United States Patent

[11] 3,575,116

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[73] Assignee Hovercraft Development Limited London, England
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[33] Great Britain
[31] 35,684/67

[54] **GAS-CUSHION LOAD-SUPPORTING APPARATUS**
5 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **104/23,** 180/118
[51] **Int. Cl.** **B61b 13/08**
[50] **Field of Search** .... 104/23 (FS), 134; 180/118, 117

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ABSTRACT: Gas cushion load supporting apparatus, particularly for a tracked air cushion vehicle, has nozzles for forming a gas curtain for containing the cushions. The nozzles are adjustable and controlled by actuating units responsive to local cushion pressure. When the cushion pressure increases locally the mass flow of curtain gas also increases locally. If the vehicle tends to roll the downgoing side of the cushion is stiffened which resists the rolling tendency.

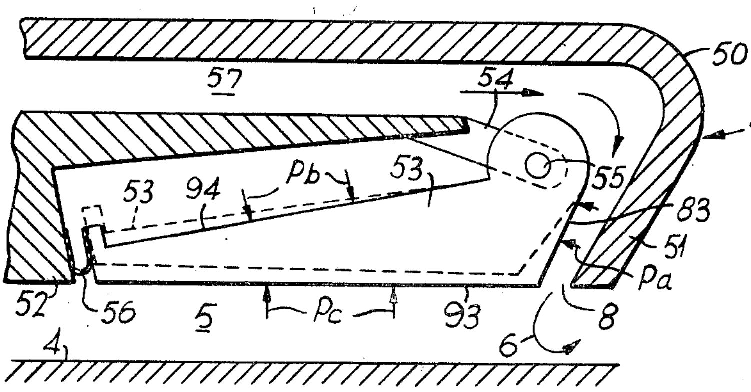

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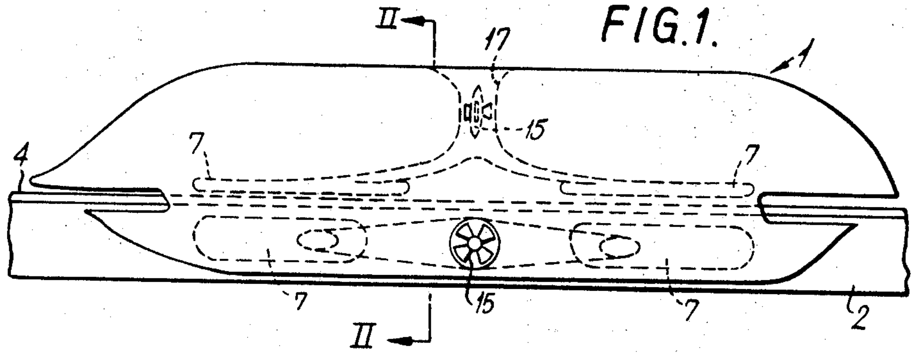
FIG.1.



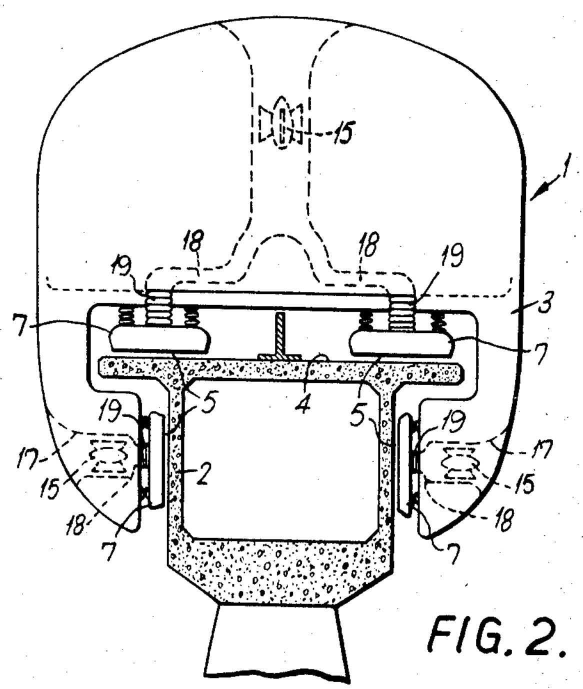


FIG. 2.

