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Pavkovich [45] **Dec. 4, 1973**

[54] **COMPUTER ASSISTED RADIATION THERAPY MACHINE**

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[73] Assignee: **Varian Associates**, Palo Alto, Calif.

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[52] **U.S. Cl.** **235/151,** 250/61.5, 250/95
[51] **Int. Cl.** **G06f 15/42,** A61n 5/00
[58] **Field of Search** .... 235/151, 61.6 H; 250/61.5

[56] **References Cited**

FOREIGN PATENTS OR APPLICATIONS

831,597 1/1970 Canada 235/151

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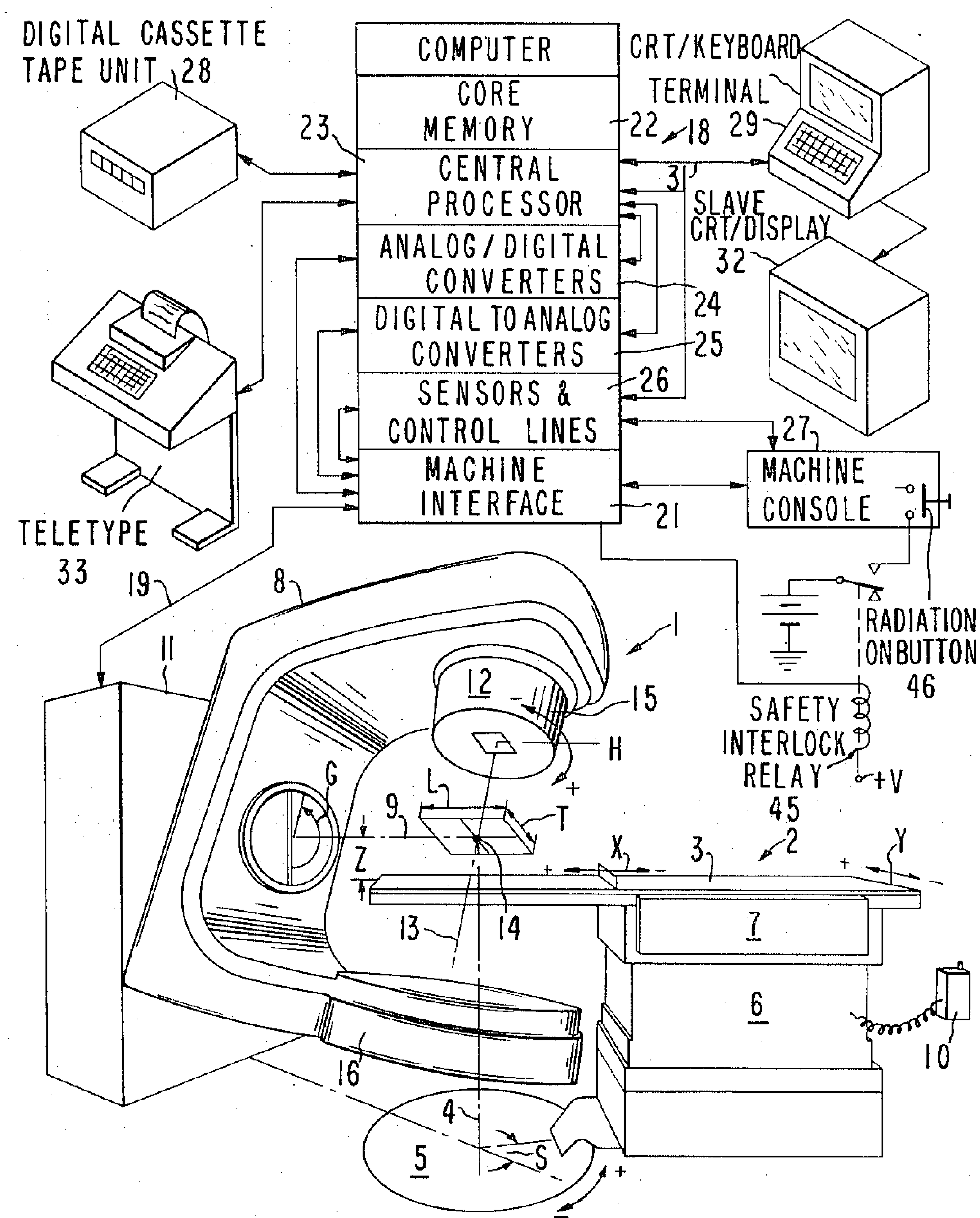
[57] **ABSTRACT**

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. Geometric and dose parameters defining a prescribed treatment plan of radiation are stored in the memory of the computer. Positional signals are derived from the various movable controls and parts of the radiation machine. The prescribed treatment parameters are compared with the actual positionings of the elements and controls of the machine to derive an interlock output when at least one of said actual parameters differs from the respective prescribed parameter. The interlock output is employed to inhibit application of radiation to the patient until the mistake is rectified.

