Nov. 22, 1949 L. S. GALSTAUN ET AL 2,488,812

GAS ANALYSIS APPARATUS

Filed April 10, 1945 3 Sheets-Sheet 1

Fig. 1

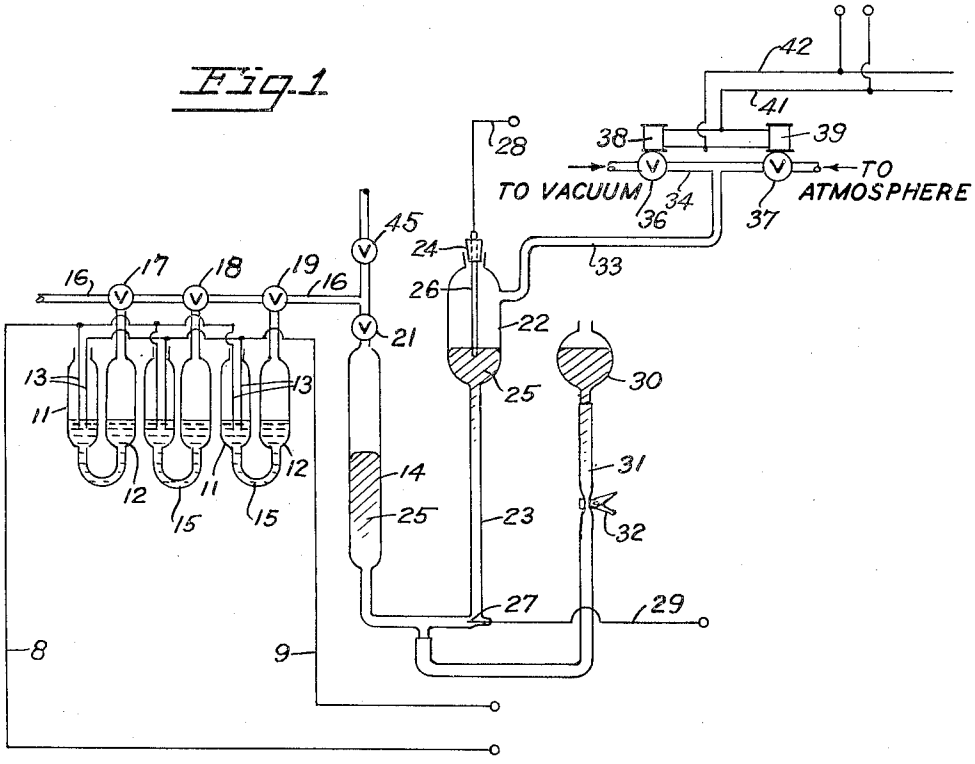
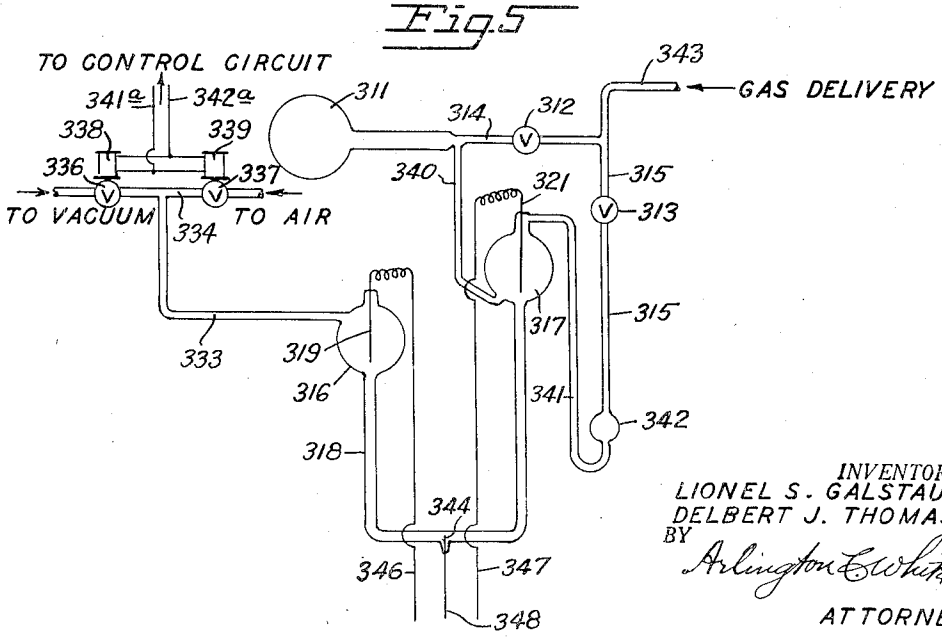


Fig. 5



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GAS ANALYSIS APPARATUS

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Fig. 2.

