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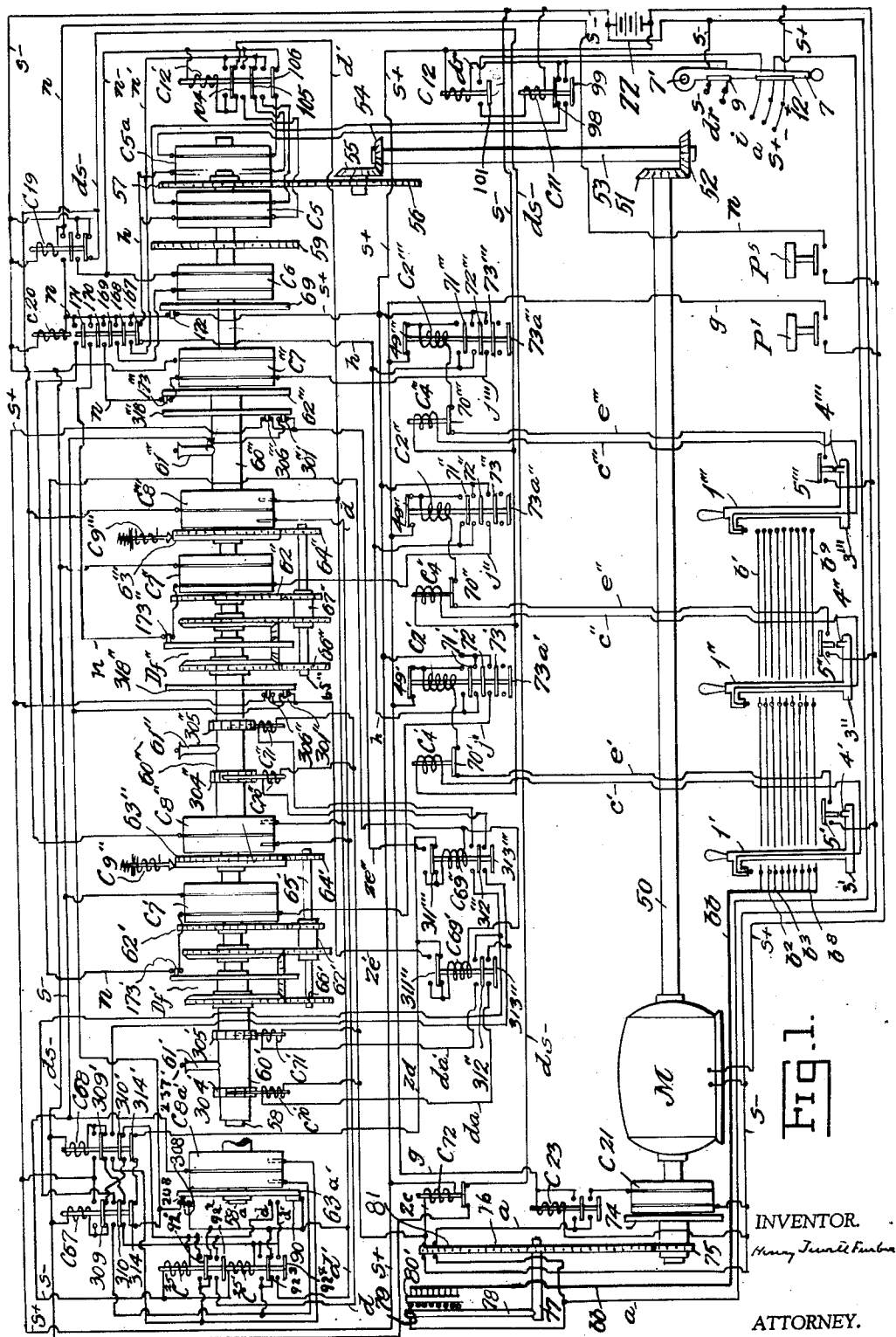
H. J. FURBER

2,190,710

CALCULATING MECHANISM

Original Filed Oct. 3, 1935

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

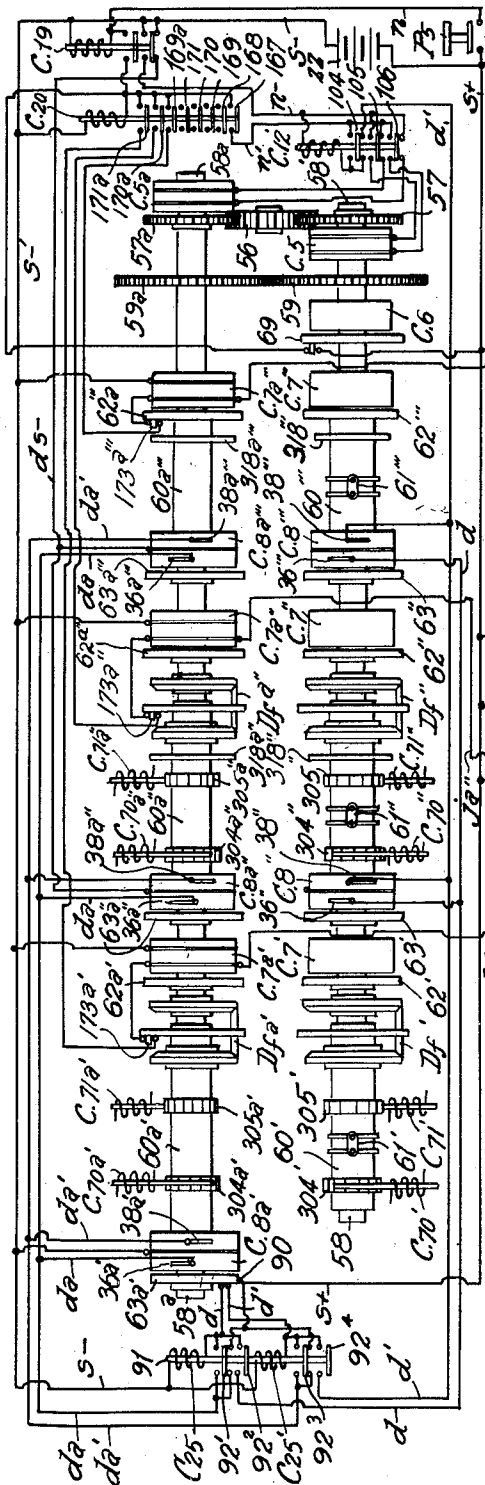


Fig. 2.

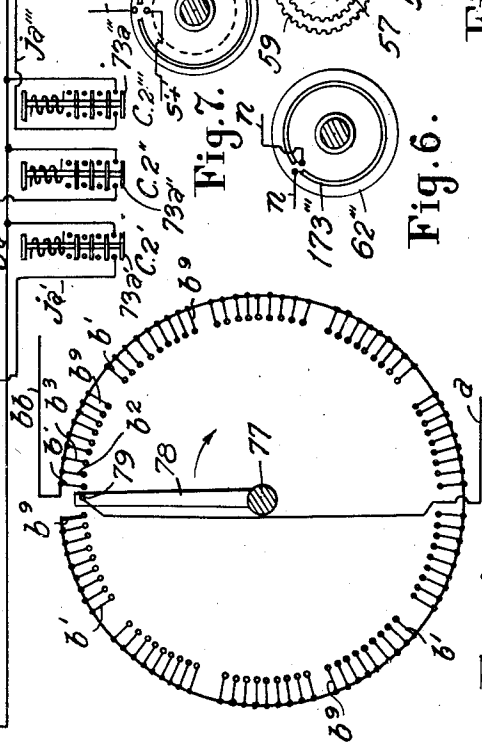
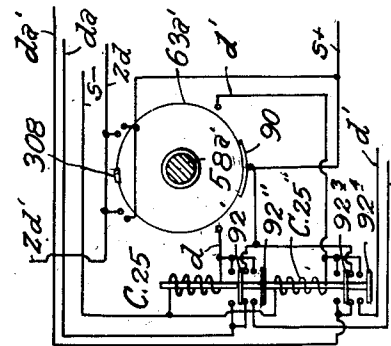


Fig. 4.



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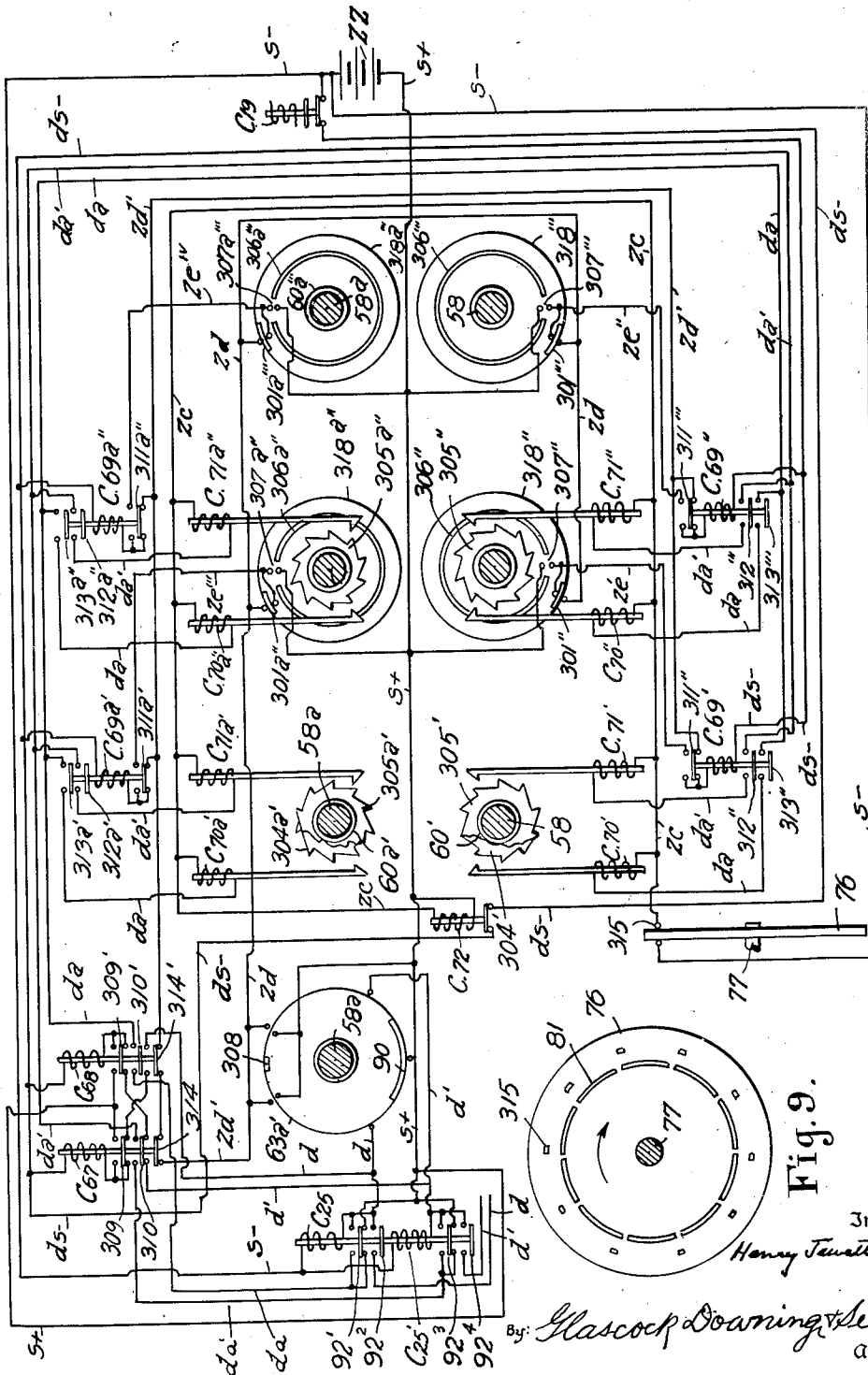


Fig. 8.

Fig. 9.

