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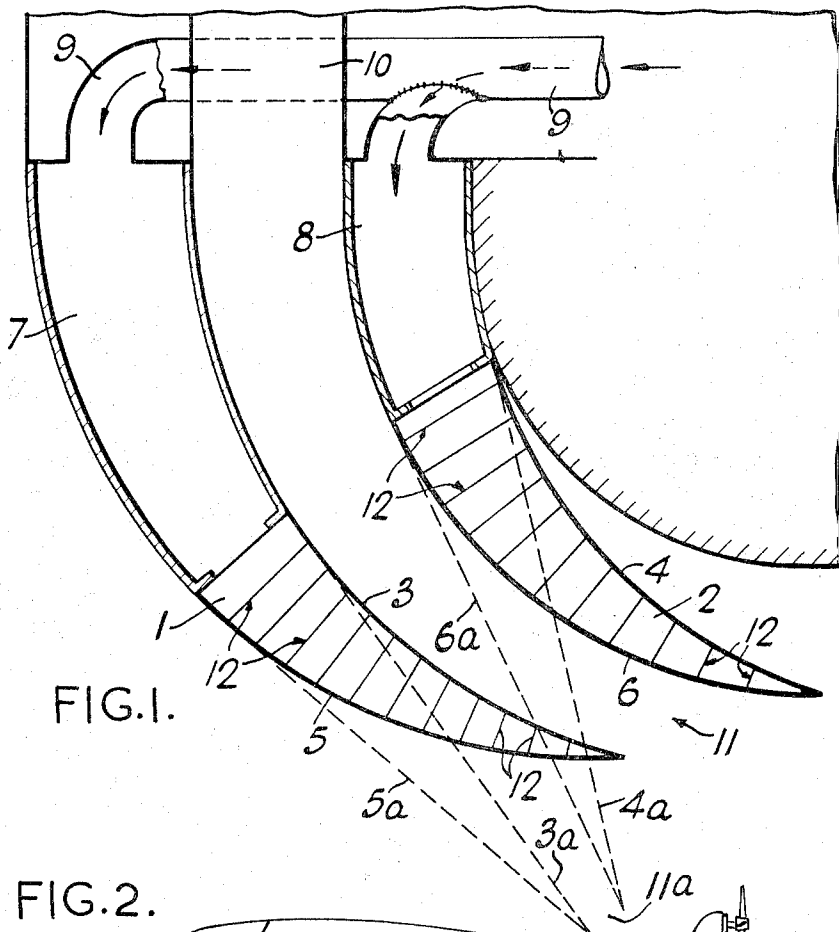
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3,289,778

INFLATABLE NOZZLE FOR SURFACE EFFECT DEVICES

Filed June 6, 1963

3 Sheets-Sheet 1



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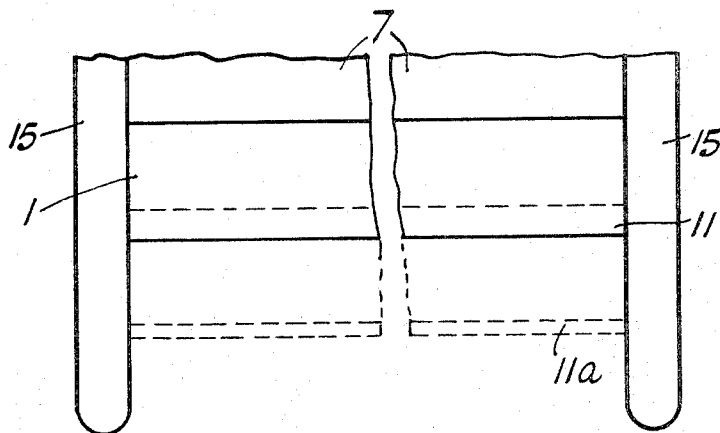


FIG. 3.

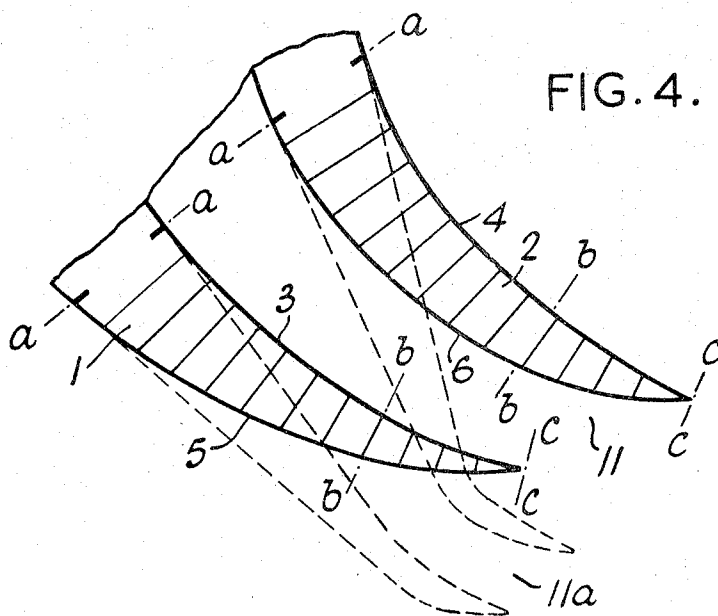


FIG. 4.

