TRITIUM CONTAMINATION MEASUREMENT - A SIMPLE AND SATISFACTORY METHOD

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1. INTRODUCTION

Tritium surface contamination is difficult to measure because of the very low energy of its pure beta emission (18.6 KeV Max.). In practical terms this means that one has to be able to detect particles with a range of 1.5 mm in air and 2 μ in a material of unit density. Furthermore, the tritium may be in the form of a thin film or a thick film, containing fluorescent, chemiluminescent, or volatile components. To be satisfactory for radiological protection purposes the measuring instrument should be able to detect all forms. The Whitlock Tritium meter described in this paper has this capability. It also has the ability to measure other more energetic betas, electron capture, X-rays and soft gamma rays.

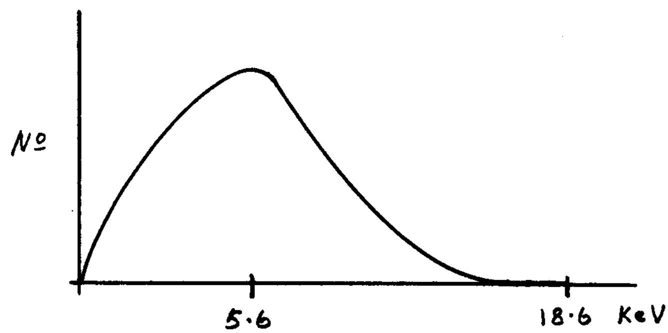
2. DEFINITIONS

2.1 A Thin Source is presumed to be a molecular layer of Tritium contamination evenly distributed over a perfectly smooth surface. 2.2 A Thick Source is similarly distributed and uniformly active but 8 μ or greater in thickness.

2.1 A Thin Source

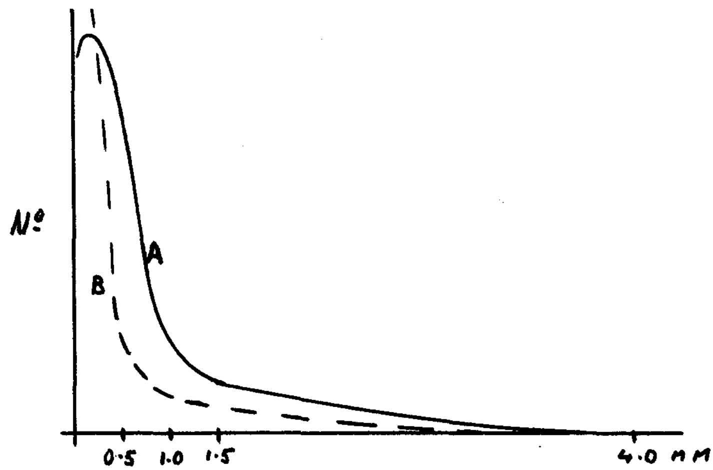
A Thin Source in a vacuum produces a spectrum of emission/energy as shown in Fig. 1

Fig. 1



In air the max. range of the max. energy (18.6 KeV) beta is approximately 4 mm. Taking geometry into account, where the mean angle of emission is in the region of 30° to the surface, then the mean range of the max. energy betas is approx. 1.5 mm. These factors apply to all energies of beta particles emitted and the result is a very degraded spectrum as in Fig. 2(A). This shows the spectrum in air of beta particles emitted from a surface.

FIG. 2



2.2 Thick Sources

Thick Sources present an even further degraded spectrum because of self absorbtion. Though the max. range of the max. energy betas is 8 μ in a material of unit density the main range of max. energy particles is only 2 μ. The spectrum of betas originating from 8 μ below the surface is overlapped by the spectra of betas from other "layers" of activity closer to the air interface. The resulting spectrum of betas in air approximates to Fig. 2(B). In both cases the feature to note is the very small number of betas with a range $>$ 1.0 mm.

3. PRACTICAL CONSEQUENCES

3.1

The sensitive area of the radiation detector has to be very close to the source ($<$ 1 mm) almost irrespective of the activity present.

3.2

Surface scratches $>$ 2 μ in depth are potentially infinitely thick sources of ^3H contamination and require the detector to be even closer to the source.

3.3

A distance variation of as little as 0.025 mm (1 thou. inch) can significantly affect the measurement.

4. THE INSTRUMENT SPECIFICATION

A Whitlock Tritium meter (WTM) is capable of measuring Tritium surface contamination with a sensitivity of 10^{-4} μ Ci/cm^2 integrated over 100 cm^2 in a measuring time of 10 seconds. It consists of a thin large area (100 cm^2) windowless plastic scintillator viewed by two 30 mm dia. photomultipliers in coincidence. Associated discriminators amplifiers, digital display, timer and H.V. supply are powered by re-chargeable batteries. The whole area of the detector is maintained at a distance of 0.5 mm $\pm$ 0.025 mm from the surface being measured by a disposable rubber molding. This molding also forms a sealing ring to exclude light, when a partial vacuum of half an atmosphere is developed in the measuring area, by manual operation of the single action vacuum pump incorporated in the body of the instrument.

