Feb. 1, 1966 C. S. COCKERELL 3,232,366

GROUND EFFECT MACHINE WITH PERMEABLE MATERIAL SUPPORT MEMBER

Filed June 13, 1962 4 Sheets-Sheet 1

FIG. 1.

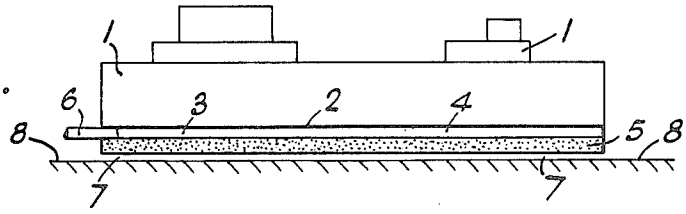


FIG. 2.

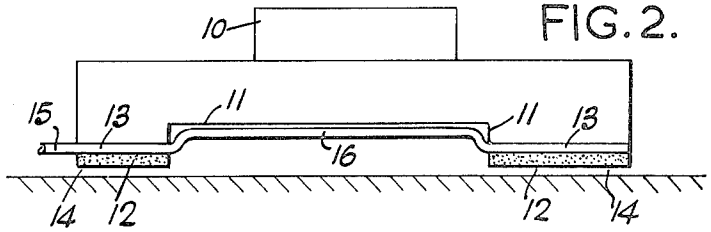


FIG. 3.

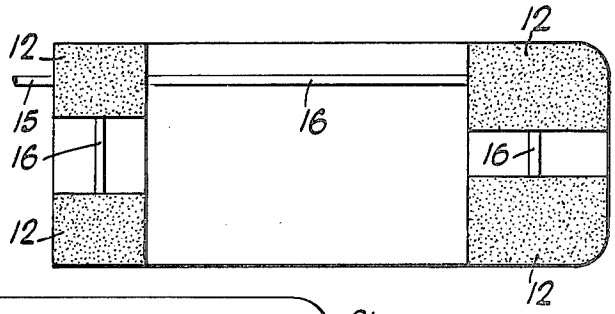


FIG. 5.

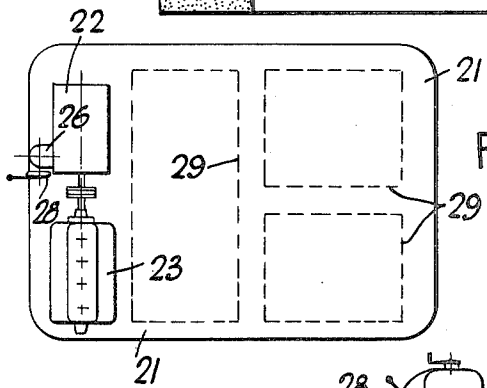
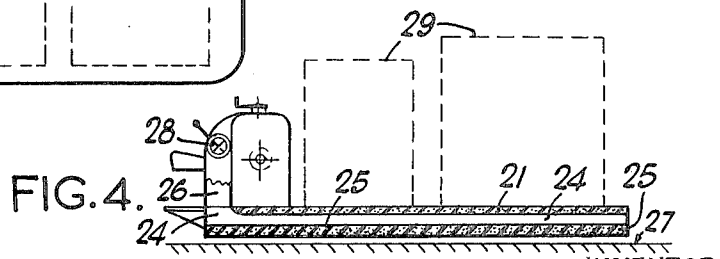


FIG. 4.



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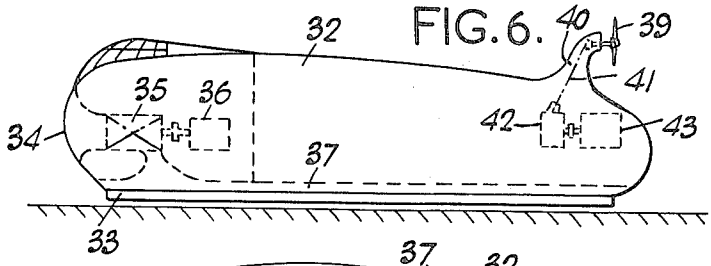
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Feb. 1, 1966 C. S. COCKERELL 3,232,366

GROUND EFFECT MACHINE WITH PERMEABLE MATERIAL SUPPORT MEMBER

Filed June 13, 1962 4 Sheets-Sheet 2

FIG. 6.



