Dec. 4, 1945. H. H. KEEN ET AL 2,390,441

ADDING AND SUBTRACTING MECHANISM

Filed Aug. 9, 1940 6 Sheets-Sheet 1

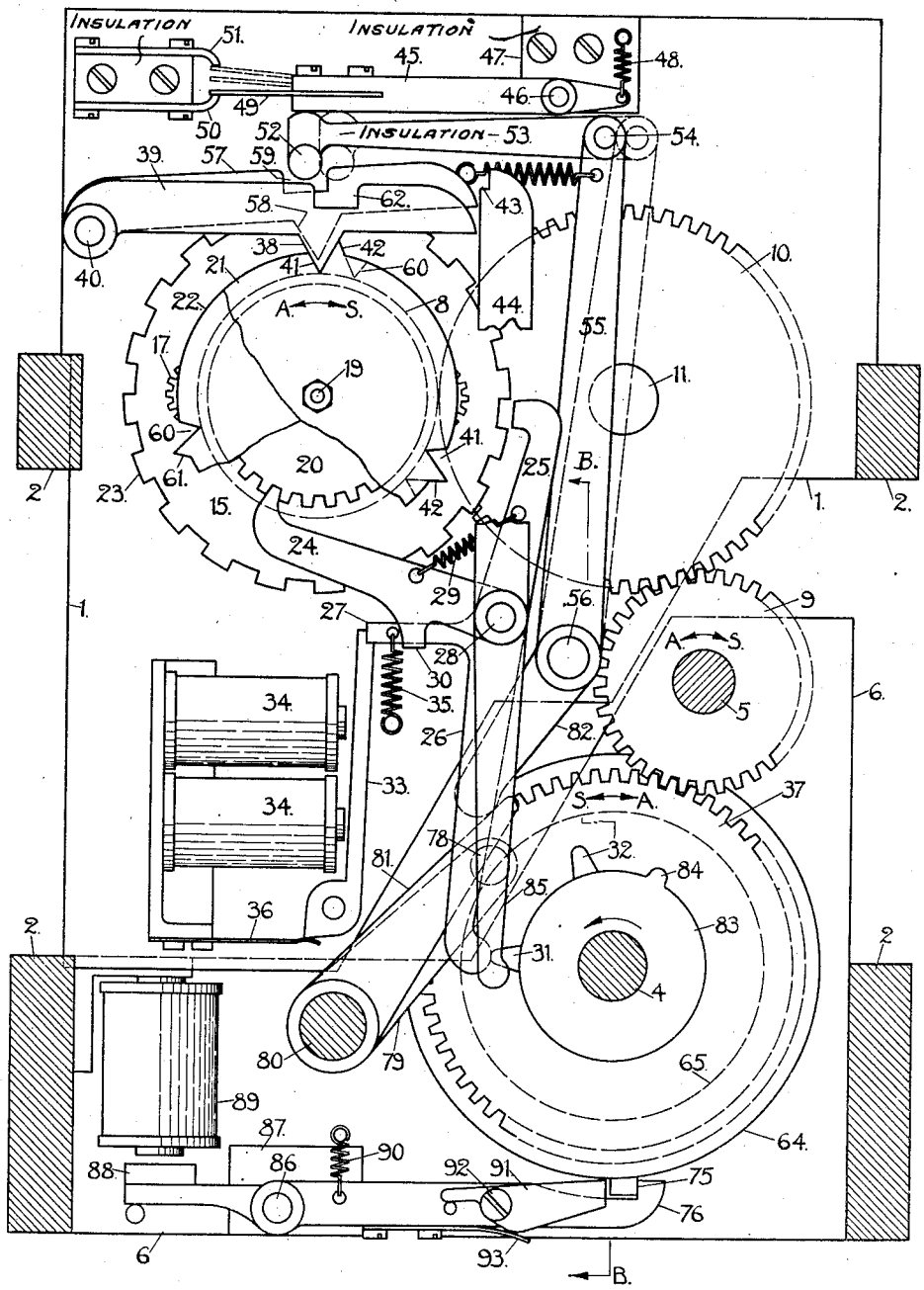


FIG. 1.

INVENTORS
Harold H. Keen
Thomas O. Wright
BY
ATTY.

Dec. 4, 1945. H. H. KEEN ET AL 2,390,441

ADDING AND SUBTRACTING MECHANISM

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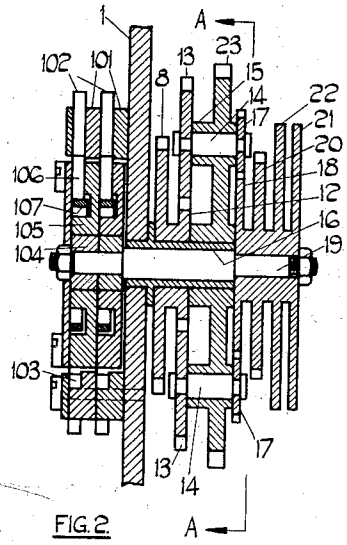


FIG. 2.

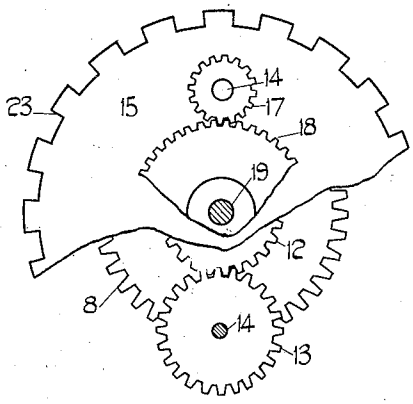


FIG. 3.

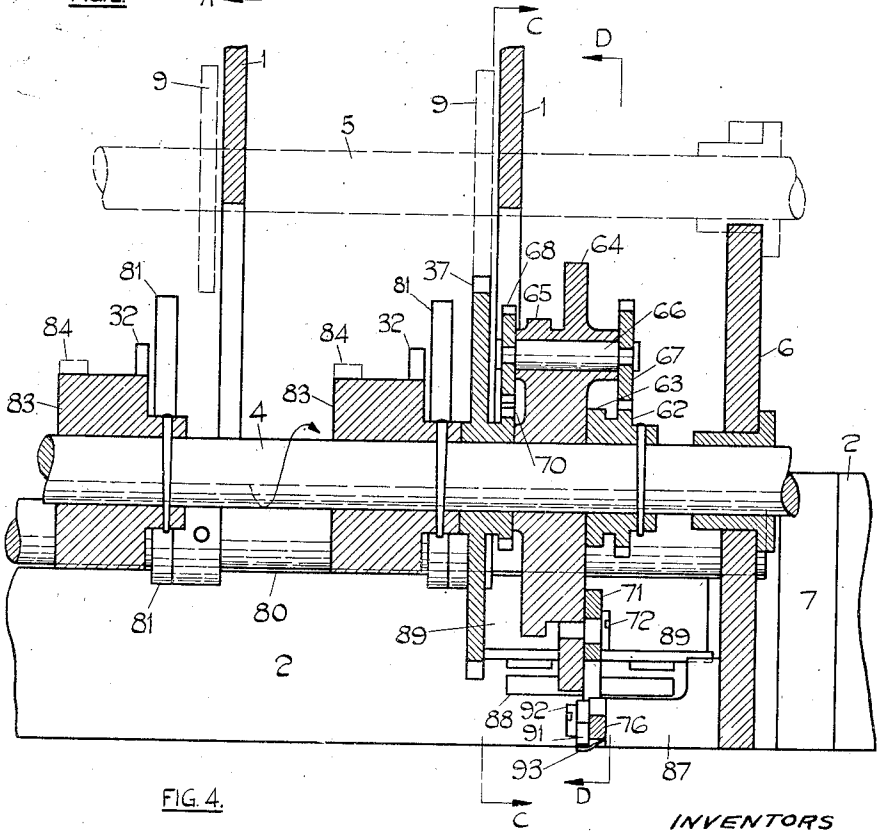


FIG. 4.

INVENTORS
Harold H. Keen
Thomas O. Wright
BY
W. M. Wilson
ATTY.

Dec. 4, 1945. H. H. KEEN ET AL. 2,390,441

ADDING AND SUBTRACTING MECHANISM

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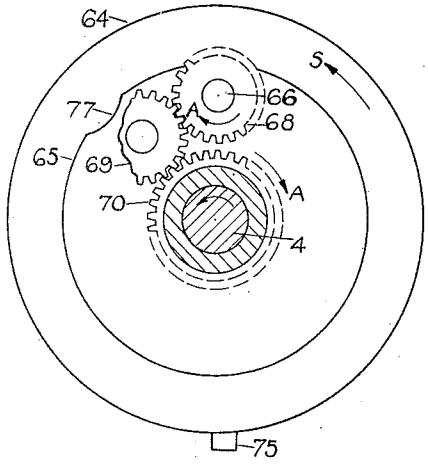


FIG. 5

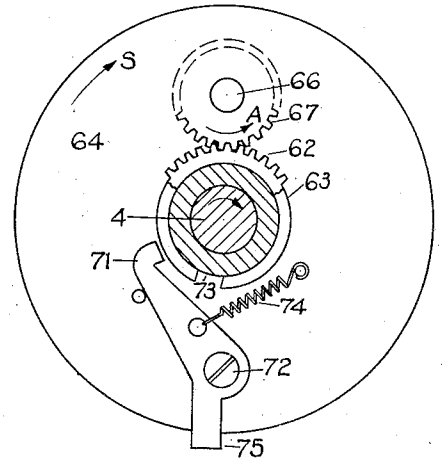


FIG. 6.

