May 19, 1970 F. L. GIRAUD 3,512,604

FLUID CUSHION SKIRT ARRANGEMENTS FOR GROUND-EFFECT MACHINES

Filed June 27, 1968 2 Sheets-Sheet 1

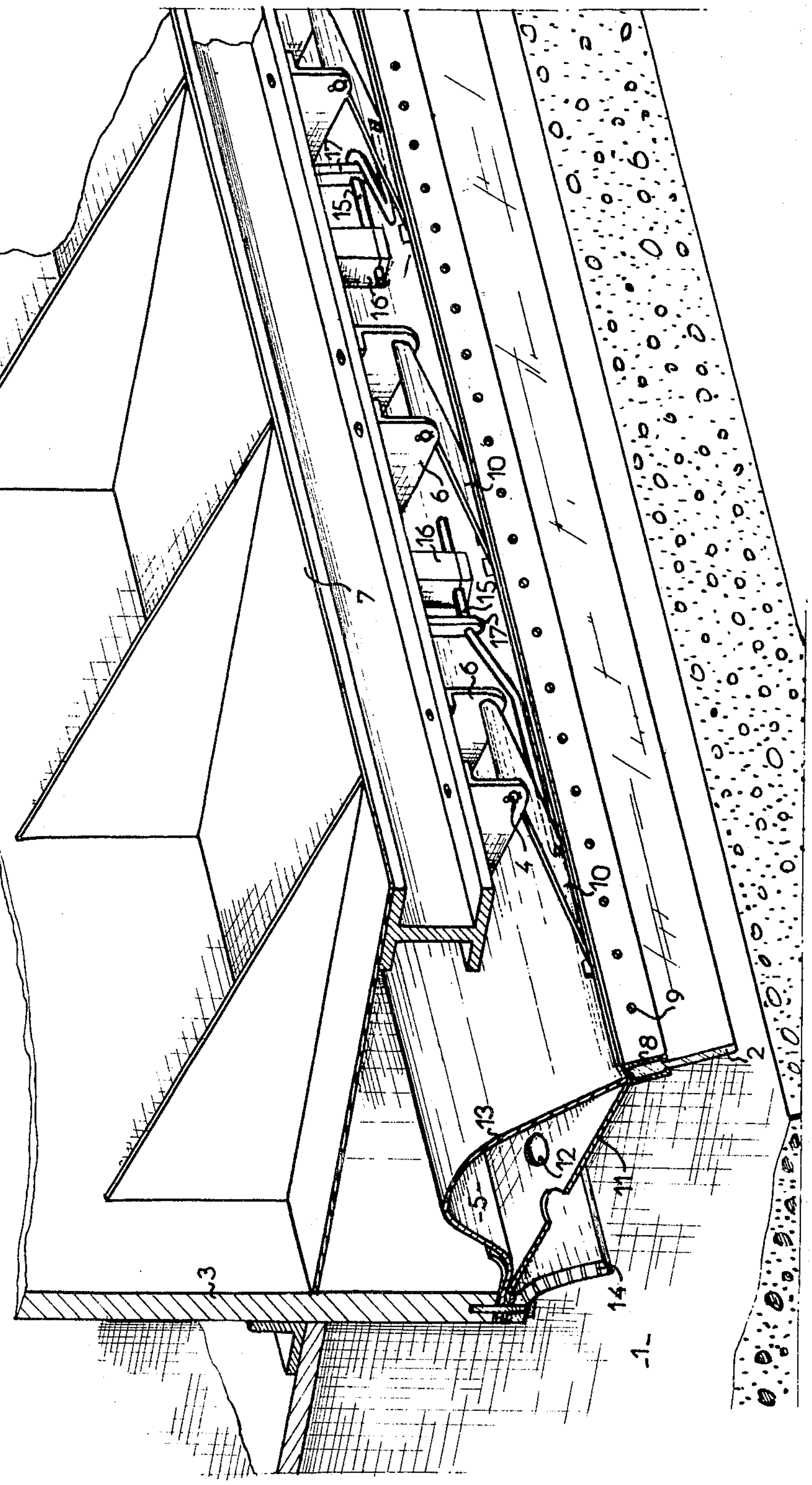

FIG. 1

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FIG. 3

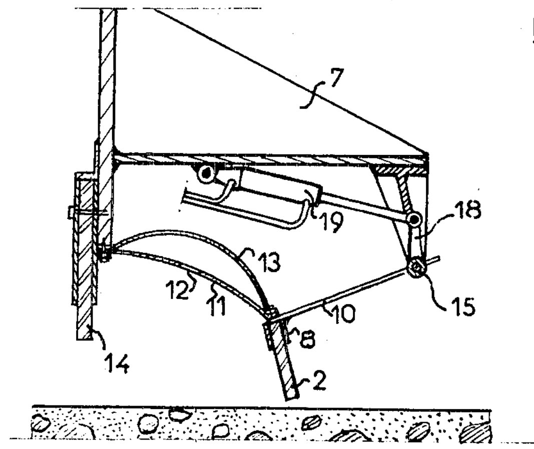


FIG. 2

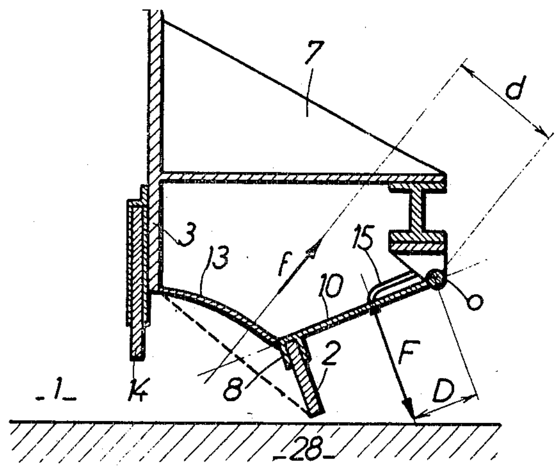
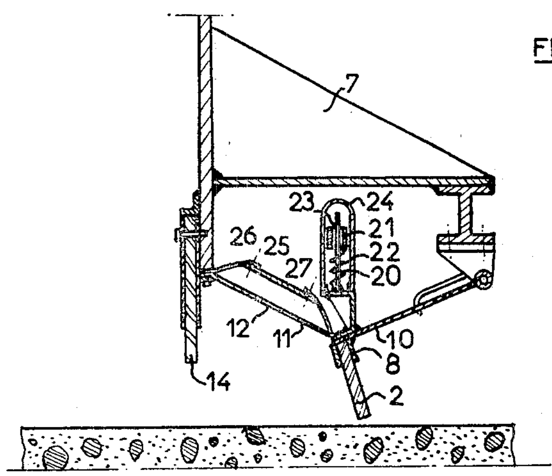


FIG. 4



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FLUID CUSHION SKIRT ARRANGEMENTS FOR GROUND-EFFECT MACHINES

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U.S. Cl. 180—127 9 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to a ground-effect machine which is supported over a supporting surface by a cushion of pressurised fluid contained by a skirt mounted on the framework of the machine, wherein increased stability is achieved by a special mounting arrangement for said skirt constituted by a diaphragm and lever arms having hinges located outside the said framework.

This invention relates to ground-effect machines which are supported on and/or guided by cushions of pressurised fluid laterally confined by skirt arrangements which, although capable of deformation, are made of solid material. The invention relates more particularly to machines or vehicles of the kind which cooperate with a specially prepared supporting surface or track in which there are only slight superficial irregularities, and to the means of confining the associated fluid cushions.

In accordance with the invention, the confining skirt arrangements used to define a fluid cushion are, on the one hand towards the exterior of the cushion, integral with a hinge arrangement disposed substantially parallel to the cushion axis and externally thereof, and on the other hand towards the interior of the cushion, integral with a diaphragm forming part of the base of the cushion. The link between the skirt and the said hinge may be effected through lever arms and any other appropriate means which will impart elasticity and damping characteristics to the device, for example a torsion bar.

The fluctuations in pressure acting on the base of the cushion tend to cause the skirt to pivot about its hinge so that the lower extremity of the skirt describes a movement in towards the interior of the cushion. This arrangement enables better suspension of the vehicle to be achieved whilst at the same time making the pressure of the cushion more uniform.