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FIG. 5.

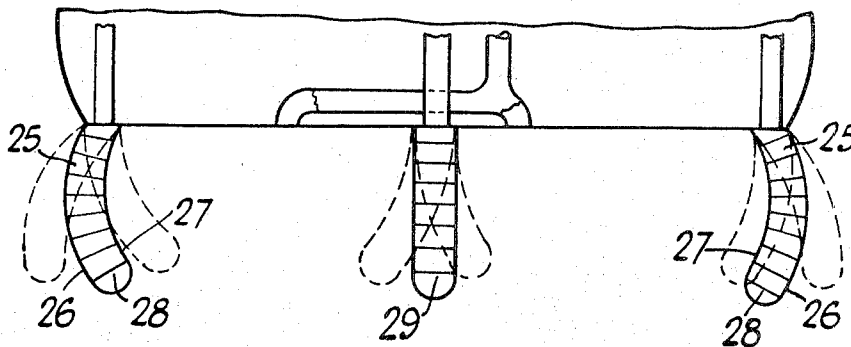
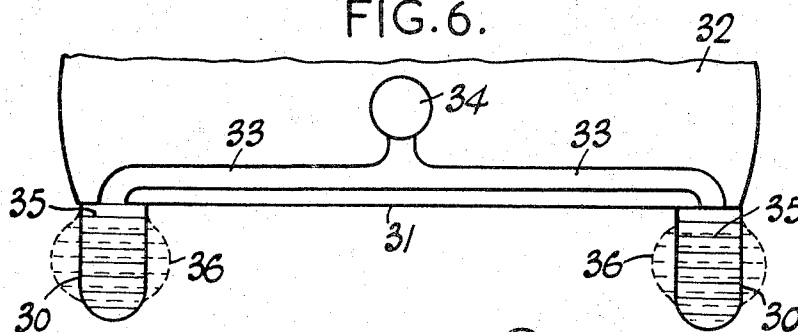
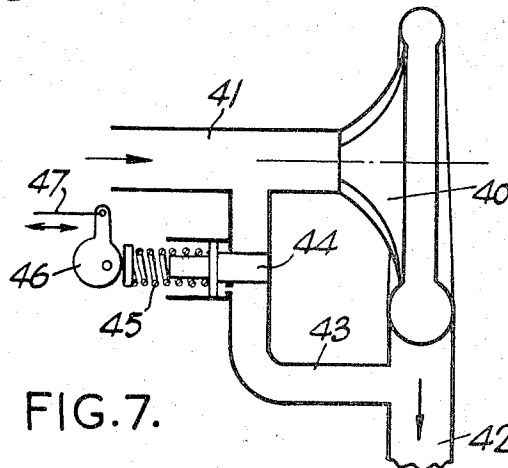


FIG. 6.



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INFLATABLE NOZZLE STRUCTURE FOR SURFACE EFFECT DEVICES

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5 Claims. (Cl. 180-7)

This invention relates to inflatable structures which are constrained to form a predetermined shape when inflated.

Such structures can be used for many purposes and one use is in vehicles adapted to be supported over a surface by one or more cushions of pressurised gas contained beneath the vehicle.

The containment of the cushion can be by structural members depending below the bottom of the vehicle, by curtains of moving fluid issuing from the bottom of the vehicle or by a combination of both. The fluid in many cases may issue from the lower edge of a structural member such as a wall.

It is often desirable that the structural members should be readily deformable so as to yield when in contact with obstacles. By yielding, damage to the structures can be avoided and possible retardation of the vehicle also prevented or reduced.

By making the structures in the form of hollow inflatable members having flexing walls and providing constraining means between the walls the structures can be caused to assume predetermined shapes when inflated and yet be readily deformable. Typical examples of such constructions are described and illustrated in Patents Nos. 3,204,932 and 3,231,037.

If the walls of the structures are of inextensible material, the structures maintain a constant shape when inflated, except when deformed by an external force, and by varying the inflation pressure the stiffness of the structure can be varied.

