Table 1

2 Body-weight (kgm.)	3* Response above background	4* Background absorption correction	5* Effective response (3 + 4)	6 Activity as equivalent gm. potassium	7 Expected normal potassium content (gm.)	8 Activity above 'normal'
66	1·2 ± 1·2	− 6·7	7·9 ± 1·2	150 ± 23	143	7 ± 23 gm. potassium
55·7	17·7 ± 1·4	− 6·3	24·0 ± 1·4	418 ± 24	117	= 296 gm. potassium or 15 nC. cobalt-60†
70·8	79·6 ± 1·2	+ 6·8	86·4 ± 1·2	1,665 ± 23	149	= 1,516 gm. potassium or 0·12 μC. mesothorium

* Units: 10^{-14} amp., for columns 3, 4 and 5. † 1 nC. = 10^{-9} C. = 37 d.p.s.

used in the shielded chamber ... radioactivity is still only 0·45 ... ual background, most of which ... vertical hemisphere. A small ... of cosmic radiation would ... ion, and for this reason ... above the subject. As it is, the ... ground is nearly equivalent and ... he emission effect (see Table 1, subject ... ion (2) is obtained from the ... known quantity (up to 5 μC. of the ... assium-42 is administered orally to the ... the apparatus response determined ... ing which period the isotope has ... ution very similar to that of the ... assium. The quantum energies of ... 31 MeV.) and of potassium-40 (1·46 ... ilar that internal absorption ... ntical for the two radiations. In ... periment, the response to a weighed ... alar' potassium chloride in a ... npared with the response to a ... potassium-42. From these data the ... ponse of the subjects (corrected for ... sorption) may be expressed in ... though this calibration procedure ... pl... to the potassium content. ... ...n of any other radioactive ... iform, a correction may be ... differences in attenuation arising ... antum energies. The total radiation ... m 5 μC. potassium-42 is 5 mrep. ... th a typical background dosage-rate ... r week.

Measurements have been made on ... rsons and on others who handle ... aterials occupationally. Three ... Table 1 to illustrate the ... easurement. Only those occupational ...

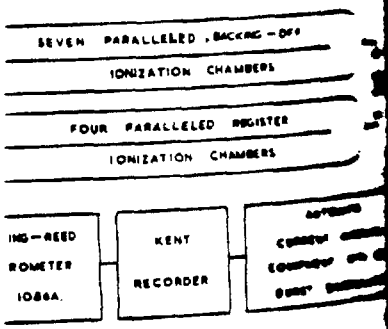

Fig. 2

radioactivity significantly in excess ... from body potassium. In a group ... persons (ten male and three female ... resident locally) the mean potassium ... all the response to potassium-40, ... 0·21 ± 0·01 per cent by weight. It ... the water phantom used for back- ... calibration is free from radio- ... This result is in agreement with that of ... 0·21 per cent, based on chemical ... and in harmony with recent measure- ... potassium (said to be ... than total) by Edelman ... 16 per cent (average for thirty-three ... 16 per cent (average for fourteen ... estimates conflict with the value ... given by Hawk, Oser and Summerson[8]. ... the probable error for a single 2-hr. ... of the body content of a ... commonly used radioactive elements; ... permissible levels suggested by the ... on Radiological Protection[10] ... for comparison. For γ-ray emitters a ... smaller than the maximum permissible ... detected; but because β-emitters are ... bremsstrahlung, the efficiency of their ... much reduced.

Table 2

Maximum permissible amount in body	Probable error for 2 hr. observation of body activity
... mg.	2 mg. (for radium in radioactive equilibrium with decay products) 4 nc. (for 5% per cent excretion of radon in breath) 2 nC. (or 1% mgm. 'old' thorium)
... μC.	1·4 nC.
... μC.	10 nC.
... μC.	1 nC.
10 μC.	2·5 μC.
2 μC.	4 μC.
1 μC.	0·5 μC.

...y of the apparatus would be much ... deep underground laboratory where ... component, responsible for the ... of the cosmic fluctuations, would be ... Stewart has recently assembled an ... a similar situation[11].

