May 27, 1952 H. T. AVERY 2,598,095
PARTIAL PRODUCT MULTIPLYING MACHINE
Original Filed Oct. 16, 1943 13 Sheets-Sheet 1

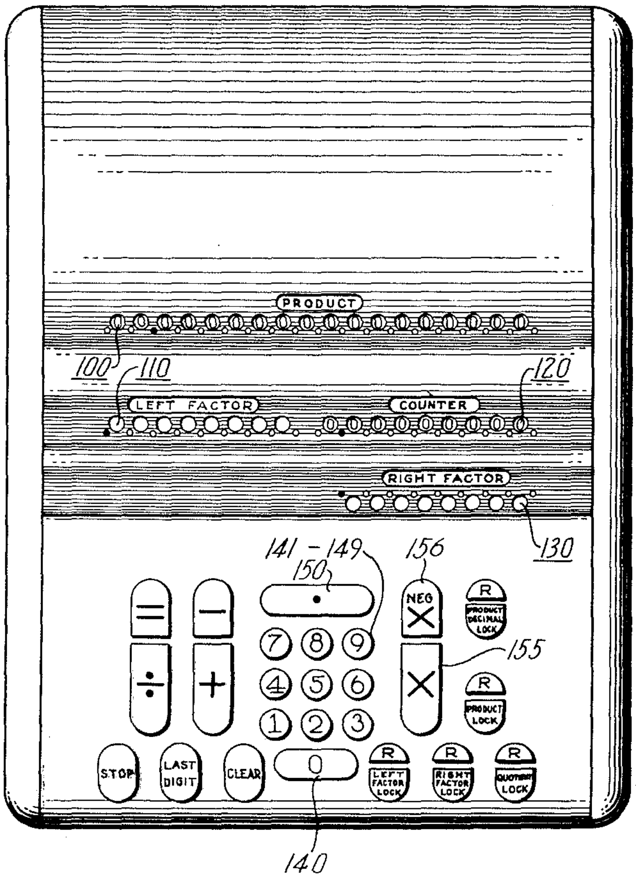

FIG. 1

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PARTIAL PRODUCT MULTIPLYING MACHINE

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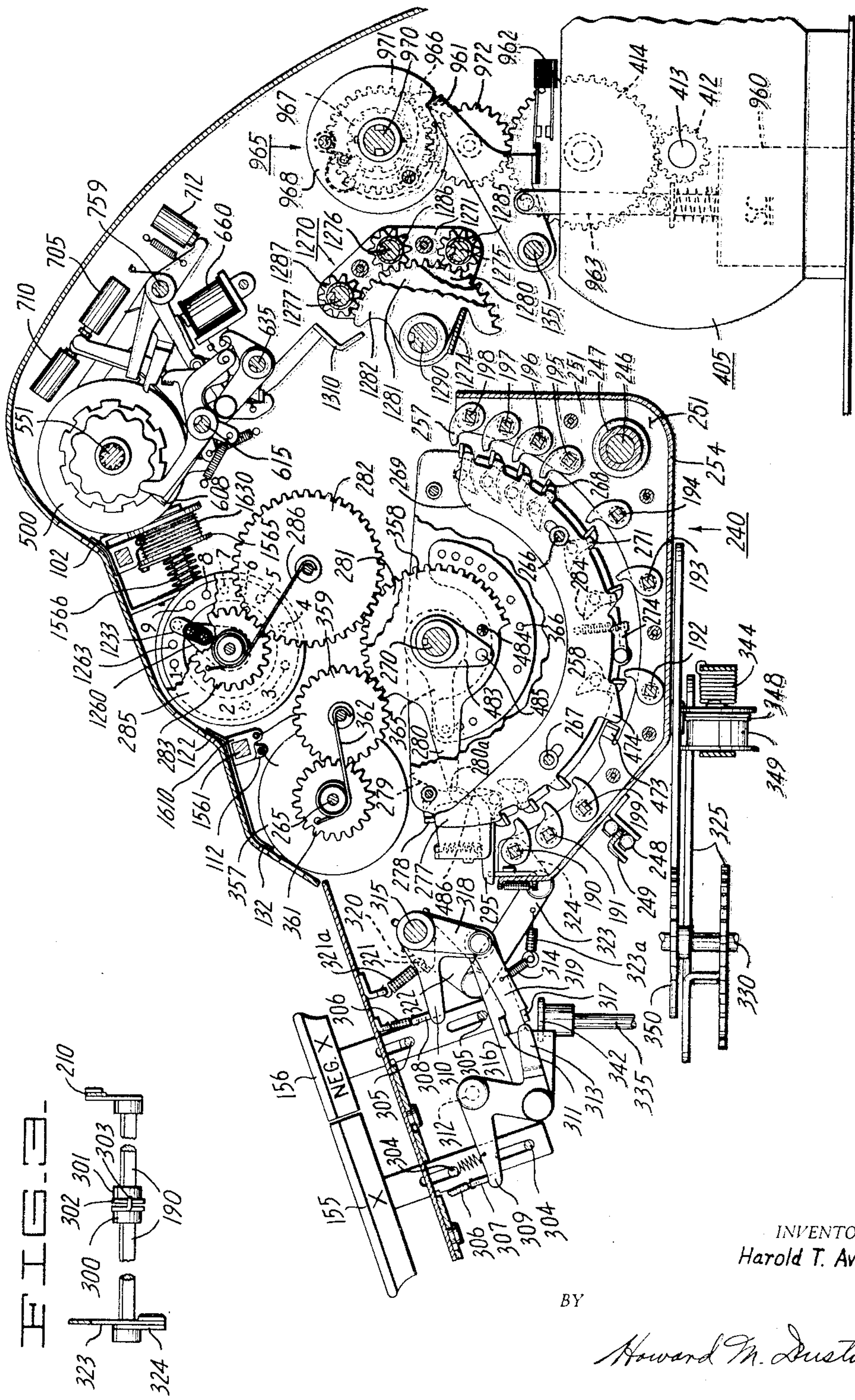

FIG. 2

FIG. 3

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PARTIAL PRODUCT MULTIPLYING MACHINE

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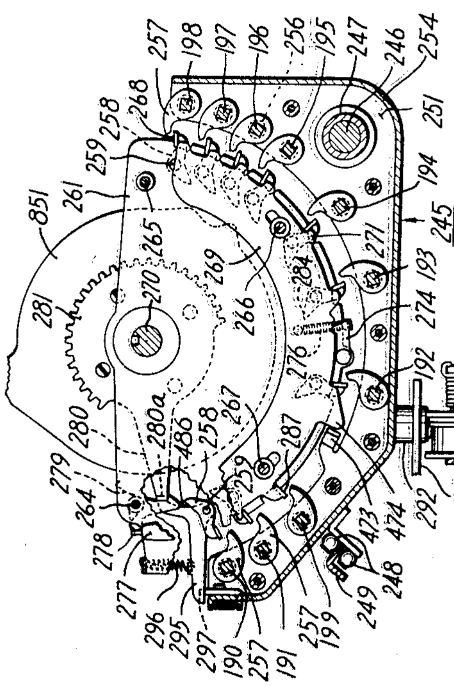

FIG_5_

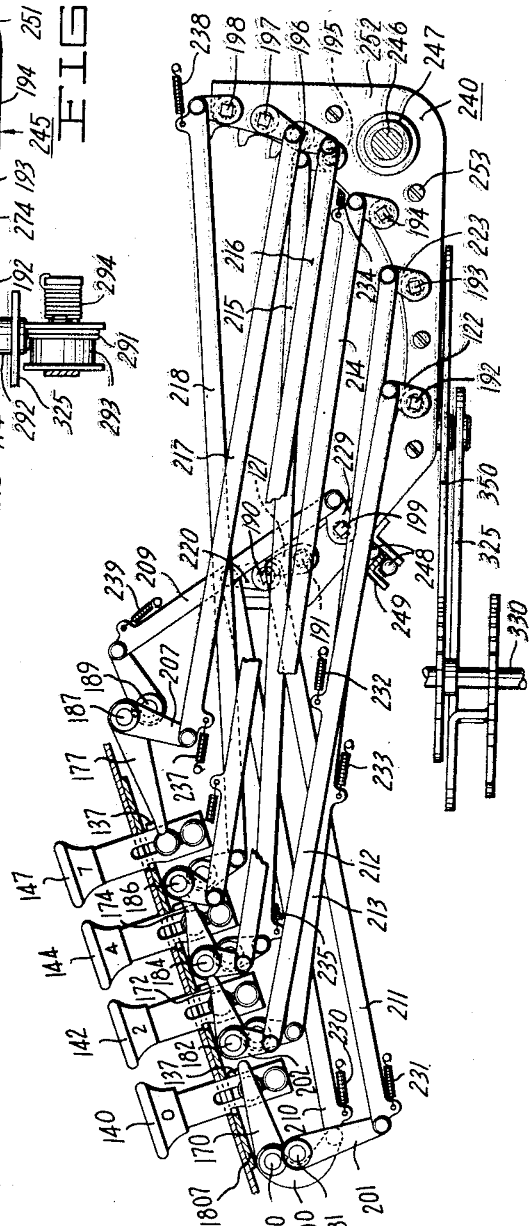

FIG_6_

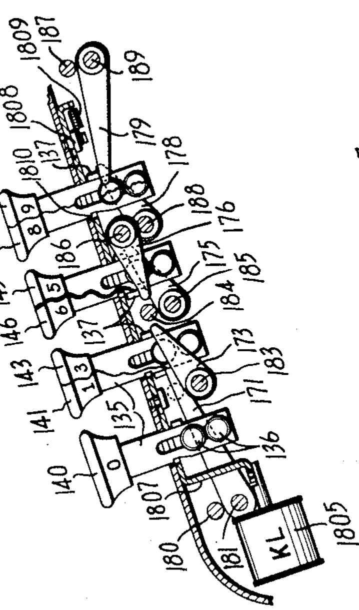

FIG_4_

INVENTOR.
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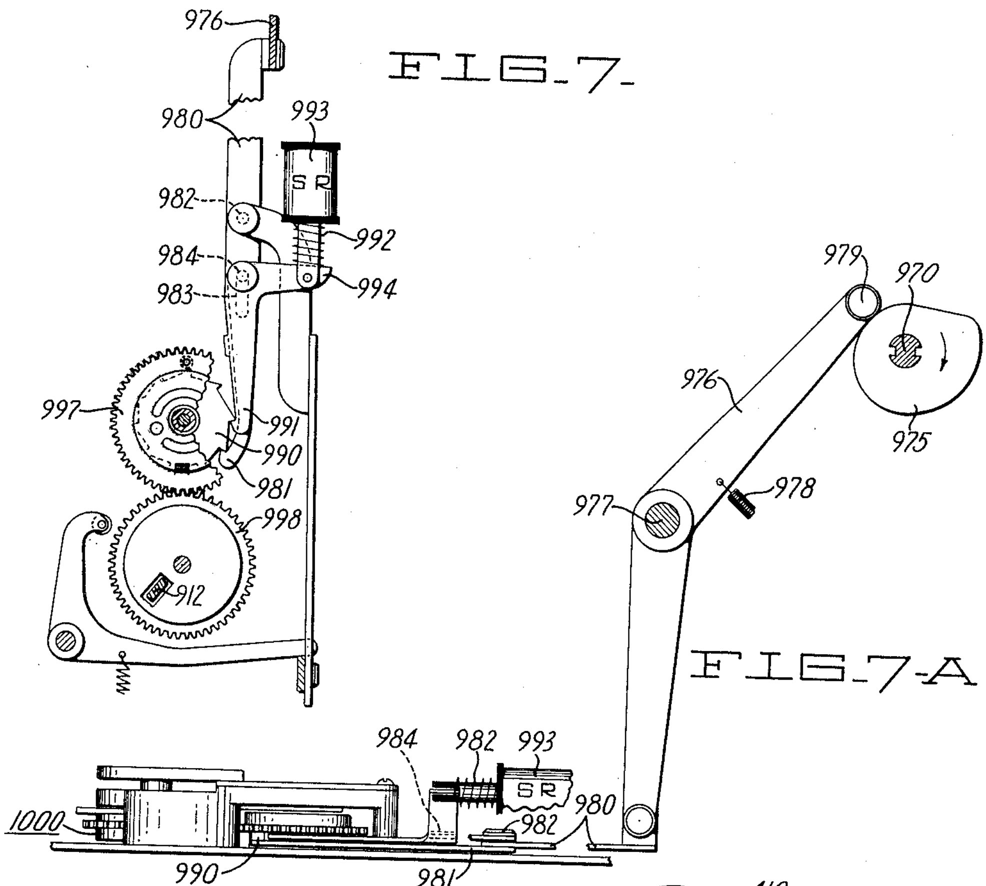
FIG. 7.



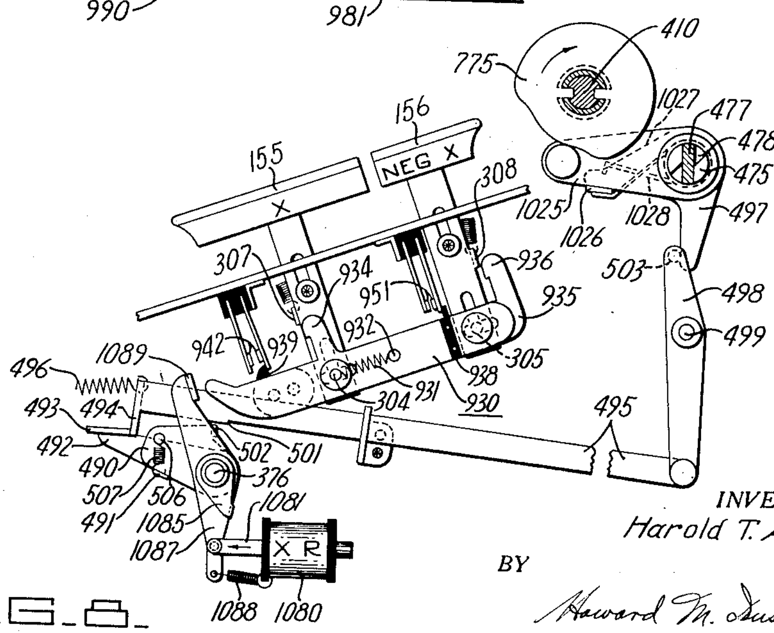


FIG. 8.

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PARTIAL PRODUCT MULTIPLYING MACHINE

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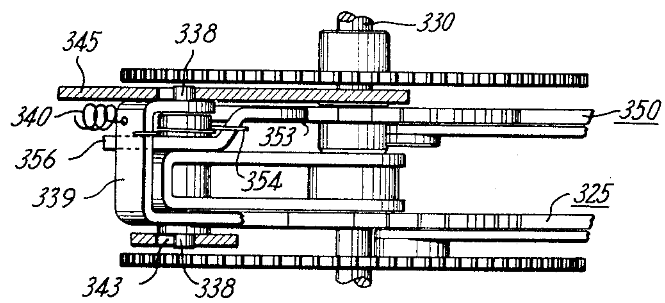

FIG. 9.

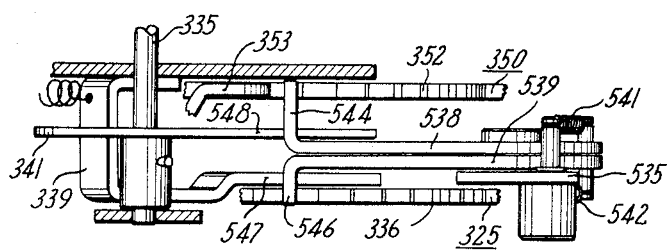

FIG. 10.

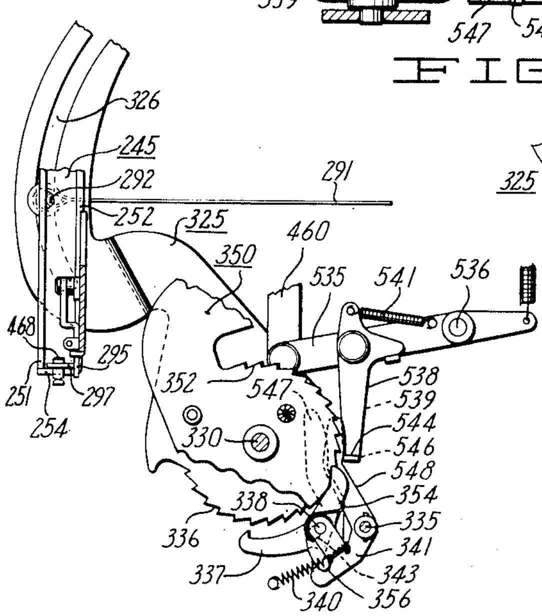

FIG. 11.

