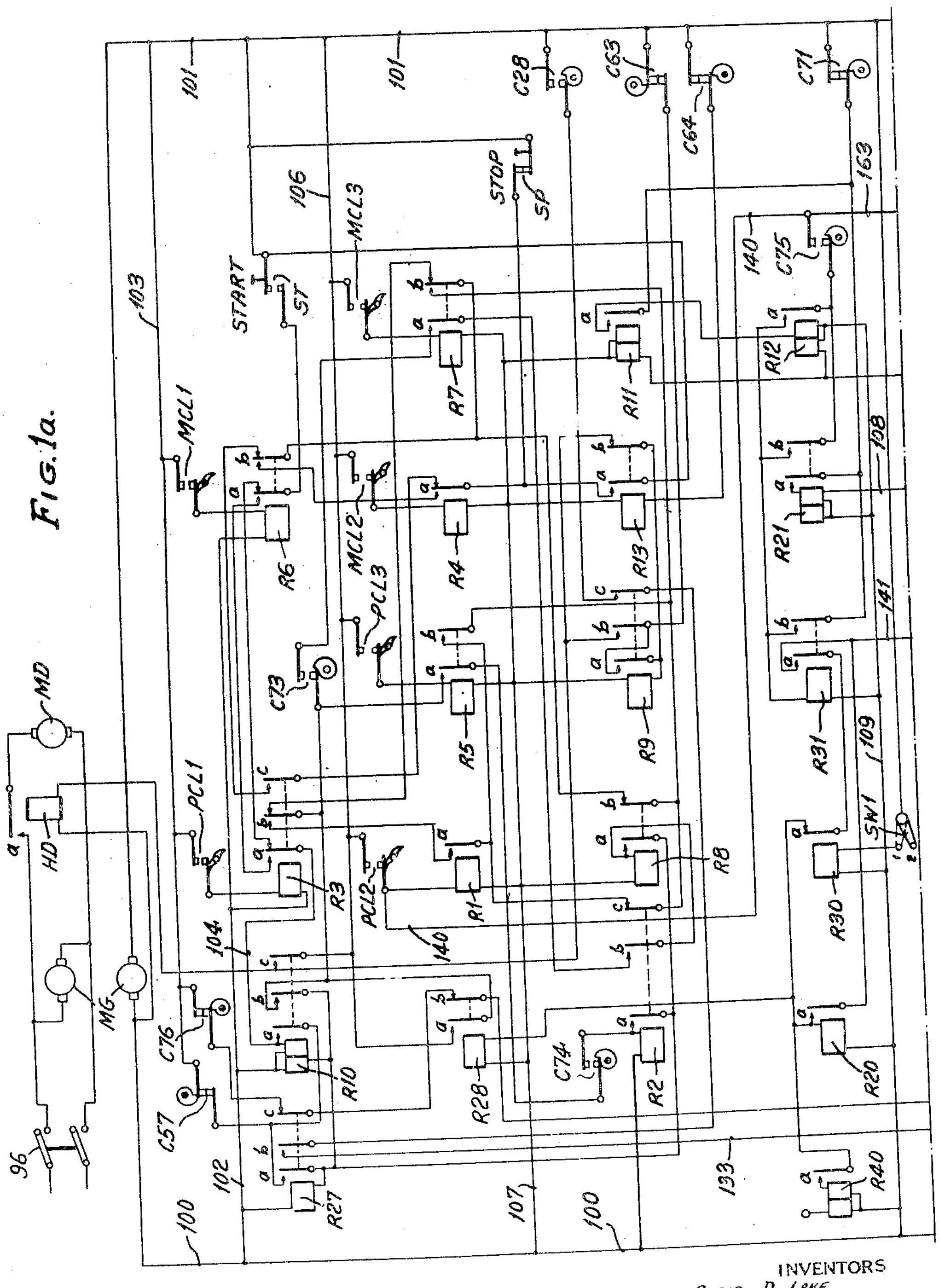
Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 1

FIG. 1a.



INVENTORS
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

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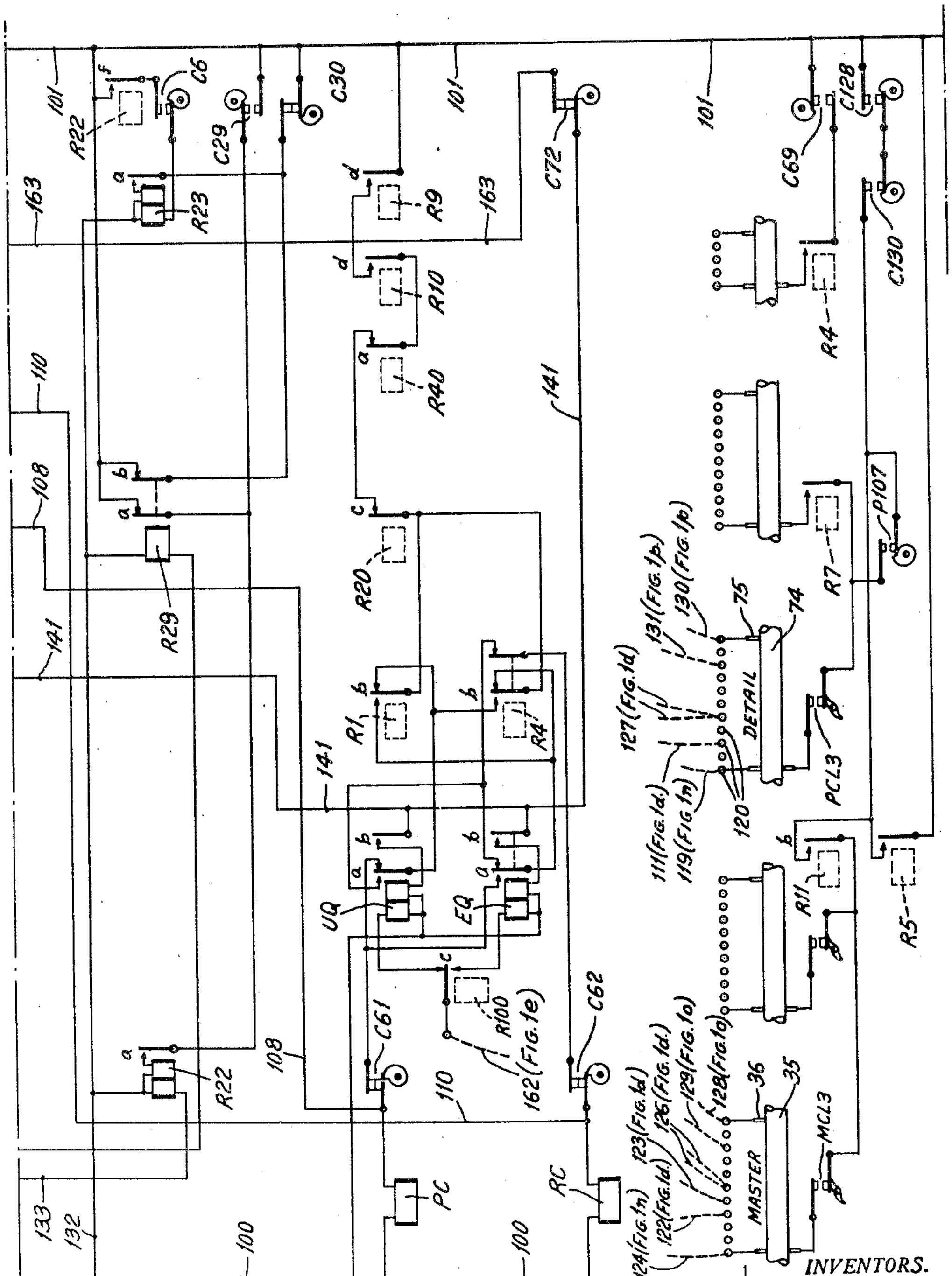


FIG. 1b.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON

BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 3

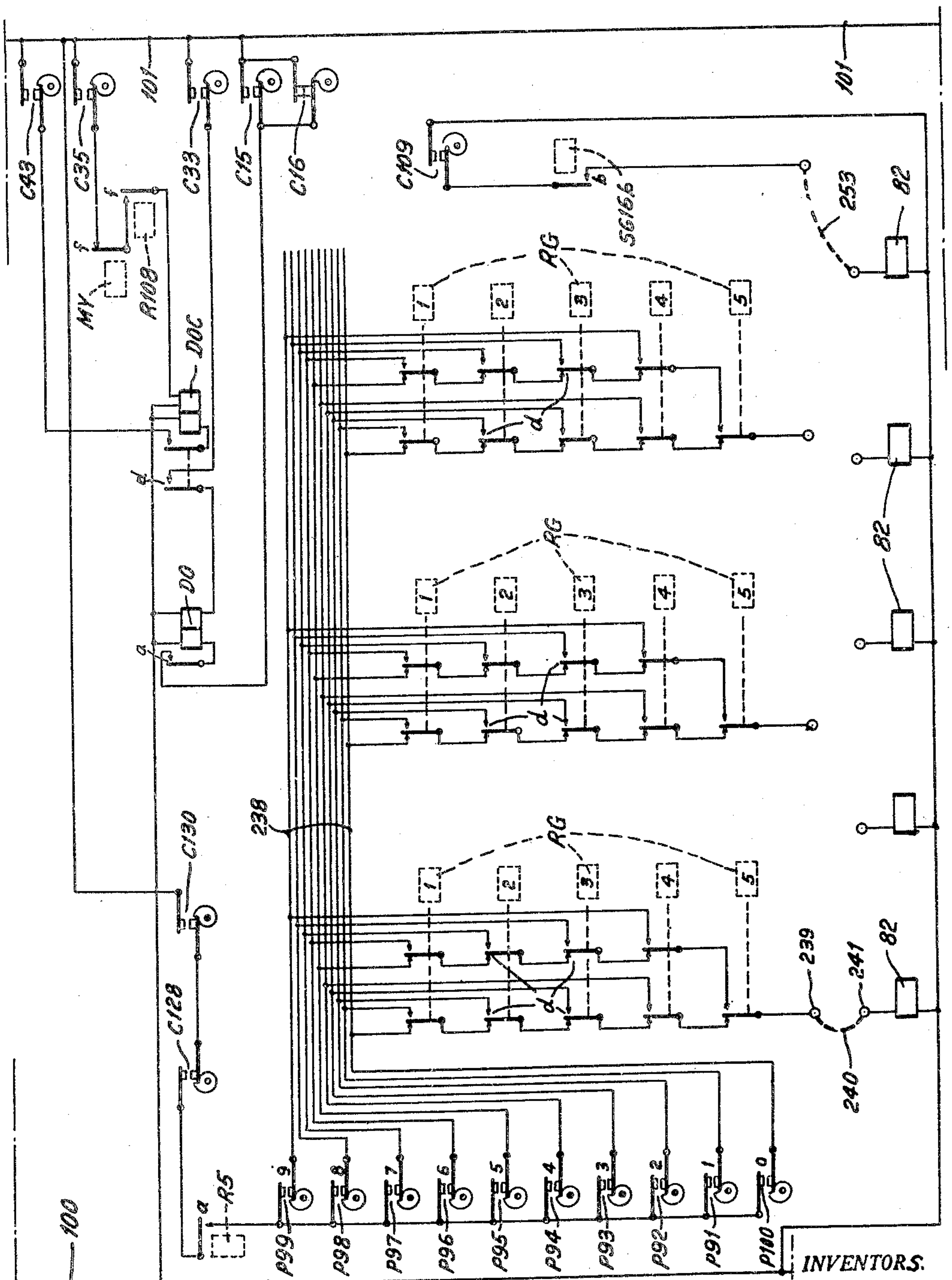


FIG. 1C.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 4

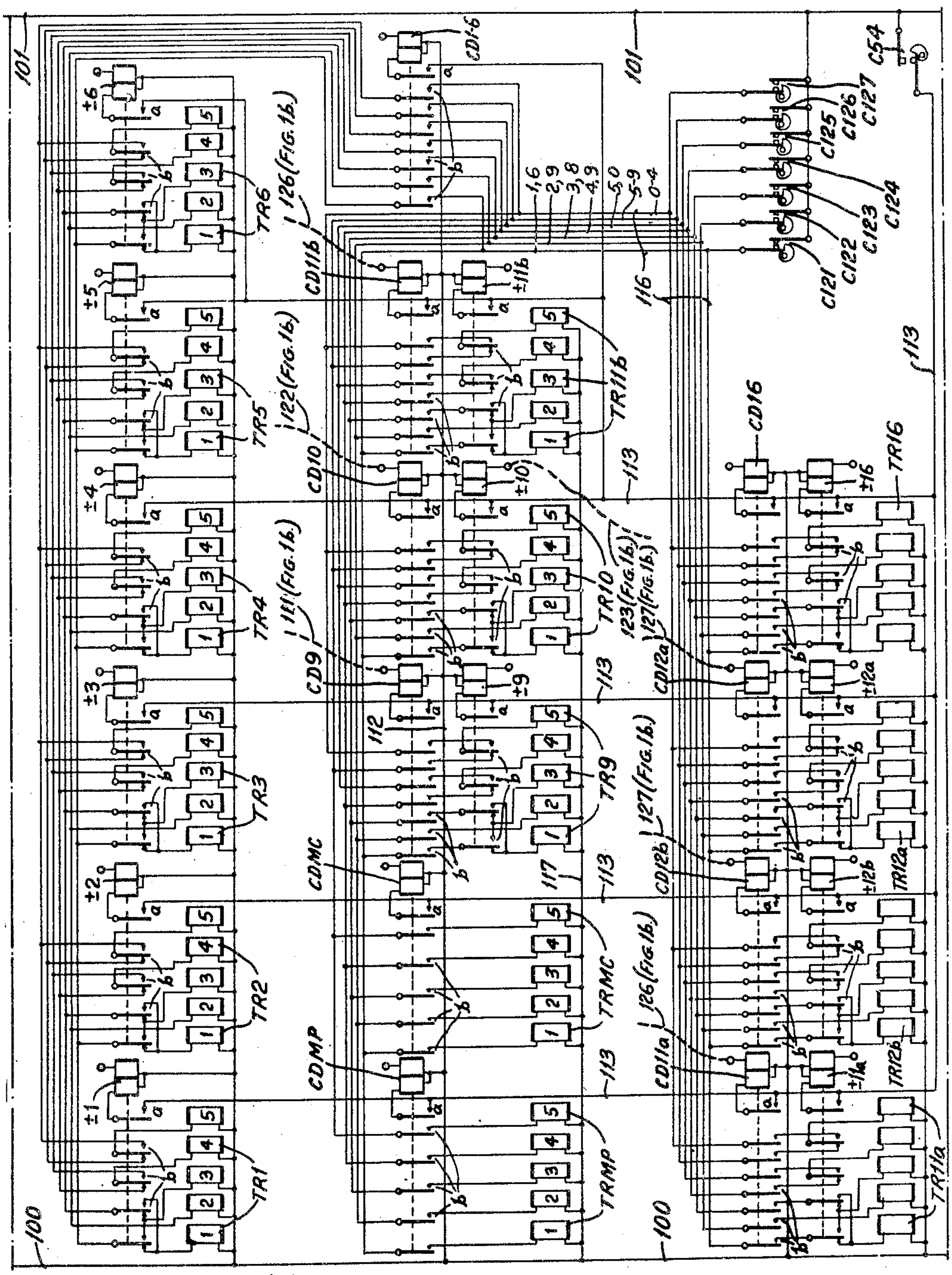
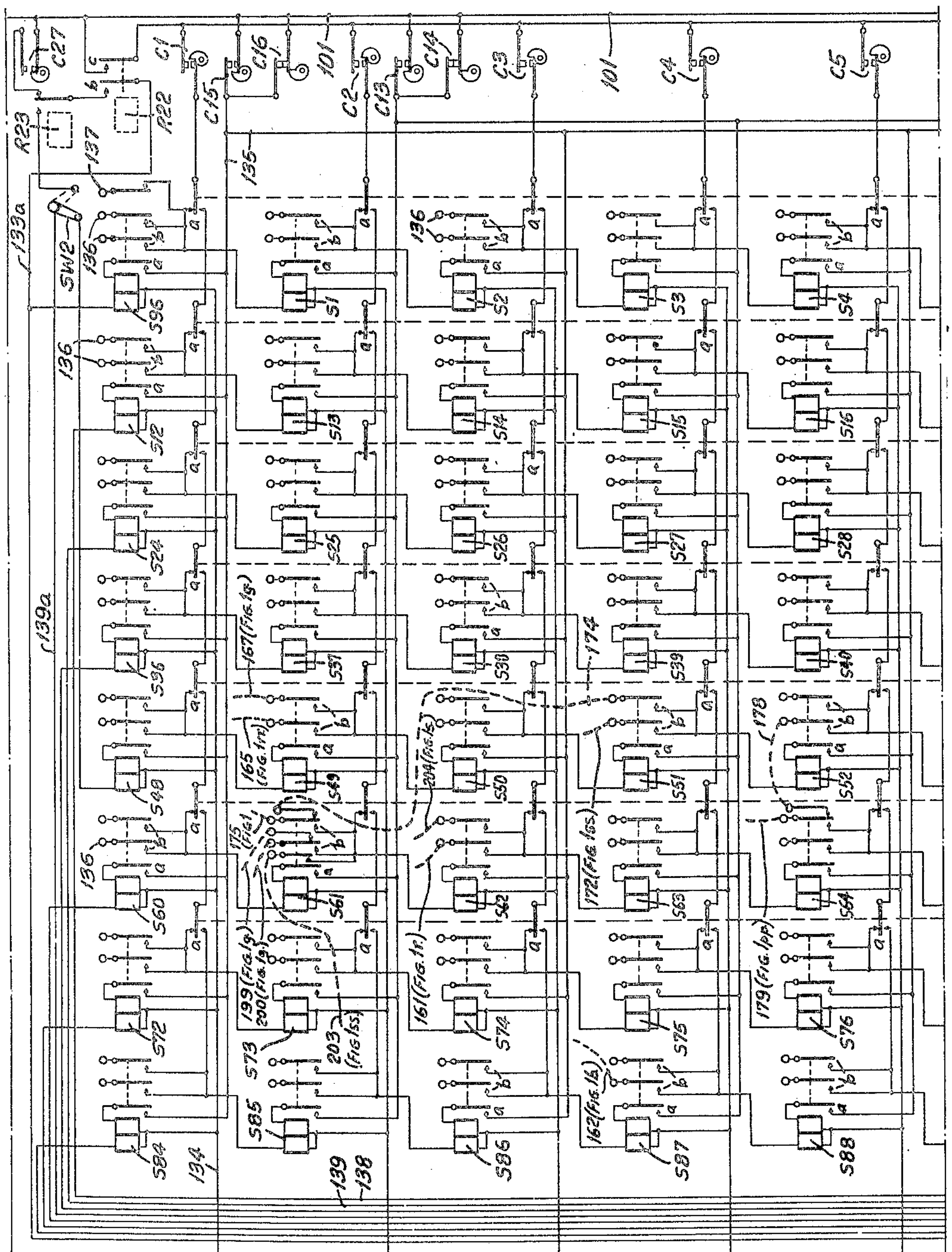


FIG. 1d.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY



100

FIG. 1e.

INVENTORS
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

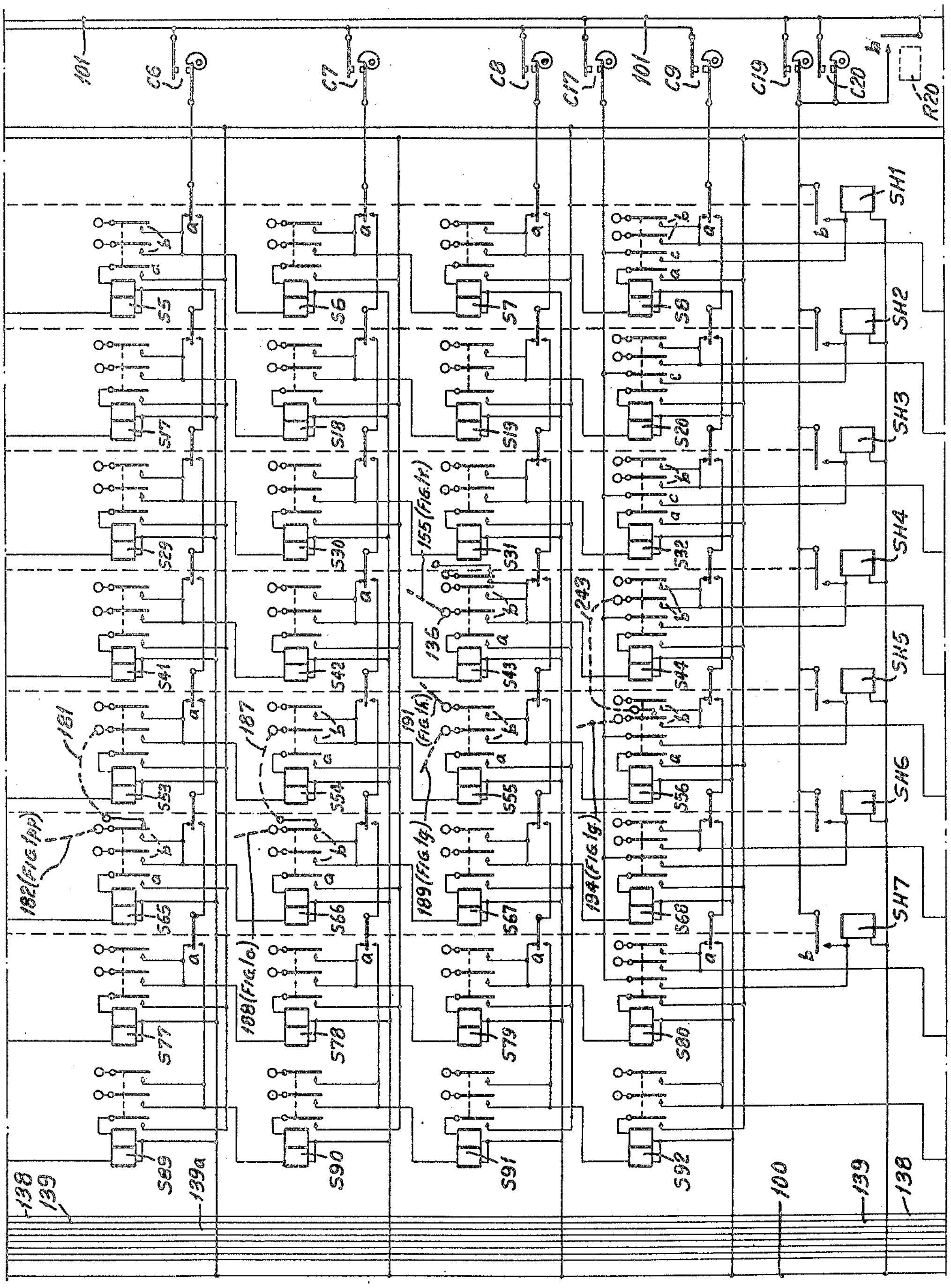


FIG. 1f.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

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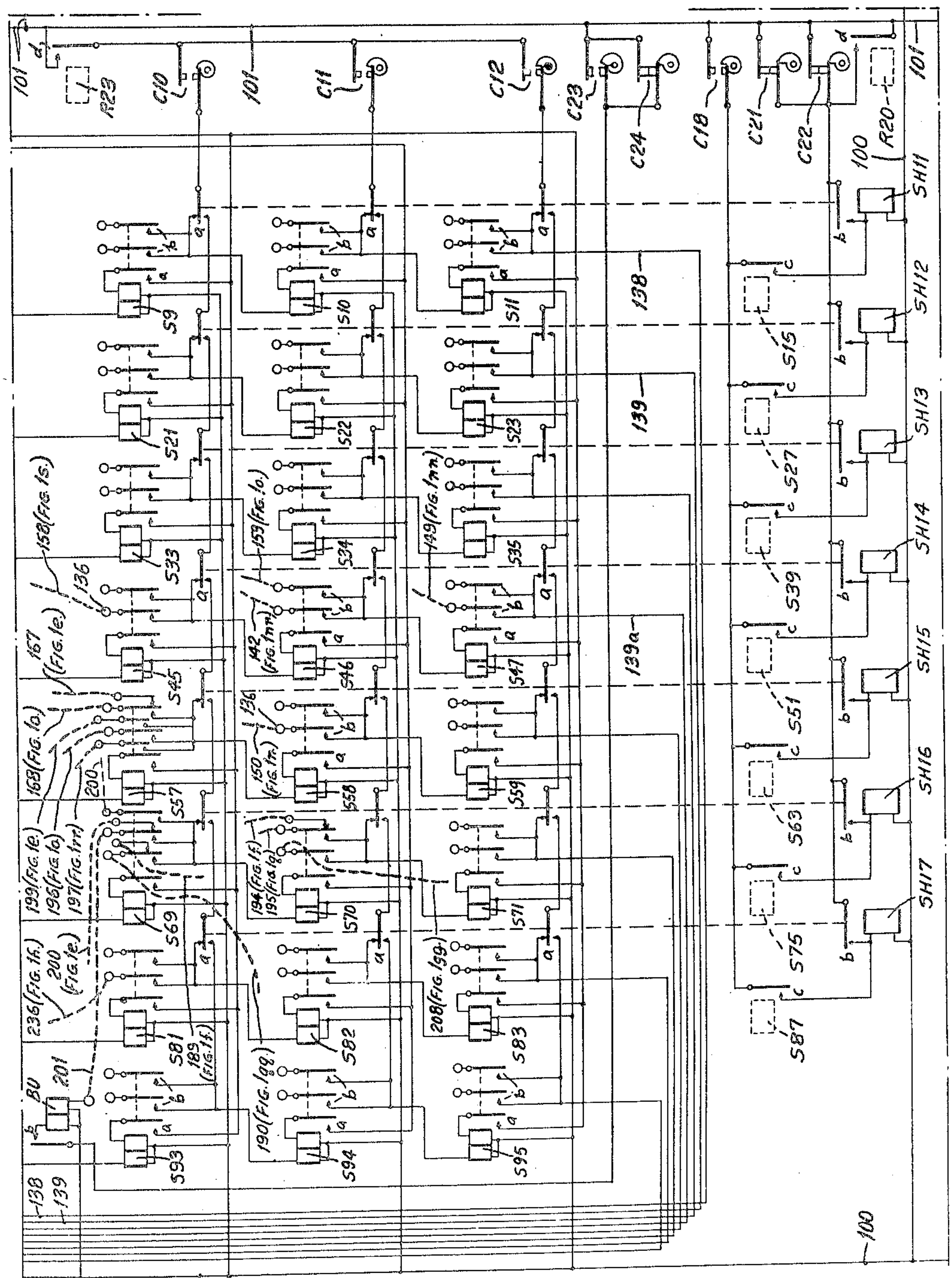

FIG. 1g

INVENTORS
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

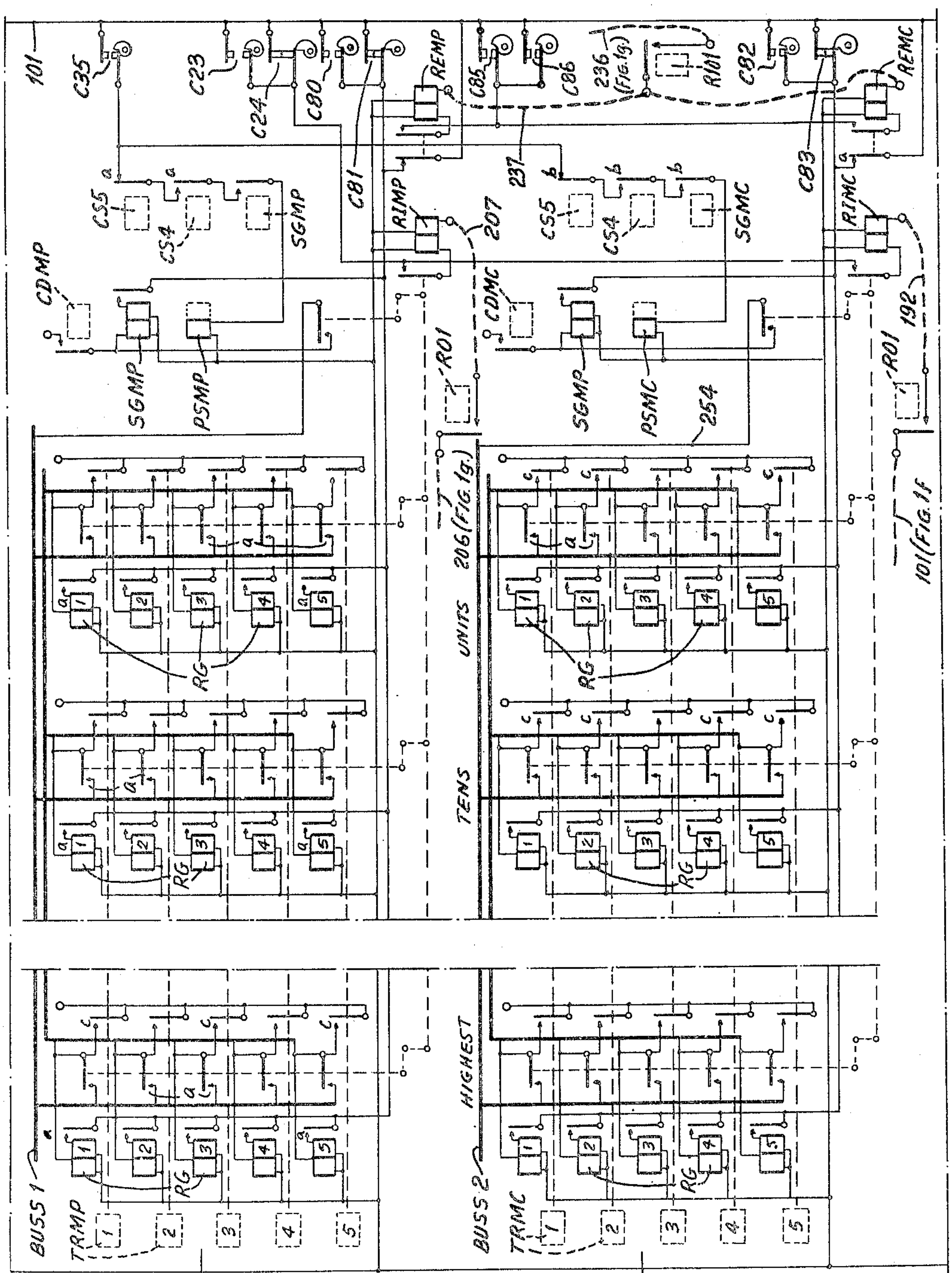

FIG. 1h.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

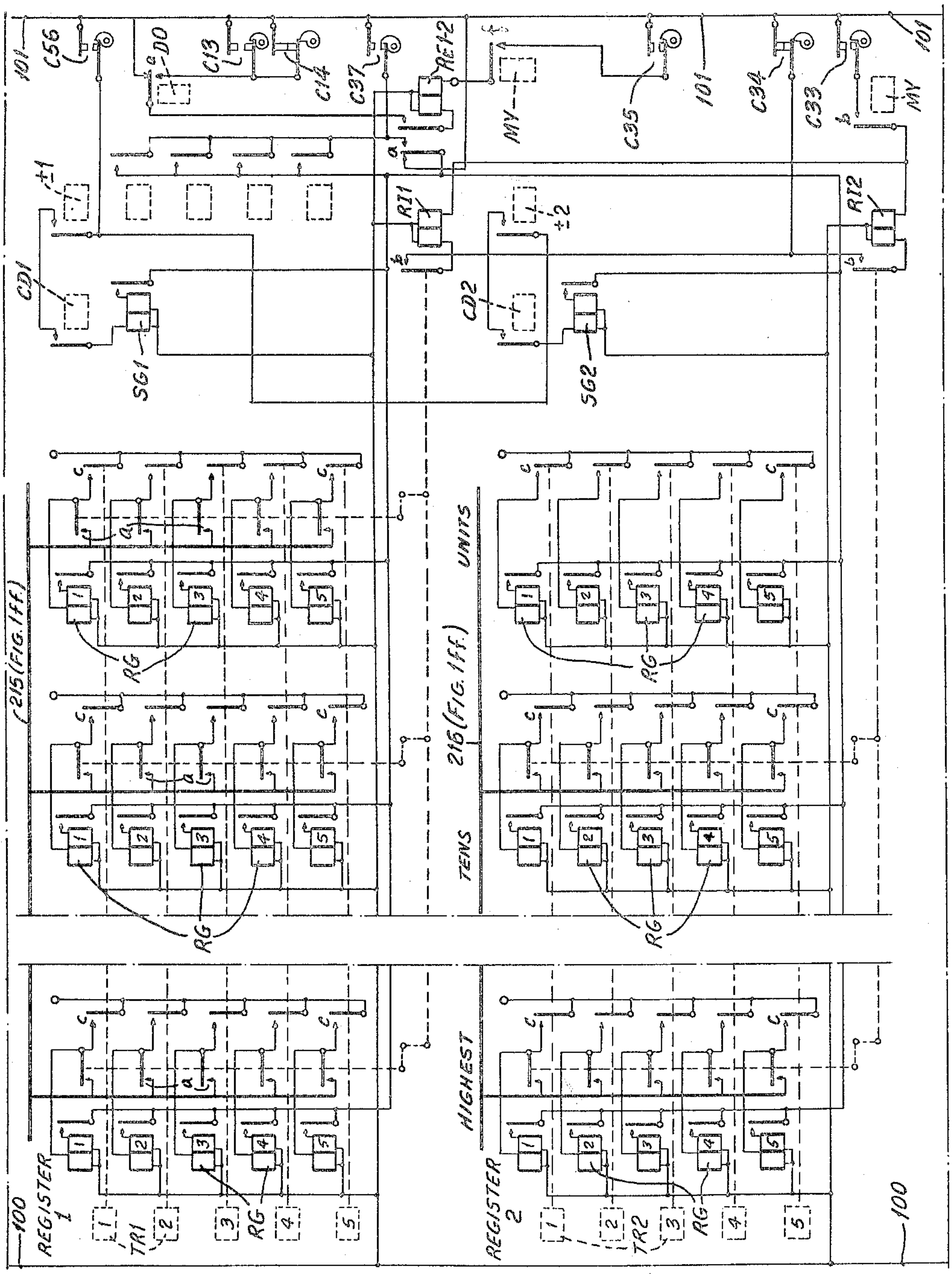

Fig. 1i

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

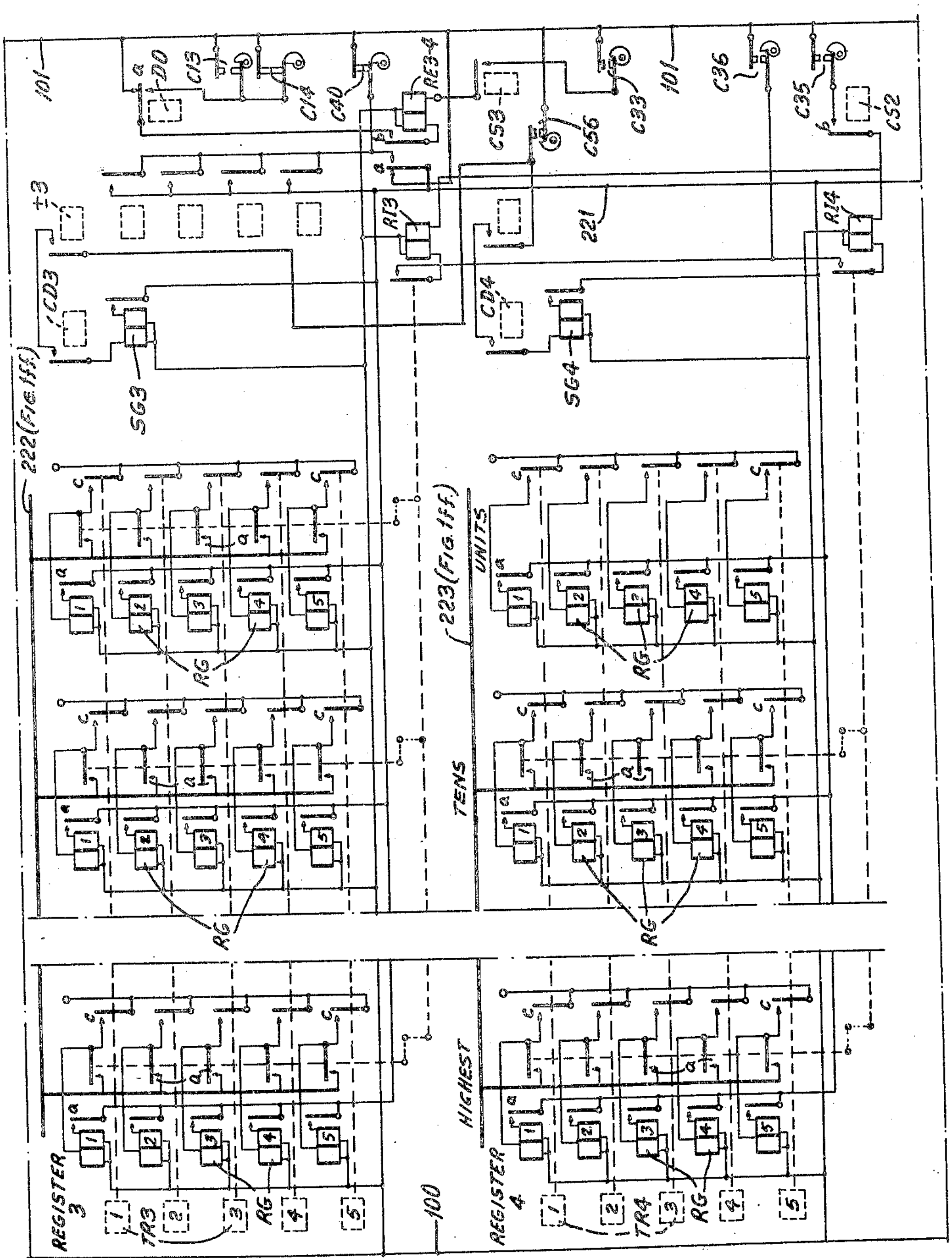

FIG. 1j.

