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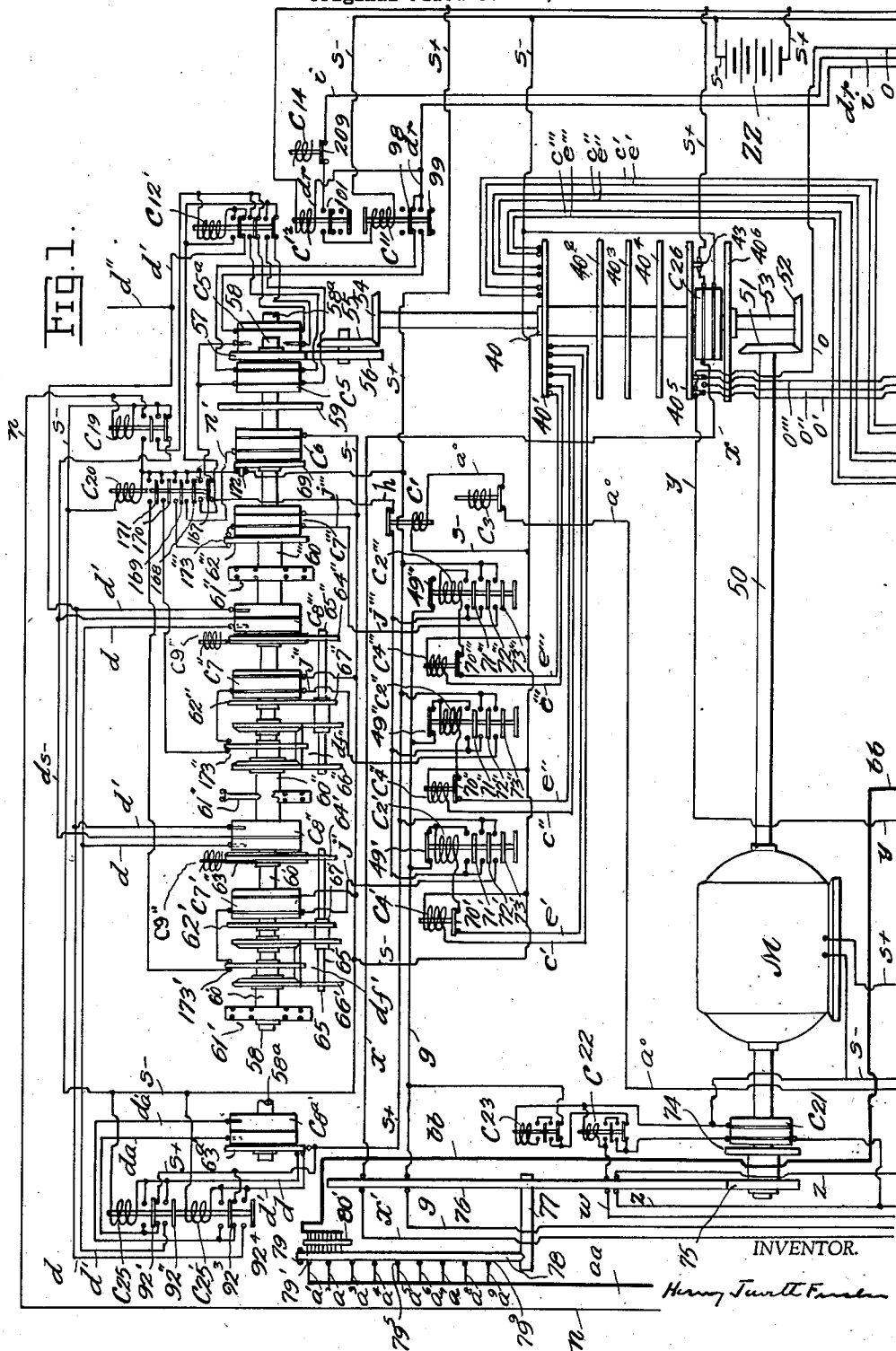
H. J. FURBER

2,236,795

MULTIPLYING MECHANISM

Original Filed Oct. 9, 1935

4 Sheets-Sheet 1



April 1, 1941.

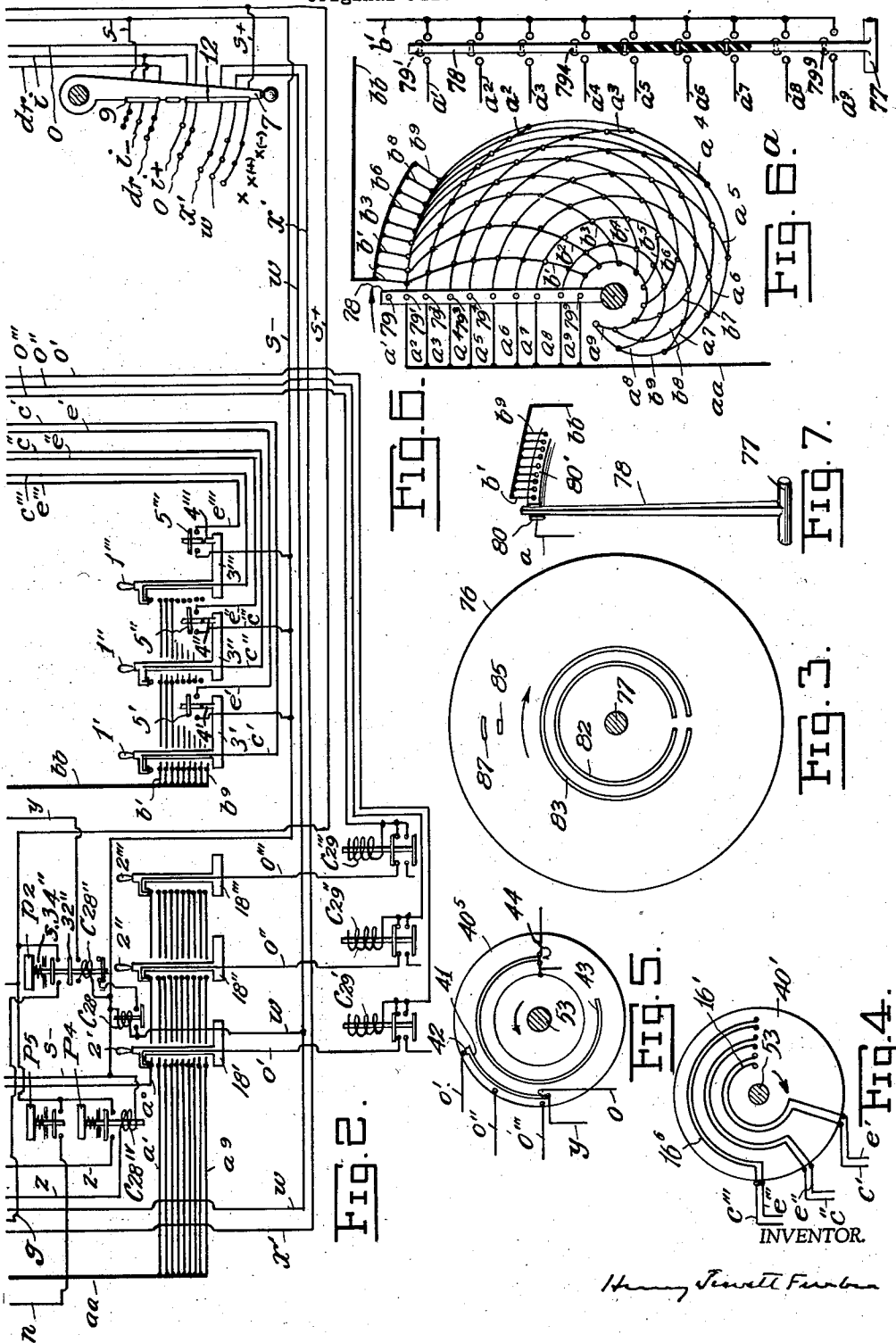
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MULTIPLYING MECHANISM

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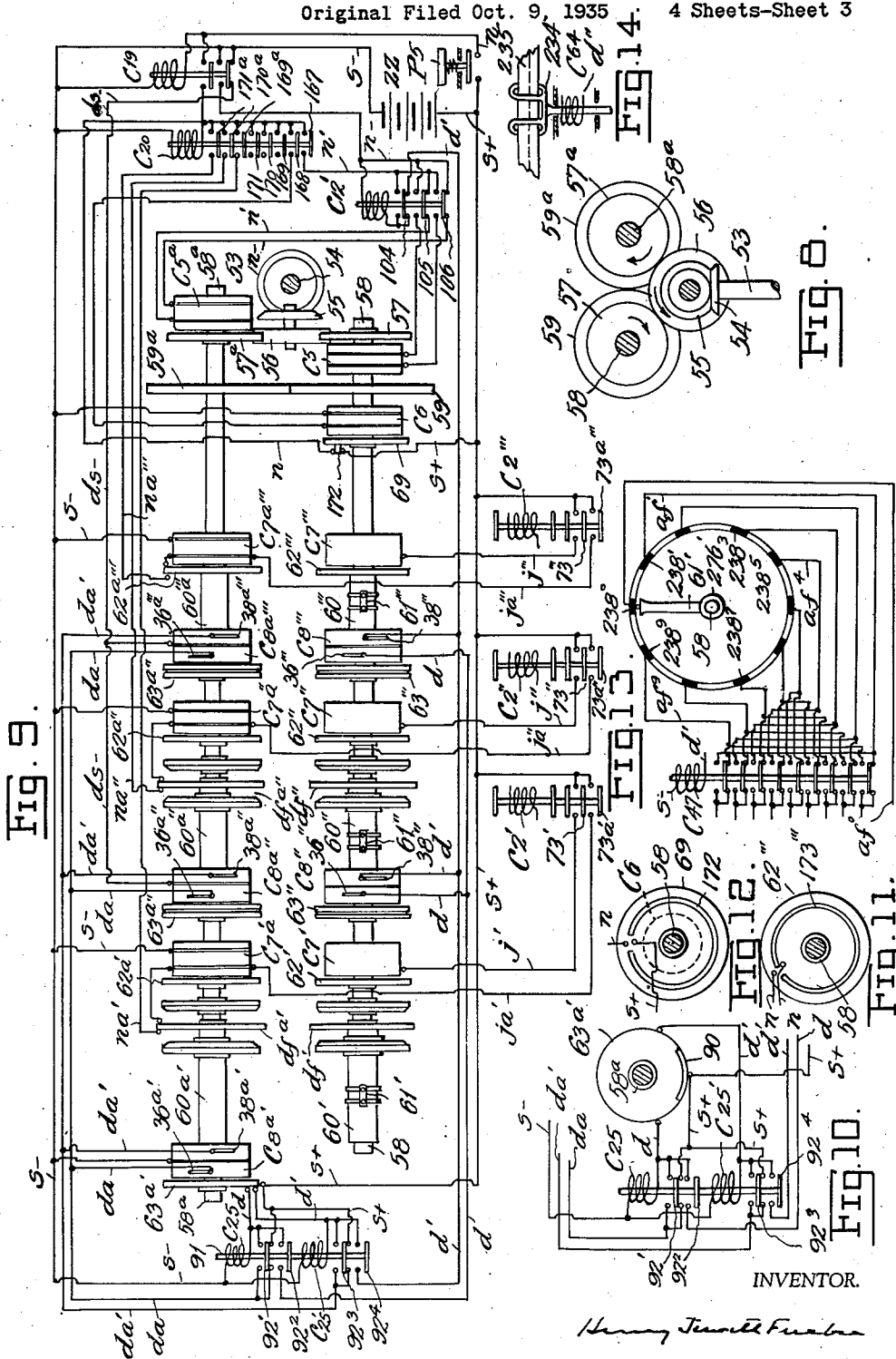
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INVENTOR.

