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(71) Applicant *(for all designated States except US)*: **FARO TECHNOLOGIES, INC.** [US/US]; 125 Technology Park, Lake Mary, FL 32746 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **CRAMER, Peter, G.** [US/US]; 101 Deer Creek Crossing, Kennet Square, PA 19348 (US). **WEST, James, K.** [US/US]; 510 Port Royal Court, Landenberg, PA 19350 (US). **BRIDGES, Robert, E.** [US/US]; 102 Quail Lane, Kennett Square, PA 19348 (US).

(74) Agent: BEDINGFIELD, Herbert, M.; Cantor Colburn LLP, 55 Griffin Road South, Bloomfield, CT 06002 (US).

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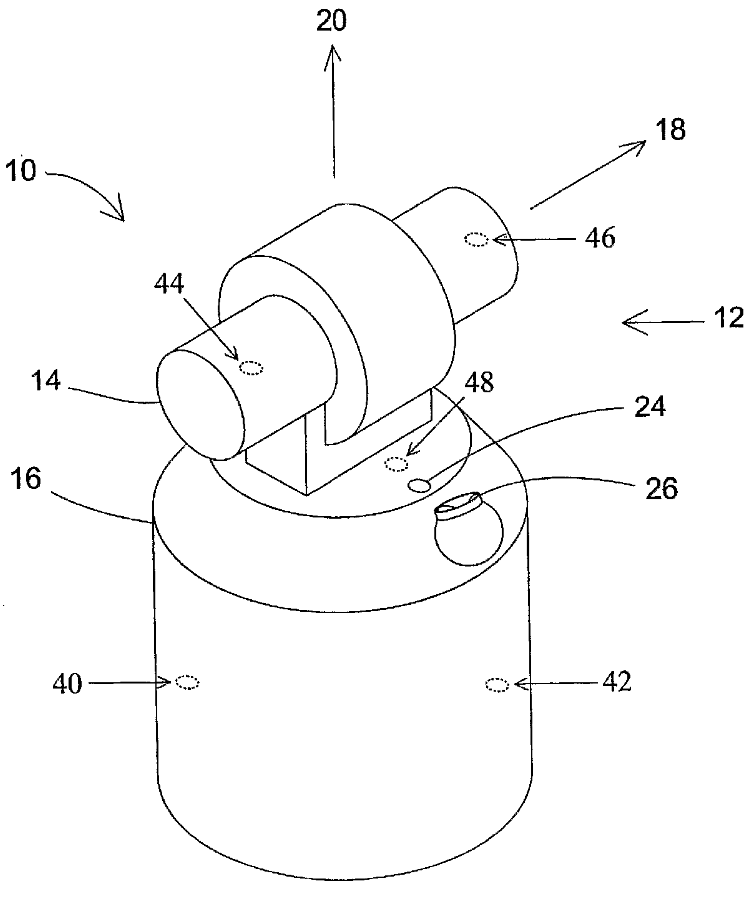
(54) Title: SELF-COMPENSATING LASER TRACKER

(57) Abstract: An apparatus and method for compensating a coordinate measurement machine is provided, which may be, e.g. a laser-based coordinate measurement machine, laser tracker, or other coordinate measurement device. In one exemplary method, such compensation comprises self-compensation of payload parameters by means of embedded tracker targets. In another exemplary embodiment, such compensation comprises self compensation of payload, azimuth-post, axis, or *RO* parameters by means of embedded temperature sensors.



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SELF-COMPENSATING LASER TRACKER

BACKGROUND

The present disclosure relates to a coordinate measuring device. One set of coordinate measurement devices belongs to a class of instruments that measure the coordinates of a point by sending a laser beam to the point. The laser beam may impinge directly on the point or may impinge on a retroreflector target that is in contact with the point. In either case, the instrument determines the coordinates of the point by measuring the distance and the two angles to the target. The distance is measured with a distance-measuring device such as an absolute distance meter or an interferometer. The angles are measured with an angle-measuring device such as an angular encoder. A gimbaled beam-steering mechanism within the instrument directs the laser beam to the point of interest. Exemplary systems for determining coordinates of a point are described by U.S. Patent No. 4,790,651 to Brown et al. and U.S. Patent No. 4,714,339 to Lau et al.

The laser tracker is a particular type of coordinate-measuring device that tracks the retroreflector target with one or more laser beams it emits. A device that is closely related to the laser tracker is the laser scanner. The laser scanner steps one or more laser beams to points on a diffuse surface. The laser tracker and laser scanner are both coordinate-measuring devices. It is common practice today to use the term laser tracker to also refer to laser scanner devices having distance- and angle-measuring capability. This broad definition of laser tracker, which includes laser scanners, is used throughout this application.

Compensation parameters are numerical values that are stored in software or firmware accessible to the tracker. These numerical values are applied to raw tracker data to improve tracker accuracy. Initially, the manufacturer of the tracker finds the compensation parameters by performing measurements called compensation procedures. Later, the tracker will be used at the customer's site to make measurements. Periodically, the tracker will be checked for accuracy by performing interim tests. If the accuracy is substandard, the tracker operator will perform one or more compensation procedures on the factory floor. These can take from a few minutes to an hour or more, depending on the particular tracker and on the tests that are required. In most cases, the main cause of reduced tracker accuracy is thermal drift, although mechanical shock can also be important. What is needed are new methods for compensating a coordinate measurement machine.

SUMMARY

The above-discussed and other deficiencies of the art are overcome or alleviated by the present apparatus and method for compensating a coordinate measurement machine, which may be, e.g. a laser-based coordinate measurement machine, laser tracker, or other coordinate measurement device. In one exemplary method, such compensation comprises self-compensation of payload parameters by means of embedded tracker targets.