INVENTORS
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY W. M. Wilson
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

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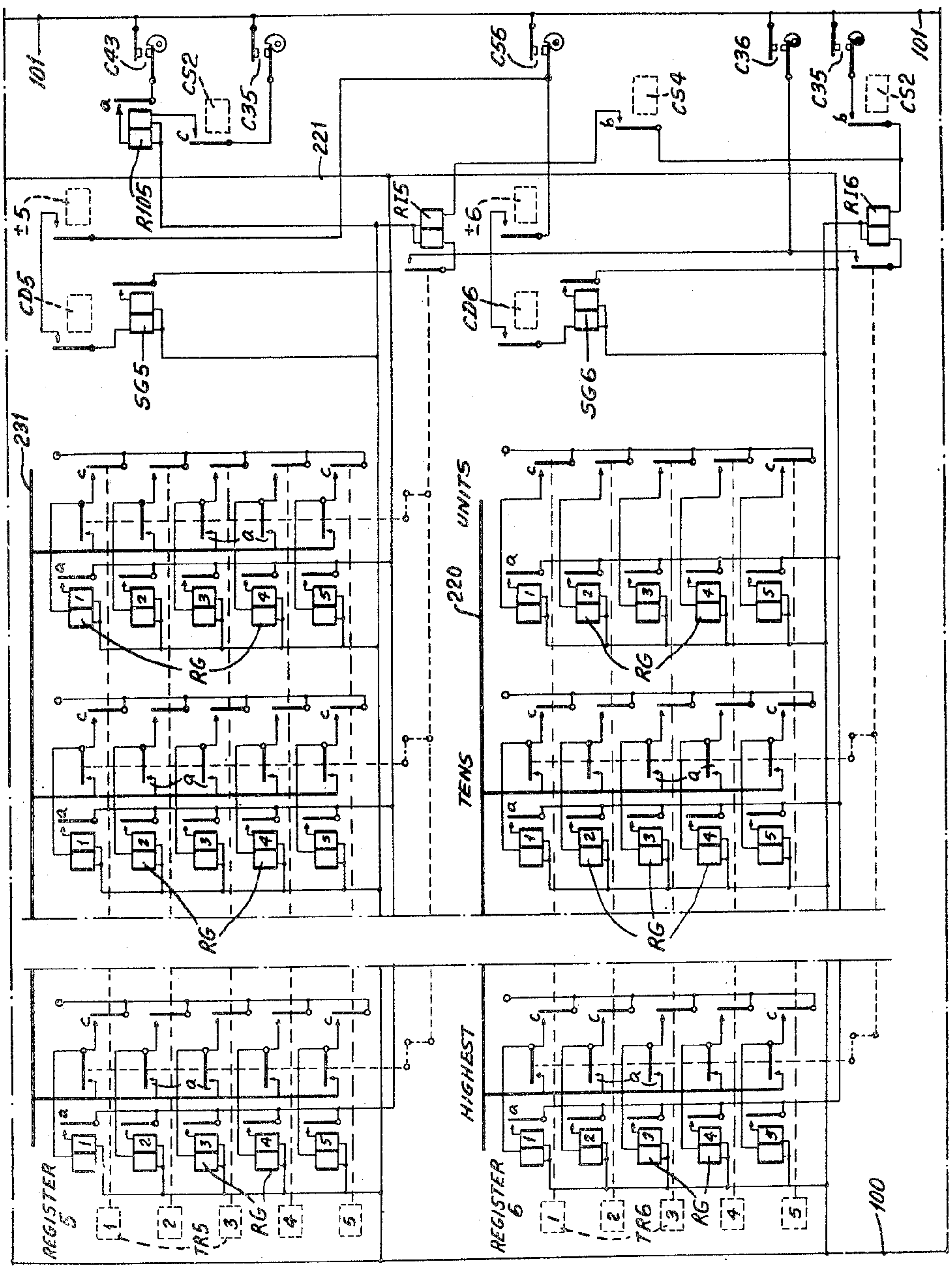

FIG. 16.

INVENTORS
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

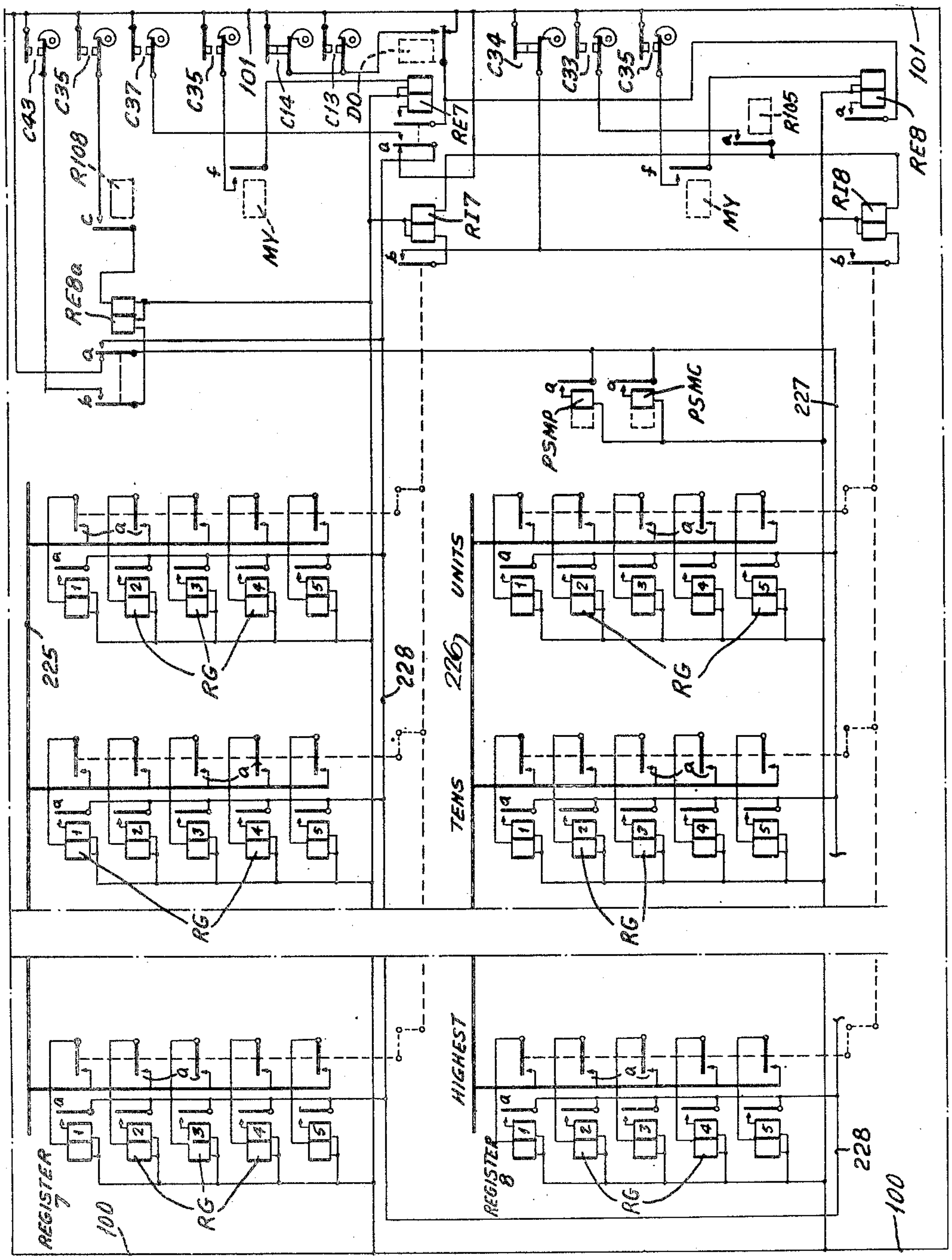

FIG. 1m.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

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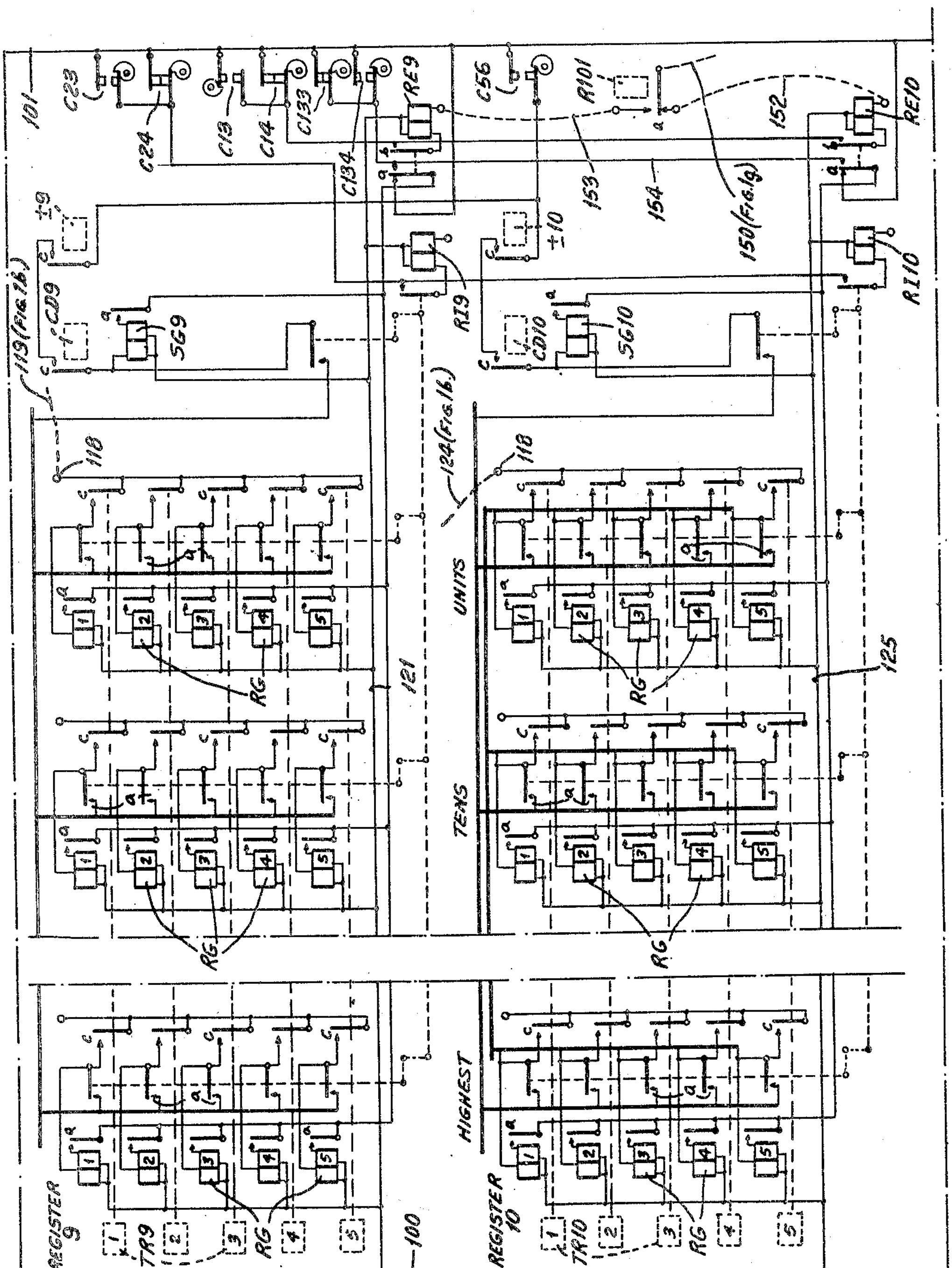

FIG 1n.

INVENTORS
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 14

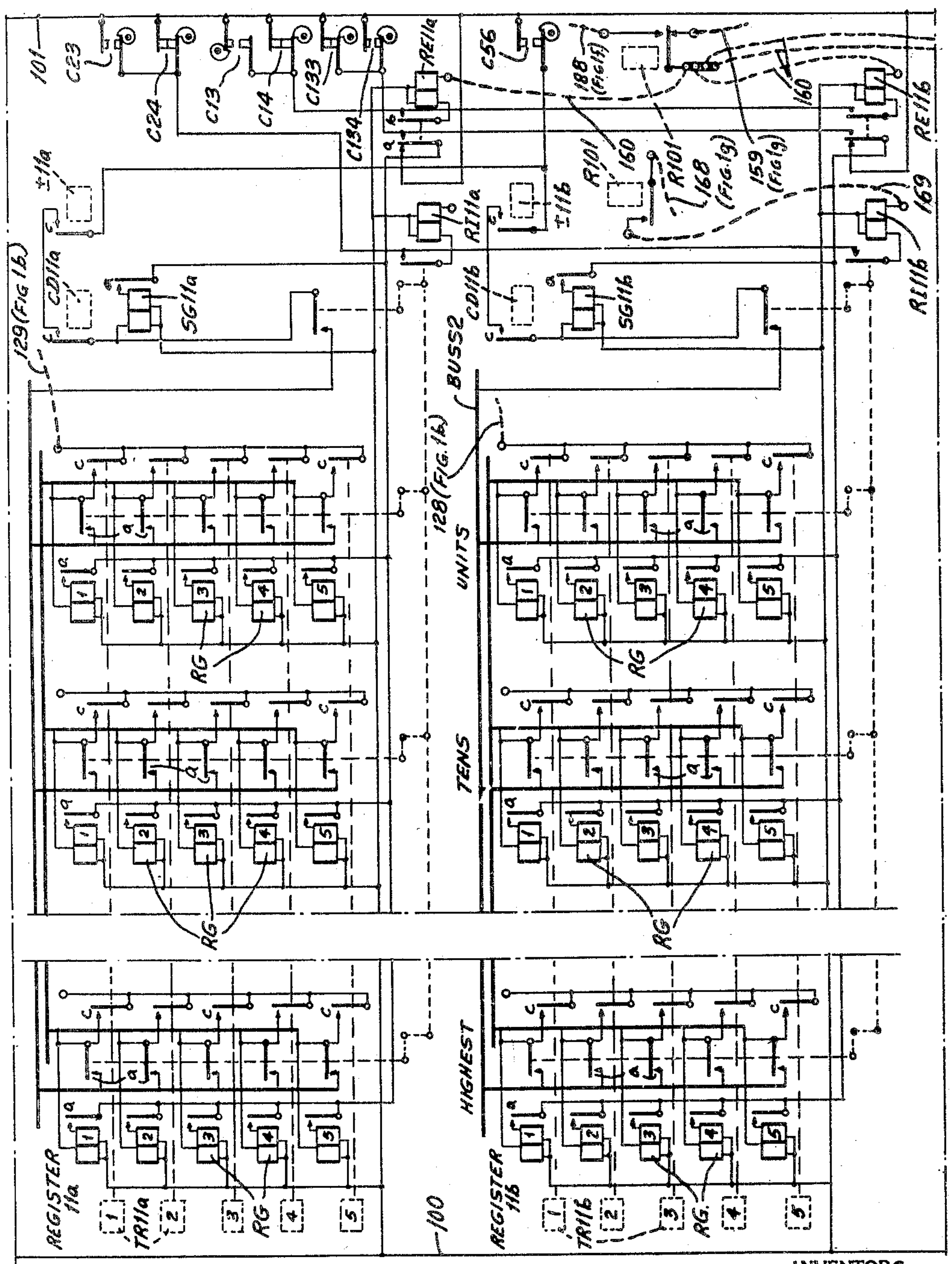

FIG. 10.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

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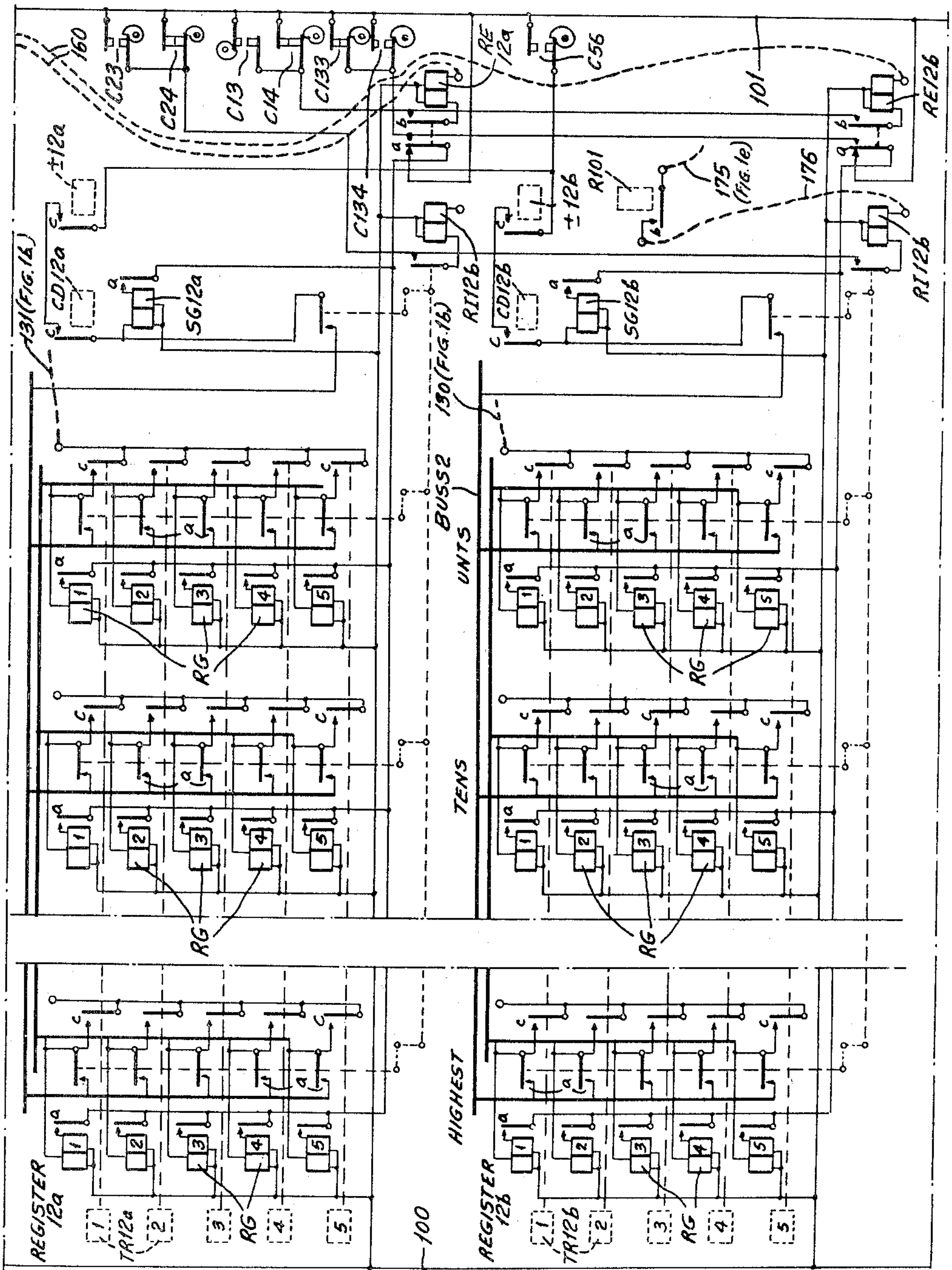

FIG. 1p.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

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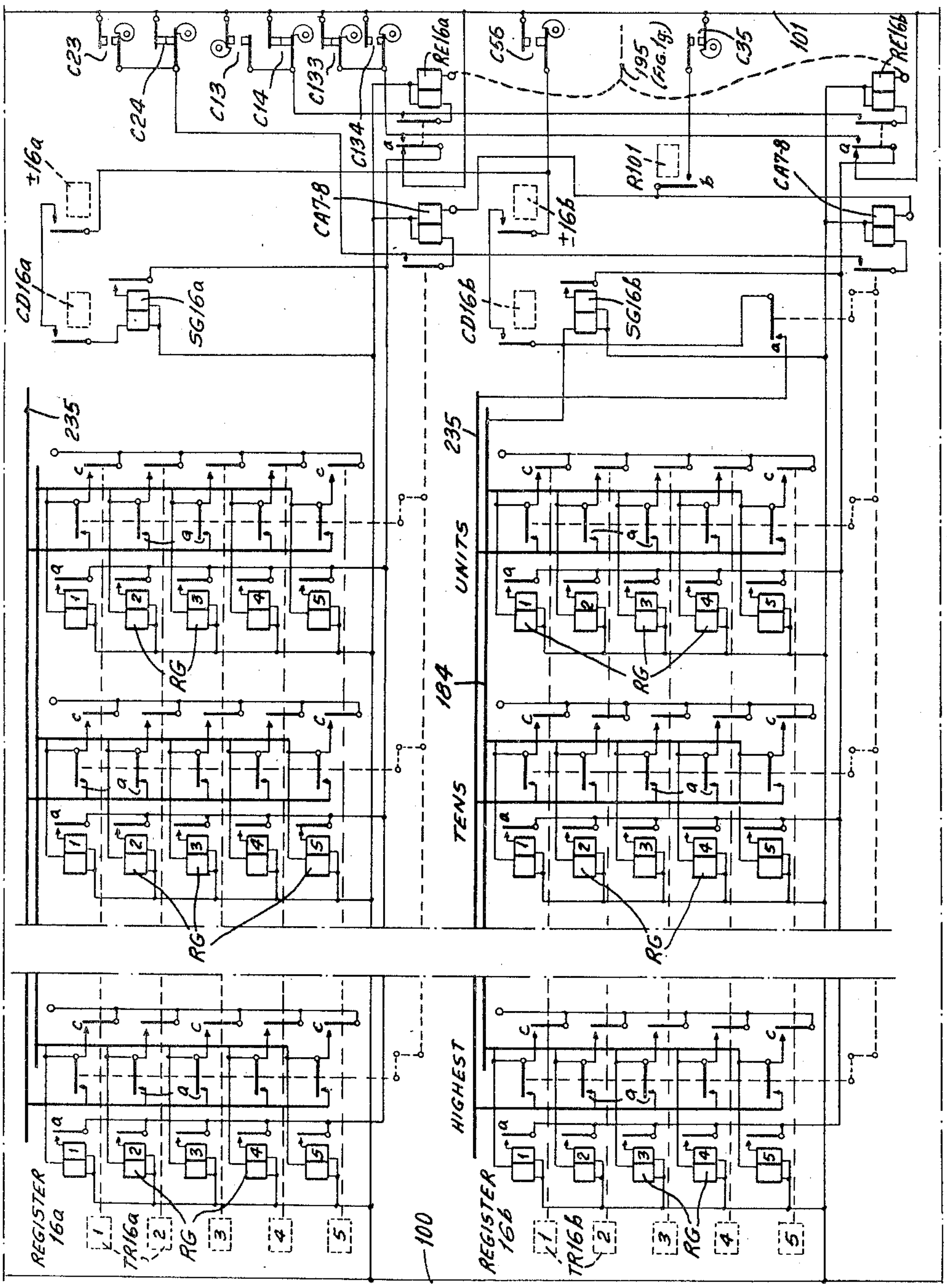

Fig. 1q.

INVENTORS
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON

BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 17

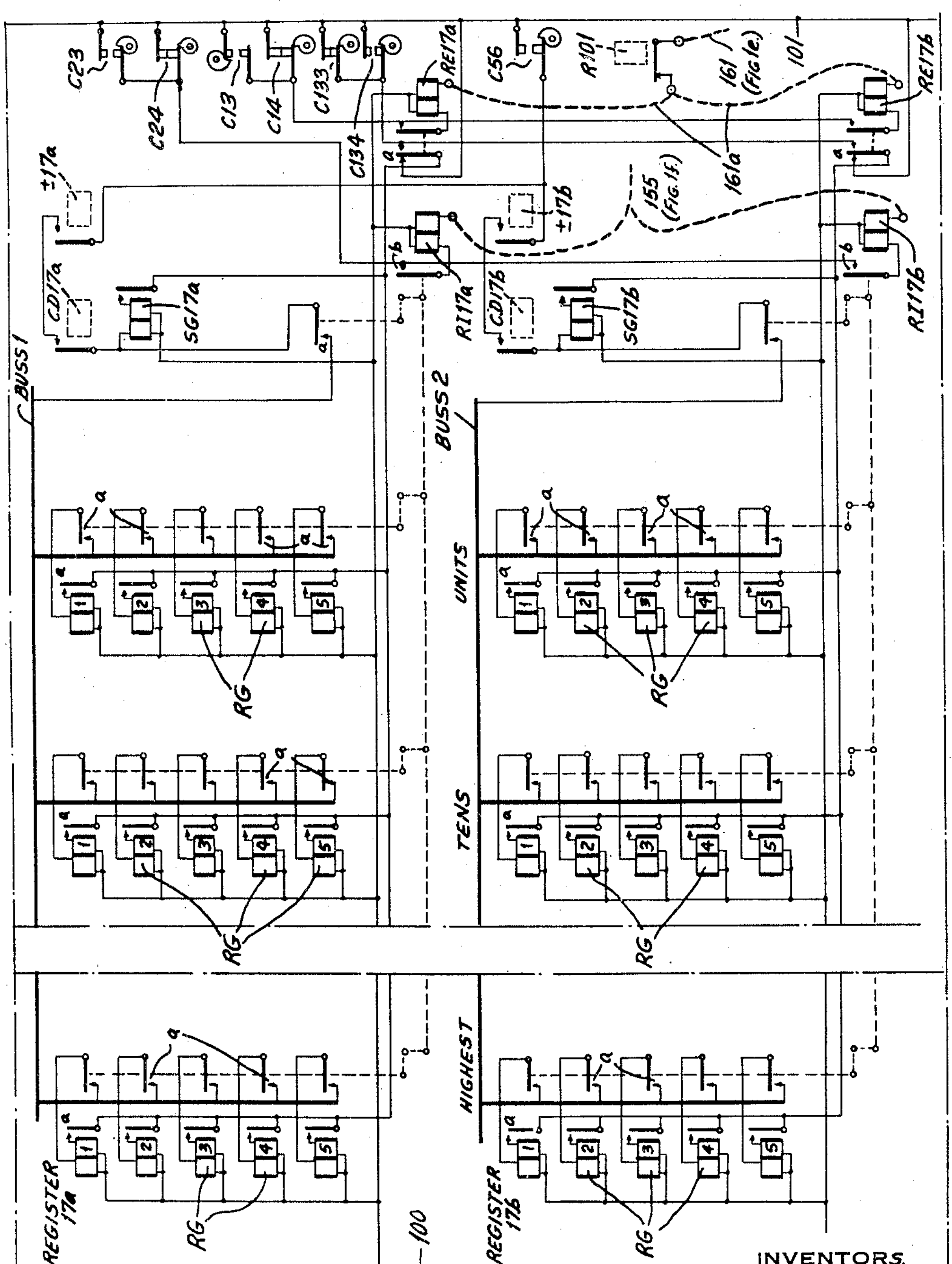

FIG. 1r.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

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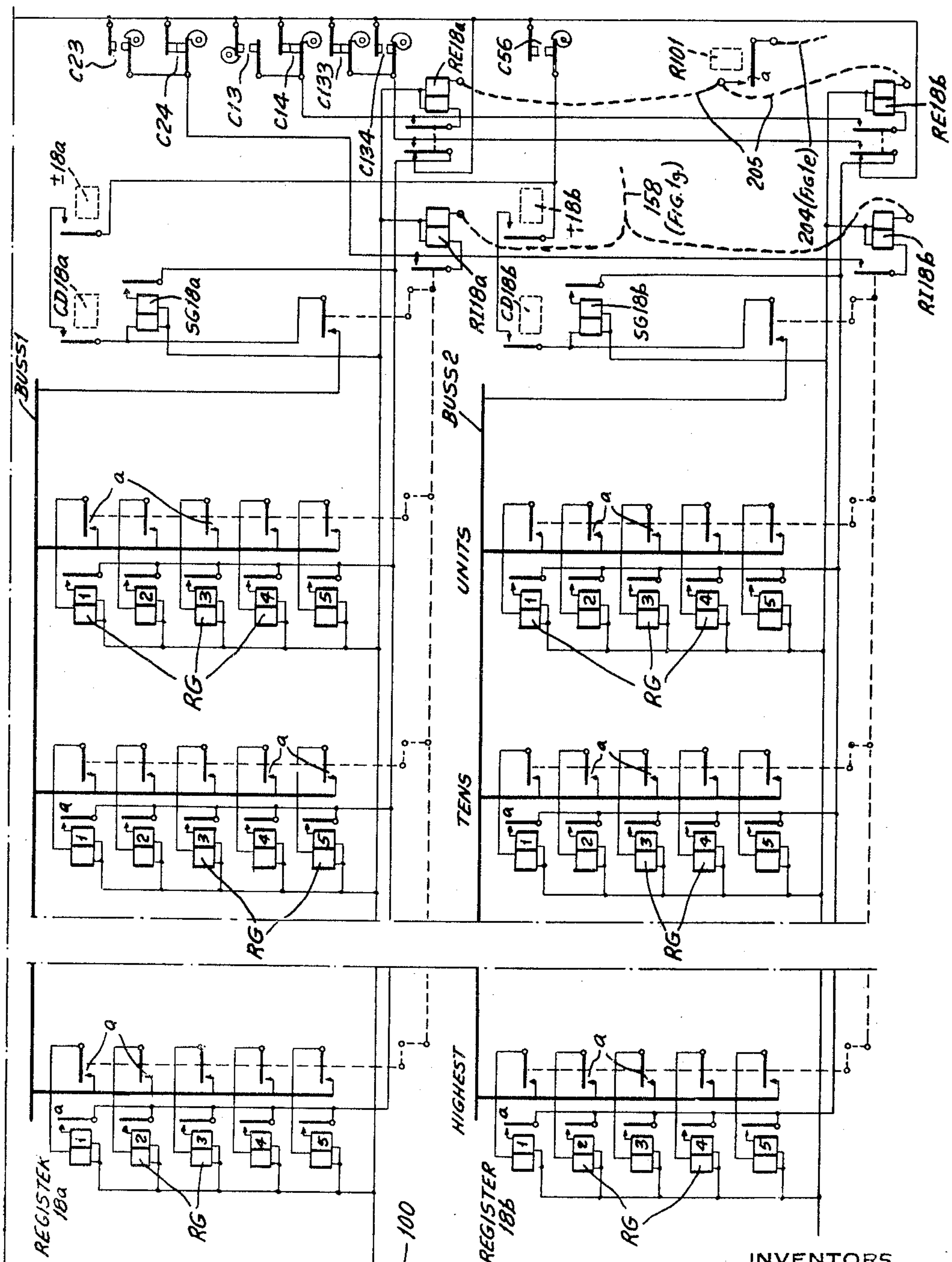

FIG. 1S.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 19

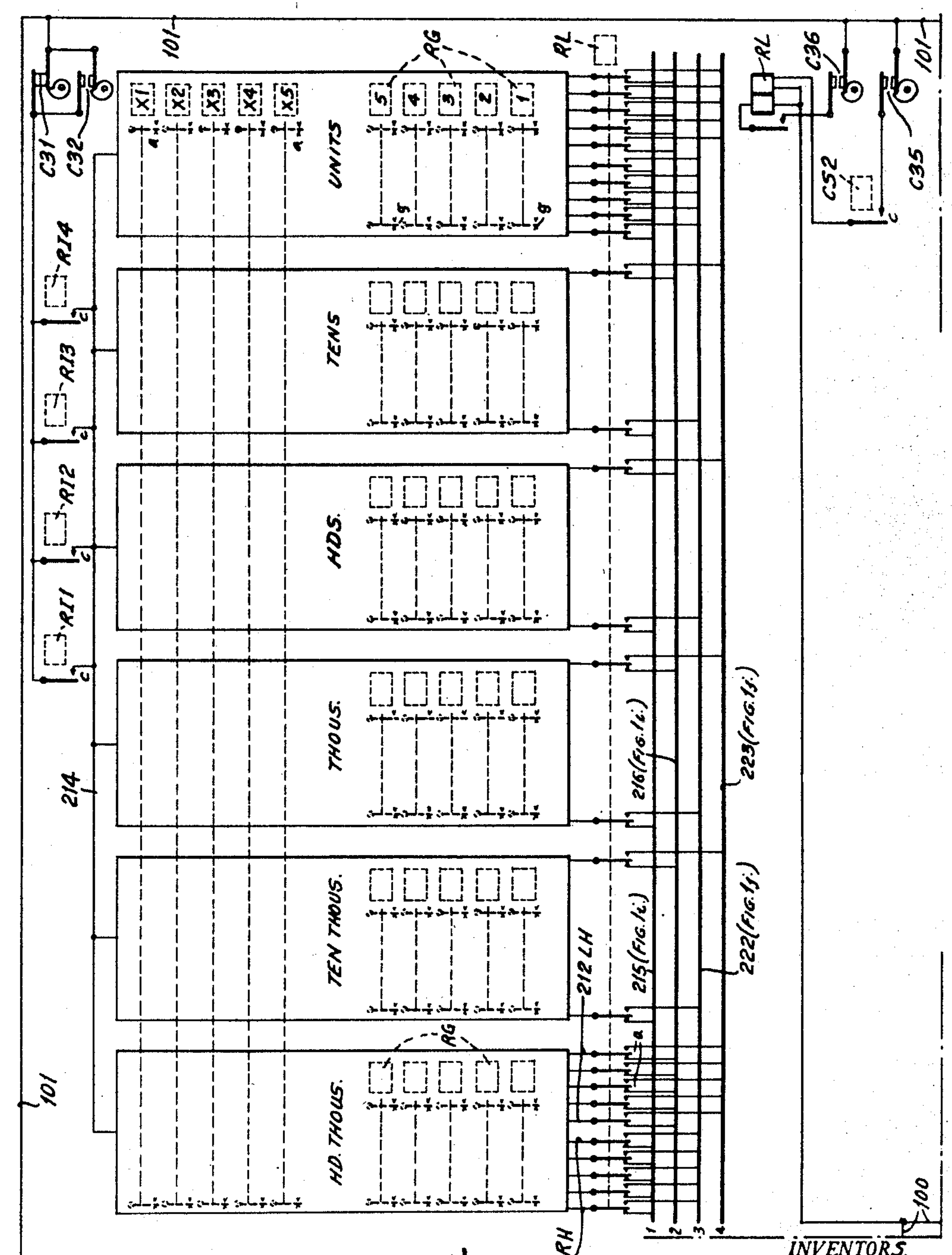

FIG. 199.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 20

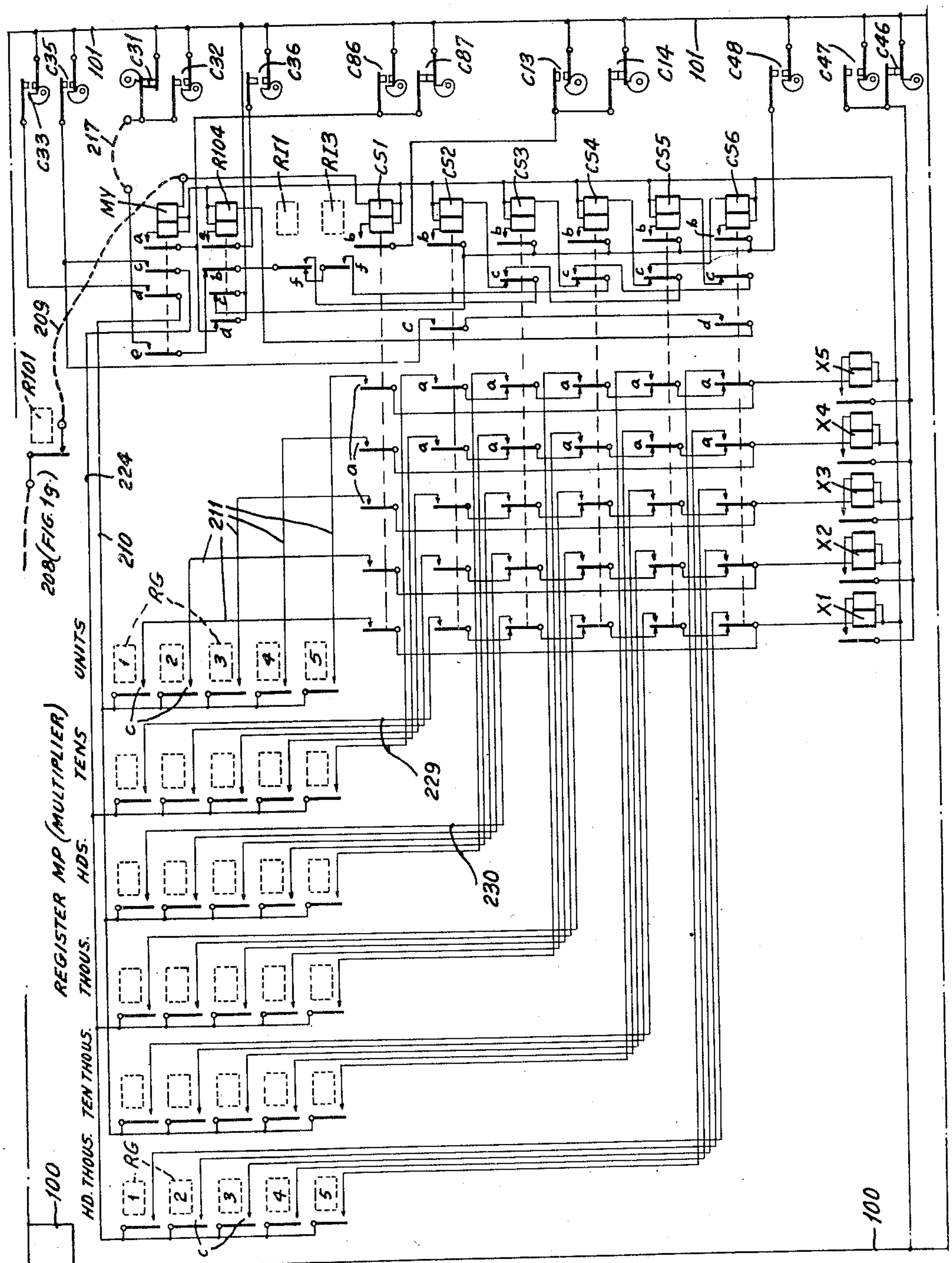

FIG. 16h.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

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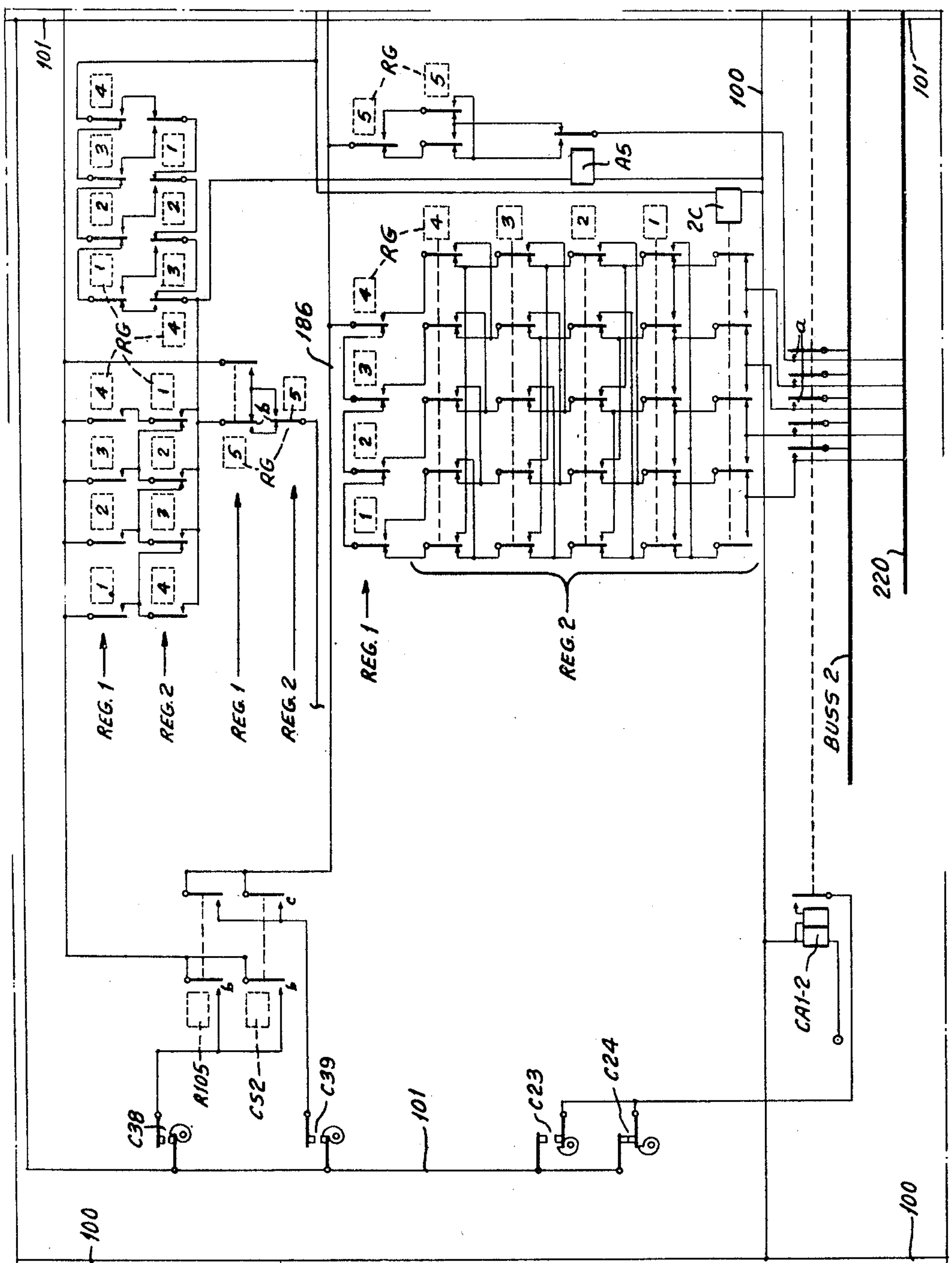

