PUBLISHED	F. MEZGER	Serial No.
MAY 25, 1943.	ELECTRICAL CALCULATING APPARATUS	269,265
BY A. P. C.	Filed April 21, 1939	17 Sheets-Sheet 1

FIG. 1.

TABLES I, UNITS

Group 0, 1

a \ b:	0	1	2	3	4	5	6	7	8	9
0	0	0	0	0	0	0	0	0	0	0
1	0	1	0	1	0	1	0	1	0	1
2	0	0	0	0	0	0	0	0	0	0
3	0	1	0	1	0	1	0	1	0	1
4	0	0	0	0	0	0	0	0	0	0
5	0	1	0	1	0	1	0	1	0	1
6	0	0	0	0	0	0	0	0	0	0
7	0	1	0	1	0	1	0	1	0	1
8	0	0	0	0	0	0	0	0	0	0
9	0	1	0	1	0	1	0	1	0	1

Group 0, 2, 4, 6, 8

a \ b:	0	1	2	3	4	5	6	7	8	9
0	0	0	0	0	0	0	0	0	0	0
1	0	0	2	2	4	4	6	6	8	8
2	0	2	4	6	8	0	2	4	6	8
3	0	2	6	8	2	4	8	0	4	6
4	0	4	8	2	6	0	4	8	2	6
5	0	4	0	4	0	4	0	4	0	4
6	0	6	2	8	4	0	6	2	8	4
7	0	6	4	0	8	4	2	8	6	2
8	0	8	6	4	2	0	8	6	4	2
9	0	8	8	6	6	4	4	2	2	0

TABLES I, TENS

Group 0, 1, 2

a \ b:	0	1	2	3	4	5	6	7	8	9
0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	1	1	1	1	1
3	0	0	0	0	1	1	1	2	2	2
4	0	0	0	1	1	2	2	2	0	0
5	0	0	1	1	2	2	0	0	1	1
6	0	0	1	1	2	0	0	1	1	2
7	0	0	1	2	2	0	1	1	2	0
8	0	0	1	2	0	1	1	2	0	1
9	0	0	1	2	0	1	2	0	1	2

Group 0, 3, 6

a \ b:	0	1	2	3	4	5	6	7	8	9
0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	3	3
5	0	0	0	0	0	0	3	3	3	3
6	0	0	0	0	0	3	3	3	3	3
7	0	0	0	0	0	3	3	3	3	6
8	0	0	0	0	3	3	3	3	6	6
9	0	0	0	0	3	3	3	6	6	6

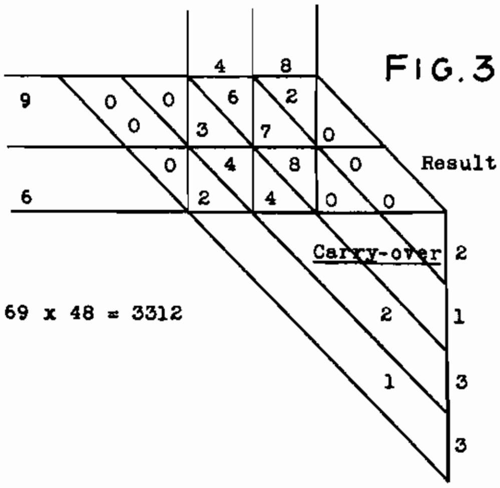


FIG. 3.

69 x 48 = 3312

Fritz Mezger Inventor
By
Young, Emery & Thompson
Attorneys.

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER

ELECTRICAL CALCULATING APPARATUS

Filed April 21, 1939

Serial No. 269,265

17 Sheets-Sheet 2

FIG. 2.

TABLES II, UNITS

Group 0, 1

a \ b:	0	1	2	3	4	5	6	7	8	9
0 5	00	01	00	01	00	01	00	01	00	01
2 7	00	01	00	01	00	01	00	01	00	01
4 9	00	01	00	01	00	01	00	01	00	01
6 1	00	01	00	01	00	01	00	01	00	01
8 3	00	01	00	01	00	01	00	01	00	01

Group 0, 2, 4, 6, 8

a \ b:	0	1	2	3	4	5	6	7	8	9
0 5	00	04	00	04	00	04	00	04	00	04
2 7	00	26	44	60	88	04	22	48	66	82
4 9	00	48	88	26	66	04	44	82	22	60
6 1	00	60	22	82	44	04	66	26	88	48
8 3	00	82	66	48	22	04	88	60	44	26

TABLES II, TENS

Group 0, 1, 2

a \ b:	0	1	2	3	4	5	6	7	8	9
0 5	00	00	01	01	02	02	00	00	01	01
2 7	00	00	01	02	02	10	11	11	12	10
4 9	00	00	01	12	10	21	22	20	01	02
6 1	00	00	10	10	20	00	00	10	10	20
8 3	00	00	10	20	01	11	11	22	02	12

Group 0, 3, 6

a \ b:	0	1	2	3	4	5	6	7	8	9
0 5	00	00	00	00	00	00	03	03	03	03
2 7	00	00	00	00	00	03	03	03	03	06
4 9	00	00	00	00	03	03	03	06	36	36
6 1	00	00	00	00	00	30	30	30	30	30
8 3	00	00	00	00	30	30	30	30	60	60

Fritz Mezger Inventor
By
Young, Emery & Thompson
Attorneys

PUBLISHED MAY 25, 1943. BY A. P. C.

F. MEZGER

ELECTRICAL CALCULATING APPARATUS

Filed April 21, 1939

Serial No. 269,265

17 Sheets-Sheet 3

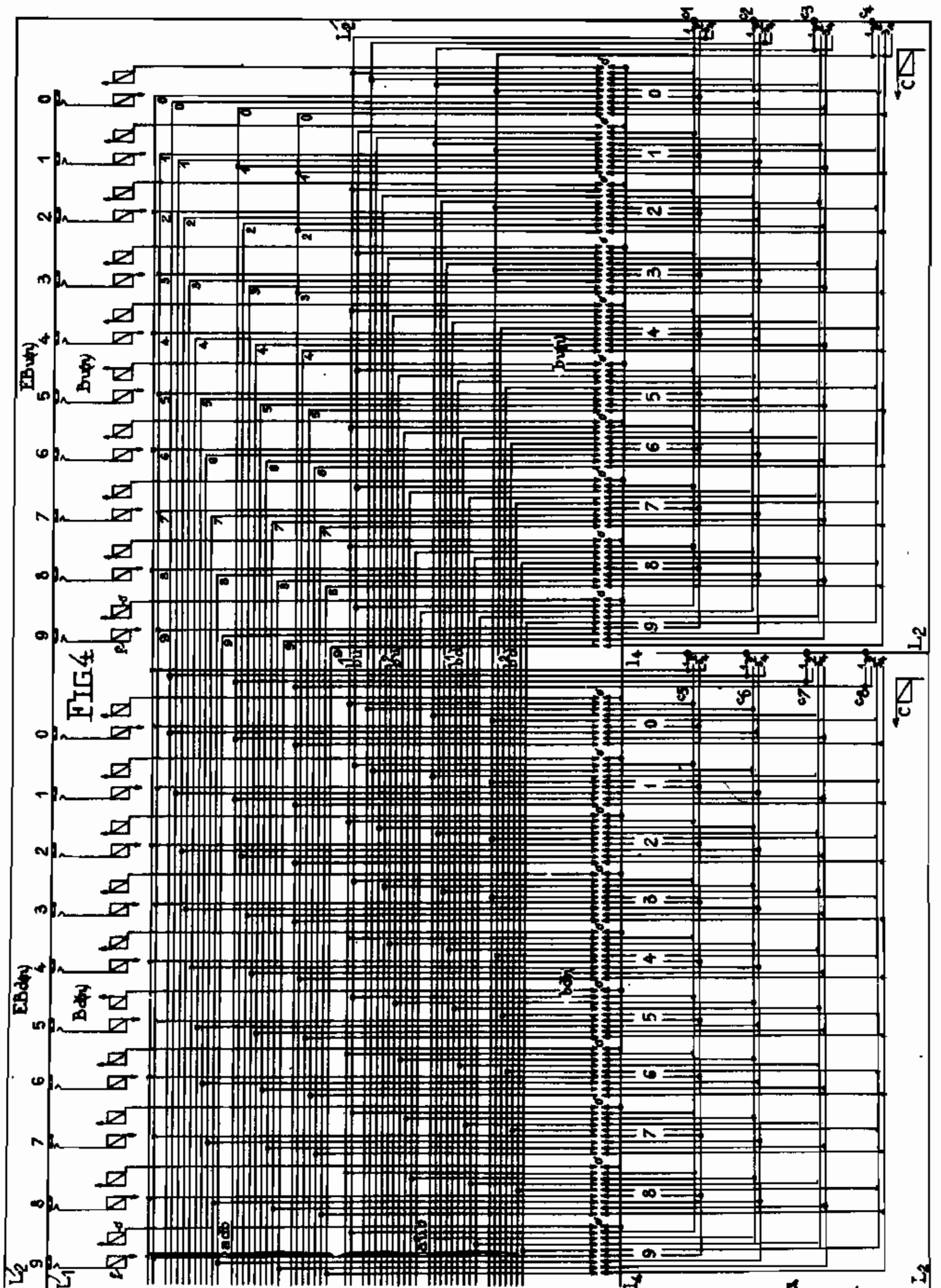


FIG. 4

Fritz Mezger Inventor

By Young, Emery & Thompson Attorneys.

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER
ELECTRICAL CALCULATING APPARATUS
Filed April 21, 1939

Serial No.
269,265
17 Sheets-Sheet 4

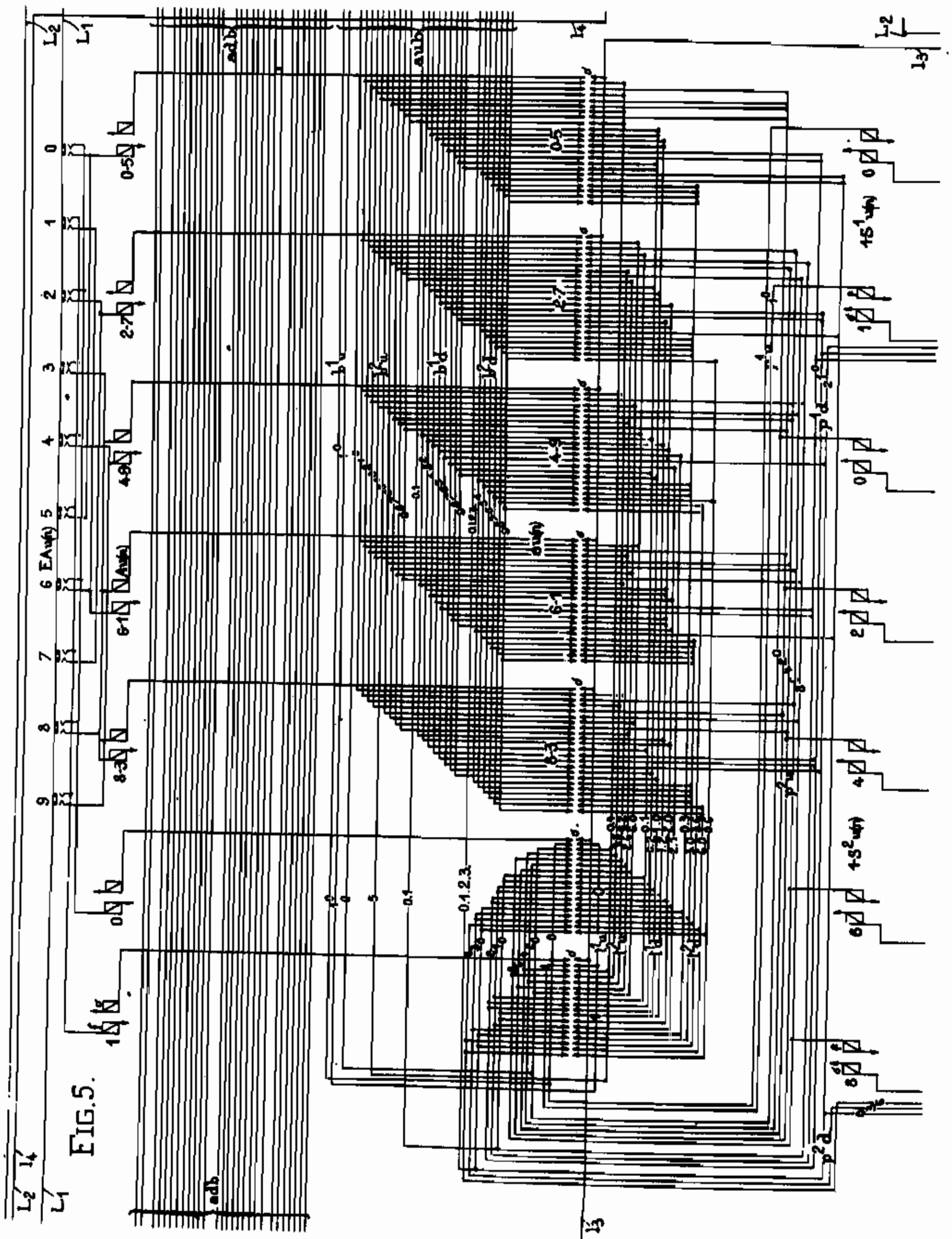


FIG. 5.

Fritz Mezger Inventor
By
Young, Emery & Thompson
Attorneys.

PUBLISHED MAY 25, 1943. BY A. P. C.

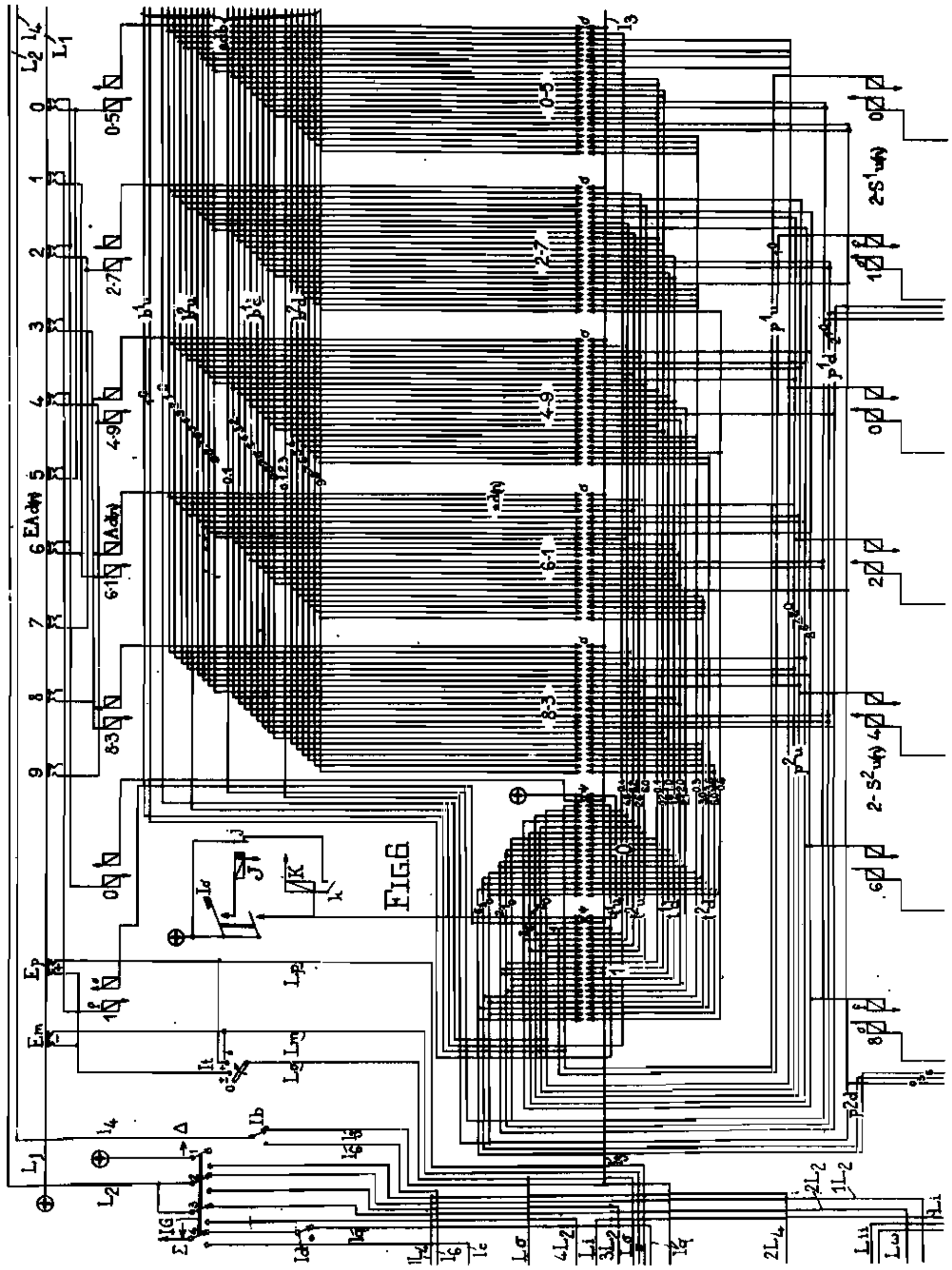
F. MEZGER

ELECTRICAL CALCULATING APPARATUS

Filed April 21, 1939

Serial No. 269,265

17 Sheets-Sheet 5



Fritz Mezger Inventor

By

Young, Emery & Thompson Attorneys.

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER

ELECTRICAL CALCULATING APPARATUS

Filed April 21, 1939

Serial No. 269,265

17 Sheets-Sheet 6

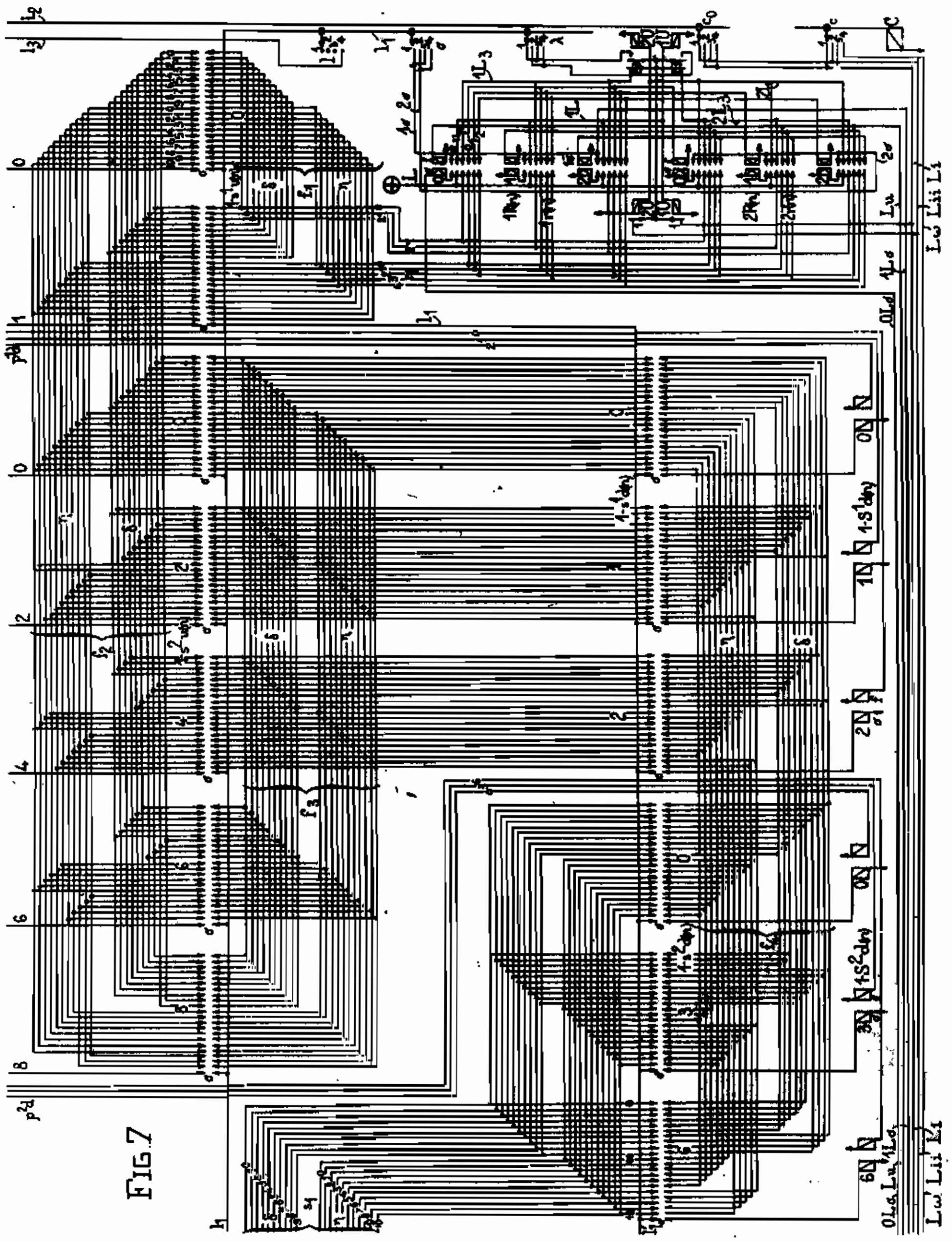


FIG. 7

Fritz Mezger Inventor

By Young, Emery & Thompson Attorneys.

PUBLISHED MAY 25, 1943. BY A. P. C.

F. MEZGER
ELECTRICAL CALCULATING APPARATUS
Filed April 21, 1939

Serial No. 269,265
17 Sheets-Sheet 7

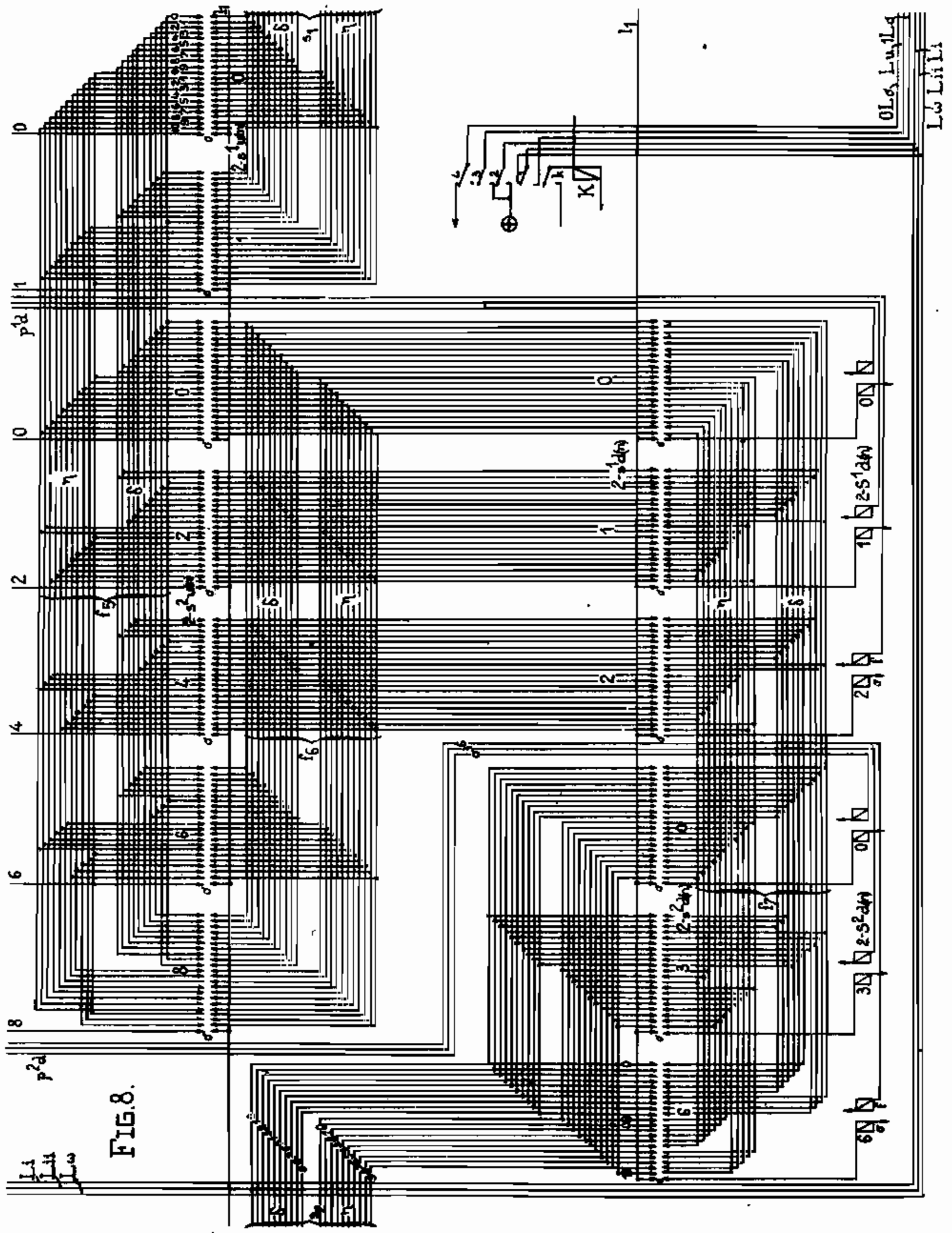


FIG. 8.