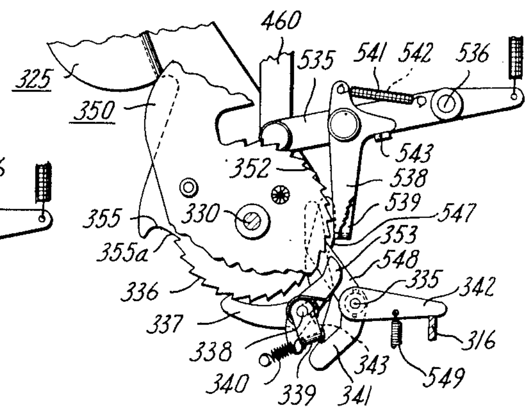

FIG. 12.

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FIG. 13.

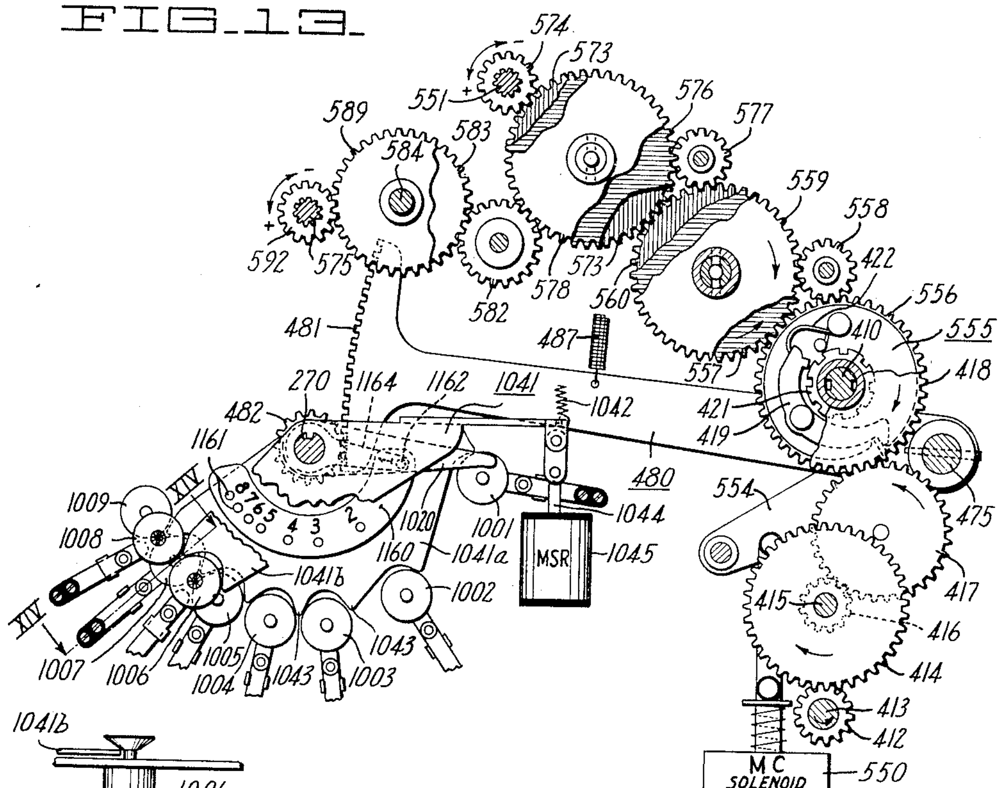
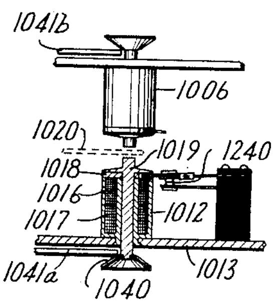


FIG. 14.



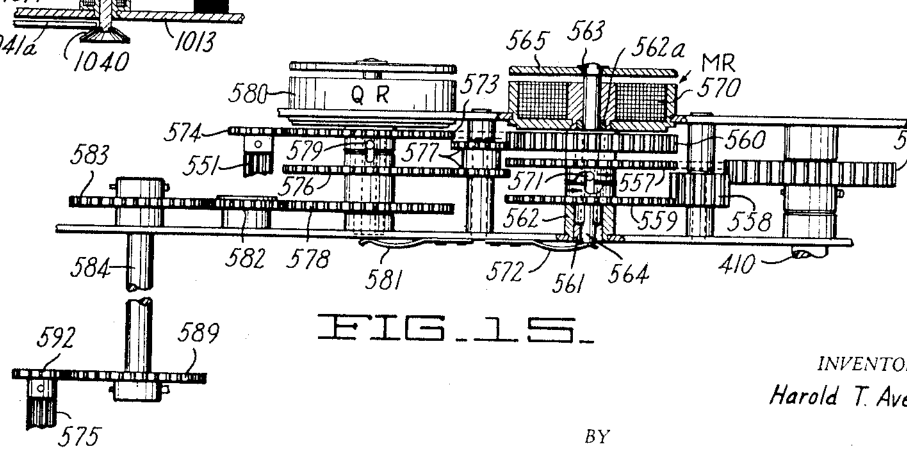


FIG. 15.

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PARTIAL PRODUCT MULTIPLYING MACHINE

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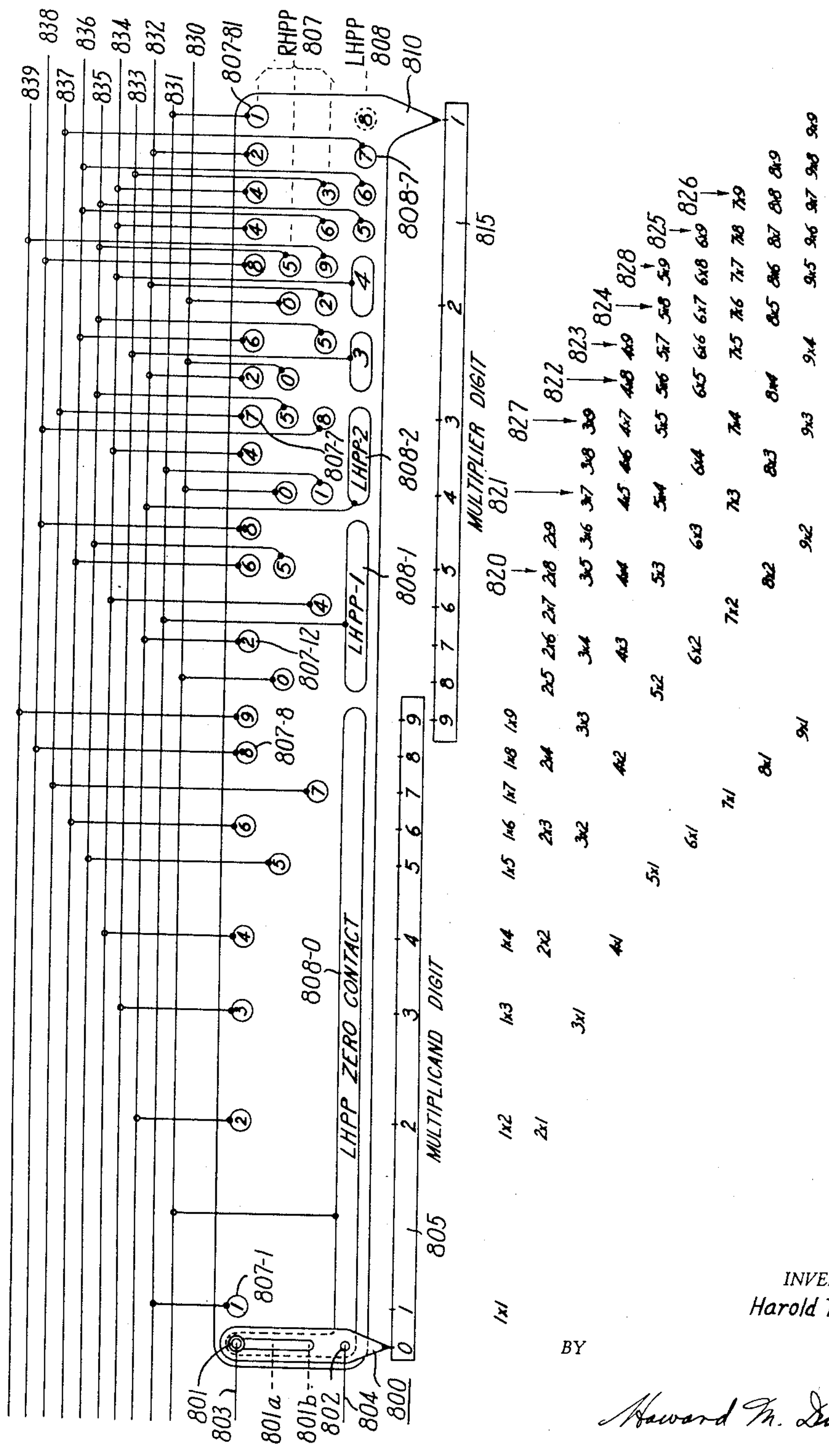

FIG. 16

INVENTOR.
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FIG. 17.

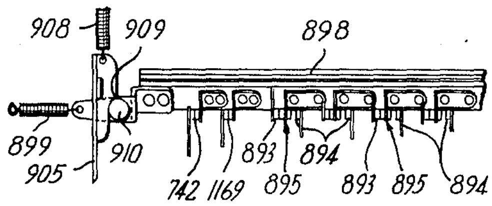
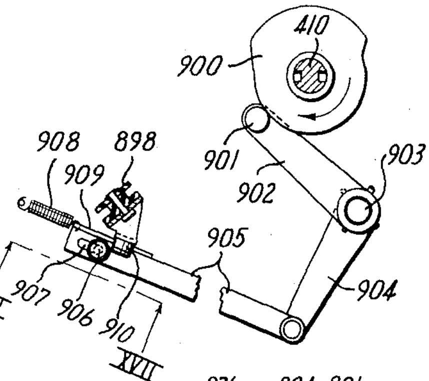
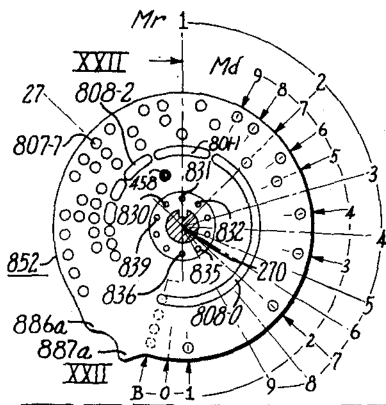
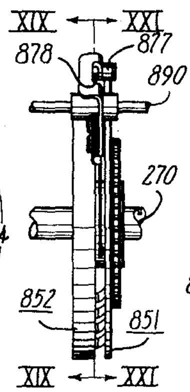


FIG. 18.







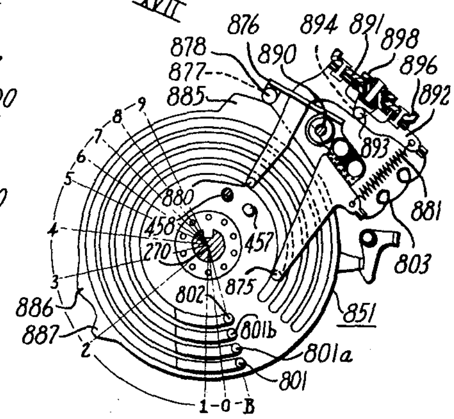


FIG. 19. FIG. 20. FIG. 21.

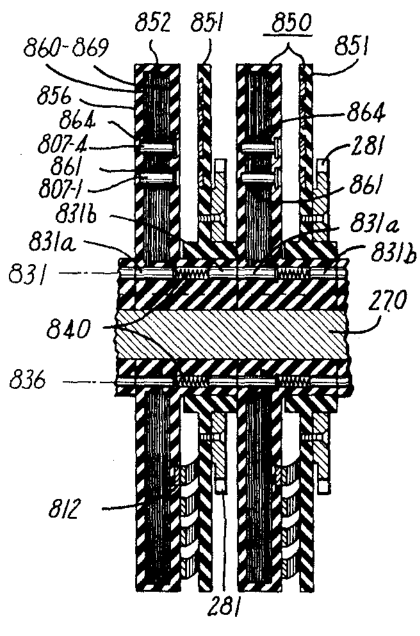


FIG. 22.

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FIG. 23.

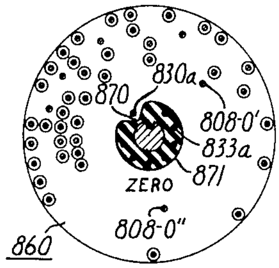


FIG. 24.

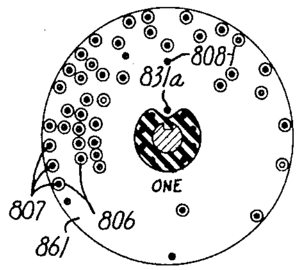


FIG. 25.

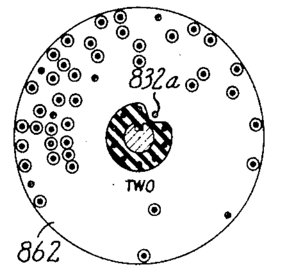


FIG. 26.

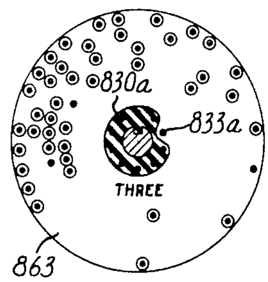


FIG. 27.

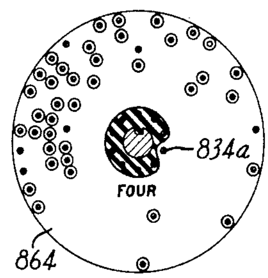


FIG. 28.

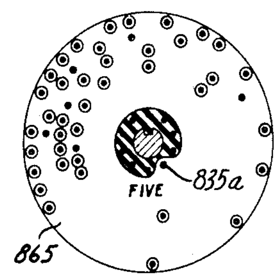


FIG. 29.

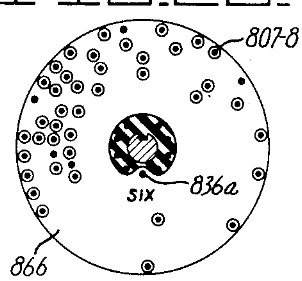


FIG. 30.

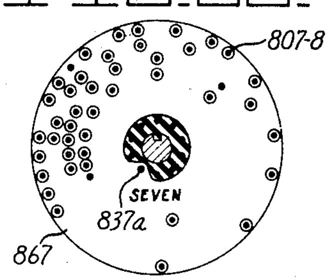


FIG. 31.

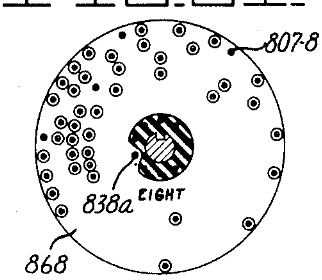
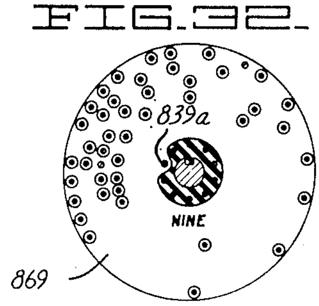


FIG. 32.



