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(54) Title: APPARATUS AND METHODS FOR CONTROLLING CHLORINE DIOXIDE CONCENTRATION

(57) Abstract: The instant invention provides apparatus and methods for controlling the concentration of chlorine dioxide in a chamber.



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APPARATUS AND METHODS FOR CONTROLLING CHLORINE DIOXIDE CONCENTRATION

5

RELATED APPLICATIONS

This application claims the benefit of US Provisional Application No.: 61/201,858, filed December 15, 2008, the contents of which are hereby incorporated herein by reference.

10 **FIELD OF THE INVENTION**

The present invention relates to methods and apparatuses for controlling chlorine dioxide concentration in an enclosed or partially enclosed space.

BACKGROUND OF THE INVENTION

15 Chlorine dioxide was discovered in the early 1800's, and was adopted by commerce in the United States in the 1940's. Chlorine dioxide has been called the ideal biocide and the ability of chlorine dioxide to reduce or eliminate viable microbes, e.g., bacteria, viruses, fungi, mold spores, algae and protozoa, is well-documented and well known. See, for example, Franklin, C.L. et al. (1991) *Am Vet Med Assoc* 198:1625-30; Korich K. G., et al. (1990) *Appl Environ Microbiol.*
20 56:1423-8; Boddie et al. (2000) *J Dairy Sci.* 83:2975-9; Lee et al. (2004) *J Food Prot.* 67:1371-6; Han et al. (2003) *J Environ Health* 66:16-21; Sy et al. (2005) *J Food Prot.* 68:1176-87; and LeChevallier M.W. et al. (1988) *Appl Environ Microbiol.* 54:2492-9.

It is believed that chlorine dioxide inactivates microorganisms by oxidizing key components of a micro-organism's membrane proteins that are vital to the membrane's structure and function.
25 Also, the oxidizing reaction that causes microorganism inactivation does not form trihalomethanes (THMs) or haloacetic acids (HAAs).

Approvals and registrations for use of chlorine dioxide in a wide variety of applications have been granted by the EPA, FDA and USDA, and such approvals and registrations have led to an increasing adoption of the use of chlorine dioxide.

There are many reasons for the ongoing expansion of chlorine dioxide use including its effectiveness against microorganisms at very low concentrations.

A major limitation to the use of chlorine dioxide is that chlorine dioxide can not be manufactured in bulk at an industrial gas plant and shipped to final use destinations. Accordingly,
5 chlorine dioxide must be generated on-site.

The use of chlorine dioxide in large scale applications is well known, however, the use of chlorine dioxide in small scale applications has not been widely adopted. The lack of adoption in small scale applications is a result of the limitations in the prior art with respect to the cost, speed, size and user friendly generation of chlorine dioxide in sufficient concentration and purity
10 to be useful. However, there are many small scale applications that would benefit from the use of chlorine dioxide as a disinfectant or sanitizing agent.

Apparatus and methods for controlling the concentration of chlorine dioxide would be beneficial for disinfection in a variety of applications including biosafety cabinets, isolators, filters, air handling equipment, food and drug processing equipment, etc.

Description of the invention

The instant invention provides apparatus and methods for controlling the concentration of chlorine dioxide in a space, e.g., biosafety cabinets, isolators, filters, air handling equipment, food and or drug processing equipment.

20 In one embodiment, the instant invention comprises an apparatus comprising a source of chlorine dioxide, a target chamber to be treated, one or more pumps, and at least two paths connecting elements of this system. The system may also comprise one or more valves. The system may also comprise a chlorine dioxide concentration sensor.

The source of chlorine dioxide may be, for example, an aqueous solution as made by a
25 variety of chlorine dioxide generating processes. For example, mixing citric acid with sodium chlorite in water will spontaneously produce a solution of chlorine dioxide.

In various embodiments of the invention, the valve(s) and/or pump(s) are arranged in the system in such a way that adjusting them controls the amount of gas circulated in the two loops and the concentration of chlorine dioxide in a target chamber. Figures 1-7 show a variety of useful arrangements of pumps, valves and sensor locations. The flow loop that contains the target chamber, but not the chlorine dioxide source is typically run at a higher gas flow rate than the flow loop that flows through the chlorine dioxide source. This higher flow rate maintains a more ~~constant~~ uniform chlorine dioxide concentration in the target chamber by increased mixing in the target chamber and therefore minimizing gradient effects due to chlorine dioxide losses in the target chamber or system. Chlorine dioxide losses may be due to, for example, leaks in the system, reaction with the chlorine dioxide by elements in the target chamber or system, or by absorption of the chlorine dioxide by elements in the target chamber or system. The flow of gas that goes through the chlorine dioxide source is set to control the amount of chlorine dioxide that enters the target chamber so the desired concentration profile can be generated in the target chamber.

The flow of gas through the chlorine dioxide chamber may be fixed, controlled manually by an operator or controlled automatically. The flow of gas through the chlorine dioxide chamber may be controlled in response to the reading on the chlorine dioxide concentration sensor either manually or automatically. If the flow is controlled automatically, feedback control well known in the art, such as PID control, may be used.

The sensor may be located in a slip stream with a different flow rate than the main circulation loop. In optical chlorine dioxide concentration sensors the light, typically in the ultraviolet range, may breakdown the chlorine dioxide into undesirable byproducts. These byproducts may include the hypochlorite ion. These byproducts may cause corrosion or other

deleterious effects to elements of the system. A lower flow through the sensor may be used to reduce the amount of byproducts. Furthermore, the sensor outflow may be vented to prevent byproducts from returning to the system. In this case the sensor flow may be lower to reduce the amount of chlorine dioxide gas lost from the system. If the outflow is vented there must also be an inlet to avoid developing too much negative pressure in the apparatus and target chamber.