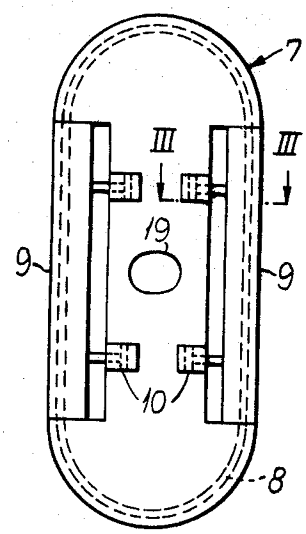


FIG. 3.

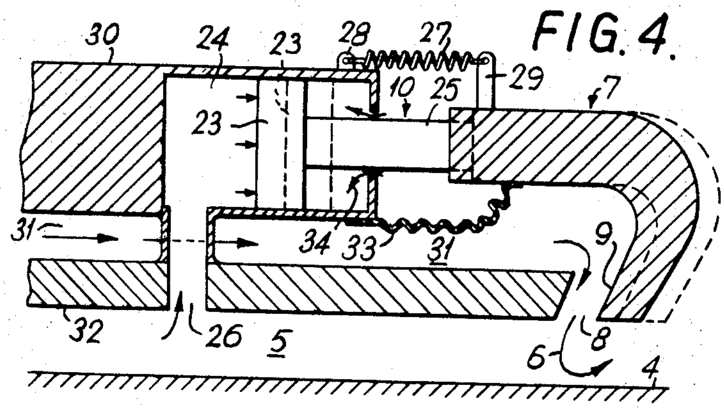


FIG. 4.

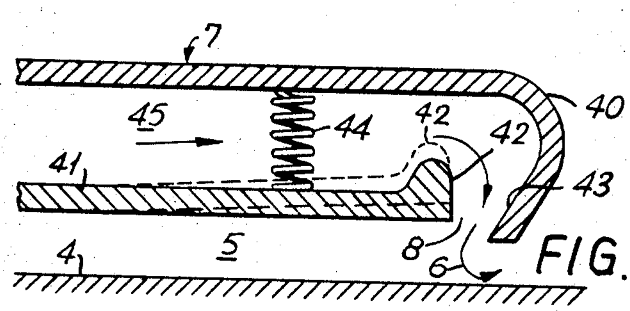


FIG. 5.

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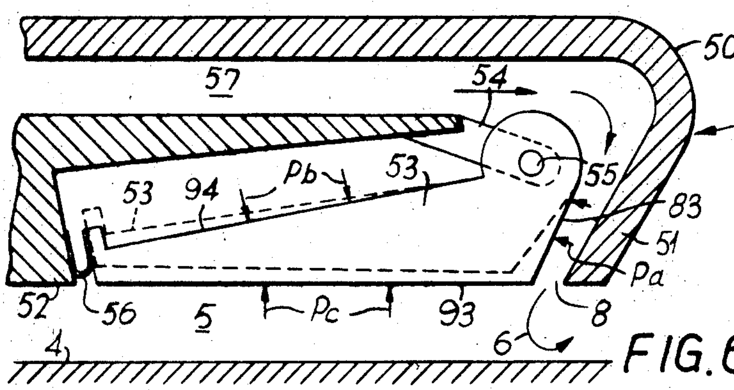

FIG. 6.

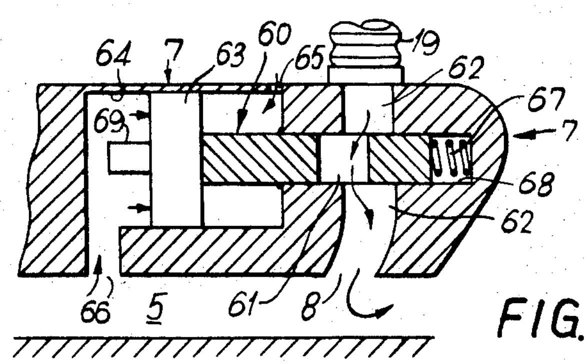

FIG. 7.