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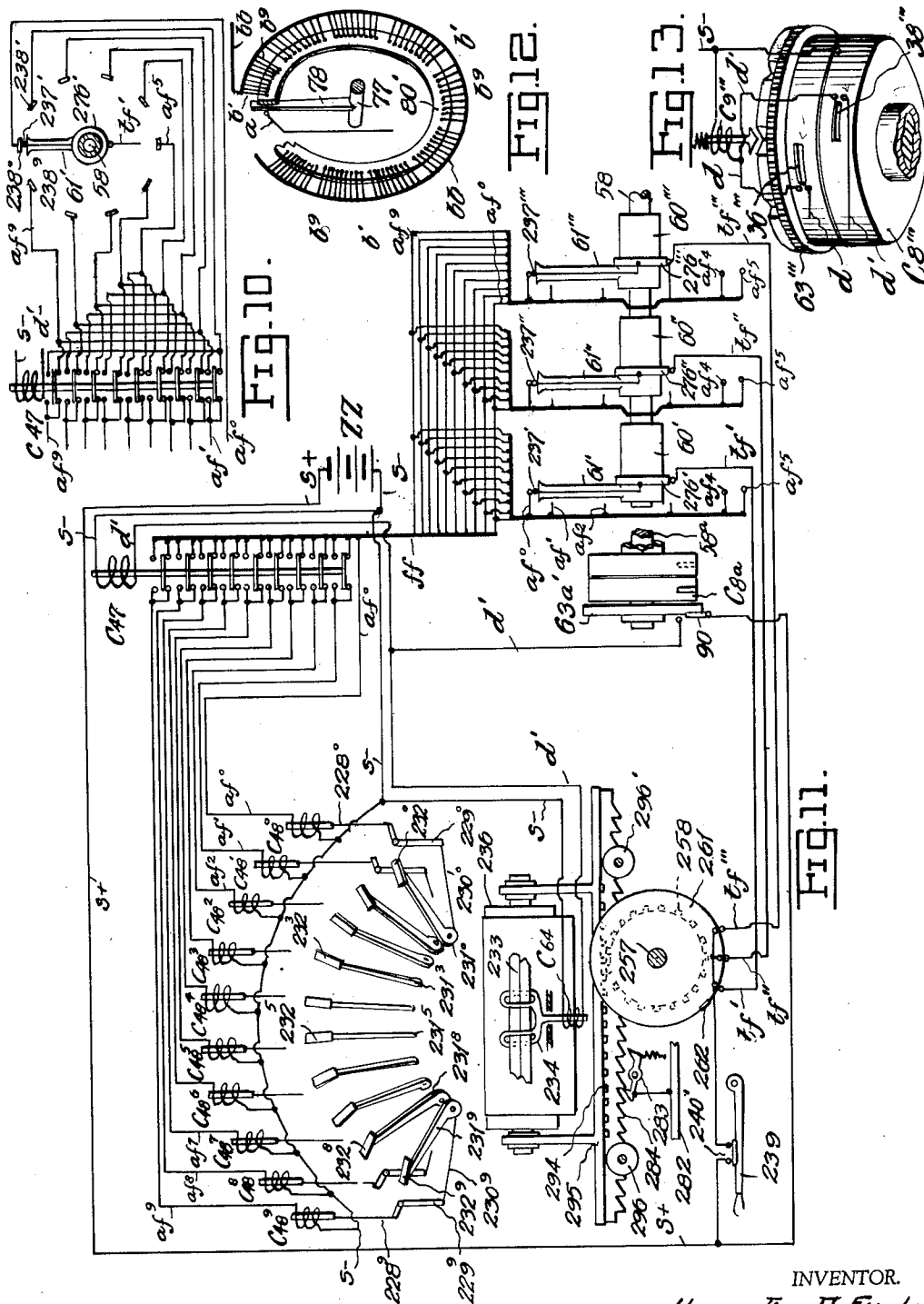
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4 Sheets-Sheet 4



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CALCULATING MECHANISM

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Original application October 3, 1935, Serial No. 44,159. Divided and this application June 15, 1936, Serial No. 85,359

9 Claims. (Cl. 235-133)

This invention relates to improvements in transfer mechanism and the present application is a division of my application Serial No. 44,159 filed on October 3, 1935, which is a continuation in part of application Sr. No. 723,595 filed May 2, 1934.

An object of this invention is to provide in computing apparatus, improved transfer means whereby tenth cyclic step carry-over shall be transmitted in additive accumulation, whether the operation be within the zone of positive quantities, or within the zone of negative quantities; and cyclic first step transfer shall be effected both when a positive quantity be subtracted from a positive quantity, and when a negative quantity be subtracted from a negative quantity.

Another object of this invention is to provide improved means whereby, during the first step of the computing apparatus from zero position, the transfer mechanism shall be automatically conditioned for cyclic tenth step transfer in additive operations and for cyclic first step transfer in subtractive operations, whether the operation be within the zone of positive or of negative quantities.

Another object of this invention is to provide improved means whereby in passing through zero from the zone of positive into the zone of negative quantities; or vice versa, as for example, in the subtraction of a larger subtrahend from a smaller minuend, the cyclic phases of transfer shall automatically be varied; so that the minuend having been reduced to zero by subtractive first step transfer, the remainder of the subtrahend shall be accumulated by additive tenth step transfer.

Another object of this invention is to provide automatic means selectively to eliminate such transitional carryover as may be developed at various orders of the computing apparatus, in operations passing from the zone of positive into the zone of negative quantities, or vice versa.

Additive accumulation by cyclic tenth step transfer, is, in earlier types of calculating apparatus, restricted to positive quantities; negative quantities being additively accumulated by cyclic first step transfer. This is obstructive to subtractive operation on negative quantities, in which, as in division or in the extraction of a radical, the reduction of the quantity to zero or to a negligible remainder is required. It is an object of this invention to remove such limitation, by improved means whereby, whether within the zone of positive or of negative quantities,

identical forms of computation may be performed in identical transfer phases.

The numbering and lettering of my copending application No. 44,159 are preserved herein. Sufficient of the mechanism therein disclosed, is reproduced in the present application, to illustrate transfer in addition and subtraction, although not restricted to these operations.

With the foregoing and other objects in view, as will appear, I now describe my invention in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic view of calculating apparatus embodying this invention, adapted to addition and subtraction.

Figure 2 is a diagrammatic plan view, showing the transfer mechanism with electrical connections.

Figure 3 is a view from the left of a disk 63a' with electrical connections, which selectively condition the phases of the transfer mechanism.

Figure 4 is a view from the right of a timing arm 78, and electrical connections, which arrest operation of accumulator arms 61', 61'', 61''', shown in Figure 1 at predetermined stages.

Figure 5 is a view from the right of transmission from shaft 53 to shafts 58, 58a, shown in Figure 2.

Figure 6 is a view from the left of a typical disk 62''' with electrical connections operative in restoring to zero position the members of a denominational order.

Figure 7 is a view from the left of a disk 69, which controls circuits to the clutch C6 shown in Figures 1 and 2, when clearing apparatus.

Figure 8 is a diagrammatic view partly in section, of selective compensating mechanism, which modifies transfer in transitional operations.

Figure 9 is a view from the right of a timing wheel 76, which closes at predetermined phases circuits to the compensating mechanism.

Figure 10 is a side view from the right of a typical accumulator arm 61', shown in Figure 1, with electrical connections.

Figure 11 is a view of mechanism employed in recording resultants and the quality thereof.

Figure 12 is a perspective view from the right illustrating the pathway of the timing arm 78, shown in Figures 1 and 4, when closing circuits to terminals of wires b'-b'' fixed to the bench 80'.

Figure 13 is a detail perspective view from upper right of a typical transfer clutch C.8' with positioning pin and electrical connections.

All wheels disclosed in figures are toothed throughout. There are no mutilated gearings. Cables carrying a plurality of wires are identified by heavy lines. Arrows indicate direction. Directional movement to the right as in Figures 5, 10 and 13, which are viewed from the right, is termed clockwise, or as positive; and movement to the left is termed contra-clockwise, or as negative.

- 10 The term "accumulator" is employed to designate collectively the members 61', 61'', 61''' (Figures 1 and 2), the members 61', 61'', 61''' being individually termed "accumulator arms."

GENERAL DESCRIPTION

- 15 The quantities subject to operation may be transmitted to the calculating unit (Figure 1), by means of electric circuits controlled by the manual levers 1', 1'', 1''', or by equivalent devices. A master switch 7 which selectively closes circuits presently described is placed at +, to cause the accumulator arms to operate in positive direction; and at -, to cause the accumulator arms to operate in negative direction the nature of the operation which shall be performed. The depression of the push button P.1, initiates transmission of motion from an electric motor M, preferably in constant operation and revolving always in the same direction, to the accumulator arms 61', 61'', 61''' (Figures 1, 10, and 11), which are elements respectively, in denominational orders of the apparatus and correspond to hundreds, tens and units. Motion is further communicated by the motor M to a progressively movable switch or timing arm 78 (Figures 1, 4,) which measures the movement of the accumulator arms 61', 61'', 61''', and arrests them at angles of displacement corresponding to quantities selected at the manual control levers 1', 1'', 1'''.
- 40 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 nature of the mathematical operation, and the positive or negative qualities of the quantities involved.

- 45 The timing wheel 76 (Figures 1, 9) closes and breaks circuits through conductors which it carries, in such selective order, as to bring the members thereby affected into operation in their proper turn.

- 50 The items or the resultants latent in the accumulator and reflected at the arms 61', 61'', 61''' are indicated at recording mechanism shown in Figures 10 and 11, and presently described, the accumulator arms each closing step by step in its angular displacement, circuits progressively corresponding to the numerals 0-9 (Figure 10).

- 55 The motor M connected through wires s+, s- with the source ZZ (Figure 1), imparts motion through the shaft 50, wheels 51, 52, shaft 53 (Figures 1, 5), wheels 54, 55, 56, and, in addition of positive quantities, through the gear 57 and clutch C.5, to the shaft 58, on which are loosely mounted the sleeves 60', 60'', 60''', carrying respectively, the accumulator arms 61', 61'', 61''', which collectively, together with transfer mechanism, are termed the accumulator. In subtraction of positive quantities, motion is transmitted from the wheel gear 56, geared armature 57a and clutch C.5a to the shaft 58a, and thence through the wheels 59a, 59, to the shaft 58 (Figures 1, 2, 3). The wheels 59a, 59 are fixed respectively upon the shafts 58a, 58, and are continually in mesh.

Motion is selectively transmitted to the sleeves 60', 60'', 60''' by the electric clutches C.7', C.7'', C.7''', which are fixed to the shaft 58. The sleeves 60', 60'', 60''' are loosely mounted on the shaft 58. The armature 62''' is integral with the sleeve 60'''. The armature 62'' floating on shaft 58, transmits motion to the sleeve 60'' through the composite idler 67'' floating on the pivot 65'', and through the differential gearing Df'', the middle member of which is integral with the sleeve 60''. The armature 62' floating on the shaft 58, imparts motion to the sleeve 60', in similar manner, through the composite idler 67' and the differential gearing Df'. The differentials Df', Df'' are introduced, in order that the accumulator arms 61', 61'', may be responsive, each to quantities originating in its own denominational order while simultaneously absorbing carry over from orders therebelow.

The manual controls comprise the levers 1', 1'', 1''' (Figure 1) corresponding respectively to the denominational orders, hundreds, tens and units.

- The master switch 7, pivoted at 7', is provided with conductors 9, 12, which, according to the position +, -, in which the master switch be manually placed, close circuits that condition the apparatus selectively for the operation which is to be performed. So closed, in addition of a positive quantity, is circuit of the wire a (Figure 1) to the timing arm 78, as follows: ZZ, s+, 12, a, terminal 79 progressively closed, as presently described, to the numeral wires b'-b⁹, for example to b³, selectively closed by lever 1' to c', C.4', s-, ZZ. Circuits of said wires b'-b⁹, may be selectively and simultaneously closed by any one or more of said levers 1', 1'', 1''', the lever 1'' closing circuit from said wire b³, for example, to wire c'' to C.4'', s-, ZZ; and the lever 1''' closing circuit, for example, of said wire b³, to c''' to C.4''', s-, ZZ. Closed likewise by master switch 7 (Figure 1) when in positive position, is circuit of the wire dr to the clutch C.5, as follows: ZZ, s-, 9, dr, bridged at 98 to C.5, h bridged at 167 (Figure 1) and one or more bridges 72', 72'', 72''' to s+, ZZ. The clutch C.5 revolves the accumulator shaft 58 (Figures 1, 2, and 5) and arms 61', 61'', 61''' clockwise, see arrow (Figure 5). The master switch 7, when placed in negative position closes the circuit of the wire a above described; and closes further to the relay C.12, circuit of the wire dr as follows: ZZ, s-, 9 dr to C.12, s+, ZZ. Master switch 7 in negative position also closes circuit of the wire i, to the relay C.11 as follows: ZZ, s+, 12, i bridged at 101 to C.11, s-, ZZ. So energized the relay C.11 closes at bridge 99 circuit of dr to the clutch C.5a, which said circuit is ZZ, s-, 9, dr bridged at 99 to C.5a, h bridged at 167 (Figures 1 and 2), and at one or more bridges 72', 72'', 72''' to s+, ZZ. If the levers 1', 1'', 1''' be active, the said circuit of wires dr and of h is closed at the respective bridges 72'', 72''', in like manner to s+, ZZ. The clutch C.5a, energized thereby, transmits motion in contra-clockwise direction, through 58a, 59a, 59, to the accumulator shaft 58 and arms 61', 61'', 61'''.
- In the addition of a negative quantity to a negative quantity the master switch 7 is placed at - to operate the accumulator in negative direction; and in the subtraction of a negative quantity from a negative quantity, the master switch 7 is placed at +, to operate the accumulator in positive direction. In the addition of a positive quantity to a negative quantity, the master

switch 7 is placed at +. In the addition of a negative quantity to a positive quantity the master switch 7 is placed at -. In the subtraction of a negative quantity from a positive quantity the master switch 7 is placed at +. In the subtraction of a positive quantity from a negative quantity the master switch 7 is placed at -, the signs + and - at the member 7, signifying positive and negative direction.