It is sometimes convenient to be able to vary the inflated shape of the structure, and according to the invention there is provided an inflatable structure constrained to form when inflated various shapes comprising two walls and constraining means connecting the walls, the walls being constrained thereby to a predetermined spaced apart relationship, in which at least part of one of the walls and/or at least part of the constraining means is/are at least partly of extensible material, the remainder being of less easily extensible material, whereby the shape of the structure can be varied by variation of the inflation pressure.

The invention will be readily understood by the following description of some embodiments with reference to the accompanying drawings in which:

FIGURE 1 is a cross-section through one embodiment,

FIGURE 2 is a side view of a vehicle embodying the invention,

FIGURE 3 is a partial end view of the vehicle illustrated in FIGURE 2,

FIGURE 4 illustrates a modification of the embodiment illustrated in FIGURE 1,

FIGURE 5 is a vertical cross-section through a vehicle embodying a further form of the invention, normal to the fore and aft axis,

FIGURE 6 is a further vertical cross-section through a vehicle embodying another form of the invention, and

FIGURE 7 illustrates diagrammatically apparatus for varying the inflation pressure of the inflatable structures.

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FIGURE 1 illustrates a nozzle which is formed by two inflatable structures 1 and 2, the structures having inner walls 3 and 4 and outer walls 5 and 6 respectively. The structures are connected at their upper ends to recuperation spaces 7 and 8 to which air is supplied by a pipe 9 from a suitable pressurising source. Air is also supplied via a duct 10 to the nozzle and issues from a supply port 11 formed by the lower end of the nozzle. The distances between the pairs of walls 3 and 5 and 4 and 6 are stabilised by cords 12 which constrain the walls to a predetermined spaced apart relationship. The construction so far described is as described in the above mentioned Patent No. 3,231,037, each of the structures 1 and 2 being of wedge-shaped cross-section and having walls of flexible air-impervious rubber-like material, such as neoprene sheeting reinforced with fabric.

When the structures are inflated by the air supplied from pipe 9 through recuperation spaces 7 and 8, they assume a shape for example as shown in full lines in FIGURE 1, the cross-sectional shape of each structure being stabilised against dilation when inflated by the cords 12 which extend between the two walls of each structure substantially normal to the central axis thereof when it is in its normal inflated shape. The cords 12 are effective only in tension and resist dilation of the structure by the inflating air; when the structure is required to collapse, however, these cords offer no resistance. As explained in the above mentioned application, if a load is applied to the structures sufficient to overcome the inflation pressure which results in zero tensions in the inner walls 3 and 4, the structures can rapidly collapse. If the inner walls 3 and 4 are made of more extensible material than the outer walls 5 and 6, then by increasing the inflation pressure the structures will alter their shape, for example to that indicated by the dotted lines 3A, 4A, 5A and 6A. By so altering the shape of the structures, the port 11 is lowered. The angle of ejection of the air is also altered and the position of ejection has moved laterally.

FIGURES 2 and 3 illustrate the application of nozzles as in FIGURE 1 to a vehicle for operating over water in which the gaseous cushion is contained along the sides of the vehicle by downwardly extending side-walls 15.

In FIGURE 2, which is a side view, nozzles are provided at each end of the vehicle, extending between the side-walls 15. As illustrated, the nozzles are in the position as shown by the full lines in FIGURE 1. By increasing the inflation pressure, the nozzles will alter in shape so that the ports 11 at the bottoms of the nozzles are lower. If the cushion space is divided, for example by an inflated member 16 extending between the side-walls at a position intermediate between the ends of the vehicle, the cushion pressure in one part can be varied relative to the other part by causing the port 11 of one nozzle to vary in height relative to the port of the other nozzle.

In the vehicle illustrated in FIGURE 2, the curtains of fluid formed from the nozzles comprise air drawn in through intakes 17 by compressors 18 driven by engines 19. The air is delivered to the nozzles via ducts 20. The nozzles, and the member 16, are inflated by air drawn in through one of the intakes 17 by a compressor 21 driven by an engine 22. The air is fed via ducts 23 to the nozzles and member 16. An example of a control system for controlling and varying the inflation pressure is described below in relation to FIGURE 7.

The effect of lowering the port 11 by increasing the inflation pressure of the nozzles is clearly seen in FIGURE 3, which is a partial end view of the vehicle illustrated in FIGURE 2, to an enlarged scale.

At the lower inflation pressure the supply port 11 is in the higher position, whilst when the inflation pressure is increased the supply port is lower at 11A.

