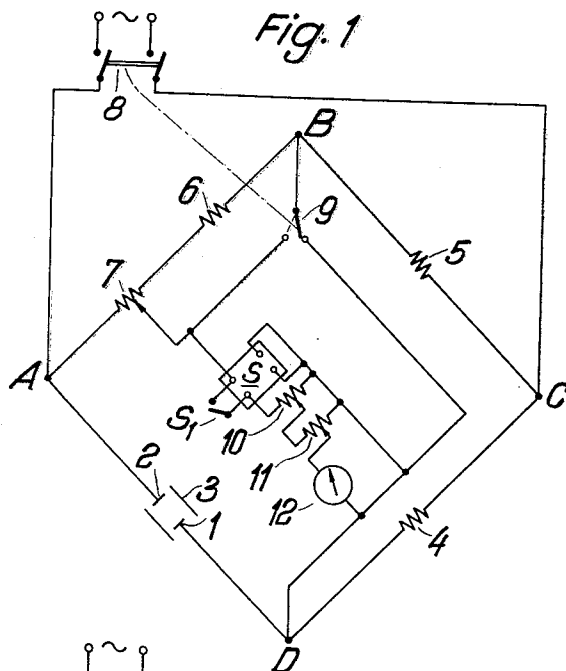
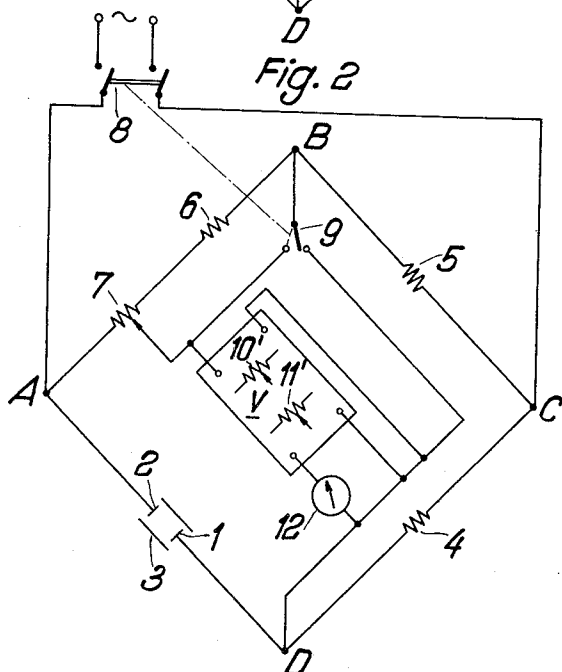


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3 Sheets-Sheet 1



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Oct. 9, 1962

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W. HUBER
APPARATUS FOR DETERMINING THE DENSITY
OF A DIRECT CURRENT

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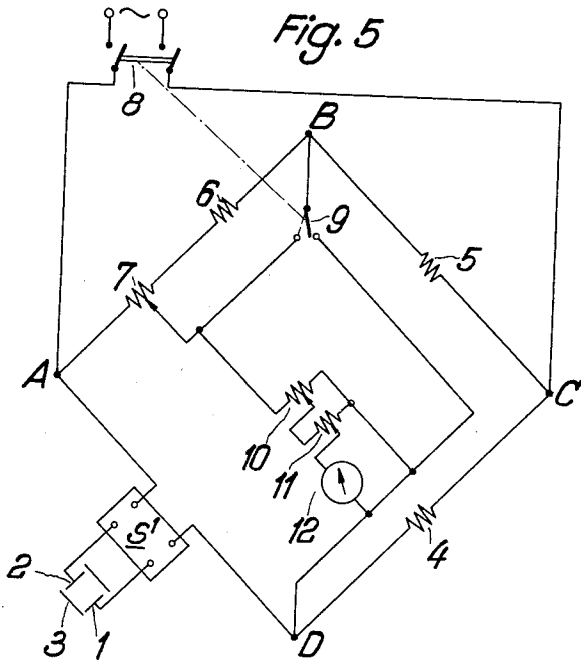
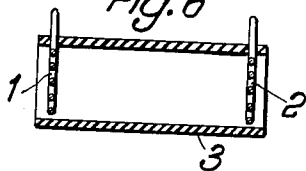
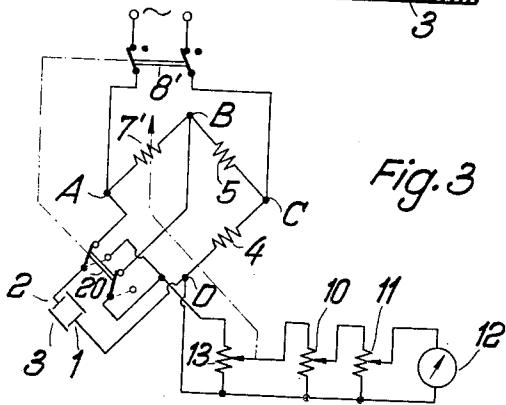


