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(54) **Apparatus for providing a clean air zone.**

(57) Apparatus for providing a clean air zone, for example in a hospital operating theatre or micro-biological clean room comprises a housing (30) preferably mounted above the zone and having a plenum chamber (P) and a fan and filter means (89, 52) operative to supply air, e.g. from inlets (39), to the plenum chamber, as well as diffuser means (40) in the form of one or more perforated plates (60, 64) arranged below the chamber so that air flows out therethrough. In order to reliably ensure a downward and outward air flow pattern, without the need for temperature controls or differential air velocities, so that influx of airborne contaminants to the sterile zone is precluded, the central diffuser area (60) is planar and successive peripheral diffuser areas (72, 73) are arranged at increasing greater angles relative to the central area so that each increasingly deflects the air outwards, e.g. at 5°, 15° or more, from the central downflow.

Advantageously the peripheral diffuser areas (perforate) and intervening imperforate areas serving as deflector vanes are formed integrally as adjacent regions of specially corrugated elongate panels (63).

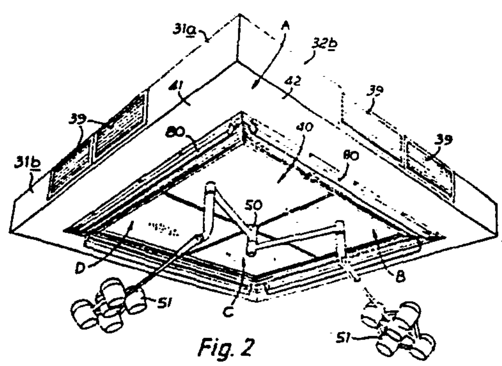

Fig. 2

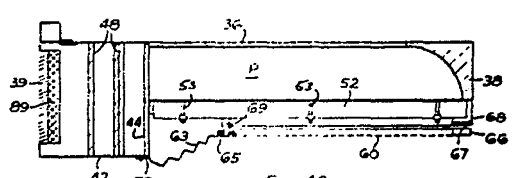

Fig 10

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APPARATUS FOR PROVIDING A CLEAN AIR ZONE

This invention relates to apparatus for providing a clean air zone, for example in surgical operating theatres, and in clean rooms for pharmaceutical production and packaging, as well as for micro-electronics' production.

The natural behaviour of air when it is discharged from an orifice or unidirectional flow diffuser is such that there is peripheral entrainment, all around the diffuser, of extraneous contaminants, which not only mix with the discharged clean air, but are also inwardly dispersed between 10° and 12°. To avoid this, without the need for restrictive drapes or side panels around the air flow zone, apparatus has been proposed for grading the rate of discharged airflow from a diffuser such that air is discharged at a higher velocity from the central area of the diffuser and at successively lower velocities from the respective areas further outward from that central zone, towards the periphery of the diffuser. Such apparatus, which was first described in U.K. Patent Specifications Nos: 1488513 and 1488514, gives rises to a downward and outward pattern of air flow from a ceiling mounted diffuser and this has proved successful in minimising contamination in the zone below the diffuser.

However, the effectiveness of the aforesaid type of graded flow diffusion system is dependant on three exacting conditions. Firstly, the temperature difference between the discharged air and the ambient air should not be more than ± 2° C. Secondly, and as described in later U.K. Patent Specifications Nos: 1555563 and 1555564, there must be equally distributed air recirculation inlets located around the periphery of the graded discharge air diffuser in order to provide a negative velocity pressure equal to that of the positive velocity pressure of the discharged air. Finally, the volume of climatic control air supplied into the graded airflow unit to mix with its recirculation air should not exceed 25% of the total volume, otherwise the negative velocity pressure created at the equally distributed air recirculation inlets is insufficient to induce the peripheral air outwards.

The difficulties involved in co-ordinating these three requirements for the effective operation of such a graded flow system in both summer and winter conditions, when alternatively cooling and heating are required, are considerable. Where these conditions are not maintained throughout the year, the outward air flow has been found to change direction and peripheral entrainment of contaminants has been found to occur. In some cases air from the central zone simply fails to reach the floor, so the clean zone is reduced. Of course, these failures are not at all apparent at the time and are only detected by occurence of contamination following by monitoring of air flows.

In order to overcome the sensitivity of graded flow systems to the aforesaid influences, the rate, and thus the total volume, of air supplied may be increased. However, this causes increased noise and, in operating theatres, also causes unacceptable drying of wounds, and wound cooling by increased evaporation, which in turn leads to hypothermia in patients. Moreover, in pharmaceutical applications, where powders must not be disturbed or flames distorted, such a high air velocity is not acceptable.

It is an object of the present invention to provide an improved clean air supply system which is not susceptible to the above-mentioned problems.

According to the present invention, apparatus for providing a clean air zone comprises supply means operative to supply clean air to a plenum chamber, and diffuser means, in the form of one or more perforated plates, arranged adjacent the chamber so that air supplied to the chamber flows out therethrough, characterised in that the diffuser means has a substantially planar central area and successive peripheral areas which are arranged at increasingly greater angles relative to the central area so that each increasingly deflects the air flow outwardly from the direction of air flow from the central area.

In use, the aforesaid apparatus provides a pattern of air flow radiating outwards from the diffuser means. Inlets distributed around the air discharge diffuser means, for recirculation of air, are no longer essential since the air flow pattern is now determined by the angle of the peripheral areas of the diffuser means rather than by the differential lower velocity of air from these areas. Furthermore the proportion of climatic control air introduced to the air supply means does not affect the air flow pattern and temperature differentials between air supplied by the apparatus and ambient air should have less influence than in the previously known arrangement.

Advantageously, deflector vanes are located between the successive peripheral areas of the diffuser means.

In one form of apparatus in accordance with the invention the successive peripheral areas of the diffuser means may comprise separate perforated plates, each connected to a respective imperforate deflector vane. In this way, the angle of each plate may be independently adjustable either upon installation, or subsequently.

In an alternative form of apparatus, equally within the scope of the invention, the successive peripheral areas of the diffuser means and the intervening imperforate deflector vanes are provided as integral portions of respective profiled panels, which are arranged around the periphery of the central area of the diffuser means. In practice, this construction is easier to install, as the relative angles of the perforated areas are fixed and do not have to be selected at the time of installation. The relative angles may be chosen beforehand, from a small number of different profile configurations as those most favourable to the site.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a diagrammatic, sectional view illustrating a first embodiment of the apparatus of the invention installed in the ceiling of a room;

Fig. 2 is a perspective view of a second embodiment of the apparatus of the invention installed on the ceiling of a room;

Fig. 3 is an enlarged side elevation of the second embodiment;

Fig. 4 is an enlarged cross-section at the mid-line of the second embodiment (along line IV-IV in Fig. 5);

Fig. 5 is a plan view of the second embodiment showing its modular construction;

Fig. 6 is an enlarged plan view of one module of the apparatus shown in Figs. 2 to 5;

Fig. 7 is an enlarged end view of the module shown in Fig. 6, in the direction of arrow VII in Fig. 6;

Fig. 8 is an underside view of the module shown in Fig. 6;

Fig. 8a is an enlarged detail of the panel end portion encircled at VIII in Fig. 8;

Fig. 9 is a diagonal section of the module shown in Fig. 6, along the line IX-IX in Fig. 6, the peripheral panel being omitted for the sake of clarity;

Fig. 10 is a cross-section along the line X-X in Fig. 6 with the strip lamp omitted; and

Fig. 11 is a fragmentary cross-section of a peripheral panel, of the embodiment of Figs. 2 to 10 along the line XI-XI in Fig. 8a, to a further enlarged scale.

Apparatus conforming to the invention is suitable for installation in the ceiling of an operating theatre to provide a clean air zone around a patient undergoing surgery, or in the ceiling of a pharmaceutical or electronic clean room to provide a clean air zone around a machine or manufacturing process, or in any other instance where minimal microbiological contamination is essential. However, instead of being installed in a ceiling, apparatus in accordance with the invention could be mounted in a mobile frame, upon a trolley, so that it can be moved from one location to another.