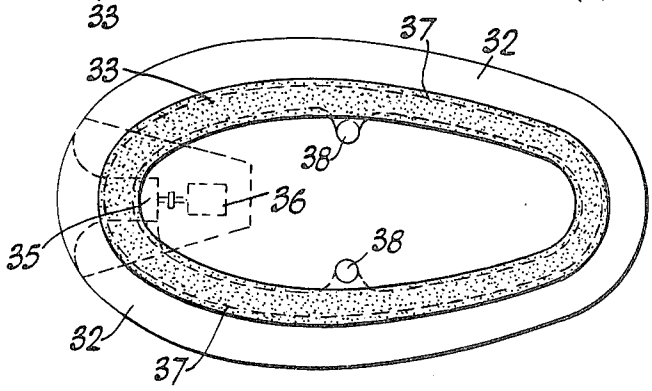


FIG. 7.

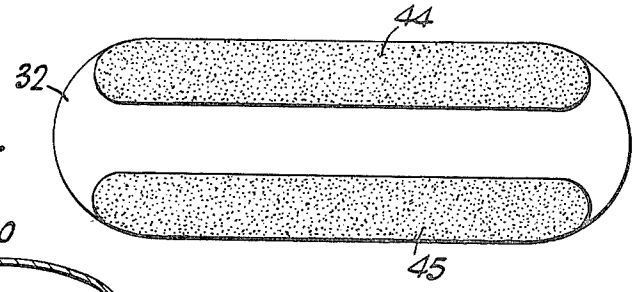


FIG. 8.

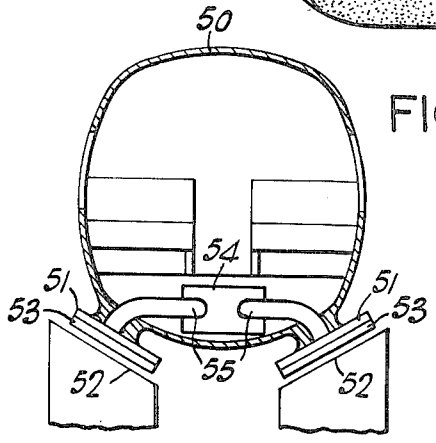


FIG. 9.

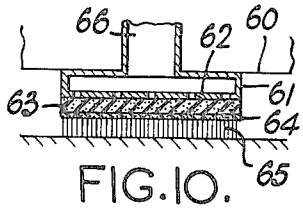


FIG. 10.

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Feb. 1, 1966 C. S. COCKERELL 3,232,366

GROUND EFFECT MACHINE WITH PERMEABLE MATERIAL SUPPORT MEMBER

Filed June 13, 1962 4 Sheets-Sheet 3

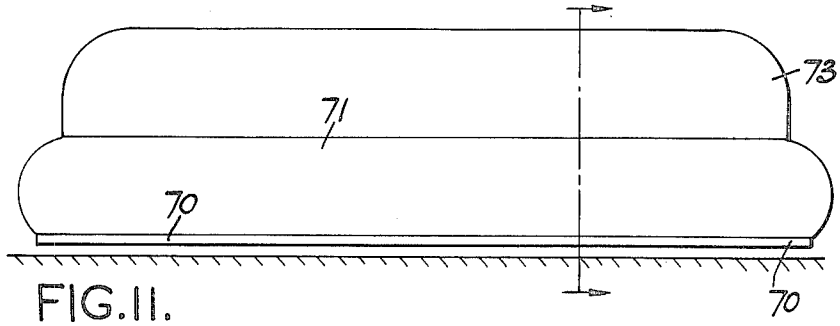


FIG.11.

