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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : A61M 16/00

A2

(11) International Publication Number: WO 90/04425

(43) International Publication Date: 3 May 1990 (03.05.90)

(21) International Application Number: PCT/GB89/01268

(22) International Filing Date: 23 October 1989 (23.10.89)

(30) Priority data:
8824865.3 24 October 1988 (24.10.88) GB

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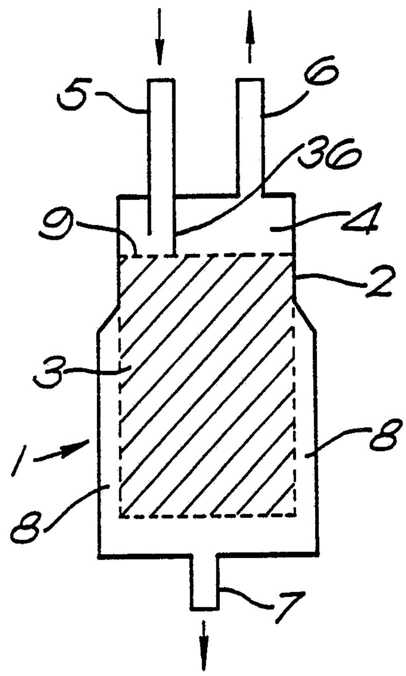
(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB, IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US.

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: GAS SAMPLING DEVICE AND WATER TRAP



(57) Abstract

A gas sampling device includes a foraminous hydrophilic element (3) for removing moisture from a gas which is to be analysed, in particular form air expired by a patient during medical treatment. In one embodiment the foraminous element (3) is incorporated in a water trap (1), and is arranged so that incoming, humid gas is directed onto the element. The water trap (1) includes a suction port (7) to enable moisture and gas to be drawn into the foraminous element (3). This reduces contamination of the outgoing gas, which is to be analysed, by incoming gas. In a further embodiment the element (3) is disposed in the main airway connecting the patient to ventilating apparatus. In this case, the element serves both to dry expired air passing to analysis apparatus, and to humidify ventilation gases passing to the patient.

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GAS SAMPLING DEVICE AND WATER TRAP

This invention relates to the removal of moisture from a flow of moisture-containing gas, in particular when the composition of the gas is to be monitored as in the ventilation of patients undergoing medical treatment, such as during anaesthesia or intensive care.

Many devices are known which remove moisture from a gas flow in a variety of different applications. Examples of such devices which indicate the technological background in this area are as follows.

US Patent No. 4272264 (Cullen et al) and Chemical Engineering, Vol. 81, No. 50, 24th November 1981, New York, US J81049609, disclose absorbent elements for drying a flow of air, for example, in an air conditioner. Similarly, WO-A-86/01165 (Wirmsberger) discloses a device for de-humidifying air in compressed-air braking systems.

US Patent No. 4673420 (Haker et al) discloses a dessicant dryer having an inlet and an outlet which may be connected into a gas line. The dryer comprises a housing enclosing a cylindrical canister which contains a dessicant. Gas flowing between the inlet and outlet flows radially through the canister.

DE-A-3020034 (Berner International GmbH) discloses apparatus for removing steam from a gas flow, and US patent No. 4662907 (Yoshida) discloses a water trap incorporating a stainless steel net, for cooling and removing the humidity from compressed air.

US Patent No. 4417574 (Talonn et al) discloses a liquid drain for patient breathing apparatus in which the drain includes a barrier which is water permeable and gas impermeable when wet.

In a water trap for a medical gas analyser manufactured by Datex Instrumentarium of Helsinki, Finland, the gas inlet is connected to a downwardly directed perforated tube in which moisture condenses and drains into a container under the influence of gravity. A gas outlet is provided to analysis apparatus, and gas passing through the perforations in the tube enters a second outlet, by-passing the analysis apparatus.

It is often necessary during anaesthesia or intensive care to ventilate the patient artificially, using, for example, a facial mask, or endotracheal tube. The gases generally used for ventilation are supplied in cylinders, and are dry. Because the use of dry gases can rapidly dry out the mucous membranes of the airways of the patient, various devices are employed to provide humidity to ventilation gases.

