

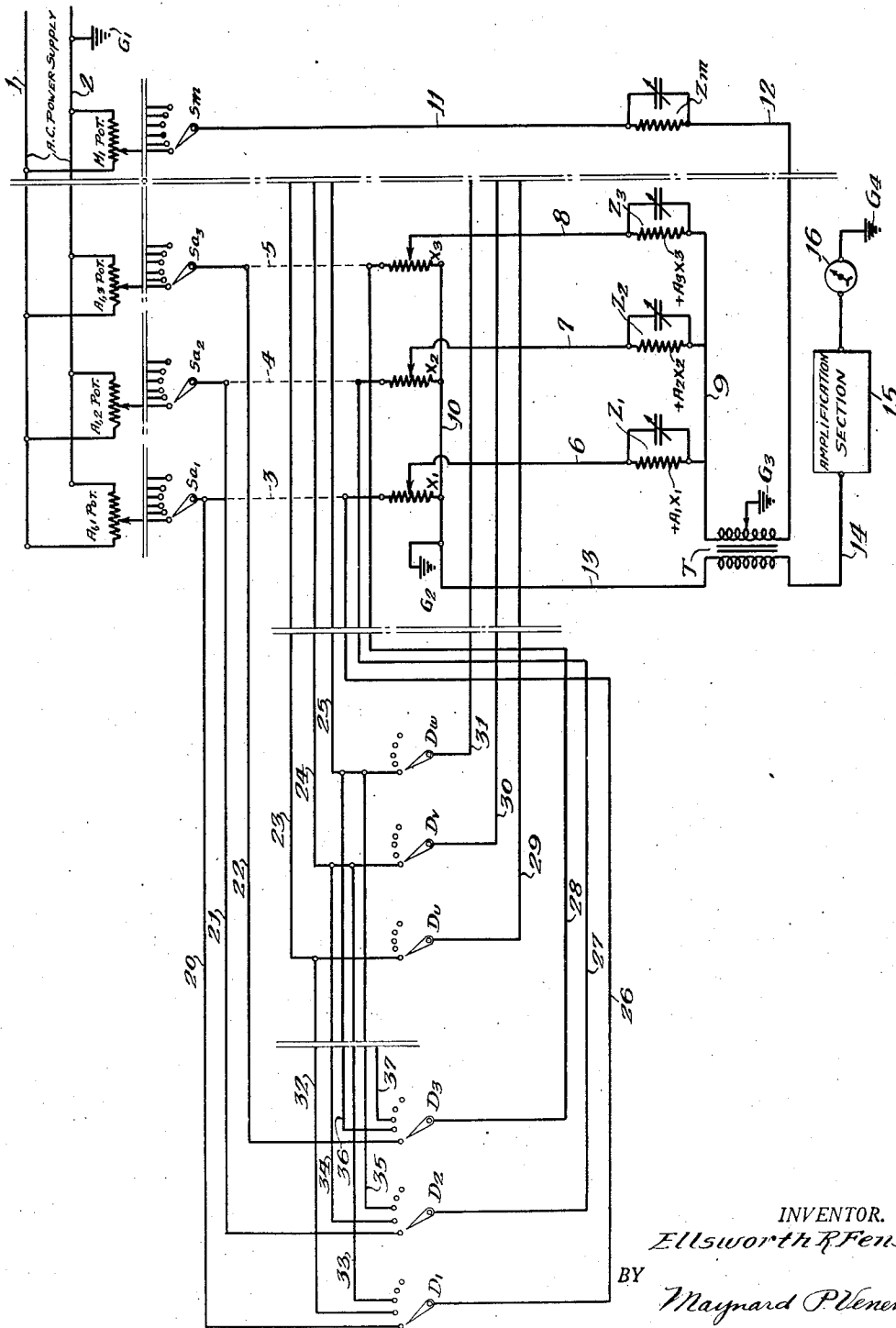
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ELECTRICAL COMPUTER

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ELECTRICAL COMPUTER

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This invention relates to an improvement in electrical computers of the voltage dividing and balancing circuit type, which are used in solving linear simultaneous equations. More specifically this invention lies in providing a novel transposition circuit so that additional linear equations may be accommodated on a given computer which is normally limited to solving a fixed number of unknown values and equations at any one setting.