Fritz Mezger, Inventor
By Young, Emery & Thompson, Attorneys

PUBLISHED MAY 25, 1943. BY A. P. C.

F. MEZGER

ELECTRICAL CALCULATING APPARATUS

Filed April 21, 1939

Serial No. 269,265

17 Sheets-Sheet 8

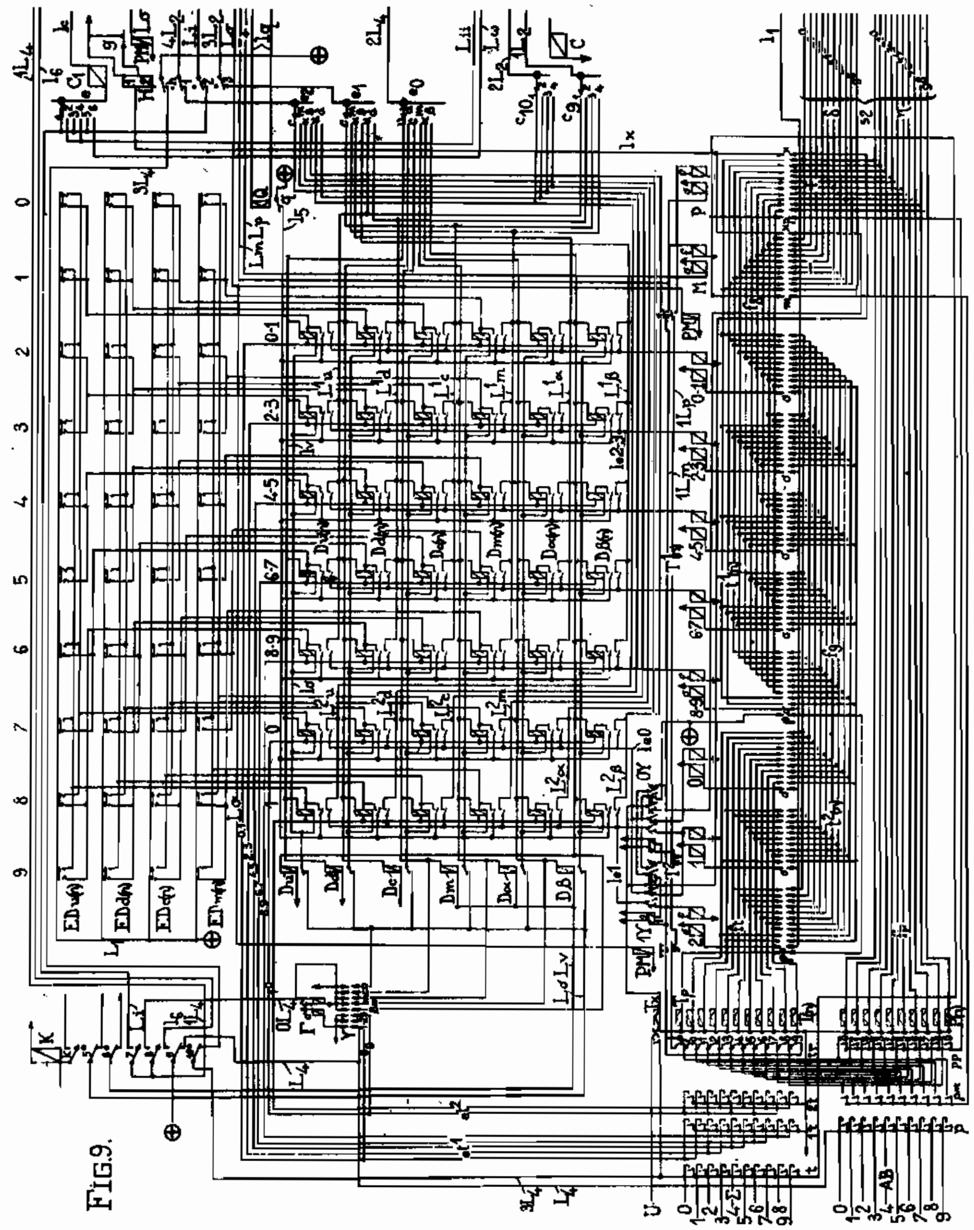


FIG. 9.

Fritz Mezger Inventor

By Young, Emery & Thompson Attorneys.

PUBLISHED | **F. MEZGER** | **Serial No.**

MAY 25, 1943. | ELECTRICAL CALCULATING APPARATUS | **269,265**

BY A. P. C. | Filed April 21, 1939 | 17 Sheets-Sheet 9

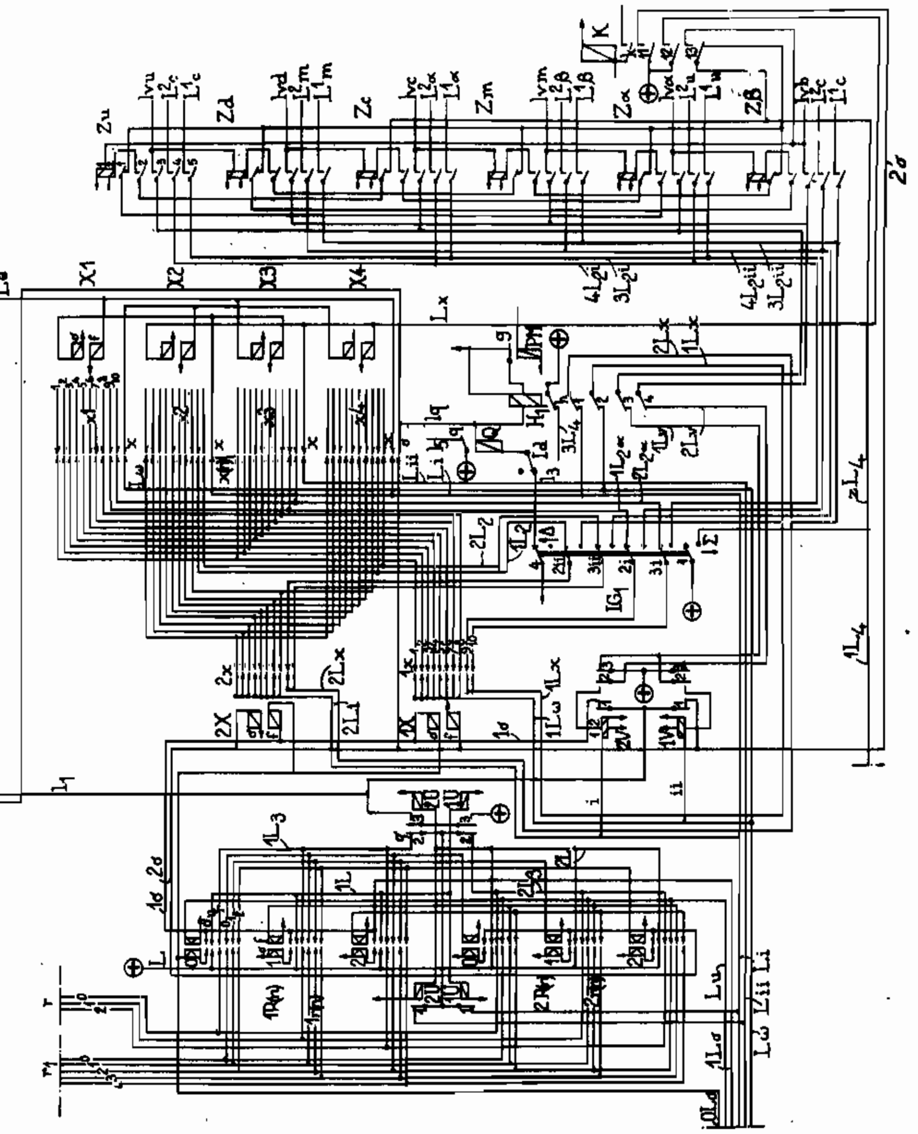


FIG.10.

Fritz Mezger Inventor

By

Young, Emery & Thompson
Attorneys

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER
ELECTRICAL CALCULATING APPARATUS
Filed April 21, 1939

Serial No.
269,265
17 Sheets-Sheet 10

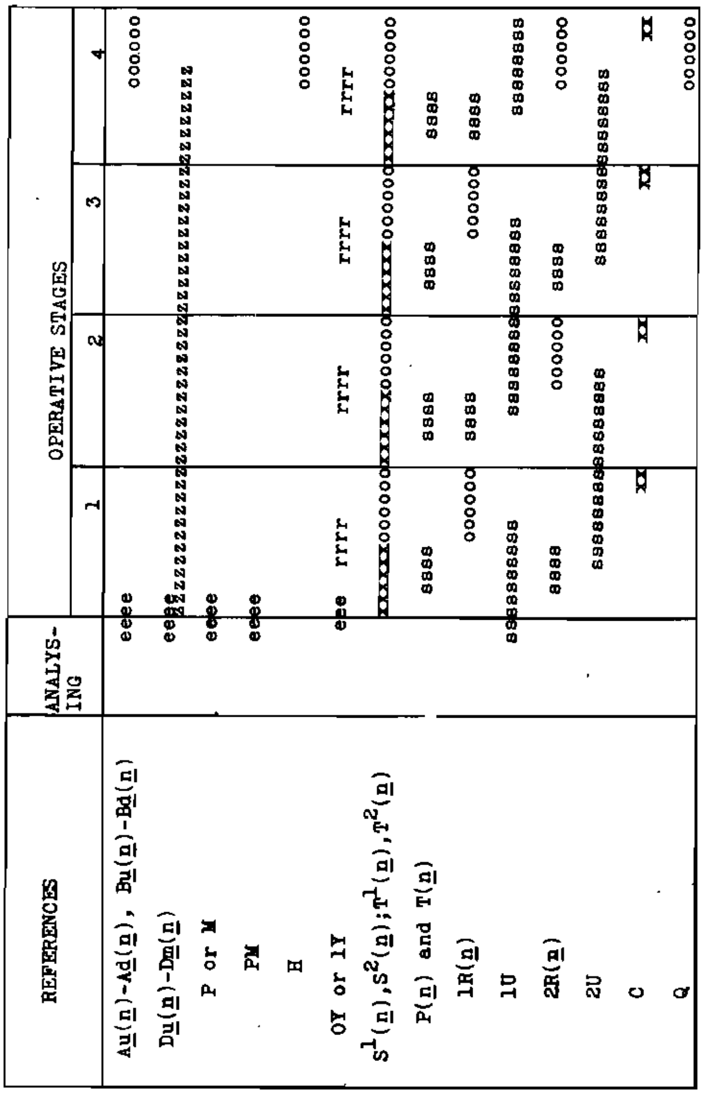


FIG. 11.

Fritz Mezger Inventor
By
Young, Emery & Thompson
Attorneys

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER

ELECTRICAL CALCULATING APPARATUS

Filed April 21, 1939

Serial No.
269,265

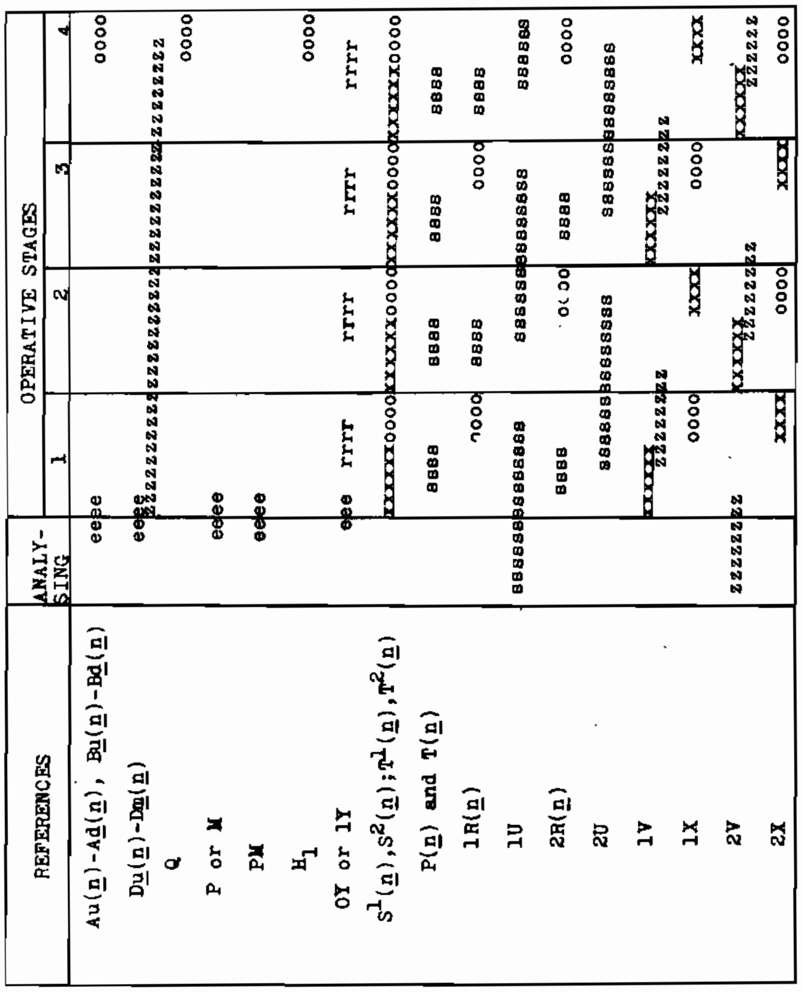


FIG. 12.

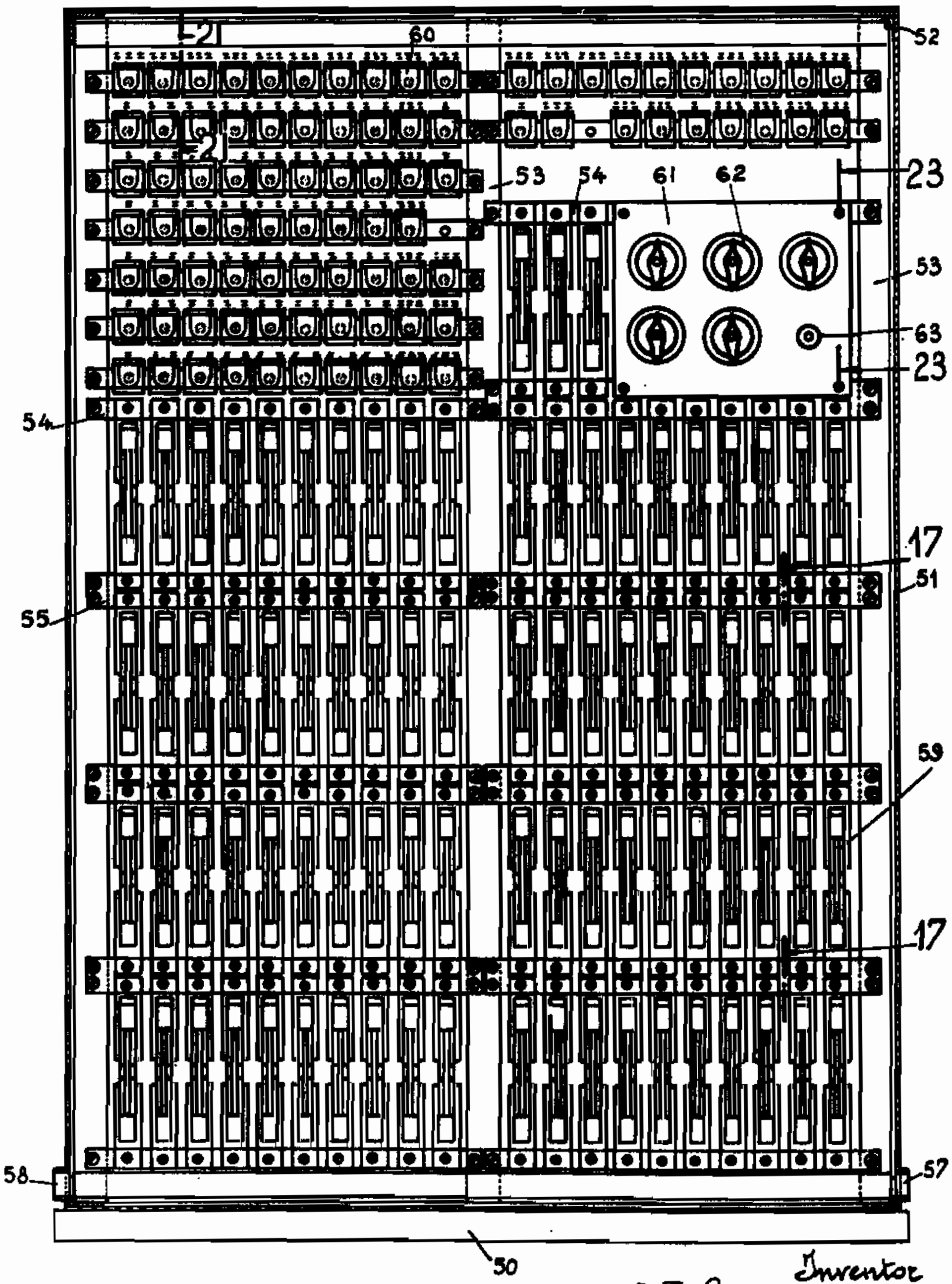
Fritz Mezger Inventor
By Young, Emery & Thompson
Attorneys.

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER
ELECTRICAL CALCULATING APPARATUS
Filed April 21, 1939

Serial No.
269,265
17 Sheets-Sheet 12

FIG.13.



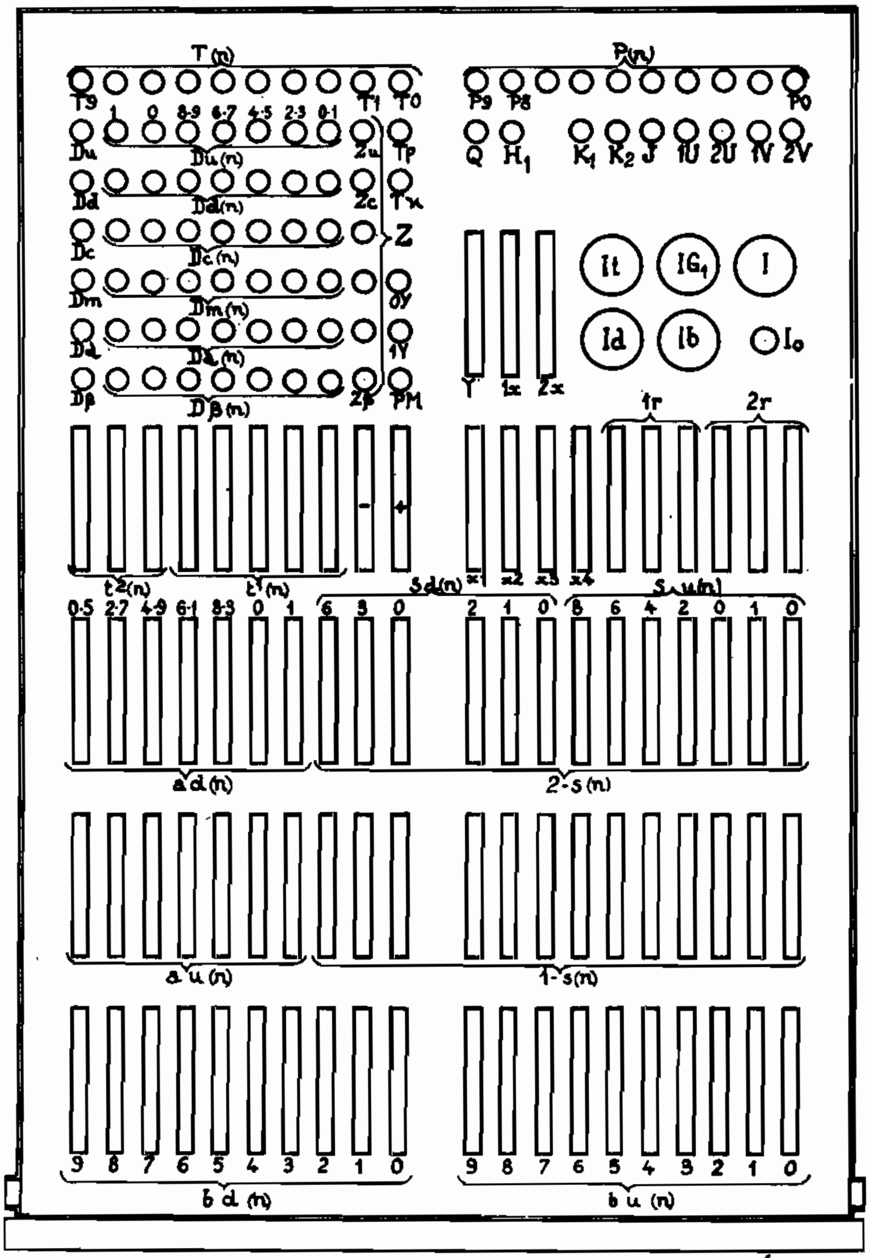
Fritz Mezger Inventor
By
Young, Emery & Thompson
Attorneys

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER
ELECTRICAL CALCULATING APPARATUS
Filed April 21, 1939

Serial No.
269,265
17 Sheets-Sheet 13

FIG.14.



Fritz Mezger Inventor
By
Young, Emery & Thompson
Attorneys

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER

ELECTRICAL CALCULATING APPARATUS

Filed April 21, 1939

Serial No.
269,265

FIG.15.

