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(54) Title: APPARATUS FOR PROVIDING INDICATION OF THE LEVEL OF AIR PRESSURE IN A TIRE

(57) Abstract: The present invention relates to an apparatus for indicating the level of air pressure in a loaded tire of a vehicle traveling along a path, that comprises a first electrical detection system for measuring the length of a first chord that corresponds to the perimeter of the tire along a first plane; a second electrical detection system for measuring the length of a second chord of the tire along a second plane; a processing system for obtaining a measurement regarding the ratio between the lengths, and for generating a pressure indication whenever the measure exceeds a predetermined threshold; a signaling system for generating a visual or audio signal whenever the pressure indication is generated and a flat surface over which the tire travels, while the first or second length is measured.

APPARATUS FOR PROVIDING INDICATION OF THE LEVEL OF AIR PRESSURE IN A TIRE

Field of the Invention

The present invention relates in general to the field of pressure determination in vehicular tires. In particular, the present invention relates to a system for providing indications regarding the level of air pressure in a pneumatic tire.

Background of the Invention

Pneumatic tires (heretofore to be referred to as, tires) lose air through normal driving (especially after hitting pot holes or curbs), permeation and seasonal changes in temperature. They can lose one or two psi (pounds per square inch) each month in the winter and even more in the summer. Not only is underinflation bad for the tires, but it's also bad for the vehicle's gas mileage, affects the way the car handles and is generally unsafe.

Because of the extra resistance originating from a rolling underinflated tire, the car's engine has to work harder. Additionally, when tires are underinflated, the tread wears more quickly. Underinflated tires also overheat more quickly than properly inflated tires, which causes more tire damage. Fig. 1 shows the cross-section of three tires, wherein the first tire (2) is underinflated, the second tire (4) is properly inflated and the third tire is overinflated (6).

Because tires are flexible, they flatten at the bottom when they roll, and form a footprint, or, contact patch at the area of contact with the ground. This contact patch rebounds to its original shape, once it is no longer in contact with the ground. This rebound creates a wave of motion, along with some friction. When there is less air in the tire, that wave is larger and the friction created is greater. If sufficient heat is generated due to greater friction, the rubber that holds the tire's cords together begin to melt and the tire fails.

Tires, therefore, should be maintained at the proper pressure, in order to achieve optimum driving conditions, as described above. Often, one cannot tell if the tires are properly inflated just by visual inspection. One method of determining the pressure in one's tires is to apply a pressure gauge to the valve stem of the tire and read the calibrated rod that is pushed out of the gauge. Using a pressure gauge is undesirable, since one's hands and/or clothing may become soiled during the process. Additionally, when one is inside his vehicle, it is inconvenient to get out of the car and check each tire individually.

WO 2004/057292 discloses a method for detecting one or more characteristic properties of a pneumatic tire, including the size and/or shape of the footprint area, the distribution of pressure on the footprint area, the inflation pressure, etc. The system comprises a plurality of arrays of deformable sensors arranged in parallel, transversal to the direction of the tires, and along the transversal direction for a distance at least equal to the width of the tire. Preferably, the various arrays of sensors are arranged in a staggered formation so as to obtain the desired resolution by providing a greater number of sensors in a predetermined detection area. Each sensor comprises a piezoelectric element that is subject to deformation as the tire passes over the sensor, and generates an electrical signal proportional to the speed of deformation, i.e., the speed of impact with the tire. The speed of deformation is measured and analyzed in order to derive the desired characteristic property of the tire. Most preferably, the speed of the tire during measurement is equal to or greater than 200km/hr. The system is, therefore, not best suited for use during normal driving conditions, where the tire speed would be much less than 200km/hr. Instead, the system would be suited for a garage/repair shop environment, where the vehicle remains stationary on a platform while its wheels rotate at the preferred speed. Hence, a convenient way for the operator of a vehicle to determine improper tire inflation during normal driving conditions and situations is not taught by WO 2004/057292.

US 6,343,506 discloses a method and apparatus for determining tire pressure utilizing twin, parallel spaced piezoelectric cables. The cables are disposed non-transversely with respect to the direction of travel of the tires, and are traversed by the vehicle to produce a voltage pulse having a wave form with a shape or profile characteristic of tire pressure, thereby enabling the pressure of the tire to be determined by analysis. The analysis includes passing tires of differing pressure over the cables and analyzing difference in the profiles of the waveforms from the voltage pulse. However, this method is still relatively complicated cumbersome.

It is therefore an object of the present invention to provide an apparatus for indicating the level of air pressure in a single tire and/or a pair of tires that are situated on a single axle and traveling along a path.

It is an additional object of the present invention to provide an apparatus for indicating the level of air pressure in tires while a vehicle is driving on the road under normal driving speeds and conditions.

It is an additional object of the present invention to provide an apparatus for indicating the level of air pressure in tires while a vehicle is traveling at slow speeds such as when entering or exiting a highway, gas station, rest stop, etc.

Additional objects and advantages of the present invention shall become apparent as the description proceeds.

Summary of the Invention

The present invention relates to an apparatus for indicating the level of air pressure a loaded tire of a vehicle traveling along a path, that comprises:

a. a first electrical detection system for measuring the length of a first chord that corresponds to the perimeter of the tire along a first plane;
b. a second electrical detection system for measuring the length of a second chord of the tire along a second plane;
c. a processing system for obtaining a measurement related to the ratio between the lengths, and for generating a pressure indication whenever the measure exceeds a predetermined threshold;
d. a signaling system for generating a visual or audio signal or any combination thereof, whenever the pressure indication is generated; and
e. optionally, an essentially flat surface over which the tire travels, while the first or second length is measured.

Preferably, the first plane is essentially coplanar with the flat surface of the tire.

Preferably, the second plane is situated at a predetermined vertical distance from, and essentially parallel to, the first plane.

The first detection system may be an optical source and detector unit; an optical source and reflector unit; an RF source and detector unit or at least one piezoelectric cable.

According to one aspect, an optical beam passes from the optical source to the detector or reflector unit through an optical fiber.

Preferably, the first detection system is situated at an angle between 0 and 90 degrees with respect to the direction of travel of the tire along the traveling path.

The second detection system may be an optical source and detector unit; an optical source and reflector unit; or an RF source and detector unit.

The processing system may analyze measures obtained from a single tire or information obtained from more than one tire of the vehicle.

The present invention also relates to an apparatus for indicating the level of air pressure in a pair of loaded tires of a vehicle traveling along a path, that comprises:

a. a first electrical detection system for measuring a first length, being the length of a chord that corresponds to the perimeter of a first tire along a plane;
b. a second electrical detection system for measuring a second length, being the length of a chord that corresponds to the perimeter of a second tire along the plane;
c. a signal processing system for obtaining a measurement related to the ratio between a first function and a second function of the lengths, and for generating a pressure

indication, whenever the measure exceeds a predetermined threshold;

d. a signaling system for generating a visual or audio signal or any combination thereof, whenever the pressure indication is generated; and
e. optionally, an essentially flat surface over which each of the tires travel, while the lengths are measured.

Preferably, each of the planes is essentially coplanar with each flat surface of the tire.

Preferably, the first and second detection system may be an optical source and detector unit; an optical source and reflector unit; an RF source and detector unit; or at least one piezoelectric cable.

According to one aspect, an optical beam passes from the optical source to the detector or reflector unit through an optical fiber.

Preferably, each detection system is situated at an angle between 0 and 90 degrees from the direction of travel of the tire.

The present invention also relates to an apparatus for indicating the level of air pressure in a pair of tires traveling along a path, that comprises:

a. an electrical detection system for successively measuring the lengths of chords that correspond to the perimeter of each of the tires along a plane;
b. a signal processing system obtaining a measurement related to the ratio between a first function and a second function of the lengths, and for generating a pressure indication

whenever the measurement exceeds a predetermined threshold;

c. signaling system for generating a visual or audio signal or any combination thereof, whenever the pressure indication is generated; and
d. optionally, an essentially flat surface over which each of the tires travel, while the lengths are measured.

Preferably, plane is essentially coplanar with each flat surface.

The detection system may be an optical source and detector unit; an optical source and reflector unit; an RF source and detector unit or at least one piezoelectric cable.

According to one aspect, an optical beam passes from the optical source to the detector or reflector unit through an optical fiber.

Preferably, the first detection system is situated at an angle between 0 and 90 degrees from the direction of travel of the tire.

