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Rotatable sensor assembly with elastomeric flap

Abstract

A sensor assembly includes a housing, a sensor unit attached to the housing, and an elastomeric flap. The sensor unit includes a shell defining a vertical axis. The shell is rotatable around the axis relative to the housing. The shell includes a lower edge and extends upward along the axis from the lower edge. The housing includes an aperture centered on the axis. The aperture defines an airflow outlet from the housing radially inside the aperture relative to the axis. The sensor unit defines an airflow inlet radially inside the lower edge relative to the axis and positioned to receive airflow from the aperture. The aperture and the lower edge define a fixed gap extending around the axis. The flap is fixed to one of the housing or the sensor unit, and the flap extends across the fixed gap toward the other one of the housing or the sensor unit.

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Background/Summary

BACKGROUND

(1) Vehicles can include a variety of sensors. Some sensors detect internal states of the vehicle, for example, wheel speed, wheel orientation, and engine and transmission values. Some sensors detect the position or orientation of the vehicle, for example, global positioning system (GPS) sensors; accelerometers such as piezo-electric or microelectromechanical systems (MEMS); gyroscopes such as rate, ring laser, or fiber-optic gyroscopes; inertial measurements units (IMU); and magnetometers. Some sensors detect the external world, for example, radar sensors, scanning laser range finders, light detection and ranging (lidar) devices, and image processing sensors such as cameras. A lidar device detects distances to objects by emitting laser pulses and measuring the time of flight for the pulse to travel to the object and back.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a perspective view of an example vehicle with an example sensor assembly.

(2) FIG. **2** is an exploded perspective view of a portion of the sensor assembly.

(3) FIG. **3** is a rear perspective view of the sensor assembly.

(4) FIG. **4** is a perspective view of a portion of the sensor assembly with a sensor unit removed for illustration.

(5) FIG. **5** is a perspective view of a portion of the sensor assembly with a housing and a gutter removed for illustration.

(6) FIG. **6** is an exploded perspective view of the sensor unit.

(7) FIG. **7** is a perspective cross-sectional view of a portion of the sensor assembly with an example flap.

(8) FIG. **8** is a perspective cross-sectional view of a portion of the sensor assembly with another example flap.

(9) FIG. **9** is a diagrammatic side cross-sectional view of the sensor assembly.

DETAILED DESCRIPTION

(10) A sensor assembly includes a housing, a sensor unit attached to the housing, and an elastomeric flap. The sensor unit includes a shell defining a vertical axis. The shell is rotatable around the axis relative to the housing. The shell includes a lower edge and extends upward along the axis from the lower edge. The housing includes an aperture centered on the axis. The aperture defines an airflow outlet from the housing radially inside the aperture relative to the axis. The sensor unit defines an airflow inlet radially inside the lower edge relative to the axis and positioned to receive airflow from the aperture. The aperture and the lower edge define a fixed gap extending around the axis. The flap is fixed to one of the housing or the sensor unit. The flap extends across the fixed gap toward the other one of the housing or the sensor unit.

(11) In an example, the elastomeric flap may be bendable between a relaxed position and a flexed position, and the elastomeric flap in the relaxed position may contact the other one of the housing or the sensor unit. In a further example, the flap in the flexed position may be spaced from the other one of the housing or the sensor unit.

(12) In another further example, the flap may be sized to bend from the relaxed position to the flexed position when subject to pressurized airflow from the aperture.

(13) In another further example, the flap in the flexed position may define a temporary gap extending around the axis. In a yet further example, the fixed gap may have a constant width extending around the axis, and the temporary gap may have a smaller width than the fixed gap.

(14) In another further example, the flap may be fixed to the housing at the aperture, and the flap in the relaxed position may contact the shell. In a yet further example, the flap may extend radially inward relative to the axis from the aperture toward the shell. In a still yet further example, the flap may have a decreasing thickness from a radially outer edge fixed to the housing to a radially inner edge.

(15) In an example, the flap may have a constant cross-section projected along a circular path centered on the axis.

(16) In an example, the flap may be fixed to the lower edge of the shell. In a further example, the flap may extend downward along the axis from the lower edge.