The general principles of the invention will be explained, first of all, with reference to Fig. 1, which shown one embodiment of the invention in highly diagrammatic manner.

Air supply means in the form of electrically operated fans (not shown) are mounted so as to direct air through a plenum chamber 10 which is provided above the level of a false ceiling 12, and also immediately above an area which is to be kept substantially free of microbial or particulate contaminants, for example the area where an operating table is to be located in a surgical operating theatre. In addition to the fans, air purifiers, heating means, cooling means and humidifiers may be provided to supply suitably conditioned, sufficiently clean air to the plenum chamber 10. In the illustrated example a terminal air filter 14 is also provided across the open lower side of the chamber 10, substantially level with the false ceiling 12.

Immediately below the filter 14, diffuser means in the form of a plurality of perforated plates, designated generally by reference numeral 20, is mounted on the false ?eiling 12. These plates 20 effectively cover the open lower face of the plenum chamber 10 and constitute the outlet for air supplied to the chamber 10 by the fans. The perforated plates comprise a large square, substantially planar central panel 21, arranged horizontally, aligned with or parallel to the ceiling 14, and a first group of narrow rectangular panels 22, which surround the central panel 21 and are disposed at an angle relative thereto, being inclined upwardly from the plane of the central panel 21 at an angle of about 20°. A second group of rectangular panels 24 in turn surround the first group 22. This second group 24 incline upwardly relative to the plane of the central panel 21 at a greater angle than the first group 22, for example, an angle of about 40° in the illustrated example. A third group of rectangular panels 26 in turn surround the second group 24 and these incline upwardly from the plane of the central panel 21 at an angle of about 60°. The panels 22, 24, 26 are all successively narrower and they are all perforated.

Each panel 22, 24, 26 is connected along its inner edge to a respective vane 23, 25, 27, which serves as an air deflector. The panels 22, 24, 26 or their respective vanes 23, 25, 27 are mounted in pivotally adjustable manner whereby the angles of inclination of the respective diffuser panels 22, 24 and 26 and the proportion of air passing therethough can be adjusted An additional deflector vane 29 is mounted at the outer edge of each outermost panel 26.

In use, the fans operate to supply clean air through the plenum chamber 10 as indicated by the arrows A. A suitable rate of air flow is 0.55m/sec. The clean air passes into the room through the perforated diffuser panels 21, 22, 24, 26, issuing in each case in a direction perpendicular to the plane of the respective panel. Thus the air flows directly downwards through the large central panel 21, as indicated by the arrows B, but is deflected outwards, at increasing angles where it passes through the inclined panels 22, 24, 26 around the periphery of the diffuser arrangement, as indicated by the arrows C.

A gap remains between the outermost deflector vane 29 and the edge of the ceiling 12 defining the open lower face of the plenum chamber 10 and air flowing therethrough is so deflected by the plate 29 that it flows substantially horizontally immediately below the ceiling 12, as indicated by the arrow D.

Overall, an air flow pattern radiating outwards in all directions from the diffuser panel arrangement is achieved. Provided this air flow is of a suitable velocity, e.g. 0.55m/sec it will sweep down to the floor of the room and outwards, eventually dissipating via air outlets at the edges of the room, and via the door or doors. Such air flow pattern is known to be advantageous in minimising aeromicrobiological contamination in the zone below the diffuser arrangement since unclean ambient air and contaminants introduced by operatives, including their natural emission of epithelial bacteria, are swept outwardly of that zone to maintain its sterility. The advantage of the present apparatus is that this pattern is achieved more reliably than with previous apparatus which relies on differential air velocities.

A second practical embodiment, which is shown in much greater detail in Figs. 2 to 11, is also ceiling mounted. This apparatus is substantially rectangular, indeed square, in plan (Fig. 5) and comprises a housing 30 which includes four dependent side walls 31, 32, 33, 34. Perforated diffuser means, designated generally by reference numeral 40, are mounted within the side walls across the outflow passage from the apparatus.

The housing 30 is constructed from four modules, A, B, C, D as shown in Figs. 2 to 5, a single module being illustrated in greater detail in Fig. 6 to 10.

Each module has a metallic outer casing 35 consisting of an upper wall 36, adjacent side wall portions a b, and inner walls 37, 38, which are not as high as the side wall portions and which abut corresponding inner walls of the two adjacent modules when all four are assembled together. The side wall portions a, b each have an air intake grille 39, so there are two in each side wall of the assembled apparatus. Although such air intake is not necessarily essential to the inventive concept, it is useful in practice because the apparatus is then self-contained so that at sites of installations where there are no suitable remote air vents already provided there is no need to undertake fresh construction of vents. Prefilters 89 are mounted at the inside of the grilles to filter out major particulate contaminents.

The side wall portins a, b connect to narrow inturned lower walls 41, 42, which further connect to upturned auxiliary walls 43, 44. The latter define an outer compartment to the apparatus. Where the two side walls a, b of each module adjoin, i.e. at each corner of the apparatus, a fan 45 is housed in this outer compartment. Each fan 45 has an outlet duct 46 extending into the inner comparment of the apparatus which constitutes a plenum chamber P. Thus, in operation, the fans 45 draw ambient air into the outer compartment through the grilles 39 (and optionally from a remote inlet as shown in Fig. 3) and supply it to the plenum chamber P.

Intermediate walls 47 are provided substantially parallel to the upper wall 36, across each corner region so as to direct the air from each fan 45 to the central region of the plenum chamber P.

All the walls of each module casing are lined internally with sheets of sound attentuation material, conveniently in the form of foamed plastics material treated with fire retardant. Additional sound attentuation panels 48 are located in the outer compartment of each module. The purpose of all this sound attentuation material is, of course, to deaden the noise of operation of the fans 45.

At the corner of each module, between the inner walls 37, 38 (i.e. opposite the fan 45) the casing is formed with a part cylindrical recess 49. When the modules A to D are assembled together these recesses 49 define a central opening through which a mounting shaft 50 of theatre lighting 51 extends (Figs. 2 to 4).

A high efficiency HEPA filter 52 is mounted across the plenum chamber, parallel with the upper wall 36 and between the auxiliary walls 43, 44 and inner walls 37, 38 of each module by means of respective fasteners 53. Below this the diffuser means 40 is mounted.

The diffuser means comprises a planar central area consisting of four substantially square perforate panels 60, one mounted to each housing module, and successive perforate peripheral areas, which are provided as respective regions of four elongate angled panels, 61 to 64, mounted along the four sides of the central area (i.e. extending between adjacent modules from corner to corner of the inner compartment). In this respect the respective ends of the four panels 61 to 64 are cut obliquely, as for a mitre joint, and are mounted, with only a slight gap 83 remaining therebetween, at the corners (see Fig. 8).

Each large planar panel 60 is formed with an upturned rim 65 along adjacent edges which face the side wall portions a, b, of the relevant module, and with an upward and inwardly directed flange 66 along its other two edges which are aligned with the inner walls 37, 38 of the module (see Fig. 10). Each panel 60 is suspended along one edge only from an inturned lower edge of an inner wall 37 by means of an elongate mounted strip 67, connected to the flange 66 and by means of pins 68. Its opposing edge is suspended by means of individual brackets 69, which can be released to allow the panel 60 to swing down, e.g. when access to the filter 52 is required.

The elongate peripheral panels 61 to 64 are corrugated, and their special angular profile is best seen in Figs. 7, 10 and 11. They include spaced, longitudinally extending perforated regions 71, 72, 73, the latter two of which lie in planes arranged angularly offset by 10° and 15° respectively from the plane of the region 71. Between the regions 71 and 72 and adjacent the region 73 there are longitudinally extending imperforate regions 74, 75, 76, which are disposed, in each case, at an oblique angle from adjacent perforate regions.