Fig. 6



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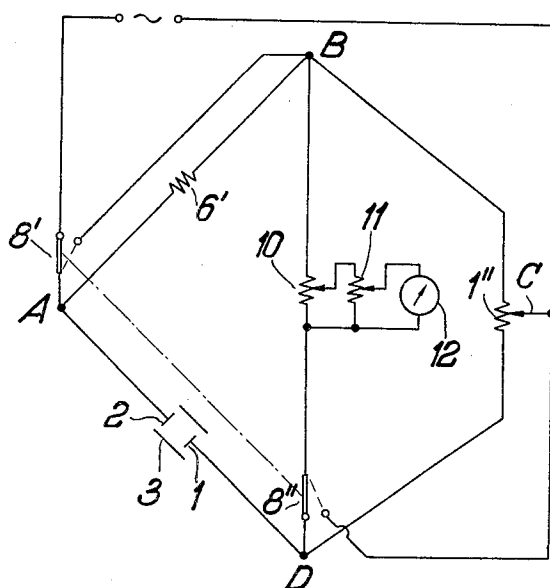
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APPARATUS FOR DETERMINING THE DENSITY
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Fig. 4



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APPARATUS FOR DETERMINING THE DENSITY OF A DIRECT CURRENT

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21 Claims. (Cl. 324--29)

The present invention refers to the art of plating or electrolytically oxidizing. More specifically, the invention concerns an apparatus for determining the density of a direct current flowing through an electrolyte used in this art.

If it is desired, to predetermine the thickness of an electrolytic deposit or to predetermine the modification of a surface of an object to a certain degree during electrolytic oxidation or electrolytic polishing, it is necessary to know the density of the current next to the particular surface area of the object to be treated. Generally, it is not enough to calculate the average current density on the basis of the known amperage and the total area of the surface to be treated. If the objects are not flat so that certain portions thereof have substantially different distances from the counter electrode, then the current density varies between these different area portions and where the distance is greatest, the current density is considerably below the average value. If the duration of the electrolytic treatment is predetermined on the basis of average current density, then those area portions which are farthest from the counter electrode obtain only an insufficient deposit or an insufficient surface treatment. If, for instance, the electrolytic deposit or the electrolytic surface treatment is intended to serve as a protection against corrosion then this purpose is not accomplished if area portions are insufficiently treated. In that case, the treatment must be continued until its effect is sufficient even at those area portions which are treated with the least current density. Consequently, the required duration of the treatment cannot be determined without knowing the local current density at those area portions which are most remote from the counter electrode.

In practice, the local current density cannot be calculated on the basis of average current density and of the three-dimensional formation of the surfaces to be treated, and such a calculation could not take into account that the polarization phenomena caused by actual current density at the electrodes in turn influenced the current density.

It is known to measure the current density by means of an amperemeter which e.g. in the case of cathodic treatment is connected with the anode and a probe electrode that may consist of a metal plate of say 16 square inches and is placed close to the desired surface area. However, with this method, it is not possible to determine the current density if the surface to be treated has a complicated three-dimensional formation, particularly if it has deep recesses. Also, the probe electrode influences the distribution of the current and polarization phenomena at the cathode are not taken into account, and in addition the electrolyte between the anode and the probe electrode constitutes a conductor in parallel with the amperemeter.