(17) In another further example, the sensor assembly may further include a gutter fixed relative to the housing and extending around the aperture, the gutter may be elongated along the lower edge and positioned directly below the lower edge relative to the axis, and the flap may extend into the gutter.

(18) In an example, the sensor assembly may further include a gutter fixed relative to the housing

and extending around the aperture, and the gutter may be elongated along the lower edge and positioned directly below the lower edge relative to the axis. In a further example, the gutter may include a channel extending from radially inside the lower edge to radially outside the lower edge relative to the axis.
(19) In an example, the sensor unit may include a sensor body fixed relative to the shell and defining a cavity radially between the sensor body and the shell relative to the axis, and the cavity may extend continuously circumferentially around the sensor body relative to the axis. In a further example, the sensor body may include a plurality of fins extending radially outward relative to the axis from the sensor body toward the shell. In a yet further example, the fins may be positioned to receive airflow from the airflow inlet, and the fins may be oriented parallel to the axis.
(20) In an example, the sensor unit may include a lidar sensing device.
(21) In an example, the sensor assembly may further include a pressurized-air source positioned to discharge airflow through the airflow outlet.
(22) With reference to the Figures, wherein like numerals indicate like parts throughout the several views, a sensor assembly **105** for a vehicle **100** includes a housing **110**, a sensor unit **115** attached to the housing **110**, and an elastomeric flap **705**. The sensor unit **115** includes a shell **205** defining a vertical axis A. The shell **205** is rotatable around the axis A relative to the housing **110**. The shell **205** includes a lower edge **210** and extends upward along the axis A from the lower edge **210**. The housing **110** includes an aperture **305** centered on the axis A. The aperture **305** defines an airflow outlet **915** from the housing **110** radially inside the aperture **305** relative to the axis A. The sensor unit **115** defines an airflow inlet **920** radially inside the lower edge **210** relative to the axis A and positioned to receive airflow from the aperture **305**. The aperture **305** and the lower edge **210** define a fixed gap **710** extending around the axis A. The flap **705** is fixed to one of the housing **110** or the sensor unit **115**, and the flap **705** extends across the fixed gap **710** toward the other one of the housing **110** or the sensor unit **115**.
(23) The sensor assembly **105** provides both cooling and water management for the rotating sensor unit **115** on the stationary housing **110**. The airflow outlet **915** defined by the aperture **305** provides a path for airflow into the shell **205**, where the airflow can cool components of the sensor unit **115**. Because the shell **205** rotates at a high rate of speed relative to the housing **110**, the fixed gap **710** is present between the shell **205** and the housing **110**. The position of the aperture **305** close to the lower edge **210** of the shell **205** permits only a small amount of the airflow to escape through the fixed gap **710** between the aperture **305** and the lower edge **210**, making the airflow from the housing **110** to the sensor unit **115** efficient despite the fact that the shell **205** moves relative to the housing **110**. Additionally, the flap **705** can occupy part or all of the fixed gap **710**, further reducing airflow escape. Because the flap **705** is elastomeric, the flap **705** may bend when contacted by the housing **110** or sensor unit **115**, permitting the flap **705** to be placed a distance away that is smaller than the fixed gap **710**.
(24) With reference to FIG. **1**, the vehicle **100** may be any passenger or commercial automobile such as a car, a truck, a sport utility vehicle, a crossover, a van, a minivan, a taxi, a bus, etc.
(25) The vehicle **100** may include a vehicle body **120**. The vehicle body **120** includes body panels **125** partially defining an exterior of the vehicle **100**. The body panels **125** may present a class-A surface, e.g., a finished surface exposed to view by a customer and free of unaesthetic blemishes and defects. The body panels **125** include, e.g., a roof **130**, etc.
(26) The sensor assembly **105** is attachable to one of the body panels **125** of the vehicle **100**, e.g., the roof **130**. For example, the housing **110** may be shaped to be attachable to the roof **130**, e.g., may have a shape matching a contour of the roof **130**. The housing **110** may be attached to the roof **130**, which can provide the sensor unit **115** and other sensors **135** mounted inside the housing **110** with an unobstructed field of view of an area around the vehicle **100**. The housing **110** may be formed of, e.g., plastic or metal.
(27) With reference to FIG. **2**, the sensor assembly **105** includes a rigid structure **215**. The housing

