

[54] **AUTOMATED RADIATION THERAPY MACHINE**

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[52] U.S. Cl.....235/151.11, 444/1

[51] **Int. Cl.**.....G05d 3/04

[58] **Field of Search**.....250/52, 61.5;
318/3-8

[56] **References Cited**

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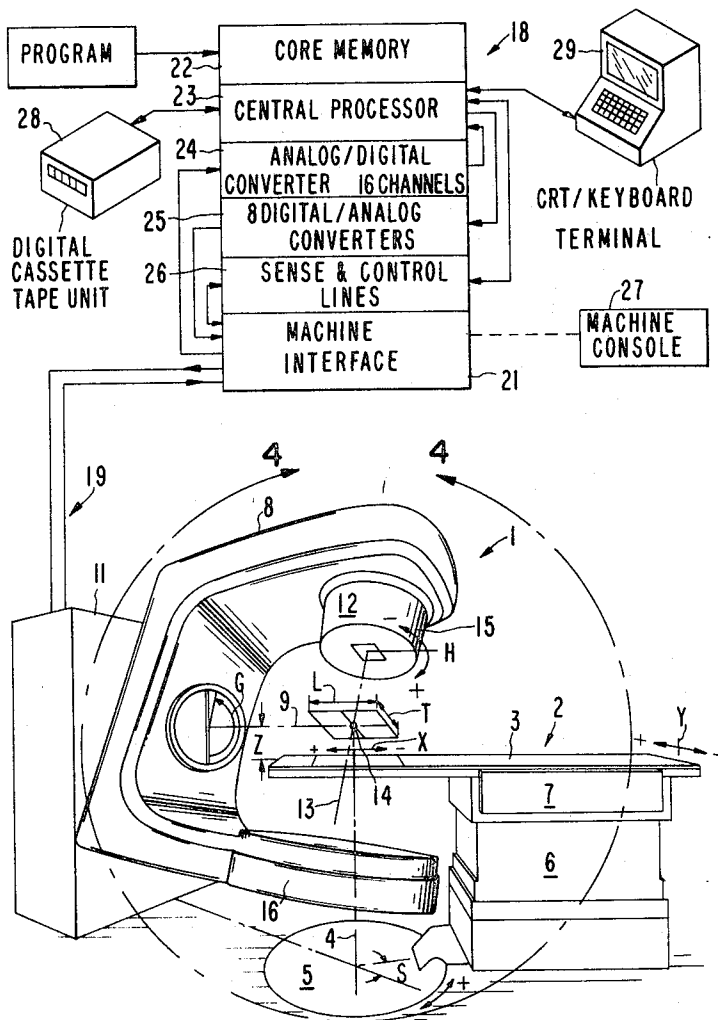
"Varian Clinac 4 Installation" by Varian Radiation Div. Palo Alto, Calif., dated RAD 1575-2M-6-69.

Primary Examiner—Eugene G. Botz
Attorney—Stanley Z. Cole and Leon F. Herbert

[57] **ABSTRACT**

A computer assisted radiation therapy machine is disclosed. The machine includes a rotatable gantry having a radiation source portion and a beam stopping portion. The gantry is rotatable about a patient treatment couch which is rectilinearly translatable in three orthogonal directions as well as being rotatable about the vertical axis. A computer controls the operations of the machine to automatically set the position of the gantry relative to the couch for treatment of a patient. The automated motions of the gantry and the couch are simultaneous for decreasing the setup time. In addition, the computer includes a collision avoidance program which averts collision between the couch or patient, and the gantry.

