

Oct. 6, 1942.

T. W. CHICK

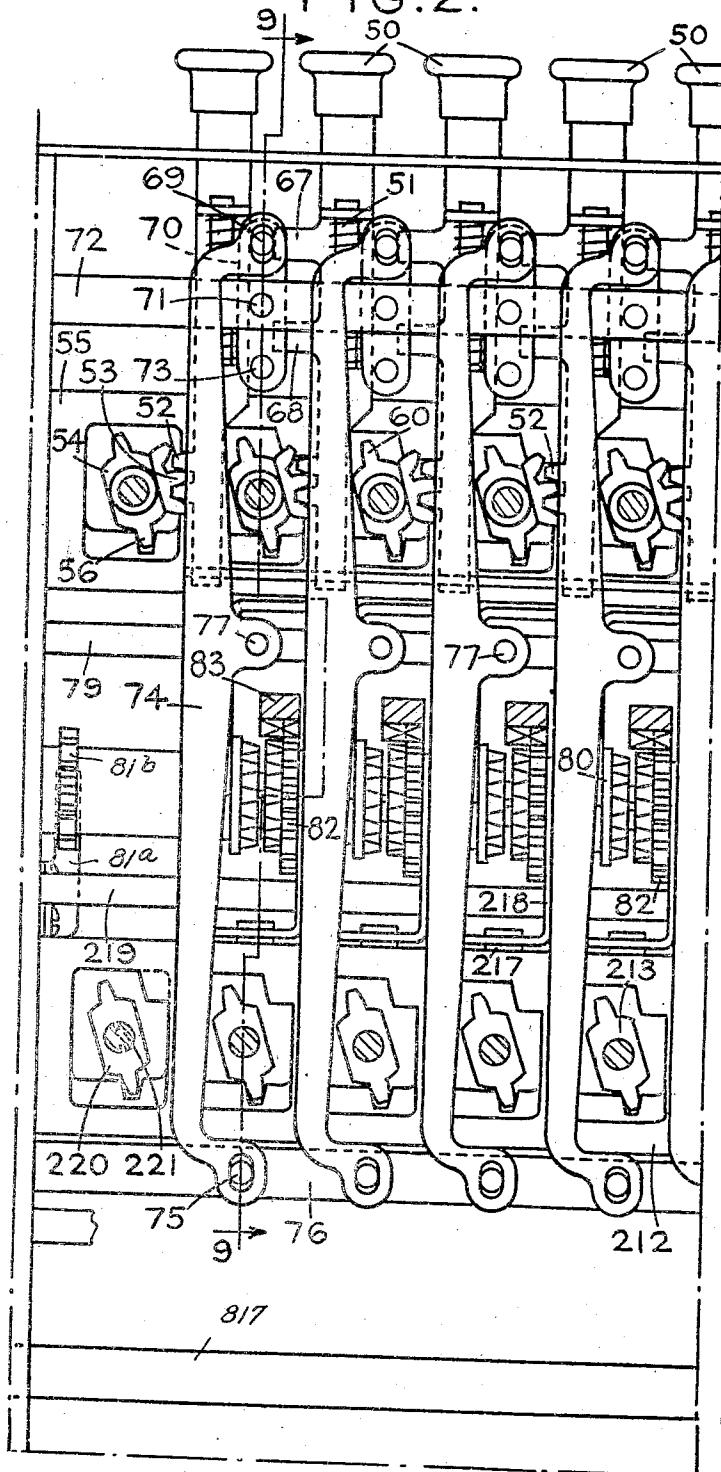
2,298,263

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FIG. 2.



INVENTOR

Thomas W. Chick
by
W. M. Wilson
att.

Oct. 6, 1942.

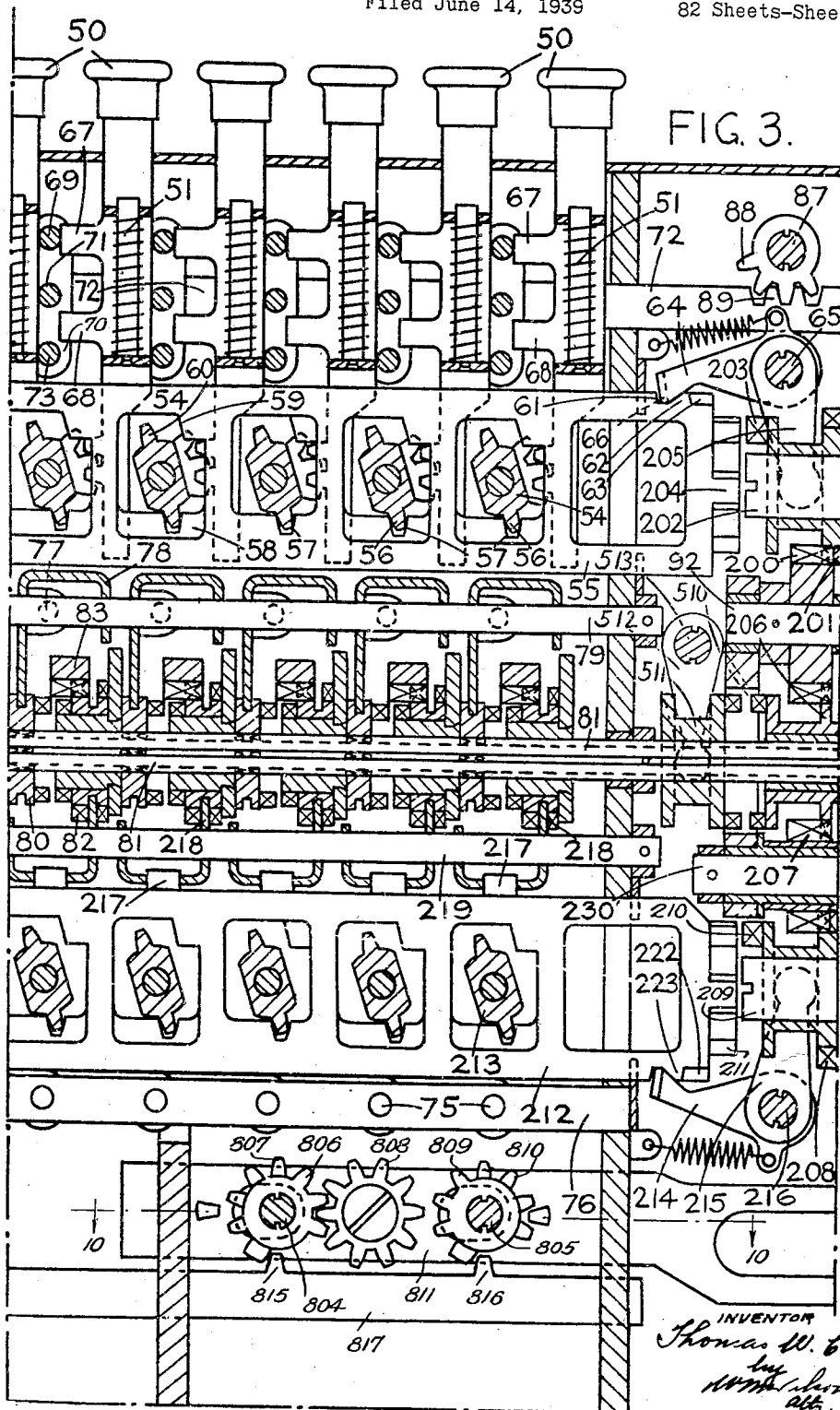
T. W. CHICK

2,298,263

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INVENTOR
Thomas W. Chick
by
Wm. H. Allen
att.

Oct. 6, 1942.

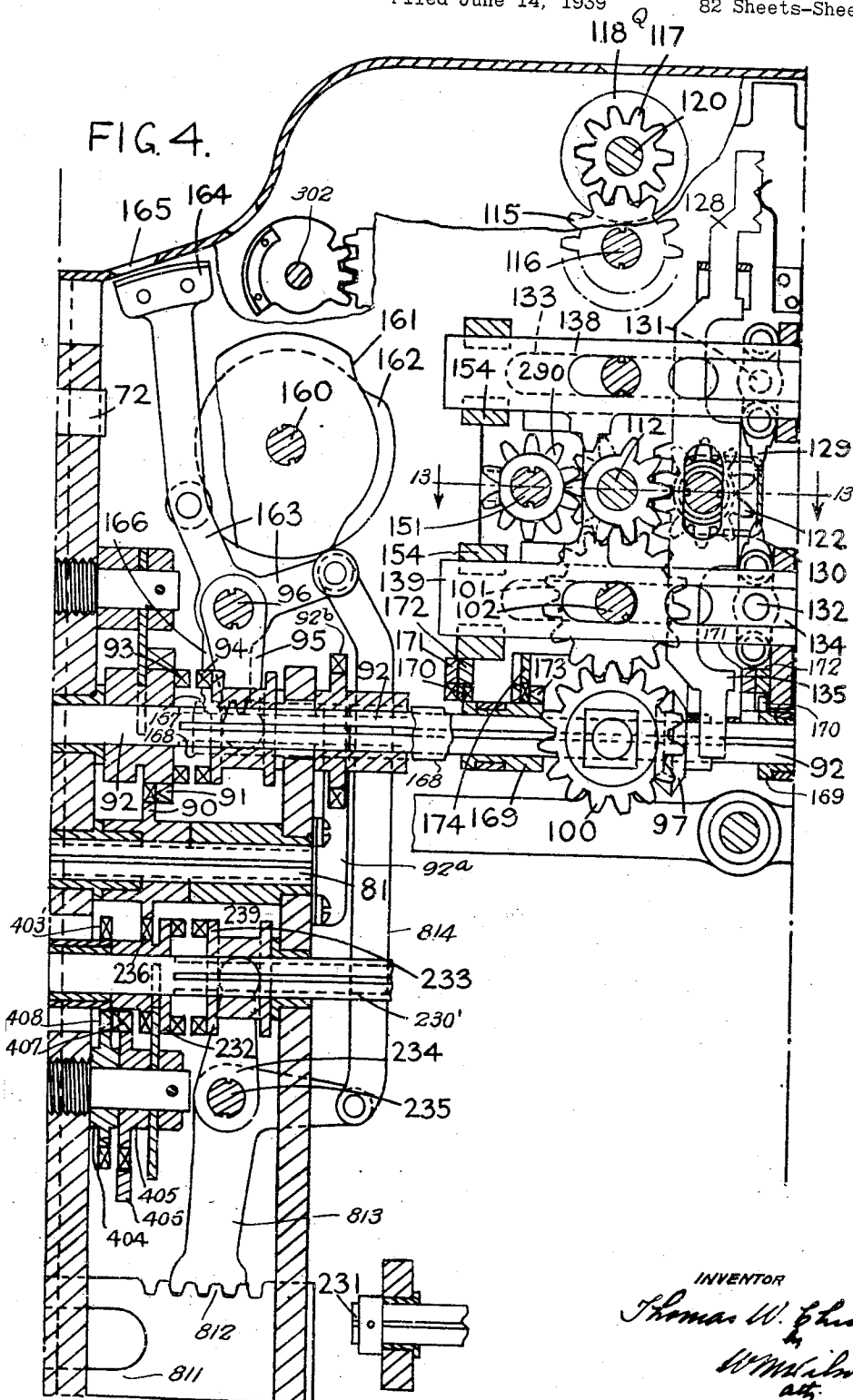
T. W. CHICK

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T. W. CHICK

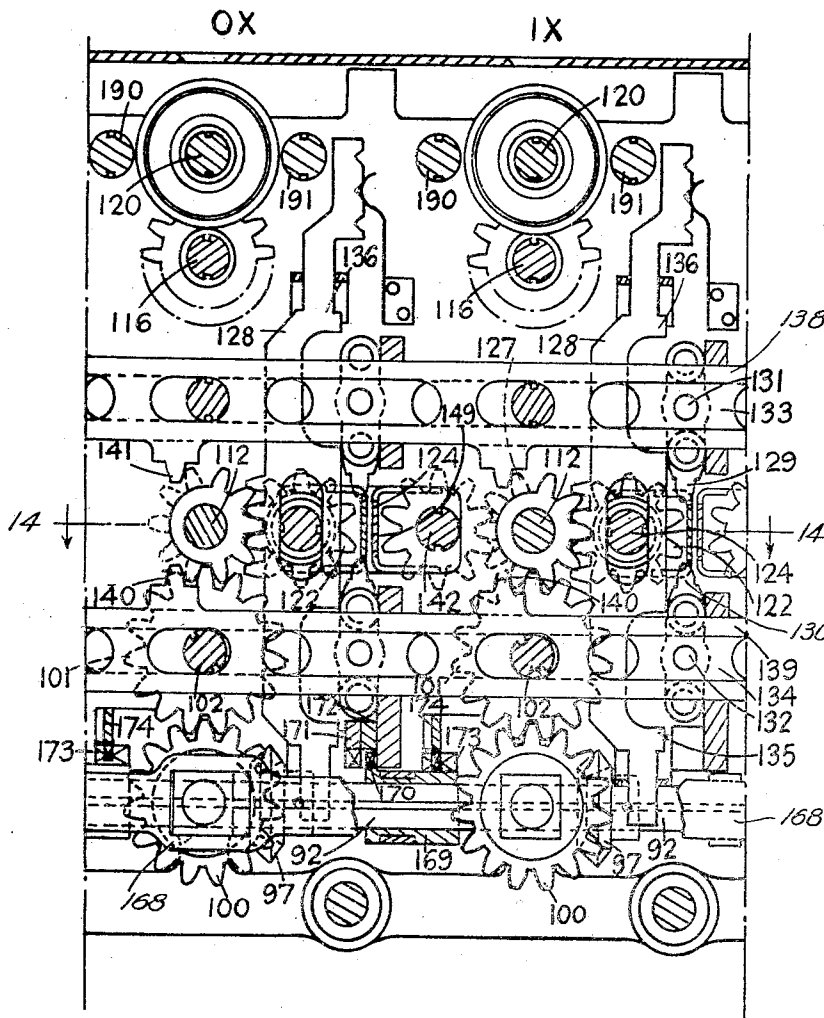
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FIG. 5.



INVENTOR

INVENTOR
Thomas W. Chick
by
Wm. Wilson
att'y.

Oct. 6, 1942.

T. W. CHICK

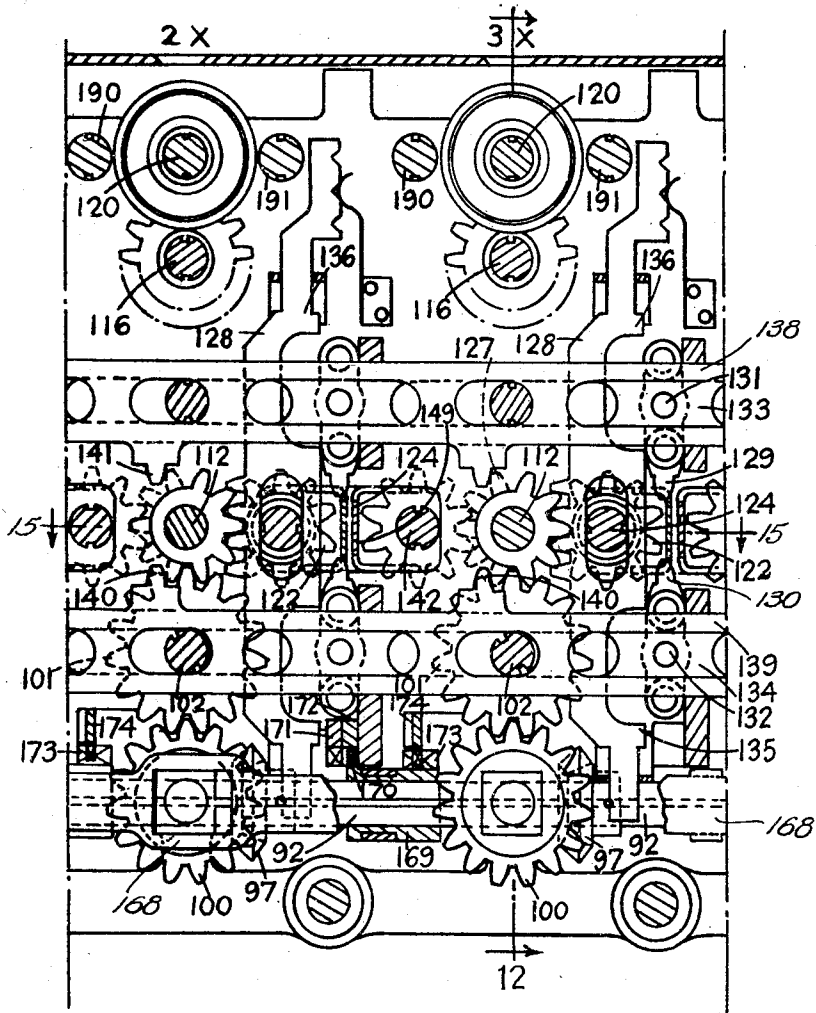
2,298,263

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FIG. 6. 12



INVENTOR

Thomas W. Chick
by
Commissioner
Atty.

Oct. 6, 1942.

T. W. CHICK

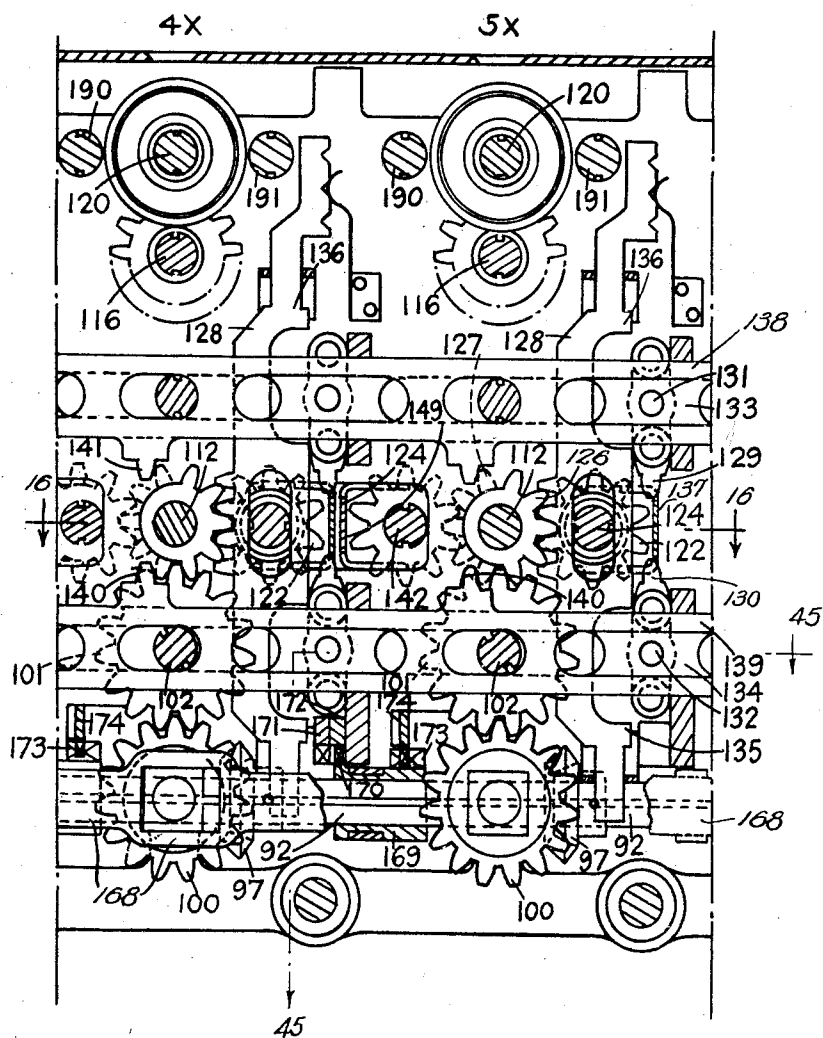
2,298,263

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FIG. 7.



INVENTOR

Thomas W. Chick
by
Wm Wilson
Atty.

Oct. 6, 1942.

T. W. CHICK

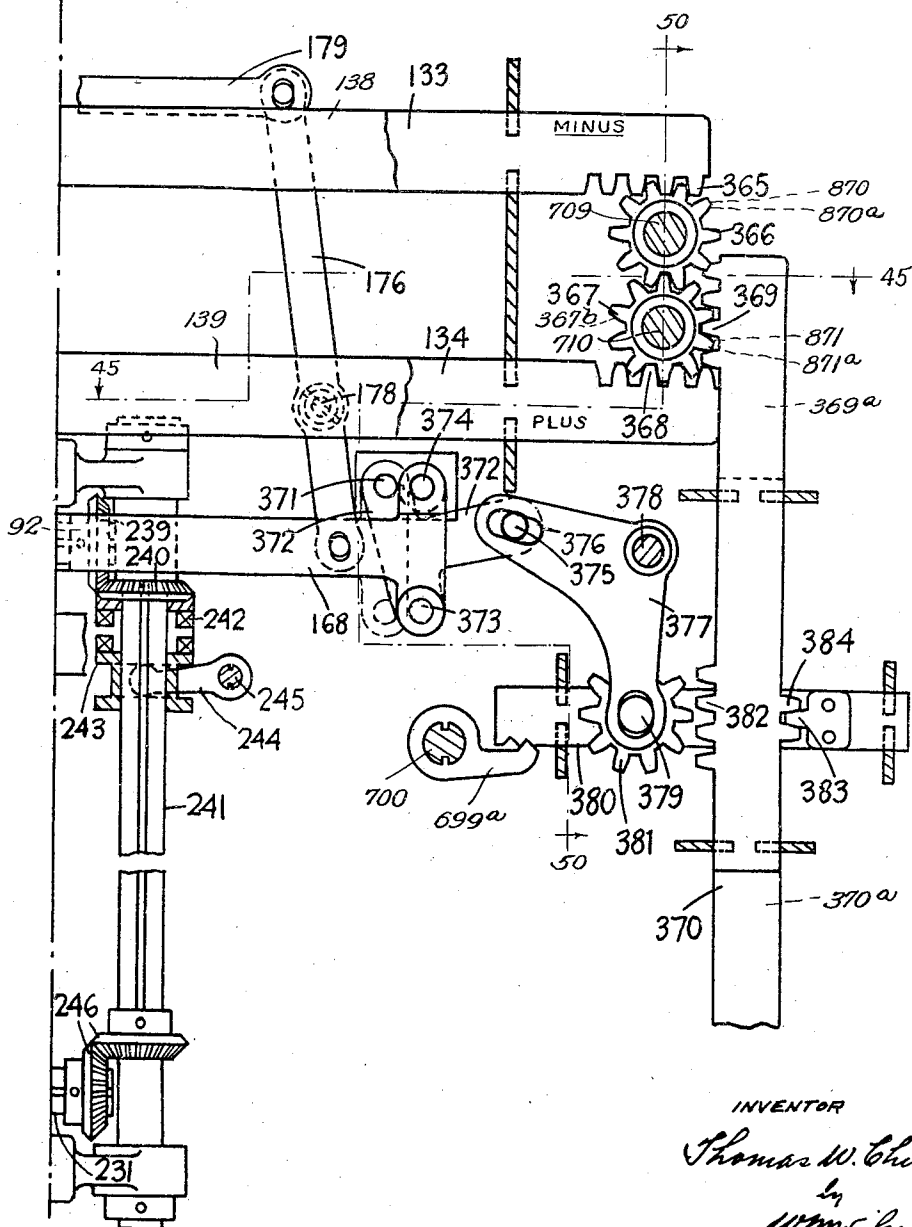
2,298,263

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FIG. 8.



INVENTOR

Thomas W. Chick

by
W. M. Wilson
att'y.

Oct. 6, 1942.

T. W. CHICK
CALCULATING MACHINE

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FIG. 9.

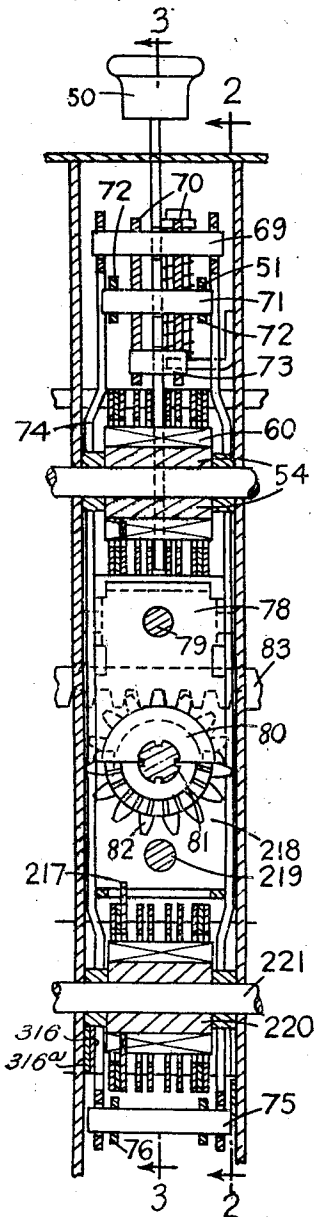
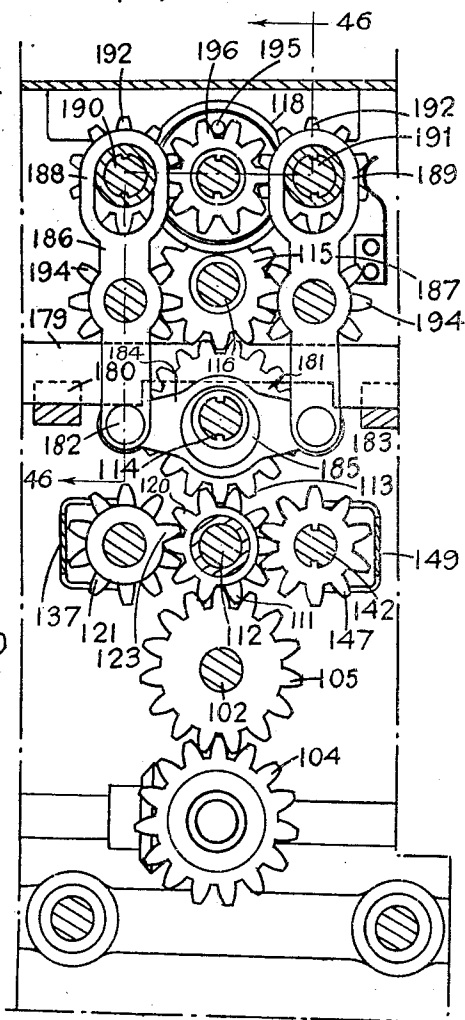


FIG. II.



INVENTOR
Thomas W. Chick
by
attorney

Oct. 6, 1942.

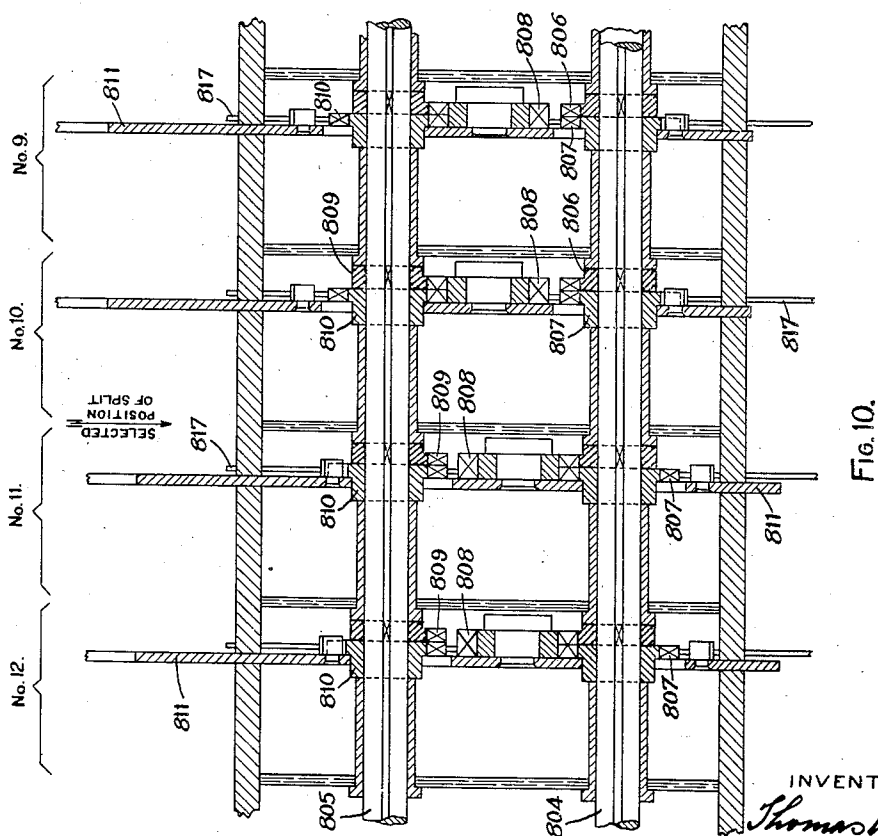
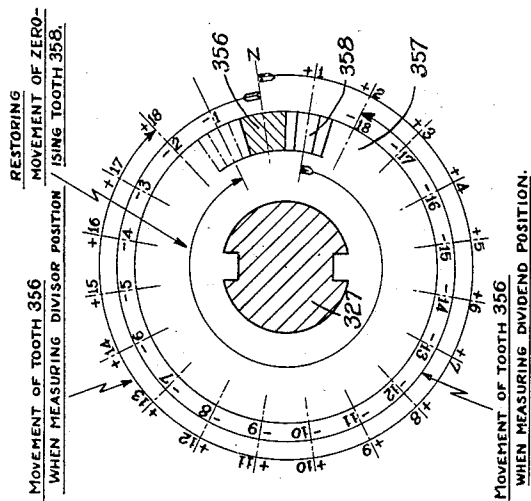
T. W. CHICK

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INVENTOR

Thomas W. Child

BY

W. M. Mahon
ATTORNEY

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T. W. CHICK

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FIG. 12.

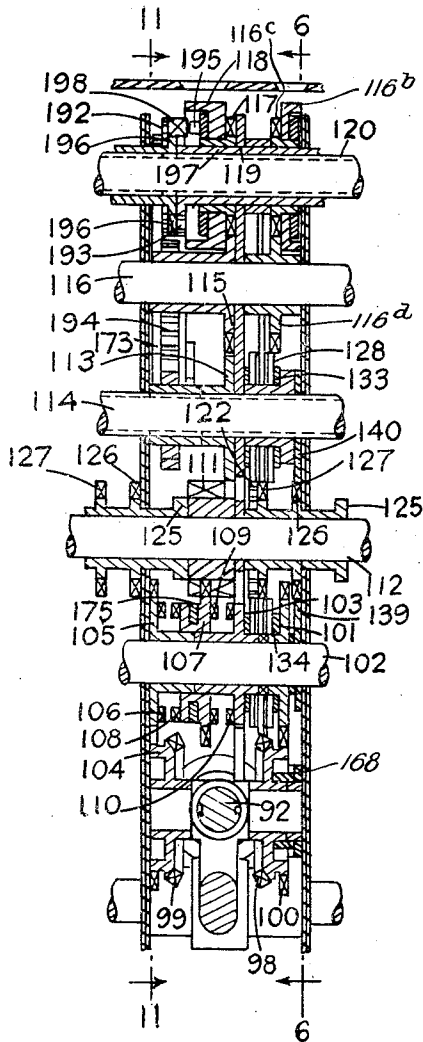


FIG. 17.

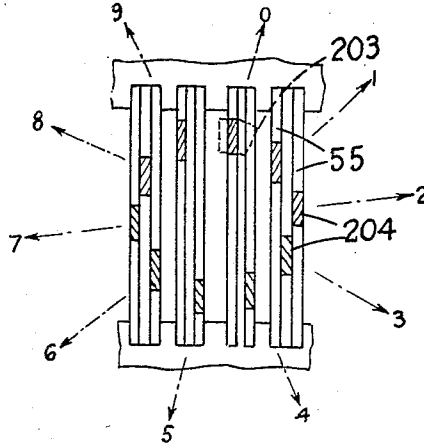
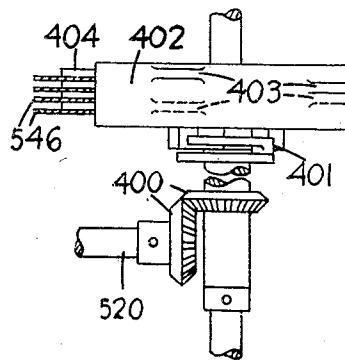


FIG. 32.



INVENTOR

Thomas W. Chick
by
W. M. Wilson
att.

Oct. 6, 1942.

T. W. CHICK

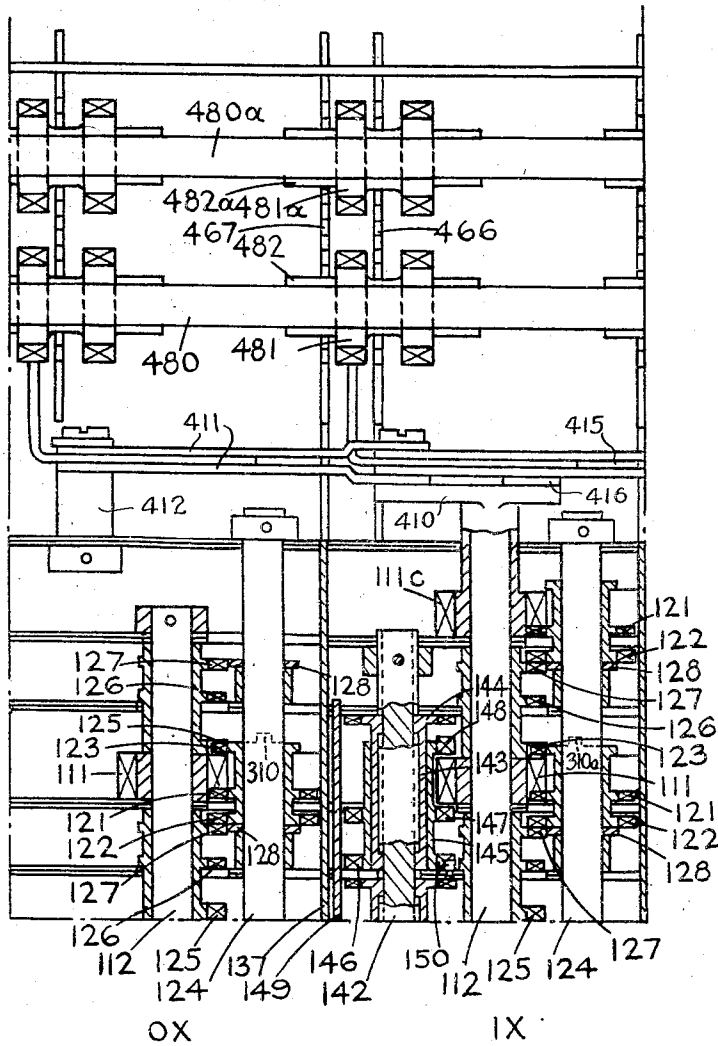
2,298,263

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FIG. 14.



INVENTOR
Thomas W. Chick
by
W. M. Wilson
att.

Oct. 6, 1942.

T. W. CHICK

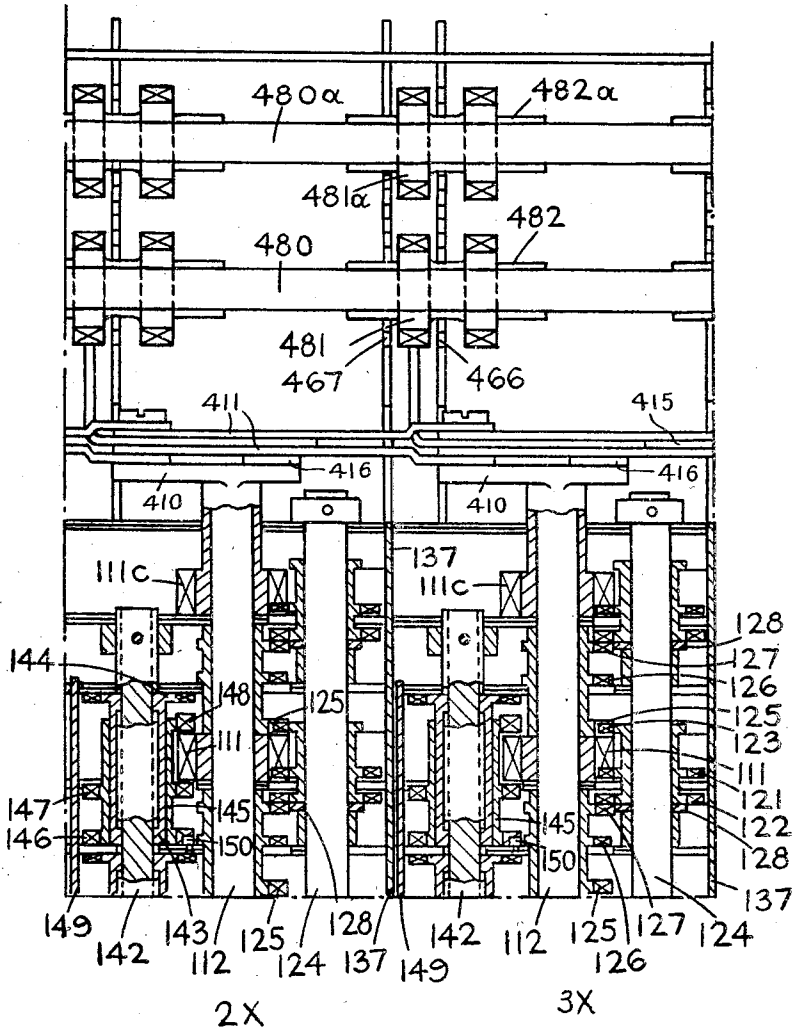
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FIG. 15.



INVENTOR

Thomas W. Chick.
by
W. M. Wilson
Att.

Oct. 6, 1942.

T. W. CHICK

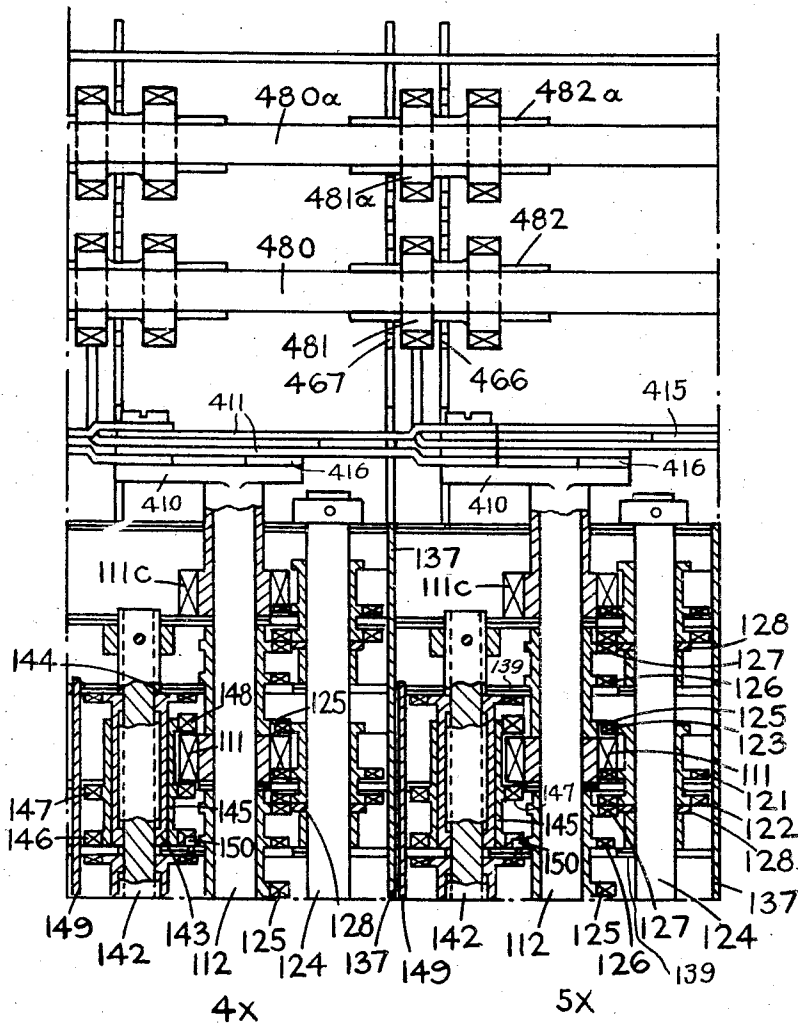
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FIG. 16.



INVENTOR

Thomas W. Chick
by
W. M. Wilson
att.

Oct. 6, 1942.

T. W. CHICK

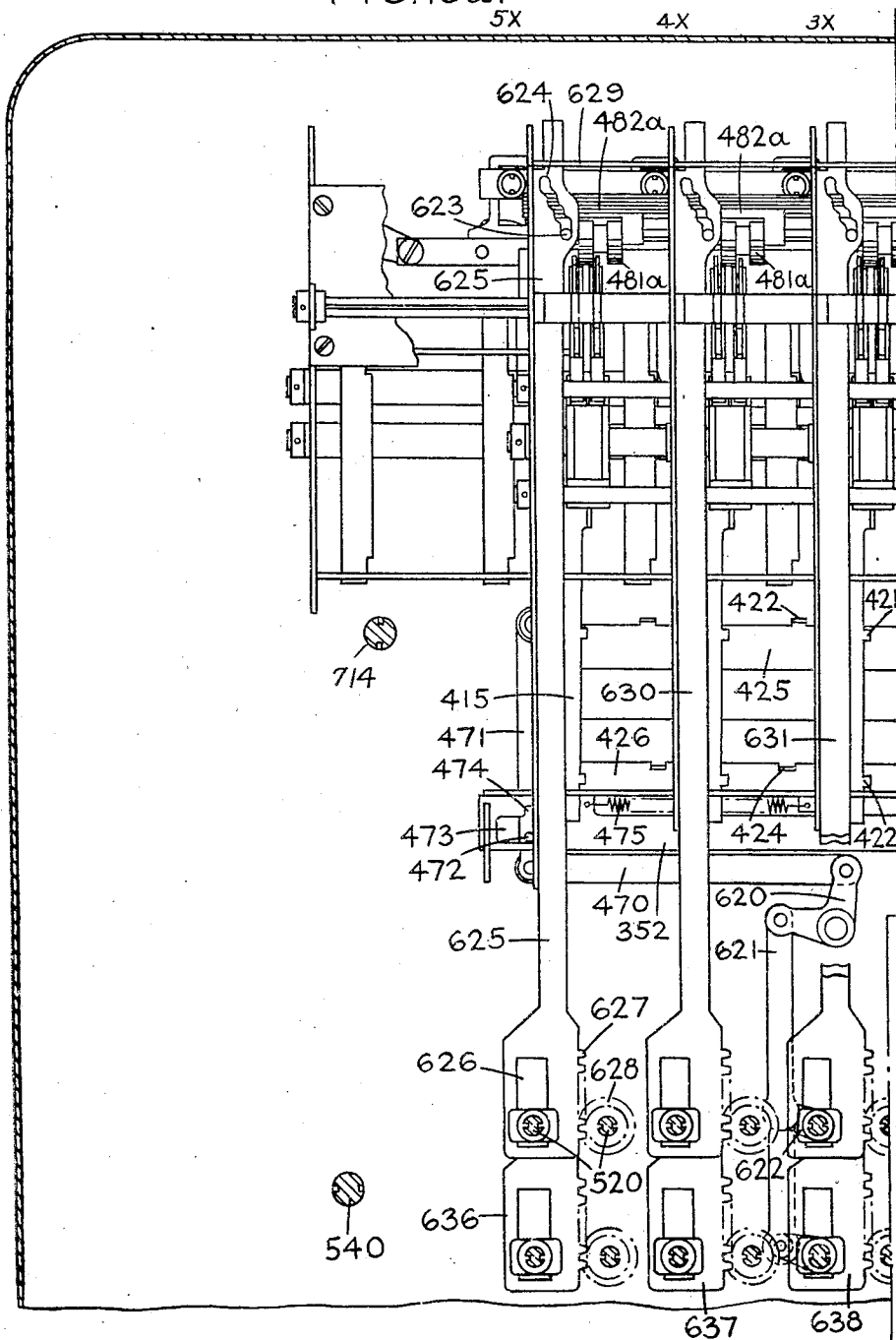
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FIG. 18a.



Thomas W. Chick
By
W. M. H. Allen
Att'y.

Oct. 6, 1942.

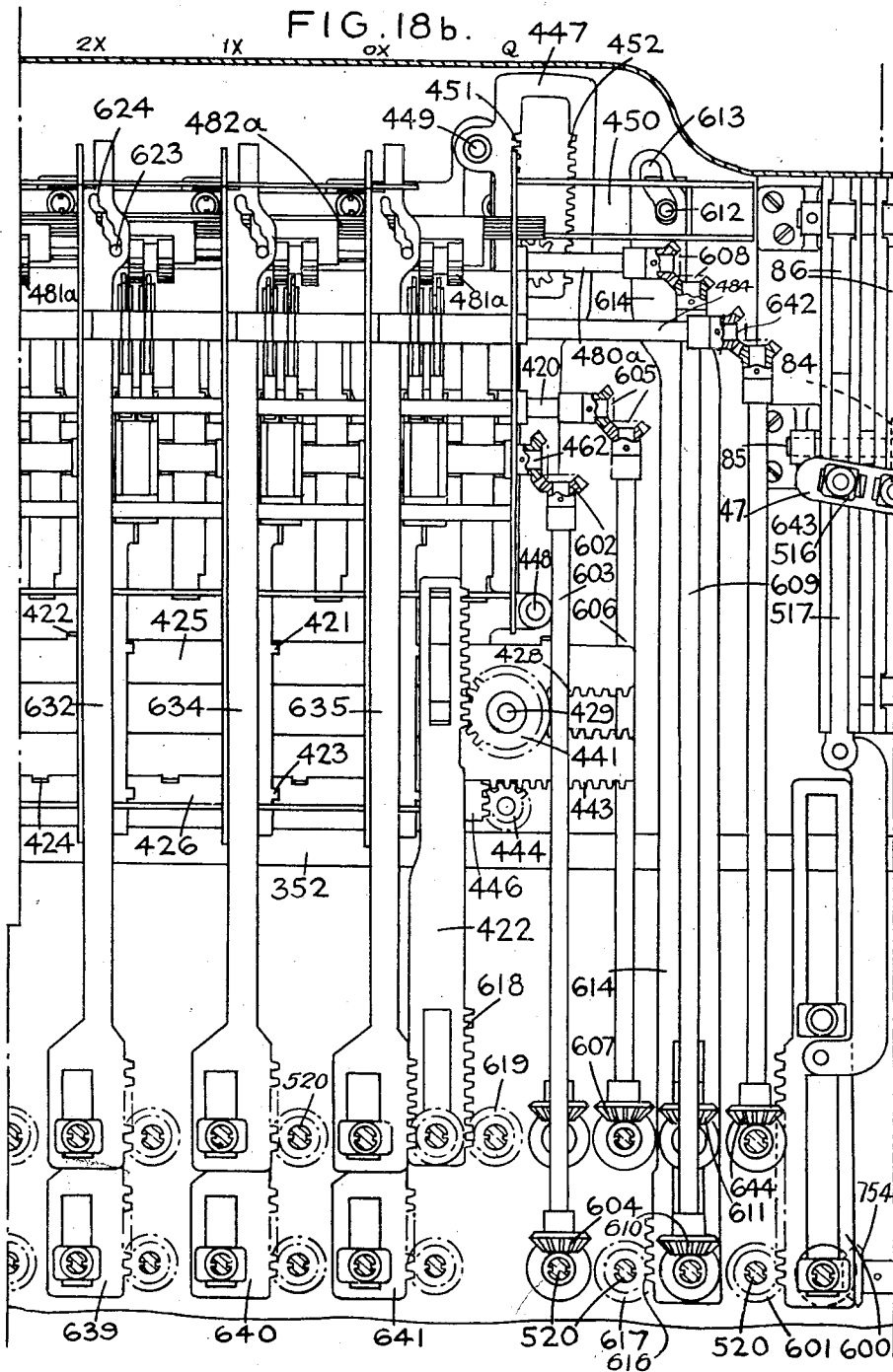
T. W. CHICK

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Thomas W. Chick
By
W. M. Mahan
ATTY.

Oct. 6, 1942.

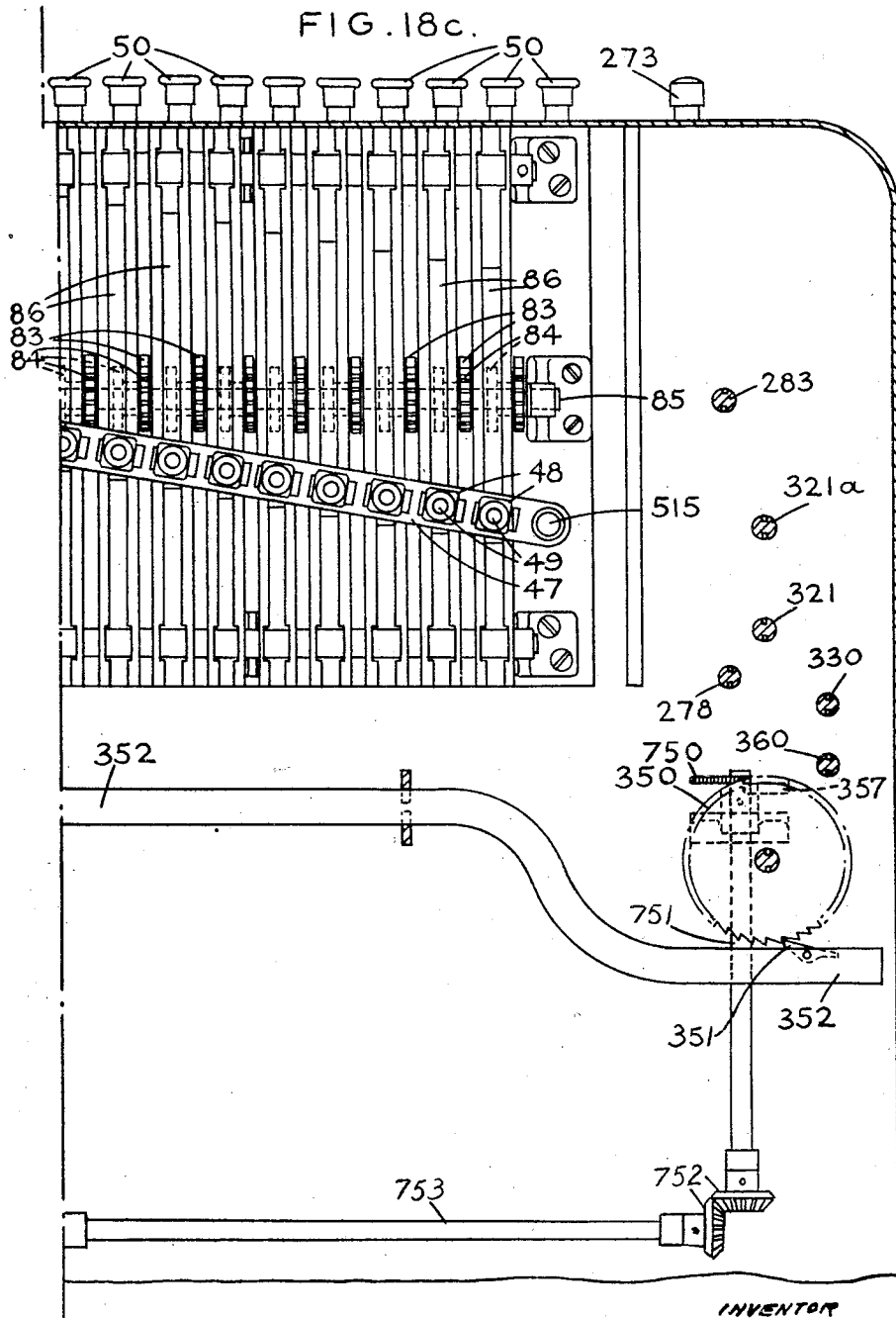
T. W. CHICK

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82 Sheets-Sheet 17



INVENTOR

Thomas W. Chick
by
Wm. W. Chick

Oct. 6, 1942.

T. W. CHICK

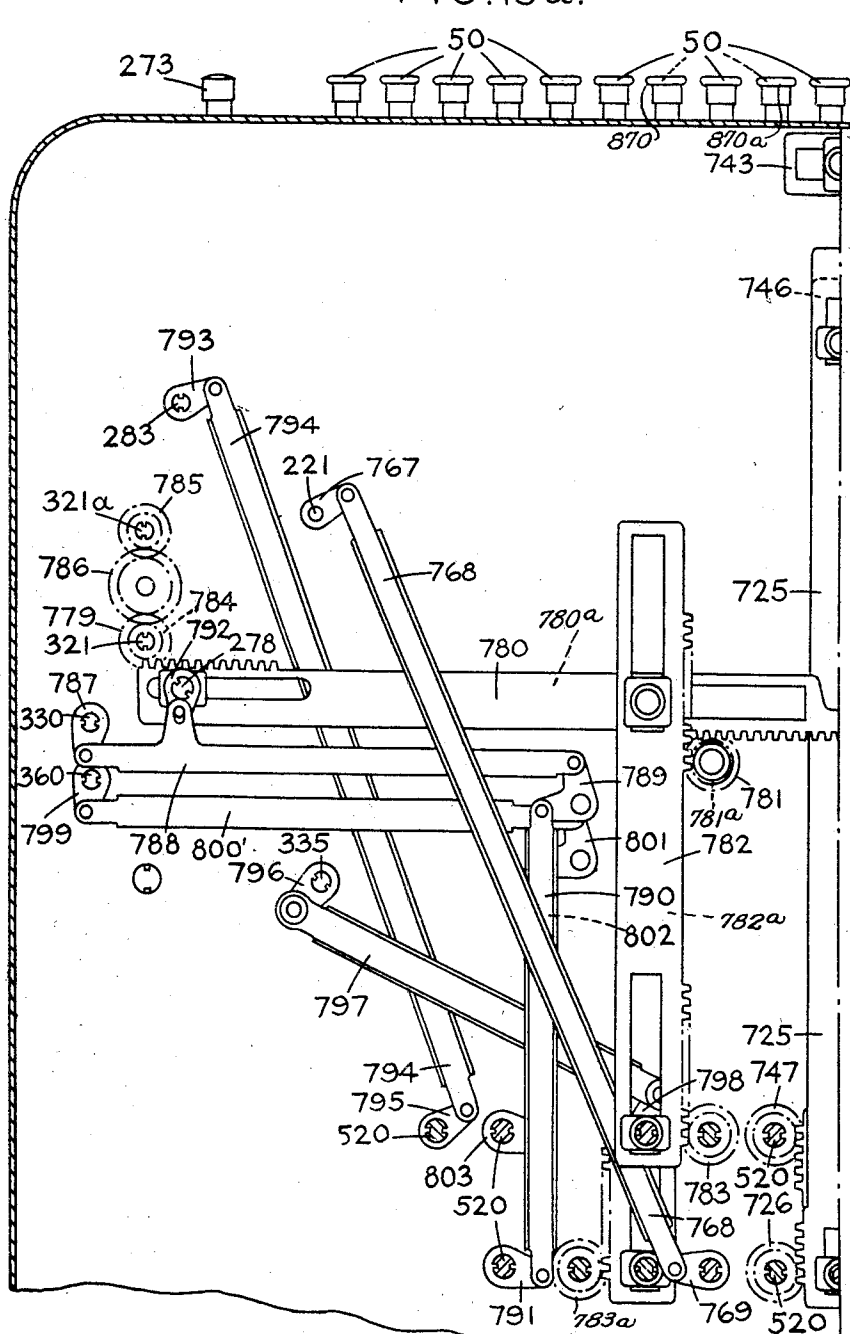
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FIG. 19a.



INVENTOR

Thomas W. Chick
by
Wm Wilson
atty.