110 and the rigid structure **215** are shaped to fit together, with the rigid structure **215** positioned inside the housing **110**, as seen in FIG. **4**. The rigid structure **215** can have a shape matching the contour of the roof **130** like the housing **110** does. The rigid structure **215** can include a mounting platform **220** for directly or indirectly mounting a bracket **225**, a gutter **230**, and the sensor unit **115**. The mounting platform **220** can be round, e.g., can have a circular or slightly elliptical shape, and can be centered on the axis A. The mounting platform **220** can be flat and horizontally level. The rigid structure **215** can be a single piece, i.e., a continuous piece of material with no internal seams separating multiple pieces. For example, the rigid structure **215** can be stamped or molded as a single piece.

(28) The sensor assembly **105** includes the bracket **225** mounted to the rigid structure **215**, e.g., fastened to the mounting platform **220**. The sensor unit **115** can be mounted to the bracket **225**, e.g., fastened through the bracket **225** to the mounting platform **220**. The bracket **225** can be a single piece, i.e., a continuous piece of material with no internal seams separating multiple pieces. For example, the bracket **225** can be stamped or molded as a single piece.

(29) The bracket **225** is shaped to accept and fix in place the sensor unit **115**, e.g., via fastening. The bracket **225** defines an orientation and position of the sensor unit **115** relative to the vehicle body **120**. The position of the sensor unit **115** affords the sensor unit **115** a 360° horizontal field of view of the environment surrounding the vehicle **100**, as shown in FIG. **1**. The bracket **225** can include a circular base **235** centered on the axis A and a plurality of arms **240** extending radially outward and axially upward from the base **235** relative to the axis A.

(30) The sensor assembly **105** includes the gutter **230**. The gutter **230** is fastened to the bracket **225**, e.g., to the arms **240** of the bracket **225**. The gutter **230** is fixed relative to the housing **110** via the bracket **225**. The gutter **230** has a circular shape centered on the axis A. The shape of the gutter **230** is addressed in more detail below.

(31) With reference to FIG. **3**, the housing **110** is mounted to the rigid structure **215** and covers the rigid structure **215**. The housing **110** contains the other sensors **135**. The housing **110** includes an upper surface **310** facing away from the rigid structure **215**, i.e., away from the vehicle body **120**, and a lower surface **905** facing toward the rigid structure **215**, i.e., toward the vehicle body **120** (shown in FIG. **9**). The housing **110** may be a single piece, i.e., a continuous piece of material with no internal seams separating multiple pieces. For example, the housing **110** may be stamped or molded as a single piece.

(32) With reference to FIG. **4**, the housing **110** includes the aperture **305** through which the sensor unit **115** passes. In the absence of the sensor unit **115** and the bracket **225**, the aperture **305** exposes the rigid structure **215**. The aperture **305** is round, e.g., has a circular or slightly elliptical shape. The aperture **305** is centered on the axis A. The aperture **305** of the housing **110** is a highest point of the housing **110**.

(33) With reference to FIG. **5**, the sensor unit **115** is attached, e.g., fastened, to the bracket **225**, e.g., to the base **235** of the bracket **225**. For example, the sensor unit **115** can be fastened to the rigid structure **215**, e.g., through the base **235** of the bracket **225**. The sensor unit **115** extends through the aperture **305**, as seen in FIG. **3**. The shell **205** extends above the aperture **305**, i.e., above the highest point of the housing **110**.

(34) Returning to FIG. **2**, the gutter **230** and the sensor unit **115** are both attached, e.g., fastened, to the bracket **225**. The dimensional tolerancing of the sensor unit **115** relative to the gutter **230** is thereby enhanced. Specifically, the fixed gap **710** between the gutter **230** and the shell **205** of the sensor unit **115** can be kept at an intended size more reliably, permitting the intended size to be smaller for less airflow escaping. The dimensional tolerancing can be further enhanced by the bracket **225** being a single piece, as well as by the gutter **230** and the sensor unit **115** directly contacting the bracket **225**, i.e., being fastened without intermediate components.