It is, therefore, a main object of this invention to overcome the deficiencies of known methods and apparatus and to provide for an apparatus permitting to determine the current density in a simple, efficient and accurate manner.

With above object in view, an apparatus according to the invention for determining the density of a direct current flowing through a particular portion of an electrolyte comprises, in combination, probe means including a pair

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of probe electrodes between which a current is adapted to flow in said electrolyte and means connected to said electrodes including adjustable resistor means and control means for adjusting said adjustable resistor means in such a manner that the resistance thereof is inversely proportional to the conductance of said electrolyte between said electrodes. The apparatus further comprises measuring means connected to said electrodes and including said adjustable resistor means and indicator means for indicating a potential difference set up by said current flowing between said electrodes, whereby by determination of said potential difference after adjustment of the resistance of said adjustable resistor means by said control means, said potential difference will be an indication of the density of said current flowing through said electrolyte between said electrodes.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings in which:

FIG. 1 is a schematic circuit diagram illustrating a basic embodiment of the invention;

FIG. 2 is a schematic circuit diagram showing a modified embodiment of the invention;

FIG. 3 is a schematic circuit diagram illustrating another embodiment of the invention;

FIG. 4 is a schematic circuit diagram illustrating still another embodiment of the invention;

FIG. 5 is a schematic circuit diagram illustrating one more embodiment of the invention; and

FIG. 6 is a cross-sectional view of probe electrode means used in any one of the embodiments of the invention.

It will be seen that with the apparatus according to the invention the local current density in the electrolyte and certain values correlated with the current density can be measured in such a manner that two probe electrodes having a predetermined surface area and being spaced from each other a predetermined distance are immersed in the electrolyte at a point where the current density is to be determined. Then the conductivity of the electrolyte is determined; the electrodes are so positioned that the direct current in the electrolyte flows in direction from one to the other electrode so that now the potential difference appearing between the electrodes can be measured whereby in view of the known constants of the components of the apparatus the local current density between the electrodes and certain other values depending thereon become known.

The apparatus can be calibrated by applying it to an electrolyte of known conductivity in which case the latter does not have to be determined and the desired indication is obtained directly.

First, a preferred form of the probe means used in the apparatus according to the invention will be described in reference to FIG. 6. As can be seen, the probe means comprise a tubular member 3, open at both ends and preferably made of glass or some other non-conductive material not affected by the electrolyte, and two electrodes 1 and 2 made of a wire mesh of platinum or so-called platinated platinum, also known as platinum covered with platinum black, or Mohr platinum or spongy platinum. The two electrodes are spaced from each other a fixed distance and mounted parallel with each other and perpendicular to the axis of the member 3.

Referring now to FIG. 1, it can be seen that the general arrangement of the apparatus constitutes a Wheat-

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stone bridge having four arms and a diagonal conductor circuit, resistors 4, 5, 6, 7, being connected in three of the four branches in the manner shown, resistor 7 being adjustable, preferably being of the potentiometer type having a slidable tap. The junction points between the four branches are marked A, B, C, and D. A source of alternating potential is connected to the junction points A and C. A double-pole switch 8 is provided for connecting the bridge to said source whenever desired. The diagonal conductor circuit comprises indicator means described further below connected between the junction point D and the tap of the potentiometer 7. A switch-over switch 9 is connected with the junction point B and auxiliary conductors lead from the junction point D and from the above mentioned tap to the alternative contacts of the switch 9 so that the point B can be alternatively connected either with the point D or with said tap. Preferably, the contact arm of the switch 9 is mechanically coupled with the arms of the switch 8 so that both these switches are moved simultaneously between the position shown in full lines and the position shown in dotted lines.

The diagonal circuit contains in series with an indicating instrument 12 two potentiometers 10 and 11 connected in cascade so that the indication of the instrument 12 can be influenced by adjustment of the potentiometers 10 and/or 11 so as to indicate a value adjustably proportionate with a potential difference causing a response of the instrument.