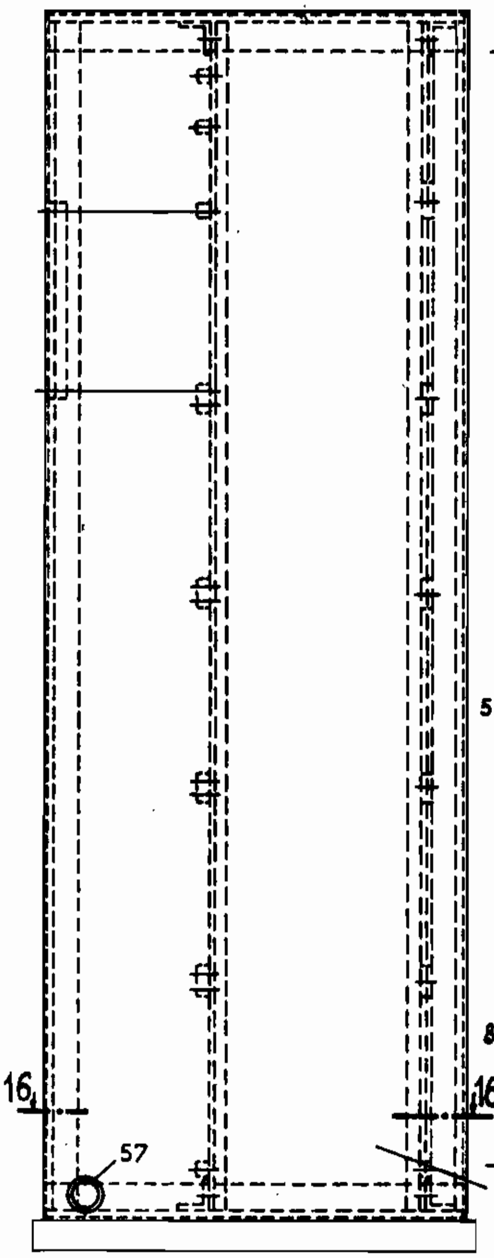
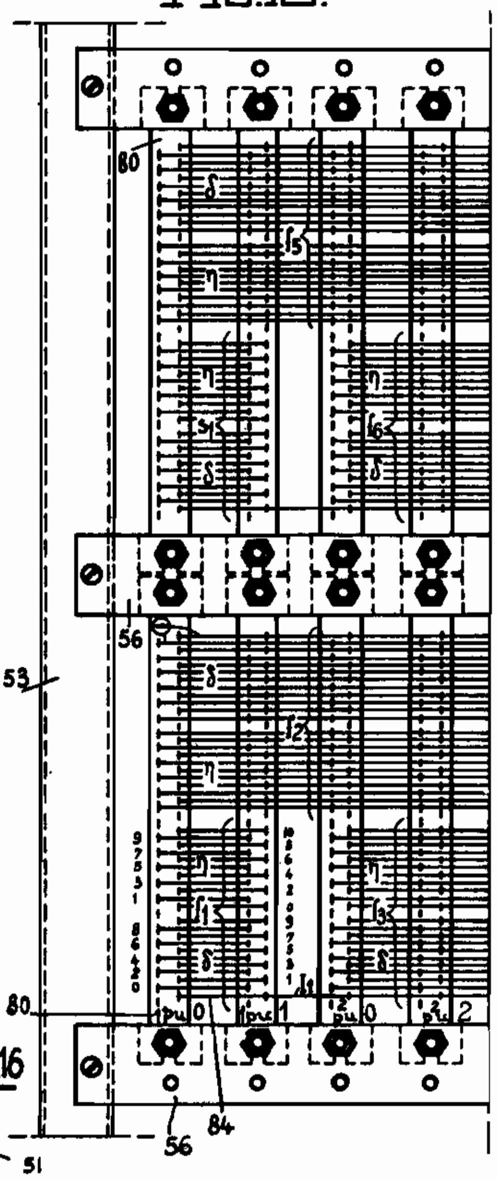


FIG.18.



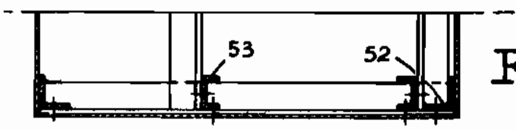


FIG.16.

Inventor
Fritz Mezger
By
Young, Emery & Thompson
Attorneys.

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER
ELECTRICAL CALCULATING APPARATUS
Filed April 21, 1939

Serial No.
269,265
17 Sheets-Sheet 15

FIG.17.

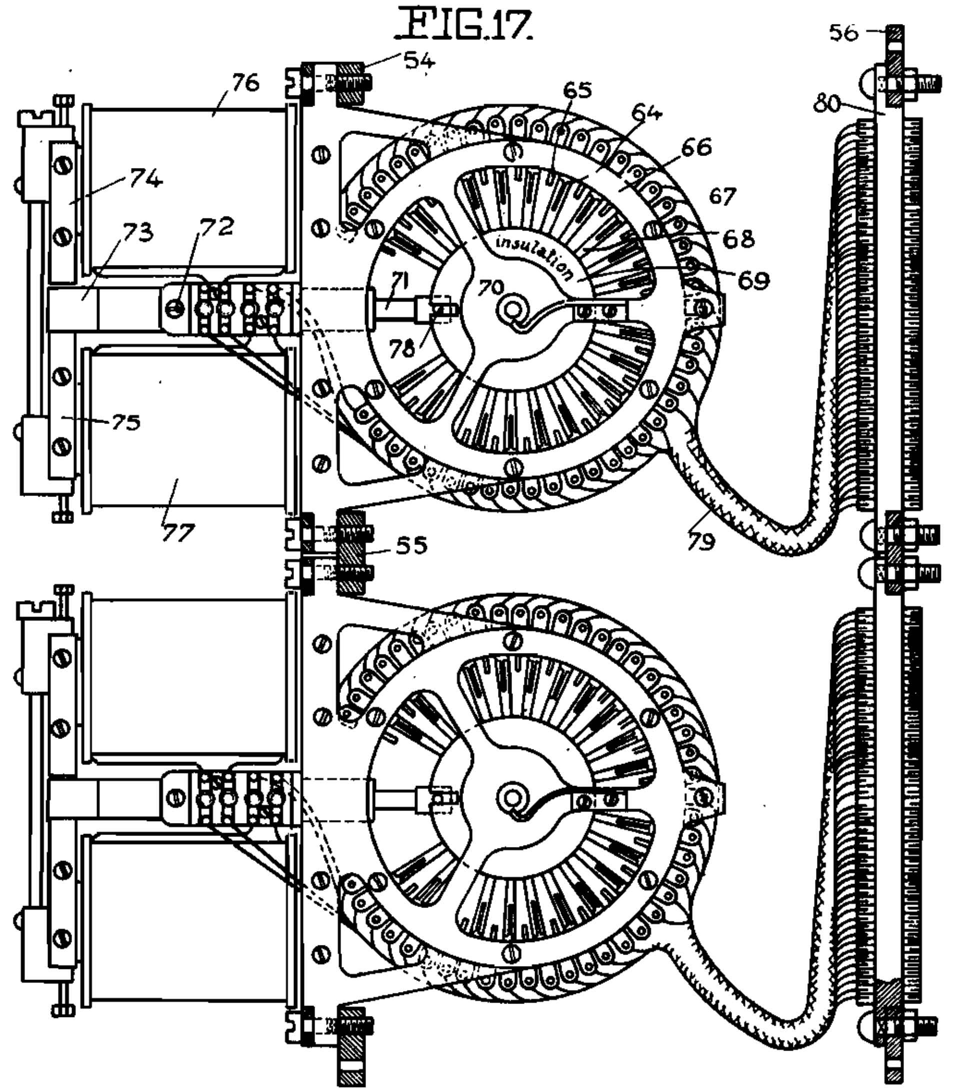
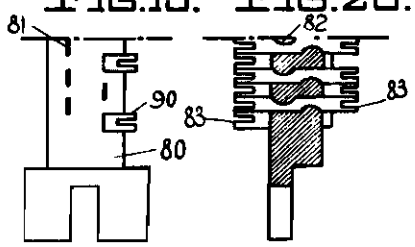


FIG.19. FIG.20.



Fritz Mezger INVENTOR
BY
Young, Emery + Thompson
ATTORNEYS

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER
ELECTRICAL CALCULATING APPARATUS
Filed April 21, 1939

Serial No.
269,265
17 Sheets-Sheet 16

FIG. 22.

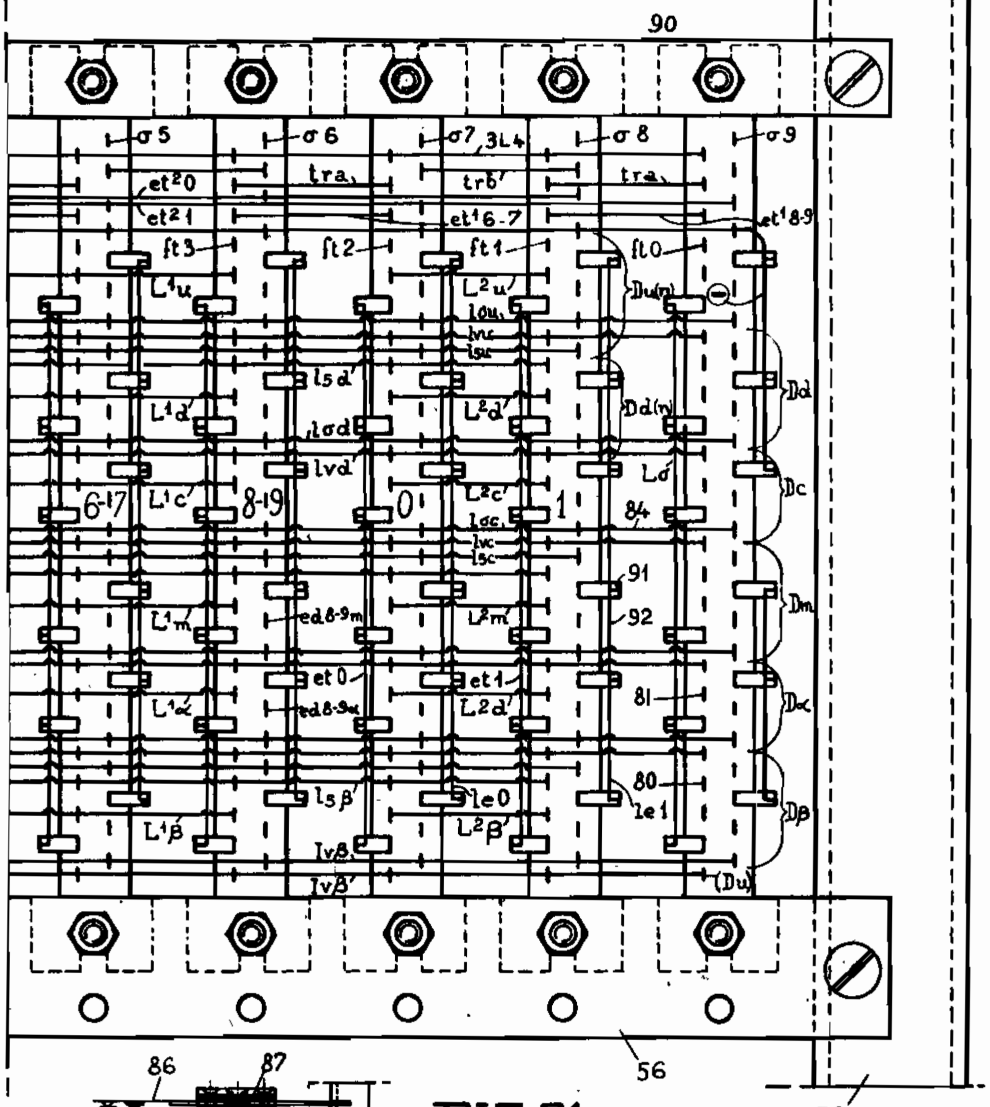
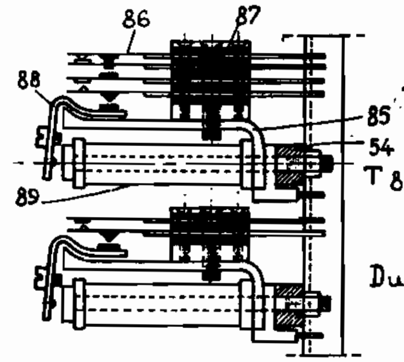


FIG. 21.



Fritz Mezger Inventor
By
Young, Emery & Thompson
Attorneys

PUBLISHED
MAY 25, 1943.
BY A. P. C.

F. MEZGER
ELECTRICAL CALCULATING APPARATUS
Filed April 21, 1939

Serial No.
269,265
17 Sheets-Sheet 17

FIG. 24.

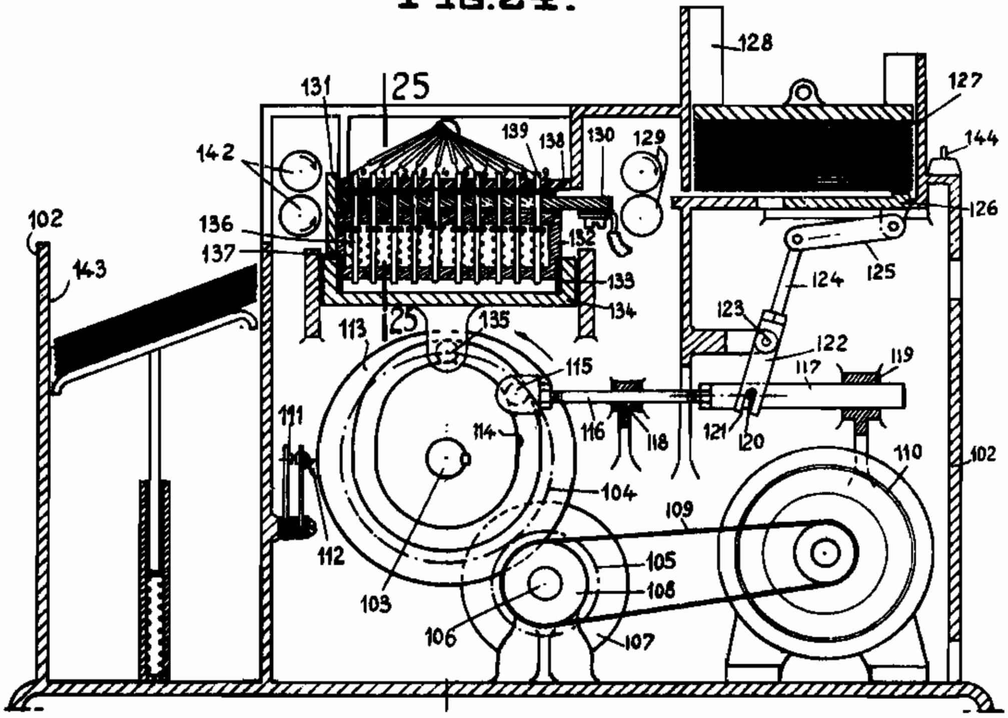


FIG. 23.

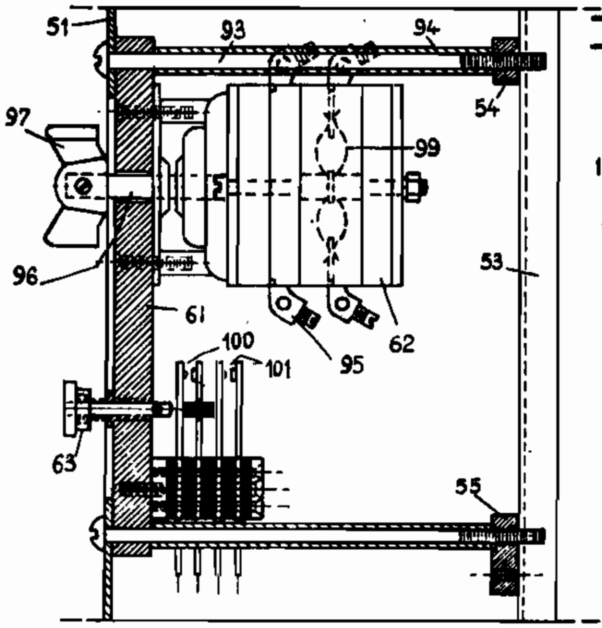
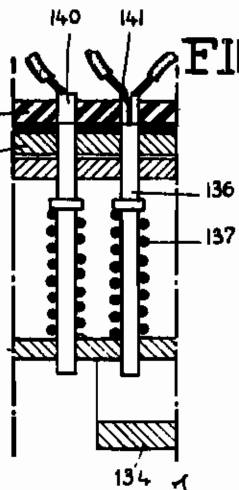


FIG. 25.



Fritz Mezger Inventor
By
Young, Emery & Thompson
Attorneys

Published May 25, 1943

Serial No. 269,265

ALIEN PROPERTY CUSTODIAN

ELECTRICAL CALCULATING APPARATUS

Fritz Mezger, Paris, France; vested in the Alien Property Custodian

Application filed April 21, 1939

This invention relates to electrical calculating apparatus and may be embodied in machines for multiplying or adding two multi-denominational terms together or for summing a series of such terms or a machine for effecting any two or more of such operations so as to evaluate, for example, arithmetical expressions of the form D±AB or ΣAB.

The apparatus according to the invention operates in a succession of stages to obtain at each stage a result digit in a normal system of notation and comprises a series of possible groups of circuits, the circuits of each group being adapted to be completed by a source of current and, with the exception of these in the last group, comprising at least one connecting winding controlling at least one contact in a circuit of the succeeding group, in a manner analogous to the links of a chain, the first group of which, corresponding to the introduction of the known quantities, comprises circuits allotted to each of the characteristic digits possible in the different denominations of the terms A, B and D which the operations for which the calculating apparatus is provided may involve, a second group of circuits allotted to each of the partial products to be added and to each of the digits of the term with which they have to be totalised in the case of the operation D±AB for the calculation of the result digit in each of the denominations and each dependent on the introduction circuits for the characteristic digits, which furnish the said partial products or which correspond to the digits of the said term, a third group, a bundle for totalisation in said normal system of notation, under the dependence of the sets of connecting windings of the second group, with, in another bundle having a common point with the other, members effecting a different totalisation by using another system of notation, or by neglecting one of the terms to be totalised, for permitting the determination of the transfer by comparison of the ranks of the wires under current at the end opposite to the common point, a fourth group of bundles for the result of the partial totals in said normal system of notation, the circuits of the second group, which correspond to the exploration of the term D being also under the dependence of the circuits of the fourth group for recording the successive totals ΣAB.

In the application of the invention to an apparatus only for adding two terms, the first group therefore comprises circuits each allocated to one of the digits possible in the different denominations of one of the terms, the second group of circuits each comprises a contact controlled by one of said first group and a contact controlled according to the stage of the operation to complete the circuit or circuits pertaining to the digits of the appropriate denomination, and the third group comprises addition switches controlled by the connecting windings of the second group and making cross-connections between an input bundle for the introduction, stage by stage, of the digits of the other term and an output bundle for the results.

Since an addition device forms an essential part of an apparatus for multiplying together two multi-denominational factors by the Arabic method (for adding the partial products and the transfer from one denomination to the next), it follows that such a multiplication apparatus may be derived from an addition apparatus by suitable modification and extension of the circuits without destroying its distinctive character.

A multiplication apparatus according to the invention may thus be regarded as a modification of a basic addition apparatus, and will comprise a first group comprising circuits each allocated to one of the digits possible in the different denominations of the two factors, a second group comprising circuits each comprising a contact controlled by one of the first group pertaining to one of the factors and a contact controlled by one of the first group pertaining to the other factor and terminating at as many sets of connecting windings as there are denominations in one of the factors, each set comprising connecting windings characteristic of the possible units and tens of the partial products involving one denomination of said one of the factors, and the third group comprising addition switches controlled by the connecting windings of the second group and making cross-connections between an input bundle for the introduction of the transfer resulting from the previous stage and an output bundle for the results.

By including in the third group of circuits of the addition apparatus plus and minus switches for effecting alternative connections in the input bundle, the plus switch connecting wires of equal rank and the minus switch connecting wires of complementary rank, it is possible to adapt the apparatus for subtraction as well as addition.

A further addition to or modification of the addition apparatus, permitting the totalisation of a series of multi-denomination terms, comprises the provision of a first group of circuits (additional to or replacing those already mentioned) including contacts controlled by the output bundle of the third group, and controlling recording relays having contacts in the second group.

The invention will be further described with reference to an example of an apparatus comprising in combination multiplication and addition apparatus having the features already set forth and permitting the evaluation of expressions of any of the forms AB, D±AB and ΣAB, that is to say for effecting a product and the algebraic sum of this product with a known term, which latter may be the result of the algebraic sum of the previously calculated products.

This apparatus possesses with the electrical devices of known calculating apparatus common points which place it in a very special group of such apparatus. These points will first of all be set forth.

An apparatus of this type comprises multiple-contact switches allocated to different numerical values (0 to 9 in the decimal system) which are capable of intervening to effect a partial operation, any one of said switches connecting by its contacts two bundles of wires in an order such that an input wire of given rank is connected to an output wire, the rank of which is determined both by the rank of the input wire and by the numerical value to which said switch is allocated. This mode of connection being effected between an input bundle in the electrical calculating device, whereof the wires may be connected separately to a source of current, and an output bundle of wires, whereof each wire is allocated to one of the numerical values which a given denomination of the result may assume, it follows that when the switches allocated to the numerical values of the different terms intervening in the partial operations relating to this denomination are closed, there corresponds to a predetermined wire under current at the input of the device, a predetermined wire under current at the output, that is to say a wire which is allocated to the numerical value of the digit of this denomination of the result of the operation effected.

In such a device, for effecting the product of two numbers, the operation of multiplication is decomposed in accordance with the Arabic method, according to which all the inter-digital partial products corresponding to a given denomination of the result are effected consecutively, while ascending at each operation from one denomination to the next higher denomination and effecting for each denomination the sum of the calculated partial products, taking into account the carry-over or transfer from the corresponding sum in the preceding denomination.

The inter-digital products of digits of a given denomination may contain units and tens; but only the units appear in the sum of the partial products pertaining to the same denomination of the result, the tens appearing only in the sum of the partial products pertaining to the next higher denomination of the result. Thus, each sum of partial products relating to a particular denomination of the result contains in addition to any possible transfer, both the units of the products of two digits corresponding to that denomination and the tens of the products of two digits corresponding to the preceding lower denomination.

In the electrical calculating device which forms the subject of our prior Patent No. 483,906 and is applicable to the calculation of arithmetical expressions of the general form D±AB, for the calculation of each denomination of the result there is established, by means of a general commutator constituted for example by a rotary cylinder, between the same input bundle and the same output bundle, a series of multi-contact switch groups which, in said series, are allocated alternately to the units of the partial products of the pairs of digits of the same denomination and to the tens of the partial products of the pairs of digits of the preceding denomination, each multi-contact switch being closed or open according to whether the numerical value to which it is allocated corresponds or not to the result of the calculation being effected. In addition, for calculating the number which has to be carried over or transferred from the sum of the partial products pertaining to a certain denomination into the sum of the partial products pertaining to the next denomination, supplementary wires are provided in the bundles, such that said bundles comprise a number of wires corresponding to that of the different possible numerical values in an auxiliary notation, for example, eleven wires for the hendecadal system, and there is effected in the device the addition in the decadal system of notation and in the hendecadal system of notation, the value of the carry-over which has to be transferred to the next denomination being deduced from the difference of the units of the sums of the partial products in these two systems.

In the accompanying drawings, Figures 1 to 3 are tables and diagrams relating to the preliminary explanation and Figures 4 to 10 show in the form of electric wiring diagrams two examples of calculating apparatus constructed according to the invention. For facilitating the explanation the apparatus shown is designed solely for the calculation of products of factors of two digits, and consequently of results of four digits at the most, and for the algebraic sum of such products with a known term of four digits, according to the expressions D±AB and

$$(\pm A_1B_1 \pm A_2B_2 \pm \ . \ . \ . \ \pm A_{n-1}B_{n-1}) \pm A_nB_n$$

Figures 11 and 12 are timing diagrams relating to the two constructions described.

Figure 13 is a front view of a machine embodying the electrical device according to the invention, the front wall of its casing having been removed.

Figure 14 is a diagrammatic representation of the same with the numerical references of the various electrical members.

Figure 15 is a side elevation of the right-hand side of the casing as shown on Figure 13.

Figure 16 is a partial horizontal section of the casing alone along line **16—16** of Figure 15.

Figure 17 is a vertical section along line **17—17** of Figure 13, at an enlarged scale.

Figure 18 is a rear view of part of the machine at a level corresponding to said section.

Figures 19 and 20 show a detail in elevation and section.

Figure 21 is a vertical section along line **21—21** of Figure 13.

Figure 22 is a rear view of the upper left-hand side part of the machine as shown on Figure 13.

Figure 23 is a section along line **23—23** of Figure 13.

Figure 24 is a sectional view of an analysing device for perforated cards, for controlling the introduction of the digits of the factors and term of an operation.

Figure 25 shows a detail, at an enlarged scale, in section taken along line **25—25** of Figure 24.

Of Figures 4 to 10:

Figure 4 shows the members for introducing and recording the digits, units and tens of one of the factors (B) and the departure of the "second circuit" bundles of wires ("second link" of the chain).

Figures 5 and 6 represent together the members for introducing and recording the digits of the other factor (A) with the termination of the bundles of the "second link", Figure 5 corresponding to the unit digits of the said factor and Figure 6 to the tens digits.

Figures 7 and 8 represent the bundles and switches for the addition of the partial products in the "third circuit", Figure 7 comprising in addition the members for recording and introducing the transfer.