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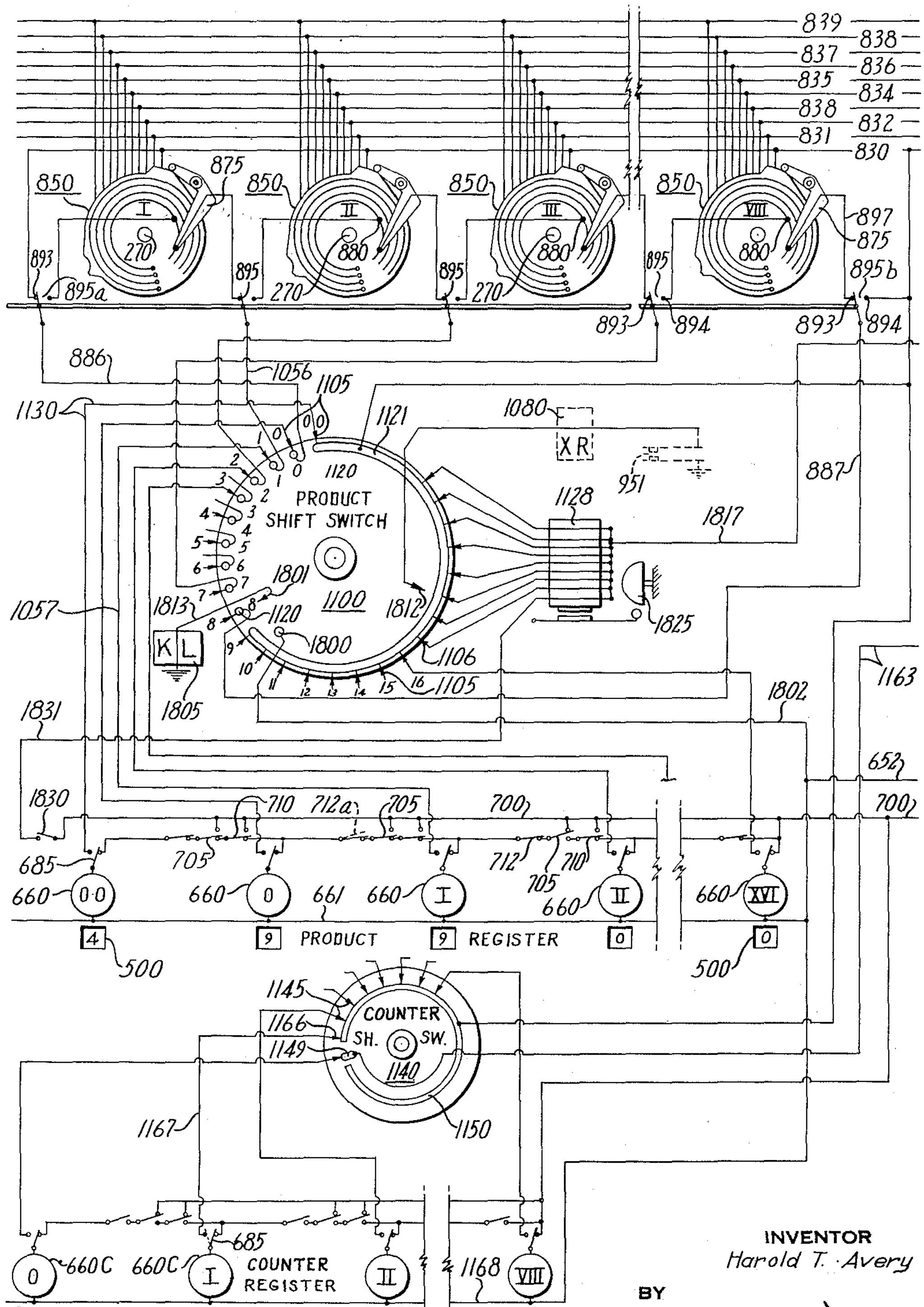

FIG. 33A.

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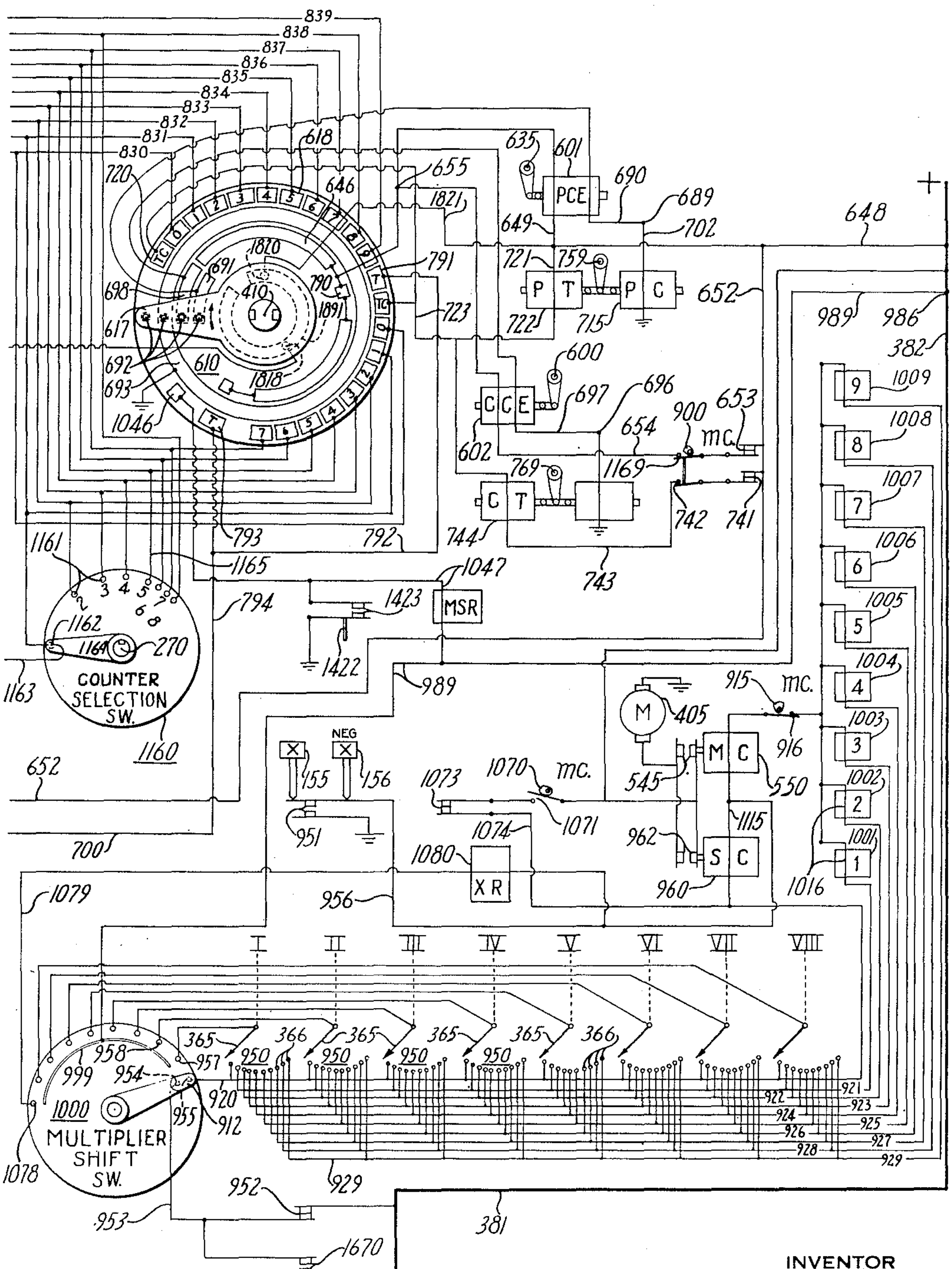

FIG. 33B.

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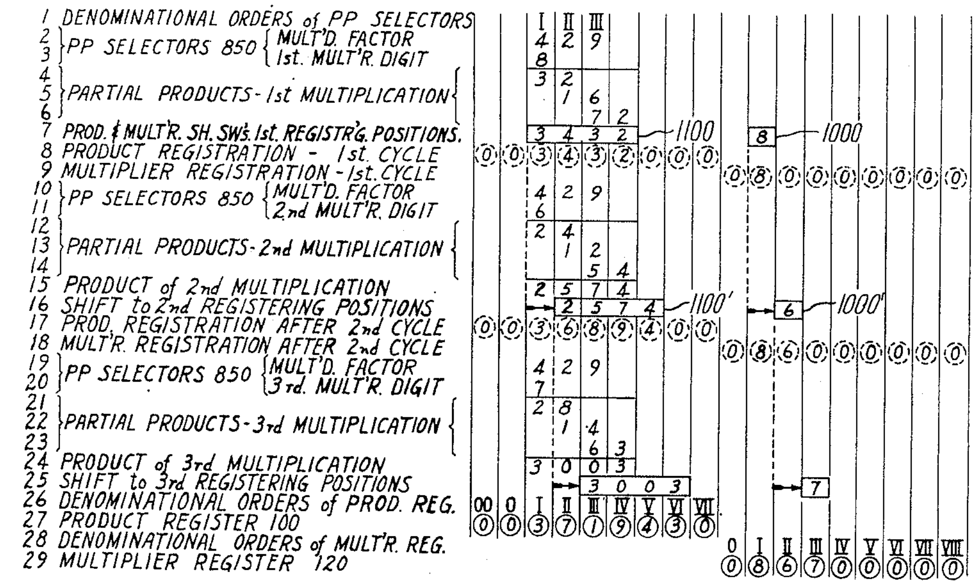

FIG. 34.

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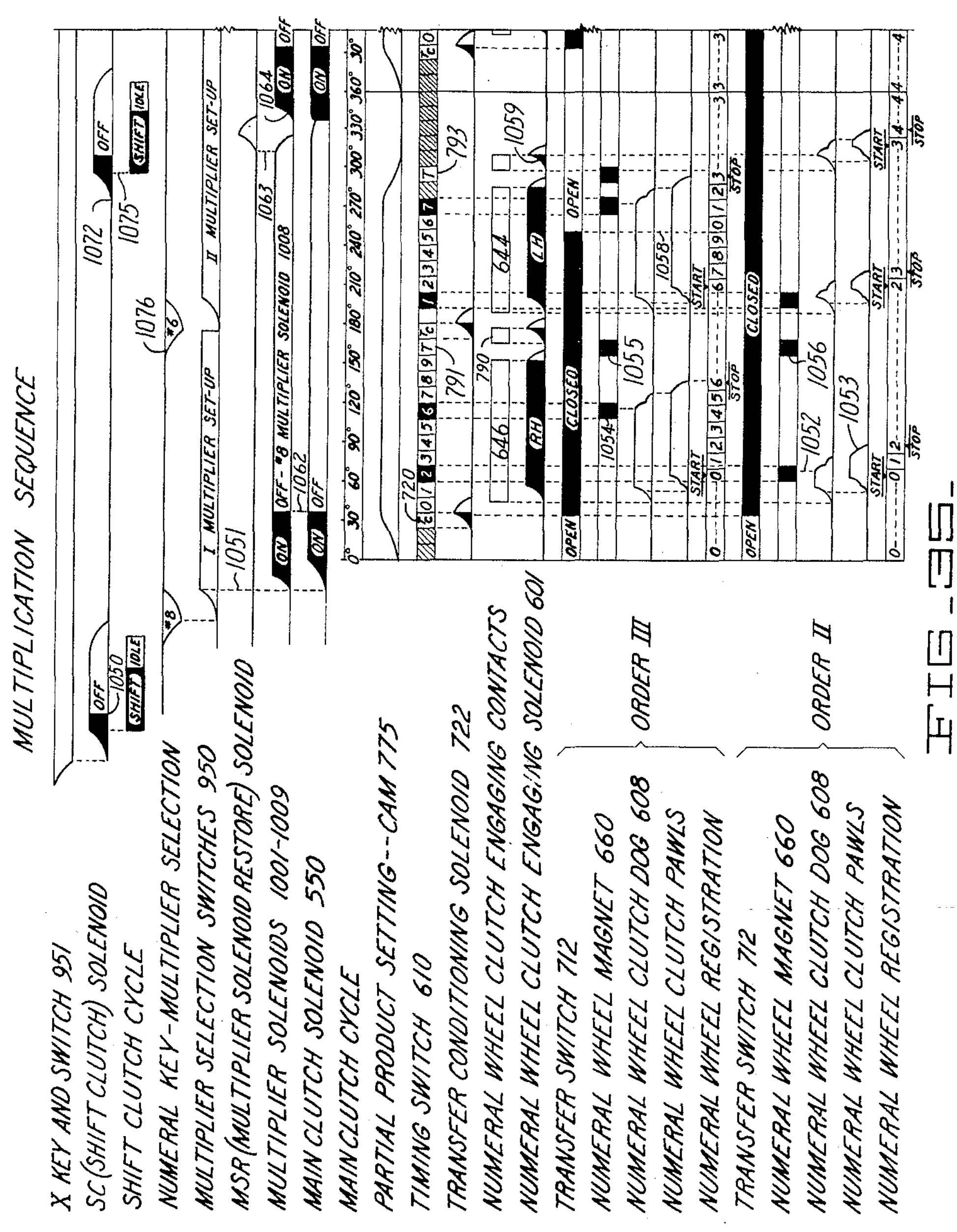

FIG. 35

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UNITED STATES PATENT OFFICE

2,598,095

PARTIAL PRODUCT MULTIPLYING MACHINE

Harold T. Avery, Oakland, Calif., assignor to Marchant Calculating Machine Company, a corporation of California

Original application October 16, 1943, Serial No. 506,519. Divided and this application December 23, 1947, Serial No. 793,503. In Canada June 12, 1947

4 Claims. (Cl. 235—61)

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The present invention relates to calculating machines and the like and more particularly concerns partial product multiplying mechanisms therefor.

An electrically controlled partial product multiplying mechanism disclosed in U. S. Patent No. 2,343,273 issued to Harold T. Avery, includes a network of electrical circuits and connections arranged according to the multiplication table. The selection of a multiplicand and multiplier digit by the numeral keys closes respective pairs of contacts and energizes a corresponding one of the network of circuits thus determining the partial products of the selected factor digits. In this mechanism there is a separate pair of contacts and a related circuit for each possible combination of the multiplicand and multiplier values, thus necessitating a great number of contacts and circuits.

The partial product selectors of present invention are based upon a modification of the slide rule principle of multiplication, departing from a true logarithmic spacing by arranging the movements of multiplicand and multiplier components of the selectors quasi-logarithmically so that those movements are in simple multiples of a given increment of movement. Electrical contacts are located upon the selectors and similarly are quasi-logarithmically spaced, with the result that the same pair of contacts and a single related circuit are used for all the various combinations of the multiplicands and multipliers that produce the same product, i. e. 1×8, 2×4, 4×2 and 8×1.

This modified form of the logarithmic scale is used in preference to a true logarthmic scale because it provides for less spatial requirements at the lower end of the scale where normally the spacing of successive increments is relatively great, and provides for greater spacing between successive increments at the higher end of the scale where normally such spacing is too close for accurate selection.

The preferred embodiment of the present invention is illustrated as an electrical controlling means for closing selected pairs of contacts. The same principle can be applied, however, to a mechanical selector having stops arranged according to a pattern similar to the pattern of electrical contacts and with the selector being positioned for mechanically controlling the entry of the partial products in a manner similar to that disclosed in the Cluley Patent No. 1,332,543 for example.

The present invention, therefore, is based upon the principle of a modified logarithmic scale of movement and pattern of elements arranged in simple multiples of a given increment so that the number of contacts or partial product elements are reduced to a minimum.

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It is therefore, a primary object of this invention to provide an improved and simplified partial product multiplying mechanism.

It is a further object of the invention to reduce the number of partial product circuits heretofore required in machines of this class.

It is a further object of the invention to reduce the number of contacts necessary in electrical partial product selecting mechanisms.

Fig. 1 is a top exterior view of the machine showing particularly the factor and result numeral wheels and the various selecting and controlling keys therefor.

Fig. 2 is a longitudinal section, as viewed from the right, showing the general arrangement of the selecting, actuating, and driving mechanisms of the machine embodying the present invention.

Fig. 3 is a detailed view of the zero selecting shaft.

Fig. 4 is a detailed view of the numeral keys and related mechanism.

Fig. 5 is a longitudinal section, as viewed from the right side of the machine, illustrating the left factor selecting mechanism and the shiftable set-up carriage therefor.

Fig. 6 is a right side view of certain of the numeral keys showing their connection to the numeral selecting shafts.

Fig. 7 is a plan view of a portion of the drive train for the multiplier shift switch.

Fig. 7A is a right side view showing the mechanism operated by the shift clutch for actuating the drive train shown in Fig. 7.

Fig. 8 is a right side view of the "X" and "Neg. X" keys, and a cam driven by the main clutch for releasing these and certain other control keys.

Figs. 9 and 10 are enlarged detail views, taken from the right of the set-up carriage shift controlling mechanism.

Fig. 11 is a detail view of certain parts of the set-up carriage shift controlling mechanism.

Fig. 12 is a detail view of the same parts shown in Fig. 11, and are shown in the position they assume during the set-up of the right factor.

Fig. 13 is a longitudinal section, as viewed from the right, showing particularly the drive train for the numeral wheel shafts and part of the multiplication controlling mechanism.

Fig. 14 is a detailed sectional view of the multiplier solenoids and related mechanism, the section being taken on the line XIV—XIV of Fig. 13.

Fig. 15 is a plan view of the numeral wheel shaft drive trains and reversing mechanism shown in Fig. 13. In this view, the left side of the machine is at the top of the figure.

Fig. 16 is a schematic diagram of the partial product selecting mechanism.

Fig. 17 is a view as indicated by the arrows XVII—XVII of Fig. 18, showing the switches for disabling the multiplier register during the left hand partial product actuating phase and for shifting the selecting circuit in the product register between the LH and RH partial product actuating phases.

Fig. 18 is a right side view of the mechanism for actuating the switches shown in Fig. 17.

Fig. 19 is a sectional view taken on the line XIX—XIX of Fig. 20, showing the multiplier side of a partial product selector.

Fig. 20 is an edge view of a typical partial product selector.

Fig. 21 is a sectional view taken on the line XXI—XXI of Fig. 20 showing the multiplicand side of a partial product selector.

Fig. 22 is an enlarged sectional view of two orders of partial product selectors, taken on the line XXII—XXII of Fig. 19, showing the construction thereof.

Fig. 23 to 32 inclusive, are sectional views of the multiplier side of a partial product selector, showing the various plates which make the electrical connections for controlling the registration of the partial products in the product numeral wheels.

