Dec. 17, 1940. N. K. ENGST 2,225,410

COMPUTING SYSTEM

Filed April 7, 1930 5 Sheets-Sheet 1

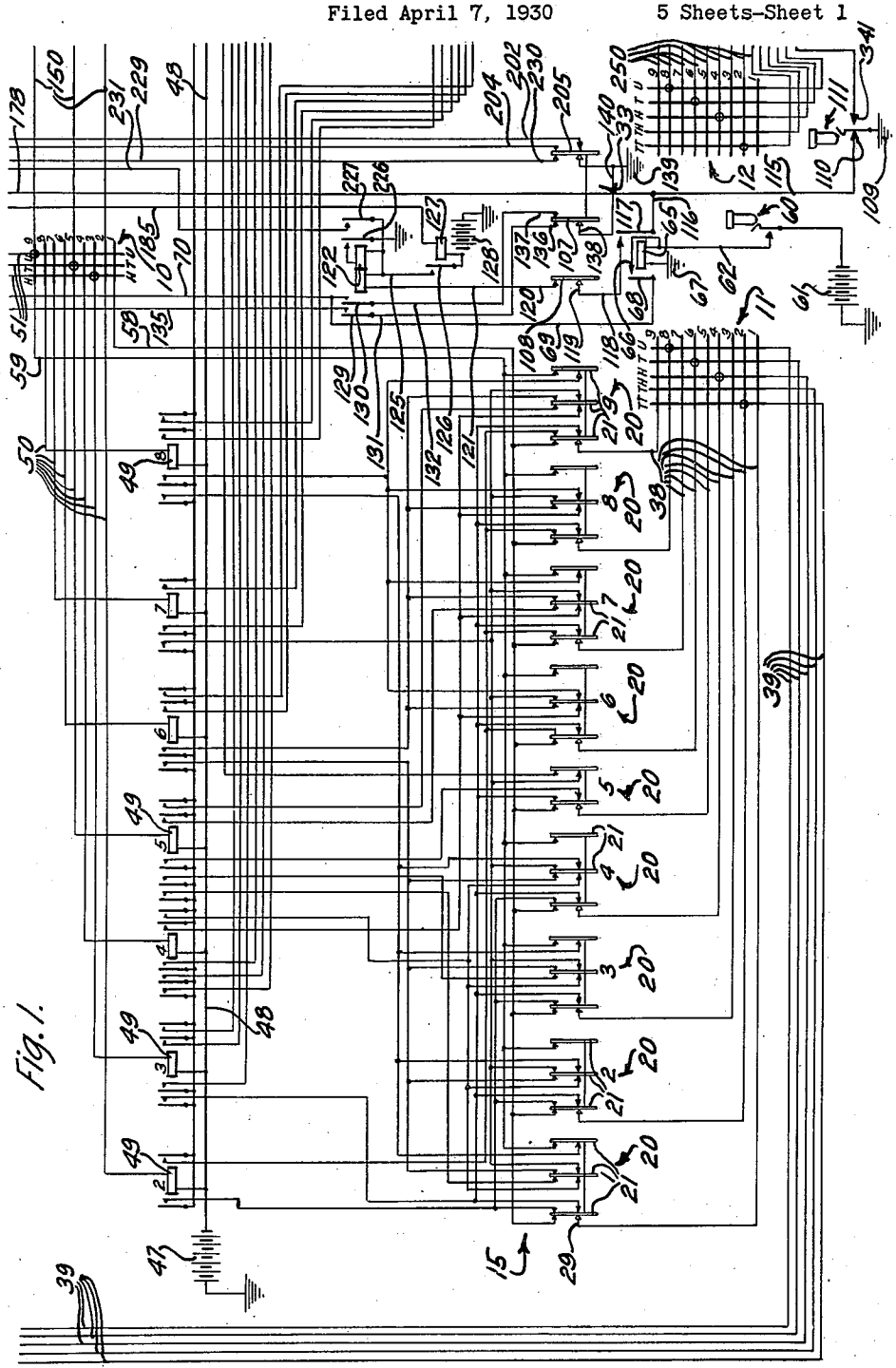


Fig. 1.

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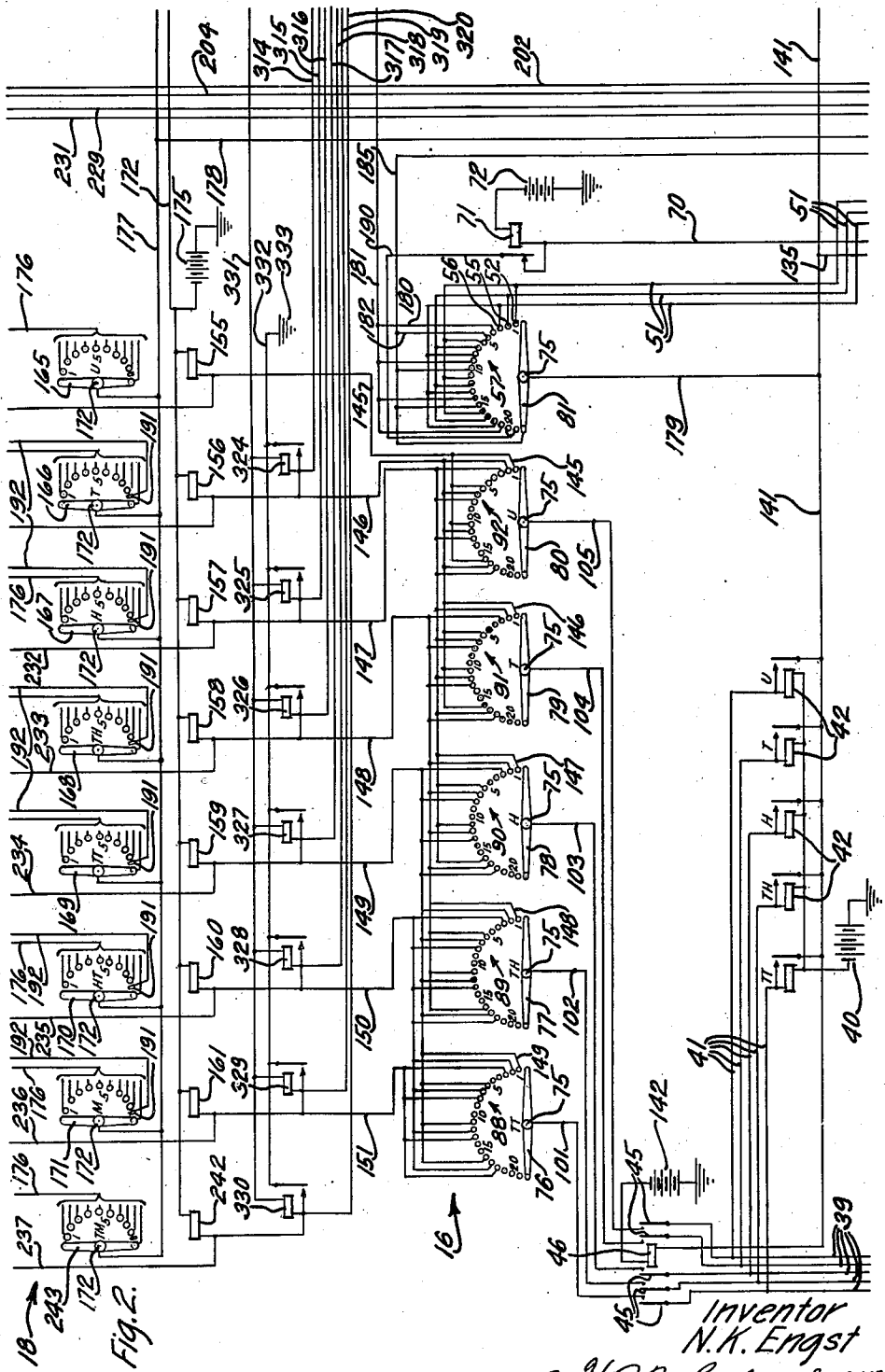


Fig. 2.

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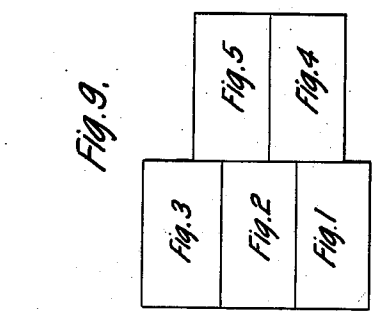


Fig. 9.

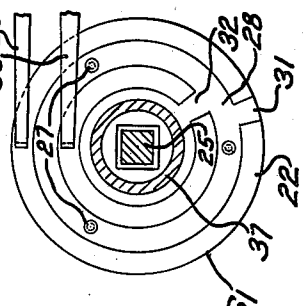


Fig. 8.

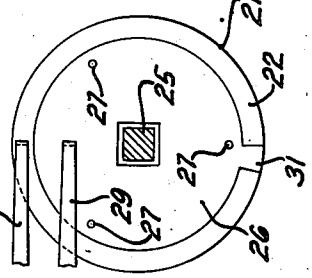


Fig. 7.

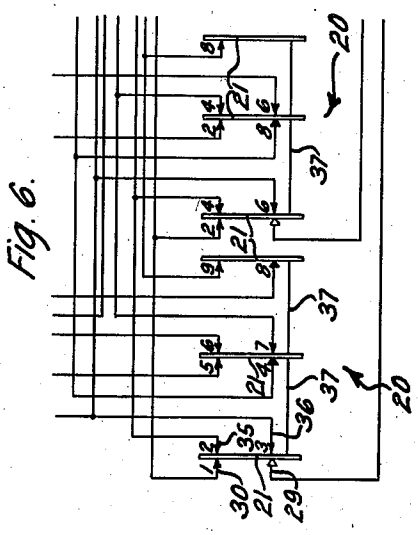


Fig. 6.

