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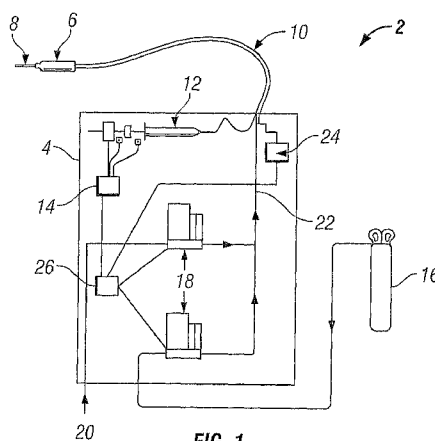


FIG. 1

(57) Abstract: The present invention relates to a calibrator for testing and recalibration of emission systems such as continuous emission systems and/or automated measuring system. The system comprises a delivery device which is arranged to deliver a test gas and/or vapour to a gas analyser. The system comprises a heater arrangement to effect evaporation of a liquid to provide the vapour, a liquid delivery system arranged to supply liquid to the heater arrangement, a test gas delivery system arranged to deliver test gas to the delivery device, and a controller for controlling the heater, liquid delivery system, evaporator and test gas delivery system. A connector beneficially connects a conduit for transporting a liquid to the gas analyser and the connector includes a nozzle having a heater arrangement.

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Calibrator

The present invention relates to a calibrator for testing and re-calibration of emission systems such as continuous emission systems and/or automated measuring systems.

5

Stack gas analysis apparatus is widely available through utilisation of a number of different techniques and is commonly used, a specific example being passing radiation through the gas and measuring the intensity of the radiation thereby obtaining data permitting calculation of the concentration of known constituents of the stack gases. Gas analysers
10 give constant readings for only a short period of time and hence require periodic calibration to provide reliable analysis. This is generally carried out by prior art systems wherein a reservoir of a liquid is heated to provide a vapour, generally a water vapour, which passes through a heated conduit, subsequently mixed with a test gas and/or air and is passed into the stack. However, there are disadvantages with such an arrangement, in
15 particular relating to heating the liquid to provide vapour and the percentage of the liquid is turned to vapour being unreliable. Heating is achieved by heating the fluid within the reservoir and pumping this vapour fluid mix through the conduit which itself is heated to substantially maintain the liquid in vaporised form. However, severe limitations are apparent with such an arrangement as it is difficult to control the percentage of vapour and
20 additionally it takes a significant period of time for the apparatus to become stable such that the calibration may be carried out.

The applicant has overcome the above-mentioned problems with the new calibration system.

25

According to a first aspect of the present invention, there is a system for calibrating a gas analyser, the system comprising a delivery device arranged to deliver a test gas and/or vapour, the system including:

- a) heater arrangement to effect evaporation of a liquid to provide the vapour;
- 30 b) a liquid delivery system arranged to supply liquid to the heater arrangement;
- c) a test gas delivery system arranged to deliver test gas to the delivery device; and

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- d) a controller for controlling the heater, liquid delivery system, evaporator and test gas delivery system.

5 The delivery device preferably comprises a connector for connecting a conduit for transporting a liquid to said gas analyser.

10 The connector preferably includes a nozzle arranged and configured to locate in a receiving aperture in said gas analyser. The connector preferably further includes said heater arrangement, said heater arrangement preferably including an electrical heater. The heater arrangement preferably substantially surrounds a compartment for receiving said liquid and a gas. The gas preferably comprises a test gas. This ensures a high degree of mixing of the vapour and test gas to a desired temperature.

15 The liquid delivery system preferably comprises a displacement pump, and even more preferably comprises a positive displacement syringe. The displacement pump is preferably operated by a means to cause a stepwise delivery of liquid, and preferably comprises a stepper motor. Using such an arrangement ensures careful control of the volume of fluid to be vaporised is maintained. The liquid delivery system preferably further comprises a conduit arranged to couple to said connector. The conduit preferably
20 comprises a capillary tube.