With reference in particular to Fig. 11, it will be seen that a hooked region 77 is formed at the inner edge margin of each panel 61 to 64, which, in use, engages over the rims 65 of two adjoining central panels 60. Preferably a rubber gasket is fitted over the rims 65 to provide a more secure connection, without excessive play. Along the outer edge margin of each panel 61 to 64, there is a substantially flat edge strip 78 which is bolted onto the underside of the lower walls 41 or 42 of adjoining housing modules, with a slight gap 79 remaining therebetween. The presence and width of this gap 79 is ensured by location of washers on the fixing bolts.

When the central panels 60 and the peripheral panels 61 to 64 are mounted in position, as illustrated, the central panels 60 are substantially horizontal and the peripheral perforate region 71 is also substantially horizontal and the other two perforate regions 72, 73 are disposed, in this particular embodiment, respectively, at approximately 10° and 15° from the horizontal. Also in this particular embodiment, as best shown in Figs. 8a and 11, the three perforate regions 71, 72 and 73 are provided respectively with three, five and five rows of elongate perforations.

Between the outermost imperforate region 76 and the flat edge strip 78, there is a further longitudinal region 81 which lies at 30° to the horitzontal, and on each panel 61 to 64 on which a respective strip lamp 80 is mounted. The lamp 80 preferably has a tapering profile, as shown, so as to minimise disturbance of the air flow pattern when the equipment is in operation. At each end, beyond the end of the respective lamp 80, the region 81 of each panel is perforated (see Figs. 8 and 8a). Disposed on an angle of 60° to the horizontal, between the region 81 for mounting the lamp 80 and the edge strip 78, is a further narrow region 82 provided with a single row of perforations.

In operation, the fans 45 draw ambient air in via the grilles 39 and the prefilters 89 (and optionally from one or more remote inlets, as shown in Fig. 3) and supply it centrally to the plenum chamber P. From there it passes via the HEPA filter 52, which should remove all remaining particulate contaminants, and out, as sterile air, via the respective perforations of the diffuser panels 60 to 64 and the predetermined gaps 83, 79, as shown by the various arrows in Fig. 11. The air flows vertically downwards from the central panels 60 and from the first perforated peripheral region 71. Where the air passes out through the second perforated peripheral region 72 it is deflected outwardly by about 5°, and where it passes out through the third perforated peripheral region 73 by about 15°. In this respect, the intervening and adjacent imperforate regions 74, 75, 76 serve as deflector vanes, helping to guide the air outwards in the aforesaid pattern. At the corners of the apparatus, air passes out downwardly through the slight gaps 83 between the adjacent mitre cut edges of the peripheral panels 61 to 64, and additionally it passes outwardly at about 30° via the additional perforations beyond the ends of the lamps 80. In this way there is no tendancy for any influx of contaminated ambient at the corners of the area below the apparatus and the sterility of this zone is maintained. Further outward air flow at about 60° occurs via the additional single row of perforations in region 82, outwardly of the lamp 80, and also virtually horizontally below the housing 30 via the gap 79. The air flow from the regions 73 and 82 is entrained around the tapering surfaces of the lamp 80 and then merges, so, again, there is no adverse disturbance which might result in influx of contaminants to the sterile zone.

The foregoing is, of course, only illustrative, not limitative of the scope of the invention and many variations are possible. The strip lights 80 are not essential and, the theatre lights 51 will of course only be appropriate where the apparatus is used in a hospital operating theatre. The modular construction is also not essential, although useful, in practice, to facilitate manufacture and installation. The precise configuration of and manner of attachment of the peripheral panels can vary in many ways as will be readily devised by designers in this technical field dependent on the air flow pattern most suitable to the site of installation. Moreover, the apparatus need not be ceiling mounted and could alternatively be mounted on a trolley, or on some other wall structure. Intermediate constructions taking some features of the embodiment of Fig. 1, and some of the embodiment of Figs. 2 to 11 are also quite possible, i.e. some peripheral panels with more than one perforate region, and some completely perforate or with merely one such region, each panel being adjustable in its orientation.

Claims

1. Apparatus for providing a clean air zone comprises a housing or canopy (30) having a plenum chamber(10; P), supply means including fan (45) and filter means (14; 89, 52) operative to supply clean air to the plenum chamber, and diffuser means (20; 40), in the form of one or more perforated plates (21, 22, 24, 26; 60 to 64) arranged adjacent the chamber so that air supplied to the chamber flows out therethrough, **characterised in that** the diffuser means has a substantially planar central area (21; 60) and successive peripheral areas (22, 24, 26; 72, 73, 81, 82) which are arranged at increasingly greater angles relative to the central area so that each increasingly deflects the air flow outwardly from the direction of air flow from the central area.

2. Apparatus as claimed in claim 1 wherein imperforate deflector vanes (23, 25, 27; 74, 75, 76) are located between the successive peripheral areas (22, 24, 26; 72, 73; 81, 82) of the diffuser means.

3. Apparatus as claimed in claim 2 wherein the successive peripheral areas of the diffuser means comprise separate perforated plates (22, 24, 26) each connected to a respective imperforate deflector vane (23, 25, 27).

4. Apparatus as claimed in claim 2 wherein the successive peripheral areas (71, 72, 73, 81, 82) of the diffuser means (40) and the intervening imperforate deflector vanes (74, 75, 76) are provided as integral portions of respective profiled panels (61 to 64), which are arranged around the periphery of the central area (60) of the diffuser means (40).

5. Apparatus as claimed in claim 4 wherein elongate lamps (80) are mounted upon the profiled panels (61 to 64) around the periphery of the diffuser means (40).

6. Apparatus as claimed in claim 5 wherein the lamps (80) have a generally tapering cross-section so as to minimise disturbance of the pattern of air flow from the diffuser means (40).

7. Apparatus as claimed in any preceding claim wherein a gap (79) is provided around the outer edge of the peripheral areas (61 to 64) of the diffuser means (40), through which air can flow outwardly in a direction substantially at right angles to the direction of air flow from the central area (60) of the diffuser means.

8. Apparatus as claimed in any preceding claim wherein the housing (30) is mounted in or on a ceiling so that the central area (60) of the diffuser means (40) has a substantially horizontal disposition, and air flow therefrom is directed downwards.

9. Apparatus as claimed in any of claims 1 to 7 wherein the housing is mounted on a trolley so as to be capable of being moved to a position above any desired area or machine.

10. Apparatus as claimed in any preceding claim wherein the housing is constructed of four substantially identical modules (A, B, C, D).

