

Aug. 9, 1932.

W. N. GREER

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ELECTRIC CONTROL SYSTEM

Filed Dec. 15, 1927

2 Sheets-Sheet 1

Fig. 1.

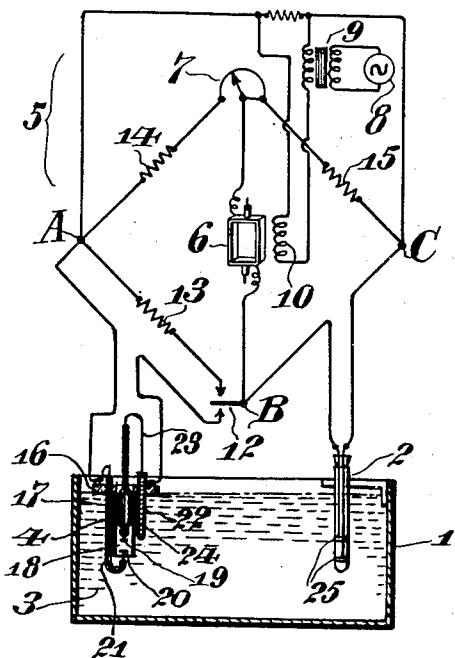


Fig. 2.

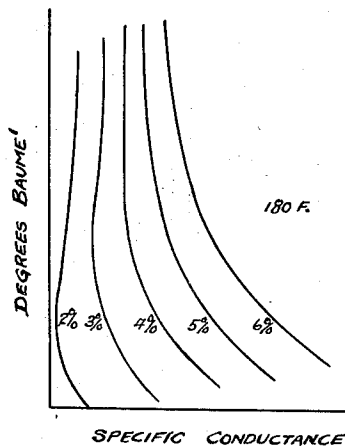


Fig. 3.

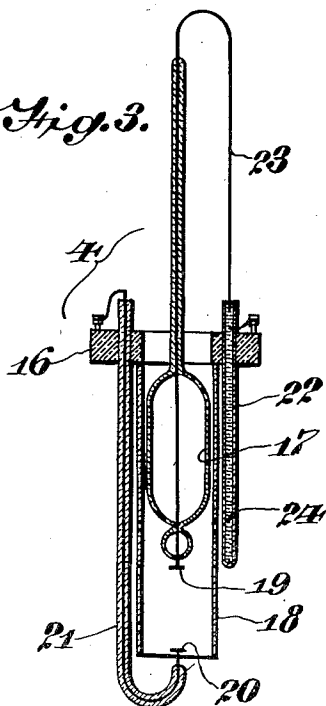
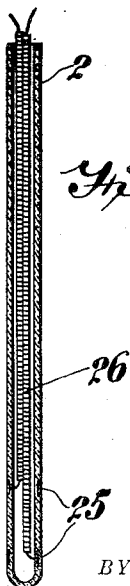


Fig. 4.



INVENTOR
Willard N. Greer
BY
Cornelius L. Chet
ATTORNEY

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2 Sheets-Sheet 2

Fig. 5.