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• April 1, 1941.

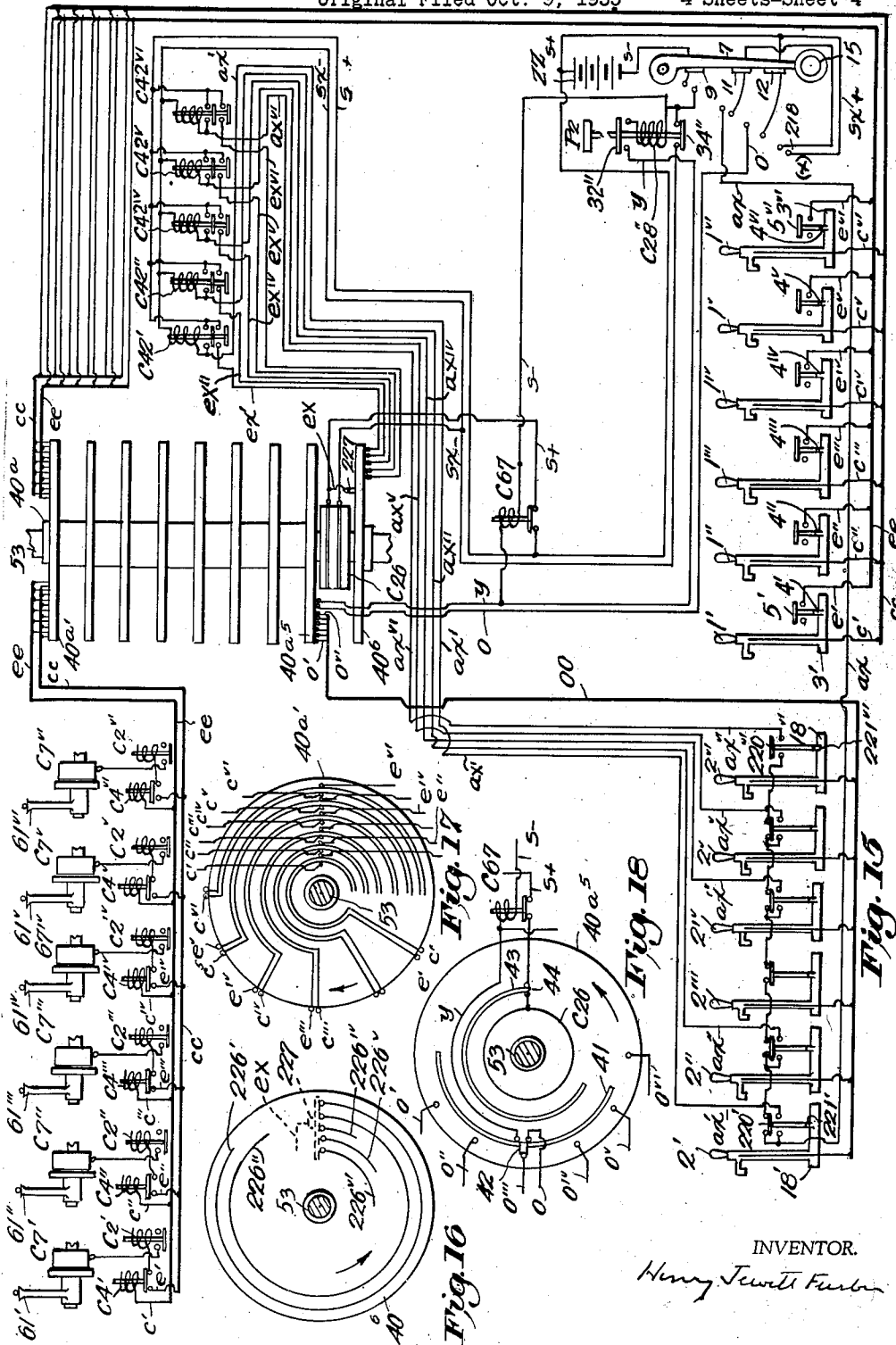
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UNITED STATES PATENT OFFICE

2,236,795

MULTIPLYING MECHANISM

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Original application October 9, 1935, Serial No. 44,159. Divided and this application July 15, 1937, Serial No. 153,843

7 Claims. (Cl. 235-61)

This invention relates to improvements in multiplying mechanism; and the present application is a division of my copending application Serial No. 44,159, filed October 9, 1935, which is a continuation, in part, of application Serial No. 723,595, filed May 2, 1934.

An object of this invention is to provide means for developing a product, whether positive or negative, and automatically to identify the quality of the product so developed.

Another object of this invention is to provide means for multiplying quantities whether whole numbers or decimal fractions and to provide means for initial upward or downward column shift accordingly as the first significant digit of the multiplier be denominationally higher or lower than the units order.

Another object of this invention is to provide improved means for arresting the operation of the accumulator arms at appropriate steps when accumulating products. This is accomplished by timing mechanism comprising a rotary contact member which closes selected circuits corresponding to the factors, at arcs of displacement mathematically proportionate to multiples component in resultant, novelty lying in the geometrical distribution of the contacts at which circuits be so closed.

The numbering and lettering of my copending application Serial No. 44,159, except the serial numbers of the figures, are preserved herein. Sufficient of the mechanism therein disclosed, is reproduced in the present application, to illustrate the operation of multiplication, although not necessarily confined thereto.

With foregoing and other objects in view, as may appear, the invention now will be described in connection with the accompanying figures, in which details superfluous to multiplication are, with view to clearness, in so far as possible suppressed.

Figure 1 is a general diagrammatic view of the calculating unit adapted to multiplication.

Figure 2 is a diagrammatic view of the manual controls at which the factors are established, and state-control means which selectively conditions the calculating unit for positive or negative computation, according to the similarity or dissimilarity in the quality of factors.

Figure 3 is a diagrammatic view from the right of the disk 76 shown in Figure 1, with various electric conductors which pass from face to face.

Figure 4 is a diagrammatic view of the disk 40' at the transmitter 40 shown in Figure 1.

Figure 5 is a view of the lower face of the disk 40^s at the transmitter 40.

Figure 6 is a diagrammatic view from the right of a timing arm 78 shown in Figure 1, with terminals corresponding to multiples, at which circuits may be closed.

Figure 6a is a diagrammatic view of the timing arm 78, as shown in Figure 1, with surface partially broken away, illustrating the relative positions of electric terminals coactive with conductors carried by said arm.

Figure 7 is a perspective view from the right, showing the pathway of the arm 78 in closing circuits between typical complementary contacts.

Figure 8 is a diagrammatic view from the right, of members shown in Figure 1, which transmit motion from shaft 53 to the shafts 58 and 58a.

Figure 9 is a diagrammatic plan view of the shafts 58, 58a, shown in Figure 8 with members and electrical connections appertinent thereto.

Figure 10 is a detail view from the left of the armature 63a' shown in Figure 9, with electrical connections.

Figure 11 is a side view from the left of the typical armature 62''' shown in Figure 1, operative in restoring an accumulator arm to zero position.

Figure 12 is a diagrammatic view from the left of the armature 69 shown in Figures 1 and 9 operative in clearing calculating unit.

Figure 13 is a diagrammatic view of a typical accumulator arm 61' with contacts which close numeral circuits to recording apparatus.

Figure 14 is a detail view of inking ribbon for identifying positive and negative resultants by different colors, with solenoid to shift position.

Figure 15 is a view of mechanism for effecting column-shift.

Figure 16 is a view of the lower face of disk 40^s adapted to six denominational accumulator orders for controlling the amplitude of column-shift.

Figure 17 is a plan view of a typical disk 40a' adapted to six denominational accumulator orders for relaying, in column-shift, actuating circuits and immobilizing circuits.

Figure 18 is a view of the lower face of the disk 40^s with circuits selectively to close circuits to receiving numbers denominationally corresponding to six orders.

All wheels disclosed in the above figures are toothed throughout, there being no mutilated gearings. The wires leading from the positive and negative poles of the source ZZ are designat-

ed respectively as wires s^+ and s^- . Cables carrying a plurality of wires are indicated by heavy lines. The direction of motion or transmission at rotary members, is indicated by arrows.

The term "accumulator" is employed to designate collectively with intervening transfer elements the members $61'$, $61''$, $61'''$ (Figure 1) of the accumulator and members $61'$, $61''$, $61'''$, 61^{iv} , 61^v and 61^vi of Figure 15, said members individually being termed "accumulator arms", as shown in Figures 1, 9, 13, 15, the accumulator arms $61'$, $61'''$ being concealed by contact benches in Figure 1.

General description

In view to simplicity and clearness the demonstrations of multiplication which immediately follow are limited to whole numbers, operations involving fractions being subsequently disclosed in connection with Figures 15, 16, 17 and 18.

The quantities subject to operation, may be transmitted to the calculating unit (Figure 1) by means of electric circuits controlled by manual levers $1'$, $1''$, $1'''$, $2'$, $2''$, $2'''$, or by equivalent devices (Figure 2). A master switch 7 is a state control which determines the nature of the operation which shall be performed. The depression of the push button P.2, (Figure 2) causes motion to be transmitted from an electric motor, M (Figure 1), preferably in constant operation and revolving always in the same direction, to the accumulator arms $61'$, $61''$, $61'''$, which are elements, respectively in progressive denominational orders of the accumulator and correspond to hundreds, tens and units. Motion is likewise communicated to a progressively movable switch or timing arm 78 (Figures 1, 6) which measures the movement of the accumulator arms $61'$, $61''$, $61'''$, and arrests such members at angles of displacement corresponding to quantities selected at the manual controls.

