

[54] **DENSITOMETERS**

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[51] Int. Cl. **G01t 1/20**

[58] Field of Search..... 250/71.5 R, 71.5 S, 83.3 D,
250/92, 363, 369, 522

[56] **References Cited**

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Primary Examiner—Archie R. Borchelt

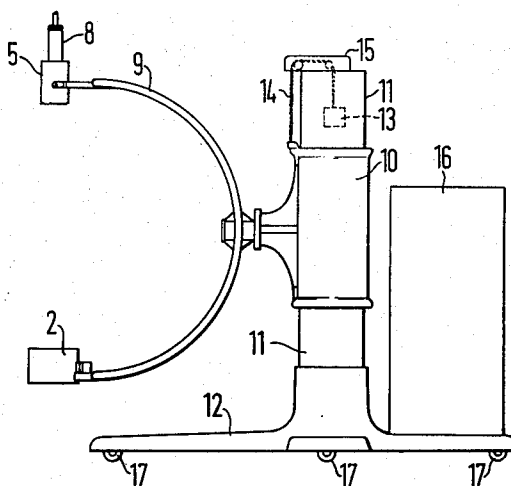
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[57] **ABSTRACT**

A densitometer for diagnostic use to indicate density variations due to respiratory and cardiac cycle movements involves use of a narrow collimated beam of γ -radiation rather than X-radiation. This leads to a significant reduction in bulk and weight so that a mobile, bedside use apparatus is possible with a trolley, a column on the trolley, and a U-member coupled to the column at its U-base and having its medial axis horizontal. The opposed U-arms respectively carry the beam source and detector, and the U-member is adjustable vertically on the column and rotationally about its medial axis to afford great flexibility of use. The use of γ -radiation also reduces the patient radiation dosage to allow regular monitoring use, and also reduces complexity of equipment, and therefore cost.

4 Claims, 7 Drawing Figures



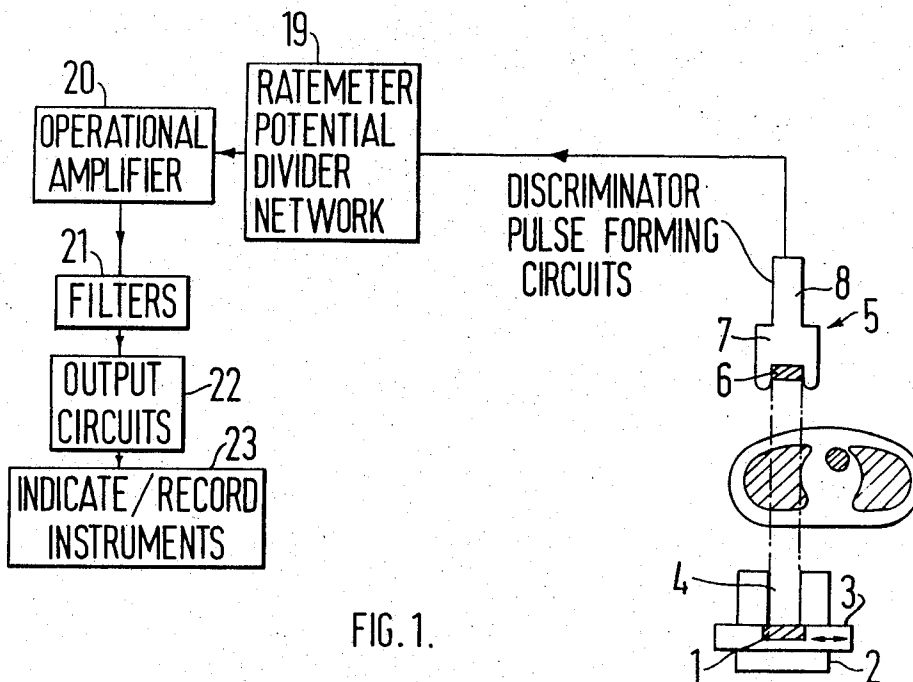


FIG. 1.

