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(54) Patient support systems.

(57) A patient support system has a fluidizable surface formed by air fluidizing a mass of fluidizable material (50), and a surface formed by a plurality of inflatable sacks (36) which may be disposed on an articulatable member. The two surfaces are disposed end to end so that the inflatable sacks (36) support the head, chest and upper torso of a patient, and the fluidized material (50) supports the buttocks. legs and feet of the patient. The fluidizable material (50) is contained by a member (66) which is at least partially collapsible so as to facilitate the patient's ingress and egress to and from the support system, the collapsible member for example comprising an air impermeable panel which can form an inflatable elastic wall (66) having one or more internal webs defining separately pressurizable compartments. A blower (40) inflates the sacks, the elastic wall (66), and the fluidizable material under the control of a microprocessor which controls actuation of various valves and the blower (40) according to signals inputted by operating personnel or supplied by various sensors which monitor the patient support system.

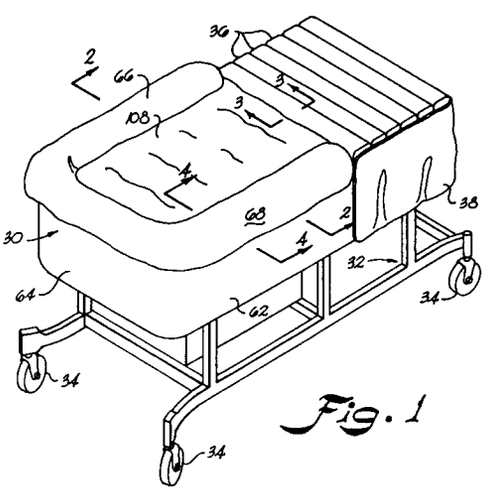

Fig. 1

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The present invention relates to patient support systems and more particularly to a patient support system which combines attributes of a fluidized air bed and a low air loss bed.

Two types of patient support systems preferred for long-term patient care include (1) air fluidized beds such as those described in US-A-3,428,973; US-A-3,866,606; US-A-4,483,029; US-A-4,564,965; US-A-4,637,083; and US-A-4,672,699 and (2) low air loss beds such as those described in US-A-4,694,520; US-A-4,745,647 and US-A-4,768,249.

Each type of support system has advantages for particular segments of the patient population. For example, patients with respiratory problems require elevation of the chest. However, this tends to cause the patient to slide toward the foot of the bed. Since a fluidized bed in the fluidised condition provides no shear forces against the patient, while some shear forces are provided by the low air loss bed, patient elevation is performed more easily in a low air loss bed. However, to overcome this slippage completely, some sort of knee gatch is required to be fitted to the bed to provide a surface against which the buttocks of a patient may be retained when the patient's chest is elevated.

Moreover, the same shear forces which assist in retaining the patient in the low air loss bed from slipping to the foot of the bed when the chest is elevated, become undesirable for patients with skin grafts. The shear forces tend to tear such skin grafts from the patient, and this is not only painful but also interrupts the healing process. The absence of shear forces in a fluidized bed permits the patient with skin grafts to move about without fear that the grafts will be torn from the patient's body. In a fluidized bed, the patient can lie on a skin graft and be confident that when he or she moves, the sheet will move with the patient across the supporting mass of fluidized material and will not displace the graft, as would happen if the patient moved across a conventional mattress, or across a low air loss bed support for that matter.

The large mass of fluidizable material required to sustain operation of a fluidized bed contributes significantly to the weight of the bed. In addition, the large mass of fluidizable material or beads requires a large blower to fluidize the beads, and such blowers require significant amounts of electricity for their operation.

The sides of a fluidised bed are rigid to retain the fluidizable material and to attach the cover sheet thereto. Ingress to and egress from the fluidised bed by patients must be performed with due regard to the rigidity of the sides of the bed.

The fluidizable material in a fluidized bed can be soiled and must be removed for cleaning at regular intervals and when particular circumstances dictate. Because of intermixing of the fluidizable material during fluidization, a localized soiling becomes distributed throughout the mass of material. Removal of the entire mass of material for cleaning is a time consuming and labor intensive task.

The present invention aims to provide an improved patient support system for long-term patient care.

It is an aim of the present invention to provide an improved patient support system providing fluidized patient support, yet facilitating elevation of the patient's upper body.

Desirably, an improved patient support system of the present invention provides fluidized patient support and reduces the overall weight of the system compared with previous systems, and beneficially it is designed to reduce the overall power requirements for fluidizing the system.

An improved patient support system providing fluidized patient support is preferably designed to facilitate patient entrance to and exit from the system.

An improved fluidized patient support system made according to the invention desirably facilitates removal of the fluidizable material and its economic maintenance.

The description which now follows is given by way of example only.

A dual mode patient support system embodying the present invention comprises a frame which supports at least one inflatable sack and preferably a plurality of sacks which support at least a portion of the patient's body, desirably including the head, chest, and upper torso of the patient.

Further in accordance with the present invention, the frame carries a fluidizable medium that supports another portion of the patient's body, desirably including the buttocks, legs, and feet of the patient. The fluidizable medium preferably includes tiny beads or spheres formed of glass, ceramics, or silicon.

Still further, the frame carries means for containing the fluidizable medium and for permitting the diffusion of air therethrough. Preferably, the means for containing the fluidizable medium and for permitting the diffusion of air therethrough includes a diffuser board permeable to air but impermeable to the fluidizable medium, a collapsible retaining means attached to the diffuser board, and a flexible cover sheet. The fluidizable material rests atop the diffuser board and is retained thereabove by the retaining means which is secured to the diffuser board in airtight fashion. The cover sheet encloses the fluidizable material by being connected to the retaining means in a fashion that is impermeable to the passage of fluidizable material.

In an alternative embodiment, the means for containing the fluidizable medium and for permitting the diffusion of air therethrough preferably

includes a plurality of discrete fluidizable cells. Each cell has an upper wall, a lower wall, and a side wall extending between the upper wall and the lower wall. Each cell contains a mass of fluidizable material therein, and the walls prevent the passage of this fluidizable material therethrough. The upper and lower walls are permeable to the passage of air therethrough, but the side wall is not. The upper wall of each cell is preferably formed as a detachably engageable section of an air permeable cover sheet. The peripheries of the cells are connected to the retaining means detachably and are also connected to one another detachably. The lower walls of the cells are maintained against the diffuser board and are detachably anchored thereto so that air passing through the diffuser board must pass through the lower walls of the cells and thereby fluidize the fluidizable material therein.

The means for detachably connecting the fluidizable cells to the diffuser board and to one another preferably include one or more attachment flaps, anchoring flaps, and attachment mechanisms. As to the latter, an air impermeable zipper or an airtight elastomeric interlocking mechanism is preferred. The upper portions of adjacent cells also can be connected by Velcro strips extending along their sidewalls.

Means are provided for detachably attaching the periphery of the air permeable cover sheet to the retaining means so as to prevent passage of the fluidizable material past this sheet attaching means. The sheet attaching means preferably includes an attachment mechanism such as an airtight zipper or a mating elastomeric interlocking mechanism. One of the engagable components of the zipper or interlocking mechanism can be secured to an end of an attachment flap that is secured to the retaining means. The attachment flap preferably is both air impermeable and impermeable to the passage of fluidizable material therethrough.

The detachable connecting means of the fluidizable cells and the detachable attachment means of the cover sheet greatly facilitate removal of the fluidizable medium for cleaning, and the cells prevent localized soiling from being distributed throughout the whole of the medium.

A preferred retaining means may include an elastic wall which can take the form of a number of different embodiments. In one embodiment, the elastic wall includes an inflatable U-shaped member with an inflatable interface sack at the open end of the U-shaped member. The U-shaped member and the interface sack can have one or more internal webs defining separately pressurizable compartments therein. In addition, deformable inserts can be disposed to fill the compartments. In another embodiment of the elastic wall, the open end of the U-shaped member is selaed by a non-rigid panel which is impermeable to the passage of both air and fluidizable material therethrough. In yet another embodiment, the elastic wall is defined by a non-rigid panel completely surrounding the fluidizable material. A portion of the panel is supported by the inflatable sacks, while the remainder of the panel is supported by a rigid sidewall which is selectively collapsible either by a grooved track mechanism or a bottom-hinged mechanism. The collapsibility of te retaining means embodiments greatly facilitates patient ingress to and egress from the dual mode patient support system of the present invention.

It is important that the air passing through the diffuser board is constrained to pass through the fluidizable medium to fluidize it. The elastic wall preferably has an attachment flap with an anchoring member at the free end thereof for anchoring the flap against the edge of the diffuser board which then is further sealed by a silicone rubber sleeve around the free edge thereof and a bead of room temperature vulcanizing compound.

Preferably, the diffuser board defines the upper member or wall of an air plenum to which air is supplied; the air then diffuses through the diffuser board to fluidize the fluidizable material supported thereabove. The means for supplying air to the plenum for fluidizing the fluidizable medium preferably includes a blower, a blower manifold, a fluidization supply manifold, one or more flow control valves, and a plurality of flexible air conduits. The diffuser board preferably has at least two tiers disposed at two different levels above the bottom of the plenum, which is subdivided into at least two chambers that are separately pressurizable from one another. One tier is disposed to support the fluidizable material that supports the patient's buttocks, and this tier is located closer to the bottom of the plenum therefore to support a relatively larger depth of fluidizable material than the second tier which supports the fluidizable material beneath the legs and feet of the patient. The reduced depth of material for supporting the legs and feet of the patient reduces the overall weight of the support system. It also enables the use of a smaller blower, which lowers the power requirements of the systems as well as further contributing to a reduction in the weight of the system.

Preferably, pressure is maintained in the air sacks and other inflatable components of the support system by connecting the blower to an air sack manifold which supplies air to pressure control valves via a plurality of flexible air conduits.

A microprocessor preferably controls the pressure provided to the inflatable components, and the rate of flow of air provided to the plenum which fluidizes the fluidizable material. The valves have a

pressure sensing device that measures the pressure at the outlet of each valve, which also is opened or closed to varying degrees by a motor. The microprocessor receives pressure information from each valve via the pressure sensing device and controls the motor to open or close the valve accordingly. Each component or group of components which it is desired be maintained at a controllable pressure or flow rate is connected to the blower via an individual pressure control valve or flow control valve, respectively. The microprocessor is preferably programmed, or programmable, to control this valve according to the desired pressure or flow rate behaviour for that particular component. Accordingly, each valve defines its own particular zone which can be subject to individual control by the microprocessor. The operating parameters can be inputted as desired by a key pad and control panel connected to the microprocessor. The microprocessor stores various control programs that can be activated via the key pad and control panel.

By way of example, one of the operational programs for the microprocessor is for the continuous mode of fluidization of the fluidizable material. Air is continuously supplied to the plenum, e.g. at a minimum mode of fluidization, a maximum mode of fluidization, and an intermediate mode of fluidization. In addition, the microprocessor can cause air to be supplied to the plenum so as to intermittently fluidize the fluidizable material. This is accomplished by turning off the fluidization for a short interval of time followed by fluidizing for a brief interval of time and repeating this sequence over and over.

Each control valve can be operated in a mode which instantaneously opens the valve. This mode of operation is useful for depressurizing an inflatable sack to facilitate an emergency medical procedure requiring a rigid surface rather than the compressible surface afforded by the inflatable sacks. The instantaneous depressurization can be controlled for instance by the key pad of the control panel of the microprocessor.

A heat exchange device can be provided to regulate the temperature of the air being used to fluidize the mass of fluidizable material.

The microprocessor controls the overall pressure and flow rates of air being supplied to the patient support system by controlling the blower via a blower control board that e.g. receives signals from a pressure sensor which monitors the pressure at the outlet side of the blower.

According to a further feature of the present invention, an aritculatable member can be attached to the frame and used to support the inflatable sacks thereon. In such articulatable embodiments, means are provided for defluidizing the mass of fluidizable material during elevation of the articulatable member. Conventional hydraulics and motors can be used to effect articulation of the articulatable member, and by way of example these hydraulics and motors are under the control of the microprocessors. In addition, a sensing device can monitor the degree of articulation of the articulatable member and furnish this information to the microprocessor. The operator may select the degree of elevation of the articulation member via the key pad and control panel, and the microprocessor then activates the hydraulics and motors until the articulation sensing device signals that the desired level of articulation has been attained. In conjunction with the elevation of the articulatable member, the microprocessor closes the flow control valve that governs the fluidization of the plenum chamber responsible for supplying air to fluidize the mass of fluidizable material beneath the buttocks of the patient. This defluidizes the mass of fluidizable material supporting the buttocks of the patient. The defluidized material beneath the buttocks of the patient acts to prevent the buttocks from moving in a direction toward the feet of the patient as weight is transferred against the buttocks during elevation of the head and chest of the patient. Thus, the defluidization of the mass of fluidizable material supporting the buttocks acts as a substitute for a knee gatch that often is required when elevating the head and chest of a patient in a conventional bed. The prevention of movement of the buttocks provides the additional benefit of restraining the patient from any slipping and sliding that might cause tissue damage to any sacral skin grafts which may have been applied to the patient.

