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DESCRIPTION

Description

TECHNICAL FIELD

[0001] The present disclosure relates generally to air-lift pumps and, more particularly, to vertically orientated lift pumps for the recirculation of fluid in aquaculture systems.

BACKGROUND

[0002] Air-lift pumps are self-contained liquid transport devices capable of moving large quantities of water. They are mechanical devices that are usually vertically oriented in the form of a tube or pipe, where the lower portion of the tube is immersed in a liquid medium. The submerged pipe is fitted with an air injection source near the bottom submerged end.

[0003] As water enters the tube from the bottom portion, gas is simultaneously streamed into the liquid. The injection of the gas may be done via a commercial product known as an air-stone. This injection of gas causes the density of the water to drop, which causes the water to rise within the tube. This then enables or draws other water to enter the tube from the bottom end. In other words, the specific gravity of the gas/water mixture lowers, causing the gas/water mixture to rise through the tube and the "heavier" water takes its place at the bottom of the tube before it is also injected with gas. As less-dense water rises in the tube above the water-line level of the tank outside the vertically-oriented tube, it will reach one or more ports where the liquid and gas are ejected.

[0004] There are many parameters that affect the performance of such air lifts, and even slight variations may cause dramatic changes in efficiency.

[0005] An example use of lift pumps is in fish aquaculture. The containment of fish within a tank tends to result in water with an excess concentration of dissolved C02 as compared to the normal concentration of C02 in air. For this scenario, when air is injected into the water via an airlift pump, the water will rise through the pump towards an open ejection port above the water line. As the water is ejected, it will tend to release its excess C02 as it seeks to reach equilibrium with the surrounding ambient air. At equilibrium, both the surrounding air and the total dissolved gas in the water will have generally the same percentage of C02.

[0006] Known airlift pumps are notoriously inefficient. It is not uncommon for an airlift pump to require 3 or more volumes of gas to move 1 volume of water. Due to their inefficiency, they are (relatively) rarely used for applications where it is necessary to lift a liquid or induce the liquid to flow. As a result, their most common use is as a means to adjust the relative dissolved gas concentrations in a liquid.

[0007] US4144841 (A) discloses a device according to the preamble of claim 1. In particular, this document describes a filtration and aeration apparatus which comprises (a) an elongated tubular member which is closed at its lower end, open at the opposite end, and provided at its lower portion with a plurality of passages which extend through the longitudinal wall of the tubular member, and (b) an air delivery means for supplying air to the interior of said tubular member at a point at or slightly below the lowermost level of said passages so that the air is discharged parallel to the length of said tubular member in the interior of said tubular member.

[0008] JP5296646 (B2) describes a stirring device including a stirring tank and an air lift pump. The air lift pump has a rising pipe that is disposed so as to be extended to a liquid surface to open a suction port at a lower section and a delivery port at the upper section, and an air pump that supplies the air to a lower section or the middle of this rising pipe in the stirring tank. The rising pipe includes a plurality of sub-rising pipes that are disposed in parallel.

SUMMARY

[0009] The invention is defined by the independent claim.

[0010] Preferred embodiments are described by the dependent claims.

[0011] This disclosure describes a device for use between an injection port and a mixing chamber within an airlift pump, the device comprising: a planar plate with multiple holes extending therethrough, the holes dimensioned to direct the gas into multiple micro-streams for streaming air from the injection port into the mixing chamber.

[0012] This disclosure also describes an airlift pump comprising:

an injection port for injecting pressurized air into the airlift pump;

a mixing chamber with perforations, the mixing chamber coupled to the injection port for receiving air from the injection port and receiving water through the perforations;

a lift tube fluidly connected to and extending from the mixing chamber;

an ejection port fluidly connected to and extending from the lift tube, the ejection port have a gas discharge aperture and a liquid discharge aperture; and

a gas streaming device positioned between the injection port and the mixing chamber, the gas streaming device having a planar body with multiple holes extending therethrough, the holes being dimensioned to direct the gas into multiple micro-streams for streaming air from the injection port into the mixing chamber.

[0013] Advantages and features of the invention will become evident upon a review of the following detailed description and the appended drawings, the latter being briefly described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Reference will now be made, by way of example, to the accompanying drawings which show an example of the present application, in which:

Figure 1 is a side cross-sectional view of an airlift pump according to an example of the present invention;

Figure 2 is a plan view of a gas streaming device in isolation used in the lift pump of Figure 1;

Figure 3 is an enlarged view of portion A of the disc of Figure 2;

Figure 4 is a sample table explaining the terms and units of the measurement in the subsequent Figures.

Figures 5-22 show testing data when the airlift pump of Figure 1 is used according to Testing Method 1.

Figures 23-26 show testing data when the airlift pump of Figure 1 is used according to Testing Method 2.

[0015] It will be understood that the unit "inch" in the figures corresponds to 2.54cm, while the unit "foot" corresponds to 30.48cm.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENT SHOWN IN THE DRAWINGS

[0016] An example embodiment of an airlift pump 10, a gas streaming device 50 for streaming air into airlift pump 10, and their use will be discussed. Airlift pump 10 will first be described.

Airlift Pump

[0017] As shown in Figure 1, airlift pump 10 generally includes an injection port 12, an injection chamber 14, a mixing chamber 16, a lift tube 18, an ejection port 20, and gas streaming device 50 positioned between injection port 12 and mixing chamber 16.

[0018] Injection port 12 is positioned at one end of airlift pump 10 and is fluidly coupled to an air supply 22 and connected to injection chamber 14. As would be understood by the skilled person, the location and dimension of injection port 12 may vary. For example an airlift pump having a 15.24 cm (6-inch) diameter may have a 5.08 cm (2-inch) diameter injection port to allow a sufficient volume of water to enter airlift pump 10 without a significant pressure drop. In another example, an airlift pump having a 2.04 cm (1-inch) diameter may have a 0.3175 cm (1/8-inch) diameter injection port. As well, injection port 12 may be positioned at the bottom or on a side of one end of airlift pump 10, so long as injection port 12 is located close to the bottom of the tank to maximize lift capacity.

[0019] Injection chamber 14 is, in turn, fluidly connected to mixing chamber 16 with gas streaming device 50 positioned therebetween. As shown, gas streaming device 50 is sealed from the surrounding liquid and is orientated horizontally or laterally between injection chamber 14 and mixing chamber 16. The height of gas streaming device 50 is as small as pre-manufactured parts may permit in order to avoid positioning a large air pocket near the bottom of the tank that may cause the unit to float. The diameter of injection chamber 14 would generally correspond with the diameter of its corresponding airlift pump. For example, a 15.24 cm (6-inch) diameter airlift pump would have a 15.24 cm (6-inch) diameter injection chamber. Mixing chamber 16, as shown, is a cylindrical tube with perforations in its walls 17. The height of mixing chamber 16 may vary, but it is typically, 20.32-30.48 (8-12 inches). This amounts to approximately a 6:1 ratio of airlift pump height to mixing chamber height. In alternative embodiments, however, this ratio may be different for particularly short or long lifts. Since mixing chamber 12 is where the surrounding water/liquid will be drawn into airlift pump 10, in order to maximize circulation, mixing chamber 12 is generally positioned as close to the bottom of the tank as possible.

[0020] The exact size and arrangement of the perforations may vary, in order to keep particulate and organisms out of airlift pump 10. That being said, the perforations typically form at least 60% open space for water or liquid to enter airlift pump 10.

[0021] Lift tube 18 is fluidly connected to, and extends from, mixing chamber 16.

[0022] Ejection port 20 is, in turn, is fluidly connected to and extends from lift tube 18. In this manner, ejection port 20 is positioned at the opposite end of airlift pump 10, opposite injection port 12. Ejection port 20 has a gas discharge aperture 24 orientated parallel to lift tube 18, and a liquid discharge aperture 26 orientated generally perpendicular to lift tube 18. Airlift pump 10 also includes a fluid flow sensor 32 integrated into ejection port 20.

[0023] In the embodiment shown, airlift pump 10 further has a bacterial media 28 suspended within lift tube 18 or attached to the inner wall lift tube 18.

[0024] Whereas specific embodiments of an airlift pump are herein shown and described, variations are possible. In some examples, for gas streaming devices larger than 15.24 cm (6 inches) in diameter, for example, injection chamber 14 may contain a diffuser, a baffle, or other mechanical means to promote uniform flow through the face of gas streaming device 50. The positioning of one or more injection ports 12 may be another mechanical means to promote even flow through gas steaming device 50.

[0025] In other examples, rather than a single gas injection port and injection chamber, airlift pump 10 includes multiple gas injection ports proximate the bottom of lift pump 10, which would be connected with one or more injection chambers.

[0026] In another example, airlift pump 10 would include multiple gas streaming devices, a gas flow control valve and a following flow rate sensor. The gas flow control valve and flow rate sensors would be configured regulate gas flow to the multiple gas streaming devices.

[0027] In another example, another fluid flow sensor would be integrated into lift tube 18.

[0028] In another example, a mechanical apparatus, such as a pump, is integrated with injection port 12 to enable adjustment and control of the gas pressure directed into injection chamber 14.

[0029] In another example, rather than having a circular cross-section throughout airlift pump 10, airlift pump 10 would have components with non- circular cross-sections.

[0030] In yet other examples, the height and/or radius of lift tube 18 may be altered to maximize the removal of gas from the liquid medium. As would be understood by the skilled person, the height and radius of lift tube 18 may be modified to accommodate different tank dimensions and air sources.

[0031] Airlift pump 10 may also be packaged and integrated with a transportable tank containing the liquid medium to be remediated by airlift pump 10.

<u>**Gas Streaming Device**</u>

[0032] Gas streaming device 50 will now be described in detail and is shown in isolation in Figures 2 and 3.

[0033] Gas streaming device 50 comprises a body with multiple holes or perforations 52 having a diameter of 0.35mm. As shown, the body is a circular plate 54 having a first face, an opposed second face, and a perimeter 56.

[0034] Plate 54 is formed from a solid hydrophobic material which can be cleaned and sterilized. Plate 54 has a thickness of 12.7mm.

[0035] Multiple holes 52 extend from the first face to the second face and are evenly spaced throughout plate 54. In particular, multiple holes 52 are spaced 0.55mm, center to center, apart from one another in a grid pattern. Multiple holes 52 are also positioned at least 0.5mm from perimeter 56 of plate 54.

[0036] While not shown in the Figures, multiple holes 52 in plate 54 contain a helical groove pattern, or rifling. In this embodiment, the rifling is orientated at a 30-degree angle with respect to the longitudinal axis of each hole.