(35) With reference to FIG. **6**, the sensor unit **115** includes a motor **605**, a sensor body **660**, at least one sensing device **610**, at least one sensor window **615**, and the shell **205**. The motor **605** is

attached to and fixed relative to the bracket **225**, as shown in FIG. **5**. The sensor body **660**, the at least one sensing device **610**, the at least one sensor window **615**, and the shell **205** are fixed relative to each other and are rotatably drivably coupled to the motor **605**.

(36) The motor **605** is fixed relative to the bracket **225** and drivably coupled to the sensor body **660** and thereby drivably coupled to the shell **205**. The motor **605** can be positioned to rotatably drive the sensor body **660** and the shell **205** relative to the housing **110** in a first direction, e.g., clockwise as seen from above, at a high speed, e.g., 600 revolutions per minute. The motor **605** can be any suitable type for rotating the sensing device **610**, e.g., an electric motor. For example, the motor **605** can include a stator (not shown) fixed relative to the bracket **225** and a rotor (not shown) rotatable by the stator around the axis A and fixed relative to the sensor body **660**.

(37) The sensor body **660** includes walls **620**, e.g., four vertical walls **620** as shown in the Figures, and a top panel **625**. The walls **620** can have the same horizontal length, e.g., the walls **620** can form a square horizontal cross-section. The horizontal cross-section can be centered on the axis A, i.e., the axis A intersects a geometric center of the horizontal cross-section of the sensor body **660**, making the rotation of the sensor body **660** balanced. The top panel **625** extends horizontally to each wall **620**. The sensing device **610** is contained inside the sensor body **660**. The sensor body **660** is positioned inside the shell **205** and fixed relative to the shell **205**.

(38) The sensor body **660** can define a cavity **630** radially between the sensor body **660** and the shell **205** relative to the axis A. The cavity **630** can extend continuously circumferentially around the sensor body **660** relative to the axis A. The term “continuously” in the context of this disclosure means that the cavity **630** is unbroken about the axis A and air may move freely within the cavity **630** and throughout the entire cavity **630**. For example, a diagonal corner-to-corner distance across the top panel **625**, i.e., a greatest width of the sensor body **660**, can be less than an inner diameter of the shell **205**.

(39) The sensor body **660** can include a plurality of thermal fins **635**. The thermal fins **635** can be positioned on the walls **620**. The thermal fins **635** can be oriented parallel to the axis A, i.e., axially relative to the axis A, e.g., elongated vertically along the respective wall **620** for the axis A being vertical. The thermal fins **635** can be positioned on all of the walls **620**. The thermal fins **635** on each wall **620** can extend parallel to each other. The thermal fins **635** can extend perpendicularly from the respective wall **620**. Each thermal fin can have a length following a direction of elongation of the thermal fin along the wall **620**, a width perpendicular to the wall **620**, and a thickness in a horizontal direction along the wall **620**. The thermal fins **635** can extend along their respective widths radially outward relative to the axis A from the sensor body **660** toward the shell **205**. The length can be significantly greater than the width, e.g., more than twice as great. The width can be significantly greater than the thickness, e.g., more than five times as great. The thermal fins **635** can be integral with the walls **620**, i.e., made of a single, uniform piece of material with no seams, joints, fasteners, or adhesives holding it together.

(40) The thermal fins **635** can be thermally conductive, i.e., have a high thermal conductivity, e.g., a thermal conductivity equal to at least 15 watts per meter-Kelvin (W/(m K)), e.g., greater than 100 W/(m K), at 25° C. For example, the thermal fins **635**, along with the walls **620**, may be aluminum. The high thermal conductivity of the thermal fins **635** helps transfer away heat generated by the sensing device **610** inside the sensor body **660**, as does the large surface area created by the geometry of the thermal fins **635**.

