United States Patent

Faw et al.

[15] **3,678,233**

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[54] **STANDARDIZED SET OF COMPENSATING FILTERS FOR MANTLE-FIELD RADIATION THERAPY**

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[52] **U.S. Cl.** **250/86,** 250/105
[51] **Int. Cl.** **H05g 3/00**
[58] **Field of Search**...250/86

[56] **References Cited**

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[57] **ABSTRACT**

A standardized set of compensating filters for "mantle-field" radiotherapy. The set of compensating filters is supported in a filter-holder interposed between the radiation source and the patient and includes a plurality of individual filter elements which are selectively combined to provide the various portions of the mantle-field of the patient with a predetermined, reproducible radiation dosage.

5 Claims, 10 Drawing Figures

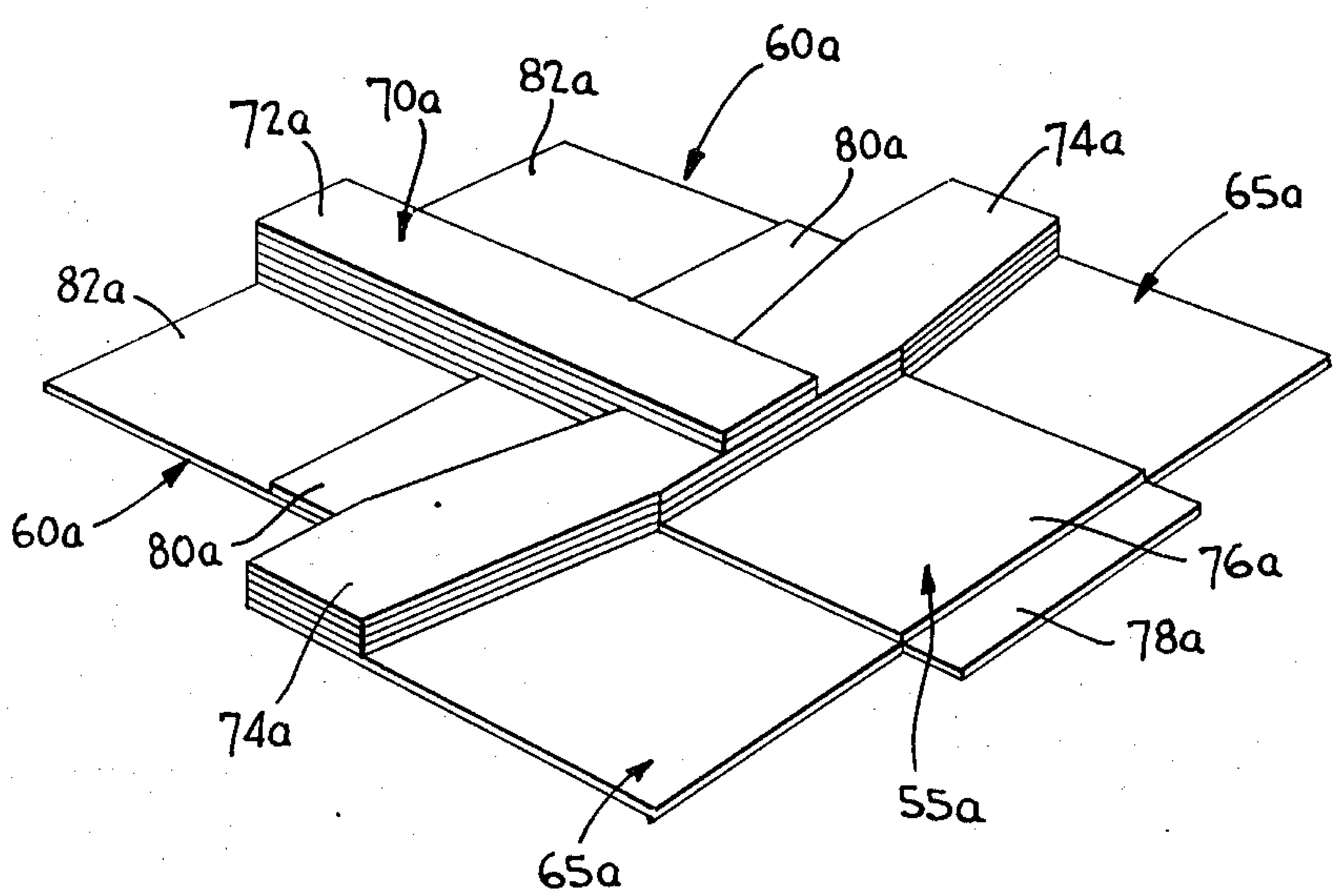

