

STABILIZED LASER PLUMB

FIELD OF THE INVENTION

[0001] The present invention relates generally to plumbing devices, and more particularly to a laser plumb that is stabilized.

BACKGROUND OF THE INVENTION

[0002] A plumb is a device used to ensure alignment along a particular axis, exploiting the force of gravity. Plumbs are used extensively in the construction and mining industries.

[0003] A simple plumb is formed by attaching a pointed weight to a thread. Although inexpensive, such plumbs are cumbersome to use: they take a long time to arrive at their position of equilibrium, and may be easily disturbed. Other plumbs make use of the gravitational orientation of water bubbles. These too, only gradually reach their equilibrium position, and are easily perturbed.

[0004] As lasers have become readily available and economical, they have been employed in laser plumbing devices. The lasers of such devices are aligned in such devices along the gravitational axis in several different ways. For example, the laser may be part of a simple pendulum.

[0005] Typically, laser plumbs perform better than conventional plumbs as the process of plumbing is less cumbersome and the time to arrive at the equilibrium position is shortened. In order to help the plumb settle faster, some laser plumbs are damped.

[0006] Once in equilibrium, however, these laser plumbs do not have the ability to maintain their orientation under the influence of external disturbances. In practical applications, it is almost impossible to eliminate external disturbances. Inaccurate plumbing can cause machines and

structures to perform poorly or fail catastrophically.

[0007] Another shortcoming of existing plumbs is the inability to measure floor tilt. Such tilt information allows for improved horizontal levelling.

[0008] Accordingly, there is a need for an improved laser plumbing device.

SUMMARY OF THE INVENTION

[0009] An exemplary laser plumb includes a laser, and a mass that is rotatable about a spin axis to stabilize the laser. The mass is mounted to a support to be pivotable about at least one axis, and preferably two axes. The two axes are perpendicular to each other and the spin axis. The laser is mounted to the mass to maintain its orientation relative to the support, as the mass rotates about the spin axis. A weight below the tilt axes aligns the spin axis with the gravitational axis. Rotating the mass about its spin axis stabilizes orientation of the laser. Preferably, the mass and laser are mounted to the support by a gimballed mount.

[0010] The exemplary plumb optionally includes markings on its base to measure a deflection of the laser from the support, thereby allowing measurement of the angle of inclination of a surface supporting the base.

[0011] In accordance with another aspect of the present invention there is provided a laser plumb, including a base; a support, extending from the base; a rotatable mass pivotably mounted to the support, for rotation about a spin axis and pivotable to allow tilting of the spin axis relative the support about a first tilt axis perpendicular to the spin axis; a weight mounted to the mass beneath the first tilt axis to align the spin axis under the influence of gravity; a laser mounted to the weight, to emit a beam of light along a beam axis, the beam axis pivotable with the mass under the influence of gravity, so as to extend in a fixed direction relative to the direction of gravity when the weight is in equilibrium under the influence of gravity; a motor to spin the mass about

the spin axis, so that the angular momentum attributable to the rotatable mass stabilizes the laser.

[0012] In accordance with a further aspect of the present invention there is provided a laser plumb including a mass that is rotatable about a spin axis, the mass mounted to a support to be pivotable about two axes, the two axes perpendicular to each other and the spin axis; a laser mounted to the mass, to maintain its orientation relative to the support, as the mass rotates about the spin axis.

[0013] In accordance with yet another aspect of the present invention there is provided a laser plumb including, a support; a gimballed gyroscope mounted to the support, the gimballed gyroscope including a flywheel rotatable about a spin axis; a weight mounted to the gyroscope to exert a force on the flywheel to align its spin axis relative to the support, toward the gravitational axis; a laser mounted to the gyroscope, to emit a light beam along an axis having a fixed orientation relative to the spin axis.

[0014] In accordance with another aspect of the present invention there is provided a laser plumb including a support; a gimballed mount mounted to the support for rotation about first and second mutually perpendicular tilt axes; a flywheel supported by the gimballed mount, rotatable about a spin axis perpendicular to the first and second tilt axes; a weight mounted to the gimballed mount, to having a centre of gravity beneath the first and second tilt axes; a laser coupled to the gimballed mount, having a fixed orientation relative to the spin axis.

[0015] In accordance with a further aspect of the present invention there is provided a method of generating a laser plumb line, by way of a laser plumb. The laser plumb includes a laser mounted to a mass. The mass is rotatable about a spin axis. The spin axis is tiltable about at least one tilt axis normal to the force of gravity. The spin axis tiltable with the mass. The method includes, generating a laser beam along a beam axis; aligning the spin axis with the force of gravity; and rotating the mass to gyroscopically stabilize the

laser beam along the beam axis.

