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(54) **GAS PRESSURE MONITOR FOR PNEUMATIC SURGICAL MACHINE**

GASDRUCKMONITOR FÜR EINE PNEUMATISCHE CHIRURGISCHE MASCHINE

SYSTÈME DE MESURE DE LA PRESSION D'UN GAZ DESTINÉ À UN DISPOSITIF CHIRURGICAL PNEUMATIQUE

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Description

Field of the Invention

[0001] The present invention relates to a pneumatic module for a surgical machine and more particularly to a safety filter monitor for such a module.

Background of the Invention

[0002] Several conditions of the eye threaten sight. Epiretinal membrane (ERM), also known as macular pucker and cellophane retinopathy, is a condition characterized by growth of a membrane across the macula, or central retina of the eye. This condition may be thought of as the growth of scar tissue across the macula, thus interfering with central vision. The ERM typically contracts, causing distortion of the central retina, thus producing distortion of vision. Most patients will note that either straight objects appear wavy and crooked and/or central vision is reduced, depending on the severity of the condition.

[0003] Epiretinal membranes may be associated with other conditions of the eye, however, the large majority are idiopathic, which means that the cause is unknown. Some of the disorders which are occasionally associated with ERM's include previous retinal detachments and surgery thereof, inflammatory conditions (uveitis), retinal tears, and branch retinal vein occlusion (BRVO) and central retinal vein occlusion (CRVO). Another condition is a macular hole. A macular hole is almost always a spontaneous development that occurs predominantly in aging women. The development of a macular hole progresses through several stages, and with each progressive stage the vision may worsen. It has been postulated that shrinkage of the vitreous humor may produce traction on the fovea (central macula), thereby producing the hole itself. However, the cause of macular holes remains under investigation.

[0004] The retina, which lines the inside of the posterior wall of the eye, may occasionally become detached for various reasons. Most commonly, retinal detachment occurs as a result of a tear or hole in the retina, which develops as a result of a posterior vitreous separation (PVS). The retinal tear or hole allows fluid to enter the subretinal space, thus detaching the retina.

[0005] The retina receives oxygen and nutrients from the underlying choroid (vascular layer) of the eye. When a retinal detachment occurs, the detached retina begins to dysfunction, and ultimately, necrosis (death) ensues as a result if the retina is not reattached to the underlying choroid. As such, a retinal detachment is an urgent condition. The detached retina should be recognized and treated promptly.

[0006] Vitreo-retinal procedures may be appropriate to treat these and other serious conditions of the back of the eye. Vitreo-retinal procedures include a variety of surgical procedures performed to restore, preserve, and enhance vision. Vitreo-retinal procedures treat conditions such as age-related macular degeneration (AMD), diabetic retinopathy and diabetic vitreous hemorrhage, macular hole, retinal detachment, epiretinal membrane, CMV retinitis, and many other ophthalmic conditions.

[0007] The vitreous is a normally clear, gel-like substance that fills the center of the eye. It makes up approximately 2/3 of the eye's volume, giving it form and shape before birth. Certain problems affecting the back of the eye may require a vitrectomy, or surgical removal of the vitreous.

[0008] A vitrectomy may be performed to clear blood and debris from the eye, to remove scar tissue, or to alleviate traction on the retina. Blood, inflammatory cells, debris, and scar tissue obscure light as it passes through the eye to the retina, resulting in blurred vision. The vitreous is also removed if it is pulling or tugging the retina from its normal position. Some of the most common eye conditions that require vitrectomy include complications from diabetic retinopathy such as retinal detachment or bleeding, macular hole, retinal detachment, pre- retinal membrane fibrosis, bleeding inside the eye (vitreous hemorrhage), injury or infection, and certain problems related to previous eye surgery.

[0009] The retinal surgeon performs a vitrectomy with a microscope and special lenses designed to provide a clear image of the back of the eye. Several tiny incisions just a few millimeters in length are made on the sclera. The retinal surgeon inserts microsurgical instruments through the incisions such as a fiber optic light source to illuminate inside the eye, an infusion line to maintain the eye's shape during surgery, and instruments to cut and remove the vitreous.

[0010] In a vitrectomy, the surgeon creates three tiny incisions in the eye for three separate instruments. These incisions are placed in the pars plana of the eye, which is located just behind the iris but in front of the retina. The instruments which pass through these incisions include a light pipe, an infusion port, and the vitrectomy cutting device. The light pipe is the equivalent of a microscopic high- intensity flashlight for use within the eye. The infusion port is required to replace fluid in the eye and maintain proper pressure within the eye. The vitrector, or cutting device, works like a tiny guillotine, with an oscillating microscopic cutter to remove the vitreous gel in a slow and controlled fashion. This prevents significant traction on the retina during the removal of the vitreous humor.

[0011] The surgical machine used to perform a vitrectomy and other surgeries on the posterior of the eye are very complex. Typically, such an ophthalmic surgical machine includes a main console to which numerous different tools are attached. The main console provides power to and controls the operation of the attached tools.

[0012] The attached tools typically include probes, scissors, forceps, illuminators, and infusion lines. Each of these tools is typically attached to the main surgical console. A computer in the main surgical console monitors and controls the operation of these tools. These tools also get their power from the main surgical console. Some of these tools are electrically powered while others are pneumatically powered.

[0013] In order to provide pneumatic power to the various tools, the main surgical console has a pneumatic or air distribution module. This pneumatic module conditions and supplies compressed air or gas to power the tools. Typically, the pneumatic module is connected to a cylinder that contains compressed gas.

[0014] Most commonly, surgeons use cylinders of nitrogen at 3600 psi. The condition and output of these cylinders affect the operation of the surgical machine.

[0015] The proper gas pressure must be provided by the pneumatic module to the tools in order to insure their proper operation. Providing too low or too high a gas pressure can lead to safety problems. Too low a gas pressure can lead to underperformance or non-performance of the operation of a tool. Too high a pressure can damage equipment or lead to a malfunction during surgery. In either case, the safety of the patient is compromised.

[0016] It would be desirable to incorporate a gas pressure monitor in an ophthalmic surgical machine to protect the patient.

[0017] US-5,417,246-A (Perkins) and US-5,239,861 are representative of the state of the art.

Summary of the Invention

[0018] The present invention provides a gas pressure monitor system for a pneumatically- powered surgical machine, and a method for monitoring gas pressure in a pneumatic module of a surgical machine, in accordance with claims which follow. The system includes a first transducer, a second transducer, and a controller. The first transducer is located upstream from a filter and is configured to read a first pressure of a gas before the gas enters the filter. The second transducer is located downstream from the filter and is configured to read a second pressure of a gas after the gas exits the filter. The controller is configured to compute a difference between the first pressure and the second pressure. A state of the filter is determined from the difference between the first pressure and the second pressure.

[0019] In another embodiment consistent with the principles of the present invention, the present invention is a gas pressure monitor system for a pneumatically-powered surgical machine. The system includes a first transducer, a second transducer, a coupling, an isolation valve, a pressure release valve, and four manifolds. The first transducer is located upstream from a filter and is configured to read a first pressure of a gas before the gas enters the filter. The second transducer is located downstream from the filter and is configured to read a second pressure of a gas after the gas exits the filter. The coupling is configured to accept gas from a gas source. The isolation valve is located between the first transducer and the filter. The pressure relief valve is located between the coupling and the first transducer. The first manifold fluidly connects the first transducer to the isolation valve. The second manifold fluidly connects the isolation valve to the filter. The third manifold fluidly connects the filter to the second transducer. The fourth manifold fluidly connects the coupling and the pressure relief valve to the first transducer.