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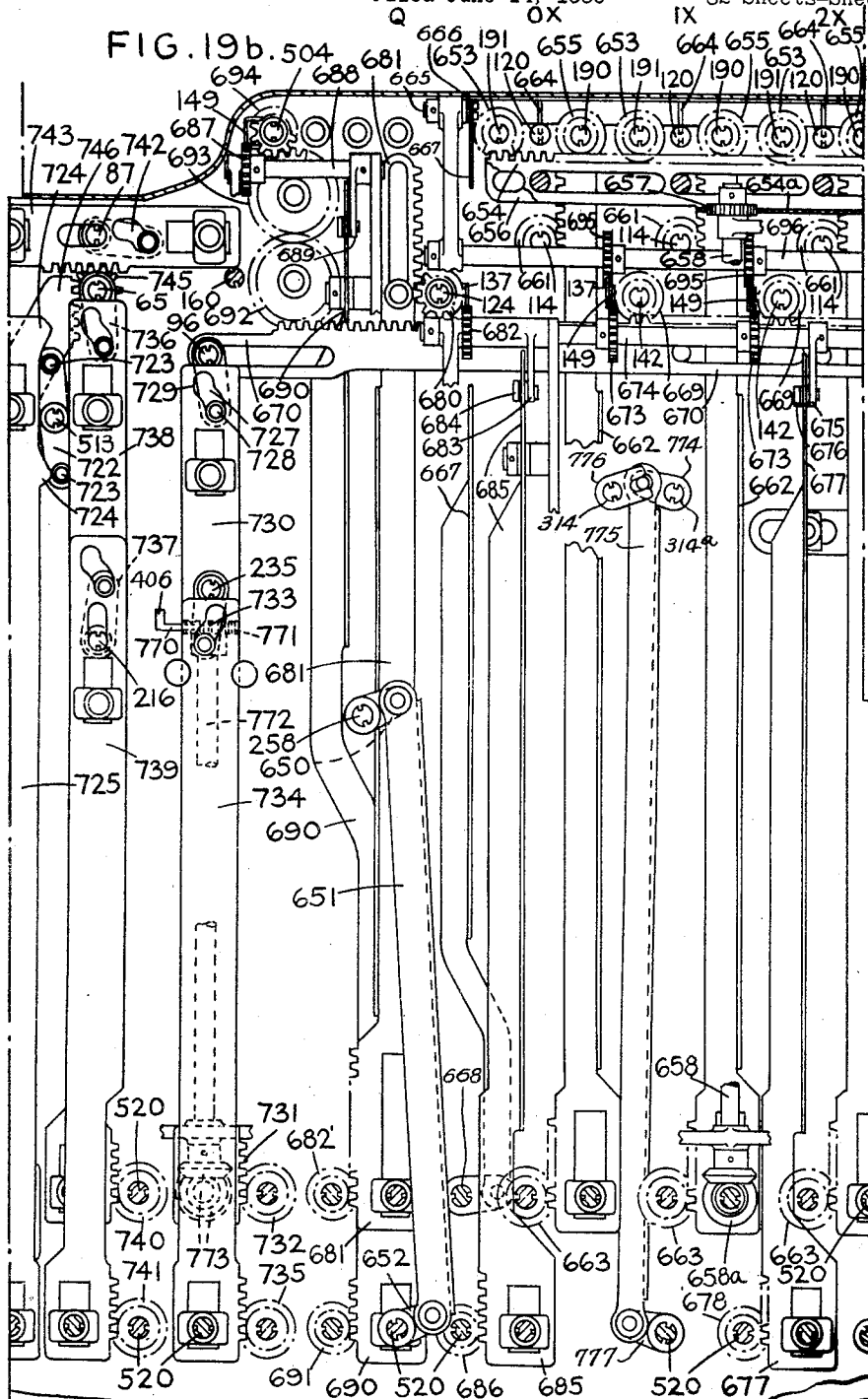
T. W. CHICK

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INVENTOR
Thomas W. Child
by
W. M. Salmon
Atty.

Oct. 6, 1942.

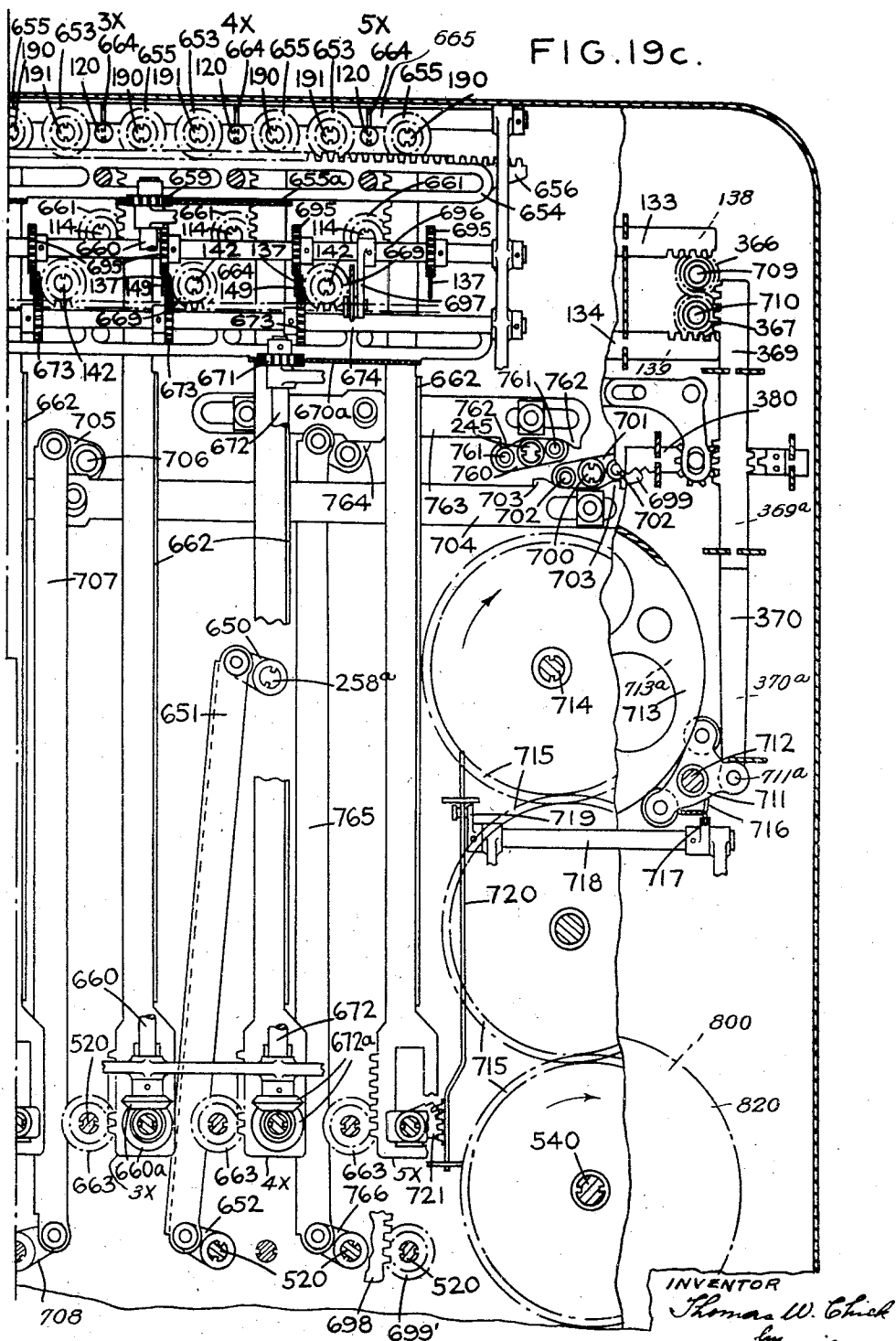
T. W. CHICK

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Oct. 6, 1942.

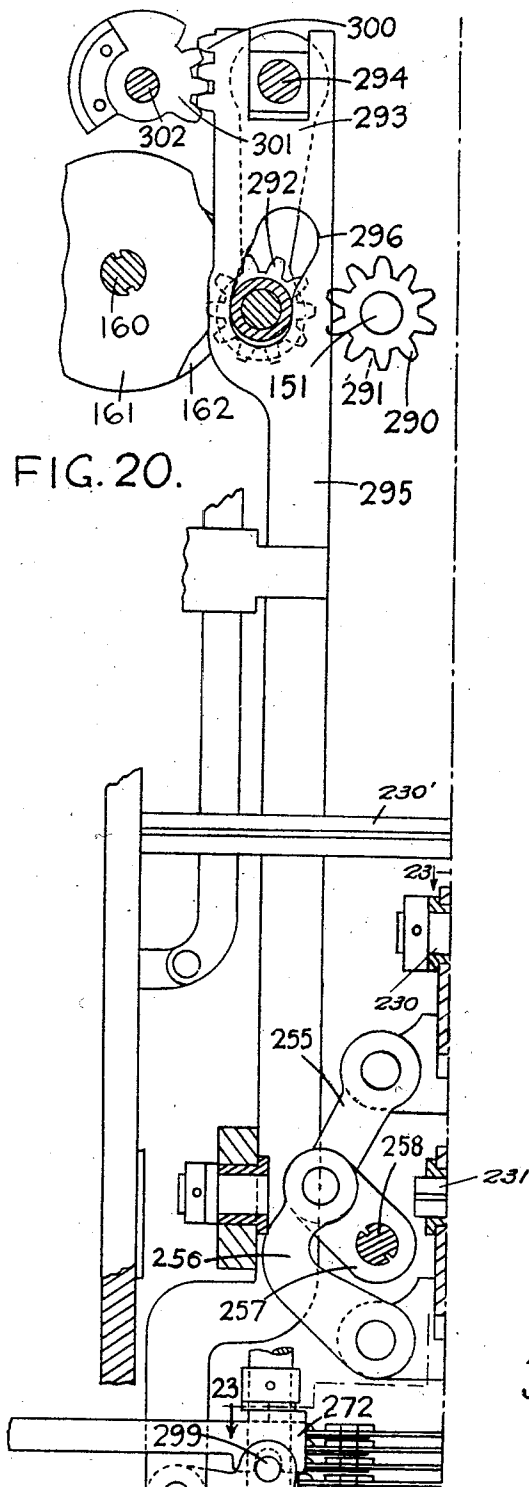
T. W. CHICK

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INVENTOR
Thomas W. Chick
by
W. W. Johnson
Atty.

Oct. 6, 1942.

T. W. CHICK

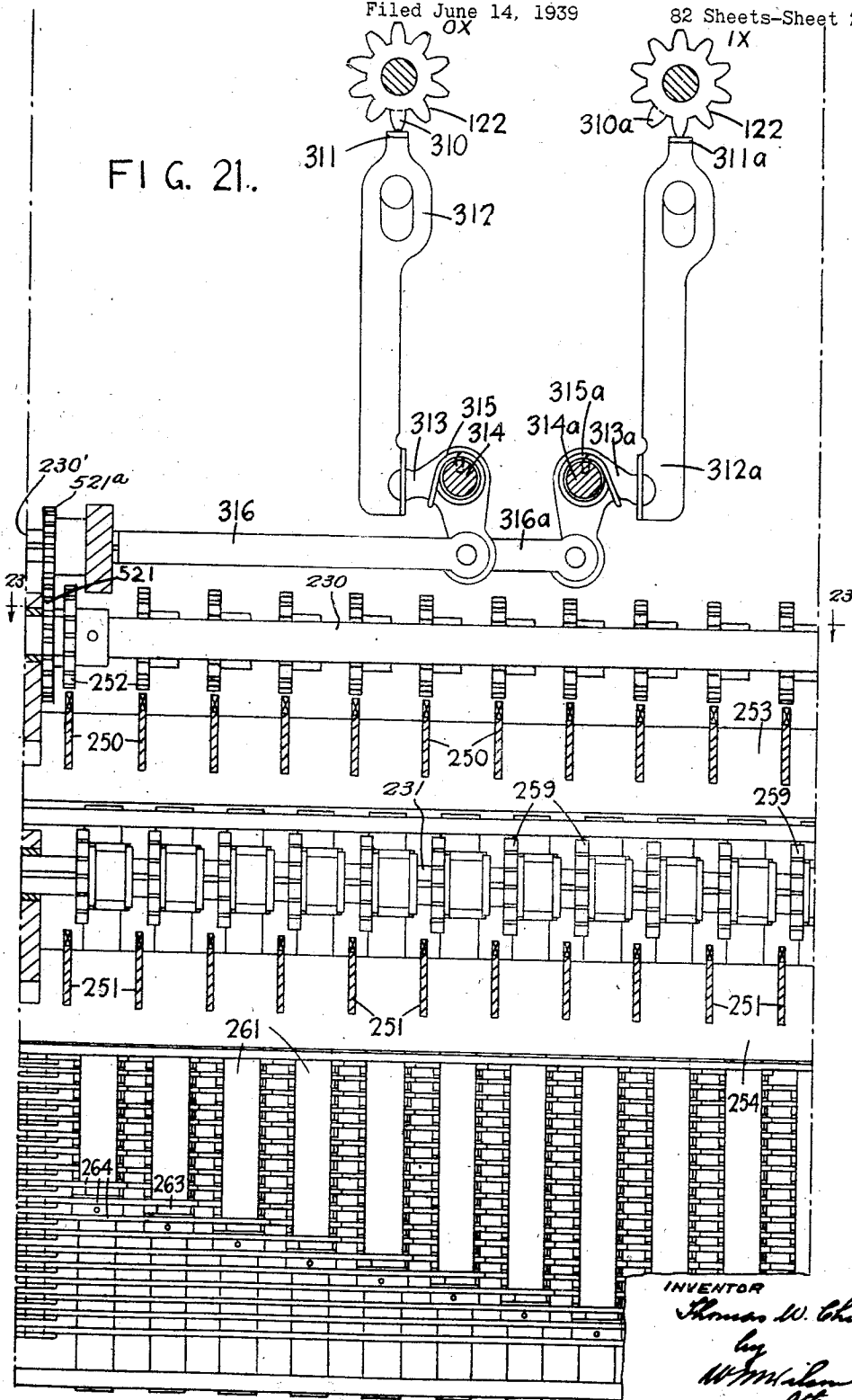
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FIG. 21.



INVENTOR
Thomas W. Chick
by
W. M. H. Allen
Att.

Oct. 6, 1942.

T. W. CHICK

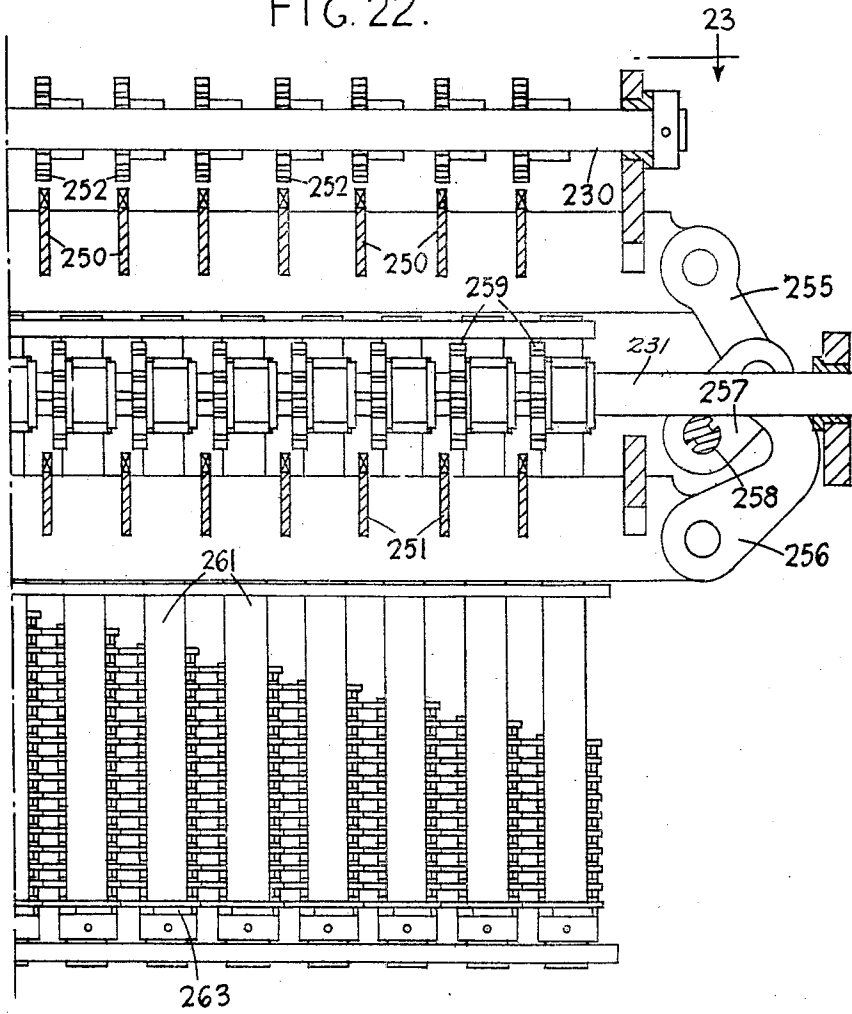
2,298,263

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FIG. 22.



INVENTOR
Thomas W. Chick
by
Wm. H. H. H.
Att'y

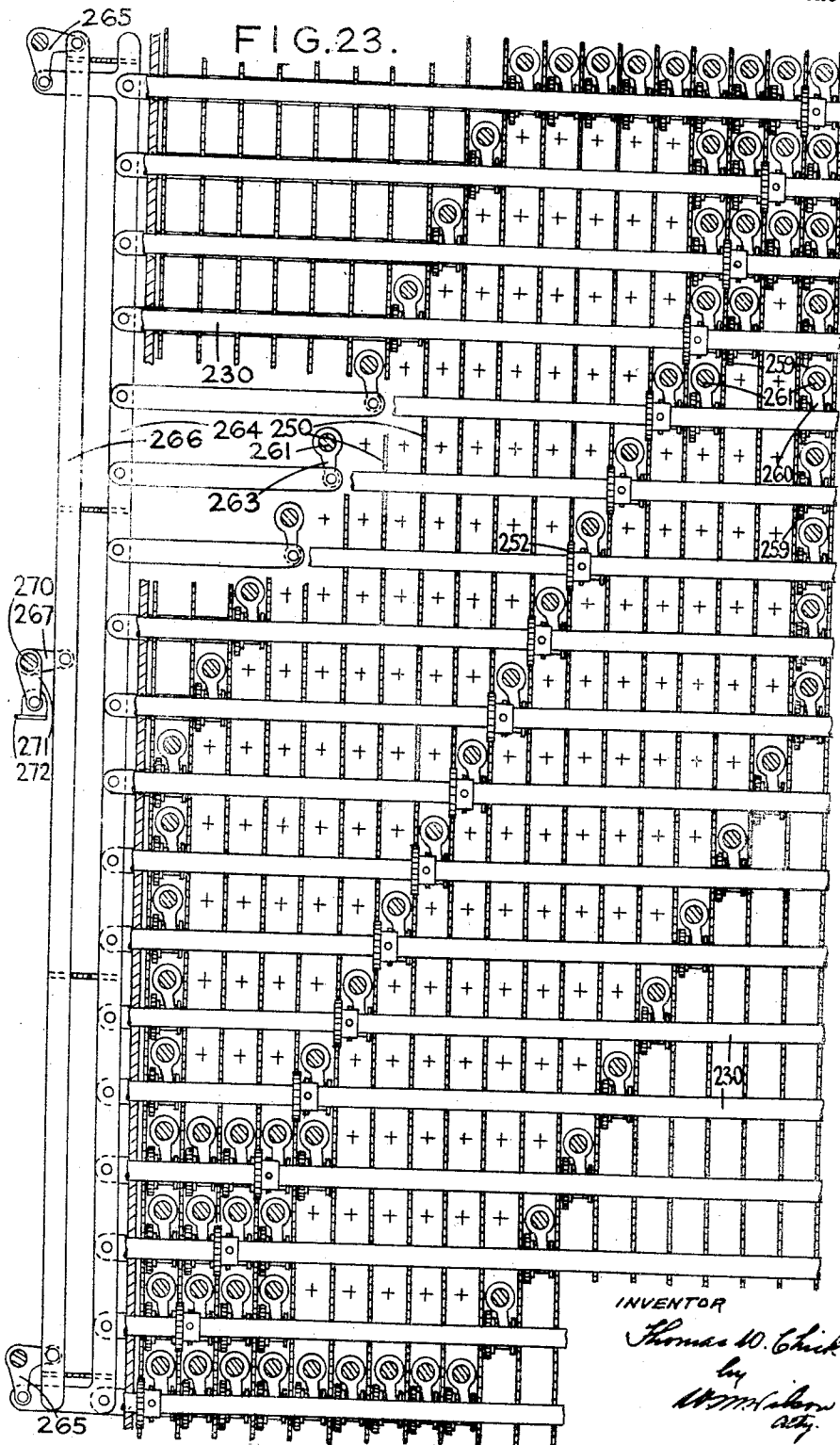
Oct. 6, 1942.

T. W. CHICK
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INVENTOR

Thomas W. Chick
by
W. M. Adams
att.

Oct. 6, 1942.

T. W. CHICK

2,298,263

CALCULATING MACHINE

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82 Sheets-Sheet 25

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer SX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 4X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 3X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 2X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 1X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" OX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Keyboard entry	0	0	0	0	1	4	9	8	0	0	0	0	0	0	0	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9

Fig. 24a

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer SX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 4X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 3X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 2X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 1X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" OX	0	0	0	0	1	4	9	8	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Keyboard entry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9

Fig. 24b

INVENTOR
Thomas W. Chick

BY

W. M. Wilson
ATTORNEY

Oct. 6, 1942.

T. W. CHICK

2,298,263

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Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	5	8	0	0	0	0	0	9	9	0	0	0	
" 4X	9	9	9	9	9	9	7	2	0	0	0	0	0	6	6	0	0	0	
" 3X	9	9	9	9	9	9	8	6	0	0	0	0	0	6	6	0	0	0	
" 2X	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	
" 1X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 0X	0	0	0	0	1	4	9	8	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Keyboard entry	0	0	0	0	0	0	1	4	0	0	0	0	0	3	3	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9

FIG. 24.f

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	4	4	0	0	0	0	1	3	2	0	0	0	
" 4X	9	9	9	9	9	9	5	8	0	0	0	0	0	9	9	0	0	0	
" 3X	9	9	9	9	9	9	7	2	0	0	0	0	0	6	6	0	0	0	
" 2X	9	9	9	9	9	9	8	6	0	0	0	0	0	3	3	0	0	0	
" 1X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 0X	0	0	0	0	1	4	9	8	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Keyboard entry	0	0	0	0	0	0	1	4	0	0	0	0	0	3	3	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9

FIG. 24.g

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	3	0	0	0	0	0	1	6	5	0	0	0	
" 4X	9	9	9	9	9	9	4	4	0	0	0	0	1	3	2	0	0	0	
" 3X	9	9	9	9	9	9	5	8	0	0	0	0	0	9	9	0	0	0	
" 2X	9	9	9	9	9	9	7	2	0	0	0	0	0	6	6	0	0	0	
" 1X	9	9	9	9	9	9	8	6	0	0	0	0	0	3	3	0	0	0	
" 0X	0	0	0	0	1	4	9	8	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Keyboard entry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9

FIG. 24.h

INVENTOR
Thomas W. Chick

BY

W. M. Wilson
ATTORNEY

Oct. 6, 1942.

T. W. CHICK

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Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 4X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 3X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 2X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 1X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section.	0	0	0	0	1	4	9	8	0	0	0	0	0	0	0	0	0	0	
Column-shift adjustment.	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9
					R										L				

Z + - Z + -
Z + - Z + -
Z + -
(1:) 2:

Fig. 25a

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	3	0	0	0	0	0	1	6	5	0	0	0	
" 4X	9	9	9	9	9	9	4	4	0	0	0	0	1	3	2	0	0	0	
" 3X	9	9	9	9	9	9	5	8	0	0	0	0	0	9	9	0	0	0	
" 2X	9	9	9	9	9	9	7	2	0	0	0	0	0	6	6	0	0	0	
" 1X	9	9	9	9	9	9	8	6	0	0	0	0	0	3	3	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section.	0	0	0	0	1	4	9	8	0	0	0	0	0	0	0	0	0	0	
Column-shift adjustment.	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9
					R										L				

Z + - Z + -
Z + - Z + -
Z + -
(1:) 2:

Fig. 25b

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	4	4	9	8	0	0	1	6	5	0	0	0	
" 4X	9	9	9	9	9	9	5	8	9	8	0	0	1	3	2	0	0	0	
" 3X	9	9	9	9	9	9	7	2	9	8	0	0	0	9	9	0	0	0	
" 2X	9	9	9	9	9	9	8	6	9	8	0	0	0	6	6	0	0	0	
" 1X	0	0	0	0	0	0	0	9	8	0	0	0	0	3	3	0	0	0	
" 0X	0	0	0	0	0	0	1	4	9	8	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Column-shift adjustment.	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9
					R										L				

Z + - Z + -
Z + - Z + -
Z + -
1: 2:

Fig. 25c

BY

INVENTOR *Thomas W. Chick*
W. M. Mason ATTORNEY

Oct. 6, 1942.

T. W. CHICK

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Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 4X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 3X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 2X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 1X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
Quotient place								↑											
Split position								*											
Registration in keyboard section.	0	0	0	0	0	0	9	8	0	0	0	3	3	0	0	0	0	0	
Column-shift adjustment.	9	8	7	6	5	4	3	<u>2</u>	1	N	1	2	3	4	5	6	7	8	9
							R							L					

$\div$
 $Z \div - Z \div -$
 $Z + - Z (+) -$
 $Z (+) -$
 $1\div (2\div)$

FIG. 25d

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	3	0	0	0	0	0	1	6	5	0	0	0	
" 4X	9	9	9	9	9	9	4	4	0	0	0	0	1	3	2	0	0	0	
" 3X	9	9	9	9	9	9	5	8	0	0	0	0	0	9	9	0	0	0	
" 2X	9	9	9	9	9	9	7	2	0	0	0	0	0	0	6	6	0	0	
" 1X	9	9	9	9	9	9	8	6	0	0	0	0	0	3	3	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
Quotient place								↑											
Split position								*											
Registration in keyboard section.	0	0	0	0	0	0	9	8	0	0	0	3	3	0	0	0	0	0	
Column-shift adjustment.	9	8	7	6	5	4	3	<u>2</u>	1	N	1	2	3	4	5	6	7	8	9
							R							L					

$\div$
 $Z \div - Z \div -$
 $Z + - Z (+) -$
 $Z (+) -$
 $1\div (2\div)$

FIG. 25e

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	3	9	8	0	0	0	4	9	5	0	0	0	
" 4X	9	9	9	9	9	9	5	3	8	0	0	0	4	6	2	0	0	0	
" 3X	9	9	9	9	9	9	6	7	8	0	0	0	4	2	9	0	0	0	
" 2X	9	9	9	9	9	9	8	1	8	0	0	0	3	9	6	0	0	0	
" 1X	9	9	9	9	9	9	5	8	0	0	0	0	3	6	3	0	0	0	
" 0X	0	0	0	0	0	0	0	9	8	0	0	0	3	3	0	0	0	0	
" Q	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
Quotient place								↑											
Split position								*											
Registration in keyboard section.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Column-shift adjustment.	9	8	7	6	5	4	3	<u>2</u>	1	N	1	2	3	4	5	6	7	8	9
							R							L					

$\div$
 $Z \div - Z \div -$
 $Z + - Z (+) -$
 $Z (+) -$
 $1\div (2\div)$

FIG. 25f

INVENTOR Thomas W. Chick

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Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 4X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 3X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 2X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 1X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section	0	0	0	0	0	0	9	8	0	0	0	3	3	0	0	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9

$\frac{1}{2}$ $\frac{1}{2}$
 $Z + -$ $Z + -$
 $Z (+) -$ $Z (+) -$
 $1\frac{1}{2}$ $(2\frac{1}{2})$

FIG. 25g

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	3	0	0	0	0	0	1	6	5	0	0	0	
" 4X	9	9	9	9	9	9	4	4	0	0	0	0	1	3	2	0	0	0	
" 3X	9	9	9	9	9	9	5	8	0	0	0	0	0	9	9	0	0	0	
" 2X	9	9	9	9	9	9	7	2	0	0	0	0	0	6	6	0	0	0	
" 1X	9	9	9	9	9	9	8	6	0	0	0	0	0	3	3	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section	0	0	0	0	0	0	9	8	0	0	0	3	3	0	0	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9

$\frac{1}{2}$ $\frac{1}{2}$
 $Z + -$ $Z + -$
 $Z (+) -$ $Z (+) -$
 $1\frac{1}{2}$ $(2\frac{1}{2})$

FIG. 25h

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	0	0	0	0	0	0	2	8	0	0	0	3	4	6	5	0	0	0	
" 4X	0	0	0	0	0	0	4	2	0	0	0	3	4	3	2	0	0	0	
" 3X	0	0	0	0	0	0	5	6	0	0	0	3	3	9	9	0	0	0	
" 2X	0	0	0	0	0	0	7	0	0	0	0	3	3	6	6	0	0	0	
" 1X	0	0	0	0	0	0	8	4	0	0	0	3	3	3	3	0	0	0	
" 0X	0	0	0	0	0	0	9	8	0	0	0	3	3	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
Quotient entry																			
Split position																			
Registration in keyboard section	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9

$\frac{1}{2}$ $\frac{1}{2}$
 $Z + -$ $Z + -$
 $Z (+) -$ $Z (+) -$
 $1\frac{1}{2}$ $(2\frac{1}{2})$

FIG. 25i

INVENTOR

Thomas W. Chick

BY

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Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 4X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 3X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 2X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 1X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	1	0	5.0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section	0	0	0	0	0	0	2	8	0	0	0	3	4	6	5	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	<u>N</u>	1	2	3	4	5	6	7	8	9
						R													

$$\begin{array}{r} \div \\ Z + - Z + - \\ Z + - Z (+) - \\ Z (+) - \end{array}$$

$$1\frac{1}{2} \quad (2\frac{1}{2})$$

Fig. 25j

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	3	0	0	0	0	0	1	6	5	0	0	0	
" 4X	9	9	9	9	9	9	4	4	0	0	0	0	1	3	2	0	0	0	
" 3X	9	9	9	9	9	9	5	8	0	0	0	0	0	9	9	0	0	0	
" 2X	9	9	9	9	9	9	7	2	0	0	0	0	0	6	6	0	0	0	
" 1X	9	9	9	9	9	9	8	6	0	0	0	0	0	3	3	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	1	0	5.0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section	0	0	0	0	0	0	2	8	0	0	0	3	4	6	5	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	<u>N</u>	1	2	3	4	5	6	7	8	9
						R													

$$\begin{array}{r} \div \\ Z + - Z + - \\ Z + - Z (+) - \\ Z (+) - \end{array}$$

$$1\frac{1}{2} \quad (2\frac{1}{2})$$

Fig. 25k

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	5	8	0	0	0	3	6	3	0	0	0	0	
" 4X	9	9	9	9	9	9	7	2	0	0	0	3	5	9	7	0	0	0	
" 3X	9	9	9	9	9	9	8	6	0	0	0	3	5	6	4	0	0	0	
" 2X	0	0	0	0	0	0	0	0	0	0	0	3	5	3	1	0	0	0	
" 1X	0	0	0	0	0	0	1	4	0	0	0	3	4	9	8	0	0	0	
" 0X	0	0	0	0	0	0	2	8	0	0	0	3	4	6	5	0	0	0	
" Q	0	0	0	0	0	0	0	1	0	5.0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	<u>N</u>	1	2	3	4	5	6	7	8	9
						R													

$$\begin{array}{r} \div \\ Z + - Z + - \\ Z + - Z (+) - \\ Z (+) - \end{array}$$

$$1\frac{1}{2} \quad (2\frac{1}{2})$$

Fig. 25m

INVENTOR *Thomas W. Chick*

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Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 4X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 3X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 2X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 1X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	1	0	7.0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section.	0	0	0	0	0	0	0	0	0	0	0	3	5	3	1	0	0	0	
Column-shift adjustment.	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9
										R									L

$$\begin{array}{r} \div \\ Z + - \\ Z + - \\ Z (+) - \end{array} \quad \begin{array}{r} \times \\ Z + - \\ Z (+) - \\ (2\div) \end{array}$$

Fig. 25n

Column No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	3	0	0	0	0	0	1	6	5	0	0	0	
" 4X	9	9	9	9	9	9	4	4	0	0	0	0	1	3	2	0	0	0	
" 3X	9	9	9	9	9	9	5	8	0	0	0	0	0	9	9	0	0	0	
" 2X	9	9	9	9	9	9	7	2	0	0	0	0	0	6	6	0	0	0	
" 1X	9	9	9	9	9	9	8	6	0	0	0	0	0	3	3	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
" Q	0	0	0	0	0	0	0	1	0	7.0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section	0	0	0	0	0	0	0	0	0	0	0	3	5	3	1	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9
										R									L

$$\begin{array}{r} \div \\ Z + - \\ Z + - \\ Z (+) - \end{array} \quad \begin{array}{r} \times \\ Z + - \\ Z (+) - \\ (2\div) \end{array}$$

Fig. 25o

Counter No.	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
Totalizer 5X	9	9	9	9	9	9	3	0	0	0	3	5	4	7	5	0	0	0	
" 4X	9	9	9	9	9	9	4	4	0	0	3	5	4	4	2	0	0	0	
" 3X	9	9	9	9	9	9	5	8	0	0	3	5	4	0	9	0	0	0	
" 2X	9	9	9	9	9	9	7	2	0	0	3	5	3	7	6	0	0	0	
" 1X	9	9	9	9	9	9	8	6	0	0	3	5	3	4	3	0	0	0	
" 0X	0	0	0	0	0	0	0	0	0	0	3	5	3	1	0	0	0	0	
" Q	0	0	0	0	0	0	0	1	0	7.0	0	0	0	0	0	0	0	0	
Quotient place																			
Split position																			
Registration in keyboard section	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Column-shift adjustment	9	8	7	6	5	4	3	2	1	N	1	2	3	4	5	6	7	8	9
										R									L

$$\begin{array}{r} \div \\ Z + - \\ Z + - \\ Z + - \end{array} \quad \begin{array}{r} \times \\ Z + - \\ Z + - \\ 2\div \end{array}$$

Fig. 25p

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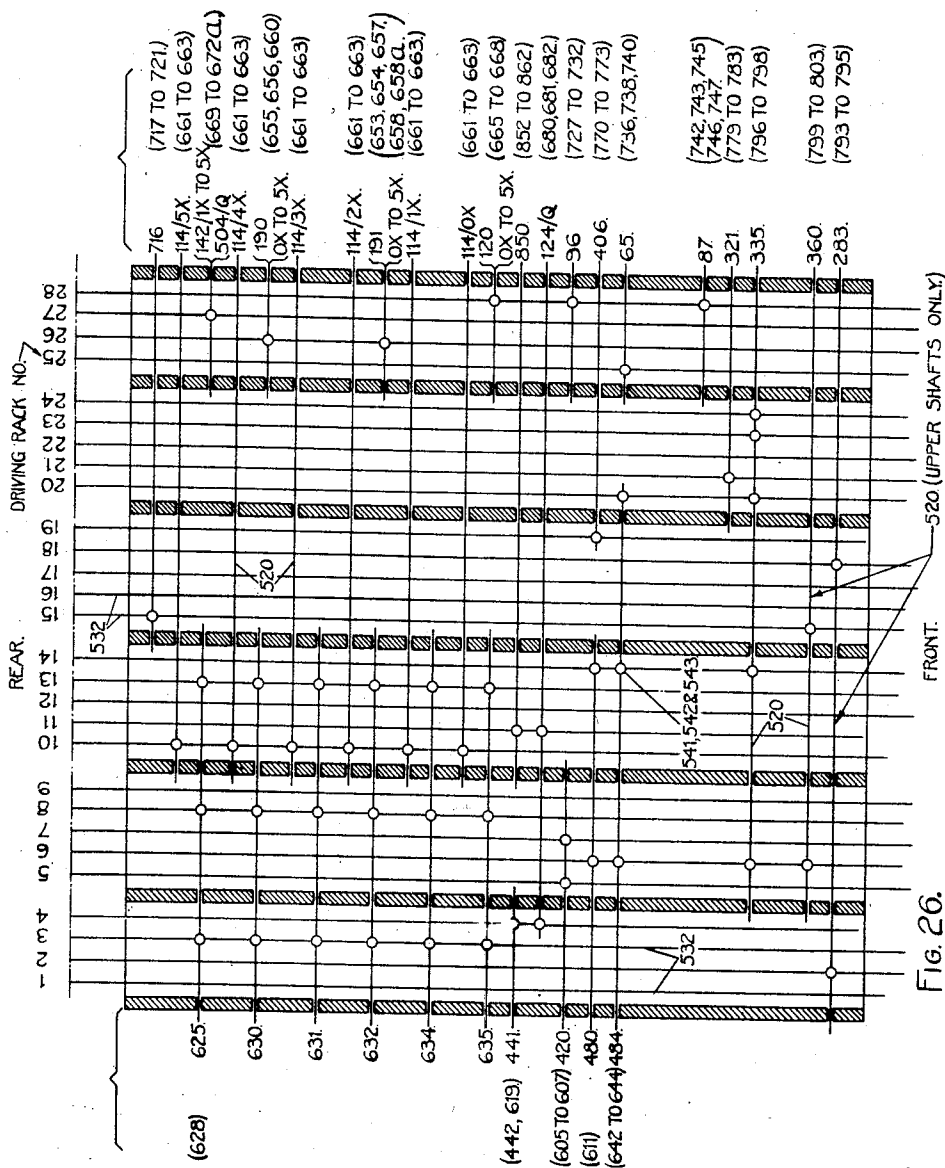
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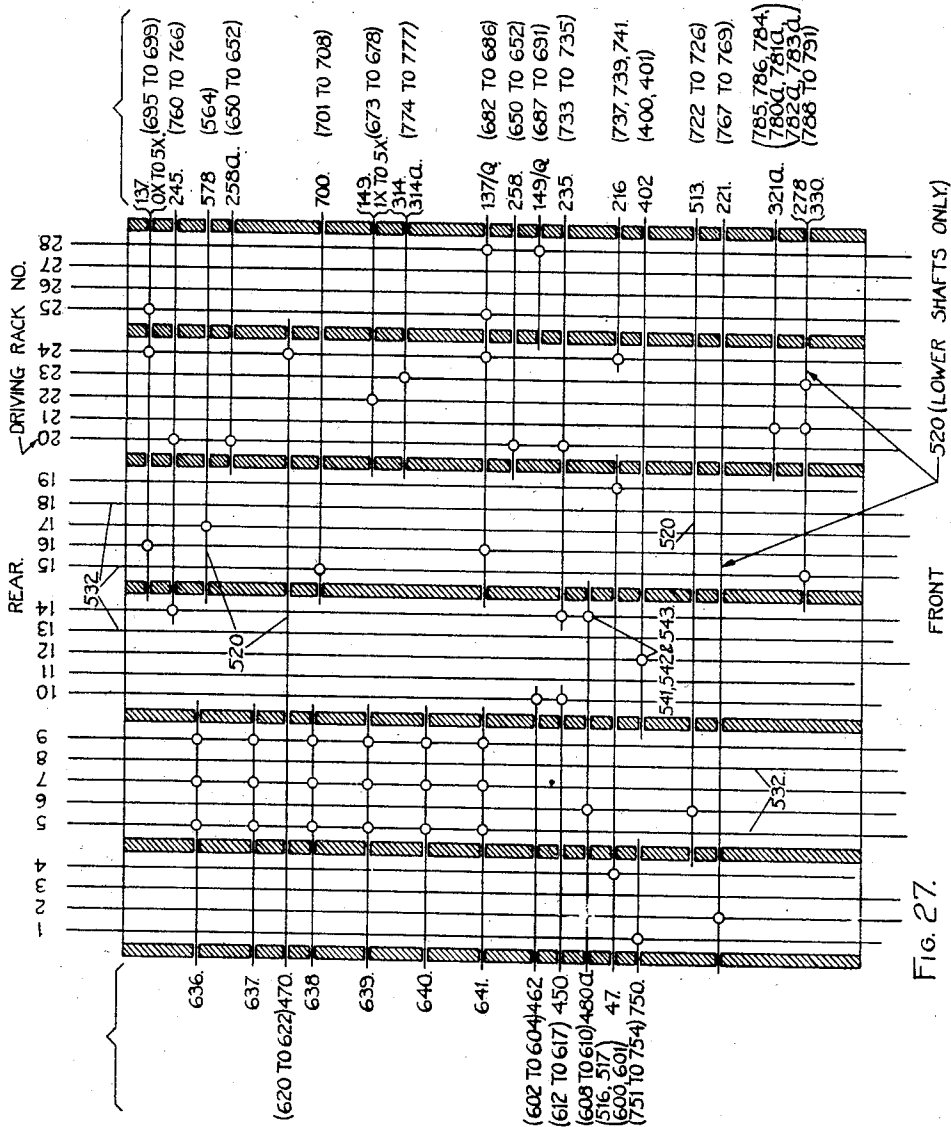
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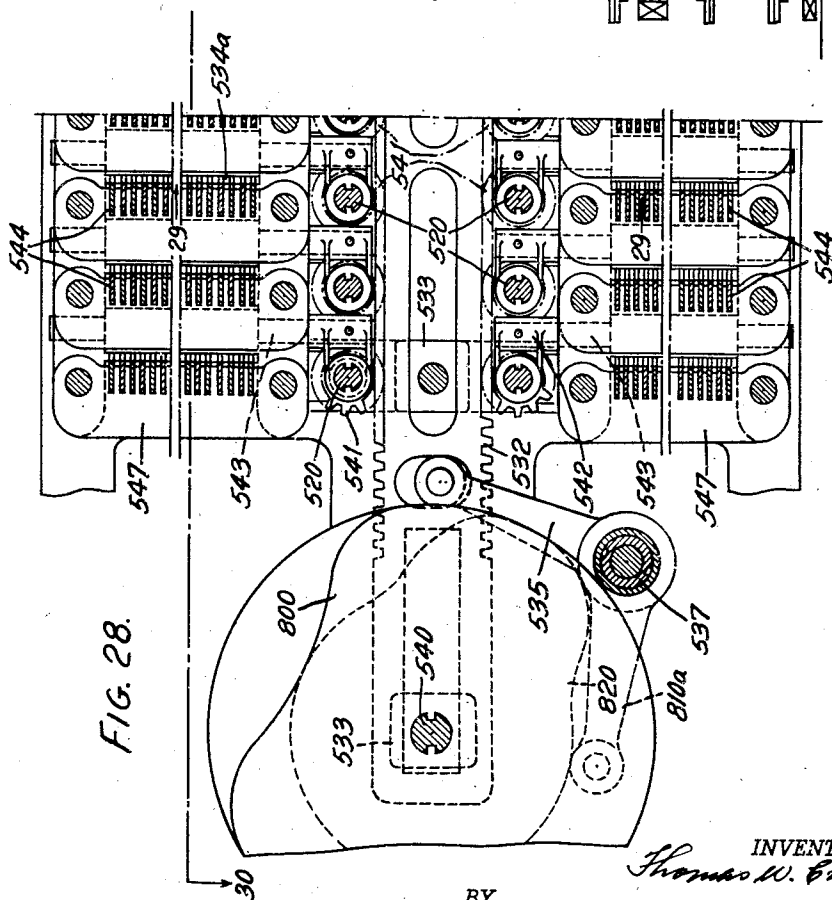
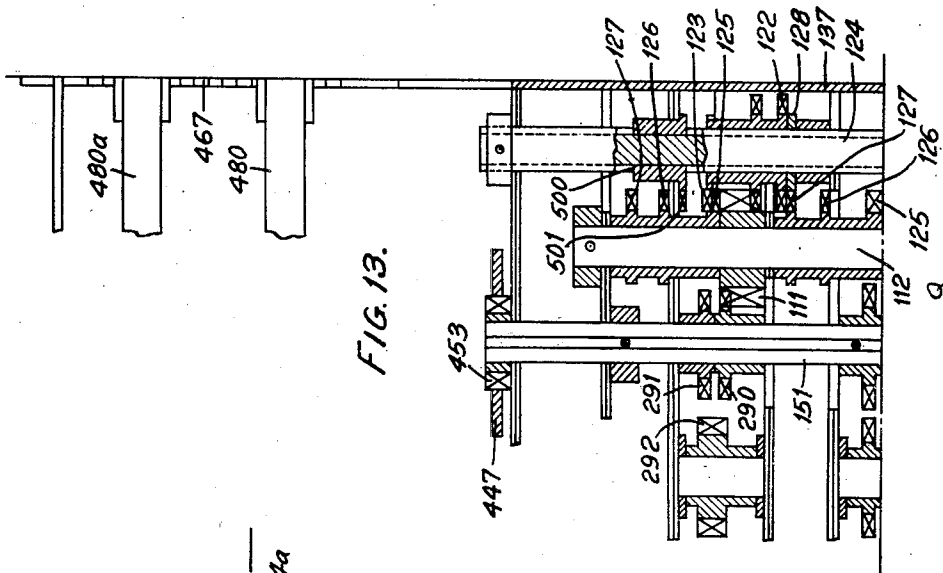
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FIG. 28^a

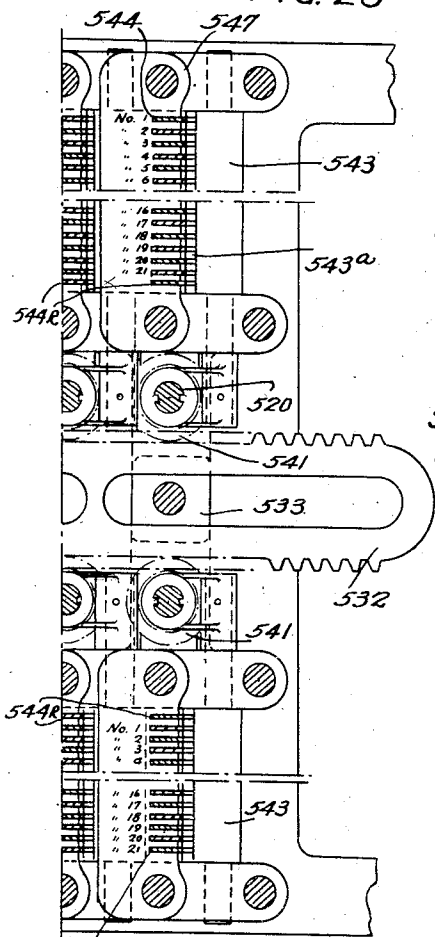


FIG. 29.

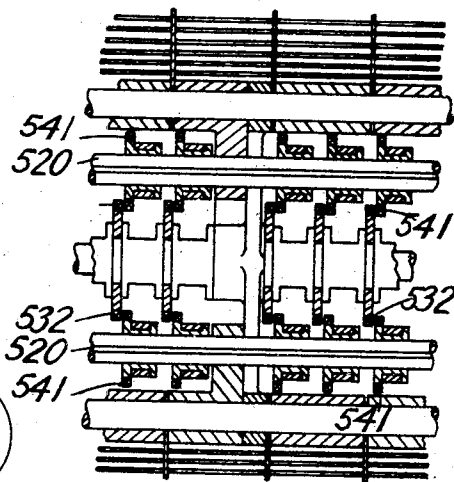
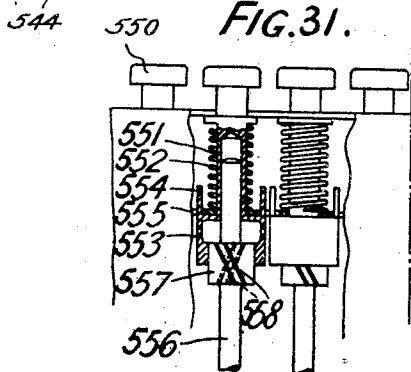


FIG. 31.



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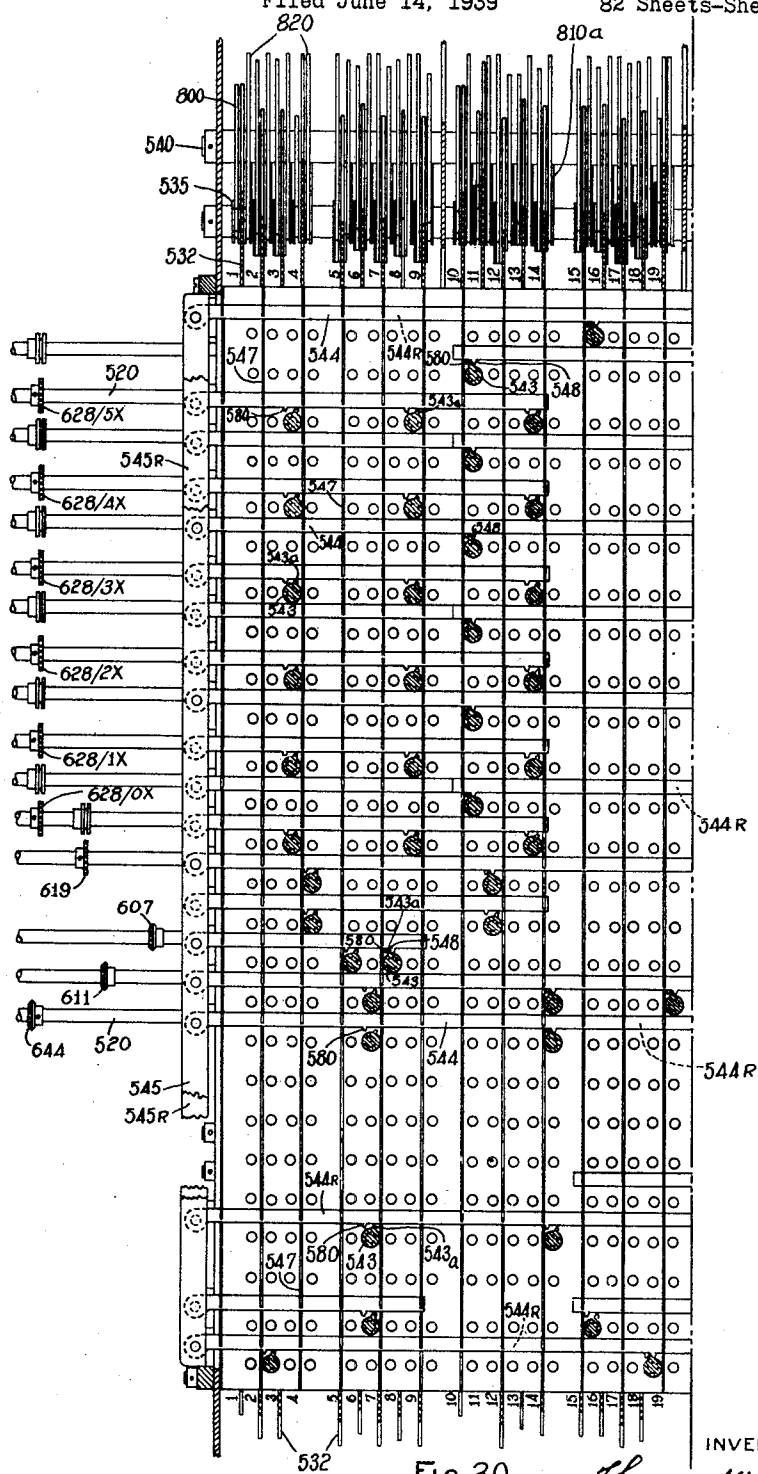


Fig. 30.

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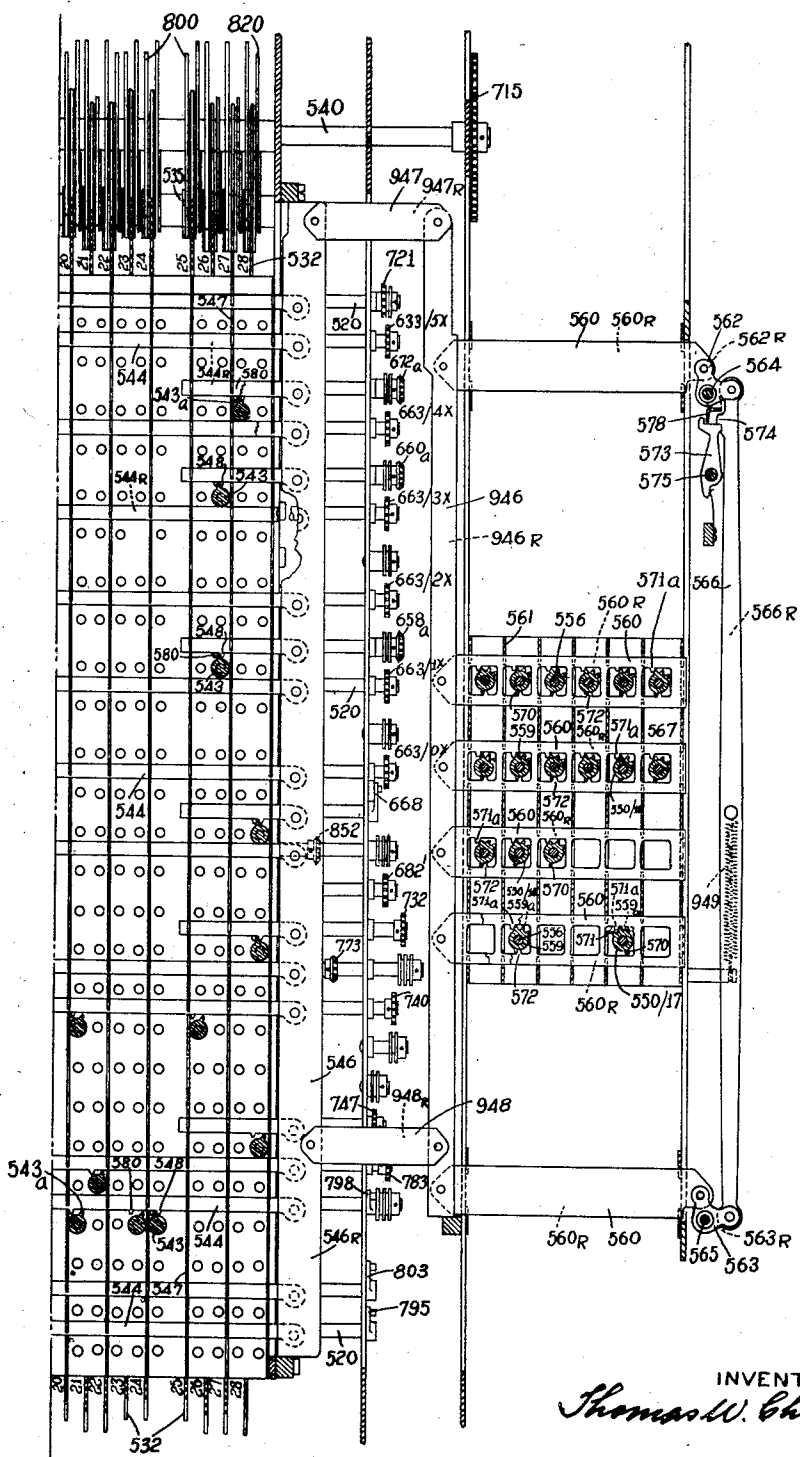


Fig. 30a.