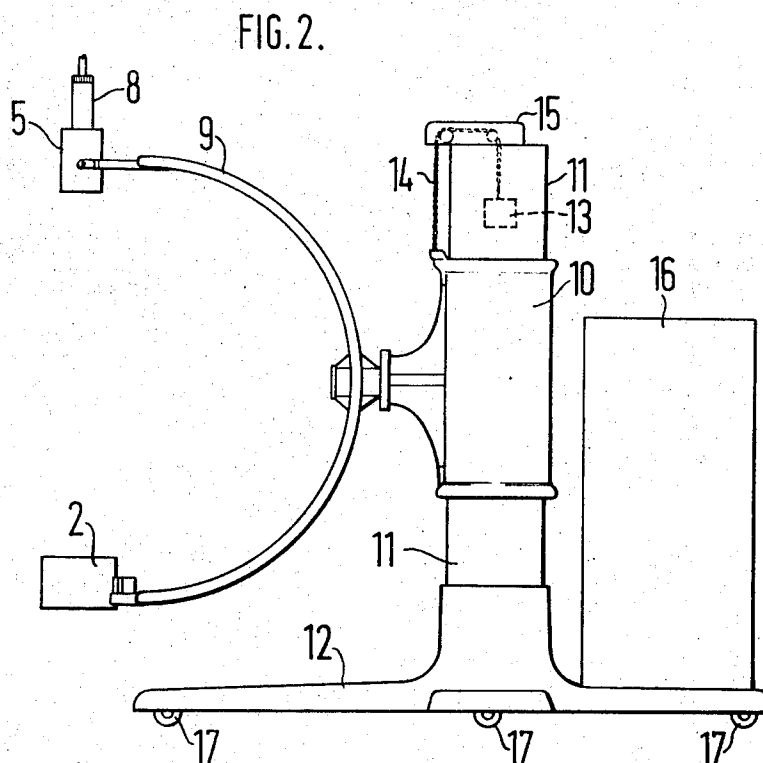
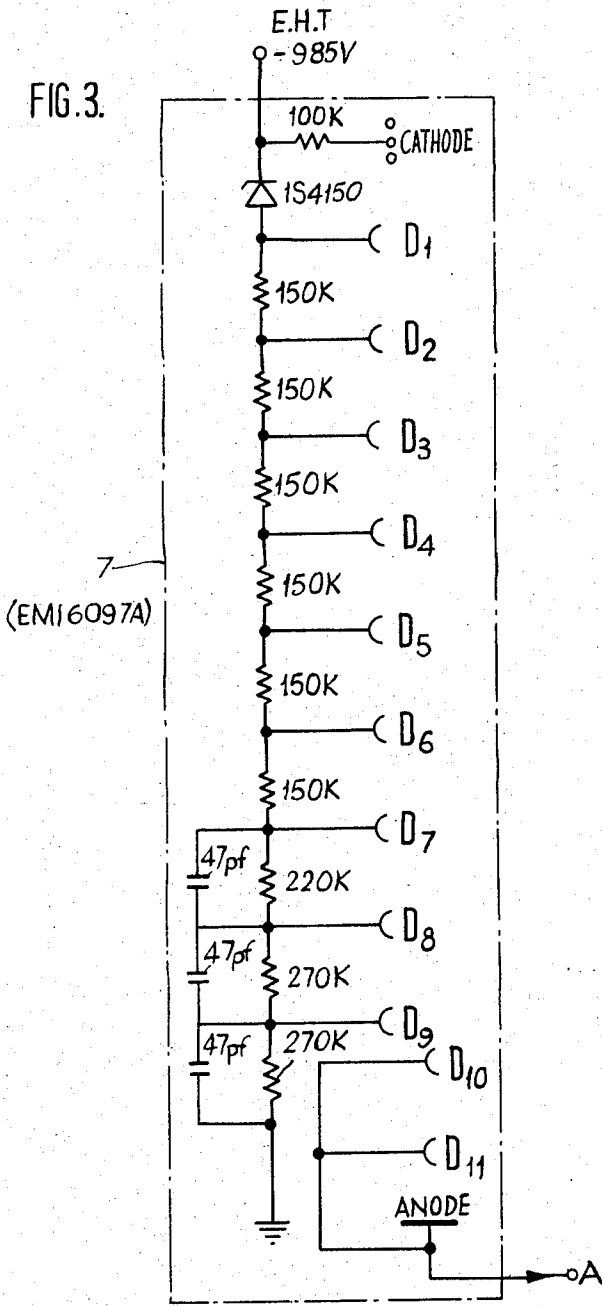
