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(54) LINEAR DISPLACEMENT SENSOR

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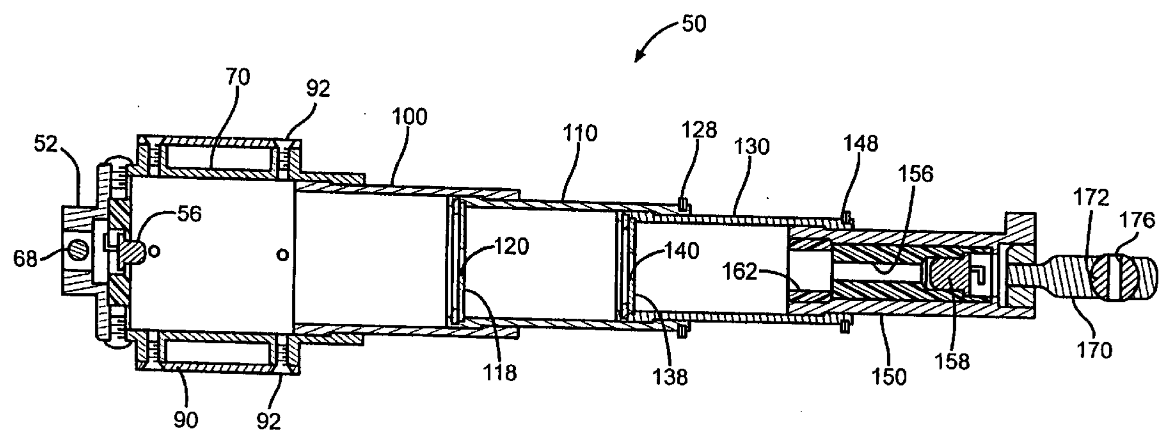
(57) ABSTRACT

A linear displacement sensor includes a plurality of nested, telescoping sections extending between two end pieces. One end piece includes a light source such as an infrared light emitting diode (emitter), and the other end includes a light sensitive device such as a phototransistor (receiver). At least one disk having a centrally disposed aperture is secured to one of the sections and reduces and limits stray or incident light within the sensor which is reflected inside the sensor and would otherwise impinge upon the receiver. Improved accuracy and linearity is provided by this device.



