June 25, 1940. E. B. DONNELL 2,206,003

INCLINOMETER

Filed June 2, 1937 2 Sheets-Sheet 1

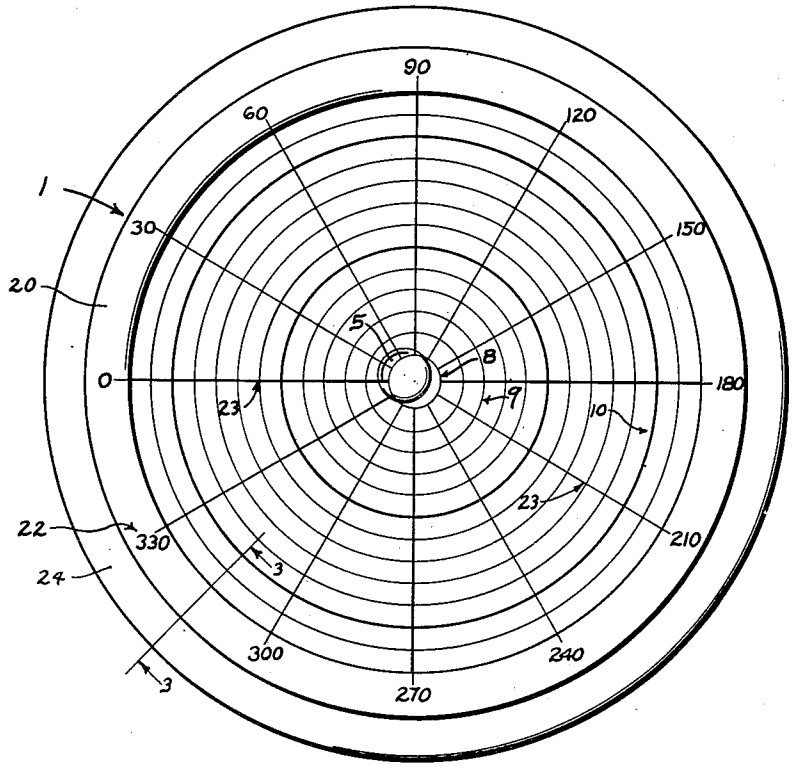


FIG. 1.

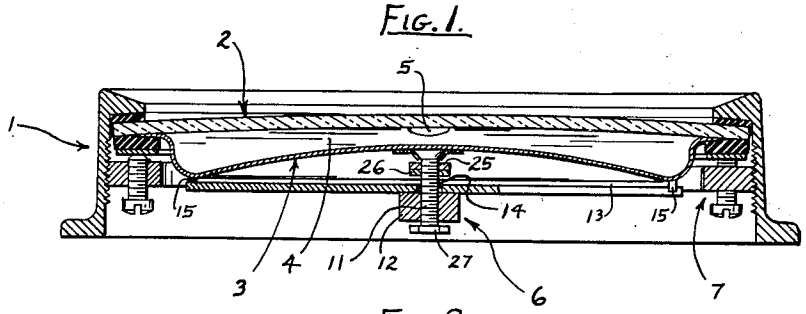


FIG. 2.

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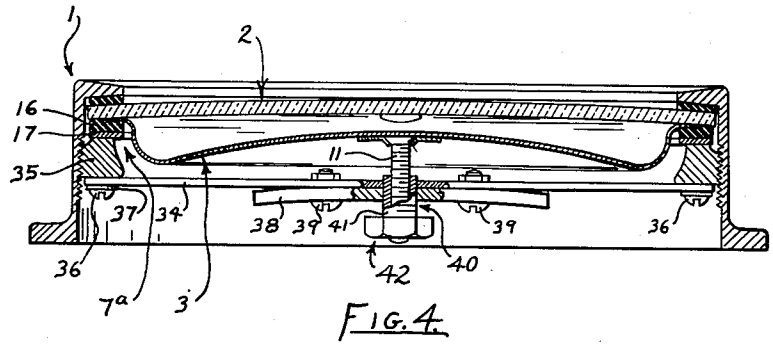


FIG. 4.