[0016] Other aspects and features of the present invention will become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In the figures which illustrate by way of example only, embodiments of the present invention,

[0018] **FIG. 1** is a perspective view of a laser plumb, exemplary of an embodiment of the present invention

[0019] **FIG. 2A** is a top plan view of a base of the laser plumb of **FIG. 1**;

[0020] **FIG. 2B** is a side elevational view of the base of **FIG. 2A**;

[0021] **FIG. 3** is an enlarged elevational view of a floor pointer assembly of the laser plumb of **FIG. 1**;

[0022] **FIG. 4A – 4C** illustrate bearing assemblies of the laser plumb of **FIG. 1**;

[0023] **FIGS. 4D-4E** illustrate alternate bearing assemblies for use in the laser plumb of **FIG. 1**;

[0024] **FIGS. 5A and 5B** illustrate a vertical pointer assembly including second and third lasers forming part of the laser plumb of **FIG. 1**;

[0025] **FIGS. 5C and 5D** illustrates alternate vertical pointer assemblies, for use in the laser plumb of **FIG. 1**;

[0026] **FIG. 6A and 6B** are perspective views of a base of the laser plumb of **FIG. 1**, in operation;

[0027] **FIG. 7A and 7B** are side elevational views of the laser plumb of

FIG. 1, in operation; and

[0028] **FIG. 8** is a front elevational view of an alternate laser plumb, exemplary of another embodiment of the present invention.

DETAILED DESCRIPTION

[0029] **FIG. 1** is a perspective view of a laser plumb **10** exemplary of an embodiment of the present invention. As illustrated, a laser forming part of a pointer assembly **18** is pivotally mounted to a base **28**.

[0030] Specifically, floor pointer assembly **18** extends from the base of a motor **16**. Motor **16** and pointer assembly **18** are supported by a second rectangular frame **24** that is mounted to a first generally square frame **26** by bearing assemblies **22b** and **22d** (individually and collectively bearing assemblies **22**) to allow pivoting about a first tilt axis **32** (i.e. the y-axis). Frame **26** in turn, is hinged by bearing assemblies **22a** and **22c** (also bearing assemblies **22**) on two opposed vertically extending supports **34** that extend upwardly at right angles from base **28**, for pivoting about a second tilt axis **30**. The first and second tilt axes are mutually perpendicular. The centers of gravity of frames **24** and **26** are also preferably coincident. Consequently frames **24** and **26** form a two-axes gimballed mount for floor pointer assembly **18**.

[0031] Motor **16** is coupled to drive a flywheel **14** to rotate about spin axis **20** when motor **16** is energized. Optionally, motor **16** or flywheel **14** may include a brake. Flywheel **14** has a high mass moment of inertia, and is also supported by frame **24** with its center of gravity intersecting the first tilt axis **32** of frame **24**. The orientation of spin axis **20** of flywheel **14** relative to base **28** varies with the orientation of frame **24**. As illustrated, flywheel **14** and pointer assembly **18** are in a fixed relationship so that pivoting of spin axis **20** also pivots pointer assembly **18**. That is, as pointer assembly **18** pivots about the first and second tilt axes, so does flywheel **14**. As will become apparent, the

high mass moment of inertia of flywheel **14** and its alignment with pointer assembly **18** increases the stability of plumb **10** during plumbing.

[0032] In the illustrated embodiment, a further horizontal-vertical pointer assembly **12** including second and third lasers is located at the highest position of plumb **10** and is also mounted to frame **24**.

[0033] Optionally, plumb **10** may include a compass **36** that may be used to locate magnetic north. Such a compass **36** may be particularly useful if plumb **10** is used in mining or construction. Preferably, compass **36** extends from base **28** and is sufficiently magnetically isolated so that any metal forming part of plumb **10** does not affect operation of compass **36**.

[0034] An exemplary base **28** of plumb **10** is illustrated in greater detail in **FIGS. 2A** and **2B**. As illustrated, base **28** includes a sturdy circular ring **70**, defining an opening **82**. Feet **72** in the form of studs are located at equal angular positions about ring **70** and extend from the bottom of base **28**. Feet **72** provide kinematic stability when the plumb **10** is placed on a resting surface. Feet **72** are preferably made of durable material, such as rubber or plastic, to withstand wear and tear. Equally spaced locating pins **76** extend upwardly from the top of circular ring **70**. These pins allow a removable generally circular plate **74** to be placed concentrically above the circular ring **70** in an accurate manner to obstruct opening **82**. Plate **74** has holes that coincide in size and position with locating pins **76**. Plate **74** includes a plurality of markers **80** in the form of concentric rings. As will become apparent, markers **80** of circular plate **74** may be used to determine the angle of tilt of any support supporting plumb **10**. Markers **80** may further include numerals indicative of the angle of tilt. Compass **36** may extend from an edge of base **28**.

