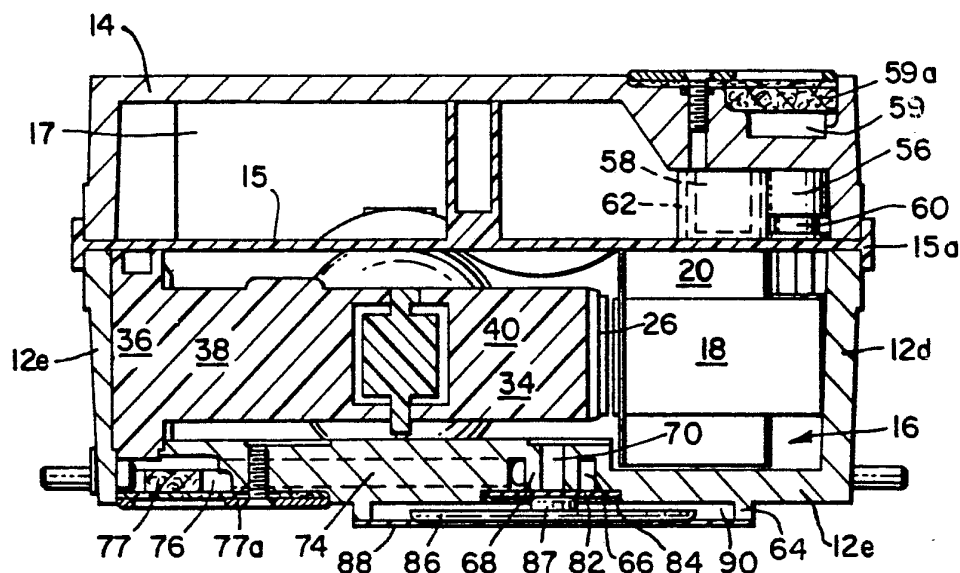




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(54) Title: IMPROVEMENTS IN VIBRATORY DIAPHRAGM PUMPS**(57) Abstract**

A pneumatic vibratory diaphragm pump, having a casing (12, 14) comprising an upper chamber (17) having an inlet (59) by which air can be drawn from outside the casing and a lower chamber (16) having an outlet (N) from which air can issue from the casing, an oscillatory armature (22) within the lower chamber to actuate a diaphragm (28b, 30b) of at least one diaphragm and valve assembly (28, 30) and drive means (80, 20) to cause oscillatory movement of the armature. Each diaphragm and valve assembly is arranged so as to induce air to be pumped by it from the upper chamber and to discharge air into the lower chamber whereafter the discharged air is issued from said outlet. Venting means (70, 74, 76) is provided to allow air which has been discharged from the casing into a container to return therefrom and exhaust from the casing when the pump is inactive.

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IMPROVEMENTS IN VIBRATORY DIAPHRAGM
PUMPS

This invention relates to a vibratory diaphragm pump which is particularly, but not exclusively, suitable for intermittent operation for example in a fluidic system for intermittent compression therapy.

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In such application the pump supplies pressurized fluid, normally air, to one or more inflatable garments when the pump is activated and allows air to evacuate from the or each garment through the pump casing when
10 the pump is deactivated in a cyclic operation. The garments typically comprise a sealed double-skinned sleeve which more usually is worn about a patient's limb to be treated and which cyclically is inflated and deflated so as to apply to that limb an intermittent
15 compressive force.

However, in a more general application the pump may be utilized to evacuate a fluid from or supply fluid under pressure to a suitable container.

One aspect of the invention provides a pneumatic vibratory diaphragm pump having a casing accommodating at one of its ends a driving coil to drive an oscillatory armature and diaphragm assembly within the casing having at least one diaphragm the arrangement being such that air pumped by each diaphragm issues into the enclosure defined by the casing prior to being transferred therefrom whereby the enclosure itself provides an expansion chamber for the pump.

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Another aspect of the invention provides a pneumatic vibratory diaphragm pump, having a casing comprising an upper chamber having an inlet by which air can be drawn from outside the casing and a lower chamber having an outlet from which air can issue from the casing, an oscillatory armature within the lower chamber to actuate a diaphragm of at least one diaphragm and valve assembly and drive means to cause oscillatory movement of the armature wherein each diaphragm and valve assembly is arranged so as to induce air to be pumped thereby from the upper chamber and to discharge air into the lower chamber from whence the discharged air issues from said outlet.

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According to a feature of this aspect of the invention the upper and lower chambers are separated by a partition which isolates said chambers from one another during operation of the pump and wherein an inlet for each diaphragm and valve assembly accommodated in the lower chamber communicates with said upper chamber.

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According to another feature of this aspect of the invention, the lower chamber is provided by a lower shell of the casing and the upper chamber is provided by an upper shell of the casing, said upper and lower shells being secured together in superposed fluid-tight relationship.

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According to yet another feature of this aspect of the invention, the upper chamber also accommodates an oscillatory armature to actuate a diaphragm of at least one further diaphragm and valve assembly and drive means to cause oscillatory movement of the armature in the upper chamber, each diaphragm and valve assembly within said casing being arranged so as to induce air to be pumped thereby from the upper chamber and to discharge air into the lower chamber from whence the discharged air issues from said outlet. In some constructions where this feature is adopted, the armature in the upper chamber may extend in the opposite direction to that of the armature in the lower chamber and the drive means for each armature is disposed at opposed ends of the casing in the respective chambers.

According to a feature of either of the aspects of the invention, venting means may be provided to allow air which has been discharged from the casing into a container to return therefrom and exhaust from the casing when the pump is inactive said venting means being arranged to close the exhaust passage when the pump is operative. Preferably, operation of the venting means to open and close the exhaust passage is automatic upon respectively deactivating and activating the pump.

Another aspect of the invention provides a vibratory diaphragm pump comprising a casing formed by a pair of superposed shells which define between them a pump chamber and wherein each shell accommodates an oscillatory armature to actuate a diaphragm of at least one diaphragm and valve assembly within that shell and drive means within that shell to cause oscillatory movement of said armature. Preferably, the armature in one shell extends in the opposite direction to that of the armature in the other shell and the drive means for each armature is disposed at opposed ends of the casing in their respective shells.

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Yet another aspect of the invention provides a vibratory diaphragm pump comprising a casing which accommodates at least one armature to actuate a diaphragm of at least one diaphragm and valve assembly and drive means to cause oscillatory movement of each diaphragm, inlet means through which air to be pumped can be induced into the casing and outlet means through which pumped air can be discharged from the casing and wherein venting means is provided automatically to allow air which has been discharged from the casing into a container to return therefrom and exhaust from the casing when the pump is deactivated. Preferably, said venting means comprises a valve controlled outlet from the casing independent of said outlet means.

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According to a feature of any of the aspects of the invention, said drive means is coupled to control means for causing intermittent operation of the pump.

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another
Yet/aspect of the invention provides an armature for a vibratory diaphragm pump which armature comprises a main body portion carrying at one end thereof a pair of opposite polarity magnets, the main body portion having a pivotal element by which the armature can be pivotally connected to a pair of diaphragm assemblies, adjacent opposed sides of the body portion, and a resilient element interconnecting the main body portion with an end part of the armature by which end part the armature can be mounted for vibratory movement of the body part relative to the end part.

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for a vibratory diaphragm pump which armature
comprises a main body portion carrying at one end
thereof a pair of opposite polarity magnets, a
5 spring steel plate having one of its ends secured to
the opposite end of the main body portion and its
opposite end secured to an end part of the armature
by which end part of the armature can be mounted for
vibratory movement of the body part relative to the
10 end part.

Yet another aspect of the invention provides an
armature for a vibratory diaphragm pump which
armature comprises a main body portion carrying at
15 one end thereof a pair of opposite polarity magnets,
said body portion including a resiliently pivotal
element having means for attachment to a pair of
diaphragm assemblies, one located adjacent each of
the opposed sides of said body portion, and
20 including a flexible portion adapted to be secured
to a fixed support so that the armature can be
caused to vibrate relative to the fixed support.

Yet another aspect of
25 the invention provides a mounting assembly for supporting
a pump casing so that the static load of the casing is
held resiliently in spaced relationship relative to a
support platform and so that the transmission of dynamic
forces between the casing and the support platform is
30 minimized, said assembly comprising a mounting element
fixed to the support platform at each of two opposed ends
of said casing, a resilient element interposed between
said casing and each mounting element by which the static
load of the casing is held in spaced relationship relative
35 to the support platform, each of said resilient elements
being connected to the casing and to respective ones of
the mounting elements and wherein the connection between
the resilient element and the support element allows for
limited universal movement of the pump casing relative to
40 the support elements.