8 Claims, 4 Drawing Figures



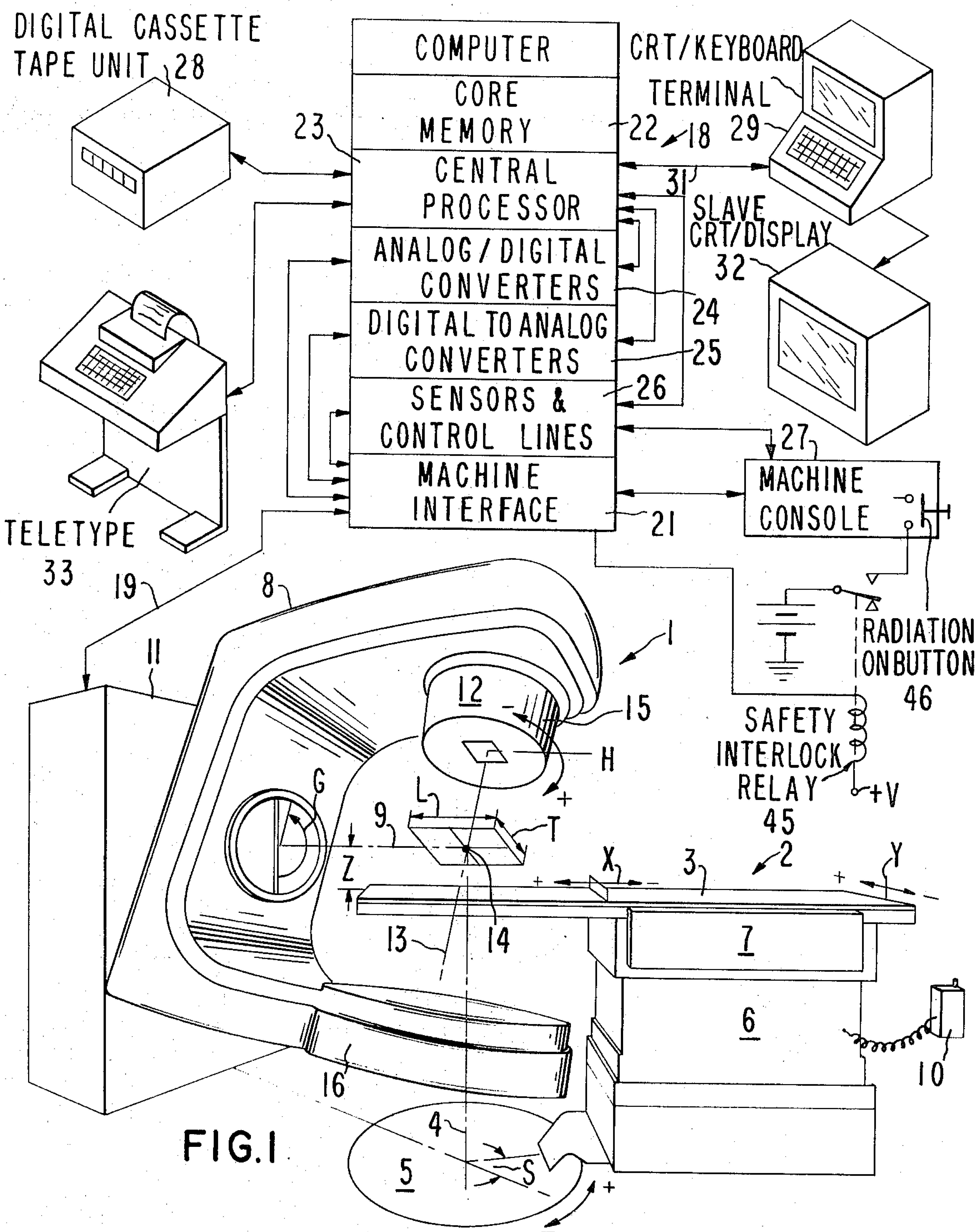
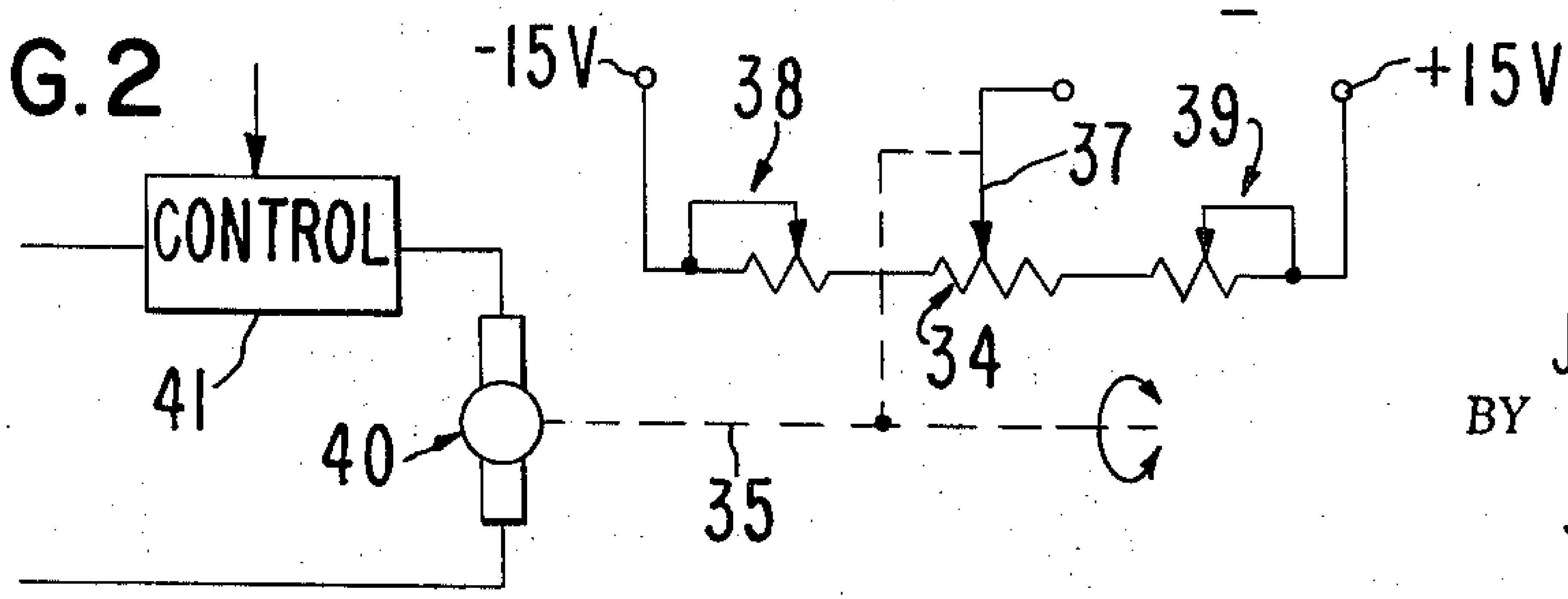