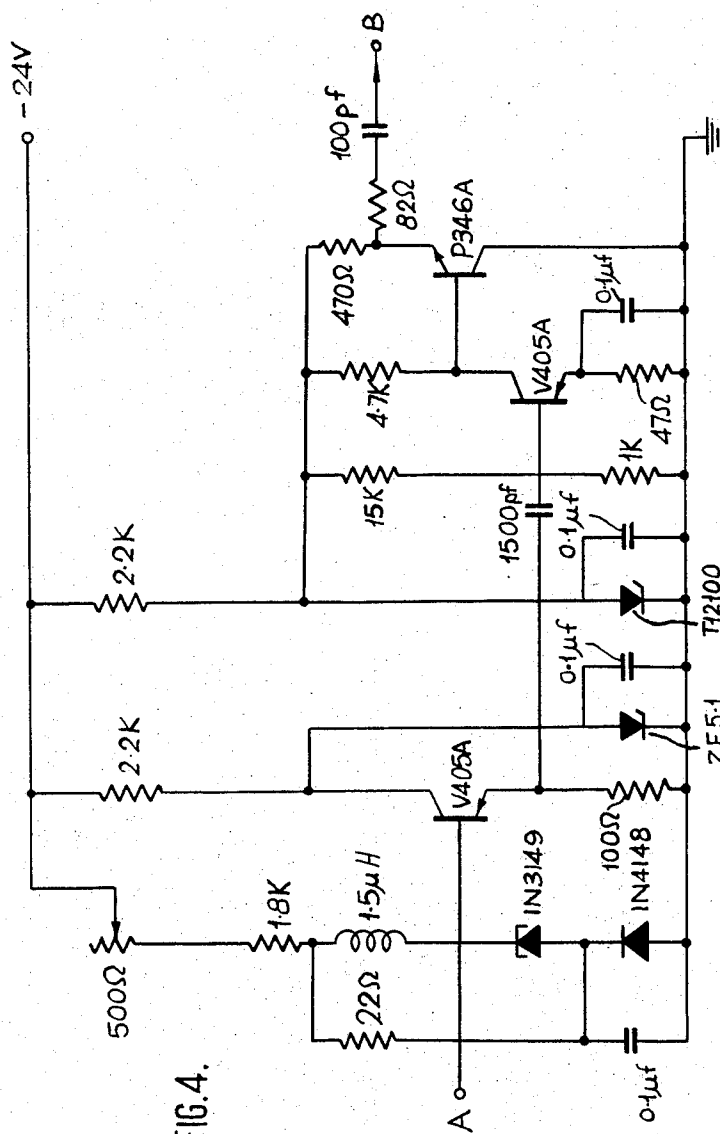
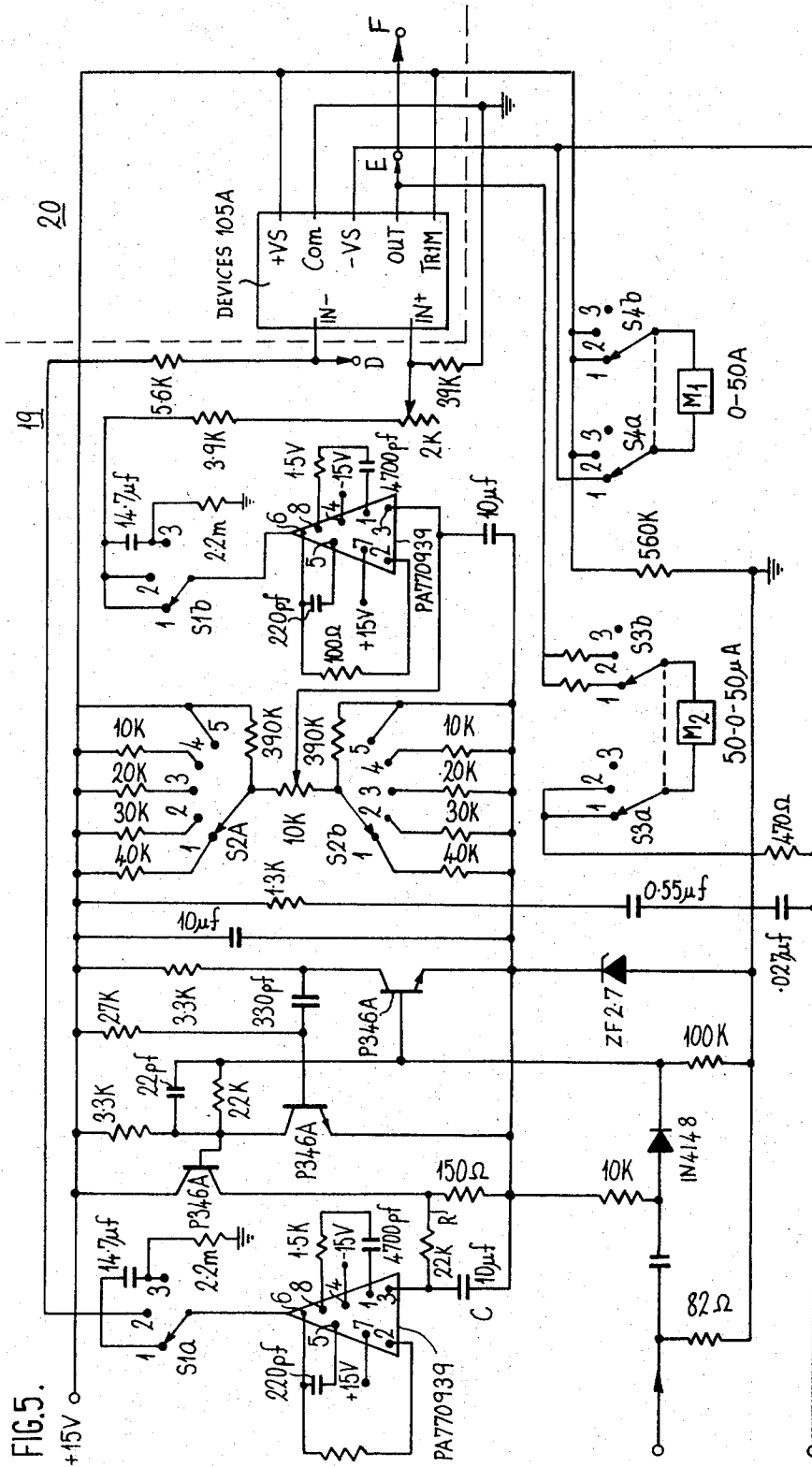