Two pumps embodying the invention will now be described by way of example, with reference to the accompanying drawings in which:-

5 FIGURE 1 is a perspective view of one pump in which the operative parts of the pump are housed in the lower shell of the casing of the pump;

10 FIGURE 2 is a plan view partly cut away of the underside of the lower shell of the pump of Figure 1;

FIGURE 3 is a side sectional view of the pump shown in Figure 1 taken along the line 3-3;

15 FIGURE 4 is an end sectional view of the pump shown in Figure 1 taken along the line 4-4;

FIGURE 5 is an end sectional view of the pump shown in Figure 1 taken along the line 5-5;

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FIGURE 6 is a plan view of the lower shell of the pump casing of Figure 1 with the internal components of the shell present;

25 FIGURE 7 is a plan view of the lower shell of the pump casing of Figure 1 with the internal components of the shell omitted;

30 FIGURE 8 is a top plan view of a partition which separates the two shells and thereby the inlet and outlet chambers of the pump shown in Figure 1;

FIGURE 9 is an underplan view of the partition shown in Figure 8;

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FIGURE 10 is an under plan view of the upper shell of the pump shown in Figure 1;

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FIGURE 11 is a perspective view of a second pump according to the invention in which the operative parts of the pump are housed in both the upper and lower shells;

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FIGURE 12 is a side cross-sectional view taken along the line 11-11 in Figure 11;

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FIGURE 13 is a top plan view of a modified partition which separates the two shells of the pump casing shown in Figures 11 and 12;

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FIGURE 14 is a plan view of the shock absorbing mounting assembly shown at the right hand end of the pump casing shown in Figure 11;

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FIGURE 15 is an end view of the assembly shown in Figure 14;

FIGURE 16 is a side view of the assembly shown in Figure 14;

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FIGURE 17 is a perspective view of one of the resilient elements incorporated in the mountings;

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FIGURE 18 is a plan view of the shock absorbing mounting assembly shown at the left-hand end and right-hand ends of the pump casing shown in Figure 1 and the left hand end of the pump casing shown in Figure 11; and

FIGURE 19 is a side view, partly broken away, of the assembly shown in Figure 18.

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Referring first to Figures 1-6 , a vibratory diaphragm pump 'P' comprises a casing 10 which is a cast aluminium structure having an open-top elongate lower shell 12 and an upper shell 14 which is fitted to the lower shell so as to provide a lid. A partition 15 is interposed between the upper end lower shells so as to create an outlet chamber 16 in the lower shell and an inlet chamber 17 in the upper shell. The partition and its relationship to chamber 16 and 17 will be described in more detail below.

The lower shell includes sidewalls 12a, 12b; endwalls 12c, 12d and a base 12e. One end of the lower shell receives a laminated ferrous E-stack 18 whose central limb 18a carries a driving coil 20. The E-stack stands on raised plinths 19, 19a formed in opposed corners of the lower shell adjacent endwall 12d.

An armature assembly, generally designated by reference numeral 22 extends longitudinally of the lower shell and centrally thereof immediately above a rib structure formed in the base and comprising longitudinal rib 21 and transverse rib 21a. The armature 22 has one of its ends secured in a downwards tapered socket 24 provided internally of the lower shell integrally formed with end wall 12c.

The opposite end of the armature terminates in a flanged head 26 adjacent the E-stack 18. The flanged head incorporates a pair of spaced magnets 28 and 30 of opposite polarity which are seated in side-by-side relationship on a common keep plate in close proximity to the E-stack limbs. The flanged head 26 is integral with a main body portion 34 of the armature which is connected to an end part 36 by means of a flat metallic leaf spring 38. Thus, the armature resiliently is mounted with respect to the lower shell and is caused to oscillate about its fixed end part 36 across the exposed ends of the E-stack limbs when elec-

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trical current is passed through coil 18.

Diaphragm valve assemblies 28 and 30 are disposed one on each side of the main body portion of the armature and each assembly comprises a valve body 28a, 30a and a flexible cup-shaped diaphragm 28b, 30b respectively, described in more detail later. Both diaphragms of the diaphragm valve assemblies 28 and 30 are connected to the armature 22 by a resilient linkage 40. For this purpose, the main body portion 34 of the armature is formed with a square cross-sectional transverse through bore 42 in which a resiliently pivotal linkage block 44 is received with clearance. Block 44 resiliently is mounted within bore 42 by a fixed pin 46 which extends through a vertical bore 48 formed in the block 44 and whose axis is perpendicular to the axis of through bore 42. Vertical bore 48 accommodates a resilient material 50 which surrounds the fixed pin 46. A pair of linkage arms 52 and 54 respectively extend outwardly from opposed faces of the linkage block 44. The arms terminate in flat cross-heads by which the linkage is connected internally of the operative faces of the diaphragms 28b and 30b, respectively. Thus, the linkage block 44 can pivot resiliently within bore 42 about fixed pin 46 as the armature body oscillates.

The resilient linkage allows the diaphragms to be flexed evenly and squarely with respect to the notional longitudinal axis of the lower shell 12 notwithstanding the arcuate path described by the oscillatory movement of the armature. Such a construction greatly reduces the stresses to which the diaphragms might otherwise be subjected, increases longevity of the diaphragms and, of course, increases the volume of air pumped thereby and hence the performance of the pump.

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Since the armature spring 38 comprises a straight metal strip which is anchored in end part 36, it is able to deflect by substantially the same amount either side of its rest position without bias in either direction, thereby operating the opposed diaphragms equally.

The armature body and end part preferably is moulded from a plastics material, the spring 38 having its opposite ends embedded in the end part 36 and main body part 34, respectively, during the moulding process. Likewise the magnets 28 and 30 together with their common keep plate also are incorporated into the armature head 26 at the time of moulding.

The end part 36 is formed as a downwardly tapered peg which mates with the tapered socket 34. Therefore, the armature and diaphragm valve assemblies can be pre-assembled whereafter that assembly can be mounted in position by driving the tapered peg end part 36 into its mating socket 34.

The diaphragms are formed from an elastomeric material such as rubber or a rubber compound or neoprene into a dished element having an internal diaphragm cavity.

In operation, when the operative face of a diaphragm is flexed by the armature outwardly i.e. away from the valve body an inlet flap valve lifts and air is drawn into the diaphragm cavity via an inlet nozzle. When the operative face of a diaphragm is next flexed by the armature inwardly i.e. towards the valve body, the inlet flap valve seats an outlet valve lifts and the air previously induced into the diaphragm cavity is expelled through an outlet orifice. Of course, this represents one cycle of operation of one of the diaphragm valve assemblies.

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As shown in Figures 3-6 and 9 , the diaphragm valve assemblies 28 and 30 are mounted within the lower shell in opposed relationship one on each side of the armature. Diaphragm valve assembly 28 is secured to sidewall 12a by a fixing screw which locates in a fixing boss of the valve body, the open ends of the inlet and outlet cavities of the valve body being sealed by a gasket 'G1'. Diaphragm valve assembly 30 similarly is secured to sidewall 12b with the imposition of gasket 'G2' . Both diaphragm valve assemblies are located with their inlet nozzles 28c and 30c upstanding uppermost of the lower shell.

Referring again to Figures 8,9 and to Figures 3 and 4 , partition 15 which is formed from a plastics material closes the open top of the lower shell and isolates the upper chamber 17 from the lower chamber 16 and also seals the casing so that at least lower chamber 16 is fluid-tight. For this latter purpose, the partition has a peripheral flange 15a which seals around the interface join between the upper and lower shells.

The partition includes a pair of spaced apertures 15b , 15c which are in registry with and seal around the inlet nozzles 28c and 30c of diaphragm valve assemblies 28 and 30 whereby the diaphragm valve assemblies are in communication with the upper chamber 17 of the casing. The upper shell is formed with a pair of inlet tubes 56 , 58 through which air is drawing into the upper chamber from outside the casing via a filter cavity 59 . The filter cavity is provided with a suitable filter 59a through which induced air passes prior to entering the chamber via the inlet tubes. In order to reduce noise the induced air passes through a labyrinth

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provided by locating the free ends of the inlet tubes in blind sockets 60, 62 respectively upstanding from the top surface of the partition and which are of larger diameter than the inlet tubes.

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In operation of the pump the diaphragms are flexed alternatively and air is drawn into the upper chamber via the filter cavity, the inlet tubes, the inlet labyrinth sockets and thence through the inlet nozzles of the diaphragm valve assemblies whereafter the induced air charge of each diaphragm valve assembly is discharged through its outlet orifice into the lower chamber 16 of the casing. Sidewall 12b of the lower casing is provided with an outlet nozzle 'N' adjacent endwall 12c through which discharged air is expelled from the casing. In applications where the pump is employed for inflating a garment of the kind used in intermittent compression therapy, the pump is activated intermittently and the outlet nozzle normally is connected to a pressure control device, through which air expelled from the pump is passed before issuing into a garment. Thus, most frequently the lower chamber 16 is under pressure of a variable amount up to e.g. 200 mm Hg above atmospheric pressure.

In order to allow an inflated garment to deflate during the period when the pump is deactivated during intermittent operation it is necessary to provide a return passage for the air through the pump.