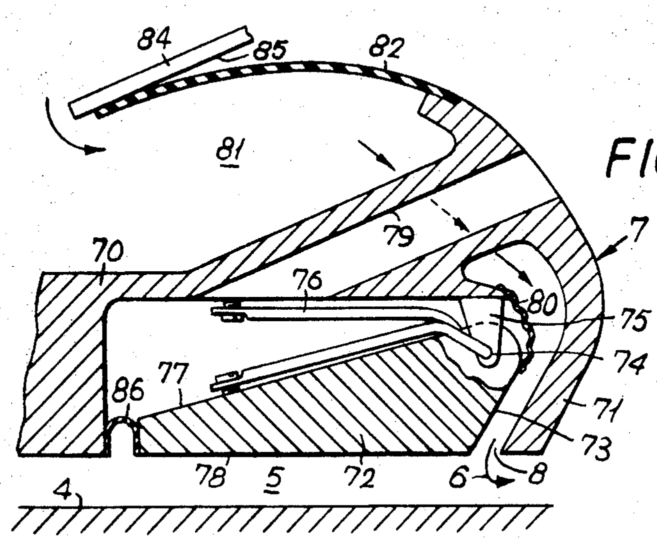

FIG. 8.

GAS-CUSHION LOAD-SUPPORTING APPARATUS

This invention relates to gas-cushion load-supporting apparatus, that is to say, to apparatus wherein a load is at least partly supported by a cushion of pressurized gas formed and contained between the apparatus and a supporting surface, at least in part, by one or more curtains of moving gas.

An example of such a load-supporting apparatus, which is of a now well-known type, is shown in British Pat. No. 995,127.

The whole of the lateral boundary of the cushion may be contained by a single fluid curtain of annular form or it may be contained in part by a wall structure or skirt attached to the apparatus and in part by a gas curtain issuing from the free or unattached edge of the wall structure.

In gas-cushion, load-supporting apparatus of the type shown in FIG. 11 of British Pat. No. 995,127, (i.e. wherein the load comprises a vehicle supported above a prepared track by laterally-spaced pairs of cushions of pressurized air formed and contained between pads carried by the vehicle body and the upper surface of the track) unintentional contact between the cushion pads and the track surface in strong winds can cause damage to the track, pads or both since these vehicles are intended to operate at high speeds (e.g. 250 m.p.h.).

According to the invention, gas-cushion load-supporting apparatus of the type wherein the load-supporting cushion is contained above a supporting surface, at least in part, by a curtain of moving gas, is provided with control means responsive to a local change in cushion pressure arranged so that increase in cushion pressure adjacent to one portion of the curtain results in an increase in the cushion containing quality of that portion of the curtain.

Thus, in the case of the vehicle described in the penultimate paragraph, a sideways roll of the vehicle will result in an increase in cushion pressure at the outboard side of the downgoing cushion pads, which increase will, if the vehicle is modified according to the present invention, result in corresponding increases in the cushion containing quality of the curtain along those sides. This will result in the cushions being stiffened locally in roll to an extent whereby there is substantially less risk of the cushion pads contacting the track.

IF there is a general increase in cushion pressure as a result of heaving of the vehicle, there will also be increase in pressure locally adjacent the whole length of the curtain which will therefore result in cushion containing quality of the curtain being increased more than at just one locality. The cushion is therefore stiffened in heave.

The cushion containing quality of the curtain can be increased by varying the angle of the curtain, since an inwardly inclined curtain has a greater cushion containing quality than a curtain at right angles to the supporting surface. Preferably the cushion containing quality of the curtain is increased by varying the mass flow of the curtain forming gas or the thickness of the curtain.

Gas-cushion load-supporting apparatus according to the invention can be used either to support a vehicle from a substantially horizontal surface, or to guide a vehicle from a substantially vertical surface.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings wherein:

FIG. 1 is a diagrammatic side view of a gas-cushion vehicle on a concrete guide and support track;

FIG. 2 is a cross section on the line II–II of FIG. 1;

FIG. 3 is a plan view of one of the air cushion support pads of FIG. 1;

FIG. 4 is a section, to an enlarged scale, taken on the lines III–III of FIG. 3; and

FIGS. 5, 6, 7 and 8 are views similar to that shown in FIG. 4 and illustrate different modifications of the air cushion support pad of FIGS. 3 and 4.

FIGS. 1 to 4 show a vehicle 1 for operating over a prepared concrete track 2 which has a vehicle body 3 supported above the upper surface 4 of the track by laterally-spaced pairs (one pair only being shown) of cushions 5 of pressurized gas. The cushions 5 are wholly contained by air curtains 6 disposed between gas-cushion load-supporting apparatus, or gas-cushion pads 7 beneath the vehicle body 3. The vehicle 1 is guided along the track 2 by further cushions 5 formed between load supporting apparatus or pads 7 on side portions of the vehicle body 3 and the sides of the track.

