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APPARATUS FOR CONTROLLING THE SUPPLY OF CURRENT
TO ELECTROPLATING VATS AND THE LIKE

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2 SHEETS--SHEET 1

FIG 1.

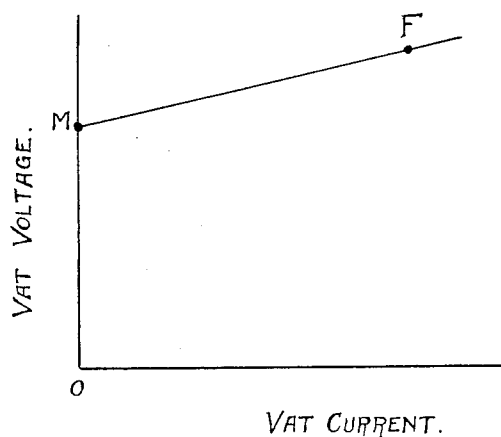
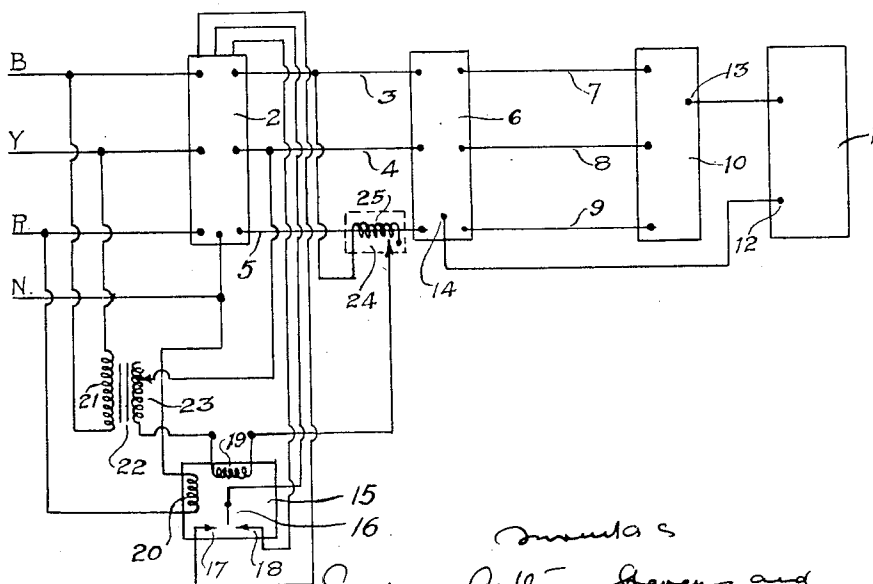


FIG 2.



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APPARATUS FOR CONTROLLING THE
SUPPLY OF CURRENT TO ELECTRO-
PLATING VATS AND THE LIKE

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This invention relates to apparatus for controlling the supply of current to electroplating vats and the like for the purpose of automatically maintaining a constant current density over the surface of the work immersed in the vat regardless of variations in the area of this surface due to the amount of character of the work and has for its object to provide improved control apparatus of this character.

It is found in practice that, in order to ensure satisfactory condition of operation the voltage maintained at the vat terminals should vary from a minimum when the vat is substantially unloaded to a maximum when the vat is fully loaded, these minimum and maximum voltages being dependent on the size of the vat, the composition concentration and temperature of the liquid electrolyte and the nature of the work.

In other words, the voltage at the vat terminals should have a predetermined adjustable rising characteristic in accordance with the current traversing the vat from an adjustable minimum voltage.

It is usual to provide apparatus for varying the voltage applied to the vat terminals and according to the invention this apparatus is arranged to be automatically controlled by a control relay or relays energised when the sum of a substantially constant voltage and a voltage proportional to the current traversing the vat is unequal to the voltage at the vat terminals or a voltage proportional to this terminal voltage, the current traversing the energising winding of the relay or relays under these conditions causing the relay to effect the operation of the control apparatus to vary the voltage applied to the vat terminals to render this voltage equal to the sum of the voltages above referred to.

The invention is illustrated in the accompanying drawings of which Figure 1 is a curve diagram showing the general nature of the voltage-current characteristic desired Figures 2 and 3 being circuit diagrams of two forms of controlling apparatus arranged in accordance with the invention.

Referring now first to Figure 1 the abscissae of which represent the current traversing the vat while the ordinates represent the voltage applied to the vat terminals it will be seen that the latter voltage varies from a minimum indicated at OM when the vat current is substantially zero (for a negligible amount of work being treated) to a maximum indicated at F when the vat is fully loaded, these minimum and maximum voltages being dependent, as above stated, on the size of

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the vat, the composition, concentration and temperature of the liquid electrolyte and the nature of the work.

