ABSTRACT: A pneumatically supported, load-carrying platform that is precisely controlled against minute excursions from a predetermined position while being cushioned against shock and vibration. The platform structure preferably is pendulously supported by a group of spaced pneumatically pressurized mounts or air springs, having individual sensors responsive to incipient deviations in the platform position and which control the pressure applied to the respective mounts so as to restore or maintain the platform within normal limits. Sensitivity of response, and adjustment of the system stability results from regulating the supply of air available to the mounts, and furnishing preestablished incremental pressures above the pressures needed for proper operation of the mounts, which incremental pressures are substantially independent of both the mount pressure and the pressure from the source of supply.
VIBRATION-ISOLATED SELF-LEVELING PLATFORM AND METHOD

BACKGROUND OF THE INVENTION

The invention relates generally to stabilized platforms and systems, and more particularly to pneumatically actuated self-leveling tables. It is becoming a problem of increasing concern in industry, particularly with the trend toward miniaturization to stabilize equipment such as production tools, instrumenta-
tion, and inspection devices, so they are isolated not only from distortions in the framework of the equipment resulting from settling in the floor or foundation, but also as a safeguard against the undesirable effects of shock and vibration resulting from outside influences. The invention has application also where it is desired to maintain a stable reference plane with respect to a movable device, or while a device is in transit, to free it of the disturbing influences introduced, for example, by the motion of the vehicle. Also in the case of miniaturized integrated circuitry, certain equipment needed for producing or inspecting minute parts often is rendered inoperable or ineffective by influences such as vibration created by heavy machinery operating in the vicinity, or by the passage of vehicular traffic in the neighboring streets, even though the equipment is firmly anchored in the ground, and even when the anchoring means is isolated from the foundation of the building in which the equipment is located.

It has been customary in recent years to support delicate equipment on such as electro-optical devices, inertial platform checkout systems, laser welders, comparators and the like, on active vibration isolators, such as servo-controlled pneumatic means, that also maintains the equipment within prescribed limits of deviation from an established norm. Typically the supporting structure comprises a table having a relatively massive platform that may be maintained in a level position, through the use of pneumatic supporting media responsive to incipient deviations in the position of the platform from the normal level position.

While devices of this sort utilizing conventional servosystem concepts have functioned reasonably well, a continuing demand has been indicated for equipment that exhibits more complete control of the dynamic response, that yet is capable of providing greater system sensitivity with reasonable response time, and stiffer responses to rapidly changing loads with reasonable freedom from overtravel and oscillation that normally is associated with transient disturbances. There is a continuing need also for a corrective action that is somehow related to the degree of disturbance, so that unusually large deviations trigger correspondingly great and rapid restoring actions.

It is accordingly an object of the present invention to provide an improved method of an apparatus for stabilizing a load-bearing platform incorporating new and useful concepts for obtaining increased sensitivity and improved dynamic control of an active servosystem for maintaining such a platform in stable condition.

SUMMARY OF INVENTION

This invention utilizes a number of design concepts that contribute to an improved structure offering advantages over what has been known heretofore. Although the principles of the invention may be applied to stabilized structures generally, for purposes of illustration the invention is illustrated as applied to a self-leveling table, herein shown as a surface plate which may be of conventional design, normally being formed of granite or cast-ferrous metal. This plate and a supporting framework together form the platform which is to be stabilized, and which receives a production tool, a sensitive instrument, or the like, that is to be isolated from vibration and stabilized against outside influences.

Additional stability is imparted to the system by supporting the platform at spaced points preferably located above the center of gravity of the platform. In the embodiment shown, the principal mass of the empty platform resides in the relatively thick surface plate; hence by supporting the platform at points near its upper extremity, a pendulous structure results with an inherently greater natural stability, which imparts additional stability to the system, as compared with those structures that are supported beneath the platform.