(41) The sensor unit **115** may be designed to detect features of the outside world; for example, the sensor unit **115** may be a radar sensor, an ultrasonic sensor, a scanning laser range finder, a light detection and ranging (lidar) device, or an image processing sensor such as a camera. In particular, the sensor unit **115** may be a lidar device, e.g., a scanning lidar device. A lidar device detects distances to objects by emitting laser pulses at a particular wavelength and measuring the time of flight for the pulse to travel to the object and back. The operation of the sensor unit **115** is performed by the at least one sensing device **610**, e.g., a lidar sensing device, inside the sensor

body **660**. For example, the sensor unit **115** can include two sensing devices **610**. The sensing devices **610** have fields of view through the sensor windows **615** encompassing a region from which the sensor unit **115** receives input. As the sensing devices **610** rotate, the fields of view encompass a horizontal 360° around the vehicle **100**.
(42) The sensor unit **115** can include at least one sensor window **615**, e.g., two sensor windows **615**, one sensor window **615** for each sensing device **610**. The sensor windows **615** can each be positioned on one of the walls **620**. Each sensor window **615** can be off-center on the respective wall **620**. For example, the sensor window **615** can be positioned closer to a trailing edge of the respective wall **620** than a leading edge of the wall **620** with respect to the first direction of rotation of the sensor body **660**. For example, each sensor window **615** can be positioned in a trailing half of the respective wall **620** with respect to the first direction of rotation. The sensor windows **615** can be flat. For example, the sensor windows **615** can have a rectangular shape. The sensor windows **615** are transparent with respect to whatever medium the sensing device **610** is capable of detecting. For example, if the sensor unit **115** is a lidar device, then the sensor windows **615** are transparent with respect to visible light at the wavelength generated and detectable by the sensing devices **610**.
(43) The shell **205** is fixedly attached to the sensor body **660**, e.g., fastened to the top panel **625** of the sensor body **660**. The shell **205** is rotatable around the axis A relative to the housing **110**, along with the sensor body **660**.
(44) The shell **205** may have radially symmetric shape, e.g., a cylindrical shape. The shell **205** can include a cylindrical portion **640** and an end portion **645**. The end portion **645** can be flat and can have a circular shape. The end portion **645** can be attached, e.g., fastened, to the top panel **625** of the sensor body **660**. The shell **205** defines the axis A. The lower edge **210** may have a circular shape. The cylindrical portion **640** can have a cylindrical shape defining the axis A, which is vertical. The cylindrical portion **640** can have a constant circular cross-section extending upward along the axis A from the lower edge **210** to the end portion **645**. The shell **205** is open at the lower edge **210**, thereby permitting airflow into the sensor unit **115** and permitting attachment of the sensor unit **115**.
(45) The shell **205** includes a plurality of slits **665**. The slits **665** extend through the cylindrical portion **640** and are elongated parallel to the axis A. The slits **665** can be positioned radially outward from the thermal fins **635** and are elongated parallel to the fins. As described below, the slits **665** permit airflow into the shell **205** to exit from the shell **205**.
(46) The sensor windows **615** can be recessed from the shell **205**. The sensor unit **115** can include window recesses **650** extending from the sensor window **615** and from the respective wall **620** radially outward to the shell **205**. The window recesses **650** can include passages **655** positioned to direct airflow entering the shell **205** across the sensor window **615**. For example, the passages **655** can be positioned in the first direction of rotation of the sensor body **660** from the respective sensor windows **615**, i.e., as the sensor body **660** rotates, each passage **655** leads the respective sensor window **615**. The passages **655** can extend vertically for a height of the respective sensor windows **615**.
(47) With reference to FIG. **7**, the lower edge **210** of the shell **205** is positioned radially inside the aperture **305** relative to the axis A. The lower edge **210** may be positioned at a same height as or below the aperture **305** relative to the axis A. The shell **205** extends above the aperture **305**, i.e., above the highest point of the housing **110**. The lower edge **210** may be positioned slightly below the aperture **305**, and most of the shell **205** is exposed above the housing **110**. Positioning the lower edge **210** below the aperture **305** can reduce airflow escaping while flowing from the housing **110** to the shell **205**.
(48) The aperture **305** and the lower edge **210** define the fixed gap **710** extending around the axis A. The fixed gap **710** is the shortest distance separating the aperture **305** and the lower edge **210**. The fixed gap **710** may have a constant width extending around the axis A. The fixed gap **710** may

be radial and/or axial relative to the axis A. For example, a radial distance from the aperture **305** to the lower edge **210** relative to the axis A may be constant around the axis A, and an axial distance from the aperture **305** to the lower edge **210** relative to the axis A may be constant around the axis A.