In the apparatus shown in Figure 2 the plating vat 1 is operated from a three-phase supply circuit the phase conductors of which are indicated at B, Y, R and the neutral conductor at N. These supply conductors are connected to the input terminals of a voltage regulator 2 of any suitable type and having an output circuit the output terminals of which are connected by conductors 3, 4, 5 to the primary windings of a three-phase main transformer 6 the secondary windings of which are connected by conductors 7, 8, 9 to the input terminals of a rectifier system 10. The terminals 11, 12 of the vat 1 are connected respectively to the output terminal 13 of the rectifier system 10 and to the neutral point 14 of the star-connected secondary windings of the transformer 6.

The operation of the voltage regulator 2 is controlled by a relay 15 of the two-element type the movable member 16 of which engages with one or other of two fixed contacts 17, 18 when the relay is energised by current traversing the winding 19 of the relay 15 in one direction or the other. The contacts 17, 18 are included in circuits controlling the operation of the regulator 2 in the usual manner to effect an increase or decrease in the voltage applied to the conductors 3, 4, 5.

The other winding 20 of the control relay 15 is connected across the neutral conductor N and the phase conductor R of the three-phase supply circuit.

The primary winding 21 of a voltage transformer 22 is connected across the phase conductors B, Y of the supply circuit the transformer 22 being provided with a secondary winding 23. The conductor 5 is provided with a quadrature current transformer 24 having a secondary winding 25 the voltage of which is proportional to the current in the conductor 5 and the relay winding 19 is connected in a circuit leading from the conductor 3 through an adjustable portion of the current transformer secondary winding 25 and an adjustable portion of the secondary winding 23 of the voltage transformer 22 to the conductor 4.

The voltage impressed upon the circuit of the relay winding 19 from the secondary winding 23 is an adjustable voltage proportional to the substantially constant voltage across the supply conductors B, Y while the voltage impressed upon this circuit from the conductors 3, 4 is proportional to the voltage at the vat terminals 11, 12. The third voltage impressed upon this circuit

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from the winding 25 of the transformer 24 is an adjustable voltage proportional to the current traversing the conductor 5 which is proportional to the current traversing the electrolyte of the vat 1.

The connections of these elements of the circuit of the relay winding 19 are so arranged that the current traversing this winding depends upon the difference between the voltage across the conductors 3, 4 and the sum of the voltages due to the transformer windings 23 and 25.

It will be evident that by varying the adjustment of the variable connection of the transformer secondary winding 23 the minimum vat terminal voltage above referred to can be varied as desired while by adjusting the variable connection of the transformer secondary winding 25 the slope of the characteristic current-voltage curve of Figure 1 can likewise be varied.

The relay winding 20 is supplied with quadrature current from the conductors R, N so that the current traversing the relay winding 19 in one relative direction or the other due to the difference above referred to will cause the relay 15 to operate to close the contacts 17 or 18 to cause the voltage regulator 2 to increase or to decrease the voltage applied to the conductors 3, 4, 5 and consequently the voltage applied to the vat terminals 11, 12 so as to restore the desired predetermined operating condition.

The predetermined minimum vat voltage indicated at OM in Figure 1 can evidently be adjusted as desired by means of the tappings on the secondary winding 23 of the transformer 22 while the slope of the current-voltage curve MF can be similarly adjusted by means of the tappings on the secondary winding 25 of the transformer 24.

Referring now to Figure 3 the terminals 11, 12 of the plating vat 1 are supplied with uni-directional current from a three-phase alternating current supply circuit through a voltage regulator 2, main transformer and rectifier system 10' which may be similar to the arrangement of Figure 2.

The control relay 26 is, in this apparatus, of the direct current polarised or central zero moving coil type comprising an energising winding 27, a movable element 28 and fixed contacts 29, 30.

The relay winding 27 is connected across the vat terminals 11, 12 in a circuit including an inductance 32, an adjustable portion of a potentiometer resistance 33, a device 34 providing an adjustable uni-directional voltage and a normally closed contact D1 of a relay D (not shown).

The potentiometer resistance 33 is connected across the terminals of a shunt 35 which are also connected to the output terminals of a three-phase rectifier system 36 the input terminals of which are connected to the star-connected secondary windings 37 of a set of current transformers 38 the primary windings of which are constituted by the conductors 3, 4, 5 connecting the voltage regulator 2 to the main transformer 10'.

