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(54) **METHOD AND APPARATUS FOR ALTERNATING PRESSURE OF A LOW AIR LOSS PATIENT SUPPORT SYSTEM.**

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## Description

The present invention relates to a method and apparatus for alternating the air pressure of a low air loss patient support system. More particularly, it relates to a bed having a frame with two sets of air bags mounted thereto, a gas source, means on each of the air bags for moving a patient supported thereon toward one side of the frame and then back toward the other side of the frame when gas is supplied to the first set of air bags and then to the second set of air bags, and means on the air bags for retaining the patient on the air bags when the patient is moved toward the respective sides of the frames.

Such a bed can be used to advantage for the prevention of bed sores and the collection of fluid in the lungs of bedridden patients. Other devices are known which are directed to the same object, but these devices suffer from several problems. In particular, U.S. Patent No. 3,822,425 discloses an air mattress consisting of a number of cells or bags, each having a surface which supports the patient formed from a material which is gas permeable but is non-permeable to liquids and solids. It also discloses an air supply for inflating the cells to the required pressure and outlets or exhaust ports to allow the escape of air. The stated purpose of the outlets is to remove condensed vapor for the cells or bags. The outlets on that mattress may be fitted with valves to regulate the air pressure in the cells as opposed to regulating the air pressure in the cells by controlling the amount of air flowing into the cells. However, the air bed which is described in that patent and which is currently being marketed under that patent is believed to have certain disadvantages and limitations.

For example, that bed has a single air intake coupler, located directly and centrally underneath the air mattress, for connection of the source of air. Access to this connection is difficult since one must be on their back to reach it. The location of the connection underneath the mattress creates a limitation in the frame construction because the air hose must pass between the bed frame members. The source of air to which the air hose is connected is a blower or air pump mounted in a remote cabinet which, because it must be portable, is mounted on casters. There are many times in actual use when the cabinet must be moved in order to wheel other equipment, such as I.V. stands, around it or for access to the patient. However, relocation of this blower unit by any significant distance requires disconnection of the air hose from the frame (inconvenient because of the location up underneath the frame) or the pendant control in order to avoid wrapping the air hose around the bed frame members. Of course, disconnection of the air hose results in the loss of air pressure in the air mattress, which is even less desirable.

Further, the bed disclosed by that patent is limited in that only a finite amount of air can be forced or pumped into the air mattress. By eliminating the outlets described in that patent entirely, the air pressure in the bags can at least be maintained at that point which represents the maximum output of the source of gas. In the case of the bed described in that patent, if it is necessary to further increase the pressure in the air bags while the outlets are being used for their stated purpose, the only way to do so is to install a larger capacity blower in the cabinet. High air pressures may be necessary, for instance, to support obese patients. A larger capacity blower generally requires more power consumption and a higher capacity circuit which may not be readily available. Also, the larger the blower, the more noise it creates which is not desirable.

Another limitation of that bed is the necessity for constant adjustment of the air pressure in the air bags on which the patient is supported. Although low air loss beds in general are used for bedridden patients, not all bedridden patients are incapable of movement. Each movement of those patients, even such movements as moving only one arm, or each time a patient incapable of movement is repositioned by attending health-care personnel, causes changes in the portion of the patient's weight supported by the sets of air bags mounted on the respective head, back, seat and leg sections of the frame of the bed. To avoid the localized increases in the pressure exerted against the skin of the patient as a result of such movements, the air pressure in that section must be readjusted. Adjustment of the air supply to one set of air bags almost invariably has an effect on the pressure in one or more adjacent sets of air bags such that it is often necessary to change the air supply to every set of air bags on the bed.

Further, low air loss beds of the type disclosed in the '425 patent are provided with means for adjusting the patient's attitude on the bed. For instance, the head of the bed can be raised to sit the patient up or the angle of the entire frame of the bed can be changed with respect to the horizontal when, for therapeutic reasons, the patient is placed in the Trendelenburg or reverse Trendelenburg positions. Those changes require re-adjustment of the air supply in each set of air bags, usually of a greater magnitude than those required as a result of the movement of the patient.

The limitations and disadvantages which characterize other previous attempts to solve the problem of preventing bed sores in bedridden patients are well characterized in G. B. Patent No.

1,474,018 and U.S. Patent No. 4,425,676.

European Patent Specification 0168213 refers to an air mattress having air cells that can be selectively inflated and deflated to change from time to time areas of the mattress providing support to a person's body, information as to the selection of air cells to be inflated or deflated being based on a patients' body weight and weight distribution being fed to a control unit.

The prior art also discloses a number of devices which function to rock a patient back and forth by the use of air pressure. For instance, U.S. Patents Nos. 3,477,071 and 3,775,781 disclose hospital beds with an inflatable device for shifting or turning a patient lying on the bed by alternately inflating and deflating one or more inflatable cushions. U.K. Patent Application No. 2,026,315 discloses a pad, cushion, or mattress of similar construction. U.S. Patent No, 3,485,240 discloses a patient support system in which two lengthwise extending sacs, each having a triangular cross section when inflated, are arranged one upon the other beneath a patient. The sacs are alternately fully inflated and completely deflated in order to roll the patient from side to side on the sacs. U.S. Patent No. 4,797,962 describes a patient support system including a set of inflatable air sacs which are maintained at a preset level of inflation by a control system including a feedback device. German Patent DE 2816642 discloses an air mattress for a bedridden person or hospital patient consisting of three longitudinal inflatable cells attached to a base sheets, the amount of air forced into each cell being varied so as to alternately rock the patient from one side of the mattress to the other. However, none of those mattresses or devices are designed for use in a low air loss patient support system. Further, the U.K. and German patents, and U.S. Patent Nos, 3,477,071 and 3,775,781, disclose devices consisting of parallel air compartments which extend longitudinally along the bed and which are alternately inflated and deflated. Such a constructions does not allow the use of the device on a bed having hinged sections corresponding to the part of the patient's body lying on the bed so that the inclination and angle of the various portions of the bed can be adjusted for the patient's comfort.

U.S. Patent No. 3,678,520 discloses an air cell for use in a pressure pad which is provided within a plurality of tubes which project from a header pipe such that the air cell assumes a comb-like conformation when inflated and viewed above. Two such air cells are enclosed within the pressure pad with the projecting tubes interdigitating, and air is alternately provided and exhausted from one cell and then the other. That device is not suitable for use on a bed having hinged sections corresponding to the parts of the patient's body lying on the bed so that the angle of inclination of the various portions of the bed can be adjusted for the patient's comfort, nor is it capable of functioning in the manner described if constructed in the low air loss conformation.

A number of patents, both U.S. and foreign, disclose air mattresses or cushions comprised of sets of cells which are alternately inflated and deflated to support a patient first on one group of air cells and then the other group. Those patents include the following U.S. patents: 1,772,310, 2,245,909, 2,998,817, 3,390,674, 3,467,081, 3,587,568, 3,653,083, 4,068,334, 4,175,297, 4,193,149, 4,197,837, 4,225,989, 4,347,633, 4,391,009, and 4,472,847, and the following foreign patents: G.B. 959,103, Australia 401,767, and German 24 46 935, 29 19 438 and 28 07 038. None of the devices disclosed in those patents rocks or alternately moves the patient supported thereon to further distribute the patient's body weight over additional air cushions or cells or to alternately relieve the pressure under portions of the patient's body.

There are also a number of patents which disclose an inflatable device other than an air mattress or cushion but which also involves alternately supplying air to a set of cells and then to another set of cells. Those patents include U.S. patent nos. 1,147,560, 3,595,223, and 3,867,732, and G.B. Patent No. 1,405,333. Of those patents, only the British patent discloses the movement of the body with changes in air pressure in the cells of the device. None of those references disclose an apparatus which is adaptable for use in a low air loss patient support system.

British Patent No. 946,831 discloses an air mattress having inflatable elongated bags which are placed side-by-side and which are in fluid communication with each other. A valve is provided in the conduit connnecting the insides of the two bags. Air is supplied to both bags in an amount sufficient to support the patient, thereby raising the patient off the bed or other surface on which the air mattress rests. Any imbalance of the weight distribution of the patient causes the air to be driven from one bag to the other, allowing the patient to turn toward the direction of the now deflated bag. An automatic changeover valve, the details of which are not shown, is said to then inflate the deflated bag while deflating the bag which was originally inflated, thereby rocking the patient in the other direction. That device is limited in its ability to prevent bed sores because when the patient rocks onto the deflated bag, there is insufficient air to support the patient up off the bed or other surface on which the air mattress rests, resulting in pressure being exerted against the patient's skin

which is essentially the same as the pressure that would have been exerted by the board or other surface without the air mattress. Even if there were enough air left in the deflated bag to support the patient, if the air mattress were constructed in a low air loss configuration, the air remaining in the bag would be slowly lost from the bag until the patient rested directly on the bed or other surface with the same result. Finally, that device is not adaptable for use on a bed having hinged sections corresponding to the parts of the patient's body lying on the bed so that the angle of inclination of the various portions of the bed can be adjusted for the patient's comfort.

The present invention represents an improved apparatus over the prior art. It is characterized by a number of advantages which increase its utility over the prior art devices, including its flexibility of use, its ability to maintain relatively constant air pressure in the air bags in spite of patient movement or changes in the attitude of the bed frame, the ability to quickly and easily replace one or more of the air bags while the apparatus is in operation, and the ease of adjustment of the air pressure in the air bags.

It is, therefore, an object of the present invention to provide a low air loss bed comprising a frame, a first set of substantially rectangular gas permeable air bags for supporting a patient thereon mounted transversely on the frame, a second set of substantially rectangular gas permeable air bags for supporting a patient thereon mounted transversely on the frame, means for connecting each of the air bags to a gas source, means integral with each of the air bags of the first set of air bags for moving the patient supported thereon toward a first side of the frame when each of the air bags in the first portion is inflated, means integral with each of the air bags of the second set of air bags for moving the patient supported thereon toward a second side of the frame when the air bags in the first set of air bags are deflated and the air bags of the second set of air bags are inflated, integral means on each of the air bags for retaining the patient alternately supported on the first or second set of air bags when the patient is moved toward the first or second sides of the frame, and means for selecting the pressure in the air bags at any given time.

It is a further object of the present invention to provide an air bed, the air pressure of which can be quickly and conveniently set to support a patient of known body weight by simply selecting a target pressure to be maintained in the air bags which results in the adjustment of the valves regulating the amount of air flowing from the air source accordingly.

Another object of the present invention is to provide a low air loss bed having an integral gas source which can be raised, lowered or tipped, and which allows the raising or lowering of a portion of the bed while maintaining a selected pressure or range of pressures in the air bags at any given time.

Another object of the present invention is to provide a low air loss bed capable of rolling a patient back and forth on the bed while safely retaining the patient thereon.

Another object of the present invention is to provide a low air loss bed capable of alternately moving a patient in one direction and then in a second direction which is divided into at least three sections approximately corresponding to the portions of the body of the patient lying thereon which are hinged to each other and provided with means for raising and lowering the sections corresponding to the body of the patient to provide increased comfort and therapeutic value to the patient while the patient is being alternately moved in the first and second directions on the bed.

Another object of the present invention is to provide a low air loss bed capable of alternately rolling a portion of a patient in one direction and then in a second direction while retaining another portion of the patient in a relatively fixed position.

Other objects and advantages will be apparent to those of skill in the art from the following disclosure.

The invention provides a method of operating a feedback-controlled patient-support system of the type having a patient support including a plurality of inflatable air bags comprising at least a first and a second separately inflatable air bag for supporting a patient and connected in variable fluid communication with an air supply means, the first air bag being adapted to roll a patient in a first direction in response to inflation control, and the second air bag being adapted to roll the patient in a second, opposite direction in response to inflation control, said air supply means being connected in variable fluid communication with said air bags for separately and alternately inflating the air bags; characterised in that the method comprises sensing the air pressure in at least a portion of the first and second air bags; and controlling said air supply means in a feedback manner by the use of means linked with the air pressure sensing means, to roll the patient first in said first direction and then in said second direction while ensuring that throughout the control operation of the air supply to raise and to lower the air pressure in the bags, the level of said air pressure in the bags is not permitted to fall below a predetermined minimum level.

The invention further provides a feedback-controlled patient support system of the type having a

patient support including a plurality of inflatable air bags connected in variable fluid communication with an air supply means, comprising a patient support including at least a first and a second separately inflatable air bag chambers for supporting a patient, the first chamber being adapted to rotate a patient in a first direction in response to inflation control, and the second chamber being adpated to rotate the patient in a second, opposite, direction in response to inflation control; air supply means connected in variable fluid communication with said air bags for selectively inflating the air bag chambers characterised by means for sensing the air pressure in the first and second chambers; and means linked with said sensing means, for controlling said air supply means in a feedback manner, to roll the patient in said first direction and then in said second direction by monitoring and controlling the air pressure in said first and second chambers, while ensuring that throughout the operation of the air supply control means, the level of air pressure in the chambers is not permitted to fall below a predetermined minimum level.

In an example of a system according to the invention, there is provided a plurality of sets of gas permeable air bags are mounted on the frame, each set of air bags corresponding to a portion of a patient to be supported in prone position on the bed. Each of a plurality of separate gas manifolds communicates with the gas source and one set of the sets of air bags. Also provided is a means for separately changing the amount of gas delivered by the gas source to each of the gas manifolds, thereby varying the amount of support provided for each portion of the patient.

Also provided is a low air loss bed comprising a bed frame having a source of gas and a plurality of sets of water vapor permeable air bags mounted thereto. Separate gas manifolds communicate with the interior of the air bags on one set of the sets of air bags and the gas source. An air control box is mounted to the bed frame and interposed in the flow of air from the gas source to the gas manifolds, and is provided with individually adjustable valves for changing the amount of gas delivered to each of the gas manifolds. The air control box is also provided with means operable to selectively open all of the valves to the atmosphere, allowing the gas to escape from each of the sets of air bags, to collapse the air bags with the result that the patient is supported by the frame of the air bed rather than the air bags.

Also provided with a low air loss bed having a bed frame and a plurality of sets of air bags mounted thereto with a plurality of gas manifolds communicating separately with the gas source and the interior of the air bags. An air control box is mounted to the bed frame in fluid connection with the gas source and the gas manifolds, and is provided with valves which are individually adjustable to change the amount of the flow from the gas source through the air control box to each of the gas manifolds. The air control box is also provided with means operable to simultaneously fully open the valves to cause the air bags to fully inflate.

Also provided is a low air loss bed having a frame and a plurality of sets of air bags mounted thereto with a plurality of gas manifolds communicating separately with the gas source and the interior of the air bags. An air control box is also mounted on the frame, the interior of the air control box communicating with the gas manifolds and the gas source and having means therein for separately changing the amount of gas delivered by the gas source to each of the gas manifolds. The air control box is also provided with means operable to heat the gas flowing through the air control box and with means operable to switch the heating means on and off in response to the temperature in the air control box. Also provided is means having a sensor in one of the gas manifolds which is operable to selectively control the heating means, the means operable to switch the heating means on and off in response to the temperature in the air control box being operable at a predetermined temperature.

Also provided is a low air loss bed comprising a frame, a first set of air bags for supporting a patient thereon mounted transversely on the frame, a second set of air bags for supporting a patient thereon mounted transversely on the frame, means for connecting each of the air bags to a gas source, each of the air bags of said first set of air bags having means integral therewith for moving the patient supported thereon toward a first side of the frame when the air bags in the first set of air bags is inflated, each of the second set of air bags having means integral therewith for moving the patient supported thereon toward the second side of the frame when the air bags in the second set of air bags is inflated and the air bags in the first set of air bags is deflated, and means on the air bags for retaining the patient supported thereon when the patient is moved toward the respective first and second sides of the frame.

Also provided is a means for controlling the pressures in the air bags corresponding to three different rotation positions. These pressures are adjustable by the operator and serve to define each rotation position according to the size and weight of a particular patient. Means are provided which cause each rotation position to be sequentially reached and maintained at a rate defined by the operator.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of a presently preferred embodiment of the low air loss bed of the present invention.

Figure 2 is a cross-sectional view of the bed of Fig. 1, showing an air bag with a second air bag therebehind taken along the lines 2-2 in Fig. 1, the second air bag being shown in shadow lines for purposes of clarity.

Figure 3 is a schematic diagram of the air plumbing of the low air loss bed of Fig. 1.

Figure 4 is a perspective view of one of the baseboards of the low air loss bed of Fig. 1.

Figure 5 is an enlarged, exploded perspective view of the underside of the baseboard of Fig. 4, showing the baseboard partially cut away to show the details of attachment of a low air loss air bag thereto.

Figure 6 is an end view of the low air loss bed of Fig. 1 with the head portion raised to show the construction of the frame and the components mounted thereto.

Figure 7 is an end view of the low air loss bed of Fig. 1 with the foot portion raised to show the construction of the frame and the components mounted thereto.

Figure 8 is a sectional view of the air box of the low air loss bed of Fig. 1 taken along the lines 8-8 in Fig. 9A.

Figures 9A and 9B are cross-sectional views taken along the lines 9A-9A and 9B-9B, respectively, through the manifold assembly of the air box as shown in Fig. 8.

Figures 10A-10D are an end view of a patient supported upon the top surface of the air bags of the low air loss bed of the present invention as that patient (10D), is rocked toward one side of the frame of the low air loss bed (10A), then toward the other side (10C) or supported on the air bags when all air bags are fully inflated (Fig. 10B).

Figure 11 is a composite, longitudinal sectional view of a portion of the foot baseboard of a low air loss bed constructed according to the teachings of the present invention taken along the lines 11-11 in Fig. 1 showing several alternate methods of attaching the air bags to the bed frame.

Figure 12 is a schematic electrical diagram of the low air loss bed of Fig. 1.

Figure 13 is a perspective view of a portion of the bed frame of the bed of Fig. 1 showing a potentiometer mounted to one frame section which is pivotally connected to an adjacent frame section.

Figure 14 is schematic diagram of the electrical cables and controls which open and close the valves to route air to the air bags of the low air loss bed of Fig. 1.

Figure 15 is a flow chart of a presently preferred embodiment of the program for controlling the operations of the low air loss bed in Fig. 1 from the control panel shown in Fig. 12.

Figure 16 is a flow chart of the general timer subroutine for controlling the operation of the low air loss bed of Fig. 1.

Figure 17 is a flow chart of the switch processing subroutine for controlling the operation of the low air loss bed of Fig. 1.

Figure 18 is a flow chart of the rotation subroutine for controlling the operation of the low air loss bed of Fig. 1.

Figure 19 is a flow chart of the valve motor subroutine for controlling the operation of the low air loss bed of Fig. 1.

Figure 20 is a flow chart of the power fail interrupt subroutine for controlling the operation of the low air loss bed of Fig. 1.

Figure 21 is an end view of an alternative embodiment of an air bag for use on the low air loss bed of Figure 1.

Figure 22 is an end view of one of the air bags for use on the low air loss bed of Fig. 1.

Figure 23 is an end view of another one of the air bags for use on the low air loss bed of Fig. 1.

Figure 24 is a general diagrammatic description of the control software for controlling the operation of the low air loss bed of Fig. 1.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Fig. 1, there is shown a bed 10 including a frame 12. The frame 12 is comprised of a plurality of sections 14', 14'', 14''' and 14'''', hinged at the points 44', 44'' and 44''', and end members 16. Cross-members 18 (Figs. 6 and 7) and braces 19 (Fig. 7) are provided for additional rigidity. The frame 12 is provided with headboard 20 at one end and a foot board 21 at the other end. The respective head 20 and foot 21 boards are actually constructed of two boards, 20' and 20'', and 21' and 21'', respectively, which are stacked one on top of the other by the vertical slats 25 on which the boards 20', 20'', 21' and 21'' are mounted.

A separate sub-frame, indicated generally at reference numeral 27 in Figs. 6 and 7, is mounted on a base 22 comprised of longitudinal beams 24, cross-beams 26 and cross-member 28 by means of a vertical height adjustment mechanism as will be described. The base 22 is mounted on casters 30 at the corners of the base 22. A foot pedal 42 is provided for braking and steering the casters 30.

Sub-frame 27 is comprised of cross beams 29, hoop brace 35, and longitudinal beams 31 (see Figs. 6 and 7). Sub-frame 27 is provided at the

corners with uprights 33, having tabs 33' thereon, for mounting of IV bottles and other equipment. Means is provided for raising and lowering the sub-frame 27 relative to the base 22 in the form of a conventional vertical height adjustment mechanism, not all of the details of which are shown. Height is adjusted by rotation of an axle under influence of a power screw, hidden from view in Fig. 7 by drive tunnel beam 37, which is powered by a motor which is also hidden from view. Power is transferred from the power screw to the axle by means of eccentric levers, the axle of which is journaled in and hidden by drive tunnel beam 37. Sub-frame 27 rises on levers which are pivotally mounted to the cross-beams of base 22. The levers and the members on which they are mounted are hidden from view in Figs. 6 and 7 by cross beam 29.

The section 14'' of frame 12 is mounted to the longitudinal beams 31 of sub-frame 27 by support members 41 (see Fig. 6). The section 14' of frame 12, with the head baseboard 52 thereon, and the section 14'''' of frame 12, with foot baseboard 46 thereon, pivot upwardly from the horizontal at the hinges 44' and 44'''', respectively. The purpose of that pivoting is to provide for the adjustment of the angle of inclination of the various parts of the body of the patient, and the details of that pivoting are known in the art and are not shown for purposes of clarity, although the motors are located within the boxes shown at 45 and are controlled by the switches 233, 235, 236, 237, 238, and 239 on control panel 346, or from the redundant controls on bed hand control 368 (see Fig. 14), and the circuitry for those functions is contained within box 43 (Fig. 7), which is shown schematically at reference numeral 367 (see Fig. 14), and is explained in more detail below.

Supports 17 are provided on the cross member 18 under head baseboard 52 which rest on the longitudinal beams 31 of sub-frame 27 when head baseboard 52 is horizontal. When foot baseboard 46 is raised (Fig. 7), cross-bar 47 rises therewith by means of the pivoting connection created by cross-bar 47 and the notches 49 in brace 19 (cross-bar 47 is shown detached from braces 19 in Fig. 7 for purposes of clarity). The sets of notches 49 provide means for adjusting the height to which cross-bar 47 can be raised, foot baseboard 46 pivoting upwardly on brackets 51 which are pivotally mounted to the longitudinal beams 31 of sub-frame 27. The tips 53 of cross-bar 47 rest on longitudinal beam 31 when foot baseboard 46 is lowered to the horizontal.