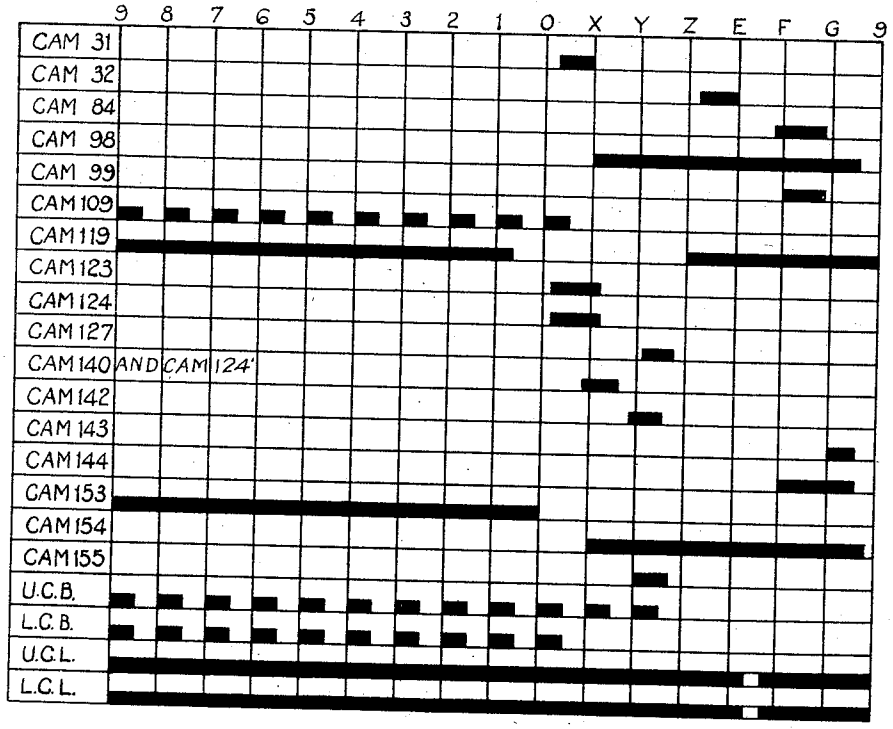


FIG. 8.

INVENTORS
Harold H. Keen
Thomas O. Wright
BY
W. Mitchell
ATTY.

Dec. 4, 1945. H. H. KEEN ET AL 2,390,441

ADDING AND SUBTRACTING MECHANISM

Filed Aug. 9, 1940 6 Sheets-Sheet 4

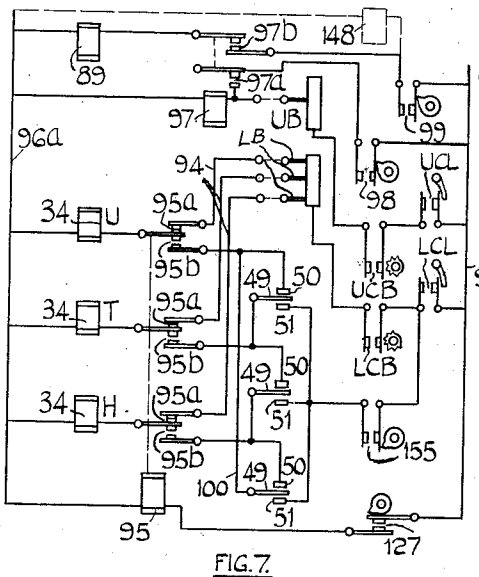


FIG. 7.

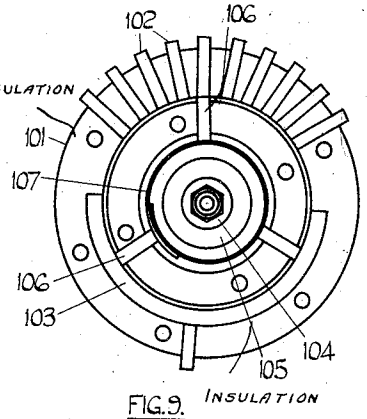


FIG. 9.

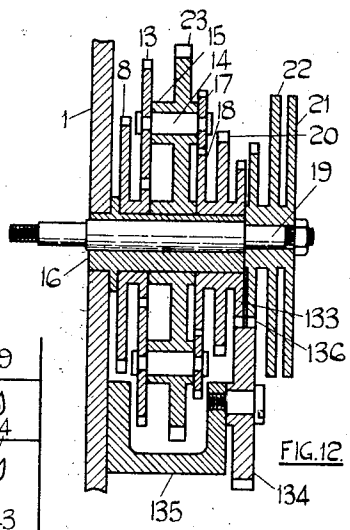


FIG. 12.

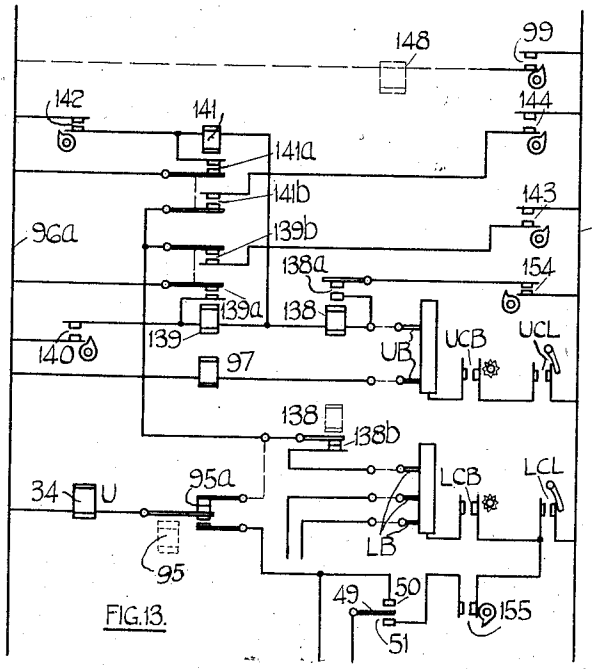


FIG. 13.

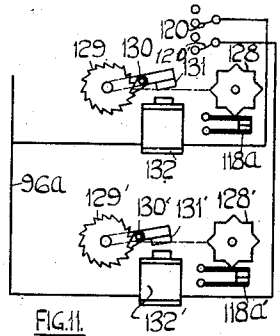


FIG. 11.

INVENTORS
Harold H. Keen
Thomas O. Wright
BY
W. M. Wilson
ATTY

Dec. 4, 1945. H. H. KEEN ET AL 2,390,441

ADDING AND SUBTRACTING MECHANISM

Filed Aug. 9, 1940 6 Sheets-Sheet 5

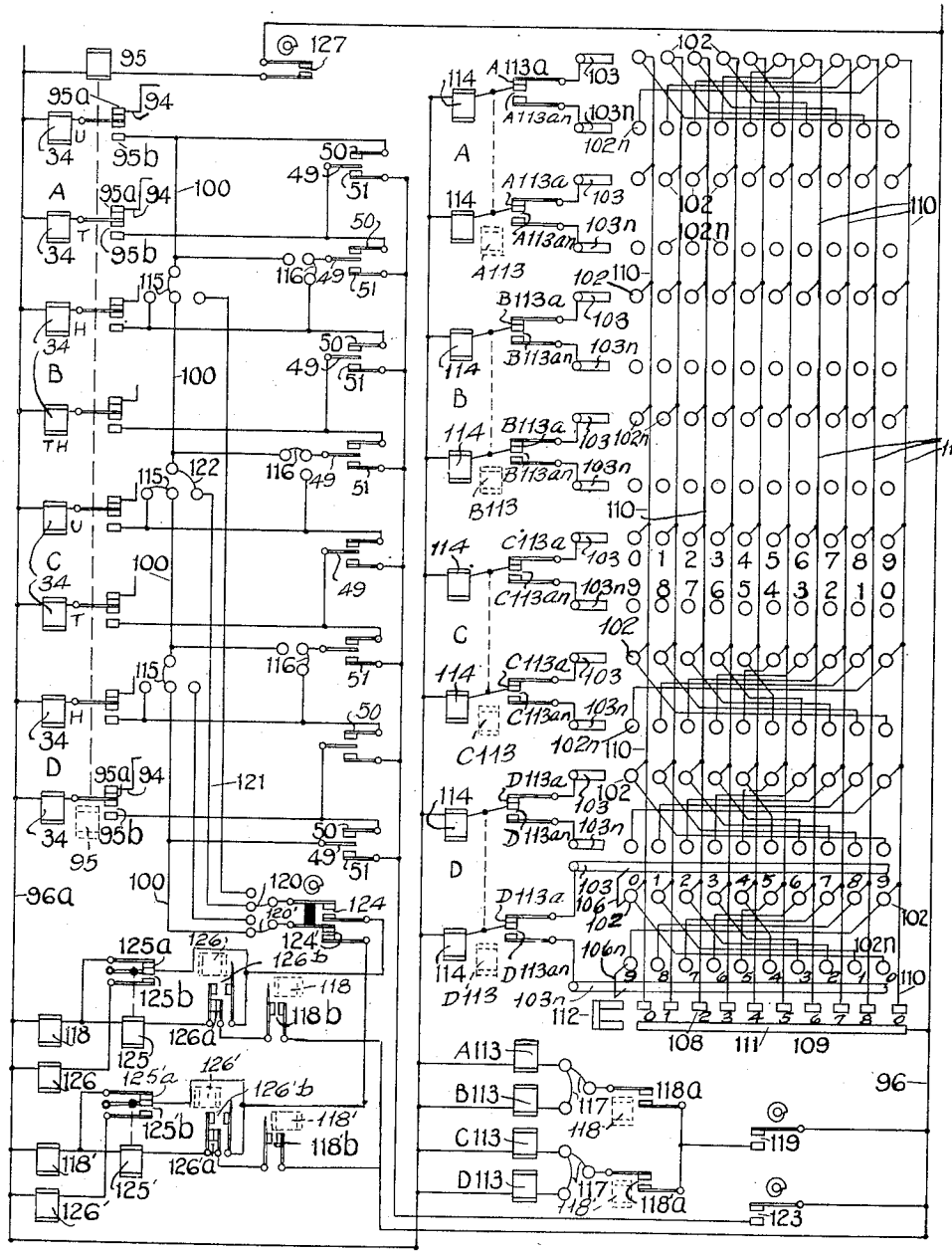


FIG. 10.

