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[54] FLUID-OPERATED SYSTEM FOR AIDING THE USER IN STANDING AND WALKING AND OTHER APPLICATIONS

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[51] Int. Cl. A43b 00/00

[58] Field of Search 128/24–26, 38–40, 128/60, 64, 1, 582, 594; 36/59, 2.5, 1

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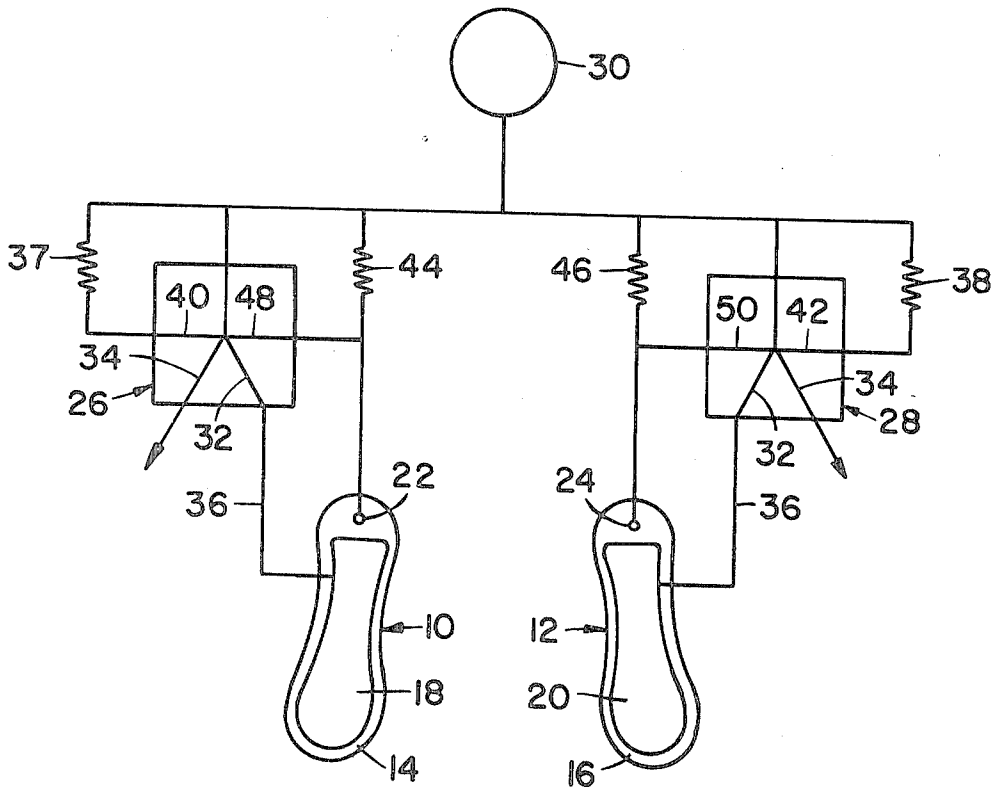
[57] ABSTRACT

A pair of shoes, hand-held members, or the like having one or more cavities therein which communicate with one or more output passages of a conventional bistable fluidic element. Fluid is supplied to the element to activate the suction forming capabilities of the shoes, a negative pressure or partial vacuum being drawn on the passages whenever one or both of the passages are in a passive condition with respect to fluid flow therein. The shoes or hand-held members adhere to a floor or other surface of contact when the soles or cavity defining parts are placed in conforming contact with the floor or surface.