FIG.1

FIG.2



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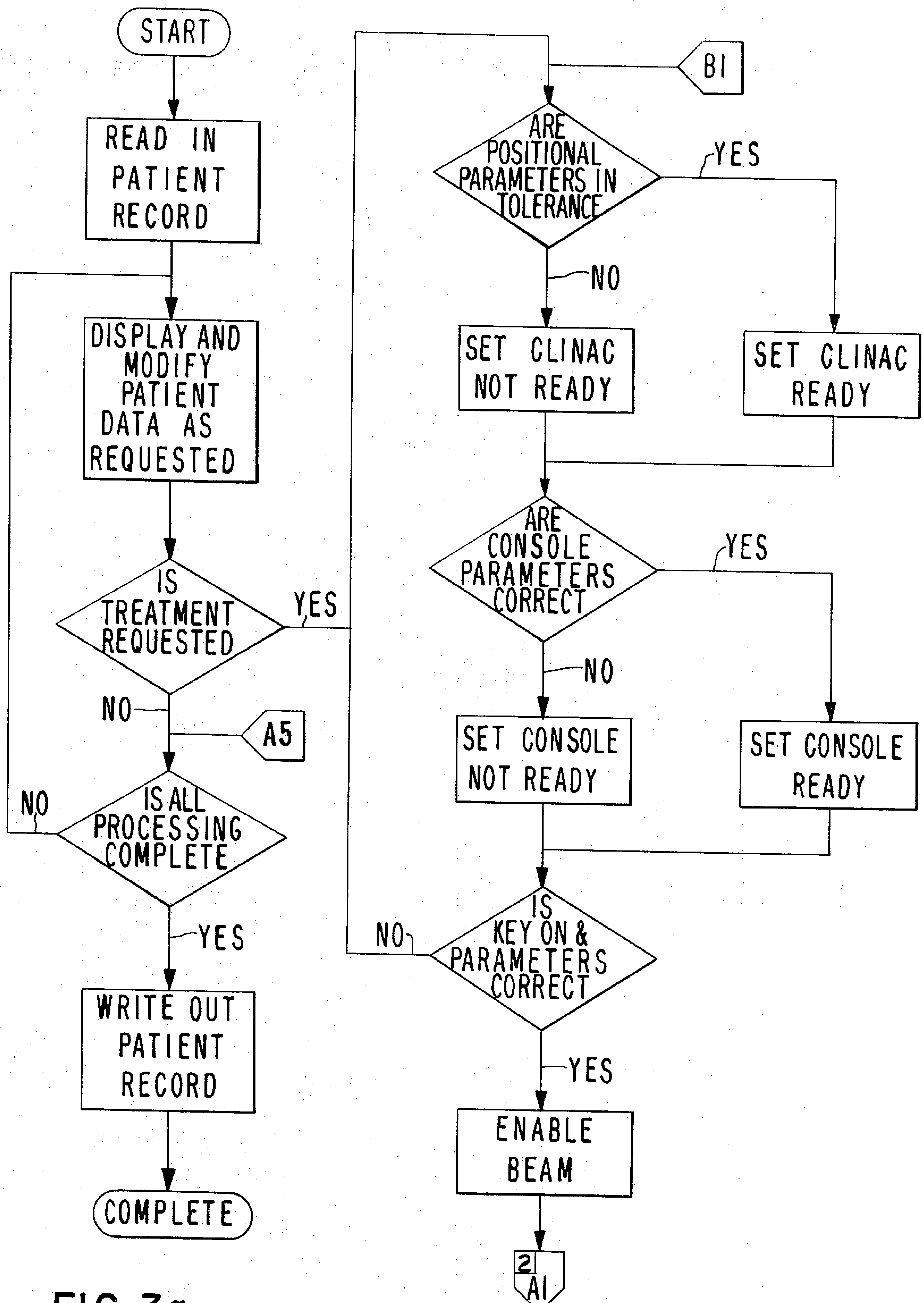
START
READ IN PATIENT RECORD
DISPLAY AND MODIFY PATIENT DATA AS REQUESTED
IS TREATMENT REQUESTED
YES
NO
A5
IS ALL PROCESSING COMPLETE
NO
YES
WRITE OUT PATIENT RECORD
COMPLETE
B1
ARE POSITIONAL PARAMETERS IN TOLERANCE
YES
NO
SET CLINAC NOT READY
SET CLINAC READY
ARE CONSOLE PARAMETERS CORRECT