INVENTORS
Harold H. Keen
Thomas C. Wright
BY
W. M. Mahon ATTY

Dec. 4, 1945. H. H. KEEN ET AL 2,390,441

ADDING AND SUBTRACTING MECHANISM

Filed Aug. 9, 1940 6 Sheets-Sheet 6

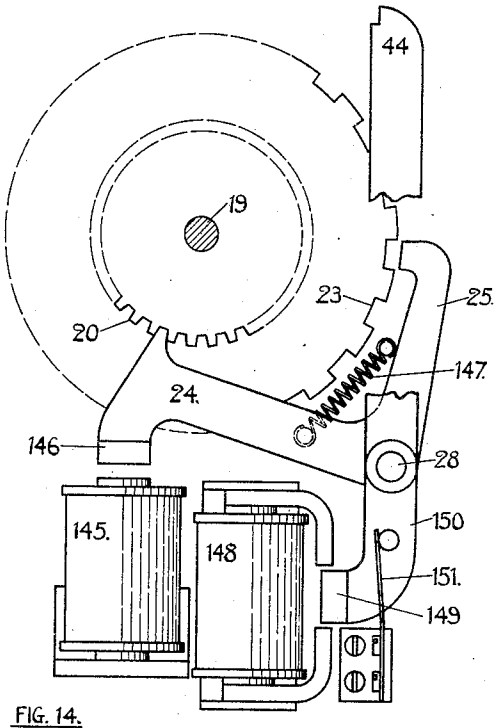


FIG. 14.

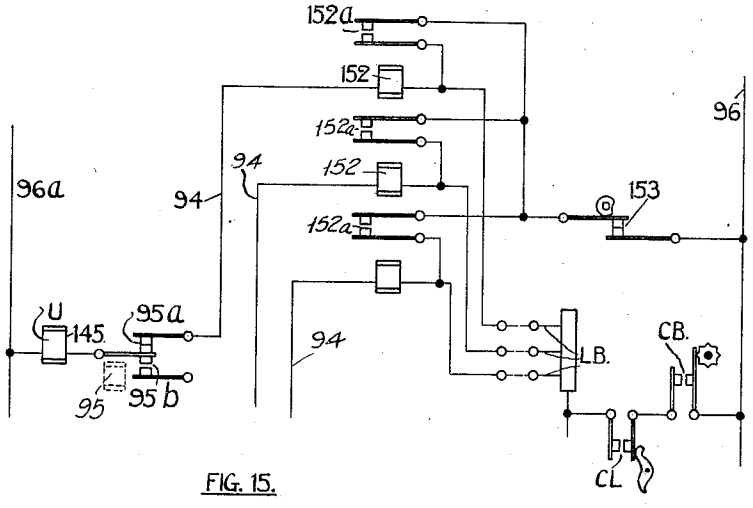


FIG. 15.

INVENTORS
Harold H. Keen
Thomas A. Wright
BY
W. M. Wilson
ATTY.

Patented Dec. 4, 1945 2,390,441

UNITED STATES PATENT OFFICE

2,390,441

ADDING AND SUBTRACTING MECHANISM

Harold Hall Keen and Thomas Oliver Wright, Letchworth, England, assignors to International Business Machines Corporation, New York, N. Y., a corporation of New York

Application August 9, 1940, Serial No. 351,948
In Great Britain August 15, 1939

6 Claims. (Cl. 235—61.8)

This invention relates to adding and subtracting mechanism of the kind comprising a number of register wheels which are rotated in one direction to add and in the reverse direction to subtract.

The invention has for its object an improved multi-denominational register, accumulator, or totalizer capable of receiving entries in all denominations, which registers a true positive or negative total, and is capable of rapid operation.

According to the invention an entry member in each denomination is turned in one direction for adding the value of a digit to the total in the totalizer and in the other direction for subtracting the value of a digit from the total in the totalizer, and a register member turns in one direction when the entry member is turned to add and in the other direction when the entry member is turned to subtract whereby entries may be made into all denominations simultaneously and transfer mechanism for each denomination operates, after passage by the register member through a predetermined position when turning in the direction for adding, to add unity to the next higher denomination, when there is a higher denomination but, in the case of the highest denomination, to add unity to the lowest denomination, and operates, after passage by the register member through the said position when turning in the direction for subtracting, to subtract unity from the next higher denomination when there is a higher denomination but, in the case of the highest denomination, to subtract unity from the lowest denomination.

The word "digit", which is normally used to mean one of the numbers 0 to 9, will be deemed to include any number up to but not including the base of the system of notation used. Thus, in the duo-decimal system, the numbers 10 and 11 are deemed to be digits.

One form of totalizer according to this invention, applicable to a statistical machine, will be described with reference to the accompanying drawings, in which:

Figure 1 is a side view of a totalizer, of which one denomination is visible.

Figure 2 is a section of the sun and planet mechanism with transfer cams and read-out commutator.

Figure 3 is a section thereof on the line AA of Figure 2, with parts broken away.

Figure 4 is a vertical section on line BB of Figure 1, showing the reversible gearing and two totalizer denomination support plates.

Figures 5 and 6 are sections showing elements of the reversible gearing, on the lines CC and DD respectively of Figure 4.

Figure 7 is a circuit diagram showing the connections of the totalizer to the circuits of a tabulating machine.

Figure 8 is a cam timing diagram.

Figure 9 is a back view of a read-out commutator.

Figure 10 is a circuit diagram showing the circuits for selecting the true total.

Figure 11 is an alternative form of part of the circuits of Figure 10.

Figure 12 is a view similar to that of Figure 2, showing an alternative form suitable for duo-decimal notation.

Figure 13 is a circuit diagram showing a circuit for duo-decimal notation.

Figure 14 shows an alternative form of certain parts of Figure 1, and

Figure 15 is a circuit diagram for the modification shown in Figure 14.

Referring to Figure 1, the parts for each denomination of the totalizer are carried on a plate 1, supported on side members 2. The parts are similar for each denomination, and two plates 1 for two denominations are shown in Figure 4. The main driving shaft 4 and the intermediate driving shaft 5 extend through all denominations of the totalizer and are carried in end plates 6, attached to the side members 2 by brackets 7. In Figure 4, the shaft 5 is shown in dotted lines as it is behind the line of the section. The shaft 5 is driven by the shaft 4 by the gear wheels 37 and 9.

The shaft 4 turns constantly counter-clockwise as seen in Figure 1. Gear wheels 37 and 9 are elements of the reversible gearing to be described, such that the shaft 5 is turned in one direction for adding and the other for subtracting. These directions are indicated for this and other shafts by double-ended arrows marked A and S.

The elements, in one denomination of the totalizer, shown to the right of the plate 1 in Figure 2 comprise a driven member, a sun and planet gearing, and parts of a register member. The driven member or gear wheel 8 is driven by the shaft 5 through the gear wheel 9 and idler gear wheel 10 turning on a stud 11 on the plate 1. A sun wheel 12 is attached to the wheel 8 and engages a pair of planet wheels 13 on shafts 14 in a cage 15. The wheels 8 and 12 and the cage 15 turn on a tubular stud 16 fixed to the plate 1. The right-hand ends (Figure 2) of the shafts 14 carry planet wheels 17 which engage a wheel 18 fixed to the shaft 19 which turns in the tubu-

lar stud 16 and passes through the plate 1 to carry the read-out commutator to the left of the plate. Also fixed to the shaft 19 are a locking plate 20 and two transfer cams 21 and 22 for adding and subtracting respectively. The cage 15 has formed on it a locking plate 23. The cam 21 is broken away in Figure 1 to show the cam 22 below it and this also is broken away to show the locking plate 20 below it. The parts 18 to 22 and the read-out commutator constitute the register member, because they all turn with the shaft 19 to register the amounts entered into the denomination of the totalizer.

The locking plate 20 and the cage locking plate 23 are locked alternatively by the two arms 24 and 25 respectively of a four-armed lever 24, 25, 26, 27, pivoted on a stud 28 on the plate 1. The arm 24 is shown pivoted independently on the stud 28 and is held in a fixed position relatively to the other arms by the spring 29 and the lug 30 which is bent downwards to engage the arm 27. This construction is for safety and, in operation, the arm 24 may be regarded as integral with the other arms of the lever. The lever is turned clockwise into the position shown by the cams 31 and 32 on the shaft 4 engaging the arm 26, and it is held in the position shown by the armature 33 of the electromagnet 34 engaging the arm 27. The spring 35 tends to turn the lever 24—27 counter-clockwise and the spring 36 tends to hold the armature 33 away from the magnet 34.

In the position of the parts shown, the arm 24 is locking the register member of the totalizer gear by engaging the locking plate 20 and, the wheel 8 being constantly turned, the cage 15 and planet wheels turn idly. Thus, the wheel 12 fixed to the wheel 8 turns the planet wheels 13, and therefore the planet wheels 17, and these roll around the wheel 18 which is fixed to the locked wheel 20, carrying the cage 15 with them. If now the magnet 34 be energised, its armature disengages from the arm 27, and the lever 24—27 is turned counter-clockwise by the spring 35, so that the arm 24 releases the locking plate 20 and, simultaneously, the arm 25 engages the locking plate 23, to hold the cage 15 stationary. Assuming the wheel 8 to be turning counter-clockwise for adding, the planet wheels 13 will be turned clockwise by the wheel 12, and the planet wheels 17 will turn the wheel 18, and therefore the whole register member counter-clockwise. The ratios of the wheel teeth are such that the register member turns one-third of a revolution for one revolution of the wheel 8, and the wheel 8 is turned sixteen revolutions for ten revolutions of the shaft 4. When the locking plate 20 is locked, the cage 15 with locking plate 23 makes half a revolution per revolution of the wheel 8. The reason for these ratios is that the register member shown is designed for decimal notation and for use with a statistical machine of the Hollerith type which operates on a particular cycle having 16 cyclic intervals customarily indicated by the following characters, which indicate points separating the intervals: 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, X, Y, Z, E, F, G. In this cycle, the value of a digit, say 6, is represented by the six intervals between the points 6 and 0, while the intervals between 0 and 9 are allocated to transfers from one denomination to another and to resetting. The shaft 4 makes one revolution per cycle, and a unit digit is therefore represented by one-sixteenth of a revolution of the shaft, and therefore by one-tenth of a revolution of the wheel 8, and by one-thirtieth of a revolution of the register member. The locking plate 20 on the register member has 30 notches, and therefore the interval between adjacent notches represents a unit digit. The register member is made to register 0 to 9 three times in a revolution for convenience in construction. When locking plate 23 is released, it makes half a turn for one turn of gear 8, as previously explained. Since gear 8 makes one tenth of a revolution in a cyclic interval, the plate 23, in such interval, will make one-twentieth of a revolution. According, plate 23 is provided with 20 notches so that it may be arrested at any twentieth part of its revolution during a chosen cyclic interval.