FIG. 11i.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY W. M. Wilson
ATTORNEY

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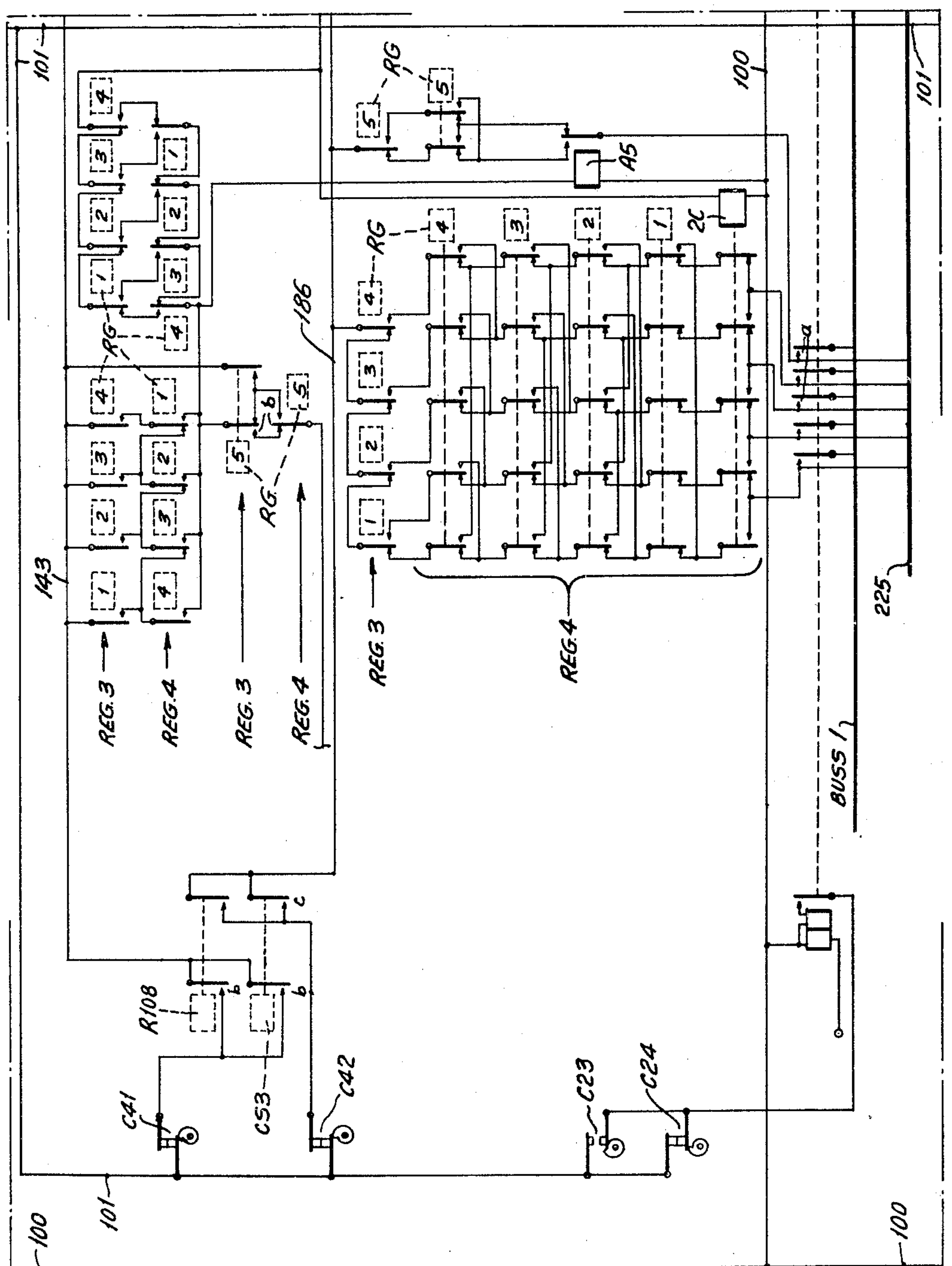

Fig. 1jj.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 23

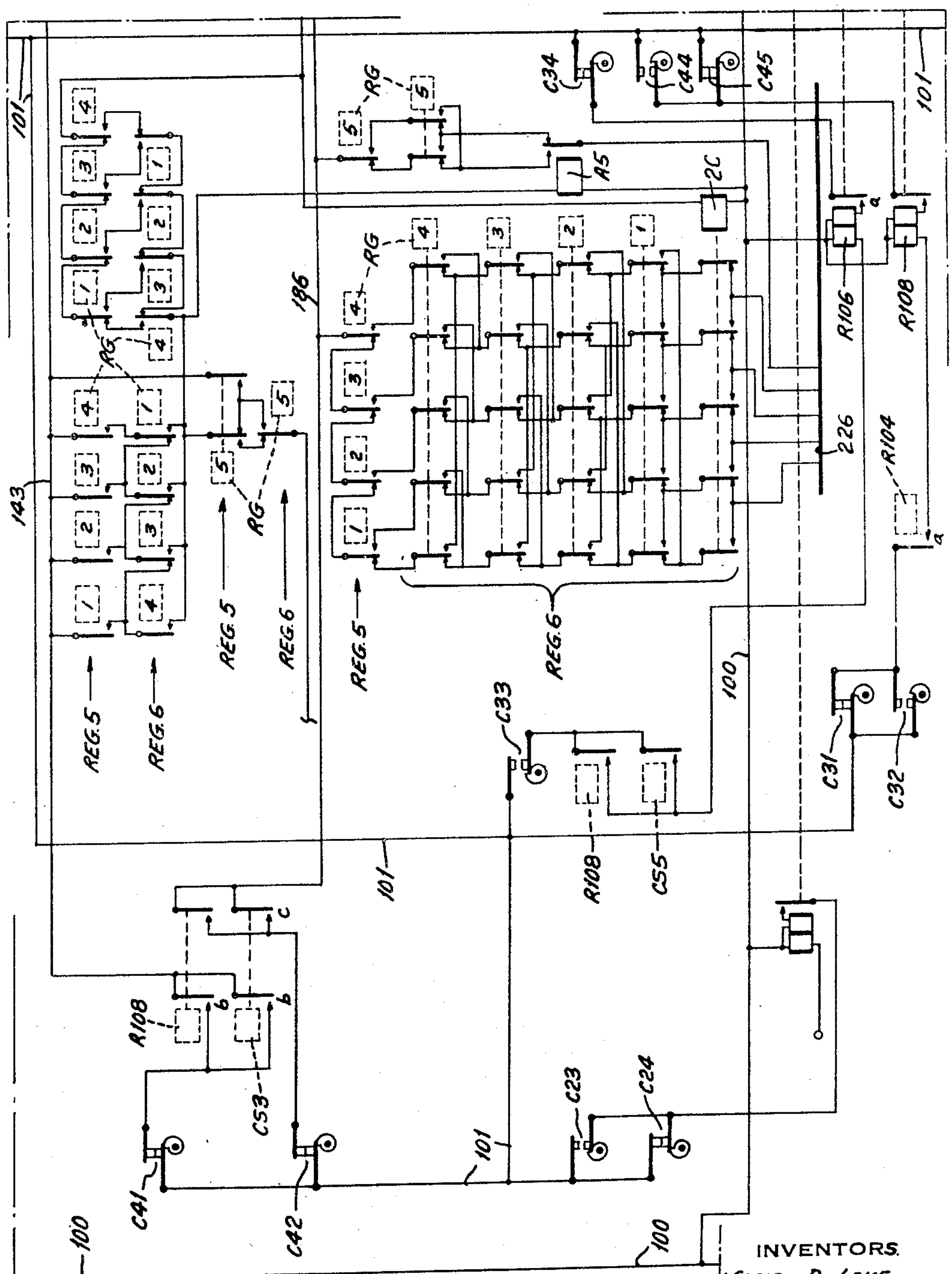

FIG. 16R.

INVENTORS
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945

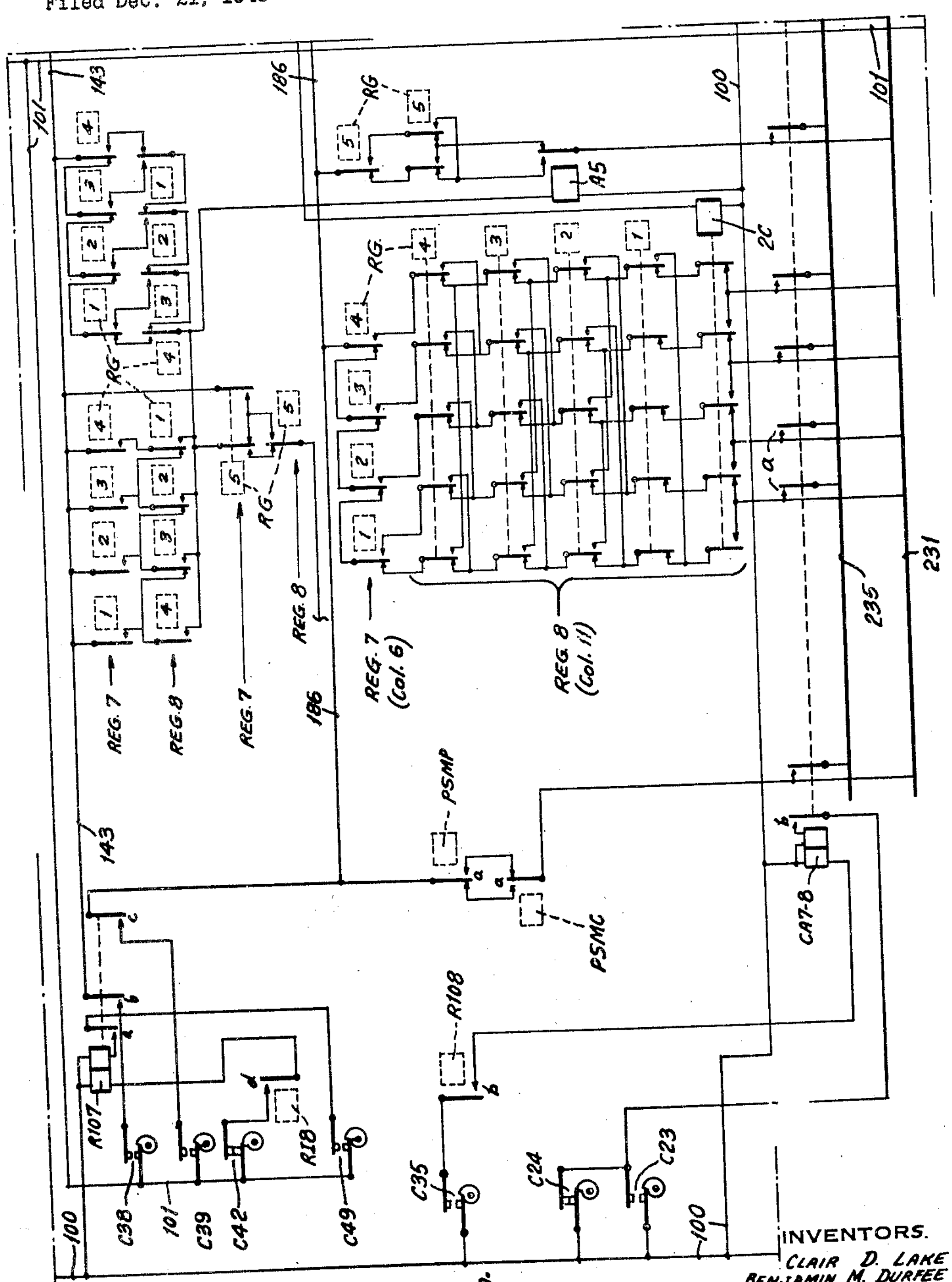

FIG. 1mm.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

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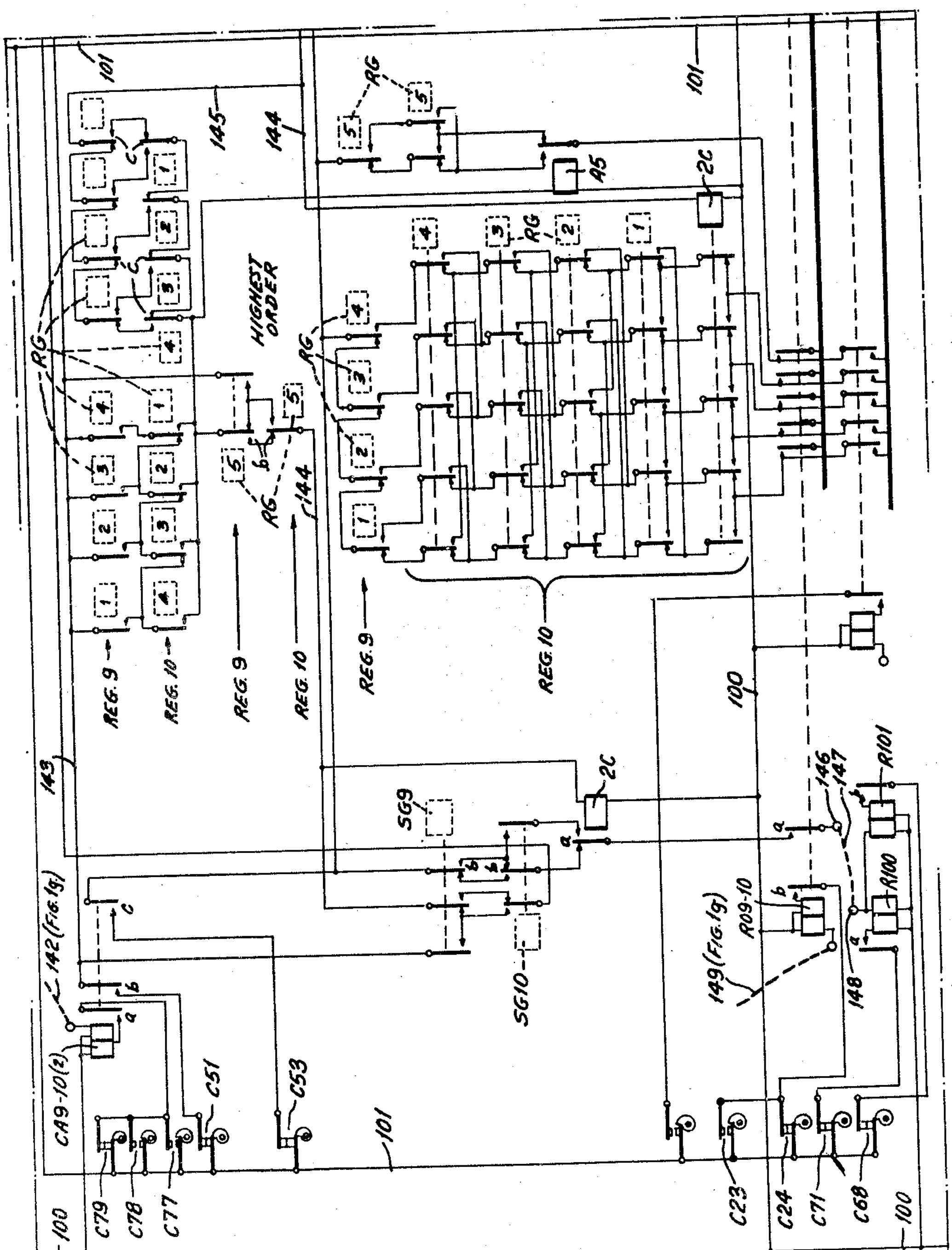

FIG. 1nn

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

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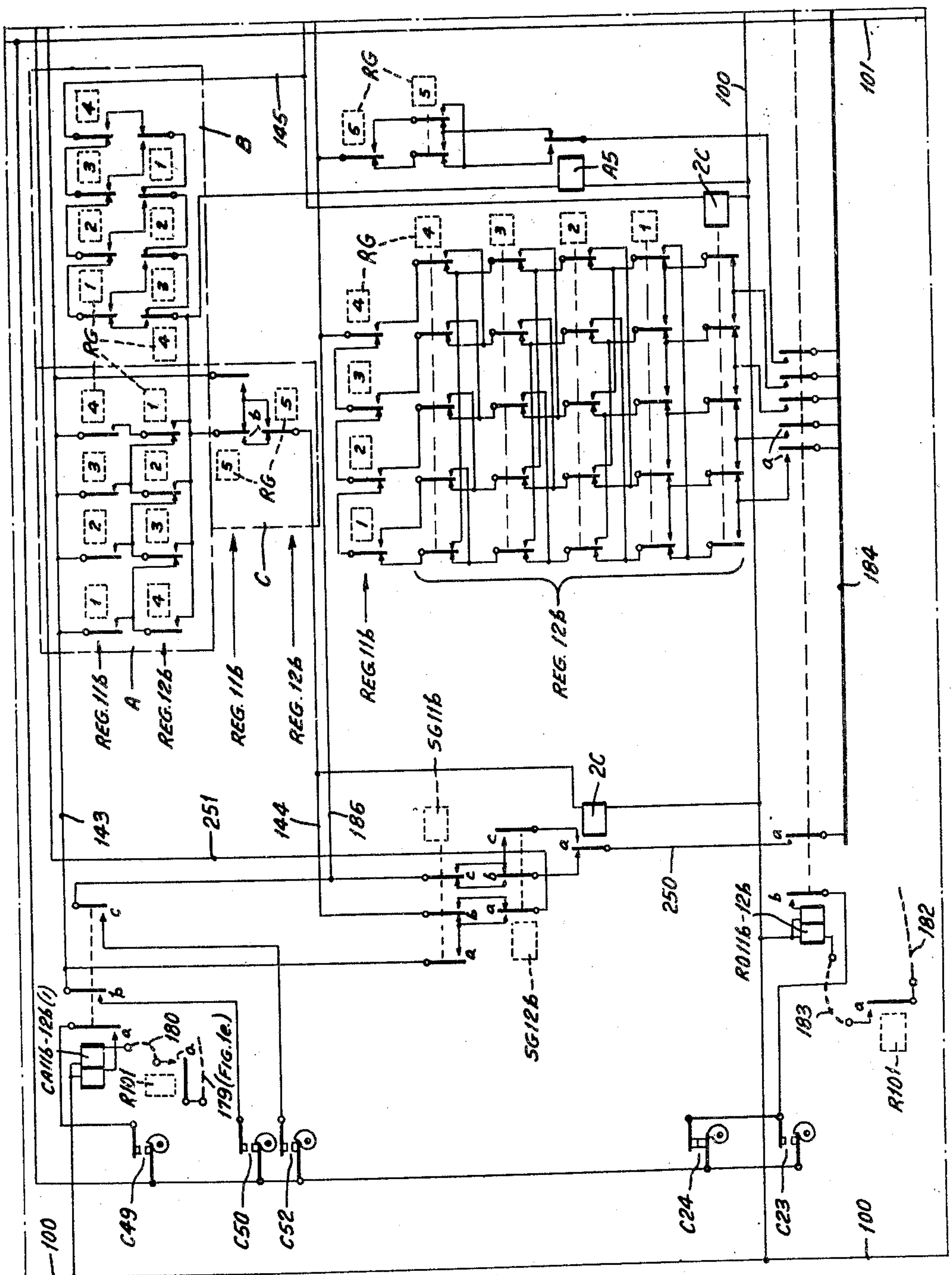

Fig. 1pp.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY W. M. Wilson
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 27

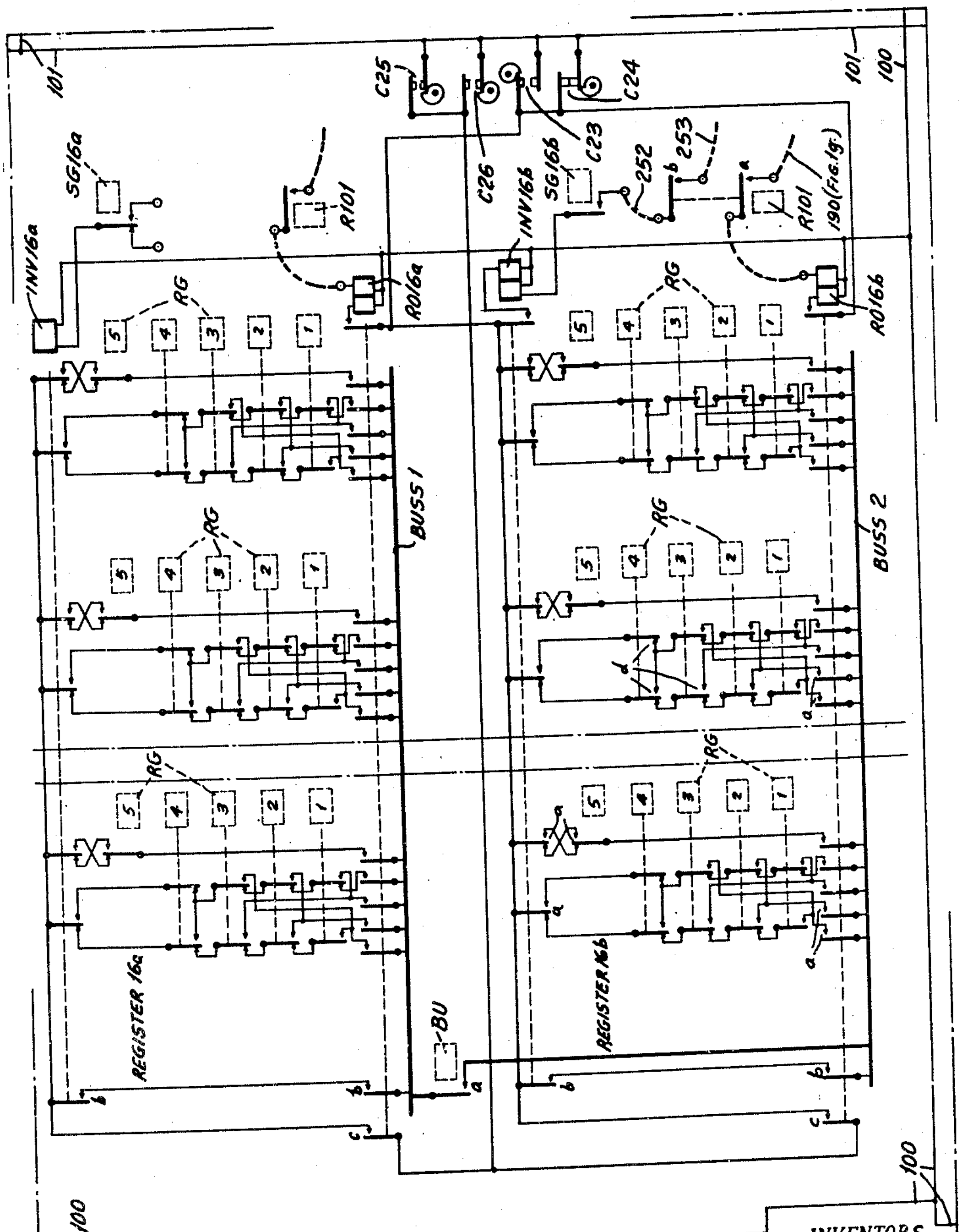

Fig. 199.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

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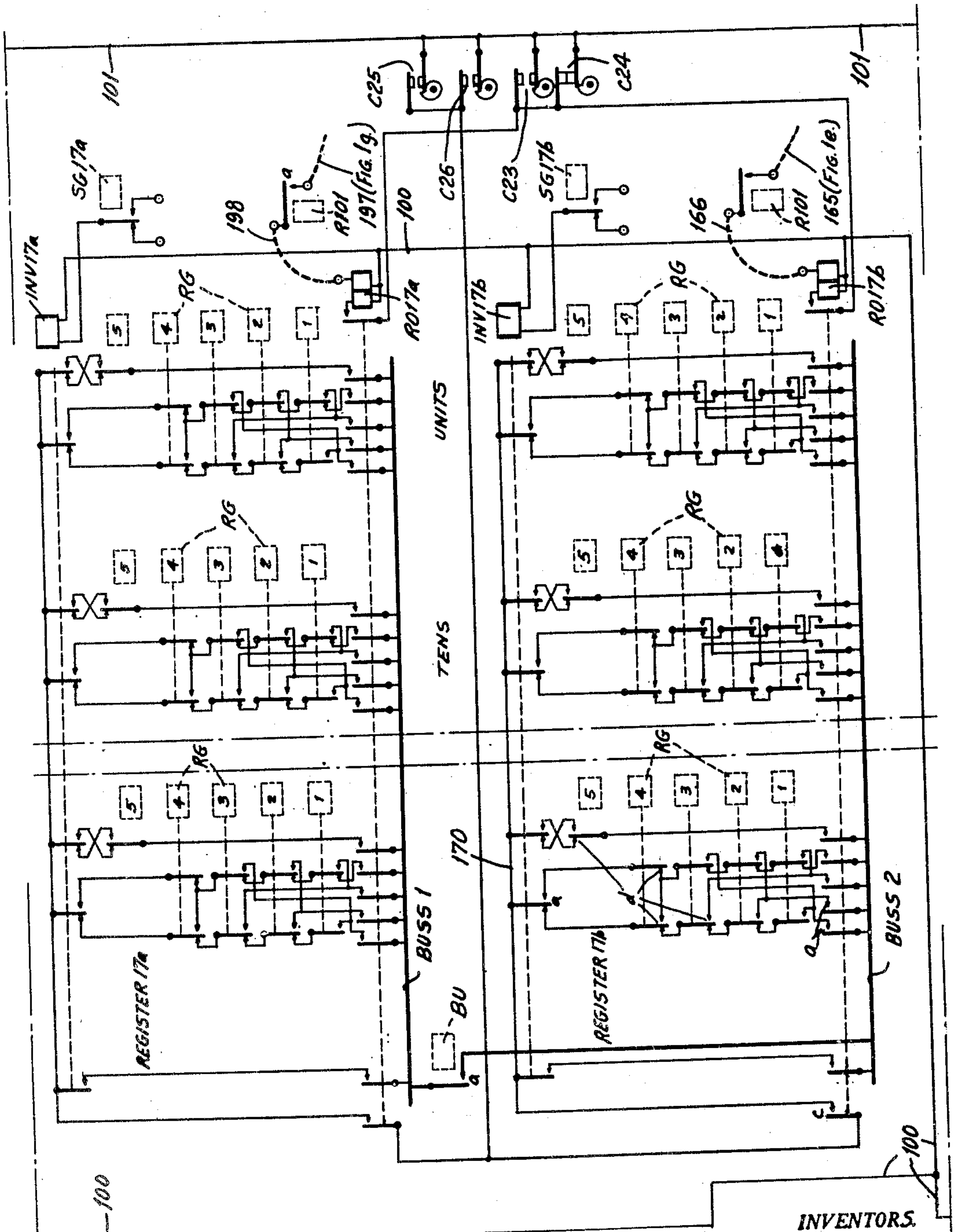

Fig. 1rr.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON

BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

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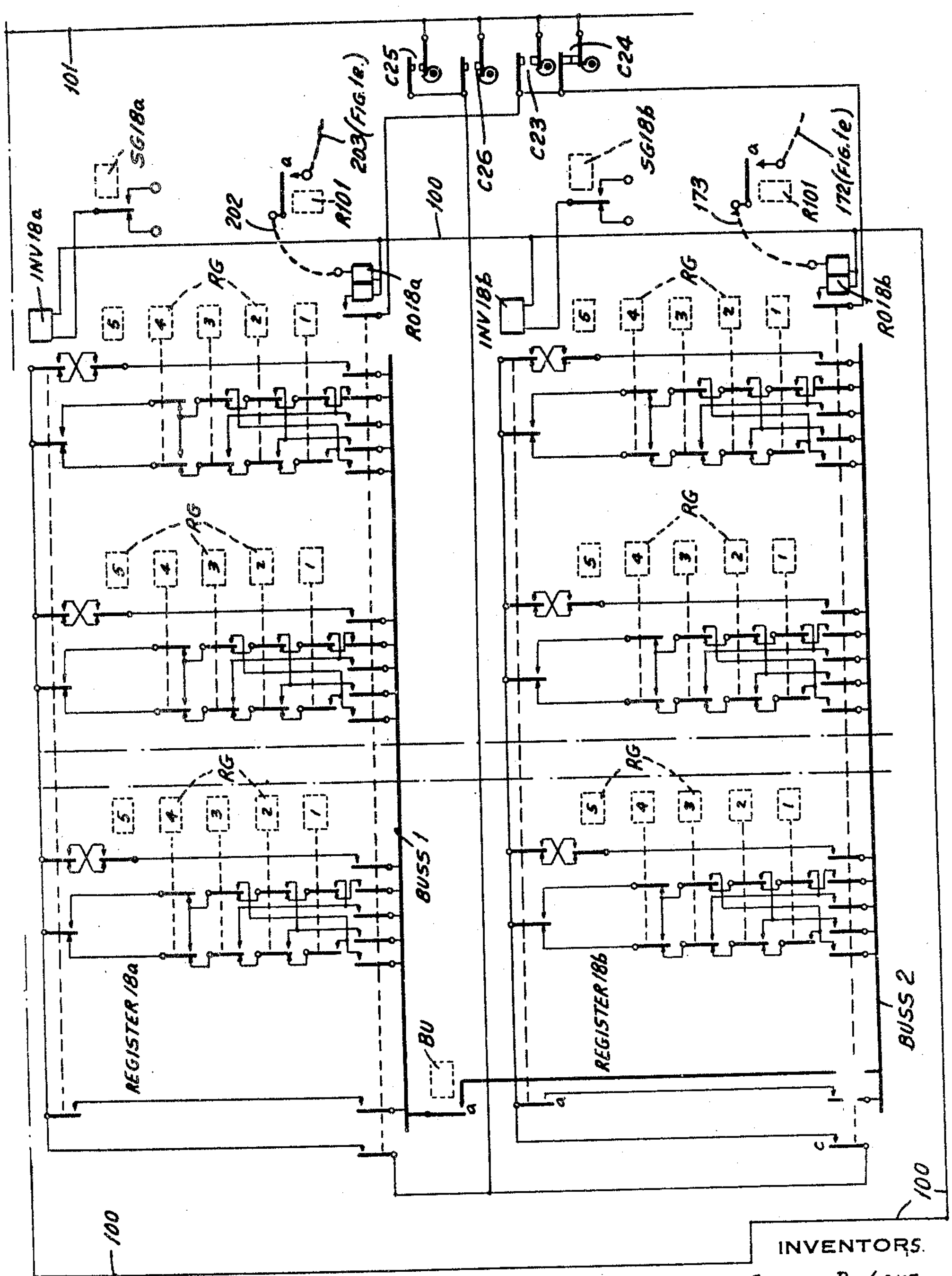

FIG. 155.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON

BY W. M. Wilson
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

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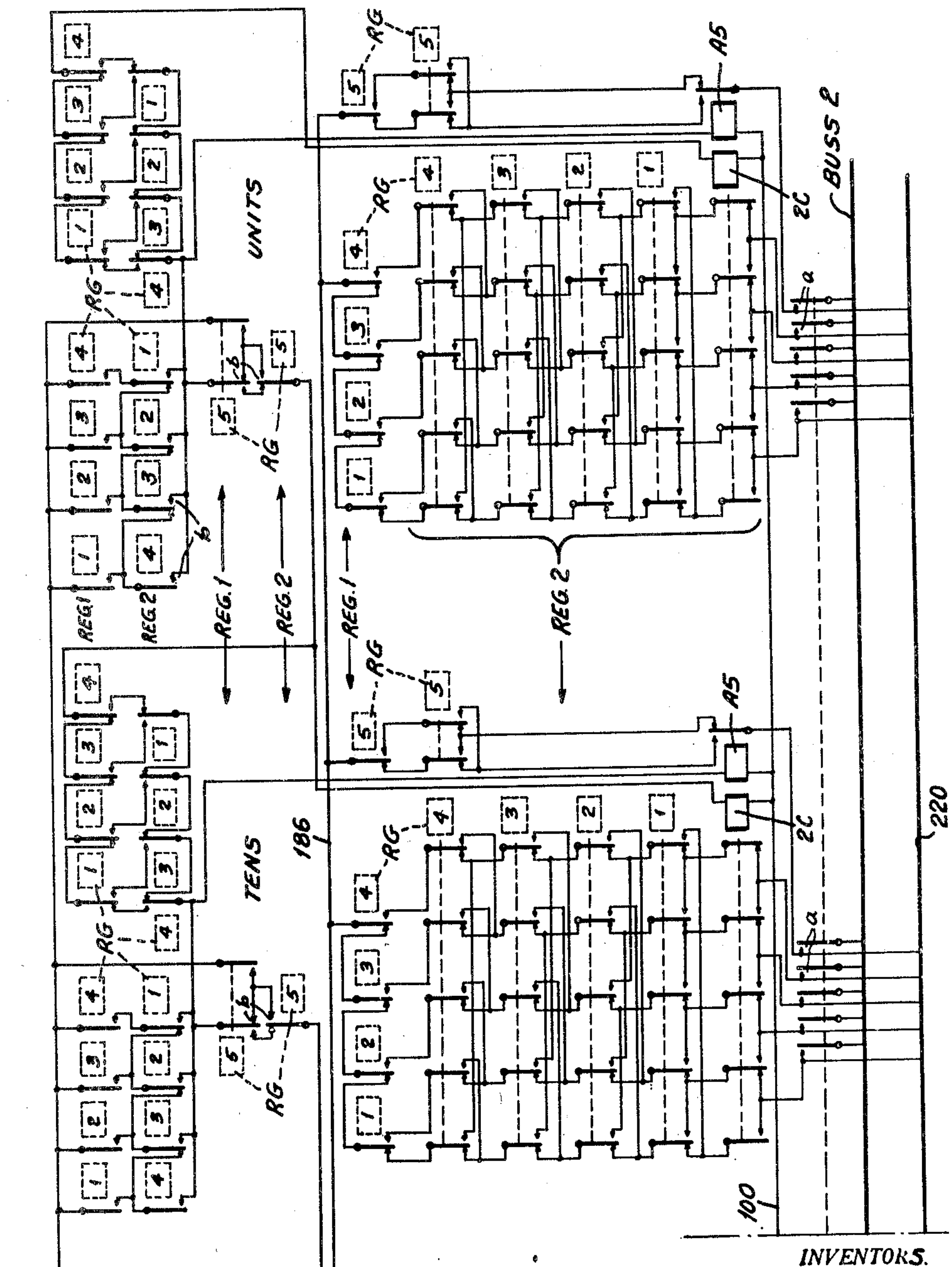

