Nov. 7, 1939. J. W. BRYCE 2,178,950

MULTIPLYING MACHINE

Filed Jan. 5, 1928 20 Sheets-Sheet 1

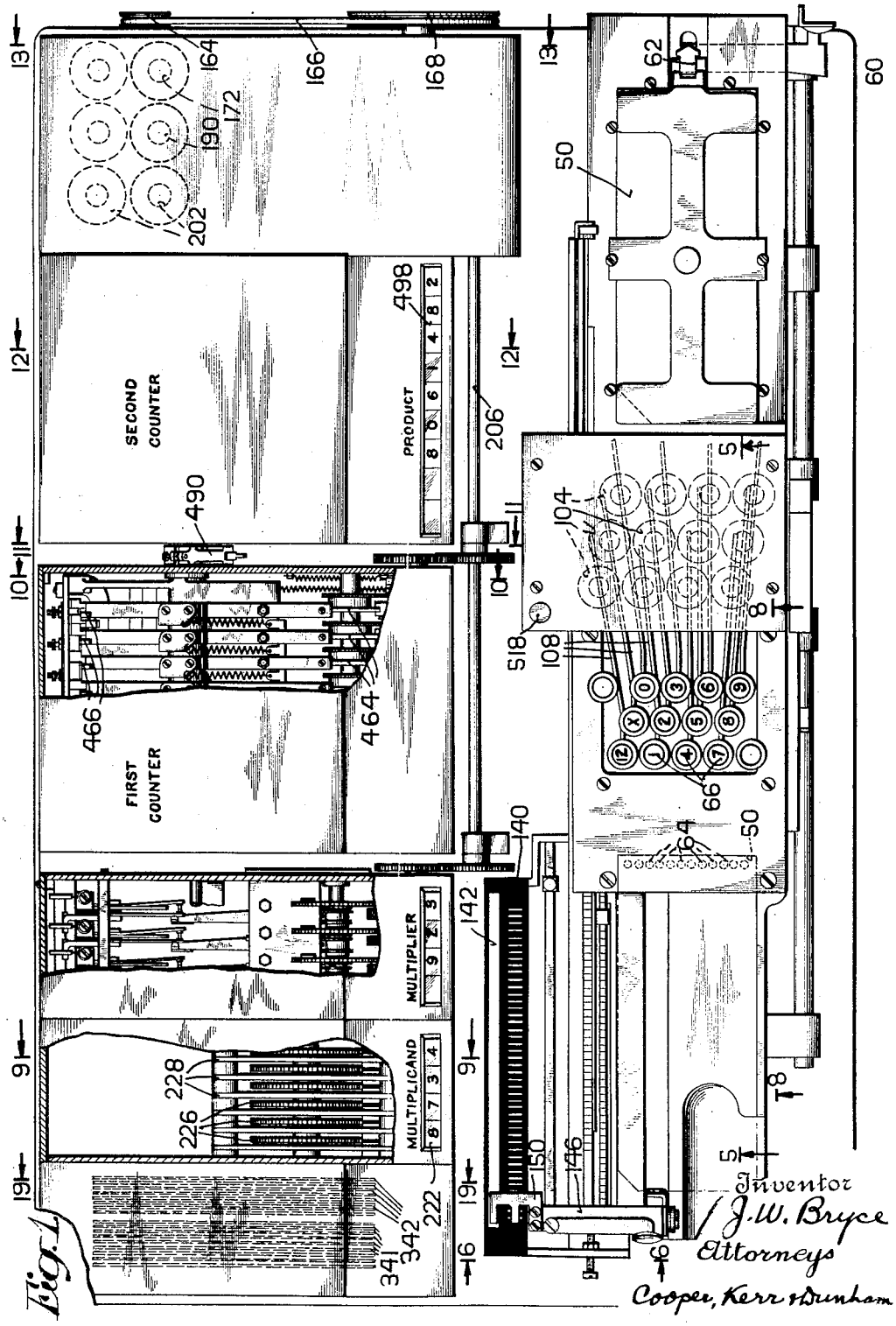

Fig. 1.

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MULTIPLYING MACHINE

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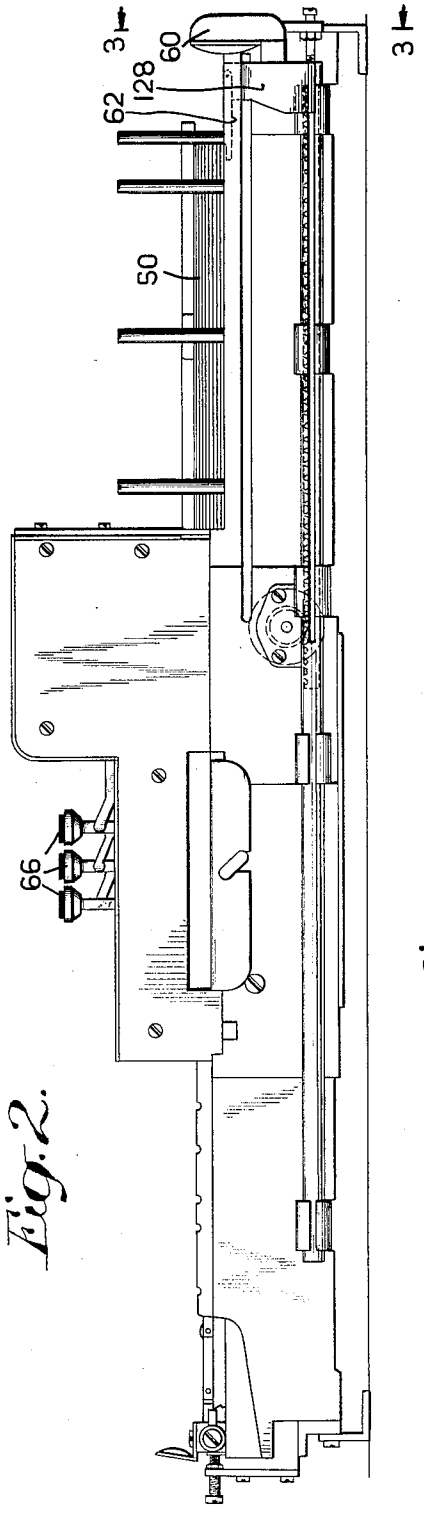
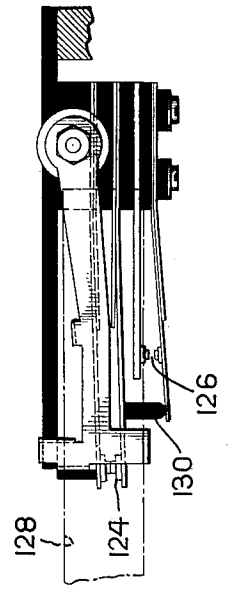


Fig. 2.



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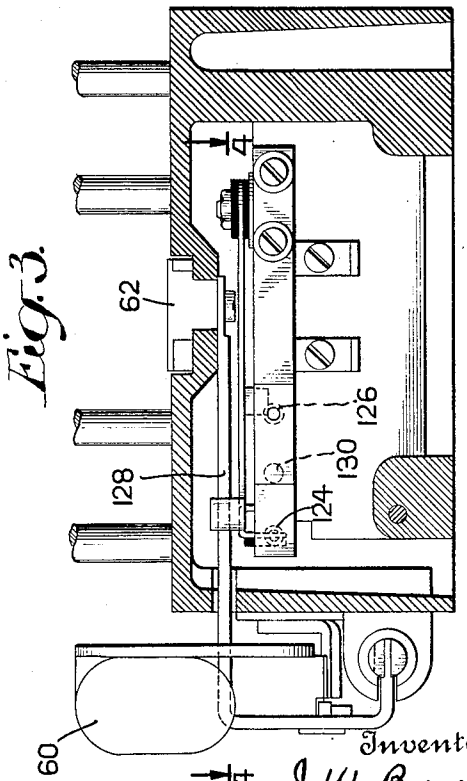

Fig. 3.

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MULTIPLYING MACHINE

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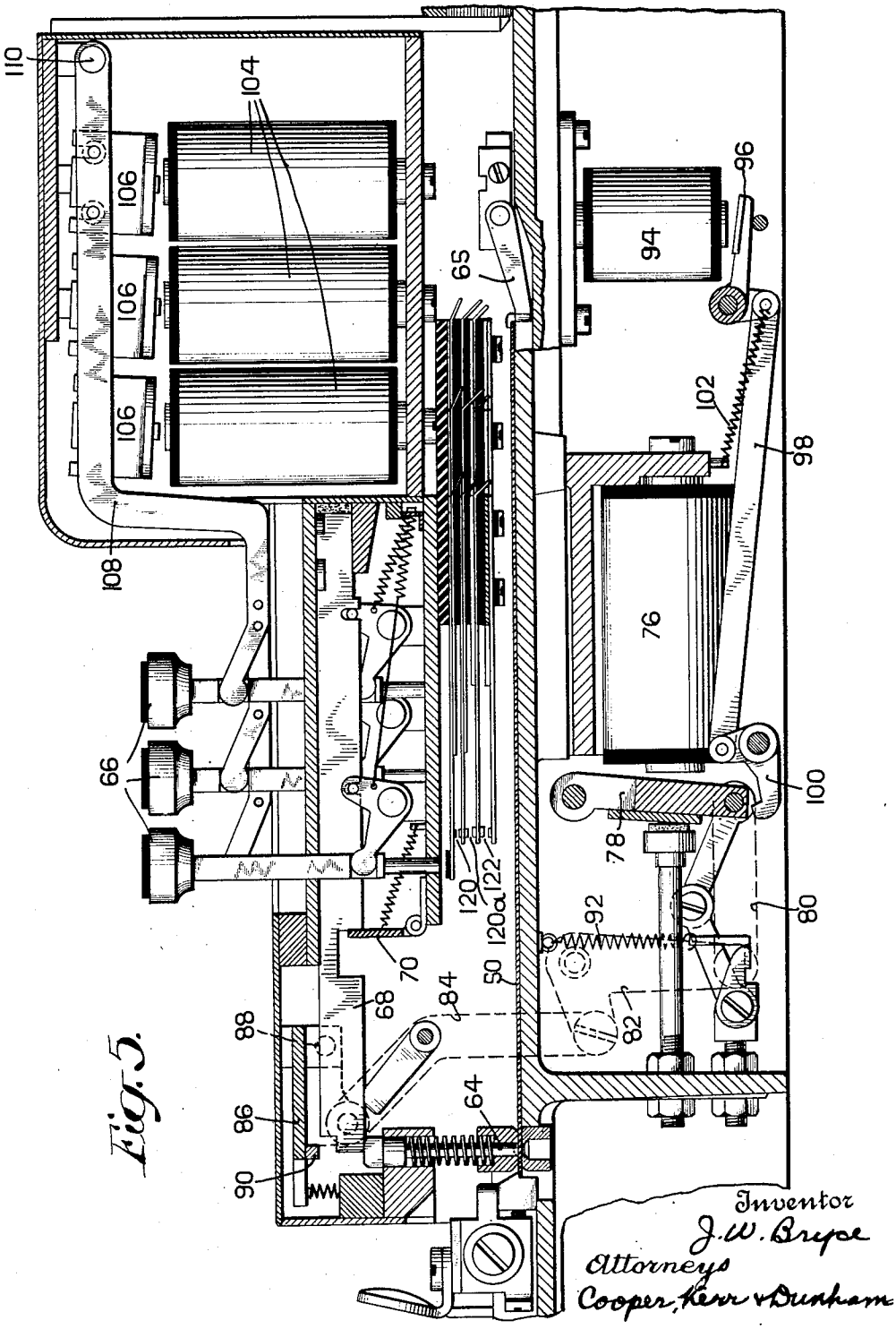

Fig. 5.

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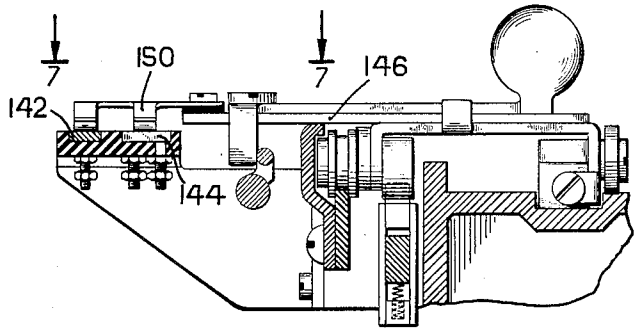
Fig. 6.



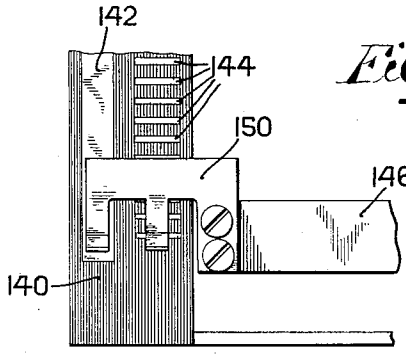


Fig. 7.

Fig. 8.

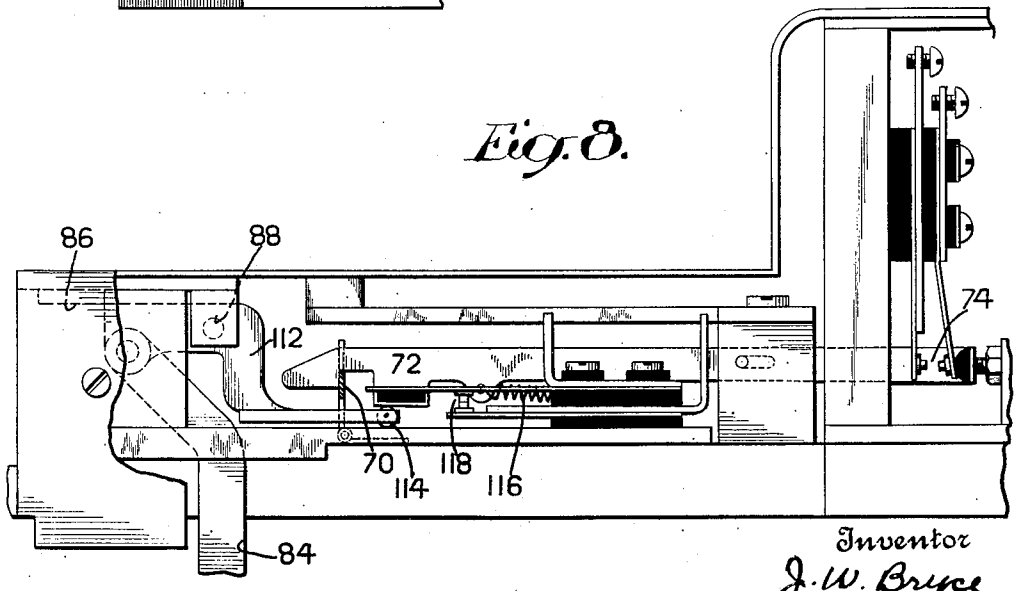


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Fig. 9.

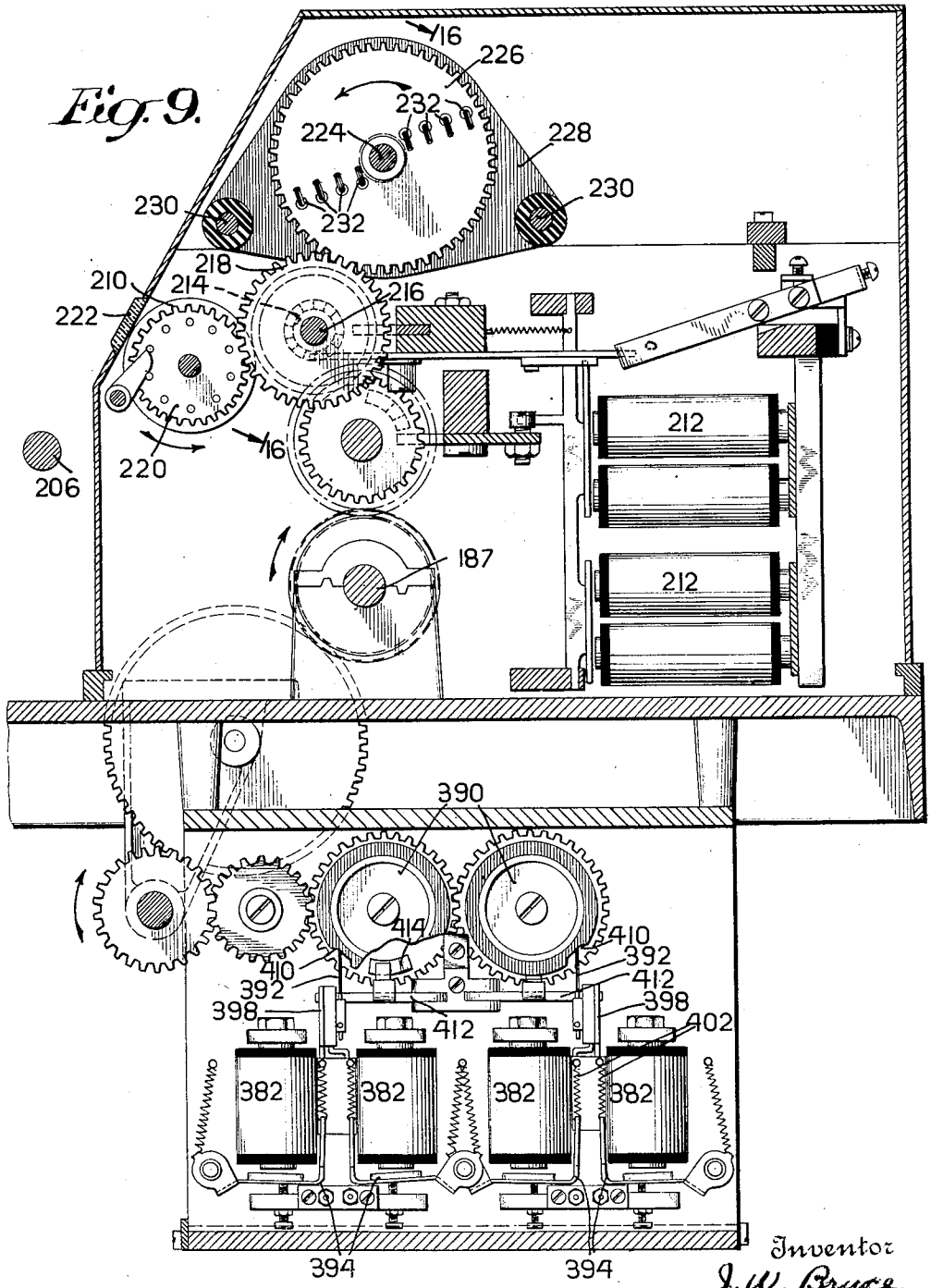

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Fig. 10.