6 Claims, 5 Drawing Figures



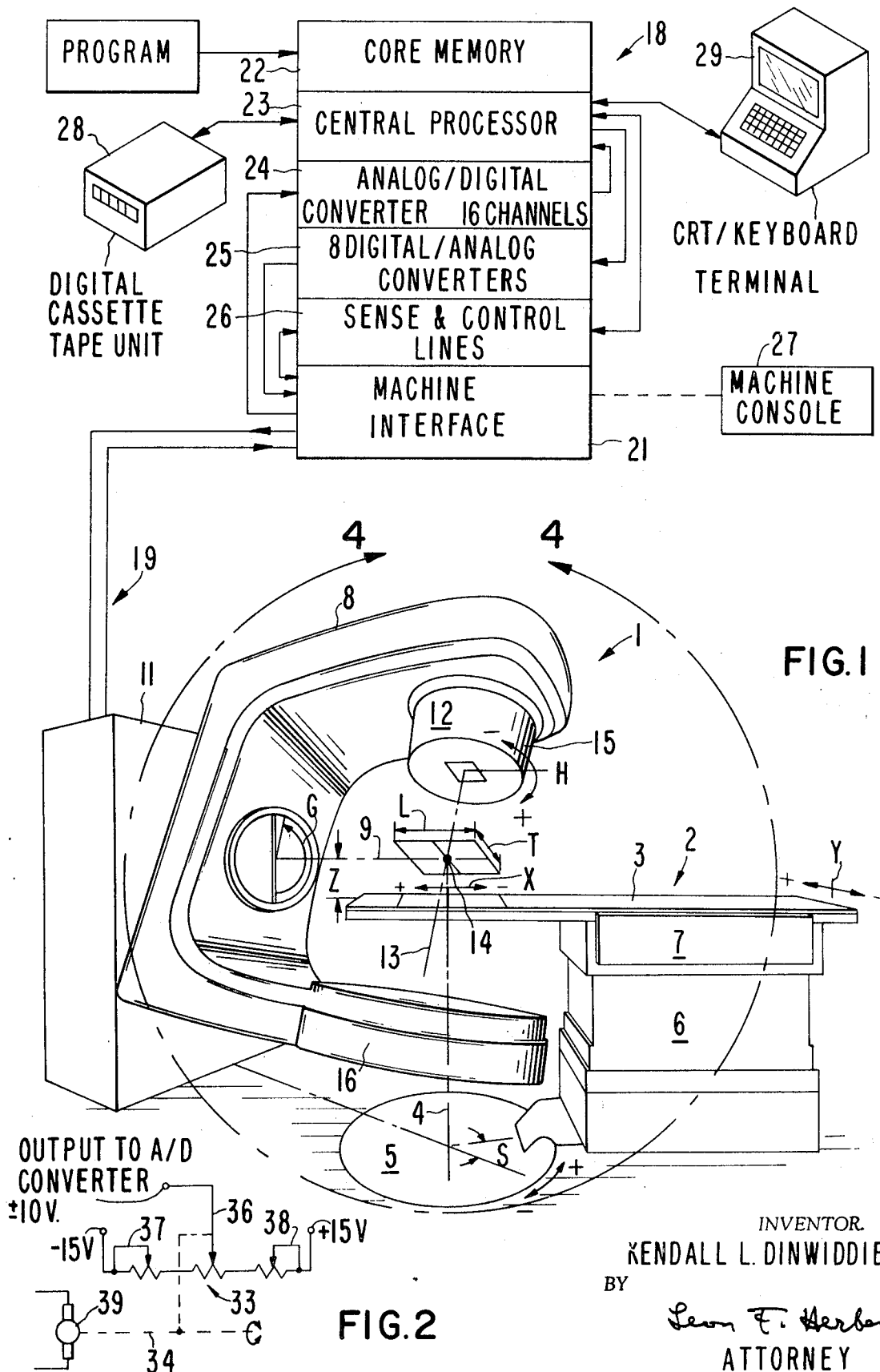
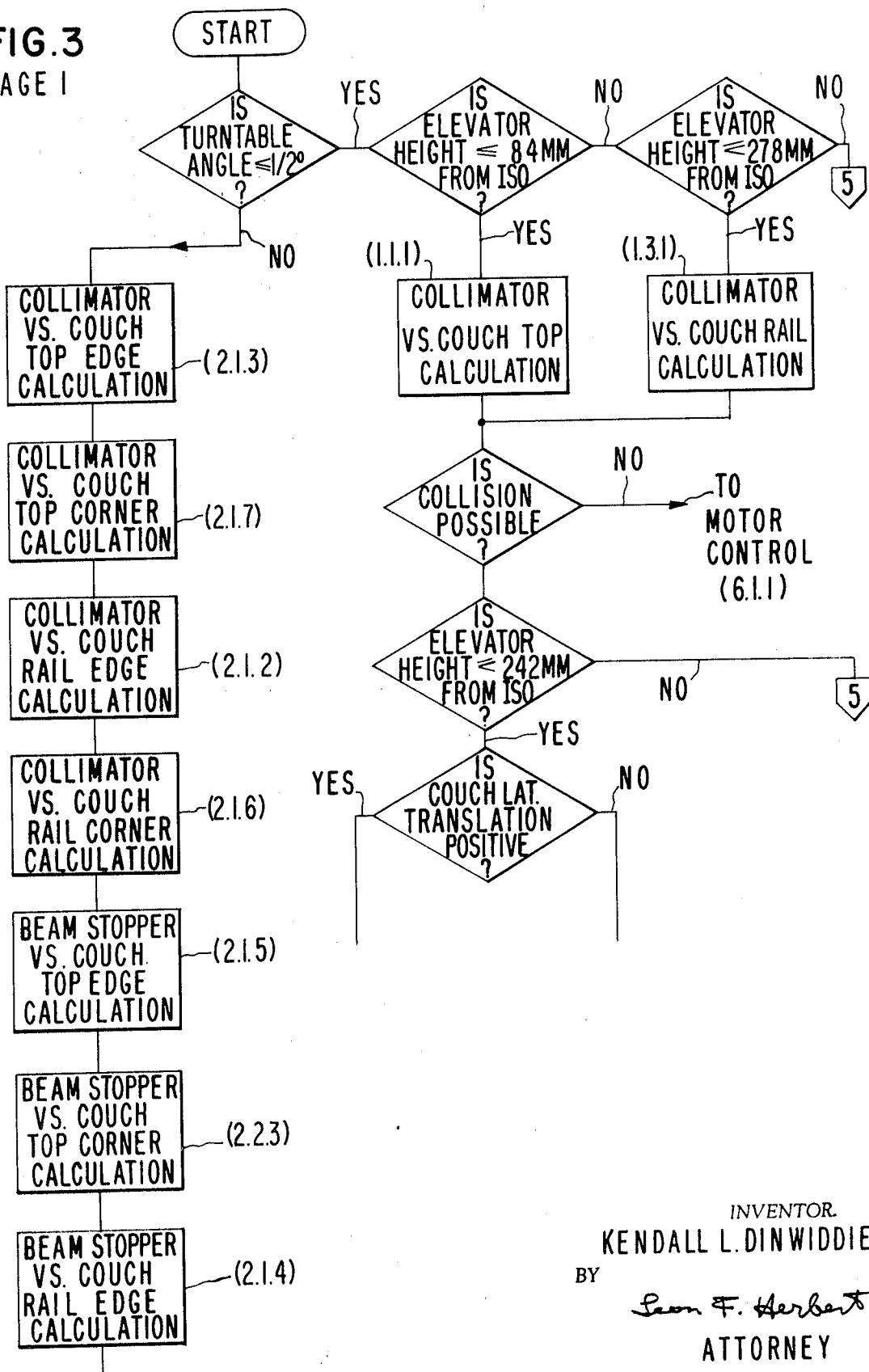