Side rails 81 are mounted to brackets 83 (see Fig. 6) which are pivotally mounted to the mounting brackets 85 mounted on the underside of head baseboard 52. Side rails 87 are mounted to brackets 89 (see Fig. 7), and brackets 89 are pivotally mounted to the mounting brackets 91. Mounting brackets 91 are affixed to the braces 19 on the underside of foot baseboard 46.

The frame 12 is provided with a feet baseboard 46, a leg baseboard 48, a seat baseboard 50 and a head baseboard 52 (shown in shadow lines in Fig. 3), each being mounted to the corresponding section 14', 14'', 14''' and 14'''' of the frame 12 by means of rivets 54 (see Fig. 11). Means is provided for releasably securing the air bags 58 to the low air loss bed 10. Referring to Figs. 2, 4, and 5, there is shown a presently preferred embodiment of that releasable securing means. In Figs. 4 and 5, there is shown a portion of the feet baseboard 46, which is provided with holes 64 therethrough which are alternating and opposite each other along the length of the feet baseboard 46, as well as leg baseboard 48, seat baseboard 50 and head baseboard 52. Every other hole 64 is provided with a key slot 11 for receiving the post 32, having retainer 34 mounted thereon, which projects through the bottom surface 79 of air bag 58, the flange 71 of which is retained between patch 69, which is stitched to the bottom surface 79 of air bag 58, and the bottom surface 72. Air bag 58 is shown cutaway and in shadow lines in Fig. 5 for purposes of clarity. Air bag 58 is also provided with a nipple 23 of resilient polymeric plastic material having an extension tab 15 integral therewith. To releasably secure the air bag 58 to feet baseboard 46, or any of the other baseboards 48, 50, or 52, post 32 is inserted through hole 64 until retainer 34 has emerged from the bottom thereof. Post 32 is then slid into engagement with key slot 11 and retainer 34 engages the bottom side of feet baseboard 46 around the margin of hole 64 to retain air bag 58 in place on feet baseboard 46. Nipple 23 is then inserted into the hole 64 opposite the hole 64 having key slot 11 therein and rotated until extension tab 15 engages the bottom of the head of flat head screw 13 to help secure nipple 23 in place.

In an alternative embodiment, the baseboards 46, 48, 50 and 52 are provided with means for releasably securing the air bags 58 to the low air loss bed 10 in the form of male snaps 56 (Fig. 11) along their edges. The air bags 58 are provided with flaps 60, each of which is supplied with female snaps 62 which mate with male snaps 56. Flaps 60 are alternatively provided with a strip of VELCRO tape 55, and the edges of baseboards 46, 48, 50 and 52 are provided with a complementary strip of VELCRO hooks 57, to secure each air bag 58 in place. Alternatively, flap 60 and baseboards 46, 48, 50 and 52 are provided with both VELCRO and snap fastening means.

The air bags 58 are substantially rectangular in shape, and are constructed of a coated fabric or similar material through which water vapor can

move, but which water and other liquids will not penetrate. The fabric sold under the trademark "GORE-TEX" is one such suitable material. The air bags 58 can include one or more outlets for the escape of the air with which they are inflated or they can be constructed in a "low air loss" conformation.

Referring to Figs. 1 and 2, air bags are shown of different configuration according to their location on the frame 12 of bed 10. For instance, the air bags mounted to the leg baseboard 48 and seat baseboard 50 are designated at reference numeral 322. Air bags 321, 322, 325 and 328 are constructed in the form of a substantially rectangular enclosure, at least the top surface 323 of which is constructed of water vapor permeable material such as described above. Air bags 321, 322, 325 or 328 are provided with means for connecting the inside of that enclosure to a source of gas, such as the blower 108, to inflate the enclosure with gas in the form of the nipple 23 (see Fig. 2) which extends through the baseboard 50 into the seat gas manifold 80 mounted thereto. Air bag 321, 322, 325 or 328 is also provided with means for releasably securing the enclosure to the low air loss bed 10 in the form of the post 32 and retainer 34 described above. Means is provided for moving a patient 348 supported on air bags 322, 325 or 328 toward one side of frame 12 when air bags 322, 325 or 328 are inflated and for retaining the patient 348 on the top surface 323 of air bags 322, 325 or 328 when patient 348 is rolled or rocked towards one side of frame 12 or the other (see Figs. 10A-10D). The means for moving patient 348 supported on air bags 322, 325 or 328 toward one side of frame 12 when the air bags 322, 325 or 328 are inflated comprises a cutout 324 in the top 323 of the substantially rectangular shape of each of the air bags 322, 325 or 328.

Each air bag 322, 325 or 328 is also provided with means for retaining a patient 348 on the top surface 323 of the air bag 322, 325 or 328 when patient 348 is rolled toward the side of frame 12 by the inflation of air bags 322, 325 or 328 in the form of a pillar 326 which is integral with each air bag 322, 325 or 328 and which, when inflated, projects upwardly to form the end and corner of the substantially rectangular enclosure of air bag 322, 325 or 328. The means for retaining patient 348 on the top 323 of air bags 322, 325 or 328 can also take the form of a large foam cushion (not shown) mounted to side rails 81 and 87 on both sides of bed frame 12. That cushion can be detachably mounted to side rails 81 and 87, or can be split so that a portion mounts to said rail 81 and a portion mounts to side rail 87. The air pressure in air bags 322, 325 or 328 is then adjusted, as will be explained, until patient 348 is rocked gently against that foam cushion on one side of bed frame 12 and then back toward the other side of bed frame 12.

As shown in Fig. 1, a plurality of air bags 58, 321, 322, 325 and/or 328 is mounted transversely on the frame 12 of bed 10. The air bags 322, 325 or 328 are divided into a first set in which the pillar 326 and cutout 324 are closer to one side of bed frame 12 than the other and a second set of air bags 322, 325 or 328 in which the pillar 326 and cutout 324 are closer to the second side of the bed frame 12. The air bags 322, 325 or 328 of the first set and the air bags 322, 325 or 328 of the second set alternate with each other along the length of baseboards 46, 48, 50, and 52. As will be explained, the first set of air bags 322, 325 or 328 is inflated with air from blower 108, thereby causing the patient 348 (not shown in Fig. 1, see Figs. 10A-10D) supported on the air bags 322 to be rolled toward the first side of bed frame 12 and then deflated while the second set of air bags 322, 325 or 328 is inflated, thereby moving the patient 348 toward the other side of bed frame 12.

The air bags 321 which are mounted on head baseboard 52 are provided with a flat top surface 323 so that the head of patient 348 is retained in a relatively constant position while the body of patient 348 is alternately rolled first toward one side of the bed frame 12 and then back toward the other side of bed frame 12. Referring to Fig. 23, an air bag 321 is shown for use under the head of patient 348. Air bag 321 is substantially rectangular in shape, but is provided with a slanted top surface 323 in the area 331 adjacent corners 448. The height of air bag 321 is less than the height of air bags 58, 322, 325 and 328 because when patient 348 lies upon air bags 58, 322, 325 and/or 328, the heavier portions, i.e., the portions of the body other than the head, sink into those air bags 58, 322, 325 and/or 328 as shown in Fig. 10D. When the patient 348 sinks into air bags 58, 322, 325 and/or 328, the head rests evenly on air bags 321 because the head does not sink into air bags 321 as far as the other portions of the body.

The air bags 328 mounted on the foot baseboard 46 and the air bags 328 mounted on a portion of leg baseboard 48 are also provided with a cutout 324 and pillar 326 as described for the air bags 322. Additionally, air bags 328 are provided with a hump 330 so that the legs of patient 348 are relatively restrained from movement during the alternate back and forth movement of patient 348, thereby helping to retain the patient 348 on the top surface 323 of air bags 58, 321, 322, 325 and 328 as well as helping to distribute the pressure exerted against the skin of patient 348 over an increased area.

Referring to Fig. 22, there is shown a side view (by "side view," reference is made to the air bag

itself; if the air bag 328 (or 321 or 322) were mounted to bed 10, the view would be an end view of the bed) of an air bag 328 having hump 330 formed in the top surface 323 thereof. As can be seen, when air bag 328 is inflated, hump 330 and pillar 326 project upwardly to help prevent the rolling of patient 348 too far to one side of bed frame 12 or the other. An alternative construction of air bag 322 is shown at reference numeral 325 in Fig. 21. Air bag 325 is provided with cutout 324 of approximately the same depth as the cutout 324 of air bags 322 and 328, but the slope of the top surface 323 in he area 327 is less than the slope of the top surface 323 in the area 329 of air bags 322 and 328. Air bag 325, in conjunction with the adjustment of the air pressure in one air bags 58, 321, 322 and/or 328, can be used under different portions of the body of patient 348 to increase or decrease the extent and speed with which patient 348 is rolled from one side of bed frame 12 to the other. For instance, air bag 325 is particularly well-suited for use under the shoulders of a patient 348.

As noted above, all of the air bags 58, 321, 322, 325 and 328 are substantially rectangular in shape with dimensions of approximately 18 x 39 inches. Each is provided with a baffle 460 attached to side walls 61 which holds the side walls 61 against bowing when the air bag 58, 321, 322, 325 or 328 is inflated. Each of the corners 448 has a radius of curvature of approximately three inches, and the depth of cutout 324 is approximately ten inches. The dimension of pillar 326 of air bags 325 and 328 in the direction shown by line 450 is approximately seven inches, as is the dimension of cutout 324 in the direction shown by line 452. The dimension of pillar 326 of air bag 322 in the direction shown by line 451 is approximately twelve inches. The dimension of the top surface 323 of air bag 325 along line 453 is approximately twenty inches, and that top surface 323 drops off into cutout 324 in a curve 455 of approximately a six inch radius. Referring to Fig. 2, the dimension of the top surface 323 along line 458 is approximately nineteen inches. The dimension of hump 330 on air bag 328 in the direction shown by line 454 is approximately five inches, and in the direction shown by line 456, the dimension is approximately two inches. The dimension of surface 333, as shown by line 458 is approximately fourteen inches.

In an alternative construction for attaching the air bags 58, 322 and 328 to the bed 10 (shown in Fig. 11), each air bag 58 (it should be understood throughout the specification that, when reference is made to an air bag 58, the air bag could also be an air bag 321, 322, 325 or 328) is provided with a flanged nipple 70, the flange 71 of which is retained between the bottom 72 of the air bag 58 between a patch 74 and the bottom 72 of the air bag. As described below, each air bag 58 is mounted separately on the baseboards 46, 48, 50, and 52 by snapping the female snaps 62 in the flaps 60 of each of the air bags 58 over the male snaps 56 on the edges of the baseboards 46, 48, 50, and 52 or with the VELCRO tape 55 and hooks 57, or both. When so positioned, the flanged nipple 70 on the bottom inside 72 of the air bag 58 projects through the holes 64 and 64' in the baseboards 46, 48, 50, or 52 over which the air bags 58 are positioned. An O-ring 68 is provided in a groove (not numbered) around each of the flanged nipples 70 to insure a relatively gas-tight fit between the flanged nipple 70 and the corresponding baseboard 46, 48, 50, or 52 through which the flanged nipples 70 project.

The use of individual air bags 58, 321, 322, 325 or 328 rather than a single air cushion allows the replacement of individual bags should one develop a leak, need cleaning or otherwise need attention. When it is desired to remove an individual air bag 58, 321, 322, 325 or 328 from its respective baseboard 46, 48, 50, or 52, post 32 is slid out of key slot 11 and retainer 34 and post 32 are removed from hole 64. Nipple 23 is then rotated until extension tab 15 rotates out of engagement with screw 13 and is pulled firmly to remove it from hole 64. In the case of air bag 58, female snaps 62 at each end of the air bag 58 are disengaged from the male snaps 56 (or the VELCRO strips peeled away from each other) on the edges of baseboards 46, 48, 50 or 52, and the air bag 58 is removed by twisting flanged nipple 70 up and out of the hole 64 in the baseboard 46, 48, 50, or 52. Removal can even be accomplished while the patient is lying on the inflated air bags 58, 321, 322, 325 or 328.

For additional security in holding air bags 58 onto baseboards 46, 48, 50 and 52, and to help insure a gas-tight fit between flanged nipple 70 and the respective baseboards 46, 48, 50 or 52 through which it projects, spring clip 73 (see Fig. 11) is inserted through nipple 70 of air bag 58. To insert the nipple 70 into hole 64, the hoop portion 75 of spring clip 73 is squeezed (through the fabric of air bag 58), causing the flanges 77 on the ends of the shank portion 101 of spring clip 73 to move toward each other so that they can enter the hole 64. Once inserted through the hole 64, flanges 77 spring apart, and will not permit the removal of nipple 70 from hole 64 without again squeezing the hoop portion 75 of spring clip 73.

Referring to Fig. 6, there is shown an end view of a bed constructed according to the present invention. Brace 102 is secured to the cross beam 29 of sub-frame 27 by means of bolts 104. Blowers 108 are mounted to the brace 102 by means of bolts 110 through the mounting plates 112 which are integral with the blower housing 116. A gasket,

piece of plywood or particle board (not shown), or other sound and vibration dampening material is interposed between mounting plates 112 and brace 102. A strip of such material (not shown) can also be inserted between brace 102 and cross beam 29. The blowers 108 include integral permanent split capacitor electric motors 114. When motors 114 are activated, blowers 108 move air out of the blower housings 116, through the blower funnels 118 and up the blower hoses 120 to the air box funnels 122 and on into the air box 124 (see Figs. 3 and 6).

Blowers 108 receive air from filter box 96 through hoses 98 (see Fig. 3). Filter box 96 is retained within a frame 100 (see Fig. 6) for ease in removal. Frame 100 is mounted to frame 27 and is, for the most part, blocked from view by cross-beam 26 of base 22 and cross beam 29 of frame 27 in Fig. 6. The second blower 108 is provided to increase the volume which is delivered to the air bags 58, thereby increasing the air pressure within air bags 58. A cover (not shown) lined with sound absorbing material can also be provided to enclose blowers 108 and thereby reduce noise.

The air control box 124 is an airtight box mounted on the underside of head baseboard 52 by brackets 125, the details of which are shown in Figs. 8, 9A, and 9B. The front of air box 124 is provided with a manifold assembly 126. Manifold assembly 126 is provided with a manifold plate 145 having holes (not numbered) therein for connection to a means for changing the amount of air supplied to the air bags 58 mounted to baseboards 46, 48, 50 and 52 in the region of the feet, legs, seat, back, and head, respectively. Gasket 115 prevents the escape of air from between air box 124 and manifold plate 145. In a presently preferred embodiment, the means for changing the amount of air supplied to the air bags 58 takes the form of a plurality of valves, indicated generally at reference numerals 128, 130a and 130b, 132a and 132b, and 134a and 134b (see also Fig. 3). Each of the valves 128, 130a and 130b, 132a and 132b, and 134a and 134b is provided with a motor 138 having a nylon threaded shaft 139 (see Figs. 8, 9A and 9B) mounted on the drive shaft (not numbered) of each motor 138 and held in place by set screw 149 in collar 148. Plug 140 moves rotatably in and out along the threaded shaft 139 when limit pin 141 of plug 140 engages one or the other of the supports 142 which are immediately adjacent that particular plug 140 and which hold the motor mounting bracket 143 to the back of the full inflate plate 144.

Full inflate plate 144, having openings 202 therein forming part of valves 128, 130a and 130b, 132a and 132b, and 134a and 134b, is mounted to the back of the manifold plate 145 by hinges 146 (see also Figs. 9A and 9B). A gasket 147 is provided to prevent the escape of air from between the full inflate plate 144 and manifold plate 145. The motors 138 are not provided with limit switches, the movement of plug 140 back and forth along the threaded shaft 139 of each motor 138 being limited by engagement of plug 140 with the opening 202 as plug 140 moves forward and by the engagement of the back side of plug 140 with collar 148 as plug 140 moves back on threaded shaft 139. An O-ring 204 is provided on plug 140 which is compressed between plug 140 and opening 202 as plug 140 moves forward into opening 202. Compression continues until the load on motor 138 is sufficient to cause it to bind and stop. The O-ring 206 which is provided on collar 148 operates in similar fashion when engaged by the back side of plug 140.

The binding of motors 138 by the loading of O-rings 204 and 206 facilitates the reversal of the motors 138 and direction of travel of plug 140 along threaded shaft 139 because threaded shaft 139 is not bound. Threaded shaft 139 is free to reverse direction and turn such that the load created by the compression of O-rings 204 or 206 is released by the turning of threaded shaft 139, and plug 140 will rotate with threaded shaft 139 until limit pin 141 contacts support 142, stopping the rotation of plug 140 and causing it to move along shaft 139 as it continues to turn.

A dump plate 150 is mounted on the outside of manifold plate 145 by means of hinges 151 (see Figs. 9A and 9B). A gasket 106 is provided to prevent the escape of air from between the manifold plate 145 and the dump plate 150. The dump plate 150 is provided with couplers 153, the interiors of which are continuous with the holes in manifold plate 145 when dump plate 150 is in the position shown in Figs. 8, 9A, and 9B, for connection of the appropriate bed frame gas supply hoses 174, 176a and 176b, 178a and 178b, and 182a and 182b, as will be explained.

Block 154 is attached to dump plate 150 by means of screws 155, and serves as a point at which the cable 156 can be anchored, by means of nut 157, so that a line 158 can slide back and forth within cable 156 to allow the dump plate 150 to be selectively pivoted away from manifold plate 145 on hinge 151. The line 158 is secured to the manifold plate 145 by the threaded cable end and locknut 159. Line 158 is secured at its other end to the bracket 183 mounted on tube 190 (see Fig. 7). Bed frame 12 is provided with quick dump levers 165 on both sides thereof, the quick dump levers 165 being connected by tube 190 so that both levers 165 provide a remote control for operation of dump plate 150 by causing the movement of line 158 through cable 156. When either of quick dump levers 165 is moved from the position shown in

Fig. 7, eccentric lever arm 181 pulls on line 158, cable 156 being anchored on bracket 183, so that line 158 moves through cable 156. The details of the anchoring of cable 156 and movement of line 158 therethrough under the influence of lever arm 181 are the same as those for the anchoring of cable 160 and movement of line 162 therethrough under the influence of lever arm 185 (see below). Movement of line 158 causes dump plate 150 to pivot away from manifold plate 145, allowing the air in air bags 58 to escape through manifolds 76, 78, 80, 82 and 84 and bed frame gas supply hoses 174, 176a, 178a, 180a, 176b, 178b, and 180b to the atmosphere from the opening thus created between manifold plate 145 and dump plate 150 so that air bags 58 will rapidly deflate. A coil spring 201' encloses line 158 within bores (not numbered) in dump plate 150 and manifold plate 145 to bias dump plate 150 and manifold plate 145 apart.

As is best shown on Figs. 8 and 9B, a separate cable 160 passes through manifold plate 145 in threaded fitting 161 so that line 162 can slide back and forth therein. The line 162 is anchored in the full inflate plate 144 by means of nut 163, which allows the full inflate plate 144 to pivot away from the manifold plate 145 on hinge 146. Pivoting of full inflate plate 144 away from manifold plate 145 in this manner removes full inflate plate 144, motor mounting bracket 143, and all other parts mounted to those parts, from the flow of air to allow the unrestricted entry of the air in air box 124 into the couplers 153 of valves 128, 130a and 130b, 132a and 132b, and 134a and 134b and on into bed frame gas supply hoses 174, 176a and 176b, 178a and 178b, and 182a and 182b, resulting in the rapid and full inflation of air bags 58 to raise the patient 348 to the position shown in Fig. 10B to facilitate patient transfer or other needs. A coil spring 201 encloses line 162 in a bore (not numbered) in manifold plate 145 and full inflate plate 144 to bias manifold plate 145 apart from full inflate plate 144.

Line 162 is anchored at its other end on lever arm 185 (Fig. 7) which is attached to the bar 195 upon which full inflate knob 193 is mounted. Bed frame 12 is provided with full inflate knobs 193 on both sides thereof, the full inflate knobs 193 being connected by bar 195 so that both control the movement of line 162 through cable 160. Cable 160 is affixed to bracket 187 by threaded cable end 199, which is mounted on the DELRIN bearing 209 which is integral with support member 210 and which receives bar 195 so that rotation of full inflate knobs 193 causes line 162 to slide therein, pivoting full inflate plate 144 on hinge 146. The weight of motors 138, supports 142 and motor mounting bracket 143 bias full inflate plate 144 toward the position in which full inflate plate 144, motor mounting bracket 143, and the parts mounted thereto, are removed from the flow of gas into the couplers 153 of valves 128, 130a and 130b, 132a and 132b, and 134a and 134b. This bias allows knobs 193 to act as a release such that either of knobs 193 need only be turned enough to move the connection between line 162 and lever arm 185 out of its over center position, at which point gravity causes the plate 144 to open. Referring to Fig. 10B, patient 348 is shown lying on air bags 322 (and/or 58, 321, 325 or 328) after full inflate plate 144 is opened. When knobs 193 are returned to their initial position, lever arm 185 turns to the point at which the connection between line 162 and lever arm 185 is rotated past 180° from the point at which line 162 approaches bar 195, i.e., over center. As noted below, microprocessor 240 includes an alarm buzzer (not shown), and switches (not shown) can be provided for activating that alarm when either of knobs 193 or levers 165 are used to inflate or deflate air bags 58, 321, 322, 325, and/or 328 respectively.

Air enters the air box 124 through air box funnels 122 in back plate 121 (Fig. 3). Air box funnel 122 is provided with a one-way flapper valve, shown schematically at reference numeral 117, so that air will not escape from the air box 124 when only one blower 108 is being operated. The air box 124 is provided with a heating strip indicated schematically at reference numeral 172. Heating strip 172 is mounted in bulkhead 133 in air box 124, effectively partitioning air box 124 into two compartments. Because air enters the air box 124 in one compartment (i.e., behind heating element 172) and leaves the air box 124 from the other compartment, a flow of air must pass through the space 135 between bulkhead 133 in which heating element 172 is mounted, being mixed and heated in the process.

Referring to Fig. 3, blowers 108 are switched on, forcing or pumping air (or other gases) received from filter box 96 through hoses 98 up the blower hoses 120, through one-way valves 117, and into air box 124. A valve 109 is provided to provide increased control of the air pressure in air bags 58, 321, 322, 325 and 328 and to seal off one of the blowers 108 so that the bed 10 can be operated on one of the blowers 108 or on blower 432 (see Fig. 7). Valve 109 is also used to restrict the flow of air from one of the blowers 108 when both blowers 108 are operating, thereby providing additional adjustability in air pressure.