YES
NO
SET CONSOLE NOT READY
SET CONSOLE READY
IS KEY ON & PARAMETERS CORRECT
NO
YES
ENABLE BEAM
2
A1

FIG. 3a

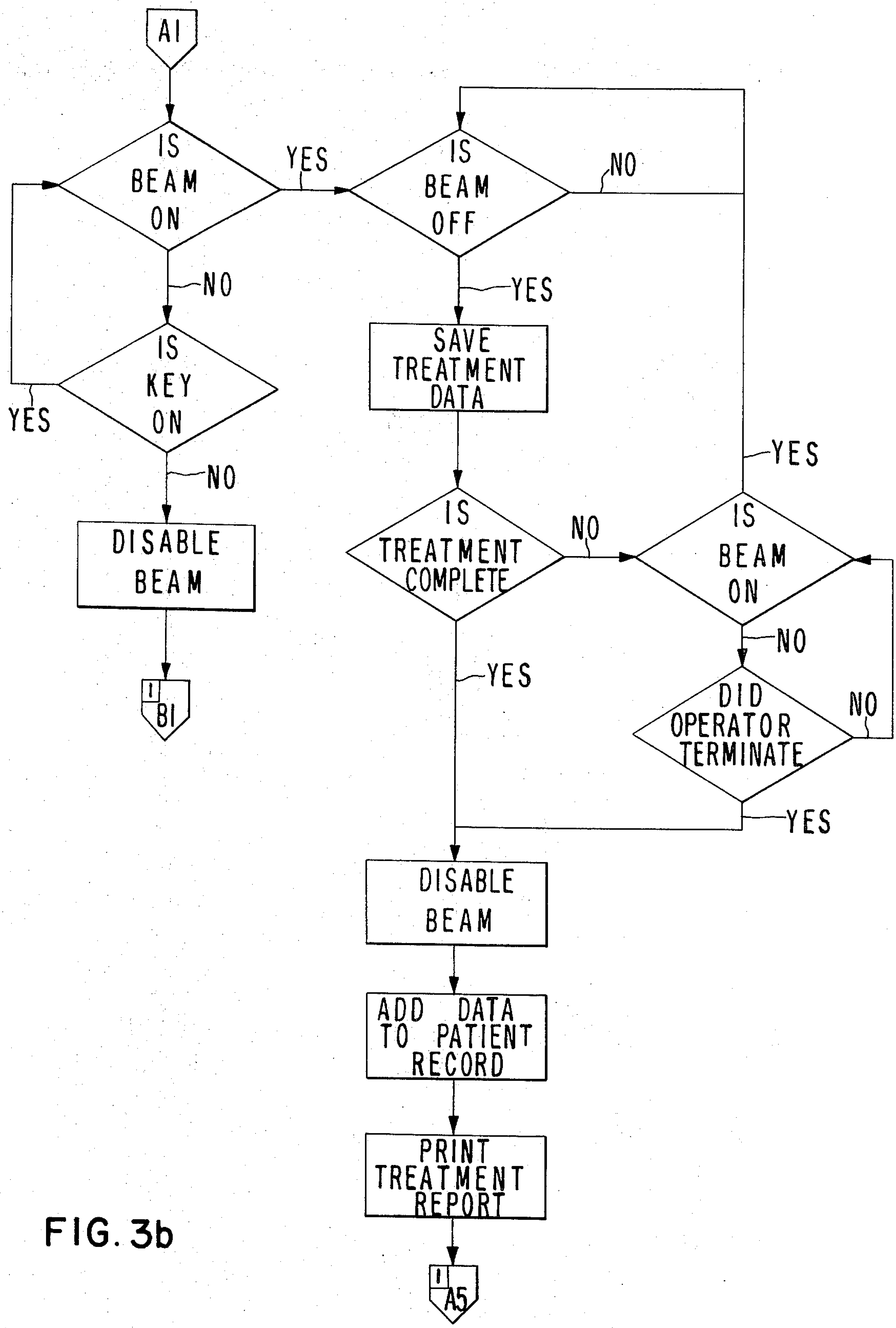
A1
IS BEAM ON
YES
NO
IS KEY ON
YES
NO
DISABLE BEAM
1 B1
IS BEAM OFF
NO
YES
SAVE TREATMENT DATA
IS TREATMENT COMPLETE
NO
YES
IS BEAM ON
YES
NO
DID OPERATOR TERMINATE
NO
YES
DISABLE BEAM
ADD DATA TO PATIENT RECORD
PRINT TREATMENT REPORT
1 A5

