

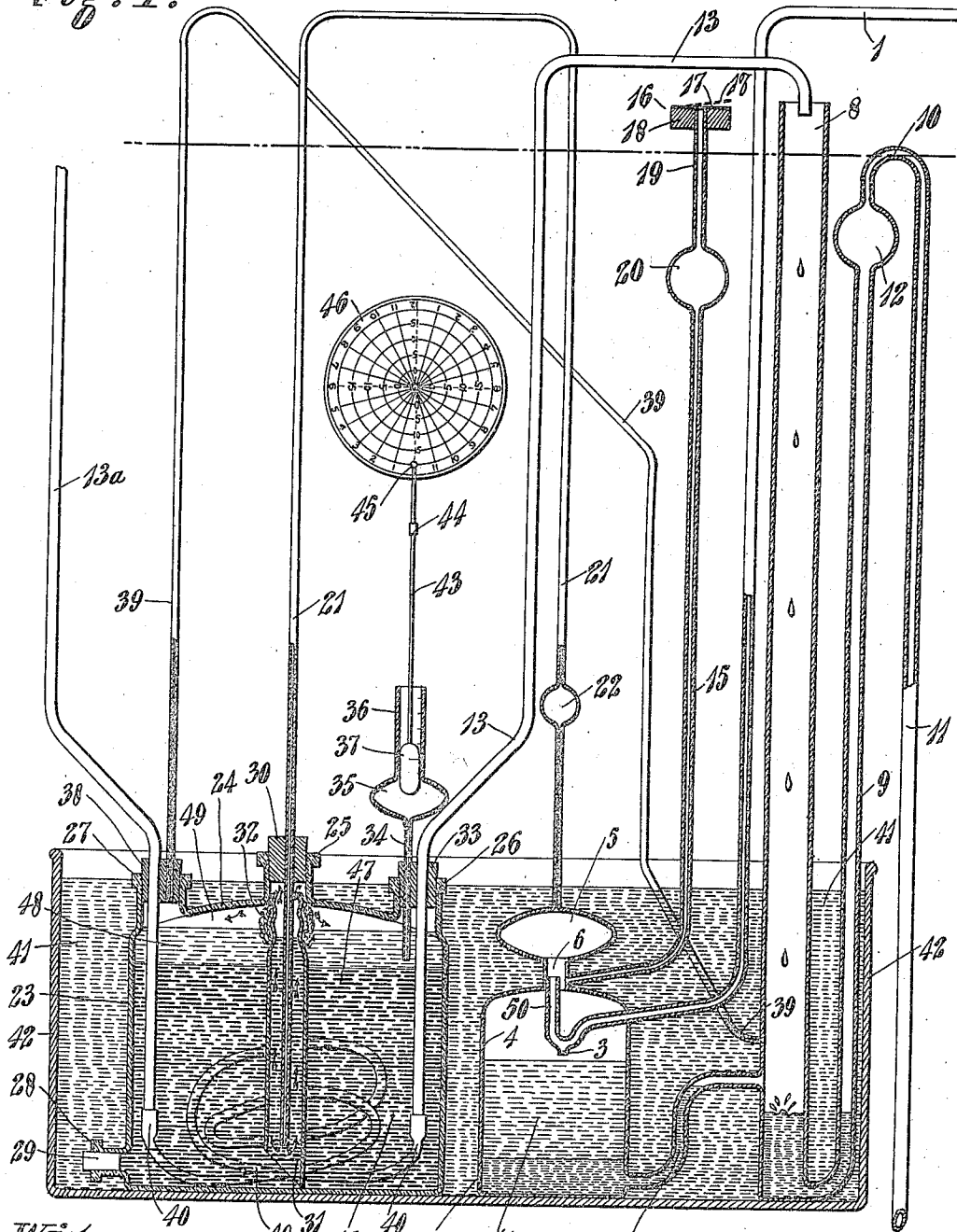
C. W. HEATH.
GAS ANALYSIS APPARATUS.
APPLICATION FILED MAR. 5, 1914.

1,124,432.

Patented Jan. 12, 1915.

2 SHEETS-SHEET 1.

Fig. 1.