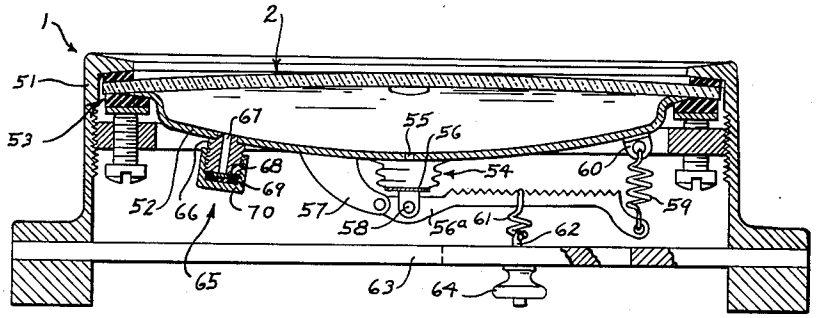


FIG. 6.

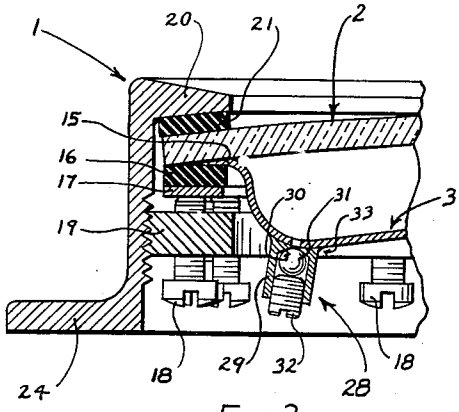


FIG. 3.

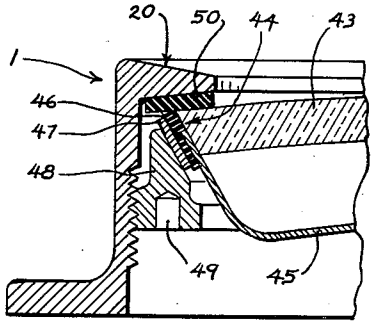


FIG. 5.

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2,206,003

INCLINOMETER

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Application June 2, 1937, Serial No. 146,064

6 Claims. (Cl. 33—212)

The present invention relates to inclinometers, and an object of the invention is to generally improve the construction and operation of devices of this class.

A further object is to provide such a device of the universal spirit level type, and further objects are to provide the following:

A structure of extreme lightness; a structure which will be substantially unaffected by atmospheric conditions; a structure which may be adjusted for prevailing atmospheric conditions.

More specifically an object is to provide a universal spirit level in which the effects of temperature changes on the structure and the contained liquid are automatically compensated, and in which pressure conditions responsible for changes in the size of the contained void or bubble may be controlled, automatically or otherwise.

A further object is to provide a structure in which the liquid containing phial may be partly of metal.

A further object is to provide an improved seal between the metal and glass parts of the phial.

A further object is to provide means for correcting inaccuracies in the curvature of the level glass.

A further object is to provide improved means for filling the phial with liquid.

Further objects and advantages will become apparent from the following specification and accompanying drawings in which:

Figure 1 is a plan view of an illustrative embodiment of the invention.

Fig. 2 is a substantially axial vertical sectional view of the same.

Fig. 3 is an enlarged sectional view on the line 3—3 of Fig. 1.

Fig. 4 is a sectional view of a modified type of bubble adjusting and compensating means.

Fig. 5 is an enlarged sectional view similar to Fig. 3 of a modified type of sealing means.

Fig. 6 is a sectional view of a modified type of expansible fluid chamber and volume controlling means.

Similar reference characters have been applied to the same parts throughout the drawings and specification.

As seen in Figs. 1 and 2, the instrument comprises generally a case, frame or housing 1 in which is fixed a transparent element or glass 2 beneath which is maintained by a container or cup or base 3 a body of liquid 4 containing a void or bubble 5 which travels to the highest point beneath closure 2 to indicate amounts of inclination or other conditions, glass 2 being slightly upwardly curved in a manner well understood in this art. Glass 2 and base 3 constitute what is generally referred to as the "phial" of the level.