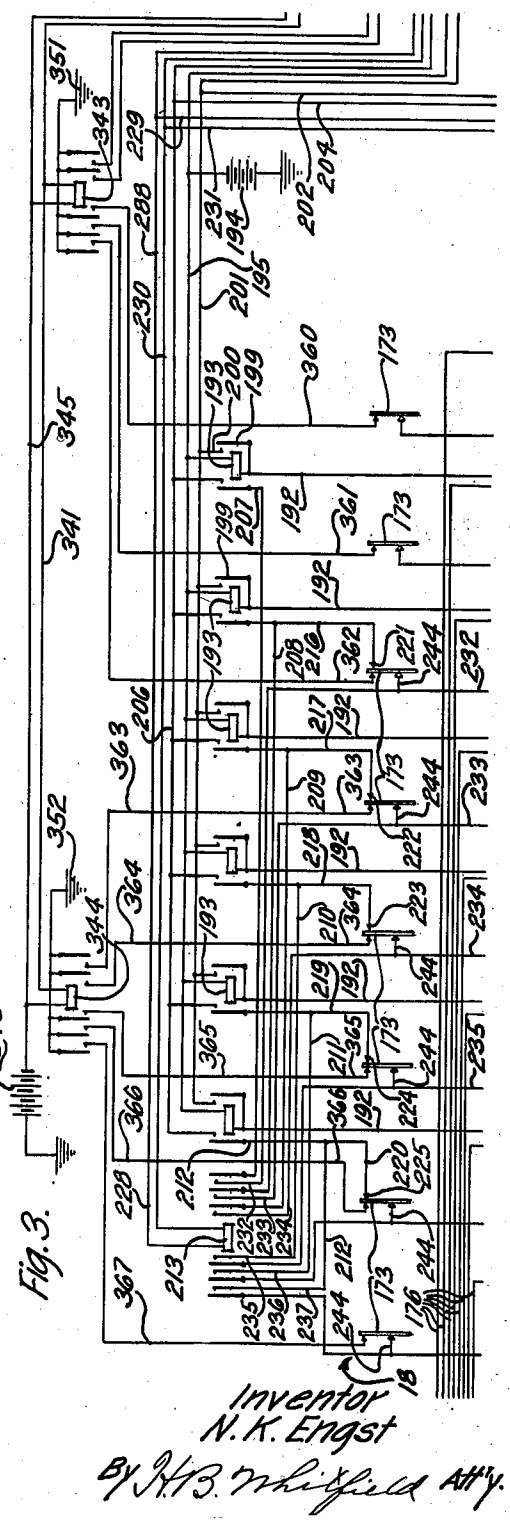


Fig. 3.

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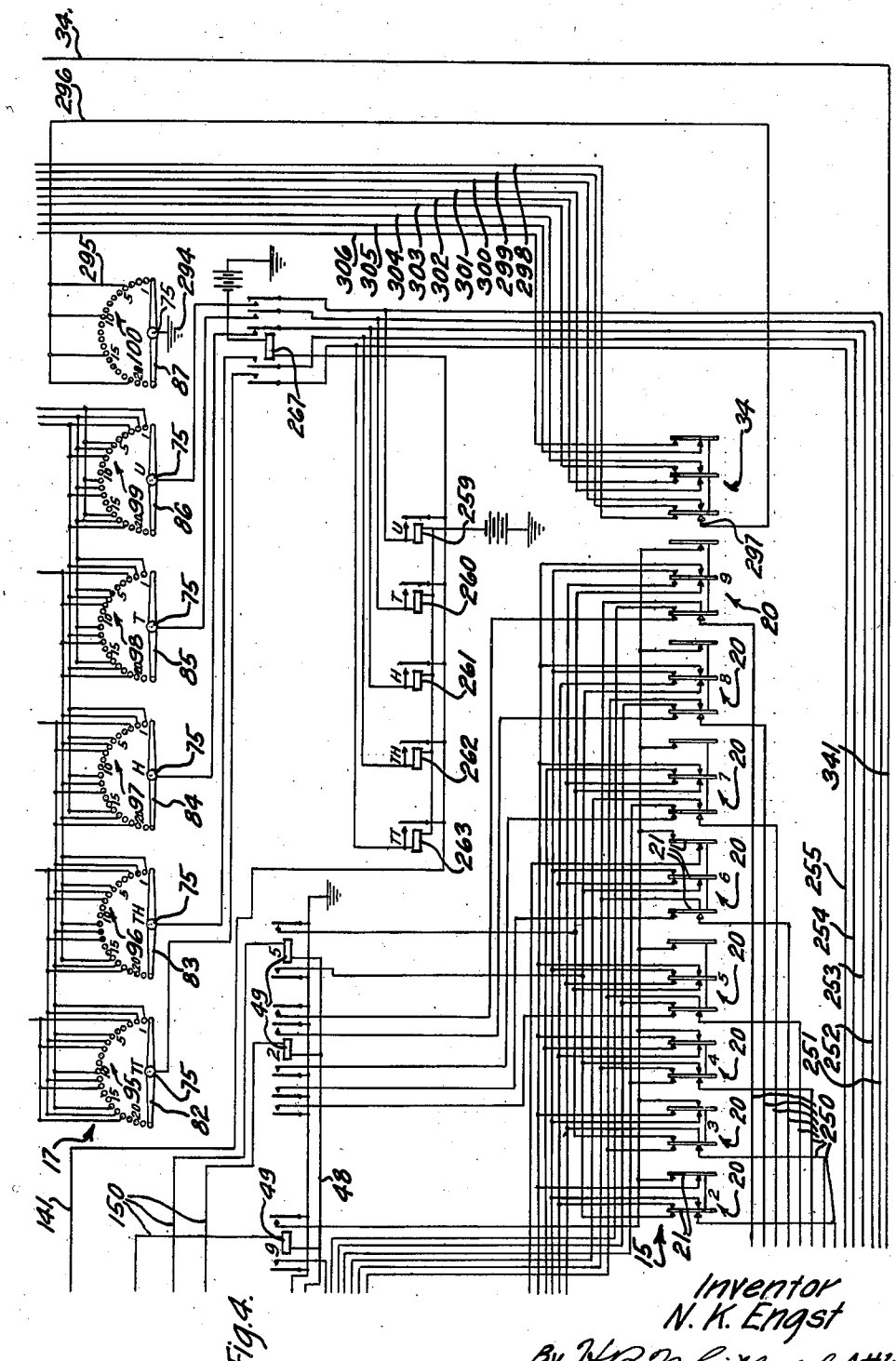


Fig. 4.

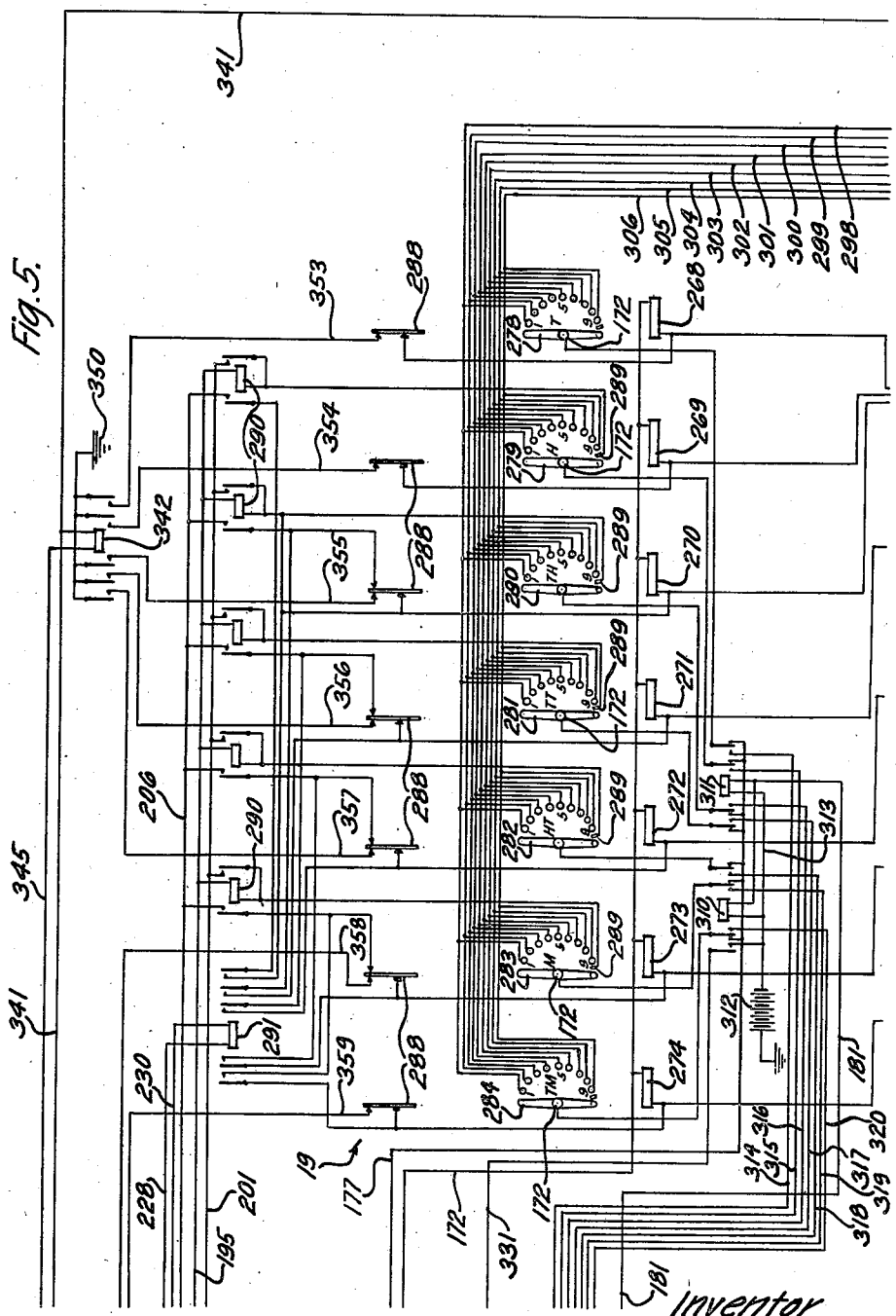
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Fig. 5.



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Patented Dec. 17, 1940 2,225,410

UNITED STATES PATENT OFFICE

2,225,410

COMPUTING SYSTEM

Norbert K. Engst, Cicero, Ill., assignor to Western Electric Company, Incorporated, New York, N. Y., a corporation of New York

Application April 7, 1930, Serial No. 442,103

18 Claims. (Cl. 235—61)

This invention relates to computing systems, and more particularly to an electrically operated mathematical multiplication system for effecting computations.

The principal object of the present invention is the provision of an efficiently operable and flexible system for accomplishing mathematical computations with a minimum expenditure of effort and time and with accuracy.

In accordance with one embodiment, the invention contemplates the provision of an electrical multiplication system for multiplying five digits by three digits, in which there are seventeen sets of electrical contact disks, in nine sets of which a contact disk represents the unit number or part of the product of one digit by another digit and is provided with an associated contact brush so that the position of the disk with respect to the brush represents the unit number or part of the particular product, and in the other eight sets of which a contact disk represents the tens number or part of each particular product. One less set is provided in the tens number or part group than in the units part group since there will be no tens part of a product of any digit multiplied by one.

The multiplicand and multiplier are set up on keys which close certain electrical circuits, whereby, beginning with units, power is fed, for each digit in the multiplier, one at a time, through contacts on the disks and through distributing brushes to separate registering devices or accumulators, depending on whether the contact disks represent the units or tens part of the particular products. The distributing brushes associated with the registering device for the units part of the product transfer the electrical connections from units to tens, tens to hundreds, hundreds to ten-hundreds, etc., and simultaneously therewith the distributing brushes associated with the registering device for the tens part of the product transfer the electrical connections from tens to hundreds, hundreds to ten-hundreds, ten-hundreds to ten-thousands, etc. As soon as the separate registering devices or accumulators have received the last partial product from the contact disks a transfer circuit is automatically rendered effective for transferring the total indicated in one register into the other register which will then indicate the final product of the multiplication.