Moreover, after the articulatable member has attained the desired angle of elevation, the microprocessor can cause a brief fluidization of the fluidizable material supporting the buttocks of the patient. The duration of this brief fluidization is no longer than required to contour the mass of fluidizable material supporting the buttocks in the sitting position. The fluidization is brief enough so that the patient does not feel a sensation of sinking into the mass of fluidizable material in the buttock zone during defluidization.

Embodiments of the present invention will now be explained in more detail by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 illustrates a perspective view of one embodiment of a patient support according to the present invention;

Fig. 2a illustrates a partial cross-sectional view of components of the patient support in a defluidized state, taken along the lines 2--2 of Fig. 1;

Fig. 2b illustrates a cross-sectional view of components of the patient support in a fluidized state, taken along the lines 2--2 of Fig. 1;
Fig. 2c illustrates a partial cross-sectional view of components of the patient support in a fluidized state, taken in a direction similar to the lines 2--2 of Fig. 1;
Fig. 3a illustrates a detailed cross-sectional view of components of the patient support of the present invention taken in a direction similar to the lines 3--3 of Fig. 1;
Fig. 3b illustrates a partial, detailed cross-sectional view of components of the patient support of the present invention taken in a direction similar to the lines 2--2 of Fig. 1;
Fig. 3c illustrates a detailed cross-sectional view of components of the patient support of the present invention, taken along the lines 3--3 of Fig. 1;
Fig. 4 illustrates a partial, detailed cross-sectional view of components of the patient support in a fluidized state, taken along the lines 4--4 of Fig. 1;
Fig. 5 illustrates a cross-sectional view of components of an embodiment of the present invention;
Fig. 6 illustrates a perspective, cut-away view of components of an embodiment of the present invention;
Fig. 7 illustrates a perspective, partially cut-away view of components of another embodiment of the present invention;
Fig. 8 illustrates a cross-sectional view of components of this embodiment of the present invention in a defluidized state;
Fig. 9 illustrates a cross-sectional view of components of this embodiment of the present invention in a fluidized state;
Fig. 10 illustrates a perspective, cut-away view of components of another embodiment of the present invention;
Fig. 11 illustrates a side, partially cut-away, plan view of components of still another embodiment of the present invention;
Fig. 12a illustrates a partial cross-sectional view of further components of an embodiment of the present invention in a fluidized state;
Fig. 12b illustrates a partial cross-sectional view of the further components of an embodiment of the present invention in a defluidized state;
Fig. 12c illustrates a partial cross-sectional view of alternative components of an embodiment of the present invention in a defluidized state;
Fig. 13 illustrates a schematic or circuit diagram of control and fluidizing components of an embodiment of the present invention;
Fig. 14 illustrates a perspective view of components of still another embodiment of the present invention; and
Fig. 15 illustrates a schematic diagram of fluidizing control components of this embodiment of the present invention.

Reference now will be made in detail to the presently contemplated, preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

Fig. 1 illustrates a preferred embodiment of the dual mode patient support system of the present invention, which is represented generally by the numeral 30. Typical overall dimensions for the patient support system are thirty-six inches (0.91 m) in width and ninety inches (2.29 m) in length.

In accordance with the present invention, the patient support system has a frame which is indicated generally in Fig. 1 by the designating numeral 32. Frame 32 can be provided with a plurality of rolling casters 34 for facilitating movement of patient support system 30. The diameter of the rotating member of each caster 34 preferably is a minimum of seven inches (17.8 cm), and each caster 34 is preferably spring-loaded. Frame 32 preferably is constructed of rigid material such as metal tube or angle capable of supporting the weight of the components carried thereon.

As shown in Figs. 10 and 11 for example, frame 32 includes an articulatable member 116. Conventional actuating means such as hydraulics and motors are provided to raise and lower the articulatable member, which pivots about an articulation joint 118. Preferably, member 116 has a range of inclination from 0° to 60° from the horizontal.

In further accordance with the present invention, there is provided at least one inflatable sack carried by the frame to support at least a portion of the patient's body. As embodied herein and shown for example in Fig. 1, frame 32 carries a plurality of inflatable sacks 36 disposed transversely across articulatable member 116. The head and upper torso of a patient preferably rest atop inflatable sacks 36, which preferably are covered by a conventional hospital sheet and/or other bedding (not shown). A continuous retaining panel 38 preferably is attached to sacks 36 and surrounds same to retain same together in an orderly fashion. Any conventional means of attachment such as snaps or zippers can be used to connect the retaining panel 38 to sacks 36. Each sack 36 preferably is ten and one-half inches (26.7 cm) in height measured above articulatable member 116 and about thirty-six inches (0.91 m) long measured in a direction transversely across member 116. The thickness of each sack 36 is approximately four and one-half inches (11.4 cm). As illustrated in Fig. 11 for example, elevation of member 116 from the horizontal position deforms the two sacks closest to

the articulation joint 118 to accommodate the change in position of member 116.

In further accordance with the present invention, means are provided for maintaining a preselected pressure in each inflatable sack. As embodied herein and shown schematically in Fig. 15 for example, the means for maintaining a preselected pressure in each inflatable sack includes a blower 40, a blower manifold 42, an air sack manifold 44, a plurality of pressure control valves 46, and a plurality of air impermeable tubes 48. Tubes 48 connect blower manifold 42 to blower 40 and to air sack manifold 44, and connect pressure valves 46 to air sack supply manifold 44 and to sacks 36. As shown in Fig. 13 for example, each pressure control valve 46 preferably includes a pressure transducer 127 which monitors the pressure at the outlet of valve 46. Each valve 46 further preferably includes an electric motor 132 to regulate the flow permitted to pass through valve 46 and accordingly the pressure being sensed by transducer 127.

As embodied herein and shown schematically in Fig. 13 for example, the means for maintaining a preselected pressure in each inflatable sack further includes a microprocessor 130. Pressure transducer 127 sends a signal to microprocessor 130 indicative of the pressure at the outlet of valve 46. Microprocessor 130 compares this signal to a signal stored in its memory corresponding to a preset pressure for that particular valve 46. Depending upon the results of the comparison, microprocessor 130 controls motor 132 to open or close valve 46 until the comparison indicates that the preset pressure has been attained. As shown in Fig. 13 for example, the preset pressure for each valve can be stored in the memory of microprocessor 130 via a key pad 154 and a control panel 156.

In yet further accordance with the present invention, a fluidizable medium is carried by the frame to support at least a portion of the patient's body. As embodied herein and shown in Figs. 2a, 2b, 4, 8, 9, 12a, 12b, and 12c for example, a plurality of tiny particles 50 forms a fluidizable medium. Preferably, each particle 50 is formed as a sphere having a diameter on the order of one thousandth of an inch (0.025 mm). Suitable materials for forming particles 50 include ceramics, glass, and silicon.

In still further accordance with the present invention, means are provided for supporting the fluidizable medium and for permitting the diffusion of air through the fluidizable medium. Preferably, the supporting and diffusing means is carried by the frame. As embodied herein and shown in Figs. 2a, 2b, 2c, 3a, 3b, 3c, 4, 6, 7, 8, 9, 10, 12a, 12b, and 12c, the means for supporting the fluidizable medium and for permitting the diffusion of air therethrough preferably includes a diffuser board 52, which preferably is formed of particle board or other air-permeable material which also happens to be impermeable to the passage of particles 50 therethrough. Diffuser board 52 is carried by frame 32. In a preferred embodiment, a perforated metal plate 54 is provided beneath diffuser board 52 to support and reinforce same. As shown in Fig. 10 for example, perforated plate 54 includes a plurality of holes 56 extending through plate 54 to allow for passage of air therethrough. Perforated plate 54 is also carried by frame 32 and preferably is fabricated of a sturdy but light weight metal such as aluminum or light gauge steel.

In further accordance with the present invention, means are provided for defining at least one air plenum beneath the supporting and diffusing means. The air plenum defining means is carried by the frame and has a predetermined section through which air is permeable. As embodied herein and shown in Figs. 2a, 2b, 2c, 3a, 3b, 4, 6, and 10, the air plenum defining means preferably includes diffuser board 52 and a tank indicated generally in Fig. 10 for example by the designating numeral 58. Diffuser board 52 preferably covers a bottom 60 of tank 58 to form the upper member defining an air plenum 97 therebetween and comprises the predetermined section of the plenum defining means through which air is permeable.

Tank 58 has a bottom 60, a pair of opposite sidewalls 61, 62, and a closed end wall 64. Tank sidewalls 61, 62 and tank end wall 64 extend substantially in a direction normal to tank bottom 60. Sidewalls 61, 62 and end wall 64 preferably are integral and form a continuous wall disposed generally vertically relative to a horizontally disposed tank bottom 60. Tank 58 has an open top and can be open at one end thereof as in Figs. 1 and 10 for example. Tank 58 can be formed of metal but preferably is formed of fiberglass or heat resistant plastics material to reduce the overall weight of the dual mode patient support system. As shown in Figs. 2b and 10 for example, tank 58 has at least one opening 59 through tank bottom 60 through which gas can be supplied to tank 58 and each air plenum. In a multi-plenum embodiment such as shown in Fig. 10, tank bottom 60 is provided with an opening for each plenum.

In a preferred embodiment of the present invention illustrated in Figs. 10, 13, and 15 for example, the plenum 97 formed between tank bottom 60 and diffuser board 52 is divided into at least two separate plenum chambers 120, 122. This arrangement enables air to be supplied to one chamber at a different flow rate than air is supplied to the other chamber or chambers. As shown in Fig. 10 for example, plenum chamber 120 is separated from plenum chamber 122 by an air impermeable di-

vider 124. Preferably, at least one plenum chamber 120 is disposed to support the buttocks of the patient, and the second plenum chamber 122 is disposed to support the legs and feet of the patient. Preferably, the superficial flow rate of the air supplied by blower 40 to the buttocks plenum chamber 120 can be regulated so as to be higher than that supplied to plenum chamber 122 for the legs and feet.

As embodied herein and shown in Fig. 10 for example, diffuser board 52 defines a first tier 41 and a second tier 43. First tier 41 defines the section of diffuser board 52 forming buttocks plenum chamber 120 and is disposed closer to tank bottom 60 than second tier 43, which defines the section of diffuser board 52 forming plenum chamber 122, and which is disposed to fluidize the material 50 supporting the legs and feet of the patient. Thus, a deeper mass of fluidizable material 50 is supported by first tier 41 of diffuser board 52 over buttocks plenum chamber 120 than is supported by second tier 43 of diffuser board 52 over leg and foot plenum chamber 122. In other words, the height of fluidizable material 50 is larger above first tier 41 of diffuser board 52 at buttocks plenum chamber 120 than above second tier 43 of diffuser board 52 at leg and foot plenum chamber 122.

A three inch (7.62 mm) differential in the height of the fluidizable material constitutes a very significant reduction in the weight of the patient support system. The typical width of the mass of fluidizable material is twenty-four to twenty-six inches (61-66 cm), and the length of same is on the order of fifty-one inches (1 m 30 cm). At a uniform depth of nine inches (22.8 cm), these dimensions define a substantial volume of fluidizable material. In the embodiment of the present invention shown in Fig. 10 for example, the mass of fluidizable material supporting the patient's buttocks typically measures eighteen inches (45.7 cm) long in the direction parallel to the length of the patient support system, and the leg and foot zone is typically thirty-three inches (84 cm) long. The height of fluidizable material above buttocks plenum chamber 120 is nine inches (22.8 cm) and the height above the leg and foot chamber 122 is six inches (15.2 cm). Accordingly, two-tiered plenum embodiments such as shown in Fig. 10 result in the reduction of a volume of fluidizable material measuring eighteen inches (45.7 cm) by twenty-six inches (66 cm) by three inches (7.6 cm). If the fluidizable material is formed of glass microspheres, this reduces the weight of the patient support system by about 150 pounds (67 kg). Moreover, this reduction in the volume of fluidizable material permits use of a smaller blower, which weighs less and thus further reduces the overall weight of the system. Furthermore, a smaller blower lowers the power requirements for operating the system.

In yet further accordance with the present invention, means are provided for supplying air to fluidize the fluidizable medium. The fluidizing means can include the plenum and the air supplying means communicates therewith. As embodied herein and shown schematically in Fig. 15 for example, the means for supplying air to fluidize the fluidizable medium preferably includes blower 40, blower manifold 42, a fluidization supply manifold 45, one or more flow control valves 126, 128, and a plurality of flexible air conduits 48, 49. Air travels from blower 40 to plenum 97 via blower manifold 42, tubes 48, a heat exchange device 51, tubes 49, a fluidization supply manifold 45, control valves 126 or 128, and opening 59 through tank bottom 60. Blower 40 preferably is capable of supplying forty cubic feet (1130 litres) of standard air per minute to the plenum at a pressure of up to twenty-eight inches of water (69.8 mbar), while simultaneously supplying air to air sacks 36 and any other components of the system which are inflatable or require air flow.