Figure 9 represents the members for introducing the term D or

$$(\pm A_1B_1 \pm A_2B_2 \pm \ . \ . \ . \ \pm A_{n-1}B_{n-1})$$

and for recording this term and the members and circuits for calculating the algebraic sum D±AB or ΣAB, and also the departure of the "fourth circuit" (results).

Figure 10 represents a modification of the control members and circuits shown in Figures 4 to 9 in the vicinity of the members dependent upon them.

The diagrams shown in Figures 4 to 9, once assembled, constitute the assembly of the electrical device for calculating the operation D±AB or ΣAB in the case in which each of the terms A and B only comprises two denominations, units and tens, and in which the term D to which it is necessary to add algebraically the product AB comprises a number of denominations equal to that of the maximum result of said product, that is to say four denominations, units, tens, hundreds and thousands.

For assembling these diagrams, the diagrams 4, 5 and 6 must be aligned from right to left so as to cause the wires of the same references of the horizontal bundles of these diagrams to correspond. Figures 7 and 8 are placed respectively below sheets 5 and 6, causing the vertical wires which enter the former while leaving the second to correspond, and Figure 9 is finally placed on the left of the group of the assembled Figures 6 and 8, the horizontal wires of the bundles leaving on the left of Figures 6 and 8 being made to correspond with those which leave on the right of Figure 9.

In the case of the device comprising the control members according to the modification shown in Figure 10, it is necessary to assemble this figure with Figure 7, replacing the transfer device shown on the right of Figure 7 by the same transfer device shown on the left of Figure 10. In the complete device thus obtained, it is furthermore necessary to omit the control members of Figures 4 to 9 which are duplicated by the modifications of Figure 10.

After a preliminary explanation concerning the number of switches necessary for calculating the products AB, reference will be made first of all to the electrical calculating device, illustrated by the assemblage of Figures 4 to 9, while explaining successively the constitution and operation of the partial devices relating:

To the introduction by the "first circuit" group and the recording in the "second circuit" group of the factors A and B, and to the calculation of the partial products pertaining to successive denominations of the result, the factors whereof are thus recorded (Figures 4 to 6): "Multiplication giving partial products";

To the recording of the partial products in the "third circuit" group by the connecting windings of the second circuit, and to the addition of these partial products to give by successive denominations the result AB and also to the calculation and recording of the transfer pertaining to this sum (Figures 6 and 7): "Addition of partial products";

To the totalisation in the "third circuit" group by successive denominations of the result D±AB or

$$(\pm A_1B_1 \pm A_2B_2 \pm \ . \ . \ . \ \pm A_{n-1}B_{n-1}) \pm A_nB_n$$

of a product AB calculated in the preceding partial devices and of a known term preliminarily introduced and recorded, and to the introduction of the results AB and D±AB or ΣAB in the "fourth circuit" group (Figure 9): "Totalisation";

To the control of the whole of the device (Figures 4 to 9): "Control".

Then, the modification of Figure 10 will be explained.

Finally, reference will be made to Figures 13 to 25 illustrating a machine in accordance with this invention having the circuit arrangement shown on the assemblage of Figures 4 to 9 modified as shown on Figure 10.

Number of switches

As stated in the foregoing, the calculation of the product AB is effected according to the Arabic multiplication, that is to say, the digits of the increasing denominations of the result are calculated successively by the addition of the digits of the same denomination of all the interdigital partial products of the factors A and B. These digits to be added are, for each denomination, in addition to the possible carry-over from the preceding addition, the units of the partial products of the same denomination and the tens of those of the preceding denomination. Their number, apart from the carry-over, is therefore at the most equal to twice the number of digits of one of the factors, and it may be considered as constant by replacing the missing digits by zero. Furthermore, these products are those which appear in the Pythagorean table, and their units are comprised between 0 and 9 and their tens between 0 and 8 (9×9=81).

It would therefore be necessary, in the "third circuit" group which comprises in series the groups of multiple switches allocated to the possible digits of the partial products, to provide 10 switches in each group of the units and 9 switches in each group of the tens. However, a simplification is possible. In fact, a digit of the units (0 to 9) may be replaced by the sum of two digits selected respectively from the two groups 0, 1 and 0, 2, 4, 6, 8 and a digit of the tens (0 to 8) by the sum of two digits selected respectively from the two groups 0, 1, 2 and 0, 3, 6.

This makes it possible, for the units, to reduce the number of switches to seven, each being allocated to one of the digits of the two groups in series, a switch being closed in each group for any digit (0 to 9) which has to intervene in the addition.

Likewise, the number of switches of the tens may be reduced from nine to six.

This double decomposition of the partial products into units and tens on the one hand and into two groups for the units and two groups for the tens on the other hand, may be represented by the complementary Pythagorean tables shown in Figure 1, in which the units digit of the result of multiplying one of the digits of the horizontal row (factor *b*) by one of the digits of the vertical column (factor *a*) is obtained by adding the numerical values read from the two tables.

On examining any one of these tables, that of the second group of the units for example, it will be seen that the same elementary result digit corresponds to the products of different factors *a*, *b*. Therefore, the connecting winding of the "second circuit" controlling the multiple switch allocated to said digit must have current passing through it for each of these products. This would be possible by terminating at this winding as many wires in parallel as the number of times this digit appears in the table, each of said wires comprising two switches allocated to the numerical values of the two factors *a* and *b* of these various products, and for the whole of the table it would be necessary to have a hundred wires. However, a simplification is possible.

This simplification is based on the observation that two values a_1 and a_2 of *a* different from 5 give the same digit when *b* is even-numbered and different units digits when *b* is odd-numbered. These values a_1 and a_2 differing from 5 being one even-numbered and the other odd-numbered there has been provided, as will hereinafter appear, in series in the line common to the products $b.a_1$ and $b.a_2$ two switches in parallel, one of which is closed when *a* is even-numbered and the other when *a* is odd-numbered and which establish the connection to the correct winding.

By effecting in the preceding tables the grouping of the factors *a* different from five and by writing side by side the result digits corresponding to *a* even-numbered and *a* odd-numbered, we obtain the "Tables II" shown in Figure 2.

It will be seen that the digits to be differentiated according to whether *a* is even or odd-numbered are:

	First group	Second group
Units	01	04, 48, 82, 26, 60
Tens	01, 02, 10, 12, 20, 21	03, 30, 36, 60, 06

It will also be remarked that these tables comprise identical columns for several values of *b*, namely, the table of the units, first group, for all the odd-numbered values of *b* on the one hand, for all the even-numbered values of *b* on the other hand, in the tens tables, for $b=0$, and $b=1$, in the first group, and for $b=0$, $b=1$, $b=2$, $b=3$ in the second group. This makes it possible to employ the same wire for a number of values of *b*.

The simplification which has been indicated above and which has been applied in the device which will now be described is obviously only one example of those which are possible. It makes it possible to reduce the multiplication switches to 7 for each denomination of the factor A and the addition switches to 7 for the units of a partial product and to 6 for the tens.

A similar division has been employed in the circuits of the second group for introducing the term D which is assimilable to a product $(D\times 1)$. The following tables of decomposition into two groups 0, 2, 4, 6, 8 and 0, 1 for the units correspond thereto.

Group 0, 2, 4, 6, 8 Multiplier: 1		Group 0, 1 Multiplier: 1	
d		*d*	
0 1	00	0 1	01
2 3	22	2 3	01
4 5	44	4 5	01
6 7	66	6 7	01
8 9	88	8 9	01

A second selection is necessary in the second group (0, 1) according as to whether *d* is even or odd. As the product $D\times 1$ only comprises digits of the units order, there is no tens table. The decomposition results in a reduction in the number of addition switches necessary.

Another method of decomposing the Pythagorean tables could be selected and other groupings in the tables obtained could be effected, for example for the units a decomposition into the groups 0, 5 and 0, 1, 2, 3, 4.

It will likewise be recalled that the electrical calculating device has been shown as provided for the operations $D\pm AB$ and ΣAB comprising factors A and B of two digits. As numerical example, D=6158, A=69, B=48, has been chosen in the operation $6158\pm 69\times 48=6158\pm 3312$.

The multiplication is shown diagrammatically in Figure 3, in which it will be seen that the partial product digits are completed to make up four by zeros in each of the additions corresponding to the four denominations of the result.

Multiplication giving partial products

The part of the device relating to the calculation of the partial products comprises on the one hand the switches allocated to the factor B (Figure 4, units and tens), and on the other hand the switches allocated to the factor A (Figure 5 for the units and Figure 6 for the tens), the latter being connected by the assemblages of wires *aub* and *adb*, each comprising four bundles of wires, namely, b^1u corresponding to group 1 units and comprising two wires, one for the even values of *b*, which as seen from the Table II, Units, group 0, 1, all correspond to the same result 00, and one for the odd values of *b* which similarly all correspond to the same result 01: b^2u corresponding to group 2 units and comprising ten wires since as seen from Table II, Units, group 0, 2, 4, 6, 8 the results are different for each value of *b*: b^1d corresponding to group 1 tens and comprising nine wires since as seen from the tables the values 0 and 1 of *b* correspond to the same results: and b^2d corresponding to group 2 tens and comprising seven wires since the same results correspond to the values 0, 1, 2 and 3 of *b*.

Referring first of all to Figure 4, it will be seen that there are ten multiple switches per denomination; these switches are denoted by the references $bu(n)$ and $bd(n)$, where *n* is one of the digits 0 to 9, and *u* and *d* indicate the units and tens denominations respectively. (Where, as in this instance, the letter *n* is in parenthesis it is intended to indicate that it is replaceable by alternative specific digits or groups of digits to indicate one member of a group indicated generically by the remainder of the reference.) Each switch is under the dependence of a control device (which for the sake of simplicity of expression will be denoted by the name of "electromagnet") $Bu(n)$, $Bd(n)$ having two windings, one of which, the closing winding *f* is the connecting winding of the "first circuit" and is adapted to receive the current of a line L_1, when a punched card analysing device, for example, establishes a connection of the introduction member EB*u*(*n*), EB*d*(*n*) pertaining to said line with the corresponding contact. The numerical value to which this winding is allocated is recalled in the figure and any member whatsoever can be denoted by its generic reference, in which *n* is replaced by the said value (for example winding *f* of the electro-magnet B*d*3). The second winding, or opening winding o is connected by a contact o of the corresponding switch to a release current input line l_4. The direction of the arrow indicating the output of the current of the windings *f* and o (second pole of a source, the first pole of which is connected to the current input line L_1 or l_4) recalls the operation of said winding; said arrow for the closing winding is directed towards the switch and for the opening winding in the opposite direction. This switch may be constructed as indicated in specification No. 487,260, that is to say, it may be a switch having two separate positions, an open position and a closed position, the movable member of the switch being controlled in one direction and in the other by two separate windings. Each multiple switch comprises in addition to the contact o, eight contacts connecting respectively to one wire out of each of the eight bundles forming the assemblages *aub*, *adb*, four pairs of wires terminating for each denomination at four contact banks c_1, c_2, c_3, c_4, (for the units of B) and c_5, c_6, c_7, c_8 (for the tens of B). Each bank has four contacts 1, 2, 3, 4 in front of which is adapted to move a movable contact connected to the current line L_2 of the "second circuit" and controlled by an electro-magnet winding C on the known step-by-step principle. The eight banks of contacts pertain to the same step-by-step distributor, referred to as "principal distributor" which forms part of the control members to be described hereinafter. The remaining two stationary contacts of each bank are connected directly to the first wire of one of the eight bundles *aub*, *adb* (wire allocated to *b*=0).

The two assemblages of wires *aub*, *adb*, leaving on the left of Figure 4, enter Figure 5 (Units of A), across which the assemblage *adb* passes without interruption and proceeds to Figure 6 (tens of A).

Referring first of all to Figure 5, it will be seen that there are seven multiple switches *au*(*n*), controlled by electromagnets A*u*(*n*) having two windings, one of which, the closing winding *f*, is adapted to receive current from the line L_1 of the "first circuit" through the introduction members EA*u*(*n*) (*n*=0 to 9), the other, the opening winding o, is adapted to receive current from a release current line l_3 through a contact o of the corresponding switch. The switches form two groups in series, one of five switches allocated to groupings of values of *a* 0 and 5, 2 and 7, 4 and 9, 6 and 1, 8 and 3, the other of two switches allocated to the differentiation of the results of each of these groups, according to whether *a* is even-numbered (by switch *au*0) or odd (by switch *au*1). The two groups of switches are connected by bundles t^2u, t^1d, t^2d, composed respectively of grouped result digit wires 04, 48, 82, 26, 60 (for the units) 01, 02, 10, 12, 20, 21 and 03, 30, 36, 60, 06 (for the tens). The contacts of the switches *au*0 and *au*1 connect these wires to one of the wires of three bundles of partial result wires corresponding to the groups 0, 2, 4, 6, 8 (for the units) 0, 1, 2 and 0, 3, 6 (for the tens). The bundle b^1u which corresponds to the "first group" of the units terminates directly at the differentiation switches. Furthermore, it only comprises two wires, one for the even-numbered values of *b* (wire 0) the other for the odd-numbered values of *b* (wire 1) and, as is shown by Table II, Units, group 0, 1, only the result digits of the odd-numbered values of *b* have to be differentiated (single wire t^1u connected by a contact of each of the switches *au*0, *au*1 to the wires of the bundle p^1u of partial results of the group 0, 1 (first group of units). The wires of the two units partial product bundles p^1u (0, 1) and p^2u (0, 2, 4, 6, 8) terminate at the closing windings *f* of electromagnets having two windings 1—S^1u(*n*) (*n*=0 or 1) and 1—S^2u(*n*) (*n*=0, 2, 4, 6 or 8). These windings *f*, which control the units switches (shown in Figure 7 in the addition device) are connecting windings of the "second circuit." The second windings o are the opening windings of the same switches. The bundles p^1d (0, 1, 2) and p^2d (0, 3, 6) issue from Figure 5. (They terminate at the closing windings of the tens switches shown in Figure 7). The wires leaving the switches *au*0–5, *au*2–7, . . . corresponding to the grouped result digits which do not require to be differentiated are connected directly to the corresponding wires of the partial product bundles.

Referring to Figure 6, exactly the same device will be found, allocated to the tens of A (in the references *u* is replaced by *d*): switches *ad*(*n*) (*n*=0–5, 2–7, 4–9, 6–1, 8–3, 0 or 1), controlled by the electro-magnets A*d*(*n*), the closing winding *f* whereof receives current from the line L_1 through the medium of the introduction members EA*d*(*n*) (*n*=0 to 9); the wires of the bundles *adb* are connected in the same way, either directly, or by the contacts of the switches and the bundles t^1u, t^2u, t^1d, t^2d, to the wires of the partial product bundles p^1u, p^2u, p^1d, p^2d; the electromagnets 2—S^1u(*n*) (*n*=0 or 1) 2—S^2u(*n*) (*n*=0, 2, 4, 6 or 8) are allocated to the units; the bundles p^1d and p^2d issue from Figure 6 and terminate at the tens electro-magnets (Figure 8). However, each of the differentiation switches comprises a supplementary contact ψ, the function of which will be indicated in the description of the control device, together with that of the control members shown in the upper left-hand corner of Figure 6.

If the factors B and A had each more than two digits, it would also be necessary to have on the one hand for the factor B an introduction and recording device for each of the other digits of B (hundreds, thousands and so forth) equal to one of those shown in Figure 4 for the units or tens (half of Figure 4), and furthermore for the factor A, an introduction and recording device for each of the other digits of A (hundreds, thousands and so forth) equal to one of those shown in Figures 5 and 6 for the units and the tens, and supplementary assemblages of connection wires *acb*, *amb* . . . each assemblage comprising as many bundles *bu*, *bd*, *bc*, *bm* . . . as the factor B has digits.

The operation of the multiplication device is as follows: The line L_1 being under current (source on the left-hand side of Figure 6), when a punched card having perforations corresponding to the characteristic digits of the factors A and B passes through the analysing device, the analysers enter said perforations (one per characteristic digit), thus establishing the connection between the line L_1 and the wire of the closing winding *f* of the recording electro-magnet corresponding to said digit. Thus, in the example chosen, where A is equal to 69, B is equal to 48, analysing of the punched card establishes the connection of the line L_1 with the following windings:

Figure 6 (tens of A=6): winding *f* of Ad0 and Ad6—1.

Figure 5 (units of A=9): winding *f* of Au1 and Au4—9.

Figure 4 (tens of B=4): winding *f* of Bd4 (units of B=8): winding *f* of Bu8.

From the energised windings *f* the current returns to the other pole of the source, thus completing the "first circuit".

The current of the first circuit source passing through the closing windings of the recording electro-magnets, the lines of contacts of switches corresponding to these electro-magnets are closed and remain closed; they will only be re-opened by the passage of current through the opening winding of each of these electro-magnets, which will be produced for the factor B (Figure 4) by the passage of current in the release line l_4, for the factor A (Figures 5 and 6) by the passage of current through the release line l_3. The contact lines remaining closed, the digits introduced are therefore recorded. Due to this fact, the punched card which was employed for the introduction of these digits is no longer necessary and the next card can now come to the analysing position ready for analysing.

The current of the second circuit arrives at the device for calculating the partial products by the line L_2 (Figure 4) from the source L (middle of right-hand side of Figure 8). The principal step-by-step distributor establishes at each operative stage (that is to say for each of the four denominations of the result) the connection between the line L_2 and the contact of the corresponding number (1 for units, 2 for tens, 3 for hundreds and 4 for thousands) of the eight banks of contacts c_1 to c_8. The passage from the contacts of a certain rank to the contacts of the next rank ("advancement") at the end of each operative stage is ensured by the electro-magnet C, the winding of which is put under current at the desired moment by the control device. In the first operative stage (contacts 1) there is only one partial product digit to calculate (decomposed into two parts), units of the product a_1, b_1, where a_1 and b_1 are the digits of the least denomination of the two factors A and B (see the diagram of the Arabic multiplication, Figure 3), the other three digits of partial products having to be 0. For this reason, the contacts 1 of all the contact banks other than c_1 and c_2 are connected to the wires 0 of the corresponding bundles. The contacts 1 of these banks of contacts c_1 and c_2 are under current and it will be seen that as the switch bu^8 is closed, the wire 0 of the b^1u and the wire 8 of the bundle b^2u are under current in the assemblage *aub* which passes to the switches of the units A. In all the other bundles, the wire 0 is under current. Referring to the multiplication scheme it will be seen that there are three digits to tbe calculated in the second operative stage (contact 2 of the contact banks) and that only the bundles b^1d and b^2d should have the wires 0 under current, this taking place by the fact that the contacts 2 of the banks c_7 and c_8 are connected directly to said zero wires.

It will be seen furthermore in the multiplication diagram, that each horizontal line of partial product digits comprises two zeros, and as there corresponds to each of these lines two bundles (first line b^1u and b^2u of *aub*, second line b^1d and b^2d of *aub*, third line b^1u and b^2u of *adb*, fourth line b^1d and b^2d of *adb*) each bank of contacts comprises two contacts connected to the wires 0 of the corresponding bundles (contacts 3 and 4 of c_1 and c_2, 1 and 4 of c_3 and c_4 and c_5 and c_6, 1 and 2 of c_7 and c_8).

Referring to Figure 5, it will be seen that the wire 0 of b^1u being under current in the first operative stage, the wire 0 of p^1u is under current and the winding *f* of 1—S^1u0 is energised, thus producing the closure of the corresponding addition switch of the "third circuit". In the bundle b^2u, the wire 8 is under current and as the switch *au*4–9 is closed (a_1=9), the wire 2 of p^2u is under current (direct connection without differentiation because *b* is even-numbered and the winding *f* of 1—S^2u2 is energised and the corresponding addition switch of the "third circuit" closed. The partial product digit (0+2)=2 is the units digit of 8×9=72. Likewise, the wires 0 of b^1d and b^2d being under current, the wires 0 of p^1d and p^2d are under current.

It must be pointed out that a_1 being odd-numbered, the differentiation switch *au*1 is closed. The multiplication scheme and the grouping tables show, however, that in the second operative stage, the tens digit of the second line for example, which corresponds to the bundles *bd* of *aud*, is 7. In each of the bundles b^1d and b^2d the wire 8 is under current, which through the medium of the switch *au*4–9, puts under current the succeeding wires of group result digits: 01 of t^1d, 36 of t^2d (as indicated by the tables); the following wires of digits of partial products are then put under current through the medium of the switch *au*1: 1 of p^1d and 6 of p^2d (as indicated by the tables).

It will likewise be seen that for each operative stage, that is to say for each position of the movable contacts of the contact banks of the principal step-by-step distributor there is in each of the bundles of digits of partial products (Figures 5 and 6) a wire and only one wire which is under current, whereby the corresponding "second circuit" connecting winding is energised.

Addition of partial products

The part of the device relating to the addition of digits of partial products, that is to say, to the calculation of the digits of the result of the product AB, comprises on the one hand the groups of switches allocated to the digits (units and tens) of the partial products relative to the units of A (Figure 7) and the groups allocated to the partial products relative to the tens of A, the highest order in the constructional example selected (Figure 8) on the other hand the "transfer device" recording the carry-over from the sum corresponding to one denomination of the result for adding it to the sum corresponding to the next denomination (Figure 7).

Referring first of all to Figure 7, there will be seen in the upper part the two groups of units switches (grouping 0, 1 on the right, grouping 0, 2, 4, 6, 8 on the left) and, in the lower part, the two groups of tens switches (grouping 0 1, 2 on the right, grouping 0, 3, 6 on the left), allocated to the partial products involving the units of A. These switches are denoted by the references *su*(*n*) for the units and *sd*(*n*) for the tens, *n* being the digit of the partial product to which a switch is allocated; a digit in the index position refers, as previously for the references of the multiplication device, to the "group" of which this switch forms part and the number 1 placed in front of the reference refers to the fact that the switch forms part of the partial addition device corresponding to the denomination 1 (last digit on the right) of the factor A. Each switch is under the dependence of an electro-magnet having two windings, whereof one, the closing winding *f*, is the connecting winding of the "second circuit" and receives current when the digit obtained in the multiplication has for its numerical value that to which the said winding is allocated. This numerical value is shown in the figure. The second winding, or opening winding o, is connected by a contact o of the switch to a release current input line l_1. The current outputs of these windings are indicated by arrows directed towards the switch for the winding *f* and in the opposite direction for o. The control windings of the units switches $1—S^1u(n)$ and $1—S^2u(n)$, as has been seen, are shown in Figure 5, but the connecting wires of the contacts o of said switches connecting them to their windings o are denoted by the figures 0, 1 and 0, 2, 4, 6, 8 of the two groups of units. The tens control windings $1—S^1d(n)$ and $1—S^2d(n)$ are shown in the lower part of the figure. Each switch also comprises, in addition to the opening contact o, 21 contacts, 10 for the decadal bundle δ, 11 for the hendecadal bundle η, the hendecadal system of notation being selected as the auxiliary system in the constructional example shown. The two bundles δ, η run parallel to one another in the diagram starting from the position f_1. The assemblage of wires formed by these two bundles passes in parallel through all the switches of each of the groups and these successive groups in series: thus starting from the position f_1 the assemblage of wires extends to the right and left and then upwardly in parallel through the switches $1—s^1u0$ and $1—s^1u1$ of the first group 0, 1 of the units to the position f_2. From this position the assemblage passes downwardly in parallel through the switches $1—s^2u(n)$ (n=0, 2, 4, 6 or 8) of the second group of the units to the position f_3. From f_3 the assemblage passes downwardly in parallel through the switches $1—s^1d(n)$ (n=0, 1 or 2) of the first group of the tens to the position f_4. Finally, from f_4 the assemblage passes upwardly in parallel through the switches $1—s^2d(n)$ (n=0,3 or 6) of the second group of the tens to the position s_1 where it leaves Figure 7 to enter Figure 8.

The bundles δ and η at f_1, at the input of the addition device, have their first wires connected by the bundles r and r_1 to the transfer device. The bundle r terminating at the first wires of the decadal bundle δ starting from the wire **0** and through which the current from the transfer device enters, comprises three wires in the example shown. It has been seen in fact that the addition of the digits of partial products relating to a certain denomination of the result AB comprises two units digits (0 to 9) and two tens digits (0 to 8, since 9×9=81), one at least of these digits being a zero (see the multiplication scheme). The partial total of a denomination ignoring any carry-over from the preceding denomination, cannot therefore exceed 9+8+9+0=26 and even with this carry-over it cannot have more than two tens. The transfer is therefore on of the digits 0, 1, 2. The bundle r_1, which relates to the hendecadal bundle η, ought then to have five wires, because, as will be explained, the difference of rank between the wires under current in r and r_1 is equal to the transfer, at the most equal to 2.