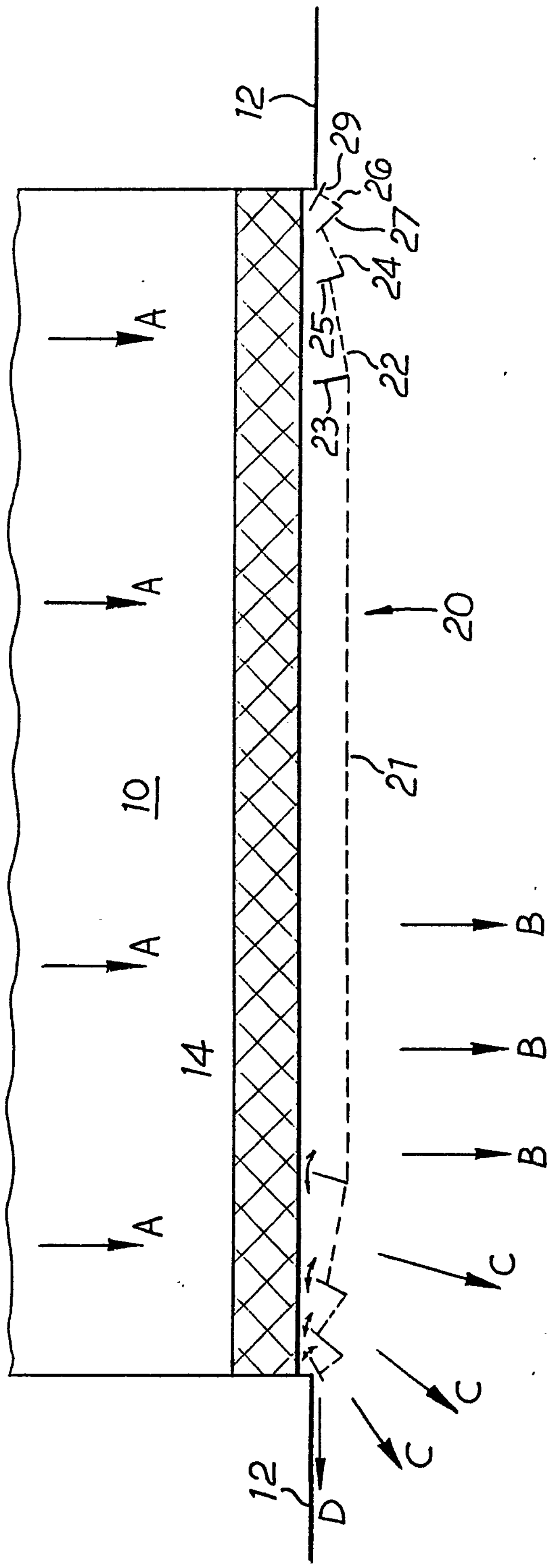

Fig.1

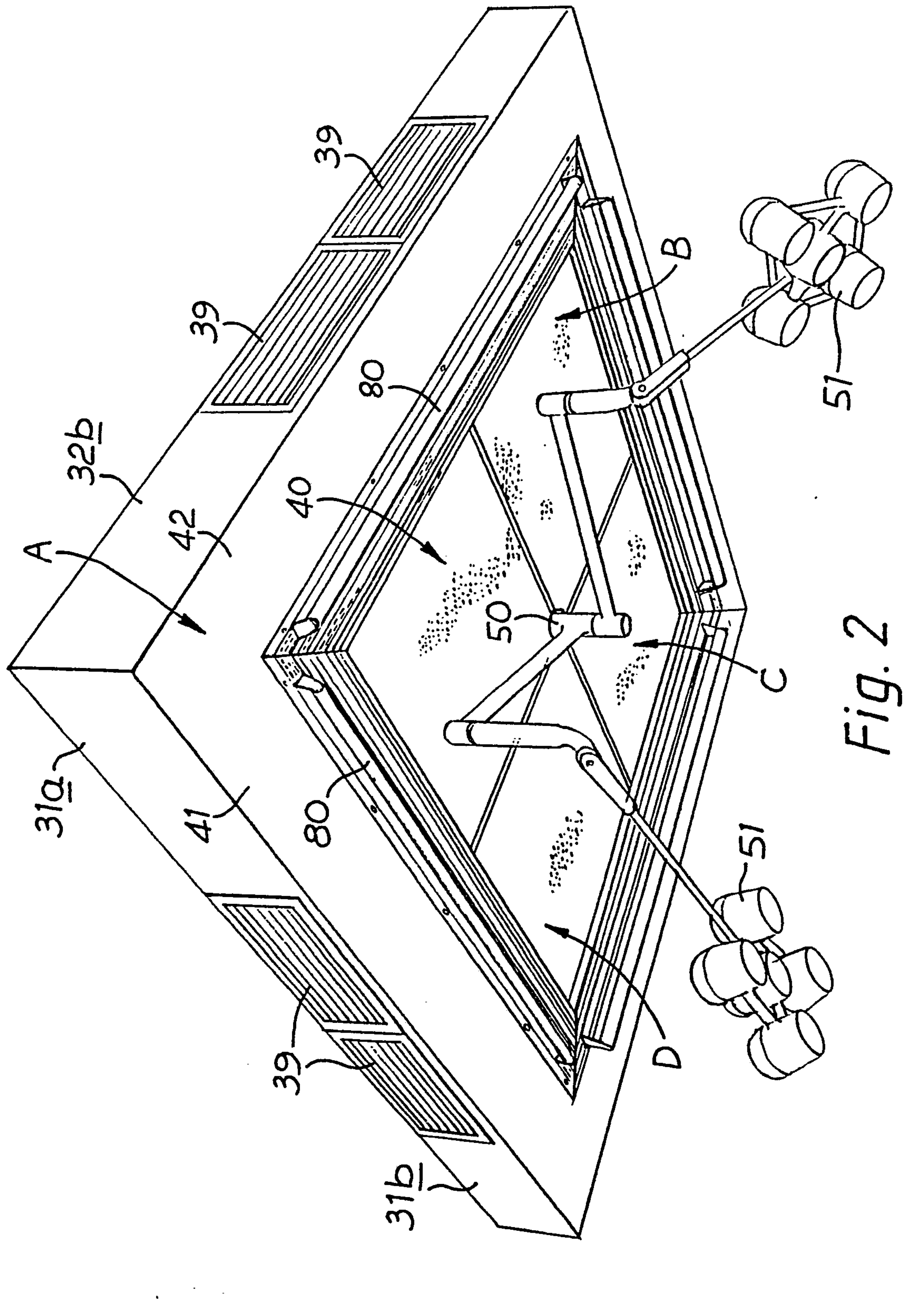

Fig. 2

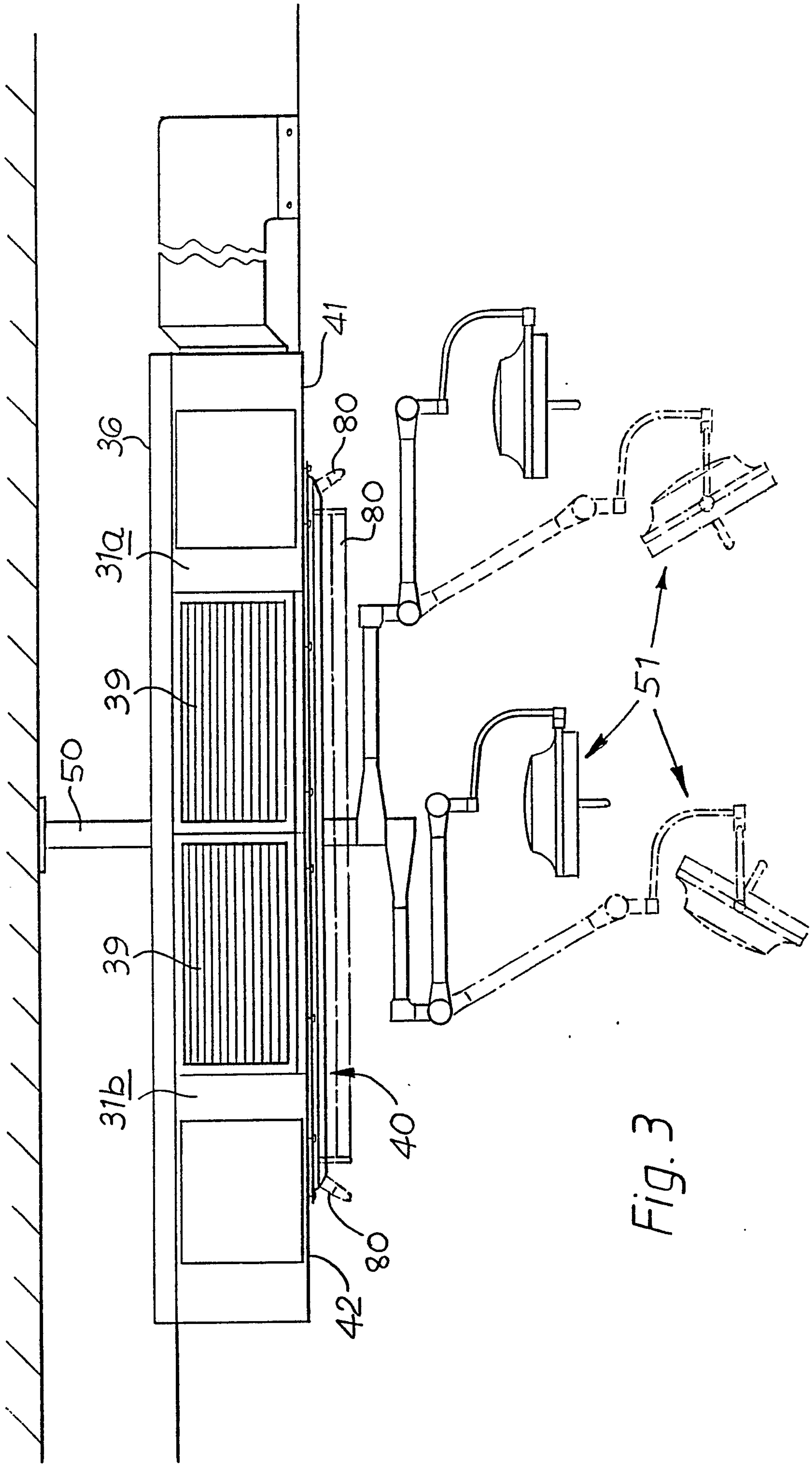

Fig. 3

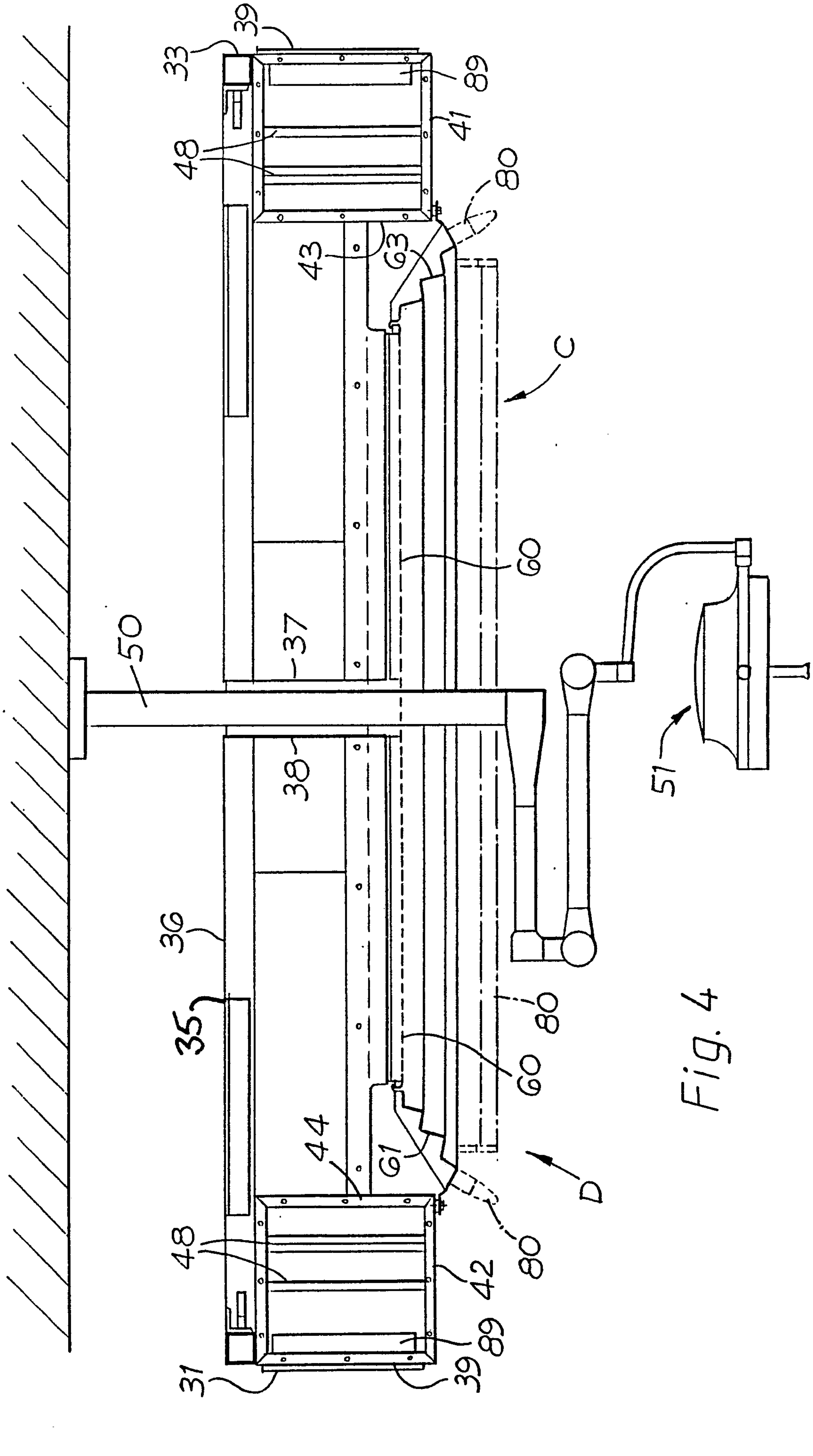