The test gas delivery system preferably comprises a second conduit arranged to supply test gas and/or air to said gas analyser. The test gas and/or air is preferably controlled by at least one mass flow controller. The conduit arranged to transport said liquid and the second
25 conduit are preferably retained in a flexible tube.

In an alternative embodiment, the heater arrangement is preferably locatable in or on said flexible tube. The heater arrangement may be arranged and configured to heat said gas. The heater arrangement is preferably mountable adjacent said gas analyser.

30

Also, according to the first aspect of the present invention, there is a connector for connecting said conduit to said gas analyser comprising a heating arrangement.

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According to a second aspect of the present invention, there is an apparatus for calibrating a gas analyser, said apparatus comprising a conduit having a first end and a second end, the first end arranged and configured to supply fluid to a gas analyser and a second end for receiving fluid from a fluid reservoir, said apparatus further comprising a heater arrangement to vaporise a portion of said fluid in said conduit for transfer from said conduit to said gas analyser.

The problem with the prior art arrangement has been overcome according to a second aspect of the present invention by providing a heater arrangement on the conduit rather than heating the fluid in the reservoir such that control of the vaporisation of a portion of the fluid can be more carefully controlled.

The apparatus preferably further comprises a connector arranged and configured to connect the first end of said conduit to said gas analyser, said connector including said heater arrangement to vaporise a volume of said liquid for transfer from said conduit to said gas analyser. A significant advantage of such a configuration is that it is not a requirement to heat the fluid until reaching the connector. It is therefore not a requirement to provide heating means along the conduit which means the apparatus may be significantly simpler to manufacture and additionally may provide a more compact arrangement enabling simple portability. Additionally, there is little or no condensation of the fluid from when it is vaporised to passing into the monitoring systems. Calibration is more accurate, and additionally the apparatus can be used quickly from turning on the apparatus as a small volume of liquid only must be vaporised at any one time. The arrangement is therefore more accurate, more simple, and enables a higher percentage of vapour to be provided by the calibration system.

The apparatus further comprises a second conduit arranged to supply at least one gas from a reservoir to said gas analyser.

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Both said first and second conduits are preferably retained in a flexible tube. The tube is preferably of a length of approximately two metres. This is suitable for the user of the apparatus to allow either access to the sample inlet point.

5 The connector preferably includes a nozzle for insertion into a receiving aperture in a monitoring system. The receiving aperture in the monitoring system may also be heated.

10 The connector is preferably also arranged and configured to receive at least one gas from said second conduit. The apparatus further comprises a test gas delivery system, and preferably includes at least one main flow controller. Mixing of the gas and vaporised fluid occurs following heating of the fluid into vaporised form. A mix of gas, vapour and air is then injected into the gas analyser for calibration.

The first conduit is preferably capillary tube.

15 The apparatus preferably further comprises a liquid delivery system to inject a pre-determined volume of fluid into the conduit. The liquid delivery system preferably comprises a displacement pump, and even more preferably comprises a positive displacement syringe pump.

20 The displacement pump is preferably operated means to provide stepwise delivery of liquid, and even more preferably comprises a stepper motor. Using such an arrangement ensures careful control of the volume of fluid to be vaporised is maintained.

25 The apparatus further comprises a controller to control the heater arrangement, liquid delivery system, and further control the test gas delivery system. The test gas is preferably controlled via at least one mass flow controller which is commonly available in the art.

30 The apparatus is preferably maintained within a portable package wherein the flexible tube extends therefrom. Again, this provides the advantage that an operator can access areas where such monitoring systems are located with relative ease.

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A connector for connecting a conduit to a gas analyser, said connector including a heater arrangement arranged to vaporise a volume of liquid received from said conduit for transfer to said gas analyser.

- 5 Also according to the second aspect of the present invention, there is a method of calibrating a gas analyser comprising the steps of providing a conduit having a first end and a second end, said first end arranged and configured to supply fluid to a gas analyser and a second end for receiving fluid from a fluid reservoir, and further providing means to vaporise a portion of said liquid for transfer from the conduit to the gas analyser, the
10 method comprising passing a volume of fluid from said reservoir into said conduit, vaporising a volume of said liquid, and transferring said volume of vaporised liquid from said conduit into said gas analyser.