[0037] Whereas a specific embodiments of a gas streaming device is herein shown and described, variations are possible. The dimensions of perforations 52 generally do not change relative to the diameter or height of airlift pump 10. However, in some examples, the size and configuration of perforations 52 may vary. For example, the holes or perforations 52 may have diameters generally between 0.2mm-0.4mm.

[0038] In other examples, multiple holes 52 are spaced 0.5mm-0.6mm apart, center to center, from one another in a grid pattern and plate 54 has a thickness between 12-13mm.

[0039] Alternately, multiple holes 52 are unevenly spaced throughout plate 102.

[0040] In other examples, rather than a solid circular plate, the body is composed of packed fiber which may be oriented vertically and/or horizontally to force the gas to flow around the fiber. The fiber would be hydrophobic and packed within perforated plates.

__Use__

[0041] Movement of fluid through the use of airlift pump 10 is indicated by the arrows in Figure 1. The movement of gas is indicated by dashed arrows, while movement of water is indicated by solid arrows. As shown, air lift pump 10 is positioned within a body of water 100 in tank 102 such that injection chamber 14 and mixing chamber 16 are submerged while ejection port 20 is above the water line.

[0042] Pressurized air is injected by air supply 22 through injection port 12 and into injection chamber 14. From there, the air is directed through gas streaming device 50 into mixing chamber 16. Gas streaming device 50 forces the gas or air into multiple streams as it enters mixing chamber 16.

[0043] The diameter and spacing of multiple holes 52 in plate 54 are set to generate, uniform small gas streams at the bottom of the pump that are as vertical as possible so as to provide uniform lift. The helical groove pattern, or rifling, of multiple holes 52 also helps to gyroscopically stabilize the gas flow as it leaves plate 54. These features help to minimize the merging of gas streams and to minimize the leakage of gas out of the perforated walls 17 of mixing chamber 16.

[0044] Plate 54 is also orientated horizontally within airlift pump 10. In this manner, multiple holes 52 are orientated generally parallel with the longitudinal orientation of airlift pump 10, which serves to help ensure the longest possible narrow vertical path for each gas stream as they leave plate 54. The uniformity of the gas streams helps to impart a more uniform lift to the liquid from the gas. A vertical stream is also beneficial to help prevent air streams from merging to form larger bubbles, which would provide less uniform lift.

[0045] As the streams of air enter mixing chamber 16, they mix with the water within mixing chamber 16. This mixing creates a water/air mixture that has a density that is less than the density of the water surrounding mixing chamber 16. Due to its lower density, the water/air mixture rises through lift tube 18 towards ejection port 20.

[0046] The rising of the water/air mixture through lift tube 18 creates a vacuum or suction within mixing chamber 16. This suction simultaneously draws water from tank 102 through perforated walls 17 into mixing chamber 16. This new water, in turn, gets mixed with the entering air streams from gas streaming device 50 and is lifted through lift tube 17.

[0047] As the water/air mixture travels up through lift tube 18, it will also travel past bacterial media 28 which may react with other particles within the water/air mixture. Bacterial media 28 enables bacteria to be used to remediate targeted impurities within the liquid such as ammonia.

[0048] As the water/air mixture reaches ejection port 20 above the water line, if the water/air mixture has a high concentration of a gas, such as CO_2, it will tend to release its excess CO_2 or other gas as it seeks to reach equilibrium with the surrounding ambient air via osmosis through gas discharge aperture 24 (and possibly through liquid discharge aperture 26). The water component would then be ejected through liquid discharge aperture 26 to return to tank 102 or to be directed to another location.

[0049] As noted above, the height and/or radius of lift tube 18 is adjusted to accommodate the depth of the surrounding liquid medium and the desired lift of the liquid medium by the pump above the water line.

Combined Use

[0050] Airlift pump 10 may be used simultaneously with one or more saturator systems in a body of water. Saturator systems are configured to conduct a gas exchange with an aqueous-phase liquid inline with the same body of water.

[0051] In particular, the saturator systems are adapted to dissolve oxygen into the water and remove carbon dioxide, such that the overall gas pressure within the fluid is relatively unchanged. An example of such a saturator system is disclosed in US 62/610,675. Each saturator system uses one or more gas infusion devices to dissolve oxygen into the water.

[0052] Each gas infusion device has a fibre module array situated between its ends where the fibre module array is made up of a polymer coated microporous fiber material. An example of such a gas infusion device is found in US7537200, to Glassford, October 31, 2003.

[0053] Used together in this manner, the saturator system oxygenates the body of water and removes carbon dioxide, while the one or more airlift pumps 10 also remove the dissolved CO_2 and remediates the ammonia to form nitrate.

[0054] Such a combined system may further include one or more oxygen tanks connected to the saturator system for supplying oxygen to the saturator system, and a compressor coupled to airlift pumps 10 to supply ambient air to generate the lift.

[0055] Such a system may also have a gas regulator operatively coupled between the oxygen tanks and the saturator system to regulate the flow of gas into the saturator system, a dissolved oxygen sensor positioned within the body of water, a saturator feed pump in fluid communication with the body of water, adapted to draw and direct water from the body of water into the saturator system, and an ammonia sensor positioned within the body of water.

[0056] A control and monitoring system may be in place to communicate with, control and coordinate each of the above components. For example, the compressor can be activated to engage airlift pumps 10 in response to the detected concentration of ammonia rising above a maximum level. The compressor may then be disengaged to deactivate airlift pumps 10 in response to the detected concentration of ammonia falling below a minimum level. In a similar manner, the gas regulator and the saturator feed pump may be activated and controlled in response to the detected concentration of oxygen falling below a minimum level. The gas regulator and the saturator feed pump may also be deactivated accordingly.

[0057] An advantage of the use of the present gas streaming device 50 in airlift pump 10 is that it is able to lift 3 or more unit volumes of liquid using only one unit volume of gas the same distance as a conventional lift pump. The increased efficiency may also enable airlift pump 10 to be economic in other applications where it is desirable to lift a liquid or induce flow.

[0058] The following tests were conducted to demonstrate this benefit.

Test Method 1

[0059] The tests were conducted using:

- Tank of water

- Source of air (pressure dependent)
- CO_2 source
- Method of CO_2 dissolution
- Airlift pump 10
- Measuring equipment (CO2, temperature, Salinity, pressure, Air flow, water flow)

[0060] CO_2 was first dissolved into a body of water to the desired level in the tank using any method known in the art. Airlift pump 10 was attached to an air source with a measurable flow, and then inserted into the body of water in the tank, ensuring that ejection port 20 was above the water line, noting that the exact location would depend on the airlift pump unit.

[0061] Air is then supplied to airlift pump 10 and the air pressure within injection chamber 14 underneath gas streaming device 10 is measured to determine actual air flow.

[0062] CO_2 levels in the tank were recorded over the course of the experiment. The CO_2 levels in the tank naturally will not be homogeneous, so it was assumed that the highest CO_2 level in the tank was at the vacuum or suction area within mixing chamber 16 and the lowest CO_2 level was at liquid discharge aperture 26. An average of these two values was used to be representative of the whole tank.

[0063] The flow of water out of liquid discharge aperture 26 was measured along with the temperature and salinity of the water within the tank. These measurements were used to create a profile of the tank concentration of CO2 over time, as well as the efficiency of airlift pump 10 (using the known amount of water leaving liquid discharge aperture 26 and the concentration in the tank. The instantaneous rate of change in CO_2 (amount removed at any given concentration) was determined by taking the derivative of the concentration over time.

<u>Test Method 2</u>

[0064] A second test method (Test Method 2), largely similar to Test Method 1, was used in situations where it was not possible to measure the water flow out of the airlift pump 10. This method involved continuously adding a known quantity of CO_2 to the tank while airlift pump 10 was in operation until equilibrium was achieved (i.e. the point at which the CO_2 being added was equal to the CO2 being removed). By determining the concentration at both the top and bottom of the airlift pump 10, the flowrate of water was calculated.

[0065] The overall results are illustrated in Figures 4 to 26.

[0066] Figure 4 is a sample table explaining the terms and units of measurement in the tables of Figures 5 to 26.

[0067] In Figures 5-14, the first graph in each Figure shows the decrease in CO_2 levels over the course of the trial (using Test Method 1). The second graph in each Figure shows the calculated rate of change in CO_2 for any concentration using the airlift pump at the parameters specified in the corresponding table. Each corresponding table shows all the fixed settings for the particular trial as well as the calculated liquid to gas ratio and the calculated percent removal.

[0068] In Figures 15 to 17, the first graph in each Figure shows the decrease in CO_2 levels over the course of the trial measurements, which were taken at both the top and bottom of the lift (using Test Method 1). The second graph in each Figure shows the calculated rate of change in CO2 for any concentration using the lift at the parameters specified in the corresponding table. Each table shows all the fixed the settings for the respective trial as well as the calculated liquid to gas ratio and the calculated percent removal.

[0069] In Figure 18, the first graph shows the decrease in CO2 levels over the course of the trial (using Test Method 1). The second graph shows the calculated rate of change in CO2 for any concentration using the lift at the parameters specified in the table. The table shows all the fixed settings for the trial as well as the calculated liquid to gas ratio and the calculated percent removal.

[0070] In Figure 19, the first graph shows the decrease in CO2 levels over the course of the trial (using Test Method 1). This is a comparison of the old and new disc (or gas streaming device) styles and shows little difference in performance at the given levels.

[0071] The old disc style was a "disc" that consisted of numerous hydrophobic hollow fibers held in place with epoxy to generate a similar effect as gas streaming device 50. However, the holes in the old disc were not always uniform or strait, or even always open, which naturally caused a drop in the efficiency and quality of gas diffusion.

[0072] The second graph shows the calculated rate of change in CO2 for any concentration using the airlift pump at the parameters specified in the table. The table shows all the fixed the settings for the trial as well as the calculated liquid to gas ratio and the calculated percent removal.

[0073] In Figures 20 to 22, the first graph in each Figure shows the decrease in CO_2 levels over the course of the trial (using Test Method 1). The second graph in each Figure shows the calculated rate of change in CO_2 for any concentration using the lift at the parameters specified in the table. The table shows all the fixed settings for the trial as well as the calculated liquid to gas ratio and the calculated percent removal.

[0074] In Figures 23 to 26, each table is representative of a trial (using Test Method 2) and shows all the fixed settings as well as the calculated water flow rate, the calculated liquid to gas ratio and the calculated percent removal rate.

[0075] As shown in Figures 5-14, 18-9, which used Disc type 1, the data generally demonstrates that airlift pump 10 works in various conditions and setups. Disc type 1 is gas streaming device 50 that is composed of packed fiber which may be oriented vertically and/or horizontally to force the gas to flow around the fiber.