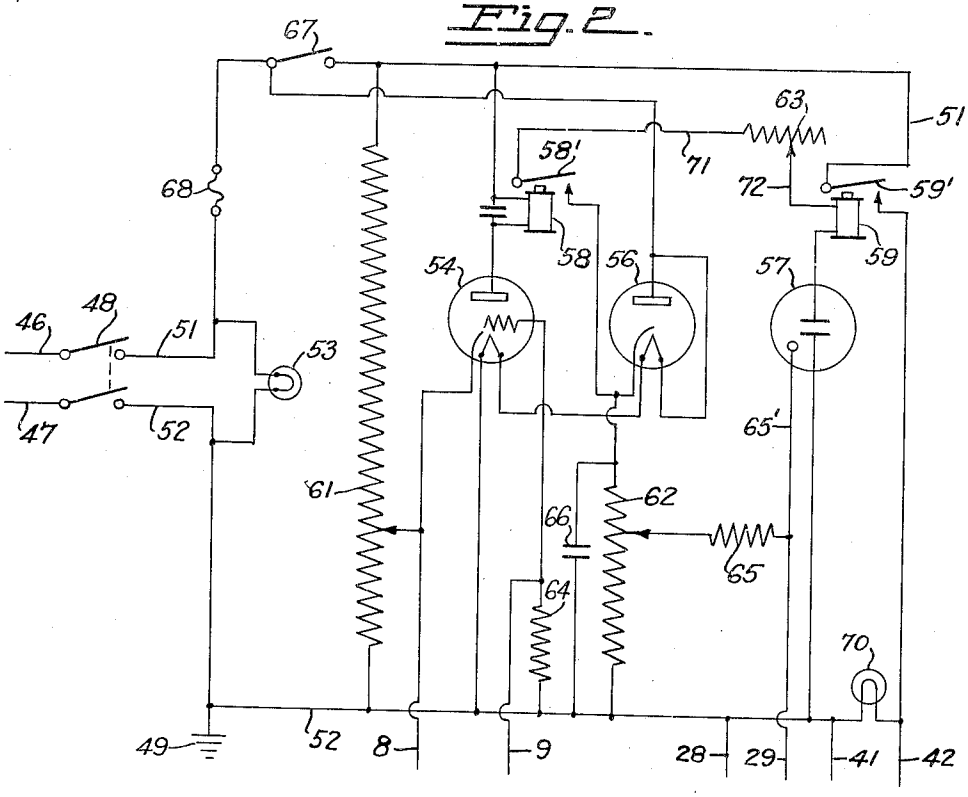
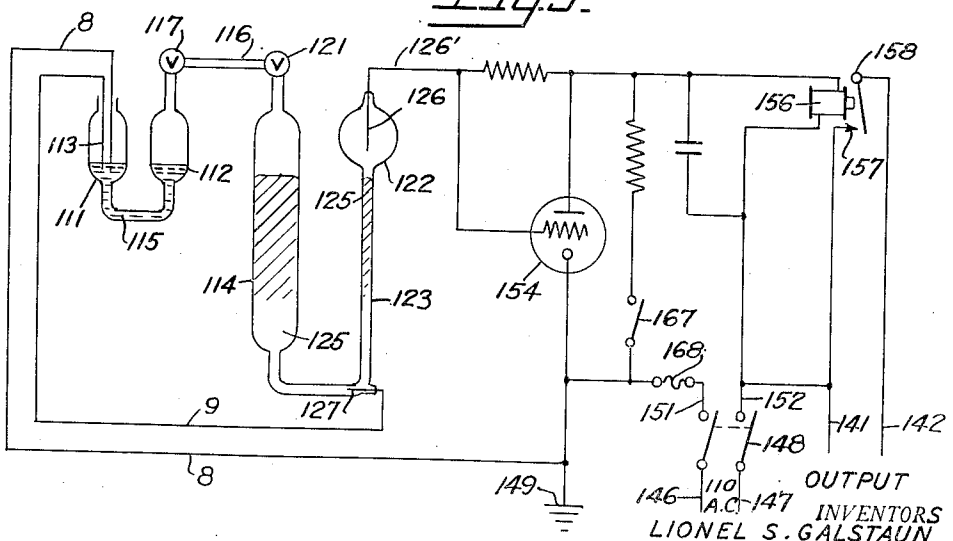


Fig. 3.



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GAS ANALYSIS APPARATUS

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Fig. 4.

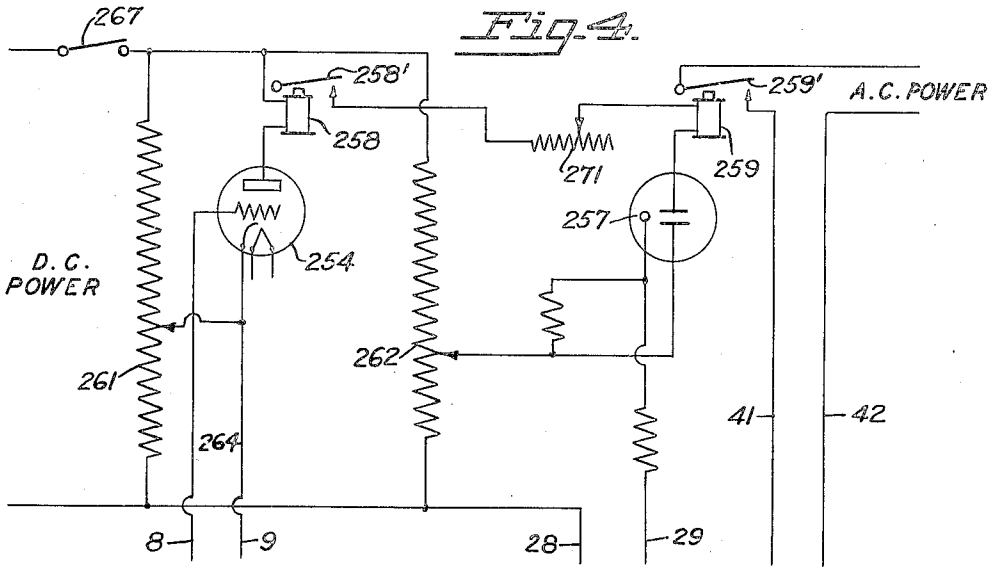
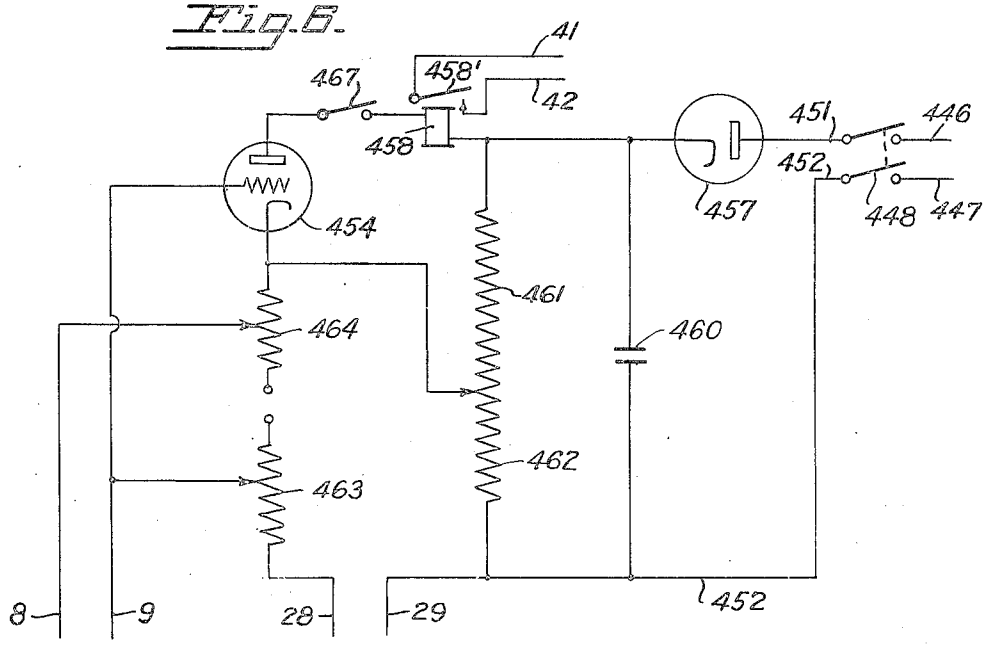


Fig. 6.