- A further problem apparent with prior art arrangements is the inaccuracy of calibration due
15 to the unpredictable quantity of vapour entering into the gas analyser. The third aspect of the present invention aims to reduce this inaccuracy.

- According to a third aspect of the present invention, there is an apparatus for calibrating an gas analyser, said apparatus comprising a conduit having a first end and a second end, said
20 first end being arranged and configured to supply fluid to the gas analyser, the second end for receiving fluid from a fluid reservoir, said apparatus further comprising means to inject a pre-determined volume of fluid into said conduit.

- The injection means preferably comprises a displacement pump. The displacement pump
25 preferably comprises a positive displacement syringe. The displacement pump is preferably operated by means to cause stepwise delivery of liquid. The means to cause stepwise delivery preferably comprises a stepper motor.

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

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Figure 1 is a schematic side view of a calibration apparatus according to an exemplary embodiment of the present invention.

Figure 2 is a schematic side view of a connector according to an exemplary embodiment of
5 the present invention.

Figure 3 is a schematic representation of an additional feature of an apparatus according to an exemplary embodiment of the present invention.

10 Referring to Figure 1, the apparatus 2 comprises a casing constructed from any light weight robust material such as polyurethane. Such an apparatus can then be carried by an operator on their back. The apparatus 2 comprises a connector 6 including a nozzle 8. The connector 6 is described in more detail with respect to Figure 2. However, the connector includes a heating arrangement selectable to ensure the desired percentage of water vapour
15 is produced. A flexible tube 10 extends between the connector and the casing 4 and contains therein a capillary tube (not shown) and a conduit (not shown) for carrying liquid and gas and/or air as required. Water is injected into the capillary tube via displacement pump 12 which is controlled in a preferred embodiment by a stepper motor 14. This ensures the exact quantity of water is injected into the capillary tube for subsequent heating
20 in the connector 6. The test gas container 16 is connectable to a mass flow controller 18 which is a standard unit known in the art. The mass flow controller for the test gas 16 controls flow of test gas to the connector 6. Air may also be provided through line 20 which again is controlled by a mass flow controller 18. The output through mass flow controller 18 may be joined to provide a single line 22 passing to the connector 6. The
25 evaporator control 24 is also provided to control the heating of the fluid in the connector 6. This, along with the stepper motor 14 and mass flow controller 18 are controlled through a control unit 26. This control unit 26 comprises a microprocessor with a switch panel and LCD display for ease of viewing by an operator. It will be appreciated that the heating arrangement could be located at any point along the tube 10 provided the water is heated to
30 be vaporised, however, locating within the connector allows most effective heating and control of the percentage vapour and temperature of vapour used in the calibration.

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Referring to Figure 2, a detailed view of the connector is shown together with a cross-section of the area indicated AA. The connector 6 comprises a nozzle 8, and a compartment 30 into which liquid and/or gas through a capillary tube 32 and gas line 34 respectively are supplied. The compartment 30 is a heated block which causes the fluid to
5 evaporate and puts the gas in an excited stated. The vapour and gas are therefore mixed in the compartment 30. As can be seen with respect to the cross-sectional view, a number of heating elements 36 ensure heating of the liquid leaving the capillary tube 32 and the gas leaving the gas line 34. An earth connection is provided and a temperature sensor 13 is present. The vapour/gas mix leaving the nozzle 8 is therefore heated and mixed to the
10 desired temperature without being allowed to cool by passing through any further conduits. An electrical supply 38 is also indicated on Figure 2, which is utilised as the heat source. The displacement pump 12 is also indicated on Figure 2. Referring again to the cross-sectional view, an insulating material 31 surrounds the inlet to the compartment 30.