The transfer device comprises two exactly identical halves; each of them comprises three switches (in the example shown where the greatest transfer is 2): $1r(n)$ for the first half, $2r(n)$ for the second half (n=0, 1 or 2). Each switch is controlled by an electro-magnet $1R(n)$ or $2R(n)$ having two windings, a closing winding *f* and an opening winding o. Allocated to each half of the transfer device (in the sense that the energisation of its electro-magnet is controlled thereby) is a supervising relay 1U for the first half, 2U for the second half, which relays comprise three contacts **1**, **2**, **3** controlling the connection of a current supply line L to the secondary lines which will be indicated hereinafter.

Each switch comprises:

A contact o, one terminal of which is connected to the opening winding of the corresponding electro-magnet, the other to an opening line 1o or 2o according to whether said switch pertains to the first or second half of the transfer device.

A contact *u*, one terminal of which is connected to the line L and the other by the line 1L or 2L to the winding of the supervising relay U of the half of the transfer device of which it forms part.

A contact *r*, one terminal of which is connected to the secondary current line $1L_3$ or $2L_3$ connected to the line L respectively by the contacts **2**, at rest, of the relays 2U and 1U, and the other terminal of which is connected to the wire of the corresponding bundle *r*, that is to say **0** for the switches *r***0**, **1** for the switches *r***1** and **2** for the switches *r***2**;

Finally, three contacts 0, 1, 2, one terminal of which is connected to the wire of the bundle r_1, the rank of which is equal to its reference increased by the numerical reference of the switch of which it forms part (thus, for the switches r_1, the contact **1** is connected to the wire **2** of the bundle r_1), the other terminal being connected to the closing winding *f* of the switch of the other half of the transfer device which has for its numerical reference the reference of said contact.

In the lower right-hand corner of the figure is again shown the winding C of the electro-magnet for advancing the principal step-by-step distributor, of which, as has been seen, eight banks of contacts c_1 to c_8 serve to distribute the "second circuit" current in the multiplication device. This winding itself receives current from a bank *c* of four contacts **1**, **2**, **3**, **4** corresponding to the four operative stages of the constructional example described. The odd-numbered contacts of said bank are connected to the current line L*i*, which is itself connected to the line L by the contact **1**, at rest, of the relay 1U, the contact **2** to the line L*ii*, connected to L by the contact **1** at rest of **2**; and the last contact (**4**) of the bank is connected to a line ω which is normally connected to the line L*ii* as will later be explained. A second bank of contacts c_0 has its contacts **1**, **2**, **3**, **4** connected in a reverse manner to the preceding contacts, odd-numbered contacts to L*ii*, even-numbered contacts to L*i*, and its movable contact connected to the line L_2 which feeds the eight contact banks c_1, c_2 . . . , c_8 (Figure 4) of the multiplication device. A bank of contacts λ has its odd-numbered contacts (**1**, **3**) connected to the contact **3** of 2U and its even-numbered contacts (**2**, **4**) to the contact **3** of 1U, when these relays are energised; its movable contact is on the release line l_1 of the addition device and also supplies the current of the line L to two contact banks *o* and l. The contact bank o has its odd-numbered contacts (**1**, **3**) connected to the opening line **1**o of the first half of the transfer device and its even-numbered contacts (**2**, **4**) to the opening line **2**o of the contacts of the second half of the transfer device. Finally, the bank l comprises three dead contacts and a last contact connected to the release line l_3 of the multiplication device. This contact may likewise be connected to a synchronising member of the analysing device.

Referring to Figure 8, exactly the same addition switch device as in Figure 7 will be found, with the switches which, in this case, are allocated to the digits (units and tens) of the partial products of the digits of B and of the tens of A (**2**—$su(n)$ and **2**—$sd(n)$; these switches are controlled by the windings o and f of the electromagnets **2**—$S^1d(n)$ and **2**—$S^2d(n)$ for the tens, and **2**—$S^1u(n)$ and **2**—$S^2u(n)$ for the units (Figure 6), the numerical value to which they correspond being recalled in Figure 8).

The assemblage of wires s_1 formed by the bundles δ and η entering on the right-hand side, after following the path e_1, **2**—$s^1u(n)$, f_5, **2**—$s^2u(n)$, f_6, **2**—$s^1d(n)$, f_7, **2**—$s^2d(n)$, leaves at s_2 to enter the lower right-hand corner of Figure 9 where, on the one hand, the wires of the same rank of the two bundles δ and η are connected together, this being possible because the hendecadal bundle has no eleventh wire in the assemblage s_2, said eleventh wire stopping at the second terminals of the corresponding contacts of the last group of switches (**2**—$s^2d(n)$ in the example shown), and on the other hand these wires each terminate at a relay P(n) (n=0 to 9) of the result AB (lower left-hand corner of Figure 9).

The operation of the addition device is as follows. One of the wires at the bundle r is under current. For example, at the commencement of the operation, the switch **1**r**0** of the transfer device being closed, because the transfer is **0** (we shall see hereinafter how the closing of this switch is ensured) the wire O of the bundle r is connected to the line L: +, L, contact **2** at rest of **2**U, **1L3**, contact r of **1**r**0**, wire **0** of r; consequently, the wire **0** of the decadal bundle δ at f_1 is under current. The operation of multiplication having been effected for the first denomination of the result, the connecting windings of the "second circuit" have closed a switch in each group of the addition device, i. e. as has been seen, for the numerical example selected: **1**—s^1u**0**, **1**—s^2u**0** and **0** switches of all the other groups. The current arriving in the wire **0** of the bundle δ at f_1 passes through all these closed switches in series (with a displacement of two ranks at the switch **1**—s^2u2) and, in the bundle δ at s_2 (Figure 8) the wire **2** is under current. In Figure 9, as already described, the wires of corresponding rank of the bundle δ and η are connected together, therefore, current enters the wire **2** of the hendecadal bundle η at s_2 and returns through the closed switches to the wire **0** of the bundel r_1 (Figure 7). There is no transfer and the current takes the following path in the transfer device: wire **0** of r_1, contact **0** of **1**r**0** (closed), winding f of **2**r**0**, which is closed and remains closed, thus recording the transfer to the next denomination.

More generally, it will be seen that, starting from the wire r representing the transfer from the preceding denomination, the circuit passes successively through a series of switches selected by the multiplication device and each representing a partial product. By the passage through each switch the rank of the wire under current is increased by the numerical value allocated to that switch, only the units digit of the sum being retained in each case. Upon arriving at the position s_2 in Figure 9 the wire under current therefore represents the units digit of the denomination of the product AB being calculated during the particular stage in progress. Part of the current then enters and flow through the hendecadal part of the addition device, passing through the same series of switches but in the reverse order. In each switch a subtraction in the hendecadal system is effected of the digit represented by the switch from the digit represented by the wire entering the switch (subtraction in the hendecadal system merely differs from that in the decadal system in that when a larger digit is to be subtracted from a smaller digit, eleven is added instead of ten to obtain a positive result digit). By the time the circuit arrives at the bundle of wires r_1, it follows therefore, that the rank of the wire r_1 which is under current corresponds to the difference between the hendecadal sum of the partial products and the decadal sum of the same partial products and of the transfer from the preceding denomination. Consequently, the difference between the digits represented by the wires r and r_1 under current gives the transfer to the next denomination. In the case of the numerical example under consideration this transfer is zero in the first stage.

The transfer device comprises two identical halves each comprising separate switches through which current may be supplied to one of the wires of the group r. In the present example the group r comprises three wires, since as already pointed out the transfer can only be 0, 1 or 2, and there are therefore three switches in each half of the transfer device. In each stage, after passing through the switch of the transfer device and the decadal part of the addition device, part of the current returns through the hendecadal part to a wire r_1 as already described and then passes through the same switch of the transfer device, this passage in effect subtracting the transfer digit so that the wire leaving the switch corresponds in rank to the transfer digit to be added in at the beginning of the next stage. The wire leaving the switch is connected to the closing winding of the switch in the other group which is allocated to that transfer digit, so that this switch is closed ready to take part in the next stage.

In more detail, the operation of the transfer device is as follows. In the first operative stage, the movable contacts of the contact banks are in position 1. Due to the fact that the switch **1**r**0** is closed, the relay **1**U is energized: +, L, contact u of **1**r**0**, winding of **1**U, —. The closing of the switch **2**r**0** puts the winding of **2**U under current: +, L, contact u of **2**r**0**, winding of **2**U, —. The relay **2**U being energised attracts its armature with the following results:

Contact 1.—Opening: breaking of the connection L—Lü;

Contact 2.—Opening: breaking of the connection through switch **1**r**0** of L— wire o of r;

Contact 3.—Closing: +, L, contact **3** of **2**U, contact **1** of the bank λ, l_1, contacts o and electromagnets o of all the addition switches, —; this results in the opening of these switches;

. . . **1**$_1$, contact **1** of the bank o, **1**o, contact o of **1**$r(n)$ (in particular of **1**r**0**), winding o of **1**R(n), —; this results in the opening of the closed switch of the first half of the transfer device.

The consequence of the opening of the switch

1r0 is to break at the contact u the energising circuit of **1**U, the armature of which is released with the following effects:

Contact 1.—Closing: +, L, contact **1** of **1**U at rest; L_i, contact **1** of the bank c, winding of the advancement electro-magnet C; this produces advancement by one step (contact **2** of c, line L_{ii} which is not under current).

Then, after the advancement: . . . L_i, contact **2** of the bank c_0, L_2, contact banks of the principal step-by-step distributor at the contact **2**; this initiates the multiplication for the second denomination of the result AB (Figures 4 to 6) and the closing of the addition switches corresponding to the digits of calculated partial products (Figures 7 and 8).

Contact 2.—Closing: +, L, contact **2** of **1**U at rest; contact r of **2r0** (which is closed), wire **0** of r, addition switches . . . Referring to the multiplication scheme, it will be seen that in the numerical example selected, the digits to be added in the second operative stage are 6, 7, 8, 0, the total of which is 21. The output wire **1** of the decadal bundle δ at s_2 being then under current, it is the same with the input wire of the same rank **1** of the hendecadal bundle η at s_2, and as the hendecadal bundle comprises the same closed switches as the decadal bundle, the rank of the wire under current in the bundle r_1 is equal to 2 (2−0=tens digit of the sum 21); it is therefore the contact **2** of **2r0** (closed) which receives the current and the winding f of **1R2** is energised; the switch **1r2** closes, recording the transfer **2** (same number as the reference of the contact through which the transfer current has passed).

Contact 3.—Opening: breaking of the connection L—bank λ.

The following remarks result from the foregoing:

The transfer is recorded alternately in one of the halves of the transfer device and in the other, said recording consisting in the closing of a switch, the numerieal reference of which is the value of the transfer;

The closing of a switch recording the transfer causes the energising of the supervising relay of the half of the transfer device of which this switch forms part;

The addition circuit of the next stage comprises the switch thus closed;

The transfer current of the addition circuit of this next stage closes a switch of the other half of the transfer device, thereby energising the other relay;

The energising of this other relay determines the release of the first half of the transfer device;

Conversely, the opening of the first switch causes the armature of the first relay to drop, thereby producing the advancement and the closing of the addition circuit comprising the switch of the new transfer.

The operation of the transfer device thus comprises two phases per operative stage, that is to say per digit of the result.

During the first phase, one of the supervising relays is energised and the "third circuit" closed by the corresponding half of the transfer device, for the addition.

In the second phase, the transfer current produces the energising of the other supervising relay (both relays are then energised, and the transfer is recorded in the half of the transfer device corresponding to said second relay.

This recording results in the release of the first relay, whence release of the first half of the transfer device and of the addition device, advancement, commencement of the first phase of the next stage, closing of the "second circuit," recording of the digits of partial products, addition.

The cycle has thus recommenced by this new operative stage.

It comprises:

In the first phase (one relay energised): multiplication, addition with the transfer recorded, recording of the new transfer.

In the second phase (second relay energised): release of the addition device, clearing the old transfer, advancement.

The preparation of the transfer device for an operation to be effected and the manner in which the principal step-by-step distributor stops at the end of this operation will be described hereinafter, in connection with the control device.

Totalisation

The part of the device which relates to totalisation (Figure 9) comprises on the one hand the switches allocated to the digits of the known term, to which the result of the calculated product AB has to be added algebraically, and on the other hand, the members for introducing and recording the known term D or the result AB which will then act as known term in a fresh totalisation. Figure 9 likewise shows the output of the "fourth circuit" (inscription of the results). Finally, the control members to be described hereinafter are also shown.

From the point of view of the inscription of the results, the device furnishes the term AB and the sum $D \pm AB$ or

$$(\pm A_1B_1 \pm A_2B_2 \pm \ . \ . \ . \ \pm A_{n-1}B_{n-1}) \pm A_nB_n$$

denomination by denomination in both output bundles AB and Σ (at the bottom and on the left of Figure 9) each of 10 wires, 0 to 9, each of which may control an inscription device of any known type (not shown), such as for example, a rotor subjected to the action of two windings at right-angles to one another and receiving currents proportional to the rank of the wire under current relatively to the extreme wires of the bundle of which it forms part and carrying a contact moving in front of fixed segments as described in French specification No. 799,434 of the 13th March, 1935.

The two bundles AB and Σ may be connected respectively to a eurrent line L_4 and $3L_4$, by lines of contacts p and t which are under the dependence of the "connecting windings" of the "third circuit," windings P(n) and T(n) (n=0 to 9) at which terminate the ten wires of the bundles fp and ft of the "product" AB and of the "total" of the algebraic sum calculated. The wires of the bundle fp are connected directly to the wires of the same rank of the bundles of the assemblage s_2 leaving the addition device. The wires of the bundle ft are connected to these same wires through the medium of the totalisation switches.

Totalisation may consist either of an addition or a subtraction. The addition is effected by the same process as for the digits of partial products, that is to say, the device comprises two groups in series of switches in parallel allocated to digits composing two by two the numerical values 0 to 9 which may intervene in the addition. The first group comprises the even-numbered digits 0, 2, 4, 6, 8, represented by the switches $t^1(n)$ (=0–1, 2–3, 4–5, 6–7, 8–9) and the second group the digits

0, 1, represented by the switches $t^2(n)$ $(n=0, 1)$. For subtraction, instead of subtracting the digit y of a certain denomination of the product AB from the digit x of the same denomination of the known term, its complement relatively to 9 $(9-y)$ is added to it. A correct digit is obtained, however, only on condition that 1 is added to the digit of the lowest denomination. We have in fact $x+(9-y)+1=(x-y)+10$, of which result the characteristic digit of this denomination is the same as that of $x-y$. The 1, added once in the lowest denomination, is introduced automatically in the next denomination by the transfer of the extra 10. Thus, in the numerical example selected where AB=3312, to obtain the difference D—AB there will be added to D:

$$6687+1=(9999-3312)+1=10{,}000-3312$$

To take into account the possible carry-over of 1 to be transferred from one denomination to the next, there has been provided in the second group 0, 1 an additional switch **2** so as to replace the switches **0**, **1** by the switches **1**, **2** and thus to introduce this transfer **1**. To form the complement relatively to 9 of a digit to be subtracted, to which corresponds a wire under current at the output of the addition device, said wire is connected to the wire of complementary rank of the totalisation bundle.

Referring to Figure 9, there will be seen in the lower right-hand part two multi-contact switches marked + and — establishing connections betwen wires of rank complementary to one another of the bundle δ at s_2 and the bundle at f_8. From f_8 the bundle passes in parallel through the group of switches $t^1(n)$ (first group: n=0–1, 2–3, 4–5, 6–7 or 8–9) to f_9, and from f_9 in parallel through the group of switches $t^2(n)$ (second group: n=0, 1 or 2) to the bundle ft. Each switch is dependent upon an electromagnet P, M, $T^1(n)$, $T^2(n)$ having two windings, closing winding f which for $T^1(n)$, $T^2(n)$ is the connecting winding of the second circuit allocated to the digit of the known term which corresponds to its reference, opening winding o which, except for P and M, are connected by a contact of the corresponding switch to the release current arrival line l_1 (common to the addition and totalisation devices).

Above the switches of the second group will be seen two "displacement relays" **0**Y and **1**Y having two windings **1**, **2** and five contacts **1**, **0**, η m, o. The control winding **1** is connected for **0**Y to the wire **1**Lp, for **1**Y to the wire **1**Lm, which the normally open contacts **1**, **2** of a "sorting relay" PM can connect respectively to the wires Lp and Lm, to which are respectively connected the winding f of P, the winding o of M and the winding o of P, the winding f of M. The winding **2** (holding winding) is connected in series by the contact m (open at rest) of its own relay and by the contact o (closed at rest) of the other relay, to an auxiliary source of current. The contacts **0** and **1** (open at rest) of the displacement relays have respectively a terminal connected to the closing windings of T^2**0** and T^2**1** for **0**Y and of T^2**1** and T^2**2** for **1**Y, the other terminal being connected to the wires le**0** and le**1**. Finally, the contacts η connect the winding of a relay $T\eta$ to two wires terminating at supplementary contacts η of the — switch for **0**Y and of the + switch for **1**Y. The switches t^1**8—9** and t^2**2** each have a supplementary contact ρ, these two contacts ρ being in series between an auxiliary source of current and the winding of a relay $T\rho$.

Corresponding to each of the relays T**9** . . . T**0**, $T\rho$ is a contact **9** . . ., **0**,ρ, closed at rest, said contacts forming a chain tr and each having, except the contact ρ, their fixed terminal connected to one of the terminals of a contact of the same rank **9** . . ., **0** of a line pp and to one of the terminals of a contact of complementary rank **0**, . . ., **9** of a line pm, said contacts being opened at rest and controlled by the relays P(n), and being connected by their second terminal to the line **3**L_4 through the medium of a second supplementary contact p or m of the + or — switches. The fixed terminal of the contact ρ and the movable terminal of the contact **9** of the chain of contacts tr are respectively connected to the lines **1**Lp and **1**Lm by two contacts **3**, **4**, closed at rest, of the sorting relay PM. The contact ρ comprises a second fixed terminal connected to the line **1**Lm. The closing windings of the electromagnets $T^1(n)$ are connected to the wires $le(n)$ $(n$=0–1, . . ., 8–9) which, with the wires $le(n)$ $(n$=0, 1) are the "second circuit" wires allocated to the digits of the two groups into which the possible numerical values (0 to 9) of the digits of the known term are decomposed.

Concerning the recording of the known term D or $(\pm A_1B_1\pm \ldots \pm A_{n-1}B_{n-1})$, it should at once be remarked that Figure 9 shows the circuits and members corresponding to all the denominations of this term, namely, for the constructional example selected, the units u, the tens d, the hundreds c, the thousands m. In the upper part will be seen four rows of members for the introduction of the term D, analogous to those of the factors A and B and denoted by the generic references ED$u(n)$, ED$d(n)$, ED$c(n)$, ED$m(n)$, aligned in ten columns, above which are recalled the numerical references 0 to 9 which n represents and the contacts of which may be connected to the "first circuit" current line L_1, for example by punched card analysers. Below this introduction device are four rows of recording relays D$u(n)$, D$d(n)$, D$c(n)$, D$m(n)$, corresponding to the same denominations of D, and two supplementary rows $D\alpha(n)$, $D\beta(n)$, the function of which will be set forth hereinafter $(n$=0–1, . . ., 8–9, 0 or 1). The relays of the same numerical reference of the six rows of relays are arranged in a column above which said reference is marked. Each relay has two windings **1**, **2** controlling two contacts open at rest, a holding contact o and a contact v which is a "second circuit" contact connecting a current arrival wire L^1u or L^2u, L^1d, or L^2d, $L^1\beta$ or $L^2\beta$ to one of the analysing wires $le(n)$ of the same numerical reference as itself $(n$=0–1, . . ., 8–9, 0 or 1). The winding **1** acts both as control winding of the armature of the relay and holding winding and for this purpose, one of its terminals is connected on the one hand to the introduction members of the digits of the same denomination to which the relay is allocated, and on the other hand, through the medium of the contact o to an auxiliary current line l_5 connected to its source by the contact q, closed at rest, of a release relay Q, the other terminal being connected to the output wire lo of the corresponding row. The winding **2** is connected by one terminal to the wire lv of the corresponding row, terminating at the winding of a relay (Dd, Dc, Dm, $D\alpha$, $D\beta$, Du) controlling a contact of the line lo of the next row, and by the other terminal to the wire of the same numerical reference as its relay in one or the other of the bundles et^1 and et^2 corresponding to the two groups. These bundles terminate at two lines **1**t and **2**t of ten contacts (0 to 9), open at rest, each of which is controlled by the relay $T(n)$ of the same rank and connects to the negative pole the wire which has the same reference as itself if it pertains to the contact line 1*t*, and the wire 0 or the wire 1, according as to whether its reference is an even or odd-numbered digit, if it pertains to the contact line 2*t*.

On the right of Figure 9, are shown two contact banks c_9 and c_{10} of the "principal step-by-step distributor" controlled by the electromagnet C (also shown in Figures 4 and 7), each comprising four fixed contacts 1, 2, 3, 4. These contacts, for the bank c_9, are connected respectively to the wires L^1u, L^1d, L^1c, L^1m of the group 1 and for the bank c_{10} to the wires L^2u, L^2d, L^2c, L^2m of the group 2 of the recording relays. Their movable contacts are connected respectively to the second circuit current arrival lines $1L_2$ and $2L_2$. Above these contact banks of the principal step-by-step distributor is shown an auxiliary step-by-step distributor controlled by an electromagnet C_1 the advancement bank *e* of which has six fixed contacts 1, 2, 3, 4, 5, 6, that is to say, two contacts more than there are denominations in the result. The odd-numbered contacts are connected to the line L*i* and the even-numbered contacts to the line L*ii*, with the exception of the last, which is connected to the line L_ω (L*i*, L*ii* and L_ω extend through Figure 8 to Figure 7). The electromagnet C_1 controls the movable contacts of three contact banks e_0, e_1, e_2, of six contacts each. These movable contacts are respectively connected to the "fourth circuit" current arrival line $2L_4$ and "second circuit" current arrival lines $3L_2$, $4L_2$. The contacts *u*, *d*, *c*, *m*, *α*, *β* of the bank e_0 are connected to the different wires *lv* of the recording relays, while the contacts *c*, *m*, *α*, *β*, *u*, *d*, of the banks e_1 and e_2 are connected respectively to the lines L^1c, L^1m . . . L^1d and L^2c, L^2m . . . L^2d of the same numerical index of the six rows of recording relays.

The wire L_σ terminating at the winding of the sorting relay PM (shown three times at different points of the figure in front of the different contacts it controls) and the wires L*p* and L*m* terminating at the winding *f* of the electromagnets P and M enter on the right of Figure 9 leaving Figure 6, where the wires L*p* and L*m* are connected to the contacts of the introduction members E*p* and E*m* for the signs + and −, and are connected to any source of current (they are here connected to L_0). The wire L_σ may be disconnected from the circuit or connected to either of these wires L*p*, L*m* directly or through the analysing device due to the switch I*t* having four contacts 0, ±, +, −.

The operation of the totalisation device will now be explained. For studying this operation, we shall consider first of all the recording of the digits of the term D, then the intervention of the term D thus recorded in the calculation of the total D±AB (AB being a product which is being calculated), that is to say, on the one hand the exploration of the successive rows of recording relays, the effect of which is the closing of certain totalisation switches, and on the other hand the passage of the current, arriving through the bundle *δ* at s_2 through said switches for terminating at the winding of a certain relay $T(n)$ controlling the inscription of the total result. It will be seen on this occasion how, if necessary, the device effects the transfer to the next denomination of the digit carried over from a certain denomination in the case of addition, and in the case of subtraction. It will then be seen how in the case of the operation Σ AB, the calculated total

$$(\pm A_1B_1 \pm \ . \ . \ . \ \pm A_{n-1}B_{n-1})$$

is recorded, then how this recording is explored for totalising with said known term a new product A_nB_n that is calculated.