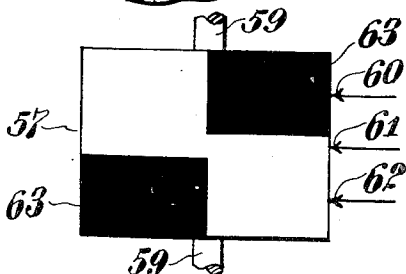
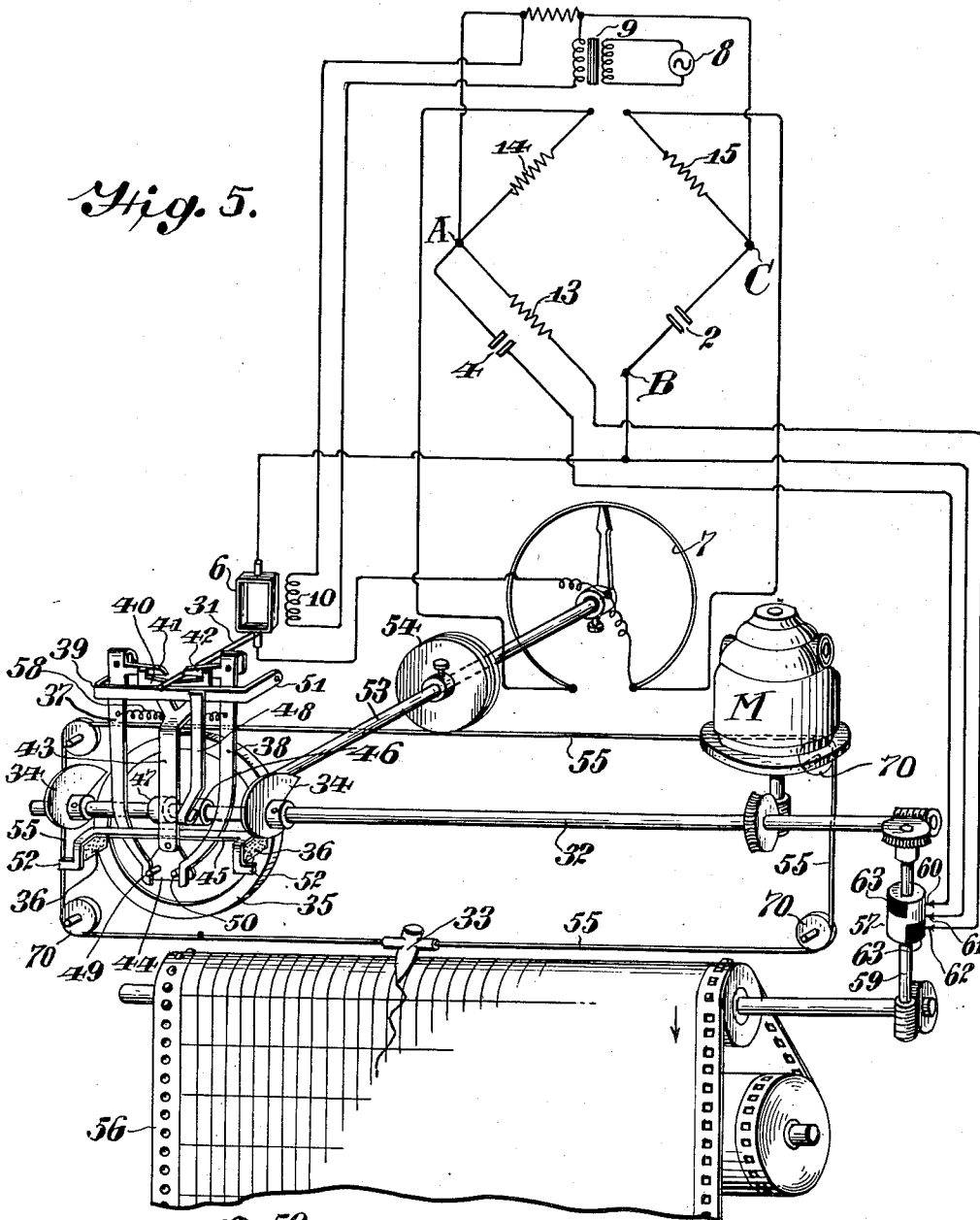


Fig. 6.

BY

INVENTOR
Willard H. Greer
CORNELIUS L. E. LUTZ
ATTORNEY

UNITED STATES PATENT OFFICE

WILLARD N. GREER, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR TO LEEDS & NORTHROP COMPANY, OF PHILADELPHIA, PENNSYLVANIA, A CORPORATION OF PENNSYLVANIA

ELECTRIC CONTROL SYSTEM

Application filed December 15, 1927. Serial No. 240,323.

My invention relates to a method of and apparatus for measuring and effecting controls in an electrical system in response to variations of a condition, as the specific gravity of a conducting solution.

My invention resides in a method of, and apparatus for measuring a fluid condition by variation of the electrical path through said fluid between a plurality of electrodes.

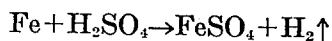
My invention further resides in a method of and apparatus for determining the acid concentration of a solution when the values for specific gravity and conductance are found.

My invention further resides in a recorder system and electrical balancing circuits whereby the specific gravity and specific conductance of a solution may be individually determined.

My invention more specifically resides in a method of and apparatus for determining the specific gravity of a conducting liquid by comparing the resistance of a varying body of the liquid with the specific conductance of said liquid.

More specifically my invention resides in hydrometer means wherein the fluid resistance between its terminals is representative of the specific gravity of a conducting fluid.