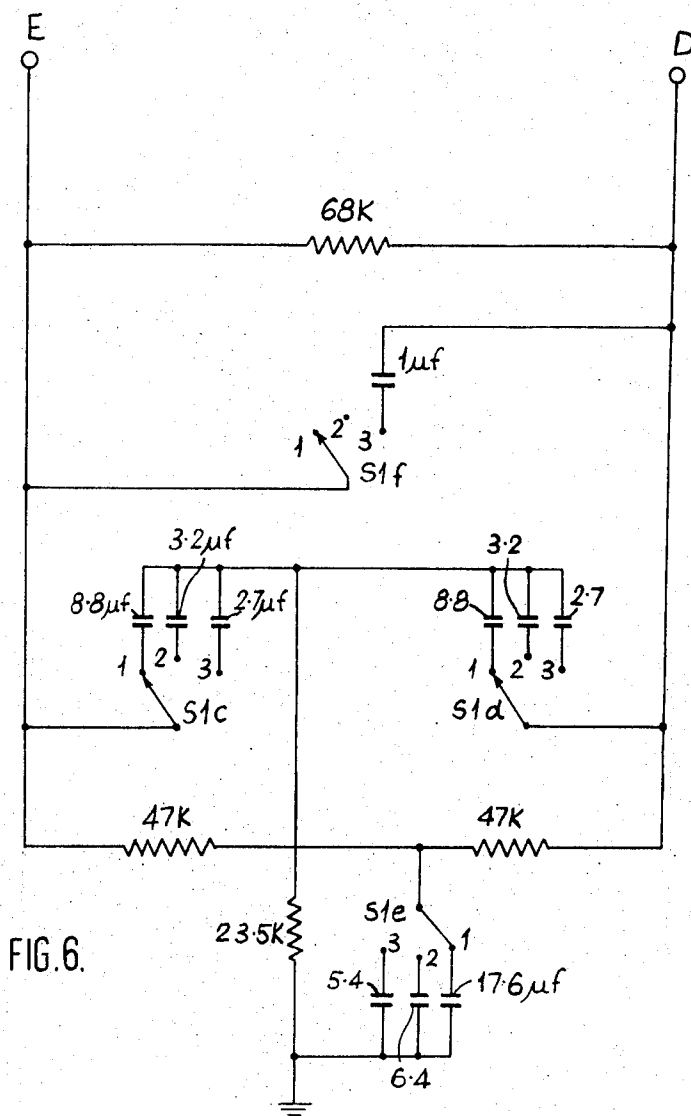
FIG. 2.