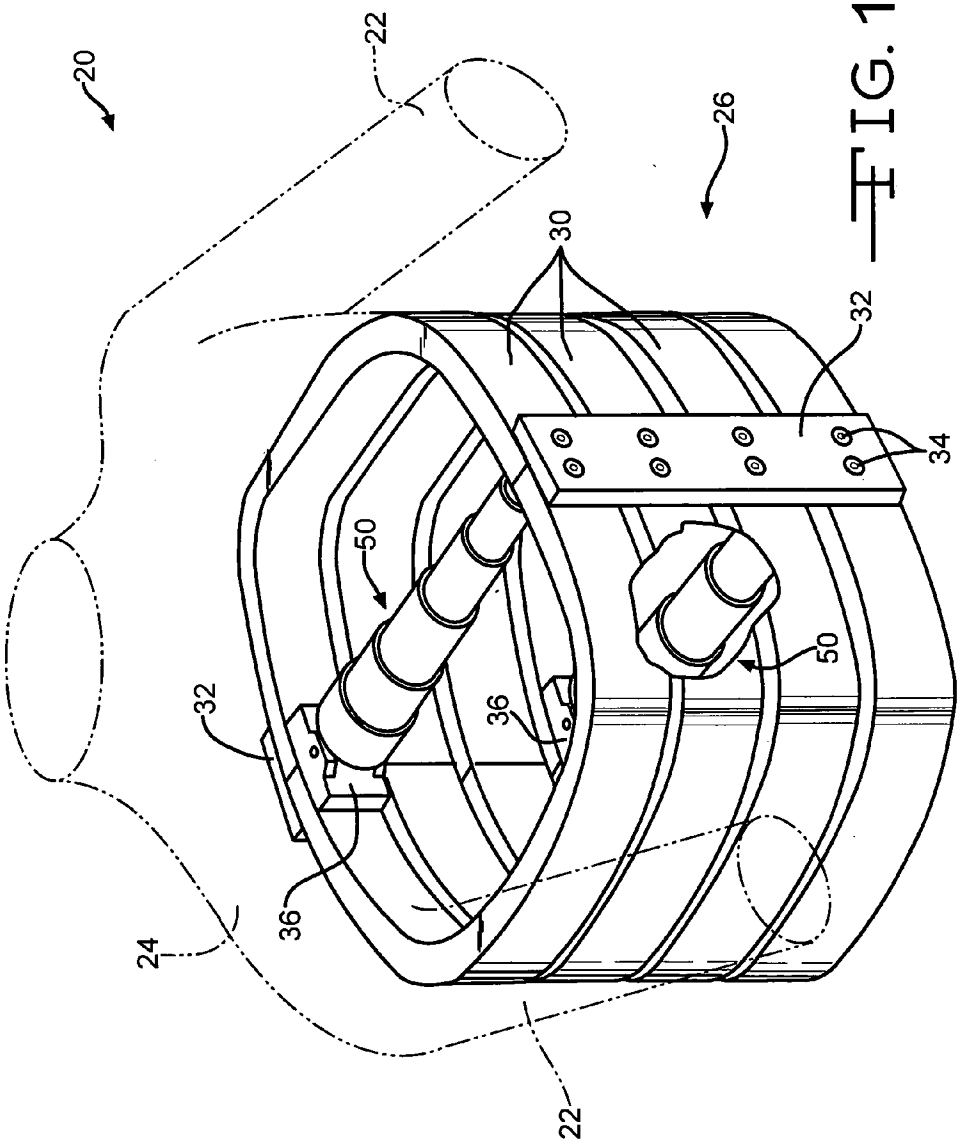
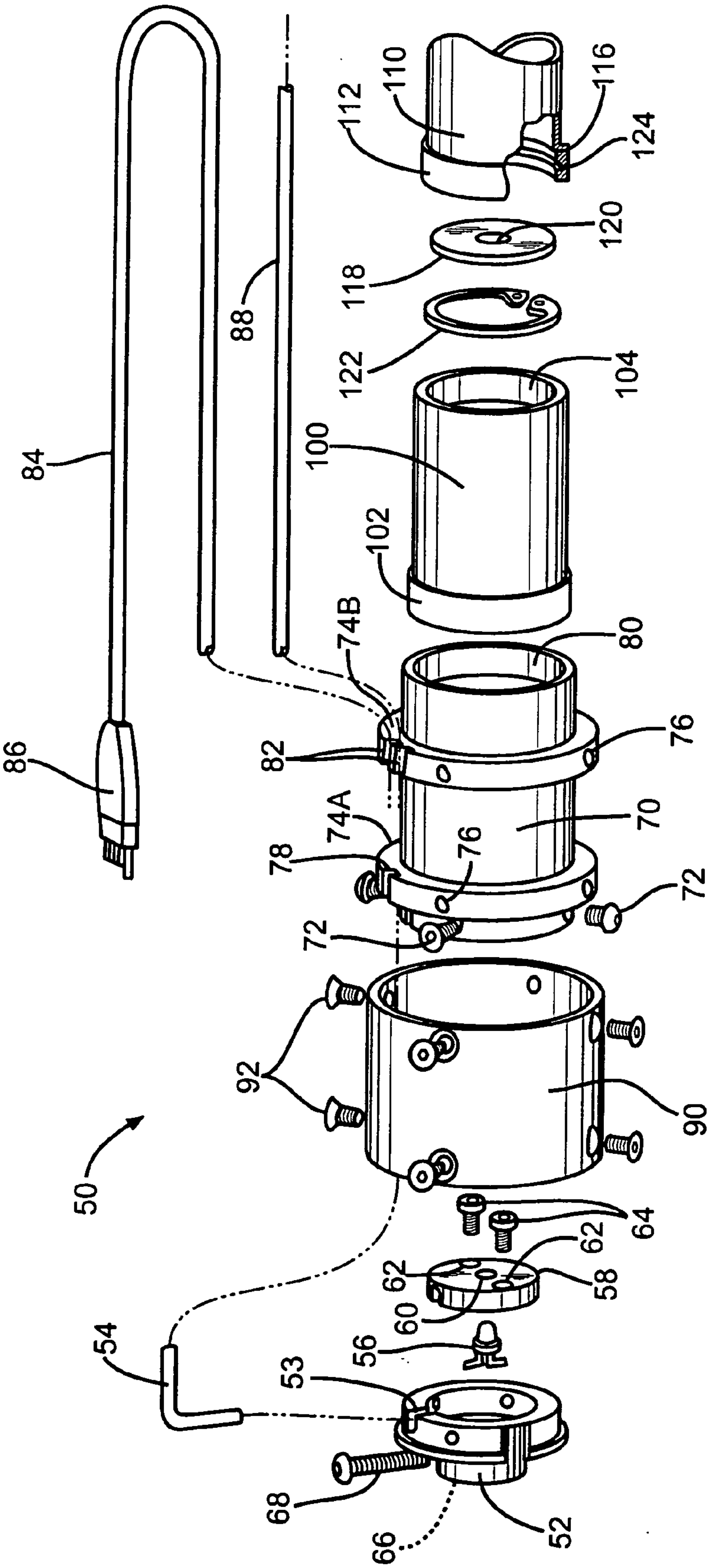