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The increased inflation pressure will increase the stiffness of the structures and also the resistance to collapse. The increase in stiffness can be prevented from becoming inconvenient by using material which will stretch easily, thereby requiring only small increases in inflation pressure. When used for vehicles operating over water, with side-walls, the supply ports can be lowered to reduce the immersion of the side-walls as explained in Patent No. 3,207,113. This normally occurs only when the water is smooth and thus contact between the nozzles and the water is less likely to occur, in which case the increased stiffness of the nozzles is not so important. The vehicle can be designed to operate with the structures inflated to a pressure which results in the supply ports being at a mid-position and suitable for water conditions which would occur for the majority of the operating time, inflation pressure being reduced when the roughness increases and increased when the water is smoother.

When a nozzle structure as illustrated in FIGURE 1 has its shape altered by varying the inflation pressure, the width of the supply port 11 is varied and also the angle of ejection of the air through port 11. This can be avoided at least to some extent by applying the invention further. Thus, as illustrated in FIGURE 4, the part *a-b* of each inner wall 3 and 4 is of extensible material and part *b-c* is of inextensible material and part *a-b* of each outer wall is of inextensible material and part *b-c* of extensible material then when the inflation pressure is increased, although the main part of the structures deflect downwards, the ends deflect upwards to give an effect by which the width of the supply port is decreased less than would otherwise occur and also results in a substantially unaltered ejection angle or at least a smaller change in ejection angle than would otherwise occur.

FIGURE 5 illustrates the application of the invention to a vehicle in which the gaseous supporting cushion is contained for at least part of its periphery by a downwardly extending inflatable structure 25. The structure is formed by spaced apart walls 26 and 27 constrained to a predetermined spaced relationship by cords 28. By varying the inflation pressure the structure 25 can be caused to assume varying shapes as indicated by the dotted lines. By making the structure in separate air tight sections, it is possible to vary one section relative to another and thus vary the centre of pressure of the gaseous cushion. By varying all the sections together the cushion area can be varied. Further, by subdividing the cushion space by similar downwardly extending inflatable structures 29 and varying the inflation pressure thereof, the relative areas of the subdivided cushion spaces can be varied. By maintaining different pressures in the subdivided cushion spaces stabilising forces can be produced on the bottom surface of the vehicle. The member 16 in FIGURE 2 can be of the same form as the inflatable structure 29 and its shape varied by variation of the inflation pressure.

Instead of the constraint between the walls of a structure being by cords, the walls can be constrained by the space between them being filled by a foamed rubber or plastic.

The shape of an inflated structure can also be varied by varying the inflation pressure if the constraint between the walls is extensible, even if the walls are unextensible. Thus, for example, as illustrated in FIGURE 6, a side wall for a vehicle can be raised and lowered by making at least some of the constraint extensible. Each side wall 30 is in the form of an inflatable flexible structure attached to the bottom 31 of the vehicle 32 and air is fed to the side walls via ducts 33 from a pressurising source 34. The structures are constrained to assume predetermined shapes by cords 35. By making the cords 35 of extensible material, such as rubber, the shape the walls 30 assume can be controllably varied. If the walls assume the shape shown in FIGURE 6 at one inflation

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pressure then by increasing the inflation pressure the walls will assume a shape somewhat as indicated by the dotted lines 36. By dividing the side walls into separate air-tight lengths by flexible diaphragms it is possible to vary the inflation pressure length to length and vary the shape. By suitable means it is possible to vary the pressure successively along a side wall to lift and lower the lower edge to pass over obstructions, such as waves.

The example illustrated in FIGURE 6 is for a vehicle in which the side walls act as the constraining means for substantially the whole vertical dimension of the gaseous cushion but it is possible to provide means for forming fluid curtains from the bottom edges of the side walls. Generally the fluid supply will be separate from the inflating fluid, although where conditions are suitable the side walls can be inflated by the fluid which then issues from the bottom edges to form curtains of moving fluid.

The invention can be applied to many inflatable structures, as for example, for parts of inflatable vehicles.

The walls of structures may be made in various ways. When inextensible, they may be of flexible material such as rubber or synthetic rubber impregnated cloth, the fabric of the cloth reinforcing the rubber or synthetic rubber and preventing it from extending. Alternatively they can be of relatively inflexible material in sections joined together flexibly. Where the walls are extensible, various materials may be used, such as the well-known one-way and two-way stretch nylon materials used in the production of clothing, impregnated with rubber, and the extensibility may vary from place to place, as by simply varying the thickness of the material. Other examples of extensible and inextensible materials usable in the present invention are disclosed in the patent to Mauney et al., Patent No. 2,743,510. Inextensible sections can be joined by extensible sections.