The present invention further relates to a method for indicating the level of air pressure in at least one loaded tire of a vehicle traveling along a path, that comprises:

a. determining the distance between a first axle and a second axle of the vehicle;
b. determining the preferred length of the contact patch of the tire;
c. determining the ratio of the distance to the preferred length;
d. storing the ratio as the preferred ratio in a database;
e. measuring the actual length of the contact patch of the tire;

f. determining the actual ratio of the distance to the measured length; and

g. comparing the preferred ratio to the actual ratio;

wherein, whenever the actual ratio is greater than the preferred ratio, the tire is overinflated, and when the actual ratio is less than the preferred ratio, the tire is underinflated.

Brief Description of the Drawings

In the drawings:

- Fig. 1 illustrates a cross-sectional front view of underinflated, properly inflated and overinflated tires;

- Fig. 2 illustrates a schematic front view of a first preferred embodiment of the present invention;

- Fig. 3 illustrates a schematic side view of a first preferred embodiment of the present invention showing the air pressure level indicator for a singe tire;

- Fig. 4 illustrates a schematic front view of a second preferred embodiment of the present invention;

- Fig. 5 illustrates a schematic top view of a second preferred embodiment of the present invention, showing the chassis of a four-wheeled vehicle wherein the present invention is used to indicate air pressure level in the two front tires;

- Fig. 6 illustrates a schematic side view of a second preferred embodiment of the present invention, showing the air pressure level indicator for a pair of tires arranged in series;

- Fig. 7 illustrates a schematic front view of a third preferred embodiment of the present invention, wherein the first embodiment is used for the measurement of each parallel tire;

- Fig. 8 illustrates a schematic top view of the second embodiment of the present invention, wherein only one laser and detector is required for the measurement of each parallel tire;

- Fig. 9 illustrates the view of Fig. 8, wherein an additional pair of tires is situated along the front axle;

- Fig. 10 illustrates the view of Fig. 8, wherein an additional axle is situated in series and in close proximity to the front axle; and

- Fig. 11 illustrates a schematic top view of the present invention, wherein the electrical detection system is a piezoelectric cable.

Detailed Description of the Preferred Embodiments

An important factor in achieving optimal vehicle performance, is the level of pressure in the vehicle's tires. Maintaining proper air pressure in each tire improves conditions such as safety, comfort, road handling, fuel economy and tire wear. The present invention relates to an apparatus for indicating improper air pressure level in tires, without requiring the operator to exit or dismount the vehicle.

The terms, "upper" and "lower" as used herein, refer to positions along an axis vertical to the ground.

The terms, "tire" and "wheel" are used interchangeably herein, and, unless otherwise stated, both terms refer to the tire itself.

The term, "underinflated" as used herein, refers to a level of air pressure in a loaded tire that is lower than the recommended level, and may result in negative effects, as described above.

The term, "overinflated" as used herein, refers to a level of air pressure in a loaded tire that is above the recommended level, and may result in negative effects, as described above.

The term, "properly inflated" as used herein refers to the recommended level of air pressure in a loaded tire, and is preferable in order to achieve optimal driving conditions, as described above.

A first preferred embodiment of the present invention, for indicating air pressure level of a single tire traveling along a path, is shown schematically in Fig. 2, and comprises an electrical detection system (10) comprising a lower laser source (12) and corresponding lower detector unit (14), upper laser source (22) and corresponding detector unit (24), an essentially flat surface, shown in the form of plate (30), over which tire (40) travels, a processing system (not shown) for interpreting the signals received from each detector unit (14), (24) and a signaling system such as display screen (32) for displaying the interpreted results from the processing system.

For the sake of simplicity, and as an illustrative example, the electrical detection system is described herein as a laser source with a corresponding detector unit. The electrical detection system may alternatively comprise any source of radiation such as a device that produces an optical or RF beam, and having a corresponding detector or reflector unit for detecting the beam. One example of an optical system is described herein below, by way of a light source that passes through an optical fiber.

For the first embodiment, the present invention is best suited for indicating tire air pressure level in a vehicle comprising one tire, or two or more tires that are arranged in series along the direction of travel of the vehicle, for instance, a motorcycle or bicycle.

Fig. 3 shows a side view of the first preferred embodiment of the present invention. The contact patch (41) of tire (40) is situated on an essentially flat surface, shown in this figure as the ground (31). Lower laser (12) is positioned essentially on the surface of ground (31), preferably planar with the contact patch (41) of tire (40). Upper laser (22) is positioned in relatively close proximity to lower laser (12), and at a height of a predetermined vertical distance (d) from lower laser (12), preferably below the central axis of tire (40). Detectors (14), (24) are situated directly opposite lasers (12), (22), and are therefore blocked from view in this figure.

When tire (40) begins traveling in the direction indicated by arrow (y), and passes lower laser (12) at point (a1), lower laser beam (13) (see Fig. 2) is obstructed from the lower detector (14) by tire (40). As tire (40) continues to travel past laser (12), lower beam (13) remains obstructed from lower detector (14) until tire (40) passes lower laser (12) at point (b1). Length (l1), or, the chord corresponding to the perimeter of tire (40) along a lower plane (16), connecting points (a1) and (b1). is the rolling distance along the lower plane (16) of tire (40), which is essentially the length of the contact patch (41).

Similarly, when tire (40) begins traveling in the direction indicated by arrow (y), and passes upper laser (22) at point (a2), upper beam (23) (see Fig. 2) is obstructed from the upper detector (24) by tire (40). As tire (40) continues to travel past laser (22), upper beam (23) remains obstructed until tire (40) passes upper laser (22) at point (b2). Length (l2), or the chord connecting points (a2) and (b2) is the rolling distance along the upper plane (26) of tire (40).

Lower beam (13) and upper beam (23) are directed essentially orthogonally with respect to the direction of travel of tire (40).

Using the equations:

$$l1 = t1 * v1 \qquad (1)$$

and

$$l2 = t2 * v2 \qquad (2)$$

wherein (l1) and (l2) were described above, and

t1 = the time it takes for tire (40) to travel the length of l1 (i.e. the time that lower sensor (12) is obstructed),

t2 = the time it takes for tire (40) to travel the length of l2 (i.e. the time that upper sensor (22) is obstructed),

v1 = the relative speed at which tire (40) travels the length of l1,

v2 = the relative speed at which tire (40) travels the length of l2,

and wherein,

$$v1 = v2 \qquad (3)$$

the ratio between the upper and lower lengths (l2:l1) may be determined.

According to the first embodiment, as the ratio (l2:l1) of upper length (l2) to lower length (l1) approaches 1 (one) (alternatively, as (d) approaches 0 (zero)), tire (40) is considered to be underinflated. Conversely, as the ratio (l2:l1) gets larger, tire (40) is considered to be overinflated. The preferred ratio (l2:l1), which signifies proper inflation of tire (40), and based on which underinflation and overinflation may be determined, varies depending on the tire type. By passing tires of differing types, having differing air pressure, past the electrical detection system (10), a reference table may be created for the preferred ratio (l2:l1) for a variety of tires.

By notifying the vehicle operator, as described below, whether any of his tires are not properly inflated, the operator will be able to act accordingly.

The ratio (l2:l1) is speed independent, in that the ratio (l2:l1) may be determined regardless of the speed at which the tire is traveling.

The essentially flat surface is required in order to assure that at least lower beam (13) (see Fig. 2), which is preferably transmitted planar with the contact patch (41) of the tire (40), is not obstructed by any object jutting up from the ground. The flat surface may be a plate (30) that is positioned planar with the ground or above ground (31), or the flat surface may be the ground itself, which has been flattened.

Referring to Fig. 2, display screen (32) indicates the level of air pressure in the tire as either underinflated, properly inflated or overinflated, by any one of visual means, for example, as shown by (32a), (32b) and (32c), wherein a tire can be shown as being in any one of the states (2), (4), (6), shown in Fig. 1, or by different or flashing colors or lights; audio means, such as either automated voice or beeping sounds; or a combination thereof. Additionally or alternatively, vehicle operators may register their license plate number, tire type and cellular or car phone number, and an SMS message may be sent to the operator indicating the same. In this case, a camera (not shown in the figures) for capturing the vehicle's license plate number is situated appropriately, and transfers this information to the processing system. Additionally or alternatively, the system may comprise a receiver unit, which may be supplied to a registered operator, and to which an appropriate signal (audio and/or visual) may be transmitted. The receiver unit may comprise a display portion for indicating air pressure level.