Other objects and advantages of the invention will be apparent from the following detailed description, reference being had to the accompanying drawings, wherein

Figs. 1, 2, 3, 4, and 5 are circuit diagrams which, when viewed collectively with Fig. 2 above Fig. 1, Fig. 3 above Fig. 2, Fig. 5 above Fig. 4 and Figs. 4 and 5 at the right of Figs. 1, 2, and 3, disclose an electrical multiplication system representing one embodiment of the invention;

Fig. 6 is an enlarged fragmentary schematic of three of the sets of contact disks representing the electrical multiplication system on the multiplying commutator;

Figs. 7 and 8 are sectional views showing opposite sides of one of the contact disks illustrating the cutting of the conducting portions thereof, and

Fig. 9 is a view showing the relative location of Figs. 1, 2, 3, 4, and 5.

Referring now to the drawings in which similar parts are designated by the same numerals in the several views, it is believed that a clear understanding of the invention will be had therefrom when considered in conjunction with the following description. In examining the circuit diagram, Figs. 1 to 5 should be arranged as shown in Fig. 9.

For the sake of clarifying the following description, it will be noted herein that the apparatus utilized in the circuit shown in Figs. 1 to 5 is either taken wholly from the telephone art or taken from the telephone art and modified slightly to perform slightly different functions than those required of like apparatus in telephony. The disk contacts forming the multiplying commutator and which represent the partial products of one digit by another digit are adaptations of sequence switches which are well known in telephone art. The modification in these switches consists principally in driving the switches continuously rather than intermittently, and utilizing in place of the clutches normally used with like switches in telephone practice, a relay which, upon actuation, permits current to be fed to the contact disks.

The distributor switches and accumulator switches, which will be described in detail hereinafter, are substantially the same as the selector switches used in dial system telephony. The distributor switches comprise a plurality of brushes insulated from each other and mounted upon and insulated from a shaft which is rotatable under control of an electromagnetically operated relay, so that the brushes will be stepped from contact to contact on the arcuate banks of contacts associated therewith upon actuation of the relay. These switches are the typical selector switches of telephone practice without any modi-

fication. The accumulator switches, however, have been modified somewhat and comprise brushes having associated therewith arcuate banks of contacts. The brush individual to each bank of contacts being connectable to a common rotating shaft at intervals by the actuation of electromagnetic clutches individual to each brush.

Referring now to Figs. 1 to 5, the multiplier key bank designated generally by the numeral 10 (Fig. 1) is represented schematically by a coordinate group of lines. The vertical lines or columns from right to left denote units (U), tens (T), and hundreds (H), and the nine rows of horizontal lines denoting the digits 1 to 9 inclusive, from bottom to top of the group. Each intersection of the lines represents an electrical contact normally open, which may be closed upon the actuation of any suitable locking key or electrical switch such as; for example, are described and shown in the patent to A. D. Hargan, 1,378,950, issued May 24, 1921.

The multiplicand key bank is represented by two coordinate groups of lines 11 and 12. The vertical lines in each group from right to left denote units (U), tens (T), hundreds (H), ten-hundreds (TH), and ten-thousands (TT), and the nine horizontal lines in each group denote the digits 1 to 9 consecutively from bottom to top. These two groups of lines represent two separate sets of contacts, the closure of any set of which will be effected upon actuation of any key which the intersection of the lines represent; that is, for example, actuation of the nine key in the tens (T) column will close the contacts represented by the intersection T—9 in both the group 11 and the group 12. As will become apparent as the description progresses, these groups of contacts 11 and 12 control the units and the tens part, respectively, of the product of the multiplication of any digit by itself or any other digit.

Any particular problem may be set up on the banks 10 and 11—12 by closing the contacts associated with the digits which go to make up the problem at the points corresponding to the digits in the multiplicand and the multiplier. These contact closures complete electrical circuits through a multiplying commutator designated generally by the numeral 15 and send electric currents to distributor switches designated generally by the numerals 16 and 17, which in turn direct the currents to accumulators designated generally by the numerals 18 and 19, for properly registering or accumulating the results.

The multiplying commutator 15 comprises an electrical multiplication table in which there are seventeen sets, designated as 20, of electrical contact disks, the nine sets shown on Fig. 1 representing the units part of the product of any digit by any other digit and the eight sets shown on Fig. 4 representing the tens part of the product of any digit by any other digit. The sets 20 representing the units part of the product of 1, 2, 3, 4, 6, 7, 8, and 9 by any digit comprise three contact disks 21, and the sets 20 representing the units part of the product of 5 by any digit and the tens part of the product of 2, 3, and 4 by any digit comprise two contact disks 21. The sets 20 representing the tens part of the product of 5, 6, 7, 8, and 9 by any digit comprise three contact disks 21. These disks are all of a similar construction, the only variants being that the position of conducting elements thereon varies as the value of the partial product of each disk varies.

The left hand disk (Figs. 1 and 6) associated with the horizontal line representing the digits 1 of the multiplicand bank 11 has been selected for illustration and will now be described in detail. Referring now to Figs. 6, 7, and 8, the contact disks 21 comprise a disk 22 of insulating material mounted on and rotatable with a common shaft 25 which is contantly rotated at a uniform speed. Secured to one side of the disk 22 is a metal plate 26, held in place by rivets 27 which extend through the disk 22 and a second metal plate 28 to hold the plates 26 and 28 in a predetermined position on the disk 22 and to electrically interconnect them. The plate 26 is so formed that, of a pair of brushes 29 and 30 associated therewith, the brush 29 always makes contact with the plate 26 and the brush 30 makes contact at a predetermined point in the rotation of the disk and for a predetermined period sufficient to send an electrical impulse transmitted to the plate 26 by the brush 29, out through the brush 30 at the time of contact between the brush 30 and a portion 31 of the plate 26. The plate 28 is electrically connected through the rivets 27 with the plate 26, and the brush 29, being constantly in contact with the plate 26, will supply electrical energy to the plate 28 whenever the brush 29 is connected in circuit with a source of electrical energy. When the brush 29 is so supplied the plate 28 will also be supplied with electrical energy and since it has two contacting portions 31 and 32 adapted to engage a pair of brushes 35 and 36 at predetermined intervals, the brushes will be supplied with electrical energy at predetermined intervals during the rotation of the disk 21. The left hand disk 21 in each set 20 has its lower left hand brush always in contact with a conducting portion thereof and the second and third disks from the left of each set are interconnected with the left hand disk by metal sleeves 37 positioned between them. Thus the lower left hand brush 29 connects the contacting portions of the disks in each set with the horizontal lines in the multiplicand banks 11 and 12. Each of the sets 20 is insulated from every other set, the conducting portions of the contact disks are insulated from the shaft 25 and the sleeves 37 are separated from the shaft 25 by insulating washers.

Fig. 6, the enlarged fragmentary schematic of the multiplying commutator, shows the arrangement of the mutiplication table for two of the sets 20 representing the units part of the products of the digits 1 and 2. The multiplication table, as illustrated, follows the series of 1×1, 1×2, 1×3, 1×4, 1×5, 1×6, 1×7, 1×8, and 1×9; 2×1, 2×2, 2×3, 2×4, 2×6, 2×7, 2×8, and 2×9, wherein each of the contacting portions of the disks represents a particular partial product, the numerals adjacent the brushes representing the units parts of the foregoing multiplications. It will be noted that there are no contacting portions provided for the units part of product of 2×5 since the units part of the product of 2×5 is zero and no circuit connections need be made to indicate zero. The same condition exists in the sets 20 provided for the products of 4×5, 5×2, 5×4, 5×6, 5×8, 6×5, and 8×5 in the nine sets 20 which represent the units part of the particular products and therefore no contacting portions are provided on those sets. The multiplication table with the above noted exceptions follows the usual order through the multiplication of the digits

3 to 9 inclusive by any digit, the tens part of the products being represented by similar contact disks.

In addition to the contact disks heretofore described, the multiplying commutator has mounted thereon a set 33 of three control contact disks and a set 34 of three transfer contact disks, the function of which will become apparent as the description progresses.

For the sake of simplifying the description, that portion of the system which controls the units part of the partial products sought, in effecting the computation, will be described first, then that portion of the system which controls the tens part of the partial products will be described, and finally the transfer mechanism which transfers the partial products from the register associated with the tens part of the products to the units part register. Referring now to Figs. 1, 2, and 3, closure of any contact in the multiplicand bank 11 will interconnect a conductor 38 associated with the horizontal line in which the contact is closed and a conductor 39 associated with the vertical line in which the contact is closed. Each of the conductors 38 connects the lower left hand brush 29 associated with a set 20 of contact disks representing the product of the digits 1 to 9 by any digit, to the corresponding horizontal line representing the digits 1 to 9 in the multiplicand bank 11 and each of the conductors 39 connects one of the vertical lines representing the units (U), tens (T), hundreds (H), ten-hundreds (TH), and ten-thousands (TT) part of the multiplicand in the banks 11 to grounded battery 40 (Fig. 2) through conductors 41 and the windings of one of five holding relays 42 which are associated with the units (U), tens (T), hundreds (H), ten-hundreds (TH), and ten-thousands (TT) contacts of the multiplicand bank 11 and to the normally open contacts 45 of a relay 46.

The closure of any contact in the multiplier bank 10 will condition a circuit from grounded battery 47 (Fig. 1) through a conductor 48, winding of one of a plurality of multiplier relays 49, (Figs. 1 and 4), one of a plurality of conductors 50, which connect the horizontal line in which the contact is closed with its associated multiplier relay 49, through the closed contact in the multiplier bank 10, one of a plurality of conductors 51 connected to the vertical lines in the multiplier bank 10 representing the units (U), tens (T), and hundreds (H) digit in which the contact has been closed to one of contacts 52, 55 or 56 on an arcuate bank of contacts 57, forming a part of the distributor 16. These conditioned circuits will be completed to ground from the distributor 16 in a manner to be described in detail hereinafter. This condition applies for the horizontal lines in the multiplier bank 10 which are associated with the digits 2 to 9 inclusive, but does not apply for the horizontal line associated with the digit 1 to which is connected a conductor 58 which runs directly to the upper left hand brush of the left hand disk of each set 20. In like manner a conductor 59 connects the horizontal line in the multiplier bank 10 associated with the digit 9 directly to the upper left hand brush of the right hand disk 21 of each set in the units part of the multiplying commutator.