Witnesses:
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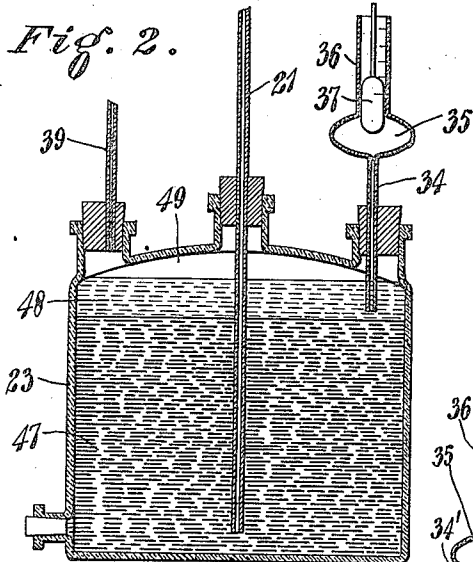
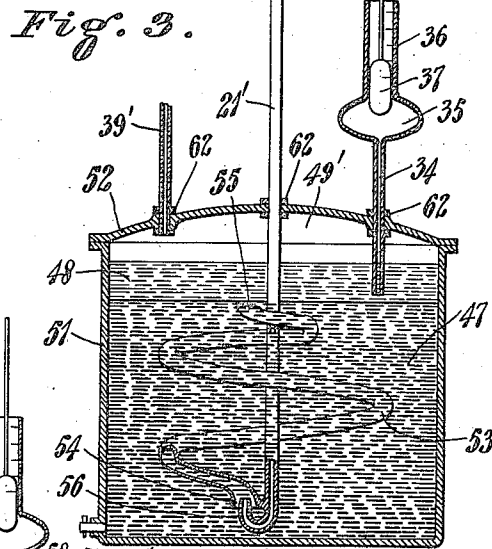
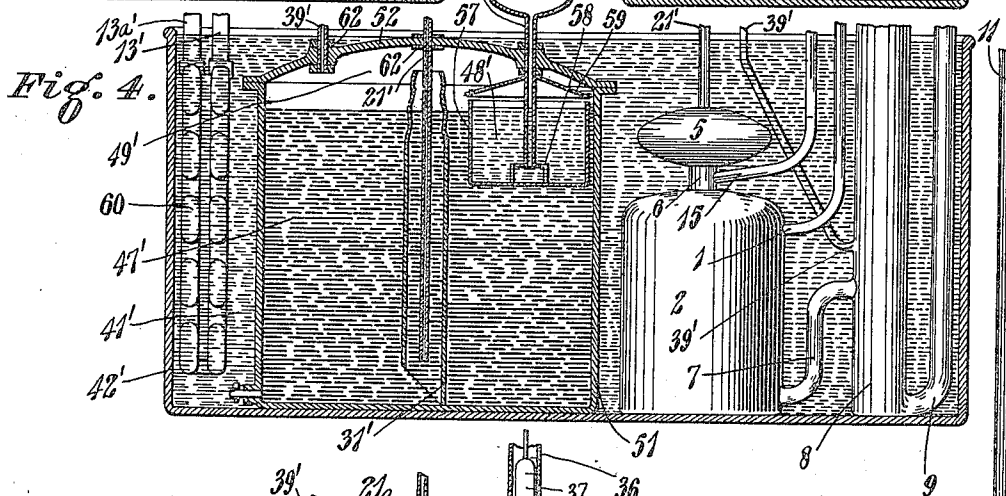
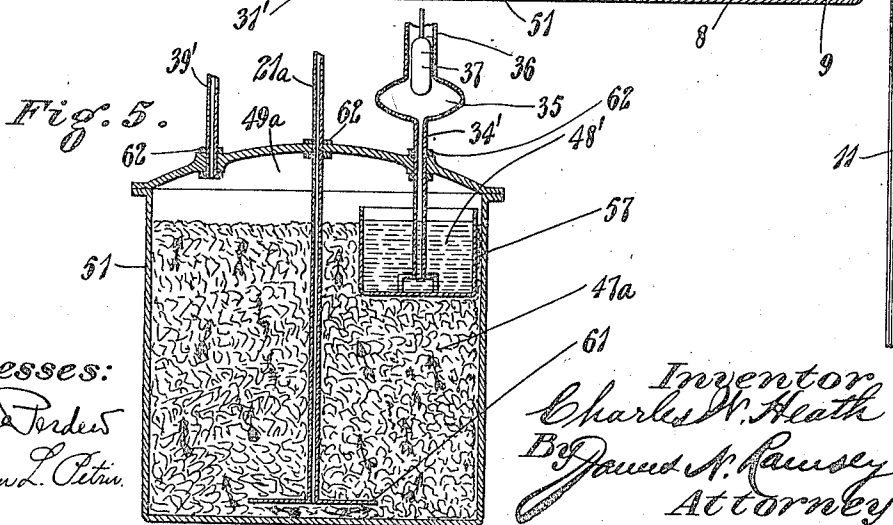
Inventor
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2 SHEETS—SHEET 2.



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UNITED STATES PATENT OFFICE.

CHARLES W. HEATH, OF CINCINNATI, OHIO.

GAS-ANALYSIS APPARATUS.

1,124,432.

Specification of Letters Patent.

Patented Jan. 12, 1915.

Application filed March 5, 1914. Serial No. 822,571.

To all whom it may concern:

Be it known that I, CHARLES W. HEATH, a citizen of the United States, and residing at Cincinnati, in the county of Hamilton and State of Ohio, have invented certain new and useful Improvements in Gas-Analysis Apparatus, of which the following is a specification.

My invention relates to means for making successive analyses of gases and indicating or recording such analyses; and its object is to provide a simple and economically constructed apparatus of this character which will operate accurately and require a minimum of attention to keep it in working order.

My invention consists in the parts and in the details of construction and arrangement of parts as will hereinafter be more fully described and claimed.

In the drawings: Figure 1 is a vertical sectional diagrammatic view of apparatus embodying my invention; Fig. 2 is a vertical section of modified absorbing and measuring means; Fig. 3 is a further modification of the same; Fig. 4 is a vertical sectional elevation of the lower part of my apparatus with another modification of the absorbing and measuring means and also of the means for retaining the temperature uniform throughout the apparatus; and Fig. 5 is a further modification of the absorbing and measuring means shown in Fig. 4, wherein solid instead of liquid absorbing material is used.

As illustrated herein, the device is especially adapted for making frequent records of the percentage of carbon dioxide in the gases leaving a furnace; although it will be understood that the apparatus may be adapted for analyzing gases other than furnace gases to ascertain the percentage of some constituent of the gas, whatever it may be.

As shown herein, the supply pipe 1 leads from the furnace or other source of gas supply from which samples of gas are to be taken for analysis. This pipe 1 leads through the side of a first measuring vessel 2 and has a downward and upward bend, at the bottom of which is an opening 3, on the interior of said vessel. This vessel 2 preferably comprises a lower main part 4 and an upper measuring chamber 5 communicating with the lower chamber 4 through a contracted neck 6. This lower chamber 4 has a pipe 7 communicating with its interior close

to its bottom and this pipe leads upwardly and over to the interior of a stand-pipe or tank 8, from the bottom of which leads the shorter leg 9 of a siphon which, extending upward, communicates through the bend 10 with the longer leg 11 of the siphon. The shorter leg 9 is provided with a bulb 12 to cause the siphon to run smoothly. Supplying water to the stand pipe or tank 8 is a pipe 13, which may communicate with any suitable source of water supply, so that it affords a small but regular supply of water to the interior of the stand pipe 8, which, for clearness, is indicated in the drawing as leaving the pipe 13 in the form of distinct drops, although a small continuous stream is generally used, so that, in any case, the stand pipe is slowly but steadily filled with water up to the level of the bend 10 in the siphon, whereupon the siphon acts, and the stand pipe is again quickly emptied down to about the level indicated in the drawing, because the water will run out through the siphon very much faster than it is supplied through the pipe 13. This intermittent siphonic action will of course continue regularly as long as water is supplied through the pipe 13. When the water rises in the stand pipe 8, it flows over through the pipe 7 into the lower chamber 4 of the first measuring vessel 2, but as the gas to be analyzed is to be drawn into this vessel 2, and as water obtained from ordinary sources usually contains substances that will absorb some of the constituents of the gas or otherwise influence the gas, and as it is necessary in practice to use such water on account of the quantity required for a continuous supply, it is necessary to prevent the contact of water with the gas that is supplied through the pipe 1 for analysis. I provide for this by placing a considerable quantity of oil 14 in the vessel 2, which, being of specific gravity less than that of the water, will remain in a distinct body supported or floating upon the water in said vessel. Thus the gas to be analyzed will come into contact only with the oil 14, which may be an oil which will not absorb a constituent of the gas.