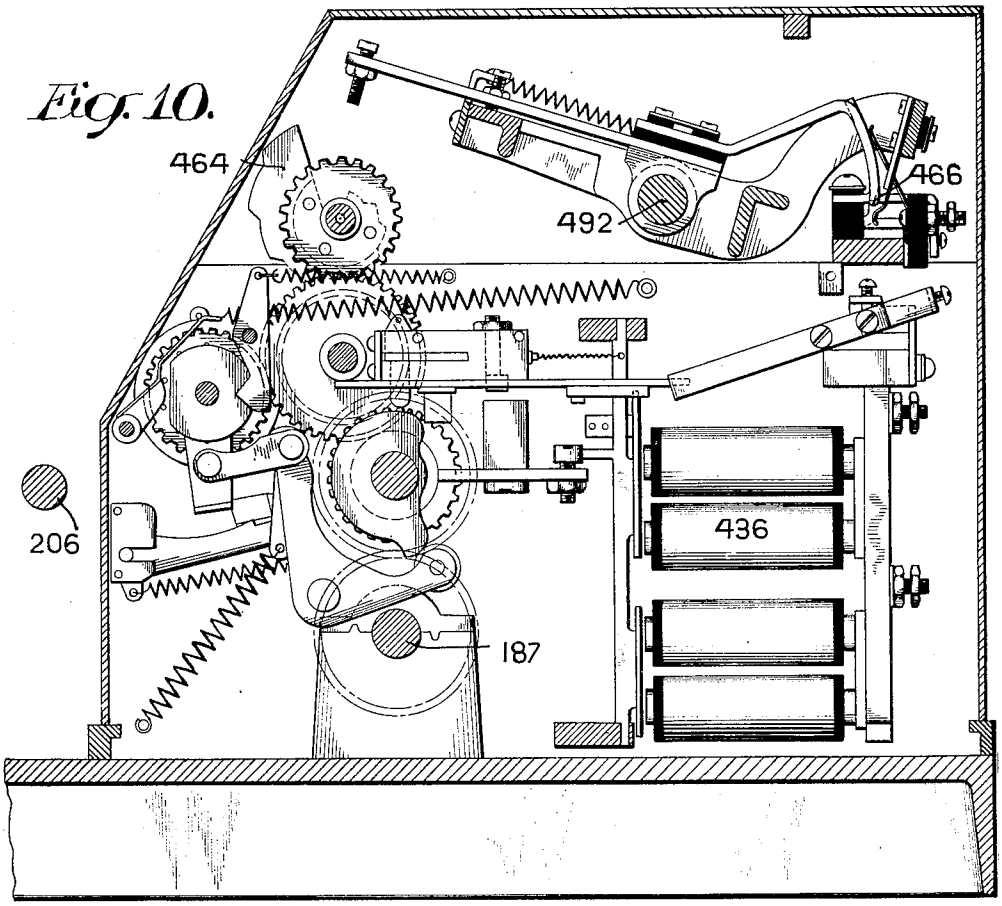

Fig. 22.

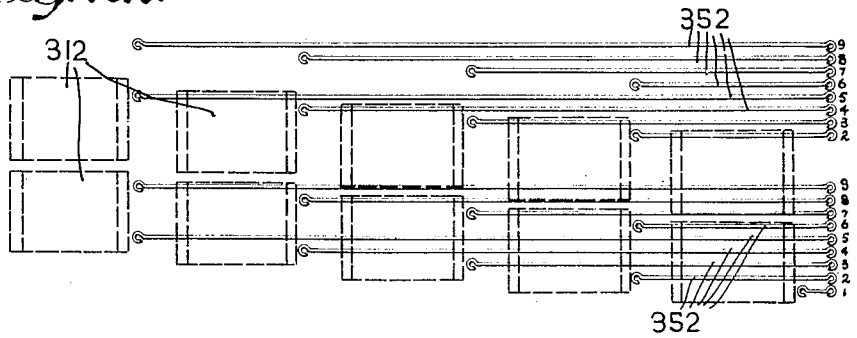

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Fig. 11.

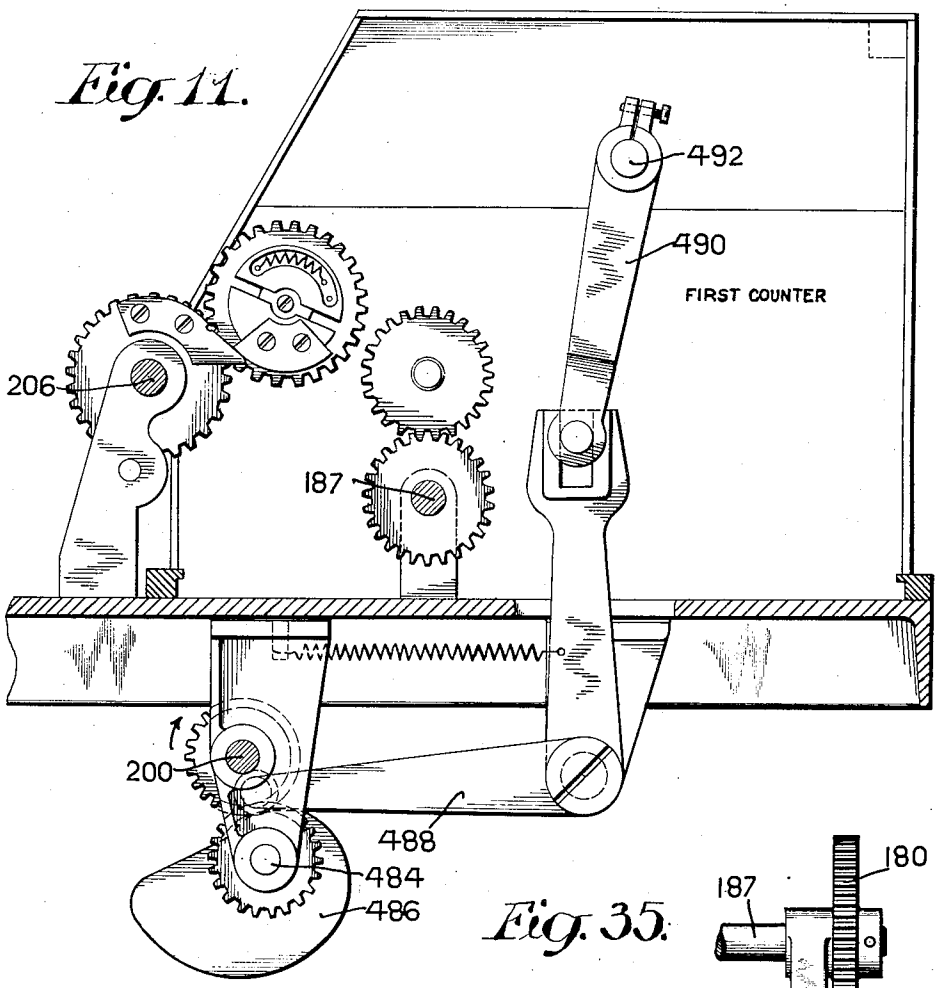

Fig. 35.

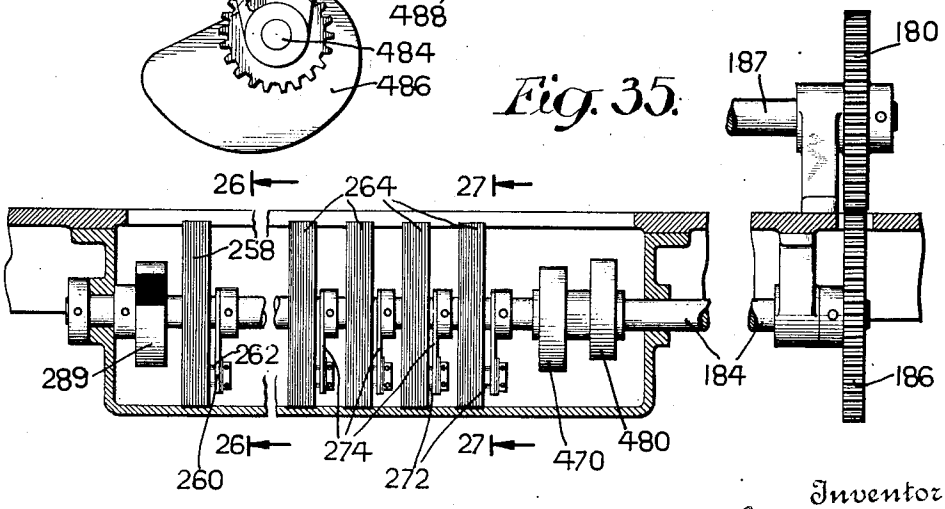

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Fig. 12.

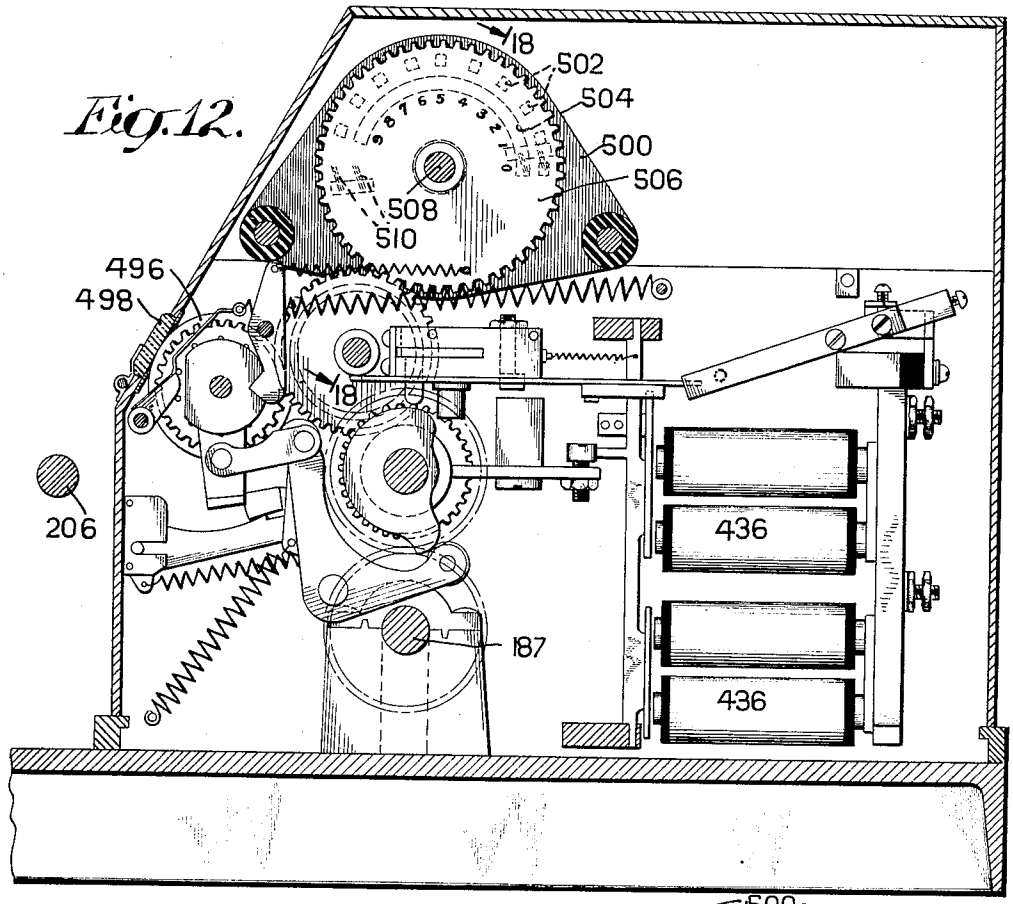

Fig. 21.

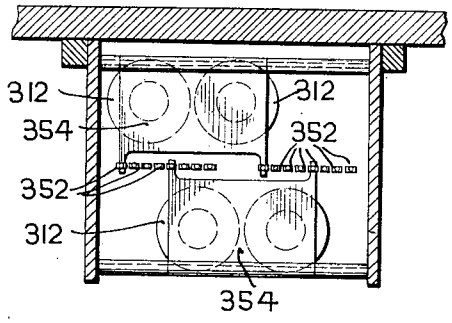

Fig. 18.

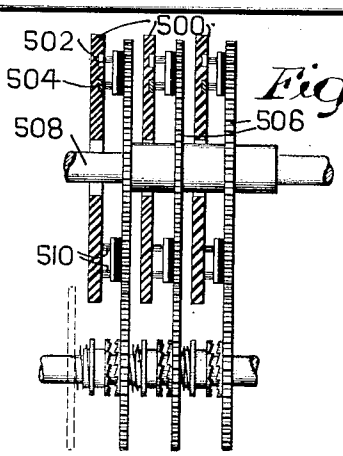

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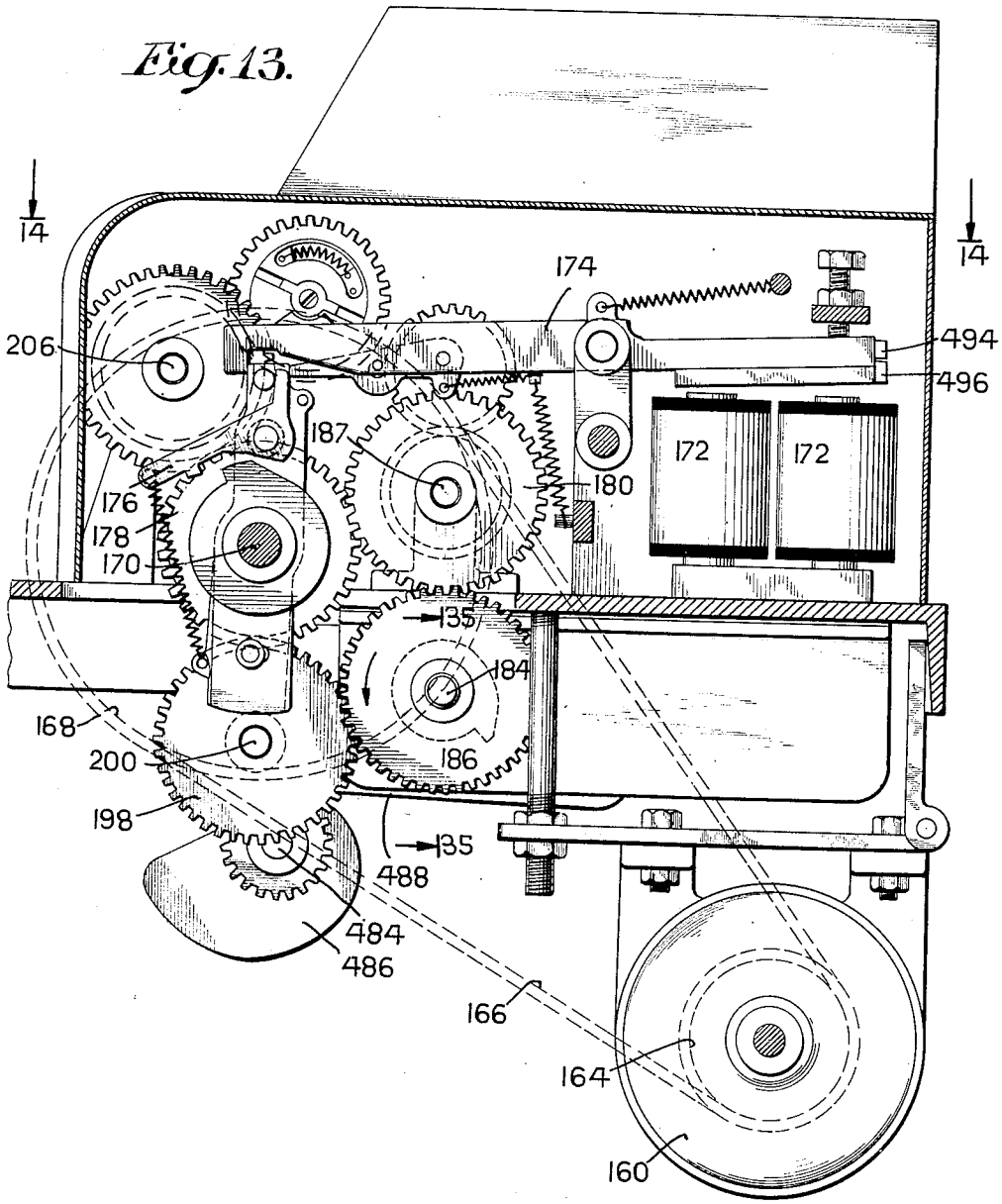
Fig. 13.