FIG. 1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74B
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52

FIG. 2A

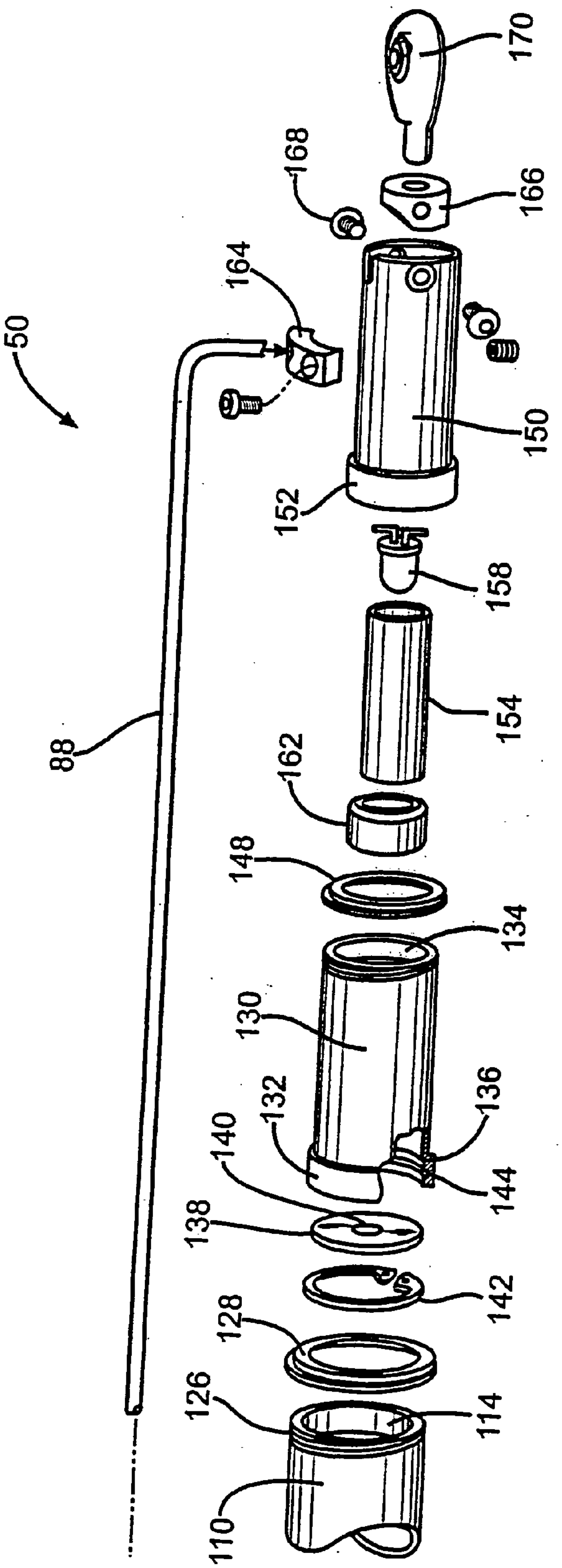
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FIG. 2B