5. THE INSTRUMENT IN USE

The instrument in use is placed on a smooth metal plaque provided as an accessory. The vacuum pump handle is released and a vacuum is established which keeps the instrument firmly in position. Under the measuring conditions now established, where the area, pressure and all important distance are kept constant, the instrument is switched on and several 10 second measurements are taken initially, to determine the background for the area, within reasonable statistics. Depressing the pump lever releases the vacuum, resets the scaler and allows the instrument to be positioned on the surface to be measured. Release of the pump lever provides a vacuum and starts a one or 10 second measurement of contamination. As each measurement is of 100 cm , large areas of laboratory working surfaces can be surveyed very rapidly. It has been shown that to obtain meaningful measurements with any detector the distance factor must be kept within very close tolerances. If this requirement cannot be met, say on floor or door handle surfaces, direct surface measurements cannot be made without the risk of a false negative. In these circumstances another accessory enables the instrument to measure wipes or smears.

6. SMEARS

Smears consisting of 50 mm dia. filter papers or aluminium discs are wiped over the contaminated surface, placed active side uppermost in a 1 mm deep recess provided and measured with the instrument. Assuming 10% of the contamination has been removed by the smear some compensation can be made by smearing ten times the normal wipe area or increasing the measurement time to 100 secs. When measuring smears the safest presumption is that the activity is being presented in a thick source form, particularly if a liquid spill has been wiped. It is interesting to measure both sides of the filter paper after wiping liquid contamination as it is often found that a small amount of activity can be detected on the side which has not been in contact with the wiped surface. This can give some indication of the total absorbed activity.

7. COMPARISON WITH LIQUID SCINTILLATION COUNTING

7.1 Instrumentally

Instrumentally the electronics are very similar apart from compactness and battery operation of the Tritium meter (WTM) and the 3 channel capability of the liquid Scintillation Counter (LSC). The major difference is apparent when one can take a representative sample of surface contamination to the LSC to obtain the advantage of the 4π geometry and the elimination of air absorbtion. This advantage is partially counter-balanced by chemical interference (quenching) of the scintillation process and a small possibility of self absorbtion. The WTM measures smears on site and information is immediately available for decisions.

7.2 Fluorescent Compounds

Fluorescent Compounds do not affect the WTM because the photomultipliers only receive light photons "piped" to them by total internal reflection. Furthermore both photomultipliers have to detect a photon within the pre-set coincidence time for an event to be recorded. Fluorescence of sufficient intensity to introduce photons through minor imperfections in the plastic scintillator surface in significant numbers would be visible to the naked eye. In LSC the fluorescence is inserted in the optical system. From then on it is the same in both instruments and the number of false events detected depends upon the timing of the coincidence circuits.

7.3 Chemiluminescence

Chemiluminescence is generated when certain chemicals are introduced into the liquid scintillation "cocktail" and false positives can be obtained from chemical "whiteness" in paper smear material. This situation is not possible with the WTM.

7.4 Thin and Thick Source Identification

Only the WTM is capable of measuring contamination directly on surfaces but it is interesting to note that in Fig. 2 the spectrum of energies eminating from a thick source is displaced to the left of that obtained from a thin source. This is similar to the spectral shift caused by different levels of quenching in an LSC. The degree of quenching can be measured by channels ratio techniques. The WTM can be fitted with pushbutton selected channels and the ratio of two successive measurements in "infinity" and "window" modes of counting would show whether a thick or thin source was being measured.

7.5 The Presence of Volatile Tritium

The presence of volatile Tritium or outgassing from the surface is indicated by the WTM by gross variability of count on successive measurements of the same surface area. During measurement the WTM produces a vacuum of $\frac{1}{2}$ atoms. in the measuring "chamber" and if under these circumstances the surface contamination changes to gaseous activity the geometry and air absorbtion characteristics drastically change. This phenomena is sometimes exhibited when measuring wet smears and if successive measurements are carefully recorded it may be possible to determine diffusion characteristics or quantify the volatile fraction. The LSC cannot give these indications.

7.6 Smears vs. Direct Measurements

The shortcoming of smears measured by either LSC or WTM is related to the nature of the surface being wiped. If the surface is covered with a large number of small scratches a large proportion of the activity could be deposited at the bottom of each miniature valley.

8. CONCLUSION

The Whitlock Tritium Meter provides a simple and satisfactory answer to the complex problem of measuring Tritium surface contamination for radiological protection purposes.