The relays C.11, C.12 (Figure 1), control the direction of motion transmitted to the accumulator arms $61'$, $61''$, $61'''$ from the motor M, consistently with the similarity or dissimilarity in quality of the quantities involved.

The wheel 76 (Figures 1, 3) closes and breaks, through conductors which it carries, circuits established at the master switch 7 (Figure 2) or closed at the push button P.2, in such selective order, as to bring the members thereby affected, into operation in their proper turn.

Said push-button is introduced, in order that the calculating unit be brought into operation, only after all other controls are properly adjusted.

Referring to Figure 1, the motor M connected with the source ZZ through the wires s^+ , s^- , and preferably in constant operation, imparts motion through the shaft 50, wheels 51, 52, shaft 53, wheels 54, 55, 56, armature 57 and the electric clutch C.5 to the shaft 58, on which are mounted the sleeves $60'$, $60''$, $60'''$, carrying respectively the differentially operated accumulator arms $61'$, $61''$, $61'''$.

Motion is selectively transmitted to the sleeves $60'$, $60''$, $60'''$, on which are fixed the accumulator arms $61'$, $61''$, $61'''$ (Figure 1) by electric clutches C.7', C.7'', C.7''' which are fixed to the shaft 58, and operate respectively on the armature 62', 62'', 62'''. The sleeves $60'$, $60''$, $60'''$ are carried by the shaft 58. The armature 62''' is integral with the sleeve $60'''$. The armature 62'' transmits motion to the sleeve $60''$, through the composite idler 67'' floating on the pivot 65'' and thence through the differential gearing 75

d_1'' , the middle member of which is integral with the sleeve $60''$. The armature 62' imparts motion to the sleeve $60'$, in similar manner, through the transmission 67' and the differential gearing d_1' . The differentials d_1' , d_1'' , are introduced, in order that the accumulator arms $61'$, $61''$ may be responsive, each to quantities originating in its own corresponding denominational order, while simultaneously absorbing the carry-over from orders therebelow.

Positioning pins C.9'', C.9''', well known to the art, are indicated in Figure 1, their purpose being to correct overdraft, and to block a lateral member of a planetary gearing when the other lateral member be alone in operation. Such positioning pins may be employed where needed.

The orbits of the accumulator arms $61'$, $61''$, $61'''$ are each divided into ten unitary steps of 36° corresponding to the numerals 0-9, (Figure 13).

Fixed on the motor shaft 50 is the electric clutch C.21, which, when energized, transmits motion through the armature 74 floating in solidarity with the pinion 75 (Figure 1) on the motor shaft 50, to the wheel 76, fixed on the shaft 77 together with the timing arm 78. The timing arm 78 synchronizes in movement with the accumulator arms $61'$, $61''$, $61'''$, moving, for example, through an arc of 3.6° , while an accumulator arm $61'$, $61''$, $61'''$ moves through an arc of 36° . It is the function of the timing arm 78 to close circuits, as it advances, which selectively arrest the accumulator arms $61'$, $61''$, $61'''$, at angles of displacement corresponding to the quantities established at the manual controls shown in Figure 2 as will hereinafter be described.

The manual control includes a series of levers, $1'$, $1''$, $1'''$, (Figure 2) at which to enter the multiplicand and corresponding respectively to the descending orders, hundreds, tens and units, of the accumulator. At the levers $2'$, $2''$, $2'''$, operative only in multiplication, the numerals of the multiplier may be established. Further controls comprise the master-switch 7 (Figure 2), the position of which regulates the electric circuits variously active in different operations.

Fixed together with the levers $1'$, $1''$, $1'''$, respectively, (Figure 2) on the axles $3'$, $3''$, $3'''$, are the cams $4'$, $4''$, $4'''$, which in normal position support the bridges $5'$, $5''$, $5'''$. Deflection of the levers $1'$, $1''$, $1'''$ displaces the cams $4'$, $4''$, $4'''$, releasing, respectively the bridges $5'$, $5''$, $5'''$, which, falling through gravity, respectively close circuits over the wires e' , e'' , e''' , (Figures 2 and 1) to the electric relays C.2', C.2'', C.2'''. These circuits parallel each the others, the relays C.2', C.2'', C.2''' provoking, respectively, movement of the accumulator arms $61'$, $61''$, $61'''$, by motor M, as presently described.

The circuit closed at the bridge $5'''$ (Figure 2) for example, when the lever $1'''$ is deflected, originates at the source ZZ and passes through the wire s^- , the bridge $5'''$, the wire e''' over the conductor 16⁶ at the disk 40' (Figures 1, 4), presently described, and over the bridge 70''' at the relay C.4''' (Figure 1) to the negative pole of the relay C.2'''. Circuit to the positive pole of the relay C.2''' is momentarily completed at the bridge 49''' through the wire g, connected with the source ZZ (Figure 1) through the wire s^+ when, as presently described, the push-button P.2, (Figure 2), is depressed. The relay C.2''' (Figure 1) is then held in stick, by circuit extending from its positive pole, over the bridges

71'', 72'', carried by the relay C.2'', and the wire s⁺, back to the source ZZ. From the bridge 72'', so closed at the relay C.2'', circuit through the wire h extends over the bridge 167 at the relay C.20, shown with parts broken away in Figure 1, and in entirety in Figure 9, to the positive poles of the clutches C.5, C.5a, circuit to the negative poles of which may be selectively controlled by the master-switch 7 (Figure 2) or otherwise, as hereinafter described. Circuit is closed, in the accumulation of positive quantities, to the negative pole of the clutch C.5 (Figure 1) which transmits motion in clockwise direction to the accumulator arms 61', 61'', 61'''. During the accumulation of negative quantities, circuit is closed to the negative pole of the clutch C.5a; and the movement of the accumulator arms 61', 61'', 61''' is reversed. The clutch C.5a (Figures 1, 9) is fixed on the shaft 58a. The armature 57a of the clutch C.5a floats on the shaft 58a. The armature 57 of the clutch C.5, floats on the shaft 58. The wheel 56 meshes with the armatures both 57 and 57a (Figure 8). Fixed respectively to the shafts 58, 58a, are the wheels 59, 59a (Figures 8, 9) in mesh one with the other, to the effect that when the clutch C.5 is energized and the shaft 58 is rotated by the motor in clockwise direction, the shaft 58a is rotated in direction opposite thereto; and when the clutch C.5a is energized, and the shaft 58a is rotated in clockwise direction, the shaft 58 is rotated in direction opposite to clockwise. The shaft 58a carries transmission largely similar to that carried by the shaft 58; and is provided with an additional clutch C.8a shown in Figure 9, with broken shaft in Figure 1, which operates as presently described.

When energized, the clutch C.5 (Figures 1, 9) clutches the armature 57 constantly revolving, and receives motion in clockwise direction, which it imparts to the shaft 58, on which are fixed the electric clutches C.7'', C.7', C.7. Retraction of the plunger of the relay C.2'' (Figure 1), for example, as heretofore described, closes, at bridge 73'', a circuit through the wire j''' to the clutch C.7''. This circuit originating at the source ZZ, passes through the wire s⁺ over the bridge 73'' through the wire j''' to the clutch C.7'' and, thence, through the wire s⁻ back to the source ZZ. The clutch C.7'' so energized, clutches and rotates its armature 62'', which is fixed together with the accumulator arm 61'', on the sleeve 60''.

In the same manner and through similar circuits, the relays C.2'', C.2', controlled respectively by the levers 1'', 1', close circuit at the bridges 73'', 73', through the wires j'', j', on the clutches C.7'', C.7' (Figure 1), whose negative poles are connected with the wire s⁻ and which transmit, respectively, motion to the accumulator arms 61'', 61', through the right lateral and middle members of the differential gearings D'', D'. The left lateral members of these last said gearings float respectively on the sleeves 60'', 60', and receive the carry over, as above described, from next lower denominational orders, permitting thereby, the simultaneous operation of all orders of the calculating unit. Transmission from the units order, at shaft 58, to the tens order, is by the clutch C.8'' fixed to sleeve 60'', geared armature 63'', gears 64'', 65'' fixed on shaft 65'', to differential D''; and from tens to hundreds order, the corresponding members, clutch C.8', geared armature 63', gears 64', 65' fixed on shaft 65' and differential D'. The re-

lays C.2'', C.2' close, at bridges 72'', 72', circuit through the wire h to the clutch C.5, in common with the relay C.2'', or in negative multiplication involving reversed motion, to the clutch C.5a.

The accumulator arms 61', 61'', 61''' when set in motion, are severally and respectively arrested at angles of displacement determined conjointly by the levers 1', 1'', 1''', and 2', 2'', 2''' (Figure 2). Extending past all levers 1', 1'', 1''', are the multiplicand wires b'-b⁹, corresponding respectively to the numerals 1 to 9. Extending past all levers 2', 2'', 2''' are the multiplier wires a'-a⁹, corresponding respectively to the numerals 0 to 9. The wires b'-b⁹ are shown as connected with terminals at the bench 80' opposite the arm 78 and as carried in a cable 8b, to the levers 1', 1'', 1'''. According to the angle at which such levers 1', 1'', 1''' be manually deflected, circuits are closed upon selected b wires (Figure 2) whence current flows through the levers 1', 1'', 1''' and the wires c', c'', c''' (Figures 2, 1) respectively, to the relays C.4', C.4'', C.4''', the connections being similar at all the levers 1', 1'', 1'''.

Let lever 1''' (Figure 2), the wire c''' and the relay C.4''' serve as an example. If the quantity corresponding to a multiplicand be 3; the lever 1''' is deflected, so that circuit is thereby closed from the wire b³ to the wire c''' carried by the lever 1''', and thence to the relay C.4'''. It is the function of the relay C.4''' when its circuit be completed at the timing arm 78, through a wire, say for example, the wire a' corresponding to the multiplier 1, and wires b³, c''' to break, at bridge 70'', circuit to the relay C.2'', causing the relay C.2'' to release its plunger. This deenergizes the clutch C.7'', which thereupon releases its armature 62'', interrupting, thereby, transmission of motion to the sleeve 60'' and the accumulator arm 61'', which is arrested at an angle of displacement corresponding in the present example to three units. The accumulator arms 61'', 61' may be similarly and respectively arrested through the action of the relays C.4'', C.4' which break circuit to the clutches C.2'', C.2' at the bridges 70'', 70'.