In another exemplary embodiment, such compensation comprises self-compensation of payload, azimuth-post, axis, or *R0* parameters by means of embedded temperature sensors.

Both methods may be referred to as self-compensation because they are compensation procedures that are performed without human intervention and without the need for external targets. The exemplary methods provide a fast, worry free way to maintain high tracker accuracy, even when temperature changes are large within the tracker's environment.

The above-discussed and other features and advantages of the apparatus and method for a self compensating laser tracker will be appreciated and understood by those skilled in the art from the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, wherein like elements are numbered alike in the several FIGURES:

FIGURE 1 illustrates a perspective view of an exemplary gimbaled beam-steering mechanism incorporating self-compensating elements; and

FIGURE 2 illustrates a top plan view of the exemplary gimbaled beam-steering mechanism of FIGURE 1.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Reference will now be made in detail to exemplary embodiments, examples of which are illustrated in the accompanying drawings.

An exemplary gimbaled beam-steering mechanism 12 of a laser tracker 10 is illustrated in FIGURE 1, comprising a zenith-rotating carriage 14 that is mounted on an azimuth-rotating base 16. The zenith and azimuth mechanical axes 18, 20 are turned to point the laser beam in the desired direction. For the sake of clarity and simplicity, this sort of gimbal mechanism 12 is assumed in the following discussion. However, other types of gimbal mechanisms are possible, and the techniques described here may also be applicable to these other types.

Self-compensation by means of embedded tracker targets

An exemplary self-compensation method provides a way to determine four payload parameters – *TX*, *TY*, *RX*, and *RY* – that describe the position and orientation of the laser beam with respect to the gimbal point of the tracker. The gimbal point is defined as the mechanical pivot point of the tracker. In an ideal tracker, the gimbal point is fixed in space, and the laser beam (or beams) passes through this point. In a real tracker, the laser beam does not pass exactly through the gimbal point but is offset slightly with respect to it. This offset, defined as the perpendicular distance from the gimbal point to the laser beam, is accounted for by the two parameters *TX* and *TY*. Here y is along the zenith axis and x is perpendicular to y and to the laser beam.

Also, in an ideal laser tracker, the laser beam is perpendicular to the zenith and azimuth mechanical axes when the zenith angle is set to 90 degrees. In a real laser tracker, the angular departure of the laser beam from this ideal condition is described by the *RX* and *RY* parameters. The direction of *RX* is along the fingers when the thumb of the right hand points in the *x* direction. The direction of *RY* is along the fingers when the thumb of the right hand points in the *y* direction.

In the current exemplary method, two embedded targets 22, 24 are placed on the body 16 of the laser tracker as shown in FIGURES 1 and 2. One of these targets 24 is a retroreflector, which may be a cube-corner, a retrosphere, or any type of device that sends the return beam back on itself. The second target 22 is a mirror, which is positioned in such a way that it can also serve as a retroreflector when the laser light is sent to the proper location on the mirror.

To determine the four parameters, measurements on each of these two targets may be performed in frontsight and backsight modes. Frontsight mode may be defined as the ordinary mode of operation of the tracker. Backsight mode may be obtained by starting in frontsight mode and then doing the following: (1) rotate the azimuth axis 20 by 180 degrees; (2) rotate the zenith axis 18 to have the negative of the original zenith angle; and (3) turn on tracking. The last step will cause the laser beam to move to the proper position on the cube-corner or mirror so that the retrace condition is established. In other words, the laser beam that passes back into the tracker follows, or retraces, the path of the outgoing laser beam. In an ideal laser tracker, the angular measurement of the embedded targets in frontsight and in backsight will be the same. In a real tracker, these angles will not be exactly the same, and the discrepancy can be used to calculate the four parameters.

For the technique described here to be applicable, two conditions must be met: (1) the mechanical structure must be stable and (2) the returning laser beam must accurately retrace the outgoing laser beam.

Referring to the first condition, the stability of the tracker structure is determined by the stability of two parameters: axis non-squareness (*AXNS*) and axis offset (*AXOF*). In an ideal tracker, the zenith mechanical axis is exactly perpendicular to the azimuth mechanical axis and the two mechanical axes are coplanar. In a real tracker, *AXNS* is the angular deviation from perpendicularity, and *AXOF* is the perpendicular distance between the two mechanical axes. For the mechanical structure to be stable, the *AXNS* and *AXOF* parameters must be stable, or at least predictable, over time.

Referring to the second condition, the accuracy of the returning laser beam will depend on the stability and proper compensation of the tracking system. Part of the returning laser light that enters the tracker splits off and strikes the position detector. The position detector gives an electrical signal that indicates where the centroid of the laser beam is located on the two-dimensional surface of the detector. If the returning laser beam exactly retraces the outgoing laser beam, it will strike a particular location, called the retrace location, on the position detector. The rest of the tracking system, which includes the angular encoders, the motors, the control electronics, and the control software, holds the laser beam near the retrace position when the tracker is in tracking mode. For the returning laser beam to accurately retrace the outgoing laser beam, the retrace location must be accurately known.