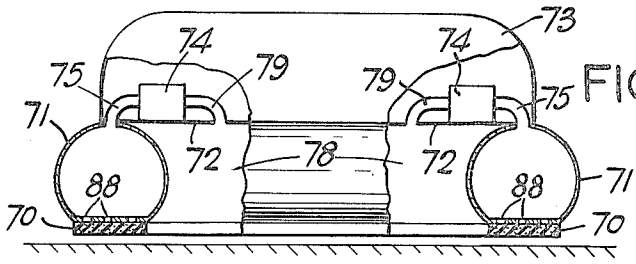
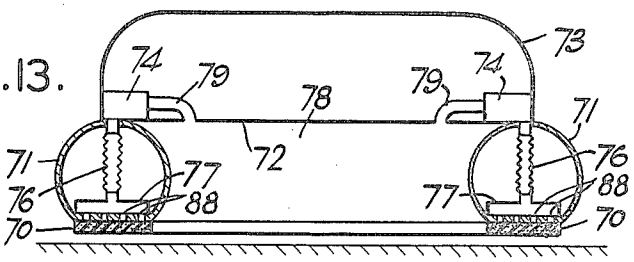


FIG.12.

FIG.13.



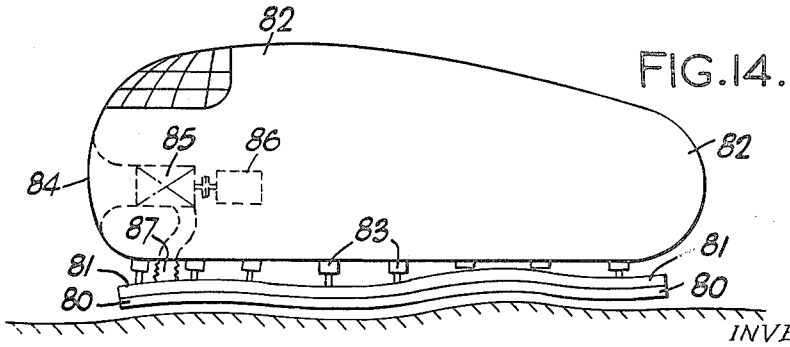


FIG.14.

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Feb. 1, 1966 C. S. COCKERELL 3,232,366

GROUND EFFECT MACHINE WITH PERMEABLE MATERIAL SUPPORT MEMBER

Filed June 13, 1962 4 Sheets-Sheet 4

FIG.15.

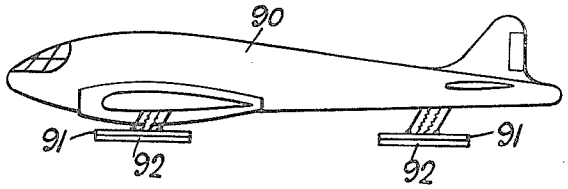
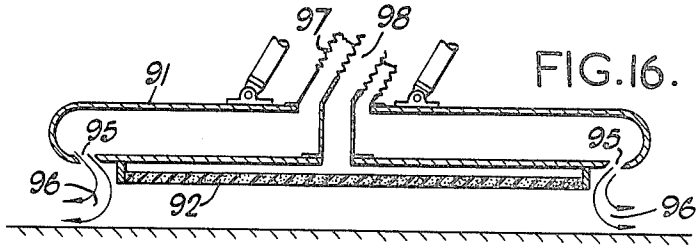


FIG.16.



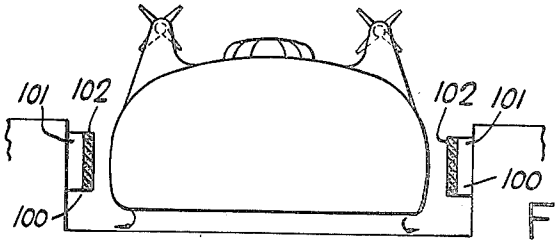


FIG.17.