The moment at which the relays C.4', C.4'', C.4''' shall break, respectively at bridges 70', 70'', 70''' circuit to the relays C.2', C.2'', C.2''' is timed by the timing arm 78 (Figures 1, 6, 6a, 7) which is rotated as above described, on the shaft 77.

The timing arm 78 carries a series of conductors 79, 79'-79⁹ which revolved in concentric arcs progressive distances from its axis by the timing arm, may close circuits between various pairs of terminals fixed, at the sides of its pathway upon benches. The position and the pathway of arm 78, between two typical benches 80, 80' is indicated diagrammatically in Figure 7, a space intervening between complementary fixed terminals as shown in Figure 6a, and the radii of the respective arcs being such as to insure escapement between successive terminals (Figure 6).

As above stated, the multiplicand may be established at the levers 1', 1'', 1''' (Figure 2) which close circuit on the wires b'-b⁹; and the multiplier may be established at the levers 2', 2'', 2''', closing in similar manner, circuit on the wires a'-a⁹, which extend severally past all the levers 2', 2'', 2''', and which are shown as carried in the cable aa to concentric groups of terminals at the arm 78 (Figures 1, 6).

Since, when the multiplier and the multipli-

cand consist of several numerals, each numeral of the multiplicand must be multiplied by each numeral of the multiplier; successive partial operations become necessary. Although multiplication is commonly performed by first multiplying by the right hand numeral of the multiplier and advancing to the left; this order of operation is not compulsory. The same resultant is obtainable by operating in the opposite direction; and the latter order of operation is herein adopted.

At the termination of each partial operation, the transmitter 40 (Figure 1) which is a progressively movable switch, closes at the disk 40⁵ (Figure 5) circuit on the wire corresponding to the numeral in the next lower order of the multiplier; and simultaneously switches at the disk 40¹ (Figure 4) the circuits corresponding to all numerals of the multiplicand to successive lower orders of the accumulator, in order that the partial products may fall in descending columns.

Assume the operation $26 \times 23 = 598$. In later disclosures descriptive of Figure 15, means are provided whereby a multiplicand such as 26 and multiplier 23 may be set up at the levers 1', 1'', 2', 2'' (Figure 2) corresponding to the tens and units orders; and the first-partial operation of multiplication be automatically shifted into the hundreds orders of the calculating unit, causing the numerals of the product 598 to fall in their proper orders. To like effect, in order that the numerals of the product 598 may fall in their proper orders, the multiplicand 26 and the multiplier 23, for purposes of present illustration, may be respectively set up at the levers 1', 1'', and 2', 2'', the disks 40¹, and 40⁵, being shown respectively in Figures 4 and 5, in position to accommodate the operation. Deflection of the levers 1', 1'', releases the bridges 5', 5'' and closes thereby circuit through the wires e', e'' to the relays C.2', C.2'' (Figure 1).

The first numeral 2 of the multiplier is established, at the lever 2' (Figure 2), so as to close circuit on the wire a², and the second numeral, 3, at the lever 2'', so as to close circuit on the wire a³. The master switch 7, is placed in position x (+), when the multiplicand and the multiplier are of the same quality; and the push-button P.2 is depressed. Were the multiplier and the multiplicand not of the same quality, the master switch 7 would be placed in position x (-), as hereinafter described.

Closed by the master switch 7 through the contact plate 9, is circuit through the wire dr (Figures 2, 1), leading normally over the bridge 88 depressed at the relay C.11 to the negative pole of the clutch C.5. An extension of the wire dr leads also to the negative pole of the relay C.12. Closed by the master switch 7 (Figure 2) at the contact plate 12, is circuit through the positive wire o (Figures 2, 1) which at the transmitter 40 (Figure 1) is progressively closed at the disk 40⁵ (Figure 5) on the wires o', o'', o''' leading over bridges at the relays C.29', C.29'', C.29''' (Figure 2) to the levers 2', 2'', 2'''. Closed likewise by the master switch 7 at the contact plate 12, is circuit from the wire s+ through the wire w (Figures 2, 1) leading through the conductor 82 at the wheel 76 (Figures 1, 3) to the relay C.22 (Figure 1); and also circuit from the wire s+ through the wire x' (Figures 2, 1) leading through the conductor 87 at the wheel 76 (Figures 1, 3) and the wire x (Figure 1), to the positive pole of the clutch C.26 (Figure 1).

Depression of the push-button P.2 (Figure 2)

completes circuit through the positive wire g, which directs initial impulse through the conductor 85 (Figure 3) at the wheel 76 (Figure 1) and the bridges 49', 49'', 49''', to the relays C.2', C.2'' and C.2'''. Operation follows, the push-button being held in depressed position by the solenoid C.28'' (Figure 2) as presently described.

The wires b'-b⁹ are shown in Figure 6, as entering the orbit of the timing arm 78, in vertical direction and extending towards its axis in the form of spirals. The wires a'-a⁹ traverse the wires b'-b⁹ in concentric arcs, the wire a' being farthest from the axis of the timing arm 78, and the wire a⁹, the least remote. At each traverse point of the a and b wires, are complementary terminals, superimposed in Figure 6 and exposed in Figure 6a, between which circuit may be closed through the conductors 79'-79⁹ carried at progressive distances from its axis by the timing arm 78. A contact 79 is indicated at arm 78 in Figure 6, which is not operative in multiplication.

Let it be assumed, that the timing arm 78 describes an arc of 3.6°, corresponding to a unitary space displacement of the accumulator arms 61', 61'', 61''' (Figure 1), when the timing arm 78 advances to one and to another of the terminals of the wires b'-b⁹, which may be closed on the wire a' through the conductor 79'. The terminals of the wires b'-b⁹ at their intersections with the wire a² in the orbit of the conductor 79², are at arcs twice as great; the terminals of the wires b'-b⁹ at their traverse points with the wire a³ are at arcs three times as great; and thus progressively the terminals of the wires b'-b⁹ which may be closed, through the conductor 79⁹, on the wire a⁹, being at arcs of 32.4°, nine times greater than the arcs between the terminals at which circuit may be closed by the conductor 79'.

If, accordingly, the arc described by the arm 78 in advancing to one and to another traverse point of the wires b'-b⁹ with the wire a', correspond to one step displacements of the accumulator arms 61', 61'', 61''' (Figure 1); the arc described by the timing arm 78 (Figure 6) in advancing to one and to another of the traverse points of the wires b'-b⁹ with the wires a² being twice as great, would correspond to two step displacements of the accumulator arms 61', 61'', 61''' (Figure 1). Similarly the arc described by the timing arm 78 (Figure 6) in passing to one and to another traverse point of wire a³, being three times as great, would correspond to three step displacements of the accumulators 61', 61'', 61''' (Figures 1, 13); and the arcs to and between intersections at wire a⁹ being nine times as great, would correspond to a displacement of the accumulator arms 61', 61'', 61''' of nine steps.

Therefore, if the wire a² be closed at the lever 2' (Figure 2) and the wire b² be closed at the lever 1', the accumulator arm 61' (Figure 1) would be displaced four steps, corresponding to the numeral 4, when arrested by completion of the circuit by the conductor 79² (Figure 6) to the relay C.4' (Figure 1), as the timing arm 78 reaches the traverse point of the wires a², b² (Figure 6).

Similarly, if the wire a³ be closed at the lever 2'' (Figure 2) and the wire b³ be closed at the lever 1'', the accumulator arm 61'' (Figure 1) would be advanced eighteen steps, when arrested at completion of circuit to the relay C.4'' by the conductor 79³, at the traverse point of the wires

a^3, b^6 (Figure 6). Hence, the step displacement of the accumulator arms is proportionate to the product of the serial numbers which identify the a and b circuits selected at the control levers (Figures 2) and completed at the timing arm 78 (Figures 1, 6).

Returning to the operation 26×23 , the multiplicand is first multiplied by the numeral 2 of the multiplier, motion being transmitted through the clutch C.5 (Figure 1) from the shaft 53 to the shaft 58, and by the clutches C.7', C.7'', respectively, from the shaft 58 to the accumulator arms 61', 61''. Motion is transmitted to the timing arm 78 from the shaft 59 through the clutch C.21 and transmission 74, 75, 76, 77, hereinbefore described. As the arm 78 advances, circuit is completed through the conductor 79², at the traverse point of wires a^2, b^2 , (Figure 6) to the relay C.4' (Figure 1) which breaks circuit at the bridge 70' to the relay C.2', and arrests the accumulator arm 61' at a displacement of four steps. As the timing arm 78 advances further, circuit is completed by the conductor 79² through the wires a^2, b^6 , (Figure 6) to the relay C.4'' (Figure 1); and the accumulator arm 61'', having described an entire revolution, is arrested at a further net displacement of two steps, a tenth step carry-over corresponding to the complete revolution of the accumulator arm 61'' being transmitted to the accumulator arm 61' (Figure 1) of the hundreds order, through the clutch C.8'' and transmission 63'', 64', 65', 66', Df', 60'. The accumulator arms 61', 61'', accordingly, reflect the numerals 5 and 2, as the resultant of the first partial operation.

Rotation of the timing arm 78, initiated by the wire g is maintained until it reaches normal perpendicular position as represented in Figure 6, by current through wire w (Figures 3, 1) to the positive pole of the clutch C.21 (Figure 1). This circuit originates at the source ZZ and passes through the wire s^+ (Figures 1, 2) contact plate 12, the wire w , the conductor 82 at wheel 76 (Figures 1, 3), the bridge at the relay C.22 (Figure 1) energized through the wire w , to the clutch C.21. The negative poles of the relays both C.21, C.22 are connected through the wires s^- with the source ZZ. The purpose of the relays both C.22 and C.23, is to prevent interference of circuits through the wires g, a and w , each of which, though in different instances, closes circuit on the clutch C.21.

Immediately before the timing arm 78 reaches the normal position shown in Figure 6, circuit is closed by the conductor 87 at the disk 76 (Figures 1, 3) through the wires x', x , (Figures 2, 1) to the positive pole of the clutch C.26 fixed to the shaft 53 (Figure 1). This circuit originates at the source ZZ, and passes through the wire s^+ (Figures 1, 2) the contact plate 12 (Figure 2), wire x' (Figures 2, 1), conductor 87 (Figures 1, 3) and wire x , to the clutch C.26 (Figure 1), whence it passes through the wire s^- back to the source ZZ.