The air escapes from the air box 124 through valves 128, 130a and 130b, 132a and 132b, and 134a and 134b into the respective bed frame gas supply hoses, 174, 176a and 176b, 178a and 178b, and 182a and 182b. Bed frame gas supply hoses 174, 176a and 176b, 178a and 178b, and 182a and

182b route the air to the manifolds 76 and 76', 78 and 78', 80 and 80', 82 and 82', and 84. Bed frame gas supply hoses 178a and 178b are connected to seat gas manifolds 78 and 78', which are connected by bed frame gas supply hoses 180a and 180b to leg Gas manifold 78 and 78'. Bed frame gas supply hoses 182a and 182b route air to back gas manifolds 82 and 82', respectively. Bed frame gas supply hose 174 routes air to head gas manifold 84. Each of the gas manifolds 76 and 76', 78 and 78', 80 and 80', 82 and 82', and 84 is mounted to the underside of the baseboards 46, 48, 50 and 52, feet baseboard 46 having gas manifolds 76 and 76' mounted thereto, leg baseboard 48 having gas manifolds 78 and 78' mounted thereto, and seat baseboard 50 having gas manifolds 80 and 80' mounted thereto. The head baseboard 52, and its corresponding section 14'''' of frame 12, is provided with two back gas manifolds 82 and 82' and head gas manifold 84.

Because the feet baseboard 46 extends beyond the end member 16 of the frame 12 at the foot of the bed, T-intersects 86 and 86' are provided from the feet gas manifolds 76 and 76', respectively, to route feet extension hoses 88 and 88' to the holes 64 and 64' at the extreme ends of the feet baseboard 46 (see Figs. 3, 7 and 11). Clamps 65 are provided to hold the feet extension hoses 88 and 88' in place on the nipples 23 in holes 64 and 64' and on T-intersects 86 and 86'. The head baseboard 52 likewise extends beyond the end member 16 of frame 12 at the head end of the bed (Figs. 3 and 6), and T-intersect 92 is provided from the head gas manifold 84 to provide air to the hole 64 at the extreme end of the head baseboard 52 by means of the head extension hose 94. A clamp 65 is provided to retain head extension hose 94 on T-intersect 92 and on the receptacle 66 in hole 64.

Air enters the gas manifolds 76 and 76', 78 and 78', 80 and 80', 82 and 82', and 84 from each respective bed frame gas supply hose 174, 176a and 176b, 178a and 178b, 180a and 180b, or 182a, and then passes down the length of each gas manifold 76 and 76', 78 and 78', 80 and 80', 82 and 82', or 84. Air escapes from the gas manifolds 76 and 76', 78 and 78', 80 and 80', 82 and 82', or 84 into the air bags 58 through the holes 64 and 64' in the baseboards 46, 48, 50 and 52, thereby inflating the air bags 58.

The holes 64 and 64' through base boards 46, 48, 50 and 52 into the respective air bags 322, 325 and 328 are staggered down the length of the frame 12 of bed 10. In other words, every other hole 64, or 64' is provided with a key slot 11 (see Fig. 4). Air bags 322, 325 and 328 are provided with a single nipple 70 or 23, respectively and a post 32 with retainer 34 thereon for engagement of key slot 11 in hole 64 or 64' at the other end thereof. The air bags 322, 325 and 328 alternate in their orientation on baseboards 46, 48, 50 and 52, resulting in about half the air bags 322, 325 and 328 being oriented with nipple 70 or 23 closer to one side of bed frame 12 than the nipple 70 or 23 of the other half of the air bags 322, 325 or 328 mounted thereon.

Because each of the bed frame gas supply hoses 174, 176a and 176b, 178a and 178b, 180a and 180b, and 182a and 182b is continuous with a corresponding gas manifold 76 and 76', 78 and 78', 80 and 80', 82 and 82', or 84, the amount of air supplied to each gas manifold 76 and 76', 78 and 78', 80 and 80', 82 and 82', or 84 can be varied using the valves 128, 130a and 130b, 132a and 132b, and 134a and 134b on the air box 124. Since each of the valves 128, 130a and 130b, 132a and 132b, and 134a and 134b controls the amount of air supplied to one of the manifolds 76 and 76', 78 and 78', 80 and 80', 82 and 82', or 84, each valve 128, 130a and 130b, 132a and 132b, 134a and 134b controls the amount of air supplied to the set of air bags 322, 325 or 328 individual gas manifold 76 and 76', 78 and 78', 80 and 80', 82 and 82', or 84.

Also shown in Figs. 3 and 7 is a portable power unit, or transporter, indicated generally at 426. Portable power unit 426 is comprised of case 428, which encloses batteries 430, blower 432 and battery charger 434, and hose 436. Hose 436 is provided with a releasable coupler 438 which mates with the coupler 440 of the hose 442 which is mounted on sub-frame 27 and which connects to air box 124 through funnel 444. Brackets 446 are mounted to subframe 27 for releasably engaging the case 428 of portable power unit 426. Portable power unit 426 provides air pressure to support a patient when an electrical outlet is unavailable, for instance, during patient transport.

As will be explained, means is provided for alternately inflating first the air bags 322 and 328 connected to back, seat, leg and feet gas manifolds 76, 78, 80 and 82, respectively, and then deflating those air bags while inflating the air bags 322 and 328 connected to back, seat, leg and feet gas manifolds 76', 78', 80' and 82'. The alternating inflation and deflation of the first set of air bags 322 and 328 and the second set of air bags 322 and 328 causes a patient 348 supported thereon to be alternately rocked in one direction and then the other (see Figs. 10A-10D) because of the alternating arrangement of the cutouts 324 on air bags 322 and 328.

To accomplish the rocking of patient 348, the appropriate air bags are alternately inflated and deflated under microprocessor control. Referring to Fig. 3, valves 130a, 132a, and 134a feed air to

manifolds 82, 80, 78 and 76. These manifolds feed air to a first set of air bags 322, 325 and 328 having their pillars 326 and cutouts 324 closer to a first side of bed frame 12. Similarly, valves 130b, 132b, and 134b feed air manifolds 82', 80', 78' and 76' which feed air to a second set of air bags 322, 325 and 328 having their pillars 326 and cutouts 324 closer to the second side of bed frame 12. Valve 128 feeds air to manifold 84 which supplies air to the air bags 321 supporting the head of patient 348. Pressures in each manifold can be controlled by microprocessor 240 by adjustment of the individual valves which supply air to each manifold. The software is programmed to move the patient sequentially to each of three positions corresponding to the pressures set by the operator. Figs. 10A, 10C, and 10D show three such positions, which are sequentially stepped through by the software.

The hump 330 in air bags 328 provides a longitudinal barrier along the top surface of the air bags 328 such that one of the legs of patient 348 is retained on either side of the longitudinal barrier created by the humps 330 even during the alternating inflation and deflation of the bags 328. In this manner, the hump 330 prevents patient 348 from rolling too far to one side of the bed frame 12 or the other. Further, the legs of patient 348 do not slide and/or rub together while patient 348 is being alternately rolled from one side of the bed frame 12 to the other. It will be understood by those skilled in the art that the air bags 328 having the humps 330 therein can be replaced by air bags 321, 322, or 325 depending upon the type of therapy and the extent of motion desired for a particular patient.

The software operates on an internal interrupt basis. That is, the software idles until a specified number of clock pulses is received, at which point an interrupt signal is generated internally by microprocessor 240. When the software detects this internal interrupt, the various functional software modules shown in Fig. 24 are executed sequentially. Since microprocessor 240 is configured to generate the internal interrupt every fifty milliseconds, the functional software modules of Fig. 24 are executed every fifty milliseconds.

Referring now to Fig. 24, there is shown a block diagram of the functional software modules used to accomplish the control functions of the present invention. Initialization and power-down routines, as described below, are also present in the software but have been omitted from this diagram for simplicity. Also omitted are the various interrupt servicing routines. Fig. 24 merely depicts the application software which is executed every fifty milliseconds by microprocessor 240.

Some of the functional modules or routines of Fig. 24 will be described in greater detail below. What follows is an overview of how these routines are integrated to accomplish the objectives of the present invention.

RAM data table 903 is a block of memory which is used to store variables needed by the control software. Those variables include software timers, status flags, switch inputs, analog data inputs, target pressure values, and a target temperature value. Software timers are simply memory contents which are initialized with a specified value and then decremented every fifty milliseconds by general timer routine 252. Switch inputs are digital inputs received from the control panel or from various switches described elsewhere. The status of these switches are stored in RAM data table 903 so that spurious switch bounce conditions can be detected, as is described in greater detail below. Status flags are memory words used by the software to communicate to the software modules a certain status which affects how a software module is to operate. For example, a status flag is used to signify whether the bed is to be rotated to the left, right, or center. Status flags can be changed by external inputs or by the timing out of certain software timers. Analog data, corresponding to values received from pressure and temperature transducers, are also stored in RAM data table 903. Also, the target pressures and temperature, which the software attempts to maintain and is adjustable by operator input, are stored in RAM data table 903.

Upon receiving the aforementioned internal interrupt, the first module to be executed by microprocessor 240 is general timer routine 252. This routine decrements the various software timers and sets certain status flags which affect the operation of other modules when a timed out condition occurs. Next, switch processing routine 254 which scans all the digital inputs is executed. When a change is detected in a digital input, the appropriate switch function routine 284 is executed. As will be described below, those switch function routines update data in RAM data table 903 according to the type of switch input change detected.

After all the digital inputs have been scanned, rotation control routine 292 is executed. Rotation control 292 determines whether valves 128, 130a and 130b, 132a and 132b, or 134a and 134b need to be opened, closed, or maintained in their present position. To make that decision, rotation control routine 292 relies on analog data from the pressure transducers, target pressure values, and status flags which tell the routine which target pressure values to use. Rotation control routine 292 sets status flags which are then read by motor valve routine 316. Motor valve routine 316 actually drives the valve motors 138 according to the decisions made by rotation control routine 292. Those

decisions are communicated to motor valve routine 316 by status flags.

Heater control routine 905 retrieves present and target temperature values from RAM data table 903, compares them, and either turns heater strip 172 on or off with a digital output. The last module to be executed as part of the internal interrupt driven loop is the display writer routine 901. This routine retrieves data from RAM data table 903 which is to be output to the control panel. Display writer routine 901 then drives the bar graph displays 356 of control panel 346 according to the data retrieved. Analog input routine 904 operates continuously according to external interrupts generated by an analog-to-digital converter shown schematically at reference numeral 800, but which is internal to control box 198 and, therefore, not shown elsewhere. Analog input routine 904 retrieves data from analog-to-digital converter 800 and updates the appropriate location in RAM data table 903.

Referring now to Figs. 15-20, the programming of microprocessor 240 will be discussed. As shown in Fig. 15, the initialization of the program is at 242. Variable memory or RAM is cleared at step 244. Before internal or external interrupts are enabled, all RAM variable contents are zeroed and those requiring specific data, such as those stored in the electrically alterable ROM described below, are initialized at step 246. Data and direction registers for the four eight bit ports of microprocessor 240 are then initialized at step 248.

The control software then idles in loop 250 until it receives a 50 millisecond interrupt from the hardware interrupt timer internal to microprocessor 240. Microprocessor 240 then sequentially executes the subroutines 252, 254, 292 and 316, diagrammed in Figs. 16-19. General timer subroutine 252 (see Fig. 16) decrements most of the software driven timers contained in the RAM, including the electrically alterable ROM power "ON" delay before erase timer, the cardiopulmonary switched "OFF" to the audible alarm "ON" delay timer, the audible beep silence timer, and the rotation timer. General timer subroutine 252 is entered from Fig. 15 at connector 253, and the first step 254 is to test to determine whether the power on/off pushbutton 851 (see Fig. 14) has been switched to the "OFF" position or the pause adjust buttons 728, 730 or 732 have been activated, a step which is required because the loop 250 runs at 50 msec intervals whenever main power cord 218 (see Fig. 12) is plugged into a power source (now shown). If either of those buttons 851 or 728, 730 or 732 have been activated, the subroutine 252 continues to step 259A, if not, the status of the rotation timer is checked at step 256, and if the target (zero) has not been attained, the timer is decremented at step 257, if target has been attained, the rotation mode is advanced to the next sequential rotation phase and the timer is re-initialized at step 258 with the respective time delay valve input by the operator using one of switches 728, 730 or 732 on control panel 346.

As will be described, temperature set switch 152 is used in conjunction with display 168 on control panel 346 (see Fig. 14) to set target temperature in air bags 321, 322, 325 and 328 by pressing and holding one or the other of switches 152A or 152B to increment or decrement the counter which advances the target temperature by an increment each time a selected number of 50 msec pulses have elapsed (or decreases by that same increment). If switch 152A or 152B has been activated by the operator, a test is made at step 259B to determine which switch was activated. If decrease/decrement switch 152B was activated, the counter is checked to determine whether the count is at minimum count at step 259C. If so, the subroutine advances to step 259, and if not, the counter is decremented at step 259D and the subroutine 252 continues to step 259. If the status check at step 259B indicates that the temperature increase increment switch 152 has been activated, the counter is checked to determine whether the count is at a maximum at step 259E. If so, subroutine 252 advances to step 259, and if not, the counter is incremented at step 259F and subroutine 252 then advances to step 259.

If the power "ON" delay timer is not zero at step 259, that timer is decremented at 260 until zero is attained, and the subroutine advances to the cardiopulmonary switched "OFF" to the audible alarm "ON" timer for similar processing at step 261. That timer is decremented at step 262 if the timer is not zero, and checked again at step 263. If the timer still has not expired, the alarm (not shown) in microprocessor 240 is activated at 264; if the timer has expired, the routine advances to the audible beep silence timer at 265. If that timer has not expired, the timer is decremented at 266, checked again at 267, and if still not expired, the alarm continues to be activated at 268. The general timer subroutine 252 is then exited when the last timer has been processed, and connects back into the control software at 270 (see Fig. 15).

The switch processing subroutine 254 is diagrammed in Fig. 17, and monitors the status of the switches on control panel 346, the switches 226 and 228 in air box 124, the status of the switches (not shown) of hand control 361 (see Fig. 14), and pressure sensor pad switches 231a and 231b. Switch processing subroutine 254 is entered from Fig. 15 at connector 272, assigns a number to each input at step 274, and processes each numbered input in loop fashion. Each input is tested for status at 50 millisecond intervals at step 276, although it

will be understood by those skilled in the art who have the benefit of this disclosure that other time intervals may likewise be appropriate for testing the status of the inputs. Switch status is tested by comparing the current switch status with the status of the switch from the last interrupt at step 278. If a change is detected, a switch bounce condition is assumed and the switch number is incremented at step 280 for processing the next switch input. If a change from the prior switch status is not detected, a switch position change test is made at step 282 and switch function is executed at step 284 if a switch change is detected. If the switch status is consistent through three successive tests, no switch position change is indicated and the switch number is incremented at step 280 as described above. Switch number is compared to a limit number at step 286, and if less then that limit number, the switch number is incremented at 285 and the above processing is repeated in loop 288 for the incremented switch number. Provision is made to initialize the switch states on power up by testing at step 287 to determine whether the first pass is being made through the switches. If so, the power down memory is read at 289 and those switches for which data is stored in the electrically alterable ROM are initialized at 283 to reflect the switch status at the time of the previous power off. Switch processing subroutine 254 is exited when the last switch number has been processed and connects back into the control software at 290.

There are separate switch function routines 284 for each functional set of operator inputs to control panel 346. Referring to Fig. 14, control panel 346 is shown as having air adjust switches 349, 350, 351, 352, 353, 354, and 355. Each air adjust switch 349, 350, 351, 352, 353, 354, and 355 is actually a pair of buttons or a rocker switch which raises or lowers the target pressure to be achieved in the air bags 58, 321, 322, 325, and 328 by each of valves 128, 130a and 130b, 132a and 132b, 134a and 134b. These target pressures are stored in memory locations by microprocessor 240. In the rotation subroutine described below, the target pressures are used as setpoints which the software attempts to achieve and/or maintain by opening and closing valves 128, 130a and 130b, 132a and 132b, 134a and 134b. There are seven target pressures corresponding to the patient's head, right leg, right body, right shoulder, left leg, left body, and left shoulder, left leg, left body, and left shoulder. The air adjust switches 349, 350, 351, 352, 353, 354, and 355 correspond to each portion of the body of patient 348. In addition, there are three rotation positions designated center, right, and left (see Figs. 10A, 10C, and 10D) for which corresponding switches 628, 340, and 632 are located on control panel 346, making a total of twenty-one target pressures in all. Microprocessor 240 issues valve control commands which cause the inflation and deflation of air bags 58, 321, 322, 325, and 328 to sequentially and repetitively achieve each of the three rotation positions. Each rotation position is defined by the seven target pressures corresponding to that position. Under normal conditions the target pressures are displayed by the bar graph displays 356 above each corresponding air adjust switch. To change a target pressure, one of the rotation position switches 628, 630, or 632 is depressed and the operator depresses either the upper or lower air adjust switch corresponding to the portion of the body of the patient for which the target pressure is to be changed. A switch function routine 284 then increments or decrements the memory location in RAM which corresponds to that target pressure. At the same time, the changing target pressure is output to the bar graph 356 corresponding to the particular air adjust switch. In this way, each of the seven target pressures for each of the three rotation positions is defined by the operator.

Another switch function routine 284 similar to that described above allows the operator to adjust the pause time, i.e., the period of time during which the patient 348 pauses in each of the positions shown in Figs. 10A, 10C, and/or 10D, for each rotation position. The pause time is stored in a timer location which the timer routine decrements after each interval interrupt. The pause times for the center, right, and left positions are adjusted by depressing pause adjust buttons 728, 730 and 732, respectively.

Another switch function routine 284 is executed when the switch processing routine 254 detects an operator input from height adjust switches 233, 235, 236, 237, 238, and 239. Switches 233 and 237 raise and lower the frame section 14' of bed 10, respectively, while switches 236 and 239 raise or lower frame section 14'''', respectively. Switches 235 and 238 raise or lower the entire frame 12 of bed 10, respectively. The switch function routine which is executed when one of those switches is depressed causes actuation of the power screws described above to effect the appropriate height adjustment.

Similarly, another switch function routine 284 allows the operator to adjust the temperature at which the air supply to air bags 321, 322, 325 and/or 328 is to be maintained. The target temperature is used as a setpoint by microprocessor 240 to control heater strip 172. The target temperature is adjusted using switches 152A and 152B, and a digital display 168 of the target temperature is driven by the software.

The rotation subroutine 292 is shown in Fig. 18. This routine is entered at connector 294 after

general timer subroutine 252 has adjusted the appropriate software timers to determine the rotation position to which the bed is to be either driven or maintained. Subroutine 292 is executed for each of valves 128, 130a and 130b, 132a and 132b, 134a and 134b to alternately inflate and deflate the two sets of air bags 322, 325 and 328 supplied with air by manifolds 76, 78, 80, and 82 and 76', 78', 80' and 82' to roll patient 348 from one side of bed frame 12 to the other. The particular valve number is read at step 296. Next, the target pressure for that particular valve set as described above is read at step 300. At step 308, the individual valve 128, 130a and 130b, 132a and 132b, or 134a and 134b may or may not be adjusted according to the output signal of potentiometer 468 which is also read at step 300. Potentiometer 468 inputs a voltage value to analog-to-digital converter 474 which converts that voltage to a digital value representing the angular displacement of a section 14', 14'', 14''' or 14'''' of bed frame 12 with respect to the adjacent section 14', 14'', 14''' or 14''''. For instance, as the section 14' of frame 12 is pivoted with respect to the section 14'', changing the distribution of the weight of the body of patient 348 supported on the air bags 321, 322, 325 and/or 328 as explained below. Accordingly, microprocessor 240 adjusts the target pressures to compensate for that change in weight distribution.

Referring to Fig. 13, two adjacent frame sections 14' and 14'' are shown joined by hinge 44'. Bracket 462 is attached to frame section 14'' by bolt 464 and nut 466. Potentiometer 468 is mounted upon bracket 462 such that the shaft 467 thereof is free to rotate throughout its entire operating range. The shaft 467 of potentiometer 468 and hinge 44' are arranged so that their axes of rotation are aligned. The shaft 467 of potentiometer 468 is journaled in frame section 14'. When frame section 14'' is pivoted with respect to section 14', connector 470 is likewise rotated, causing the rotation of the shaft 467 of potentiometer 468, resulting in a change in the output voltage of potentiometer 468 which is proportional to the angular displacement between frame sections 14' and 14''. That change in output results in a signal which is transmitted by wire 472 to microprocessor 240 (see Fig. 12). The output signal of potentiometer 468 is adjusted so that, for each increment in the elevation of frame section 14' from the horizontal of about 15°, the pressure in the sets of air sacs mounted on baseboards 48 and 50 is increased by about 20% above the base pressure until a maximum angle of 45° from the horizontal is reached.

The threaded shafts 139 of the motors 138 which open or close valves 128, 130a and 130b, 132a and 132b, and 134a and 134b turn very slowly such that the time a motor 138 has been running is used in a linear proportion type algorithm as the timer increments to calculate the theoretical pressure in the coupler 153 of each valve 128, 130a and 130b, 132a and 132b, or 134a and 134b at step 302. Next, the actual pressure from the air chuck 212 (see Figs. 8, 9A, and 9B) corresponding to the particular valve 128, 130a and 130b, 132a and 132b, or 134a and 134b is read at step 304. The pressure from air chucks 212 is transmitted by air pressure lines 213 to pressure transducers (not shown) mounted in control box 198. The pressure transducers are of a type suitable for reading pressures in the range of about 0-1 psig available Microswitch Corp. (Freeport, Illinois) and Sensym Corp. (Sunnyvale, California). The pressure transducers input a voltage proportional to the particular pressure to an analog-to-digital converter within control box 198 which then inputs to microprocessor 240. The actual pressure is then compared to the target pressure at step 306. A decision is then made to either maintain, close, or open the valve and implemented at steps 308a, 308b, or 308c which cause valve motor subroutine 316 to execute the appropriate action at will be described below.

After execution of step 308, provision is made for display of the air pressure in the couplers 153 of valves 138, 130a and 130b, 132a and 132b, and 134a and 134b on bar graphs 356. The operator selects whether actual or target pressures are displayed at step 310 by whether switches 628, 630 or 632 (see Fig. 14) have been actuated. Actual display data is calculated at step 312 and output at 314 to bar graphs 356 at step 314. If one of switches 628, 630 or 632 has been actuated, target display data is calculated at step 315 and output at 314 as before. Rotation subroutine 292 is then exited at connector 298.