The supports for the platform may comprise conventional pneumatic mounts, sometimes called air springs, that functionally comprise pressurized chambers, each having a movable piston or diaphragm on which a portion of the platform rests, the piston or diaphragm being urged upwardly in response to the pressure within the chamber. As many of these air mounts or springs are used as are necessary for proper supporting action, though in a preferred form of the invention four are employed, with the points of support being located at the corners of the illustrated rectangular platform. A group of sensing devices located close to the air mounts detect incipient deviations in the position of the respective portions of the platform with which each of the devices is associated, and the sensing devices control the flow of pneumatic fluid to the supporting mounts at a time and in a manner effective to restore the individually supported portions to their normal positions. Special valve design provisions regulate the flow of air or other pneumatic fluid with the help of pressure-regulating means employed to maintain an input pressure that represents a constant increment over the normal pressure required for proper functioning of the air mounts. Additional features of the invention include a mechanism for throttling and diverting portions of the fluid from the source to a damping chamber, to selectively modify the response of the air mount. The valve mechanism is designed also to compensate for unusual excursions in the platform position so as to provide a more rapid and a more effective corrective action in the air pressure when such unusual circumstances arise.

BRIEF DESCRIPTION OF THE DRAWINGS

While the scope of the invention is comprehended by the language of the claims which are appended to the following specification, and which distinctly point out and claim the subject matter of the invention, it is believed that a better understanding of the inventive concepts may result by reference to the accompanying drawings, illustrating some specific embodiments, and in which:

FIG. 1 is a modified perspective view of a table structure adapted to support a surface plate, with certain portions of the framework and housing being broken away to illustrate features of the invention;

FIG. 2 is a vertical sectional view of a slightly variant form of air mount and its relationship to one of the tubular table legs, with certain parts being shown in elevation;

FIG. 3 is a vertical sectional view taken generally along the line 3-3 of FIG. 1 to show the generally pendulous nature of the platform support; and

FIG. 4 is a vertical cross-sectional view of an enlarged embodiment of an air control valve, with related sensing and pressure-regulating mechanisms.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring again to the drawings and more particularly to FIG. 1 thereof, the device comprises a table 10, preferably having a plurality of tubular supporting legs 11 and suitable reinforcing structural members 12. A sheet metal skirt 13 may be secured to the legs for aesthetic purposes and to increase the overall rigidity of the table. A stabilized structure such as a platform 14, to be isolated from the surrounding support, is illustrated as a weldment formed from suitable structural steel members, and is provided with horizontal flanges 15 projecting outwardly from the ends of the platform at its upper extremity, and from which the platform preferably is supported. A plurality of lateral members 16 secured to the platform 14 near the lower extremity serve as a support for a suitable working surface provided, as shown in FIGS. 1 and 3 by a relatively massive surface plate 17, illustrated in FIG. 1 in phan-
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3, tomm lines. The upper exposed surface 18 of the plate 17 constitutes a relatively precisely formed plane that is to be maintained in a stable state, and which provides a support for a tool, a measuring instrument or the like 19, also illustrated in FIG. 1 in phantom lines.

The platform 14 is supported at several spaced points, as previously indicated, to provide the maximum degree of equilibrium. A pneumatically cushioned air mount or spring 21 is interposed at the top of each leg 11, or at such other points of the table as will provide stable support for the platform. In the embodiment shown, the mounts 21, located at the top of the legs 11, support the platform 14 pendulously, as best seen in FIG. 3. With the arrangement illustrated, the platform accordingly has four major points of support, two of which may operate in tandem, as will appear, to provide the stability normally associated with a three-point support. Optionally two of the supports shown at one end of the table and functioning in tandem might be replaced by a single centrally positioned unit to provide three-point support. In a typical application, a surface plate may measure 24 inches by 36 inches and weigh 250 pounds. A resulting stabilizing pendulous moment of 250 pounds inches is created when the points of support are located an inch above the center of gravity of the combined platform mass.

The air spring 21 may be of any conventional design and is illustrated in FIG. 2 as comprising a pressurized chamber 22 formed of a base plate 23, tubular sidewalls 24, and a flexible diaphragm 25 that flexes in the manner of a bellows. The diaphragm 25 preferably is made of suitable elastomeric material, or an elastomically recovered vegetable or nylon fabric that is capable of forming with the base and sidewalls a fluid tight chamber. A plunger 26 having a cover plate 27 is partially enclosed by a lower cup-shaped portion of the diaphragm 25, and is movable in a vertical direction as the diaphragm flexes in response to fluid pressure within the chamber 22.

A suitable arrangement may be provided for securing the diaphragm 25 relative to the plunger 26, and for hermetically sealing the diaphragm relative to the housing of the air mount 21. For example, the diaphragm may be cemented to the bottom of the plunger 26, or a clamping plate 31 with suitable fasteners may be utilized. As best seen in FIG. 2 the diaphragm has a radial flanged portion 32 which may be sealed between a clamping ring 33 and a flange 34 of the cover plate 27 from the air by cap screws 35. The air spring is rendered functional by the admission of pressurized pneumatic fluid through a tube 36, and inlet connection 37 communicating with an air control valve as will appear.