Fig. 111.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

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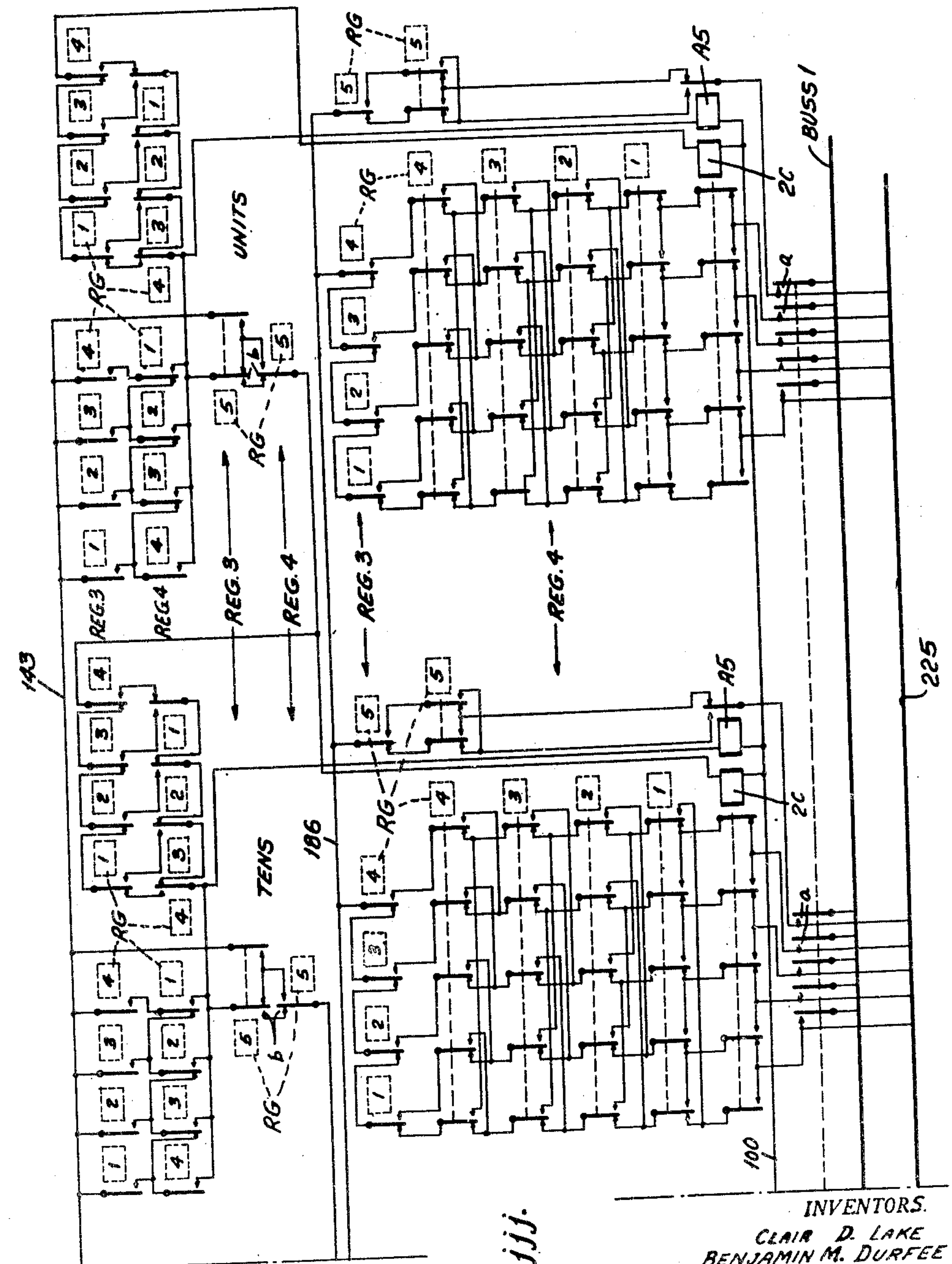

FIG.1jjj.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON

BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 32

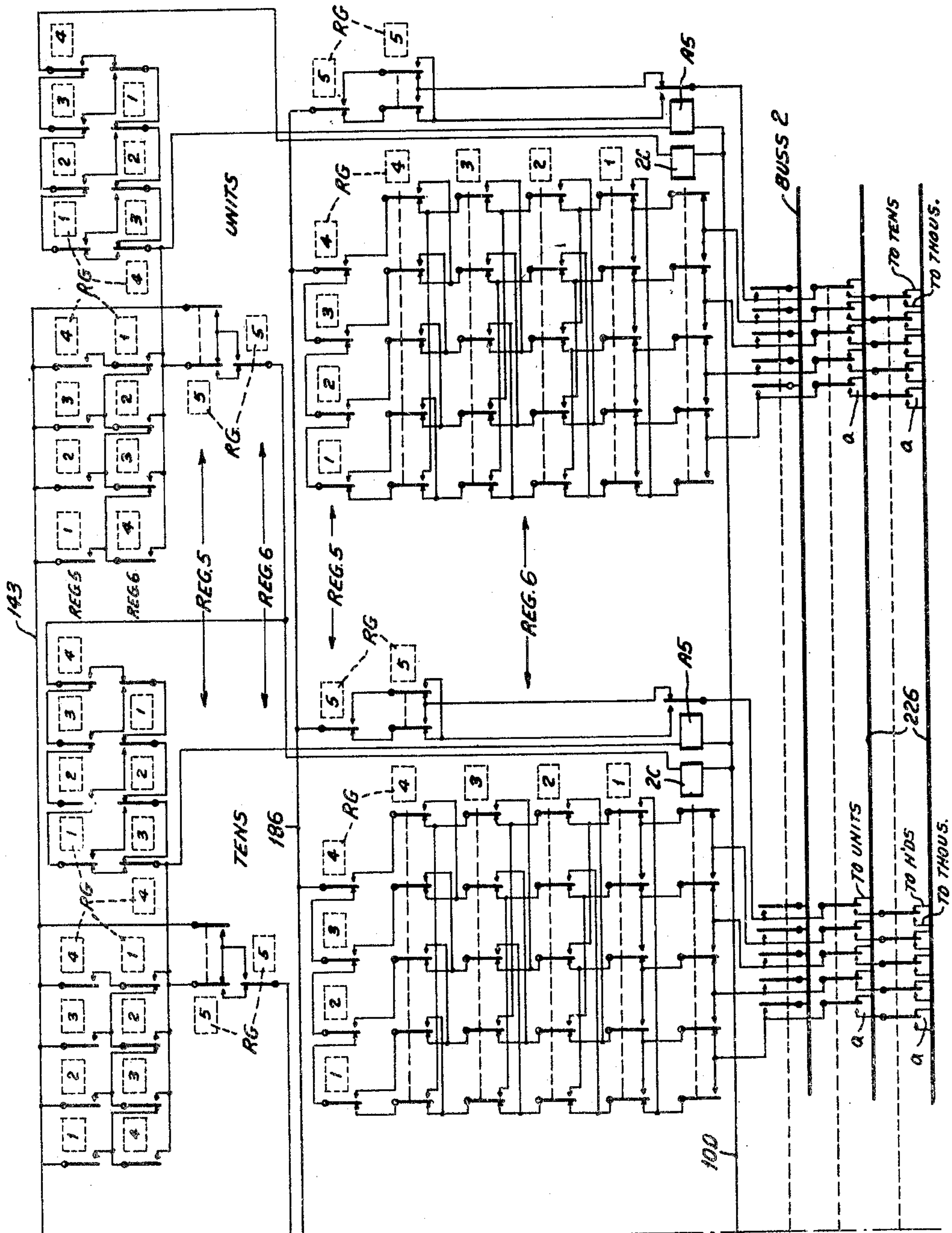

FIG. 166R.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON

BY W. M. Wilson
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

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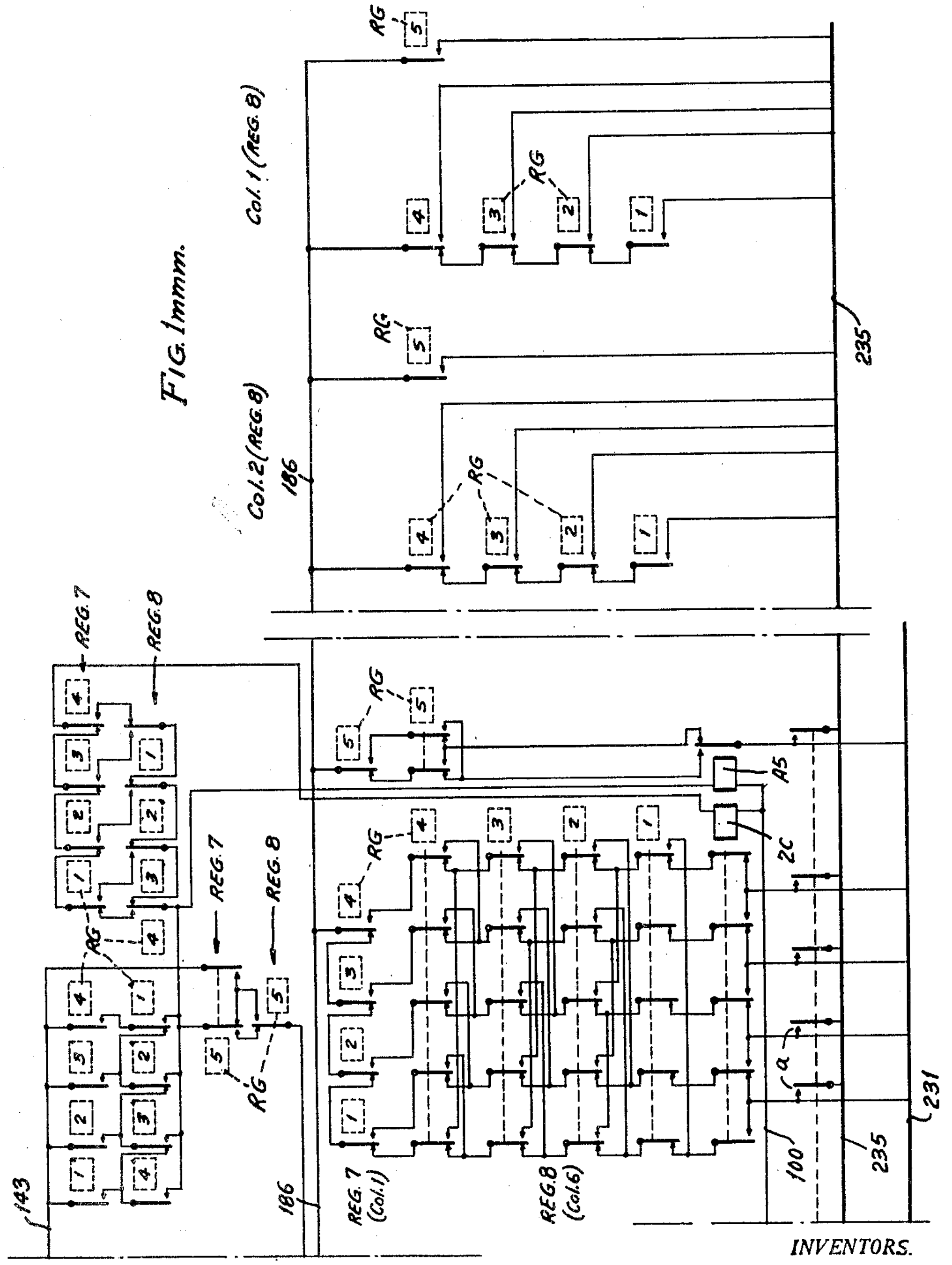
FIG. 1mmm.



INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON

BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 34

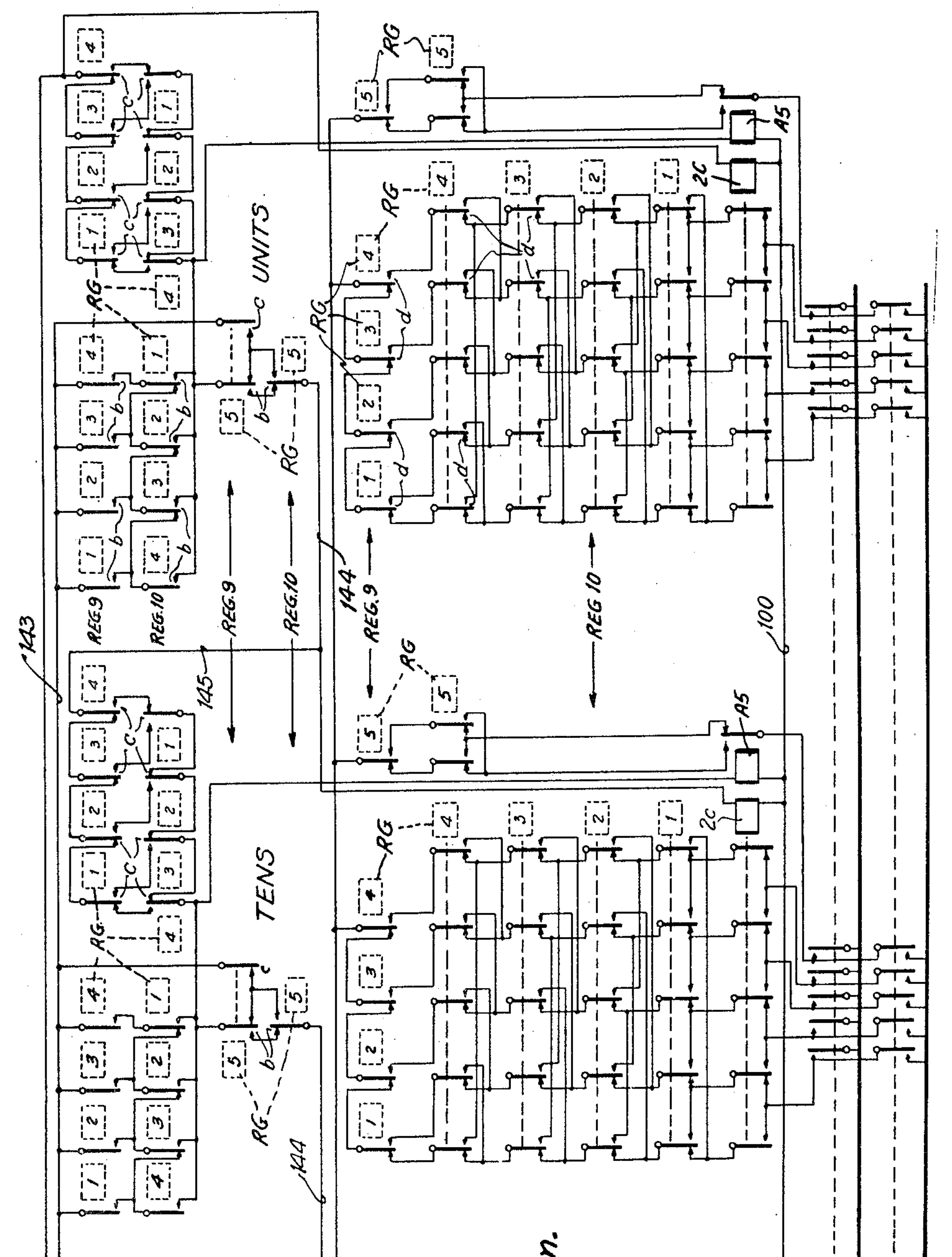


FIG. 1nnn.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 35

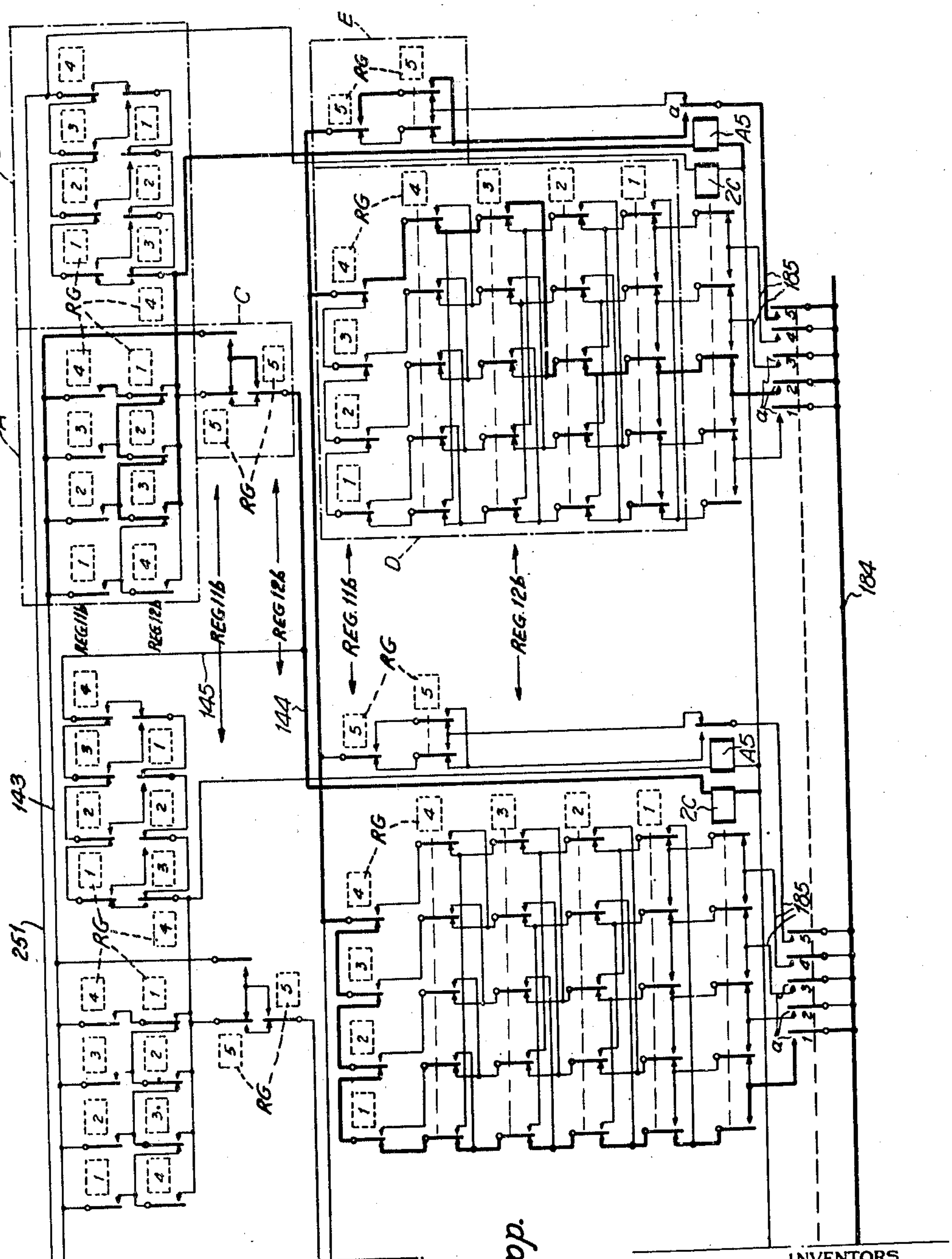


Fig. 1ppp.

INVENTORS
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature] ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

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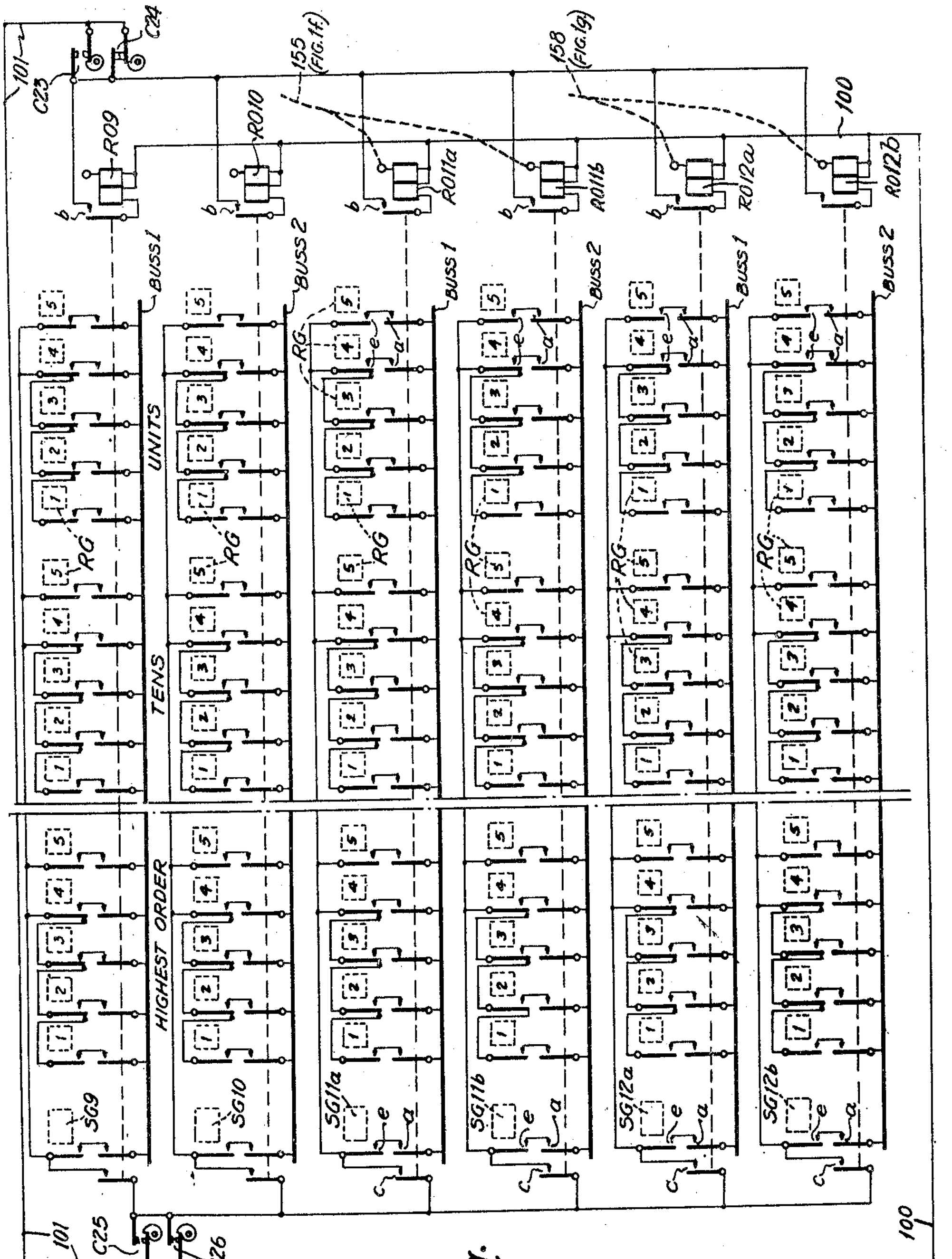

FIG. 1qqq.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

RECORD CONTROLLED CALCULATING MACHINE

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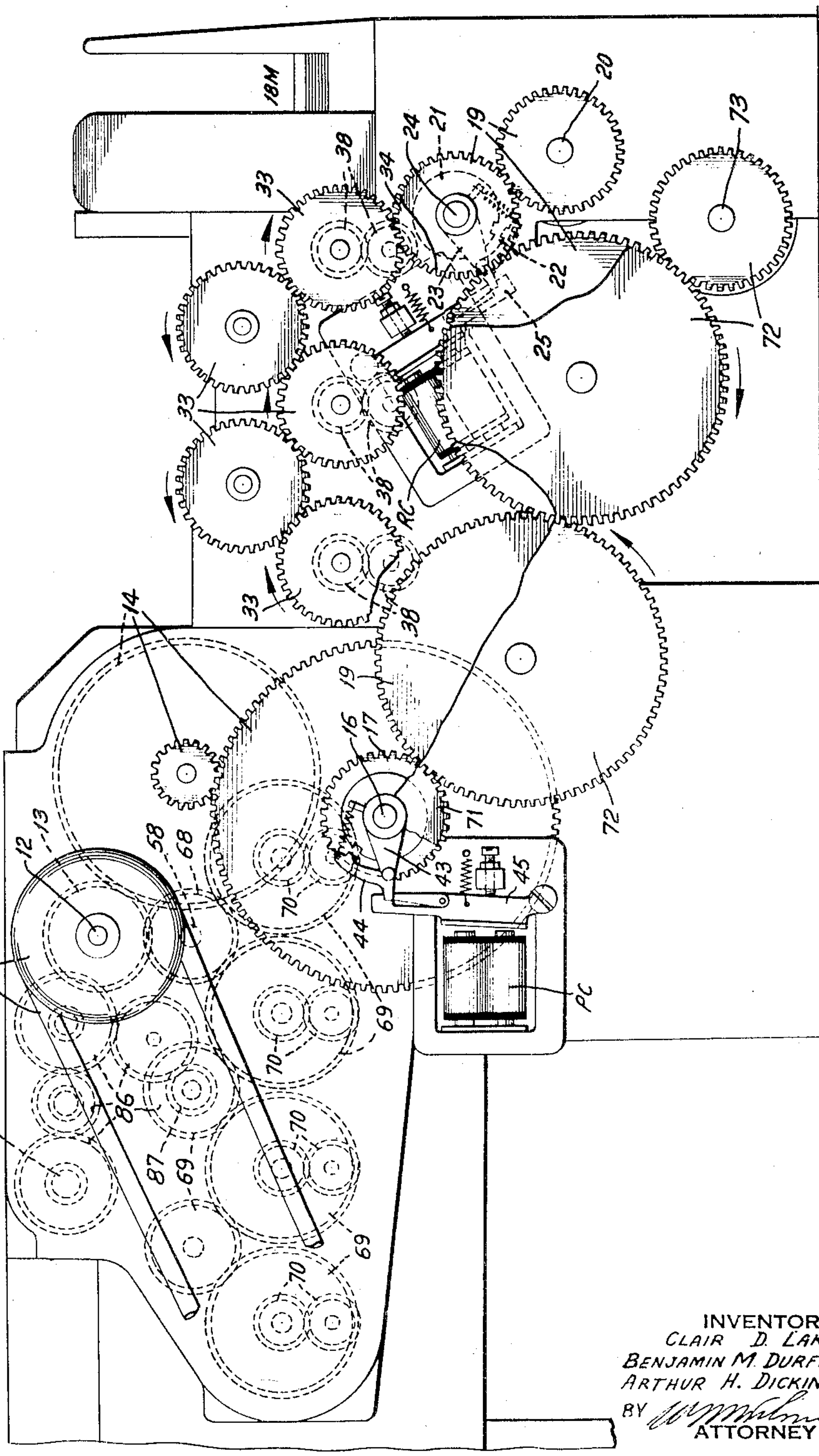
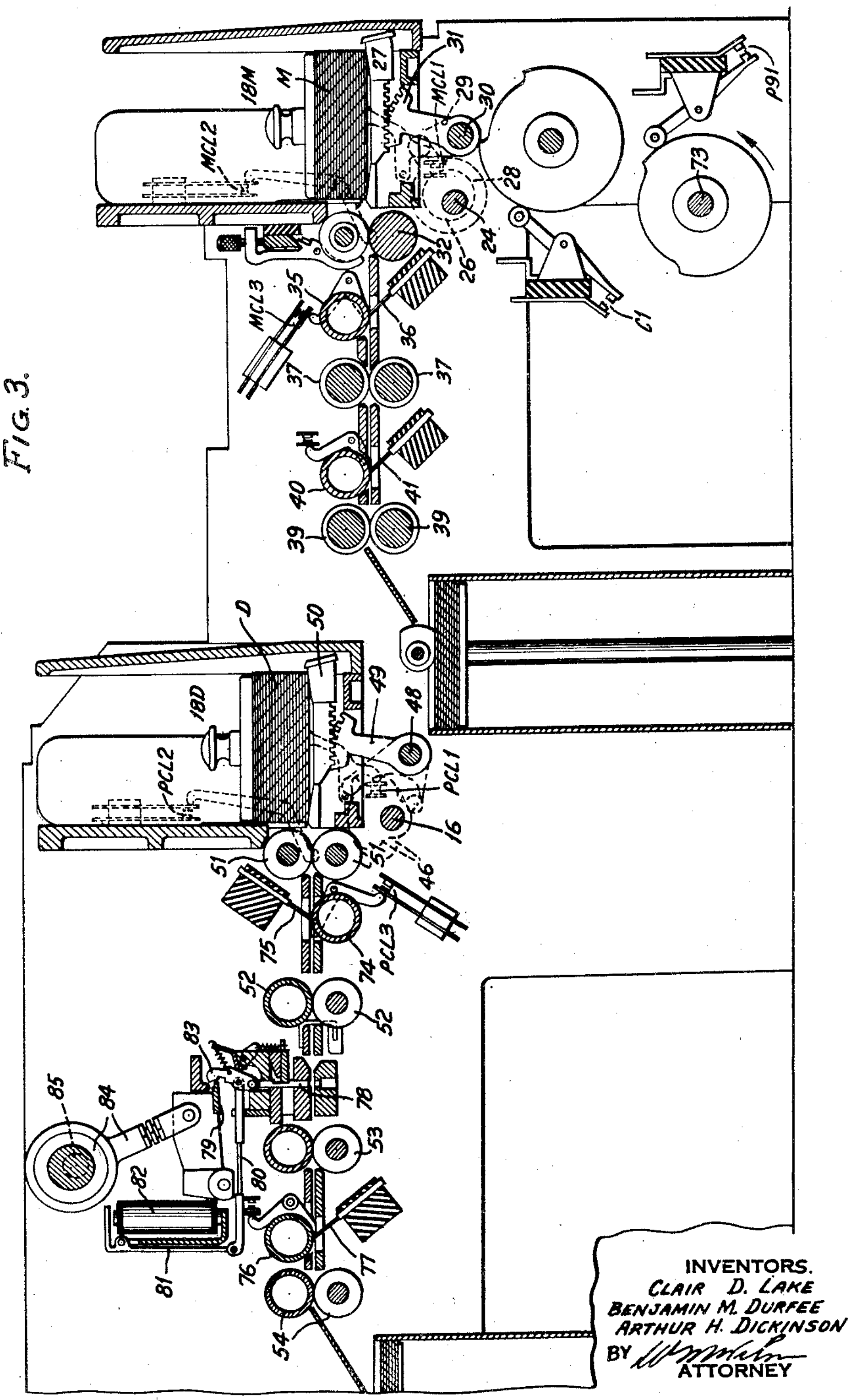
FIG. 2.



INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

FIG. 3.



INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

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FIG. 4.

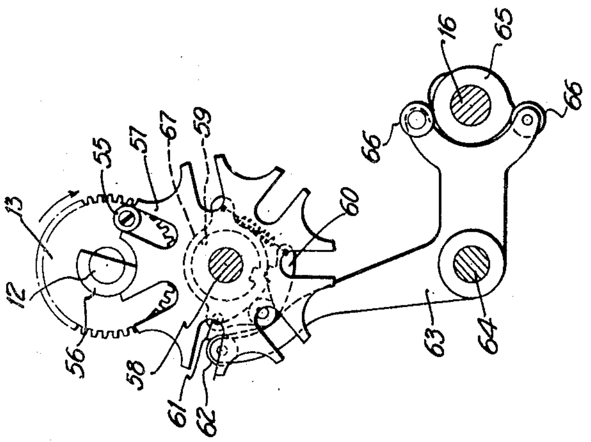
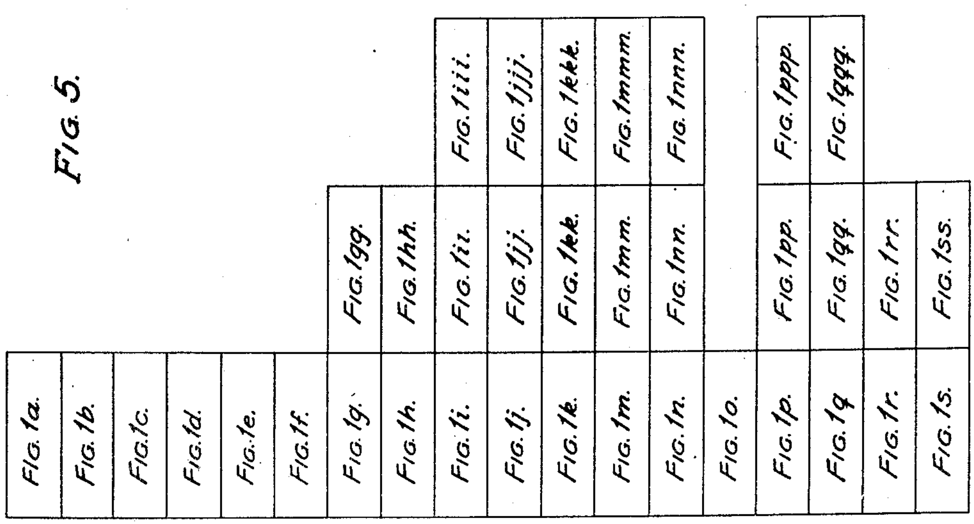


FIG. 5.



INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

FIG. 7.

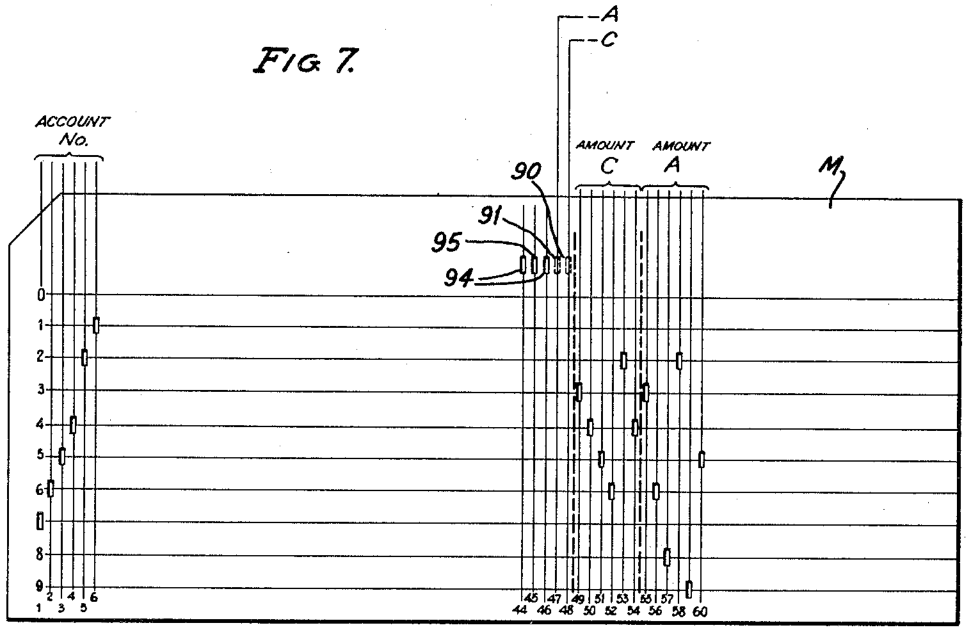
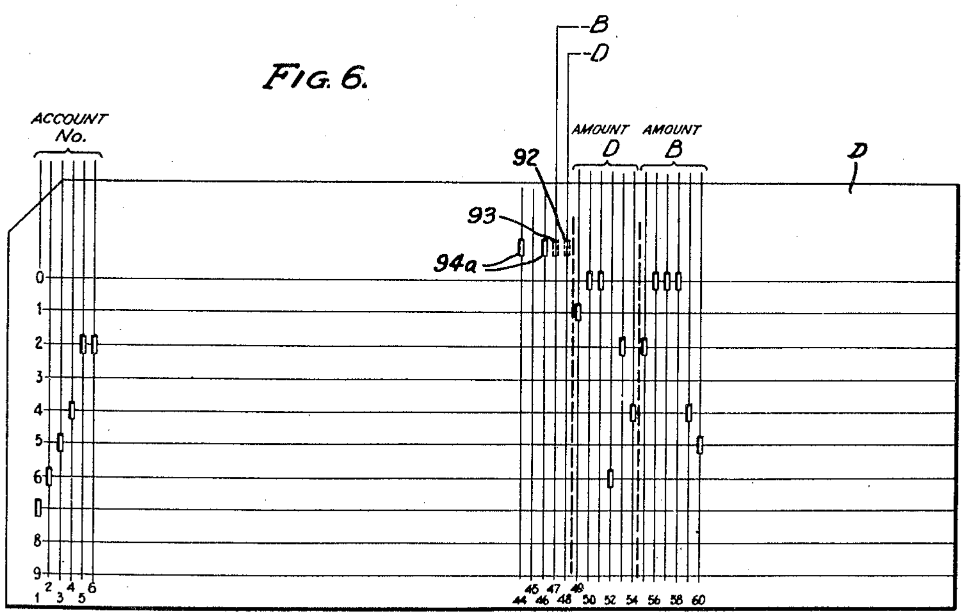


FIG. 6.



INVENTORS
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON
BY [signature]
ATTORNEY

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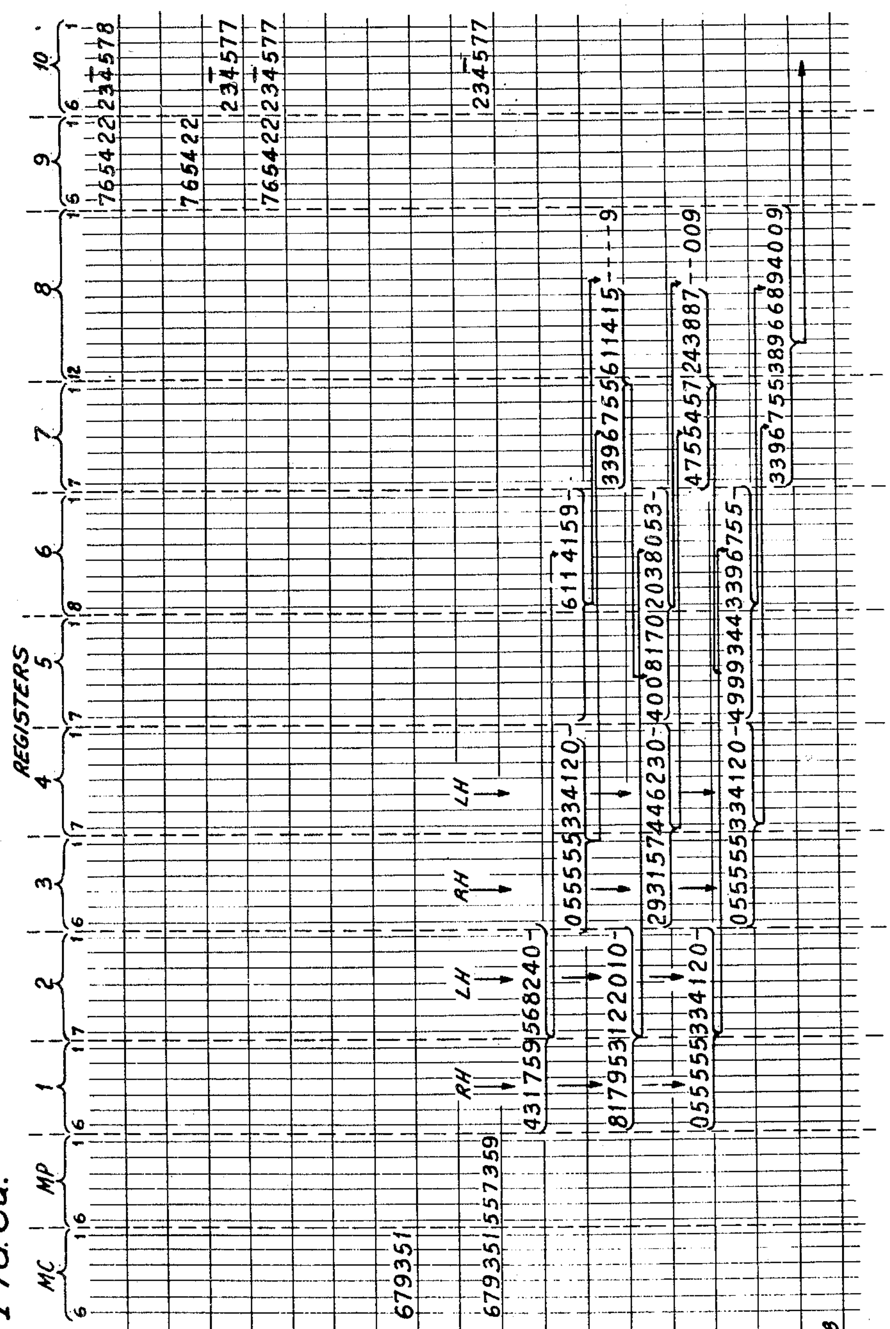

FIG. 8a.