A device S is further connected in series with the indicator means and will be described further below.

The apparatus operates as follows:

The probe means comprising the tube 3 and electrodes 1, 2 which are connected in the fourth branch of the bridge between A and D is immersed in the electrolyte and the switch 8 is moved into its first position shown in dotted lines whereby also switch 9 is moved into its first position shown in dotted lines. Now the instrument 12 will indicate a potential difference because it cannot be expected that the bridge A, B, C, D, is immediately in balanced condition. By moving the sliding tap along the potentiometer 7 the bridge can be balanced. It is to be noted that in this position of the switch 9 the portion of the branch A, B located between B and the tap is shunted so that the resistor 6 and a portion of the potentiometer 7 are ineffective. It is evident that after balancing the bridge the resistance (or conductance) between point A and the tap is proportional to the resistance (or conductance) existing in the electrolyte between the probes 1 and 2. If the resistors 4 and 5 are equal then the just mentioned resistances or conductances are also equal. It can be seen that the adjustment of the potentiometer 7 is directly proportional with the conductivity of the electrolyte.

If now the switches 8 and 9 are moved into their second position shown in full lines, the supply of alternating voltage to the bridge is interrupted and the junctions points B and D are directly connected with each other whereby the resistors 4 and 5 in the branches B, C, D are shunted.

Now the probe electrodes 1 and 2 are immersed in the same electrolyte which is passed by a direct current used for the electrolytic process. The tube 3 is to be oriented in such a manner that its axis points in the direction of the flow of said current in the portion of the electrolyte that is to be examined. It can be seen that now the instrument 12 will indicate a potential difference. The magnitude of this potential difference is determined by the potential difference appearing between the probe electrodes 1 and 2, subject to voltage division in accordance to the ratio of division existing at the resistors 6, 7 and at the potentiometers 10 and 11.

Since the conductance between the point A and the tap as set along the resistor 7 during the preceding balancing of the bridge is proportional with the conductivity

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of the electrolyte, the conductance between the above mentioned tap and the now directly connected points B, D will be the larger, the smaller is the conductivity of the electrolyte. Consequently, the potential difference existing between the tap of resistor 7 and the connected points B, D and applied to the instrument 12 via the potentiometers 10 and 11 will be the greater, the greater is the conductivity of the electrolyte. If the resistors 6 and 7 are suitably dimensioned the potential difference just mentioned will be practically proportional (within tolerances compatible with the purpose of the particular test) with the conductivity of the electrolyte. Now, since the potential difference between the probe electrodes 1 and 2 is, under the assumption of a given current density in the electrolyte, inversely proportional with the conductivity thereof, while the output potential of the voltage divider arrangement 6, 7 is practically proportional to said conductivity, it follows that the output potential of the voltage divider 6, 7 is an indication of the current density within the tube 3 which indication is practically independent of the conductivity of the electrolyte. Therefore, the instrument 12 can be calibrated directly in terms of amperes per square inch as an indication of current density.

In order to properly orient the tube 3 parallel with the direction of the current in the electrolyte at the particular spot the tube is to be turned until the indicating instrument 12 responds with the maximum deflection of its pointer.

The potentiometers 10 and 11 are provided for the purpose of making it possible to calibrate the instrument 12 in such a manner that if the apparatus is used in connection with a plating process, the instrument will directly indicate the amount of metal deposited per unit of time on a unit of surface area. The potentiometer 10 is to be adjusted in such a manner that the ratio between its output and input potential is proportional with the electro-chemical equivalent weight of the metal to be deposited. For this purpose, the adjustment scale along this potentiometer can be advantageously marked, instead of with figures indicating the ratio of voltage division, with corresponding figures indicating electro-chemical equivalent weights. In addition, or alternatively, index markings may be applied corresponding to certain specific metals. In particular, one point of that scale can be predetermined by calculation on the basis of the output potential of the voltage divider 6, 7 associated with a particular current density and on the basis of the sensitivity of the instrument 12. Instead of calculating the position of said point, this point may also be determined empirically. The remaining points of the scale are automatically determined by the dividing characteristic of the potentiometer 10. Moreover, the potentiometer 10 may be adjusted so as to obtain an indication of the thickness of a deposit obtained during a unit of time, in which case the scale of this potentiometer would contain suitable index marks provided with numerals and/or references to particular metals. This adjustment of the potentiometer is done in such a manner that the ratio between its output and input potentials is proportional with the electro-chemical equivalent of the metal to be deposited and inversely proportional with the specific gravity thereof. The calibration of this scale can be performed again in a manner similar to the one set forth above taking into account the specific gravity of the metal to be deposited.