INVENTOR
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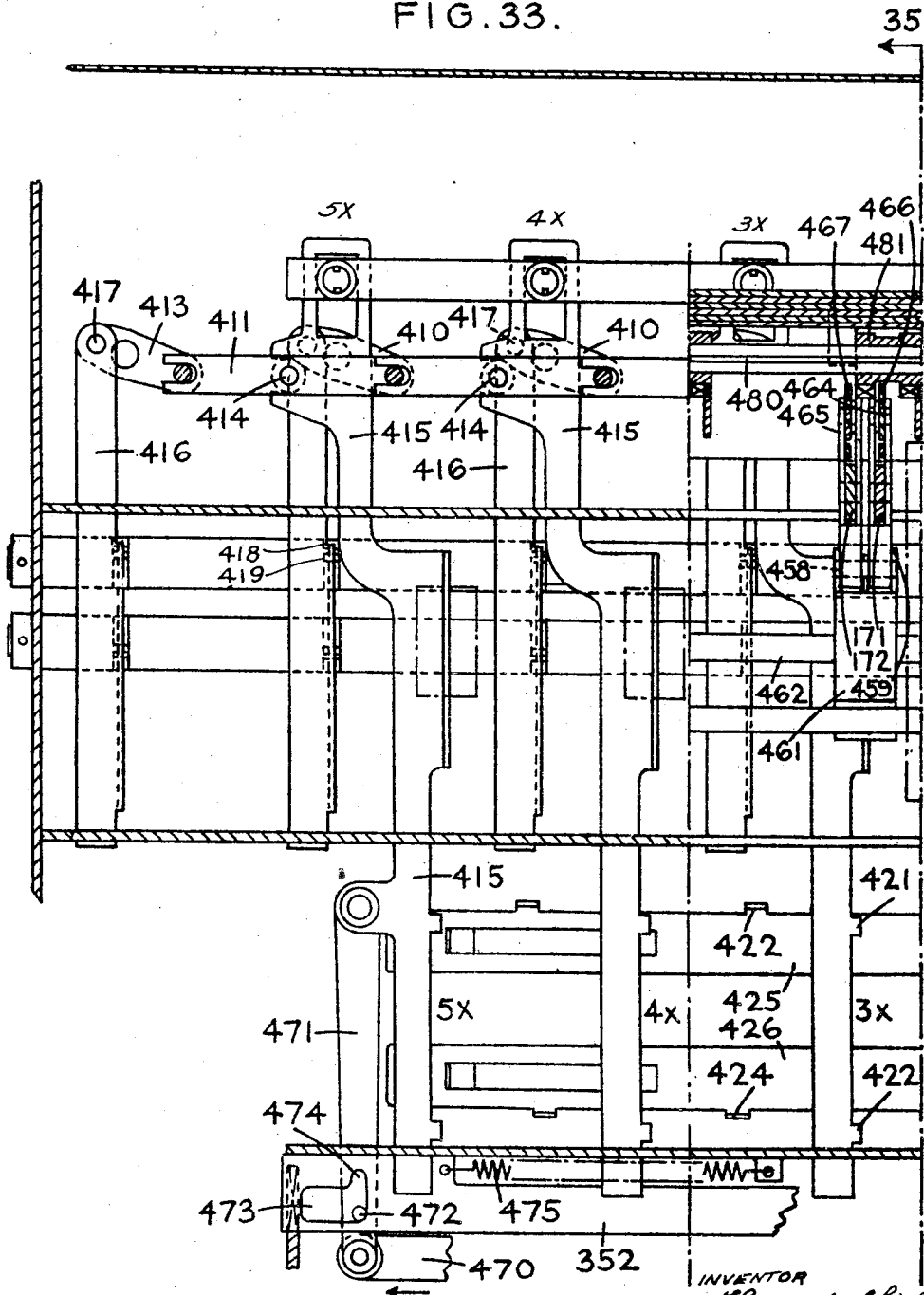
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FIG. 33.



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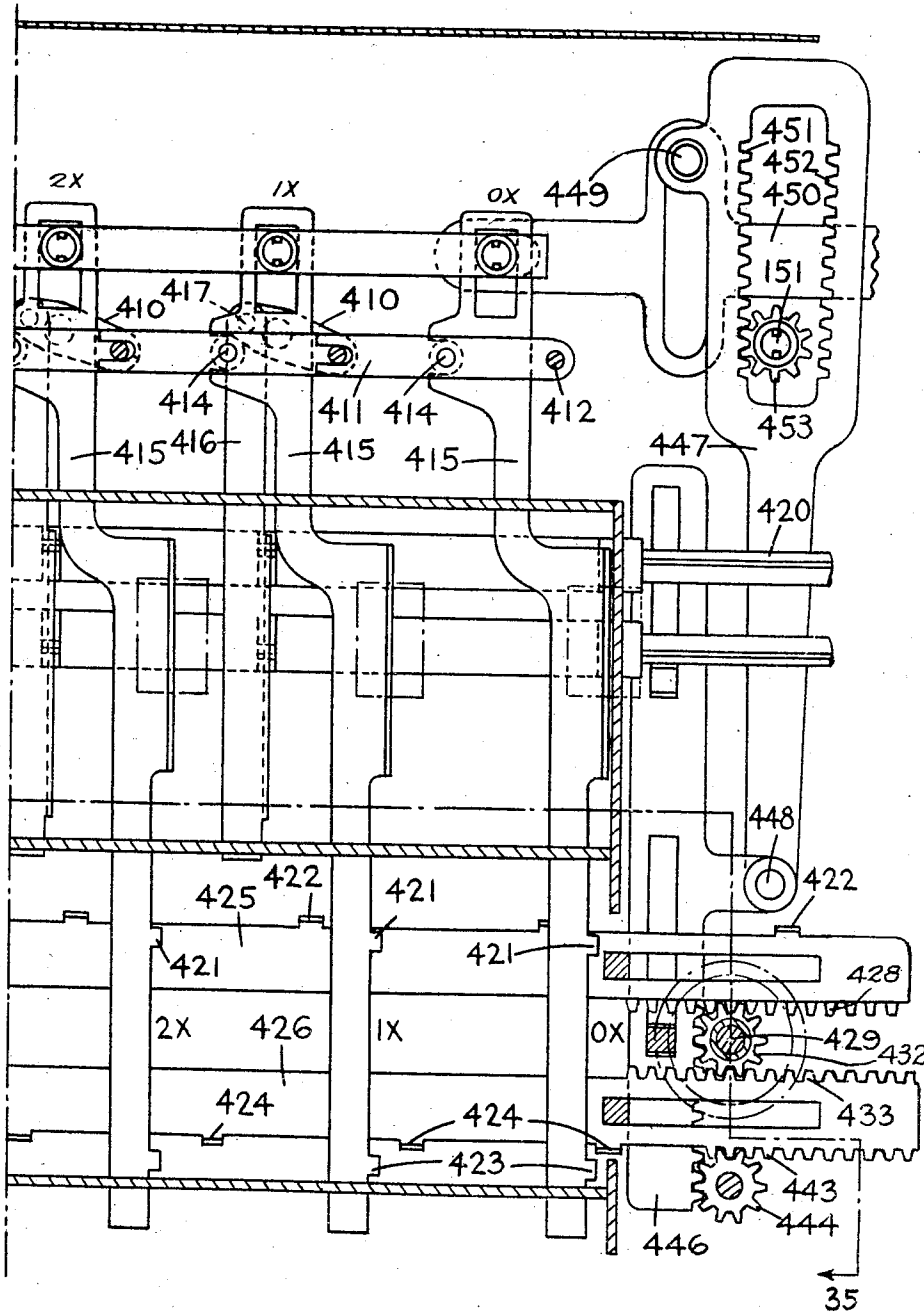
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FIG. 34.



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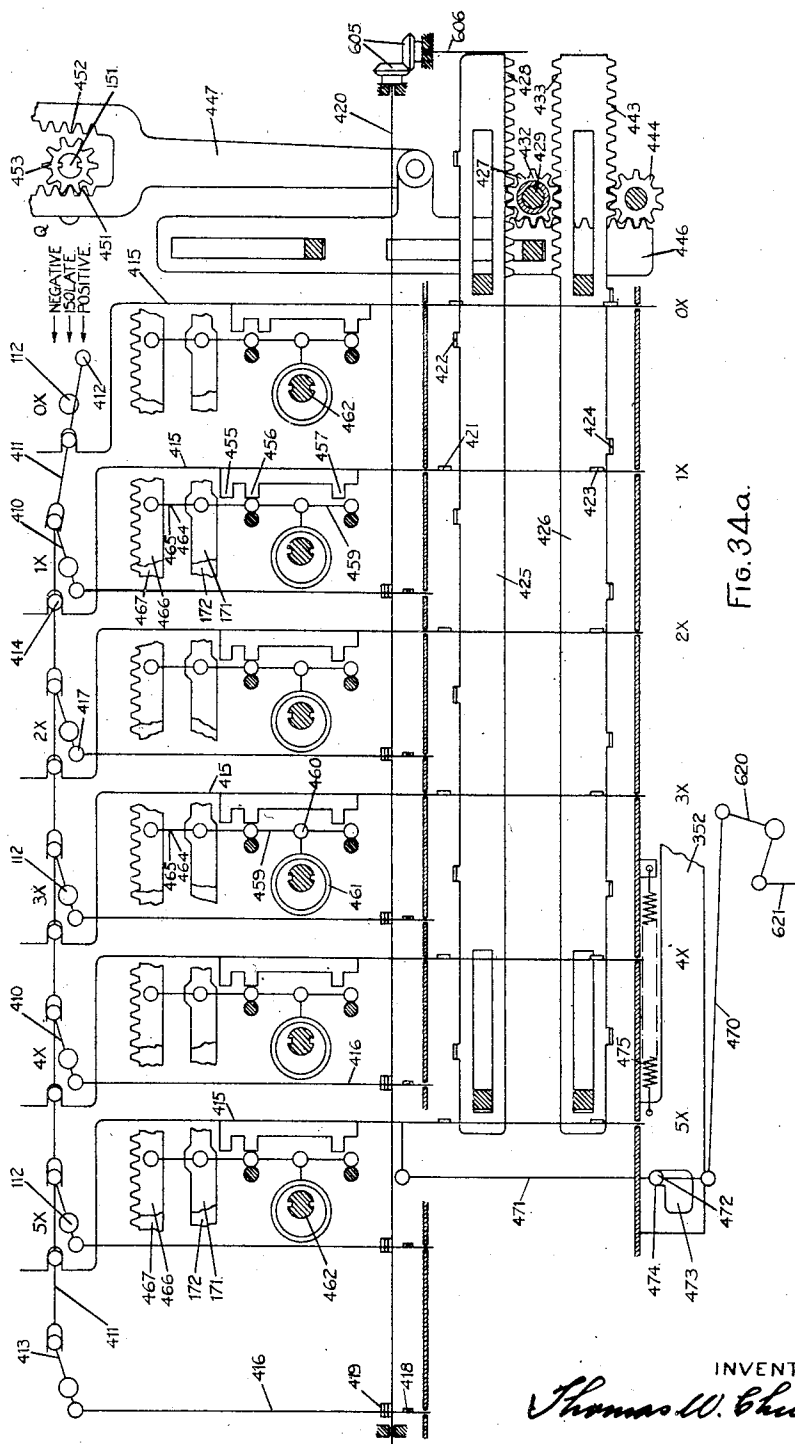
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INVENTOR
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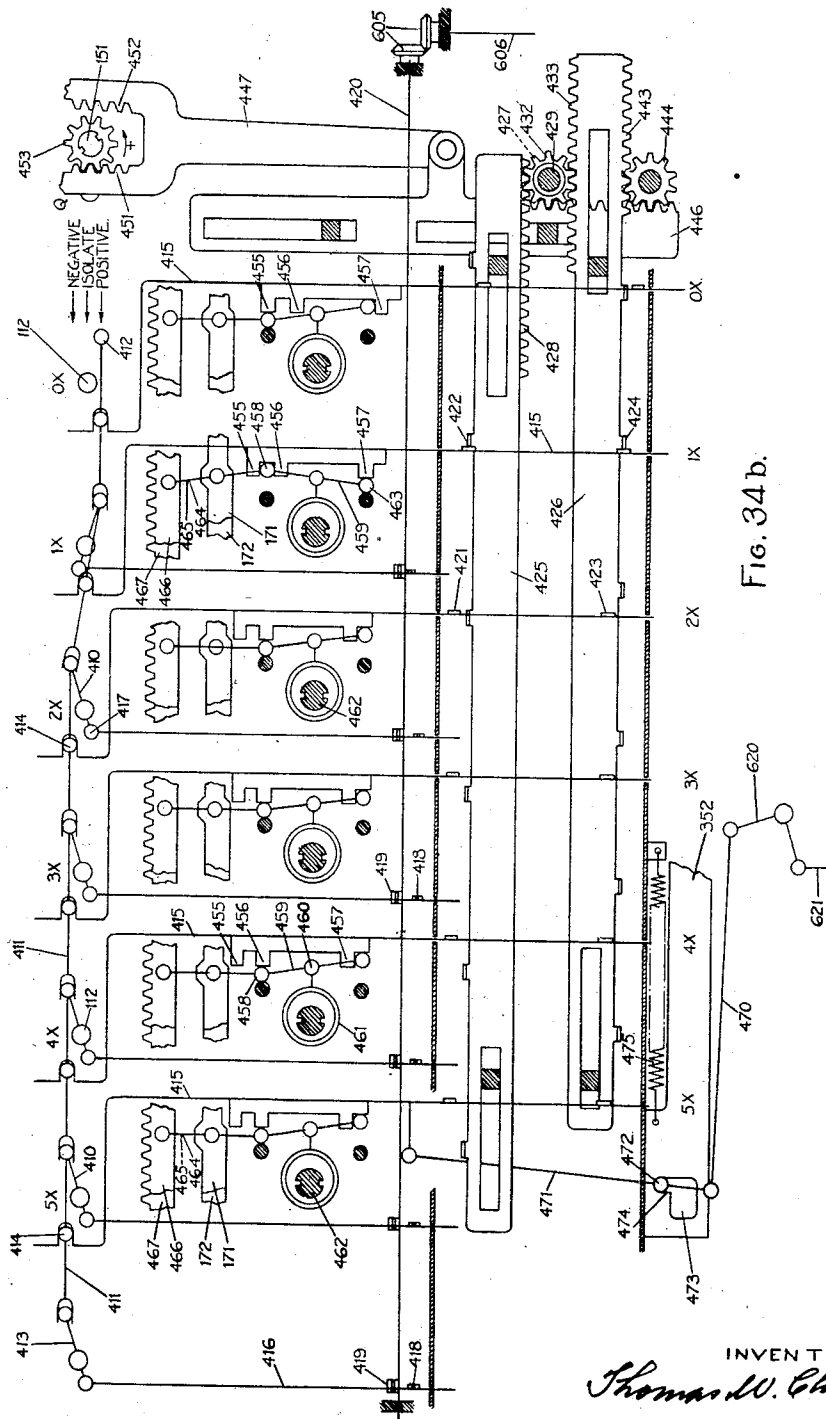


Fig. 34 b.

INVENTOR
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BY

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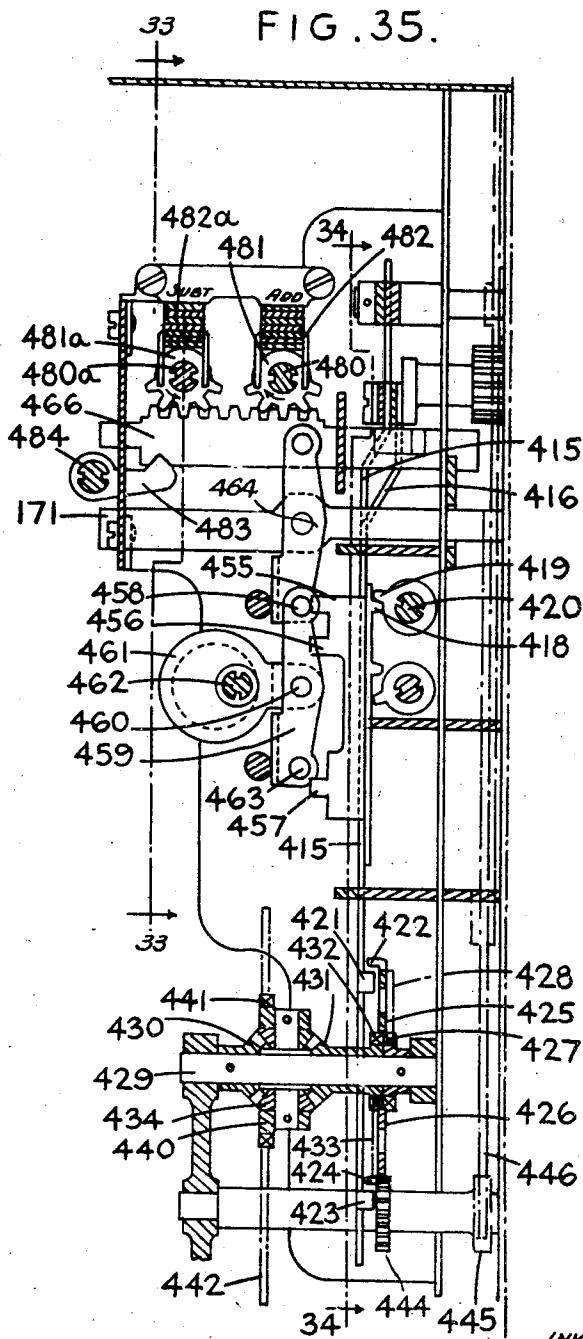
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W. M. Wilson
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Oct. 6, 1942.

T. W. CHICK

2,298,263

CALCULATING MACHINE

Filed June 14, 1939

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ZEROIZING UPPER 1X TO 5X, USING CONTROL KEY 550/1.

DRIVING RACK (1) NO. COUNTS POWER	(3) PRINCIPAL PART DRIVEN.	(4) PURPOSE.	(5) TIMING OF RACK MOVEMENTS a b c d e f
1. 6F	ROTATE WHEEL 750.	ZEROIZE SHAFT 327 AND CAM 331.	
6. 2F	ROCK SHAFT 335. " " 360.	DISENGAGE ROCKERS 341 WHILE ZEROIZING CAM 331. LIFT TOOTH 358 ON GEAR 357 INTO PATH OF TOOTH 356 ON DISC 355 FOR ZEROIZING CAM 331.	
7. 2R	ROCK SHAFT 420.	RAISE ARMS 410 AND SPECIAL ARM 413 TO NEGATIVE POSITION.	
10. 5F	ROTATE SHAFT 114 IN 1X. " " " 2X. " " " 3X. " " " 4X. " " " 5X.	LIFT YOKES 187 IN UPPER 1X; ALSO LIFT 187 IN LOWER 1X IDLY. " " " 2X; " " " 3X; " " " 4X; " " " 5X. " " " 2X; " " " 3X; " " " 4X; " " " 5X. " " " 3X; " " " 4X; " " " 5X; " " " 2X. " " " 4X; " " " 5X; " " " 2X; " " " 3X.	
17. 1R	ROCK BAIL 578.	RELEASE NO. 1 CONTROL PLATES AND CONTROL KEY 550/1.	
18. 1F	ROCK SHAFT 283.	RELEASE ANY LATCHED SHIFT KEY 273.	
26. 9R	ROTATE SHAFTS 190 IN OX TO 5X.	ZEROIZE UPPER 1X TO 5X (OX IS NOT ZEROIZED BECAUSE THE OX SHAFT 114 IS NOT ROTATED).	
28. 2R	SLIDE SHAFTS 120 IN OX TO 5X.	SELECT OX TO 5X FOR ZEROIZING IN BOTH PORTIONS; BUT ONLY UPPER 1X TO 5X WILL BE ZEROIZED BECAUSE SHAFT 114 IN OX AND SHAFTS 191 IN OX TO 5X ARE NOT ROTATED.	

FIG. 36.

FIG. 36b.

ZEROIZING LOWER 1X TO 5X, USING CONTROL KEY 550/4.

DRIVING RACK (1) NO. COUNTS POWER	(3) PRINCIPAL PART DRIVEN.	(4) PURPOSE.	(5) TIMING OF RACK MOVEMENTS. a b c d e f
10. 5F	ROTATE SHAFT 114 IN 1X. " " " 2X. " " " 3X. " " " 4X. " " " 5X.	LIFT YOKES 187 IN LOWER 1X; ALSO LIFT 186 IN UPPER 1X IDLY. " " " 2X; " " " 3X; " " " 4X; " " " 5X. " " " 2X; " " " 3X; " " " 4X; " " " 5X. " " " 3X; " " " 4X; " " " 5X; " " " 2X. " " " 4X; " " " 5X; " " " 2X; " " " 3X.	
17. 1R	ROCK BAIL 578.	RELEASE NO. 4 CONTROL PLATES AND CONTROL KEY 550/4.	
18. 1F	ROCK SHAFT 283.	RELEASE ANY LATCHED SHIFT KEY 273.	
26. 9R	ROTATE SHAFTS 191 IN OX TO 5X.	ZEROIZE LOWER 1X TO 5X; LOWER OX IS NOT ZEROIZED BECAUSE THE OX SHAFT 114 IS NOT ROTATED.	
28. 2R	SLIDE SHAFTS 120 IN OX TO 5X.	SELECT OX TO 5X FOR ZEROIZING IN BOTH PORTIONS; BUT ONLY LOWER 1X TO 5X WILL BE ZEROIZED BECAUSE SHAFT 114 IN OX AND SHAFTS 190 IN OX ARE NOT ROTATED.	

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2,298,263

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Filed June 14, 1939

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SIMULTANEOUS ENTERING { DIVISOR MULTIPLES NEGATIVELY IN UPPER 1X TO 6X } USING CONTROL
MULTIPLICAND MULTIPLES POSITIVELY IN LOWER 1X TO 6X } KEY 550/3
FIVE CYCLES.

DRIVING RACK		(3) PRINCIPAL PART DRIVEN	(4) PURPOSE	(5) USED IN CYCLE NO. 1 2 3 4 5	(6) TIMING OF RACK MOVEMENTS a b c d e f
6.	2F.	ROCK SHAFT 480.	MWVE 172 IN 5X LEFTWARD TO SET ALL WHEELS 107 BELOW THE SPLIT IN "ADD" POSITION.	X X X X X	
			DITTO IN 4X.	X X X X	
			DITTO IN 3X.	X X X	
			DITTO IN 2X.	X X	
			DITTO IN 1X.	X	
		ROCK SHAFT 490a.	MWVE 171 IN 5X RIGHTWARD TO SET ALL WHEELS 107 ABOVE THE SPLIT IN "SUBTRACT" POSITION.	X X X X X	
			DITTO IN 4X.	X X X X	
			DITTO IN 3X.	X X X	
			DITTO IN 2X.	X X	
			DITTO IN 1X.	X	
		ROCK SHAFT 484.	RELEASE 466, 467 WHILE OPERATED BY 480 OR 490a.	X X X X X	
5.	1R.	POSITION CAM BAR 636 (1 STEP DOWN)	MESH GEAR 481 WITH RACK 467 FOR ADDING IN LOWER 5X.	X X X X X	
	" "	" " " 637 (" " ")	DITTO IN LOWER 4X.	X X X X	
	" "	" " " 638 (" " ")	DITTO IN LOWER 3X.	X X X	
	" "	" " " 639 (" " ")	DITTO IN LOWER 2X.	X X	
	" "	" " " 640 (" " ")	DITTO IN LOWER 1X.	X	
4.	10F.	OSCILLATE BAR 47	RECIPROCATATE RACKS 83 DIFFERENTIALLY.	X X X X X	
13.	3F.	POSITION CAM BAR 625 (3 STEPS DOWN)	MESH GEAR 484a WITH RACK 466 FOR ADDING IN UPPER 5X.	X X X X X	
	" "	" " " 630 (" " ")	DITTO IN UPPER 4X.	X X X X	
	" "	" " " 631 (" " ")	DITTO IN UPPER 3X.	X X X	
	" "	" " " 632 (" " ")	DITTO IN UPPER 2X.	X X	
	" "	" " " 633 (" " ")	DITTO IN UPPER 1X.	X	
16.	2F.	OPERATE BARS 137 IN OX TO 5X (IN OX IDLY).	DISENGAGE WHEELS 122 FROM THE MEMBERS 129 AND 130.	X X X X X	
12.	3A.	ROTATE CAMS 402 THROUGH 1/6 REVOLUTION DURING EACH OF THE FIVE CYCLES.	BING INTO ACTION ADDITIONAL CONTROL PLATES (NO. 18 IN EACH GROUP). DITTO (NO. 19 IN EACH GROUP). DITTO (NO. 20 " " "). DITTO (NO. 21 " " "). RELEASE CONTROL PLATE NO. 21 IN EACH GROUP.	X X X	
17.	1R.	ROCK BAIL 578.	RELEASE CONTROL PLATES NOS. 3, 18, 19 AND 20.		
15.	2F.	ROCK SHAFT 700.	ALIGN AND HOLD BARS 380.	X X X X X	
21.	9R.	ROTATE SHAFT 321a.	MEASURE NUMBER OF "NINES" ON LEFT OF HIGHEST DIGIT IN DIVISOR AND ENTER NUMBER POSITIVELY ON DIFFERENCING DEVICE.		X
23.	2F.	ROCK SHAFT 330 (R 278 IDLY).	ENGAGE CLUTCH 328.		X
	" "	" " 314a (R 314 IDLY).	RECORD POSITION OF EACH DIGIT IN 1X OF VALUE OTHERWISE THAN "9"		X
	" "	" " 335.	DISENGAGE ROCKERS 341 WHILE SETTING DIFFERENCING DEVICE.		X
28.	8R.	ROCK SHAFT 87.	READ KEYBOARD SETTINGS.	X X X X X	
	" "	" " 96.	ENGAGE CLUTCHES 93, 94.	X X X X X	
—	—	OPERATE TRANSFER BARS 133, 134.	ANSWER TRANSFER CALLS IN 1X TO 5X	X X X X X	
—	—	OPERATE BARS 138, 139.	CENTRALIZE LOCK-BARS 128.	X X X X X	
7.	2R.	ROCK SHAFT 420.	RAISE ARMS 410 AND SPECIAL ARM 413 TO NEGATIVE POSITION.		X

FIG. 36a.

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Oct. 6, 1942.

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2,298,263

CALCULATING MACHINE

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ZEROIZING UPPER OX USING CONTROL KEY 550/7
AND A SHIFT KEY 273 WHEN COLUMN-SHIFTING.

DRIVING RACK NO.	(3) PRINCIPAL PART DRIVEN.	(4) PURPOSE	(5) TIMING OF RACK MOVEMENTS					
			a	b	c	d	e	f
1. 6F	ROTATE WHEEL 760.	ZEROIZE SHAFT 327 AND CAM 331.						
2. 1F	ROCK SHAFT 221.	RELEASE SLIDES 212.						
	" " 283.	" LATCHED SHIFT KEY 273.						
6. 2F	ROCK SHAFT 360.	LIFT TOOTH 358 ON GEAR 357 INTO PATH OF TOOTH 356 ON DISC 355 FOR ZEROIZING CAM 331.						
	" " 480a.	MOVE 171 IN OX RIGHTWARD TO SET ALL WHEELS 107 ABOVE THE SPLIT IN 'SUBTRACT' POSITION.						
	" " 513.	ENGAGE CLUTCHES 510, 511.						
7. 2R	ROCK SHAFT 420.	RAISE ARMS 410 AND SPECIAL ARM 423 TO NEGATIVE POSITION.						
	POSITION CAM BAR 637 TWO STEPS DOWN. MESH GEAR 481 WITH RACKS 466, 467 IN OX.							
13. 3F	POSITION CAM BAR 637 TWO STEPS DOWN.	MESH GEAR 481 WITH RACK 466 IN OX.						
14. 3F	RECIPROCATE BAIL 850.	RESTORE RACKS 250, 251 LEFTWARD.						
18. 5F	ROTATE SHAFT 114 IN OX.	LIFT YOKES 106 IN UPPER OX; ALSO LIFT YOKES 107 IN LOWER OX IDLY.						
14. 2F	ROCK SHAFT 235.	ENGAGE CLUTCHES 232, 233.						
	" " 245.	" " 242, 243.						
	" " 480.	MOVE 171 IN OX LEFTWARD TO SET ALL WHEELS 107 ABOVE THE SPLIT IN 'ADD' POSITION. MOVE 172 IN OX LEFTWARD TO SET ALL WHEELS 107 BELOW THE SPLIT IN 'ADD' POSITION.						
19. 10F	OSCILLATE BAR 47.	RECIPROCATE RACKS 83 DIFFERENTIALLY TO RE-ENTER AMOUNT IN OX WHEN A SHIFT KEY 273 IS ALSO USED.						
	OPERATE RACK 406.	RESET GEARS 204, 208.						
17. 1R	ROCK BAIL 570.	RELEASE NO. 7 CONTROL PLATES AND KEY 550/7.						
15. 2F	POSITION BAR 700.	ALIGN AND HOLD BARS 380.						
	" " 716.	CHANGE TRANSFER ACTION TO LATER TIMING.						
20. 2F	ROCK SHAFTS 258, AND 258a	RAISE AND LOWER RACKS 250, 251.						
	ROCK SHAFT 335.	(1) DISENGAGE ROCKERS 341 WHILE ZEROIZING CAM 331.						
	" " 484.	(2) DISENGAGE ROCKERS 341 WHILE USING SETTING OF LATCHED SHIFT KEY 273. RELEASE 466, 467 WHILE OPERATED BY 480 OR 480a.						
25. 2F	OPERATE BARS 137 IN OX TO 5X (IN 1X TO 5X IDLY).	DISENGAGE WHEELS 122 FROM TOE MEMBERS 129 AND 130.						
24. 2R	ROCK SHAFT 216.	SET UP ZEROIZED AMOUNT ON LOWER SLIDES 212.						
26. 3R	ROTATE SHAFTS 190 IN OX TO 5X (IN 1X TO 5X IDLY).	ZEROIZE UPPER OX (UPPER 1X TO 5X ARE NOT ZEROIZED BECAUSE THE 1X TO 5X SHAFTS 114 ARE NOT ROTATED).						
28. 2R	ROCK SHAFT 96.	ENGAGE CLUTCHES 93, 94.						
	SLIDE SHAFTS 120 IN OX TO 5X (IN 1X TO 5X IDLY).	SELECT OX TO 5X FOR ZEROIZING IN BOTH PORTIONS BUT ONLY UPPER OX WILL BE ZEROIZED BECAUSE SHAFTS 114 IN 1X TO 5X AND SHAFT 191 IN OX ARE NOT ROTATED.						
	OPERATE TRANSFER BARS 139, 134.	ANSWER TRANSFER CALLS IN OX WHEN AMOUNT IN UPPER OX IS, BY COLUMN-SHIFTING, ADDED TO AMOUNT IN LOWER OX.						
	OPERATE BARS 138, 139.	CENTRALIZE LOCK BARS 120.						

COLUMN NO. 2 COL. NO. 18

FIG. 36c.

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ZEROIZING LOWER OX. USING CONTROL KEY 550/10
AND A SHAFT KEY 273 WHEN COLUMN-SHIFTING.

DRIVING RACK (1) (2) (3) (4) (5) (6)	(3) PRINCIPAL PART DRIVEN.	(4) PURPOSE	(6) TIMING OF RACK MOVEM					
			a	b	c	d	e	f
1. 63F	ROTATE WHEEL 750.	ZEROIZE SHAFT 327 AND CAM 331.						
2. 1F	ROCK SHAFT 221. " " 283.	RELEASE SLIDES 212 " LATCHED SHIFT KEY 273.						
3. 1F	POSITION CAM BAR 635 ONE STEP DOWN.	MESH GEAR 481a WITH RACK 467 IN OX.						
6. 2F	ROCK SHAFT 360. " " 480a. " " 513.	LIFT TOOTH 358 ON GEAR 357 INTO PATH OF TOOTH 356 ON DISC 355 FOR ZEROIZING CAM 331. MOVE 172 IN OX RIGHTWARD TO SET ALL WHEELS 107 BELOW THE SPLIT IN "SUBTRACT" POSITION. ENGAGE CLUTCHES 510, 511.						
7. 2R	ROCK SHAFT 420. POSITION CAM BAR 641 TWO STEPS DOWN	RAISE ARMS 410 AND SPECIAL ARM 413 TO NEGATIVE POSITION. MESH GEAR 481 WITH RACKS 466, 467 IN OX.						
11. 9F	RECIPROCATATE BAIL 850.	RESTORE RACKS 250, 251 LEFTWARD.						
10. 5F	ROTATE SHAFT 114 IN OX.	LIFT YOKES 187 IN LOWER OX, ALSO LIFT YOKES 186 IN UPPER OX IDLY.						
14. 2F	ROCK SHAFT 235. " " 245. " " 480.	ENGAGE CLUTCHES 232, 233 " " 242, 243 MOVE 171 IN OX LEFTWARD TO SET ALL WHEELS 107 ABOVE THE SPLIT IN "ADD" POSITION. MOVE 172 IN OX LEFTWARD TO SET ALL WHEELS 107 BELOW THE SPLIT IN "ADD" POSITION.						
19. 10F	OSCILLATE BAR 47. OPERATE RACK 406.	RECIPROCATATE RACKS 83 DIFFERENTIALLY TO RE-ENTER AMOUNT IN OX WHEN A SHIFT KEY 273 IS ALSO USED. RESET GEARS 201, 208.						
17. 1R	ROCK BAIL 578.	RELEASE NO. 10 CONTROL PLATES. AND KEY 550/10.						
18. 1F	ROCK SHAFT 283.	RELEASE LATCHED SHIFT KEY 273.						
15. 2F	POSITION BAR 700. " " 716. ROCK SHAFT 484.	ALINE AND HOLD BARS 380. CHANGE TRANSFER ACTION TO LATER TIMING. RELEASE 466, 467 WHILE OPERATED BY 480 OR 480a.						
20. 2F	ROCK SHAFT 258 AND 258a. ROCK SHAFT 335.	RAISE AND LOWER RACKS 250, 251 (1) DISENGAGE ROCKERS 341 WHILE ZEROIZING CAM 331. (2) DISENGAGE ROCKERS 341 WHILE USING SETTING OF LATCHED SHIFT KEY 273.						
25. 2F	OPERATE BARS 197 IN OX TO 5X (IN 1X TO 5X IDLY).	DISENGAGE WHEELS 122 FROM TOE MEMBERS 129, 130.						
24. 2R	ROCK SHAFT 276.	SET UP ZEROIZED AMOUNT ON LOWER SLIDES 212.						
26. 9R	ROTATE SHAFTS 191 IN OX TO 5X (IN 1X TO 5X IDLY).	ZEROIZE LOWER OX (LOWER 1X TO 5X ARE NOT ZEROIZED BECAUSE THE 1X TO 5X SHAFTS 114 ARE NOT ROTATED).						
28. 2R	ROCK SHAFT 96 SLIDE SHAFTS 120 IN OX TO 5X (IN 1X TO 5X IDLY).	ENGAGE CLUTCHES 93, 94. SELECT OX TO 5X FOR ZEROIZING IN BOTH PARTIANS, BUT ONLY LOWER OX WILL BE ZEROIZED BECAUSE SHAFTS 114 IN 1X TO 5X AND SHAFT 190 IN OX ARE NOT ROTATED.						
—	OPERATE TRANSFER BARS 138, 139.	ANSWER TRANSFER CALLS IN OX.						
—	OPERATE BARS 138, 139.	CENTRALIZE LOCK BARS 128.						

FIG. 37.

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SIMULTANEOUS DIVISION & MULTIPLICATION:
SUBSEQUENT CYCLES, USING CONTROL KEYS.

	550/1	FOR THE DIVIDING & MULTIPLYING OPERATION WITHOUT RECORDING RESULTS.
	550/1	FOR ENTERING A POSITIVE PRODUCT RESULT
	550/12	" " " NEGATIVE "
	550/14	" " " POSITIVE QUOTIENT "
	550/15	" " " "

[illegible]

FIG. 37a.

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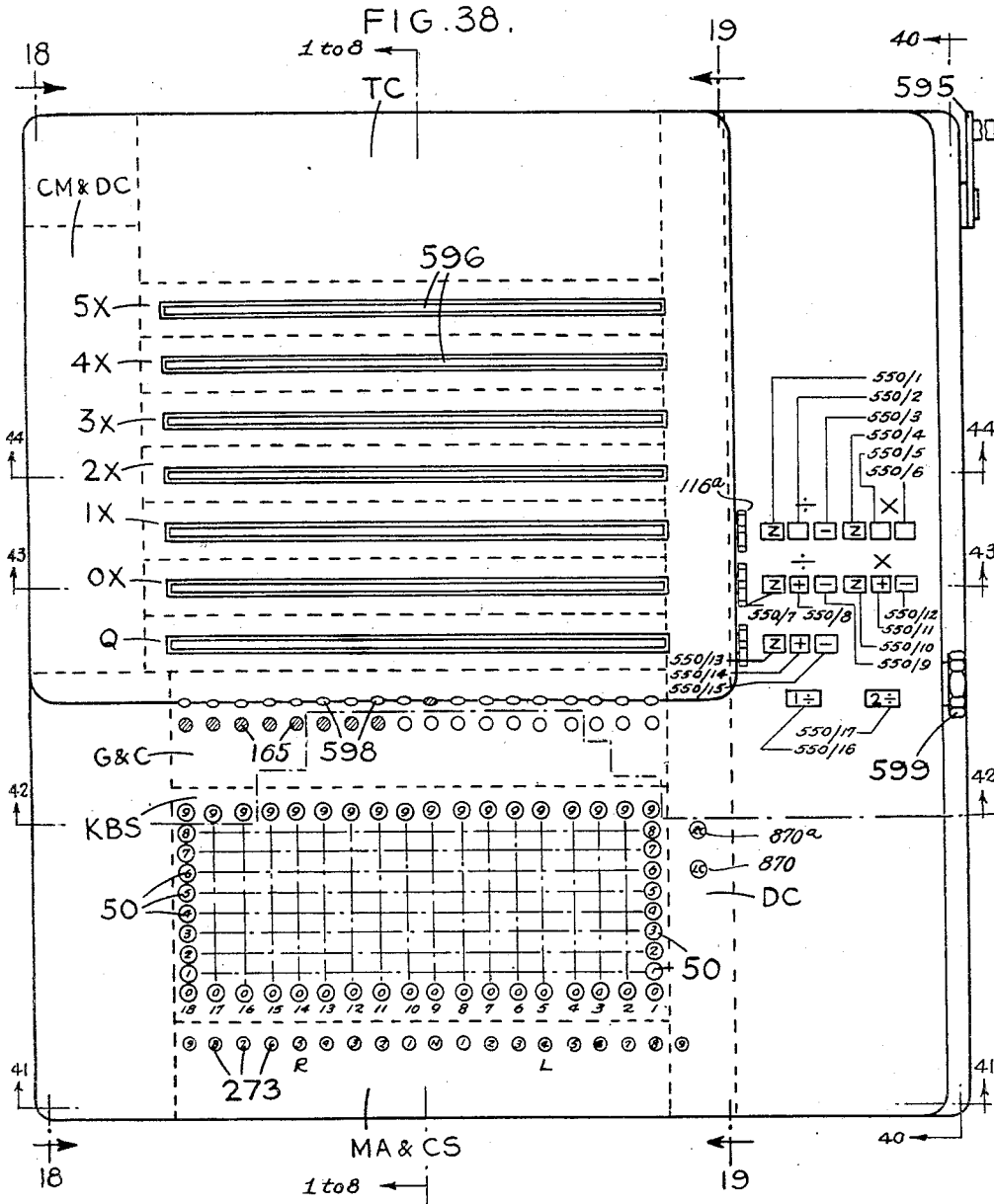
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INVENTOR

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by
Wm. Adams
Atty

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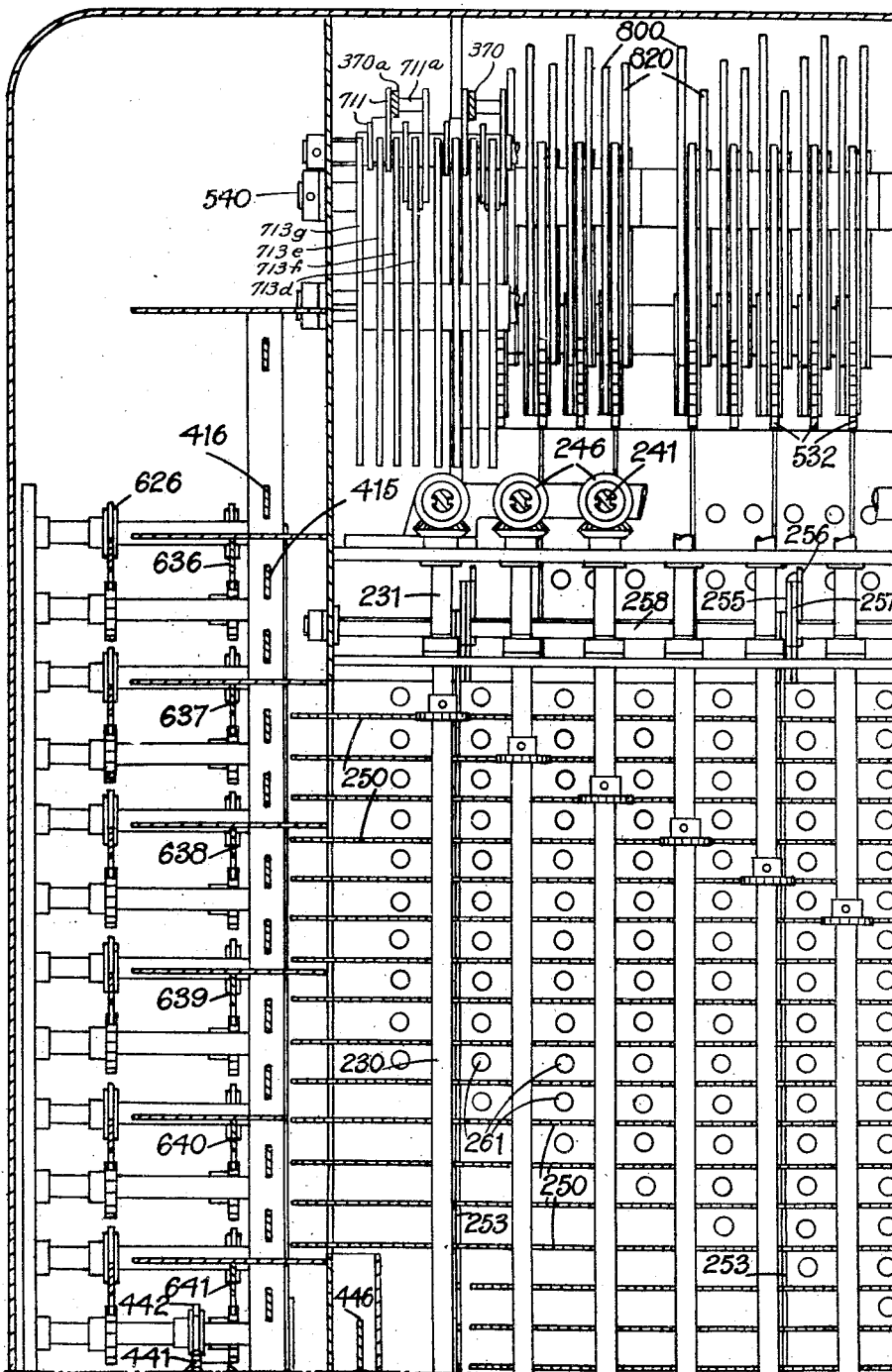


Fig. 39a.

INVENTOR
THOMAS W. CHICK
BY *W. W. Gibson*
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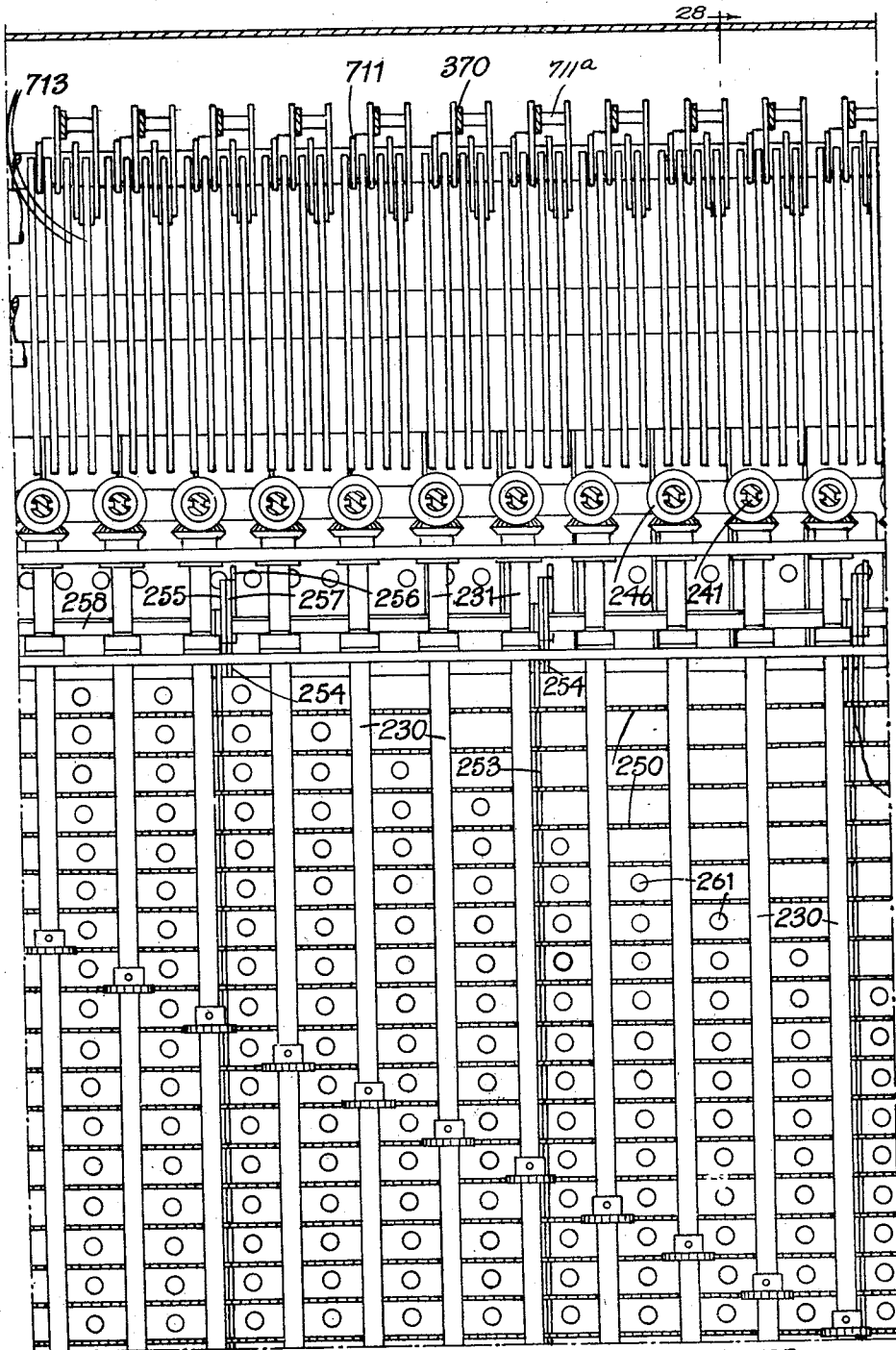


Fig. 39b.

INVENTOR
THOMAS W. CHICK
BY *W. M. Miller*
ATTORNEY

Oct. 6, 1942.

T. W. CHICK

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CALCULATING MACHINE

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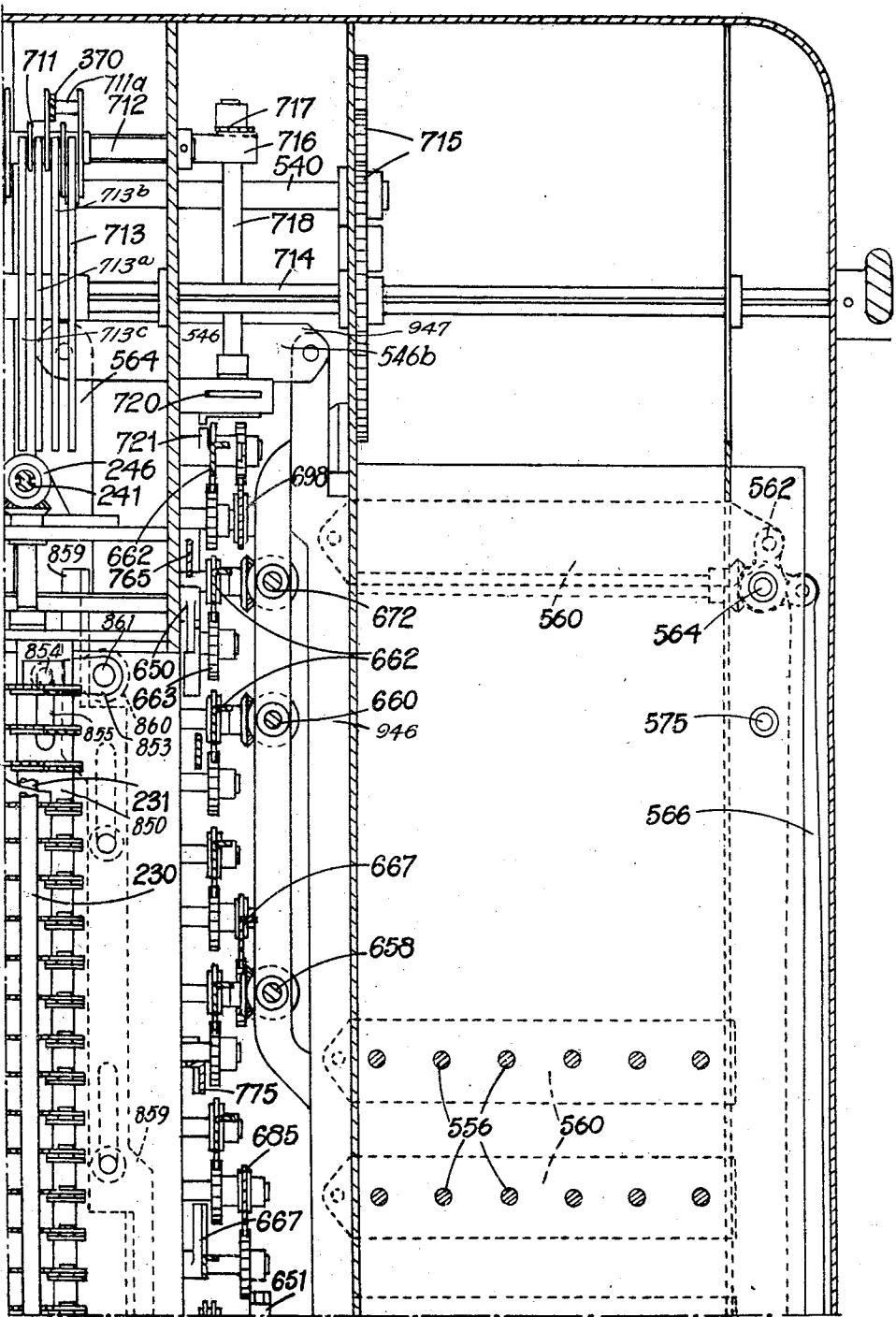


Fig.39c.

INVENTOR
THOMAS W. CHICK
BY *W. M. Wilson*
ATTORNEY

Oct. 6, 1942.

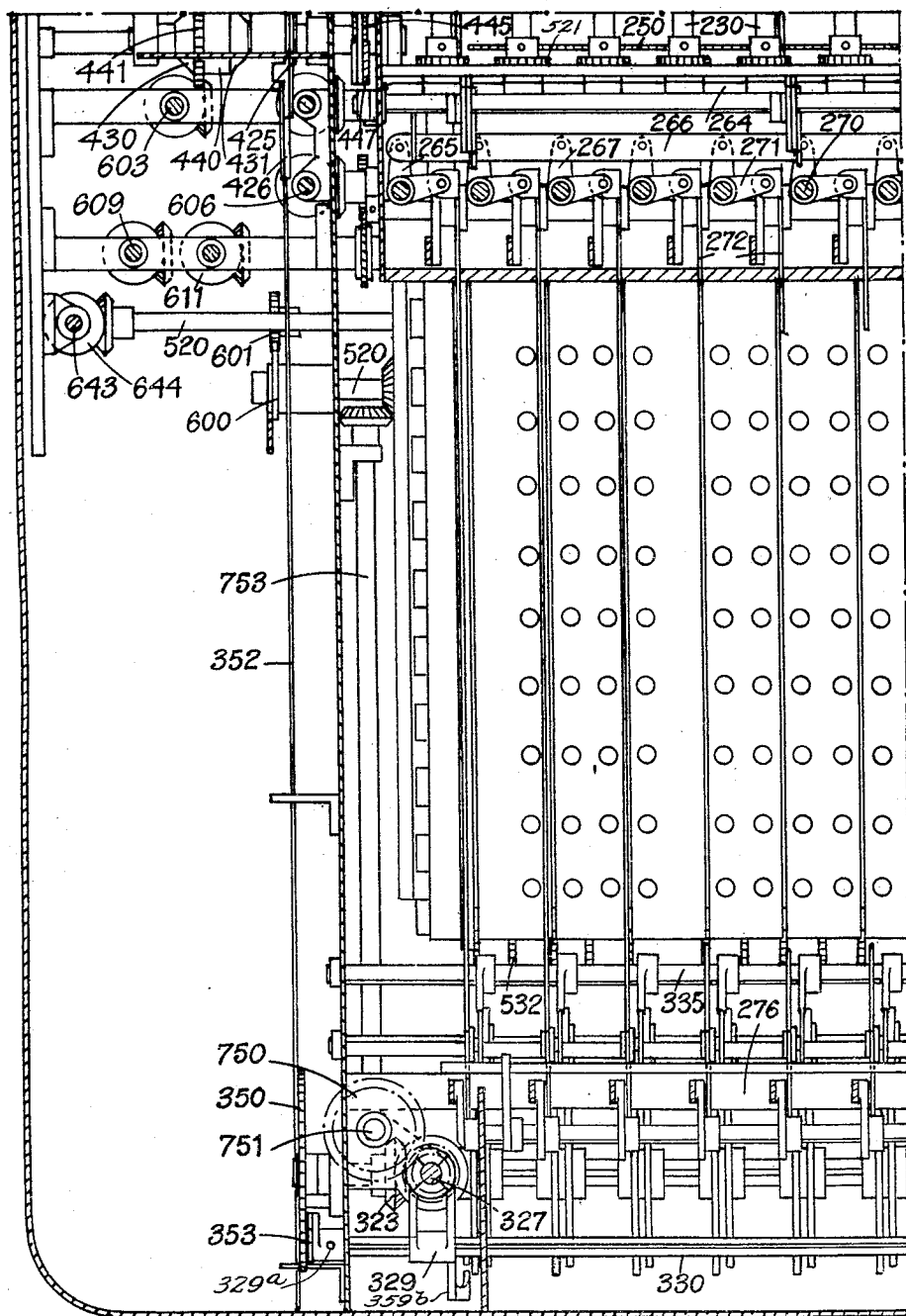
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INVENTOR
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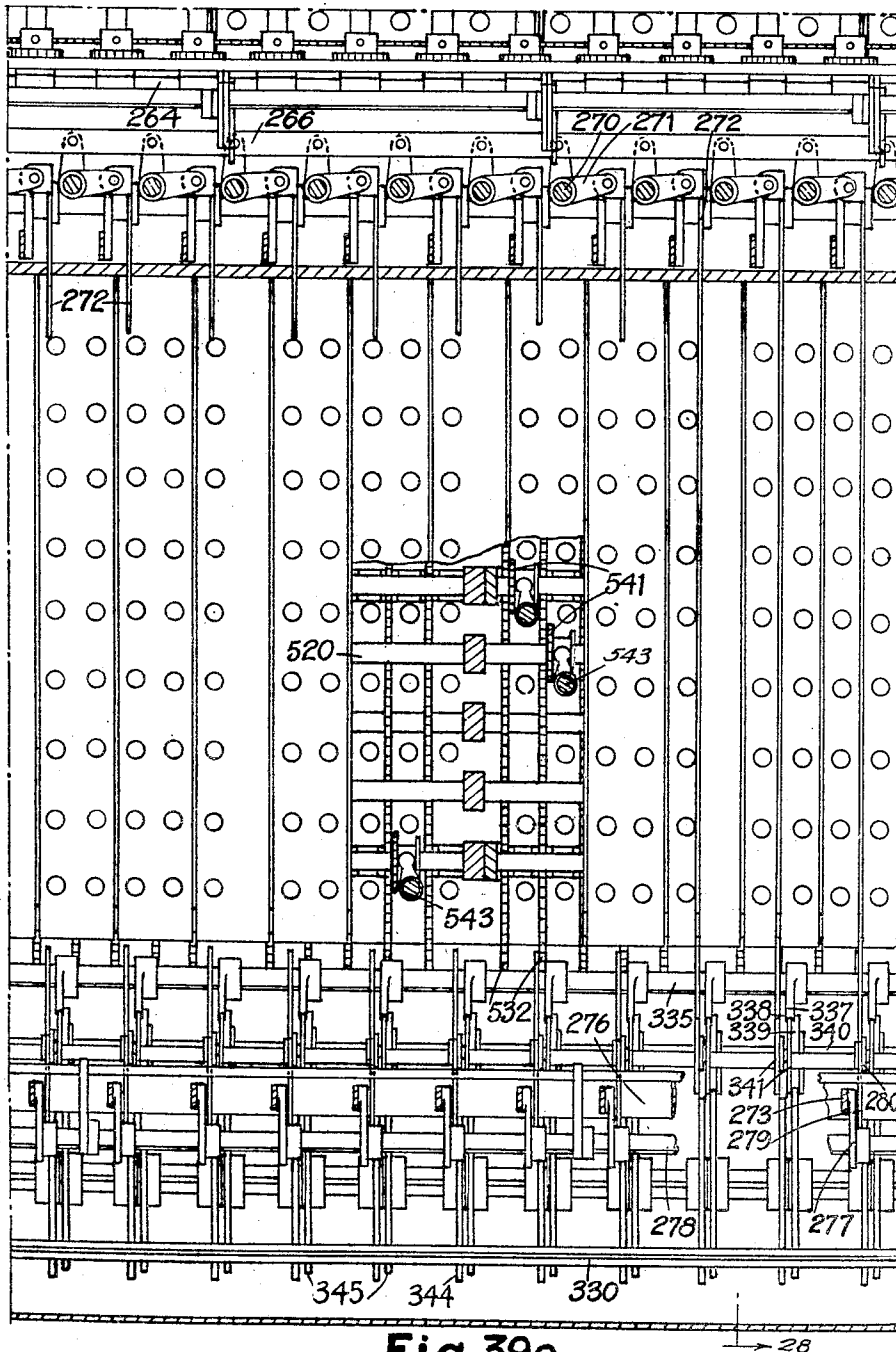
T. W. CHICK

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INVENTOR
THOMAS W. CHICK
BY *W. M. Mahan*
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T. W. CHICK

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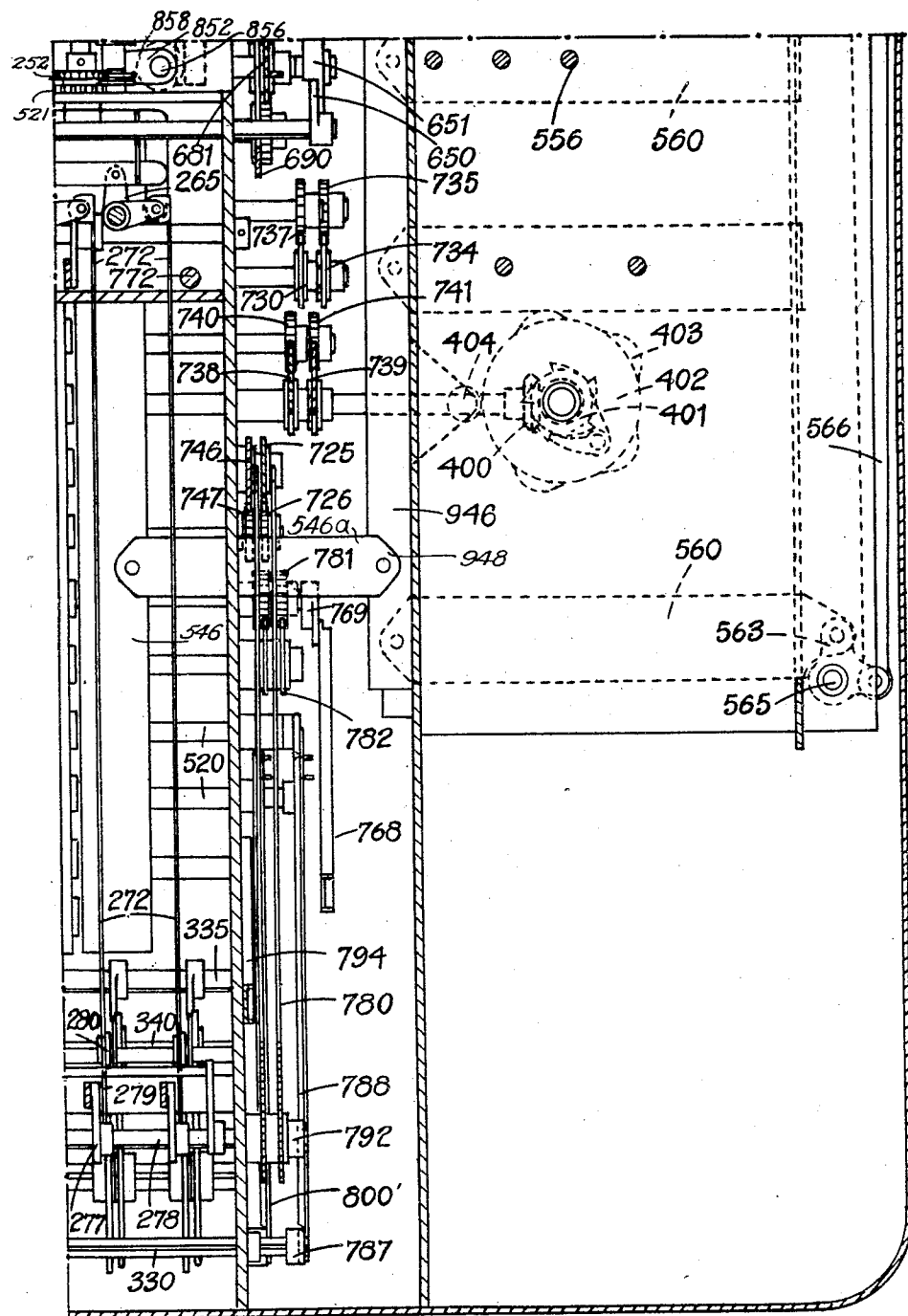


Fig. 39f.