The device 34 comprises a set of three primary cells 39 connected in series with one another, the cell terminals being connected to contacts 40 adjacent pairs of which can be bridged by a potentiometer resistance 41. The conductors 42, 43 leading from the potentiometer resistance 33 and the relay contact D1 are connected respectively to an adjustable contact 44 of the potentiometer resistance 41 and the outer terminals of the outer cell 39. A meter 45 is connected

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across the conductors 42, 43 for the purpose of indicating the voltage of the set of cells 39.

The fixed contacts 29, 30 of the control relay 26 are as in the apparatus of Figure 2 arranged to control the operation of a voltage regulator in the usual manner to adjust the voltage applied to the conductors 3, 4, 5.

In operation, the current traversing the circuit of the winding 27 of the control relay is, as in the apparatus of Figure 2, due to the difference between the sum of a constant voltage and a voltage proportional to the current traversing the vat and the voltage across the vat terminals. In the apparatus of Figure 3 the constant voltage is the voltage across the conductors 42, 43 derived from the set of cells 39 and adjusted by means of the potentiometer resistance 41 and its contact 44. The voltage proportional to the current traversing the vat 1 is derived from the potentiometer resistance 33, the circuit of the control relay winding 27 including the vat terminals 11, 12 and the relay contact D1 of the relay D which is energised so long as the current supply to the apparatus is intact.

The inductance 32 is provided for the purpose of preventing ripple variations in the current traversing the winding 27 of the control relay 26 and if desired a condenser 55 may be connected in parallel with the relay winding 27 (as indicated in dotted lines) for the same purpose.

In the event of current traversing the control relay winding 27, due to the sum of the constant voltage of the device 34 and the voltage of the potentiometer resistance 33 becoming unequal to the voltage across the vat terminals 11, 12 the relay 26 is energised to cause its movable element 28 to engage with either the fixed contact 29 or the fixed contact 30 of the control relay 26 according to the direction of the current traversing the relay winding 27. This current direction will evidently depend upon whether the voltage across the vat terminals 11, 12 is greater or less than the sum of the voltages due to the device 34 and to the potentiometer resistance 33.

The operation of the apparatus of Figure 3 is otherwise substantially the same as that of the apparatus of Figure 2 and will be readily understood without further description.

The minimum vat terminal voltage and the slope of the current voltage characteristic curve can be varied as in the apparatus of Figure 2 by adjusting the variable connections of the device 34 and the potentiometer resistance 33 respectively.

The invention is evidently not limited to the particular arrangements of apparatus above described and illustrated by way of example.

Having thus described our invention, what we claim is:

1. Apparatus for continuously controlling the supply of direct current from an alternating current source to a resistive load, comprising in combination, voltage regulating means connected to the alternating current source and having an output circuit; a rectifier system inserted between said output circuit and the resistive load; a polar relay having an operating winding and at least one contact controlling said voltage regulating means; a current source having a substantially constant voltage; means for deriving a control voltage proportional to the current supplied to the resistive load; means for deriving a control voltage proportional to the voltage across the resistive load; and an electric circuit includ-

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ing in series said operating winding of said polar relay, said current source having a substantially constant voltage, said means for deriving a control voltage proportional to the current supplied to the resistive load, and said means for deriving a control voltage proportional to the voltage across the resistive load, said means for deriving a control voltage proportional to the voltage across the resistive load being connected in opposition to said current source having a substantially constant voltage and said means for deriving a control voltage proportional to the current supplied to the resistive load whereby said operating winding of said polar relay is energized when the sum of the constant voltage and the voltage proportional to the current supplied to the resistive load differs from the voltage across the resistive load so that said contact of said polar relay controls said voltage regulating means so that the voltage across the resistive load has a predetermined value when the current supplied to the resistive load is substantially zero and increases as the current supplied to the resistive load increases.

2. Apparatus for continuously controlling the supply of direct current from an alternating current source to a resistive load, comprising in combination, voltage regulating means connected to the alternating current source and having an output circuit; a rectifier system inserted between said output circuit and the resistive load; a polar relay having a first and a second operating winding and a contact having an inoperative position and two operative positions controlling said voltage regulating means; a current source having a substantially constant voltage; means for deriving a control voltage proportional to the current supplied to the resistive load; means for deriving a control voltage proportional to the voltage across the resistive load; an electric circuit including in series said first operating winding of said polar relay, said current source having a substantially constant voltage, said means for deriving a control voltage proportional to the current supplied to the resistive load, and said means for deriving a control voltage proportional to the voltage across the resistive load, said means for deriving a control voltage proportional to the voltage across the resistive load being connected in opposition to said current source having a substantially constant voltage and said means for deriving a control voltage proportional to the current supplied to the resistive load whereby said first operating winding of said polar relay is energized when the sum of the constant voltage and the voltage proportional to the current supplied to the resistive load differs from the voltage proportional to the voltage across the resistive load so that said contact of said polar relay controls said voltage regulating means so that the voltage across the resistive load has a predetermined value when the current supplied to the resistive load is substantially zero and increases as the current supplied to the resistive load increases; and circuit means connecting said second operating winding of said polar relay to said alternating current source.

