

RESERVE COPY. PATENT SPECIFICATION

944,503



Inventor: CHRISTOPHER SYDNEY COCKERELL.

Date of filing Complete Specification: March 21, 1960.

Application Date: March 23, 1959.

No. 94406/63

(Divided out of No. 944502).

Complete Specification Published: December 18, 1963.

© Crown Copyright 1963.

944,503

Index at Acceptance:—B7 K.

International Classification:—B 64 c.

COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Vehicle for travelling over Land and/or Water

We, HOVERCRAFT DEVELOPMENT LIMITED, a British Company, of 1 Tilney Street, London, W.1., do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to vehicles for operating over a surface and which are supported above that surface by one or more cushions of pressurised gas.

The specification of Letters Patent No. 854,211 describes and claims a vehicle which comprises means for causing a fluid to issue from the lower part of the vehicle in such a way as to result in the formation and maintenance of at least one curtain of moving fluid which travels across the gap that in operation exists between the surface over which the vehicle is to hover or travel and the structure of the vehicle and, together with the said structure and surface, encloses a space into which the said fluid, or gas other than the said fluid, flows so as to result in the formation of a pressurised cushion or cushions by which the vehicle is wholly or partly supported, the pressure of the cushion causing, and in its turn being contained due to a change of direction of the moving fluid which results in a curvature of the curtain and in which the means for forming the curtain are such that in cruising conditions the thrust due to the stream of fluid finally leaving the vehicle is substantially less than the weight of the vehicle when loaded.

The same system of support is applicable to mobile platforms and to aircraft and aircraft carriers such as those described and claimed in the specifications of Letters Patent Nos. 893715, 894644, 895341. The term vehicle as used herein is to be understood, where the context permits, as includ-

ing mobile platforms, aircraft and aircraft carriers.

The present invention is based on the concept that a restoring force tending to stabilise the vehicle can be made available by forming one or more further cushions of pressurised gas which surround or are distributed around the periphery of the main or primary cushion supporting the vehicle.

According to the invention there is provided a vehicle for travelling over a surface and which in operation is supported above that surface on cushions of pressurised gas, said vehicle including means for forming at least one primary cushion of pressurised gas and means for forming at least one secondary cushion surrounding or distributed around the periphery of said primary cushion and adapted to exert stabilising forces on said vehicle.

For convenience the further cushion or cushions will be referred to as the secondary cushion or cushions, the zone of pressure extending over the remainder of the underside of the vehicle and serving primarily to support it being called the primary cushion. Where the cushion or cushions are contained for at least part of their peripheries by curtains of moving fluid formed one within the other, the outermost curtain system will be referred to as the primary curtain, while the inner curtain system will be referred to as the secondary curtain. It will be assumed for convenience in the following descriptions of certain embodiments of the invention that where curtains are referred to the curtain-forming fluid is air, although it can be another gas, such as engine exhaust gases or a liquid such as, for example sea water.

For a better understanding of the invention, and to show how the same may be

45

50

55

60

65

70

75

80

85

[Price 4s. 6d.]

put into effect, reference will now be made to the accompanying drawings like parts having like references, in which:—

Figure 1 is a side elevation of a vehicle embodying the invention,

Figure 2 is a diagrammatic front elevation of the vehicle illustrated in Figure 1, showing one form of air flow when the vehicle is tilted, the tilting being shown to an exaggerated degree of clarity.

Figure 3 is an inverted plan view of the vehicle illustrated in Figures 1 and 2.

Figures 4 to 11 are diagrammatic inverted plan views of vehicles embodying the invention, illustrating various port configurations for obtaining compartmentation of the secondary cushion.

Figures 12a and 12b are diagrammatic inverted plan views illustrating a further port arrangement, showing two operating conditions.

Figure 13a and 14b are diagrammatic illustrations of a modification applied to an embodiment of the invention, showing two operating conditions.

Figure 14 is a diagrammatic illustration in a further modified form of the arrangement illustrated in Figure 13.

Figure 15 is a diagrammatic vertical cross section of the bottom portion of the vehicle embodying a further feature of the invention.

Figure 16 is a diagrammatic partial cross section of a vehicle showing a further embodiment of the invention.

Figure 17 is a further diagrammatic partial cross section showing a modification of Figure 16.

Figure 18 is an alternative form of the embodiment illustrated in Figure 17.

Figure 19 is a diagrammatic partial cross section illustrating a further embodiment of the invention.

Figure 20 is a partial plan view of the detail of a flap as used in the embodiments illustrated in Figures 16, 17 and 18.