The plunger 26 is shown in an equilibrium position, wherein the pressure within the chamber 22 applied to the diaphragm balances the weight applied to the plunger 26. A threaded cavity 38 may receive a threaded stud 39 by which the weight of the platform 14 and load 19 may be transmitted from the flange 15 to the plunger 26. It will be observed that the plunger 26 floats within its supporting enclosure, and has limited freedom in both horizontal and vertical directions. A certain amount of lateral damping may be introduced by controlling the dimensions of the diaphragm 25. It will be observed in FIG. 2 that a smaller diameter portion of the diaphragm extends upwardly about the plunger or piston 26, while a depending larger diameter portion 28 is joined to it by a shifting intermediate section 29. In cross section the flexing reentrant part of the diaphragm resembles a hairpin, the length of which determines the degree of diaphragm motion, while inversely contributing to lateral damping; the shorter the reentrant loop, the greater the damping factor.

A portion of the air flowing through inlet connection 37 may be diverted from the pressurized chamber 22 by means of a controlled bypass 41, the amount of diverted flow being regulated in part by a needle valve or throttle 42, consisting essentially of an adjustable orifice. In this manner, a predetermined amount of the pneumatic fluid may be caused to flow into one of the tubular legs 11, which being sealed at both top and bottom forms a damping chamber 43. The plunger 26 is responsive to the pressure within the chamber 22, which is affected by the amount of inlet air being diverted through tube 41, which in part is determined also by the pressure within the chamber 43. Accordingly the response of the plunger 26 may be controlled in great measure by the setting of the needle valve 42 and the stabilizing effect of the damping chamber 43. In a typical installation the volumetric capacity of the damping chamber should be a multiple of and preferably at least three times the volumetric capacity of the pressurized work chamber 22. Also, in a typical system the natural response frequency might vary through a range of from 0.6 Hz. to 2.0 Hz., the frequency being regulated in large measure by the valve 42 opening. Opening the valve tends to bypass more of the fluid to the chamber 43, to decrease the natural frequency and increases the response time, producing a "softer" correction, while closing the valve 42 increases the natural frequency and the "stiffness" of the system.

In accordance with the laws of physics, the force exerted upwardly on each plunger 26 is the product of the effective area of the diaphragm 25 and the pressure within the chamber 22. In a typical installation the effective area of the diaphragm 25 and the springs 21 may be of the order of 7.5 square inches. Assuming pressure within the chamber of 80 p.s.i., the theoretical maximum upward thrust would be 600 pounds, or if four such mounts were provided per installation, the total capacity of such a table would be 2,400 pounds. If the dead load weight of the platform were 400 pounds, the useful capacity of such a table for live loads would be 2,000 pounds.

As indicated earlier, the air spring 21 is actuated in response to a control valve of improved design. Referring again to the drawings, and more particularly to FIGS. 1, 3 and 4, such a valve 44 includes a valve body 46 having an inlet port 45, illustrated as a standard threaded opening for receiving pipe or tubing that may be connected with a suitable source of compressed pneumatic fluid, not illustrated. Customarily, well cleansed dry air of the type available in most industrial shops, and under a suitable pressure commonly around 100 p.s.i. is most economical for the purpose, though the relatively low fluid consumption of the present system often justifies the use of bottled gas, such as nitrogen, particularly for mobile applications. The pressure, whether regulated from cylinders, or from a pressure-regulated compressor and storage system, primarily determines the load of the plunger 26 against the platform mass. In any case it must be made adequate so that a predetermined somewhat lower pressure available within the work chamber 22 exerts the required lifting effort on the piston 26.

As best seen in FIG. 4, valve 44 includes also an outlet port 47, which communicates with the air springs, and a vent port 48 for discharging bled air to the atmosphere. Communication of the ports 48 of all valves in a single installation are connected together through suitable plastic or metal tubing, so as to have a common discharge point. The valve 44 has a centrally bored passage 49 extending from the top to the bottom of the valve, with different diameter portions that form chambers communicating with the respective ports 45, 47 and 48 as will appear. An inlet chamber 51 is formed by an enlargement of the passage 49, being closed off at the bottom by a suitable base plate 52, which extends across and seals the base of the valve 44. The inlet chamber 51 communicates directly with the inlet port 45 and hence normally contains air at high pressure, which under static conditions therefore equals the pressure of the source. A valve disc 53 normally seals off the top of the chamber 51, being urged against a valve seat 55 by a compression spring 54, and being gasketed, if desired, for a more complete seal.