FIG. 3
PAGE 1



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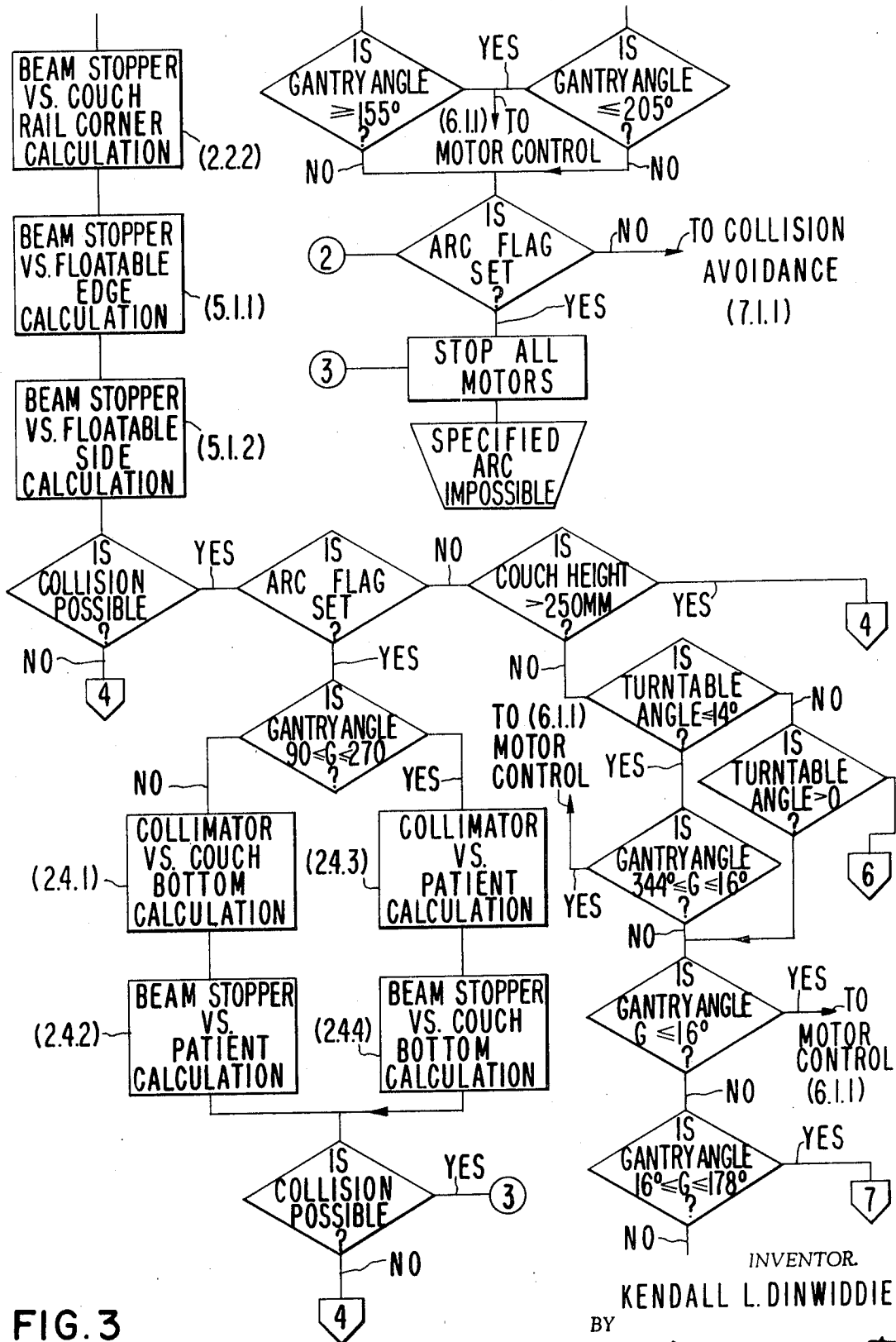
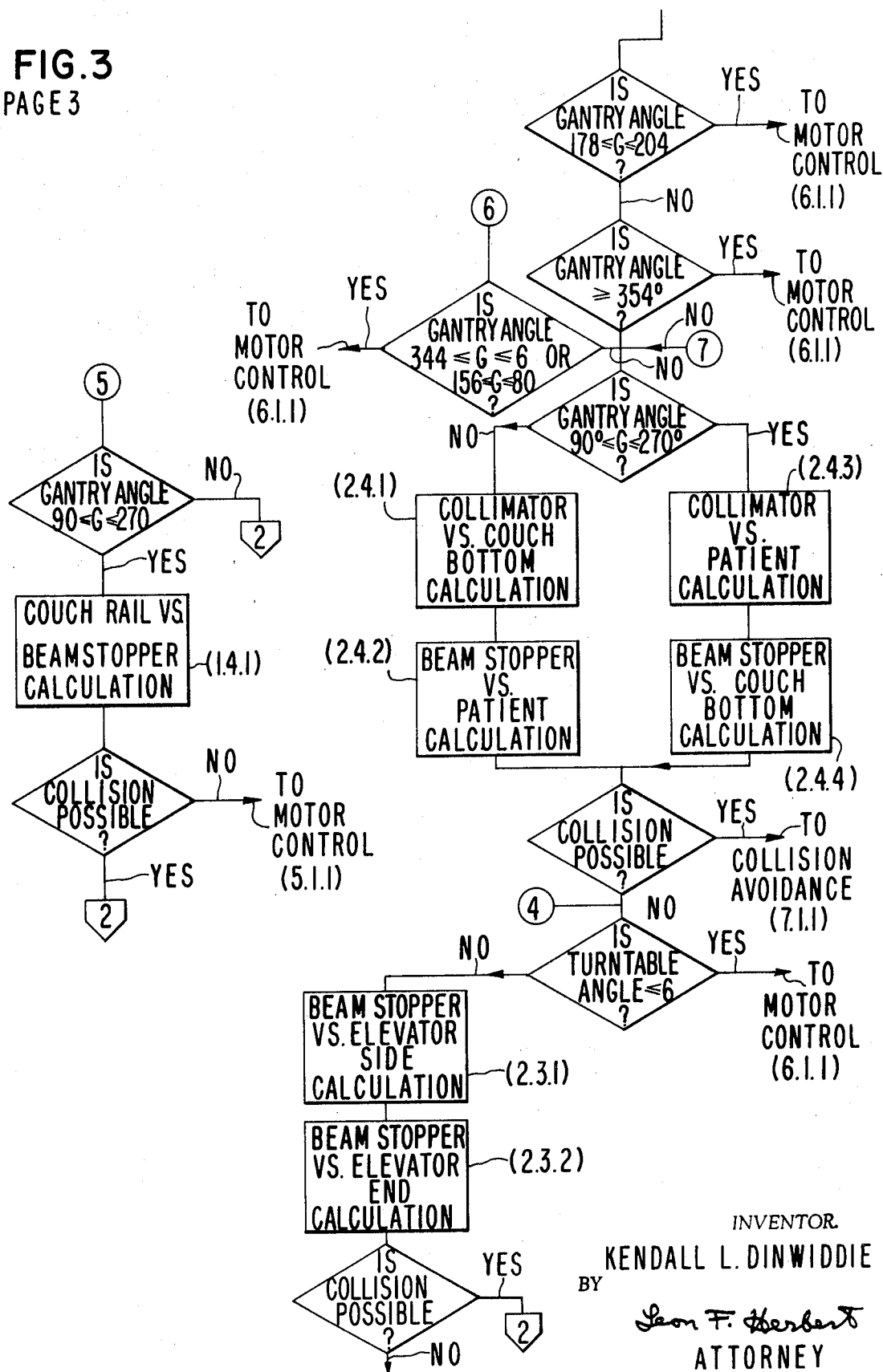