In the usual computer which is limited to solving a fixed number of equations, it is necessary to solve a larger number of equations by more than one complete operation. In other words any group or portion of the entire set of equations must be first reduced and the results used in one or more successive operations to effect the final solution of the entire set. A step-wise operation such as this is tedious and the chances for human errors in reading dials and resetting values leads to a greater number of inaccuracies in effecting the solution of the problem. The form of equations handled in this type of apparatus are of the type:

$$\begin{aligned} A_{1,1}X_1 + A_{1,2}X_2 + A_{1,3}X_3 + \dots + A_{1,n}X_n &= M_1 \\ A_{2,1}X_1 + A_{2,2}X_2 + A_{2,3}X_3 + \dots + A_{2,n}X_n &= M_2 \\ A_{3,1}X_1 + A_{3,2}X_2 + A_{3,3}X_3 + \dots + A_{3,n}X_n &= M_3 \\ A_{n,1}X_1 + A_{n,2}X_2 + A_{n,3}X_3 + \dots + A_{n,n}X_n &= M_n \end{aligned}$$

where the coefficients A and the constant terms M have fixed values, either positive or negative, for each equation. The process of solving a group of these equations consists in finding suitable magnitudes for each of the X's so that when these values are substituted in any of the equations, the left and right sides are equal.

Computers of this type employ what is known as the iterative, or successive approximation method, it being necessary to carry out the balancing operation repeatedly until the proper X values are found. In other words, it is necessary to set up electrically each coefficient or A value, and each value for M, multiply each A by the corresponding X, and then adjust all the X's successively and repeatedly until the right and left hand sides of each of the above equations are respectively equal.

Adjustable resistances, potentiometers, or other voltage dividing means are incorporated within the given computer, with dials or knobs being furnished, for setting the A, X and M values respectively. The various dials may be calibrated individually, or a calibrated decade potentiometer, or like voltage divider, may be used in a comparison circuit to set in the known

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values and read back those being determined. Where a decade is used, suitable switching is employed to bring the comparison circuit into operation with the proper A, M, or X adjustable voltage dividing means.

Computers of this type are commonly used for solving simultaneous linear equations and determining unknown values from mass spectrometer data obtained in making the analysis of some material, such as a gaseous hydrocarbon mixture. In petroleum research work it is frequently desired to analyze a hydrocarbon sample for butane and lighter components, so that it is often necessary to set up 15 or more simultaneous linear equations to determine the amount of each of these 15 or more gaseous components which may be present. Thus, where a computer is available for use which can only handle 12 equations and unknowns it is necessary to employ a tedious two-step operation or make use of a longer calculation with a mechanical calculator. However, the transposition switch and circuit arrangement of this invention is particularly flexible in its operation, as will be more fully explained hereinafter, so that any column or group of columns can be transposed to any other position in the matrix to permit any predetermined variable to be used to determine product sums for any desired equation. In other words, the improved apparatus is made useful for conveniently handling a larger number of equations than normally possible by the fixed size of the computer.

In the usual problem, as provided by analysis data, the coefficients of a set of simultaneous equation form a matrix having a certain number of open coefficient points, or an open quadrant, because of part of the A coefficients being equal to zero, within the simultaneous equation setup. Thus, when presented with a problem having more simultaneous equations than the computer could normally handle, the unused potentiometers may be made use of, by this invention, to accommodate additional coefficients and equations and to provide desired checks on product sums, so that a quicker and more accurate solution of the entire problem is made in general by one setting of the apparatus. The elimination of several operations on the computer together with reduction in use of mechanical computers results in a valuable saving in time, as well as the reduction of errors in calculation.

The accompanying drawing and the following description thereof will serve to show diagrammatically and in a simplified manner the basic circuit of one type of computer with transposi-

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tion circuits connected in combination therewith, as provided by this invention, to provide greater flexibility and use of the apparatus.

