March 21, 1950 T. D. MORGAN 2,500,997

ELECTRICAL COMPUTING DEVICE

Filed July 13, 1944

Fig. 1

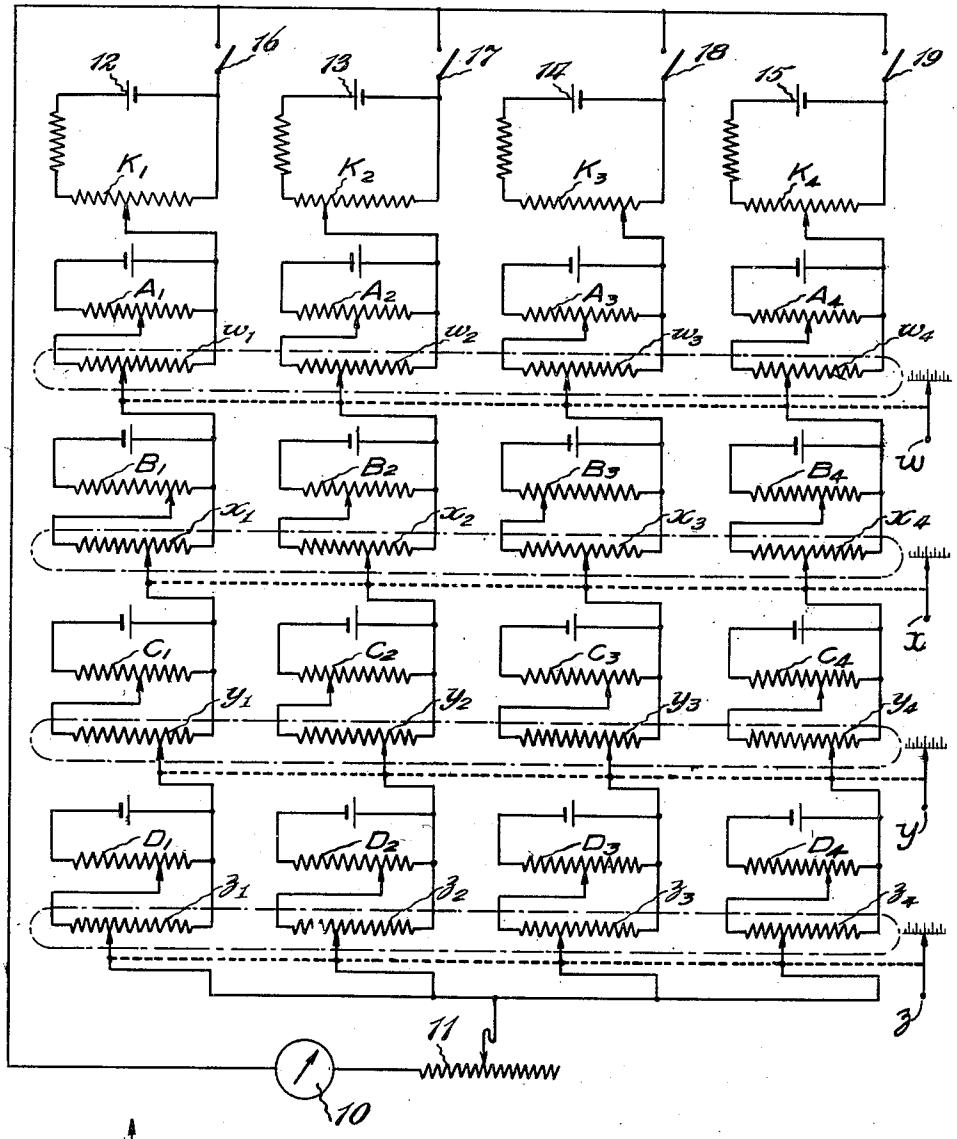
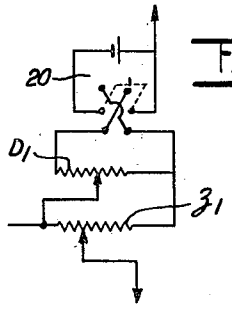


Fig. 2



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ELECTRICAL COMPUTING DEVICE

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2 Claims. (Cl. 235—61)

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The present invention relates to a device for solving systems of simultaneous linear equations which are solvable by the well known method of iteration or successive approximations. Such systems of equations which are capable of practical solution by this method will be herein termed convergent systems of simultaneous equations.