The processing system of the present invention (not shown in the figures) comprises a remotely stationed, or on-site computing unit comprising a reference table and, when necessary, a registration database. The processing may be carried out by uncomplicated software, as known in the art.

A second preferred embodiment of the present invention, for indicating air pressure level in a pair of tires on a single axle, is shown schematically in Fig. 4, and comprises all of the elements of the first embodiment, *mutatis mutandis*, with the following differences. The second preferred embodiment comprises an electrical detection system comprising right wheel laser source (52) and corresponding detector (54) and left wheel laser source (62) and corresponding detector (64). Right plate (30a) and left plate (30b) are situated between right and left wheel laser (52), (62) and detectors (54), (64), respectively. Lower beams (13) are directed essentially orthogonally with respect to the direction of travel of tires (40a), (40b).

For this embodiment, the present invention is best suited for indicating tire air pressure level in a vehicle having at least two tires arranged in parallel along the axle perpendicular to the direction of travel of the vehicle, for instance, a typical four-wheel car.

Fig. 5 shows a top view of the chassis and wheels of a four-wheeled vehicle, wherein front right tire (40a) is situated between right wheel laser (52) and right wheel detector (54), and front left tire (40b) is situated between left wheel laser (62) and left wheel detector (64). Alternatively, lasers (52), (62) may be interchanged with detectors (54), (64), such that lasers (52), (62) are situated at the inside of wheels (40a), (40b), and detectors (54), (64) situated at the inside of tires (40a), (40b). Contact patches (41a), (41b) are shown by dotted lines in front tires (40a) and (40b) respectively. Contact patch (40a) is larger than contact patch (40b), indicating that right tire (40a) is underinflated.

Fig. 6 shows front left tire (40b), properly inflated, partially blocking front right tire (40a), which is underinflated. The contact patch of each tire (40a), (40b) is situated on an essentially flat surface, shown in this figure as the ground (31). For clarity's sake, lasers (52) and (62) are not shown in this figure, but the position of each laser (52), (62) is indicated by respective reference numbers (52) and (62), as being positioned on the surface of ground (31), essentially planar with each other as well as with the contact patch (41a), (41b) of each tire (40a), (40b).

Using the equation:

$$\text{Deviation} = (l4-l3)/(l4+l3), \qquad (4)$$

wherein,

l3 = the chord connecting points (c1) and (d1), or, the rolling distance along the plane (58) of contact patch (41b) of tire (40b) from point (c1) to point (d1),

l4 = the chord connecting points (c2) and (d2), or, the rolling distance along the plane (60) of contact patch (41a) of tire (40a) from point (c2) to point (d2),
and wherein l3 and l4 are determined according to equations (1) to (3) as described above, the Deviation, which is the ratio indicating divergence from proper inflation for a particular tire, may be determined.

If the Deviation ratio results in a positive number, left tire (40b) is more inflated than right tire (40a). If the ratio results in a negative number, right tire (40a) is more inflated than left tire (40b). Additionally, as the absolute value of the resulting ratio approaches 0 (zero) the right or left tire (depending on the sign of the non-absolute value ratio) is understood to be properly inflated. As the absolute value of the resulting ratio approaches 1 (one) the right or left tire (depending on the sign of the non-absolute value ratio) is understood to be underinflated.

The preferred value of the resulting ratio, based on which an overinflated or underinflated tire may be determined, varies according to the type of tire. A reference table may be compiled as described above for the first embodiment.

According to the second embodiment, it is assumed that only one tire from each pair of parallel tires situated on the same axle would be underinflated.

Display means for the second embodiment may be similar to that of the first embodiment, or, alternatively, display means (32a), as shown in Fig. 4, may display the chassis of the vehicle, with an outline of each wheel, and wherein an improperly inflated tire is indicated by any visual and/or audio means as described above.

A third preferred embodiment of the present invention, for indicating air pressure level in a pair of tires traveling along a path, is shown schematically in Fig. 7, and comprises all of the elements of the first and second embodiments, *mutatis mutandis*, with the following differences. The third embodiment comprises an electrical detection system (50) comprising right tire (40a) lower and upper laser sources (52a), (62a) and right tire (40a) lower and upper detectors (54a), (64a), as well as left tire (40b) lower and upper laser sources (52b), (62b) and left tire (40b) lower and upper detectors (54b), (64b). Right plate (30a) and left plate (30b) are situated between laser sources and detectors respectively.

In the third embodiment, the air pressure level of a tire is indicated by calculating the ratio (l2:l1) of the upper length (l2) to lower length (l1) for each tire (40a), (40b), as described above for the first embodiment. The resulting ratio's are compared with each other in order to determine whether one tire is underinflated. If the ratio's are not essentially equal, the tire having a smaller ratio is considered to be underinflated.

Although an additional set of upper and lower lasers and detectors is required according to the third embodiment in comparison to the first embodiment, the method of determining air pressure level is advantageous over that of the first embodiment. This is due to the fact that no experimentation is necessary in order to create a reference table of the preferred ratio of (l2:l1) for different tire types.

According to one aspect of the second and third embodiments, for indicating air pressure level in a pair of tires traveling along a path, the laser sources that are planar with the contact patch may be oriented at an angle less than 90 degrees from the direction of travel. Fig. 8 shows this aspect of the third embodiment, wherein only one laser (72) and detector (74) is required in order to determine air pressure level in each one of the tires (40a), (40b) arranged in parallel along axle (42). Laser (72) is situated at an angle (β) with respect to the direction of travel (y) of tires (40a), (40b), such that contact patch (41b) of tire (40b) passes beam (73) before contact patch (41a) of tire (40a) reaches beam (73). Beams (73a), (73b), (73c) are virtual beams, and show the points (e and g) at which beam (73) becomes obstructed from detector (74), and points (f and h) at which beam (73) resumes being detected by detector (74). The length (l5) along the direction of travel from point (e) to point (f) of contact patch (41b) is measured and compared to the length (l6) along the direction of travel from point (g) to (h), as described above in the second embodiment, *mutatis mutandis*. In Fig. 8, right tire (40a) is underinflated as indicated by contact patch (41a) being larger than contact patch (41b) of left tire (40b).

Even when taking an angular measurement of the tires of a large truck, wherein more than one tire is situated at each end of a single axle, as shown in Fig. 9, or wherein the tires are situated in series in close proximity to one another, as shown in Fig. 10, the length of the contact patches may be measured accordingly.

In an alternative aspect, according to all embodiments, lower plane (l1) or (l3) may be measured by utilizing an electrical detection such as a piezoelectric cable (20), as shown in Fig. 11, instead of a laser and detector unit. Cable 20 is positioned at an angle (α) with respect to the direction of travel (y), such that the entire contact patch (41b) of left tire (40b) rolls over cable (20) before contact patch (41a) of right tire (40a) reaches cable (20). Alternatively, two separate piezoelectric cables (not shown) may be provided, wherein each cable is situated in front of each tire (40a), (40b), and oriented parallel to axle (42), (essentially orthogonal to the direction of travel (y)), such that each tire (40a), (40b) may roll over each cable essentially in tandem. Subjecting the piezoelectric cable (20) to mechanical stress, caused, in this case by the passage of tires (40a), (40b) over it, produces an electrical impulse. The time it takes for each tire (40a), (40b) to pass over piezoelectric cable (20) may be determined by measuring the duration of the impulse. By utilizing equation (1) as described above, one may further determine the length of each contact patch (41a), (41b), in order to determine whether one of the tires (40a), (40b) is not properly inflated.

When utilizing piezoelectric cable (20) to indicate air pressure level of a single tire, cable (20) may be essentially at a 90 degree angle to the direction of travel (y).

In an alternative aspect, according to all embodiments, lower plane (11) or (13) may be measured by utilizing an optical fiber arranged in a similar manner to piezoelectric cable (20) shown in Fig. 11, for allowing the entire contact patch (41b) of left tire (40b) to roll over the optical fiber before contact patch (41a) of right tire (40a) reaches the optical fiber. Alternatively, also similar to piezoelectric cable (20), two separate optical fibers may be provided, wherein each optical fiber is situated in front of each tire (40a), (40b), and oriented parallel to axle (42), (essentially orthogonal to the direction of travel (y)), such that each tire (40a), (40b) may roll over each optical fiber, essentially in tandem.