The operation of entering into the totalizer the value of a digit, say 6, resulting from the operation of the statistical machine is as follows: At the point 6 in the cycle, the magnet 34 is energised and the related register member begins to turn; at the point 0, the cam 31 strikes the arm 26, thus locking the register member and resetting the lever 24—27. In the interval 6 to 0 therefore the register member has been turned through an angle comprising six notches of the plate 20 and representing the digit 6. The operation is the same if the digit is to be subtracted, except that the register member turn in the opposite direction.

The transfer mechanism will now be described. It is of the known type in which all transfer between the different denominations are made simultaneously. Thus, if the totalizer stood at 19999 and 1 were added, the four transfers required to give the result 20000 are made simultaneously. This is effected by causing the parts in a denomination to take up a "long transfer" position, when, in adding, 9 is registered in that denomination (assuming the totalizer to be for decimal notation). If a transfer is effected from one denomination by adding 1 to the next higher denomination when the parts of this latter are in long transfer position, a transfer is also effected by adding 1 to the second higher denomination.

This type of simultaneous transfer may be effected mechanically or electrically. In the totalizer shown it is effected partly mechanically and partly electrically. Considering first the transfer mechanism operable during adding, a transfer pawl 38 on an arm 39 pivoted to the plate 1 at 40, engages the adding transfer cam 21. This has a notch 41 constituting the long transfer step, preceding a projection 42, constituting the ordinary or short transfer step. The pawl 38 engages the notch 41, as shown in Figure 1, when the register member stands at 9, and is raised by the projection 42 as the register member passes from 9 to 0. When the arm 39 is so raised its right-hand end is engaged by the step 43 on the lever arm 44 which is pivoted on the stud 28 and is urged counter-clockwise by a spring (not shown). Thereby the arm 39 is held in its raised position whenever the register member passes from 9 to 0. Above the arm 39, a contact arm 45 is pivoted at 46 to an insulating block 47 and is urged downwards by a spring 48. The contact blade 49 of the arm is shown in its lowest position making contact with the contact piece 50, and it can occupy an upper position, shown in dotted lines, in which it makes contact with the contact piece 51. It can also occupy an intermediate position, also shown in dotted lines, in which no contact is made. The contact arm 45 is operated by the arm 39 by means of an interposer 52 on the

end of an arm 53 pivoted at 54 to an arm 55 of a lever which is pivoted to the plate 1 at 56. It will be understood that arm 53 is suitably insulated from contact arm 45 and for this purpose, arm 53 may be made of insulating material. It will be clear, further, that contacts 50 and 51 are carried by support plate 1 through insulation. The arm 55 remains in the position shown during adding operations. When the pawl 38 is in the notch 41, the contact blade 49 is allowed to rest on the contact 50. The parts are then in long transfer position, the register member being at 9. In passing to 0, when the arm 39 is held in its raised position, the contact blade 49 is pressed by the interposer 52 and arm 53 against the upper contact 51. The parts are then in short transfer position, to control additive transfer of 1 to the next higher denomination. When the pawl 38 is engaging the rim of the cam 21 the contact blade 49 is in its intermediate position, in which no contact is made. It may be noted that there are three notches 41 in the cam 21, in positions corresponding to the three 9 positions, each notch preceding a projection 42.

Before describing how the transfers are completed as a result of contacts with the pieces 50 and 51, there will be described the devices for making the same contacts at the appropriate times during a subtracting operation.

In subtracting, the transfer must be effected when the register member passes from 0 to 9, and the long transfer position must be taken up when the register member is at 0. For this purpose, a second cam 22 is fixed to the register member, shown behind the adding cam 21 in Figure 1, and has three projections 61 immediately behind the projections 42 of the cam 21, and also three notches 60 which precede the projections 61 when the cam is moving in the direction for subtracting. A second arm 57, with pawl 58, pivoted at 40 engages the cam 22, and is similar to the arm 39 with pawl 38, except that it has a notch 59 which is immediately below the interposer 52 when this is in the position shown for adding. By reason of the notch 59, the arm 57 is raised and lowered by the projections 61 and notches 60 without striking the interposer, and is therefore ineffective. Now when the reversible gearing, which releasably drives the register members, is operated to change from adding direction to subtracting direction, the arm 55 is moved to the right into the position shown in dotted lines, by means to be described later. Thereby the arm 53 is moved to bring the interposer 52 into the position shown in dotted lines in which it is clear of the notch 59 in the arm 57, but is over a similar notch 62 in the arm 39. In this way the arm 57 is made effective to actuate the contact arm 45, while the arm 39 becomes ineffective. Therefore, in subtracting, when the register member reaches 0, the pawl 58 drops into the notch 60, and allows the blade 49 to rest on the contact 50 to effect a long transfer and, in passing from 0 to 9 the arm 57 is latched in its raised position by the arm 44 and moves the blade 49 into contact with the piece 51, to effect the short transfer.

The reversible gearing will now be described with reference to Figures 1, 4, 5 and 6. The shaft 4 carries, fixed to it, a gear wheel 62 and notched disc 63 and, loose on it, a disc support 64, with cam plate 65. The support 64 carries a shaft 66 having, at one end, a gear wheel 67 engaging the gear wheel 62 and, at the other end, a gear wheel 68. The wheel 68 engages an idler wheel 69, pivoted on the support 64, which in turn engages a gear wheel 70 attached to the gear wheel 37 and loose on the shaft 4. The support 64 carries a pawl 71 pivoted to it at 72 which is adapted to enter a notch 73 in the disc 63 under the tension of the spring 74. When the pawl 71 is in the notch 73, the support 64 is locked to the disc 63 and shaft 4 and the gear wheels 67 and 68 are prevented from turning. The whole assembly therefore turns with the shaft 4 and carries with it the gear wheels 70 and 37. The parts are then turning in the direction for subtracting, indicated in the drawings by arrows with "S."

One end 75 of the pawl 71 projects beyond the edge of the support 64 and is adapted to be caught and held by the arm 76 (Figure 1). When so held, the pawl 71 is withdrawn from the notch 73 and it and the support 64 are held stationary. Then the wheel 62 fixed on the shaft 4 drives the wheel 70 through the gear wheels 67, 68 and 69, and the wheel 70, to which the wheel 37 is fixed, is turned in the opposite direction to that of the shaft 4, the parts turning in the direction for adding, as indicated by the arrows with "A." The ratios of the teeth of the wheels 62, 67, 68 and 70 are such that the speed of the wheels 70 and 37 is the same as that of the shaft 4, but in the opposite direction.

The cam disc 65 has a depression 77 in which, when the support 64 is held stationary, the roller 78 on the arm 79 (Figure 1) rests. The arm 79 is fixed to a shaft 80 pivoted in the end plates 6 and carries, at each denomination of the totalizer, an arm 81 adapted to engage the arm 82 of the lever arm 55 pivoted at 56. When the support 64 with cam disc 65 is stationary, that is to say in adding, the arms 79, 81 and 82 are in the positions shown in Figure 1, and the arm 55 is in the position shown in full lines. When the support 64 turns, that is to say in subtracting, the arms 79 and 81 are turned counterclockwise as the depression 77 passes from under the roller 78, and thereby the arm 55 is moved into the position shown in dotted lines. In this way, when the reversible gear is operated in the direction for subtracting, the arm 55 is moved to place the interposer 52 in the position to make the subtraction transfer mechanism effective. The shaft 4 carries at each denomination a cam block 83, with two cams 31 and 32 for resetting the lever 24, 25, 26, 27 and a cam 84 for striking the tail 85 of the arm 44 to unlatch the pawl arms 39 and 57. The timing of these cams will be described later.

The arm 76 is operated to release the pawl 75 and support 64 as follows: The arm is pivoted at 86 to a support 87 fixed on the end plate 6 and carries the armature 88 of an electromagnet 89. It is normally held in the position shown by a spring 90. A latch 91 is pivoted to the arm 76 at 92 and forms with the arm a slot in which the projection 75 is retained. The latch is normally held in the position shown by the spring 93. When the magnet 89 is energised, the arm 76 is rocked clockwise to release the support 64 which then turns counterclockwise, as viewed in Fig. 1. When the magnet is de-energised the projection 75, on reaching the arm 76, depresses the latch 91 and is held by the end of the arm, the latch then springing back into the position shown.