During such anaethesia or intensive care, it is frequently desirable to sample the gas mixture expired by the patient, for example so as to monitor the presence in the mixture of oxygen, CO_2, anaesthetic gases and the like. In the past, such sampling has been carried out by providing a sample port to appropriate analysis apparatus, from a point on the duct by which ventilation gases are led to and from the patient. Gases sampled at this point are generally warm (near body temperature of 37°C) and humid. As the gas passes down the sample line, which may be for example, 1 to 2 metres long, to the analyser unit, the water vapour contained in the gas may condense into droplets on the wall of the sample line. Such droplets of water tend to accumulate, and if they enter the analyser itself may give rise to contamination effects, and affect the reading of the cell. Previous methods to overcome this problem have involved the introduction of small water traps into th sample line. However, known water traps generally hav the disadvantage of producing gas-mixing in the gas flow, so attenuating the cyclical changes in gas composition during the breathing cycle.

According to a first aspect of the present invention there is provided a water trap for removing moisture from a flow of gas, which water trap includes a chamber containing a foraminous, preferably hydrophilic, element for retaining water removed from the flow of gas, the chamber having a gas inlet duct for directing incoming gas onto the foraminous element and a gas outlet duct, wherein the trap includes a suction port for drawing moisture and gas into the foraminous element.

Preferably, the water trap includes means for applying suction to only a portion of the foraminous element adjacent the interface between the element and gas in the chamber, so as to prevent moisture being drawn completely through the foraminous element into the suction port. Said means may comprise at least one channel extending from the suction port to the said portion of the element.

In order to achieve effective moisture removal from the gas flow, it is preferred that the foraminous element separates a first portion of the chamber, which portion contains the gas inlet and gas outlet ducts, from a second portion of the chamber, which portion contains the suction port.

In its first aspect, the invention extends to a device for sampling gases used in the ventilation of a patient undergoing medical treatment which apparatus comprises a conduit having a first connector for connection to ventilation apparatus for the patient, and a second connector for connection with means for conducting ventilation gases into the airway of the patient, a water trap as previously described, and a gas extraction duct extending between the interior of the conduit and the inlet duct to the wate trap. Suchr a gas sampling device may include means for analysing the sampled gases.

Most gas sampling analysers discharge the used sample of gas to atmosphere after analysis. Two problems can arise from this practice. First, because the discharged gas containing anaesthesia gases and vapours, is a source of polution in the atmosphere of the operating room or intensive care room. Secondly, if a low-flow closed circuit breathing system is in use, then the removal of the sampled gas volume (e.g. 0.3 to 0.5 l/min) may upset the dynamics of the low flow circuit to a significant extent.

Accordingly, in a preferred embodiment of the gas sampling device, a gas return duct is provided for returning analysed gases to the conduit. In this case, it is necessary to ensure that gas extracted from the conduit for analysis is not contaminated by sampled gas returning to the conduit. Accordingly, it is preferred that:

(i) the gas extraction and gas return ducts are longitudinally spaced along the conduit and open into the interior of the conduit at different radial positions within the conduit, and/or

(ii) the gas extraction and gas return ducts face away from each other within the conduit, and the open end of the gas return duct faces the direction of flow of air expired by the patient.

Feature (ii) enables the extraction and return ducts to be used in the manner of pitot tubes. Thus, in a preferred embodiment, means are provided for determining the pressure differential between gases in the two ducts so that the flow rate of gas through the conduit may be determined.

The gas sampling device previously described may be used as part of apparatus for ventilating a patient undergoing medical treatment, which apparatus further comprises means for supplying a ventilating gas to the said conduit and means for coupling the said conduit with the airways of the patient, for example, a face mask or an endotracheal tube.

In its first aspect, the invention extends to a method of removing moisture from a flow of gas using a water trap as previously described, and a method of monitoring a gas used for ventilation of a patient undergoing medical treatment which method is carried out using the above described apparatus.

According to a second aspect of the present invention there is provided a gas sampling device for use in ventilation apparatus for a patient undergoing medical treatment, which device includes a first conduit for connection to ventilation apparatus for the patient, a second conduit for connection with the device for conducting ventilation gases to the airway of the patient, a foraminous, preferably hydrophilic, element disposed between the first and second conduit such that at least a proportion of moisture present in expired air delivered to the second conduit is removed by the foraminous element on passage therethrough to the first conduit, and a sample port for sampling gases for analysis from the side of the foraminous element which faces the first conduit.