A specific use of the invention is in determining the percentage of acid concentration in a pickling bath for cleaning steel rods, wires, sheeting, etc. The pickling bath generally is a dilute solution of sulphuric acid, usually $2\frac{1}{2}$ to 5%; the temperature range being from 160° F. to 205° F. The iron reacts with the sulphuric acid evolving hydrogen and forming ferrous sulphate according to the equation,



As the cleaning process is continued the ferrous sulphate will increase to the point where the solution is too inactive for economical operation. At that point it is cheaper to dump the solution and make a fresh bath rather than increase the acid concentration further. This decrease in activity of the solution is due to decreased ionization of the acid caused by the increased sulphate concentra-

tion. A graphical relation between the specific conductance and the content of ferrous sulphate may be obtained experimentally for different acid concentrations ranging from 2 to 6%, the solution containing from 0 to 2.7 pounds per gallon of ferrous sulphate. In practice the temperature range may vary from 160° F. to 205° F. but the data taken at 180° F. is sufficiently accurate since the temperature coefficient of these solutions is small and may be neglected. Further data on the relation between the FeSO_4 content and specific gravity may be obtained experimentally, the results being graphically recorded to show the relation between the ferrous sulphate content and the specific gravity in degrees Baumé. By combining the results shown by the two different sets of curves the chart shown by Fig. 2 is obtained whereby the specific conductance and specific gravity in degrees Baumé are represented for different acid concentrations of the solution.

In determining the specific gravity of the solution, the principle that a cylindrical vessel of length L cm and cross section $f\text{cm}^2$, between two electrodes of the same cross section, has the resistance $C = \frac{L}{f}$, according to

Kohlrausch (Leitvermögen der Elektrolyte, page 12), is utilized to a certain degree in the specific hydrometer element shown by applicant. If the resistance between electrodes 19 and 20 is a function of their geometrical relation, other things being constant, this resistance can be interpreted in specific gravity units. In pickling solutions the specific conductance changes as the pickling process proceeds due to the increase in ferrous sulphate content. However the ratio of the resistance between electrodes 25 of the conductance element to the resistance between electrodes 19 and 20 will be a measure of the specific gravity if the cell constant of electrodes 19 and 20 is a certain function of the specific gravity, since any change in specific conductance of the solution would be balanced out by this ratio. In other words the resistance between electrodes 19 and 20 being proportional to both the specific conductance and the geometrical relation of the electrodes,

while the resistance between the electrodes 25 is proportional only to the specific conductance, the distance between them being fixed, it follows that the resistance between electrodes 19 and 20 is proportional to the specific gravity since the specific gravity of the solution is also proportional to the space factor of electrodes 19 and 20. It is seen therefore that a measure in relative specific gravity units may be obtained in the manner shown in Fig. 1, whereby a common factor, i. e., the specific conductance, is balanced out of the resistances between electrodes 25 and electrodes 19 and 20. Therefore the resistance between electrodes 19 and 20 may be expressed as

$$R = \frac{1}{c} f(G)$$

where c = conductivity of the solution and $f(G)$ depends upon geometrical relation of the cooperating elements. It will be noted that relative motion of the electrodes changes $f(G)$ only.

For an illustration of some of the forms my invention may take, reference may be had to the accompanying drawings, in which:

Fig. 1 shows diagrammatically the application of a Wheatstone bridge or balancing circuit, shown generally by 5, for use in connection with a body of conducting fluid having hydrometer and conductance elements therein.

Fig. 2 shows a chart whereby the percentage of acid concentration in the fluid may be determined.

Fig. 3 is a cross sectional view of the hydrometer shown in Fig. 1.

Fig. 4 is a cross section of the conductance element shown in Fig. 1.

Fig. 5 shows the details of a recorder mechanism and electrical balancing circuits as used in connection with applicant's invention.

Fig. 6 is a development of the surface of the commutator shown in Fig. 5.

Referring to Fig. 1, 8 is source of alternating potential for the Wheatstone bridge AC having a galvanometer coil 6 connecting across the bridge, one end terminating in the slide wire resistance 7, the other end at connection B. The field for the galvanometer consists of coil 10 which is energized by the source of potential through the transformer 9. Balancing resistances 13, 14 and 15 are connected in separate branches of the circuit. In parallel with the resistance 13 is connected hydrometer element 4 having a casing 18 which is supported by a float member 16 and adapted to move vertically within the casing. The float supports an electrode mounting 21 whereby an electrode 20 is disposed near the bottom of the casing which is open. The float also supports the

tube 22 having a conducting fluid therein such as a mercury adapted to contact at all times with a connecting member 23 which is carried by the buoyant member 17. At the lower end of said member is disposed an electrode 19 adapted to be bridged by the conducting solution to complete electrical contact with electrode 20. The float member has binding posts mounted thereon for connections to the Wheatstone bridge as shown in Fig. 1. As the hydrometer moves vertically in the casing, due to changes in the specific gravity of the solution, connection will be maintained through the mercury body 24 and contact 23 with a minimum resistance to the hydrometer operation.