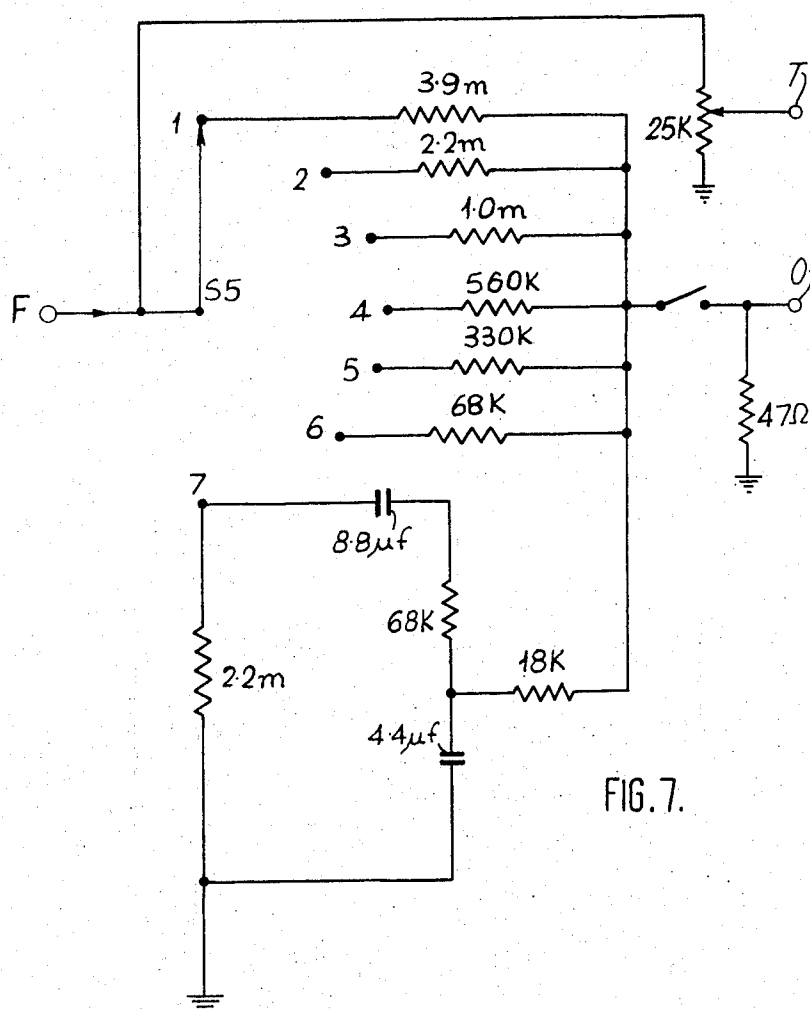
FIG. 3.