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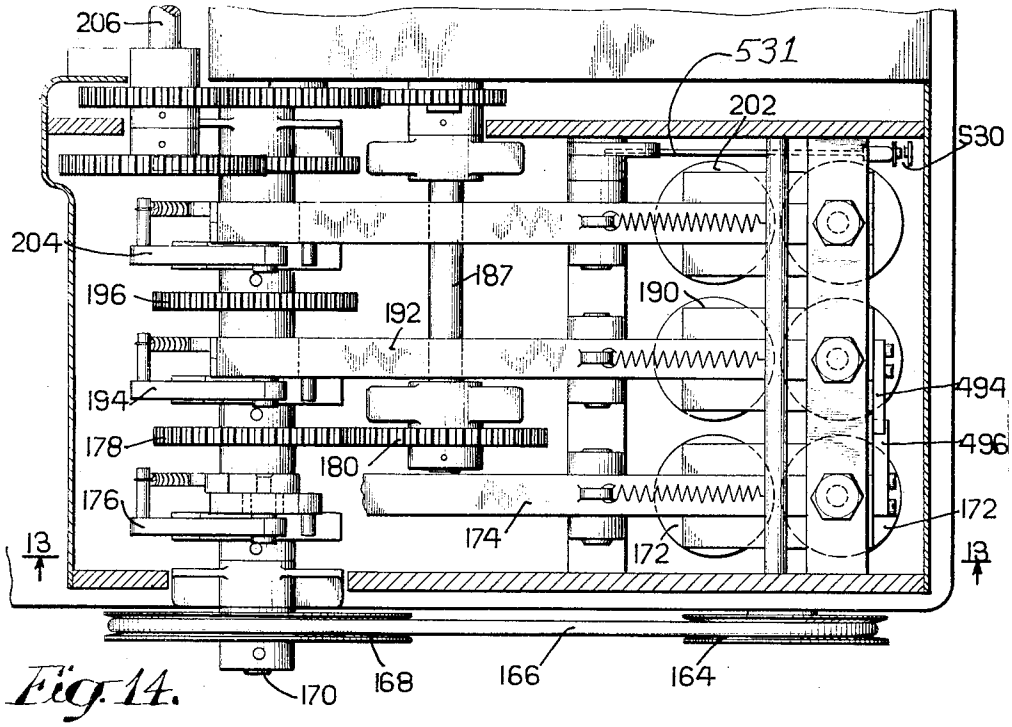

Fig. 14.

Fig. 26.

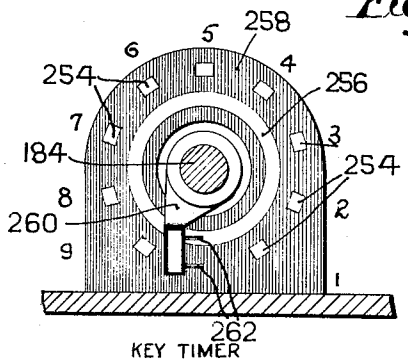

Fig. 27.

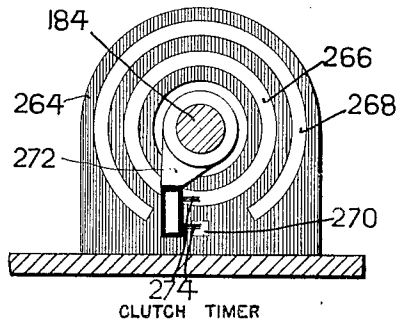

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Fig. 15.

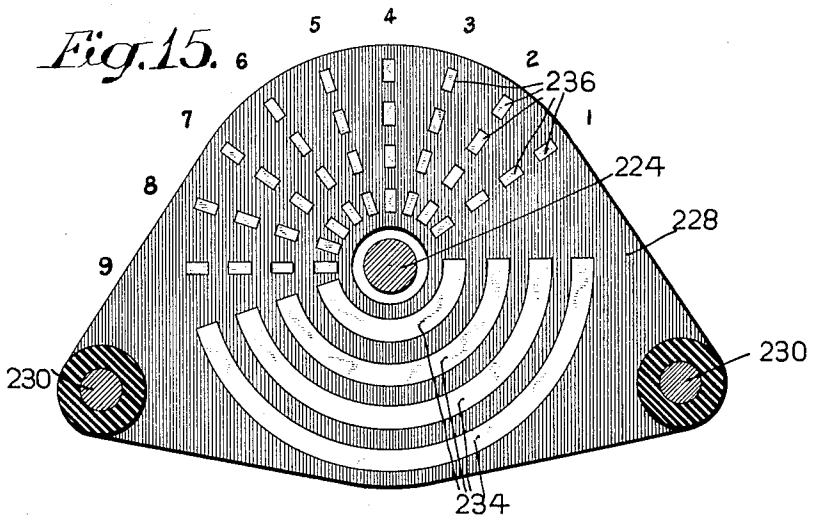

Fig. 16.

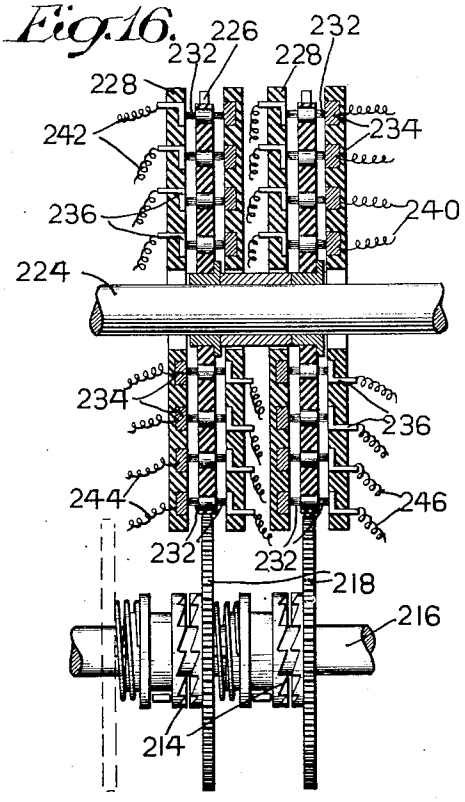

Fig. 17.

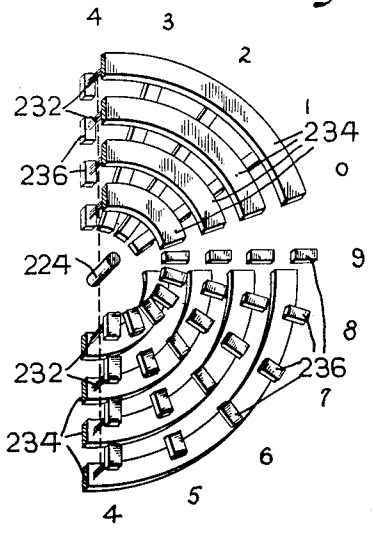

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Fig. 19.

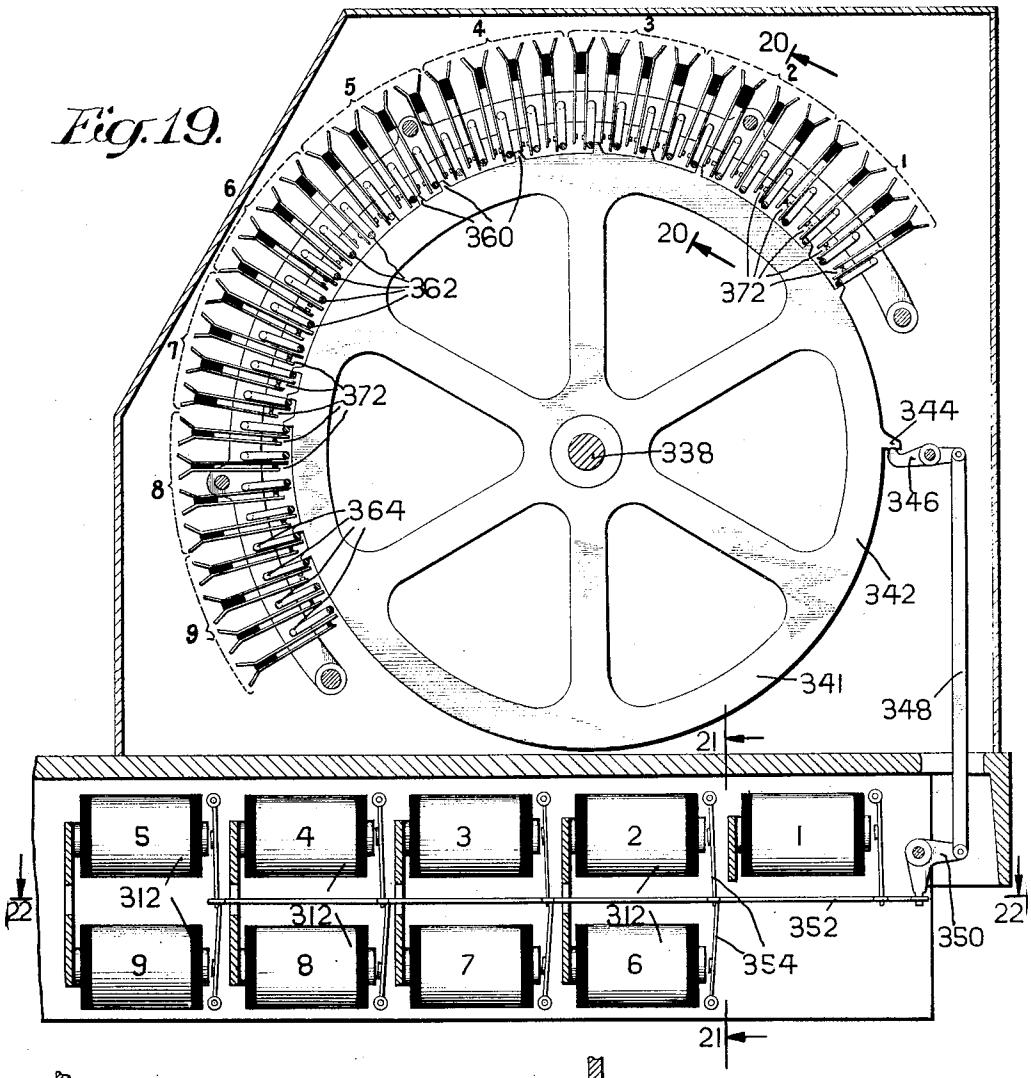
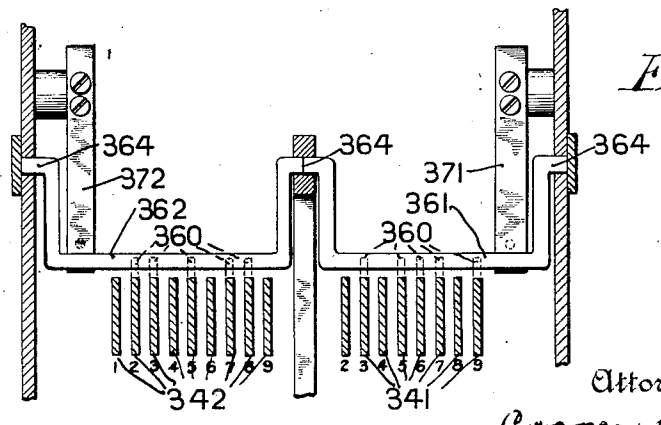


Fig. 20.



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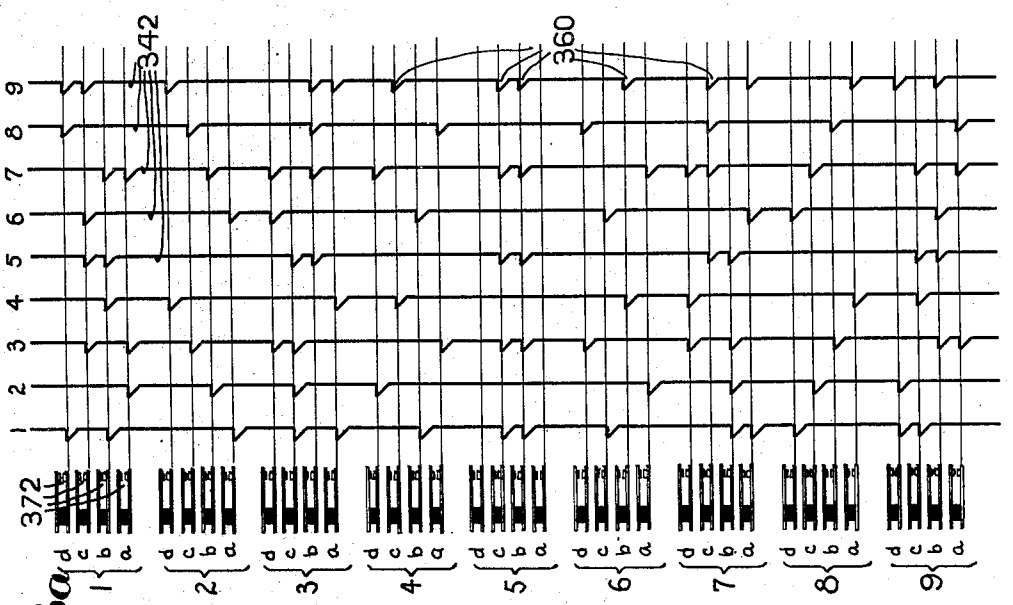

Fig. 23a.

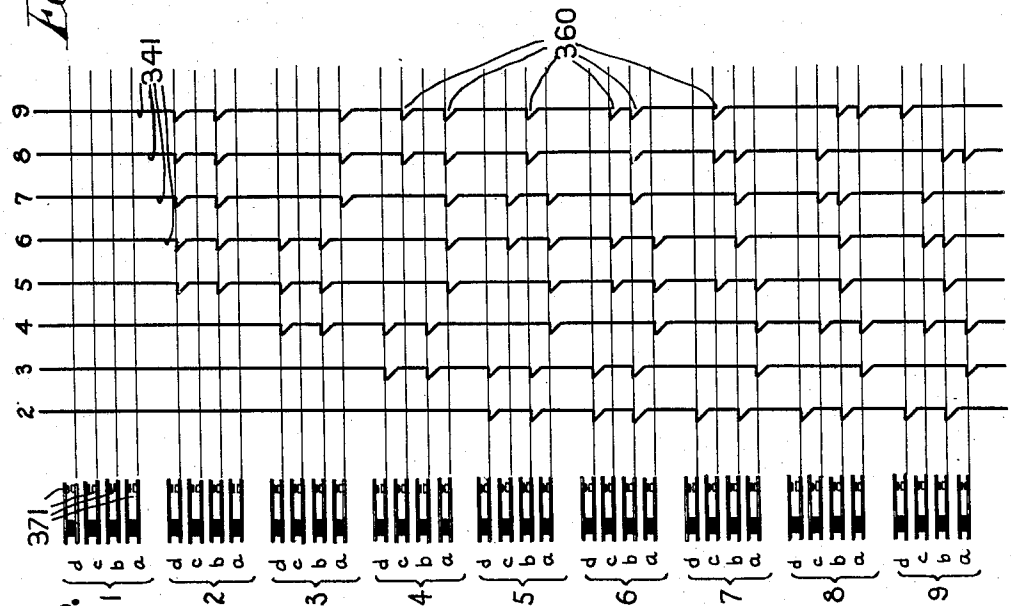

Fig. 23.

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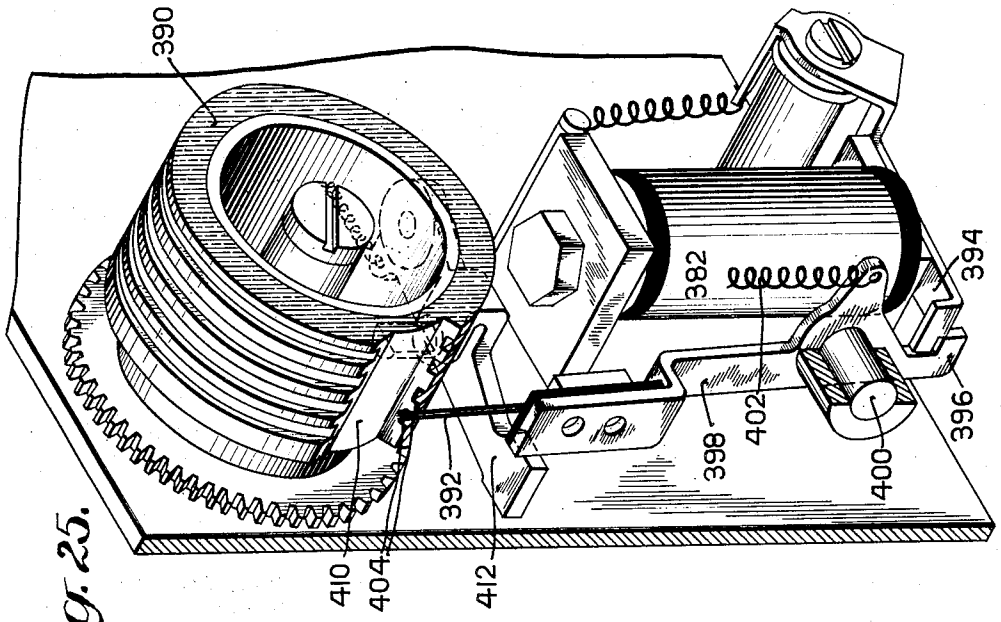

Fig. 25.