... was supported throughout by the ... Council, including a maintenance ... (P. R. J. B.). We are indebted to Messrs. Appleby and Taylor of this Department for technical assistance with the construction and assembly of the apparatus. [June 25.

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DETERMINATION OF TOTAL BODY RADIOACTIVITY USING LIQUID SCINTILLATION DETECTORS

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IN the course of developing equipment for other problems[1], we have made some measurements of the total radioactivity content of several humans and a dog, using a technique which may have other applications in biophysics. The equipment used consists of a liquid scintillation detector in the shape of a cylinder 30 in. in diameter and 30 in. high, surrounded by *RCA* type 5819 photomultipliers, forty-five of which were used in these measurements. Cylindrical steel inserts, 14 in. in diameter in one case and 20 in. in diameter in another, 32 in. high and 0·015 in. thick, were placed in the tank, leaving an annular region filled with liquid scintillator (toluene–terphenyl–α-naphthyl phenyl oxazole). A lead shield 5 in. thick was placed around the assembly, leaving only the top of the insert open. The forty-five photomultipliers were connected in parallel and their output fed through a linear amplifier to a ten-channel pulse-height analyser (see Fig. 1).

Energy calibration. In order to determine the pulse-height corresponding to a given γ-ray energy, a cobalt-60 source was placed in several different locations in the insert and the pulse-height spectra were measured. The results for both inserts are shown in Fig. 2. This spectrum was independent of position of source over the central half of the tank

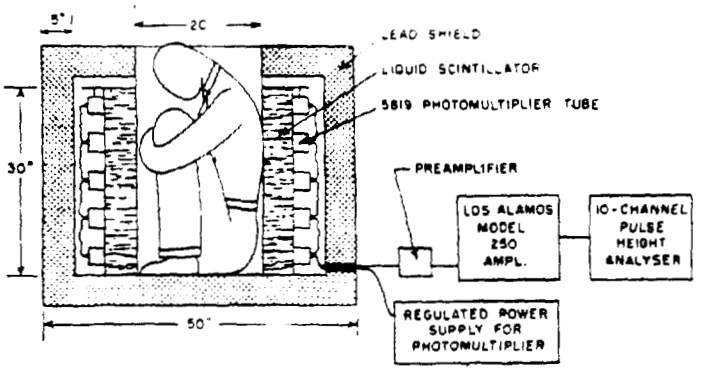

Fig. 1. Sectional view of detector with block diagram of associated electronics

axis. As the source approached the top or bottom, the peak became less well defined. The line represents pulses resulting from the complete Compton degradation of one of the cobalt-60 γ-rays (1·17 and 1·32 MeV. respectively), and the broadening of the high-energy side results from those cases in which both γ-rays are detected simultaneously.

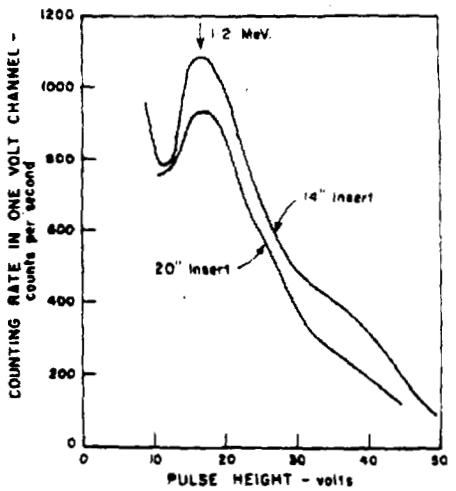

Fig. 2. Counting-rate against pulse height due to a cobalt-60 source placed in the inserts

Data obtained with a dog. A dog of approximately 35 lb. weight was anæsthetized and counted in the small insert. A solution containing 0·1 μC. radium in equilibrium with its decay products was injected in the femoral vein, and (five min. after injection) the dog was again 'counted'. The total counting-rates obtained in the interval 5–35 V., corresponding to 0·3–2·0 MeV., are given in Table 1. The total counting-time for each run was 300 sec.

