

Jan. 2, 1940.

N. M. WOOD

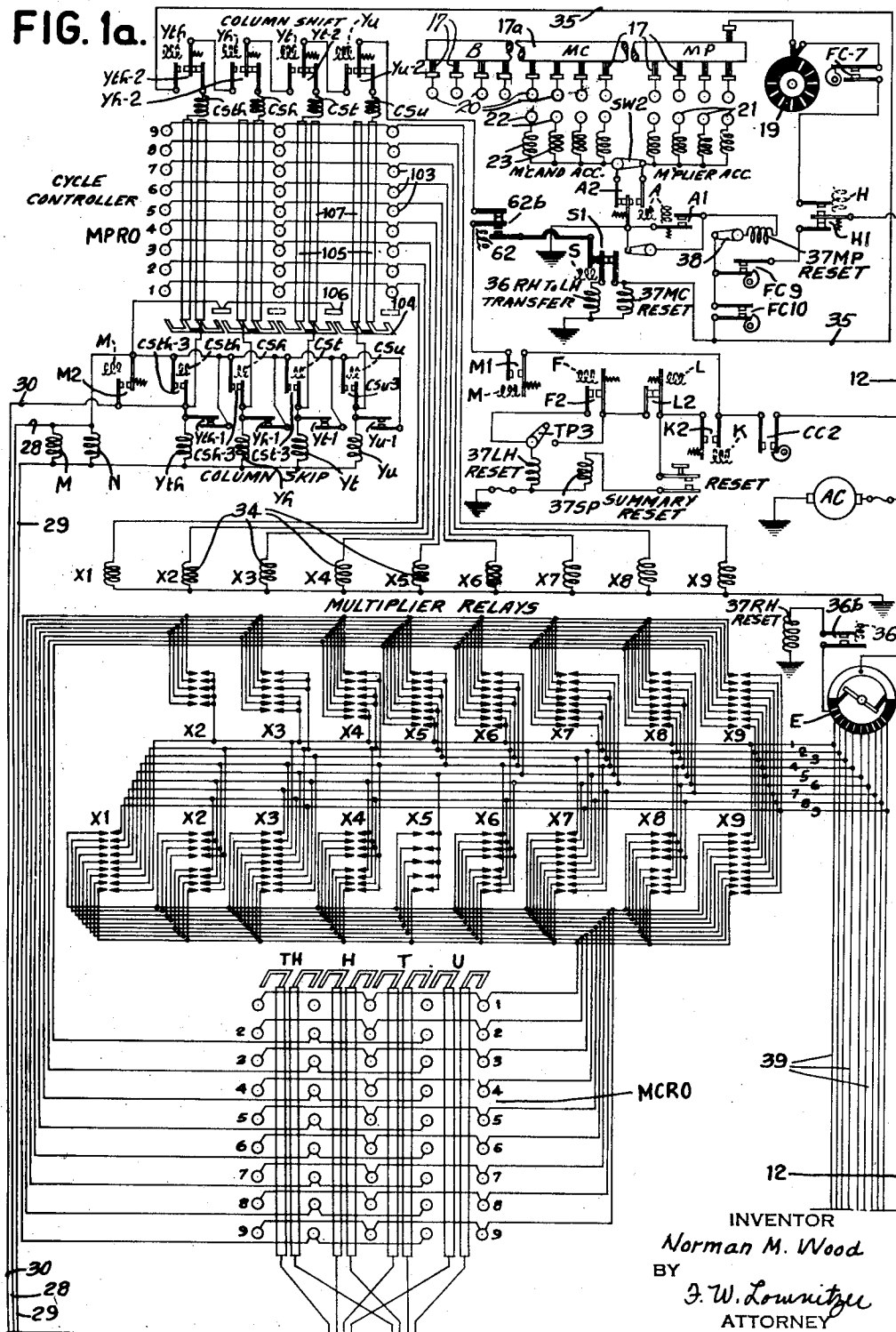
2,185,697

MULTIPLYING MACHINE

Filed June 17, 1937

8 Sheets-Sheet 1

FIG. 1a.