The fluidization of the mass of fluidizable material 50 preferably is carried out at different modes of fluidization. In a continuous mode of operation, air is continuously supplied to flow through at least one plenum chamber. There are essentially four continuous modes of operation for fluidization. The zero mode of fluidization embodies the condition when the amount of air passing through the mass of fluidizable material is insufficient to fluidize same. This occurs when the superficial velocity of air through the flow area presented by the fluidizable material is on the order of 0.01 feet per second (0.3 cm/sec). At the minimum mode of fluidization, sufficient air is passing through the fluidizable material 50 to render same fluidized and thus reduce shear forces to essentially zero. At a minimum mode of fluidization the superficial velocity of the air passing through the fluidizable material is on the order of 0.05 feet per second (1.52 cm/sec)-.The maximum mode of fluidization is that which renders the fluidization turbulent and occurs at about a superficial flow velocity of 0.08 feet per second (2.44 cm/sec). An intermediate mode of fluidization occurs between the minimum mode of fluidization and the maximum mode of fluidization and generally begins at a superficial velocity of about 0.06 feet per second (1.8 cm/sec). In the intermittent mode of operation, the air flow is turned off for an interval of time and then turned on for an interval of time. The repetition of this sequence constitutes the intermittent fluidization mode of operation.

In yet further accordance with the present invention, means are provided for independently supplying air to each plenum chamber at indepen-

dently preselected air flow rates. As embodied herein and shown schematically in Figs. 13 and 15 for example, the means for separately supplying air to each plenum chamber at independently preselected air flow rates includes a flow control valve 126 for regulating the supply of air to plenum chamber 120 and a flow control valve 128 for regulating the supply of air to plenum chamber 122. The means for independently supplying air to each separate plenum chamber at a separate flow rate further includes a microprocessor 130 programmed to regulate flow control valve 126 and flow control valve 128. The means for supplying air to each separate plenum chamber at a separate flow rate further includes a pressure sensing device such as a pressure transducer 127 disposed to measure the pressure at the outlet of each flow control valve 126, 128.

In still further accordance with the present invention, means also are provided for intermittently supplying air flow to at least one of plenum chambers 120, 122. In this way, the mass of fluidizable material disposed above at least one of plenum chambers 120, 122 and preferably one or both plenum chambers 120, 122 can be fluidized intermittently. As embodied herein and shown in Figs. 13 and 15 for example, the means for intermittently supplying air flow to at least one plenum chamber preferably includes a microprocessor 130 controlling actuation of the flow control valve 126 or 128 which regulates air flow to the plenum chamber which is selected for an intermittent mode of air flow supply. Each plenum chamber 120, 122 is supplied with air through respective flow control valve 126, 128. The amount of air flow permitted to pass through each flow control valve 126, 128 is controlled by microprocessor 130 according to a preprogrammed set of instructions stored in the memory of microprocessor 130.

For example, during a given interval of time between one and five minutes, the appropriate flow control valve 126 or 128 is closed to prevent any air flow from reaching the respective plenum chamber 120 or 122. In other words, the fluidizable material supported above such plenum chamber is maintained in an unfluidized state. After the passage of this predetermined interval, which can be preset via a control panel which inputs the desired interval into the appropriate set of instructions stored in microprocessor 130, microprocessor 130 opens the appropriate flow control valve to permit at least a minimum level of fluidization of material 50 supported above the corresponding plenum chamber and maintains this minimum fluidization for about one-half to ten seconds for example. One or both or neither plenum chamber can be operated according to the intermittent mode of fluidization, as desired by selecting this mode on the control panel which sends the appropriate signal to microprocessor 130.

In further accordance with the present invention, means are provided for retaining the fluidizable medium generally above the supporting and diffusing means and thus above the air plenum. The retaining means is carried by the frame. As embodied herein and shown in Figs. 1, 2a, 2b, 2c, 2d, 3a, 3b, 4, 6, 7, 8, 9, 10, 11, 12a, 12b, and 12c for example, the means for retaining the fluidizable medium generally above the supporting and diffusing means preferably includes a wall, flexible or elastic, which exits in a number of different embodiments. As shown in Fig. 1 for example, the wall typically is indicated generally in the figures by the designating numeral 66. As shown in Figs. 1, 2a, 2b, 10, and 14 for example, elastic wall 66 can comprise an inflatable U-shaped member 68. As shown in Figs. 2a, 2b, and 10 for example, inflatable U-shaped member 68 preferably comprises a plurality of internal webs 70 which subdivide the interior space of member 68 into a plurality of compartments 72a, 72b and 72c. At least a single web 70 defines two compartments 72, and the lower compartments are the ones closer to diffuser board 52. In some embodiments, the upper compartments can be separately pressurizable from the lower ones. As shown in Figs. 3a, 8, 9 and 14 for example, elastic wall 66 can include an inflatable interface sack 67 extending across the open end of tank 58 and providing the interface between the fluidizable material 50 and inflatable sacks 36. As shown in Figs. 3a, 8, 9, and 14 for example, interface sack 67 preferably includes two compartments 77, 79 which are separated by web 70 and separately pressurizable. As shown in Fig. 14 for example, elastic wall 66 comprises interface sack 67 and U-shaped member 68. U-shaped member 68 comprises upper compartments 75 and lower compartment 73. Interface sack 67 is disposed across the open end of U-shaped member 68. By supplying air to each of compartments 73, 75, 77, and 79 via a separate pressure valve 46, the lower compartments 73, 79 can be maintained at a higher pressure than the upper compartments 75, 77. This facilitates enhancing the comfort of the patient coming into contact with upper compartments 75, 77, while providing more rigidity to lower compartments 73, 79, which bear more of the burden of retaining fluidizable material 50. The lower pressure renders upper compartments 75, 77 more deformable than the lower compartments and thereby facilitates patient ingress and egress to and from the fluidizable support. Interface sack 67 can be integrally formed with U-shaped member 68 by having common exterior wall panels. In other embodiments, the exterior wall panels of U-shaped member 68 and interface sack 67 can be joined in

air-tight fashion. As shown in Fig. 14 for example, interface sack 67 is configured with the same exterior dimensions as inflatable sacks 36 and is largely indistinguishable from them when judged by outward appearances.

In the embodiments of elastic wall 66 illustrated in Figs. 2a, 2b, 3b, 4, 6, and 10 for example, the uppermost compartment 72a is larger than the lower compartments 72b, 72c and forms an overhanging portion 74 which extends over the free edge of sidewalls 61, 62 and end wall 64 of tank 58. As shown in Fig. 3b for example, an elastomeric fastener 104 retains a securing flap 105 by press fitting flap 104 into a receptacle therefor, and so secures the elastic wall to the sidewall of the tank. In an embodiment such as shown in Fig. 7 for example, all compartments 72 are similarly configured. As shown in Fig. 2c for example, an embodiment of an uppermost compartment 76 has a hemispherical shape and does not have an overhanging portion.

As shown in Figs. 3c, 10, 12a, 12b, and 12c, one alternative embodiment of elastic wall 66 comprises a non-rigid panel 78 which is impermeable to the passage of both air and fluidizable material. Panel 78 preferably is formed of a fabric coated with polyurethane or the like. As shown in Fig. 3c for example, panel 78 rests against an inflatable sack 36, which together with the other inflatable sacks 36 provide sufficient rigidity to retain the fluidizable material generally above diffuser board 52.

As shown in Fig. 6 for example, an embodiment of elastic wall 66 can include a plurality of deformable inserts 80 disposed within and substantially filling each compartment formed by an embodiment of impermeable panel 78 which has been configured to completely envelope inserts 80. Each insert 80 preferably is formed of polyurethane foam or a polymeric deformable material. Moreover, some compartments can include an insert 80, while other compartments need not include an insert 80.

As shown in Figs. 12a-12c for example, the means for retaining the fluidizable material over a predetermined air permeable section of the plenum defining means can include a rigid tank sidewall 81, an elastic wall embodiment such as a flexible impermeable panel 78, and an air permeable sheet 108 connected to air impermeable panel 78. Though not shown in Fig. 12, panel 78 can be disposed without interruption around the sides and closed end of tank 58, and an interface sack 67 can be used to retain the fluidizable material at the open end of tank 58. In other embodiments, panel 78 completely surrounds the fluidizable material.

In order to facilitate patient ingress to and egress from the patient support system, at least a section of rigid sidewall 81 is selectively collapsible, either via a grooved track mechanism as illustrated schematically in Fig. 12b or by a bottom hinged mechanism illustrated schematically in Fig. 12c. Air permeable sheet 108 is impermeable to passage of fluidizable material therethrough and is joined at its periphery to panel 78 by an air tight means of attachment such as an air tight zipper 112 or an elastomeric attachment 114 (Fig. 5).

The manner by which the retaining means confines the fluidizable medium generally above the supporting and diffusing means is most easily explained by reference to Figs. 3 and 4 for example. The elastic wall has an attachment flap 82. The free end of attachment flap 82 has an anchoring member, which can for example be a cord 86 in some embodiments (Figs. 3c, and 7) or a elcro strip 88 in others (Figs. 3a, 3b, 4, and 6). As shown In Figs. 3a, 3b, 4, and 6 for example, a rigid clamping channel 90 rests atop tank bottom 60. The free edge of diffuser board 52 is surrounded by a silicone rubber sleeve 92 to form an air-impermeable fitting around the entire free edge of diffuser board 52. In a preferred embodiment, a plurality of support posts 94 (Fig. 4) separates diffuser board 52 and perforated metal plate 54 from tank bottom 60 and support diffuser board 52 and plate 54 above tank bottom 60. Attachment flap 82 extends between the outer surface of an inner leg 96 of clamping channel 90 and sleeve 92. Then attachment flap 82 extends around inner leg 96 so that the anchoring member (86 or 88) extends beyond the inner surface of inner leg 96 as shown in Figs. 3c and 4 for example. Clamping channel 90 is secured to tank bottom 60 via a clamping bolt 98 and a nut 100. Thus, attachment flap 82 is secured in air tight fashion between tank bottom 60 and the free end of inner leg 96 of clamping channel 90. A bead 84 of an air impermeable sealant is applied between sleeve 92 of diffuser board 52 and elastic wall 66. Bead 84 preferably is formed of any room temperature vulcanizing compound (RTV), such as a silicone rubber composition which hardens after exposure to air at room temperature. In this way, air entering a plenum 97 formed between diffuser board 52 and tank bottom 60 cannot escape past the free edge of diffuser board 52 or inner leg 96 of clamping channel 90. Furthermore, elastic wall 66 is air impermeable. Thus, air entering plenum 97 under pressure from blower 40 must pass up through diffuser board 52 into the fluidizable material supported thereabove.

Fig. 3a illustrates one embodiment of interface sack 67 of elastic wall 66 which extends across the open end of tank 58. Tank bottom 60 supports the free edges of perforated plate 54 and diffuser board 52, and silicone rubber sleeve 92 surrounds the free edge of diffuser board 52 to prevent air

from escaping through the free edge of diffuser board 52. A clamping channel 90 secures and seals attachment flap 82 against sleeve 92 in an air-tight fashion and has an anchoring flange 106. In this embodiment, the anchoring member comprises a velcro strip 88 which attaches to a mating velcro strip secured to the underside of anchoring flange 106 of clamping channel 90. Clamping bolts 98 are used to secure clamping channel 90 against tank bottom 60 and diffuser board 52. Moreover, clamping channel 90 can be provided with openings (not shown) through which tubes (not shown) or other conduits for supplying gas to elastic wall 66 can be passed.

Figs. 3c and 10 illustrate another preferred embodiment of elastic wall 66 which extends across the open end of tank 58. Tank bottom 60 supports the free edges of perforated plate 54 and diffuser board 52, and silicone rubber sleeve 92 surrounds the free edge of diffuser board 52 to prevent air from escaping through the free edge thereof. A clamping member 90 secures and seals attachment flap 82 of panel 78 against sleeve 92 in an air-tight fashion and has an inner leg 96. As shown in Fig. 3c in this embodiment, the anchoring member comprises a cord 86 which rests against the inner surface of inner leg 96. Clamping channel 90 is secured to tank bottom 60 via a clamping bolt 98 and nut 100. Thus, attachment flap 82 is secured in air-tight fashion between inner leg 96 of clamping channel 90 and silicon sleeve 92. A bead 84 of RTV compound is applied between sleeve 92 and flexible panel 78. In this way, air entering a plenum 97 formed between diffuser board 52 and tank bottom 60 cannot escape past the free edge of diffuser board 52 or inner leg 96 of clamping channel 90. Furthermore, air impermeable panel 78 forces air entering plenum 97 and passing through diffuser board 52 to pass through the fluidizable material before exiting through an air permeable sheet 108 connected to panel 78 via an air-tight zipper 112 for example.

In still further accordance with the present invention, there is provided a flexible cover sheet. As embodied herein and shown in Figs. 1, 2, 3c, 4, 7, 8, 9, and 12 for example, the flexible cover sheet is formed by an air permeable sheet 108, which is connected to the retaining means so as to contain the fluidizable material and simultaneously permit the fluidizing air to escape. Air permeable sheet 108 is preferably formed of a fine mesh fabric that is impermeable to the passage of the fluidizable material therethrough. Air permeable sheet 108, the retaining means 66, and the diffuser board 52 are connected to one another and thereby cooperate to provide means for containing the fluidizable medium and for permitting the diffusion of air therethrough.