[0020] In another embodiment consistent with the principles of the present invention, the present invention is a gas pressure monitor system for a pneumatic module. The system includes a first transducer, a second transducer, a coupling, an isolation valve, a pressure release valve, logic, and four manifolds. The first transducer is located upstream from a filter and is configured to read a first pressure of a gas before the gas enters the filter. The second transducer is located downstream from the filter and is configured to read a second pressure of a gas after the gas exits the filter. The coupling is configured to accept gas from a gas source. The isolation valve is located between the first transducer and the filter. The pressure relief valve is located between the coupling and the first transducer. The first manifold fluidly connects the first transducer to the isolation valve. The second manifold fluidly connects the isolation valve to the filter. The third manifold fluidly connects the filter to the second transducer. The fourth manifold fluidly connects the coupling and the pressure relief valve to the first transducer. The logic is configured to compute a difference between the first pressure reading and the second pressure reading. When the difference between the first pressure reading and the second pressure reading is greater than a second amount, an indication that the filter needs service is provided. When the first pressure reading is greater than a first amount, the pressure release valve is opened and the isolation valve is closed. When the second pressure is less than a third amount, the isolation valve is closed.

[0021] In another embodiment consistent with the principles of the present invention, the present invention is a method for monitoring gas pressure in a pneumatic module of a surgical machine. The method includes sensing a first pressure of a gas upstream from a filter and sensing a second pressure of a gas downstream from the filter. If the first pressure is greater than a first amount, a pressure relief valve is opened, and an indication of high gas pressure is provided. If the second pressure is less than a second amount, an indication of low gas pressure is provided.

[0022] In another embodiment consistent with the principles of the present invention, the present invention is a method for monitoring the state of a filter in a pneumatic module of a surgical machine. The method includes sensing a first pressure of a gas upstream from a filter, sensing a second pressure of a gas downstream from the filter, computing a difference between the first pressure and the second pressure, and comparing the difference to a value to determine a state of the filter.

[0023] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are intended to provide further explanation of the invention as claimed. The following description, as well as the practice of the invention, set forth and suggest additional advantages and purposes of the invention.

Brief Description of the Drawings

[0024] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments of the invention and together with the description, serve to explain the principles of the invention.

Figure 1 is a block diagram of a pneumatically-powered ophthalmic surgery machine according to an embodiment of the present invention.

Figure 2 is a schematic of a gas pressure monitor system for a pneumatically powered surgical machine according to an embodiment of the present invention.

Figure 3 is a flow chart of one method of operation according to an embodiment of the present invention.

Figure 4 is a flow chart of one method of operation according to an embodiment of the present invention.

Detailed Description of the Preferred Embodiments

[0025] Reference is now made in detail to the exemplary embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used throughout the drawings to refer to the same or like parts.

[0026] Figure 1 is a block diagram of a pneumatically powered ophthalmic surgical machine according to an embodiment of the present invention. In Figure 1, the machine includes gas pressure monitor system 110, proportional controller 120, proportional controller 130, and tools 140, 150, 160, and 170. The tools 140, 150, 160, and 170 can be, for example, scissors, vitrectomy probes, forceps, and injection or extraction modules. Other tools may also be employed with the machine of Figure 1.

[0027] As shown in Figure 1, gas pressure monitor system 110 is fluidly coupled via a manifold to proportional controller 120 and proportional controller 130. A single manifold may connect gas pressure monitor system 110 to proportional controller 120 and proportional controller 130, or two separate manifolds may connect gas pressure monitor system 110 to proportional controller 120 and proportional controller 130, respectively. Proportional controller 120 is fluidly coupled to tools 140 and 150 by, for example, a manifold and tubing. Likewise proportional controller 130 is fluidly coupled to tools 160 and 170, by, for example, a manifold and tubing.

[0028] In operation, the pneumatically powered ophthalmic surgery machine of Figure 1 operates to assist a surgeon in performing various ophthalmic surgical procedures, such as a vitrectomy. A compressed gas, such as nitrogen, provides the power for tools 140,150, 160, and 170. The compressed gas passes through gas pressure monitor system 110, through one or more manifolds to proportional controllers 120 and 130, and through additional manifolds and/or tubing to tools 140, 150, 160, and 170.

[0029] Gas pressure monitor system 110 functions to monitor the pressure of compressed gas from a gas source as it enters the machine. As further discussed below, gas pressure monitor system acts to ensure the safety of the operation of the machine.

[0030] Proportional controllers 120 and 130 serve to distribute the compressed gas received from gas pressure monitor system 110. Proportional controllers 120 and 130 control the pneumatic power delivered to tools 140, 150, 160, and 170.

[0031] Tools 140, 150, 160, and 170 are all pneumatically powered. In such a case, compressed gas powers the operation of these tools. Various valves, manifolds, and tubing are used to direct compressed gas from gas pressure monitor system 110, through proportional controllers 120 and 130, and into tools 140, 150,160, and 170. This compressed gas actuates cylinders, for example, in tools 140, 150, 160, and 170.

[0032] Figure 2 is a schematic of a gas pressure monitor system for a pneumatically powered surgical machine according to an embodiment of the present invention. In Figure 2, the gas pressure monitor system includes a gas source 205, coupling 210, manifold 215, pressure release valve 220, first transducer 225, second transducer 230, isolation valve 235, filter 240, manifold 245, controller 250, manifold 255, interface 260, manifold 265, interface 270, and interface 275. While all of these components are depicted in Figure 2 as being of part of gas pressure monitor system 110, a subset of these components may comprise gas pressure monitor system 110 as described in the appended claims.

[0033] In the embodiment of Figure 2, gas source 205 is fluidly coupled through coupling 210 to manifold 215. Manifold 215 fluidly couples pressure release valve 220, coupling 210, and first transducer 225. In this manner, a single manifold connects gas source 205 to first transducer to 225 and pressure release valve 220.

[0034] First transducer 225 is fluidly coupled to isolation valve 235 via manifold 245. Isolation valve 235 is fluidly coupled to filter 240 via manifold 255. Filter 240 is fluidly coupled to second transducer 230 via manifold 265.

[0035] Controller 250 receives signals from first transducer 225 via interface 260 and from second transducer 230 via interface 270. In this manner, first transducer 225 is electrically coupled to controller 250 via interface 260. Second transducer 230 is electrically coupled to controller 250 via interface 270. Interface 275 is an output of controller 250. In this example, interface 275 carries output signals from controller 250 to other components of gas pressure monitor system 110 such as isolation valve 235 and pressure release valve 220.

[0036] The gas pressure monitor system 110 of Figure 2 includes gas source 205. Gas source 205 is typically a bottle or cylinder of compressed gas. In many cases, surgeons utilize cylinders of compressed nitrogen. In other cases, surgeons utilize a source of compressed air. In either case, gas source 205 is a source of compressed gas that provides the pneumatic power for the pneumatically powered ophthalmic surgery machine.