Referring now to Figures 2, 3 - 5 and 7, Figures 2 and 3 - 5 show the underside of the lower casing 12 of the pump on which base 12e is formed with an upstanding annular wall 64. Centrally within the annular wall the base has a blind annular bore 66 occupied by an upstanding cylindrical platform 68. Platform 68 is

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formed with a through bore 70 which passes through transverse rib 21a. and communicates internally of chamber 16. The upper surface of platform 68 is substantially flush with a shoulder 72 set into base around the mouth of the annular bore. An exhaust passageway 74 is formed through the longitudinal rib of the lower shell one end of which opens into the annular bore 6 and the opposite end of which opens into an outlet cavity 76 formed adjacent end wall 12e of the base. The outlet cavity may be filled with an air permeable noise insulating material 77 held in place by a suitable porous cover 77a to allow air to be exhausted therethrough. A transfer passageway 78 extends through the transverse rib 21a of the base and has one open end 79 located within that area of the base defined by the annular wall 64. Within the lower shell sidewall 12a is formed with an elongate scalloped portion 80, the lowermost end of which includes the other open end 81 of transfer passageway 78. Transfer passageway 78 communicates with the upper chamber 17 by means of a transfer tube 78a which depends downwardly from partition 15 and has its free end sealingly seated against the open end 81 of the transfer passageway within the scalloped portion 80 in sidewall 12a.

The annular bore 66 and through bore 70 are both covered by a disc 82 of flexible non-porous material the periphery of which held on the shoulder 72 by a securing ring 84 and the disc 82 provides a valve to control the flow of air through the bore 70.

A valve disc actuating plate 86 is held over the valve disc 82 by a flexible diaphragm ring 88 whose inner periphery is secured to the plate 86 and whose outer periphery is secured to the annular wall 64. The diaphragm ring and plate assembly thereby covers the

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5 base area defined by the annular wall and forms between itself and that base area an enclosed pocket 90. The plate can therefore move towards and away from the valve disc upon flexing of the diaphragm ring. The face of plate 86 within the pocket 90 is provided with a projection 87 in registry with the valve disc and which pushes downwardly on the valve disc when the actuating plate moves towards the base.

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When the pump is inactive, the valve disc 82 and the plate assembly 86, 88 are relaxed whereby the annular bore 66 communicates with the through bore 70 and plate 86 is disengaged from the valve disc 82. When the pump is activated, on the initial induction strokes of the diaphragm assemblies 28, 30, air is evacuated from the pocket 90 via the transfer passageway 78 and transfer tube 78a because transfer tube opens into upper chamber 17 and air is being drawn in from the upper chamber by the opposed pump diaphragms. Thus, the valve disc actuating plate 86 is drawn towards the base, such movement being allowed by flexing of the diaphragm ring 88, so that the projection carried by plate 86 pushes against the disc 82 and causes it to seat and seal off the through bore 70. Air which is discharged from the diaphragm assemblies cannot then issue through the through bore 70 and therefore is exhausted from the lower shell only through the discharge nozzle/^{'N'} of the pump. When the pump is deactivated, plate 86 returns to its rest position as the diaphragm ring 86 relaxes so that air may be expelled from an inflated garment back through the discharge nozzle, the through bore 70 and thence the annular bore 66 and is exhausted through the outlet cavity 76 via exhaust passageway 74.

A further pump 'F' embodying the invention is shown in Figures 11 and 12. In this construction, the lower shell of the pump is as described above but the lid 14 is substituted by an upper shell which is of similar overall construction to the lower shell. Thus, the upper shell also contains a driving coil and an armature assembly which operates a pair of opposed diaphragm assemblies. The upper shell 14' is fitted to

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the lower shell in top-to-toe relationship whereby the driving coil 18' in the upper shell is at the opposite end of the casing to that of the lower shell as best seen in Figure in which like parts are designated like reference numerals with the addition of suffix "'" e.g. upper shell 14'. In this construction, the flap valves within the valve bodies in the upper shell 14' are reversed in position so that inlet nozzles become outlet nozzles and outlet orifices become inlet orifices.

The partition 15' for this modified pump includes two sets of nozzle apertures 15b', 15c', 15d and 15e. The inlet nozzles 28c, 30c of the lower shell diaphragm assemblies protrude into the upper chamber 14' through apertures 15b', 15c' and draw air in the direction of arrow 'a'. Conversely the outlet nozzles 28c', 30c' of the upper shell diaphragm assemblies protrude into the lower chamber through apertures 15d and 15e and pump air in the direction of arrow 'a'. Thus, air is induced from the upper chamber into both the upper and lower diaphragm assemblies and pumped directly into the lower chamber.

In order to connect together the upper and lower shells in the case of the pump shown in Figure having a shallow (lid) upper shell at one end, screw fasteners pass through suitable apertures 'f1' in the lower shell and thence through sealing tubes 't' integral with partition 15 and locate in connecting nuts in the upper shell. At the opposite end, screw fasteners pass through the suitable apertures in the upper shell and thence through sealing tubes 't1' (which extend from the opposite face of the partition 15 to tubes 't') and locate in connecting nuts 's' which secure the E-stack to the lower shell. In the case of the double pump

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- arrangement where the two shells are similar screw fasteners pass through apertures at one end of the lower shell, thence through sealing tubes in partition 15' and locate in connecting nuts which secure the E-stack to the upper shell. A similar arrangement exists at the opposite end of the pump but in which the screw fasteners pass down from the upper shell and through oppositely directed sealing tubes in partition 15'.
- 10 The assembled pump is supported on a base by mounting assembly 'A' at the right-hand end of the pump casing and mounting assembly 'Z' at the left-hand end of the casing. Assembly 'A' comprises mounting cradle 96.; front plate 98; pump outlet valves V1 and V2, and resilient elements E1, E2. Assembly 'Z' comprises a mounting cradle 96a similar to cradle 96 but fixed to the pump casing in a reversed position i.e. in which it is turned through 180° relative to cradle 96.
- 20 The cradle 96 comprises an elongate 'L'-shaped bracket comprising upright face 114, base 116 and end walls 118, 120 respectively. Outrigger feet 122 and 124 extend from

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respective ones of the end walls by which the mounting assembly is secured to a base. Assembly 'A' is secured to the pump casing by a pair of similar resilient elements E_1 , E_2 as shown in Figure 5 and with the upright face 114 of cradle 96 engaged against the adjacent end face of the pump casing.

Referring particularly to Figure 16, a resilient element 'E' is formed from an elastomeric material e.g. rubber and comprises a hollow, generally cylindrical body portion, 126 having a central bore 128. The body portion is outwardly flared at diametrically opposed locations to form upper and lower flat support platforms 130, 132 which are co-extensive with the cylindrical body. A first bore 134 is formed through the cylindrical body adjacent upper platform 130 and a similar bore 136, but of smaller diameter, is provided adjacent the lower platform 132. Both bores 134 and 136 have axes parallel to that of central bore 128. At one axial end of the body portion, the upper bore 134 is co-axial with an integral extension tube 138.

In assembly 'A' the resilient elements ' E_1 ' and ' E_2 ' are secured at spaced locations adjacent the ends of cradle 96 each by a fixing pin 'p' which passes through lower bore 136 and through aperture 140 formed in upright face 114. Tube 138 is received in aperture 142 in the upright face, the aperture 142 being significantly larger than the diameter of the tube. A connecting pin 144 extends through tube 138, upper bore 134 and into a portion of the end wall of the pump casing thereby connecting the cradle to the pump. When correctly positioned the upper platform 130 of each element ' E_1 ', ' E_2 ' engages a base portion of the pump casing (in this construction provided by a rebated corner) and the lower platform seats on a support base. In assembly 'A', front plate 98 carries a pair of pump outlet valves V_1 , V_2 and is connected to the upright face 114 of cradle 96 by means of screw-threaded fasteners which pass through spacer tubes ' t_1 ' - ' t_3 '. The assembly is secured to base 'B' by

suitable fasteners which interconnect support studs with the outrigger feet.