Another object of the present invention is to achieve damping of the movements of the skirt arrangement in accordance with the invention, through the provision of a pneumatic chamber which communicates with said cushion through orifices in a wall of said chamber in order to produce a pressure loss between the two. This damping can be supplemented by the provision of a tuned resonator or vibrator the vibrations of which are automatically made to occur in antiphase with those developing in the skirt arrangement, thus having the effect of cancelling out skirt vibrations.

The following description with reference to the accompanying drawings is given by way of example only and illustrates how the invention may be put into effect. In the drawings:

FIG. 1 is a pictorial view of a skirt arrangement embodying the invention;

FIG. 2 is a diagram of the forces at work in the skirt arrangement;

FIG. 3 is a sectional view of an alternative embodiment of the invention; and

FIG. 4 is a sectional view of another alternative embodiment, to which a supplementary damping device has been added.

In the arrangement in accordance with the invention, as shown in FIG. 1, a cushion of pressurised fluid **1** is confined at least at one side by a flexible skirt **2**. This skirt is integrally fixed by some appropriate means such as rivets or bolts **9**, to a profiled member **8** advantageously of U-section, this member itself being fixed in rigid fashion to arms **10** in order that the skirt-arm assembly can pivot about pins **4**.

The pins **4** are lodged in yoke plates **6** fixed rigidly to the framework **3** of the vehicle for example through a bracket **7**.

The skirt **2** is held in position by a system of springs and a damping system, constituted for example by torsion bars **15** mounted in bearings **17**, each bar bearing at one end against the internal face of the arm **10** and at the other end being fixed in a clamping block **16**. The damping function can for example be produced by arranging for the bearings **17** to bind on the torsion bars **15** with a certain degree of friction.

It will be noted that the pins **4** (hinge pins) are disposed substantially outside the base of the cushion and preferably parallel to the axis thereof.

The skirt **2** is likewise integral with a deformable chamber **5** in the form of a diaphragm **11** containing orifices **12** directly opposite the cushion **1**, and with a second, continuous, fluidtight diaphragm **13**, the two diaphragms being fixed in sealed fashion at their peripheries and attached on the one hand to the fillet or profiled member **8** and on the other hand along the framework **3**. In the bottom plane of the framework **3**, a wall **14** is fixed, preferably made of a nonrigid material, which entraps the diaphragms **11** and **13**. This wall is designed to act as a support when the vehicle is resting upon the surface **28**, and to confine an auxiliary fluid cushion in the event, that due to some accident, the normal skirt arrangement in accordance with the invention is damaged.

The operation of the device is as follows:

Once the fluid cushion is established, its pressure is exerted against the diaphragm **11** and tends to displace the skirt **2** against the force exerted by the spring **15**, towards the cushion interior so that its lower extremity describes an inward movement. Trials carried out have indicated that this arrangement produces damping of the movements which the skirt otherwise makes.

Part of the fluid cushion penetrates into the chamber **5** through the orifices **12** and thus acts as a pneumatic damper out of phase with pressure fluctuations in the cushion due to the pressure loss developed between the two spaces.

It is possible, in a variant embodiment, to discard the wall **11** and use exclusively the wall **13**. FIG. 2 illustrates a design of this sort and at the same time schematically illustrates the forces which are exerted when the skirt **2** moves inwards under the effect of an increase in pressure in the cushion **1**. f is the effective force which is the resultant of the pressures applied to the assembly of skirt **2** and diaphragm **13**, the force F represents the force exerted by the spring **15**, d is the torque arm provided by the lever for the force f in relation to the point O which is situated on the axis of articulation, and D is the torque arm presented by the lever vis-a-vis the force F in relation to said same point O.

Since the axis or pin **15** is substantially higher than the skirt **2**, when the latter is lifted it moves towards the interior of the space **1**, towards the left (in FIG. 2), resulting in an angular displacement $\Delta\alpha$ of the arm **10** and the skirt **2** and an increase of Δ (F.D.) in the torque exerted by the spring **15**.