The *RX* and *RY* parameters are found by performing a backsight measurement on the embedded mirror 22. If the zenith angle in frontsight is ZE_{FS} and the zenith angle in backsight is ZE_{BS}, then the backsight angle will approximately equal the negative of the frontsight measurement, and the sum of the two angles will be a small value,

$$\Delta ZE = ZE_{BS} + ZE_{FS}. \tag{1}$$

The *RY* parameter is given by

$$RY = \Delta ZE \,/\, 2. \tag{2}$$

If the azimuth angle in frontsight is AZ_{FS} and the azimuth angle in backsight is AZ_{BS}, then the backsight angle will be bigger than the frontsight angle by approximately pi radians. The change in the azimuth angle is a small number,

$$\Delta AZ = AZ_{BS} - \pi - AZ_{FS}. \tag{3}$$

The *RX* parameter is given by

$$RX = \tfrac{1}{2}\,[\Delta AZ + \tan^{-1}(\cos(ZE)\cdot\sin(AXNS) \,/\, \sin(ZE))]. \tag{4}$$

The *TX* and *TY* parameters are found by performing a backsight measurement on the embedded cube-corner. If *d* is the distance from the gimbal point to the embedded retroreflector, the *TX* and *TY* parameters can be found from

$$TX = \tfrac{1}{2}\,\Delta ZE\cdot d - AXOF\cdot\cos(ZE), \tag{5}$$

$$TY = \tfrac{1}{2}\,\Delta AZ \cdot d \cdot \sin(ZE). \qquad (6)$$

Self-compensation by means of embedded temperature sensors

Most of the changes in tracker parameters result from the thermal expansion or contraction of components within the tracker. In an exemplary embodiment, temperature sensors embedded at multiple locations within the laser-tracker structure monitor the temperature changes. The collected temperature data enable the compensation parameters to be adjusted in real time. Temperature related adjustments are made to the following parameters: (1) payload, (2) azimuth-post, (3) axis non-squareness, and (4) $R0$.

Compensation of payload parameters by means of temperature sensors

With reference to FIGURE 2, the payload is the physical structure within the tracker that is rotated by the azimuth mechanical axis. In one exemplary embodiment, one or more temperature sensors 30 embedded within the payload provide information on the temperature of components 32 within the payload. These components 32 include optical components such as beam splitters and lenses and mechanical components on which the optical components are mounted.

Expansions or contractions of the elements within the payload can cause a slight shifting in the four offset and angle parameters, RX, RY, TX, and TY. In a carefully constructed tracker, the slight changes in these parameters are proportional to the change in the payload temperature.

Initially the four angle parameters may be determined in either of two ways: by a pointing compensation or by a self-compensation with the embedded mirror and embedded cube-corner. The self-compensation method with the embedded mirror and cube-corner was discussed above. The pointing compensation is a measurement procedure that is carried out at the factory and that can also be carried out at the customer site, if desired. In this procedure, a spherically mounted retroreflector (SMR) is measured in frontsight and backsight at a small number of locations. The spherically mounted retroreflector is a metal sphere into which a cube-corner retroreflector is mounted with the apex of the cube-corner at the center of the sphere. At the time of the compensation, the values of the parameters are recorded as RX_0, RY_0, TX_0, and TY_0 along with the initial temperature of the payload as $T_{PAYLOAD\_0}$. Later, as the temperature of the payload changes to $T_{PAYLOAD}$, the change in payload temperature is defined as

$$\Delta T_{PAYLOAD} = T_{PAYLOAD} - T_{PAYLOAD\_0}. \qquad (7)$$

The values of the four parameters as corrected in real time are

$$RX = RX_0 + k_{RX} \cdot \Delta T_{PAYLOAD}, \qquad (8)$$

$$RY = RY_0 + k_{RY} \cdot \Delta T_{PAYLOAD}, \qquad (9)$$

$$TX = TX_0 + k_{TX} \cdot \Delta T_{PAYLOAD}, \qquad (10)$$

$$TY = TY_0 + k_{TY} . \Delta T_{PAYLOAD}. \qquad (11)$$

The proportionality constants k_{RX}, k_{RY}, k_{TX}, and k_{TY} may be determined by placing a representative tracker within an enclosure and then varying the temperature while simultaneously measuring the embedded mirror and cube-corner targets in frontsight and backsight modes to monitor the values in RX, RY, TX, and TY. The proportionality constants are found by taking the change in parameter value divided by the change in temperature.

Compensation of azimuth-post parameters by means of temperature sensors

As illustrated by the exemplary tracker of Figures 1 and 2, the tracker may sit on a structural base called the azimuth post. A mechanical axis that sits within the azimuth post rotates on bearings and provides the azimuth motion to the tracker. The exemplary tracker is mounted at the bottom of the azimuth post. In one embodiment, the tracker is mounted in an upright position, so an expansion of the azimuth post causes the gimbal point to increase in height.

Temperature sensors 40, 42 attached to the azimuth post monitor the temperature of the post. At the start of a measurement session, the temperature of the azimuth post is $T_{AZ\_POST\_0}$. As the measurement proceeds, the change in temperature from the initial value is

$$\Delta T_{AZ\_POST} = T_{AZ\_POST} - T_{AZ\_POST\_0}. \tag{12}$$

In response to the change in temperature, the height of the gimbal point will change by