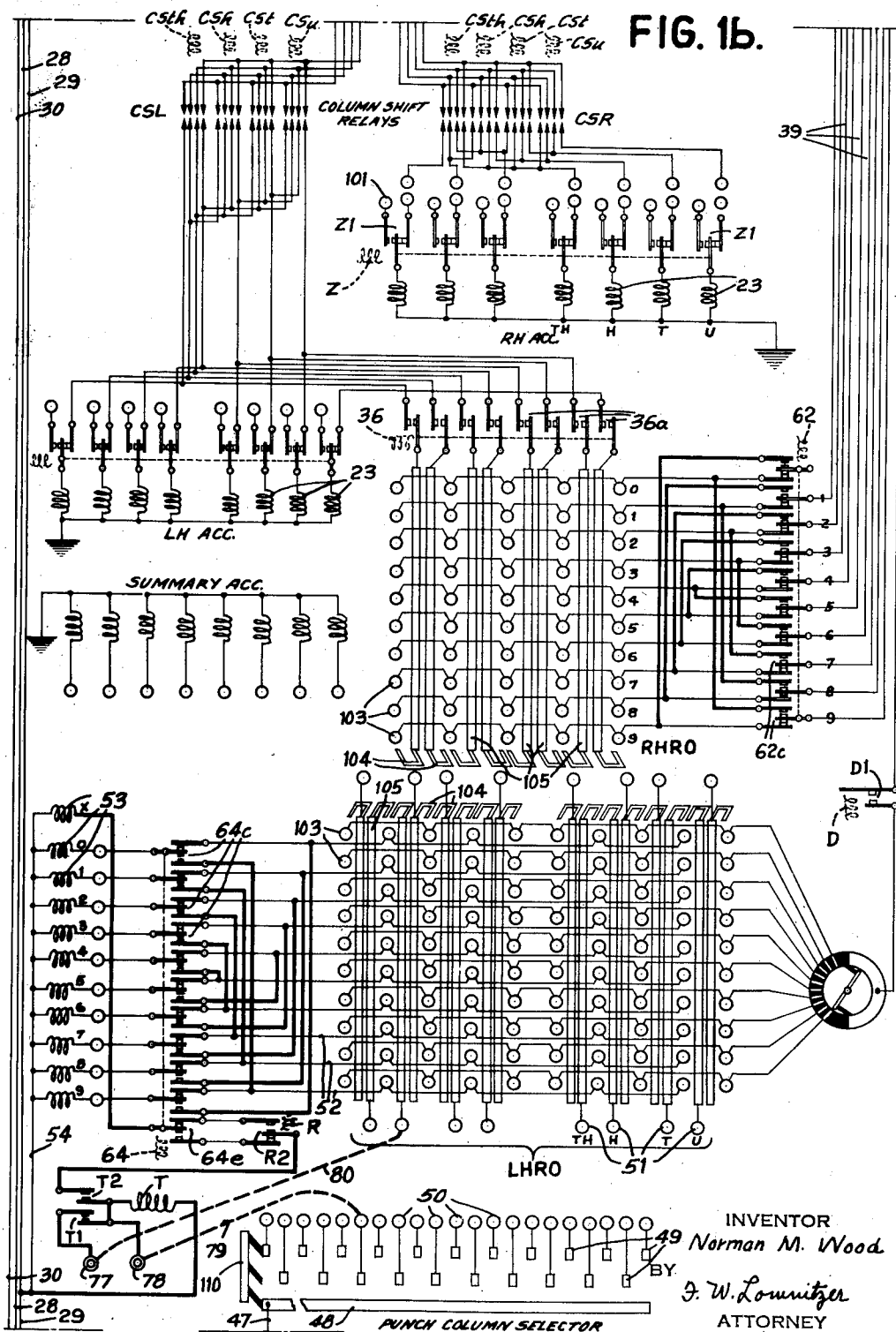


INVENTOR  
Norman M. Wood  
BY  
J. W. Lowmiller  
ATTORNEY

**2,185,697**

Filed June 17, 1937

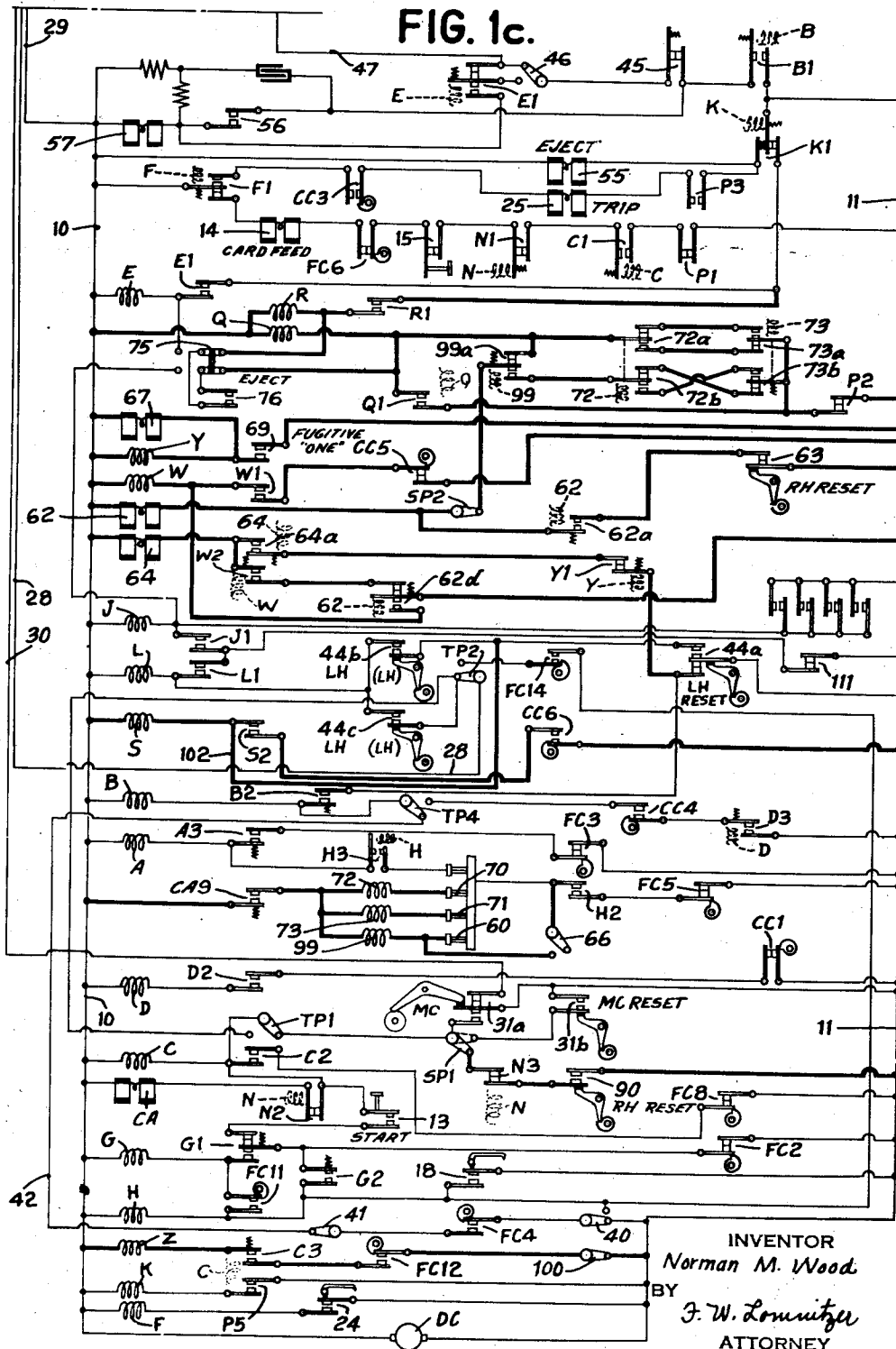
**FIG. 1b.**



**2,185,697**

Filed June 17, 1937

**FIG. 1c.**



Jan. 2, 1940.

N. M. WOOD

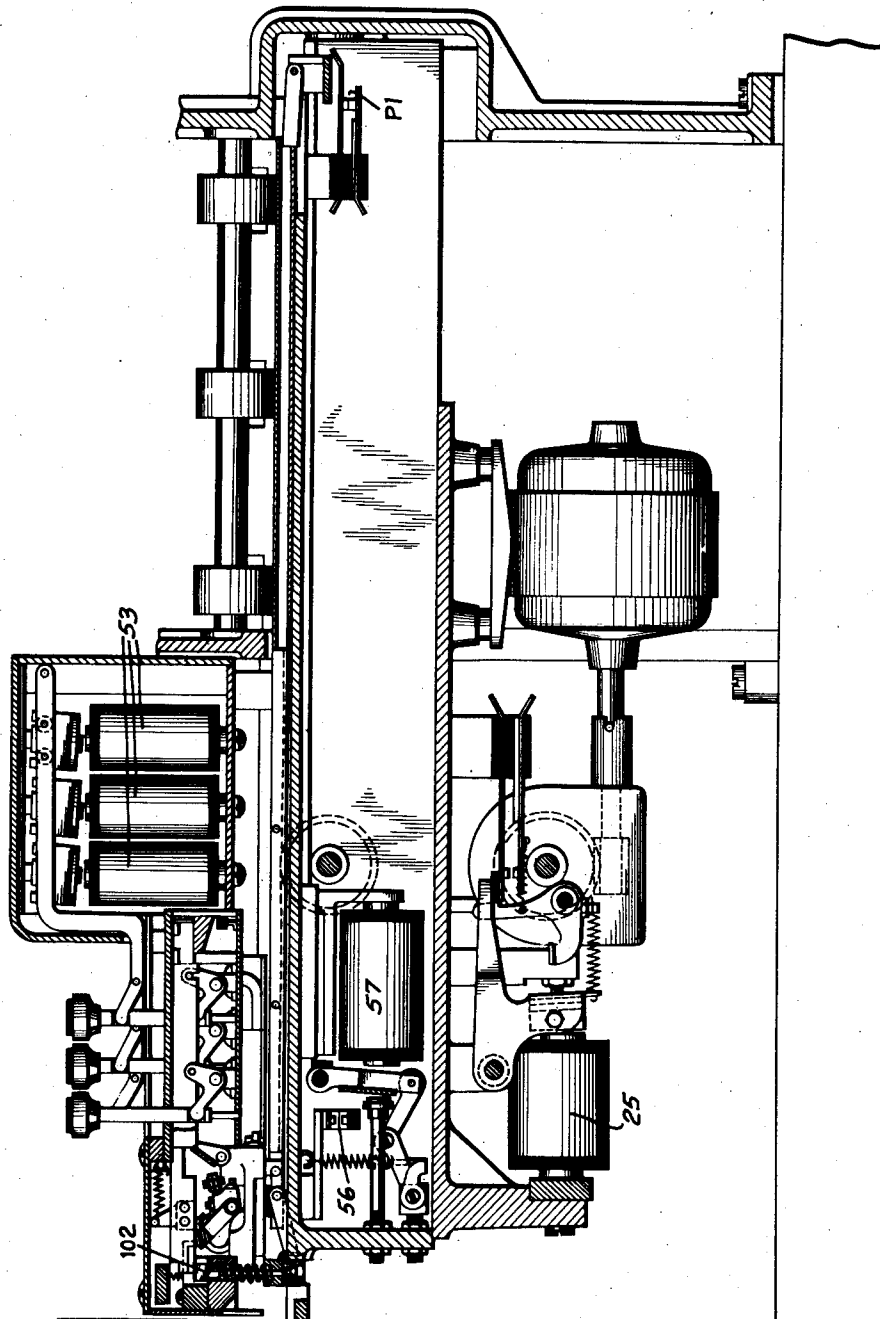
2,185,697

MULTIPLYING MACHINE

Filed June 17, 1937

8 Sheets-Sheet 4

FIG. 2.



INVENTOR  
Norman M Wood  
BY  
J. W. Lomnitz  
ATTORNEY

Jan. 2, 1940.

N. M. WOOD

2,185,697

MULTIPLYING MACHINE

Filed June 17, 1937

8 Sheets-Sheet 5

FIG. 3.

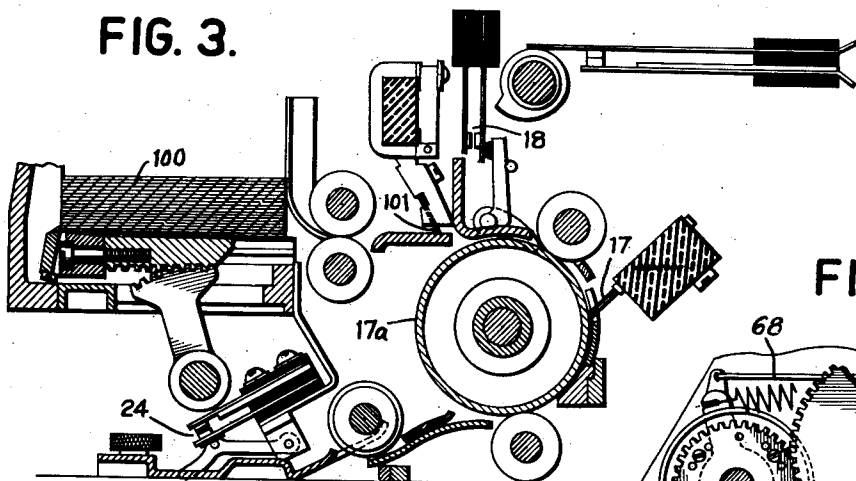


FIG. 4.

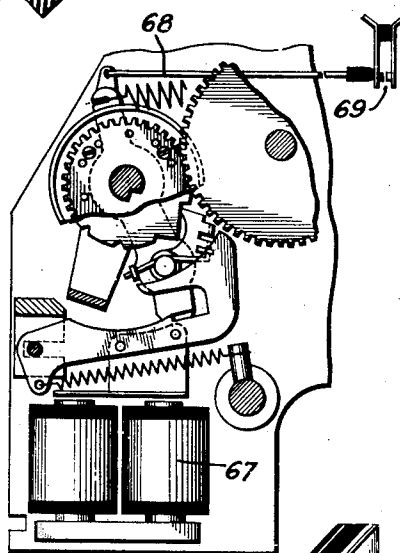
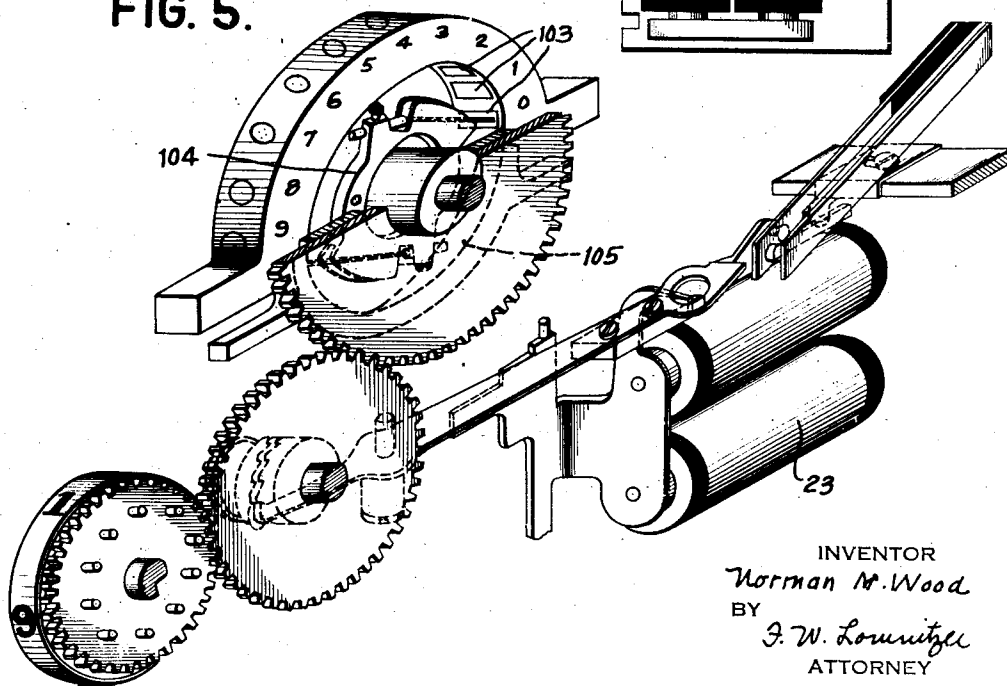


FIG. 5.