INVENTORS.
CLAIR D. LAKE
BENJAMIN M. DURFEE
ARTHUR H. DICKINSON

BY [signature]
ATTORNEY

Dec. 6, 1949 C. D. LAKE ET AL 2,490,362

RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 42

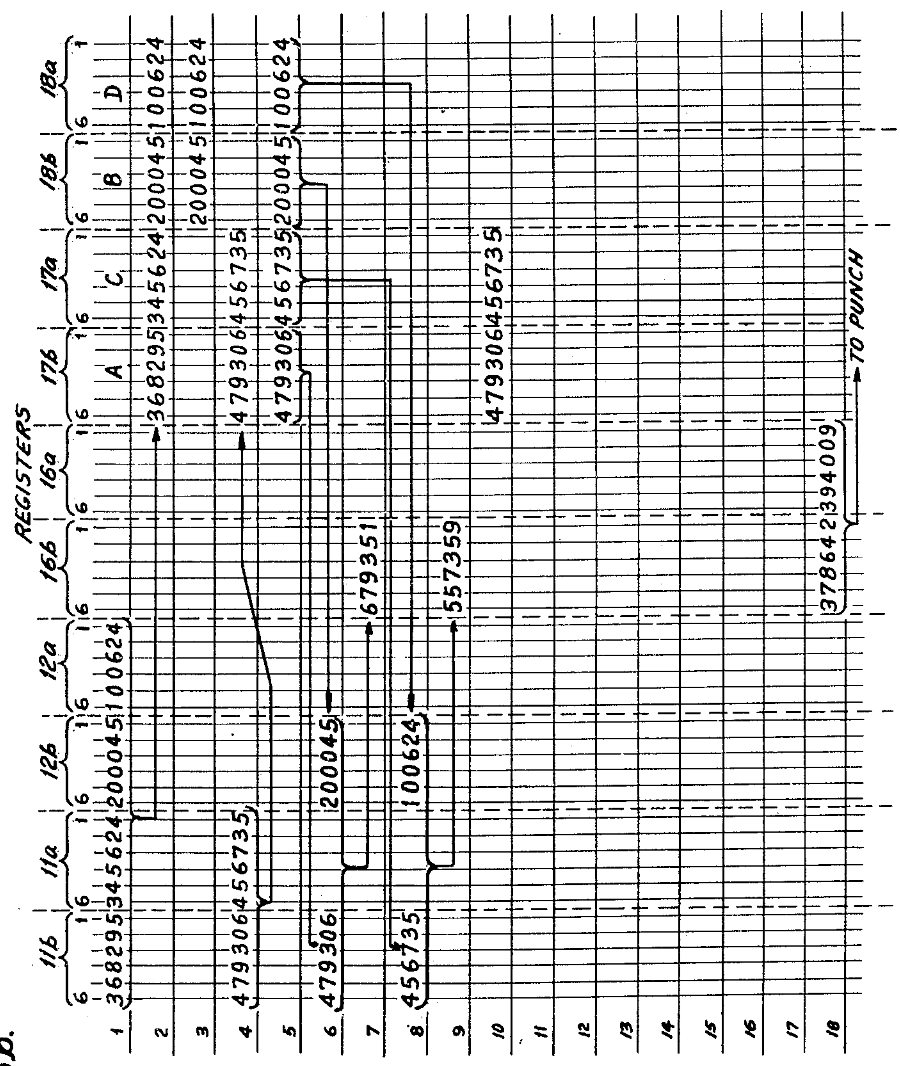

FIG. 8b.

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RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 43

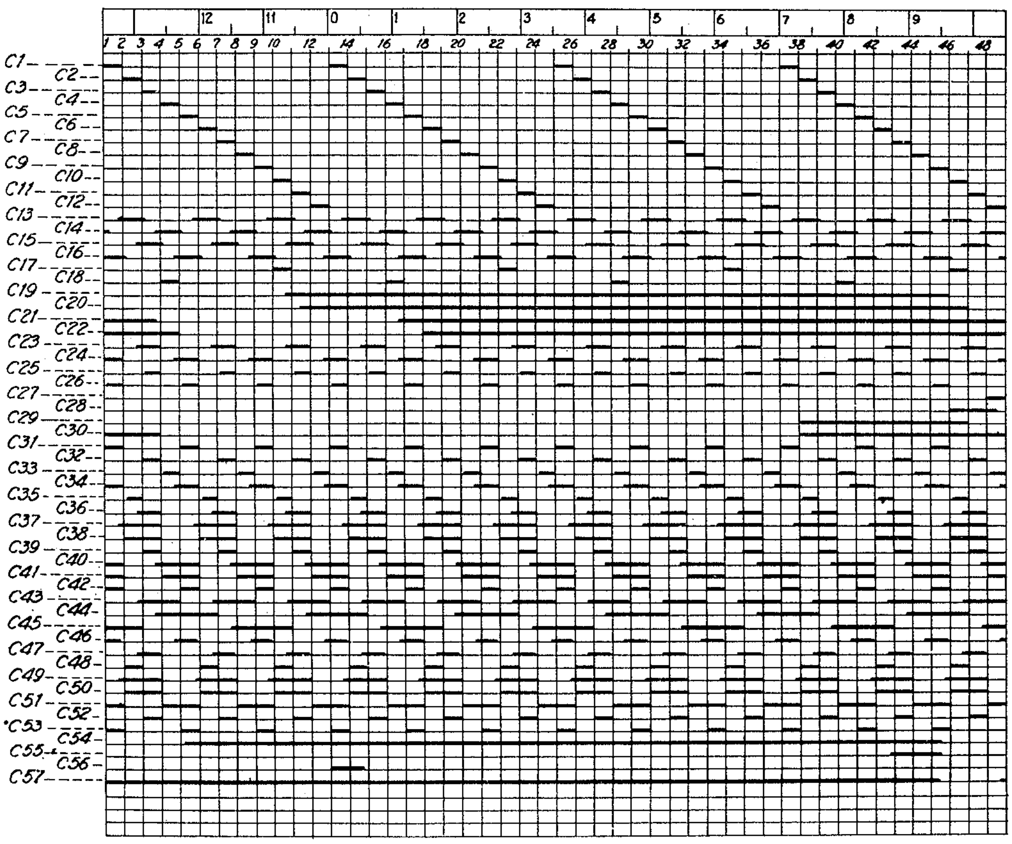

FIG. 9a.

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RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 44

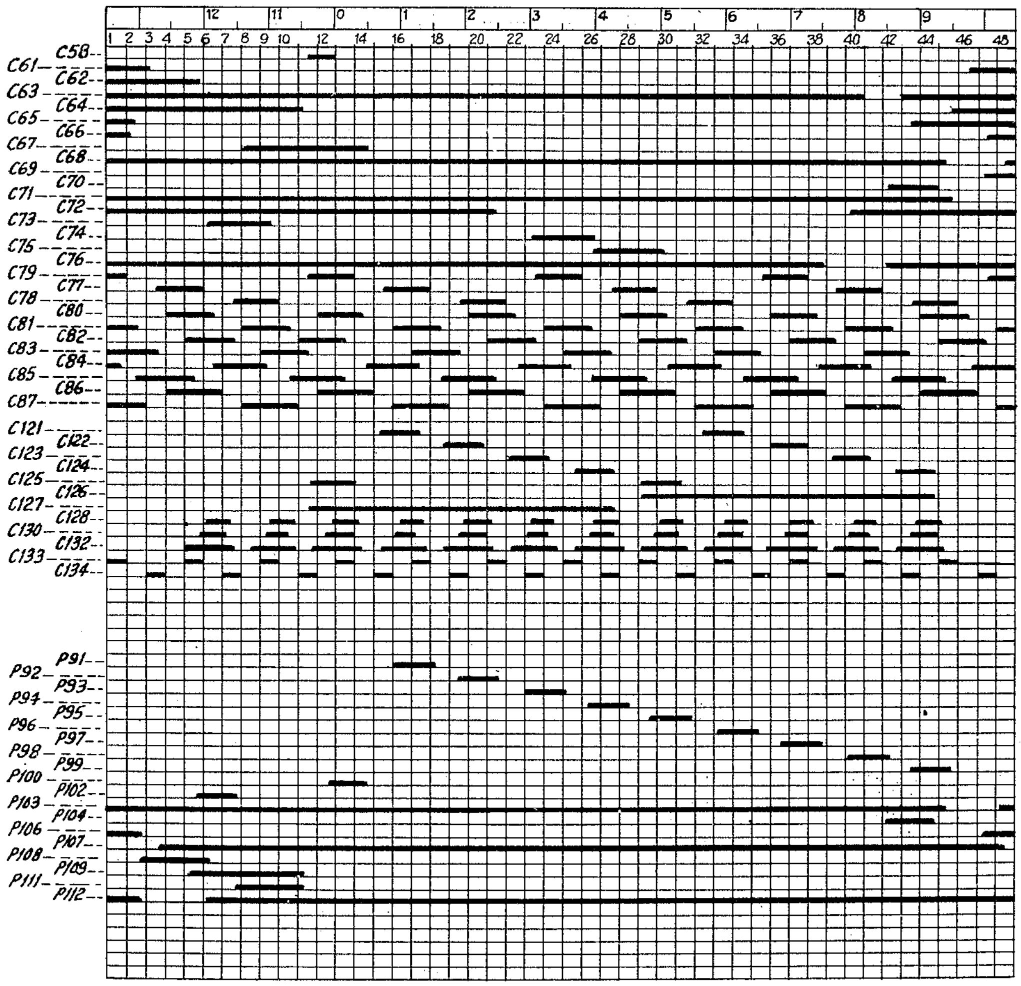

FIG. 9b.

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RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 45

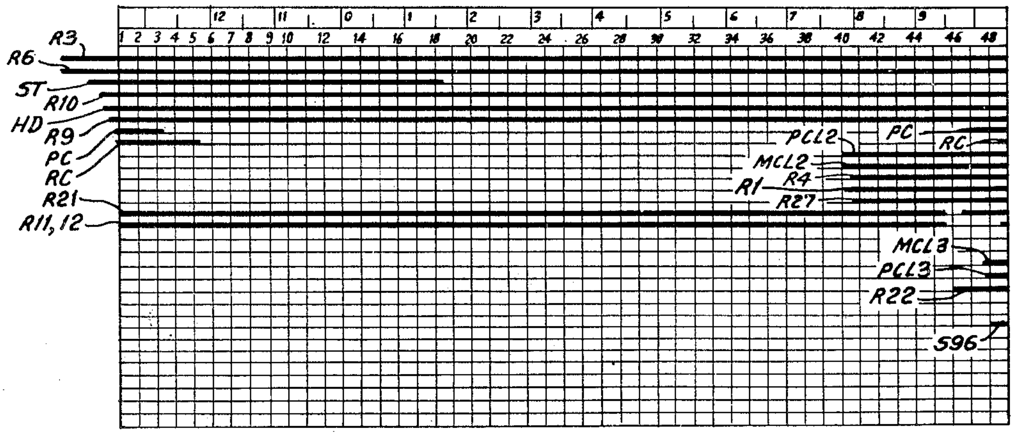
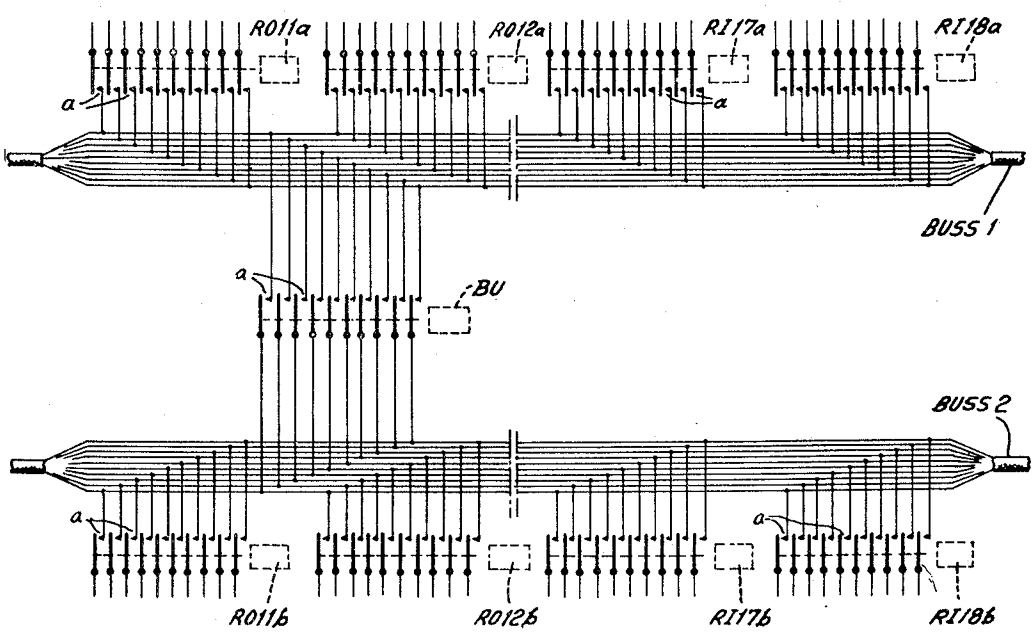


FIG. 10a.

FIG. 11.



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RECORD CONTROLLED CALCULATING MACHINE

Filed Dec. 21, 1945 51 Sheets-Sheet 46

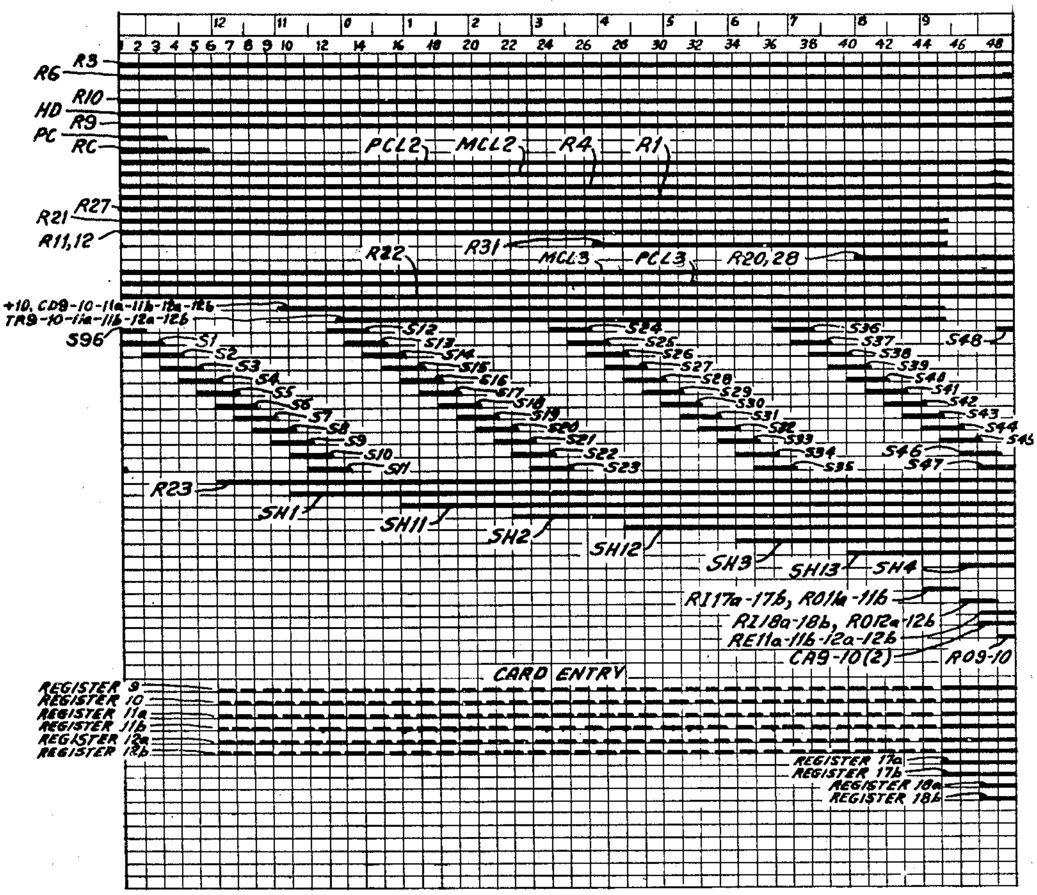

FIG. 10b.

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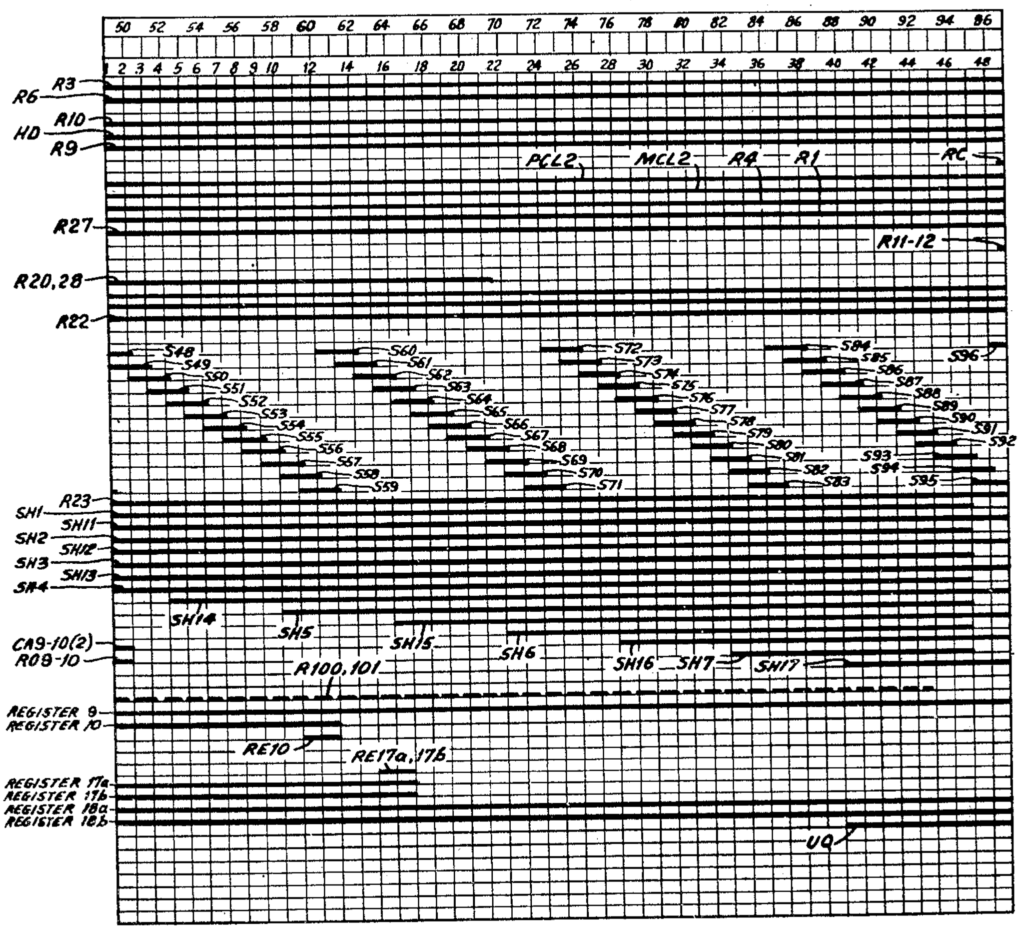

FIG. 10c.

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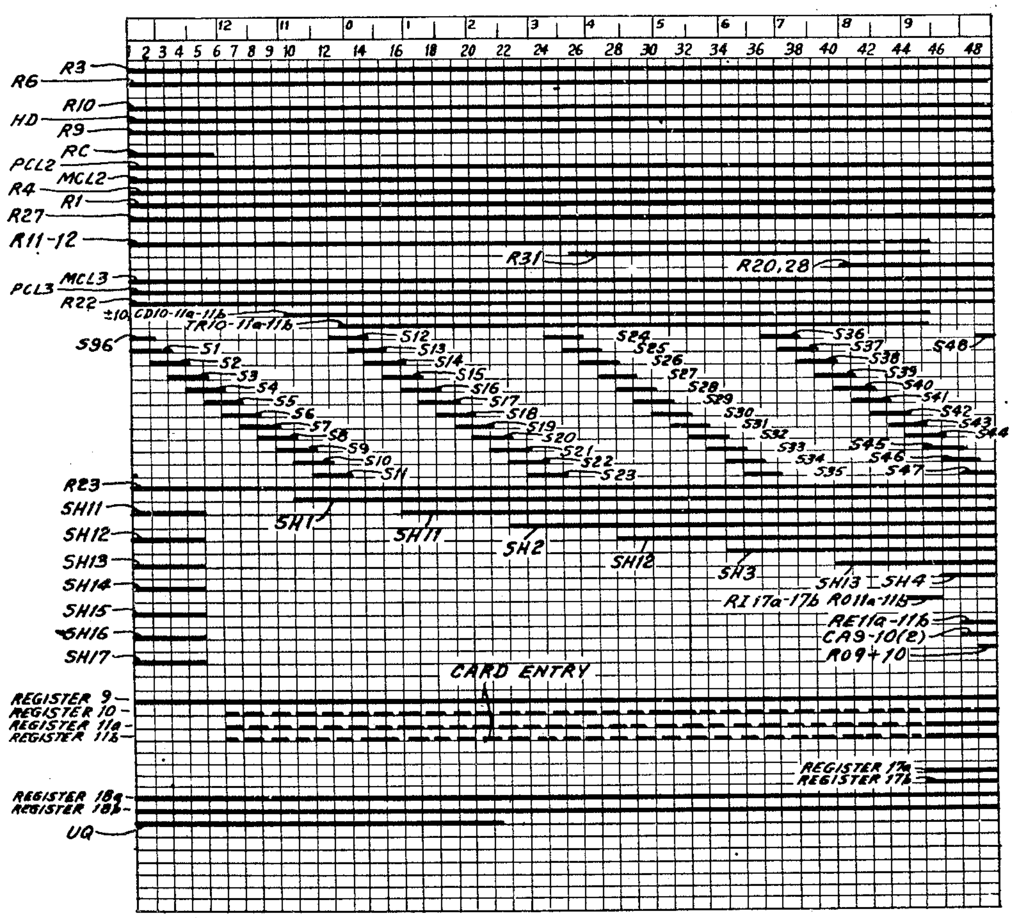

FIG. 10d.

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RECORD CONTROLLED CALCULATING MACHINE

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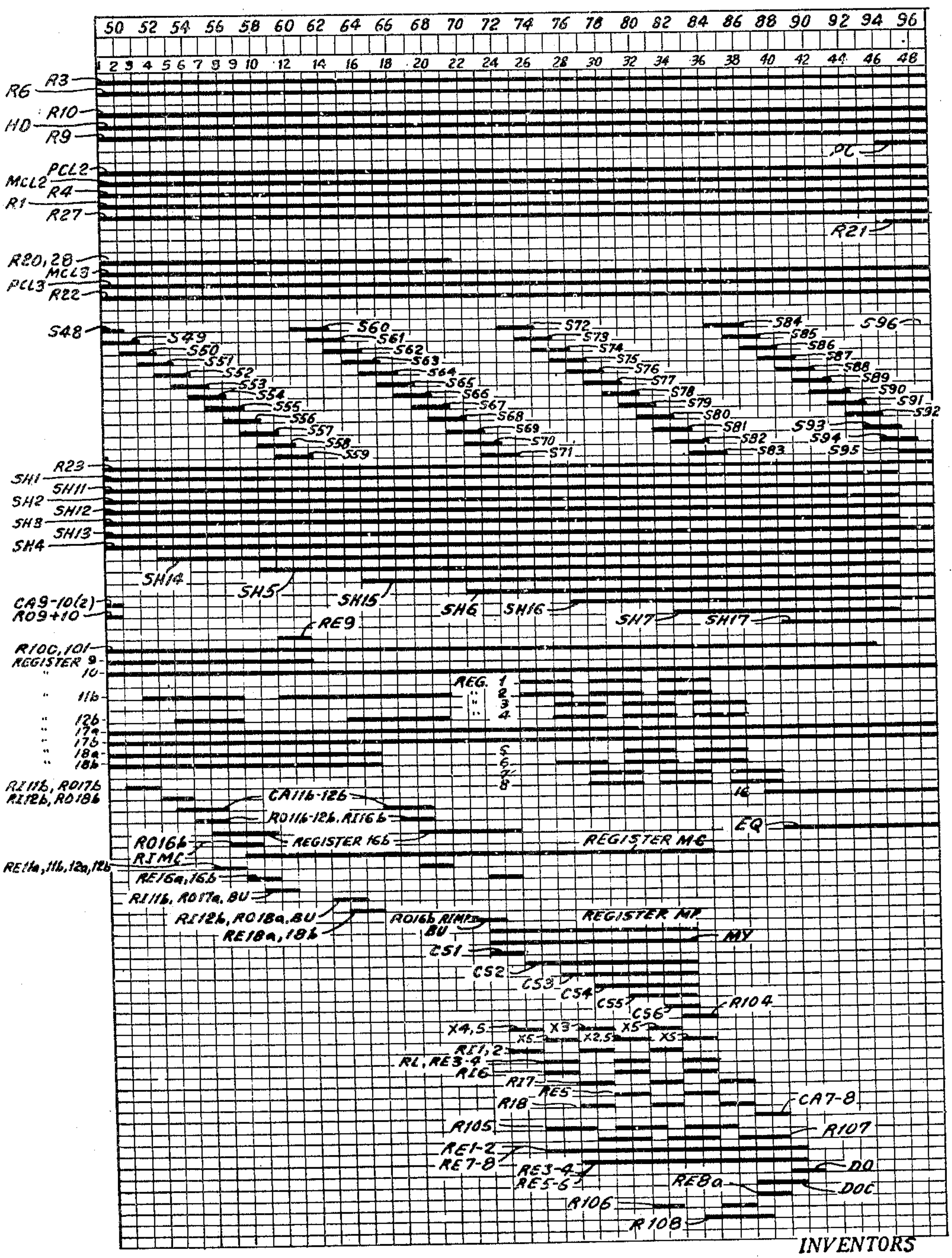

FIG. 10e.

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RECORD CONTROLLED CALCULATING MACHINE

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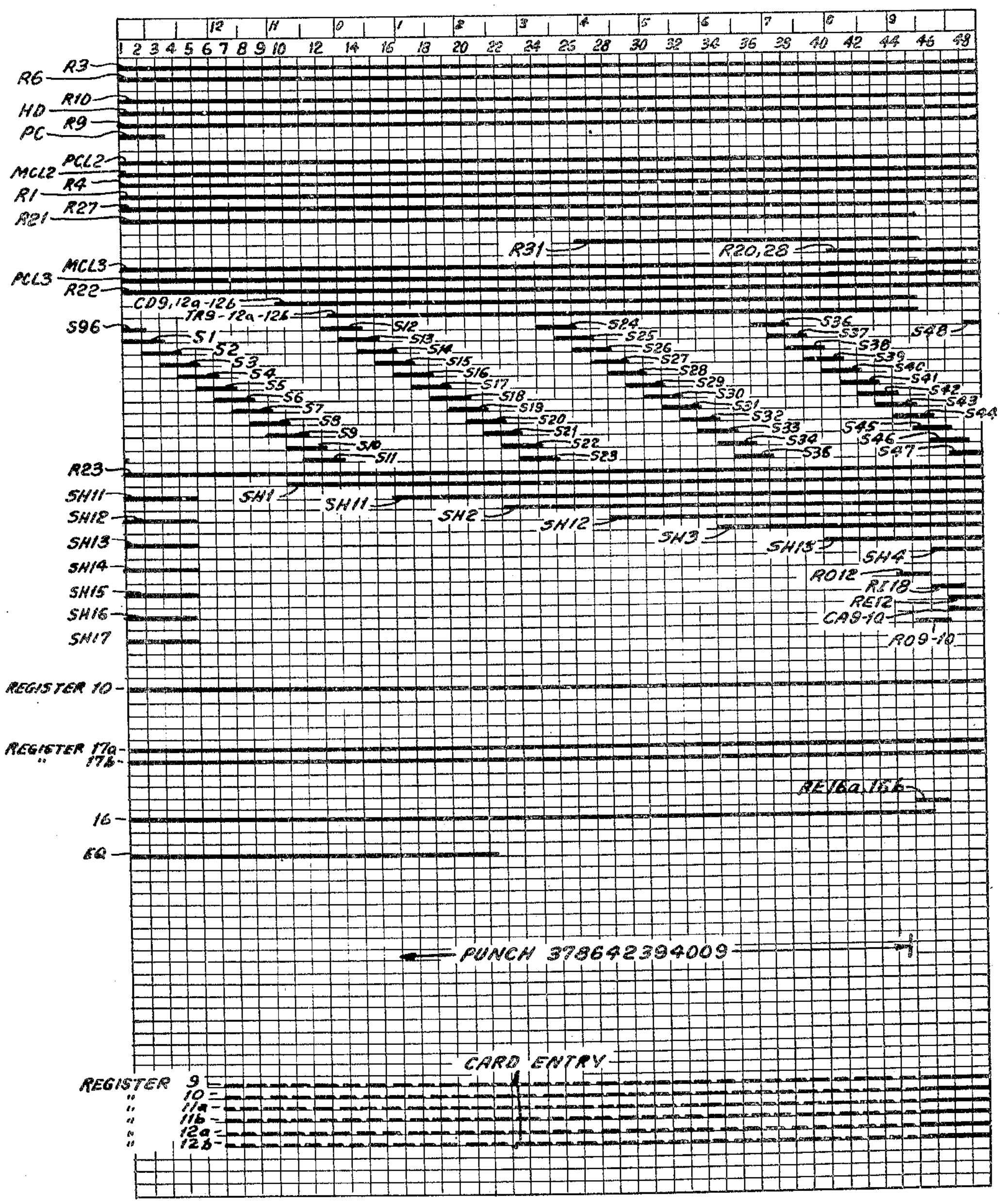

FIG. 10f.

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RECORD CONTROLLED CALCULATING MACHINE

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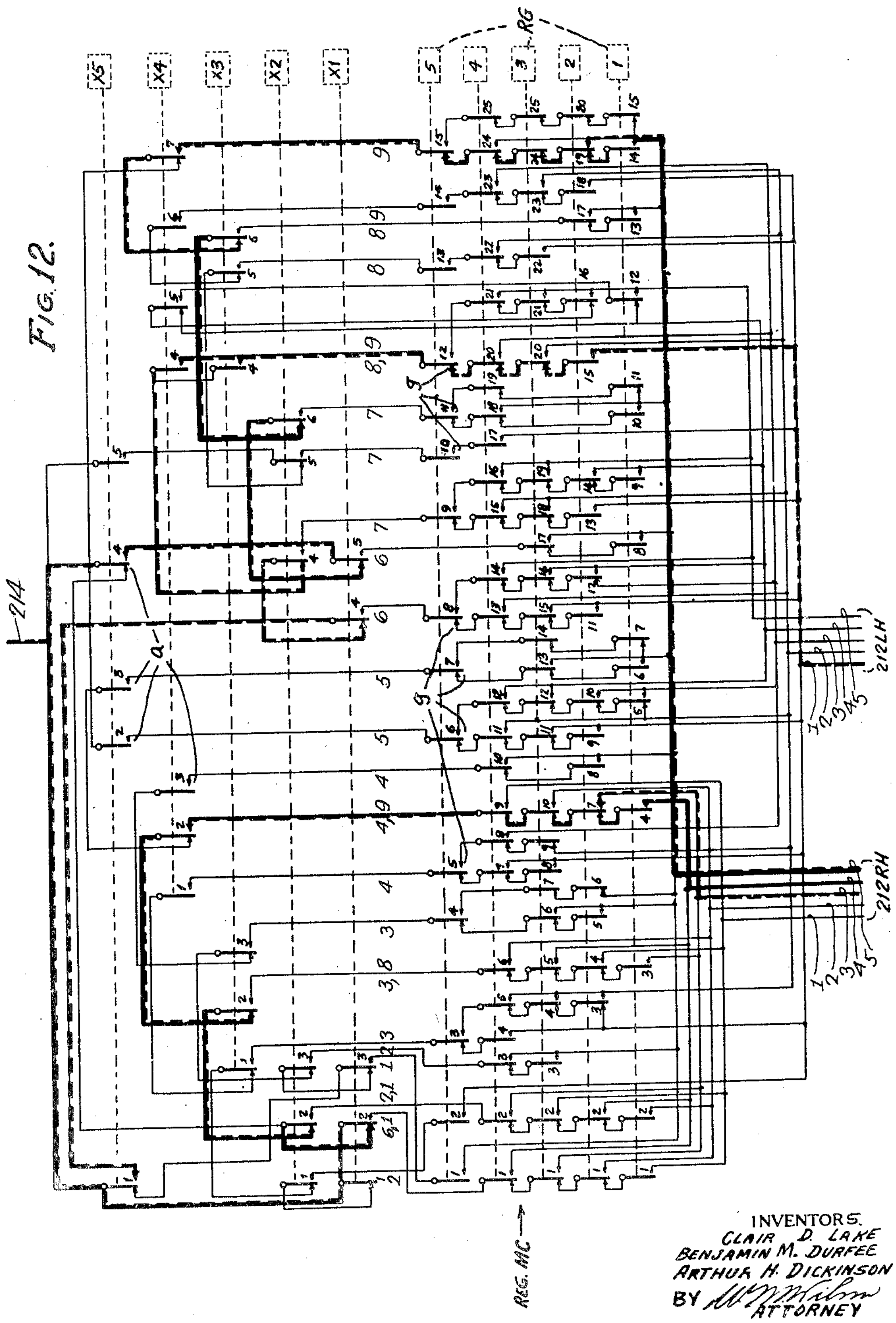
FIG. 12.



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Patented Dec. 6, 1949

2,490,362

UNITED STATES PATENT OFFICE

2,490,362

RECORD CONTROLLED CALCULATING MACHINE

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Application December 21, 1945, Serial No. 636,526

20 Claims. (Cl. 235—61.7)

The present invention concerns calculating machines and particularly machines of the record card controlled type. The principal object of the invention is to provide an improved calculating machine in which computing operations are effected through accumulating mechanisms of the electrical or relay type.

An object of the invention is to provide an improved relay multiplying arrangement wherein partial products are obtained and combined in a novel manner to arrive at the final product.

A further object of the invention is to provide an improved relay multiplying system in which partial products are obtained and gathered together in a more rapid manner than has heretofore been accomplished.

A further object of the invention is to provide an improved accumulating mechanism in which two amounts may be entered either concurrently or successively and the sum or difference obtained in response to the emission of a pair of successive electrical impulses, the first of which predetermines tens carrying requirements and the second completes the circuit through an adjusted adding chain to transmit the sum to a desired destination.

A more specific object of the invention resides in the provision of accumulating mechanism of the aforementioned type wherein the tens carry determining part may be separately utilized to determine the relative magnitude of the amounts.

A further object of the invention resides in the provision of an improved device for reading amounts on record cards represented as decimal notations, translating such amounts into a predetermined code combination, and incidentally inverting the amount into the form of a complementary value.

A still further object of the invention resides in the provision of improved mechanism for handling two sets of record cards for each of which there is provided a separately driven feeding mechanism. In the operation of the apparatus, cards are fed by both feeding mechanisms. Identifying designations are sensed thereon and compared. If they are found to be in agreement, amounts derived from these cards are cross added and multiplied in accordance with a predetermined setup and the ultimate result is recorded back on one of the two cards. If the comparison

indicates a disagreement, one of the cards is retained and the other replaced by a new card of the same type. Comparison is repeated and the process conducted over again in accordance with the results of the further comparison. In the computing operation, the factors involved in the multiplying operation may be derived wholly from one type of card or from the other or one factor may be obtained from one card and one factor from the other card.

A still further object of the invention lies in the provision of a so-called sequence control mechanism in which provision is made for emitting a sequence of impulses at spaced intervals during a cycle of operations of the machine. Provision is made for causing the sequence of impulses to extend throughout two successive cycles or to extend throughout a single cycle and then repeat during the next following cycle.

A further object of the invention resides in the provision of novel circuit arrangements for determining the algebraic signs of terms entered into and derived by the computing mechanism to obtain the algebraic sign of the ultimate result.

In the operation of the machine, digits are represented in what is known as the quinary system of notation. To this end five elements (relays) are employed having assigned values 1, 2, 3, 4 and 5. The several digits are represented on these elements by a setting or operation thereof in the following combinations.

digit	element	digit	element
1	1	6	1 and 5
2	2	7	2 and 5
3	3	8	3 and 5
4	4	9	4 and 5
5	5	0	none

The digits 1 to 5 are termed the first pentad of the quinary system and the digits 6 to 9 are termed the second pentad.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of example, the principle of the invention and the best mode, which has been contemplated, of applying that principle.

In the drawings:

The figure designated 1 followed by lower case letters when arranged in the order indicated in Fig. 5 constitute a wiring diagram of the electrical circuits of the machine.

Fig. 2 is an outside elevation of the driving mechanism for the card feeding device.

Fig. 3 is a central section parallel to the elevation in Fig. 2 showing the essential card feeding, sensing, and punching devices of the machine.

Fig. 4 is a detail showing the mechanism for effecting step by step advance of the detail cards past the punching station.

Fig. 5 is a chart showing the manner in which the figures of the circuit diagram are to be arranged.

Figs. 6 and 7 show representative detail and master cards perforated in accordance with a specific problem.