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Fig. 4

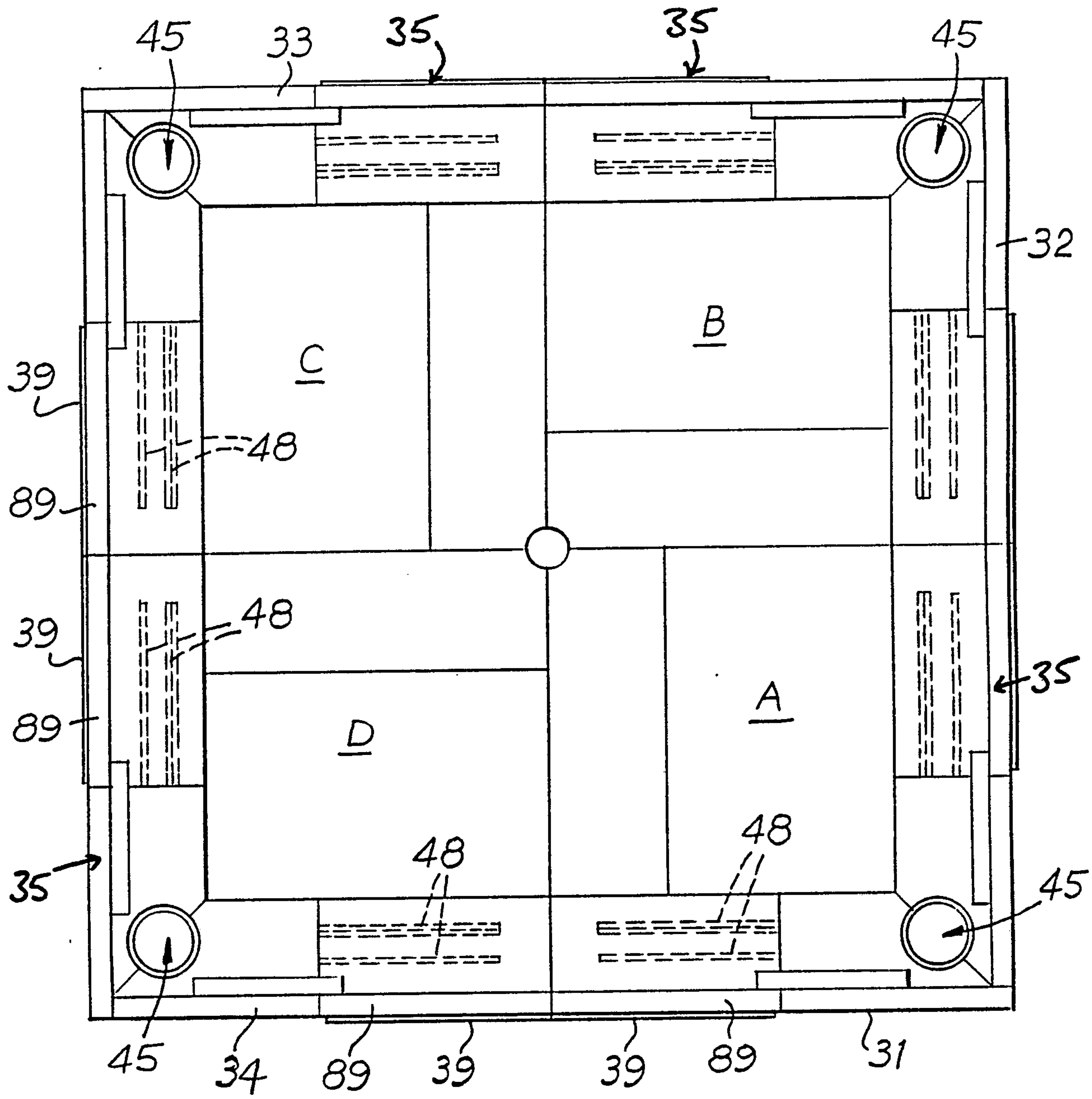
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Fig. 5