INVENTOR
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BY *Wm. M. Mikes*
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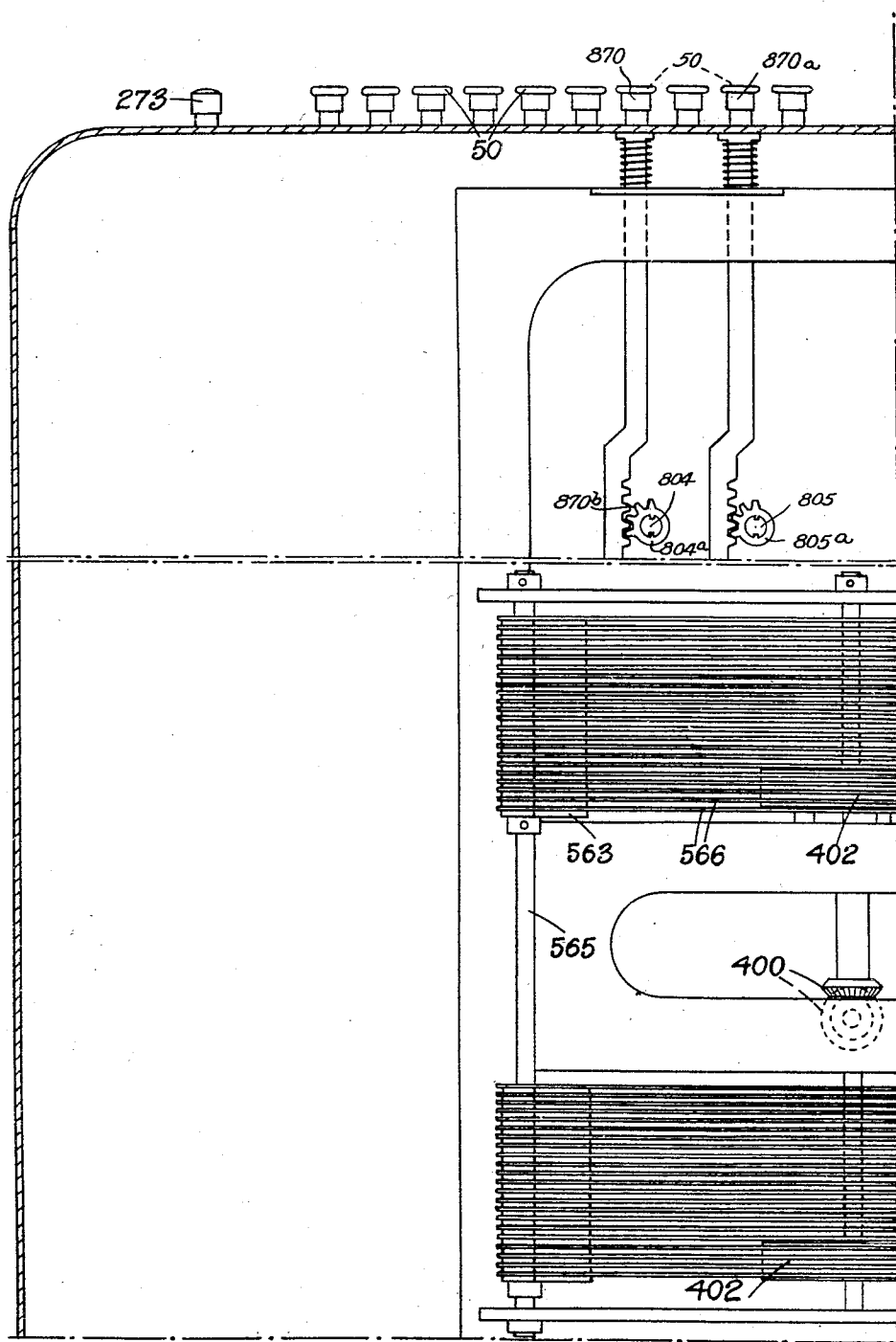


Fig. 40a.

INVENTOR
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BY *W. M. M. M. M.*
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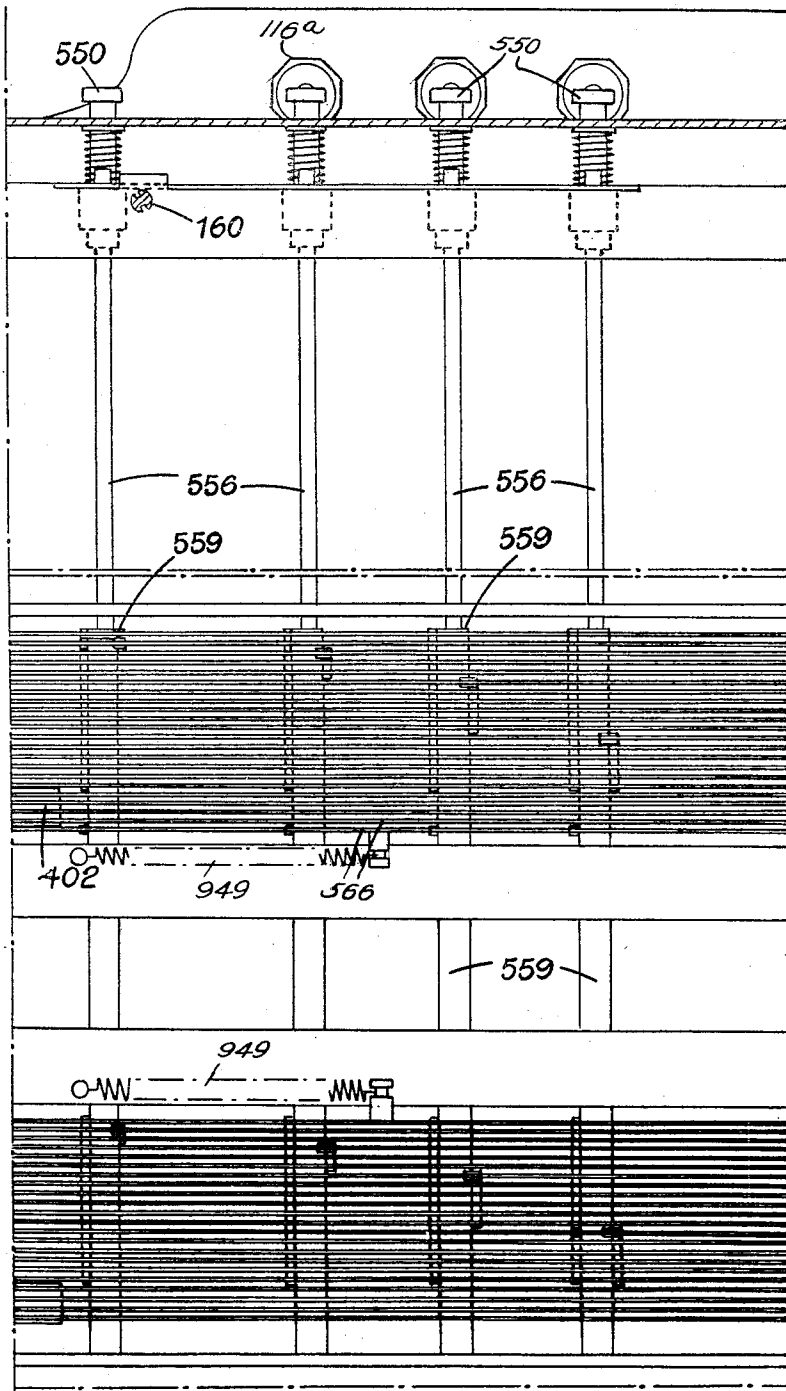


Fig. 40b.

INVENTOR
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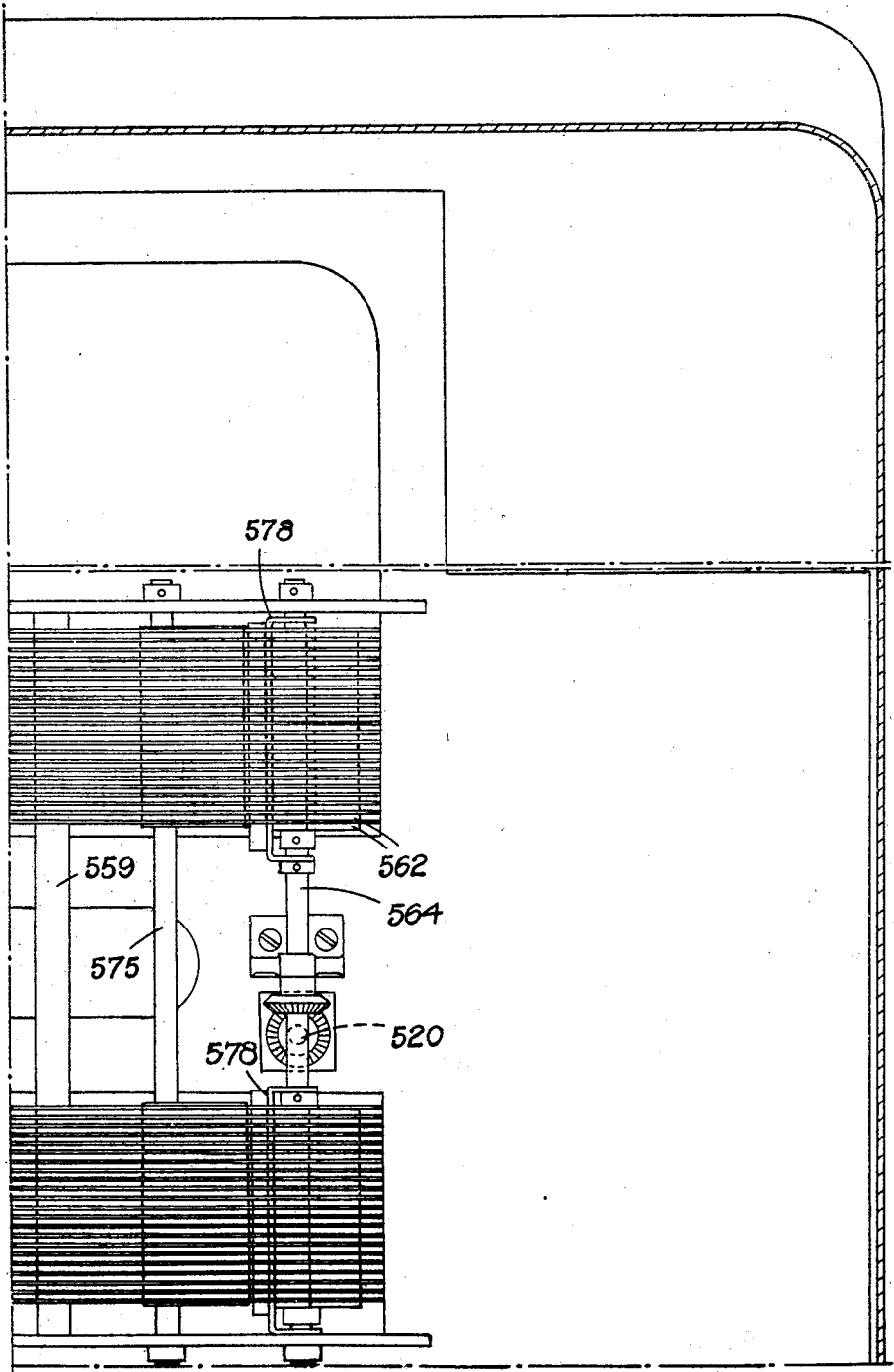


Fig. 40c.

INVENTOR
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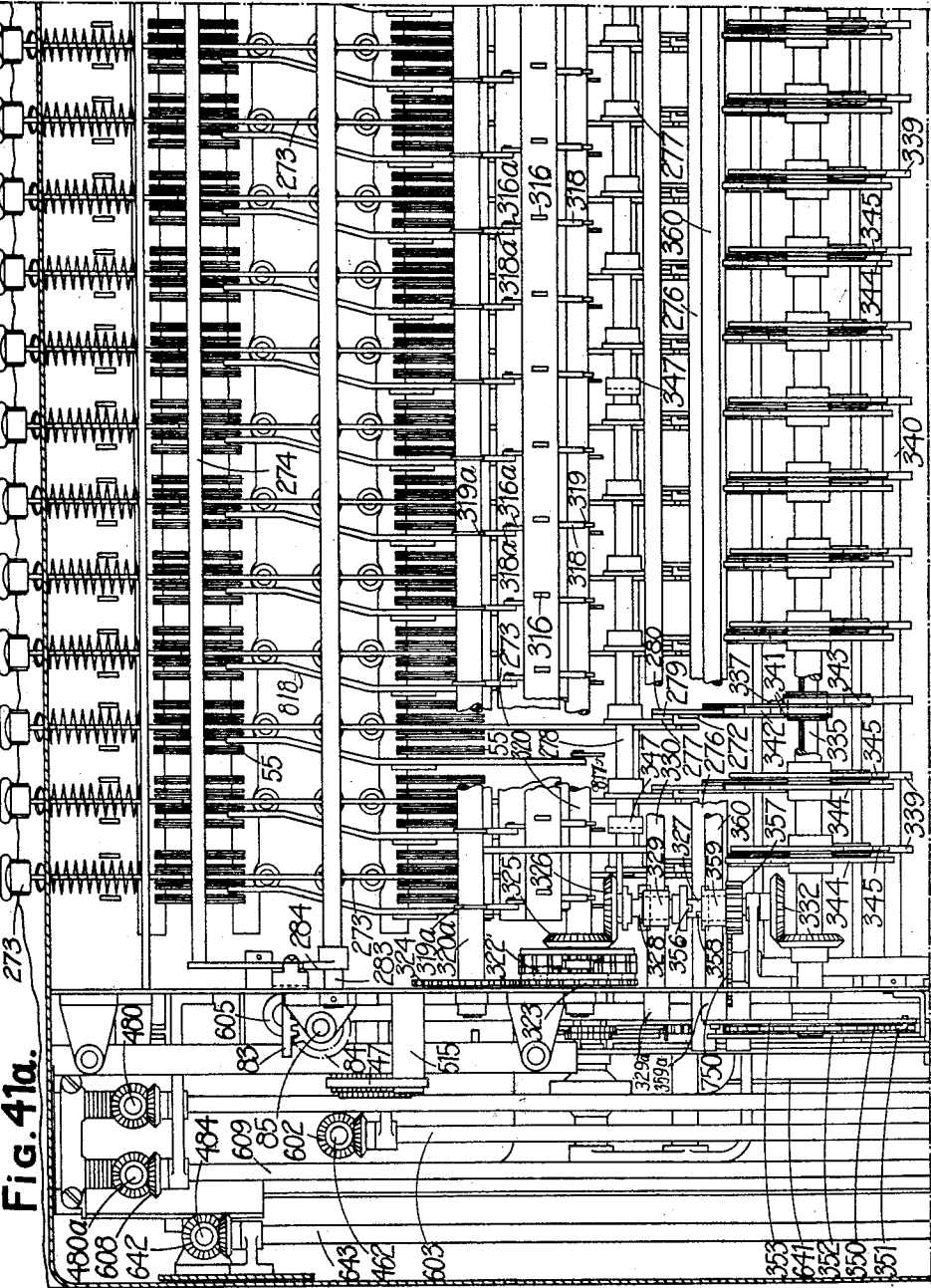
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INVENTOR
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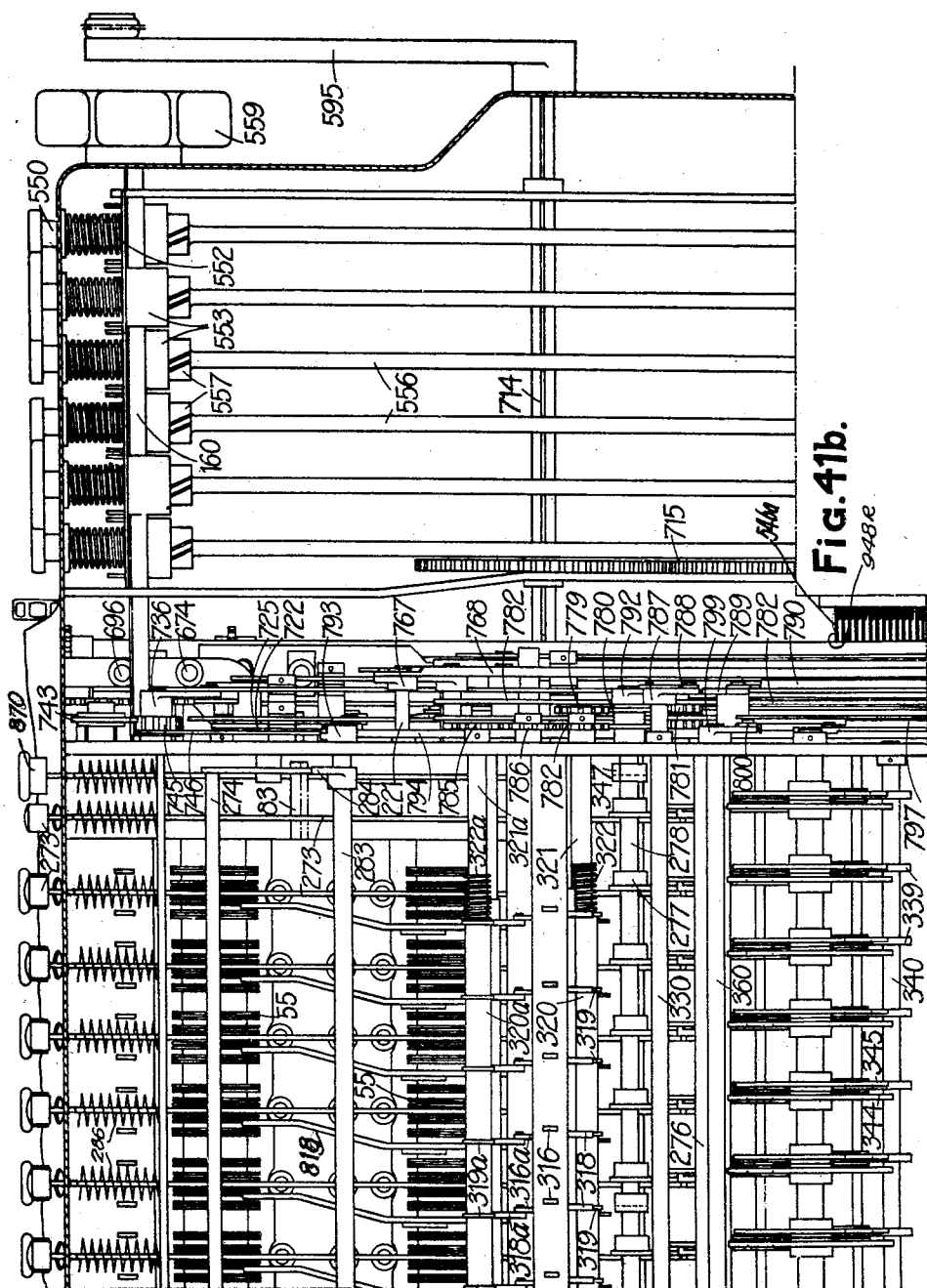


Fig. 41b.

INVENTOR
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Oct. 6, 1942.

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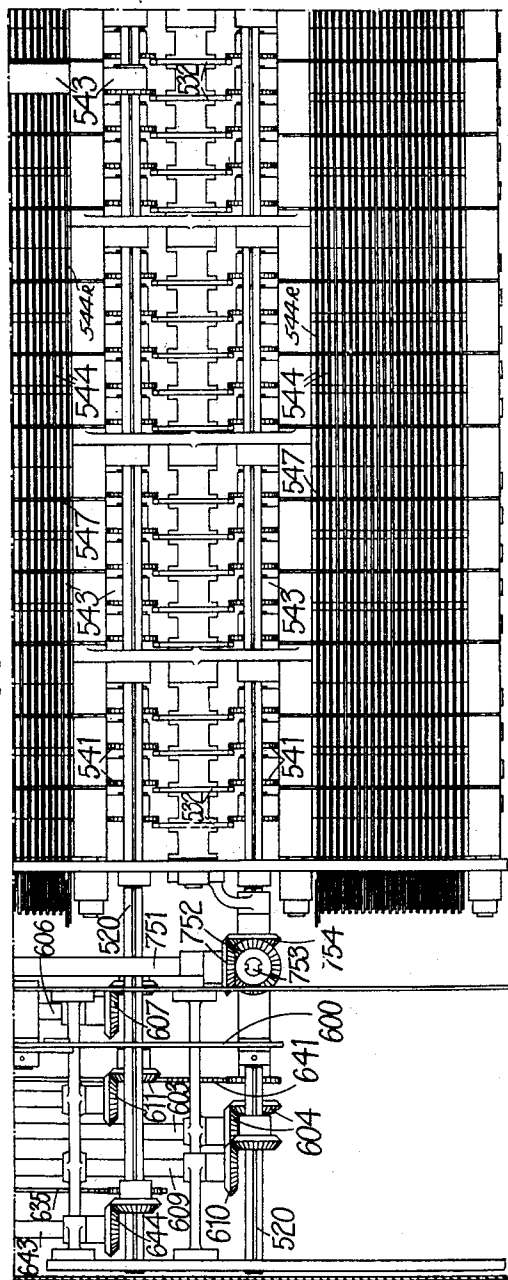
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CALCULATING MACHINE

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Fig. 41c.



INVENTOR
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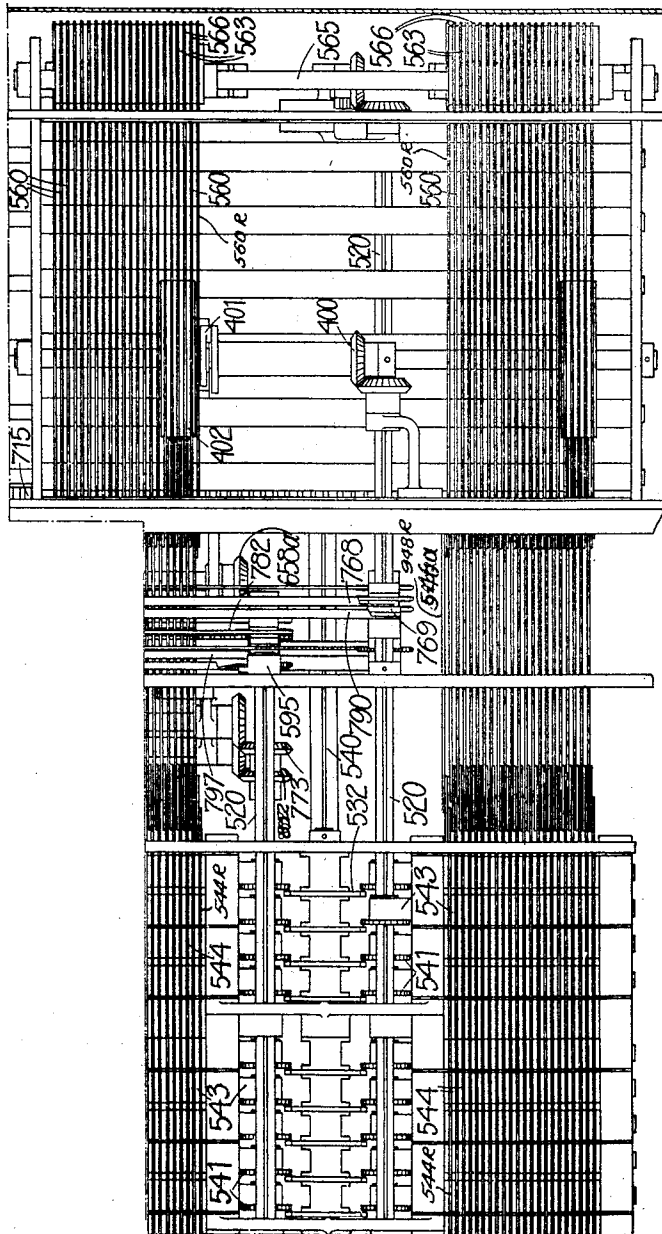
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Fig. 41d.



INVENTOR
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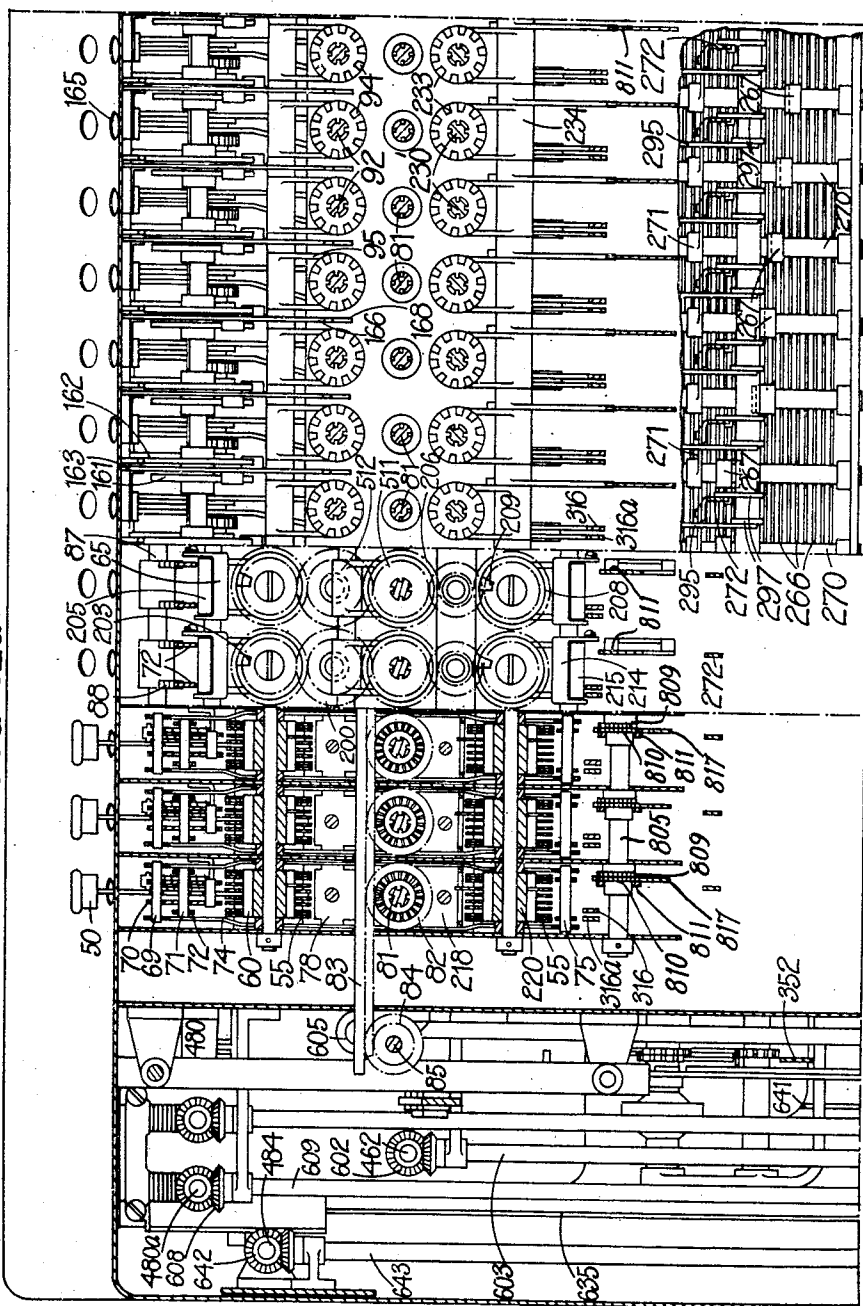
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Fig. 42a



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Oct. 6, 1942.

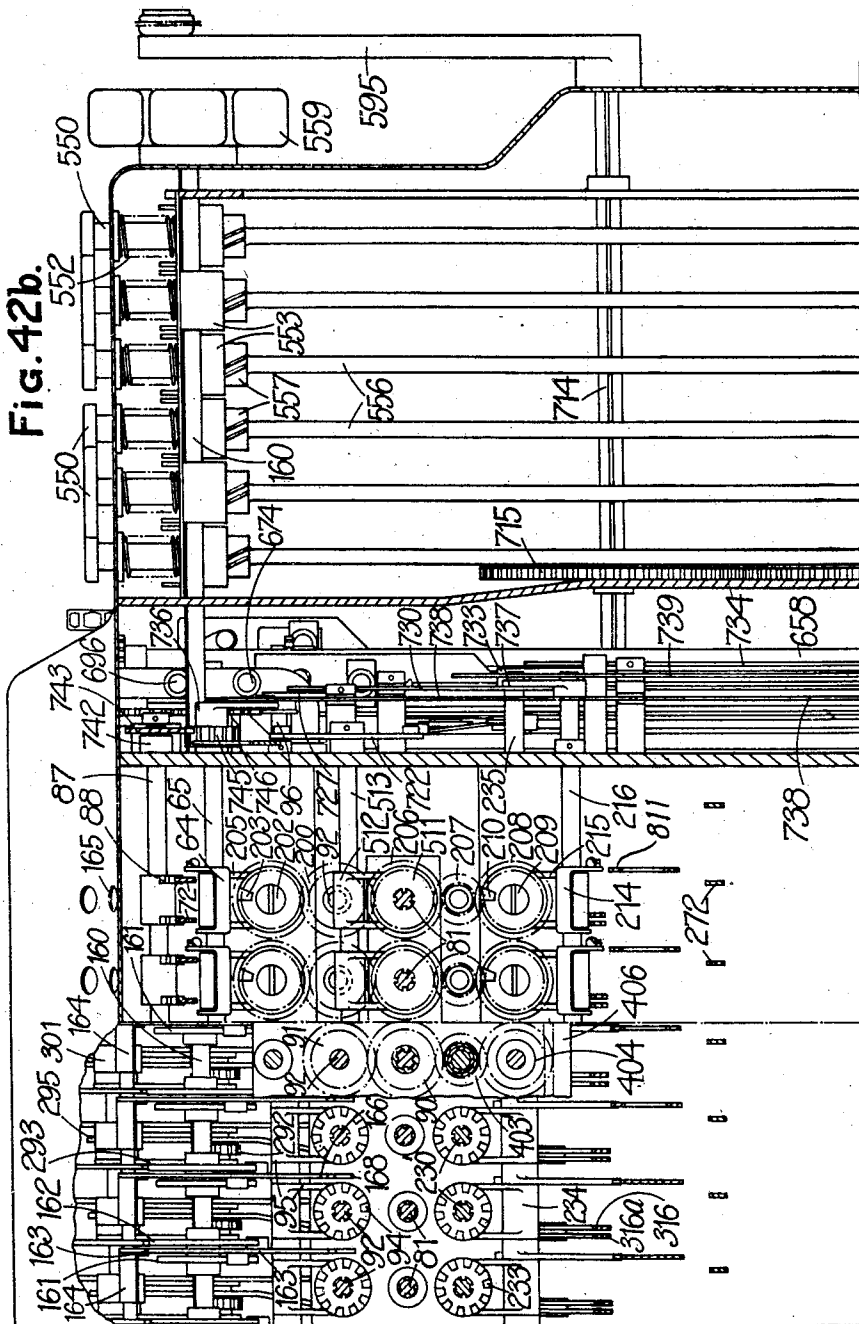
T. W. CHICK

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Filed June 14, 1939

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INVENTOR
THOMAS W. CHICK
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Oct. 6, 1942.

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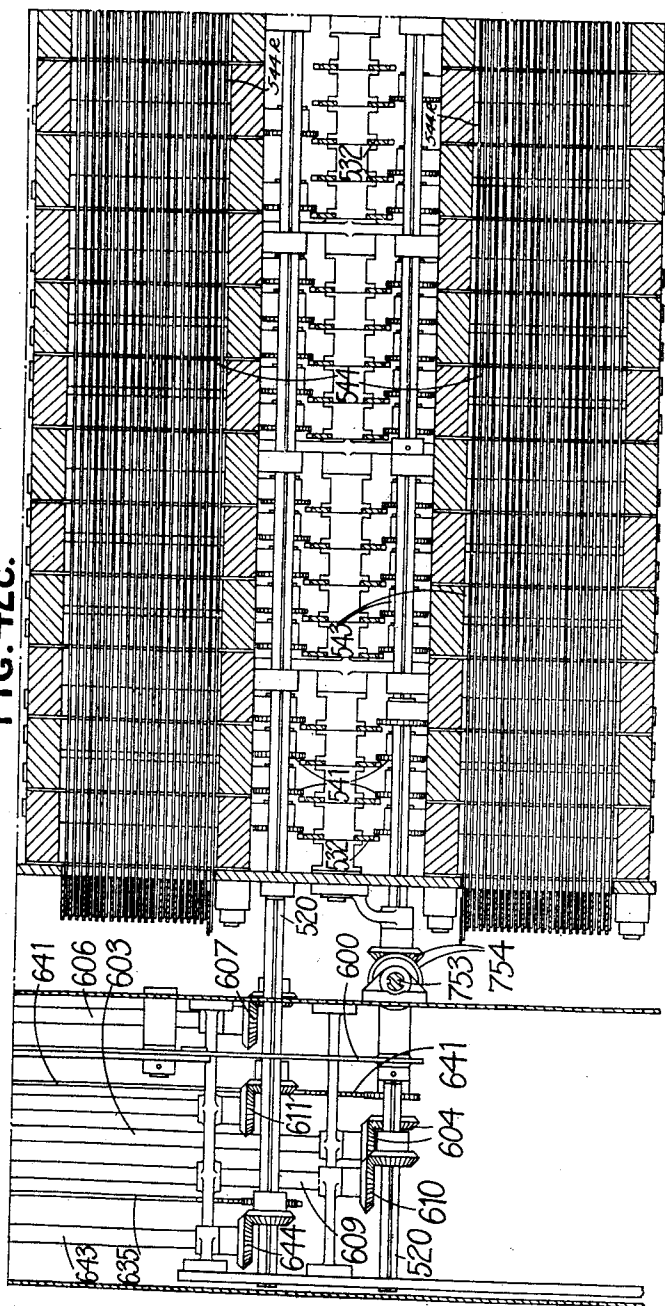
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Fig. 42c.



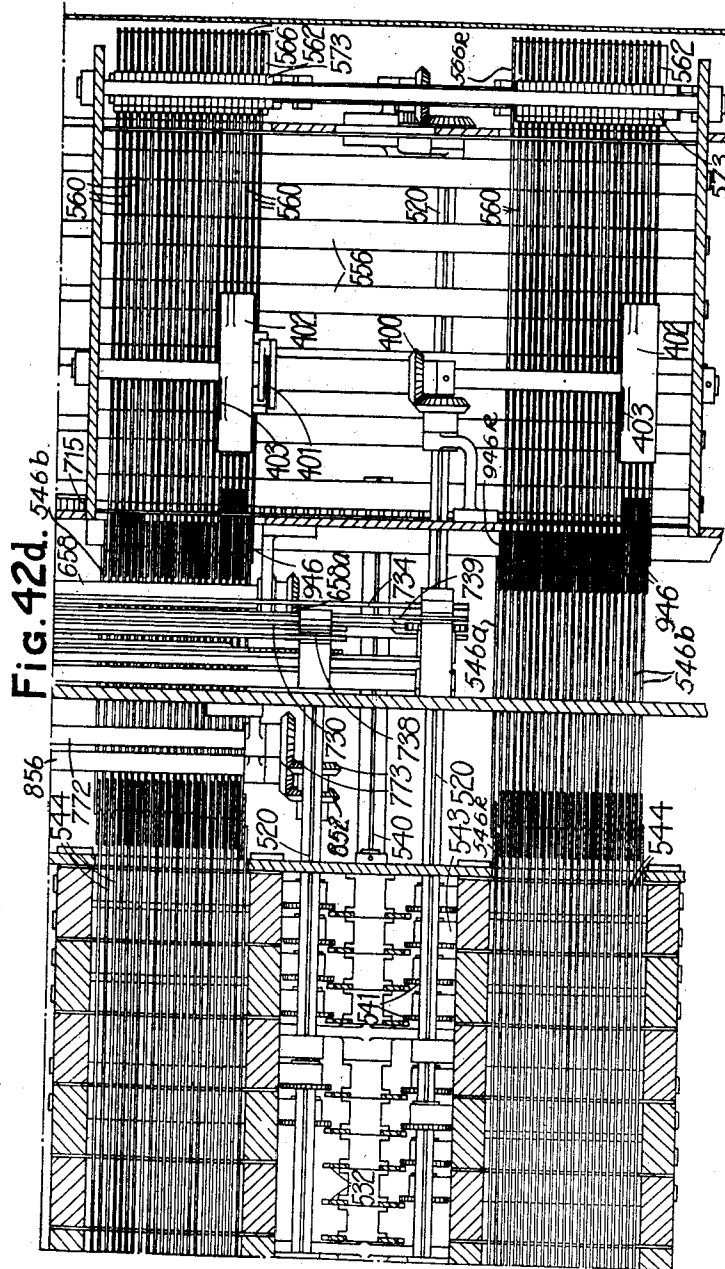
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INVENTOR
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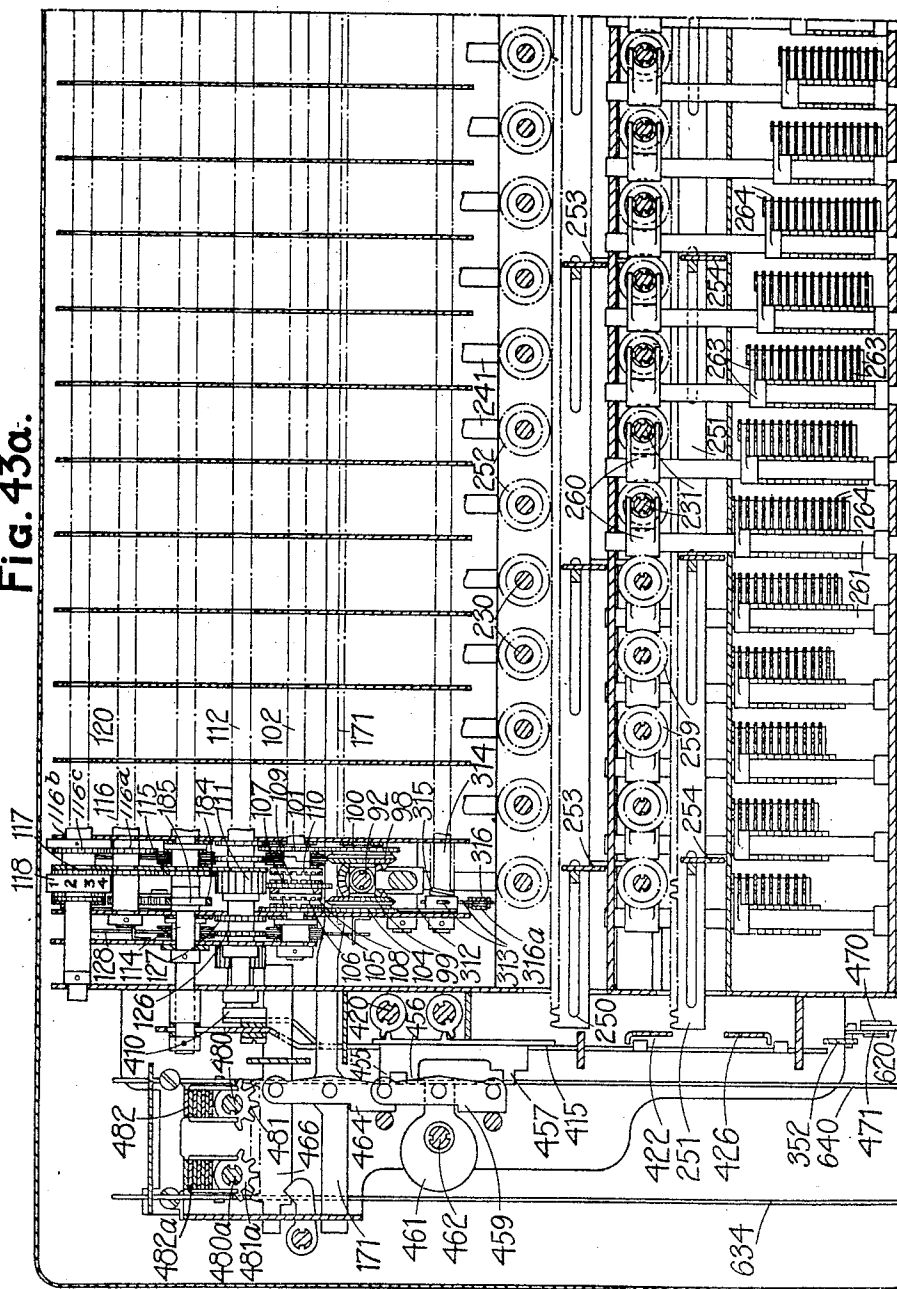
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Fig. 43a.



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Oct. 6, 1942.

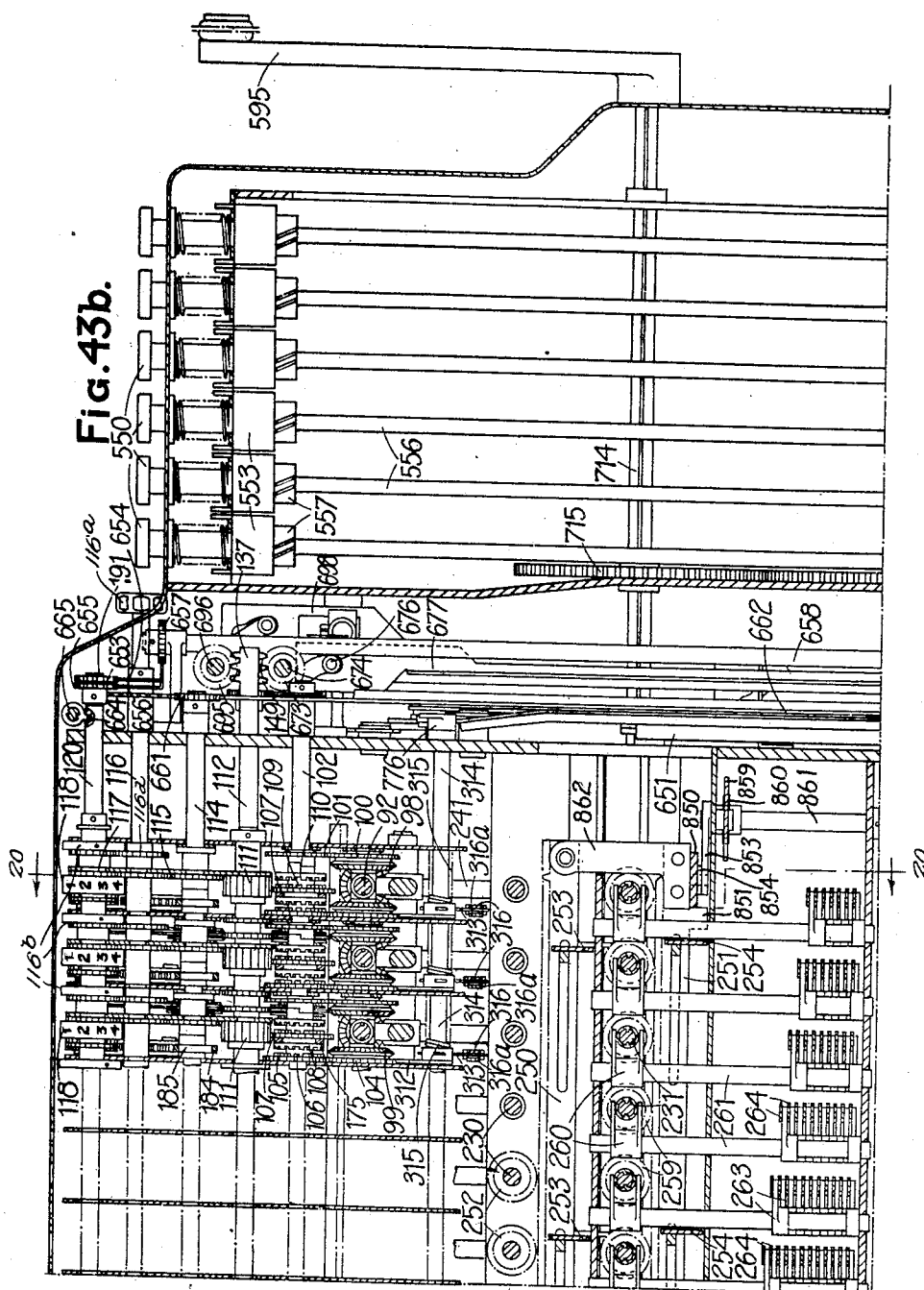
T. W. CHICK

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CALCULATING MACHINE

Filed June 14, 1939

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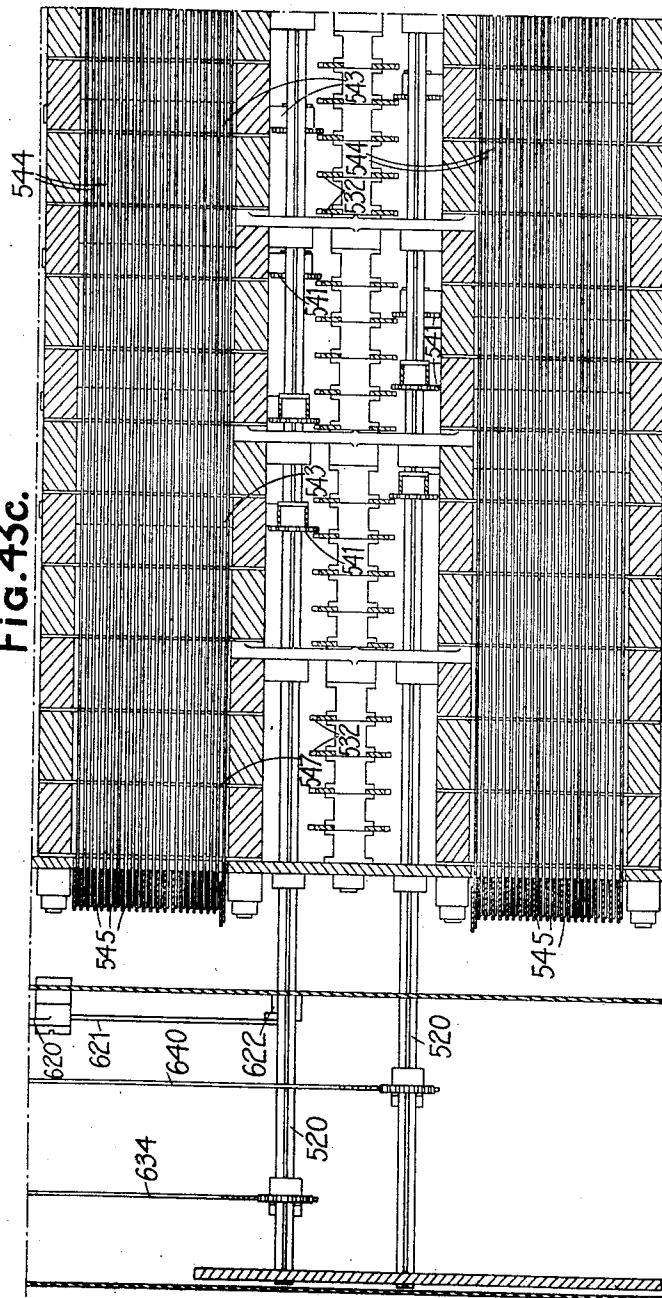
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Fig. 43c.



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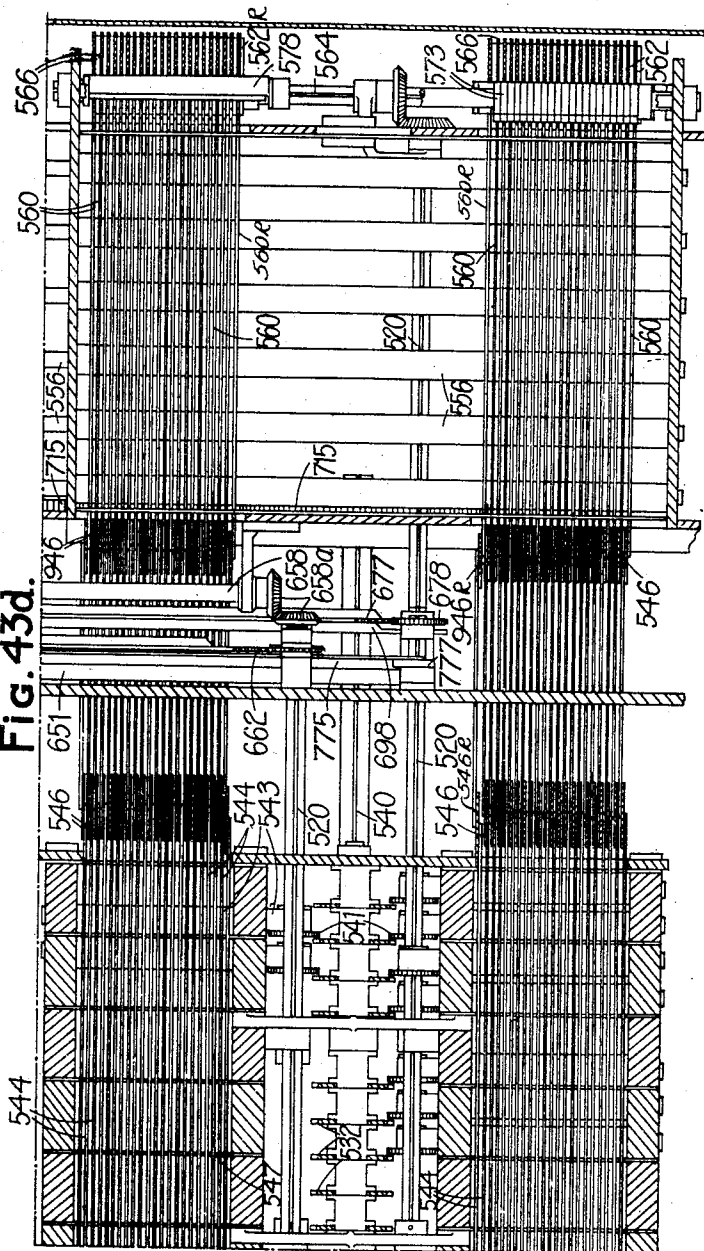
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Fig. 43d.