FIG. 3
PAGE 2

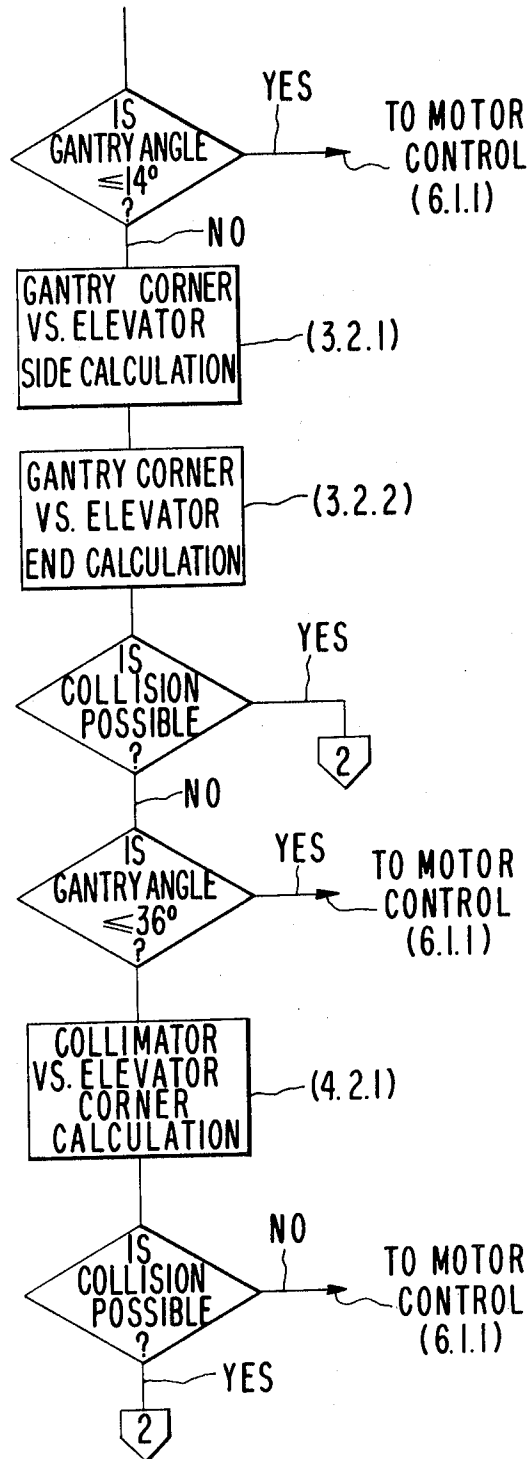
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FIG. 3
PAGE 3