The optical fiber is preferably flexible, and may be bent or curved according to the curvature of the road along which the vehicle travels. The optical fiber may be rest along the upper surface of the road, or may lie within a furrow that is dug along the width of the road. The optical fiber may be exposed, or covered by a suitable covering such as a thin rubber surface.

An optical source is situated at one end of the optical fiber and a detector (or reflector) unit is situated at the other end. The two ends of the optical fiber may be situated on opposite sides of the path, or alternatively, the optical fiber may comprise a U-shape such that each end is situated on the same side of the path. An optical beam passes through the optical fiber from the optical source to the detector unit. When a tire passes over the optical fiber, the optical beam is at least partially obstructed, and is therefore at least partially prevented from reaching the detector unit. The detector unit detects the attenuated light beam, or no beam at all, while the tire passes over the optical fiber.

The change in intensity of the optical beam, as detected by the detector unit, is translated to an electrical signal. The time it takes for each tire (40a), (40b) to pass over the optical fiber may be determined by measuring the duration of the signal. By utilizing equation (1) as described above, one may further determine the length of each contact patch (41a), (41b), in order to determine whether one of the tires (40a), (40b) is not properly inflated.

An alternative method for indicating the inflation level of a tire comprises first determining the distance between front (or, a first) axle (42) and rear (or, a second) axle (42') for a large number of vehicle models, and storing this information in a database. The ratio between said distance and the length of contact patch (41b) is then determined. The preferred ratio which indicates a proper inflation level of the tire for each vehicle model is predetermined and recorded in the database. If the measured (or, actual) ratio is larger than the preferred ratio, the tire is overinflated. If the measured (or, actual) ratio is smaller than the preferred ratio, the tire is underinflated.

When utilizing an optical fiber to indicate air pressure level of a single tire, the optical fiber may be essentially at a 90 degree angle to the direction of travel (y).

It is important to note that the angles (α) and (β) as shown in the figures herein are not necessarily drawn to scale, and therefore, the angular value should not be extrapolated based on the figures. In reality, the angles (α) and (β) may differ substantially than shown. Additionally, contact patches shown in the figures are not drawn to scale relative to the tires, but are shown enlarged for illustrative purposes. In reality, contact patches are much smaller relative to the tires. Moreover, although the front right tire is typically shown in the figures to be the underinflated tire, it is understood that any one of the vehicle's tires on each axle may be underinflated when utilizing the present invention.

The present invention may be positioned along a road or highway while operating a vehicle at normal driving speeds, or at an entrance or exit thereto or from, where a vehicle generally drives at slow speeds. Similarly, the present invention may be positioned at a rest stop at the side of a road, at a gas station, at a toll booth, etc.

While some embodiments of the invention have been described by way of illustration, it will be apparent that the invention can be carried into practice with many modifications, variations and adaptations, and with the use of numerous equivalents or alternative solutions that are within the scope of persons skilled in the art, without departing from the spirit of the invention or exceeding the scope of the claims.

<u>Claims</u>

1. An apparatus for indicating the level of air pressure in a loaded tire of a vehicle traveling along a path, said apparatus comprising:
    a. a first electrical detection system for measuring the length of a first chord that corresponds to the perimeter of said tire along a first plane;
    b. a second electrical detection system for measuring the length of a second chord of said tire along a second plane;
    c. a processing system for obtaining a measurement related to the ratio between said lengths, and for generating a pressure indication whenever said measure exceeds a predetermined threshold;
    d. a signaling system for generating a visual or audio signal or any combination thereof, whenever said pressure indication is generated; and
    e. optionally, an essentially flat surface over which said tire travels, while said first or second length is measured.

2. An apparatus according to claim 1, wherein the first plane is essentially coplanar with the flat surface of the tire.

3. An apparatus according to claim 1, wherein the second plane is situated at a predetermined vertical distance from, and essentially parallel to, the first plane.

4. An apparatus according to claim 1, wherein the first detection system may be chosen from any one of the group consisting of:
    a. an optical source and detector unit;
    b. an optical source and reflector unit;
    c. an RF source and detector unit; and

   d. at least one piezoelectric cable.

5. An apparatus according to claim 4, wherein an optical beam passes from the optical source to the detector or reflector unit through an optical fiber.

6. An apparatus according to claim 4, wherein the first detection system is situated at an angle between 0 and 90 degrees with respect to the direction of travel of the tire along the traveling path.

7. An apparatus according to claim 1, wherein the second detection system may be chosen from any one of the group consisting of:
   a. an optical source and detector unit;
   b. an optical source and reflector unit; and
   c. an RF source and detector unit.

8. An apparatus according to claim 1, wherein the processing system may perform any one of the group comprising:
   a. analysis of measures obtained from a single tire; and
   b. analysis of information obtained from more than one tire of the vehicle.

9. An apparatus for indicating the level of air pressure in a pair of loaded tires of a vehicle traveling along a path, said apparatus comprising:
   a. a first electrical detection system for measuring a first length, being the length of a chord that corresponds to the perimeter of a first tire along a plane;

b. a second electrical detection system for measuring a second length, being the length of a chord that corresponds to the perimeter of a second tire along said plane;

c. a signal processing system for obtaining a measurement related to the ratio between a first function and a second function of said lengths, and for generating a pressure indication, whenever said measure exceeds a predetermined threshold;

d. a signaling system for generating a visual or audio signal or any combination thereof, whenever said pressure indication is generated; and

e. optionally, an essentially flat surface over which each of said tires travel, while said lengths are measured.

10. An apparatus according to claim 9, wherein each of the planes is essentially coplanar with each flat surface of the tire.

11. A apparatus according to claim 9, wherein the first and second detection system may be chosen from any one of the group consisting of:

a. an optical source and detector unit;
b. an optical source and reflector unit
c. an RF source and detector unit; and
d. at least one piezoelectric cable.

12. An apparatus according to claim 11, wherein an optical beam passes from the optical source to the detector or reflector unit through an optical fiber.

13. An apparatus according to claim 11, wherein each detection system is situated at an angle between 0 and 90 degrees from the direction of travel of the tire.

14. An apparatus for indicating the level of air pressure in a pair of tires traveling along a path, said apparatus comprising:
    a. an electrical detection system for successively measuring the lengths of chords that correspond to the perimeter of each of said tires along a plane;
    b. a signal processing system obtaining a measurement related to the ratio between a first function and a second function of said lengths, and for generating a pressure indication whenever said measurement exceeds a predetermined threshold;
    c. signaling system for generating a visual or audio signal or any combination thereof, whenever said pressure indication is generated; and
    d. optionally, an essentially flat surface over which each of said tires travel, while said lengths are measured.

15. An apparatus according to claim 14, wherein the plane is essentially coplanar with each flat surface of the tire.

16. An apparatus according to claim 14, wherein the detection system may be chosen from any one of the group consisting of:
    a. an optical source and detector unit;
    b. an optical source and reflector unit;
    c. an RF source and detector unit; and
    d. at least one piezoelectric cable.

17. An apparatus according to claim 16, wherein an optical beam passes from the optical source to the detector or reflector unit through an optical fiber.

18. An apparatus according to claim 14, wherein the first detection system is situated at an angle between 0 and 90 degrees from the direction of travel of the tire.