Figs. 33A and 33B when combined form a wiring diagram illustrating the electrical controls for the partial products multiplying mechanism.

Fig. 34 is a schematic representation of a typical multiplication problem showing the partial products which produce the numeral value of the product.

Fig. 35 is a timing chart of the sequence of multiplication operations.

GENERAL DESCRIPTION

This is a division of the Avery patent application No. 506,519, filed October 16, 1943, now Patent No. 2,467,419, issued April 19, 1949. The invention is embodied in a calculating machine in which both factors of a multiplication are entered by means of the same "ten key" keyboard. The operator enters the first factor of a multiplication into a multiplicand or left factor receiving device by selectively depressing the value keys of the keyboard in the same manner that one would "write" that factor on a typewriter. Then upon depression of a multiplier conditioning key the ten keys of the keyboard become multiplier entry and operation start keys. The operator then "writes" the multiplier digits upon the keyboard and the multiplying operation is carried out regardless of the speed with which the keys are depressed.

In the problem 98215×625, for example, the operator successively depresses the 9, 8, 2, 1, and 5 numeral keys (Fig. 1) whereupon the digits 9, 8, 2, 1, 5 successively appear in the numeral wheels of the left factor indicator **110**. The operator next depresses the "X" key **155** which conditions the machine for the entry of the multiplier digits into the right factor indicator and also for a multiplying operation of the machine in response to such depression. The depression of the first numeral key after depression of the "X" key initiates a multiplying operation during which operation additional multiplier digits may be set up. In the above example, therefore the machine starts multiplying upon depression of the 6 key for entry of the multiplier digit "6" into the right factor indicator **130**, and enters the product of six times the multiplicand into the product register **100**. Concurrently with the entry of the product, a "6" is entered into the counter register **120**. As soon as the multiplication by 6 is ended the next multiplication by 2 is started and the multiplying operation continues through any successive multipliers that may have been entered. If the operator stops depressing the value keys during entry of the multiplier factor digits then the machine stops at the end of the multiplication by the last digit set up and waits for further entries or for a last digit correction if the operator so desires. At the end of the multiplying operation the correct product appears in a result register; also the multiplicand and multiplier values stand in respective factor indicator dials, and the multiplier or accumulated multipliers, as the case may be, stands in a counter register. From the foregoing it is seen that both the multiplicand and multiplier factors may be entered into the machine by depressing the various keys of the ten key keyboard. The entry mechanisms for both factor receiving devices will now be described.

Factor entry mechanism

The machine embodying the present invention includes a keyboard entry mechanism which is fully disclosed and claimed in the Avery application Serial No. 581,514, filed March 7, 1945, now Patent No. 2,459,862, issued January 25, 1949, and titled "Ten Key Entry Mechanism." Reference to this patent may be had for a full description of the specific mechanism included therein.

The entry mechanism effects entry of the values into the factor numeral wheels by means of a shiftable set-up carriage mechanism, which moves ordinally step by step into operative relation with successive numeral wheels. There is one set-up carriage for each factor indicator **110** and **130** (Fig. 1) and each carriage is adapted to assume either a full step or half step position. When a carriage is in its full step position it is rendered effective to determine the setting of the numeral wheel with which it is aligned, and when it is in its half step position it is rendered ineffective to control the setting of any numeral wheel. The carriages are so related that when the first of the two carriages, for example, is shifted into its full step position, the second carriage is retained in a half step position so that depression of a selected numeral key effects entry of the digit corresponding to the numeral, delineated thereon, into only that numeral wheel with which the first carriage is aligned. Depression of a control key, such as the "X" key **155**, then is adapted to escape the first carriage into its half step position and the second carriage into its full step position so that subsequent depressions of the numeral keys then effect entry of digits into the factor indicator associated with the second carriage.

Factor selection switches are positioned concurrently with the rotation of the factor numeral wheels and are adapted to condition certain selection circuits described hereinafter, in accordance with the position to which the numeral wheels are rotated.

Keyboard

Depression of the numeral keys **140–149** (Figs. 1 and 6) causes rocking of shafts **180–189** and of the selection shafts **190–199** in the manner described in the above mentioned Patent No. 2,459,862. Slidably mounted upon the shafts **190–199** (Fig. 5) are levers **257**, which, as described hereinafter, are used as selective stops for positioning both the partial product switching mechanisms and the factor indicator numeral wheels associated therewith.

Set-up carriages

As described briefly hereinbefore, there is a left factor and right factor set-up carriage, each of which is controlled by the numeral keyboard and effects entry of selected digits into the left and right factor numeral wheels respectively. These two carriage are identical, the right factor carriage **240** being shown in Figs. 2 and 6, the left factor carriage **245** being shown in Fig. 5. They are mounted and maintained upright on a common stationary shaft **246** by bushings **247** and have two rollers **248** which are rotatably mounted on studs integral with the factor carriage and are guided by a stationary supporting member **249**. Each carriage is composed of a flat plate **251** (Figs. 2 and 5) which forms the left side frame plate of the carriage and a second plate **252** (Fig. 6) which forms the right side frame plate of the carriage. The latter plate has a flange **254** (Figs. 2 and 5) which is bent toward the left adjacent the edge of the plate **251**, thereby forming a U-shaped section, in the trough of which is mounted the internal mechanism of the carriage all as is clearly shown in the previously mentioned Patent No. 2,467,419. The two frame plates **251** and **252** are held together as a rigid integral unit by a bushing **247** (Fig. 5) and six screws **253** (Fig. 6) carrying spacers between the plates for maintaining rigidity of the carriage. Clearance holes **256** (Fig. 5) are provided in the side plates of each carriage for the selection shafts **190** to **199** so the carriage may be shifted transversely without the shafts binding.

Mounted on the selection shafts within the trough of the U-shaped section of each carriage are levers **257** which are fitted to and therefore rock with the shafts, and at the same time are slidable thereon, with the carriage, as it shifts from order to order during the set-up operation. The levers **257** are operatively associated with a plurality of blocking levers **258** (Figs. 2 and 5) which are freely pivoted on studs **259** mounted on the stationary brace plates **261**. There is one such brace plate in each denominational order and these plates are held in place by the rods **264** to **267**, inclusive (Fig. 5), and are spaced by suitable spacers mounted on the rod. These rods and the selection shafts **190** to **199** are supported at their ends by the machine framework.

Movement of any lever **257** and its associated lever **258** releases the selecting arm **280** in the order with which the set-up carriage is currently associated so as to effect rotation of the related numeral wheel and position the selection switching mechanism. Each selecting lever **258** has an ear **268** which, in addition to being engaged by its associated lever **257**, extends across the plane of an arcuate plate **269** which is slidable on shafts **266** and **267**, one such arcuate plate **269** being located adjacent to each of the brace plates **261**. Lugs **271** are located on each plate **269** in front of the ears **268** so that clockwise rocking of any one of the levers **258** slides plate **269** clockwise about the central shaft **270**. A pawl **274** is pivotally mounted on each stationary plate **261** and is pressed into one or the other of the two notches in its respective plate **269** by a spring **276**, so as to retain the latter plate in either of its two positions.

The upper forward end of each plate **269** terminates in a nose **277**, as shown in Figs. 5 and 6, which nose is adapted to rock a latch **278** clockwise about the stationary shaft **264** against the pressure of a torsion spring **279**. A hook on the latch **278** normally underlies a laterally extended ear **280***a* of the arm **280**. A gear segment **281** is integral with the arm **280** which is freely pivoted on shaft **270**. There is one such arm and gear segment in each denominational order of the left factor indicator and each is geared to its associated numeral wheel by gears such as **282** and **283** (Fig. 2). The arrangement is therefor such that depression of a selected key, for example the number "3" key, rocks shaft **193** (Figs. 5 and 6) counter-clockwise. The lever **257**, mounted on this shaft in the left factor set-up carriage, in turn, rocks the nose **284** (Fig. 5) of its associated lever **258** upwardly into the path of ear **280***a* so that when the arm **280** is released by latch **278**, a torsion spring **286** (Fig. 2) drives gears **283**, **282**, and **281**, and rotates arm **280** counter-clockwise until the ear **280***a* is blocked by the nose **284** of the "3" blocking lever **258**. The levers **258** are located around the center of shaft **270** in such positions as to limit the rotation of the arm **280** and its associated numeral wheel **285** (Fig. 2) by amounts indicative of the numeral keys depressed. The number 9 shaft **199** is out of its natural position, however, and is so located as to shorten the number 9 connecting link **209** (Fig. 6). It will be noted further that the number 9 lever **257** (Fig. 5) has no lever **258** associated with it, but instead engages an ear **287** formed directly on the plate **269** for tripping latch **278**. The arm **280** in the case of a nine selection is blocked in its extreme counter-clockwise position by shaft **265** (Fig. 5).

A disc **851** is secured to each left factor arm **280** and segment **281** and is rotated an amount corresponding to the numeral value selected and indicated on its respective left factor numeral wheel.

This disc carries a plurality of brushes which cooperate with a set of contacts explained hereinafter and determine the selection of the partial product circuits used in multiplication and division.

Set-up carriage shifting mechanism

After a digit is entered into a selected numeral wheel the carriage is shifted toward the right one step to a position where the levers **257** mounted in the carriage are aligned with the levers **258** associated with the next numeral wheel to the right. A flexible cable **291** (Fig. 5) is attached to a stud **292** (Fig. 11) mounted on the left factor carriage **245** while the other end is wound around a spool **293** (Fig. 5). A spring **294** tends to rotate the spool and thus pull the carriage toward the right (Fig. 11). Rightward movement is normally blocked by one of a series of levers **295**, there being one such lever in each order mounted on the same stationary stud **259** which supports the zero blocking lever 258 (Fig. 5). A spring 296 tends to rock lever 295 clockwise, but this movement is prevented by the ear 280a of arm 280. When the arm is released by latch 278 and moves downwardly the spring 296 is then free to rock the stop lever 295 clockwise and out of the path of a lug 297 slidably mounted on the carriage, as shown in Fig. 5, and described more in detail hereinafter. The carriage is then free to move toward the right under urge of the spring driven cable until the lug 297 strikes the next stop lever 295. The set up of another digit in the next order again releases the carriage and so on after each digital value is set up.

The same keyboard effects entry of digital values into the right factor indicator 130 (Fig. 1) as well. In multiplication, the operator depresses the "X" key 155 or the "Neg. X" key 156 after entry of the multiplicand factor into the left factor indicator, and among other functions explained hereinafter the above "X" keys release the left factor set-up carriage, effect the blocking thereof in a half step inoperative position, and escape the right factor set-up carriage from its half step position into its operative full step position. Now assuming that the desired number of multiplicand digits have been set up, the machine is in condition to receive the setting of the first digit of the multiplier.

Taking these operations in the above order, the "X" key 155 or "Neg. X" key 156 (Fig. 2) is adapted to rock the zero selecting shaft 190 so as to release the left factor carriage. This shaft is divided, as shown in Fig. 3, and has hubs 300 and 301 integral with the left and right sections of the shaft, respectively. A flange integral with the hub 301 has a nose 302 which overlies a lateral extension 303 on the flange of hub 300, so that the left half of the shaft, which controls only the left factor set-up may be rocked counter-clockwise (as viewed in Fig. 2) by the "X" or "Neg. X" keys without rocking the right half associated with the right factor indicator, but when the right half of the shaft is rocked by the linkage from the zero numeral key, the nose 302 depresses the lateral extension 303 and rocks the left half of the shaft. This arrangement is provided to enable the "X" keys to release the left factor carriage without releasing the right factor carriage, and at the same time to enable the zero numeral key to rock both parts of the shaft for controlling entry of a zero in either the left or right factor indicator.

When the left factor carriage is released by the "X" or "Neg. X" key, as described above, the stud 292 (Fig. 11) mounted thereon moves toward the right. An arm 325, pivoted on a vertical shaft 330, has a slot 326 in which the stud slides, the shape of this slot being such that equal linear steps of the carriage effect equal angular steps of the arm. Therefore, by blocking the arm 325 in a half step position, the carriage may be prevented from moving into its next operative full step position, and this is accomplished by operation of the following mechanism in response to rotation of a shaft 335.

The arm 325 is shown in Fig. 11 in the position six steps from its initial position. For example, as if five multiplicand digits had been set up and the carriage had been shifted ready to receive the sixth digit. It will be noted that there are a series of ratchet teeth 336 on the arm 325 and a pawl 337 adapted to move about a stud 338 into engagement with any one of the teeth. This pawl is formed into a bail, as shown in Fig. 9, and has a web 339, to which a spring 340 is attached to urge the pawl in a clockwise direction. A latch 341 (Fig. 11) is secured to the shaft 335 and normally retains the pawl 337 in the position shown in Fig. 11 against the tension of spring 340, but when the "X" or "Neg. X" key 155 or 156 is depressed the shaft 335 and latch 341 are rocked counter-clockwise by mechanism described in the above mentioned application to release pawl 337. This counter-clockwise rocking of shaft 335 removes the hook of latch 341 (Fig. 11) from in front of the web 339, whereupon the spring 340 is free to rock the pawl 337 into engagement with a ratchet tooth 336 as shown in Fig. 12.

Stud 338 is integral with the pawl 337 and is journaled in an elongated hole 343 in a stationary frame plate 345 (Fig. 9). This hole 343 is indicated by the broken lines 343 (Fig. 11), from which it can be seen that the stud is normally held in the right end of the slot by latch 341, but when released from restraint of this latch it is moved into the left end thereof as shown in Fig. 12, by the combined pull of spring 340 and the ratchet teeth 336 of arm 325. The length of the elongated hole is such that when the stud moves from the right to the left end thereof, the arm 325 and the left factor set-up carriage are permitted to advance, but are limited to half a step where they remain until the machine is cleared.

So far in this description it has been assumed that a five digit multiplicand has been entered into the left factor indicator, the "X" key has been depressed, and the left factor carriage has moved into its half step or inoperative position. Next, the right factor carriage must be rendered operative so as to effect entry of multiplier digits into the right factor indicator.

The right factor carriage also has a stud (not shown) to which is connected a flexible cable 348 (Fig. 2) urged toward the right by a second spring urged spool 349 around which the cable is wound in a manner described in connection with the left factor carriage. The right factor carriage arm 350 is connected to the right factor carriage 240 by means of a pin and slot connection, similar to that described for the left factor carriage, so that rightward movement of carriage 240 causes a clockwise movement, as viewed in Fig. 12, of arm 350. Arm 350 is provided with a series of teeth 352 which cooperate with a pawl 353 freely mounted on stud 338 and urged counter-clockwise into engagement with the teeth 352 by a torsion spring 354 (Fig. 11). An arm 356 of pawl 353 lies behind the web 339 so that when the spring 340 (Fig. 11) rocks pawl 337 and its integral web 339 clockwise to the position shown in Fig. 12 the pawl 353 is rocked out of engagement with the right factor ratchet 352 and releases the arm 350 and the right factor set-up carriage which is then blocked in its first full step operative position by the first one of the series of stops 295 (Fig. 2) in exactly the same way described in connection with the left factor set-up carriage.

The right factor set-up carriage 240 (Fig. 2) also has a series of levers 257, each being adapted upon actuation to rock into blocking position a selected one of the blocking levers 258 in the current active order of the right factor indicator 130, thereby setting the arm 280 in said order. The arm 280 in each order transmits its movement to its associated numeral wheel 357 (Fig. 2) by means of the segment 358, gears 359, and 361, there being a spring 362 connected to gear

361 to provide the torque for the above train.

An arm 365 having a brush insulated therefrom, is integral with each of the arms 280 of the right factor or multiplier selecting mechanism, which brush sweeps across a plurality of contacts 366 mounted on an insulating plate fixed on the machine frame. These contacts are located at positions corresponding to the angular positions of stops 258 with respect to shaft 270, and have values 0 to 9, reading counterclockwise from the position of arm 365. There is one brush and series of contacts for each numeral wheel in the right factor indicator 130, which brushes and contacts condition certain multiplier selecting circuits, described hereinafter, for multiplication by the multiplier digits thus set up.

It is to be understood that the parts and operation of the right factor set-up mechanism not specifically described are the same as those disclosed hereinbefore in connection with the left factor set-up mechanism. The principal difference between the two mechanisms is that the left factor arms 280 (Fig. 5) set the discs 851 which compose the multiplicand side of the partial product selecting mechanism, while the right factor arms 280, select the contacts 366 to later determine energization of their respective multiplier solenoids, which then control the setting of the multiplier sides of the partial product selecting mechanism. This difference is due to the fact that all multiplicand digits are multiplied by only one multiplier digit at a time and that while the multiplicand side of the partial product mechanism may be directly set by the present selection mechanism the multiplier selection must be stored and later utilized to determine the setting of the multiplier side of the partial product mechanism by electrical means controlled by the multiplier selecting switches.