For the reasons previously given, such a gas sampling device may include a sample return port for returning sampled gases to the side of the foraminous element which faces the second conduit.

According to a further aspect of the invention there is provided apparatus for ventilating a patient undergoing medical treatment comprising means defining a flow path for a ventilating gas, means for supplying a ventilating gas to the flow path, means for coupling the flow path with the airways of a patient undergoing medical treatment, a foraminous element disposed within the flow path for removing at least a proportion of moisture present in air expired by the patient, and means for sampling ventilating gas in the flow path on the side of the foraminous element which faces the supply means for the ventilating gas. Again, such apparatus may include means for returning sampled ventilating gases to the flow path on the side of the foraminous element which faces the patient coupling means.

The foraminous element serves not only to remove moisture from gases expired by the patient, and thereby minimise interference with the readings of the gas analyser, it also serves to some extent to humidify gas supplied from the ventilation apparatus to the patient. The gas is sampled from the ventilation apparatus side of the element, which is relatively dry, and returned to the patient or "wet" side of the foraminous hydroscopic element.

The ventilation apparatus in accordance with the invention may include suitable means, such as a solenoid valve, for selectively enabling and preventing the return of the sampled ventilating gases to the gas flow path. It is convenient also to provide a pressure transducer for producing a signal indicative of pressure in the air flow path, on the side of the foraminous element which faces the patient. Return of the sampled gas to this side of the foraminous element can interfer with pressure sensed by the transducer. There is therefore preferably provided means for applying an off-set to the signal from the transducer, in dependence upon whether or not the solenoid valve is set to return the ventilating gases to the flow path.

The ventilation apparatus in accordance with the invention may preferably comprise means for dispensing an anaesthetic vapour into the ventilating gas and/or means for measuring the amount of anaesthetic gas present in the sampled gas.

The gas sampling apparatus in accordance with both the first and the second aspects of the invention preferably include a non-reversible connector for connecting the sample port and the sample return port, or the gas outlet duct from the water trap and the gas return duct as appropriate, to analysis apparatus.

It will be appreciated that the invention in its second and further aspects extends to a method of monitoring the composition of gas used for ventilation of a patient undergoing medical treatment using apparatus in accordance with said second and further aspects of the invention.

The foraminous elements mentioned above may be formed of any suitable material capable of removing at least a proportion of water from a gas, such as, for example, a metal or cellulose material, or a plastics material. The element may be, for example, a mesh, net, foam, or a fibrous or paper-like element. A hydrophilic substance, such as glycerol or lithium chloride, may be incorporated in, or on the surface of, the porous element.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a schematic view of a water trap in accordance with a first aspect of the present invention;

Figure 2 illustrates a preferred form of gas sampling device for use with the water trap of Figure 1;

Figure 3 illustrates gas analysis apparatus;

Figure 4 shows a gas sampling device in accordance with a second aspect of the invention.

The water trap of Figure 1, indicated generally at 1, for removing moisture from a flow of gas, comprises a chamber 2 containing a foraminous element 3 of a hydrophilic material. The element 3 defines a space 4 at the end of the chamber containing the gas inlet duct 5 and gas outlet duct 6. A gas suction duct 7 opens into the opposite end of the chamber to the inlet and outlet ducts, and gas channels 8 extend from the suction duct 7 towards the portion of the element 3 adjacent the interface 9 between the element and the space 4. A pin-like projection 36 on the gas inlet duct 5 extends from the end of the duct 5 to the interface 9 with the foraminous element 3. It will be understood that the projection 36 need only extend sufficiently far towards the interface 9 that a water droplet reaching the end of the projection 36 contacts the interface 9. Thus, the projection 36 need not actually contact the interface 9 and statements herein that the projection extends "to the interface 9" should be construed accordingly.

In operation, the inlet duct 5 is connected to the supply of gas from which moisture is to be removed.

The inlet duct 5 directs incoming gas onto the element 3, so that water droplets in the gas are carried by virtue of their momentum into the foraminous material. Those water droplets having insufficient momentum to be projected directly onto the element 3 tend to coalesce on the pin-like projection 36 where they are temporarily retained by surface tension. Under the influence of the flow of incoming gas, these droplets move gradually towards the end of the projection 36 and hence onto the foraminous element 3. Thus, while the provision of the projection 36 is a preferred feature only, its presence assists in removing moisture from the incoming gas. In some embodiments, more than one projection 36 may be provided.