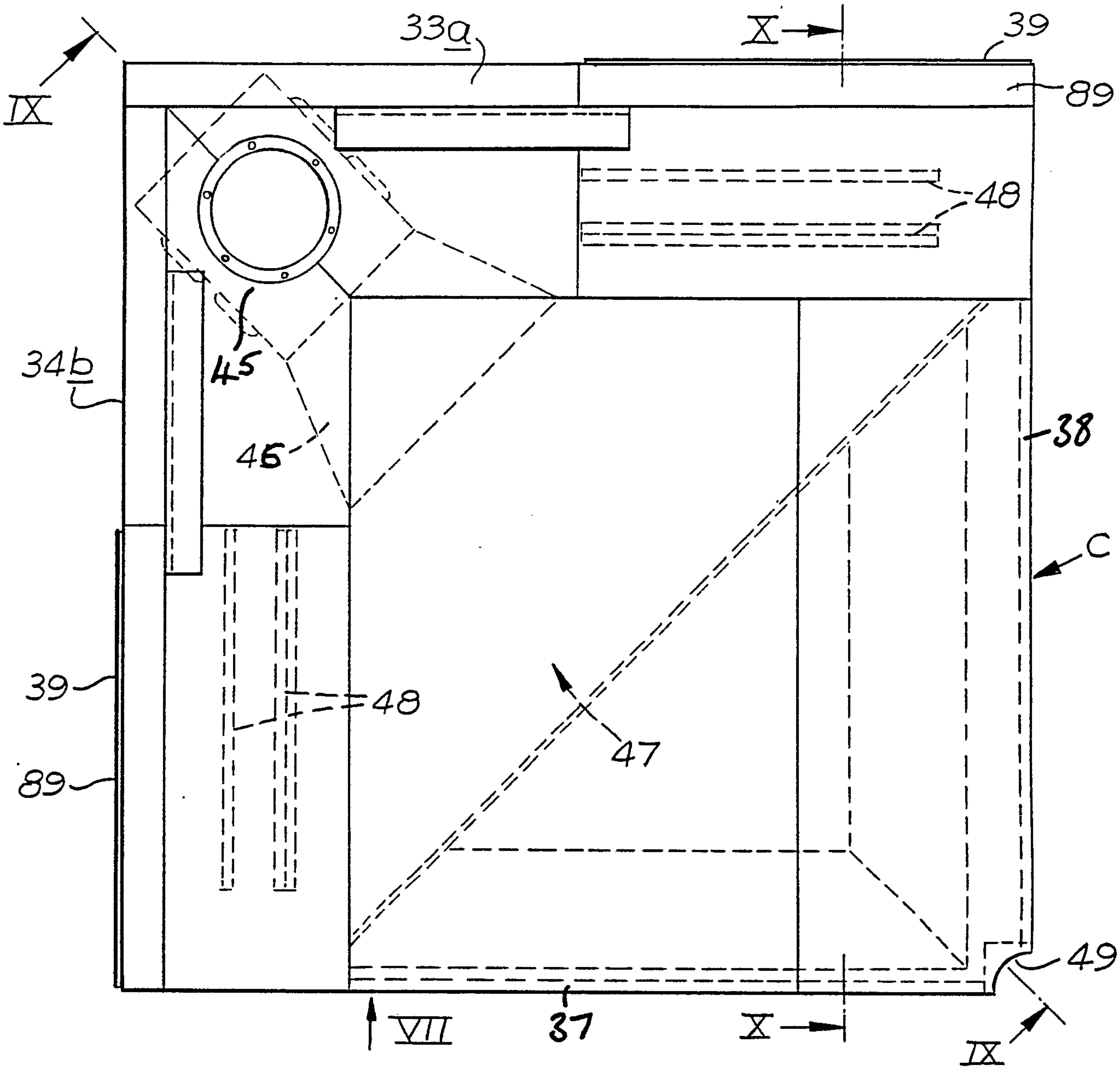

Fig. 6

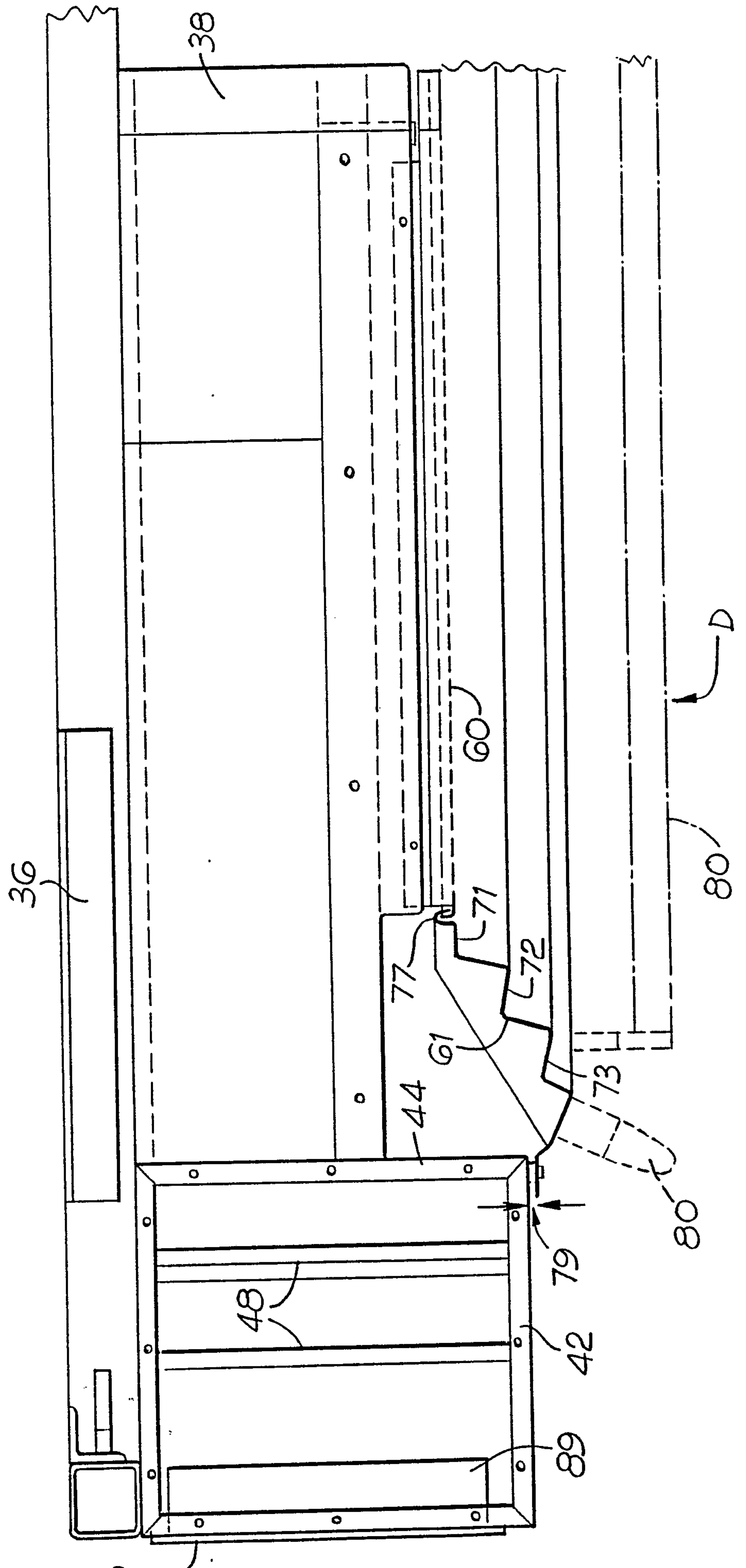

Fig. 7

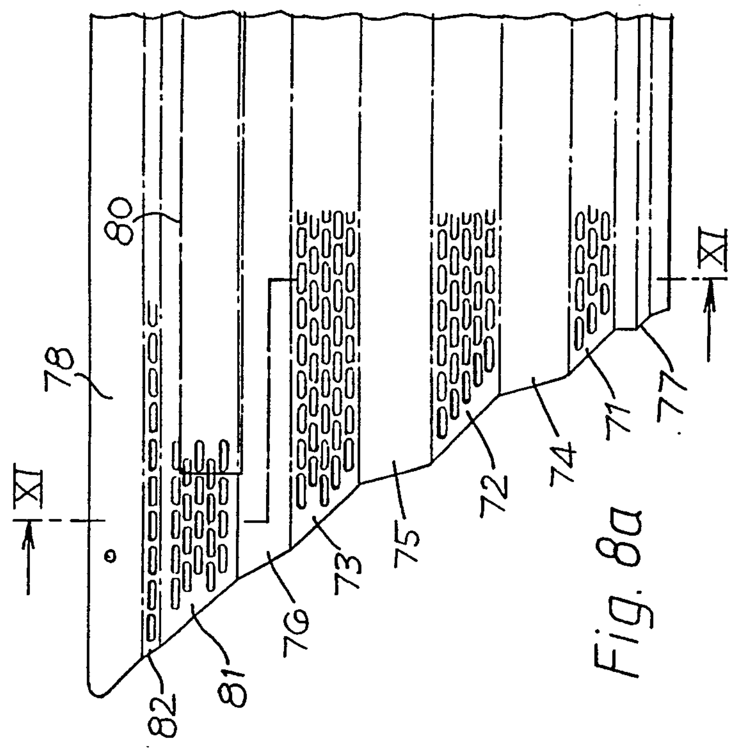