Although the device may be utilized in solving any convergent system of n linear simultaneous equations of the type above mentioned it will be described in connection with the determination of percentages of the various constituents of a hydrocarbon mixture. Recently, infrared spectrophotometry has been used for the purpose of analyzing hydrocarbons, as is described in some detail in National Petroleum News for May 3, 1944, section 2, at page R274. Such analysis of hydrocarbons by means of infrared spectrophotometry offers many advantages over other analysis methods but requires a large amount of computation which the present invention eliminates. In analyzing petroleum hydrocarbons to determine the percentages of the constituents of a mixture the infrared spectrophotometer is utilized in the following manner, it being assumed that the analyst knows the wave lengths at which each constituent of the mixture has as large an extinction coefficient as possible when compared with the extinction coefficients of the other constituents. The analyst then, by the use of the spectrophotometer, determines the total extinction produced by a sample of the mixture at each of the selected wave lengths, there being, of course, one wave length for each mixture constituent. For example, if a four component mixture be considered the procedure will be to first analyze a sample of this mixture at a wave length L_1, this wave length being chosen to cause as great an extinction as possible with respect to the first component of the mixture as compared with the extinction caused by the remaining components thereof. In a similar manner, a second extinction value will be determined for the sample at a wave length L_2 chosen to cause as great an extinction as possible due to the second component of the mixture as compared with the remaining components. In a similar manner, readings will be taken at wave lengths L_3 and L_4. Then, since the total extinction brought about by the mixture at any wave length must be

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equal to the sum of the extinctions brought about by each of the components of the mixture a set of equations may be written as follows:

$$(1)\quad A_1w+B_1x+C_1y+D_1z=K_1$$
$$(2)\quad A_2w+B_2x+C_2y+D_2z=K_2$$
$$(3)\quad A_3w+B_3x+C_3y+D_3z=K_3$$
$$(4)\quad A_4w+B_4x+C_4y+D_4z=K_4$$

In these equations w, x, y, and z are the percents of the components of the mixture; A_1, A_2, A_3 and A_4 are the extinction coefficients for component w at wave lengths L_1, L_2, L_3 and L_4 respectively; B_1, B_2, B_3 and B_4 are the extinction coefficients for component x at wave lengths L_1, L_2, L_3 and L_4 respectively; C_1, C_2, C_3 and C_4 are the extinction coefficients for component y at wave lengths L_1, L_2, L_3 and L_4; D_1, D_2, D_3 and D_4 are the extinction coefficients for component z at wave lengths L_1, L_2, L_3 and L_4 respectively; and K_1, K_2, K_3 and K_4 are the total extinction coefficients at wave lengths L_1, L_2, L_3 and L_4 respectively.

As has been stated, equations of this type may be solved by the method of systematically making successive approximations of the percentage of each component so that the approximations approach the correct solution to the problem and repeating the approximations until the difference between successive approximations becomes less than the experimental error of the original data, at which time an answer will be at hand which is consistent in accuracy with the accuracy of the experimental data. However, this method requires a very considerable knowledge of mathematical procedure and considerable time. Further, even when reduced to a routine procedure the time element is still large and a knowledge of the effect of starting with a particular approximation is required in order to reduce the time to the minimum possible.

The present invention provides electrical circuits including potentiometers which are adjusted in accordance with the experimental data and through which the results may be read directly in a minimum of time.

It is an object of this invention to provide electrical means for solving simultaneous equations.

It is another object of the invention to provide a device for solving such simultaneous equations resulting from the infrared spectrophotometer analysis of petroleum hydrocarbons.

It is a further object of the invention to provide such an electrical computer which shall be simple in construction and easy to operate.

Other objects and features of the invention will appear when the following description is considered in connection with the annexed drawing, in which:

Figure 1 is a schematic wiring diagram of my invention; and

Figure 2 is a schematic circuit diagram showing the manner in which reversing switches are utilized to insert negative coefficients.