After the keys controlling the multiplicand bank 11 and the multiplier bank 10 have been actuated to close contacts conditioning the hereinbefore described circuits, a start key 60 (Fig. 1) may be actuated to close its contacts and connect grounded battery at 61 to a conductor 62, leading to one end of the winding of a locking relay 65, hereinafter termed the starting relay, and to a stationary contact 66 thereof. The other end of the winding of the starting relay 65 is connected to ground at 67 and the relay will be energized upon actuation of the starting key 60, attracting its armature 68 thereby to complete a circuit from ground 67 through the winding of the relay 65, stationary contact 66, armature 68, a conductor 69 connected thereto, and from the conductor 69 through a conductor 70 to one end of the winding of an electromagnet 71, the other end of which winding is connected to grounded battery at 72. It will thus be apparent that upon actuation of the start key 60 a circuit will be completed for maintaining the relay 65 energized until a circuit, to be described hereinafter, is completed to de-energize it. The electromagnet 71 requires more current to operate it than does the relay 65 and the electromagnet will not be operated at this time but the means for operating it will be described hereinafter.

The electromagnet 71 forms a part of the distributor switches 16 and 17, and upon energization and release will rotate a shaft 75 common to both distributors, one step for each energization to bring brushes 76 to 87 inclusive into contact with successive contacts on arcuate banks of contacts 88 to 92 inclusive, 57 and 95 to 100 inclusive, respectively. The brushes 76 to 80 inclusive have connected thereto conductors 101 to 105 inclusive which, upon energization of the relay 46, will be connected through the contacts 45 of the relay 46 to conductors 39 which are associated with the ten-thousands (TT), ten-hundreds (TH), hundreds (H), tens (T), and units (U) rows of digits in the multiplicand bank 11 respectively. The first time, in each cycle of operation of the distributor switch 16, that the electromagnet 71 is energized, it will rotate the shaft 75 and move each of the brushes 76 to 81 off the first contact in each arcuate bank, which first contact is a dead contact, and into engagement with the second contact 1 of the banks.

The time of energization of the relay 46 (Fig. 2) is controlled by contact disks 107 and 108 (Fig. 1) of the set 33 of three control contact disks. The contact disk 108 is adapted for a predetermined portion of each revolution of the multiplying commutator shaft 25 to connect ground at 109 through a normally closed contact 110 of a zero return key designated 111, conductors 115 and 116, the right hand movable contact 117 of the starting relay 65 (which it will be assumed, has been energized) conductor 118, a brush 119 which constantly engages the conducting portion of the disk 108, through the conducting portion of the disk to a brush 120. The brush 120 is connected through a conductor 121 to one end of a winding of a control relay 122 which will be energized for that portion of each revolution of the commutator shaft, during which the circuit is completed through the contact disk 108, since the other end of this winding of the relay is connected through a conductor 125, and a normally closed contact 126 of a release relay 127 connected to grounded battery at 128. Upon being energized, the control relay 122 will attract its armatures 129 and 130 to connect conductors 131 and 132 to conductors 135 and 70, respectively. The conductors 131 and 132 are connected to brushes 136 and 137, respectively, associated with the control contact disk 107 of the set 33, which has its lower brush 138 constantly in engagement with a

conducting portion thereof, and connected to grounded battery 139 by a conductor 140. With the above described circuit connections in mind, it will be aparent that for a predetermined portion of each revolution of the multiplying commutator shaft 25 (assuming that the start key 60 has been operated) ground will be connected through the control contact disk 107, brush 136, conductors 131 and 135 to a conductor 141 connected to one side of the winding of the relay 46 which will thereupon be energized since the other side of its winding is connected to grounded battery 142 (Fig. 2).

The electromagnet 71 will be energized once for each revolution of the commutator shaft 25 under control of the control contact disks 107 and 108 by the contact disk 107 connecting ground at 139 through the brush 137, conductors 132 and 70, and will advance the brushes 76 to 87 inclusive into engagement with successive contacts in their associated arcuate banks of contacts in the distributor switches 16 and 17 each time it is energized. Assuming that the relay 46 has been energized as described hereinbefore, the first time the electromagnet 71 is energized, it will connect the vertical rows of contacts in the multiplicand bank 11 associated with the units (U), tens (T), hundreds (H), ten-hundredths (TH) and ten-thousands (TT) digits through the conductors 39 associated therewith the conductors 105, 104, 103, 102, and 101 to conductors 145, 146, 147, 148, and 149, respectively, by moving the brushes 80, 79, 78, 77, and 76 into engagement with contacts on the arcuate banks of contacts connected to the conductors 145 to 149 inclusive, respectively. The second time the electromagnet 71 is energized, the brushes 80, 79, 78, 77, and 76 will be moved into engagement with conductors on the arcuate banks of contacts connected to conductors 146, 147, 148, 149, and 150, and the third time the brushes 80, 79, 78, 77 and 76 will be moved into engagement with contacts on the arcuate banks connected to conductors 147, 148, 149, 150, and 151. The fourth and fifth times the brushes are advanced, they will engage contacts to which no conductors are connected and the sixth to tenth times, the eleventh to fifteenth times and sixteenth to twentieth times the brushes are advanced, the connections made in the first to fifth moves will be repeated.

The conductors 145 and 151 inclusive are connected to one side of the windings of electromagnets 155 to 161 inclusive, respectively. The other side of the windings of the electromagnets 155 to 161 are connected through a conductor 172 to grounded battery at 175 and the electromagnets will be energized when ground is connected thereto. When energized, the electromagnets 155 to 161 serve to connect brushes 165 to 171, respectively, to a common shaft 172, which is rotated constantly in synchronism with the shaft 25, and to rotate the brushes for the duration of the energization of the associated electromagnet. Rotatable with each of the brushes 165 to 171 is a contact disk 173, the purpose of which will become apparent as the description progresses. The movement of the brushes 165 to 171 is therefore controlled by the electromagnets 155 to 161 and the length of time that any of the electromagnets 155 to 161 is energized, will determine the amount of rotation of its associated brush 165 to 171. The accumulator switch 18 serves as a register to indicate the result of a computation and readings may be taken therefrom in terms of the position of the brushes 165 to 171 on the arcuate banks of ten contacts each, associated wtih the brushes or suitably numbered dials (not shown) might be provided to assist in reading the result.

If it is desired to permanently record the result of the computation, the result may be transmitted from the accumulator switch through a plurality of output cables 176, each of which comprises ten leads connected to individual contacts on the arcuate bank associated with the brushes 165 to 171, inclusive. Any suitable type of electrically operated recording mechanism may be used for this purpose, it being necessary only to make the recording mechanism operable when ground is supplied thereto since the brushes 165 to 171 are normally connected to ground. A type of recording mechanism which would be particularly adapted for use in making permanent records of the results of computations performed by applicant's apparatus is disclosed in the duplicating apparatus forming the subject matter of Patent No. 1,881,631, issued on October 11, 1932, to H. G. Johnstone. Ground is normally supplied to the brushes 165 to 171 from a conductor 177, connected to a conductor 178, which is connected through the lead 115 and the zero return key 111 in its normal position (Fig. 1) to ground at 109.

The step by step rotation of the shaft 75 of the distributor switch 16 not only advances the brushes 76 to 80 a step at a time to cause them to engage successive contacts in their associated banks of contacts, but also imparts a step by step rotary motion to the brush 81 associated with the arcuate bank of contacts 57. The first time in each half revolution of the shaft 75 that the magnet 71 is actuated, the brush 81 will be moved from the first or dead contact of the bank 57 into association with contact 52 to thereby complete a circuit from ground at 139 (Fig. 1) through the conductor 140, contact disk 107, brush 136, conductor 131, closed contact 129, conductors 135 and 141 to a conductor 179, connected to the brush 81 and through the brush 81 to contact 52, the conductor 51 associated with the vertical line representing the units part of the multiplier in the multiplier key bank 10, thence through any closed contact in the multiplier key bank 10, one of the conductors 50, 58 or 59, associated therewith to one end of the winding of one of the relays 49 and from the other end of the winding on one of the relays 49 through the conductor 48 to grounded battery at 47. The second time the electromagnet 71 is energized, it will advance or step the brush 81 into engagement with the contact 55, connected by one of the conductors 51 to the tens row of contacts in the multiplier bank 10, and the third time the electromagnet 71 is energized it will interconnect the brush 81 with the line representing the hundreds digits in the multiplier bank 10. The time of actuation of the electromagnet 71 is so controlled that a partial product of the digits set up in the multiplicand bank 11 by the units digit set up in the multiplier bank 10 will be transmitted to the accumulator switch 18 and thereupon the electromagnet 71 will again be actuated to step the brushes 76 to 81 into engagement with the second contacts in their associated arcuate banks of contacts thereby associating the brushes 76 to 80 with the next higher order of the register or accumulator 18 and moving the brush 81 into engagement with the contact on its associated bank 57 which connects ground through the tens column of the multiplier bank 10 and as soon as the partial product of the digits set up in the multiplicand bank 11 by the digit set up

in the tens row of the multiplier bank 10 has been transmitted to the accumulator switches, the electromagnet 71 will be again actuated to connect ground through the hundreds column in the multiplier bank. After the brush 81 has been successively associated with the contacts 52, 55, and 56, it will, upon the next actuation of the electromagnet 71, be moved into association with the next successive contact on the bank 57 to thereby connect ground from the brush 81 through a conductor 180 and a conductor 181 to actuate the transfer mechanism for transferring the tens part of the product of all of the digits of the multiplicand by each digit in the multiplier from the accumulator switch 19 into the accumulator switch 18, as will be described in detail hereafter. The next time the electromagnet 71 is energized, the brush 81 will engage the fifth live contact on the bank 57 to complete a circuit from ground through the brush 81, a conductor 182, conductor 185 to the windings of the release relay 127 which will thereupon be energized to attract its armature 126, breaking the circuit to the control relay 122 which will release its armatures and break the circuits controlled by the control contact disks 107.

The circuit connections completed in the first five movements of the brush 81 will be duplicated in the sixth to tenth and eleventh to fifteenth movements of the brush, and the connections completed in the first four movements of the brush 81 will be duplicated in the sixteenth to nineteenth movements thereof, but the twentieth and twenty-first movements of the brush will connect ground through the brush, the twentieth and twenty-first contacts of the bank 57, a conductor 190 and the normally closed contacts of the electromagnet 71 to one end of the winding thereof, the other end of which is connected to grounded battery 72, thereby operating the electromagnet 71 twice to advance the brushes 76 to 87 over the twentieth and twenty-first contacts on their associated banks without completing any other circuits than those just described, and stepping the brushes into engagement with the twenty-second contacts on their associated banks.

This variation in the advancement of the brushes is necessitated in order to use selector switches without modifying them since in telephone practice the selector switches used have twenty-two contacts in each arcuate bank. The brush 81 upon engaging the twenty-second contact on its associated bank 57 duplicates the connections made when the brushes engaged the fifth, tenth, and fifteenth contacts on the bank. From the foregoing, it will be apparent that for each half revolution of the shaft 75 supporting the brushes 76 to 87, four separate and distinct problems may be computed.