The valve disc 53 while in the closed position forms the bottom of an intermediate-pressure chamber 56, being defined also as an enlargement of the passage 49. The top of the chamber 56 is essentially closed by a second valve disc 57 which is urged upwardly against a seat 58 by a spring 59, compressed as shown between the two valve discs 53 and 57. The spring index of the spring 59 is less than that of spring 54 so
that moderate pressure applied downwardly against the disc 57 causes it to unseat without disturbing the disc 53. The latter however will in turn be unseated. The deflection of the disc 57 continues beyond a predetermined point, such as may be associated with sudden increases in the load on the platform, or during startup operations, at which times the high-pressure inlet chamber 51 communicates directly with the outlet port 47, and high-pressure air or other fluid passes freely from the source to the respective inlet connections 37 of the air springs, until an equilibrium condition is reached.

At other times during normal cycling periods, the pressure in the intermediate pressure chamber 56 is maintained at a constant increment above that at the outlet port 47, and independent of the inlet pressure, through the use of a pressure regulator 61 preferably incorporated within the valve body 44. The regulator valve 61 itself is of generally conventional design and incorporates a high-pressure chamber 62 communicating with inlet chamber 51. A valve, preferably comprising a hardened ball 63 is held against seat 64 by a compression spring 65, assisted also by the relatively high-pressure in the chamber 62 acting against the ball. The ball may be depressed to admit high-pressure air as by a pin 66 responding to the motion of a diaphragm 67 or piston diaphragm 69 to which the pin is attached. The piston 67, shown with an O-ring 69 for hermetic seal, operates within a close-fitting cylinder 68 and the piston functions as a moving partition dividing the cylinder into a lower-pressure chamber 71 above the piston, and a higher-pressure chamber 72 below the piston. A heavy-duty regulator spring 73 bears downwardly against the piston 67 with a force determined by the position of a regulating screw 74 threaded into the regulator body and operable through a head 75 with the aid of a suitable adjusting tool. Alternatively, the head may be shaped as a thumb wheel shown in broken lines, for ease of operation. A locknut 76, or similar device which may include a finger lever 77 for quick-locking action, holds the screw 74 in adjusted position. The lower-pressure chamber 71 communicates with the outlet port 47 through duct 78, and thus imparts substantially the prevailing air spring pressure to the piston 67, assisting spring 73 in exerting downward pressure. In an equilibrium condition, however, this pressure is not adequate to open valve 63 introducing new air to the mounts, until the system signals a change in the platform position, as will appear.

Another type of improved design, best seen in FIGS. 1 and 4, transmits positional data from the platform 14 to the air control valve in a manner to produce corrective action, and upon completion of the corrective servo action, to erase the original signal. The sensor 79 comprises a smooth cylindrical rod 81 that smoothly slides within upper and lower small-diameter portions of the bored passage 49, and particularly within a close-fitting plastic bushing 83, with good lubricating properties, sealed within the passage 49. The lower end of the rod 81 rests freely upon the valve disc 57 but the rod is insufficient weight itself to open the valve. The clearance between the periphery of the rod, and the surrounding portion of the bushing 82 are minimal, to reduce leakage, which may be even more closely controlled by employing a sealing ring 83, located within a sealed-off zone or groove in the rod. The ring 83 may be of circular cross section, and it may be of moderately deformable elastomeric material, typically using tetrafluoroethylene or a related product having a low coefficient of friction. It is fitted to the surrounding hole preferably with a slight interfering fit so as to provide a relatively smooth sliding action for the rod 81, with no significant leakage of air past the ring. With small travel of the rod 81, the ring 83 may even tend to roll in its groove, reducing the frictional effects normally associated with sliding rings. A port 84 allows for the continuous bleeding of such a small amount of air from the system as leaks into a bore 85 between the bottom of the sensing rod 81 and the valve disc 57. The rate of flow is controlled by the type of finish used on the adjoining surfaces, the type of materials used on the mating ports, and the resulting tightness of the fit. The flow need be sufficient only to provide a gradual continuous reduction in the pressure exerted on the pistons 26 so that after a predetermined interval a new equilibrium condition is reached. The volume of the pressurized fluid within an air spring, contracts the diaphragm, producing a measurable lowering of the platform 14. This deviation from an originally established normal position may be infinitesimal, that is, in microns, but it is faithfully transmitted to the sensing rod 81, in any convenient manner, preferably through a filamentary linkage that transmits axial forces, but lacks rigidity to exert significant lateral forces that might cause binding of the sensing rod.