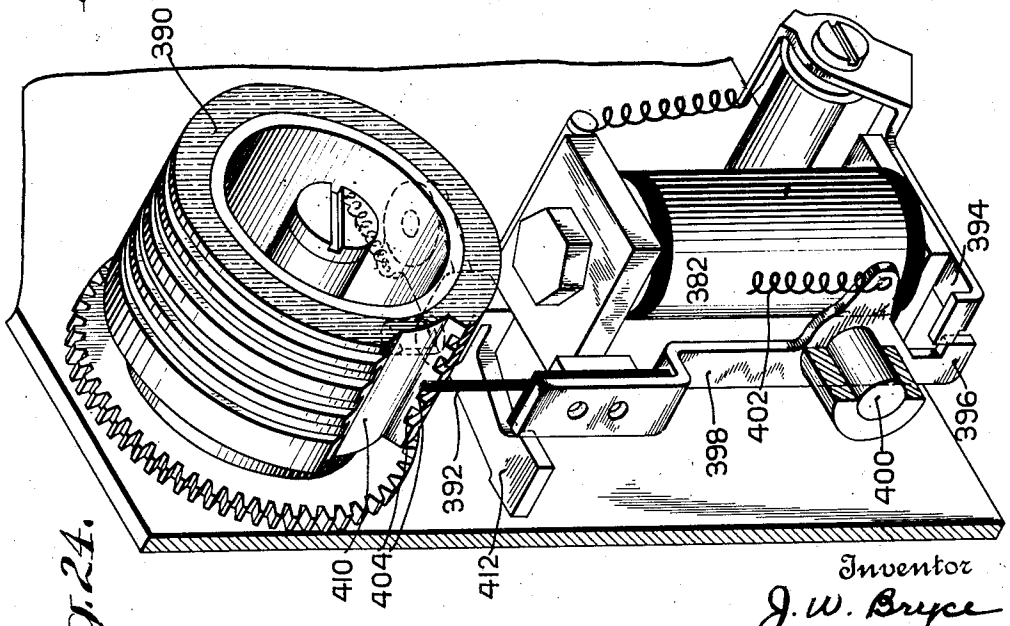

Fig. 24.

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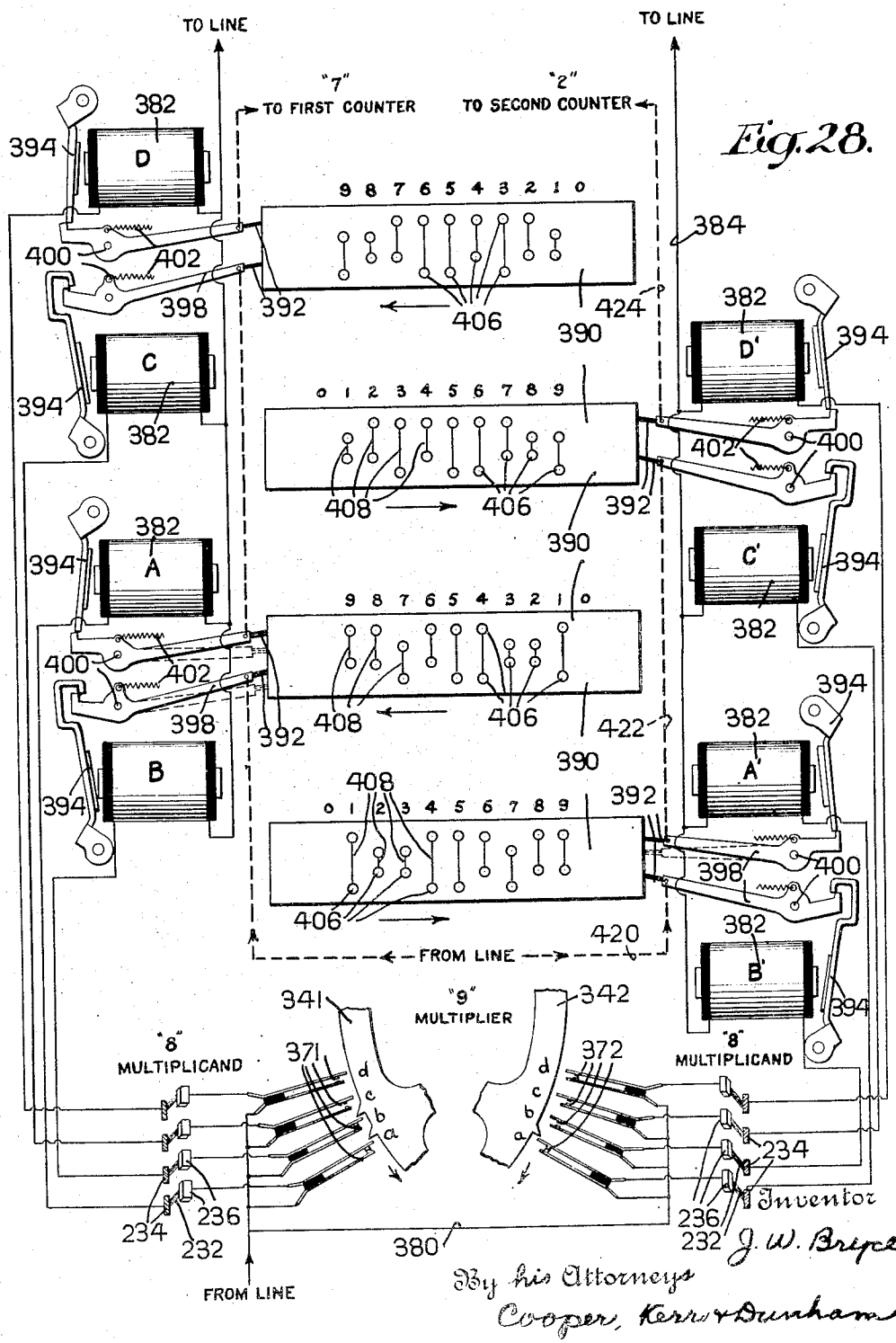

Fig. 28.

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Fig. 29.

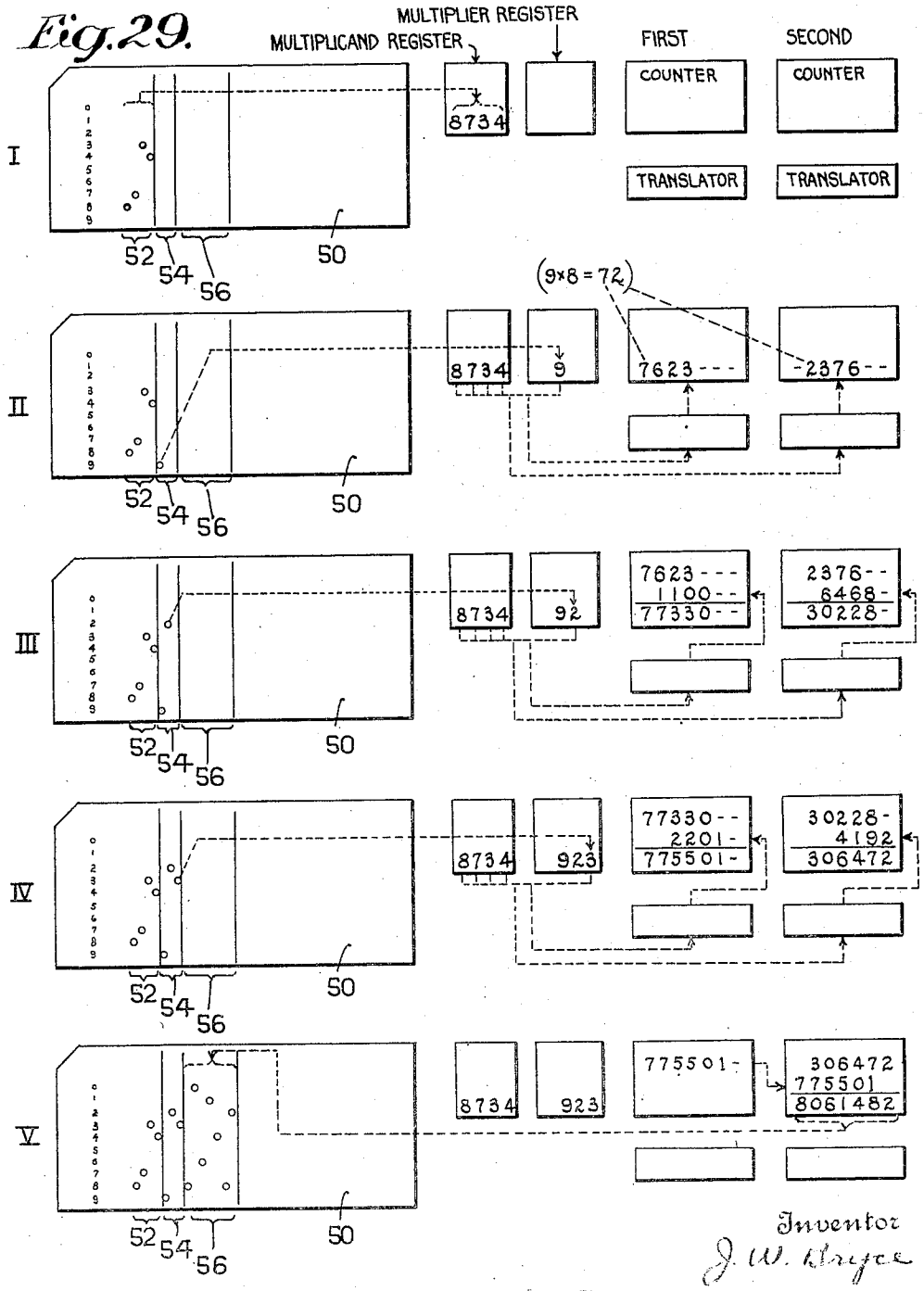

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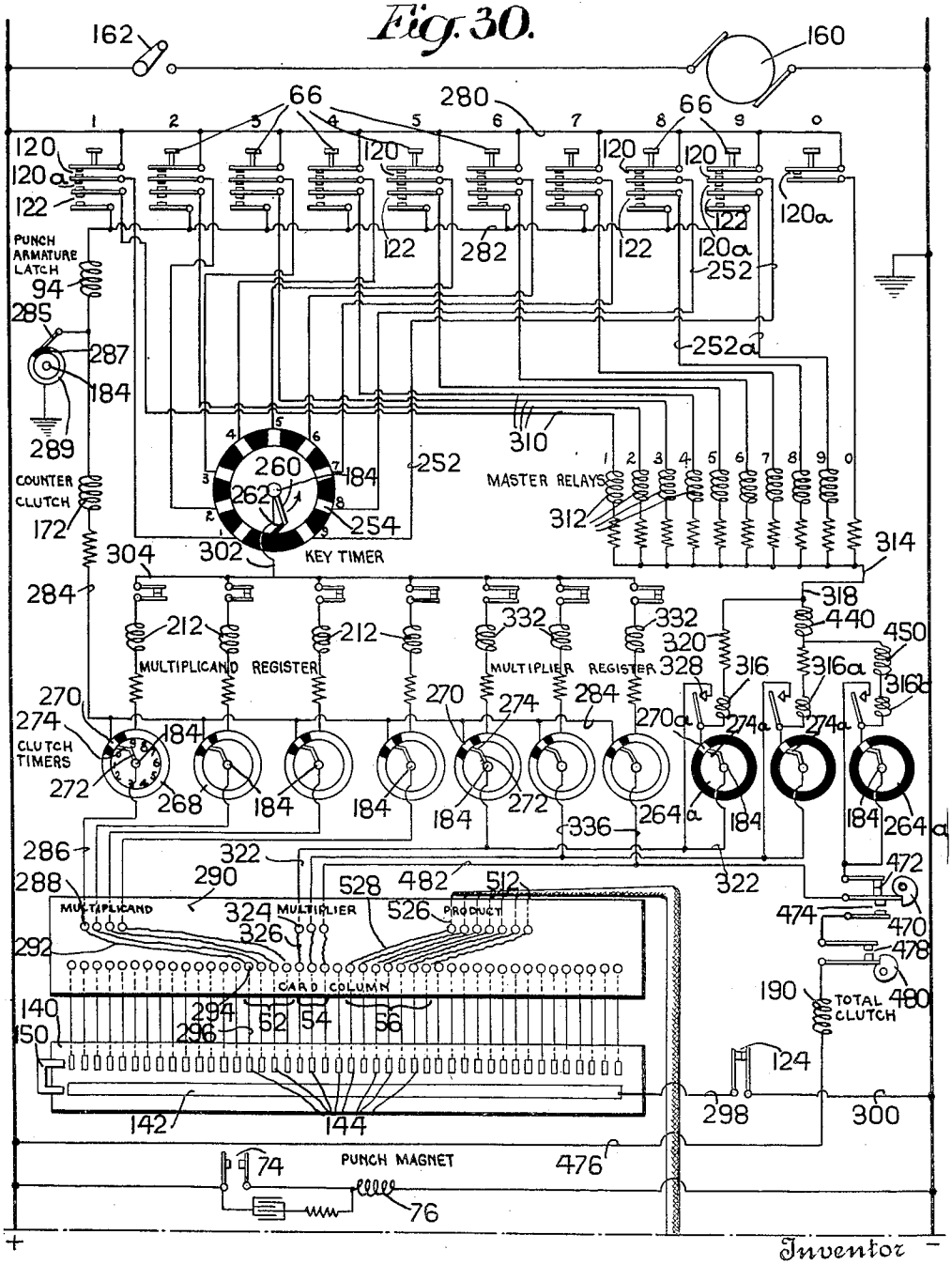
Fig. 30.



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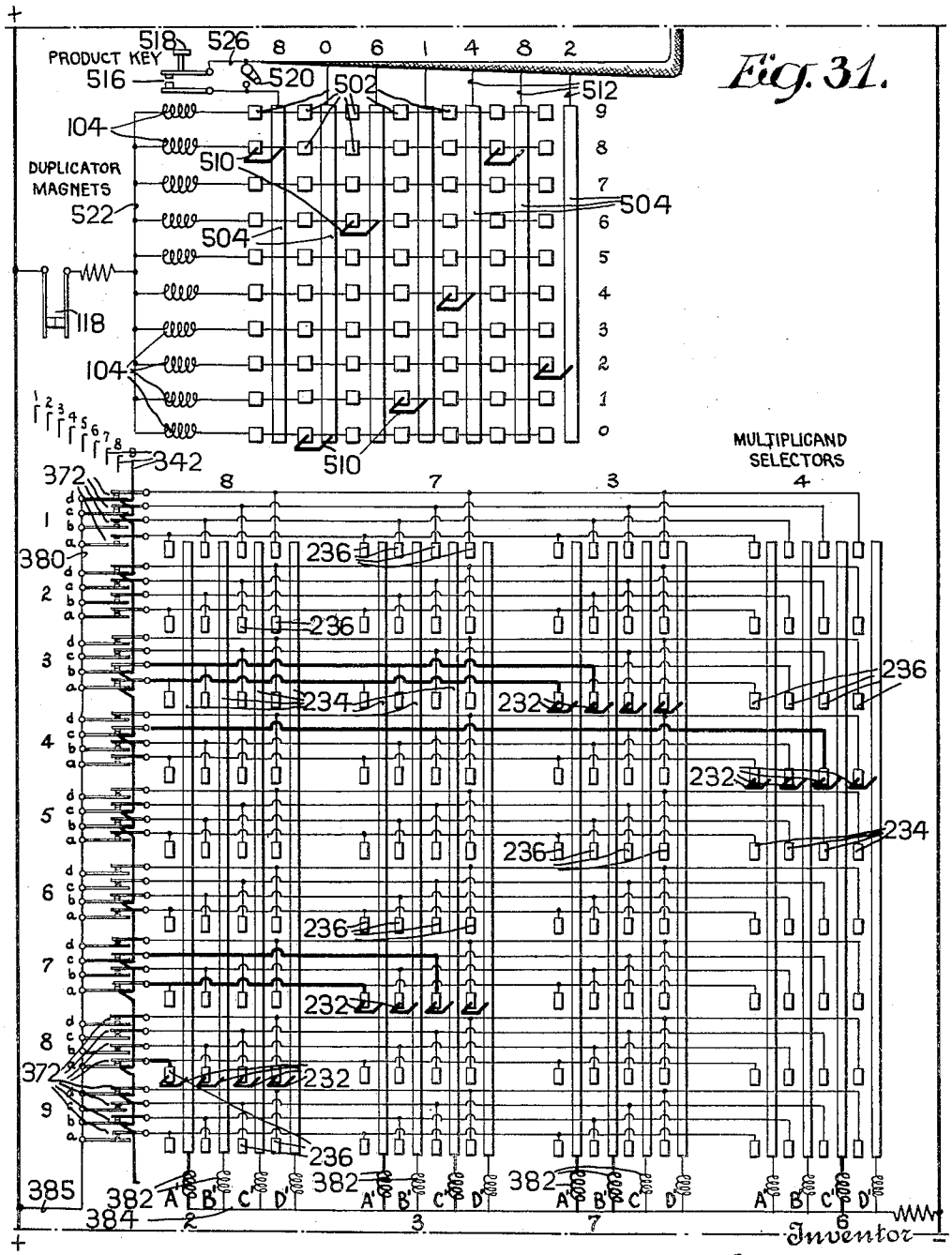

Fig. 31.