FIG. 3b

COMPUTER ASSISTED RADIATION THERAPY MACHINE

DESCRIPTION OF THE PRIOR ART

Heretofore, the mechanical setup of a radiation therapy machine has been automated for decreasing the setup time and improving the accuracy of the mechanical setup for a radiation therapy treatment. In the prior machine, the desired positional information for the mechanical setup of the machine was punched into cards according to a prescribed plan of treatment. A deck of cards representing the setup for the prescribed plan of treatment was fed into a card reader. The output of the card reader was fed to control circuits for sequentially controlling the mechanical motions of various movable parts of the machine for geometrically positioning the gantry and treatment couch according to the prescribed plan of treatment. A four digit visual display was provided for displaying the position of each of the mechanically movable elements of the radiation therapy machine.

While the aforecited automated radiation therapy machine substantially decreased the setup time and improved the accuracy of the setup, it still leaves room for operator error or machine error, as the operator must compare the readout positions of the various movable elements against a treatment plan to see that each of the elements is in the desired position. In addition, the operator must set the treatment time for the radiation dose according to the treatment plan, thereby introducing further chance of error.

It is desired to obtain an improved automated radiation therapy machine which automatically checks the geometric and control setup of the radiation therapy machine against a prescribed treatment plan to render an output indicative of a discrepancy therebetween, whereby operator errors are minimized.

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 means for automatically checking the setup of the radiation machine against a prescribed plan of treatment and noting any discrepancies therebetween and initiating an interlock output which inhibits application of radiation to the patient until the discrepancy between the treatment plan and the actual settings of the machine have been eliminated, whereby treatment mistakes are minimized.

Another feature of the present invention is the same as the preceding feature wherein the means for automatically comparing the treatment plan against the actual settings of the machine comprises a programmed general purpose computer.

In another feature of the present invention, display means are provided for displaying to the operator the prescribed treatment plan and the actual settings of the radiation machine such that the operator is readily apprised of any discrepancies therebetween.

In another feature of the present invention, the prescribed settings for the radiation therapy machine are recorded on storage means, such as magnetic tape, disc or paper tape, and the machine includes means for reading the prescribed settings of the machine from the storage.

In another feature of the present invention, the prescribed settings of the machine for administering a certain treatment are read from a treatment storage means and fed into the memory of the computer. The computer is programmed to read the prescribed machine settings from its memory for comparison with the actual settings of the machine.