Leading from the vessel 2 above the pipe 1 is the surplus-gas outlet pipe 15, which, as here shown, leads from the neck 6 of said vessel 2. It extends to a height above the level of the bend 10 in the siphon, and has, covering its upper end, a check valve 16, opening outwardly as indicated by the dot-

ted lines. As here shown, this check valve consists of a flexible flap 17, one side of which is fixed to a base 13 fitting around the terminal part 19 of the pipe 15. This flap 17 may be of thin rubber or other suitable material. A bulb 20 is provided in the surplus-gas outlet pipe 15 to add to its capacity, for reasons which will hereinafter be more fully described. Leading from the top of the gas-collection chamber 5 of the vessel 2 is the delivery tube 21 through which the gas is forced out of the first measuring chamber 2.

With the construction thus far described, and with the water periodically rising and falling in the stand pipe 8, the body of oil 14 will be periodically forced upward and allowed to descend in the first measuring vessel 2 and in the tube 21 leading therefrom. When the oil 14 is down to the level shown in the drawing it will have drawn a quantity or charge of gas in through the pipe 1, which gas will occupy the upper space in the lower chamber 4 of the vessel 2 and in the neck 6 and measuring chamber 5, as well as tending to rise through the tube 21. The stand pipe 8 now steadily filling, the oil 14 will be forced up under the head of water thus accumulating, and will first form a liquid seal in the bend of the supply pipe 1 adjacent to the opening 3, and then continue rising and force part of the gas out of the vessel 2 through the gas outlet pipe 15, pushing the valve 16 open, so that the gas thus escapes to the atmosphere. This ejection of surplus gas continues until the oil has sealed the mouth of this surplus-gas outlet pipe 15, whereupon it will have closed off a definite volume of gas in the measuring chamber 5, which is the volume of gas to be analyzed. The valve 16, being under atmospheric pressure, and being very light, will insure a constant pressure in each charge of gas.

As the oil 14 continues to be forced up, it forces the gas out of the measuring chamber 5 into the tube 21. This tube 21 is provided with a bulb 22 so that any oil which may adhere to the lower end of the tube 21 from the previous analysis will not be carried along with the gas any farther than this bulb 22, from where it will later run back to the vessel 2 below. This delivery pipe 21 may lead up above the level of the bend 10 in the siphon and then over and down into the combined absorption and measuring vessel 23. This vessel is very conveniently made up with the use of a Wulf bottle having a slightly arched top 24 and three necks 25, 26 and 27, and also having a suitable drain outlet 28 with closing means 29 near its bottom. The neck 25 in the center of the bottle has a stopper 30 with an opening through which the tube 21 extends, fitting tightly therewith. This tube 21 extends down near to the bottom of the vessel 23 and is sur-

rounded by an absorption and circulating tube 31 that has its bottom open at an angle so that it may rest on the bottom of the vessel 23 but will allow circulation from the surrounding interior of the vessel 23 up into the tube 31. This tube extends up, preferably into the neck 25, opening around the tube 21 just below the stopper 30, and preferably having material 32 such as fine iron wire or shavings, with interstices, held in a mass around the upper opening of the tube 31, and some distance down on the outside therefrom.

The neck 26 has a stopper 33 with an opening through which a stem 34 extends down into the vessel, fitting tightly into the stopper 33; and the upper end of this stem has a float chamber 35 with a graduated neck 36 in which a float 37 may pass up or down. The other neck 27, at the opposite side of the vessel 23, has a stopper 38, and an escape tube 39 extends down through an opening in this stopper communicating with the interior of the vessel 23 at the bottom of the stopper and fitting the opening in the stopper tightly. This escape tube 39 extends up above the level of the bend 10 in the siphon and then extends over and downward and opens into the stand pipe or tank 8 a short distance above the opening of the pipe 7 therein.

In order to maintain the same temperature in the first measuring vessel 2 and in the combined absorption and measuring vessel 23, I may lead the supply of water for the stand pipe or tank 8 through the combined absorption and measuring vessel 23. Thus, each of the stoppers 33 and 38 in the necks 26 and 27, respectively, has a second opening. Through the opening in the stopper 33 the supply pipe 13 extends some distance down into the vessel 23, and another section 13^a of the supply pipe extends through this other opening in the other stopper 38 some distance down into the vessel 24. A flexible tube 40 is coiled around in the interior of the vessel 24 and its respective ends are slipped over the ends of the pipes 13 and 13^a inside the vessel. Thus, the water, before it is supplied to the stand pipe 8, must pass around through the flexible coil 40. This tends to equalize the temperatures of the driving liquid, and absorbing and measuring liquids in vessel 23 and thus insure that the temperatures of the contents of the vessel 2 and of the vessel 23 will be the same.

To further insure uniformity of temperature throughout the apparatus, I may submerge the vessels 2 and 23, as well as the stand pipe 8, in a body of water 41 contained in a tank 42, as shown in the drawing.

The float 37, as here shown, has a rod 43 fixed to it and extending up through a guide 44, with its upper end provided with suit-

able record-making means 45 to coact with a chart 46, which is made to revolve at a constant rate, so that the relative height of the float 37 at different times may be recorded on this chart 46. The details of this recording mechanism, not forming part of the present invention, need not be further described or illustrated herein.

