July 13, 1965 C. S. COCKERELL 3,194,333

GROUND EFFECT MACHINES WITH SUPPLY AND RECOVERY PORTS IN A COMMON DUCT

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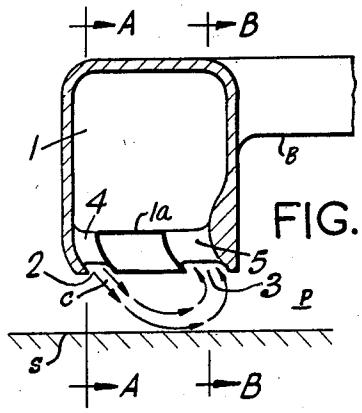


FIG.1.

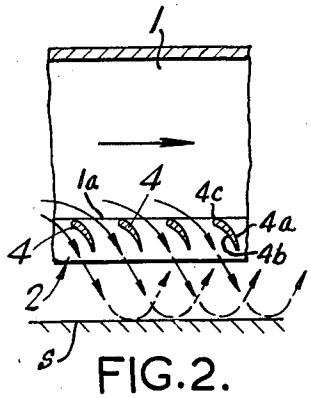


FIG.2.

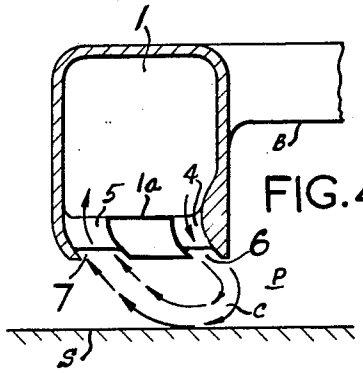


FIG.4.

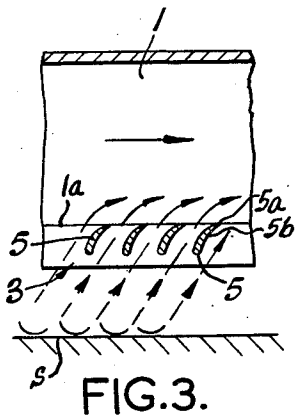


FIG.3.

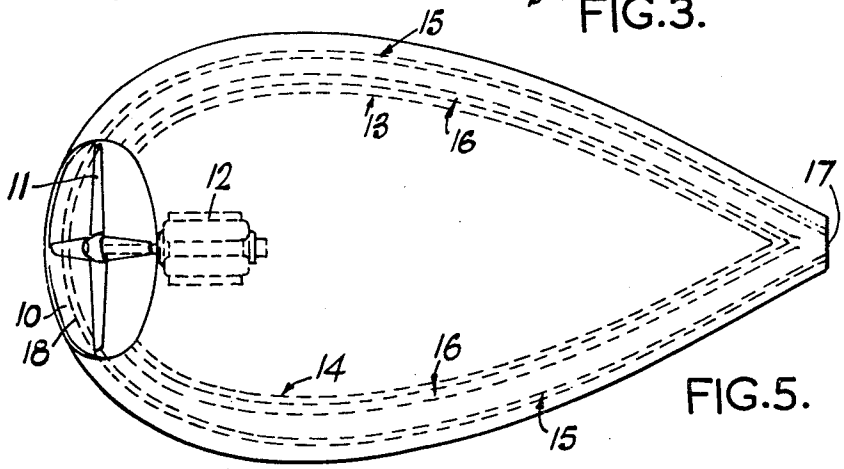


FIG.5.

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FIG.6.

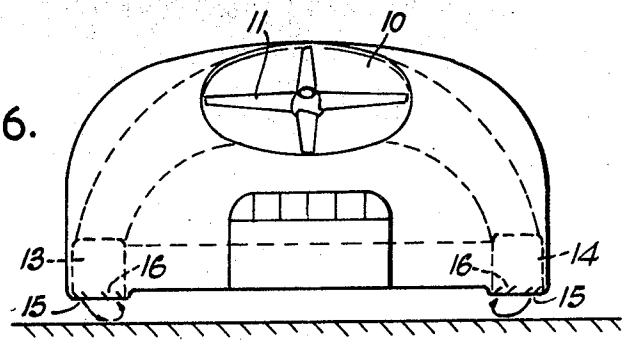


FIG.7.