The operation of the totalizer under control of record cards passed through a Hollerith tabulating machine will now be described with reference to Figures 7 and 8. Figure 7 shows only

the relevant parts and circuits of a tabulating machine, and Figure 8 indicates by thick black lines the times of operation of the different cams. Each card is passed through two reading stations in which its records are read by brushes. These are indicated by the letters UB and LB indicating upper and lower brushes. The lower brushes read the values of the digits in the different denominations of the number to be entered into the totalizer, and wires **94** lead from these brushes through relay contacts **95***a* to the magnets **34** in each denomination, the circuit being completed from the supply line **96** to the line **96***a*, through the usual circuit breaker LCB and card lever contact LCL. The different denominations, of which three only are shown, are indicated by the letters U, T, and H, respectively signifying units, tens, and hundreds. The magnet **89** is normally not energised, so that the support **64** in the reversible gearing is held stationary, and the gearing operates in the direction for adding. As already explained, when a digit, say 6, is read by the lower brushes, the circuit is completed to energise the magnet **34** in the appropriate denomination, and the related register member starts turning. At the point 0 in the cycle, the cam **31** causes the register member to stop turning, the value 6 having then been added. For rapid operation, the cam **31** operates a little after 0, as shown in Figure 8, to allow for lag in operation of the magnet **34** and lever **24**, **25**, **26**, **27**. Suppose that the number previously registered by the totalizer was 166 and that a number 126 is added, then the unit register member will have moved to 2, and in passing from 9 to 0, the arm **39** in the units denomination will have been raised into latched position, in which the blade **49** makes contact with the contact piece **51**, to control a short carry. The tens register member will have moved to 8, and the hundreds register member to 2, and the blades **49** in those denominations will be in their intermediate positions, making no contact. A little after the point Y in the cycle, cam contact **127** completes the circuit through the transfer relay magnet **95**, opening the contacts **95***a* and closing the contacts **95***b*. A circuit is then completed from the line **96** through the LCL contacts, cam contacts **155**, the contact **51** in the units denomination, to blade **49**, thence through the contacts **95***b* and magnet **34** in the tens denomination, to the line **96***a*. The tens denomination register member will then start to add but, after an interval sufficient to enable it to add 1, cam **32**, a little after point Z, moves the lever arm **26** to stop the turning of the register member. Thereby the transfer from the units to the tens denomination is effected, and the register member will stand at **292**. A little before the point F in the cycle, cam **84** strikes the arm **85** to release the transfer arm **39**. Since the tens register member now stands at 9, its transfer arm **39** will have allowed the blade **49** to make contact with contact piece **50**, to make a long transfer. If now a number 108 be added by the next card, a transfer will be effected as before from the units to the tens denomination, but the circuit through contact **51** and blade **49** in the units denomination can be completed both through contacts **95***b* and magnet **34** in the tens denomination and also through contact **50**, blade **49**, contacts **95***b*, and magnet **34** in the hundreds denomination. Therefore, 1 will be added to each of the tens and hundreds register members, and the number registered will be 400.

When the number recorded on a card is to be subtracted, this is indicated on the card by a special designation hole at one of the points X or Y, and this hole is sensed by the upper brushes. The presence of such a hole causes a circuit to be completed through relay magnet **97** thereby closing contacts **97***a* and *b*. Since cam contact **98** is closed from X to $G^{1/2}$, a holding circuit for relay **97** is completed through contacts **97***a* and contacts **97***b* remain closed. Then at point F cam contact **99** completes the circuit through contacts **97***b* and the magnet **89**. The support **64** is then released, and the totalizer parts turn in the direction for subtracting during the following cycle, which is the cycle in which the card passes the lower brushes. The magnet **89** is energized only momentarily, during the interval from F to G, and therefore the support **64** is released only during a single revolution of the shaft **4**. As far as the circuits in Figure 7 are concerned, the operation of subtracting the number is the same as that of adding it, but the subtraction transfer is made operable, under control of the reversible gearing, to effect transfers at the appropriate points.

The total registered in the totalizer may be indicated in various ways, by appropriate devices fixed to the register members. Thus, digit indicating wheels may be fixed to the shafts **19** on the left hand side of the plates **1**, as seen in Figure 2. These will indicate the correct total, within the capacity of the totalizer, or the balance of the amounts added and subtracted, provided that the total of the amounts subtracted does not exceed the total of the amounts added. If it does exceed the total of the amounts added, so that the total represents a negative amount, this total may be shown in three different ways. In the totalizer so far described, if, when the register members stood at 000, one were subtracted, the register members would show 999 which is the tens complement of 1. In many operations, of statistical machines negative numbers are conveniently expressed as nines complements, by which minus 1 is expressed as 998. The totalizer can be arranged to indicate the nines complement of a negative total by the provision of a transfer mechanism to the highest denomination, as shown in Figure 7 in the case of the hundreds denomination, connection being made by the wire **100** from the blade **49** to the units denomination. Then, in subtraction, if the hundreds register member passes from 0 to 9, digit 1 is subtracted from the units denomination and the subtraction, for instance of one from 000 would give the result 998, which is the nines complement. The third way is to show the total as a true number, whether positive or negative. Thus the same number 001 would be shown whether a unit were added or subtracted from 000, but an indication would be given to show whether the number shown was positive or negative. This can be done by using for instance two indicating wheels on the register member in each denomination, the number indicated on one wheel being the nines complement of that on the other wheel, and by providing an auxiliary denomination for indicating purposes only. This auxiliary denomination will then stand at 0 so long as the total in the totalizer is positive but will move to 9 if an amount be subtracted greater than the positive total. One of the indicating wheels in each denomination will show a digit of the true positive total if the auxiliary denomi-

nation shows 0, and the other indicating wheel will show a digit of the true negative total if the auxiliary denomination shows 9.

The circuits of Figure 7 will effect this if it be assumed that the totalizer has units and tens denominations only, the hundreds denomination serving as auxiliary denomination. Then when, in subtraction, the tens denomination passes from 0 to 9, the auxiliary hundreds denomination, previously at 0, will move to 9, and will transfer one by subtracting it from the units denomination, and the negative indicating wheel will show a true negative total. When, by addition, the tens denomination passes from 9 to 0, the auxiliary hundreds denomination will move back to 0 and will transfer one by adding it to the units denomination, and the positive indicating wheel will show a true positive total.

The following example shows the operation, the subtraction and addition of 1 being shown as a separate step. The letters AD mean auxiliary denomination. It should be noted that corresponding digits in the two indicating wheels always add up to 9.

	True total	A. D.	Indicating positive	Wheels negative
Totalizer at	+44	0	44	55
Subtract 65	−21	9	79	20
Subtract 1		9	78	21
Subtract 12	−33	9	66	33
Add 58	+25	0	24	75
Add 1		0	25	74

When the totalizer is used in connection with statistical or other calculating machines, it is generally required that the amount registered should be printed or should be transferred into another totalizer in which calculations are effected on it. For this purpose the register member order shown is provided with two read-out commutators. These are shown in section in Figure 2 and in place with the cover rings removed in Figure 9. The two commutators are similar and each consists of a ring of insulating material 101, fixed to the plate 1, in which are embedded ten contact pieces 102, extending over one-third of the circumference. The contact pieces are thus separated by an angular distance equal to that of the notches on the locking plate 20. Opposite these contact pieces is a common contact strip 103 embedded in the ring 101, and extending over half the circumference. Keyed to the shaft 19 of the register member is a metal bushing 104 carrying a ring of insulating material 105 in which three contact brushes 106 at 120 degrees apart are adapted to slide. These are pressed outwards against the contact pieces 102 and strip 103 by a coiled spring 107, which serves also to connect the brushes together electrically. In rotating, therefore, as soon as one of the brushes, in passing over the ten contact pieces 102, has connected them successively to the common contact strip 103, through one of the other brushes, the succeeding brush connects them successively to the common contact strip.

In the circuit diagram Figure 10, showing eight denominations of a totalizer, the positive commutators are represented diagrammatically by the contact pieces 102 and the negative by the contact pieces 102*n*, and the common strips by the reference letters 103 and 103*n* respectively. Likewise, the brushes of the positive and negative commutators are distinguished as 106 and 106*n*, as indicated for the denomination at the bottom of Fig. 10. As seen in this diagram, the contact pieces of the positive and negative commutators of a denomination are connected electrically so that contact piece 9 on one is connected to 9 on the other, 8 to 8, 7 to 7, and so on. For simplicity of illustration, the wiring between the contact pieces of the positive and negative commutators of some of the denominations has been omitted in Fig. 10, and the contact pieces 103 and 103*n* are shown in juxtaposition to all their associated contact pieces only for the denomination shown at the bottom of this figure. It will be understood, however, that the wiring between the contact pieces of each pair of commutators and the strips 103 and 103*n* of each such pair are the same for each denomination. The contact pieces of the positive commutators of all denominations are connected to contacts 108 of an emitter 109 by wires 110. The emitter 109, with common strip 111 and brushes 112 is of the ordinary type used in Hollerith tabulating machines and serves to connect the supply line 96 successively to the contact pieces of all the commutators. The common strips 103 and 103*n* are connected respectively to contacts A113*a* to D113*a* and A113*an* to D113*an* of the four relays A113 to D113. Normally, contacts A113*a* to D113*a* are closed, thereby connecting the positive commutators to magnets 114. Thus, if the lowermost denominations shown in Fig. 10 registered the positive value 5, a positive value readout circuit for this denomination would be closed during operation of the emitter 109 as the brush 112 reached the "5" contact 108, as follows: from line 96, via common emitter strip 111, brush 112, "5" contact 108, connected wire 110, the "5" contact piece 102 of the said denomination, the brush 106, common strip 103, and, via the connected contacts D113*a*, through the lowermost magnet 114, to line 96*a*. In a manner explained later, when a negative number stands in the totalizer containing the denomination, the associated one of the A113*a* to D113*a* contacts is opened and the associated one of the A113*an* to D113*an* contacts is closed. The value represented in the negative commutator will then be read out. For example, if the lowermost denomination in Fig. 10 registers the negative value 3, a negative value readout circuit through the related magnet 114 will extend from line 96 via the emitter 109, in "3" position, to the "3" contact piece 102 of the denomination, thence via the connection to the "3" contact piece 102*n* of this denomination, brush 106*n*, strip 103*n*, contacts D113*an*, and through the lowermost magnet 114 to the supply line 96*a*. The magnet 114 may be the magnet in a tabulating machine causing the digit registered in the denomination of the totalizer to be printed, or it may represent, for instance, the actuating magnet of a totalizer to which the reading of the denomination is transferred.

