm in depth, because of the difficulty in defining an exact anatomical boundary or interface. It has been used successfully to provide chest, liver, and kidney scans on a number of individuals undergoing routine assay for radionuclides at Livermore.

References

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- [2] E. DOLGUIREV, et al. "The Methods of Absolute Calibration of Equipment for Measurements of Pu-210, Pu-239, and Am-241 in Human Body" (Proceedings of 3rd International Congress IRPA, Washington, D. C. Sept. 1973) Conf. Report 730907, p.2.

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