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Fig. 32.

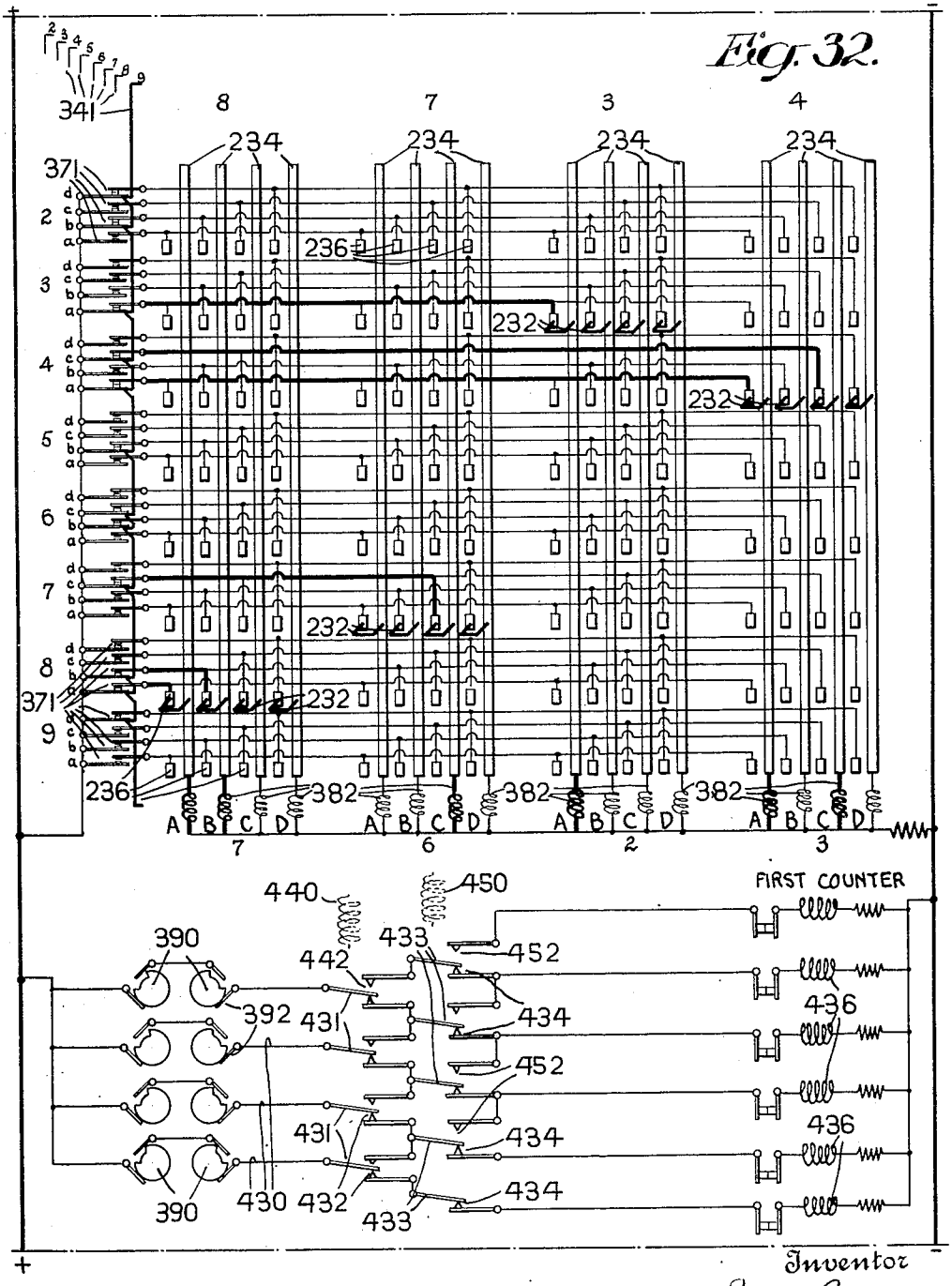

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Fig. 33.

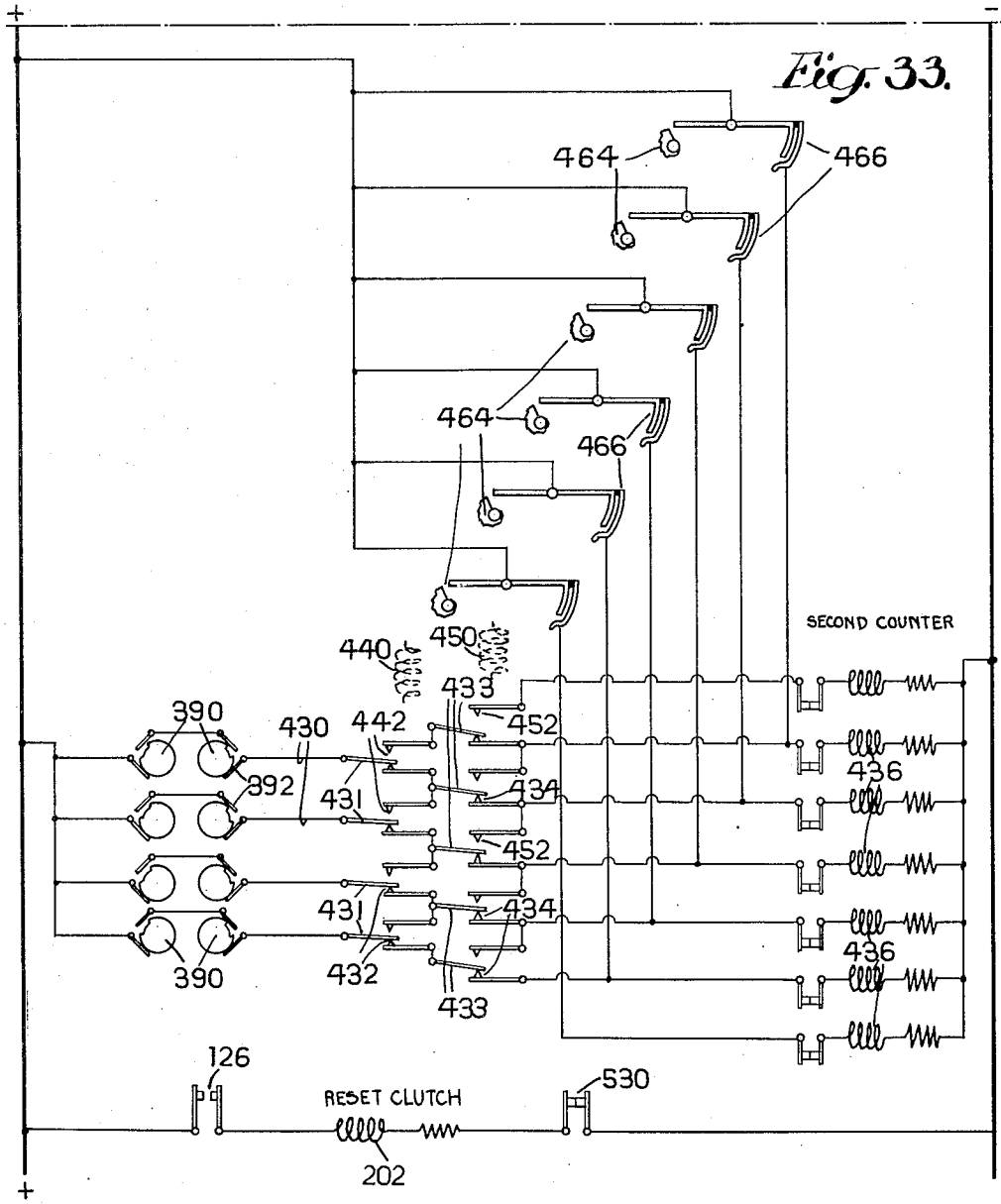
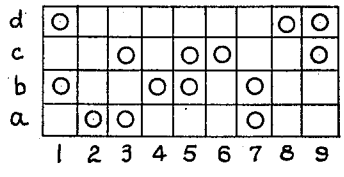


Fig. 34.



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Patented Nov. 7, 1939

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UNITED STATES PATENT OFFICE

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MULTIPLYING MACHINE

James W. Bryce, Bloomfield, N. J., assignor, by mesne assignments, to International Business Machines Corporation, New York, N. Y., a corporation of New York

Application January 5, 1928, Serial No. 244,594

45 Claims. (Cl. 235—61)

This invention relates to multiplying machines and novel methods of multiplication.

Heretofore multiplying machines have been devised which set up the multiplier and multiplicand by suitable keys. In some of these machines multiplication has been effected by successive addition, viz. by first adding the multicand into an accumulator the number of times indicated by a first order digit of the multiplier, then shifting the entering mechanism and adding the multiplicand the number of times indicated by the second order digit, then shifting again and adding for the third order, and so on. All such machines require a series of independent accumulating steps which in number will equal the sum of the digits of all the orders in the multiplier. Thus to multiply a number by 923 will require 14 separate entering or accumulating operations.

Other machines have been devised utilizing a partial product principal for multiplication. For each order of digits in the multiplier two accumulating steps are required. With such machines, to multiply by 923 requires six accumulating steps. A machine of this type devised by the present inventor is shown in Patent No. 1,622,279.

Obviously the time required for a multiplying operation is a direct function of, and is directly dependent upon, the number of steps or operations, whether carried out manually or by a motor drive. With multipliers having many digits this time factor often becomes exceedingly important.

It is therefore one of the primary objects of the present invention to provide a multiplying machine and method of multiplication which will save time by reducing the number of operations required. According to the present invention provision is made for carrying out multiplication by a novel method and by a novel machine whereby the actual operation of multiplying may be effected in a less number of steps than heretofore. The number of operations required by the present machine, taking into account and retaining reasonable simplicity of the mechanism, is represented by the number of digits in the multiplier plus one. Thus the multiplying of a number by 923 requires only four multiplying steps, viz. one for each order of the multiplier, plus one extra operation for assembling the product. When high numbers are used the saving of time is readily apparent. For example with the fastest previous commercial machines the multiplication of a number by 6,783,294 would require fourteen accumulating steps. With the present machine only eight steps are required and simplicity of mechanism is retained.

A further object of the present invention resides in the provision of a multiplying mechanism of such character that the machine is capable of being extended for higher capacities by merely increasing the columnar capacity of the accumulators. The part of the mechanism which takes in the multiplicand and combines it with the multiplier to obtain product representations is suitable for an indefinite capacity without change or addition. For example the multiplying section is adapted without change or additional parts to multiply numbers such as 8734×923 or larger numbers such as 9734216×923761. The controlling requirements are sufficient register and accumulator capacity to handle the factors and the product.

Another object of the present invention resides in the provision of a construction which will take the digital values of one of the factors entering into the product, for example the multiplier, and coordinate these values with the other factor, and set up the product not in digital values but by combinational representations. In this way the set-up of the product is vastly simplified. With the present machine the product digit of any order may be represented by one or two of four machine elements selected according to a code, in place of one machine element selected from ten. In other words, in the present invention four parts are made to do the work of ten.

Another object of the invention is to disclose a multiplying apparatus which is simple in operation, of low cost, and easily kept in order.

Another object is to provide a machine which will furnish a permanent record of each multiplication or transaction, preferably by perforating the multiplicand, multiplier and product in a record card suitable for use in well known types of tabulating and sorting machines.

A further object of the present invention resides in a novel combination of punching machine and multiplying machine, each machine controlling the operation of the other. For example the factors of a computation entered upon the punching machine may control the action of the multiplying machine. Furthermore, after the computation has been effected, which proceeds as the second factor is entered, the multiplying machine may control the punching machine to record the product.

A further object of the present invention resides in the provision of means for selectively

associating the punching machine and the multiplying machine.

A further object of the present invention resides in the provision of various automatic devices for speeding up and safeguarding various multiplying and punching operations.

Further objects reside in the provision of novel merging and multiplying devices which are adapted for general computing machine uses and which are not limited to the precise embodiment herein shown, and particularly are not limited to cooperation with the punching devices.

A further object of the present invention resides in the provision of a machine which enters the factors of a problem upon a record card and which as well enters upon the same card the results of the computation. Such operations are carried out as the computation is being effected.

Further and other objects and advantages will be hereinafter set forth in the accompanying specification and claims, and shown in the drawings, which by way of illustration show what is now considered to be the preferred embodiment of the invention.

Fig. 1 is a plan view of the complete machine, partly cut away to show interior mechanism.

Fig. 2 is a front view of the card punching device.

Fig. 3 is an enlarged sectional view on the line 3—3 of Fig. 2.

Fig. 4 is a cross section on the line 4—4 of Fig. 3.

Fig. 5 is an enlarged cross section on the line 5—5 of Fig. 1.

Fig. 6 is a partially sectional end view on the line 6—6 of Fig. 1.

Fig. 7 is a fragmentary view on line 7—7 of Fig 6.

Fig. 8 is an enlarged sectional view on the line 8—8 of Fig. 1.

Fig. 9 is an enlarged cross section on the line 9—9 through the multiplicand register and translators.

Fig. 10 is an enlarged cross section through the first partial product counter, on the line 10—10 of Fig. 1.

Fig. 11 is a side view of the first partial product counter, on the line 11—11 of Fig. 1, showing reset devices.

Fig. 12 is an enlarged cross section through the final counter, on the line 12—12 of Fig. 1.

Fig. 13 is a cross section through the clutch control devices, on the line 13—13 of Figs. 1 and 14.

Fig. 14 is a sectional plan view of the clutch control devices, on the line 14—14 of Fig. 13.

Fig. 15 is an enlarged detail view of the multiplicand selector as shown in the upper part of Fig. 9.

Fig. 16 is an enlarged cross section through the center of the contact devices in Figs. 9 and 15, showing their connection with the register wheels. The view is on the line 16—16 of Fig. 9.

Fig. 17 is a perspective phantom view of the metallic portions of the contact devices of Figs. 15 and 16.

Fig. 18 is a cross section on the line 18—18 of Fig. 12 showing the "reading out" contact devices of the final counter and their connections to the register wheels of that counter.

Fig. 19 is an enlarged cross section on the line 19—19 of Fig. 1, showing the multiplier discs, the magnets which operate them, and the contacts controlled by them.

Fig. 20 is a cross section on the line 20—20 of Fig. 19.

Fig. 21 is a cross section on the line 21—21 of Fig. 19.

Fig. 22 is a plan view showing the arrangement of multiplier magnets and call wires actuated thereby, on the line 22—22 of Fig. 19.

Figs. 23 and 23A are diagrammatic views of the multiplier discs.

Fig. 24 is a perspective view of a translator unit in normal position.

Fig. 25 is a perspective view of a translator unit in shifted position.

Fig. 26 is a detail of the multiplicand key timer.

Fig. 27 is a detail of the multiplicand clutch timer.

Fig. 28 is a diagram showing the method of producing the components of the product and the method of entering them into their respective counters.

Fig. 29 is a diagram showing the scheme of operation of the whole apparatus from the punching of the multiplicand to the punching of the product.

Figs. 30, 31, 32 and 33 taken together form a circuit diagram of the apparatus, the bottom of each sheet joining the top of the next sheet in the order named.

Fig. 34 is the translator code.

Fig. 35 is a section taken on the line 35—35 of Fig. 13.

In the embodiment of the invention herein disclosed a card punch of well known type is provided. The punch is operable either manually or electrically. To carry out a multiplying operation the multiplicand is manually punched in the multiplicand field of the record card. Then the multiplier is manually punched in the multiplier field of the card. Registers are provided which set up both those factors for inspection by the operator.

As the first multiplier digit is punched, partial products of the complete multiplicand and that particular multiplier digit are set up in suitable accumulators. As the other multiplier digits are punched in order, the partial products formed by those digits with the multiplicand are added successively to the partial products already standing in the partial product accumulators. After the last digit of the multiplier has been punched the machine automatically combines or assembles the two partial products to form the complete product. This complete product then appears in one of the partial product accumulators, and the machine automatically punches the amount in the product field of the card. If desired, the machine may be arranged to require a manual operation by the operator to initiate the product-punching operation, thus giving him an opportunity to inspect the product before punching it. It may happen also that the product is to appear in a non-adjacent field on the card, and that other data may be punched in fields between the multiplier and product fields. Such a condition is met by the non-automatic manually initiated product-punching operation. Under non-automatic conditions the product stands in its accumulator until the operator presses the product key, whereupon the machine goes ahead and punches the product in the card.