The circuit diagram in Figure 10 shows the manner in which the true total, whether positive or negative, registered by the totalizer is read out to the magnets 114, and also shows the manner in which a plurality of denominations (eight being shown in the drawings) may be connected so as to form either a single totalizer or a plurality of independent totalizers. In the drawings, the denominations are shown permanently connected in pairs, but divisible so that two totalizers of two and six denominations or four and four denominations can be formed, and the plug connections shown are for two totalizers of

four and four denominations. From this diagram it will be clear how any number of denominations may be connected so as to form any combinations of them into totalizers. When a totalizer has a fixed number of denominations, reversible gearing, with a single intermediate shaft 5, as shown in Figs. 1 and 4, and controlled by a single magnet 89 and associated relay 97—97a—97b, as shown in Fig. 7, may be used for all the denominations. When, however, a number of denominations are to be capable of being combined together to form one, two or more totalizers, a plurality of reversible gearings, each with its related magnet 89 and relay 97—97a—97b, must be provided. In the arrangement shown in Figure 10, in which the denominations are permanently connected in pairs, reversible gearing and an associated magnet 89 with control relay is provided for the two denominations of each pair, and two wheels 9, one for each denomination, may be conveniently mounted on a sleeve on a fixed shaft, one of the wheels 9 being driven by the wheel 37. If it be desired that any one denomination be capable of being connected with any others to form a totalizer, each denomination must be provided with its own reversible gearing, controlled by a related magnet 89 and relay 97—97a—97b, and the wheels 9, one for each denomination, may be mounted on studs on the plates 1. The entry magnets 34, transfer relays 95 with their contacts 95a and 95b and transfer contacts 49, 50 and 51 are shown as in Figure 7, but only the wires 94 leading to the lower brushes are shown, and the circuits for operating the reversing control magnets 89 and associated relays 97—97a—97b, with the upper brushes, are omitted, since circuits for each magnet 89 and associated relay are such as shown in Fig. 7. The four pairs of denominations are distinguished by the letters A, B, C, D. The connections shown give two independent totalizers, one of which may be called the A—B totalizer, composed of pairs of denominations A and B, so arranged that the units and tens denominations of the totalizer A—B are in pair A and the hundreds and thousands (TH) denominations are in pair B. The other totalizer may be called C—D, with pair of denominations so arranged that the units and tens denominations are in pair C and the hundreds and thousands denominations are in pair D. The wire 100 which, in Figure 7 connects the contact blade 49 of the highest denomination to the contact 95b of the lowest denomination, to transfer one, is divided, in Figure 10, by plug connections 115, and the connections shown join the contact 49 of the thousands denomination in B to the contact 95b units denomination in A, and the contact 49 of the thousands denomination in D to the contact 95b of the units denomination in C. Plug connections 116 are also provided whereby the contact blade 49 of the highest denomination in each pair may be connected either to the wire 100 or to the contact 95b in the first denomination in another pair.

There will now be described the manner in which selection is made between the positive and negative read-out commutators, so that the commutators which register the true total, positive or negative, are connected to the magnets 114. Heretofore this selection has commonly been made by allocating one denomination of the totalizer to the function of selection, so that this denomination is not available as one of the adding or subtracting denominations. By the devices shown in Figure 10, selection is made while all denominations are available for adding or subtracting. This is possible because means are provided to store, in effect, the sign of the amount registered by the totalizer. In short, considering the totalizer A—B and the embodiment shown in Fig. 10, upon passage of the totalizer from a positive to a negative amount registration, a relay 118 is energized and held until the totalizer returns to a positive amount registration. The relay 118 when in energized status enables the true figures of a negative amount to be read out and when in deenergized status enables the positive amount to be read out. Since means are provided to store, in effect, the sign of the registered amount, the highest denomination of the totalizer may be used to receive any of the digits of the notation since it is unnecessary to resrict the positions of the highest denomination to the 9 and 0 positions as indications of negative and positive amounts, respectively. A detailed description of the sign storing means and the means related thereto is given in succeeding portions of the specification. An any cycle in which the amount registered is a totalizer is to be read out to energize magnets 114, the emitter 109 completes negative value or positive value readout circuits, such as previously traced, depending on whether the amount in the totalizer is negative or positive. When the registered amount in the totalizer A—B is positive, the contacts A113a and B113a will be closed and positive value readout circuits will be formed to read out the registered amount. On the other hand, if the registered amount is negative, contacts A113an and B113an will be closed and negative value readout circuits will be completed. Similarly, negative or positive value readout circuits will be completed for reading out the totalizer C—D depending upon whether contacts C113an and D113an or C113a and D113a are closed. The adjustment of these several contacts is controlled by their correspondingly lettered relays coils A113 to D113. By plug connections 117, the four relay coils A113, B113, C113, and D113 can be connected as desired to the two contacts 118a and 118'a of the two relays 118 and 118'. With the plugging shown in Fig. 10, if contacts 118a are closed, coils A113 and B113 will be energized upon closure of cam contacts 119, and if contacts 118'a are closed, coils C113 and D113 will be similarly energized. Relays 118 and 118' are elements of a selection means for selecting either the positive or negative commutators of totalizers to be read out. Two such selection means are required for the arrangement shown in Fig. 10, each such selection means being under control of one of the totalizers A—B and C—D. To provide for the requisite control, by the totalizer A—B of the selection means including relay 118, the highest denomination (TH) of this totalizer has its contact blade 49 connected by means including plugwires 116, 122, and 120 to the cam contacts designated 124 which lead via normally closed contacts 125a to relay 118. Similarly, the highest denomination of totalizer C—D is connected by means including plugwire 120' to cam contacts 124' which lead via normally closed contacts 125'a to relay 118'. It may be mentioned that cam contacts 124 and 124' are commonly operated and timed.

Now so long as the register member of the highest denomination registers a true positive number, that is to say any number from 0000 to

9999, the contact blade 49 makes no contact with contact 51, but if, in subtraction, the number is decreased below 0000 to become negative, the highest denomination passes from 0 to 9 and the contact 49—51 is made. Then a circuit is completed from line 96 through cam contacts 123, contacts 51—49 of the highest denomination of, say, totalizer A—B, plug connection 126, cam contacts 124, contacts 125*a* of relay 125, which are normally closed, relay 118 to line 96*a*. Thereby relays A113 and B113 are operated to close contacts A113*an* and B113*an* to make the negative commutators of totalizer A—B effective. This circuit through relay 118 will not be completed on the following cycle, because contacts 49—51 will no longer be made. Provision therefore is made to retain a circuit through relay 118, as follows: Relay 118 also closes contact 118*b*, to establish a circuit from line 96, contacts 118*b*, normally closed contacts 126*a*, relays 125 and 118 to line 96*a*. Relay 125 is not however energized until cam contacts 124 are opened, because it is shunted by the circuit through these contacts. When contacts 124 are opened, relay 125 becomes energized and closes its contacts 125*b* to connect contacts 124 through relay 126 to line 96*a*. Thereby a circuit is prepared through relay 126 when contacts 49—51 are next made. So long as they are not made, that is to say, so long as the totalizer does not pass back from 9 to 0 in its highest denomination, the circuit remains through relay 118 by way of its contacts 118*b* and contacts 126*a*. When the totalizer does so pass back, contacts 49—51 are made to complete the circuit through relay 126, whereby its contacts 126*b* are first made and then contacts 126*a* broken. The circuit through relays 118 and 125 is then maintained through contacts 126*b* until cam contacts 124 open, when relay 118 is de-energised to make the positive commutators again effective. The parts are then again in normal position. In a similar manner, when the totalizer C—D passes from a positive to a negative value, the contacts 49—51 of the highest denomination in this totalizer close and when cam contacts 123 and 124' close, a circuit makes from line 96 via contacts 123, 49—51 in the TH denomination of C—D, wire 100, plugwire 120', cam contacts 124', contacts 125'*a*, and relay 118' to line 96*a*. This relay is held energized until these contacts 49—51 again close as a result of the totalizer C—D passing back to a positive value. The means for maintaining 118' energized is similar to the means described for maintaining 118 energized, with the relays 125' and 126' functioning in the same way as the relays 125 and 126. It may be observed from the timing chart, Fig. 8, that cam contacts 127 which close to cause transfers to be carried out are timed to make after the cam contacts 123 and 124 and 124' have closed and opened. If a totalizer registered, say, positive amount 9314 and in a cycle, 9382 were subtracted, the denominations would register, before the transfer period, 0032. The tens denomination transfer contacts 49—51 would be closed and the contacts 49—50 in the hundreds and thousands denominations would be closed. In such a case, the circuit of the selection relay 118 or 118' is made via the closed 49—51 contacts and the contacts 49—50 of the higher denominations. Assuming, for instance, that this example were applied to totalizer A—B, the circuit of relay 118 would make from line 96 via contacts 123, contacts 49—51 of the tens denomination, in A, thence via a plugwire 116, contacts 49—50 of the hundreds denomination, contacts 49—50 of the thousands denomination, another plugwire 116, plugwire 122, line 121, plugwire 120, cam contacts 124, contacts 125*a*, and through relay 118, to line 96*a*. In this manner, the selection means anticipates the transfer operation which will bring the highest denomination of the totalizer from a zero value position to a negative 1 value position. Likewise, if passing back of a totalizer from a negative value to a positive value is to be effected as a result of a long carry, the selection means anticipates this result by energizing the prepared 126 or 126' relay magnet by way of one short carry contact and following long carry contacts. The present invention is not concerned with means for denoting the sign of the balance read out of a totalizer. It is manifest, however, that each of the magnets A113 to D113 may control sign denoting means in the same way as magnet 124 of Kolm Patent 2,019,863 controls sign printing means or in the same way as the printing of an asterisk is controlled in Peirce Patent 2,056,363. For the circuit network shown in Fig. 10 where magnets A113 and B113 are plugged together for common operation, only one of these magnets may suffice to control sign denoting means for the totalizer A—B. Similarly, only one of the magnets C113 and D113 need be utilized to control sign denoting means for totalizer C—D.