$$\Delta Z_{GIMBAL} = k_{AZ\_POST} \cdot \Delta T_{AZ\_POST}. \tag{13}$$

In the exemplary tracker, electronics along the side of the tracker may heat the azimuth post unevenly. In this case, temperature gradients within the azimuth post may cause the post to bend. This bending will have two effects. First, it will cause the gimbal point to move by ΔX_{GIMBAL} and ΔY_{GIMBAL} in the plane perpendicular to azimuth axis. Note that the directions X and Y do not generally correspond to the directions x and y discussed previously. Second, the temperature gradients will cause the end of the azimuth post to change direction. The carriage that contains the zenith axis is mounted on the end of the azimuth post, so the bending of the azimuth post will cause a change in the direction of the laser beam leaving the tracker. The changes in the angular directions of the end of the azimuth post are referred to as $\Delta AngX_{AZ\_POST}$ and $\Delta AngY_{AZ\_POST}$. Here $\Delta AngX_{AZ\_POST}$ and $\Delta AngY_{AZ\_POST}$ are the angular directions given by the curl of the fingers when the thumb of the right hand is pointed in the X or Y direction, respectively. The parameters associated with the bending of the azimuth post are associated with the change in temperature on the opposite sides of the azimuth post. If the representative temperature differences between the two sides of the azimuth post in the X and Y directions are $\Delta T_{AZ\_POST\_X}$ and $\Delta T_{AZ\_POST\_Y}$, then the changes caused by post bending are given by

$$\Delta X_{GIMBAL} = k_{AZ\_POST\_X\_GIMBAL} \cdot \Delta T_{AZ\_POST\_X}, \tag{14}$$

$$\Delta Y_{GIMBAL} = k_{AZ\_POST\_Y\_GIMBAL} \cdot \Delta T_{AZ\_POST\_Y}, \tag{15}$$

$$\Delta AngX_{AZ\_POST} = k_{AZ\_POST\_X\_ANGLE} \cdot \Delta T_{AZ\_POST\_Y}, \tag{16}$$

$$\Delta AngY_{AZ\_POST} = k_{AZ\_POST\_Y\_ANGLE} \cdot \Delta T_{AZ\_POST\_X}. \tag{17}$$

Note that these four quantities are in the frame of reference of the overall tracker structure, which is fixed relative to the laboratory. By contrast, the quantities TX, TY, RX, and RY are in the payload frame of reference, which rotates in the azimuth and zenith directions and is not fixed relative to the laboratory. These different compensation effects are combined by first performing a mathematical transformation from one frame of reference to the other.

The constants of proportionality in the equations (14) – (17) are found by varying the temperature of the ambient environment while the tracker makes repeated measurements of four SMR targets. All four SMRs are located in approximately the same horizontal plane. Two of the SMRs are relatively close to the tracker and have an angular separation, as measured from the tracker, of approximately 90 degrees. The other two SMRs are farther from the tracker and have the same angular separation. As the gimbal points move, the indicated position of the four targets will change. The nearer targets will be affected relatively more by the change in the direction of the end of the azimuth post and relatively less by the movement in the gimbal ΔX and ΔY than the targets farther from the tracker. This difference in sensitivity allows the four constants of proportionality to be extracted from the equations.

Compensation of the axis non-squareness parameter by means of temperature sensors

Previously it was explained that in an ideal tracker the zenith mechanical axis is exactly perpendicular to the azimuth mechanical axis. In a real tracker, the angular deviation from perpendicularity is called the axis non-squareness. In calculations of target position, the effect of axis non-squareness is removed by the axis non-squareness (*AXNS*) parameter. In a carefully constructed laser tracker, the axis non-squareness will be stable and relatively unaffected by ambient air temperature. However, a relatively large motor may be needed to obtain fast zenith movements. This motor is mounted on the zenith mechanical axis and may generate considerable heat if rapid movements are performed for an extended period. This heat may cause a thermal expansion near one end of the azimuth axis. This can result in a movement of the zenith mechanical axis, with the result that the *AXNS* parameter is changed. To account for the change in the *AXNS* parameter in real time, temperature sensors 44, 46 are placed on each end of the zenith axis. The difference in these temperatures is called ΔT_{ZE_AXIS} and the corresponding change in the *AXNS* parameter is

$$\Delta AXNS = k_{AXNS} \cdot \Delta T_{ZE\_AXIS}. \quad (18)$$

To find the constant of proportionality k_{AXNS} in this equation, the temperature difference ΔT_{ZE_AXIS} is monitored while the change in the *AXNS* parameter is also measured. If the payload parameters *RX*, *RY*, *TX*, and *TY* are accurately known, then the *AXNS* parameter can be easily determined by simply measuring SMRs at three different distances from the tracker in frontsight and backsight modes. For example, the SMRs may be placed in magnetic nests that are glued to the floor at distances of 2, 4, and 6 meters from the tracker. As discussed previously, the payload parameters can be accurately determined by means of the on-tracker mirror and cube-corner, so the three-target approach is a good one. An even more-accurate approach to determining the *AXNS* parameter is to construct a fixture to hold SMRs equidistant from the tracker in a semicircular pattern within a vertical plane. The targets would then be measured in frontsight and backsight modes. The advantage of this approach is that it enables calculation of the *AXNS* parameter independently of *RX*, *RY*, *TX*, and *TY*. However, because the *AXNS* parameter can be accurately determined without this special fixture, the approach that uses three floor targets is usually preferable.

A parameter that is closely related to the *AXNS* parameter is the *AXOF* parameter. As discussed previously, in an ideal tracker the azimuth and zenith mechanical axes lie are coplanar. In a real tracker, the *AXOF* is the perpendicular distance between the two mechanical axes. It is possible to compensate *AXOF* to account in real time for temperature changes. However, in a carefully constructed tracker, the *AXOF* parameter is small, perhaps 10 micrometers, and the change in the parameter is relatively insensitive to the change in temperature. For this reason, it is usually not necessary to compensate for the *AXOF* parameter in real time.