The movement of the hydrometer float 16 in response to changes in specific gravity of the solution varies the distance between the electrodes 19, 20 and therefore the resistance or conductivity of the fluid path between them, or more generally, the float movement varies the length/area ratio of the conductive path between the electrodes. Otherwise stated, the length-area ratio of the path between electrodes 19, 20 is a function of the specific gravity $[f(G)]$.

On the opposite side of the bridge between BC a conductance element 2 is connected, which consists of an insulating casing open at the upper end and closed at the lower end having conducting wires 26 leading therein and connected to ring contacts 25 disposed on the exterior of the casing and insulated from each other so as to be bridged only by the conducting fluid. A switch 12 is located at B so as to balance the conductance element 2 with either resistance 13 or the hydrometer element 4.

The balancing of the circuit is accomplished by a self-balancing recorder shown in Fig. 5 in which a motor M drives through suitable gearing at constant speed a shaft 32. Cam 46 mounted on the shaft is adapted to rock, through the connecting arm 48, the yoke member 39 pivoted at 51. Arm 43 is pivoted so as to be actuated by cam 47 in a direction away from the clutch member 35, and has pivoted at its lower end bar 45 having offset portions 52 at its opposite extremities and also cork blocks or the like, 36, thereon, adapted to engage the wheel 35 so as to act as a clutch. Mounted on bar 45 is a triangular plate 44 having pins 49 and 50 at its lower edge. Pivotaly mounted and disposed within the yolk structure are two arms 37 and 38 normally urged together by spring 58. The lower extremities of these arms engage pins 49 and 50 respectively in a manner that will be presently explained.

The galvanometer coil 6 has an arm 31 mounted thereon to oscillate with the galvanometer movement and is normally disposed between the overhanging arms 41 and 42 of pivoted members 37 and 38. On yoke

member 39 is disposed oppositely inclined edges and stop members at its limits. When the galvanometer coil 6 is energized due to an unbalance of the Wheatstone bridge, the arm 31 will move to either the right or left and so will be disposed underneath one of the arms 41 or 42. Assuming movement to the right, cam 46 actuating rock member 39 through the lever 48 will clamp the pointer arm between the inclined right edge of member 40 and arm 42, and upon further tilting of yoke 39 the arm 38 will be moved in a clockwise direction about its pivot engaging pin 50 and tilting the bar 45 in a clockwise direction. This movement takes place while cam 47 is holding arm 43 away from the disc and therefore there is no positive contact between the clutch members. When the clutch engages with wheel 35 in its tilted position, the left cam 34 mounted on shaft 32 will engage the left offset member 52 and rotate bar 45 counter-clockwise and consequently clutch wheel 35. The clutch wheel is connected to shaft 53 operating a sliding contact for engagement with the slide-wire resistance 7. It will be seen therefore that the recording apparatus is self-balancing since adjustments of the slide-wire resistance will continue until the pointer 31 is again in its neutral position, the arm 45 thereby being in a horizontal position and not engaged by cams 34 so as to move the wheel 35. On the shaft 53 is a wheel 54 having a wire 55 positively connected thereto so as to move a recording pen 33 along a chart 56, which is operated through suitable gearing by motor M. Geared to the motor driving means is a commutator element 57 which may be used in place of the switch 12 shown in Fig. 1. The commutator element comprises a drum member mounted on shaft 59, having spaced alternating strips of insulation 63 to break the circuit between common contact 61 and contacts 60, 62, and rotates at constant speed so as to connect alternately the circuit with the hydrometer element and the balancing resistance 13.