Figure 21 is a diagrammatic illustration of a control system for controlling the flaps in Figures 16 to 19.

Figure 22 is a diagrammatic partial cross section of a vehicle illustrating a further embodiment of the invention.

Figure 23 is a diagrammatic vertical cross section of the bottom of a vehicle illustrating another embodiment of the invention and

Figure 24 is a diagrammatic vertical cross section of the bottom of a vehicle illustrating a further embodiment of the invention.

Figures 1, 2 and 3 show a form of vehicle in which a stepped pressure distribution is obtained by forming a primary cushion surrounded by a secondary annular cushion at a pressure during normal operation intermediate between the primary cushion pres-

sure and atmosphere. The vehicle has a base portion 1 which carries a passenger and/or freight carrying portion 2. The portion 2 may also contain the engines driving the air compressors which supply the air for forming the curtains. As will be seen in Figure 3 the bottom of the vehicle has two ports 3 and 4 the outer or primary port being adjacent to the periphery of the base 1 of the vehicle and the inner or secondary port 4 being spaced inwardly from and extending substantially parallel to the primary port.

When in operation, air curtains are formed by air issuing from the ports 3 and 4 and form and maintain a primary cushion 5 and a secondary annular cushion 6. The pressure of the annular cushion 6 is intermediate between that of the primary cushion and atmosphere.

If the vehicle for any reason tilts, as shown to an exaggerated degree in Figure 2, the radius of curvature of the primary curtain formed by port 3 decreases at that part of the vehicle which approaches the surface so that the pressure of the secondary cushion increases locally. The increase in pressure in the secondary cushion tends to cause a local splitting of the inner or secondary curtain so that it tends to flow inwards.

Further inclination of the vehicle causes all the air ~~forming~~ the secondary curtain to flow inwards and a part of the air forming the outer or primary curtain also splits off from the main curtain flow to form an inwardly directed jet 7 as shown.

If the inner or secondary curtain is directed horizontally inwards as it leaves the bottom of the vehicle, it cannot sustain an increase in pressure of the secondary cushion to a pressure above that of the main cushion, as the ~~curtain~~ can only sustain a pressure which is directed against its convex face. Hence the maximum righting moment which can be produced is that obtained by increasing the secondary cushion pressure until it is substantially equal to that of the primary cushion.

If, however, the secondary curtain is directed vertically downwards as it leaves the vehicle, it will be deflected outwards by the excess of the primary cushion pressure over the secondary cushion pressure until such time as a local lowering of the vehicle causes the secondary cushion pressure to rise above that of the primary cushion, whereupon the secondary curtain will be deflected inwards. Thus by directing the secondary curtain vertically downwards, a larger restoring or righting moment can be produced and the stability of the vehicle is improved, but at the expense of efficiency, as the inwardly directed jet is the more efficient from the point of



view of power required to raise the vehicle given height.

The effect just mentioned is progressive as the initial direction of the secondary curtain varies from the horizontal to the vertical. It is therefore advantageous to effect a compromise between maximum stability and maximum efficiency by directing the jet at an intermediate angle between 45° and 60° to the horizontal.

The local increase in pressure of the secondary cushion can be prevented from dispersing to the remainder of the secondary cushion, with a consequent increase in the stabilising effect by dividing the annular secondary cushion into compartments as shown in Figures 4 and 5 or by dividing the secondary cushion into separate compartments by various configurations of either the primary port, the secondary port or both, as shown diagrammatically in Figures 6 to 11.

In Figures 4 and 5 radial ports 8 are formed in the bottom of the vehicle and connect the primary and secondary curtain ports 3 and 4. Four radial ports 8 are shown in Figure 4 and eight in Figure 5, the number of ports being variable and depending on size of vehicle, and the degree of stability required. The ports 8 may be arranged to deliver the air vertically or some horizontal component of direction may be given to the air for propulsion purposes or for manoeuvring the vehicle.

In order to avoid sharp intersections of jets or curtains, such as are shown in Figures 4 and 5, the configurations shown in Figures 6 to 11 may be used. It will be seen that the ports 8 of Figures 4 and 5 of generally radial orientation are constituted in Figures 6 to 11 by part of the secondary curtain port, by part of the primary curtain port or both. In Figure 11 the compartmentation of the secondary cushion is formed by the intersecting of two continuous ports.