Recording of the data.—When a punched card having perforations corresponding to the characteristic digits of the term D passes through the analysing device, the analysers establish for each denomination the connection of the line L_1 with the windings 1 of the relays allocated to the numerical value of the digit of that denomination. These windings are energised and are maintained energised due to the closing of the holding contacts o. The corresponding contacts *v* are therefore closed. Thus, for the numerical example selected D=6158, there are, for the units, the following circuits in the first group:

+, L_1 ED*u*8, winding 1 of D*u*8—9, *lo* of the row *u*, contact of D*u* at rest, L*o*, . . . , −; the armature of D*u*8—9 is attracted:

Contact o: closure: contact *q*, l_5, contact o of D*u*8—9, winding 1 of D*u*8—9, *lo* . . . ; the contact *v* is held closed. The contact of the relay D*u* remaining in the position of rest, the holding circuit will only open by the breaking of the holding circuit, namely, by the opening of the contact *q* when the relay Q is energised for the release of all the recording D.

Likewise, in the second group, the contact *v* of the relay D*u*0 is closed.

This recording is effected in the same way for all the rows of the relays, that is to say, for all the denominations of the term D.

Exploration of the recording.—Starting with the principal step-by-step distributor in the position 1 (contact 1 of the banks c_9 and c_{10}) the exploration circuits (second circuit) are the following:

+, . . ., $1L_2$, contact 1 of c_9, contact *v* of D*u*8—9, *le*8—9, winding *f* of $T^1$8—9; closing of the switch $t^1$8—9;

+, . . ., $2O_2$, contact 1 of c_{10}, contact *v* of D*u*0, *le*0, contact 0 of 0Y or 1Y (it will be seen later that one of these relays is energised), winding *f* of $T^2$0 or $T^2$1: closing of the corresponding switch.

The totalisation switches being thus closed, they will remain so until the release wire l_1 is under current (after the recording of the transfer resulting from the addition of the digits of partial products by the transfer device).

Intervention of the sign of totalisation.—The signs + and − may likewise be introduced by means of punched cards, and according to the sign, the wire L*m* or L*p* is put under current at the moment of analysing. It will be supposed first of all that in each case the wire L_σ is likewise under current (± contact of the switch I*t*, Figure 6). That one of the electromagnets M and P whose winding *f* is under current closes its switch and the current arriving through one of the wires of the bundle *δ* at s_2 follows the path: . . . s_2 switch − or +, f_8, a switch $t^1(n)$, f_9, a switch $t^2(n)$, *ft*, $T(n)$; the armature of the result relay $T(n)$ is attracted and the corresponding contact of the line of contacts *t* in particular is closed, connecting the line $3L_4$ to one of the wires of the bundle Σ. Furthermore, simultaneously, the relay $P(n)$ corresponding to the wire under current at s_2 is energised and the contact of the same rank of the line of contacts p connects the line L_4 to the corresponding wire of the bundle AB. The digits of a certain denomination of the product AB and of the total are transmitted simultaneously to the inscription devices for the results.

Case of addition.—When at the moment of analysing, the wire Lp is under current, the + switch closes and remains closed, and its contact p connects the contact line pp to the current line $3L_4$. The wire $L\sigma$ also receiving current, the relay PM is energised, whereby its contacts 1, 2 are closed, thus connecting Lp to $1Lp$ and Lm to $1Lm$, and its contacts 3, 4 are opened. The wire $1Lp$ being under current, the winding 1 of the 0Y is also. This relay attracts its armature with the following effects;

The contact o in opening breaks the holding circuit of 1Y: +, contact o of 0Y, contact m of 1Y, winding 2 of 1Y, —; neither of the two windings of 1Y being any longer energised, the armature of this relay drops and its contact o closes;

The contact m of 0Y in closing establishes the holding circuit through the contact o of 1Y and winding 2 of 0Y; the armature of this relay will therefore remain attracted as long as the relay 1Y is not energised.

The contact η (the function of which will be seen hereinafter) and the contacts 0, 1 are closed, these two latter connecting the exploration wires $le0$ and $le1$ to the windings f of T^20 and T^21. When analysing is terminated, the current is broken in the wires $L\sigma$ and Lp. The armature of the relay PM drops and its contacts 1 and 2 open, breaking the connections of Lp and Lm to $1Lp$ and $1Lm$, and its contacts 3 and 4 close, connecting these two latter wires to the ends of the chain of contacts tr. The + switch remains closed, the displacement relay 0Y remains energised (non-displaced or direct connection of the second circuit in the second group of the known term).

In the numerical example D+AB, 6158+3312, it has been seen that for the units, the exploration wire $le0$ was under current. The switch t^20 is therefore closed and the current arriving in the wire 2 of the bundle δ at s_2 passes through the switches +, t^18—9, t^20, and the winding of the relay T0 (8+2=10). A carry-over of 1 has therefore to be transferred to the next denomination. For this purpose, it is merely necessary that during the calculation of the digit of this next denomination, the relay 1Y should be energised in place of the relay 0Y, because that adds one unit to the digit of the "second group" of D.

This "displacement" is effected automatically. It is based on the following considerations. Let x be the digit of the actual denomination of D, y the digit of the same denomination of the product AB (bundle fp), z the units digit of their sum (bundle ft). There are two cases to be considered.

First case.—The sum of $x+y$ is less than 10. In this case z is equal to one of or greater than either of the terms of this sum, and in particular equal to or greater than the term y. The closing of the contact of the line pp corresponding to y puts under current the wire arriving at the contact of the same rank of the chain of contacts tr: $3L_4$, contact p of the + switch, ppy, fixed terminal of try. The current cannot pass through the chain of contacts of higher rank because the contact z forms part of this chain and is open. It passes through the chain of contacts of lower rank and arrives at the line $1Lp$ through the contact 3, closed at rest, of the relay PM, and to the closing winding 1 of the relay 0Y, which, as has been seen, is already energised. No change is produced.

Second case.—The sum $x+y$ is equal to or greater than 10. In this case, z which is equal to $x+y-10$ is smaller than either of the terms of this sum, particularly the term y. Thus a contact of lower rank than that which receives the current from the line of contacts pp is open in the chain of contacts tr and the current of the line $3L_4$ passes through the chain of contacts of higher rank, thus putting the line $1Lm$ under current. The closing winding 1 of the relay 1Y is energised, which breaks the holding circuit of 0Y, the armature of which drops and closes the holding circuit of 1Y, the armature of which remains attracted, establishing by its contacts 0 and 1 the displaced connection $le0$, $le1$ to T^21, T^22 for the calculation of the digit of the next denomination.

It should be remarked that when there is a transfer (1) which is added to the total of the digits x and y of a certain denomination, what is compared with y is in reality $z+1$. As $z=x+y-10$, $z+1=x+y-9$, however, and it may happen that $z+1$ is equal to y. This will be the case when $x=9$. Despite this, the relay 1Y should be energised. In this case, however, during the exploration of the digit of this denomination of the term D, on the one hand, the exploration wire $le8$—9 has been under current and the switch t^18—9 is closed, and on the other hand the exploration wire $le1$ has been under current and in consequence of the "displacement" which introduces the transfer, the switch t^22 is closed: the winding of the relay $T\rho$ has been connected by the contacts ρ of the two switches to the auxiliary source of current. The armature of this relay has been attracted and the contact ρ has connected the corresponding end of the chain of contacts tr to the wire $1Lm$. It is therefore still this wire which receives the current, as is necessary for ensuring the transfer to the next denomination.

Case of subtraction.—It has been seen that in the case of a subtraction which is effected by adding to the successive digits of D the complements relatively to 9 of those of AB, it is necessary in the lowest denomination, therefore at the commencement of the operation, to add 1 to the total of this addition. This is effected automatically. At the moment of analysing, the wires $L\sigma$ and Lm are under current. The — switch is closed and the relay PM is energised, thus putting the wire $1Lm$ under current by its contact 2. The relay 1Y is energised and establishes the displaced connection necessary for adding a unit to the total. It will remain energised in the next stage of operation for which, the relay PM being inoperative, its winding 1 is connected to the contact 9 of the chain tr, only if the sum $x+(9-y)$ equals or exceeds 10, in this case, the comparison employs the contact line pm in circuit: $3L_4$, contact m of the — switch, pmy, fixed contact of $tr(9-y)$.

Capacity of the calculating device.—The relay $T\eta$ serves for controlling a signalling device which operates when the capacity of the calculating device is exceeded. It has been shown that at the commencement of the operation, the relay 0Y is energised in the case of an addition and the relay 1Y in the case of a subtraction. As the operation continues, the relay 1Y is energised whenever the sum of two digits of a denomination equals or exceeds **10**, that is to say, whenever there is a transfer to the next denomination, whether the digit of the product intervenes by itself (case of addition) or by its complement (case of subtraction). If the capacity of the machine is not to be exceeded, it is necessary that in the last operative stage, there should be no transfer in the case of an addition and on the contrary that there should be a transfer in the case of subtraction. This is evident in the case of addition. In the case of subtraction, if the product to be deducted exceeds the known term, which would give a negative total, the complement of this product is less than the complement of the known term. It follows that the sum of the known term and of the complement of the product is less than 10,000 and that there is no transfer from the addition of the thousands digits. In the contrary, there is a transfer if the product is less than the known term, the case for which the capacity of the machine is not exceeded. It follows that if the capacity of the machine is exceeded, the relay **1**Y in the case of addition and the relay **0**Y in the case of subtraction is energised at the end of the last operative stage. In the first case (case of addition) the current arriving at the end of this stage into the line lq from the line l**3** (end of operation release, last position of the principal step-by-step distributor bank l on right-hand side of Figure 7) energises the relay $T\eta$: . . . l_3, lq, $l\eta$, contact η of the + switch, contact η of **1**Y, winding of the relay $T\eta$ —. The armature of $T\eta$ is attracted and its contact connects the line **3**L_4 to the wire U which terminates at the signalling member (not shown). In the case of subtraction, the relay **0**Y being energised if the capacity of the machine is exceeded, the relay $T\eta$ receives current by the contacts of the — switch and of the relay **0**Y, which likewise puts under current the wire U of the signalling member.

Recording of the characteristic digits of a previously calculated product AB and exploration of this recording.—This recording is effected when ΣAB is calculated. For such an operation, the auxiliary step-by-step distributor is employed in place of the banks c_9 and c_{10} of the principal step-by-step distributor. It has been shown that each time a wire is under current in the bundle ft, the relay $T(n)$, corresponding to the result digit to which the wire is allocated, is energised. It then closes the corresponding contacts of the lines of contacts **1**t and **2**t. These contacts connect to the negative terminal two wires of the bundles et^1 and et^2, namely, those whose references correspond to the two digits of the groups (0–1, 2–3, 6–7, 8–9 and 0, 1) into which the digit of the result is decomposed. In the row of recording relays corresponding to the denomination of this digit, two relays are energised. Thus, if we assume that the first product A_1B_1 of the series to be totalised is the product 3312 of the numerical example previously taken, the first operation consists in adding this product to 0000. For this purpose the totalisation switches +, t^1**0** and t^2**0** are closed by means of preparation members forming part of the control device described later. When in the first stage (units denomination) the relay T**2** is energised, the closing of the contacts **2** in the contact lines **1**t and **2**t establishes the following circuits:

—, contact **2** of **1**t, wire **2**, **3** of et^1 . . . ;
—, contact **2** of **2**t, wire **0** of et^2 . . . ;

The choice of the row of recording relays corresponding to the denomination in question is effected by the bank of contacts e_0 of the auxiliary step-by-step distributor. Thus, the movable contact of this bank on u, the recording circu ts are completed as follows:

. . . wire **2**, **3** of et^1, winding **2** of Du**2**—**3**, wire lv of the row u, contact u of e_0, **2**L_4, . . . , +;
. . . wire **0** of et^2, winding **2** of Du**0**, wire lv of row u, . . . , +.

The relays Du**2**—**3** and Du**0** are closed, recording the digit 2 in the row u.

For the exploration, the auxiliary step-by-step distributor intervenes by its bank of contacts e_1, e_2, establishing a connection between the current input lines **3**L_2, **4**L_2 and one of the wires L^1u, L^2u, . . . $L^1\beta$, $L^2\beta$ of the six rows of relays of the two groups $Du(n)$ . . . $D\beta(n)$. Thus, for the exploration of the row u (fifth contact u of the banks e_1 and e_2) the following circuit will be established for the second group (if the recorded digit is 2):

+, . . . , **4**L_2, contact u of e_2, L^2u, contact v of Du**0**, wire le**0**, . . .

It is therefore possible to record denomination by denomination the digits of the products AB as they are calculated, and to explore denomination by denomination the rows of relays of a recording. The processes of these recordings and explorings are combined in such a manner that each row of relays is alternately explored and records a fresh digit. The digits of all the denominations of the known term have to remain recorded at the same time until they intervene in the calculation of the digits of the successive denominations of the next totalisation, and therefore the recording of a fresh digit can only be effected in the supplementary rows of relays. According to the form of construction shown, two thereof have been provided α and β and the rows u . . . β intervene by rotation. In this case, therefore, the references $udcm$ no longer serve to distinguish the lines pertaining to particular denominations.

Recording and exploring process.—For examining this process, it will be supposed for example that the movable contacts of the auxiliary step-by-step distributor are at the second position from the top. The following circuits are established:

Contact bank e_0: contact d: +, . . . , **2**L_4, contact d of e_0, wire lv of the row d, . . . : this wire being under current the row d records the digit corresponding to the closed contacts of the lines of contacts **1**t and **2**t; furthermore, the winding of the relay Dc is under current; this relay being energised attracts its armature and is contact in opening breaks the holding circuit of the recording relays of the row c, the armatures of which drop. These relays are therefore now released and are thus able to record the digit of the next denomination of the total.

Banks of contacts e_1 and e_2: contacts m: + . . . , **3**L_2, contact m of e_1, L^1m, . . . ; and: +, . . . , **4**L_2, contact m of e_2, L^2m, . . . ; whereby exploration of the row m is ensured.

Thus, while the row d records a digit, the row e is released and the row m is explored. At the commencement of the calculation ΣAB, when $\pm A_1B_1$ is recorded, the rows c to β, which are explored as the digits $\pm A_1B_1$ starting from the lowest order are recorded in the rows u to m are set to record zero (relay **0**—**1** of group 1 and **0** of group 2 energised in each row) by the preparation members of the control device described later, so that at each operative stage, the totalisation switches are closed and allow the current to pass. When all the digits of $\pm A_1B_1$ have been recorded, and as the calculation of the digits of A_2B_2 is proceeding, the total $\pm A_1B_1 \pm A_2B_2$ is recorded, the units of this total being recorded in the row α, the tens in the row β, the hundreds in the row u (which had been explored during the recording of the units of the total and released during the recording of the tens . . . etc.

Finally, the recording of the digits of the successive denominations is effected at each operative stage in a row situated after the explored row and separated from it by the released row, this being done according to a closed cycle. The linking together of these successive denominations follows from the fact that the contacts of the banks of contacts of the auxiliary step-by-step distributor are arranged in an endless chain according to any device well known in the art.

Control

The control members of the device are shown in the various Figures 4 to 9 in proximity to those dependent upon them in order to avoid excessive complication. While collected under the same name, they have nevertheless various functions. Some are subjected to an external intervention. These are the preparation and starting members for preparing the calculating device for an operation to be effected and for starting its automatic operation. The others are automatic devices. These are the safety members for producing stoppage in the case of an incident in the operation.

Preparation and starting of the whole of the calculating device.—Referring to Figure 6, there will be seen in the upper left-hand part:

A general reversing switch IG having four contacts **1**, **2**, **3**, **4** and capable of assuming two positions, one Δ on the right corresponding to the case in which the "known term" is D (operation D±AB), the other Σ on the left, corresponding to the case in which the "known term" is the total of a preceding operation, recorded by the recording relays (operation ΣAB):

In the Δ position, this reversing switch establishes the following connections:

Contact 1.—Dead segment.

Contacts 2 and 3.—Connection of the second circuit current line L_2 to the lines **1**L_2, **2**L_2 feeding the banks c_9, c_{10} of the principal step-by-step distributor.

Contact 4.—Connection to negative of the output wire of the winding of the release relay Q: this relay is then in shunt circuit on the released wire l_3 of the switches of factor A and is energised when the opening current of these switches passes through said wire (contact **4** of the contact bank **1**, Figure 7); its contact q (Figure 9) in opening then breaks the holding current line l_5 of the recording relays, the armatures whereof drop, thus clearing the recording of the term D in all the rows of relays.

In the Σ position, the reversing switch IG establishes the following connections:

Contact 1.—Connection of a "first circuit" source with the line **2**L_4 feeding the bank e_0 of the auxiliary step-by-step distributor, and with a line **1**L_4 feeding a preparation member shown in Figure 9.

Contacts 2 and 3.—Connection of the second circuit current line L_2 to the lines **3**L_2, **4**L_2 feeding the banks e_1, e_2 of the auxiliary step-by-step distributor.

Contact 4.—Connection to the negative of the output wire lc of the winding of the advancement electro-magnet C_1 of said auxiliary step-by-step distributor.

A switch I*b* which, in one position, connects the release wires l_4, l_3 in such a manner that the opening current for the switches of the factor A produces the opening of those of the factor B and, in the other, connects the release wire l_4 of B to a wire l_6 which is only under current during the "preparation."

A switch I*d* which in one position connects negative to the output wire l_q of the winding of the release relay Q (D variable at each operation) and the contact of which, in the other position is on a dead segment (D constant for a number of operations).

The sign switch I*t* which, as has been shown, in the position **0**, disconnects the wire $L\sigma$ and which allows said wire to be connected by the analysing device to either of the wires lp and lm in the ± position and connects the wire $L\sigma$ to the wire Lp or Lm in the + or − positions. It is thus possible, in a sequence of products AB to totalise all the terms, whether they have a + sign or a − sign, or to totalise only the terms having one or the other of these signs. It has been seen, in fact, that the said wire $L\sigma$ terminates at the winding of the sorting relay PM and that this relay should be energised for the selection of the displacement relay **0**Y or **1**Y appropriate to the operation to be effected. This sorting relay PM comprises in addition a contact g which, as will be seen, controls the putting into circuit of the auxiliary step-by-step distributor each time the wire $L\sigma$ is under current, that is to say, each time the term A_pB_p calculated has a sign such that this term should be totalised. If this is not the case, the auxiliary step-by-step distributor remains out of circuit and the totalisation switches which have been opened by the current of the release wire l_1 remain open, breaking the connection of the third circuit terminating at the totalisation relay $T(n)$.

A bipolar switch provided with a preparation button I*o* connecting the windings of a relay K and a relay J to an auxiliary source.

The relay K or preparation relay is likewise shown in Figures 8 and 9 with preparation contacts for the transfer device and totalisation device. In Figure 6 there has been shown only one of these contacts k, holding contact closing, when the relay K is energised, a holding circuit comprising the contact j, closed at rest, of the relay J which is a delayed release relay. The winding of the relay K may likewise be connected to another auxiliary current source by the contacts ψ of the switches *ad***0** and *ad***1**.

The operation of the preparation relay K is as follows. When the preparation button I*o* is depressed, the relays K and J are energised. The relay K attracts its armature (its contacts are then in the preparation position), the holding contact k is closed, but the contact j opens and the holding circuit K remains interrupted. Conversely, when the preparation button I*o* is released, the contact k opens but the contact j only closes with delay so that the holding circuit of the relay K is open at k before being closed at j. When, in the course of the operation of the calculating device, the two switches *ad***0** and *ad***1** are closed at the same time (which in the case of control by punched cards may occur if there is no longer any card passing below the analysers, for example when the card magazine is empty), the winding of the relay K is put under current through the medium of the contacts ψ. Its armature is attracted to the preparation position and held by the holding circuit, closed by the contact j at rest, until the button Io is depressed. Obviously, the contacts ψ could be provided on other switches which are not to be closed at the same time and an equivalent safety device would be obtained.

Preparation and starting of the transfer device. Referring to Figure 8, there will be seen the relay K, its contact k and its contacts **1**, **2**, **3**, **4** relative to the preparation of the transfer device and connected respectively to the wires L*ii*, L*i*, L*u*, **0**L*o*. At rest, these contacts establish the following connections:

Contact **1** connects L*ii* to L_ω.

Contacts **2** and **3** are on dead segments.

Contact **4** connects to negative the wire **0**L*o* (output of the winding o of the electro-magnet **1**RO of the transfer device). When the armature of the relay K is attracted (preparation):

Contact **1** connects L*ii* to **1**L*o* (wire connected to the release wire **1**o of the first half of the transfer device).

Contacts **2** and **3** put under current the lines L*i* and L*u* (L*u* is connected to the winding *f* of the electro-magnet **1**RO of the transfer device).

Contact **4** breaks the connection of wire **0**L*o* to negative.

Referring to Figure 7, it will be seen that, the line L*i* being under current, the odd-numbered contacts of the advancement bank c receive current. If therefore the movable contact of this bank is on an odd-numbered contact, advancement to the next even-numbered contact takes place. On the other hand, the line L*u* being under current, the closing winding of the electro-magnet of the switch **1***r***0** is energised and this switch closes, because the circuit of the corresponding opening winding is broken at the contact **4** of the relay K. This switch, in closing connects by its contact *u* the line L to the winding of the relay **1**U. The armature of this relay is attracted and by its contact **3**, which closes, the release current arrives at the even-numbered contacts of the bank λ, thereby determining through the medium of the bank o the passage of the release current through all the opening windings of the second half of the transfer device. If the relay **2**U was under current, because one of the switches of this second half of the transfer device was closed, this current is then interrupted and the armature of the relay **2**U drops. Closing of the contact **1** of this relay follows and the current arrives at the line L*ii*, that is to say, at the even-numbered contact **2** of the advancement bank c. It follows that the principal step-by-step distributor moves with a continuous movement. However, it stops at the last contact (**4**) of the advancement bank, because the connection of the line L*ii* to the line L_ω is interrupted at the contact **1** of the relay K. It should be remarked that as the first half of the transfer device also receives the release current, due to the connection by the contact **1** of the relay K of the line L*ii* to the line **1**L*o*, all the switches **1***r*(*n*) except **1***r***0** open, even if the contact bank being in its last position at the commencement of the preparation, the wire **1***o* cannot receive the current of the contact bank *c*. Thus, at all events, at the last position the step-by-step distributor is stopped and the switch **1***r***0** alone is closed. Furthermore, the release wire l_1 is under current, likewise the release wire l_3 (last contact of the bank *l*), which effects at the same time as the opening of the addition switches, the opening of the switches of the factor A, the opening of the switches B being effected due to the connection of the wire l_4 to the wire l_3 if the release switch I*b* (Figure 6) connects l_3 to l_4. (If the switch I*b* connects l_4 to l_6, the release of B is effected, as will be seen hereinafter, as soon as the preparation button Io is depressed which puts the wire l_6 under current.) When a synchronising member is provided for synchronising the analysing device, this member receives current when the principal step-by-step distributor has arrived in its last position. From that moment, the analysing device is ready to effect analysing and may be held stopped in this position.

When the preparation button Io is released and the armature of the relay K drops, its contacts **2** and **3**, in opening, interrupt the current in the lines L*i* and L*u*, the effect of which is to interrupt the current at the odd-numbered contacts of the advancement bank c and in the closing winding of the electro-magnet **1**R**0**. The circuit of the opening winding of this electro-magnet is no longer interrupted by the contact **4** of the relay K, but the opening current cannot pass because the movable contact of the bank c is on an odd-numbered contact. The line L*ii* is still under current through the medium of the contact **1** of the relay **2**U at rest, and as the contact **1** of the relay K now establishes the connection between the line L*ii* and the line L_ω, the last contact (**4**) of the advancement bank c receives current and the principal step-by-step distributor advances by one step and comes to the position **1** (because the contacts of the banks form an endless chain). The opening circuit of the switch **1***r***0**, however, remains open at the contact **1** of the relay **2**U and this switch remains closed. The contact **1** of the bank c_0 connects the line L*ii* to the first circuit current line L_2 and the operation commences as soon as the introduction of the factors is produced (by analysing a punched card). It has been seen in fact (operation of the transfer device) that at this moment the multiplication device calculates the digits of the partial products of the first denomination, that the corresponding addition switches are closed and that current is sent into the wire **0** of the bundle *r*, connected to the line $\mathbf{1}L_0$ by the contact *r* of **1***r***0**, the line $\mathbf{1}L_3$ being connected to the line L by the contact **2**, at rest, of the supervising relay **2**U. It has likewise been seen that after the starting calculation proceeds automatically.