The accumulator switch 18 in receiving the partial products transmitted thereto from the multiplying commutator 15, may in the course of a particular problem, have partial products transmitted thereto which, when accumulated, will total more than 9, at which time it becomes necessary to have any particular brush to which such products have been transmitted, pass from the position where it indicates 9, into the position where it will indicate zero, and it will also be necessary to add 1 to the next higher denominational register represented by one of the brushes 165 to 171 in the next higher denominational accumulator switch. In order to accomplish this operation, which will hereinafter be termed the "carry," any form of carry mechanism may be used, but the following form has been selected because of its simplicity. An auxiliary contact 191 is provided on each of the arcuate banks of contacts associated with the brushes 166 to 171, which is positioned between the contacts which represent 9 and zero. Any of the brushes, upon engaging the contact 191, will complete a circuit from ground at 109 (Fig. 1) through the conductors 115, 178 and 177 through the contact 191, a conductor 192 connected thereto to the winding of one of a plurality of carry relays 193 associated therewith and having the other side of its winding connected to grounded battery at 194 through a common conductor 195. The right hand contact 199 of each of the carry relays is connected to the conductor 192 and upon energization of its associated relay 193, will engage a contact 200 connected to a conductor 201.

The conductor 201 is connected through a conductor 202 to a contact disk 205 forming a part of the set 33 of control contact disks and having the lower left hand brush associated therewith connected to ground at 139. The conducting portion on the disk 205 associated with the lower right hand brush is such that ground will be connected therethrough to complete a circuit for holding operated any carry relay which received an energizing impulse from one of the brushes 166 to 171.

Any carry relay 193, upon being energized as described hereinbefore, will attract its contacts, the right hand contact completing the locking circuit just described, and the left hand contact of the particular relay or relays 193 which have been energized will complete circuits from a common conductor 206, connected through a conductor 204 and the contact disk 205 to ground at 139; to conductors 207, and/or 208, and/or 209, and/or 210, and/or 211, and/or 212, depending on the relay or relays which have been energized. The conductors 207 to 212 inclusive are connected to the right hand movable and left hand stationary contacts (Fig. 3) of a carry control relay 213, and the conductors 208 to 212 inclusive, are connected by conductors 216 to 220 inclusive, to brushes 221 to 225 inclusive, associated with the contact disks 173, which rotate with the brushes 167 to 171, respectively, of the accumulator switch 18. The relay 213 has one side of its winding connected by conductors 228 and 229 to a brush 230 associated with the control contact disk 205, and has its other side connected by conductors 230 and 231 to a normally open contact 227 of control relay 122. However, the control relay 122 is energized early in the cycle of operation of the circuit and will be held operated since its left hand front contact 226 connects ground through the relay to grounded battery at 128 until the release relay 127 is operated, and since the relay 122 is locked in its operated position, grounded battery at 128 will be connected through the right hand front contact thereof to the conductor 231.

At a predetermined point early in the cycle of rotation of the commutator shaft, the contact disk 205 will connect its brush 230 to ground at 139, thereby to energize the relay 213, and hold it operated for practically the entire cycle. The right hand stationary and left hand movable contacts of the relay 213 are connected through conductors 232, 233, 234, 235, 236, and 237 to the electromagnets 157, 158, 159, 160, 161, and an electromagnet 242 respectively. The electromagnet 242 controls the operation of a brush 243 in

the same manner that the electromagnets 155 to 161 control the brushes 165 to 171 respectively, and the brush 243 in engaging its associated contacts may be utilized to actuate a recording device through one of the cables 176 in the same manner as the brushes 165 to 171.

Upon energization of any of the relays 193, they will condition for operation circuits running from grounded battery at 175 (Fig. 2) through the electromagnets 155 to 161 and 242 which are associated with the particular relays 193 which have been energized, through the closed contacts of the carry control relay 213, to the left hand movable contacts of the relays 193 and from the left hand stationary contacts of the relays 193, conductors 206 and 204 to the upper right hand brush associated with the contact disk 205. The cutting of the conducting portion of the contact disk 205 associated with the upper right hand brush is such that at a point in the cycle of rotation of the commutator shaft at which the partial product of the digits of the multiplicand by one digit of the multiplier has been transmitted to the accumulator switch 18, contact will be made between the brush and the conducting portion to connect ground to the hereinbefore described conditioned circuit long enough to energize the relays 155 to 161 and 242 which have been conditioned for operation, a length of time sufficient to move their associated brushes to the point where they will add one to the registered partial products.

The carry circuit just described will function for the majority of cases, but obviously it alone would not operate to give the correct result if there were a multiple carry to be executed; that is, if for example, the brushes 167 and 168 were both resting on the ninth contact of their respective banks and the brush 166 passed from the ninth contact to the zero contact, thereby making a carry necessary. Therefore, there has been provided circuit connections for effecting a multiple carry which will now be described. It will be apparent that no multiple carry circuit connections are necessary for the banks of contacts representing units and tens, and controlled by the brushes 165 and 166 respectively, since in any problem of multiplication the units parts of the result never has additional digits added thereto during the process of multiplication and therefore the units and tens are not provided with multiple carry circuit connections. However, since it is possible to have nine or less registered in the tens part of the accumulator switch, and in a given problem one or more up to nine may be added to the digit registered in that part of the switch, each of the conductors 232 to 237 inclusive has a brush 244 connected thereto which engages the contact disk 173 associated with the electromagnets 157 to 161 and 242, which brushes 244 always make contact with a conducting portion of the disks 173. The addition of these circuit connections will simultaneously add one to all of the denominational registers in the accumulator switch 18 which are conditioned for operation through the ordinary carry connections or in the event that there is a multiple carry to be effected. The brushes 221, 222, 223, 224, and 225 engage the conducting portion of the contact disks 173 only when their associated denominational registers in the accumulator switch indicate 9. In the event that adjoining registers are to pass from 9 to zero in the effecting of a computation, the following circuit connections will be completed; for example, assume that the brushes 166, 167, and 168 are resting on the ninth contact of their associated banks and that the digit 3 is added to the denominational register associated with the brush 166. The brush 166 will pass from engagement with the ninth contact into engagement with the second contact of its associated bank, and in so doing will pass over the auxiliary contact 191 associated therewith. Since the brush 166 is connected to ground at this time as described hereinbefore, it will, in passing over the contact 191 complete a circuit from ground through the conductor 192, the associated relay 193, conductor 195 to grounded battery at 194, energizing the relay 193 which will, as pointed out hereinbefore, remain locked in its operated position. Simultaneously with the operation of the relay 193, circuits will be conditioned from the upper right hand brush associated with the contact disk 205 through conductor 204, left hand contact of the relay 193, conductor 207, contacts of the energized carry control relay 213, conductor 232, brush 244, brush 221 engaging the conducting portion of the contact disk 173, conductors 216 and 208, contacts of the energized carry control relay 213, conductor 233, its associated brush 244, contact disk 173, brush 222, conductors 217 and 209, contact of the energized carry control relay 213, conductor 234, to the winding of the electromagnet 159. Now since the control contact disk 205 will supply ground from 139 through its upper right hand brush, conductor 204, conductor 206, to the left hand contact of the relays 193 which have been energized through the disks 173 through the conductors 232, 233, and 234 to energize the electromagnets 157, 158, and 159 for the purpose of stepping brushes 167, 168, and 169 ahead one contact, the denominational registers in the accumulator switch 18 representing tens (T), hundreds (H), ten-hundreds (TH), and ten-thousands (TT) will register 2 0 0 1, respectively.

From the foregoing description, it is believed that it will be apparent that the units part of the products of all of the digits in the multiplicand by all the digits in the multiplier in any particular problem will be indicated upon the accumulator switch 18 due to the completion of the hereinbefore described circuits. Referring now to that portion of the multiplying commutator which controls the tens part of the partial products of any selected problem, as shown in Fig. 4, it comprises the hereinbefore described sets 20 of contact disks 21, all of which are operable in exactly the same manner as were the disks associated with the units part of the problem and it will also be apparent that the accumulator switch 19 will have transmitted thereto the results of the tens part of the computation which will be directed to the accumulator switch 19 through the selector switch 17.

In the part of the mechanism which computes the tens part of the product of the digits of the multiplicand by the digits of the multiplier, it will be noted that the horizontal line associated with the digit 1 is not connected in circuit with any part of the multiplying commutator 15 since there will be no tens part of the product of any digits times one. The horizontal lines of the multiplicand bank 12 associated with the digits 2, 3, 4, 5, 6, 7, 8, and 9, are connected through conductors 250 to the lower left hand brushes of the sets 20 of contact disks 21 associated with the digits 2, 3, 4, 5, 6, 7, and 9, and the vertical lines associated with the units (U), tens (T), hundreds (H), ten-hundreds (TH), and ten-

thousands (TT), denominational digits of the bank 12 are connected through conductors 251, 252, 253, 254, and 255 to holding relays 259, 260, 261, 262, and 263, respectively, in the same manner that the conductors 39 and 41 connect the vertical lines of the multiplicand bank 11 to the holding relays 42 associated therewith and the conductors 251 to 255 are connected to the movable contacts of a relay 267, the purpose of which is the same as the relay 46 in that portion of the mechanism assigned to the units part of the products. The brushes 82 to 86 in the distributor switch 17 complete connections through their associated banks 95 to 99 in the same manner as do the brushes 76 to 80, described hereinbefore in connection with the units part of the problem and will actuate electromagnets 268, 269, 270, 271, 272, 273, and 274 for controlling the operation of brushes 278, 279, 280, 281, 282, 283, and 284, in the accumulator 19 for registering the tens (T) to ten-millions (TM) denominations in the tens part of the products. The brushes 278 to 284 have contact disks 288 associated therewith, similar to the contact disks 173, and which perform the same function in the tens part of the problem that the disks 173 perform in the units part, and auxiliary contacts 289, similar to the auxiliary contacts 191. Carry relays 290 and 291 similar to the carry relays 193 and 213, cooperating with the electromagnets 268 to 274 and the contact disks 288 effect a carry and/or a multiple carry where necessary in the tens part of the partial products. Since the circuit connections effected in computing the tens part of a particular problem are similar to those described hereinbefore in connection with the units part of a problem, the foregoing brief description of the analogy therebetween will, it is believed, obviate the necessity of further describing the circuit connections effected in computing the tens part of a product.