INVENTOR  
Norman M. Wood  
BY  
J. W. Lowmiller  
ATTORNEY

Jan. 2, 1940.

N. M. WOOD

2,185,697

MULTIPLYING MACHINE

Filed June 17, 1937

8 Sheets-Sheet 6

FIG. 8.

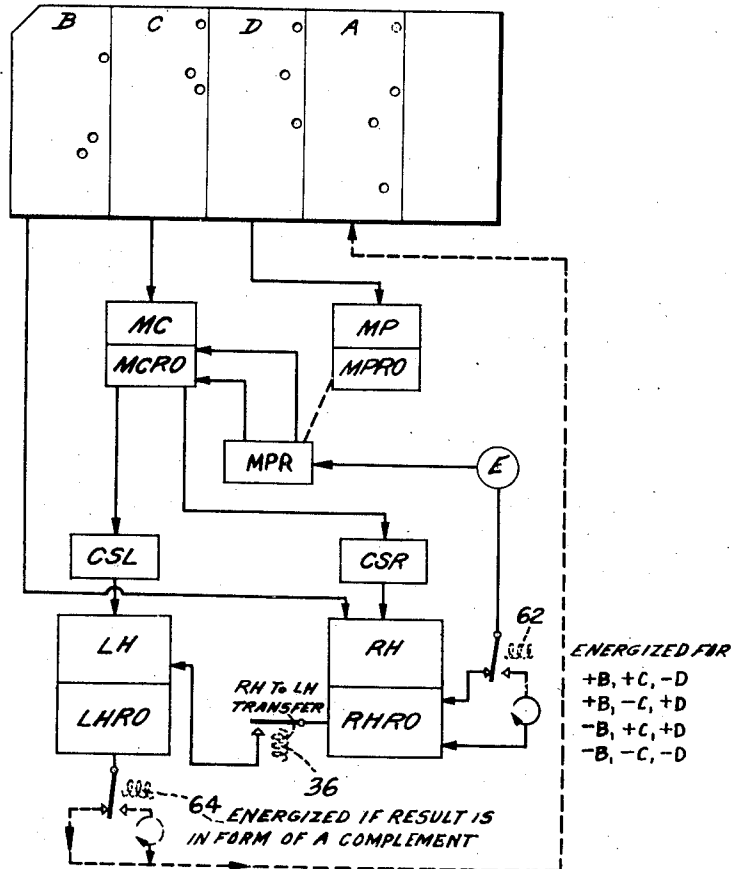


FIG. 6.

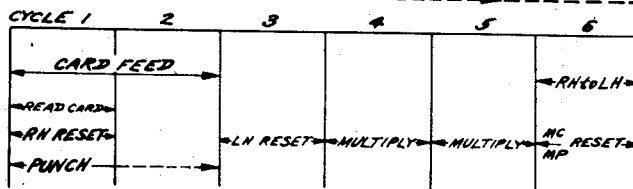
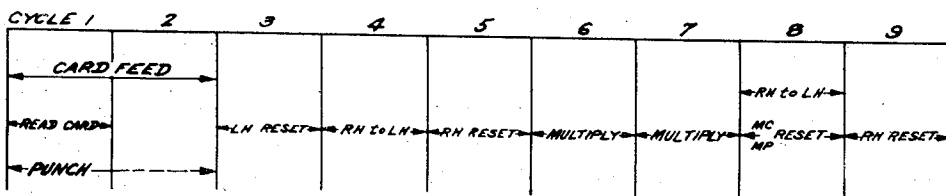


FIG. 7.



INVENTOR  
Norman M. Wood  
BY  
J. W. Lounitzer  
ATTORNEY

Jan. 2, 1940.

N. M. WOOD

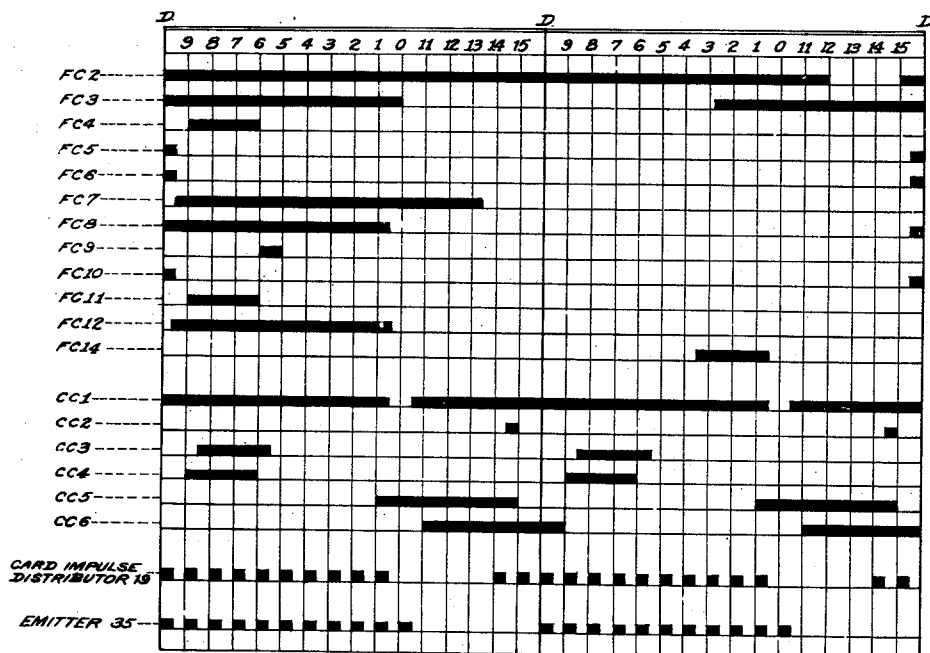
2,185,697

MULTIPLYING MACHINE

Filed June 17, 1937

8 Sheets-Sheet 7

FIG. 9.



INVENTOR

Norman M. Wood

BY

J. W. Lounitz

ATTORNEY

Jan. 2, 1940.

N. M. WOOD

2,185,697

MULTIPLYING MACHINE

Filed June 17, 1937

8 Sheets-Sheet 8

FIG. 10.

|                     | I                                                                        |    |     |           | II                                                                       |    |     |           | III                                                                      |    |     |                | IV                                                                       |    |     |                |
|---------------------|--------------------------------------------------------------------------|----|-----|-----------|--------------------------------------------------------------------------|----|-----|-----------|--------------------------------------------------------------------------|----|-----|----------------|--------------------------------------------------------------------------|----|-----|----------------|
|                     | $\begin{matrix} +B+C+D \\ +B-C-D \end{matrix} \bar{B} < \bar{C} \bar{D}$ |    |     |           | $\begin{matrix} +B+C+D \\ +B-C-D \end{matrix} \bar{B} > \bar{C} \bar{D}$ |    |     |           | $\begin{matrix} -B-C+D \\ -B+C-D \end{matrix} \bar{B} < \bar{C} \bar{D}$ |    |     |                | $\begin{matrix} -B-C+D \\ -B+C-D \end{matrix} \bar{B} > \bar{C} \bar{D}$ |    |     |                |
|                     | ACCUMULATORS                                                             |    |     |           | ACCUMULATORS                                                             |    |     |           | ACCUMULATORS                                                             |    |     |                | ACCUMULATORS                                                             |    |     |                |
| CYCLES              | MC                                                                       | MP | RH  | LH        | MC                                                                       | MP | RH  | LH        | MC                                                                       | MP | RH  | LH             | MC                                                                       | MP | RH  | LH             |
| CARD FEED 1         | D                                                                        | C  | B   |           | D                                                                        | C  | B   |           | D                                                                        | C  | B   |                | D                                                                        | C  | B   |                |
| ENTRY 2             | 12                                                                       | 14 | 21  |           | 12                                                                       | 14 | 200 |           | 12                                                                       | 14 | 21  |                | 12                                                                       | 14 | 200 |                |
| LH RESET 3          |                                                                          |    |     |           |                                                                          |    |     |           |                                                                          |    |     |                |                                                                          |    |     |                |
| MULTIPLY 4          |                                                                          |    | 4-  | 8         |                                                                          |    | 4-  | 8         |                                                                          |    | 4-  | 8              |                                                                          |    | 4-  | 8              |
| MULTIPLY 5          |                                                                          |    | 1-- | 2-        |                                                                          |    | 1-- | 2-        |                                                                          |    | 1-- | 2-             |                                                                          |    | 1-- | 2-             |
|                     |                                                                          |    | 161 | 28        |                                                                          |    | 340 | 28        |                                                                          |    | 161 | 28             |                                                                          |    | 340 | 28             |
| RH TO LH TRANSFER 6 |                                                                          |    |     | 161       |                                                                          |    |     | 340       |                                                                          |    |     | 161            |                                                                          |    |     | 340            |
|                     |                                                                          |    |     | 189       |                                                                          |    |     | 368       |                                                                          |    |     | 189            |                                                                          |    |     | 368            |
|                     |                                                                          |    |     | PUNCH 189 |                                                                          |    |     | PUNCH 368 |                                                                          |    |     | PUNCH 189      |                                                                          |    |     | PUNCH 368      |
|                     |                                                                          |    |     |           |                                                                          |    |     |           |                                                                          |    |     | PUNCH "X" HOLE |                                                                          |    |     | PUNCH "X" HOLE |

FIG. 11.