Of the configurations of Figures 6 to 11, Figures 7, 9 and 11 give rise to the least trouble from cross flow between compartments. Other considerations affecting the choice of configuration are as follows:— If a port has a concave curve, as seen from a cushion space within the curtain formed from the port, of a radius of curvature which is too small in relation to the height of the vehicle above the surface there is a danger that the flow pattern may switch locally to a mode in which the secondary jet or part thereof clings to the underside of the vehicle. This mode causes a local loss of lift, since it is characterised by a low positive or even a negative lift. With curtain-forming jets at an angle of 45° to the horizontal and at a cruising hover-height of 1.5 ft. and a maximum hover-height of 3.0

ft. when travelling over the troughs of waves, the minimum radius of curvature is of the order of 3 ft. if switching to the undesirable mode just mentioned is to be avoided. From this point of view the arrangements of Figures 7 and 8 are preferred.

Another arrangement involving port configurations including low radii of curvature is that of Figure 11. On the other hand the small acute angles at which the curtains intersect produce a similar effect to that of ports of small radius of curvature, since entrainment of air from the space between the curtains is likely to occur where the curtains are close to each other. This entrainment leads to a low-pressure area between the curtains and a loss of lift. The difficulty can, however, be mitigated by providing inlet ports 10 in the spaces in which the curtains are adequately separated and connecting them by ducts in the vehicle with outlet ports 11 in the spaces where the curtains approach undesirably close to each other, whereby a measure of pressure equalisation between the two regions is brought about by a flow of air through the connecting ducts. A system of this kind could also be adopted with some advantage in the configurations of Figures 9 and 10 and possibly Figures 6, 7 and 8.

Yet another method of compartmenting the secondary cushion as shown in Figures 12a and 12b, is to blank off the inner or secondary curtain port 4 at appropriate points 12 around its circumference. This has the effect of causing gaps to be formed in the secondary curtain which will cause air from the primary cushion to be ejected through the gaps in the secondary curtain to form curtains extending across the secondary cushion as at 13 in Figure 12a. When, due for example to the front tipping down or to a head pressure formed by the forward motion of the vehicle, the pressure in the front compartment increases then the curtains formed by the air issuing through the gaps in the secondary curtain will be deflected as shown in Figure 12b. Pressure increases in any of the other secondary cushion compartments will cause other deflections of the dividing curtains. Where the secondary curtain issues from the port 4 without any horizontal component other than one inwards towards the primary cushion, the dividing curtains formed through the gaps will be vertical. However if the secondary curtain air is given a further horizontal directional component such as by vanes in the port, then the gap in the secondary curtain, and thus also the dividing curtains will not be vertical.

Figures 13a and b illustrate arrangements for improving the efficiency of a curtain, particularly a secondary curtain, from a

stability point of view. As stated previously, a vertical curtain gives increased stability, but loses efficiency due to easier deflection by the cushion pressure. 5 that is the curtain can only support or contain a lower cushion pressure. This can be overcome to some extent as follows:-- The secondary curtain port 22 is formed in a recessed chamber 23 formed in the bottom 10 of the vehicle. Level with the bottom of the vehicle, in the form of a diaphragm across the chamber are two sets of curved vanes 24 having their chords arranged vertically, the vanes extending either side 15 of a central vane in line with the port 22. The vanes are curved in their vertical cross section, the radius of curvature varying between a maximum at the outside and a minimum at the centre, beneath the port 22, 20 the concave sides of one set of vanes facing the concave sides of the other set. Ports 25 are provided so that the cushion pressures can act on the curtain as it issues from the port 22. Figure 13a shows the 25 normal operation of the system. The curtain issues from the port 22 and is deflected by the primary cushion pressure $P+p$. The curtain is then deflected by the left hand set of vanes 24 and is curved round and 30 issues with a direction towards the primary cushion which increases its efficiency. When a local lowering of the vehicle by tilting occurs then, as shown in Figure 13b, the secondary cushion pressure increases and becomes, for example, $P+p$. This pressure 35 acts on the curtain issuing from the port 22 and deflects it, as shown. The curtain is then deflected by the right hand set of vanes 24, issuing in a direction towards the secondary cushion. The curtain thus issues 40 from the vanes in a direction towards the higher cushion pressure, whichever it may be, and is able to support a greater pressure, or pressure difference. 45 Figure 14 is a modification of the arrangement shown in Figures 13a and b. Normally the secondary curtains in configurations such as are shown in Figures 3 to 12, are caused to issue with a direction 50 towards the primary cushion. This is because normally the secondary curtain or curtains for the most of the time will be operating to contain the primary cushion and only for a comparatively small portion of the 55 time will they be affected by the stabilising forces. Figure 14 is, therefore, an arrangement in which the port and vanes are arranged to provide for a maximum efficiency in one direction. The curtain issues 60 from port 26 with a direction, shown by full lines, towards the primary cushion, little or no deflection of the curtain being caused by the inner vanes 27, thus avoiding losses. As the pressure difference between the primary and secondary cushions decreases 65

however, the curtain is deflected less by the primary cushion, until, when the secondary cushion pressure is greater than the primary cushion pressure, the curtain is deflected as shown by the dotted lines 28 and flows 70 through outer vanes 29 which are so curved as to have a strong deflecting action on the curtain. The curtain issuing from these vanes may be deflected to the extent that it issues in a direction towards the secondary 75 cushion in these circumstances and is thus able to support a larger increase in pressure of the secondary cushion over the primary cushion.