[0076] As shown in Figures 15-17, 19-22, which used Disc type 2, the data generally shows that, while similar to the results for Disc type 1, there is a small improvement in efficiency at a lower pressure. Disc type 2 is the first printed disc with the same nominal dimension and spacing as the fiber disc of Disc Type 1.

[0077] Figures 23-26 illustrate data generated when using Disc types 3, 4, and 5. The hole and spacing sizes of Disc types 3-5 are smaller than that of Disc type 2. In particular, for Disk type 3, the holes were between 0.3 and 0.4 mm and the pinch was between 0.45 and 0.55mm. For Disk type 4, the holes were between 0.15 and 0.25 mm and the pinch was between 0.35 and 0.45mm. For Disk type 5, the holes were between 0.175 and 0.225 mm and the pinch was between 0.25 and 0.35 mm.

[0078] The data indicates that the smaller holes with smaller spacing produces better results at lower pressures, since smaller bubbles are produced and the overall area of open space increases.

[0079] Accordingly, it is shown that embodiments of the present invention are able to lift 3 or more unit volumes of liquid using only one unit volume of gas the same distance as a conventional lift pump.

[0080] Whereas a specific embodiment of the method is herein shown and described, variations are possible.

[0081] Accordingly, the invention should be understood to be limited only by the accompanying claims.

REFERENCES CITED IN THE DESCRIPTION

Cited references

liability in this regard.

Patent documents cited in the description

- US4144841A [0007]
- JP5296646B [0008]
- US62610675B [0051]
- US7537200B [0052]

HØJEFFEKTIV MAMMUTPUMPE

PATENTKRAV

1. Gasstrømningsindretning (50) til anvendelse mellem en injektionsport (12) og et blandekammer (16) inden i en mammutpumpe (10), hvilken indretning (50) omfatter:

en plan krop (50) såsom en plade, hvor den plane krop med multiple huller (52) strækker sig derigennem, idet hullerne er dimensioneret til at lede gassen ind i multiple strømme til strømning af gassen fra injektionsporten (12) ind i blandekammeret (16),

kendetegnet ved, at

hullerne (52) i kroppen (50) indeholder et spiralformet rillemønster med henblik på gyroskopisk at stabilisere gasstrømmen, efterhånden som den forlader kroppen (50).

2. Gasstrømningsindretning (50) ifølge krav 1, hvor de multiple huller (52) er jævnt fordelt i hele kroppen (50).

3. Gasstrømningsindretning (50) ifølge krav 1, hvor de multiple huller (52) er ujævnt fordelt i hele kroppen (50).

4. Gasstrømningsindretning (50) ifølge et hvilket som helst af de foregående krav, hvor den plane krop (50) er en plade med en første flade og en anden flade, og hullerne (52) strækker sig fra den første flade til den anden flade.

5. Gasstrømningsindretning ifølge et hvilket som helst af de foregående krav, hvor de multiple huller (52) har diametre mellem 0,3 mm og 0,4 mm.

6. Gasstrømningsindretning (50) ifølge et hvilket som helst af kravene 1 til 4, hvor de multiple huller (52) har diametre mellem 0,15 og 0,25 mm.

7. Gasstrømningsindretning (50) ifølge et hvilket som helst af de foregående krav, hvor hullerne (52) er placeret fra hinanden med en afstand på 0,5 mm-0,6 mm fra midte til midte i et gittermønster.

8. Gasstrømningsindretning (50) ifølge et hvilket som helst af de foregående krav, hvor hullerne (52) er positioneret mindst 0,5 mm fra en perimeter af kroppen.

9. Gasstrømningsindretning (50) ifølge et hvilket som helst af de foregående krav, hvor

kroppen er en plade, der har en tykkelse mellem 12 og 13 mm.

10. Gasstrømningsindretning (50) ifølge et hvilket som helst af de foregående krav, hvor det spiralformede rillemønster i hullerne (52) er orienteret i en vinkel på 30 grader i forhold til hullets (52) længdeakse.

11. Gasstrømningsindretning (50) ifølge et hvilket som helst af de foregående krav, hvor kroppen består af pakket fiber.

12. Gasstrømningsindretning (50) ifølge krav 11, hvor den pakkede fiber er orienteret vertikalt med henblik på at tvinge gassen til at strømme omkring fiberen.

13. Gasstrømningsindretning (50) ifølge krav 11, hvor den pakkede fiber er orienteret horisontalt med henblik på at tvinge gassen til at strømme omkring fiberen.

14. Gasstrømningsindretning (50) ifølge et hvilket som helst af kravene 1 til 10, hvor kroppen omfatter en trykt skive.

15. Mammutpumpe (10), der omfatter:

en injektionsport (12) til injicering af trykluft ind i mammutpumpen (10);

et blandekammer (16) med perforeringer, hvor blandekammeret (16) er koblet til injektionsporten (12) til modtagelse af luft fra injektionsporten (12) og modtagelse af vand igennem perforeringerne;

et løfterør (18), der er fluidforbundet med og strækker sig fra blandekammeret (16);

en udstødningsport (20), der er fluidforbundet med og strækker sig fra løfterøret (18), hvor udstødningsporten (20) har en gasudtømningsåbning (24) og en væskeudtømningsåbning (26); og

en gasstrømningsindretning (50) ifølge et hvilket som helst af de foregående krav, hvor gasstrømningsindretningen (50) er positioneret mellem injektionsporten (12) og blandekammeret (16).