In further accordance with the present invention, means are provided for detachably attaching the periphery of the air permeable cover sheet to the retaining means so as to prevent passage of the fluidizable material past this sheet attaching means. The sheet attaching means preferably prevents passage of particles therethrough having a narrowest dimension greater than 30 microns. The sheet attaching means is further preferably configured so as to be easily engagable and disengagable without great manual strength or dexterity. As embodied herein and shown in Fig. 12 for example, the sheet attaching means includes an attachment mechanism such as an airtight zipper 112. In an alternative embodiment shown in Figs. 3, 4, and 10 for example, the means for attaching sheet 108 to the retaining means preferably includes a flexible attachment flap 110 connected to an attachment mechanism such as an air-tight zipper 112. Attachment flap 110 preferably is impermeable to the passage of air therethrough and to the passage of fluidizable material therethrough. An alternative embodiment of an attachment mechanism is generally designated by the numeral 114 illustrated in Fig. 5 for example, and comprises an elastomeric interlocking mechanism. Mechanism 114 includes two mating elastomeric members 113, 115, and both members join together to form an air-tight seal. The two elastomeric members are easily deformable to come apart and join together when manipulated manually. The ease with which the embodiments of the sheet attaching means can be engaged and disengaged by hand greatly facilitates the removal of the fluidizable material whenever replacement or decontamination is desirable. It also greatly facilitates replacement of air permeable sheet 108 whenever Soiling of same requires that it be changed.

In accordance with the present invention, means are provided for supplying air at a plurality of independently determinable pressures to separate pressure zones of the patient support system and at a plurality of independently determinable air flow rates to separate flow rate zones of the patient support system. In a preferred embodiment illustrated in Figs. 14 and 15 for example, the various facilities of the patient support system requiring a supply of air are assigned a separate valve to facilitate effecting independent levels of pressurization and/or rates of air flow. These various facilities include air sacks 36, air plenum 97, air plenum chambers 120, 122, interface sack 67 and inflatable components of elastic wall 66. Each valve segregates a separate zone, and thus air from blower 40 is provided to a plurality of separately controllable zones. Each separate zone is controlled by either a pressure control valve 46 or a flow control valve 126, 128. Each pressure control valve and flow

control valve is controlled by microprocessor 130 such as shown in Fig. 13 for example. Each pressure control valve 46 and flow control valve 126, 128 has a pressure sensing device which measures the pressure at the outlet of the valve and sends a signal indicative of this pressure to microprocessor 130. As embodied herein, a transducer 127 provides a suitable pressure sensing device. Each valve 46, 126, 128 further comprises an electrically operated motor 132 which opens and closes each valve. Microprocessor 130 controls the motor 132 of each valve, and a preselected pressure or flow for each valve can be selected and stored in the memory of microprocessor 130 via key pad 154 and control panel 156. Microprocessor 130 is programmed to control each motor 132 so as to regulate the pressure or flow through its valve in accordance with the preselected value of pressure or flow stored in the memory of microprocessor 130. Similarly, microprocessor 130 can be programmed to change the preselected pressure or flow through one or more of valves 46, 126, 128.

As shown in Fig. 15, for example, individual sacks or groups of sacks can be associated with a single zone which is supplied by a single pressure control valve 46. Accordingly, all of the sacks controlled by a single pressure control valve 46 can be maintained at the same pressure by the microprocessor, which uses the valve's transducer 127 to monitor the pressure at the valve's outlet.

In one embodiment illustrated in Figs. 14 and 15 for example, eight different zones are independently maintainable at different pressures and/or flow rates of air by blower 40. Zone 1 includes a plurality of inflatable sacks 36, which preferably lack any air escape holes. Blower 40 provides sufficient air to the sacks 36 in zone 1 to maintain them at a pressure between one and twenty inches of water (2.5 and 49.8 mbar). Zone 2 includes a plurality of air sacks 36, which preferably are provided with air escape holes (not shown) that permit air to flow out of the sacks from the upper surface supporting the patient or from the side surfaces away from the patient. Blower 40 supplies air to sacks 36 in zone 2 at a flow rate of about two cubic feet per minute (56.6 litres/min) and a pressure of between two and ten inches of water (5 and 24.9 mbar). Zone 3 includes upper compartment 77 of interface sack 67, and blower 40 supplies air thereto at a pressure between one and twenty inches of water (2.5 and 49.8 mbar). Since no air escape holes are provided in interface sack 67, the flow rate of air provided to compartment 77 is essentially zero. Zone 4 includes lower compartment 79 of interface sack 67, and blower 40 supplies air thereto at a pressure of between one and twenty inches of water (2.5 and 49.8 mbar) and the flow rate of air is essentially zero. Zone 5 includes upper compartments 75 of U-shaped member 68 of elastic wall 66. Compartments 75 lack any air escape holes, and blower 40 supplies air to compartments 75 at a pressure of between zero and twenty-two inches of water (U-54.8 mbar) and a flow rate which is essentially zero. Zone 6 includes lower compartment 73 of U-shaped member 68, and compartment 73 similarly lacks any air escape holes. Blower 40 supplies air to compartment 73 in pressure zone 6 at a pressure of between ten and twenty-two inches of water (24.9 and 54.8,mbar), and the air flow rate is essentially nil. Zone 7 is a flow rate zone and includes buttocks plenum chamber 120 of plenum 97 illustrated in Fig. 10 for example. Similarly, zone 8 includes plenum chamber 122, which is disclosed to provide air to fluidize the mass of fluidizable material 50 disposed to support the legs and feet of the patient. During fluidization of the mass of fluidizable material, blower 40 supplies air in zone 7 to buttocks plenum chamber 120 at a pressure between sixteen and twenty-two inches of water (39.9 and 54.8 mbar) and a flow rate between five and twelve cubic feet per minute (142 and 340 litres/min). Similarly, blower 40 supplies air in zone 8 to legs and feet plenum chamber 122 during fluidization of the mass of fluidizable material thereabove at a pressure of between ten and eighteen inches of water (24:9 and 44.9 mbar) and a flow rate of between five and twenty-eight cubic feet per minute (142 and 743 litres/min).

If it is desired to permit egress from or ingress to the patient support system embodiment shown in Fig. 14 for example, the pressure control valve supplying air to compartments 75 can be controlled by microprocessor 130 through suitable controls on key pad 154 so as to reduce the pressure within compartments 75. The reduced pressure renders them soft enough to permit the patient to slide over them relatively easily. At the same time, the pressure control valve regulating the pressure in compartment 73 of elastic wall 66 can be maintained high enough to provide sufficient rigidity to the remainder of the elastic wall so as to prevent the fluidizable material from unduly deforming elastic wall 66 while the patient is entering or exiting the fluidizable support. Similarly, upper compartment 77 and lower compartment 79 of interface sack 67 can be maintained at different pressures if each is supplied by a different pressure control valve 46. In this way, the lowermost compartment 79 can be maintained at a higher pressure than upper compartment 77 to facilitate retaining the mass of fluidizable material. Maintaining a lower pressure in upper compartment 77 permits it to be compressed for the comfort of the patient, of when the articulatable member is raised to form an angle of inclination with the horizontal as shown in Fig. 11

for example. The pressure in compartment 77 can be lowered automatically by suitable programming of the microprocessor to control the pressure in compartment 77 during articulation of member 116.

Each control valve 46 can be operated in a so-called dump mode which permits instantaneous opening of the valve so as to permit instantaneous depressurization through the valve. Thus, pressure control valves 46 are capable of operating as would a solenoid valve insofar as depressurization is concerned. This mode of valve operation permits instantaneous deflation of inflatable sacks 36 for example. Such deflation is desirable to permit a cardiopulmonary resuscitation (CPR) procedure to be performed on a patient. Such procedure requires a rigid surface rather than the compressible surface provided by inflatable sacks 36. Key pad 154 of control panel 156 signals microprocessor to trigger the pressure control valves 46 to the dump mode.

As shown schematically in Fig. 15 for example, a heat exchange device 51 also can be provided to regulate the temperature of the air supplied to fluidize the mass of material 50. As shown schematically in Fig. 13 for example, microprocessor 130 also controls heat exchange device 51, which includes a heater 53 and a heat exchanger 55. A temperature probe 57 can be provided and disposed so as to measure or record the temperature inside fluidizable material 50 and provide a signal to microprocessor 130. Microprocessor 130 then activates heater 53 to regulate the temperature of the mass of fluidizable material according to predetermined temperature range parameters stored in the memory of microprocessor 130. Microprocessor 130 also can display the temperature on control panel 156 for example.

Microprocessor 130 controls blower 40 via a blower control board 131 and receives signals from a pressure sensor 150 which monitors the pressure at the outlet side of blower 40. Microprocessor 130 also controls articulation of articulatable member 116, for instance via conventional hydraulics and/or motors indicated schematically in Fig. 13 by the articulation package designated 152. Sensing devices also are included in this articulation package 152, as indicated schematically in Fig. 13 by the return arrow toward microprocessor 130. These sensing devices provide microprocessor 130 with information regarding the degree of articulation of articulatable member 116.

In yet further accordance with the present invention, means are provided for defluidizing the mass of fluidizable material during elevation of the articulatable member. As embodied herein and shown schematically in Fig. 13 for example, the means for defluidizing the mass of fluidizable material during elevation of the articulatable member preferably includes articulation package 152 and microprocessor 130. As embodied herein, articulation package 152 contains conventional hydraulics and motors to raise articulatable member 116 and further includes sensing devices to monitor the degree of articulation of member 116. Instructions concerning the degree of elevation of articulation member 116 are inputted to microprocessor 130 by the operator via key pad 154 and control panel 156. Microprocessor 130 then activates the hydraulics and motors until the articulation sensing device signals that the inputted level of articulation has been attained. In conjunction with the actuation of the conventional hydraulics and motors to begin elevating articulatable member 116, microprocessor 130 causes flow control valve 126 governing fluidization of buttocks plenum chamber 120 (shown in Fig. 10 for example) to close. This defluidizes the mass of fluidizable material supporting the buttocks of the patient. The defluidization of material 50 supporting the buttocks of the patient acts to prevent the buttocks from moving in a direction toward the feet of the patient as weight is transferred against the buttocks during elevation of the head and chest of the patient. Thus, the defluidization of the mass of fluidizable material supporting the buttocks acts as a substitute for a knee gatch that often is required when elevating the head and chest of a patient on the articulatable member of a conventional low air loss bed. The prevention of movement of the buttocks has the added beneficial result of restraining the patient from any slipping and sliding that might cause tissue damage to any sacral skin grafts which may exist on the patient.

After the articulatable member has attained the desired angle of elevation, the microprocessor preferably is programmed to signal flow control valve 126 to open for a very brief period of time. The duration of this brief period is no longer than required to contour the mass of fluidizable material for supporting the buttocks in the sitting position which has been attained by the patient. For example, the duration of this brief period is not long enough to result in the patient feeling the sensation of sinking into the mass of fluidizable material in the buttocks zone.

In further accordance with the present invention, means are provided to facilitate replacement of the mass of fluidizable material. As embodied herein and shown in Figs. 7-9 for example, the means for facilitating replacement of the fluidizable material preferably comprises at least one fluidizable cell 134, and preferably a plurality of cells 134. Each fluidizable cell 134 has an upper wall 136, a lower wall 138, and a sidewall 140 extending between and connecting the upper wall and the lower wall. Each cell 134 contains a mass of fluidizable material 50 therein, and walls 136, 138, and 140

prevent passage of the fluidizable material therethrough. Each upper wall 136 and each lower wall 138 of each fluidizable cell 134 is permeable to the passage of air therethrough. Each sidewall 140 of each fluidizable cell 134 is impermeable to passage of air therethrough.

The upper walls are connected in air impermeable fashion to the retaining means surrounding the cells. An air impermeable seal is formed between the elastic wall and at least a portion of the periphery of each upper wall 136 of each fluidizable cell 134. This is preferably accomplished as shown in Figs. 8 and 9 for example, in which each fluidizable cell 134 is connected to the retaining means such as elastic walls 66 via an attachment flap 110 and an attachment mechanism such as air-tight zipper 112. Each upper wall 136 of each fluidizable cell preferably is formed as a disengagable section of an air permeable cover sheet 108. Preferably, the remaining portion of the periphery of each upper wall 136 is connected to the remaining portion of the periphery of each upper wall of each adjacent fluidizable cell 134 via respective attachment flaps 110 and zippers 112 for example. In an alternative embodiment shown in Figs. 8 and 9 for example, velcro strips 88 are provided to connect adjacent sidewalls 140 of adjacent cells 134. These strips 88 preferably are located near the interface between upper wall 136 and sidewall 140 of each cell 134. In this way all of the upper walls 136 of cells 134 are connected to and/or disposed alongside one another.

In another alternative embodiment shown in Fig. 7 for example, the adjacent cells are connected to one another at the vertical edges of the narrow ends of sidewalls 140 via attachment flaps 110 and an attachment mechanism such as zippers 112. Since all of the cells are connected to one another, the upper walls 136 of cells 134 are combined to form an air permeable surface which functions equivalently to air permeable sheet 108 to prevent passage of the fluidizable material therethrough while at the same time permitting passage of air therethrough in order to allow air to pass through fluidizable material 50 and fluidize same.