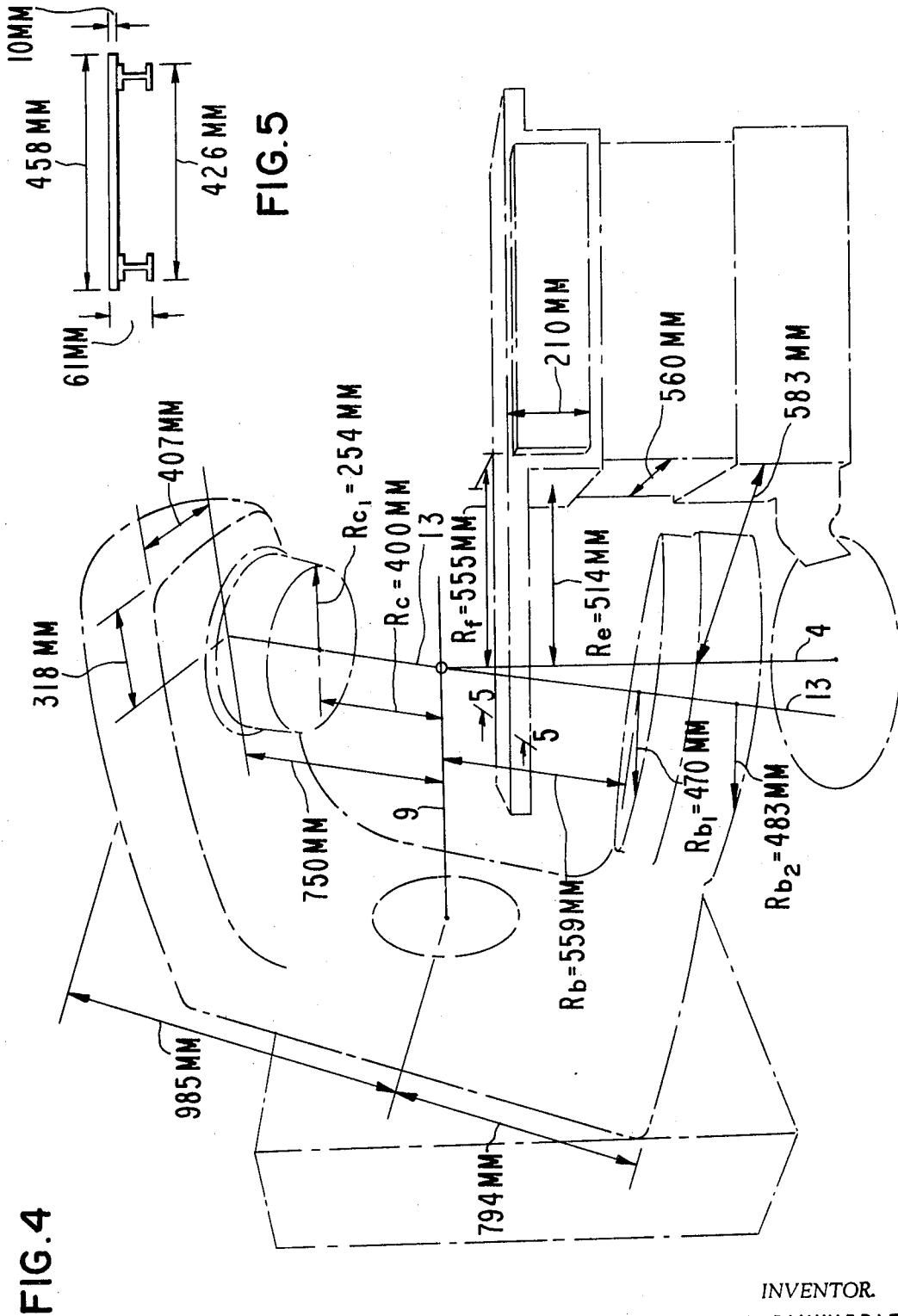


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FIG. 3
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AUTOMATED RADIATION THERAPY MACHINE

DESCRIPTION OF THE PRIOR ART

Heretofore, the geometrical setup of a radiation therapy machine has been automated for decreasing the setup time and improving the accuracy of the setup for a radiation therapy treatment. In the prior machine, the desired positional information of the machine for treatment of a patient was punched into cards, a deck of cards representing each geometrical setup for the gantry and couch. The cards were fed into a card reader, the output of the card reader being fed to control circuits, for sequentially controlling the motions of the gantry and couch for positioning the gantry relative to the couch to achieve a setup of the machine prior to radiation therapy. The cards were read sequentially and the setup motions of the gantry and couch were obtained sequentially.

The problem with the prior art automated radiation treatment machine was that the setup was obtained sequentially such that before motion of one element could be started the setup of another element must be completed. For example, rotation of the gantry had to be completed before rotation of the couch to the desired position. It is desired to reduce the setup time of the radiation therapy machine even more such that a greater number of patients can be treated for a given amount of machine time.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved automated radiation therapy machine.

One feature of the present invention is the provision of simultaneous setup motions of the gantry and treatment couch such that the setup time for the machine can be greatly reduced.

In another feature of the present invention, the couch and gantry are translatable over paths which interfere and the simultaneous motions of the gantry and the couch are monitored to determine and to give an output determinative of an impending collision between the couch and gantry.

In another feature of the present invention, means are provided for sensing an impending collision between the gantry and couch and the machine is controlled in such a way as to avert the impending collision while causing the gantry and couch to move to the desired setup positions.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram, partly in block diagram form, of an automated radiation therapy machine incorporating features of the present invention,

FIG. 2 is a schematic circuit diagram for deriving signals determinative of the position of the respective movable parts of the machine,

FIG. 3 is a program flow chart for a computer which controls the setup and avoids collision between the gantry and couch portions of the radiation therapy machine of the present invention,

FIG. 4 is a view similar to that portion of FIG. 1 delineated by line 4—4 showing dimensions, and

FIG. 5 is a sectional view of the structure of FIG. 4 taken along line 5—5 in the direction of the arrows.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a computer controlled radiation therapy machine incorporating features of the present invention. The radiation machine, such as a CLINAC IV made by Varian Associates, includes a couch 2 having a table portion 3 which receives the patient to be treated. The couch is rotatable about a vertical axis 4 by means of a turntable 5 to which the couch 2 is affixed. The couch includes an elevator portion 6 for translating the couch in the vertical direction Z. In addition, the couch 2 includes X and Y motorized drivers for translating the table 3 in the X and Y directions.

A generally C-shaped gantry 8 is rotatable by 359° about a horizontal axis 9. The gantry 8 is rotatably supported from a stand 11. A source of radiation, such as a linear accelerator producing a high energy electron beam which is directed against an X-ray producing target, produces a beam of X-rays emanating from a collimator head portion 12. The X-rays are directed out of the radiating head portion 12 in a beam having an axis 13 which intersects the gantry axis of rotation 9 at a position identified as the isocenter 14 which is also intersected by the turntable axis 4. The head portion 12 includes two sets of movable beam defining jaws which are movable to define the length L, and thickness T of the field of the X-ray beam as collimated by the beam defining jaws. The source 12 is enclosed in a barrel shaped collimator housing 15. The source housing 15, along with the beam defining jaws, are rotatable about the beam axis 13. The gantry 8 includes a beam stopping portion 16 disposed along the beam axis 13 and holding an X-ray absorbing material, such as lead, for stopping and absorbing the X-ray beam.

A digital computer 18, such as a Varian Data Machines model 620/i general purpose digital computer, is coupled to the radiation therapy machine 1 via the intermediary of a control cable 19 and an interface 21. The computer 18 includes a core memory portion 22 interconnected to a central processor 23 which includes the address and arithmetic unit. Sixteen channels of multiplexed analog-to-digital conversion 24 are provided for converting analog output signal derived from the radiation therapy machine 1 to digital form which are in-turn fed into the central processor 23 for use therein and in the memory 22. Eight digital-to-analog converters 25 are provided for converting digital output signals from the central processor 23 into analog signals which in-turn are fed into the radiation therapy machine 1 via the intermediary of the interface 21. Sensor and control lines 26 are provided for sensing and controlling functions of the radiation therapy machine 1 via the interface 21. A machine console 27 is coupled to the radiation therapy machine 1 and to the computer 18 via the machine interface 21.

A digital cassette tape unit 28 is coupled via suitable cables to the central processor 23 for reading digital data stored in the patient's individual cassette into the central processor 23 and memory 22. In addition, out-

puts from the processor are recorded back into the patient's cassette via the tape unit 28. A cathode ray tube/keyboard terminal 29 is coupled to the central processor 23 via cable 31 for displaying data read from the memory through the central processor and for controlling certain operations of the radiation therapy machine 1 via the computer 18.