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Fig. 8a

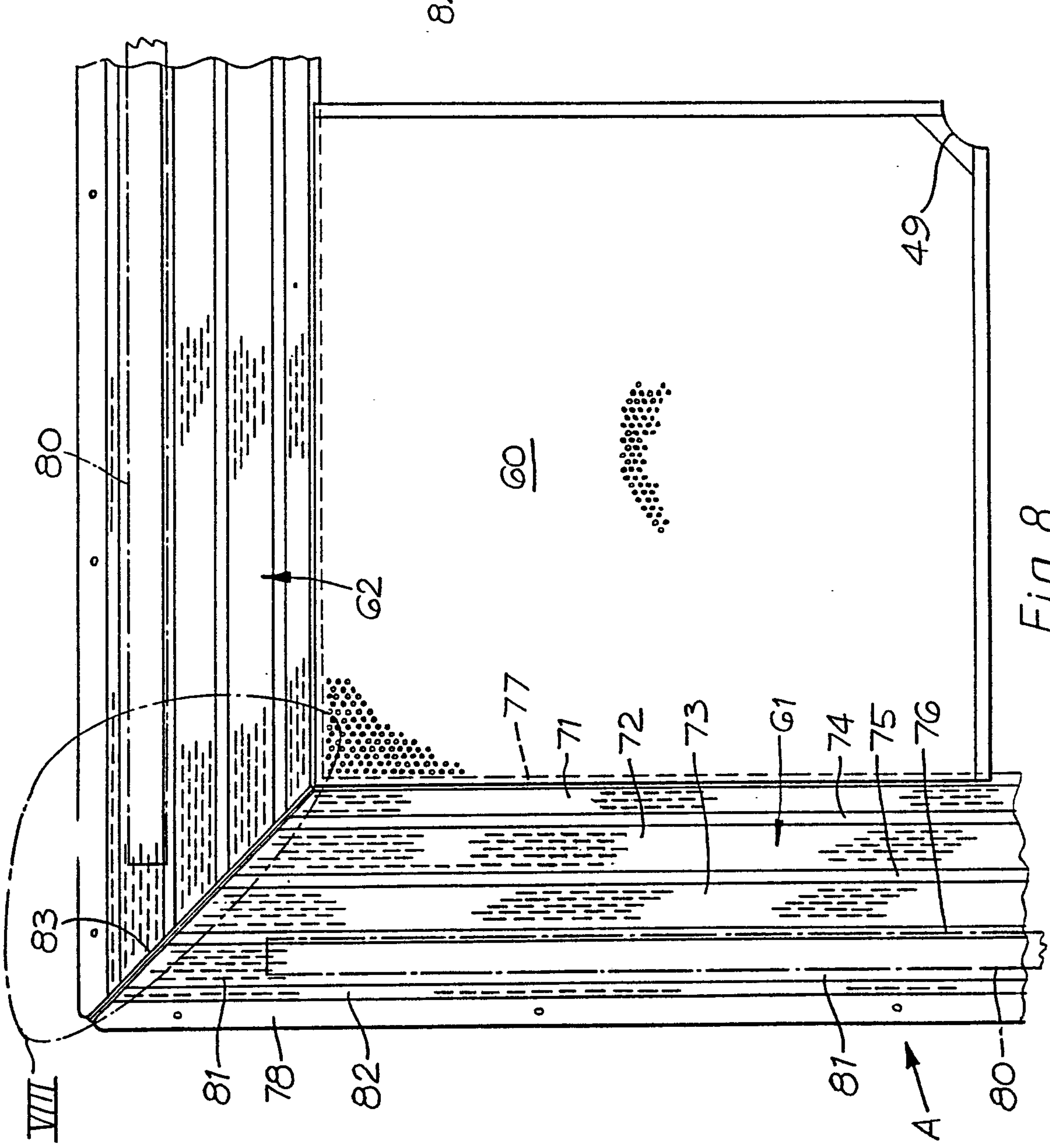
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Fig. 8