The operation of the apparatus and method of determining specific gravity and percent acid concentration is as follows:

The apparatus is connected as shown diagrammatically in Fig. 1, the conductance and hydrometer elements both being immersed in a pickling bath 3 in tank 1. Through the motor driven commutator the specific conductance and specific gravity in degrees Baumé may be periodically recorded. For instance when the switch 12 throws resistance 13 in circuit the specific conductance of the solution is determined through the recording means by creating an unbalance in the circuit resulting in a deflection of the galvanometer which operates to restore the balance as previously explained. When the switch

12 connects the hydrometer element 4 in the circuit, the bridge is again unbalanced and the cooperation of the galvanometer and slide-wire resistance through the recorder mechanism restores the balance and at the same time records the degree of unbalance. The specific gravity and specific conductance of the solution at a given point may therefore be recorded on the chart individually and without appreciable difference in time. These two values being known, they are referred to the chart in Fig. 2 and the percentage of acid concentration readily obtained thereon. While solutions of different acidity may have the same specific conductance, or the same specific gravity, they do not have the same specific conductance and specific gravity at the same time, so that the degree of acidity of a solution is uniquely determined by the concurrent values of its specific gravity and specific conductance.

It is obvious that the electrodes 19 and 20 may be shaped and designed to produce varying degrees of resistance with the movement of the hydrometer, so that within given limits of specific gravity the recording apparatus may be rendered more sensitive and thereby measure the changes in density of the fluid more accurately.

The method described for the determination of acidity, may be considered as a method for determining hydrogen ion concentration, which is directly related to degree of acidity; and inasmuch as the method described is suitable for determining acidity, it is available also for determining the degree of alkalinity, or hydroxyl ion concentration, to which degree of alkalinity is directly related.

What I claim is:

1. An electrical measuring system comprising a balanceable electrical measuring network, relatively fixed electrodes disposed in a conducting solution connected in one branch of said network, relatively movable electrodes likewise disposed in said solution and connected in another branch of said network, and means for balancing the differences in potentials representative of the resistances between said pairs of electrodes.

2. In an electrical measuring and recording system, a balanceable electrical measuring network, impedances in different branches of said network comprising resistances between different pairs of electrodes respectively disposed in a conducting solution, means for effecting relative movement of the electrodes of one of said pairs in response to variations in specific gravity of said solution, means relating said impedances to said network for measuring and recording the specific gravity of said solution, and means individually relating one of said impedances to said network for measuring and recording the specific conductance of said solution.

3. The method of determining the specific gravity of a solution, which comprises comparing the electrical resistance of a path, in the solution, whose conductivity is a function of the specific gravity and specific conductance of the solution, with the electrical resistance of a path, in the solution, whose conductivity is a function of its specific conductance. 70
 4. In the determination of the acidity of a solution, the method which comprises the steps of comparing the conductivity of a path, in the solution, which varies with specific gravity and specific conductance, with the conductivity of a path, in the solution, which varies with the specific conductance to measure the specific gravity of the solution, and measuring the resistance of said second path to determine the specific conductance of the solution. 75
 5. The method of determining the specific gravity of a solution, which comprises comparing the resistance of a path in said solution of constant length and area with the resistance of a second path the ratio of whose length to area is determined by the specific gravity of the solution. 80
 6. The method which comprises balancing the resistance of a conductive path in a solution against a standard resistance to determine the specific conductance of the solution, and balancing the resistance of said path against the resistance of a second path whose length to area ratio is a function of specific gravity, to determine the specific gravity of said solution. 85
 7. A system for determining the acidity of a solution comprising a balanceable bridge network, and means including said network for successively determining the specific gravity of the solution and its specific conductance. 90
 8. An electrical system comprising a conductivity cell whose resistance varies with change in specific conductance of a solution, a conductivity cell whose resistance varies with change in specific gravity and specific conductance of said solution, measuring means, and selective means for connecting said first cell or both of said cells with said measuring means to determine respectively the specific conductance and specific gravity of the solution. 95
 9. An electrical system comprising a conductivity cell whose resistance varies with the specific conductance of a solution, a conductivity cell whose resistance varies with the specific gravity and specific conductance of the solution, and means connected with said cells for measuring specific gravity of said solution. 100
 10. An electrical system comprising a Wheatstone bridge, a conductivity cell whose resistance varies with specific conductance of a solution included in one arm of said bridge, a conductivity cell whose resistance varies with the specific gravity and specific conductance of said solution included in another arm of said bridge, a resistance adjustable to balance said bridge, and a scale associated with said adjustable resistance for indicating the specific gravity of said solution. 105
 11. An electrical system comprising a balanceable electrical bridge network, a conductivity cell whose resistance varies with the specific conductance of a solution included in one branch of said network, a conductivity cell whose resistance varies with the specific gravity and specific conductance of said solution including in another branch of said network, a resistance adjustable to balance said network, and a scale associated with said adjustable resistance for indicating the specific gravity of said solution. 110
- WILLARD N. GREER. 115

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