The sensor outflow may be sent through a gas scrubbing device to remove the undesirable byproducts. If the scrubber also reduces the amount of chlorine dioxide in the sensor flow stream the sensor flow rate may be kept low to reduce the amount of chlorine dioxide lost in the scrubber.

10 **Brief Description of the Drawings**

Figure 1 depicts an apparatus of the invention comprising a chlorine dioxide source, a target chamber, an air circulating device, and a valve.

Figure 2 depicts the apparatus of Figure 1 further comprising a concentration sensor.

Figure 3 depicts the apparatus of Figure 1 further comprising a concentration sensor in the target chamber.

Figure 4 depicts the apparatus of Figure 2 further comprising a controller.

Figure 5 depicts an apparatus of the invention comprising a chlorine dioxide source, a target chamber, two air circulating device, and a concentration sensor.

Figure 6 depicts an apparatus of the invention comprising a chlorine dioxide source, a target chamber, an air circulating device, a concentration sensor, a gas scrubbing device and a valve.

Figure 7 depicts an apparatus of the invention comprising a chlorine dioxide source, a target chamber, an air circulating device, a concentration sensor, an inlet, an outlet and a valve.

Figure 8 is exemplary data of chlorine dioxide concentration vs. time from a testing using the invention.

Detailed Description

5 The instant invention provides methods and apparatus for controlling the concentration of chlorine dioxide in a target chamber.

 In exemplary embodiments the invention utilizes chlorine dioxide generators described in, for example, US patent 7,534,398, US patent publication 2008/029507A1, or International patent application PCT/US2009/49924, all of which are incorporated herein by reference. These
10 previously described chlorine dioxide generators can be used to create an aqueous solution of chlorine dioxide which can be the source of chlorine dioxide in the instant invention.

 Alternatively, an aqueous solution of chlorine dioxide may be made by other methods that are well known in the art. For example, chlorite and an acid may be combined with water to spontaneously generate an aqueous solution of chlorine dioxide.

15 The target space or chamber to be treated is an enclosed, or partially enclosed, space that is to be disinfected, deodorized or otherwise treated with chlorine dioxide, by a targeted concentration profile over time of chlorine dioxide. The target chamber may be part of the apparatus or the target chamber may be connected to the apparatus. Examples of typical target spaces or chambers include filters, biological safety cabinets (BSCs), isolators, air handling
20 equipment, and food and drug processing equipment. The target chamber may also be a series of elements in a system and/or connecting elements of a system such as a variety of chambers and the piping that connects the chambers. An exemplary concentration profile is 900 ppm for 60 min to reduce the bacterial population by 6 logs. A variety of other concentration profiles may

be desired. Factors influencing concentration profiles are: target organisms, kill rates, time available for disinfection, and humidity level. Exemplary organisms include bacteria, bacterial spores, viruses and fungi.

5 The chlorine dioxide sensor may be any of a variety of sensors. For example, the sensing technology may be optical or ion-sensitive field effect transistor.

The pump may be any kind of gas moving device. A diaphragm pump, a fan and a blower are examples of useful gas moving devices.

The valve may be an on/off type or proportional type. For example, the valve may be a needle valve. If the valve is an on/off type it may be pulse width modulated to control the flow.

10 The controller may be any kind of devices capable of taking in a measurement signal and outputting a control signal. For example, the controller could be a microcontroller or a programmable logic controller (PLC).

The gas scrubber may, for example, be activated carbon matrices or work by bubbling gas through an aqueous solution that reacts with the undesirable byproducts.

15 Figure 1 depicts exemplary apparatus 50 of the invention. The apparatus 50 comprises a chlorine dioxide source 1, a target chamber 4, an air circulating device 5, and a valve 7. The components are arranged so there are two gas flow loops. The first loop 12, includes the chlorine dioxide source 1, target chamber 4, and air circulating device 5. The second loop 13 includes the target chamber 4, the air circulating device 5 and the valve 7. The valve 5 may be
20 set or adjusted to control the relative flow between the first loop 12 and the second loop 13 to control the concentration of chlorine dioxide in the target chamber 4.

The valve 7 is adjusted to control the relative flow through the chlorine dioxide source 1 and through the target chamber 4. In one aspect of the invention the flow in the target chamber 4

is high to maintain good mixing and distribution of the chlorine dioxide while the flow through the chlorine dioxide source 1 is relatively lower. In one aspect of the invention the valve 5 is manually controlled to adjust the flow rate.

Figure 2 depicts an exemplary apparatus 50 of the invention. As depicted in Figure 2 the apparatus 50 further comprises a concentration sensor 2. The reading on the concentration sensor 2 may be used when setting or adjusting the valve to maintain a desired concentration of chlorine dioxide in the target chamber. The concentration sensor 2 may be located in a variety of places in the apparatus 50. For example, as in Figure 2, the concentration sensor 2 may be located next to the pump, or, for example, as in Figure 3, concentration sensor 2 may be located in the target chamber 4.

Figure 3 depicts an exemplary apparatus 50 of the invention with an alternate arrangement of elements for the apparatus 50 shown in Figure 2. The concentration sensor 2 is shown in the target chamber 4. The valve 7 is shown in first loop 12.