An improvement in stability can also be 80 obtained by providing that the outer or primary curtain port is higher than the inner or secondary curtain port. If there is a local variation in height, so that a part of the vehicle approaches the surface, the ratio of 85 the height of the secondary curtain to that of the primary curtain increases at this locality. As a result the local pressure of the secondary cushion can build up to 90 values greater than would be the case if the ports were of equal height with the vehicle in the horizontal position. Such a vehicle is illustrated in Figure 15. The bottom surface of the vehicle is slanted upwards between the inner secondary port 30 95 and the outer primary port 31, so that the port 31 is higher than port 30. As explained above, with such a construction, if, for example, the rear of the vehicle were to approach closer to the surface, as by tilting 100 of the vehicle the ratio of the height of the secondary curtain from port 30 to that of the primary curtain from port 31, increases. This enables the pressure of the secondary cushion to be built up to a higher 105 pressure than would otherwise be the case. Slanting of the outer portion of the bottom surface is also advantageous for vehicles for use over water in that it affords some hydrodynamic lift to the vehicle, should 110 contact occur between the bottom surface and the water.

It is possible, in vehicles having two curtain systems as described herein, to provide means for altering the trim of the 115 vehicle. This may be accomplished by diverting part of the air which would otherwise flow to the inner curtain, to the outer curtain, or vice versa, thus bringing about an increase or decrease in the secondary 120 cushion pressure at that location, so that the relevant part of the vehicle tends to rise or fall. Various methods of carrying this out are shown in Figures 16 to 19.

Figure 16 shows a simple arrangement in 125 which two ports 34 and 35 are supplied with air by ducts 36 and 37 respectively. A hinged flap 38 is mounted at the junction of the two ducts 36 and 37, the position of the flap controlling the amount of air fed 130

from a compressor via duct 39 which enters each of the ducts 36 and 37. By rotating the flap one way, anti-clockwise in Figure 16, the amount of air flowing to the inner curtain is reduced and that flowing to the outer curtain is increased. This leads to a local increase in pressure of the secondary cushion and an upward force on the bottom of the vehicle. Reverse rotation of the flap has the reverse effect. It may be advisable to provide stops to prevent such operation of the flap as will result in the total shutting off of the air flow to the ports 34 and 35.

Figures 17 and 18 are variations of the system shown in Figure 16. In these examples, the outer curtain is formed from two ports 40 and 41, fed by two ducts 42 and 43 respectively, the inner curtain being formed from a single port 44 fed by a duct 45. A hinged flap 46 operates to vary the air flow to the ducts 43 and 45 only, the air flow to the duct 42 being separate. Operation of the flap varies the relative air flow to the two ports 41 and 44 with the above described effect. In Figure 17 the ducts 42 and 43 are raised so that air from a compressor flows smoothly into the duct 45. In Figure 18 the ducts 42 and 43 are not raised and a curved guide vane 47 is hinged on the flap 46 to give a smooth entry into the duct 45. There is no need for a limit stop in these latter cases as there is always air flowing to the port 40 for the formation of a curtain.

In the example shown in Figure 19 each curtain is formed from two ports, the outer curtain by ports 50 and 51 fed by ducts 52 and 53 and the inner curtain by ports 54 and 55 fed by ducts 56 and 57 respectively. In each pair of ducts the outer duct, 52 and 56, is wider than the inner duct. A hinged valve member 58, formed from two parallel flaps 58a and 58b, is mounted at the junction of the ducts, movement of the valve member varying the flow of air into the outer duct of each curtain forming system. Air passes between the parallel flaps 58a and 58b into the inner duct 53 of the outer curtain system and flows below the valve into the inner duct 57 of the inner curtain system. The air flow into each of the inner ducts 53 and 57 is virtually unaffected by any movement of the valve member, only the relative flows to the outer ducts 52 and 56 being varied.