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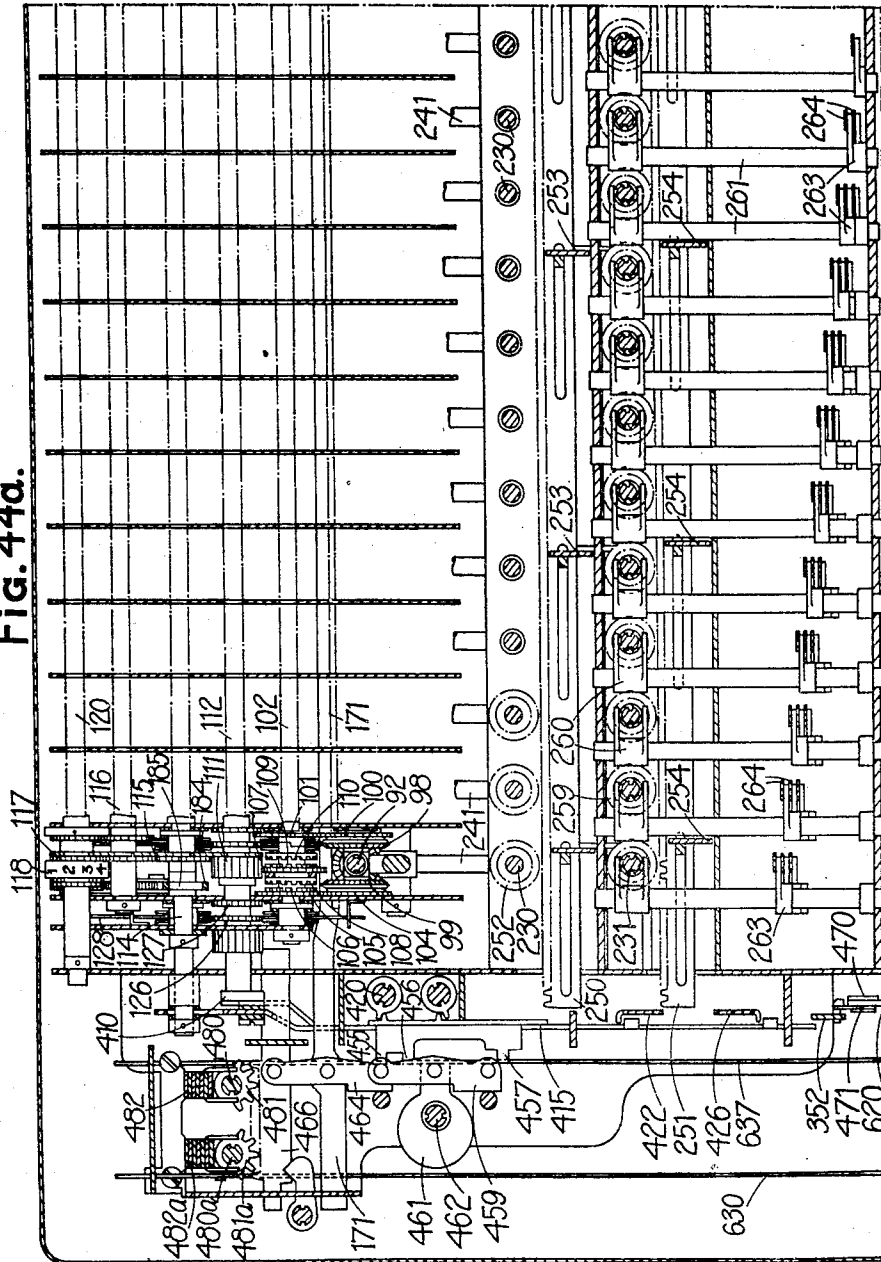
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Fig. 44a.



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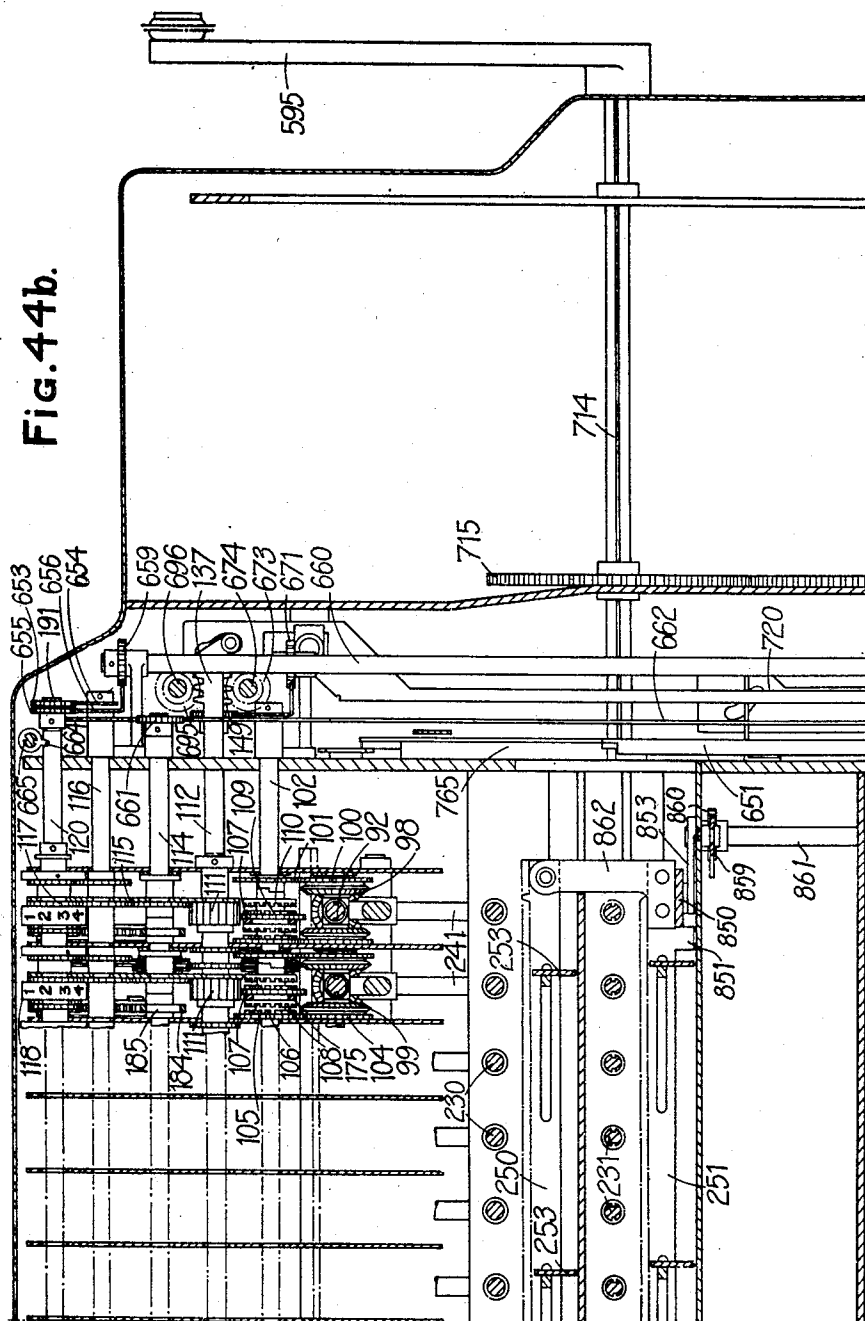
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Fig. 44b.



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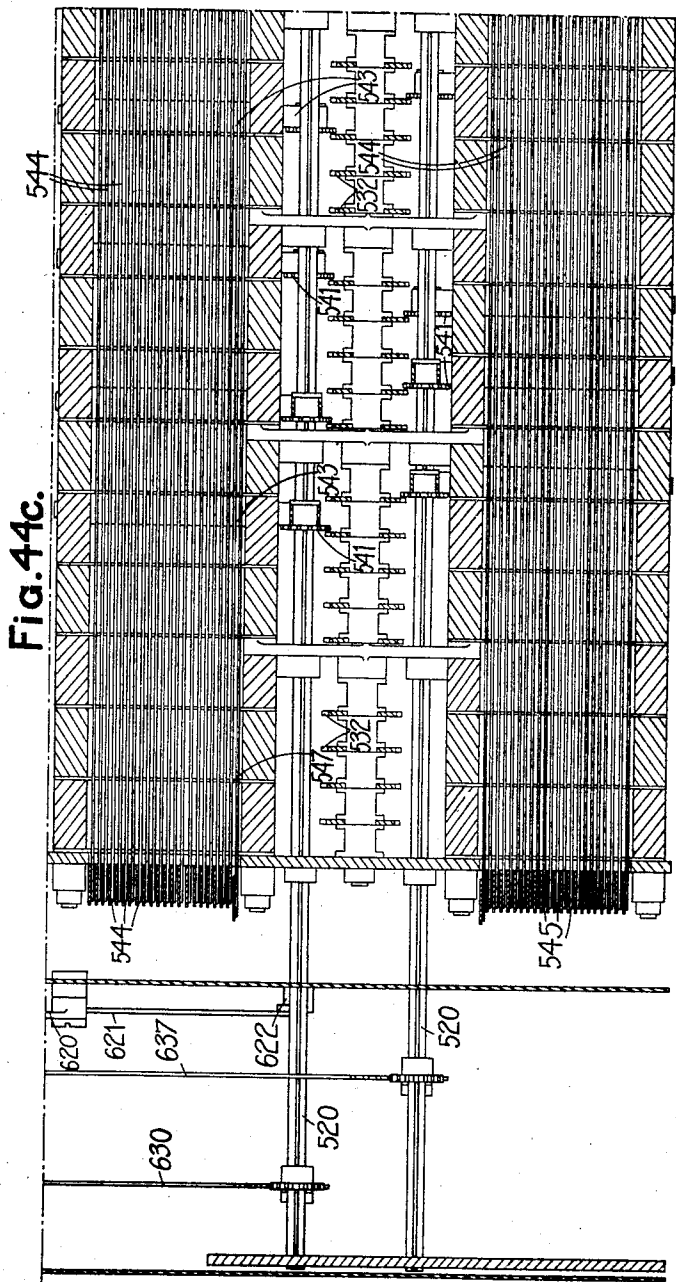
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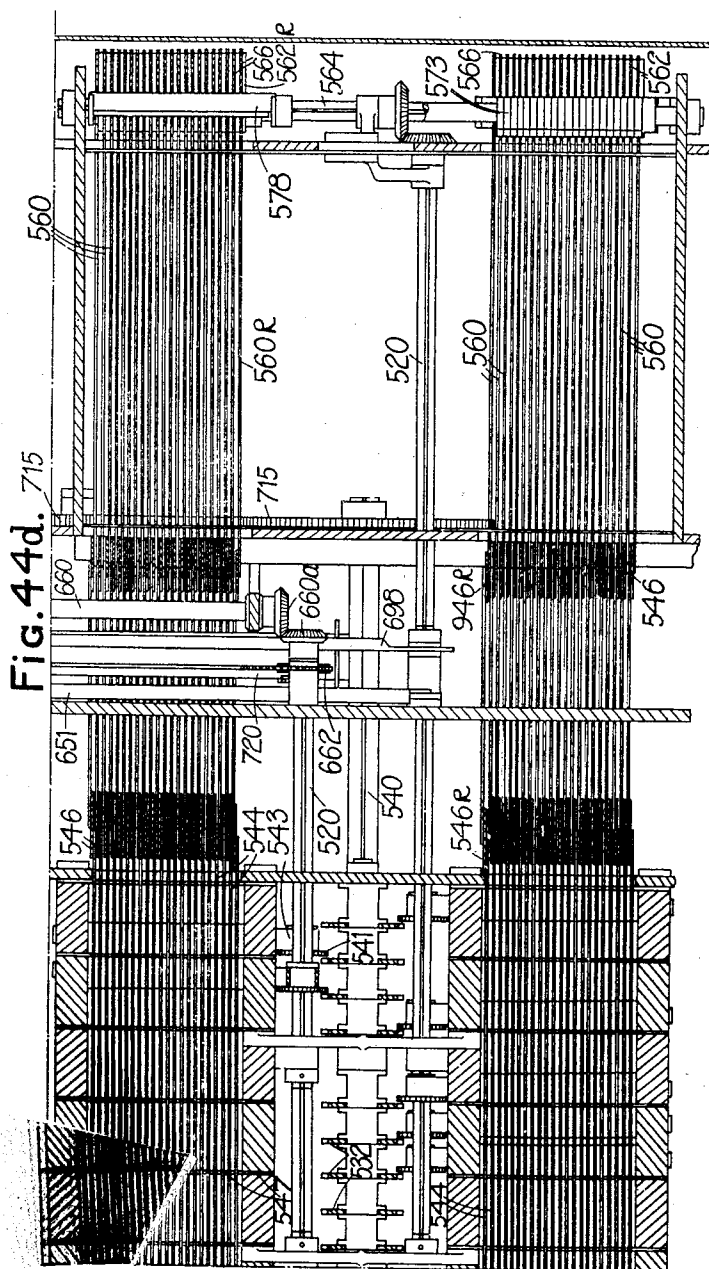
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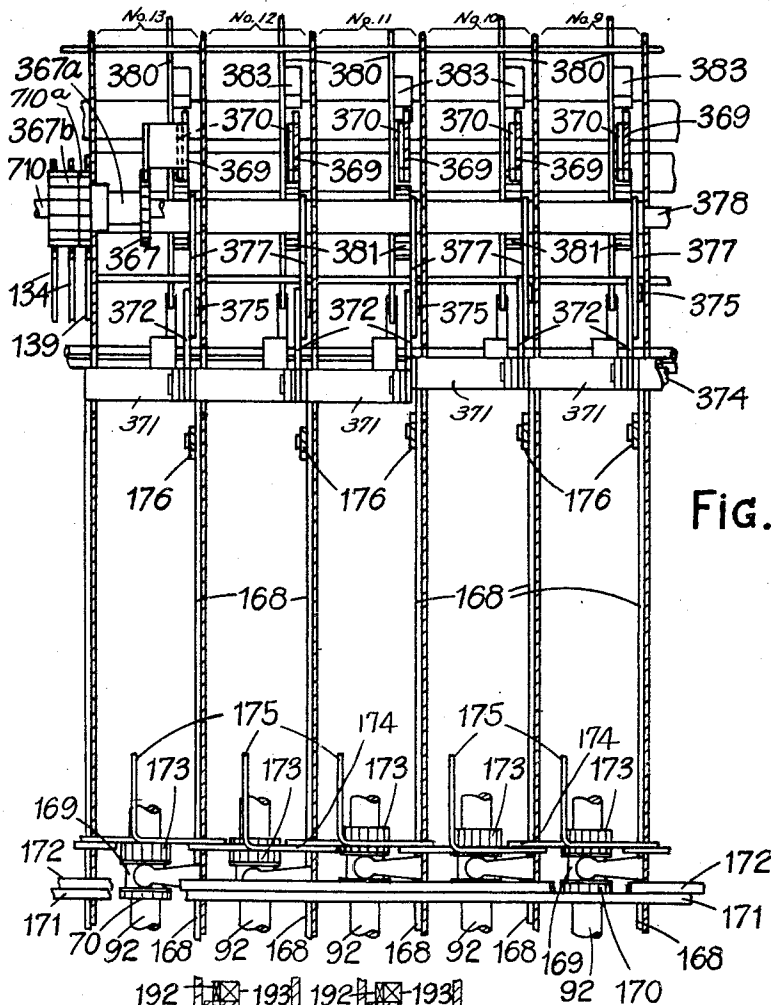


Fig. 45.

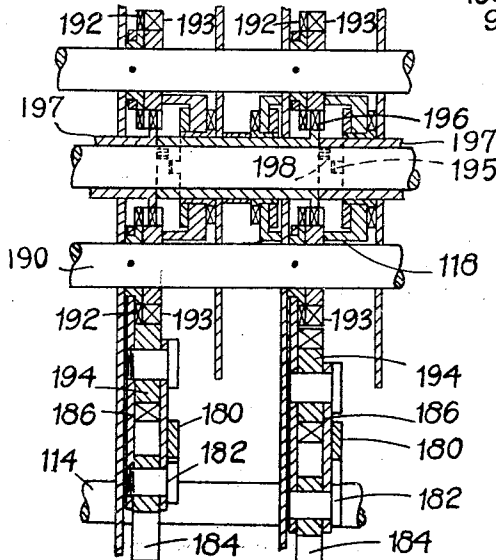


Fig. 46.

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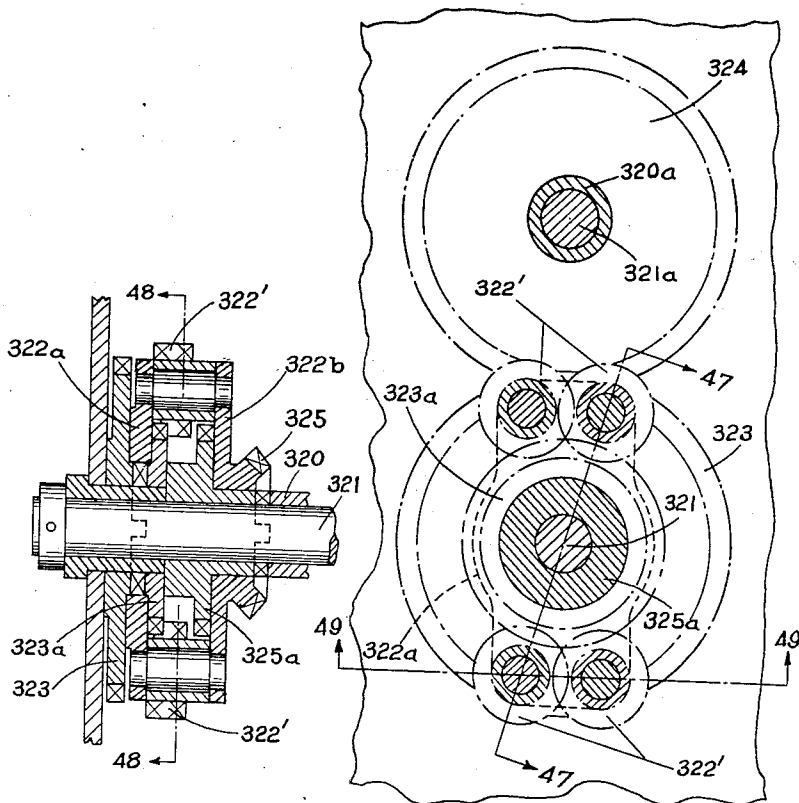


FIG. 47.

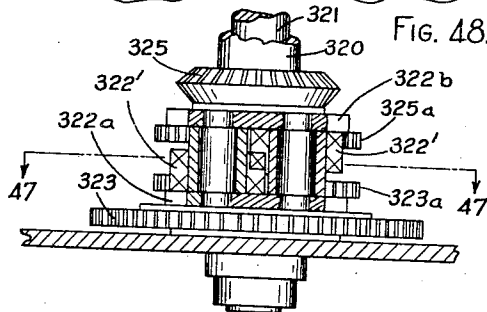


FIG. 49.

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CALCULATING MACHINE

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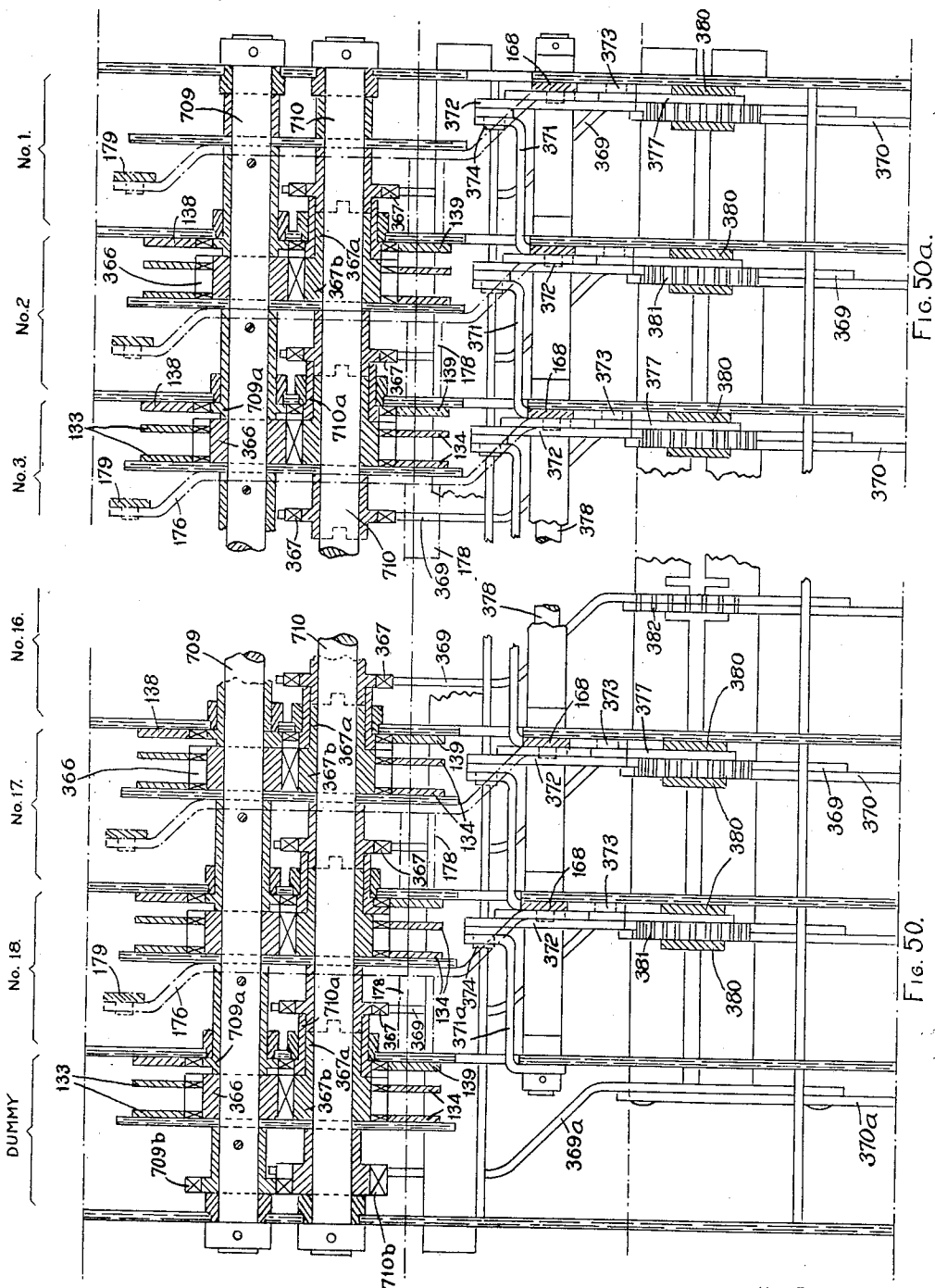


Fig. 50a.

Fig. 50.

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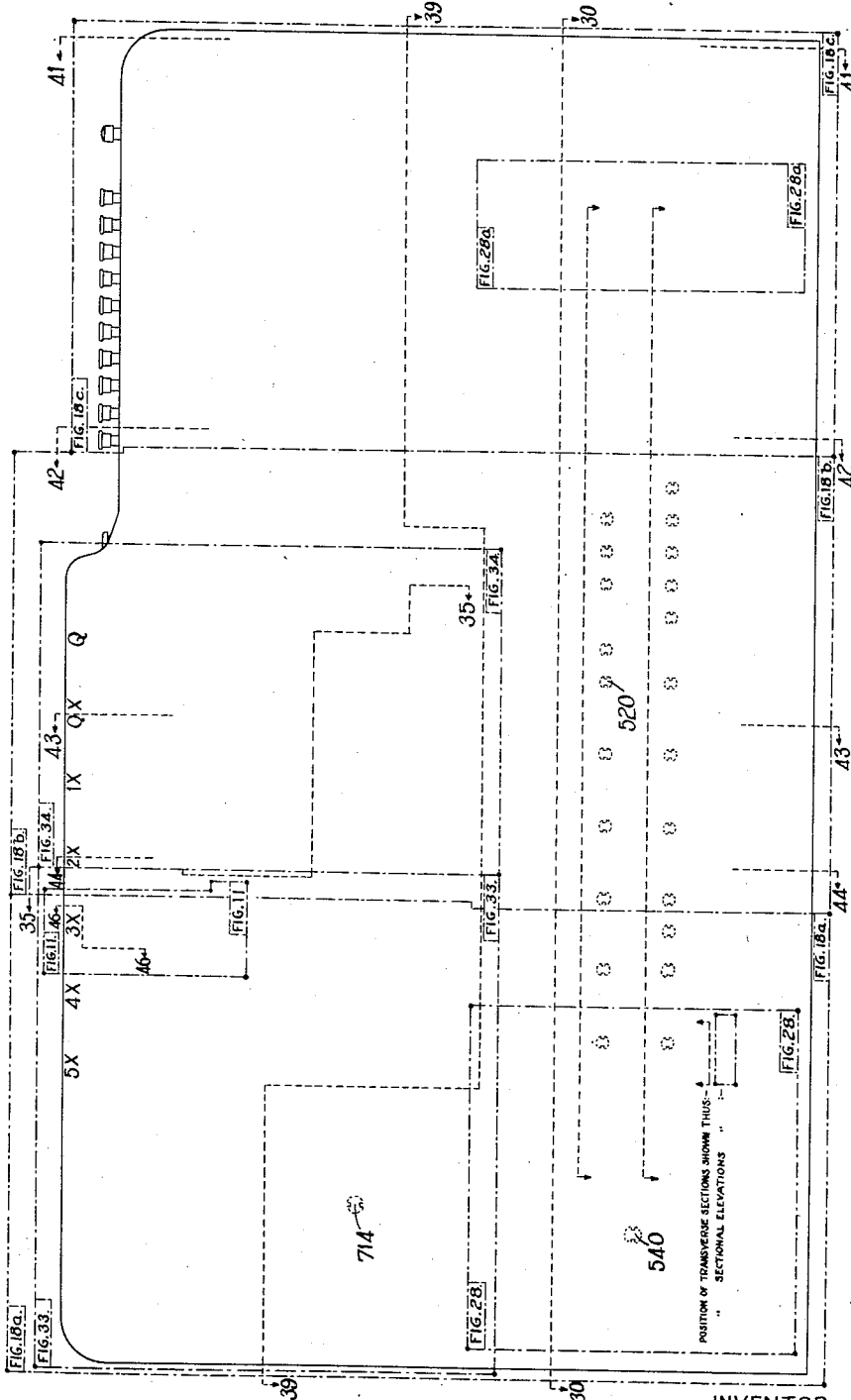


Fig. 51a.

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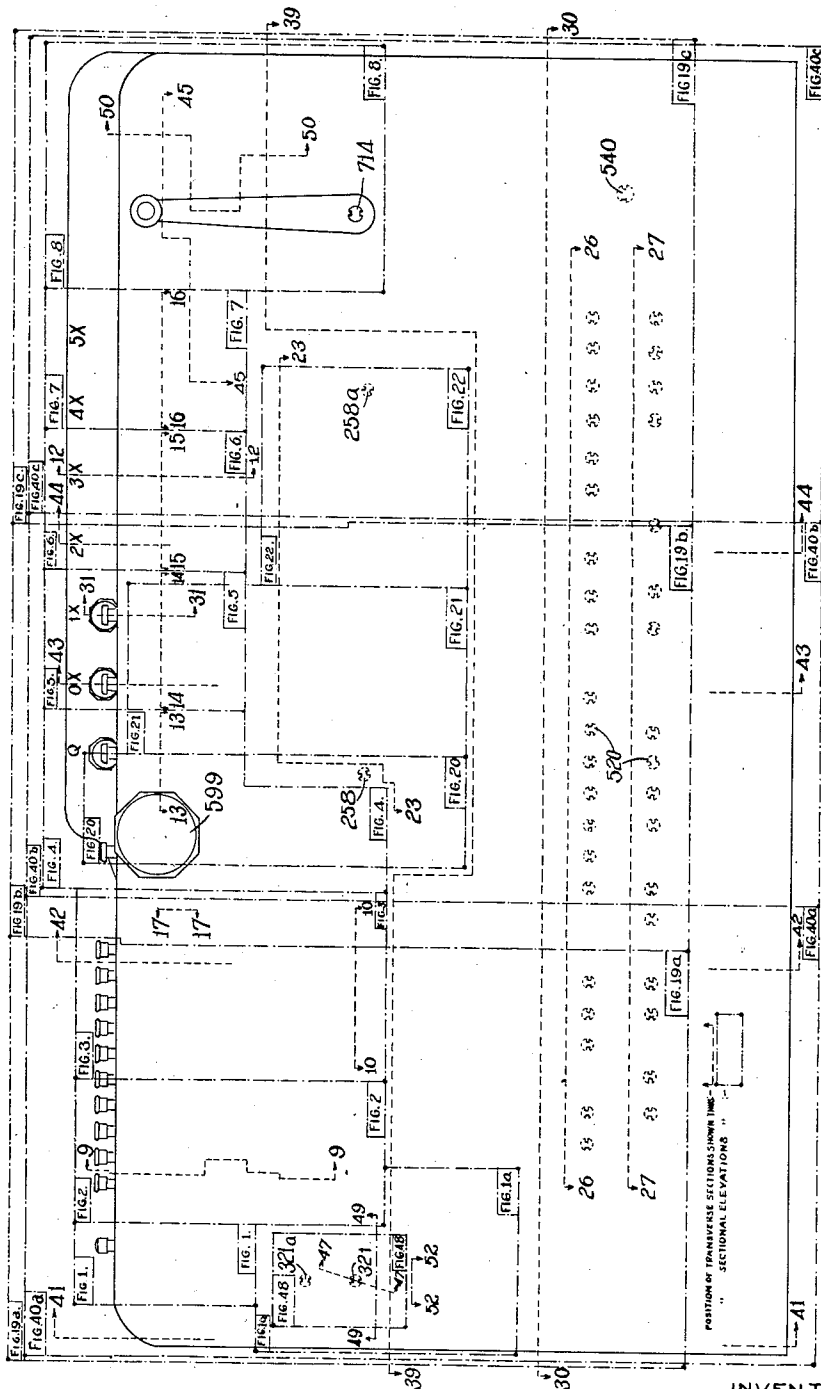
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CALCULATING MACHINE

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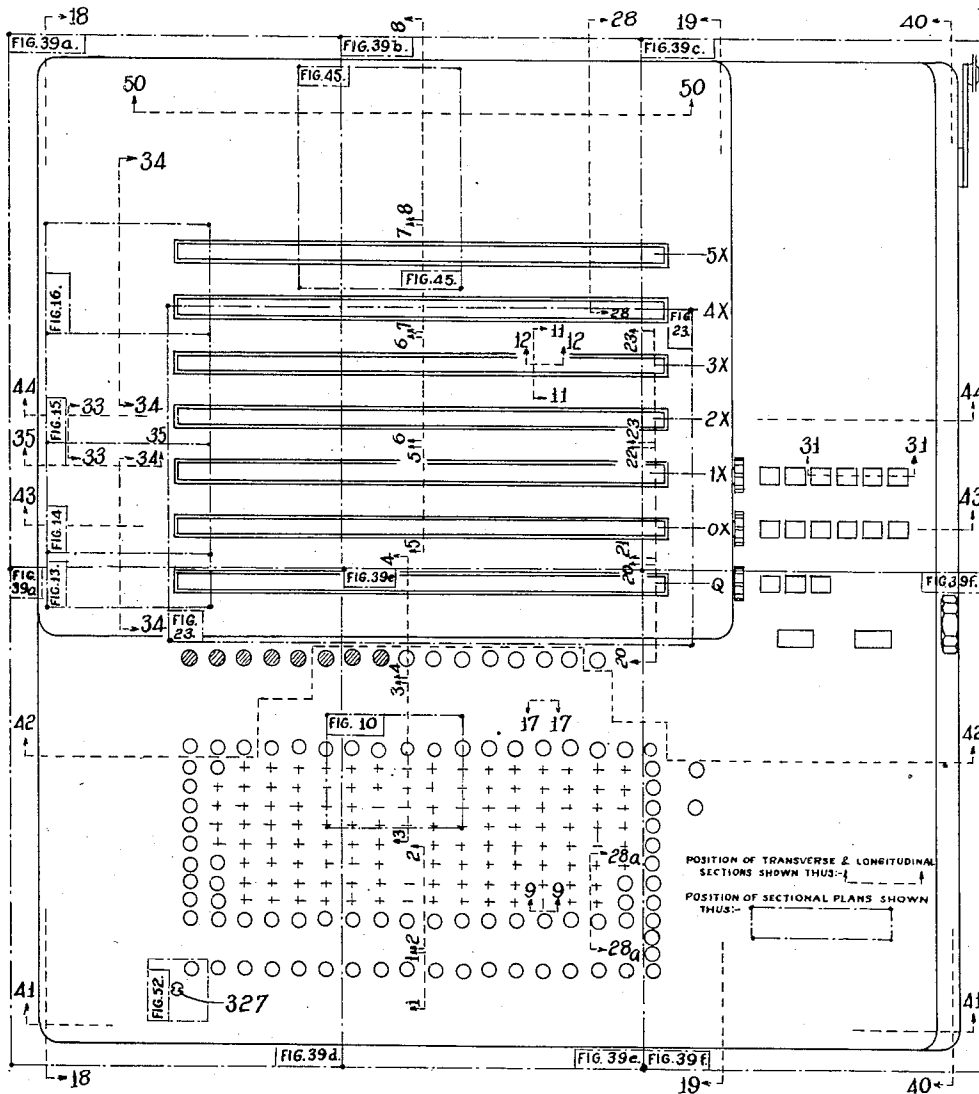


Fig. 51c.

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UNITED STATES PATENT OFFICE

2,298,263

CALCULATING MACHINE

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Application June 14, 1939, Serial No. 279,034

21 Claims. (Cl. 235—61)

This application is an improvement on the earlier machine of my United States application Serial No. 214,921 dated June 21, 1938, and relates to calculating machines.

Calculating machines at present on the market perform division by repeated subtraction of the divisor from the dividend and require an average of 6.5 cycles per quotient digit. Such machines have been arranged to perform multiplication by the method of repeated addition of the multiplicand and they require an average of 4.5 cycles per multiplier digit. Such machines are, thus, slow in operation. Multiplying machines are on the market which only require one cycle per multiplier digit but such machines do not perform division.

One object of this invention is to provide a machine that performs division at a much higher speed than the machines referred to above. The speed of the machine may be as high as one cycle only per quotient digit but economy of mechanism can be obtained by operating at lower speeds such as 1.5 or 2 cycles per quotient digit.

Another object is to provide a machine that will multiply or divide at high speed.

Another object of this invention is to provide a calculating machine comprising a plurality of totalizers, means for calculating predetermined multiples of a divisor and registering them each in a separate one of the totalizers, means for entering the upper part of a dividend into each totalizer concurrently in such manner as to obtain in each the difference between the upper part of the dividend and the multiple originally in that totalizer, canvassing means for canvassing the totalizers to select the totalizer containing the smallest difference of a predetermined sign, means for registering the said difference as the upper part of the dividend for the next step of the calculation, and means for registering the digit corresponding to the multiple related to the selected totalizer as a quotient digit.

Another object is to provide a calculating machine that performs both division and multiplication and comprises means for calculating predetermined multiples of a divisor or multiplicand, dividing means for concurrently comparing the multiples with an upper part of a dividend, selecting the largest multiple that is not greater than the said upper part of the dividend, registering the digit corresponding to the selected multiple as a quotient digit, and obtaining the difference between the selected multiple and the upper part of the dividend and registering the

difference as the upper part of the dividend for the next stage of the division, and multiplying mechanism comprising means for selecting those of the said multiples of the multiplicand that correspond to the various digits of a multiplier and means for summing the selected multiples each multiplied by a power of ten appropriate to the multiplier digit to which it corresponds.

Another object is to provide a machine that divides a dividend by a divisor and concurrently multiplies the multiplicand by the quotient of the divisor and dividend. The machine calculates predetermined multiples of a divisor and the corresponding multiples of a multiplicand, compares the multiples of the divisor with a dividend to select the largest multiple that is not greater than the dividend and the corresponding multiple of the multiplicand, subtracts the selected multiple of the divisor from the dividend, sets the difference as the new dividend for the next step of the calculation and sums the selected multiples of the multiplicand each multiplied by an appropriate power of ten.

With such a machine some of the denominational sections will be used for division and others for multiplication so that the machine is divided into two portions and a further object is to provide means for splitting the machine between any two denominational sections into the two said positions whose size can thus be varied as desired.

The machine may be arranged to obtain each quotient digit in a single cycle only by using, as the multiples, all the products of the divisor and each digit in the notation of the dividend, that is the digits 0 to 9 in the case of the decimal notation. Alternatively, the machine may use fewer multiples so that a simpler multiple-forming mechanism may be used. In such a machine some, at least, of the quotient digits may require two or more cycles to obtain so that the machine speed, measured by the reciprocal of the number of cycles required to perform a calculation, will be reduced although this may be offset by the possibility of running the machine at a higher speed owing to the lesser amount of mechanism to be driven.

If a series, such as once and twice, or once, twice and three times, or once to five times, having no discontinuity is used, machine time may be saved by only performing a cycle, if, in the preceding cycle for the same quotient denomination the dividend was less than the greatest multiple. Thus with the series once to five times, one cycle only is needed to obtain 0, 1, 2, 3 or 4

as a quotient digit, but if the dividend is five times or greater than five times the divisor a second cycle is required and the quotient digit is obtained as $5+0$, $5+1$, $5+2$, $5+3$, or $5+4$. The average number of cycles with this series is 1.5 cycles.

Another object of this invention is to provide means for measuring the positions of the highest significant figures of the divisor and the dividend to determine their relative displacement as registered in the machine and column-shift mechanism adjustable in accordance with the said relative displacement at each stage of the calculation to correlate the dividend and the multiples of the divisor.

Other objects and advantages of the invention will be apparent from the following description of one form of embodiment comprising an 18-column key-set and handle-operated machine employing the decimal notation and based upon the five-multiple series of once to five times the divisor.

In the drawings:

Figures 1, 1a, 2, 3, 4, 5, 6, 7 and 8 form a vertical section through the keyboard, totalizers and measuring apparatus of the machine. Figure 1a should be arranged below Figure 1 and the remaining figures in order on the right of Figure 1.

Fig. 2 is also indicated as a section taken on lines 2—2 of Figure 9.

Figure 3 is further designated as a section on line 3—3 of Figure 9.

Figure 6 is indicated as a section on line 6—6 of Figure 12.

Figure 9 is a vertical section on the line 9—9 of Figure 2 through one section of the keyboard.

Figure 10 is a section on the line 10—10 of Figure 3 and shows the operation of the mechanism for splitting the clearing of the keyboard.

Figure 11 is a view of one totalizer as seen from the opposite side of the machine to Figures 4 to 7. This figure is a section on the line 11—11 of Figure 12.

Figure 12 is a section on the line 12—12 of Figure 6 through one totalizer.

Figures 13, 14, 15 and 16 together form a horizontal section through the highest denomination of the totalizers and through canvassing mechanism on the lines 13—13, 14—14, 15—15 and 16—16 of Figures 4 to 7 respectively.

Figure 17 is an end view of certain slides in the keyboard section of the machine.

Figures 18a, 18b and 18c together form a vertical section along the line 18—18 of Figure 38, as seen from the left.

Figures 19a, 19b and 19c together form a vertical section through the machine on the line 19—19 of Figure 38. These figures form an elevation of the right-hand side of the machine with the control keys and mechanism removed.

Figures 20, 21 and 22 together form a vertical section through the machine and show column shift mechanism, quotient place mechanism and part of the measuring apparatus. These figures are in the same plane as Figures 1 to 8, and if Figures 1 to 8 are superimposed on Figures 20, 21 and 22, a complete vertical section through the calculating part of the machine is formed.

Figure 23 is a section on the line 23—23 of Figures 20, 21 and 22 and forms a plan of the column shift mechanism.

Figures 24a to 24h are diagrams showing the operations of the machine and the results obtained at each stage during the entering of a

dividend, a divisor and a multiplicand during an example of a calculation.

Figures 25a to 25p are diagrams showing the operation of the machine and the results obtained at each stage during an example of a calculation.

Figures 26 and 27 are conventional diagrams to illustrate in plan the arrangement of the driving cams and connections to various parts.

Figures 28 and 28a are together a vertical section through the driving mechanism on the line 28—28 of Figures 39b and 39e.

Figure 29 is a section on the line 29—29 of Figure 28.

Figures 30 and 30a together constitute a section on the line 30—30 of Figs. 28 and 28a showing a part of the control mechanism in action.

Figure 31 shows the construction of the control keys of the machine.

Figure 32 is a detail of a cycle-controlling cam provided in the control mechanism.

Figures 33 and 34 together form a sectional elevation on the line 34—34 of Figure 35. The right-hand part of Figure 33 is, however, a section on the line 33—33 of Fig. 35.

Figures 34a and 34b are conventional diagrams to illustrate the action of the multiple totalizer selecting mechanism.

Figure 35 is a vertical section through the canvassing mechanism on the line 35—35 of Figures 33 and 34.

Figures 36 to 36d and 37 to 37c are timing diagrams for the machine.

Figure 38 is a somewhat diagrammatic plan of the machine.

Figures 39a to 39f inclusive (with Figures 39a, 39b and 39c arranged side by side and Figures 39d, 39e and 39f arranged side by side below Figures 39a to 39c) form a horizontal section through the machine which is taken on a plane lying just below the mechanism shown in Figures 2 and 3 and extending across the entire machine. This section shows the relationship between the column shift mechanism, the main drive and the controlling connections.

Figures 40a, 40b and 40c arranged side by side in that order form an outside elevation of the machine as seen from the right in Figure 38 and with the cover broken away. This view is taken substantially on the line 40—40 of Figure 38.

Figures 41a to 41d arranged with Figures 41a and 41b side by side and Figures 41c and 41d side by side below Figures 41a and 41b form a front elevation of the machine with the cover broken away. This view is taken substantially on the line 41—41 of Figure 38.

Figures 42a to 42d arranged in the same way as Figures 41a to 41d form a vertical section through the machine on the line 42—42 of Figure 38. These figures show the keyboard and the gearing between the keyboard section of the machine and the totalizers.

Figures 43a to 43d arranged in the same way as Figures 41a to 41d form a vertical section on the line 43—43 of Figure 38. This view shows the totalizer OX together with the column shift mechanism and the drive and control mechanism in section.

Figures 44a to 44d arranged in the same way as Figures 41a to 41d form a vertical section on the line 44—44 of Figure 38. The view is similar to that of Figures 43a—43d except that it is taken through the totalizer 3X.

Figure 45 is a horizontal section on the lines 45—45 of Figures 7 and 8 and shows the mechanism in five sections of the machine by which

the machine can be split into a multiplying and dividing part. Only those parts involved in splitting the machine are shown in this view; and

Figure 46 is a development of a section along the line 46—46 of Figure 11 and shows from underneath the mechanism for splitting the means for zeroizing a totalizer.

Figures 47, 48 and 49 are sectional views showing the detailed construction of a part of the means for correlating the dividend and divisor.

Figures 50 and 50a are together a sectional elevation on the line 50—50 of Figure 8 and shows the construction of a part of the tens transfer mechanism and of the means for interrupting the transfer sequence in accordance with the position of the split.

Figures 51a, 51b and 51c are side elevation and plan views of the machine showing the relative positions of the lines through which the sectional views comprising the various figures have been taken.

Figure 52 is a section on the line 52—52 of Figure 1a and shows the action of the column shift resetting means.

GENERAL DESCRIPTION

Keyboard, totalizers and splitting

In Figure 38, which is a somewhat diagrammatic plan of the machine, columns of depressible keys 50 form the keyboard for the entry of numerical data into the machine. There are eighteen columns, numbered 1 to 18 from the right, each column containing ten keys marked "0" to "9" in the order shown. Any setting in a column can be cleared by depressing the "0" key in that column. For a general clearing of all the columns to the left of the split, a clearing key 870 is provided, and for the clearing of all the columns to the right of the split there is provided a similar key 870a, the number of columns cleared in either case depending upon the position of the split.

The results at each stage of a calculation are indicated by totalizers marked Q, 0X, 1X, 2X, 3X, 4X and 5X. The dials of these totalizers are denominationally in line with the corresponding keyboard columns and are visible through windows 596.

The splitting of the machine into two portions includes the splitting of the keyboard and all the totalizers except the one marked Q, so that all the denominations to the left of the split may be utilized for dividing and all those to the right for multiplying. In the case of the totalizer Q, splitting is unnecessary for a reason that will be apparent at a later stage. The position of the split is determined by the column capacity required in each portion of the machine. This position may be varied by manually rotating a knob 599, and is signified by indicators showing through windows 165, there being a separate indicator for each denomination. Each indicator has two positions, one showing a red signal and the other a white one. All the indicators on the left of the split show the red signal and all those on the right show the white one; thus, the split is indicated by the point at which the signal colors change.

Quotient results are shown in Q and this totalizer is also adapted for use as a multiplier register. Within limits that will be defined, any portion of 0X may be utilized as a dividend register without regard to the position of the split, but product results are only shown in the lower portion of 0X. The upper portions of the

totalizers 1X to 5X are mainly employed for registering the predetermined multiples of the divisor entered negatively, the series of multiples chosen for this embodiment being once to five times arranged in factorial order. The lower portions of these totalizers are mainly employed for registering the predetermined multiples of the multiplicand entered positively and in the same factorial order as the divisor multiples.

Control keys

For controlling the functioning of the various parts of the machine in accordance with the operation required, control keys 550/1 to 550/17 are provided and each operation of the machine is effected by rotating the handle 595 through one or a number of complete revolutions after setting an appropriate one or more of the control keys. The principal use of each key is set forth in Table 1 following:

Table 1

Control key No.—	Purpose	Number of machine cycles
550/1	Simultaneously zeroizing upper portion of each of 1X to 5X.	One.
550/2	Spare key: available for any other operation.	
550/3	Simultaneously entering divisor multiples negatively in upper 1X to 5X and multiplicand multiples positively in lower 1X to 5X.	Five.
550/4	Simultaneously zeroizing lower portion of each of 1X to 5X.	One.
550/5	Spare key: available for any other operation.	
550/6	do.	
550/7	Zeroizing upper portion of 0X.	Do.
550/8	Entering an amount positively in upper portion of 0X, especially a dividend or multiplier.	Do.
550/9	Entering an amount negatively in upper portion of 0X.	Do.
550/10	Zeroizing lower portion of 0X.	Do.
550/11	Accumulating a product result positively in lower 0X.	Indefinite.
550/12	Accumulating a product result negatively in lower 0X.	Do.
550/13	Zeroizing whole of Q.	One.
550/14	Entering quotient result positive in Q.	Indefinite.
550/15	Entering quotient result negative in Q.	Do.
550/16	Controlling preparatory cycle in dividing and multiplying operations.	One.
550/17	Controlling subsequent cycles in dividing and multiplying operations.	Indefinite.

Other uses for the control keys, either separately or in combination, will become apparent as the description proceeds.

Entering dividend

The dividend is set up on the keyboard in any convenient position but preferably to the left of the split, and the control key 550/8 is depressed. The machine is then operated through one cycle, whereupon the dividend appears in 0X, each digit being in line with its set-up on the keyboard. Near the end of the cycle the control key is released.

Entering multiplier

As will later be explained, a multiplier is entered as though it were a dividend, the same control key 550/8 being used.

Entering divisor and multiplicand multiples

To enter the divisor multiples, the divisor is set up on the keyboard to the left of the split, the control key 550/3 is depressed, and the machine is operated through five cycles by rotating the handle 595 once for each cycle. During these cycles the divisor multiples are built up in their respective totalizers by a series of successive subtractions, the results being as shown in Table

2, each multiple being registered as a complement.

To enter the multiplicand multiples, the multiplicand is set up on the keyboard to the right of the split, the same control key 550/3 is depressed and the machine is operated through five cycles. During these cycles, the multiplicand multiples are built up in their respective totalizers by a series of successive additions, the results being as shown in Tables 3 and 4.

The divisor multiples and the multiplicand multiples may be built up simultaneously if desired by entering both amounts on the keyboard, depressing the appropriate control key, then operating the machine through five cycles.

Whether the divisor and multiplicand multiples are entered separately or simultaneously, the depressed control keys are not released until the completion of the fourth cycle.

It will readily be appreciated that a divisor must not be entered with its highest digit in the highest denomination of the machine, but instead at least one denomination should be reserved on its left to accommodate in the multiple totalizers the tens entry relating to the multiples of that digit.

Operating machine in dividing and/or multiplying cycles

The construction of the mechanism is such that it always performs a multiplying cycle in the lower portion simultaneously with each dividing cycle in the upper portion, using the quotient result in the upper portion as a multiplier in the lower portion.

If no multiplicand factor has been entered, the accompanying multiplication is that of multiplying a blank or zero multiplicand by the quotient result, which gives a blank or zero product. In that case the machine is said to perform "division only," because only data for a dividing operation has been entered, the factors and results appearing in the totalizers as shown in Table 2.

If a dividend entry in OX is divided by "one" as the divisor, the resulting quotient in Q will be identical with the dividend. If there is a multiplicand entry, the latter will be simultaneously multiplied by the quotient result but, because the quotient result is identical with the dividend entry, it is equally correct to say that the multiplicand entry is multiplied by the dividend entry. Thus, to multiply together two factors, one factor is entered as a dividend and divided by "one," the other factor is entered as a multiplicand. The machine is then said to perform "multiplication only" because only data for a multiplying operation has been entered, the factors and results appearing as in Table 3.

When a dividend entry is divided by an amount other than "one" and a multiplicand entry is simultaneously multiplied by the quotient result, the machine is said to perform "division and multiplication simultaneously," because data for both a dividing and a multiplying operation have been entered. The factors and results then appear as in Table 4.

In the present embodiment, no means are shown for performing simultaneously a dividing operation and an independent multiplying operation in which the multiplier amount is other than the quotient result, for the reason that duplex action of that kind is not included in the purpose of the invention.

In "division only" quotients may be entered

either positively by using control key 550/14 or negatively by using key 550/15, and quotients may be totaled, if desired, by omitting to clear the totalizer Q before commencing the next calculation. The totalizer may be cleared by depressing the key 550/13. Also in "division only," the position of the split is immaterial as long as there are sufficient denominations in the upper portion to accommodate all the digits of the divisor multiples. It may even be moved, if preferred, to the extreme right so that the upper portion of the machine includes all the denominations and the lower none, thus virtually converting the machine into a dividing machine only. An intermediate position for the split is preferred, however, in order to minimize its adjustment in general use. In "multiplication only," multipliers may be totaled as in "division only" because each multiplier is reentered as a quotient in Q. Products may also be totaled, using control key 550/11 for positive entries and 550/12 for negative entries.

Table 2
DIVISION ONLY

Totalizer	Upper portion	Lower portion
5X	Five times the divisor entered negatively.	Blank.
4X	Four times the divisor entered negatively.	Do.
3X	Three times the divisor entered negatively.	Do.
2X	Twice times the divisor entered negatively.	Do.
1X	Once times the divisor entered negatively.	Do.
0X	Dividend entered positively.	Dividend: alternative position.
Q	Quotient result entered positively or negatively.	

Table 3
MULTIPLICATION ONLY

Totalizer	Upper portion	Lower portion
5X	Five times "one" entered negatively.	Five times the multiplicand entered positively.
4X	Four times "one" entered negatively.	Four times the multiplicand entered positively.
3X	Three times "one" entered negatively.	Three times the multiplicand entered positively.
2X	Twice times "one" entered negatively.	Twice times the multiplicand entered positively.
1X	Once times "one" entered negatively.	Once times the multiplicand entered positively.
0X	Multiplier entered positively.	Product result entered positively or negatively.
Q	Multiplier reentered positively or negatively.	

Table 4
SIMULTANEOUS DIVISION AND MULTIPLICATION

Totalizer	Upper portion	Lower portion
5X	Five times the divisor entered negatively.	Five times the multiplicand entered positively.
4X	Four times the divisor entered negatively.	Four times the multiplicand entered positively.
3X	Three times the divisor entered negatively.	Three times the multiplicand entered positively.
2X	Twice times the divisor entered negatively.	Twice times the multiplicand entered positively.
1X	Once times the divisor entered negatively.	Once times the multiplicand entered positively.
0X	Dividend entered positively.	Product result entered positively or negatively.
Q	Quotient result reentered positively or negatively.	

Correlating dividend with divisor and skipping "zeros" in dividend or multiplier

It was stated as an object of the invention to provide means for measuring the positions of the

highest significant figures of the divisor and dividend and to correlate the latter with the divisor at each stage of the calculation. There are two methods of accomplishing this. As will be shown later, every dividing or multiplying series of cycles is commenced with a special preparatory cycle using the control key 550/16. During this cycle, no quotient or product result is entered. Each subsequent cycle, using the control key 550/17, is a result entering cycle.

One method of correlation is to measure the positions of the significant digits on entering the amounts and then effect an aligning column shift of the dividend in the preparatory cycle. In each of the subsequent cycles in which the quotient result is less than "5", the basic adjustment receives a supplementary adjustment of one place leftward so as to move the quotient signal rightward one place in readiness for the next quotient entry.

The second method is to measure the positions of the significant digits, not on entering the amounts but early in each cycle, with the result that any intermediate "zeros" in the difference isolated from the previous cycle will cause an extra shift of the latter one place leftward for each "zero" encountered so that, what in the first method would be a blank cycle giving "0" as a quotient result, would in the second method be entirely omitted.

Each method has advantages but the first method has been chosen to illustrate the invention.

It will be appreciated that the foregoing applies equally well to the correlating of the divisor "one" and the multiplier treated as a dividend as described in reference to "multiplication only" for either method may be applied.

With the present machine a dividend and a divisor may be entered with like denominations in any relationship, provided that the divisor is entered wholly on the left of the split. The dividend may be entered anywhere in OX without reference to the position of the split, but in this embodiment its highest digit must not be more than nine columns from the highest digit of the divisor. In the preparatory cycle the machine automatically column-shifts the dividend in whichever direction is required to align its highest digit with that of the divisor. This feature is of particular value in an extended calculation where, for example, a product result in the lower portion of OX is required to act as a dividend or multiplier in a subsequent calculation.

Quotient place indicating

Quotient place indicating is effected by showing a signal through a window 598 in whichever denomination the quotient will be entered during the cycle, and the column-shifting of a dividend in one direction is always accompanied by a corresponding shift of the quotient place signal in the opposite direction. The position for entering the first quotient digit is dependent upon the position of the signal when commencing the calculation, and also upon the amount the dividend is shifted to align it with the divisor. An example of a calculation given later in the description will show how the commencing position is influenced by these two circumstances. If the highest digits are already in alignment, there will be no aligning shift and consequently the first quotient entry will be made in whichever column is occupied by the signal. The position of the signal can be adjusted before entering the factors

by column-shifting a blank amount in one or other portion of OX.

Quotient entering

As set forth in the objects of the invention, with the series of multiples once to five times the divisor, an extra cycle for the same quotient denomination is required if the quotient entry is "5". In this extra cycle the machine is required to ascertain whether "5" is the true quotient or whether it is only a partial quotient. If it is the true quotient, then the quotient entry in the extra cycle will be "0". If it is only a partial quotient, then the quotient entry in the extra cycle will be either "1, 2, 3 or 4" and, because this entry is made in a denomination already containing "5", the final or true quotient result will be "6, 7, 8 or 9".

In a "true-quotient" cycle or an "extra-quotient" cycle, the entering of the quotient value is always followed by a rightward shift of the quotient signal to the position required for the quotient entry in the next cycle. It is therefore always possible to tell if the last quotient figure calculated is a true quotient by observing whether or not the quotient indicator has moved to the next column.

Column-shifting

The column-shifting means disclosed in this specification is applicable to (a) automatic shifting of a dividend or product amount in OX during a calculating cycle: (b) manual shifting of an amount already in OX.

(a) Automatic shifting has already been referred to under "correlating dividend with divisor and skipping 'zeros' in dividend or multiplier." It applies only to the upper and lower portions of OX and only takes place during a dividing and/or multiplying series of operations, the means for manual shifting being held locked. Each automatic shift takes place during the calculating cycle in which it is required, the maximum shift (in this embodiment) of nine columns in either direction requiring no more movement of the mechanism than that necessary to effect a shift of only one column. The amounts in both portions of OX are shifted simultaneously in automatic working as though they formed only one amount.

(b) Any possible automatic shift can be performed manually by latching down an appropriate one of a number of shift keys 273 and, whichever of the zeroizing control keys 550/7 or 550/10 controls the clearing of the amount to be shifted, then rotating the handle one turn.