15 In use, the liquid water from the displacement pump 12 is delivered to the connector local to the point of injection into the monitoring system which may for example be a continuous emission system and/or automated measuring system. Once vaporised, the water is mixed with the test gas and dilution gas as required. The dilution gas will be air inserted through line 20. Again, such an arrangement avoids the need for the calibrator to
20 have a heated line as heating of the liquid and gas (although beneficial but not essential) occurs immediately prior to conducting the gas analysis. Rapid response and minimal warm up time are therefore achieved.

The specification of such an apparatus is that water vapour samples of up to 60% by
25 volume. An accuracy of 1% of water vapour level over the range 10% - 60% is achieved and a supply of 230/100V, 60/60Hz is utilised. Such a unit will weigh approximately 10 kilos and water concentration in mg/nm^3 and percentage, set point, actual concentration, evaporating temperature, individual mass flow and water rates are displayed. The connection to the continuous emission system in the nozzle may be 6mm or $\frac{1}{4}$ inch
30 insulated tube.

Three specific performance operations are envisaged and described by way of example only:

Calibrator - W

5

Water Vapour Generator - This enables the generation of water vapour up to 60% for one hour at gas flow rate of 5litres/minute. The water vapour concentrations can be adjusted in between 0 and 60% water vapour by volume.

10 Calibrator - WD

Water Vapour Generator/Test Gas Divider - This enables the humidification of test gas up to a water vapour content of 60% and 5 litres per minute gas flow rate. The test gas and water vapour concentrations can be adjusted independently. The device can be used to
15 verify the correct operation of extractive CEM's (continuous emission system) sample preparation components. If the system requires the removal of water vapour by introducing for example humidified Sulphur Dioxide (SO₂) it can be determined if a proportion of the soluble gas is also removed. The humidified gas should if possible be injected at the stack take off to fully challenge the sample system.

20

Calibrator - D

Test Gas Divider - This enables linearisation test to be carried out on the CEM (continuous emission system) utilising only one cylinder of test gas per species. The gas is blended
25 with air to enable the linearisation test in accordance with the requirements of both European EN14181 and US EPA. Typically one cylinder of test gas per range is connected to the calibrator in turn, (zero and four concentrations of each as cylinder) is applied and the resultant CEM's reading recorded. The saving in the test gas cylinders make the calibrator a very cost effective approach to linearisation testing.

30

Referring to Figure 3, there is a schematic representation of an alternative embodiment of the present invention for the use in calibration of an analyser with elemental mercury. This

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can be provided in addition to the arrangement as outlined above as adds to the features and benefits of the arrangement. In a first embodiment in accordance with the arrangement as described in Figure 1, a mercuric (Hg_2) salt solution may be provided in water. The displacement pump 12 then delivers aqueous mercuric salt solution to the connector 6 wherein heating takes place, selectable to ensure that the correct volume of vapour is produced at the correct temperature. In a second embodiment as indicated in Figure 3, there is no displacement pump 12 or the displacement pump 12 is turned off and mercury vapour is passed through the line 22 and into the connector 6. The connector 6 may or may not provide heat to the mercury vapour depending on specific requirements. In addition, a line 40 is provided to either join with the line 22 or is independent of line 22 but in any event enables air to pass to the connector 6 in order to mix with the mercury vapour passing within the line 22. Mercury vapour is provided through the addition of a mercury reservoir 42 which contains liquid mercury. An inlet 44 is provided to the reservoir 42 and air is pumped through the inlet 44 into the liquid mercury within the reservoir 42. An outlet is provided from the reservoir 42 such that air containing mercury passes into the line 22. In this way, metallic mercury vapour (HgO) at a controlled level can be used to calibrate the analyser. It will be appreciated that the air injected into the reservoir 42 and through line 40 is controlled through a mass flow controller or alternatively via a displacement pump which is controlled via controller 18.

The benefits of such an arrangement is that it can be incorporated into the apparatus 2 as previously disclosed without causing significant increase in size of the apparatus but providing the significant advantage of additional calibration technique as required for a specific analyser.