DRIVING MECHANISM

Motive power is employed to drive the various mechanisms of the present machine through three principal clutches, which are selectively engageable, namely, a main clutch, a shift clutch, and a clear clutch. The description and operation of each of these clutches is fully disclosed in the aforementioned Patent No. 2,467,419 and only a brief description of the pertinent parts necessary for the understanding of the operation of the multiplication mechanism will be given herein.

Main clutch

The main clutch is used to drive numerous control cams and ordinal numeral wheel clutches. A main timing switch is also driven by the main clutch in synchronism with the numeral wheel drive shafts and is adapted to control certain electro-magnetic devices described hereinafter, which, in turn control the action of the numeral wheel clutches in accordance with the setting of the selecting mechanism.

The main clutch is driven by the motor through gear 412 (Fig. 13) fixed to the electric motor shaft 413, gears 414, 416, 417, and 418. The latter gear is fixed to a main clutch driving disc 421, and forms an integral unit freely rotatable on the clutch shaft 410. The main clutch is of the same type of construction as the clutch in the Avery et al. Patent Number 2,162,238 issued June 13, 1939. A main clutch (MC) solenoid 550 (Fig. 13) is energized upon depression of certain of the control keys explained hereinafter and effects engagement of the main clutch when the solenoid pulls the clutch control dog 554 down, whereupon the clutch pawl 419 is released and a spring 422 rocks the pawl into engagement with the rotating drive disc and is driven therewith. This pawl 419 is pivotally mounted on a clutch disc 555, which disc is keyed to the shaft 410. Therefore when the clutch is disengaged as shown in Fig. 13, the gear 418 and disc 421 rotate idly, but when the clutch is engaged the pawl 419, clutch disc 555, and shaft 410 rotate with the driving disc 421.

Downward rocking of the main clutch control dog 554 also starts the electric motor for driving the clutch, and this is accomplished by providing a switch not shown which is normally held open by the main clutch dog 554 (Fig. 13), but when the clutch control dog is rocked to clutch engaging position, the switch is allowed to close and thereby connect the motor to the main power line of the machine.

Drive to numeral wheels

The transmission train between the main clutch and the numeral wheels includes a gear 556 (Fig. 15) which is fixed to the end of the main clutch shaft 410 and drives directly to a gear 557, and also through a reverse idler 558 to a gear 559. Therefore whenever the main clutch is engaged the two gears 557 and 559 rotate in opposite directions as indicated by the arrows in Fig. 13, and may be selectively coupled to a gear 560, so as to drive that gear and therefore gear 573 and gear 574 integral with a product numeral wheel drive shaft, in either direction as fully described in the aforementioned Patent No. 2,467,419. By means of this reversing mechanism either positive or negative actuation of the product numeral wheels may be effected, depending upon whether the "X" or negative "X" key is depressed, as will be fully described hereinafter.

In addition to providing power drive for the product numeral wheels, as just described, the counter numeral wheels (Fig. 1) are likewise driven by motor power, and a transmission drive train is therefore provided to drive the counter shaft 575 (Figs. 13 and 15). This train derives its power from the product gear train and is therefore subject to control of the product reverse mechanism described above. The counter numeral wheels are also adapted to receive and accumulate multipliers, and therefore ordinarily are arranged to be driven in a positive direction simultaneously with positive drive of the product numeral wheels during multiplication.

REGISTERS

Each ordinal numeral wheel of the product and counter registers is actuated by an ordinal clutch which forms a part of the numeral wheel clutch assembly. To enter a selected digit in a numeral wheel 593 (Fig. 2) the clutch is engaged at a fixed time in a digitation phase of the actuating cycle, and is disengaged at a selected time during the remaining part of the phase to stop the numeral wheel in accordance with the digital value selected. This type of clutch is shown and described in the U. S. Patent No. 2,416,369 issued February 25, 1947, to Harold T. Avery, to which reference may be had for a description of the parts of the clutch and control mechanism therefore.

The control of the numeral wheel clutches is derived from the operation of a timing switch, adapted to effect energization of certain electromagnets or solenoids which exert a direct control over the clutches. This timing switch 610 (Fig. 33B) includes a stationary insulating disc having a plurality of contacts molded or otherwise mounted thereon, and an arm 617. This arm is mounted for rotation with the main clutch shaft 410 and is driven in time with the numeral wheel drive shafts, which are also driven by the main clutch. The arm 617 carries four brushes shown by dotted lines in Fig. 33B, and identified by the reference numeral 692. Since the four brushes are electrically connected and could as well be a single brush spanning the four circles of contact, these brushes will be considered as a single brush 692 and referred to as such hereinafter.

Engagement of the numeral wheel clutches is affected at a fixed time early in the main clutch cycle by movement of the brush 692 onto contact 646, thereby connecting that contact to the ground contact ring 693, and completing the circuit from the main line 381 through leads 648 and 649 and through the PCE (product clutch engaging) solenoid 601 to the junction point 655, and also from the lead 648 through a parallel circuit including lead 652, the normally closed contacts 653 and 1169, lead 654, and CCE (counter clutch engaging) solenoid 602 to the junction 655, and therefrom to the contact 646, brush 692, and the contact ring 693 to ground. Closure of the above circuit at the fixed time in the cycle therefore energizes the solenoids 601 and 602 to effect engagement of the product and counter numeral wheel clutches, as fully described in the aforementioned Avery Patent No. 2,416,369.

Inasmuch as the product and counter numeral wheel clutches are the same insofar as the present description is concerned, only the product mechanism will be described. Disengagement of a product numeral wheel clutch is caused by an ordinal clutch control magnet 660 (Figs. 2 and 33A) which is energized at a selected time in the cycle. The numbered contacts 618 (Fig. 33B) are spaced relatively to the movement of the numeral wheel so that the brush 692 mounted on the arm 617 sweeps from one contact to the next synchronously with the movement of the numeral wheel from one numeral to the next. A plurality of partial product selectors, described hereinafter in connection with partial product multiplication, are adapted to connect selected ones of the contacts 618 of the timing switch into the digitation control circuits controlling the magnets 660 in such a way that if one of the partial product selectors in a given order is set for a five product selection for example, the number 5 selection circuit connected to the number 5 contact 618 only is closed, and as the numeral wheel, in the order with which it is associated, approaches the fifth digit from an initial position, the brush 692 passes onto the number 5 contact and completes the circuit from ground through the contact ring 693, brush 692, the number 5 contact 618, the lead 835 (Figs. 33B and 33A), through a respective partial product selector 850, the switch 895, a product shift switch 1100 described hereinafter, through the selected numeral wheel control magnet 660 to the lead 661 which is connected to the main line, thereby causing energization of this magnet and disengagement of the numeral wheel clutch as the numeral wheel enters its fifth position.

Digitation and transfer phase switches

Each calculating cycle of the present machine is composed of two digitation phases which are provided to enable entry of the RHPP (right hand partial products) and LHPP (left hand partial products), under control of the partial product selectors 850 (Fig. 33A) which will be described in detail hereinafter. For the purpose of the instant description, however, it is sufficient to understand that each product register magnet 660 is controlled by a digitation circuit during the RHPP and LHPP digitation phases, and is controlled by a transfer circuit during the two transfer phases, one of which latter phases follows each of the two digitation phases so as to effect the entry of transfer increments resulting from the entry of the partial product digits. Switches 685 (Fig. 33A) which correspond to the swtches of the same number in said Avery Patent Number 2,416,369 are provided in each order of the product register to connect the magnet 660 in its denominational order, first into the digitation circuit for entry of the RHPP digit, then into the transfer circuit, back into the digitation circuit for entry of LHPP digit, and then again into the transfer circuit.

PARTIAL PRODUCT MULTIPLICATION

As previously mentioned the present partial product multiplying mechanism is based on a modified slide rule principle which effects a saving of parts in the machine and simplifies the operation thereof.

It should be understood that while the partial product mechanism is disclosed hereinafter only in connection with multiplication that this same mechanism is also used in division operatons During such operations the multiplicand side of the partial product selectors are set by the left factor receiving device in accordance with the divisor value set therein and the multiplier side of the partial product selectors are set in accordance with the quotient digit which is estimated by the division mechanism disclosed and claimed in the divisional application Serial No. 554,558, filed September 18, 1944, since abandoned in lieu of the continuation in part application Serial No. 81,501, filed March 15, 1949, now Patent No. 2,538,826, issued January 23, 1951. The present partial product multiplying mechanism thus multiplies the divisor by the estimated quotient digit and negatively enters the product into the accumulator register which contains the dividend or current dividend all as is fully described in the last mentioned patent.

The above mentioned simplification is primarily effected by so arranging the contacts that the same contacts are used for all problems which result in a given product. For example, in setting up of the problems 3×8, 4×6, 6×4 and 8×3, the same contacts which determine the value of the resulting product are brought into operation. This result is accomplished by spacing the selection contacts at ratios of distance corresponding to a modified or quasi-logarithmic relationship and by advancing the contacts and brushes through steps similarly corresponding to the quasi-logarithms of the multiplicand and multiplier factor digits to thereby bring the brushes upon the contacts corresponding to the units and tens partial products digits of the multiplicand and multiplier digits selected. In order to position the brushes squarely on the face of the proper contacts in each instance, the successive spacing of certain of the selection steps are made in simple multiples of a selected increment of distance. In order to not spread out unduly or have to graduate the selection range too finely, the entire selection range from 1 to 9 is divided into sixteen equal increments of distance, and the various selection positions are spaced from each other by the number of increments listed in the following table.

TABLE A

Selection	Increments
1	
	5
2	
	3
3	
	2
4	
	2
5	
	1
6	
	1
7	
	1
8	
	1
9	

It will be noted that this is only a rough approximation to a logarithmic scale, the spacing from the 5 to 9 selection being in accordance with a straight linear scale, and yet it will be observed that the number of increments of distance separating 1 and 2 is the same as that separating 2 and 4, 3 and 6, and 4 and 8, namely, five increments in each case. Furthermore, the distance separating 2 and 3 is the same as that separating 4 and 6, and 6 and 9, namely, three increments in each case. Similarly, it will be found that practically all ratios which occur more than once between the various digits from 1 to 9 are, in this arrangement, separated by the same number of increments of distance each time they occur.

Fig. 16 illustrates this arrangement schematically, in which the block **800** carries two contact brushes **801** and **802**, from which current may flow through the wires **803** and **804**, respectively, in a manner hereinafter described. The block **800** is advanced toward the right in accordance with the multiplicand selection, as indicated on the scale **805**. A contact plate **810** carries a group of RHPP and LHPP contacts **807—0** to **807—9** and **808—0** to **808—7**, respectively, arranged in selected sizes and locations as shown.

It will be noted that there are no contacts **808—8** and **808—9**. No such contacts are needed inasmuch as an 8 is the highest possible LHPP, i. e. 9×9=81, furthermore no electrical control means are required to effect an 8 LHPP since the controls are so arranged that in multiplication an 8 LHPP is effected automatically unless a lower value LHPP is selected. An 8 LHPP contact **808—8** is indicated in dotted lines on the schematic lay out to show that such selection is obtained as described above.

The plate **810** is moved toward the left in accordance with the multiplier digit selected as indicated by the scale **815**, the length of the various steps being graduated so as to equal to the corresponding steps of the multiplicand scale **805**.

At the bottom of Fig. 16, all possible single digit multiplications are listed in such an arrangement that each multiplication appears directly below the contact on contact block **810** upon which the brushes **801** and **802** will rest when the corresponding multiplication is set up. For instance, directly beneath contact **807—8** there appear the multiplications 1×8, 2×4, 4×2, and 8×1. If contact block **800** is brought opposite the digit 1 on the scale **805** and block **810** is brought opposite the digit 8 on scale **815**, brush **801** will be resting on the number "8" contact **807—8** and the brush **802** will come to rest on the zero contact **808—0**; and if the blocks are similarly moved to set up any of the problems 2×4, 4×2, or 8×1 it will be found that these same brushes will be resting on these same contacts. Similarly, in the multiplication of, for example, 6×2, the block **800** is moved opposite the digit 6 on scale **805** and block **810** is moved opposite the digit 2 on scale **815**, then the brush **801** will rest on the number "2" contact **807—2** and brush **802** will rest on the number "1" contact **808—1**, and similarly for the other multiplications listed.

In partial product multiplication of, for example, seven times nine equals sixty-three, the 6 is sometimes referred to as the tens partial product and the 3 the units partial product, but to avoid confusion between the tens partial product and the term "tens transfer" the 6 and 3 will be referred to hereinafter as the left hand and right hand partial products and abbreviated LHPP and RHPP.

It will be noted that the products of the multiplications listed in each column are the same except in columns **820**, **821**, **822**, **823**, **824**, **825**, and **826**, were two different products result from the multiplications listed, and in columns **827** and **828** where three different products result therefrom. This conflict of different products falling in the same column is due to the fact that the scales for the multiplicand and multiplier are not truly logarithmic throughout, but in order to maintain the relative value of the different steps in whole increments of distance, and to make them truly enough logarithmic to clear up all such conflicts it would be necesary to spread the selection movement so greatly or to narrow down the increments of distance so finely as to be quite undesirable in producing a compact, dependable machine. In the interest of compactness and over-all simplicity the arrangement shown is, therefore, regarded as preferable in the particular machine embodying this feature.

It will be noted that whenever more than one product appears in any vertical column the extra products involve either a five or seven multiplicand or multiplier, and that whenever three products appear in a column the five multiplier or multiplicand gives rise to one product, and the seven to a second product, while multiplication of two factor digits, in which both multiplicand and multiplier digits or any of the other figures from 1 to 9 except 5 or 7, gives rise to the third product. Therefore, by an arrangement to be described hereinafter, the brush 801 is adapted to be moved to the position **801***a* whenever a five multiplier or multiplicand is involved and to the position **801***b* whenever a seven multiplier or multiplicand is involved, and will remain in the position shown in all other cases, except when a given order or the multiplicand selection mechanism is set at zero, or is unset and stands in a blank position. In the physical embodiment, the zero contact **808—0** (Fig. 19) is connected to both LHPP and RHPP circuits by the stationary brush **880** (Fig. 21) and the brush **875** which is adjustable to contact the brushes **801**, **801***a*, **801***b*, **802**. To avoid confusion between the contacts **801** and **802** and to simplify the schematic illustration of Fig. 16, the contact **801** is shown in its upper position and the zero contact **808—1** is shown with an upturned extension underlying the contact **801**.

The RHPP and LHPP contacts are connected to wires 830 to 839, leading from a timing switch described hereinbefore and receive electrical impulses at times in the machine cycle which are indicative of the digits 0 to 9. A selected impulse is thus transmitted from the corresponding RHPP contacts to the brush 801 and therefrom to its respective numeral wheel clutch control magnet during the RHPP digitation phase of the machine cycle. When this phase is completed the RHPP brush 801 is switched out of circuit and the LHPP brush 802 is switched in, to similarly conduct a selected LHPP impulse from leads 830 to 839, through a selected LHPP contact, brush 802 and lead 804, to the next higher numeral wheel clutch magnet for effecting entry of the LHPP digit.

Partial product selectors

The physical embodiment of the arrangement shown schematicaly in Fig. 16 includes a partial product selector 850 (Fig. 22), operatively associated with each denominational order of the multiplicand or left factor indicator, there being eight such orders and selectors in the present machine. Each selector 850 is composed of a multiplicand disc 851 and a multiplier disc 852, the arrangement being such that each disc 851 is set according to the multiplicand digit selected in its respective order while all the discs 852 are simultaneously set according to a selected multiplier digit and are successively reset during the multiplication problem according to each successive digit of the multiplier factor. By means of this arrangement all the multiplicand digits are multiplied by sucessively selected multiplier digits, one at a time, and each partial product selector determines the RH and LH partial products of the respective multiplicand digit times the current multiplier digit.

Ten plates or laminations 860 to 869 are individually insulated and molded or otherwise enclosed in a casing 856 made of insulating material. The casing is keyed to the shaft 270 (Figs. 5 and 22), which shaft is successively set to a series of rotational positions corresponding to multiplier digits selected by mechanism including a series of multiplier solenoids described hereinafter, this setting corresponding to the movement of plate 810 (Fig. 16) along the scale 815. Each lamination 860 to 869 (Fig. 22) represents one of the digits "zero" to "nine" and is connected to its respective lead 830 to 839 (Fig. 19) corresponding to the leads of the same number in Figs. 16 and 33A and 33B. Of these, the number 1 conductor 831 and the number 6 conductor 836 are shown in Fig. 22 and the construction there shown is typical for all of these conductors. The conductor 831, for instance, comprises pins 831*a* and 831*b* in each ordinal selector, each pin 831*a* being fixed in its casing 856 and each pin 831*b* being slidable in a hole in the hub of the plastic casing. Springs 840 are compressed between the pins to conduct current from one pin to the next and to press the pin 831*b* against the adjacent pin 831*a* in the next order to the right, each line of pins 830–839 (Figs. 19 and 22) being connected by a flexible lead to the conductor of the same number in Figs. 33A and 33B.