Upon the completion of any particular problem of multiplication up to the point where the accumulator switches 18 and 19 register the units part and the tens part of the product, respectively, a transfer must be effected from the accumulator switch 19 to the accumulator switch 18. The brush 87 associated with the arcuate bank of contacts 100 at this time will have been stepped into engagement with the fourth contact on the bank 100 and will connect ground at 294 through the fourth contact, conductors 295 and 296, to the lower left hand brush 297 associated with the set 34 of transfer contact disks. The set 34 of transfer contact disks are similar in construction to the other contact disks and have conducting portions thereon which represent the digits 1, 2, 3, 4, 5, 6, 7, 8, and 9, respectively, from left to right (Fig. 4) and are connected through conductors 298, 299, 300, 301, 302, 303, 304, 305, and 306 to the first to ninth contacts on each of the arcuate banks of contacts in the accumulator switch 19, respectively, and will connect ground through brushes 278, 279, 280, 281, 282, 283, and 284 to the contacts of a pair of transfer relays 310 and 311. One end of each of the windings of the relays 310 and 311 is connected to grounded battery at 312 through a common conductor 313 and the other end of each of the winding of these relays is connected through conductors 181 and 180 to the fourth contact on the arcuate bank of contacts 57 forming a part of the distributor switch 16 and since all of the brushes of the distributor switch are advanced from contact to contact in unison and the brush 81 is connected to ground, upon closure of the circuit through brush 136 on contact disk 107 the transfer relays 310 and 311 will be energized to attract their movable contacts completing circuits from the brushes 278 to 284 through conductors 314, 315, 316, 317, 318, 319, and 320, respectively, to one side of the winding of transfer help relays 324, 325, 326, 327, 328, 329, and 330, respectively. The other side of the windings of the transfer help relays are connected through a common conductor 331 to the left hand back contact of transfer relay 310 and through the left hand back contact to grounded battery at 312. The completion of circuits to any of the transfer help relays 324 to 330 will energize them and cause them to attract their armatures to hold them operated since their armatures are connected by a common conductor 332 to ground at 333. Ground at 333 will also be connected through the armatures of the energized relays 324 to 330 to one side of the windings of predetermined ones of the electromagnets 156 to 161 and/or 242, dependent upon which of the relays 324 to 330 are energized and the ground connection to the electromagnets 156 to 161, and 242 will be maintained until relays 310 and 311 are deenergized due to the removal of the ground connection therefrom. Since ground is connected to the transfer relays 310 and 311 through the bank 57 of the distributor switch 16, conductors 179, 141, 135, and 131 and the contact disk 107, the relays 310 and 311 and such of the relays 324 to 330, and electromagnets 156 to 161 and 242 as had been energized will be simultaneously released under control of the contact disk 107.

It should be noted that the differential timed impulses impressed upon the conductors 298 to 306 by the set 34 of transfer contact disks are selected in accordance with the position of the brushes 82 to 86 and will control the transfer of the number registered on the tens accumulating register 19 from that register to the units accumulating register 18.

Just subsequent to the release of the transfer relays 310 and 311 the electromagnet 71 will be energized and released to step the brushes 76 to 87 into engagement with the fifth contact on their associated banks and operate the release relay 127 to stop the operation of the circuits. At this time the accumulator switch 18 will have registered therein the final result of the problem and the permanent record may be made therefrom as pointed out hereinbefore.

After a reading has been taken from the accumulator switch 18 or a record made therefrom, the mechanism may be set to zero or normal by the completion of the following circuits: The zero return key 111 may be operated manually to disconnect ground from its contact 110 and connect it to a contact 340 connected through a conductor 341, (Figs. 1, 4, 3, and 5) to one side of the windings of zero return relays 342, 343, and 344. The other side of the windings of the relays 342, 343, and 344 are connected through a conductor 345 to grounded battery 346 (Fig. 3) and the relays will be energized to attract their movable armatures upon such operation of the zero return key 111. The movable contacts of the zero return relays 342, 343, and 344 are connected to ground at 350, 351 and 352, respectively, and upon actuation will connect ground through conductors 353 to 367 to the upper left hand brush associated with the contact disks 288 and 173 rotatable with the brushes 278 to 284, 165 to 171 and

243, respectively, which indicate the tens (T), hundreds (H), ten-hundreds (TH), ten-thousands (TT), hundred-thousands (HT), millions (M), and ten-millions (TM) denomination representing the tens part of the product and the units (U), tens (T), hundreds (H), ten-hundreds (TH), ten-thousands (TT), hundred-thousands (HT), millions (M), and ten-millions (TM) denominations, representing the units part of the product.

The upper left hand brush associated with the contact disks 288 and 173 makes contact therethrough at all times except when the brushes of the accumulator switches 18 and 19 rest on zero and upon ground being supplied to the upper left hand brush a circuit will be completed through the contact disk or disks to the lower left hand brush associated therewith, the windings of one or more of the electromagnets 155 to 161 inclusive, 242 and 268 to 274, inclusive, the conductor 172 to grounded battery at 175 to thereby rotate the brushes of the accumulator switches to their zero position whereupon the contact disks will break the circuit, leaving the accumulators in their normal position registering zero.

A better understanding of the mechanism will be had by referring to the following description of the operation thereof wherein the connections completed in computing a particular problem will be described briefly. Assume that it is desired to multiply the number 20468 by the number 359, and that the accumulator switches 18 and 19 are in their normal position registering zero. The number 20468 may be set up in the multiplicand banks 11 and 12 by actuating the keys represented by the horizontal lines 2, 4, 6, and 8 in the vertical columns assigned to the ten-thousands (TT), hundreds (H), tens (T), and units (U), as indicated by the circles at the intersection of these lines. It will be noted that no key has been depressed in the vertical column representing the ten-hundreds (TH) denomination of the multiplicand. The purpose of this will become apparent as the description progresses. The number 359 may be set up in the multiplier bank 10 by closing the contacts in the positions indicated by the circles in the hundreds (H), tens (T), and units (U) vertical lines of the multiplier bank 10.

After the problem has been set up on the multiplier bank 10 and multiplicand banks 11 and 12, the start key 60 may be depressed, momentarily completing the circuit to the starting relay 65, causing it to attract its armatures and connect ground 67 through its winding, contact 68, conductors 69 and 70, to the winding of the distributor switch electromagnet 71 and grounded battery at 72, thereby locking the starting relay 65 in its operated position. Upon operation of the relay 65 a circuit will be completed from ground at 109 through the contact 110, conductors 115 and 116, contact 117 of the starting relay 65, conductor 118, to brush 119 and as the contact disk 108 reaches a predetermined point in its rotation (it being constantly rotated with the shaft 25), through the contact disk 108 of the set 33 of control contact disks, conductor 121 to control relay 122 through the left hand winding of the control relay, a conductor 125, normally closed contact 126 of release relay 127 to grounded battery at 128 thereby energizing the control relay 122 and causing it to attract its contacts. Upon attraction of the contacts of the relay 122, its contact 130 will be connected to the conductor 70 and, upon rotation of the commutator shaft 25, will connect ground at 139 through the brush 137, conductors 132, 70, and 69, contact 68 of the starting relay 65 to short circuit the starting relay, thereby releasing it. However, the control relay 122, upon being energized through the operation of the starting relay 65, will be locked in its operated position until released by the operation of the release relay 127, since its left hand front contact 226 is connected to ground and upon actuation of the relay will complete a circuit from ground through contact 226 the right hand winding of the control relay, and the normally closed contact 126 of the release relay 127 to grounded battery at 128.

Simultaneously with the release of the starting relay 65 the brush 137 will connect ground at 139 through the contact disk 107, conductors 132 and 70, the winding of the electromagnet 71 to grounded battery at 72 energizing the electromagnet momentarily and then releasing it to step the brushes 76 to 87 into engagement with the first contact on their associated banks.

Just subsequent to the completion of the movement of the brushes 76 to 87 into engagement with the first contacts on their associated banks, and for substantially the remainder of the rotation of the contact disk 107, the control relay 122 having been locked in its operated position, the control contact disk 107 will connect ground at 139 through the conductor 140, brush 136, conductors 131, 135, 141, windings of the relays 46 and 267 to grounded battery at 142 and at the relay 267 energizing the relays 46 and 267. Ground will also be connected from the conductor 141 through the conductor 179, brush 81, contact 52 of the bank 57, conductor 51 to the closed contact at 9 in the units (U) column of the multiplier bank 10, conductor 59 to the brushes associated with the contact disks in the units part of the multiplying commutator representing the digit 9 times itself and every other digit except 5, and through the conductor 150 associated with the horizontal row representing the digit 9 in the multiplier bank to the winding of the relay 49 representing the multiplier digit 9 through conductor 48 to grounded battery at 47 to energize the relay 49 representing the digit 9 of the multiplier.

The relay 49, upon being energized will attract its contacts which are connected to ground thereby to supply ground to the brushes associated with the contact disks representing the multiplier digit 9 in that portion of the multiplying commutator which controls the tens part of the product and to the brush associated with the contact disk representing the product of multiplier digit 9 times the multiplicand digit 5 in that portion of the multiplying commutator 15 representing the units part of the product. In this manner all of the brushes associated with the contact disks in the multiplying commutator 15 representing the multiplier digit 9 have ground connected thereto, and as commutator shaft 25 rotates, ground will be connected through those brushes to the lower left hand brushes of each set 20 of contact disks 21 at predetermined intervals and in the following order. All contact disks which represent the partial product 9 will make contact first, then the disks which represent 8, etc., at regular intervals to the contact disks which represent the partial product 1 which will make contact last. Ground will, in this order be connected through the conductors 38 and 250, closed contacts in the multiplicand banks 11 and 12 which represent 8 in the units column, 6 in the tens column, 4 in the hundreds

column, and 2 in the ten-thousands column, and simultaneously through the conductors **39** and **251**, **252**, **253**, and **255** through the closed contacts of the relays **46** and **267** to the brushes **76**, **78**, **79**, **80**, **82**, **84**, **85**, and **86** in the distributor switches **16** and **17**. This ground connection is made only momentarily by the conducting portions of the contact disks, but will complete circuit connections to the windings of the holding relays **42**, **259**, **260**, **261**, and **263**, and since the other side of the windings of the holding relays are connected to grounded battery, they will be locked in their operated position until their connection to ground is broken through the operation of the control contact disk **107**. Simultaneously with the release of the holding relays, the relays **46**, **49** and **267** will be released since they also receive their ground from the control contact disk **107** through the brush **137**. While locked in their operated position, the holding relays will connect ground under the control of the control contact disk **107** through their contacts to the conductors **39**, **251**, **252**, **253**, and **255** to the brushes **76**, **78**, **79**, **80**, **82**, **84**, **85**, and **86**, in the distributor switches **16** and **17**.

In summing up, it will be apparent that since the holding relays are energized one at a time, depending upon the quantitive value of the digit to be sent from the multiplying commutator, through the distributor switches, and since they are all deenergized at the same time, ground will be connected through the brushes **76** to **80**, and **82** to **86**, a length of time dependent upon the value of the digit to be indicated in the accumulator switches. In the particular problem selected for illustration, the holding relays **42** associated with the units (U), tens (T), hundreds (H), and ten-thousands (TT) lines in the bank **11**, will be energized for lengths of time sufficient to transmit 2, 4, 6, and 8 to the accumulator banks of contacts representing units (U), tens (T), hundreds (H), and ten-thousands (TT) in the accumulator switch **18**, and the holding relays **259**, **260**, **261**, and **263** will connect ground through the brushes **86**, **85**, **84**, and **82**, respectively, for lengths of time sufficient to transmit 7, 5, 3, and 1, to the tens (T), hundreds (H), ten-hundreds (TH), and hundred-thousands (HT) banks of the accumulator switch **19**. This is accomplished by the brushes **80**, **79**, **78**, and **76** connecting ground to one side of the windings of the electromagnets **155**, **156**, **157**, and **159**, and the brushes **86**, **85**, **84**, and **82**, connecting ground to one side of the windings of the electromagnets **268**, **269**, **270**, and **272**, the other side of which windings are connected through the conductor **172** to grounded battery at **175**. In response to the circuit connection so completed the brushes **165**, **166**, **167**, **169**, **278**, **279**, **280**, and **282** will be connected to the constantly rotating shaft **172** for a length of time sufficient to advance them into engagement with their second, fourth, sixth, eighths, seventh, fifth, third, and first contacts respectively.