Referring to Figs. 1 and 14, an auxiliary control panel 850 is mounted on footboard 21 having push button switches 851, 357, 358, 852, and 853 mounted therein. Pushbutton 851 is the main power on/off switch. Depressing pushbutton 358 puts the low air loss bed 10 in the oscillating patient therapy mode whereby microprocessor 240 steps sequentially through the three previously programmed rotation positions. Activating pushbutton 358 places the bed 10 in the air suspension therapy mode, i.e., stopping rotation of the patient 348 at any position intermediate the two extreme positions shown in Figs. 10A and 10C. Depressing one of pushbuttons 852 or 853 causes the microprocessor 240 to maintain the bed in one of the previously programmed left or right rotation positions.

The valve motor subroutine 316, diagrammed in Fig. 19, converts valve motor movement commands generated by the switch processing and rotation subroutines 254 and 292, respectively, into

valve motor operations, i.e., starting, braking, coasting, and reversing each of the motors 138 used to open and/or close valves 128, 130a and 130b, 132a and 132b, and 134a and 134b. Valve motor subroutine 316 is entered at connector 318. Each motor 138 is assigned a number at step 320 and is tested for its requested status, i.e., run or stop, and direction as compared to current status at step 370. Whenever a running motor 138 is requested to stop, the status of that motor is tested at step 372, and if stopped or stopping, the brake timer is tested at step 374 to determine whether the brake timer is zeroed. If the brake timer is not zeroed, the brake timer is decremented at step 376 and tested again at step 378 to determine whether the brake timer is zeroed. If so, the brake is released at step 380 and the number assigned to that motor 138 is compared to the limit number at step 382 to determine whether that motor 138 is the last motor. If the status of the motor 138 is running at step 372, the motor 138 is turned off and the brake set at step 388, and timer is then initialized at step 390. If the motor 138 is not the last motor, the motor timer is decremented at step 386 and the above processing repeated.

Referring again to step 370, if the requested status of the motor 138 tested is that the motor 138 is to run, the current motor status is tested at 392. If the status of the motor 138 being tested is that the motor 138 is stopped or stopping, the requested status and the current status of the motor are compared to determine whether they are the same at step 394. If the requested status and the current status are not the same, the brake timer is tested to determine whether the brake timer is at zero at step 396. If the brake timer is not zeroed, the brake timer is decremented at step 398 and the number assigned that motor 138 is tested at step 382 to determine whether that motor 138 is the last motor. If motor 138 is not the last motor, the motor timer is decremented at step 386 and the above processing repeated. If the brake timer is zeroed at step 396, the direction of rotation of motor 138 is reversed at step 400, motor 138 is turned on at step 402, the motor run timer is initialized at step 404, and the number assigned to that motor 138 is tested at step 382 to determine whether that motor 138 is the last motor. If motor 138 is not the last motor, the motor timer is decremented at step 386 and the above processing repeated. If the requested status and the current status are the same at step 394, motor 138 is turned on at step 402, the motor run timer is initialized at step 404, and the number assigned to that motor 138 is tested to determine whether that motor 138 is the last motor. If motor 138 is not the last motor, the motor timer is decremented at step 386 and the above processing repeated.

Returning to step 392, if the current status of motor 138 is that the motor 138 is running, the requested status and the current status are compared at step 406 to determine whether they are the same. If requested and current status are not the same, motor 138 is switched off and the brake is set at 388, the brake timer is initialized at step 390, and processing continues as described above. If the requested and current status of motor 138 are the same, the motor run timer is tested at step 408 to determine whether the run timer is zeroed. If the run timer is not zeroed, the motor run timer is decremented at step 410 and tested again at step 412 to determine whether the run timer is zeroed. If so, motor 138 is turned off at step 414, the number assigned to motor 138 is compared to the limit number at step 382 to determine whether motor 138 is compared to the limit number at step 382 to determine whether motor 138 is the last motor, and processing continues as described above. If the run timer is zeroed at step 408 or 412, the number assigned to motor 138 is compared to the limit number at step 382 to determine whether motor 138 is the last motor and processing continues as described above.

A power fail interrupt subroutine 416, diagrammed in Fig. 20, writes certain controller configuration parameters such as blower and rotation mode status in the electrically alterable ROM in the event of a power failure or when low air loss bed 10 is unplugged. Power fail interrupt subroutine 416 is entered upon receipt of an interrupt from an external hardware interrupt (not shown). If the electrically alterable ROM power on delay before erase timer (EEROM timer) tested at step 418 is zeroed, i.e., if low air loss bed 10 has been powered on for more than a few seconds such that the electrically alterable ROM is available for writing, the aforementioned parameters are stored to memory at step 420 and the EEROM timer is initiated at step 422 before returning to the codes before the interrupt at step 424. If the EEROM timer is not zeroed at step 418, low air loss bed 10 has probably just been powered on and the memory is not available for writing. Should the control software (see Fig. 15) receive a power interruption that generates the power fail interrupt and performs the memory write but does not actually interrupt power to the control software, power fail interrupt subroutine 416 initializes the EEROM timer and will be available to rewrite the memory after the EEROM timer has once again timed out.

As noted above, the frame 12 is hinged at 44', 44'' and 44''', allowing the baseboards 46 and 52 to be raised from the horizontal, changing the angle of inclination for the comfort of 348 patient or for therapeutic purposes. However, especially when head baseboard 52 is raised, the deviation from the

horizontal places a disproportionate amount of the weight of patient 348 on the air bags 322 over the legs 48 and seat 50 baseboards. In a presently preferred embodiment of the present invention, there are only three air bags 322 mounted on each of the baseboards 48 and 50, such that a great proportion of the patient's weight, which is spread out over more than 20 of the air bags 58, 322 and 328 when the sections 14', 14'', 14''' and 14'''' are all in the same horizontal plane, is concentrated onto as few as six of the air bags 322. Pressure sensor pad switches 231a and 231b (see Fig. 14) are placed flat on legs baseboard 48 and seat baseboard 50 so that, in the event a portion of the patient's body contacts either one of those switches 231a or 231b, the above-described buzzer is activated by microprocessor 240, and can be silenced by activation of switch 347 by the operator, and the air pressure in air bags 322 mounted to seat baseboard 50 can be raised by the operator.

Referring to Fig. 12, there is shown a schematic electrical diagram of a low air loss bed constructed according to the teachings of the present invention. Alternating current enters the circuitry in electric cord 218, which is connected to power distribution board 219. Power distribution board 219 includes a power supply module 220 to supply power to microprocessor 240 through cable 211 and solid state relays to control each of the blowers 108 and heater strip 172. Power distribution board 219 provides power to the motors (not shown) within boxes 45 for raising, lowering and positioning the frame 12 of low air loss bed 10 by means of lead 223 which connects to the junction box 224 of bed circuitry 43. Power distribution board 219 also powers the electric motors 114 of blowers 108. Each of the blowers 108 is provided with a capacitor 236, and switch 192 is provided on control panel 346 for deactivation of one of the blowers 108 by virtue of the connection provided by cable 243 to switch 241 on blowers 108.

Referring to Fig. 14, a temperature sensor, shown schematically at 194, is located in seat manifold 80. When the target temperature set by the operator using switches 152A or 152B and display 168 is less than the temperature of the air in seat manifold 80, heating strip 172 is switched on by microprocessor 240. Heating strip 172 is provided with current by wires $167_i$ and $167_o$ from main power supply module 220 (see Fig. 12). Switch 191 on control panel 346 is used to activate or deactivate heating strip 172.

Limit switches 226 and 228 are provided in manifold plate 145 and on full inflate plate 144, respectively (see Figs. 4, 8, 9A and 14). Limit switch 226 is closed when push button 230 is engaged by dump plate. When push button 230 is disengaged by the movement of dump plate 150 away from manifold plate 145 under the influence of levers 165, the circuit is opened and blowers 108 are shut off. Limit switch 228 is affixed to full inflate plate 144 by screws 232, and the circuit is open when lever arm 234 engages manifold plate 145. When full inflate plate 144 is opened under the influence of full inflate knobs 193, limit switch 228 is closed, activating both blowers 108 if not already on and the buzzer which is incorporated into microprocessor 240. A switch 347 is provided on control panel 346 to silence that buzzer.

Control panel 346 is connected to controller 198 by ribbon connectors 200. Controller 198 includes microprocessor 240 and the other necessary circuitry. Controller 198 is provided with plug-type receptors 205 for receiving the plugs 207 of cables 108, 211, 225, 227 and 229.

Cable 208 connects controller 198 to temperature sensor 194 and the pressure sensor pad switches 231. Cable 211 connects directly to power distribution board 219 and feeds power to controller 198 while conducting control signals to power distribution board 219 to control the functions of blowers 108 and heating strip 172. Cables 170a and 170b are provided with separate wires $184_i$ and $184_o$ for each motor 138, thereby conducting low voltage D.C. current to each of the motors 138. Cable 170a is also provided with separate wires $226_i$ and $226_o$ and $228_i$ and $228_o$ connecting separately to limit switches 226 and $228_i$ respectively.

Cable 227 is provided with plugs 359 and the other end from plug 207 for engaging a complementary plug 360 on a separate hand control 361 which duplicates the function of switches 349-358 on control panel 346. Hand controls 361 are shown schematically in Fig. 14 because they merely duplicate keyboard 346 functions. Plugs 359 are provided on both sides of bed frame 12 (not shown in Fig. 14) to facilitate easy access by hospital personnel with hand control 361.

Cable 229 is provided with plugs 362 and 363 at the other end from plug 207 for engaging complementary plugs 364 and 366, respectively. Plug 364 is located in the circuitry of the board frame 12 in circuit box 43 (see Fig. 7), shown schematically at box 367. Plug 366 is located on a hand control, shown schematically at 368, which duplicates the function of switches 233 and 235-239 on control panel 346. When hand control 368 is used to adjust the angle of inclination of head and foot baseboards 54 and 46, respectively, signals generated by activation of the switches (not shown) on hand control 368 are transmitted directly to the circuitry 367 of bed frame 12.

Although the present invention has been described in terms of the foregoing preferred embodiments, this description has been provided by way of explanation only and is not to be construed as a

limitation of the invention, the scope of which is limited only by the following claims.

## Claims

1. A method of operating a feedback-controlled patient-support system of the type having a patient support (10) including a plurality of inflatable air bags comprising at least a first and a second separately inflatable air bag (322) for supporting a patient (348) and connected in variable fluid communication with an air supply means (108), the first air bag (322) being adapted to roll a patient in a first direction in response to inflation control, and the second air bag (322) being adapted to roll the patient in a second, opposite direction in response to inflation control, said air supply means (108) being connected in variable fluid communication with said air bags (322) for separately and alternately inflating the air bags; characterised in that the method comprises sensing the air pressure in at least a portion of the first and second air bags; and controlling said air supply means (108) in a feedback manner by the use of means (240) linked with the air pressure sensing means, to roll the patient first in said first direction and then in said second direction while ensuring that throughout the control operation of the air supply to raise and to lower the air pressure in the bags, the level of said air pressure in the bags is not permitted to fall below a predetermined minimum level.

2. A method as claimed in claim 1, characterised in that a baseline pressure is selected in the first and second air bags by selection means (628 and 349), first and second target pressures to which at least a portion of the first and second air bags are to be inflated are selected by said selection means; and the air pressure in the air bags (322) is compared by control means (240), linked with said sensing means, to the target pressure selected for each of said first and second air bags and, then, alternately inflating the first air bag to its selected first target pressure when the air pressure in said first air bag is lower than its first target pressure so as to roll the patient in said first direction as said first air bag is inflated, and inflating the second air bag to its selected second target pressure when the air pressure in said second air bag is lower than its second target pressure so as to roll the patient in said second direction.

3. A method as claimed in claim 2, characterised in that timer means (252) are provided to control the intervals at which said bags are maintained at said first and second target pressures and when said bags are inflated and deflated.

4. A method as claimed in claim 1, characterised in that the air pressure sensing means includes a probe in the air supply to said air bags (322).

5. A method as claimed in claim 1, characterised in that a microprocessor (240) is provided to control the air pressures in said bags.

6. A method as claimed in claim 1, characterised in that said air supply means (124) is arranged to selectively inflate said bags to support a patient thereon for maintaining low interface pressures and to roll a patient thereon and sensing the air pressure in said bags and for maintaining a controlled, variable, amount of air pressure in said bags during inflation and deflation of said bags to uniformly roll a patient supported on said bags, the air bags and the air bags of each said first and second set of air bags being oriented transversely relative to said patient support.

7. A method as claimed in claim 6, characterised in that baseline air pressures in said air bags (322) are set by said controlling means.

8. A method as claimed in either one of claims 6 and 7, characterised in that target air pressures in said bags (322) are set by said controlling means.

9. A method as claimed in claim 8, characterised in that said controlling means are provided with timer means to determine the intervals between said pressures and when said bags are inflated and deflated.

10. A method as claimed in claim 1, characterised in that in addition to setting a pre-determined minimum level for air pressure in said sacs, there is also set a predetermined upper or target level greater than said minimum level.

11. A method as claimed in claim 10, characterised by the step of inflating and deflating at least a portion of adjacent bags between said target pressure and said minimum pressure.

12. A feedback-controlled patient support system of the type having a patient support including a plurality of inflatable air bags connected in variable fluid communication with an air supply

means, comprising :

a patient support (10) including at least a first and a second separately inflatable air bag chambers (322) for supporting a patient (348), the first chamber being adapted to rotate a patient in a first direction in response to inflation control, and the second chamber being adpated to rotate the patient in a second, opposite, direction in response to inflation control;

air supply means (108) connected in variable fluid communication with said air bags (322) for selectively inflating the air bag chambers, characterised by :

means for sensing the air pressure in the first and second chambers (322); and

means linked with said sensing means, for controlling said air supply means (108) in a feedback manner, to roll the patient in said first direction and then in said second direction by monitoring and controlling the air pressure in said first and second chambers (322), while ensuring that throughout the operation of the air supply control means, the level of air pressure in the chambers is not permitted to fall below a predetermined minimum level.

**13.** A system as claimed in claim 12, characterised in that said control and sensor means maintain at least predetermined air minimum pressures in said bags during rolling.

**14.** A system as claimed in claim 12, characterised in that the plurality of air bags is mounted to an articulated frame, having controlling means (240) for controlling the provision of pressurised gas to a plurality of air bags (322) in response to pressures sensed in said air bags to inflate the same, a first set of said air bags being mounted to a first section (14'') of a frame (12); said control means including means for increasing the pressure in the first set of said air bags responsive to pivoting of a second section (14') of said frame relative to the first section of said frame.

**15.** A system as claimed in claim 14, characterised in that the frame (12) is articulatable to vary the position of a patient lying on the support system, said frame including an articulatable first section (14'') and the plurality of elongated inflatable air sacs (322 and 328) being arranged atop said frame; gas supply means (124) in communication with each of said air bags for supplying gas to same, the control means (240) being associated with said gas supply means and said air bags for controlling supply of gas to each of said air bags according to predetermined target pressure values and according to a plurality of predetermined groups of said air bags, each said group defining a separate support zone; there being further provided means (468) associated with said frame (12) for sensing one of a plurality of degrees of articulation of said first section of said frame; control means (240) operatively associated with the articulation sensing means to vary gas pressure in said air bags according to the degree of elevation of the first section of the frame as determined by said articulation sensing means; and pressure sensing means in fluid communication with said air bags for sensing pressures in said air bags; said control means being operatively associated with said pressure sensing means to control gas pressure in said air bags (322) in response to the pressures sensed by said pressure sensing means.

**16.** A system as claimed in claim 15, characterised in that said control means is further provided with a valve control circuit and a multi-outlet, variable flow, gas valve means having at least one motor (138) for varying the flow through one of the outlets of said gas valve means; said valve control circuit being provided with a power supply for driving said motor(s) (138) of said valve means, said power supply being connected to said motor to drive same and adjust the flow of said at least one outlet; said control means (240) further comprising articulation pressure adjustment means; pressure sensing means in fluid communication with said air bags (322) for sensing pressures in said air bags; and said control means (240) operatively associated with said pressure sensing means to control gas pressure in said air bags (322) in response to the pressures sensed by said pressure sensing means.

**Patentansprüche**

**1.** Verfahren zum Betreiben eines durch Rückkopplung gesteuerten Patienten-Auflagesystems des Typs, das eine Auflage (10) für einen Patienten mit einer Vielzahl von aufblasbaren Luftsäcken hat, die wenigstens einen ersten und einen zweiten getrennt aufblasbaren Luftsack (322) zur Auflage eines Patienten (348) aufweist und in Form einer regelbaren Fluid-Verbindung mit einem Luftzufuhrmittel (108) verbunden ist, wobei der erste Luftsack (322) darauf abgestimmt ist, einen Patienten in Reaktion auf die Aufblassteuerung in einer ersten Richtung zu rollen, und der zweite Luftsack (322) darauf abgestimmt ist, einen Patienten in Reaktion auf die Aufblassteuerung in

einer zweiten, der entgegengesetzten, Richtung zu rollen, wobei das Luftzufuhrmittel (108) in regelbarer Fluid-Verbindung mit den Luftsäcken (322) verbunden ist, um die Luftsäcke getrennt und abwechselnd aufzublasen; dadurch gekennzeichnet, daß das Verfahren das Messen des Luftdrucks in wenigstens einem Abschnitt des ersten und des zweiten Luftsacks; und die Steuerung des Luftzufuhrmittels (108) in Form einer Rückkopplung durch die Verwendung von Mitteln (240), die mit dem Luftdruck-Meßmittel verbunden sind, einschließt, um den Patienten zuerst in der ersten Richtung und dann in der zweiten Richtung zu rollen, wobei gewährleistet wird, daß während des Vorgangs der Steuerung der Luftzufuhr zum Anheben oder Senken des Luftdrucks in den Säcken der Pegel des Luftdrucks in den Säcken nicht unter einen festgelegten Mindestwert absinken kann.

**2.** Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß in den ersten und zweiten Luftsäcken ein Meßlinien-Druck durch Wählmittel (628 und 349) gewählt wird, erste und zweite Zieldrücke, auf die wenigstens ein Abschnitt des ersten und des zweiten Luftsacks aufzublasen sind, durch das Wählmittel gewählt werden; und der Luftdruck in den Luftsäcken (322) durch ein Steuermittel (240), das mit dem Meßmittel verbunden ist, mit dem Zieldruck, der für Jeden der ersten und zweiten Luftsäcke gewählt wurde, verglichen wird und dann abwechselnd der erste Luftsack auf den gewählten ersten Zieldruck aufgeblasen wird, wenn der Luftdruck in dem ersten Luftsack niedriger als der erste Zieldruck ist, um so den Patienten in der ersten Richtung zu rollen, wenn der erste Luftsack aufgeblasen wird, und der zweite Luftsack auf den gewählten zweiten Zieldruck aufgeblasen wird, wenn der Luftdruck in dem zweiten Luftsack niedriger als der zweite Zieldruck ist, um so den Patienten in der zweiten Richtung zu rollen.

**3.** Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß Zeitgebermittel (252) vorhanden sind, um die Intervalle zu steuern, während der die Luftsäcke bei dem ersten und zweiten Zieldruck gehalten werden, und um zu steuern, wann die Luftsäcke aufgeblasen und abgelassen werden.

**4.** Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß das Luftdruck-Meßmittel eine Sonde in der Luftzufuhr zu den Luftsäcken (322) einschließt.

**5.** Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß ein Mikroprozessor (240) vorgesehen ist, um die Luftdrücke in den Luftsäcken zu steuern.

**6.** Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß das Luftzufuhrmittel (124) so angeordnet ist, daß die Luftsäcke selektiv aufgeblasen werden, um einen Patienten auf diesen zu tragen, und daß die Grenzflächen-Drücke niedrig gehalten werden, um einen Patienten auf diesen zu rollen, und daß der Luftdruck in den Luftsäcken gemessen wird und daß während des Aufblasens und Luft-Ablassens der Luftsäcke ein kontrolliertes, regelbares Maß an Luftdruck in den Luftsäcken aufrechterhalten wird, um einen auf diesen Luftsäcken aufliegenden Patienten gleichmäßig zu rollen, wobei die Luftsäcke und die Luftsäcke jedes des ersten und zweiten Satzes von Luftsäcken im Verhältnis zur Auflage des Patienten quer angeordnet sind.

**7.** Verfahren nach Anspruch 6, dadurch gekennzeichnet, daß die Meßlinien-Luftdrücke in den Luftsäcken (322) durch das Steuermittel festgelegt werden.

**8.** Verfahren nach einem der Ansprüche 6 und 7, dadurch gekennzeichnet, daß die Zielluftdrucke in den Luftsäcken (322) durch das Steuermittel festgelegt werden.

**9.** Verfahren nach Anspruch 8, dadurch gekennzeichnet, daß das Steuermittel mit einem Zeitgebermittel versehen ist, um die Intervalle zwischen den Drücken und die Zeitpunkte zu bestimmen, wann die Luftsäcke aufgeblasen und abgelassen werden.

**10.** Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß neben der Festlegung eines bestimmten Mindestpegels für den Luftdruck in den Luftsäcken auch ein bestimmter oberer oder Zielpegel festgelegt wird, der größer als der Mindestpegel ist.

**11.** Verfahren nach Anspruch 10, gekennzeichnet durch den Schritt des Aufblasens und des Luft-Ablassens wenigstens eines Abschnitts von nebeneinanderliegenden Luftsäcken zwischen dem Zieldruck und dem Mindestdruck.

**12.** Durch Rückkopplung gesteuertes Patienten-Auflagesystem des Typs, das eine Auflage für einen Patienten hat, die eine Vielzahl von aufblasbaren Luftsäcken einschließt, die in Form einer regelbaren Fluid-Verbindung mit einem

Luftzufuhrmittel verbunden sind, das folgende Element umfaßt:

eine Patienten-Auflage (10), die wenigstens eine erste und eine zweite getrennt aufblasbare Luftsack-Kammer (322) zum Tragen eines Patienten (348) einschließt, wobei die erste Kammer darauf abgestimmt ist, einen Patienten in Reaktion auf die Aufblassteuerung in einer ersten Richtung zu drehen, und die zweite Kammer darauf abgestimmt ist, den Patienten in Reaktion auf die Aufblassteuerung in einer zweiten, entgegengesetzten, Richtung zu drehen;

ein Luftzufuhrmittel (108), das in Form einer regelbaren Fluid-Verbindung mit den Luftsäcken (322) verbunden ist, um die Luftsack-Kammern aufzublasen, gekennzeichnet durch;

ein Mittel zur Messung des Luftdrucks in der ersten und zweiten Kammer (322); und

ein Mittel, das mit dem Luftdruck-Meßmittel verbunden ist, um das Luftzufuhrmittel (108) in Form einer Rückkopplung zu steuern, um den Patienten durch Überwachung und Steuerung des Luftdrucks in der ersten und zweiten Kammer (322) in der ersten und dann in der zweiten Richtung zu rollen, wobei gewährleistet ist, daß während der Arbeit des Luftzufuhr-Steuermittels der Pegel des Luftdrucks in den Kammern nicht unter einen bestimmten Mindestpegel fallen kann.