- 10 Fixed together with the levers 1', 1'', 1''', on the shafts 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''', releases their corresponding bridges, which falling, close circuits respectively, over the wires e', e'', e''', to the relays C.2', C.2'', C.2'''. These relays, so energized close at bridges 73', 73'', 73''' circuit to the clutches C.7', C.7'', C.7''', which transmit motion, respectively to the accumulator arms 61', 61'', 61'''.

- 20 Fixed on the motor shaft 50, is the clutch C.21, which, when energized, transmits motion through the armature 74, pivoted in solidarity with the pinion 75 on shaft 50, to the timing wheel 76 fixed to the shaft 77, together with the timing arm 78 (Figures 1, 4).

- 25 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 moves a unitary step of 36°.

- 30 The accumulator arms 61', 61'', 61''', when set in motion, are respectively, arrested at angles of displacement determined by the manual levers 1', 1'', 1'''. Leading from terminals at the bench 80' (Figure 1) on which wire a may be closed by the timing arm 78, are the wires b¹-b⁹, corresponding to the numerals 1 to 9. These wires are shown as carried in the cable bb, and as severally extended past all the levers 1', 1'', 1'''.

- 40 According to the angles at which such levers be deflected, selected b circuits are closed on the wires c', c'', c''', to the relays C.4', C.4'', C.4'''. Let lever 1''', wire c''' and the relay C.4''', serve as an example. If the quantity involved in an operation be 3; the lever 1''', corresponding to the units order, is manually deflected so that the wire b³ is closed on the wire c''' to the relay C.4'''. It is the function of the relay C.4''', when circuit be completed at the revolving timing arm 78 (Figures 1, 4), through the wires a, b³, c''', to retract its plunger and break at bridge 70''' circuit to the relay C.2''', causing this latter relay to release its plunger and break circuit to the clutch C.7'''. Motion of the sleeve 60''' and of the accumulator arm 61''', is thereby arrested, at an angular displacement corresponding to three units, and closes circuit to recording mechanism presently described (Figures 10 and 11). The accumulator arms 61', 61'', when operated, are similarly arrested through action of the relays C.4', C.4'', which break circuit respectively, at bridges 70', 70'', to the relays C.2', C.2''.

- 65 The timing arm 78 (Figures 1, 4) carries a conductor 79, which, in its orbit, may close circuit of the wire a progressively to the wires b¹, b⁹ (Figures 1, 4) the terminals of the b wires being so spaced, that movement of the timing arm 78 to one and then another of the terminals of the b wires, corresponds to a unitary step displacement of an accumulator arm 61', 61'', 61'''. The pathway of the timing arm 78 in so closing circuit to the terminals of wires b¹-b⁹, is shown in Figure 12. The terminals of the wires

b¹-b⁹, as shown in Figure 4, are recurrent in successive groups; in order to obviate the necessity of restoring the timing arm 78, at the beginning of each new operation, to the perpendicular position shown as normal in Figures 1, 4, and 12. Between each two said successive groups of b¹-b⁹ terminals, is a vacant space corresponding to zero, from any one of which the timing arm 78 may enter a new operation of addition or subtraction, the single typical group of b¹-b⁹ terminals shown in Figure 1, being otherwise sufficient, completely to illustrate the operation of the timing arm 78 and contact 79. The step displacement of the accumulator arms, coincide accordingly, with the serial number of the b wire 15 or wires closed at the levers 1', 1'', 1'''. It thus appears that the movement of the accumulator arms 61', 61'', 61''' respectively, is provoked by circuits through the wires e', e'', e''', to the relays C.2', C.2'', C.2'''; and is arrested by circuits closed through the wires c', c'', c''', to the relays C.4', C.4'', C.4''', when the timing arm 78 reaches the terminals of the b wire or wires closed at the levers 1', 1'', 1'''.

In order that it be not necessary to restore 25 the timing arm 78 to normal perpendicular position, as shown in Figure 4, at the conclusion of each operation, terminals of the b wires are recurrent throughout the orbit of the conductor 79, a zero space separating each series, at any 30 of which an operation may begin.

Addition

Assume, as an example, that the quantity 232 be transmitted to the accumulator arms 61', 61'', 61''' (Figure 1) by an operation of addition. The levers 1', 1'', 1''' are closed respectively on the wires b², b³, b². Deflection of the levers closes at bridges 5', 5'', 5''', circuit to the relays C.2', C.2'', C.2'''. The master switch 7 is 40 placed in position +, closing the positive wire a to the timing arm 78 and the negative wire dr over bridge 98 at the relay C.11 to the clutch C.5. The relay C.11 remains deenergized in the addition of positive quantities. Levers and master switch having been adjusted, the push button P.1 is momentarily depressed, imparting through the wire g an initial impulse to the clutch C.21, and over the bridges 49', 49'', 49''' to the relays C.2', C.2'', C.2''', which are then 50 held in stick by circuit s+, closed over the bridges 71', 72', at relay C.2' and corresponding bridges at relays C.2'', C.2'''. The circuits so closed originate at the source ZZ and extend through the wire s-, bridges 5', 5'', 5''', wires 55 e', e'', e''', to the negative poles of the relays C.2', C.2'', C.2''', and from their positive poles, through the wire s+, back to the source ZZ. The relays C.2', C.2'', C.2''', when severally so energized, close at the respective bridges 73', 73'', 73''' circuits to the clutches C.7', C.7'', C.7''', respectively and serially as follows: (1) Source ZZ, s+73', j', C.7', s-, ZZ; (2) Source ZZ, s+, 73'', j'', C.7'', s-, source ZZ; and (3) Source ZZ, 65 s+, 73''', j''', C.7''', s-, source ZZ. Closed likewise by the relays C.2', C.2'', C.2''' at the bridges 72', 72'', 72''' are circuits to the clutch C.5 respectively and serially as follows: (1) ZZ, s+, 72', h bridged at 167 to C.5, dr bridged at 98, to 9, 70 s-, ZZ; (2) ZZ, s+, 72'', h bridged at 167 to C.5, dr bridged at 98 to 9, s-, ZZ; and (3) ZZ, s+, 72''', h bridged at 167 to C.5, dr bridged at 93 to 9, s-, ZZ. So energized the clutch C.5 imparts movement in clockwise direction to the shaft 58 75

and through clutches C.7', C.7'', C.7''', to the accumulator arms 61', 61'', 61'''.

Depression of the push button P.1, transmits momentary impulse to the relay C.23 and the clutch C.21. The circuit so closed at P.1 is as follows: ZZ, s+ bridged at P.1 to wire g, C.23, s—, ZZ. The relay C.23 so energized as P.1 is depressed, bridges to the clutch C.21, circuit of the wire g as follows: ZZ, s+ bridged at P.1 to wire g, bridged at C.23 to C.21, s—, ZZ. This impulse brings into operation the clutch C.21 which rotates the timing wheel 76 sufficiently to close through a conductor 81 (Figure 9) carried by the timing wheel 76, circuit of the wire a to the relay C.23, which is thereby held in stick, and closes over its lower bridge circuit of wire a to the clutch C.21. The circuit so closed to C.23 through wire a originates at source ZZ (Figure 1) and extends through s+, 12, a, closed at 81 (Figures 1 and 9), and upper bridge at C.23 to said C.23, s—, to ZZ. The circuit of wire a to C.21, is as follows: ZZ, s+, 12, closed at 81 and lower bridge at C.23, to C.21, s— to ZZ. The conductor 81 is of such amplitude that circuit to the clutch C.21 is thereby sustained, until the termination of the operation, and the timing arm (Figure 4) reaches a neutral position between two series of b terminals.

Rotation of the accumulator arms continues, until the timing arm 78, moving from a neutral position and carrying the conductor 79 (Figure 4) closes the wire a on a terminal of the wire b² closed through the levers 1', 1'', 1''' on the wires c', c'', (Figure 1) respectively to the relays C.4', C.4'', the negative poles of which are connected through the wire s— back to the source ZZ. The relays C.4', C.4'', so energized break at bridges 70', 70'', respectively, circuits e', e'', to the relays C.2', C.2'', which break circuit to the clutches C.7', C.7'', and arrest the accumulator arms 61', 61'', at a displacement of two steps, corresponding to the wire b² and the first and last digits of the quantity 232. Circuits still being closed at the relay C.2', to the clutches C.5, C.7'', the accumulator arm 61'' continues to rotate until the timing arm 78 carries the conductor 79 to the terminal of the wire b³, where circuit is closed from the wire a through the wire b³ closed by the lever 1'' to the relay C.4'', which in turn breaks circuit e'', to relay C.2''. Circuit is thereby broken to the clutches C.7'', C.5, the accumulator arm 61'', being arrested at a three step displacement, corresponding to the second digit of the quantity 232. The circuit of the wire h now being open, clutch C.5 ceases to rotate the shaft 58.

Assume that to the quantity 232 entered at the accumulator, 389 were added in manner above described, levers 1', 1'', 1''', closing respectively on the wires b³, b⁸, b⁹, and the push button P.1, being again depressed. This would involve carry over, the sum being 621. Under conditions assumed, as later will be more fully described, circuit is closed at the relay C.25 (Figures 2, 3) on the wire d which leads to the clutches C.8'', C.8''' integral respectively with the sleeves 60'', 60''', which carry the accumulator arms 61'', 61'''. The circuit closed to the relay C.25 (Figures 1, 2, and 3) is ZZ, s+, 90 closed on wire d to C.25, s—, ZZ, s+ being constantly closed to 90 which is rotated to close at its respective extremities circuit of s+ to wire d or d'. Carried by the clutches C.8'', C.8''' are contact bands 36'', 36''' so placed relatively to the terminals of the wire d, that the clutches, C.8'', C.8''', re-

volved clockwise by shaft 58 in the addition of positive quantities (see arrow on member 57, Figure 5) are energized at each tenth cyclic step; and clutching their respective armatures 63'', 63''' (Figures 1 and 2) floating on shaft 58, transfer, during each such tenth step, additive carry over to next higher denominational orders. The armatures 63'', 63''' are provided at their peripheries with spur gears, to operate transmission presently described. The circuit closed at said contact band 36'' to C.8'' (Figure 2) is as follows: ZZ, s+, 90 closed on wire d (Figure 3) bridged at 92² to 36'', C.8'', ds—, lower bridge at C.19, s—, ZZ. The circuit closed at said contact band 36''' to C.8''' is ZZ, s+, 90 closed on wire d (Figure 3) bridged at 92² to 36''' (Figure 2), C.8''', ds—, lower bridge at C.19, s—, to ZZ. The clutch C.8'' of the tens order transmits carry over (Figure 1) to the hundreds order for example, through 63'', 64', 65', 66' to Df', the left hand member whereof floats on, and the middle member is integral with the sleeve 60' which carries the accumulator arm 61' of the hundreds order. Transmission from the units order to the tens, is similarly effected through transmission 63'', 64'', 65'', 66'', Df'' and sleeve 60''. In present example, 232+389=621, the accumulator arm 61''' performs a complete revolution, transmitting carry over to the tens order; and is arrested at a net displacement of one step. The accumulator arm 61'' advanced eight steps, plus a carry over, transmits a carry over to the hundreds order; and is arrested at a net displacement of two steps. The accumulator arm 61', is advanced three steps plus carry over; and is arrested at a net displacement of six steps. The resultant entered at the accumulator is thus 621.

The wire d leading to the contact bands 36'', 36''', remains active, as presently explained, so long as operations remain within the zone of positive quantities. When within the zone of negative quantities, the wire d' is active. When the accumulator be at zero circuits of both wires d and d' are open.

Subtraction

In subtraction in positive quantities the same circuits are closed by the master switch 7, as in addition, and further, at the conductor 12, the circuit of the wire i which leads over the bridge 101 closed by the relay C.12 to the positive pole of the relay C.11, whose negative pole is connected through wire s— back to the source ZZ. The circuit closed to relay C.11 is ZZ, s+, 12, i bridged at 101 to C.11, s—, ZZ. The relay C.11 so energized switches at bridge 99, the circuit dr to the clutch C.5a. The circuit to the clutch C.5a, is ZZ, s—, 9, dr bridged at 99 to C.5a, h bridged at 167 and a bridge 72', 72'', 72''' to s+, ZZ. Motion is transmitted through shaft 58a and wheels 59a, 59 (Figures 2, 5) in contra-clockwise direction to the shaft 58 and thereby to the accumulator arms 61', 61'', 61'''. The operation of levers 1', 1'', 1''', of the push button P.1, and of the timing arm 78 moving in unchanged direction, remains as in addition.