FIGS. 3 and 4 show one of the supporting apparatus 7 that supports the vehicle 1 from the upper surface 4 of the track 2. The air to form a curtain 6 is discharged from nozzles 8 extending around the periphery of the pad 7. Side portions of the outer wall 9 of the nozzles 8 are movable laterally and, as explained more fully hereinafter, control means including four piston-operated actuating units 10 are provided which are responsive to changes in pressure at the respective side of the cushion 5. The units operate in pairs to increase the flow of curtain-forming air through the movable part of the nozzle 8 along the respective side of the cushion and hence to increase the cushion containing quality of the curtain at that side.

Air for the support and guide cushions 5 is provided by compressors 15. The air is drawn in through intakes 17 and is discharged from each compressor 15 through ducts 18. Flexible ducts 19 connect the ducts 18 with the air cushion pads 7.

The piston-operated actuating units 10 comprise pistons 23 movable in cylinders 24. The outer faces of the pistons 23 carry actuating rods 25 which are welded to the movable side portions of the nozzle wall 9. The inner faces of the pistons 23 are subjected to pressure at the sides of the cushions 5 through sensing ducts 26 connecting the interior of the cylinders 24 with the spaces occupied by the cushions. Tension springs 27 extend between anchorages 28 and 29 attached to the cylinders 24 and movable nozzle wall portions 9 respectively. The inner ends of the cylinders 24 are integral with the upper surfaces 30 of the cushion pads 7 and the ducts 19 (of FIG. 2) supply the nozzles 8 by way of spaces 31 formed between the upper surfaces 30 and bottom surfaces 32 of the pads 7. The movable side portions of the nozzle wall 9 are sealably connected, by means of flexible seals 33, to the underside of the structure 30. The interior of each cylinder 24 on the outboard side of the piston 23 is open to atmosphere as shown by the arrows 34.

In operation pressurized air flows through the internal space 31 of each pad 7 and discharges through the annular nozzle 8 to initially form, and thereafter contain, the associated cushion 5. Normally the side portions of the nozzle outer wall 9 are in the position shown in full lines in FIG. 4 and are held in this position by the opposing forces of air at cushion pressure acting on the inboard faces of the pistons 23 and tension in the springs 27.

Should there be relative movement of one side of a cushion pad 7 and the track surface towards each other, this will result in a local increase in cushion pressure on that side. The pistons 23 of the units 10 on that side of the pad 7 will respond to the increase in cushion pressure by overcoming some of the tension in the springs 27 and moving outwardly, as shown in the dotted lines. This movement will cause corresponding outward movement of the nozzle wall portion 9 (as shown in dotted lines) whereby the mouth of the nozzle 8 is widened locally to increase the flow of curtain-forming air. The increase in airflow increases still further the local pressure of the cushion 5 so as to stiffen locally the cushion to an extent whereby there is less risk of the relative movement of the pad 7 and track surface 4 contacting each other. Heave stiffness of the cushion 5 is also increased. The guide pads 7 can be similar to the support pads 7.

FIG. 5 shows an alternative air-cushion supporting apparatus or pad 7 comprising a casing 40 housing a centrally-disposed base 41. The base 41 has an upstanding flange 42 which forms an inner wall of the nozzle 8, the outer wall of the nozzle being formed by the inwardly directed rim 43 of the casing 40. The base 41 is connected to and spaced from the casing 40 by a series of compression springs 44 distributed in a ring adjacent the flange 42.

In operation, curtain-forming air flows to the nozzle 8 by way of the space 45 defined by the base 41 and casing 40. Under normal operating conditions the base 41 remains horizontally balanced by the opposing forces of cushion pressure and compression in the springs 44. However, should relative movement between the pad 7 and track surface occur which results in a local increase in pressure of the cushion 5, the base 41 will respond to this increase by moving upwardly at the locality of the increase in pressure. This upward movement of the base 41 (indicated by the dotted lines) will result in local widening of the mouth of the nozzle 8 to achieve the effect referred to above in connection with FIG. 4.

In the alternative arrangement shown in FIG. 6, an air cushion supporting apparatus or pad 7 comprises a casing 50 with an inwardly disposed rim 51 which defines the outer wall of the nozzle 8, a base 52 disposed centrally within the casing 50 and a series of movable nozzle members 53 attached to and distributed aRound the periphery of the base 52.