[0037] Coupling 210 is an input port that receives compressed gas from gas source 205. In most cases, coupling 210 is a standard connector on a manifold designed to connect to tubing from gas source 205. Coupling 210 allows compressed gas from gas source 205 to enter gas pressure monitor system 110 and provide pneumatic power to the machine.

[0038] Pressure release valve 220 is a valve configured to open if the pressure in manifold 215 is too high. In this manner, pressure release valve 220 operates to release compressed gas from manifold 215 if the pressure of that compressed gas exceeds a certain threshold. In many cases, pressure release valve 220 has a set point that can be adjusted. For example, pressure release valve 220 may have a user adjustable set point. In such a case, an engineer may be able to set the set point at 200 lbs per square inch (psi), and pressure release valve 220 opens when the pressure of the compressed gas in manifold 215 exceeds 200 psi. In other embodiments consistent with the present invention, pressure release valve 220 is controlled by controller 250. In such a case, controller 250 maybe able to send electrical signals via interface 275 to controller pressure release valve 220.

[0039] In the embodiment of Figure 2, isolation valve 235 is a standard two way valve. In this case, isolation valve 235 has two positions - on and off. When isolation valve 235 is turned on, gas is allowed to flow from manifold 245 to manifold 255. When isolation valve 235 is turned off, gas is not allowed to flow from manifold 245 to manifold 255. In the embodiment of Figure 2, isolation valve 235 is depicted as being turned off. Isolation valve 235 maybe controlled by controller 250. In this manner, controller 250 sends signals via interface 275 to isolation valve 235 to control its operation. For example, controller 250 may send a signal via interface 275 to isolation valve 235 to turn it to an on position.

[0040] In the embodiment of Figure 2, filter 240 serves to filter compressed gas passing from manifold 255 to manifold 265. Filter 240 also acts as a water separator. In this manner, filter 240 serves to filter objects from the compressed gas as it passes from manifold 255 to manifold 265. Filter 240 also serves to remove water from the compressed gas as it passes from manifold 255 to manifold 265. In the embodiment of Figure 2, filter 240 filters the compressed gas before it enters the remainder of the machine.

[0041] First transducer 225 and second transducer 230 operate to read an atmospheric pressure of the gas contained in manifold 215 and manifold 265 respectfully. In this manner, first transducer 225 reads the pressure of the compressed gas after it exits gas source 205, enters coupling 210, and enters manifold 215. Likewise, second transducer 230 reads the pressure of the compressed gas as it exits filter 240 and enters manifold 265. In other words, first transducer 225 reads the pressure of the compressed gas that is located in the manifold adjacent to first transducer 225. Likewise, second transducer 230 reads the pressure of the compressed gas that is adjacent to it in manifold 265.

[0042] In the embodiment of Figure 2, first transducer 225 and second transducer 230 are common pressure transducers. First transducer 225 and second transducer 230 are capable of reading pressure of a compressed gas and sending an electrical signal containing information about the pressure of the compressed gas to controller 250. First transducer 225 sends a signal corresponding to the pressure of the compressed gas that it reads via interface 260. Likewise, second transducer 230 sends a signal about the pressure of the compressed gas via interface 270 to controller 250.

[0043] Controller 250 is typically an intergraded circuit capable of performing logic functions. Controller 250 is typically in the form of a standard intergraded circuit package with power, input, and output pins. In various embodiments, controller 250 is a valve controller or a targeted device controller. In such a case, controller 250 performs specific control functions targeted to a specific device, such as a valve. For an example, a valve controller has the basic functionality to control a valve. In other embodiments, controller 250 is a microprocessor. In such a case, controller 250 is programmable so that it can function to control valves in gas pressure monitor system 110 as well as other components of the machine. In other cases, controller 250 is not a programmable microprocessor, but instead is a special purpose controller configured to control different valves that perform different functions.

[0044] Controller 250 is configured to receive signals from first transducer 225 via interface 260 and from second transducer 230 via interface 270. These signals, for example, correspond to readings of gas pressure in manifold 215 and manifold 265, respectively. Controller 250 is also configured to send output signals via interface 275. As noted, these output signals from controller 250 are typically sent to valves, such as isolation valve 235, via interface 275.

[0045] Manifolds 215, 245, 255, 265 are all configured to carry compressed gas. In the embodiment of Figure 2, these manifolds are machined out of a metal, such as aluminum. These manifolds are air tight, contain various fittings and couplings, and are designed to withstand relatively high gas pressures. These manifolds maybe manufactured as individual pieces or they maybe manufactured as a single piece. For example, manifold 215 and manifold 245 maybe a single continuous manifold. In this manner, manifold 215 and manifold 245 are machined from a single piece of aluminum. In such a case, one end of manifold 215 and manifold 245 is designed to house coupling 210,another end is designed to house pressure release valve 220, another end is designed to accommodate isolation valve 235, and another end is designed to accommodate first transducer 225.

[0046] Interface 260 and interface 270 are designed to carry signals from first transducer 225 and second transducer 230 to controller 250. In this case, interface 260 and interface 270 are common electrical conductors such as wires. Likewise, interface 275 carries signals from controller 250 to isolation valve 235, for example. Interface 275 maybe one or more wires or buses designed to carry electrical or data signals.

[0047] The gas pressure monitor system 110 of Figure 2 provides compressed gas to the remainder of a surgical machine. In operation, compressed gas from gas source 205 passes through coupling 210 and into manifolds 215 and 245. First transducer 225 reads the pressure of the compressed gas in manifolds 215 and 245. Compressed gas is also allowed to travel from manifolds 215 to the input of pressure release valve 220. As depicted in Figure 2, pressure release valve 220 is turned off. Therefore, the pressure of compressed gas is allowed to maintain itself in manifolds 215 and 245. Isolation valve 235 is also turned off.

[0048] First transducer 225 reads the pressure of the compressed gas in manifold 215 and 245. If the pressure of the compressed gas is too great, pressure release valve 220 opens and allows the compressed gas to vent to the atmosphere. If the pressure of the compressed gas in manifolds 215 and 245 is too low, then isolation valve 235 remains in the closed or off position. In this manner, first transducer 225 reads a pressure of the compressed gas after it enters gas pressure monitor system 110. If the pressure is too high, pressure release valve 220 is opened. If the pressure is too low, isolation valve 235 remains closed to prevent the low pressure gas from entering the remainder of the system. If the pressure of the compressed gas is within an acceptable range, then isolation valve 235 is opened and the compressed gas is allowed to pass into manifold 255, through filter 240, and into manifold 265.

[0049] When the compressed gas enters manifold 265, second transducer 230 measures the pressure of that gas. First transducer 225 measures the pressure of the compressed gas in manifolds 215 and 245 and sends a signal corresponding to this pressure via interface 260 to controller 250. Likewise, second transducer 230 measures the pressure of the compressed gas in manifold 265 (after it has passed through filter 240) and sends a signal corresponding to this pressure via interface 270 to controller 250. Controller 250 compares the pressure read by first transducer 225 to the pressure read by second transducer 230. For example, controller 250 may calculate a difference between the pressure read by second transducer 230 and the pressure read by first transducer 225. This difference corresponds to a pressure drop across filter 240.