The dried, or partially dried, gas is removed from the chamber via the outlet duct 6. The suction duct 7 is connected to a suitable pump so that suction is applied to the foraminous element 3. This tends to draw moisture and gas into the element. The channels 8 enable suction to be applied to only the portion of the foraminous element adjacent the interface 9. This prevents moisture being drawn completely through the foraminous element into the suction duct 7.

Use of the suction duct has particular advantage when the composition of the outgoing gas is to be monitored, and the composition of the incoming gas is varying with time. Since mixing of gas in the space 4 with gas within the foraminous element 3 tends to occur in the region of the interface 9, the outgoing gas may be contaminated by gas from the foraminous element. Use of the suction duct 7 ensures that interface gases are drawn into the foraminous material, allowing variations in the composition of the sampled gas to be followed more accurately by analysis apparatus.

For dealing with gas flow rates through the trap of approximately 0.5 litres per minute the space 4 may have dimensions of approximately 10 mm x 5 mm x 1.5 mm. Suction is generally applied to the suction duct 7 so as to draw gas through the foraminous element at a rate typically equal to 50% of the total gas flow rate through the trap. In general, however, the volume of the space 4 is optimised for a particular flow rate, or range of flow rates, so as to provide minimum interference with gas flowing through the trap.

A further advantage of the water trap discussed above is that, since the volume of the foraminous element 3 is significantly larger than the volume of the space 4, effective absorption of moisture is achieved over a wide range of orientations of the trap. This advantage will be particularly apparent when the trap is to be a disposable component, for example as part of apparatus for sampling gas expired by a patient during medical treatment, when it is likely that there will be little control of the orientation of the device.

Figure 2 shows a gas sampling device suitable for use with the water trap of Figure 1 for sampling a moisture-containing gas, for example air expired by a patient during medical treatment such as anaethesia or intensive care. A conduit 10 has first and second tapered connectors, 11 and 12 respectively, for connection, for example, between patient ventilating apparatus (not shown but of conventional form) and a device such as an endotracheal tube or facial mask (also not shown). In this case, the direction of flow of air expired by the patient is shown by the arrow in Figure 2. The gas extraction duct 13 is connected to the gas inlet duct 5 of the water trap 1, and has an open end which protrudes into the gas stream through the conduit. A sample of the expired air is thus drawn via the duct 13 through the water trap 1, and passes via the gas outlet duct 6 to suitable analysis apparatus. After sampling, the sampled gas may be returned to the main gas flow through the conduit via the gas return duct 14.

In the embodiments shown, the extraction and return ducts, 13 and 14 respectively, are longitudinally spaced along the conduit, with the gas return duct 14 positioned "downstream" of the extraction duct 13 with respect to the direction of flow of air expired by the patient through the conduit. In addition, the open ends of the ducts 13 and 14 face directly away from one another along the direction of flow of expired gas, and open into the gas stream at different radial positions within the conduit. These features minimise the risk of contamination of gas extracted for sampling by sampled gas returning to the conduit. This arrangement also enables the ducts 13 and 14 to be used in the manner of pitot tubes, so that, by measurement of the pressure differential between the two tubes, the flow rate of gas through the conduit may be determined.

Figure 3 illustrates apparatus for analysing gas sampled by the device of Figure 2 together with the water trap of Figure 1. The sampling device is coupled to the analysis apparatus by means of the non-reversible connector 15 which connects with the gas outlet duct 6 from the water trap and the gas return duct 14, as indicated in the figure. The analysis apparatus comprises a non-reversible connector 16, adapted to mate with the connector 15, so as to convey sampled gases from the gas outlet duct 6 to a sample cell 17 of generally conventional form. The gas mixture is analysed in sample cell 17, and an output is provided indicative of the content in the sample of, for example, oxygen, carbon dioxide, anaesthetic gas etc. Gas is removed from sample cell 17 by means of a pump 18.

A solenoid 19, operable by a control switch 20, may be operated so as to direct output from pump 18 either to an exhaust port 21, or via duct 22, through filter 23, and back to the connector 16. From connector 16, the sample is returned to the conduit via gas return duct 14.

A pressure transducer 24 is provided in the apparatus for measuring the pressure in the airway of the patient. The sensed pressure can be displayed on a gauge or the like (not shown). Means are provided in the form of offset control 25 for applying an offset to the indicated pressure on the pressure display 27, when the solenoid 19 is switched to return sampled gas via the return duct 14.