|                     | I                                                                        |    |     |           | II                                                                       |    |     |                | III                                                                      |    |     |                | IV                                                                       |    |     |                |
|---------------------|--------------------------------------------------------------------------|----|-----|-----------|--------------------------------------------------------------------------|----|-----|----------------|--------------------------------------------------------------------------|----|-----|----------------|--------------------------------------------------------------------------|----|-----|----------------|
|                     | $\begin{matrix} -B+C+D \\ -B-C-D \end{matrix} \bar{B} < \bar{C} \bar{D}$ |    |     |           | $\begin{matrix} -B+C+D \\ -B-C-D \end{matrix} \bar{B} > \bar{C} \bar{D}$ |    |     |                | $\begin{matrix} +B+C-D \\ +B-C+D \end{matrix} \bar{B} < \bar{C} \bar{D}$ |    |     |                | $\begin{matrix} +B+C-D \\ +B-C+D \end{matrix} \bar{B} > \bar{C} \bar{D}$ |    |     |                |
|                     | ACCUMULATORS                                                             |    |     |           | ACCUMULATORS                                                             |    |     |                | ACCUMULATORS                                                             |    |     |                | ACCUMULATORS                                                             |    |     |                |
| CYCLES              | MC                                                                       | MP | RH  | LH        | MC                                                                       | MP | RH  | LH             | MC                                                                       | MP | RH  | LH             | MC                                                                       | MP | RH  | LH             |
| CARD FEED 1         | D                                                                        | C  | B   |           | D                                                                        | C  | B   |                | D                                                                        | C  | B   |                | D                                                                        | C  | B   |                |
| ENTRY 2             | 12                                                                       | 14 | 21  |           | 12                                                                       | 14 | 200 |                | 12                                                                       | 14 | 21  |                | 12                                                                       | 14 | 21  |                |
| LH RESET 3          |                                                                          |    |     |           |                                                                          |    |     |                |                                                                          |    |     |                |                                                                          |    |     |                |
| RH TO LH TRANSFER 4 |                                                                          |    |     | 9978      |                                                                          |    |     | 9799           |                                                                          |    |     | 9978           |                                                                          |    |     | 9799           |
| RH RESET 5          |                                                                          |    |     |           |                                                                          |    |     |                |                                                                          |    |     |                |                                                                          |    |     |                |
| MULTIPLY 6          |                                                                          |    | 4-  | 8         |                                                                          |    | 4-  | 8              |                                                                          |    |     |                |                                                                          |    | 4-  | 8              |
| MULTIPLY 7          |                                                                          |    | 1-- | 2-        |                                                                          |    | 1-- | 2-             |                                                                          |    | 1-- | 2-             |                                                                          |    | 1-- | 2-             |
|                     |                                                                          |    | 14- | 10006     |                                                                          |    | 14- | 9827           |                                                                          |    | 14- | 10006          |                                                                          |    | 14- | 9827           |
|                     |                                                                          |    |     | 7         |                                                                          |    |     | 7              |                                                                          |    |     | 7              |                                                                          |    |     | 7              |
| RH TO LH TRANSFER 8 |                                                                          |    |     | 14-       |                                                                          |    |     | 14-            |                                                                          |    |     | 14-            |                                                                          |    |     | 14-            |
|                     |                                                                          |    |     | 147       |                                                                          |    |     | 9967           |                                                                          |    |     | 147            |                                                                          |    |     | 9967           |
|                     |                                                                          |    |     | PUNCH 147 |                                                                          |    |     | PUNCH 32       |                                                                          |    |     | PUNCH 143      |                                                                          |    |     | PUNCH 32       |
|                     |                                                                          |    |     |           |                                                                          |    |     | PUNCH "X" HOLE |                                                                          |    |     | PUNCH "X" HOLE |                                                                          |    |     | PUNCH "X" HOLE |

INVENTOR

Norman M. Wood

BY

W. M. Wilson  
ATTORNEY

## UNITED STATES PATENT OFFICE

2,185,697

## MULTIPLYING MACHINE

Norman M. Wood, London, England, assignor to  
International Business Machines Corporation,  
New York, N. Y., a corporation of New York

Application June 17, 1937, Serial No. 148,624  
In Great Britain October 21, 1936

6 Claims. (Cl. 235—61.8)

This invention relates to improvements in multiplying machines and more specifically to machines of the record card controlled type.

The principal object of the invention is to provide improvements in such machines whereby certain problems may be more expeditiously solved.

A further object of the invention is to provide means for determining the arithmetical sign of an equation in accordance with the arithmetical signs of its terms.

According to the present invention, a record controlled multiplying machine includes two sign-detecting relays each adjustable automatically under the control of indications on the record according to whether a factor is positive or negative into a "positive" or a "negative" condition, and a control device normally positioned into a "positive" condition in which it remains when both the relays are in their "positive" or in their "negative" condition, but adjustable into a "negative" condition when one of the relays is in its "positive" condition and the other is in its "negative" condition, and arranged to control the operation of the machine in accordance with its adjusted condition.

The invention is applicable to machines arranged to obtain the sum of, or difference, between the product of two factors read from the record and a number read from the record. According to such a machine, the number is always added to or subtracted from the product and the result is obtained as a true number or a complement, and a second control device is provided which, when the result is a complement, causes the machine to record the complement of the result and which cooperates with the first control device to control the recording of an indication of the sign of the result. In accordance with a further feature of this invention, a third sign-detecting relay is provided which is adjustable into a "positive" or a "negative" condition in accordance with an indication on the record of the sign of the number and which cooperates with the first and second sign-detecting relays to determine the adjustment of the first control device which, in turn, is arranged to determine whether the number shall be added to or subtracted from the product in accordance with its adjustment.

Further objects of the instant invention reside in any novel feature of construction or operation or novel combination of parts present in the embodiment of the invention described and shown in the accompanying drawings whether within

or without the scope of the appended claims and irrespective of other specific statements as to the scope of the invention contained herein.

In the drawings:

Figs. 1a, 1b, and 1c, taken together and placed one above the other in the order named, constitute a wiring diagram of the electric circuits of the machine.

Fig. 2 is a cross sectional view of the punching mechanism of the machine.

Fig. 3 is a cross sectional view of the card feeding and analyzing mechanism.

Fig. 4 is a detail of mechanism for adding an "elusive" one.

Fig. 5 is a detail in isometric of an order of one of the accumulators.

Fig. 6 is a diagram showing the sequence of cycles under two conditions of operation.

Fig. 7 is a similar diagram showing the order of cycles for handling the equations.

Fig. 8 is a diagrammatic representation of the various units of the machine, showing the manner in which they are interconnected for the transfer of numbers between the various units.

Fig. 9 is a timing diagram of the cam controlled contacts.

Figs. 10 and 11 are diagrams showing the sequence of operations involved in handling specific problems.

## Standard operation

Before explaining the improvements of the invention, a brief explanation will be given of the manner in which the machine operates in performing simple multiplying operations, that is, the multiplication of two factors and the performing of the product back on the record card. The mechanical structure of the machine is substantially the same as that of Patent No. 1,933,714, granted November 7, 1933, to J. M. Cunningham, and of Patent No. 1,944,665, granted January 23, 1934, to D. J. Oldenboom. Reference may also be had to the copending application of R. A. Rowley, Serial No. 49,671, filed November 14, 1935, which has a disclosure similar to the present case.

The machine comprises a card feeding section, punching mechanism, multiplicand and multiplier registers MC and MP respectively and two partial product accumulators LH and RH (Fig. 8). The two registers and the two accumulators are constituted by conventional Hollerith accumulators of the kind used in tabulating machines. Such an accumulator is controlled by accumulator magnets of which there is one for each denomination and in which the digit added

in any denomination is determined by the time in the cycle at which the corresponding accumulator magnet is energized.

The sequence of operations when multiplying two factors together in the normal manner will first be explained with reference to Fig. 8. The operation of the machine in evaluating a more complex expression will then be described in detail with reference to the circuit diagram.

Referring to Fig. 8 cards containing factors C and D that are to be multiplied are inserted into the machine. These cards are fed one by one past a reading station. As a card passes the reading station, factors C and D are read from it and entered into the registers MC and MP. The card is then passed to the punching mechanism through which it is advanced into position to receive the product in a field A. As indicated in Fig. 6, a card feeding cycle occupies two machine cycles and the card is read in the first of these cycles. In the third cycle, the accumulator LH is reset. Assuming that the multiplier contains two significant digits, cycles 4 and 5 will be occupied by multiplying operations. The multiplying operations are controlled by multiplying relays designated MPR (Fig. 8). These relays are selectively energized under the control of reading-out mechanism MPRO of the register MP and, in conjunction with the reading-out mechanism MCRO of the register MC, selectively transmit electrical impulses to the accumulator magnets of the accumulators LH and RH. The timing of these impulses is controlled by an emitter or rotary commutator E. The impulses received by the accumulator magnets of the accumulators LH and RH are so timed that each accumulator adds a partial product of the multiplicand and the multiplier digit. Relays CSL and CSR direct these impulses to the appropriate denominations of the accumulators in accordance with denomination of the multiplier digit by which multiplication is being effected. In cycle 6, the registers MC and MP are reset and the partial product obtained in the accumulator RH is transferred to the accumulator LH. The transfer is effected by impulses transmitted by the emitter E through reading-out mechanism RHRO of the accumulator RH. During the next two cycles the product obtained in the accumulator LH is recorded on the card under the control of the reading-out mechanism LHRO of that accumulator. Concurrently a new card feeding cycle occurs during which the two factors of the next computation are read. The accumulator RH is also reset during the first of the two cycles in which card feeding and punching occur.

#### Improved operation

The present machine is designed to evaluate the expression  $(\pm C)(\pm D) \pm B$ , where any one of the terms (B, C and D) concerned may be either positive or negative. The eight conditions that may arise are set out below together with the operation performed by the machine:

1.  $+B, +C, +D: B+CD$
2.  $-B, +C, +D: -B+CD$
3.  $+B, -C, -D: B+CD$
4.  $-B, -C, -D: -B+CD$
5.  $+B, -C, +D: -(-B+CD)$
6.  $-B, -C, +D: -(B+CD)$
7.  $+B, +C, -D: -(B+CD)$
8.  $-B, +C, -D: -(B+CD)$

In the first two cases, C and D are both positive while in cases 3 and 4, C and D are both negative. In any of these cases the product will be positive and therefore B is either added to the product or subtracted from the product in accordance with its sign. If the result is positive, it is obtained as a true number and recorded on the card from which the factors were obtained. If the result is negative, it is obtained as a complement but is recorded as a true number together with an indication that it is negative.