[0050] In some cases, as filter 240 wears, it becomes less efficient at transferring compressed gas. In such a case, the pressure read by the first transducer 225 is higher than the pressure read by second transducer 230. This means that a pressure drop has occurred across filter 240. As filter 240 becomes more worn or more dirty, the pressure of the compressed gas in manifold 265 as read by second transducer 230 may drop to a level that is too low to safely operate the machine. In such a case, filter 240 needs to be replaced or serviced. In this manner, first transducer 225 and second transducer 230 serve to monitor a state of filter 240. If the state of filter 240 is such that it needs to be serviced or replaced, then controller 250 may provide an indication in the form of illuminating a light emitting diode on a surgical console to indicate that filter 240 needs to be replaced or serviced. In addition, if the pressure read by second transducer 230 falls below a safe level, then controller 250 may turn isolation valve 235 off.

[0051] The gas pressure monitor system 110 of Figure 2 implements various safety features in the ophthalmic surgery machine of Figure 1. The first of these features is to cause high pressure compressed gas to be vented via pressure release valve 220 so that it does not damage the rest of the surgical machine. In addition, venting high pressure compressed gas via pressure release valve 220 helps to prevent injury to the patient. In this case, if compressed gas with too high of pressure were allowed to enter the remainder of the surgical machine, the tools 140, 150, 160, and 170 may malfunction and injure a patient. In addition, the high pressure compressed gas may damage various components of the surgical machine. Therefore, if controller 250 receives a signal indicating that the pressure of the compressed gas in manifolds 215 and 245 is above a safe level, then controller 250 opens pressure release valve 220. Alternatively, pressure release valve 220 may be set at a set point equal to the upper limit of a safe range of pressure for compressed gas. In such a case, if the pressure of the compressed gas in manifold 215 exceeds the set point, pressure release valve 220 opens.

[0052] The gas pressure monitor system 110 of Figure 2 also prevents the introduction of compressed gas with too low a pressure into the remainder of the surgical machine. In this case, first transducer 225 senses that the compressed gas in manifold or manifold 245 is at too low a pressure. First transducer 225 sends a signal via interface 260 to controller 250 indicating such. Controller 250 receives this signal and causes isolation valve 235 to remain closed. In this manner, compressed gas in manifold 245 is not allowed to pass into manifold 255 and the remainder of the machine. If the pressure of the compressed gas is too low, then the surgical machine may not operate properly. For example, if the pressure of the compressed gas is too low, then the pneumatic power provided to tools 140, 150, 160, and 170 may not be sufficient to safely operate them. In such a case, the unsafe operation of these tools may injure the patient.

[0053] The gas pressure monitor system 110 of Figure 2 also allow for the constant monitoring of the state of filter 240. In this case, first transducer 225 and second transducer 230 act in tandem to monitor the condition of filter 240. If filter 240 were to become clogged, for example, then the surgical machine may not be operated safely. In such a case, controller 250 receives signals from first transducer 225 and second transducer 230 indicating this unsafe condition. In addition, first transducer 225 and second transducer 230 can constantly monitor the condition of filter 240 to ensure that it is operating properly. In such a case, controller 250 may provide an indication that filter 240 may need to be repaired or replaced. Typically, a pressure reading by second transducer 230 of the compressed gas in manifold 265 (after it has passed through filter 240) provides an indication of the state of the filter 240. In one case, second transducer 230 may determine that the pressure of the compressed gas in manifold 265 is below a safe level. In such a case, controller 250 may close or turn off the isolation valve 235. This prevents the low pressure compressed gas from entering the remainder of the machine and causing unsafe operation.

[0054] Figure 3 is a flow chart of one method of operation according to an embodiment of the present invention. In Figure 3, a first pressure of a gas upstream from a filter is sensed in 305. In 310, a second pressure of a gas downstream from the filter is sensed. In 315 a determination is made as to whether the first pressure is greater than a first amount. In 315, if the first pressure is greater than a first amount, then in 320, a pressure relief valve is opened. In 330 an indication of high gas pressure is provided. If the first pressure is not greater than a first amount in 315, then in 335 a determination is made as to whether the second pressure is less than the second amount. An indication of low gas pressure is provided in 345. If the second pressure is not less than a second amount in 335, then an isolation valve is opened in 350. After the isolation valve is opened in 350, the process returns to 305 and a first pressure of a gas upstream from a filter is sensed.

[0055] In the embodiment of Figure 3, the gas pressure monitor system 110 senses a first gas pressure on one side of a filter and a second gas pressure on the other side of the filter. If the first gas pressure upstream from the filter is greater than a safe amount, then the pressure release valve is open to vent the high pressure gas. If the second pressure reading, corresponding to the gas pressure downstream from the filter is less than a safe amount, then the isolation valve remains in the closed position thus preventing the low pressure gas from reaching the remainder of the system and possibly causing an unsafe condition. In the embodiment of Figure 3, gas pressure monitor system serves to ensure that the pressure of the compressed gas entering of the ophthalmic surgical machine is within a safe range.

[0056] Figure 4 is a flow chart of another method of operation according to an embodiment of the present invention. In 405, a first pressure of a gas upstream from a filter is sensed. In 410, a second pressure of a gas downstream from the filter is sensed. In 415, the difference between the first pressure and the second pressure is computed. In 420, a determination is made as to the pressure drop across the filter. In 420, if the pressure drop across the filter is acceptable, then in 425 an isolation valve is opened. In 430, a determination is made as to whether the filter needs service. For example, this determination can be based on the difference between the first pressure and the second pressure computed in 415. If the filter needs service in 430, then in 435 an indication that the filter needs service is provided. In 430, if the filter does not need service, then the process returns to 405, and a first pressure of a gas upstream from a filter is sensed.

[0057] In 420, if the pressure drop across the filter is not acceptable, then in 445, an indication of low gas pressure is provided. In 450, and indication that the filter needs service is provided.

[0058] In the embodiment of Figure 4, the first pressure reading and the second pressure reading are used to determine a state of the filter. In addition, these pressure readings also determine an unsafe condition for the surgical machine. The difference between the first pressure (upstream from the filter) and the second pressure (downstream from the filter) corresponds to a pressure drop across the filter. If the pressure drop across the filter is too great, this indicates that the filter needs to be replaced or serviced. In one case, if the filter is clogged, then the pressure drop across the filter can be very great leading to an unsafe operation of the machine. The gas pressure monitor system 110 of the present invention thus ensure the safe operation of the machine and also ensures that a patient will not be harmed by the operation of the machine with an unsafe gas pressure.

[0059] From the above, it may be appreciated that the present invention provides an improved system and methods for monitoring the gas pressure in a pneumatic module of a surgical machine. The present invention provides safety features designed to protect the patient and the surgical machine from harm due to high or low gas pressure. In addition, the present invention provides a system for monitoring a filter component of the pneumatic module. The present invention is illustrated herein by example, and various modifications may be made by a person of ordinary skill in the art.

[0060] Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope of the invention being indicated by the following claims.

Claims

1. A gas pressure monitor system (110) for a pneumatically-powered surgical machine comprising:

a first transducer (225) located upstream from a filter (240), the first transducer configured to read a first pressure of a gas before the gas enters the filter;
a second transducer (230) located downstream from the filter, the second transducer configured to read a second pressure of a gas after the gas exits the filter;
an isolation valve (235) located upstream of the filter;
a controller (250) configured to compute a difference between the first pressure and the second pressure;
wherein the controller is configured to determine a state of the filter (240) from the difference between the first pressure and the second pressure;
wherein the controller is configured to close the isolation valve unless:

a) the first pressure is within a safe range of pressures and
b) the difference between the first pressure and the second pressure is less than a determined amount or the second pressure is greater than a predetermined threshold.