Each pin 830*a* to 839*a* (Figs. 23 to 32, inclusive) is connected to its respective lamination or contact plate 860 to 869 as follows: in line with the pin 830*a* (Fig. 23), for example, is a lug 870 of plate 860 having a hole which is a press fit for pin 830*a*, while a large clearance hole 871 is provided in this contact plate for passage of all the other pins, such as pin 833*a*, which latter hole may be partially filled by the insulation material of the casing 856, as shown also in Fig. 22. Pin 830*a* only is thus connected to the number "0" plate 860 and to only that plate, while as indicated in Fig. 24, pin 831*a* is similarly connected to the number "1" plate 861 only, and as indicated in Figs. 25 to 32, inclusive, each of the remaining pins 832*a* to 839*a*, inclusive, is similarly connected to only its respective plate 862 to 869, inclusive.

Each plate 860 to 869 has a plurality of holes 806 (Fig. 24) which are located angularly in positions corresponding to the linear position of the respective RHPP contacts in Fig. 16. A plurality of pins 807 such as the number 4 pin 807—4 and the number 1 pin 807—1 (Fig. 22) are fixed in the casing 856 and extend through the plates 860 to 869, inclusive. Each pin passes through clearance holes in all plates except one, to which one plate, it is connected by a press fit into a smaller hole, as for example each number 4 pin 807—4 (Fig. 22) passes through the clearance holes in all plates except the number 4 plate 864. Similarly, each number 1 pin 807—1 is connected to only the number 1 plate 861. Referring again to Figs. 23 to 32, the double circles indicate the points at which the pins do not connect with the plate, the inner circles representing the pins, and the outer circles the clearance holes. The single circles indicate the pins which are in contact with the plates, as for example the number 8 RHPP contact 807—8 (Figs. 16 and 31) is connected to only the number 8 plate 868, and the zero LHPP contact 808—0 (Fig. 16) is connected to the zero plate 860 (Fig. 23) by two pins 808—0′ and 808—0″, which pins pass through clearance holes in all the other plates.

The aforementioned multiplicand side of the partial product selector which may be more briefly termed the multiplicand disc 851 (Figs. 21 and 22), is fixed to the gear segment 281 (Fig. 5), in each order of the left factor selecting mechanism, and is therefore selectively set by movement of arm 280 to selected numeral positions corresponding to the movement of pointer 800 (Fig. 16) to selected digital positions on the scale 805. Each disc 851 has four contact strips (see Fig. 21) which terminate in brushes 802, 801, 801*a*, and 801*b*, corresponding respectively to the brushes designated in Fig. 16 as brush 802 and as brush 801 in the 801, 801*a* and 801*b* positions, the only difference being that in the physical embodiment shown in Fig. 21 the four separate brushes are fixed relative to each other, there being a stationary LHPP arm 880 which always rests on the contact strip of the LHPP brush 802 only, and an RHPP arm 875 which is adapted to be shifted onto any one of the four contact strips. The latter arm is fixed to and insulated from a lever 876 (Fig. 21) which is pivoted on a shaft 890 and urged counter-clockwise by a spring 881. Two rollers 877 and 878 are mounted on arm 876 and roll on the periphery of the discs 851 and 852, respectively, so as to limit the counter-clockwise movement of arm 875. A zero lug 885 is so located on each multiplicand disc 851 that when a given order of the multiplicand or left factor selecting mechanism stands in the blank position shown in Fig. 5 or is set to the zero position, the zero lug rocks arm **875** to its extreme clockwise position in which it rests on the contact strip of the brush **802**. Therefore when a multiplicand disc **851** is set at zero, the brush **802** rests on the zero contact **808—0** (Fig. 19) regardless of the setting of the multiplier disc **852**, and since both the arms **875** and **880** engage the contact strip of the brush **802** when a zero multiplicand digit is selected in any order, the RH and LH partial products involving a zero multiplicand digit are always zeros regardless of the value of the multiplier digit selected. There is no zero lug on the multiplier disc **852** (Fig. 19) because when a zero digit occurs in any order of the multiplier factor no multiplication cycle takes place in that order, but instead there is a shift operation explained hereinafter.

There are two other lugs **886** and **887** on disc **851** (Fig. 21) and lugs **886***a* and **887***a* on disc **852** (Fig. 19), which are so located that when either disc **851** or **852** is set to a position corresponding to a seven multiplicand or multiplier respectively, the respective lug **887** or **887***a* rocks the arm **875** onto the contact strip of the brush **801***b*. The latter brush may, therefore, rest on any of the contacts in line with the **801***b* position of brush **801** (Fig. 16), depending upon the selection, and in any such case when a seven multiplicand is involved such as 7×1, 1×7, 7×2, 2×7, etc., the brush **801***b* rests on the corresponding RHPP contact described hereinbefore in connection with Fig. 16.

Similarly, if a five multiplicand or multiplier is set up, the lug **886** or **886***a* moves under the roller **877** or **878** and limits the arm **875** (Fig. 21) for movement onto the contact strip of brush **801***a*. The contacts shown schematically in Fig. 16, which are in line with the **801***a* position of brush **801** are connected to only the "0" or "5" timing switch leads, therefore when the arm **875** (Fig. 21) is positioned on the contact strip of brush **801***a*, the arm conducts timed impulses indicative of a five or zero RH partial product digit from the brush **801***a* to the digitation control circuit described hereinafter.

When any other multiplier or multiplicand, namely, a 1, 2, 3, 4, 6, 8, or 9 is set up the rollers **877** and **878** (Fig. 21) are rocked downwardly by spring **881** and are limited by the normal circumference of the discs **851** and **852**, whereupon the arm **875** rests on the outer contact strip of the brush **801**, so as to render the outer circle of contacts (Fig. 19) effective to control entry of the RH partial product digits.

The positions of the multiplicand and multiplier selection discs **851** and **852** are indicated in Fig. 19 by characters B, 0, 1–9 on one arc and 1–9 on a second arc. The brushes **801**, **801***a*, **801***b*, and **802** are shown in Fig. 21, in their normal blank position designated by the character B. The dotted radial lines number 0 to 9 indicate the position to which the brushes are set to correspond to the digits 0 to 9 entered into the left factor indicator. The same positions of the same brushes are shown by dotted lines in Fig. 19 and the inner arc of numbers B, 0, 1–9, designated *Md*, represent the positions to which the brushes are so set. The disc **852** is shown in Fig. 19 in its number one position, which is its normal position. The center of the keyway of shaft **270** is used as an index point and is correspondingly numbered "1," and the outer arc of the numbers 1 to 9 designated "*Mr*" indicate the positions to which all the discs **852** are set in accordance with a selection multiplier digit.

From the foregoing it may be seen that in a problem such as 3×9=27, for example, the brushes are moved from the normal position B, counterclockwise to the number 9 position, and the disc **852** is moved from the number 1 to the number 3 position. These two relative movements position the brushes on the contacts falling on the dotted radial line designated "27," wherein the brush **802** engages the LHPP contact **808—2** and the brush **801** engages the RHPP contact **807—7**, corresponding to the product 27. Since neither of the factors involved a 5 or 7, the arm **875** (Fig. 21) is positioned on contact strip **801**, and since the brush **880** normally rests on the contact strip of the brush **802**, the machine is conditioned for the entry of 27 into the product register.

As stated hereinbefore there is an RHPP digitation phase and an LHPP digitation phase of each actuating cycle. During the first phase RH partial product digit is entered into a selected product numeral wheel, and during the second phase each corresponding LH partial product digit is entered into the product numeral wheel in the respective next higher order. To accomplish this nine "RHPP-LHPP digitation switches" **895** are provided, namely, one switch on either side of each of the eight partial product selectors **850**, as shown in Figure 33A. These are double throw switches, having a contact **893** connected to the partial product selector immediately to the left and a contact **894** connected to the selector immediately to the right of the switch. During the RHPP phase the switches **895** assume the position shown to connect the RH selector arms **875** to the associated numeral wheel control magnets **660**, and during the LHPP phase the switches are all shifted toward the right to connect the LH brush arm **880** to the next higher order numeral wheel magnets **660**, whereby the RH partial product digit selected by a given selector is entered into an associated order of the product register, and the LH partial product digit is entered into the next higher order of said register. The two digitation switches **895***a* and **895***b*, to the left of the I selector **850** and to the right of the VIII selector **850**, respectively, are connected on one side to the zero timing switch lead **830**. By means of this arrangement the lead **886**, for example, which transmits a timed impulse from the I partial product selector during the LHPP phase is adapted to transmit a zero impulse to its associated numeral wheel magnet during the RHPP phase; and similarly the lead **887** which transmits the selected impulse from the VIII selector to the associated magnet **660** during the RHPP phase, is adapted to transmit a zero impulse thereto when the switch **895***b* is shifted to the right during the LHPP phase.

The nine switches **895**, four of which are shown in Fig. 17, are situated transversely in the machine, intermediate the partial product selectors, as follows. The contacts **893** (Fig. 21) carried by arms **892** are mounted on and insulated from a stationary frame number **896** and are connected to their respective RHPP arms **875** by leads **803**; while the other contacts **894** are mounted on the stationary LHPP arms **880**. The shiftable arm of each switch **895** has two contacts which engage either of the contact **893** or **894**, each arm being mounted on a slide **898**, made of insulating material. A spring **899** (Fig. 17) pulls the slide toward the left at the beginning of the cycle so as to close the RHPP circuits, including, in each order, the arm 875 (Fig. 21), lead 803, contact 893, switch 895 (Fig. 33A) and ordinal leads such as lead 1056 to an electrical shift switch 1100, described hereinafter, which connects the foregoing circuit to the selected product numeral wheel control magnet 660.

The mechanism for actuating the above switches at the correct time in the cycle includes a cam 900 (Fig. 18) which is mounted on the main clutch shaft 410 and therefore rotates one revolution in the direction of the arrow during each cycle. During the first half cycle when the RHPP digitation is effected, a roller 901 merely rolls around the concentric low portion of the cam without effecting any movement to arm 902. Before the LHPP digitation phase is started, however, the cam rocks arm 902 downwardly and holds it there as the roller rides on the concentric raised portion of the cam. Arm 902 is secured to shaft 903 which has a second arm 904 fixed thereto. A link 905 is connected to arm 904 and is guided on a stationary stud 906 extending through an elongated hole 907, to allow the link to slide back and forth. A spring 908 normally maintains the link in the leftward position shown, but when the arm 902 is rocked down by cam 900 the link 905 is pulled toward the right. A camming surface 909 (Fig. 17) then engages a roller 910 to cam the slide 898 toward the right and to open the contacts 893 and to close the contacts 894. The RHPP digitation circuits are thus opened and the LHPP digitation circuits closed.

Solenoid control of multiplier setting

As explained hereinbefore, the multiplicand side of the partial product selectors are individually set by movement of the left factor arms 280 (Fig. 5) in accordance with the different digits of the multiplicand factor, while the multiplier selection switches, including the arms 365 (Fig. 2) are selectively set on the contacts 366 according to the movement of the right factor arms 280 in their respective orders. The multiplicand digits may be multiplied by only one multiplier digit at a time; therefore, the multiplier selection switches serve as a storage device for the multiplier factor and are utilized digit by digit, to control the multiplication. These multiplier switches 950, comprising the arms 365 and contacts 366, are shown diagrammatically in Fig. 33B but illustrated in greater detail in Fig. 2, there being one arm 365 and related mechanism for each numeral wheel in the right factor indicator 130 (Fig. 1), as indicated by Roman numerals in Fig. 33B.

The selection switches 950 are normally disconnected from the multiplier control circuit and it is necessary to effect movement of the brush 912 of the multiplier shift switch 1000 from the normally ineffective position in which it is shown in Fig. 33B onto one of the contacts 957, 958, et cetera, before the setting of any of the switches 950 may become effective to control the multiplication. This preliminary shift switch movement is accomplished by depression of the "X" or "Neg. X" key following the set up of the multiplicand factor, which depression closes a main multiplication control switch 951, thereby completing the circuit including the normally closed switch 952 connected to the main line 381 (Fig. 33B), lead 953, stationary contact 954, brush 912, a second stationary contact 955, the zero multiplier selection lead 920, a winding of the SC (shift clutch) solenoid 960, leads 1115 and 956, switch 951 to ground. Energization of the SC solenoid closes a motor switch 962 and the circuit through the electric motor 405, and also effects engagement of a shift clutch which advances the multiplier shift switch brush 912 one step counter-clockwise, to connect the I multiplier selection switch 950 into the multiplication control circuit described hereinafter.

The closure of the aforementioned main multiplication control switch 951 is effected by the following "X" and/or "Neg. X" key mechanism. A latch bar 930 (Fig. 8) is longitudinally slidable on the two studs 304 and 305 which support the "X" and "Neg. X" keys described hereinbefore. This latch is urged toward the left by a spring 931, tensioned between a stud 932 of the bar and the stationary stud 304, but normally prevented from such leftward movement by the ear 307 on the "X" key stem, which ear blocks a hook 934 on the latch bar when the key is in raised position. A second latch bar 935 is similarly mounted and has a hook 936 which is blocked by the ear 308 on the "Neg. X" key stem. When either of these keys is depressed its respective latch bar is free to move toward the left, whereupon the respective hook 934 or 936 moves over the top of the associated ear 307 or 308 and latches the respective key in depressed position. An insulation lug 938 is mounted on each bar so that the switch 951 is closed when either key is depressed. The bar 935 only, namely, the one associated with the "Neg. X" key, has a second lug 939 which, when moved toward the left, allows a negative multiplication switch 942 to close. Except for this latter switch and lug 939, both keys and related mechanism are the same, therefore, throughout the remainder of this description reference will be made only to the "X" key, and it may be assumed that the same operation will result from the depression of the "Neg. X" key except that closure of the switch 942 energizes the MR and CR solenoids which cause the product register to operate negatively and counter register to operate additively. This effects what is known in the art as "negative multiplication."

The closure of the switch 951 (Fig. 8) and the resulting energization of the SC solenoid (Fig. 33B) by the related circuit described immediately hereinbefore, causes engagement of the shift clutch as follows and thereby causes a preliminary shift cycle. The SC solenoid 960 (Fig. 2) is connected to the shift clutch control dog 961 by a link 963, so that energization of the solenoid pulls the clutch control dog downwardly to clutch engaging position. The shift clutch 965 is similar in construction to that of the main clutch hereinbefore described and comprises briefly a clutch dog 966 which, when released by the control dog 961, rocks into engagement with a drive disc 967, freely mounted on the shift clutch shaft 970. A gear 971 is integral with the drive disc and meshes with a gear 972 driven by the same gear 414 which drives the main clutch, shown in Fig. 13. A clutch disc 968 on which the pawl 966 is pivotally mounted is keyed to the shaft 970 and when the clutch is engaged the drive disc drives the clutch disc and shaft one revolution in a clockwise direction for each cycle of the clutch. The main clutch and shift clutch gear trains are such that the shift clutch is driven at approximately five times the speed of the main clutch, so that a shift cycle may be effected during the latter part of the main clutch cycle as will appear later.

A cam **975** (Fig. 7A) is mounted for rotation with the shift clutch shaft **970** and is adapted to rock a lever **976** counter-clockwise about a stationary shaft **977**, a spring **978** being provided to maintain the roller **979** (mounted on said lever) against the cam and to normalize the shift mechanism when the cam returns to its full cycle position shown. A link **980** connects the lower end of lever **976** to a pawl **981** (Fig. 7) to which the link is pivotally attached by means of a stud **982**. This pawl has an elongated hole **983** which is guided by a stud **984** fixed to the machine frame. When the shift clutch is engaged and link **980** is pulled upwardly, as viewed in Fig. 7A, or rearwardly with respect to the machine, the hook on pawl **981** rotates a ratchet wheel **990** counter-clockwise a distance slightly in excess of one tooth. The ratchet is held in the position one tooth advanced by a holding pawl **991**, while the pawl **981** returns to the position shown to engage the next tooth. The holding pawl is pivoted on the stationary stud **984** and urged clockwise by a spring **992**.

A gear **997** is fixed to the ratchet **990** and meshes with a second gear **998** which drives the brush **912**, said brush being shown diagrammatically in connection with the multiplier shift switch in Fig. 33A. The product shift switch **1100** (Fig. 33A) is connected to the multiplier shift switch by a suitable gear train described in the above mentioned Patent No. 2,467,419. The arrangement is such that this preliminary shift cycle moves the product shift switch to a position for causing entry of the product digits into the I, II, III, etc., orders of the product register, and the brush **912** is shifted from contact **955** (Fig. 33B) to contact **957** at the same time, so as to open the circuit to the SC solenoid and limit the shift clutch to one cycle of operation.