In accordance with the present invention, means are provided for connecting the fluidizable cells to diffuser board 52. As embodied herein and shown in Figs. 7, 8, and 9 for example, the means for connecting the fluidizable cells to diffuser board 52 preferably includes an attachment flap 82, an anchoring flap 83, and a means for securing the attachment flap to the anchoring flap without permitting passage of air thereby. Preferably, the lower portion of sidewall 140 near lower wall 138 of each fluidizable cell has an attachment flap 82. One end of an anchoring flap 83 is secured to diffuser board 52. Where there are a plurality of fluidizable cells, the attachment flap of the fluidizable cell closest to elastic wall 66 attaches via an embodiment of the connecting means to the anchoring flap which extends from the edge of diffuser board 52. In an alternative embodiment shown in Fig. 6 for example, anchoring flap 83 extends from the base of the elastic wall instead of from the diffuser board. In both cases, the flow of air through the diffuser board is constrained to pass through lower walls 138 of cells 134 and cannot leak between cells 134 and elastic wall 66 for example.

As embodied herein and shown in Figs. 8 and 9 for example, the means for attaching the attachment flap to the anchoring flap preferably comprises an air impermeable zipper 112. An alternative embodiment of the attaching means includes an airtight elastomeric attachment mechanism 114 such as shown in Fig. 5 for example. In either case, the connecting means is selectively engagable and disengagable to permit removal of each fluidizable cell and substitution of a replacement fluidizable cell for the removed cell.

As shown in Figs. 7, 8, and 9 for example, a plurality of fluidizable cells can be disposed transversely across diffuser board 52 and connected thereto via attachment flaps 82 located on sidewall 140 near lower wall 138 of each cell 134 and anchoring flaps 83 disposed in spaced relation on diffuser board 52.

In still further accordance with the present invention, means are provided for containing the fluidizable medium. One embodiment of the means for containing the fluidizable medium includes a fluidizable cell 134 such as shown in Figs. 7, 8, and 9 for example. Another embodiment of the means for containing the fluidizable medium preferably includes an embodiment of elastic wall 66, air permeable sheet 108, and diffuser board 52 such as shown in Figs. 2b, 4, and 12 for example.

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope of the claimed invention. Thus, it is intended that the present invention cover modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

Claims

1. A method of providing support to a patient, comprising the steps of:

a) supporting a first portion of the patient on a first surface formed by an air fluidizable mass of material (50);

b) the method being characterized by the step of supporting a different portion of the

patient on a second surface (36) wherein the first and second surfaces are non-overlapping with respect to each other.

2. A method as claimed in claim 1, wherein an articulatable member (116) is used to carry the second surface (36).

3. A method as claimed in claim 2, further comprising the steps of:

inclining the first portion of the patient by elevating one end of the articulatable member (116); and

reducing the level of fluidization of the mass of material (50) forming the first surface (50).

4. A method as claimed in claim 3, further comprising the step of:

a) regulating the rate of defluidization during elevation of the second surface (36) so as to restrain slipping or sliding of the buttocks that causes tissue damage to existing sacral skin grafts on the patient; or

b) reducing the level of fluidization until the mass of material (50) is completely defluidized; or

c) after ceasing to elevate the one end of the articulatable member (116), increasing the level of fluidization of the mass of material (50) for a brief period sufficient to contour the mass of material (50) for the support of the buttocks in the sitting position of the patient.

5. A method as claimed in claim 3, further comprising the step of after ceasing to elevate the end of the second surface (36), increasing the level of fluidization of the mass of material (50) for at least a brief period.

6. A method as claimed in claim 5, wherein the duration of the brief period is in the range of $\frac{1}{2}$ to $1\frac{1}{2}$ seconds.

7. A method as claimed in claim 2, further comprising the steps of:

a) reducing the level of fluidization of the mass of material (50) forming the first surface until the mass of material is completely defluidized; and

when the mass of material (50) is completely defluidized, then inclining the first portion of the patient by elevating one end of the articulatable member (116); or

b) using pressurized air to support the upper torso, chest and head of the patient above the articulatable member (116).

8. A method as claimed in claim 1, wherein either

a) the fluidizable mass of material is contained with an elastic interface member (67) that is disposed to support the portion of the patient between the first portion and the second portion; or

b) the fluidizable mass of material (50) is contained with an elastic inflatable wall (66) having at least one compartment (75) and the method further comprising the step of:

reducing the pressure within the compartment (75) of the wall to facilitate patient ingress and/or egress from the patient support system.

9. A patient support system, comprising:

a frame (32);

a fluidizable medium (50) carried by the frame to support at least a portion of the patient's body; and

a means (66, 108, 52, 134) for containing the fluidizable medium (50) and for permitting the diffusion of air therethrough, the containing and diffusing means being carried by the frame (32), characterized in that the system includes another surface (36) carried by the frame (32) to support at least another portion of the patient's body adjacent the fluidizable medium (50).

10. An apparatus as claimed in claim 9, wherein the means for containing the fluidizable medium (50) and for permitting the diffusion of air therethrough includes a retaining means (66).

11. An apparatus as claimed in claim 10, further comprising:

an air permeable sheet (108) connected to the retaining means so as to prevent passage of fluidizable material (50) between the retaining means and the sheet, the sheet being impermeable to passage of the fluidizable material therethrough; and

a means (112 or 114) for detachably attaching the sheet to the retaining means so as to prevent passage of the fluidizable medium past the attaching means.

12. An apparatus as claimed in claim 10, wherein:

a) the retaining means includes an inflatable interface sack (67) separating the fluidizable medium (50) from the other surface (36); and, optionally,

b) the inflatable interface sack (67) includes two separately pressurizable compartments (77, 79) separated by a web (70); in which case, further optionally comprising:

at least one deformable member (80)

disposed within at least one of the compartments.

13. An apparatus as claimed in claim 9, wherein:

the means for containing the fluidizable medium (50) and for permitting the diffusion of air therethrough includes a nonrigid panel (78) separating the fluidizable medium (50) from the other surface (36); and, optionally,

the nonrigid panel (78) forms compartments (72, 72a, 72b, 72c, 73, 75, 76, 77, 79) which receive inserts (80).

14. An apparatus as claimed in claim 9, further comprising:

an articulatable member (116) carried by the frame (32), the articulatable member being disposed to carry the other surface (36) disposed adjacent to the fluidizable medium (50); and

a means (130, 152, 126, 120) for defluidizing the mass of fluidizable material (50) during elevation of the articulatable member (116).

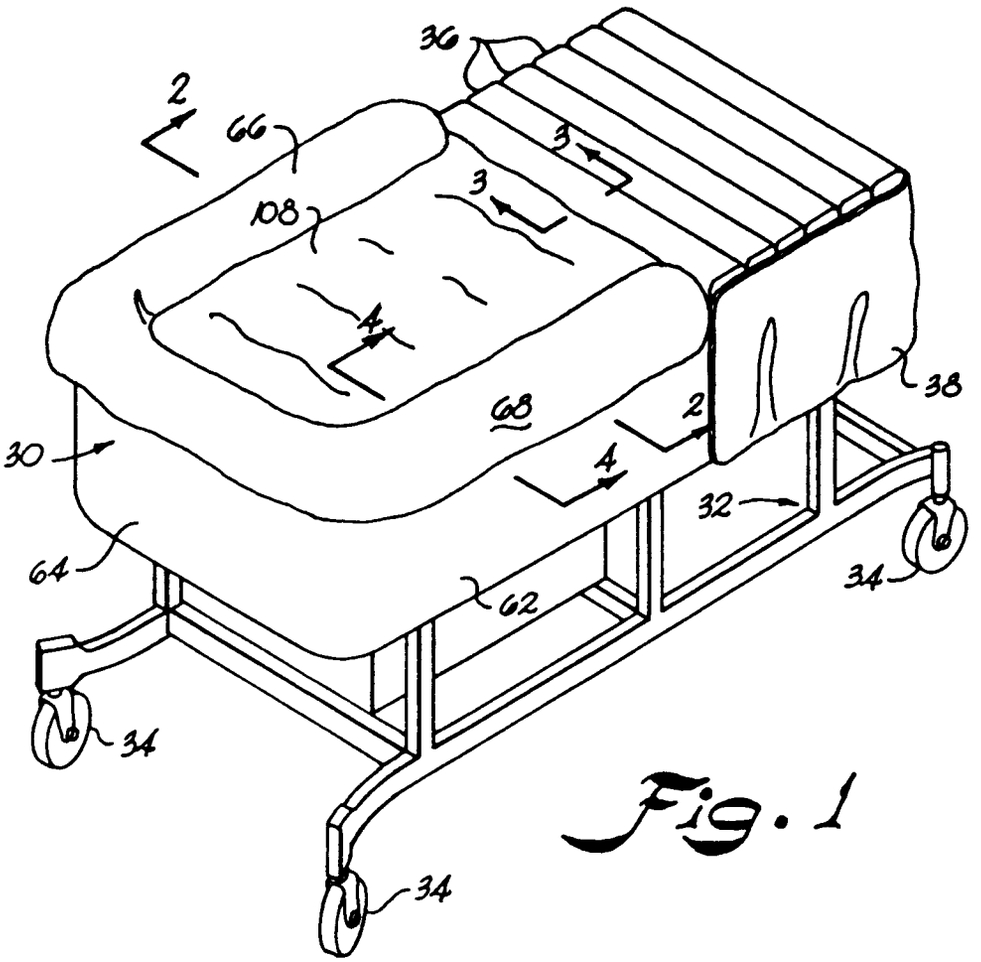


Fig. 1

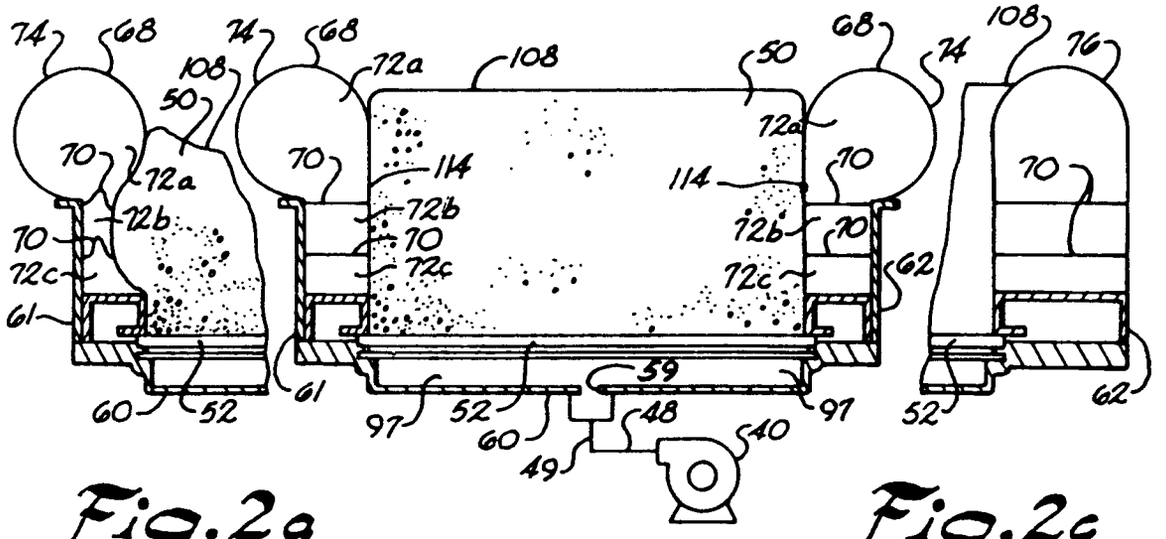
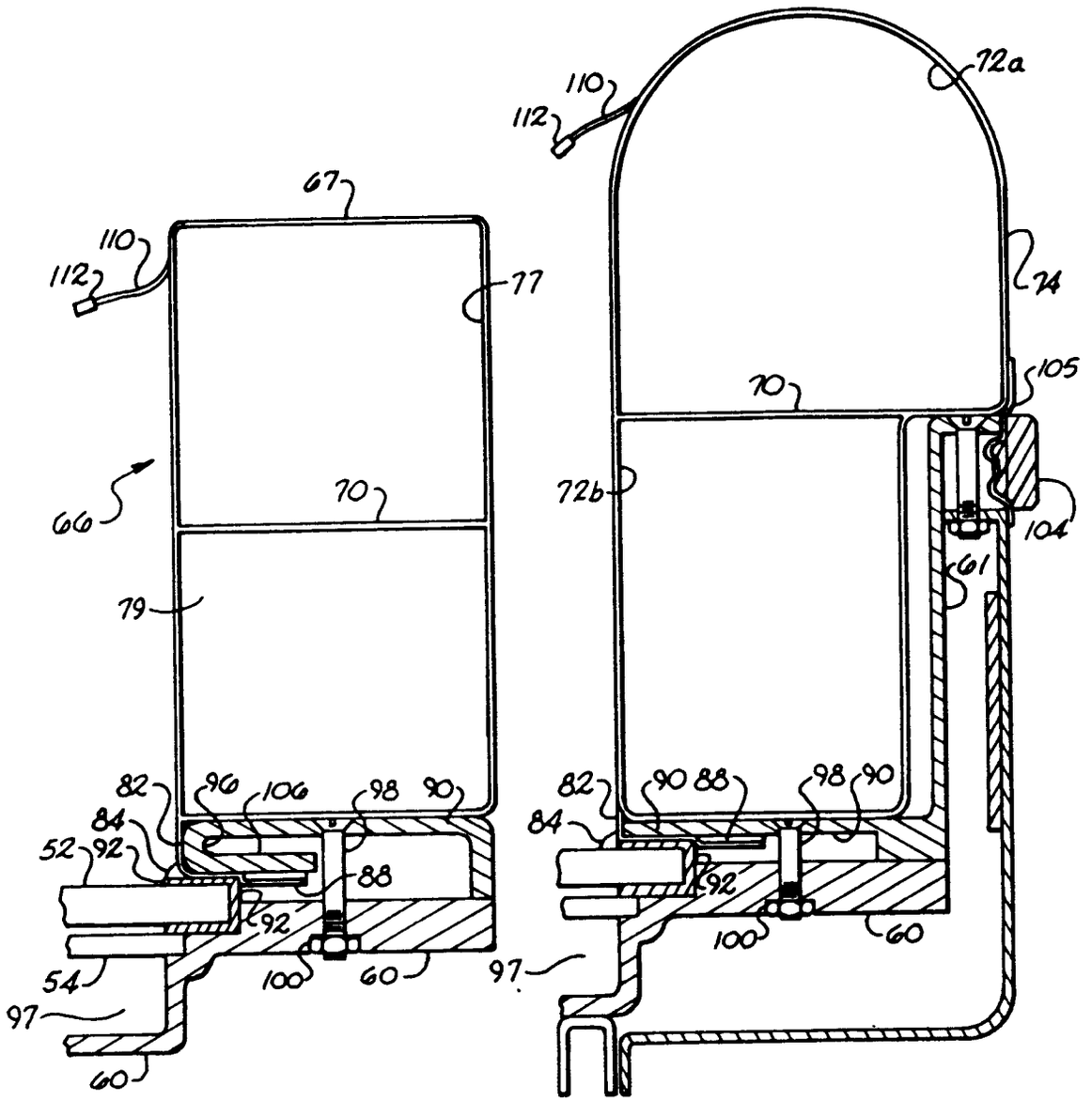