2. The system of claim 1, wherein when the difference between the first pressure and the second pressure is greater than a predetermined amount, an indication is provided that the filter (240) needs service.

3. The system of claim 2,
wherein the isolation valve (235) is located upstream from the first transducer (225), and the isolation valve is fluidly coupled to the first transducer via a manifold (245).

4. The system of claim 2, wherein the indication that the filter (240) needs service is provided by illuminating a light emitting diode.

5. The system of claim 1, wherein a useful life of the filter (240) is calculated using the difference between the first pressure and the second pressure.

6. The system of claim 1, further comprising:

a coupling (210) configured to accept gas from a gas source (205);
a pressure relief valve (220) located between the coupling (210) and the first transducer (225);
a first manifold (245) fluidly connecting the first transducer (225) to the isolation valve (235);
a second manifold (255) fluidly connecting isolation valve (235) to the filter (240);
a third manifold (265) fluidly connecting the filter (240) to the second transducer (230);
a fourth manifold (215) fluidly connecting the coupling (210) and the pressure relief valve (220) to the first transducer (225); and
logic configured to compute a difference between the first pressure reading and the second pressure reading;
wherein when the difference between the first pressure reading and the second pressure reading is greater than a second predetermined amount, an indication that the filter (240) needs service is provided, when the first pressure reading is greater than a first predetermined amount, the pressure release valve (220) is opened and the isolation valve (235) is closed, and when the second pressure reading is less than a third predetermined amount, the isolation valve is closed.

7. A method of monitoring gas pressure in a pneumatic module of a surgical machine comprising:

sensing (305) a first pressure of a gas upstream from a filter;
sensing (310) a second pressure of a gas downstream from the filter;
if (315) the first pressure is greater than a first predetermined amount, opening (320) a pressure relief valve and providing (330) an indication of high gas pressure; and
if (335) the second pressure is less than a second predetermined, amount, providing (345) an indication of low gas pressure;
opening (350) an isolation valve upstream from the filter only when:

c) the first pressure is within a safe range of pressures and
d) the difference between the first pressure and the second pressure is less than a determined amount or the second pressure is greater than a predetermined threshold.

8. A method for monitoring the state of a filter in a pneumatic module of a surgical machine comprising:

sensing (405) a first pressure of a gas upstream from a filter;
sensing (410) a second pressure of a gas downstream from the filter;
computing (415) a difference between the first pressure and the second pressure; and
comparing (420) the difference to a value to determine a state of the filter,

opening (350) an isolation valve upstream from the filter only when:

a) the first pressure is within a safe range of pressures and
b) the difference between the first pressure and the second pressure is less than a determined amount or the second pressure is greater than a predetermined threshold.

9. The method of claim 8, further comprising using the difference between the first pressure and the second pressure to determine if the filter needs service.

10. The method of claim 9, further comprising providing an indication that the filter needs service (435,450).

11. The method of claim 8, further comprising determining if an unacceptable pressure drop exists across the filter; and
keeping an isolation valve in a closed position if an unacceptable pressure drop exists across the filter.

12. The method of claim 9, further comprising determining if a pressure drop across the filter is acceptable; and
opening an isolation valve (425) if the pressure drop across the filter is acceptable.

Patentansprüche

1. Gasdruck-Überwachungssystem (110) für eine pneumatisch angetriebene chirurgische Maschine, mit:

einem ersten Messwertgeber (225), der sich stromaufwärts eines Filters (240) befindet,
wobei der erste Messwertgeber dazu konfiguriert ist, einen ersten Druck eines Gases zu erfassen, bevor das Gas in den Filter eintritt;
einem zweiten Messwertgeber (230), der sich stromabwärts des Filters befindet, wobei der zweite Messwertgeber dazu konfiguriert ist, einen zweiten Druck eines Gases zu erfassen, nachdem das Gas aus dem Filter ausgetreten ist;
einem vor dem Filter angeordneten Absperrventil;
einer Steuerung (250), die zum Berechnen einer Differenz zwischen dem ersten und
dem zweiten Druck konfiguriert ist;
wobei die Steuerung so konfiguriert ist, dass sie einen Zustand des Filters (240) aus der Differenz zwischen dem ersten und dem zweiten Druck bestimmt;
wobei die Steuerung zum Schließen des Absperrventils konfiguriert ist, sofern nicht:

a) der erste Druck innerhalb eines sicheren Druckbereichs liegt, und
b) die Differenz zwischen dem ersten und dem zweiten Druck kleiner ist als ein vorgegebener Wert, oder der zweite Druck höher ist als ein vorgegebener Schwellenwert.

2. System nach Anspruch 1, bei dem dann, wenn die Differenz zwischen dem ersten und dem zweiten Druck größer ist als ein vorgegebener Wert, eine Anzeige bereitgestellt wird, dass das Filter (240) einer Wartung bedarf.

3. System nach Anspruch 2, bei dem das Absperrventil (235) vor dem ersten Messwertgeber (225) angeordnet ist und das Absperrventil über eine Verteilerleitung (245) fluidisch mit dem ersten Messwertgeber gekoppelt ist.

4. System nach Anspruch 2, bei dem die Anzeige, dass das Filter (240) einer Wartung bedarf, durch Leuchten einer Leuchtdiode bereitgestellt wird.

5. System nach Anspruch 1, bei dem die nutzbare Lebensdauer des Filters (240) anhand der Differenz zwischen dem ersten und dem zweiten Druck berechnet wird.

6. System nach Anspruch 1, ferner aufweisend:

eine Kupplung (210), die zur Aufnahme von Gas aus einer Gasquelle (205) konfiguriert ist;
ein Überdruckventil (220), das zwischen der Kupplung (210) und dem ersten Messwertgeber (225) angeordnet ist;
eine erste Verteilerleitung (245), die den ersten Messwertgeber (225) mit dem Absperrventil (235) fluidisch verbindet;
eine zweite Verteilerleitung (255), die das Absperrventil (235) mit dem Filter (240) fluidisch verbindet;
eine dritte Verteilerleitung (265), die das Filter (240) mit dem zweiten Messwertgeber (230) fluidisch verbindet;
eine vierte Verteilerleitung (215), die die Kupplung (210) und das Überdruckventil (220) mit dem ersten Messwertgeber (225) fluidisch verbindet; und
eine Logik, die zum Berechnen einer Differenz zwischen dem ersten Druckwert und dem zweiten Druckwert konfiguriert ist;
wobei dann, wenn die Differenz zwischen dem ersten und dem zweiten Druckwert größer ist als ein zweiter vorgegebener Wert, eine Anzeige bereitgestellt wird, dass der Filter (240) einer Wartung bedarf, und wenn der erste Druckwert höher ist als ein erster vorgegebener Wert, das Überdruckventil (220) geöffnet und das Ab-

sperrventil (235) geschlossen wird, und das Absperrventil geschlossen wird, wenn der zweite Druckwert kleiner ist als ein dritter vorgegebener Wert.