Under conditions 5 and 6, C is negative and D is positive while under conditions 7 and 8, D is negative and C is positive. In any of these cases the product will be negative. The machine will add B to the product when B is negative and subtract B from the product when B is positive and will then reverse the sign of the result. Thus, if the result is a true number, it will be recorded on the card together with an indication that it is negative while if it is a complement, it will be recorded as a true number. The indication that an amount is negative is made by a special hole in the card and the absence of such a hole indicates that the amount is positive.

When a card is read, the amounts C and D are entered into the registers MC and MP in the usual manner, while the amount B is entered into the accumulator RH. Since the accumulator RH is normally being reset while the card is being read it is necessary, as indicated in Fig. 7 to delay the card feeding cycle and consequently the punching cycle until after this accumulator has been reset. In other words the resetting of the accumulator RH occurs in a special cycle (No. 9 in Fig. 7). Just before the card is read, the machine determines whether the amounts B, C and D are positive or negative and is adjusted to add B to the product CD or to subtract from that product as may be required. In the third cycle the accumulator LH is reset. If B is to be added to CD, the multiplying operations are then initiated and proceed in the normal manner, one partial product being obtained in the accumulator LH and the other in the accumulator RH. The latter will be added to the factor B which has been entered into the accumulator RH. This sum will then be transferred to the accumulator LH to give the result  $B+CD$ . If the result is a true number, it will be recorded on the card. If it is a complement, a relay 84 is energized and inverts the recording circuits so that the true amount is recorded.

If B is to be subtracted from CD, the multiplying operations are suspended for two cycles and the resetting of the accumulator LH is followed by a cycle in which the factor B in the accumulator RH is transferred as a complement to the accumulator LH. During this cycle a relay 62 is energized and inverts the transferring circuits so that the complement of B is transferred. In the next cycle, the accumulator RH is reset after which the multiplying operations occur in the usual manner and the partial product in the accumulator RH is transferred to the accumulator LH. This accumulator will thus contain the sum of the complement B and the product CD. This sum will be equal to the difference between B and CD. As before, it is recorded on the card and is converted into the true number form when it is a complement.

### Circuit diagram

The operation of the machine will now be described in detail with reference to the circuit diagram.

In the circuit diagram, Figs. 1a, 1b, and 1c, the circuits and electrical devices which have been added to the wiring arrangement of a standard commercial multiplying machine such as shown in the patents referred to, are emphasized by heavy lines to more clearly indicate the manner in which the improvements have been incorporated in such machine.

After record cards bearing perforations representative of the factors to be multiplied have been placed in the feed magazine of the machine and after the various preliminary plug connections have been made for directing the entries into the accumulators, the main line switch (not shown) is closed to place the machine in operation during which the section of the generator designated DC (Fig. 1c) supplies current to DC lines 10 and 11 and a section designated AC (Fig. 1a) supplies current to ground and to a line 12. The start key contacts 13 (Fig. 1c) are now closed by depression of the start key button, which completes the circuit from the DC line 10, through a relay coil C, contacts 13 now closed, upper contacts G1, cam contacts FC2, to line 11. Magnet CA and contact N2 are in parallel with coil C and the magnet is thus energized with the coil C. The coil C establishes a holding circuit through its contacts C2 and the cam contacts FC8.

The coil C, when energized, also closes a pair of contacts C1, shown in the upper part of Fig. 1c, which will complete a circuit from line 10, normally closed relay contacts F1, card feed clutch magnet 14, cam contacts FC6, stop key contacts 15, relay contacts N1, contacts C1, a pair of contacts P1, to line 11. Energization of card feed clutch magnet 14 will cause withdrawal of a card from the magazine 100 (see Fig. 3) and will advance it to the analyzing brushes 17. In transit to the brushes 17, the card first passes a pre-sensing station, generally designated 101. During this movement of the card, the usual card lever is engaged to close card lever contacts 18 (lower part of Fig. 1c) which complete a circuit from line 11, contacts 18, relay magnet H, to line 10.

In starting up the machine, it is necessary to hold down the start key to maintain the contacts 13 closed during the first complete card feeding cycle, or, alternatively, to depress the start key a second time. At the beginning of the second cycle, the closure of cam contacts FC11 will energize relay magnet G through a circuit including card lever contacts 18. Relay magnet G will close its normally open contacts G1, setting up a holding circuit through cam contacts FC2, and will also close relay contacts G2 to provide a further holding circuit through the card lever contacts 18. These two holding circuits alternate in maintaining relay magnet G energized as long as cards continue to feed from the magazine 100. The relay magnet H is also provided with a holding circuit, which extends through card lever contacts 18, or serially through relay contacts G2 and cam contacts FC2.

Energization of relay magnet H will cause shifting of its contacts H1 (upper part of Fig. 1a) to the reverse of the position shown, thereby supplying current to the distributor 19 which supplies current to the contact roll 17a of the an-

alyzing brushes 17. As the card proceeds to pass the analyzing brushes, circuits will be completed to the accumulators selected to receive entries in accordance with the perforations in the record card; that is, as the card traverses the brushes 17, the multiplier factor will be entered into the multiplier accumulator and the multiplicand factor will be entered into the multiplicand accumulator.

The entering circuits extend from the AC generator through line 12 to the now closed contacts H1, cam contacts FC7, distributor 19, brush contact roll 17a between which and the brushes 17 the card passes. From the contact roll, the circuits extend through the perforations in the card, the brushes 17 which sense the fields in which the multiplier and multiplicand factors are perforated, to plug sockets 20, from which suitable plug connections are made to sockets 21 and sockets 22 of the multiplier and multiplicand accumulators respectively, to effect energization of the adding magnets 23 of the related accumulators. The entering circuit, after passing through the magnets 23, continues through normally closed contacts A2 to ground.

After the first card has traversed the brushes 17, it is fed into the punching unit of the machine and upon its arrival there, it causes closure of punch card lever contacts 24 (see Fig. 3 and bottom of Fig. 1c) which cause energization of the relay magnet F. The closure of the normally open contacts F1 (upper part of Fig. 1c), establishes a circuit from line 10, now closed contacts F1, cam contacts CC3, trip magnet 25 of the punching mechanism (see Fig. 2) which functions to trip clutch mechanism to further advance the card to punching position. The circuit continues through eject contacts P3 and relay contacts K1 which at this time are in a position reverse to that shown. The contacts K1 are controlled by relay magnet K which is energized through last column contacts P5 in the punching unit. These contacts P5 are closed whenever the card advancing carriage of the punching unit is in last column position, which position it occupies when the operation of the entire machine is first started, so that upon starting, relay K is energized and its contacts K1 are in shifted position. When relays K and F are both energized, a circuit is completed when contacts CC2 close, which is traceable from line 12, contacts CC2 (Fig. 1a), K2, L2, F2, to reset magnet 31LH of the LH accumulator, thereby initiating resetting of the same.

The cards are handled in the card punching unit in the customary manner as set forth in the above mentioned patents. After the preceding analyzed card has been advanced column by column past the line of punches 102 (Fig. 2) and as the left hand component accumulator LH is being reset, a circuit is completed which extends from line 11 (Fig. 1c), contacts 44a, 44b, and 44c (which are closed while the LH accumulator is resetting), switch TP2, wire 28 (Figs. 1b and 1a), through relay magnets M and N in parallel, wire 29 (Figs. 1b and 1c) to line 10. Relay magnet M closes its contacts M2 (Fig. 1a) to provide a holding circuit for the relays extending from line 10, wire 29, relays M and N, contacts M2, wire 30, to the normally closed contacts 31a (Fig. 1c) and line 11. Contacts 31a are opened during the operation wherein the MC accumulator is reset and until such time, relay magnets M and N will remain energized. These are the master relay magnets of the cycle controller unit

and they call the cycle controller into operation to determine the location of significant figures in the multiplier. The circuit through wire 28 also extends to the zero segments 106 of the readout unit of the multiplier accumulator designated MPRO. If any of the brushes of the MPRO stand at zero, selected ones of the column skip magnets Yu, Yt, etc. will be energized according to which denominational orders of the multiplier contain zeros. The magnets Yu, Yt, etc., control contacts Yu-2, Yt-2, etc., through which circuits are completed to the column shift relay magnets CSu, CSt, etc., and to the multiplying relay magnets 34.

In those positions in which the multiplier digit is zero, the associated magnet Yu, Yt, etc., will be energized and the related contacts Yu-2, Yt-2, etc., will be shifted from the position shown in the diagram so that the related magnet CSu, CSt, etc., will be disconnected from the circuit which is traceable from line 12, cam contacts CC2, relay contacts M1, normally closed contacts Yu-2, relay magnet CSu, through the appropriate readout spot 103 in one order of the readout section MPRO, to the corresponding readout magnet 34, and thence to ground. The function of the contacts Yu-2, Yt-2, etc., is to direct the multiplying relay selecting circuits through only those positions in which significant figures occur in the multiplier and to skip the positions in which zeros occur.

With a particular magnet 34 energized, for example the X5 magnet 34, the related contacts shown in the center of Fig. 1a will become closed and with the emitter E in constant operation, impulses will be emitted through the contacts of the times 5 multiplier relay 34 and thence through the readout device of the multiplicand accumulator designated MCRO, and thereafter, through the column shift relay contacts CSL and CSR (Fig. 1b) to the adding magnets 23 of the RH and LH accumulators which thus received the right and left hand partial product entries respectively. The CSL and CSR relay contacts are controlled by the relay magnets CSu, CSt, etc., and serve to effect the proper denominational allocation of the partial product entries. Thus, when multiplying is being effected by the units digit of the multiplier, the units magnet CSu is energized and the units order sets of contacts CSL and CSR are closed.

Energization of a relay magnet CSu, CSt, etc., (Fig. 1a) will also close a pair of contacts CSu-3, CSt-3, etc., which will cause energization of the relay magnets Yu, Yt, etc., in the order in which multiplying is taking place. This, in turn, will shift the related pair of contacts Yu-2, Yt-2, etc., so that when cam contacts CC2 again close, the aforetraced circuit will be directed through the magnet CSu, CSt, etc., in the order containing the next higher significant figure and will skip the magnets CSu, CSt, etc., in positions in which zeros are present.