7 Claims, 2 Drawing Figures



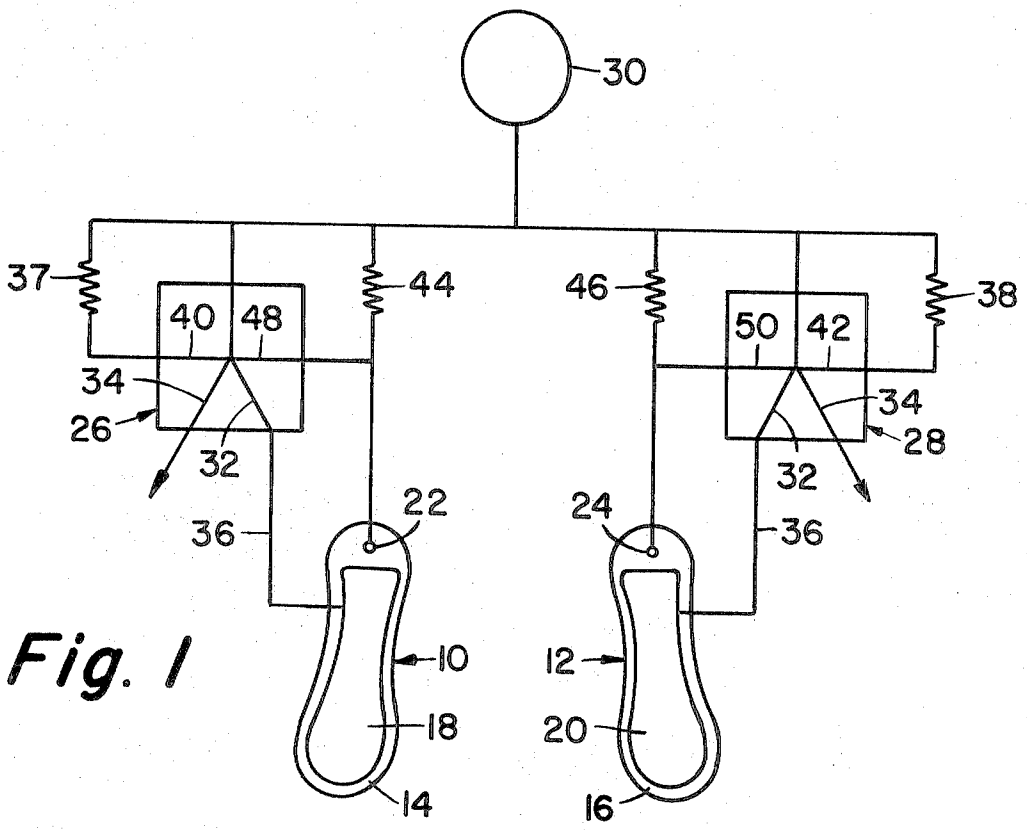


Fig. 1

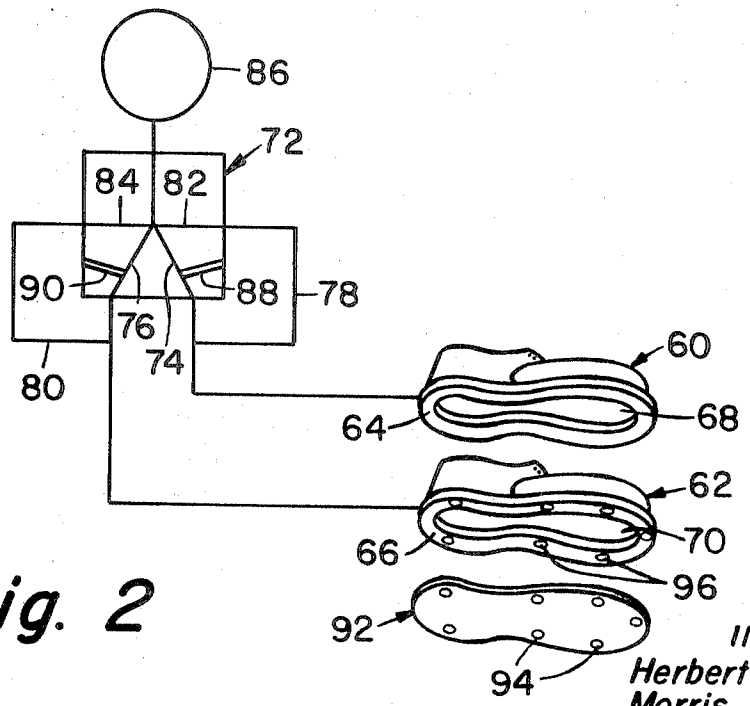


Fig. 2

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FLUID-OPERATED SYSTEM FOR AIDING THE USER IN STANDING AND WALKING AND OTHER APPLICATIONS