Fig. 2a

Fig. 2c

Fig. 2b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90
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84
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88
92
54
97
100
60
60
110
112
72a
74
105
70
72b
104
61
82
90
88
98
90
84
92
100
60
97

Fig.3a Fig.3b

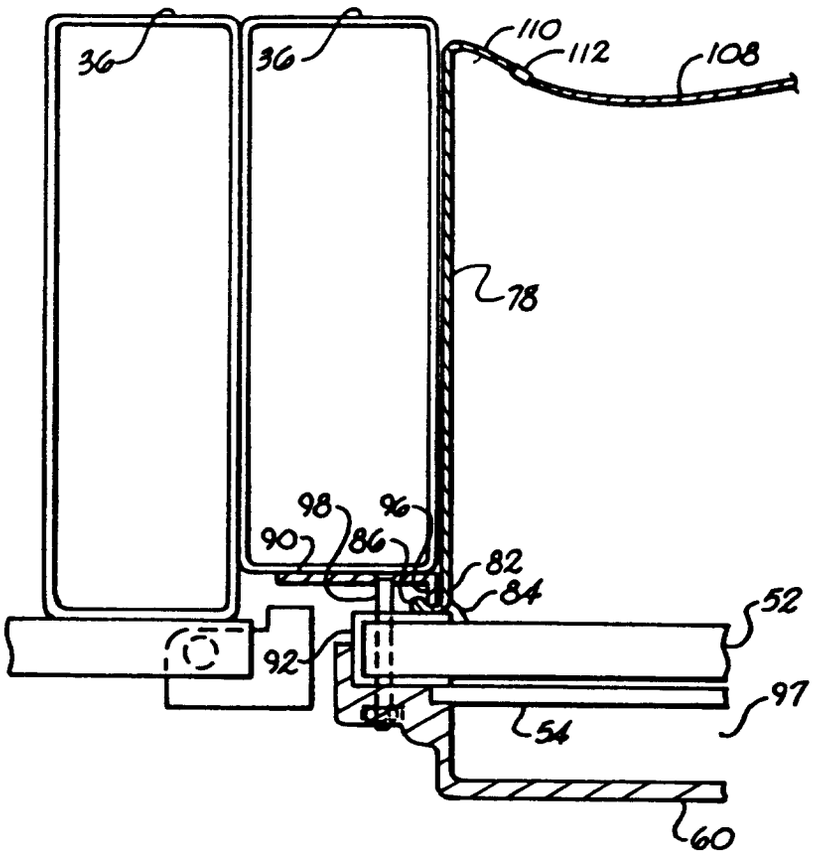
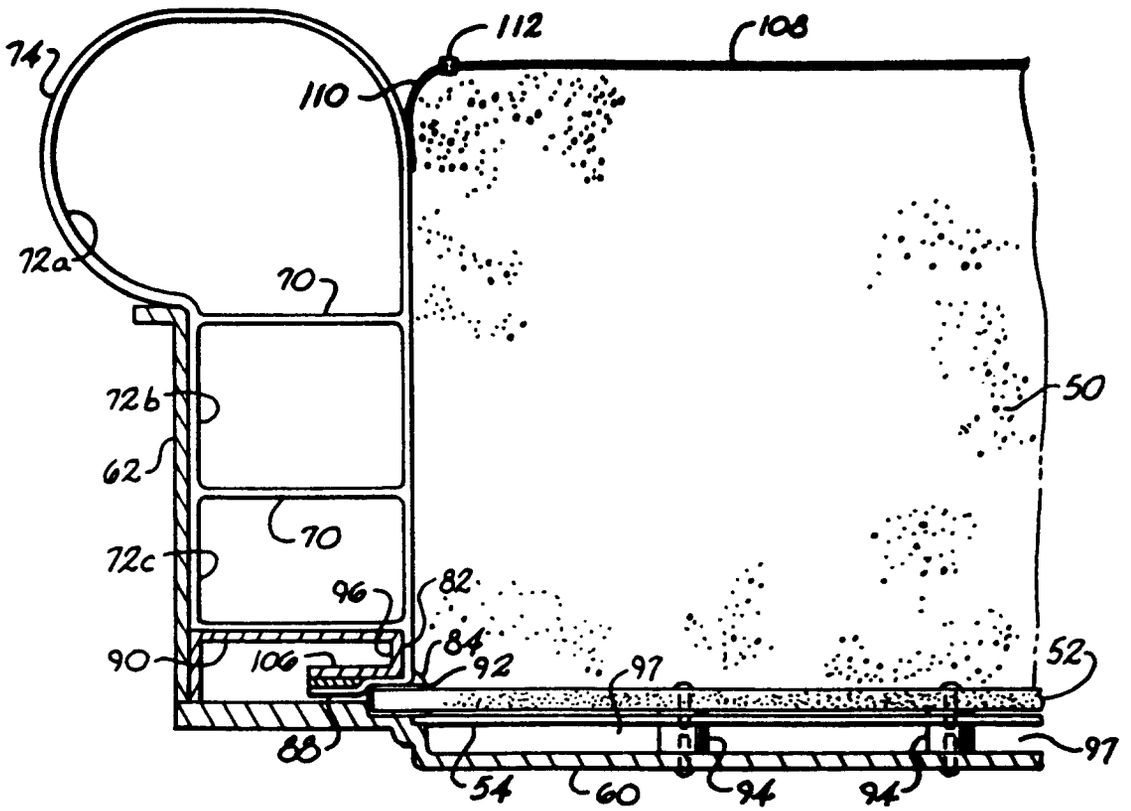


Fig.3c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108
110
72a
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72b
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62
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72c
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82
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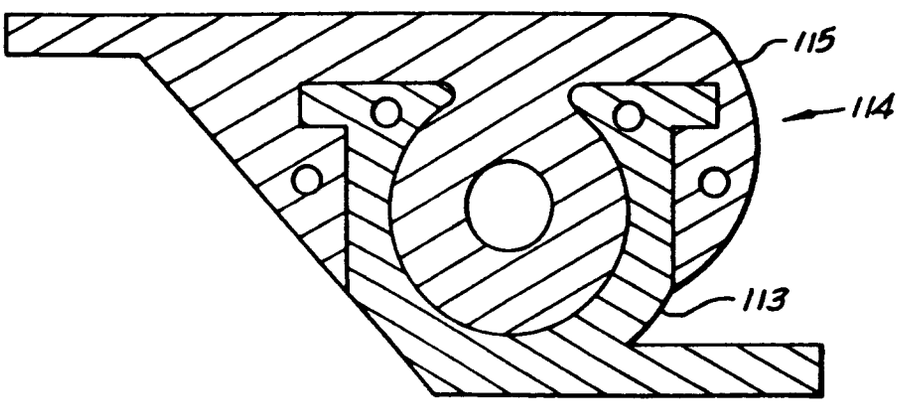
90
106
92
97
52
88
97
54
60
94
94

Fig. 4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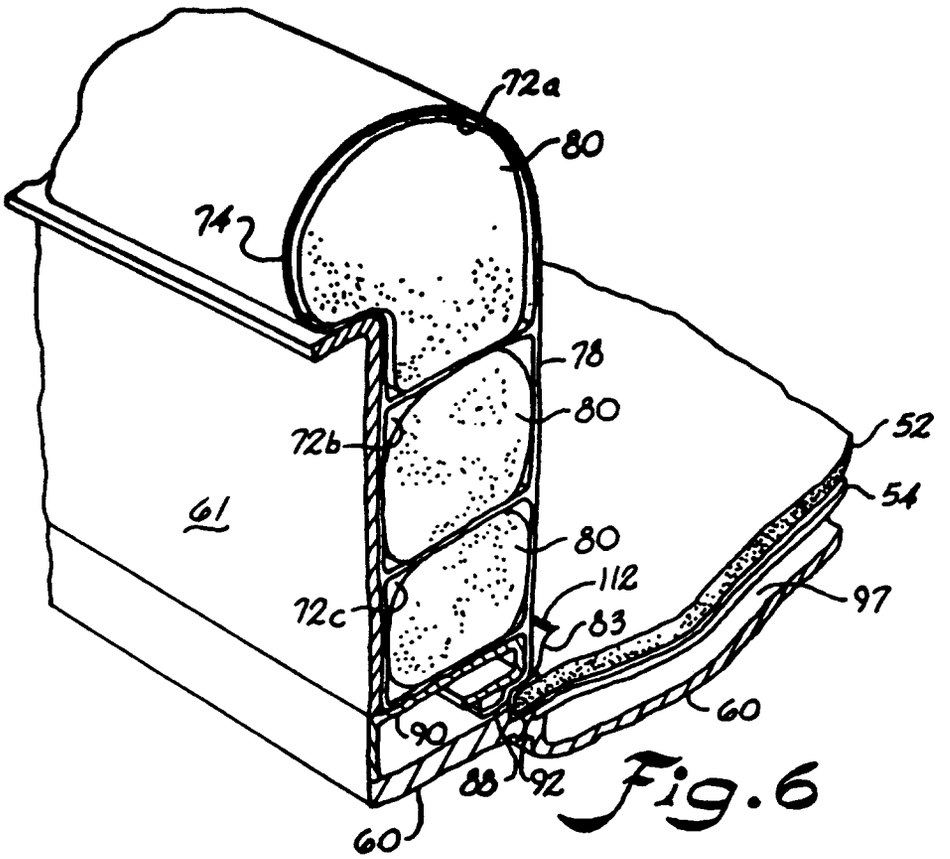
114
113

Fig. 5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72b
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54
61
80
112
72c
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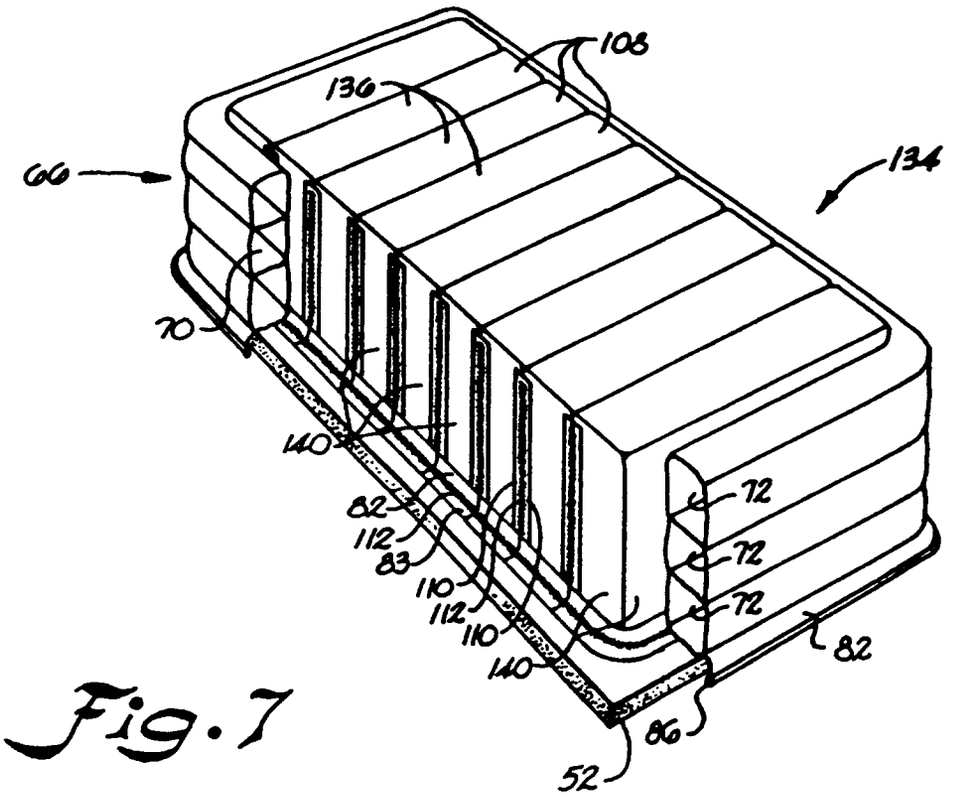
97
90
60
88
92
60