7. Verfahren zum Überwachen des Gasdrucks in einem pneumatischen Modul einer chirurgischen Maschine, mit:

Erfassen (305) eines ersten Drucks eines Gases stromaufwärts eines Filters;
Erfassen (310) eines zweiten Drucks eines Gases stromabwärts des Filters;
Öffnen (320) eines Überdruckventils und Bereitstellen (330) einer Anzeige für zu hohen Gasdruck, wenn (315) der erste Druck höher ist als ein erster vorgegebener Wert; und
Bereitstellen (345) einer Anzeige für zu niedrigen Gasdruck, wenn (335) der zweite Druck niedriger ist als ein zweiter vorgegebener Wert;
Öffnen (350) eines Absperrventils vor dem Filter nur dann, wenn:

c) der erste Druck innerhalb eines sicheren Druckbereichs liegt, und
d) die Differenz zwischen dem ersten und dem zweiten Druck kleiner ist als ein vorgegebener Wert, oder der zweite Druck höher ist als ein vorgegebener Schwellenwert.

8. Verfahren zum Überwachen des Zustands eines Filters in einem pneumatischen Modul einer chirurgischen Maschine, aufweisend:

Erfassen (405) eines ersten Drucks eines Gases stromaufwärts eines Filters;
Erfassen (410) eines zweiten Drucks eines Gases stromabwärts des Filters;
Berechnen (415) einer Differenz zwischen dem ersten und dem zweiten Druck; und
Vergleichen (420) der Differenz mit einem Wert, um den Zustand des Filters zu bestimmen;
Öffnen (350) eines Absperrventils vor dem Filter nur dann, wenn:

a) der erste Druck innerhalb eines sicheren Druckbereichs liegt, und
b) die Differenz zwischen dem ersten und dem zweiten Druck kleiner ist als ein vorgegebener Wert, oder der zweite Druck höher ist als ein vorgegebener Schwellenwert.

9. Verfahren nach Anspruch 8, das ferner das Verwenden der Differenz zwischen dem ersten und dem zweiten Druck zum Bestimmen, ob der Filter einer Wartung bedarf, aufweist.

10. Verfahren nach Anspruch 9, das ferner das Bereitstellen einer Anzeige aufweist, wonach der Filter einer Wartung bedarf (435, 450).

11. Verfahren nach Anspruch 8, das ferner die Bestimmung aufweist, ob ein unzulässiger Druckabfall über das Filter vorliegt; und
bei dem ein Absperrventil in einer geschlossenen Position gehalten wird, wenn ein unzulässiger Druckabfall über dem Filter vorliegt.

12. Verfahren nach Anspruch 9, das ferner die Bestimmung aufweist, ob ein Druckabfall über dem Filter zulässig ist; und
bei dem ein Absperrventil (425) geöffnet wird, wenn der Druckabfall über dem Filter zulässig ist.

Revendications

1. Système de surveillance de pression de gaz (110) pour un dispositif chirurgical pneumatique comprenant :

un premier transducteur (225) situé en amont d'un filtre (240), le premier transducteur étant configuré pour lire une première pression d'un gaz avant que le gaz ne pénètre dans le filtre ;
un second transducteur (230) situé en aval du filtre, le second transducteur étant configuré pour lire une seconde pression d'un gaz après que le gaz soit sorti du filtre,
une vanne d'isolement (235) située en amont du filtre ;
un système de commande (250) configuré pour calculer une différence entre la première pression et la seconde pression ;
dans lequel le système de commande est configuré pour déterminer un état du filtre (240) à partir de la différence entre la première pression et la seconde pression ;
dans lequel le système de commande est configuré pour fermer la vanne d'isolement à moins que :

a) la première pression soit comprise dans une plage de pressions non dangereuse et
b) la différence entre la première pression et la seconde pression est inférieure à une quantité déterminée ou la seconde pression est supérieure à un seuil prédéterminé.

2. Système selon la revendication 1, dans lequel, lorsque la différence entre la première pression et la seconde pression est supérieure à une quantité prédéterminée, une indication est fournie selon laquelle le filtre (240) nécessite un entretien.

3. Système selon la revendication 2, dans lequel la vanne d'isolement (235) est située en amont du premier transducteur (225), et la vanne d'isolement est fluidiquement couplée au premier transducteur par l'intermédiaire d'un collecteur (245).

4. Système selon la revendication 2, dans lequel l'indication selon laquelle le filtre (240) nécessite un entretien est fournie par l'allumage d'une diode électroluminescente.

5. Système selon la revendication 1, dans lequel une vie utile du filtre (240) est calculée en utilisant la différence entre la première pression et la seconde pression.

6. Système selon la revendication 1, comprenant en outre :

un couplage (210) configuré pour accepter du gaz provenant d'une source de gaz (205) ;
une vanne de décharge de pression (220) située entre le couplage (210) et le premier transducteur (225) ;
un premier collecteur (245) reliant fluidiquement le premier transducteur (225) à la vanne d'isolement (205) ;
un deuxième collecteur (255) reliant fluidiquement la vanne d'isolement (235) au filtre (240) ;
un troisième collecteur (265) reliant fluidiquement le filtre (240) au second transducteur (230) ;
un quatrième collecteur (215) reliant fluidiquement le couplage (210) et la vanne de décharge de pression (220) au premier transducteur (225) ; et
un circuit logique configuré pour calculer une différence entre la première lecture de pression et la seconde lecture de pression ;
dans lequel, lorsque la différence entre la première lecture de pression et la seconde lecture de pression est supérieure à un deuxième montant prédéterminé, une indication selon laquelle le filtre (240) nécessite un entretien est fournie, lorsque la première lecture de pression est supérieure à une première quantité prédéterminée, la vanne de décharge de pression (201) est ouverte et la vanne d'isolement (135) est fermée, et lorsque la seconde lecture de pression est inférieure à une troisième quantité prédéterminée, la vanne d'isolement est fermée.

7. Procédé de surveillance de pression de gaz dans un module pneumatique d'un dispositif chirurgical comprenant les étapes consistant à :

détecter (305) une première pression d'un courant de gaz en amont d'un filtre ;
détecter (310) une seconde pression d'un courant de gaz en aval du filtre ;
si (315) la première pression est supérieure à une première quantité prédéterminée, ouvrir (320) une vanne de décharge de pression et fournir (330) une indication de pression de gaz élevée ; et
si (335) la seconde pression est inférieure à une deuxième quantité prédéterminée, fournir (335) une indication de pression de gaz faible ;
ouvrir (350) une vanne d'isolement en amont du filtre seulement lorsque :

c) la première pression est comprise dans une plage de pressions non dangereuse et
d) la différence entre la première pression et la seconde pression est inférieure à une quantité déterminée ou la seconde pression est supérieure à un seuil prédéterminé.

8. Procédé de surveillance de l'état d'un filtre dans un module pneumatique d'un dispositif chirurgical comprenant les étapes consistant à :

détecter (405) une première pression d'un courant de gaz en amont d'un filtre ;
détecter (410) une seconde pression d'un gaz en aval du filtre ;
calculer (415) une différence entre la première pression et la seconde pression ; et
comparer (420) la différence par rapport à une valeur pour déterminer un état du filtre,
ouvrir (350) une vanne d'isolement en amont du filtre seulement lorsque :

a) la première pression est comprise dans une plage de pressions non dangereuse et
b) la différence entre la première pression et la seconde pression est inférieure à une quantité déterminée ou la seconde pression est supérieure à un seuil prédéterminé.