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UNITED STATES PATENT OFFICE

2,488,812

GAS ANALYSIS APPARATUS

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Application April 10, 1945, Serial No. 587,638

3 Claims. (Cl. 23—254)

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The invention, in general, relates to governing the flow of fluids and more particularly relates to means for automatically and recurrently reversing the flow of fluids in a closed system.

While the hereinafter described invention is entirely suitable for adaptation to a variety of types of equipment designed for handling, measuring or moving gases or fluids, including Toepler pumps and similar apparatus, the invention has especially been devised for adaptation to Orsat analyzers and similar laboratory precision equipment. For purposes of explanation only, the invention will be particularly described in the latter environment.

A primary object of our invention is to provide automatic reversing control apparatus thereby eliminating the requirement of manual operation of equipment having as its essential function the alternate reversal of the flow of fluids through a chamber or series of chambers.

More specifically, it is an object of this invention to provide apparatus of the aforementioned character for automatically and repeatedly causing a confined gas to pass over or through an absorbing medium, such as in an Orsat analyzer for gases, without carry-over of liquids confined in the system.

A still further object of our present invention is to provide an automatic reversing control of the indicated nature which affords the operation of equipment of the aforementioned character, such as an Orsat analyzer, or other equipment for measuring the volume of a given gas or fluid absorbed by a liquid, in a minimum of time and with a minimum of labor.

Other objects of the invention, together with some of the advantageous features thereof, will appear from the following description of a preferred embodiment as well as certain modified embodiments of our invention which are illustrated in the accompanying drawings. It is to be understood that we are not to be limited to the precise embodiments shown, nor to the precise arrangement of the various parts thereof, as our invention, as defined in the appended claims, can be embodied in a plurality and variety of forms.

Referring to the drawings:

Figure 1 is a diagrammatic view of a portion of a preferred embodiment of our invention, as applied to the operation of an Orsat gas analyzer.

Figure 2 is a diagrammatic view of an electrical circuit forming a part of the preferred embodiment of our invention illustrated in Figure 1.

Figure 3 is a diagrammatic view of a modified electrical circuit adapted to be incorporated with

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that portion of the preferred embodiment of our invention illustrated in Figure 1.

Figure 4 is a diagrammatic view of another modification of our electrical circuit adapted to be incorporated with that portion of the preferred embodiment of the invention shown in Figure 1.

Figure 5 is a diagrammatic view of a portion of a preferred embodiment of our invention, as applied to the operation of a Toepler pump, the illustrated apparatus being adaptable for incorporation in any one of the electrical circuits shown in Figures 2, 3, 4 or 6.

Figure 6 is a diagrammatic view of still another electrical circuit for connection with those partial embodiments of our invention illustrated in Figures 1 or 5, or like equipment.

In its preferred form, the automatic reversing control of our invention preferably comprises apparatus confining fluids, such as a gas and a liquid, in a closed system, and means for automatically and repeatedly moving the fluids within the system first in one direction and then in the other direction.

With particular reference to Figures 1 and 2 of the annexed drawings, it will be observed that we provide in our preferred embodiment of our invention, as applied to an Orsat gas analyzer, a plurality of absorption units integrally connected together for communication with one another, each consisting of a reservoir tube 11 and an absorption tube 12. On each of the reservoir tubes 11 is mounted, so as to extend within the same to adjacent the bottom thereof, a pair of electrodes 13 which are connected into opposite sides of one of the electrical circuits hereinafter more specifically described. As shown, the tubes 11 and 12 are supported at the same level, and it is of course to be understood that the gas absorbing liquid, or reacting solution employed in the tubes 11 and 12 is electrically conductive. A preferred embodiment of our invention, as applied to an Orsat analyzer, also includes a calibrated burette 14 integrally connected for communication with the series of absorption tubes 11 and 12 by means of a manifold 16. The manifold tube 16 is conveniently provided with a series of conventional stop-cocks 17, 18 and 19 for controlling the admission of liquid and gas into the absorption tubes 12 of the absorption units, and a conventional stop-cock 21 also is provided in the burette 14 for controlling movement of gas and liquid between the burette 14 and the absorption units through the manifold tube 16.

In addition to the foregoing elements, we provide a reservoir 22 for holding a quantity of mercury 25, or similar non-reacting liquid; the reservoir 22 preferably being integrally connected to the burette 14 by means of tubing 23 for establishing communication between these elements and to permit the mercury 25 partially to occupy the burette and partially to occupy the reservoir 22 as well as the tubing 23. A suitable stopper 24 for the mercury reservoir 22 serves to mount an electrode 26 which extends within the reservoir to adjacent the bottom thereof, and we provide a second electrode 27 piercing the tubing 23 and extending into the mercury therein contained; such electrodes also being connected into one of the electrical circuits by leads 28 and 29, respectively, hereinafter described. The mercury reservoir 22 preferably is adjustable in relation to the burette 14 insofar as mercury levels are concerned but once the adjustment is made for a given apparatus it requires no further adjustment.

Departing from a conventional Orsat gas analyzer, and for use in conjunction with the burette 14 and the mercury reservoir 22, we provide a bulb 30 for holding a reserve supply of mercury or other non-reacting liquid; the bulb 30 being placed in communication with the burette 14 as well as reservoir 22 by means of a flexible tubing 31 which is controlled by a suitable pinch clamp 32. By raising and lowering the level bulb 30, the levels of the mercury in the burette 14 and the mercury reservoir 22 can readily be adjusted to any desired relationship.