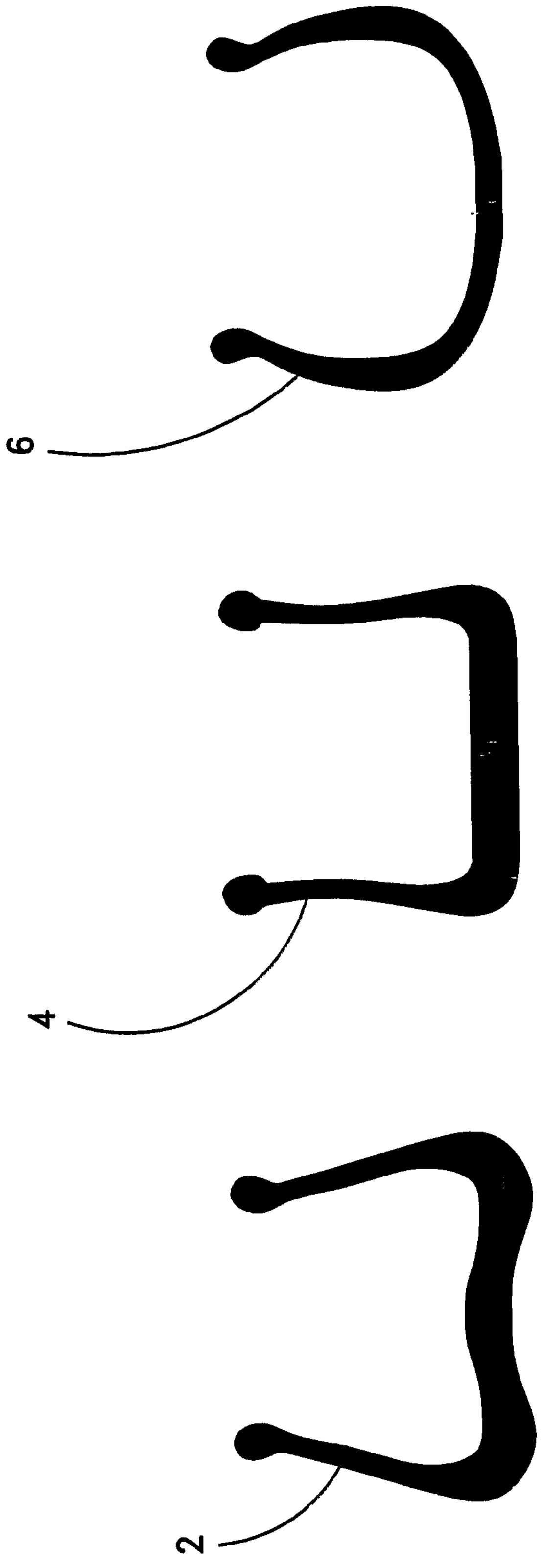

Fig. 1

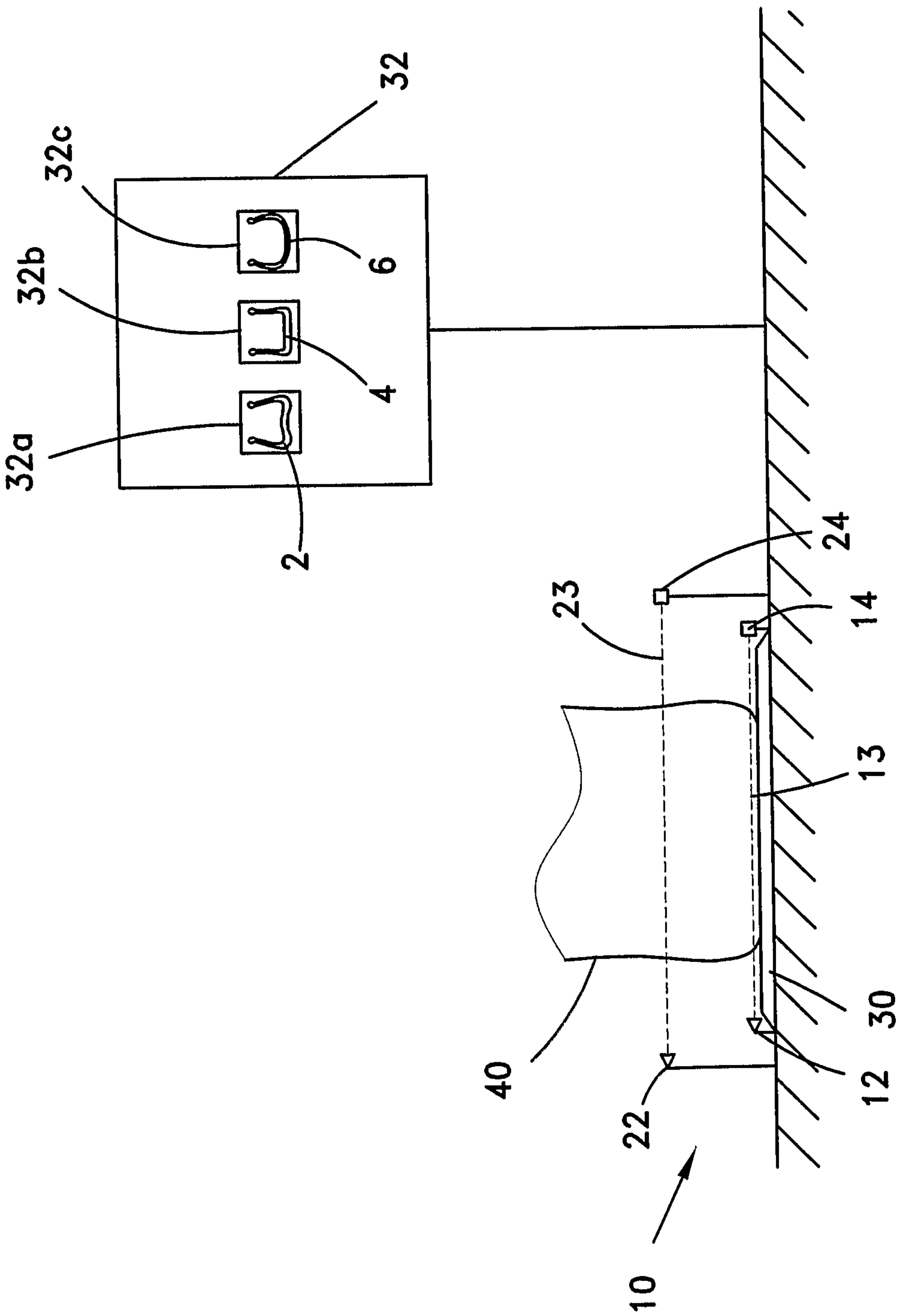

Fig. 2

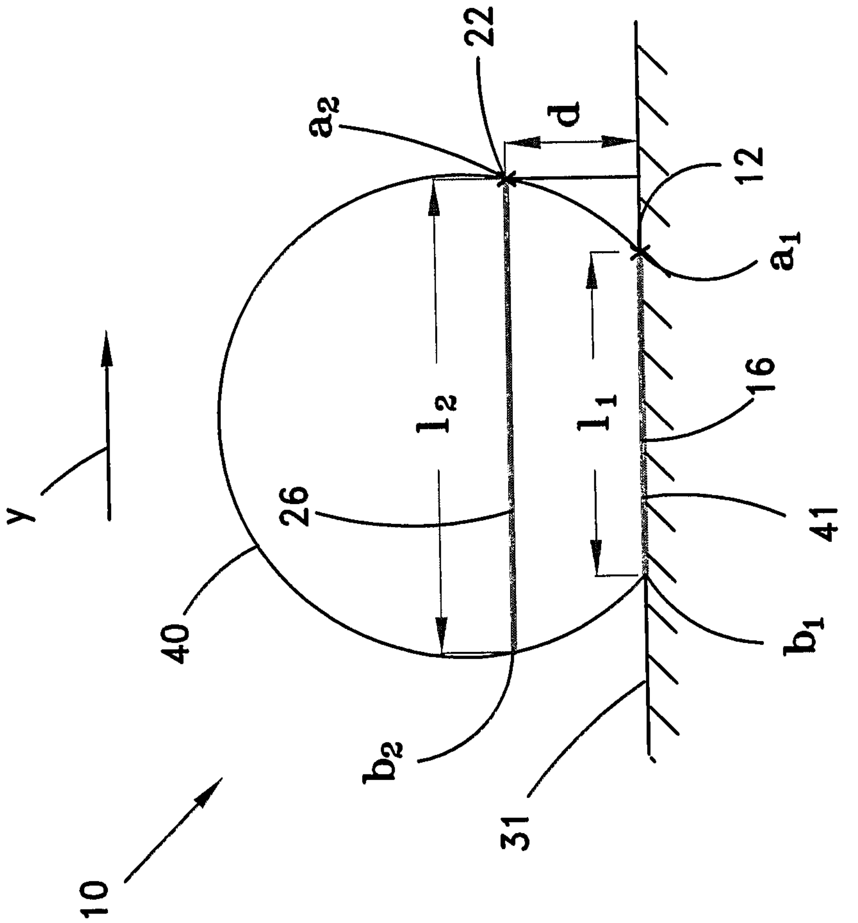