Compensation of the R0 parameter by means of temperature sensors

The parameter *R0* is defined as the distance from the gimbal point to the home position of the tracker. The home position 26 is located at a magnetic nest that is rigidly affixed to the tracker structure. In the exemplary tracker, the magnetic nest is located near the lower portion of the tracker so that the angular range of the tracker is not obstructed. The value of the $R0$ parameter is determined at the factory, or at the customer site, by a compensation procedure. In this procedure, two magnetic nests are glued to instrument stands, and the heights of the instrument stands are adjusted so that the centers of SMRs placed within these nests are at the same height as that of the gimbal point of the tracker. First, the tracker is placed directly in line with, but outside of, the two instrument stands. The tracker measures the distance to an SMR placed in the first nest and also to an SMR placed in the second nest. The difference in distance between these two SMR locations is the true distance between the two SMRs. Next the tracker is moved in line with, but between, the two instrument stands. Again the tracker measures the distance to an SMR placed in each of the two nests. In an ideal tracker the sum of the distances as measured with the tracker between instrument stands is exactly equal to the distance measured with the tracker outside of the two instrument stands. The discrepancy between these two values is used to correct the $R0$ value.

At the time that the $R0$ compensation procedure is performed, the initial $R0$ value, $R0_0$, and the initial temperature representative of the path between the gimbal and home points, T_{R0_0}, are recorded from at least one temperature sensor 48. To correct $R0$ in real time, the initial temperature is subtracted from the current temperature T_{R0} to get the temperature difference:

$$\Delta T_{R0} = T_{R0} - T_{R0\_0}. \tag{19}$$

The change in the $R0$ parameter is given by

$$\Delta R0 = k_{R0} \cdot \Delta T_{R0}. \tag{20}$$

The constant of proportionality k_{R0} is found at the factory by placing an SMR in the home position and using the interferometer or the absolute distance meter within the tracker to monitor the change in the distance to the SMR as a function of the temperature T_{R0}.

While reference is made to exemplary placement of temperature sensors, it should be noted that any placement within or on the tracker effective to provide indications of temperature change relevant to the parameter to be measured are contemplated herein.

Further it will be apparent to those skilled in the art that, while exemplary embodiments have been shown and described, various modifications and variations can be made to the apparatus and method for self-compensation of a laser tracker disclosed herein without departing from the spirit or scope of the invention. Accordingly, it is to be understood that the various embodiments have been described by way of illustration and not limitation.

What is claimed is:

CLAIMS

1. A self-compensating laser tracker, comprising:

a laser source;

a support on which the laser source is positioned, at least a portion of the support or laser source configured to permit redirection of a laser beam emitted from the source; and

at least two reflecting members provided on the support, wherein the support or laser source is configured to permit direction of the laser beam to said at least two reflecting members.

2. A self-compensating laser tracker in accordance with claim 1, wherein one of said at least two reflecting members comprises a retroreflector.

3. A self-compensating laser tracker in accordance with claim 1, wherein one of said at least two reflecting members comprises a mirror.

4. A self-compensating laser tracker in accordance with claim 1, wherein one of said at least two reflecting members comprises a reflecting member embedded in said support.

5. A self-compensating laser tracker in accordance with claim 1, wherein one of said at least two reflecting members comprises a retroreflector and a second of said at least two reflecting members comprises a mirror.

6. A self-compensating laser tracker in accordance with claim 1, wherein said support comprises a gimbaled mechanism configured to permit re-direction of said laser beam.

7. A self-compensating laser tracker in accordance with claim 1, wherein said gimbaled mechanism comprises a zenith-rotating carriage mounted to an azimuth-rotating base.

8. A self-compensating laser tracker, comprising:

a laser source;

a support on which the laser source is positioned, at least a portion of the support or laser source configured to permit redirection of a laser beam emitted from the source; and

at least one temperature sensor provided within or on said laser source or support.

9. A self-compensating laser tracker in accordance with claim 8, wherein the support comprises an adjustable payload, and wherein one of said at least one temperature sensor is provided on or within said payload.

10. A self-compensating laser tracker in accordance with claim 9, wherein one of said at least one temperature sensor is provided on or within an optical component of said payload.

11. A self-compensating laser tracker in accordance with claim 10, wherein one of said at least one temperature sensor is provided on or within a beam splitter, a lens or a fiber optic component.

12. A self-compensating laser tracker in accordance with claim 8, wherein at least a portion of the support comprises an azimuth post, and wherein one of said at least one temperature sensor is provided on or within a portion of said azimuth post.

13. A self-compensating laser tracker in accordance with claim 12, wherein at least two temperature sensors are provided on or within different portions of said azimuth post.

14. A self-compensating laser tracker in accordance with claim 13, wherein said at least two temperature sensors are provided at opposing end portions of said azimuth post.

15. A self-compensating laser tracker in accordance with claim 8, wherein the support comprises a zenith rotating carriage, and wherein one of said at least one temperature sensor is provided on or within said zenith rotating carriage.

16. A self-compensating laser tracker in accordance with claim 15, wherein at least two temperature sensors are provided on or within different portions of said zenith rotating carriage.

17. A self-compensating laser tracker in accordance with claim 16, wherein said at least two temperature sensors are provided at opposing end portions of said zenith rotating carriage.

18. A self-compensating laser tracker in accordance with claim 8, wherein at least a portion of the support comprises a gimbal having a gimbal point, and wherein one of said at least one temperature sensor is provided at said gimbal point.

19. A self-compensating laser tracker in accordance with claim 18, wherein at least a portion of the support comprises a home position, and wherein one of said at least one temperature sensor is provided on or within a portion of said home position.