This displacement towards the left produces a reduction in the horizontal projection of the surface area affected by the pressure of the fluid cushion located beneath the diaphragm **13** and the skirt **2**, and therefore a reduction in the effective force *f*. At the same time that the effective force *f* is reduced in magnitude, its direction of action changes so that the torque arm *d* increases, the changing moment being equal to $\Delta(f.d.)$. However, the spring is so designed that

$$\frac{\Delta(F.D)}{F.D} \text{ is greater than } \frac{\Delta(f.d)}{f.d}$$

i.e., the stiffness of the system increases, due to the spring characteristic, as the distance between the skirt **2** and the supporting surface increases. However, the stiffness also increases because, as the skirt **2** displaces away from the supporting surface, the wall **14** approaches it. Consequently, the cross section for the escape of fluid between the extremity of the wall **14** and the supporting surface reduces, and the stiffness of the cushion confined by the wall **14** becomes progressively higher. This stiffness is substantailly higher than that of the confining system **2–10–12–13–15**. The stiffness of the system can also be kept constant where the relative changes in torque are equal:

$$\frac{\Delta(F.D)}{F.D} = \frac{\Delta(f.d)}{f.d}$$

FIG. 3 illustrates a variant embodiment of the arrangement for returning the skirt-arm assembly, in which the initial stress in the torsion bar **15***a* is controlled in known manner through the medium of a link **18** and a hydraulic ram **19**, although any other kind of system could be employed such as for example an electromechanical or hydropneumatic one.

The said link is fixed rigidly to the end of the torsion bar **15***a* which was previously clamped in the block **16**; the latter block is replaced by a bearing.

In order to produce supplementary damping, it is possible to attach to the profiled member **8**, to which the skirt **2** is fixed, a system generally referred to as a matched resonator or vibrator.

FIG. 4 illustrates a system of this sort, of known design. At the bottom end of a rod **20** fixed to the profiled member **8**, a mass **21** is attached which contains a longitudinal recess **23** enabling it to slide along the rod **20** and is held in the central position by a spring **22**. This assembly is lodged in the housing **24**. The spring-mass system constitutes an inertia block resonator system which starts to vibrate at the same time as the skirt **2** but in antiphase therewith, thus damping and cancelling out any tendency to vibrate.

It will be noted that in this case the deformable skirt is constituted by a rigid plate **25** fixed in a sealed fashion to two deformable diaphragms **26** and **27**.

It should be understood that the invention is in no way limited to the embodiments described and that it includes equivalent technical means.

I claim:

1. In a ground-effect machine which is supported over a supporting surface by a cushion of pressurised fluid contained by a skirt mounted on the framework of the ma-

chine, an improvement in the mounting means for the said skirt according to which said mounting means comprises:

a diaphragm connecting the said skirt and the said framework and bounding the fluid cushion therebetween;

lever arms attached to said skirt and extending outwardly therefrom on the outside of said fluid cushion; and

means affording pivotal mountings for said lever arms on the outside of the machine framework.

2. A ground-effect machine according to claim **1**, including means biassing said lever arms about their respective pivots in opposition to the pressure of the fluid cushion acting on the diaphragm.

3. A ground-effect machine according to claim **2**, including a damping system operatively connected to said skirt.

4. A ground-effect machine according to claim **1**, comprising in addition a second skirt situated inside the fluid cushion, said second skirt being shorter than the first-mentioned skirt.

5. In a ground-effect machine which is supported over a supporting surface by a cushion of pressurised fluid contained by a skirt mounted on the framework of the machine, an improvement in the mounting means for the said skirt according to which said mounting means comprises:

a diaphragm connecting the skirt and the said framework and bounding the fluid cushion therebetween;

lever arms fixed to said skirt extending outwardly therefrom and pivotally mounted on hinges carried by the machine framework;

biassing means acting on said lever arms in opposition to the pressure of the fluid cushion; and

a damping system operatively connected to said skirt.

6. A ground-effect machine according to claim **5**, wherein the biassing means is constituted by a spring torsion bar for each lever.

7. A ground-effect machine according to claim **6**, wherein each spring torsion bar is associated with an adjustable hydraulic ram for adjusting the initial torsion of the bar.

8. A ground-effect machine according to claim **5**, wherein the damping system comprises a deformable chamber communicating with the interior of the cushion through calibrated orifices in a wall of said deformable chamber.

9. A ground-effect machine according to claim **5**, wherein the damping system comprises an inertial resonator.

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A. HARRY LEVY, Primary Examiner

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