In the second position, which the brush **912** thus assumes, it partially completes an open circuit from the junction point **986** on the main line **381**, to contact strip **999** and from there through brush **912** and contact **957** to the open I switch **950**. The phrase "partially completed open circuit," or the equivalent, will be used hereinafter to describe the closure of one or more, but less than all the open switches in a circuit, which closures precede the final completion of that circuit.

Following depression of the "X" key, depression of the first numeral key in setting up the multiplier factor results in the positioning of the arm **365** (Fig. 33B) in the "I" order on the particular related contact **366** corresponding to the digital value of the numeral key depressed, which positioning then closes the above open circuit from the main line and the "I" arm **365** through the selected one of the parallel leads **921** to **929** and one of the windings **1016** of its respective multiplier solenoid **1001** to **1009**, and therefrom through the normally closed switch **916**, through the MC solenoid, lead **956**, and switch **951** to ground. If a zero is selected as the first multiplier digit the circuit is closed through the zero lead **920**, thereby reenergizing the solenoid **969** to effect a second shift cycle in the same manner as hereinbefore described for the first or preliminary shift cycle.

With reference to multiplication by a significant digit, the multiplier solenoids **1001** to **1009** first condition the multiplier setting mechanism for controlling the actual setting which is effected by the subsequent operation of the main clutch. Although the multiplier solenoids and the MC solenoid are in the same circuit and are energized at the same time, the multiplier solenoids have a much lighter load than the MC solenoid and are constructed to operate much faster, with the result that the MC solenoid will not operate to complete engagement of the main clutch until arm **365** has come to rest on the finally selected contact **366** and the selected multiplier solenoid has operated.

Although the multiplier solenoids operate faster than the MC solenoid, they are nevertheless made to operate slow enough to not release their armatures during the short interval of time the brush on arm **365** is in contact with any one of the contacts **366** as the brush sweeps across the contacts. The type of solenoid shown as the MC solenoid is inherently slower than that shown as the multiplier solenoid, but either or both may be modified in any of a number of different ways to operate within a considerable range of speed of response according to the particular requirements of each. These modifications may be made in accordance with a number of well known methods of increasing or decreasing the secondary losses, in order to lengthen the time for producing an operating magnetic flux. For instance, one method is to short circuit a selected portion of the winding turns of the solenoid coil.

In order to prevent overheating of the multiplier and MC solenoids (Fig. 33B), a cam **915** is adapted to open the switch **916** in the above described multiplier control circuit for the majority of the cycle. The identification *mc* is shown immediately above the cam and switch, and indicates here and where it appears elsewhere in the wiring diagram, that the cam and switches so identified are operated by the main clutch. During the period the current is off, the main clutch cannot disengage until the end of the cycle regardless of whether the main clutch solenoid is energized or not. Furthermore, the multiplier solenoids described immediately hereinafter, are of the polarized type which are normally held in ineffective position by permanent magnetism and are moved to effective setting position by an opposing electromagnetic field which is established in response to the closure of a control circuit such as the one described above. Once the permanent magnetism is thus overcome and a selected solenoid moves to setting position, it remains in the latter position until recocked by auxiliary means described hereinafter; therefore, the current for the multiplier solenoids may be cut off by the above mechanism at any time after the initial energization of the selected solenoid.

A typical multiplier solenoid is shown in section in Fig. 14, and includes a casing **1012**, made of any ferromagnetic alloy, which is riveted to or otherwise mounted on a machine frame plate **1013**. Two coils **1016** and **1017** are fitted into the casing **1012**, the first of which coils is used in multiplication and shown in Fig. 33B, while the second coil is used for other purposes. A permanent magnet **1018** is fixed to a solenoid plunger **1019**, which plunger is made of non-magnetic material such as austenitic stainless steel or beryllium copper. When the solenoid is deenergized, which is normally the case, the permanent magnet **1018** "sticks" to the casing **1012** and holds the plunger in the position shown. When a selected solenoid is energized, however, an opposing electromagnetic field is established which overcomes the permanent magnetic force, and forces the plunger and permanent magnet upwardly as viewed in Fig. 14. When any magnet such as the present permanent magnet 1018 is separated from another magnetic body, the effective force of the magnetic field is reduced rapidly as the separation increases; therefore after the current to the solenoid is cut off by the mechanism described hereinbefore, the force of the spring of the relay switch 1240 is sufficient to hold the plunger ejected, where it remains until it is recocked by the following mechanism.

A cone shaped member 1040 is riveted to the lower end of the plunger 1019, as viewed in Fig. 14, and when the plunger is ejected the cone moves upwardly until it abuts the frame plate 1013. A bail 1041 (Fig. 13) is mounted for free rocking movement on shaft 270 and is urged counter-clockwise by a spring 1042. An armature stem 1044 of an MSR (multiplier solenoid restore) solenoid 1045 is connected to the bail 1041 and limits the counter-clockwise movement of the bail to the position shown.

The bail 1041 includes two plates 1041*a* and 1041*b*, the first of which has a plurality of tips 1043 which normally lie beyond the periphery of the cones of the solenoids 1001 to 1005, inclusive, and 1007 and 1009, with enough clearance to permit free travel of the cone during ejection of the plunger; while the tips of the second plate lie in similar proximity to the periphery of the cones of the solenoids 1006 and 1008. The MSR solenoid is energized near the end of the main clutch cycle by means described immediately hereinafter, which energization pulls the plunger 1044 downwardly, as viewed in Fig. 13, and rocks the bail clockwise a limited amount. Upon such movement of the bail, the tips 1043 engage the cones 1040 which act as camming surfaces, as shown in Fig. 14, thereby causing any plunger 1019 which has been ejected to retract to ineffective position such as that in which the plunger 1019 is shown in Fig. 14. The engagement of the permanent magnet 1018 with the casing 1012 of the solenoid, causes the permanent magnet to "stick" to the casing with sufficient force to overcome the effect of the spring leaf of relay 1240 after the MSR solenoid is deenergized and the bail 1041 is returned to the position shown in Fig. 13 by spring 1042.

The MSR solenoid is energized as follows. As described hereinbefore the arm 617 of the timing switch 610 (Fig. 33B) is rotated one revolution during each main clutch cycle. Near the end of the cycle and after the actuation and transfer phases are completed, the brush 692 engages a contact 1046 and closes a circuit including the lead 989, connected to the main line, a lead 1047 passing through the MSR solenoid to contact 1046, and therefrom through the brush 692 and the contact ring 693 to ground. As soon as the brush 692 passes off the contact 1046 the circuit is opened and the MSR solenoid is deenergized and allows the spring 1042 (Fig. 13) to restore the bail 1041 and its plate so that the tips 1043 will be out of the way of the cone and allow reenergization of a selected multiplier solenoid at the beginning of the next cycle.

The multiplier solenoids are located on an arc about shafts 270 (Fig. 13) and are arranged in steps angularly spaced to correspond to the steps separating the blocking levers 284 (Fig. 5), but arranged in the reverse direction, i. e., the latter are adapted to block counter-clockwise movement of arm 260 in positions indicative of selected numeral values, while the solenoids 1001 to 1009 (Fig. 13) are arranged to similarly block clockwise movement of an arm 1020. These opposite movements correspond to the respective opposite movements of the elements 800 and 810 (Fig. 16) described hereinbefore.

The aforementioned arm 1020 (Fig. 13) is reciprocated once during each multiplication cycle by operation of the main clutch. A yieldable driving mechanism is provided between the main clutch and arm 1020, however, so that the arm may be blocked in any one of its positions by a corresponding multiplier solenoid, while the main clutch and camming mechanism, described immediately hereinafter, operate through a fixed cycle. A cam 775 (Fig. 8) is keyed to the main clutch shaft 419 and therefore makes one complete revolution in a clockwise direction for each cycle of the main clutch. A cam follower 1025 is freely mounted on the shaft 475 and is rocked downwardly by the cam early in the main clutch cycle. A substantially horizontal arm 1027, fixed to the shaft, overlies an ear 1026 formed on the cam follower and extends across the plane of the arm. A torsion spring 1028 is wound around the shaft 475 and urges the arm 1027 downwardly against the ear 1026. The downward movement of the cam follower is transmitted through the spring to arm 1027 and shaft 475. An arm 480 (Fig. 13) having gear teeth 481 which mesh with a gear 482, is fixed to the shaft 475 so that when the shaft is rocked counterclockwise by the aforementioned main clutch cam, the arm 480 is rocked downwardly and drives the gear 482 and shaft 270 clockwise. The arm 1020 which is keyed to the shaft 270 is therefore rocked clockwise until it is blocked by the projected plunger of one of the solenoids 1001–1009. The drive train including shaft 270, gears 482 and 481, arm 480, shaft 475 and arm 1027 (Fig. 8) is thus blocked, whereupon spring 1028 yields as the cam follower rocks its full extent.

From the foregoing then, the arm 1020 (Fig. 13) and shaft 270 are rocked to a position corresponding to the value of the multiplier solenoid selectively energized, and since the partial product selector discs 852 (Fig. 22) in each order of the selecting mechanism are keyed to the shaft 270, all of said discs are set to the position corresponding to the selected multiplier digit and held in set position for the greater part of the multiplication cycle. The multiplicand side of the partial product selectors 850 having previously been set, as explained hereinbefore, the partial product circuits are thus established for controlling the multiplication operation. The entire sequence of a typical multiplication operation will now be outlined by following through the sequence as applied to a typical example.

SEQUENCE OF MULTIPLICATION OPERATIONS

A simple problem has been chosen for illustrating a typical multiplication so as not to complicate the timing chart with the showing of the registration of a great number of partial products. It should be understood, however, that the machine is capable of determining and registering eight LH and eight RH partial product digits in a single multiplication cycle and performing the "transfer of tens" following the registration of each. In the following description of the problem 429×8 it will be sufficient, for the understanding of the multiplication sequence, to consider the registration in only two numeral wheels, namely, those in the II and III orders shown in Table B, below.

TABLE B

Multiplicand	4	2	9	----
Multiplier	8	----	----	----
	3	2	----	----
	----	1	6	----
	----	----	7	2
Registration	----	4	3	----
	I	II	III	IV

Denominational orders of product register illustrated in Fig. 34.

After the multiplicand factor —4—2—9— is set up in the I, II, and III partial product selectors **850** (Fig. 33A), the operator depresses the "X" key, which gives rise to the sequence of operations charted in Fig. 35 and described below:

Partial products selection—Fig. 35

Line 1, depression of the "X" key closes switch **951** (Fig. 33B) which;

Line 2, energizes the SC (shift clutch) solenoid which

Line 3, engages shift clutch,

(*a*) shift clutch moves brush **912** (Fig. 33B) off of contacts **954** and **955**, which opens the circuit to the SC solenoid, cutting the current off at the time designated as **1050** (Fig. 35) where the black (current on) portion of the curve on line 2 joins the white (current off) portion, thereby limiting the shift clutch to one cycle,

(*b*) brush **912** (Fig. 33B) moves onto contact **957**. Machine stops at end of shift clutch cycle until numeral key corresponding to first multiplier digit is depressed.

(*c*) product shift switch **1100** (Fig. 33A) shifts one step counterclockwise into position for entry of the LHPP and RHPP into the numeral wheels **500** per Table B.

Line 4, depression of the number 8 numeral key sets up the first multiplier digit and:

Line 5, releases arm **365** of the I switch **950** and sets it on number 8 contact **366** (Fig. 33B),

(*a*) this completes the circuit through the number 8 multiplier solenoid **1008** and through the MC solenoid. (The dotted line **1051** indicates that line 5 starts lines 7 and 8.)

Line 7 number 8 solenoid **1008** is energized and its plunger ejected.

Line 8 MC solenoid is energized.

Line 9, main clutch starts its first cycle as result of line 8, and:

Line 10, cam **775** (Fig. 8) drives partial product arm **1020** and shaft **270** (Fig. 13) until they are blocked by the plunger of the number 8 multiplier solenoid **1008**.

(*a*) shaft **270** sets multiplier sides of all the partial product selectors **850** (Figs. 22 and 33A) to number 8 position during the first part (illustrated as being the first 30°) of the main clutch cycle.

(*b*) cam **915** (Fig. 33B), driven by the main clutch, cuts current off at **1062** (Lines 7 and 8, Fig. 35)

Line 11, arm **617** of timing switch **610** (Fig. 33B) is also driven by the main clutch.

(*a*) brush **692** (Fig. 33B) first engages the TC (transfer conditioning) contact **720** which,

Line 12 energizes the PT (product transfer) solenoid **722** (Fig. 33B) which:

closes switch **712** in each order (lines 15 and 20, Fig. 35).

RHPP digitation phase

Line 13, the timing switch contact **646** is engaged by brush **692** (Fig. 33B), which:

Line 14, energizes the PCE (product clutch engaging) solenoid **601** (Fig. 33B) which:

Lines 17 and 22, rocks the numeral wheel clutch dogs in the various denominational orders to clutch engaging position which:

Lines 18 and 23, releases clutch pawls to engage the driving shaft **551** which:

Lines 19 and 24, starts driving the numeral wheels at the points designated "start."

The number 2 and number 6 RH contacts (see Fig. 35, line 11, and Fig. 33A, and also Table B above) are switched into the RH digitation circuits from the timing switch to the II and III numeral wheel magnets **660**, respectively, by the setting of the partial product selectors **850**, which also switches in to the LH digitation circuits to these respective magnets the number 1 and number 7 LH contacts respectively; therefore, the number 2 contact (line 11), first:

Line 21, energizes the II numeral wheel magnet **660** which:

Line 22, trips the dog **608** in the II order at **1052** which:

Line 23, rocks the clutch pawls out of engagement at **1053** whereupon:

Line 24, the II numeral wheel stops at the point designated "stop" after having advanced from 0 to 2.

The number 6 contact (line 11) which is connected to the III magnet **660** by the II partial product selector **850** (Fig. 33A) and the product shift switch next:

Line 16, energizes the III magnet **660** at **1054** which:

Line 17, trips the dog **608** in the III order which:

Line 18, rocks the pawls out of engagement,

Line 19, whereupon the III numeral wheel stops after having advanced from 0 to 6.

RHPP transfer phase

Switches **685** (Fig. 33A) are shifted to the transfer position shown before the transfer phase starts.

Since the numeral wheels did not pass from 9 to 0, the switches **712** (lines 15 and 20) remain closed and:

when the brush **692** (Fig. 33B) engages the T (transfer) contact **791** (line 11):

Lines 16 and 21, the magnets **660** are energized at **1055** and **1056** to disable the numeral wheel clutch control dogs **608** so that when brush **692** engages—

Line 13, the contact **790**,

Line 14, thereby causing energization of the clutch engaging solenoid **601** then this operation is ineffective,

Lines 17 and 22, and therefore the clutch dogs **608** are not rocked to clutch engaging position and no transfer is effected.

LHPP digitation phase

Before this phase starts, the switches **895** (Fig. 33A) are shifted to the right from the position shown, by mechanism explained hereinbefore, so as to connect the partial product selectors **850** to the circuit through the next higher order numeral wheel selection magnets **660**; as for example, the multiplication 2×8 (see Table B) is set up in the II partial product selector 850, therefore during the RHPP digitation phase, this selector is connected to the magnet 660 controlling the III numeral wheels for effecting entry of the 6 therein, and during the LHPP phase this selector is connected to the magnet 660 controlling the II numeral wheel for entry of the 1 therein.

This LHPP phase is substantially the same as the RHPP phase except for the numeral wheel registration, and may be followed in Fig. 34 without detailed comment. The principal difference is that III numeral wheel (line 19, Fig. 35) passes from 9 to 0 at 1058, and—

LHPP transfer phase

Line 15, opens its associated switch 712 which controls the entry of a transfer increment into the II numeral wheel as follows: When the timing switch brush engages the T contact 793 (line 11) the circuit to the II magnet 660 is open so that:

Line 21, the II magnet 660 is not energized and therefore:

Line 14, the operation of the clutch engaging solenoid 601 at 1059, is effective to:

Line 22, rock to clutch engaging position the clutch dog 608 (Fig. 2) in the II order, which is controlled by the III order transfer switch 712, but it is so rocked for only that interval of time to allow:

Line 24, the numeral wheel to advance one step from 3 to 4.

Ordinal shift in multiplication

In multiplication by a multidigit multiplier, such as in the problem 429×867, shown schematically in Fig. 34, the operator first sets up the multiplicand 429, depresses the "X" key, and then sets up the multiplier 867. The machine normally starts multiplying immediately after the set-up of the first multiplier digit "8" and while "429" is being multiplied by "8," the operator depresses the number "6" key for setting up the second multiplier digit. This second depression would normally occur at a time such as that shown by line 4 (Fig. 35) and effects setting of the II switch 950 (Fig. 35, line 5, and Fig. 33B) to the number "6" position. Before the multiplication can start in the second order, it is necessary to shift the multiplier shift switch 1000 one step so as to connect the II multiplier set-up switch 950 into the circuit controlling the multiplication operation, and to shift the product shift switch 1100 (Fig. 33A) otherwise known as a column shift switch one step for connecting the partial product selectors to respective lower orders of the product register.