Figure 4 illustrates an alternative form of gas sampling device, in accordance with a second aspect of the invention, for use in ventilation apparatus for a patient undergoing medical treatment.

The sampling device 28 is adapted to fit between patient ventilating apparatus (not shown but of conventional form), to which it is connected by means of conduit 29, and a device such as an endotracheal tube or facial mask (also not shown) to which it is connected by means of conduit 30. Connectors 29 and 30 are of a tapered design, to facilitate rapid assembly of the apparatus. A foraminous, hydrophilic element 31 is positioned between conduits 29 and 30. Gas expired by the patient passes via conduit 30, through the foraminous element 31, to conduit 29. Most of the water vapour in the expired gas is condensed out by element 31, so that, at the end of expiration, the element 31 is warm and saturated. Subsequently during inspiration, the relatively dry gas entering via conduit 29 is warmed and humidified by passage through the element 31. Thus, element 31 acts as a humidifier for the ventilating gases passed to the patient.

A sample port 32 is provided on the "dry" side of the element 31 (i.e. the side of the element 31 which faces the ventilator) and may be connected by duct 33 directly to the non-reversible connector 15 for coupling to the analysis apparatus of Figure 3. A sample return port 34 is disposed on the opposite side of the element 31 to the port 32, and is also connected to the non-reversible connector 15 by means of the return duct 35.

The foraminous elements 3 and 31 may consist of a number of materials, for example, cellulose, metal or plastic fibres, plastic foam, or a metallic mesh or paper-like element impregnated with one or more hydrophilic chemical substances such as glycerol or lithium chloride. It may also be advantageous to add a chemical to the porous material which changes colour when saturated with water, so that some visual indication of the degree of saturation of the device is provided.

It will of course be appreciated that a wide range of other arrangements are possible, in addition to those specifically disclosed above.

CLAIMS

1. A water trap for removing moisture from a flow of gas, which water trap includes:

a chamber containing a foraminous element for retaining water removed from the flow of gas, the chamber having a gas inlet duct for directing incoming gas onto the foraminous element, and a gas outlet duct,

wherein the trap includes a suction port for drawing moisture and gas into the foraminous element.

2. A water trap as claimed in Claim 1 including means for applying suction to only a portion of the foraminous element adjacent the interface between the element and gas in the chamber.

3. A water trap as claimed in Claim 2 wherein said means for applying suction to only a portion of the foraminous element comprises at least one channel extending from the suction port to the said portion of the element.

4. A water trap as claimed in any one of the preceding claims wherein the foraminous element separates a first portion of the chamber, which portion contains the gas inlet and gas outlet ducts, from a second portion of the chamber, which portion contains the suction port.

5. A water trap as claimed in any one of the

preceding Claims including at least one elongate projection on the gas inlet duct which projection extends from the open end of the gas inlet duct inside the chamber to the surface of the foraminous element.

6. A device for sampling gases used in the ventilation of a patient undergoing medical treatment which apparatus comprises:

a conduit having a first connector for connection to ventilation apparatus for the patient, and a second connector for connection with means for conducting ventilation gases into the airway of the patient,

a water trap as claimed in any one of the Claims 1 to 5 and

a gas extraction duct extending between the interior of the conduit and the inlet duct to the water trap.

7. A device as claimed in Claim 6, including means for analysing the sampled gases, and a gas return duct for returning analysed gases to the conduit.

8. A device as claimed in Claim 7, wherein the gas extraction and gas return ducts are longitudinally spaced along the conduit and open into the interior of the conduit at different radial positions within the conduit.

9. A device as claimed in Claim 8, wherein the gas

extraction and gas return ducts face away from each other within the conduit, and the open end of the gas return duct faces the direction of flow of air expired by the patient.

10. Apparatus for ventilating a patient undergoing medical treatment, which apparatus comprises:

a gas sampling device as claimed in any one of Claims 6 to 9;

means for supplying a ventilating gas to the said conduit and

means for coupling the said conduit with the airways of the patient.

11. Apparatus as claimed in any one of Claims 7 to 10 including a non-reversible connector for connecting the gas outlet duct from the water trap and the gas return duct to analysis apparatus.

12. Apparatus as claimed in any one of the preceding claims wherein the foraminous element is formed of a metal or cellulose material, or a plastics material.