The constraining means, again, can comprise various arrangements. A series of cords can be used, or perforated diaphragms, or the shape can be filled or partly filled with a foamed material which can be inextensible or extensible as the case may be. When extensible, the extensibility can be varied from place to place in the structure. Extensible or inextensible walls can be used in combination, together with extensible and inextensible constraining means also in combination.

Where structures are to return to their original shape when the inflation pressure is restored to the datum level, clearly the extensible materials must be of an elastic nature, so that they can regain their original dimensions. The terms extensible and less easily extensible are intended to be interpreted as restricted in this way.

FIGURE 7 illustrates diagrammatically an example of a variable pressure system for inflating the various structures. The compressor 40 draws in air through a duct 41 and expels it into a duct 42. The duct 42 leads to the inflatable structures. A by-pass 43 connects the outlet of the compressor with the inlet, flow through the by-pass being controlled by a pressure control valve 44. The control valve 44 is loaded by a spring 45 having an abutment which is movable by a cam 46. The cam 46 is rotated via a flexible control wire 47, operated by the driver for example. Once a pressure has been built up in the inflatable structures to a value dictated by the control valve 44, the valve opens and the flow from the compressor outlet flows through the by-pass 43 back to the inlet of the compressor. By rotating the cam 46 the loading of the spring 45 can be increased and thus the inflation pressure increased. Where all of the inflatable structures are to be controlled in unison, only one control system as in FIGURE 7 need be provided. If however the inflation pressures of the nozzles at each end of the vehicle illustrated in FIGURE 2 are to be varied relative to one another, then it will generally be most convenient to provide a system as in FIGURE 7 at each end of the vehicle. The compressor 40 can be quite small as once

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the structures are inflated any mass flows to the structures are very small.

The inflation of the inflatable structures can be of any suitable fluid. Generally inflation in vehicles supported by gaseous cushions is usually air or exhaust gases or a mixture thereof. In other applications other gases can be used.

We claim:

1. A flexible nozzle comprising two spaced apart members forming a port between their free ends, each of said members being in the form of an inflatable structure constrained to form when inflated various shapes dependent upon the inflation pressure and comprising a pair of inner and outer spaced apart gas-impervious walls of flexible material defining an inflatable space therebetween, constraining means connecting said walls and constraining the latter to said spaced apart relationship, the parts of said inner and outer walls adjacent said port being of inextensible and extensible material, respectively, and the remaining parts of said inner and outer walls being of extensible and inextensible material, respectively, means for supplying inflation gas to the space defined by said walls, and means for controlling and varying the inflation pressure in said space, whereby the characteristics of the nozzle may be varied by variation of the inflation pressure.

2. A flexible nozzle as claimed in claim 1 wherein the characteristics of the nozzle varied by variations of the inflation pressure varies the angle of ejection from the nozzle.

3. A vehicle for travelling over a surface and which in operation is supported above the surface by at least one cushion of pressurised gas formed beneath the vehicle in which the cushion is contained for at least part of its periphery by an inflatable structure, wherein the inflatable structure is constrained to form when inflated various shapes dependent upon the inflation pressure, said structure comprising a pair of inner and outer spaced apart gas-impervious walls, the inner wall being closer to the gas cushion than the outer wall, constraining means connecting said walls and constraining the latter to said spaced apart relationship, at least the major part of the inner wall being of extensible material and at least the major part of the outer wall being of less easily extensible, flexible material, means carried by the vehicle for supplying gas under pressure to inflate said structure, and means oper-

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able while the vehicle is in operation for controlling and varying the pressure of said gas, whereby the shape of the structure can be varied by varying the inflation pressure.

4. A vehicle as claimed in claim 3 wherein the part of the inner wall which is of extensible material is connected to the part of the outer wall which is of less easily extensible, flexible material, and said constraining means are themselves of less easily extensible material, whereby a bending strain is applied to the structure by the inflation pressure.

5. A vehicle for travelling over a surface and which in operation is supported above the surface by at least one cushion of pressurised gas formed beneath the vehicle in which the cushion of pressurised gas is contained at the upper part of its periphery by a flexible nozzle and at the lower part of its periphery by a curtain of moving fluid issuing from the bottom of the nozzle, the nozzle comprising two spaced apart members, at least one member being of the form of an inflatable structure constrained to form when inflated various shapes depending upon the inflation pressure and comprising a pair of spaced apart gas-impervious walls defining an inflatable space therebetween, constraining means connecting said walls and constraining the latter to said spaced apart relationship, part of the structure being of extensible material and the remainder being of less extensible material, means for supplying gas to the space between said walls to inflate said structure, and means for controlling and varying the inflation pressure in said space, and means for supplying a fluid under pressure to said nozzle.

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