RAPID MONITORING OF PERSONNEL FOR INTERNAL CONTAMINATION

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Introduction

There is a need to monitor persons for ingested radioactive materials. This requirement is related to both radiation workers and to the public at large where affected by such incidents as Chernobyl and the more recent problem in Brazil with caesium.

For many years this need has been met by the use of whole body monitors. However these are extremely expensive to install and operate and as a consequence are not available in all centres that need them. This means that persons may have the worrying experience of travelling a long distance to be exposed to a claustrophobic experience where in most cases there is no contamination problem at all.

Recently however a number of simple monitors have been developed which are cheap enough to be installed in most establishments and are able to confirm the necessity or not of the more thorough investigative properties of the whole body monitor.

Practical Limitations of Measuring Internal Contamination

The problems involved in designing equipment to meet this need are great. One being the typical person to be monitored, who is not typical.

Heights of European adults vary from 143.5 to 194cm (excepting the 1 in 1000 extreme). If equipment was designed to check the chest of a tall standing man it would be over the head of a small woman. Height adjustments to equipment can be time consuming and can be embarassing to some users. However if the user is sitting down the variation in shoulder height is only 48 to 64.4cm and the variation in the height of the mid point of the lung even less. So one should seat the user.

The user can also be slim or rotund; the thickness of the trunk varying from 14 to 43cm. Figure 1 shows the variation in sensitivity with position of a point source of caesium through a body using a large area detector (100mm x 100mm). The variation will be even greater with smaller area detectors. So even in the case of a thin person the variation of performance through the body is 14.1 even assuming critical organs start 2cm from the body extremity. If however two detectors are used front and back the performance approximates to Figure 2.

How can even this variation in detection efficiency be reduced? By the use of large area detectors. As well as the obvious increase in counting efficiency and uniformity of response in planes parallel to the plane of the detector, uniformity of response is also increased at right angles to this plane as illustrated in Figure 3.

We are therefore drawn to the use of two large area detectors with the user seated to provide the most uniform response to ingested material. There are however structural as well as background limitations to be considered in deciding on the area of the detector i.e. E^2/B should be maximised as much as possible.

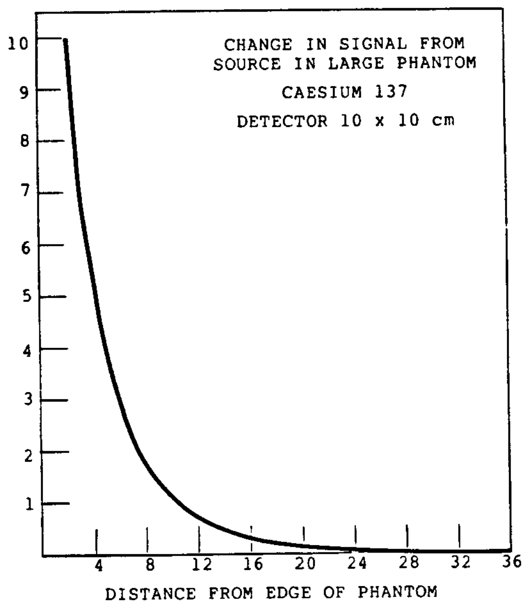

FIGURE 1

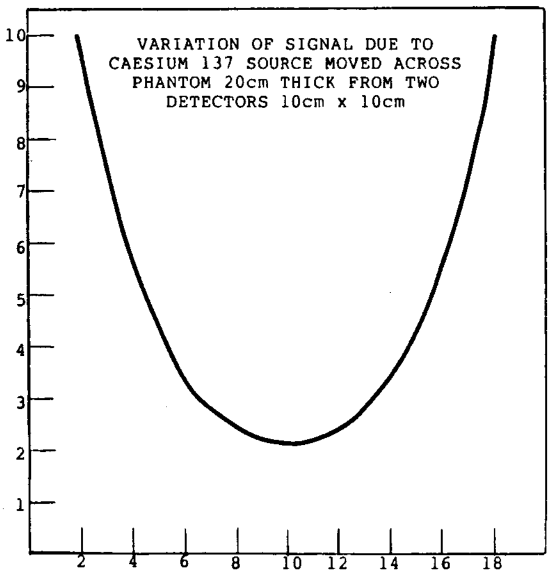

FIGURE 2

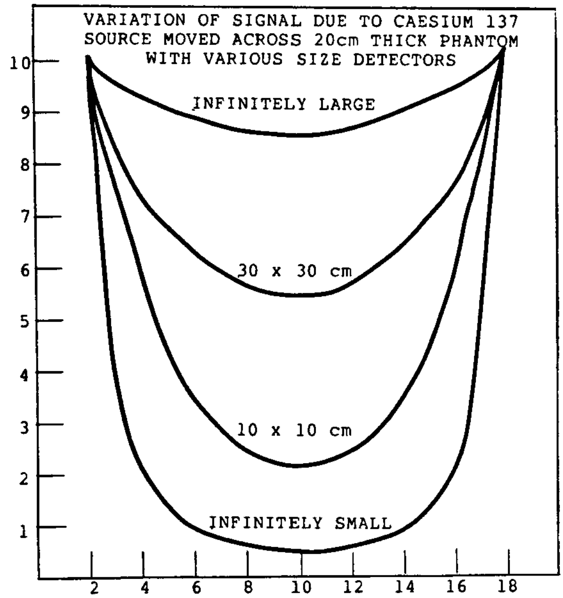

FIGURE 3

FIGURE 4

Design

For high sensitivity to gamma radiation the scintillation counter is ideal and to obtain large areas the only economic solution is the use of plastic or liquid. Very large inorganic crystal scintillators would be prohibitively expensive. Liquids have containment problems.