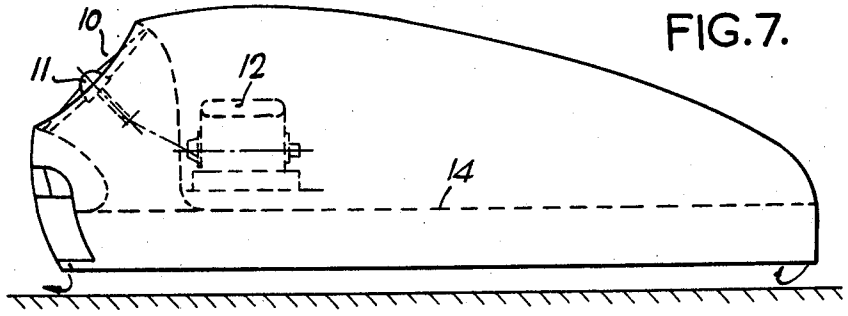
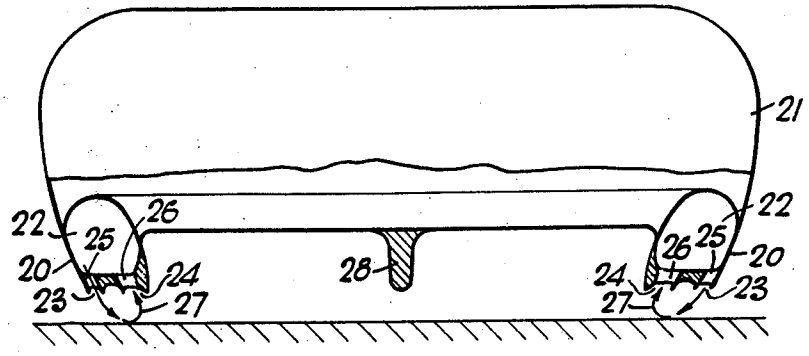


FIG.8.



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FIG. 9.

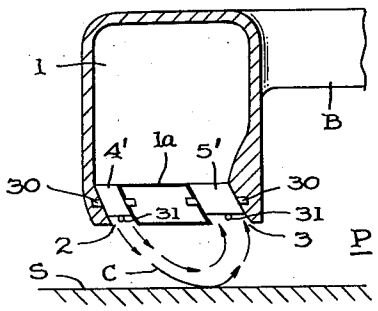


FIG. 10.

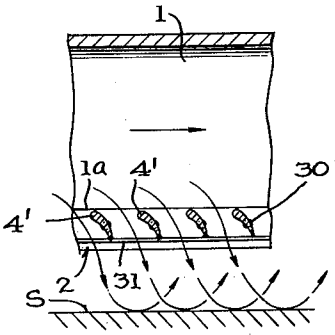


FIG. 12.

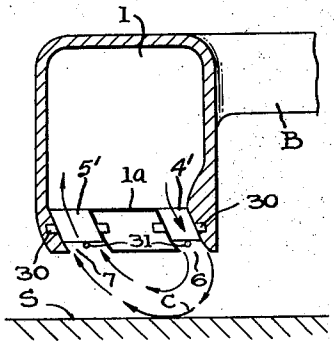
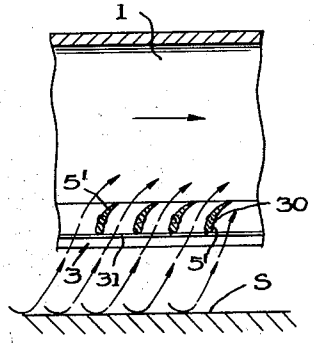


FIG. 11.



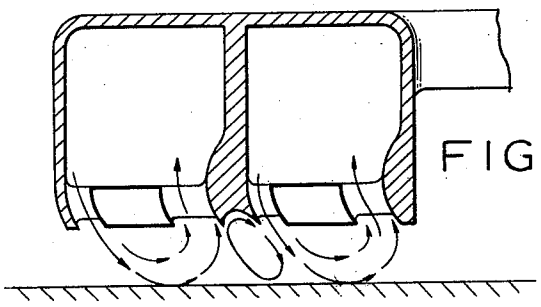


FIG. 13.

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GROUND EFFECT MACHINES WITH SUPPLY AND RECOVERY PORTS IN A COMMON DUCT

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Claims priority, application Great Britain, Apr. 5, 1960, 12,095/60
11 Claims. (Cl. 180—7)

This invention relates to vehicles in which provision is made for the ejection of one or more jets of fluid through one or more annular supply ports, or series of supply ports in an annular configuration, in the bottom of the vehicle to form one or more fluid curtains, the ejection of the fluid resulting in the formation of a cushion of pressurised fluid, the said cushion being contained beneath the vehicle, at least in part, by the said fluid curtain, and in which at least part of the fluid forming the said curtain is recovered through at least one recovery port or series of recovery ports in an annular configuration. Such vehicles are described in the specifications of co-pending application Serial No. 837,428, filed Sept. 1, 1959.