Figs. 8*a* and 8*b* taken together constitute a chart showing the order in which entries are made into the several registers of the machine.

Figs. 9*a* and 9*b* constitute a timing chart of the cam controlled contacts of the machine.

Figs. 10*a* to 10*f* placed in the order named from left to right constitute a sequence diagram showing the order in which the more important relays and other current responsive devices are energized and the periods during which they are maintained in energized condition.

Fig. 11 is a fragmentary circuit showing the manner in which various electrical units are cross connected through the utilization of common busses or multiple wire cables.

Fig. 12 shows the wiring arrangement for obtaining left and right hand partial products of a multiplier digit and a single multiplicand digit.

The record card feeding, reading and punching mechanism is similar to that shown in the Page and Beattie Patent No. 2,372,909, granted April 3, 1945, and such mechanism will, therefore, be but briefly described. Reference may be made to such patent and also to the Lake Patent No. 2,032,805, granted March 3, 1936, for details of construction.

The drive motor MD (represented in Fig. 1*a*) has belt-and-pulley connection 11 (Fig. 2) with a shaft 12 on which there is secured a gear 13. Through reduction gearing generally designated 14, the gear 13 drives a gear 17 integral with the last gear 14 of the chain and freely rotatable on the so-called punch unit drive shaft 16. Gear 17 through a chain of gears 19 drives a shaft 20 upon which is mounted a series of cams for operating contacts prefixed C, as C1, C2, etc. (Fig. 3). These are so-called constantly running cams, the timing of whose contacts is shown in the timing chart (Figs. 9*a* and 9*b*).

Integral with one of the right hand gears 19 (Fig. 2) is a clutch driving disk 21 freely rotatable on a shaft 24 known as the reading unit drive shaft. Cooperating with disk 21 is a clutch pawl 22 pivoted on an arm 23 secured to shaft 24, and normally held in declutching position by armature latch 25 of a clutch magnet RC. Upon energization of magnet RC, pawl 22 will be released for engagement with constantly rotating disk 21 and shaft 24 will be driven.

In Fig. 3, shaft 24 through an eccentric cam and strap 26, 28 will oscillate an arm 29, secured to rod 30 to similarly oscillate toothed sector 31 and reciprocate card picker slide 27 to feed the bottom card M from hopper 18M to feed rollers 32 and thence to rollers 37 and 39, which pass the card to the discharge hopper. The rollers 32, 37 and 39 are driven by a gear 34 (Fig. 2) secured to shaft 24, through a chain of gearing generally designated 33 which drives pinions 38 attached to the ends of the feed roller shafts.

Intermediate the rollers 32, 37 (Fig. 3) is a contact roller 35 and cooperating sensing brushes 36, and intermediate rollers 37, 39 is a second contact roller 40 and cooperating sensing brushes 41. The action is such that during the first revolution of shaft 24 a card M is fed from hopper 18M up to brushes 36, during a second revolution the card traverses the brushes and advances up to brushes 41. During a third cycle, the card traverses brushes 41 and passes to the discharge hopper.

In Fig. 2, gear 17 has integral therewith a clutch driving disk 42 in constant rotation and freely mounted on shaft 16. Cooperating with disk 42 is a clutch pawl 44 pivoted on an arm 43 secured to shaft 16 and normally held in declutching position by armature latch 45 of a clutch magnet PC. Upon energization of magnet PC, pawl 44 will be released for engagement with constantly rotating disk 42 and shaft 16 will be driven.

In Fig. 3 shaft 16 has secured thereto a pair of complementary cams 46 for oscillating a double armed follower 47 secured to rod 48 and thus oscillate toothed sector 49 and reciprocate card picker slide 50 to feed the bottom card D from hopper 18D to feed rollers 51 and thence to rollers 52, 53 and 54 to the discharge hopper.

These feed rollers 51 to 54 are driven with a step-by-step motion in the following manner. In Fig. 4, the constantly rotating gear 13 carries a roller 55 and a locking element 56 which cooperate with a Geneva wheel 57 to rapidly step the wheel around a rod 58, upon which it is freely mounted. Integral with wheel 57 is a clutch driving disk 59 and cooperating with the disk is a clutch pawl 60 whose arm 61 is normally engaged by roller 62 on a lever 63, to hold the clutch disengaged. Lever 63 is pivoted at 64 and carries a pair of follower rollers 66 in cooperation with a pair of complementary cams 65 secured to shaft 16. Thus, when shaft 16 is coupled for rotation, cams 65 will rock lever 63 to free pawl 60 for engagement with clutch disk 59.

Pawl 60 is pivoted on a plate 67 secured to rod 58 so that the latter is accordingly rotated with an intermittent motion. In Fig. 2, rod 58 has a gear 68 secured thereto which drives a chain of gears 69 and these drive pinions 70 attached to the ends of the feed roller shafts.

Shaft 16 (Fig. 2) has a gear 71 secured thereto which through gearing 72 drives a shaft 73 upon which is mounted a series of cams for operating contacts prefixed P, as P91, P92, etc. (Fig. 3). These are so-called punch contact cams which turn only when the punch clutch PC is energized, and the timing of their contacts is shown in the timing chart (Fig. 9*b*).

Intermediate rollers 51 and 52 (Fig. 3) is a contact roller 74 and cooperating sensing brushes 75, and intermediate rollers 53 and 54 is a contact roller 76 and cooperating sensing brushes 77. Intermediate rollers 52 and 53 is a punching mechanism comprising punches 78 and an oscillating actuating bar 79. The upper end of the punch has a hook 83 pivoted thereto which is connected by a call rod 80 to the armature 81 of magnet 82. When magnet 82 is energized, rod 80 is drawn to the left to rock hook 83 into engagement with bar 79, whereupon the bar will force the hook and connected punch 78 down to perforate the card. Bar 79 is oscillated through an eccentric cam and strap device 84 from a shaft

86 which in Fig. 2 is driven through gearing generally designated 86 from a pinion 87 integral with one of the chain of gears 69. Thus, the punch bar is reciprocated only when detail cards are fed and the gear ratio is such that shaft 85 is rotated once for each step of advance of the card.

The action is such that during the first revolution of shaft 16 a card D is fed from hopper 18D up to brushes 75; during a second revolution the card traverses brushes 75 and advances up to the punches 78. During a third cycle, the card traverses the punches and is perforated thereby advancing up to brush 77. During a fourth cycle the card traverses brushes 77 and passes to the discharge hopper.

With the arrangement described, the two card feeding mechanisms or units may be independently operated by selective energization of the RC and PC clutch magnets, or they may be concurrently operated by concurrent energization of the magnets.

It is thought that the above general description of the operation of the mechanical devices will suffice to give an understanding of the operation thereof. For further details of construction and operation, reference may be had to the Lake and Page patents referred to.

The registers

The machine is provided with a plurality of registers which comprise generally denominationally ordered sets of relay magnets with appropriate circuit connections thereto for entering amounts, retaining them, and reading them out. Figs. 8*a* and 8*b* indicate that there are twenty-two registers as designated across the top of the figures, and vertical lines indicate their denominational capacities. The connections to to several of the registers are arranged to be made selectively by plug connections, and in other case the connections are through fixed wiring. This arrangement is designed to secure maximum flexibility for solution of a diversity of problems with a minimum of manual plug connections. Several pairs of the registers have read-out contacts interconnected in an adding chain, so that with an amount set in each register of a pair the sum thereof may be read out and through fixed wiring entered into another register.

Figs. 8*a* and 8*b* indicate generally the characteristics of the several registers as follows. Registers 9, 10, 11*b*, 11*a*, 12*b* and 12*a* are pluggable to receive entries from record cards. (Registers MC, MP and 1 to 6 are also similarly pluggable but are not for the problem to be explained.) Registers 11*b*, 11*a*, 12*b*, and 12*a* are wired to transfer their entries to registers 17*b*, 17*a*, 18*b* and 18*a*, respectively, and these latter registers are wired to transfer their entries back to registers 11*b* from 17*b* and 17*a* and to 12*b* from 18*b* and 18*a*.

Registers 11*b* and 12*b* are provided with the cross adding connections so their sum is transferred through fixed wiring to register 16*b*, and the latter is connected to transfer to registers MC and MP selectively.

Registers 1 and 2 are wired to receive partial product component entries from a multiplying device and through cross-adding connections the sum in these two registers is entered in register 6, which in turn is provided with cross-add connections with register 5 to enter such sum in register 8.

Registers 3 and 4 also are wired to receive partial product component entries and are wired to cross-add the entries and transfer the sum to register 7 which cross-adds with register 8 to enter such sum in register 5.

Registers 7 and 8 have their cross-add connections also wired to enter the sum in registers 16*b* and 16*a* and the latter are plug connectable to control punching mechanism.

Problem

In explaining the operation of the machine, a representative problem will be considered and the various steps involved will be described in their order of occurrence. It will be assumed that a group of master cards M is placed in the related supply hopper 18M with the cards arranged in serial order according to account numbers perforated therein, so that they feed in succession in ascending sequence. A similar group of detail cards D is placed in hopper 18D to feed in the same order. It will be assumed that the file of master cards is complete and that the detail cards may be fewer in number with gaps occurring in the detail series but that for each detail card there is a corresponding master card.

Figs. 7 and 6 illustrate representative master and detail cards each having an account number perforated in columns 1 to 6 thereof. In addition, the card M has amounts C and A perforated therein and the card D has amounts B and D perforated therein.

The machine is to concurrently feed a master and detail card and effect a comparison of their account numbers. If there is disagreement, the master card is advanced and a new master card fed and compared with the first detail card. Feeding and comparing of successive master cards will take place until the master card whose account number agrees with that of the first detail card arrives, and thereupon the machine will cause the amounts A and B and the amounts C and D to be cross added, and these separate sums will then be multiplied to obtain the result $(A+B)\ (C+D)$ which will then be punched into selected columns of the detail card D.

The algebraic signs of the four amounts may be indicated by a perforation in the well known 11 or X position of a selected card column. Thus, in Fig. 7 if amount A is negative, an X hole 90 is present in column 48; if amount C is negative an X hole 91 is present in column 47. Also, in Fig. 6, if amount B is negative, an X hole 92 is present in column 48 and if amount D is negative, an X hole 93 is present in column 47. When an amount is positive, no X hole is present in the related column 47 or 48. In carrying out the present problem, it will first be assumed that all amounts are positive, so that none of the holes 90 to 93 is present.

Both cards M and D are provided with perforations 94 and 94*a* in columns 44 and 46 which control the conversion of the data from the decimal system in which it is arranged on the cards into a five position code as will be explained hereinafter.

The master card M has in addition an X hole 95 in column 45, which will cause the account number of this card to be entered in the form of a 9's complement. It may be stated at this time that comparison of account numbers is effected by the method of complementary addition, wherein if two numbers are in agreement the sum of one and the 9's complement of the other will result in a series of 9's, whereas if the account number of the detail card is added to the 9's complement of a lower master card, there will occur a so-called carry from the highest order indicative of a disagreement. For the conditions stated, whenever there is a non-agreement, this carry will occur since the master will always have the lower value.

The circuit diagram

The circuit diagram extends through a number of figures which, when arranged in the order shown in Fig. 5, constitute the complete wiring arrangement. In the circuit the relays are generally shown adjacent to their related contacts, but in numberous instances to avoid confusing extension of wires from sheet to sheet, the contacts are shown separated from their relay magnets but in such cases the relays are shown in dotted outline adjacent to the contacts for ready identification. Also, where wires would extend between non-adjacent sheets the connections are interrupted and suitably labeled to indicate which wires are connected together. In many cases, groups of wires are included in cables or busses, and such are identified by legend and by heavy lines. Where a number of circuits extend to a common pair of cam contacts, the showing of such contacts is repeated rather than attempt to extend the lines to a single one, and it may be assumed that like identified cam contacts represent the same element or that duplicate contacts with the same timing are provided. In either case the contact timing will be in accordance with the timing as shown in the diagram Figs. 9*a* and 9*b*.

As a preliminary, main switch 96 (Fig. 1*a*) is closed to provide current to the motor generator MG which will place current on main lines 100 and 101 between which the circuits hereinafter to be traced will be completed.

Starting circuits

Master cards M and detail cards D perforated as shown in Figs. 7 and 6 are placed in their respective magazines, whereupon they will close the so-called card lever operated hopper contacts. For the detail cards, card lever contacts PCL1 (Figs. 1*a* and 3) will close to energize relay R3 through a circuit from line 100, wire 102, relay R3, contacts PCL1 and wire 103 to line 101, and for the master cards contacts MCL1 will close to energize relay R6 through a parallel circuit (see sequence diagram, Fig. 10*a*). The cards are placed in the magazines in position to feed with the 12 index point positions leading. The start key is now operated to close its contacts ST, completing a circuit from positive side of line 100, wire 102, relay R10, wire 104, *a* contacts of relay R3 (now shifted), *a* contacts of relay R6 (shifted), contacts ST, to line 101. Relay R10 closes its *a* contacts establishing a holding circuit from line 100, wire 102, relay R10, its *a* contacts, contacts C57 and wire 103 to line 101. The relay R10 also closes its *c* contacts to energize heavy duty relay HD through a circuit from line 100, relay HD, *c* contacts of relay R10 and wire 106 to line 101. Relay HD in turn closes its *a* contacts to complete a circuit to the drive motor MD from the main source of current through switch 96. With motor MD in operation, the several constantly running gears and contact devices of Figs. 2 and 3 are in operation, starting from the so-called D position indicated in Figs. 9*a* and 9*b*.

Concurrently with the energization of relay HD,

a circuit is traceable from line 100, wire 107, relay R9, normally closed *b* contacts of relay R13, *c* contacts of relay R10, wire 106 to line 101. Relay R9 closes its *a* and *b* contacts, which are in series and through the *c* contacts of relay R10 provide a holding circuit for relay R9 direct to line 101, while the *a* contacts of relay R9 set up a separate holding circuit through cam contacts C63.

A circuit is now traceable from line 101 (Fig. 1*b*), *d* contacts of relay R9 (now closed), *d* contacts of relay R10 (also closed), *a* contacts of relay R40, *c* contacts of relay R20, *b* contacts of relay R1, *a* contacts of relay UQ, cam contacts C61, clutch magnet PC to line 100. A parallel circuit through the pickup coil of relay R21 branches at the cam contacts C61, through wire 108 (Fig. 1*a*), through the pickup coil of relay R21 and wire 109 to line 100. A parallel circuit branches through the *c* contacts of relay (Fig. 1*b*), *b* contacts of relay R4 through the *a* contacts of relay EQ, *c* contacts of relay R4, cam contacts C62 to clutch magnet RC to line 100 and in parallel through wire 110 (Fig. 1*a*) to the pickup coils of relays R11 and R12.

The concurrent energization of the two clutch magnets PC and RC will cause the bottom cards to be fed from the two magazines during the now ensuing cycle of operations, which is designated as cycle 1 in Fig. 10*a*. At the end of the cycle, the leading edges of the master and detail cards will have been advanced up to the sensing brushes 36 and 75 respectively (Figs. 3 and 1*b*) and with the leading edges of the cards extending between the brushes and their contact rollers 35 and 74 respectively. As the master and detail cards advance to this position and at the time in the cycle indicated in Fig. 10*a*, they close their respective card lever contacts MCL2 and PCL2 (Fig. 3), which in Fig. 1*a* energize relays R4 and R1 respectively, through wires 106 and 107. A circuit is now traceable through the holding coil of relay R10, traceable from line 100, wire 102, holding coil of relay R10, *b* contacts of relay R10, *b* contacts of relay R3 (now shifted), *a* contacts of relay R1, *c* contacts of relay R2, *b* contacts of relay R8, *b* contacts of relay R6 (shifted), *a* contacts of relay R4 (shifted), stop key contacts SP, to line 101. This provides a further holding circuit for the relay R10 which together with the holding circuit through contacts C57 will keep the relay energized as long as cards are advanced from the hoppers.

A relay R27 is energized in parallel with the holding coil of relay R10 and this closes its *a* contacts to provide a holding circuit through cam contacts C57 as well as the holding path already traced for the holding coil of relay R10, so that relay R27 remains energized concurrently with relay R10. Relay R27 controls the initiation of the operation of the sequence control relays which will be explained hereinafter under the chapter heading "Sequence control relays."

Just before the end of the cycle, the cards close card lever contacts MCL3 and PCL3 (Figs. 1*b*, 3 and 10*a*), and these contacts will remain closed while the cards now pass their respective sensing brushes 36 and 75. The machine continues through a second card feed cycle (represented in Fig. 10*b*), since the relays R9 and R10 are held energized through the circuits traced, so that the clutch magnets PC and RC become reenergized when contacts C61 and C62 close in the latter part of the first cycle, as indicated in Fig. 10*a*

Entering the account number in registers 9 and 10

As the master card M passes the brushes 36, the account number will be sensed by brushes 36 and entered into register 10 and concurrently the account number on the detail card D will be sensed by brushes 75 and entered into register 9. These account numbers are recorded in the record cards as decimal notations, whereas the registers are arranged to receive data in combinational code form. The code employed is a 5-place code having the values 1, 2, 3, 4 and 5 in which the digits are represented by a value which equals, or a pair of values whose sum equals, the digit to be registered. Each of said sums includes the value 5 plus one of the lesser values.

As the detail card D passes brushes 75, the X perforation 94*a* termed the "code control hole" in column 44 (Fig. 6) is sensed and will complete a circuit traceable from line 101 (Fig. 1*b*), contacts C128, C130, P107, contacts PCL3, contact roller 74, X hole 94*a* in the card to the related brush 75. From here a plug connection 111 (Fig. 1*d*) is made to the winding of a relay designated CD9, and thence through wire 112 to line 100. This relay closes its *a* contacts, to provide a holding circuit through wire 113 and cam contacts C54.

Referring now to Fig. 1*d*, there is provided a series of contacts designated C121—C127 which close at times indicated in the time chart (Fig. 9*b*) as the card traverses the brushes 75. Specifically, contacts C121 close at the 1 and 6 card hole sensing times, contacts C122 close at the 2 and 7 times, C123 at the 3 and 8 times, C124 at the 4 and 9 times, C125 at the 0 and 5 times, C126 closes from 5 to 9 and C127 closes from 0 to 4 inclusive. Accordingly, impulses are transmitted through these contacts from line 101 to groups of wires generally designated 116. Connected to one set of these wires are seven *b* contacts of the relay CD9, so that with these *b* contacts closed circuits will be completed to energize a set of relays termed translate relays, and for the particular entry now being described are identified as TR9 for the 9 set of translater relays.

Tracing one of the energizing circuits as an example, current flows from line 101 (Fig. 1*d*), contacts C121 at the 1 card hole sensing time, the 1, 6, wire 116, the left hand *b* contacts of the relay CD9, the *b* contacts of the relay designated ±9 to the 1 relay of the group of translate relays designated TR9 and wire 117 to line 100. The tracing of circuits through the other contacts C122 to C127 will disclose that the group of relays TR9 will be energized to represent the several digits as the corresponding digital positions pass the sensing brushes 75, that is, when the 1 hole is sensed the 1 relay TR9 will be energized and, when the 9 hole is sensed, the 4 and 5 relays TR9 will be energized and so on.

Referring now to Fig. 1*n*, the TR9 set of translate relays closes groups of contacts designated *c*, and it will be apparent that these contacts close at times determined by the initial controlling cam contacts C121—C127. For each denominational order of the 9 register, one side of the *c* contacts are wired to a plug socket 118 from which plug connections 119 are made to plug sockets 120 related to brushes 75 that traverse the card columns in which the account number is perforated. Tracing the circuit for the units order column of the example shown in Fig. 6, namely, for the digit 2 in column 6 of the detail card, a circuit is traceable when the 2 perforation is sensed, from related brush 75 (Fig. 1*b*), socket 120, plug connection 119 (Fig. 1*n*), plug socket 118 of the units order of register 9, the *c* contacts of the 2 translate relay TR9 in this order, pickup winding of the 2 register relay RG for the units order, and wire 121 to line 100. This RG relay closes its *a* contacts to provide a holding circuit from line 100, wire 121, through the holding coil of relay RG, *a* contacts of the 2 relay RG, *a* contacts of relay RE9 to line 101.

Through similar circuits for other orders the register relays RG will be energized singly or in combinations to set up therein the digits perforated in the account number field of the detail card (Fig. 6), and such setting will be retained until the *a* contacts of relay RE9 are shifted from the position shown.

The account number on the master card is entered into register 10 in the same manner, except that in this case the account number is entered as the 9's complement. This complementary entry is effected by energizing the ±10 relay in Fig. 1*d*, whose *b* contacts when shifted will connect the *b* contacts of the relay CD10 to the 10 set of translate relays TR10 complementarily. The energization of the ±10 relay is effected concurrently with energization of the code relay CD10, under control of the X perforation 95 in column 45 of the master card (see Fig. 7).

When the X perforation 94 in column 44 is sensed, it will complete a circuit to energize relay CD10, through a plug connection 122 (Figs. 1*b* and 1*d*) and a holding circuit will be provided therefor through contacts C54 in exactly the same manner as explained for the energization of the relay CD9 in response to the sensing of the X hole 94*a* in column 44 of the detail card.

The master brush 36 which traverses column 45 will complete a circuit upon sensing of the X hole 95 in this column through plug connection 123 (Figs. 1*c* and 1*d*), pickup coil of relay ±10 to line 100, which relay closes its *a* contacts to establish the holding circuit through contacts C54. Tracing the specific entry circuit for the units order digit of the account number in the master card, the circuit extends from the related brush 36 (Fig. 1*b*), through plug connection 124 (Fig. 1*n*), socket 118, through the 3 and 5 contacts *c* of the translate relay TR10 in this order, the 3 and 5 relays RG and wire 125 to line 100. These RG relays close their *a* contacts to establish a holding circuit through the *a* contacts of relay RE10.

Briefly, then, as the master and detail cards pass their respective brushes 36 and 75 during cycle 2, the X holes 94 and 94*a* prepare the register entry circuits to receive the sensed data in coded form and in addition, the X hole 95 in the master card inverts the circuits, so as to cause the account number of the master card to be entered in the form of a 9's complement.

Registering the sign of the master card entry.—Referring to Fig. 1*n*, the code relay CD10 closes its *c* contacts and the ±10 relay also closes a pair of *c* contacts so that, when contacts C56 close, a circuit is traceable from line 101, through contacts C56, the *c* contacts just referred to, the register sign relay designated SG10 and wire 125 to line 100. This relay will close its *a* contacts to establish a holding circuit through the *a* contacts of relay RE10 along with the amount representing relays RG. The corresponding sign relay SG9 for register 9 will not be energized, since for this register only relay CD9 is energized and its relay ±9 is not.

Entering into registers 11a, 11b, 12a, 12b

Concurrently with the entries in registers 9 and 10, the amounts A and C on the master card and the amounts B and D on the detail card (Figs. 7 and 6) are entered into registers 11b, 11a, 12b and 12a, respectively. This is effected as follows. The master card is provided with an X hole in column 46 which will pick up code control relays designated CD11b and CD11a (Fig. 1d). Concurrently, an X hole in column 46 of the detail card will pick up similar relays designated CD12b and CD12a. For the master card the pickup circuit is from the appropriate brushes 36, through connections 126 (Figs. 1b and 1d) to relays CD11a and CD11b. For the detail card, the pickup circuit is from the appropriate brush 75, through the connections 127 (Figs. 1b and 1d) to the relays CD12a and CD12b. These relays will close their related *a* contacts to provide holding circuits through contacts C54 and will close their *b* contacts in Fig. 1d, so that impulses from the C121 to C127 contacts will energize the translate relays in the 11a, 11b, 12a and 12b sets of register relays in accordance with the selected combinational code in the same manner as explained for register 9.

It will be assumed that the amounts A, B, C and D are all of positive sign so that their associated ± relays are not picked up at this time, and accordingly the *b* contacts of these ± relays in Fig. 1d remain in the positions shown. As explained for the 9 register, the translate relays control related *c* contacts, so that entry circuits through these contacts will set up the relays RG in the four registers 11a, 11b, 12a and 12b (Figs. 1o and 1p) in exactly the same manner as explained for register 9. For register 11b the entry circuit for the units order digit extends through the appropriate brush 36, through connection 128 (Figs. 1b and 1o). For register 11a, the entry will be through connection 129. For register 12b, the entry is through the connection 130, and for register 12a the entry is through connection 131.

In the charts Figs. 8a and 8b, there is indicated along the horizontal line 1 the values entered in the several registers with the minus sign accompanying the entry in register 10 to indicate that this is a negative or complementary entry.

Sequence control relays

Each card feed cycle is divided into forty-eight so-called points as indicated in Figs. 10a, 10b, etc. and through the relay mechanism now to be described there will be an impulse emitted for each of these forty-eight points in succession and for each cycle of operation of the machine. The impulses are emitted to plug sockets from which connections are selectively made to various controlled units of the machine, so that they may be selectively called into action at any one of the forty-eight points.

Referring to Figs. 1a and 10a, it will be recalled that relay R27 was energized along with the holding coil of relay R10 near the end of the first cycle of operation. This relay closes its *b* contacts to energize relay R22 (Fig. 1b) from line 100, wire 132, pickup coil of relay R22, wire 133 (Fig. 1a), *b* contacts of relay R27, *c* contacts of relay R9 (now closed) and cam contacts C28 to line 101. Relay R22 closes its *a* contacts, establishing a holding circuit from line 100, holding coil of relay R22, *a* contacts of relay R22, contacts C29, to line 101. A further holding circuit extends through contacts C28 to line 101. In Fig. 1e, relay R22 closes a pair of *b* contacts so that, when cam contacts C27 close, a circuit is completed from line 101, contacts C27, *b* contacts of relay R23, *b* contacts of relay R22, wire 133a, a so-called sequence relay S96, and wire 134 to line 100. Relay S96 closes its *a* contacts which set up a holding circuit through wire 135 and contacts C15 or C16, so that this relay is held energized over into the beginning of the following cycle as indicated in Figs. 10a and 10b.

Relay R22 closes a pair of *c* contacts (Fig. 1e) so that, when cam contacts C1 close at the 1 point of the cycle (which is the second cycle for operations under consideration), a circuit is completed from line 101, *c* contacts of relay R22, C1, *a* contacts of relay SH1 (relay SH1 is shown on Fig. 1f), *b* contacts of relay S96, to plug sockets 136. From here, plug connections may be made to whatever current responsive device it may be desired to have operate at this point. Other plug connections made from sockets 137 would have a reverse effect, that is, the contacts of relay S96 connected to socket 137 are normally closed so that a circuit therethrough is completed if the relay is not energized, while with the relay energized the circuit is through socket 136 and not through socket 137.

The circuit through the *a* contacts of relay SH1 also extends through relay S1 which closes its *a* contacts to provide a holding circuit through the contacts C13 or C14. Relay S1 shifts its *b* contacts so that, when contacts C2 close, an impulse is transmitted to plug sockets 136 of this group and concurrently to relay S2, which will hold through its *a* contacts and cam contacts C15 or C16.

In this sequential manner the series of relays S1 to S11 are energized in succession and each in turn is held energized for the period indicated in Fig. 10b. During this sequence of operations, when cam contacts C6 close to energize relay S6 (Fig. 1f), they also energize relay R23 (Fig. 1b) through *f* contacts of relay R22. Relay C6 is here shown as a separate contact to simplify the wiring. Relay R23 closes its *a* contacts to provide a holding circuit through *b* contacts of relay R29 and also closes its *d* contacts (Fig. 1g) which connects cam contacts C10, C11 and C12 to line 101 to render them effective later in the cycle.

At the time relay S8 (Fig. 1f) is energized, it closes a pair of *c* contacts to energize relay SH1, through contacts C17 (at the 10 point in the cycle as indicated in Fig. 10b), and this relay in turn closes its *b* contacts to provide a holding circuit through contacts C19 or C20. Relay SH1 shifts its several *a* contacts so that, when contacts C1 (Fig. 1a) close for a second time during this cycle (at the 13 point), the circuit therethrough will extend to the *a* contacts of relay SH2 and *b* contacts of relay S12 to plug sockets 136 of this relay. Just prior to this (at the 12 point), contacts C12 complete the circuit to relay S12 from line 101 (Fig. 1g), contacts C12, *a* contacts of relay SH11, wire 138 (Figs. 1f and 1e), relay S12 and wire 134 to line 100. The circuit is held through contacts C15, C16. Relay S12 will thus be energized and held from the 12 to the 14 point in the cycle and then in succession, and in the same manner as explained for relays S1 to S11 the second group S12—S23 will be energized and held as indicated in Fig. 10b.

During this sequence, when relay S15 is energized, it closes its *c* contacts (Fig. 1g) so that relay SH11 will be energized through cam contacts C18. SH11 shifts its *a* contacts for the three sets of impulse control contacts of the S9, S10 and S11 relays, so that contacts C10, C11 and C12 during these repeat operations now energize relays S22, S23 and S24, the last being through wire 139 to Fig. 1e. During the sequence in which the relays S12 to S23 are energized, energization of relay S20 (Fig. 1g) closes its c contacts to energize relay SH2 through contacts C17. Relay SH2 shifts its a contacts so that during the next or third operation of the contacts C1—C12 the set of relays S24—S35 will be energized in succession in the now familiar manner, as indicated in Fig. 10b and during this series relay S27 will close its c contacts (Fig. 1g) to energize relay SH12, whose a contacts provide for the control of impulses through the S34, S35 and S36 relays. Closure of the contacts C1—C12 in succession will pick up the remaining relays S36 to S96 one after the other as indicated in Figs. 10b and 10c, and thereafter the entire procedure will be repeated commencing with relay S1.

Referring now to Figs. 1a and 10a, it will be recalled that relays R21 and R12 were energized concurrently with the card feed clutch magnets PC and RC. Relay R12 closes its a contacts and relay R21 closes its b contacts, so that when contacts C75 close after the 26 point in cycle 2, a circuit is traceable from line 101, wire 106, card lever contacts PCL2, wire 140, contacts C75, a contacts of R12 or b contacts of R21, or both, and relay R31 to line 100. This relay R31 closes a pair of a contacts so that later, when contacts C72 (Fig. 1b) close, a circuit is traceable from line 101, wire 106 (Fig. 1a), contacts PCL2, wire 140, wire 163 (Fig. 1b), contacts C72, wire 141 (Fig. 1a), a contacts of relays R31 and R30 to relays R20 and R28 and to line 100. Relay R20 will close its b contacts (Fig. 1f) to provide an additional holding circuit across the cam contacts C19 and C20 for the SH1 to SH7 relays, and closes its d contacts (Fig. 1g) across the cam contacts C21 and C22 for the SH11 to SH17 relays, so that these relays when picked up will remain energized for the period indicated in Figs. 10b to 10d. Relay R20 also opens its c contacts (Fig. 1b) to prevent reenergization of the card feed clutch magnets until these contacts reclose.

Single cycle operation.—In the description of the sequence relays, it was explained that the relays were energized in succession S96, S1, S2 . . . S95 and back to S96. This succession is utilized in so-called 2-cycle operations where a greater number of operations are required than can be effected in a single cycle. In cases where single cycle operations are desired, the relays S48 to S95 are not called into operation and the sequence is S96, S1, S2 . . . S47, and then back to S96. This is brought about as follows. In Fig. 1a a switch SW1 is moved to its closed or 1 position at the commencement of operations and will cause energization of relay R30 to open its a contacts which as explained are in the pickup circuit of relays R20 and R28. As a result, the holding periods of the relays generally designated SH (Figs. 1f and 1g) are not prolonged through the b and d contacts of relay R20. Thus, for example, relay SH1 becomes deenergized near the end of the same cycle in which it is initially energized by opening of contacts C19, C20. In Fig. 1e a switch SW2 is set in its dotted line position for single cycle operation so that, when relay S47 has been energized, the next impulse from contacts C12 (Fig. 1g) occurring at point 48 will complete a circuit from line 101, contacts C12, a contacts of SH11, SH12 and SH13 (shifted), a contacts of SH14 (normal), wire 139a, (Figs. 1f, 1e), switch SW2, b contacts of relay R23 (shifted), b contacts of relay R22 (shifted), wire 133a, relay S96 and wire 134 to line 100.

Comparing the account numbers in registers 9 and 10

It will be recalled that the account number on the detail card was entered into register 9 and the 9's complement of the account number on the master card was entered in register 10. These two amounts are compared by adding them together. The result of the cross addition will indicate whether the amounts are alike or different. The manner in which this is effected is as follows: A preliminary connection 142 is made from the plug socket 136 related to the b contacts of relay S46 (Fig. 1g) so that at the 47 point in the cycle, when contacts C11 close following completion of the amount entries, there will be a circuit traceable from line 101, d contacts of relay R23, C11, a contacts of relays SH11, SH12 and SH13 (shifted), a contacts of relay SH14 in normal position, b contacts of relay S46, to its socket 136, connection 142 (Fig. 1nn), relay CA9—10(2) to line 100. This relay closes its a contacts to provide a holding circuit through cam contacts C79 until cycle point 50 (Fig. 10c).

Referring to Figs. 1nn and 1nnn, there is shown a circuit network controlled by the register relays RG in the 9 and 10 registers and including a network controlled by the sign relays SG of these two registers. This circuit network is divided into an upper and lower section. The upper section determines the sign of the result and also determines tens carry conditions between orders, while the lower section obtains the algebraic sum of the two values set up in the pair of registers. The manner of operation will be apparent by considering the specific example chosen for illustration, for which the relays RG for register 9 are set up for the value 765422, and the relays for the 10 register are set up in accordance with the 9's complement 234578. In addition, the sign relay SG of register 10 is also energized. The relay CA9—10(2) will have closed its b contacts (Fig. 1nn) so that a circuit is completed when contacts C51 close at point 48, traceable from line 101, contacts C51, b contacts of the cross-add relay CA9—10(2), wire 143 (Fig. 1nnn), contacts b of the 2 relay RG in the right hand or units order of the 9 register (shifted), the b contacts of the 3 relay RG of the 10 register (shifted), b contacts of the 5 magnet RG for register 9 (normal), the b contacts of the 5 relay RG for register 10 (shifted), wire 144, carry relay 2C in the tens order to line 100.

The circuit branches through a wire 145 to the tens order where it continues through the c contacts (normal) of the 4 and 3 relays RG of the 9 register, the c contacts of the 2 relay of the 9 register (shifted), the c contacts of the 2 relay for the 10 register (shifted), serially through the c contacts of the 3 and 4 relays RG, the b contacts of the 5 relay for the 9 register (normal), the b contacts (shifted) of the 5 relay for the 10 register, wire 144, to carry magnet 2C of the hundreds order (not shown) and line 100 as for the tens order.

The circuit also branches through wire 145 to the next or hundreds order, through which the circuit will continue to the corresponding wire 145 for the hundreds of thousands or highest order (Fig. 1nn), where it will continue through the contacts of the 4, 3 and 2 relays of the 9 register (the 2 relay being shifted), c contacts of the 2, 3 and 4 magnets in the 10 register (the 2 relay being shifted), the b contacts of the 5 relay for the 9 register (shifted), and the contacts of the 5 magnet for the 10 register (normal) to wire 144 and carry magnet 2C and line 100. The energization of magnet 2C in this highest order indicates that the value on the detail card is greater than the value on the master card. Further description of the summation mechanism involved in the comparison of two numbers will be found under the heading "Cross-adding amounts A and B in registers 11b and 12b" below.

From inspection of these circuits it will be found that if the two amounts were alike, no circuits would be completed to any of the carry magnets 2C. Relay 2C in the highest order will shift a pair of a contacts. Immediately following the energization of the relay 2C, cam contacts C53 close momentarily and will complete a circuit through the a contacts of relay 2C if they are not shifted, i. e. if the amounts entered in registers 9 and 10 are alike. This circuit is traceable from line 101, contacts C53, c contacts of the relay CA9—10(2) now closed, b contacts of the sign relay SG9, b contacts of relay SG10 (now shifted under control of the master card X hole), a contacts of relay 2C, a contacts of a relay RO9—10 (now shifted), as will be presently explained, to a plug socket 145, from which a connection 147 is made to a socket 148 and a relay R100 to line 100.

The relay R100 closes its a contacts to provide a holding circuit through cam contacts C71, which hold relay R100 for the period indicated in Fig. 10c by a broken line, since it is not effective for the example chosen. The a contacts of relay RO9—10 (Fig. 1nn) are shifted upon energization of relay RO9—10 associated with the 9 and 10 registers, and this relay is energized through a sequence impulse completed at the 48 time. This circuit is traceable from line 101, d contacts of relay R23 (Fig. 1g), C12, a contacts of relays SH11, SH12 and SH13 in shifted position, a contacts of SH14 in normal position, b contacts of relay S47, related plug socket 136, the connection 149 (Fig. 1nn) to relay RO9—10 associated with the 9 and 10 registers to line 100.

This relay closes its b contacts to provide a holding circuit through contacts C23 or C24. Since, for the example chosen the two account numbers are not in agreement, the relay R100 will, of course, not be energized.

Resetting register 10

As a consequence of the disagreement, the machine will now clear out the data set up under control of the master card M, and a new master card will be fed and sensed and the data thereon will be set up in the registers 10, 11a and 11b. A plug connection 150 is made from socket 136 associated with the b contacts of relay S58 (Fig. 1g) so that at the 59 point (11 point of cycle 2) in the cycle a circuit is completed through such contacts to connection 150 (Fig. 1n), through the normally closed a contacts of relay R101, the connection 152 to relay RE10 and wire 125 to line 100.

The controlling relay R101 will be energized if the account numbers on the two cards are alike, and this relay is connected in parallel with relay R100 (Fig. 1nn) so that it will be energized concurrently therewith. Through its b contacts (Fig. 1nn) relay R101 is held by a circuit through contacts C68. For the present example, where the account numbers are not in agreement, the relays R100 and R101 are not energized, so that the circuit through relay RE10 will be completed and held through contacts C13 or C14.

It might be pointed out at this time that where there is an agreement and relay R101 becomes energized, its a contacts shift to direct the impulse from connection 150 (Fig. 1n) through connection 153 to relay RE9 instead of RE10. In Fig. 1n, shifting of a contacts of relay RE10 will break the holding circuit to the register relays of the 10 register, so that the amount standing therein will be canceled. This opening of the holding circuit is under cam control through the following arrangement: a contacts of relay RE10 are arranged to make-before-break, so that the holding circuit is momentarily transferred through a wire 154 to contacts C133 and C134, so that the holding circuit is maintained until these contacts open. The relays RE10 and RE9 close b contacts to provide circuits through holding coils of the relays to contacts C13 and C14, so that when these relays are picked up by the sequence impulse they are held for a short period after the termination of the sequence impulse and until control contacts C133 and C134 have taken over the register holding circuits.