Referring now to FIG. 2, there is shown one of the circuits for generating an analog positional signal determinative of the position of one of the variable parameters of the radiation machine 1, such as: gantry angle G, housing angle H, couch position in the X, Y, and Z directions, etc. The positional signal circuit of FIG. 2 includes a potentiometer 33, as of 10 K ohms, attached to the drive shaft 34 which generates the motion of the parameter being controlled, such that a full scale motion of the parameter being varied results in generating a full scale plus 10 volts to minus 10 volt analog output derived from the pick-off 36 of the potentiometer 33. -15 volts and +15 volts, respectively, are applied to opposite ends of the potentiometer 33 through trimming potentiometers 37 and 38 provided at the ends of the potentiometer 33. The trimming potentiometer provide for calibration of the range and end points for each positional output readout. One turn 0.25 percent linearity, 0.095 percent resolution potentiometers 33 are utilized on the beam collimator jaws, as position indicators. Ten turn 0.1 percent linearity, 0.019 percent resolution potentiometers 33 are provided for each of the other analog positional readouts.

Each of the motorized controlled motions of the radiation machine 1 is driven by a shunt-wound dc motor 39 operated by an SCR controller. With exception of the gantry rotation controller, each controller is open-loop providing full output in response to a 6-volt dc signal, decreasing to 0 output at 0.5 volts dc (± 0.5 volt dead band). The gantry speed control is closed loop, speed regulated, full speed output in response to a 12 volt dc input, again with ± 0.5 volt dead band. The turntable drive is equipped with a brake which is engaged when the input voltage to the motor controller is zero. The couch longitudinal and lateral motions have switch actuated electric clutches engaging their respective drives.

Control of each motion of the radiation therapy machine is obtained by direct digital control. Positions of each of the eight analog motions are sampled, by sampling the output of each potentiometer 33, every 50 milliseconds, 10 microseconds required for each sample. Sampling is controlled by the central processor 23 and is effected through the interface 21 to the positional control circuits of FIG. 2 coupled to the drive for each of the driven elements of the radiation therapy machine 1. The motions are sufficiently fast so as to alter their feedback from 0 to full scale in 15 seconds. Assuming a 12-bit plus sign analog-to-digital converter, the analog-to-digital converter output will vary a maximum of one least-significant bit in 3.6 milliseconds, allowing observation of at most four least-significant bit changes at every reading.

The core memory 22 has stored therein the permissible ranges of values for the various adjustable parameters of the radiation therapy machine 1. More particularly, the permissible values stored in the memory are as follows: gantry angle, G, 0 to 359°; turntable angle,

S, -90° to +90°; couch X direction travel, X, -856 to +544 millimeters; couch Z direction travel, Z, -20 millimeters to +560 millimeters; radiation head angle, H, -90° to +90°; X-ray beam field length, L, at 80 centimeters from the source, 0 to +320 millimeters; beam radiation field width, T, at 80 centimeters from the source, 0 to +320 millimeters. Also stored in the memory of the computer are: a range of permissible radiation dose times of 0 to 9.9 minutes; dose range of 0 to 999 rads; permissible wedge numbers 0 to 7; gantry stop angle, between 1 and 359°, for arc therapy; and rads per degree for arc therapy, between 0.50 and 5.00.

The output of the digital cassette tape unit 28 is fed into the central processor 23 and stored in the memory 22. The information transferred from the cassette to the memory of the computer includes the patient's identification number, his name, the diagnosis of his condition, the portal definition of eight separate radiation portals, each including an identifying numbers 1-8 and a definition of the quantities, G, S, X, Y, Z, H, L, T, dose, time, dose for each of the defined portals, whether the individual treatment will involve arc therapy, and if so the start and stop gantry angles G and the rads per degree, and information as to which if any wedge is to be employed and whether blocks are to be employed. In addition, information stored in the memory 22 from the patient's cassette, includes the sequence of how the portal definitions are to be administered, i.e., the treatment plan, the monitored cumulative dose per portal, and the total cumulative dose for the patient.

Once this information has been stored in the computer 18, the keyboard terminal 29 is actuated for displaying desired information from the memory on the display of the keyboard terminal 29. On a proper command from the keyboard terminal, the central processor 23, causes to be displayed from the memory 22, on the cathode ray tube display of the terminal 29, the next treatment to be given. For example a certain radiation portal is defined with the desired set points for the quantities of G, S, X, Y, Z, H, L, T, etc. Opposite the desired values for the aforementioned quantities, which define the treatment to be given, is displayed the corresponding present position of each setting of the radiation therapy machine 1. The present values are obtained from the outputs of the positional circuits of the type shown in FIG. 2 as converted to digital form via the analog-to-digital converters 24, and as fed to the display tube of the keyboard terminal 29 from the central processor 23. Upon depressing the proper command button of the keyboard terminal 29, the central processor 23 causes the positional signals to be monitored and to be compared with the desired position signals to derive error signals which are fed to the controllers for causing the radiation therapy machine 1 to take the positions defined by the treatment plan being executed.

When starting, each position is read, compared with its desired set point, and voltage applied to its controller in an ascending linear manner to full scale in order to provide "soft" acceleration and eliminate excessive current surge through upstream circuit breakers. The desired starting periods are determined empirically, suitable values include 500 milliseconds for gantry rotation, 200 milliseconds for couch elevator motion, and 100 milliseconds for all other motions.

An anti-collision program is stored in the memory 22 and the central processor 23 continually checks for the possibility of a collision between the gantry 8 and the couch 2 in a manner more fully disclosed below. Each controller has full voltage applied until either impending collision is detected or the respective movable element approaches its desired set point. As each desired set point is reached, the corresponding control voltage is reduced in a linear manner inside a proportional band until the indicated position is inside a tolerance band, typically 0.1 percent of full scale, at which time the control voltage is set to zero. Once again, values for proportional and tolerance bands are established empirically. When each motion has been brought to a stop at its respective set point, control returns to the display-input-output routines.