Although this specification discloses means for punching a permanent record of each transaction, it should be understood that the broad features of this invention may be carried out by any suit-

able device which has keys or equivalent means for initiating the operations.

For purpose of illustration the present specification uses the number 8734 as the multiplicand and 923 as the multiplier, the product being 8061482.

The method used by the machine in solving the above problem may be understood from the schematic diagram in Fig. 29. In this diagram the record card **50** has a multiplicand field **52**, a multiplier field **54**, and a product field **56**. These fields may be adjacent or non-adjacent each other. The remaining spaces on the card may be used for any other statistical data.

When the multiplicand 8734 is punched in field **52**, the same number is set up in the multiplicand register. Nothing appears in the partial product counters or accumulators.

When the first digit of the multiplier, "9", is punched in field **54**, "9" appears in its appropriate position in the multiplier register, and the partial products of 8734 times "9" appear in the first and second partial product accumulator or counter, all as shown in step II of the diagram. For brevity of description the first and second partial product accumulators will be referred to henceforth simply as the first and second counters or accumulators.

In carrying out the above operation the machine multiplies each digit of the multiplicand by "9", securing four minor products: $8\times9=72$; $7\times9=63$; $3\times9=27$; and $4\times9=36$. The first digits of those minor products are entered in appropriate columns in the first counter and the second digits are entered in the second counter but stepped one space to the right, all as shown in the section of the diagram marked II.

When "2", the second digit of the multiplier, is punched in field **54**, it appears in its appropriate location in the multiplier register and the partial products of "2" times the multiplicand digits are entered in the partial product accumulators, one space to the right of the partial products already in those counters. The newly entered partial products are added to the previously entered partial products, with the result that 77330 appears in the first counter and 30228 in the second counter, all as indicated in section III of the diagram.

When "3", the third and last digit of the multiplier, is punched in field **54**, it appears in its appropriate location in the multiplier register and the partial products of 3 times the multiplicand digits are entered in the partial product accumulators, one space to the right of the partial products already in those counters. The newly entered partial products are added to the previously entered partial products, with the result that 775501 appears in the first counter and 306472 in the second counter, all as indicated in section IV of the diagram.

After the final digit "3" of the multiplier has been entered as indicated in section IV, the machine combines the partial products standing in the two counters and shows the true product 8061482 in the second counter as in section V. This product is then punched by the machine in product field **56** of the card, the product-punching operation being initiated either manually by the operator, or automatically by the machine.

The general arrangement of the various elements of the complete apparatus may be understood from Fig. 1. Extending across the front of the machine is the key punch, which is of a well known type fully described in the patent to F. L. Lee et al. No. 1,772,186, dated August 5, 1930. In the rear of the punching device are placed, in order, the multiplier set-up mechanism, the multiplicand and multiplier registers, the two partial product accumulators, and an assembly of machine control devices. Fig. 1 shows the device after the multiplying operation is completed. The multiplicand and multiplier appear in their respective registers and the finished product appears in the second counter, ready for the operator to initiate the operation of punching the product on the same card in which the multiplican and multiplier are already punched.

The card punching device may be sufficiently understood for present purposes by reference to Figs. 1 to 8 inclusive. With a stack of cards **50** in the magazine, handle **60** is moved to the left by the operator, causing picker **62** to engage the bottom card of the stack and move it to the position shown in Fig. 5 with the first card column underneath the row of twelve punches **64**, and with pusher device **65** in position behind the card. Handle **60** is immediately restored to its position at the right by a restoring spring. Then when the operator depresses one of the punch keys **66** the appropriate interposer bar **68** is moved to the left to a position over the proper punch **64**. Movement of any interposer bar **68** to the left moves bail **70**, which in turn moves bar **72** to the left (Fig. 3) and closes contacts **74**. Closure of contacts **74** energizes punch magnet **76**, causing armature **78** to swing to the right. This movement of armature **78**, through link **80**, bell crank 82, and link **84**, swings actuator **86** downwardly about its pivot **88**. Bar **90** carried by actuator 88 contacts with the top of the interposer bar that was moved to the left, resulting in the punch under that bar being forced through the card at the proper index position to represent the digit corresponding to the depressed key **66**. As soon as a punching operation is completed the escapement mechanism of the punch operates through pusher **65** to advance the card one step to the left so that the next index column will register with the row of punches **64**.

Normally, after armature **78** has been drawn to the right by magnet 76, the armature is immediately restored by spring 92, but in the present invention when the punches are on computing columns it is necessary, as will appear, to prevent immediate restoration of the armature and movement of the card. This is accomplished by magnet **94**, which through its armature **96** and link **98** actuates latch **100** to hold armature **78** to the right until magnet **94** is deenergized and armature **96** is restored by spring **102**. Energization of magnet **94** is timed by the operation of the machine.

Keys **66** may be operated electrically, instead of manually, by means of duplicator magnets **104**, there being one magnet **104** operatively connected to each key **66** by means of armature **106** and lever **108** pivoted at **110**. It will be evident from Fig. 5 that if any magnet **104** be energized its armature, by means of its lever **108**, will draw down a key **66**.

Referring to Fig. 3, arm **112** is a rearward extension of depresser **86**. When **86** is depressed, arm **112** rises and the roller **114** in the end thereof raises bar **72** until it clears its notch in bail **70**, whereupon bar **72** is drawn to the right by spring **116**. The raising of bar **72** breaks contact **118** which is in circuit with magnets **104**, and the movement of **72** to the right opens contact **74**, thereby deenergizing punch magnet **76** and per-

mitting armature 78 and other punch parts to restore as soon as magnet 94 permits.

Depression of any key 66 closes two contacts 120 and 120a individual to that particular key, and contacts 122. This is true of all except the zero key, which has only the 120a contact as the 120 and 122 contacts are not necessary in connection with that digit.

At the right end of the machine are contacts 124 and 126, so arranged that bar 128, which moves in unison with handle 60, closes contact 124 and opens contact 126 whenever handle 60 and bar 128 are at their position to the right (Figs. 3 and 4). Insulating stud 130 serves to interconnect the spring leaves of contacts 124 and 126 so that whenever one contact closes the other opens. When handle 60 is drawn to its left hand position, 126 is closed to energize the reset clutch, and 124 is open to prevent circuits forming therethrough, as will appear when the circuit diagram is discussed.

At the rear of the punching machine, toward the left end thereof, is an insulating plate 140 (Figs. 6, 7 and 30). It may be explained that the view of parts 140 and 150 in Fig. 30 is taken from the back of the showing in Fig. 1 and that the brush 150 traverses from left to right. Set into plate 140 and extending lengthwise of the machine is a metallic strip 142. Parallel with strip 142 is a row of metallic blocks 144, there being one block 144 corresponding to each index column on the record card. Blocks 144 are spaced the same distance apart as the index columns on the cards.

Attached to the card carriage through bar 146 is a bifurcated metallic contact brush 150 (Figs. 6, 7, 30) having one finger constantly in contact with strip 142, and the other finger arranged to contact successively with blocks 144. Whenever card index column number one is under the row of punches 64, brush 150 is in such position that block 144 corresponding to card column number one is electrically connected through member 150 to strip 142. As the card is stepped along by the escapement device bar 146 and brush 150 move accordingly so that whenever any card column is under the punches, the block 144 associated with that column is electrically connected to strip 142. At the bottom of Fig. 30 the above relationship beween card columns and the commutator is shown diagrammatically. The function of that and other contact devices may also be understood from Fig. 30.

However, before considering any circuit diagrams it should be understood that power for the machine is furnished by a motor 160 (Figs. 1, 13, 14 and 30), running continuously while the machine is in operation. The motor is started or stopped by switch 162. Motor pulley 164, by belt 166 and pulley 168, drives shaft 170. Mounted on shaft 170 within the compartment at the right of the second accumulator (Fig. 1) are three one-revolution clutches of a type well known in tabulating machines. Each clutch is controlled by a magnet in such manner that when an impulse is sent through the magnet the clutch causes an appropriate gear to make a single revolution. Referring to Figs. 13 and 14, when magnet 172 is energized it rocks armature lever 174, engaging clutch 176 and causing gear 178 to make one revolution. Gear 178 is in mesh with a similar gear 180 on shaft 187 (Fig. 14) which operates the registers and counters of the machine and which is therefore known as the counter drive shaft.

Below shaft 187 and parallel therewith is a shaft 184, on which is keyed a gear 186 in mesh with gear 180. Gears 180 and 186 are of the same diameter, therefore shaft 184 rotates at the same speed as shaft 187 (Fig. 35).

When magnet 190 is energized it rocks arm 192 to actuate clutch 194 to rotate gear 196 one revolution, which in turn rotates gear 198 and shaft 200 (Fig. 13). This train of mechanism serves to actuate the stepped cams in the first partial product counter to transfer the amount standing therein to the second partial product counter. This mechanism is therefore known as the "reading out" device.

In like manner, energization of magnet 202 actuates reset shaft 206, through clutch 204.

The multiplicand register is in its essential features a well known Hollerith accumulator with transfer devices omitted. Each indicating element 210 is differentially controlled by its magnet 212 through a clutch of the type shown at 214 (Figs. 9, 16). The clutches are on clutch shaft 216. The driven member of each clutch is attached to a gear 218 which through gear 220 actuates an indicating element 210, readable through window 222.

Supported above shaft 216 and parallel thereto is a shaft or rod 224, upon which are mounted for rotation a number of gears 226 of insulating material such as fibre, Bakelite, etc. Each gear 226 is in mesh with a gear 218 on the clutch shaft and therefore turns in harmony therewith. On each side of each gear 226 is a flat stationary non-conducting plate 228 supported on rods 230 attached to the frame of the machine. Set into each gear 226 are two sets of contact brushes 232, four brushes in each set. The sets of brushes are on opposite sides of shaft 224 as indicated in Fig. 9. Each brush extends through gear 226 and is so shaped as to contact with the surface of commutator plates 228 on each side of gear 226, the points of contacts being all on a plane through the center of shaft 224, also as indicated in Fig. 9. When a gear 226 rotates it is evident that the brushes 232 follow circular paths on plates 228.

Set into the faces of plates 228, in the paths of brushes 232, are the arcuate metallic strips 234 and the set of blocks 236, arranged as in Fig. 15. Blocks 236 are in nine radial rows of four each, each row corresponding to a digit from 1 to 9, no contact blocks being necessary for digit "0".

As above described, there is a commutator plate 228 on each side of gear 226. Each plate is provided with contact strips 234 and blocks 236, but whereas in one of the plates 228 the strips are at the bottom of the plate and the blocks at the top thereof, in the other plate of the pair, the strips are at the top and the blocks at the bottom. In other words, the strips of one plate are opposite blocks on the other plate, and whenever one end of a brush 232 is in contact with a contact block 236 on one side of gear 226 the other end of the same brush is in contact with strip 234 on the other side of gear 226 (Figs. 16, 17). When one set of brushes 232 is in contact with the upper set of blocks 236 representing any particular digit, the other set of brushes 232 is on the lower set of blocks representing the same digit.

The above described mechanism is known as the "multiplicand selector".

One set of blocks 236 of the selector is used for setting up the partial product in the first

counter, and the other set is used for setting up the other partial product in the second counter, as will appear.

Gears 218, 220, and 226 are so proportioned that brushes 232 always come to rest on contact blocks 234 representing the same digit that appears on wheel 210 at window 222.

Figs. 26 and 35 show a commutator known as a "key timer". It is also shown diagrammatically in Fig. 30. It comprises contact blocks 254 and contact strip 256 set into the surface of an insulating plate 258. An arm 260, fast on shaft 184, carries on its outer end a bifurcated brush 262 insulated from arm 260 and so placed that as shaft 184 revolves brush 262 establishes electric connection between strip 256 and each block 254 in succession from block representing "9" to block representing "1".

Another commutator known as the "clutch timer" is shown in Fig. 27 and indicated diagrammatically in Fig. 30. It comprises an insulating plate 264 into the surface of which are set two circular contact strips 266 and 268. Strip 266 forms a complete circle, but 268 has two gaps in its circle thereby providing an individual contact block 270, as indicated in Fig. 27. Arm 272, fast on shaft 184, carries at its outer end a bifurcated brush 274. Normal position is shown in the figure, with one finger of brush 274 on strip 266 and the other on block 270. Electric contact is thus formed between 270 and 266, but when arm 272 moves, the circuit is broken until the outer brush makes contact with strip 268. As shown in Fig. 35, there are four clutch timers, one for each multiplicand index column, other like timers being used (not shown in Fig. 35 but shown in Fig. 30) for the multiplier columns.

With the above in mind it is easy to understand what occurs when the card being punched has advanced to place the first column of the multiplicand field 52 under the punches. The multiplicand used for descriptive purposes is 8734. When the operator presses key 66 corresponding to the first digit of the multiplicand, that is, "8", contacts 120, 120*a* and 122 under the "8" key are closed. Contact 120 forms a circuit from left of line through common wire 280, contact 120 at "8" and wire 252 to contact block 254 at the "8" position of the key timer.

Current cannot flow past block 254 until brush 262 moves, as will be explained.

Depression of key 66 as above also closes contact 122 under the "8" key and establishes another circuit as follows: from left of line through wire 280, contact 120, 120*a*, contact 122, common wire 282, armature latch magnet 94, counter clutch magnet 172, wire 284, clutch timer block 270, brush 274, wire 286, plug 288 in plug board 290, wire 292, plug 294, wire 296, block 144, brush 150, strip 142, wire 298, contact 124, and wire 300 to right side of line.

When magnet 172 is energized, shaft 184 begins to revolve, as already explained, carrying with it key timer brush 262 and clutch timer brush 274. When brush 274 leaves block 270, magnet 172 is deenergized, thus assuring that clutch 176 will be disengaged and shaft 187 come to rest at the end of the revolution. Before the circuit is broken by brush 274 a supplemental circuit is formed through a brush 285 in order to keep latch magnet 94 energized until the revolution of shaft 187 is nearly completed. Brush 285 rests on a commutator mounted on shaft 184. This commutator comprises an insulating block 287 and a grounded contact strip 289. Revolution of shaft 184 brings strip 289 into contact with brush 285 before brush 274 leaves contact 270 and holds a circuit through magnet 94 until block 287 again comes under brush 285 near the end of the revolution of shaft 184.

With shaft 184 revolving, brush 262 of the key timer passes over blocks 254 in order from 9 to 1. When the brush reaches the live block, which in this case is the block representing "8", the circuit is completed from wire 252 through block 254 at "8", brush 262, wire 302, common wire 304, left hand register magnet 212, contact strip 268, wire 286, wire 292, wire 296, block 144, brush 150, strip 142 to right of line as before. The energization of magnet 212 through contact block 254 at the "8" position actuates the proper clutch 214 to set up "8" on indicator wheel 210 and to place one set of brushes 232 on the upper set of selector blocks 236 representing "8" and the other set of brushes 232 on the lower set of selector blocks 236 representing "8".

In like manner keys 66 are successively depressed to set up the other multiplicand digits "7", "3" and "4" until finally the complete multiplicand 8734 is set up in the multiplicand register and may be read through window 222 as in Fig. 1.

The setting up of the number on the indicator wheels is primarily for the convenience of the operator, so that he may check his operations as he goes along. The important part of the above described operation, so far as the performance of the multiplying operation by the machine is concerned, is the fact that the multiplicand digits are all set up under brushes 232 for subsequent use the "7", "3", and "4" being set up in the same manner as the "8" described above. This condition is represented diagrammatically in Fig. 31. The diagram at the bottom of the sheet represents the upper set of contacts 236, while the diagram at the top of Fig. 32 represents the lower set of contacts. As will later appear, the lower set is used to obtain the first partial product and the upper set of contacts is used to obtain the second partial product.

For illustrative purposes the number 923 is used as a multiplier. When the punches are standing over the first column of multiplier field 54 and key 66 representing "9" is depressed, a circuit is formed as follows: from left of line through wire 280, contacts 120 and 120*a* at "9", wire 252*a*, wire 310, master relay 312, wire 314, wire 318, resistance 320, switch magnet 316, rotary timer 264*a*, with its brush 274*a* on shaft 184 and having a live spot 270*a* and the remainder insulated, wire 322, plug 324, wire 326, block 144, brush 150, strip 142, wire 298, contact 124 and wire 300 to right of line. Energization of magnet 316 closes switch 328 and establishes and maintains a circuit (for one cycle) through contact 120*a* at "9". At the same time a circuit is closed from wire 280 through contacts 120, 120*a* and 122 through wire 282 to armature latch magnet 94, clutch magnet 172, wire 284, the spot 270 on multiplier clutch timer, through its brush 274, wire 322 and as before to right of line.

Energization of magnet 172 causes shaft 184 to make one revolution and, as explained in the case of the multiplicand sends a timed impulse through brush 262, wire 304, multiplier register magnet 332, wire 336, wire 322 to right of line as before. The multiplier register is similar to the multiplicand register, except that it lacks the selector mechanism mounted on the multiplicand

register. As each multiplier digit is punched the digit is set up on a register wheel so as to be readable at window **222** as in Fig. 1.