DENSITOMETERS

This invention concerns densitometers and more particularly, but not exclusively, those suitable for use in measuring human lung functions.

X-ray apparatus has already been developed for this purpose as can be seen, for example, from an article entitled "A Simple Fluorodensitometer for Observing Changes in the X-ray Density of the Lungs" by E. Leask and G. R. Sutherland appearing at pages 395-396 of "Bio-Medical Engineering," August, 1966. More generally, in the use of such apparatus, a beam of X-radiation of constant intensity is passed through the chest, the emergent radiation being detected to indicate the variations in absorption which occur during the respiration and cardiac cycles as a result of the movement of air and blood into and out of the lungs. It has been shown that certain pathological conditions are capable of modifying the normal respiratory and vascular patterns of movement, and these modifications can be detected by use of the above techniques.

However, while the apparatus in question is clearly useful, it suffers from certain disadvantages.

As indicated above, the radiation source must be constant, and a constant X-ray output can only be achieved by expensive modification of standard equipment. Also, the radiation dosage involved with the existing apparatus is sufficiently high — approximately half that which obtains for normal X-ray screening — that use at intervals with a single patient, in order to monitor progress during treatment, say, involves undesirable risk. Lastly, the existing apparatus is bulky and heavy, as is usual with X-ray screening equipment, and in consequence it has been used only in a fixed site manner.

An object of the invention is to reduce these disadvantages. This can be achieved by using an isotope source, instead of X-radiation, to provide a narrow collimated beam of γ -radiation. This change of radiation source has led, in turn, to development of a different detection arrangement from that of the existing apparatus.

In order to explain these changes more fully, it is convenient to describe an exemplary embodiment of apparatus according to the invention as illustrated by the accompanying drawings, in which:

FIGS. 1 and 2 schematically illustrate the embodiment in terms of more general function and housing, and

FIGS. 3 to 7 are circuit diagrams of different parts of the embodiment.

Considering the drawings, and initially FIG. 1: the isotope source is indicated at 1 housed in a lead container 2 having a lever mechanism whereby the source can be exposed to emit a narrow beam of γ -rays as a result of suitable collimation. The lever mechanism is indicated in FIG. 1 by showing the source mounted in a slide 3 reciprocable in the main housing to expose the source to a collimation channel outlet 4 or completely enclose the source.

The channel 4 is aligned with a detector assembly 5 including a fluorescent scintillation detector 6, photomultiplier 7, and discriminator and pulse forming circuit 8.

As shown by FIG. 2, the container 2 and detector assembly 5 are mounted on the ends of a generally U-

shaped member 9 in substantially predetermined relative dispositions. The mode of mounting can, of course, allow for fine adjustment of this relative disposition to provide precise alignment and desired spacing.

The U-member 9 is itself rotatably mounted at its U-base on a support in the form of a sleeve 10 which, in turn, is axially slidably mounted on a column 11 upstanding on a trolley platform 12. The U-member 9 is rotatable about a horizontal axis, conveniently its medial axis, extending radially of the sleeve to afford rotation up to about 120° from the vertical in one sense and up to about 90° from the vertical in the other sense, whereby a patient can be examined in lying, sitting or standing positions independently of the side from which the apparatus approaches the patient. The sleeve 10 is vertically slidable on the column 11 in association with a counter-weight 13 located within the column and connected to the sleeve 10 by a flexible link 14 passing over suitable rollers or guides 15 at the top of the column.