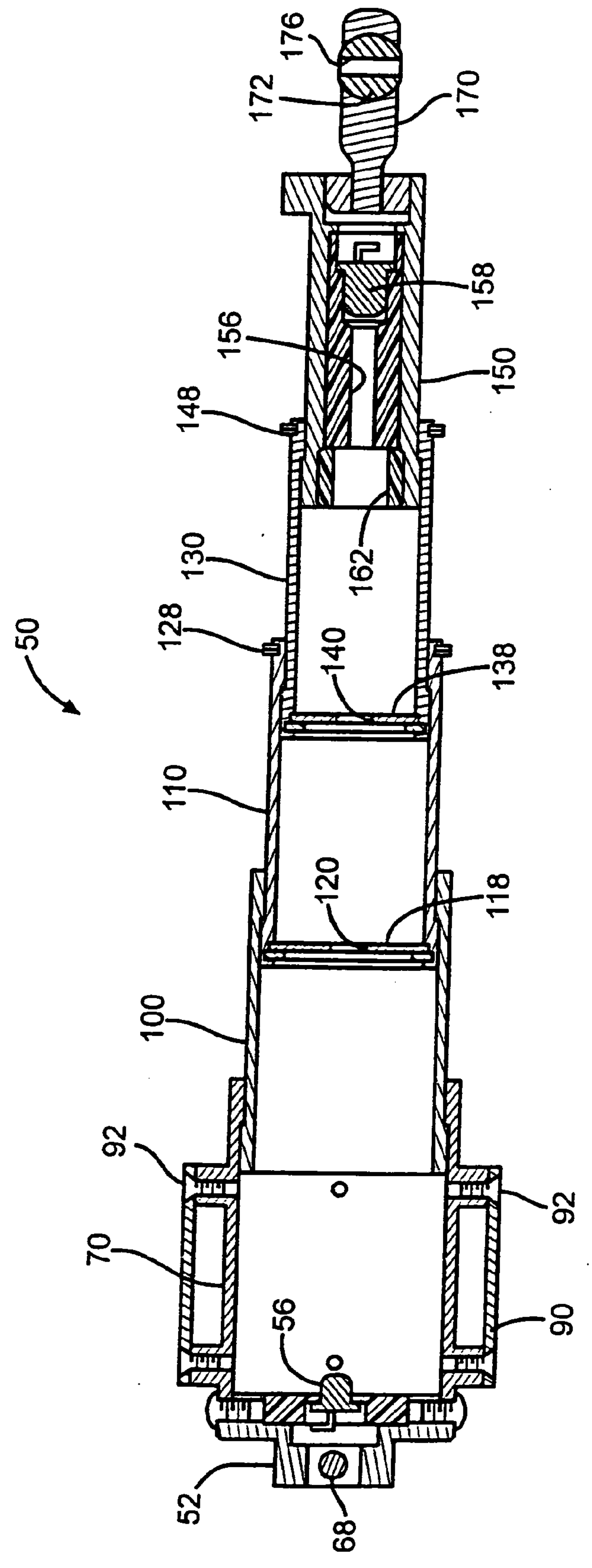
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FIG. 3

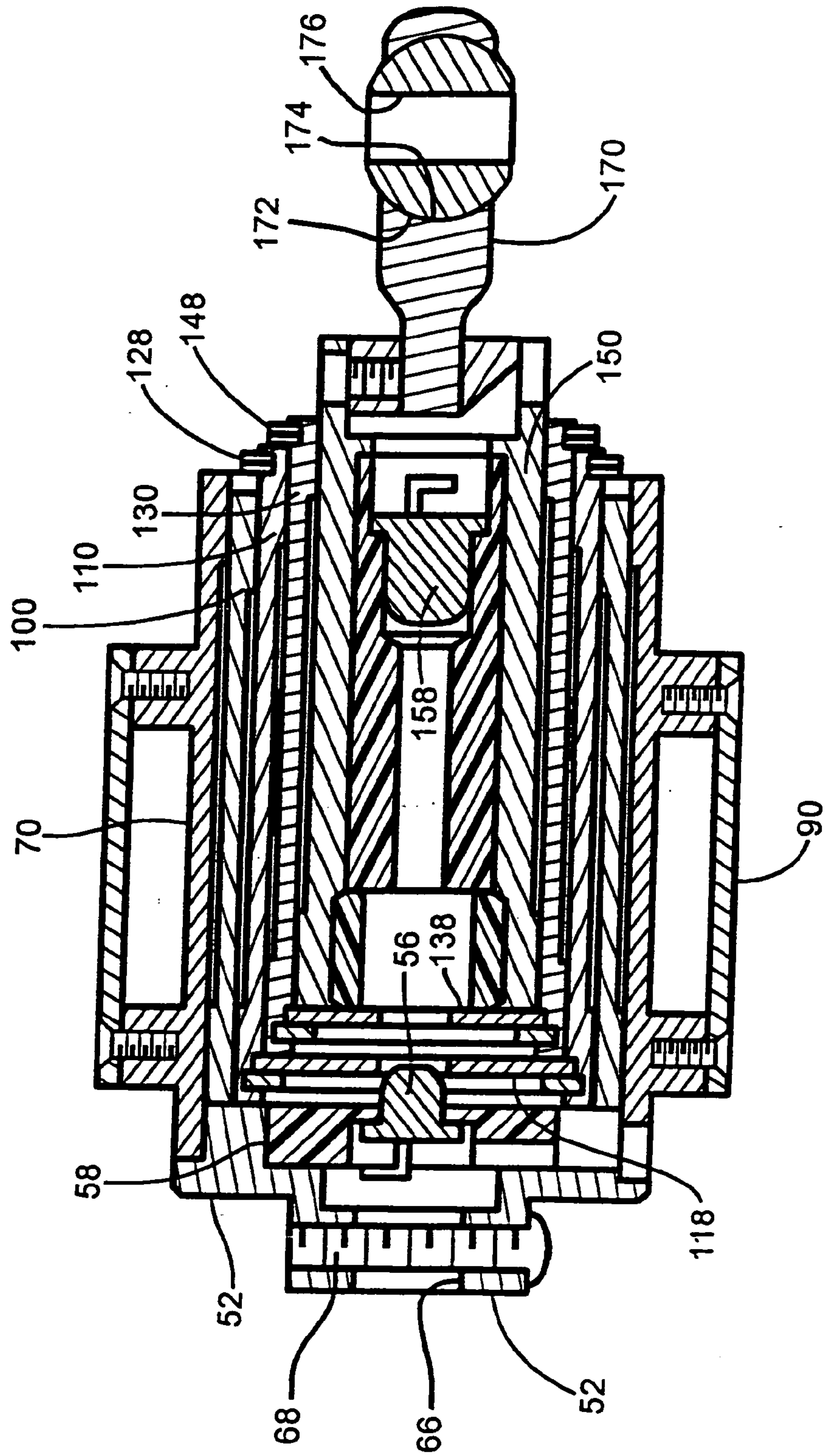
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FIG. 4