Referring to figures 17 and 18, assembly 'Z' comprises a
5 cradle 96a and a pair of the resilient elements E_1 , E_2 .
However, in this assembly the resilient elements are
mounted within the cradle. To this end, the base 116a of
the cradle is formed with a retaining frame 145, 147 adjacent
10 each end wall of the cradle, each to receive one of the
resilient elements E_1 and E_2 . Within each retaining frame
the base is formed with an aperture into which the lower
support 132 of the associated resilient element is located.
The resilient element is mounted in the cradle so that the
upper support platform stands proud of the cradle end walls
15 ready to receive a base portion of the pump casing. As in
assembly 'A', the tube 138 extends through oversized aper-
ture 142a in upright face 114 and a connecting pin 144a passes
through the tube into the pump casing as described earlier.
In order to secure each resilient element within its
20 retaining frame a fixing pin, 'p' extends through the lower
bore 136 of the resilient element and is received in an
aperture, provided in upright face 114a and in an aperture
formed in an opposed wall 'w' of the retaining frame. As
in the other assembly the pump casing is supported on the
25 upper platforms of the resilient elements, but in assembly
'Z' the cradle is offered up to the pump end wall with the
upright face of the cradle facing in the opposite direction
relative to the pump casing as compared with assembly 'A'.
30 The resilient elements 'E' in each of the mounting
assemblies 'A' and 'Z' allow vibratory motion of the
casing and other limited movement caused e.g. by shock
forces to be substantially absorbed so that vibratory
motion, in particular, is not transmitted to a base
35 which may form a part of an outer enclosure in which the
pump casing is housed. Moreover, the arrangement by
which the extension tube 138 is received in the oversized
aperture 142 or 142a in the upright face 114, 114a of the

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mounting cradle 96, 96 a respectively permits limited universal movement of the pump casing relative to each mounting assembly. However, such movement is restricted by the rigid connecting pin 144 or 144a which engages the periphery of the aperture 142, 142a respectively thereby to limit movement of the pump casing so that undue pitching and/or yawing of the casing is minimised. Rolling vertical and horizontal movement of the pump casing relative to the mounting assemblies is limited by the resilient nature of the resilient elements 'E'.

CLAIMS

1. A pneumatic vibratory diaphragm pump having a casing accommodating at one of its ends a driving coil to drive an oscillatory armature and diaphragm assembly within the casing having at least one diaphragm, characterised in that air pumped by each diaphragm issues into the enclosure defined by the casing prior to being transferred therefrom whereby the enclosure itself provides an expansion chamber for the pump.
2. A pneumatic vibratory diaphragm pump, characterised by a casing comprising an upper chamber having an inlet by which air can be drawn from outside the casing and a lower chamber having an outlet from which air can issue from the casing, an oscillatory armature within the lower chamber to actuate a diaphragm of at least one diaphragm and valve assembly and drive means to cause oscillatory movement of the armature, each diaphragm and valve assembly being arranged so as to induce air to be pumped thereby from the upper chamber and to discharge air into the lower chamber from whence the discharged air issues from said outlet.

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3. A pump according to claim 2, further characterised in that the upper and lower chambers are separated by a partition which isolates said chambers from one another during operation of the pump and wherein an inlet for each diaphragm and valve assembly accommodated in the lower chamber communicates with said upper chamber through said partition.

4. A pump according to claim 2, further characterised in that the lower chamber is provided by a lower shell of the casing and the upper chamber is provided by an upper shell of the casing, said upper and lower shells being secured together in superposed fluid-tight relationship.

5. A pump according to any of claims 2 to 4 further characterised in that the upper chamber also accommodates an oscillatory armature to actuate a diaphragm of at least one further diaphragm and valve assembly and drive means to cause oscillatory movement of the armature in the upper chamber, each diaphragm and valve assembly within said casing being arranged so as to induce air to be pumped thereby from the upper chamber and to discharge air into the lower chamber from whence the discharged air issues from said outlet.

6. A pump according to claim 5, further characterised in that the armature in the upper chamber extends in the opposite direction to that of the armature in the lower chamber and the respective drive means for each armature is disposed at opposed ends of the casing in the respective chambers.

7. A pump according to any of the preceding claims further characterised by venting means to allow air which has been discharged from the casing into a container to return therefrom and exhaust from the casing

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when the pump is inactive said venting means being arranged to close said exhaust when the pump is operative.

5 8. A pump according to claim 7 further characterised in that operation of the venting means to open and close the exhaust is automatic upon respectively deactivating and activating the pump.

10 9. A vibratory diaphragm pump comprising a casing which accommodates at least one armature to actuate a diaphragm of at least one diaphragm and valve assembly and drive means to cause oscillatory movement of each diaphragm, inlet means through which air to be pumped
15 can be induced into the casing and outlet means through which pumped air can be discharged from the casing and characterised in that venting means is provided automatically to allow air which has been discharged from the casing into a container to return therefrom and
20 exhaust from the casing when the pump is deactivated.

25 10. A pump according to claim 9, further characterised in that said venting means comprises a valve controlled outlet from the casing independent of said outlet means.

30 11. A pump according to any of the preceding claims characterised in that said drive means is coupled to control means for causing intermittent operation of the pump.

35 12. An armature for a vibratory diaphragm pump which armature comprises a main body portion carrying at one end thereof a pair of opposite polarity magnets, characterised in that the main body portion has a pivotal element by which the armature can be pivotally

5 connected to a pair of diaphragm assemblies adjacent
opposed sides of the body portion, a resilient element
interconnecting the main body portion with an end part
of the armature by which end part the armature can be
mounted for vibratory movement of the body part rela-
tive to the end part.

10 13. An armature according to claim 12 further chara-
cterised in that said resilient element comprises a
spring steel plate.

15 14. A mounting assembly for supporting a pump casing
so that the static load of the casing is held resil-
iently in spaced relationship relative to a support
platform and so that the transmission of dynamic forces
between the casing and the support platform is minim-
ised, said assembly comprising a mounting element fixed
to the support platform at each of two opposed ends of
said casing, a resilient element interposed between
20 said casing and each mounting element by which the
static load of the casing is held in spaced relation-
ship relative to the support platform, each of said
resilient elements being connected to the casing and to
respective ones of the mounting elements and wherein
25 the connection between the resilient element and the
support element allows for limited universal movement
of the pump casing relative to the support elements.

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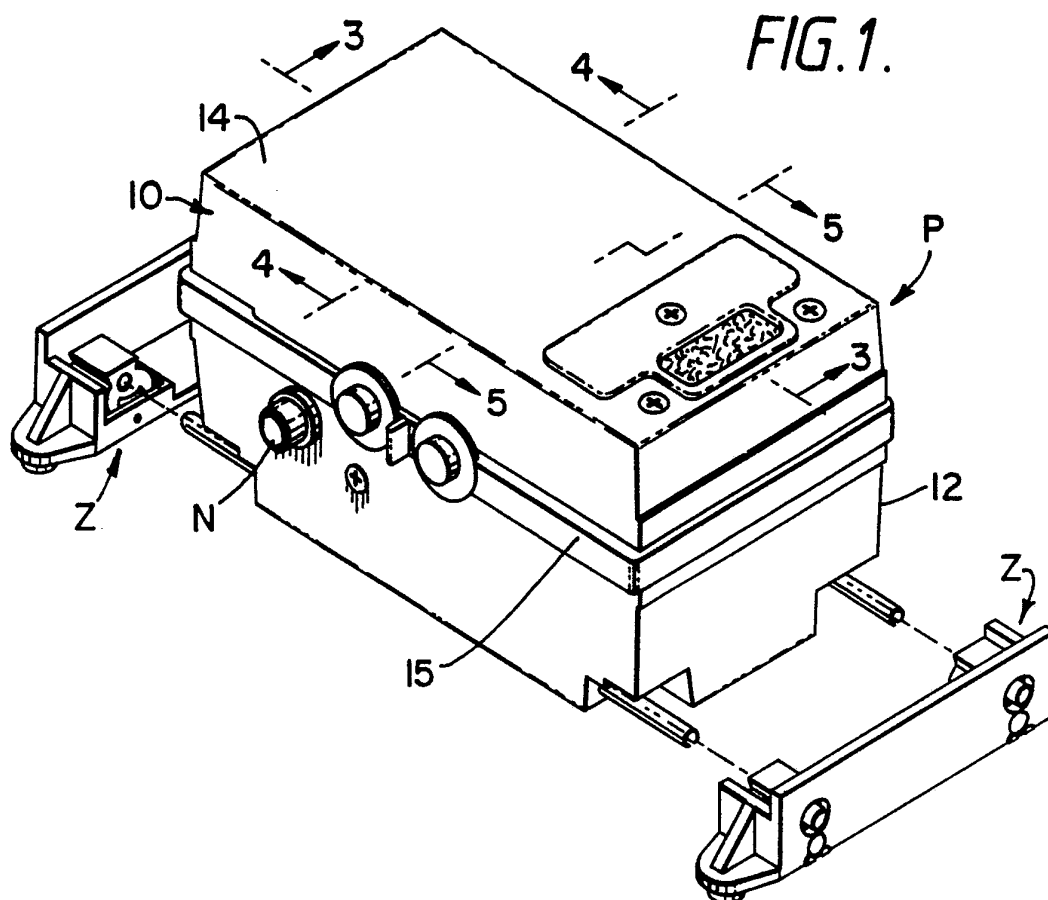
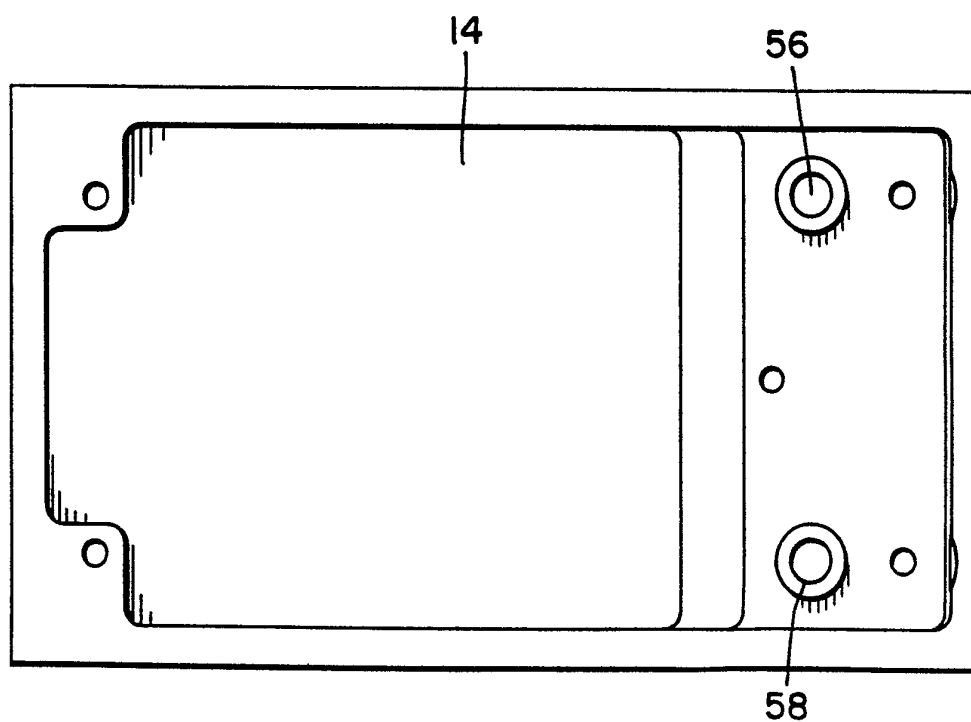