As an added precaution to the buildup of pressure within the intermediate-pressure chamber 56, as might occur if a foreign particle blocks full seating of valve 63, a tiny bleed hole, 60 typically made with a 0.01 drill, may extend through the disc 57, to connect chamber 56 with the air springs. A similar result might be obtained by having a controlled degree of porosity at the joint between the disc 57 and the seat 58, as by employing mating surfaces of predetermined roughness. The amount of leakage however is not of a magnitude to materially disturb the moderate differential pressure between the chamber 56 and the port 47. As shown in FIGS. 1 and 4, a straightened wire 86, for example of hardened stainless steel or music wire, extends from the sensing rod 81, and is secured beneath the platform. Threaded stems 85 may be soldered or otherwise attached to one or both ends of the wire, and the assembly is adjustably secured by screw threads to the sensing rod and bracket respectively, and held in the desired relationship to these parts as by locknuts 89. Assuming that the platform 14 is in its normal position, the system will be in equilibrium under comparable parts of the air spring 21 and of the valve 44 and regulator 61 in the positions shown in FIGS. 2 and 4. If an additional load is applied to the platform, or if in the passage of a time interval the piston 26 retracts, the slight resulting incipient downward motion of the platform applies a pressure to wire 86 opening valve 57 by a sufficient amount to cause a corrective flow of air from the intermediate-pressure chamber 56 through port 47 to the inlet connections 37, tending to restore the platform to its original position. Simultaneously with the slight opening of valve 57, air from the intermediate-pressure chamber 56 also flows through port 78 and increases the pressure within the lower-pressure chamber 71, helping to actuate valve 63 sufficiently to restore the predetermined position of the intermediate pressure chamber 56. Similarly if the load on the platform is lightened, the platform tends to rise on its air spring supports, and the incipient motion, transmitted through the relatively fine wire 86 lifts the rod 81 from the disc 57, allowing free bleeding of air from the air springs via the outlet port 47 to the bore 88 and out through the vent 48.

A deviation of the platform has been found to occur, with corrective servo action, when less than one-twentieth ounce of load change occurs on the platform. The resulting deviation in millimeters or micrometers often is not discernible to the naked eye so that the motion might properly be considered as incipient motion. Obviously the motion is real and can be detected with suitable instruments. In short, the regulator, by being responsive to the difference between the pressures of the mount and of the intermediate pressure chamber respectively, maintains the latter chamber at a reasonably constant pressure that nevertheless is substantially independent of the actual mount pressure, and of the magnitude of the pressure of the air source, so that the device functions properly over the full range of supply pressures. The "softness" of the response of the system is a measure of the functional relation of the differential pressure between the chamber 56 and that at the outlet port 47. Assuming a fixed setting of the bleed valve 42, the lower the pressure in chamber 56 relative to port 47, the more softness, or delay in the corrective action, but the greater the sensitivity.

It has been found desirable as a practical matter to maintain a constant differential in chamber 56, of say 10 or 15 p.s.i., as compared with an input pressure of some 100 p.s.i. and a
mount pressure of perhaps 70 to 80 p.s.i. Obviously the response of the system may be varied by controlling the differential pressure by adjustment of the regulator screw 74. For normal operating conditions therefore the dynamic response of the system may be matched to particular load or operating conditions merely by adjusting the constant differential pressure by means of the regulator, and/or controlling the damping action by varying the amount of air bypassed to the damping chamber.

At startup with the inlet 45 shut off from the supply, all air will have been bled from the system, the platform will be in its lowest position, and the rod 81 will have been depressed to an abnormal secondary position, well below its normal operating range. Consequently, valve 57 will be fully open, and spring 56 compressed sufficiently to open valve 53. Hence when high-pressure air is admitted to chamber 51, the air flows directly to port 47 through valves 53 and 57, bypassing regulator 61, the intermediate chamber pressure and directly through to the air springs 21 and damping chamber 43. This action appreciably reduces the startup time, possibly by a matter of several minutes, and may represent more than a 10-fold saving in startup time over currently known equipment. A similar abnormal operating condition may arise when a heavy load is suddenly applied to the table, in which case a quick downward responsive movement of the rod 81 to a secondary position imparted by axial motion of the filament 86, opens both valves 56 and 53, giving more immediate response by briefly connecting the air springs directly with the pressurized source, until equilibrium is reached. Since the filament 86 is relatively flexible any lateral motion at one end of the wire relative to the other end results in a compliant motion of the wire without imparting significant lateral forces to the rod 81.