The potentiometer 11 functions in an analogous manner for taking into account the cathodic efficiency.

If the apparatus is used in connection with electrolytic surface modification e.g. anodic oxidation or anodic polishing, the potentiometer 10 may be provided with index marks associated with the surface modifications of specific metals in which case the instrument 12 is calibrated directly in units of time concerning the duration of the electrolytic treatment. The calibration of

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the adjustment scale of the potentiometer 10 and of the instrument 12 may be carried out empirically.

Referring now to FIG. 2 which shows an embodiment generally identical with that of FIG. 1, it can be seen that the potentiometers 10 and 11 are replaced by an amplifier device V including two amplification controls 10' and 11' which may be used and adjusted exactly in the same manner as the potentiometer 10 and 11, and calibrated analogously. The amplifier V may be either of the electron tube or of the transistor type.

If the entire circuit is equipped with resistor means of high ohmic values, the platinum electrodes can be dimensioned comparatively very small and the instrument 12 can be made highly sensitive, also in the case of FIG. 2 sufficient amplification can be provided, so that a relatively small spacing of the probe electrodes will be sufficient. Consequently, it will be possible to determine by means of the apparatus according to the invention the current density and correlated values even within very small areas and in connection with complicated surface formations. In this manner e.g. the amount of deposit per unit of time and the required duration of an electrolytic process can be determined simply, rapidly and reliably under ordinary operating conditions.

The balancing of the bridge circuit is ordinarily carried out while temporarily the flow of current through the electrolyte is interrupted. However, it is also possible to carry out the balancing of the bridge without such an interruption of the current through the electrolyte provided that the direct current component appearing between the probe electrodes is prevented by a blocking device S connected in series with the indicator instrument 12 as shown in FIG. 1 (provided the direct current in the electrolyte does not have substantial pulsations) from entering the instrument 12. If, however, the direct current pulsates considerably at a certain frequency, then the alternating voltage applied to the bridge should have a frequency differing from the frequency of said pulsation. In this case, the blocking device S would have to be a filter device which prevents the pulsations of the direct current from entering the instrument 12. Of course, during the determination of the potential difference between the electrodes 1 and 2, i.e. when the switches 8 and 9 are in their second position, a by-pass switch S₁ must be closed in order to shunt the filter device.

As a material for the probe electrodes not only the above mentioned platinum but also other material like graphite, antimony, gold, tantalum and other platinum metals e.g. rhodium may be used. Also, alloys of such metals are suitable. The electrodes do not have to be formed as a wire mesh but may also have the form of rings or pins.

Referring now to FIG. 3, which is generally based on the same concept as the other embodiments of the invention, it can be seen that a variable resistor 7' is provided in the bridge branch A, B the resistance of which is proportional with the conductivity of the electrolyte after balancing of the bridge, the control of the resistor 7' being mechanically coupled with a potentiometer 13 in such a manner that the dividing ratio between output voltage and input voltage is proportional to the just mentioned resistance of the resistor 7' and therefore also proportional with the conductivity of the electrolyte. The potentiometer 13 is connected in cascade with the previously described potentiometers 10 and 11. A switch-over switch 20 is provided between the electrodes 1, 2 and the remaining parts of the arrangement.