LINEAR DISPLACEMENT SENSOR

BACKGROUND OF THE INVENTION

[0001] The invention relates generally to displacement sensors and more particularly to displacement sensors having a telescoping body with a radiation source at one end and a radiation sensor at the other.

[0002] Measurement of the distance or displacement between two points in real time may be achieved by a wide variety of sensors. One of the oldest linear sensors utilizes a resistive element having a sliding electrical contact. The resistive element is secured to one member and the contact is secured to the other member. As the members translate relative to one another, the resistance or voltage output varies and indicates the present sensed position. Today, many different designs utilizing moving magnetic or electromagnetic members, Hall Effect sensors and optical devices provide accurate and repeatable translation and position sensing.

[0003] Optical devices utilizing a radiation source such as an LED and a radiation or light sensitive receiver such as a phototransistor are also capable of distance measurement. These, as well as many other sensors, operate on the physical principal that the intensity of a radiation beam diminishes or increases with the square of the distance between the source and the sensor. Optical displacement sensors thus have a distinct advantage in that no mechanical connection need be present between the two members or features between which distance is being sensed. However, the device must be configured and the sensor must be mounted such that it is not subjected to incident or any light other than the direct light beam emitted by the radiation source. The lack of mechanical connection between the sensed elements or feature makes an optical sensor particularly attractive for sensing displacement in anthropomorphic test dummies (ATDs) also known as crash test dummies because of the rapid, though somewhat limited translation. The present invention is directed to an optical sensor for use in such devices.

BRIEF SUMMARY OF THE INVENTION

[0004] A linear displacement sensor includes a plurality of nested, telescoping sections extending between two end pieces. One end piece includes a light source or emitter such as an infrared light emitting diode (LED), and the other end includes a light sensitive device or receiver such as a phototransistor. At least one disk having a centrally disposed aperture is secured to one of the sections and reduces and limits stray or incident light within the sensor which may be reflected inside the sensor and impinge upon the receiver. Improved accuracy and linearity is provided by this device.

[0005] Thus it is an object of the present invention to provide an optical linear displacement sensor having a radiation source spaced from a radiation sensor and enclosed within a telescoping housing.

[0006] It is a further object of the present invention to provide an optical linear displacement sensor having radiation source and radiation sensor configured within a housing which minimizes the measurement of stray or incident light from the radiation sensor.

[0007] It is a still further object of the present invention to provide an optical displacement sensor having a radiation source, a radiation sensor disposed within a telescoping housing and at least one disk having an aperture disposed between said source and sensor.

[0008] Further objects and advantages of the present invention will become apparent by reference to the following description of the preferred embodiment and appended drawings which in like reference numbers refer to the same component, element or feature.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIG. 1** is a fragmentary perspective view of the ribcage portion of an anthropomorphic test dummy utilizing the present invention;

[0010] **FIGS. 2A and 2B** are exploded views of a linear displacement sensor according the present invention;

[0011] **FIG. 3** is a full, sectional view of a linear displacement sensor according to the present invention; and

[0012] **FIG. 4** is a full, sectional view of a completely telescoped linear displacement sensor according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Referring now to **FIG. 1**, an upper torso portion of an anthropomorphic test dummy (ATD) is illustrated and generally designated by the reference number **20**. The upper torso portion **20** includes left and right arms **22** which may be covered and defined by a resilient, elastic covering **24** such as a silicone rubber. The upper torso portion **20** also includes a ribcage assembly **26** as well as other components and assemblies (not illustrated) simulating a human torso. The upper torso portion **20** may be scaled to simulate adults, adolescents, children, toddlers or infants.