FIG. 10.



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FIG. 2.

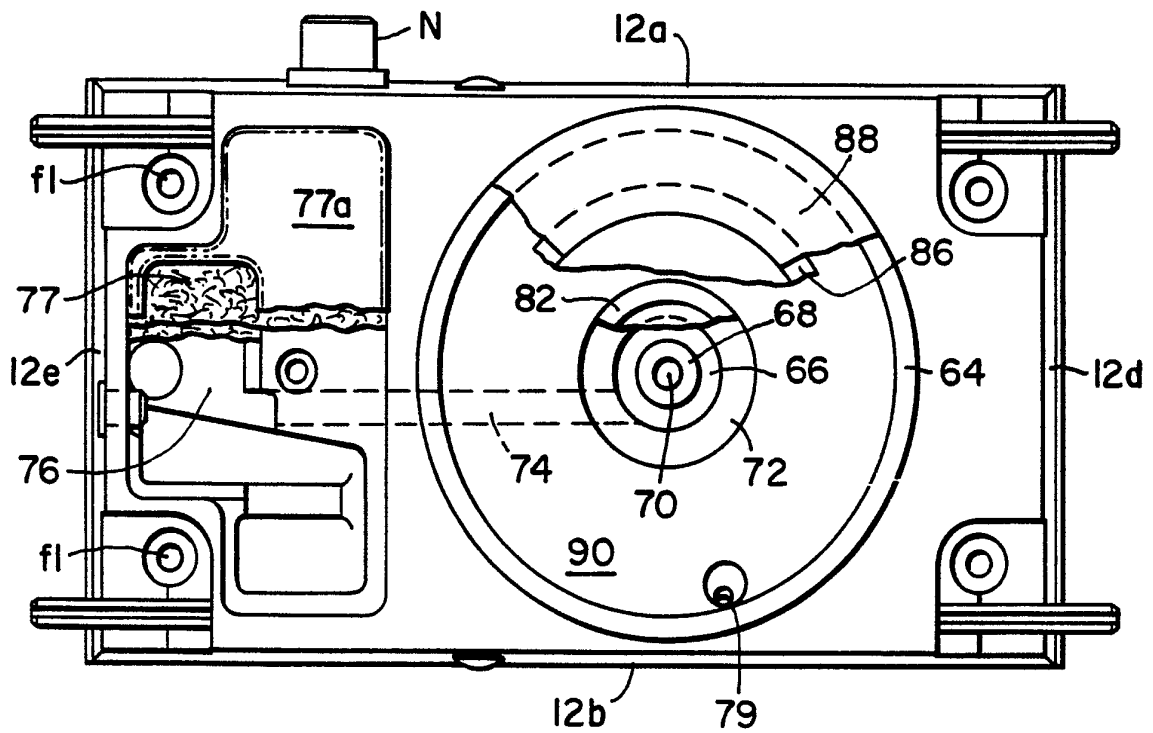
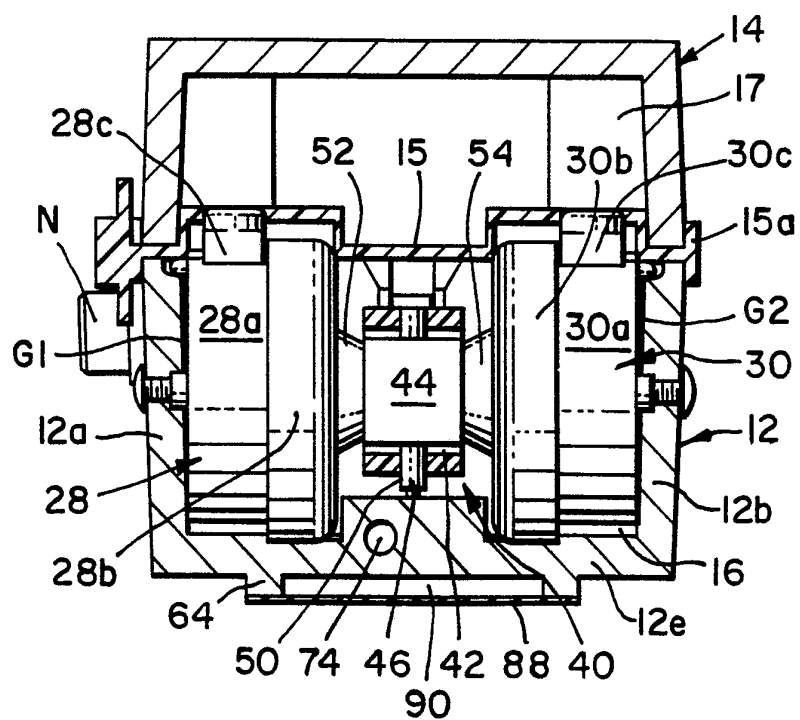


FIG. 4.