Fig. 3

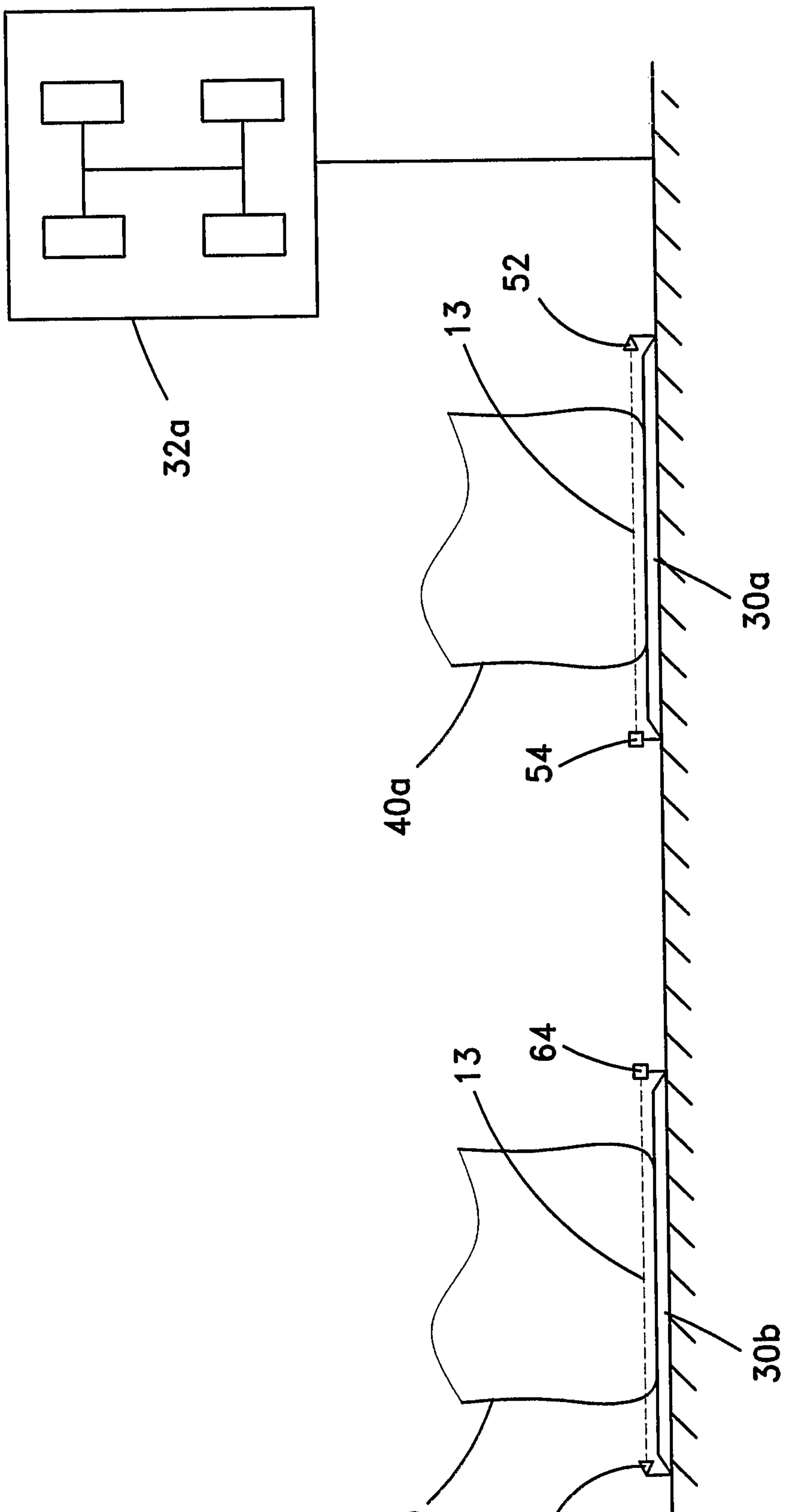

Fig. 4

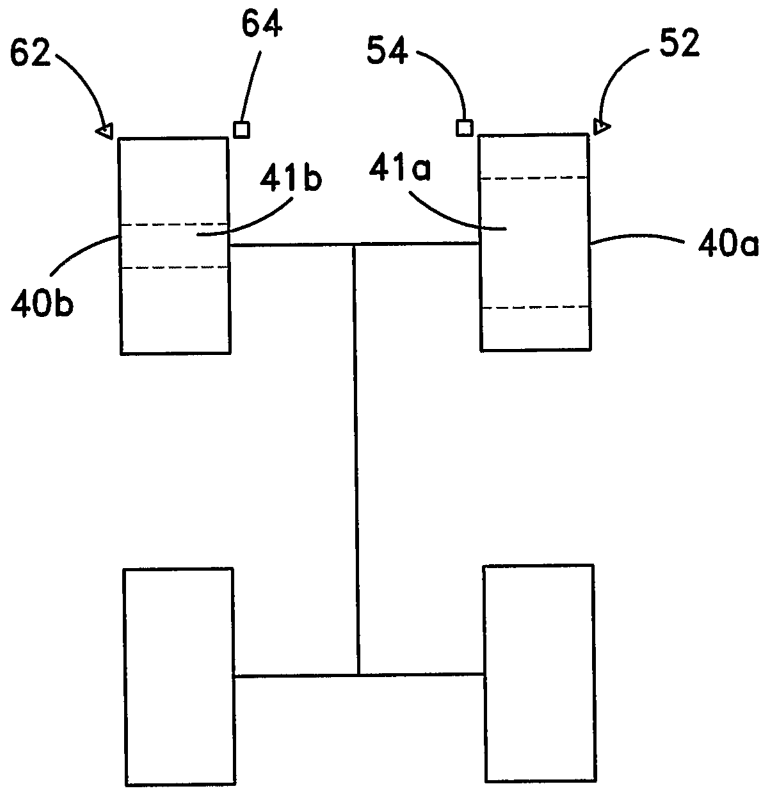

Fig. 5

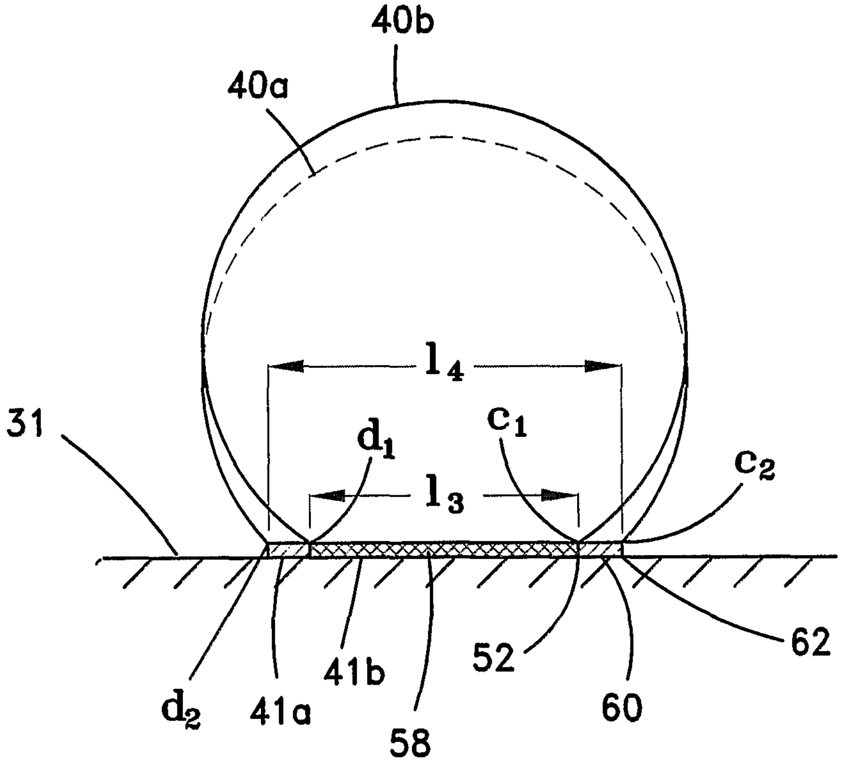