In accordance with our invention, we further modify the standard Orsat gas analyzer equipment by providing means for venting the mercury reservoir 22 to the atmosphere affording the creation of a vacuum therein whenever desired as well as egress of the air to the atmosphere. To this end, the mercury reservoir is formed with an integral tube 33 communicating with and connected to a manifold tube 34 which is open at both ends and in which we mount a pair of magnetically operable valves 36 and 37 for controlling admission and egress of air to and from the mercury reservoir 22 as well as controlling the vacuum applied to the mercury in the reservoir 22. Valves 36 and 37 are energized and de-energized alternately in response to the magnetization and de-magnetization of suitable magnets 38 and 39, respectively, which are interposed in one of the electrical circuits hereinafter described by means of the lead lines 41 and 42, respectively. The arrangement preferably is such that when magnet 38 is energized its associated valve 36 opens and when magnet 39 is energized its associated valve 37 closes, both magnets being energized simultaneously but opposite action being had with respect to the valves in that one opens and the other closes.

Before placing the system under automatic control, certain adjustments must be made to condition the equipment or system for automatic operation. In reviewing these adjustments, it must be remembered that any one pair of the absorption units 11 and 12 can be selected as the unit for holding a selected re-acting solution 15 in which a portion of a sample gas will be absorbed in the operation of the analyzer apparatus, and while three sets of absorption units are illustrated in Figure 1 of the drawings, it is contemplated that but one set, or one re-acting solution 15, will be utilized in testing or measuring the amount of a given gas sample that

will be absorbed by such re-acting solution. The first adjustment step is to load the analyzer with a predetermined quantity of a selected re-acting solution 15 and a predetermined amount of a selected non-reacting solution or liquid, such as mercury 25. This is readily accomplished by pouring the different re-acting solutions into tubes 11 of the absorption units through the large openings or mouths at the tops thereof, the re-acting solutions assuming the same levels in the tubes 11 and tubes 12. The mercury is introduced into the analyzer by pouring the same through bulb 30 from which it passes, with clamp 32 open, into the burette 14, the reservoir 22 and tube 23. After the desired amount of mercury is placed in these elements, the clamp 32 is closed and an auxiliary supply is poured into the bulb 30. To condition the system further, a vacuum is applied to tube 16 to effect the drawing up of the re-acting solution 15 into tubes 12 above the tops thereof. With cocks 17, 18 and 19 closed and cocks 21 and 45 open, the gas sample to be analyzed is introduced into the system between the re-acting solution and the mercury 25, and the main cock 45 is then closed, and a burette reading taken. Thereafter, the valve 17, 18 or 19 is opened, depending upon which set of absorption units is to be employed, and, with burette cock 21 open, the level of the re-acting solution in tubes 11 and 12 is adjusted to a desired relationship and so that both of the electrodes 13 are definitely out of contact with the re-acting solution. The stop cock controlling the selected absorption unit is then closed and the volume of gas sample, at atmospheric pressure, is then recorded by reading the calibration on burette 14. The stop cock controlling the absorption unit being employed is then opened and the gas is allowed to flow to the desired or selected absorption tube 12 by raising the level bulb 30 until the mercury in the burette 14 is near the top thereof. The movable electrode 26 in the top of the mercury reservoir 22 is then adjusted by raising or lowering the reservoir 22 and so that the electrode 26 just fails to contact the mercury in the reservoir. It is to be observed that at this stage of the adjustments the electrodes 13 in tube 11 of the absorption unit will be in contact with the re-acting solution 15. Clamp 32 of the tube 31 leading from the level bulb 30 is then closed, and the automatic reversing control apparatus is brought into play by closing the main and auxiliary control switches of one of the electrical circuits hereinafter described.

Upon closing the automatic control circuit, the magnetically operated valve 36 opens and the magnetically operated valve 37 will close. Vacuum is at once applied to mercury reservoir 22 drawing the mercury up thereinto from the burette 14, and simultaneously withdrawing gas from the selected absorption unit 12 into the burette. Also, the reacting solution 15 simultaneously rises in tube 12 until both electrodes are no longer in contact with the solution 15, thus breaking the circuit but the circuit again shortly closes by virtue of the contact of the mercury with the electrode 26 in reservoir 22. Just prior to the re-closing of the circuit, however, the magnetically operated valves 36 and 37 are automatically de-energized by the breaking of the circuit and the vacuum in reservoir 22 is released by the opening of valve 37 and admission of air. Consequently, the level of the mercury in reservoir 22 drops to seek its own level or natural level, or

at the same level as the mercury level in burette 14. This, the circuit is momentarily broken again and the gas is moved from the burette, by virtue of the dropping of the mercury, into the tube 12 of the absorption unit effecting, in turn, movement of the re-acting solution 15 partially into tube 11 of the absorption unit with the result that the solution again makes full contact with electrodes 13 and the circuit against is closed. This cycle is repeated again and again automatically until the main or auxiliary switch of the electrical circuit is opened by the operator to take the system off the automatic control, which is usually done after the operator has checked the calibration reading on burette 14 a number of times and finds it the same indicating that no further absorption of the gas by the re-acting solution 15 is taking place. Upon eliminating the automatic control, the operator can open the pinch clamp 32 and lower the level bulb 30 to a point where the re-acting solution 15 rises above the top of the absorption tube 12. Stop-cock 21 is then closed and bulb 30 lowered so that the mercury level in bulb 30 is at the same level as the mercury level in the burette 14; and at this point the calibration of the burette 14 is again read and recorded indicating the residual volume of the gas. The percentage of gas absorbed is then calculated by taking the different between the second and first readings of the calibrations.