FIG. 2

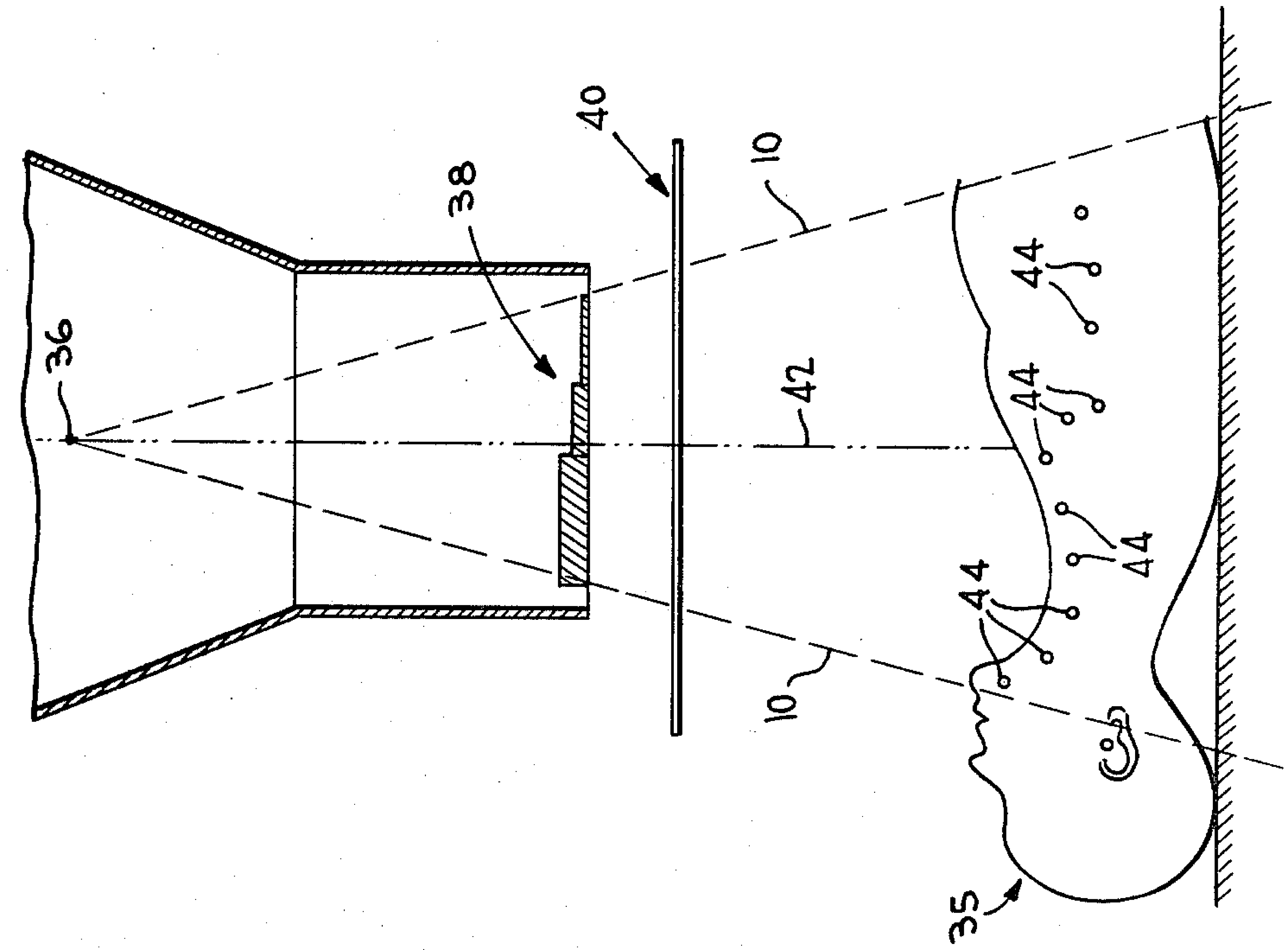

FIG. 1

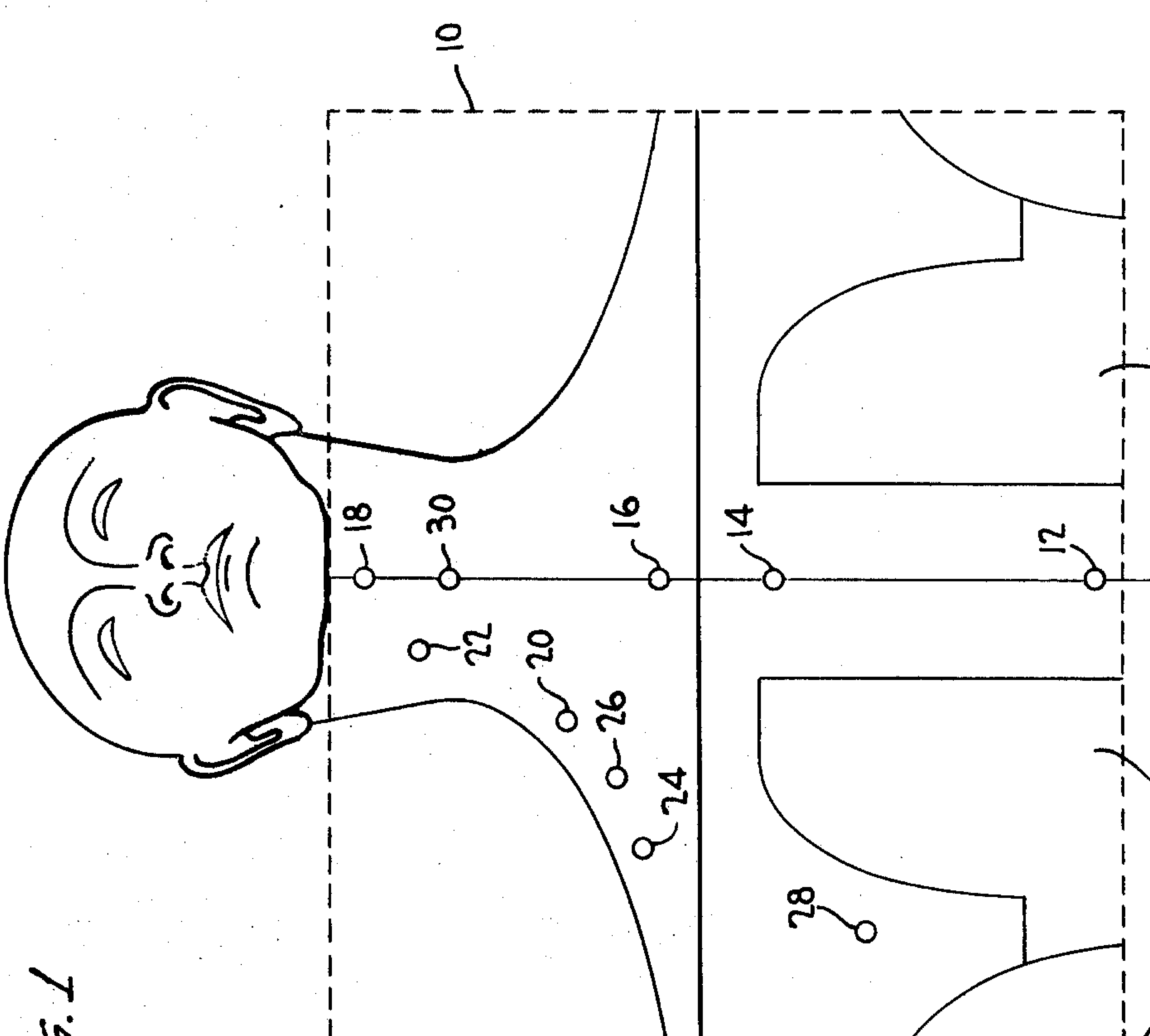

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FIG. 3

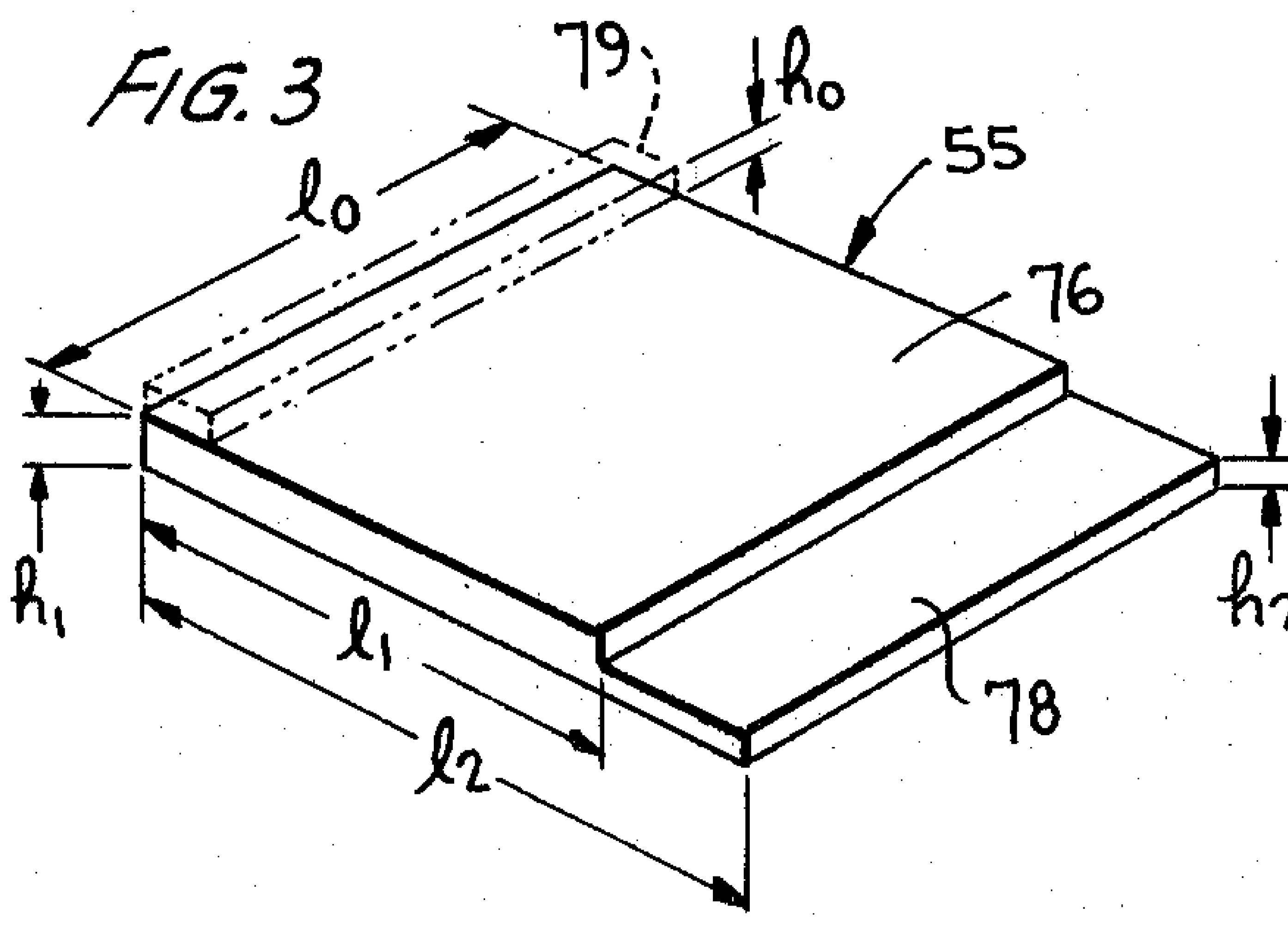

FIG. 4

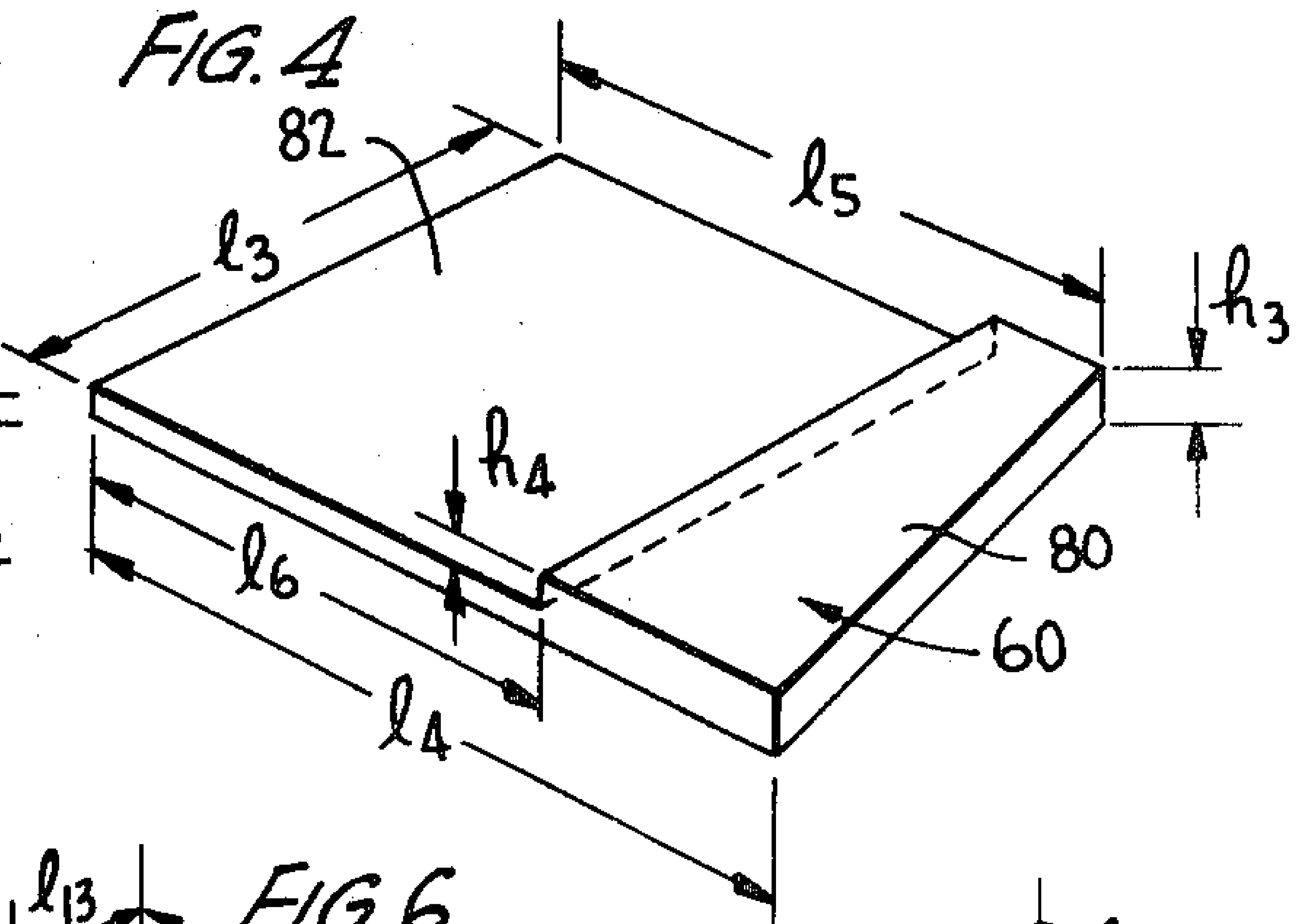

FIG. 5

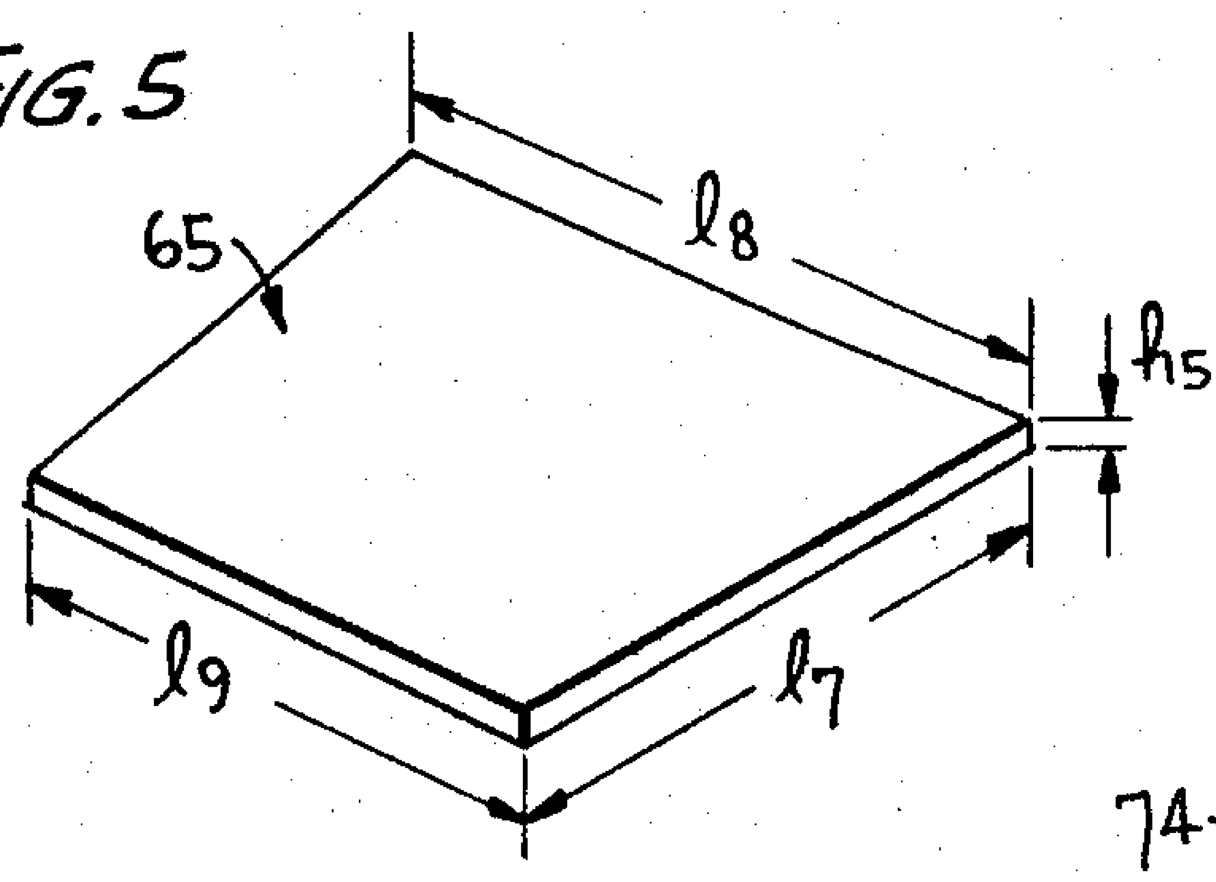

FIG. 6

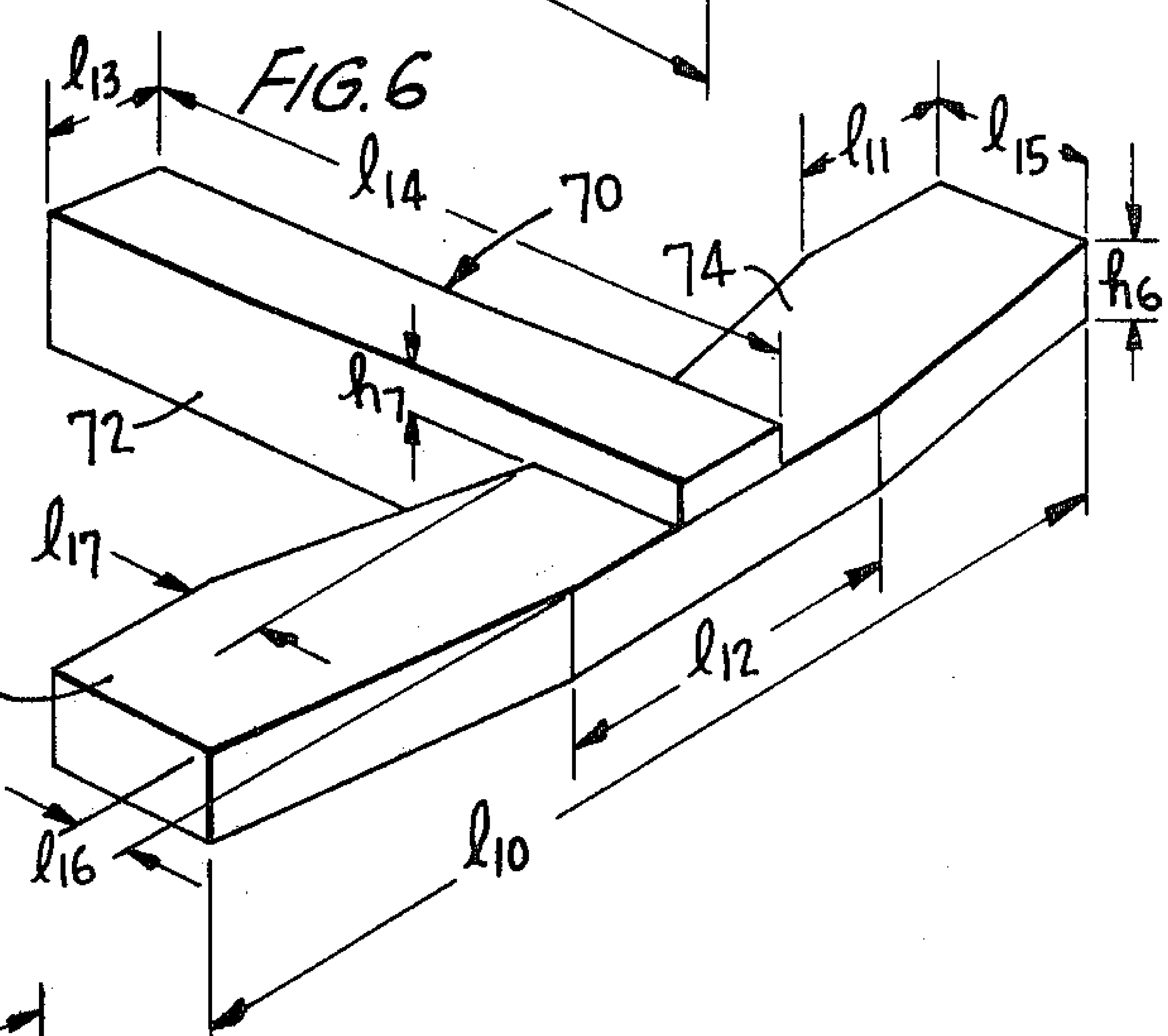

FIG. 7

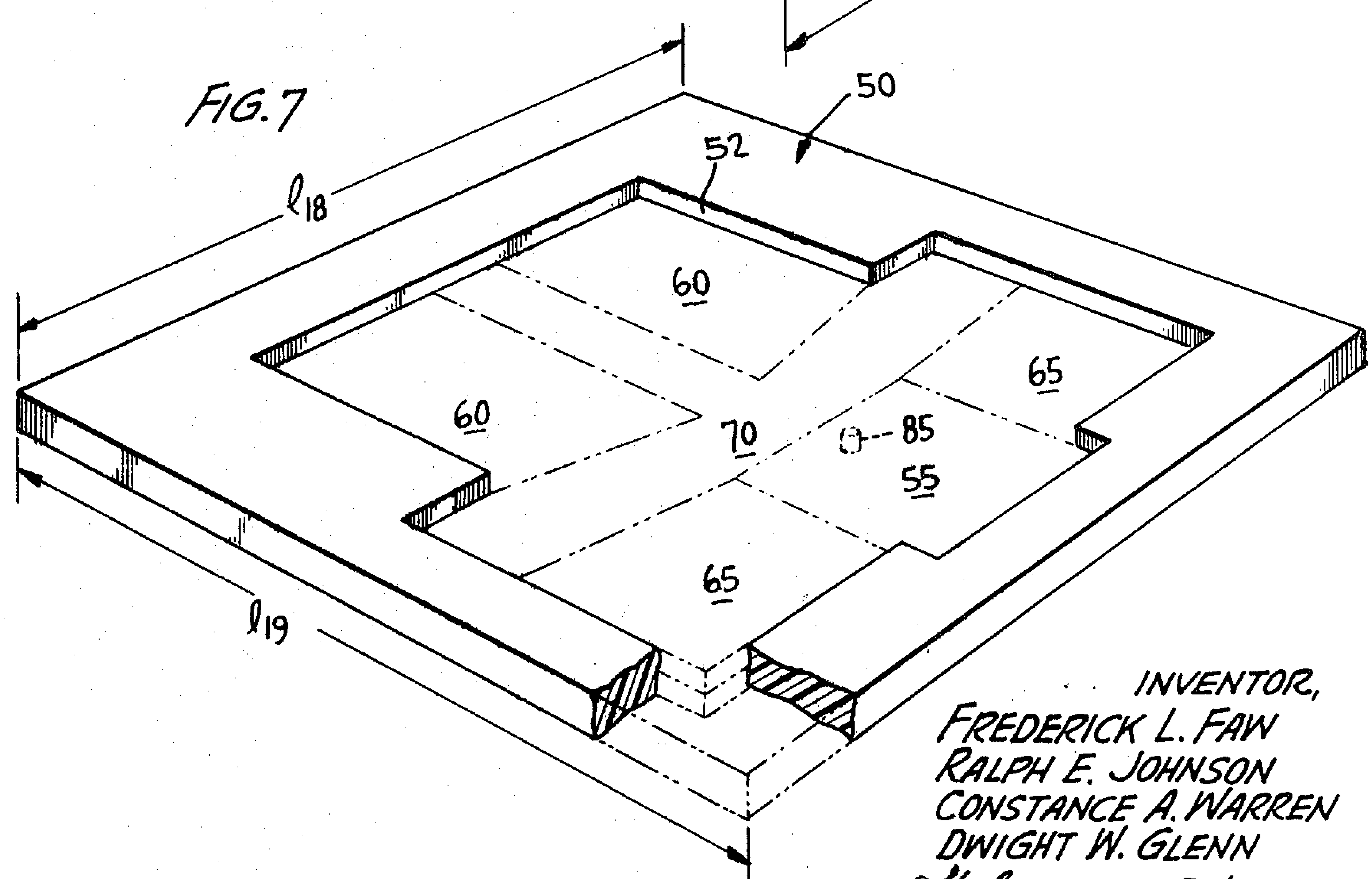

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FIG. 8

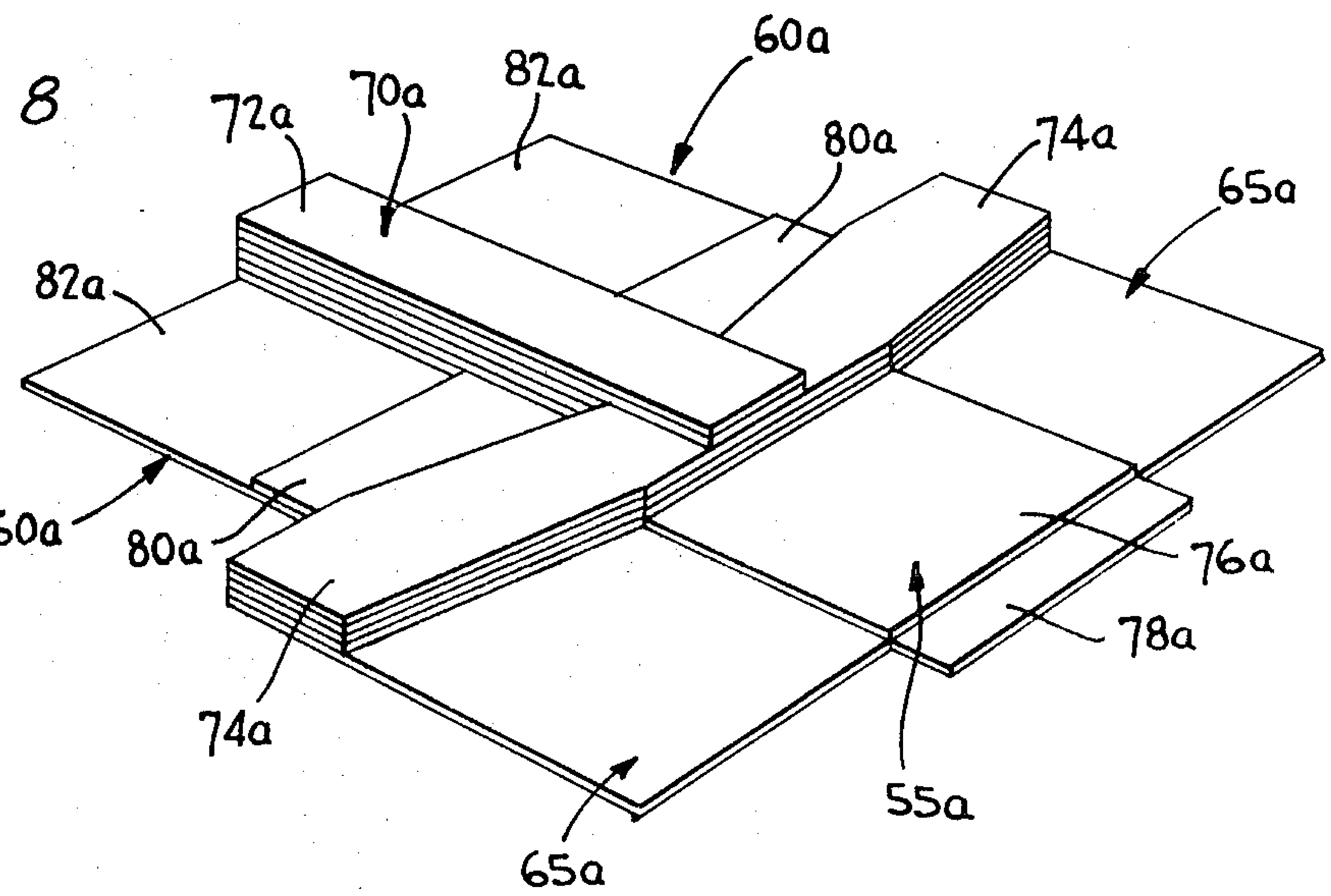


FIG. 9

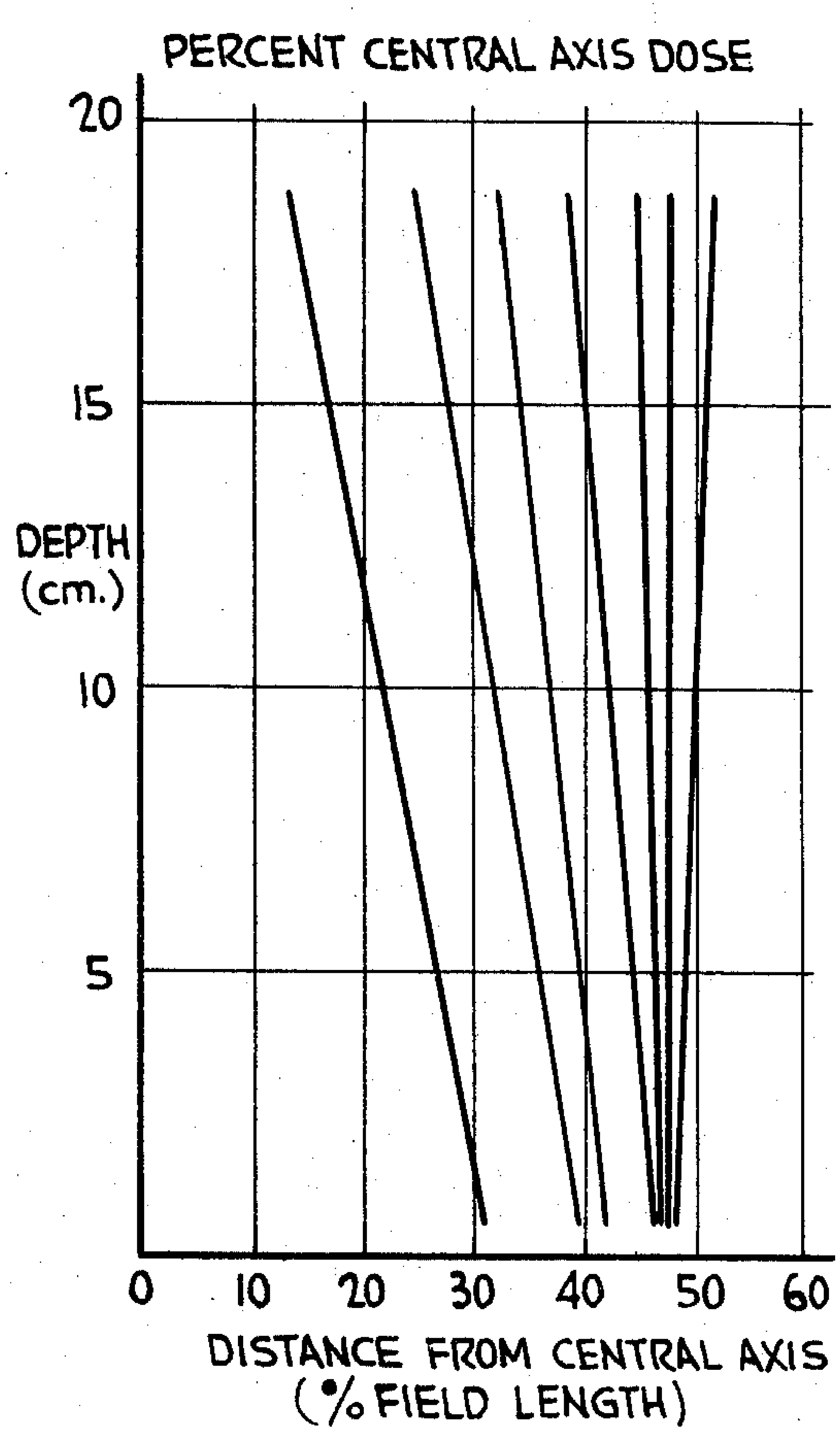
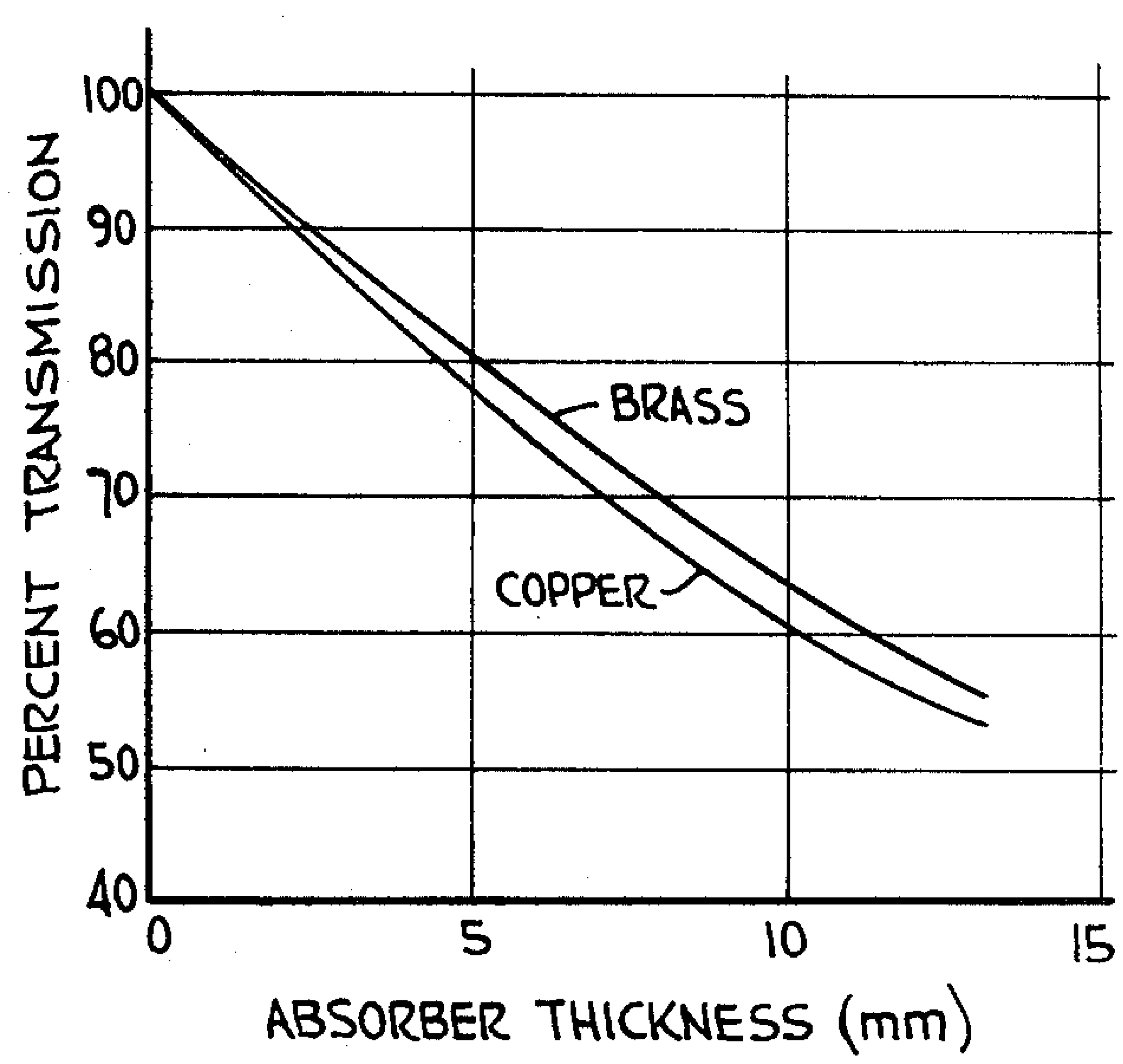


FIG. 10



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STANDARDIZED SET OF COMPENSATING FILTERS FOR MANTLE-FIELD RADIATION THERAPY

The instant invention relates to radiation therapy, and relates particularly to a standardized set of compensating filters to be interposed between a patient and a radiation source during radiation treatment of the mantle-field of the patient.