SUBSTITUTE SHEET

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FIG. 3

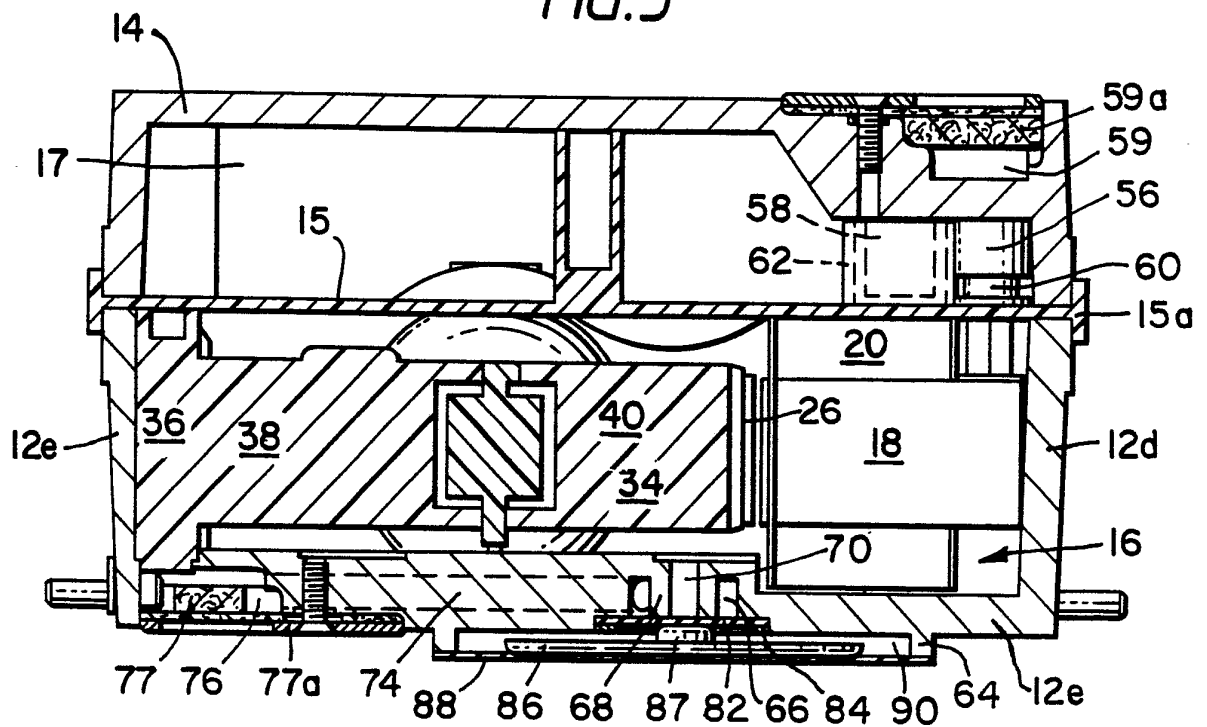
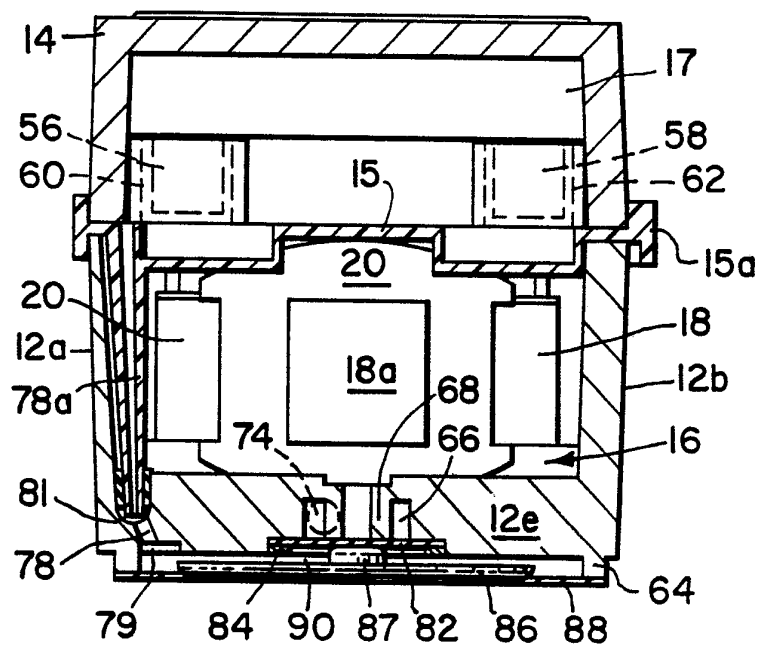


FIG. 5.



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FIG. 6.

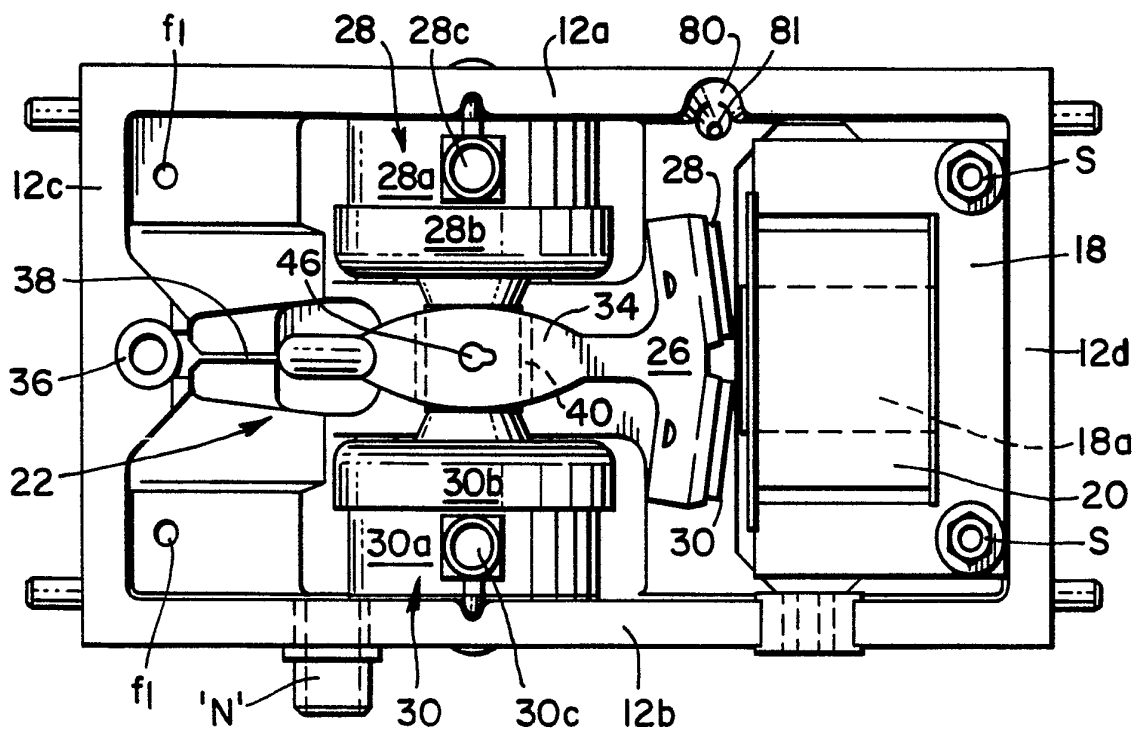
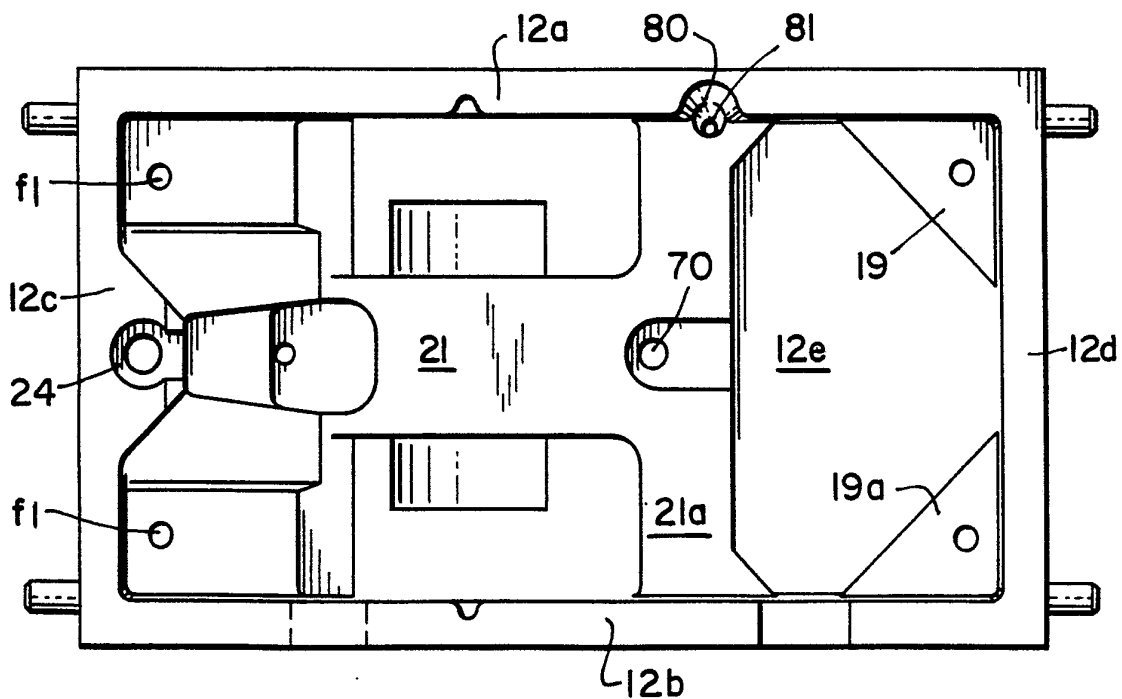


FIG. 7.



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FIG. 8.