20. A self-compensating laser tracker in accordance with claim 8, wherein at least a portion of the support comprises a gimbal having a gimbal point, and wherein at least a portion of the support comprises a home position, and wherein one of said at least one temperature sensor is provided at said gimbal point, at said home position, or approximately along a line between said gimbal point and said home position.

21. A self-compensating laser tracker, comprising:

a laser source;

a support on which the laser source is positioned, at least a portion of the support or laser source configured to permit redirection of a laser beam emitted from the source;

at least two reflecting members provided on the support, wherein the support or laser source is configured to permit direction of the laser beam to said at least two reflecting members; and

at least one temperature sensor provided within or on said laser source or support.

22. A self-compensating laser tracker in accordance with claim 21, wherein one of said at least two reflecting members comprises a retroreflector and a second of said at least two reflecting members comprises a mirror.

23. A self-compensating laser tracker in accordance with claim 21, wherein the support comprises one or more of an adjustable payload, an azimuth post, a zenith carriage, a gimbal having a gimbal point, and a home position, and wherein one of said at least one temperature sensor is provided on or within said payload, said azimuth post, said zenith carriage, said gimbal point, said home position or approximately along a line between said gimbal point and said home position.

24. A method of self-compensation of a laser tracker, comprising:

utilizing a laser tracker source to measure in frontsight mode the distance to a first reflective target fixed to or embedded within the support of a tracker;

utilizing a laser tracker source to measure in backsight mode the distance to a first reflective target fixed to or embedded within the support of a tracker;

using the frontsight and backsight measurements of the first reflective target to calculate angular departure of the laser beam relative to a theoretical ideal;

utilizing a laser tracker source to measure in backsight mode the distance to a second reflective target fixed to or embedded within the support of a tracker; and

calculating offset of the laser beam relative to a gimbal point of the laser tracker.

25. A method of self-compensation in accordance with claim 24, wherein said first reflective target is a mirror.

26. A method of self-compensation in accordance with claim 24, wherein said second reflective target is a retroreflector.

27. A method of self-compensation in accordance with claim 24, wherein said angular departure is described by RX and RY parameters, which are calculated according to the following: $RY = \Delta ZE / 2$; $RX = \frac{1}{2} [\Delta AZ + \tan^{-1}(\cos(ZE) \cdot \sin(AXNS) / \sin(ZE))]$; wherein $\Delta ZE = ZE_{BS} + ZE_{FS}$; and wherein $\Delta AZ = AZ_{BS} - \pi - AZ_{FS}$.

28. A method of self-compensation in accordance with claim 24, wherein said offset is described by TX and TY parameters, which are calculated according to the following: $TX = \frac{1}{2} \Delta ZE \cdot d - AXOF \cdot \cos(ZE)$ and $TY = \frac{1}{2} \Delta AZ \cdot d \cdot \sin(ZE)$.

29. A method of self-compensation of a laser tracker, comprising:

calculating or recording an angular departure or offset parameter within a first time period;

calculating or recording temperature data from at least one temperature sensor provided within or on a portion of said laser tracker within said first time period;

calculating or recording temperature data from said at least one temperature sensor provided within or on a portion of said laser tracker within a second time period; and

calculating a temperature corrected value of said at least one parameter based on a comparison of temperature data from said first time period and said second time period.

30. A method of self-compensation of a laser tracker in accordance with claim 29, comprising calculating a proportionality constant for said temperature correction by varying temperature of the portion of the temperature sampled laser tracker while simultaneously measuring said at least one parameter.

31. A method of self-compensation of a laser tracker in accordance with claim 29, wherein said at least one parameter is calculated according to one of the following: $RX = RX_0 + k_{RX} \cdot \Delta T$; $RY = RY_0 + k_{RY} \cdot \Delta T$; $TX = TX_0 + k_{TX} \cdot \Delta T$; $TY = TY_0 + k_{TY} \cdot \Delta T$, wherein k is said proportionality constant.

32. A method of self-compensation of a laser tracker in accordance with claim 29, wherein said at least one temperature sensor is provided within or on a portion of a laser tracker payload.

33. A method of self-compensation of a laser tracker, comprising:

calculating or recording an azimuth post parameter within a first time period;

calculating or recording temperature data from at least one temperature sensor provided within or on said azimuth post within said first time period;

calculating or recording temperature data from said at least one temperature sensor provided within or on said azimuth post within a second time period; and

calculating a temperature corrected value of said at least one parameter based on a comparison of temperature data from said first time period and said second time period.

34. A method of self-compensation of a laser tracker in accordance with claim 33, comprising calculating a proportionality constant for said temperature correction by varying temperature of the portion of the temperature sampled azimuth post while simultaneously measuring said at least one parameter.

35. A method of self-compensation of a laser tracker in accordance with claim 34, wherein said temperature corrected parameter indicates the temperature induced change of height of the gimbal point of said laser tracker according to the following: $\Delta Z_{GIMBAL} = k_{AZ\_POST} \cdot \Delta T_{AZ\_POST}$., wherein k is the proportionality constant.

36. A method of self-compensation of a laser tracker in accordance with claim 33, wherein at least two temperature sensors are provided on different sides of said azimuth post.