DRAWINGS

Drawing

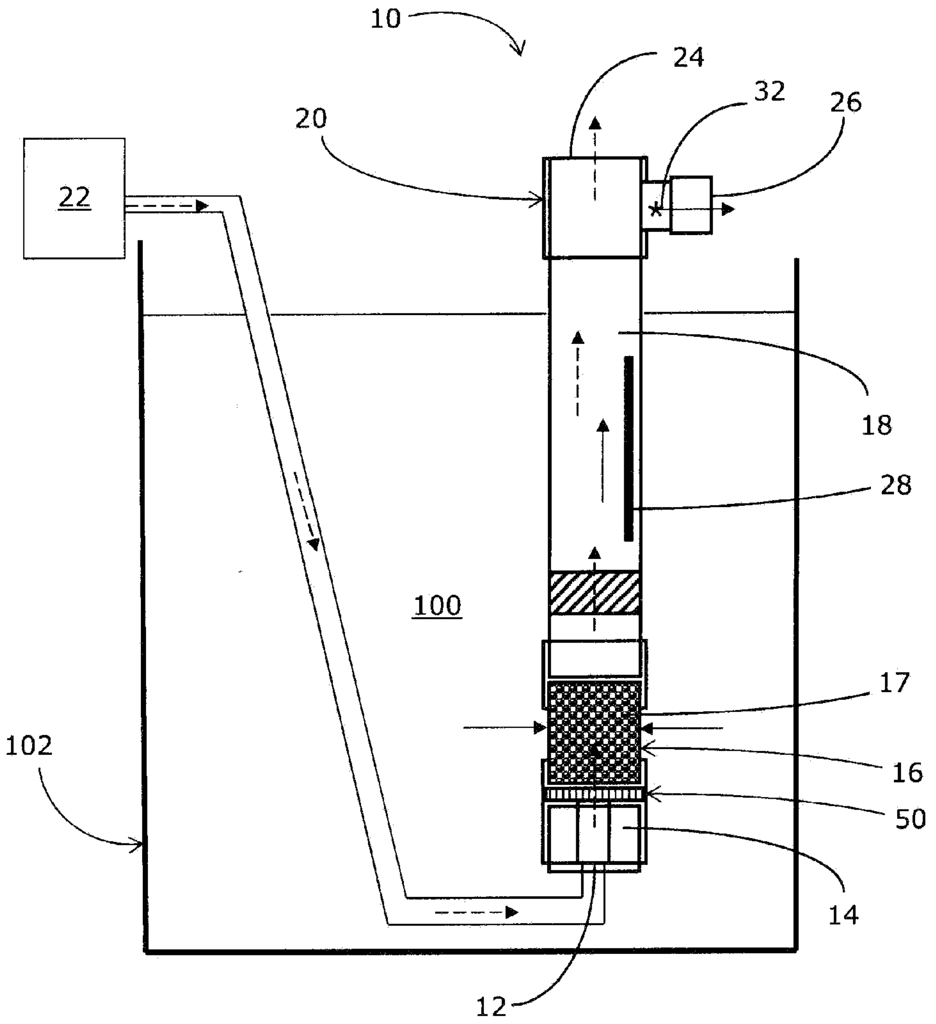


FIGURE 1

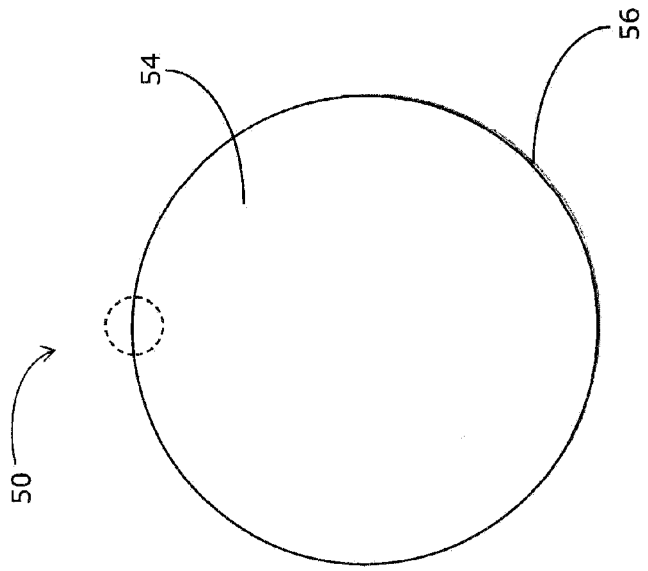


FIGURE 2

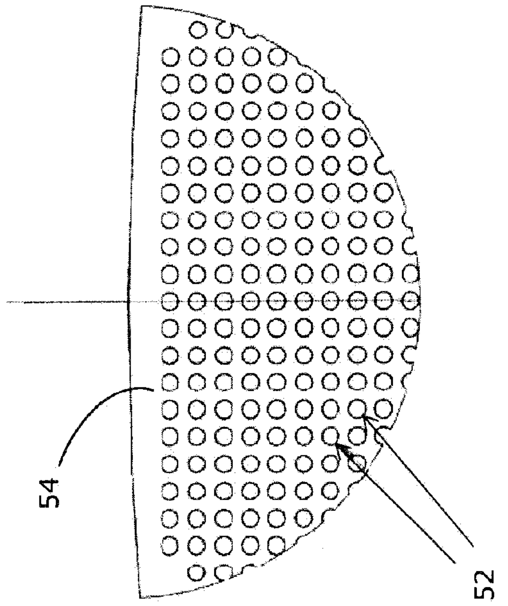


FIGURE 3

FIGURE 4

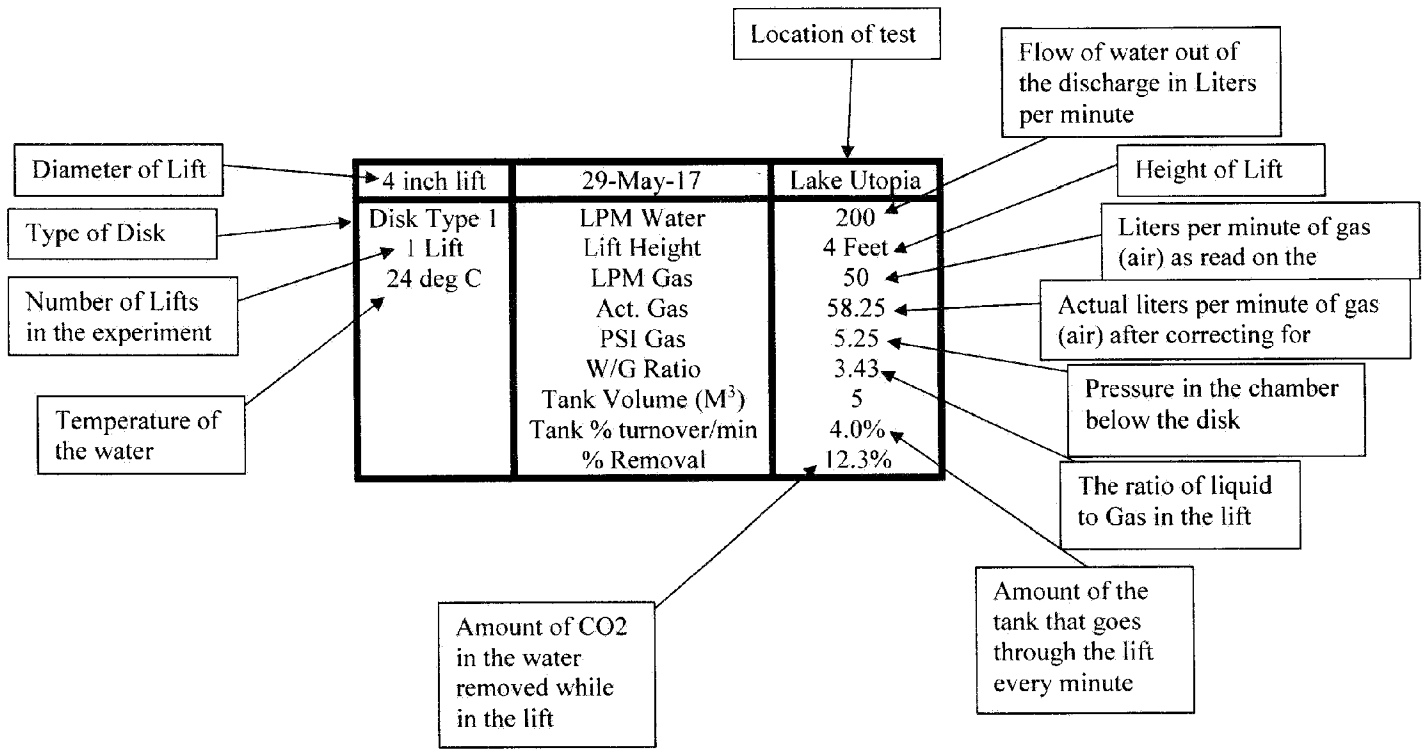
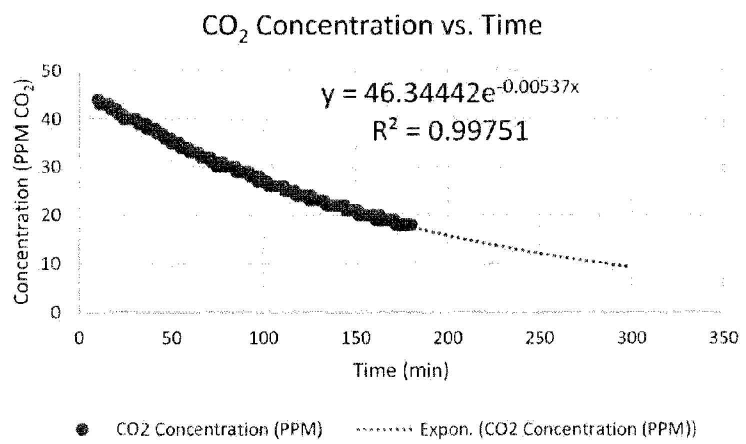
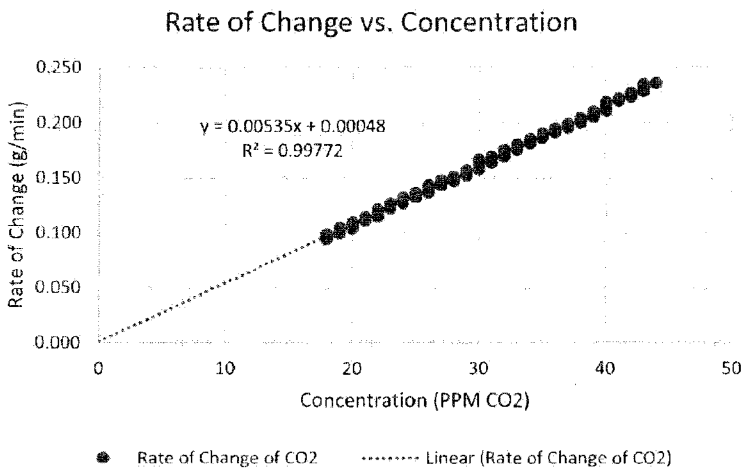

Location of test
Flow of water out of the discharge in Liters per minute
Diameter of Lift
Height of Lift
Type of Disk
Liters per minute of gas (air) as read on the
Number of Lifts in the experiment
Actual liters per minute of gas (air) after correcting for
Temperature of the water
Pressure in the chamber below the disk
The ratio of liquid to Gas in the lift
Amount of the tank that goes through the lift every minute
Amount of CO2 in the water removed while in the lift
4 inch lift
29-May-17
Lake Utopia
Disk Type 1
1 Lift
24 deg C
LPM Water
Lift Height
LPM Gas
Act. Gas
PSI Gas
W/G Ratio
Tank Volume (M3)
Tank % turnover/min
% Removal
200
4 Feet
50
58.25
5.25
3.43
5
4.0%
12.3%

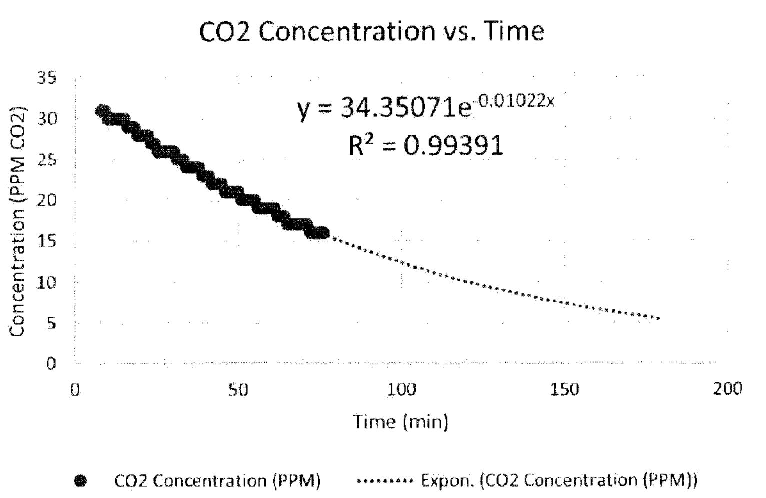
FIGURE 5

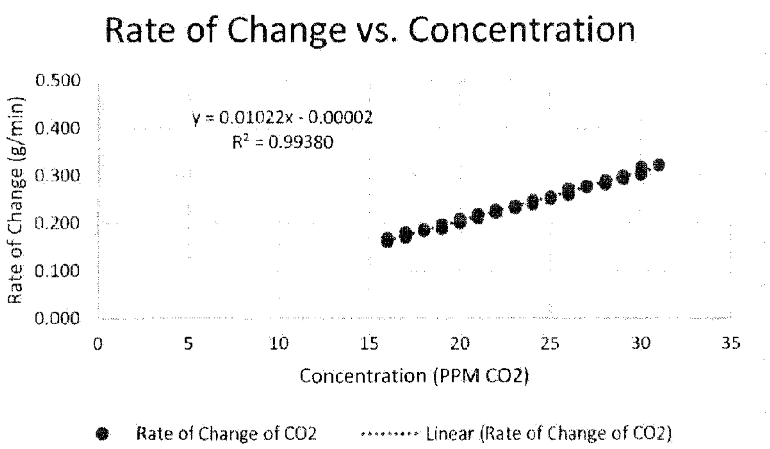




4 inch lift	29-May-17	Lake Utopia
Disk Type 1	LPM Water	200
1 Lift	Lift Hight	4 Feet
10 deg C	LPM Gas	50
	Act. Gas	58.25
	PSI Gas	5.25
	W/G Ratio	3.43
	Tank Volume (M^3)	5
	Tank % turnover/min	4.0%
	% Removal	12.3%

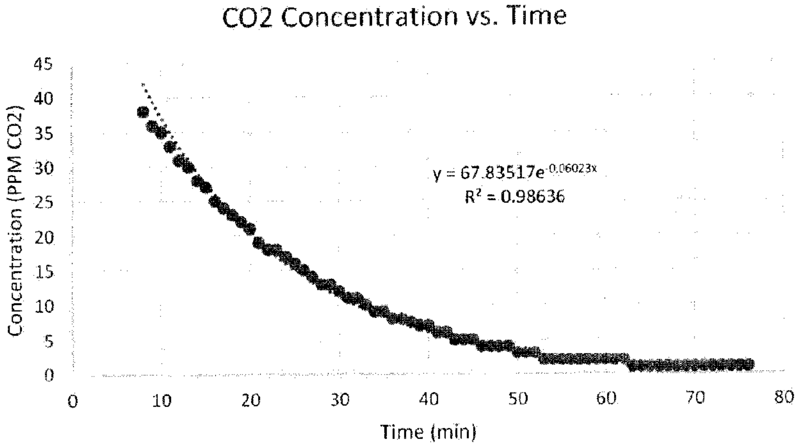
FIGURE 6

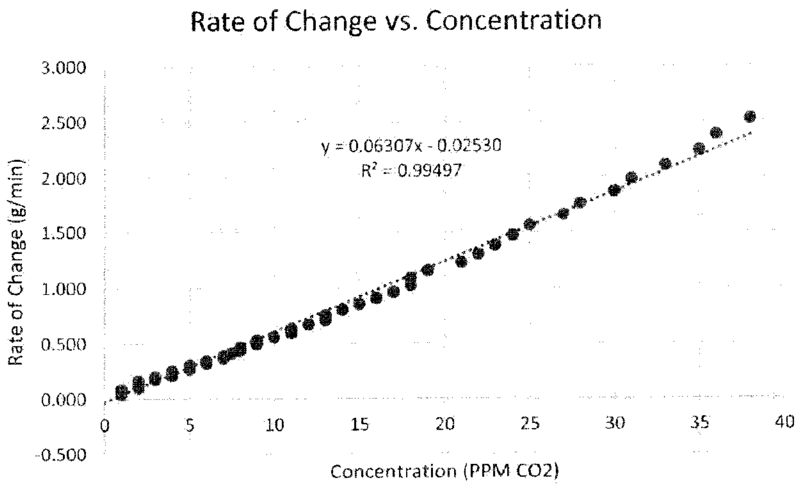




4 inch lift	1-Jun-17	Lake Utopia
Disk Type 1	LPM Water	300
1 Lift	Lift Hight	4 Feet
15 deg C	LPM Gas	80
	Act. Gas	101.7934416
	PSI Gas	9.1
	W/G Ratio	2.94714468
	Tank Volume (M^3)	5
	Tank % turnover/min	6.0%
	% Removal	16.2%