Were the minuend 574, for example, set up at the accumulator 61', 61'', 61''' (Figure 1), and the quantity 232 again set up, as hereinbefore described, at the levers 1', 1'', 1''', to serve now as a subtrahend; the accumulator arm 61' would be reversed two steps by motion transmitted from the motor M through the coils C.5a, C.7'; and be arrested at a net displacement of three steps, when the timing arm 78 (Figures 1, 4) reaches,

and closes circuit at a terminal of the wire b^2 . The accumulator arm $61''$ would be reversed three steps and be arrested at a net displacement of four steps, when the timing arm 18 reaches the terminal of the wire b^3 ; and the accumulator arm $61'''$ already arrested as the timing arm 18 closes on the terminal of the wire b^2 , is reversed two steps and rests at a net displacement of two steps. The remainder at the accumulator $61'$, $61''$, $61'''$ would accordingly be 342.

Movement of the timing arm 18 is maintained, as in addition, until it reaches a neutral position between two series of b terminals.

Transfer mechanism

The shafts 58, 58a (Figures 1, 2) are rotated simultaneously as hereinbefore described. The shaft 58 carries the accumulator arms $61'$, $61''$, $61'''$; together with the clutches $C.8''$, $C.8'''$, which transfer carry-over. The mechanism carried by shaft 58a is a circuit controller; and will be designated by this term, in following pages, clearly to distinguish it from the accumulator carried by shaft 58. The said circuit controller is provided with transfer mechanism; and its purpose is, as presently described, solely to conduct the transfer phases of the accumulator, so that the clutches $C.8''$, $C.8'''$, which transfer additively a carry over of positive quantity during each cyclic tenth step and transfer subtractively a denominational unit of positive quantity during each cyclic first step, when operating within the zone of positive quantities, shall, to similar effect, transfer additively a carry over of negative quantity during each cyclic tenth step and shall transfer subtractively a denominational unit of negative quantity during each cyclic first step, when operating within the zone of negative quantities.

In Figure 2, the shafts 58, 58a are shown in plan view. In Figure 1, they are shown with the shaft 58a largely obscured. In Figure 1, the clutch $C.8a'$ and armature $63a'$ at the extremity of the shaft 58a, appear with the shaft 58a broken, to distinguish shaft 58a from the shaft 58.

The shaft 58a (Figure 2) carries the sleeve $60a'$, $60a''$, $60a'''$ of the circuit controller which are rotated respectively by the clutches $C.7a'$, $C.7a''$, $C.7a'''$ as the sleeves $60'$, $60''$, $60'''$ of the accumulator, carried by the shaft 58 are 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, 2) through the wires j' , ja' , to the clutches $C.7'$, $C.7a'$. Circuit is closed simultaneously at the bridges $73''$, $73a''$, through the wires j'' , ja'' to the clutches $C.7''$, $C.7a''$, and circuit is closed simultaneously, at the bridges $73'''$, $73a'''$, through the wires j''' , ja''' , to the clutches $C.7'''$, $C.7a'''$. The circuits so closed to $C.7'$, $C.7''$, $C.7'''$ of the accumulator, have been already traced. The circuits to the clutches $C.7a'$, $C.7a''$, $C.7a'''$ of the circuit controller are as follows: Circuit to $C.7a'$ is ZZ, s+ bridged at $73a'$ (Figure 2) to ja' , $C.7a'$, s—, to ZZ. Circuit to $C.7a''$ is ZZ, s+ bridged at $73a''$ to ja'' , $C.7a''$, s—, to ZZ. Circuit to $C.7a'''$ is ZZ, s+ bridged at $73a'''$ to ja''' , $C.7a'''$, s—, to ZZ.

The armature of the clutch $C.7a'$ is the wheel $62a'$ which floats on shaft 58a and transmits motion to the sleeve $60a'$, through a composite idler not shown but similar to the idler $67'$ (Figure 1), and the differential Dfa' (Figure 2) the middle member of which is fixed to the sleeve $60a'$. The armature of the clutch $C.7a''$ is the wheel $62a''$,

which floats on the shaft 58a and transmits motion to the sleeve $60a''$ through a composite idler similar to idler $67''$ (Figure 1), and the differential Dfa'' (Figure 2), the middle member of which is fixed to the sleeve $60a''$. The armature of the clutch $C.7a'''$ is the disk $62a'''$ fixed to the sleeve $60a'''$.

The carry-over, at the circuit controller on 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 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 2) 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 $60a''$, and transmission similar to the transmission $64'$, $65'$, $66'$, (Figure 1), and the differential Dfa' (Figure 2), the left lateral member of which floats on the sleeve $60a'$.

Integral with the sleeve $60a'$ of the circuit controller is a clutch $C.8a'$ (Figures 1, 2) similar to the clutches $C.8a''$, $C.8a'''$, which transmits carry-over to an order consisting of a single member, the armature $63a'$. This order is higher than the highest order or the accumulator and corresponds to thousands, in the present drawings. The armature $63a'$ carries a conductor 90 (Figures 2, 3) which controls duplicate circuits to the clutches $C.8a'$, $C.8a''$, $C.8a'''$ of the circuit controller and, $C.8''$, $C.8'''$ of the accumulator. When circuit of the wire d is closed by the conductor 90; the relay $C.25$ is energized by the circuit ZZ, s+, 90, d to $C.25$, s—, ZZ; and d is bridged at $92'$ to da' . When d' is closed by the conductor 90; the relay $C.25'$ is energized by the circuit ZZ, s+, d' to $C.25'$, s—, ZZ; and d' is bridged at 92^3 to da' . Said circuits (Figures 2 and 3) to the clutch $C.8a'$, are ZZ, s+, 90, d , $92'$, da' , $36a'$, $C.8a'$, s—, ZZ; and secondly, ZZ, s+, 90, d' , 92^3 , da' , $38a'$, $C.8a'$, s—, ZZ. Said circuits to clutch $C.8a''$ are ZZ, s+, 90, d , $92'$, da' , $36a''$, $C.8a''$, ds —, lower bridge at $C.19$, s—, ZZ; and secondly, ZZ, s+, 90, d' , 92^3 , da' , $38a''$, $C.8a''$, ds —, lower bridge at $C.19$, s—, ZZ. Said circuits to clutch $C.8a'''$ are ZZ, s+, 90, d , $92'$, da' , $36a'''$, $C.8a'''$, ds —, lower bridge at $C.19$, s—, ZZ; and secondly, ZZ, s+, 90, d' , 92^3 , da' , $38a'''$, $C.8a'''$, ds —, lower bridge at $C.19$, s—, ZZ. Said circuits to the accumulator clutch $C.8''$ (Figures 1 and 2) are ZZ, s+, 90, d bridged at 92^2 to $36''$, $C.8''$, ds —, lower bridge at $C.19$, s—, ZZ; and secondly, ZZ, s+, d' , bridged at 92^4 to $38''$, $C.8''$, ds —, lower bridge at $C.19$, s—, ZZ. Circuits to accumulator clutch $C.8'''$, are ZZ, s+, 90, d bridged at 92^2 to $36'''$, $C.8'''$, ds —, lower bridge at $C.19$, s—, ZZ; and secondly, ZZ, s+, 90, d' bridged at 92^4 to $38'''$, $C.8'''$, ds —, lower bridge at $C.19$, s—, ZZ.

Only after an initial step displacement be completed in some order of the circuit controller at shaft 58a, is circuit of the wire d or d' closed by the conductor 90 (Figure 3) to the accumulator clutches $C.8''$, $C.8'''$ (Figure 2), and these said clutches may accordingly be displaced in either direction during said initial step at the circuit controller, without subtractive transfer from accumulator orders thereabove. The contact bands $36''$, $36'''$, $38''$, $38'''$, extend each through 36° of arc less escapement at the terminals of wires d , d' .

In Figure 13 is shown the clutch $C.8'''$ which is typical of all the transfer clutches. Its arma-

ture 63''' is provided with two rims, one being a spur-gear which meshes with 64'' (Figure 1); the other carrying ten notches into one of which, at each successive step of its displacement, the angular extremity of an electric positioning pin C.9''' enters, to correct overdraught; block one lateral member of the differential D', when the other lateral member is alone in operation; and to insure precision in the transfer. C.9''' is energized during transfer by circuit of the wire *d* or of the wire *d'*. Circuit of the wire *d*, is ZZ, s+, 90 bridged at 92'' (Figures 1 and 13) and by the contact band 36''' to C.9''', s-, ZZ. Circuit of the wire *d'*, is ZZ, s+, 90 bridged at 92' and by the contact band 38''' to C.9''', s-, ZZ.

The terminals of the wires *d*, *d'* are so placed relatively to the respective contact bands 36''', 38''' that when the clutch C.8''' is energized by circuit of the wire either *d* or *d'*, C.8''' withdraws against a spring, its plunger from the above said notches. Similar, or other types of positioning pins well known to the art, may be employed at other rotary members where required.

When the circuit controller at shaft 58a is in zero position, and the circuit of wire neither *d* nor *d'* is active; circuit is closed from the wire s+ directly to the wire *da* and its terminals at the transfer clutches C.8a', C.8a'', C.8a''' (Figure 2). These terminals are so positioned, relatively to the contact bands 36a', 36a'', 36a''' fixed to said respective clutches and extending through 36° of arc less escapement from the terminals of wire *da*, that at the initial step of a said clutch C.8a', C.8a'', C.8a''', contra-clockwise, (as in the addition at the accumulator of a positive quantity to zero) the said transfer clutch C.8a', C.8a'', or C.8a''', initially displaced, is energized by the circuit *da* and transfers subtractive carry over, which causes all said transfer clutches of higher order at the circuit controller to transfer subtractive carry over, displacing thereby the armature 63a' to the position at which circuit of the wire *d* is closed through the conductor 90 (Figure 3) fixed to the periphery of said 63a'. Said circuit of *da* to the clutch C.8a' (Figure 2) originates at the source ZZ and extends through wire s+, bridged at 92' depressed to *da*, 36a', C.8a', s- to source ZZ. The corresponding circuit to clutch C.8a'' originates at source ZZ and extends through s+ bridged at 92' depressed to *da*, 36a'', ds-, lower bridge at C.19, s-, to ZZ. The corresponding circuit to clutch C.8a''' originates at source ZZ and extends through s+ bridged at 92' depressed to *da*, 36a'', C.8a'', ds-, lower bridge at C.19, s-, to ZZ.

Likewise, when the circuit controller is in zero position, circuit of the wire *da'*, above traced, is closed to terminals cooperative with said clutches C.8a', C.8a'', C.8a''' (Figure 2). These last said terminals are so positioned relatively to the contact bands 38a', 38a'', 38a''', fixed to said respective clutches and extending through 36° of arc less escapement from the terminals of wire *da'*, that at the initial step of a said transfer clutch C.8a', C.8a'', C.8a''', clockwise (as when at the accumulator a negative quantity be added to zero), the said transfer clutch C.8a', C.8a'' or C.8a''', initially displaced, is energized by the circuit of *da'*, and transfers subtractive carry over, which causes each said clutch of higher order at the circuit controller, to transfer subtractive carry over and displace the armature 63a' to the position at which the conductor 90

closes circuit of the wire *d'*. The said circuit of *da'* to the clutch C.8a' originates at the source ZZ and extends through s+, bridged at 92³, depressed to *da'*, 38a', C.8a', s-, to ZZ. Corresponding circuit to clutch C.8a'' originates at source ZZ and extends through s+, bridged at 92³ depressed to *da'*, 38a'', C.8a'', ds-, lower bridge at C.19, s-, to ZZ. Corresponding circuit of clutch C.8a''' originates at source ZZ and extends through s+ bridged at 92³, depressed to *da'*, 38a''', C.8a''', ds-, lower bridge at C.19, s- to ZZ.

When the wire *d* is closed by the conductor 90, circuit ZZ, s+, 90, *d*, C.25, s-, ZZ is completed to the relay C.25. The relay C.25 so energized displaces the members 91, which likewise may be displaced by the relay C.25' when energized and closes at the bridge 92², circuit through an extension of the wire *d* to the clutches C.8'', C.8''', the contact bands 36'', 36''' at which are so placed relatively to the terminals of the wire *d*, that the clutches C.8'', C.8''' are energized during each tenth step displacement clockwise in every revolution, and during such tenth step displacement transfer additively a positive, carry-over. At each first-step displacement in opposite direction within the zone of positive quantities the clutches C.8'', C.8''', borrow. So long as the operation be within the range of positive quantities, the wire *d* is active.

When the wire *d'* is closed by the conductor 90, circuit ZZ, s+, 90, *d'*, C.25', s-, ZZ is completed to the relay C.25'. The relay C.25' so energized, closes at the bridge 92² 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 during every tenth step displacement in every revolution opposite to clockwise, and at such tenth step displacement transfer additively a negative carry-over. At each cyclic first step displacement clockwise, within the range of negative quantities, the clutches C.8'', C.8''', borrow. So long as the operation be within the zone of negative quantities, the wire *d'* is active.