Referring now to the drawing, there is shown diagrammatically within the right hand portion thereof a simplified wiring diagram of an adjustable potentiometer type of electrical computer. A plurality of adjustable potentiometers $A_{1,1}$, $A_{1,2}$, etc., and an M_1 potentiometer are connected in parallel to lines 1 and 2 which supply a suitable alternating current. Line 2 is suitably grounded at G_1 . In like manner, a plurality of n rows of adjustable potentiometers, (similar to the row shown in the drawing), are provided in a manner to be easily connected in parallel with the power supply. Thus a separate row or series of A potentiometers is available for each of (n) simultaneous equations. Connecting with each of the A potentiometers in each of the n rows is an operational switch having a deck to connect with and to correspond with each of the plurality of n columns. These decks are indicated diagrammatically as S_{a1} and S_{a2} , etc., with a deck S_m connecting to each of the M_1 , M_2 , etc., potentiometers. The operational switch provides means for connecting each of the A potentiometers, for each simultaneous equation, into the circuit in the manner desired for the operations of setting A 's, X 's, M 's and solution.

The respective A potentiometers may be connected with a series of other adjustable potentiometers X_1 , X_2 , X_3 , etc., by means of the operational switch and by suitable lines, such as 3, 4, and 5. Thus, after all of the A values and M values for each equation have been set into each of the plurality of n rows of potentiometers, the computer is made ready for adjusting the X potentiometers to balance the equations.

The center tap of each X potentiometer connects with individual impedances Z_1 , Z_2 , Z_3 , etc., by means of the respective lines 6, 7, and 8, etc. These impedances are provided to maintain proper phase adjustment within the type of computer shown and to provide the means of "adding" the voltages proportional to $(A \times X)$. Each center tap from the X potentiometers and the respective Z impedance connect in parallel circuits, the impedance ends connecting with line 9, while the end terminals of the series of X potentiometers X_1 , X_2 , etc., connect with line 10, which in turn is grounded at G_2 . The line 9 connects with one portion of one coil of a bridging transformer T , this transformer coil being divided in half and grounded by the ground connection G_3 . Thus, in the plurality of parallel circuits, which are formed, the first circuit comprises the portion of the potentiometer X_1 between line 10 and the center tap, line 6, impedance Z_1 , line 9, the one-half portion of the coil of transformer T , and the ground between G_2 and G_3 . In like manner, similar circuits are formed with the other X potentiometers and the respective impedances to connect in parallel across the same portion of the transformer T .

The operational switch, through deck S_m , connects each of the M potentiometers through line 11, impedance Z_m line 12, and grounds G_1 and G_3 to the other one-half portion of the coil of the transformer T . This arrangement causes the latter circuit to oppose the other portion of the divided coil of the transformer T , which connects with the X circuits, and thus provides means for balancing the sum of the latter against the M circuits. When each of the X potentiometers are properly adjusted the series

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of parallel X circuits will balance the M circuit and there will be equal but opposite current flow in the two halves of the divided coil of the transformer. Thus there will be no voltage developed on the other side (secondary) of the transformer.

The current flow, or alternately, the absence of current flow in the secondary of the transformer T provides means for visually observing whether or not the circuits are all in balance. One side of the secondary coil of the transformer T , is connected by means of line 13 to the ground G_2 , while the other end of the coil connects through line 14 to a suitable amplification section 15, a suitable ammeter or oscilloscope 16, and the ground G_4 . A current or voltage indicating circuit is thus completed through grounds G_2 , G_4 , the indicator 16, the amplifier 15, and the secondary coil of the transformer T , and provides the desired visual means for ascertaining when the series of $(A \times X)$ circuits are in balance with the M circuits.

In making the final solution for the X values in the type of computer shown, after the various A coefficients for each equation are set in, with the first row of A potentiometers in the circuit, the X_1 potentiometer is adjusted until the current indicator 16 shows a null value, then with the second row of A potentiometers in the circuit, the X_2 potentiometer is adjusted until it shows a null value and in like manner the remaining X potentiometers are adjusted to a balance. However, as noted hereinabove, computers of this type operate on a successive approximation method so that it is necessary to repeat the balancing operations beginning with the X_1 potentiometer and continuing on through with the remainder. Normally, three or four corrective adjustments may be required to effect a balance of all of the circuits and provide the solution to the unknowns and the equations, to the point where upon returning to each equation, it is found that no further adjustment in the respective X potentiometer is needed to bring the current meter or oscilloscope 16 to a null point.

On the left hand portion of the drawing, there is indicated diagrammatically a multiple deck switch and a series of transposition circuits which are connected in a predetermined manner with the electrical computer device, so that there is provided by the invention an improved computing apparatus.