3. Apparatus for continuously controlling the supply of direct current from a three-phase current source to a resistive load, comprising in combination, a three-phase voltage regulating means connected to the three-phase current source and having a three-phase output circuit; a rectifier system inserted between said output circuit and the resistive load; a polar relay having a first and

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a second operating winding and a contact having an inoperative position and two operative positions controlling said voltage regulating means; means for deriving a substantially constant voltage from across the first and second phases of said three-phase current source; means for deriving from the third phase of said output circuit a control voltage proportional to the current supplied to the resistive load; means for deriving a control voltage proportional to the voltage across the resistive load from across the first and second phases of said output circuit; an electric circuit including in series said first operating winding of said polar relay, said current source having a substantially constant voltage, said means for deriving a control voltage proportional to the current supplied to the resistive load, and said means for deriving a control voltage proportional to the voltage across the resistive load, said means for deriving a control voltage proportional to the voltage across the resistive load being connected in opposition to said current source having a substantially constant voltage and said means for deriving a control voltage proportional to the current supplied to the resistive load whereby said first operating winding of said polar relay is energized when the sum of the constant voltage and the voltage proportional to the current supplied to the resistive load differs from the voltage proportional to the voltage across the resistive load so that said contact of said polar relay controls said voltage regulating means so that the voltage across the resistive load has a predetermined value when the current supplied to the resistive load is substantially zero and increases as the current supplied to the resistive load increases; and circuit means connecting said second operating winding of said polar relay to said alternating current source.

4. Apparatus for continuously controlling the supply of direct current from an alternating current source to a resistive load, comprising in combination, voltage regulating means connected to the alternating current source and having an output circuit; a rectifier system inserted between said output circuit; and the resistive load; a direct current polar relay having an operating winding and at least one contact controlling said voltage regulating means; a direct current source having a substantially constant voltage; means for deriving a control voltage proportional to the current supplied to the resistive load; means for deriving a control voltage proportional to the voltage across the resistive load; and an electric circuit including in series said operating winding of said polar relay, said current source having a substantially constant voltage, said means for deriving a control voltage proportional to the current supplied to the resistive load, and said means for deriving a control voltage proportional to the voltage across the resistive load, said means for deriving a control voltage proportional to the voltage across the resistive load being connected in opposition to said current source having a substantially constant voltage and said means for deriving a control voltage proportional to the current supplied to the resistive load whereby said operating winding of said polar relay is energized when the sum of the constant voltage and the voltage proportional to the current supplied to the resistive load differs from the voltage across the resistive load so that said contact of said polar relay controls said voltage regulating means so that the voltage across the resistive load has a predetermined value when the current supplied

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to the resistive load is substantially zero and increases as the current supplied to the resistive load increases.

5. Apparatus for continuously controlling the supply of direct current from an alternating current source to a resistive load, comprising in combination, voltage regulating means connected to the alternating current source and having an output circuit; a first rectifier system inserted between said output circuit and the resistive load; a direct current polar relay having an operating winding and at least one contact controlling said voltage regulating means; a direct current source having a substantially constant voltage; a current transformer operatively connected to said output circuit; a second rectifier system connected to said current transformer and having an output; a potentiometer connected to said output of said second rectifier system, said potentiometer being supplied by said rectifier system with a D. C. voltage proportional to the current supplied to the resistive load; means for deriving a control voltage proportional to the voltage across the resistive load; and an electric circuit including in series said operating winding of said polar relay, said current source having a substantially constant voltage, said potentiometer supplied with a D. C. voltage proportional to the current supplied to the resistive load, and said means for deriving a control voltage proportional to the voltage across the re-

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sistive load, said means for deriving a control voltage proportional to the voltage across the resistive load being connected in opposition to said current source having a substantially constant voltage and said potentiometer supplied with a D. C. voltage proportional to the current supplied to the resistive load whereby said operating winding of said polar relay is energized when the sum of the constant voltage and the voltage proportional to the current supplied to the resistive load differs from the voltage across the resistive load so that said contact of said polar relay controls said voltage regulating means so that the voltage across the resistive load has a predetermined value when the current supplied to the resistive load is substantially zero and increases as the current supplied to the resistive load increases.

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