The use of wide-field techniques in clinical radiotherapy frequently results in considerable tumor dose inhomogeneity because, in part, of the variation in physical characteristics of the irradiated volumes. Such a situation is exemplified by the so-called "mantle-field" which is widely employed in the treatment of Hodgkin's disease. Although shielding of normal uninvolved tissues, such as the lung, has received attention, detailed consideration of the tumor dose inhomogeneities using this technique has not been adequately dealt with. There is a marked difference in the relative depth of the critical tumor volumes, that is, the lymph nodes, in various anatomic sites. The dose distribution is further complicated by the non-normal incidence of the radiations on the patient as produced by the irregular surfaces included in the mantle field treatment portal. In general the lower mediastinal area tends to be underdosed using this technique as a consequence of (1) the relatively greater tumor depth than for other target volumes, and (2) the inherently lower dose rate at the margin of the field. Conversely, the superficial cervical and supraclavicular lymph nodes receive a markedly higher daily dose than the mid-mediastinal lymph nodes.

Both beam modifying and compensating filters have been used in clinical radiology heretofore. With the advent of megavoltage radiotherapy, compensating filters often replaced bolus so that skin sparing could be preserved.

A primary object of the instant invention is the provision of a standardized set of compensating filters for "homogenizing" the tumor dose distribution, both temporal and spatial, for the mantle field. This invention provides, in effect, for "individualized custom" filters, which may be easily and rapidly assembled and which will insure a uniform dosage distribution for individual patients.