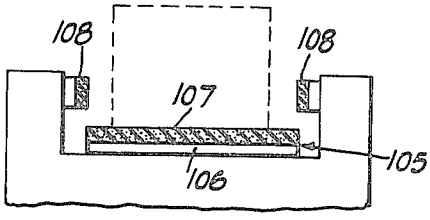
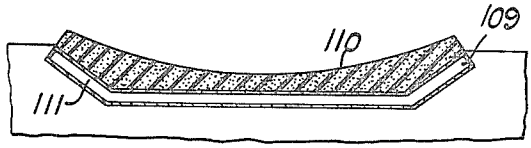


FIG.18.

FIG.19.



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United States Patent Office

3,232,366

Patented Feb. 1, 1966

3,232,366

GROUND EFFECT MACHINE WITH PERMEABLE MATERIAL SUPPORT MEMBER

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Filed June 13, 1962, Ser. No. 202,238

Claims priority, application Great Britain, June 13, 1961, 21,275/61

3 Claims. (Cl. 180—7)

This invention relates to means for supporting a structure, member or body, or any other load out of contact with a surface.

It is known to support a load over a surface by means of a cushion of pressurised gas, the cushion of gas being contained at its periphery either by downwardly extending members beneath which the gas escapes through a small clearance or by curtains of moving fluid which flow across the gap between the underside of the load and the surface over which the load is supported. In some instances a combination of downwardly extending members and fluid curtains has been used.

The present invention is concerned with an alternative arrangement in which a film of gas is maintained between the member and the surface so that at least part of the load is supported by the member. Where the member only partly supports the load, it is possible to form a cushion of pressurised gas which supports the remainder of the load.

According to the invention there is provided load supporting means for supporting a structure, member or body out of contact with a bearing surface comprising a support member located between the structure, member or body and the bearing surface, said support member comprising a body of material permeable to a fluid, said body of material having a boundary face presented either towards the surface or towards the structure, member or body and flexibly displaceable therefrom, and means for feeding pressurised fluid through said permeable body to maintain a film of pressured fluid between the boundary face and the bearing surface or between the boundary face and the structure, member or body. As used herein, the term "permeable" means a porous member or body of material which allows the passage of fluid through the pores or interstices thereof so that the fluid issues from the boundary face thereof over substantially its entire area.

The permeable material support member can be flexible and it may be more resistant to gas flow in directions parallel to said boundary surface than in directions normal thereto. For example, the material may be of tubular texture having tubules extending therethrough normal to the boundary surface or it may be in the form of a pile fabric. Alternatively or in addition means may be provided for restricting or preventing escape of gas through the lateral boundaries of said body or said body may have an area of boundary surface great in relation to its dimension normal thereto, i.e. it may have a large area/thickness ratio whereby the escape of gas laterally from the body is small in relation to the flow of gas through said boundary surface, under operating condition. Various of these expedients may be used in combination according to the clearance required to be established between the support member and the surface over which it is to operate and the degree of irregularity of the surface.

According to the invention in one form a support member of the nature above described may circumscribe or at least partially circumscribe a space between the load and the surface within which a pressurised gas cushion may be built up.

The invention will be readily understood by the following description of certain embodiments in conjunction with the accompanying drawings in which:

FIGURE 1 is a side view of a load supported by one embodiment of the invention.

FIGURE 2 is a side view of a load supported by another embodiment of the invention.

FIGURE 3 is an inverted plan view of the arrangement illustrated in FIGURE 2.

FIGURE 4 is a vertical cross-sectional elevation of a load carrying vehicle embodying the invention.

FIGURE 5 is a plan view of the vehicle illustrated in FIGURE 4.

FIGURE 6 is a side view of a further form of vehicle embodying the invention.

FIGURE 7 is an inverted plan view of the vehicle illustrated in FIGURE 6.

FIGURE 8 is a similar view to that of FIGURE 7 illustrating a modification thereof.

FIGURE 9 is a transverse cross-section of another form of vehicle embodying the invention.