Where 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'.

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'''.

An initial step displacement as the circuit controller passes from zero position, into either positive or negative quantities, causes transfer subtractive carry-over, as above described, at the clutches C.8a', C.8a'', C.8a''', which displaces the armature 63a'. Conversely, as the calculating unit returns to zero position, through either positive or negative quantities, a last step displacement of a clutch C.8a', C.8a'', C.8a''', causes an additive carry-over to be transferred 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'''.

The transfer mechanism above described, is adequate and efficient in operation within the range of quantities both positive and negative,

provided the operation does not pass through zero from positive into negative quantities or vice versa. Should an operation so pass through zero complementary numerals become the measure of angular displacements and, transitional carry-over may occasion deficiency in denominational units reflected by members at shaft 58a, and an excess at shaft 58. This may be compensated as follows:

When, as previously described, the disk 63a' is carried back to zero, the carry-over circuits da, da' are both active at shaft 58a; whereas, at shaft 58, the carry-over circuits both d and d' are open. The effect of this is, that at shaft 58a each lower order which passes through zero with disk 63a', effects a double subtractive transfer from the order next above; and, at shaft 58, each lower order omits an additive carry-over to the order next above. In such event, above said deficiency and excess of transfer units, as presently described are both eliminated; and resultants are correct.

The several orders, all other than the hundreds order of the circuit controller at shaft 58a, may, however, not be at zero when the disk 63a' is carried through zero; or displacement may not carry them thereto. In this event, such next higher order may be deprived of a required step displacement at shaft 58a, measured in complementary digits, and at shaft 58 the displacement of the next higher order may be one step in excess. Examples:

(a) 111-999=-888. All orders pass simultaneously through zero, at shafts both 58, 58a. The circuit controller at shaft 58a is displaced proportionately to the numerals 998; and the accumulator at shaft 58 reflects the quantity -888. Resultant is correct.

(b) 622-743=-121. The tens and units orders at both circuit controller and accumulator, pass zero before the hundreds order of the circuit controller displaces the disk 63a'. Members at shaft 58a are displaced proportionately to the numerals 121. Accumulator reflects the quantity -231. Compensation is required to add a step to tens and hundreds orders at shaft 58a, and to subtract a step from tens and hundreds orders at shaft 58.

(c) 199-911=-712. At neither shaft is the tens and units order displaced to zero. Members at shaft 58a are displaced proportionately to the numerals 712, the accumulator reflects the quantity, -822. Compensation adds a step in the tens and hundreds orders at shaft 58a; and subtracts a step in tens and hundreds orders at shaft 58.

(d) 155-478=-323. The tens and unit order at both shafts, pass zero after the disk 63a'. Members at shaft 58a are displaced proportionately to the numerals 323; and the accumulator reflects the quantity, -433. Compensation adds a step, at shaft 58a in tens and hundreds orders; and subtracts a step in tens and hundreds orders at shaft 58.

(e) 342-475=-133. The tens order at both shafts passes zero with the hundreds order of the circuit controller, and the units order before. Members at shaft 58a are displaced proportionately to the numerals 233, and the accumulator reflects the quantity, -143. A step is added to the tens order at shaft 58a, and is subtracted in the tens order at shaft 58.

(f) 537-675=-138. The units order is displaced to zero at neither shaft. At shaft 58a the tens order passes zero with the hundreds order

of the circuit controller. At shaft 58, the tens order passes zero before the hundreds. At shaft 58a the members are displaced proportionately to the numerals 238. At shaft 58 the accumulator reflects the quantity, -248. A step is added only in the tens order at shaft 58a; and a step is subtracted in both tens and hundreds orders at shaft 58.

Numerically similar positive remainders would be developed; were negative subtrahends and smaller negative minuends involved, the mechanism then operating in reverse direction, the state-control T (Figure 1), as hereinbefore explained, be placed at -, to operate the accumulator in negative direction to accumulate a negative minuend; and being placed at +, to operate the accumulator in positive direction to subtract a negative subtrahend from a negative minuend.

Required compensation is effected by severally displacing sleeves 60', 60'', 60a', 60a'', together with the members fixed thereon, under the influence of the solenoids C.70', C.71'; C.70'', C.71''; C.70a', C.71a'; C.70a'', C.71a'', arranged in pairs; relays C.67, C.68 which determine which solenoid of respective pairs shall operate; and the relays C.69', C.69'', C.69a', C.69a'', which select the orders of the accumulator and of the circuit controller at which compensation shall be effected.

Compensation is effected at sleeve 60' (Figures 2, 8) by the solenoids C.70', C.71'; at sleeve 60'', by the solenoids C.70'', C.71''; at sleeve 60a', by the solenoids C.70a', C.71a'; and at sleeve 60a'', by the solenoids C.70a'', C.71a''. In the absence of decimal fractions, no compensation is required at the units order, which accumulates no carry over.

The solenoids above designated are similar in action. The armature of each said solenoid terminates in a latch which, when the solenoid is energized, operates on a ratchet wheel fixed to the sleeve 60', 60'', 60a', 60a'' of a corresponding order. Solenoids C.70', C.71', for example (Figure 8), operate respectively on ratchet wheels 304' 305', rotating subtractively at shaft 58, the accumulator sleeve 60' of hundreds order in respective opposite directions, according to the positive or negative quality of the denominational unit in excess. The solenoids C.70'', C.71'', similarly subtract at the accumulator sleeve 60'' of the tens order. Solenoids C.70a', C.71a' add respectively, a denominational unit at the sleeve 60a' in the hundreds order of the circuit controller; and solenoids C.70a'', C.71a'' respectively, add at the sleeve 60a'' of tens order at the circuit controller, according to the positive or negative quality of the deficient units. In Figure 8 the ratchet wheels 305', 305a' are broken away showing the opposed positions of ratchet wheels 304', 304a'.

Since the defective carry-over at each higher order originates at the order next below; compensation may properly be controlled by action of each such lower order on the order next above. Operation of the solenoids C.70', C.71' (Figures 2 and 8) corresponding to the hundreds order of the accumulator, is determined by the position of members in the tens order of the accumulator when the disk 63a' (Figure 8) of the circuit controller in passing to or through zero position, breaks, at the conductor 338, circuit of the wire zd. Operation of the solenoids C.70'', C.71'' corresponding to the tens order of the accumulator, is similarly determined by the position of the members in the units order of the

accumulator. Similarly, operation of the solenoids C.70a', C.71a' corresponding to the hundreds order of the circuit controller, is determined by the position of members in the tens order of the circuit controller; and operation of the solenoids C.70a'', C.71a'' corresponding to the tens order of the circuit controller, is determined by the position of members in the units order of the circuit controller.

10 The solenoids C.71', C.71'', C.71a', C.71a'', are active only in operations which pass from the zone of positive into the zone of negative quantities; and the solenoids C.70', C.70'', C.70a', C.70a'', are active only in operations which pass from the zone of negative quantities into the zone of positive quantities. The solenoids C.71', C.71'', C.71a', C.71a'' are conditioned by the relay C.67, active in operations which originate within the zone of positive quantities; and the solenoids C.70', C.70'', C.70a', C.70a'' are conditioned by the relay C.68, active in operations which originate within the zone of negative quantities.

25 The relay C.67 (Figure 8) active in an operation originating within the zone of positive quantities, is energized by circuit of the wire d, closed as hereinbefore described as, for example in the accumulation of a positive minuend, when the conductor 90 closes on the wire d. The circuit so closed to the relay C.67 originates at the source ZZ and extends through s+, 90, d, bridged at 310' and 309 to C.67, ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ. The relay C.67 so energized closes at bridge 309 raised, circuit of the wire s+ by which C.67 then is held in stick. The last said circuit originates at the source ZZ and extends through the wire s+, 309, C.67, ds—, bridged at 72 and lower bridge at C.19 to s—, ZZ. The relay C.67 so held in stick, closes at bridge 310 circuit of the wire da', selectively closed by the relays C.69a', C.69a'', C.69', C.69'', at the respective bridges 312a', 312a'', 312'', 312''', as presently described, to the solenoid C.71a', C.71a'', C.71', C.71''. The circuit so closed, to C.71a', originates at the source ZZ and extends through s+, 90, d', bridged at 923, da' bridged at 310 and 312a' to C.71a', zc, conductor 315 (Figures 8 and 9), to s—, to ZZ. The circuit closed to the solenoid C.71a'', originates at source ZZ, and extends through s+, 90, d' bridged at 923, da' bridged at 310, and 312a'' to C.71a'', zc, conductor 315 to s—, to ZZ. The circuit closed to the solenoid C.71', originates at source ZZ, and extends through s+, 90, d' bridged at 923, da' bridged at 310 and 312'' to C.71', zc, conductor 315 to s—, to ZZ; and the circuit selectively closed to the solenoid C.71'', originates at source ZZ and extends through s+, 90, d' bridged at 923, da' bridged at 310 and 312''' to C.71'', zc, conductor 315, to s—, to ZZ. If at the termination of an operation, the disk 63a' be at zero and circuit of the wire d' open; circuit is closed by the conductor 90 from ZZ, s+, to the wire da' and selectively, as above traced, to the solenoids C.71a', C.71a'', C.71', C.71''. In operations which pass from the zone of positive into the zone of negative quantities, the solenoids C.71', C.71'' as presently described, effect, as selectively required, subtractive compensation at the hundreds and tens orders, respectively, of the accumulator; and the solenoids C.71a', C.71a'' effect, as selectively required, additive compensation at the hundreds and tens orders, respectively, of the circuit controller at shaft 58a.

The relay C.68 active in an operation originating within the zone of negative quantities, is energized by circuit of the wire d', closed as hereinbefore described, as for example in the accumulation of a negative minuend, when the conductor 90 closes on the wire d'. The circuit so closed originates at the source ZZ and extends through s+, 90, d' bridged at 310 and 309' to C.68, ds— bridged at 72 and lower bridge at C.19 to s—, ZZ. The relay C.68 so energized closes at 309' circuit of the wire s+ by which it is held in stick, the last said circuit being, ZZ, s+, 309', C.68, ds— bridged at 72 and lower bridge at C.19 to s—, ZZ. The relay C.68, so held in stick, closes at bridge 310' circuit of the wire da, selectively closed by the above said relays C.69a', C.69a'', C.69', C.69'', at the respective bridges 313a', 313a'', 313'', 313''', as presently described, to the solenoids C.70a', C.70a'', C.70', C.70''. The circuit so closed to the solenoid C.70a', is ZZ, s+, 90, d' bridged at 92' to da bridged at 310' and 313a' to C.70a', zc, conductor 315 (Figures 8 and 9) to s—, ZZ. The corresponding circuit closed to C.70a'' is, ZZ, s+, 90, d' bridged at 92' to da bridged at 310' and 313a'' to C.70a'', zc, conductor 315 to s—, ZZ. The corresponding circuit closed to C.70' is ZZ, s+, 90, d' bridged at 92' to da bridged at 310' and 313' to C.70', zc, conductor 315 to s—, ZZ. Corresponding circuit to C.70'' is ZZ, s+, 90, d' bridged at 92' to da bridged at 310' and 313''' to C.70'', zc, conductor 315 to s—, ZZ. If at the termination of an operation the disk 63a' be at zero and circuit of the wire d open; circuit is closed by the conductor 90 from ZZ, s+ to the wire da and selectively, as above traced, to the solenoids C.70a', C.70a'', C.70', C.70''. In operations which pass from the zone of negative into the zone of positive quantities, the solenoids C.70', C.70'' effect as selectively required, subtractive compensation at the hundreds and tens orders, respectively, of the accumulator; and the solenoids C.70a', C.70a'' effect, as selectively required, additive compensation at the hundreds and tens orders, respectively, of the circuit controller at shaft 58a.

To the sleeves 60'', 60''', 60a'', 60a''', are respectively fixed the disks 318'', 318''', 318a'', 318a''', provided with the conductors 301'', 301''', 301a'', 301a''', and the circular conductors 306'', 306''', 306a'', 306a''' (Figure 8). Initial displacement of any order of the circuit controller as said circuit controller passes from zero position displaces, as already described the disk 63a'. Such displacement causes the conductor 308 to close circuit of the wire s+ to the wire zd leading to the conductors 301'', 301''', 301a'', 301a''', and thence through the wires ze', ze'', ze''', ze'', respectively, to terminals at the relays C.69', C.69'', C.69a', C.69a''. An extension zd' of the wire zd transmits an impulse over their lowest bridges to the relays C.69', C.69'', C.69a', C.69a''. In order that the circuit of the wire zd' impart to the relays C.69a', C.69a'', C.69', C.69'' (only a momentary impulse, circuit of the wire zd' to the last said relays, is broken at the bridge 314 or 314', when the respective relays C.67, C.68, are energized.