[0035] Floor pointer assembly **18** is more particularly illustrated in **FIG. 3**. As illustrated, floor pointer assembly **18** includes a laser **50** that generates a laser beam along a beam axis. This laser beam points in a generally vertical direction so that it can be used to vertically align horizontal-vertical pointer

assembly 12 in relation to a prescribed point. In the illustrated embodiment, laser 50 is mounted along a central longitudinal axis of floor pointer assembly 18. Optionally, a sleeve 52 that is generally cylindrical in shape extends about pointer assembly 18 about the bottom end of motor 16.

[0036] As noted, pointer assembly 18 along with flywheel 14 are mounted to base 28 by the gimbaled mount formed of frames 24 and 26. As frames 24 and 26 pivot about their tilt axes, so does the orientation of beam axis of laser 50. Conveniently, the orientation of beam axis of laser 50 is parallel to spin axis 20 of flywheel 14.

[0037] Since the center of gravity of the motor 16, sleeve 52 and floor pointer assembly 18 is lower than bearing assemblies 22a, 22b, 22c and 22d (and thus first and second tilt axes) motor 16 sleeve 52 and pointer assembly 18 acts as a gravitational pendulum, supported by the gimbaled mount formed by frames 24 and 26. The weights of the motor 16 and the sleeve 52 are generally sufficient to allow free pivoting of the gravitational pendulum, and thus the spin axis 20 of flywheel 14. As will be appreciated, while flywheel 14 is not rotating about its spin axis 20, tilting of frames 24 and 26 to align assembly 18 to the force of gravity is only resisted by the friction of bearing assemblies 22. Optionally, an additional weight 54, in, for example the form of cylindrical ring, may be fitted to the sleeve of the pendulum and floor position locating assembly 18.

[0038] Example bearing assemblies 22, 22' used to mount frames 24 and 26 (that may be used as assemblies 22a-22d, FIG. 1) are further illustrated in FIGS. 4A-4F. As illustrated, an example bearing assembly 22 is formed of a rotating shaft 62 mounted on a bearing 60. Optionally, bearing assembly 22 may include damping to reduce settling times of frames 24 and 26 (FIG. 1). As illustrated in FIG. 4C, the bearing assembly 22 may include a fluid container 64 that houses a viscous fluid 66 in fluid communication with shaft 62. Essentially, the viscous fluid 66 inhibits the rotational movement of shaft 62. Of course, container 64 and shaft 62 should be sealed to avoid fluid

leakage.

[0039] An alternative damped bearing assembly **22'** illustrates in **FIGS. 4D** and **4E** includes permanent magnets **68'** mounted in proximity to shaft **62'**. In bearing assembly **22'**, shaft **62'** should be formed of ferromagnetic or include a ferromagnetic attachment. The degree of damping may be altered by varying the distance between the shaft and permanent magnets and the strength of the magnets.

[0040] Horizontal-vertical pointer assembly **12** of plumb **10** is more particularly illustrated in **FIGS. 5A** and **5B** (**FIGS. 5A** and **5B** illustrate top and side plan views of assembly **12**, respectively). As illustrated, assembly **12** includes two additional lasers; a laser **40** that is fixed and points vertically upwards along the plumb line when plumb **10** is in equilibrium. A further laser **42** at a right angle to laser **40** can be rotated within a plane that is normal to the plumb line. Vertically extending laser **40** is mounted on a stationary base **46** that is essentially a low profile solid cylinder that extends upward from frame **24** (**FIG. 1**). Laser **40** preferably extends co-axially with the axis of rotation of flywheel **14**. Laser **42** is mounted on a movable rotary base **44** that is essentially a circular ring that fits and rotates freely about the stationary base **46**. Laser **42** is mounted at the rim of rotary base **44**, and thus will point in different directions as laser **42** is rotated about stationary base **46**. A set screw **48** allows rotary base **44** to be locked in an angular position relative to stationary base **46**.

[0041] Alternate horizontal/vertical laser pointer assemblies **12'** that may be used in place of pointer assembly **12** are illustrated in **FIGS. 5C** and **5D**. As illustrated, two lasers **40** and **42** may be replaced by a single laser **40'** and a suitable beam splitter **58** or prism **58'**. Beam splitter **58** (**FIG. 5C**) is rotatable about its central axis, and is mounted atop vertical laser **40'**. Beam splitter **58** ensures that a vertically directed beam emanating with laser **40'** is split, so that a 50% of the beam is directed in the vertical direction, and the other 50% of the beam is directed in a horizontal plane perpendicular thereto.