**13.** System nach Anspruch 12, dadurch gekennzeichnet, daß das Steuer- und Meßmittel während des Rollens zumindest einen festgelegten Mindest-Luftdruck in den Luftsäcken aufrechterhält.

**14.** System nach Anspruch 12, dadurch gekennzeichnet, daß die Vielzahl von Luftsäcken an einem Gelenkrahmen angebracht wird, der ein Steuermittel (240) hat, um in Reaktion auf die in den Luftsäcken gemessenen Drücke die Bereitstellung eines unter Druck stehenden Gases für eine Vielzahl von Luftsäcken (322) zu steuern, um diese aufzublasen, wobei ein erster Satz der Luftsäcke an einer ersten Sektion (14'') eines Rahmens (12) angebracht ist; wobei das Steuermittel ein Mittel zur Erhöhung des Drucks im ersten Satz der Luftsäcke in Reaktion auf eine Schwenkbewegung einer zweiten Sektion (14') des Rahmens im Verhältnis zu der ersten Sektion des Rahmens einschließt.

**15.** System nach Anspruch 14, dadurch gekennzeichnet, daß der Rahmen (12) mit Gelenken versehen ist, um die Position eines Patienten, der auf dem Auflagesystem liegt, zu verändern, wobei der Rahmen eine mit Gelenken versehene erste Sektion (14'') einschließt und die Vielzahl der langgestreckten, aufblasbaren Luftsäcke (322 und 328) oben auf dem Rahmen angeordnet ist; Gaszufuhrmittel (124) in Verbindung mit Jedem der Luftsäcke, um diesen Gas zuzuführen, wobei das Steuermittel (240) dem Gaszufuhrmittel und den Luftsäcken zugeordnet ist, um die Zufuhr von Gas zu Jedem der Luftsäcke nach bestimmten Werten des Zieldrucks und gemäß einer Vielzahl von festgelegten Gruppen von Luftsäcken zu steuern, wobei jede der Gruppen eine gesonderte Auflagenzone definiert; daß außerdem folgende Elemente bereitgestellt werden: Mittel (468), die dem Rahmen (12) zugeordnet sind, um einen aus einer Vielzahl von Graden der Gelenkstellung der ersten Sektion des Rahmens zu messen; Steuermittel (240), die funktionell mit dem Meßmittel für die Gelenkstellung verbunden sind, um den Gasdruck in den Luftsäkken dem Grad der Anhebung der ersten Sektion des Rahmens entsprechend, die durch das Meßmittel für die Gelenkstellung bestimmt wird, zu variieren; und Druckmeßmittel in Fluid-Verbindung mit den Luftsäcken, um die Drücke in den Luftsäcken zu messen; wobei das Steuermittel funktionell dem Druckmeßmittel zugeordnet ist, um den Gasdruck in den Luftsäcken (322) in Reaktion auf die Drücke, die von dem Luftdruckmeßmittel gemessen werden, zu steuern.

**16.** System nach Anspruch 15, dadurch gekennzeichnet, daß das Steuermittel außerdem versehen ist mit einem Ventil-Steuerkreis und einem Gasventilmittel mit mehreren Austrittsöffnungen und veränderlichem Durchfluß, das wenigstens einen Motor (138) hat, um den Durchfluß durch eine der Austrittsöffnungen des Gasventilmittels zu verändern; wobei der Ventil-Steuerkreis mit einer Stromversorgung versehen ist, um den (die) Motor(en) (138) des Ventilmittels anzutreiben, wobei die Stromversorgung mit dem Motor verbunden ist, um diesen anzutreiben und den Durchfluß durch die wenigstens eine Austrittsöffnung zu regulieren; wobei das Steuermittel (240) außerdem folgende Elemente aufweist: Druckeinstellmittel für die Gelenkverbindung; Druckmeßmittel in Fluid-Verbindung mit den Luftsäcken (322), um die Drücke in den Luftsäcken zu messen; und wobei das Steuermittel (240) funktionell mit dem Druckmeßmittel verbunden ist, um den Gasdruck in den Luftsäcken (322) in Reaktion auf die Drücke, die durch das Druckmeßmittel gemessen werden, zu steuern.

## Revendications

1. Procédé de commande d'un système de support d'un patient à commande par réaction, du type comportant un support du patient (10) englobant plusieurs coussins d'air gonflables, comprenant au moins un premier et un deuxième coussins d'air gonflables séparément (322) pour supporter un patient (348), et connectés par une communication à fluide variable à un moyen d'amenée d'air (108), le premier coussin d'air (322) étant destiné à faire rouler un patient dans une première direction en réponse à la commande de gonflage, et le deuxième coussin d'air (322) étant destiné à faire rouler le patient dans une deuxième direction opposée en réponse à la commande de gonflage, ledit moyen d'amenée d'air (108) étant connecté par une communication à fluide variable auxdits coussins d'air (322) pour gonfler séparément et alternativement les coussins d'air; caractérisé en ce que le procédé comprend la détection de la pression d'air dans au moins une partie des premier et deuxième coussins d'air; et par la commande dudit moyen d'amenée d'air (108) par réaction par l'intermédiaire d'un moyen (240) relié au moyen de détection de la pression d'air, pour faire rouler le patient d'abord dans ladite première direction et ensuite dans ladite deuxième direction, tout en assurant que pendant toute l'opération de commande de l'amenée d'air, pour augmenter et abaisser la pression d'air dans les coussins, le niveau de ladite pression d'air dans les coussins ne puisse pas tomber au-dessous d'un niveau minimal prédéterminé.

2. Procédé selon la revendication 1. caractérisé en ce qu'une pression de base est sélectionnée dans les premier et deuxième coussins d'air par l'intermédiaire d'un moyen de sélection (628 et 349), en ce que des première et deuxième pressions cibles auxquelles au moins une partie des premier et deuxième coussins d'air doit être gonflée, sont sélectionnées par ledit moyen de sélection; et en ce que la pression d'air dans les coussins d'air (322) est comparée par un moyen de commande (240) relié audit moyen de détection, à la pression cible sélectionnée pour chacun desdits premier et deuxième coussins d'air, le premier coussin d'air étant ensuite alternativement gonflé à sa première pression cible sélectionnée lorsque la pression d'air dans ledit premier coussin d'air est inférieure à sa première pression cible, de sorte à faire rouler le patient dans ladite première direction lorsque ledit premier coussin d'air est gonflé, et le deuxième coussin d'air étant gonflé à sa deuxième pression cible sélectionnée lorsque la pression d'air dans ledit deuxième coussin d'air est inférieure à sa deuxième pression cible, de sorte à faire rouler le patient dans ladite deuxième direction.

3. Procédé selon la revendication 2, caractérisé en ce que des moyens de minuterie (252) sont prévus pour commander les intervalles auxquels lesdits coussins sont maintenus auxdites première et deuxième pressions cibles ainsi que les moments de gonflage et de dégonflage desdits coussins.

4. Procédé selon la revendication 1, caractérisé en ce que le moyen de détection de la pression d'air englobe une sonde dans l'amenée d'air vers lesdits coussins d'air (322).

5. Procédé selon la revendication 1, caractérisé en ce qu'un microprocesseur (240) sert à la commande des pressions d'air dans lesdits coussins.

6. Procédé selon la revendication 1, caractérisé en ce que ledit moyen d'amenée d'air (124) est agencé de sorte à gonfler sélectivement lesdits coussins pour y supporter un patient, en vue du maintien de pressions d'interface peu élevées et d'y faire rouler un patient, à détecter la pression d'air dans lesdits coussins et à maintenir une valeur de pression d'air commandée et variable dans lesdits coussins pendant le gonflage et le dégonflage desdits coussins, pour faire rouler uniformément un patient supporté sur lesdits coussins, les coussins d'air et les coussins d'air de chacun desdits premier et deuxième groupes de coussins d'air étant orientés transversalement par rapport audit support du patient.

7. Procédé selon la revendication 6, caractérisé en ce que les pressions d'air de base dans lesdits coussins d'air (322) sont réglées par ledit moyen de commande.

8. Procédé selon l'une quelconque des revendications 6 et 7, caractérisé en ce que les pressions d'air cibles dans lesdits coussins (322) sont réglées par ledit moyen de commande.

9. Procédé selon la revendication 8, caractérisé en ce que lesdits moyens de commande comportent des moyens de minuterie pour déterminer les intervalles entre lesdites pressions ainsi que les moments de gonflage et de dé-

gonflage desdits coussins.

**10.** Procédé selon la revendication 1, caractérisé en ce qu'en plus du réglage d'un niveau minimal prédéterminé de la pression d'air dans lesdits coussins, il y a aussi réglage d'un niveau cible ou supérieur, dépassant ledit niveau minimal.

**11.** Procédé selon la revendication 10, caractérisé par l'étape de gonflage et de dégonflage d'au moins une partie de coussins adjacents entre ladite pression cible et ladite pression minimale.

**12.** Système de support d'un patient à commande par réaction, du type comportant un support de patient englobant plusieurs coussins d'air gonflables connectés par une communication à fluide variable à un moyen d'amenée d'air, comprenant:

un support du patient (10) englobant au moins une première et une deuxième chambres à coussins d'air gonflables séparément (322) pour supporter un patient (348), la première chambre étant destinée à faire tourner un patient dans une première direction, en réponse à la commande de gonflage, et la deuxième chambre étant destinée à faire tourner le patient dans une deuxième direction opposée, en réponse à la commande de gonflage;

un moyen d'amenée d'air (108) connecté par une communication à fluide variable auxdits coussins d'air (322), pour gonfler sélectivement les chambres à coussins d'air, caractérisé par:

un moyen pour détecter la pression d'air dans les première et deuxième chambres (322); et

un moyen relié audit moyen de détection, pour assurer la commande par réaction dudit moyen d'amenée d'air (108), de sorte à faire rouler le patient dans ladite première direction et ensuite dans ladite deuxième direction en surveillant et commandant la pression d'air dans lesdites première et deuxième chambres (322), tout en assurant que pendant le fonctionnement du moyen de commande d'amenée d'air le niveau de la pression d'air dans les chambres ne puisse pas tomber au-dessous d'un niveau minimal prédéterminé.

**13.** Système selon la revendication 12, caractérisé en ce que lesdits moyens de commande et de détection maintiennent au moins des pressions d'air minimales prédéterminées dans lesdits coussins au cours du roulement.

**14.** Système selon la revendication 12, caractérisé en ce que les plusieurs coussins d'air sont montés sur un cadre articulé, comportant un moyen de commande (240) pour la commande de l'amenée de gaz sous pression à plusieurs coussins d'air (322) en réponse aux pressions détectées dans lesdits coussins d'air, en vue de les gonfler, un premier groupe desdits coussins d'air étant monté sur une première section (14'') d'un cadre (12); ledit moyen de commande englobant un moyen pour accroître la pression dans le premier groupe desdits coussins d'air, en réponse au pivotement d'une deuxième section (14') dudit cadre par rapport à la première section dudit cadre.

**15.** Système selon la revendication 14, caractérisé en ce que le cadre (12) peut être articulé pour changer la position d'un patient reposant sur le système de support, ledit cadre englobant une première section articulable (14'') et les plusieurs coussins d'air allongés gonflables (322 et 328) étant agencés en haut dudit cadre; un moyen d'amenée de gaz (124) communiquant avec chacun desdits coussins d'air pour leur amener du gaz, le moyen de commande (240) étant associé avec ledit moyen d'amenée de gaz et avec lesdits coussins d'air pour assurer la commande de l'amenée du gaz à chacun desdits cousins d'air, en fonction de valeurs de pressions cibles prédéterminées et en fonction de plusieurs groupes prédéterminés desdits coussins d'air, chacun desdits groupes définissant une zone de support séparée; un moyen (468) étant en outre associé avec ledit cadre (12) pour détecter un de plusieurs degrés d'articulation de ladite première section dudit cadre; un moyen de commande (240) associé en service avec le moyen de détection de l'articulation pour faire varier la pression du gaz dans lesdits coussins d'air en fonction du degré d'élévation de la première section du cadre, comme déterminé par ledit moyen de détection de l'articulation; et un moyen de détection de la pression, en communication de fluide avec lesdits coussins d'air, pour détecter les pressions dans lesdits coussins d'air; ledit moyen de commande étant associé en service avec ledit moyen de détection de la pression pour commander la pression du gaz dans lesdits coussins d'air (322) en réponse aux pressions détectées par ledit moyen de détection de la pression.

**16.** Système selon la revendication 15, caractérisé en ce que ledit moyen de commande comporte en outre un circuit de commande à soupape et une soupape de gaz à plusieurs orifices de

sortie et à écoulement variable, comportant au moins un moteur (138) pour faire varier l'écoulement à travers l'un des orifices de sortie dudit moyen de soupape de gaz; ledit circuit de commande à soupape comportant un bloc d'alimentation pour entraîner ledit (lesdits) moteur(s) (138) dudit moyen de soupape, ledit bloc d'alimentation étant connecté audit moteur pour entraîner celui-ci et ajuster l'écoulement à travers ledit au moins un orifice de sortie; ledit moyen de commande (240) comprenant en outre un moyen d'ajustement de la pression d'articulation; un moyen de détection de la pression, en communication de fluide avec lesdits coussins d'air (322) pour détecter les pressions dans lesdits coussins d'air; et ledit moyen de commande (240) étant associé en service avec ledit moyen de détection de la pression pour commander la pression du gaz dans lesdits coussins d'air (322) en réponse aux pressions détectées par ledit moyen de détection de la pression.

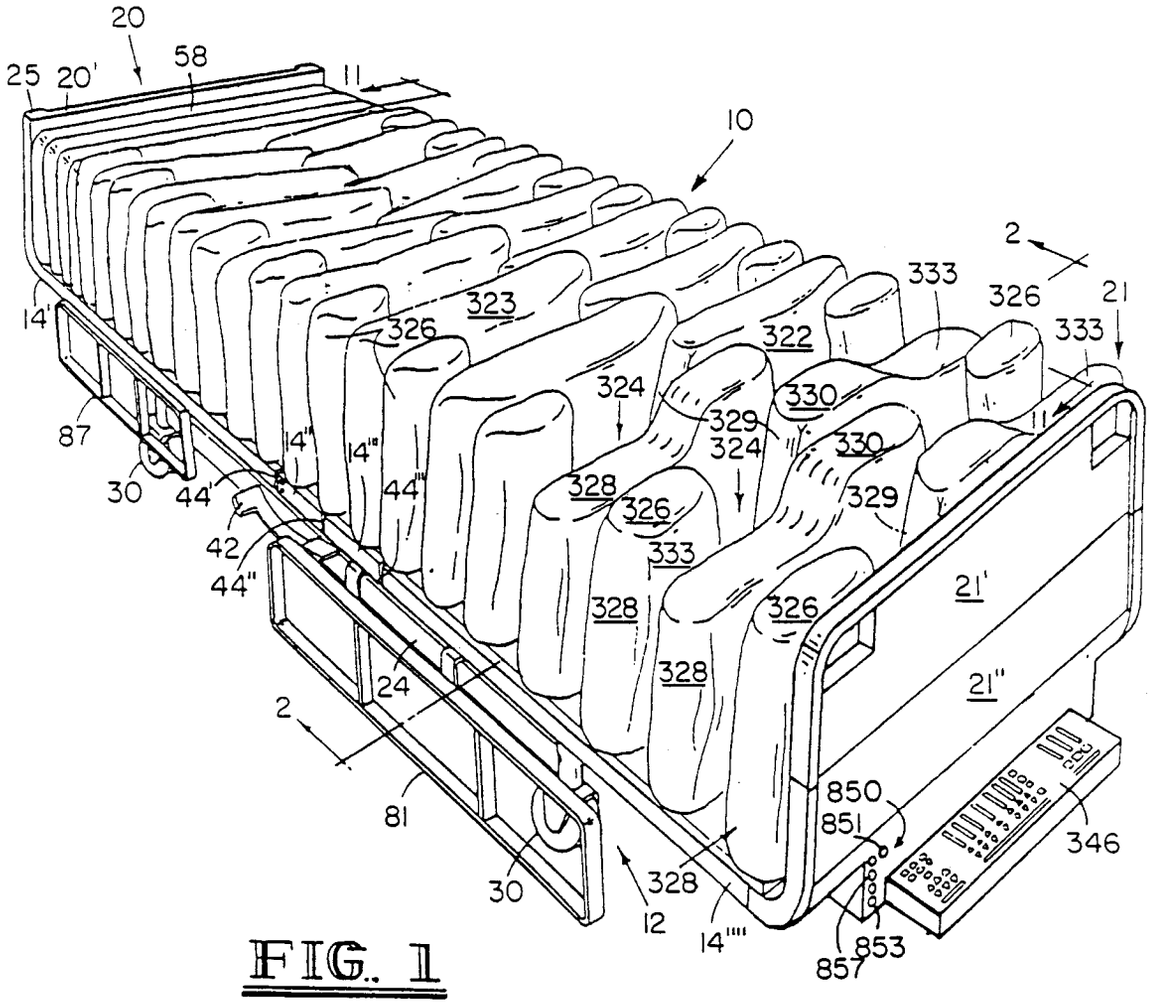
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FIG. 1

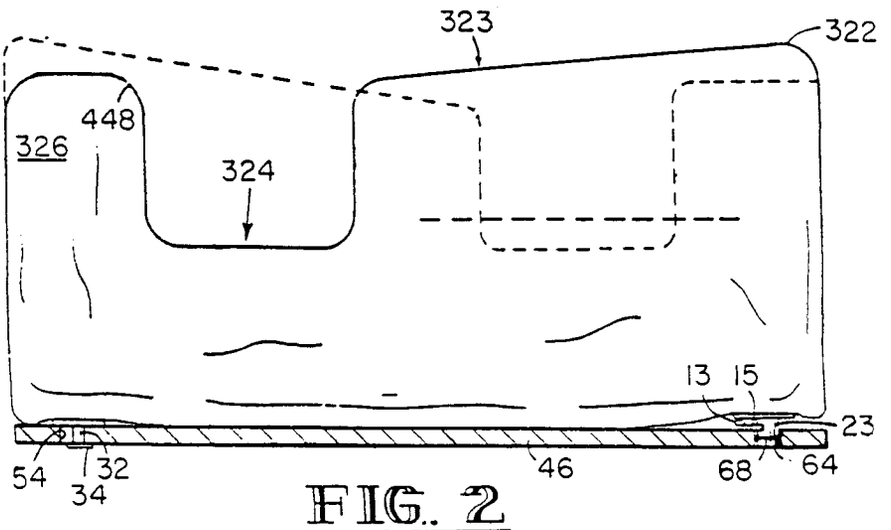
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FIG. 2

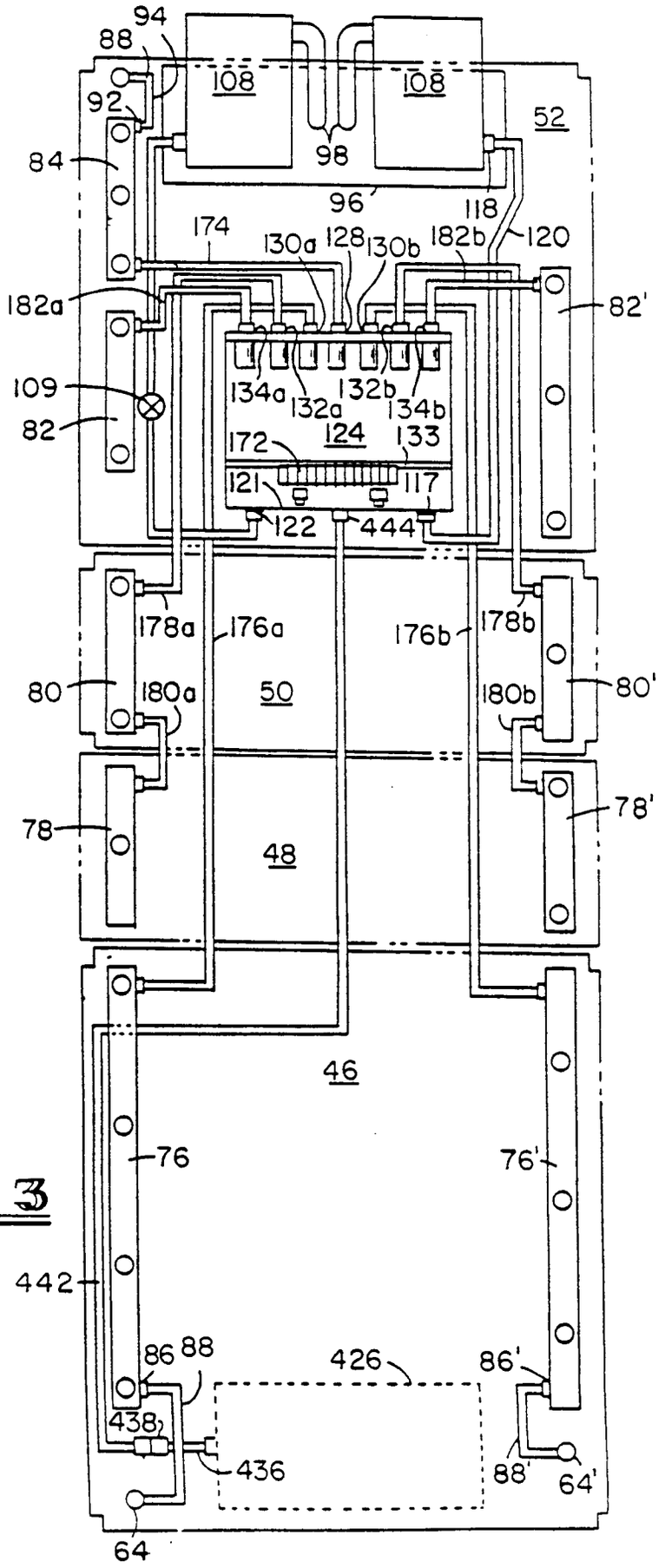
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FIG. 3