The clutch C.26 so energized and in continuous rotation, clutches the transmitter 40 which floats upon the shaft 53, and operating on the wires o', o'', o''' (Figures 1, 2, 5) as presently described, shifts current from the wire o , after the first partial operation, from the lever 2' closed on the wire a^2 corresponding to the first numeral of the multiplier, to the lever 2'', closed on the wire a^3 corresponding to the second numeral of the multiplier. Simultaneously, the

transmitter 40 (Figure 1) switches at the disk 40' (Figure 4) the current of the wire e' together with the current of the wire c' , both closed by the lever 1' (Figure 2) and corresponding to the first numeral of the multiplicand, from the relays C.2', C.4', respectively, to the relays C.2'', C.4''. In similar manner, at the disk 40' (Figure 4) current of the wire e'' , together with current from the wire c'' , closed by the lever 1'' and corresponding to the second numeral of the multiplicand, are switched respectively from the relays C.2'', C.4'', to the relays C.2''', C.4''' (Figure 1).

Through the action of the transmitter 40, the operation of multiplication is accordingly shifted to the next lower orders of the calculating unit corresponding to next lower denominations.

The transmitter 40, as shown in Figure 1, comprises six disks 40', 40², 40³, 40⁴, 40⁵, 40⁶, the disks 40², 40³, 40⁴, being operated only in division. The disk 40⁵ carries at its lower face (Figure 5), a conductor 41 to which is attached a contact 42. Closed on the conductor 41 is the wire o (Figures 5, 1). Closed successively by the contact 42, as the disk 40⁵ is rotated, are the wires o', o'', o''' , which lead each respectively over the upper bridges at the relays C.29', C.29'', C.29''' (Figure 2) normally closed to the levers 2', 2'', 2'''. The arc of the conductor 87 at the wheel 76 (Figures 1, 3) is exactly sufficient to sustain current to the clutch C.26 (Figure 1) while the clutch C.26 displaces the transmitter 40 from the position at which the contact 42 (Figure 5) closes on the wire o' , to successive positions at which it closes on the wire o'' , and then on the wire o''' . Circuit is thereby shifted downwards after the first partial multiplication, from the lever 2' (Figure 2) and the wire a^2 corresponding to the first numeral of the multiplier, into connection with the lever 2'' and the wire a^3 corresponding to the second numeral of the multiplier and eventually, were there three numerals in the multiplier, likewise to the lever 2'''.

The disk 40' (Figures 1, 4) carries a series of circuit conductors 16'-16⁶. On these conductors at the faces of the disk 40', float terminals of the several wires $c', e', c'', e'', c''', e'''$, through which, in normal position current is directed to the relays C.4', C.2', C.4'', C.2'', C.4''', C.2''' (Figure 1) through extensions of the wires $c', e', c'', e'', c''', e'''$, leading respectively from the opposite extremities of the concentric conductors 16'-16⁶. These last said terminals are spaced at arcs, which permit current through the several wires $c', e', c'', e'', c''', e'''$ to be switched respectively, to the corresponding relays of next lower orders, as the clutch C.26 (Figure 1) displaces progressively the transmitter 40.

Circuit o being shifted, by the transmitter 40 at the disk 40⁵ from the lever 2' (Figure 2) closed on the wire a^2 corresponding to the first numeral of the multiplier 23, to the lever 2'' closed on the wire a^3 corresponding to the second numeral thereof, and the c and e wires having been switched at the disk 40' to corresponding relays of next lower orders, permitting the deflected levers 1', 1'', to operate respectively thereon; the wheel 76 (Figure 1) revolving, again momentarily completes, at the conductor 85 (Figures 1, 3) circuit through the wire g (Figure 1) to the relays C.2'', C.2''' and the multiplicand 26 is multiplied by the numeral 3, the push-button P.2 (Figure 2) being held depressed by the solenoid C.28''.

The circuit of this solenoid C.28'' originates at

the source ZZ (Figure 1), and passes through the wire *o* (Figures 1, 2), the conductor 41 at the disk 40⁵ (Figures 1, 5), the wire *y* (Figures 1, 2) the bridge 32'', the solenoid C.28'' (Figure 2) and thence back through the wire *s*- (Figures 2, 1) to the source ZZ. Circuit to the solenoid C.28'' remains active, until multiplication is finally completed, when, after successive shifts at the transmitter 40 (Figure 1), the wire *y* (Figure 5) is thrown into open circuit, as current from conductor 41 advancing, fails. Circuit to the solenoid C.28'' is thereby broken and the push-button P.2 is restored to normal position by the action of a spring s.34'' (Figure 2).

The second partial operation having been initiated by impulse through the wire *g* as circuit is again completed through the conductor 85 (Figure 3), to the relays C.2'', C.2''', (Figure 1). The wheel 76 (Figure 1) and the timing arm 78 enter on a second revolution; the wire *a*³ corresponding to the second numeral 3 of the multiplier, in turn operating on the wires *b*², *b*⁶, corresponding to the multiplicand 26. As the timing arm 78 (Figures 1, 6) advancing, closes through conductor 79³ the wire *a*³ upon the wire *b*² the accumulator arm 61'' (Figure 1) is arrested at an advance of six steps, which added to its original net displacement of two steps give the accumulator arm 61'' an angular displacement of eight steps. The accumulator arm 61''' is in turn arrested, as the timing arm 78 reaches the terminals of the wires *a*³, *b*⁶ (Figure 6) and, having described a complete revolution, rests at a net displacement of eight steps, the ten units corresponding to the complete revolution of the accumulator arm 61''' being transmitted as carry-over to the accumulator arm 61'', which is thereby advanced an extra step. The final displacement of the accumulator arms 61', 61'', 61''' reflects accordingly, 598, the product.

Should a zero appear in the multiplier, and consequently a partial multiplication be suspended; transmission of motion from the shaft 53 (Figure 1) to the shaft 58, is interrupted, by breaking the circuit of the wire *h* to the clutch C.5. This is accomplished by means of the relay C.1. Said relay C.1 is in a circuit which originates at the source ZZ and passes through the wires *s*⁺, *o* and wire *o'*, *o''*, *o'''* (Figures 1, 2), already traced, progressively to the levers 2', 2'', 2''' (Figure 3) as hereinabove described, and thence through the wire *a*⁰ over the bridge at the relay C.3 (Figure 1) to the positive pole of the relay C.1, the negative pole whereof is connected through the wire *s*- back to the source ZZ. If the wire *a*⁰ be closed at the lever 2', 2'', 2''' (Figure 2) which at the time be receiving current from a wire *o'*, *o''*, *o'''*, the relay C.1 (Figure 1) breaks at the bridge carried at the upper extremity of its plunger, circuit through the wire *h* to the clutch C.5, or as it may be in negative multiplication to the clutch C.5a. If there be successive zeros in the multiplier, action at the relay C.1, is repeated.

In order to insure the presence of the arm 78 in normal perpendicular position as shown in Figure 6, when initiating an operation in multiplication, the push-button P.4 (Figure 2) is manually depressed. It is held in such position by the solenoid C.28^{iv} on which circuit is thereby closed and which is held in stick, through a current which, originating at the source ZZ (Figure 1) passes through the wire *s*⁺ (Figures 1, 2), bridge at the push-button P.4 (Figure 2), the wire *z* (Figures 2, 1), conductor 83 (Figure 3) at the wheel 76 (Figure 1) to the positive poles of the relay C.21

(Figure 1) and solenoid C.28^{iv} (Figure 2), the negative poles whereof, are connected through the wire *s*- with the source ZZ (Figure 1). The relay C.21, so energized, transmits motion through the transmission 74, 75, 76, 77, until, as the timing arm 78 reaches normal perpendicular position (Figure 6), circuit to the clutch C.21 and the solenoid C.28^{iv} is broken at the conductor 83 (Figure 3), arresting thereby the timing arm 78 in normal perpendicular position (Figure 6), and releasing the push-button P.4 (Figure 2).

In order to provide that the transmitter 40 (Figure 1) be in normal position, when initiating an operation of multiplication, the conductor 43 (Figure 5) carried at the lower face of the disk 40⁵ (Figure 5), closes circuit on the positive pole of the clutch C.26 (Figure 1). When the shifts of circuit incident to the operations of multiplication have been completed, such final shift carries the extremity of the conductor 43 into contact with the fixed terminals 44. The circuit so closed by the conductor 43 originates at the source ZZ (Figure 1), and passes through the wire *s*⁺ and the conductor 43 (Figure 5) to the positive pole of the clutch C.26 (Figure 1), the negative pole whereof, as already stated, being connected, through the wire *s*-, back to the source ZZ. The clutch C.26 so energized, clutches the transmitter 40 and rotates it onward to normal position, the arc of the conductor 43 (Figure 5) being such that when the transmitter reaches normal position, circuit to the clutch C.26 fails.

Multiplication of mixed quantities—positive and negative

In operations of multiplication, when a negative quantity enters with a positive, the master switch 7 (Figure 2) is placed in position *x*(-). In this position the master switch 7 closes the same circuits, as in multiplication of quantities of similar quality, except that through the wire *i* a positive current is closed at the contact plate 12 (Figure 2), to the relay C.11, over the bridge 209, and the bridge 101 at the relay C.12, which is energized, as hereinbefore described, by the wire *dr*. The relay C.11 so energized switches at the bridge 99, current from the wire *dr* to the clutch C.5a which transmits motion in direction opposite to clockwise, as hereinbefore described, to the accumulator arms 61', 61'', 61''' (Figure 1). The operation is similar in all particulars to the multiplication of two positive quantities or as it might be of two negative quantities, except that the direction of motion of said arms is reversed, carry over, as presently described, being effected by the transfer clutches C.8''', C.8'', during each tenth step and "borrowing" during each first step, in which ever direction from zero position the accumulator be initially displaced.

The product in multiplication is automatically added or subtracted, according to its positive or negative quality, to or from any quantity which the accumulator 61', 61'', 61''' (Figure 1) already may reflect. Should a positive quality, for example, be already latent at the accumulators 61', 61'', 61''' (Figure 1) and, the factors being of dissimilar quality, a greater negative product be transmitted thereto; the quantity reflected at the counters 61', 61'', 61''', would first be reduced automatically to zero by operation in the nature of subtraction; and on passing through zero, operation would follow in the nature of addition, until the negative resultant be completed.