Other objects and advantages of the instant invention will be seen by reference to the following detailed description and the accompanying drawings, wherein:

FIG. 1 is a schematic showing of a typical mantle-field illustrating the lung blocks and approximate field margins, the numbered points referring to the data in Table 2 hereinafter;

FIG. 2 is a schematic illustration of the treatment position for the mantle-field technique showing the relative positions of the compensating filter, the radiation source, the patient and the lymph nodes;

FIG. 3 is a perspective view of a mediastinal filter means according to the instant inventive concepts, a modified embodiment thereof being shown in dotted lines;

FIG. 4 is a perspective view of a lateral cervical filter means according to the instant inventive concepts;

FIG. 5 is a perspective view of an axillary filter means according to the instant inventive concepts;

FIG. 6 is a perspective view of a midline cervical and supraclavicular filter means according to the instant inventive concepts;

FIG. 7 is a perspective view of a filter holder according to the instant invention, partly broken away for illustrative clarity, and showing in dot-dash lines the position of the various filter means in the assembled relationship;

FIG. 8 is a perspective view of an assembly of slightly modified filter means according to this invention;

FIG. 9 is a graphical representation of decrement lines for field sizes greater than 20 cm for the Theratron 80* (* Tradename of Atomic Energy of Canada Ltd.) cobalt unit; and

FIG. 10 is a graphical representation of the transmission of Cobalt 60 gamma rays by copper and brass.

Like reference characters refer to like parts throughout the several view of the drawings.