Conversely when a load is removed from the platform, as when the load is hoisted by a crane, a sudden significant raising of the platform by the air springs logically ensues. The rod 81 then is lifted by wire or filament 86 allowing air to bleed through bore 88 and out of port 84 and vent 48. The port 84 may be of limited size, restricting the flow somewhat, unless the load change is of such magnitude to cause rod 81 to rise to a secondary upper position, wherein the O-ring 83 is clear of the bushing 82 and no longer seals the passage 49. The normal clearance of even a few thousandths of an inch between rod 81 and the passage 49 then provides a peripheral escape path whose cross section exceeds that of port 84, and which contributes significantly to the bleeding of air from the air springs directly to exhaust chamber 91 and vent 48, thereby more quickly stabilizing of the platform. In extreme cases, as when the platform or the surface plate is lifted suddenly from its supports, the rod 81 even have been forcibly ejected completely from their housings by the force of the air in the mount system, the wires 86 likely being deformed in the process if their upper ends are contained. The sudden ejection of the sensor rods operates as a fuse or safety mechanism to protect the air springs and other parts of the system by completely venting the air springs to the atmosphere through the open passageway 49.

Various connections between valves and air springs may be arranged, according to the required nature of support, and the degree of control needed. If the need is simply to maintain height at a given point, a single valve and sensor may be used, and a group of air springs connected in tandem to the single outlet port 47. Since three points are needed to define a plane, any system requiring orientation of a plate requires at least three sensors and controls, with at least one neighboring air spring operating in each. Likewise, if a pendulous platform needs control only as to height, a single spring and valve is sufficient. With the system illustrated, four separated air springs are used, each of two being controlled by separate valves and sensors, and the remaining two being operated in tandem by the third valve and sensor.

We claim:

1. A self-leveling vibration-isolated mounting system comprising a platform, pressure-responsive pneumatic means for adjustably supporting said platform, a sensor responsive to deviations in the position of said platform from a predetermined norm, and valve means operable by said sensor for conducting pneumatic fluid from a pressurized source to said pneumatic means, said valve means including an inlet port for connection to said pressurized source of pneumatic fluid, an intermediate-pressure chamber for receiving pneumatic fluid from said inlet port, an outlet port for receiving pneumatic fluid from said intermediate pressure chamber, and pressure regulator means operative to maintain a substantially constant differential between the pressure acting at said outlet port and the pressure in said intermediate chamber;

2. A vibration-isolated mounting system as claimed in claim 1, wherein said differential is maintained substantially independent of the pressures at said ports.

3. The invention of claim 1, wherein said valve means includes a valve body enclosing said regulator means.

4. The invention of claim 1, wherein said regulator means is operable to control the flow of said fluid by a predetermined moderate portion of the difference in the pressures between said inlet and outlet ports.

5. A vibration-isolated mounting system as set forth in claim 1, wherein said pressure-responsive pneumatic means supports said platform at a point above the center of gravity of said platform, to render said platform pendulous.

6. A vibration-isolated mounting system as set forth in claim 1, wherein said sensor includes a flexible filamentary member extending between said platform and said valve means, said member being sufficiently rigid as to transmit between said platform and said valve means relative motion axial of said filamentary member while being compliant to motion of said platform transversely of said member.

7. A vibration-isolated mounting system as set forth in claim 1, wherein the response time of said pressure-regulator means exceeds the natural period of said system.

8. A vibration-isolated mounting system as set forth in claim 1, including a damping chamber also communicating with said valve means and with said pneumatic means, and a throttle device for regulating the proportion of fluid flowing from said source to said pneumatic means and to said damping chamber respectively.

9. Apparatus as claimed in claim 7, wherein said damping chamber has a volumetric capacity substantially greater than the volumetric capacity of said pneumatic means.