The embodiments of the present invention have been described by way of example only and will be appreciated by a person skilled in the art that variations and modifications may be made without departing from the scope of the appended claims. Additionally, it will be appreciated that the features of each aspect of the present invention may be interchanged and are therefore preferred features of all aspects.

Claims

1. A system for calibrating a gas analyser, the system comprising a delivery device arranged to deliver a test gas and/or vapour, the system including:
 - a) heater arrangement to effect evaporation of a liquid to provide the vapour;
 - b) a liquid delivery system arranged to supply liquid to the heater arrangement;
 - c) a test gas delivery system arranged to deliver test gas to the delivery device; and
 - d) a controller for controlling the heater, liquid delivery system, evaporator and test gas delivery system.
2. A system according to claim 1 wherein said delivery device comprises a connector for connecting a conduit for transporting a liquid to said gas analyser.
3. A system according to claim 2 wherein said connector includes a nozzle arranged and configured to locate in a receiving aperture in said gas analyser.
4. A system according to any of claims 2 or 3 wherein the connector includes said heater arrangement.
5. A system according to any preceding wherein said heater arrangement includes an electrical heater.
6. A system according to any preceding claim wherein said heater arrangement substantially surrounds a compartment for receiving said liquid and a gas.
7. A system according to any preceding claim wherein said gas comprises a test gas.
8. A system according to any preceding claim wherein said liquid delivery system comprises a displacement pump.

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9. A system according to claim 8 wherein said displacement pump comprises a positive displacement syringe.
- 5 10. A system according to claims 8 or 9 wherein said displacement pump is operated by a means to cause stepwise delivery of liquid.
11. A system according to claim 10 wherein said means to cause stepwise delivery of said liquid comprises a stepper motor.
- 10 12. A system according to any preceding claim wherein said liquid delivery system further comprises a conduit arranged to couple to said connector.
13. A system according to claim 12 wherein said conduit comprises a capillary tube.
- 15 14. A system according to any preceding claim wherein said test gas delivery system comprises a second conduit arranged to supply test gas and/or air to said gas analyser.
- 20 15. A system according to any preceding claim wherein said test gas and/or air is controlled by at least one mass flow controller.
16. A system according to claim 12 and 14 wherein said conduit arranged to transport said liquid and the second conduit are retained in a flexible tube.
- 25 17. A system according to claim 16 wherein said heater arrangement is locatable in or on said flexible tube.
- 30 18. A system according to any preceding claim wherein said heater arrangement is arranged and configured to heat said gas.

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19. A system according to claim 17 wherein said heater arrangement is mounted adjacent said gas analyser.
- 5 20. An apparatus for calibrating a gas analyser, said apparatus comprising a conduit having a first end and a second end, the first end arranged and configured to supply fluid to a gas analyser and a second end for receiving fluid from a fluid reservoir, said apparatus further comprising a heater arrangement to vaporise a volume of said fluid in said conduit for transfer from said conduit to said gas analyser.
- 10 21. Apparatus according to claim 20 further comprising a connector arranged and configured to connect the first end of said conduit to said gas analyser, said connector including said heater arrangement to vaporise a portion of said liquid for transfer from said conduit to said gas analyser.
- 15 22. Apparatus according to any of claims 20 to 21 further comprising a second conduit arranged to supply at least one gas from a reservoir to said gas analyser.
- 20 23. Apparatus according to any of claims 20 - 22 wherein said first and second conduits are retained in a flexible tube.
24. Apparatus according to claim 20 wherein said connector includes a nozzle for insertion into a receiving aperture in a monitoring system.
- 25 25. Apparatus according to claim 21 and 22 wherein said connector is arranged and configured to receive at least one gas from said second conduit.
- 30 26. Apparatus according to any of claims 20 - 25 further comprising a test gas delivery system, said test gas delivery system including at least one mass flow controller.