13. Apparatus as claimed in any one of Claims 1 to 12, wherein the foraminous element is a mesh, net, or foam, or is a fibrous or a paper-like element.

14. Apparatus as claimed in any one of the preceding claims wherein the foraminous element comprises a hydrophilic substance.

15. A method of removing moisture from a flow of gas characterised in that the method employs a water trap as claimed in any one of Claims 1 to 5.

16. A method of monitoring a gas used for ventilation of a patient undergoing medical treatment, which method is carried out utilising apparatus as claimed in any one of Claims 6 to 9.

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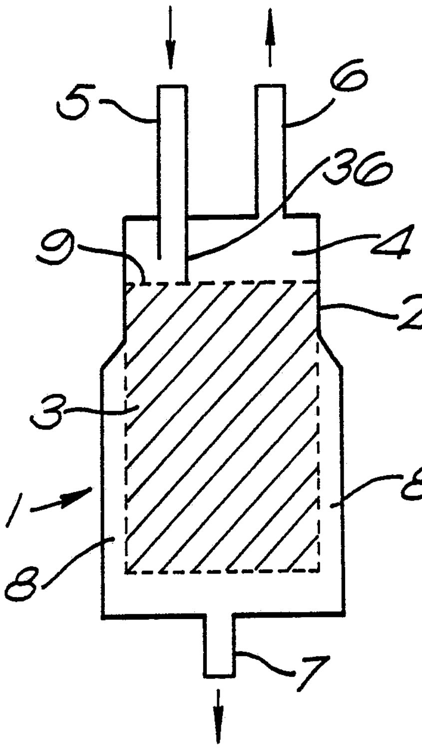