Fig.6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83
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112
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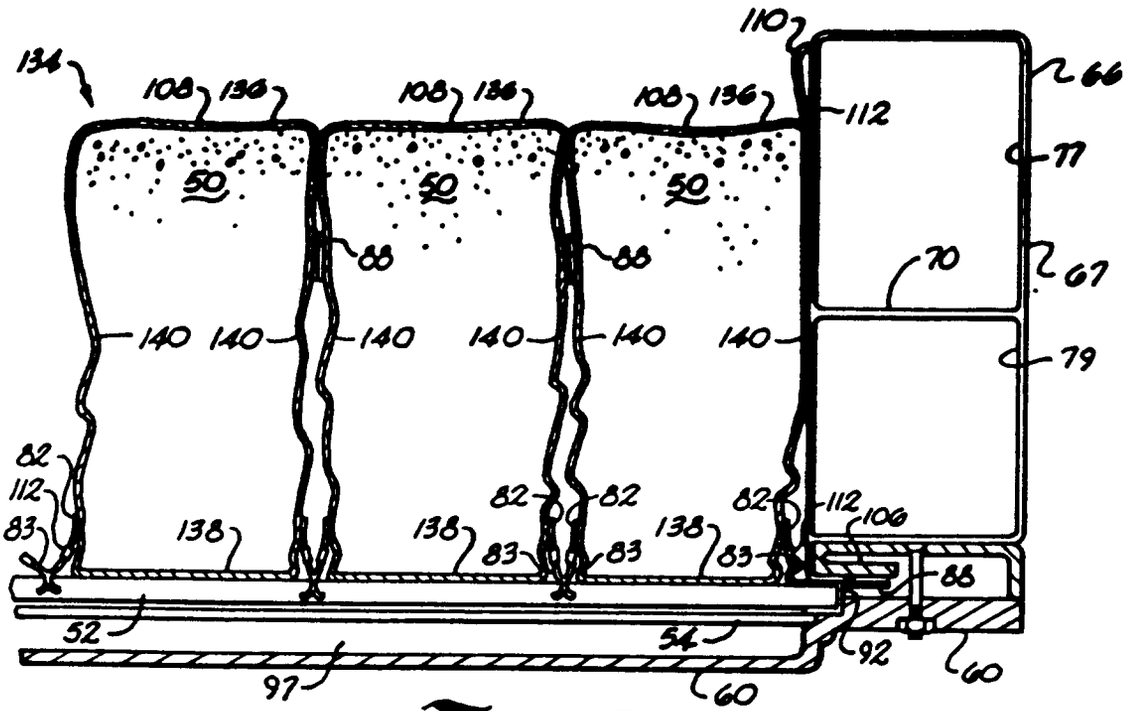
140
72
72
72
82
86
52

Fig.7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108
136
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83
138
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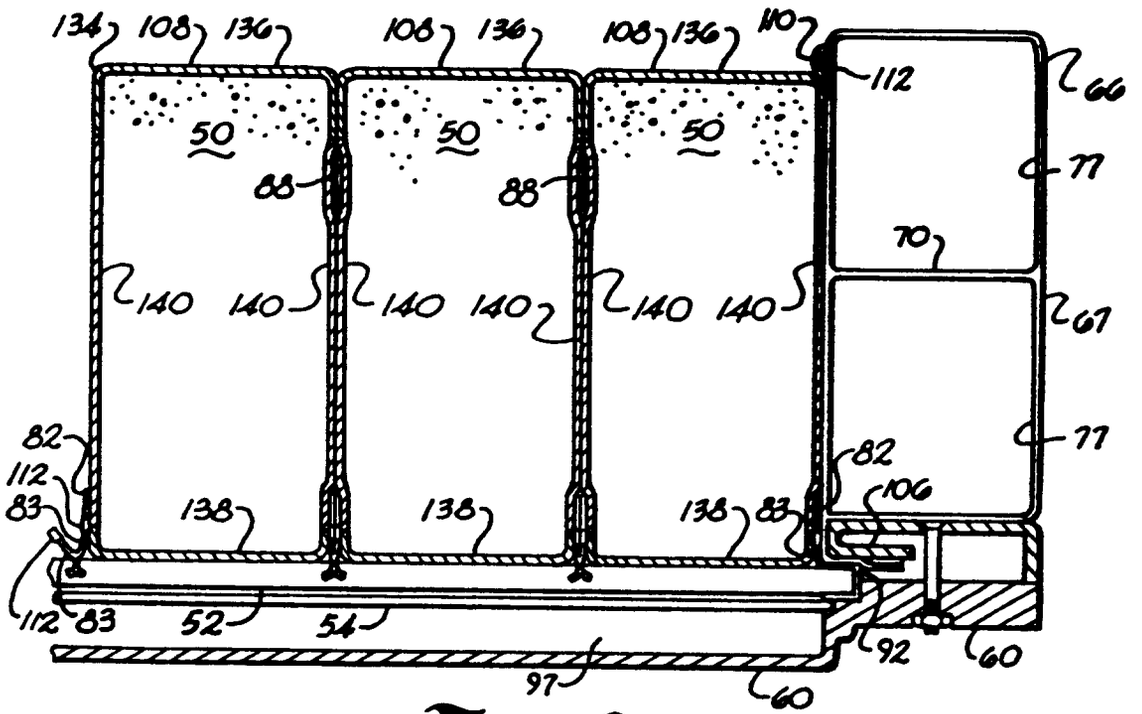
54
97
60
92
110
66
77
70
67
79
106

Fig.8


134
108
136
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82
112
83
138
52
54
97
60
92
110
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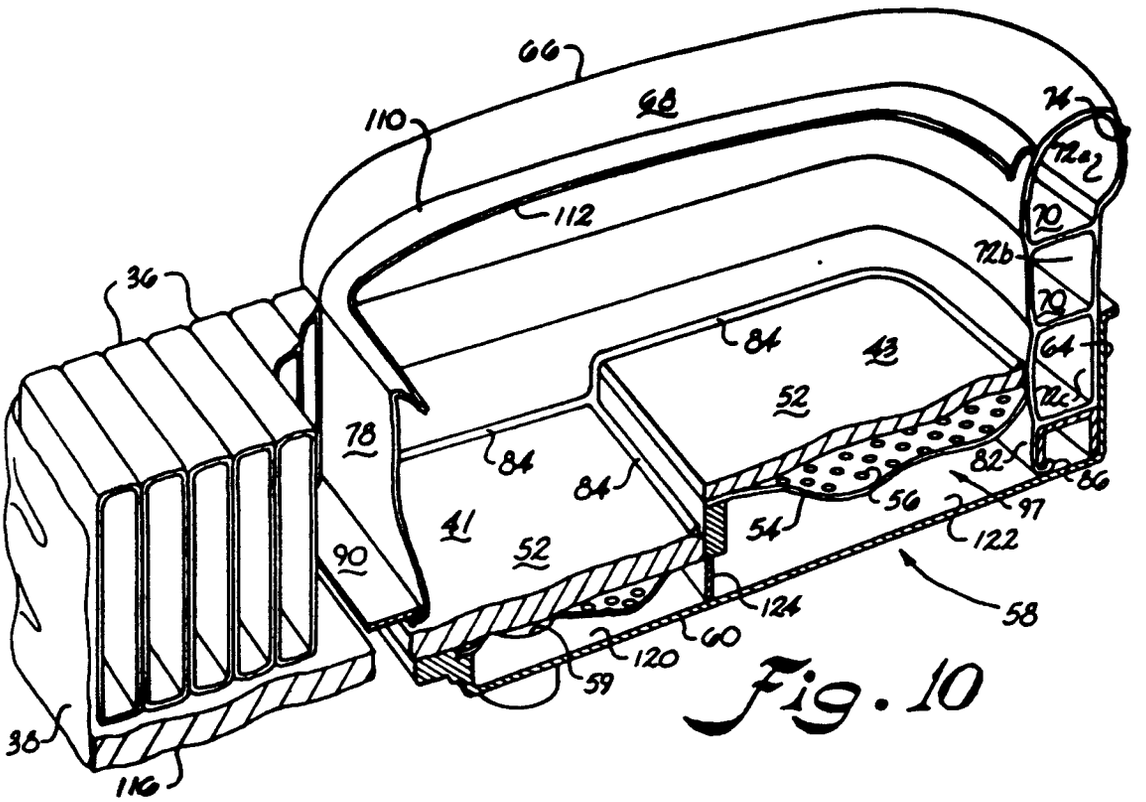
77
70
67
106

Fig.9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68
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72a
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72b
70
64
72c
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52
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41
52
56
97
54
122
90
124
58
60
120
59
38
116