Figure 4 depicts an exemplary apparatus 50 of the invention. As depicted in Figure 4 the apparatus 50 further comprise a controller 3. In one aspect of the invention the controller 3 is electrically connected to the concentration sensor 2 and the three-way valve 6. The controller 3 will input the signal from the concentration sensor 2 and output a control signal to the three-way valve 6 to adjust the flow between the first loop 12 and the second loop 13. In a related embodiment, not shown, the controller is connected to the valve in alternate locations as shown in Figure 2 and Figure 3.

Figure 5 depicts an exemplary apparatus 50 of the invention. The apparatus 50 comprises a chlorine dioxide source 1, a target chamber 4, and two air circulating devices 5. The components are arranged so there are two gas flow loops. The first loop 12, includes the

chlorine dioxide source 1, target chamber 4, and an air circulating device 5. The second loop 13 includes the target chamber 4, and the second air circulating device 5. The air circulating devices 5 may be set or adjusted to control the relative flow between the first loop 12 and the second loop 13 to control the concentration and mixing of chlorine dioxide in the target chamber 4.

Figure 6 depicts an exemplary apparatus 50 of the invention. As depicted in Figure 6 the apparatus 50 further comprise a slip stream loop 14. In one embodiment of the invention the concentration sensor 2 is located on the slip stream loop 14. In a related embodiment of the invention a gas scrubber 10 is located on the slip stream loop 14.

Figure 7 depicts an exemplary apparatus 50 of the invention. As depicted in Figure 7 the apparatus 50 further comprises an inlet 8 and an outlet 11. In one embodiment of the invention the concentration sensor 2 is located on the outlet 11.

What is claimed is:

1. An apparatus for controlling the concentration of chlorine dioxide gas in a target chamber
5 comprising,

a chlorine dioxide source,

10 a gas moving device,

a valve,

a first flow path that includes the chlorine dioxide source, and

15 a second flow path that does not include the chlorine dioxide source.

2. The apparatus of claim 1, further comprising a sensor.

3. The apparatus of claim 2, further comprising a controller.

20 4. The apparatus of claim 3, where the controller maintains a concentration of chlorine dioxide to deliver controlled dosage.

5. The apparatus of claim 4, wherein the controlled dosage is 50 ppm-min to 60,000 ppm-
25 min to the target chamber.

6. The apparatus of claim 4, where the controller maintains a controlled concentration of chlorine dioxide for a controlled period of time.

7. The apparatus of claim 1, wherein the chlorine dioxide source is an aqueous solution of chlorine dioxide.

8. The apparatus of claim 1, wherein the air moving device is a diaphragm pump, a fan or a
5 blower.

9. The apparatus of claim 1, wherein the sensor is an optical sensor.

10. The apparatus of claim 1, wherein the valve is a proportional valve.

10 11. The apparatus of claim 1, wherein the valve is a 3-way valve.

12. The apparatus of claim 2, further comprising a third flow path.

15 13. The apparatus of claim 12, wherein the concentration sensor is located in the third path.

14. The apparatus of claim 13, further comprising a gas scrubber.

15. The apparatus of claim 1, further comprising a gas inlet and a gas outlet.

20 16. The apparatus of claim 15, further comprising a gas scrubber.

17. An apparatus for controlling the concentration of chlorine dioxide gas in a target chamber comprising,

25 a chlorine dioxide source,

a gas moving device,

a second gas moving device,

a flow path that does not include the chlorine dioxide source, and

5 a second flow path that does include the chlorine dioxide source.

18. The apparatus of claim 17, further comprising a sensor.

19. The apparatus of claim 18, further comprising a controller.

10

20. The apparatus of claim 19, where the controller maintains a concentration as a function of time of chlorine dioxide to deliver a controlled dosage to the target chamber.

15 21. The apparatus of claim 20, where the controller maintains a controlled concentration of chlorine dioxide.

22. The apparatus of claim 21, wherein the chlorine dioxide source is an aqueous solution of chlorine dioxide.

20 23. The apparatus of claim 51, wherein at least one of the air moving devices is a diaphragm pump.

24. The apparatus of claim 17, wherein the sensor is an optical sensor.

25 25. The apparatus of claim 17, wherein the valve is a proportional valve

26. The apparatus of claim 17, wherein the valve is a 3-way valve.

27. The apparatus of claim 18, further comprising a third flow path.

28. The apparatus of claim 27, wherein the concentration sensor is located in the third path.

29. The apparatus of claim 28, further comprising a gas scrubber.

5

30. The apparatus of claim 17, further comprising a gas inlet and a gas outlet.

31. The apparatus of claim 30, further comprising a gas scrubber.

10 32. A method for controlling the concentration of chlorine dioxide gas in a target chamber comprising,

providing the apparatus of any one of claims 1-31, and

starting the apparatus;

15

thereby controlling the concentration of chlorine dioxide in a chamber.