Referring now to the drawing it will be seen that there are provided a plurality of potentiometers K_1, K_2, K_3 and K_4 which potentiometers are to be set in accordance with the readings of total extinction as mentioned hereinabove. It will be noted that each of these potentiometers is in a circuit which passes through additional potentiometers and may be closed through a galvanometer 10.

Thus, the circuit extending from potentiometer K_1 proceeds from its adjustable contact to a potentiometer A_1 and thence through potentiometer w_1 and its adjustable contact to potentiometer B_1; thence through adjustable contact of potentiometer B_1 to potentiometer x_1 through its adjustable contact to potentiometer C_1, thence through its contact to potentiometer y_1, thence to potentiometer D_1, potentiometer z_1 and to the galvanometer 10 through the variable resistance 11.

The circuits for potentiometers K_2, K_3 and K_4 are similar to the one just above described and lead also to the galvanometer through the variable resistance 11. Each of the potentiometers K_1, K_2, K_3 and K_4 has in circuit therewith a battery respectively designated 12, 13, 14 and 15 and each of the potentiometers A_1 through D_4 has in its circuit a battery, the latter batteries (16 in number) being poled oppositely to the batteries 12, 13, 14 and 15. Further, each galvanometer circuit has in series therewith a switch respectively designated 16, 17, 18 and 19, these switches being used to close the separate circuits through the galvanometer, one at a time in an order which will be described hereinafter. It should be noted that the potentiometers w_1, w_2, w_3 and w_4 have their movable contacts mechanically interconnected and that these contacts are operated by a handle w which cooperates with a scale to indicate its setting. In like manner, the potentiometers x_1, x_2, x_3 and x_4 are mechanically interconnected and connected to an adjusting knob or handle x, and likewise the y potentiometers and the z potentiometers respectively are interconnected and are connected to operating handles y and z. Further, the potentiometers A_1, A_2, A_3 and A_4 . . . D_4 are provided with scales (not shown) so that their position may be adjusted.

In using the computer the potentiometer K_1 is set to a position such that its scale indicates the measured extinction at wave length L_1, potentiometer K_2 is set so that its scale indicates the measured extinction at wave length L_2 potentiometer K_3 is set so that its scale indicates the measured extinction at wave length L_3 and potentiometer K_4 is set so that its scale indicates proportionately to the measured extinction at wave length L_4.

Also potentiometers A_1 through D_1 are set to indications proportional to the extinctions brought about by pure substances w, x, y and z respectively at wave length L_1, potentiometers A_2 through D_2 are set to indications proportional to the extinctions brought about by pure substances w, x, y and z respectively at wave length L_2, potentiometers A_3 through D_3 are set to indications proportional to the extinctions brought about by pure substances w, x, y and z respectively at wave length L_3, and potentiometers A_4 through D_4 are set to indications proportional to the extinctions brought about by pure substances w, x, y and z respectively at wave length L_4.

Switch 16 is now closed thereby completing a circuit through potentiometers K_1, w_1, B_1, x_1 C_1, y_1, D_1, z_1, rheostate 11 and galvanometer 10. Adjusting knob or handle w is then operated until the galvanometer reading is zero. This adjustment is equivalent to making the first approximation in the mathematical solution of the equations (and assuming that the total extinction brought about in the sample was due solely to the extinction owing to the pure substance w). It will be noted that the setting of the knob w has caused adjustment of potentiometers w_2, w_3 and w_4 as well as of w_1 thereby making the same assumption as to the remaining circuits as was made with respect to the one just considered.

In the next step of the procedure switch 16 is opened and switch 17 closed thereby completing a circuit through the potentiometers bearing subscripts 2 and through rheostat 11 and galvanometer 10. The knob or handle x is now operated until the galvometer again reads zero. This amounts to setting up electric potentials such that the total extinction represented in potentiometer K_2 is balanced out by the settings of the remaining potentiometers. It should be noted that in this as well as in the other three circuits the battery in the circuit of potentiometer K_2 is poled oppositely to the batteries of the circuits of potentiometers A, B, C and D.