FIGURE 10 is a vertical cross-section through a support member according to the invention.

FIGURE 11 is a side view of a further form of load carrying means embodying the invention.

FIGURE 12 is a vertical cross-section through the apparatus illustrated in FIGURE 11.

FIGURE 13 is a similar cross-section to that of FIGURE 12 but illustrating a modification thereof.

FIGURE 14 is a side view of a further form of vehicle embodying the invention.

FIGURE 15 is a side view of an aircraft embodying the invention.

FIGURE 16 is a vertical section of one of the support members illustrated in FIGURE 15, to an enlarged scale.

FIGURE 17 illustrates a further embodiment of the invention.

FIGURE 18 is a cross-section through another embodiment.

FIGURE 19 is a similar view to that of FIGURE 18 illustrating a modification thereof.

FIGURE 1 illustrates the application of the invention to supporting a load clear of a surface. The load **1** can be of varying configuration provided it has a substantially flat bottom surface **2**. To the bottom surface is attached a member **3** which comprises a hollow top portion **4** and a permeable support member **5**.

When it is desired to lift the load **1** pressurised air is supplied to the hollow portion **4** by means of a pipe **6** from any suitable source. The air percolates through the permeable support member **5** to form a thin layer or clearance **7** between the bottom of the support member and the surface **8** over which the load is to be supported. The clearance **7** is exaggerated in FIGURE 1 for clarity and is normally quite small. The arrangement can be used for moving various loads, a particular example being heavy machinery. The support member can form part of the mounting means for the machine when it is in position or extendable feet may be provided.

The invention as illustrated in FIGURE 1 can also be applied to loads which do not have a flat surface extending for the entire base of the load. This is illustrated in FIGURES 2 and 3. The load **10** has a recessed bottom surface **11** having a central portion which is higher than the end portions. Members **12** are attached to the bottom surface at the ends each comprising a hollow portion **13** and permeable support member **14**. Air is supplied by a pipe **15**, the support members being connected by means of further pipes **16**. The operation of the arrangement is as that illustrated in FIGURE 1.

The invention can also be applied to loads, which have no flat bottom surface at all by providing suitable attach-

ment means. For example the support member or members can be attached by means of short struts or legs to the bottom surface of the load.

This invention is also applicable to structures and the like on which it is desired to put loads for transport. One such example is a platform truck such as is used in factories. FIGURES 4 and 5 illustrate such a truck which comprises a platform **21** at one end of which is mounted a compressor **22** driven by an engine **23**. A cavity **24** is formed in the bottom surface of the platform **21**, the cavity being closed at its lower limit by a permeable support member **25**. A duct **26** connects the compressor **22** to the cavity **24**.

In operation, air is fed by the compressor **22** via the duct **26**, to the cavity **24**. The air percolates through the support member **25** and forms a thin layer of air between the bottom of the support member and the surface **27** over which the truck is to move. The truck is thus supported on a thin layer of air and is very easily moved. As the load is spread over the entire area of the platform the loading on the surface **27** is low. When the truck is at the position at which it is to be loaded or unloaded, the air supply to the cavity can be shut off, either by shutting off the engine **23** or by providing a valve **28** in the duct **26**. Articles to be carried on the truck are placed on the platform as indicated at **29**. The truck can be moved by pushing or in any other suitable manner.

A vehicle for transporting passengers and/or freight is illustrated in FIGURES 6 and 7. The vehicle comprises a body portion **32** having a permeable support member **33** attached to and extending round the periphery of the bottom surface. An intake **34** is provided at the front of the vehicle, communicating with the inlet of a compressor **35** driven by an engine **36**. The outlet of the compressor **35** is connected to a duct **37** formed inside the body **32**. The bottom surface of the duct is perforated to allow air to flow from the duct **37** to the support member **33**. A plenum chamber is formed within the support member and air is fed to this plenum chamber, preferably directly from the duct **37** via ports **38**. Alternatively the plenum chamber may be fed from a separate source. The support member thus acts to form a seal round the plenum chamber.