The machine continues multiplying operations during which the partial products are entered in succession into the LH and RH accumulators. After a multiplying cycle has been effected, for each significant multiplier digit, all of the magnets Yu, Yt, etc., will have been energized and all of the contacts Yu-2, Yt-2, etc., will be in their shifted position so that on the next following cycle the closure of cam contacts CC2 will complete the circuit which extends through all of the now closed contacts Yu-2, Yt-2, etc., and wire 35 to the relay magnet 36 and the

multiplicand reset magnet 37MC. A parallel circuit also extends through cam contacts FC10 and multiplier reset magnet 37MP.

If switch 38 is open, the multiplier accumulator will not be reset and the factor therein will become a so-called "fixed" multiplier for succeeding multiplying operations. The relay magnet 36 closes its contacts 36a (Fig. 1b), which connect the readout sections of the RH accumulator designated RHRO, to the adding magnets 23 of the LH accumulator, thus directing the sum of the right hand partial products into the LH accumulator to produce the complete product. These circuits are controlled from the emitter E (Fig. 1a) through a group of wires generally designated 39, which extend to the readout device RHRO.

In Fig. 5 is shown a section of an accumulator to illustrate the mechanical arrangement of the readout section which is the same for all the accumulators. For each order there are commutator segments 103 which are electrically connected through the brush structure 104 to the common arcuate conducting strip 105. The position of the brush corresponds to the value entered on its associated accumulating wheel and connects the segment 103 having such value to the strip 105. In the circuit diagram the segments and strips are represented as circles and vertical bars, respectively.

During the cycle in which the MC accumulator is reset concurrently with the RH to LH transfer operation, the normally closed contacts 31a (Fig. 1c) which are operated by a cam on the MC reset shaft will open to interrupt the circuit to the cycle controlling relay magnets Yu, Yt, etc., thus causing deenergization of all these magnets and the interruption of their related circuits. The RH to LH transfer relay magnet 36 closes a pair of contacts 36b (Fig. 1a) through which a circuit is completed by the emitter E after the amount in the RH accumulator has been transferred to the LH accumulator. This circuit is traceable from line 12, through emitter E, which, when the brushes thereof are at the zero segment, will continue through contacts 36b to the reset magnet 37RH which functions to initiate resetting of this accumulator.

Referring now to Fig. 1c, the contacts 31b are closed along with the shifting of contacts 31a when the MC accumulator is resetting, thereby completing a circuit from line 11, contacts 31b, switches SP1 and TP1, relay magnet C, to line 10. Relay magnet C establishes a holding circuit through contacts C2 as before and also closes contacts C1 to complete the circuit through the card feed clutch magnet 14 as traced above. This causes the next card to be fed to the analyzing brushes 17 where the new factors will be entered into the accumulators and in the case of "fixed" multiplier operation wherein the multiplier accumulator is not reset, only a multiplicand factor will be entered into the MC accumulator in preparation for the next series of multiplying operations.

During the operation of card feeding, the cam contacts FC4 close, completing a circuit from line 11, switch 40, cam contacts FC4, switch 41, wire 42, switch TP4, relay B, to line 10. Energization of magnet B will close its contacts B2 to provide a holding circuit through normally closed contacts 44a associated with the reset devices of the LH accumulator. The magnet B will also close its contacts B1, thereby establishing a circuit from line 11, contacts B1, con-

tacts 45 in the punching unit, switch 46, wire 47 (Fig. 1b) to the common conducting strip 48 of the punch column selector.

The strip 48 is connected in succession by a brush 110 to the segments 49 as the record card moves step by step past the column of punches 102 in the punching unit and in those columns that are plug connected to the readout device LHRO, will complete circuits from segments 49 to sockets 51 and through the LHRO device to wires 52 which extend to the punch selecting magnets 53 (see also Fig. 2) whose common return wire 54 extends through wire 29 to line 10. While the step-by-step punching of the product takes place in the card, the new factors are entered into their appropriate accumulators and when the card is completely punched and advanced to its last column position, relay magnet K will be energized as before to close its normally open contacts K1 and complete a circuit through the eject magnet 55 (Fig. 1c) which causes the ejection of the punched record from the machine.

As explained in the above mentioned patents, the energization of any of the magnets 53 will advance a related interposer into operative relationship with a corresponding punch 102 and the advancement of any interposer will cause closure of a pair of contacts 56 (Fig. 1c) which complete a circuit from line 10, through the punch magnet 57, contacts 56 and B1, to line 11. The punch magnet serves to press the selected interposer against the punch to effect a perforation in the corresponding position in the card column. The feeding of a new card to the brushes will again cause closure of card lever contacts 18, causing energization of magnet H to permit the impulse distributor 19 to supply current to the card analyzing brushes 17.

The operation of the machine as thus far described is substantially the manner in which multiplying operations are performed in the patents referred to and in commercial machines. In Fig. 6 is indicated the sequence of cycles where the multiplier factor contains two significant figures, resulting in two multiplying cycles.

Where the machine handles the equation including the term B and factors C and D, sockets 20 associated with the field B (Figs. 1a and 8) of the card are connected to sockets 101 (top Fig. 1b) associated with the accumulator magnets 23 of the right hand accumulator. As the card passes the brushes 17 which sense the field in which the B term is perforated, the holes in it will permit the brushes to make contact with the roll 17a and complete differentially timed circuits to the various accumulator magnets 23. These circuits include the normally open contacts H1, which are now closed, the cam contacts FC7 and a commutator 19, which serves to prevent sparking of the brushes. The circuits for the magnets 23 of the accumulator RH include normally open contacts Z1. These contacts are closed at this time by a relay coil Z (bottom Fig. 1c) which is energized on the closure of cam contacts FC12, through a circuit including switch 100, which is closed for this type of operation, and contacts C3 of the relay C which is energized in card feeding cycles. When it is desired merely to multiply two factors together, the switch 100 is opened.

Before describing the calculating operations, involving the features of the invention, the control for the sign of the factors will be described.

It has been explained that at the beginning of

the second card feeding cycle, the brushes 60, 70 and 71 (center Fig. 1c) will engage the sign-designating holes in the record. If the number B is negative, the brush 60 will engage a hole and will complete a circuit extending through cam contacts FC5, contacts H2 of the relay H, the brush 60, a relay coil 99 and contacts CA9, closed by the coil CA which is energized at this time. A similar circuit is completed through the brush 70 and a relay coil 72 if the multiplicand C is negative while a third circuit may be completed through the brush 71 and relay coil 73 if the multiplier D is negative. When the relays 72, 73 and 99 are deenergized, they are in what may be termed their "positive" condition and, when energized, in their "negative" condition. The relay coil 72 controls triple contacts 72a (top Fig. 1c) and triple contacts 72b while the relay coil 73 controls triple contacts 73a and triple contacts 73b. The relay coil 99 controls contacts 99a. If all three factors are positive the three coils 72, 73 and 99 will be deenergized and their contacts will be in the positions shown. These contacts are in a circuit which includes a relay coil 62, a switch SP2, which is closed for this type of operation, and contacts P2 which are provided in the punch and which prevent improper operation of the machine should the punch parts not be in a proper position. With the contacts of the relays 72, 73 and 99 in their normal positions, no circuit is completed to the relay coil 62, since the normally open contacts 99a interrupt the branch through the contacts 72b and 73b while the contacts 72a and 73a interrupt the connection through the normally closed contacts 99a. If both the factors C and D are negative, both the coils 72 and 73 will be energized and their contacts will shift. The shifting of these contacts will not, however, allow of a circuit being completed to the relay coil 62. Thus the relay 62 will not be energized when the factor B is positive and C and D are either both positive or both negative.

If the factor C alone is negative, the coil 72 will be energized and its contacts will shift. The circuit will then be completed through the contacts P2, the normally closed contacts 73a, the normally open contacts 72a, the normally closed contacts 99a, the switch SP2 and the relay coil 62. A similar circuit will be completed if the factor D is negative and the coil 73 becomes energized. Thus if B is positive and either C or D is negative and therefore their product CD is negative, the coil 62 will be energized. If B is negative, the coil 99 becomes energized, shifts its contacts 99a thereby disconnecting the contacts 72a, 73a from the coil 62. If C and D are both positive, a circuit is completed through the normally closed contacts 73b, the normally closed contacts 72b, the contacts 99a, the switch SP2 and the coil 62. If all three factors are negative, all three coils 72, 73 and 99 are energized and the coil 62 is energized over a circuit including the normally open contacts 73b, 72b and 99a. Thus, the coil 62 is energized if B is negative and C and D are either both positive or both negative. The circuits just traced require that the coils 72 and 73 should either both be energized or both be deenergized so that the relay coil 62 will not be energized if C is positive and D is negative, or vice versa, and only one of the coils 72 and 73 is energized. Thus the coil 62 is not energized when B is negative and either C or D, and therefore their product CD, is negative.

On referring to the table of conditions of

operation given previously, it will be noted that the coil 62 is not energized whenever B is to be added to CD but is energized whenever B is to be subtracted from CD and this coil determines whether addition or subtraction should take place.

When the coil 62 is energized it closes its contacts 62a to provide a holding circuit including reset contacts 63 which are opened when the accumulator RH is reset. The coil 62 also shifts contacts 62b (top Fig. 1a). During the resetting of the accumulator LH, contacts 44a (center Fig. 1c) close to complete a circuit including a line 102 to a relay coil S which closes its contacts S2 to provide a holding circuit for itself through cam contacts CC6. Coil S also shifts contacts S1 (top Fig. 1a). During the resetting of the accumulator LH a circuit is completed from the line 11 (Fig. 1c) through the contacts 44a, 44b, 44c (which close while the accumulator LH is being reset), the switch TP2, a line 28, which extends to Fig. 1a, relay coils M and N, a line 29, which extends back to Fig. 1c and the line 10. The coil N opens its contacts N1 (Fig. 1c) in series with the card feeding clutch magnet 14, its contacts N2 in series with the relay coil CA and its contacts N3 in series with the relay coil C so as to prevent card feeding operations being initiated during calculating cycles. The coil M closes its contacts M2 (Fig. 1a) to provide a holding circuit for itself and the coil N from the line 29 through the contacts M2, a line 30 and contacts 31a (bottom Fig. 1c) to the line 11. The contacts 31a are opened during resetting of the accumulator MC so that the coils M and N remain energized till this accumulator is reset.