BACKGROUND OF THE INVENTION

Man has now demonstrated his ability to live and perform useful work functions in the weightless environment of extraterrestrial space for extended periods of time. In the near future it is planned that man will journey to the moon on a voyage that will last about 2 weeks. At present, plans are being studied for the construction of a manned earth orbiting laboratory in which men will live and work together for even longer periods of time. Eventually it is said that man will extend the present frontiers of space exploration beyond the moon to the neighboring planets, Mars and Venus, by journeying there on voyages of many months durations. The problem of how man will control his movement within the atmosphere containing confines of his spacecraft, space platform, space station and the like while in weightless state so that he may perform useful work during these extended periods is already receiving much attention. The instant invention is applicable to a solution of this problem.

Another application of the instant invention is in the field of medical rehabilitation, physical therapy, and the like. The instant invention can be utilized so as to automatically massage parts of the body, such as the feet, legs, arms, and the like for remedial or hygienic purposes to stimulate the circulatory system, nervous system, and the like.

SUMMARY OF THE INVENTION

It is, therefore, an object of the instant invention to provide a fluid operated system to aid the user thereof in standing, walking, and the like within the confines of an atmosphere containing environment, particularly under circumstances of weightlessness or reduced gravity.

It is a further object of the instant invention to provide a fluid operated system for massaging the body so as to aid the user in the stimulation of the circulatory system, nervous system, and the like.

Briefly, in accordance with the instant invention, there is provided a member defining a cavity which can be closed in a substantially airtight manner. A bistable fluidic element having a first and second output passage is connected so that the first passage communicates with the cavity. Fluid to operate the element is supplied thereto from a suitable fluid supply, and means is provided for rendering the first passage passive with respect to the flow of the fluid therein so as to form a negative pressure, relative to ambient pressure, in the cavities for at least a minimum predetermined period of time. Additional objects, features and advantages of the instant invention will become apparent to those skilled in the art from the following detailed description and attached drawing on which, by way of specific examples, only the preferred embodiments of the instant invention are illustrated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically illustrates, in one embodiment of the instant invention, a pair of suction forming shoes as viewed from the bottoms thereof, and a diagram of associated fluidic circuitry.

FIG. 2 schematically illustrates, in another embodiment of the instant invention, a pair of suction forming shoes, as viewed obliquely, and a diagram of associated fluidic circuitry.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1 there is shown a pair of shoes 10 and 12 having soles 14 and 16 respectively the bottom surfaces or rims of which define openings into a pair of recessions or cavities 18 and 20. The soles 14 and 16 can be constructed of any material suitable for forming a substantially airtight seal of the cavities 18 and 20 against a floor or surface, not shown, against which the rims conformably contact. Particularly suitable materials include those which are flexible, compressible and resilient in character such as natural or synthetic rubber, and the like which can readily be compressed against a surface of contact by the wearer so as to form the required seal thereagainst.

Small openings 22 and 24 in the rims of the soles 14 and 16 in the heel areas thereof are entrances to a pair of passages which extend upwardly through the heel areas and out the back sides of the soles 14 and 16 in any convenient manner to permit connection thereof of conventional fluid back pressure sensing devices. In this manner, means is provided for determining when the rims of the soles 14 and 16, either singularly or simultaneously, are in rim conforming contact with the floor or surface as later more fully explained.

To operate and control the suction forming properties of the shoes 10 and 12 numerous external fluidic circuit configurations can be provided. The particular fluidic circuit shown in FIG. 1 permits either of the shoes 10 and 12 to adhere to a surface upon rim conforming contact therewith independent of the circumstances encountered by the other. A pair of conventional fluidic bistable elements 26 and 28, such as flip-flops and the like, receive driving or operating fluid under pressure from a suitable, preferably regulated fluid supply 30. Each of the elements 26 and 28 have two stable output states, one being represented by the fluid flowing in an output passage 32, the other being represented by the fluid flowing in an output passage 34.