Preparation and starting of the totalisation device. Referring to Figure 9, there will be seen the relay K, its contact *k*, and its contacts **5**, **6**, **7** and **8**, **9**, **10** relating to the preparation of the totalisation device, and connected respectively to the wires Lo, L*v*, $\mathbf{1}L_4$ (**7** and **8**), a source of current, and the wire $\mathbf{3}L_4$. At rest, these contacts establish the following connections:

Contacts **5** and **6** connect the common wires L*o* and L*v* to negative.

Contacts **7** and **8** are on dead segments.

Contact **9** connects the source of current to the "fourth circuit" current line L_4.

Contact **10** closes the line $\mathbf{3}L_4$.

When the armature of the relay K is attracted (preparation):

Contacts **5** and **6** break the connection of the wires L*o* and L*v* to negative.

Contacts 7 and 8 connect the line 1L_4 respectively to line Li and to line 0L_4.

Contact 9 connects the source of current to the wire l_6 for the final release of the factor B (release switch Ib (Figure 9) connecting l_4 to l_6 and not to l_3).

Contact 10 breaks the line 3L_4.

It will be seen hereinafter what occurs when the button Io is depressed (preparation) and then released (starting).

Below the relay K is shown a preparation switch γ which serves for recording 0 in the four rows of recording relays c . . . β for starting the calculation ΣAB, and which is under the dependence of an electro-magnet Γ having two windings, a closing winding f connected to the line 0L_4 and an opening winding o connected to one of the terminals of the first contact 1 of the switch γ, the other terminal whereof is connected to the line L_4. When the switch γ is closed, the contacts 2 and 3 connect the wires 0 of the bundles et^1 and et^2 to negative. The contacts β, α, m, c then connect to 0L_4 the wires lv of four rows of recording relays β, α, m, c. The last contact o connects the common wire Lo to negative.

On the right of Figure 9, the summation relay H will be seen between the electro-magnets C and C_1 of the two step-by-step distributors. This relay comprises two windings 1, 2 and four contacts h, 1, 2, 3. The winding 1 is connected on the one hand to lq, that is to say to l_3, and on the other hand directly to negative. The winding 2 on the contrary is connected to the negative through the medium of the contact g of the sorting relay PM, and connected to a source of current by the contact h of its own armature when the relay H is energised. This contact connects to the source the line 3L_4 when it is at rest. Likewise at rest, the contacts 1, 2 and 3 close the lines 4L_2, Li, 3L_2. They are each on a dead segment when the relay H is energised.

In regard to the operation, there are two cases to consider.

Case of the operation D±AB. The general reversing switch IG is in the Δ position. The line 1L_4 is therefore not under current, but the line 3L_4 is connected to the "fourth circuit" source by the contact h at rest of the relay H and the movable contacts of the banks c_9 and c_{10} of the principal step-by-step distributor are connected to the "second circuit" current line L_2.

When the preparation button is depressed and the relay K is consequently energised, the movable contacts of the banks c_9 and c_{10} advance to the last position (4), being actuated by the electro-magnet C of the principal step-by-step distributor, which as has been seen, is under current until this position is attained (the circuit of the winding of the electro-magnet C_1 is broken at the contact 4 of the general reversing switch IG). The holding circuits of the recording relays are broken at the contact 5 of the relay K. Furthermore, when the principal step-by-step distributor has arrived at its last position, these holding circuits are also broken at the contact q of the relay Q which is then energised, and the armatures of all these relays being at rest, the "second circuit" is broken by their contacts v. Likewise the "fourth circuit" is broken at the contacts 9 and 10 of the relay K. On the contrary, the wire l_6 is under current, resulting in the opening of the switches of the factor B if the release wire l_4 is connected to the wire l_6 by the switch Ib. It will thus be seen, considering the release produced by the transfer device, that the entire calculating device is in the release position and that the four principal circuits are open.

The principal step-by-step distributor will only advance to the position 1 at the moment of starting, when the armature of the relay K drops, puting the line L_ω under current. At the same time, the wire Lo of the holding circuits of the recording relays will be connected to negative, as also will be the "first circuit" output wire Lv of the three rows of relays m, α, β. The fourth circuit is again closed. The device will be ready to operate and as soon as analysing commences, calculation will also commence.

Case of the operation Σ AB. It has been seen that in this case, the general reversing switch IG (Σ position) connects the lines 1L_4 and 2L_4 and hence the movable contact of the bank c_0 of the auxiliary step-by-step distributor to a source of current, and those of the banks c_1 and c_2 to the second circuit current line Lal the output lc of the winding of the electro-magnet C_1 of this step-by-step distributor being connected to negative. (The electro-magnet of the principal step-by-step distributor is obviously not out of circuit, but as its banks c_9 and c_{10} are not connected to the line L_2, they do not receive current.) It should be remarked that as the connection of the winding of the relay Q to negative is broken, this relay cannot be energised.

When the preparation button is depressed and the relay K is consequently energised, the odd-numbered contacts of the advancement bank e of the auxiliary step-by-step distributor receive current even if the relay H has remained energised, because the line Li is connected to the line 1L_4. The even-numbered contacts, except the last, are also under current, because they are connected to the line Lii which, as has been seen, is under current during the preparation. The auxiliary step-by-step distributor therefore advances to its last position (contact 6) and stops there because the line L_ω is not under current.

The attraction of the armature of the relay K, by closing the contacts 7 and 8, puts the secondary line 0L_4 under current; the closing winding f of the electro-magnet Γ is energised and the switch γ closes, connecting to negative by its contacts c, m, α, β the wires lv of the last four rows of relays (the connection to negative by the common wire Lv of the wires lv of the last three rows is cut at the contact 6 of the relay K) and by its contact o the common wire Lo, the connection of which to negative has been interrupted by the contact 5 of the relay K. However, as the breaking at the contact 5 is produced with the closing of the switch γ, the recording relays have been released before the output wires of their windings 1 are re-connected to negative. The and 0L_4 being under the current, the wires lv of the last four rows are under current, and the following circuits are established, for example, for the relays of the group 1 of the row α; + . . . , 1L_4, contact 8 of the relay K, 0L_4, contact α of γ wire lv of the row α, winding 2 of DαO—1, wire O.l of et^1 contact 2 of γ, —.

The four rows c, m α, β record 0.

When the armature of the relay K drops (starting), the fourth circuit is closed at the contact 9. The line L_4 being under current, the opening winding q of the electro-magnet Γ receives current through the medium of contact 1 of its switch γ. The latter opens, breaking the connection to negative by the switch γ of the wire Lo and the connection of the last four rows to the wire 0L_4. The connection of the wire L_0 to negative is re-established at the contact 5 of the relay K, the windings D_a, D_α and DS to negative at the contact 6 of the relay K. The wires L_v of the remaining rows are already connected to negative through the windings D_u, D_d and D_c. At the same time, the fourth circuit is likewise reestablished at the contact 10^1 of this relay. Furthermore, the line L_ω as has been seen being under current, the auxiliary step-by-step distributor advances by one step to the position 1, and as soon as analysing commences, calculation commences. It should be remarked that if the sign switch It is at the position 0, or if no sign is introduced during analysing, the wire L_σ and hence the sorting relay PM does not receive current and the summation relay H, which is energized by the release current, arriving at the wire l_q through the release wire l_3, remains energised (holding circuit closed: +, h, winding 2 of H, g, —), the auxiliary step-by-step distributor does not then receive current and remains in position 1, since the line L_i is broken at the contact 2 of the relay H and is no longer connected to the line 1L_4 under current by the contact 7 of the relay K.

Safety members.—It has been seen that when the two multiplication switches *ad*0 and *ad*1 are closed at the same time, the relay K is energised and remains so until the preparation button Ic is depressed.

The summation relay H also functions as a safety member. In fact, when during the calculation ΣAB, the first term $\pm A_1B_1$ has been calculated (and recorded if necessary), the principal step-by-step distributor arriving at its last contact produces, as has been seen, the release of the factor A (or of the factors A and B) putting the release wire l_3 under current (contact 4 of the bank *l*, Figure 7); the relay H is energised disconnecting the auxiliary step-by-step distributor. If the next term A_2B_2 has a sign for which the sorting relay PM is energised, the armature of the summation relay H drops and the auxiliary step-by-step distributor is brought into circuit again; the totalisation device calculates and records the sum of this term A_2B_2 and of the term $\pm A_1B_1$ already recorded the auxiliary step-by-step distributor advancing by one step at each operative stage from the contact 5 of the advancement bank *e* at which it was stopped (recording of the units in the row α, of the tens in β, the hundreds in *u*, of the thousands in *d*) and stopping at the contact 3 of the bank *e* at the end of this operation. It will be seen that the auxiliary step-by-step distributor always stops at an odd-numbered contact. If, on the contrary, any one of the terms A_qB_q during calculation has a sign for which the sorting relay PM is not energised, the armature of the summation relay H is held by its holding circuit and the auxiliary step-by-step distributor remains out of circuit; it remains stopped on the odd-numbered contact of the bank *e* which it has attained, because the line L_i to which this contact is connected does not receive current.

On the other hand, it has been seen that when the sorting relay PM, at the commencement of the calculating operation of a term A_pB_p which has to be totalised, has current passing through it, the closing of its contacts 1 and 2 puts under current one of the displacement relays 0Y or 1Y. Each of these relays controls the holding circuit of the other connected permanently to a source of current, and therefore one of these relays is always energised.

Modification of the distribution

The distribution, that is to say, the control of the circuits of the calculating device for each operative stage, is attained in the construction shown in Figures 4 to 9, by means of step-by-step distributors similar to those employed in automatic telephony. According to the modification shown in Figure 10, the principal and auxiliary step-by-step distributors are replaced by chains of electro-magnets or relays.

The left-hand part of Figure 10 reproduces the transfer device of Figure 7 with the exception of the principal step-by-step distributor and with the sole difference that the contacts 3 of the supervising relays are directly in series between the line l_1 and a source of release current. The right-hand part of the figure shows the two chains, the centre one replacing the principal step-by-step distributor and that on the right the auxiliary step-by-step distributor.

It will be recalled that for the example considered in which there are four operative stages (four denominations of the result), each bank of contacts of the principal step-by-step distributor of the construction which has been described comprises four fixed contacts, each corresponding to a different stage. To the ten fixed contacts, for example, the contacts 1 (or 2, 3, 4) which correspond in the ten banks $c_1, c_2, \ldots, c_{10}$ of contacts to a given operative stage, there corresponds in Figure 10 a bundle of ten wires for said stage, which bundle comprises a multi-contact stage switch *x*1 (or *x*2, *x*3, *x*4). The line L_2 of Figure 7 is not required. Each stage switch is controlled by an electromagnet X1, X2, X3, X4, having two windings, a closing winding *f*, and an opening winding o. The linking together of the electro-magnets X is obtained by the connection of the closing winding of one of them to the opening winding of that which is two ranks in front of it: thus, the closing winding of X3 is connected to the opening winding of X1 and so forth. Furthermore, the closing winding of each of the electromagnets is connected to a terminal of an eleventh contact *x* of the switch corresponding to the preceding electromagnet, the other terminal of said contact being connected to one of the wires L_i, L_{ii}, L_ω according to the rank of the electromagnet considered: even-numbered rank to L_i, odd-numbered rank to L_{ii}, except that of rank 1, which is connected to L_ω in such a manner that the current passing in said line produces the opening of the last switch *x*4. The switch *x*4 comprises a twelfth contact *o*, one terminal of which is connected to the release wire l_3 of the multiplication device. The contacts 1 to 10 of the odd-numbered bundles on the one hand and the contacts 1 to 10 of the even-numbered bundles on the other are connected to the ten contacts of alternation switch 1*x* and 2*x*, the first eight wires of these bundles (distribution to the multiplication device) directly and the last two (distribution to the totalisation device D±AB) through the medium of the four contacts 2*i*, 3*i*, and 2*ii* and 3*ii* of the general reversing switch IG_1 which replaces the general reversing switch IG of Figure 6. In each alternation switch, the ten contacts are connected by their second terminal to the line L_ω (connected to L_{ii} during operation) or to the line L_i according as to whether they correspond to odd-numbered or even-numbered stages (alternation switches $1x$ or $2x$), the first eight directly by wires $1L\omega$ and $2Li$, the last two through the medium of lines $1Lx$ and $2Lx$ and contacts 1 and 2 of the summation relay H_1 which replaces the summation relay H of Figure 9. Each of the alternation switches is controlled by an electromagnet, 1X or 2X, comprising a closing winding f and an opening winding o. The closing winding f of 1X and the opening winding o of 2X are connected to the opening line 2o of the second half of the transfer device. The closing winding f of 2X and the opening winding o of 1X are connected on the one hand to the opening line 1o of the first half of the transfer device and on the other hand to the wire 0Lo (normally connected to negative).

Associated with the supervising relays 1U and 2U are 1V and 2V, each having two windings, one 1 being connected, for the relay 2V, by the wire i to the line Li and for the relay 1V by the wire ii to the line $L\omega$ (normally connected connected to Lii). The second winding 2 is a holding winding. Each relay comprises three contacts 1, 2, 3, the contact 1 closed at rest, connecting the release wire l_1 of the addition device to one of the opening lines 1o or 2o, according as to whether it pertains to 2V or 1V; the contact 2, open at rest, establishes the connection of the holding winding 2 of its own energised relay, 1V or 2V; with a wire $1Lv$ or $2Lv$ connected to positive by the contact 3, at rest, of the other relay 2V or 1V; these two wires, $1Lv$ and $2Lv$ are "fourth circuit" lines connected to the contacts 3 and 4, closed at rest, of the summation relay H_1.

The device just described serves for distributing the current for the calculation of totals D±AB. Its operation is as follows. It has been seen that during the operation of the transfer device, any operative stage, that is to say, the duration of operation for the calculation of the digit of a given denomination of the result, is decomposed into two phases. In the first phase, one of the supervising relays (1U for example, odd-numbered stage), is energised and the current is supplied to the addition device by the contact 2 of the other relay (2U) which is at rest. In the second phase, that is to say, after the digit of the result has been obtained and the transfer has been recorded in the half of the transfer device corresponding to the second relay, the latter is energised by the current which passes through the contact u of the switch closed for recording the transfer, and the release line l_1 and the opening line (1o or 2o) of the first half of the transfer device have current passing through them. The opening of the switch which was closed in this half of the transfer device interrupts the energising of the first supervising relay, the armature whereof drops (first phase of the following stage), which, through the contact 1 of said relay, sends current to the line Li and through the contact 2 of said relay, to the addition device for the calculation of the digit of the partial result of the next denomination (even-numbered). Thus, in the first phase of an operative stage, only one of the supervising relays is energised, while in the second phase of the same stage, the supervising relays are both energised simultaneously. The two auxiliary supervising relays 1V and 2V operate on the contrary alternately. When in an operative stage one has been energised by the current passing into its first winding through the contact 1 of the supervising relay, the armature of which has dropped, said auxiliary relay has attracted its armature; the latter is held by the holding circuit comprising its own contact 2 and the contact 3, at rest, of the other auxiliary relay, until the first winding of the latter is energised in the next operative stage. Thus, these auxiliary relays 1V and 2V are under the dependence of the supervising relays 1U and 2U, the relay 1V being energised when at the commencement of an odd-numbered stage 1U remains energised and the current of the third circuit passes through the first half of the transfer device, the relay 2V when, in an even-numbered stage, the current passes through the second half of the transfer device. That one of the auxiliary relays which is energised during an operative stage remains energised for the entire duration of said stage, and in the second phase of this stage, when the transfer is recorded and the second supervising relays is energised, the line l_1 being then connected to its source of current by the contacts 3 of the two supervising relays, the release current of this line passes through the contact 1, at rest, of the other auxiliary relay, to the opening line of the half of the transfer device to which said first relay corresponds, that is to say, to the line 1o for an odd-numbered stage and to the line 2o for an even-numbered stage. While the two supervising relays are both energised, the third circuit (addition) is broken.

The passage of the current to the line 1o in the second phase of an odd-numbered stage produces the opening of the alternation switch $1x$ and the closing of the alternation switch $2x$. When the armature of the supervising relay 1U has dropped in the first phase of the next stage (even-numbered) the line $2Li$ is under current likewise the line $2Lx$ connected to Li by the contact 1, at rest, of the relay H_1. The current therefore arrives in the course of the first phase of said stage at the even-numbered bundles and will pass to that one of these bundles whereof the switch $x(n)$ is closed. If the switch $x2$ is closed (stage corresponding to the calculation of the second digit of the result), the current passing through the contact x of said switch energised the opening winding of the electromagnet X1 and the closing winding of the electromagnet X3. The switch $x3$ is closed for the next stage. In this stage (first phase) the passage of the current through the contact x of $x3$ will result in the opening of $x2$ and the closing of $x4$, etc. There is, therefore, always at least one switch closed, and that one the reference of which corresponds to the actual operative stage receives in the first phase the current of the alternation switch 1X or 2X, according to whether said stage is odd-numbered or even-numbered. The passage of the current through this switch produces the opening of the one which precedes it and the closing of the one which follows it. Consequently, in the second phase, the switch which follows it is closed and is ready for the next stage.

The distribution action is briefly as follows:

Odd-numbered stage: "third circuit" comprising a switch of the first half of the transfer device for the calculation of the result digit of rank $\pi+1$ (odd-numbered).

First phase: Alternation switch $1x$ and stage switch $x\ (\pi+1)$ closed; supervising relay 1U and auxiliary relay 1V energised; sending of current through the second and third circuits; opening of $x\pi$ closing of $x\ (\pi+2)$.

Second phase: relays 1U, 1V, 2U energised; opening of the transfer switch $1r(n)$ and of the alternation switch $1x$, closing of $2x$; during this phase the second and third circuits are broken.

Even-numbered stage (result digit of rank $\pi+2$)

First phase.—supervising relay 2U and auxiliary supervising relay 2V energised: current sent through the second and third circuits; opening of $x(\pi+1)$ closing of $x(\pi+2)$.

Second phase.—relays 2U, 2V, 1U energised; opening of the transfer switch $2r(n)$ and of the alternation switch $2x$, closing of $1x$ interruption of the second and third circuits.

In the case of the calculation of successive totals ΣAB, the current distribution is effected by the chain of relays shown on the right-hand of Figure 10. This chain comprises six relays, Z*u*, Z*d*, Z*c*, Z*m*, Zα, Zβ corresponding to the different rows of recording relays and ensuring the distribution in the same way as the banks e_0, e_1, e_2, of the auxiliary step-by-step distributor of Figure 9, each of said relays comprising two windings 1, 2 and five contacts 1, 2, 3, 4, 5. The first two contacts are connected in the linking circuits of the relays. Of the last three contacts of each of these relays (Z*u*, . . . Zβ) the contact 3, open at rest, serves to establish the connection of the line *lv* of the row of recording relays of the same reference (*u*, . . . β) of the totalisation device with the line 1L*v* or 2L*v* according to whether the relay is of odd-numbered rank (*u*, c, α) or even-numbered rank (*d*, *m*, β) and the contacts 4 and 5, open at rest, serve to establish the connection of the exploration lines L^2c and L^1c or L^2m and L^1m, or . . . , of the two groups of relays of the row of recording relays (*c*, *m*, . . . *d*) with the lines $3L_2i$ and $4L_2i$ or $3L_2ii$ and $4L_2ii$, according as to whether the relay of the chain is of even-numbered or odd-numbered rank. The control winding 1 of each relay is connected to the line *lv* of the relay of preceding rank, its holding winding 2 is connected by the contact 2, open at rest, to the contact 1, closed at rest, of the second relay situated after it and by this contact to the line $zL4$ through the medium of the contact 13, closed at rest, of the preparation relay K, except for the relay Zc for which the connection to the line zL_4 is direct.

The distribution is effected in the following manner. At the commencement of the operation, the relay Z*u* is, as will be seen, energised. The auxiliary supervising relay 1V being energised and the relay 2V at rest, the wire 1L*v* being therefore under current, the recording wire *lvu* receives current, the winding 1 of the relay Z*d* is energised and the armature of this relay is attracted and held by the holding winding 2 until the relay Z*m* is energised. At the same time, due to the fact that the wire *lvu* is under current, the first digit of the total is recorded in the row *u* of recording relays and the armatures of the relays of the row *d* drop; the wires $3L_2i$ and $4L_2i$ being under current (contacts 9 and 10 of the alternation switch $1x$ which is closed) the row c of recording relays is explored by wires L^1c and L^2c. At the next stage, the relay Z*d* being closed and the recording wire *lvd* under current, the relay Z*c* is energised, which breaks the holding circuit of the relay Z*u*, the armature of which drops, while at the same time the second digit of the total is recorded in the row of recording relays *d*, the row c being liberated and the row *m* explored. We thus have again, in the process of recording and exploring, the successive intervention of the rows of recording relays according to a closed cycle. In the present form of construction, however, the succession of one row to the next does not require the delay corresponding to the time required for the advancement of the step-by-step distributor. The relay in activity in fact prepares the relay which follows in the chain and the delay is reduced to that of the operation of the supervising relays U.

In regard to the control of the calculating device, Figure 10 shows some of the control members of first construction provided with the index 1 in the case where they are modified. The preparation relay K comprises three contacts 11, 12, 13 in addition to the contacts 1 to 10, not shown, of Figures 8 and 9 (the contact 7, Figure 9, is however, omitted). The contacts 11 and 12 connect to positive, when the relay K is energised, the line 2o and the line L*x*, which terminate at the closing winding of the last stage switch ($x4$); the contact 13 then connects the winding 1 of the relay Z*u* to the line zL_4; it has been seen that at rest this contact connects this line to the contacts 1 of all the relays except the third, Zc, which is already connected. The general reversing switch IG_1 effects the same reversals of circuit as the reversing switch IG, but with doubling of the contacts 2 and 3. The summation relay H_1 which corresponds to the relay H, comprises four contacts 1, 2, 3, 4, closed at rest, in addition to the contact *h*, the first two between the lines L*i*, Lω and 2L*x*, 1L*x*, the last two on the lines 1L*v*, and 2L*v*. The sorting relay PM has likewise been shown with its contact *g* of the holding circuit H_1, the release relay Q, the winding of which is on the line l_q connected to the release line l_3 and comprising the switch Id shown in the position for which D varies at each operation.

When the preparation button Io (not shown in Figure 10) is depressed, it has been seen that the armature of the preparation relay K is attracted, and that the contacts, 1 to 4 on the one hand and 5 to 10 on the other effect the necessary connections for the preparation of the transfer device (closure of 1*r*O, energising of 1U) and of the totalisation device. Furthermore, the contacts 11 and 12 put the lines 2o and L*x* under current and the winding *f* of the alternation electro-magnet 1X and the electro-magnet X4 of the stage switch are energised; the alternation switch $1x$ and the stage switch $x4$ are closed, while the switches of the second half of the transfer device are opened and the armature of the relay 2U in dropping puts by means of its contact 1 the line L*ii* under current; it is known, however, that the line L*ii* instead of being connected to the line Lω, is connected to the wire 1Lo (contact 1 of the relay K). It follows that 1Lo is put under current which produces the opening of the switches of the first half of the transfer device except 1*r*O, because the winding *o* of its electromagnet is not connected to negative. For the same reason and although the line 1o connected to 1Lo is now under current, the windings *f* of 2X and o of 1X are not energised; the alternation switch $1x$ alone remains closed. On the contrary, the lines 1o and 2o being both under current the same is the case for the line l_1 connected to one of these lines by the contact 1 of the auxiliary supervising relay, the armature of which has dropped, because these relays, each of which controls the holding circuit of the other, cannot remain energised at the same time. The current passing through l_1 releases the addition device. On the other hand, the stage switch x_4 in closing has connected by its contact o the line l_3 to the line **2**o, which produces the release in the "second circuit", and by its contact x the closing winding of X**1**, to the line Li which is under current, thereby closing the switch x**1**. For timing the analysing with the calculation a synchronisation device may be provided on the analysing device and be connected by a line Le to one of the closing windings of the stage switch x**1** or x**2**, according to the manner in which synchronising is effected.