In Figure 2 of the accompanying drawings, we have diagrammatically illustrated one embodiment of electrical control circuit which can successfully be utilized in conjunction with the preferred embodiment of our invention partially shown in Figure 1. While other control circuits may be used and applied to different embodiments of our invention, the circuit shown in Figure 2 is preferred for application to an Orsat analyzer. As shown, a pair of leads 46 and 47 are connected to a source of alternating current, not shown, and these leads are connected to one pair of contacts of a main switch 48. It is to be understood that the alternating current circuit may be of any desired voltage and frequency provided capacities of other elements hereinafter mentioned are suitable and correspond. Preferably, to avoid danger of injury from high voltage, and as a protection to the operator, one side of the circuit is grounded as indicated at 49. The other pair of contacts of main switch 48 receive a pair of leads 51 and 52 which provide a closed circuit, and a pilot light 53 is conveniently connected across leads 51 and 52 to assist the operator whenever he desires to make examination of conditions. The preferred electrical circuit includes an electronic tube 54 which may be a triode, tetrode, beam power amplifier, thyratron or other type of grid controlled electronic tube, and the same is interposed in the circuit across the leads 51 and 52. The circuit also includes a rectifier tube 56 and a grid controlled glow discharge tube 57, both associated with the tube 54, together with a relay 58 operated by the electronic tube 54 and a relay 59 operated by the tube 57. Suitable adjustable resistors 61, 62 and 63 are interposed in the circuit in association with the tubes 54, 56 and 57, as well as short resistors 64 and 65, and a condenser 66, all as hereinafter described. A secondary or auxiliary control switch 67 for the circuit is interposed in lead 51, as well as a fuse 68, all for the convenience of the operator.

With both switches 48 and 67 closed, the filaments of electronic tube 54 and of rectifier tube 56 become heated. In passing, it may be observed that tubes 54 and 56 may be enclosed in a single envelope and these are obtainable commercially as they are sold under the trade designations of 117N7GT or 117P7GT. The heating of the filament of tube 56 develops a direct current voltage across the adjustable resistor 62, and the condenser 66 which is associated with the resistor 62 is of sufficient capacitance to afford typical direct current operation of the grid controlled glow discharge tube 57 through the short resistor 65 and lead 65'. The tube 57 must be a gas or vapor filled triode ignited by positive grid voltage, relative to its cathode, and capable of operating the relay 59; tubes of this character being commercially available under the trade designations OA4G or IC2I. It is clear that the closing of the circuit places the grid of tube 54 at cathode potential and that the tube passes sufficient current to close relay 58 and apply a direct current voltage to the glow discharge tube 57, this occurring when electrodes 13 are in contact with the re-acting solution 15 in the tube 11 of the absorption unit since the tube 54 is connected with electrodes 13 through the leads 8 and 9, as shown in Figure 1. Since electrode 26 is not in contact with the mercury in reservoir 22 when the electrodes 13 are in contact with the re-acting solution 15, positive voltage is appied to the grid of the tube 57 permitting current to pass for closing the relay 59 which applies alternating current, flowing through leads 41 and 42, to the magnets 38 and 39 for operating the valves 36 and 37 of the modified Orsat analyzer depicted in Figure 1 of the drawings. It may be observed that we have interposed a pilot light 70 across the leads 41 and 42 to indicate to the operator the condition of this portion of the electrical circuit. It is clear, of course, that the pilots 53 and 70 are not essential to the operation but are only included for the convenience of the operator.

In the operation of the system, it is clear that almost simultaneously with the ignition of the tube 57 and energization of the magnets 38 and 39 as well as operation of valves 36 and 37, the mercury rises in reservoir 22 to effect contact with electrode 26, thereby removing positive voltage from the grid of glow discharge tube 57. However, conduction of current has already commenced and, therefore, grid control has been lost and tube 57 continues to conduct current to relay 59 until the electrodes 13 break contact with the re-acting solution 15 by displacement of the same into the absorption tube 12 of the absorption unit.

Upon breaking of the circuit when electrodes 13 lose contact with the re-acting solution 15, a negative bias is applied to the grid of tube 54 shutting off the current and thus opening the relay 58 as well as its associated switch 58' which thus opens the plate circuit of the tube 57 since the switch 58' is connected to the plate circuit of tube 57 by means of a lead 71, adjustable resistor 63 and the resistor tap lead 72. Because of the opening of the plate circuit of tube 57, the relay 59 and its associated switch 59' also opens resulting in the de-energization of the magnets controlling the valves 36 and 37 to release the vacuum in reservoir 22 and allow the mercury which had been drawn up into the reservoir to return or drop to its former level and partially to occupy burette 14. This action displaces the gas from burette 14 and moves it into the absorption tube 12 which, in turn, displaces the re-acting solution so that some of it occupies the reservoir tube 11 to re-establish contact with the electrodes 13 therein. As a result, the circuit is

again closed; the tube 54 conducts current to relay 58 to close the same as well as its associated switch 58' thus again applying plate voltage to the glow discharge tube 57. However, tube 57 does not conduct any current until the mercury in reservoir 22 drops below the electrode 26 and breaks contact therewith to allow the grid of tube 57 to receive positive voltage. Hence, relay 59 does not close until the mercury in reservoir 22 actually breaks contact with the electrode 26 and when it does the cycle is completed and repeats itself again and again until the operator opens switch 67.

Summarizing the operation of the automatic reversing control of our invention, as applied to an Orsat analyzer, it will be observed that in each cycle the following occurs: (1) Mercury is drawn up by vacuum into reservoir 22, thus drawing gas from the absorption tube 12 of the absorption unit; (2) electrodes 13 break contact with the reacting solution 15 as it leaves tube 11 of the absorption unit; and (3) the triode 54 ceases to conduct current and the magnets controlling the valves 36 and 37 are de-energized until the mercury in the reservoir 22 has returned to its initial level just below the contact or electrode 26. Simultaneously, gas is displaced from burette 14 to the tube 12 and the reacting solution returns to its initial position in tube 11 to make contact again with electrodes 13. These steps recur again and again until operations cease upon the opening of the switch 67. It should be observed that although the volume of the gas in burette 14 decreases as absorption of the gas occurs, there is no interference with the operation of the system since the cycle is controlled by the liquid levels in tube 11 and reservoir 22.