In operation, air is drawn in through the intake **34** by the compressor **35** and is fed to the duct **37**. From the duct **37** the air passes through the perforated bottom surface of the duct and percolates through the support member **33** to form a thin layer of air between the bottom surface of the support member **33**, and the surface over which the vehicle is operating. Air is also fed to the plenum chamber and the weight of the vehicle is partly supported by the pressure in the plenum chamber and partly by the permeable support member **33**. The vehicle can be propelled by air propellers **39**, mounted on pylons **40** at the rear of the vehicle, and driven by shafting **41** and gearing **42** by engines **43**.

Instead of the support member **33** extending over the whole bottom surface of the vehicle, or around the entire periphery it can be in the form of separate sections. Such an arrangement is illustrated in FIGURE 8, which is an inverted plan view similar to that of FIGURE 7 in which two sections **44** and **45** of permeable material are provided located adjacent to each side of the vehicle.

As the film of air between the permeable support member or members and the surface over which the vehicle is operating is comparatively thin, the vertical irregularities of the surface are required to be less than this thickness if contact between the member and the surface is to be avoided. When operating over a firm surface, therefore, it is preferable that the surface is prepared by levelling. This preparation of the surface can be extended so that in addition to providing a comparatively smooth track over which the vehicle operates it can also provide directional control of the vehicle. FIGURE 9 is a transverse cross-section of a vehicle operating over such a prepared track. The vehicle comprises a body portion **50** having two members **51** attached to its bottom surface, one along each side of the vehicle. The supporting members **51** are inclined slightly to the horizontal, as shown, and cooperate with similarly inclined tracks **52**. Permeable supports **53** are attached to the bottom surfaces of the members **51** and are supplied with air from a compressor **54** via ducts **55**.

The clearance between the permeable support member and the surface can be increased for the same air flow, or maintained at a nominal value by a decreased air flow, by attaching a multiplicity of fibres beneath the permeable member. Such a construction is illustrated somewhat diagrammatically in FIGURE 10. The bottom surface **60** of the vehicle has attached to it a duct **61** having a perforated bottom surface **62** to which is attached a permeable support member **63**. To the bottom surface of the support member is attached a layer of permeable material **64** having a pile surface **65**. Air is fed to the duct **61** via pipe **66** from any convenient source, and flows to the permeable member **63** through the perforated surface **62**. The air percolates through the member **63** and the layer of permeable material **64**. The pile surface **65** acts as a labyrinth and restricts the flow of air to the outside atmosphere. Thus a similar clearance as obtained in the examples described above, can be maintained with a reduced air flow. Alternatively with the same air flow as in the above examples, an increased clearance can be obtained.

In a further form of vehicle or load carrying device the permeable support member can be flexibly attached to the body of the vehicle. Thus, for example as shown in FIGURES 11, 12 and 13 a permeable support member **70** is attached to the bottom of a flexible tube **71** attached to the periphery of the bottom surface **72** of the vehicle body **73** to form a plenum chamber **78**. As illustrated in FIGURE 12 the flexible tube **71** is inflated by air fed into the tube by means of a duct **75** connected to a compressor **74**. A duct **79** connects the plenum chamber **78** and the compressor **74** through which air can be fed to the plenum chamber. The bottom surface of the tube **71** is perforated and air flows from the tube through the perforations **88** to the permeable support member **70**. The air percolates through the support member and forms a thin film of air between the member and the surface. By such an arrangement the vehicle can operate over a surface having irregularities which exceed the thickness of the air film as the tube **71** can deflect to ride over the irregularities. FIGURE 13 shows an alternative construction to that shown in FIGURE 12 in which the tube **71** is completely sealed. The air from the compressor **74** is fed via a series of flexible pipes **76** to a duct **77** formed in the bottom of the tube **71**. The bottom of the tube is perforated, as before, and air flows direct from the compressor via the pipes **76** to the duct **77** and thence to the permeable support member **70**. The support member in such arrangements is flexible either by being of flexible material or by being made in sections flexibly connected.