(49) The gutter **230** is elongated along the aperture **305** and along the lower edge **210** of the shell **205**. The gutter **230** is positioned directly below the lower edge **210** relative to the axis A, i.e., straight downward. The gutter **230** includes a channel **715**. The channel **715** has a u- or v-shaped cross-section that follows the lower edge **210** of the shell **205**. The channel **715**, specifically the cross-section of the channel **715**, extends from radially inside the lower edge **210** to radially outside the lower edge **210** relative to the axis A, as well as from radially inside the aperture **305** to radially outside the aperture **305** relative to the axis A. A radially outer edge of the channel **715** can be flush against the lower surface **905** of the housing **110** at or radially outside of the aperture **305** relative to the axis A. The position and shape of the gutter **230** helps the gutter **230** catch fluid, e.g., rain or washer fluid, draining from an outside surface of the cylindrical portion **640** of the shell **205**.

(50) Returning to FIGS. **3** and **4**, the housing **110** includes at least one drain hole **315**, e.g., four drain holes **315**, positioned to receive fluid from the gutter **230**. The drain holes **315** extend radially outward relative to the axis A from the gutter **230**. The drain holes **315** extend from the lower surface **905** of the housing **110** at the gutter **230**, i.e., from inside the housing **110**, to the upper surface **310** of the housing **110**, i.e., to outside the housing **110**. Fluid can flow from the gutter **230** through the drain holes **315** and down the housing **110** toward the roof **130** of the vehicle **100**.

(51) With reference to FIGS. **7** and **8**, the flap **705** is fixed to one of the housing **110** (e.g., the aperture **305**) or the sensor unit **115** (e.g., the lower edge **210** of the shell **205**). The flap **705** extends across the fixed gap **710** toward the other one of the housing **110** or the sensor unit **115**. The flap **705** may extend circumferentially relative to the axis A along the aperture **305** and along the lower edge **210**. The flap **705** may have a cross-section, e.g., in a plane extending radially and axially relative to the axis A, projected in a circular path around the axis A.

(52) The flap **705** is elastomeric, i.e., is rubber-like, i.e., has a low Young's modulus and a high failure strain. For example, the flap **705** may be EPDM (ethylene propylene diene monomer) rubber. Being elastomeric permits the flap **705** to bend when contacting the other one of the housing **110** or the sensor unit **115**, so the flap **705** can be located closer to the other one of the housing **110** or the sensor unit **115** than the fixed gap **710**.

(53) With reference to FIG. **7**, in a first example, the flap **705** may be fixed to the housing **110**, e.g., at the aperture **305**. The flap **705** may be sealed to the aperture **305** or to the gutter **230**, e.g., the radially outer edge of the channel **715**, completely around the axis A.

(54) The flap **705** may extend radially inward relative to the axis A from the aperture **305** toward the shell **205**, e.g., radially inward and axially upward from the aperture **305** toward the shell **205**, e.g., the lower edge **210** of the shell **205**. The flap **705** may have a constant cross-section projected along a circular path centered on the axis A. The flap **705**, specifically the constant cross-section, may have a decreasing thickness from a radially outer edge fixed to the housing **110** to a radially inner edge.

(55) The flap **705** may be bendable between a relaxed position and a flexed position, by virtue of being elastomeric. In FIG. **7**, the flap **705** in the relaxed position is shown in solid lines, and the flap **705** in the flexed position is shown in hidden lines. More specifically, the flap **705** may be elastically bendable between the relaxed position and the flexed position, i.e., bendable without plastic deformation of the flap **705**. The flap **705** may thus be capable of repeated bending between the relaxed position and the flexed position.