While we have illustrated the preferred embodiment of our invention with electrodes 13 contacting the reacting solution in tube 11 and electrode 26 contacting the mercury in reservoir 22, operations may be carried out by placing the electrodes 13 in the tubes 12 of the absorption units, adjacent the tops thereof, instead of in tubes 11, as shown, and by mounting the electrodes 26 and 27 in the top of the burette 14, and then by modifying the electrical circuit of Figure 2 slightly. With these dispositions of the electrodes, the short resistor 64 should be changed so as to be disposed across the leads 8 and 9 which connect the electrodes 13 into the circuit, and the tap lead to adjustable resistor 61 connected to lead 8 should be removed and connected to ground; while lead 9 should be connected to the tap to adjustable resistor 61. The tap lead containing short resistor 65 and leading from line 29 to the adjustable resistor 62 should be connected to ground while the grounded line 28 should be connected to the tap of the adjustable resistor 62. With these changes in the circuit, cyclical operations will occur as before. However, the first arrangement is preferred because of possible danger from explosions where explosive gases or mixtures are being analyzed. Moreover, special equipment must be used in the second arrangement whereas in the former almost a conventional Orsat analyzer may be employed.

In Figure 3 of the drawings, we have illustrated diagrammatically, a modified electrical circuit employing but one triode and an impulse relay with suitable resistors, auxiliary control switch and fuse, for utilization with the equipment shown in Figure 1. For convenience, we have illustrated schematically in Figure 3 an

Orsat analyzer apparatus of somewhat the conventional type which includes a pair of absorption tubes 111 and 112 for holding the re-acting solution 115, with electrodes 113 mounted in tube 111, together with a calibrated burette 114 supported adjacent the absorption tubes and in communication therewith by means of the manifold tube 116 in which a conventional stop-cock 117 is mounted. This equipment also includes a stop-cock 121 for the burette 114 and a mercury reservoir 122 integrally connected for communication with the burette 114 by means of the tube 123. Electrodes 126 and 127 are mounted respectively in the reservoir 122 and the tube 123. In this modification, one of the electrodes 113 is connected by lead 8 to electrode 127 while the other electrode 113 is connected to the modified electrical circuit by means of the lead 9, as hereinafter described. Similarly, electrode 126 is connected through lead 126' to the electrical circuit of Figure 3. As in the preferred embodiment, the reservoir 122 is vented to the atmosphere through an open-ended manifold tube, not shown, in which the magnetically operated valves are mounted; the magnets for operating such valves being energized and de-energized in response to the closing and opening of the circuit, all not shown. To this end, we have provided a pair of lines 146 and 147 for conducting alternating current from a source thereof, not shown, to one pair of contacts of a main switch 148; the circuit being grounded as indicated at 149 for the protection of the operator from high voltages. A pair of leads 151 and 152 are connected to the other pair of contacts of main switch 148 to provide a closed impulse relay circuit which includes a triode 154 and an impulse relay 156 having a pair of contacts 157 and 158 for transmitting current impulses to the leads 141 and 152 connected to the magnets, not shown, for operating the valves which control the vacuum in and the air admission to mercury reservoir 122. A suitable auxiliary switch 167, together with a suitable fuse 168, are connected in the circuit, as shown.

In the operation of the automatic reversing control as modified by the electrical circuit illustrated in Figure 3 of the drawings, a gas sample to be analyzed is introduced into the Orsat analyzer through stop-cock 121 after the re-acting solution 115 and the mercury 125, or other non-reacting liquid has been admitted. In this arrangement, when the auxiliary switch 167 of the automatic reversing control is closed, the re-acting solution 115 in tube 111 will be making contact with electrodes 113 but the mercury in reservoir 122 will not be making contact with electrode 126. Line voltage will be applied to the grid of tube 154 and the tube will conduct current for actuating impulse relay 156 which, in turn, effects energization of the magnets controlling the valves in the manifold tube in communication with the reservoir, through the contacts 157 and 158 of the relay 156. When a vacuum is applied, as in the preferred embodiment of the invention shown in Figures 1 and 2, to the mercury reservoir 122, contact between the mercury drawn up and the electrode 126 is established resulting in the shutting off of power flowing through the triode 154 to impulse relay 156 causing the relay to be conditioned for reversal of current. While the applied vacuum is sufficient to draw enough mercury into reservoir 122 to cause the re-acting solution 115 to leave tube 111 to an extent that electrodes 113 are no

longer in contact therewith, the contacts 157 and 158 of the impulse relay 156 are not energized so that the magnets controlling the valves in the manifold tube in communication with the reservoir 122 are de-energized, and air is admitted to the reservoir 122 and the vacuum is released. As a result, the mercury in reservoir 122 drops and seeks its initial level with the consequent moving of the re-acting solution 115 back into tube 111 to an extent that electrodes 113 are again contacted. The cycle then repeats itself with the impulse contacts 157 and 158 again becoming energized and de-energized recurrently, and the liquids and gas being moved alternately to and fro until the total amount of gas that can be absorbed by the re-acting solution 115 is effected at which time the operator opens the switch 167 to break the circuit.

Another modified electrical circuit for automatically reversing the flow of fluids in a closed system, such as in an Orsat analyzer apparatus, is diagrammatically illustrated in Figure 4 of the annexed drawings. The principal differences in this modified circuit from the circuit illustrated in Figure 2 are that the rectifier tube is eliminated in the modified circuit, and the grid controlled glow discharge tube thereof requires negative grid voltage instead of positive voltage to prevent conduction of current to its relay and prevent its operation. In describing the circuit of Figure 4, reference will be made from time to time to the elements of the Orsat apparatus depicted in Figure 1 of the drawings with which the modified circuit of Figure 4 is adapted to be used for automatic reversing control of the fluids in the apparatus. Before alluding to the circuit of Figure 4, it may be observed that the usual adjustments of the Orsat apparatus are made prior to placing the same on the circuit for automatic reversing control, as hereinabove explained.