An alternative form of device for operating the contacts 118*a* and 118'*a* is shown diagrammatically in Figure 11. In the alternative form, the contacts 118*a* are operated by a cam 128 which is on the shaft of a ratchet wheel 129 with ratchet pawl 130 on the armature 131 of an electro magnet 132. The ratchet wheel 129 has twice as many teeth as the cam 128 has projections so that, when operated step by step by the magnet 132, the contacts 118*a* are alternatively closed and opened. The magnet 132 is arranged to be energized by a circuit which starts in the same way as the circuit for coil 118 (Fig. 10); i. e., from line 96 via contacts 123, the contacts 49—51 of the highest order of totalizer A—B, the plugwire 122, line 121, and to the plugwire 120. The circuit is completed, as indicated in Fig. 11, from plugwire 120 through magnet 132, to line 96*a*. It will be noted that cam contacts 124 are unnecessary here because it is not required to maintain magnet 132 energized, whereas in the Fig. 10 form, the magnet 118 must be held energized by means including a relay 125 which is shunted by contacts 124 and does not take effect until the latter contacts open. On the other hand, with the means shown in Fig. 11, the magnet 132 need be energized only momentarily to effect a step of movement of ratchet 129 and connected cam 128. The cam 128 itself holds the contacts 118*a* in adjusted position until magnet 132 is again energized by a succeeding closure of contacts 49—51 (occurring upon a reverse movement of the highest order through the critical position). In a similar manner, the magnet 132' may be energized by a circuit which extends from line 96 (Fig. 10) via cam contacts 123, the contacts 49—51 of the highest order of totalizer C—D, thence via wire 100 to plugwire 120'. The circuit will be completed, as shown in Fig. 11, from plugwire 120' through magnet 132', to line 96*a*. Energization of magnet 132' attracts armature 131; thereby rocking pawl 130' to effect a step of movement of the ratchet 129' which is rigidly connected to cam 128'. Cam 128' operates contacts 118'*a*, the function of which is the same as that of the contacts 118'*a* in Fig. 10. Consequently, referring to the A—B

totalizer, starting from a positive total, the circuit of magnet 132 is completed by closing of contacts 51—49 when the total becomes negative, and the cam 128 is then arranged to close the contacts 118a to connect the negative commutators in circuit. When the contacts 51—49 are next closed, on the total becoming positive, the cam 128 is actuated to open the contacts 118a to connect the positive commutators in circuit.

As explained previously, each denomination of a totalizer will have means for manifesting a positive balance and means for manifesting a negative balance. The positive balance manifesting means will manifest a digit of the true positive total, and the negative means will manifest a digit of the true negative total. The digits of the two manifesting devices simultaneously at index positions always add up to 9, as explained before. Thus, in Fig. 10, where the manifesting means are negative and positive readout commutators, when a brush 106 of the positive commutator is on the 0 spot, the brush 106 of the companion negative commutator is on the 9 spot. Now, assume the totalizer is at 0 positive starting position and has four denominations. When all four denominations are to receive entries of any of the digits of the notation, the capacity of the totalizer is 9999, negative or positive. Assume that plus 9999 is entered. None of the register members will pass from 9 to 0 and, hence, carries will not be effected. The positive commutators will manifest 9999 and such total may be read out therefrom during a total taking operation. Assume, instead, that minus 9999 is to be entered. With the totalizer in zero positive start position, the brushes of the negative commutators will be initially on the 9 spots of the four negative commutators of the totalizer. The entry of negative 9999 causes the register members to move in a subtract direction through nine steps in each order. Each negative commutator brush will thus move from 9 to 0, 0 to 1, and so on to the 8 spot. But, when a register member moves in a subtract direction from negative 9 indicating position to negative 0 indicating position, the register member is also moving in a subtract direction from positive 0 indicating position to positive 9 indicating position. As explained before, during such movement, lug 61 of negative transfer cam 22 is effective to operate an arm 57 to cause contact arm 45 to engage its contact 49 with contact 51. Consequently, during the transfer period after entry of negative 9999, negative 1 will be carried from each order to the next higher order and from the highest order to the units order. At the end of the carry entry period, the negative commutators will have their brushes engaged with their 9 spots. Further, since contacts 49—51 of the highest order were closed, the circuit of related magnet 118 will be closed upon closure of cam contacts 123 and 124. Accordingly, the negative commutators will be effective during total taking operation, and negative total 9999 will be read out.

Assume, next, that positive 5000 is entered during an entry or card cycle. When the negative registration is 9999, the positive registration is the nines complement; i. e., 0000. The addition of 5000 during the first card cycle moves the register denominations to positive 5000 positions and to negative 4999 positions. Assume that the next entry is positive 4999. At completion of this entry, the register member will be in positive positions 9999 and in negative positions 0000. The negative commutators will still be effective for total readout operations, so that a total taking operation at this time would cause the true balance 0000 to be read out. Assume a next entry of positive 1. The entry of positive 1 in the units order advances it from positive 9 to positive 0 position and from negative 0 position to negative 9 position. As the units order moves in an adding direction from 9 to 0, additive carry of 1 is effected to the tens order and, through the long carry contacts 49—50 of the tens, hundreds, and thousands order, positive 1 is carried also to the hundreds, thousands, and units orders. At the end of this entry and carry period, the totalizer will be in positive 0001 position. As 1 was carried to the thousands order, its related transfer contacts 49—51 were closed. Hence, upon closure of cam contacts 123 and 124, magnet 126 is energized, causing deenergization of magnet 118, so that the positive commutators will be rendered effective for total readout.

The same principle of operation is applicable where the highest order of the totalizer is not to be used for receiving entry from the card of any number 1 to 9. Thus, in the totalizer discussed previously in connection with Fig. 7, there were three orders, of which the hundreds order was to be used merely as a negative or positive balance detecting means. Assume entry of maximum positive 99 in such a totalizer. There will be no carry effected from any order to the next. The positive commutators will be effective and 99 will be read out in a total taking cycle. Assume, instead, that maximum negative entry 99 were made. Then, as the units order moved in a subtract direction from positive 0 position to positive 1 position, carry contacts 49—51 would be closed. Similarly, carry contacts 49—51 of the tens order would be closed. Accordingly, during the carry period, 1 will be carried in a subtractive direction from units to tens order and from tens to hundreds orders. Further, with the hundreds order initially at 0 position and the totalizer conditioned for subtraction, a notch 60 of negative carry cam 22 will be receiving the projection 58 of arm 57 (Fig. 1) and the arm will be in control of interposer 53. Hence, the contacts 49—50 of the hundreds order will be closed. Thus, upon entry of negative 99, a long negative carry will be effected from the hundreds to the units order. At the end of carry operations, the register members will be in positive value positions 900. As the hundreds order moved in a subtract direction from positive 0 to positive 9 position, contacts 49—51 were closed. Hence, upon closure of cam contacts 123 and 124, magnet 118 will be energized and the negative commutators selected for readout operation. With the register members in positive 900 positions, the negative registration is 099. As usual, when the highest order is merely a kind of balance detecting order, no total is taken therefrom. Hence, with the negative commutators of the tens and units order reading 99, this negative balance will be read out during a total taking operation.

The operating circuits for the magnets 89 of the reversing gears are not shown in Figure 10, because each circuit is similar to that shown in Figure 7. As explained each of the four pairs of denominations A, B, C, D, has its own reversible gearing and related magnet 89 and associated relay 97—97a—97b. The two circuits for the relay coils 97 of the denominations A and B will both be connected to the single brush of the upper brushes, which reads the subtraction designating hole pertaining to the numbers to be

entered into the totalizer A—B. Similarly the two circuits for the relay coils 97 of the denominations C and D will be connected together to the brush which reads the subtraction designating hole pertaining to the numbers to be entered into the totalizer C—D.

In the arrangement shown the positive commutators are normally effective and the selecting means operate to cause the negative commutators to become effective, but the reverse arrangement, in which the negative commutators are normally effective can equally well be used. In such reverse arrangement, it will be understood that the starting position of the totalizer will be negative position 0 which corresponds to positive position 9.

The totalizer shown and described is arranged to operate on the decimal notation, but it will operate on other notations if the transfer cams have the appropriate number of notches and projections and the locking plates 20 and 23 the appropriate numbers of teeth. Thus, a denomination may be arranged to add and subtract halves (units of ten shillings for example) by providing fifteen notches and projections on the transfer cams instead of three. Or a denomination may be arranged to operate on the duodecimal notation (units of pence for example) by providing the locking plates 20 and 23 with 36 and 24 teeth respectively instead of 30 and 20, the transfer cam having three notches and projections. Thereby the magnet 34 may be energised at any of twelve points in a cycle. The indicating wheels or read-out commutators on the register member will be given the appropriate indication, or segments and connections.

In punched cards, however, it is the usual practice to record digits in the duodecimal notation by recording the digits 9 to 0 in the positions usual in the decimal notation and to record the digits 10 and 11 in two positions at the X and Y points respectively in the cycle. Since these positions follow the 0 position instead of immediately preceding the 9 position, it is customary to read the duodecimal column by upper brushes during a cycle previous to the cycle in which the card is read by the lower brushes and to register the hole read in a "pence translator" which emits an impulse to the entry magnet at the proper point in the next cycle. As such translators are well known, their arrangement need not be described.

Alternatively, a duodecimal column may be read and registered in the totalizer without the use of a translator as follows. The register member of the totalizer, comprising the transfer cams and indicating or read-out devices, is not fixed to the wheel 18 and the locking plate 20, as shown in Figures 1 and 3, but is geared to them by gear wheels with ratio 10 to 12, so that the transfer cams turn through 120 degrees from one transfer portion to the next while the locking plate 20 turns through the space of 12 teeth. A convenient arrangement for this is shown in Figure 12, which, by comparison with Figure 2, shows the modifications necessary. The locking plate 20 is loose on the sleeve 16 and is fixed to a wheel 133 of 40 teeth which engages a pinion 134 pivoted on a bracket 135 fixed to the plate 1. The shaft 19 is eccentric in the sleeve 16 and carries a wheel 136 of 48 teeth and the two transfer cams 21 and 22. The wheel 136 engages the pinion 134, the eccentricity of the shaft 19 being made equal to the difference between the radii of the wheels 133 and 136. Thereby the transfer cams and shaft 19 are geared to the locking plate 20 in the ratio 10 to 12.