A quantity of liquid 47 is placed in the combined absorption and measuring vessel 23, this liquid being such that it will absorb a constituent of the gas, the percentage of which constituent is to be determined. Thus, in analysis of furnace gas for carbon dioxid, the liquid 47 will be caustic potash. Upon top of this liquid 47 is placed a quantity of mineral oil 48 which, owing to its specific gravity being less than that of the liquid 47, will remain in a distinct body above the liquid 47. This oil 48 is excluded from the interior of the absorption tube 31 however, and in here the liquid 47 rises to a height at which it is balanced by the body of oil 48 outside the tube. The stem 37 before mentioned terminates above the level of the absorbing liquid 47 outside the tube 31, so that at no time is this stem exposed to any liquid other than the oil 48.

When the oil 14 is forced up and discharges the definite volume of gas from the measuring chamber 5 into the tube 21, this gas is forced up through the tube and over and down into the interior of the vessel 23, where it escapes inside the absorption tube 31 and bubbles up through the absorption liquid 47 inside the tube, as indicated by the small arrows, and passing up into the neck 25 and then outward into the space 49 above the oil 48, being compelled to pass through the interstices of the material 32. The tube 31 is sufficiently narrow to cause the bubbles on rising through it to carry small bodies of the absorbing liquid 47 out over the top of said tube where it wets the filtering material through which the gas must pass. The bubbling of the gas through the absorption liquid inside the tube 31 greatly contributes to the completeness of absorption owing to the rolling action of the bubbles which brings each particle of the gas in contact with the absorbing liquid. The gas that escapes into the space 49 above the oil 48 will be the residue, and this would now escape from the vessel 23 through the escape tube 39 were it not that this tube has been sealed by the rising of the water in the stand pipe or tank 8 which rise of water has caused the oil 14 to be forced up and forced the gas from the first measuring vessel 2 over into the combined absorption and measuring vessel 23. The gas, being unable to escape, will press down on the upper surface of the oil 48, and since the absorption liquid 47 is incompressible, the oil 48 will be forced up through the tube 34 and into the float cham-

ber 35 where it will raise the float 37. The rise of this float 37 will be indicated on the graduated neck 36, and, if the recording mechanism be used, will be recorded on the chart 46. The greater the volume of the residue entering the space above the oil 48, the farther will the oil be forced up through the stem 34 and into the float chamber 35, and the farther will the float 37 be raised. The markings of the chart 46 are such that a greater rise of the float 37 will indicate a lesser percentage of constituent absorbed from the gas, so that the percentage of absorbed constituent is determined by a subtracting process with the volume of residue as a basis for the calculation.

When the liquid in the stand pipe 8 has reached the level of the bend 10 in the siphon the siphon will be started to work, automatically, and the liquid will commence to fall in the stand pipe 8, and supply pipe 1, as will also the oil 14 in the upper part of the first measuring vessel 2 and emptying the entrance of the delivery pipe 21. The measured quantity of gas having been forced over into the combined absorption and measuring vessel 23, the fall of the oil 14 will now create a partial vacuum in the delivery tube 21, gas measuring chamber 2, and upper part of the lower chamber 4 of the first measuring vessel 2. Atmospheric air will be prevented from entering the first measuring vessel 2 by the action of the check valve 16 which will close tightly under the atmospheric pressure; but as soon as the partial vacuum begins to exist a new charge of gas will begin to enter, bubbling up through the oil and will fill the space above the oil, ready to be forced over into the combined absorption and measuring chamber 23 through the delivery tube 21 when the oil 14 is forced up the next time. An upward extension 50 from the bend adjacent to the opening 3 in the supply pipe 1 serves to guide the incoming bubbles of gas away from the mouth of the surplus-gas outlet tube.

Some slight leakage of the valve 16 under atmospheric pressure, as the oil 14 falls in the vessel 2, is liable to occur; and since it is highly important to prevent any mixture or atmospheric air with the charge of gas that is to be analyzed, I make the volume of the surplus-gas outlet-tube 15 so great with respect to the rapidity of action of the device, as determined by the rapidity of rise and fall of water in the stand pipe 8, that the maximum amount of atmospheric air that may enter, even when the valve 16 would be leaking considerably, will not be sufficient to fill the pipe 15 and emerge into the interior of the vessel 2 during the interval of time required for the oil 14 to fall and then rise again to the point where it can seal the mouth of said pipe 15. It is for

the purpose of insuring ample capacity for the pipe 15 under all operating conditions that it is provided with the bulb 21 as before alluded to. In actual practice, however, this 5 bulb is not usually needed, because the length of the pipe 15 itself gives it sufficient capacity and usually there is very little trouble caused from the valve leaking.

When the water falls in the stand pipe 8, 10 as just described, it unseals the opening of the escape tube 39 into the stand pipe 8, and then the residue that was held above the oil 48 in the combined absorption and measuring chamber 23 will escape up through this 15 tube and over and down into the stand pipe 8 and from there to the atmosphere, assisted by the pressure of the oil 48, which will then fall from the float chamber 35 through the stem 34 and regain its position as shown in 20 the drawing ready to be forced up again by the residue from the next charge of gas analyzed.

The above operations will continue periodically, and with the recording apparatus a corresponding number of markings 25 will be made on the chart 46 in locations therearound corresponding to the periods of analysis; and with its locations numbered properly, as by indicating the hours of the 30 day, and with the chart rotated at the proper rate, as by a clock mechanism properly regulated, a chronological record of percentages will be made upon the chart 46 due to these periodical operations of my apparatus. 35

In analyzing flue gases, the considerable quantity of moisture contained therein is condensed in the first measuring vessel and also in the absorption means, especially 40 where these containers are surrounded by water as in the tank 42. In my apparatus this moisture is not carried over into the absorption and residue-measuring means, but sinks through the oil 14 and mingles 45 with the actuating liquid, being carried out therewith into the siphon and from there discharged. Where this moisture is not condensed at the beginning of the measuring of the charge of gas, but is allowed to 50 be carried over to the absorption liquid, it dilutes the liquid and reduces its efficiency as an absorbing medium, and increases its volume, so that after the apparatus has been operated for a while the absorption 55 vessel would be entirely filled with liquid. In apparatus where this is allowed it is necessary to frequently draw off some of the absorbing liquid as well as to renew its strength on account of the collection of 60 moisture from the gas that is being analyzed; and to have special means to drain the first measuring vessel.