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27. Apparatus according to any of claims 20 - 26 wherein said apparatus further comprises a liquid delivery system to inject a pre-determined volume of fluid into the conduit.
- 5 28. Apparatus according to claim 27 wherein said liquid delivery system comprises a displacement pump.
29. Apparatus according to claim 25 wherein said displacement pump comprises a positive displacement syringe pump.
- 10 30. Apparatus according to any of claims 25 - 26 wherein said displacement pump is operated by a stepper motor.
- 15 31. Apparatus according to any of claims 17 - 27 further comprising a controller to control the heater arrangement, liquid delivery system, and further control the test gas delivery system.
- 20 32. Apparatus according to any of claims 2 - 31 further comprising a reservoir arranged to receive mercury therein, the reservoir having an inlet for receiving a gas and an outlet for release of the gas, wherein the gas downstream of the reservoir having mercury therein is arranged to be transferred to the connector.
- 25 33. Apparatus according to claim 32 comprising a gas delivery system to inject a predetermined volume of gas into the receptacle.
34. Apparatus according to any of claims 32-33 comprising means to enable mixing of the gas downstream of the reservoir with a further gas.
- 30 35. A connector for connecting a conduit to a gas analyser, said connector including a heater arrangement arranged to vaporise a volume of liquid received from said conduit for transfer to said gas analyser.

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36. A connector according to claim 35, wherein the connector includes a chamber in communication with a gas inlet and a liquid inlet to the chamber.

37. A connector according to claim 35 or 36, wherein the heater arrangement comprises an electrical resistance heater.

38. A method of calibrating a gas analyser comprising the steps of providing a conduit having a first end and a second end, said first end arranged and configured to supply fluid to a gas analyser and a second end for receiving fluid from a fluid reservoir, and further providing means to vaporise a portion of said liquid for transfer from the conduit to the gas analyser, the method comprising passing a volume of fluid from said reservoir into said conduit, vaporising a volume of said liquid, and transferring said volume of vaporised liquid from said conduit into said gas analyser.

39. An apparatus for calibrating a gas analyser, said apparatus comprising a conduit having a first end and a second end, said first end being arranged and configured to supply fluid to the gas analyser, the second end for receiving fluid from a fluid reservoir, said apparatus further comprising means to inject a pre-determined volume of fluid into said conduit.

40. An apparatus according to claim 39 wherein said injection means comprises a displacement pump.

41. An apparatus according to claim 40 wherein said displacement pump comprises a positive displacement syringe.

42. An apparatus according to any of claims 40 - 41 wherein said displacement pump is operated by means to cause stepwise delivery of liquid.

43. An apparatus according to claim 42 wherein said means to cause stepwise delivery comprises a stepper motor.

44. A system as hereinbefore described with reference to claims 1 - 19 with reference to the accompanying drawings.
- 5 45. Apparatus as hereinbefore described with reference to claims 20 - 31 with reference to the accompanying drawings.
46. Apparatus as hereinbefore described with reference to claims 36 - 40 with reference to the accompanying drawings.