The trolley platform 12 has a longitudinal axis extending from the column base forwardly below and parallel to the axis of rotation of the U-member 9, and also rearwardly to provide a platform area to support a console or rack assembly 16 for electronic and recording units discussed hereinafter. The platform also extends laterally relative to the aforementioned axes from the base of the column to give a generally cruciform shaping. This lay-out, with the provision of castors 17 towards the extremities of the platform afford a well-balanced, mobile structure with a high degree of stability. Also, this lay-out is such that the apparatus can be used in association with standard hospital beds with the trolley platform projecting forwardly beneath the bed and the column adjusted vertically for the U-member to pass around the bed and patient thereon in the manner of a caliper.

Returning to consideration of FIG. 1: emergent radiation strikes the scintillation detector 6 to generate light pulses which are converted to electrical current pulses. These current pulses are passed into the discriminator and pulse forming circuit 8 which is adjustable so that only pulses produced in the detector by absorption of γ -rays of predetermined energy level are allowed to trigger pulse formation. In any event, pulses of predetermined amplitude and duration are produced and applied to a ratemeter and associated potential divider network 19. The ratemeter produces a quasi-D.C. voltage which is balanced by the potential divider network.

An operational amplifier 20 is used to amplify the difference in signal between the ratemeter and potential divider network, and operates in association with selectable filters 21. The filters 21 are selectable with associated ratemeter modes to give outputs relevant to different patterns of variation in the absorption cycle under examination. The filter outputs can be applied by an output circuit 22 to different forms of recording or indicator instruments 23, such as tape recorder, pen recorder and other appropriate instruments.

Turning now to more particular consideration of an apparatus embodiment resulting from initial development of the invention; the isotope form chosen was a 1 Curie Cs 137 source (Amersham Type CDC 91) and the scintillation detector a 2×2 inch sodium iodide crystal. These are mounted at 75 cm. spacing between source and crystal centre, with the source exposed

through a 1 cm. diameter opening and sharply collimated to give a beam diameter of 1.7 cm. midway between source and crystal. More generally the choice of a Cs 137 source for the present application was preferred since there is minimal modulation of the beam by rib movements during the respiratory cycle, minimal scatter of radiation to other sites in the patient's body, and negligible exposure to the investigators, while results of adequate statistical accuracy are obtained for the relevant application at low cost both financially and in terms of radiation dosage for the patient relative to the existing X-ray sources.

The embodiment in question measures the absorption of 0.66 MeV Cs 137 photons in the crystal, the number of such photons measured in a given time being uniquely related to the mass of material within the volume defined by the beam, and independently of the position of the material position in the beam path.

The electronic circuits of the embodiment are illustrated in more detail in FIGS. 3 to 7. FIG. 3 shows the dynode chain of the photomultiplier, negative pulses being fed from the anode and last two dynodes directly into the tunnel diode discriminator and pulse forming circuit of FIG. 4. Adjustment of the 500Ω potentiometer in FIG. 4 affords the photon energy level discrimination referred to earlier, and for each triggering action a 5 volt pulse of 0.25μs width is produced. The circuit of FIG. 4 is capable of operating at pulse rates up to 0.5Mc/s which permits achievement of the required statistical accuracy.

The ratemeter, potential divider and operational amplifier are shown in FIG. 5, the ratemeter producing its voltage across the capacitor C which, together with resistor R, defines the time constant as 0.22s.

In FIG. 5; switch S1 is associated with filter selection as discussed below; switch S2 affords a coarse balance control between ratemeter and divider network signals; switch S3 is associated with metering of the operational amplifier output with fine output metering at position S3/1, coarse output metering at position S3/2, and meter cut out at position S3/3; and switch S4 permits metering of the negative potential supply in position S4/1 and positive potential supply in position S4/2, while the meter is cut out in position S4/3.

The filter circuits of FIG. 6 are selectable between switching positions S1/1, S1/2 and S1/3 to give a satisfactorily uniform output from 0-1 cps for investigating respiratory phenomena alone, an output between 0-2 cps to indicate both respiratory and vascular phenomena together, and an output between 0.8-3 cps to indicate vascular phenomena alone, respectively.