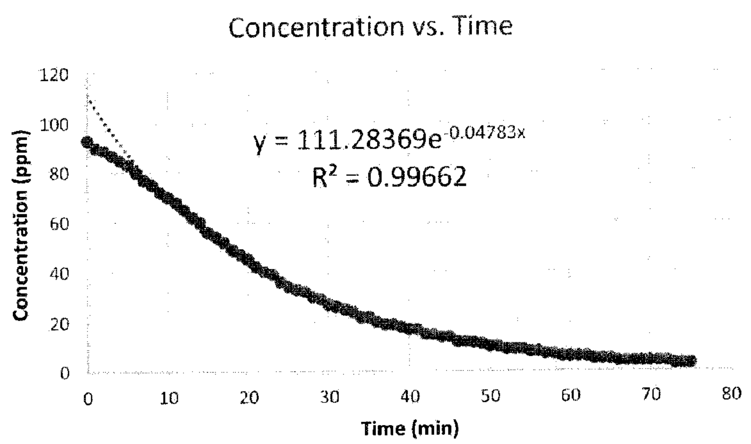
FIGURE 7

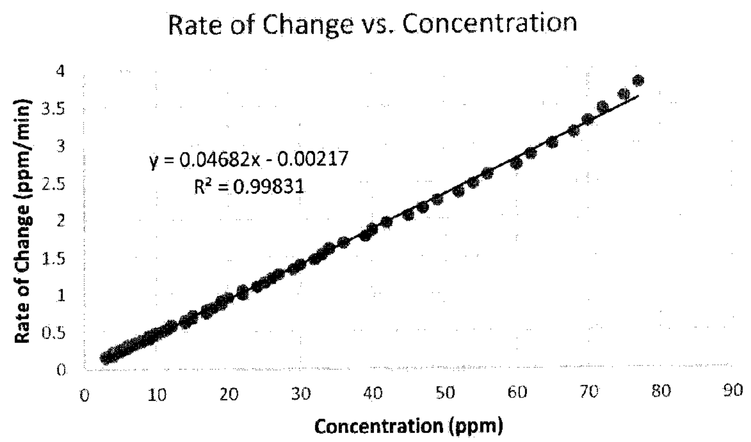




4 inch lift	18-May-17	Huntsman
Disk Type 1	LPM Water	400
2 Lift	Lift Hight	3 Feet
10 deg C	LPM Gas	100
	Act. Gas	109.7306535
	PSI Gas	3
	W/G Ratio	3.645289507
	Tank volume (M^3)	0.3
	Tank % turnover/min	133.3%
	% Removal	18.3%

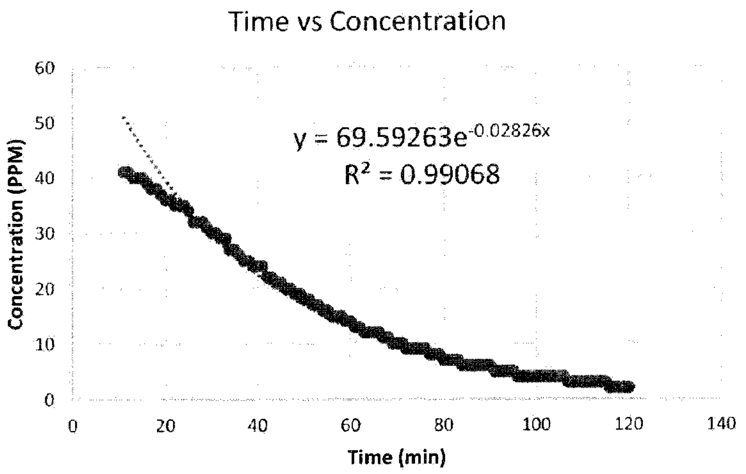
FIGURE 8

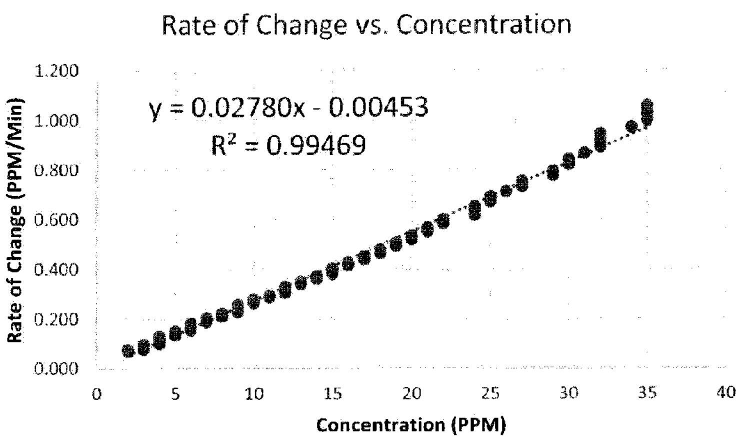




4 inch lift	17-May-17	inVentures
Disk Type 1	LPM Water	200
3 Lifts	Lift Hight	4 feet
12 deg C	LPM Gas	116
	Act. Gas	127.2875581
	PSI Gas	3
	W/G Ratio	1.571245477
	Tank volume (M^3)	0.8
	Tank % turnover/min	25%
	% Removal	18.4%

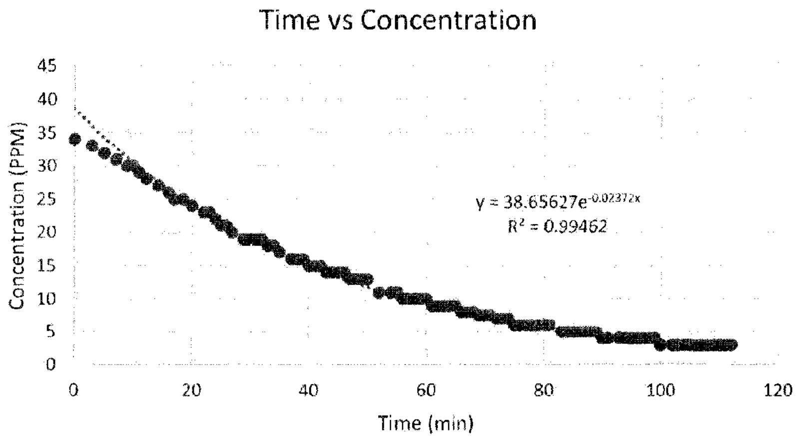
FIGURE 9

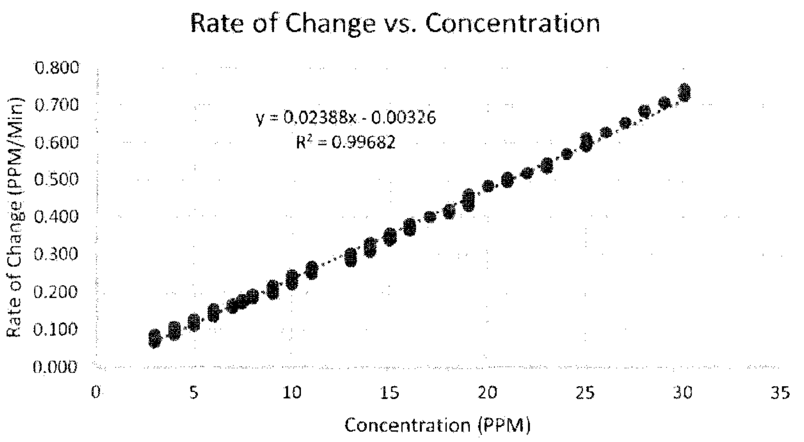




4 inch lift	17-May-17	inVentures
Disk Type 1	LPM Water	80
1 Lift	Lift Hight	3 Feet
13 deg C	LPM Gas	40
	Act. Gas	43.9
	PSI Gas	3
	W/G Ratio	1.82
	Tank volume (M^3)	0.8
	Tank % turnover/min	10%
	% Removal	25.8%

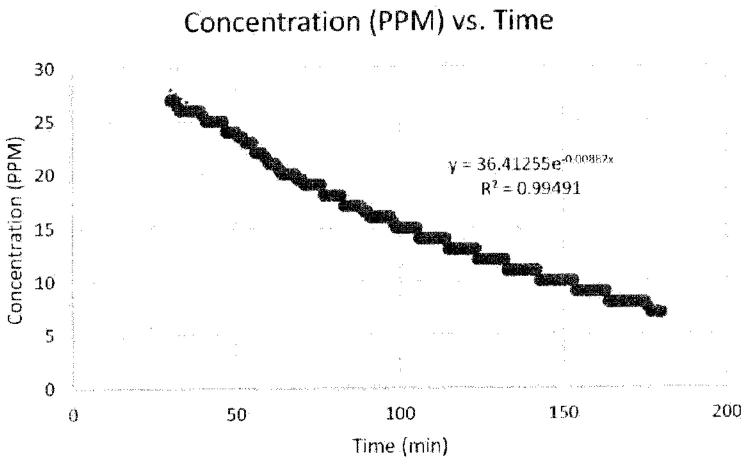
FIGURE 10

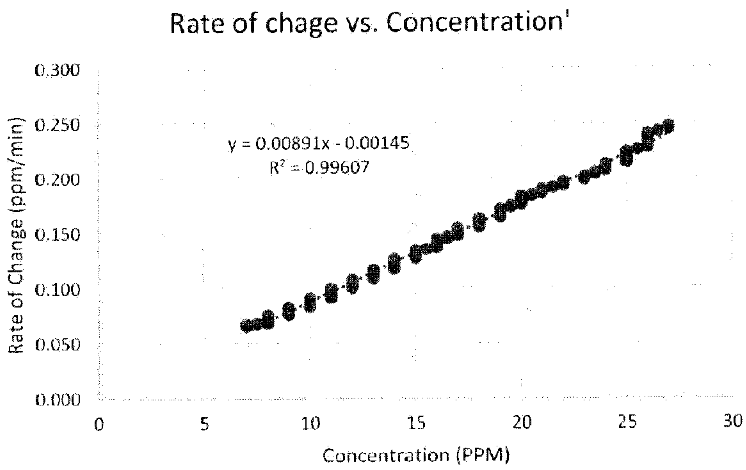




4 inch lift	18-May-17	Huntsman
Disk Type 1	LPM Water	160
1 Lift	Lift Hight	3 Feet
15 deg C	LPM Gas	80
	Act. Gas	87.8
	PSI Gas	8
	W/G Ratio	1.82
	Tank volume (M^3)	1.6
	Tank % turnover/min	10.0%
	% Removal	16.9%