Referring to Figure 9, the shaft 58a carries the sleeves 68a', 68a'', 68a''' which are rotated re-

spectively by the clutches C.1a', C.1a'', C.1a''' simultaneously with the sleeves 60', 60'', 60''', carried by the shaft 58 and rotated by the motor M through the clutches C.7', C.7'', C.7'''. Circuit is closed simultaneously at the bridges 73', 73a', respectively (Figures 1, 9) through the wires j', ja', to the clutches C.7', C.1a'. Circuit is closed simultaneously at the bridges 73'', 73a'', through the wires j'', ja'', to the clutches C.7'', C.1a''; and circuit is closed simultaneously, at the bridges 73''', 73a''', through the wires j''', ja''', to the clutches C.7''', C.1a''', the negative poles of the clutches C.7', C.1a', C.7'', C.1a'', C.7''', C.1a''' being all connected through the wire s- with the source ZZ.

The armature of the clutch C.1a' is the geared wheel 62a' (Figure 9) which floats on the shaft 58a and transmits motion to the sleeve 60a', through a composite idler not shown but similar to the idler 61' (Figure 1), and the differential dfa' (Figure 9) the middle member of which is fixed to the sleeve 60a'. The armature of the clutch C.1a'' is the geared wheel 62a'', which floats on the shaft 58a and transmits motion to the sleeve 60a'' through a composite idler similar to idler 61'' (Figure 1), and the differential dfa'' (Figure 9), the middle member of which is fixed to the sleeve 60a''. The armature of the clutch C.1a''' is the disk 62a''' fixed to the sleeve 60a'''.

The carry-over, at the shaft 58a, is transmitted from the sleeve 60a''' to the sleeve 60a'', by the clutch C.8a''' integral with the sleeve 60a''', the geared armature 63a''' floating on the shaft 58a and transmission similar to the pinion 64'' (Figure 1) pivot 65'', and the pinion 66'', to the left lateral member of the differential dfa'' (Figure 9) which floats on the sleeve 60a''. The carry-over is in like manner transmitted from the sleeve 60a'' to the sleeve 60a', by the clutch C.8a'' fixed to the sleeve 60a'', the geared armature 63a'' and transmission similar to the transmission 64', 65', 66' (Figure 1), and the differential dfa' (Figure 9), the left lateral member of which floats on the sleeve 60a'.

Integral with the sleeve 60a' is a clutch C.8a' (Figures 1, 9) similar to the clutches C.8a'', C.8a''' which transmits carry-over to a denominational order consisting of a single member, the armature 63a'. This order is higher than the highest order of the accumulator and corresponds to thousands, in the present drawings. The armature 63a' carries a conductor 90 (Figures 9, 10) which governs duplicate circuits to the clutches C.8a', C.8a'', C.8a'''.

The negative pole of the clutch C.8a' is connected with the source ZZ, through the wire s-. The negative poles of the clutches C.8a'', C.8a''', C.8'', C.8''' are connected with the wire ds- leading over the lower bridge at the relay C.19 to the source ZZ. The transfer clutches and appertinent elements at the shaft 58a may be termed the circuit controller.

When the accumulator (Figure 9) is in zero position, the clutches C.8'', C.8''' are in open circuit, the circuit of the wire d leading to the positive contact bands 36'', 36''' being broken at the bridge 92², and the circuit of the wire d' to the positive contact bands 38'', 38''' being broken at the bridge 92⁴. The clutches C.8'', C.8''' may then be displaced from zero in either direction without borrowing and thereby displacing higher orders. The contact bands 36'', 36''', 38'', 38''', extend each through 36° of arc.

When the accumulator is at zero, circuit is

closed to terminals cooperative with the clutches C.8a', C.8a'', C.8a''' through the wires both da, closed on the wire s+ leading from the source ZZ, at the bridge 92², and through the wire da', closed on the wire s+ at the bridge 92³. The terminals of wires da, are in such position relatively to the positive contact bands 36a', 36'', 36a''' which extend through 36° that if a clutch C.8a', C.8a'', C.8a''' be initially displaced from zero in direction opposite to clockwise, as in the addition or multiplication of positive quantities, a quantity is borrowed throughout ascending orders of the circuit controller, at shaft 58a; and the armature 63a' (Figures 9, 10) is displaced 36° in direction opposite to clockwise.

The terminals of the wire da' are in such position relative to the positive contact bands 38a', 38a'', 38a''', which extend through 36°, that if a clutch C.8a', C.8a'', C.8a''' be displaced from zero in clockwise direction, as in the subtraction of a positive quantity, a quantity is borrowed throughout ascending orders at shaft 58a, and the armature 63a' is displaced 36°, in clockwise direction, (clockwise movement in Figure 10 being towards the left, because of viewpoint).

So long as operations remain within the zone of positive quantities, the armature 63a', displaced in direction opposite to clockwise, closes circuit from the wire s+ through the conductor 90, carried by the armature 63a, to the wire d. So long as operations be within the zone of negative quantities, the armature 63a', displaced in clockwise direction, closes circuit from the wire s+ through the conductor 90, to the wire d'.

When the wire d is closed by the conductor 90, circuit is completed to the relay C.25, the negative pole of which is connected through the wire s- back to the source ZZ. The relay C.25 so energized retracts the plunger 91, common to the relay C.25', and closes at the bridge 92², circuit through an extension of the wire d to the terminals cooperative with the clutches C.8'', C.8''', the contact bands 36'', 36''' which are so placed relatively to the terminals of the wire d, that the clutches C.8'', C.8''' are energized at each tenth space displacement clockwise in every revolution, and at such tenth space displacement transmit a positive carry-over. At each first-space displacement in opposite direction within the zone of positive quantities the clutches C.8'', C.8''' borrow. So long as operation remains within the zone of positive quantities, the wire d is active.

When the wire d' is closed by the conductor 90, circuit is completed to the relay C.25', the negative pole of which is connected through the wire s- back to the source ZZ. Therelay C.25' so energized, retracts the common plunger 91; and closes at the bridge 92⁴ circuit through an extension of the wire d' to the clutches C.8'', C.8''', the contact bands 38'', 38''' at which, are so placed relatively to the terminals of the wire d', that the clutches C.8'', C.8''' are energized at every tenth space displacement in every revolution opposite to clockwise, and at such tenth space displacement transmit a negative carry-over. At each first space displacement clockwise, within the zone of negative quantities, the clutches C.8'', C.8''' borrow. So long as the operation remains within the zone of negative quantities, the wire d' is active.

When the wire d is active, circuit is broken at the bridge 92³ from the wire s+ to the wire da', which remains open, and is closed at the bridge 92' from the wire d through the wire da to the clutches C.8a', C.8a'', C.8a''', which, so

long as the operation remains within the zone of positive quantities, borrow while the clutches C.8'', C.8''' are transmitting positive additive carry-over; and transmit carry-over, while the clutches C.8'', C.8''' borrow.

When the wire d' is active, circuit is broken at the bridge 92' from the wire s^+ to the wire da , which remains open, and is closed at the bridge 92³ from the wire d' through the wire da' to the clutches C.8a', C.8a'', C.8a''', which so long as the operation remains within the zone of negative quantities borrow while the clutches C.8'', C.8''' are additively transmitting negative carry-over; and transmit carry-over, while the clutches C.8'', C.8''' borrow.

The initial step displacement as the circuit controller passes from zero position, into either positive or negative quantities, causes borrowing, as above described, at the clutches C.8a', C.8a'', C.8a''', which displaces the armature 63a'. Conversely, as the circuit controller returns to zero position, through either positive or negative quantities, the last unit displacement of a clutch C.8a', C.8a'', C.8a''', causes a carry-over to be transmitted to the armature 63a', which is thereby restored to normal position, throwing the wires d , d' , and the clutches C.8'', C.8''' again into open circuit; and permitting the bridges 91', 91³ again to close circuit from the wire s^+ through the wires both da and da' , to the clutches C.8a', C.8a'', C.8a'''.

As hereinbefore disclosed, the direction of movement at the accumulator (Figures 1, 9) is conditioned by the master switch 7 (Figure 2) accordingly as the factors be similar or dissimilar in quality. If there be a quantity already latent at the accumulator, to which the product be added, or from which the product be subtracted; the quality of the net resultant is distinguished according to the direction of displacement of the disk 63a' (Figure 10), which when the resultant is negative closes the circuit of the wire d' to the solenoid C.64 (Figure 14), causing said solenoid to elevate an inking ribbon 233 of dual color, and identify the quality of the quantity in red. If the resultant be positive, the said solenoid remains inactive, and the quality is identified in black. The extension of the wire d' designated as wire d'' , is shown in Figure 1 which leads to the solenoid C.64. If the accumulated quantity be positive, the step displacement of accumulator arms reads from zero to the right; and to the left, if negative. Relays such as C.47 (Figure 13) are energized by the wire d' , when negative, and so shift numeral circuits such as af^1 - af^9 , that the steps may be measured serially from 1 to 9 and not by complementary numerals, whichever such direction be.

Column shift

With view to simplicity in demonstration, multiplication as described in earlier pages has been limited to three orders of whole numbers, and the receiving members in which to enter factors have been arbitrarily selected. Means now may be disclosed for extending computation into fractions, with automatic column-shift permitting the factors to be entered at receiving members of corresponding orders. Referring to Figure 15, the mechanism therein shown, since it is predicated on whole numbers and on fractions, provides for initial column-shift to denominationally higher or lower orders, preparatory to computation of the product at selective accumulator members, and the eventual identification of its denominational recorded value by a decimal point.

Referring to Figure 15, the mechanism operative in establishing the position of the decimal point and not hereinbefore described, comprises in addition to the accumulator arms 61', 61'', 61''', corresponding to hundreds, tens and units, the accumulator arms 61^{iv}, 61^v, 61^{vi}, corresponding to tenths, hundredths and thousandths; the electric button 15 at the master switch 7, which closes circuit to the bridges 220'-220^{vi}, the relays C.42'-C.42^{vi} and the armature 40⁶, together with electrical connections. The transmitter 40, previously shown in Figure 1, is shown in Figure 15, as modified to accommodate six accumulator arms and identified as 40a, in which the disk 40⁵ (Figure 18) is substituted for the disk 40⁶ (Figure 5). The elements of the calculating unit are similar in principle howsoever many denominational orders it may comprise; and further description is accordingly limited to the automatic assignment of resultants to their proper columns, and their operation relatively to the position of the decimal point.

In multiplication the circuits closed at the levers 1'-1^{vi} are shifted upwards or downwards as many orders as the first digit of a multiplier lies to the left or to the right of the units order. Products are thereby developed in their proper denominational orders, at corresponding orders of the calculating unit; assigning the decimal point thereby to its proper place.