Table 1. Summary of Results for Experiment on a Dog

Item	Counts per sec.
Background	1,594
Dog before injection, less background	98
0·1 μC. radium solution alone in tank, less background (centrally placed)	1,911
Dog after injection of 0·1 μC. radium, less background	977

From the table it is seen that: (a) The counting efficiency per disintegration for the bare source was about 50 per cent. (b) The counting-rate from 0·1 μC. of radium in the dog was 879 per sec., giving an overall counting efficiency of about 25 per cent.

Data obtained with humans. The large insert was used for the measurements on humans, who were able by doubling up to be entirely within the insert. The energy gates were the same as in the previous experiment. A background run was made before and after each measurement. The average background counting-rate for twelve runs was 837 ± 6 per sec., and the fluctuations, though greater than statistical, appeared random and consistent with a Gaussian distribution having a standard deviation of 6 sec.$^{-1}$. The fluctuations are presumably due to a slight instability of the discriminator and the rapid rise of background-rate at low energies.

The results of measurements made using various humans are summarized in Table 2. All subjects except 'P. H.' were counted in their normal clothing, and no effort was made to remove radioactive contamination such as might be expected to settle in the hair. The subjects 'W. B.' and 'P. M.' are at present working with radioactive materials; the clothes of 'W. B.' were counted separately, and gave 637 counts per sec. It may be, therefore, that the rather high remaining count was due to external contaminants.

Table 2. Summary of Results for Experiments with Human Beings

Subject	Sex	Weight (lb.)	Counts per sec. above background
'W. L.'	M	130	57
'D. F.'	F	105	30
'W. B.'	M	145	801
'P. M.'	M	160	784
'L. B.'	M	140	42
'E. A.'	M	135	75
'P. H.'	M	140	80
'D. H.'	F	125	57
'G. L.'	F	125	63

Counting efficiency for radium and potassium-40 in humans. The principal natural source of radioactivity in the body is potassium-40. Information on the harmful effects of radioactive isotopes is based principally on persons exposed to radium poisoning. Two experiments were performed to determine the efficiency with which these elements were detected in the counter.

In the first, a mock human form was made by pouring 100 lb. of water into a shaped plastic bag in the insert. The counting-rate was determined before and after the addition of 450 gm. of normal potassium chloride to the water. The net counting-rate from the potassium was 125 sec.$^{-1}$, or 0·52 counts per gm. normal potassium per sec. This number is to be compared with the disintegration-rate[2] of 3·6 γ-rays per gm.-sec., giving an efficiency of 14 per cent. The potassium content of a 70-kgm. person[3] is approximately 150 gm., so the counting-rate expected from potassium alone is about 78 sec.$^{-1}$. It was concluded that most of the activity seen in all subjects except 'W. B.' and 'P. M.' was due to potassium-40.

The efficiency for detecting radium in this counter was determined by counting Dr. Wright Langham ('L.') holding a 0·2 μC. standard radium source against his stomach, so that the source was entirely shielded by his body as he sat in the insert. The net counting-rate was 1,133 sec.$^{-1}$, yielding an efficiency of 15 per cent. The statistical fluctuations in the background (± 6 sec.$^{-1}$) correspond to an uncertainty in the total radium of 10^{-9} C. The precision with which it is possible to determine the radium content appears to be limited by the uncertainty in the amount of other radioactive substances present in the body, and by the uncertainty in the degree of elimination of radon, which upsets the radioactive equilibrium of the subsequent daughter products. Most of the gamma-rays detected probably come from radium. It is interesting that, although one of the subjects ('P. H.') has worked for many years with radium, thorium and mesothorium, his radium content appears to be not greater than about 0·01 μC.

Conclusions. In view of the foregoing, it is possible with a counter of this design to determine the total radium content of the body at levels well below the present set tolerance (0·1 μC.), and to make similar determinations for any source giving sufficiently energetic γ-rays. In the absence of the radium group, the potassium content of the body can be measured with good accuracy, and it is quite conceivable that application of these techniques could yield important results in the study of the role of potassium in the metabolic process. These measurements can be made in short times *in vivo* with little inconvenience to the subject.