In vehicles of the type described in the above mentioned specifications the fluid which is ejected through the supply ports is supplied by means of at least one duct, the fluid being fed into the duct by a suitable compressor or the like. The fluid recovered through the recovery ports is again generally fed to at least one further duct, the fluid in this duct being used in various ways such as by recirculating it back to the initial curtain, using it to form a further curtain or for propulsion or other purposes.

The amount of fluid remaining in the duct feeding the supply port, or ports, decreases as the distance from the compressor increases, due to the fluid being ejected through the supply port. The required cross sectional area of the duct decreases, therefore, from one end to the other. Conversely, the amount of fluid in the recovery duct increases as more recovered fluid is fed to it and the required cross section increases up to the point of utilisation of the recovered fluid. To use ducts of constant cross sectional area is inefficient in weight and space. The use of tapering ducts does not always provide the most efficient and economical method.

The provision of a common duct for the fluid for the supply port or ports and for the recovered fluid such that the decrease in volume due to the ejection of curtain fluid is counterbalanced by the increasing volume of recovered air is a convenient form of installation and according to the invention there is provided a vehicle of the type described in which co-acting supply and recovery ports are formed in a wall of a common duct, and in which there is provided means for causing a flow of energised fluid through the common duct, ejection means in the supply port or ports and induction means in the recovery port or ports whereby when a flow of energised fluid occurs through the duct the ejection means causes at least part of the energised fluid to be discharged through the supply port to form the curtain and the induction means causes at least part of the fluid forming the curtain to be induced through the recovery port into the duct.

Generally the fluid is a gas and for convenience is hereinafter referred to as air, although other gases such as exhaust gases can be used.

Certain embodiments of the invention will now be described by way of example in conjunction with the accompanying drawings in which:

FIGURE 1 is a vertical cross section through the periphery of a vehicle, illustrating one embodiment of the invention,

FIGURE 2 is a fragmentary cross section on the line A—A of FIGURE 1,

FIGURE 3 is a fragmentary cross section on the line B—B of FIGURE 1,

FIGURE 4 is a cross section similar to FIGURE 1, illustrating an alternative arrangement,

FIGURE 5 is a plan view of a vehicle embodying the invention,

FIGURE 6 is a front elevation of the vehicle illustrated in FIGURE 5,

FIGURE 7 is a side elevation of the vehicle illustrated in FIGURE 5,

FIGURE 8 is a vertical cross section normal the fore and aft axis, of a further form of vehicle embodying the invention,

FIGURES 9, 10, 11 and 12 are cross sections similar to FIGURES 1, 2, 3 and 4, respectively, illustrating modifications of the arrangements shown in the latter figures wherein the vanes are rotatably mounted, and

FIGURE 13 is a cross section similar to FIGURE 1 illustrating another form of the invention.

FIGURES 1–3 illustrate the application of the invention to an air curtain system in which the curtain forming air is recovered through recovery ports situated inboard of the supply ports. A duct 1 is formed round the periphery of the bottom of the vehicle. A supply port 2 and a recovery port 3 are formed in the bottom wall of the duct, the ports being annular or composed of a series of ports in an annular configuration, the recovery port 3 being substantially parallel to and inboard of the supply port 2. Fixed in the supply port 2 are vanes 4 of aerofoil cross section, having one surface 4*a* convex and the other surface 4*b* concave. The leading edges 4*c* of the vanes are level with the inner bottom surface 1*a* of the duct 1, the concave faces facing against the direction of flow of air through the duct when the vehicle is in operation. The shape and disposition of the vanes is readily seen in FIGURE 2 which is a cross section on the line A—A of FIGURE 1. Further vanes 5 of similar cross section are fixed in the recovery port, the vanes having their trailing edges 5*a* level with the inner bottom surface 1*a* of the duct 1. Their concave faces 5*b* face in the same direction as the air flow in the duct, and the shape and disposition of the vanes 5 is shown in FIGURE 3 which is a cross section on the line B—B of FIGURE 1.