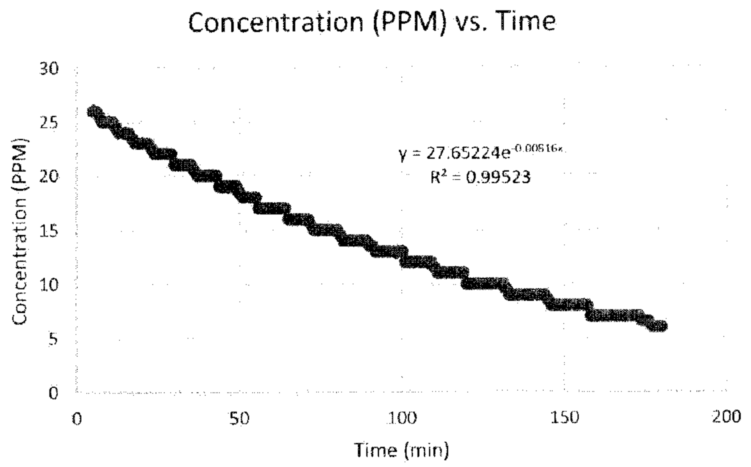
FIGURE 11

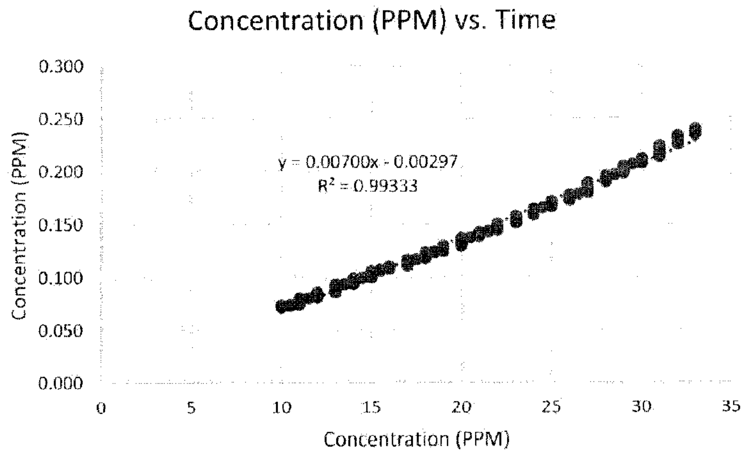




4 inch lift	24-Jul-17	Huntsman
Disk Type 1	LPM Water	300
1 Lift	Lift Hight	6 Feet
14 deg C	LPM Gas	80
	Act. Gas	99.4
	PSI Gas	8
	Tank size (M^3)	8.5
	W/G Ratio	3.02
	Tank % turnover/min	3.5%
	% Removal	20.8%

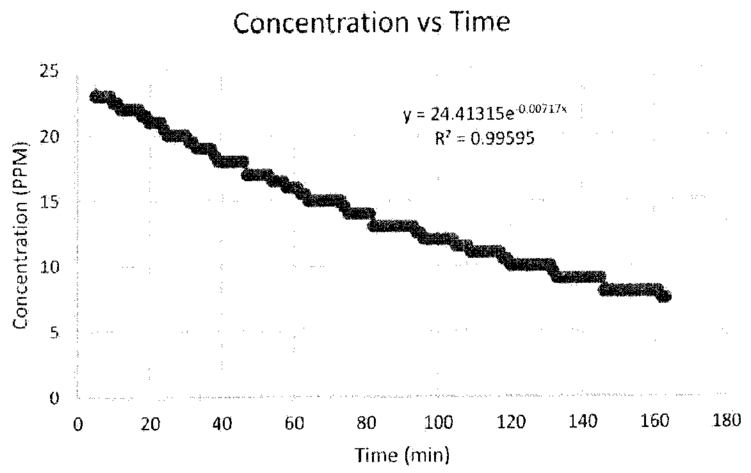
FIGURE 12

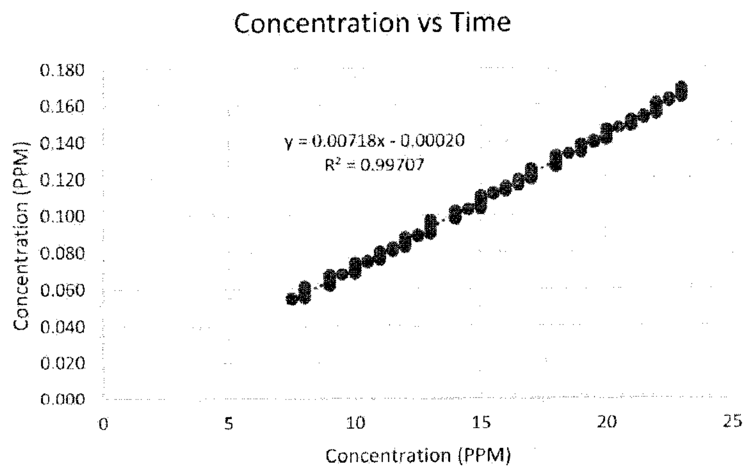




4 inch lift	25-Jul-17	Huntsman
Disk Type 1	LPM Water	300
1 Lift	Lift Hight	6 Feet
16 deg C	LPM Gas	80
	Act. Gas	87.8
	PSI Gas	8
	Tank size (M^3)	8.8
	W/G Ratio	3.42
	Tank % turnover/min	3.7%
	% Removal	19.7%

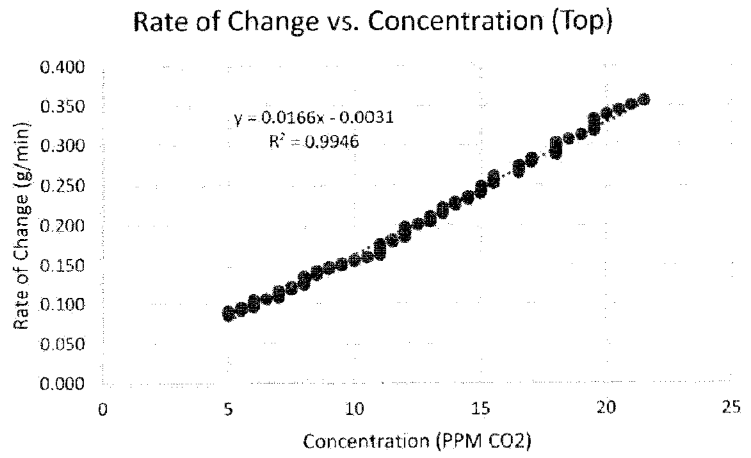
FIGURE 13

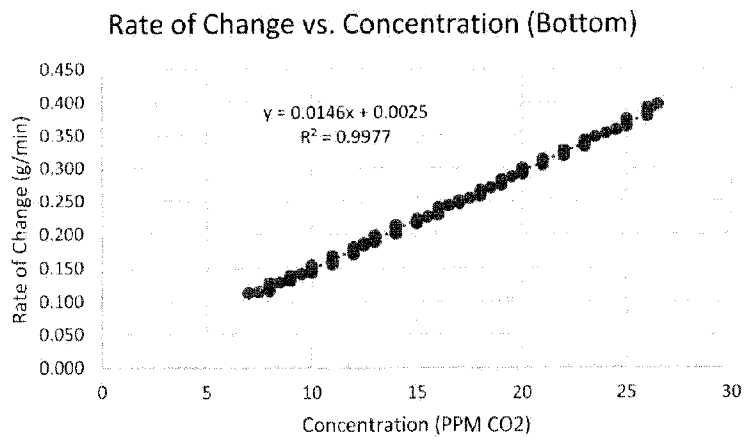




4 inch lift	4-Aug-17	Huntsman
Disk Type 1	LPM Water	236
1 Lift	Lift Hight	6 Feet
16 deg C	LPM Gas	80
	Act. Gas	87.8
	PSI Gas	8
	Tank size (M^3)	8.8
	W/G Ratio	2.69
	Tank % turnover/min	2.7%
	% Removal	22.9%

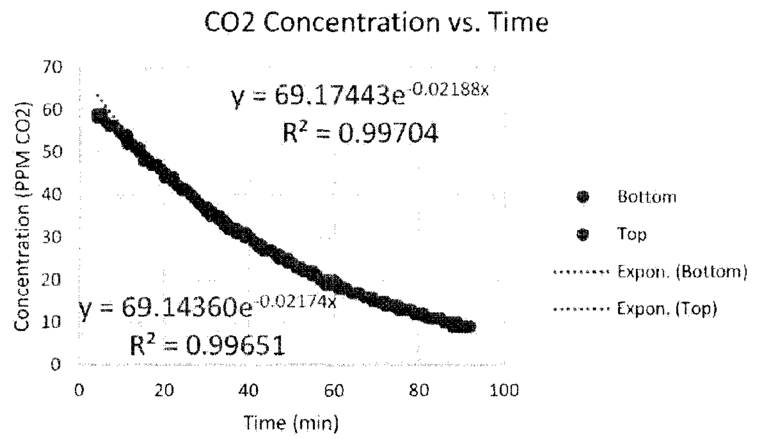
FIGURE 14

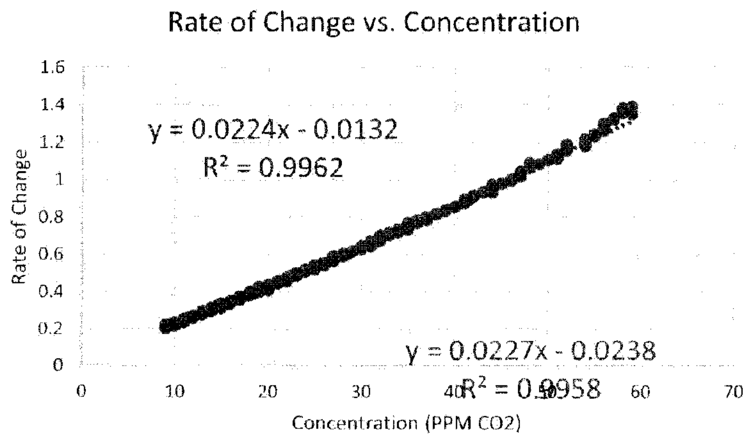




6 inch lift	30/8/2017	Huntsman
Disk Type I	LPM Water	600
1 Lift	Lift Hight	6 Feet
16 deg C	LPM Gas	210
	Act. Gas	230.4
	PSI Gas	3
	Tank size (M^3)	8.8
	W/G Ratio	2.60
	Tank % turnover/min	6.8%
	% Removal	22.3%