The output passages 32 communicate with the cavities 18 and 20 through suitable fluid conductive lines 36 which are preferably flexible and of any convenient length. The remaining output passages 34 of each of the elements 26 and 28 are not connected to the circuit and thus communicate directly with the surrounding atmosphere, which condition is represented by arrows.

The elements 26 and 28 are biased in a conventional manner by means of fluid resistors or restrictors 37 and 38, respectively, which are connected between the supply 30 and control ports 40 and 42, respectively. In this manner, the flow of fluid into each of the elements 26 and 28 from the supply 30 is directed along the passages 32 and into the cavities 18 and 20, respectively, when neither of the soles 14 and 16 are in rim conforming contact with a surface. In this output state or operating condition the passages 32 are active and the passages 34 are passive with respect to fluid flow therein.

To counteract the effect of biasing so as to activate and maintain the suction forming properties of the soles 14 and 16 when either or both of the latter are in rim conforming contact with a surface, conventional back pressure sensing means is provided. The sensing means of the instant example consists of a pair of fluid resistors or restrictors 44 and 46 which are connected between the fluid source 30 and the openings 22 and 24, respectively. The downstream ends of the restrictors 44 and 46 are also connected to control ports 48 and 50, respectively. The biasing restrictors 37 and 38 are selected so that their fluid restriction values are greater than the restriction values of the sensing restrictors 44 and 46, respectively. This permits the maximum back pressure signal pressures introduced at the control ports 48 and 50, which result from the sealing or closing of the openings 22 and 24 against a surface, to predominate in magnitude over the bias pressures introduced at the ports 40 and 42, respectively. Accordingly, closing the openings 22 and 24 increases the back pressure present at the ports 48 and 50 to a maximum value, overcomes the effect of biasing on the ports 40 and 42, and switches the fluid flowing in the elements 26 and 28 to the passages 34 there to be exhausted to the surrounding atmosphere. In this state or condition of the elements 26 and 28, the passages 32 are passive and the passages 34 are active with respect to fluid flow. This condition will be maintained on either of the elements 26 and 28 so long as one of the openings 22 or 24 which generates a back pressure signal to the corresponding element 26 or 28 is maintained in a sealed condition. Similarly, both elements 26 and 28 will be simultaneously maintained in this condition so long as both openings 22 and 24 remain closed at the same time.

It is a well-known property of fluidic bistable elements that when one of the output passages thereof is active, the other passage, being passive, will exhibit a negative pressure therein relative to ambient so as to entrain ambient fluid into the passive passage through the downstream end. However, when the downstream end of the passive passage is blocked so that no atmospheric fluid can be entrained therein, the low pressure within the passage tends to form suction and draw a partial vacuum on the passage blocking surface. This principle is utilized in the instant invention to form a suction or partial vacuum in the cavities **18** and **20** so as to cause the soles **14** and **16** to adhere to a floor or surface. To form such adherence one of the shoes **10** or **12** is placed in rim conforming contact with a floor or surface so as to form an airtight seal of one of the cavities **18** or **20**. This seals one of the openings **22** or **24** thus introducing a high back pressure sensing signal at one of the control ports **48** or **50**, overcomes the effect of bias on one of the ports **40** or **42** and diverts the flow of fluid in one of the elements **26** or **28** to atmosphere through one of the output passages **34**. One of the passages **32** now being in a passive condition presents a negative pressure relative to ambient to a corresponding cavity **18** or **20** with the result that the corresponding sole **14** or **16** adheres to the surface.