33. The method of claim 32, wherein the valve is adjusted to control the concentration of chlorine dioxide.

20

34. The method of claim 32, wherein the controller is set to control the concentration of chlorine dioxide

35. The method of claim 32, wherein the target chamber is a filter.

25

36. The method of claim 32, wherein the target chamber further comprises an element to be disinfected.

FIG. 1

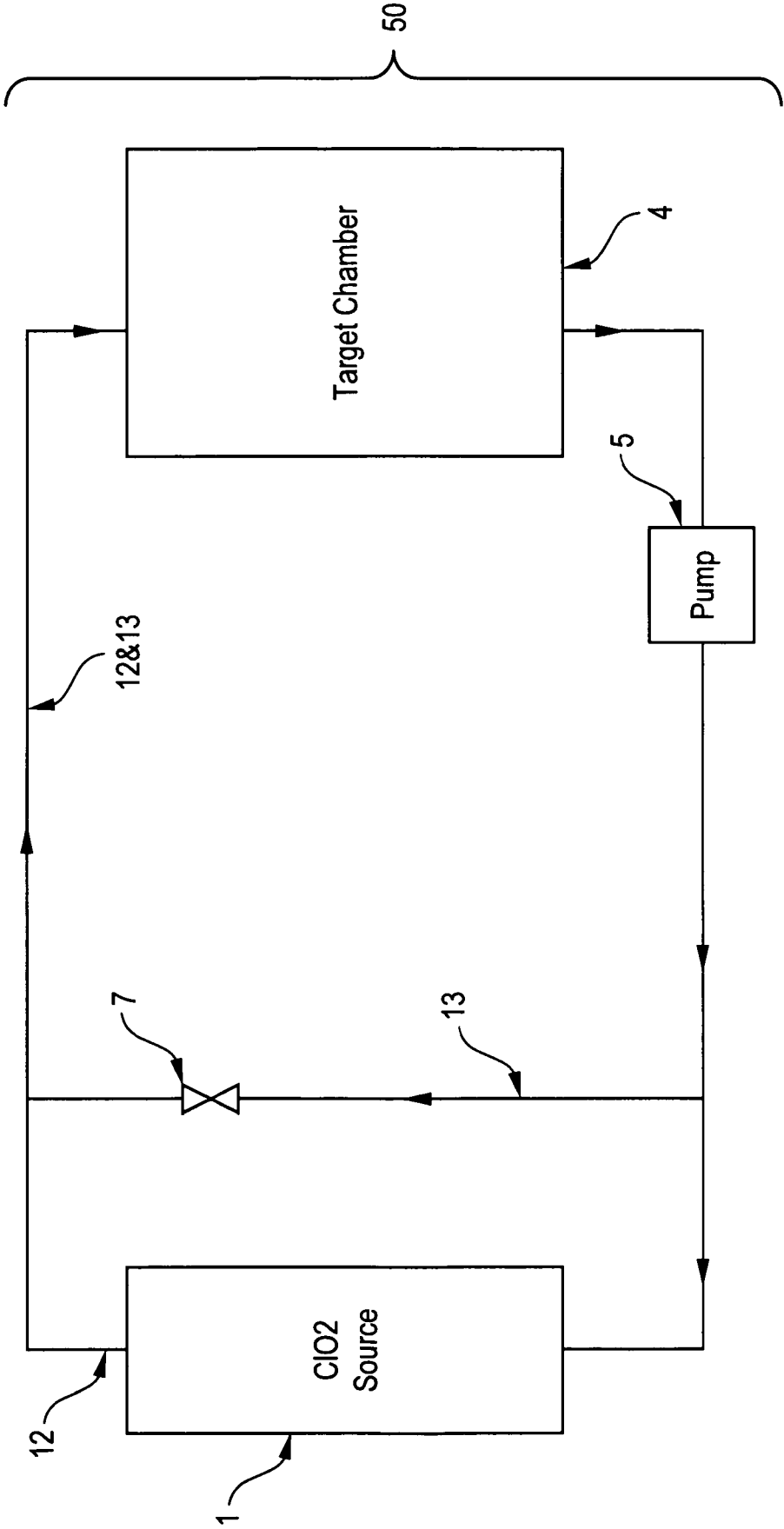


FIG. 2

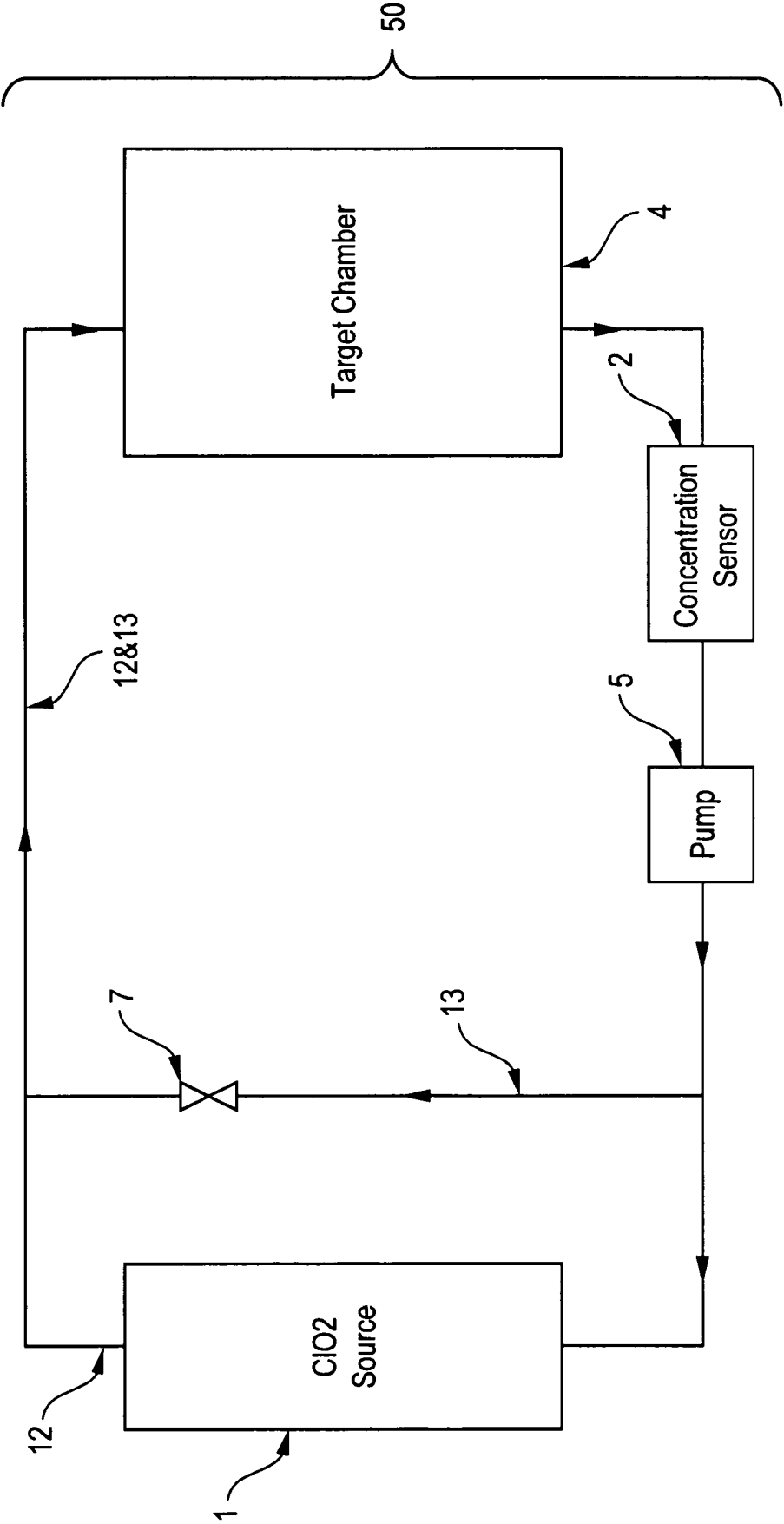


FIG. 3