Fig. 10

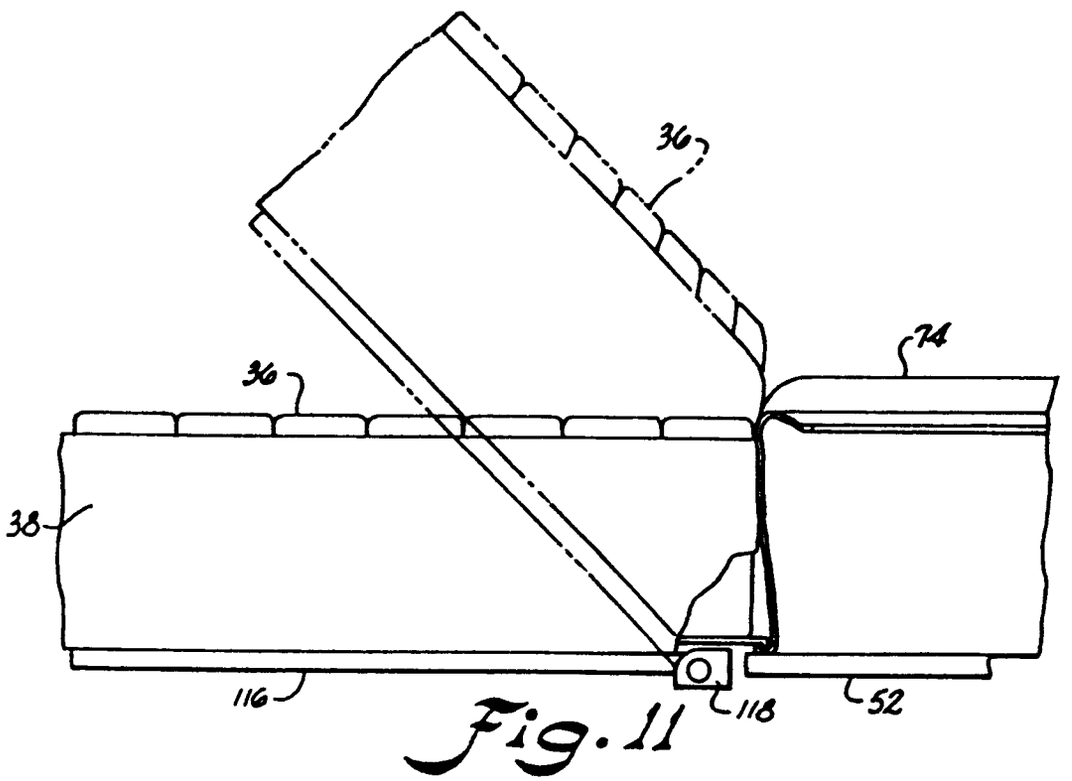

36
74
36
38
116
118
52

Fig. 11

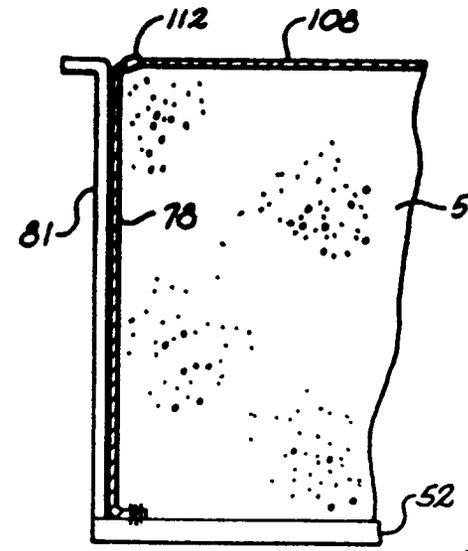


Fig. 12a

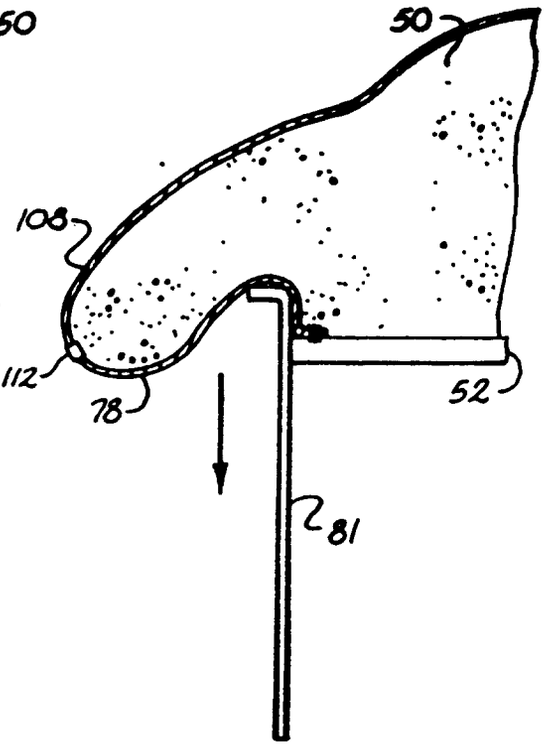


Fig. 12b

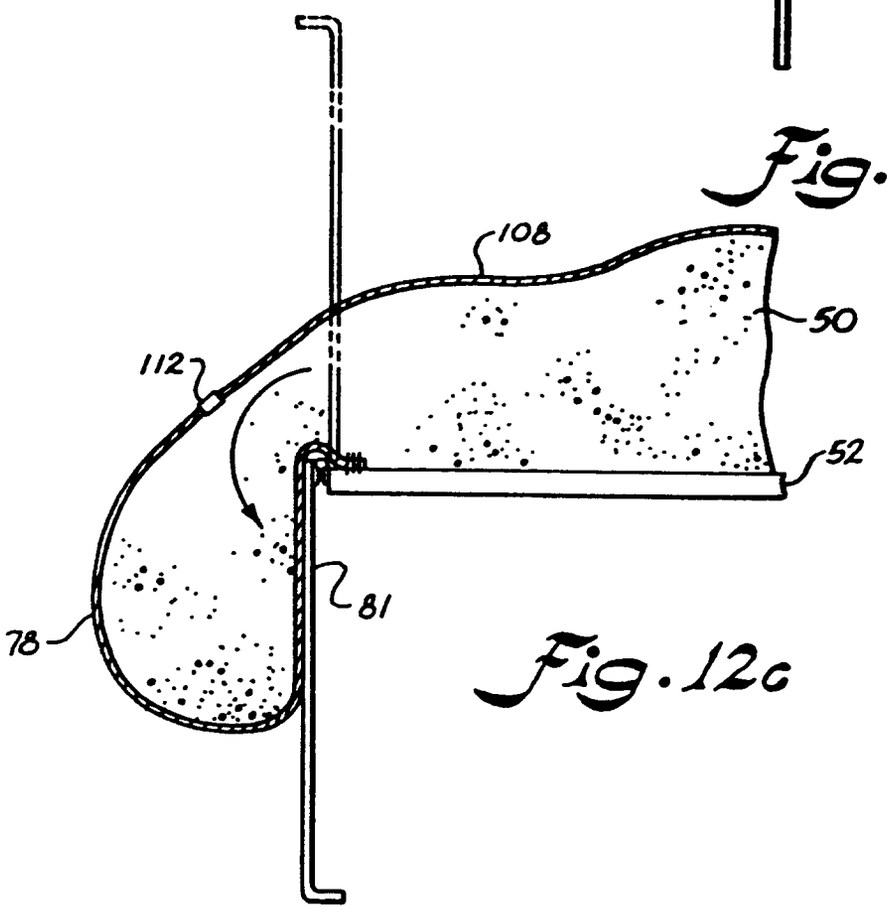
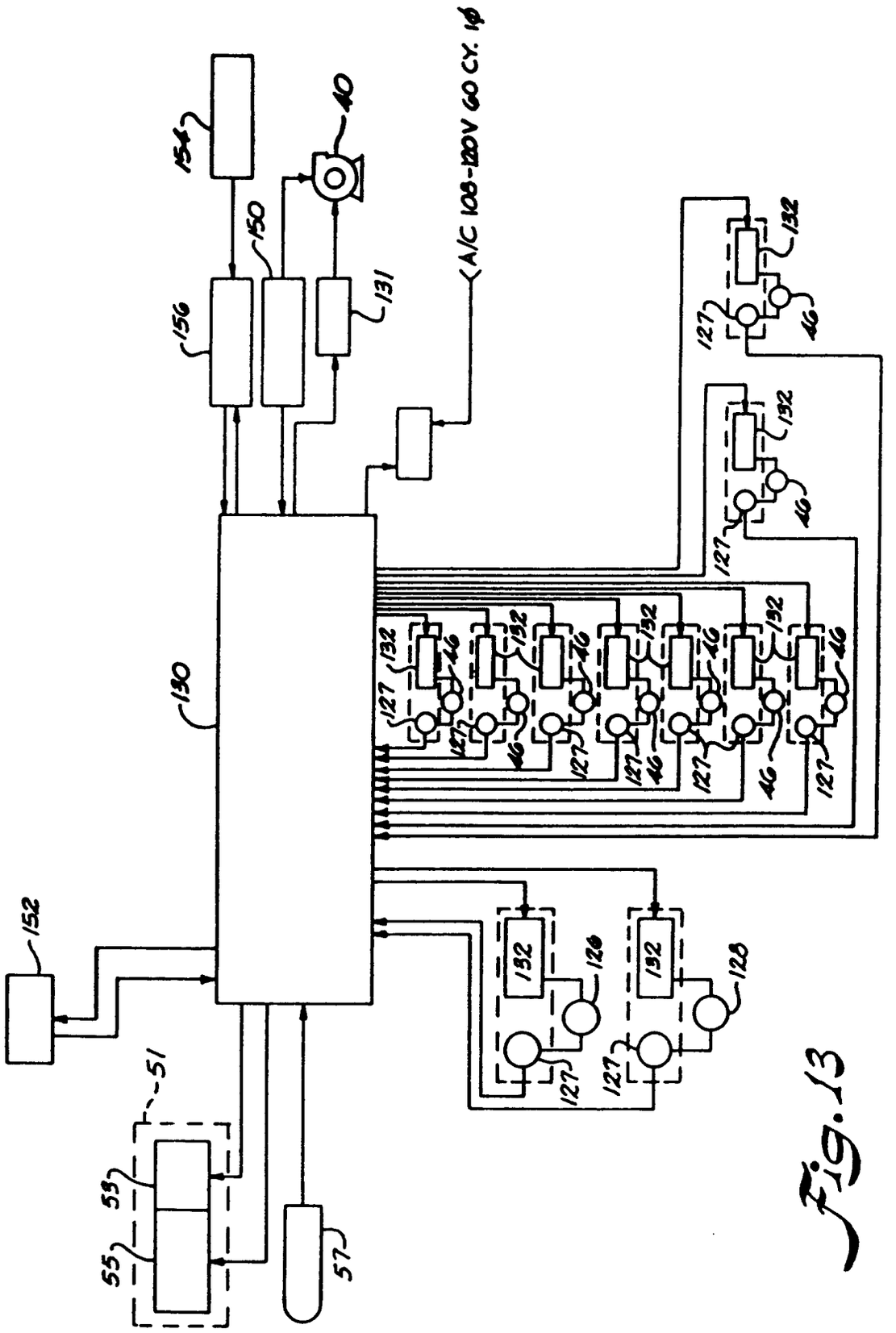


Fig. 12c


A/C 108-120V 60 CY. 1Φ
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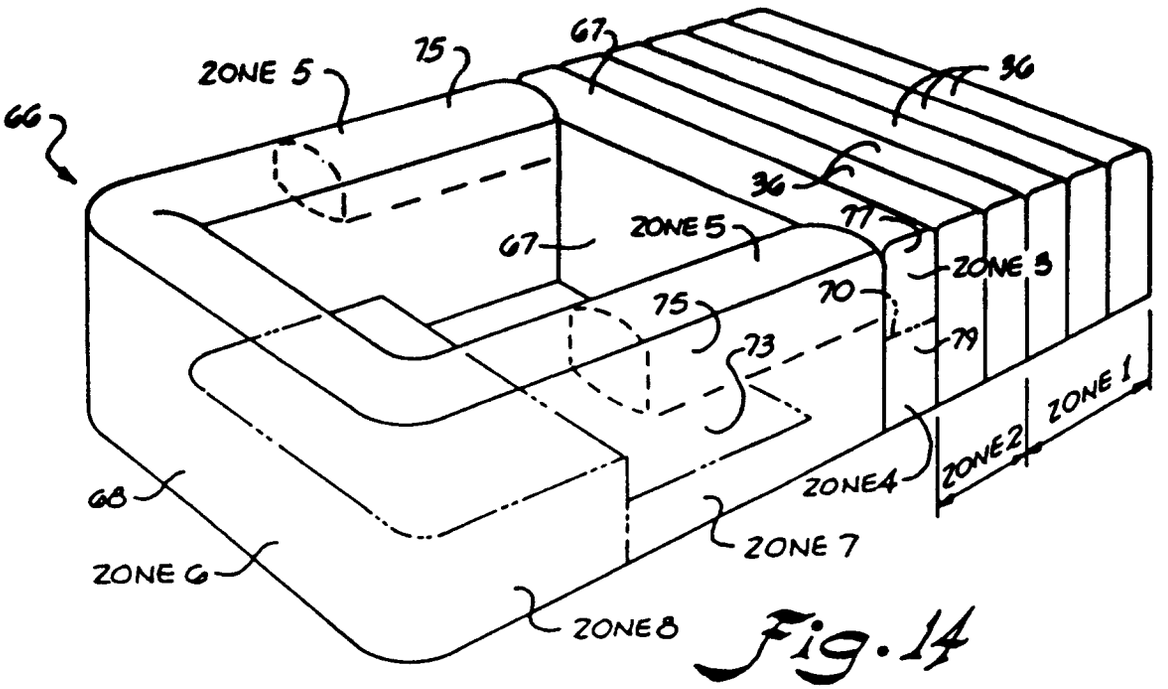
40
150
156
131
130
152
51
53
55
57
132
126
127
46

Fig. 13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ZONE 5
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36
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ZONE 5
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70
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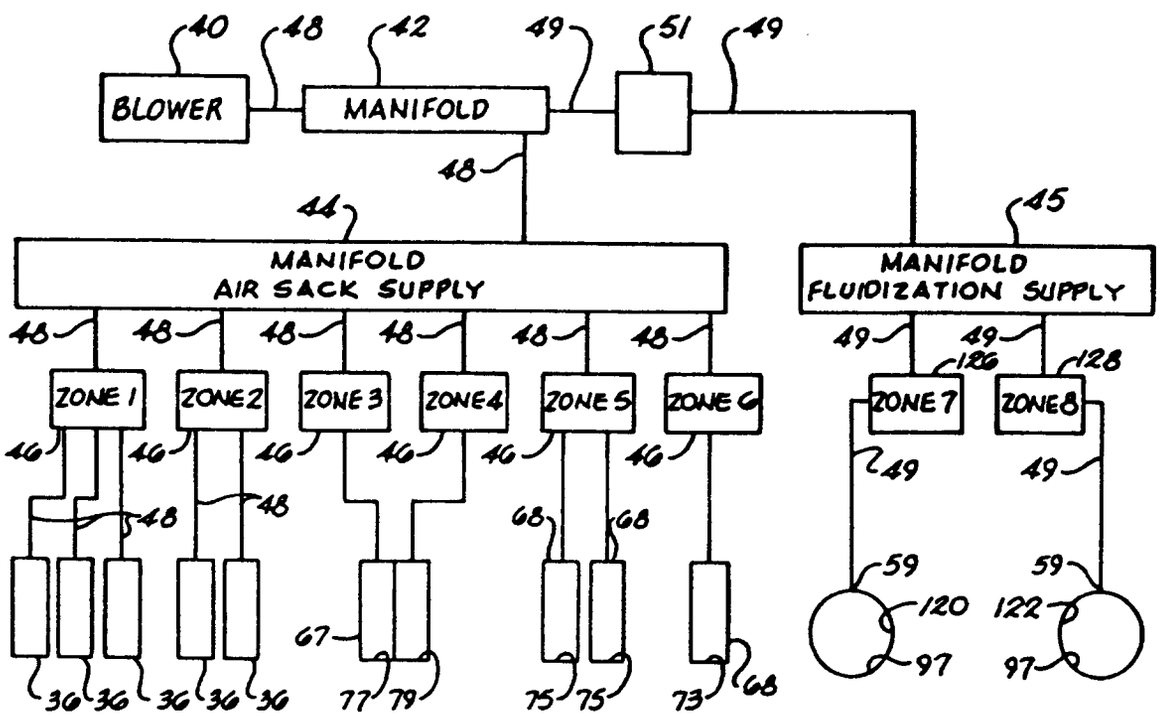
79
73
ZONE 1
ZONE 2
ZONE 4
68
ZONE 7
ZONE 6
ZONE 8

Fig. 14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42
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49
BLOWER
MANIFOLD
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45
MANIFOLD
AIR SACK SUPPLY
MANIFOLD
FLUIDIZATION SUPPLY
48
48
48
48
48
48
49
49
126
128
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
ZONE 7
ZONE 8
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48
68
68
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120
122
97
97
67
36
36
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36
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77
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75
75
73
68

Fig. 15