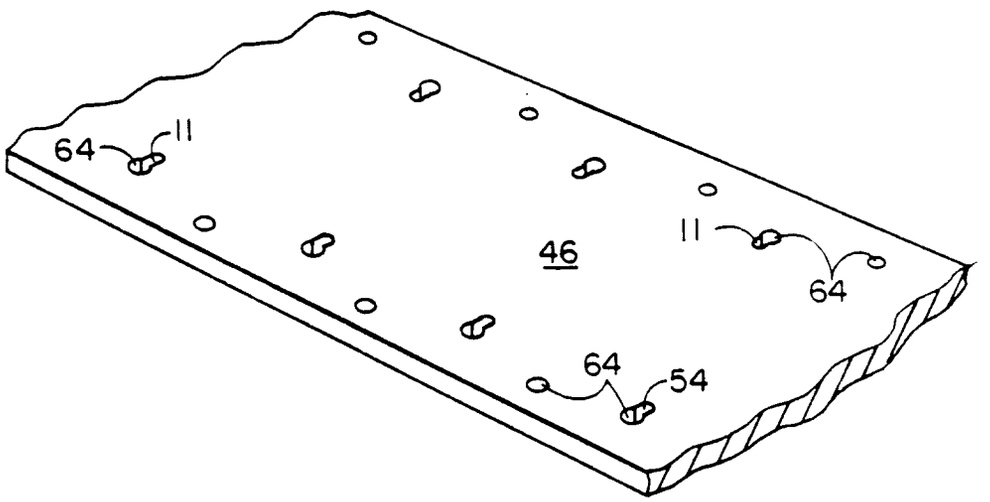


FIG. 4

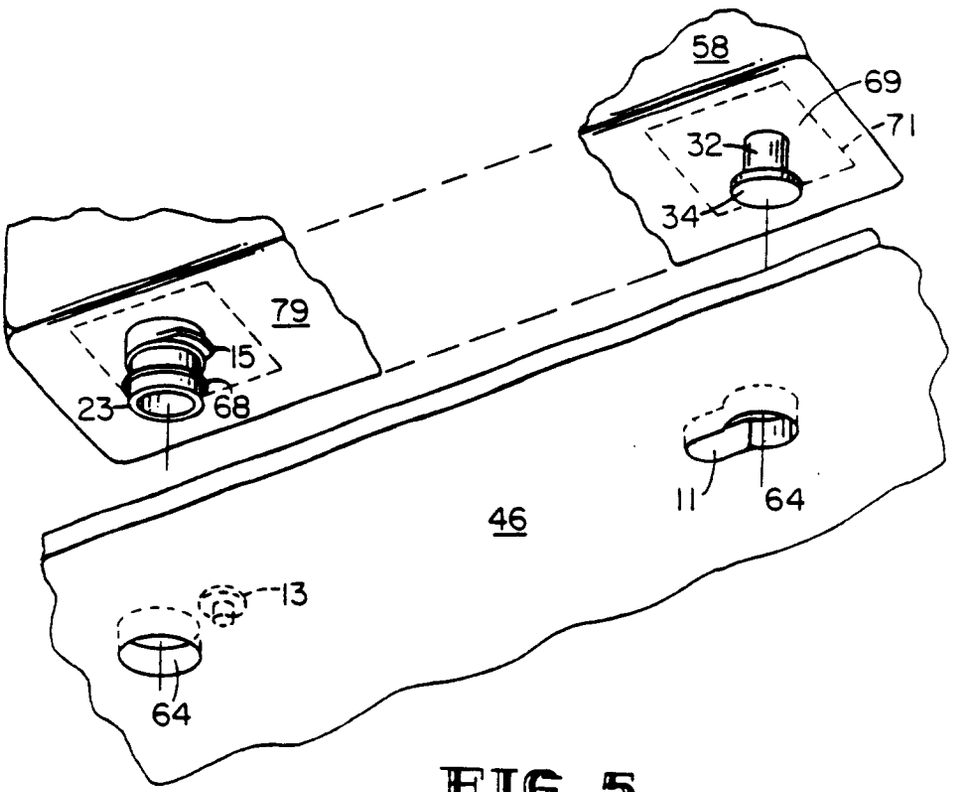


FIG. 5

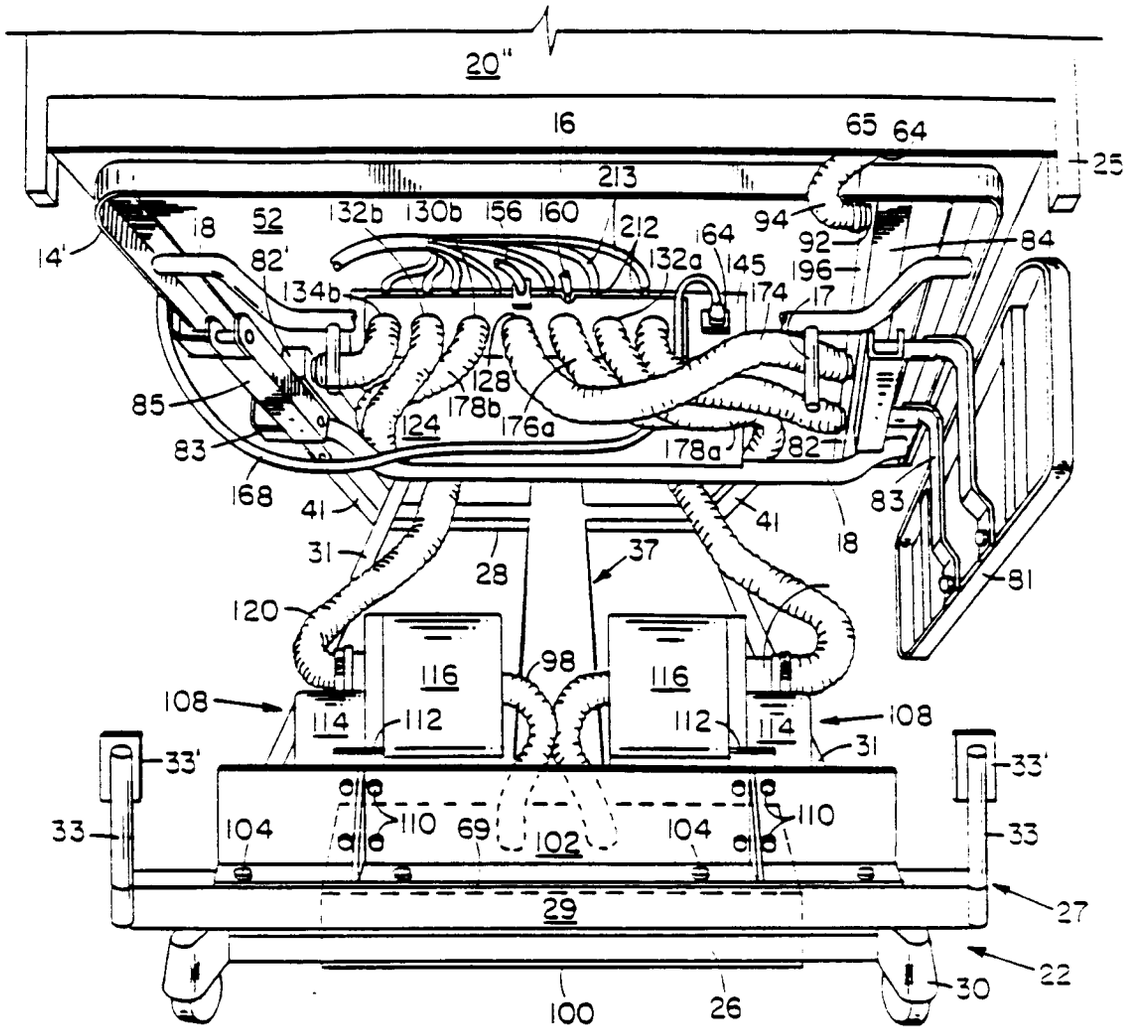
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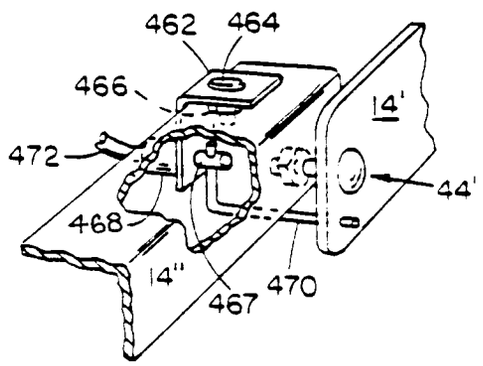
FIG. 6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470

FIG. 13

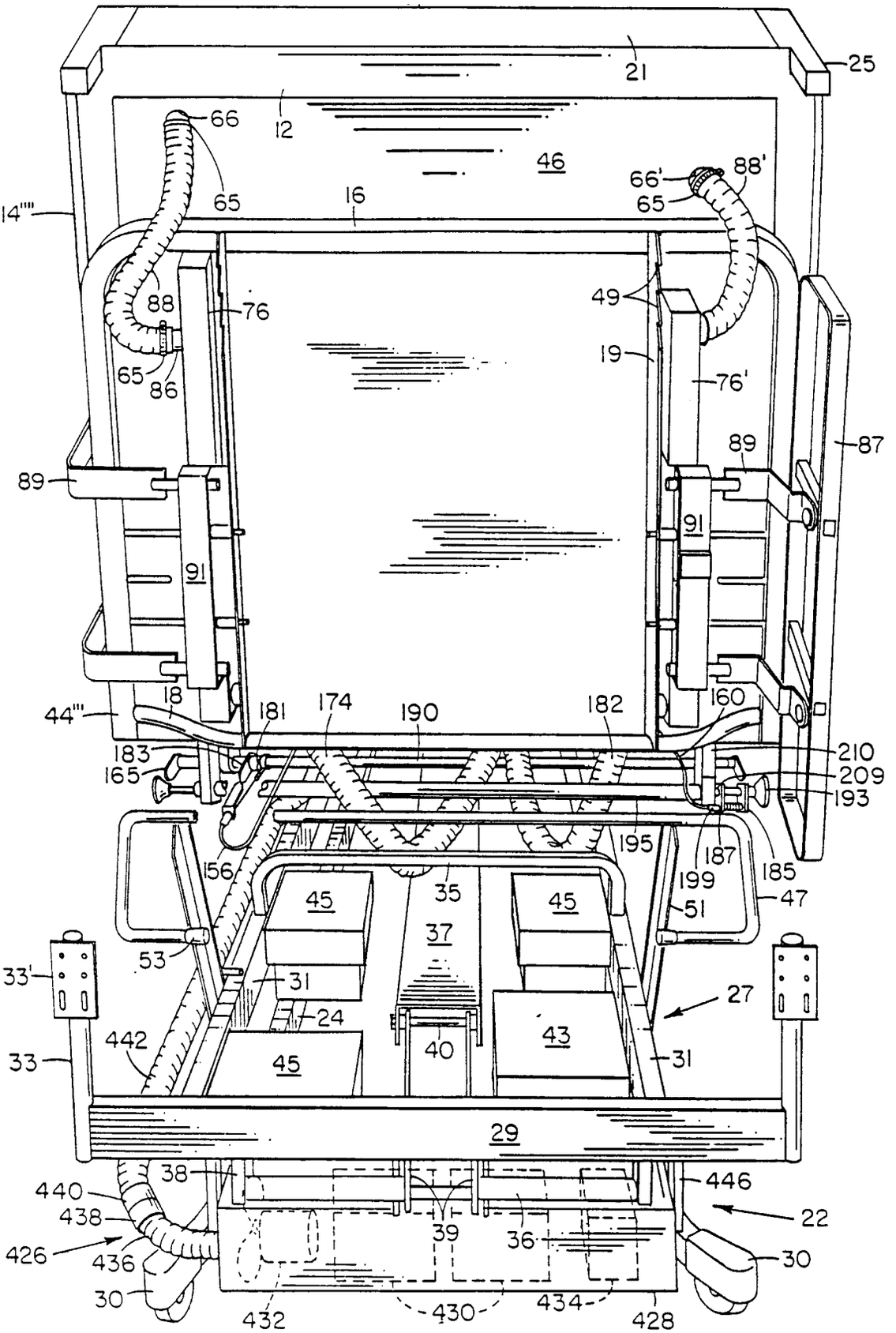
21
25
66
12
46
66'
88'
65
16
65
14""
88
76
49
19
76'
65
86
89
87
89
91
91
18
44'''
181
174
190
182
160
183
210
165
209
193
195
187
156
199
185
35
45
45
51
47
37
53
33'
31
27
24
442
43
40
31
33
45
29
38
446
440
22
438
39
36
426
436
30
30
432
430
434
428

FIG. 7

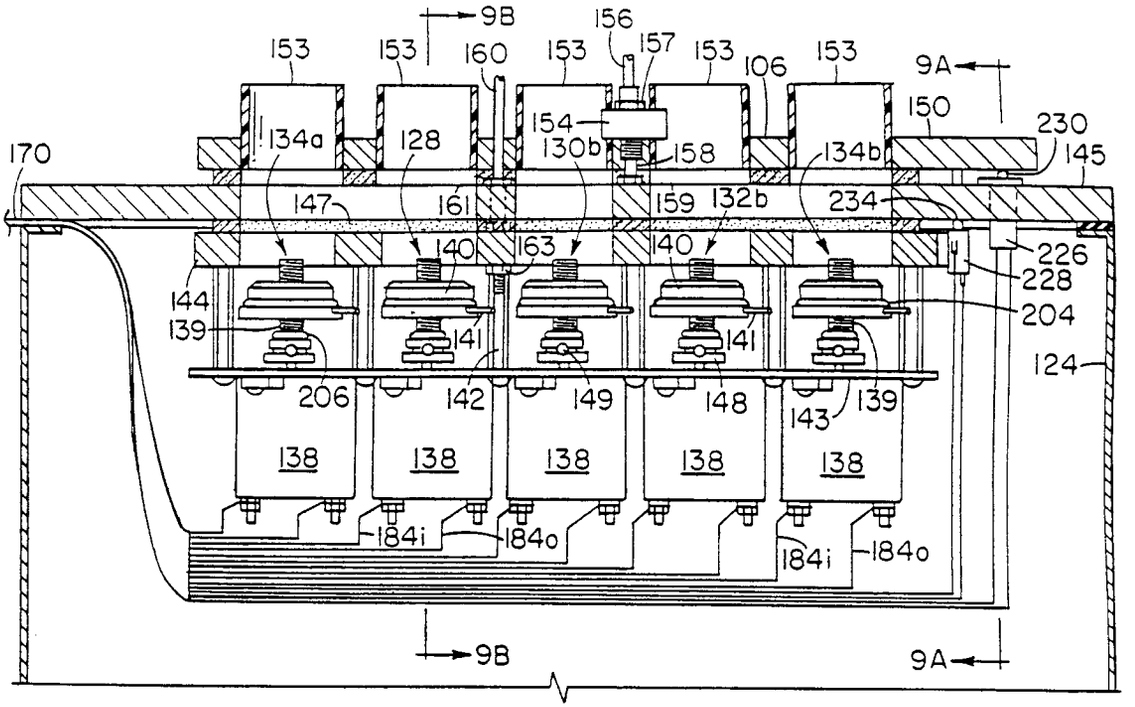


FIG. 8

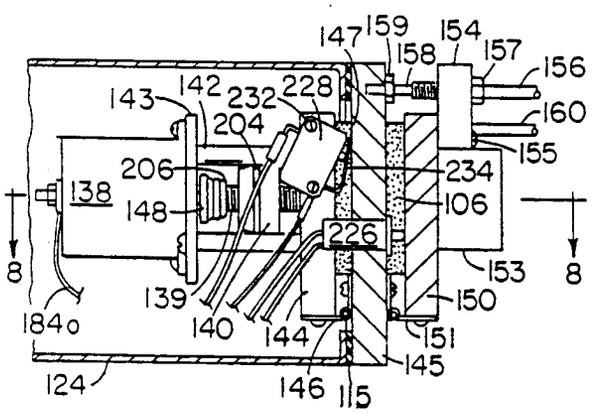


FIG. 9A

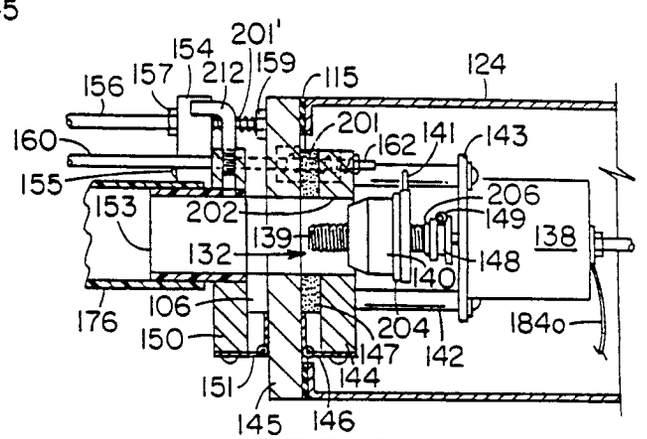


FIG. 9B

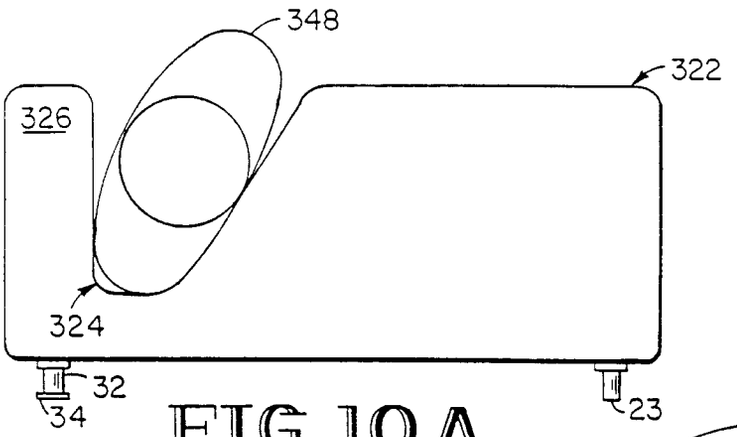


FIG. 10A

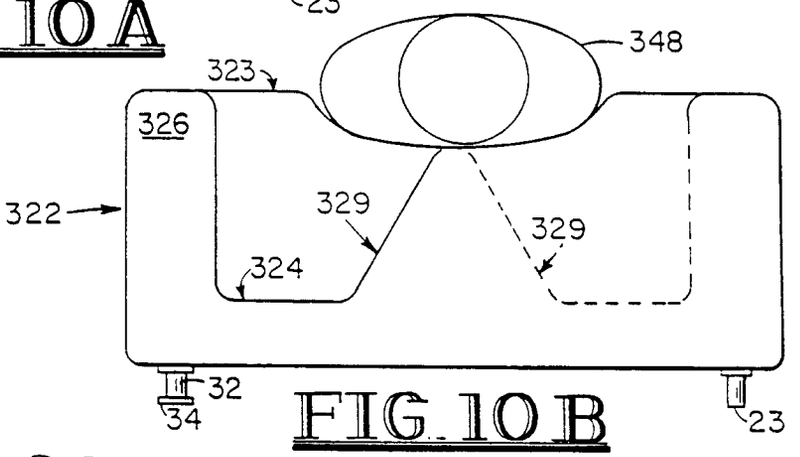


FIG. 10B

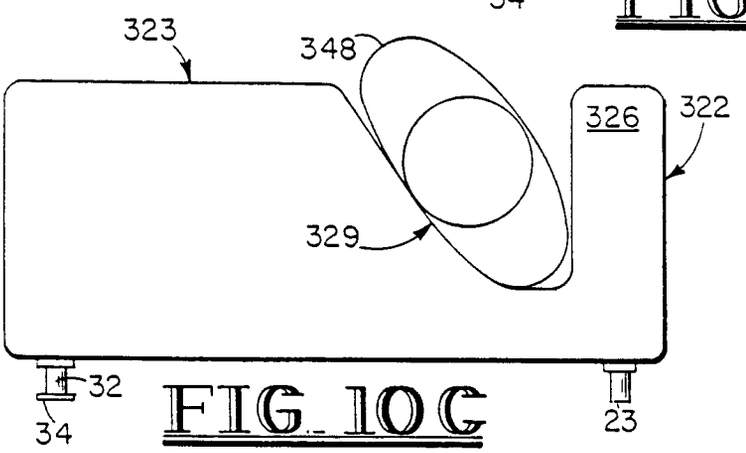


FIG. 10C

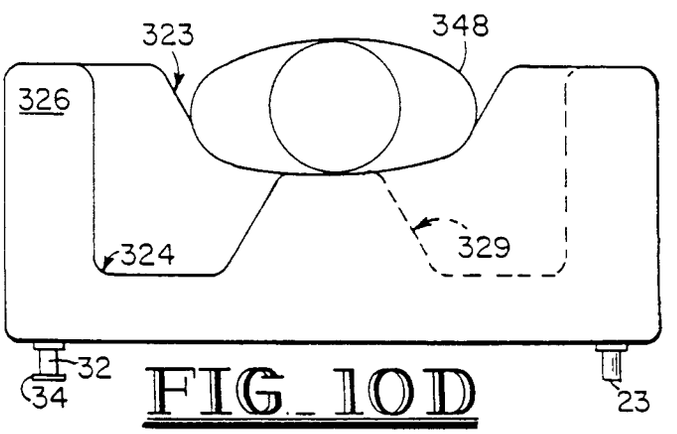


FIG. 10D

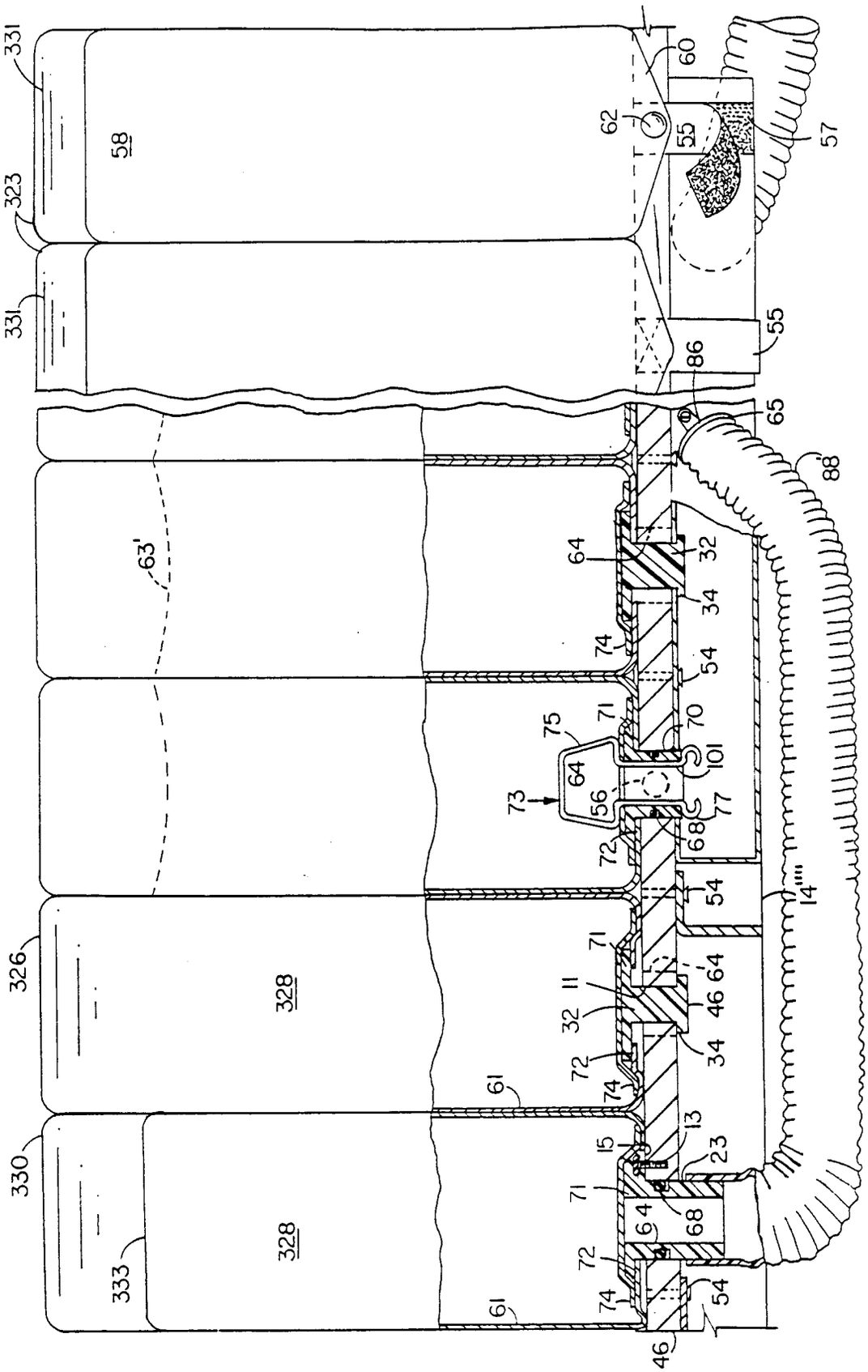
331
323
331
326
330
333
58
328
328
63'
61
61
62
60
55
57
55
86
65
88
64
32
34
74
54
71
75
70
64
101
73
56
77
68
72
54
14""
71
64'
46
11
32
34
72
74
13
15
23
71
64
68
72
74
54
46