Fig. 6

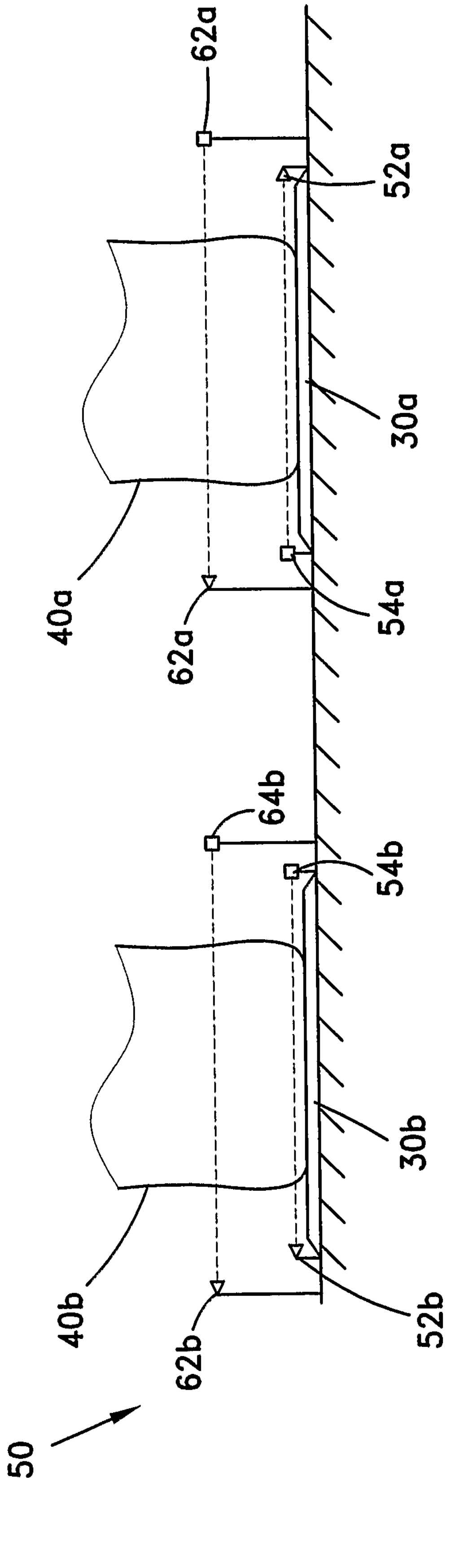

Fig. 7

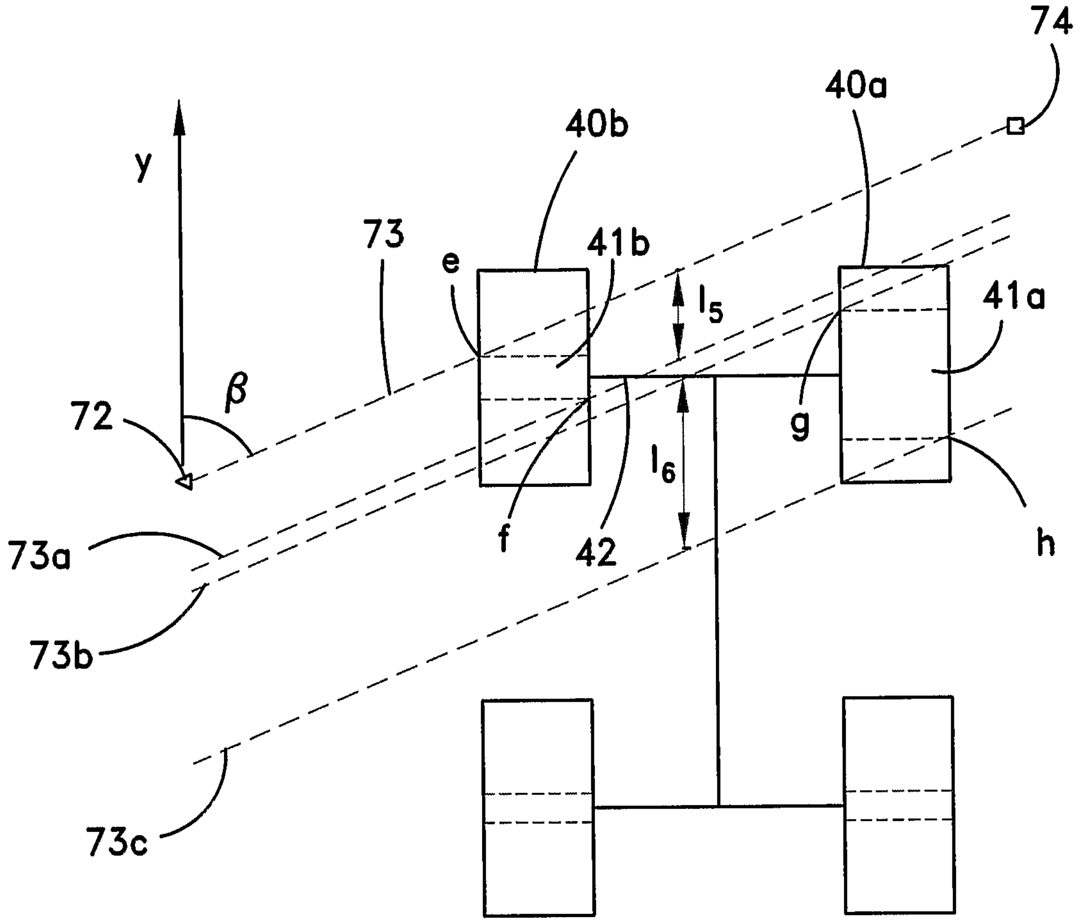

Fig. 8