Identification of the highest denominational order of a multiplier is accomplished by means of the wires ax , (Figure 15), leading to bridges at the levers 2'-2^{vi}, the circuits of these wires being closed at the master switch 7.

The outer extremity of the master switch 7 is provided with a button 15. When the master switch 7 is advanced to position (x), the button 15 is momentarily depressed closing and immediately breaking at the terminals 218 the circuit of the wire sx^+ leading from the source sz , to various members, as now shall be described. The wire ax on which circuit is so closed through the contact plate 11 from the wire sx^+ passes first to and over the bridge 220', at the lever 2', and thence, to and over the bridges 220''-220^{vi} at the levers 2'-2^{vi}. The bridges 220'-220^{vi} are normally supported by the cams 221'-221^{vi}, fixed to the shafts 18'-18^{vi} of the levers 2'-2^{vi}, and are released, each when its corresponding lever be deflected. So released, the bridges 220'-220^{vi}, in falling, close respectively circuit on the wires ax - ax^vi ; of which only the circuit closed at the highest deflected lever becomes active; since each bridge in falling, breaks the circuit of the wire ax to all bridges therebelow. The circuit ax - ax^vi which thus is active, identifies the highest order of the multiplier and, by energizing as presently described the clutch C.26, operates the required shift of circuits at the transmitter 40a which shall cause the first numeral of a product, to fall in proper column. At lever 2''', corresponding to the units order, the bridge 220''' breaks circuit without closing one. Since, if the first digit of the multiplier be of the units order; no shift of circuits is required.

Let the operation $31.17 \times 23.2 = 723.144$, be assumed as an example. The product is 723.144, of which the numeral 7 should fall in the hundreds order, the numerals following thereon falling successively in the orders therebelow, and the decimal fraction always assuming its position to the right of the decimal point, howsoever many decimal orders there may be.

The first numeral of the multiplicand in the

present example, is established, by deflecting the lever 1'' (Figure 15) corresponding to the tens order of the accumulator members, and the remaining numerals of the multiplicand by the deflection of denominally descending levers, as hereinafore described.

The first numeral of the multiplier is similarly established by deflecting the lever 2'', corresponding to the tens order, and the remaining numerals of the multiplier by the deflection of successive levers therebelow. The master switch 7 is placed in position (x) (Figure 15) and circuit is momentarily closed at the terminals 218, by depression of the button 15.

The highest order at which circuit is closed by the levers of the multiplier is the tens order; and the wire ax'' is rendered active, the circuit of which passes to the positive pole of the relay C.42'', the negative pole of which, as are the negative poles of all the C.42 relays, is closed on the wire sx^- .

The relay C.42'' energized as the button 15 carried by the master switch 7 is momentarily depressed, retracts its plunger; and is held in stick through the higher bridge at the relay C.42'' by current from the wire sx^+ ; closing over its lower bridge, current from the wire sx^+ to the wire ex'' which leads to the conductor 226'' (Figure 16) carried by the disk 40^b (Figure 15), from which conductor 226'' current is transmitted to the positive pole of the clutch C.26 (Figure 15) through the wire ex from the terminal 227 (Figures 15, 16) common to all the ex wires. Circuit is completed to the negative pole of the clutch C.26, in such operation, through the wire sx^- closed at the master switch 7. The clutch C.26 so energized and constantly revolving, clutches and rotates the transmitter 40a and the disk 40^b, to an angle of displacement corresponding to the arc of the conductor 226'' (Figure 16). Such angle of displacement, as shown in Figure 16, is 324°, being such, that the wires c'' , e'' (Figure 17) normally closed by the lever 1'' to the relays C.4'', C.2'' (Figure 1) of the tens order, are switched to extensions of the wires c' , e' , (Figure 15) leading to the relays C.4', C.2', of the hundreds order, the c , e , circuits at lower orders being simultaneously switched at the disk 40a', each to the order next above. The first partial multiplication is thereby shifted from the tens to the hundreds order of the calculating unit, and the first numeral of the product is developed at the accumulator arm 61'. Should a carry-over be developed, it would automatically be transmitted to an eventual next higher accumulator arm, in manner hereinafore described, the quantity so transmitted being, nevertheless, generated at the hundreds order. The circuit of the wire o (Figure 18) which is closed selectively to the levers 2'-2^{vi} corresponding to the multiplier, through the wires $o'-o^{vi}$, is closed normally on the wire o''' leading to the lever 2''' corresponding to the units order. As the c , e wires of the multiplicand are shifted one denominational order upwards, the circuit of the wire o is switched denominationally upwards in like measure at the disk 40a⁵ (Figure 18) breaking circuit to the units lever 2''' and closing circuit on the wire o'' to the lever 2'' corresponding to the order of the tens, and the first numeral of the present multiplier. In similar manner, the wire o will always close circuit, during the first partial operation, to the lever 2'-2^{vi}, corresponding to the first digit of the multiplier; closing circuits progressively

to lower levers as successive partial operations are shifted downward by the transmitter 40a.

The initial shifts of the c , e , o circuits having been effected, the push-button P.2 is depressed, breaking at the bridge 34'' the circuit of the wire sx^- to the negative pole of the clutch C.26 (Figure 15), and closing the circuit of the wire g , as hereinafore described, to the relays C.2'-C.2^{vi}. The operation of multiplication follows, and in the example $31.17 \times 23.2 = 723.144$, the first numeral 7 of the product, is reflected at the accumulator number 61', corresponding to the hundreds column; with descending numerals following in order.

If the operation were $400 \times .002 = .8$; the lever 1' corresponding to the hundreds order is deflected to establish the multiplicand; and the lever 2^{vi} corresponding to the thousandths order is deflected, to establish the multiplier. The first digit of the multiplier is three columns to the right of the units column. From the lever 2^{vi}, the circuit through the wire ax^{vi} is closed to the relay C.42^{vi} which completes circuit through the wire ex^{vi} and the conductor 226^{vi} (Figure 16) to the clutch C.26. The wires c' , e' are thereby shifted downwards to the relays C.4^{iv}, C.2^{iv} (Figure 15) at the tenths order, this three order shift of the multiplicand downwards corresponding to the number of columns at which the highest significant digit of the multiplier .002 falls to the right of the units column. Accompanying this shift of the c , e wires three denominational orders downwards, is a shift of the circuit o three orders downwards, switching current (normally closed on the wire o'''), to the wire o^{vi} leading to the lever 2^{vi}. The resulting quantity is developed at the tenths order, and the product is .8.

Were the operation $.02 \times 400 = 8$; the levers 1', 2' (Figure 15) would be deflected, and the c , e circuits of the multiplicand .02 would be shifted upwards two denominational orders to the units order, these two orders upwards corresponding to the number of columns the highest digit of the multiplier 400, falls to the left of the units column.

The wire o would be switched upwards two denominational orders in like measure, current thereby being closed from the wire o to the wire o' leading to the lever 2'. The resultant 8 would be developed at the units order; and the numeral 8 would be reflected in the units column.

Depression of the push button P.2, initiating, after shift of circuits, the operation of multiplication breaks the circuit of the wire sx^- , to the clutch C.26, and relays C.42'-C.42^{vi}, at the bridge 34''.

It is, as hereinafore described, a function of the conductor 43 (Figure 18) to operate in restoring the transmitter 40 to normal position. To prevent premature action by the conductor 43, the circuit leading from the terminals 44 to the clutch C.26 is broken by the relay C.67 until computation be completed. The relay C.67 is in a circuit which originates at the source ZZ (Figure 15) and passes through the wire s^+ , contact-plate 12, wire o , conductor 41 (Figure 18), wire y , relay C.67, and the wire s^- , back to the source ZZ. The last shift of circuits, in operation of multiplication, as conductor 87 (Figure 3) closes circuit, as hereinafore described, to the clutch C.26, carries the conductor 41 beyond the terminal of the wire o , and closes circuit from the conductor 43 to the terminals 44. The relay C.67 releasing its plunger completes circuit to the clutch C.26, and the arc of the conductor 43 is

such that circuit to the clutch C.26 is maintained until the position of the transmitter 40a is restored to normal.

Restoration of the calculating unit to zero position

Depression of the push button P.5 (Figure 2) closes a circuit which originates at the source ZZ (Figure 1) and passes through the wire s⁺ (Figures 1, 2), the bridge at the push button P.5 (Figures 2, 9), the wire n to the relay C.19, (Figures 2, 9), best shown in Figure 9, and over the upper bridge on the plunger thereof, to the relay C.20, circuit being closed from the negative poles of the relays both C.19, C.20, through the wire s⁻, back to the source ZZ. The relay C.19 so energized, retracts its plunger; and, when completing circuit at its upper bridge to the relay C.20; closes at its lower bridge circuit to the negative pole of the relay C.12', and to terminals at the plunger of the relay C.12'. The relay C.20 breaks, at the bridge 167, circuits through the wire h (Figure 1) to prevent interference of circuit with the wire n; and closes at the bridge 168 (Figure 9) circuit to the positive pole of the clutch C.6, fixed to the shaft 58. At the bridge 167 circuit is closed to terminals at the plunger of relay C.12', through the wire n'.

The relay C.12' determines direction of motion at the shafts 58, 58a, during restoration of the calculating unit to zero position. The positive pole of the relay C.12' is connected with the wire d'. If, when restoration to zero position be initiated, a positive quantity be accumulated at the shaft 58, circuit of the wire d' is open at the conductor 90 (Figure 10); the relay C.12' (Figure 9) closes at the bridges 105, 106, depressed, circuit through the wires n- closed by C.19 at lower bridge and through n', to the negative and positive poles of the clutch C.5a, and motion of the shaft 58 is opposite to clockwise. If a quantity accumulated at the shaft 58 be negative; the wire d' is active as hereinbefore described, and energizes over the bridges 92', 104, the relay C.12', which is then held in stick over the bridge 104 by current through the wire n'. The relay C.12' so energized, closes at the bridges 105, 106 raised, circuit to the clutch C.5; and clockwise motion follows at the shaft 58.

Responsive to the clutch C.6, and floating on the shaft 58, is the armature 69 (Figures 1, 12) which carries a conductor 172, extending, except at a slight arc, throughout the circumference of the disk. Momentary depression of the push button P.5 (Figure 2) imparts initial impulse to the clutch C.5 or C.5a and C.6. The clutch C.5 or C.5a revolving, transmits motion to the shafts 58, 58a; and the clutch C.6 clutching and revolving the disk 69 causes the conductor 172 (Figures 1, 9, 12) to close a circuit from the wire s⁺ extended from the source ZZ, which holds the relays C.19, C.20 in stick, and sustains current to the clutches C.5 or C.5a and C.6, after the initial impulse imparted through the push button P.5. The conductor 172 (Figure 12) is of such arc as to sustain current throughout a single revolution of the shaft 58, this being sufficient to restore to zero position, the members of the calculating unit.