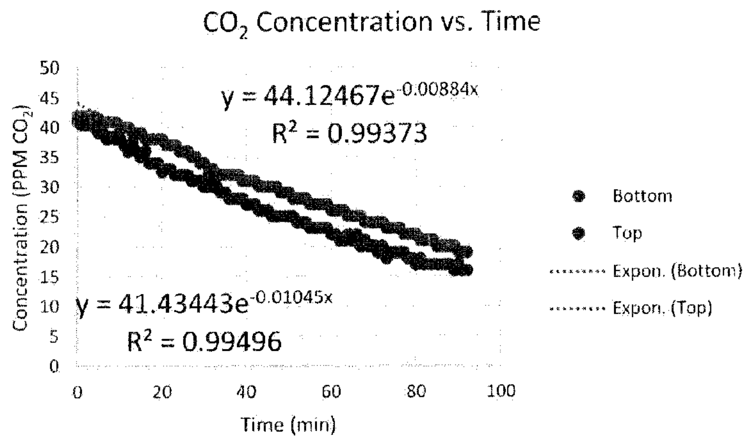
FIGURE 15

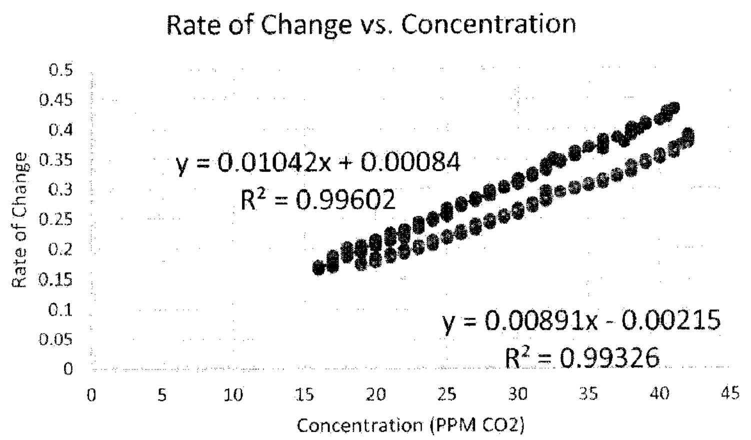




6 inch lift	15-Jan-18	Quoddy
Disk Type 2	LPM Water	1100
1 Lift	Lift Hight	6 Feet
~4 deg C or less	LPM Gas	1274.4
	Act. Gas	1368.46
	PSI Gas	4
	Tank size	8.8
	W/G Ratio	0.804
	Tank % turnover/min	12.4%
	% Removal	16.4%

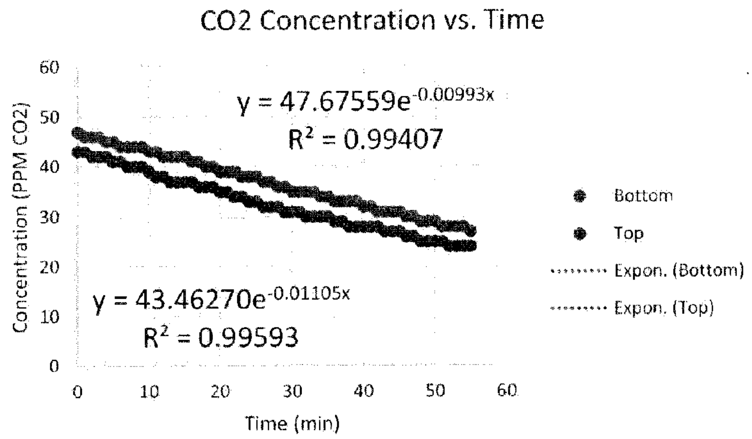
FIGURE 16

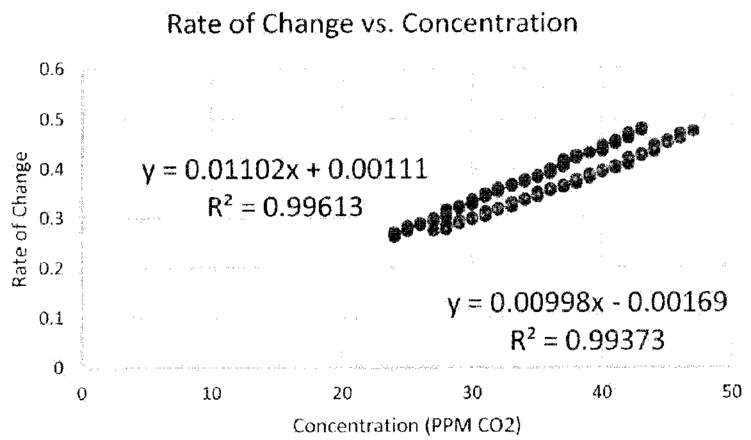




6 inch lift	16-Jan-18	Quoddy
Disk Type 2	LPM Water	950
1 Lift	Lift Hight	6 Feet
~5 deg C or less	LPM Gas	566.4
	Act. Gas	608.2
	PSI Gas	4
	Tank size	8.7
	W/G Ratio	1.562
	Tank % turnover/min	10.8%
	% Removal	8.6%

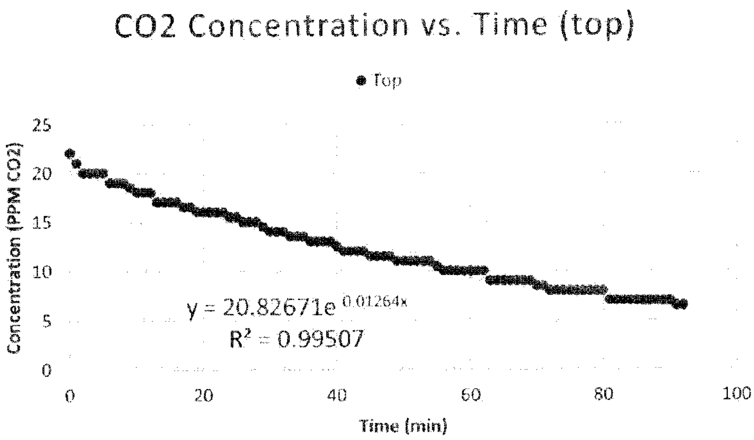
FIGURE 17

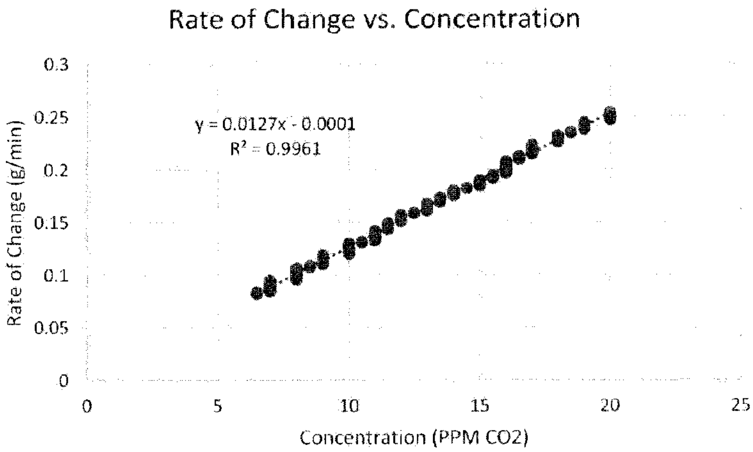




6 inch lift	17-Jan-18	Quoddy
Disk Type 2 1 Lift ~5 deg C or less	LPM Water	800
	Lift Hight	6 Feet
	LPM Gas	297.36
	Act. Gas	324.0
	PSI Gas	4
	Tank size	8.7
	W/G Ratio	2.47
	Tank % turnover/min	9.1%
	% Removal	9.6%

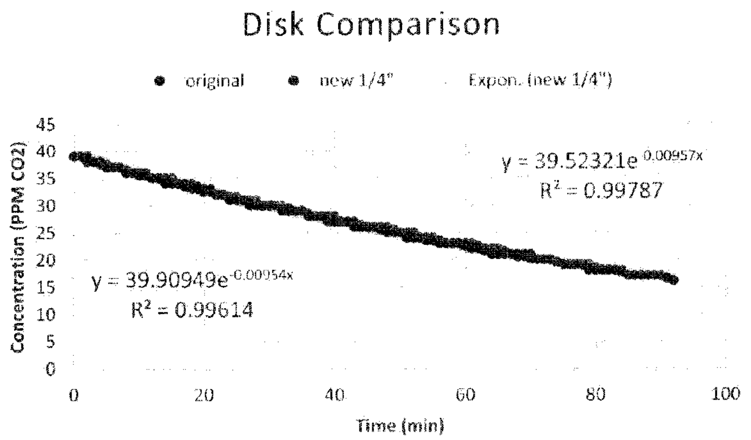
FIGURE 18

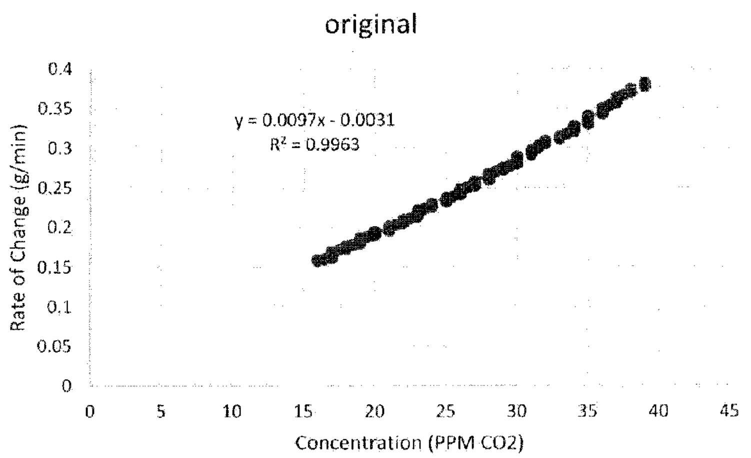




6 inch lift	11-Dec-17	Quoddy
Disk Type 1	LPM Water	600
1 Lift	Lift Hight	6 Feet
5.5 deg C	LPM Gas	210
	Act. Gas	238.4
	PSI Gas	4.25
	Tank size	8.8
	W/G Ratio	2.52
	Tank % turnover/min	6.8%
	% Removal	17.0%