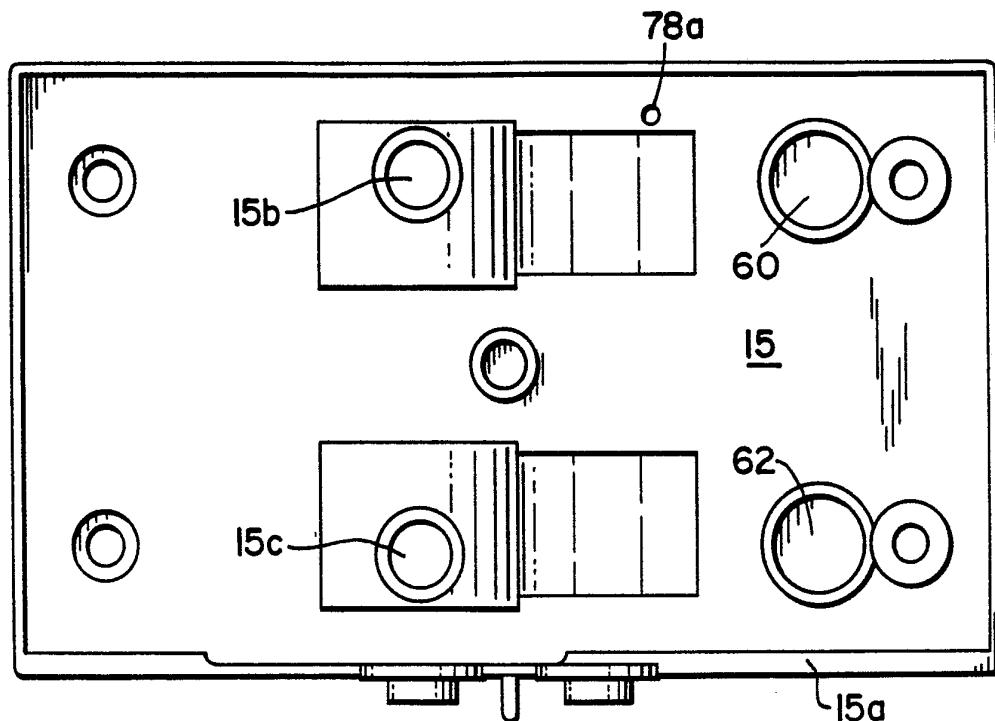
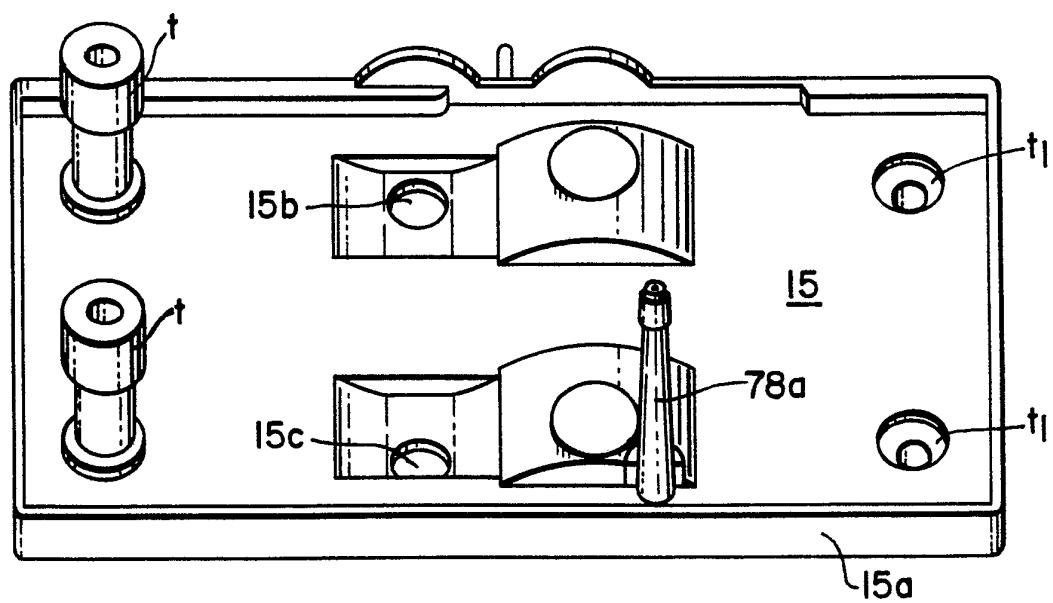


FIG. 9.



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FIG. 11.

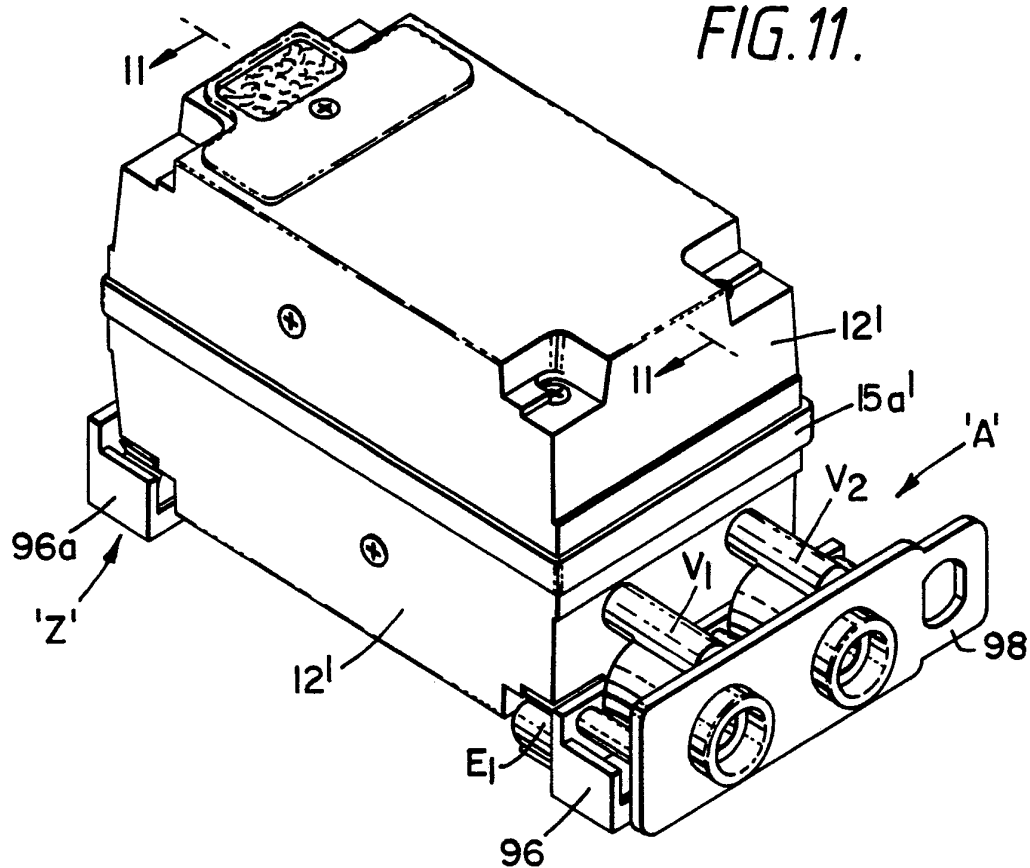
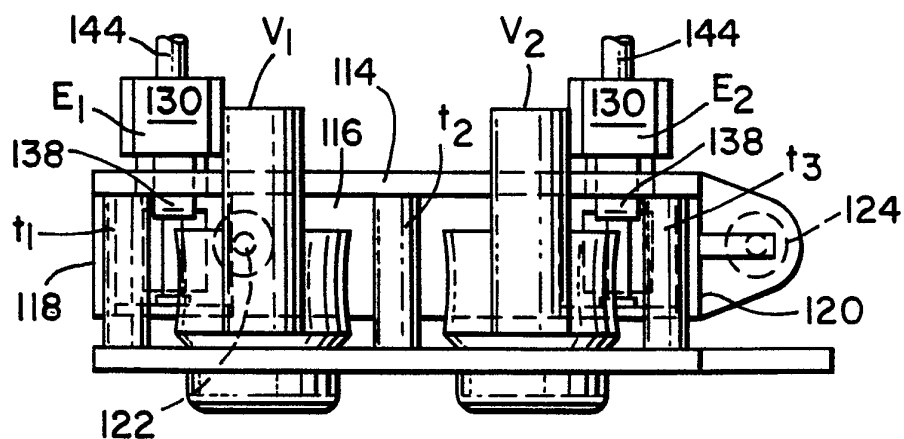


FIG. 14.



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FIG.12.