In the arrangements shown in Figures 16 to 19, where the flap or valve controls a port following a circular configuration, it must be made of flexible material or sectors of stiff material with radial joints of flexible material as shown in Figure 20, which is a plan view of a suitable flap for use in Figure 18.

It will be understood that in order to produce the moment necessary to effect the

desired control on the trim of the vehicle it is necessary to control the flap valve so that it is deflected at the correct circumferential location or locations. It has been mentioned above that the flap valve must be flexible and it may therefore be deflected by providing a sufficient number of operating levers.

It is an advantage to provide for diversion of air from the inner to the outer curtain at the locality at which the vehicle is to be raised; and from the outer to the inner curtain at the diametrically opposite point, the position of the flap valve varying progressively between the two points. With this in view, a linkage which gives the correct orientation of flap valve position around the vehicle should be provided and such a linkage is shown in Figure 21. A ring 60 is mounted in gimbals 61 around the fan casing, the latter being placed centrally in the vehicle. The orientation of the ring 60 is controlled by four hydraulic jacks 62 controlled from the cockpit. Control rods or wires 63 operate the flap valve 46.

Figure 22 illustrates diagrammatically an alternative method of varying the relative flows of air to the primary and secondary curtain ports, using a sliding flap or plate. A flat plate 65 is mounted on the bottom surface of the vehicle, arranged to slide inwardly and outwardly over the openings 66 and 67, the plate being provided with ports 68 and 69. The ports 68 and 69 co-operate with the openings 66 and 67 respectively to define the actual position at which the curtain forming air issues. The widths of the ports 68 and 69, and their positioning relative to the openings 66 and 67, is such that in a mid position equal flows of air occur through the ports 68 and 69, whilst in one extreme position or the other, a flow of air occurs through one or other of the ports equal to the combined flows when the ports are in the mid position, no flow occurring through the other port. Flows of air between these two extremes will occur depending upon the position of ports 68 and 69 relative to the openings 66 and 67. Air is fed to the ports via a duct 70.

As only the outer edge of opening 66 and the inner edge of opening 67 normally take an effective part in defining the width of the actual opening through which the curtain forming air flows, these openings are made wider than the ports 68 and 69. Vanes may be provided in the openings 66 and 67. Whilst the flat plate is shown as being fitted inside the bottom of the vehicle, it can readily be fitted on the outside, but is liable to be damaged. Again, the relative positionings of the ports and openings can be reversed, the ports 68 and 69 being formed in the bottom of the vehicle and

the openings 66 and 67 being formed in the sliding plate 65.

As stated above, the compartmentation of the supporting cushion can be obtained.

- 5 partially or wholly by the use of a structural member or structural members. Generally, the member or members will be positioned so that it or they are parallel to the intended direction of movement of the vehicle, al-
- 10 though a flexible construction can be used for a member or members, positioned at an angle to the direction of movement of the vehicle. Alternatively the member or mem-
- 15 bers may only project downwards a portion of the total cushion height, being either rigid or flexible, and a curtain or curtains of fluid may issue from the bottom of the member or members.

- 20 Figure 23 illustrates diagrammatically a construction primarily for a vehicle operating over water, in which the inner secondary curtains are replaced partially by keel-like members 90 having ports 91 at their bottom edge. Such a form of structural
- 25 member may be used parallel to and at any angle to the direction of movement of the vehicle. The members 90 may be rigid or flexible.

- 30 Figure 24 illustrates diagrammatically the shaping of the bottom of the vehicle so as to replace the inner curtains. The shaping forms two projections 92 and 93 which approach the surface close enough to create a restriction which is effective
- 35 to enable a pressure difference to occur between the cushion compartments on either side of the restriction. Provision may also be made for the ejection of fluid from the projections 92 and 93 to form curtains.
- 40 Alternatively flexible members may be attached to the projections.

- 45 Where the variation of the flow of air to the various ports, and/or the moving of the position of a port or ports, is used for varying the trim of a vehicle, this provides a convenient means for maintaining the attitude of the vehicle over obstacles such as rocky ground or waves at sea.
- 50 Taking as an example, a vehicle travelling over waves at sea, the trim of the vehicle can be controlled by a simple mechanism, such as gyroscopically controlled valve so that the vehicle remains on a substantially even keel.

- 55 The operation is as follows.