However plastic detectors have a very poor energy resolution, but, the primary intention is to detect contamination not to identify it. The use of plastic phosphor also has the advantages of mechanical robustness and stability with temperature change, making instrumentation easy to maintain and allowing for designs which can can be used by unskilled operators.

There is however a major problem in using very large gamma sensitive detectors, and that is the high sensitivity to background. The effect can be minimised by monitoring the background when not in use and subtracting this rate from the measured value. The user can however have considerable effect on the level of background both absorbing it and scattering it. To assess this effect a fairly standard sized person, known to have no internal contamination, can be used during setting up to determine the effect of the user on the radiation background being measured. This information can then be stored and subsequently used to adjust the background count subtracted from the measured count.

The front detector can be made moveable against the body so that information can be provided as to whether the user is thin (ectomorphic) or rotund (endomorphic) so that further adjustments to the background signal can be made to account for body shapes. The thickness of the body can also be taken into account in calculating the contamination present. The signal to unit contamination relationship is highest for thin persons and this relationship is calculated on the assumption that the contamination is in the centre of the body. If the contamination is elsewhere the indication of contamination is likely to be slightly higher than the true contamination level. This depends on the variation of response of the equipment to contamination at that place from that at the centre.

Conclusion

We took account of all the considerations given above in the design of the equipment shown in Figure 4. This equipment is extremely simple to operate and can if necessary be used by personnel without supervision. The only precautions necessary are to limit persons standing or moving near the equipment when operated in an elevated or very directional background environment since they will disturb that environment considerably.

The minimum detectable activities that can be achieved when used for 10 seconds in a 0.1mSv/h (10μR/h) background are as follows allowing 3.1 S.D on background.

^{60}Co	180Bq	(5nCi)
^{54}Mn	370Bq	(10nCi)
^{137}Cs	440Bq	(12nCi)
^{133}Ba	440Bq	(12nCi)
^{57}Co	930Bq	(25nCi)

The equipment has the advantage of high sensitivity to contamination trapped in any organ so no ingestion hazard should be missed even if the location of the entrapment is unforeseen.

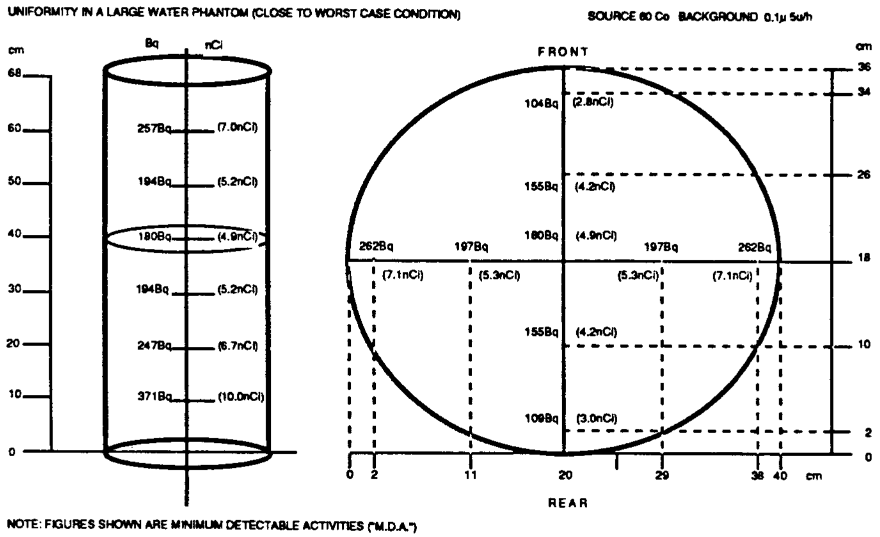

FIGURE 5

A measure of the effectiveness of the use of the very large scintillation counters is illustrated in Figure 5; the water phantom simulating almost the most rotund. The uniformity with the 340mm by 300mm and 300mm by 600mm detectors is in fact very slightly better than would be indicated by Figure 3, this is due to the fact that the advantageous effects of scattering had not been taken into account in the preliminary calculations. One case where the performance of the final equipment proved better than that indicated by the initial theoretical predictions. The variation with Caesium 137 are very very similar.

The technique used in this personnel monitor can also be used elsewhere where very high levels of sensitivity are required to detect small quantities of materials which may be anywhere in fairly large objects. A prime example is the monitoring to de minimus levels of sacks of waste prior to shipment from nuclear sites to standard domestic or other garbage dumps.