Since this counter was not designed specifically for the purpose of the present experiment, it should be possible to simplify and improve the system for this type of measurement. For example, the ten-channel analyser could be replaced by a single-channel analyser, or perhaps merely a scaler with a discriminator. Where good energy resolution is not an important factor, it would probably be possible to use many fewer photomultiplier tubes without serious loss of counting-rate. The size of the detector could be increased considerably to accommodate the subjects more comfortably. If smaller animals are to be counted, the counter size and number of tubes could be reduced. Such a counter is being built at this laboratory for studies on dogs.

The background due to cosmic rays was by no means negligible, and would be reduced materially either by additional shielding or by going to sea-level from the altitude of 7,300 ft. at which these experiments were carried out.

It might be possible to reduce background further without seriously impairing the efficiency of detection for the radiation of interest by a more judicious choice of the energy gates.

The superiority of the counter described here over Geiger counters is marked by its high efficiency, energy discrimination for γ-rays, and relatively large volume.

This work was done under the auspices of the United States Atomic Energy Commission. Our thanks are due to Dr. Wright Langham for stimulating conversations and for his generous support.

[May 20.

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OBITUARIES

Prof. H. E. Fierz-David

SCIENCE in Switzerland has sustained a great loss in the death on August 25, at Zurich, of Prof. Hans Eduard Fierz-David. Born at Zurich on January 5, 1882, Fierz-David began his education in his native city, eventually specializing in chemistry and prosecuting further studies in London and Munich. In the earlier part of his career he obtained a varied experience of applied chemistry, in particular with the International Nickel Company, also in brewing chemistry, and somewhat later with the firm of J. R. Geigy at Basle. Eventually he developed a special interest in synthetic dyes and the technology of dyes, dyeing processes, and textile fibres. Thus, in 1917 he was appointed to the chair of organic chemical technology, in the Eidgenössische Technische Hochschule, Zurich—a post which he filled with distinction over a long period, until his retirement as emeritus professor. His field of work is reflected in a series of standard publications, including "Grundlegende Operationen der Farbenchemie", "Künstliche organische Farbstoffe", "Fortschritte der Teerfarben und verwandter Industriezweige", and (with E. Merian) "Abriss der chemischen Technologie der Textilfasern".

A cultured man of wide interests, Fierz-David had an international outlook. He was a good linguist, and he cherished the humanistic aspect of his science. This last feature of his character found effective expression in the elegant historical study of alchemy and chemistry which he published at Basle in 1945 under the title, "Die Entwicklungsgeschichte der Chemie". Significantly, he dedicated this book to his friend, C. G. Jung; for among his varied interests he was a member of the Psychological Club of Zurich. Although an apostle of progress in chemistry and its applications, he deplored the methods of 'mass-production' and the intense specialization to which students are subjected in many modern teaching laboratories. Moreover, he recognized the enormous importance of a human relationship between teachers and students. Looking back to his own student-days, in a letter written a few years ago, he crystallized his feelings for a past order of things into a single sentence: "In this age, one has forgotten how to live".

JOHN READ

Mr. W. N. Croft

WILLIAM NOBLE CROFT, who died on July 10 in his thirty-eighth year, joined the Geological Department of the British Museum (Natural History) as palæobotanist early in 1939, and almost at once set off on a British–Swedish–Norwegian Expedition to Spitsbergen, mainly to investigate Devonian fossils, reaching England again just after the Second World War broke out. Before joining the Royal Engineers, Croft completed a paper on a Lower Devonian flora of the Welsh borderland, though his stratigraphical work on this area is still unpublished. Immediately on leaving the army, he went to the Antarctic for a year as geologist and palæontologist to the Falkland Islands Dependencies Survey; some of the results of this work have recently been published in the Survey's "Scientific Reports". In palæobotany, Croft's main interest centred on Devonian plants; last year he published an account of some Devonian charophytes known as trochilisks, and he had almost completed a paper on blue-green algæ from the Rhynie chert. He was an accomplished technician,