It will be observed that there are nineteen of the keys 273; eighteen are arranged one in each denomination and one on the extreme right. Each is marked with a designating numeral to show the amount of column-shift it controls. The shift key in column 9 and marked "N" is called the "normal" or "no shift" key because it adjusts the mechanism to give no column-shift when operated as above but, although no column-shift is effected, another purpose is served as will later be described in reference to the details of the mechanism. The other keys are arranged in two groups, one group on the left of the normal key for rightward shifts and the other group on the right for leftward shifts. A rightward shift of an amount in OX is accompanied by a leftward shift of the quotient signal and vice versa. With the quotient signal in the normal column and using, for example, the "2" key in column 11, the selected amount in OX is moved rightward

two places and the quotient signal is moved leftward two places from column 9 to column 11. When the quotient signal is moved from the normal position, it will always move to the same column as the operative shift key, no matter which key is selected. If the same key is used a second time, the amount in OX will be moved rightward a further two places and the quotient signal will be moved leftward another two places to column 13. If used a third time, the amount will be moved a total of six places rightward and the signal a total of six places leftward to column 15. Using the "6" key in the first shift cycle instead of the "2" key three times in succession would have produced the same amount of shift. From this example it will be understood that each shift key controls in each manual column-shift cycle an amount of shift comprising a complete step through as many denominations as are signified by its designating numeral and in a direction corresponding to its group. If a shift takes an amount in OX beyond the capacity of the machine in either direction, the part not within the capacity will be lost; thus, column-shifting an amount beyond the capacity of the machine provides an alternative method of clearing it. If the quotient signal is already displaced from the normal position when a shift is made, it will be moved from the displaced position through the same number of places as though it were moved from the normal position.

The "9" key on the extreme right is an extra shift key provided to enable a maximum rightward shift of nine columns to be balanced by an equal shift of nine columns leftward. It will be noted that this key has no quotient place signal, none being needed for this purpose.

In manual shifting, an amount in one portion of OX may be shifted to the other portion. If there is an amount already standing in that portion, then the first amount may be so shifted that it may be added to the standing amount.

In some calculations it may be preferred to have the quotient signal in some predetermined commencing position. The signal may be column-shifted to that position by leaving the upper or lower portion of OX blank, then using that portion for a blank column-shift operation which will move the signal to the predetermined position.

Transmitting a result from totalizer to keyboard

In a continued series of calculations it frequently occurs that a product or quotient result is required to be set up on the keyboard for use as a factor in a later calculation. A part of the mechanism for this purpose is incorporated in the drawings, but as it is not essential to the description of the present invention it will only be referred to briefly.

Clearing totalizers

An amount in the upper portion of IX may be cleared by depressing the zeroizing key 550/1 and rotating the handle 595. If at the same time there is an amount in any of the upper portions of 2X to 5X, this amount will also be cleared by the same operation. The lower portions of IX to 5X may be similarly cleared by using the key 550/4. The upper portion of OX may be cleared by depressing the key 550/7 and rotating the handle. The lower portion of OX may likewise be cleared by using the key 550/10.

Decimal point indicators

An indicator is provided in each of the totalizers Q, OX and IX. They are independent and each may be manually adjusted by the rotation of a knob 116a to any one of eighteen possible positions. As the splitting of the machine provides for the entry of two amounts in each of the totalizers OX and IX as described, and because there is only one indicator for each totalizer, each indicator can only be used on one side of the split at a time, but this suffices for ordinary requirements. In the case of the totalizer Q, this circumstance does not arise for the totalizer is not split and only one amount at a time is entered. Thus, in "division only," where the factors and results are disposed as in Table 2, the IX indicator is utilized to point off the divisor in the upper portion of IX, and the OX indicator to point off the dividend in whichever portion of OX it has been entered. In "multiplication only," where the factors and results are as set forth in Table 3, the IX indicator is moved to the lower portion to point off the multiplicand, and likewise the OX indicator to point off the product result in OX. In "simultaneous division and multiplication" where the factors and results are as shown in Table 4, both the OX and the IX indicators may be employed in either portion of their respective totalizers according to the requirements of the calculation. As already described, the factors may be entered in any position in their respective totalizers, provided that sufficient room is left for the results so that, when entering a factor in which the units denomination is known, it follows that the decimal point position for that factor is known and the indicator can, therefore, be adjusted to that position. For the position of the decimal point in the results, the customary rule is applied, namely, that the number of decimal places in the quotient is equal to the number of places in the dividend minus the number in the divisor, and the number of decimal places in the product is equal to the number of places in the multiplier plus the number in the multiplicand. In the case of a product, it is preferred to position its decimal point an additional column leftward of that obtained by the foregoing rule owing to the operation of the column-shift means as will be explained.

Example of division and multiplication simultaneously

A specific example of a simultaneous dividing and multiplying operation will now be given. Let it be required to divide 1498 by 14 and at the same time multiply the resulting quotient by 33.

The totalizers are first cleared of all values by depressing control keys 550/1, 550/4, 550/7, 550/10 and 550/13 and then rotating the handle 595 one turn. This cycle zeroizes both the upper and lower portions of each totalizer, the depressed control keys remaining latched down until near the end of the cycle when they are released. The keys 870 and 870a are also depressed to clear the keyboard of any previous settings. Neither of these keys is latched down and each is effective without rotation of the handle 595.

The split is now adjusted to give sufficient capacity for the dividing and multiplying operations; in this case, between columns 10 and 11 will be suitable. The machine is now ready for

entering the given data and commencing the calculation.

In Figures 24a to 24h are set forth the various steps involved at each stage of the calculation. Each figure shows the values in the totalizers and on the key board at the beginning or at the end of a stage in each cycle of operation; also, which control keys are depressed and whether or not any of them are released at the end of a cycle. The position of the split is shown by an asterisk and the position of the quotient place signal by an arrow. The latching of a column-shift key 273 or an equivalent column-shift adjustment is denoted by an underlining of the designating number which represents it. The depressing of a control key at the beginning of a cycle is marked by a bracket, and its release during a cycle by the omission of the bracket. Decimal point indications are shown as normal decimal points.

Entering dividend amount

With the machine cleared, the dividend "1498" is entered on the key-board to the left of the split in, say, columns 11 to 14, as shown in Figure 24a. The control key 550/8 is set and the handle 595 given one rotation, whereupon the dividend appears in the upper portion of OX as shown in Figure 24b, the key 550/8 is released and the keyboard is cleared.

Entering divisor and multiplicand multiples

The divisor "14" is entered on the keyboard to the left of the split in, say, columns 11 and 12, and the multiplicand "33" on the right in columns 4 and 5, these positions being chosen as described. The control key 550/3 is set as shown in Figure 24c and on rotating the handle once the divisor is entered negative in the upper part of 5X and the multiplicand positively in the lower part of the same totalizer, as shown in Figure 24d. It will be noted that the control key 550/3 is not released. On rotating the handle a second time, the amounts are again entered in 5X and also in 4X as shown in Figure 24e, the control keys again being held. Rotating the handle a third time causes the amounts to be entered in 5X, 4X and 3X as shown in Figure 24f, the control keys still being held. A fourth rotation enters the amounts in 5X, 4X, 3X and 2X as shown in Figure 24g; a fifth enters them in 5X, 4X, 3X, 2X and 1X as shown in Figure 24h; in the fourth cycle the key 550/3 is released. The machine now contains the multiples of the divisor entered negatively and registered as complements in their respective totalizer, and the corresponding multiples of the multiplicand entered positively and registered as true amounts. Thus, the totalizer 1X registers the divisor 14 as its complement 99999986 and the multiplicand 33 as a true amount. The totalizer 2X registers 99999972 as the complement of 28, or twice the divisor, and 66 which is twice the multiplicand. In the same way, the totalizers 3X, 4X and 5X register the appropriate multiples of the divisor negatively and of the multiplicand positively. The upper portion of the totalizer OX registers the dividend. Finally, the decimal points are adjusted as shown in Figure 24h to conform to the decimal point rule already referred to.

Correlating dividend with divisor

When the dividend was entered, the dividend and divisor aligning means, referred to under "correlating of dividend with divisor and skipping

"zeros" in dividend or multiplier," automatically measured the position of the highest figure in the dividend by sensing the number of zeros on its left as entered in OX, and then subtractively entering that number on a differencing device whereby column-shifting for aligning the dividend is controlled. When the divisor entry was made in 1X during the fifth multiple entering cycle, similar measuring means ascertained the position of the highest figure in the divisor by sensing the number of nines on the left of its complement as entered in 1X and then additively entering that number on the differencing device. It will be observed in this case that the number of zeros is four and the number of nines is six. Subtracting four on the differencing device and then adding six leaves a difference of plus two. This difference sets up a call in which the numeral amount determines the number of denominations through which the dividend must be column-shifted to align its highest figure with that of the divisor and the algebraic sign determines the direction of the column-shift, in this case rightward, for plus means rightward and minus means leftward. The actual column-shifting of the dividend in answer to this call does not take place, however, until the first dividing and multiplying cycle. It will be appreciated that the same amount of column-shift would have been called for if the divisor multiples had been entered before the dividend instead of after, for adding the six first on the differencing device and then subtracting the four will produce the same algebraic result of plus two.

Preparatory dividing and multiplying cycle

To commence the calculation, the operator depresses the control key 550/16, and afterwards operates the machine through its first simultaneous dividing and multiplying cycle as shown in Figures 25a, 25b and 25c.

The following description of this cycle is split up into six parts, (a) to (f), to facilitate reference in describing the action of the machine.

(a) In this cycle, which in essence is a preparatory cycle, the canvassing mechanism, which in every dividing and multiplying cycle is employed to ascertain which totalizer in its upper portion contains the smallest positive amount, is utilized to isolate the totalizer OX. In all preparatory cycles it is always OX that is isolated because OX is the only totalizer containing a positive amount in its upper portion.

Each denomination of OX is then connected directly to the corresponding denomination of the keyboard section, and at the same time the totalizers 1X to 5X are each directly connected in each denomination to multiple resetting mechanism, whereby the multiple values can be restored in the totalizers after each comparing operation as will be described. The totalizer OX is not provided with resetting mechanism because any divisor multiple corresponding to the quotient digit "0" will itself be of zero value so that there are never any multiple digits otherwise than "0" to reset, which result is achieved when required by operating the clearing means of this totalizer as will be explained in (b).

(b) All the totalizers OX to 5X are then cleared automatically with the result that because of the connections described in (a) the dividend amount in OX is transmitted without column-shift to the keyboard section, while the divisor and multiplicand multiples in 1X to 5X are transmitted to the multiple resetting mechanism of their re-

spective totalizers and each without any column-shift.

In a preparatory cycle the quotient entering mechanism is not operated because, owing to the OX totalizer being always the one to be isolated, the quotient result is always "0." This leaves the machine as shown in Figure 25a.

(c) The dividend amount transmitted to the keyboard section is next registered therein in a manner analogous to a keyboard setting.

The column-shift mechanism remains adjusted to give a shift of two places rightward in accordance with the algebraic difference of "plus two" set up in the differencing device as described in "correlating of dividend with divisor and skipping 'zeros' in dividend or multiplier." The quotient signal also remains in column 11 as shown in Figure 25b.

(d) By means of the multiple resetting mechanism the multiples are again entered in totalizers 1X to 5X as shown in Figure 25b.

(e) Immediately following the resetting of the multiples, the dividend registration on the keyboard mechanism is employed as though it were a keyboard setting to control the entering of the dividend positively and concurrently in all the totalizers OX to 5X but column-shifted two places rightward to align its highest figure with that of the divisor in 1X. This is equivalent to multiplying each divisor multiple by the second power of ten and concurrently subtracting it from the dividend in each case. Thus, the divisor multiples are compared with an upper part of the dividend and give the results shown in Figure 25c in which it will be noted that each totalizer is left registering in its upper portion the difference between the dividend and one hundred times the divisor multiple originally in it. In the lower portion of each totalizer the multiplicand multiples remain at reset, but these also must be considered as having been multiplied by the second power of ten, for each is now a partial product and one of them will be selected in the next cycle to form the first product result.

Actually, the tens transfers of the comparing operation take place during (f), but it is more convenient in this preliminary outline to consider the comparing operation as having been completed in the part (e).

It will also be noted that the differences in the totalizers OX and 1X are positive while those in the totalizers 2X to 5X are negative. It will further be noted that the units and tens denominations of the dividend have been entered in OX to 5X on the right of the split, but this causes no difficulty since the values concerned are entered in denominations in which the dials are already standing at zero and so this lower portion of the dividend is merely registered therein until required in the next cycle as will be explained.

(f) Finally, the dividend registration on the keyboard section is cleared and the control key 550/16 is released, leaving the machine in the condition shown in Figure 25c.

Subsequent dividing and multiplying cycles

After the preparatory cycle the operator depresses the control key 550/17 and either of the control keys 550/11 or 550/12, depending upon whether the product result is required to be entered positively or negatively in lower OX. If the quotient result is also required, either of the keys 550/14 or 550/15 is depressed depending

upon whether the quotient result is required to be entered positively or negatively in Q. The machine is then operated through a number of cycles until the calculation is completed.

The operations performed during these subsequent cycles are in general the same as those performed during the preparatory cycle, except that each of these subsequent cycles is a quotient and product entering cycle and there are a number of minor differences in the functioning of the mechanism.

As in the preparatory cycle, the description of each subsequent cycle will be split up into six parts (a) to (f).

First subsequent cycle

(a) Early in the first subsequent cycle, the multiple totalizers OX to 5X are canvassed to ascertain which in its upper portion after the comparing operation of the preparatory cycle contains the smallest positive difference and, when this totalizer (1X in this case) has been found, the mechanism isolates it from the other multiple totalizers and connects it to the keyboard section in the same way as the totalizer OX was connected in the preparatory cycle, except that the connection is made through the column-shift means instead of direct. At the same time, the totalizers 1X to 5X are connected to their respective resetting mechanisms.

(b) All the totalizers OX to 5X are then cleared with the following result. In the preparatory cycle the column-shift mechanism was adjusted to give a shift of two places rightward which means that an amount registered in the keyboard section was transmitted from that section to the totalizers with that particular amount of shift. If at any time following such an operation one of the totalizers were selected as described and then cleared, the amount in the totalizer would be transmitted back to the keyboard section with a contrary shift of two places leftward, provided that the connection and the column-shift mechanism were unaltered, because the second transmission would be a reversal of the first. Accordingly, when the totalizers are cleared, and because of the connection set up between the isolated 1X and the keyboard section through the column-shift mechanism, the isolated difference "98" is transmitted to the keyboard section with a contrary shift of two places leftward from its position in 1X so as to return this difference to the denominations 11 and 12 it originally occupied as part of the dividend. At the same time the partial product "3300" in the lower portion of 1X is likewise transmitted to the keyboard section with a shift of two places leftward. It will thus be seen that the amount in the lower portion of the isolated totalizer, the partial product "3300" in this case, is transmitted as though it were part of a difference comprising the amount "980003300".

The other differences and their associated partial products in the totalizer 2X to 5X are transmitted to their respective resetting mechanisms but are later cleared as they represent quotient values and product results that can be discarded after the totalizer containing the smallest positive difference has been found.

During the transmission of the difference "98" and partial product "3300" from the isolated totalizer 1X to the keyboard section, the quotient value "1" corresponding to this totalizer is entered in Q in the hundreds denomination, i. e. column 11, as indicated by the quotient signal

which has occupied that position since the beginning of the preparatory cycle. This leaves the machine as shown in Figure 25d.

(c) The difference "98" and partial product "3300" are now registered in the keyboard section. The difference occupies the original denominations 11 and 12, but the selected partial product "3300" being shifted two places leftward with the difference "98" now forms in the denominations 7 to 4 a record of the product "3300" which is once times "33" multiplied by the second power of ten, because the quotient entry has been made in the hundreds denomination, column 11. The reason for returning the difference to the original denominations will be explained at a later stage, but it will be noted that the column-shift setting of two places rightward in this cycle will be utilized as a basic setting throughout the calculation as described in reference to the first method in "correlating of dividend with divisor and skipping 'zeros' in dividend or multiplier."

At the same time the differencing device, which is still set at "plus two," now receives through means associated with the isolating mechanism the superimposed setting of "minus one," and this leaves the device with a difference of "plus one," which means a call to column-shift the difference "98" and partial product "3300" one place rightward when entering these amounts in the totalizers for the comparing operation to be described in part (e) of this cycle.

(d) The multiples are again reset in 1X to 5X as shown in Figure 25e, and the column-shift mechanism is adjusted to give a shift of one place rightward in accordance with the new call set up by the differencing device as described in (c) of this cycle. At the same time the quotient signal moves to column 10 as shown in Figure 25e.

(e) Following the resetting of the multiples, the difference "98" and partial product "3300" registered in the keyboard section are positively and concurrently entered in the upper and lower portion respectively of each of the totalizers 0X to 5X with a shift of one place rightward. This is equivalent to multiplying each divisor multiple by the first power of ten and concurrently subtracting it from the dividend in each case. Thus, the divisor multiples are compared with the isolated difference or remainder resulting from the comparing operation in the latter part of the preparatory cycle, such remainder being now used as though it were a new dividend.

This gives the result shown in Figure 25f, in which it will be noted that with the one exception of 0X, which registers a positive difference, each totalizer registers in its upper portion a negative difference which is the difference between the remainder "98" and ten (i. e. the first power of ten) times the divisor multiple originally in it. In its lower portion each totalizer registers the corresponding multiplicand multiple, multiplied by the first power of ten because the quotient signal (which is also the multiplier digit signal) is in the tens denomination, plus the partial product "3300". One of these partial product sums will be selected in the next cycle to form the second product result.

(f) The registrations on the keyboard section are now cleared and the control keys are released. However, in Figure 25f the keys are shown as being still held depressed, for it is presumed that the operator is continuing to hold

them depressed during these subsequent cycles and until the calculation is completed.

Second subsequent cycle

(a) At the beginning of the second subsequent cycle, the totalizers 0X to 5X are canvassed as in the previous cycle, and 0X is found to contain the smallest positive difference "98". The mechanism isolates 0X and connects it to the keyboard section through the existing setting of the column-shift means. The totalizers 1X to 5X are connected to their respective resetting mechanisms.

(b) The totalizers 0X to 5X are then cleared with the result that the difference "98" in the upper portion of 0X and the partial product sum "3300", comprising the first partial product "3300" plus zero times "33", multiplied by the first power of ten because the quotient entry will be in the tens denomination, are both transmitted to the keyboard section but with a contrary shift of one place leftward from their position in 0X so as to return these values to the denominations previously occupied. It will be observed that the difference and partial product sum isolated in this cycle are identical with those isolated in the previous cycle. This circumstance only occurs when the quotient value in the cycle is "0" as in this case, for then the selected divisor and multiplicand multiple are also of zero value, so that the difference from the previous cycle is undiminished in the present cycle and likewise the partial product sum is not increased.

The other differences and their associated partial product sums in the totalizers 1X to 5X are discarded in the same way as the unwanted differences and partial product sums in the previous cycle.

During the above action of the machine in this cycle, the quotient value "0" corresponding to the isolated totalizer 0X is entered in Q in the tens denomination, column 10, as shown in Figure 25g.

(c) The difference "98" and partial product sum "3300" are now registered in the keyboard section as shown in Figure 25g, the difference being undiminished and the partial product not increased as explained in (b).

Because the quotient value in this cycle is less than "5", the differencing device which is still set at "plus one" now receives the supplementary setting of "minus one." This leaves the device with a difference of "zero" which means a call to enter the difference "98" and partial product sum "3300" with no column-shift when entering these amounts in the totalizers for the comparing operation to be described in (e) of this cycle.

(d) The divisor and multiplicand multiples are again reset in 1X to 5X as shown in Figure 25h, and the column-shift mechanism is adjusted to give "no shift" in accordance with the new call set up by the differencing device as described in (c) of this cycle. At the same time the quotient signal moves to column "9" in Figure 25h.

(e) After the resetting of the multiples, the difference "98" and partial product sum "3300" registered in the keyboard section are positively and concurrently entered in the upper and lower portion respectively of each of the totalizers 0X to 5X with no column-shift. This is equivalent to multiplying each divisor multiple by the zero power of ten and concurrently subtracting it from the dividend "98" in each case. Thus, the divisor multiples are compared with the isolated difference or remainder resulting from the com-

paring operation in the latter part of the previous cycle, such remainder being used in the present cycle as a new dividend.

This gives the result shown in Figure 25i, in which it will be seen that each of the totalizers OX to 5X in its upper portion shows a positive difference which is the difference between the new dividend "98" and once (i. e. the zero power of ten) times the divisor multiple originally in it. In its lower portion each totalizer shows the corresponding multiplicand multiple, multiplied by the zero power of ten because the quotient signal (which is also the multiplier digit signal) is in the units denomination, plus the second partial product sum "3300". One of these partial product sums will be selected in the next cycle to form the third product result.

(f) The registrations on the keyboard section are now cleared. The control keys are released by the machine but are still held depressed by the operator.

Third subsequent cycle

(a) At the beginning of the third subsequent cycle, the mechanism ascertains that the totalizer 5X contains the smallest positive difference "28". It then isolates it from the other multiple totalizers and connects it to the keyboard section as in the previous cycles, and again the connection is direct because the contrary shift in this cycle is still at "normal".

At the same time the totalizers 1X to 5X are connected to their respective resetting mechanisms.

(b) The totalizers OX to 5X are then cleared with the result that the difference "28" in the upper portion of 5X and the associated partial product sum "3465" in the lower portion, comprising the second partial product sum "3300" plus five times "33" multiplied by the zero power of ten because the quotient entry will be in the units denomination, are transmitted to the keyboard section but with no contrary shift as stated above. The difference is returned to the denominations originally occupied as part of the dividend; while the partial product sum is likewise returned to the denominations occupied by the partial product sum registered in the keyboard section in the previous cycle.

The other differences and their associated partial product sums are discarded as in the previous cycles.

During the above, the quotient value "5" corresponding to the isolated totalizer 5X is entered in Q in the units position, column 9, as shown in Figure 25j.

(c) The difference "28" and partial product sum "3465" are now registered in the keyboard section as shown in Figure 25j.

Because the quotient value in this cycle is "5", then for the reason described under "quotient entering" the differencing device, which is still in the "normal" position, does not receive the supplementary adjustment as in the first and second subsequent cycles, so that the column-shift adjustment remains unchanged throughout the rest of the cycle and in consequence the quotient place signal is not moved from column 9. As explained under the heading referred to, the superimposed setting is not applied when the machine is required to perform an extra cycle for the purpose of ascertaining whether or not there is any additional quotient beyond the amount "5" already entered.

(d) The divisor and multiplicand multiples are again reset in the totalizers 1X to 5X as shown

in Figure 25k. The column-shift mechanism remains adjusted to give "no shift" because of the need for the extra cycle, and the quotient signal remains in column 9.

(e) Following the resetting of the multiples, the difference "28" and partial product sum "3465" registered in the keyboard section in the previous cycle are positively and concurrently entered in the upper and lower portion respectively of each of the totalizers OX to 5X with no column-shift. This is equivalent to multiplying each divisor multiple by the zero power of ten and concurrently subtracting it from the dividend "28" in each case. Thus, the divisor multiples are compared with the isolated difference or remainder resulting from the comparing operation in the previous cycle, such remainder being used in this cycle as a new dividend, and the comparison is effected with the same column-shift setting as in the previous cycle because the quotient amount resulting from the comparison is required, in the next cycle, to be added to the quotient amount already entered in the present cycle.

This gives the result shown in Figure 25m in which it will be observed that each of the totalizers OX and 1X in its upper portion shows a positive difference, 2X shows a zero difference which is reckoned as positive because there are no nines in its higher denominations while 3X, 4X and 5X each show a negative difference. Each difference, whether positive or negative, is the difference between the new dividend "28" and once (i. e. the zero power of ten) times the divisor multiple originally in it. In its lower portion each totalizer registers a new partial product sum comprising the corresponding multiplicand multiple multiplied by the zero power of ten, because the quotient signal (which is also the multiplier digit signal) is in the units denomination, plus the third partial product sum "3465". One of these partial product sums will be selected in the next cycle to form the fourth product result.

(f) As in the previous cycles, the keyboard section is now cleared. The control keys are released by the machine but still held by the operator.

This leaves the machine in the condition shown in Figure 25m.

Fourth subsequent cycle

The product result "3531" could be read off from the totalizer 2X at this stage, because it will be observed that the difference in 2X is of zero value which signifies the end of the division, but the quotient is not yet complete as shown by the fact that the signal has not moved from column 9. It is therefore preferred to perform an "extra-quotient" cycle, so that the product results can be registered in OX and the quotient be completed in Q.

(a) In this cycle, the totalizers OX to 5X are canvassed and 2X is found to contain the smallest positive difference which in this case is zero. The mechanism isolates 2X and connects it to the keyboard section but with no contrary shift, as the column-shift means is still at "normal". The totalizers 1X to 5X are connected to their respective setting mechanisms.

(b) The totalizers OX to 5X are then cleared. The isolated difference being zero, no significant values are transmitted from the upper portion of OX to the denominations in the keyboard section originally occupied by the dividend, but the

associated fourth partial produce sum "3531" in the lower portion is returned with no column-shift to the denominations occupied by the partial product sums registered in the keyboard section in previous cycles. The sum "3531" comprises the fourth partial product sum "3465" plus twice times "33" multiplied by the zero power of ten, because the quotient entry will be made in the units denomination.

The other differences and their associated partial product sums are dealt with in the manner already described.

The quotient value "2" corresponding to the isolated totalizer 2X is entered in Q in the units denomination, column 9. This extra amount is added to the partial quotient "5" already in that denomination, thus making a true quotient of "7" as shown in Figure 25n.

(c) The partial product sum "3531" is now registered in the keyboard section as shown in Figure 23n.

Because the quotient entry in this cycle is less than "5", the differencing device receives the supplementary setting of "minus one" which leaves the device with a difference of "minus one". This means a call to enter the isolated difference, which is zero, and the partial product sum which is "3531", both of which are now registered in the keyboard section, with a column-shift of one place leftward when entering these amounts in the totalizers for the comparing operation to be described in (e) of this cycle.

(d) The divisor and multiplicand multiples are then reset as shown in Figure 25o, and the column-shift mechanism is adjusted to give a shift of one place leftward in accordance with the new call set up by the differencing device as described in (c) of this cycle. At the same time the quotient signal moves to column 8 as shown in Figure 25o.

(e) After the resetting of the multiples, the zero difference and the fourth partial product sum "3531" registered in the keyboard section are positively and concurrently entered in the upper and lower portions respectively of each of the totalizers OX to 5X with a column-shift of one place leftward. This is equivalent to multiplying each divisor multiple by one-tenth (i. e. the first negative power of ten) and concurrently subtracting it from the new dividend, which is zero, in each case. Thus, the divisor multiples are compared with the isolated zero difference resulting from the comparing operation in the previous cycle.

This gives the result shown in Figure 25p. It will be seen in this figure that OX in its upper portion shows a zero difference which is reckoned as positive, and that each of the totalizers 1X to 5X shows a negative difference. Each difference is the difference between the new dividend, which is zero, and one-tenth (i. e. the first negative power of ten) times the divisor multiple originally in it. In its lower portion each totalizer shows the corresponding multiplicand multiple multiplied by the first negative power of ten because the quotient signal (which is also the multiplier digit signal) is in the first decimal denomination, plus the partial product sum "3531". One of these partial product sums would be selected in the next cycle, if the operation of the machine were continued, to form the fifth product result.

(f) The registrations on the keyboard section are cleared and the control keys are released both by the machine and the operator, for no

further quotient or product results are possible when the difference in OX is zero.

Continuing to operate the machine beyond this point without releasing the control keys merely column-shifts the product result leftward one place with each operation. It will thus be seen that, when the upper portion of 2X showed a zero difference and the product "3531" occupied the lower portion as shown in Figure 25m, the product held the correct relationship with the decimal point standing between columns 4 and 5. When the machine had been operated through a further cycle to complete the quotient result, the product "3531" appeared in OX, but relatively to the decimal point, ten times too big. This is due to the operation of the column-shift mechanism and should always be allowed for by placing the decimal point one more place leftward than that given by the decimal point rule usually employed.

Keyboard

The machine is provided with a keyboard comprising a plurality of columns of keys 50 (Figures 2, 3, 38 and 42a). Each of these columns comprises 10 keys. Each key can be depressed against the action of spring 51 which tends to move the key upwardly and each key is provided with teeth 52 (Figure 2) meshing with a gear sector 53. The gear sector is secured to a rocking bail 54.

There is a separate rocking bail 54 for each key and each rocking bail co-operates with a plurality of locking slides 55. There is a separate slide 55 for each key and each bail 54 has a tooth 56 which enters a notch 57 in the slide corresponding to the same key so that, when the bail rocks clockwise, it moves this slide to the left.

Each slide has only one notch 57 and is cut away as at 58 opposite the remaining bails 54, that is, it can only be moved by one bail. Each slide is provided with a lug 59 opposite another tooth 60 of each bail except the one that moves it. When a bail is rocked, it moves its associated slide to the left and moves to the right any other slide which may be displaced to the left by means of its tooth 60 engaging the related lug 59 on the latter slide. It will be noted that the slide shown in Figure 3 has a notch 57 co-operating with the third bail from the right and has no lug 59 opposite this bail so that this slide can be moved by the bail in question.

Each slide 55 has a notch 61 and a tooth 62 except that associated with the zero key. This latter slide has the notch 61 but is shaped as shown at 63 in Figure 3 so that it does not have a tooth.

A spring pressed pawl 64 is provided for each group of slides 55 and is pivoted on a rod 65. The nose 66 of the pawl normally rests in the notches 61 of the slides but, if a slide 55 is moved to the left, the nose 66 rides over the tooth 62 on this slide and engages behind the tooth 62 to hold the slide to the left. In so doing the nose 66 will release any slide which was previously displaced to the left so that it can be restored to the right by the related key spring 51.

Since the zero slide 55 has no tooth 62, it will not be held to the left by the pawl 64 but will be restored to the right as soon as the zero key is released. It will, however, rock the pawl 64 as it moves to the left so as to release any other slide that may be displaced to the left. The zero slide 55 thus serves as a means of clearing the column of keys.

The zero key is the left hand one in Figure 2 and merely serves to actuate the zero slide. The remaining nine keys control a differential mechanism in the following manner.

Each key, except the zero key, is provided with two lugs 67 and 68.

Normally the upper lug 67 is opposite a pin 69 on the end of a floating lever 70 which is pivoted at 71 on a slide 72 having teeth 89 (Fig. 3) meshing with a gear sector 88 on a shaft 87 rocked by a cam on the mainshaft when required.

The floating lever 70 has a second pin 73 which is normally free to move to the right.

A lever 74 is provided for each key except the zero key and is pivoted at its lower end 75 on a fixed member 76. The upper end of each lever 74 has a slot embracing the pin 69. If the slide 72 is moved to the right, each pin 69 will be prevented from moving to the right by the lug 67 if the related key 50 is not depressed. Under these conditions each floating lever 70 rocks counterclockwise and its pin 73 moves to the right under the lug 68.

If a key 50 is depressed its lug 68 moves opposite the related pin 73 so as to prevent it moving to the right when the slide 72 moves to the right while its lug 67 moves below the related pin 69. Thus, when the slide 72 moves to the right, the floating lever 70 associated with the depressed key will rock clockwise and will move the pin 69 to the right. The lever 74 will thus be rocked clockwise about its pivot 75.

Each lever 74 is pivoted at 77 on a striking member 78 which is slidable along a rod 79 (see Figure 3). The striking lever 78 engages one part 80 of a dog clutch, which is splined on a differential shaft 81. When a lever 74 is rocked as explained above its part 80 is meshed with the clutch teeth on a gear wheel 82. There are nine gear wheels 82 one for each digit key and these gear wheels are freely rotatable on the shaft 81.

It will be understood that there is a differential shaft 81 for each column of keys (see Figures 42a and 42b) and a gear wheel 82 for each key except the zero keys. All the gear wheels 82 for the keys of the same digital value mesh with a rack 83 (see also Figure 42a), there being one rack for each transverse row of keys and each rack is given a movement proportional to the digital value of its row of keys. Thus the racks will move respectively one step, two steps . . . up to nine steps.

For this purpose each of the racks 83 meshes with a separate gear wheel 84 (Figures 18b and 18c), each gear wheel constituting a pair of spaced gears fixed together, all being rotatable on a shaft 85 (see also Figure 42a). Each gear wheel 84 also meshes with a separate vertical rack 86. Each vertical rack carries a pin 49 fitting into a shoe 48. The shoes are supported in slots in a bar 47 which is pivoted at one end at 515. The bar 47 is oscillated about its pivotal connection and the proportions are such that the vertical rack 86 nearest the pivot of the bar will move one step, the next will move two steps and so on to the last rack which will move nine steps. The bar 47 is preferably given a simple harmonic motion from the main drive mechanism of the machine. The left hand end of link 47 is connected by a link 517 (Figure 18b) to a rack 600 which is mounted for vertical reciprocation, and the teeth of rack 600 mesh with a gear on one of a number of shafts, all of which have the same designation, 520.

It may be explained at this time that all of the

mechanisms to be operated in carrying out the functions of the machine are connected to one or another of the shafts 520. These shafts in turn are driven from the main drive shaft 540 of the machine (Figure 19c) which has gear connection 715 with a shaft 714. Upon the extremity of shaft 714 is a handle 595 (Figure 44b) through which the machine is operated. As will be explained more specifically under the heading "Control and drive mechanism," the shafts 520 are selectively coupled for oscillation by cams on the main drive shaft 540 so that, when shaft 540 is rotated, certain shafts 520 operated at predetermined times during the cycle and the related mechanisms operate. From the foregoing it will be understood that each gear wheel 84 has a simple harmonic movement proportional to the digital value of its key. The depression of key 50 moves the related clutch part 80 to engage the associated gear wheel 82 so that the corresponding shaft 81 is driven by the gear wheel 82 with simple harmonic motion and to an extent proportional to the digital value of the depressed key. The mechanism through which the bar 47 is oscillated will be explained later.

In entering an amount, the proper keys are depressed and the machine is operated through a cycle by turning handle 595 a complete revolution, which causes the main shaft 540 to also make a complete turn. During this cycle a shaft 87 (Fig. 3) is first rocked in a manner to be explained later. Under the heading "The keyboard and differential mechanism" it is explained that shaft 87 (see Figure 19b) has connection with shaft 65 and through a vertical bar 738 with a gear 740 on another of the shafts 520. Gear sectors 88 mesh with gear teeth 89 in the slide 72 so that the slides are moved to the right when shaft 87 rocks and the proper clutches 80-82 are engaged. The bar 47 is then given its counterclockwise stroke about its pivot 515 (see Fig. 18c) so that all the gear wheels 82 rotate and the various shafts 81 are driven through angles proportional to the digits set up on the keyboard. The shaft 87 is then restored so that the clutches 80, 82 are disengaged. After this the bar 47 and the racks 83 are restored to their initial position.

Each shaft 81 has a gear wheel 90 (Figure 4) keyed on it and each of these gear wheels meshes with a gear wheel 91 which is rotatable on a related totalizer drive shaft 92. It will be understood that there is a totalizer shaft 92 for each differential shaft 81 (see also Figures 42a and 42b).

Each gear wheel 91 has clutch teeth 93 cooperating with a clutch element 94 splined on the shaft 92. Each clutch element 94 can be moved to the left by a striking arm 95 to engage the teeth 93 and clutch the wheel 91 to the shaft 92.

The arms 95 are keyed on a shaft 96 which, when rocked, engages all the clutches 93, 94 so that each shaft 81 will drive the corresponding shaft 92. The manner in which the shaft 96 is rocked will be explained later. Suffice it to say at the present time that it is rocked concurrently with the rocking of shaft 87 so that, when the racks 83 are moved to rotate shaft 81, the extent of rotation will be transmitted to the shaft 92.

When the shaft 81 is not clutched to the shaft 92, it is yieldingly held in its last position by a leaf spring 81a (Figure 2) which engages the teeth of a gear wheel 81b fixed on the shaft 81 and having the same number of teeth as the clutch 80. A similar spring and gear wheel 92a and 92b (Fig-

ure 4) respectively are provided for holding the shaft 92.

The Totalizers

The shafts 92 can drive any one or more of seven totalizers Q (Figure 4) 0X 1X (Figure 5) 2X 3X (Figure 6) 4X 5X (Figure 7). The seven totalizers are substantially the same in construction and accordingly the totalizer 5X shown in Figures 7 and 11 will first be described as typical of the remainder. The differences in the totalizers will be described afterwards. The shaft 92 has seven bevel wheels 97 fastened on it.

The bevel wheel 97 for each totalizer drives a pair of bevel wheels 98 and 99 (Figure 12) in opposite directions (see also Figures 43a and 44a, which figures show the totalizers 0X and 4X, respectively). The bevel wheel 98 is integral with gear wheel 100 which meshes with the gear wheel 101 rotatable on a shaft 102. One part 103 of a dog clutch is rotatable with the wheel 101. A gear wheel 104 is integral with the bevel wheel 99 and meshes with a gear wheel 105 having teeth 106 forming another part of the dog clutch.

The wheel 105 is also rotatable on the shaft 102 and turns in the opposite direction to the wheel 101. A gear wheel 107 is rotatable about the shaft 102 and can be moved axially to engage either clutch teeth 108 with the teeth 106 or clutch teeth 109 with the clutch teeth 110 of the clutch part 103.

Thus the wheel 107 can be clutched to the wheel 101 to turn in one direction or to the wheel 105 to turn in the other direction depending upon whether the digit transmitted through the totalizer drive shaft is to be added or subtracted. The wheel 107 meshes with a gear wheel 111 (Figures 11 and 12) rotatable on a shaft 112 and this wheel in turn meshes with a wheel 113 rotatable on a shaft 114. The wheel 113 meshes with a wheel 115 rotatable on a shaft 116 and the wheel 115 meshes with a wheel 117 secured to an indicator wheel 118 which rotates on a sleeve 119. The sleeve 119 is supported on a shaft 120. The gearing is such that the index wheel 118 turns through a number of steps equal to the number of steps of movement of the shaft 92 and forwardly or rearwardly, depending on whether the totalizer is to add or subtract respectively. Transfers from one denomination to the next are effected by the following mechanism which is shown in Figures 7 and 16. The gear wheel 111 meshes with gear wheel 121 which is integral with a transfer receiving gear wheel 122 and a transfer calling tooth 123. The assembly 121, 122 and 123 is rotatable on a shaft 124. The assembly 121, 122 and 123 completes one revolution for each revolution of the dial 118 (Figure 11) and each time the dial 118 turns from nought to nine or from nine to nought, the transfer calling tooth 123 engages and rocks a single toothed wheel 125.

The wheel 125 will turn in one direction if the dial has turned from nought to nine and one unit must be carried to the next denomination, but it will turn in the opposite direction if the dial has turned from nine to nought and a unit must be borrowed from the next denomination. The single tooth wheel 125 is integral with gear sectors 126 and 127 in the next higher denominational section of the machine. The gear sector 127 meshes with rack teeth on the transfer lock bar 128.

The transfer lock bar controls two toe members 129 and 130 which are pivoted at 131 and 132 respectively on transfer actuating bars 133 and

134 respectively. The bars 133 and 134 are moved to the left in Figures 7 and 8. The mechanism which controls the operation of bars 133 and 134 is shown in Figure 19c and is described in detail later under the heading "Setting an amount in the totalizer on the differential mechanism."

In the position shown the lower end of the upper toe member 129 is locked while its upper end is free so that it will rock counterclockwise idly. The upper end of the lower toe member 130 is also locked and will rock clockwise idly. If the transfer lock bar 128 has been moved up owing to the rotation of the transfer calling gears 125, 126, 127, the upper end of the lower toe member 130 will be unlocked, while the lower end of this toe member will be locked by a locking portion 135 of the transfer lock bar. The toe member 130 will thus rock counterclockwise to engage and turn the transfer receiving wheel 122 one step. This movement is transmitted through the wheel 121 to the main driving train of the totalizer so that the dial is turned one step. The toe member 129 is still locked at its lower end and has no effect on the movement of the wheel 122. If the transfer lock bar 128 is moved downwardly from the position shown in Figure 7 the upper end of the upper toe member is locked by the part 136 and this toe member will rock clockwise to turn the wheel 122 one step.

It will be appreciated that the transfer lock bar 128 is moved in one direction when a carry is to be made to its denomination and in the other direction when borrowing is required from its denomination and that the toe members 129 and 130 turn the wheel 122 in opposite directions to effect a carry or a borrowing as the case may be. There is a transfer bar 133 and a transfer bar 134 for each denominational section of the machine (see Figure 44a) and these bars are operated in succession by cams on the shaft carrying the handle 595 starting with the bars in the lowest section but one so that the transfers are effected in succession. Each pair of denominational bars serves for all seven totalizers in its particular denomination.

After all the transfers have been effected a striking bar 137 (Fig. 16) is operated by a cam on the mainshaft so as to shift the assembly 121, 122, 123 towards the top of Figure 16 and thus move the tooth 123 clear of the tooth 125 and the wheel 122 clear of the toe members 129 and 130. The transfer bars 133 and 134 are then restored to the right to the position shown and concurrently transfer centralizing bars 138 and 139 are moved to the right. The bars 138 and 139 are provided with teeth 141 and 140 which engage the two extreme teeth of the sector 126 and restore the sector 127, the transfer tooth 125 and the transfer lock plate 128 to their normal positions. This restores the transfer mechanism to its normal position.

Resetting the multiples

The totalizers 1X to 5X are employed respectively to register once, twice, three, four and five times a divisor and/or a multiplicand and also for the purpose of obtaining the difference between a multiple of the divisor and a dividend and/or a partial product. After such difference or partial product has been obtained in one of these totalizers, the totalizer is cleared and the original multiple or multiples is reset on it. The totalizers 1X to 5X are provided with the following mechanism for resetting the multiples as

shown for the totalizer 4X in Figure 16. Keyed on a shaft 142 are a number of sleeves 143, one in each section of the machine. Each sleeve carries a resetting tooth 144. A second sleeve 145 is rotatable on the sleeve 143 and is formed with two gear wheels 146 and 147 and with a single tooth 148.

All the sleeves 145 on shaft 142 are held by a striking bar 149 in position shown in Figure 16, with a pin 150, carried by a fixed part of the machine, engaged with the teeth of the gear wheel 146 so as to lock the sleeve 145.

After the multiples have been calculated and registered in the totalizers 1X to 5X, the striking bars 149 are shifted by means of a cam on the mainshaft so as to bring the gear wheels 147 on the sleeves 145 into mesh with the respective gear wheels 111 in the main totalizer gear train. This movement also moves the gear wheel 146 clear of the pin 150 so that the sleeve 145 is free to rotate. Each sleeve 145 will thus partake of the movements of the related totalizer gear train during the subsequent entries into the totalizer and the zeroizing of the totalizer. The sleeves 145 are not shifted sufficiently to bring their respective teeth 148 into the path of the teeth 144 at this stage. Assume that one denomination of one totalizer is to register -6 negatively as a digit of a negative multiple. The related gear wheel 111 will have turned 6 steps in the negative direction during the formation of the multiple, but the associated sleeve 145 will remain in its zero position as its wheel 147 is not then meshed with the wheel 111. If 9 is now added into the denomination after the sleeve 145 has been shifted to mesh the wheels 147 and 111, both the wheels will turn 9 steps in the positive direction, so that the wheel 147 registers 9 and the wheel 111 will register $9-6=3$. If the wheel 111 (and the gear train) is now zeroized, both the wheels 111 and 147 will turn 3 steps in the negative direction to register $3-3=0$ and $9-3=6$. If now the wheel 147 is zeroized, it and the wheel 111 will turn $\frac{1}{2}$ of a revolution negatively leaving the wheel 111 registering -6. Thus the multiples can be reset by zeroizing the sleeves 145. When however the multiples are to be reset, the striking bars 149 are moved further to bring the teeth 148 into the path of the teeth 144 and the shafts 142 are turned through nine-tenths of a revolution so that the teeth 144 pick up the related teeth 148 and restore the sleeves 145 to their initial zero positions.

Since the sleeves 145 were coupled in the main totalizer gear trains when the latter were registering the multiples, they will restore the gear trains to their original multiple-registering settings, thus resetting the multiples on the totalizers.

The totalizer OX registers nought times the divisor or the multiplicand and since this multiple is zero, it need neither be calculated nor reset on the totalizer OX. The multiple resetting gear for this totalizer is therefore omitted as shown in Figure 14, but the zeroizing mechanism is retained.

The totalizer Q is not provided with the same form of zeroizing mechanism as explained later, but instead has a sleeve 500 keyed on its shaft 124, as shown in Figure 13. This sleeve is provided with a single tooth 501. During transfer operations the assembly 121, 122, 123 is not moved far enough to bring the transfer-calling tooth 123 into the path of the tooth 501. When it is desired to zeroize the totalizer Q, the striking

bar 137 is given an extra stepping movement so as to bring the transfer tooth 123 into the path of the tooth 501. The shaft 124 is then rotated through nine-tenths of a revolution to pick up the transfer tooth 123 and restore it to its zero position. Since the wheel 121 is in mesh with the wheel 111, the gear train and the totalizer will also be restored to its normal position.

Decimal point indicators

As explained under "General description," an adjustable decimal point indicator is provided for each of the totalizers Q, OX and 1X. The indicator for each totalizer comprises a series of wheels 116b (Figs. 12, 43a, and 43b), of which there is one in each denomination arranged on the right of the result indicator wheel 118. Each wheel 116b is secured to a gear wheel 116c rotatable on the sleeve 197 in the same denomination. Meshing with each gear 116c is another gear wheel 116d splined on the shaft 116 so that, when the shaft is manually rotated by means of the knob 116a, all the indicator wheels 116b are rotated together and each through the same amount. Each indicator 116b has one mark or signal representative of a decimal point and the wheels 116b are assembled in relationship to the gears 116d so that adjacent marks are helically arranged one-twentieth of a turn apart. Thus, by rotating the knob 116a the decimal point indication may be caused to appear between any two adjacent result indicators 118. An aligning spring of the type shown in Figure 11 for aligning the wheel 192 may be employed to align one of the gears 116c or 116d to hold the shaft 116 in any set position; or, if preferred, the shaft may be frictionally held.

Splitting the machine

The present machine is arranged to perform division in its left hand or upper denominations and multiplication in its lower or right hand denominations. The machine can be split into a dividing and a multiplying part between any two denominational sections. The position of the split is determined by manually rotating a shaft 160 (Figure 4) which carries a plurality of pairs of complementary cams 161 and 162. There is a pair of cams in each section of the machine and the pairs are helically disposed on the shaft 160 so as to become operative in succession as the shaft is rotated (see also Figure 42b).

Each pair of cams operates a separate bell-crank lever 163 and these levers are pivoted on the shaft 96. With the shaft 160 in one extreme position, all the levers 163 will be in the position shown in Figure 4. Each lever carries an indicator 164, one half of which is visible at a window 165. The two halves of the indicator will be differently coloured so that, in the position of the shaft 160 assumed, all the indicators 164 will show white, for example, at the window 165. As the shaft 160 is rotated, the bell-crank levers 163 will be rocked counterclockwise in succession and the indicators 164 will be moved in succession to show red. The levers 163 are rocked in succession starting at the lowest or right hand section of the machine and the split occurs between where the change over from red to white occurs in the window 165.

A gear sector 166 is formed integral with each lever 163 and meshes with rack teeth 167 in a slide 168. There is one slide 168 in each section of the machine and they will be moved to the right in Figures 4, 5, 6 and 7 when the related

bell-crank levers 163 are rocked. Thus all the slides 168 in the upper dividing part of the machine will be disposed in their leftward position (as shown by the slide dotted in Figure 4), while all the slides in the lower multiplying part of the machine will be disposed in a rightward position (as shown in full lines in Figures 5, 6 and 7). Each slide acts as a striking bar either to hold sleeves 169 in the position shown in Figures 4, 5, 6 and 7 or to shift them to the right along the shaft 92 in the same section of the machine. Each sleeve 169 has a gear sector 170 which is thus positioned in mesh either with a rack 171 or with a rack 172 (see Figure 45). Each sleeve 169 also has a gear sector 173 which is in mesh with a rack 174 in either position of the sleeve. Thus each rack 174 in the dividing part of the machine will be coupled to the related rack 171 and each rack 174 in the multiplying part of the machine will be coupled to the related rack 172. Each rack 174 is integral with a striking member 175 (Figure 12) by which the gear wheel 107 is adjusted either to a neutral position or to an adding position or to a subtracting position. There is a separate striking member 175 and rack 174 for each gear wheel 107, but the racks 171 and 172 are common to all the gear wheels 107 in the totalizer. It will be seen that the gear wheels 107 in the dividing part of the totalizer can be set for addition or subtraction by moving the rack 171 of that totalizer in one or other direction. The gear wheels 107 in the multiplying part of the same totalizer can be set in the same way by means of the rack 172.

Clearing multiple totalizers

Each slide 168 (Figure 8) is connected by a lever 176, pivoted at 178, to a bar 179 so that the bar 179 moves to the left when the slide 168 moves to the right. The bar 179 is provided with projections 180 (Figure 11) and recesses 181 in its lower edge so that in its rightward position it obstructs upward movement of a pin 182, but not of a pin 183, while, in its leftward position, it obstructs movement of the pin 183 but permits movement of the pin 182. It should be mentioned that Figure 11 is a view looking in the opposite direction to Figures 2 to 7 so that the bar 179 will be to the left in Figure 11 when the corresponding bar 168 is to the left in Figures 4, 5, 6, and 7 although these bars actually move in opposite directions.

The pins 182 and 183 are carried at the ends of a lever 184 which is mounted on an eccentric 185 secured on the shaft 114. A yoke 186 is supported by the pin 182 and a yoke 187 is supported by the pin 183. The yokes are guided for vertical movement by means of slotted portions 188 and 189 which embrace shafts 190 and 191. When the eccentric 185 is rotated through half a revolution by a cam on the mainshaft one or other end of the lever 184 will be obstructed so that it will rock to raise the yoke 186 or the yoke 187 as the case may be. A gear wheel 192 (Figure 12) is keyed on the shaft 190 while a gear wheel 193 is rotatable on this shaft. When the yoke 186 is raised both these gear wheels 192 and 193 will mesh with the gear wheel 194 carried by the yoke 186 so that they will be coupled together. A pin 195 (Figures 11 and 12) is secured inside the index dial 118. A gear wheel 196 is rotatable on the shaft 120 and is integral with a sleeve 197.

The sleeves 197 abut against one another so

that they can be moved axially with the shaft 120, when the latter is moved by a cam on the mainshaft as will be described, so as to bring a projecting portion 198 of one of the teeth of the gear wheel 196 into the path of the pin 195. This movement also brings the gear wheel 196 into mesh with the gear wheel 193 and out of mesh with the gear wheel 192 (Fig. 46). The gear wheel 196 is thus coupled through the gear wheels 193, 194, 192 to the shaft 190 so that, if this shaft is turned through nine-tenths of a revolution, it will rotate the gear wheel 193 to the same extent and the projecting portion 198 will pick up the pin 195 and turn the dial 118 to zero together with the related gear train. Similar gears 192 and 193 are carried by the shaft 191 and can be coupled together by gear 194 carried by the yoke 187. Thus, if the yoke 187 is raised, the wheel 196 will be driven from the shaft 191 instead of from shaft 190, the shaft 190 is used for zeroizing the dividing part of the totalizer and the shaft 191 for zeroizing the multiplying part of the totalizer.

The keyboard is also split so that either the left-hand or right-hand part can be cleared separately by depressing one or other of two clearing keys 870 and 870a (Figures 38, 40a and 41b). The stem of the key 870 has rack teeth 870b meshing with a gear 804a on a shaft 804 (Figures 3 and 10) so that teeth 870b rock shaft 804 when the key is depressed while the other key 870a drives a shaft 805 in the same way. The shaft 804 is thus rotated when the key for clearing the left-hand part of the keyboard is depressed, while the shaft 805 is rotated when the key for clearing the right-hand part of the keyboard is depressed. A number of gear sectors 806, one for each section of the machine, are splined on the shaft 804 and each sector 806 has a gear wheel 807 associated with it. The gear wheels 807 are rotatable on the shaft 804 and each of them can be coupled to the associated sector 806 by means of a coupling gear 808, of which there is one in each section.

In the position shown in Figure 3, the gear wheel 808 meshes with the sector 806 and the associated wheel 807. The shaft 805 carries, in the same way, gear sectors 809 splined on it and gear wheels 810 rotatable on it (see also Figure 42a). Each gear wheel 808 is rotatable on a slide 811 which can be shifted to the right so as to disengage the wheel 808 from the sector 806 and wheel 807 and mesh it with the sector 809 and wheel 810. Thus, if the shaft 804 is rotated, it will drive gear wheel 807 in each section of the machine in which the slide 811 is in the position shown in Figure 3, but it will not drive the gear wheel 807 in each section in which the slide 811 is shifted to the right. In a similar way, the shaft 805 will not drive the gear wheel 810 in the sections in which the slide 811 is in the position shown in Figure 3, but will drive the gear wheel 810 in each section in which the slide 811 has been shifted to the right. The slides 811 have rack teeth 812 (Figure 4) meshing with a gear sector 813 which is connected by a link 814 to the bell-crank lever 163. As the shaft 160 is rotated, it will rock the bell-crank levers 163 so that those in the sections to the left of the split will be in the position shown in Figure 4, and the corresponding slides 811 will be in the position shown in Figures 3 and 4. The levers 163 to the right of the split will be rocked from the position shown in Figure 4, so

that the slides 811 are shifted to the right from the position shown.

Thus, rotation of the shaft 804 by the clearing key 370 will rotate the gear wheels 807 in the sections to the left of the split, while rotation of the shaft 805 by the other key 370a will rotate the gear wheels 810 in the sections to the right of the split. The gear wheel 807 and the gear wheel 808 in each section cooperate with teeth 815 and 816 on the slide 817 so that either of them, when rotated, moves the slide to the right. Each slide 817 is connected by a two-armed lever 818 (Fig. 1a) pivoted at 819 to the locking slide 55 (Figure 1) so as to move the slide in the same way as it is moved by the depression of the zero key 50. This, as explained previously, gives the effect of unlocking any other slide 55 that may be latched by the pawl 64 (Figure 3) and thus releases any depressed key. It will thus be seen that each portion of the keyboard can be cleared by depressing the corresponding clearing key.

Setting an amount in the totalizer on the differential mechanism

It will be understood from the foregoing that a totalizer can be zeroized as a whole or in part by rotating both or one of the shafts 190 and 191 after having rocked shaft 114. The gear trains of the totalizers will be driven so that the gear wheels 107 (Figure 12) will also be driven. If these wheels are in their neutral position, the amount originally in the totalizer will be cleared from the machine, but if the gear wheels 107 are set in the subtracting position during the zeroizing operation, the backward movement of the dials will be transmitted to the shafts 92 so as a forward movement of those shafts.

As shown in Figure 3, a gear wheel 206 is rotatable on each shaft 81. This gear is formed with clutched teeth 510 co-operating with a clutch element 511 splined on the shaft 81. The clutch element 511 can be moved to engage the teeth 510 by an arm 112 splined on a shaft 113. Thus, by rocking the shaft 513, each gear 206 can be clutched to the related shaft 81. If the clutches 93, 94 are also engaged, each totalizer drive shaft 92 will drive a related gear 206 in the same section of the machine. Each gear wheel 206 meshes with a gear wheel 200 and each gear wheel 200 meshes with the gear wheel 201 rotatable and slidable on a stud 202. A single lug 203 is carried by the gear wheel 201 and the angular position of this lug 203 is adjusted in accordance with the position of the gear wheel 201. Each slide 55 is provided with a lug 204 and these lugs are arranged in a circle as shown in Figure 17.

The lug 203 is initially opposite the lug 204 on the zero slide 55 but is adjusted by the rotation of the shaft 92 opposite the lug 204 on the slide 55 corresponding to the digit which has been cleared from the corresponding section of the totalizer. Each gear 201 can be moved to the left in Figure 3 by means of a striking arm 205 keyed on the shafts 65 which may also be rocked when required. After the zeroizing operation, the shaft is rocked to move all the gear wheels 201 to the left so that each lug 203 moves the slide 55 which has its lug 204 opposite the lug 203 to the left and thereby sets up the appropriate digit, corresponding to the position of the lug 203, on the keyboard. This operation, however, forms no essential part of the invention and is described only in order to show the purpose of the parts referred to. When this opera-

tion is required, a special control key for the purpose may be provided.