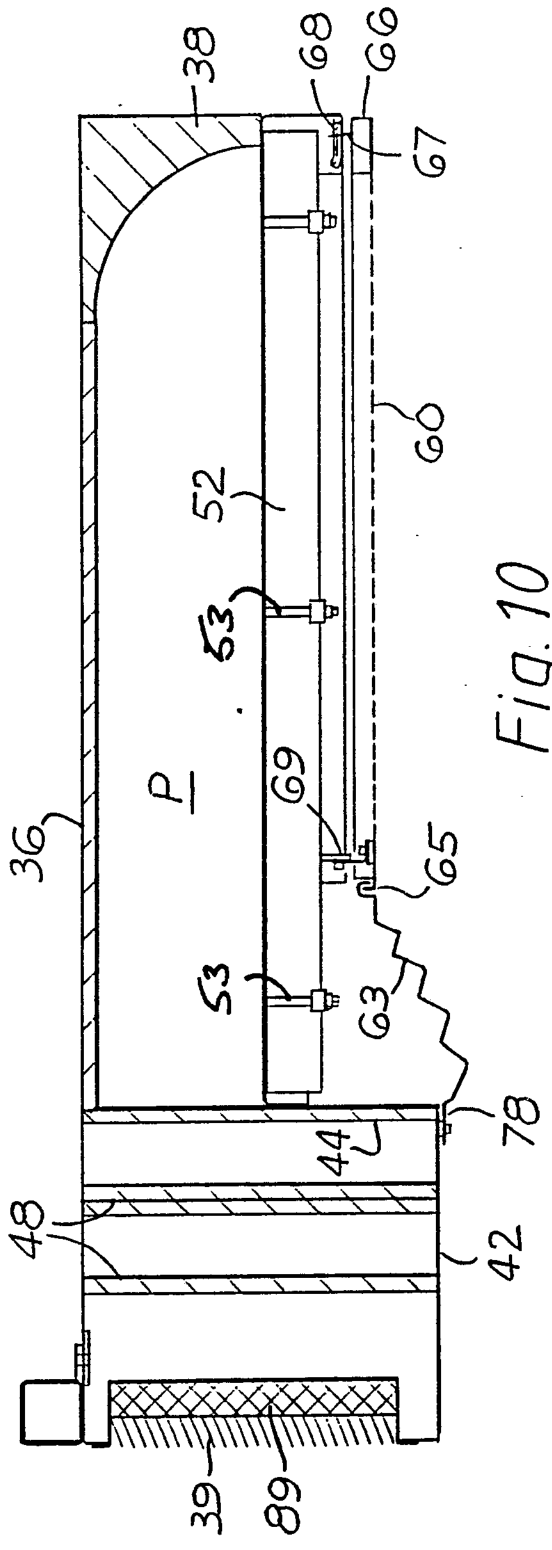
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Fig. 10

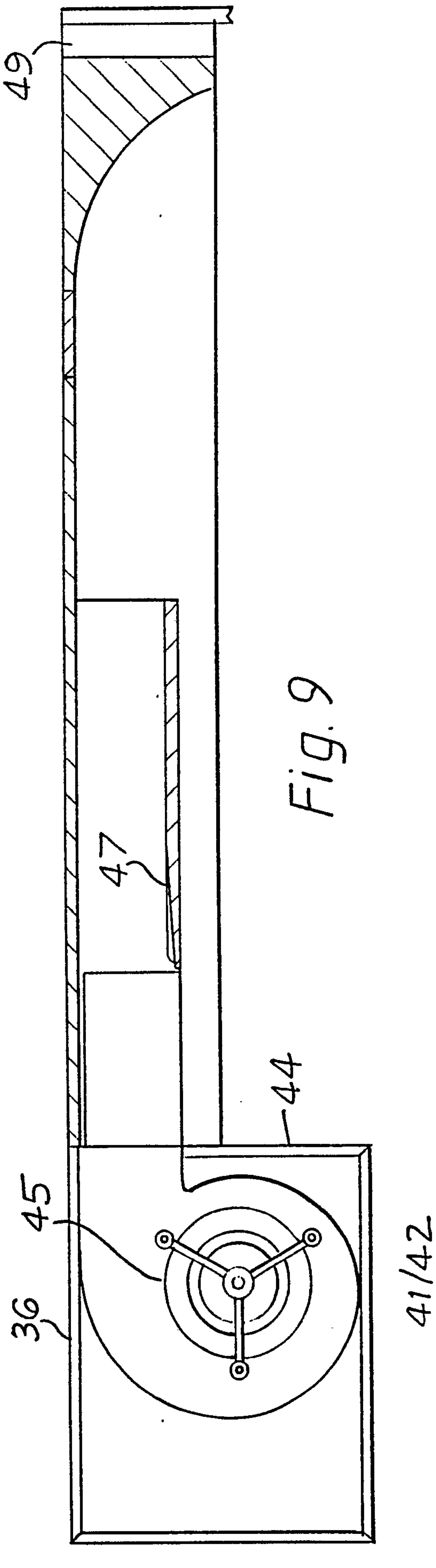
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Fig. 9

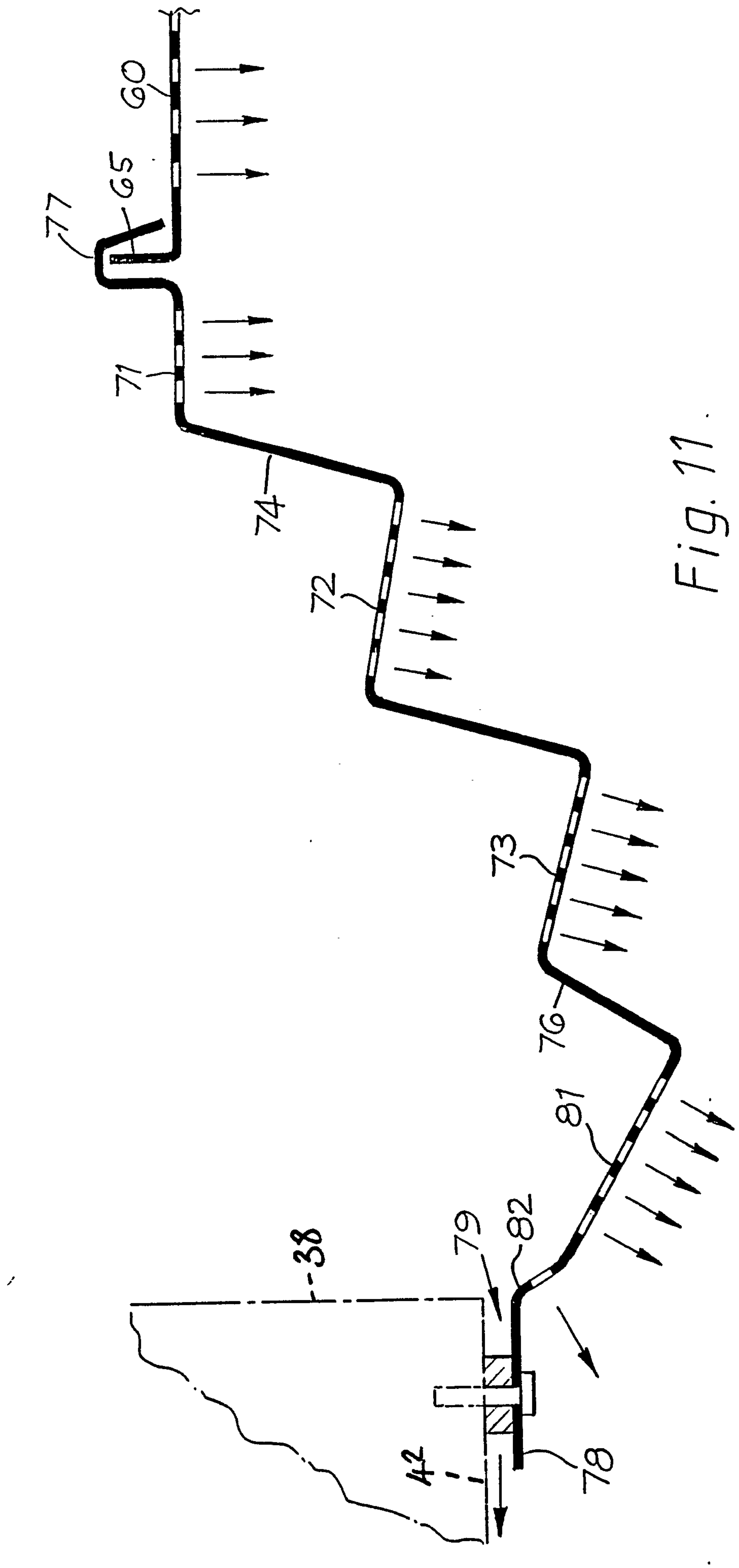

Fig. 11