[0014] The ribcage assembly **26** includes a plurality of generally circular or oval, two piece rib assemblies **30** which may be secured together, for example, at their front and rear by vertical bars **32** and suitable threaded fasteners **34**. Within the interior of the ribcage assembly **36** are disposed mounting blocks **36** which receive and secure a pair of linear displacement sensor assemblies **50** according to the present invention within the ribcage assembly **26**. The linear displacement sensor assemblies **50** provide information in real time regarding the relative front to back displacement or compression of the rib assemblies **30** as they undergo movement during a crash test. At the outset, it should be understood that while the linear displacement sensor assemblies **50** are illustrated within an anthropomorphic test dummy ribcage, the assembly **50** has wide application as a linear displacement sensor and the following description is intended to be illustrative and exemplary only.

[0015] Referring now to **FIGS. 2A and 2B**, the linear displacement sensor assembly **50** includes a first or rear end cap **52** having a radial slot **53** which receives an electrical cable **54** which provides electricity to an infrared light emitting diode (LED) **56**. The light emitting diode **56** is retained within the rear end cap by a cover or disk **58** having a diode receiving opening **60** as well as openings **62** for receiving threaded fasteners **64** which seat within rear end cap **52**. A blind aperture **66** is adapted to receive a complementarily sized pin or stub shaft (both not illustrated) extending from one of the rib assemblies **20** illustrated in **FIG. 1** which may be secured to the end cap **52** by a set screw **68**, illustrated in **FIG. 4**.

[**0016**] The rear end cap **52** and associate components are received within a main housing or first cylindrical section **70** and retained thereby a plurality of radially oriented fasteners **72**. The main housing or first cylindrical section **70** includes a pair of spaced apart collars **74A** and **74B**, which are preferably integrally formed with the first section **70** and include a plurality of such threaded openings **76**. The first collar **74A** includes a single longitudinal slot **78** which receives the electrical cable **54**. The second collar **74B** includes two longitudinal slots **82** which receive a first power and signal cable **84** having a suitable multiple conductor connector **86** as its termination and a second electrical cable **88**. A cylindrical cover **90** defines an inside diameter just slightly larger than the outside diameter of the collars **74A** and **74B** and fits thereover. The axial space between the collars **74A** and **74B** may be occupied by electronic components, circuit boards and the like (not illustrated) which drive and process signals to and from the radiation source and sensor. These components form no portion of the present invention. The cylindrical cover **90** is maintained in place upon the main housing or first cylindrical section **70** by a plurality of radially oriented set screws or threaded fasteners **92** received within the threaded openings **76**. The main housing or first section **70** includes a first shoulder **80** on its inner surface opposite the rear end cap **52**.

[**0017**] As illustrated in **FIG. 3**, axially, slidably and telescopingly received within the first section **70** is a second tubular or cylindrical section **100**. The second section **100** includes an enlarged diameter second end region or flange **102** which has a diameter just slightly less than the inside diameter of a major portion of the axial length of the first cylindrical section **70** but which interferes with the first shoulder **80**. Similarly, the second section **100** includes a second shoulder **104** which slightly reduces the inside diameter of the second section **100** at its end opposite the rear end cap **52**.

[**0018**] Disposed axially, slidingly and telescopingly within the second section **100** is a third cylindrical section **110**. The third cylindrical section **110** includes a third enlarged diameter end region or flange **112** which has an outside diameter just slightly less than the inside diameter of a major portion of the second section **100** but which interferes with the second shoulder **104** therein. The third cylindrical section **110** likewise includes a third interior shoulder **114** on the inner surface of the third section **110** at its end opposite the rear end cap **52**. The third cylindrical section **110** also includes a shoulder or step **116** against which a first plate or disk **118** having a first circular aperture or orifice **120** is received.