- When the front of the vehicle meets a wave, which causes a locally reduced height and thus a locally increased pressure rise in the cushion, the vehicle tends to lift at the front. A suitably controlled valve de-
- 60 tects this rise and varies the flow of air to the curtain, or curtains, at the front, or varies the position of the curtain forming port or ports, so that the cushion pressure is decreased or the centre of pressure
- 65

moved, in a sense to counteract the lifting tendency caused by the wave. A reverse effect is created when the front end is over a wave trough. Such a trim control can be used to counteract undesirable 70 movements of the vehicle at any point on its periphery. The vehicle thus operates on a substantially even keel and does not have imposed upon it undesirable vertical accelerations due to passing over obstructions. 75

However, when a vehicle is operating over waves a number of times longer than the length of the vehicle, or over land undulations having characteristics similar to long waves, there is not the same need to 80 maintain the vehicle on an even keel as the vertical accelerations are quite moderate. The vehicle can thus travel at a constant height from the surface following the surface profile. In order to obtain such an 85 operating mode when a control means responsive to attitude variation of the vehicle is used for the said curtain flow and/or position variation, it is necessary to provide an override which renders the control means 90 inoperative when for example the vertical accelerations or the frequency of the vertical movement is below a predetermined value. Alternatively the response of the control means responsive to attitude variations may 95 be given a suitable time constant rather than override so that its effectiveness gradually approaches zero for very slow variations.

Attention is drawn to specification 100 No. 9900/59 (Serial No. 944502) from which the present application is divided and to copending application No. 34407/63 (Serial No. 944504).

WHAT WE CLAIM IS:—

1. A vehicle for travelling over a surface and which in operation is supported above that surface on cushions of pressurised gas, said vehicle including means for forming at least one primary cushion of pressurised 110 gas and means for forming at least one secondary cushion surrounding or distributed around the periphery of said primary cushion and adapted to exert stabilising forces on said vehicle. 115

2. A vehicle as claimed in claim 1 including means for forming a secondary cushion of pressurised gas extending entirely around the perimeter of the primary cushion of pressurised gas. 120

3. A vehicle as claimed in claim 1 including means for forming a series of secondary cushions of pressurised gas which extend in a continuous formation around the perimeter of the primary cushion of 125 pressurised gas.

4. A vehicle as claimed in claim 1 including means for forming a series of secondary cushions of pressurised gas spaced apart and distributed around the perimeter 130



the openings 66 and 67 being formed in the sliding plate 65.

As stated above, the compartmentation of the supporting cushion can be obtained, partially or wholly by the use of a structural member or structural members. Generally, the member or members will be positioned so that it or they are parallel to the intended direction of movement of the vehicle, although a flexible construction can be used for a member or members, positioned at an angle to the direction of movement of the vehicle. Alternatively the member or members may only project downwards a portion of the total cushion height, being either rigid or flexible, and a curtain or curtains of fluid may issue from the bottom of the member or members.

Figure 23 illustrates diagrammatically a construction primarily for a vehicle operating over water, in which the inner secondary curtains are replaced partially by keel-like members 90 having ports 91 at their bottom edge. Such a form of structural member may be used parallel to and at any angle to the direction of movement of the vehicle. The members 90 may be rigid or flexible.

Figure 24 illustrates diagrammatically the shaping of the bottom of the vehicle so as to replace the inner curtains. The shaping forms two projections 92 and 93 which approach the surface close enough to create a restriction which is effective to enable a pressure difference to occur between the cushion compartments on either side of the restriction. Provision may also be made for the ejection of fluid from the projections 92 and 93 to form curtains. Alternatively flexible members may be attached to the projections.

Where the variation of the flow of air to the various ports, and/or the moving of the position of a port or ports, is used for varying the trim of a vehicle, this provides a convenient means for maintaining the attitude of the vehicle over obstacles such as rocky ground or waves at sea. Taking as an example, a vehicle travelling over waves at sea, the trim of the vehicle can be controlled by a simple mechanism, such as gyroscopically controlled valve so that the vehicle remains on a substantially even keel.

The operation is as follows.

When the front of the vehicle meets a wave, which causes a locally reduced height and thus a locally increased pressure rise in the cushion, the vehicle tends to lift at the front. A suitably controlled valve detects this rise and varies the flow of air to the curtain, or curtains, at the front, or varies the position of the curtain forming port or ports, so that the cushion pressure is decreased or the centre of pressure

moved, in a sense to counteract the lifting tendency caused by the wave. A reverse effect is created when the front end is over a wave trough. Such a trim control can be used to counteract undesirable movements of the vehicle at any point on its periphery. The vehicle thus operates on a substantially even keel and does not have imposed upon it undesirable vertical accelerations due to passing over obstructions.