The anti-collision program examines all possible collision modes for the current combination of radiation therapy machine parameters. If safety envelopes around proximate members are invaded, all motions are stopped. The final increment above the actual physical dimensions for defining the safety envelope has been selected at approximately 1 inch. When imminent collision is detected and motions stopped, the program causes the four motional prime candidates for collision; namely, gantry rotation, couch rotation, couch lateral displacement, and couch elevation, to be moved briefly, i.e., for 5 seconds, toward their neutral positions. Then this motion is stopped, another attempt is made at the desired set points by causing the various motions to resume tracking toward their desired set points. If this new attempt is unsuccessful, all motion is stopped and the sequence repeats for a certain predetermined number, such as five times. If after five attempts collision is still imminent, all motions are stopped with finality and an error message is displayed on the cathode ray tube of the keyboard terminal 29.

Referring now to FIG. 3 and the four sheets of drawings included as a part thereof, there is shown the simplified flow chart for the collision avoidance program, showing the types of possible collisions, how their probability is determined, and the sequence of calculations made to determine impending collision.

In the program flow chart conventional nomenclature has been employed for designating the functions. More particularly, a diamond shaped box means a simple decision function, a rectangular box means a calculation. The numbers in parenthesis associated with each box is the algorithm employed in the calculation and is found in the table of algorithms below. The flow chart reads from top to bottom and from left to right. The home plate-shaped boxes indicate that the flow diagram continues on another page and the other page is entered at the circular box with the same number employed in the home plate box. If the flow diagram branch terminates with an arrow leading into a circular box with a number, the program continues on that same page above at the position marked with a circular box with the same number and with an arrow entering the box. The inverted trapezoid-shaped box indicates that a message is displayed on the CRT display 29, or printed, conforming to that message marked inside the box.

The control algorithm for automation of the radiation therapy machine 1 is designed to provide rapid simultaneous motion of the eight mechanical adjust-

ments of the radiation therapy machine to prescribed set points as provided in the treatment plan stored in the memory. Potential collision is monitored, prevented, avoided if possible, and if otherwise inevitable due to erroneous set points all motions are stopped and an error message is displayed. Each motion is sequentially "soft started" in order to avoid overloading the control circuits.

For the purposes of the anti-collision program the couch is defined to include a patient. It is assumed the patient occupies a volume of space above the table top 45.7 cm wide, 203.2 cm long, 25 cm high, flat ends, and with curved sides tangent to the side edge of the table top 3 and curving to the upper side of the patient zone with a radius of curvature of 40 cm.

The control algorithm is divided into four sections: (1) the control logic tree (2) collision testing sub-routines, (3) motion control sub-routine, and (4) collision avoidance sub-routine.

TABLE OF ALGORITHMS

(Dimensionless numbers are in millimeters)

(1.1.1) The main branch in the logic occurs based on whether the patient couch is aligned with the gantry axis (angle $S \leq \frac{1}{2}^\circ$). If so, and couch height (Z) is less than or equal to 84 mm, the most likely collision is between the collimator housing and the edge of the couch top which can occur if:

$$(Z + 10)^2 + [229 + |Y|]^2 > R_c^2$$

where Y represents couch lateral translation and R_c is the radius to the collimator housing from isocenter in millimeters. 10 is the thickness of the couch table top and 229 is half the width of the couch. If collision is impossible, the motion control sub-routine (6.1.1) is called.

(1.3.1) If $S = 0$ but Z is between 84 and 278 mm, the most likely collision is between the collimator housing and the edge of a couch rail, possible if:

$$(Z + 61)^2 + [213 + |Y|]^2 > R_c^2$$

If collision is not possible, the motions control sub-routine (6.1.1) is called. 61 is the thickness of the rail and table and 213 is half the distance between the outer edges of the rails.

(1.4.1) If rail/collimator collision is possible, Z is greater than 242 mm, and G is between 90° and 270° , the possibility of collision between the couch rails and the beamstopper is examined:

$$(Z + 61)^2 + [213 + |Y|]^2 > R_b^2$$

where R_b is the radius to the beamstopper from isocenter in millimeters.

(2.1.2) Couch rail edge and collimator housing:

$$[(|Y| + 213) \times |\sec(s)| + 254 |\tan(s)|]^2 > R_c^2 - (Z + 61)^2$$

(2.1.3) Couch top edge and collimator housing:

$$[(|Y| + 213) \times |\sec(s)| + 254 |\tan(s)|]^2 > R_c^2 - (Z + 10)^2$$

(2.1.4) Couch rail edge and beamstopper:

$$[(|Y| + 213) \times |\sec(s)| + 470 |\tan(s)|]^2 > R_b^2 - (Z + 61)^2$$

(2.1.5) Couch top edge and beamstopper:

$$[(|Y| + 229) \times |\sec(s)| + 470 |\tan(s)|]^2 > R_b^2 - (Z + 10)^2$$

(2.1.6) Couch rail corner and collimator housing:

$$[(|Y| + 213) \times |\cos(s)| + X |\sin(s)|]^2 > R_c^2 - (Z + 61)^2$$

(2.1.7) Couch top corner and collimator housing:

$$[(|Y| + 229) \times |\cos(s)| + X |\sin(s)|]^2 > R_c^2 - (Z + 10)^2$$

(2.2.2) Couch rail corner and beam stopper:

$$[(|Y| + 213) \times |\cos(s)| + X |\sin(s)|]^2 > R_b^2 - (Z + 61)^2$$

(2.2.3) Couch top corner and beam stopper:

$$[(|Y| + 229) \times |\cos(s)| + X |\sin(s)|]^2 > R_b^2 - (Z - 10)^2$$

(2.3.1) Beam stopper and elevator side:

$$R_b(1 - \Delta) - 280 |\sec(s)| |\csc(G)| - R_{b1}(1 + \Delta) |\tan(s) \cos(A) + \cos(G) \sin(A)| |\csc(G)| < 0$$

where:

$A = ATN [|\cot(s)| |\cos(G)|]$, Δ is a cushion factor of 1", 280 is half the elevator width, R_{b1} is the radius of the beam stopper in mm and if $S > 17^\circ$; and

$$R_b(1 - \Delta) |\sin(G)| - R_{b1}(1 + \Delta) |\sin(B)| - 585 |\sin(s)| < 0$$

where

$$B = ATN [|\tan(A)| |\cos(G)|] \text{ and}$$

$$A = \frac{ACS[585] |\cos(G)|}{R_{b1}(1 + \Delta)}$$

if $6^\circ < s < 17^\circ$

(2.3.2) Beam stopper and elevator end:

$$R_c |\csc(s)| - 794 |\sin(G)| - R_{b2}(1 + \Delta) [\cos(A) |\cot(s)| + \sin(A) |\cos(G)|] < 0$$

where

$A = ATN [|\tan(s)| |\cos(G)|]$ and R_c is the radius from turntable axis to the elevator end, and R_{b2} is the radius of the farside of the beamstopper from beam axis 13.