FIG 11

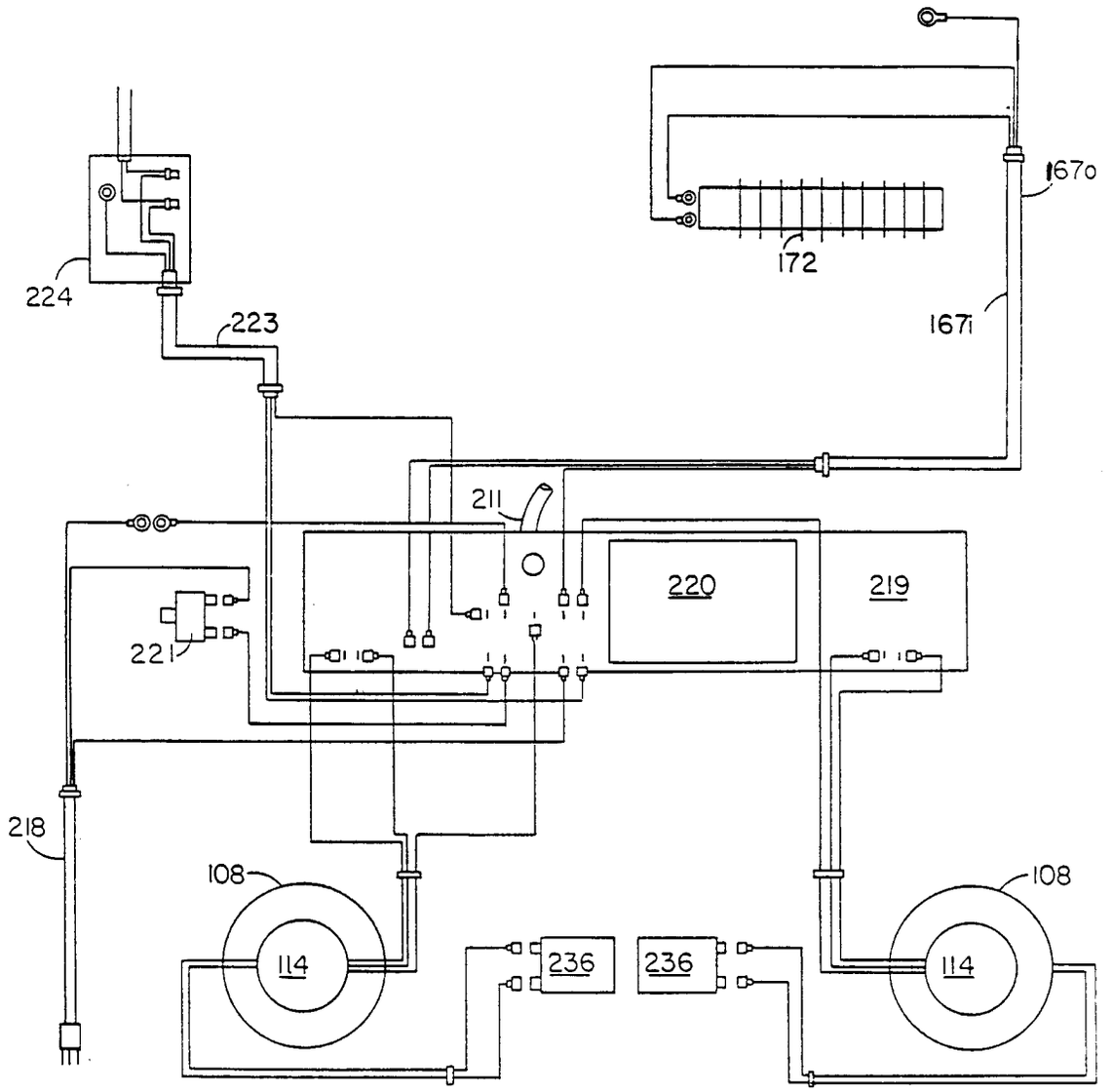
224
223
167o
172
167i
211
220
219
221
218
108
108
114
236
236
114

FIG. 12

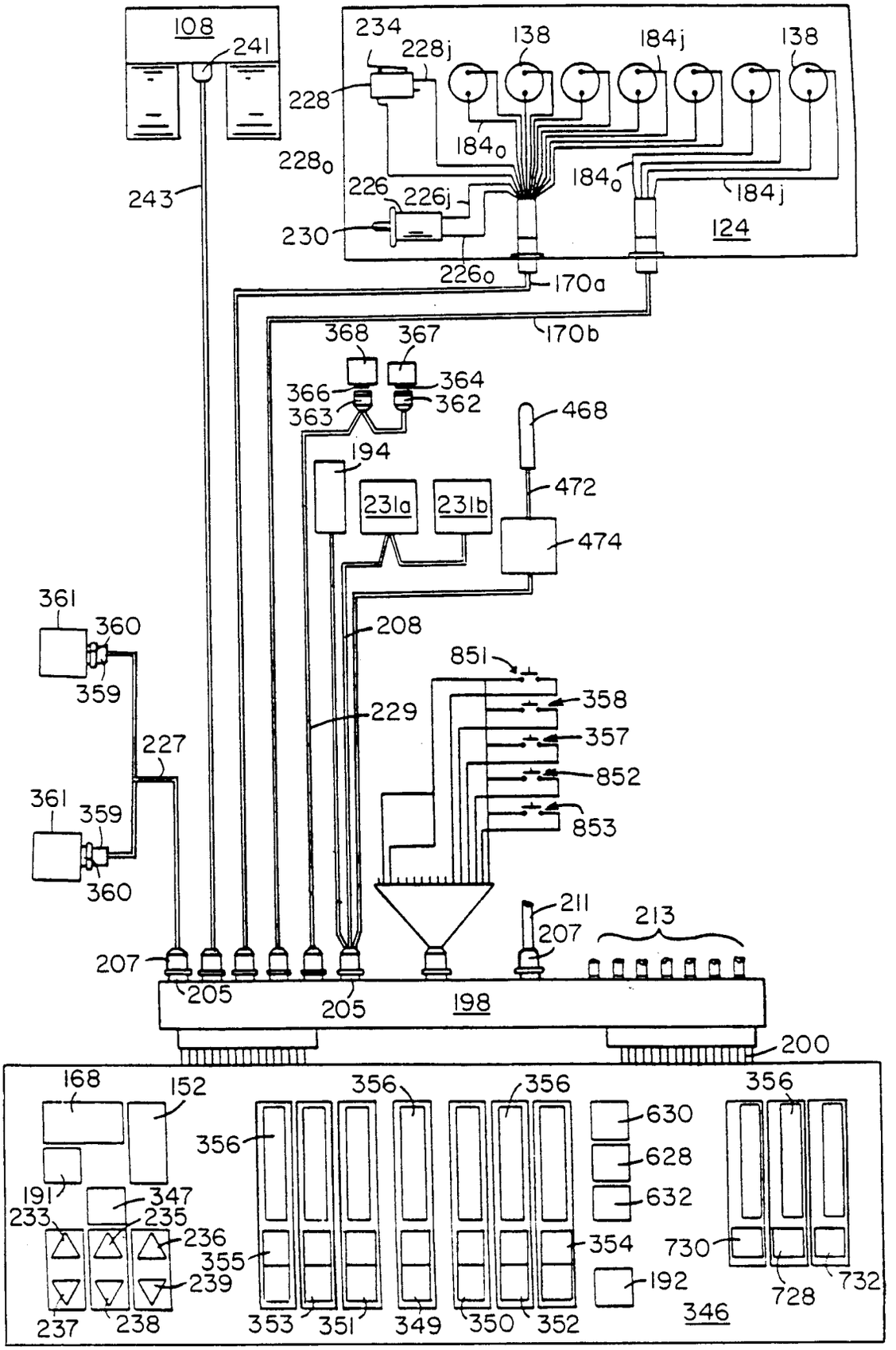
108
241
234
228j
138
184j
138
228
184o
228o
226
226j
184o
184j
243
230
124
226o
170a
170b
368
367
366
364
363
362
468
194
472
231a
231b
474
361
360
208
851
359
358
229
357
227
852
361
359
853
360
211
213
207
207
205
205
198
200
168
152
356
356
356
356
630
628
632
191
347
233
235
236
354
730
355
239
192
732
728
237
238
353
351
349
350
352
346

FIG. 14

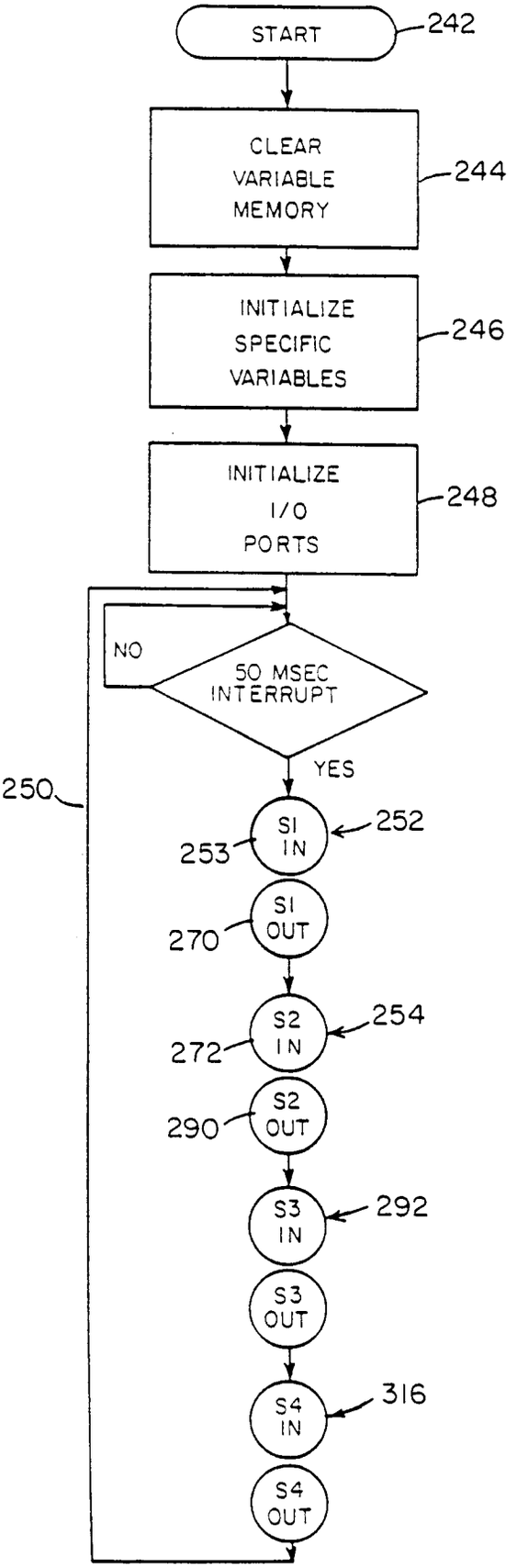
START
242
CLEAR VARIABLE MEMORY
244
INITIALIZE SPECIFIC VARIABLES
246
INITIALIZE I/O PORTS
248
NO
50 MSEC INTERRUPT
YES
250
SI IN
252
253
SI OUT
270
S2 IN
254
272
S2 OUT
290
S3 IN
292
S3 OUT
S4 IN
316
S4 OUT

FIG. 15

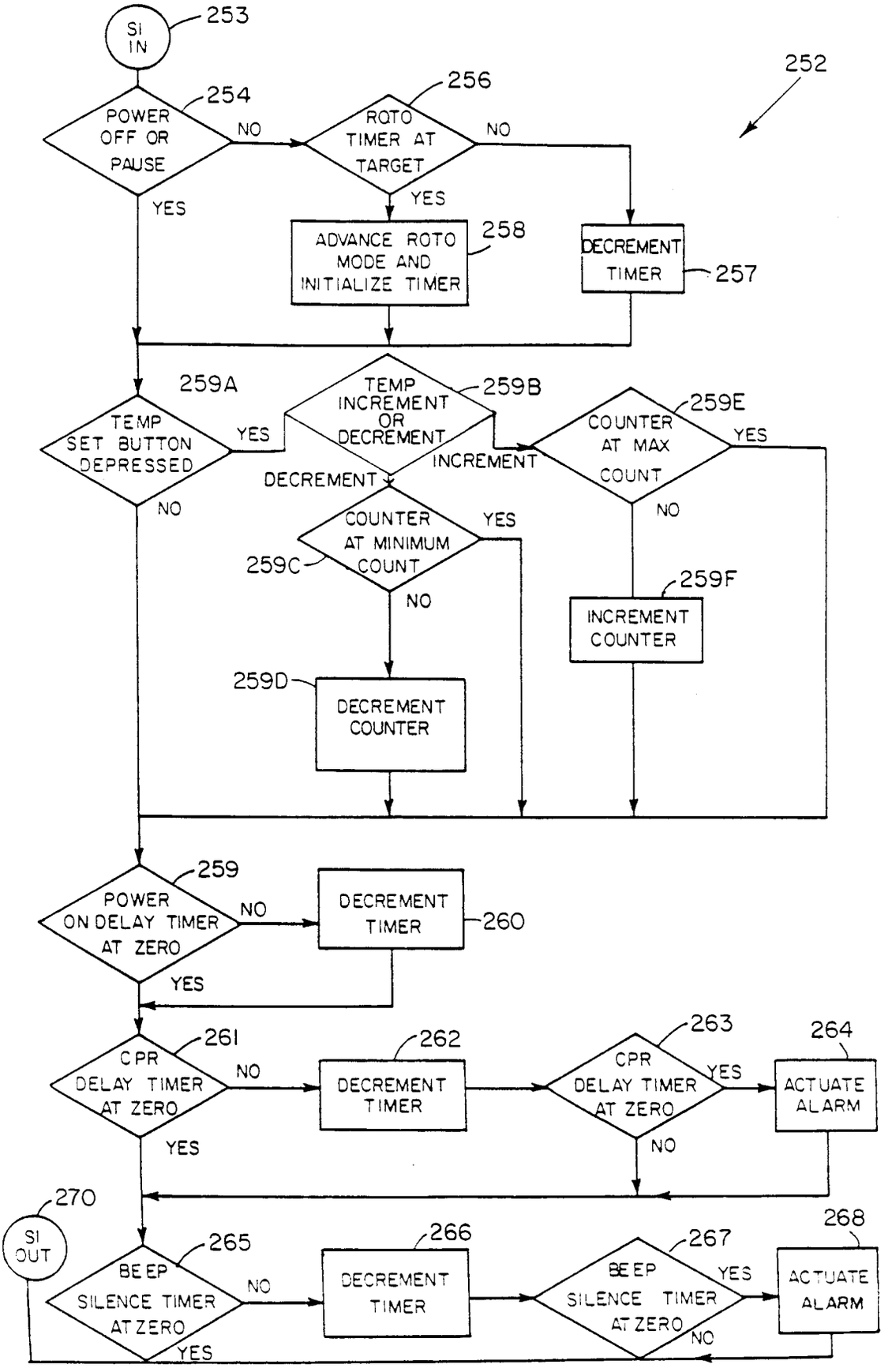
SI IN
253
252
POWER OFF OR PAUSE
254
NO
ROTO TIMER AT TARGET
256
NO
YES
YES
ADVANCE ROTO MODE AND INITIALIZE TIMER
258
DECREMENT TIMER
257
259A
TEMP SET BUTTON DEPRESSED
YES
NO
TEMP INCREMENT OR DECREMENT
259B
DECREMENT
INCREMENT
COUNTER AT MAX COUNT
259E
YES
NO
COUNTER AT MINIMUM COUNT
259C
YES
NO
INCREMENT COUNTER
259F
DECREMENT COUNTER
259D
POWER ON DELAY TIMER AT ZERO
259
NO
DECREMENT TIMER
260
YES
CPR DELAY TIMER AT ZERO
261
NO
DECREMENT TIMER
262
CPR DELAY TIMER AT ZERO
263
YES
ACTUATE ALARM
264
NO
YES
SI OUT
270
BEEP SILENCE TIMER AT ZERO
265
NO
DECREMENT TIMER
266
BEEP SILENCE TIMER AT ZERO
267
YES
ACTUATE ALARM
268
NO
YES

FIG. 16

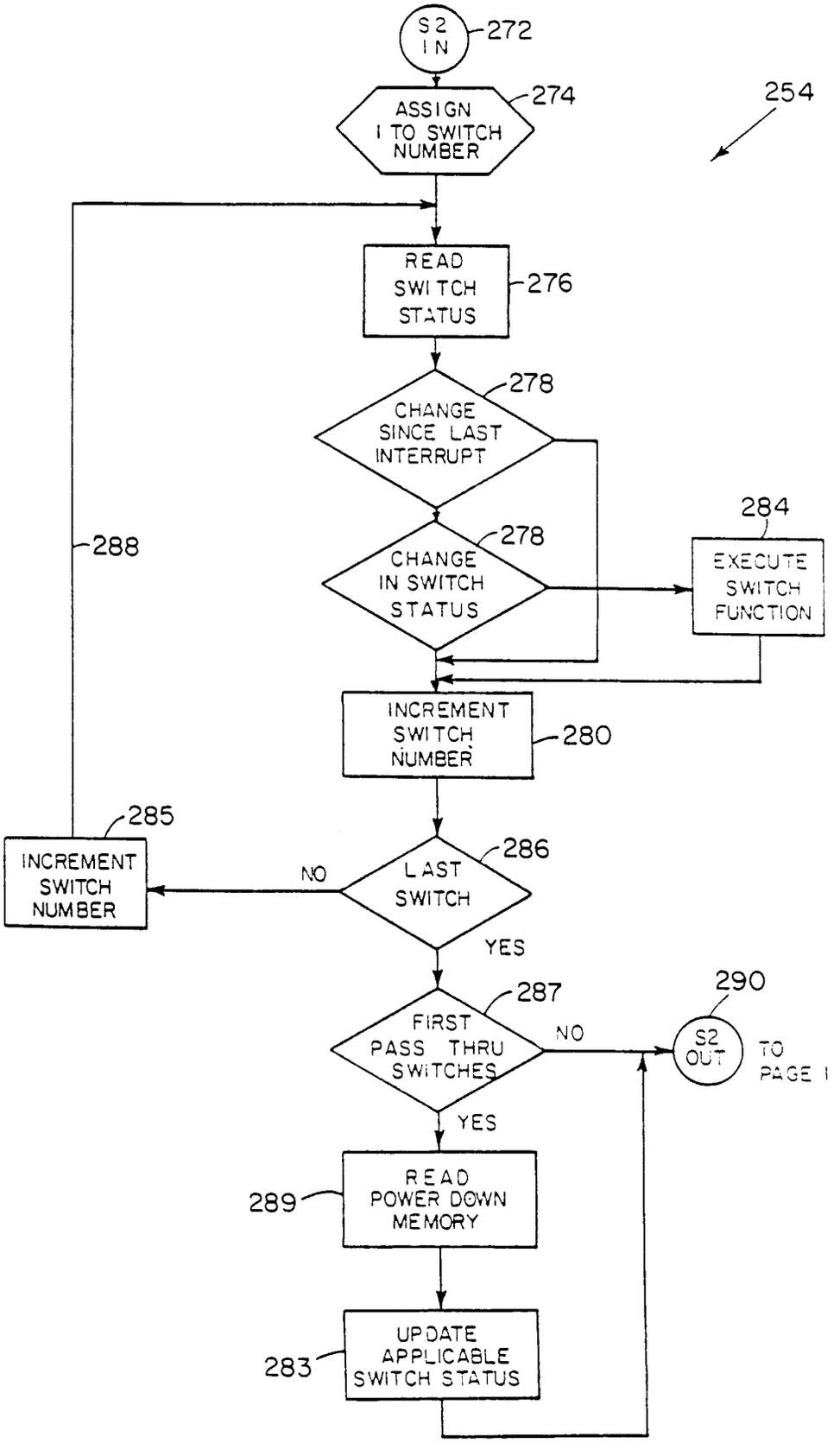
S2 IN
272
ASSIGN I TO SWITCH NUMBER
274
254
READ SWITCH STATUS
276
CHANGE SINCE LAST INTERRUPT
278
CHANGE IN SWITCH STATUS
278
284
EXECUTE SWITCH FUNCTION
288
INCREMENT SWITCH NUMBER
280
285
INCREMENT SWITCH NUMBER
NO
LAST SWITCH
286
YES
290
FIRST PASS THRU SWITCHES
287
NO
S2 OUT
TO PAGE 1
YES
READ POWER DOWN MEMORY
289
UPDATE APPLICABLE SWITCH STATUS
283