As shown, the second modified electrical circuit of our invention, as applied to an Orsat analyzer or like equipment, preferably is provided with elements powered by direct current. The circuit includes a triode tube 254 and a grid controlled flow discharge tube 257; the tube 254 operating a relay 258 and its associated switch 258' while tube 257 operates relay 259 and its associated switch 259'. The electrodes 13 of the Orsat analyzer are connected through leads 8 and 9 to the triode 254 of the modified circuit; the electrodes 26 and 27 to the tube 257 through leads 28 and 29; and the magnetically operated valves 36 and 37 are connected to the relay switch 259' through the leads 41 and 42. Requisite adjustable resistors 261, 262 and 263 are provided for controlling the magnitude of the current applied to the tubes, and a suitable switch 267 is interposed in the circuit for opening and closing the same whenever desired. When the switch 267 is in open position, electrodes 13 are making contact with the reacting solution 15 in tube 11 while electrode 26 is not in contact with the mercury in reservoir 22. The grid of triode 254 is at cathode potential. When the switch 267 is closed, positive voltage is applied to the plate of tube 254 and current flows through the coil of relay 258 closing the switch 258'. The closing of switch 258' effects the application of a positive voltage through small resistor 271 to the plate of grid controlled glow tube 257. Since the contact 26 is open, the grid of tube 257 is substantially at cathode potential and current starts to flow closing relay 259 and its associated switch 259' thus energizing the magnets controlling valves 36 and 37 through leads 41 and 42. Upon opening of valve 36 and simultaneous closing of valve 37 through energization of magnets 38 and 39, a vacuum is created or applied in reservoir 22 drawing mercury from the burette 14, the gas from tube 112 and re-acting solution from tube 11, all as previously explained. Electrical contact between electrode 26 and the mercury in reservoir 22 is then established and as a result a negative bias is applied to the grid of glow tube 257. However, since the tube 257 is conducting direct current, grid control is lost until conduction stops. Therefore, tube 257 still continues to conduct current to relay 259. When most of the gas has been withdrawn from tube 12, the electrodes 13 are no longer in contact with the reacting solution so that a negative bias is applied to the grid of tube 254 and the current flowing to relay 258 is cut off opening the switch 258'. This stops the current through tube 257 opening relay switch 259' and the magnets 38 and 39 are de-energized opening valve 37 and closing valve 36 to release the vacuum in reservoir 22 by the admission of air. Consequently, the mercury in reservoir 22 returns to its initial level moving the gas back into tube 12 and, in turn, part of the re-acting liquid back into tube 11 to make contact again with the electrodes 13. Since current again flows from tube 254 to its relay 258 and positive voltage is again applied to the tube 257 to re-establish grid control, the tube 257 is again conditioned for action but current does not flow in tube 257 until the mercury 25 in reservoir 22 drops below electrode 26 removing the negative bias on the grid of tube 257. When the mercury has dropped to its initial level the cycle repeats.

From the above examples, it is obvious that automatic reversing control is obtained by the momentary make and break between the electrodes 13 and reacting solution 15, and the electrode 26 and the mercury 25. Once the magnets controlling the valves 36 and 37 are energized they remain energized until solution electrodes 13 momentarily break contact. Once the magnets controlling valves 36 and 37 become de-energized they remain de-energized until the mercury electrode 26 momentarily breaks contact. It is to be understood that it is not necessary to employ mercury in the system, since other materials or liquids that are suitable electrical conductors may be used as long as a clear break is afforded between the same and the electrode 26.

We have indicated above that our hereinabove described invention is not limited to application to an Orsat analyzer. As a further adaptation of our invention, reference is made to Figure 5 of the accompanying drawings wherein a preferred embodiment of the invention is shown as adapted to a Toepler pump, a device utilized in laboratories for transporting gases or fluids without contamination from one apparatus to another for further analysis or treatment with other chemicals or reacting solutions. As illustrated in Figure 5, we provide a chamber 311 for holding a quantity of a gas to be transferred to other equipment without contamination, the gas having been received in chamber 311 from an Orsat analyzer or other apparatus, with stop cocks 312 and 313 in tubes 314 and 315, respectively, closed and with a predetermined quantity of mercury already introduced into the system. The equipment also includes a pair of mercury reservoirs 316 and 317 in communication with one another by means of integral tubing 318; the reservoir 316 having an electrode 319 sealed in the top thereof and the

reservoir 317 having an electrode 321 sealed in its top. Reservoirs 316 and 317 are supported at different levels with reservoir 316 at a slightly lower elevation than reservoir 317, and at such elevation that when the mercury rises therein its highest level will be below the level of the tip of the electrode 321 in the reservoir 317. The difference between elevations of these two reservoirs should be equal to or greater than the absolute pressure of the vacuum system, as expressed in terms of height of mercury, or other confining liquid.

In accordance with our invention, the reservoir 316 is vented to the atmosphere through tubing 333 and a manifold 334 which is open at both ends and in which is mounted a pair of magnetically operable valves 336 and 337; this arrangement being similar to the manifold 34 and valves 36 and 37 of the embodiment of our invention shown in Figure 1 of the drawings in conjunction with mercury reservoir 22 of that embodiment. As shown, a magnet 338 is provided for controlling valve 336 and a magnet 339 for controlling valve 337; magnets 338 and 339 being interposed in the electrical circuit and being energized and de-energized in response to momentary make and break of the circuit hereinafter described. In the Toepler pump embodiment of our invention, we also provide a by-pass tube 340 between chamber 311 and reservoir 317, and an outlet tube 341 from mercury reservoir 317 which leads through a bulb 342 to discharging tube 343 through tube 315. As shown, a third electrode 344 is mounted in the tubing 318 connecting mercury reservoirs 316 and 317, and electrodes 319, 321 and 344 are connected into the electrical circuit selected by means of leads 345, 347 and 348, respectively.

Preliminarily to placing the Toepler pump embodiment of our invention under automatic control, the system to which the gas from the chamber 311 is to be delivered is initially evacuated and part of the gas is transferred from chamber 311 by opening valve 312 with valve or cock 313 closed, thus equalizing pressures between chamber 311 and the discharging or outlet tube 343. Valve 312 is then closed and the control circuit turned on. With the circuit closed, valve 336 opens and valve 337 closes upon energization of the control magnets 338 and 339, and when contact between the electrode 321 and the mercury in reservoir 317 is about to break, by-pass tube 340 opens and gas from chamber 311 passes into reservoir 317 filling the space therein. When contact between electrode 321 and the mercury breaks, the valve 336 closes and valve 337 opens because of the de-energization of the magnets 338 and 339, thus releasing the vacuum holding the mercury in reservoir 316 returning the mercury to reservoir 317 to overflow the same slightly pushing the gas through bulb 342 to the discharging tube 343. At this point, the mercury breaks contact with electrode 319 in reservoir 316, valve 336 again opens and valve 337 closes creating a vacuum again in reservoir 316 to draw the mercury again from the reservoir 317, thus repeating the cycle. The magnets 338 and 339 are connected into the selected electrical circuit by means of the leads 341*a* and 342*a*, respectively.