Other features and advantages of the present invention will become apparent upon 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 settings of the respective variable parameters of the radiation therapy machine, and

FIGS. 3*a* and 3*b* are a computer program flow chart for the computer assisted radiation therapy machine of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, there is shown a computer controlled radiation therapy machine incorporating features of the present invention. The radiation machine 1, such as a CLINAC[R] radiation therapy machine model 4 or 35, commercially available from Varian Associates, or a THERATRON 80 automated cobalt 60 radiation machine made by Atomic Energy of Canada Limited of Ottawa, Canada, includes a couch 2 having a table portion 3 which receives the patient to be treated. The couch 2 is rotatable about a vertical axis 4 by means of a turntable 5 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 includes motorized drives for translating the table 3 in the lateral Y direction and longitudinal X direction. A control pendant 10 is connected to the couch 2 via suitable cable for manual control of the various portions of the radiation machine 1 and for allowing automatic control of the radiation machine 1 by the computer.

A generally C-shaped gantry 8 is rotatable by 359° about a horizontal axis 9. The gantry 9 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 target, produces a beam of X-rays emanating from a collimator head portion 12. As an alternative, in the case of the cobalt machine, the cobalt serves as a source of X-ray radiation, and is housed within the 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, as of lead, 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 beam defining jaws, are rotatable about the beam axis 13. The gantry 8 includes a beam stopping portion 16 disposed along the X-ray 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 Machine 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 units. 16 channels of analog-to-digital converters **24** are provided for converting analog output signals derived from the radiation therapy machine **1** to digital form which are in-turn fed into the central processor **23** for use therein and for use in the memory **22.** Eight channels of 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 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.**

The Varian data machines 620/i computer **18** is a system oriented digital computer. It has a total memory capacity of 12,388 words of 16 or 18 bits and is plug-in expandable. The memory is magnetic core with 1.8 microseconds full cycle and 700 nanoseconds access time. The arithmetic is parallel, binary, fixed points, 2's complement. It has seven addressing modes and over 100 standard instructions. In addition, to the standard equipment which comes with the Varian 620/i computer, the computer **18** includes, a 620/i expansion chassis, two 620/i memory modules providing an extra 8,192 words, a 620/i–17 optional package, a 620/i–51 paper tape reader, an acquisition and control unit, and the 620/i machine interface **21.**

The 620/i–17 optional package contains hardware multiply/divide, extended addressing, real time clock, power fail/restart, and eight level priority interrupts. The 620/i–51 accessory is a high speed paper tape reader which provides for rapid means to load the memory should a program be lost or scrambled for some reason. It is an input device only and will not punch. It reads at 300 characters per second. The acquisition and control unit contains the following: 7 or 12 bits plus sign programmable sample-and-hold, 16 channels or multiplexed analog-to-digital conversion **24,** and the 8 channels of 9 bit plus sign digital-to-analog converters **25** plus 16 sense and 8 control lines **26.** In addition, the acquisition and control unit contains the BCD registers and controller for the BCD information available from the radiation machine **1.**

A digital cassette tape unit **28,** such as a model 100 COMPUCORDER available from Datatronics, Inc. of Rochester, N.Y., is coupled by 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, outputs from the processor **23** are recorded back into the patient's cassette via the tape unit **28.** A cathode ray tube/keyboard terminal **29,** such as a model ALPHA 103A CRT/ keyboard terminal, commercially available from Beehive Medical Electronics, Inc. of Salt Lake City, is coupled to the central processor **23** via cable **31** for displaying data read from the memory **22** through the central processor **23** and for controlling certain operations of the radiation therapy machine **1** via the computer **18.**

The CRT terminal **29** forms the major input-output device for the computer **18** and includes an alpha numeric display. It has a standard typewriter keyboard and four-way cursor control. In addition, it has an 11 inches CRT screen with 20 lines and 40 characters per line. The CRT terminal **29** has type-over capability using the cursor as well as line-erase and screen-clear. It has its own internal character generator with **64** characters ASC II set. A remote slave cathode ray tube (CRT) **32** is provided for remote data observation. A standard ASR **33** teletype unit is coupled to the central processor **23** via suitable cables to provide a hard copy printout and to serve as a backup input for the CRT/keyboard terminal **29** and for the paper tape reader accessory of 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 **34,** as of 10 k ohms, attached to the drive shaft **35** via mechanical coupling **36.** Drive shaft **34** generates the motion of the parameter being controlled, such that a full-scale motion of the parameter being varied or controlled results in generating a full scale +10 volts to −10 volts analog output deprived from the pickoff **37** of the potentiometer **34.** −15 volts and +15 volts, respectively, are applied to opposite ends of the potentiometer **34** through trimming potentiometers **38** and **39** provided at the ends of the potentiometer **34.** The trimming potentiometers **38** and **39** provide for calibration of the range and the end points for each positional output readout. One turn 0.25 percent linearity, 0.095 percent resolution potentiometers **34** are utilized on the beam collimator jaws, and position indicators. Ten turn 0.1 percent linearity, 0.019 percent resolution potentiometers **34** are provided for each of the other analog positional readouts.