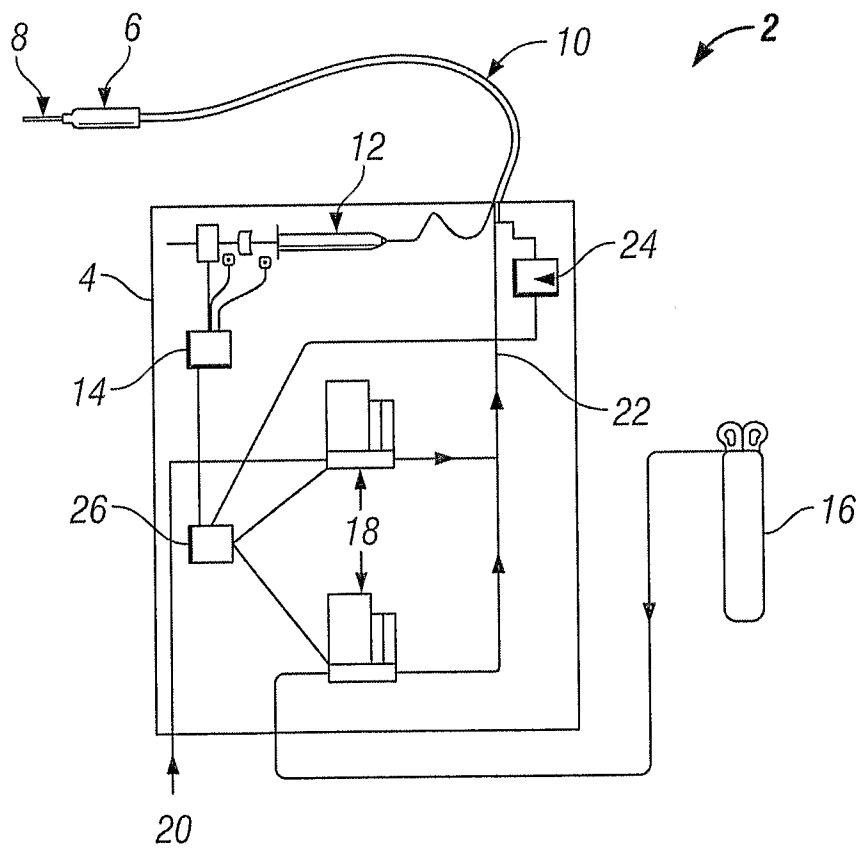
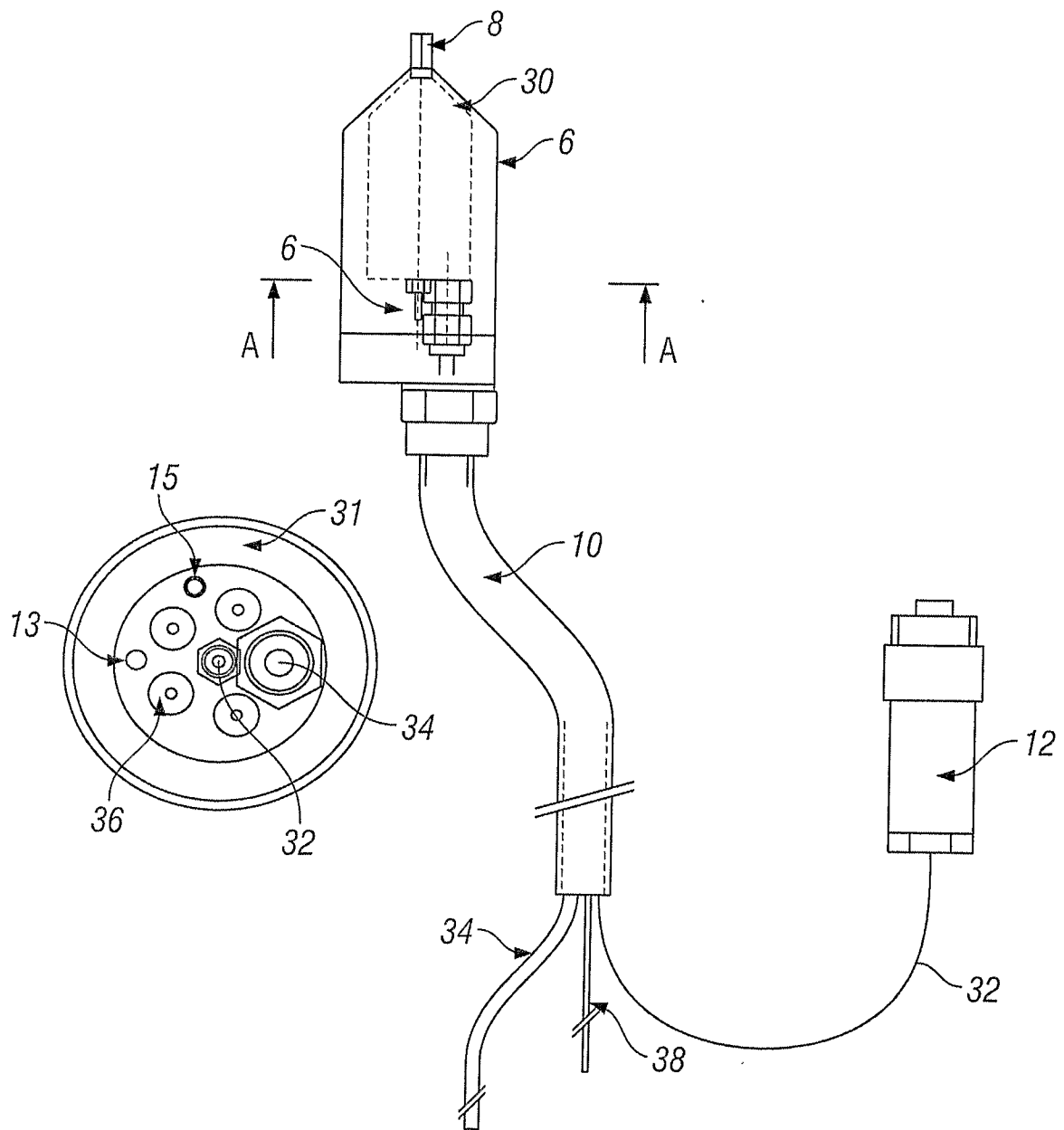