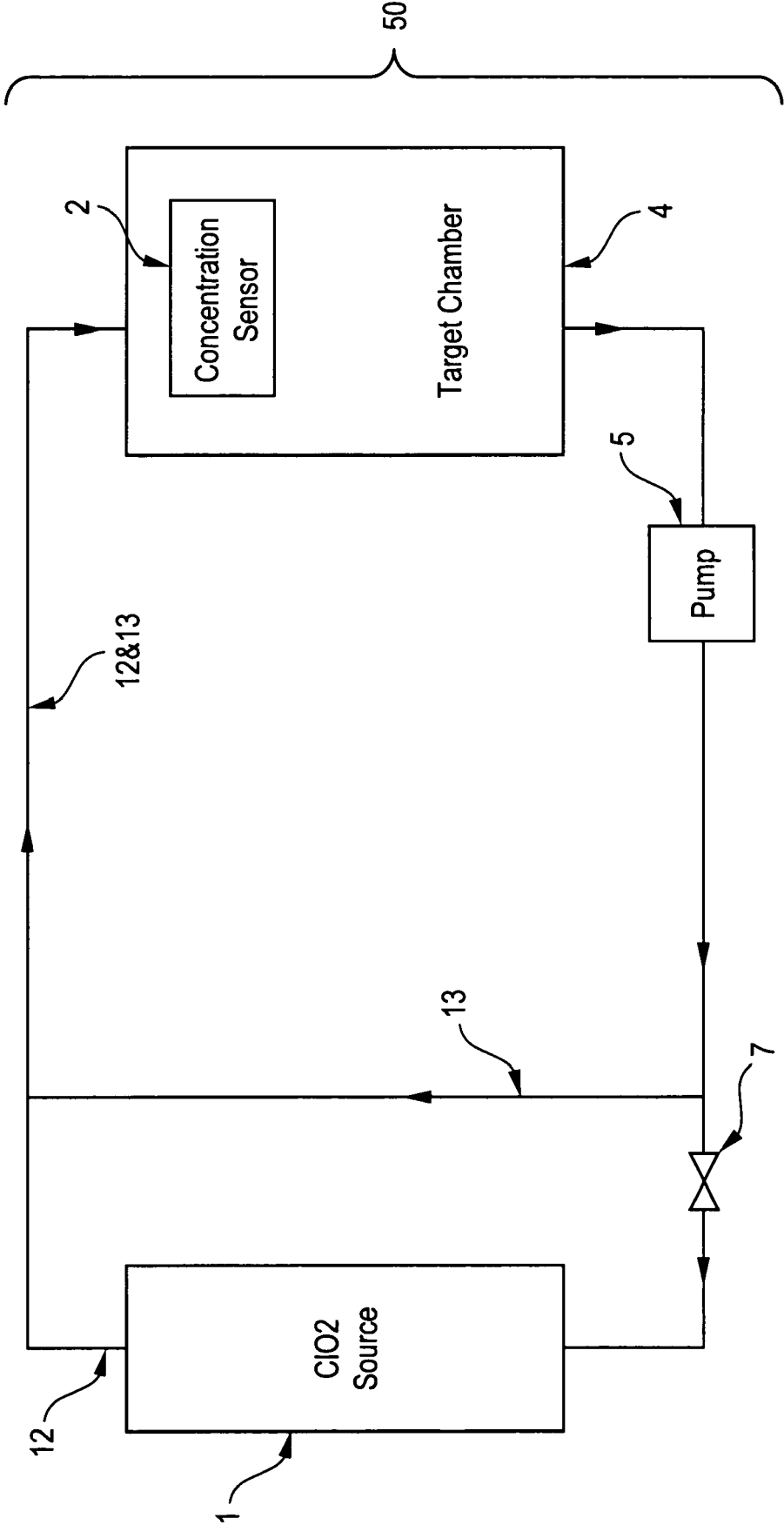


FIG. 4

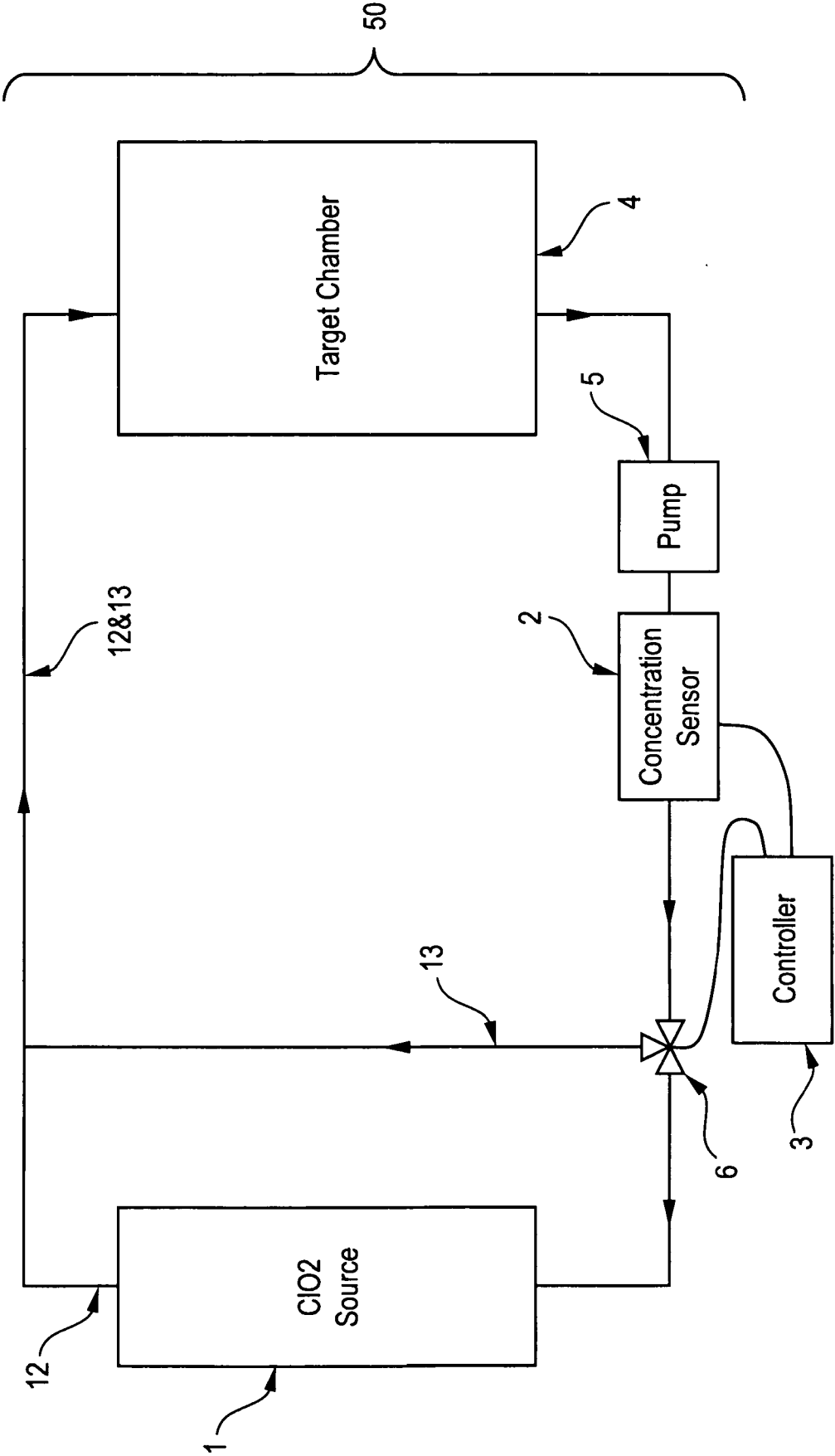


FIG. 5

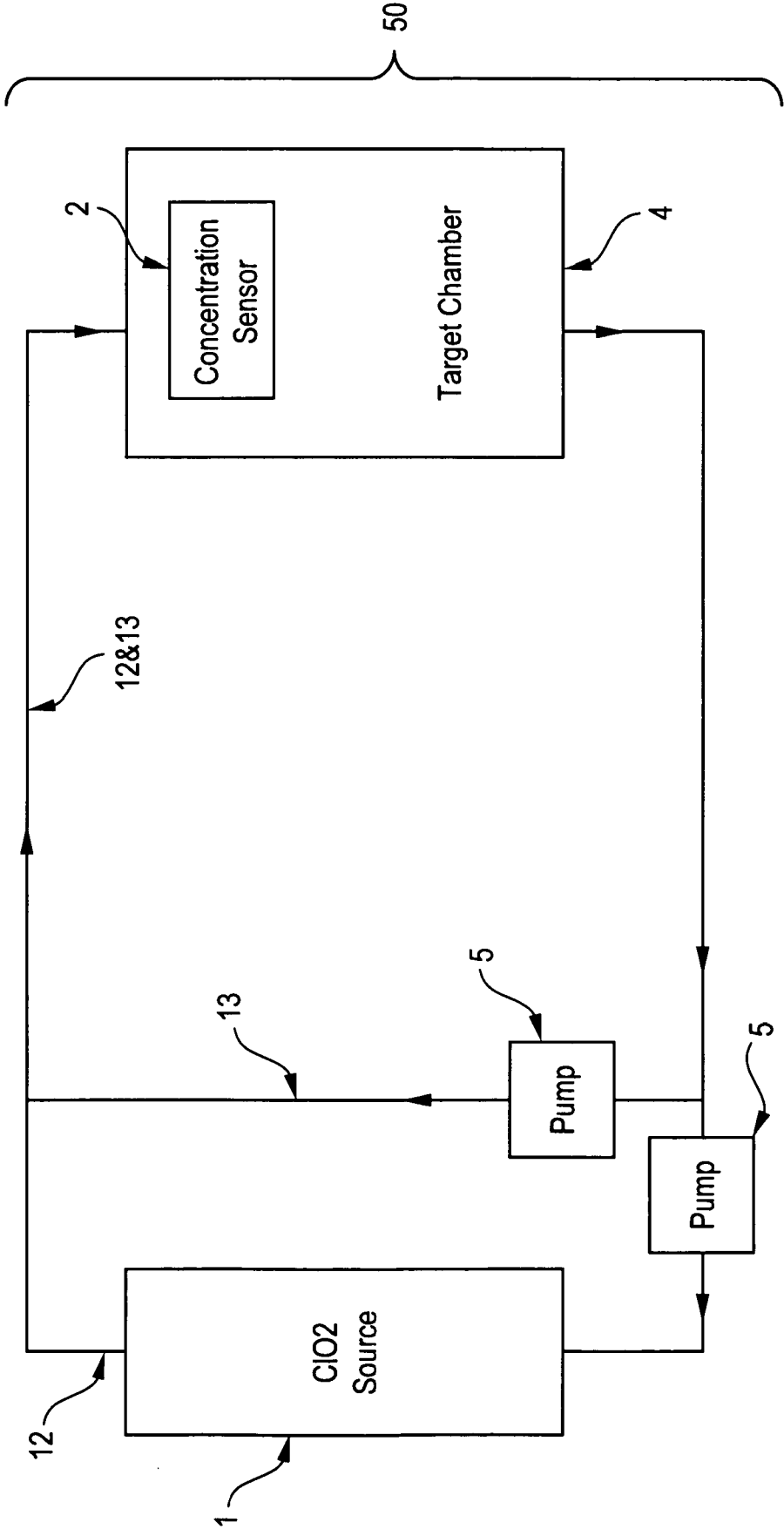
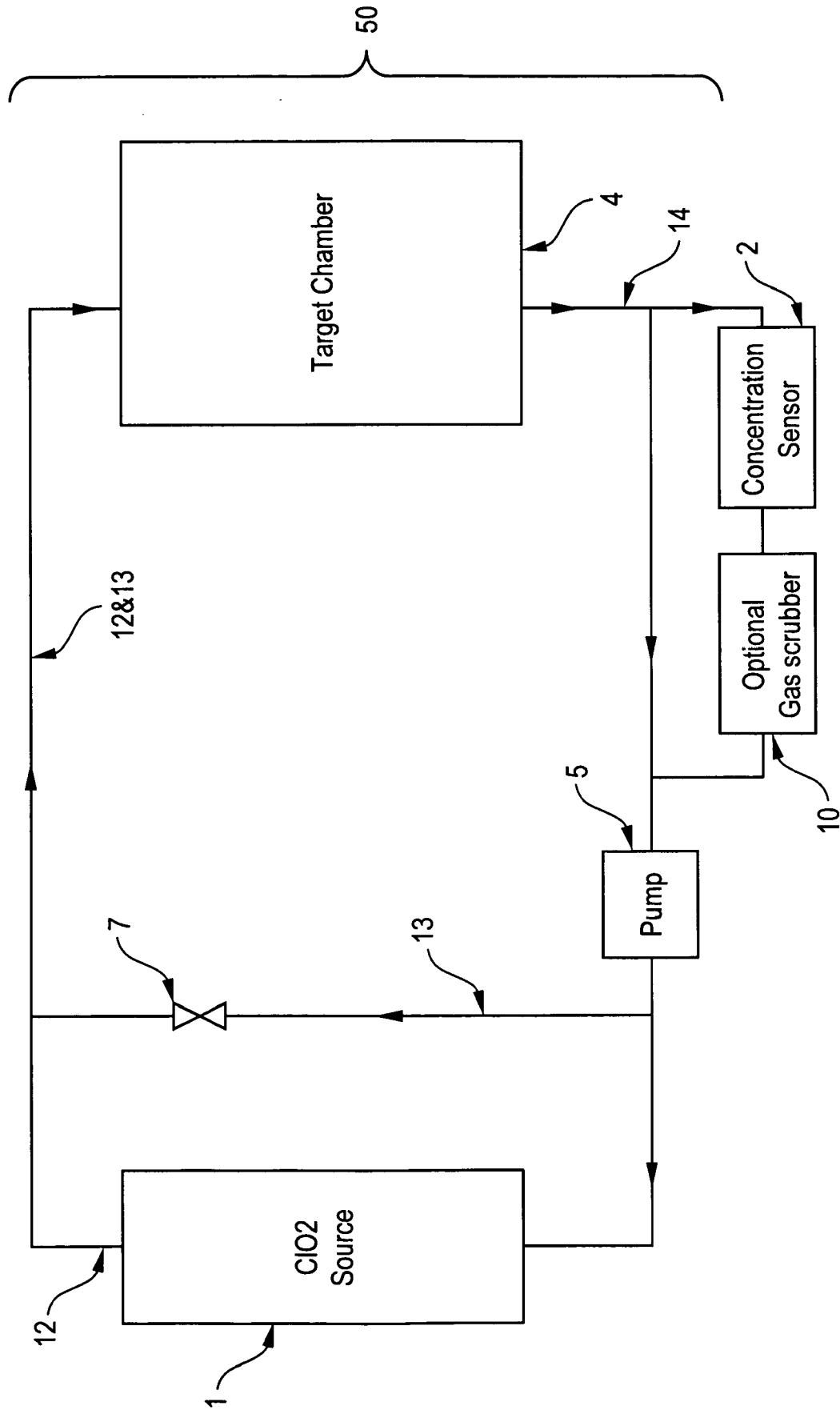