[**0019**] The first aperture or orifice **120** preferably has a diameter approximately equal to the diameter of the infrared light emitting diode **56** and preferably just slightly larger than the diameter of the beam emitted by the light emitting diode **56**. A nominal diameter of 0.19 inches (4.83 mm) has been found suitable. It should be appreciated that smaller diameter, though increasingly reducing or eliminating any stray or incident light within the sensor **50**, may themselves affect the intensity of axially transmitted light passing therethrough which, of course, is unacceptable. Larger diameter apertures **120** will have a diminishing impact upon such axially transmitted light but may, as their diameter increases, permit increasing transmission of angular or oblique stray or incident light which is objectionable. Again, the diameter of the light source, i.e., the light emitting diode **56** or the diameter of its light beam, are the best guides for determining the diameter of the first aperture or orifice **120**. The range of 0.15 inches to 0.25 inches (3.81 mm to 13.1 mm) will encompass a typical range of diameters of the first aperture or orifice **120** for commonly sized and encountered light emitting diodes such as the diode **56** and the associated light beam.

[**0020**] A conventional snap ring **122** retains the first disk **118** in position against the shoulder or step **116** in the end of the third section **110** as it is received within a circumferential channel **124**. On the outside of the third cylindrical section **110**, proximate the end having the interior shoulder **114**, is a circumferential groove **126** which receives a snap ring, a multiple turn shop ring, a wave washer or a similar retaining device **128**. The snap ring **128** limits the axial travel of the third section **110** into the second section **100** as will be readily appreciated.

[**0021**] Disposed axially, slidingly and telescopingly within the third cylindrical section **110** is a fourth cylindrical section **130**. The fourth cylindrical section **130** includes an enlarged diameter fourth end region or flange **132** which has an outside diameter just slightly less than the inside diameter of a major portion of the third section **110** but which interferes with the third shoulder **114** therein. The fourth cylindrical section **130** likewise includes an interior shoulder or flange **134** on the inner surface of the fourth section **130** at its end opposite the rear end cap **52**. The fourth cylindrical section **130** also includes a shoulder or step **136** against which a second plate or disk **138** having a second circular aperture or orifice **140** is received. The second aperture or orifice **140**, like the first aperture or orifice **120** preferably has a diameter approximately equal to the diameter of the infrared light emitting diode **56** or just slightly larger than the diameter of the beam emitted by the light emitting diode **56** and just slightly smaller than the first aperture or orifice **120**. A nominal diameter of 0.18 inches (4.57 mm) has been found suitable.

[**0022**] It should be appreciated that smaller diameter apertures **140**, though increasingly reducing or eliminating any stray or incident light within the sensor **50** may themselves affect the intensity of axially transmitted light which is unacceptable. Larger diameter apertures **140** will have a diminishing impact upon the axially transmitted light, but may, as their diameter increases, permit increasing angularly or obliquely transmitted stray or incident light which is objectionable. Once again, the diameter of the light source, i.e., the light emitting diode **56** or the diameter of its light beam, are the best guides to determining the diameter of the second aperture or orifice **140**. The range of 0.14 inches to 0.23 inches (3.56 mm to 5.8 mm) will thus typically encompass a useful range of diameters of the second aperture or orifice **140** for commonly sized and encountered light emitting diodes, such as the diode **56** and the associated light beam.

[**0023**] A conventional snap ring **142** retains the disk **138** in position against the shoulder **136** and the end of the fourth cylindrical section **130** as it is received within the circumferential channel **144**. On the fourth cylindrical section **130**, proximate its end having the interior shoulder **134** is a circumferential groove **146**, a multiple turn snap ring, a wave washer or similar retaining device which receives a snap ring **148**. The snap ring **148** limits axial travel of the fourth cylindrical section **130** into the third cylindrical section **110**.

[**0024**] Lastly, the sensor assembly **50** includes a fifth section **150** which is again tubular or cylindrical and includes an enlarged diameter end region or flange **152** which has an outside diameter just slightly less than the major portion of the inside diameter of the fourth cylindrical section **130** and which interferes with the fourth shoulder **134** therein. Disposed within the fifth cylindrical section **150** is a tubular mount **154** having a stepped interior passageway **156** illustrated in **FIG. 3**, which receives and restrains photo detector or a light sensitive transducer such as a phototransistor **158**. The tubular mount **154** is received within the fifth cylindrical section **150** and retained thereby an annular collar **162**. The electrical cable **88** is connected to the output terminals of phototransistor **158** and a cable clamp **164** secures same to the fifth cylindrical section **150**. An internal end plug **166** is received within the open end of the fifth cylindrical section **150** and retained thereby suitable fasteners **168**. Secured to the end plug **166** is a ball joint assembly **170** which may be utilized to attach the sensor assembly **50** to one component of a device such as the rib assembly **20**, illustrated in **FIG. 1**. The ball joint assembly **170** includes a spherical bearing **172** received within a complementarily configured race or retainer **174**. A through passageway **176** in the spherical bearing **172** facilitates attachment of the ball joint assembly **170** to, for example, one of the rib assemblies **20**, as noted above.