In the case in which the general reversing switch IG_1 is in the Δ position shown (calculation of D+AB), the lines IIL_4 and zL_4 do not receive current; all the relays Z are at rest and their chain remains unused. In this case, when the button Io is released (starting), the armature of the relay K drops and the lines **2**o and Lx no longer receive current, but the line Lit under current is now connected to L_ω. It follows that the auxiliary supervising relay IV is energised and the lines IIL_ω and IIL_x cause current to arrive at the alternation switch **1**x which is closed, and to the stage switches of odd-numbered ranks.

When the general reversing switch IG_1 is on the contrary in the Σ position (calculation of ΣAB) the line IIL_4 corresponding to that of the same reference in Figure 9 and the line zL_4 are under current during the preparation, the armature of the relay K being attracted. The contact **13** then connecting to the line zL_4 the winding **1** of the relay Zu, the latter is energised and attracts its armature which is held by the holding circuit: +, . . . zL_4, contact **1** at rest of Zc, contact **2** closed of Zu, winding **2** of Zu, —. When the lines **1**Lv, **3**L_2t and **4**L_2t receive current, the wires lvu, L^1c, L^2c are then under current. As before, the calculation commences when the armature of the relay K having dropped, the wires **1** to **8** leaving the switch x**1** are themselves also under current. Furthermore, the contact **13** of the relay K, being now at rest, connects to their current source the contacts **1** of the circuits of the holding windings of the relays of the chain.

The tables shown in Figures 11 and 12 indicate the periods of passage of the principal currents of the calculating device in the four operative stages, comprised by an operation D±AB, in the constructional example selected where the result comprises four characteristic digits at the most. Figure 11 relates to the first method of distribution, Figure 12 to the modification. Each table comprises on the right in addition to a column relating to the analysing, four columns relating to the operative stages 1 to 4. On the left are indicated the references of the principal members of the device. In the right-hand columns, the passage of a current through the member referred to in one of the lines of the left-hand column is indicated by different letters according to the circuit, said letters being juxtaposed on a length of this line which corresponds to the time of passage of such current, referred to the duration of an operative stage shown by the width of one of the columns 1 to 4. The letters referring to the nature of the current are as follows:

eeeeee...	First circuit current
xxxxxx..	Second circuit current
ssssss....	Third circuit current
rrrrrr....	Fourth circuit current
oooooo..	Release current
zzzzzz...	Holding current

For convenience, the following key is given relating to the references of the first column:

Figure 11

$Au(n)$—$Ad(n)$, $Bu(n)$—$Bd(n)$	Electro-magnets for recording the factors A and B
$Du(n)$—$Dm(n)$	Relay for recording the term D
P or M	Electro-magnets of the sign of the + or — totalisation
PM	Sorting relay
H	Summation relay
OY or 1Y	Displacement relay
$S^1(n)$, $S^2(n)$, $T^1(n)$, $T^2(n)$	Electro-magnets of the addition and totalisation switches
$P(n)$ and $T(n)$	Relays of the result AB and of the total result
$1R(n)$	Electro-magnet of a switch of the first half of the transfer device.
1U	Corresponding supervising relay
$2R(n)$	Electro-magnet of a switch of the second half of the transfer device.
2U	Corresponding supervising relay
C	Electro-magnet for advancing the principal step-by-step distributor
Q	Release relay.

Figure 12

$Au(n)$—$Ad(n)$, $Bu(n)$—$Bd(n)$	Electro-magnets of the recording switches
$Du(n)$—$Dm(n)$	Relay for recording the term D
Q	Relay for releasing the term D
P or M	Electro-magnets of the sign of the + or — totalisation
PM	Sorting relay
H^1	Summation relay
OY or 1Y	Displacement relay
$S^1(n)$, $S^2(n)$: $T^1(n)$, $T^2(n)$	Electro-magnets of the addition and totalisation switches
$P(n)$ and $T(n)$	Relay of the result AB and of the total result
$1R(n)$	Electro-magnet of a switch of the first half of the transfer device
1U	Corresponding supervising relay
$2R(n)$	Electro-magnet of a switch of the second half of the transfer device
2U	Corresponding supervising relay
1V	Auxiliary supervising relay of 1U
1X	Electro-magnet of the odd-numbered alternation switch
2V	Auxiliary supervising relay of 2U
2X	Electro-magnet of the even-numbered alternation switch.

Referring now to Figures 13 to 25, the machine will be described which comprises the electrical calculating device of Figures 4 to 9 and the control members according to the modification shown in Figure 10. All electrical members forming part of the calculating device, with exception of the introduction members and sources of current are accommodated in a casing (Fig. 13) standing upon a base **50** and having front, top and back formed by metal sheets **51** joined at the corner by angles iron **52**. A number of frames **53** run round the interior of the casing and vertically from top to bottom in the middle of the same, and serve to support horizontal bars such as **54**, **55** and **56** (Fig. 17) having screwed on them the various electrical members of the calculating device. Apertures **57** and **58** are provided at the bottom of the side walls for the passage of the cable of current supply and of the cable of the result bundles of wires AB and Σ.

In the lower part of the casing there are several superposed rows of multiple switches **59**, the numerical references of which are given by Figure 14. Going from bottom upward, there is a first row of multiple switches comprising the two groups of ten switches corresponding to the units and tens denominations of the factor B, $bu(n)$ and $bd_1(n)$. The second and third rows comprise the multiple switches allocated to the digits of the factor A and of the partial products, the second row comprising the seven switches of the units denomination of the factor A, $au(n)$ and the thirteen switches allocated to the digits of the corresponding partial products **1**—$s(n)$, (groups **1**—$su(n)$ and **1**—$sd(n)$) the third row comprising the seven switches of the tens denomination of the factor A, $ad(n)$ and the thirteen switches allocated to the digits of the corresponding partial products $2—s(n)$ which, as already explained, form groups identical to those of $1—s(n)$. A further row comprises, on the left-hand side as shown on Figures 13 and 14, the ten multiple switches of the totalisation device, i. e. the switches + and −, and the two groups $t^1(n)$, $t^2(n)$. On the same row, but on the right-hand part, there are provided the two groups of three transfer switches **1***r* and **2***r* and the four multi-contact stage switches x^1 to x^4.

In the upper part of the casing there are accommodated the various relays **60** of the calculating device, the six relays columns of the totalisation device (Fig. 9) being grouped together above the totalisation multi-contact switches $t^1(n)$, $t^2(n)$. Starting from the left-hand side of the casing as shown on Figures 13 and 14, there is first the column of relays $D\alpha$ . . . $D\beta$, then the seven columns allocated to the digits of the two groups into which each denomination digit of D is decomposed. These relays form the six rows $D\alpha(n)$ . . . $D\beta(n)$ to which correspond the relays of the chain of relays $Z\alpha$ . . . $Z\beta$ for the current distribution to the totalisation device forming the ninth column Z. A further column comprises sorting relay PM, displacement relays **0**Y and **1**Y, relay T_κ and relay T_ρ. The other relays T form a row of ten relays T**0** . . . T**9** at the uppermost part of the casing. On the same row, but on the left-hand side of the casing, there are the ten relays $P(n)$. Another row, below said relays $P(n)$ comprises the supervising relays **1**U, **2**U, **1**V, **2**V, preparation relay K, divided into two relays K_1 and K_2 mounted in parallel, and having a common delayed release relay J, summation relay H_1 and release relay Q. Below said row of relays there are further multiple switches comprising the preparation switch γ and the two alternation switches **1***x*, **2***x* and a board **61** (Fig. 13) bearing control members **62** and **63**. These members comprise (Fig. 14) the general reversing switch IG_1, the release switches I*b* and I*d*, the sign switch I*t*, the preparation button Io and a further switch I for the general control of current supply for the various circuits of the device.

The various electrical members included in the machine will now be described and an explanation given of the manner in which the connection between the similar members are made. In fact, all the multi-contact switches are of the same construction and all the relays are of the same type, comprising a number of contacts appropriate to their function.

The construction of a multi-contact switch **59** will first be described, with reference to Figure 17. It comprises a ring of fixed contact **64**, **65** mounted insulated in a frame **66**. The contacts **64** are wider than the contacts **65** and are arranged alternately therewith. Each contact **64**, **65** is provided with a tab **67** for making soldered connection to the wiring. A ring of splitted moving contacts **68** are embedded in a disc **69** of insulating material mounted on a spindle **70** supported in bearings in the frame **66**. The disc **69** carrying the movable contacts is driven in reciprocatory rotation about its spindle **70** by one end of a lever **71** pivoted to the frame **66** at **72** and forming at its other end a movable armature **73** placed between the poles **74**, **75** of two electro-magnets **76**, **77**. When the magnet **76** is energised, the lever **71** is moved in a clockwise direction and by means of a pin **78** on its right-hand end on Figure 17 moves the insulating disc **69** in an anti-clockwise direction, so that one part of the slit of the movable contacts **78** moves off a wide fixed contact **64** onto the adjacent narrow fixed contact **75**. Each wide contact **64** is thus electrically connected to the adjacent narrow contact **65**. The excitation of the other electro-magnet **77** conversely returns all the moving contacts to the position shown on Figure 17. These electro-magnet operated units are mounted in the casing with an arrangement as have been described with reference to Figure 13, each been screwed on and between two horizontal bars such as **54** and **55**, with their electro-magnets in front as shown on Figure 13. From the tabs **67** a number of wires forming a bundle **79** lead to a connection frame fixed on the rear part of the casing and by means of which the wiring between the switches of a row of switches is effected.

This frame comprises a series of similar bars of insulating material **80** (Figs. 17 to 20) with metal blades **81** embedded therein. Each blade **81** is internally to the bar shaped so as to form notches **82** for locking them in the insulating material and splitted externally at **83** at both external ends. On each bar, the blades form two rows in staggered arrangement. To each multi-contact switch corresponds a bar **80**, all the bars of the same row being aligned between two bars **56** and screwed on these bars. The blades **81** of the various bars are thus aligned in the transverse direction of the bars, as shown on Figure 18, so that they may be connected by wires **84** engaged into the slits **83** and soldered on the blades. Thus the wires may be easily disconnected, for instance when there is necessary to take a switch out of the casing, what can be effected after the screws have been removed by pulling from the front part of the casing the assemblage formed by the switch **59** and its bar **80**.

The portions of connection frames shown on Figure 18 correspond to the four first multi-contact switches of the two rows of switches relating to the addition of partial products when starting from the right-hand wall of the casing as shown on Figure 13. On this figure, the wiring bears the same numerical reference as used in the diagram (Figs. 7 and 8). For instance the lower frame comprises the assemblage f_1 of bundles δ, η connecting the switches of the first group 0, 1 of the units and the assemblage f_2 of bundles δ, η connecting this group of switches to the five switches of the group 0, 2, 4, 6, 8 of the units and the assemblage f_3 of bundle δ, η connecting this group of switches to the first group of switches allocated to the tens. The coils of the electro-magnets of each multi-contact switch are the closing winding *f* and the opening winding o to which reference has been made in connection with the electrical diagrams. The blades of the lowermost row of blades as shown on Figure 18 which correspond to the positive terminal of the closing windings are each connected to the respective wire of the bundle p^1u and p^2u. The blades of the second row, which correspond to the positive terminal of the opening windings are connected to the release current input l_1. The blades of each of the last two rows at the top of the frame which correspond to the negative terminal of the windings are soldered to wires denoted by the sign −, connecting them to negative.

The type of relays used in the machine will now be described, for example, with reference to Figure 21. Such a relay comprises a frame **85** bolted on the corresponding horizontal bar 54. Each relay has a number of blades 86 in superposed arrangement supported by the frame 85 by means of insulating blocks. According to the number of connection to be made by the relay, there are one, two or three groups of blades 88 which are operated by a common oscillating armature 88 actuated by the coil 88 of the relay. The two relays shown on Figure 21 correspond to the relay T8 and Du1. The relay Du1 has only the two contacts o and v. The relay T8 has three groups of contacts disposed along the width of its movable armature. The middle group comprises the contact 8 closed at rest of the chain of contacts tr and the contact of the same rank opened at rest of the line of contacts t and the groups on both side have each only the contact of the same rank opened at rest of the lines of contacts $1t$ and $2t$.

For the wiring between the relays there is provided a connection frame similar to that used for the wiring between the multi-contact switches, and comprising a bar 80 for each column of relays. Figure 22 shows the portion of this frame corresponding to the relays T9 to T5 and to the six rows ($u, d, \ldots \beta$) of relays Du . . . Dβ and Du(n) . . . Dβ(n) (n=1, 0, 8–9, and 6–7). The numerical references which n represents are recalled on the bar 80. All the bars 80 are screwed in transverse alignment on two horizontal bars 90, 56 fixed on the frame irons 53 of the casing. Some of the blades 81 are left staying on the bars and receive connecting wires 84 in the transverse direction of the bars, other have been bent sidewise as shown at 90 on Figures 19 and 20 to have soldered on them connecting wires 92 parallel to the length of the bars and in a plane different from that of the transverse wiring. The numerical references for the wires are the same as used on the diagram of the totalisation device shown on Figure 9. Further references have been devised for wires which are not denoted on this diagram. The blades of the uppermost row have soldered on them the wires $\sigma 9$, $\sigma 8$ . . . (not shown) of the result bundle Σ and are connected to a terminal of contact t of the corresponding relays the other terminal of which is connected by means of the blades of the second row to wire 3L4. Then, there are two rows of blades for the connections of the chain of contacts tr (wires tra, trb) the connection to the chain of contacts pp and pm (Fig. 9) being made directly by wires forming a bundle not shown. Two further rows of blades connected to one terminal of the contacts $1t$, $2t$ are affected to the connection of these contacts in the lines of contact they form the numerical references indicating the wires of the bundle et^1et^2 to which these cross connections are connected in turn, a further row corresponding to the other terminal of said contacts and being connected to negative by the wire denoted by the sign —. The blades of the next row, which are connected to a terminal of the coil of the corresponding relays, receive the corresponding wires of the bundle ft (not shown) from the row of the totalisation switches, while the other terminal is connected to the wire —. Other transverse connections are made corresponding to a wire lo, a wire lv and a wire ls for each row of relays Du(n) . . . Dβ(n) and for cross connection between one terminal of the contact v of these relays, the corresponding wires being denoted by the numerical reference of the lines L^1u . . . and $L^1\beta$ and L^2u . . . $L^2\beta$ receiving current from the corresponding contacts of the distribution relays Z. The blades 90 on one side of each bar 80 corresponding to a column of relays D(n) which are connected to the other terminal of the contact v of these relays receive the wire $le(n)$ connected to the closing winding of the corresponding totalisation switch. The blades 90 on the other side of each bar 80 receive a wire $et(n)$ of the bundles et^1 and et^2 for the energisation of the relays D(n) for recording of the characteristic digits of a previously calculated product, a further blade $ed(n)$ of the type 81 being connected for each relays to a wire for recording of the characteristic digits of the known term D when the calculation proceeds with such a known term. The blades 90 of one side of the bar corresponding to the column of relays Du . . . Dβ receive the wire denoted as Lo and, on the other side, the wire denoted as Lv establishes the connection between one terminal of the windings of the relays Dm, Dα, Dβ and the other terminal is connected to the wire Lo of the same row. For the relays Du, Dc, Dm, the first terminal of the windings are connected to the previously mentioned wire—the end of which is soldered on the corresponding blades 90.

Regarding the control members of the device, it has been seen with reference to the diagram shown on Figures 4 to 9 and the modification of Figure 10, that there are four control switches and a control button. As already mentioned, the switches are fixed on the board 61 and a further control switch I is provided for the interruption of the feeding currents of the device. All the control switches are denoted by the same reference number 62 while the preparation button is denoted by 63 on the board shown on Figure 13. As shown on Figure 23, the board 61 is fixed against the rear face of the front plate 51 and on two horizontal bars 54, 55 in front of the frame 53 by screws 93 passing through spacing sleeves 94. The switches 62 are accommodated in the space thus formed. All these switches are of the same construction each comprising, in accordance with the circuits it has to control, a number of fixed contacts 95 embedded in insulation disc in superposed arrangement. A central spindle having an external handle 97 bears insulated movable contacts 99 circularly disposed on the shaft and which close or open the corresponding circuits, according to the position of the handle. The return spring preparation button 63 may close two contacts 100 and 101 for the control of the relay K and J.

The connections between the various electrical members of the machine other than the wirings described with reference to the connection frames are to be seen on the diagram of Figures 4 to 10.

The two bundles of ten wires, AB and Σ issuing from the relay P(n) and T(n) form the cable leaving the machine by the aperture 58 and serve to control electrical punching machines of the type shown in United States Patent No. 1,772,186. Such a machine comprises a carriage feeding the card step by step through a punching mechanism operated by a number of electro-magnets allocated to the figures 0 to 9 and which will be connected to the ten wires 0 to 9 of one of these result bundles.

The calculating device receives current from the various source of currents and from the introduction members for the digits of the factors and term, through a bundle of wires forming a cable passing through the aperture 57 of the casing.

An electrical sensing machine will now be described which allows it to introduce in the calculating device the said digits recorded on perforated cards. Such a device is shown on Figure 24. A frame 182 houses in its lower part an horizontal main shaft 103 carried by bearings in the frame. On this shaft is keyed a gear 104 in mesh with a gear 105 mounted idle on a shaft 106 and forming part of an electromagnetically operated clutch of known construction comprising a plate 107 keyed on the shaft 106; this latter bears a pulley 108 driven through a belt 109 by an electrical motor 110. The clutch is brought into gear by the energisation of a magnet receiving current from the wire *Le* connected to the closing winding of the stage switch *x1* of Figure 10. Declutching is effected by a contact 111 connected to the release magnet of the clutch and operated by a boss 112 of a circular cam 113 keyed on shaft 103. This cam has a slotted face for actuation of the feeding mechanism and the sensing device which will now be described. In the slot 114 runs a roller 115 pivoted at the end of an horizontal rod 118 adjustably mounted on a rod 117, their assembly being reciprocably guided by bearing 118 and 119. A boss 120 on rod 117 is lodged in a slot 121 of a lever 122 pivoted at 123 and comprising an adjustable rod 124 connected by a crank 125 to a card pusher 126 sliding in the frame and acting on the lowermost perforated card 127 contained in a magazine 128. These cards are made of insulation material. When picked out from the magazine 126 by the pusher 126, the card will be driven by feeding rollers 129 in continuous rotation and thrown on the table 130 of the sensing device against a stop 131 fixed on the side of a vertically reciprocable pins box 132. The table 130 is insulated from the frame and connected to the closing winding of the electro-magnet of the stage switch *x2* shown on Figure 10. The pins box 132 is fixed through insulation to a vertically reciprocable yoke 134 on which is pivoted a roller 135 running in the slot 114 of the cam 113. The sensing pins 136 are guided in the box and returned to their upper position by spring 137. There are eight rows of ten pins allocated to the digits 0 to 9 of the various denominations of factors A and B and of term D. They receive current from the table 130. Above this table, a plate of insulation material 138 fixed to the frame comprises contacts 139 embedded therein. These contacts are shown at an enlarged scale on Figure 25. There are two types of contacts according to the rows of the sensing pins to which they correspond. Some of them 140 for the introduction of factor B are single contacts and the other 141 for the introduction of factor A and term D are double and separately connected to corresponding windings of the electro-magnets or relays of the two groups in which the digits of these factor or term are decomposed. To these contacts are soldered wires forming a bundle which join the lines from the sources of current to form the cable entering the calculating device at 57. When the stop 131 is in its lower position, the card is thrown out of the sensing device by a known roller (not shown) continuously driven and resiliently contacting said card. This latter is driven by rollers 142 in continuous rotation and thrown into the receptacle 143. A control switch 144 is provided on frame 102 to control the motor.

The operation of the sensing machine in connection with the calculation is as follows. A group of perforated cards recording the digits of the factors and term are placed in the magazine 128. The motor 110 is started and drives shaft 106 in continuous rotation. The clutch being out of gear, shaft 103 and cam 113 remain at rest. The handles of the switches 62 corresponding to numerical references IG_1, *Ib*, *Id*, *It* are driven into the desired position. Then the control switch I is closed, supplying current to the calculating device, which operates as has been explained with reference to the modification shown on Figure 10. Depression of control button Io energised relay K which effects the necessary connection for the preparation of the transfer device and the totalisation device. It has been seen that the closing winding of the stage switch *x1* is then energised by the current received from contact *x* of *x4* (Fig. 10). This current also energises the closing electro-magnet of the clutch of the sensing apparatus and the clutch is brought into gear. Then shaft 103 is driven and slot cam 113 rotates pulling the sensing box downward and the actuating rod 116—117 in the direction of the left-hand side of Figure 24. During the downward stroke of pins box 132, stop 131 is depressed and the card which was kept in the sensing device thrown out into the receptacle 143. After half a revolution of the cam, the card pusher 126 begins its feeding stroke pushing a card into engagement with rollers 129 which throw it into the sensing device where it is stopped by stop 131 which begins its upward movement together with the pins box. The pins which fall into perforation are brought into connection with the fixed contacts 139, and pins box remains at its uppermost position while contact 111 has been closed by boss 112 of the cam 113 thus energising the releasing magnet of the clutch. No current more passes through the pins until the first calculation stage is reached when the closing winding of the stage switch *x2* receives current together with the table 130 which is connected to this winding. The digits recorded by the perforated card are thus introduced in the calculation device and the calculation starts.

The current is cut off at the end of the first phase of the first stage, but the card remains in the sensing device and the pins in their sensing position until the calculation is completed when the closing winding of the last stage switch *x4* again receives current and the closing magnet of the clutch is again energised. Then the card is thrown out of the sensing device and replaced by the next card and a new calculation starts without interruption.

In the course of each calculation the result digits are successively recorded by perforations on a card fed through the punching machine.

It should be recalled that the constructional example described and shown has been provided for the calculation of operations comprising at the most four denominations of the result. If one of the factors A or B had a number of digits greater than two, it would be necessary to provide on the one hand devices for introducing and recording the digits of these factors corresponding in number to the denominations of said factors and addition switch groups in a number corresponding to the total number of digits of the two factors, and on the other hand in the distribution devices, contacts for each bank of the principal step-by-step distributor, or stage switches in a number equal to said total. Likewise, there would be necessary, in a number equal to this total increased by two, rows of recording relays and of contacts per bank of the auxiliary step-by-step distributor or relays of the chain of relays. Finally, the transfer device would have to comprise a number of switches equal to the digit of the largest transfer which may intervene in the calculation. Furthermore, it is evident that the calculating device according to the invention is capable of effecting operations on decimal numbers, although in the preceding description the last digit on the right has been termed the units digit. In order to effect an operation comprising numbers with more or less decimals, each number will be given as many decimals as the number which has the most by adding zeros. The last digit on the right will be taken as the units digit and the decimal point will be replaced in the result of the operation.

As has been seen, the device described makes it possible to effect not only operations AB, D±AB, ΣAB, but also to effect operations by keeping B constant and for the totalisations by keeping D or B, or D and B constant and to totalise the products, irrespective of their sign or only those which have one of the signs plus or minus. Finally, the totalisation device shown in Figure 9 in itself constitutes, independently of the other partial devices, a device which may be used for carrying out additions and subtractions.

In addition, the invention is by no means limited to the particularly described construction of the circuits necessary for the operations. In particular, relays may be employed in place of the various multi-contact switches having two control windings, an opening and a closing winding, appearing in the diagrams and vice-versa. The circuits may likewise be adapted to other groupings of the digits of the Pythagorean tables, comprise the use of other systems of notation and undergo modifications of arrangement or control, while remaining within the scope of the appended claims.

FRITZ MEZGER.