In operation air is caused to flow continuously through the duct 1 by one or more compressors or the like. Some of the air is ejected through the vanes 4 in the supply port 2 in the form of a curtain C flowing inwards toward the centre of the bottom B of the vehicle. As a cushion P of pressurised air builds up beneath the vehicle, the vehicle tends to lift, and the curtain of air is deflected, part flowing into the recovery port 3. The recovery of air through the recovery port is enhanced by the induction effect of the air in the duct 1 flowing past the trailing edges 5*a* of the vanes 5. As the cushion of pressurised air beneath the vehicle builds up it is lifted off the surface S and eventually an equilibrium condition is reached in which the curtain of air from the supply port flows first downwards and inwards until it reaches the surface when it is deflected inwards. The cushion of pressurised air then deflects the curtain round and upwardly towards the bottom surface of the vehicle, the air flowing into the recovery port 3 assisted by the aforementioned induction effect, as can be seen in FIGURES 1 and 3.

The supply port 2 is shown in FIGURE 1 as being directed inwards towards the centre of the vehicle at about 45° with the vertical but this angle may be varied.

In an alternative arrangement, as illustrated in FIGURE 4, the relative positions of the supply and recovery ports are reversed, the supply port 6 being on the inside and the recovery port 7 on the outside. The air curtain

will then have the form shown, flowing first downwards and inwards and being deflected round and outwards by the cushion pressure.

The provision of a common duct provides a convenient system for vehicles in which the recovered air is used for propulsion. FIGURES 5, 6, 7 and 8 illustrate two forms of such vehicles.

In the vehicle shown in FIGURES 5, 6, and 7, air is drawn in through an intake **10** by a propeller **11**. The propeller is driven by a motor **12**. The air is forced by the propeller into two ducts **13** and **14** positioned one along each side of the vehicle and extending substantially the length thereof. The cross section of the ducts **13** and **14** are for example similar to that shown in FIGURE 1. A supply port **15** and a recovery port **16** are formed in the bottom wall of the duct for the supply and recovery of the air and the arrangement of the vanes in the ports **15** and **16** is similar to that shown in FIGURES 2 and 3. The ducts **13** and **14** are terminated at their rear ends to form propulsion nozzles **17** and the recovered air plus any additional air which flows through the ducts is expelled from the nozzles **17** and propels the vehicle. Some of the air entering the ducts **13** and **14** at the front of the vehicle is fed to a port **18** formed in the bottom of the vehicle and extending across the front of the vehicle, to form a curtain. This curtain may be of a simple form, like the single curtain shown in co-pending application Serial No. 627,925, filed December 12, 1956, or of the type in which at least part of the curtain-forming air is recovered into the vehicle through a recovery port and then reissues through a supply port so as to either recirculate in the curtain or form a second curtain, as shown in co-pending application Serial No. 809,699, filed April 29, 1959.

The invention is particularly applicable for vehicles in which side walls extend downwards on each side of the vehicle, substantially for the length thereof, such as are described and illustrated in the co-pending application Serial No. 819,968, filed June 12, 1959. FIGURE 8 is a vertical cross section normal to the longitudinal axis of such a vehicle. A side wall **20** extends along each side of the vehicle projecting downwards from the main body **21** of the vehicle. Each side wall comprises a duct **22** through which energised air is caused to flow. Supply ports **23** and recovery ports **24** are formed in the bottom walls of the side walls and vanes **25** and **26** are positioned in the supply ports **23** and recovery ports **24** respectively, as described above. The flow of energised air through the ducts **22** results in the formation of air curtains **27** as described above and the air is eventually expelled from propulsion nozzles at the rear ends of the ducts **22** in a similar manner as in FIGURE 5. Further air curtains are formed across the back and front of the vehicle by any suitable means, such as those disclosed in the above-mentioned co-pending application Serial No. 819,968 and the corresponding Australian Patent No. 232,436.

The cushion space may be subdivided by further structural members depending from the bottom surface of the vehicle, as shown at **28** in FIGURE 8, for example. Alternatively the cushion space may be subdivided by further air curtains formed from additional supply ports in the bottom surface of the vehicle, such as those shown in the previously mentioned co-pending application Serial No. 627,925 and the corresponding British Patent No. 854,211. Subdivision by air curtains is preferable when in a direction transverse to the direction of movement of the vehicle. Curtains of air may also be formed from the bottom edges of any depending structural members as disclosed in the above-mentioned co-pending application Serial No. 819,968 and Australian Patent No. 232,436. The member **28** in FIGURE 8 may be provided with a supply port in the bottom edge and a duct leading from the air supply to the port. Such an air curtain will normally issue in a vertically downward direction. By subdividing the cushion space, the stability of the vehicle is improved.