The nozzle members 53 have outer side faces 83 which form the inner movable walls of the nozzle 8 and the members 53 are pivoted adjacent to the end that constitutes the movable nozzle walls to brackets 54 welded to the base 52 by torsion shafts 55 which bias the members 53 in a clockwise sense (as viewed in FIG. 6) so as to keep the mouth of the nozzle 8 open at all times. The side faces 83 are inclined to the vertical and the pivot pins 55 are disposed adjacent the outer ends of the nozzle members 53. The other ends of the nozzle members 53 make a movable airtight connection with the base 52 by flexible seals 56 of the rolling diaphragm type. Adjacent nozzle members 53 are sealed to each other by flexible seals (not shown) which allow relative movement of the nozzle members 53.

In operation pressurized air is supplied to the nozzle 8 by way of a space 57 between the base 52 and casing 50. Under normal conditions each nozzle member 53 is maintained in the horizontal position, shown in unbroken lines with the flat base surface 93 in line with the bottom surface of the base 52, by the downwardly acting forces *Pb* of air supplied to the upper surface 94 of the member, which forces are opposed by the upwardly acting forces *Pa* and *Pc* acting on the outer side face 83 and base surface 93 respectively. However, should relative movement between the pad 7 and track surface 4 result in a local increase in cushion pressure, the movable nozzle member 53 at the locality will respond to the increase by clockwise movement, as viewed in FIG. 6, assisting the bias applied by the torsion shaft 55, due to the increase applied by the increased value of *Pc*. This movement, which results in local widening of the nozzle 8, is indicated by the dotted lines in FIG. 6 and has the same effect described in connection with FIG. 4. The nozzle members 53 which provide the movable walls of the nozzles are effectively also the actuating unit and the control means for varying the cushion containing quality of the curtain.

FIG. 7 illustrates another alternative structurally closer to that of FIGS. 3 and 4 than either of those of FIGS. 5 and 6. Instead of the thickness of the cushion-containing air curtain 6 being adjusted locally so as to vary, also locally, the stiffness of the cushion 5, the thickness of the curtain can remain unchanged while the mass flow of the curtain-forming air is varied. This also varies the cushion containing quality of the curtain.

As shown in FIG. 7 the single duct 19 is replaced by two ducts (one only being shown), each supplying pressurized air to a side portion of a cushion pad 7. Flow of air from a duct 19 to one of the plurality of nozzles 8 is controlled by a rodlike valve member 60 having a valve port 61 and movable across a passageway 62 connecting the duct 19 with the nozzle 8. THe valve 60 is moved by a piston 63 housing in a cylinder 64. The valve side of the piston 63 is open to atmosphere by way of an aperture 65 in the cylinder 64 and the other side thereof is open to the side of the cushions 5 by way of a passageway 66. The valve member 60 is urged towards a closed position by a compression spring 67 housed in a blind-ended hole 68 locating the valve member, and a stop 69 on the piston 63 prevents the valve member 60 from closing completely.

Under normal conditions the valve member 60 is balanced by the opposing forces of cushion pressure and the spring 67 whereby the valve port 61 occupies a midway position with respect to the passageway 62. However, should the pressure of the cushion 5 change locally, this change will cause the piston 63 to move the valve member 60 one way or the other. Thus, the mass flow of curtain-forming air passing to the nozzle 8 is increased or decreased so as to vary locally the stiffness of the cushion 5 in the desired way.

All the arrangements of pads 7 described above could be connected to the vehicle 1 by some kind of gas suspension system which provides progressively increasing resistance to movement of the pad towards the vehicle for example the kind shown in FIG. 8 described below.

FIG. 8 shows a gas-cushion load-supporting apparatus or pad 7 which has similarities with the pad 7 shown in FIG. 6. The air-cushion supporting device or pad 7 of FIG. 8 has a base 70 to which is rigidly connected a rim 71 which forms the outer wall of the nozzle 8. A series of movable nozzle members 72 are attached to and distributed around the periphery of the base 70.

The nozzle members 72 have outer faces 73 which form the inner movable walls of the nozzle 8 and the members 72 are pivoted at 74 to brackets 75. A spring 76 biases the member 72 downwardly. Each member 72 has a base surface 78 and an upper surface 77 opposite the base surface 78. The operation of the apparatus 7 is similar to that of the apparatus of FIG. 6 except that the upper surface 77 of each nozzle member 72 is not subject to the pressure of the air supply, but is subject to atmospheric pressure. This is achieved by providing passages 79 leading from outside the apparatus and by providing a flexible seal 80 between the member 72 and part of the base 70.