10. In a stabilized structure having pneumatic positioning means responsive to controlled pressure of air for adjusting the position of said structure, and a sensor responsive to deviations in the position of said structure from a predetermined normal position for regulating the flow of compressed air to said positioning means, the improvement comprising an air control valve having an inlet chamber for communication with a supply of air under pressure, an outlet port for communicating with said pneumatic positioning means, an intermediate-pressure chamber, a first-valve means actuated by said sensor for conducting air from said intermediate-pressure chamber to said outlet port, and regulator valve means having pressure-responsive means communicating respectively with said outlet port and with said intermediate-pressure chamber, and being operable by a differential pressure between said outlet port and said intermediate-pressure chamber for controlling the passage of air from said inlet chamber to said intermediate-pressure chamber.

11. Apparatus as claimed in claim 10, but including a second valve means actuated by said sensor in response to an abnormal deviation in the position of said structure from a predetermined normal position, said second valve means then being operable to bypass said regulator valve means, and to connect said outlet port directly with said inlet chamber.

12. Apparatus as claimed in claim 10, wherein said regulator valve means includes a movable member for controlling the flow of air from the supply of air under pressure to said intermediate chamber, in response to a substantially constant differential pressure that is substantially independent of the
magnitude of the supply pressure but normally a relatively small part of the supply pressure.

13. Apparatus as claimed in claim 10, wherein said regulator valve pressure-responsive means includes a lower-pressure chamber communicating with said pneumatic means, spring means, a higher-pressure chamber communicating with said intermediate-pressure chamber, and a movable partition separating said lower-pressure chamber from said higher-pressure chamber, said partition being urged by said spring means and by the pressure in said lower-pressure chamber in a direction to admit air from said inlet chamber, and being urged by the pressure in said higher-pressure chamber to block the flow of air from said inlet chamber.

14. Apparatus as claimed in claim 10, including means for regulating the effective force of said spring means.

15. Apparatus as claimed in claim 10, including a bleed path extending between said intermediate-pressure chamber and said outlet port, said path allowing continuous predetermined minimal flow of air to bypass said first-valve means to help in minimizing the differential pressure between said intermediate-pressure chamber and said outlet port.

16. A vibration-isolated mount, comprising a load-bearing platform, a plurality of air springs supporting said platform at spaced points, a valve for each of said air springs, sensing means associated with each of said valves for controlling the flow from a source of air under pressure to said respective springs in response to deviations in the position of said platform from an established norm, and regulator means for reducing the pressure from said source to a substantially constant increment above a normal pressure required in said air springs for the support of said platform.

17. The method of supporting a stabilized structure within predetermined limits from an established normal position, comprising adjustably supporting the structure pneumatically with fluid under normal pressure, detecting incipient deviations in the position of said structure from said normal position as during a reduction in said normal pressure, varying the pressure of said fluid applied to said structure in accordance with said deviations so as to restore said normal position, and maintaining the upper limit of said applied fluid pressure at an established increment above said normal pressure.

18. In a self-leveling platform having pneumatic supporting and positioning means responsive to controlled pressure of air for adjusting the level of said platform, and a sensor responsive to deviations in the position of said platform from a predetermined normal position for regulating the flow of compressed air to said positioning means, the improvement comprising an air control valve having an inlet chamber for communication with a supply of air under pressure, an outlet port for communicating with said pneumatic positioning means, and vent means, said sensor including means operable when said sensor is moved in one direction from a normal position to admit compressed air to said outlet port, and being operable when in a normal position to bleed small predetermined quantities of leakage air from said outlet port to said vent means, said sensor also including means when said sensor is moved in the opposite direction to provide paths of successively increased cross section and accordingly of progressively reduced resistance to the flow of air from said outlet port to said vent means as the motion of said sensor increases.

19. Apparatus as claimed in claim 18, wherein said sensor includes a rod normally responsive to the motion of said platform and being slidably contained within a close-fitting bore within said valve, said rod being sufficiently responsive to the air pressure at said outlet port when said platform moves beyond predetermined limits as to be ejected from said bore, whereupon said bore provides an additional path for venting air from said outlet port.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,578,278 Dated May 11, 1971

Inventor(s) Norman C. Pickering et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 75, "ports" should read -- parts --.
Column 6, line 15, "071" should read #71 --. Column 8, line 48, "sense" should read -- sensor --. Column 10, lines 1 and 2, "positions" should read -- position --.

Signed and sealed this 16th day of May 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCALK
Commissioner of Patents