37. A method of self-compensation of a laser tracker in accordance with claim 33, wherein said temperature corrected azimuth parameter indicates temperature induced movement of the gimbal point in the plane perpendicular to the azimuth axis, calculated by $\Delta X_{GIMBAL} = k_{AZ\_POST\_X\_GIMBAL} \cdot \Delta T_{AZ\_POST\_X}$ and $\Delta Y_{GIMBAL} = k_{AZ\_POST\_Y\_GIMBAL} \cdot \Delta T_{AZ\_POST\_Y}$, wherein the representative temperature differences between the two sides of the azimuth post in the X and Y directions are $\Delta T_{AZ\_POST\_X}$ and $\Delta T_{AZ\_POST\_Y}$, and wherein k is a proportionality constant

38. A method of self-compensation of a laser tracker in accordance with claim 33, wherein said temperature corrected azimuth parameter indicates temperature induced change in the direction of the azimuth post, calculated by $\Delta AngX_{AZ\_POST} = k_{AZ\_POST\_X\_ANGLE} \cdot \Delta T_{AZ\_POST\_Y}$ and $\Delta AngY_{AZ\_POST} = k_{AZ\_POST\_Y\_ANGLE} \cdot \Delta T_{AZ\_POST\_X}$., wherein the representative temperature differences between the two sides of the azimuth post in the X and Y directions are $\Delta T_{AZ\_POST\_X}$ and $\Delta T_{AZ\_POST\_Y}$., and wherein k is a proportionality constant.

39. A method of self-compensation of a laser tracker in accordance with claims 37 or 38, wherein the proportionality constant is calculated by varying the temperature of the environment incident to said temperature sensors while said tracker makes repeated measurements of four retroreflective targets, wherein said targets are located in approximately the same horizontal plane, wherein two of said four retroreflective targets have an angular separation of approximately 90 degrees, and wherein two of said retroreflective targets are further from the laser tracker and have an angular separation of approximately 90 degrees.

40. A method of self-compensation of a laser tracker, comprising:

calculating or recording an axis non-squareness parameter within a first time period;

calculating or recording temperature data from at least two temperature sensors provided within or on separate portion of said laser tracker on and along said zenith axis within said first time period;

calculating or recording temperature data from said at least two temperature sensors within a second time period; and

calculating a temperature corrected value of said axis non-squareness parameter based on a comparison of temperature data from said first time period and said second time period.

41. A method of self-compensation of a laser tracker in accordance with claim 40, wherein said temperature sensors are located on opposite ends of the laser tracker zenith axis.

42. A method of self-compensation of a laser tracker in accordance with claim 40, comprising calculating a proportionality constant for said temperature correction by varying temperature of the portion of the temperature sampled zenith axis while simultaneously measuring said axis non-squareness parameter.

43. A method of self-compensation of a laser tracker in accordance with claim 42, wherein the axis non-squareness parameter is measured by measuring the distance from the laser tracker to three retroreflectors at different distances in frontsight and backsight modes.

44. A method of self-compensation of a laser tracker in accordance with claim 42, wherein said temperature corrected parameter indicates the temperature induced deviation from perpendicularity of the zenith and azimuth axes according to the following: $\Delta AXNS = k_{AXNS} \cdot \Delta T_{ZE\_AXIS}$., wherein k is the proportionality constant.

45. A method of self-compensation of a laser tracker, comprising:

calculating or recording an R0 parameter within a first time period;

calculating or recording temperature data from at least one temperature sensor provided within or on a portion of said laser tracker such that the measured temperature is representative of the temperature of the path between the gimbal point of the laser tracker and at least one home point within said first time period;

calculating or recording temperature data from said at least one temperature sensor within a second time period; and

calculating a temperature corrected value of said R0 parameter based on a comparison of temperature data from said first time period and said second time period.

46. A method of self-compensation of a laser tracker in accordance with claim 45, wherein the change in the R0 parameter is calculated according to $\Delta R0 = k_{R0} \cdot \Delta T_{R0}$. and wherein k is a proportionality constant.

47. A method of self-compensation of a laser tracker in accordance with claim 45, wherein the proportionality constant is calculated by placing said laser tracking in said home position and monitoring the change in distance to the home point as a function of temperature.