Rotation of splitter **58** about its central axis controls the actual orientation of the horizontal beam within the plane. Alternatively, a removable prism **58'** (**FIG. 5D**) also rotatable about its central axis may be placed atop laser **40'** to redirect a vertical beam from laser **40'** in a horizontal plane when required.

[0042] A suitable electric power supply for powering motor **16** and lasers **40**, **42** and **50** may be housed in an appropriate housing that may be mounted to plumb **10**, or may be separate therefrom. Power to each of lasers **40**, **42** and **50** and motor **16** may be independently and individually controlled, allowing an operator to energize one or more of the lasers **40**, **42** or **50** or motor. Optionally the speed of motor **16** can be varied through control of its power supply. If flywheel **14** or motor **16** are equipped with a brake, a momentary switch may be used to bring the rotation of the motor and flywheel to a halt.

[0043] In operation, plumb **10** is placed above a point to be plumbed on floor or the like, as best illustrated in **FIGS. 1**, **6A-6B** and **7A-7B**. Motor **16** is preferably not initially energized: flywheel **14** thus does not initially rotate about its spin axis **20**. Downwardly extending laser **50** is aimed at a point of interest. Laser **50** remains generally plumb as frames **24** and **26** pivot about bearing assemblies **22a-22d** under the influence of gravity on laser **50** (and motor **16** and sleeve **52**). The force of gravity on laser **50**, motor **16** and sleeve **52** also pivot flywheel **14**, so that its spin axis **20** aligns with the gravitational axis.

[0044] Once laser **50** is plumb its beam axis is aligned to the gravitational axis. Vertical laser **40**, in turn, points vertically upward, and defines a plumb line. Laser **40** will project a point upward toward any ceiling, and directly above the point of interest. Horizontal laser **42**, points in a horizontal plane, normal to the plumb line. The direction of horizontal laser within the plane may be adjusted, by rotating rotary base **44** relative to stationary base **46**. Once laser **42** points in the desired horizontal direction, locking screw **48** may be tightened. This fixes the angular orientation of horizontal laser **42** relative to

assembly 12 to prevent further motion. Graduated markings on assembly 12 and horizontal laser 42 may be used to determine the pointing direction of the horizontal level laser 42.

[0045] Now, once laser 50 emits a beam along parallel to the gravitational axis, flywheel 14 may be driven by the motor 16 from rest to rotate to a prescribed constant operating speed to stabilize the orientation of pointer assembly 18, and thus lasers 50, 40 and 42. Rotating flywheel 14 in conjunction with gimbaled mount supporting flywheel 14 and floor pointer assembly 18 acts as a gyroscope, stabilizing the orientation of the spin axis 20 of flywheel 14 and pointer assembly 18. The angular momentum of flywheel 14 resists any perturbation of spin axis 20 of flywheel 14. Consequently, the orientation of pointer assembly 18 is similarly stabilized. In this way, plumb 10 is ideal for use in environments where stability is required, or in the presence of perturbations from external forces, such as gusts of wind and vibrations caused by proximate machinery and debris.

[0046] Downward extending laser 50 creates a light spot on the point of interest, through opening 82 in base 28. Thereafter, tilt measuring plate 74 may be interposed between the point of interest and the beam of laser 50, on base 28. The tilt of the floor may be determined by reading gradations off the position of the laser light spot in relation to the concentric markings on the circular plate 74. For example, **FIGS. 6A** and **7A** illustrate plumb assembly 10 on a level floor. By contrast, **FIG. 6B** and **7B** illustrates plumb 10 on a tilted floor, having an angle of inclination θ .

[0047] The height of horizontal laser 42 from the locating point is simply given by $h_2 + h_1/\cos \theta$, where h_2 is the distance between the second tilt axis 30 and laser 42, and h_1 is the distance between the bottom of base 28 and this tilt axis, as illustrated in **FIG. 7B**. In the case of a horizontal floor, as illustrated in **FIG. 7A**, the height is merely given by $h_1 + h_2$. For a tilted floor, the tilt angle θ is obtained using measuring plate 74, as detailed above.

[0048] As should now be appreciated, a stabilized laser plumb need not

include a gimballed mount for its pointer assembly. As such, plumb 10 could easily be modified to replace the gimballed mount formed by frames 24 and 26 with another mount. As for example illustrated in FIG. 8 pointer assembly 18 could be mounted above base 28 by way of a universal joint. As illustrated, this universal joint may be formed as a ring 44 within a ring mount 46, allowing pivoting of weight 50 about two axes perpendicular to the force of gravity. Other mounts are similarly possible.