My utilization of the lighter liquid 14 upon the heavier actuating liquid in the first 65 measuring vessel, and my use of the lighter

liquid 48 on the heavier absorption liquid 47 in the absorption and measuring vessel, are analogous in allowing a liquid collected above the lighter liquid to sink down 70 through the lighter liquid and mingle with the heavy liquid below. In each instance the liquid collecting in the space above the lighter liquid is prevented from passing from this space to a succeeding part of the apparatus where it would be highly objectionable, but is allowed to pass freely to 75 a body of liquid with which it is congruent, and where it is not objectionable, but is adapted to unite with this body of liquid and contribute to the performance of its 80 particular function.

By placing the oil 48 above the absorption liquid 47 I am enabled to use the single vessel 23 and thereby greatly simplify 85 the apparatus, and, at the same time, the indicating and registering device comprising the float 37 is not affected by the absorption liquid 47, as usually occurs where a solution, such as caustic potash, is used, as 90 the absorbing liquid and this solution on coming in contact with the air crystallizes on the float or other element of the indicating and recording apparatus. Since only oil 95 enters the float chamber and comes in contact with the float 37, there is no crystallization or other accumulation in this part of the apparatus, so that the weight of the float is maintained uniform and there is no obstruction or friction to modify the action of the float. 100

In addition to the elimination of crystallization in the measuring apparatus comprising the float 37, the corroding influences of the absorbent solution are also eliminated in this part of the apparatus, so that I am enabled to construct the stem 34, float chamber 35 and its neck 36, as well as the float 37, of any suitable material, regardless of what influence the absorbent liquid might have thereon. Thus, these parts may be 110 made of copper or brass or any other convenient material which would be corroded by such absorbent solutions as caustic potash, and the presence of solder in the construction of these parts will be permissible. 115 Where absorbent solutions, like caustic potash, are allowed to enter the delicate measuring means it has generally been necessary to construct these parts of blown glass, which is expensive and, owing to their necessary fineness, extremely fragile. It will 120 thus be seen that by the provisions herein described I am enabled to provide a more economically constructed and more durable and practical device. 125

By employing the absorption tube 31 within this single vessel 23 and causing the gas to bubble up through it, a passage through the oil is afforded for the gas, and the absorption liquid is made to circulate 130

and bring a constant supply of new particles into contact with the gas, so that the full absorption capacity of the body of liquid 47 is utilized and it is therefore unnecessary to renew it so frequently. This absorption tube 31, extending above the body of oil 48, thus allows the escape of the residue from the absorption liquid on the interior of this tube to press on the upper surface of the oil. Thus, the measuring is accomplished by a liquid in the same vessel with the absorption liquid, without changing the position of the absorption liquid or acting upon it in any substantial manner, but at the same time allowing a thoroughly effective circulation and contact of gas and absorption liquid which is not had where the gas merely makes contact with the surface of the absorption liquid either previous to the passage of this residue to a separate vessel for measurement, or for direct action upon the absorption liquid to cause it to act in indicating or recording the measurement of the residue. Thus, while the advantage of prolonged contact of the absorbent liquid with the gas or residue is attained, the absorbent liquid thus present above the oil 48 cannot enter the stem 34 or chamber 35 with any materially greater facility than can the main body of absorbent liquid.

The maintenance of a uniform temperature in the initial charge of gas and in the residue is highly important on account of the great change of volume which a gas undergoes upon a slight change of temperature. I have greatly facilitated this maintenance of uniform temperature throughout the different parts of the apparatus by having the oil 14 in direct contact with the actuating liquid that enters the first measuring vessel 2 through the passage 7, and by having the oil 48 in direct contact with the absorbent solution 47 in the combined absorbing and measuring means. Thus, the actuating liquid or water passing through the tubes 13^a, 40 and 13 must pass first through the oil 48 then through the absorbing liquid 47 and then again through the oil 48, and then coming from the stand pipe 9 through the pipe 7 will come into direct contact with the oil 14 in the first measuring vessel. These respective liquids in the first measuring vessel and in the combined absorption and measuring device are directly in contact, and thereby best adapted to be of the same temperature; and are maintained distinct by no more complicated means than their differences in specific gravity; while each liquid is adapted to perform its peculiar function without having such performance interfered with or modified by the other liquid to the detriment of the analysis.

The flexible tube 40 coiled inside the ves-

sel 23 may be of rubber where the liquid 47 which it is submerged in is caustic potash, but it is terminated below the body of oil 48 since the rubber would be deteriorated by the oil. The tubes 13 and 13^a to which the flexible tube 40 is connected are preferably of glass, they extending down through the body of oil 48 and not being injured thereby.

The solution used as the absorbing medium, such as caustic potash used for absorbing the carbon dioxide gas, may be provided with this single purpose in view without reference to its suitability as a measuring medium, as where the absorbing liquid is caused to rise and fall under pressure of the residue or successively under the pressure of the charge of gas and then of the residue. Thus, the absorbing medium may be almost a saturated solution, if required, and no particular attention need be given to its specific gravity at any time, as in devices where this liquid is used as the measuring medium and wherein its specific gravity must be maintained constant so that it will always rise an equal distance under the pressure of any given amount of residue.

In my apparatus, using oil as a measuring medium, an oil may be selected which will not evaporate or crystallize, and which will not change its specific gravity, and which will not corrode metals; so that no weight or obstruction is added in the measuring or indicating device, no discrepancy is encountered due to change of specific gravity of the measuring liquid, and economy of materials and durability are attained, as before alluded to.

When the residue emerges from the upper end of the tube 31 into the neck 25, it has carried particles of absorbing liquid up with it, and when it passes through the interstices of the material 32, most of these particles will be trapped in this material; also these particles of absorbent liquid will be deposited on the under side of the top 24, which is preferably arched as shown, and these particles will collect and run down to the edge of the vessel 23. This affords a considerable exposure of absorbent liquid in the space 49 so that the contact of the gas or residue with the absorbent liquid is prolonged even after the escape from the main body of absorbent liquid and the absorption is thereby rendered more thorough and complete. On account of the greater specific gravity of the absorbent liquid compared with that of the oil 48, that which has been trapped in the material 32 will rapidly sink through the oil 48 as soon as it runs down and makes contact with the oil, while the absorbent liquid collected on the under surface of the top 24 will run along this under surface down to the edges of the oil 48 and will then sink rapidly

through the oil and return to the main body of absorbent liquid below the oil.