9. Procédé selon la revendication 8, comprenant en outre l'étape consistant à utiliser la différence entre la première pression et la seconde pression pour déterminer si le filtre nécessite un entretien.

10. Procédé selon la revendication 9, comprenant en outre l'étape consistant à fournir (435, 450) une indication selon laquelle le filtre nécessite un entretien.

11. Procédé selon la revendication 8, comprenant en outre l'étape consistant à déterminer si une chute inacceptable de pression se produit dans le filtre ; et l'étape consistant à conserver une vanne d'isolement dans une position fermée si une chute inacceptable de pression se produit dans le filtre.

12. Procédé selon la revendication 9, comprenant en outre l'étape consistant à déterminer si une chute de pression dans le filtre est acceptable ; et l'étape consistant à ouvrir une vanne d'isolement (425) si la chute de pression dans le filtre est acceptable.

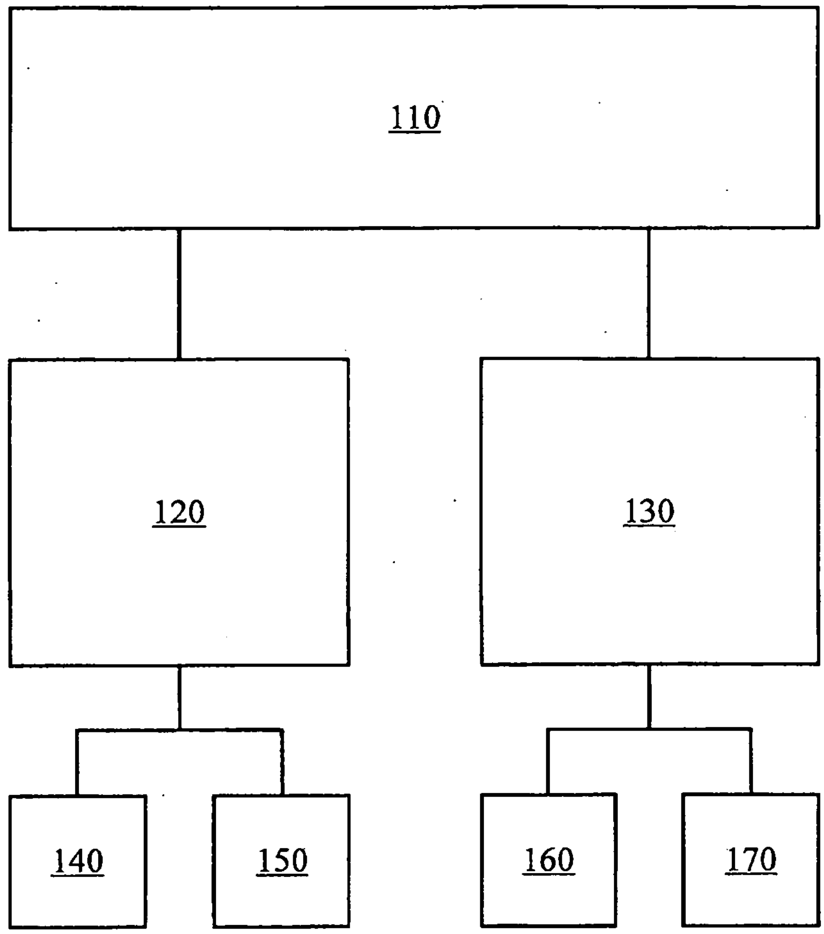


Fig. 1

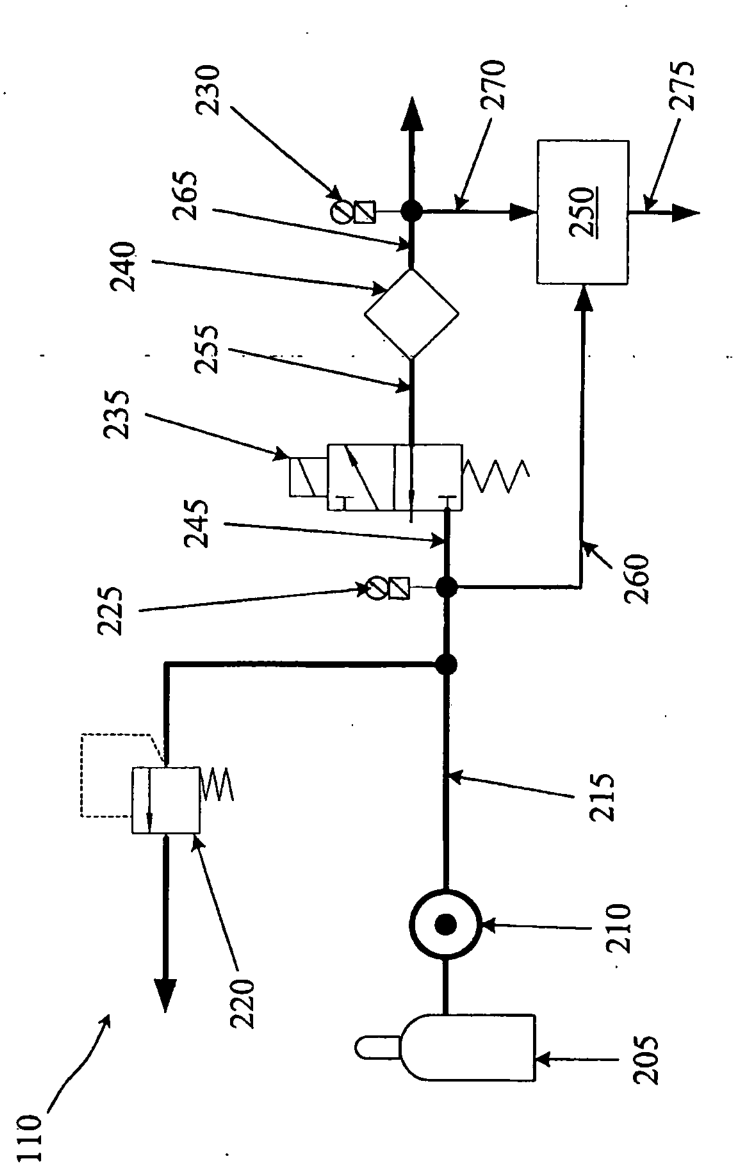
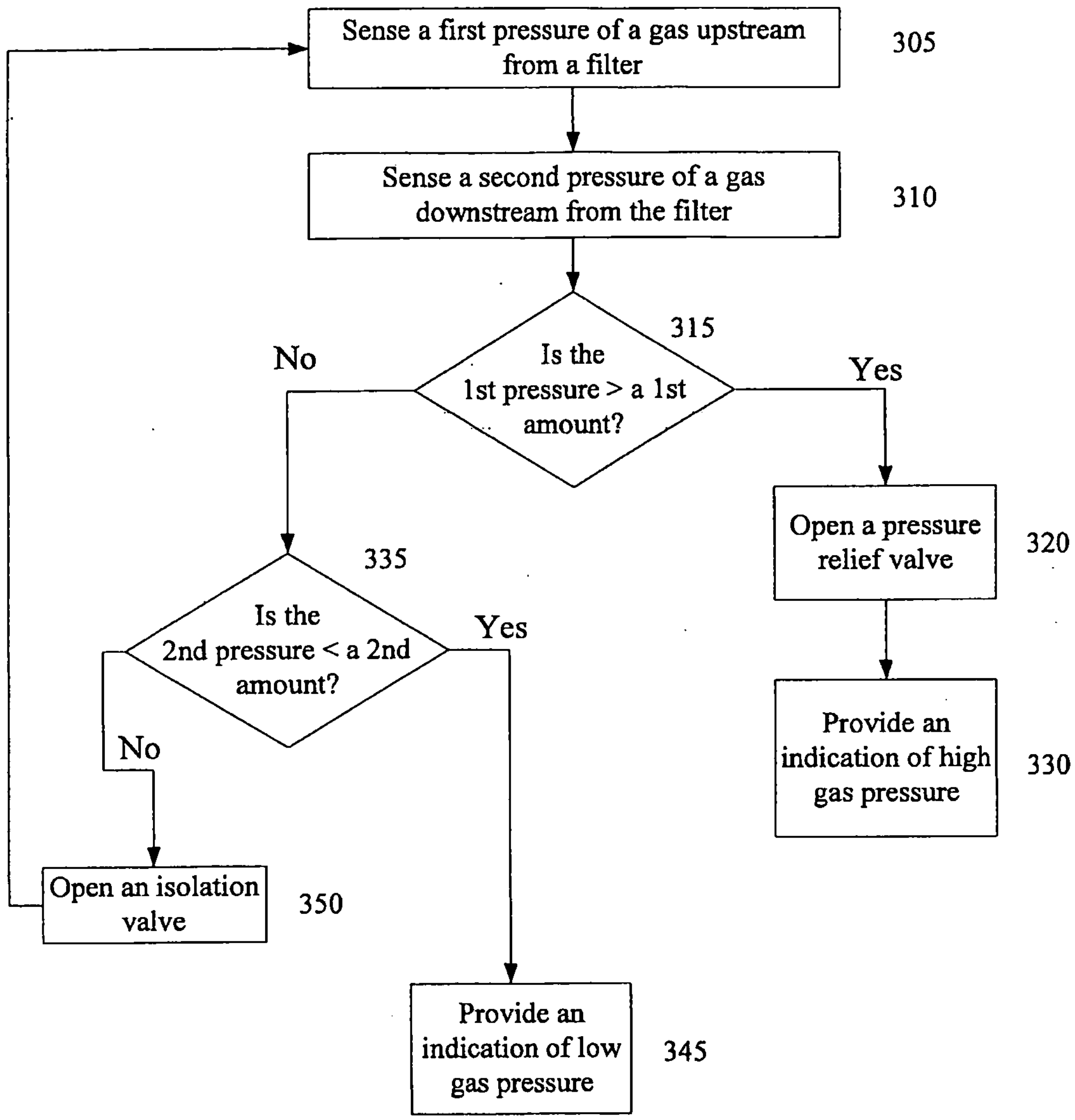