Means generally denoted by numeral 6 is provided for adjusting the size of the bubble and compensating for changes in temperature or other conditions, and sealing means generally denoted by numeral 7 is provided for obtaining a fluid-tight joint between closure 2 and base 3 as will be presently more fully described.

For greatest usefulness in indicating amounts of tilting, closure 2 is provided with a series of concentric circles such as 8—9—10—etc., the middle circle 8 representing zero inclination, and the others representing various amounts as indicated by registration of the outer edge of the bubble therewith.

Various values may be assigned to these circles such for example as degrees of inclination or ounce-inches of unbalance when the instrument is used in connection with a balancing machine as fully described in the copending application of John Leonard Taylor, Serial No. 752,587, filed Nov. 12, 1934. For accurate indication of the bubble against these circles it is desirable that the bubble remain of a constant size, preferably equal to the circle 8, and the manner in which this is accomplished forms an important part of the present invention.

As seen in Fig. 2, base 3 is provided with a tension member 11 fixed with the middle portion thereof and extending downwardly, member 11 being preferably threaded and having an adjusting nut 12 thereon normally pulling downwardly on member 11, and pressing upwardly on a strap or spring 13. Spring 13 has a bore 14 through which the member 11 extends, and is seated at its ends in a pair of saddles or abutment portions 15—15 preferably fixed on or near the edge portions of base 3. When nut 12 is tightened base 3 yields downwardly and spring 13 may yield upwardly, and this change in the shape of the base 3 results in a change in the position of the bottom of the phial, and consequently in the volume, or capacity of the liquid chamber. This results in a change in the pressure therein, and in a change in the size of the bubble as above outlined.

If the liquid resists this change in volume, as is normally the case, adjustments of nut 12 will result merely in a change in the deflection of spring 13, later changes in volume of the combined liquid and gas being followed up automatically by changes in the amount of distortion of the spring and base, since the two form a rather stiff diaphragm which, while adjustable as to shape, may

yield somewhat to changes in pressure within the phial.

The degree of stiffness of this assembly may be varied by changing the material, thickness, or contour of base 3, and also the material, thickness, shape, width, or other characteristics of spring 13, and by experiment or otherwise this degree of stiffness is so chosen as to compensate automatically for temperature changes and prevent substantial change in the size of the bubble.

Bubble 5 constitutes a quantity of vapor or gas, usually largely air, and is accordingly compressible, and this, if means was not provided to prevent it, would lead to a change in size of the bubble as the body of liquid 4 expanded and contracted with changes in temperature. Furthermore, most liquids are capable of containing more or less gas in solution, and this complicates the problem by causing the bubble under certain conditions to be literally dissolved into the liquid.

The quantity of gas which a liquid will contain appears to vary directly with the pressure of the mixture, and inversely with the temperature thereof, and also, with most liquids the pressure within a chamber such as that illustrated varies directly with the temperature. The bubble may therefore be controlled by controlling the pressure within the phial, and compensation effected for changes in temperature which would otherwise cause a change in the size of the bubble.

Raising the pressure in the phial will immediately reduce the size of the bubble by compressing the gas of which it is composed, and will subsequently, and over a considerable period of time, for example an hour, cause a progressive further reduction in size as part of the gas is absorbed by the liquid under the increased pressure. The size of the bubble may be increased in a directly analogous manner by reducing the pressure within the vial, and some means of changing the pressure within the vial accordingly permits changing the size of the bubble at will, and also preventing changes in its size caused by changes in temperature or other outside conditions.

The preferred manner of doing this is to make the base 3 of thin sheet material, preferably metal, and of a contour to be slightly flexible. As seen in Fig. 2, the base 3 extends downwardly from the edge portion, and is arched upwardly in the middle portion to approach the glass 2, leaving, however, sufficient clearance to prevent interference with the bubble at the nearest point. Other contours are contemplated for the base, and have been found satisfactory, so, although this shape is at present preferred, it is to be understood that the invention is not limited to this type of base, nor in fact by anything except the subjoined claims.