However, when a vehicle is operating over waves a number of times longer than the length of the vehicle, or over land undulations having characteristics similar to long waves, there is not the same need to maintain the vehicle on an even keel as the vertical accelerations are quite moderate. The vehicle can thus travel at a constant height from the surface following the surface profile. In order to obtain such an operating mode when a control means responsive to attitude variation of the vehicle is used for the said curtain flow and/or position variation, it is necessary to provide an override which renders the control means inoperative when for example the vertical accelerations or the frequency of the vertical movement is below a predetermined value. Alternatively the response of the control means responsive to attitude variations may be given a suitable time constant rather than override so that its effectiveness gradually approaches zero for very slow variations.

Attention is drawn to specification No. 9900/59 (Serial No. 944502) from which the present application is divided and to copending application No. 34407/63 (Serial No. 944504).

WHAT WE CLAIM IS:—

1. A vehicle for travelling over a surface and which in operation is supported above that surface on cushions of pressurised gas, said vehicle including means for forming at least one primary cushion of pressurised gas and means for forming at least one secondary cushion surrounding or distributed around the periphery of said primary cushion and adapted to exert stabilising forces on said vehicle.

2. A vehicle as claimed in claim 1 including means for forming a secondary cushion of pressurised gas extending entirely around the perimeter of the primary cushion of pressurised gas.

3. A vehicle as claimed in claim 1 including means for forming a series of secondary cushions of pressurised gas which extend in a continuous formation around the perimeter of the primary cushion of pressurised gas.

4. A vehicle as claimed in claim 1 including means for forming a series of secondary cushions of pressurised gas spaced apart and distributed around the perimeter



944,503

7

of the primary cushion of pressurised gas.

5. A vehicle as claimed in any one of the preceding claims comprising means for causing a fluid to issue from the lower part of the vehicle and form at least one curtain of moving fluid, said curtain forming at least part of the periphery of at least one of the cushions.

6. A vehicle as claimed in claim 5 comprising means for setting up at least one further or secondary curtain of moving fluid inboard of the first or primary curtain of moving fluid so as to contain between the two curtains the said secondary cushion or cushions of pressurised gas.

7. A vehicle as claimed in claim 3 wherein the secondary cushions have a common boundary with the primary cushion, said boundary being formed at least in part by a secondary curtain of fluid issuing from a supply port formed in the lower part of the vehicle comprising means for forming gaps in said curtain whereby gas can flow from the primary cushion through said gaps to form curtains of fluid flowing horizontally so as to form the boundaries between the adjacent secondary cushions of pressurised gas.

8. A vehicle as claimed in claim 1, or claim 3 or claim 4, comprising a first supply port formed in the lower part of the vehicle and extending to define a space beneath the vehicle, at least one further supply port extending partly inboard of the first supply port, intersecting the first supply port and extending partly outboard of the first supply port, and means for causing a fluid to issue from the supply ports to form primary and secondary curtains of moving fluid enclosing said primary cushion and said secondary cushions.

9. A vehicle as claimed in claim 6 or claim 8 in which the ports from which the fluid forming said curtains issues meet together so as to form regions within a cushion at which the fluid curtains extend close to one another comprising outlet transfer ports communicating with said regions and inlet ports communicating with regions in which said curtains are widely separated and ducts connecting each said outlet port to an inlet port.

10. A vehicle as claimed in any one of the preceding claims comprising at least one structural member depending below the vehicle, said structural member forming at least part of a boundary of a cushion.

11. A vehicle as claimed in claim 10 wherein at least part of the structural member is of flexible construction.

12. A vehicle as claimed in claim 10 or claim 11 wherein means are provided for causing a fluid to issue from the structural member to form at least one curtain of moving fluid which constitutes a further

part of the boundary of a cushion.

13. A vehicle as claimed in any one of the preceding claims in which at least part of the boundary of a cushion, is formed by a curtain of moving fluid issuing from the lower part of the vehicle, comprising means for varying the flow of fluid forming said curtain so as to vary the flow of gas to said cushion.

14. A vehicle as claimed in claim 13 in which said curtain issues from a supply port formed in the lower part of the vehicle, wherein the means for varying the flow of fluid forming the curtain comprises means for varying the width of the supply port.

15. A vehicle as claimed in claim 6, or claim 8 or claim 9 including means for diverting to the secondary curtain at a selected location a part of the fluid which would otherwise flow to the primary curtain, and/or diverting to the primary curtain at a selected location a part of the fluid which would otherwise flow to the secondary curtain.

16. A vehicle as claimed in claim 15 wherein the primary curtain comprises two parts, an inner part and an outer part immediately adjacent, comprising means for supplying a constant flow of fluid to one part of the primary curtain, and means for varying the relative flows of fluid to the other part of the primary curtain and to the secondary curtain.