[**0025**] Although the foregoing description relates to a linear displacement sensor **50** having five telescoping sections, it should be appreciated that a sensor having two, three, four, six or more telescoping sections is fully within the ambit of this invention as the invention is readily useable with devices having essentially any number of sections. The choice of the number of telescoping sections will typically be affected by the nominal initial and final distances between the components to be sensed, the difference between the open and closed or collapsed positions of the components and the space, i.e., transverse dimensions available for the sensor. Furthermore, while the use of two aperture disks has been found to achieve excellent operation, significant improvement in measurement accuracy will be achieved by the use of a single aperture disk (relative to not using any aperture disks) and more than two disks may be used if desired. If a single aperture disk is utilized, preferably it will be located at (or near) and remain at (or near) the mid-point between the radiation emitter and receiver during operation.

[**0026**] It should also be noted that radiation sensors other than light emitting diodes and sensors other than phototransistors may be utilized in the disclosed invention. Finally, given the high linear measurement accuracy, repeatability and hysteresis of the disclosed linear displacement sensor assembly **50**, it will be appreciated that it will have broad application beyond anthropomorphic test dummies and be useable in any application requiring its capabilities.

[**0027**] The foregoing disclosure is the best mode devised by the inventors for practicing this invention. It is apparent, however, that devices incorporating modifications and variations will be obvious to one skilled in the art of displacement sensors and more particularly to displacement sensors having a telescoping body with a radiation source at one end and a radiation sensor at the other. Inasmuch as the foregoing disclosure is intended to enable one skilled in the pertinent art to practice the instant invention, it should not be construed to be limited thereby but should be construed to include such aforementioned obvious variations and be limited only by the scope and spirit of the following claims.

1. A linear displacement sensor comprising, in combination,

a first end having a source of radiation,

a second end having a receiver sensitive to such radiation,

a telescoping housing extending between said first end and said second end, said housing having at least a first larger section and a second, smaller section disposed within said first section, and

a plate disposed within said housing and defining an aperture,

whereby said aperture transmits direct radiation and reduces transmission of incident radiation.

2. The linear displacement sensor of claim 1 wherein said housing has three sections.

3. The linear displacement sensor of claim 1 wherein said housing has five sections.

4. The linear displacement sensor of claim 1 wherein said housing includes means for securing to two components to be measured.

5. The linear displacement sensor of claim 4 wherein said means for securing includes a ball joint.

6. The linear displacement sensor of claim 1 further including a second plate defining a second aperture.

7. The linear displacement sensor of claim 6 wherein said apertures have distinct diameters.

8. A linear displacement sensor comprising, in combination,

a first end having a source of radiation,

a second end having a receiver sensitive to such radiation,

a telescoping housing extending between said first end and said second end, said housing having at least a first larger diameter section and a second, smaller diameter section disposed within said first section, and

a disk disposed within said housing and defining a central aperture,

whereby said aperture passes a direct radiation and reduces passage of incident radiation.

9. The linear displacement sensor of claim 8 wherein said housing has three sections.

10. The linear displacement sensor of claim 8 wherein said housing has five sections.

11. The linear displacement sensor of claim 8 wherein said housing includes means for securing to two components to be measured.

12. The linear displacement sensor of claim 11 wherein said means for securing includes a ball joint.

13. The linear displacement sensor of claim 8 further including a second plate defining a second aperture.

14. The linear displacement sensor of claim 13 wherein said apertures have distinct diameters.

15. A linear displacement sensor comprising, in combination,

a telescoping body having at least a first hollow section and a first closed end and a second section slidably disposed within said first section and having a second closed end,

a radiation source disposed in one of said closed ends and a radiation receiver disposed in another of said closed ends to receive radiation from said radiation source, and

at least one disk disposed between said radiation source and said radiation receiver having an aperture for passing radiation from said radiation source.

16. The linear displacement sensor of claim 15 wherein said radiation source is a light emitting diode.

17. The linear displacement sensor of claim 15 wherein said radiation receiver is a phototransistor.

18. The linear displacement sensor of claim 15 wherein said radiation source generates a beam of radiation and said aperture has a diameter approximately equal to said beam of radiation.

19. The linear displacement sensor of claim 15 wherein said telescoping body has at least five sections.

20. The linear displacement sensor of claim 15 wherein said telescoping body includes means for attaching devices to be measured.

* * * * *