(56) The flap **705** in the relaxed position may contact the shell **205**, e.g., at the lower edge **210**. The flap **705** may contact the shell **205** fully around the axis A. The flap **705** may thus prevent entry by rain or other debris when the flap **705** is in the relaxed position.

(57) The flap **705** in the flexed position, specifically the constant cross-section, may curve away from the shell **205**. The flap **705** in the flexed position may define a temporary gap **720** extending around the axis A. The temporary gap **720** may be radial and/or axial relative to the axis A. The temporary gap **720** is a smallest distance in cross-section between the flap **705** and the shell **205**. The temporary gap **720** may have a smaller width than the fixed gap **710**, thereby permitting less airflow than the fixed gap **710** without the flap **705** present.
(58) The flap **705** may be sized to bend from the relaxed position to the flexed position when subject to pressurized airflow from the aperture **305** (produced as described below). When pressurized airflow is traveling through the aperture **305**, the flap **705** is pushed to the flexed position. In the absence of the pressurized airflow traveling through the aperture **305**, the flap **705** is in the relaxed position.
(59) With reference to FIG. **8**, the flap **705** may be fixed to the shell **205**, e.g., to the lower edge **210** of the shell **205**. The flap **705** may extend downward along the axis A from the lower edge **210**, e.g., toward the gutter **230**. The flap **705** may extend into the gutter **230**, e.g., radially between the radially inner edge and the radially outer edge of the gutter **230**. The flap **705** may be spaced from the gutter **230**. The flap **705** may be attached to the lower edge **210** from a radially inside corner to a radially outside corner of the lower edge **210**. The flap **705** may extend downward to one or more edges. The flap **705** may define an axial gap **805** to the gutter **230**, i.e., a distance parallel to the axis A from the flap **705**, e.g., the one or more edges of the flap **705**, to the gutter **230**, e.g., to the floor of the channel **715**. The axial gap **805** may be smaller than the fixed gap **710**, thereby permitting less airflow than the fixed gap **710** without the flap **705** present.
(60) With reference to FIG. **9**, the sensor assembly **105** includes a pressurized-air source **910**. The pressurized-air source **910** can be positioned inside the housing **110**. The pressurized-air source **910** may be any suitable type of blower, e.g., a fan, or suitable type of compressor, e.g., a positive-displacement compressor such as a reciprocating, ionic liquid piston, rotary screw, rotary vane, rolling piston, scroll, or diaphragm compressor; a dynamic compressor such as an air bubble, centrifugal, diagonal, mixed-flow, or axial-flow compressor; or any other suitable type.
(61) The pressurized-air source **910** can be positioned to supply airflow from the housing **110** through the aperture **305** into the shell **205**, e.g., to discharge airflow between the arms **240** of the bracket **225** and then through the airflow outlet **915** defined by the aperture **305**. For example, the pressurized-air source **910** can be fluidly connected to a space between the rigid structure **215** and the housing **110** through which the pressurized air can flow to the bracket **225**, then between the arms **240**, then exiting through the airflow outlet **915**. The aperture **305** defines the airflow outlet **915** passing radially inside the aperture **305** relative to the axis A, e.g., radially inside an inner edge of the channel **715** of the gutter **230**.
(62) The sensor unit **115** defines the airflow inlet **920** radially inside the lower edge **210** of the shell **205** relative to the axis A. The airflow inlet **920** is positioned to receive airflow from the aperture **305**, e.g., the airflow inlet **920** encircles the airflow outlet **915**, i.e., the lower edge **210** encircles the radially inner edge of the channel **715** of the gutter **230**. The thermal fins **635** and the slits **665** are positioned to receive airflow from the airflow inlet **920**. For example, airflow that passes from the housing **110** through the airflow inlet **920** passes between the thermal fins **635** and then exits the sensor unit **115** through the slits **665**. The airflow thus transfers heat from the sensor body **660**, thereby cooling the sensor body **660** and the sensing device **610**. The airflow is vertical through the airflow inlet **920**, and the vertical orientation of the thermal fins **635** and the slits **665** facilitates smooth airflow.
(63) The flap **705** provides for low levels of lost airflow from the housing **110** to the sensor unit **115**. Because the flap **705** is flexible, the flap **705** may be located closer to the lower edge **210** (if attached to the housing **110**) or closer to the aperture **305** (if attached to the sensor unit **115**) than a distance between the aperture **305** and the lower edge **210**. In other words, the temporary gap **720** in FIG. **7** or the axial gap **805** in FIG. **8** are smaller than the fixed gap **710**, thereby permitting less