To break the suction thus formed on either or both of the soles **14** and **16**, the wearer of the shoes **10** and **12** needs only to lift a heel portion of one or both of the soles **14** and **16** to permit one or both of the openings **22** and **24** to communicate with the atmosphere. This requires no great force or leverage since the heel portion of the soles **14** and **16** do not adhere to the surface and the soles **14** and **16** are quite flexible. Lifting of the heels to expose the openings **22** and **24** to atmosphere permits fluid to be vented therefrom, thus reducing the back pressure on the ports **48** and **50**, and permitting the bias signals on the ports **40** and **42** to activate the passages **32** and break the suction on the soles **14** and **16**.

The circuit configuration of the instant example permits both shoes **10** and **12** to adhere positively to a floor or surface when desired, such as when a wearer wishes to stand with both feet upon a surface at the same time. Also, since each of the shoes **10** and **12** is operated independent of the other, there is no difficulty encountered in walking, where either shoe adheres to the surface and the other is free thereof at any given instant of time. The switching action of the elements **26** and **28** can easily be made rapid enough to break the vacuum on the shoes **10** and **12** between the time the heel is first lifted to expose the openings **22** and **24**, to atmosphere, and the time at which the rest of the sole area would naturally follow in the natural walking process.

With the circuitry of the instant example, it does not matter whether the elements **26** and **28** are of the load sensitive variety or not. That is to say, switching between output states of the elements **26** and **28** is not obtained by loading or blocking the active output passage of the element, but rather by fluid control signals introduced at the control ports thereof. If a load sensitive element were utilized it would certainly change its output state when the active passage thereof were blocked or heavily loaded. However, an output state changing back pressure is also applied to a control port of the device at the same time because of the use of back pressure sensors, so that the element would change states just the same even if it were load insensitive.

The system of the instant example lends itself to utility particularly as a means for aiding the user in standing and walking within the confines of an atmosphere containing weightless environment such as a space station, space platform, spacecraft, and the like. The concept of the surface adhering shoes **10** and **12** can readily be applied to hand-held or hand-attached suction forming members, and the like and such equivalent devices are to be considered as within the scope of the instant invention. Also, it should be noted that the positioning of the openings **22** and **24** in the rims of the soles **14** and **16** is optional, though they should preferably be located in a manner convenient for the connection of the lines leading to the back pressure sensing circuitry. The fluidic circuitry of the example is capable of being compactly and conveniently stored in a small belt or backpack so as to be carried by the user. Then, only one long fluid supply line leading from the circuit pack to the supply **30** will be required to operate the system. Or, except for possibly some additioning inconvenience to the user, the circuitry can be located at a fixed position remote to the user with appropriate lengths of fluid lines extending from the circuit package to the shoes **10** and **12** to operate the cavities **14** and **16** and the openings **22** and **24**.

Referring now to FIG. **2** there is shown an example of how the instant invention can be adapted to medical, physiological, or therapeutic uses. A pair of shoes **60** and **62**, having soles **64** and **66** similar to the type previously described, include a pair of cavities **68** and **70**. A bistable fluidic element **72** controls the suction forming capabilities of the shoes **60** and **62** by means of output passages **74** and **76** which communicate with the cavities **68** and **70**, respectively. This system operates in a fully automatic oscillatory mode due to the presence of a pair of fluid feedback loops **78** and **80** connected between the downstream ends of the passages **74** and **76**, respectively, and a pair of control ports **82** and **84**, respectively. Fluid to drive or operate the element **72** is supplied thereto in a conventional manner by a suitable fluid supply **86**.

