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Air duct airflow sensor

Abstract

An airflow sensor system for an air duct including a damper positioned therein is provided. The controller is configured to determine, via a first pressure sensor, a first airflow measurement based on a first one or more pressure measurements. The controller is further configured to determine, via a second pressure sensor and a damper position sensor, a second airflow measurement based on a second one or more pressure measurements and one or more damper position measurements. The first airflow measurement and the second airflow measurement have a first uncertainty value and a second uncertainty value associated therewith. The controller is further configured to determine an estimated airflow based on weighted values of the first airflow measurement and the second airflow measurement. The weighted values are based on the airflow measurements and the uncertainty values associate therewith.

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Background/Summary

BACKGROUND

(1) The present disclosure generally relates to air duct airflow sensors. Air dampers are mechanical valves used to permit, block, and control the flow of air in air ducts. Generally, a pressure sensor is incorporated to detect and measure the air pressure in the air duct. Pressure measurements can be used to determine the amount of airflow through the duct and to actuate a damper mechanism to open or close, thus affecting airflow. Various pressure measurement devices may have varying levels of uncertainty associated with the pressure measurements.

SUMMARY

(2) One implementation of the present disclosure is an airflow sensor system for an air duct. The air duct includes a duct wall and an axial bore that extends from an inlet of the air duct to an outlet of the air duct for conveying an airflow through the air duct from the inlet to the outlet. The airflow sensor assembly includes a first pressure sensor, a second pressure sensor, a damper position sensor, and a controller. The damper position sensor is configured to detect one or more damper position measurements associated with a damper located within the axial bore. The controller is configured to determine, via the first pressure sensor, a first airflow measurement based on a first one or more pressure measurements. The first airflow measurement has associated first uncertainty value. The controller is further configured to determine, via the second pressure sensor and the damper position sensor, a second airflow measurement based on a second one or more pressure measurements and one or more damper position measurements. The second airflow measurement has an associated second uncertainty value. The controller is further configured to determine a first weighted value of the first airflow measurement based on the first uncertainty value. The controller is further configured to determine a second weighted value of the second airflow measurement based on the second uncertainty value. The controller is further configured to determine an estimated airflow based on the first weighted value and the second weighted value. In some embodiments, the first weighted value increases relative to the second weighted value in response to an increase of the second uncertainty value relative to the first uncertainty value.

(3) Another implementation of the present disclosure is a method of operating an air duct. The method includes measuring a first differential pressure measurement regarding an airflow within the air duct with a first pressure sensor. In some embodiments, the first differential pressure measurement has an associated first uncertainty value. The method further includes measuring a second differential pressure measurement regarding the airflow with a second pressure sensor. In some embodiments, the second differential pressure measurement has an associated second uncertainty value different than the first uncertainty value. The method further includes sending, via the first pressure sensor, the first differential pressure measurement to a controller. The method further includes sending, via the second pressure sensor, the second differential pressure measurement to the controller. The method further includes determining, via the controller, a first airflow measurement based on the first differential pressure measurement. In some embodiments, the first airflow measurement has a third uncertainty value based on the first uncertainty value. The method further includes determining, via the controller, a second airflow measurement based on the second differential pressure measurement. In some embodiments, the second airflow measurement has a fourth uncertainty value based on the second uncertainty value. The method further includes determining, via the controller, an estimated airflow based on the first airflow measurement, the second airflow measurement, the third uncertainty value, and the fourth uncertainty value. In some embodiments, the estimated airflow has an associated fifth uncertainty value that is less than the third uncertainty value and the fourth uncertainty value.

(4) Yet another implementation of the present disclosure is a controller for operating an air duct. The controller includes one or more processors and a memory. The one or more processors are configured to measure, via a number of pressure sensors, a number of differential pressure measurements regarding an airflow within the air duct. The one or more processors are further configured to determine a number of uncertainty values regarding the number of differential pressure measurements. In some embodiments, a first uncertainty value of the number of uncertainty values is different than a second uncertainty value of the number of uncertainty values. The one or more processors are further configured to determine an estimated airflow based on the number of differential pressure measurements and the number of differential pressure measurements. In some embodiments, the estimated airflow has an associated third uncertainty value that is less than the first uncertainty value and the second uncertainty value.

(5) Those skilled in the art will appreciate that the summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of the devices and/or processes described herein, as defined solely by the claims, will become apparent in the detailed description set forth herein and taken in conjunction with the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The drawings disclose exemplary embodiments in which like reference characters designate the same or similar parts throughout the figures of which:

(2) FIG. **1**A is an isometric view of an air duct assembly, according to some embodiments;

(3) FIG. **1**B is a partial isometric view of the air duct assembly of FIG. **1**A, according to some embodiments;
(4) FIG. **2** is a side cross-sectional view of an air duct airflow sensor assembly, according to some embodiments;
(5) FIG. **3** is a side cutaway view of the air duct assembly of FIG. **1**, according to some embodiments;
(6) FIG. **4** is a top elevation view of the air duct assembly of FIG. **1**, according to some embodiments;
(7) FIG. **5** is another top view of the air duct assembly of FIG. **1**, according to some embodiments;
(8) FIG. **6** is a side cross-sectional view of the air duct assembly taken along the line A-A of FIG. **5**, according to some embodiments;
(9) FIG. **7** is a detail view B-B of the air duct assembly of FIG. **6**, according to some embodiments;
(10) FIG. **8** is a detail view C-C of the air duct assembly of FIG. **6**, according to some embodiments;
(11) FIG. **9** is a flow diagram showing a controller controlling the position of an air damper of an air duct, according to some embodiments;
(12) FIG. **10** is a flow diagram of a method for determining an adjusted position of an air damper of the air duct of FIG. **9**, according to some embodiments; and
(13) FIG. **11** is a plot depicting a characteristic curve of a damper, according to some embodiments.

DETAILED DESCRIPTION

(14) Before turning to the figures, which illustrate certain exemplary embodiments in detail, it should be understood that the present disclosure is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology used herein is for the purpose of description only and should not be regarded as limiting.

(15) The present disclosure relates to air duct assemblies, including, but not limited to, determining a measure of airflow within an air duct. In some embodiments, one or more sensors may be used to determine one or more airflow measurements within the air duct. Such airflow measurements may have an uncertainty value associated therewith. In some embodiments, systems and methods provide reduce the uncertainty associated with pressure measurements of an airflow sensor, thereby improving the control of damper mechanisms.

(16) Uncertainty values represent a deviation between a measured value and an actual value. Depending on the implementation of an air duct assembly (or some other system leveraging a determination of airflow measurements), various sensors may be used to determine (e.g., measure) conditions associated with the air duct (e.g., air pressure, air velocity, air temperature, humidity, etc.). Such conditions may be used to determine airflow measurements. However, these conditions may be determined via systems and/or methods that result in an uncertainty value associated with the measurement of such conditions. Accordingly, in some systems, airflow measurements may be associated with uncertainty values.

(17) In some embodiments, an air duct assembly may include two or more pressure sensors. The two or more pressure sensors may have different uncertainty values associated with airflow measurements that the two or more pressure sensors are used to determine. Advantageously, the airflow measurements determined by the two or more pressure sensors may be fused (e.g., algebraically juxtaposed, cross-referenced, etc.) in a weighted-average method that provides a resulting estimation of airflow that has a determinable uncertainty value associated therewith. The weighted-average method of determining the estimation of airflow may be based on the airflow measurements and their associated uncertainty values. In some embodiments, the determinable uncertainty value associated with the estimated airflow may be less than the uncertainties associated with the airflow measurements provided by the one or more pressure sensors. The systems and methods provided herein may allow for improved accuracy in airflow measurement systems in some embodiments. In some embodiments, the air duct assembly provided for herein may be used to control a damper (e.g., a valve, an airflow resistor, a vent, etc.) to adjust airflow within the air duct in response to a desired setpoint airflow condition within the air duct.

(18) Turning now to FIG. **1**A, a perspective view of an air duct assembly **1** is shown, according to some embodiments. As shown, the air duct assembly **1** includes a first end **2**, a second end **3**, an interior wall **4**, an exterior wall **5**, and a control assembly **100**. The first end **2**, second end **3**, interior wall **4**, and exterior wall **5** may form an air duct body containing an axial bore through which air may flow. The control assembly **100** may be provided within a housing **6**. In some embodiments, the first end **2** and/or the second end **3** may be in fluid communication with one or more spaces (e.g., rooms, environments, chambers, outdoor areas, etc.) in order to transfer an amount of airflow (e.g., transfer air at a volumetric flow rate) from one space to another. A fan (or other actuating device) may act to create a pressure gradient (e.g., negative) within the air duct assembly **1**. For example, a fan may be located on the second end **3** to create a negative pressure gradient running from the first end **2** to the second end **3**, thus drawing air across the air duct assembly **1** from the first end **2** to the second end **3**. In some embodiments, the first end **2** is operable as an inlet for the airflow of the air duct assembly, while the second end **3** is operable as an outlet for the airflow of the air duct assembly. Alternatively, the fan is located on the first end **2** to create a negative pressure gradient running from the second end **3** to the first end **2**, thus drawing air across the air duct assembly **1** form the second end **3** to the first end **2**. Thus, although generally described herein as a system that draws air from the first end **2** to the second end **3** of the air duct assembly, it should be appreciated that the air duct assembly **1** is operated to draw air in either direction at varying velocities, depending on the implementation. While depicted as forming a circular cross-section, the air duct

assembly **1**, (particularly with reference to the interior wall **4** and the exterior wall **5**) is formed in any geometrical configuration suitable for the systems and methods described herein (e.g., a square, rectangle, ellipse, etc.).

(19) Referring now to FIG. **1**B, another perspective view of the air duct assembly **1** depicted in FIG. **1**A is shown, according to some embodiments. As depicted in FIG. **1**B, a portion of the air duct assembly **1** towards the first end **2** is cut away to provide a perspective view of the interior of the air duct assembly **1** (e.g., within the interior wall **4**). As shown, the air duct assembly **1** may include an air damper assembly **50**. In some embodiments, the air damper assembly **50** is positioned within the interior wall **4** to control a volume of air flowing through the air duct assembly **1** from the first end **2** to the second end **3**, or vice-versa (depending on the implementation). In some embodiments, the air damper assembly **50** is operated such that the air duct assembly **1** facilitates a variable air volume (VAV) system. For example, the first end **2** of the air duct assembly **1** may draw air from a space. A remote device (such as a remote device **7** as depicted with reference to FIG. **9**) may communicate, to the control assembly **100**, a setpoint (e.g., desired, selected, scheduled, etc.) airflow to be drawn from the space (e.g., based on changing conditions of the space or adjustments to the conditions of the space). While the fan (described above with reference to FIG. **1**A) operates at a constant speed, an airflow being drawn through the air duct assembly **1** is adjusted by the air damper assembly **50** in order to affect a change in airflow being drawn from the space in some embodiments. In some embodiments, the air damper assembly **50** is operated by the control assembly **100** to decrease a difference between the setpoint airflow and a measured airflow. In some embodiments, the measured airflow is determined by the control assembly **100**, as described in greater detail herein. Thus, as described in greater detail herein, the control assembly **100** is configured to receive a setpoint airflow from the remote device **7**, determine a measured airflow within the air duct assembly **1**, and control the air damper assembly **50** accordingly. The air damper assembly **50** is “opened” (e.g., rotated such that the air damper assembly **50** is closer to, or is in, a parallel position with respect to the direction of airflow traveling through the air duct assembly **1**). In some embodiments, when the air damper assembly is fully opened, air is able to freely travel through the air duct assembly **1**, e.g., as dictated by the speed of the fan, depending on the structure of the air damper assembly **50**. The air damper assembly **50** is “closed” (e.g., rotated such that the air damper assembly **50** is closer to, or is in, a perpendicular position with respect to the airflow traveling through the air duct assembly **1**). In some embodiments, when the air damper assembly is fully closed, air is completely (or substantially) blocked from traveling through the air duct assembly **1**, despite the operation of the fan. While depicted as generally forming a circular damper, the air damper assembly **50** is formed in any geometrical configuration suitable for the systems and methods described herein (e.g., a square, rectangle, ellipse, etc.).

(20) Referring now to FIGS. **2** and **3**, a side-view of an interior of the air duct assembly **1** is shown (e.g., within the interior wall **4** and the housing **6**), according to some embodiments. The control assembly **100** may include various sensors and be configured to receive one or more pressure measurements in order to determine a measured airflow within the air duct assembly **1**. In other words, the control assembly **100** is operable within the air duct assembly **1** as an airflow sensor system. For example, the control assembly **100** of the air duct assembly **1** may include a first pressure sensor assembly **20** and a second pressure sensor assembly **30**. The first pressure sensor assembly **20** may detect one or more pressure measurements via a first set (e.g., one or more) of ports (e.g., apertures, openings, holes, etc.) **21** disposed on a first body **23** and/or a second set of ports **22** disposed on a second body **24**. Likewise, the second pressure sensor assembly **30** may detect one or more pressure measurements via a third set of ports **31** and/or a fourth set of ports **32**. The third set of ports **31** and/or the fourth set of ports **32** is disposed within a body of the air duct assembly **1** such that they extend from the exterior wall **5** to the interior wall **4**. The first pressure sensor assembly **20** and/or the second pressure sensor assembly **30** is communicably coupled to a measurement receiver **40**. The measurement receiver **40** is communicably coupled to a controller **90** of the control assembly **100** (depicted in greater detail below with reference to FIG. **4**) in order to facilitate the communication of one or more pressure measurements from the first pressure sensor assembly **20** and/or the second pressure sensor assembly **30** to the controller **90**. Thus, the first pressure sensor assembly **20** and the second pressure sensor assembly **30** is communicably coupled to the controller **90** in order to provide pressure measurements in some embodiments. The controller **90** may, in turn, control the position of the air damper assembly **50** based on the pressure measurements (and/or a determination of airflow based thereon), as described in greater detail below.

(21) As shown, the first pressure sensor assembly **20** is positioned between the first end **2** of the air duct assembly **1** and the second pressure sensor assembly **30** in some embodiments. In other embodiments, the first pressure sensor assembly **20** is positioned between the third set of ports **31** and the fourth set of ports **32**. For example, the first pressure sensor assembly **20** is positioned intermediate the air damper assembly **50** and the third set of ports **31**, or intermediate the air damper assembly **50** and the fourth set of ports **32**. In other embodiments still, the second pressure sensor assembly **30** is positioned between the second pressure sensor assembly **30** and the second end **3** of the air duct assembly **1**. In even other embodiments, the first pressure sensor assembly **20** is positioned in some other arrangement suitable to perform the systems and methods described herein.

(22) As suggested above, the first pressure sensor assembly **20** may include the first body **23** and the second body **24**. For example, the first body **23** and/or the second body **24** is annular (e.g., hollow) members (e.g., probes) disposed in a substantially parallel arrangement within the air duct assembly **1** (e.g., within the interior wall **4**). The first body **23**

may form an outer wall (e.g., surrounding an inner annular duct (e.g., path, conduit, tube, etc.), and the first set of ports **21** is disposed thereon. Likewise, the second body **24** may form an outer wall, and the second set of ports **22** is disposed thereon. In some embodiments, the first body **23** and the second body **24** are rigidly coupled to one another in order to maintain a particular arrangement relative to one another. In other embodiments, the first body **23** and the second body **24** are not coupled to one another. In this sense, while depicted as extending in a parallel fashion, the first body **23** and the second body **24** is arranged in any manner relative to one another and/or relative to the other components of the air duct assembly **1** in order to perform the systems and methods described herein.

(23) In some embodiments, the first pressure sensor assembly **20** is operable as a pitot tube and thus operate to determine a dynamic pressure “pickup” between the first set of ports **21** and the second set of ports **22**. As such, the first pressure sensor assembly **20** is operable to determine a first pressure measurement via the first set of ports **21** and/or a second pressure measurement via the second set of ports **22**. In some embodiments, the first pressure measurement via the first set of ports **21** and/or the second pressure measurement via the second set of ports **22** is compared (e.g., by the controller **90**) in order to determine a first differential pressure measurement.

(24) In some embodiments, the first set of ports **21** is disposed in alignment (or some other operable geometry) on the first body **23** facing toward the first end **2** (e.g., against the direction of airflow through the air duct assembly **1**). The first set of ports **21** may measure a stagnation pressure of the air flowing through the air duct assembly **1**, such as a stagnation pressure measurement **901** with reference to FIG. **901**. In other words, the first set of ports **21** may measure the static pressure at a stagnation point of the airflow within the air duct assembly **1**. The stagnation point is a result of the orientation of the first set of ports **21** on the first body **23** of the first pressure sensor assembly **20** directly (or substantially directly) against the direction of airflow through the air duct assembly **1** in some embodiments. Accordingly, at such a “stagnation point,” the fluid velocity of the airflow is zero (or substantially zero), thus converting kinetic energy of the airflow into pressure energy (isentropically) in some embodiments. In other embodiments, the first set of ports **21** is disposed on the first body **23** in other orientations relative to the first end **2** and may accordingly be used to determine other characterizations of air pressure associated with the air flowing through the air duct assembly **1**, such as static pressure.

(25) In some embodiments, the second set of ports **22** are be disposed in alignment (or some other operable geometry) on the second body **24** facing away (to some degree, at least) from the first end **2**. For example, the second set of ports **22** is oriented on the second body **24** directly downstream with respect to the airflow (e.g., facing the second end **3** of the air duct assembly **1**). As another example, the second set of ports **22** is oriented perpendicular with respect to the first set of ports **21** and/or the path of the airflow traveling from the first end **2** to the second end **3**. The second set of ports **22** may measure a static pressure of the airflow within the air duct assembly **1**, such as a static pressure measurement **902** with reference to FIG. **9**. Thus, in some embodiments, the second set of ports **22** may measure a static pressure of the “free stream” airflow.

(26) In some embodiments, the first set of ports **21** and the second set of ports **22** is fluidly coupled to a first conduit (e.g., a tube, pipe, etc.) **25** via the first body **23** and the second body **24** (respectively). The first conduit **25**, in turn, is fluidly coupled to the measurement receiver **40**. In some embodiments, the first conduit **25** may form two distinct channels each fluidly coupled to the first set of ports **21** (via the first body **23**) or the second set of ports **22** (via the second body **24**). In other embodiments, the conduit **25** forms a single channel. Accordingly, the first pressure sensor assembly **20** is used by the measurement receiver **40** to detect the stagnation pressure measurement **901** via the first set of ports **21** and the static pressure measurement **902** via the second set of ports **22**. The measurement receiver **40** may in turn provide the stagnation pressure measurement **901** and the static pressure measurement **902** to the controller **90**, which may determine a first differential pressure measurement based thereon. As described in greater detail below, the first differential pressure measurement is used to determine a first airflow measurement.

(27) Referring now to FIGS. **4-7**, the second pressure sensor **30** is shown in greater detail, according to some embodiments. As shown, FIG. **5** depicts a side cross-sectional view of the air duct assembly taken along the line B-B of FIG. **4**. FIG. **5** identifies details B-B and C-C, which are shown with greater particularity in FIGS. **6** and **7** (respectively).

(28) Referring particularly to FIG. **5**, the third set of ports **31** and the fourth set of ports **32** is disposed in alignment (or some other operable geometry) within the air duct assembly **1**, extending from the return exterior wall **5** to the interior wall **4**. Thus, the third set of ports **31** and the fourth set of ports **32** is in fluid communication with the interior of the air duct assembly (e.g., within the interior wall **4**) in order to detect one or more pressure measurements on either end of the air damper assembly **50**. For example, the first set of ports **31** may measure a static pressure of the airflow upstream relative to the air damper assembly **50** (e.g., closer to the first end **2** than the air damper assembly **50**), such as an upstream static pressure measurement **903** with reference to FIG. **9**. The second set of ports **32** may measure a static pressure of the airflow downstream relative to the air damper assembly **50** (e.g., closer to the second end **3** than the air damper assembly **50**), such as a downstream pressure measurement **904** with reference to FIG. **9**. Accordingly, a difference between the upstream static pressure measurement **903** and the downstream static pressure measurement **904** may indicate a static pressure drop (e.g., pressure differential) due to the restriction of airflow resulting from the position of the air damper assembly **50** (e.g., the position of a surface **53** of the air damper

assembly **50** that blocks airflow depending on a rotational position of the surface **53** about a shaft **55** of the air damper assembly). As described in greater detail below, the static pressure drop is interpreted by the controller **90** in order to determine a second airflow measurement, which is based on a rotational position of the air damper assembly **50**.

(29) As shown, the third set of ports **31** and the fourth set of ports **32** may each include multiple ports and be disposed in a ring-shape (or some other operable geometry) about the interior wall **4**. In other embodiments, the third set of ports **31** and the fourth set of ports **32** may each include only a single port. The third set of ports **31** is fluidly coupled to the measurement receiver **40** via a second conduit **33** and the fourth set of ports **32** is fluidly coupled to the measurement receiver **40** via a third conduit **34**. In some embodiments, the second pressure sensor assembly **30** includes a first sleeve **37** and a second sleeve **38**, as depicted in greater detail below with reference to FIGS. **6** and **7**. The first sleeve **37** is operable to facilitate the fluid communication between the third set of ports **31** and the second conduit **33**. Likewise, the second sleeve **38** is operable to facilitate the fluid communication between the third set of ports **32** and the third conduit **34**. The measurement receiver **40** may in turn provide the upstream static pressure measurement **903** and the downstream static pressure measurement **904** to the controller **90**, which may determine a second differential pressure measurement. As described in greater detail below, the second differential pressure measurement is used to determine a second airflow measurement.

(30) Referring now to FIGS. **6** and **7**, details B-B and C-C of FIG. **6** are shown in greater particularity, according to some embodiments. As shown, the first sleeve **37** and the second sleeve **38** is located generally over the third set of ports **31** and the fourth set of ports **32**, respectively. Each of the first sleeve **37** and the second sleeve **38** may form recessed areas about the exterior wall **5**. For example, the second sleeve **38** may form a recess **39** fluidly coupled to the fourth set of ports **32** via an aperture **41**. Accordingly, the measurement receiver **40** may detect the downstream static pressure measurement **904** using the fourth set of ports **32** via a third conduit **34** fluidly coupled to the recess **39** via an attachment point **36** at the aperture **41**. The first sleeve **37** is similarly operable, according to some embodiments. For example, the measurement receiver **40** may detect the upstream static pressure measurement **903** using the third set of ports **31** via a second conduit **33** fluidly coupled to a recess enclosed by the first sleeve **37** by an aperture.

(31) Referring now to FIG. **8**, the control assembly **100** is shown in greater detail, according to some embodiments. As shown, the control assembly **100** includes the controller **90**, the air damper assembly **50**, the measurement receiver **40**, a power supply **60**, an actuator **70**, and a position sensor **80**.

(32) In some embodiments, the position sensor **80** may measure the position of the air damper assembly **50**. The position sensor **80** is configured to sense condition data (e.g., rotational position, movement, speed, etc.) associated with the air damper assembly **50**, and communicate the condition of the air damper assembly **50** to the controller **90**. For example, the position sensor **80** may determine a current (e.g., previous, original, measured) damper position, such as a damper position measurement **905** with reference to FIG. **9**, and communicate the damper position measurement **905** to the controller **90**. In some embodiments, the position sensor **80** is an ultrasonic or laser sensor that detects proximity, a Bluetooth® low energy (BLE) sensor that detects proximity of a BLE tag positioned on the air damper assembly **50**, or some other type of sensor. For example, the position sensor **80** may determine a relative position of the surface **53** of the air damper assembly **50**, and interpret the relative position of the surface **53** to determine a rotational position of the air damper assembly **50** as a whole. In other embodiments, the position sensor **80** is a component of the actuator **70** and determines a position of the air damper assembly **50** in accordance with the operation of the actuator **70** as described below.

(33) In some embodiments, the actuator **70** is a stepper motor. In other embodiments, the actuator **70** is another type of motor. The actuator **70** may operate to move (e.g., translate) the rotational position of the air damper assembly **50** based on one or more commands provided by the controller **90**. For example, the actuator **70** is operable to rotate the air damper assembly **50** via the shaft **55** extending along a central axis of the air damper assembly **50** (e.g., bisecting the surface **53** of the air damper assembly **50**).

(34) As suggested above, the position sensor **80** may determine a current position of the air damper assembly **50** in accordance with the operation of the actuator **70** (e.g., rather than providing a position measurement of the air damper assembly **50** independent of the actuator **70**). In some implementations, the position sensor **80** is a motion sensing roller within the actuator **70** that uses an optical, mechanical, or electrical system to detect rotation of the air damper assembly **50**. The motion sensing roller may measure the angle and/or frequency of rotations of the shaft **55**, which is used to determine the rotational movement (e.g., a starting rotational position, an ending rotational position, a rotational speed, etc.) of the air damper assembly **50**. In other implementations, particularly where the actuator **70** is a stepper motor, the actuator **70** may include the position sensor **80** as an electrical sensor. Rotation of the shaft **55** may result in rotation a motor core included in the actuator **70**. The rotation of the motor core induces an electrical current in one or more electrical coils included actuator **70**. The position sensor **80** (implemented as an electrical sensor) detects the induced electrical current in the one or more electrical coils and provides a corresponding signal to indicate a rotational position of the air damper assembly **50**. A frequency of pulses of the induced current may also be used to indicate a speed at which the air damper assembly **50** is rotating.

(35) The actuator **70** may use electricity supplied by main power. The main power is converted through use of a

transformer and/or AC to DC converter (e.g., the power supply **60**) to achieve the electrical supply that the actuator **70** requires. In other embodiments, the actuator **70** is powered by the power supply **60**, which is an independent battery. In other embodiments still, the power supply **60** is a supplemental battery used in addition to mains power. Where the actuator **70** is powered by the power supply **60**, the actuator **70** is able to control the rotational position of the air damper assembly **50** in the event of a power failure (the main power, for example). Where the power supply **60** is rechargeable, it is recharged by main power.

(36) In some embodiments, the controller **90** is communicably coupled to the position sensor **80** and use information provided by the position sensor **80** to determine the current position of the air damper assembly **50**. This information is used to adjust a position of the air damper assembly **50** in response to a difference between a setpoint airflow value (stored by the controller **90**, communicated to the controller **90** by the remote device **7**, etc.) and an estimated airflow value determined by the controller **90**. In some embodiments, the controller **90** is configured to communicate using a wireless communication protocol, including but not limited to, Wi-Fi (e.g. 802.11x), Wi-Max, cellular (e.g. 3G, 4G, LTE, CDMA, etc.), LoRa, Zigbee, Zigbee Pro, Bluetooth, Bluetooth Low Energy (BLE), Near Field Communication (NFC), Z-Wave, 6LoWPAN, Thread, RFID, and other applicable wireless protocols. In various embodiments, the controller **90** is communicably coupled to some or all of the components of the control assembly **100**. For example, the controller **90** may receive power data from the power supply **60** regarding a battery life status of the power supply **60** (e.g., in instances where the power supply **60** is an independent power source used to power the control assembly **100**).

(37) In other embodiments, the controller **90** includes some or all of the components of the control assembly **100**. The controller **90** (and the control assembly **100** as a whole, depending on the implementation) may include one or more processors, memory, circuity, and so on in order to facilitate the systems and methods described herein, as described in greater detail below.

(38) Referring to FIG. **9**, a flow **900** for controlling the position of the air damper assembly **50** is shown, according to some embodiments. In some embodiments, the controller **90** may receive the stagnation pressure measurement **901** and the static pressure measurement **902** from the first pressure sensor assembly **20** as suggested above; the upstream static pressure measurement **903** and the downstream static pressure measurement **904** from the second pressure sensor assembly **30**; and the damper position measurement **905** from the position sensor **80**, as suggested above. The controller **90** may further receive a setpoint airflow value **906** from the remote device **7**. For example, the remote device **7** is configured to provide the controller **90** with a desired airflow value (e.g., an amount of airflow discharged via the outlet or second end **3**). As described in greater detail below with reference to FIG. **10**, the controller **90** may determine a first measured airflow value via the pressure measurements **901** and **902** and a second measured airflow value via the pressure measurements **903** and **904**. As suggested above, the first measured airflow and the second measured airflow may include an uncertainty value. Based on the first measured airflow value, the second measured airflow value, and the uncertainty values associated therewith, the controller **90** may determine an estimated airflow value of a greater accuracy (e.g., a lower uncertainty value) than the first measured airflow value and the second measured airflow value, according to some embodiments. The controller **90** may then compare the estimated airflow value to the setpoint airflow value **906**, and provide the actuator **70** with a damper position update **907** in order to decrease a difference between the estimated airflow value and the setpoint airflow value **906**, should one exist.

(39) Referring to FIG. **10**, a flow **1000** for controlling the position of the air damper assembly **50** is shown, according to some embodiments. At process **1001**, the controller **90** may determine a first differential pressure measurement ΔP.sub.meas1 as provided by the first pressure sensor assembly **20**. For example, the first differential pressure measurement ΔP.sub.meas1 is based on the stagnation pressure measurement **901** and the static pressure measurement **902** determined by the first pressure sensor assembly **20**. At process **1002**, the controller **90** may determine a second differential pressure measurement ΔP.sub.meas2 as provided by the second pressure sensor assembly **30**. For example, the second differential pressure measurement ΔP.sub.meas2 is based on the upstream static pressure measurement **903** and the downstream static pressure measurement **904**.

(40) At process **1003**, ΔP.sub.meas1 is used to determine a first volumetric air flow rate (e.g., a first airflow measurement Q.sub.meas1). For example, the stagnation pressure measurement **901** and the static pressure measurement **902** is applied to Bernoulli's equation, detailed below as Equation 1.

(41) $P_1 + \frac{\rho}{2}v_1^2 = P_2 + \frac{\rho}{2}v_2^2$. Equation1

(42) P.sub.1 is the stagnation pressure measurement **901** (P.sub.stag) and P.sub.2 is the static pressure measurement **902** of the free stream airflow (P.sub.free). v.sub.1 is the velocity at the stagnation point of the airflow. v.sub.1 is assumed to be zero due to the orientation of the first set of ports **21**. v.sub.2 is the velocity of the free stream of airflow v.sub.free. Accordingly, the measured difference between P.sub.stag and P.sub.free (ΔP.sub.meas1) is used to determine v.sub.free. However, the second set of ports **22** may measure an air pressure that is less than the true (e.g., actual) static pressure of the free stream airflow. For example, the obstruction of airflow due to the presence of the second body **24** may result in the second set of ports **22** measuring the pressure of airflow that is in the “wake” of the second body **24**, and thus less than the pressure of the true static pressure of the air flowing through the air duct assembly **1**. Thus, a “pick up” gain K is applied to ΔP.sub.meas to correct for the difference between the measured

difference in static pressure between P.sub.stag and P.sub.free and the true difference in static pressure between P.sub.stag and P.sub.free. Thus, ΔP of Equation 1 is expressed as ΔP.sub.meas1, provided below in Equation 2. Equation 2, in turn, is rearranged to solve for v.sub.free as expressed in Equation 3 provided below.

(43) $\Delta P_{\text{meas1}} = P_{\text{stag}} - P_{\text{free}} = K\frac{\rho}{2}v_{\text{free}}^2$. Equation2 $\sqrt{\frac{2\Delta P_{\text{meas1}}}{\rho K}} = v_{\text{free}}$. Equation3

(44) Accordingly, at process **1003**, the controller **90** may determine a first airflow measurement Q.sub.meas1 as provided by the first pressure sensor assembly **20**. By applying the cross-sectional area of the air duct assembly **1** (A.sub.d) to v.sub.free, a volumetric flow rate of the air flowing though the air duct assembly **1** via the dynamic pressure pickup is determined to represent Q.sub.meas1, as expressed below in Equation 4.

(45) $Q_{\text{meas1}} = A_d\sqrt{\frac{2\Delta P_{\text{meas}}}{\rho K}} = A_d v_{\text{free}}$. Equation4

(46) At process **1004**, the controller **90** may determine a second airflow measurement Q.sub.meas2. For example, the upstream static pressure measurement **903** and the downstream static pressure measurement **904** is used to determine a measurement of air velocity, which in turn is used to determine a second volumetric air flow rate (e.g., a second airflow measurement Q.sub.meas2). Referring to Equation 1 above, P.sub.1 is the upstream static pressure (P.sub.US), P.sub.2 is the downstream static pressure (P.sub.DS), v.sub.US is the upstream air velocity, and v.sub.DS is the downstream air velocity. Thus, Equation 1 is expressed as second measured pressure differential as detailed below in Equation 5.

(47) $\Delta P_{\text{meas2}} = P_{\text{US}} - P_{\text{DS}} = \frac{\rho}{2}v_{\text{US}}^2 - \frac{\rho}{2}v_{\text{DS}}^2$. Equation5

(48) In some embodiments, the second differential pressure measurement ΔP.sub.meas2 is used to determine the second airflow measurement Q.sub.meas2 based on the static pressure drop provided by the second pressure sensor assembly **30** through differential equations or other algebraic means. In other embodiments, rather than determining

(49) $\frac{\rho}{2}v_{\text{US}}^2 - \frac{\rho}{2}v_{\text{DS}}^2$, the pressure drop ΔP.sub.meas2 is modeled as a relationship between the volumetric air flow and a flow coefficient C.sub.v as expressed below in Equation 6, and rearranged to solve for Q.sub.meas2 as expressed below in Equation 7.

(50) $\Delta P_{\text{meas2}} = \frac{Q^2}{C_v^2}$. Equation6 $Q_{\text{meas2}} = C_v\sqrt{\Delta P_{\text{meas2}}}$. Equation7 While depicted as a square root relationship between Q.sub.meas2 and ΔP.sub.meas2, other relationships is used, such as a different exponent or a different equation entirely.

(51) In some embodiments, depending on various adjustments to the orientation of the air damper assembly **50**, the flow coefficient C.sub.v is a function of the rotational position Θ (e.g., the damper position measurement **905**) of the air damper assembly **50**. Accordingly, Q.sub.meas2 is further expressed as detailed below in Equation 8.

Q.sub.meas2=*f*(Θ)√{square root over (Δ*P*.sub.meas2)} Equation 8.

(52) Equation 8 is referred to as a “damper's characteristic curve,” and is unique to each damper (e.g., shape, structure, etc.), such as the air damper assembly **50**. In some cases, dampers may correspond to a characteristic curve that equates a position of the damper normalized between a zero-percent open (e.g., fully closed, perpendicular to the airflow through the air duct assembly **1**, etc.) position and a one-hundred-percent open (e.g., fully open, parallel to the airflow through the air duct assembly **1**, etc.) position. An example damper characteristic curve **1101** is depicted with on a plot **1100** with reference to FIG. **11** (dep. associating a normalized rotational position measurement **1102** (Θ) with a flow coefficient **1103** (C.sub.v). Using the damper's characteristic curve (or another equation that similarly models a damper characteristic curve), C.sub.v is determined as suggested above based on the damper position measurement **905**, and thus Q.sub.meas2 is determined accordingly based on the upstream static pressure measurement **903** and the downstream static pressure measurement **904**.

(53) At process **1005**, the controller **90** may determine a first uncertainty (e.g., an uncertainty value, a propagation of multiple uncertainty values, etc.) associated with the first airflow measurement Q.sub.meas1. For example, Q.sub.meas1 may have some uncertainty value associated with it, as a result of uncertainties (e.g., error bands) regarding the operation the first pressure sensor assembly **20** measuring P.sub.stag and P.sub.free, and thus P.sub.meas1. In other words, any of the aforementioned measured values is a result, at least in part, of a deviation between the first airflow measurement Q.sub.meas1 and an actual value of the first airflow.

(54) At process **1006**, the controller **90** may determine a second uncertainty associated with the second airflow measurement Q.sub.meas2. For example, Q.sub.meas2 may have some uncertainty value associated with it as a result of uncertainties regarding the operation the second pressure sensor assembly **30** measuring ΔP.sub.meas2 (via P.sub.US and P.sub.DS) and Θ. In other words, any of the aforementioned measured values is a result, at least in part, of a deviation between the second airflow measurement Q.sub.meas2 and actual values of the second airflow.

(55) In some embodiments, based on the number of variables used by the controller **90** to determine Q.sub.meas1 and Q.sub.meas2, propagation of uncertainties σ.sub.prop1 and σ.sub.prop2 is determined (respectively). In general, a propagation of uncertainty σ.sub.prop may identify a summation of the effects on a function *f* (e.g., the determination of Q.sub.meas1 and Q.sub.meas2) by uncertainty of the variables σ.sub.x.sub.i measured and applied to the function, as detailed below in Equation 9.

(56) $\sigma_{\text{prop}} = \sqrt{\sum_i \left(\frac{\partial f}{\partial x_i}\sigma_{x_i}\right)^2}$. Equation9

(57) In regards to process **1005** and Q.sub.meas1, σ.sub.prop is determined as σ.sub.prop1 based on the uncertainty σ.sub.ΔP.sub.meas1 associated with ΔP.sub.meas1 according to Equation 10 below.

(58) $\sigma_{\text{prop1}} = \frac{dQ_{\text{meas1}}}{d\Delta P_{\text{meas1}}}\sigma_{\Delta P_{\text{meas1}}}$. Equation10

(59) In regards to process **1006** and Q.sub.meas2, σ.sub.prop is determined as σ.sub.prop2 based on the uncertainties σ.sub.ΔP.sub.meas2 and σ.sub.Θ associated with ΔP.sub.meas2 and Θ according to Equation 11 below.

(60) $\sigma_{\text{prop2}} = \sqrt{\left(\frac{dQ_{\text{meas2}}}{d\Delta P_{\text{meas2}}}\sigma_{\Delta P_{\text{meas2}}}\right)^2 + \left(\frac{dQ_{\text{meas2}}}{d\theta}\sigma_{\theta}\right)^2}$. Equation11

(61) At process **1007**, the controller **90** may mathematically fuse (e.g., link, relate, cross-reference) the first airflow measurement Q.sub.meas1 and the second airflow measurement Q.sub.meas2 via a weighted averaging based on the first propagation of uncertainty or σ.sub.prop1 and the second propagation of uncertainty σ.sub.prop2. Thus, a first weighting factor is applied to Q.sub.meas1 and a second weighting factor is applied to Q.sub.meas2 to determine an estimated flow rate Q.sub.Est. In some embodiments, the weighting factors is based on inverse-variance weighting. Advantageously, inverse-variance weighting is a method of aggregating two or more variables to potentially minimize (or decrease) the uncertainty associated with the aggregated value relative to the uncertainties of the values aggregated. In general, given a sequence of variables y.sub.i with variances σ.sub.i.sup.2, the inverse-variance weighted average {dot over (y)} is given by Equation 12 below, which is applied to Q.sub.meas1 and Q.sub.meas2 as given by Equation 13 below in order to yield Q.sub.Est

(62) 0 $\dot{y} = \frac{\sum_i \frac{y_i}{\sigma_i^2}}{\sum_i \frac{1}{\sigma_i^2}}$. Equation12 $Q_{\text{Est}} = \frac{\frac{Q_{\text{meas1}}}{\sigma_{\text{prop1}}^2} + \frac{Q_{\text{meas2}}}{\sigma_{\text{prop2}}^2}}{\frac{1}{\sigma_{\text{prop1}}^2} + \frac{1}{\sigma_{\text{prop2}}^2}}$. Equation13

(63) In some embodiments, as indicated by Equation 13 above and the systems and methods disclosed herein, as the uncertainty regarding the first airflow measurement increases relative to the uncertainty regarding the second airflow measurement, its representation relative to the second airflow measurement in terms of the estimated airflow (e.g., how much the value of Q.sub.meas1 numerically contributes to the calculation of Q.sub.Est relative to Q.sub.meas2) decreases, and vic-versa. As suggested above, the uncertainty σ.sub.Est of Q.sub.Est may thus be less than the uncertainties of Q.sub.meas1 and/or Q.sub.meas2. For example, given Equation 13 above, the uncertainty of Q.sub.Est is determined as provided by Equation 14 below.

(64) $\sigma_{\text{Est}} = \sqrt{\frac{1}{\frac{1}{\sigma_{\text{dyn}}^2} + \frac{1}{\sigma_{\text{static}}^2}}}$. Equation14

(65) In some embodiments, the air duct assembly **1** is operable to determine the estimated airflow Q.sub.Est (with an improved uncertainty value σ.sub.Est) without necessarily completing processes **1008** and **1009** below. For example, the controller **90** may determine Q.sub.Est and transmit Q.sub.Est to a remote device, such as the remote device **7** in order to provide a status of the air duct assembly **1**. In such cases, the flow **1000** may stop here. In other embodiments, the flow **1000** continues in accordance with processes **1008** and **1009** as described below.

(66) At process **1008**, the controller **90** may compare the estimated airflow to a setpoint airflow. For example, the controller **90** may have received the setpoint airflow value **906** from the remote device **7** with reference to FIG. **9**. In turn, the controller **90** may compare the setpoint airflow value **906** to Q.sub.Est.

(67) In some cases, if the controller determines that Q.sub.Est is greater than the setpoint airflow value **906**, the controller **90** may determine that the airflow traveling through the air duct assembly **1** is greater than the desired (e.g., selected, optimized, required, etc.) airflow traveling through the air duct assembly **1** as requested by the remote device **7**. Thus, the controller **90** may determine that the airflow is decreased in order to decrease a difference between and the setpoint airflow value **906** and adjust the position of the air damper assembly **50** accordingly, as described in greater detail below with reference to process **1009**.

(68) In other cases, if the controller determines that Q.sub.Est is less than the setpoint airflow value **906**, the controller **90** may determine that the airflow traveling through the air duct assembly **1** is less than the desired airflow traveling through the air duct assembly **1** as requested by the remote device **7**. Thus, the controller **90** may determine that the airflow is increased in order to decrease a difference between and the setpoint airflow value **906** and adjust the position of the air damper assembly **50** accordingly, as described in greater detail below with reference to process **1009**.

(69) In other cases, still, the controller **90** may determine that Q.sub.Est is equivalent (or substantially so) to the setpoint airflow value **906**. For example, the controller **90** may determine that Q.sub.Est is within an acceptable threshold range relative to the setpoint airflow value **906**. In some embodiments, the acceptable threshold range is a percentage deviation as provided below in Equation 15.

(70) In other embodiments, the acceptable threshold range is an absolute value difference between Q.sub.Est and the setpoint airflow value **906** as provided below in Equation 16. In such various cases where the controller **90** determines that Q.sub.Est is equivalent to the setpoint airflow value **906** or within an acceptable threshold range, the controller **90** may determine that no update to the position of the air damper assembly **50** is necessary, and thus the

controller **90** may not adjust the position of the air damper assembly **50** as described below with reference to Process **1009**.
(71) At process **1009**, the controller **90** may adjust a damper position of the air damper assembly **50** based on the comparison of Q.sub.Est and the setpoint airflow value **906**. For example, the controller **90** may provide the damper position update **907** to the damper actuator **70**.
(72) The construction and arrangement of the systems and methods as shown in the various exemplary embodiments are illustrative only. Although only a few embodiments have been described in detail in this disclosure, many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.). For example, the position of elements can be reversed or otherwise varied and the nature or number of discrete elements or positions can be altered or varied. Accordingly, all such modifications are intended to be included within the scope of the present disclosure. The order or sequence of any process or method steps can be varied or re-sequenced according to alternative embodiments. Other substitutions, modifications, changes, and omissions can be made in the design, operating conditions and arrangement of the exemplary embodiments without departing from the scope of the present disclosure.
(73) As utilized herein with respect to numerical ranges, the terms “approximately,” “about,” “substantially,” and similar terms generally mean +/−10% of the disclosed values, unless specified otherwise. As utilized herein with respect to structural features (e.g., to describe shape, size, orientation, direction, relative position, etc.), the terms “approximately,” “about,” “substantially,” and similar terms are meant to cover minor variations in structure that may result from, for example, the manufacturing or assembly process and are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the disclosure as recited in the appended claims.
(74) It should be noted that the term “exemplary” and variations thereof, as used herein to describe various embodiments, are intended to indicate that such embodiments are possible examples, representations, or illustrations of possible embodiments (and such terms are not intended to connote that such embodiments are necessarily extraordinary or superlative examples).
(75) The term “coupled” and variations thereof, as used herein, means the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent or fixed) or moveable (e.g., removable or releasable). Such joining may be achieved with the two members coupled directly to each other, with the two members coupled to each other using a separate intervening member and any additional intermediate members coupled with one another, or with the two members coupled to each other using an intervening member that is integrally formed as a single unitary body with one of the two members. If “coupled” or variations thereof are modified by an additional term (e.g., directly coupled), the generic definition of “coupled” provided above is modified by the plain language meaning of the additional term (e.g., “directly coupled” means the joining of two members without any separate intervening member), resulting in a narrower definition than the generic definition of “coupled” provided above. Such coupling may be mechanical, electrical, or fluidic.
(76) References herein to the positions of elements (e.g., “top,” “bottom,” “above,” “below”) are merely used to describe the orientation of various elements in the FIGURES. It should be noted that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.
(77) The hardware and data processing components used to implement the various processes, operations, illustrative logics, logical blocks, modules and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose single- or multi-chip processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, or, any conventional processor, controller, microcontroller, or state machine. A processor also may be implemented as a combination of computing devices, such as a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. In some embodiments, particular processes and methods may be performed by circuitry that is specific to a given function. The memory (e.g., memory, memory unit, storage device) may include one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage) for storing data and/or computer code for completing or facilitating the various processes, layers and modules described in the present disclosure. The memory may be or include volatile memory or non-volatile memory, and may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure. According to an exemplary embodiment, the memory is communicably connected to the processor via a processing circuit and includes computer code for executing (e.g., by the processing circuit or the processor) the one or more processes

described herein.

(78) The present disclosure contemplates methods, systems and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

(79) Although the figures and description may illustrate a specific order of method steps, the order of such steps may differ from what is depicted and described, unless specified differently above. Also, two or more steps may be performed concurrently or with partial concurrence, unless specified differently above.

(80) It should be noted that the flow **900** shown in FIG. **9** may include any of the features discussed with respect to the other embodiments disclosed elsewhere herein, including the use of a single pressure sensor assembly, multiple pressure sensor assemblies, multiple air damper assemblies, multiple air ducts, multiple ports of the pressure sensor assemblies, differing types of sensors, actuators, etc. Similarly, any of the features of FIG. **9** may be incorporated into the other embodiments disclosed herein. All such combinations of features are to be understood to be within the scope of the present disclosure.

(81) It is important to note that any element disclosed in one embodiment may be incorporated or utilized with any other embodiment disclosed herein. For example, the second pressure sensor assembly **30**, shown as positioned in FIG. **1**A, may be incorporated in the air duct assembly that includes the first pressure sensor assembly **20**, shown as positioned in FIG. **2**. Although only one example of an element from one embodiment that can be incorporated or utilized in another embodiment has been described above, it should be appreciated that other elements of the various embodiments may be incorporated or utilized with any of the other embodiments disclosed herein.

Claims

1. An airflow sensor system for an air duct comprising a duct wall and an axial bore that extends from an inlet of the air duct to an outlet of the air duct for conveying an airflow through the air duct from the inlet to the outlet, the airflow sensor system comprising: a first pressure sensor configured to detect a first one or more pressure measurements; a second pressure sensor configured to detect a second one or more pressure measurements; a damper position sensor configured to detect one or more damper position measurements associated with a damper located within the axial bore; and a controller configured to: determine, based on the first one or more pressure measurements, a first airflow measurement having an associated first uncertainty value; determine, based on the second one or more pressure measurements and the one or more damper position measurements, a second airflow measurement having an associated second uncertainty value; determine a first weighted value of the first airflow measurement based on the first uncertainty value; determine a second weighted value of the second airflow measurement based on the second uncertainty value; and determine an estimated airflow based on the first weighted value and the second weighted value, wherein the first weighted value increases relative to the second weighted value in response to an increase of the second uncertainty value relative to the first uncertainty value.
2. The system of claim 1, wherein an uncertainty value associated with the estimated airflow is less than at least one of the first uncertainty value and the second uncertainty value.
3. The system of claim 1, wherein the damper is transitionable between a plurality of positions to regulate the conveyance of the airflow though the air duct from the inlet to the outlet, and wherein the controller is further configured to selectively control the operation of the damper to selectively transition between a current position of the damper and an updated position of the damper based on the estimated airflow.
4. The system of claim 1, wherein the first pressure sensor is positioned intermediate the inlet and the second pressure sensor, wherein the first pressure sensor comprises: one or more probes extending into the axial bore; a first set of one or more ports disposed on the one or more probes, the first set of one or more ports is configured to detect at least one pressure measurement of the first one or more pressure measurements; and a second set of one or more ports disposed on the one or more probes, the second set of one or more ports is configured to detect at least one pressure measurement of the first one or more pressure measurements and positioned closer to the outlet than the first set of one or more ports, and wherein the second pressure sensor comprises: a third set of one or more ports disposed within

the duct wall, the third set of ports configured to detect at least one pressure measurement of the second one or more pressure measurements and positioned closer to the outlet than the second set of ports; and a fourth set of one or more ports disposed within the duct wall, the fourth set of ports configured to detect at least one pressure measurement of the second one or more pressure measurements and positioned closer to the outlet than the third set of one or more ports.
5. The system of claim 1, wherein determining the first airflow measurement based on the first one or more pressure measurements comprises: determining a first differential pressure measurement based on the first one or more pressure measurements; and determining the first airflow measurement based on the first differential pressure measurement, and wherein determining the second airflow measurement based on the second one or more pressure measurements and the one or more damper position measurements comprises: determining a second differential pressure measurement based on the second one or more pressure measurements; and determining the second airflow measurement based on the second differential pressure measurement and the one or more damper position measurements.
6. The system of claim 2, wherein the first set of ports faces towards the inlet and a velocity associated with the airflow at the first set of ports is assumed to be zero.
7. The system of claim 4, wherein the first uncertainty value is based on propagated uncertainty values regarding: the at least one pressure measurement of the first one or more pressure measurements detected by the first set of ports; and the at least one pressure measurement of the first one or more pressure measurements detected by the second set of ports, and wherein the second uncertainty value is based on propagated uncertainty values regarding: the at least one pressure measurement of the second one or more pressure measurements detected by the third set of ports; the one or more damper position measurements; and the at least one pressure measurement of the second one or more pressure measurements detected by the fourth set of ports.
8. The system of claim 5, wherein the damper is located within the axial bore intermediate the third set of ports and the fourth set of ports, the damper is transitionable between a plurality of positions to regulate the conveyance of the airflow though the air duct from the inlet to the outlet, and the controller is further configured to: determine a current position of the damper based on the one or more damper position measurements; and control the operation of the damper to selectively transition between the current position of the damper and an updated position of the damper based on a comparison of the estimated airflow and a setpoint airflow.
9. The system of claim 8, wherein the setpoint airflow is transmitted from a remote device to the controller.
10. The system of claim 8, wherein the first uncertainty value is based on propagated uncertainty values regarding: at least one pressure measurement of the first one or more pressure measurements detected by the first set of ports; and at least one pressure measurement of the first one or more pressure measurements detected by the second set of ports, and wherein the second uncertainty value is based on propagated uncertainty values regarding: at least one pressure measurement of the second one or more pressure measurements detected by the third set of ports; at least one pressure measurement of the second one or more pressure measurements detected by the fourth set of ports; and at least one of the one or more damper position measurements.
11. A method of operating an air duct, the method comprising: measuring a first differential pressure measurement regarding an airflow within the air duct with a first pressure sensor, the first differential pressure measurement having an associated first uncertainty value; measuring a second differential pressure measurement regarding the airflow with a second pressure sensor, the second differential pressure measurement having an associated second uncertainty value different than the first uncertainty value; sending, via the first pressure sensor, the first differential pressure measurement to a controller; sending, via the second pressure sensor, the second differential pressure measurement to the controller; determining, via the controller, a first airflow measurement based on the first differential pressure measurement, the first airflow measurement having a third uncertainty value based on the first uncertainty value; determining, via the controller, a second airflow measurement based on the second differential pressure measurement, the second airflow measurement having a fourth uncertainty value based on the second uncertainty value; and determining, via the controller, an estimated airflow based on the first airflow measurement, the second airflow measurement, the third uncertainty value, and the fourth uncertainty value, the estimated airflow having an associated fifth uncertainty value that is less than the third uncertainty value and the fourth uncertainty value.
12. The method of claim 11, further comprising operating, via the controller, a valve positioned within the air duct and transitionable between a plurality of positions to regulate the airflow, wherein the operation of the valve is based on the estimated airflow.
13. The method of claim 12, further comprising: determining a current position of the valve with a valve sensor, the current position of the valve having a sixth uncertainty value; and sending, via the valve sensor, the current position to the controller, wherein operating the valve comprises controlling the valve to selectively transition between the current position and an updated position of the valve, and wherein one of the third uncertainty value and the fourth uncertainty value is further based on the sixth uncertainty value.
14. The method of claim 12, wherein operating the valve comprises controlling the valve to selectively transition between a current position and an updated position in order to decrease a difference between the estimated airflow

and a setpoint airflow.
15. The method of claim 14, wherein the setpoint airflow is provided to the controller via a remote device.
16. A controller for operating an air duct, the controller comprising one or more processors and a memory storing instructions that, when executed by the one or more processors, cause the one or more processors to: obtain, via a plurality of pressure sensors, a plurality of differential pressure measurements regarding an airflow within the air duct; determine a plurality of uncertainty values regarding the plurality of differential pressure measurements, wherein a first uncertainty value of the plurality of uncertainty values is different than a second uncertainty value of the plurality of uncertainty values; and determine an estimated airflow based on the plurality of differential pressure measurements and the plurality of uncertainty values, wherein the estimated airflow has an associated third uncertainty value that is less than the first uncertainty value and the second uncertainty value; and control, based on the estimated airflow, an actuator to move a damper positioned within the air duct between a plurality of positions to regulate the airflow.
17. The controller of claim 16, wherein the estimated airflow is further based on a current position of the plurality of positions of the damper.
18. The controller of claim 16, wherein the instructions further cause the one or more processors to receive a setpoint airflow from a remote device, and control the actuator to selectively transition the damper between a current position and an updated position of the plurality of positions in order to decrease a difference between the estimated airflow and the setpoint airflow.
19. The controller of claim 16, wherein the instructions further cause the one or more processors to determine a current position of the plurality of positions based on measuring, via an electrical sensor, one or more electric impulses generated by the actuator in response to a movement of the damper.