It may be well at this point to mention that reversing switches may be used in circuit of all the batteries in order that any negative terms in the data may be taken care of by merely operating the corresponding switch. The manner in which such a reversing switch is connected is shown in Figure 2 wherein a double pole double throw switch 20 has its blades connected to opposite terminals of the battery, and its two opposite sets of terminals connected to the fixed terminals of potentiometer D_1 so that movement of the switch from one position to the other changes the polarity of the battery connection to the potentiometer. Also, switches may be put in series with all of the batteries to open the battery circuits and these switches may be mechanically interconnected so that when the device is not in use all batteries may be open circuited.

The drawing herein illustrates the complete operation of the device of my invention in its simplest form. It will be obvious to those skilled in the art that without departing from my invention suitable switches may be provided to permit the use of the same battery in place of the batteries 12, 13, 14 and 15. In a like manner, a second single battery may supply potentiometers A_1, A_2, A_3 and A_4 successively. Also a third single battery may supply potentiometers B_1, B_2, B_3 and B_4 successively, and the same is true of C_1, C_2, C_3, C_4, etc. Moreover, a single potentiometer may be switched successively to various positions instead of using the series of ganged potentiometers w_1, w_2, w_3, w_4; x_1, x_2, x_3 and x_4, etc.

It will be seen that the adjustment of knob x has effected an adjustment of all the x potentiometers and has thereby altered the current which flows through the K_1 circuit. However, the K_2 circuit although it was modified by setting of the

w handle has been adjusted subsequently thereto, and consequently, the zero reading of the galvanometer persists at this moment.

Now switch 17 is opened, switch 18 closed and handle y adjusted until the galvanometer 10 again reads zero. As before, the adjustment of the y handle alters the setting of all potentiometers y_1, y_2, y_3 and y_4 and, consequently, the circuits in the K_1 and K_2 circuits would, if now tested, no longer have zero values.

Following this switch 18 is opened, switch 19 closed and handle C adjusted until the galvanometer again reads zero.

The operations above described are repeated until no readjustment of the adjusting handles or knobs w, x, y and z are necessary to give zero readings on galvanometer 10. When this occurs readings are taken from the scales associated with the handles w, x, y and z and these readings give directly (in percentage) the proportions of the constituents w, x, y and z of the original mixture.

From the above it will be seen that each variable, each constant and each coefficient in the equations hereinabove set forth has its electrical counterpart in the diagram of the figure and that by inserting the values into these electrical counterparts and successively and repeatedly adjusting the circuits respresentative of one of the four simultaneous equations until the galvanometer reads zero, the equations are solved and the percentages of the constituents of the mixture are readable directly from the dials or scales of the instrument.

It will of course be understood that while the above description and example has considered the analysis of a hydrocarbon mixture having four components and a device for solving equations resulting from such analysis it is entirely within the scope of this invention to extend the system to any number of components. For example, if a seven component mixture were to be analyzed the system would be extended to seven circuits each comprising a K potentiometer and seven of the coefficient potentiometers (such as A—D) and of the associated potentiometers such as w representing the seven components of the mixture. Furthermore, as has been indicated hereinabove, although the computer of my invention has been described in connection with solving simultaneous equations resulting from the analysis of hydrocarbon mixtures the system is applicable to various types of mixtures.

Consequently, I wish to be limited not by the

foregoing specification, but solely by the appended claims.

What is claimed is:

1. In a device for solving convergent systems of linear simultaneous equations, in combination, a plurality of networks each representing an equation to be solved, each network including a cell representing a constant term, said cell including a potentiometer, a current source connected in series therewith, and a reversing switch for changing the polarity of the voltage drop produced across said potentiometer by the current source, and a cell representing each variable term, each such cell including a first potentiometer, a battery connected in series therewith, a reversing switch for changing the polarity of the voltage drop produced across said potentiometer by said current source, and a second potentiometer having one terminal connected to the slider of said first potentiometer and its other terminal connected to a fixed terminal of said first potentiometer, leads connecting the slider of each second potentiometer to a fixed potentiometer terminal of the next succeeding cell, a galvanometer, a variable resistance connected in series therewith, a plurality of switches for connecting said galvanometer and resistor in circuit selectively with the respective networks, and means for simultaneously adjusting said second potentiometers by sets, each set including one second potentiometer from each network.

2. A device for solving convergent systems of linear simultaneous equations as set forth in claim 1 in which the potentiometer of each cell representing a constant term has a fixed resistor connected in series therewith.

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