(2.4.1) If G is between 270° and 90° , collimator housing and couch rail:

$$R_c |\cos(G)| - R_{c1}(1 + \Delta) |\sin(G)| < Z + 61$$

where

R_{c1} is the radius of the collimator housing

(2.4.2) Beamstopper and patient:

$$R_{b1}(1 + \Delta) |\sin(G)| - R_b(1 - \Delta) |\cos(G)| > Z - 250$$

where

250 is the assumed thickness of the patient

(2.4.3) If G is between 90° and 270° , collimator housing and patient:

$$R_{c1}(1 + \Delta) |\sin(G)| + R_c(1 - \Delta) |\cos(G)| > Z - 250$$

(2.4.4) Beamstopper and couch rail:

$$R_b(1 - \Delta) |\cos(G)| - R_{b1}(1 + \Delta) |\sin(G)| < Z + 61$$

(3.2.1) Gantry corner and elevator side:

$$750 |\sin(G)| - 407 |\cos(G)| |\cos(s)| - 318 |\sin(s)| - 280 < 0$$

(3.2.2) Gantry corner and elevator end:

$$[514 |\sec(s)| - 318 |\cot(s)| - 985 |\sin(G)| - 407 |\cos(G)|] < 0$$

(4.2.1) Collimator housing and elevator corner:

Collision imminent if $S > 36^\circ$ and G is between 80° and 90° or $S > -36^\circ$ and G is between 270° and 280° . If this test indicates impending collision and the arc flag is not set, the collision avoidance sub-routine is called. If the arc flag is set and collision is indicated, the program

exits with an error message display. If no collision is possible, the motion control sub-routine is called.

(5.1.1) Beamstopper vs. float table edge:

$$[(|Y| + 280) |\sec(s)| + 470 |\tan(s)|]^2 > R_b^2 - (Z + 210)^2$$

(5.1.2) Beamstopper vs. float table sides:

$$R_b(1 - \Delta) - (280 + |Y|) |\sec(s)| |\csc(G)| - R_{b1}(1 + \Delta) |\tan(s) \cos(A) + \cos(G) \sin(A)| |\csc(G)| < 0$$

where

$$A = ATN [|\cot(s)| |\cos(s)|]$$

(6.1.1) Motion control sub-routine

Monitors each of the eight mechanical positions and compares each against its respective setpoint. Each motion is assigned a tolerance band and a proportional control band. For each motion, if the error between the setpoint and measured position exceeds the tolerance band, voltage is applied to direct the motion toward the setpoint. If no control voltage is currently being applied, a timed voltage increase to maximum is applied to provide "soft" acceleration, thereby reducing peak current to within the limits of the control circuitry. Proximity to each setpoint is continually monitored, and when a motion moves within the proportional control band, control voltage is reduced linearly to zero within the tolerance band.

(7.1.1) Collision avoidance sub-routine first stops all mechanical motions and resets a counter. For a timed interval, the turntable, gantry and couch X and Z motions are driven toward their respective zero positions. Another attempt is then made to achieve the intended setup. If, after a preset number of trials imminent collision remains indicated, all motions are stopped and an error message displayed.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In a radiation apparatus, couch means for supporting a patient to receive radiation, radiation source means for directing a beam of radiation onto the patient, rotatable support means for supporting said radiation source, means for rotating said support means in a locus of points about said couch means, means for translating said couch means relative to the locus of points traversable by said support means, means for establishing signals corresponding to prescribed positions of said support means and said couch means, means for generating positional signals representative of the actual positions of said support means and said couch means, means for comparing the respective prescribed position signals with the respective actual position signals to derive control signals, and means for applying the control signals to said support rotation means and said couch translation means for simultaneously rotating and translating said support and couch means to the desired positions, whereby the setup time to set the prescribed positions of said support means and said couch means is minimized, and wherein said couch means is translatable over a locus of points in interference with the locus of points traversable by said

support means such that collisions between said couch means and said support means is possible, means for monitoring simultaneous translation of said couch and support means, taking into account the prescribed positional signals for said support and couch means, for determining when said support and couch means are on collision courses and producing an output determinative of the collision course.

2. The apparatus of claim 1 including, means responsive to the collision determinative output signal for controlling said support rotation means and said couch translation means for averting the collision.

3. The apparatus of claim 2 wherein said control means responsive to the collision signal for averting the collision includes, means for stopping translation of said support and couch means, and means for con-

trolling said support and couch translating means for translating said support and couch means toward predetermined neutral positions for a given time, and means for causing said support and couch means to resume tracking towards the prescribed positions.

4. The apparatus of claim 5 wherein said control means for averting the collision includes, computer means programmed to avert the collision.

5. The apparatus of claim 3 wherein said control means for averting the collision includes, computer means programmed for averting the collision.

6. The apparatus for claim 1 wherein said means for determining when the said support and couch means are on collision courses includes, computer means programmed to determine such collision.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,720,817
DATED : March 13, 1973
INVENTOR(S) : KENDALL L. DINWIDDIE

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 10, line 6: change "5" to --2--

Signed and Sealed this

fifth Day of August 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

PC-100
5/8

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,720,817 Dated March 13, 1973

Inventor(s) KENDALL L. DINWIDDIE

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the Abstract page, on the line reciting the name of the assignee:

Change: "Jarian" to --Varian--.

Signed and sealed this 2nd day of July 1974.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents