

# US Patent & Trademark Office

## Patent Public Search | Text View

---

United States Patent Application Publication

20250264163

Kind Code

A1

Publication Date

August 21, 2025

Inventor(s)

Ke; Chang

---

## GAS FLOW VALVE AND METHODS OF OPERATING THEREOF

---

### Abstract

A gas flow valve includes a plunger configured to move between a closed position and one or more open positions within a housing. The gas flow valve further includes a force sensor configured to measure a force exerted by the plunger in the closed position and further configured to induce vibration responsive to being energized to dislodge particles from one or more surfaces of the gas flow valve.

---

<b>Inventors:</b>	<b>Ke; Chang (Sunnyvale, CA)</b>
<b>Applicant:</b>	<b>Applied Materials, Inc. (Santa Clara, CA)</b>
<b>Family ID:</b>	<b>1000008576820</b>
<b>Appl. No.:</b>	<b>19/198780</b>
<b>Filed:</b>	<b>May 05, 2025</b>

---

### Related U.S. Application Data

parent US continuation 18235459 20230818 parent-grant-document US 12313180 child US 19198780

---

### Publication Classification

**Int. Cl.:** **F16K31/06** (20060101); **B04C3/06** (20060101); **F16K37/00** (20060101)

**U.S. Cl.:**

**CPC** **F16K31/0655** (20130101); **B04C3/06** (20130101); **F16K37/0041** (20130101);  
**Y10T137/428** (20150401); **Y10T137/4322** (20150401)

---

## Background/Summary

RELATED APPLICATION [0001] This application is a continuation of U.S. application Ser. No. 18/235,459, filed Aug. 18, 2023, the content of which is hereby incorporated by reference in its entirety.

### TECHNICAL FIELD

[0002] Embodiments of the present disclosure relate, in general, to a valve for controlling a flow of gas.

### BACKGROUND

[0003] Various manufacturing systems (e.g., for semiconductor applications) may include gas flow valves to control the amount of gas flowed e.g., to a process chamber. Gas flow valves may actuate based on controller inputs. Controllers may use sensor data, such as flow sensor data, to cause gas flow valves to actuate to meet target flow rates. In some manufacturing systems, process gases (e.g., gases used during semiconductor fabrication processes) and/or cleaning gases (e.g., gases used to clean a manufactured device and/or a chamber used in manufacturing an electronic device) may have precise delivery targets including high mass flow rates as well as the ability to precisely control low flow rates. Additionally, gas flow valves are subject to wear and leakage which may be caused by particles carried in the gas flow. These particles can damage the valve and other downstream components.

### SUMMARY

[0004] Certain embodiments of the present disclosure relate to a gas flow valve including a housing configured to receive a flow of gas. The gas flow valve further includes a plunger configured to move between a closed position and one or more open positions within the housing. The gas flow valve further includes a position sensor configured to measure a distance associated with a difference in position of the plunger between the closed position and the one or more open positions. The gas flow valve further includes a force sensor coupled to the plunger and configured to measure a force exerted by the plunger in the closed position on a sealing surface.

[0005] In another aspect of the disclosure, a gas flow assembly includes a valve including a housing configured to receive a flow of gas. The valve further includes a plunger configured to move between a closed position and one or more open positions within the housing. The valve further includes a position sensor configured to measure a distance associated with a difference in position of the plunger between the closed position and the one or more open positions. The valve further includes a force sensor coupled to the plunger and configured to measure a force exerted by the plunger in the closed position on a sealing surface. The gas flow assembly further includes a particle trap forming a chamber configured to separate particles from the flow of gas. The gas flow assembly further includes a processing device configured to cause the valve to actuate to control the flow of gas based on sensor data from one or more of the position sensor or the force sensor.

[0006] In another aspect of the disclosure, a method includes receiving position data from a position sensor configured to measure a distance associated with a difference in position of a gas valve plunger configured to move between a closed position and one or more open positions. The method further includes receiving force data from a force sensor coupled to the plunger and configured to measure a force exerted by the plunger in the closed position on a sealing surface. The method further includes causing the plunger to actuate between the closed position and the one or more open positions based on one or more of the position data or the force data.

---

## Description

## BRIEF DESCRIPTION OF DRAWINGS

[0007] The present disclosure is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings in which like references indicate similar elements. It should be noted that different references to “an” or “one” embodiment in this disclosure are not necessarily to the same embodiment, and such references mean at least one.

[0008] FIG. 1 illustrates an exemplary system that includes a processing chamber, a gas source, and a flow control apparatus, in accordance with embodiments of the present disclosure.

[0009] FIG. 2A is a schematic diagram of a gas stick assembly in accordance with embodiments of the present disclosure.

[0010] FIG. 2B is a perspective view of a gas stick assembly in accordance with embodiments of the present disclosure.

[0011] FIGS. 3A-3B are cutaway side views of a gas flow valve assembly in accordance with embodiments of the present disclosure.

[0012] FIGS. 4A-4B illustrate cutaway side views of a gas flow valve in accordance with embodiments of the present disclosure.

[0013] FIGS. 5A-5B are flow diagrams of methods of controlling a gas flow valve in accordance with embodiments of the present disclosure.

[0014] FIG. 6 is a block diagram illustrating a computer system for use in accordance with the embodiments of the present disclosure.

## DETAILED DESCRIPTION OF EMBODIMENTS

[0015] Embodiments described herein relate to a gas flow valve (also referred to as a gas flow control valve, a proportional gas flow control valve, etc.), a gas flow system incorporating the same, and a method of controlling the gas flow valve. Generally, it is advantageous to proportionally control the flow of gas to a system such as a substrate manufacturing system. Conventional gas flow control valves are passive devices which actuate based on control inputs (e.g., from a controller). Control inputs are typically based on target gas flow rates and flow rate sensor data. However, conventional gas flow control valves can suffer from poor precision, repeatability, reliability, and cleanliness.

[0016] Often, gas flow control valves wear over time with continued use. For example, the sealing surfaces inside the valve can deteriorate and/or erode, leading to mechanical or electrical hysteresis in the valve. This hysteresis causes drift in valve performance which can cause incorrect or unexpected gas flow rates to be allowed through the valve responsive to actuation caused by the controller. Deterioration of the valve sealing surfaces can also lead to gas leakage that can worsen over time, further damaging the valve and erroneously introducing gas into a manufacturing process when the gas valve should be closed. Further, the deterioration of traditional gas flow control valves leads to particle generation. The generated particles are carried by the gas flow and can further damage the valve, cause reliability issues in the valve, or damage the downstream manufacturing process and/or associated components, and/or contaminate an in-process substrate. Because traditional gas flow control valves lack internal sensors that can detect valve wear and/or particles, the effects of wear and/or particles in the valve are not sufficiently compensated for in traditional control algorithms. Thus, traditional gas flow control valves may suffer from a lack of precision, especially as the health of internal components deteriorate or wears over time.

Compensating for valve wear and deterioration of performance over time would be advantageous.

[0017] Aspects and implementations of the instant disclosure address the above-described and other shortcomings of conventional gas flow valves by providing a gas flow control valve having one or more sensors, and/or actuators. In some embodiments, a gas flow control valve includes a housing. The housing may have one or more internal passages to receive a flow of gas. The gas may be a process gas such as nitrogen, Argon, etc. The gas may be a corrosive gas, for example a gas used in substrate etching operations. In some embodiments, the flow control valve housing contains

movable mechanical components such as a plunger assembly and one or more sensors to measure one or more metrics associated with the valve. In some embodiments, the housing includes one or more actuators remove particles from the valve by causing one or more valve components to vibrate to dislodge particles. In some embodiments, the housing includes a particle trap to trap particles. In some embodiments, the housing additionally contains one or more sealing surfaces to stop the flow of gas (e.g., when the valve is closed). In some embodiments, the one or more sealing surfaces include an elastomer seal that is contacted by the plunger assembly when the valve is closed (e.g., when the plunger assembly is in a closed position).

[0018] In some embodiments, the plunger assembly (e.g., a plunger) is configured to move between a closed position (e.g., when the valve is closed) and one or more open positions within the housing (e.g., when the valve is opened). While in a closed position, a bottom face of the plunger contacts a sealing surface of the gas flow valve to block the flow of gas through the housing. The plunger can be moved to one or more open positions to allow gas to flow. In some embodiments, an increased distance of the bottom face of the plunger from the sealing surface allows an increased gas flow rate through the valve. In some embodiments, the plunger is caused to move by an actuator, such as an electrical actuator or a pneumatic actuator. In some embodiments, an electromagnetic coil coupled to the housing is energized to move the plunger. In some embodiments, the electromagnetic coil induces an electromagnetic force on the plunger to overcome force of a spring that holds the plunger normally closed or normally open. In some embodiments, a controller causes the plunger to open and close to proportionally control the flow of gas through the valve.

[0019] In some embodiments, a position sensor is configured to measure the position of the plunger. In some embodiments, the position sensor measures the position of the plunger relative to the position sensor. For example, the position sensor may measure the distance between the position sensor and a surface of the plunger. In some embodiments, the position sensor is a capacitive displacement sensor located within the housing. The position sensor may be disposed within the housing above the plunger (e.g., opposite a sealing surface) and may measure the distance between the sensor and the top of the plunger. Sensor data from the position sensor may be sent to a controller. Because the distance between the top of the plunger and the bottom of the plunger (e.g., the length or height of the plunger) is known, the controller can determine the distance between the bottom face of the plunger and the sealing surface of the gas flow control valve. The controller can thus determine how far “open” the valve is based on the position sensor data.

[0020] In some embodiments, a force sensor is coupled to the bottom face of the plunger. In some embodiments, the force sensor can measure the force exerted by the plunger in the closed position on the sealing surface. In some embodiments, the force sensor is a piezoelectric module that outputs an electrical signal corresponding to the sensed force. In some embodiments, the force sensor is bonded to the bottom face of the plunger. The force sensor may contact the sealing surface of the valve when the plunger is in the closed position to stop the flow of gas. In some embodiments, the force sensor can be induced to vibrate by providing an electrical current to the sensor. For example, a piezoelectric module may vibrate when provided with electrical current. In some embodiments, vibration of the force sensor may cause particles on the sealing surface to become dislodged. The dislodged particles may be carried away by the flow of gas. In this case, the force sensor acts as an actuator, which actively cleans the particles from the valve by causing the valve components to vibrate.

[0021] In some embodiments, the health of the sealing surface can be determined (e.g., by the controller) based on the force sensor data and the position sensor data. In some embodiments, the controller can calculate a stress-strain curve of the sealing surface using the force data and the position data. The calculated stress-strain curve can be compared to a stress-strain curve of a sealing surface in good condition. In some embodiments, when the calculated stress-strain curve fails to meet a threshold criterion (e.g., the calculated stress-strain curve substantially differs from

the known good stress-strain curve, etc.), the controller can determine that the sealing surface has deteriorated beyond a threshold condition. In some examples, the controller can determine that an elastomer sealing surface (e.g., an o-ring seal, etc.) has worn or deteriorated when the stress-strain curve calculated using the force data and the position data fails to meet a threshold condition.

[0022] In some embodiments, the controller can determine that the valve is leaking based on the force sensor data. In some examples, a leak between the sealing surface and the plunger will cause the force sensor to sense fluctuations in applied force. The controller may identify these fluctuations in force as a leak. In some embodiments, the controller may cause the plunger to be closed (e.g., actuated to the closed position) with more force to stop the leak.

[0023] In some embodiments, a particle trap is coupled to the outlet of the gas flow valve. The particle trap may have a chamber to induce a cyclonic flow within the chamber. In some embodiments, centrifugal force may cause the particles to move to the outer radius of the chamber and contact the chamber walls. The chamber walls may be rough so that the particles adhere to the chamber walls. In some embodiments, the particles are collected in a removable (e.g., detachable) receptacle which can be periodically removed to dispose of the collected particles. Substantially particle-free gas may flow through a collection tube in the chamber of the particle trap to exit the system.

[0024] Embodiments of the present disclosure provide advantages over conventional systems described above. Particularly, some embodiments described herein provide a gas flow control valve that can be actuated based on sensor data collected from integral sensors. For example, the plunger of a valve described herein can be actuated to open to a target position based on position data received from a position sensor. In another example, the plunger can be more tightly closed based on force data received from a force sensor. In some embodiments described herein, the gas flow control valve can monitor the health of the sealing surface using one or more of the position sensor or the force sensor by comparing a calculated stress-strain curve to a threshold criterion (e.g., known good values) which can be advantageous to avoid unscheduled downtime to replace valve components. In some embodiments described herein, the gas flow valve can detect a leak and perform appropriate operations to remedy the leak such as apply a greater force to close the valve. In some embodiments described herein, the gas flow valve includes a in-situ particle cleaning feature to dislodge particles, making the valve cleaner than conventional gas flow valves. In some embodiments, the gas flow valve includes a particle trap to collect particles in the gas flow, providing cleaner gas with fewer particles as compared to a conventional gas flow valve. In some embodiments, because of the advantages of the gas flow valve described herein, a manufacturing system can more accurately process substrates with fewer errors and less scrap, leading to an overall increase in system throughput. Gas flow control valves described in at least some embodiments herein can provide improved precision, improved repeatability, improved reliability, and/or improved cleanliness as compared to traditional gas flow control valves. For example, gas flow control valves described in some embodiments herein may avoid mechanical and/or electrical hysteresis, may reduce wearing of parts, and/or may reduce contamination accumulation, which may result in one or more of the aforementioned improvements over traditional flow control valves.

[0025] FIG. 1 depicts a system **100** that includes a processing chamber **101**, a gas source **160**, and a flow control apparatus (e.g., gas stick assembly **200**) in accordance with embodiments of the present disclosure. The processing chamber **101** may be used for processes in which a corrosive plasma environment is provided. For example, the processing chamber **101** may be a chamber for a plasma etcher or plasma etch reactor, a plasma cleaner, and so forth. In alternative embodiments, other processing chambers may be used, which may or may not be exposed to a corrosive plasma environment. Some examples of chamber components include a chemical vapor deposition (CVD) chamber, a physical vapor deposition (PVD) chamber, an ALD chamber, an IAD chamber, an etch chamber, and other types of processing chambers. In some embodiments, processing chamber **101**

may be any chamber used in an electronic device manufacturing system.

[0026] In one embodiment, the processing chamber **101** includes a chamber body **102** and a showerhead **130** that encloses an interior volume **106**. The showerhead **130** may include a showerhead base and a showerhead gas distribution plate (GDP), which may have multiple gas delivery holes **132** (also referred to herein as channels) throughout the GDP. Alternatively, the showerhead **130** may be replaced by a lid and a nozzle in some embodiments, or by multiple pie shaped showerhead compartments and plasma generation units in other embodiments. The chamber body **102** may be fabricated from aluminum, stainless steel, or other suitable material such as titanium. The chamber body **102** generally includes sidewalls **108** and a bottom **110**.

[0027] An outer liner **116** may be disposed adjacent the sidewalls **108** to protect the chamber body **102**. The outer liner **116** may be fabricated to include one or more apertures. In one embodiment, the outer liner **116** is fabricated from aluminum oxide.

[0028] An exhaust port **126** may be defined in the chamber body **102**, and may couple the interior volume **106** to a pump system **128**. The pump system **128** may include one or more pumps and throttle valves utilized to evacuate and regulate the pressure of the interior volume **106** of the processing chamber **101**.

[0029] The gas source **160** may be coupled to the processing chamber **101** to provide process and/or cleaning gases via supply line **112** to the interior volume **106** through a showerhead **130**. The flow control apparatus may be coupled to the gas source **160** and processing chamber **101**. The flow control apparatus may be used to measure and control the flow of gas from the gas source **160** to interior volume **106**. An exemplary flow control apparatus is described in greater detail below with respect to FIGS. 2A-2B. In some embodiments, flow control apparatus includes a gas flow valve as described herein. In some embodiments, one or more gas panels **160** may be coupled to processing chamber **101** to provide gases to the interior volume **106**. In such embodiments, one or more flow control systems may be coupled to each gas source **160** and processing chamber **101**. In other embodiments, a single flow control apparatus may be coupled to one or more gas panels **160**. In some embodiments, the flow control apparatus may comprise a flow ratio controller to control the flow of gases to the processing chamber **101** (e.g., through one or more supply lines **112**), or to other processing chambers.

[0030] In some embodiments, a separate flow control apparatus is used for each gas supplied to the processing chamber. In embodiments, each flow control apparatus is or includes a gas stick assembly, as described and illustrated below with respect to FIGS. 2A-2B.

[0031] The showerhead **130** may be supported on the sidewall **108** of the chamber body **102**. The showerhead **130** (or lid) may be opened to allow access to the interior volume **106** of the processing chamber **101**, and may provide a seal for the processing chamber **101** while closed. The gas source **160** may be coupled to the processing chamber **101** to provide process and/or cleaning gases to the interior volume **106** through the showerhead **130** or lid and nozzle (e.g., through apertures of the showerhead or lid and nozzle).

[0032] In some embodiments, one or more sensor assemblies **170** may be disposed within the interior volume **106**. For example, one or more sensor assemblies **170** may be located near (e.g., within 10 centimeters of) the showerhead **130**. As another example, one or more sensor devices may be located near (e.g., within 10 centimeters of) the substrate **144**, which may be used to monitor conditions near the reaction site.

[0033] In one embodiment, the substrate support assembly **148** includes a pedestal **152** that supports an electrostatic chuck **150**. The electrostatic chuck **150** further includes a thermally conductive base and an electrostatic puck bonded to the thermally conductive base by a bond, which may be a silicone bond in one embodiment. The thermally conductive base and/or electrostatic puck of the electrostatic chuck **150** may include one or more optional embedded heating elements, embedded thermal isolators, and/or conduits to control a lateral temperature profile of the substrate support assembly **148**. The electrostatic puck may further include multiple

gas passages such as grooves, mesas, and other surface features that may be formed in an upper surface of the electrostatic puck. The gas passages may be fluidly coupled to a source of a heat transfer (or backside) gas such as helium via holes drilled in the electrostatic puck. In operation, the backside gas may be provided at controlled pressure into the gas passages to enhance the heat transfer between the electrostatic puck and a supported substrate **144**. The electrostatic chuck **150** may include at least one clamping electrode controlled by a chucking power source.

[0034] FIG. 2A illustrates a schematic diagram of a gas stick assembly in accordance with embodiments of the present disclosure. A plurality of gas stick assemblies may receive gasses from a plurality of gas supplies. For example, a processing device may include a different gas stick assembly for each type of gas that is delivered into a process chamber. As shown, gas flows from left to right through the gas stick assembly. In some embodiments, gas stick assembly **200** includes a hybrid valve **201**, which may be a first component of the gas stick assembly **200**. A hybrid valve may include a manual valve and a valve that can be automatically actuated (e.g., a pneumatic valve, electrical valve, etc.). Hybrid valve **201** may receive a gas from a gas source (not illustrated). The hybrid valve **201** may direct the gas to a purge valve **202** via one or more passages. The purge valve **202** may be configured to purge the gas stick assembly **200**. In some embodiments, gas stick assembly **200** includes a regulator **203**. The regulator **203** may receive the gas from the purge valve **202**. The regulator **203** may regulate the flow of the gas through the gas stick assembly **200**. In some embodiments, a filter **204** is coupled downstream of the regulator **203**, and receives the flow of gas from the regulator **203**. In some embodiments, an upstream valve **205** may receive the gas from the regulator **203** and direct the gas flow to a mass flow controller **206**. The mass flow controller **206** may control the flow of gas through the gas stick assembly **200**. In some embodiments, a downstream valve **207** receives the gas from the mass flow controller or other upstream component. The downstream valve **207** may direct the gas toward a gas destination (e.g., a processing chamber; not illustrated). In some embodiments, one or more of the hybrid valve **201**, upstream valve **205**, or downstream valve **207** include one or more integral sensors such as a force sensor and/or a position sensor as described herein. In some embodiments, one or more of the hybrid valve **201**, upstream valve **205**, or downstream valve **207** are actuated based on force sensor data and/or position sensor data as described herein. In some embodiments, one or more of the hybrid valve **201**, upstream valve **205**, or downstream valve **207** include a particle trap configured to trap particles in the gas flow.

[0035] FIG. 2B illustrates a perspective view of a gas stick assembly **200** in accordance with embodiments of the present disclosure. A plurality of gas stick assemblies may receive gasses from a plurality of gas supplies. For example, a processing device may include a different gas stick assembly for each type of gas that is delivered into a process chamber. As shown, gas flows from left to right through the gas stick assembly.

[0036] In some embodiments, gas stick assembly **200** includes a base **209**. Gas stick assembly **200** may receive a gas (e.g., from a gas source) via gas coupling **208**. In some embodiments, gas stick assembly **200** includes hybrid valve **201**, purge valve **202**, regulator **203**, filter **204**, upstream valve **205**, mass flow controller **206**, and/or downstream valve **207**. In some embodiments, each of hybrid valve **201**, purge valve **202**, regulator **203**, filter **204**, upstream valve **205**, mass flow controller **206**, and/or downstream valve **207** are coupled to a gas stick assembly base **209**.

[0037] FIG. 3A illustrates a cutaway side view of a gas flow valve assembly **300A** in accordance with embodiments of the present disclosure. In some embodiments, gas flow valve assembly includes a housing **302** that houses various mechanical components and/or sensor components. In some embodiments, plunger **304** is disposed within housing **302**. Plunger **304** may be ferrous. In some embodiments, plunger **304** is a magnetized iron or steel rod. Housing **302** may include base **312** having one or more internal passages through which a gas can flow. In some embodiments, base **312** is constructed of stainless steel. In some embodiments, base **312** is welded to housing **302**. In some embodiments, gas enters through gas inlet **362** and exits through gas outlet **364**.

When the plunger **304** is in one or more open positions (e.g., as illustrated), gas is allowed to flow past sealing surface **314**. In some embodiments, sealing surface **314** is made up of an elastomer seal, such as an o-ring seal, etc. In some embodiments, an elastomer seal is bonded within a groove formed in base **312**.

[0038] In some embodiments, an electromagnetic coil **308** can induce an electromagnetic force to move the plunger **304** against the force of a spring force. In some embodiments, the electromagnetic coil **308** can be energized with an electric current and/or a voltage. In some embodiments, spring **306** holds the plunger **304** in a normally closed position. In some embodiments, spring **306** holds the plunger **304** in a normally open position. Spring **306** may include one or more springs. In some embodiments, spring **306** is a coil spring that pushes on a top surface of the plunger **304**. In some embodiments, spring **306** is made of a substantially corrosion-resistant metal such as stainless steel.

[0039] In some embodiments, a bellows **310A** is configured to isolate a first interior portion of housing **302** from a second interior portion of housing **302**. In some embodiments, bellows **310A** separates a gas-flow portion of the valve assembly **300A** from a sealed portion of the valve assembly **300A**. In some embodiments, bellows **310A** flexes as plunger **304** moves between a closed position and one or more open positions. For example, the flexing of bellows **310** is illustrated in FIGS. **4A** and **4B**. FIG. **4A** illustrates a cutaway side view of a gas flow valve **400A** in accordance with embodiments of the present disclosure. FIG. **4B** illustrates a cutaway side view of a gas flow valve **400B** in accordance with embodiments of the present disclosure. FIG. **4A** shows plunger **304** in an open position while FIG. **4B** shows plunger **304** in a closed position. In some embodiments, bellows **310A** is in a compressed state when plunger **304** is in an open position as shown in FIG. **4A**. In some embodiments, bellows **310A** is in an extended state when plunger **304** is in a closed position as shown in FIG. **4B**. The flow of gas through the valve may be stopped when the plunger **304** is in the closed position. When in the closed position, the plunger **304** and/or the force sensor **332** form a seal with sealing surface **314** to stop the flow of gas. In some embodiments, bellows **310A** is a metal bellows. Bellows **310A** may be substantially corrosion-resistant. In some embodiments, bellows **310A** may be made from stainless steel. In some embodiments, bellows **310A** is coupled to a portion of housing **302**. In some embodiments, bellows **310A** is welded to the housing **302**.

[0040] Referring to FIG. **3B**, a cutaway side view of a gas flow valve assembly **300B** in accordance with embodiments of the present disclosure is illustrated. In some embodiments, diaphragm **310B** separates the gas-flow portion of the valve assembly **300B** from the sealed portion of the valve assembly **300B**. In some embodiments, diaphragm **310B** flexes as plunger **304** moves between a closed position and one or more open positions. In some embodiments, diaphragm **310B** is a metal diaphragm. Diaphragm **310B** may be substantially corrosion-resistant. In some embodiments, diaphragm **310B** may be made from stainless steel. In some embodiments, diaphragm **310B** is coupled to base **312**. In some embodiments, diaphragm **310B** is coupled between base **312** and housing **302**. In some embodiments, diaphragm **310B** is welded to the housing **302** and/or to the base **312**.

[0041] Referring again to FIG. **3A**, in some embodiments, a position sensor **334** is coupled to the bottom of a cap **303** at the top of the housing **302**. In some embodiments, position sensor **334** is coupled by one or more mechanical fasteners and/or an adhesive or bonding agent. In some embodiments, position sensor **334** is screwed into cap **303**. In some embodiments, position sensor **334** measures the position of plunger **304**. In some embodiments, position sensor **334** is a capacitive displacement sensor. In some embodiments, a capacitive displacement sensor is a non-contact measuring device that can measure the position and/or the change of position of a conductive target. In some embodiments, position data collected by the position sensor **334** is transmitted (e.g., via wires, via wireless communication, etc.) to the controller **340**. In some embodiments, the controller **340** determines the position of the plunger **304** based on the position



data. In some embodiments, the controller **340** causes the plunger to move based on the position data. In some examples, the controller **340** provides an output signal to the electromagnetic coil **308** to cause the plunger **304** to move. The controller may receive position data (e.g., from the position sensor **334**) indicating that the plunger **304** is at a non-target position. The controller may determine a new output signal (e.g., based on the received position data) to the electromagnetic coil to cause the plunger **304** to move to the target position. In some embodiments, the controller **340** can determine the distance between the sealing surface **314** and the bottom surface of the plunger **304** (e.g., the bottom surface of the force sensor **332** coupled to the bottom surface of the plunger **304**). For example, the controller **340** can infer the gap between the bottom surface of the plunger **304** and the sealing surface **314** using the position data and the known height (e.g., length, etc.) of the plunger **304**. The controller **340** can cause the plunger **304** to move (e.g., by providing an output signal to the electromagnetic coil **308**) to increase or decrease the size of the gap.

[0042] In some embodiments, a force sensor **332** is coupled to the bottom of the plunger **304**. In some embodiments, the force sensor **332** is coupled to the second end of the plunger opposite the first end, where the spring **306** applies force to the first end of the plunger **304**. In some embodiments, force sensor **332** is bonded to the bottom of plunger **304** by an epoxy layer **352**. Epoxy layer **352** may be an adhesive layer to bond force sensor **332** to plunger **304**. In some embodiments, force sensor **332** is coupled to plunger **304** by one or more mechanical fasteners. In some embodiments, force sensor **332** is a piezoelectric module. In some embodiments, a piezoelectric module includes one or more crystals configured to convert mechanical energy into electrical energy. In some embodiments, a piezoelectric module is configured to sense applied force.

[0043] In some embodiments, force sensor **332** is configured to measure force applied by the plunger **304**. In some embodiments, force sensor **332** senses the amount of force applied by the plunger **304** onto the sealing surface **314** when the plunger **304** is in the closed position, such as illustrated in FIG. **4B**. In some embodiments, force sensor **332** contacts the sealing surface **314** when plunger **304** is in the closed position to block the flow of gas through the valve. In some embodiments, an electrical signal indicative of the magnitude of the force applied on the sealing surface **314** is sent to the controller **340**. In some embodiments, one or more wires routed through the plunger **304** via a through-hole **305** electrically connect the force sensor **332** with the controller **340**.

[0044] In some embodiments, the controller **340** can determine whether a leak is present at the sealing surface **314** when the plunger **304** is in the closed position. Leaking gas (e.g., through the sealing surface **314** when the plunger **304** is in the closed position) may induce a vibration that is sensed by the force sensor **332**. The vibration may be evidenced by small fluctuations in the applied force sensed by the force sensor **332**. In some embodiments, when the controller **340** determines that gas is leaking, the controller **340** may cause the plunger **304** to increase the force applied to the sealing surface. The controller **340** may cause a signal to be sent to the electromagnetic coil **308** to cause the plunger to apply a greater force on the sealing surface **314** either by increasing the current and/or voltage applied to the electromagnetic coil **308** or by decreasing the current and/or voltage applied to the electromagnetic coil **308** so that the plunger (e.g., via the force sensor **332**) applies an increased force to the sealing surface **314**.

[0045] In some embodiments, the controller **340** can determine the health of the sealing surface **314** using force data from the force sensor **332** and position data from the position sensor **334**. In some embodiments, the controller **340** calculates a stress-strain curve of the sealing surface **314**. In some examples, the controller **340** can sense displacement (e.g., strain) of the sealing surface **314** as the applied force (e.g., stress) is increased on the sealing surface **314** as the plunger **304** is moved to the closed position. The controller **340** may correspond the strain indicated by position data (e.g., from the position sensor **334**) with the stress indicated by force data (e.g., from force sensor **332**) to calculate a stress-strain curve. In some embodiments, the controller **340** compares the calculated

stress-strain curve with a known healthy stress-strain curve for the sealing surface **314**. The known healthy stress-strain curve may correspond to the stress-strain curve of the sealing surface **314** in good condition such as when new or unused. The known healthy stress-strain curve may be associated with a threshold criterion for comparing the calculated stress-strain curve. As the sealing surface **314** deteriorates over time and/or with use, the stress-strain curve may drift and/or change. In some embodiments, the controller **340** may determine the health of the sealing surface **314** based on the drift and/or change in the stress-strain curve. In some embodiments, the controller may determine that the sealing surface **314** is in an unhealthy state responsive to determining that the calculated stress-strain curve has exceeded a threshold condition. The controller **340** may output a notification (e.g., to a technician, etc.) that the sealing surface **314** should be serviced or replaced when the sealing surface is in an unhealthy condition.

[0046] In some embodiments, the controller **340** can determine the health of the spring **306** using force data from the force sensor **332**. In some embodiments, spring **306** provides the force to move the plunger **304** to the closed position. Spring force (e.g., from spring **306**) may hold the plunger **304** closed to stop the flow of gas. The force sensor **332** may sense the spring force applied by the spring **306** to hold the plunger **304** in the closed position. As the spring **306** wears with use, the spring force applied by the spring **306** may decrease over time. The force data may indicate the decrease in spring force. In some embodiments, the controller **340** can determine the condition of the spring **306** based on the force data indicative of the spring force. The controller **340** may determine that the spring **306** is in an unhealthy condition when the force indicated by the force data (e.g., from the force sensor **332**) falls below a threshold value. In some embodiments, the controller **340** may output a notification that the spring **306** should be serviced or replaced when the spring is in an unhealthy condition.

[0047] In some embodiments, the controller **340** can initiate a self-cleaning procedure to dislodge particles from the sealing surface **314**. In some embodiments, the controller can send a command (e.g., an electronic signal) to induce vibration in the force sensor **332** to dislodge particles from the sealing surface **314**. For example, where the force sensor **332** is a piezoelectric module, the controller can send an electrical signal to the piezoelectric module to excite the piezoelectric crystals and induce vibration. The vibration may cause particles which have collected on the sealing surface **314** to become dislodged. The flow of gas through the valve may carry the dislodged particles away from the sealing surface **314**. In some embodiments, to cause the particles to become dislodged, the plunger **304** is opened so that the force sensor **332** contacts the sealing surface **314** but does not create a seal to stop the flow of gas. Vibration induced in the force sensor **332** may dislodge particles and flowing gas may carry the dislodged particles away.

[0048] In some embodiments, particle trap **320** is coupled to base **312**. In some embodiments, particle-laden gas flows into the particle trap **320** through an inlet and into a separator module **322**. Particles may be separated from the flowing gas and collected in a detachable receptacle **324**. Substantially particle-free gas may flow up through collection tube **326** and out through gas outlet **364**. In some embodiments, a cyclone or vortex is induced in the gas flow within separator module **322**. In some embodiments, the cyclonic flow is induced in the separator module **322** by introducing the gas flow tangentially into the module. The cyclonic flow in the gas flow may cause particles to be forced to the walls of the separator module **322** due to centrifugal force. In some embodiments, the walls of the separator module **322** are rough so that particles adhere to the walls. In some embodiments, particles move down the walls of the separator module **322** and fall into the detachable receptacle **324**. The detachable receptacle **324** may be configured to be periodically removed for cleaning. In some embodiments, the detachable receptacle **324** can be detached from the separator module **322** so that the detachable receptacle **324** can be emptied of collected particles. In some embodiments, detachable receptacle **324** is coupled to the separator module **322** by one or more mechanical fasteners. In some embodiments, a seal, such as an o-ring seal, seals the interface between the separator module **322** and the detachable receptacle **324**. In some

embodiments, separator module **322** is coupled to an upper portion of particle trap **320** by one or more mechanical fasteners. In some embodiments, a seal (e.g., an o-ring seal, an elastomer seal, etc.) seals the interface between the separator module **322** and the upper portion of the particle trap **320**. In some embodiments, the upper portion of the particle trap **320** couples the particle trap **320** to the base **312**. In some embodiments, the separator module **322**, the detachable receptacle **324**, the upper portion of the particle trap **320**, and/or the collection tube **326** are made of a substantially corrosion-free metal such as stainless steel.

[0049] FIGS. **5A-5B** are flow diagrams of methods of controlling a gas flow valve in accordance with embodiments of the present disclosure. FIG. **5A** is a flow diagram of a method **500A** for controlling a gas flow valve such as gas flow valve assemblies **300A**, **300B** or flow valves **400A** or **400B** in accordance with embodiments of the present disclosure. In some embodiments, method **500A** is performed and/or caused to be performed by processing logic that includes hardware (e.g., circuitry, dedicated logic, programmable logic, microcode, processing device, etc.), software (such as instructions run on a processing device, a general purpose computer system, or a dedicated machine), firmware, microcode, or a combination thereof. In some embodiments, method **500A** is performed, at least in part, by a controller a gas flow valve assembly (e.g., controller **340**).

[0050] For simplicity of explanation, method **500A** is depicted and described as a series of operations. However, operations in accordance with this disclosure can occur in various orders and/or concurrently and with other operations not presented and described herein. Furthermore, in some embodiments, not all illustrated operations are performed to implement method **500A** in accordance with the disclosed subject matter. In addition, those skilled in the art will understand and appreciate that method **500A** could alternatively be represented as a series of interrelated states via a state diagram or events.

[0051] In some embodiments, at block **502**, processing logic receives position data from a position sensor. The position sensor may be configured to measure a distance associated with a difference in position of a gas flow valve plunger configured to move between a closed position and one or more open positions. In some embodiments, the position sensor is a capacitive displacement sensor. In some embodiments, position data is indicative of the position of the plunger relative to the sensor.

[0052] In some embodiments, at block **504**, processing logic receives force data from a force sensor. In some embodiments, the force sensor is coupled to the plunger. The force sensor may measure a force exerted by the plunger in the closed position on a sealing surface. In some embodiments, the force sensor is a piezoelectric module that outputs an electrical signal responsive to sensing an applied force.

[0053] In some embodiments, at block **506**, processing logic causes the plunger to actuate between the closed position and the one or more open positions based on one or more of the position data or the force data. In some embodiments, the processing logic causes the plunger to open to a more open position or a less open position based on the position data. In some embodiments, the processing logic causes the plunger to close based on the position data indicating the plunger is in an open position. In some embodiments, the processing logic causes the plunger to exert a greater force on the sealing surface responsive to the force data indicating a gas leak or an insufficient sealing force.

[0054] FIG. **5B** is a flow diagram of a method **500B** for controlling a gas flow valve such as gas flow valve assemblies **300A**, **300B** or flow valves **400A** or **400B** in accordance with embodiments of the present disclosure. In some embodiments, method **500B** is performed and/or caused to be performed by processing logic that includes hardware (e.g., circuitry, dedicated logic, programmable logic, microcode, processing device, etc.), software (such as instructions run on a processing device, a general purpose computer system, or a dedicated machine), firmware, microcode, or a combination thereof. In some embodiments, method **500B** is performed, at least in part, by a controller a gas flow valve assembly (e.g., controller **340**).

[0055] For simplicity of explanation, method **500B** is depicted and described as a series of

operations. However, operations in accordance with this disclosure can occur in various orders and/or concurrently and with other operations not presented and described herein. Furthermore, in some embodiments, not all illustrated operations are performed to implement method **500B** in accordance with the disclosed subject matter. In addition, those skilled in the art will understand and appreciate that method **500B** could alternatively be represented as a series of interrelated states via a state diagram or events.

[0056] In some embodiments, at block **512**, processing logic causes a gas valve plunger to substantially actuate to a target position responsive to receiving position data indicating the plunger is disposed at a non-target position. In some embodiments, processing logic determines (e.g., based on position data received at block **502**) that the plunger position does not match the target plunger position. The processing logic may cause the plunger to be actuated so that the plunger position substantially matches the target plunger position.

[0057] In some embodiments, at block **514**, processing logic causes the plunger to increase force exerted on the sealing surface responsive to receiving force data indicating a gas leak. In some embodiments, processing logic determines (e.g., based on force data received at block **504**) that gas is leaking past the sealing surface. The processing logic may determine that a leak exists based on force data that reflects fluctuations in applied force of the plunger on the sealing surface.

Processing logic may cause the plunger to exert more force on the sealing surface to stop the leak.

[0058] In some embodiments, at block **516**, processing logic determines a condition of an elastomer seal on a sealing surface based on a stress-strain curve calculated using position data and force data. In some embodiments, processing logic calculates the stress-strain curve using position data and/or force data receiving from the position sensor and/or the force sensor when the plunger is actuated to the closed position. In some embodiments, processing logic compares the calculated stress-strain curve with a baseline stress-strain curve (e.g., a known healthy stress-strain curve, a threshold criterion, etc.) to determine the condition of the elastomer seal. In some embodiments, processing logic outputs a notification (e.g., to a technician), indicative of the condition of the elastomer seal. The notification may be output responsive to the calculated stress-strain curve failed to meet a threshold criterion.

[0059] In some embodiments, at block **518**, processing logic causes a piezoelectric module to vibrate to dislodge particles from the sealing surface. In some embodiments, the piezoelectric module is the force sensor. In some embodiments, the vibration of the piezoelectric module causes particles to be dislodged from the sealing surface. The dislodged particles may be carried away by the flow of gas. The piezoelectric module may be caused to vibrate when the force data and/or the position data indicate to the processing logic that excess particles are on the sealing surface.

Dislodged particles may be collected in a particle trap.

[0060] FIG. **6** illustrates a diagrammatic representation of a machine in the exemplary form of a computer system **600** within which a set of instructions (e.g., for causing the machine to perform any one or more of the methodologies discussed herein) may be executed. In alternative implementations, the machine may be connected (e.g., networked) to other machines in a LAN, a WAN, an intranet, an extranet, or the Internet. The machine may operate in the capacity of a server or a client machine in client-server network environment, or as a peer machine in a peer-to-peer (or distributed) network environment. The machine may be a personal computer (PC), a tablet PC, a PDA, a cellular telephone, a web appliance, a server, a network router, switch or bridge, or any machine capable of executing a set of instructions (sequentially or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term “machine” shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein. Some or all of the components of the computer system **600** may be utilized by or illustrative of any of the electronic components described herein.

[0061] The exemplary computer system **600** includes a processing device (processor) **602**, a main

memory **604** (e.g., ROM, flash memory, dynamic random access memory (DRAM) such as synchronous DRAM (SDRAM) or Rambus DRAM (RDRAM), etc.), a static memory **606** (e.g., flash memory, static random access memory (SRAM), etc.), and a data storage device **620**, which communicate with each other via a bus **610**.

[0062] Processor **602** represents one or more general-purpose processing devices such as a microprocessor, central processing unit, or the like. More particularly, the processor **602** may be a complex instruction set computing (CISC) microprocessor, reduced instruction set computing (RISC) microprocessor, very long instruction word (VLIW) microprocessor, or a processor implementing other instruction sets or processors implementing a combination of instruction sets. The processor **602** may also be one or more special-purpose processing devices such as an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a digital signal processor (DSP), network processor, or the like. The processor **602** is configured to execute instructions **640** for performing the operations discussed herein.

[0063] The computer system **600** may further include a network interface device **608**. The computer system **600** also may include a video display unit **612** (e.g., a liquid crystal display (LCD), a cathode ray tube (CRT), or a touch screen), an alphanumeric input device **614** (e.g., a keyboard), a cursor control device **616** (e.g., a mouse), and a signal generation device **622** (e.g., a speaker).

[0064] Power device **618** may monitor a power level of a battery used to power the computer system **600** or one or more of its components. The power device **618** may provide one or more interfaces to provide an indication of a power level, a time window remaining prior to shutdown of computer system **600** or one or more of its components, a power consumption rate, an indicator of whether computer system is utilizing an external power source or battery power, and other power related information. In some implementations, indications related to the power device **618** may be accessible remotely (e.g., accessible to a remote back-up management module via a network connection). In some implementations, a battery utilized by the power device **618** may be an uninterruptable power supply (UPS) local to or remote from computer system **600**. In such implementations, the power device **618** may provide information about a power level of the UPS.

[0065] The data storage device **620** may include a computer-readable storage medium **624** (e.g., a non-transitory computer-readable storage medium) on which is stored one or more sets of instructions **640** (e.g., software) embodying any one or more of the methodologies or functions described herein. These instructions **640** may also reside, completely or at least partially, within the main memory **604** and/or within the processor **602** during execution thereof by the computer system **600**, the main memory **604**, and the processor **602** also constituting computer-readable storage media. The instructions **640** may further be transmitted or received over a network **630** via the network interface device **608**. While the computer-readable storage medium **624** is shown in an exemplary implementation to be a single medium, it is to be understood that the computer-readable storage medium **624** may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions **640**.

[0066] In the foregoing description, numerous details are set forth. It will be apparent, however, to one of ordinary skill in the art having the benefit of this disclosure, that the present disclosure may be practiced without these specific details. While specific embodiments have been described herein, it should be understood that they have been presented by way of example only, and not limitation. The breadth and scope of the present application should not be limited by any of the embodiments described herein, but should be defined only in accordance with the following and later-submitted claims and their equivalents. Indeed, other various implementations of and modifications to the present disclosure, in addition to those described herein, will be apparent to those of ordinary skill in the art from the foregoing description and accompanying drawings. Thus, such other implementations and modifications are intended to fall within the scope of the present

disclosure.