Instead of the permeable member being attached to a flexible member attached directly to the vehicle body, it may be flexibly attached by other means such as springs or pneumatic or hydraulic rams. In FIGURE 14 a permeable support member **80** is attached to a duct **81**, the whole assembly being attached to the vehicle body **82** by rams **83**. Air is drawn in through an intake **84** by a compressor **85** driven by an engine **86**. The air is fed to the duct **81** via flexible pipes **87**. The permeable support member **80** and the duct **81** may be of flexible construction or they may be of rigid sections flexibly connected together.

The invention may be used as take off and landing aids for aircraft. This is illustrated in FIGURES 15 and 16. The aircarft **90** has a number of pads **91**, on the bottom surfaces of which are fixed permeable sup-

port members 92, the members extending over the whole of the surface or only round the periphery. The pads at the front of the aircraft may be retractable into the fuselage. The small clearance provided by the air film is likely to be sufficient for taxying but increased clearances are desirable at other times particularly when landing. This can be accomplished as shown in FIGURE 16, which is a vertical cross-section through a pad, by causing air to issue from a port or ports 95 adjacent to the periphery of the pads, to form one or more air curtains 96. By this means a cushion, or cushions, of pressurised air can be formed beneath each pad to support it at an increased clearance for high speeds. On landing, for example, the air curtains are formed and as the aircraft approaches the surface the cushion of air is formed. As the aircraft reduces speed, the air forming the air curtains is gradualy cut off until the pads are supported only by the thin film of air percolating through the permeable support members 92. The air supply to the supporting members 92 and to the ports 95 can separate as shown being supplied by coaxial flexible pipes 97 and 98.

In the examples so far described, the load has been considered as being supported over a surface, the support member or members being attached to the load. The invention is also applicable to other forms of supporting a load. Thus, for example, it may be desired to support a load sideways. One typical application is for fenders as used to prevent damage to ships and the like when coming alongside, or tied up to, a loading quay.

FIGURE 17 illustrates the application of the invention to the docking of vehicles of the type which are supported by one or more cushions of pressurised gas. Such vehicles can be constructed of relatively thin material and can be readily damaged. To prevent such damage one or more support members 100 can be attached to the sides of the quay or dock, each member comprising a hollow portion 101, with a layer of permeable material 102 on its outer face. When a vehicle is entering the dock, or while it is tied up, air can be fed to the permeable material via the hollow portion 101 of each member. If the vehicle tends to come into contact with the side of the dock a layer of pressurised air will form between the permeable material 102 and the side of the vehicle. If the vehicle is entering the dock then it can continue mooring without damaging its skin.

A further application of the invention is to supporting a load over a surface by means of one or more support members attached to the surface. FIGURE 18 is a cross section through an arrangement such as a conveyor. The surface of the conveyor is in the form of a support member 105 comprising a lower hollow member 106 having an upper surface which is perforated and to which is attached a layer of permeable material 107. If desired, further members 108 can be provided at each side to prevent articles from falling off the conveyor.

Instead of being flat, the support member can be contoured to suit the shape of the load being supported. Thus, as illustrated in FIGURE 19 the support member 109 has the permeable material 110 shaped to form a concave form. Where it is desired to support a load having a complex shape, such as, for example, a human body, or part of a body, then the permeable material can be shaped by moulding or other methods to follow closely the shape of the body or part of the body. Air can be supplied to the permeable material by means of hollow members 111.

The permeable members, in the various examples described above, can be of differing forms. For example they may be substantially rigid, being of a sintered material or foamed plastic. Alternatively they can be flexible such as of sponge rubber or plastic.

The members can be arranged to have porosity, or flow, in one direction only, i.e. normal to the bottom surface, or can be arranged to have porosity in all directions. In this latter case it is preferable to seal the peripheral edge to restrict loss of air.