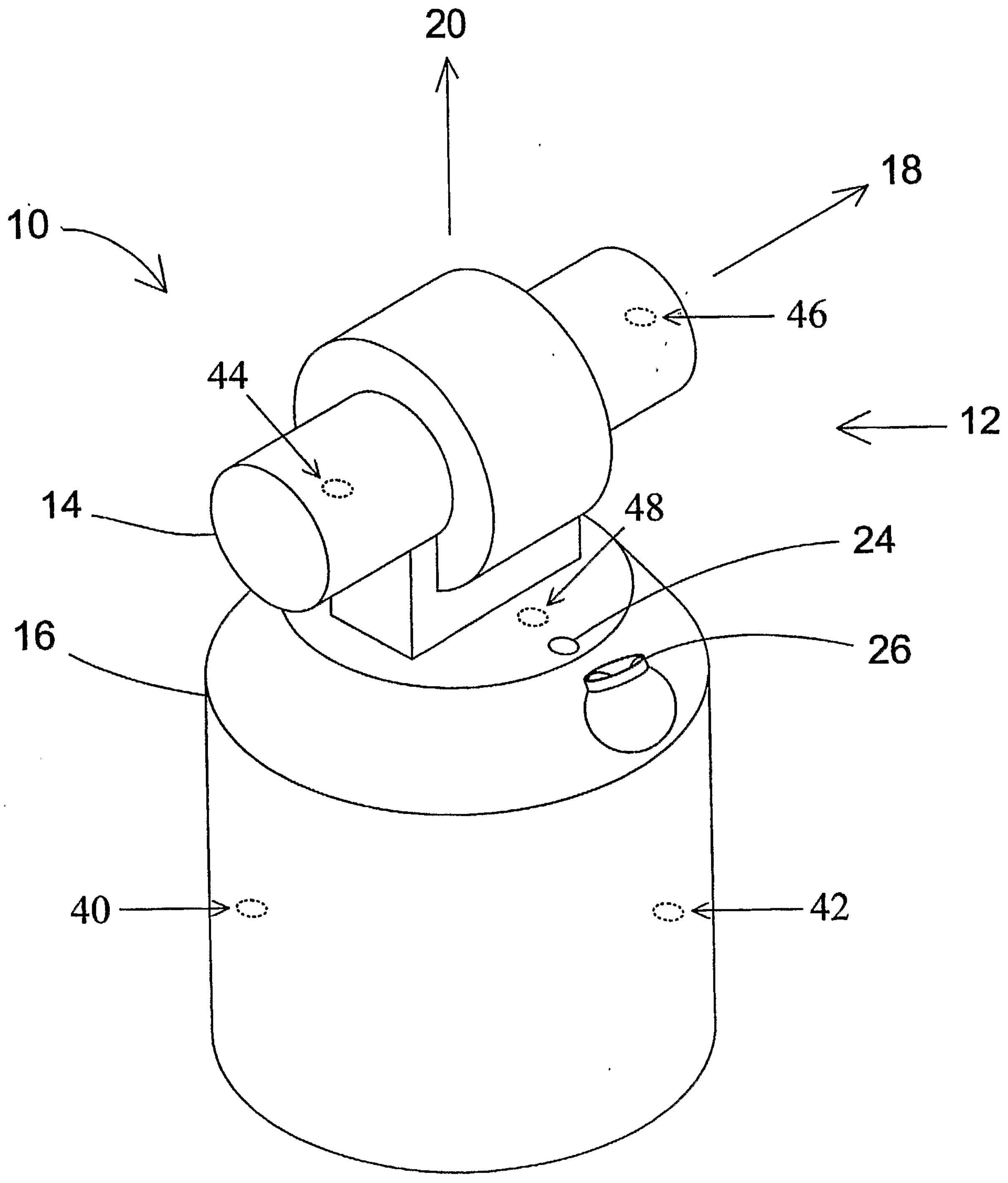

FIGURE 1

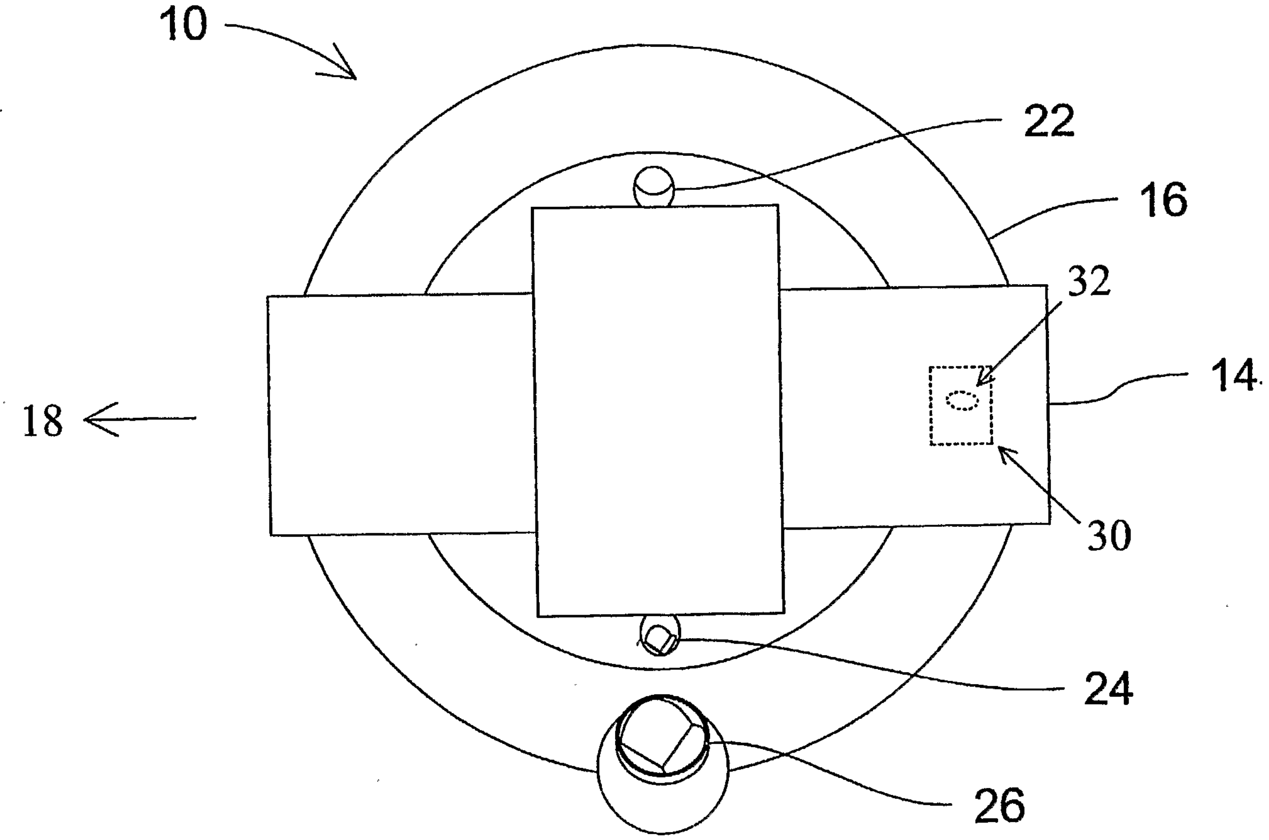

FIGURE 2