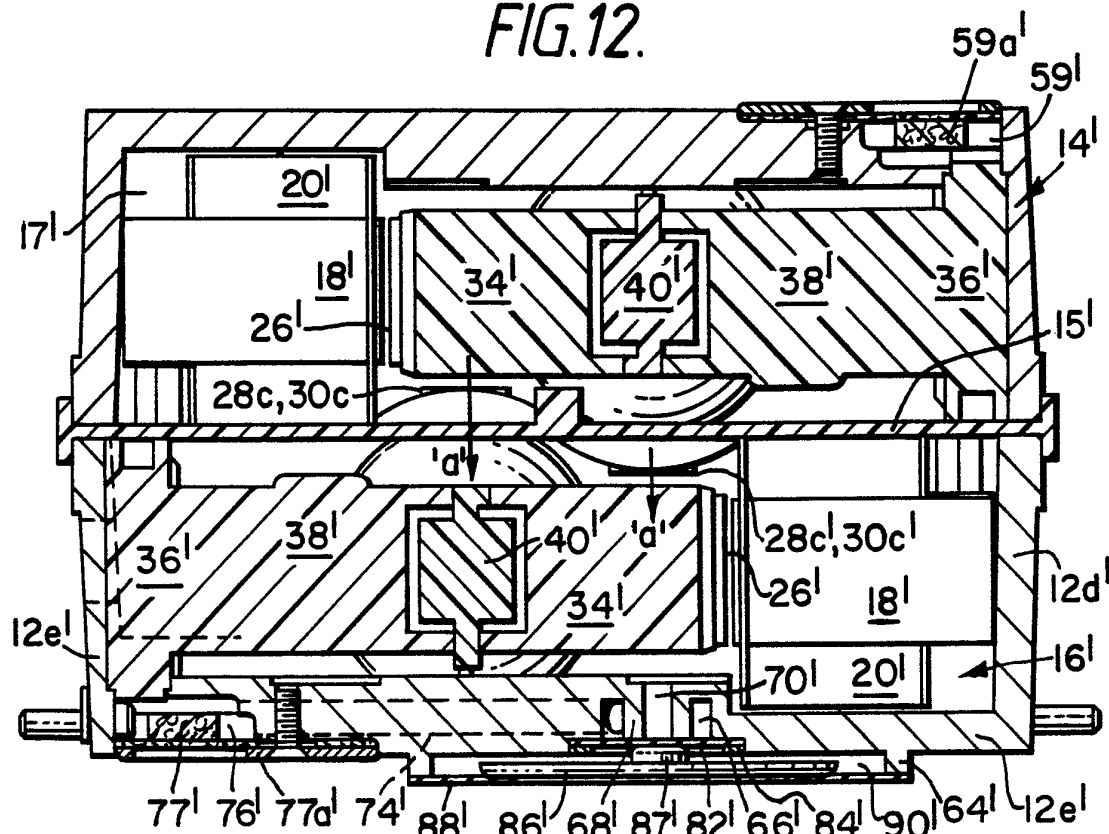
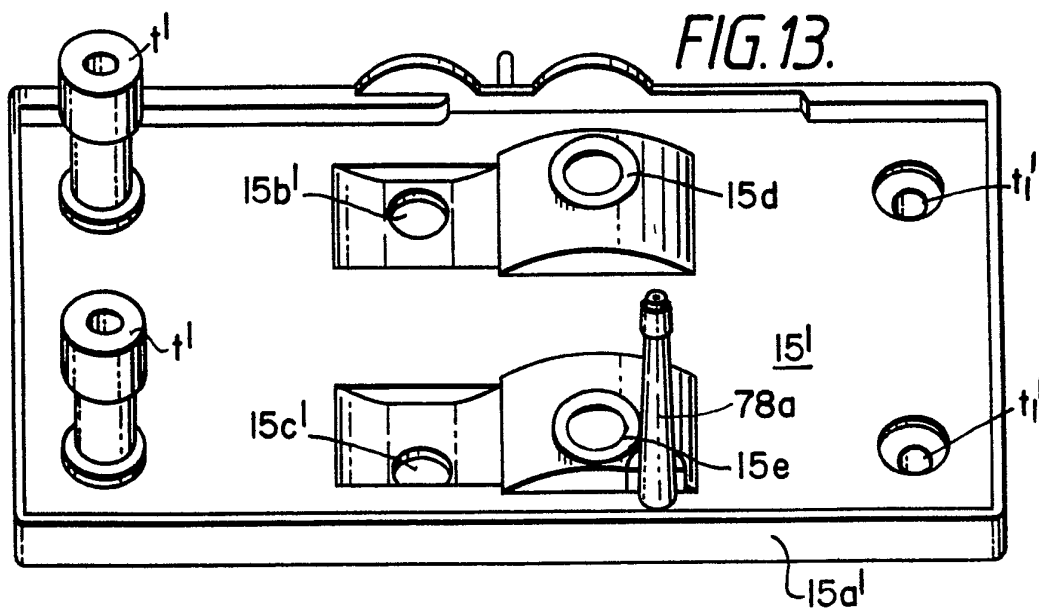


FIG.13.



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FIG. 15.

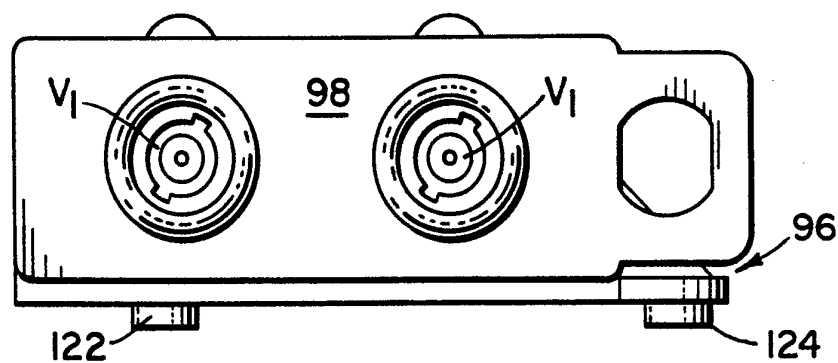


FIG. 16.

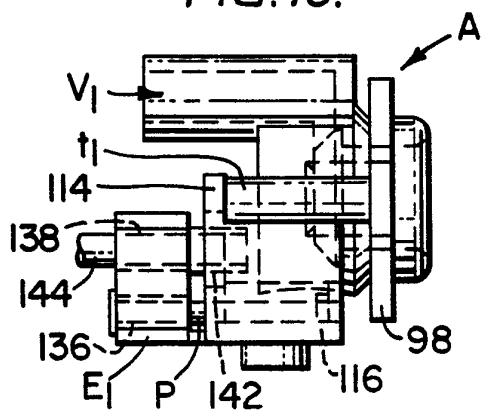


FIG. 17.

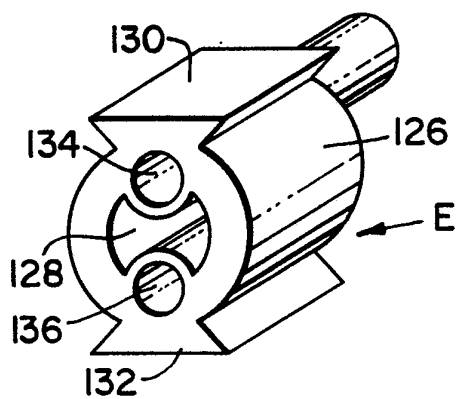


FIG. 18.

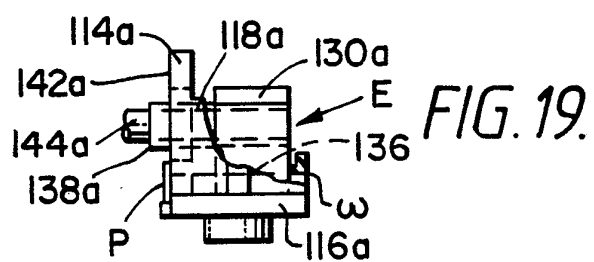
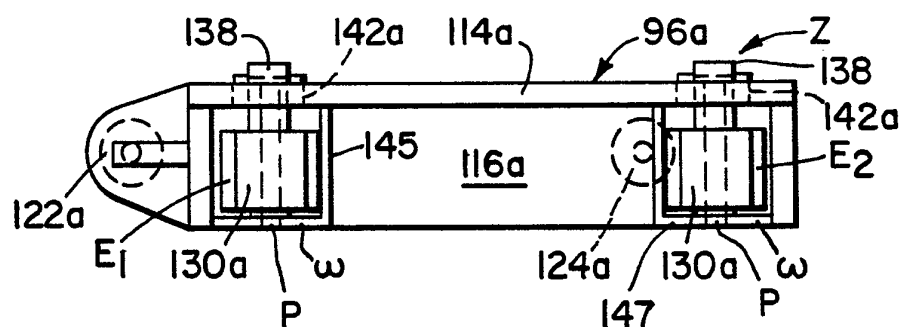
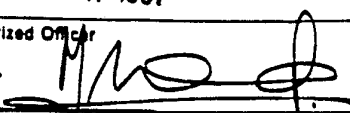


FIG. 19.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 86/00759

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC ⁴ : F 04 B 45/04; F 04 B 41/02		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC ⁴	F 04 B; A 61 H	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	FR, A, 2151876 (KOLFERTZ) 20 April 1973 see page 4, line 13 - page 6, line 13; page 6, line 95 - page 7, line 12; figures 1-4	1
A	--	2-5,12,13
X	FR, A, 2339756 (KOLFERTZ) 26 August 1977 see page 6, line 9 - page 7, line 27; figures 1-3	1
A	--	13
A	DE, A, 1938430 (KOLFERTZ) 18 February 1971 see page 3, paragraph 5 - page 5, line 3; figures 1,2	1,12,13

¹⁰ Special categories of cited documents: ¹⁰ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
24th March 1987	24 APR 1987	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	M. VAN MOL 	

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 86/00759 (SA 15537)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 06/04/87

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		GB-A- 1389869	09/04/75
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		FR-A- 2056184	14/05/71
		US-A- 3635592	18/01/72
		GB-A- 1289649	20/09/72
		SE-B- 360435	24/09/73

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