The above said circuit (Figure 8) to the relay C.69a', is ZZ, s+, 308, zd', bridged at 314, 314', and 311a', C.69a', ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ. Corresponding circuit so closed to C.69a'' is ZZ, s+, 308, zd' bridged at 314, 314', and 311a'', C.69a'', ds—, bridged at 72 and lower bridge at C.19 to s—, to

ZZ. Corresponding circuit so closed to C.69' is ZZ, s+, 308, zd' bridged at 314, 314', and 311'', C.69', ds— bridged at 72, and lower bridge at C.19 to s—, to ZZ; and corresponding circuit to C.69'' is ZZ, s+, 308, zd' bridged at 314, 314' and 311''', C.69'', ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ.

The relays C.69a', C.69a'', C.69', C.69'', if the respective disks 318a'', 318a''', 318'', 318''' be not displaced as circuit of the wire zd' is closed, are then held in stick by circuit through an extension of zd', namely, the wire zd closed by the conductors 301a'', 301a''', 301'', 301''' fixed respectively to the disks 318a'', 318a''', 318'', 318'''. The circuit so closed to C.69a' is ZZ, s+, 308, zd, bridged at 201a'', to ze''' bridged at 311a' raised, to C.69a', ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ. Corresponding circuit to C.69a'' is ZZ, s+, 308, zd bridged at 301a''' to ze''' bridged at 311a'' raised to C.69a'', ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ. Corresponding circuit to C.69' is ZZ, s+, 308, zd, bridged at 301'' to ze' bridged at 311'' raised, to C.69', ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ; and corresponding circuit to C.69'' is ZZ, s+, 308, zd bridged at 301''' to ze''' bridged at 311''' raised, to C.69'', ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ.

If a disk 318a'', 318a''', 318'', 318''' be displaced and circuit of the wire zd be broken at the respective conductors 301a'', 301a''', 301'', 301''', as circuit is momentarily closed to said several relays C.69a', C.69a'', C.69', C.69'' through the wire zd', these said relays are nevertheless held in stick, through circuit closed by the respective conductors 306a'', 306a''', 306'', 306''' at such of the disks 318a'', 318a''', 318'', 318''' as may be displaced. The circuits so closed to the respective relays C.69a', C.69a'', C.69', C.69'' are as follows:

Circuit to the relay C.69a', is ZZ, s+, 306a'', ze''' bridged at 311a' raised, C.69a', ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ. Corresponding circuit to C.69a'' is ZZ, s+, 306a''', ze''' bridged at 311a'' raised, C.69a'', ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ. Corresponding circuit to C.69' is ZZ, s+, 306'', ze' bridged at 311'' raised, C.69', ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ; and corresponding circuit to C.69'' is ZZ, s+, 306''', ze''' bridged at 311''' raised, C.69'', ds— bridged at 72 and lower bridge at C.19 to s—, to ZZ. Held in stick by circuit of s+, the relays C.69', C.69'', C.69a', C.69a'' close circuit at their bridges 313'', 313''', 313a', 313a'', on the extensions of the wire da, leading respectively to the positive poles of the solenoids C.70', C.70'', C.70a', C.70a''. At bridges 312'', 312''', 312a', 312a'' circuit is closed on the extensions of the wire da' leading respectively to the positive poles of the solenoids C.71', C.71'', C.71a', C.71a''. Quantities having been accumulated, if subtraction follow, the relays C.69', C.69'', C.69a', C.69a'', will all remain in stick until compensation be effected; unless the operation pass through zero; in which event circuit will be broken to those of last said relays whose corresponding disks, 318'', 318''', 318a'', 318a''', chance to be at zero when circuit be broken by the disk 63a' at conductor 308. For in such case current fails such relays from the wires both zd open at 308 and s+ open at their corresponding circular conductors 306'', 306''', 306a'', 306a'''. The relays so deenergized break circuit

of the wires da, da', to the respective solenoids C.70', C.71', C.70'', C.71'', C.70a', C.70a'', C.71a'', which they control. The relays C.69', C.69'', C.69a', C.69a'', all operate to similar effect.

Example

At the initial displacement of any order from zero, the disk 63a' closes the circuit of the wire s+ through the conductor 308 to the wire zd as hereinbefore described and to its extension zd'. The relay C.69a'', which may serve as the example, receives an impulse over bridge 311a'' from the wire zd', and closes the bridge 311a'' on the terminal of the wire ze''''. If the disk 318a''' be at zero; circuit is closed at the conductor 301a''', from the wire zd to the wire ze''' to C.69a''. If the disk 318a''' be displaced from zero, circuit is closed by the circular conductor 306a''', at the terminals 307a''', from the wire s+ to the wire ze''' to C.69a''. In either event the relay C.69a'' is held in stick, closing at bridge 312a'' circuit of the wire da' to the solenoid C.71a'', and at the bridge 313a'', circuit of the wire da to the solenoid C.70a''. Assume that subtraction follows. If the operation pass through zero, the disk 63a' breaks the circuit of the wire zd at the conductor 308. Should the disk 318a''' then be at zero or should it pass to or from zero, while circuit of the wire zd is open; current flows through the wire ze''' to the relay C.69a'' neither from the conductor 301a''' closed on the open wire zd, nor from the wire s+ which is open at the circular conductor 306a'''. The relay C.69a'' deenergized, breaks at bridge 312a'' circuit of the wire da' to the solenoid C.71a'', and at the bridge 313a' circuit of the wire da to the solenoid C.70a''. With circuit of the wire ze''' so broken at the units order to the relay C.69a'', no correction is effected at the tens order by the solenoids C.70a'', C.71a''. Should the disk 318a''' not be at zero as the operation passes through zero and the disk 63a' breaks circuit of the wire zd, circuit remains closed to the circuit controller C.69a'' though the wire ze''' from the circular conductor 306a'''. Compensation by the solenoid either C.70a'' or C.71a'' follows, accordingly as circuit da' or da be closed by the circuit controller C.67 or C.68, as hereinbefore described.

Circuit of the wire da', closed by the relay C.67 which is thrown into stick by the circuit of wire d when an operation originates in the zone of positive quantities, becomes active only if the operation pass into the zone of negative quantities. Circuit of the wire da closed by the relay C.68, which is thrown into stick by circuit of wire d' when an operation originates in the zone of negative quantities, becomes active only if the operation pass into the zone of positive quantities. Hence, unless a subtrahend be greater than the minuend and the operation pass through zero, neither the solenoids C.70', C.70'', C.70a', C.70a'' in circuit of the wire da, nor the solenoids C.71', C.71'', C.71a', C.71a'' in circuit of the wire da', will operate compensation. Should the relay C.67 be active and the operation pass through zero, then the solenoids C.71', C.71'', C.71a', C.71a'', to which circuit be completed by the relays C.69', C.69'', C.69a', C.69a'', through the wire da', effect compensation. Should the relay C.68 be active and the operation pass through zero in opposite direction, the solenoids C.70', C.70'', C.70a', C.70a'', to which circuit be completed by the relays C.69', C.69'', C.69a', C.69a'', through the wire da, effect compensation.

It is true that circuit of the wires both da , da' are active, when the disk 63a' be only carried back to zero and before it passes through. But the mathematical operation of subtraction will then have passed through zero, unless all orders be at zero. For an extra step displacement is required at the highest order, to carry the disk 63a' back to zero, unless the lower orders of the circuit controller at shaft 58a, by reaching zero, have completed carry-over. Should the operation pass through zero and the disk 63a' then rest at zero, compensation in the hundreds order of the circuit controller will displace the disk 63a' through zero, renewing the circuits zd , zd' , while closing, according to direction of displacement, circuit of the wire d or d' , and conditioning, thereby, for subsequent transitional operation in opposite direction, the relay either C.67 or C.68 which may have been inactive during transition in a present operation.

At the timing disk 76 (Figure 9) the contacts 315 are recurrent and so placed at intervals of 36° , that circuit from the wire $s-$ to the wire zc be momentarily closed at the termination of each operation in subtraction or addition, as the disk 76 carries the timing arm 78 from a terminal of the wire b^8 to a neutral position between series of b wires (Figure 4).

The wire zc energized as above, imparts, as the disk 76 revolves, a momentary impulse to the negative poles of the solenoids C.70', C.70'', C.70a', C.70a'', C.71', C.71'', C.71a', C.71a'', bringing those thereof into action to whose positive poles circuit be completed at the relays C.67 or C.68 and relays C.69', C.69'', C.69a', C.69a'', through the wire da or da' .

Let it be assumed that, by one or a series of operations, a positive subtrahend, for example, be developed at the accumulator 61', 61'', 61''' (Figures 1, 2), and that the relay C.67 close circuit da' operative on the solenoids C.71a', C.71a'', C.71', C.71'' (Figure 8). In such case, if the minuend be greater than the subtrahend, and the operation pass through zero into negative quantities; the wire da' becomes active, and the solenoids C.71a', C.71a'', C.71', C.71'' to which circuit be completed at the relays C.69a', C.69a'', C.69', C.69'', retract their plungers, on receiving impulse through the wire zc , and selectively effect compensation for transitional carry over at the respective shafts and orders to which they correspond. Should the subtrahend be smaller than the minuend and the operation fail to pass through zero, then circuit of the wire da' remains open and the solenoids inert.

Conversely, if a negative minuend be involved, the relay C.68 (Figure 8) is active, closing circuit of the wire da to the solenoids C.70a', C.70a'', C.70', C.70'', if a greater negative subtrahend be subtracted, the operation passes through zero into positive quantities, and the wire da becoming active causes selected solenoids C.70a', C.70a'', C.70', C.70'', to effect compensation. If the subtrahend be smaller than the minuend; the operation does not pass through zero into positive quantities, and, the circuit da remaining open, last said solenoids will fail to act.

In the circuit of the wire zc is the relay C.72 (Figures 1 and 8) whose circuit is as follows: ZZ, $s+$, C.72, zc , conductor 315, $s-$, ZZ. Each impulse transmitted through the wire zc at the termination of an operation, causes the relay C.72 momentarily to break at the bridge carried by its plunger, circuit of the wire $ds-$ to the negative poles of the relays C.67, C.68, and also

to the relays C.69a', C.69a'', C.69', C.69'', causing those thereof which may be active, to break all circuits thereby closed. The circuit of the wire $ds-$ is, however, immediately restored, at the disk 76 revolving breaks the circuit of the wire zc . If it is, for example, the relay C.67 which so releases its plunger before an accumulated quantity is reduced to zero; the wire d still being closed at the disk 63a' imparts again initial impulse to the relay C.67 which again is placed in stick. At the same moment the relays C.69a'', C.69a', C.69', C.69'', likewise deenergized, will again be thrown into stick by the wire zd' , preparatory to a future computation. If, on the other hand, all orders be at zero, circuit of the wires d , d' , zd' are open, and the said relays are disabled.

If, when a minuend be positive and the relay C.67 be active, the operation pass through zero to a negative remainder; then, when circuit of the wire $ds-$ be renewed at the bridge of the relay C.72, circuit d to the positive pole of the relay C.67 fails. For on passing through zero into negative quantities, the wire d is open and the wire d' is closed. In such case, however, the relay C.68 receives an initial impulse through the wire d' and is thrown into stick, closing circuit of the wire da at bridge 310' raised. The relays C.69a', C.69a'', C.69', C.69'', are, as before, thrown into stick by impulse through the wire zd' ; and such thereof as remain active when an operation pass back through zero into positive quantities, complete circuit through the wire da to their corresponding solenoids C.70a'', C.70a', C.70', C.70'', by which compensation is in turn selectively effected, by displacement of members at the different orders in opposite direction to that effected when an operation of subtraction passes through zero from positive into negative quantities.

Should a disk such for example as 318a''' pass through its zero position while the wire zd be closed; circuit to the relay C.69a'' is sustained, through the conductor 301a'''. But if the disk 63a' pass to zero, as the disk 318a''' pass from zero; circuit is broken through the wire zd to the relay C.69a'', before the disk 318a''' be sufficiently displaced, to close circuit to the relay C.69a'' through the conductor 306a'''.

Examples

(g) 93-212=-119. The tens order of the circuit controller at shaft 58a is displaced from zero as the disk 63a' passes to zero. The tens order of the accumulator does not reach zero. At neither the circuit controller nor the accumulator does the units order reach zero. At the circuit controller members are displaced in degree proportionate to the numerals 219. The accumulator reflects the quantity -229. No compensation is effected in the hundreds order of the circuit controller; since circuit to C.69a' (Figure 8) is open. Compensation in the hundreds order of the accumulator is effected and also compensation in the tens order of both circuit controller and accumulator.

(h) 141-223=-82. In neither circuit controller nor accumulator does the tens order reach zero. At both circuit controller and accumulator, the units order passes from zero as the disk 63a' passes to zero; and circuits of relays both C.69', C.69a'' are open. The circuit controller is displaced in degree proportionate to the numerals 92. The accumulator reflects the quantity -182. At neither circuit controller nor accumulator is

there compensation at the tens order. At both circuit controller and accumulator compensation is effected in the hundreds order.