The vanes **4** and/or **5** of FIGURES 1 to 4 and the vanes **25** and/or **26** of FIGURE 8 may be mounted in their respective ports so that they are capable of rotation about horizontal axes. For example, as shown in FIGURES 9–12, the vanes **4'** and **5'** may be mounted on horizontal pivots **30** and rotated about the axes thereof by flexible wires or cables **31** suitably attached to the vanes at positions offset from said axes. Such rotation acts to vary the angle of incidence of the vanes relative to the air flow through the ducts **1** or **22**. By this means, the mass flow of the air curtains may be varied either for the whole length of the vehicle, or locally. Directional components may also be imposed on the air forming the curtains to provide propulsion, steering moments or the like or combinations of these.

Multiple curtain systems may be formed for a part or whole of the periphery of the vehicle by the provision of two or more ducts, substantially parallel to each other for a part or the whole of the periphery of the vehicle, as shown in FIGURE 13.

I claim:

1. A vehicle of the type described comprising a duct positioned round at least part of the periphery of the bottom of the vehicle, the longitudinal axis of the duct being substantialy parallel to the periphery of the vehicle, supply and recovery ports formed in the wall of the duct and extending along said duct parallel to the longitudinal axis thereof, means for causing a flow of energised fluid through the duct in a direction parallel to its longitudinal axis, ejection means in the supply port whereby when a flow of fluid occurs through the duct in a direction parallel to said longitudinal axis at least part of the fluid is ejected through the supply port to form a curtain, and induction means in the recovery port whereby at least part of the fluid forming the curtain is induced through the recovery port into the duct to rejoin the fluid flowing axially through said duct.

2. A vehicle as claimed in claim **1** in which the duct comprises a section formed along each side of the vehicle in the bottom thereof, flow of fluid through the said duct sections causing the formation of a curtain of fluid beneath each duct section, separate curtain forming means being provided at the front and rear of the vehicle for closing any gap which occurs between the curtains formed beneath the duct sections along the sides of the vehicle.

3. A vehicle as claimed in claim **1** in which the duct extends along each side of the vehicle and round the rear of the vehicle, separate curtain forming means being provided at the front of the vehicle.

4. A vehicle as claimed in claim **2** in which the duct sections along the sides of the vehicle depend from the bottom surface of the vehicle in the form of walls.

5. A vehicle as claimed in claim **1** in which the duct terminates in a propulsion nozzle, and at least part of the fluid flowing through the duct is ejected through the propulsion nozzle.

6. A vehicle as claimed in claim **1** in which the ejection means in the supply port comprises a series of vanes normal to the flow of fluid through the duct, and having a positive angle of incidence relative to such flow.

7. A vehicle as claimed in claim **6** in which means are provided for varying the angle of incidence of the vanes.

8. A vehicle of the type described comprising a duct positioned around at least part of the periphery of the bottom of the vehicle, the longitudinal axis of the duct being substantially parallel to the periphery of the vehicle, supply and recovery ports formed in the wall of the duct and extending along said duct parallel to the longitudinal axis thereof, means for causing a flow of energised fluid through the duct in a direction parallel to its longitudinal axis, ejection means in the supply port whereby when a flow of fluid occurs through the duct

in a direction parallel to said longitudinal axis at least part of the fluid is ejected through the supply port to form a curtain, and induction means in the recovery port whereby at least part of the fluid forming the curtain is induced through the recovery port into the duct to rejoin the fluid flowing axially through said duct, said induction means comprising a series of vanes normal to the flow of fluid through the duct, and having a negative angle of incidence relative to such flow.

9. A vehicle as claimed in claim 8 in which means are provided for varying the angle of incidence of the vanes.

10. A vehicle of the type described comprising a duct positioner round at least part of the periphery of the bottom of the vehicle, the longitudinal axis of the duct being substantially parallel to the periphery of the vehicle, supply and recovery ports formed in the wall of the duct and extending along said duct parallel to the longitudinal axis thereof, means for causing a flow of energised fluid through the duct in a direction parallel to its longitudinal axis, ejection means in the supply port comprising a first series of vanes normal to the flow of fluid through the duct, and having a positive angle of incidence relative to such flow, whereby when a flow of fluid occurs through the duct in a direction parallel to said longitudinal axis at least part of the fluid is ejected through the supply port to form a curtain, and induction means in the recovery

port comprising a second series of vanes normal to the flow of fluid through the duct, and having a negative angle of incidence relative to such flow, whereby at least part of the fluid forming the curtain is induced through the recovery port into the duct to rejoin the fluid flowing axially through said duct.

11. A vehicle as claimed in claim 10 including means for varying the angles of incidence of said first and second series of vanes.

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