Transfer from registers 11a, 11b to 17a, 17b

The amount values entered into registers 11a and 11b from the master card must also be cleared. These amounts have in the meantime been transferred to registers 17a and 17b. It will now be explained how the amounts in registers 11a and 11b were transferred to registers 17a and 17b.

At point 44 a circuit was completed from the related plug socket 136 of relay S43 (Fig. 1f), through connection 155 which branches through two relays designated RO11a, RO11b (Fig. 1qqq) associated with registers 11a, 11b and two relays designated RI17a, RI17b (Fig. 1r) associated with registers 17a, 17b. These relays close b contacts to provide holding circuits through contacts C23 and C24. Referring to Fig. 1qqq, the relay RO11a associated with the 11a register closes contacts designated a, wired to e contacts of relays RG of register 11a which are set to represent the value 345624 entered in this register (Fig. 8b). The a contacts associated with relay RO11b of register 11b are similarly wired to related e contacts for that register. Relay RO11a of the 11a register closes contacts designated c and upon closure of cam contacts C25 and C26, circuits are completed from line 101, contacts C25, C26, c contacts of RO11a, thence through e contacts of relays RG in the separate orders, a contacts of RO11a to a cable designated Buss 1 which extends to a contacts of relay RI17a (Fig. 1r) of register 17a. Through these wires and lines, the circuits continue to relays RG of the register 17a to enter therein of the amount standing in register 11a. These relays RG close their related a contacts to provide holding circuits as already explained, through the a contacts of relay RE17a.

In a similar manner, the amount standing in register 11b is transferred to register 17b. Thus, in Fig. 1qqq relay RO11b closes its contacts a which are wired to e contacts of register 11b set to represent the value 368295. Relay RO11b closes contacts designated C1, so that through cam contacts C25, C26 circuits are completed from line 101, contacts C25, C26, c contacts of relay RO11b, e contacts of relays RG in the separate orders of register 11b, a contacts of relay RO11b, to a cable designated Buss 2 which extends to *a* contacts of relay RI17*b* (Fig. 1*r*) of register 17*b*. The circuits continue to the relays RG in the several orders to effect a setting therein of the amount standing in register 11*b* and close the *a* contacts of relays RG to provide holding circuits through the *a* contacts of relay RE17*b*.

The transfer from registers 11*a* and 11*b* to 17*a* and 17*b* is concurrent and, as explained, the circuits are directed through cables called Buss 1 and Buss 2. In Fig. 11 is shown schematically the general manner in which the busses are wired. Buss 1 comprises a multiplicity of wires, only ten of which are shown, and these wires are connected to contacts of a number of relays such as RO11*a*, RO12*a*, RI17*a*, RI18*a*, etc. Likewise, the wires of Buss 2 are connected to contacts of other relays. By energizing any two relays related to Buss 1, for example, the related or corresponding contacts thereof will be connected in series as for the circuits explained above; the *a* contacts of RO11*a* were connected in series with the *a* contacts of RI17*a*. Where contacts associated with Buss 1 are to be connected to contacts associated with Buss 2, a relay BU is energized so that, for example, circuits from *a* contacts of RO11*a* will be directed to Buss 1, thence through *a* contacts of BU to Buss 2 and thence to *a* contacts of whichever relay associated with Buss 2 has been energized. The busses thus serve as main trunk lines or cables for routing circuits from any one of certain relays to any one of certain other relays. In the main circuit diagram, these busses are represented as heavy lines and identified by the legends Buss 1 or Buss 2 for simplification of the wiring.

Transfer from registers 12a, 12b to 18a, 18b

At sequence point 46, through a plug connection 158 (Fig. 1*g*) a circuit is completed to four relays RO12*a*, RO12*b* (Fig. 1*qqq*) and RI18*a*, RI18*b* (Fig. 1*s*) associated with registers 12*a*, 12*b* and 18*a*, 18*b* respectively in the same manner as the corresponding relays for registers 11*a*, 11*b* and 17*a*, 17*b*. They similarly close their related contacts, so that through contacts C25 and C26 (Fig. 1*qqq*) a transfer will be effected from registers 12*a* and 12*b* to registers 18*a* and 18*b*, through Buss 1 and Buss 2 in the same manner as explained for transfer of the amounts from registers 11*a* and 11*b*. The time of this transfer is indicated in Fig. 10*b*, and the amounts set in the separate registers at this point are indicated along lines 1 and 2 of Figs. 8*a* and 8*b*.

In Fig. 1*qqq*, the sign relays SG11*a*, etc. have *e* contacts wired to *a* contacts of the RO relays so that, when the transfer is effected, if a sign relay is in energized condition a circuit is completed through its *e* contacts to Buss 1 or Buss 2 and thence (see Fig. 1*r*, for example) through a pair of *a* contacts of relay RI17*a* to the sign relay SG17*a*. Thus, when an amount is transferred as explained, the sign thereof is also transferred therewith, if negative.

Resetting registers 11a, 11b, 12a and 12b.—At point 47 a second impulse is transmitted from plug socket 136 of relay S46, connection 159 and a pair of *a* contacts of relay R101 (Fig. 1*o*), and thence through connections 160 (Figs. 1*o* and 1*p*) associated with the relays RE11*a*, RE11*b*, HE12*a* and RE12*b* which in the already described manner set up holding circuits through contacts C14 and C13. These magnets will shift their related *a* contacts to momentarily transfer the register relay holding circuits to contacts C133 and C134 upon the opening of which the RG relays of these four registers will become deenergized.

Resetting registers 17a, 17b.—At point 63 (15 point of cycle 3) through the now familiar circuits, relays RE17*a* and RE17*b* (Fig. 1*r*) are energized through connection 161 (Fig. 1*e*), closed contacts of relay R101, connection 161*a*. They will shift their *a* contacts to deenergize the relays RG in these two registers, so that at this time the setting remaining in the registers will be as indicated along line 3 of Figs. 8*a* and 8*b*, where it is shown that entries are now contained only in register 9 and registers 18*a* and 18*b*. It will be noted that transfer from registers 11*a* and 11*b* to 17*a* and 17*b* occurred before the comparison of the amounts in registers 9 and 10. The circuit design is such that the transfer occurs before the comparison so that in the event of a disagreement the transfer will have been an idle operation, and the registers 17*a* and 17*b* must be closed as explained. If there is agreement, the settings are available for subsequent operations.

Clutch magnet RC.—At point 88 (point 40 of cycle 3) in the cycle (Fig. 10*c*), an impulse is transmitted from one of the sockets 136 related to the sequence relay contacts S87*b*, through a connection 162 (Fig. 1*e*), *c* contacts of relay R100 (Fig. 1*b*) to either of the relays UQ or EQ to line 100. Since for the problem chosen there is an unequal condition, relay R100 will not have been energized, so that the circuit just traced will go through relay UQ and, as a result, *a* and *b* contacts of relay UQ will be shifted. Relay UQ closes its *b* contacts to provide a holding circuit through its holding coil, contacts C72, wire 163 (Fig. 1*a*), wire 140 and card lever contacts PCL2 to line 101.

At the end of the cycle, when contacts C62 (Fig. 1*b*) close, the clutch circuit will be completed to energize magnet RC as explained before under the heading Starting circuits. However, the circuit for the clutch magnet PC will not be completed due to the shifting of *a* contacts of relay UQ. Accordingly, during the fourth card feeding cycle, a card will feed from the master card magazine and the second master card will advance past the sensing brushes 36. As it does so, circuits will be completed in the same manner as explained for the first master card to enter the account number in register 10 and amounts A and C into the registers 11*b* and 11*a*, also in the same manner as already explained.

In Fig. 10*d*, it is indicated that during this cycle 4, wherein the second master card passes brushes 36, the relays ±10, CD10, CD11*a* and CD11*b* are energized for the period represented and that as a result the relays TR10, TR11*a* and TR11*b* are also energized to direct the entries from card M into the related registers in coded form.

The account number on the master card will again be entered in the form of a 9's complement into register 10 and the sequence of operations will be repeated to ascertain the sign of the resultant entries into registers 9 and 10 as explained in connection with Figs. 1*nn* and 1*nnn*. Assuming that the account numbers are the same for both cards, there will be a resulting energization of relays R100, R101 (Fig. 1*nn*) indicating equality. This energization occurs upon closure of contacts C53 at the beginning of cycle 5 (see Fig. 10*e*).

In Figs 8*a* and 8*b* it is indicated along line 4 that a new entry has been made into registers 10, 11a and 11b from the second master card and that the entry into 11a and 11b is also made in registers 17a and 17b by transfer in the same manner as previously explained. Thereafter, the 11a and 11b registers will be reset in the same manner as before, leaving the amounts standing in the registers as represented along line 5 of Figs. 8a, 8b.

Transfer from register 17b to 11b

At the beginning of the fifth cycle, an impulse is emitted at the 50 sequence point (point 2 of cycle 5) from socket 136 (of relay S49, Fig. 1e), through connection 165 (Fig. 1rr) to energize relay RO17b, through a pair of *a* contacts of relay R101 now closed, and connection 166 which will close its *b* contacts to provide the usual holding circuit. This relay shifts a set of *a* contacts in Fig. 1rr, in preparation for reading out the amount standing in register 17b. At the same time there is a parallel circuit completed from another socket 136, through connection 167 (Fig. 1e), thence through normally closed *b* contacts of relay S57 (Fig. 1g) and connection 168 (Fig. 1o) to a pair of *b* contacts of relay R101 (now closed) and connection 169 to relay RI11b which closes contacts generally designated *a* associated with the register 11b. With these two relays RI11b and RO17b energized, circuits will be completed to transfer the amount in register 17b to 11b under control of cam contacts C25 and C26 of Fig. 1rr. A representative circuit is traceable as follows: line 101, contacts C25, C26, a pair of *c* contacts of relay RO17b to wire 170, thence through a pair of *a* contacts of a relay INV17b in the highest or left hand order, for example, thence through *d* contacts of relays RG settable in accordance with the digit in such order, *a* contacts of relay RO17b, Buss 2 (Fig. 1o), from which the circuit continues through *a* contacts of relay RI11b to the register relays RG and line 100. The relays RG provide the usual holding circuits so that at this point the amount A in register 17b has been transferred to register 11b.

It may be mentioned at this point that the *a* contacts of relay INV17b are in the position shown, for additive transfer and the *d* contacts of relays RG are interconnected so that, if *a* contacts of INV17b are in shifted position, the transfer will be in accordance with the 9's complement of the digit standing in each order.

Transfer from register 18b to 12b

Through circuits substantially the same as those already traced, the amount standing in register 18b will be transferred to register 12b. This is brought about by an impulse at the 52 point, at which time a circuit is completed from socket 136 of relay S51 (Fig. 1e), through connection 172 (Fig. 1ss) and *a* contacts of relay R101 and the connection 173 to relay designated RO18b which will shift the related *a* contacts associated with this register. Concurrently, there is another impulse from a second socket 136 at the 52 point through connection 174, normally closed *b* contacts of relay S61 and connection 175 (Fig. 1p), *b* contacts of relay R101, and connection 176 to relay RI12b. This relay closes its *a* contacts and also sets up a holding circuit. Through cam contacts C25 and C26 (Fig. 1ss) transfer circuits are completed through *c* contacts of RO18b, *a* contacts of relay INV18b, *d* contacts of relay RG to Buss 2, extending to Fig. 1p, where the circuits continue through *a* contacts of RI12b to the register relays RG associated with register 12b.

Cross-adding amounts A and B in registers 11b and 12b.—The A amount 479306 and the B amount 200045 are now standing in registers 11b and 12b respectively, and the next step is to cross-add these two amounts and enter the sum thereof in register 16b. This is brought about as follows: At sequence point 53 a pickup circuit for cross-add relay CA11b—12b(1) is completed from socket 136 of relay S52 (Fig. 1e), connection 178, normally closed *b* contacts of relay S64, connection 179 (Fig. 1pp), *a* contacts of relay R101, connection 180 to relay CA11b—12b(1) and line 100.

Relay CA11b—12b(1) closes a pair of *a* contacts to provide a holding circuit therefor through contacts C49. At 54 sequence point, a circuit is completed from socket 136 associated with relay S53 (Fig. 1f), connection 181, normally closed *b* contacts of relay S65, connection 182, *a* contacts of relay R101 (Fig. 1pp), connection 183 to relay RO11b—12b. Relay RO11b—12b closes a group of *a* contacts, one side of which is connected through a cable 184 (Fig. 1q) directly to relays RG of register 16b.

In each denominational order there is provided one set of contacts controlled by the two registers which determine tens carry conditions and through which circuits are completed in advance of the actual cross-adding circuits. Thus, if the two digits set up in an order total 10 or more, a circuit will be completed through the contacts to energize a carry relay designated as 2C for the next higher order. In order to explain the principle of operation of the cro- -adding circuits for one denominational order, the contacts set up by the register relays RG are separated into groups enclosed in rectangles designated A, B and C (Fig. 1ppp).

In section A are contacts set to represent digits 1 to 4 of both registers and, whenever the sum of the two digits represents 5, a circuit is completed through this section to energize a relay magnet designated A5 in the same denominational order. A circuit will also be completed through section A whenever the sum of the digits set therein totals 6, 7, or 8. Thus, relay A5 will also be energized by a circuit through section A whenever the sum of the digits is 5–8 inclusive.

In section C are contacts set up to represent a 5 entry in each of the two registers. If one of the digits represented in this section is set up and the setting in section A is also set up to represent digits from 5 to 8, a circuit to relay A5 will branch through section C to also energize the carry relay 2C in the higher order. If a 5 is set up for both registers in section C, the relay 2C will not be energized through the contacts in section A. Under such conditions the relay 2C will be energized through a circuit extending around the contacts of section A and directly through the contacts in section C. If the sum of the digits represented in sections A and C is less than 5, the relays A5 and 2C will not be energized through the contacts of these sections. Thus, generally speaking, the contacts in sections A and C might be called carry determining contacts in that, if the sum of the two digits set up aggregates 10 or more, both relays A5 and 2C will be energized and, if they aggregate 5 to 8 inclusive, only relay A5 will be energized.

In section B the contacts are set to represent the code values 1 to 4 in the two registers where, for example, contacts 1 to 4 are set to represent digits 1 to 4 or digits 6 to 9. These contacts function for carry on carry conditions wherein a circuit from a lower order branches from magnet 2C, for example, through wire 145 to contacts in the B section of the next higher order. If setting of such contacts represents 4 only or a sum of 4, a circuit will extend therethrough to the A5 magnet of such higher order. If such higher order has its section C contacts set to represent 5 for either register, the circuit will also branch through section C to energize the carry relay 2C, in the next higher order and this in turn will branch through wire 145 to the next order. Inspection will show that if the contacts in section B are set to complete a circuit therethrough, the contacts in section A will not be in condition to complete a circuit.

A group of contacts closed in a rectangle or section D are set by the register relays RG and wired in accordance with the table of addition for the digits 1 to 4, with 5's cast out, of the two registers. In section E the contacts are set to represent the values 5 for the two registers, and these contacts are wired in accordance with the sum of 5 in both registers or a 5 in one or the other. The circuits through section E are connected to *a* contacts of relay A5, which are preset in accordance with the conditions prevailing in A and B so that, if there is only one setting of a 5 in section E and relay A5 is not energized, there will be a circuit completed through section E and the *a* contacts of relay A5 to a 5 wire of a group of wires 185. If relay A5 is energized indicating that the sum of the two digits is 5 or more and that one of the sets of contacts in section E is also set, a circuit will not be completed to the 5 wire 185. Also, if both sets of contacts in section E are set at 5 as well as *a* contacts of relay A5, the circuit will be completed to the 5 wire 185 to cause a 5 to be read out of this order as will be presently explained.

Just below section D is a set of carry contacts which are shifted when the carry is called for by the next lower order. These contacts are wired in the adding chain extended through the contacts in section D, so that circuit connections are shifted one digit higher through the carry contacts and the sum of the two digits set in any order will be transmitted through wires 185.

To summarize the foregoing, let us consider a pair of specific digits set up on the units order of registers 11*b* and 12*b*, namely, digits 9 and 8 set on registers 11*b* and 12*b* respectively. The circuits established by the setting of the contacts in accordance with these digits are emphasized in heavy lines on Fig. 1*ppp* so that their tracing may be facilitated, and it will be observed that the circuits extend through the several sections to the 2 and 5 wires 168 in the units order and also that the carry relay 2C is energized to carry a 1 into the tens order. It will thus be observed that the arrangement provides for a so-called predetermination of tens carry conditions which is utilized as above explained in connection with registers 9 and 10 for determining the sign of the result in a pair of registers in conjunction with the signs of the separate values.

With relay CA11*b*—12*b*(1) energized as explained, it will close a pair of *b* contacts in Fig. 1*pp* so that, when contacts C50 close, a circuit is completed from line 101, contacts C50, *b* contacts of the relay, wire 143, thence through the A, B and C sections of the sets of register contacts to the A5 and carry relays to line 100, energizing them in accordance with the values set up on the two registers. Shortly thereafter, when contacts C52 close, another circuit is completed from line 101, contacts C52, a pair of *c* contacts of the relay CA11*b*—12*b*(1), wire 186, from which circuits branch through the D and E sections of the contacts and through the *a* contacts of relay RO11*b*—12*b* and the wire cable 184 (Fig. 1*q*) to the register relays RG of register 16*b* and line 100. In this manner the sum of the values standing on registers 11*b* and 12*b* is obtained and entered into register 16*b* under control of the pair of impulses from the cam contacts C50 and C52.

Resetting registers 11b and 12b.—At the 55 point in the cycle (point 7 of cycle 5), an impulse is transmitted from the appropriate socket 136 of relay S50 (Fig. 1*f*), through a connection 187, *b* contacts of relay S66, connection 188 (Fig. 1*o*) to the *a* contacts of relay R 101 now shifted, thence through connections 160 and thence in parallel through the reset relays RE11*a*, RE11*b*, RE12*a* and RE12*b* to line 100. The energization of these magnets as already explained will cause resetting of their respective registers. Registers 11*a* and 12*a* do not contain entries at this time, so this is an idle operation in so far as they are concerned.

Transfer from register 16b to register MC.—At point 56 there is a circuit completed from socket 136 of relay S55 (Fig 1*f*), connection 189, *b* contacts of relay S69 (Fig. 1*g*), connection 190 (Fig.1*qq*), *a* contacts of relay R101, and relay RO16*b* associated with the register 16*b*. At the same time, a second circuit is traceable from another socket 136 of relay S55 and connection 191, *a* contacts of relay R101 (Fig. 1*h*), connection 192, and relay RIMC associated with register MC. Under control of cam contacts C25, C26 a transfer circuit is now traceable from line 101, contacts C25, C26 (Fig. 1*qq*), *c* contacts of relay RO16*b*, *a* contacts of INV16*b*, *d* contacts of relays RG in the several orders of register 16*b*, *a* contacts of relay RO16*b* now closed, Buss 2 (Fig. 1*h*), *a* contacts of relay RIMC associated with the MC register and relays RG to line 100. The usual holding circuits are established so that the MC register now contains the sum of the amounts A and B which were initially read from the cards M and D respectively.

Resetting registers 16a and 16b.—At sequence 57, a circuit extends from a socket 136 of relay S56 (Fig. 1*f*), through connection 194, *b* contacts of relay S70 (Fig. 1*g*), connection 195 (Fig. 1*q*) to relays RE16*b* and RE16*a* in parallel to line 100. Energization of these relays will cause clearing of the setting in registers 16*a* and 16*b* in the now familiar manner.

Transfer from register 17a to 11b

At sequence 58 a circuit is completed through a socket 136 of relay S57 (Fig. 1*g*), connection 168, *b* contacts of relay R101 (Fig. 1*o*), to relay RI11*b* which will condition register 11*b* to receive an entry therein. At this same time a circuit extends from another socket 136 of relay S57, connection 197 (Fig. 1*rr*), a pair of *a* contacts of R101, connection 198 to relay RO17*a* associated with register 17*a* to condition this register for reading out, and circuits are now conditioned for transferring the amount standing in register 17*a* to 11*b*. The readout circuits from register 17*a* (Fig. 1*rr*) extend to Buss 1 and the readin circuits for register 11*b* (Fig. 1*o*) extend to Buss 2. Accordingly, it is necessary to connect the two busses so that transfer circuits may be completed.

Intermediate the two busses are a group of relay contacts *a* (see Fig. 11) controlled by relay BU.

At sequence 58 a circuit will be completed from a socket 136 of relay S57, connection 199, *b* contacts of relay S61 (Fig. 1*e*), connection 200, *b* contacts of relay S69 (Fig. 1*g*), connection 201 to relay BU. Relay BU closes a pair of *b* contacts to provide a holding circuit through cam contacts C23—C24.

The transfer circuits are traceable from contacts C25, C26 (Fig. 1*rr*), *c* contacts of relay RO17*a*, thence through *a* contacts of relay INV17*a* and the *d* contacts of relays RG in the several orders of the register 17*a* and *a* contacts of RO17*a* to Buss 1. From here the circuits extend through *a* contacts of relay BU to the wires of Buss 2 (Fig. 1*o*), thence through the *a* contacts of RI11*b* of register 11*b* and the relays RG of this register.

Reset register 9.—At sequence 59 (point 11 of cycle 5, Fig. 10*e*), a circuit is completed from socket 136 of relay S58 (Fig. 1*g*), connection 150 (Fig. 1*n*), *a* contacts of R101, connection 153 to relay RE9 to effect resetting of register 9.

Transfer from register 18a to 12b

At sequence 62, a circuit is completed through *b* contacts of relay S61 (Fig. 1*e*) to connection 175 (Fig. 1*p*), *b* contacts of R101, connection 176 to relay RI12*b*, which will prepare register 12*b* to receive an entry. At sequence 62, a further circuit is traceable from *b* contacts of relay S61 (Fig. 1*e*), connection 203 (Fig. 1*ss*), a pair of *a* contacts of R101, connection 202 to relay RO18*a* associated with register 18*a*. This will condition register 18*a* for readout operations. A third circuit at sequence 62 is traceable from socket 136 of relay S61, through connection 200 (Fig. 1*e*), *b* contacts of relay S69 (Fig. 1*g*), connection 201 to the buss-to-buss relay BU.

The transfer circuit from register 18*a* to 12*b* is now traceable from line 101, contacts C25, C26 (Fig. 1*ss*), *c* contacts of RO18*a*, *a* contacts of INV18*a* of register 18*a* and the *d* contacts of relays RG, thence through *a* contacts of RO18*a* to Buss 1, thence through *a* contacts of BU (now closed) to Buss 2 (Fig. 1*p*), *a* contacts of RI12*b* and relays RG to line 100.

Resetting registers 18a and 18b.—At sequence 63, a circuit is traceable from socket 136, relay S62 (Fig. 1*e*), connection 204 (Fig. 1*s*), *a* contacts of relay R101, connections 205 to relay RE18*a* and RE18*b* to effect resetting of these two registers at this time.

Cross-adding amounts C and D in registers 11b and 12b

At sequence 65 an impulse will be transmitted from *b* contacts of relay S64 (Fig. 1*e*), through circuits already traced from sequence 53, through connection 179 (Fig. 1*pp*) to energize relay CA11*b*—12*b*(1). This will condition registers 11*b* and 12*b* for cross-adding as already described. At sequence 66 another circuit is completed through contacts of relay S65, connection 182 and circuits already traced to pick up relay RO11*b*—12*b* (Fig. 1*pp*) related to the 11*b* and 12*b* cross-adding circuits, and the sum of the amounts in registers 11*b* and 12*b* will be entered into register 16*b* as before through cable 184 (Fig. 1*q*).

Resetting registers 11a, 11b, 12a and 12b.—At sequence 67 a circuit is traceable through contacts of relay S66 (Fig. 1*f*) and connection 188 (Fig. 1*o*) as already traced to energize relays RE11*a*, RE11*b*, RE12*a* and RE12*b* to reset these registers.

Transferring from register 16b to MP

At sequence 70 (point 22 of cycle 5, Fig. 10*e*), a circuit is completed through contacts of relay S69 (Fig. 1*g*) and connection 190 (Fig. 1*qq*) to energize relay RO16*b* of register 16*b* in the same manner as already described for sequence 56 to prepare this register for reading out to the MP register. Also at point 70 a further circuit is completed through a further pair of *b* contacts of relay S69, connection 206 (Fig. 1*h*), a pair of *a* contacts of relay R101, connection 207 to relay RIMP of the MP register. Also at sequence 70 there is a further circuit through another pair of contacts of relay S69 and connection 201 to relay BU. The amount in register 16*b* is accordingly transferred to register MP, through circuits traceable from line 101, contacts C25, C26, (Fig. 1*qq*), *c* contacts of RO16*b*, *a* contacts of INV16*b*, *d* contacts of RG, *a* contacts of RO16*b*, Buss 2, *a* contacts of BU, Buss 1 (Fig. 1*h*), *a* contacts of RIMP, relays RG to line 100.

At sequence 71 the circuit is completed through connection 195 (Figs. 1*g* and 1*q*) as already traced to energize relays RE16*a* and RE16*b*. At this point all registers are clear except 17*a*, 17*b*, 10, MC and MP, which last two contain amounts 679351 and 557359 as indicated on line 10 of Fig. 8*a* and the machine is now ready to multiply these amounts.

Multiplying

At sequence 71 a circuit is completed through contacts of relay S70, connection 208 (Fig. 1*hh*), a pair of contacts of relay R101, connection 209 to energize relay MY and a relay CS1 in parallel. Relay MY closes a pair of *a* contacts to provide a holding circuit through cam contacts C87 and C86 and also through *d* contacts of relay R104. Relay CS1 closes a pair of *b* contacts to provide a circuit through the holding coil of the relay and contacts C13, C14.

General statement of multiplying principles

The general principle involved in multiplying two amounts may best be explained by reference to Fig. 8*a* where on line 10 the factors to be multiplied are represented in columns designated MC and MP. As a first step in the multiplying operation, the multiplicand is multiplied by the units digit 9 of the multiplier, and the right and left hand components or partial products are entered into registers 1 and 2 as indicated along line 11. Thereafter, these partial products are added together and the complete product of the multiplicand times the units digit is entered into register 6. In this process, the initial entry of the left partial product is effected with a column displacement one position to the left so that, when the partial products are combined, the addition is effected with the register orders in coinciding alignment so that no special column shift devices are acquired.

In the next step of the procedure, the multiplicand is multiplied by the tens digit 5 of the multiplier and the resulting partial products entered into registers 3 and 4, again with a column displacement of the left hand partial product. These partial products are then added together and entered into register 7 as indicated along line 13. Thereafter, in succession, the multiplicand is multiplied by each of the remaining digits of the multiplier, and in each case the partial products are first obtained and then added together so that the apparatus successively obtains the complete product of the multiplicand times each separate multiplier digit.

As noted along line 13, when the product obtained by the tens digit of the multiplier is entered into register 7, the product obtained by the units digit is entered into register 8. These two amounts are then added together and entered into register 5 as indicated along line 14, so that this latter register now contains the complete product of the multiplicand times the two lowest order multiplier digits. This product is then added to a product obtained by multiplying according to the hundreds digit of the multiplier to obtain in register 8 an amount representing the full product of the multiplicand times the three lowest orders of the multiplier. Thereafter, this product is added to the sub-product obtained by the highest order digit of the multiplier, the tens of thousands order, and finally, as indicated on line 17, the product obtained by the highest order of the multiplier and contained in register 7 is added to the amount in register 8 which represents the cumulative total obtained by the lowest order digits of the multiplier. The adding together of the amounts in registers 7 and 8 will then produce the final result.

Briefly stated, the apparatus obtains a cumulative product beginning with the digits order, and as each separate product is obtained it is added to the preceding ones as represented in Fig. 8*a*. A particular feature of the accumulating or summing devices lies in the arrangement whereby complicated column shift devices are obviated. This may best be pointed out in connection with register 8, wherein it will be noted that upon the first entry therein (line 13) the units digit 9 is entered in the right hand column of the register and the remaining digits are entered into the six highest orders. Upon the next entry into the register (line 15), the two lowest orders of the result are entered into the second and third columns of the register, and upon the third entry (line 17) the two lowest orders of the result are entered into columns 4 and 5. Whenever the amounts in registers 7 and 8 are cross added, the entries in only the six highest orders of register 8 are involved, and the entries in the right portion are not disturbed inasmuch as these represent digits of the final product. With this arrangement, the cross adding operations involving registers 7 and 8 permit fixed alignment of column 6 of register 8, with column 1 of register 7 for cross adding purposes so that this relationship need not be changed for subsequent and repeated additions of amounts in these two registers.

In Fig. 1*i* relay MY closes its *b* contacts to energize relays RI1 and RI2 through contacts of C33 at cycle point 72. These relays will prepare registers 1 and 2 for readin operations and will close their *b* contacts to provide holding circuits through contacts C34. Closure of contacts C33 will also complete a circuit from line 101, contacts C33 (Fig. 1*hh*), *d* contacts of relay MY now closed, wire 210, *c* contacts of relays RG related to the first or units order of the register MP in which the units digit (9 for the example) of the multiplier is set. From here the circuit continues through the group of five wires 211, *a* contacts of relay CS1 now closed, to relays of a group of five relays prefixed X and line 100. Through this circuit the multiplier digit of the units column is set up on the X relays and multiplying will be controlled in accordance with this X relay setting. The X relays close their *b* contacts to hold through contacts C46, C47.

The X relays shift their *a* contacts (Figs. 12 and 1*gg*) which are interconnected as shown with a group of *g* contacts related to the multiplicand register MC. There are six sets of *g* contacts indicated in Fig. 1*gg*, one for each denominational order of the MC register and each set is settable in accordance with the digit standing in the corresponding order. The separate Figure 12 shows the arrangement in one such set. There is a set of *a* contacts of the X relays for each order of *g* contacts and these *a* contacts are set to the same multiplier digit in each order, as indicated in Fig. 1*gg*. The wiring arrangement in each order between the *a* contacts of the X relays and the *g* contacts of the RG relays is in accordance with the multiplication table for two digits, and the contacts will complete circuit connections to a group of wires designated 212RH and 212LH in accordance with the right and left hand components of the product of the two digits. The circuits for entering partial product values is traceable from line 101, cam contacts C31 or C32 (Fig. 1*gg*), wire 213, through *c* contacts of relays RI1 to RI4, wire 214, thence through the multiplying circuit network of Fig. 12 to wires 212RH and 212LH. From wires 212RH the circuits continue through normally closed *a* contacts of a relay RL (Fig. 1*gg*) and cable 215 (Fig. 1*i*), *a* contacts of relay RI1 to the register relays RG of the 1 register.

Concurrently, circuits from wires 212LH continue through further *a* contacts of relay RL and cable 216 (Fig. 1*i*), *a* contacts of relay RI2 and the relays RG associated with register 2. In this fashion the product of the multiplicand times the units order digit of the multiplier will be entered into registers 1 and 2 with the left hand components of such products being entered in register 2 and the right hand components in register 1. It will be noted in Fig. 1*i* that the entry into register 2 is offset one column to the left so that the entries of the values will be as indicated on line 11 of the chart diagram (Fig. 8*a*).

For the present example, where the multiplier digit is 9 the circuit through the units section of the multiplying relays (Fig. 12), wherein the multiplicand digit of 1 as set is indicated by heavy full lines extending from wire 214 to the 4 and 5 wires 212RH. No circuit is completed for the left hand set of wires since this component is zero.

If the multiplicand digit had been 2, there would be other circuits indicated in heavy dotted lines from wire 214 to the 1 wire 212LH and to the 3 and 5 wires 212RH, thus representing 9 times 2 equals 18 by directing current through the 3 and 5 wires 212RH and the 2 wire 212LH.

In Fig. 12, the impulse circuit from wire 214 extends through the *a* contacts which are arranged so that the impulse may enter the set of *g* contacts of the multiplicand register at several points through the intermediate wires which are labeled to represent the digit for which they may conduct the circuits. Thus, when multiplying by the digits 1 or 5, two circuit paths are available; as indicated for the multiplier digits 2, 3, 4, 6, three paths are available, and for the multiplier digits 7, 8 and 9 four paths are available. From these paths selections are made in accordance with the multiplicand digits set up to direct the circuits to the lines 212RH and 212LH in accordance with the quinary system. It is for this reason that several paths are provided as, for example, where the product is 18 three paths are required to the three result lines as explained. Thus, a pair of digits is set up in quinary code on the upper and lower sets of contacts. These are connected together and to wires 212RH and 212LH in accordance with what may be termed the quinary multiplication table to obtain and send the tens digit of the product (as a quinary number) to wires 212LH and the units digit to wires 212RH.

It will be understood that in each of the other multiplying relay sections of Fig. 1gg, similar circuits are concurrently completed and directed through cables 215 and 216 to enter the complete components of 9 times the multiplicand into the 1 and 2 registers in the orders indicated on line 11 of Fig. 8a.

When cam contacts C31 close at cycle point 73 (Fig. 1hh), there is a circuit completed from line 101, contacts C31, connection 217, e contacts of relay MY now closed, b contacts of relay R104, f contacts of RI1 now shifted, c contacts of relay CS3 and relay CS2 to line 100. Relay CS2 will condition the column shift circuits for multiplying by the tens digit of the multiplier. Relay CS2 closes its b contacts to provide a holding circuit through c contacts of relay R104 which are normally closed.

Relays RG of registers 1 and 2 will be held through their a contacts (Fig. 1i) and a contacts of reset relay RE1—2. When this latter relay is energized, the holding circuit is transferred to cam contacts C37 which keeps the RG relays energized until cycle point 76. At point 74, when contacts C35 close, relay RE1—2 becomes energized through a circuit from line 101, contacts C35, f contacts of MY now closed, and relay RE1—2 to line 100. Relay RE1—2 holds through contacts a of a relay DO until this relay is energized.

Thus, when relay MY becomes energized, it initiates a chain of events at the commencement of which the multiplying relays X4 and X5 are energized in response to the units order digit 9 of the multiplier 557359. Relays RI1 and RI2 are energized and circuits are completed to enter the left and right hand components of the multiplicand times the units multiplier digit into registers 2 and 1 respectively, where they are held for the period indicated in Fig. 10e.

Cross-add registers 1 and 2 into register 6.— These two components are now to be added to form the complete product of the multiplicand times the units digit of the multiplier and entered into register 6 as represented on line 12 of Fig. 8a. This is effected as follows.

In Fig. 1k, when contacts C35 close, they complete a circuit through a pair of b contacts of relay CS2 to energize relay RI6, and this closes its b contacts to set up a holding circuit through contacts C36 and register 6 is now prepared to receive an entry. At this time contacts C35 also energize a relay R105 through a pair of c contacts of relay CS2 and the relay R105 is then held through cam contacts C43.

In Fig. 1ii, when contacts C38 close, the carry circuits will be set up in the network of Figs. 1ii and 1iii so that, when a point later at sequence 75 contacts C39 close, circuits are completed from line 101, contacts C39, c contacts of relay CS2 to wire 186 and through the adding network of registers 1 and 2 and around the a contacts of relay CA1—2 to cable 220 (Fig. 1k), a contacts of relay RI6 to line 100. The holding circuit extends through wire 221 (Fig. 1j) to the a contacts of relay RE3—4.

While the product of the multiplicand and the units digit of the multiplier is being entered in register 6, the partial products of the multiplicand times the tens digit 5 of the multiplier are entered into registers 3 and 4, and this is effected as follows. At cycle point 74, contacts C35 (Fig. 1j) close to energize relays RI3 and RI4, through b contacts of CS2 (now closed), which hold through contacts C36, thus conditioning these registers to receive entries.

In Fig. 1gg contacts C35 complete a further circuit through now closed c contacts of relay CS2 to energize relay RL which holds through contacts C36 and shifts its gang of a contacts so that the wires 212RH are now connected to cable 222 and the wires 212LH are now connected to cable 223.

In Fig. 1hh contacts C35 also complete a circuit from line 101, contacts C35, c contacts of relay MY, wire 224, the c contacts of relays RG in the tens order of the multiplier register MP, group of wires 229, a contacts of relay CS2 now closed, and thence to the X relays and line 100. For the example chosen, the tens digit of the multiplier is 5, so that the relay X5 is energized and held.

Now at point 75 (part 27 of Fig. 10e) when contacts C32 (Fig. 1gg) close, the partial product entering circuits are completed from line 101, c contacts of relays RI3 and RI4, wire 214, multiplying relays in the sections set to represent the multiplicand to appropriate wires 212RH and 212LH, cables 222, 223 (Fig. 1j), and thence through a contacts of RI3 and RI4 to their related relays RG and line 100. This entry is indicated on line 12 of Fig. 8a and is similar to the previous entry into registers 1 and 2, in that the left hand component in register 4 is entered one order to the left. It will be noted that the partial product entries into registers 3 and 4 are concurrent with the entries of the units digit product into register 6.

At point 75, when contacts C32 (Fig. 1hh) close, a circuit is completed from line 101, connection 217, e contacts of relay MY, b contacts of R104, f contacts of RI1 (in normal position), f contacts of relay RI3 (now closed), c contacts of relay CS4 and relay CS3 to line 100. This relay then holds through its b contacts and c contacts of relay R104 for the period indicated in Fig. 10e.

At point 76 when contacts C33 close (Fig. 1j), a circuit is completed through now closed f contacts of relay CS3 to energize relay RE3—4 and this relay will close its b contacts to provide a holding circuit through a contacts of relay DO, which will hold the relay energized for the period indicated in the Figure 10e.

The two components in registers 3 and 4 are now to be added together to form the complete product of the multiplicand times the tens digit of the multiplier and entered into register 7 as indicated on line 13 of Fig. 8a. Concurrently with this operation, the value standing in register 6 and the value in register 5 (which is zero at this time) are to be added together and their sum entered into register 8, also as indicated on line 13 of Fig. 8a. This is effected as follows: In Fig. 1m, upon closure of contacts C33 at point 76, a circuit is completed through a pair of a contacts of relay R105 (now closed) to energize relays RI7 and RI8. These relays close their b contacts to provide holding circuits through contacts C34. In this manner registers 7 and 8 are conditioned to receive entries. At point 76, closure of contacts C41 (Fig. 1jj) will complete the carry determining circuits through b contacts of relay CS3 (now closed) to the wire 143 so that the carry relays 2C are adjusted according to tens carry requirements. At point 77 the cross-add circuits are completed and these will be traceable from line 101, contacts C42, c contact of relay CS3 to the wire 186, thence through the adding chain of contacts to cable 225 (Fig. 1m), the a contacts of relay RI7 and the RG relays of register 7 to line 100. Hold circuits are again established for the RG relays through the a contacts of relay RE7.