Each of the motorized control motions of the radiation machine **1** is driven by a shunt-wound dc motor **40** operated by an SCR controller **41.** 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 dead band volts). The gantry speed control is closed loop, speed regulated, full speed output in response to a 12-volt dc input, against with ±0.5 dead band volts. The turntable drive is equipped with a brake which is engaged when the input voltage of 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 **1** is obtained by direct digital control. Positions of each of the eight analog motions are sampled, by sampling the output of each potentiometer **34,** 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 FIGS. **2** coupled to the drive **35** for each of the driven elements of the radiation therapy machine **1.** The driven motions are sufficiently fast so as to alter their feedback from zero to full scale in 15 seconds. Assuming a 12-bit plus sign analog-to-digital converter output will vary a maximum of one least-signifant bit in 3.6 milliseconds, allowing observation of at most four least-significant bit changes at every reading.

Each patient has in his file a digital type cassette. For treatment of a patient, his cassette is loaded into the tape unit 28 and a command from the keyboard terminal 29 causes the tape to be read into the central processor 23 and stored in the memory 22 of the computer 18. The information transferred from the cassette to the memory 22 of the computer 18 includes the patients identification number, his name, the diagnosis of his condition, the portal definition of eight separate radiation treatment portals, each including an identification number 1–8 and a definition of the quantities, G, S, X, Y, Z, H, L, T, and 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. Wedges serve to shape the intensity of the radiation beam, and blocks serve to protect certain portions of the patient being treated for radiation emanating from the beam. In addition, information stored in the memory 22 from the patient's cassette, includes a 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 22 on the display of the keyboard terminal 29. On a proper command from the keyboard terminal 29, the central processor 23 causes to be displayed, from the memory 22, on the cathode ray tube display 29, the next treatment to be given. For example, a certain radiation portal is defined on the visual alphanumeric CRT display, with the prescribed set points for the quantities of G,S,X,Y,Z,H,L,T, etc. Opposite the prescribed values for the aforementioned quantities, which define the treatment to be given, is displayed the corresponding present position of each of the settings of the radiation therapy machine 1. Positional values are obtained from the output 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 sent to the display tube of the keyboard terminal 29, from the central processor 23. Upon depressing the proper command button on the machine control pendant 10, the central processor 23 causes the actual positional signal to be monitored and to be compared with the prescribed positional signal 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.

An anti-collision program is stored in the memory 22 and the central processor, in conformance with the program, continually checks for the possibility of a collision between the gantry 8 and the couch 2. If imminent collision is determinted, an anti-collision subroutine is executed to avert the collision. The radiation machine is positioned in accordance with the predetermined prescribed plan. The geometric set points can be achieved in less than 30 seconds because all of the geometric motions of the radiation machine are obtained simultaneously.

As each of the geometric parameters achieves its set point, the set point value is displayed on the cathode ray tube opposite the corresponding prescribed value for the treatment plan being executed. Thus, all the set point values for the quantities G, S, X, Y, Z, H, L, and T are achieved automatically and presented automatically. The planned values for dose, time, rads per degree, stop angle, wedge and blocks are displayed but these adjustments are made manually from the machine console 27. Each of the manual adjustments from the machine console 27 has a BCD positional output signal generator of conventional design coupled thereto in the conventional manner. As the manually adjustable parameters are set, the corresponding positional value is fed into the computer 18 and presented on the display adjacent the planned value. Each wedge and block is separately coded with electrical connections and electrical connections are made to these coded connections for feeding an input signal to the computer 18 corresponding to the particular wedge or block employed. Thus wedge and block information is also fed to the computer and presented on the display 29.

The computer 18 is programmed to compare the prescribed value for all of the aforementioned geometric and other machine parameters against the set point values achieved for each of the adjustable parameters. If all of the prescribed values do not conform to the set point values, the computer 18 generates an interlock output signal which is fed via the machine interface 21 to actuate a relay 45 which opens a circuit in the machine console 27 and prevents energization of the radiation ON button 46 in the machine console 27 such that the beam of radiation cannot be turned onto the patient until all of the actual set point values for the variable parameters of the radiation machine conform to the prescribed values. This greatly reduces the probability of the operator making a mistake and delivering a dose of radiation to the patient which is not called for by the prescribed treatment plan. Tolerances in the mechanical settings can be built into the system to compensate for uncertainties in patient positioning on the treatment couch 2.

Throughout the treatment, the computer 18 monitors the radiation machine parameters and gives constant feedback to the therapist and technologist. After treatment, the patient status information on the cassette is updated by updating the patient treatment plan in the memory 22 and transferring the updated information from the memory 22 of the computer 18 to the patient's cassette. A hard copy printout of the administered treatment details is readout of the updated memory and typed by the teletype 33.