Thus, assuming normal atmospheric temperature and atmospheric pressure within the phial, the bubble the exact size of circle 8, and downward distortion of base 3 and upward distortion of spring 13, a rise in temperature will cause a tendency for more gas to come out of solution in the liquid to increase the size of the bubble and the pressure in the phial. This temperature rise will also cause an increase in the volume of the liquid in the phial greater than the corresponding increase in volume of the chamber caused by the expansion of the solid parts of the device, and tend to cause an extreme rise in pressure.

This would not only compress the bubble, owing to the natural elasticity of the gas of which it is composed, but also exceed the rise in pressure caused by the tendency of the gas to come out of solution, as above explained. Thus if no rise in pressure were permitted in the chamber, the bubble would increase with rise in temperature, while, if the phial were unyielding, the bubble would decrease with rise in temperature.

By suitably choosing the stiffness of the base and spring, the phial may be made to yield just enough to prevent reduction of the bubble by excessive pressure, but not enough to permit increase of the bubble by gas coming out of solution. Compensation for a falling temperature is automatically effected in an exactly analogous manner by the production of a sub-atmospheric pressure in the phial, and an upward yielding of the base 3 and spring 13.

Adjustment of the stiffness of a given assembly may be had by varying the initial distortion given the parts before the liquid is introduced for the reason that the shape given to base 3 results in its resiliency characteristic varying from the conventional straight line of the ordinary spring, the distortion per unit increase in stress being less and less as the pull is increased. The assembly will therefore offer greater resistance to changes in the volume of the phial if nut 12 is relatively tight than it will if the nut is relatively loose.

If a temperature test indicates that the base should be stiffer the phial may be opened and the nut 12 tightened, after which the size of the bubble is adjusted by introducing more liquid. If the base should be more flexible the procedure is reversed, in either case the phial being closed again after the bubble is adjusted, and the final slight adjustment made by slight movement of nut 12. All this presupposes a fluid-tight seal between the closure 2 and the base 3, and this may be obtained in a number of ways, the following having been found satisfactory.

Referring more particularly to Fig. 3, base 3 has a flange portion 15 having an outside diameter somewhat less than that of glass 2, and arranged to be pressed into intimate contact therewith through a resilient gasket 16 of rubber or other suitable sealing material which overlaps flange 15 and directly contacts the glass beyond the edge thereof as clearly shown in the figure. In this manner substantially all direct contact of the liquid with the gasket material is prevented and any damaging effect of the one on the other is greatly inhibited. If desired the contacting surfaces of flange 15 and glass 2 may be ground together so as to effect a substantially fluid-tight seal at this point independently of the gasket, seepage of fluid past the ground joint being prevented by the contact of the gasket with the glass beyond the rim of the flange as before.

Pressure is applied to the gasket in the present instance by a pressure ring 17 forced into contact with the gasket by any suitable pressure exerting means such as a plurality of spaced screws 18—18 carried in a ring-nut 19, or other suitable element carried in housing 1. The multiple screws facilitate the applying of an intense evenly distributed pressure to the ring and gasket and may be used to apply an uneven pressure if desirable to correct slight inaccuracies in the glass or for similar purposes.

Casing 1 has an upper inwardly extending flange 20, for receiving the upward thrust of glass 2, a suitable cushioning gasket 21 being preferably interposed between the glass and flange as shown, although the glass might bear

directly against the flange if desirable. With the illustrated construction the glass is carried entirely in rubber or similar material, and liability of breakage from shocks, expansion strains or the like is minimized.

Flange 20 may be provided with graduations indicating angles or directions as indicated at 22, Fig. 1, and these may register with radial or other suitable graduations 23—23 on glass 2 to indicate the direction as well as the amount of tilting of the instrument, or apparatus to which it is attached. This avoids the necessity of engraving numbers or other characters on the glass.

An attaching flange or base 24 is fixed with casing 1 and for protection of the flexible bottom of base 3 from excessive distortion and possible damage, stop nuts 25 and 26 are placed between spring 13 and base 3. Another stop nut 27 may be permanently or otherwise fixed on screw member 11 to limit the downward travel of adjusting nut 12.