It may be observed that the electrical circuit of Figure 2 of the accompanying drawings can be used in conjunction with the Toepler pump embodiment of our invention if the resistor 64 thereof is replaced by a conductor or lead, while the electrical circuit of Figure 3 may be employed without change. Moreover, the circuit of Figure 4 of the drawings may be utilized with the Toepler pump embodiment by replacing resistor 264 with a conductor. It may be added that the tubing 341 from the top of reservoir 317 to the bulb 342 is preferably made a capillary tubing so that when the mercury returns from reservoir 317 to reservoir 316 in the second stage of each cycle, the mercury column will break thus preventing syphoning of mercury from the reservoir 317 into the line 341. If it is desired to reduce the frequency of the cycle of operations, a restriction can be placed in the tubing 333 between the valve manifold 334 and the reservoir 316.

In Figure 6 of the accompanying drawings, we have illustrated diagrammatically another modification of electrical circuit for use with either the Orsat analyzer or the Toepler pump embodiments of our invention. As shown, and as applied to the Orsat analyzer embodiment of the invention, this modified circuit includes a main control switch 448 of which one pair of contacts are connected to a source of alternating current, not shown, by means of the leads 446 and 447. The other pair of contacts of main switch 448 are engaged by a pair of main circuit leads 451 and 452, the circuit including a grid-controlled vacuum tube or triode 454 of suitable capacity to operate a relay 453, a rectifier 457 for producing direct current voltage, and a conventional filtering condenser 456 connected across a potentiometer which is designated by the reference numerals 461 and 462. The resistors 463 and 464 of the circuit are grid resistors for the triode 454, as indicated by the diagrammatic showing of Figure 6. As in the other circuits described above, we provide an auxiliary switch for the convenience of the operator which is designated by the reference numeral 467, and the conductors from the various elements of the Orsat analyzer are interposed into the circuit as in the previously described circuits. For example and with reference to Figures 1 and 6, conductors 8 and 9, respectively, from the electrodes 13 of the absorption unit 11, 12, are connected to the grid of triode 454 through resistors 463 and 464; the conductors 28 and 29 from the electrodes 26 and 27 are connected into main circuit line 452; and the conductors 41 and 42 from the magnets controlling the valves 36 and 37 are connected to the contacts of the relay switch 453' operated by relay 453.

Initially, the circuit is closed with the re-acting solution of the absorption unit in contact with the electrodes 13 and, at this stage, the electrode 26 is out of contact with the mercury of the reservoir 22. Under these conditions, the grid of triode 454 is connected to the cathode through resistor 464 and conductors 8 and 9. Moreover, since there is no contact between the electrode 26 and the mercury in reservoir 22, there is no grid bias across resistor 464, and the grid of triode 454 is at cathode potential. Switch 467 is then closed to place the system under automatic reversing control and, as a result, triode 454 conducts sufficient current to relay 453 as to effect a closing of relay switch 453' which controls the power to the magnetically operable valves 36 and 37, see Figure 1 of the drawings. Because of the opening of valve 36 and simultaneous closing of valve 37, when relay switch 453' closes, mercury is drawn up into reservoir 22 closing the circuit containing electrodes 26 and 27. During the immediately succeeding portion of the cycle, current flows through resistors 463 and 464 thus applying

a fraction of the negative potential of resistor **462** to the grid of triode **454**, thus reducing the current conducted through relay **458** to an intermediate value but not sufficiently low as to allow the relay switch **458'** to open. The mercury continues to rise in reservoir **22** until contact is entirely broken between the reacting solution in tube **11** and the electrodes **13** and, at this point the electrical circuit is broken through resistors **463** and **464** while the grid is connected to the most negative potential through resistor **463** and leads **28** and **29** from electrodes **26** and **27**. This negative bias is of sufficient value to reduce the current through relay **458** to zero resulting in the opening of the relay switch **458'** and breaking of current supply to the magnets controlling valves **36** and **37**. As a result, valve **36** closes and valve **37** opens with a venting of mercury reservoir **22** and resulting rise of the re-acting solution in tube **11** of the absorption unit to contact electrodes **13** again. This again places an intermediate negative bias on the grid of triode **454** allowing an intermediate value of current to flow to relay **458** but not of sufficient value to close relay switch **458'**. The mercury continues to fall in reservoir **22** until out of contact with electrode **26** and, at this point, the circuit through resistors **463** and **464** is again opened placing the grid of triode **454** at cathode potential through resistor **464**; whereupon full current again flows to relay **458** and relay switch **458'** closes to repeat the cycle.

It will be clear that the hereinabove last described circuit takes advantage of a well known characteristic of relays; namely, the power required to close a relay is far greater than the power required to hold the relay closed.

We claim:

1. Orsat apparatus comprising in combination a mercury reservoir and a U-type absorption tube, a burette in communication with said absorption

tube, a conduit establishing communication with said mercury reservoir and said burette, a first pair of electrodes consisting of a first electrode mounted within said reservoir and a second electrode disposed in said conduit, a second pair of electrodes disposed in one arm of said absorption tube, a pair of valves in spaced relationship electrically actuated by a pair of magnets, one of said valves connecting to a vacuum means, the other of said valves connecting to the atmosphere, a conduit connecting said valves, a tube establishing communication between said valves and said reservoir, and an electrical circuit containing all of said electrodes and said magnets.

2. Orsat apparatus as defined in claim 1 in which the electrical circuit comprises an electronic tube connected to said second pair of electrodes, a glow-discharge tube, a first relay operated by said electronic tube for applying direct current voltage to said glow-discharge tube when said second pair of electrodes are connected into the circuit and the circuit is closed, and a second relay operated by said glow-discharge tube for applying alternating current to said magnets to actuate said valves.

3. Orsat apparatus as defined in claim 1 in which the electrical circuit comprises a triode, and an impulse relay operated by said triode for energizing said magnets to actuate said valves.

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