Any detail of the prescribed overall radiation treatment plan or any one of the prescribed parameters of an individual portal descriptions can be easily changed during the course of treatments. The operator pushes an EDIT button on the CRT keyboard terminal 29 and types in the appropriate change at the keyboard. Two levels of edit capability are incorporated. Certain major changes, such as overall treatment plan, can only be initiated by supervisory personnel with a special access key which serves to complete an interlock circuit in an interface between the CRT/keyboard terminal 29 and the central processor 23. If the therapist desires periodic examination before certain treatments can be administered to the patient, he can require that some one of supervisory rank be present at a given treatment by typing in an appropriate legend in the overall treatment plan.

The radiation head portion **12** of the radiation therapy machine **1** includes a dosimeter for monitoring the dose of radiation as given. The output from the dosimeter is employed for measuring the dose given and for updating the cumulative total of radiation given at each radiation portal and the total cumulative radiation given for all portals. This update information is transferred from the computer to the patient's cassette upon termination of each treatment. In this manner, all the information for an updated treatment plan is recorded in the patient's individual cassette. A computer program flow chart for the aforedescribed computer program is shown in FIGS. 3*a* and 3*b*.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made wihout 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.

RELATED CASES

The simultaneous motion and anti-collision program are described and claimed in copending U.S. application Ser. No. 93,327 filed Nov. 27, 1970, the feature of editing and updating the treatment plan is disclosed and claimed in copending U.S. application Ser. No. 93,331 filed Nov. 27, 1970, both applications are assigned to the same assignee as the present invention.

What is claimed is:

1. In a radiation therapy apparatus, couch means for supporting a patient to receive radiation, radiation source means for applying radiation to the patient, means for supporting and moving said radiation source means about said couch means, means for establishing outputs corresponding to prescribed positions of said source means and said couch to define a prescribed treatment plan of radiation for the patient, means for generating positional outputs representative of the actual positions of said couch and radiation source means, means for comparing the prescribed positional outputs of said radiation source means and said couch means with actual positional outputs of said radiation source and couch means to derive an interlock output when at least one of such actual positional outputs differs from the respective prescribed positional output, interlock means responsive to the interlock output for inhibiting application of radiation to the patient, whereby treatment mistakes are minimized.

2. The apparatus of claim **1** wherein said means for comparing the prescribed positional outputs of said radiation source and couch means with the actual positional outputs thereof, to derive an interlock, includes, a programmed general purpose computer.

3. The apparatus of claim **1** including, display means for displaying to an operator the prescribed positions of said radiation source and couch means and the actual positions of said radiation source means and said couch means.

4. The apparatus of claim **1** wherein said means for establishing the prescribed positional output of said radiation source and said couch means includes, information storage means for storing a prescribed treatment plan which includes information defining the prescribed positions of said radiation source means and said couch means, and means for reading the prescribed positional definitions from said information storage means.

5. The apparatus of claim **4** wherein said information storage means includes, a storage tape, and wherein said information reading means includes, a tape reading means.

6. The apparatus of claim **4** including general purpose computer means having a memory, said information storage means including first storage means for storing the treatment plan of prescribed positional information of said radiation source and couch means for each given patient, said computer means being programmed to transfer the prescribed positional information from said first storage means into said memory of said computer means, and said computer being programmed to read the prescribed definitions from said memory of said computer to establish the prescribed positional outputs of said radiation source means and said couch means.

7. In a radiation therapy apparatus, couch means for supporting a patient to receive radiation, radiation source means for applying radiation to the patient, means for supporting and causing relative movement between said radiation source means and said couch means, means for establishing outputs corresponding to prescribed relative positioning of said source means and said couch means to define a prescribed treatment plan of radiation for the patient, means for generating positional outputs representative of the actual relative positioning of said couch means and radiation source means, means for comparing the prescribed positional outputs of the relative positioning of said radiation source means and said couch means with actual positional outputs of the relative positioning of said radiation source and couch means to derive an interlock output when at least one of such actual positional outputs differs from the respective prescribed positional output, and interlock means responsive to the interlock output for inhibiting application of radiation to the patient, whereby treatment mistakes are minimized.

8. The apparatus of claim **7** in which said means for causing relative movement between said radiation source means and said couch means includes means for moving each of said couch means and radiation source means relative to the other, said means for comparing said prescribed and actual positional outputs comprises a computer programmed to derive error signals representative of difference between said prescribed and actual positions and to feed said signals to said means for moving said couch means and radiation source means, whereby said actual relative positioning is automatically caused to coincide with said prescribed relative positioning.

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