FIG. 17

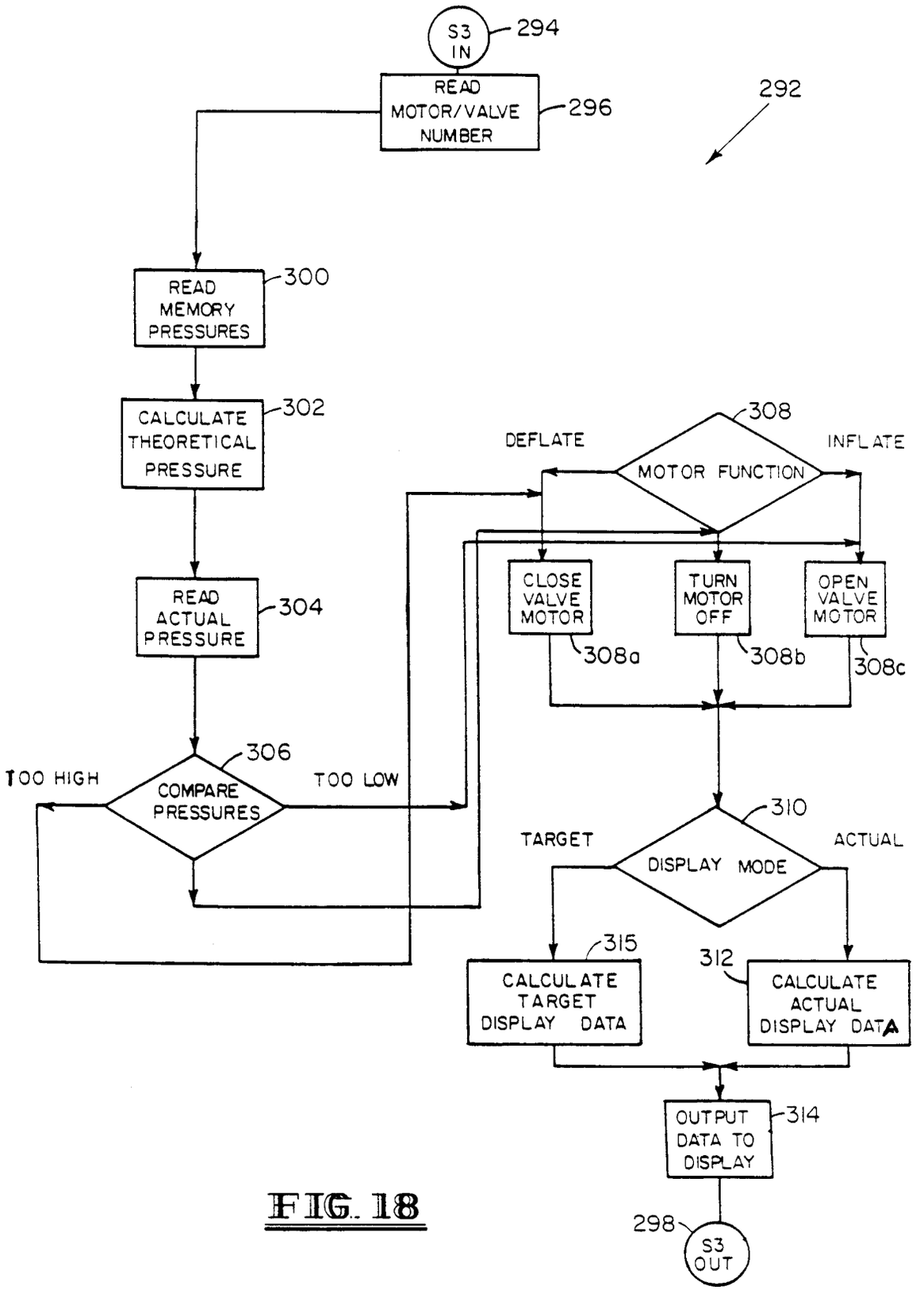
S3 IN
294
READ MOTOR/VALVE NUMBER
296
292
READ MEMORY PRESSURES
300
CALCULATE THEORETICAL PRESSURE
302
READ ACTUAL PRESSURE
304
COMPARE PRESSURES
306
TOO HIGH
TOO LOW
MOTOR FUNCTION
308
DEFLATE
INFLATE
CLOSE VALVE MOTOR
308a
TURN MOTOR OFF
308b
OPEN VALVE MOTOR
308c
DISPLAY MODE
310
TARGET
ACTUAL
CALCULATE TARGET DISPLAY DATA
315
CALCULATE ACTUAL DISPLAY DATA
312
OUTPUT DATA TO DISPLAY
314
S3 OUT
298

FIG. 18

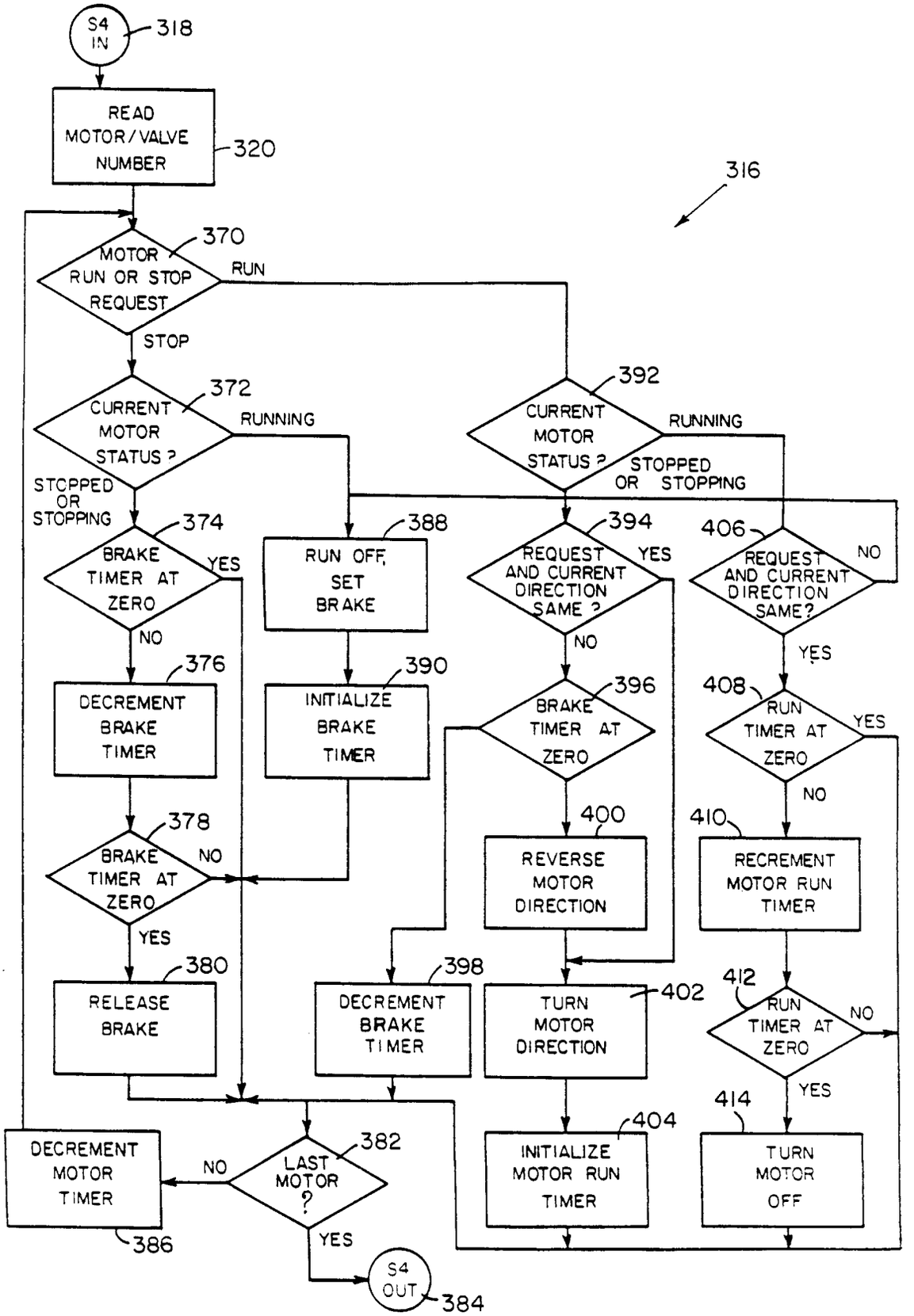
S4 IN
318
READ MOTOR/VALVE NUMBER
320
316
MOTOR RUN OR STOP REQUEST
370
RUN
STOP
CURRENT MOTOR STATUS ?
372
RUNNING
STOPPED OR STOPPING
392
CURRENT MOTOR STATUS ?
RUNNING
STOPPED OR STOPPING
BRAKE TIMER AT ZERO
374
YES
NO
RUN OFF, SET BRAKE
388
REQUEST AND CURRENT DIRECTION SAME ?
394
YES
NO
REQUEST AND CURRENT DIRECTION SAME?
406
NO
YES
DECREMENT BRAKE TIMER
376
INITIALIZE BRAKE TIMER
390
BRAKE TIMER AT ZERO
396
RUN TIMER AT ZERO
408
YES
NO
BRAKE TIMER AT ZERO
378
NO
YES
REVERSE MOTOR DIRECTION
400
RECREMENT MOTOR RUN TIMER
410
RELEASE BRAKE
380
DECREMENT BRAKE TIMER
398
TURN MOTOR DIRECTION
402
RUN TIMER AT ZERO
412
NO
YES
DECREMENT MOTOR TIMER
386
NO
LAST MOTOR ?
382
YES
INITIALIZE MOTOR RUN TIMER
404
TURN MOTOR OFF
414
S4 OUT
384

FIG. 19

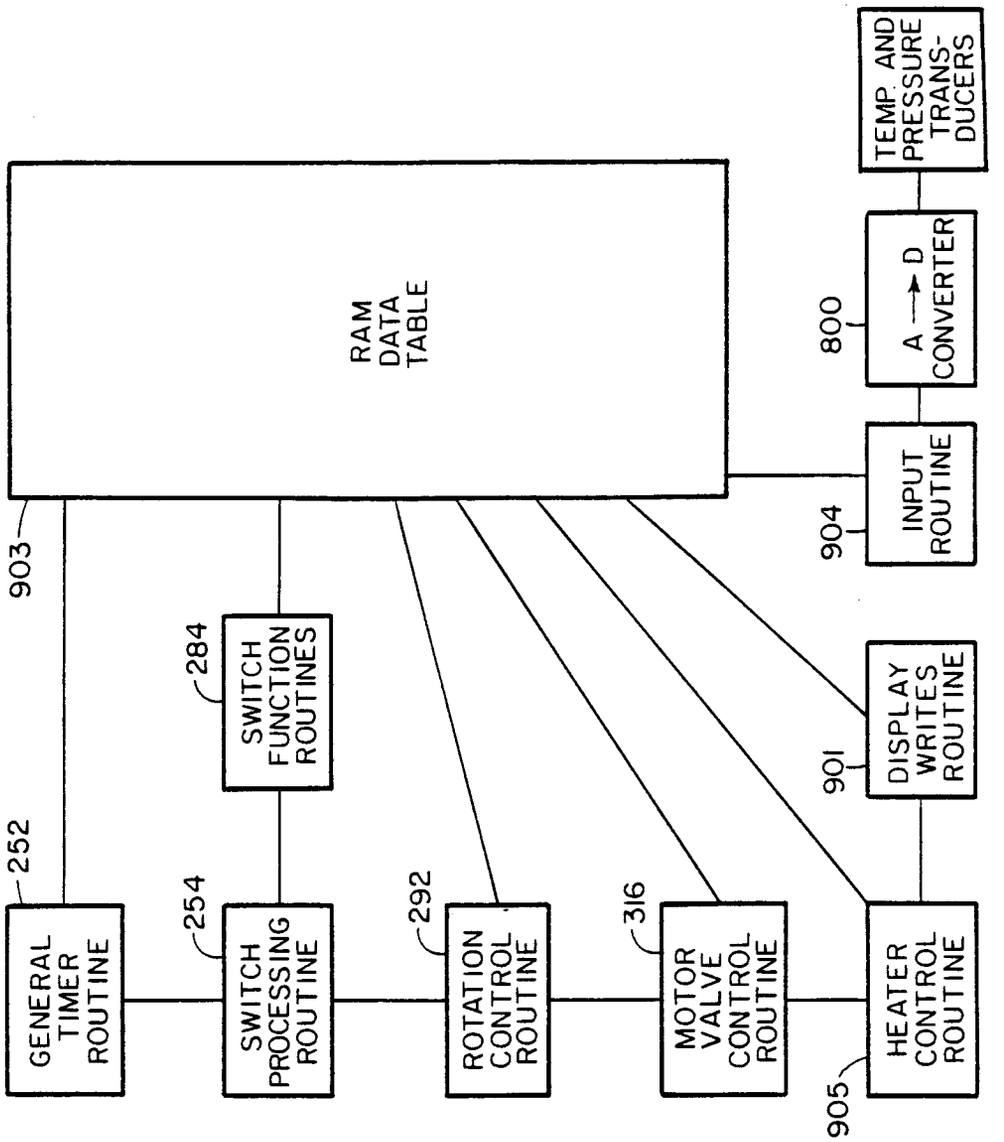
RAM DATA TABLE
903
TEMP. AND PRESSURE TRANS-DUCERS
800
A → D CONVERTER
904
INPUT ROUTINE
901
DISPLAY WRITES ROUTINE
905
HEATER CONTROL ROUTINE
316
MOTOR VALVE CONTROL ROUTINE
292
ROTATION CONTROL ROUTINE
254
SWITCH PROCESSING ROUTINE
252
GENERAL TIMER ROUTINE
284
SWITCH FUNCTION ROUTINES

FIG. 24

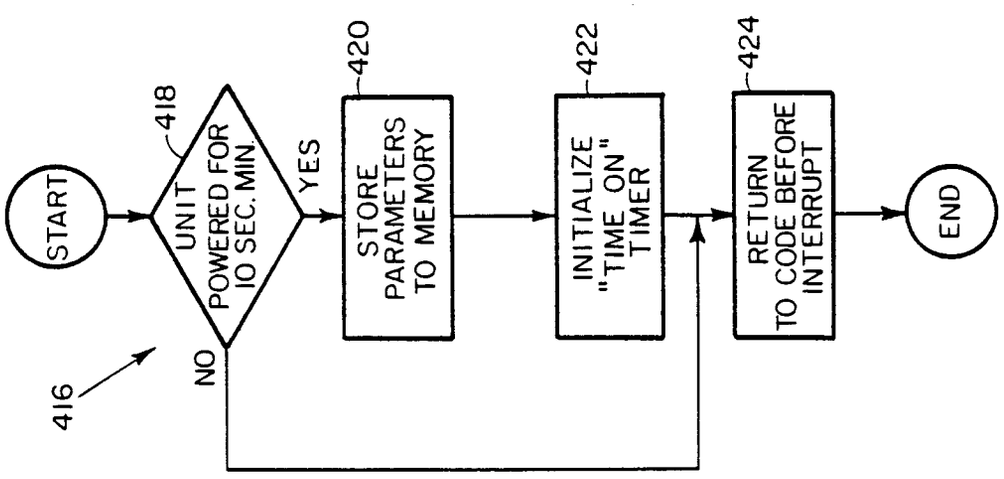
START
UNIT POWERED FOR 10 SEC. MIN.
418
YES
NO
416
STORE PARAMETERS TO MEMORY
420
INITIALIZE "TIME ON" TIMER
422
RETURN TO CODE BEFORE INTERRUPT
424
END

FIG. 20

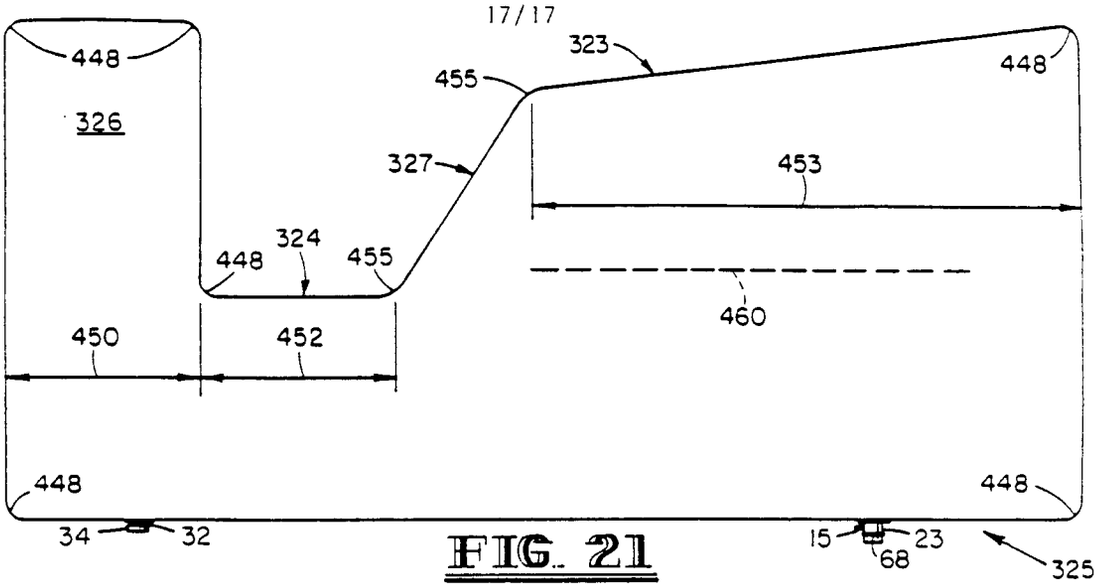


FIG. 21

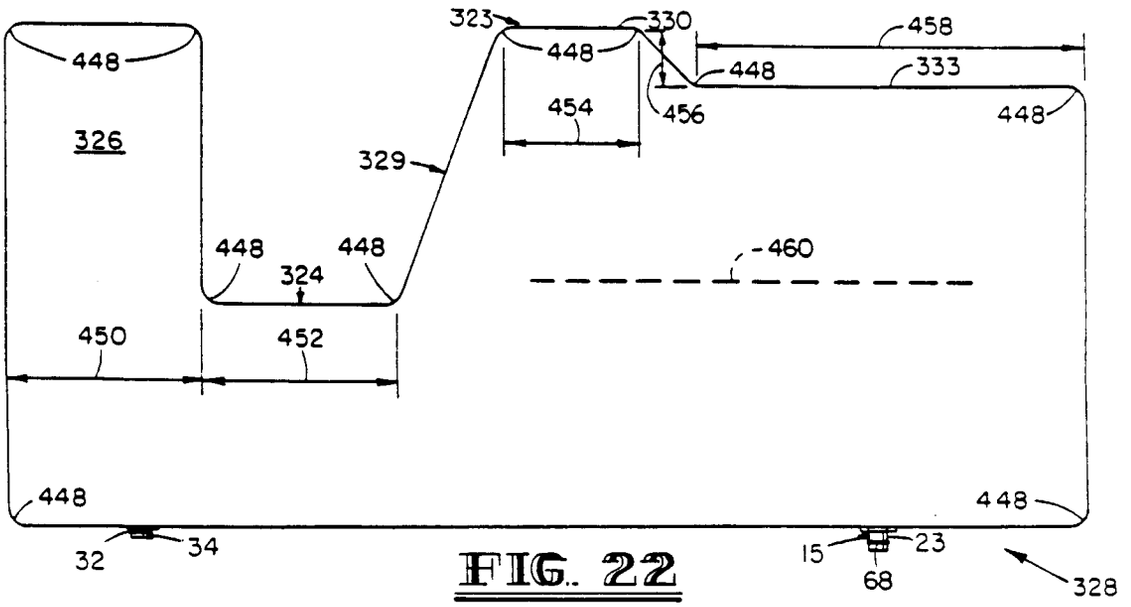


FIG. 22

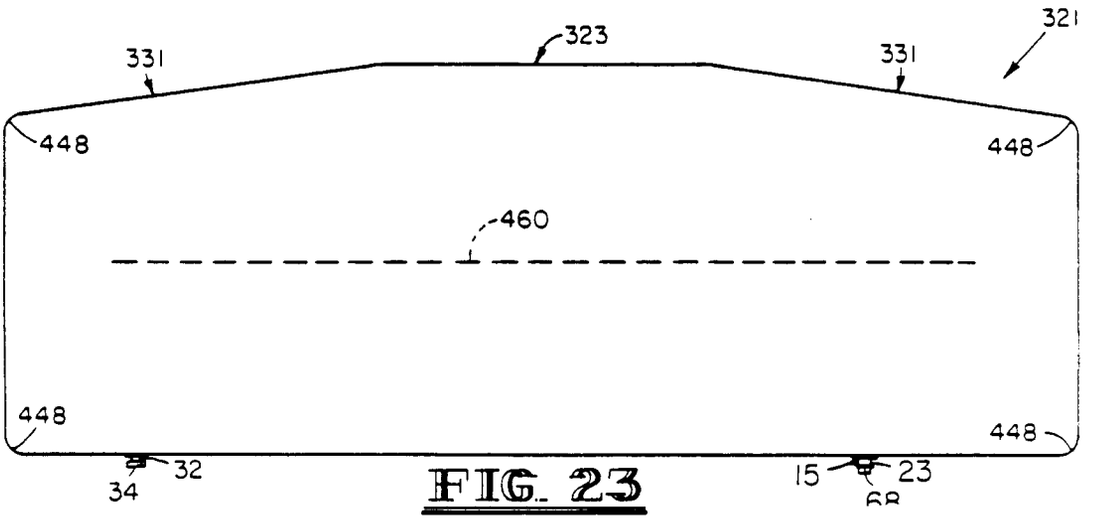


FIG. 23