FIG. 6



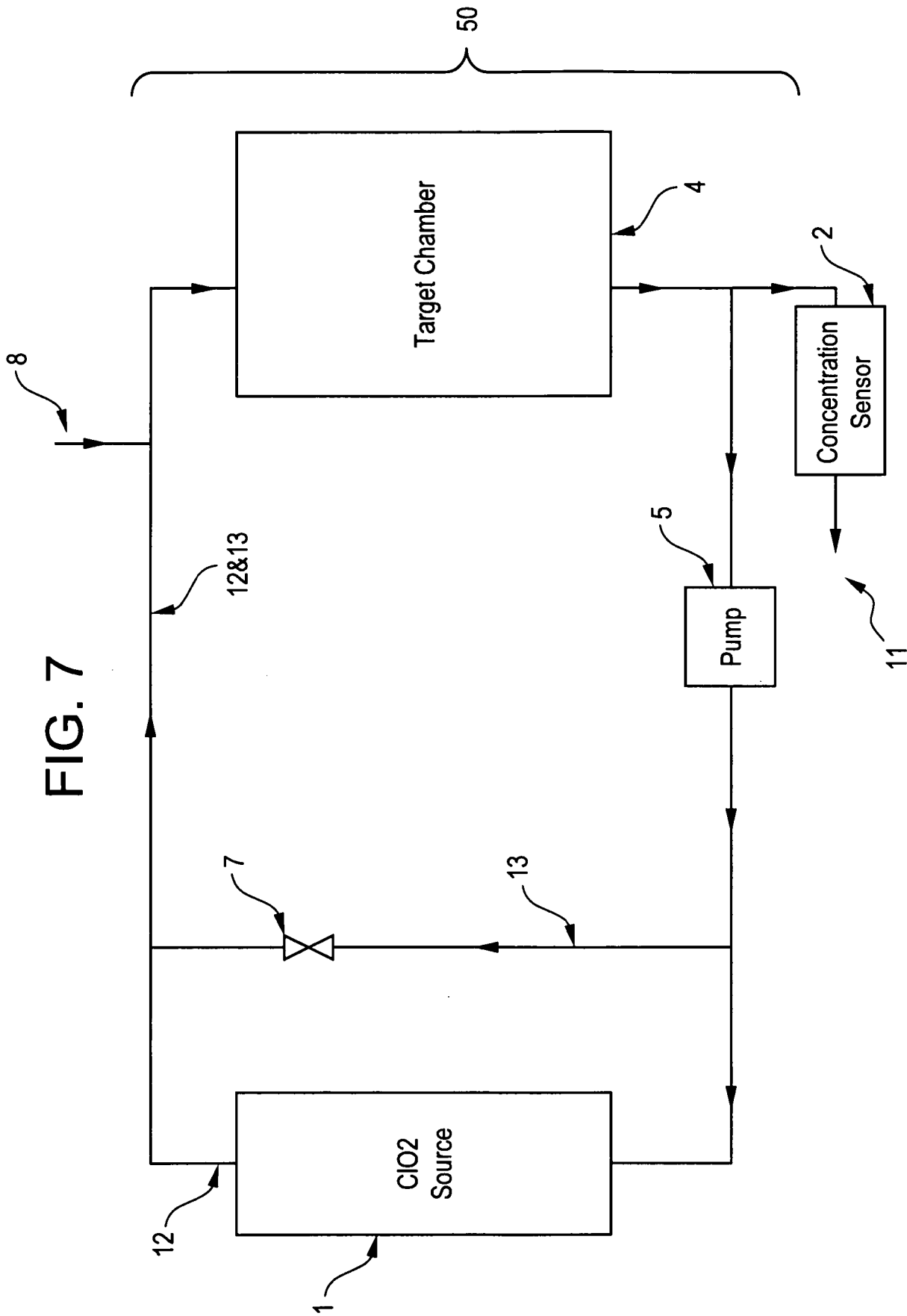


FIG. 8

ClO2 Concentration profile data from a system configured as in figure 2.
Valve is manually controlled to target >900 ppm.

Test #266