17. A vehicle as claimed in claim 16 wherein both the primary curtain and the secondary curtain comprise two parts, an inner part and an outer part immediately adjacent, comprising means for supplying a constant flow of fluid to one part of each curtain, and means for varying the relative flows of fluid to the other parts of each curtain.

18. A vehicle as claimed in claim 17 wherein the curtain forming fluid is fed to the various parts of the curtains through separate ducts, the duct feeding one part of the secondary curtain terminating at its upstream end with pivoted members which are linked so as to remain parallel and together constitute a valve for varying the relative flows of fluid to the said other parts of each curtain.

19. A vehicle as claimed in claim 16 or claim 17 or claim 18, wherein the flow of fluid to one part of a curtain is fed through a duct which is wider than the duct through which is fed the fluid to the other part of a curtain.

20. A vehicle as claimed in any one of the claims 10 to 19 wherein the port or ports from which the curtain fluid issues extend in an annular or part annular configuration and the means for varying the flow of fluid forming the curtain or curtains comprises a flap or like valve of annular

or part annular configuration, said valve comprising sectors of stiff material with radial joints of flexible material.

21. A vehicle as claimed in any one of the claims 15 to 19 wherein means are provided for diverting fluid from the primary curtain to the secondary curtain at one locality and simultaneously diverting fluid from the secondary curtain to the primary curtain at another locality which is radially opposed to the first locality, relative to the centre of gravity of the vehicle.

22. A vehicle as claimed in claim 15 in which the fluid forming the curtains flows through ports formed in the bottom surface of the vehicle, comprising at least one valve for varying the relative effective widths of the supply ports.

23. A vehicle as claimed in claim 6 or claim 7 or claim 8 or claim 9 wherein the secondary curtain is formed by a jet of fluid which passes through a region in which it is exposed on its two sides to the two regions between which it is to sustain a pressure difference, so as to be deflected by said pressure difference, and then through a diaphragm having curved vanes for re-directing said jet, the curvatures of said vanes being so arranged as to impart to the jet a measure of redirection in the sense towards the region of higher pressure.

24. A vehicle as claimed in claim 23 in which the secondary curtain forms a boundary between a primary cushion and a secondary cushion and is exposed on the one side to the pressure of said primary cushion and on the other to the pressure of the said secondary cushion wherein the jet is directed, when the pressure of the primary cushion is predominant, towards a region at one end of said diaphragm where the vanes thereof exert no deflection upon it and is directed, when the pressure cushion is predominant, towards a region at the other end of the diaphragm where the vanes thereof exert a deflection upon it in a sense towards the secondary cushion.

25. A vehicle as claimed in claim 6 or claim 7 or claim 8 or claim 9 in which the fluid forming the primary and secondary curtains issues through supply ports formed in the lower part of the vehicle, wherein the supply port through which the fluid forming the primary curtain issues is higher

than the supply port through which the fluid forming the secondary curtain issues.

26. A vehicle as claimed in any one of the preceding claims in which at least part of a boundary of a cushion is formed by a curtain of moving fluid, wherein the fluid is ejected with an inclination inwards away from the boundary of the cushion.

27. A vehicle as claimed in claim 26 in which the curtain forming fluid issues from the vehicle in a downward direction toward the surface above which the vehicle is to be supported wherein the curtain forming fluid issues at an angle between 45° and 60° to the vertical.

28. A vehicle as claimed in any one of the preceding claims in which at least part of the boundary of a cushion is formed by a curtain of moving fluid flowing from the vehicle toward the surface wherein the curtain is in the form of a closed vortex.

29. A vehicle as claimed in any one of the claims 13 to 22 including control means connected to the means for varying the flow of curtain forming fluid and responsive to variations in attitude of the vehicle, said control means being arranged to operate the means for varying the flow of curtain forming fluid so as to produce a stabilising moment on the vehicle in opposition to said variations in attitude of the vehicle.

30. A vehicle as claimed in claim 29 including override means responsive to vertical accelerations of the vehicle, said override means operating to override said control means where the vertical accelerations of the vehicle are below a predetermined value.

31. A vehicle as claimed in claim 29 including override means responsive to the frequency of the variations in attitude of the vehicle, said override means operating to override said control means when the frequency of the variations in attitude to the vehicle is below a predetermined value.

32. A vehicle as claimed in claim 29 wherein said control means includes means for varying the response of the control means in accordance with a time constant, whereby the operation of the control means reduces as the frequency of the attitude variations of the vehicle reduces.

H. W. GRACE,

Chartered Patent Agent,
Agent for the Applicants.