Means for filling the phial, and adjusting the size of the bubble therein is provided as generally designated by numeral 28, Fig. 3. Various expedients are contemplated for this purpose, that shown having been found to be satisfactory. It consists of a body portion 29 bored longitudinally to provide a central passageway and a seat portion or shoulder 30 against which a closure member such for example as a steel ball 31 is forced with considerable pressure by means such as a screw 32 threaded in the bore of body 29. The body portion is fixed to the level base 3 in any suitable manner as by soldering at 33, but any fastening means may be used which will give a mechanically strong and fluid-tight connection.

Fig. 4 shows a modified arrangement for adjusting the stiffness of the base or back of a level phial according to the present invention. In this arrangement a glass 2, and a base 3, which may be identical with those of Figs. 1 and 2 are arranged in a case 1, and sealed by a suitable sealing means generally denoted by numeral 7a. Movements, or stiffness of the bottom of base 3 are controlled by a spring or bridge 34 anchored at its ends to some stationary part of the structure, such for example as a ring 35 constituting part of the sealing device 7a to be later described, although the spring may be connected to the base 3 by suitable means after the manner of spring 13 above described. The spring is anchored, however, so as to resist movement either up or down, as by means of screws 36–36, slight longitudinal movement of the ends of the spring due to flexing or bowing thereof being permitted by sliding of the spring under the screw heads, a bearing washer 37 being interposed if desired.

Spring 34 is made substantially more flexible than above described spring 13, and its effective length, and accordingly its effective stiffness, may be adjusted by clamping it in contact with a substantially rigid bar or strap element 38 as by means of bolts or the like 39–39, the spring and bar 38 being suitably arranged with slots or the like so that the positions of the bolts may be shifted lengthwise of the spring. Means is provided for connecting screw 11 and bar 38 or spring 34 for communicating the stiffness of the spring to base 3, in the present instance bar 38 being threaded at 40 to receive a sleeve portion 41 of an adjusting nut generally denoted by numeral 42, the interior of the sleeve being threaded and engaged with the screw. The pitches of the two threads is different so that turning of the nut results in a slight movement of bar 38 in the direction of the axis of screw 11. The threads are preferably fitted tightly to avoid clearance so that movements of the level base 3 in the manner above described are transmitted to spring 34 without lost motion. Adjustment of nut 42 will adjust pressure conditions in the phial in the same manner as in the case of the above described nut 12, and by suitably choosing the pitch of the two threads, the adjustment may be made more or less critical as desired. Other well known means of connecting the base and spring for relative adjustment are contemplated as equivalent.

In this embodiment the phial is filled and the bubble brought to correct size at room temperature with the spring 34 under no initial stress, and any later tendency of the base 3 to move either up or down is resisted by spring 34 owing to the positive connection between the nut 42 and bar 38. If a temperature test indicates that the spring is too stiff, bolts 39–39 may be loosened and moved nearer screw 11 and again tightened, while, if the spring appears to be too flexible, the nuts may be adjusted in the opposite direction. Slight adjustment, or correction of the size of the bubble may be made by adjusting the position of nut 42.

Seal 7a is similar to seal 7 except for the omission of screws 18, ring-nut 35 bearing directly on pressure ring 17, and, through threaded engagement with the case 1, forcing the pressure ring into contact with the gasket 16. Suitable means may be provided for turning the ring.

A further modification of the sealing means is shown in Fig. 5. In this arrangement a glass 43 is provided with a beveled edge portion 44 against which is pressed the outer rim of a base or cup 45, which may be ground to the glass if desired, a ring 46 of suitable gasket material such as rubber being arranged about edge portion 44 overlapping the edge portion of cup 45 so as to bear partly on the metal and partly on the glass, a pressure ring 47 being pressed against the gasket by means of a ring nut 48 threaded in the case 1, and rotated by means of a spanner or the like not shown, inserted in bores such as 49. The upward thrust of glass 43 resulting from the pressure of nut 48 is taken on a gasket or cushion 50 interposed between the glass and the upper rim 20 of casing 1.