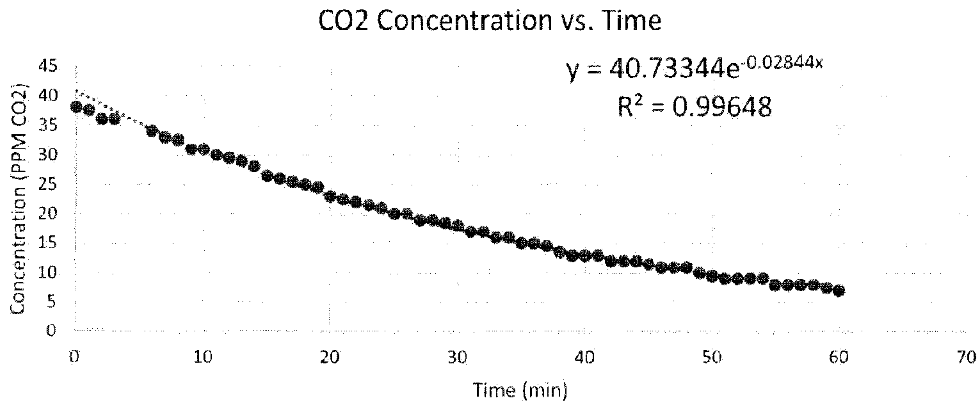
FIGURE 19

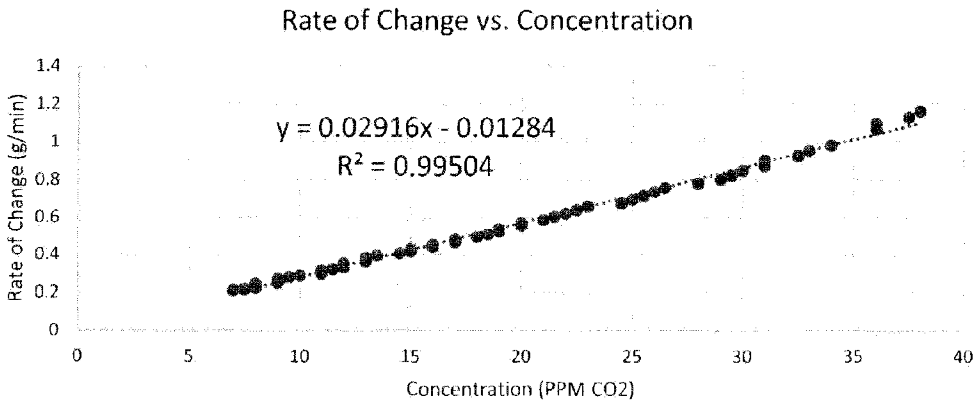




6 inch lift	12-Dec-17	Quoddy
1 Lift	LPM Water	550
Disk Type 1	Lift Hight	6 Feet
Disk Type 2	LPM Gas	175
~5 deg C or less	Act. Gas	197.4
	PSI Gas	4
	Tank size	8.8
	W/G Ratio	2.79
	Tank % turnover/min	6.2%
	% Removal	14.4%

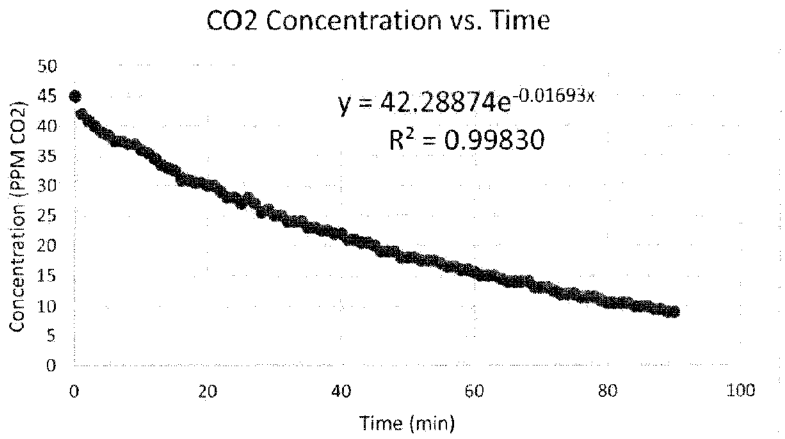
FIGURE 20

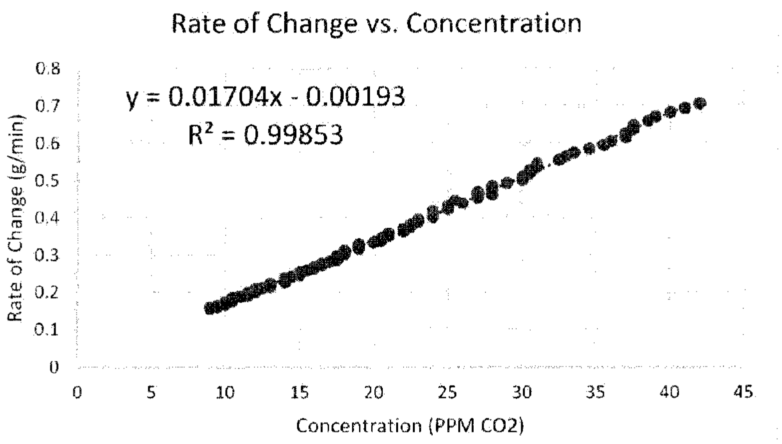




6 inch lift	13-Dec-17	Quoddy
Disk Type 2	LPM Water	1200
1 Lift	Lift Hight	6 Feet
~4 deg C or less	LPM Gas	1557.6
	Act. Gas	1647.7
	PSI Gas	4
	Tank size	8.8
	W/G Ratio	0.729
	Tank % turnover/min	13.6%
	% Removal	20.1%

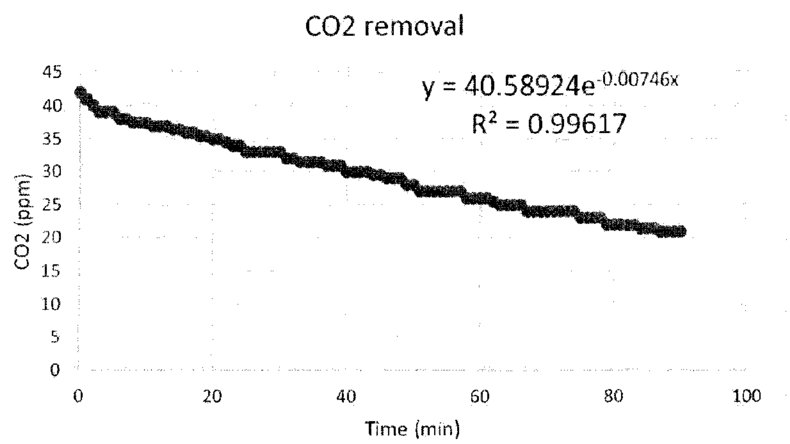
FIGURE 21

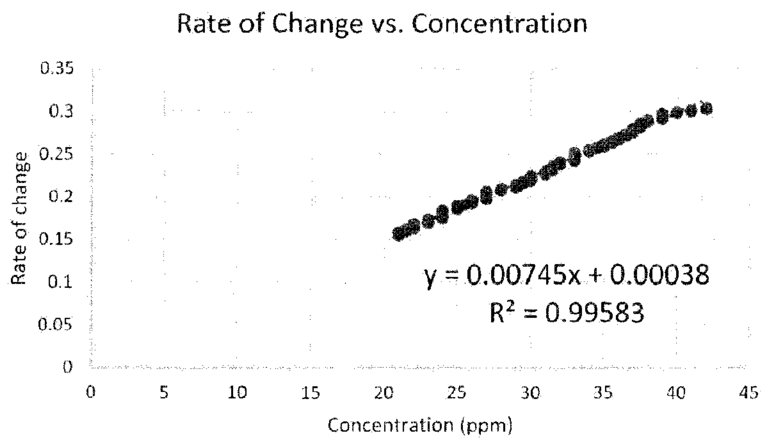




6 inch lift	13-Dec-17	Quoddy
Disk Type 2	LPM Water	1000
1 Lift	Lift Hight	6 Feet
~4 deg C or less	LPM Gas	849.6
	Act. Gas	921.7
	PSI Gas	4
	Tank size	8.8
	W/G Ratio	1.086
	Tank % turnover/min	11.3%
	% Removal	14.9%

FIGURE 22





6 inch lift	15-Jan-18	Quoddy
Disk Type 2	LPM Water	900
1 Lift	Lift Hight	6 Feet
~4 deg C or less	LPM Gas	424.8
	Act. Gas	460.8
	PSI Gas	4
	Tank size	8.8
	W/G Ratio	1.957
	Tank % turnover/min	10.2%
	% Removal	7.2%

FIGURE 23

6 inch lift	22-Aug-18	Quoddy
Disk Type 3	LPM Water	700
1 Lift	Lift Hight	6 Feet
24 deg C	LPM Gas	220
	Act. Gas	249.1
	PSI Gas	4
	Tank size	9.2
	W/G Ratio	2.79
	Tank % turnover/min	7.5%
	% Removal	20.6%

FIGURE 24

6 inch lift	30-Aug-18	Quoddy
Disk Type 4	LPM Water	561
1 Lift	Lift Hight	6 Feet
26.8 deg C	LPM Gas	220
	Act. Gas	243.8
	PSI Gas	3.2
	Tank size	9.2
	W/G Ratio	2.3
	Tank % turnover/min	6.1%
	% Removal	27.3%

FIGURE 25

6 inch lift	24-Sept-18	Quoddy
Disk Type 4	LPM Water	641
1 Lift	Lift Hight	6 Feet
18.5 deg C	LPM Gas	220
	Act. Gas	243.8
	PSI Gas	3.2
	Tank size	9.2
	W/G Ratio	2.63
	Tank % turnover/min	7.0%
	% Removal	22.0%

FIGURE 26

6 inch lift	25-Sept-18	Quoddy
Disk Type 5	LPM Water	526
1 Lift	Lift Hight	6 Feet
18.5 deg C	LPM Gas	231
	Act. Gas	247.5
	PSI Gas	2.2
	Tank size	9.2
	W/G Ratio	2.13
	Tank % turnover/min	5.7%
	% Removal	25.6%