Ganged switch having a multiple deck construction is provided, with a portion of the decks being indicated in the drawing as D_1 , D_2 , D_3 , D_a , D_v and D_w . One terminal of the D_1 deck connects by means of a line 20 (in place of line 3), to the stator bar center tap of deck S_{a1} the operational switch, which accommodates one column of A coefficients. One terminal of the deck D_2 connects, by means of a line 21 in place of line 4, such that it in turn connects with the stator bar center tap of deck S_{a2} of the operational switch, which controls the second column of A coefficients. In like manner the lines 22, 23, 24 and 25 of the transposition circuits which are shown in the drawing connect a deck of the gang switch with the respective rows and columns of A coefficients. The center tap of deck D_1 connects with the X_1 potentiometer by means of line 26, the center tap of deck D_2 connects with the X_2 potentiometer by means of line 27, and the center tap of D_3 connects with the X_3 potentiometer by means of line 28. In a similar manner the center tap of the successive decks connect with the other X potentiometers. The other decks

indicated in the drawing, D_u , D_v and D_w , connect to potentiometers which are not shown by means of the respective lines 29, 30 and 31.

Inter-connecting wires between the various decks of the transposition circuit switch are provided in a predetermined manner so that A coefficients from any selected position or grouping may be transposed to any other predetermined position. In the drawing there are shown only a portion of intermediate connecting lines which are possible to effect such a transposition. A second terminal of the deck D_1 has a line 32 connecting it with the line 23, which in turn attaches to the first terminal of the deck D_u . A third terminal of the deck D_1 has a line 33 connecting to line 24. A second terminal of the deck D_2 has a line 34 connecting with line 24, which in turn connects with the first terminal of deck D_v . A third terminal from the deck D_2 has a line 35 connecting to line 25. A second terminal from the deck D_3 has a line 36 connecting with line 25, which in turn connects with deck D_w .

It may thus be seen from this partial diagram that the operation of the multiple decks of the transposition switch is such as to transpose A coefficients which have been set on the unused potentiometers due to zero A coefficients in the series of simultaneous equations which are set into the apparatus from one portion of the computer to other positions.

For example, a study of the matrix for equations set up from mass spectrometer data usually shows that there are several A coefficients having a zero value, or that frequently an entire quadrant has no A values to be set in. Therefore, after the apparatus has been used to obtain the unknown X values, it may be used to obtain product sums for additional equations. The A values of the additional equation may be set in on the unused quadrant or in the unused positions and the transposition switch and circuits employed to effect the connection between the new A values and the proper X potentiometers so that the desired product sums can be obtained.

Somewhat more specifically, let it be assumed that the percentage composition of a given gaseous hydrocarbon sample is to be determined from mass spectrometer data and with aid of twelve by twelve computer. Twelve simultaneous, linear equations may be set up with twelve unknown values, X_1 through X_{12} , by lumping total butenes, thus the components to be determined comprise butenes, n-butane, isobutane, butadiene, propane, propene, ethane, ethene, methane, carbon monoxide, nitrogen and hydrogen. However, three additional equations may be written which will provide product sums which in turn can be used to calculate the percentage composition of the butene split, in other words, the amount of 1-butene, 2-butene, and isobutene, and by the use of the transposition circuits, those additional equations may be handled on the apparatus as will be hereinafter explained.

The twelve basic equations are arranged properly, with the largest coefficients on the diagonal and the smaller ones to the right of each equation, so that rapid convergence is obtained by the computer. It will be assumed that in the twelve equations, all values in the equations 1 through equation 6, and in columns 7 through 12, are zero, since it frequently occurs in this type of analysis problem. Thus, there is an entire quadrant which is being unused in the computer. This permits using this quadrant for inserting the three additional equations for the butene split,

plus any three other equations, such as check equations which are necessary to check the X values which are being determined. These additional equations are of the form;

$$\begin{aligned} A_{1,2}X_2 + A_{1,3}X_3 + \dots + A_{1,6}X_6 &= M_{13} \\ A_{2,2}X_2 + A_{2,3}X_3 + \dots + A_{2,6}X_6 &= M_{14} \end{aligned}$$

etc., with the M's, or product sums, being the desired values, and the equations making use of the X values which are determined. However, before setting in the coefficients for these additional equations, the unused quadrant should be equated to zero, that is, polarity switches or other switching means of the computer should be operated to prevent the new coefficients from affecting the X_7 through X_{12} values in the solution of the 12 basic equations. The computer is then operated to balance the simultaneous equations and to determine the X_1 through X_{12} values.