The operation of the system is typically as follows: Assume that initially fluid flows out of the element **72** through the passage **74** and is vented to atmosphere through the cavity **68**, the sole **64** not being in rim conforming contact with a floor or surface. As the fluid flows toward the shoe **60** past the downstream end of the passage **74**, a portion of the fluid is diverted through the loop **78** and introduced as a control signal at a control port **82**. After a sufficient elapse of time, dependent upon the length and resistance of the loop **78** to fluid flow, the control signal pressure at the port **82** increases to a level sufficient to switch the output state of the element **72**. When the switching occurs, the flow of fluid in the element **72** is diverted from the passage **74** to the other passage **76**. This renders the passage **74** passive and the passage **76** active with respect to fluid flow. If under these conditions the sole **64** is flush with a surface, a partial vacuum will be drawn on the surface from the passage **74** through the cavity **68**. Accordingly, during the period of time that the passage **76** is active, a portion of the fluid flowing therethrough therethrough is being diverted to the loop **80** to the control port **84** causing a build up of pressure thereat. Eventually, depending on the length and resistance to fluid flow of the loop **80**, the pressure at the port **84** will reach a level sufficient to switch the output state of the element **72** back to its initial condition, thus completing a cycle of operation of the system.

The periodic switching of the output states of the element **72** causes constriction and expansion of the soles **64** and **66** in an oscillatory and alternating manner when the latter rest flush against a floor or surface so as to seal off the cavities **68** and **70**. The switching frequency can be adjusted as desired by increasing or decreasing the lengths of the loops **78** and **80**, or their respective resistances to fluid flow, or both. The magnitude of the construction and expansion of the soles **66** and **68** in turn produces a corresponding constriction and expansion of the soles **66** and **68** in turn produces a corresponding constriction and expansion of the shoes **60** and **62**, respectively, about the feet of the wearer, and can be adjusted by adjusting the volume flow rate of the fluid from the supply **86**. To prevent the simultaneous heavy loading or blocking of the passages **74** and **76** from shutting off the flow of fluid to the element **72**, a pair of high-resistance vents **88** and **90** are provided which communicate between the surrounding atmosphere and the passages **74** and **76**, respectively. The vents **88** and **90** should only be large enough in cross section to prevent back pressure from backing upstream through the passages **74** and **76** and cutting off fluid flow in the element **72** altogether. If the vents **88** and **90** are too large in cross section they will permit an excessive amount of fluid from the surrounding atmosphere to be entrained into the passages **74** and

76 when either of the latter are passive, thus destroying the suction forming effect of such passage.

The constriction and expansion of the shoes 60 and 62 about the feet of the wearer aids in the stimulation of blood circulation and of the nerve system in the feet. In a modification of the instant example, the cavities 68 and 70 can be completely enclosed so as to form pockets which are isolated from the feet of the wearer. An example of how this can be done is illustrated in FIG. 2. A sole conforming plate 92 is fixedly attached to the bottom of the sole 66 in any convenient manner so as to form a substantially airtight seal of the cavity 70. Holes 96 can be formed through the sole 66 around the periphery thereof conforming to holes 94 in the plate 92, and the sole 66 and plate 92 then bolted together by means of suitable threaded fasteners. The loading of the passages 74 and 76 in this manner permits the use of the shoes 60 and 62 for therapeutic purposes by one who is paralyzed or bedfast. The arms and leg can likewise be stimulated with the instant invention by using arm or leg bands, or other suitable pocket containing apparel wherein the pockets are sealed, isolated from the surrounding atmosphere, and communicate with at least one of the passages 74 and 76 in the manner illustrated with respect to the shoes 60 and 62.

To illustrate the suction forming capabilities of the system of the instant invention, a system of the type as shown in FIG. 2 was construction and the data taken from measurements thereon is given in Table 1. Column 1 represents the pressure of the power stream fluid supplied to the element 72 from a regulated power source 86. The element 72 was a standard "two-times size" bistable device manufactured by the Coring Glass Works, Corning, New York, Catalog No. 190417. Column 2 represents the control port pressures required to switch the output state of the element 72 from one blocked passage 74 or 76 to the other at the various power supply pressures given in column 1, expressed in percent of power supply pressure. And, column 3 represents the negative pressures relative to ambient pressure, produced on the passive passages 74 and 76, which pressures are available to create suction in the cavities 68 and 70 when the soles 64 and 66 are in rim conforming contact with a floor or other surface.

TABLE 1

1	2	3
10 p.s.i.g.	30%	−3.0 p.s.i.g.
6 p.s.i.g.	30%	−2.0 p.s.i.g.
3 p.s.i.g.	30%	−0.8 p.s.i.g.