FIG. 1

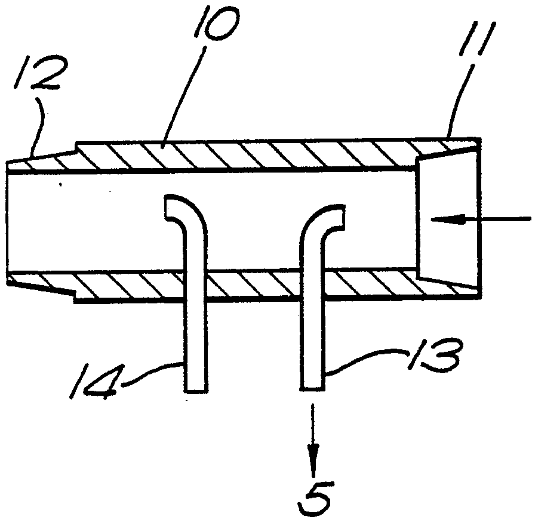


FIG. 2

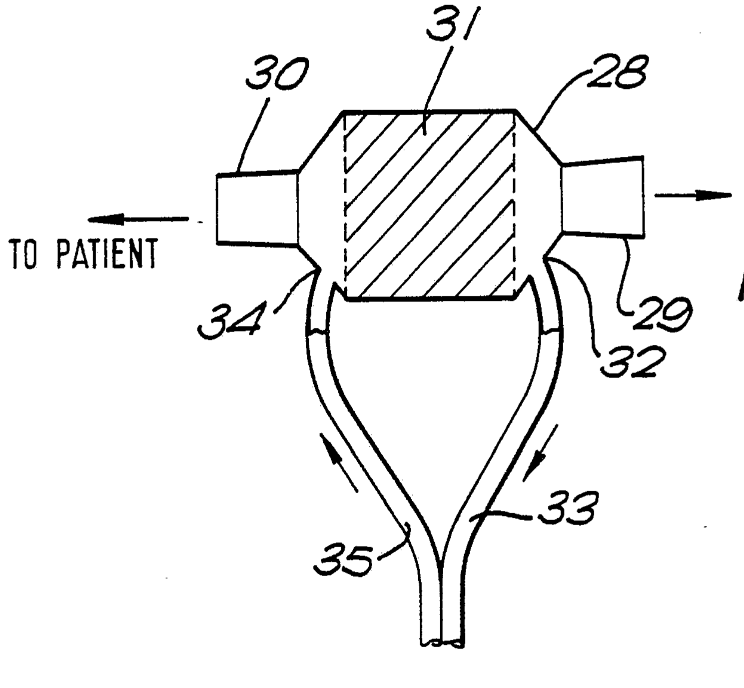
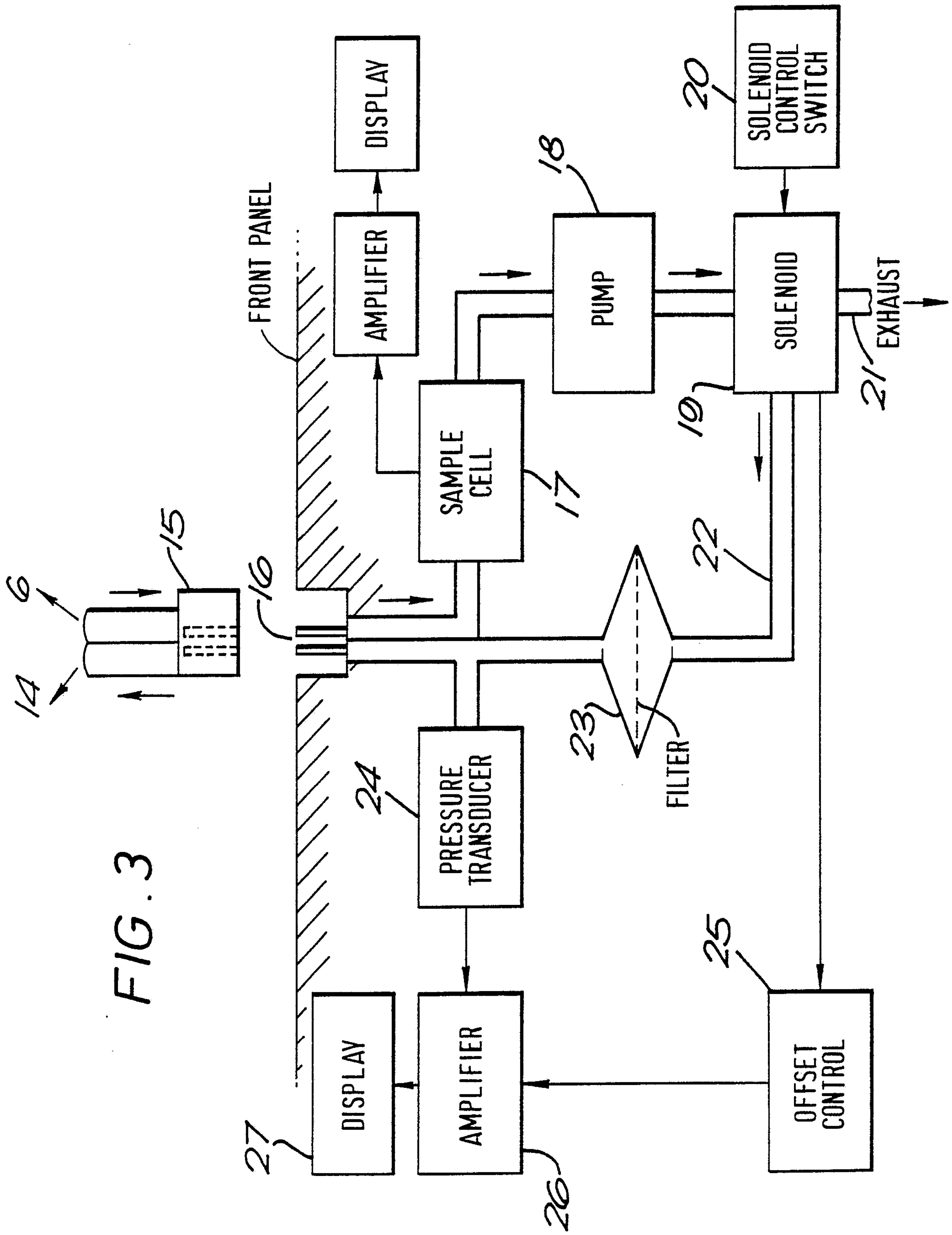


FIG. 4


DISPLAY
AMPLIFIER
FRONT PANEL
PUMP
18
SOLENOID CONTROL SWITCH
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SOLENOID
EXHAUST
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10
SAMPLE CELL
17
22
6
14
15
16
FILTER
23
PRESSURE TRANSDUCER
24
25
OFFSET CONTROL
DISPLAY
AMPLIFIER
27
26

FIG. 3