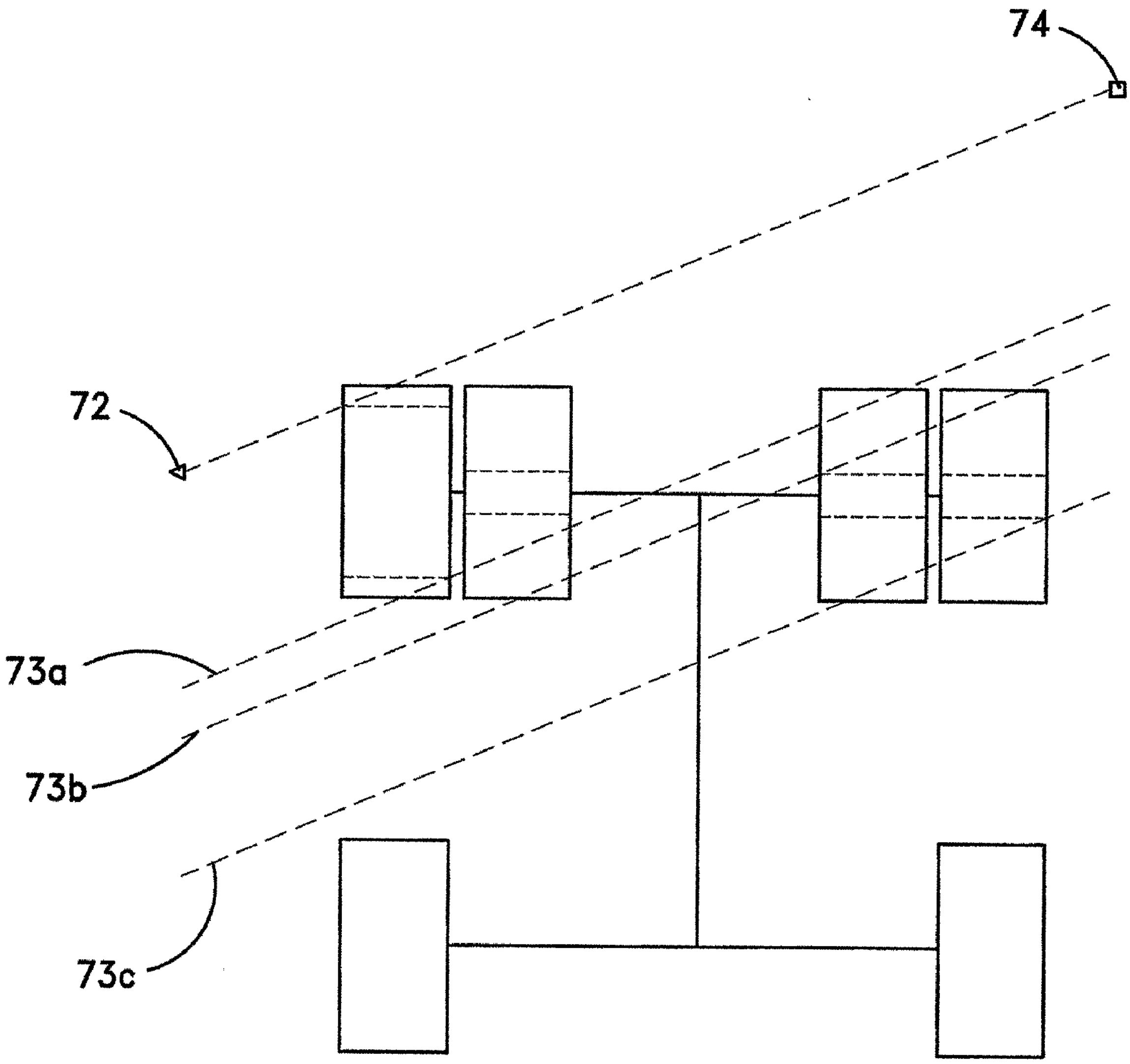

Fig. 9

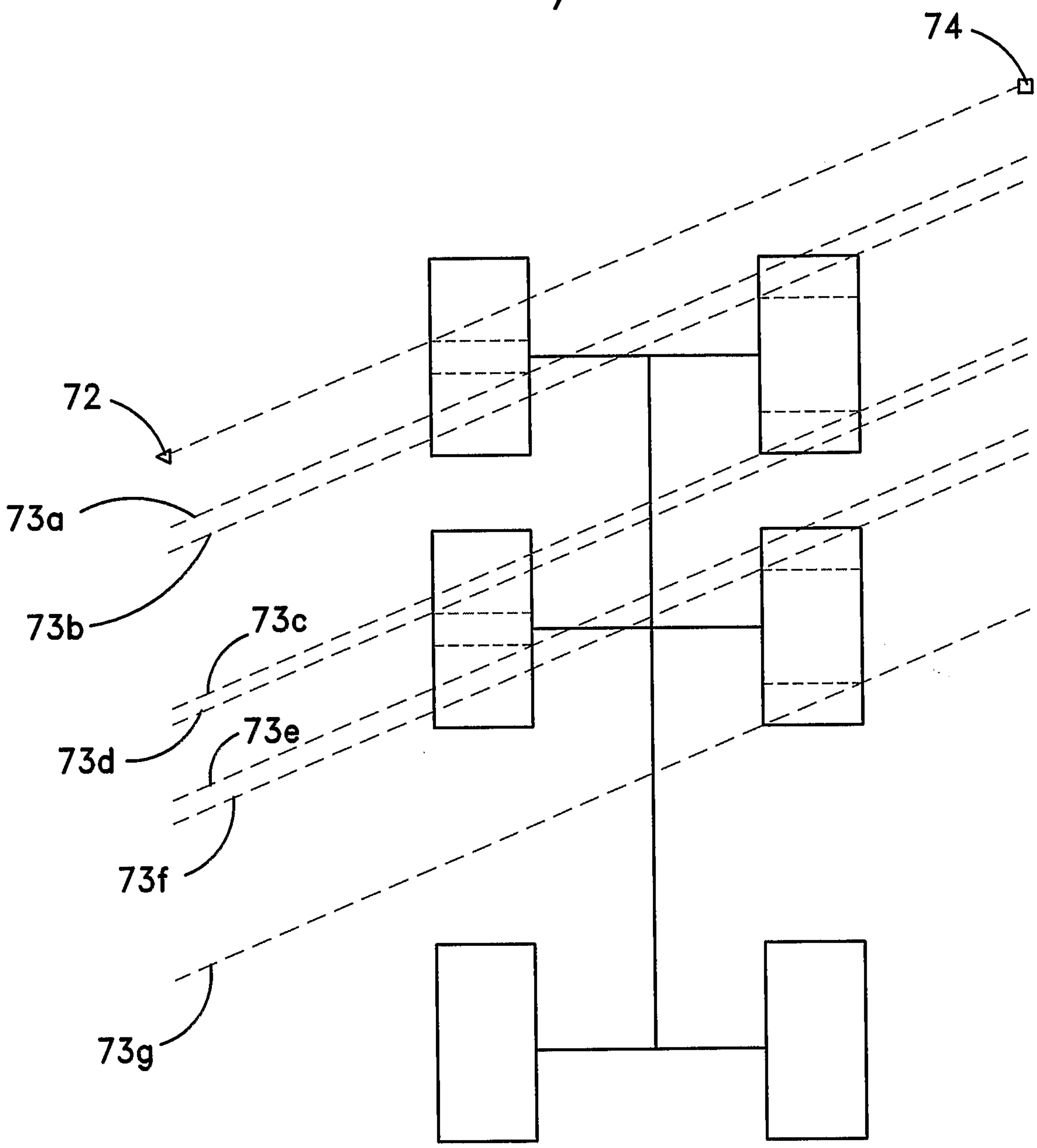

Fig. 10

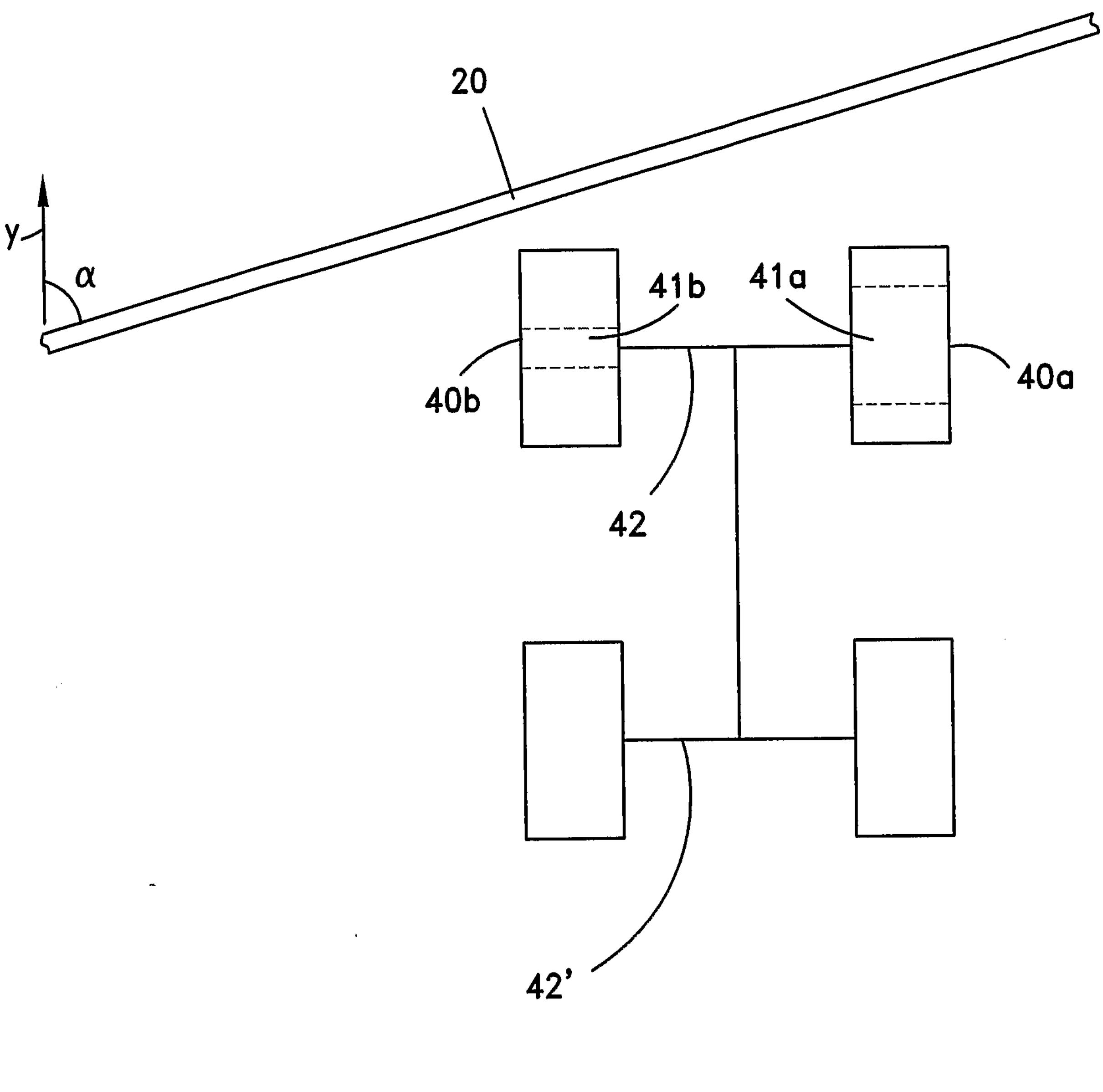

Fig. 11