Although the instant invention has been described with respect to specific details of certain embodiments thereof, it is not intended that such details limit the scope of the instant invention except insofar as set forth in the following claims.

We claim

1. A fluid operated system comprising
a member defining a cavity forming a substantially airtight compartment with respect to the surrounding atmosphere,
a bistable fluidic element having an input passage and first and second output passages, said first output passage communicating with said cavity,
means for supplying a fluid under pressure connected to said input passage, a first stable state of said fluidic element occuring when said fluid flows through said first output passage and a negative pressure exists within said second output passage, a second stable state occuring when said fluid flows through said second output passage and a negative pressure exists within said first output passage, and
means for switching said fluidic element from from said first stable state to said second stable state.

2. The system of claim 1 wherein said member is a shoe having a sole defining said cavity.

3. The system of claim 1 further comprising means for partially venting said fluid from said first and second output passages.

4. The system of claim 1 wherein said fluidic element further comprises at least one control port and wherein said switching means comprises a fluid feedback loop connected between said first output passage and one of said control ports for diverting a portion of said fluid from said first output passage to said one control port.

5. The system of claim 1 further comprising
back pressure sensing means responsively communicating between an orifice in said member and said first control port, said element being caused to switch to said second stable state when at least a predetermined value or pressure is sensed by said sensing means, and
fluid biasing means connected to said second control port, said element being caused to switch to said first stable state when said pressure sensed by said sensing means is below said predetermined value.

6. A fluid operated system comprising
first and second shoes, each of said shoes having a discrete cavity, each said shoe being adapted to constrict and expand about one foot of a wearer as a function of the pressure within said cavity,
a bistable fluidic element having an input passage, first and second control ports, and first and second outlet passages, said first outlet passage communicating with said cavity of said first shoe, said second outlet passage communicating with said cavity of said second shoe,
means for supplying a fluid under pressure connected to said input passage, and
first and second fluid feedback loops, said first feedback loop being connected between said first control port and said first outlet passage said-second feedback loop being connected between said second control port and said second outlet passage in such a manner that said fluid alternately flows through said first and second outlet passages at a preselectable frequency.

7. A fluid operated system comprising
first and second shoes, each of said shoes having a sole including a rim defining a cavity, said rim being adapted to form a substantially fluidtight seal with a surface against which said shoes are adapted to be disposed,
first and second bistable fluidic elements, each of said elements having an input passage, first and second control ports, and first and second outlet passages, said first outlet passage of said first element communicating with said cavity of said first shoe, said first outlet passage of said second element communicating with said cavity of said second shoe, said second outlet passages of said first and second elements communicating with the environment in which said shoes are adapted to be utilized,
first and second fluid back pressure sensing means connected to said first control ports of said first and second elements, respectively, said first sensing means providing a first fluid back pressure signal when said rim of said first shoe is in contact with said surface, said second sensing means providing a second fluid back pressure signal when said rim of said second shoe is in contact with said surface,
means for supplying a fluid under pressure connected to said input passages of each of said elements, a first stable state of each of one of said elements occuring when said fluid flows through said first output passage and a negative pressure exists within said second output passage of the respective element, a second stable state occuring when said fluid flows through said second output passage and a negative pressure exists within said first output passage of the respective element, and
first and second fluid biasing means connected to said second control ports of said first and second elements, respectively, said first biasing means switching and maintaining said first element in said first stable state when said first back pressure signal is less than a first predeter-

mined level, said second biasing means switching and maintaining said second element in said first stable state when said second back pressure signal is less than a second predetermined level, said first sensing means being operatively associated with said first element in opposition to said first biasing means for switching and maintaining said first element in said second stable state when said first back pressure signal is at least equal to said first level, said second sensing means being operatively associated with said second element in opposition to said second biasing means for switching and maintaining said second element in said second stable state when said second back pressure signal is at least equal to said second level.

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