[0049] Of course, the above described embodiments are intended to be illustrative only and in no way limiting. The described embodiments of carrying out the invention are susceptible to many modifications of form, arrangement of parts, details and order of operation. The invention, rather, is intended to encompass all such modification within its scope, as defined by the claims.

WHAT IS CLAIMED IS:

1. A laser plumb, comprising
 - a base;
 - a support, extending from said base;
 - a rotatable mass pivotably mounted to said support, for rotation about a spin axis and pivotable to allow tilting of said spin axis relative said support about a first tilt axis perpendicular to said spin axis;
 - a weight mounted to said mass beneath said first tilt axis to align said spin axis under the influence of gravity;
 - a laser mounted to said weight, to emit a beam of light along a beam axis, said beam axis pivotable with said mass under the influence of gravity, so as to extend in a fixed direction relative to the direction of gravity when said weight is in equilibrium under the influence of gravity;
 - a motor to spin said mass about said spin axis, so that the angular momentum attributable to said rotatable mass stabilizes said laser.
2. The plumb of claim 1, wherein said rotatable mass is pivotably mounted to said support, for pivoting about a second tilt axis perpendicular to said first tilt axis and said spin axis.
3. The plumb of claim 2, further comprising a first frame and a second frame, said second frame supporting said weight and said mass, said first frame mounted to said support for pivoting about said first tilt axis; said second frame mounted to said first frame for rotation relative thereto about a second pivot axis, normal to said first axis.
4. The plumb of claim 3, wherein said support extends normal to said base.
5. The plumb of claim 4, wherein said base comprises markings to measure

a degree of deflection of said beam axis from said support.

6. The plumb of claim 5, wherein said markings are arranged in a plurality of concentric circles on said base.
7. The plumb of claim 6, wherein said base defines an opening and further comprises a removable plate to cover said opening, said removable plate bearing said markings.
8. The plumb of claim 5, further comprising a first bearing assembly to mount said first frame to said support for pivoting about said first tilt axis; and a second bearing assembly to mount said second frame to said first frame for pivoting about said second tilt axis.
9. The plumb of claim 8, wherein said first and second bearing assemblies are damped, to damp movement of said pointer assembly.
10. The plumb of claim 9, wherein each of said bearing assemblies is hydraulically damped.
11. The plumb of claim 9, further comprising a magnet in proximity to said bearing assembly, to damp said movement of said pointer assembly.
12. The plumb assembly of claim 2, wherein said laser is parallel to said spin axis.
13. The plumb assembly of claim 2, further comprises a second laser mounted to said weight to produce a laser beam parallel to said beam axis.
14. The plumb assembly of claim 13, further comprising a third laser mounted to said weight to produce a laser beam normal to said beam axis.
15. The plumb assembly of claim 14, wherein said third laser is rotatably mounted to adjust orientation of said laser beam within a plane, normal to said beam axis.
16. The plumb assembly of claim 2, further comprising a compass.

17. A laser plumb comprising

a mass that is rotatable about a spin axis, said mass mounted to a support to be pivotable about two axes, said two axes perpendicular to each other and said spin axis;

a laser mounted to said mass, to maintain its orientation relative to said support, as said mass rotates about said spin axis.

18. A laser plumb comprising,

a support;

a gimballed gyroscope mounted to said support, said gimballed gyroscope comprising a flywheel rotatable about a spin axis;

a weight mounted to said gyroscope to exert a force on said flywheel to align its spin axis relative to said support, toward the gravitational axis;

a laser mounted to said gyroscope, to emit a light beam along an axis having a fixed orientation relative to said spin axis.

19. A laser plumb comprising

a support;

a gimballed mount mounted to said support for rotation about first and second mutually perpendicular tilt axes;

a flywheel supported by said gimballed mount, rotatable about a spin axis perpendicular to said first and second tilt axes;

a weight mounted to said gimballed mount, to having a centre of gravity beneath said first and second tilt axes;

a laser coupled to said gimballed mount, having a fixed orientation relative to said spin axis.

20. A method of generating a laser plumb line, by way of a laser plumb comprising:

a laser mounted to a mass, said mass rotatable about a spin axis, said spin axis tiltable about at least one tilt axis normal to the force of gravity, said spin axis tiltable with said mass;

said method comprising,

generating a laser beam along a beam axis;

aligning said spin axis to the gravitational axis;

rotating said mass to gyroscopically stabilize said laser beam along said beam axis.