If circuit be completed during compensation, through an active wire d or d' , to the transfer clutches $C.8''$, $C.8'''$, or through an active wire da or da' , to the transfer clutches $C.8a''$, $C.8a'''$; said clutches to which circuit be so completed, effect compensation by transfer in orders next above.

(*b*) $2-111=-109$. At neither circuit controller nor at accumulator, does the units order reach zero. The tens order of the circuit controller reaches zero with the disk $63a'$; and relay $C.69a'$ is deenergized. The tens order at the accumulator passes from zero with the disk $63a'$; and the relay $C.69'$ is inactive. The circuit controller is displaced in degree proportionate to the numerals 109. The accumulator reflects the quantity -119. In the tens order of the circuit controller, compensation is effected through the relay $C.69a''$ and the solenoid $C.71a''$. In the hundreds order of the circuit controller the relay $C.69a'$ and solenoid $C.71a'$ are deenergized; but compensation is effected by the transfer clutch $C.8a''$ which is energized by the wire da' , as the said clutch $C.8a''$ is displaced by the solenoid $C.71a''$. At the accumulator, compensation is effected in the tens order by the solenoid $C.71''$ circuit to which is closed by the relay $C.69''$.

(*c*) $306-505=-199$. At neither the circuit controller nor the accumulator does the units order reach zero. At the circuit controller the tens order does not reach zero. At the accumulator, the tens order rests at zero as the disk $63a'$ passes to zero; and the relay $C.69'$ is deenergized. The circuit controller is displaced in degree proportionate to the numerals 199. The accumulator reflects the quantity -209. At the circuit controller compensation is effected in the hundreds order through the relay $C.69a'$ and solenoid $C.71a'$ and in the tens order through the relay $C.69a''$ and the solenoid $C.71a''$. At the accumulator compensation is effected in the tens order through the relay $C.69''$ and solenoid $C.71''$. At the hundreds order of the accumulator, the relay $C.69'$ is deenergized and circuit to the solenoid $C.71'$ remains open. But as the operation passed through zero, circuit of the wire d' became active; and when the transfer clutch $C.8''$, which is at zero, is displaced by the solenoid $C.71''$ during compensation, the said clutch $C.8''$ effects subtractive transfer at the accumulator in the hundreds order.

Were, as an example, the positive quantity 50 to be subtracted from the positive quantity 30, the wire d would operate until the minuend were reduced to zero; and the negative remainder -20 would then be accumulated, as circuit is closed on the wire d' , by adding the twenty units negative remainder, without mechanically subtracting from orders thereabove. In other words, on passing through zero, the mechanical operation of addition is substituted for the mechanical operation of subtraction and vice versa, the subtraction of an excess in a positive subtrahend being mechanically effected, by the addition of a negative quantity to zero, and not by the subtraction of a positive quantity. Were the quantity -50 subtracted from the quantity -30; the accumulator at the shaft 58 rotated in positive direction, would reduce the negative minuend to zero by subtraction, and accumulate the positive remainder +20 by an operation in the nature of

addition, when current is switched at the conductor 90 from the wire d' to the wire d .

When the net displacement of the accumulator arms $61'$, $61''$, $61'''$ (Figures 1, 10, and 11) is clockwise, reflecting thereby a positive quantity, their step displacements read from zero to the right. When their net displacement is in the opposite direction reflecting a negative quantity, their step displacements read from zero to the left. The quantities so reflected may be suitably recorded by mechanism which now may be described.

Referring to Figure 10, a typical accumulator arm $61'$ is shown carrying at its upper extremity the contact 237', in the orbit of which, as said accumulator arm be revolved, are the terminals 238^0-238^9 of the respective numeral wires af^0-af^9 to which the contact 237' may selectively close circuit, according to the angular displacement of the accumulator arm $61'$. The accumulator arms $61''$, $61'''$ (Figures 1 and 11) are similar in construction and in operation to the accumulator arm $61'$, and similarly close circuits to the wires af^0-af^9 . Encircling the sleeves $60'$, $60''$, $60'''$, at the base of the accumulator arms $61'$, $61''$, $61'''$, and wired respectively to the contacts 237', 237'', 237''', are the conductors 276', 276'', 276''' (Figures 10 and 11) in permanent contact with the terminals of the respective wires tf' , tf'' , tf''' , which extend from fixed terminals at the disk 261, and on which circuit may be successively closed from the wire $s+$, by a conductor 282 fixed to the disk 261, when the said disk be revolved, as presently described. The wires af^0-af^9 to which circuit may be closed by the contacts 237', 237'', 237''', extend over bridges of the relay $C.47$, to the respective solenoids $C.48^0-C.48^9$.

The resultant is reflected in the angular displacement of the accumulator arms $61'$, $61''$, $61'''$; as they severally close, at the termination of a mathematical operation, circuit through the selective numeral wires af^0-af^9 , to the solenoids $C.48^0-C.48^9$, which are operative in recording corresponding numerals of the resultant.

The plunger of the solenoids $C.48^0-C.48^9$, are respectively connected by means of draw-wires 228^0-228^9 with the bell-cranks 229^0-229^9 , which are in turn, connected by the draw-wires 230^0-230^9 , as well known to the art, with the pivoted type-bars 231^0-231^9 . The said type-bars 231^0-231^9 carry at their upper extremities the types 232^0-232^9 corresponding to the numerals 0-9. When energized by circuits closed at the accumulator arms $61'$, $61''$, $61'''$, and presently traced; the solenoids corresponding to the selected circuits, retract successively their plungers, each throwing its corresponding type 232^0-232^9 against a platen 236 and printing thereby upon a suitable medium 235, the numeral corresponding to the type. The type bars may be immediately restored to normal position, when circuit to their corresponding solenoids is interrupted, by springs not shown, in manner well known to the art.

The platen 236 (Figure 11) is shown as mounted on the carriage 295 which travels on the roller bearings 296, 296'. The said platen may be manually displaced against a spring not shown, and its position adjusted in manner common to a typewriter platen and well known to the art. Fixed to the carriage 295 is a rack 294 which meshes with the gear 258 fixed together with the disk 261 on the shaft 257.

At the termination of a mathematical opera-

tion, the platen 236 may be manually so adjusted, that the disk 261, revolved by the rack 296, and the gear wheel 258, carries the conductor 262 to a position at the left of the t' , t'' , t''' terminals, as shown in Figure 11. The lever 239 is now closed on the terminals 240' of the wire $s+$; and the platen is released to the left, and permitted to travel by any suitable means such as the well-known letter spacing bar 282, escapement dog 283, and rack 284, causing, thereby, the disk 261 to advance the conductor 262 step by step into positions at which it closes circuit of the wire $s+$ successively on the terminals of the wires t' , t'' , and t''' .

Assume that an accumulated resultant were the positive quantity 358; and the accumulator arms 61', 61'', 61''' respectively closed circuit on the wires a^3 (Figure 10), a^2 , and a^1 . The circuit closed by the conductor 262 and the accumulator arm 61', originates at the source ZZ and extends through $s+$ bridged at 240', 262, t' , 276', 61', a^3 , bridged at relay C.47 to solenoid C.48³, $s-$, ZZ. The solenoid C.48³ so energized retracts its plunger and causes the numeral 3 to be recorded at the platen 236. The circuit closed by the conductor 262 and the accumulator arm 61'', originates at the source ZZ and extends through $s+$, bridged at 240', 262, t'' , 276'', 61'', a^2 bridged at C.47, C.48², $s-$, ZZ. The solenoid C.48² so energized causes the numeral 5 to be recorded at the platen 236. The circuit closed by the conductor 262 and the accumulator arm 61''', originates at the source ZZ, and extends through $s+$ bridged at 240', 262, t''' , 276''', 61''', a^1 bridged at C.47, C.48¹, $s-$, ZZ. The solenoid C.48¹ so energized causes the numeral 8 to be recorded at the platen 236.

If the quantity accumulated be negative the step displacements of the accumulator arms 61', 61'', 61''' must be enumerated from zero to the left, since complementary numerals become the measure of resultant. To render such complementary numerals mechanically available, the wires a^1-a^3 which normally extend to the solenoids C.48¹-C.48³, are switched by the relay C.47 to the solenoids C.48³-C.48¹ of complementary serial number. The circuit of a^3 remains undisturbed. For example, circuit of the wire a^3 which normally leads over the highest bridge at the relay C.47 to the solenoid C.48³, is switched over the lowest bridge at the relay C.47, to the solenoid C.48¹, and the circuits of wires a^2-a^1 , are similarly switched to solenoids C.48²-C.48¹ of complementary serial number. The relay C.47 is energized and automatically switches the circuits of said wires a^1-a^3 , when a negative quantity be latent at the accumulator, and circuit of the wire d' is closed by the conductor 90 at the disk 63a' (Figures 2, 3, 11). The circuit of the relay C.47 originates at the source ZZ and extends through $s+$, 90, d' , C.47, $s-$, ZZ.

In order visually, to indicate the positive or negative quality of a resultant, an inking ribbon 233 is provided (Figure 11) of dual colors, for example black and red, which is carried in a frame 234 attached to the plunger of a solenoid C.64. The circuit of the solenoid C.64 originates at the source ZZ, and extends through $s+$, 90, d' , C.64, $s-$, ZZ. When the resultant is a positive quantity and the solenoid C.64 is inactive; the black margin of the ribbon 233, is exposed to the types 232⁰-232⁹; and the quantity is recorded in black. When the resultant is a negative quantity, C.64 is energized by circuit of the wire d' , and contracting its plunger, places the inking ribbon 233 in

such position that the types 232⁰-232⁹ descend upon its red margin and record the quantity in red.

Restoration of the calculating unit to zero position

Depression of the push-button P.5 (Figure 1) closes a circuit which originates at the source ZZ (Figure 1) and passes through the wire $s+$, the bridge at the push-button P.5 (Figures 1, 2), the wire n to the relay C.19, circuit being closed from the negative pole of the relay C.19, through the wire $s-$, back to the source ZZ. The relay C.19 so energized, completes circuit at its upper bridge to the relay C.20; and closes at its lower bridge circuit $n-$ to the negative pole of the relay C.12' as presently described, and to terminals at the relay C.12'. The circuit of the relay C.20 originates at the source ZZ, and extends through the wire $s+$ bridged at P.5 to wire n , bridged at C.19 to C.20, $s-$, ZZ. The relay C.20 so energized, breaks, at the bridge 167, circuits through the wire h to prevent interference of circuit with the wire n . At the bridge 167, raised, circuit is closed to terminals at the plunger of the 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 mechanism 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 latent at the shaft 58, circuit of wire d' is open at the conductor 90 (Figures 2, 3); and the relay C.12' closes at the bridges 105, 106, depressed, circuit through the wires $n-$, 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 latent at the shaft 58 be negative; the wire d' is active as hereinbefore described, and energizes over the bridges 92⁴, 104, the relay C.12', which is then held in stick over the bridge 104 by current through the wire n' . The initial circuit closed to the relay C.12' through the wire d' , is ZZ, $s+$, 90, d' bridged at 92⁴ and 104 to C.12', $n-$ over the lower bridge raised at the relay C.19 to $s-$, ZZ. The circuit which then retains the relay C.12' in stick after receiving initial impulse through circuit of the wire d' , is ZZ, $s+$, 172 (Figures 1 and 7), n bridged at 167 raised to n' , C.12', $n-$, lower bridge raised at C.19, $s-$, ZZ. 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, 7) 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 imparts initial impulse to the clutches 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 to close a circuit from the wire $s+$, extended from the source ZZ and connected with the wire n , 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 7) 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 displaced members of the accumulator and circuit controller (Figures 1 and 2).

The initial circuit (Figure 2) closed as above by P.5 to C.5, is ZZ, s+, P.5, n, upper bridge raised at C.19 and bridge 167 raised to n' bridged at 105 raised to C.5, n— bridged at 106 raised and lower bridge raised at C.19 to s—, ZZ. The corresponding circuit closed by P.5 to C.5a is ZZ, s+, P.5, n, upper bridge raised at C.19 and bridge 167 raised, n' bridged at 105 depressed to C.5a, n— bridged at 106 depressed, and lower bridge raised at C.19 to s—, ZZ. Initial circuit closed to C.6 (Figure 1) is ZZ, s+, P.5, n, upper bridge raised at C.19, bridge 168 raised to C.6, n—, lower bridge raised at C.19, s—, ZZ. The circuit closed to the clutch C.5 by the conductor 172 (Figures 1 and 7) after the initial impulse through P.5 is ZZ, s+ bridged by conductor 172 to extension of wire n bridged at 168 raised to n' bridged at 105 raised to C.5, n— bridged at 106 raised and lower bridge raised at C.19 to s—, ZZ. Corresponding circuit closed by 172, to C.5a, is ZZ, s+ bridged at 172 to extension of wire n bridged at 168 raised to n' bridged at 105 depressed to C.5a, n— bridged at 106 depressed and lower bridge raised at C.19 to s—, ZZ. Circuit closed by 172 to C.6 is ZZ, s+ bridged at 172 to extension of wire n bridged at 168 to C.6, n— bridged at C.19 to s—, ZZ.