As shown in Fig. 2, the vessel 23 has the absorption tube 31 and filtering material 32 omitted, and the gas escapes from the bottom of the tube 21 and is disseminated throughout the body of absorption liquid 47, from which the residue bubbles up through the oil 48 to the space 49 thereabove, and acts to push the oil 48 up through the stem 34 into the float chamber 35 and its neck 36, to act on the float 37 therein, as hereinbefore described. In this view, the pipes 13 and 13^a and the flexible coil 40 are also omitted, although it will be understood that these parts may be used in conjunction with this modification if desired.

In the modification shown in Fig. 3 the combined absorption and measuring vessel 51 has a removable cover 52 for the admission of a coiled absorption tube 53 which has an open lower end 54 near the bottom of the vessel and an open upper end 55 just below the upper surface of the absorption liquid 47, so that the oil 48 floating on the absorption liquid 47 does not enter and is not in contact with this tube, while the gas delivery tube 21' has its lower end 56 bent upward and entering the lower end 54 of the absorption tube 53. By this means, the absorption liquid 47 is caused to circulate through the spiral absorption tube 53 along with the gas delivered therein from the tube 21', so that a prolonged travel of the absorption liquid and gas together, accompanied with ebullition, is caused and the residue escapes from the upper end 55 of the absorption tube 53 and bubbles up through the oil 48 to the space 49' thereabove, to press on the oil 48 as before described. No absorption liquid is carried into the space 49, but a very thorough absorption is effected during the circuitous passage of the gas through the absorption liquid, inside the tube 53, without the effect of the prolonged association of the gas and absorption liquid in the space 49, such as is afforded by the apparatus as shown in Fig. 1.

In Fig. 4, a separate vessel 57 is suspended in the vessel 51 from the removable top 52 thereof, being, as here shown, secured to the lower end of the stem 34' of the float chamber 35 by means of a yoke 58 extending out from the lower end of the stem 34' and attached to the bottom of the vessel 57, thereby leaving the lower end of the stem 34' open into the vessel 57. As here shown, the absorption tube 31' is provided similar to the absorption tube 31 in the previous examples, but the filtering material 32 is omitted. It will be understood however, that any of the foregoing forms of absorption tubes may be used in this connection or the absorption tube may be omitted, as in

Fig. 2. The body of oil 48' is contained in the vessel 57, and the vessel is sunken into the absorbent liquid 47' which is contained in the vessel 51. The top of the vessel 57 being open, the residue in the space 49' may press upon the surface of the oil 48 and cause it to rise through the stem 34' into the float chamber 35 and its neck 36, to act on the float 37 as described with reference to the preceding examples. Since the particles of absorbent liquid will be carried up and deposited on the under side of the top 52 to run down therealong back to the main body of liquid, it may be desirable to provide a shield 59 over the top of the vessel 57, so that the absorbing liquid will not drop into the oil 48' in this vessel 57; the shield however, leaving free communication between the space 49' and the surface of the oil 48' in the vessel 57.

Another modification, shown in Fig. 4, is that of the means for insuring uniform temperature throughout the apparatus. Instead of passing pipes 13 and 13^a into the absorbing and measuring vessel 51 the pipe 13' and the pipe 13^a forming part of the supply to the stand pipe or tank 8 are connected to opposite ends of a circulating coil 60 which is submerged in the water 41' in the tank 42' between the absorbing and measuring vessel 51 and the adjacent end of the tank. The temperatures of the water supplied to the stand pipe 8 and of the water 41' at this end of the tank are equalized by this means, as well as due to the stand pipe 8 and its siphon and the first measuring vessel 2 being submerged in the water 41' at that end. The circulation of the actuating liquid through coils outside the absorbing vessel in the water 41' obviates the necessity of using a flexible tube submerged in caustic potash where a Wulf bottle is used, as shown in Fig. 1, which arrangement is not so desirable as one like that shown in Fig. 4, because even the best of rubber tubing is deteriorated in a short time by the caustic potash or other active chemical used as the absorbing medium.

In Fig. 5, the absorbing and measuring vessel 51 is used, and the vessel 57 is suspended therein as described with reference to Fig. 4, and contains the oil 48', but instead of the absorbent medium being a liquid it is supplied in the form of flakes or sticks 47^a with which the vessel 51 is filled for the greater part, leaving a space 49^a within the top of the vessel communicating with the surface of the oil 48' in the vessel 57. The delivery pipe 21^a extends down through the solid absorbent material 47^a and opens near the bottom of the vessel within the mass of absorbent material, and preferably has a baffle 61 extending out all around its lower end to spread the gas out

around the sides of the vessel at the bottom and cause it to be disseminated throughout the mass of sticks or flakes of absorbent material 47^a, which will absorb the desired constituent and allow the residue to pass into the space 49^a and act on the oil 48' in the manner hereinbefore described.

Where the vessel is provided with a removable top for the introduction of the interior details it is preferably made of iron where caustic potash is used as the absorbing medium, and the gas delivery tube 21' or 21^a as the case may be, and the stem 34 or 34' as the case may be, as well as the escape tube 39' in any of the examples, pass through the cover of the vessel with suitable lock nuts 62 as shown, these lock nuts as well as the connection of the cover to the vessel being provided with suitable means, such as gaskets, to insure against escape of the gas or residue from the vessel.