Another arrangement for controlling the conditions within the level phial is shown in Fig. 6. Here a glass 2 is held in a case 51 together with a base or cup 52, and maintained in fluid-tight relation therewith by means of a seal generally denoted by numeral 53 which may be of an illustrated or any suitable type. Unlike the previously described bases, this base is not flexible, but substantially rigid and unyielding, and other means are used for controlling internal pressure conditions as follows:

An expansible chamber or bellows 54 is arranged beneath base 52 and communicates with the interior of the phial through a port or opening 55. Chamber 54 has a lower head 56 which will tend to be moved up and down with changes in the pressure within base 52, and this movement may be resisted to any desired degree by any suitable means such as a lever 56 fulcrumed on a bracket 57, preferably fixed with the under side of base 52, and pivoted to head 56 at 58. The free end of lever 56 is controlled by a tension spring 59 anchored at 60 on base 52, and pulling

in an upward direction, a second tension spring 61 pulling downwardly on the lever, for example between spring 59 and pivot 58. Spring 61 is stretched between a portion of the upper surface of the lever and an adjusting screw 62, extending through a slot in a bridge or brace member 63 and carrying an adjusting nut 64 which may be turned to change the tension in springs 59 and 61. By shifting the position of spring 61 along lever 56 the degree of stiffness or resistance to movement of head 56 may be changed at will.

A modified arrangement of filler opening is shown in this embodiment of the invention, the same being generally designated by numeral 65 and consisting of a body portion 66 fixed with base 52 and providing a central bore 67 closed at its outer end by a disk 68 of suitable material such as metal, the disk being pressed against the end of the body portion by an element of gasket material 69 held in place by a cap 70 threaded to body portion 66. Disk 68 is preferably of a diameter somewhat less than that of body portion 66 so that gasket element 69 overlaps the edges of the disk and directly contacts body portion 66. Thus, while the liquid is protected from contact with the gasket by the interposition of the metal, the metal is not required to make a fluid-tight contact with the body portion 66, although the metal may be ground to a seat on the body portion if desired.

The above being a full and complete description of illustrative embodiments of the invention, what is claimed as new and desired to be secured by Letters Patent of the United States is:

1. In an inclinometer a transparent element and a container for liquid beneath said element, said container having a yieldable bottom portion, and adjusting member fixed with said yieldable bottom portion, a resilient bridge member spanning said yieldable bottom portion and means engaged between said resilient bridge member and said adjusting member, supported by said bridge member and arranged to exert, through said adjusting member, a resilient distorting force upon said yieldable bottom portion.

2. In an inclinometer a transparent element and a container for liquid beneath said element, said container having a yieldable bottom portion, an adjusting member connected with said yieldable bottom portion, a resilient bridge member spanning said yieldable bottom portion, means for adjusting the degree of resiliency of said resilient bridge, and means engaged between said resilient bridge and said adjusting member and arranged to transmit the resistance to distortion of said bridge through said adjusting member to said yieldable bottom portion.

3. In an inclinometer a transparent element and a container for liquid beneath said element, said container having a yieldable bottom portion, an adjusting member connected with said yieldable bottom portion, a resilient bridge member spanning said yieldable bottom portion, means for adjusting the degree of resiliency of said resilient bridge, and means engaged between said resilient bridge member and said adjusting member, supported by said bridge member and arranged to exert, through said adjusting member, a resilient distorting force upon said yieldable bottom portion.

4. An inclinometer as set forth in claim 3 including means for manually adjusting the degree of distorting force transmitted by said resilient bridge through said adjusting member to said yieldable bottom portion.

5. In an inclinometer a transparent element and a container for liquid beneath said element, said container having a yieldable portion, a resilient bracing element connected with said yieldable portion so as to transmit the resistance to distortion of said bracing member to said yieldable portion.

6. In an inclinometer a transparent element and a container for liquid beneath said element, said container having a yieldable portion, a resilient bracing element connected with said yieldable portion so as to transmit the resistance to distortion of said bracing member to said yieldable portion, and means for connecting said yieldable portion and said resilient bracing element and adapted for adjusting the position of said yieldable portion relatively to said resilient element whereby to introduce a distorting force between said yieldable element and said bracing member.

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