Referring now to FIG. 4, a potentiometer 7'' and a change-over switch combination 8', 8'' may be arranged in such a manner that the partial resistance located between the tap marked C' and one end of the potentiometer 7'' constitutes during the balancing of the bridge

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one branch thereof the resistance of which is proportional with the conductivity of the electrolyte, while during the determination of the potential difference at the probe electrodes 1, 2 these electrodes are connected with both ends of the potentiometer 7'' because in this case the switch means 8', 8'', are moved into their positions shown in dotted lines, so that the potential to be measured is that one which exists between the tap C' and the above mentioned end of the potentiometer 7''. In this embodiment the dividing ratio of the potentiometer 7'' is adjusted in the balancing of the bridge circuit in such a manner that the proportion between output and input potential is proportional with the conductivity of the electrolyte. The potentiometer 7'' is arranged in cascade with the previously described potentiometers 10 and 11.

Referring now to FIG. 5, which is otherwise identical with that of FIG. 1, amplifier means S' are connected between the probe electrodes 1, 2 and the bridge branch A, D. These amplifier means may consist of one or more tube or transistor stages. In this case the various above mentioned voltage divider means may also be replaced by amplification control means. It is however advisable to use in direct connection with the probe electrodes an electron tube amplifier because this type of amplifier is characterized by a large input resistance which is of advantage in this type of measuring potential differences with the aid of probe electrodes.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of apparatus for determining the density of a direct current flowing through an electrolyte differing from the types described above.

While the invention has been illustrated and described as embodied in apparatus for determining the density of a direct current flowing through a particular portion of an electrolyte, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. Apparatus for determining the density of a direct current flowing through an electrolyte, comprising, in combination, a source of alternating current; bridge circuit means connectable to said source and comprising three bridge arms each including resistor means, at least one of said resistor means being adjustable, a fourth bridge arm including probe means immersible in the electrolyte and including a pair of probe electrodes spaced from each other for accommodating therebetween a portion of said electrolyte and enabling a current to flow directly through said portion of said electrolyte between said electrodes when the latter are immersed in said electrolyte, said electrodes having each a predetermined surface area and being spaced from each other a predetermined distance, and diagonal conductor means including indicator means in circuit with said adjustable resistor means for indicating a potential difference appearing across said diagonal conductor means; and means for alternatively connecting said bridge circuit with said source for determining the conductivity of said electrolyte by balancing said bridge circuit through adjustment of said adjustable resistor means, and, on the other hand, for disconnecting said bridge circuit means from said source and for altering the connections between said indicator means and said electrodes for determining the current density between said electrodes in

said electrolyte by determining the potential difference appearing between said electrodes as indicated by said indicator means after said adjustment of said adjustable resistor means for determining said conductivity of said electrolyte

2. Apparatus as claimed in claim 1 wherein said electrodes are made of platinum wire mesh and are mounted substantially parallel with each other.

3. Apparatus as claimed in claim 2 wherein said probe means comprise a tubular member of non-conductive material open at both ends, said electrodes being mounted within said tubular member substantially perpendicular to its axis.

4. An apparatus as claimed in claim 1, wherein said one adjustable resistor is provided with adjusting means for adjusting the same for balancing said bridge circuit means, and wherein said diagonal conductor means comprise potentiometer means in circuit with said indicator means, said adjusting means being mechanically coupled with said potentiometer means so that when said adjustable resistor is adjusted so as to establish a balanced condition of said bridge circuit means determining the conductivity of said electrolyte, the adjusted ratio between input and output voltage at said potentiometer is proportional to the specific conductivity of said electrolyte.