This shifting is shown schematically in Fig. 34 where the Roman numerals (line 1) specify the denominational orders of the partial product selectors 850 (lines 2 and 3) and correspond to the selectors of like character in Fig. 33A. In the instant example, the multiplicand sides of the selectors (disc 851, Fig. 22) of the I, II, III orders are set at "429" (line 2) and all the multiplier sides thereof (disc 852, Fig. 22) are set to the position corresponding to the first multiplier digit "8" (line 3) by the mechanism described hereinbefore, so as to select the corresponding partial products shown in lines 4 to 6, inclusive. The rectangle 1100 (line 7) schematically represents the product shift switch of the same number in Fig. 33A, and after the preliminary shift thereof into its first operative position as mentioned hereinbefore, it conditions the machine for entry of the product "3432" into the I, II, III, and IV denominational orders (line 26) of the product register 100 (line 27). The schematic illustrations in lines 26 and 27 correspond to the product register of the same number in Fig. 33A, and the dotted circles in lines 8 and 17 represent the same product numeral wheels which fall in the respective vertical columns, and the numerals within the corresponding dotted circles show the registrations in the same numeral wheels at different stages in the solution of the problem. Similarly, the rectangle 1000 (line 7) represents the multiplier shift switch of the same number in Fig. 33B, which conditions the machine for entry of the first multiplier digit "8" into the I order (line 28) of the multiplier register 120 (line 29).

Following the digitation phases and concurrent with the second transfer phase of the first multiplication cycle, the product shift switch 1100 is shifted one step toward the right to its 1100′ position as shown by the arrow in line 16 so that the product digits of the second multiplication (line 15) will be entered into the four numeral wheels one order respectively to the right of those into which the first product digits were entered, i. e., into the II, III, IV, and V orders (line 26) instead of the I, II, III, and IV orders, respectively. During the second multiplication cycle the multiplicand sides of the partial product selectors remain set at "4 2 9" (line 10) and the multiplier sides thereof are all reset to correspond to the second multiplier digit "6" (line 11). The resulting product digits "2 5 7 4" are therefore entered into those numeral wheels (line 17) which are directly under the numbers in the rectangle in its 1100′ position (line 16), which added to the product of the first multiplication advance the product numeral wheels to the positions shown in line 17 after the second cycle is complete. The multiplier shift switch is similarly shifted to its 1000′ position, shown in line 16, simultaneously with the shift of the product shift switch and effects entry of the second multiplier digit in the II order of the multiplier register as shown in lines 18 and 29. Near the end of the second multiplication cycle the one step shifts shown schematically on line 25 occur, so as to effect the entry of the product of the multiplicand factor (line 19) and the third multiplier digit 7 (line 20) into the III, IV, V, and VI orders of the product register, and the 7 (line 25) into the III order of the multiplier register. At the end of the multiplication problem the product numeral wheels thus stand at "3 7 1 9 4 3" (line 27) and the multiplier register stands at "8 6 7" (line 29).

The shifting of the product and multiplier shift switches, referred to above, is initiated during the latter part of the main clutch cycle by a cam 1070 (Fig. 33B) which is driven by the main clutch and adapted to close a switch 1071 at the time designated as 1072 (Fig. 35, line 2). This switch closes the circuit including the connection from the main line 381 (Fig. 33B) to the contacts 1073, lead 1074 (Fig. 33B), through the SC (shift clutch) solenoid, lead 956, switch 951 to ground, thus, with reference to Fig. 35:

Line 2, the SC solenoid effects engagement of:

Line 3, the shift clutch at the time designated 1075.

Line 4, During the multiplication cycle shown in Fig. 35 the operator would normally depress the number 6 numeral key at approximately the time designated 1076.

Line 5, which would set the II switch **950** (Fig. 33B) to the position corresponding to the second multiplier digit. The II switch **950** is out of circuit, however, until multiplier shift switch brush **912** is shifted onto contact **958** (Fig. 33B).

Line 6, The MSR solenoid is energized at the time designated **1063** by movement of the brush **692** (Fig. 33B) onto the contact **1046**, described hereinbefore, which causes:

Line 7, restoration of the number 8 multiplier solenoid plunger.

The multiplier shift switch brush **912** is shifted one step counter-clockwise (Fig. 33B) during the above described shift clutch cycle and as soon as the brush **912** reaches the contact **958** to switch the II selection switch **950** into circuit, the switch **916** also closes, whereby

Line 7, the number 6 multiplier solenoid is energized at **1064**.

Line 8, Before the main clutch can disengage, the MC solenoid is reenergized by closure of the multiplication control circuit including the second shift switch contact **958** (Fig. 33B) and the II multiplier selection switch **950** described above. The MC solenoid energization is shown by the black portion of line 8 marked "on" so that:

Line 9, the second main clutch cycle continues immediately after the first cycle without interruption, thus repeating the multiplication operations as described in connection with Fig. 34.

From lines 3, 8, and 9 (Fig. 35), described above, it will be noted that the shifting operation is completed during the latter part of the main clutch cycle and the multiplication control mechanism is in condition to control multiplication by the next multiplier digit. Therefore, the main clutch operates continuously throughout multiplication by successive multiplier digits without interruption by the shifting mechanism.

The machine will stop operating in multiplication when an unset multiplier selection switch **950** (Fig. 33B) is thrown into circuit by the brush **912**, as for example if the multiplier factor includes three digits, the machine will stop when the unset IV switch **950** is thrown into circuit. This unset selection switch opens the circuit to the MC solenoid and thus prevents restart of the next multiplication cycle. If an eight digit multiplier is set up, however, the machine will stop when the multiplier shift switch shifts beyond the VIII position. Under such conditions the movement of the brush **912** (Fig. 33B) onto the contact **1078** closes the circuit from the contact **999** (which is connected to the main line as previously described) to lead **1079**, through an XR (X-Neg. X key release) solenoid **1080**, lead **956**, switch **951** to ground. Energization of the XR solenoid (Fig. 8) ejects its plunger **1081** which rocks a lever **1087** clockwise. An ear **1089** at the top of lever **1087** slides the lock-bars **930** and **935** toward the right to release the "X" or "Neg. X" keys. The return of the lock-bar then allows the main multiplication switch **951** to open the multiplication circuit. This switch **951** also opens the circuit through the XR solenoid, and a spring **1088** then restores lever **1087** to the position shown. The "X" or "Neg. X" key may be released if the multiplication is stopped before the multiplier shift switch reaches its end position, such release being effected by the operation of the clear key as fully described in Patent No. 2,467,419.

SHIFTING MECHANISM

Normally the product and multiplier shift switches shift together, however, in certain operations not disclosed herein, the switches are shifted relative to each other and for this reason said switches are separated and independently driven.

The product shift switch **1100** is diagrammatically illustrated in Fig. 33A and is also represented schematically in Fig. 35, its mechanical construction being fully described in the aforementioned Patent No. 2,467,419.

In Fig. 33A this switch is shown with arrows representing the stationary brushes and with circles and the arcuate strip **1121** representing the movable contacts. The eighteen stationary brushes **1105** are respectively connected to the control magnets **660** for the eighteen product numeral wheels (Fig. 1) by means of individual leads and digitation-transfer switches, such as lead **1130** (Fig. 33A) and switch **685** connected to the 00 magnet **660**. The nine movable contacts **1120** are connected to the nine LHPP-RHPP digitation switches **895** described hereinbefore, for making connections selectively to the eight partial product selectors **850**. When the switch **1100** is in the position shown, the connections are such that the 0 to VIII product numeral wheels **500** are conditioned to receive the product. It will be recalled, however, that there is a preliminary shift prior to actual multiplication which shifts the switch so that the entries will be made in the I to IX orders of the product register. Subsequent shifting operations between multiplying cycles move the contacts **1120** one step counter-clockwise, each shift, to positions successively adapted for entering the products into the II to X, III to XI product numeral wheels, etc., after each of the shifting steps following multiplication by the successive multiplier digits.

It will be recalled that in order to prevent engagement of a numeral wheel clutch at the start of a digitation period, its magnet **660** must be energized by a zero impulse at the engagement period. Therefore, all off-board product numeral wheel magnets i. e., those magnets which are not connected to the partial product selectors, receive a zero impulse. The contact strip **1121** (Fig. 33A) is connected to the zero timing switch lead **830** and receives a zero impulse at the start of each LHPP and RHPP digitation phase. The stationary contacts **1105**, which are not connected to the nine contacts **1120**, are positioned on the contact strip **1121** and transmit this zero impulse to all off-board magnets and thus prevent engagement of their respective off-board numeral wheel clutches.

Multiplier and counter shift switches

The multiplier shift switch **1000** (Fig. 33B) and the counter shift switch **1140** (Fig. 33A) always shift together and could as well be a single switch except for design reasons. Although shown separately in the wiring diagram they are mounted in a common casing, and are geared in a direct ratio.

The mechanical construction of these switches is fully disclosed in the aforementioned Patent No. 2,467,419.

The counter shift switch is related to the counter register in very much the same way the product shift switch is related to the product register, namely, it selects which order of the register is to be controlled for actuation and supplies zero impulses to the off-board numeral wheel magnets. The counter register registers the multiplier in multiplication, as well as the quotient in division: therefore, its operation will be described at this time in its relation to multiplication. Reviewing first the function the counter register in registering the multiplier, with reference to Fig. 1: when the numeral keys are depressed during the selection of the multiplier factor the multiplier digits are selectively entered into the right factor indicator 130, and during the multiplication operation when the partial product of each successive multiplier digit is registered in the product register 100, that multiplier digit is concurrently registered in the counter register 120. By means of this arrangement the clearance of the counter register may be disabled in a series of multiplications whereby the multipliers may be accumulated in register 120 while the individual multiplier factors may be entered and checked in the right factor indicator.

When the shaft 270 (Figs. 13 and 33A) is successively set under control of the multiplier solenoids corresponding to the successive multiplier digits selected, a counter selection switch 1160 (Fig. 33B) is set accordingly. This switch includes a plurality of stationary contacts 1161 representative of the multiplier digits 1 to 8 (see also Fig. 13), and also includes a brush 1162 carried by an arm 1164, which is insulated from but fixed to the same shaft 270 which sets the multiplier sides of the partial product selectors. The number 1 to number 8 contacts 1161 are connected to the number 1 to number 8 timing switch leads 830 to 838, and the brush 1162 is connected to the counter shift switch 1140 (Fig. 33A) by a lead 1163 and therefrom to a selective counter numeral wheel control magnet 660–C. It will be noted that there is no number "9" contact on switch 1160. This is because no electrical control means are required to effect a nine entry since all the numeral wheel clutches are disengaged after nine increments of movement, by release of the clutch engaging mechanism explained hereinbefore in the section headed "Registers." The construction of the counter register shown at the bottom of Figure 33A and its control and switching mechanism is the same as that of the corresponding parts related to the product register, and reference may be had to the latter for a detailed description of the counter numeral wheel actuating mechanism. Briefly, the counter numeral wheels are actuated by individual ratchet clutches, one of which clutches is engaged at a fixed time at the beginning of the actuating cycle and is disengaged at a selected time to stop the numeral wheel after advancing a number of positions corresponding to the multiplier digit selected.

The counter shift switch 1140 (Fig. 33A) is shown in its initial position, from which position it is shifted one step clockwise during the preliminary shift cycle preceding multiplication, as explained hereinbefore in the description of line 2 (Fig. 35). This positions the contact 1149 on the brush 1166 connected to the I counter magnet 66–C, so that if, for example the first multiplier digit is a "5," the brush 1162 (Fig. 33B) is set on the number "5" contact 1161 and a number "5" impulse is transmitted to the I control magnet over the circuit including the number "5" timing switch contact 618, leads 835, and 1165, the number "5" contact 1161, brush 1162, lead 1163, contact 1149, and brush 1166, lead 1167, switch 685 through the I magnet to the lead 1168 and leads 652 and 646 connected to the main line. The counter shift switch contact 1150 is connected to the zero lead 830 and transmits a zero impulse to all other counter magnets for preventing engagement of their respective clutches.

The actuation of the counter register occurs during the RHPP digitation phase, and during the LHPP digitation phase it is disabled by operation of the cam 900 (Fig. 33B) which is driven by the main clutch and opens a switch 742 in the circuit through the CT solenoid, and also a switch 1169 in the circuit through the counter clutch engaging CCE solenoid. This cam 900 is shown in Fig. 18 and as explained hereinbefore, shifts the bar 898 toward the right (Fig. 17) during the LHPP phase, thereby opening switches 742 and 1169.

I claim:

1. In a partial product multiplying mechanism for calculating machines; the combination of, factor selecting mechanism including, a multiplicand factor member and a multiplier factor member each movable to a plurality of positions to establish in accordance with an approximate logarithmic scale a mechanical representation of the factor digits zero to nine, the spacings of said positions being composed of whole multiples of a given increment of distance, a plurality of operating elements mounted on one of said members and located thereon at approximately logarithmic spacings composed of whole multiples of said given increment, said elements being arranged in groups and corresponding respectively to the partial product digits of the multiplication table, each element of said group corresponding to a different partial product digit, cooperating elements mounted on the other one of said members, with means for moving said two factor members each individually to the one of said positions corresponding to a respective multiplicand or multiplier factor digit to bring said cooperating elements into operative relationship with one of said groups of operating elements, means operable in response to movement of either of said members to a position thereof which corresponds to a five factor digit to render said cooperating elements effective to select one of the operating elements of said group; and means operable in response to movement of either of said members to a position corresponding to a seven factor digit to render said cooperating elements effective to select another one of the operating elements of said group.

2. A partial product multiplying mechanism for calculating machines comprising; a partial product selection member having a plurality of positions corresponding to the digits one to nine inclusive, said positions being located according to a scale in which the divisions thereof are composed of whole multiples of a given increment, factor setting mechanism operable to set said member to the one of said positions which corresponds to a selected factor digit, a plurality of elements which represent respective partial product digits of the multiplication table and which are located on said member in groups segregated in accordance with the occurrence of certain factor digits, a second partial product selection member having a plurality of positions corresponding to the digits one to nine inclusive, said positions being located according to a scale in which the divisions thereof are composed of whole multiples of the same given increment, second factor setting mechanism operable to set the second member at the one of said positions

which corresponds to a selected digit of a second factor, a device carried by said second member and moved thereby into selected relation to the elements located on the first member, and means operable under control of either of said factor setting mechanisms upon setting of either respective member to a position corresponding to a certain factor digit to operatively associate said device with the elements of the corresponding one of said groups.

3. In a calculating machine having a product register and partial product multiplying mechanism comprising, a partial product selection member having a plurality of positions corresponding to the digits one to nine inclusive, said positions being located according to a scale in which the divisions thereof are composed of whole multiples of a given increment, factor setting mechanism operable to set said member to one of said positions which corresponds to a selected factor digit, a plurality of elements which represent respective partial product digits of the multiplication table and which are located on said member in groups segregated in accordance with the occurrence of certain factor digits, means controlled by each element to cause registration in said register of the partial product digit corresponding to said element, a second partial product selection member having a plurality of positions corresponding to the digits one to nine inclusive, said positions being located according to a scale in which the divisions thereof are composed of whole multiples of the same given increment, a second factor setting mechanism operable to set the second member at the one of said positions which corresponds to a selected digit of a second factor, a device movable by said second member into selective relation to the elements located on the first member, and means operable under control of either of said factor setting mechanisms upon setting of either respective member to a position corresponding to a certain factor digit to enable a respective one of said groups of elements and to disable the other groups of elements.

4. In a calculating machine having a product register and means for registering therein the product of a multiplicand digit times a multiplier digit comprising, a multiplier selecting mechanism including a member movable to a plurality of positions representative of different multiplier digits, a multiplicand member movable to a plurality of positions representative of different multiplicand digits, a plurality of contacts mounted for movement with one of said members and a brush cooperating with said contacts and mounted for movement with the other one of said members, said plurality of contacts being arranged in approximate logarithmic relation relative to each other and in groups segregating the contacts which conflict due to the departure from true logarithmic relation of certain of the contacts; in combination with setting means operable to move said brush onto a contact in one of said groups in response to movement of one of said selection members to a position corresponding to a certain respective multiplicand or multiplier digit and to move said brush onto a contact in another one of said groups in response to movement of one of said selection members to a positive corresponding to another multiplicand or multiplier digit.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,236,795	Furber	Apr. 1, 1941
2,432,569	Gleser et al.	Dec. 16, 1947

FOREIGN PATENTS

Number	Country	Date
423,189	Germany	Dec. 24, 1925