[0067] References were made to the accompanying drawings, which form a part of the description and in which are shown, by way of illustration, specific embodiments. Although these disclosed embodiments are described in sufficient detail to enable one skilled in the art to practice the embodiments, it is to be understood that these examples are not limiting, such that other embodiments may be used and changes may be made to the disclosed embodiments without departing from their spirit and scope. For example, the blocks of the methods shown and described herein are not necessarily performed in the order indicated in some other embodiments. Additionally, in some other embodiments, the disclosed methods may include more or fewer blocks than are described. As another example, some blocks described herein as separate blocks may be combined in some other embodiments. Conversely, what may be described herein as a single block may be implemented in multiple blocks in some other embodiments. Additionally, the conjunction “or” is intended herein in the inclusive sense where appropriate unless otherwise indicated; that is, the phrase “A, B, or C” is intended to include the possibilities of “A,” “B,” “C,” “A and B,” “B and C,” “A and C,” and “A, B, and C.”

[0068] The words “example” or “exemplary” are used herein to mean serving as an example, instance, or illustration. Any aspect or design described herein as an “example” or “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects or designs. Rather, use of the words “example” or “exemplary” is intended to present concepts in a concrete fashion. When the term “about” or “approximately” is used herein, this is intended to mean that the nominal value presented is precise within  $\pm 10\%$ .

[0069] In addition, the articles “a” and “an” as used herein and in the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form. Reference throughout this specification to “an embodiment,” “one embodiment,” “some embodiments,” or “certain embodiments” indicates that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrase “an embodiment,” “one embodiment,” “some embodiments,” or “certain embodiments” in various locations throughout this specification are not necessarily all referring to the same embodiment.

[0070] Some portions of the detailed description may be presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the manner used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is herein, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, or otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

[0071] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as “receiving,” “retrieving,” “transmitting,” “computing,” “generating,” “processing,” “reprocessing,” “adding,” “subtracting,” “multiplying,” “dividing,” “optimizing,” “calibrating,” “detecting,” “performing,” “analyzing,” “determining,” “enabling,” “identifying,” “modifying,” “transforming,” “applying,” “causing,” “storing,” “comparing,” or the like, refer to the actions and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (e.g., electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers

or other such information storage, transmission, or display devices.

[0072] Furthermore, although the present disclosure has been described herein in the context of a particular implementation in a particular environment for a particular purpose, those of ordinary skill in the art will recognize that its usefulness is not limited thereto and that the present disclosure may be beneficially implemented in any number of environments for any number of purposes. Accordingly, the claims set forth below should be construed in view of the full breadth and spirit of the present disclosure as described herein, along with the full scope of equivalents to which such claims are entitled.

## Claims

1. A gas flow valve, comprising: a plunger configured to move between a closed position and one or more open positions within a housing; and a force sensor configured to measure a force exerted by the plunger in the closed position and further configured to induce vibration responsive to being energized to dislodge particles from one or more surfaces of the gas flow valve.
2. The gas flow valve of claim 1, further comprising: a particle trap forming a chamber configured to separate particles from the flow of gas, wherein at least a portion of the particle trap is configured to be removed for cleaning.
3. The gas flow valve of claim 2, wherein the particle trap is configured to induce a cyclone in the flow of gas within the chamber to separate the particles from the flow of gas.
4. The gas flow valve of claim 1, wherein the force sensor is configured to contact a seal when the plunger is in the closed position.
5. The gas flow valve of claim 1, further comprising: a spring within the housing configured to hold the plunger in the closed position or in an open position of the one or more open positions; and an actuator configured to actuate the plunger between the closed position and at least one of the one or more open positions.
6. The gas flow valve of claim 1, further comprising: a barrier configured to isolate a first portion of the housing from a second portion of the housing, wherein the plunger is disposed in the first portion of the housing and gas is to flow through the second portion of the housing.
7. The gas flow valve of claim 1, wherein the force sensor is a piezoelectric module.
8. The gas flow valve of claim 1, further comprising: a position sensor configured to measure the position of the plunger.
9. A gas flow assembly, comprising: a valve comprising: a plunger configured to move between a closed position and one or more open positions within a housing; and a force sensor configured to measure a force exerted by the plunger in the closed position and further configured to induce vibration responsive to being energized to dislodge particles from one or more surfaces of the valve; a particle trap forming a chamber configured to separate particles from the flow of gas; and a processing device configured to cause the valve to actuate to control the flow of gas based on sensor data from at least the force sensor.
10. The gas flow assembly of claim 9, wherein the particle trap is configured to induce a cyclone in the flow of gas within the chamber to separate the particles from the flow of gas.
11. The gas flow assembly of claim 9, wherein the force sensor is configured to contact a seal when the plunger is in the closed position.
12. The gas flow assembly of claim 9, wherein the valve further comprises: a barrier configured to isolate a first portion of the housing from a second portion of the housing, wherein the plunger is disposed in the first portion of the housing and gas is to flow through the second portion of the housing.
13. The gas flow assembly of claim 9, wherein the force sensor is a piezoelectric module.
14. The gas flow assembly of claim 9, further comprising: a position sensor configured to measure the position of the plunger.

- 15.** The gas flow assembly of claim 14, wherein the processing device is further configured to cause the plunger to actuate based on position sensor data.
- 16.** The gas flow assembly of claim 9, wherein the processing device is further configured to cause the plunger to increase force exerted based on force data from the force sensor indicating a gas leak.
- 17.** The gas flow assembly of claim 14, wherein the processing device is further configured to determine a condition of a seal based on sensor data received from the position sensor and from the force sensor.
- 18.** The gas flow assembly of claim 9, wherein the processing device is further configured to prepare a notification of one or more of a gas leak or a condition of a seal based on sensor data received from at least the force sensor.
- 19.** A method, comprising: receiving force data from a force sensor associated with a plunger of a gas valve and configured to measure a force exerted by the plunger in a closed position; causing the plunger to actuate between the closed position and one or more open positions based at least in part on the force data; and causing the force sensor to vibrate to dislodge particles from one or more surfaces of the valve. **20** The method of claim **19**, further comprising: receiving position data from a position sensor configured to measure the position of the plunger; and causing the plunger to substantially actuate based on the position data.
-