5. Apparatus for determining the density of a direct current passing through an electrolyte, comprising, in combination, a bridge circuit means comprising four bridge arms respectively connected by junction points located between adjoining arms, and a diagonal conductor circuit connecting two opposite first junction points and comprising indicator means for indicating a potential difference appearing between the ends of said diagonal conductor circuit; energy supplying circuit means for applying an alternating voltage to the other two junction points; resistor means connected in three of said bridge arms, at least one of said resistor means being adjustable for balancing said bridge circuit means; probe means including a pair of probe electrodes adapted to be immersed in said electrolyte and connected in the fourth one of said bridge arms, said electrodes having each a predetermined surface area and being spaced from each other a predetermined distance for accommodating therebetween a portion of said electrolyte and enabling a current to flow directly through said portion of said electrolyte between said electrodes when the latter are immersed in said electrolyte; bypass means arranged for being connectable in parallel with two of said bridge arms associated therewith for shunting the latter; and switch-over means connected with said bypass means and comprising at least one first switch means connected in said energy supplying circuit means, and at least one second switch means connected in said diagonal conductor circuit, both said switch means being movable between a first position in which said energy supply circuit and said diagonal conductor circuit are completed, respectively, for applying said alternating voltage to said bridge circuit means and for connecting said indicator means operatively in said bridge circuit, while rendering said bypass means inoperative, and a second position in which said supply circuit and said diagonal conductor circuit are interrupted, while said bypass means are connected to shunt said bridge arms associated therewith, whereby when said switch means are in said first position and said probe electrodes are immersed, the conductivity of said electrolyte, after balancing said bridge circuit means by adjusting said adjustable resistor means, is indicated by the amount of adjustment of said adjustable resistor means, and when said switch means are in said second position the current density between said electrodes in said electrolyte is indicated by the potential difference appearing between said electrodes and indicated by said indicator means after determination of said conductivity of said electrolyte by said adjustment of said adjustable resistor means.

6. Apparatus as claimed in claim 5 wherein said probe

electrodes are made of platinum wire mesh and are mounted substantially parallel with each other.

7. Apparatus as claimed in claim 6 wherein a tubular member of non-conductive material open at both ends is provided for supporting said probe electrodes, the latter being mounted within said tubular member substantially perpendicular to its axis.

8. Apparatus as claimed in claim 5 including amplifiers means having its output terminals connected in the fourth one of said bridge arms, and having its input terminals connected with said probe electrodes.

9. Apparatus as claimed in claim 5 wherein said adjustable resistor means is a potentiometer type resistor including a slidable top, and wherein said diagonal conductor circuit comprises one circuit portion connected between one of said two opposite first junction points and said slidable top and including said indicator means, and two auxiliary conductors, one of which serving as said bypass means for shunting the two bridge arms connected to said two opposite first junction points, the other one of said two auxiliary conductors serving as a shunt for the bridge portion between said top and the other one of said opposite two first junction points, said second switch means being arranged between said last mentioned junction points and the ends of said auxiliary conductors for alternatively connecting said last mentioned junction point with either one of said auxiliary conductors.

10. Apparatus as claimed in claim 9, wherein said indicator means comprise an indicating instrument and adjustment potentiometer means in circuit therewith for influencing the instrument indication so as to indicate a value adjustably proportionate with said potential difference.

11. An apparatus as claimed in claim 10, wherein said adjustment potentiometer means comprise a first and a second adjustment potentiometer connected in cascade.

12. An apparatus as claimed in claim 11, wherein condenser means are connected in said diagonal conductor circuit in series with said indicator means for preventing said direct current flowing between said probe electrodes from entering said indicator means during operation of said apparatus while said switch means are in said first position.

13. Apparatus as claimed in claim 11 wherein filtering means are connected in said diagonal conductor circuit in series with said indicator means for preventing pulsations of said direct current at a frequency different from that of said alternating voltage, from entering said indicator means during operation of said apparatus while said switch means are in said first position, and a switch device connected in parallel with said filtering means for shunting the latter during operation of said apparatus while said switch means are in said second position.

14. An apparatus as claimed in claim 10, for use in connection with producing electrolytic metal deposits on an object in said electrolyte, wherein said indicator means is calibrated to indicate the amount of metal deposited per unit of time on a unit of surface area of said object, and wherein said adjustment potentiometer means comprise a first, second and third potentiometer means connected in cascade, said first potentiometer means being adapted to adjust said potential difference across said diagonal circuit in accordance with the conductivity of said electrolyte, said second potentiometer means being adapted to adjust said potential difference in proportion to the electro-chemical equivalent weight of the metal being deposited, and said third potentiometer means being adapted to adjust said potential difference in proportion to the cathodic efficiency of said electrolytic process.