The output circuit is shown in FIG. 7 with one output T for supply to a tape recorder and another 0, with switch S5 giving selection of six degrees of sensitivity, for supply to a galvanometer recorder or oscillograph display.

Trials with this more particular embodiment indicate that pulsatile changes of slightly less than 0.1 gm./cm.² in a 12 gm./cm.² mass can be clearly identified on the electromagnetic oscillograph trace. Moreover, if signal averaging techniques are used on the tape recording, it is possible to measure pulsatile changes of 0.03 gm./cm.² in a 12 gm./cm.² mass when sixty pulses are recorded.

While the present invention has been more particularly described with reference to the embodiment thereof developed initially, it is not intended to be limited thereto in more general scope since modifications in detail are clearly possible. Indeed a further embodiment has now been developed which involves various improvements. Firstly, uranium is used in place of lead for the source housing to make the apparatus lighter in weight. Secondly a selection of absorbers are employed for introduction into the beam path to compensate in some measure for differing thicknesses of patients and beds. Ideally, this compensation is such that the flux incident on the detector always has the same mean value and, given this improvement, the design of the ratemeter has been optimised. Also, a more powerful source (a 2 Curie source of Cs 137) is used together with finer collimation, and this permits study of heart chambers and the larger individual vascular channels. With this further embodiment it is now possible to measure pulsatile changes of 0.03 gm./cm.² in a 22 gm./cm.² mass when sixty pulses are recorded.

Also, while the illustrated embodiment has been described with reference to more particular medical applications, it can be used for investigating other cyclically recurring phenomena which result in a nett change in mass in a small, defined cylindrical volume in a medium, the equivalent radiological thickness of which is less than 20 cm. of water, and where the frequency range of the pulsatile changes in mass is between 0 and 2.5 cps. A similar consideration regarding more general application also applies to other embodiments of the invention.

I claim:

1. A densitometer for diagnostic use to indicate density variations due to respiratory and cardiac cycle movements in a human subject, comprising:

- a. a trolley platform;
- b. a column upstanding from said platform;
- c. a support mounted on said column for axial adjustment therealong;
- d. a U-shaped member having a first U-arm, a U-base, and second U-arm, disposed with its medial axis substantially horizontal, and mounted at its U-base on said support for rotation about said medial axis;
- e. a screened radiation unit housing a γ-ray isotope source, which unit is mounted on the free end of said first U-arm and is formed with a collimation channel outlet directed towards the free end of said second U-arm;
- f. a mechanism selectively operable between first and second conditions in which said source is respectively wholly screened in said unit from said outlet and exposed to said outlet to emit a γ-ray beam therefrom;
- g. a detector unit mounted on the free end of said second U-arm, which unit includes a fluorescent scintillation detector device aligned with said collimation channel outlet for response to said beam, and a photomultiplier operably related with said detector device to generate electrical signals in response to scintillation events in said device;
- h. a discriminator and pulse forming circuit connected with said photomultiplier to form electrical output pulses in response to said signals representing absorption of γ-rays of a predetermined energy level in said detector device;
- i. a ratemeter connected with said circuit to form a D.C. voltage representation of said pulses;

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- j. a potential divider network connected with said ratemeter to balance said D.C. voltage;
- k. an operational amplifier connected with said ratemeter and said network to provide a difference signal output therebetween;
- l. at least two low pass filters having different, but overlapping bandwidths representing respective components of respiratory and vascular cycle movements, and switches to selectively connect said filters with said amplifier for response to said difference signal output; and
- m. indicator means connected with said filters to display or record the signal components passed thereby.

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2. A densitometer according to claim 1 wherein said filters have respective bandwidths of 0-2 cps to represent both respiratory and vascular cycle movements in combination, and of 0.8-3 cps to represent vascular cycle movements alone.

3. A densitometer according to claim 2 comprising a third one of said filters having a bandwidth of 0-1 cps to represent respiratory cycle movements alone.

4. A densitometer according to claim 1 wherein said filters have respective bandwidths of 0-1 cps and 0.8-3 cps to represent respiratory and vascular cyclic movements in substantially mutual exclusion.

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