The coil M also closes its contacts M1. Normally the closure of these contacts initiates multiplying operations. When, however, the coil 62 is energized, closure of the contacts M1 initiates a transferring operation by completing a circuit from the line 12 through contacts CC2, the contacts M1, the normally open contacts 62b, the normally open contacts S1 and a relay coil 36. This coil closes contacts 36a (Fig. 1b) so as to connect the accumulator magnets 23 of the accumulator LH to the reading-out mechanism RHRO. This mechanism comprises a number of segments 103 which correspond to the various digits as indicated in Fig. 1b and brushes 104 which are differentially positioned in accordance with the digits registered in the accumulator to connect common segments 105, one for each denomination, to the appropriate segments 103. The segments 103 are normally connected through contacts 62c and lines 39 to the emitter E in such a way that each segment can transmit an impulse generated by the emitter and timed to correspond to the digital value of the segment. With the coil 62 energized, the contacts 62c are shifted and invert the connections between the segments 103 and the lines 39 in such a way that the zero segments are connected to transmit an impulse at the nine time, the one segments at the eight time, and so on, the nine segments being disconnected. The impulses transmitted will therefore correspond to the complement to nine of the number B in the accumulator RH. These impulses are transmitted through the contacts 36a to the accumulator magnets 23 of the accumulator LH so that the complement of B is entered into this accumulator.

Coil 36 closes its contacts 36b (right Fig. 1a) so that the emitter E may complete a circuit, after the transfer has been effected, through

contacts 36b to a magnet 37RH which in known manner engages the accumulator RH to a reset shaft by which it is reset to zero in the next cycle. During this resetting operation, the contacts 63 (right Fig. 1c) open and deenergize the coil 62. When, early in the next cycle, the cam contacts CC2 (Fig. 1a) close, they complete a circuit through the contacts M1, normally closed contacts 62b to contacts 32a and the completion of this circuit initiates multiplication as has been described.

After the multiplicand has been multiplied by all digits of the multiplier, all the coils Yu, Yt, etc., will be energized and all the contacts Yu-2, Yt-2, etc., will have shifted. When the contacts CC2 next close, they will complete a circuit extending through the contacts M1, 62b and 32a, a line 35 and hence through a magnet 37MC and through the normally closed contacts S1 and the magnet 36. The circuit also extends through cam contacts FC10 and a magnet 37MP, switches 38 being closed. The magnets 37MC and 37MP initiate the resetting of the registers MC and MP. The magnet 36 closes its contacts 36a (Fig. 1b) to prepare the circuits for transferring the amount in the accumulator RH to the accumulator LH. Since the coil 62 is now deenergized, the contacts 62c will be in their normal position and the actual amount registered in the accumulator RH will be transferred. As before the magnet 37RH (Fig. 1a) will be energized after the transfer so that the accumulator RH is reset in the next cycle.

If the amount B is to be added to the product, the relay 62 is not energized and its contacts 62b (Fig. 1a) are in the position shown when the contacts M1 close. The multiplying operations are therefore initiated and commence in the cycle following the resetting of the accumulator LH. The transfer of the complement of B to the accumulator LH is thus suppressed and the amount B is left standing in the accumulator RH.

Referring to Fig. 10, there is shown diagrammatically, the sequence of operations involved for the four conditions I, II, III, IV in the first two of which B and CD are both positive and in the last two B and CD are both negative, so that in all cases the result is the sum of the two terms B and CD, the only difference being that for I and II the sign of the result is positive and for III and IV the sign of the result is negative. The determination of the final result sign in these four cases is made directly under control of the relays 72, 73 and 98. For I and II, no circuits can be completed through the contacts of these relays, but for III and IV either of the contacts 73a or 72a are shifted due to the unlike sign of C and D so that relay Q is picked up which in turn picks up relay R which closes its contacts R2 to cause an "X" hole to be punched at the proper time, indicating that the result is negative. The circuits involved will be specifically traced hereinafter.

It will be noted that for the conditions enumerated in Fig. 10, multiplying operations follow immediately after the LH reset cycle as illustrated in Fig. 6, since there is to be no intervening transfer of the B amount to the LH accumulator. Also, the conditions of I and II are alike except that for I, B is less than CD and for II, B is greater than CD. Conditions III and IV differ in the same respect.

It is well known that if a number is subtracted by adding its nines complement, the result, if

"negative," will be a nines complement, while, if "positive," will be one less than the true difference. In order to simplify recording a "negative" result, it is preferred to obtain the "negative" result as a nines complement. Provision is made for adding the missing unit, the so-called fugitive unit, to a positive result to make it correct. During the entries of partial products directly or by transfer into the accumulator LH, the complementary amount previously transferred to it from the accumulator RH will be converted, provided the product is greater than the amount standing in the accumulator as a complement into the true amount by the addition of the partial products and the accumulator will pass through zero, the highest denomination attempting to effect a carry operation when this occurs. The carry mechanism for this denomination is arranged as shown in Fig. 4 to close a pair of contacts 69 (top Fig. 1c) when it turns from 9 to 0 and these contacts energize a relay coil Y and a magnet 67. This magnet trips the carry mechanism for the units denomination of the accumulator LH so that the fugitive unit is added as though by a carry operation. It will be appreciated that the energization of the coil Y is indicative of the fact that the result has been obtained as a true number, and not as a complement, and does not therefore require to be converted when being recorded.

When the coil 62 is energized, it shifts its contacts 62d (center Fig. 1c) thereby energizing a coil W which closes its contacts W1 to maintain itself energized through cam contacts CC5. These contacts are timed to maintain the coil W energized for a short time after the coil 62 becomes deenergized. When the coil 62 deenergizes, a circuit is completed through the contacts 62d, contacts W2 closed by the coil W and a coil 64. This coil closes its contacts 64a, providing a holding circuit for itself including contacts Y1. The function of the relay 64 is to convert the result obtained in the accumulator LH into its complement. If the result in the accumulator LH is a true number, the coil Y will be energized and will open its contacts Y1, thus deenergizing the coil 64. On the other hand, if the result in the accumulator LH is a complement, the coil Y would not be energized and the coil 64 will remain energized.

The segments 103 (bottom Fig. 1b) of the mechanism LHRO are connected by wires 52 through normally closed contacts 64c to punch magnets 53. Each of these punch magnets corresponds to a different digit and selects a punch for punching a hole to represent that digit. With the contacts 64c in their normal position, the magnets 53 will be energized to select the punches for punching holes representing the amount in the accumulator LH. If the coil 64 is energized, contacts 64c will shift and the connections between the segments 103 of the magnets 53 will be inverted so that the holes punched will represent the nines complement of the amount in the accumulator LH, and, since this amount is a complement, these holes will represent the true result.

A fresh card feeding cycle and the punching operation are initiated in the following manner. During the resetting of the accumulator RH, reset contacts 90 (center Fig. 1c) close and complete a circuit through the contacts N3, the switch SP1, a switch TP1 and the coil C. This coil initiates the card feeding cycle in the manner previously described. It might be mentioned

that for ordinary multiplying operations, the switch SP1 is thrown so that the coil C is energized through contacts 31b which are closed during the resetting of the multiplicand accumulator, so that the coil C is energized one cycle earlier. Early in this card feeding cycle, cam contacts FC4 (bottom Fig. 1c) close and a circuit is completed through a switch 40, the contacts FC4, switch 41, a line 42, a switch TP4, and a relay coil B. This coil closes its contacts B2 to provide a holding circuit for itself. Coil B also closes contacts B1 (top Fig. 1c) thereby providing a circuit from the line 11 through the contacts B1, contacts 45, switch 46, a line 47 to common segment 48 (Fig. 1b) of punch column selector. The punch comprises a row of punches, controlled by the magnets 53, past which the card is fed step by step. A brush 110 moves with the card and connects the segment 48 to segments 49 in turn. Each segment 49 corresponds to a card column and those corresponding to the columns in which the result is to be recorded are connected by plug connections between sockets 50 and 51 to the mechanism LHRO so that the circuits may continue through each section of the mechanism LHRO in turn to the proper magnets 53. The card is automatically stepped one column after each punching operation and, when the result has been completely punched, the card is ejected.

#### *Determining the sign of the result*

If the result recorded on the card is negative, a special hole is made in the selected column under the control of the punch magnet 53 marked X in Fig. 1b. If the result is positive, this hole is omitted. Consider first of all the case in which the product is a positive amount as in the case in the first four conditions of operation given previously. Under these conditions the result will be positive if it is a true number and negative if it is a complement. Thus under these conditions the special hole should be punched if the coil 64 is energized when recording the product. If, on the other hand, the product is negative (the last four conditions given previously) a positive amount will be obtained as the complement and a negative amount as the true amount. This arises from the fact that the machine always subtracts B from the product CD and never subtracts the product from B.

It is therefore necessary for the machine to determine whether the product will be positive or negative. This is effected by a circuit through the contacts 72a, 73a (Fig. 1c). If one but not the other of these contacts shifts, as the result of C or D, but not both being negative, the product will be negative. Under these conditions a circuit is completed through a coil Q. This coil closes its contacts Q1 and provides a holding circuit through the contacts P2.

This circuit is held during the punching operations.

At the end of the card feeding cycle the card is delivered to the punch in position to be fed by a first card rack. In this position it closes card lever contacts 24 (bottom Fig. 1c) which energize relay coil F. This coil shifts its contacts F1. A previous card is fed past the punches by a second card rack and, after punching has been completed, the rack moves to a last column position and closes contacts P5. These contacts energize a relay coil K which shifts its contacts K1.