Referring now to the drawings, and more particularly to FIG. 1, a schematic illustration of the mantle-field of a patient will be seen, the dashed lines **10** indicating the approximate field margins and the lung blocks being designated as **11**. Reference to the numbered points **12–30** will be made hereinafter with respect to Table 2.

In FIG. 2, a schematic illustration of the treatment position for the mantle-field technique of a patient **35** is shown with the source of radiation being designated by the reference numeral **36**, the set of compensating filters of the instant invention being designated generally by the reference numeral **38**, a platform for conventional field shaping blocks being designated generally by the reference numeral **40**, the center of the field on the sternal notch being designated by the reference numeral **42**, and the lymph nodes to be treated being designated by the reference numerals **44**. As will be seen by FIG. 2, there is a significant difference in the relative depth of the lymph nodes in the various anatomic sites.

As will be also seen from FIG. 2, there is a marked difference in the source-to-surface (skin) distance at various points in the mantle-field as well as a difference in radiation due to the distance of a given anatomic point from the center **42** of the field. The instant inventive concepts compensate for each of the foregoing parameters.

Referring now to FIG. 7, a filter holder according to this invention is designated generally by the reference numeral **50** and is formed of a plastic material having a depression **52** corresponding in shape to the overall outline of the set of compensating filters. The filter set includes a mediastinal filter means shown in FIG. 3 and designated generally by the reference numeral **55**, a pair of mirror-image lateral cervical filter means, one of which is shown in FIG. 4 and designated generally by the reference numeral **60**, a pair of mirror-image axillary filter means, one of which is shown in FIG. 5, and designated generally by the reference numeral **65**, and a midline cervical and supraclavicular filter means shown in FIG. 6, and designated generally by the reference numeral **70**. The location of the individual filter elements in the filter holder **50** is shown by the dot-dash lines in FIG. 7.

The midline cervical and supraclavicular filter means **70** as shown in FIG. 6 is generally T-shaped and includes a midline cervical portion **72** forming the stem of the T and a pair of mirror-image supraclavicular portions **74** forming the cross-bar of the T.

The midline cervical portion **72** of the filter means **70** is the relatively thickest portion of all of the filter elements. The reason for this will be recognized from the showings in FIGS. **1** and **2**. First of all, the lymph nodes to be treated by this area are relatively shallow. Additionally, certain of the lymph nodes are directly in line with the center **42** of the radiation field. Those lymph nodes toward the edge of the field, such as in a chin portion of the patient, are somewhat closer to the radiation source **36**. Thus, the relative thickness of the midline cervical portion **72** of the filter means **70** compensates for the foregoing conditions, in addition to reducing the radiation dose to the cervical spinal cord.

The supraclavicular portions **74** of the filter means **70** are relatively thicker than the other filter means, but somewhat thinner than the midline cervical portion **72**. The supraclavicular portions **74** are between the collar bone of the patient **35** and the radiation source **36**, whereby the length of these portions is merely designed to be sufficient to cover the collar bone area.

The mediastinal filter means **55** is positioned centrally above the cross-bar of the T of the midline cervical and supraclavicular filter means **70** in the assembled relationship of the filter elements. This filter means **55** includes a portion **76** juxtaposed to the cross-bar of the T of the cervical and supraclavicular filter means, which is relatively thicker than the remainder **78** of the mediastinal filter means **55**, but relatively thinner than the midline cervical and supraclavicular filter means **70**. An even further step **79**, shown in dotted lines in FIG. 3, may be provided for certain applications. It will be noted from FIG. 2 that the lymph nodes covered by the mediastinal filter means are located relatively deep with relation to the skin surface, whereby a greater dosage of radiation is necessary to provide uniform treatment. The thinner portion 78 of the mediastinal filter means 55 is that portion located toward the edge of the radiation field.

Similarly, the lateral cervical filter means 60 includes a relatively thicker portion 80 positioned adjacent the underside of the cross-bar of the T of the midline cervical and supraclavicular filter means 70 and a relatively thinner portion 82 positioned toward the edge of the radiation field.

Finally, the axillary filter means is relatively thin throughout and is positioned on opposite sides of the mediastinal filter means 55.

The individual filter means may be milled from solid metallic blocks as in the embodiment of FIGS. 3–6 or built-up from thin sheets as in the embodiment of FIG. 8 where portions similar to the embodiment of FIGS. 3–6 are designated by the same reference numeral followed by the suffix "*a*."

The filter means of the instant invention was particularly designed for use with Cobalt 60 teletherapy so as to deliver a homogeneous dose to the various lymph node regions included within the mantle-field tissue volume. Initially, the filters were individually constructed for each patient. After analyzing the characteristics of such custom filters for 64 patients, a standard set of components was designed from which "individualized" filters could be easily and rapidly assembled.

The custom filters for the 64 patients were constructed in the following manner: 2 1/4;

The perpendicular source-to-surface distance (SSD) of 20 to 30 surface points within the mantle-field portal were measured with conventional equipment. A tumor depth was arbitrarily assigned to each point following the scheme shown in Table 1.

TABLE 1

Lymph Node Depths in the Mantle-field*

Area	Depth from anterior surface
Mediastinum	One-half the antero-posterior diameter
Neck (Midline)	2 cm
Neck (Lateral)	Two-thirds the antero-posterior diameter
Supraclavicular	3 cm
Axillae	One-half the antero-posterior diameter

*The arbitrarily assigned tumor depths are for our technique of irradiating the mantle-field through an anterior treatment portal except for the mediastinum which is irradiated through a posterior portal on alternate days.

A relative dose, D, at the tumor depth for each point was calculated from the following:

$$D = OD \times DD \times (90/SSD)^2$$

where OD is the off-axis dose, DD the central axis depth dose for a 30 × 30 cm field, and 90 and SSD is the source-skin distances respectively to the center of the field and the point being calculated. The off-axis dose (OD) is the ratio of the dose rate at a point off the central axis to the dose rate at the same depth on the central axis. (See FIG. 9.)

Percent transmission is calculated from the relative dose for each point by the following:

$$\%\ \text{Transmission} = 100 \times D/D_{min}$$

where D is the relative dose for the point and D_{min} is the minimum relative dose of all points. In nearly every instance, D_{min} refers to the relative dose at the lower margin of the mediastinum. The filters were constructed of 1/32-inch copper sheet with the thickness for each portion of the filter being determined from the percent transmission and the graph shown in FIG. 10. The copper filter was fastened to a 0.25-inch Lucite plate which fit into the filter holder on the Cobalt 60 unit.

The transmission characteristics of these custom filters were checked using LiF dosimetry in a presdwood phantom. Each point used to determine the filter was checked with dosimeters being placed at the appropriate coordinates (depth, SSD, and distance from the central axis). Dosimetric measurements were made for the following number of points under each filter: five to nine in the mediastinum, five to eight in the midline neck, three in each axilla and each side of the neck, and two in each supraclavicular region. On the average, the tumor dose at the various points under the filter was 4,000± 165 rads with an intended uniform tumor dose of 4,000 rads.

The information collected in designing these 64 custom filters was then reviewed and four anatomic areas were identified for purposes of determining the measurement ranges. For each of the four anatomic areas, namely the midline cervical-supraclavicular, lateral neck, axillary, and mediastinal areas, a set of subfilters was constructed to encompass the range of measurements encountered in the 64 custom filters. These subfilters have been constructed of brass which has nearly the same absorption coefficient as copper but better machining properties, (See FIG. 10), although other easily machinable metals may be used with appropriate alterations in thickness, depending on the absorption coefficient.

The subfilters are combined in an appropriate manner for each patient to form a composite filter as schematically illustrated in FIG. 7. In this fashion, a semi-customized compensating filter can be assembled rapidly for each individual patient with a standard set of components. It has been demonstrated with LiF dosimetry that these standard filters produce as homogeneous a dose distribution as the more laboriously constructed custom filters. Table 2 summarizes a representative dose-distribution measured in a Machlet-Alderson Rando Phantom Man with thermoluminescent dosimeters. The points selected for measurement are those schematically illustrated in FIG. 1, using the tumor depths given in Table 1.