The clutches C.7', C.7'', C.7''', C.7a', C.7a'', C.7a''' (Figures 1, 2) 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 the similar conductors 173', 173'', 173''' (Figure 6). The conductor 173' (Figures 1, 6) 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'''. Circuit of wire n to the clutch C.7' originates at the source ZZ, and extends through s+ bridged by 172 (Figures 1 and 7) to extension of wire n bridged at 171 and 173', to C.7', s—, ZZ. Circuit to C.7'' is ZZ, s+ bridged by 172 to extension of n bridged at 170 and 173'' to C.7'', s—, ZZ. Circuit to C.7''' is ZZ, s+ bridged at 172 to extension of n bridged at 169 and 173''' to C.7''', s—, ZZ. The operation at all orders is substantially alike. Referring to Figure 6, 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 clutch 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''' be 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 the circuits above traced similarly closed and broken, leading to the clutches C.7', C.7'' (Figure 1). 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 2, to the clutch 7a'''; from the bridge 170a to the clutch C.7a''; and from the bridge 171a to the clutch C.7a'. Conductors 173a', 173a'', 173a''' (Figure 2) similar to the conductor 173''' (Figure

6), are carried by the disk 62a''', and by the middle members of the planetary gearings Dfa'', Dfb'', which break circuit respectively to the clutches C.7a''', C.7a'', C.7a', as the sleeves 60a''', 60a'', 60a' and the transfer clutches C.8a', C.8a'', C.8a''' thereon mounted are restored to zero position. Circuit so closed to the clutch C.7a' (Figure 2) is ZZ, s+ bridged by 172 to extension of n bridged at 171a and 173a' to C.7a', s—, ZZ. Corresponding circuit to C.7a'' is ZZ, s+ bridged by 172 to extension of n bridged at 170a and 173a'' to C.7a'', s—, ZZ. Corresponding circuit to C.7a''' is ZZ, s+ bridged by 172 to extension of n bridged at 169a and 173a''' to C.7a''', s—, ZZ.

During 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 the clutch C.8a' whose negative pole is connected with the wire s—, and which restores to normal position the armature 63a'.

I claim:

1. In a calculating apparatus for computing quantities whether positive or negative in quality, an accumulator comprising members corresponding to denominational orders and operative in respective positive and negative directions to accumulate positive and negative quantities, means selectively to operate the members in positive direction either to add a positive quantity to an accumulated positive quantity or to subtract a negative quantity from an accumulated negative quantity, or to operate the members in negative direction either to add a negative quantity to an accumulated negative quantity or to subtract a positive quantity from an accumulated positive quantity, reversible transfer mechanisms of convertible first and tenth step cyclic phases between the several orders of said members, and operative by the members of next respective lower order, means automatically to convert said phases according to the quality of the accumulated quantity and the directional operation of said members, to cause the transfer mechanisms to transmit tens carry-over in the addition of a quantity to an accumulated quantity similar in quality at each tenth step, and to borrow at each cyclic first step in the subtraction of a quantity from an accumulated quantity similar in quality, whether the quality of the quantities component in the computations is positive or negative.

2. In a calculating apparatus for computing quantities whether positive or negative in quality, an accumulator comprising members corresponding to denominational orders operative step by step from zero position in respective positive and negative directions to accumulate positive and negative quantities, means selectively to operate the members in positive direction either to add a positive quantity to an accumulated positive quantity or to subtract a negative quantity from an accumulated negative quantity, or to operate the members in negative direction either to add a negative quantity to an accumulated negative quantity or to subtract a positive quantity from an accumulated positive quantity, reversible transfer mechanisms of convertible first and tenth step cyclic phases differentially convertible according to the directional operation of said members and the quality of the accumulated quantity, between the several orders of said members, means automatically to convert the said phases to condition the said mechanisms to transmit tens carry-over in the addition of a quantity

to an accumulated quantity similar in quality at each tenth step, and to borrow at each cyclic first step in the subtraction of a quantity from an accumulated quantity similar in quality, the last said means including an electric clutch in each said transfer mechanism operative by the said members of respective next lower order, in directions corresponding to the directional operation of said members, dual circuits to the clutches corresponding to the respective positive or negative quality of the accumulated quantity, a circuit controller comprising members corresponding to denominational orders of which the highest order is denominationally higher than the highest order of the accumulator members, transfer mechanism between the several orders of the circuit controller members of first and tenth step cyclic phases to operate cyclic first step transfer coincidentally with the initial step of the first operated accumulator member from zero position in either direction, to close, at the highest order of the circuit controller members, the circuit corresponding to the quality of the quantity accumulated by the accumulator during said initial step.

3. In a calculating apparatus for computing quantities positive and negative in quality, an accumulator operative through zero comprising members corresponding to denominational orders and operative in respective positive and negative directions to accumulate positive and negative quantities, means selectively to operate the members in positive direction either to add a positive quantity to an accumulated positive quantity or to subtract a negative quantity from an accumulated negative quantity, or to operate the members in negative direction either to add a negative quantity to an accumulated negative quantity or to subtract a positive quantity from an accumulated positive quantity, reversible transfer mechanisms of first and tenth step cyclic phases convertible according to the directional operation of said members and the quality of the accumulated quantity between the several orders of said members and operative by the members of respective next lower order in directions corresponding to the directional operation of said members, to transmit tens carry-over in the addition of a quantity to an accumulated quantity similar in quality at each tenth step and to borrow at each cyclic first step, in the subtraction of a quantity from an accumulated quantity similar in quality, whether the component quantities computed be positive or negative, and means automatically to convert the phases of the transfer as the accumulator passes through zero from positive into negative quantities or vice versa, and cause the direction in which the transfer mechanisms transmit tens carry-over and the direction in which said mechanisms borrow, each respectively to be reversed.

4. In a calculating apparatus for computing quantities positive and negative in quality, an accumulator operative through zero comprising members corresponding to denominational orders operative step by step from zero position in respective opposite directions to accumulate positive and negative quantities, means selectively to operate the members in positive direction either to add a positive quantity to an accumulated positive quantity or to subtract a negative quantity from an accumulated negative quantity, or to operate the members in negative direction either to add a negative quantity to an accumulated negative quantity or to subtract a positive quantity from an accumulated positive quantity, reversible

transfer mechanisms of first and tenth step cyclic phases convertible according to the directional operation of the mechanisms and the quality of the accumulated quantity, between the several orders of said members, an electric clutch in each said transfer mechanism operative by the members of next respective lower order in directions corresponding to the directional operation of said members, dual circuits corresponding to the respective positive or negative quality of the accumulated quantity to condition the said clutches, a circuit controller operative coincidentally with the initial step from zero position of the first operated accumulator member in either direction, to close the said circuit corresponding to the quality of the quantity accumulated by the accumulator during said initial step, and cause the transfer mechanisms in the accumulator to transmit tens carry-over in the addition of a quantity to an accumulated quantity similar in quality at each tenth step and to borrow at each cyclic first step in the subtraction of a quantity from an accumulated quantity similar in quality, and means when the accumulator passes through zero from positive into negative quantities or vice versa and the quality of the accumulated quantity changes, to cause the circuit controller to break the first said circuit and close the other circuit, automatically to convert the phases of the transfer and cause the direction in which the transfer mechanisms in the accumulator transmit tens carry-over in addition and the direction in which last said mechanisms borrow in subtraction each respectively to be reversed.

5. In a calculating apparatus for performing computations in quantities positive and negative in quality involving transitional carry-over, an accumulator operative through zero comprising members corresponding to denominational orders and operative step by step from zero position in respective positive and negative directions to accumulate positive and negative quantities, means selectively to operate the members in positive direction either to add a positive quantity to an accumulated positive quantity or to subtract a negative quantity from an accumulated negative quantity, or to operate the members in negative direction either to add a negative quantity to an accumulated negative quantity or to subtract a positive quantity from an accumulated positive quantity, reversible transfer mechanisms of first and tenth step cyclic phases convertible according to the directional operation of said members and the quality of the accumulated quantity, between the several orders of the members and operative by the members of next respective lower orders in directions corresponding to the directional operation of said members, and automatic means to compensate the orders of the accumulator members which may be affected by transitional carry-over as the accumulator passes through zero from positive into negative quantities or vice versa.

6. In a calculating apparatus, an accumulator operative through zero from positive into negative quantities or vice versa and comprising members corresponding to denominational orders operative from zero position in respective positive and negative direction to accumulate positive and negative quantities, means selectively to operate the members in positive direction either to add a positive quantity to a positive accumulated quantity or to subtract a negative quantity from an accumulated negative quantity, or to operate the members in negative direction either to add a

negative quantity to an accumulated negative quantity or to subtract a positive quantity from an accumulated positive quantity, reversible transfer mechanisms of first and tenth step cyclic phases convertible according to the directional operation of said members and the quality of the accumulated quantity, an electric clutch in each said mechanism operative by the said members of respective next lower order in directions corresponding to the directional operation of said members, dual circuits to the clutches corresponding to the respective negative or positive quality of the accumulated quantity, a circuit controller operative coincidentally with the accumulator members to close the said circuit corresponding to the quality of the first accumulated quantity, and as the accumulator passes through zero, to break the last said circuit and close the other circuit to the clutches to convert the transfer phases and cause the direction of operation in which the transfer mechanisms transmit tens carry-over and the direction in which the said mechanisms borrow, each respectively to be reversed.

7. In a calculating apparatus for computing quantities whether positive or negative in quality, an accumulator comprising members corresponding to denominational orders, operative step by step in respective positive and negative directions to accumulate positive and negative quantities, means selectively to operate the members in positive direction either to add a positive quantity to an accumulated negative quantity or subtract a negative quantity from an accumulated positive quantity, or to operate the members in negative direction either to add a negative quantity to an accumulated positive quantity or to subtract a positive quantity from an accumulated negative quantity, reversible transfer mechanisms of convertible first and tenth step cyclic phases between the several orders of said membs and operative by the members of next respective lower order, and means automatically to convert said phases according to the quality of the accumulated quantity and the directional operation of said members to cause the said transfer mechanisms to transmit tens carry-over in the subtraction of a quantity from an accumulated quantity dissimilar in quality at each tenth step and to borrow at each cyclic first step in the addition of a quantity to an accumulated quantity dissimilar in quality thereto.

8. In a calculating apparatus for computing in quantities whether positive or negative in quality, an accumulator comprising members corresponding to denominational orders operative step by step from zero position in respective positive and negative directions to accumulate positive and negative quantities, reversible transfer mechanisms of first and tenth step cyclic phases differentially conditioned according to the directional operation of said members and the quality of the accumulated quantity, between the several orders of said members, a clutch in each transfer mechanism operative by the said members of next

respective lower order in directions corresponding to the directional operation of said members, dual circuits to the clutches respectively corresponding to the positive or negative quality of the accumulated quantity, a circuit controller comprising members corresponding to denominational orders of which the highest order is denominationally higher than the highest order of the circuit controller members, transfer mechanisms in the circuit controller of first and tenth step cyclic phases controlled by the circuit controller members of next respective lower order and operative coincidentally with the initial step of the first operated accumulator from zero position, to cause by first cyclic step transfer the highest order of the circuit controller members to close the said circuits corresponding to the quality of the quantity accumulated by the accumulator during said initial step, and an adjustable state-control to predetermine the directional operation of said accumulator members and conjointly with the circuit controller condition the transfer mechanisms in the accumulator differentially to operate transfer of the different phases.

9. In a calculating apparatus for computing quantities whether positive or negative in quality, an accumulator comprising members corresponding to denominational orders operative step by step from zero position in respective positive and negative directions to accumulate positive and negative quantities, reversible transfer mechanisms of first and tenth step cyclic phases between the several orders of the accumulator members differentially conditioned according to the directional operation of said members and the quality of the accumulated quantity, a clutch in each transfer mechanism operative by the said members of next respective lower order in directions corresponding to the directional operation of said members, dual circuits to the clutches respectively corresponding to the positive or negative quality of the accumulated quantity, a circuit controller comprising members corresponding to denominational orders of which the highest order is denominationally higher than the highest order of the circuit controller members, transfer mechanisms in the circuit controller of first and tenth step cyclic phases controlled by the circuit controller members of next respective lower order and operative coincidentally with the initial step of the first operated accumulator member from zero position, to cause by first cyclic step transfer the highest order of the circuit controller members to close the said circuit corresponding to the quality of the quantity accumulated by the accumulator during said initial step, and an adjustable state-control to predetermine the directional operation of said accumulator members and conjointly with the circuit controller condition the transfer mechanisms in the accumulator differentially to operate transfer of the different phases.

HENRY JEWETT FURBER.