The digits from 9 to 0 are entered into the denomination by energising the magnet 34 at the appropriate points in the cycle as in a decimal denomination. The digits 10 and 11 are entered by energising the magnet at the G and F points respectively, that is, at one and two points respectively before the 9 point. These positions are read by the upper brushes and the energising of the magnet 34 is controlled by the circuits shown in Figure 13. These circuits are additional to those shown in Figure 7 and are shown applied to the units denomination; the circuits of Figure 7 are not therefore repeated in full in Figure 13. The upper brush of the brushes UB which reads the duodecimal column is connected to a relay 138 and then, in parallel circuits, through relay 139 and cam contact 140 and through relay 141 and cam contact 142. Cam contact 140 closes at X, so that if the said upper brush makes contact at an X hole indicating a digit 10, the circuit through relays 138 and 139 is complete. The relay 138 closes its contacts 138*a* to establish a holding circuit through relay 139 after the hole has passed the brush, such circuit extending from line 96*a* via the holding contacts 139*a*, relay 139, relay 138, relay contacts 138*a* and cam contacts 154. The auxiliary contacts 139*b* are also closed during this time in circuit with the cam contacts 143 and contacts 95*a* of the units order entry magnet 34. Cam contact 143 closes at G in the cycle which is 1 index point ahead of 9 in the following cycle and thereby enters the value 10. In the parallel circuit cam contact 142 closes at Y to energise relay 141 in the event of a hole being present at the 11th or Y index point on the card, the circuit being maintained by relay contacts 141*a*, relay coil 141, relay 138, relay contacts 138*a* and cam contact 154. Cam contact 144 closes at F in the cycle 2 index points head of 9 in the following cycle and completes the circuit through the closed contacts 141*b*, contacts 95*a* and the units order entry magnet 34, thereby entering the value 11. Provision is made to prevent similar entries being made in other denominations by the opening of contacts 138*b* in the circuit between contacts 95*a* and the lower brush through the energisation of relay 138 consequent upon either a 10 or 11 hole being present in the column. Other values 9 to 0 can thus be sensed by the lower brush and effect energisation of the units order entry magnet 34 through the normally closed contacts 138*b* at the appropriate times.

The register member may be controlled in other ways than by the magnet 34 with cams 31, 32 and 84. For example, the cams may be dispensed with by the arrangement shown in Figure 14. This figure shows the modifications to be introduced into the arrangement of Figure 1, parts remaining without modification not being shown, excepting the locking plate 20 and the locking plate 23. The magnet 34 is replaced by the magnet 145 which, when energised attracts the armature 146 on the arm 24 of the two-armed lever 24, 25 pivoted, as in Figure 1, at 28. As in Figure 1, the arms 24 and 25 are adapted to lock the two plates 20 and 23 respectively. When the magnet 145 is energized, arm 24 disengages from the locking plate 20 and arm 25 locks the plate 23, and the register member is then turned. When the magnet 145 ceases to be energised, a spring 147 returns the lever 24, 25 into the position shown, in which the register member is locked by the plate

28. The register member then turns during the period in which the magnet 145 is energised, and the number read from a punched card can be entered into the register member by keeping the magnet energised from the point in the cycle at which the digit recorded is read until point 0 in the cycle. Similarly, carry value 1 can be entered by energising the magnet 145 for a period equal to the interval between two successive points in the cycle, and this may be effected by causing the transfer cam 127 (Figure 7) to close its contacts for this period. The arm 44 of the lever which latches the transfer arms may be unlatched by means of the magnet 148, which, when energised, attracts the armature 149 on the other arm 150 of the lever 44, 150, into the position shown. The lever 44, 150 is spring-pressed counter-clockwise by the spring 151. The magnet 148 may be included in the circuit of cam contact 99, as shown in dotted lines in Figure 7. The modification in the circuits of Figure 7 required to energise the entry control magnet for the period representing the digit read is shown in Figure 15. The lines 94, instead of running directly from the lower brushes LB to the contacts 95a of the entry control magnets 34, as in Fig. 7, pass through relays 152 to entry magnets such as 145, one of which is shown in Fig. 15. These relays have holding contacts 152a which maintain the circuit from line 96, cam contact 153, contacts 152a, relay 152, wire 94, contacts 95a, entry control magnet 145 to line 96a. This circuit is broken at point 0 by the cam contact 153.

While there has been shown and described and pointed out the fundamental novel features of the invention as applied to the illustrated structures, it will be understood that various omissions and substitutions and changes in the form and details of the structures illustrated and in their operation may be made by those skilled in the art without departing from the spirit of the invention. It is the intention therefore to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. In combination, denominational orders of register members, gearing to move the members in one direction to add and in the opposite direction to subtract values, a common entry control magnet for governing the extent of such movement of a member in either direction, means to selectively govern the direction in which said gearing moves said members, a circuit for energizing the magnet to cause the related member to receive a carry entry movement from the gearing, switch means in said circuit, a pair of alternatively effective transfer devices operated by the preceding order member to close the switch means, and means controlled by the gearing, in accordance with the direction of movement of the members affected thereby, for selectively rendering one of said devices effective and the other ineffective, whereby one of the devices will be effective during adding operation and the other will be effective during subtracting operation.

2. In combination, a denominational order register member, means to actuate the member in ascending direction during addition and in descending direction during subtraction, said member including an adding transfer cam and a subtraction transfer cam, a single transfer switch, means for operating said switch under control of either cam and including selectively shiftable interponent means for placing the switch under control of either cam, means for selectively shifting the interponent means to place the switch either under control of the adding transfer cam to be operated thereby as the register member moves during addition to a predetermined positive value position or under control of the subtraction transfer cam to be operated thereby as the register member during subtraction moves to a predetermined negative value position, transfer effecting means to effect a transfer from said order register member to another order register member, and a circuit effective under control of said switch for bringing about operation of the transfer effecting means.

3. In a machine having denominational order register members, including the highest order member, movable variable, differential extents in positive direction or in opposite, negative direction to receive entries of positive or negative values, respectively, and having carry contacts closed by the highest order member to control carry to the units order member as the highest order member during variable, differential entry receiving movement in either direction traverses a critical position, the combination of positive and negative value readout commutators for each order register member to respectively register true positive and negative balances, a common emitter having direct wiring to the positive commutators and complementary wiring to the negative commutators of all the orders, a readout circuit for each order closed through said emitter and having alternative switching connections to be adjusted into circuit either with the negative or the positive commutator of the order, adjusting means for adjusting the switching connections of the orders to shift said connections from the readout commutators pertaining to one sign balance to the readout commutators pertaining to the opposite sign balance, means under control of said carry contacts, when closed, to operate said adjusting means, and means for maintaining the adjusting means in operation after reopening of the carry contacts.

4. In a machine having a totalizer provided with denominational order register members, including the highest order member, movable variable, differential extents in positive direction or in opposite, negative direction to receive entries of positive or negative values, respectively, and having carry contacts closed under control of the highest order member to control carry to the units order member as the highest order member during variable entry receiving movement in either direction traverses a critical position, the combination of positive and negative electrical, value readout members in each order connected for common movement and complementarily wired to one another, a readout circuit for each order having alternative switching connections to the positive and negative readout members, relay means for shifting the switching connections from the readout members pertaining to one sign balance to the readout members pertaining to the opposite sign balance, a circuit for operating said relay means, said circuit including said carry contacts, means for completing said circuit after the carry contacts have closed upon the highest order register member traversing the critical position while moving to receive an entry of a value of one sign, a holding circuit for the relay means closed after said carry contacts have reopened, and means for breaking the holding circuit when the carry switch is again closed during movement of the highest order register member through said

critical position when receiving entry of a value of the opposite sign.

5. In a machine having a totalizer provided with denominational order register members, including the highest order member, movable variable, differential extents in positive direction or in opposite, negative direction to receive entries of positive or negative values, respectively, and having carry contacts closed under control of the highest order member to control carry to the units order member as the highest order member during variable entry receiving movement in either direction traverse a critical position, the combination of positive and negative electrical, value readout members in each order connected for common movement and wired complementarily to one another, a readout circuit for each order having alternative switching connections to the positive and negative readout members, means for shifting the switching connections from either the positive to the negative readout members or vice versa, a stepping device for rendering said shifting means effective to shift the switching connections in one direction and then in the opposite direction upon successive steps of actuation of the device, a magnet operating upon each energization thereof to effect a step of actuation of the stepping device, and a circuit closed under control of said carry contacts each time the highest order member traverses the critical position, while receiving an entry, for momentarily energizing said magnet.

6. In a machine having a totalizer with denominational order register members, including the highest order member, movable variable, differential extents in one direction to receive positive value entries and in opposite direction to receive negative value entries and of which the highest order member passes in one direction through a critical position upon change in the totalizer balance from one sign to the opposite sign and passes in the opposite direction through the critical position upon change in the totalizer balance from the opposite sign to the previous sign; the combination of readout circuits for reading out the true figures of a negative balance in the totalizer, alternative readout circuits for reading out the true figures of a positive balance in the totalizer, means for switching from the readout circuits for one sign balance to the readout circuits for the opposite sign balance, contacts closed by the highest order register member upon passing in either direction through the critical position, and electrical means alternately rendered effective and ineffective, to operate the switching means, under control of the contacts and by successive closures of the contacts by the highest order register member upon successive reversals in sign of the balance in the totalizer.

HAROLD HALL KEEN.
THOMAS OLIVER WRIGHT.