TABLE 2

Doses to Points in the Mantle Field Irradiated with

Cobalt-60 Teletherapy Using A Standard Filter Technique

Area	Point*	Measured Tumor Dose (rads)
Lower Mediastinum	12	4160
Upper Mediastinum	14	4100
Lower neck (Midline)	16	4260
Upper neck (Midline)	18	4180
Lower neck (Lateral)	20	3740
Upper neck (Lateral)	22	4120
Supraclavicular	24	4060
Supraclavicular	26	4340
Axilla	28	3780
Spinal Cord		
	30	4100
	16	4420
	12	3140

* The numbers refer to the points shown schematically in FIG. 1.

The requirement for using these standard compensating filters for mantle-field radiotherapy is adherence to a consistent treatment plan. The center of the field (central axis) must be precisely reproducible for each patient, so that the break in filter thickness between the lower mid-cervical and mediastinal filter means will remain centered over the sternal notch. Likewise, the filters have been designed for placement in a filter holder located 45 cm from the source. For other relative filter locations between the source and patient, as well as for other treatment distances, the filter means need only have their size adjusted, the scaling easily being done using the similar triangles concept from plane geometry.

Exemplary dimensions for the individual filter means are shown in Table 3, the dimensions given being in inches:

TABLE 3

Exemplary Dimensions

Mediastinum Filter Means

Length i_1	i_2	Identification Case A	Case B	Case C*
1 3/16	1 9/16	A	F	
1 3/8	1 7/8	b	G	
1 9/16	1 3/16	C	H	L
1 13/16	2 7/16	D	J	M
2	2 3/4	E	K	N
i_0 = 2 3/4				

*Case C = Case B plus step 79 1/16×3/4×2 3/4

For Case A: h_0=0; h_1=1/16; h_2=1/32;
For Case B: h_0=0; h_1=1/8; h_2=1/16;
For Case C: h_0=1/16; h_1=1/8; h_2=1/16;

Lateral Ceruical Filter Means

Height, h_3	Identification
0	II 1/32
1/16	III
3/32	IV
1/8	V
5/32	VI
h_4=1/32	i_3=2; i_4=3 i_5=2 7/16; i_6=

Axilla Filter Means

Height, h_5	Identification
0	*a*
1/32	*b*
1/16	*c*
3/32	*d*
1/8	*e*
5/32	*f*
i_7=2 3/8; i_8=2 1/4; i_9=2	

Midline Cervical and Supraclavicular Filter Means

Height, h_6	Identification
9/32	1
5/16	2
11/32	3
3/8	4
13/32	5
7/16	6
15/32	7
1/2	8
h_7=3/16; i_{10}=7 3/8; i_{11}=1 5/16; i_{12}=2 3/4; i_{13}=3/4; i_{14}=3 13/16; i_{15}=1 1/8; i_{16}=1/4; i_{17}=9/16.	

Filter Holder i_{18}=9 1/4 i_{19}=10 1/2

It is to be understood that the above dimensions are illustrative of a preferred set of compensating filters for the mantle-field, according to the instant inventive concepts. It will be noted that a total of 32 separate elements are provided with the lateral cervical and axillary filter means being made to form pairs.

The recess **52** in the filter holder **50** is approximately one-sixteenth inch with a small plastic locator shown in dotted lines at **85** being used with the mediastinum filter means **55** since these elements vary in length.

Heretofore, the construction of individual custom filters from the mantle-field technique required a considerable amount of time. The entire procedure took several hours including measurement of the patient's contour, calculation of thickness and design of the filter, reduction in size for beam divergence, and final construction. Utilizing the standardized set of filters of the instant invention, "individualized" compensating filters can be assembled in about 15 minutes, including the time for patient measurement. The only measurement required to select the correct individual filter elements for specific patients are four antero-posterior patient thicknesses and two source-surface distances at preselected points in the field. It has been found that the required standardization of the treatment, such as centering the field at a uniform location, is not a constraint to the radiotherapist. Rather, standardization has tended to facilitate the daily reproduction of accurate treatment conditions for the medial and technical staff alike.

A variety of treatment port arrangements may be used for irradiation of the mantle-field. A single anterior field tends to overdose the anterior mediastinal structures, including the heart, although the cervical, supraclavicular and axillary regions can be satisfactorily irradiated through an anterior field only, particularly when the arms are extended over the head to expose the axillae. A second option is the use of parallel opposing mantle-fields which requires alternating the patient between the supine and prone positions for successive treatments. This can be accomplished but requires considerable care to obtain perfect matching of the anterior and posterior fields. It has been found relatively simpler to treat the entire mantle-field through an anterior field except for the mediastinum which on alternate days is irradiated through a posterior port. This permits the patient to remain in a supine position and takes advantage of the isocentric mount on the Theratron 80 for precise matching of the anterior and posterior mediastinal ports.

Unless compensating filters are used, a "shrinking field" technique is usually used, whereby the field size is appropriately reduced as the desired tumor dose to different lymph node areas is reached. With this technique, the time-dose relationship to different areas varies considerably. With the compensating filter of this invention, all nodal areas receive the desired tumor dose at the same dose rate. This has resulted in visibly more uniform skin reactions and has improved patient tolerance to treatment, especially by reducing the radiation pharyngitis caused by intensive dose fractions to the cervical region. Introduction of these compensating filters into routine use has not compromised the therapeutic effectiveness in any manner. Over an extended period, during which 80 patients with Hodgkin's disease have been treated with the use of the compensating filters of this invention, only one recurrence has developed within the treated field. This recurrence was observed at the margin of the treated area and was quite likely the result of underdosage due to sub-optimal field placement.

Thus, it will now be seen that there is herein provided a standardized set of compensating filters for use in radiation treatment of the mantle-field which provides all the advantages set forth hereinabove, and others which will be readily recognized by those skilled in the art. Accordingly,

What is claimed is:

1. A clinical radiotheraphy device for mantle field irradiation comprising a set of compensating filters to be interposed between a patient and a radiation source, said set of compensating filters including a filter holder, and a plurality of individual filter elements, selected filter elements being combined and supported by said filter holder to simultaneously provide selected portions of the mantle-field of a patient with different predetermined, reproducible, radiation dosages, said individual filter elements including lateral cervical filter means, midline cervical and supraclavicular filter means, axillary filter means and mediastinal filter means, said midline cervical and supraclavicular filter means being generally T-shaped including a midline cervical portion forming the stem of the T and a pair of mirror-image supraclavicular portions forming the crossbar of the T, said midline cervical and supraclavicular filter means being relatively thicker than the remainder of said filter means.

2. The improvement of claim 1 wherein said individual filter elements are formed of brass.

3. The improvement of claim 1 wherein said filter holder is formed of plastic and includes a recessed portion corresponding in shape to the overall outline of said set of compensating filters.

4. The improvement of claim 1 wherein said lateral cervical filter means comprises a pair of mirror-image lateral cervical filter members positioned on opposite sides of said midline cervical portion in said filter holder, said lateral cervical filter members each including a portion juxtaposed to said supraclavicular portions of said midline cervical and supraclavicular filter means which is relatively thicker than the remainder of said lateral cervical filter members.

5. The improvement of claim 1 wherein said mediastinal filter means is positioned centrally of the crossbar of the T of said midline cervical and supraclavicular filter means on the side of said crossbar opposite to the stem of the T, said mediastinal filter means including a portion juxtaposed to the crossbar of the T of said cervical and supraclavicular filter means which is relatively thicker than the remainder of said mediastinal filter means.

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