The gear wheel 200 has driving connection with a gear wheel 208 through gear wheels 206 and 207. The gear wheel 208 is slidable on a stud 209 and is provided with a lug 210 similar to lug 203. The lug 210 co-operates with lugs 211 on slides 212 which correspond to slides 55. The slides 212 co-operate with bails 213 corresponding to the bails 54 and each group of the slides 212 co-operates with a pawl 214 corresponding to the pawl 64. The gears 208 can be slid to the left by means of arms 215 secured on a shaft 216 corresponding to the shaft 65 (Figure 42b). The lower slides 212 can be set by means of the gear wheels 208 in the same way as the upper slides 55 can be set by the gear wheels 201, the gears 201 and 208 being of the same diameter so that they rotate through the same amount when the shaft 81, or 92, is rotated.

Each slide 212 is provided with a lug 217 to engage a separate striking member 218. Striking members 218 are slidable along a rod 219 and engage each a separate gear wheel 82 (see Figure 42a) so that, when a slide 212 is moved to the left, it moves a related gear wheel 82 to the left to engage it with the clutch part 80 and couple it with its shaft 81.

Thus, if a shaft 92 turns six steps during a zeroizing movement, the slide 212 corresponding to six will be shifted to the left and will couple its gear wheel 82 to the shaft 81 so that the latter can be turned six steps when the racks 83 are operated. The lower set of slides 212 includes a zero slide which co-operates with a bail 220 similar to the bails 213 except that it is keyed on a shaft 221. This zero slide has no lug 211 so that it cannot be operated by sliding the gear wheel 208. After an amount set on the slides 212 has been transmitted through the shafts 81, the slides 212 can be reset in readiness to receive another amount by rocking the shaft 221 so as to move the zero slide to the left and thereby rock the pawl 214 to release the previously shifted slide. The bail 220 will restore this slide to its normal position. As in the case of the upper slides the zero slide is not cut away at 222 to provide a tooth 223 so that it is not held by the pawl 214, but is restored to normal when the shaft 221 is restored.

Splitting transfer action

As explained before, the transfer actuating bars 133 and 134 (Figures 8, 45 and 50) are operated in succession. For this purpose each bar 133 is formed with rack teeth 365 which mesh with an idler gear wheel 366 and each wheel 366 meshes with a gear wheel 367b. Each wheel 367b lies behind a similar wheel 367 and is clutched to it as shown in Figure 50. This wheel 367 meshes with rack teeth 368 on the related bar 134 and also with a vertical rack 369. Each vertical rack 369 is associated with a second vertical rack 370 (Figures 39b, 39c and 19c) and the vertical racks 370 are operated in succession from cams on the operating shaft 714, as will later be explained. If a rack 370 is coupled to the related rack 369 it will operate both the transfer bars 133 and 134 in the same section of the machine. The slides 168 which control the split have T-shaped ends 371 best as shown in Figures 50 and 50a and a T-shaped lever 372 is pivoted at 373 to the slide 168 in the same section and at 374 to the slide 168 in the next higher section. All the slides 168 in the upper dividing part

of the machine are to the left while all the slides in the lower multiplying part are to the right. The section shown in Figure 8 is the highest section of the multiplying part of the machine so that the section behind it in this figure is the lowest in the dividing section of the machine and the ends of the slides 168 in these two sections will be in the position shown and will cause the T-shaped lever 372 to tilt into the position shown. This lever carries a pin 375 riding in a slot 376 in a bell crank lever 377. The lever 377 is pivoted at 378 and has a slot embracing a short shaft 379. The shaft 379 projects from a slide 380 and carries a gear wheel 381. It will be observed that this gear wheel is held out of mesh with rack teeth 382 provided on both the related rack 369 and the related rack 370. The slide 380 carries a tooth 383 which engages teeth 384 on the rack 369 so as to lock that rack against movement. Thus movement of the rack 370 will not be transmitted to the transfer bars 133 and 134 in the lowest dividing section of the machine. In the case of all the other sections, each slide 168 will be in the same position as the slides in the two adjacent sections so that the pin 374 will be immediately above the pin 373 and the T-shaped lever 372 will not be tilted but will hold the bell crank lever rocked counter-clockwise from the position of Figure 8. The gear wheel 381 will then be held in mesh with the teeth 382 on both the racks 369 and 370 while the tooth 383 will be clear of the teeth 384. The gear wheel 381 serves to couple the rack 369 to the rack 370 so that the transfer mechanism will be operated in these sections. It will be shown later in the description that the racks 370 are operated successively at one time in some cycles and at another time in other cycles.

It will be observed that the slide 168 in the No. 1 section is not provided with an upper bent portion 371 as there is no lever 372 on its right with which it can cooperate, but that the lower portion of its T-shaped end pivots a pin 373 as in the higher sections. This enables the No. 1 section to be included in the dividing portion of the machine when the split is adjusted to the right of that section. There is no slide 168 in the dummy section, but there is a part 371a similar to the bent portion 371 of a slide 168 and this part is fastened to the frame of the machine so that it permanently pivots the pin 374 in the No. 18 section in coaxial alignment with any of the other pins 374 that have been moved towards the front of the machine as shown in Figure 45 in the case of sections Nos. 11, 12 and 13. By this arrangement, the most leftward position to which the split can be adjusted is between sections Nos. 17 and 18, thus leaving a minimum of one section (No. 18) in the dividing portion of the machine for the entering of a dividend or multiplier amount comprising only a single digit.

Column shift mechanism

From the foregoing description it will be understood that an amount can be transmitted from the shafts 81 through the gearing 90, 91 and the clutches 93 and 94 (Figure 4) to the shafts 92 without column shift.

A column shift mechanism is provided so that an amount can be transmitted from the shafts 81 to the shafts 92 with column shift in either direction. This mechanism comprises a set of upper shafts 230 (Figures 3, 4, 20, 21, 22, 39a, 39b) and a set of lower shafts 231. Each shaft 81 can be connected to a related upper shaft 230

by engaging clutch elements 232 and 233. The clutch element 233 is splined on a shaft 230' and can be slid along to engage the clutch element 232 by an arm 234 keyed on a rock shaft 235. The clutch element 232 is integral with a gear wheel 236 which meshes with the gear wheel 90 keyed on the shaft 81. Each shaft 230' drives the related shaft 230 through gear wheels 521 and 521a (Figure 21). Each shaft 92 has a bevel wheel 239 (Figure 8) secured on it and this wheel meshes with a bevel wheel 240 rotatable on a shaft 241. The bevel wheel 240 has clutch teeth 242 co-operating with a clutch element 243 splined on the shaft 241. The clutch element 243 can be moved to engage the clutch by an arm 244 secured on a rock shaft 245. Each shaft 241 can drive or be driven by a related lower column shift shaft 231 through bevel gearing 246. In connection with this drive it will be observed that the gear wheel 236 is smaller than the gear wheel 90, so that the shaft 230' will rotate proportionately faster than the shaft 81 when the clutch 232, 233 is engaged. But the gear wheel 521a is smaller than the gear wheel 521 in the same proportion as the wheels 236 and 90, so that the shaft 230 will be driven at the same speed as the shafts 81 and 92. Also, because the gears 206 and 207 are coaxial with the gears 90 and 236 respectively, the gear 207 will rotate at the same higher speed as the shaft 230'. But because the gear 207 is an idler between the gears 206 and 208, its higher speed of rotation is of no disadvantage. Proportioning the gears in this way instead of making them all the same diameter enables the height of the machine to be slightly reduced.

As shown in Figures 20, 21, 22, and 23, the column shift mechanism comprises a set of upper racks 250 and a corresponding set of lower racks 251. Each rack 250 is rigidly secured to the rack 251 below it (Figures 39a, 39b, 39c, 43a and 43b). Each shaft 230 has a single gear wheel 252 pinned on it and these gear wheels are arranged in a diagonal row as shown in Figures 23 and 39b so that each one is over a different rack 250. The racks are supported in combs 253 and 254 which are supported by links 255 and 256 at each end. Each pair of links 255 and 256 is pivoted on the end of an arm 257. The arm 257 in Figure 20 is splined on a shaft 258, while the arm 257 in Figure 22 is splined on a shaft 258a. By rocking the shafts 258 and 258a in opposite directions, the combs 253 and 254 are raised to mesh each rack 250 with a different gear wheel 252. Thus each double rack 250, 251 is driven by a different one of the shafts 230.

A number of gear wheels 259 are splined on the shafts 231 and are normally positioned out of alignment with the lower racks 251 as shown. Each of these gear wheels can be moved over the adjacent rack 251 by means of an arm 260 secured on a rock shaft 261. There is one shaft 261 for each gear 259 and a single diagonal row of these shafts are rocked at a time in order to bring a diagonal row of the wheels 259 over the racks 251.

If the diagonal row of wheels 259, which is immediately below the row of wheels 252, is thus shifted, each shaft 230 can drive the shaft 231 below it through its gear wheel 252, the related double rack 250, 251, and the shifted gear wheel 259 on the lower shaft 231. This row of wheels 259 is known as the "normal" row because their operation produces no column-shift in either direction. They serve only to transmit an amount from the shafts 81 to the shafts 92 in the same

sections or vice versa. If the diagonal row of wheels 259 to the right of the wheels 252 is shifted, each shaft 230 will drive its own double rack 250, 251 and this rack will in turn drive the shaft 231 in the next lower denomination of the machine. In the first case each shaft 81 will drive the related shaft 230 which latter will drive the related shaft 231 and this shaft 231 will drive the related shaft 92 so that the amount will be transferred by the shafts 81 to the shafts 92 and hence to the totalizers, without a column shift. In the latter case, each shaft 81 will drive the related shaft 230 which will drive the shaft 231 in the next lower section of the machine, this shaft 231 driving the associated shaft 92. Each shaft 81 will thus drive the shaft 92 in the next lower section of the machine so that the amount will be transmitted with a column shift of one denomination to the right. Other diagonal rows of the wheels 259 can be shifted to adjust the column shift mechanism for column shifting an amount from one up to nine denominations either to the right or to the left. The column shift mechanism shown is for an eighteen section machine but can be modified to suit any number of sections.

It should be mentioned that the movement of the shafts 92 obtained by zeroizing a totalizer as explained previously may be used to drive the shafts 81 through the shafts 231, the column shift racks 250, 251 and the shafts 230. If the clutch 510, 511 is engaged, the wheels 208 will be positioned so that they can be used to set the amount cleared from the totalizer on the differential mechanism. The amount can thus be set up on the totalizer with any required column shift within the capacity of the machine but the direction of the column shift will be reversed. Thus if the mechanism is set for a column shift of four denominations to the right when an amount is transmitted from the differential mechanism to a totalizer, that is from the shafts 81 to the shafts 92, the amount cleared from a totalizer will be transmitted to the differential mechanism by a reverse drive with a column shift of four denominations to the left.

As shown in Figures 23 and 43a each shaft 261 has an arm 263 secured on it. As shown in Figures 21 and 43a the arms 263 are arranged at a number of different levels but with the arms 263 on a diagonal row of the shafts 261 on the same level. The ends of all the arms 263 at each level are pivoted on a separate comb member 264. Thus by shifting one of the comb members 264 to the left in Figures 20, 21 and 22 one diagonal row of the shafts 261 is rocked to shift one row of the wheels 259 over the racks 251. The racks 250, 251 are then raised and the mechanism is conditioned for column shifting. After the amount has been transmitted through the column shift mechanism, the racks are lowered and then restored in the conventional manner by means of a restoring bail 850 (Figures 39c and 43b).

This bail cooperates with lugs 851 on the racks 251 and is supported by means of two crank arms 852 (Figure 39f) and 853 (Figure 39c). The crank pin 854 on the arm 853 rides in a slot 855 in the restoring bail as shown in Figure 39c. The crank pin, not shown, on the arm 852 rotates in a similar slot in the bar, so that the bail can be reciprocated by rocking the crank arms 852 and 853 toward one another through half a revolution and then restoring them. The arm 852 is secured on a vertical shaft 856 which is driven

by bev gearing 857 from one of the shafts 520, as shown in Figure 42d. A gear 858 (Figure 39f) is secured to the shaft 856 and meshes with a rack 859 (Figure 39c) which also meshes with a gear wheel 860 secured on a shaft 861 to which the crank arm 853 is secured. In this manner, the two crank arms are rocked in opposite directions by means of the same main drive shaft 520. The manner in which the drive shaft 520 is operated will be explained later.

The combs 264 are pivoted at each side to a bell-crank lever 265 (Figure 23) and each lever is pivoted to a common link 266 (see also Figures 39a, 39e and 39f). The link is pivoted to a lever 267 secured on a shaft 270. Thus by rocking the shaft 270, the link 266 is moved and moves each side of the comb 264 equally. There is a separate shaft 270 for each comb 264 and the levers 267 are arranged at different positions along the shafts to co-operate with links 266 and combs 264.

Each shaft 270 is arranged in a different section of the machine and has a lever 271 (Figures 20 and 23) secured to its upper end. Each lever 271 is pivoted to a separate bar 272 so that, by moving the bar along to the left, the corresponding shaft 270 is rotated and shifts its comb 264.

Nineteen column shift keys 273 (Figures 1, 1a, 41a and 41b) are provided at the front of the machine. Any one of the keys may be set, in conjunction with either of the control keys 550/7 or 550/10 as will later be described, to accomplish a shift of an amount in OX when the operating handle 595 is rotated one turn. When one of these keys is depressed, it is latched down by a latch 274 which is common to all the keys and engages a projection 275. The lower end of the key is forced into a crowding lock device 276 (Figure 1a) which serves, in a well known way, to ensure that only one key is depressed at a time. The depressed key also rocks a bell crank lever 277 about a shaft 278 and this lever, through a link 279, rocks a lever 280 about a pivot 281. There is a key 273, bar 272, shaft 270, link 279, bell crank 277 and lever 280 associated with each comb 264 controlling a row of gears 259. Each one of the bars 272 is pivoted to the lever 280 at 282 and will thus be moved to the left by the depression of its key. Thus, the key in column 9 marked "N" is connected through its corresponding bar 272 with the comb 264 whereby the normal row of gears 259 is made operative. The keys on the left of the "normal" key and marked "1" to "9" are similarly connected through their respective bars 272 to the combs whereby rightward shifts of from one to nine denominations may be accomplished, the amount of shift being determined by the key selected. In the same way the keys on the right of the "normal" key are used for leftward shifts. From the foregoing, it will be seen that an amount in OX may be set on the shafts 92 transmitted directly (i. e., without column shift) to the slides 212, then re-entered in OX with column shift by operating the differential racks 83 so as to return the amount through the shafts 230', shafts 230, racks 250 and 251, the appropriate row of gears 259 made operative by the selected key 273, shafts 231, vertical shafts 241, shafts 92 and hence to the dials. At the end of a column shift cycle a shaft 283 (Figure 1) is rocked so that the projections 284 rock the latch 274 about its pivot 285 to release the depressed key which is restored by a spring 286.

Other details relating to manual column shifting will be described later in reference to Figures 36c and 37.

Automatic column shifting is described under "measuring apparatus" and in the detailed description of the movements of the mechanism in an actual example of a calculation.

Quotient place mechanism

As shown in Figure 13 each gear wheel 111 in the quotient totalizer meshes with the gear wheel 290 which is rotatable on a shaft 151. Adjacent to each wheel 290 is a wheel 291 which is splined on the shaft 151. As shown in Figure 20 a gear wheel 292 is provided for each section of the machine and each of these wheels is supported independently by a separate pair of arms 293. The arms 293 hang from a fixed shaft 294. In the position shown in Figure 20 the wheel 292 does not mesh with the associated wheels 290, 291 so that rotation of the shaft 151 will not be transmitted to the wheel 290 or to the totalizer train. The hub of each wheel 292 extends through a slot 296 in a slide 295, there being one slide for each section of the machine. If the slide 295 is pulled down, the slot 296 will cam the arms 293 to move the wheel 292 into mesh with both the associated wheels 290 and 291. The movement of the shaft 151 will then be transmitted through the wheels 291, 292, 290 and 111 to the totalizer. By this means a quotient digit can be entered into the section of the machine which has its slide 295 lowered. Each slide 295 is pivoted to a bell crank lever 297 (Figures 20 and 42a). Each bell crank lever is pivoted on a rod 298 and carries a pin 299 engaging a notch in one of the bars 272. If this bar 272 is moved to the left, it will depress the slide 295 in the same section of the machine. Each slide 295 has rack teeth 300 meshing with teeth on an indicator 301 so as to rock it about a shaft 302. The indicator then indicates the section of the machine into which the quotient digit will be entered.

There are nineteen of the column shift keys and of these eighteen are arranged one in each section and each controls the entry of the quotient digit into its own section. The nineteenth key is arranged to the right of the others (Figure 41b) and controls the column shift mechanism to give a leftward shift of nine places, but it has no quotient place indicator, no coupler gear wheel and no quotient entering mechanism. Other particulars relating to the quotient entering and indicating mechanism are given later in the description of the movements of the mechanism in an actual example of a calculation.

Measuring apparatus

With the present machine a dividend and a divisor may be entered with their units digits in the same section of the machine instead of being entered with their highest digits in the same section as is the usual practice when performing division. The machine will then automatically measure the position of the highest figures of the divisor and dividend and adjust the column shift mechanism to column shift the dividend to such an extent that its highest figure is in the same section as the highest figure of the divisor. This is effected by measuring apparatus as shown in Figures 21, 1 and 1A.

The dividend is entered into the totalizer OX which will contain zeros to the left of the highest significant figure of the dividend. The divisor is entered subtractively into the totalizer

IX and will thus be registered as a complement. This totalizer will, therefore, contain nines to the left of the highest significant digit of the divisor. The transfer wheel assembly 121, 122, 123 in each section of the OX totalizer is provided with a projecting tooth 310 (Figures 14 and 21) which, when a totalizer section is at zero, is immediately above a nose 311 of a slide 312 so that the slide cannot move up. The slide can be raised by a bell crank lever 313 which is rotatable on a shaft 314. Each lever 313 is connected to the shaft 314 by a coil spring 315 so that, by rocking the shaft 314 clockwise, the lever 313 can be rocked clockwise if the slide 312 is free to move. If a totalizer section is at zero, the slide 312 in that section will be prevented from moving by the tooth 310 and the bell crank lever 313 will not be rocked. If the section is not at zero, the slide 312 can move and the corresponding bell crank lever 313 will be rocked and will move a link 316 to the left. On restoring the shaft 314, the slide 312 and link 316, if they have been moved, will be restored with the shaft. The corresponding parts for the totalizer IX have been given the same references with the suffix *a* and operate in the same way except that the slides 316a move to the right and that each tooth 310a is positioned to obstruct its slide 312a when the totalizer section registers nine.

Each slide 316 is slotted to embrace a pin 317 (Figure 1a) on a stop member 318 which is pivoted on a rod 399. There is a stop member for each section of the machine and each stop member will be rocked when its slide 316 moves to the left. Thus the stop members 318 will be rocked in those sections of the machine which do not contain zero in the dividend totalizer. Rocking a stop member 318 moves it into the path of a separate projection 319 on a sleeve 320 (see Figures 41a and 41b). The sleeve 320 is rotatable on a shaft 321, which can be rotated one complete turn by means of a cam on the main-shaft, and this sleeve is connected to this shaft by a coil spring 322 so that it will rotate with the shaft until it is arrested by the engagement of one of the projections 319 with its stop member 318. The projections 319 are arranged in a helix so as to pass the stop members 318 in succession commencing with the projection in the highest section of the machine.

Assuming that the dividend has been entered in the position shown in Figure 24b, the highest significant figure will be in column 14 of the machine and there will be a "0" in each of the higher sections or columns. Then the stops 318 in the sections 15 to 18 will not be rocked so that the four leading projections 319 can move past these stops. The fifth projection will, however, engage the stop 318 in column 14 and the sleeve 320 will be held after having moved a number of steps proportional to the number of the higher sections of the dividend totalizer that contains zero.

An exactly similar arrangement is controlled by the divisor slides 316a so that a sleeve 320a is moved through a number of steps proportional to the number of consecutive nines in the highest part of the divisor totalizer. In the example of a calculation the number of nines is six.

The differencing device comprises an epicyclic gear group (Figures 1a, 41a, 47, 48 and 49) in which there are two sun wheels 323a and 325a and two pairs of planet wheels 322', one planet wheel in each pair meshing with the sun wheel 323a and the other planet wheel in each pair

meshing with the other sun wheel 325a. The planet wheels in each pair are meshed together and each wheel is mounted on an axle carried between planet arms 322a and 322b. The sun wheel 325a is secured to the sleeve 320, and the other sun wheel 323a to a gear wheel 323. The gear wheel 323 meshes with a gear wheel 324 secured to the sleeve 320a. The two sleeves will rotate the sun wheels in opposite directions so that the planet carrier will turn through an angle equal to the difference between the movements of the sleeves. Thus the planet carrier will turn a number of steps equal to the difference between the number of zeros to the left of the highest figure of the dividend and the number of nines to the left of the highest figure of the divisor. This difference is the number of sections through which the dividend must be column shifted.

The planet carrier is formed with a bevel gear 325 which meshes with a bevel wheel 326 rotatable on a shaft 327. The bevel wheel can be clutched to the shaft 327 by means of a clutch 328 operated by an arm 329 on a shaft 330. The shaft 327 drives a cam 331 by means of bevel gearing 332. The cam is formed in a number of sections, one for each denomination of the machine, and each section has a cam projection 333 and a complementary depression 334. When a dividend or a divisor is entered, the clutch 328 is engaged before the shafts 321 and 321a are rotated and is disengaged after the shafts have been rotated. The shafts are then restored, with the result that the sleeves 320, 320a and all the parts in the differencing device driven by them are also restored. This leaves the cam displaced from the normal position by an extent equal in size and direction to the required column shift. In every cycle in which there may be a change in the column shift setting a shaft 335 is rocked counterclockwise to the position shown in Figure 1a so as to move a pin 336 to the right by means of an arm 337 and a link 338. There is a separate pin in each section of the machine and each pin is supported by a separate lever 339 pivoted on a rod 340. Each pin 336 carries a rock lever 341 which also carries the pivot pin 281 for a related lever 280. When the shaft 335 is restored by a counterclockwise rotation from the position shown in Figure 1a, the rock lever 341 is thus moved towards the cam, the setting of which may have become changed since the shaft was rocked, and, if a projection 333 is opposite a roller 343 on the lever 341, the lever will be rocked counterclockwise about the projection 333. The rocking movement is permitted by the depression 334 which receives another roller 342 on the lever 341. The movement of the lever 341 causes the lever 280 to rock and thus moves the bar 272 to the left to set the column shift mechanism. The projections 333 and depressions 334 are arranged helically so that only one rock lever 341 will rock counterclockwise. The remainder will rock clockwise owing to the roller 342 engaging an enlarged peripheral portion 344 of the cam, a reduced peripheral portion 345 of the cam permitting the roller 343 to move. This rocking movement of one of the levers 341 moves the related bar 272 slightly to the right but this does not affect the operation of the machine. It will be apparent that the particular lever 341 that rocks to move its bar 272 to the left is dependent on the setting of the cam 331. This setting in turn depends on the relative position of the highest figures of the dividend and the divisor. Thus the machine is adjusted for column

shift appropriate to the particular dividend and divisor entered. Before the shaft 335 is rocked, the shaft 283 (Figure 1) is rocked to release any depressed key 273 and the shaft 278 (Figure 1a) is rocked. A ball 346 is carried by arms 347 secured on this shaft and is thus raised to engage a projection 348 on each key stem so as positively to hold them up and prevent accidental depression of the keys.

A ratchet wheel 350 is secured to the cam 331 and can be stepped round by a pawl 351 which is carried by a slide 352. This slide is reciprocated once in each multiplying or dividing cycle of the machine whenever there is a true-quotient or extra-quotient cycle so as to step the cam 331 round one unit of movement which represents the supplementary setting of "minus one" referred to in the "example of division and multiplication simultaneously." This causes the amount of column shift to change by one denomination leftward when required. As explained later, the slide 352 is not operated in any cycle when the same column shift setting is required in an extra-quotient cycle. It is necessary to disengage the pawl 351 from the ratchet wheel 350 when setting the cam 331 by means of the shaft 327. For this purpose a link 353 is connected by a pin and slot connection to the arm 329 (see Figure 41a) which engages the clutch 328 and extends under a lug 354 on the pawl so that the pawl 351 is rocked clear of the ratchet wheel when the clutch 328 is engaged.

It is necessary to restore the cam 331 to a normal setting in which it will set the machine for no column shift whenever a dividend or a divisor is cleared from the machine. For this purpose a disc 355 is pinned on the shaft 327 and carries a single tooth 356. A gear wheel 357 is loose on the shaft and has a single tooth 358 projecting. The gear wheel can be slid along the shaft by an arm 359 secured on a shaft 360. When the gear wheel is moved upwardly and then rotated its tooth 358 will pick up the tooth 356 and restore the shaft 327 and the cam 331 to the normal position wherein a zero stop pin 331a on the highest section of the cam 331 contacts the end of a stop lever 359b as shown in Figure 1a. This stop lever is integral with the arm 359 and is only moved into the path of the pin 331a when the arm 359 is raised for zeroizing the shaft 327. The arm 359 is also connected by a pin and slot connection to the link 353 to raise it and rock the pawl 351 clear of the ratchet wheel.

Control and drive mechanism

The various parts of the machine requiring to be operated are connected each to a separate shaft 520 in the base of the machine. Where a number of similar parts require to be operated in the same manner under all circumstances they may be connected to the same shaft 520. The shafts 520 are arranged in two planes as shown in Figures 28, 43d, 18a and 18b and the connection is taken from each part to the most convenient one of the shafts 520. Thus, for example, the bar 47 (Figure 18c) requires to be oscillated about its pivot 515. It is connected by a slipper 516 to a vertically sliding bar 517. This bar is connected to a rack 600 (see also Figures 41a and 41c) meshing with a pinion 601 secured on one of the shafts 520, so that, by oscillating this shaft the bar 517 is reciprocated and the bar 47 is oscillated. Similar connections can be made to the various rock shafts, striking bars and corresponding parts.

Each shaft 520 has a number of gear wheels 541 splined on it and each of these wheels can be moved from an idle position as shown in Figures 30 and 39c into mesh with an adjacent related rack 532. Each wheel 541 thus forms a device for coupling its secondary driving shaft 520 to a related main driving rack 532. Each wheel is moved along its shaft by a striking arm 542 secured to a long pinion 543 having a single long tooth 543a as shown in Figures 28, 28a and 30. Each long pinion forms an actuating part for the related coupling gear wheel and extends through a group of control plates. Each control plate comprises a number of bars 544 connected at one end to a bar 545 and at the other end to a plate 546 so as to be movable as a unit. The bars 544 slide in comb members 547 (see Figures 28, 44c, 44d, 42c and 42d) which support and space the control plates. Each bar has one or more teeth 548 (Figure 30) or may have no such teeth. The teeth are so positioned that each engages an adjacent long pinion 543 and rocks it to engage the related wheel 541 with the related rack 532. When the control plate having that tooth is moved to the left in Figure 29, it engages one or more of the wheels 541 with the related racks 532 and couples the related shafts 520 to the related racks 532.

Each of the shafts 520 must be turned through a predetermined extent to impart the required movement to the connected part or parts when a gear wheel 541 is meshed with a rack 532, and then be restored to its initial position in order to restore the parts. For this purpose each rack 532 is supported on blocks 533 (Figures 28 and 28a) and reciprocated by means of a pair of complementary cams 800 and 820 fixed on the shaft 540 which is driven by gearing 715 from the main operating shaft 714. The periphery of the cam 800, which is the driving cam, constantly engages a roller mounted on a follower arm 535 which is keyed to a boss 537 mounted on a cross-shaft.

The periphery of the cam 820, which is the complementary cam, constantly engages a roller mounted on a follower arm 810a also keyed to the boss 537. Another arm similar to the arm 535 carries another roller coaxial with the roller on the arm 535, and this other roller engages a vertical slot in the rack 532 so that with each turn of the shaft 540 the rack 532 is reciprocated in accordance with the contour of the cam. There is a plurality of such racks and cams and each pair of cams is arranged to impart to its rack a predetermined movement or movements at a predetermined time or times and to restore the rack to its initial position at another predetermined time or times. There are as many pairs of cams and racks as there are different kinds of movements to be imparted to the various operative parts of the machine at the same or different times. When a part or group of parts is required to operate at one time in one cycle and at a different time in another cycle, the corresponding shaft 520 carries two gear wheels 541 associated with the two sets of racks and cams that produce the appropriate movement at the appropriate times, and this system is extended so that the number of gear wheels on each shaft 520 is proportional to the number of different conditions under which, as to amount and direction of movement and timing, the related part has to operate.

It will be appreciated that each rack may drive several cross-shafts where similar or simultaneous though dissimilar movements of a part or

group of parts are required at the same time or times in different sections of the machine, and that alternatively each cross-shaft may be driven by either of several racks where a movement is required at one time in one cycle and at a different time in another cycle.

To illustrate the above in reference to the present embodiment, Figures 26 and 27 show diagrammatically and in conventional form the arrangement of the driving racks 532, the cross-shafts 520 and the gear wheels 541 for the upper and lower groups of control plates respectively. A circle at the intersection of the line representing a rack 532 with that representing a cross-shaft 520 shows the position of a group of parts comprising one of the gear wheels 541, and its related long pinion 543. The racks 532 are numbered as shown at the top of each figure. The figures on each side show the part operated in the case of each cross-shaft 520, and the figures in brackets refer to the principal driving connection between the part operated and the related shaft 520. The driving connections will be described at a later stage.

It will be understood that the various control plates referred to above are identical except for the position of their teeth 548 (Figure 26) so that a control plate can readily be made and inserted which is designed to cause any combination of parts to operate with any timing provided by the available racks 532. Thus, the machine can be made to perform any operation within its capacity by inserting a suitable control plate. If an operation calls for a timing or extent or direction of movement of a part which cannot be obtained from any rack 532 in the machine, a further rack, pair of driving cams and related gear wheel or wheels 541 can be added, space being, preferably, left for this. Additional parts may be connected to an existing shaft 520 or an addition shaft 520 may be provided. The arrangement is thus very flexible and can easily be modified to suit the operations the machine is to perform, in most cases the only modification being the addition or substitution of a control plate.

As shown in Figures 28 and 28a, the control plates are arranged in two groups one above the racks 543 and the other below those racks. The upper group of control plates control the gear wheels 541 on the upper shafts 520 and the lower group of control plates control the wheels on the lower shafts. Thus, if an operation requires the actuation of parts connected some to the upper shafts 520 and others to the lower shafts 520, two control plates must be used to control the operation, one member from each group.

The control plates are moved to their operative positions by control keys 550 (Figures 3, 38 and 43b) each allocated to a different machine operation. Each key has a tubular stem 551 and is pressed upwards by a spring 552. The lower end of the stem 551 is enlarged at 553 and has upstanding ears 554 which project through openings in a fixed plate 555 so that the key stem 551 cannot rotate. An actuating shaft 556 is journaled at its upper end in the stem 551 and is also supported at its lower end by suitable frame members as shown in Figures 41d, 42d and 43d so that it can rotate but not move axially. The shaft 556 is formed with an enlarged portion 557 having two helical splines 558 which engage in helical slots in the part 553 of the key stem 551. Thus, when the key is depressed, it rotates the actuating shaft 556 which operates one or more control

plates as will now be described with reference to Figures 27 and 43d.

The part 546 (see Figures 30 and 30a) of each control plate is connected to another plate 946 by bars 947 and 948. The plate 946 has a number of plates 560 connected to it and these plates slide in comb members 561 with corresponding plates of the various setting members in vertical alignment. The two outer plates 560 of each control plate are connected to bellcrank levers 562 and 563 pivoted on rods 564 and 565 and interconnected by a link 566 so as to force all the plates of the related control plate to move equally when one of them is moved. The actuating shafts 556 extend through openings 567 in the plates 560 so that each passes through one plate 560 of every control plate. Each shaft 556 has a pinion 559 secured to it and each pinion has three teeth on one side and a single tooth 570 on its other side. One opening only in the plates of each control plate is formed with teeth 571 meshing with the related pinion 559 while all the remaining openings in those plates have each a single tooth 572.

Thus, depression of a control key 550 (Figures 31 and 43b) causes the related pinion 559 to turn and this pinion causes the plate or plates 560 with which it meshes to move to the left in Figures 30 and 43d and thus moves the related control plate or plates to the operative position. At the same time the pinion 559 that is turned brings its tooth 570 into engagement with the teeth 572 on the remaining plates 560 through which it passes so as to lock the related control plates out of action or move them to their inoperative position if they are not in that position. The locking of the unwanted control plates also locks the remaining control keys since it locks the related pinion 559, so that only one control key can be depressed at once. The teeth 572 may, however, be arranged so that control plates that control complementary operations do not become locked if one of them is moved to its operative position while control plates controlling conflicting operations are locked. This allows of more complex operations being performed by depressing two or more control keys but introduces a risk of two keys being depressed in error. In Table 6 the additional keys that may be used in the same cycle with the control key first selected are marked with an "X." Thus, reading horizontally, the keys 550/4, 550/7, 550/10 and 550/13 may be used with the key 550/1 as the operations they control do not conflict. The other keys are presumed to be locked as described.

Table 6

Control key 550 selected	Additional control keys that may be used in the same cycle																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1				X			X			X			X				
2																	
3																	
4	X						X			X			X				
5																	
6																	
7	X			X						X			X				
8																	
9																	
10	X			X			X						X				
11																	
12																	
13	X			X			X			X			X				
14																	
15													X	X			X
16													X	X			X
17													X	X			X

Each control plate is held in its operative position by a separate related latch 573 which engages a tooth 574 on the related link 566 and holds it and the control plate displaced. The latches are pivoted on a shaft 575 and are rocked to release the operative control plates by a bail 578 which is rocked, for this purpose, about the shaft 564 at the end of each cycle by a connection to one of the shafts 520 (see Figure 43d).

When a control plate is restored it does not restore any of the long pinions 543 it may have operated. These pinions are restored by two restoring members (Figures 26 and 42c) which are identical with the control plates except as explained below, the identical parts having the same number but with the letter "R" affixed. There is one restoring member in each group of control plates, and each of its bars 544R has a tooth 580 associated with each pinion 543, but it has no teeth 548. Also, each of its plates 560 has a single tooth 571a associated with each pinion 559. Before any of the keys 550 is depressed, each tooth 571a contacts a continuation 559a of the central one of the three teeth 571 on each pinion 559. When a key 550 is depressed, its tooth 559a, by reason of its contact with the related tooth 571a on the restoring member, moves the latter leftward to the position shown in Figure 30. This movement occurs simultaneously with the leftward movement of the control plate being set, with the result that all the pinions 543 in the group are unlocked by the leftward movement of the teeth 580, and all those that are required to engage their wheels 541 with the related racks 532 are rocked for that purpose by the teeth 548. The restoring member, which for convenience is referred to as the restoring member 544R, has no related latch 573, so that when the bail 578 is rocked to release the operative control plates in each group and the pinion 559 connected with each plate is restored by the spring 552 to inoperative position, the restoring member 544R ceases to be held leftward by a tooth 571a whereupon a spring 949 connected to its link 566R restores the member 544R and its teeth 580 engage any operated pinions 543 and restore them to the initial position, in which their associated wheels 541 are disengaged from the related driving rack 532 as shown in Figure 39e.

In each group of control plates there is a plate for each control key and four additional plates associated with the plate relating to the key 550/3, making twenty-one plates in each group. These are arranged in the machine in the order in which the keys are numbered for reference commencing at the top with No. 1, and with the four additional plates at the bottom in each group numbered from eighteen to twenty-one. The four additional plates in each group are employed in cycles 2 to 5 when entering the multiples, and their operation is as follows:

The multiple entering key 550/3 operates control plate 544 (plate No. 3) (Figure 42d) in each group, an assembly of parts 544, 545 and 546 associated with a control key being referred to for convenience as a control plate 544, and calls into operation all the necessary parts for entering the divisor and multiplicand amounts into the totalizer 5X. This control plate does not cause operation of the shaft 520 which rocks the bail 578, so that the control plate is not restored at the end of the first cycle. But it does cause one of the shafts 520 to turn a cam 402 in each group through one-fifth of a revolution. The shaft 75 drives the cam through bevel gearing 400 and a

ratchet device 401 which is oscillated so as to turn the cam 402 on its return stroke. Each cam 402 is provided with four cam rises 403 which are spaced 72° apart. These rises are arranged helically and operate on rollers 404, one on each of the four additional control plates. Each of these plates, except for the rollers 404, comprises a similar assembly of parts 544, 545 and 546; but, because they are controlled by the cam 402 instead of a control key, they are referred to for convenience as the control plates 546 (Nos. 18 to 21). The cam is stepped round in each of the first four cycles so that it operates upon the plates 546 in succession, each becoming latched by the pawl 573 in operative position. Thus, in the first cycle, only the No. 3 control plate in each group will be operative; in the second cycle, the Nos. 3 and 18 plates will be operative; in the third, the Nos. 3, 18 and 19; in the fourth, the Nos. 3, 18, 19 and 20. Near the end of the fourth cycle, the cam 402 is rotated through its fourth one-fifth of a revolution and thereby brings into operation the fourth additional control plates (No. 21 in each group) and momentarily latches them, but almost immediately afterwards the bail 578 is rocked under the control of one of the No. 20 plates to release all the plates from being latched so that plates Nos. 3, 18, 19 and 20 in each group are free to return to their inoperative position. The unlatching of the No. 3 plates in the fourth cycle also releases the control key 550/3. Plate No. 21 in each group, however, is still held in its operative position by reason of its contact with the fourth cam rise, and this plate takes over all the operative functions performed by the plates that are now released.

Thus, in the fifth cycle, only the No. 21 plates are operative; and, near the end of the cycle, when the cam 402 is rotated through a fifth one-fifth of a revolution and has thus regained its starting point, the cam rise which held each No. 21 plate in operative position is removed from contact with its plate and consequently allows the restoring spring of each plate to return it to its inoperative position. This, in turn, frees any of the long pinions 543 which have been operated and they are then restored to inoperative position by the restoring member 544R in each group. It should be mentioned that all the plates are apertured as shown in Figures 30, 39c and 39f to permit the passage of driving connections from some of the shafts 520 to the various parts of the machine to be operated and that the cams are located in this aperture.

The key-controlled plates 544 (No. 3 in each group) cause the coupling of the totalizer 5X to the shafts 92 during the first multiple entering cycle. Near the end of the first cycle, the first cam-controlled plate 546 (plate No. 18) in each group causes the coupling of the totalizer 4X to the shafts 92, so that during the second cycle the divisor and multiplicand are entered in 4X as well as in 5X, and near the end of the cycle the second cam-controlled plate 546 (plate No. 19) in each group is made operative. During the third cycle the amounts are entered in 3X, 4X and 5X and the third cam-controlled plate 546 (plate No. 20) in each group is made operative. In the fourth cycle the amounts are entered in 2X, 3X, 4X and 5X and the fourth cam-controlled plate 546 (plate No. 21) is made operative. Near the end of the fourth cycle all the operative plates are restored except the No. 21 in each group which, as explained above, now takes over all the operative functions performed

by the released plates during that cycle. In the fifth and last cycle, under the control of the No. 21 plates, the amounts are again entered in 2X, 3X, 4X and 5X and also in 1X. The No. 21 plates also control the rocking of the shaft 314a (Figure 21), and the rotation of the shaft 321a (Figure 1a), so that the measuring apparatus operates to measure the position of the divisor in 1X and adjust the cam 331 accordingly. Other details relating to these operations are given later under "entering divisor and multiplicand multiples" when describing the movements of the mechanism during an actual example of a calculation.

Entering a dividend

A dividend is set up on the keyboard, preferably to the left of the split, the control key 550/8 is depressed and the handle 595 given one turn, whereupon the dividend is entered in upper 0X and the control key is released.

The numbers of the various parts that are actuated in this cycle are set forth in the timing diagram (Figure 36d). The first column gives the designating numbers of the racks 532 that are utilized. The second column shows the number of units of movement of each rack and also shows, by means of the letters "F" or "R", whether the commencement of that movement is towards the front of the machine or towards the rear. The third column gives the number of the principal part or parts driven by each rack; the fourth column shows the purpose of their being operated; the fifth column shows which parts are operated when a dividend amount is entered positively and which parts when an amount is entered negative. When a part is used, a cross is marked against it in the appropriate column. Thus, the parts that are used are readily distinguished by reading the appropriate column vertically.

The sixth column shows in diagrammatic form the timing, extent and direction of each driving rack used. The driving movement of each rack is shown by a sloping thick line, a restoring movement by a sloping thin line, and no movement by a horizontal line.

When the key 550/8 is depressed, it positions the control plate 544 (plate No. 8) (Figure 30a) in each control plate group and thereby couples all the parts to be operated to the racks 532 in the manner described. The turning of the shaft 540 through handle 595 moves all the racks, but only those that are coupled by a wheel 541 (Figures 28 and 39e) to the required operative parts are effectively used. The others reciprocate idly.

Thus, early in the cycle, the cam bar 541 (Figures 14 and 18b) is moved downward three steps to mesh the OX gear 481 with its related rack 466, and shaft 480 is rocked (Figure 18b) to move the OX rack 171 (Figures 5, 35, 45) leftward to the adding position in upper OX, coupling the wheel 107 with the wheel 105 (Figure 12) by clutches 106, 108, in each denomination above the split.

At about the same time the shaft 700 (Figures 8, 19c) is rocked to lock the bars 380 and immediately afterwards the shaft 87 is rocked (Figure 3, 19b) to read the keyboard settings so as to engage the clutches 80, 82 (Figures 2, 3) relating to the depressed keys. Concurrently, the shaft 96 is rocked (Figures 4, 19b) to couple the shafts 81 to the shafts 92 through the clutches 93, 94.

Bar 47 is now moved counterclockwise (Figures 18b, 18c) so as to move the racks 83 to set up the

dividend on the dials in upper OX through its shafts 81, shafts 92, clutches 106, 108, and the totalizer gear train in each denomination.

The shaft 480 is then restored to return the rack 171 to its neutral position, and so disengage the clutches 106, 108. At the same time the shaft 87 is restored, and also the shaft 96 to disengage the clutches 93, 94. Immediately afterwards, the cam bar 641 is restored and concurrently with the restoring of this part the transfer actuating bars 133 and 134 (Figures 5, 8, 19c) are actuated to effect the necessary transfers when the dividend is formed as the sum or difference of two or more numbers entered in succession.

During the transfer action the racks 83 are restored by the return movement of the bar 47, and immediately following the transfer action the shaft 314 (and 314a) (Figure 21) is rocked to record the position of each significant digit in the totalizer OX by setting a stop member 318 (Figure 1a) for each such digit. The bars 137 (Figure 14) in totalizers OX to 5X are also operated (Figure 19b) to disengage the wheels 122 from the toe members 129, 130 (Figure 7), and the lock bars 128 are centralized by the bars 138, 139.

The clutch 328 is engaged by rocking the shaft 330 and then shaft 321 is rotated (clockwise in Figure 1a) to measure the number of consecutive "zeros" on the left of the dividend in the manner described. Thus, in the example of a calculation, the dividend "1498" was entered in OX with four "zeros" on the left of its first significant digit. Therefore, the sleeve 320 and the sun wheel 325a are turned through four steps in a negative direction until a projection 319 contacts the most leftward of the rocked stop members 318 which is in column 14 and signifies the position of the highest significant digit in the dividend. This movement is imparted through the planet carrier of the gearing 322' and its bevel gear 325 to the shaft 327 and thence to the cam 331. The rockers 341 are disengaged from the cam 331 while shaft 321 is rotated.

Finally, the clutch 328 is disengaged, the shafts 321 and 700 are restored, and the ball 670 is rocked to release the No. 8 control plates and with them to key 550/9. Other restoring movements will be apparent from the timing diagram (Figure 36d).

The keyboard is then cleared by depressing the key 870. This leaves the machine in the condition shown in Figure 24b, with the dividend amount "1498" entered in OX in columns 11 to 14.

It will be observed that, when entering an amount negatively, using the key 550/9, as for example when the dividend is required to be the difference between two separate amounts entered in succession, the only difference between the parts made operative by the No. 9 plate in each group as compared with the No. 8 plates is that rack 171 is moved rightward instead of leftward so as to set upper OX to subtract, the cam bar 630 being positioned three steps down for this purpose instead of the cam bar 641. In all other respects, a positive dividend entering cycle is identical with a negative one.

Entering divisor and multiplicand multiples

The divisor is set up on the keyboard to the left of the split and the multiplicand to the right. The control key 550/3 is set and the handle 595 is rotated five times whereupon the divisor multiples are entered negatively in their respective totalizers above the split, and the multiplicand

multiples are entered positively in their respective totalizers below the split. At any time after the fourth cycle, the control key may be released and finally both portions of the keyboard are cleared.

The parts that are brought into operation in this series of cycles are set forth in the timing diagram (Figure 36a), which is arranged in a similar manner to Figure 36d, except that it covers the timing for five cycles instead of one and has reference to the totalizers 1X to 5X instead of the totalizer OX. In order to distinguish which parts are used in each cycle, the fifth column is headed "used in cycle No." so that, when a part is used in a cycle, an "X" is marked against it in the column headed by the number of the cycle. Thus, the parts that are used in each cycle are readily distinguished by reading the appropriate column vertically.

Table 7

FIRST MULTIPLE ENTERING CYCLE, USING CONTROL PLATE NO. 3 IN EACH GROUP

Driving rack No.—	Principal part driven	Purpose
6	Rock shaft 480	Move 172 in 5X leftward to add in lower portion.
30	Rock shaft 480a	Move 171 in 5X rightward to subtract in upper portion.
	Rock shaft 484	Release 466, 467, while operated by 480 or 480a.
5	Position cam bar 636 (one step down).	Mesh 5X gear 481 with related rack 467 to add in lower 5X.
4	Oscillate bar 47	Reciprocate racks 83.
13	Position cam bar 625 (three steps down).	Mesh 5X gear 481a with related rack 466 to subtract in upper 5X.
16	Operate bars 137 in OX to 5X.	Disengage wheels 122 from toe members 129, 130.
23	Rock shaft 87	Read keyboard settings.
	Rock shaft 96	Engage clutches 93, 94.
15	Rock shaft 700	Align and hold bars 380.
12	Rotate cams 402 through first one-fifth of a revolution.	Bring into operation first additional control plates (No. 18 in each group) for use in the next cycle.

Table 8

SECOND MULTIPLE ENTERING CYCLE, USING CONTROL PLATES NOS. 3 AND 18 IN EACH GROUP

Driving rack No.—	Additional parts brought into operation by control plate No. 18	Purpose
5	Position cam bar 637 (one step down).	Mesh 4X gear 481 with related rack 467 to add in lower 4X.
13	Position cam bar 630 (three steps down).	Mesh 4X gear 481a with related rack 466 to subtract in upper 4X.
12	Rotate cams 402 through the second one-fifth of a revolution.	Bring into operation second additional control plates (No. 19 in each group) for use in next cycle.

Table 9

THIRD MULTIPLE ENTERING CYCLE, USING CONTROL PLATES NOS. 3, 18 AND 19 IN EACH GROUP

Driving rack No.—	Additional parts brought into operation by plate No. 19	Purpose
5	Position cam bar 638 (one step down).	Mesh 3X gear 481 with related rack 467 to add in lower 3X.
13	Position cam bar 631 (three steps down).	Mesh 3X gear 481a with related rack 466 to subtract in upper 3X.
12	Rotate cams 402 through the third one-fifth of a revolution.	Bring into operation third additional control plate (No. 20 in each group) for use in next cycle.

Table 10

FOURTH MULTIPLE ENTERING CYCLE, USING CONTROL PLATES NOS. 3, 18, 19 AND 20 IN EACH GROUP

Driving rack No.—	Additional parts brought into operation by control plate No. 20	Purpose
5.....	Position cam bar 639 (one step down).	Mesh 2X gear 481 with related rack 467 to add in lower 2X.
13.....	Position cam bar 632 (three steps down).	Mesh 2X gear 481a with related rack 466 to subtract in upper 2X.
12.....	Rotate cams 402 through the fourth one-fifth of a revolution.	Bring into operation fourth additional control plate (No. 21) in each group for use in next cycle.
17.....	Rock bail 578.....	Release control plates Nos. 3, 18, 19 and 20.

Table 11

FIFTH MULTIPLE ENTERING CYCLE, USING CONTROL PLATE NO. 21 IN EACH GROUP

Driving rack No.—	Parts brought into operation	Purpose
7.....	Rock shaft 420.....	Move arms 410 and special arm 413 to negative position.
6.....	Rock shaft 480.....	Move 172 in 1X to 5X leftward to add in lower portion of each totalizer.
	Rock shaft 480a.....	Move 171 in 1X to 5X rightward to subtract in upper portion of each totalizer.
	Rock shaft 484.....	Release 466, 467, while operated by 480 or 480a.
5.....	Position cam bars 636, 637, 638, 639 and 640 (one step down).	Mesh gears 481 with their related racks 467 to add in lower 1X to 5X.
4.....	Oscillate bar 47.....	Reciprocate racks 83.
13.....	Position cam bars 625, 630, 631, 632 and 634 (three steps down).	Mesh gears 481a with their related racks 466 to subtract in upper 1X to 5X.
16.....	Operate bars 137 in OX to 5X.	Disengage wheels 122 from toe members 129, 130.
28.....	Rock shaft 87.....	Read keyboard settings.
	Rock shaft 96.....	Engage clutches 93, 94.
15.....	Rock shaft 700.....	Align and hold bars 380.
21.....	Rotate shaft 321a.....	Measure number of "nines" on left of divisor entry in upper 1X, etc.
12.....	Rotate cams 402 through the fifth one-fifth of a revolution.	Release control plate No. 21 in each group.
23.....	Rock shaft 330.....	Engage clutch 328.
	Rock shaft 314a.....	Record position of each digit in 1X otherwise than "9."
	Rock shaft 335.....	Disengage rockers 341 while rotating 321a.

Referring again to the example of a calculation, the movements of the mechanism during the entering of the multiples when the divisor is "14" and the multiplicand is "33" will now be described.

First multiple entering cycle

During the first cycle the divisor is entered negatively in upper 5X and concurrently the multiplicand is entered positively in lower 5X. The cam bar 636 is moved downward one step to mesh the 5X gear 481 with its related rack 467, and at the same time the cam bar 625 is moved downward three steps to mesh the 5X gear 481a with its related rack 466. Shaft 480 is then rocked to move the 5X rack 172 leftward to the adding position for entering the multiplicand in lower 5X, thus coupling all the clutches 106, 108 therein below the split, and at the same time shaft 480a is rocked to move the 5X rack 171 rightward to the subtracting position for entering the divisor in upper 5X, thus coupling all its clutches 109, 110 therein above the split.

During the rocking of shafts 480 and 480a, shaft 87 is rocked to read the keyboard settings to engage the related clutches 80, 82; also the

shaft 96 to engage the clutches 93, 94, and the shaft 700 to lock the bars 380.

Bar 47 is now operated to move the racks 83 leftward to enter the divisor in upper 5X negatively through its shafts 81, shafts 92, clutches 109, 110, and the totalizer gear train in each denomination above the split, and to enter the multiplicand in lower 5X positively through its shafts 81, shafts 92, clutches 106, 108, and the totalizer gear train in each denomination below the split.

Shafts 480 and 480a are then restored to return the 5X racks 171 and 172 to neutral position. At the same time shaft 87 is restored, and also the shaft 96 to disengage the clutches 93, 94. Immediately afterwards, the cam bars 636 and 625 are restored and concurrently the transfer actuating bars 133 and 134 commence to move in succession.

During the transfer action the racks 83 are restored by the return movement of the bar 47, and immediately after the transfer action the bars 137 in totalizers OX to 5X are operated to disengage the toe members 129, 130, and the lock bars 128 are centralized by the bars 138, 139. These latter movements operate idly in this cycle, if the totalizers 1X to 5X contain no previous entry.

Towards the end of the cycle the shaft 700 is restored to release the bars 380, and the cams 402 are rotated clockwise one-fifth of a revolution to bring into action the first of the additional control plates (No. 18 in each group) for use in the next cycle. Each plate becomes latched in its operative position as already described and remains so latched, together with the No. 3 plates, until the end of the fourth cycle.

This leaves the machine in the condition shown in Figure 24d. Other restoring movements will be apparent from the diagram (Figure 36a).

In Table 7 is given a list of the parts made operative by the control plate No. 3 in each group as set by the key 550/3 and used in this first cycle.

Second multiple entering cycle

On reference to Figure 36a and Table 8 in which is given a list of parts made operative in this cycle, it will be observed that all the parts that are used in the first cycle are again used in the second cycle, so that the divisor and multiplicand are entered a second time in 5X under the control of the No. 3 plates. At the same time the divisor and multiplicand are also entered in 4X under the combined control of the plates Nos. 3 and 18 in each group. The control plate No. 18 causes the 4X cam bar 637 to move downward one step at the same time as the 5X cam bar 636 is moved, being both now coupled to the same driving rack 532 (rack No. 5). Likewise, the 4X cam bar 630 is moved downward three steps at the same time as the 5X cam bar 625 is moved, being both now coupled to the same driving rack 532 (rack No. 13). Thus, the gears 481 and 481a in 4X and 5X are positioned together so that, when the shaft 480 is rocked, the racks 172 in 4X and 5X are moved leftward to add the multiplicand in lower 4X and 5X. When the shaft 480a is rocked, the racks 171 in 4X and 5X are moved rightward to subtract the divisor in upper 4X and 5X.

Thus, when the shafts 87, 96 and 700 are rocked and when the racks 83 are reciprocated, the amounts are entered in 4X as well as in 5X so that, after the transfer action and the restora-

tion of the parts, the 4X totalizer registers once times the divisor and multiplicand and the 5X twice times the divisor and multiplicand.

The cams 402 are rotated through a second one-fifth of a revolution to bring into operation the second additional control plates (No. 19 in each group) for use in the next cycle, and these plates also become latched and remain so until the end of the fourth cycle.

This leaves the machine in the condition shown in Figure 24e.

Third multiple entering cycle

In the third cycle, referred to in Table 9 in which is given a list of the parts made operative in that cycle, all the parts that were used in the second cycle are used again under the combined control of the plates Nos. 3 and 18. At the same time the divisor and multiplicand are also entered in 3X under the combined control of the plates Nos. 3, 18 and 19 in each group, the plate No. 19 causing the cam bars 638 and 631 to position the 3X gears 481 and 481a respectively when the 4X and 5X gears are positioned. Thus, when the shaft 480 is rocked, the racks 172 in 3X, 4X and 5X are moved leftward to enter the multiplicand in these totalizers and, when the shaft 480a is rocked, the racks 171 in these same totalizers are moved rightward to enter the divisor.

When the shafts 87, 96 and 700 are rocked and the racks 83 are reciprocated, the amounts are entered in 3X as well as in 4X and 5X so that, after the transfer action and the restoration of the parts, these three totalizers register once, twice and three times, respectively, the divisor and multiplicand as shown in Figure 24f.

The cams 402 are rotated through a third one-fifth of a revolution to bring into operation and also latch until the end of the fourth cycle the third addition control plates (No. 20 in each group).

Fourth multiple entering cycle

In the fourth cycle as shown in Figure 36a and Table 10, all the parts that were used in the third cycle are used again under the combined control of plates Nos. 3, 18 and 19. At the same time the amounts are also entered in 2X under the combined control of the plates Nos. 3, 18, 19 and 20. The plate No. 20 causes the cam bars 639 and 632 to position the 2X gears 481 and 481a, respectively, when the 3X, 4X and 5X gears are positioned. When the shaft 480 is rocked, the racks 172 in 2X, 3X, 4X and 5X are moved leftward to enter the multiplicand in these totalizers and, when the shaft 480a is rocked, the racks 171 in these same totalizers are moved rightward to enter the divisor.

Rocking the shafts 87, 96, and 700 and reciprocating the racks 83 cause the amounts to be entered in 2X as well as in 3X, 4X and 5X and, after the transfer and restoring actions, these four totalizers register once, twice, three and four times, respectively, the divisor and multiplicand as shown in Figure 24g.