It will be understood, with reference to the various modifications shown, that the peculiar details thereof are interchangeable among them; and also that various other modifications may be found desirable; and I do not wish to be understood as being limited to any of the details specifically described herein, but

What I claim as new and desire to secure by Letters Patent is:

1. In gas-analysis apparatus, a combined absorption and residue-measuring means, comprising a vessel, means for delivering a measured charge of gas into said vessel, a body of liquid in said vessel adapted to absorb a constituent of said gas, another body of liquid in said vessel, remaining distinct from the absorbent liquid, said vessel having a space inclosed above this other liquid, into which the residue from the absorbent liquid is delivered, said residue pressing upon the surface of this other liquid, and means into which some of this other liquid is displaced when its surface is pressed upon, this means being adapted for measuring the amount of this liquid displaced, means for allowing escape of said residue from said space, means for controlling the delivery of gas to the vessel and means for controlling the escape of the residue from said space in the vessel.

2. In gas-analysis apparatus, a combined absorption and residue-measuring means comprising a vessel, means for delivering a charge of gas into said vessel, a body of liquid in said vessel adapted to absorb a constituent of said gas, another body of liquid therein, supported upon the absorbent liquid and remaining distinct therefrom, said vessel having a space inclosed above this other liquid, means for delivering the residue from the absorbent liquid to this space, said residue pressing upon the surface of

this other liquid, and means into which some of this other liquid is displaced when its surface is pressed upon, this means being adapted for measuring the amount of this liquid displaced, means for allowing escape of said residue from said space, means for controlling the delivery of gas to the vessel, and means for controlling the escape of the residue from said space in the vessel.

3. In gas-analysis apparatus, combined absorbing and residue-measuring means comprising a solution tending to crystallize in contact with air and being absorbent to a constituent of a gas, and a liquid substantially free from tendency to crystallize in contact with air, means for passing said gas through said absorbent solution, means for receiving and holding the residue therefrom to press upon the surface of the non-crystallizing liquid, and means into which the non-crystallizing liquid may rise under the pressure of the residue, and whereby its rise is measured, said absorbent solution remaining out of the measuring means, whereby its crystallization in the measuring means is eliminated, means for controlling the passage of the gas and means for controlling the escape of the residue.

4. In gas-analysis apparatus, a combined absorbing and residue-measuring means comprising a caustic solution, an oil supported on the caustic solution and remaining distinct therefrom, means for passing a gas into the caustic solution whereby a constituent of the gas is absorbed by said solution, means for receiving and confining the residue adjacent to the upper surface of the oil, measuring means into which the oil may rise under pressure of the residue, means for controlling the passage of said gas and means for controlling the escape of the residue, said caustic solution remaining out of the measuring means, whereby crystallization of the caustic solution in the measuring means is eliminated, and whereby action of the caustic solution on the material of the measuring means is eliminated.

5. In gas-analysis apparatus, a single vessel of material to resist the action of a caustic solution, a caustic solution in said vessel, an oil floating on the caustic solution and remaining in a body distinct from the solution, means for passing a gas into the caustic solution, whereby a constituent of the gas is absorbed by the solution, means for delivering the residue from the caustic solution to a part of said vessel above the upper surface of the oil, measuring means into which the oil may rise under the pressure of the residue, said measuring means being composed of material less capable of resisting the action of the caustic solution than is the material of said vessel, and the caustic solution thus remaining out of said measur-

ing means, whereby its action on the material of the measuring means is eliminated, means for controlling the passage of said gas, and means for controlling the escape of the residue.

6. In gas-analysis apparatus, a single vessel of material to resist the action of a caustic solution, a caustic solution in said vessel, an oil floating on the caustic solution and remaining in a body distinct from the solution, means for passing a gas into the caustic solution, whereby a constituent of the gas is absorbed by the solution, means for delivering the residue from the caustic solution to a part of said vessel above the upper surface of the oil, measuring means into which the oil may rise under the pressure of the residue, said measuring means being composed of material less capable of resisting the action of the caustic solution than is the material of said vessel, and the caustic solution thus remaining out of said measuring means, whereby its action on the material of the measuring means is eliminated, means for permitting and controlling flow of an actuating liquid, to periodically deliver definite charges of said gas into said caustic solution, and means for circulating said actuating liquid adjacent to said caustic solution and said oil, but maintaining said actuating liquid distinct from said solution and said oil, and means whereby the actuating liquid controls escape of the residue from the absorbing and measuring means.

7. In gas-analysis apparatus, a single vessel, an absorbent solution therein, said vessel being of material to resist the action of said solution, an oil floating on the solution and remaining in a body distinct from the solution, means for passing a gas into the solution, whereby a constituent of the gas is absorbed by the solution, means for delivering the residue from the solution to a part of said vessel above the upper surface of the oil, measuring means into which the oil may rise under the pressure of the residue, said measuring means being composed of material less capable of resisting the action of the solution than is the material of said vessel, and the solution thus remaining out of said measuring means, whereby its action on the material of the measuring means is eliminated, means for permitting and controlling flow of an actuating liquid to periodically deliver definite charges of said gas to said solution, and means whereby said actuating liquid controls escape of the residue.

8. In gas-analysis apparatus, a single vessel, an absorbent solution therein, said vessel being of material to resist the action of said solution, an oil floating on the solution and remaining in a body distinct from the solution, means for passing a gas into the solution, whereby a constituent of the gas

is absorbed by the solution, means for delivering the residue from the solution to a part of said vessel above the upper surface of the oil, measuring means into which the oil may rise under the pressure of the residue, said measuring means being composed of material less capable of resisting the action of the solution than is the material of said vessel, and the solution thus remaining out of said measuring means, whereby its action on the material of the measuring means is eliminated, means for permitting and controlling flow of an actuating liquid to periodically deliver definite charges of said gas to said solution, and means for conducting said actuating liquid adjacent to said solution and said oil, comprising tubes leading through the oil and into the solution and composed of material adapted to resist the action of the oil and of the solution, and a flexible tube connecting the ends of these tubes and submerged in the solution, composed of material adapted to resist the action of the solution, and means whereby said actuating liquid controls escape of the residue.