air to escape.
(64) The disclosure has been described in an illustrative manner, and it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation. Many modifications and variations of the present disclosure are possible in light of the above teachings, and the disclosure may be practiced otherwise than as specifically described.

Claims

1. A sensor assembly comprising: a housing; a sensor unit attached to the housing; and an elastomeric flap; the sensor unit including a shell defining a vertical axis; the shell being rotatable around the axis relative to the housing; the shell including a lower edge and extending upward along the axis from the lower edge; the housing including an aperture centered on the axis; the aperture defining an airflow outlet from the housing radially inside the aperture relative to the axis; the sensor unit defining an airflow inlet radially inside the lower edge relative to the axis and positioned to receive airflow from the aperture; the aperture and the lower edge defining a fixed gap extending around the axis; the flap fixed to one of the housing or the sensor unit; and the flap extending across the fixed gap toward the other one of the housing or the sensor unit.
2. The sensor assembly of claim 1, wherein the elastomeric flap is bendable between a relaxed position and a flexed position, and the elastomeric flap in the relaxed position contacts the other one of the housing or the sensor unit.
3. The sensor assembly of claim 2, wherein the flap in the flexed position is spaced from the other one of the housing or the sensor unit.
4. The sensor assembly of claim 2, wherein the flap is sized to bend from the relaxed position to the flexed position when subject to pressurized airflow from the aperture.
5. The sensor assembly of claim 2, wherein the flap in the flexed position defines a temporary gap extending around the axis.
6. The sensor assembly of claim 5, wherein the fixed gap has a constant width extending around the axis, and the temporary gap has a smaller width than the fixed gap.
7. The sensor assembly of claim 2, wherein the flap is fixed to the housing at the aperture, and the flap in the relaxed position contacts the shell.
8. The sensor assembly of claim 7, wherein the flap extends radially inward relative to the axis from the aperture toward the shell.
9. The sensor assembly of claim 8, wherein the flap has a decreasing thickness from a radially outer edge fixed to the housing to a radially inner edge.
10. The sensor assembly of claim 1, wherein the flap has a constant cross-section projected along a circular path centered on the axis.
11. The sensor assembly of claim 1, wherein the flap is fixed to the lower edge of the shell.
12. The sensor assembly of claim 11, wherein the flap extends downward along the axis from the lower edge.
13. The sensor assembly of claim 11, further comprising a gutter fixed relative to the housing and extending around the aperture, wherein the gutter is elongated along the lower edge and positioned directly below the lower edge relative to the axis, and the flap extends into the gutter.
14. The sensor assembly of claim 1, further comprising a gutter fixed relative to the housing and extending around the aperture, wherein the gutter is elongated along the lower edge and positioned directly below the lower edge relative to the axis.
15. The sensor assembly of claim 14, wherein the gutter includes a channel extending from radially inside the lower edge to radially outside the lower edge relative to the axis.
16. The sensor assembly of claim 1, wherein the sensor unit includes a sensor body fixed relative to the shell and defining a cavity radially between the sensor body and the shell relative to the axis, and the cavity extends continuously circumferentially around the sensor body relative to the axis.

17. The sensor assembly of claim 16, wherein the sensor body includes a plurality of fins extending radially outward relative to the axis from the sensor body toward the shell.
18. The sensor assembly of claim 17, wherein the fins are positioned to receive airflow from the airflow inlet, and the fins are oriented parallel to the axis.
19. The sensor assembly of claim 1, wherein the sensor unit includes a lidar sensing device.
20. The sensor assembly of claim 1, further comprising a pressurized-air source positioned to discharge airflow through the airflow outlet.