A flexible seal 86 movably connects the end of the member 72 with the base 70.

Gas is fed to the nozzle 8 from a chamber 81 formed by the base 70, a flexible membrane 82, and a supporting structure 84 forming part of the vehicle 1. Gas is fed to the chamber 81 from the fans 15 in the vehicle 1. The membrane 82 is connected to an inclined surface 85 of the supporting structure 84, and when the pad 7 moves towards the vehicle the membrane 82 will progressively engage the surface 85 and will provide a progressively increasing resistance to movement of the pad 7 towards the vehicle.

We claim:

1. A gas-cushion load-bearing apparatus including gas curtain forming means for forming a curtain of moving gas for peripherally containing, at least in part, a load-bearing gas cushion formed between the apparatus and a cooperating surface, gas supply means for supplying pressurized gas to the curtain forming means, the curtain forming means comprising a first, inner, member and a second, outer, member carried by and spaced apart generally radially of the apparatus and defining therebetween a gas outlet port through which gas issues to form the gas curtain, the said first member being mounted for limited rotation about an axis which is orientated generally peripherally of the apparatus and having a first surface exposed to the gas cushion pressure which pressure produces a turning moment about the said axis in one direction, and biassing means biassing the first member in the opposite direction against the turning moment and effective to cause the first member to adopt a predetermined angular position about the said axis when the gas cushion pressure has a predetermined value, the first member having a second surface partly defining the gas outlet port and movable relatively to the second member in a manner to vary the mass flow of the curtain forming gas through the gas outlet port when a variation in cushion pressure from the said predetermined value causes a corresponding rotational movement of the first member about the said axis the variation in the mass flow of the curtain forming gas being in a sense to increase the variation in cushion pressure.

2. A gas-cushion load-bearing apparatus including gas curtain forming means for forming a curtain of moving gas for peripherally containing, at least in part, a load-bearing gas-cushion formed between the apparatus and a cooperating surface, gas supply means for supplying pressurized gas to the curtain forming means, the curtain forming means comprising a first, inner, member and a second, outer, member carried by and spaced apart generally radially of the apparatus and defining therebetween a gas outlet port through which gas issues to form the gas curtain, the said first member being mounted for limited rotation about an axis which is orientated generally peripherally of the apparatus and having a first surface exposed to the gas cushion pressure which pressure produces a turning moment about the said axis in one direction, and biassing means biassing the first member in the opposite direction against the turning moment and effective to cause the first member to adopt a predetermined angular position about the said axis when the gas cushion pressure has a predetermined value, the first member having a second surface partly defining the gas outlet port and movable away from the second member in a manner to increase the mass flow of the curtain forming gas through the gas outlet port when an increase in cushion pressure above the said predetermined value causes a corresponding rotational movement of the first member about the said axis.

3. A gas-cushion load-bearing apparatus including gas curtain forming means for forming a curtain of moving gas for peripherally containing, at least in part, a load-bearing gas cushion formed between the base of the apparatus and a cooperating surface, gas supply means for supplying pressurized gas to the curtain forming means, the curtain forming means comprising a first, inner, member and a second, outer, member carried by and spaced apart generally radially of the apparatus and defining therebetween a gas outlet port through which gas issues to form the gas curtain, the said first member being mounted for limited rotation about an axis which is orientated generally peripherally of the apparatus and having a first surface exposed to the gas cushion pressure which pressure produces a turning moment about the said axis in one direction, and a second surface exposed to a different gas pressure which pressure produces about the said axis a second turning moment opposing the first turning moment, and spring biassing means producing a third turning moment of the first member about the said axis such that the first member adopts a predetermined angular position about the said axis when the gas cushion pressure has a predetermined value, the first member having a third surface partly defining the gas outlet port and movable away from the second member in a manner to increase the mass flow of the curtain forming gas through the gas outlet port when an increase in cushion pressure above the said predetermined value causes a corresponding rotational movement of the first member about the said axis.

4. A gas-cushion load-bearing apparatus according to claim 3, wherein the second surface of the first member is exposed to atmospheric pressure.

5. A gas-cushion load-bearing apparatus according to Claim 3, including a rolling diaphragm connected to the base of the apparatus and to the first member between the first and second surfaces thereof for providing a movement-accommodating gas seal separating said first and second surfaces.