9. In gas-analysis apparatus, means for periodically delivering definite charges of gas to be analyzed, comprising an actuating liquid liable to affect the gas, a liquid floating on the actuating liquid and substantially inert with respect to the gas, means for permitting and controlling the flow of the actuating liquid to cause it to raise and lower the inert liquid, a measuring chamber in which the inert liquid traps a definite charge of gas each time it is lowered and raised, a combined absorbing and measuring means comprising a solution absorbent to a constituent of the gas and liable to crystallize in contact with air, and a liquid floating on the absorbent solution and less liable to crystallize in contact with air, a tube leading from the measuring chamber and opening into the absorbent solution, whereby the definite charge of gas is passed into the absorbent solution and said constituent absorbed, means for receiving and holding the residue above the upper surface of the floating liquid, means into which the floating liquid may rise under pressure of the residue and whereby said rise may be measured, said absorbent solution remaining undisturbed under the pressure of the residue and thereby remaining out of the measuring means, an outlet for the residue, and means whereby the actuating liquid controls said outlet, and means for maintaining uniform temperature in the charge of gas in the measuring chamber and of the residue above the floating liquid in the absorbing and measuring means, comprising a passage for the actuating liquid adjacent to the absorbent solution and adjacent to the floating liquid in the absorbing and measuring means, whereby the temperature of this ac-

tuating liquid is equalized with that of the absorbent solution and with that of the floating liquid in the absorbing and measuring means, and also with that of the floating liquid that traps the gas in the measuring chamber.

10. In gas-analysis apparatus, gas-measuring and delivering means, and constituent-absorbing and residue-measuring means, each comprising two liquids of different specific gravities and different properties, the one being maintained above the other and distinct therefrom by the difference of specific gravity, and each of said means having a space inclosed above the upper liquid comprised therein, in which space liquid collects during the operation of the apparatus, the liquid collecting in each space being congruent with the lower liquid comprised in the respective means, and being adapted to pass down through the upper liquid comprised therein and to mingle with the lower liquid.

11. In gas-analysis apparatus, a series of operative means adapted to successively receive gas, each comprising two liquids of different specific gravities and different properties, the one being maintained above and distinct from the other by its difference of specific gravity, and the presence of any of the lower liquid comprised in each means in a successive means in the series being detrimental to the operation of the respective successive means, liquid, congruent with the lower liquid comprised in each means, collecting above the upper liquid in the respective means but passing down through the upper liquid by virtue of its greater specific gravity, and mingling with the lower liquid comprised in the means and thereby remaining out of the respective successive means.

12. In gas-analysis apparatus, a combined absorbing and measuring means comprising a vessel, a solution therein absorbent to a constituent of the gas to be analyzed, a tube opening into this absorbent liquid and delivering said gas into this absorbent solution near the lower part thereof, a liquid within said vessel of specific gravity and properties different from those of the absorbent solution, floating upon and maintained distinct from the absorbent solution in said vessel, and said vessel having a closed space above this floating liquid, another tube surrounding the tube in the absorbent solution and extending up through the floating liquid and opening into said space whereby the residue passes from the absorbent solution into said space above the floating liquid and presses on the surface of the floating liquid, and measuring means into which the floating liquid may rise under pressure of the residue.

13. In gas-analysis apparatus, a combined

absorbing and measuring means comprising a vessel, a solution therein absorbent to a constituent of the gas to be analyzed, a tube opening into this absorbent liquid and delivering said gas into this absorbent solution and delivering said gas into the solution near the lower part thereof, a liquid within said vessel of specific gravity and properties different from those of the absorbent solution floating upon and maintained distinct from the absorbent solution in said vessel, and said vessel having a closed space above this floating liquid, another tube surrounding the tube in the absorbent solution and extending up through the floating liquid and opening into said space whereby the residue passes from the absorbent solution into said space above the floating liquid and presses on the surface of the floating liquid, and measuring means into which the floating liquid may rise under pressure of the residue.

14. In gas-analysis apparatus, a combined absorbing and measuring means comprising a vessel, a solution therein absorbent to a constituent of the gas to be analyzed, a tube opening into this absorbent liquid and delivering said gas into this absorbent solution and delivering said gas into the solution near the lower part thereof, a liquid within said vessel of specific gravity and properties different from those of the absorbent solution floating upon and maintained distinct from the absorbent solution in said vessel, and said vessel having a closed space above this floating liquid, another tube surrounding the tube in the absorbent solution and extending up through the floating liquid and opening into said space whereby the residue passes from the absorbent solution into said space above the floating liquid and presses on the surface of the floating liquid, and measuring means into which the floating liquid may rise under pressure of the residue, said absorbent solution remaining out of the measuring means, means adjacent to the opening of this other tube in this space having interstices through which the residue must pass, said residue carrying particles of the absorbent solution out of this tube which are received in these interstices, thereby prolonging the contact of the residue with the absorbent solution and increasing the thoroughness of absorption of the constituent, this absorbent solution, thus entering the space, sinking through the floating liquid to the main body of absorbent solution thereby remaining out of said measuring means, means for controlling passage of gas into the vessel and means controlling the escape of residue from the vessel.

15. In gas-analysis apparatus, a vessel, gas-absorbing means in said vessel for absorbing a constituent from the gas to be

analyzed and leaving a residue therefrom, a liquid in said vessel which will not absorb the gas to be analyzed and distinct from said gas-absorbing means, means for forcing measured samples of gas into said absorbing vessel, means whereby said non-absorbing liquid is displaced by said residue to indicate the amount of said constituent absorbed, and means for disposing of the residue after the analysis has been made.

16. In gas-analysis apparatus, a vessel, gas-absorbing liquid in said vessel for absorbing a constituent from the gas to be analyzed and leaving a residue therefrom, a liquid in said vessel which will not absorb gas to be analyzed and distinct from said gas-absorbing liquid, means for forcing measured samples of gas into said absorbing vessel, means whereby said non-absorbing liquid is displaced by said residue to indicate the amount of said constituent ab-

sorbed, and means for disposing of the residue after the analysis has been made.

17. In an apparatus for gas analysis, a vessel, gas-absorbing liquid in said vessel for absorbing a constituent from the gas to be analyzed and leaving a residue therefrom, another liquid in said vessel distinct from said absorbing liquid, an open tube extending upwardly in said vessel in said gas-absorbing liquid, means for discharging measured samples of gas within said tube, means whereby said other liquid is displaced by said residue to indicate the amount of constituent absorbed, and means for disposing of the unabsorbed gas after the analysis is made.

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Witnesses:

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