The clutches C.7', C.7'', C.7''', C.7a', C.7a'', C.7a''' (Figures 1, 9) are active, in restoring to zero position the accumulator arms 61', 61'', 61''' and such other members at the shafts 58, 58a, as may be displaced. The clutches C.7', C.7'', C.7''', are energized to restore members on shaft 58, by circuits of the wire n which pass

respectively, over the bridges 171, 170, 169 at the relay C.20 (Figure 1) and conductors 173', 173'', 173''', circuits being completed from the negative poles of the clutches C.7', C.7'', C.7''' through wires s- back to the source ZZ. The conductor 173' (Figure 11) is carried by the middle member of the planetary gearing Df'. The conductor 173'' is carried by the middle member of the planetary gearing Df''; and the conductor 173''' is carried by the member 62'''. The operation at all orders is substantially alike. Referring to Figures 1, 11, the conductor 173''', for example, extends throughout the circumference of the member 62''' except at a slight arc, at which, if the member 62''' and the accumulator arm 61''' be already at zero position, circuit is open to the relay C.7''' (Figure 1). If the accumulator arm 61''' and the member 62''' be displaced; circuit is completed through the conductor 173''' to the clutch C.7''', which clutching, in manner hereinbefore described, the member 62''', transmits motion to the member 62'', until circuit to the clutch C.7''' is broken at the conductor 173''', as the accumulator arm 61''' and the member 62''' reach zero. The accumulator arms 61'', 61' are restored to zero position, by circuits similarly closed and broken, leading to the clutches C.7'', C.7' (Figures 1, 9). The members carried by the shaft 58a may be restored to zero position in similar manner, by extensions of the wire n leading respectively from the bridge 169a at the relay C.20 shown in entirety in Figure 9, to the clutch C.7a''', from the bridge 170a to the clutch C.7a''; and from the bridge 171a to the clutch C.7a'. Conductors similar to the conductor 173''' (Figure 11) are carried by the disk 62a''', and by the middle members of the planetary gearings dfa'', dfa', which break circuit respectively to the clutches C.7a''', C.7a'', C.7a', as the sleeves 60a''', 60a'', 60a' reach zero position corresponding members of fractional denomination may be restored by similar means to zero position.

During the restoration to zero, circuit to the clutches C.8'', C.8''', C.8a'', C.8a''', through the wire ds- is broken at the lower bridge at the relay C.19, and the carry-over mechanism is inactive, except as to the clutch C.8a' whose negative pole is connected with the wire s-, and which restores to normal position the armature 63a'.

Having now fully described my invention and its manner of operation, I claim:

1. In a calculating apparatus for multiplying quantities one by the other, a rotary timing arm, conductors carried by the timing arm at progressive distances from its axis and displaceable by the timing arm in concentric arcs, selective numeral circuits corresponding to a multiplicand, selective numeral circuits corresponding to a multiplier traversing the circuits corresponding to the multiplicand in the arcs of said conductors, spaced complementary contacts in the circuits at the points of traverse, means angularly to displace the timing arm between the complementary contacts from zero position to cause a said conductor to close circuit between the complementary contacts of the selected factor circuits, the points of traverse being so placed that the degree of angular displacement of the timing arm from zero position to the traverse point of the selected factor circuits is proportionate to the product of the numerals to which the last said circuits correspond.

2. In an electrically actuated calculating apparatus for multiplication, an accumulator comprising angularly displaceable members corre-

sponding to decimal orders, denominational clutches to operate the members, means to render the clutches effective at the zero point of a cycle and including actuating circuits corresponding to the orders of the multiplicand to energize the clutches, digital circuits corresponding to the numerals of the multiplicand, digital circuits corresponding to the numerals of a multiplier, immobilizing circuits and devices controlled by last said circuits, means including a progressive timing member operative from zero position and synchronized with the accumulator members for closing a said digital circuit corresponding to a selective numeral of the multiplier on the digital circuits corresponding to the numerals of the multiplicand for selectively completing the immobilizing circuits to energize said devices and break the actuating circuits to deenergize the clutches when operative in variable degree according to the products of the multiplicand numerals multiplied by said numeral of the multiplier.

3. In an electrically actuated calculating apparatus for multiplying one by the other quantities whether positive or negative, an accumulator comprising members corresponding to decimal orders and angularly displaceable in respective opposite directions to accumulate a positive or negative product, denominational clutches to operate the members, means to render the clutches effective at the zero point of a cycle and including actuating circuits corresponding to the orders of the multiplicand to energize the clutches, reversible driving means for operating the clutches to add or subtract the accumulated product from any previously accumulated quantity latent in the accumulator accordingly as the said quantity and the accumulated product be similar or dissimilar in quality, digital circuits corresponding to the numerals of the multiplicand, digital circuits corresponding to the numerals of the multiplier, immobilizing circuits and devices controlled by last said circuits, means including a progressive timing member operative from zero position and synchronized with the accumulator members for closing a digital circuit corresponding to a numeral of the multiplier on the digital circuits corresponding to the numerals of the multiplicand for selectively completing the immobilizing circuits to energize said device and break the actuating circuits to deenergize the clutches when operative in variable degree according to the products of the multiplicand numerals multiplied by said numeral of the multiplier.

4. In an electrically actuated calculating apparatus for multiplication, an accumulator comprising members corresponding to decimal orders to accumulate a product, denominational clutches to operate the members, means to render the clutches effective at a zero point in a cycle and including actuating circuits corresponding to the orders of the multiplicand to energize the clutches, digital circuits corresponding to the numerals of the multiplicand, digital circuits corresponding to the numerals of the multiplier, immobilizing circuits and devices controlled by last said circuits, means including a progressive timing member operative from zero position and synchronized with the accumulator members to close a digital circuit corresponding to a selective numeral of the multiplier on the digital circuits corresponding to the numerals of the multiplicand for selectively completing the immobilizing cir-

cuits to energize said devices and break the actuating circuits to deenergize the clutches when operative in variable degree according to the products of the multiplicand numerals multiplied by a said numeral of the multiplier, a transmitter provided with switch elements, a clutch to operate the transmitter, means including a conductor synchronized with the timing member to energize last said clutch after partial operations, severally to close the circuits corresponding to the successive numerals of the multiplier and shift the said actuating and immobilizing circuits, into cooperative connection with the accumulator members of progressively lower orders to cumulate a final product.

5. In an electrically actuated calculating apparatus for multiplying quantities involving whole numbers or decimal fractions, an accumulator comprising members corresponding to decimal orders, denominational clutches to operate the members, means to render the clutches effective at the zero point of a cycle and including actuating circuits corresponding to the significant orders of the multiplicand to energize the clutches, digital circuits corresponding to the significant numerals of the multiplicand, a digital circuit corresponding to the numeral of a multiplier, immobilizing circuits and devices controlled by last said circuits, means including a progressive timing member operative from zero position and synchronized with the accumulator members and provided with contacts operative on terminals paired in decreasing radii at increasing angles to close the digital circuit corresponding to the numeral of the multiplier on the digital circuits corresponding to the numerals of the multiplicand for selectively completing the immobilizing circuits to energize said devices and break the actuating circuits to deenergize the clutches when operative in variable degree according to the products of the multiplicand numerals multiplied by the said numeral of the multiplier.

6. In an electrically actuated calculating apparatus for multiplying quantities involving whole numbers or decimal fractions, an accumulator comprising members corresponding to decimal orders, denominational clutches to operate the members, means to render the clutches effective at the zero point of a cycle and including actuating circuits corresponding to the significant orders of the multiplicand to energize the clutches, digital circuits corresponding to the significant numerals of the multiplicand, digital circuits corresponding to the significant numerals of the multiplier, immobilizing circuits and devices controlled by last said circuits, means including a progressive timing member operative from zero position and synchronized with the accumulator members to close a selective digital circuit corresponding to a numeral of the multiplier on the digital circuits corresponding to the numerals of the multiplicand for selectively completing the immobilizing circuits to energize said devices and break the actuating circuits to deenergize the clutches when operative in variable degree according to the products of the multiplicand numerals multiplied by a said numeral of the multiplier, and means for column shift comprising a transmitter provided with switch elements, a clutch to operate the transmitter, means including selective conductors of different amplitude and a denominational circuit corresponding to the initial significant numeral of the multiplier to energize the last said clutch and cause the transmitter to shift the said circuit correspond-

ing to said initial numeral of the multiplier, and said actuating and immobilizing circuits, upwards or downwards into cooperative connection with the accumulator members denominationally higher or lower than the orders of the multiplicand, commensurately with the denominational value of said initial significant numeral of the multiplier above or below the units order.

7. In an electrically actuated calculating apparatus for multiplying quantities involving whole numbers or decimal fractions, an accumulator comprising members corresponding to decimal orders, denominational clutches to operate the members, means to render the clutches effective at the zero point of a cycle and including actuating circuits corresponding to the significant orders of the multiplicand to energize the clutches, digital circuits corresponding to the significant numerals of the multiplicand, digital circuits corresponding to the significant numerals of the multiplier, immobilizing circuits and devices controlled by last said circuits, means including a progressive timing member synchronized with the accumulator members operative from zero position and to close a selective digital circuit corresponding to a numeral of the multiplier on the digital circuits corresponding to the numerals of the multiplicand for selectively completing the immobilizing circuits to energize said devices and break the actuating circuits to deenergize the

clutches when operative in variable degree according to the products of the multiplicand numerals multiplied by said numeral of the multiplier, and means for column shift comprising a transmitter provided with switch elements, a clutch to operate the transmitter, conductors corresponding to variable degrees of column shift, and means including a denominational circuit corresponding to the highest significant order of the multiplier closed to a said conductor to energize the last said clutch and cause the transmitter to switch the digital circuit corresponding to the initial significant numeral of the multiplier, the said actuating circuits and the said immobilizing circuits, upwards or downwards into cooperative connection with the accumulator members denominationally higher or lower than the orders of the multiplicand commensurately with the denominational value of said initial significant numeral of the multiplier above or below the units order; and means including a conductor synchronized with the timing member to actuate the last said clutch after each partial operation and cause the transmitter to switch current to the circuit corresponding to the denominationally next lower numeral of the multiplier and shift said actuating and immobilizing circuits into cooperative connection with the accumulator members of progressive lower orders.

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