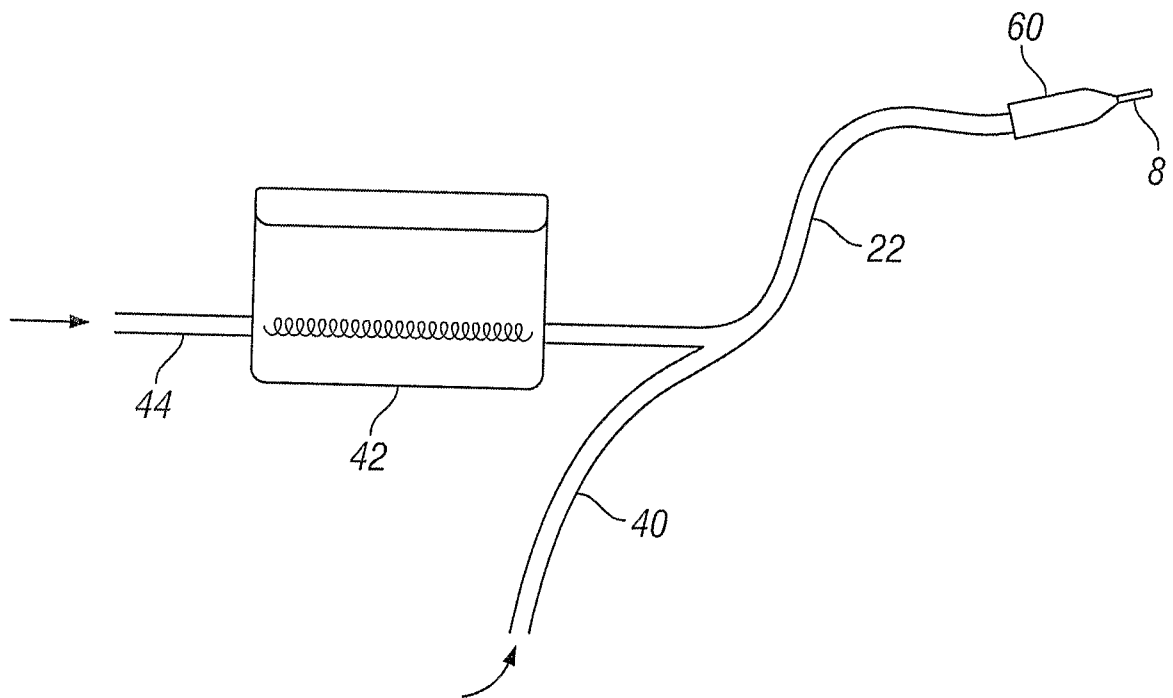


FIG. 1

**FIG. 2**

**FIG. 3**