Of course, to obtain correct product sums in the additional equations, the computer only multiplies A's and X's having the same subscript. The transposition switch and circuits accomplish this in this example, by turning it to the tap or taps, which transpose the A's from columns 7 through 12 into proper alignment with the X's in columns 1 through 6, or conversely makes the effective operation of switching the variables obtained from X_1 through X_6 to the positions of X_7 through X_{12} , respectively.

Without the transposition switch and circuits, each X value would have to be read and manually reset over in the proper column. This leads to possible errors and inaccuracies and considerable time spent in carrying out given necessary calculations, so that it is again noted that this invention is almost invaluable to those who use electrical computers to any extent. There are of course many other types of equations and problems which bring into use the improvement of this invention, as will be apparent to those who are familiar with this type of analysis and computations.

In the foregoing description and in the accompanying drawing, the various voltage dividing means have been referred to as potentiometers, however, it is not intended to limit this invention to being used with any specific type of adjustable voltage dividers or to any specific type of computer whether using series or parallel methods of adding AX voltages. Also, it may again be pointed out that the wiring diagram of the computer which is shown in this drawing is of a simplified diagrammatic form so that any desirable commercial computer may properly have additional parts and features which are not shown in this drawing.

I claim as my invention:

1. In an electrical computing apparatus suitable for solving a fixed number of unknowns and simultaneous equations, and having in combination, a suitable voltage supply, a multiplicity of voltage dividing means arranged into a plurality of circuits, calibrated means connective with said voltage dividing means for adjusting the latter to correspond with known coefficients and constants and operative to bring said circuits into balance, and indicating means to observe the balancing of said circuits, the improvement which comprises providing in combination therewith, a multiple deck switching means, a plurality of transposition circuits, wiring means connecting the decks of said switching means to said balanceable circuits of said computing apparatus, whereby but one deck connects to but one circuit,

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and additional wiring means in said transposition circuits connecting said decks with one another in a manner joining said voltage dividing means from one circuit to another within said computing apparatus, whereby an additional number of equations over and above the aforesaid fixed number may be solved conveniently on said apparatus.

2. In an electrical computing apparatus of the voltage dividing type suitable for solving a plurality of (n) unknown values within a series of (n) linear simultaneous equations and having in combination, a plurality of (n) rows of adjustable potentiometers, with each row having a plurality of $(n + 1)$ of said potentiometers connecting with a suitable voltage supply, multiple deck switching means connected to bring one of said rows at a time into operation, an additional plurality of (n) adjustable potentiometers with one for each but one of said $(n + 1)$ adjustable potentiometers, wiring means separately connecting said additional adjustable potentiometers with said multiple deck switching means whereby the latter potentiometers may be connected to each of the first said potentiometers in said plurality of rows, an impedance coil connecting with each of last said additional adjustable potentiometers to form therewith (n) parallel circuits, and another impedance coil connecting with the deck of said switching means which has no second adjustable potentiometer connecting thereto

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to form an (M) circuit, means connecting said plurality of (n) circuits across a one-half portion of a coil of a bridging transformer, means connecting the remaining impedance coil in said (M) circuit to the other one-half portion of said coil of said transformer, and a current flow indicator connecting with the opposing coil of said transformer in an independent current indicating circuit, whereby the circuits connecting to the opposing one-half portions of the bridging transformer may be balanced, the improvement which comprises providing in combination therewith, a plurality of transposition circuits, a transposition circuit multiple deck gang switch, wiring means connecting a terminal of each deck of the latter switch to the center tap of the stator of first said multiple deck switching means in a manner having one deck of said transposition gang switch join with one deck of the first said multiple switching means whereby one deck of the former joins with one of the plurality of (n) circuits, and additional wiring connecting terminals between decks of the multiple deck gang switch of said transposition circuit whereby first said adjustable potentiometers from a portion of said plurality of (n) circuits may be effectively transposed to other positions in said apparatus.

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No references cited.