15. An apparatus as claimed in claim 14, wherein at least one of said potentiometer means is provided with a calibration and index means for setting the same thereby so as to produce the desired respective potential difference.

16. Apparatus as claimed in claim 10, for use in connection with producing electrolytic metal deposits on

an object in said electrolyte, wherein said indicator means is calibrated to indicate the thickness of a metal layer deposited per unit of time on a surface area of said object, and wherein said adjustment potentiometer means comprise a first, second and third potentiometer means connected in cascade, said first potentiometer means being adapted to adjust said potential difference across said diagonal circuit in accordance with the conductivity of said electrolyte, said second potentiometer means being adapted to adjust said potential difference in proportion to the ratio between the electro-chemical equivalent weight of the metal being deposited, and the specific gravity of said metal being deposited and said third potentiometer means being adapted to adjust said potential difference in proportion to the cathodic efficiency of said electrolytic process.

17. An apparatus as claimed in claim 10 for use in connection with a process for electrolytically modifying the surface of an object in said electrolyte, wherein said indicator means is calibrated to indicate directly the time required to produce under given conditions the desired surface modification, and wherein said adjustment potentiometer means comprise a plurality of potentiometer means connected in cascade, a first potentiometer means thereof being adapted to adjust said potential difference in accordance with the conductivity of said electrolyte, and other potentiometer means of said plurality thereof being adapted to adjust said potential difference in accordance with the type of said surface modification, with the type of material the surface of which is to be modified, with the type of electrolyte being used, and with the cathodic efficiency of said electrolytic process.

18. Apparatus as claimed in claim 9, wherein said indicator means comprise an indicating instrument and amplifier means in circuit therewith, said amplifier means including amplification control means for influencing the instrument indication so as to indicate a value adjustably proportionate with said potential difference.

19. An apparatus as claimed in claim 18 for use in connection with producing electrolytic metal deposits on an object in said electrolyte, wherein said amplification control means comprise a first, a second and a third amplification control device, each provided with a calibration and index means for adjusting thereby the respective control device in accordance with the conductivity of said electrolyte, with the electro-chemical equivalent weight of the metal being deposited, and with the cathodic efficiency of said electrolytic process, respectively.

20. An apparatus as claimed in claim 18, for use in connection with producing electrolytic metal deposits on an object in said electrolyte, wherein said amplification control means comprise a first, a second and a third amplification control device, each provided with a calibration and

index means for adjusting thereby the respective control device in accordance with the conductivity of said electrolyte, with the ratio between the electro-chemical equivalent weight of the metal being deposited and the specific gravity thereof, and with the cathodic efficiency of said electrolytic process, respectively.

21. Apparatus for determining the density of a direct current flowing through an electrolyte, comprising, in combination, a source of alternating current; bridge circuit means connectable to said source and comprising three bridge arms each including resistor means the resistor means of two of said arms being of the potentiometer type having a slidable tap member constituting the junction point between said two arms so that the portions of said potentiometer on opposite sides of the variable position of said tap member constitute the resistor means in said two arms, a fourth bridge arm including probe means comprising a pair of probe electrodes adapted to be immersed in said electrolyte, said electrodes having each a predetermined surface area and being spaced from each other a predetermined distance for accommodating therebetween a portion of said electrolyte and enabling a current to flow directly through said portion of said electrolyte between said electrodes when the latter are immersed in said electrolyte, and diagonal conductor means including indicator means in circuit with said adjustable resistor means for indicating a potential difference appearing across said diagonal conductor means; and means for alternatively connecting said bridge circuit with said source for determining the conductivity of said electrolyte by balancing said bridge circuit through adjustment of said potentiometer type resistor means, and, on the other hand, for disconnecting said bridge circuit means from said source and for shunting the resistor means in the third one of said bridge arms and for connecting said tap member with said indicator means, thereby altering the connections between said indicator means and said electrodes for determining the current density between said electrodes in said electrolyte by determining the potential difference appearing between said electrodes as indicated by said indicator means after said adjustment of said adjustable resistor means for determining said conductivity of said electrolyte.

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