When the contacts K1 shift, they energize an eject magnet 55 which trips eject mechanism by which the card is ejected from the punch. During its operation, the eject mechanism closes contacts 76. The closure of these contacts connects a relay coil R parallel with the relay coil Q so that the coil R becomes energized and closes its contacts R1. During the ejecting operation contacts P3 close. A circuit may then be completed through the contacts F1, contacts CC3, a magnet 25, the contacts P3 and the contacts K1. The magnet 25 engages a clutch to couple both the card racks to a motor and closes contacts to energize this motor. The motor drives both the card racks towards one another so that the card just delivered into the punch is transferred from the first card rack to the second card rack. At the beginning of this card rack movement, the contacts P5 re-open, deenergizing the relay K so that its contacts are restored to normal. This provides a holding circuit for the relay coil R through the contacts R1 and K1. The movement of the first card rack is arranged to reset the eject mechanism of the punch which results in the contacts 76 re-opening so that the relay coils R and Q are no longer connected in parallel. At the end of its movement, the first card rack also opens contacts P2 breaking the holding circuit for the relay coil Q which becomes deenergized. Thus, the relay R will be held energized until punching has been completed on the card now in the punch, while the relay Q is deenergized in readiness for re-energization under the control of the next card. The first card rack moves to its normal position in readiness to receive the next card while the second card rack carries the card through the punching mechanism to the punching position. The movement of the card racks and the control of the contacts in the punch is described in the above patents and need not be described in detail herein.

Referring now to the bottom left corner of Fig. 1b the coil R controls contacts R2. Assuming that the product is positive so that the coil R is not energized, the recording of the special hole would depend upon the position of contacts 64e. A plug connection 79 is made from the socket 78 to the socket 50 corresponding to the column in which the special hole is to be made. If a digit is also to be recorded in this column, a plug connection 80 is made from the socket 77 to the appropriate socket 51. When the brush 110 completes the connection to the socket 50 in question, the circuit will be continued from this socket through the socket 78 and a coil T. This coil closes its contacts T1 and T2. The contacts T1 continue the circuit through the plug connection 80 and the appropriate denomination of the mechanism LHRO to the appropriate magnet 53. Assuming that a complement has been obtained in the accumulator LH so that the relay 64 is energized, the contacts 64e will be shifted and the circuit through the plug connection 79 will continue through the contacts T2, R2 and 64e to the magnet 53 marked X. This magnet will select a punch for making the special hole. If the result is a true amount, the contacts 64e will not shift and the circuit just traced will not be established. The special hole will not therefore be made.

If the product is negative, the coil R will be energized and its contacts R2 will be shifted. Then a circuit will be completed through the contacts T2, R2, 64e, if the contacts 64e are in their normal position, that is, if the amount in the accumulator LH is a true amount. This circuit

will not be completed if the contacts 64e are shifted, that is, if the amount in the accumulator LH is a complement. Thus the special hole will be made if the result is negative but not when it is positive.

In Fig. 11 the sequence of operations is summarized for the conditions I, II, III, IV, wherein the amount B is to be subtracted from CD by having its nines complement added thereto. In each of these cases the setting of relays 99, 72 and 73 has predetermined that B is to be transferred from RH to LH and has energized relay magnet 62 which suspends multiplying operations until the complemental transfer is effected and the RH accumulator reset. Energization of 62 has also caused energization of relay 64 for all four conditions. For condition I, however, the relay 64 is deenergized again when the amount in LH passes from a complement to a true number and no "X" hole is punched. For condition II, the relay 64 remains energized and an "X" hole is punched. For condition III, both relay 64 and R are initially energized, the former due to the energization of relay 62 and the latter due to energization of relay Q in response to a difference in signs between C and D. With both 64 and R energized, no "X" hole circuit is completed as for condition IV, but for III where CD is greater than B, the amount in LH passes from a complement to a true number, deenergizing 64 so that with R alone energized the "X" hole is punched.

The resetting of the accumulator LH is effected in the following manner. During the previous resetting of this accumulator, a coil L was energized through the contacts 44a and 44b. This coil closes its contacts L1 to maintain itself energized through contacts 111. When the relay coils K and F are energized at the conclusion of punching they close their contacts K2 and F2 (Fig. 1a). At the same time the contacts 111 (Fig. 1c) open to deenergize the coil L. The contacts 111 are opened, when the contacts P5 close, by the movement of the second card rack to the last column position. The coil L allows its contacts L2 (Fig. 1a) to close so that a circuit is completed when the contacts CC2 close to energize a coil 37LH which initiates the resetting of the accumulator LH. During this resetting operation of the contacts 44a and 44b reclose to reenergize the coil L which opens its contacts L2 to prevent further resetting operations.

The machine will also multiply two factors together and record the product together with the special hole if the product is negative. This merely involves omitting the plug connection to the sockets 101 (Fig. 1b) associated with the accumulator RH, opening the switch 100 (Fig. 1c) so that the coil Z is not energized and throwing the switch SP1 so that the card feeding cycle is initiated concurrently with the resetting of accumulator RH. The switch SP2 (Fig. 1c) is also opened so that the coil 62 would not become energized. The multiplying operations occur in the normal manner but the coils 72 and 73 are selectively energized in accordance with the signs of the factors as indicated on the card and in turn control the energization of the coil R in the manner previously described. The relay 64 will not be energized and its contacts 64e (Fig. 1b) remain in their normal position so that the punching of the special hole depends solely on the condition of the contacts R2 and will be effected when the product is negative.

The machine may also be used to obtain the

sum or difference between two numbers B and C which may be either positive or negative. To do this the numbers are punched on the cards together with unity in a particular column. The machine is plugged up so that B is entered into the accumulator RH, C into the accumulator MC and unity into accumulator MP. The machine thus proceeds to convert B into its complement, if necessary, and to multiply C by unity and then add it to B or the complement of B. The sign of the result will be indicated by the presence or absence of the special hole.

The machine may also evaluate the expression  $CD+B$  and  $CD-B$  where C and D are known to be positive and B is either positive or negative for all the cards inserted into the machine at a time. Under these conditions it is not necessary for the special holes to be made in the card to indicate the signs of the factors. If B is positive, the cards will be merely run through the machine and all three factors will be treated as positive owing to the absence of the special sign-indicating holes. If B is to be treated as negative a switch 66 is closed thereby short circuiting the brush 60 so that the coil 99 will be energized for each card.

While there has been shown and described and pointed out the fundamental novel features of the invention as applied to a single modification, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its 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 as follows:

1. In a multiplying machine, means for sensing a record card for representations representing the terms of an algebraic expression, one of which terms includes a pair of factors, factor receiving devices under control of a part of said sensing means, a pair of accumulators, means controlled by another part of said sensing means for entering one of the terms into one of said accumulators, transferring means for transferring the amount in said accumulator to the other accumulator in the form of a complement, means for sensing the record card for designations representing the arithmetic signs of said term and of the factors included in the other term, and means controlled by said sign sensing means in accordance with all sign designations for causing said transferring means to transfer the entered amount to the second accumulator.

2. In a multiplying machine, means for sensing a record card for representations of an amount B and two factors C and D of an algebraic expression, factor receiving devices under control of a part of said sensing means, a pair of accumulators, means controlled by another part of said sensing means for entering the amount B into one of said accumulators, transferring means for transferring the amount B from the first accumulator to the second in the form of a complement, means for sensing the card for designations representing the arithmetic signs of the three amounts and means controlled by said sign sensing means for causing the transferring means to transfer the amount B to the second accumulator when D only, C only, or B only are negative or when B, C, and D are all negative.

3. In a multiplying machine, comprising means

for sensing three amounts from a record card, two factor receiving devices for receiving two of said amounts under control of a part of said sensing means, multiplying means controlled by said receiving devices, a product receiving accumulator and a sub-product receiving accumulator for receiving values under control of said multiplying means, means controlled by another part of said sensing means for entering the third amount into said sub-product accumulator, and means for subtractively transferring the amount entered in the sub-product accumulator to the product accumulator, the combination of means for sensing the record card for designations representing the arithmetic signs of said amounts, means for signifying whether the product accumulator contains a true number or a complement, means for effecting a designation of the arithmetic sign of the result, and means controlled by said sign sensing means and said signifying means for controlling the operation of said result sign designation effecting means.

4. The invention set forth in claim 3 in which means are provided and controlled by said sign sensing means for causing said transferring means to transfer the third amount to the product accumulator when the three amounts are negative or when only one of the amounts is negative.

5. The invention set forth in claim 3 in which means are provided and controlled by said sign sensing means to precondition the control means for the said sign designation effecting means to designate the result as negative when the two factors are unlike in sign and means are provided and controlled by said signifying means for suppressing the preconditioned control means when the result in the product accumulator changes from a complement to a true number.

6. In a multiplying machine, comprising means for sensing three amounts from a record card, two factor receiving devices for receiving two of said amounts under control of a part of said sensing means, multiplying means controlled by said receiving devices, a product receiving accumulator and a sub-product receiving accumulator for receiving values under control of said multiplying means, means controlled by another part of said sensing means for entering the third amount into said sub-product accumulator and means for transferring the amount entered in the sub-product accumulator to the product accumulator in the form of a complement, the combination of means for sensing the record card for designations representing the arithmetic signs of said amounts, means for effecting a designation of the sign of the result, means for controlling said designation effecting means, means controlled by said sign sensing means when the sign of only one of the three amounts is negative or when all are negative for rendering said complement transferring means effective, further means controlled by said sign sensing means when the amounts entered into said factor receiving devices are unlike in sign for preconditioning said control means for the designation effecting means to enable the latter to effect a designation, means for signifying whether the product accumulator contains a true number or a complement and means controlled by said signifying means when the product accumulator contains a true number for rendering the preconditioned control means ineffective.

NORMAN M. WOOD.

## CERTIFICATE OF CORRECTION.

Patent No. 2,185,697.

January 2, 1940.

NORMAN M. WOOD.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 74, for (B+CD) read (-B+CD); page 4, second column, line 1, for "multiplicant" read multiplicand; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 5th day of March, A. D. 1940.

(Seal)

Henry Van Arsdale,  
Acting Commissioner of Patents.

## CERTIFICATE OF CORRECTION.

Patent No. 2,185,697.

January 2, 1940.

NORMAN M. WOOD.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 74, for  $(B+CD)$  read  $(-B+CD)$ ; page 4, second column, line 1, for "multiplicant" read multiplicand; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 5th day of March, A. D. 1940.

(Seal)

Henry Van Arsdale,  
Acting Commissioner of Patents.