Energization of magnet **172** causes shaft **184** to revolve, as previously described, carrying with it brush **274***a* of rotary timer **264***a*. When brush **274***a* leaves block **270***a*, the circuit through resistance **320** and master relay **312** is maintained by contact **328** which is now closed as above described and is shunted around contact **270***a* and brush **274***a*.

The rotary timers **264***a* are provided to prevent the tying together of the wires **322** and **336** during the part of the cycle when picking off the timed impulses to actuate the multiplier register.

Simultaneously with the setting up of the multiplier digits, the multiplying operation is being carried out, as will now be described.

The factor merging device by which the multiplication is effected is fully disclosed in Patent No. 1,850,577, dated March 22, 1932, to which reference may be had for a clearer understanding of the fundamental action of this part of the mechanism. The aforesaid application shows a single denominational device as distinguished from the more complex multidenominational device herein described.

Mounted for rotation on shaft **338** in a compartment at the left end of the machine are two sets of "set-up" discs (Figs. 1, 19, 20, 21, 22, 23, 23A). There are eight discs **341** in one set and nine discs **342** in the other set. Each set-up disc **342** corresponds to a digit from 1 to 9 inclusive. There is no **341** disc corresponding to the "1" digit for a reason which will later appear. Each disc **341** and **342** is provided with a projection **344** (Fig. 19) against which operates the free end of a lever **346**, the other end of which is connected by link **348** to a bell crank **350**, which in turn is connected by a call wire **352** to the armature **354** of a relay **312**.

Each armature **354** is operatively connected as above to two set-up discs, one **341** disc and one **342** disc, both corresponding to the same multiplier digit. That is, if any master relay **312** be energized, its associated armature **354** and the two call wires **352** connected thereto will be drawn to the left (Fig. 19), and two levers **346** will be rocked against ears **344** of two discs, one in the **341** group and one in the **342** group, and those two discs will be rotated counterclockwise about shaft **338**. Both the rotated discs correspond to the same digit, which is a digit of the multiplier. Thus when the multiplier **923** is used and key **66** representing "9" is depressed, the two "9" discs will be rotated; when the "2" key is depressed both "2" discs will turn, and when key "3" is depressed both "3" discs will take new positions.

Each disc of the **341** group is provided with a plurality of projections or teeth **360** (Fig. 19) located on the rim of the disc as shown in diagram Fig. 23. Each disc of the **342** group is provided likewise with projections **360** as in diagram Fig. 23A.

When any **341** disc is rotated as above, every tooth **360** on that disc moves a bail **361**, and likewise whenever a disc **342** is rotated every tooth on it moves a bail **362**. Bails **361** and **362** are pivoted about the circumference of the discs on pivots **364** (Figs. 19 and 20). Each bail **361** is in position to close a contact **371**, and each **362** is in position to close a contact **372**.

Contacts **371** and **372** are arranged in groups of four, each corresponding to one of the positions of the code shown in Fig. 34, in which the combination "*b*" and "*d*" represents "1"; "*a*" alone represents "2"; "*a*" and "*c*" represent "3", and so on.

Careful inspection of Figs. 23 and 23A will show that when discs **341** and **342** representing any particular digit are moved upwardly (counterclockwise in Fig. 19) those discs set up combinations of contacts **371** and **372** representing every possible product of that digit by all digits from 1 to 9 inclusive, the right hand component of the product being set up in contacts **372** (Fig. 23A) and the left hand component being in contacts **371** (Fig. 23). For instance, if the "9" discs be moved upwardly, teeth **360** close contacts **372** at "*b*" and "*d*" positions in the nine group, meaning "1", while teeth **360** close contact **371** at "*d*", meaning "8", thus indicating that the product of "9" times "9" is 81. Likewise 9 times 8 is shown to be 72 by the closure of **371** contacts "*a*" and "*b*" in the "8" set, and **372** contact at "*a*" in the "8" set. "9" times "1" is indicated by the closure of contacts "*c*" and "*d*" in the upper group in Fig. 23A, thus indicating a product "9". As there is no left hand component to that product no contacts are closed in the **371** group.

Discs **341** and **342** represent the multiplier digit. Each group of four contacts **371** represents the left hand digit of a product, and each group of contacts **372** represents the right hand digit of a product. When the multiplicand digit is "1" there is never any left hand component of the product, and therefore no need for the upper group of **371** contacts, which may therefore be omitted if desired. Likewise, when the multiplier digit is "1" there is never any left hand component and the "1" disc **341** may be omitted, which accounts for the fact that only eight discs are shown in the **341** group.

Diagrams (Figs. 31 and 32) show the status of the multiplying process at this point at the machine operation. Here are found diagrammatically represented the contacts above described, at the instant all the digits of the multiplicand, **8734**, are being multiplied by the first digit "**9**" of the multiplier. At the left of the diagrams are found the complete sets of **371** and **372** contacts in the positions to which they have been shifted by the rocking of the "9" discs **341** and **342**. In these positions every possible right hand component of the product of 9 times all digits has been set up in code form by contacts **372**, and every possible left hand component of those products has been set up by contacts **371**. It only remains for the machine to select the proper components and transmit them to the partial products counters.

It will be remembered that the selectors on the multiplicand register have their brushes **232** standing on the upper and lower sets of **236** contacts representing in order 8, 7, 3 and 4. This condition is shown in the diagrams in which on the first set of **236** and **234** contacts, brushes **232** are at the "8" position in both upper and lower sections of the diagram; the second set of brushes is at the "7" position; the third set at "3" and the fourth set at "4", corresponding to the multiplicand digits placed at the top of the diagram. The circuits may now be traced. In the upper diagram current flows from left of line through wire **380**, contact **372** at "*a*" position in contact group designated "8", contact block **236**, brush **232**, contact strip **234**, magnet **382** of translator "AA'", and wire **384** to right of line. This sets up "2", the right hand component of "72" in the "'" translator, as will appear. That particular circuit, representing digit "2", is the only closed

circuit obtained by the combination of the "8" multiplicand digit and a "9" multiplier digit. In the second section of the upper diagram the only closed circuits may readily be traced from wire **380** through the two closed contacts **372** at "7" position, through translators A' and C', thus setting up "3" as the right hand component of the product of 9 times 7. In like manner circuits may be traced through the third and fourth positions of the upper diagram to set up "7" and "6" as the right hand components of the products of 9 times 3 and 9 times 4 respectively.

In the lower diagram, in similar manner, circuits may be traced to energize magnets **382** of four sets of translators A, B, C and D, and set up the left hand components 7, 6, 2 and 3 of the above products.

Whenever a multiplier digit key **66** is pressed, the components of the products of that digit by all multiplicand digits are instantly set up as above described and transmitted to the partial product counters through the selector, all left hand components going to the first counter and all right hand components to the second counter.

The setting up of the partial products resulting from depression of the "9" multiplier key has been described. When the "2" and "3" keys are depressed the components resulting from this multiplication with the multiplicand digits will be added to the partial products in the counters.

The operation has been followed in detail as far as the translators, which will now be briefly described. They will be found fully described in my Patent No. 1,880,409, dated October 4, 1932.

Each translator comprises two rotating commutators and four magnets, each of which magnets controls a shiftable brush. Each commutator is designated **390** and the magnet **382** and the shiftable brush **392**. The commutators are driven by a train of gears from shaft **187** as shown in Fig. 9. Each translator is arranged substantially as shown in perspective in Figs. 24 and 25. Each magnet **382** has a pivoted armature **394** which in its normal position (Fig. 24) acts as a stop for the lower end **396** of brush lever **398** upon the other end of which is carried brush **392**. Lever **398** is pivoted at **400**, the lower end of the lever being urged toward armature **394** by spring **402**. It will be noted (Figs. 24 and 25) that brush **392** is positioned to bear on the commutator in one of two circumferential grooves **404**. In the bottoms of the grooves are rows of contacts **406**, interconnected by wires **408** as indicated in the diagrammatic development of the commutator in Fig. 28. For clarity of illustration, only one brush is shown in Figs. 24 and 25, but in reality there are two brushes **392** and independent control device therefor as indicated in Fig. 28. When any magnet **382** is energized its armature **394** is drawn to a position to release end **396** of brush lever **398**, permitting the lever to rock about its pivot **400** and cause brush **392** to traverse the next adjoining groove from its normal groove. Fig. 24 shows normal position, and Fig. 25 shows shifted position of the parts. It will be noticed that normal position of the brush is in the second groove from the left, while its shifted position is in the first groove from the left. Energization of magnets **382** is so timed that shifting of brushes takes place while the brushes are in the cut-away portion **410** of the commutator surface. Restoration of brushes **382** and armatures **394** is brought about by levers **412** actuated by cams **414** (Fig. 9) on the sides of the commutator gears.

The purpose of the translators above described is to transform the combinational representations of the partial products into single timed impulses suitable for actuating the accumulators. How this is accomplished may be understood from diagram Fig. 28. As explained, the "9" disc **342** has closed contact **372** at "*a*" position, meaning "2", while "9" disc **341** has closed contacts "*a*" and "*b*," meansing "7". It is now desired to send a timed impulse meaning "7" to the first counter and a times impulse meaning "2" to the second counter.

Commutators **390** rotate, in the direction indicated by the arrows, in synchronism with the counter drive shaft so that the commutator digit positions pass brushes **398** just as the index positions of a card pass the analyzing brushes in the familiar Hollerith tabulating machine, and if a circuit is momentarily formed through the brush at any digit position, that digit is entered into the accumulator. With brushes **392** in normal positions as represented by full lines of Fig. 28 no circuit can be completed through any of them. However, when one or more brushes are shifted in accordance with the code a circuit is completed. For instance when magnet A' is energized as explained, its brush **392** is shifted downwardly to dotted line position to traverse a different row of contacts **406**, and when the commutator rotates a circuit is formed from line through wire **420** (dotted), brush **392** at B', lower and upper contacts **406** at "2", brush **392** at A', wire **422**, brush **392** at C', upper and lower contacts **406** at "2", brush **392** at D', and wire **424** to other side of line. Formation of this circuit sends a timed impulse meaning "2" to add "2" in the proper column of the second partial products counter. No other circuit is closed except "2".

In like manner, shifting of brushes **392** at A and B to dotted positions will send a "7" impulse (and only a "7" impulse) to the first counter.

Simultaneously with the above described operation the other digits representing the complete product of 8734 by "9" are being entered through their respective translators in proper columns of the first and second accumulators as indicated in section II of Fig. 29.

At this point the machine has completed the operation of multiplying the complete multiplicand by the first digit of the multiplier and has entered the result in the partial product counters. The above entering operation is completed in substantially the time required to depress the punch key **66**.

In exactly the same manner is the multiplicand multiplied by the other digits of the multiplier, first by "2" and then by "3".

It will be noted in Fig. 29 that the partial products obtained by each successive digit of the multiplier must be set successively one column further to the right in the accumulators. This is brought about automatically as follows. Between the translators and the counters are magnetically controlled contacts as indicated diagrammatically in Figs. 32 and 33. With contacts in normal position as shown, the impulses from the four translators **390** will flow through wires **430**, switch blades **431**, contacts **432**, blades **433** to the four highest order coils **436** of the counter corresponding to the four columns used in section II of Fig. 29. It will be understood that the four highest order coils **436** are the four coils which are disposed in the relatively lowermost positions on Fig. 32.

When key **66** is depressed to enter the second

digit of the multiplier, magnet 440 (Fig. 30) is energized. This magnet is operatively connected as indicated in Figs. 32 and 33, to all switch blades 431 and, when energized, raises blades 431 to close contacts 442 and consequently the impulses sent to the counters as a result of the multiplication of the multiplicand by the second multiplier digit will pass from translators 390 through wires 430, blades 431, contacts 442, blades 433, contacts 434, the impulse from each translator passing to the next lower order counter magnet 436 than before, thus entering the digits one column further to the right, as indicated in section III of Fig. 29.

When the third multiplier digit key is depressed, current flows through coil 450 in series with coil 440 (Fig. 30) with the result that all blades 433 are raised as well as blades 431 and the impulses from translators flow through wires 430, contacts 442, blades 433, and contacts 452 to a set of four magnets 436 one order lower than before, so that the third partial products are entered one column further to the right as indicated in section IV of Fig. 29.

This step marks the completion of the operation of multiplying 8734 by 923 and the entering of the partial products into their respective counters. The next step in the operation is to combine the partial products by reading into the second counter the amount standing in the first counter whereby the finished product may be obtained in the second counter.

The first counter (Figs. 1 and 10) is in every way a regular Hollerith type accumulator, with stepped reading out cams 464 and their associated contact devices 466. In regular tabulating machines the stepped cams and contact devices are used for controlling mechanism to print the amount standing on the accumulator. For this purpose they may be found fully described in the patents to C. D. Lake, No. 1,822,594, dated September 8, 1931 and Reissue Patent No. 16,304. In the present machine the reading out devices of the first counter are used for transmitting to the second counter the amount in the first counter so that the two partial products may be added together to produce the finished product. To bring about that result each contact device 466 is wired to the appropriate magnet circuit of the second counter as shown diagrammatically in Fig. 33.

Operation of the above reading-out mechanism occurs automatically after the last digit of the multiplier has been punched and its multiplying cycle has been completed, but before the escapement device has moved brush 150 from its position corresponding to the last multiplier digit. This control is brought about by the control of magnet 94 and punching armature 78 as previously described. Referring to Fig. 30, cam 470 is provided and arranged to break contacts 472 and make contacts 474. Cam 480 is adapted to make contacts 478. The cams are so timed that 470 opens contacts 472 just at or after the end of the entering operation upon a computing cycle and immediately afterward contacts 478 are closed by cam 480. The contacts 472 are timed so as not to open up until after current has been permitted to flow to magnet 450 through the holding relay 316b. Accordingly, upon a computing and entering cycle, contacts 472 do not open until the complete entry is made. Further cam 470 after every multiplying cycle has been initiated, breaks contact 472 and then makes contact 474. Current flows through contact 472 only when the last multiplier key is depressed and while brush 150 is in position to permit current to flow from block 144 to strip 142 at the last multiplier column. With brush 150 in that position and contact 474 closed, current flows from left of line through wire 476, total clutch magnet 190, contact 478 (closed by cam 480), contact 474, wire 482, wire 326, block 144, brush 150, strip 142, wire 298, contact 124 and wire 300 to right of line. The energization of magnet 190 engages clutch 194 (Figs. 13 and 14) and through a train of gears turns shaft 484 and cam 486 one revolution. During this revolution cam 486 rocks bell crank 488, which in turn moves arm 490 to rock shaft 492 (Figs. 10 and 11) to actuate contacts 466 and send the proper timed impulses to the second counter and thereby set up the finished total in that counter as indicated in section V of Fig. 29.

When magnet 190 is energized to actuate the reading-out device lever 192 (Fig. 14) is drawn down by magnet 190. A plate 494 on the end of lever 192 engages a similar plate 496 on the end of clutch lever 174 and actuates lever 174 to engage the counter clutch 176. This means that clutches 194 and 176 are so interlocked that the reading-out device cannot be actuated without the counter shaft being in motion, which is necessary in order that the second counter may operate to accumulate the amount being read into it.

The machine now stands as in Fig. 1, with the multiplicand and multiplier standing on their registers, and the product standing on the second counter where it may be read on elements 496 through window 498. The next and only remaining step is to punch that product in the product field 56 of the card.

The second counter is shown in Fig. 12. It is a regular Hollerith type accumulator except that the usual reading-out devices in the upper part of the structure have been replaced by a product commutator comprises a stationary insulating plate 500 (Fig. 18) corresponding to each element of the accumulator. Each plate 500 has set into its surface circumferentially spaced contacts 502, and an arcuate contact strip 504. Beside each plate 500 is a gear 506 free to rotate on shaft 508. Mounted on the side of each gear 506 and insulated therefrom is a bifurcated brush 510, one finger of the brush being arranged to traverse blocks 502 and the other to contact with strip 504. Each gear 506 is driven in timed relationship with and by its corresponding accumulator element so that brush 510 always stands on contact block 502 representing the same digit as is displayed by the accumulator element.

The product commutator is shown diagrammatically at the top of Fig. 31 with brushes 510 in position to read the product 8061482. Each column of the product field 56 is connected by a wire 512 to a contact strip 504 corresponding to that column. Wire 512 corresponding to the first column of the product field is provided with normally open contact 516 which may be closed by depression of the product key 518, or may be permanently closed by switch 520.

When the first card column of the product field 56 is moved by the escapement device, either due to the operation of a spacing key or due to the operation of punch keys for placing numerical data on the card or as a result of the entry of the last digit of the second factor, to a position under punches 64, if contact 516 and switch 520 are open, the machine stops. If key 518 be

depressed the first digit of the product will be punched and the machine will automatically punch the other digits of the product in succeeding columns of the product field. If switch 520 be closed when the first product column is reached the punching of the product proceeds without any manual operation being required. That is, if the product field 56 is adjacent the multiplier field, when the last multiplier key has been punched the escapement device moves the card along so the first product column is under the brushes, and if switch 520 be closed the punching of the product proceeds automatically. If switch 520 be open the machine stops, and starts again when key 518 is depressed.