In each revolution of the multiplying commutator subsequent to the time when any of the accumulator switches **18** or **19** have completed their registering operation, the following circuit connections are completed: Ground will be connected to the control contact disk **205**, brush **230**, conductors **229**, and **228**, windings of carry control relays **213** and **291**, conductors **230** and **231**, contact **227** of control relay **122**, conductor **125**, contact **126** of release relay **127** to grounded battery to energize the carry control relays **213** and **291**. However, since at this time there were no carries necessary, the energization of the carry control relays is of no import.

Shortly after the release of the holding relays under control of the control contact disk **107** through its left hand brush **136**, ground will be connected momentarily through the control contact disk **107**, right hand brush **137**, conductors **132** and **70** through the winding of the electromagnet **71** to grounded battery at **72**, thereby to energize and release the electromagnet **71** to step the brushes **76** to **87** into engagement with the second contact on their associated arcuate banks of contacts. At this time the accumulator switches **18** and **19** have registered therein the units and tens parts, respectively, of the product of 20468×9, and a reading thereof would be as follows:

Accumulator switch 18								Accumulator switch 19						
TM	M	HT	TT	TH	H	T	U	TM	M	HT	TT	TH	H	T
0	0	0	8	0	6	4	2	0	0	1	0	3	5	7

The brush **81** of the distributor switch **16**, upon engaging its second contact **55**, will connect ground at **139** through the control contact disk **107**, brush **136**, conductors **131** and **135**, conductor **141** to again energize the relays **46** and **267**, through the conductor **179**, brush **81**, contact **55**, the conductor **51** associated with the vertical line representing the tens (T) denominational column of the multiplier bank **10** through the closed contact **5** to the relays **49** associated with the digit 5 of the multiplier, through the windings of the relays to grounded battery at **47**, thereby energizing the relays **49** associated with the digit 5 of the multiplier to connect ground through the multiplying commutator and at predetermined intervals through the conductors **38** and **250** to the closed contacts in the multiplicand banks **11** and **12**, the conductors **39** and **251** to **255** to the contacts of the relays **46** and **267**. The relays **46** and **267** having been energized, ground will be connected through their contacts to the brushes **82** to **86** at predetermined intervals primarily under control of the contact disks **21** associated with the multiplier digit 5 and maintained thereon through the holding relays **259** to **263** which were also energized under control of the same contact disks **21** in the multiplying commutator **15** and locked in operated position under control of the control contact disk **107**. The completion of these circuits will connect ground through the second contacts on the arcuate banks of contacts in the distributor switch **17** to the electromagnets **269**, **270**, **271**, and **273**, respectively, for a length of time sufficient to move the brushes **279**, **280**, **281** and **283**, a distance sufficient to add 4, 3, 2, and 1 thereto, respectively. It will be noted at this time that no circuits were completed in the units part of the problem for advancing the brushes of the accumulator switch **18**. This condition is due to the fact that in the particular problem selected, namely 20468×359 the units part of the partial product of 5×20468 is 0,0,0,0,0, and since

the brushes of the accumulator switch 18 need not be advanced, the circuit connections necessary for their advancement are not completed.

The brushes 279, 280, 281, and 283 having been advanced 4, 3, 2, and 1 contacts, respectively, and the relays 46, 49, 259 to 263 and 267 having been de-energized, a reading of the accumulator switches 18 and 19 at this time would disclose the fact that the brush 165 is on the second contact, brush 166 on the fourth contact, brush 167 on the sixth contact, brush 168 on the start or zero contact, brush 169 on the eighth contact, brushes 170, 171 and 243 on the zero contact, brush 278 is on the seventh contact, brush 279 is on the ninth contact, brush 280 is on the sixth contact, brush 281 is on the second contact, brushes 282 and 283 are on the first contacts and brush 284 is on the zero contact of their respective banks. At this time the electromagnet 71 is energized momentarily as described hereinbefore to step the brushes of the distributor switches 16 and 17 into engagement with the third contacts on their respective banks of contacts.

As described hereinbefore in connection with the multiplication of 20468 by the digit 9, a carry circuit is energized early in the cycle of operation of the multiplying commutator; however, the carry is again of no import, since none of the brushes in the accumulator switches have passed from the position where they indicate 9 to a position where they would indicate zero. Just after the electromagnet 71 operates to advance the brushes of the distributor switches 16 and 17 into engagement with the third contacts of their associated banks the relays 46 and 267 will be energized.

On engaging its third contact, the brush 81 will connect ground through the contact 56, conductor 51 associated with the vertical line representing the hundreds denomination in the multiplier bank 10, the conductor 50 associated with the digit 3 horizontal line of the multiplier bank 10, to the relay 49 associated with the digit 3 of the multiplier, through the winding of this relay 49 to grounded battery at 47, thereby to energize the relay 49 associated with the digit 3 of the multiplier and connect ground through its contacts to the brushes associated with the contact disks 21 of the sets 20 in the multiplying commutator which represent the product of any digits by 3. At predetermined times in the cycle of rotation of the multiplying commutator, the contact disks 21 will connect ground through the lower left hand brushes of each set 20, conductors 38 and 250 to the horizontal lines representing the digits 2, 4, 6, and 8 in the multiplicand banks 11 and 12 though the closed contacts indicated by the circles, conductors 39, 251, 252, 253, and 255 to the holding relays 42 and 259, 260, 261, and 263 and through the contacts of the relays 46 and 267 to the brushes 82, 84, 85, 86, 76, 78, 79, and 80. Ground, will thus be connected under control of the control contact disk 107 through the brushes 82, 84, 85, 86, 76, 78, 79, and 80, to the electromagnets 272, 271, 270, 161, 159, 158, and 157 to advance the brushes 282, 281, 280, 171, 169, 168, and 167, 1, 1, 2, 6, 2, 8, and 4 contacts, respectively. At this time the brushes 278, 279, 280, 282, and 283 will be resting upon their seventh, ninth, eighth, third, second, and first contacts respectively, and the brushes 165, 166, 167, 168, 169, 170, and 171 will be resting on their second, fourth, zero, eighth, zero, first, and sixth contacts, respectively. Simultaneously with the release of the electromagnets 157, 158, etc., the control contact disk 107 will also release the relays 46, 49, and 267.

The brushes 167 and 169, it will be noted, have passed from the position where they indicate 9 in the position where they indicate zero, and therefore a carry of 1 to the next higher denomination must be effected. As pointed out hereinbefore, the carry relays 213 and 291 are actuated early in the cycle of rotation of the multiplying commutator 15, thereby attracting the movable contacts and conditioning the carry circuits as described hereinbefore for actuation. Brushes 167 and 169 in passing over the auxiliary contacts 191 connect ground under control of the control contact disk 107 and brush 137 through the conductors 192 to the relays 193 associated with the brushes 167 and 169. The other end of the winding of the relays 193 are connected to grounded battery at 194 and upon actuation of the relays 193 associated with the brushes 167 and 169 they will remain locked in their operated position since their right hand contacts are connected through the conductors 201 and 202 and the contact disk 205 to grounded battery at 139 for practically the entire cycle of rotation of the multiplying commutator. In attracting their left hand contacts, the relays 193 associated with brushes 167 and 169 will connect the conductors 208 and 210 through the conductor 206 and 204 to the upper right hand brush of the control contact disk 205 which once in each cycle of the multiplying commutator and just prior to the release of the relays 213 and 291 will connect ground to the conducting portion thereof to the conductors 204, 206, 208, 210, the contacts of the energized relay 213, conductors 233 and 235 to the winding of the electromagnets 158 and 160. The other side of the winding of the electromagnets 158 and 160 being connected to ground at 175 they will be energized under control of the control contact disk 205 long enough to advance their associated brushes 168 and 170 into engagement with the next contact on the contact banks with which they are associated, so that with the accumulator switches 18 and 19 at this point will register as indicated below:

Accumulator switch 18							Accumulator switch 19					
M	HT	TT	TH	H	T	U	M	HT	TT	TH	H	T
6	1	0	9	0	4	2	1	2	3	8	9	7

As soon as the accumulator switches register the above amounts, connection between the brush 238 and the control contact disk 205 will be broken to release the carry holding relays 213 and 291.

Immediately after the connection of the ground which actuates the carry relays 193 has performed its function, the control contact disk 107 will again connect ground to the electromagnet 71 to step the brushes of the distributor switches 16 and 17 into engagement with the fourth contact on their associated banks and in so doing ground will be connected through the brush 136 associated with the control contact disk 107, conductors 135 and 178, the fourth contact on the bank 57, conductors 180 and 181, to the transfer relays 310 and 311, energizing them thereby to connect the brushes 278, 279, 280, 281, 282, 283, and 284 of accumulator switch 19 through their associated contacts to the conductors 314, 315, 316, 317, 318, 319, and 320, connected to the transfer help relays 324 to 330, re-

spectively. The brush 87 of the distributor switch 17, in engaging its fourth contact, will connect ground at 294 through the conductors 295 and 296 to brush 297 associated with the set 34 of contact disks and one at a time through the conductors 298 to 306 connected to the contacts on the arcuate banks of contacts associated with the brushes 278 to 284. As the multiplying commutator rotates through its cycle, ground will be connected through the brushes 279, 280, 278, 281, 282, and 283, successively, the interval between the time at which the ground connection is made through the brush 278 and 281, being equal to the time difference between 7 and 3, the numbers which these brushes indicate as being registered in the accumulator switch 19. The transfer contact disks of the set 34 are so formed that in each cycle of the multiplying commutator the brushes from right to left (Fig. 4) make contact momentarily and successively to connect ground through their associated conductors to the contacts of the accumulator switch 19. It will thus be apparent that assuming that the cycle of operation of the set 34 transfer contact disks is divided into nine units, in the first unit ground will be connected through the conductor 306, brush 279 engaging the ninth contact on the hundred bank of the accumulator switch 19, contacts of the transfer relay 311, conductor 315, winding of transfer help relay 325, conductor 331, left hand back contact of the transfer relay 310 to grounded battery 312 thereby energizing the electromagnet 157 and the transfer help relay 325 which will lock in its operated position upon attracting its contact to connect ground therethrough and through the conductor 147 to the electromagnet 157. As the next contacting portion of the set 34 of contact disks (equivalent to 8) engages the second brush from the right (Fig. 4), ground will in the same manner be supplied to the electromagnet 158, in the third unit of the cycle of rotation of the multiplying commutator ground will be connected to electromagnet 156, in the seventh unit the electromagnet 159, in the eighth unit of the electromagnet 160, and in the ninth unit the electromagnet 161 will have ground supplied thereto and will thereby be energized. All of the electromagnets 156 to 161 and 242 which are energized as described hereinbefore, will continue to connect ground at 333 through the conductor 332, contacts of their associated transfer help relays until the ground connection to the transfer relays 310 and 311 is broken at brush 136 associated with the control contact disk 107. This break occurs as soon as the transfer has been completed and at this time the accumulator switch 18 will have the final product 7348012 registered therein since the product 123897 in the millions to tens registers of the accumulator switch 19 has been transferred thereto, and carries have been effected where necessary in the same manner as they were effected in computing the units part of the problem.