In Figs. 1kk and 1kkk when contacts C41 close at point 76, the carry determining circuit is completed from line 101, contacts C41, b contacts of relays CS3 to wire 143. At the following point, the cross-add circuit is completed from line 101, contacts C42, c contacts of relays CS3 to wire 186. In Fig. 1kkk it will be noted (see also Fig. 8a) that there is no entry contained in the units order of either register 5 or 6, so that no cross-add circuits are completed through this order. In the tens order, which contains a 9 for the present example, the circuit from wire 186 extends through the adding chain, thence through the normally closed contacts of a relay designated R106 to cable 226. In the higher orders (Fig. 1kk) the circuit from wire 186 extends through the adding chain directly to cable 226, through which the circuits continue to (Fig. 1m) the a contacts of relays RI8 and relays RG to line 100, and as before they set up holding circuits. Reference to Fig. 8a will show that the entry into register 8 is directed so that the entry from the tens order of registers 5 and 6 are entered in the first or units order of register 8, and that the higher order digits are separated from the units entry by four spaces. The entries in the units order of register 8 are part of the ultimate product and for this reason the holding circuits for register 8 are split so that the first five columns are maintained through a holding circuit traceable from line 100 (Fig. 1m), the relays RG in the five lowest orders (two of which are shown), the a contacts of relays RG, wire 227, a contacts of a relay designated RE8a to line 101.

In the higher orders the holding circuit extends from line 100, the relays RG in such higher orders (of which only one is shown), wire 228 to the a contacts of relay RE7 and thence to line 101. At this point in the operation, relay RE7 is energized (see Fig. 10e) so that the holding circuit is effected through contacts C37 and will break when these contacts next open.

Multiplication by the hundreds digit 3.—Concurrently with the above entries into registers 7 and 8, the partial products of the multiplicand times the hundreds digit will be obtained and entered into registers 1 and 2. This is effected as follows: With relay CS3 now energized, the multiplying relays X will be selected and energized upon closure of contacts C33 at point 76, through the d contacts of relay MY, the c contacts of relays RG in the hundreds order (Fig. 1hh), a group of wires 230, thence through the a contacts of relay CS3 (now shifted) to the appropriate X relays and line 100. In the same manner as previously explained and as diagrammatically represented in Fig. 10e and Fig. 8a, the multiplying circuits are completed through the devices represented in Fig. 1gg to cables 215 and 216, which direct the components into registers 1 and 2 as shown along line 13 of Fig. 8a. Concurrently with the multiplying operation, contacts C31 in Fig. 1hh complete the circuit through connection 217, e contacts of relay MY, b contacts of relay R104, f contacts of relay RI1 (shifted), c contacts of CS3 (shifted), c contacts of CS5 (normal) and relay CS4 to line 100. Relay CS4 will condition the column shift circuits for multiplying by the thousands digit of the multiplier and also closes its b contacts to provide a holding circuit through the contacts of relay R104.

It may be pointed out that registers 1 and 2 were cleared of their first setting upon opening of contacts C37 (see Fig. 1i and 10e). It may also be noted that the relay RE1—2 is held continuously energized so that, when this second entry is made in registers 1 and 2, the entries will be held through the a contacts of relays RE1—2 and through the contacts C37, so that the holding is co-extensive with the period of closure of contacts C37.

Cross-adding registers 1 and 2.—In the same manner as previously explained, the amounts standing in registers 1 and 2 are now cross-added and their sum entered into register 6 as indicated along line 14 of Fig. 8a. The circuits involved are explained under the heading "Cross-add registers 1 and 2 into register 6," so the same are not here repeated.

Concurrently with this entry into register 6, the partial products of the multiplicand times the thousands digit of the multiplier are entered into registers 3 and 4, and this also is effected in the familiar manner with the entries made as represented along line 14 (Fig. 8a). During this entry the relay RL is again energized as designated in Fig. 10e so that the multiplying circuits are switched from registers 1 and 2 to registers 3 and 4.

Cross-adding registers 7 and 8 into register 5.—In Fig. 1k, when contacts C35 close at point 78, the circuit is completed through b contacts of relay CS2, the b contacts of relay CS4 to magnet RI5 and in parallel therewith the relay RI6 is, of course, also energized. In this manner, register 5 is conditioned to receive an entry along with the conditioning of register 6. Referring to Figs. 1mm and 1mmm, a relay R107 is energized at point 77 through a circuit from line 101, contacts C42, d contacts of relay RI8 and relay R107 which sets up the holding circuit through its a contacts and cam contacts C49. Thereafter, when contacts C38 close, the usual carry determining circuits extending from wire 143 are completed and a point later when contacts C39 close current is suplied to wire 186 for cross-adding the amounts standing in registers 7 and 8. These two registers are not wired in columnar alignment but have a displacement best represented by the following table:

	Columns										
Register 7						7	6	5	4	3	2	1
Register 8	11	10	9	8	7	6	5	4	3	2	1

Thus, in the cross-addition the setting in column 1 of register 7 is added to the setting in column 6 of register 8 and so on. Accordingly, the circuits from wire 186 continue through the adding chain to a cable 231 (Fig. 1k) and thence through the a contacts of relay RI5 and the RG relays of register 5 in the columnar positions indicated on line 14 of Fig. 8a. The cable 231 (Fig. 1mm) extends to the 6 to 11 columns in register 8 and the corresponding 1 to 7 columns of register 7 only so that the entry standing in columns 1 to 5 of register 8 is not read out but will remain in the register.

Following this, there will now take place a series of operations during which the X relays are energized in accordance with the tens of thousands digits of the multiplier and the resulting right and left hand components entered into registers 1 and 2, respectively. Concurrently with this operation, the amounts standing in registers 3 and 4 are cross-added and the resulting sum entered into register 7. Also at the same time, the amounts standing in registers 5 and 6 are cross-added and the results entered in register 8. These operations are represented along line 15, Fig. 8*a*, and the circuits involved are the same as already explained, so that the same need not be repeated at this time. It will be noted on line 15 that the entry of register 8 is such that the two digits 00 are entered into the second and third column positions, while the remaining digits are entered in the higher section of the register.

The manner in which the amount entered is split is as follows. Referring to Fig. 1*kk*, upon closure of contacts C33, a circuit is completed from line 101 through contacts C33, *b* contacts of relay CS5, which are closed at this time (see Fig. 10*e*), relay R106 to line 100. This relay closes its *b* contacts to provide a holding circuit for contacts C34.

In Fig. 1*kkk*, relay R106 shifts its *a* contacts so that the cross-add circuits in the units order extend from the wire 186, through the adding chain and the now closed *a* contacts of relay R106 to cable 226 (Fig. 1*m*), wherein the wires from the cables extending from the units order connect to the tens order of register 8. In the same manner, the adding circuit from the tens order of Fig. 1*kkk* extends through now shifted *a* contacts of relay R106 and normal contacts of a relay R108 to cable 226, wherein the wiring is such that this entry is directed into the hundreds order of register 8. This is represented along line 15 of Fig. 8*a*.

Following this, the aforedescribed operations are repeated to obtain and enter right and left hand components of the multiplicand times the highest order digit of the multiplier into registers 3 and 4. The selecting and controlling circuits are similar to those already described and involve the energization of the column shift relay CS6 so that the appropriate X relays are selected and the resulting entry into register 3 and 4 will be as indicated along line 16, Fig. 8*a*. Concurrently with this operation, the amount standing in register 7 is cross-added with the part of the amount standing in the six highest orders of register 8 and this result entered into register 5 as shown in Fig. 8*a*. Also at this time, the amounts in registers 1 and 2 are cross-added, entered into register 6 in the same manner involving the same circuits as described for the prior transfer from registers 1 and 2 to register 6, with the exception that this time the circuit (Fig. 1*ii*) goes through *b* contacts of relay R105 instead of *b* contacts of relay CS2.

Concurrently with the operations represented on line 16, Fig. 8*a*, and as indicated on Fig. 10*e*, relay R104 is energized through a circuit from line 101, contacts C35, *c* contacts of relay CS2 (now closed), *d* contacts of relay CS6 (also closed) and relay R104 to line 100. The relay will close its *a* contacts to provide a holding circuit through contacts C36 for the period indicated in Fig. 10*e*. Energization of this relay will open the holding circuit for the several CS relays and also relay MY.

The next following operations as represented on line 17 of Fig. 8*a* involve the cross-adding of the amounts in registers 3 and 4 and their entry into register 7, and this is effected in the same manner as previously described. Concurrently, the amounts in registers 5 and 6 are cross-added and entered into register 8. For this last entry, it will be noted that the units digit of the sum obtained is 4 and is to be entered in the 4th order of register 8. For this purpose, it is necessary to effect a shifting of the entering connections which is brought about under the control of a relay R108 (Fig. 1*kk*). The energizing circuit for this relay is through contacts C31 or C32 and a pair of *a* contacts of relay R104. A holding circuit is provided through the *a* contacts of the relay and cam contacts C44 and C45 which will hold this relay energized for a period indicated in Fig. 10*e*.

The relay R106, Fig. 1*kk*, is energized a point after relay R108, and this is effected through a circuit from line 101, contacts C33, a pair of *b* contacts, relay R108, the relay R106 to line. The usual holding circuit will extend through contacts C34 in Fig. 1*kkk*. The entries in the units and tens orders of registers 5 and 6 will now be directed through shifted contacts of relay R106 and shifted contacts of relay R108 to cable 226, wherein the wires are arranged so that the entries in these two orders are directed to the 4th and 5th columns of register 8 as indicated on line 17 of Fig. 8*a*. It should be noted that at this time there is no accompanying entry into registers 1 and 2, since with relay MY now deenergized there will be no circuits completed to the X relays.

After cycle point 86, relay RE8*a* (Figs. 10*e* and 1*m*) is energized through a circuit from line 101, C35, *c* contacts of relay R108 (now closed), relay RE8*a* to line 100. The relay shifts its *a* contacts which are of the make-before-break type to transfer the holding circuits for the relays RG in columns 1 to 5 of register 8 to the circuit that holds the remaining relays of this register. Relay RE8*a* also closes a pair of *b* contacts to provide a holding circuit through contacts C43. As a result, the relays RG in the lower orders of register 8 which, it will be recalled, remained energized to retain the entries in these orders, will now be reset along with the rest of the register after the amount therein has been cross-added with the amount in register 7 and transferred to register 16, which operation will be described presently.

Also at cycle point 86, there is a circuit completed (Fig. 1*mm*) from line 101, contacts C35, a pair of *b* contacts of relay R108, relay CA7—8 to line 100. This relay will close its *b* contacts to provide a holding circuit through contacts C23 and C24 for a period indicated in Fig. 10*e*. This relay will shift its *a* contacts of which there is a set for each order of register 7, 8 to connect the adding chain to cable 235, which extends to Fig. 1*q* and through which the entry will be effected into register 16*a* and 16*b*.

Also at point 86 of the cycle, a relay designated DOC (Fig. 1*c*) is energized through a circuit from line 101, contacts C35, a pair of *f* contacts of relay MY (now closed), a pair of *f* contacts of relay R108, and relay DOC to line 100. A holding circuit through contacts C43 will maintain the relay for the period indicated in Fig. 10*e*. Relay DOC closes a pair of *d* contacts so that at cycle point 88 when contacts C33 close a circuit is completed to energize relay DO which will set up a holding circuit through contacts C15 and C16.

Transferring from registers 7—8 to 16

The transfer circuits from registers 7—8 to 16 are similar to others already described and may be briefly stated as follows: with relay R107,

Fig. 1mm, energized the carry determining circuits are established through contacts C38 and the b contacts of relay R107. Following this, upon closing of contacts C39 the circuit goes through c contacts of relay R107 to the common wire 186, then through the adding chain of the several orders to the cable 235, Fig. 1q, from which the circuits extend to a contacts of relays CA7—8 to the relays RG and line 100. The wires in cable 235 are arranged to direct the entries to registers 16a and 16b as indicated on Fig. 8b along line 17. This entry in registers 16a and 16b will now be held until the amount therein has been punched back into the detail card D.

Resetting registers MP and MC.—At sequence 82, a circuit is traceable in Fig. 1g from line 101, contacts d of relay R23, contacts C10, the a contacts of relays SH11 to SH16 (shifted), the a contacts of relays SH17, b contacts of relay 81 to a plug socket 136 and from thence through a plug connection 236, Fig. 1h, a pair of a contacts of relay R101 and plug connection 237 to relays REMP and REMC. These relays will set up holding circuits through contacts C85 and C86. The holding circuit for the register MP is maintained for a short period after the energization of the relays and this holding is through contacts C80 and C81 upon the opening of which the register relays RG of register MP will become deenergized which will be at point 83.

For the register MC, the holding circuit will be maintained through contacts C82 and C83 until cycle point 84 as indicated in Fig. 10e.

Initiation of detail card feeding

At cycle point 88, the circuit from contacts of relay S87, Fig. 1e, is again established through connection 162, Fig. 1b, c contacts of relay R100 (now shifted) to relay EQ and the line 100. This relay will set up a holding circuit through its b contacts, wire 141, contacts C72, wire 163, Fig. 1a, wire 140, contacts PCL2, and wire 106 to line 101. This circuit will keep relay EQ energized as indicated in Fig. 10e and 10f. The punch clutch magnet PC will now be energized when contacts C61 close through a circuit traceable from line 101, d contacts of relays R9 and R10 (closed), a contacts of relay R40, c contacts of relay R20 (now also closed), b contacts of relay R4, a contacts of relay EQ (shifted), contacts C61 and magnet PC to line 100.

As the result of the energization of the magnet PC, the detail card D is caused to advance past the row of punches 78, Fig. 3, and concurrently therewith the second detail card will pass sensing brushes 75, and the account number on the second detail card will be sensed at such time. This new account number will be entered into register 9 and compared with the account number of the first master card, which latter is still retained in register 10. If the account numbers of the cards are in agreement, a new sequence of multiplying operations takes place to obtain the product $(A+B)\times(C+D)$ and this result is subsequently punched in the second detail card.

If the two cards are not in agreement, the entries standing in registers 10, 17a and 17b will be cleared and new entries will be effected under control of a new master card M.

It will be assumed in the following that the second detail card has the same account number as the first which, of course, corresponds to the account number standing in register 10. With the detail card feed mechanism in operation, the cam contacts prefixed P rotate with the timing indicated in Fig. 9b. Of these, contacts P91 to P100 will emit impulses to a group of wires generally designated 238 in Fig. 1c. The wires 238 are connected to contacts of relays RG associated with registers 16a and 16b and constitute a readout device for the amount standing in these registers. Their arrangement is such that the coded representations in the register will be read out as decimal values for the control of the card punching mechanism. In Fig. 1c, each denominational order of the register has a plug socket 239 from which a plug connection 240 is made to a socket 241 of a selected punch magnet 82. Tracing a specific punch control circuit, as an example let it be assumed that the highest order of register 16b is set to represent the digit 3; accordingly, at the 3 card index time of cycle 6 a circuit will be completed from line 101, contacts C130 and C128, a pair of a contacts of relay R5 (now closed), contacts P93 to the 3 wire of the group 238, thence to the left hand contact d of the 3 relay RG in the highest order of the register, thence to socket 239, connection 240, and punch magnet 82 to line 100.

At cycle point 45, Fig. 10f, a circuit is completed to effect resetting of registers 16a and 16b which is traceable from line 101 (Fig. 1f), contacts C9 to b contacts of relay S44 and plug connection 243 to a pair of b contacts of relay S56, thence through connection 194, Fig. 1g, a pair of b contacts of relay S70, connection 195, Fig. 1q, to the relays RE16a and RE16b, and line 100. In the now familiar manner, this will effect clearing of these two registers.

Inspection of Fig. 10f representing cycle 6 in the operation will indicate the sequence in which the various relays function during the punching and sensing operations taking place. It will be noted that an entry will be made into registers 9 and 12 and that near the end of the cycle the account numbers standing in registers 9 and 10 are compared in the same manner as explained in connection with cycle 4, so that following cycle 6 operations take place in the same manner as explained in connection with cycle 5. If at the end of cycle 6 it is determined that the entries in registers 9 and 10 are not alike, the succeeding cycle of operations will follow in the same manner as explained in cycle 3.

Sign control

In the foregoing, it was assumed that the amounts A, B, C and D were all positive. Provision is made so that any one of these amounts may have a negative sign through circuit arrangements now to be described, and it will be pointed out how the resulting sign of the ultimate product is obtained and recorded on the detail card along with the product itself. If one of the amounts is negative, the cards of Figs. 6 and 7 will contain appropriate perforations 90 to 93 as already explained and, when the cards are sensed, these perforations will pick up the ± relays for the appropriate register. The effect of this may be illustrated in connection with register 11b; for example. Referring to Fig. 1o, during the sensing of record card, if the amount is to be entered to 11b, the relays CD11b will be energized and also the relay ±11b in the manner already explained so that upon closure of contacts C56 a circuit is completed from line 101, c contacts of relays ±11b and CD11b, relay SG11b to line 100. This relay sets up the holding circuit along with the RG relays of the register through the *a* contacts of relay RE11*b*. Accordingly, whenever the sign of the entered amount is negative, the sign relay with the general prefix SG is energized along with the amount retaining relays RG. It will also be recalled that a negative amount is entered into the selected register in the form of a 9's complement.

Let it be assumed now that the amounts in registers 11*b* and 12*b* are to be cross-added. The circuits involved in this are shown in Fig. 1*pp* where several contacts are shown as being controlled by the sign relay SG11*b* and other contacts adjacent thereto controlled by the corresponding sign relay SG12*b* related to the second register. Various combinations of conditions might exist between these two relays; that is, both will be energized if the two amounts are negative; neither will be energized if the amounts are positive; and one or the other will be energized if only one of the amounts is negative and the other positive. According to the condition present at the time, the adding circuits are completed, a circuit will extend through the contacts of these two sign relays to a wire 250 which is connected through a pair of *a* contacts of relay RO11*b*—12*b* to the cable 184. Intermediate the wires 250 and contacts SG12*b* are contacts of a carry relay 2C which in the familiar manner is energized if the addition of the two amounts involves a carry through the highest order; that is, if the negative amount is smaller than the positive amount, or if both amounts are negative. Taking, for example, the specific condition where the amount in register 11 is greater than the amount in register 12, a circuit will be completed upon closure of contacts C52 through the *c* contacts of CA11*b*—12*b*(1), *c* contacts of relay SG11*b* (shifted), *b* contacts of relays SG12*b* and 2C (normal), wire 250, *a* contacts of RO11*b*—12*b*, cable 184, Fig. 1*q*, from which a wire extends to relay SG16*b* and line 100. In this manner the sign resulting from the addition of the two amounts in registers 11*b* and 12*b* is set up on the sign relay of register 16*b*. Similar circuits are traceable for the other conditions specified.

In connection with the case where both amounts are negative, there will be an additional carry circuit to relay 2C in the lowest order of the adding mechanism for entry of a fugitive one. Specifically, a circuit is completed under these conditions upon closure of contacts C50, Fig. 1*pp*, *b* contacts of relay CA11*b*—12*b*, *a* contacts of relays SG11*b* and SG12*b* both shifted to a wire 251 which extends across Fig. 1*ppp* to relay 2C in the lowest or units order. This is the usual highest to lowest order carry required as an incident of the addition of two negative amounts. A circuit is also completed through wire 251, Fig. 1*pp*, from the wire 144 of the highest order of the registers whenever the sum of the two amounts involves a carry through the highest order.

Sign transfer from register 16b to MC.—If the amount in register 16*b* is negative, it will, of course, stand therein as a 9's complement. In the transfer of this amount to the MC register, it is necessary to convert this amount back to its true value but retain the negative sign thereof. Referring to Fig. 1*qq*, the sign relay SG16*b* will have closed a pair of *b* contacts connected through wire 252 to a pair of *b* contacts of relay R101 which in turn are plug connected through connection 253 to plug socket 136 of sequence relay S69 (shown on Fig. 1*qq* for simplification). The contacts of relay S69 are connected over to socket 136 of relay S55, through connection 254 so that an impulse is transmitted at either or both cycle points 56 and 70, through connection 253, *b* contacts of relay R101, *b* contacts of relay SG16*b* to relay INV16*b* to line 100. A holding circuit is provided through contacts C23 and C24. Now when the amount in register 16*b* is transferred to register MC, the circuit initiated upon closure of contacts C25 and C26, Fig. 1*qq*, will extend through the *a* contacts of relay INV16*b*, and thence through the *d* contacts of the register relays and the *a* contacts of relays RO16*b* to Buss 2 from which the circuits extend to register MC (Fig. 1*h*) for entry therein in the now familiar manner.

For transfer of the sign, a circuit extends through a pair of *b* contacts of relay INV16*b*, Fig. 1*qq*, to a pair of *b* contacts of relay RO16*b* to Buss 2 from which, in Fig. 1*h*, a wire 254 conducts the circuit through a pair of *a* contacts of relays RIMC to the sign relay SGMC, so that this relay now takes the negative sign indication and by closing its usual holding contacts the reading will be retained. In exactly the same manner the amount standing in register 16*b*, if it is of negative value at the time the amount is to be transferred to register MP, will have its relay INV16*b* picked up at cycle point 70 through the same circuits, and the amount will be inverted back to its true value, and the sign relay SGMP, in Fig. 1*h*, will be energized and held.

Sign of the product.—During multiplying operations, when contacts C35 close at cycle point 78, a circuit is completed from line 101, contacts C35, *a* contacts of relay CS5, *a* contacts of relay CS4 which is closed at this time (see Fig. 10*e*), a pair of *a* contacts of relay SGMP to a relay designated PSMP. A parallel circuit is also completed through contacts C35 through *b* contacts of relays CS5, CS4 and SGMC to relay designated PSMC. These relays close *a* contacts shown in Fig. 1*m*, where they will be maintained energized through the special holding circuit provided for the first five columns of register 8 which, as explained, extends to contacts of relay RE8*a*. It will be understood, of course, that either, neither, or both the factors in registers MC and MP may be negative.

Referring now to Fig. 1*mm*, the relays PSMP and PSMC shift *a* contacts so that at the time that contacts C39 close to complete the cross-adding circuits through registers 7 and 8, a branch will extend through the aforesaid *a* contacts to cable 235, if the product's sign is negative. This cable extends to register 16*b*, Fig. 1*q*, from which it branches through right hand *a* contacts of relays CA7—8 to the sign relay SG16*b* which set up the usual holding circuit. At this time, the product is accordingly contained in register 16*b* as a true number together with a sign indication if the sign is negative. During the subsequent punching operations, a pair of *b* contacts (Fig. 1*c*) will be in closed position so that, when cam contacts C109 close at the X or 11 time in the punching cycle, a circuit will be completed from line 100, contacts 109, *b* contacts of relay SG16*b*, and a plug connection 253 to a selected punch magnet 82, whereby if the final product is negative, the appropriate indication will be made on the detail card.

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

What is claimed is:

1. In a multiplying machine, an entry receiving device settable to represent a multiplicand, an entry receiving device settable to represent a multiplier, a first, second, third and fourth pair of registers controlled by electrical impulses, a partial product forming mechanism controlled by said multiplicand and multiplier settable devices and capable of transmitting impulses representative of both left and right hand components of partial products to said registers, switching means for causing the multiplying mechanism to form and transmit partial product components for each multiplier digit in succession, beginning with the units order digit, further switching means for causing the components of the units and alternate orders to be transmitted to the said first pair of registers, each component to a separate register of the pair; and for causing the components of the tens and alternate orders to be transmitted to the said second pair of registers, each component to a separate register of the pair; each left hand component being entered into the related register with a columnar displacement one order to the left, circuits completed by the registers of the first pair, during transmission of components to the second pair, for entering the total of the settings therein into the register of the third pair, further circuits completed concurrently therewith, for entering the total of the settings in the registers of the fourth pair into the other register of the third pair, circuits completed by the registers of the second pair, during transmission of components to the first pair, for entering the total of the settings therein into a register of the fourth pair, and still further circuits completed concurrently therewith by the registers of the third pair for entering the total of the settings therein into the other register of the fourth pair.

2. In a multiplying machine, an entry receiving device settable to represent a multiplicand, an entry receiving device settable to represent a multiplier, a first, second, third and fourth pair of registers controlled by electrical impulses, a partial product forming mechanism controlled by said multiplicand and multiplier settable devices and capable of transmitting impulses representative of both left and right hand components of partial products to said registers, switching means for causing the multiplying mechanism to form and transmit partial product components for each multiplier digit in succession, beginning with the units order digit, further switching means for causing the components of the units and alternate orders to be transmitted to the said first pair of registers, each component to a separate register of the pair; and for causing the components of the tens and alternate orders to be transmitted to the said second pair of registers, each component to a separate register of the pair; each left hand component being entered into the related register with a columnar displacement one order to the left, circuits completed by the registers of the first pair, during transmission of components to the second pair, for entering the total of the settings therein into a register of the third pair, and circuits completed by the registers of the second pair, during transmission by components to the first pair, for entering the total of the settings therein into a register of the fourth pair.

3. In a multiplying machine, an entry receiving device settable to represent a multiplicand, an entry receiving device settable to represent a multiplier, two pairs of registers, further plural registering means, a partial product forming mechanism controlled by said multiplicand and multiplier settable devices and capable of transmitting impulses representative of both left and right hand components of partial products to said registers, switching means for causing the multiplying mechanism to form and transmit partial product components for each multiplier digit in succession, beginning with the units order digit, further switching means for causing the components of the units and alternate orders to be transmitted to the said first pair of registers, each component to a separate register of the pair; and for causing the components of the tens and alternate orders to be transmitted to the said second pair of registers, each component to a separate register of the pair; each left hand component being entered into the related register with a columnar displacement one order to the left, circuits completed by the registers of the one of said pairs, during transmission of components to the other pair for entering the total of the settings therein into one of said further registering means, circuits completed by the registers of said other pair, during transmission of components to the said one pair for entering the total of the settings therein into another of said further registering means, and means controlled by both said further registering means for adding together the totals transmitted thereto.

4. In a machine of the class described, a denominationally ordered summation mechanism, each denominational order unit thereof comprising two sets of five relays each, the relays of each set representing the values 1, 2, 3, 4 and 5 upon which the digits may be represented combinationally with the representation of all digits higher than 4 including the relay whose value is 5, means for entering a pair of decimal numbers, one in each of said sets of relays, a tens carry relay for each denominational order unit, a separate 5's relay for each denominational order unit, means controlled by the relays representing the values 1 to 4 in each unit for energizing the related 5's relay when the sum represented by said relays is 5 or more, means controlled by all the value representing relays in each unit for energizing the tens carry relay in the next higher order when the sum represented by said relays is 10 or more, a set of five readout wires for each denominational order unit, one wire for each of the values 1, 2, 3, 4 and 5, a circuit completed through the 5 representing wire of said set, under control of the said separate 5's relay and the 5 representing relays, when the sum of the two digits in the order is 5 to 9, and a further circuit completed selectively through one of the remaining wires of said set under control of the said tens carry relay and the 1 to 4 representing relays when the sum of the two digits in the order is 1 to 4 or 6 to 9.

5. In a machine of the class described, a summation mechanism, each denominational order unit thereof comprising two sets of five relays each, the relays of each set representing the values 1, 2, 3, 4 and 5 upon which the digits may be represented combinationally with the representation of all digits higher than 4 including

the relay whose value is 5, means for entering a pair of decimal numbers, one in each of said sets of relays, a tens carry relay for each denominational order unit, means controlled by the relays representing the values 1 to 4 of each unit for ascertaining whether the sum of the said values equals or exceeds 5, a 5's relay controlled thereby, a set of five total receiving relays, to receive the sum combinationally, means controlled by the relays representing the value 5 and by said 5's relay, for causing entry of the 5's value of the sum into said receiving relays, means controlled by the relays representing the values 1 to 4 of the digits to be added and by the related tens carry relay for causing entry of the 1 to 4 values of the sum into said receiving relays, and tens carry means controlled by the relays of each denominational order unit for controlling the tens carry relay of the next higher order in accordance with tens carry requirements.

6. In a machine of the class described, a denominational order unit of a multidenominational summation mechanism, comprising two sets of five relays each, the relays of each set representing the values 1, 2, 3, 4 and 5 upon which two digits may be represented combinationally, with the representations of all digits higher than 4 including the relay whose value is 5, a set of five combinational result relays, one for each of the values 1, 2, 3, 4 and 5, means controlled by the 1 to 4 value relays of said first two sets for ascertaining whether the sum of the two digits is 5 or more, means controlled by said last named means and by the 5 value relays of said two sets for entering a 5 in said result relays when the units digit of the result contains a 5 in combination, and means controlled by the 1 to 4 value relays for entering digits 1 to 4 in said result relays when the units digit of the result contains one of said digits in combination.

7. In a machine of the class described, a denominational order unit of a multidenominational summation mechanism, comprising two sets of five relays each, the relays of each set representing the values 1, 2, 3, 4 and 5, upon each set of which a digit may be represented in the quinary system of numeration, a plurality of contacts, each relay effecting adjustment of a number of said contacts, a 5's relay, means for transmitting an impulse through certain of said contacts to energize said 5's relay when the sum of the two digits set up on the relays whose values are 1 to 4 exceeds 4, a set of five result relays upon which a result digit may be represented in the quinary system, means for transmitting an impulse through contacts controlled by the relays whose value is 5 and said 5's relay to energize the 5 relay of said result set if an odd number of said three last named relays is set, and means for transmitting an impulse through contacts controlled by the relays whose values are 1 to 4 to energize the 1 to 4 relays of said result set in accordance with the sum represented on said 1 to 4 value relays with 5's cast out.

8. In a machine of the class described, a denominational order unit of a multidenominational summation mechanism comprising two sets of five relays each, the relays of each set representing the values 1, 2, 3, 4 and 5 upon each set of which a digit may be represented in the quinary system of numeration, contacts settable under control of said relays to represent the number of multiples of 5 contained in the sum of the two digits. five result relays having the values 1, 2, 3, 4 and 5, a circuit completed through said contacts to energize the 5 result relay when the number of multiples of 5 is odd, further contacts settable by the 1 to 4 relays of said first named two sets of relays, and circuits completed therethrough to selectively energize one of the 1, 2, 3 or 4 result relays to supplement the quinary setting on the result relays in accordance with the units digit of the sum of said two digits.

9. In a machine of the class described, a denominational order unit of a multidenominational summation mechanism comprising two sets of five relays each, the relays of each set representing the values 1, 2, 3, 4 and 5, upon each set of which a digit may be represented in the quinary system of numeration, a plurality of contacts settable by each of said relays, means for transmitting an impulse through certain of said contacts to ascertain whether a tens carry is required in the summation of the two digits set up, and whether the sum of the values set up on the 1 to 4 relays exceeds 4, a tens carry relay and a 5's relay energized in response to said impulse, a set of five result relays, means for transmitting a second impulse through further contacts of the first named sets of relays and contacts of said 5's relay to energize said result relays in accordance with the quinary representation of the units digit of the sum.

10. In a machine of the class described, a decimally ordered comparing mechanism, each order of which comprises two sets of five relays each, the relays of each set representing the values 1, 2, 3, 4 and 5, means for setting up a true number on one set of relays and the 9's complement of another number on the second set, according to the quinary system of numeration, said number whose complement is set up being equal or less than the true number which is set up, a set of contacts controlled by each relay, circuit connections between said contacts, a current responsive device, and means responsive to a single electrical impulse for completing a circuit through said connections to energize said device when the two numbers set up are of different values.

11. In a machine of the class described, a partial products forming mechanism comprising a set of five multiplicand relays upon which a multiplicand digit is settable in accordance with the quinary system of notation, a set of five multiplier relays upon which a multiplier digit is settable in accordance with the quinary system of notation, contacts adjusted by said relays, circuit connections between the contacts interconnecting the same in accordance with the table of multiplication, a set of five left hand component relays, a set of five right hand component relays, means for transmitting a single current impulse to said contacts and through said connections, to energize the component relays in accordance with the quinary representation of the left and right hand components of the product of the two digits set up.

12. In a machine of the class described, a partial products forming mechanism comprising a set of five multiplicand relays upon which a multiplicand digit is settable in accordance with the quinary system of notation, a set of five multiplier relays upon which a multiplier digit is settable in accordance with the quinary system of notation, contacts adjusted by said relays, circuit connections between the contacts interconnecting the same in accordance with the table of multiplication, two pairs of registers, responsive to current

impulses, means for transmitting a succession of current impulses to said contact and through said connections to enter a pair of components of partial products into said registers for each of said impulses, and means for rendering the two pairs of registers alternately responsive to the successive current impulses.

13. In a machine of the class described, a partial products forming mechanism comprising a set of five multiplicand relays upon which a multiplicand digit is settable in accordance with the quinary system of notation, a set of five multiplier relays upon which a multiplier digit is settable in accordance with the quinary system of notation, contacts adjusted by said relays, circuit connections between the contacts, interconnecting the same in accordance with the table of multiplication, two pairs of registers, responsive to current impulses, resetting means for each pair of registers, means for transmitting a succession of current impules to said contacts and through said connections to enter a pair of components of partial products into said registers for each of said impulses, means for rendering the two pairs of registers alternately responsive to the successive current impulses, and means for rendering the two resetting means alternately effective, each prior to the entry of components into the related register.

14. In a machine of the class described, means for sensing a master card for designations representing classification data and multiplicand data, means for sensing a detail card for designations representing classification data and multiplier data, a first pair of registers controlled by said sensing means to receive the classification data sensed, a second pair of registers controlled by said sensing means to receive the factor data sensed, multiplying mechanism including a product register controlled by the second pair of registers to obtain the product of said multiplicand and multiplier data and manifest the product in said product register, means controlled by the first pair of registers for comparing the classification data entered therein, means controlled thereby when the classification data derived from the two cards agree for rendering the multiplying mechanism effective, and means controlled by the product register for recording the product in one of said cards.

15. In a machine of the class described, means to feed a file of master cards, one by one, means to feed a file of detail cards, one by one, means to sense a master card for designations representing classification data and multiplicand data, means to sense a detail card for designations representing classification data and multiplier data, a first pair of registers controlled by said sensing means to receive the classification data sensed, a second pair of registers controlled by said sensing means to receive the factor data sensed, multiplying mechanism including a product register controlled by the second pair of registers to obtain the product of said multiplicand and multiplier data and manifest the product in said product register, means controlled by the first pair of registers for comparing the classification data entered therein, means controlled thereby when the classification data derived from the two cards are unlike for clearing one of each of said first and second pairs of registers, further means controlled thereby for feeding the card whose data is cleared, and still further means controlled thereby for causing the sensing means to enter new data from another card of the file fed.

16. In a machine of the class described, a plurality of feeding means, each for feeding in succession records of one of a plurality of files of records from a related supply station to a related discharge station, means for each feeding means for sensing data designations in the respective files of records, a plurality of registers, means for initiating and effecting a sequence of operations wherein a record is fed by each feeding means to the related sensing means, and said sensing means causes classification data to be entered from the records into certain of the registers and factor data to be entered into certain others of the registers, comparing means controlled by said certain registers, multiplying means controlled by said other registers, means effective, upon entry of data in said registers, for rendering the comparing means effective, means controlled thereby when the classification data of the two records sensed are in agreement for initiating and effecting an operation of said multiplying means to obtain the product of the factor data entered in said other registers, and further means controlled by the comparing means when the classification data are in disagreement for clearing the registers containing data derived from one of the records.

17. In a machine of the class described, a plurality of feeding means, each for feeding in succession records of one of a plurality of files of records from a related supply station to a related discharge station, means for each feeding means for sensing data designations in the respective files of records, a plurality of registers, means for initiating and effecting a sequence of operations wherein a record is fed by each feeding means to the related sensing means, and said sensing means causes classification data to be entered from the records into certain of the registers and factor data to be entered into certain others of the registers, comparing means controlled by said certain registers, multiplying means controlled by said other registers, means effective, upon entry of data in said registers, for rendering the comparing means effective, means controlled thereby when the classification data of the two records sensed are in agreement for initiating and effecting an operation of said multiplying means to obtain the product of the factor data entered in said other registers, and further means controlled by the comparing means when the classification data are in disagreement for clearing the registers containing data derived from one of the records, and still further means controlled by the comparing means when the classification data are in disagreement for causing the feeding means related to said one of the records to feed said record to its discharge station and advance the next record in the file to the sensing means, said sensing means entering new data from said second record into the cleared registers.

18. In a machine of the class described, a series of relays, a set of contacts for each, means for emitting a sequence of electrical impulses to energize said relays in succession, each energizing impulse, upon energizing a relay, also branching through the contacts of the previously energized relay of the series, the energization of the last relay of the series being followed by reenergization of the first relay of the series whereby the relays are energized in response to said sequence of impulses repeatedly and in succession, a plurality of controlling devices responsive to electrical impulses, and means for selectively con-

necting said devices to the contacts of the relays to route the said branching impulses thereto and render the devices effective accordingly.

19. In a machine of the class described, a series of relays, a set of contacts for each, means for emitting a sequence of electrical impulses to energize said relays in succession, each energizing impulse, upon energizing a relay, also branching through the contacts of the previously energized relay of the series, the energization of the last relay of the series being followed by reenergization of the first relay of the series whereby the relays are energized in response to said sequence of impulses repeatedly and in succession, a plurality of controlling devices responsive to electrical impulses, means for selectively connecting said devices to the contacts of the relays to route the said branching impulses thereto and render the devices effective accordingly, and switching means settable to cause reenergization of the first relay of the series to occur when a predetermined other relay in the series has been energized whereby less than all of the relays in the series will be energized in repeated succession.

20. In a multiplying machine, means for sensing records for representation of amounts A, B, C and D of an algebraic expression, and for sensing designations representing the arithmetic signs of said amounts, a plurality of entry receiving registers, means under control of said

sensing means for entering the amounts together with their signs into said registers, factor receiving registers, adding means controlled by said entry receiving registers to obtain the algebraic sum of $A+B$ and of $C+D$ and enter the said sums into the factor receiving registers together with the resulting signs of each sum, a result register, and multiplying means controlled by said factor registers for obtaining the product of the sums therein and the resulting sign and entering the result and its sign into said result register.

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