Fig. 2



Sense a first pressure of a gas upstream from a filter
305
Sense a second pressure of a gas downstream from the filter
310
Is the 1st pressure > a 1st amount?
315
No
Yes
Open a pressure relief valve
320
Provide an indication of high gas pressure
330
Is the 2nd pressure < a 2nd amount?
335
Yes
No
Open an isolation valve
350
Provide an indication of low gas pressure
345

Fig. 3

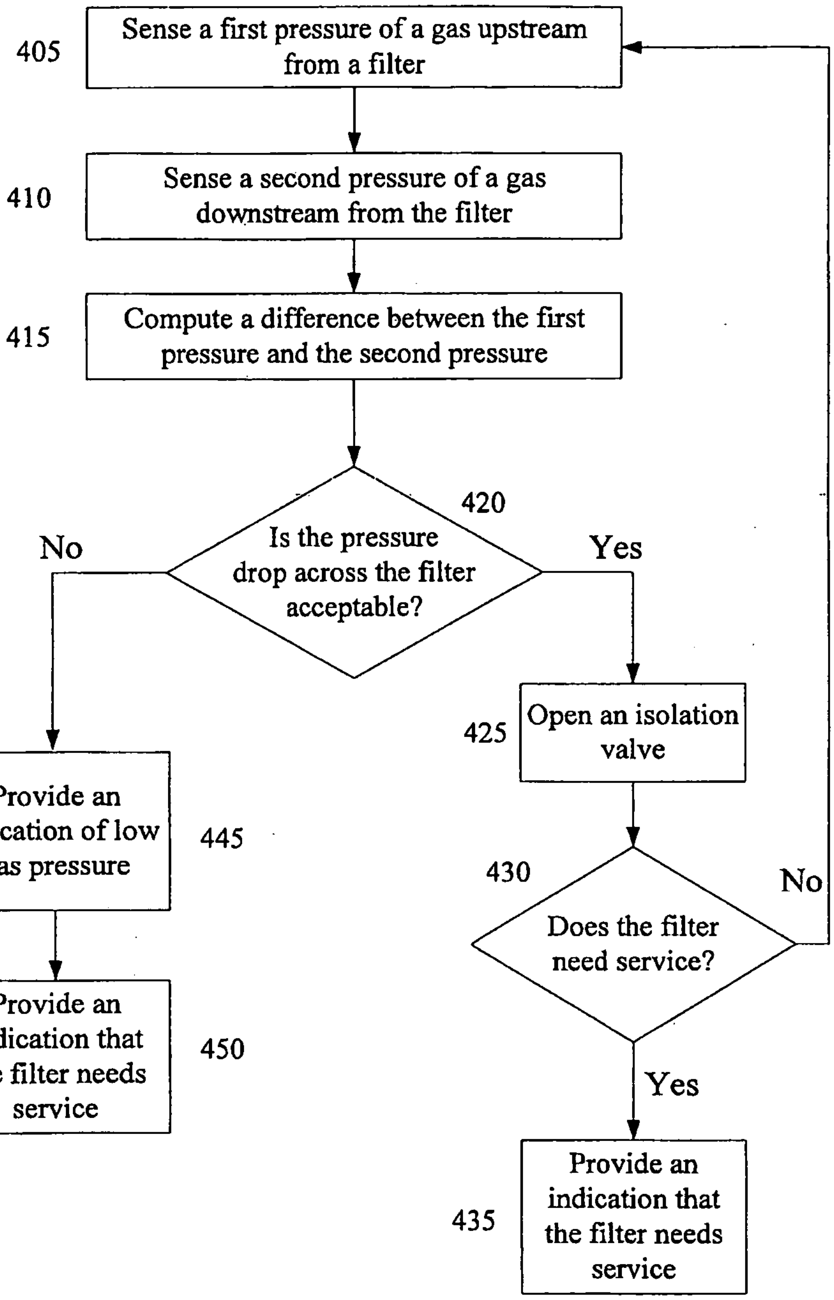

405
Sense a first pressure of a gas upstream from a filter
410
Sense a second pressure of a gas downstream from the filter
415
Compute a difference between the first pressure and the second pressure
420
Is the pressure drop across the filter acceptable?
No
Yes
425
Open an isolation valve
430
Does the filter need service?
No
Yes
435
Provide an indication that the filter needs service
445
Provide an indication of low gas pressure
450
Provide an indication that the filter needs service

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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