The problem having been completed, the position of the brushes 165 to 171 and 243 upon their associated banks of contacts indicates the final result. This record may be taken visually or since the brushes are connected to ground through the conductors 177 and 176, a permanent record may be made by completing circuits not shown through the cables 176 in any well known manner, whereupon the zero return key 111 may be actuated to connect ground through the conductors 340, 341 to the zero return relays 342, 343, and 344, the other sides of the windings of which are connected through the conductor 345 to grounded battery at 346, thereby to energize the relays and connect ground through their contacts to the conductors 353 to 367 and through the conducting portions of the contact disks 173 and 288 to one side of the winding of the electromagnets 268 to 274, 155 to 161 and 242, causing the brushes 278 to 284, 165 to 171, and 243 to rotate to the position where they indicate zero, at which time the contact disks 173 and 288 will break the circuit, de-energizing the relays and leaving the accumulator switch brushes in their zero or normal position.

Although a particular and specific description has been given of an electrical multiplication system for multiplying five digits by three digits, it is to be understood that the invention is to be limited only by the scope of the appended claims and that by adding similar apparatus and connecting it in the same manner as described hereinbefore, problems of any length might be expeditiously computed.

What is claimed is:

1. In a computing system, electrical circuits, factor storing means comprising circuit connections settable to represent a multiplicand and a multi-digit multiplier, rotatable multiplying means for multiplying all digits of the multiplicand by one digit of the multiplier in each cycle of rotation, an accumulator for registering the tens part of each product so effected, an accumulator for registering the units part of each product so effected, and means operable just subsequent to the multiplication of the digits in the multiplicand by the last digit in the multiplier for transferring the tens part of the product from the tens accumulator to the units accumulator.

2. In an electrical computing system, means for setting up multi-digit factors before the start of a computing operation, a multiplying means including elements representing the units part of computations of a plurality of digits and elements representing the tens part of the computations of the same digits, a plurality of accumulators sequentially operable means for completing electrical circuits through the setting up means and the multiplying means to transmit electrical impulses representing the result of the units part and the tens part of the computations to separate accumulators and means controlled by the sequentially operable means for establishing circuit connections and for automatically transferring results from one accumulator to another.

3. In a computing system, means for storing multi-digit factors of a mathematical problem, computing means having multiplication table characteristics and controlled by the factor storing means, means for accumulating the units part of the result of a computation under control of said computing means, means for accumulating the tens part of the result under control of said computing means, and means for transferring the partial result from one of the accumulating means to the other accumulating means to obtain the true result.

4. In a computing system, electrically controlled accumulators, means for storing a multi-digit multiplier and a multi-digit multiplicand of a problem, total transfer circuits intermediate said accumulators, means controlled by the storing means for establishing contacts representing subproducts, and sequential control means for establishing electrical circuits for introducing the

units subproducts into one accumulator and the tens subproducts into another accumulator and for subsequently completing said total transfer circuits to combine the subproducts in one of the accumulators to obtain the complete result.

5. In an electrical computing system, means for storing a multi-digit multiplicand and a multi-digit multiplier, multiplying means associated with the setting up means, a left-hand component accumulator, a right-hand component accumulator, distributing means for establishing electrical circuit connections from the multiplying means to the accumulators to effect their operation, means for successively advancing the distributing means after the completion of the multiplication of each digit of the multiplier and all the digits of the multiplicand, transfer relays, means actuated with the distributing means for actuating the transfer relays, and means operable after the completion of the multiplication of all of the digits of the multiplier by all of the digits of the multiplicand and after the operation of the transfer relays for transferring a total from one accumulator to the other.

6. A multiplying machine with a cyclically operated circuit establishing device which in one cycle of operation closes contacts representing the digits of all right-hand and left-hand components of partial products of the multiplication tables for the digits 1 to 9 inclusive, multi-denominational factor storing means for each factor for controlling said device, circuits for transmitting differentially timed multi-denominational product representing impulses under the conjoint control of said storing means and the cyclically operated device, said impulses representing said products by their relative timing, and two accumulators for receiving said right and left-hand components of partial products respectively.

7. A calculating machine for performing multiplication including a plurality of partial product accumulating means, an impulse emitter which is cyclically operated in synchronism with the plural accumulating means to make one complete rotative cycle for one entering cycle of the said accumulating means, said emitter having a plurality of spots thereon to represent the digits of the notation employed in the computation, factor entry means for both factors of the computation including contacts which are closed to store the digits of both factors to be computed, means under the control of one of the factor entry means for coordinating the emission of differentially timed impulses from the emitter to represent all partial products involving the first entered factor, means under the control of the other factor entry means for providing a multi-denominational selection of the differentially timed impulses representative of the particular partial products involving the other factor which is of multi-denominational form.

8. In a multiplying machine in which an emitter and a factor storing means for storing a multi-digit factor conjointly cause and control the impression upon two sets of lines of differentially timed impulses representative of all of the possible partial products of all of the digits of the notation times a digit of the entered factor, one set of lines for impulses representative of right-hand components of partial products and the other set of lines for impulses representative of left-hand components, accumulating means, and multi-denominational factor entry impulse selecting means cooperating with both of the sets of lines to select out therefrom and denominationally allocate impulses representative of the right and left hand components of the partial products of the second factor times the first factor, and other partial product impulse lines extending directly from the last mentioned multi-denominational selecting means to the accumulating means.

9. In a calculating machine having an emitter including contacts representative of the partial products of the multiplication tables for all digits for emitting impulses which are differentially timed so that by their individual timing they are individually representative of the digits of a notation, a plurality of digit lines leading therefrom, each of which receives an impulse pertaining to one digits only, means for storing a multi-digit factor, a double set of selectors including contacts for storing another multi-digit factor, one set for right-hand components and the other set for left-hand components, said digit lines being associated with each set of selectors, and selectively operable electromagnetic coordinating switching means controlled by said first storing means for rendering effective the emitter to send impulses over the digit lines as controlled by the second means for storing a multi-digit factor.

10. A multiplying machine including in combination, plural product receiving devices multi-digit multiplier entry receiving means with an associated read out means, means including multiplier control multi-contact relays selectively called into action under the control of the aforesaid read out means, dual multiplicand entry receiving devices to control the transmission of impulses representative of left-hand and right-hand components of partial products, an impulse emitter having a potential capability of emitting differentially timed impulses, representative of partial products lines leading from contacts of the multiplier relays to the dual multiplicand receiving devices through the emitter, product receiving means for receiving impulses transmitted from the emitter over said lines, and multi-contact column shift electrical means intermediate the dual multiplicand receiving means and the product receiving means and controlled for column shifting by the read out means of the multiplier entry receiving means.

11. In a computing system, a plurality of accumulators for accumulating results of computations, normally open electrical circuits interconnecting the accumulators for total transfer operations, a plurality of electrical transfer relays, electrical contacting means for operating the transfer relays to close the electrical circuits and emitter means for transmitting impulses over said electrical circuits to transfer a result from one accumulator to another accumulator.

12. In a computing system, computing means, a plurality of accumulators controlled by the computing means for indicating results, means for transferring results from one accumulator to another accumulator including a normally ineffective continuously movable control commutator, and sequence means for enabling said continuously movable control commutator upon completion of entries into said accumulators to cause a transfer by said transfer means.

13. In a computing system, means for storing multi-digit factors, a multiplying means having a commutator controlled by the storing means for multiplying the stored factors in a continuous operation, a plurality of subproduct accumulators

controlled by the multiplying means for accumulating subproducts, a denominational distributor mechanism for controlling the entry of the digits of said subproducts into proper denominational orders of the accumulators, electrical contact making means operated with the multiplying means and the distributor mechanism for establishing electrical circuits to transfer at the end of a computation the subproducts from one accumulator to another accumulator to obtain a final result.

14. In a computing system, a plurality of accumulators for accumulating components of products, a multiplying commutator for controlling the accumulators, means for storing two multi-digit factors and for controlling the multiplying commutator in accordance with the entered factors, means for transferring a component of the product from one accumulator to another, and sequence control means for causing operation of said transferring means after said product components are accumulated.

15. In a computing system, electrical circuits, means for making circuit connections to set up a multiplicand and a multi-digit multiplier, continuously rotating multiplying means for multiplying all digits of the multiplicand by a successive digit of the multiplier in each cycle of rotation, an accumulator for registering the tens part of each product under control of said multiplying means, an accumulator for registering the units part of each product under control of said multiplying means, and means effective upon completion of partial product registration for transferring the partial products from one accumulator to the other accumulator to obtain the final product.

16. In a computing system, a plurality of accumulators for accumulating results, normally open electrical circuits interconnecting the accumulators, a plurality of transfer relays, a plurality of transfer help relays, control timing means for operating the transfer relays for partially completing said circuits, and an emitter for energizing the transfer help relays to complete said electrical circuits to transfer a result from one accumulator to another accumulator.

17. In an electrical computing system, accumulators, means for actuating the accumulators, a cyclically operable multiplying device having a plurality of rotatable contact elements representing multiplication tables, means for pre-setting a multi-digit multiplicand and a multi-digit multiplier to establish circuits through the multiplying device in successive cycles thereof to control the actuating means for the accumulators, and means comprising devices operable with said multiplying device for establishing circuit connections to automatically transfer information from one accumulator to another.

18. A multi-denominational multiplying device comprising circuit controllers for storing a multi-digit multiplier, circuit controllers for storing a multi-digit multiplicand, a plurality of digital multiplier relays controlled by said first circuit controllers, a cyclically timed impulse emitter cooperating with both of the aforesaid controllers and with the plurality of relays so as to emit in one cycle thereof a plurality of differentially timed impulses which are representative of the products of a single digit of the multiplier and a multi-digit multiplicand, said circuit controllers and cyclically timed impulse emitter operating upon another cycle of operation of the cyclically timed impulse emitter for computation which involves said multi-digit multiplicand and another single digit of the multiplier, a plurality of accumulators controlled by said timed impulses for indicating partial results, and means for transferring the partial results from one accumulator to another accumulator to indicate the final result.

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