The paths of the product circuits may be followed from the diagrams at the bottom of Fig. 30 and top of Fig. 31. At the first product position a circuit is formed from left of line through contact 118, common line 522, duplicator magnet 104 at "8" position, block 502, brush 510, strip 504, contact 516 (or switch 502), wire 526, wire 528 at plug board, block 144 at first column of field 56, brush 150, strip 142, contact 124 to right of line. Energization of duplicator magnet 104 at "8" depresses the "8" punch key and perforates the first product index column 56 at position "8". The card is moved automatically step by step to the other product columns and circuits are closed by brush 150 successively through blocks 502, brushes 510, to energize the proper duplicator magnet 104 at each card column. At all product columns except the first, current flows direct from strip 504 through wire 512 to the plug board without passing through any switch or contact.

Completion of the above punching operation leaves the card as shown at section V of Fig. 29 with multiplicand, multiplier, and product punched in their respective fields.

Closing of reset contact 126 by moving handle 60 to its extreme left hand position in the manner previously described energizes reset clutch magnet 202 to engage reset clutch 204, whereby reset shaft 206 (Figs. 1, 13, 14, 33) is rotated one revolution to restore all registers and counters to zero in well known manner. Contact 530 is opened by the machine when the reset clutch is engaged by means of a member 531 (see Fig. 14) which is displaced by the rocking of the armature of the reset magnet 202, thereby preventing the re-energization of reset magnet 202, which would cause more than one revolution of reset shaft 206. Contacts 530 reclose upon the return of the armature of the reset magnet toward the end of the revolution of the one revolution clutch, at which time contacts 126 will have been opened by the return of the handle 60 to the right.

In the machine described the reset of all registers and accumulators is effected simultaneously. The machine is thus shown for simplicity of illustration. It is of course obvious that, by using the selective counter or register reset clutch devices well known in the tabulator art, such as those shown in Lake Reissue Patent No. 16,304, any of the factors or the products may be retained in the machine. Thus if the multiplicand register was not reset it would be unnecessary to again enter that amount upon subsequent computations, and a number of computations using different multipliers with the same multiplicand could be carried out. Such repeated multiplicand would not then appear upon subsequent record cards. If the product counter is not reset all products computed upon the machine will be accumulated therein, and such total may be punched or read at will.

In the illustrative example used above, the numbers each had exactly the proper number of digits to exactly fill the fields on the card devoted to multiplicand, multiplier, and product. In case the multiplicand or multiplier do not have enough digits to fill their respective fields 52 and 54, the operator simply manipulates punch keys 66 so that the significant digits are at the right of their fields and the column to the left of the significant figures are punched with zeros. Likewise, when the machine punches the product in the card the space to the left of the significant figures is filled with zeros.

Certain features of the present invention are shown, but not claimed in Patent No. 1,850,577 issued March 22, 1932.

I claim:

1. A multiplying machine with means for setting up the multiplicand, means for setting up the multiplier, and inter-relating devices for forming partial products and comprising in combination means in said inter-relating devices for setting up the digits of the partial products by combinational representations, each set of which are less in number than the number of digits which may be represented thereby, and means for analyzing said combinations and entering the partial products corresponding thereto into accumulating means.

2. A multiplying machine with means for entering the multiplicand, means for entering the multiplier and inter-relating devices for forming partial products and comprising in combination means in said inter-relating devices for setting up the digits of the partial products by combinational representations, each set of which are less than the number of digits which may be represented thereby, accumulating means of dual form, means for analyzing said combination and entering the partial products corresponding thereto into the dual accumulating means, said means entering both components of the partial products into the dual accumulating means in one machine cycle, and means operative in another machine cycle for subsequently gathering together the previously secured separate accumulation of the components in one section of the dual accumulating means.

3. A multiplying machine with a product forming means which receives the two factors of a multiplication, one of which may be of multi-denominational form, and comprising in combination means for receiving the factors as whole numbers, and means for converting the factors into combinational representatons and into products, said last mentioned means having provisions for concurrently setting up a plurality of combinational representations which are representative of the partial products of all of the digits of the factor which is in multi-denominational form times one of the digits of the other factor.

4. A multiplying machine with a product forming means, means for entering thereinto the two factors of a computation, means in said machine for receiving and retaining one multi-denominational factor, and means for merging said multi-denominational factor with one of the denominational digits of the other factor, said means comprising devices having multiplication table characteristics, said devices including devices controlled by the means which receives the multi-

denominational factor and by the other factor entry means which are adapted to form combinational representations of the partial products.

5. A multiplying machine with a product forming means, means for entering thereinto the two factors of a computation, means in said machine for receiving and retaining one multi-denominational factor, and means for merging said factor with another multi-denominational factor, said means comprising devices for successively merging the digits of the second multi-denominational factor with all of digits of the first multi-denominational factor, said last mentioned means including devices upon which are set up combinational representations in succession of each partial product of all the digits of the first factor with each of the digits of the second factor.

6. A multiplying machine with a ten key form of factor-entering means for both factors, selecting means for determining which of the two factors is to be entered into the machine upon the operation of the common ten key means, means for combining the factors successively into partial products as the second factors are entered, said means including devices for forming combinational representations of the partial product amounts, means converting the combinational representations back to single representations of whole numbers accumulating means, and means for entering the whole numbers into the accumulating means.

7. The invention set forth in claim 6, in which the accumulating means separately accumulates the partial products and in which means is provided for reading out one of the separate accumulations of the partial products and combining the same with the other accumulation to form the complete product.

8. The invention set forth in claim 6, in which the accumulating means separately accumulates the partial products and in which means is provided for automatically reading out one accumulation of one set of the separate partial products upon the completion of the entry of the second factor of the computation and for combining the same with the other set to form the complete product.

9. The invention set forth in claim 6, in which the accumulating means separately accumulates the partial products and in which means is provided for reading out one of the separate accumulations of the partial products and combining the same with the other accumulation in the other accumulator to form the complete product, and in which means is provided for again reading out the complete product from the accumulator in which both sets of accumulations are gathered together.

10. The invention set forth in claim 6 in which the accumulating means separately accumulates the partial products and in which means is provided for reading out one of the separate accumulation of the partial products, and combining the same with the accumulation to form the complete product, and in which means is provided, automatically called into action upon the completion of the combining of the separate accumulations for reading out the complete product.

11. A multiplying machine having a product forming device which includes a plurality of combinational set-up devices which are capable of setting combinational representations of the products of all of the digits of one of the factors of multi-denominational form times one of the digits of the other factor, and means controlled by the first mentioned factor to be multiplied for selecting the combination representing the product, the aforesaid combinational set-up devices being in sets each set being capable of representing more digits than there are elements in the set.

12. A multiplying machine having means for forming partial products of the factors to be multiplied, said means comprising in combination, set-up means for setting up a combinational representation of the digits of the partial products, means cooperating with the set-up means for analyzing said combinations, and means controlled by said last mentioned means for entering the partial products so represented and set up into accumulating means.

13. A multiplying machine having means for forming components of partial products of the factors to be multiplied, in combination with dual accumulating means operating conjointly in a single machine cycle for accumulating the components of said partial products, and means for transferring the accumulation of one set of components from one accumulating means to the other to obtain the complete product of the factors.

14. A multiplying machine having a product forming means which includes a plurality of combinational set-up devices, each set of said devices including means for representing a digit by a combinational set-up of elements which are less in number than the digits which may be represented thereby, and means for setting up upon said devices representations of the products of all of the digits of one factor of multi-denominational character times one of the digits of the other factor.

15. A multiplying machine with product forming devices, and including in combination therewith, two accumulators for separately accumulating the components of the partial products and one of said accumulators being adapted to accumulate together in one accumulation the aforesaid accumulations of components, and entering means of the ten key type for entering both factors of the to be performed computation into the product forming devices.

16. A combined card punching and multiplying machine comprising multiplying devices of the electromagnetically controlled partial products type and punching devices, means for concurrently effecting punching of card records by the punching device with the factors of a computation and for entering said factors into the aforesaid multiplying devices under electromagnetic control.

17. A machine of the class described including multiplying devices, product receiving means and punching devices, said punching devices comprising a set of punches, a manual means and a supplemental means for actuating the same for punching records, means controlled by the aforesaid manual means for entering both the factors of a computation into the multiplying devices as both said factors are punched by the punching devices, and means for controlling the aforesaid supplementary means by the product receiving means for punching the product formed in the product receiving means upon a record.

18. The invention set forth in claim 17 in which the manual means controls means to successively enter the digits of the various denominational orders of the factors into the multiplying devices and effect successive denominational order

punching of both of the factors, and in which means are provided to control the supplemental means so that it successively receives and causes punching of the various denominational orders of the result or product.

19. A machine of the class described including in combination, a multiplying device and a punching device, means for successively entering multi-denominational factors into the multiplying device, and means associated with the aforesaid means for successively controlling the punching device to cause successive digital punching of both multi-denominational factors on a record.

20. A multiplying machine with means for entering therein the multiplicand and the multiplier, and interrelating devices for forming partial products of said multiplicand and multiplier and including in combination accumulating means for concurrently accumulating in one machine and accumulating cycle and in two separate accumulators the left hand and right hand components of the partial products formed by the aforesaid interrelating devices, and means for subsequently gathering together into one of the two separate accumulators both accumulations of components.

21. The invention set forth in claim 20 in which the last mentioned means for gathering together the component accumulations gathers the same with one accumulation in tens relation to the other accumulation.

22. A multiplying machine with means for entering the two factors of a computation into the machine and for controlling the operation of the machine in accordance with such entries, means controlled by the aforesaid means for combining the factors to form partial products, dual accumulating means for separately accumulating right and left hand components of the partial products as combined by the foregoing means, and means for gathering together the separate accumulations and for forming a final product in one of the said accumualtors.

23. A punching machine with punching devices for making perforated records, a multiplying attachment for said punching machine, said attachment including means to receive the factors of a computation as they are punched by the perforating devices of the punching machine, means in the multiplying attachment controlled in accordance with entered factors for forming and setting up a product, and means controlled by the portion of the aforesaid means which sets up the product to deliver back said product to be punched by the perforating devices of the punching machine.

24. A machine of the class described including in combination, a punching machine having keys for controlling the making of perforated records, a multiplying machine of the partial products type for multiplying the factors of a to be performed computation, said punching machine having punch selectors therein controlled by the keys thereof, and means controlled by said selectors for entering the factors into the partial products type of multiplying machine as they are punched by the punching machine.

25. A combined punching and multiplying machine, with punching means and multiplying means, said multiplying machine including means for receiving both of the factors as they are punched by the punching means, means under control of the aforesaid last mentioned means for automatically effecting multiplication of the factors by the multiplying machine as punching proceeds upon the entry and punching of the record factor, means for setting up the product, and means controlled by said set up means for delivering back the product from the multiplying machine to the punching machine and for effecting product punching operations by the punching machine.

26. A multiplying machine with a set of ten keys for entering both factors for computation thereinto, electrically controlled product forming devices controlled by the successive action of said ten keys in entering the second factor after the first factor of the computation has been entered by the operation of said keys for forming partial products, means for separately accumulating the partial products under the control of the aforesaid devices, and means for thereafter gathering together in one accumulator the accumulation of partial products from the other accumulator to obtain the whole product.

27. A multiplying machine including a pair of accumulators, means for forming right and left hand components of partial products concurrently and for entering the left hand components into one accumulator and concurrently therewith entering the right hand components into the other accumulator, and means cooperating with aforesaid accumulators for entering the reading of one accumulator into the other accumulator to form the complete product.

28. A term merging device for a computing machine including combinational set-up devices which are controlled in accordance with an entered term of the to be performed computation to set up by combinational representations a plurality of computations based upon said term, and means controlled by the entering of the other term of the computation for selecting that combinational representation of the computation which defines the merged result of both terms.

29. A computing device with means for entering two terms of a to be performed computation therein, said means including the devices for entering each and both of the entered terms directly as true numbers, calculating means for solving equations involving said terms and for giving the third term of the equation, said means including a term merging means which includes a combinational set-up device upon which a converted translated merged representation of said terms is set up to show the third term of the equation by a combinational representation thereof.

30. A term merging calculating device for computing machines adapted to be controlled in accordance with two terms which when merged by the computation give a multi-denominational result, said devices including combinational set-up means for setting up by combinational representations all of the digits which are possible in both denominational components of the result.

31. The invention set forth in claim 30 in which the setting of the denominational components is effective by means which forms both component set-ups simultaneously.

32. The invention set forth in claim 30 in which means is provided for selecting from the combinational set-ups the particular terms which represent the merging of the two terms.

33. In a computing machine having a combination means for entering separately thereinto the numerical terms of a to be performed computation, calculating means for merging a plurality of numerical terms into a new computative result, said last mentioned means including de-

vices for first forming a plurality of computative results and for thereafter selecting out from said plurality of results a single computative result, said last mentioned merging means including means for representing the merged result in combinational form by a set-up of elements which are less in number than the highest possible digital value of the result.

34. A computing machine with a plurality of combinational set-up devices adapted when set up to represent a numerical table by combinational representations of each numerical term of said table, means controlled by the entry of one of the numerical terms of the computation into the machine for setting up said devices to form said table, and means controlled by the entry of the other term of the computation into the machine for selecting which set or sets of devices as set by the aforesaid setting means is or are to be effective for controlling the operation of the machine in giving forth the result.

35. A computing machine with means for effecting mergers of numerical terms entered therein which comprises a plurality of sets of devices, each set adapted to be set up in a combinational way to represent a numerical term by a combinational representation thereof, means for setting up a plurality of said sets of devices to represent a numerical table by a plurality of combinational representations thereof, and means for selecting which of the settable devices are to be effective for giving forth a particular result.

36. A computing machine with a plurality of sets of controlling devices therein variously settable to represent numerical tables by their combinational settings, means for effecting a setting of a multiplicity of sets of said devices to form the desired table, said means effecting a set-up of each set of devices in a combinational way, and means for selecting the set or sets of devices which are to be effective for controlling the operation of the machine.

37. A computing machine with controlling devices therein, comprising elements variously settable to denote by their settings representations of arithmetical tables of computation, and means for setting said elements in combinational set-ups to form combinational representations of the individual numerical values of the table which are to be represented.

38. A computing machine including in combination, a plurality of combinational set-up devices, each set comprising a plurality of elements which are less in total number than the highest possible digital value which may be represented thereby, means for setting up a plurality of said sets in accordance with arithmetical tables and to represent the values of the tables by combinational settings of said elements, and means for selecting certain of said sets so set up for a controlling operation to give forth a result.

39. A combined card punching and multiplying machine, including manually actuated means for successively entering the factors of a to be performed computation into the multiplying machine and for punching the said factors upon a record card, means for multiplying the factors and creating left and right hand components of partial products of such factors, means for separately accumulating the components of partial products, means initiated automatically upon the manual punching and entering of the last term of the last factor for accumulating in one accumulator with the components already accumulated therein the accumulation of components from the other accumulator, and means which is automatically called into action when the components have been gathered together and accumulated in one accumulator for transferring the whole product back to the punching machine.

40. The combination of an higher-order-digit product register, a lower-order-digit product register, and means for simultaneously determining a plurality of partial products and simultaneously passing the higher and lower order digits thereof to the respective product registers.

41. In a computing system, a plurality of accumulators for accumulating component parts of sub-products, and means for controlling the operation of the accumulators including means for automatically transferring the accumulated component parts of a product from one accumulator to the other at the end of a computation to cause the receiving accumulator to indicate the final result of the computation.

42. A multiplying machine with means for entering therein two factors of a computation, means for combining the factors into partial products, component means separately accumulating the partial product components, and means for accumulating together the separate accumulations, said last mentioned accumulating means being called into action automatically upon the entry of the last digit of the second entered factor.

43. A punching mechanism for making perforated records including keys for controlling punching operations and having in combination therewith a multiplying attachment with receiving means controlled by the aforesaid keys and adapted to receive factors of a computation as they are punched, and means therein to form a product and to deliver back to the punching machine said product to be punched thereby.

44. In an electrical computing system, means for setting up a multiplicand and a multiplier, multiplying means associated with the setting up means, a tens accumulator, a units accumulator, means for distributing electrical currents from the multiplying means to the accumulators to effect their operation, means for advancing said distributing means after the completion of the multiplication of one digit of the multiplier with all the digits of the multiplicand, and means operable after the completion of the multiplication of all of the digits of the multiplier by all of the digits of the multiplicand for transferring a total from one accumulator to the other.

45. In a machine of the class described, including a multiplying means of the partial products type having an accumulator which ultimately gathers together a summation of partial products and a punching device of the successive column by column type, and means for controlling the actuation of the punching device from the aforesaid accumulator of the multiplying means to punch a card record of the complete product formed by the multiplying means, said last mentioned means comprising devices for successively controlling the punching device from different orders of the accumulator order by order to cause successive digit punching of a multi-denominational result by the punching device.

JAMES W. BRYCE.

CERTIFICATE OF CORRECTION.

Patent No. 2,178,950. November 7, 1939.

JAMES W. BRYCE.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 6, second column, line 72, for "AA'" read "A'"; page 8, second column, line 43, for the word "comprises" read comprising; page 10, first column, line 22, claim 6, after "means" second occurrence, insert cooperating with the aforesaid means; 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 19th day of December, A. D. 1939.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.