The form will often be dictated by the particular use or by the particular arrangement. Thus where the arrangement is for supporting and moving loads over very smooth surfaces then the substantially rigid form can be used. For use over rougher surfaces the more flexible forms of sponge rubber or plastic would normally be used. Where the roughness of the surface is likely to exceed the air film thickness, such as when flexibly attached sections are used, as in FIGURES 11 and 14, and where fairly high speeds are likely to be encountered, as in FIGURES 15 and 16, then a support member comprising a multiplicity of fine flexible tubes could provide an advantageous arrangement. The tubes are arranged to hang vertically, and if contact occurs with the surface, from time to time, then the bottoms of the tubes can erode without materially interfering with the operation of the support member. The tubes can either be arranged to hang freely but closely together, or they can be attached to one another, for example by adhesive, to form a resilient compact mass.

Where a layer of pervious material having a pile or like surface is used, the material forming the layer may be of a fibrous nature, which will form the pile, or the material may have the pile forming fibres woven into it.

A vehicle supported over a surface by a permeable member will have an initial degree of stability as any variation in its attitude with respect to the surface will also result in a variation of local clearance. This will produce a local increase in the pressure of the air in the film at the smaller clearance and a decrease in the pressure at the greater clearance, this pressure difference tending to correct the attitude of the vehicle. The stability can be increased by providing downward extending projections which, in the event of a variation in attitude of the vehicle touch or almost touch the surface and tend to sub-divide the area beneath the permeable member into a series of compartments. Such projections could be formed, for example, by strips of material which have a pile surface.

Whilst the examples described above have referred to the use of air to form the film between the boundary surface of the support member and the supporting surface, other gases can readily be used. Thus where expedient exhaust gases from a propulsion engine can be used or a mixture of air and exhaust gases. For medical use, sterilised air or other gases or sterilised liquids can be used.

I claim:

1. Load supporting means for supporting a load over a surface comprising a support member beneath the load, said support member comprising a body of material permeable to a fluid, said body of material having a boundary face presented towards the surface and flexibly displaceable from the surface, means including said body of permeable material circumscribing a space between said load and said surface within which a cushion of pressurised gas can be built up, means for supplying pressurised gas to said space, and means for causing pressurised fluid to percolate through the permeable body and to issue from said boundary face over substantially the entire area thereof to maintain a film of pressurised fluid between the boundary face and the surface.

2. A vehicle adapted to be supported above a surface on a relatively thin layer of fluid comprising a body and at least one load supporting means attached to said body, said load supporting means being as claimed in claim 1.

3. A vehicle adapted to be supported above a surface on a relatively thin layer of fluid comprising a body, a support member beneath said body comprising a body of material permeable to said fluid, said body of material having a boundary face presented downwards towards

the surface over which the vehicle is operating, means for causing pressurised fluid to percolate through said permeable body and to issue from said boundary face over substantially the entire area thereof to maintain a film of pressurised fluid between said boundary face and said surface, means including said body of permeable material circumscribing a space between the vehicle body and the surface within which a cushion of pressurised gas can be built up, and means for supplying pressurised gas to said space, said body of permeable material having a greater permeability in a vertical direction than in a horizontal direction.

References Cited by the Examiner

UNITED STATES PATENTS

1,169,682	1/1916	Sargent.	
2,395,727	2/1946	Devol.	
2,676,851	4/1954	Sylvest	302—29
2,918,183	12/1959	Petersen et al.	
2,938,590	5/1960	Barnett	180—7
3,013,505	12/1961	Burke	180—7
3,052,483	9/1962	Petersen	180—7
3,055,312	9/1962	Jay et al.	180—7
3,055,446	9/1962	Vaughan	180—7
3,082,836	3/1963	Billman	180—7
3,090,327	5/1963	Crowley	180—7
3,104,496	9/1963	Macks	180—7 X
3,140,753	7/1964	Bertin	180—7

FOREIGN PATENTS

1,238,499	7/1960	France.

OTHER REFERENCES

Publication "Design News," May 23, 1960, pages 6 and 7.

A. HARRY LEVY, *Primary Examiner.*