The cams 402 are rotated through a fourth one-fifth of a revolution to bring into operation the fourth additional control plates (No. 21 in each group) and momentarily latch them, but almost immediately afterwards the bail 578 is rocked to release all the plates from being latched so that plates Nos. 3, 18, 19 and 20 in each group are free to return to their inoperative position. The unlatching of the No. 3 plates

also releases the control key 550/3. Plate No. 21 in each group, however, is still held in its operative position by reason of its contact with the fourth cam rise, and this plate takes over all the operative functions performed by the plates that are now released.

Fifth multiple entering cycle

In the fifth cycle, as shown in Figure 36a and Table 11, the parts that were used in the fourth cycle are used again in the fifth to enter the amounts in 2X to 5X under the control of the No. 21 plate in each group. This plate also controls at the same time the entry of the amounts in 1X. Thus, early in the cycle the cam bars 636, 637, 638, 639 and 640 relating to the totalizers 1X to 5X respectively are each moved downwards one step to mesh its gear 481 with its related rack 467. At the same time the cam bars 625, 630, 631, 632 and 634 are each moved downwards three steps to mesh its gear 481a with its related rack 466. When the shaft 480 is rocked, the racks 172 in 1X to 5X are moved leftward for entering the multiplicand positively in these totalizers and, when the shaft 480a is rocked, the racks 171 in these same totalizers are moved rightward for entering the divisor negatively.

Rocking the shafts 87, 96 and 700 and reciprocating the racks 83 causes the amounts to be entered in 1X to 5X and, after the transfer and restoring actions, these five totalizers register once, twice, three, four and five times respectively the divisor and multiplicand, as shown in Figure 24h.

Immediately after the transfer action the shaft 314a (and 314 idly) is rocked to record the position of each digit in 1X of value otherwise than "nine" by setting a stop member 318a for each such digit.

The bars 137 in OX to 5X are operated to disengage the wheels 122 from the toe members 129, 130, and the lock bars 128 are centralized by the bars 138, 319. The clutch 328 is engaged by rocking the shaft 330 and remains engaged while the shaft 321a is rotated (clockwise in Figure 1a) to measure the number of consecutive "nines" on the left of the divisor in 1X in the manner described. Thus, in the example, the divisor was entered in 1X and six "nines" on the left of its first significant digit. Therefore, the sleeve 320a and the sun wheel secured to it are turned through six steps in a positive direction until a projection 319a contacts the most leftward of the rocked stop members 318a which is in column 12 and signifies the position of the highest significant digit in the divisor. This movement is imparted through the planet carrier of the gearing 322' and its bevel gear 325 to the shaft 327 and hence to the cam 331, leaving it displaced two units of movement in a positive direction, which position calls for an aligning column-shift of two places rightward in the preparatory dividing cycle.

Near the end of the cycle the shaft 700 is restored to release the bars 380 and the cams 402 are rotated through a fifth one-fifth of a revolution, thus regaining their starting position. The cam rise which held each No. 21 plate in operative position during this fifth cycle is thereby removed from contact with its plate so that each of the latter is now free to return, under the influence of its restoring spring, to its inoperative position. This return of the No. 21 plates also frees the operative long pinions 543

which are then restored to inoperative position by the restoring member 581 in each group. The restoring springs are not shown in the drawings in order to avoid confusion. It should be mentioned that the gear 541 meshing with the driving rack No. 12 remains in mesh therewith until the driving pressure on it is relieved, whereupon the restoring member 581 is free to restore the gear 541 to inoperative position.

It will be noted that the arms 410 are raised to the negative position by the shaft 420.

Other actuating and restoring movements are the same as those already described in reference to the preceding multiple entering cycles as shown in Figure 36a.

This leaves the machine in the condition shown in Figure 24h.

Preparatory cycle

A description of the functioning of the mechanism during the preparatory cycle will now be given, reference being made to the example of a calculation to illustrate the various steps in the cycle. The description will be divided into six parts, (a) to (f), and each part should be read in conjunction with the corresponding part in the example.

The timing diagram, Figure 37c, is arranged somewhat similarly to the previous diagrams, except that the fifth column is omitted. The sixth column is divided by vertical dotted lines into six parts marked (a) to (f) to correspond to the six parts into which the description of the cycle is divided. The same divisions by vertical dotted lines have been shown in all the timing diagrams to facilitate comparison and reference.

In Figures 25a to 25c are shown the results as they appear in the totalizers, etc. at the end of the second, fourth and sixth stage of the preparatory cycle. Reference is made in the example to how these results are built up arithmetically, but the details were not shown in the figures referred to. These details are now given in Table 12 in the form of an analysis of the results at the end of the cycle and some reference to their use in the first subsequent cycle which follows.

The operator depresses the control key 550/16 and then operates the machine through a single cycle, assuming that a dividend, a divisor, and a multiplicand have been entered as described, that the position of the split has been adjusted, and that the quotient signal has been moved to the required position (column 11).

When the control key is depressed, it positions the control plate No. 16 in each group of plates and thereby couples all the parts to be operated to the appropriate racks 532 as described.

Preparatory cycle: (a) Isolating OX totalizer and connecting it to the keyboard section

The first action is to release any latched shift key 273 by rocking shaft 283 (Figures 1, 19a), then lock the keys in released position by rocking shaft 278 (Figures 1a, 19a). Because OX is the only multiple totalizer containing a positive amount of its upper portion, it is the only totalizer with its related slide 415 (Figure 34) in an intermediate position. Consequently, when in the beginning of the cycle the shaft 462 (Figure 34a) is rotated to isolate the totalizer containing the smallest positive amount, the upper end of the OX lever 459 and the lower ends of the levers 464 and 465 pivoted to it are moved to the right and thus set the OX bars 171 and 172 rightward

to the subtract position in both portions. The upper ends of the levers 459 in the other totalizers are obstructed by the projections 456 on their related slides 415 which have been lifted to their highest position by the rocking of the shaft 420 in the dividend or multiple entering cycle. Consequently, the bars 171 and 172 in those totalizers are not moved from neutral position.

At the same time the shafts 114 (Figure 11) are rotated to lift the yokes 186 to mesh the coupler gears 194 in upper OX to 5X with their related gears 192 and 193, and to lift the yokes 187 to mesh the coupler gears 194 in lower OX to 5X with their related gears 192 and 193.

Shafts 120 (Figure 12) in OX to 5X are positioned rightward to bring each projection 198 into the path of the pin 195 on its related dial 118. These movements condition each of the totalizers OX to 5X for zeroizing in both portions.

Striking bars 149 (Figure 14) in 1X to 5X are moved leftward one step to engage reset gears 145 with gears 111 to set the resetting gear in each totalizer to record its multiple when the totalizer is cleared.

The shaft 96 (Figure 4) is rocked to couple shafts 81 to shafts 92 through clutches 93, 94.

Shaft 513 (Figure 3) is rocked to couple each shaft 81 to its related gear train 206, 207, 208, through clutches 510, 511.

These movements directly connect each dial in OX to the corresponding gear 208 in the keyboard section.

It will be noted that the shaft 335 (Figure 1a) is holding the rockers 341 in contact with the cam 331, and that in consequence one of the rockers is holding in operative position the related diagonal row of gears 259 that will give the aligning column-shift called for by the position of the cam, this column-shift in the case of the given examples being two places rightward. The other rockers will hold their related gears 259 in an inoperative position as described. This adjustment of the column-shift mechanism, however, is ineffectual at this stage of the cycle because the transmission from OX to the shafts 81 is direct as described above, the shafts 235 and 245 not being operated. The operative rocker 341 also holds its related quotient place signal showing in accordance with the column-shift call. Thus, in the example the signal is showing in column 11.

The striking bar 716 (Figure 19c) is shifted laterally to move the rockers 711 from engagement with the cams 713 used for amount entering cycles to engagement with the other set of cams that are used for dividing cycles.

Shafts 258 and 258a (Figures 19c, 20) are rocked to raise the racks 250, 251 (Figure 21) but the movement is an idle one at this stage and is only performed because an existing rack (No. 20) used in subsequent cycles has been selected by the control plate for raising the racks again in (e) of the present cycle.

Preparatory cycle: (b) Transmitting dividend from OX to the keyboard section

All the totalizers OX to 5X are now cleared by the rotation of the shafts 193 and 191 (Fig. 11). Since OX is the only totalizer coupled to the shafts 92, the latter receive the dividend from this totalizer and through the various connections described in (a) set the wheels 208 (Fig. 3) in accordance with the digits of the dividend; thus, the dividend is transmitted to the keyboard section without column-shift. The divisor and

multiplicand multiples in 1X to 5X are transmitted to the multiple resetting wheels 145 (Fig. 14) of their respective totalizers, each without column-shift.

Ball 850 operates to free the racks 250, 251 (Figure 22); but the movement is an idle one in this stage of a preparatory cycle.

This leaves the machine as shown in Figure 25a.

Preparatory cycle: (c) Registering dividend in keyboard section

The shaft 216 (Figure 3) is then rocked to cause the dividend to be registered on the lower slides 212 of the differential mechanism in the keyboard section.

At the same time, the bars 149 (Figures 5, 14) in 1X to 5X are moved another step leftward to bring the tooth 148 on the reset gear 145 in each denomination of each totalizer into the path of the related tooth 144 in readiness to reset the multiples in the totalizers by zeroizing the gears 145 in (d).

Shaft 96 (Figure 4) is restored to disengage clutches 93, 94; and shaft 513 (Figure 3) is restored to disengage clutches 510, 511.

Shafts 258 (Figure 20) and 258a are restored to lower the racks 250, 251.

Shafts 120 (Figure 12) in 0X to 5X are restored leftward to remove the projections 192 out of the path of the pins 195 on the dials 146.

Shafts 114 (Figure 11) in 0X to 5X are restored to lower the yokes 186 and 187 in the upper and lower portions respectively of each totalizer.

Shaft 462 (Figures 33, 35) is restored to return the bars 171 and 172 in 0X to neutral, and restore all the levers 459, 464 and 465 that have been moved idly.

Preparatory cycle: (d) Resetting the multiples

The shafts 142 (Figures 6, 14) in 1X to 5X are now turned through nine-tenths of a revolution so that the teeth 144 pick up the related teeth 148 and restore to their initial zero positions any of the reset gears 145 that have been displaced. This restores the totalizer gear trains to their original multiple-registering settings, thus resetting the multiples in the totalizers.

The shafts 190 and 191 (Figure 11) are restored.

Cam bars 636, 637, 638 (Figure 18a) 639, 640 and 641 (Figure 18b) are each moved down two steps to mesh gears 481 with racks 466 and 467 in the totalizers 0X to 5X.

Shaft 420 (Figure 18b) is rocked to ensure that the arms 410 and the special arm 413 are raised to negative position.

This leaves the machine in the condition shown in Figure 25b.

Preparatory cycle: (e) Comparing dividend with multiples

The striking bars 149 (Figure 14) are restored to their multiple-receiving positions still meshing with the gears 111.

Shaft 480 (Figure 35) is now rocked to move the racks 466 and 467 (Figure 14) leftward in each of the totalizers 0X to 5X. This movement swings the levers 464 and 465 in each totalizer about their pivots 458 so as to move the bars 171 and 172 respectively leftward to set the wheels 107 in both portions of each totalizer to the adding position by engaging clutches 106, 108.

Shaft 235 (Figure 4) is rocked to couple the column-shift shaft 230' to the shaft 81 through clutches 232, 233, and gears 236 and 90.

Shaft 245 (Figure 8) is rocked to engage the clutches 242, 243.

Shafts 258 (Figure 20) and 258a are also rocked to raise the racks 250 and 251. These movements connect the shafts 81 to the shafts 92 through the column-shift mechanism so that the shafts 81 may drive the shafts 92 with the amount of column shift, two places rightward, represented by the particular row of gears 259 made operative through the rockers 341 by the position of the cam 331 (Figure 1a).

Bar 47 (Figure 18b) is now rocked counter-clockwise to operate the racks 83 with the result that the shafts 81, the related clutches 232 and 233 (Figure 4), shafts 230', shafts 230, racks 250 and 251, the operative row of gears 259 and their respective shafts 231, vertical shafts 241 (Figure 8), clutches 242 and 243, shafts 92, clutches 106 and 108 (Figure 12), and the gear trains and dials of each totalizer are all driven through amounts proportional to the digits registered on the slides 212. Thus, the dividend is transmitted additively and concurrently to each of the totalizers 0X to 5X with the necessary aligning column-shift, two places rightward, to effect the result indicated in Figure 25c.

The ball 850 again moves rightward to release the racks 250 and 251. The gears 201 and 208 are reset to zero position by the rack 406 as described. The shafts 142 in 1X to 5X are restored.

Preparatory cycle: (f) Transfer action and restorations

The shaft 216 (Figure 3) is rocked to release the slides 212 and thereby disengage the clutches 80, 82 that were set in (c) to record the dividend.

The shaft 420 (Figure 18b) is restored to free the arms 410 to receive a positive setting in those totalizers which, after the transfer action, will contain a positive difference.

Shafts 235 (Figure 4) and 245 (Figure 8) are restored to disengage the clutches 232, 233 and 242, 243 respectively.

Cam bars 636, 637, 638, 639, 640 and 641 are now restored to return the gears 481 to their neutral position.

Shaft 480 is restored to move the bars 171 and 172 in 0X to 5X to neutral position to disengage the clutches 106, 108 in the gear trains of each totalizer.

The striking bars 149 are now returned to their initial position to disengage the reset gears 145 from the gears 111 and reengage them with their related pins 150. This is done in case the calculation is abandoned at their stage, for in that circumstance the next operation may be one not requiring the use of the reset mechanism. If the calculation is contained, the reset gears are reengaged with the gears 111 in part (a) of the next cycle and so continue their purpose without any change in their relationship to the gears 111, for they receive no rotational motion during the change-over from engagement with their related gears 111 to engagement with their related pins 150 and vice versa.

In the meantime, the bars 133, 134 (Figures 7, 8) are being actuated in succession by the other set of cams 713 to effect the positive transfers called for as a result of the positive entry of the dividend in each totalizer. If the positive entry in a totalizer is sufficient to leave it regis-

tering a positive amount, a positive unit will be transferred to the dummy section of the machine and the wheel 111c (Figure 16) will be rotated to rock its arm 410 down again. Thus, in the example, as shown in Figure 25c and Table 12, the 0X and 1X totalizers contain a positive difference while the 2X to 5X totalizers show a negative difference, so that the 1X arm 410 will be moved down while all the others are left up as shown diagrammatically in Figure 34b. This action so disposes the links 411 that the 0X canvassing slide is moved to its lowest position, the 1X slide is moved to its intermediate position, while the 2X to 5X slides are left in their highest position. This completes the actual comparing operation in which the dividend "1498" is concurrently compared with the divisor multiples, each of which is considered to be multiplied by the second power of ten, as shown in Table 12, because the quotient signal is in the hundreds denomination of Q. For the same reason, the multiplicand multiples are also considered to be multiplied by the second power of ten. If it is desired to ascertain the product result ("3300") at this stage by inspection of the totalizers, it may be read from the totalizer containing the smallest positive difference, the decimal point being considered as having been moved three places rightward, i. e., two places from its original setting because each multiplicand multiple is multiplied by the second power of ten and one place to offset the additional column leftward referred to under "decimal point indicators." This result is the product of 33×100 , 100 being the quotient at this stage of the calculation according to this reading.

The striking bars 137 in 0X to 5X disengage the transfer wheels 122 from their related toe members 129 and 130; and the bars 138, 139, centralize the lock-bars 128.

During the transfer action the bail 850 is restored leftward and returns with it any of the racks 250, 251, that were displaced during the comparing operation.

The rack 406 is restored at the same time as the bail 850.

The bar 47 is also returned to its initial position so as to restore the racks 83.

The striking bar 716 is restored to return the rockers 711 to engagement with the cams 713.

Other restoring movements in this cycle are shown in the diagram (Figure 37c).

Finally, the bail 578 is rocked to release the control key 550/16.

This leaves the machine as shown in Figure 25c.

Subsequent cycles

Following the preparatory cycle, the operator depresses the control key 550/17 and either of the control keys 550/11 or 550/12 depending upon whether the product result is required to be entered positively or negatively in lower 0X. If the quotient result is also required, either of the keys 550/14 or 550/15 is depressed depending upon whether the quotient result is required to be entered positively or negatively in Q. In the following description it is assumed that a positive product and a positive quotient are required so as to correspond with the example already given. Therefore, the keys 550/11 and 550/14 are depressed as well as the key 550/17.

Tables 13 to 16 are an analysis of the results at the end of each subsequent cycle.

First subsequent cycle: (a) Isolating required totalizer and connecting it to the keyboard section

The shafts 278 and 283 (Figure 1) are rocked to lock the shift keys as in the preparatory cycle. The totalizers are now in the condition shown in Figure 25c and Table 12, the positions of the slides 415 for this condition are illustrated in Figure 34b. It will be observed that the 0X slide 415 is in its lowest position, the 1X slide is in its intermediate position, and the 2X to 5X slides are still in their highest position. Consequently, when the shaft 462 is rotated the upper end of the 1X lever 459 and the lower ends of the levers 464 and 465 pivoted to it are moved to the right and thus set the 1X bars 171 and 172 rightward to the subtract position in both portions. In the 0X totalizer the upper end of the lever 459 is obstructed by the projection 455 on the slide 415 whilst its lower end 463 is free to move, while in the totalizers 2X to 5X the upper end of each lever 459 is obstructed by the projection 456 on its slide 415 and its lower end 463 is free. The levers 464 in 0X and 2X to 5X are, therefore, not moved and their bars 171 and 172 remain held in neutral position. This completes the isolating of the totalizer containing the smallest positive difference, in this case the 1X.

At the same time the shafts 114 (Figure 11) in 0X to 5X are rotated to lift the yokes 186 and 187 and the shafts 120 (Figure 12) are positioned rightward to condition the totalizers for zeroing as in the preparatory cycle.

Striking bars 149 (Figure 14) in 1X to 5X are moved leftward one step to reengage reset gears 145 with gears 111 for recording the multiples on the reset gears when the totalizers are cleared. Shaft 235 (Figure 4) is rocked to couple the column-shift shaft 230' to the shaft 81 through clutches 232, 233, and gears 236 and 90.

Shaft 245 (Figure 8) is rocked to couple the column-shift shafts 231 to the shafts 92 through clutches 242, 243 on the vertical shafts 241.

Shaft 513 (Figure 3) is rocked to couple each shaft 81 to its related gear train 206, 207, 208, through clutches 510, 511.

Shafts 258 and 258a are rocked to raise the racks 250 and 251.

These movements connect each dial in the isolated totalizer 1X to one of the gears 208 and with the same shift of two places rightward as in (e) of the preparatory cycle because the row of gears 259 displaced by the cam 331 is still held in operative position and each gear 259 now meshes with its appropriate rack 251. Therefore, the contrary shift employed in (b) of this cycle will be two places leftward.

When entering a quotient result positively, the bar 450 holds the rack 447 in the position shown in Figures 18b and 34, the teeth 451 meshing with gear 453 (Figure 13). But when the quotient result is to be entered negatively, the bar 450 is moved, in part (a) of each subsequent cycle, to its other position so as to mesh the teeth 452 with the gear 453.

First subsequent cycle: (b) Transmitting isolated difference to keyboard section: Canvassing: Entering quotient digit

All the totalizers 0X to 5X are now cleared by rotating shafts 190 and 191 (Figure 11). Since 1X is the only totalizer coupled to the shafts 92, the latter receive the difference "98" and partial product "3300" from 1X and transmit these amounts through the vertical shafts 241 and

horizontal shafts 231, on which are splined the operative diagonal row of gears 259, to the racks 251 and 250 with contrary shift of two places leftward. The shaft is a contrary one, to the left instead of to the right, because the drive is a reversal of the drive in (e) of the preparatory cycle in order to return the difference "98" to the denominations it originally occupied in the keyboard section as a part of the dividend entry. The racks 250 being in mesh with their respective gears 252 on the related shafts 230 which in turn are geared to the shafts 230' transmit the column-shifted amounts through the clutches 232, 233, wheels 236 and 90 to the shaft 81, then through clutches 510, 511 and finally through gears 206 and 207 to the wheels 208. Thus, the amounts are transmitted from 1X to the keyboard section with contrary shift as stated.

The other differences and their associated partial products in 2X to 5X are transmitted to their respective resetting wheels 145 without column-shift. The 0X totalizer is cleared as already explained.

The bail 850 moves rightward to free the racks 250 and 251.

Wheel 441 (Figure 18b) is operated to drive the canvassing racks 425, 426 (Figure 34b) until their projections 422 and 424 respectively contact the canvassing slide 415 of the isolated totalizer 1X. The rack 425 moves nine units and the rack 426 one unit, which latter movement represents the quotient result. This movement is communicated to the shaft 151 by the rack 447 and then to the quotient dial in column 11 of the totalizer Q through the coupler 292 which couples the gear 291 on the shaft to the related gear 290 in the totalizer gear train in that column as described. Thus, the totalizers 0X to 5X are canvassed and the quotient result entered.

This leaves the machine as shown in Figure 25d.

First subsequent cycle: (c) Registering difference and partial product in keyboard section: Changing column-shift setting

The difference "98" and partial products "3300" are now registered on the slides 212 in the same manner as the dividend was registered in (c) of the preparatory cycle.

Bars 149 are moved to prepare the reset gears for the resetting of the multiples as in (c) of the preparatory cycle.

Shafts 235, 245, 258, 258a and 513 are restored in order to disconnect the racks 250, 251 from the gears 252 and 259 for later restoring of the racks in part (d).

Shafts 120, 114 and 462 are restored as in part (c) of the preparatory cycle.

The ratchet wheel 350 (Figure 1a) which forms the final element in the differencing device now receives the superimposed setting of "minus one" because the quotient result is less than "5". Referring again to Figure 34b, it will be observed that the 5X slide 415 being in its highest position places the pin 472 in the narrow part of the opening 473 so that, when the bar 470 is oscillated, the bar 352 is moved with it and, as a result, the pawl 351 imparts one unit of movement in a negative direction to the wheel 350. Thus, the position of the cam 331 is changed from a setting of "plus two" to a setting of "plus one", which means a column-shift of one place rightward.

During the movement of the cam 331 the shaft 335 is rocked to disengage the rockers 341 and disable the quotient signal by restoring the op-

erative bar 295. In the same movement the corresponding coupler 292 is restored to free the shaft 151 and the "two places rightward" row of gears 259 are restored to inoperative position.

First subsequent cycle: (d) Resetting the multiples

The shaft 142 (Figure 5) are now rotated to restore the multiples as in the preparatory cycle, the unwanted differences and their associated partial product sums which were recorded on the resetting wheels in (b) being discarded as already explained.

The shafts 190, 191 are restored.

Gear 441 (Figure 18b) is restored to return the canvassing racks 425, 426. This also restores the rack 447 which remains in mesh with the gear 453 on the shaft 151, but rotating the shaft 151 during the restoring of the rack 447 is no disadvantage for it will be recalled that the shaft was disengaged from the quotient dial in (c) of this cycle.

Cam bars 636, 637, 638 (Figure 18a), 639, 640 and 641 (Figure 18b) are each moved down two steps to mesh gears 481 with racks 466 and 467 in each of the totalizers 0X to 5X.

Bail 850 is restored leftward to return any of the racks 250, 251 that were displaced in (b).

Shaft 335 (Figure 1a) is restored to reengage the rockers 341 with the cam 331. This movement also sets the diagonal row of gears 259 that will give a column-shift of one place rightward, and at the same time it sets the quotient signal in column 10 and operatively engages the coupler 292 (Figure 20) in that column.

This leaves the machine as shown in Figure 25e.

First subsequent cycle: (e) Comparing isolated difference with multiples

The action of the comparing mechanism is the same as in (e) of the preparatory cycle except in the following particulars and in that different values are involved.

The shafts 235 and 245 are operated by the driving rack No. 20 in subsequent cycles instead of No. 14 as in the preparatory cycle.

When the bar 47 is moved, the difference "98" and partial product "3300" are transmitted additively and concurrently to the multiple totalizers with a shift of one place rightward instead of two places as in (e) of the preparatory cycle. Since these amounts were transmitted from 1X to the keyboard section with a contrary shift of two places leftward, and now back to the totalizers with a shift of one place rightward, they will have been shifted in the multiple totalizers a net amount of one place leftward. In general, it will be observed that throughout the subsequent cycles the amounts are shifted one place leftward for each rightward shift of the quotient signal in every "true quotient" or "extra quotient" cycle.

First subsequent cycle: (f) Transfer action, etc.

The action is the same as in (f) of the preparatory cycle except in the following particulars.

The transfers are appropriate to the transfer calls set up in (e) of this cycle.

As 0X is the only multiple totalizer containing a positive difference (see Figure 25f and Table 13) none of the links 411 is moved as a result of the comparing operation. Consequently, the 0X slide 415 will be in its intermediate position and each of the other slides will be in its

highest position. This completes the comparing operation. The difference "98" is concurrently compared with the divisor multiples and each multiple is considered to be multiplied by the first power of ten, as shown in Table 13, because the quotient signal is in the tens denomination of Q. During the comparing operation the partial product "3300" was additively and concurrently transmitted to the lower portions of OX to 5X with the same column-shift of one place rightward, so that after the transfer action a partial product sum is formed in each totalizer comprising, as already explained, the corresponding multiplicand multiple multiplied by the first power of ten plus the partial product "3300."

The product result ("3300") at this stage may be read from the totalizer (OX) containing the smallest positive difference ("98"), the decimal point being considered as having been moved two places rightward from its setting, i. e., one place rightward because each partial product sum is multiplied by the first power of ten and one place rightward to offset the additional column leftward as already explained. This result is the product of 33×100 , 100 being the quotient at this stage of the calculation according to this reading.

This leaves the machine as shown in Figure 25f.

Second subsequent cycle: (a) Isolating required totalizer and connecting it to the keyboard section

The action of the mechanism is the same as in (a) of the first subsequent cycle except in the following particulars.

The totalizers are now in the condition shown in Figure 25f and Table 13. Because OX is the only multiple totalizer containing a positive difference, the links 411 and their slides 415 are disposed in exactly the same positions as in (a) of the preparatory cycle, so that when the shaft 462 is rotated the OX totalizer will be isolated in the manner described in (a) of that cycle.

The various shafts and bars that are operated in this part to connect each dial in the OX totalizer to one of the gears 208 are the same as those employed in (a) of the first subsequent cycle. The column-shift adjustment is one place rightward as in (e) of that cycle because the cam 331 is still set to give that amount of shift. Therefore, the contrary shift employed in (b) of this cycle will be one place leftward.

Second subsequent cycle: (b) Transmitting isolated difference to keyboard section: Canvassing: Entering quotient digit

The action is the same as in (b) of the first subsequent cycle except that the values involved are different as shown in Figure 25g and that the column-shift setting is one place instead of two places rightward.

The difference "98" and partial product sum "3300" in OX are transmitted to the gears 208 with a contrary shift of only one place leftward so as to return the isolated difference to the denominations it originally occupied as part of the dividend entry.

The other differences and their associated partial product sums in 1X to 5X are transmitted to their respective resetting wheels 145.

Because the OX slide 415 (Figure 34b) is in its intermediate position as explained in reference to the preparatory cycle, the canvassing rack 426 will contact the projection 423 thereon immediately the wheel 441 commences to be operated, while the rack 425 will be moved nine

units. Consequently, the rack 447, shaft 151 and quotient dial in column 11 will not receive any movement. Thus, the quotient value "0" is entered in Q.

This leaves the machine as shown in Figure 25g.

Second subsequent cycle: (c) Registering difference and partial product sum in keyboard section: Changing column-shift setting

The difference "98" and partial product sum "3300" are now registered on the slides 212 in the same manner as the amounts in (c) of the preceding cycles.

Bars 149 are moved to prepare the reset gears for resetting the multiples and various restoring movements take place as in the preceding cycle.

Because the quotient result is less than "5," the ratchet wheel 350 now receives the superimposed setting of "minus one," the pin 472 being raised to engage the bar 352. Thus, the position of the cam 331 which stood at "plus one" is now changed to "normal." At the same time the quotient signal in column 10 is restored, the "one place rightward" row of gears 259 is restored to inoperative position, and the corresponding coupler 292 is restored to free the shaft 151.

Second subsequent cycle: (d) Resetting the multiples: Readjusting column-shift

The action is the same as in (d) of the first subsequent cycle, except that when the shaft 335 is restored to reengage the rockers 341 with the cam 331 the "normal" row of gears 259, which will give no column-shift in either direction, will be made operative. The same movement sets the quotient signal in column 9 and operatively engages the coupler 292 in that column.

This leaves the machine as shown in Figure 25h.

Second subsequent cycle: (e) Comparing isolated difference with multiples

The action of the comparing operation is similar to (e) of the first subsequent cycle except that different values are involved and the column-shift setting gives no shift instead of one place rightward.

When the bar 47 is moved, the difference "98" and partial product sum "3300" are transmitted additively and concurrently to the multiple totalizers with no column-shift. Since these amounts were transmitted from OX to the keyboard section with a contrary shift of one place leftward, and now back again to the totalizers with no column-shift, they will have been shifted in the multiple totalizers a net amount of one place leftward.

Second subsequent cycle: (f) Transfer action, etc.

The action is the same as in (f) of the first subsequent cycle except in the transfer action, which is appropriate to the transfer calls set up in (e) of this cycle, and in the following particulars.

Each difference in the totalizers OX to 5X is a positive one as shown in Figure 25i and Table 14, and consequently the 1X to 5X arms 410 will be rocked down. The only arm left up will be the special one 413. The OX to 4X slides 415 are thereby placed in their lowest positions, while the 5X slide 415 is lowered to its intermediate position. This completes the comparing opera-

tion in which the difference "98" is concurrently compared with the divisor multiples each of which is now considered to be multiplied by the zero power of ten, as shown in Table 14, because the quotient signal is in the units denomination of Q. During the comparing operation the partial product sum "3300" was additively and concurrently transmitted to the lower portions of OX to 5X with no column-shift, so that after the transfer action a new partial product sum is formed in each totalizer comprising, as already explained, the corresponding multiplicand multiple multiplied by the zero power of ten plus the partial product sum "3300".

The product result ("3465") at this stage may be read from the totalizer (5X) containing the smallest positive difference ("28"), the decimal point being considered as having been moved one place rightway from its setting, i. e. no movement from its setting, because each partial product sum is multiplied by the zero power of ten and one place rightward to offset the additional column leftward as already explained. This result is the product of 33×105 , 105 being the quotient result at this stage of the calculation according to this reading.

This leaves the machine as shown in Figure 25i.

Third subsequent cycle: (a) Isolating required totalizer and connecting it to the keyboard section

The action is the same as in (a) of the previous cycle except in the following particulars.

The totalizers are in the condition shown in Figure 25i and Table 14. It will be observed that all the differences are positive but that the smallest is registered in 5X. Accordingly, all the arms 410 have been moved down, thereby disposing the links 411 so as to position the OX to 4X canvassing slides 415 in their lowest position, and the 5X slide in its intermediate position. Therefore, when the shaft 462 is rotated in this part of the cycle the 5X totalizer will be isolated in the manner already described.

The various shafts and bars that are operated in this part to connect each dial in the 5X totalizer to one of the gears 208 are the same as those employed in (a) of the previous cycle, but with "normal" contrary shift as in (e) of that cycle, for the cam 331 is still set to give no shift.

Third subsequent cycle: (b) Transmitting isolated difference to keyboard section: Canvassing: Entering quotient digit

The action is the same as in (b) of the previous cycle except that the values are different as shown in Figure 25j, and the column-shift setting is "normal" as in (e) of the previous cycle instead of one place rightward.

The difference "28" and partial product sum "3465" in 5X are transmitted to the gears 208 with "normal" contrary shift so as to return the isolated difference to the denominations it originally occupied as part of the dividend entry.

The other differences and their associated partial product sums in 1X to 4X are transmitted to their respective resetting wheels 145. The OX totalizer is cleared as already explained.

Because the 5X slide 415 is in its intermediate position as explained in (a) of this cycle, the canvassing rack 426, when the wheel 441 is operated, will contact the projection 423 on the slide when it has traveled five units while the rack 425 will travel four units. The rack 447 will transmit the movement of the rack 426 to the shaft 75

151 and quotient dial in column 9. Thus, the quotient value "5" is entered in Q.

This leaves the machine as shown in Figure 25j.

Third subsequent cycle: (c) Registering difference and partial product sum in keyboard section: Column-shift setting

The difference "28" and partial product sum "3465" are now registered on the slides 212 in the same manner as the amounts in (c) of the previous cycles.

Bars 149 are moved to prepare the reset gears for resetting the multiples and various restoring movements occur as in the other subsequent cycles.

Because the 5X slide 415 is in its intermediate position, the pin 472 (Figure 34b) does not engage the bar 352 when the bar 470 is operated. Consequently, the ratchet wheel 350 does not receive the superimposed setting as in the previous cycles, and the setting of the cam 331 which now stands at "normal" is not changed. At the same time, the "normal" row of gears 259, the quotient signal and the tumbler 292 in column 9 are restored to inoperative position. This means that the next cycle will be an "extra quotient" cycle, in which the quotient result will be required to be entered in column 9 again and added to the "5" already entered in (b) of the present cycle.

Third subsequent cycle: (d) Resetting the multiples

The action is the same as in (d) of the preceding cycle. When the shaft 335 is restored to reengage the rockers 341 with the cam 331, the "normal" setting is restored so that the next comparing operation will be made with the same column-shift setting as in the previous cycle and likewise the next quotient entry will be made in the same column of the totalizer Q.

This leaves the machine as shown in Figure 25k.

Third subsequent cycle: (e) Comparing isolated difference with multiples

The action of the comparing operation is similar to (e) of the preceding cycle except that different values are involved.

When the bar 47 is moved, the difference "28" and partial product sum "3465" are transmitted additively and concurrently to the multiple totalizers with "normal" contrary shift as in the preceding cycle. Since these amounts were transmitted from 5X to the keyboard section in (b) of this cycle with no column-shift, then back to the totalizers in this part of the cycle again with no column-shift, they will have been entered in the multiple totalizers without change of denominational position.

Third subsequent cycle: (f) Transfer action, etc.

The action is the same as in (f) of the preceding cycle except that the transfer action is appropriate to the transfer calls set up in (e) of this cycle. It also differs in the following particulars.

It will be observed in reference to Figure 25m and Table 15 that the 2X totalizer contains a zero difference; its arm 410 will, therefore, be rocked down. The 0X and 1X totalizers contain a positive difference, so that their arms 410 will also be rocked down. The totalizers 3X to 5X each contain a negative difference so that their arms 410 will remain up. This will so dispose the arms 411 that the 0X and 1X canvassing slides 415 will be in their lowest position, the 2X slide will be in its

intermediate position and the 3X to 5X slides will be in their highest position. This completes the comparing operation in which the difference "28" is concurrently compared with the divisor multiples each of which is again considered to be multiplied by the zero power of ten, as shown in Table 15, because the quotient signal is still in the units denomination of Q. During the comparing operation the partial product sum "3465" was additively and concurrently transmitted to the lower portions of 0X to 5X also with no column-shift, so that after the transfer action a new partial product sum is formed in each totalizer comprising, as already explained, the corresponding multiplicand multiple multiplied by the zero power of ten plus the partial product sum "3465".

The final product result ("3531") may be read from the totalizer (2X) containing the smallest positive difference ("0"), the decimal point being considered as having been moved in the same manner as in the preceding cycle.

But at this stage of the calculation the quotient is not complete. A fourth subsequent cycle is, therefore, necessary, in which the quotient will be completed and also in which the final product will appear in the product portion of totalizer 0X.

This leaves the machine in the condition shown in Figure 25m.

Fourth subsequent cycle: (a) Isolating required totalizer and connecting it to the keyboard section

The action is the same as in (a) of the previous cycle except in the following particulars.

The totalizers are in the condition shown in Figure 25m and Table 15. It will be observed that all the differences are negative except the 0X which has a zero difference. Consequently, all the arms 410 will remain up, thereby so disposing the links 411 that the canvassing slides 415 will remain in their highest position while the 0X slide remains in its intermediate position. When, therefore, the shaft 462 is rotated in this part of the cycle the 0X totalizer will be isolated as already described in reference to (a) of the second subsequent cycle.

The various shafts, etc. that are operated in this part to connect each dial in the 0X totalizer to one of the gears 208 are the same as those employed in the previous cycle, but with "normal" contrary shift as in (e) of that cycle, for the cam 331 is still set to give no shift.

Fourth subsequent cycle: (b) Transmitting isolated difference to keyboard section: Canvassing: Entering quotient digit

The action is the same as in (b) of the previous cycle except that the values are different as shown in Figure 25n. The column-shift setting is still at "normal" as in (e) of the previous cycle.

The difference "0" and partial product sum "3531" in 2X are transmitted to the gears 208 with "normal" contrary shift.

The other differences and their associated partial product sums in 0X, 1X and 3X to 5X are transmitted to their respective setting wheels 145.

Because the 2X slide 415 is in its intermediate position as explained in (a) of this cycle, the canvassing rack 426, when the wheel 441 is operated, will contact the projection 423 on the slide when it has traveled two units, while the rack 425 will travel seven units. The rack 447 will transmit the movement of the rack 426 to the shaft 151 and quotient dial in column 9. Thus, the extra quotient value "2" is entered in

column 9 and added to the partial quotient already entered therein, making a true quotient of "7".

5 Fourth subsequent cycle: (c) Registering difference and partial product sum in keyboard section: Column-shift setting

The difference "0" and partial product sum "3531" are now registered on the slides 212.

10 Bars 149 are moved to prepare the reset gears for resetting the multiples and various restoring movements occur as in other subsequent cycles.

15 Because the 5X slide 415 is in its highest position the pin 472 engages the bar 352 when the bar 470 is operated, so that the ratchet wheel 350 receives the superimposed setting of "minus one." Thus, the position of the cam 331 which stood at "normal" is now changed to a setting of "minus one" which is a call for a column-shift of one place leftward. It will be noted that the column-shift direction has now changed from rightward to leftward. At the same time the quotient signal in column 9 is restored, the "normal" row of gears 259 is restored to inoperative position and the corresponding coupler 292 is restored to free the shaft 151.

Fourth subsequent cycle: (d) Resetting the multiples: Readjusting column-shift

The action is the same as in the preceding cycle, except that when the shaft 335 is restored to reengage the rockers 341 with the cam 331, the "one place leftward" row of gears 259 will be made operative. The same movement sets the quotient signal in column 8 and operatively engages the coupler 292 in that column.

This leaves the machine as shown in Figure 25o.

40 Fourth subsequent cycle: (e) Comparing isolated difference with multiples

The action of the comparing operation is similar to (e) of the preceding cycle except that different values are involved.

45 When the bar 47 is moved, the difference "0" and partial product sum "3531" are transmitted additively and concurrently to the multiple totalizers with a column-shift of one place leftward. Since these amounts were transmitted from 0X to the keyboard section in (b) of this cycle with no-column-shift, then back to the totalizers in this part of the cycle with column-shift of one place leftward, they will have been shifted in the multiple totalizers a net amount of one place leftward.

Fourth subsequent cycle: (f) Transfer action, etc.

60 The action is the same as in (f) of the preceding cycle except that the transfer action is appropriate to the transfer calls set up in (e) of this cycle. It also differs in the following particulars.

65 On reference to Figure 25p and Table 16, it will be observed that the totalizers 1X to 5X contain a negative difference while the 0X totalizer contains a zero difference which is reckoned as positive. Consequently, the arms 410, links 411 and canvassing slides 415 are all disposed as in (f) of the first subsequent cycle. This completes the comparing operation in which the difference "0" is concurrently compared with the divisor multiples each of which is considered to be multiplied by the first negative power of ten as shown in Table 16, because the quotient sig-

nal is in the first decimal denomination of Q. During the comparing operation the partial product sum "3531" was additively and concurrently transmitted to the lower portions of 5X to 5X also with a column-shift of one place leftward, so that after the transfer action a new partial product sum is formed in each totalizer comprising, as already explained, the corresponding multiplicand multiple multiplied by the first negative power of ten plus the partial product sum "3531."

Thus, the final product result "3531" now appears in the product registering portion of 0X and in correct relationship to the decimal point as set in accordance with the rule stated.

Continuing to operate the machine beyond this point without releasing the control keys, which have been manually held depressed throughout the subsequent cycles, merely column-shifts the product result leftward one place with each operation, shifts the quotient indicator rightward and enters in Q a succession of zero values.

It may be mentioned that operating the machine with only the control key 550/17 depressed causes the mechanism to perform the dividing and multiplying operation but it does not enter the product or the quotient results in the dials. The results are only entered when the parts controlled by the keys 550/11, 550/12, 550/14 or 550/15 as shown in Figure 37c are brought into operation.

Table 12

ANALYSIS OF RESULTS AT END OF PREPARATORY CYCLE (SEE ALSO FIG. 25c)

	Upper	Col. No.—			
		12	11	10	9
5X	$1498 - (14 \times 5 \times 10^0) =$	5	5	0	2
4X	$1498 - (14 \times 4 \times 10^0) =$	4	1	0	2
3X	$1498 - (14 \times 3 \times 10^0) =$	2	7	0	2
2X	$1498 - (14 \times 2 \times 10^0) =$	1	3	0	2
1X	$1498 - (14 \times 1 \times 10^0) =$	—	—	9	8
0X	$1498 - (14 \times 0 \times 10^0) =$	1	4	9	8

1X will be isolated in the next cycle, so that the quotient result will then be $(1 \times 10^0) = 100$.

	Lower	Col. No.—						
		8	7	6	5	4	3	2
5X	$33 \times 5 \times 10^0 =$	—	—	1	6	5	0	0
4X	$33 \times 4 \times 10^0 =$	—	—	1	3	2	0	0
3X	$33 \times 3 \times 10^0 =$	—	—	—	9	9	0	0
2X	$33 \times 2 \times 10^0 =$	—	—	—	6	6	0	0
1X	$33 \times 1 \times 10^0 =$	—	—	—	3	3	0	0
0X	$33 \times 0 \times 10^0 =$	—	—	—	—	—	—	0

The partial product result isolated in the next cycle will be $33 \times 1 \times 10^0 = 3300$.

The registration in the keyboard section in the next cycle will be: Smallest positive difference=98; partial product, 3300.

Table 13

ANALYSIS OF RESULTS AT END OF FIRST SUBSEQUENT CYCLE (SEE ALSO FIGURE 25f)

	Upper	Col. No.—			
		12	11	10	9
5X	$98 - (14 \times 5 \times 10^0) =$	6	0	2	—
4X	$98 - (14 \times 4 \times 10^0) =$	4	6	2	—
3X	$98 - (14 \times 3 \times 10^0) =$	3	2	2	—
2X	$98 - (14 \times 2 \times 10^0) =$	1	8	2	—
1X	$98 - (14 \times 1 \times 10^0) =$	—	4	2	—
0X	$98 - (14 \times 0 \times 10^0) =$	—	9	8	—

0X will be isolated in the next cycle, so that the quotient result will then be $100 + (0 \times 10^0) = 100$.

	Lower	Col. No.—						
		8	7	6	5	4	3	2
5X	$3300 + (33 \times 5 \times 10^0) =$	—	—	4	9	5	0	—
4X	$3300 + (33 \times 4 \times 10^0) =$	—	—	4	6	2	0	—
3X	$3300 + (33 \times 3 \times 10^0) =$	—	—	4	2	9	0	—
2X	$3300 + (33 \times 2 \times 10^0) =$	—	—	3	9	6	0	—
1X	$3300 + (33 \times 1 \times 10^0) =$	—	—	3	6	3	0	—
0X	$3300 + (33 \times 0 \times 10^0) =$	—	—	3	3	0	0	—

The partial product sum isolated in the next cycle will be $3300 + (33 \times 0 \times 10^0) = 3300$.

The registration in the keyboard section in the next cycle will be: Smallest positive difference=98; partial product sum=3300.

Table 14

ANALYSIS OF RESULTS AT END OF SECOND SUBSEQUENT CYCLE (SEE ALSO FIGURE 25f)

	Upper	Col. No.—			
		12	11	10	9
5X	$98 - (14 \times 5 \times 10^0) =$	2	8	—	—
4X	$98 - (14 \times 4 \times 10^0) =$	4	2	—	—
3X	$98 - (14 \times 3 \times 10^0) =$	5	8	—	—
2X	$98 - (14 \times 2 \times 10^0) =$	7	0	—	—
1X	$98 - (14 \times 1 \times 10^0) =$	8	4	—	—
0X	$98 - (14 \times 0 \times 10^0) =$	9	8	—	—

5X will be isolated in the next cycle, so that the quotient result will then be $100 + (5 \times 10^0) = 105$.

	Lower	Col. No.—						
		8	7	6	5	4	3	2
5X	$3300 + (33 \times 5 \times 10^0) =$	—	3	4	6	5	—	—
4X	$3300 + (33 \times 4 \times 10^0) =$	—	3	4	3	2	—	—
3X	$3300 + (33 \times 3 \times 10^0) =$	—	3	3	9	9	—	—
2X	$3300 + (33 \times 2 \times 10^0) =$	—	3	3	6	6	—	—
1X	$3300 + (33 \times 1 \times 10^0) =$	—	3	3	3	3	—	—
0X	$3300 + (33 \times 0 \times 10^0) =$	—	3	3	0	0	—	—

The partial product sum isolated in the next cycle will be $3300 + (33 \times 5 \times 10^0) = 3465$.

The registration in the keyboard section in the next cycle will be: Smallest positive difference=28; partial product sum=3465.

Table 15

ANALYSIS OF RESULTS AT END OF THIRD SUBSEQUENT CYCLE (SEE ALSO FIGURE 25m)

	Upper	Col. No.—			
		12	11	10	9
5X	$28 - (14 \times 5 \times 10^0) =$	—	4	2	—
4X	$28 - (14 \times 4 \times 10^0) =$	—	2	8	—
3X	$28 - (14 \times 3 \times 10^0) =$	—	1	4	—
2X	$28 - (14 \times 2 \times 10^0) =$	—	—	0	—
1X	$28 - (14 \times 1 \times 10^0) =$	—	1	4	—
0X	$28 - (14 \times 0 \times 10^0) =$	—	2	8	—

2X will be isolated in the next cycle, so that the quotient result will then be $105 + (2 \times 10^0) = 107$.

	Lower	Col. No.—						
		8	7	6	5	4	3	2
5X	$3465 + (33 \times 5 \times 10^0) =$	—	3	6	3	0	—	—
4X	$3465 + (33 \times 4 \times 10^0) =$	—	3	5	9	7	—	—
3X	$3465 + (33 \times 3 \times 10^0) =$	—	3	5	6	4	—	—
2X	$3465 + (33 \times 2 \times 10^0) =$	—	3	5	3	1	—	—
1X	$3465 + (33 \times 1 \times 10^0) =$	—	3	4	9	8	—	—
0X	$3465 + (33 \times 0 \times 10^0) =$	—	3	4	6	5	—	—

The partial product sum isolated in the next cycle will be $3465 + (33 \times 2 \times 10^0) = 3531$.

The registration in the keyboard section in the next cycle will be: Smallest positive difference=0; partial product sum=3531.

Table 16
ANALYSIS OF RESULTS AT END OF FOURTH
SUBSEQUENT CYCLE (SEE ALSO FIGURE 25p)

	Upper	Col. No.—			
		12	11	10	9
5X	$0 - (14 \times 5 \times 10^{-1}) =$	7.0			
4X	$0 - (14 \times 4 \times 10^{-1}) =$	5.6			
3X	$0 - (14 \times 3 \times 10^{-1}) =$	4.2			
2X	$0 - (14 \times 2 \times 10^{-1}) =$	2.8			
1X	$0 - (14 \times 1 \times 10^{-1}) =$	1.4			
0X	$0 - (14 \times 0 \times 10^{-1}) =$	0.0			

0X will be isolated in the next cycle, so that the quotient result will then be $107 + (0 \times 10^{-1}) = 107.0$.

	Lower	Col. No.—						
		8	7	6	5	4	3	2
5X	$3531 + (33 \times 5 \times 10^{-1}) =$	3	5	4	7.5			
4X	$3531 + (33 \times 4 \times 10^{-1}) =$	3	5	4	4.2			
3X	$3531 + (33 \times 3 \times 10^{-1}) =$	3	5	4	0.9			
2X	$3531 + (33 \times 2 \times 10^{-1}) =$	3	5	3	7.6			
1X	$3531 + (33 \times 1 \times 10^{-1}) =$	3	5	3	4.3			
0X	$3531 + (33 \times 0 \times 10^{-1}) =$	3	5	3	1.0			

The partial product sum isolated in the next cycle will be $3531 + (33 \times 0 \times 10^{-1}) = 3531.0$.

The registration in the keyboard section in the next cycle will be: Smallest position difference = 0; partial product sum = 3531.0.

It may now be explained why the isolated difference in a subsequent cycle is registered in the keyboard section in the denominations it originally occupied as a part of the dividend. It is done to avoid changing the column-shift (except for the supplementary setting of "minus one" when required) between the transmitting of an isolated difference from its totalizer to the keyboard section in part (b) and the returning of that difference from the keyboard section to the multiple totalizers during the comparing operation in part (e). This has been referred to under "correlating dividend with divisor, etc." as the first method. By the second method referred to under that heading, the cam 331 is zeroized in each subsequent cycle and then readjusted by the measuring mechanism to a new position whereby the dividend will be correlated with the divisor as though the cycle was a preparatory one. This second method has the advantage that it permits the skipping of one cycle for each intermediate "zero" in the dividend and for each additional "zero" on the left of the isolated difference as measured by the rotation of the shaft 321, but it has the disadvantage that the measuring mechanism and the zeroizing mechanism of the cam 331 are operated in every dividing cycle instead of in the dividend and divisor entering cycles only.

It may sometimes occur that the aligning shift in a preparatory cycle may be one more place rightward than is needed owing to the fact that the machine is unable to distinguish whether the most rightward of the "nines" on the left of the divisor entry in 1X is a complementary significant figure or a "nine" which arises from a negative transfer. For example, a divisor of "1" is entered in column 11 and a dividend of "999" in columns 11 to 13. The divisor entry in 1X will read "99999999" and the dividend entry in 0X will read "00000999". Now, there are seven "nines" (columns 12 to 18) on the left of the divisor entry in column 11 of 1X and that entry produces another "nine" in that column, making eight "nines" in all. When the shaft 321a is rotated to measure the number of "nines" on the left of the divisor entry in 1X, the "nine" in col-

umn 11 will be included in the number measured, with the result that the cam 331 will receive a setting of "plus eight" instead of "plus seven," as would be the case if the divisor had been otherwise than "1" except "0". When the shaft 321 is rotated to measure the number of "zeros" on the left of the dividend entry in 0X, the cam will receive a setting of "minus five." These settings together leave the cam with a net setting of "plus three," which means that in the preparatory cycle the dividend amount will be transmitted from the keyboard section to the totalizers with an aligning shift of three places rightward. But for correct alignment in this case, as an inspection of the entries will reveal, a shift of only two places rightward is required, an error of one place rightward in excess of the true requirement occurring for the reason stated above.

In the preparatory cycle, when this condition arises, the machine completes the comparing operation in (e) and (f) of that cycle, using the incorrect shift as though it were correct, and this results in all the totalizers 1X to 5X remaining negative. In the first subsequent cycle, this causes the 0X totalizer to be isolated in (a) of that cycle and a quotient value of "0" to be entered in Q during (b) and, because the quotient value is less than "5", the link 470 (which is only operated in subsequent cycles) engages the slide 352, and imparts to the cam 331 in (c) the superimposed setting of "minus one" as already explained. This leaves the cam with a setting of "plus two," so that in the comparing operation during (e) and (f) of this cycle, the dividend is transmitted from the keyboard section to the totalizers with the correct aligning shift of two places rightward. It will thus be seen that, when this condition arises, the quotient entry in the first subsequent cycle is "0", and that automatically in (c) of that cycle the first superimposed setting of "minus one" cancels the error, after which the result entering cycles proceed as described. The action is precisely the same in principle when the aligning shift is a negative one.

A somewhat similar circumstance arises when the first significant digit in the divisor is greater than that in the dividend. For example, a divisor of "9" is entered in column 11 and a dividend of "111" in columns 11 to 13. The divisor entry in 1X will read "99999991" and the dividend entry in 0X will read "00000111". There are seven "nines" on the left of the divisor entry in column 11 of 1X, so that when the shaft 321a is rotated, the cam 331 will receive a setting of "plus seven." When the shaft 321 is rotated to measure the number of "zeros" on the left of the dividend entry in 0X, the cam will receive a setting of "minus five," leaving a net setting of "plus two" which means that the aligning shift in the preparatory cycle will be two places rightward. But an inspection of the entries will reveal that while this amount of shift will correctly align the first significant digit in the dividend with that in the divisor, it is nevertheless one place rightward in excess of the true requirement. This case is now shown to be similar to the first case described, for in each case the first superimposed setting of "minus one" will cancel the excess shift; and, for the same reason as in the first case, the quotient entry in the first subsequent cycle will be "0", after which the result entering cycles proceed as described. It will be found that the action is precisely the same in principle when the aligning shift is a negative one.

Zeroizing upper 1X to 5X

For this operation, the control key 550/1 is used. This key positions the No. 1 control plate in each group of plates 544 and thereby couples all the parts to be operated to the appropriate racks 532 as described. The machine is then operated through a single cycle.

Also, when zeroizing upper 1X to 5X, the cam 331 is zeroized, so that when the multiples of a new divisor are entered in upper 1X to 5X the cam may be set in accordance with the new number of "nines" on the left of the entry in upper 1X in the manner already described in reference to Figure 36a.

The timing is shown in Figure 36, and to facilitate reference the description is again divided into six parts, (a) to (f).

(a) Shaft 283 is rocked to release any latched shift key 273.

Shafts 114 in 1X to 5X are rotated to lift the yokes 186 in upper portion of each totalizer to mesh the coupler gears 194 with their related gears 192 and 193.

Shafts 120 in 0X to 5X are positioned rightward to bring each projection 196 into the path of the pin 195 on its related dial 118. These movements of shafts 114 and 120 together condition both upper and lower portions of 1X to 5X for zeroizing.

Shaft 335 is rocked to disengage the rockers 341 from cam 331.

Also shaft 360 is rocked to lift tooth 356 into the path of tooth 356 to condition cam 331 for zeroizing.

(b) Shafts 190 in 0X to 5X are rotated. This clears upper 1X to 5X, but not upper 0X because the 0X shaft 114 was not rotated in (a). The lower portions are not cleared because shafts 191 are not rotated.

At the same time wheel 750 is rotated, thereby zeroizing shaft 327 and cam 331.

(c) Shafts 335, 360, 114 in 1X to 5X, 120 and wheel 750 are restored.

(d) Shafts 190 are restored and shaft 420 is rocked to raise arms 410 and special arm 413 to negative positions in case the next operation of the machine is performed with the key 550/16.

(e) No movements.

(f) Shafts 283 and 420 are restored, and bail 578 is rocked to release the No. 1 control plates and the key 550/1.

Zeroizing lower 1X to 5X

In this operation (see Figure 36b) control key 550/4 positions the No. 4 control plate in each group of plates 544. On rotating the handle 595,

(a) Shaft 283 is rocked as when using key 550/1.

Shafts 114 in 1X to 5X are rotated to lift yokes 187 in lower portion of each totalizer to mesh the coupler gears 194 with their related gears 192 and 193.

Shafts 120 in 0X to 5X are positioned rightward. These movements of shafts 114 and 120 together selectively condition both upper and lower portions of 1X to 5X for zeroizing.

(b) Shafts 191 in 0X to 5X are rotated. This clears lower 1X to 5X, but not lower 0X because the 0X shaft 114 was not rotated in (a). The upper portions are not cleared because shafts 190 are not rotated.

(c) Shafts 114 and 120 are restored.

(d) Shafts 191 are restored.

(e) No movements.

(f) Shaft 283 is restored. Bail 578 is rocked

to release the No. 4 control plates and the key 550/4.

Zeroizing upper 0X: Reentering amount with column-shift

For this operation (see Figure 36c) the control key 550/7 positions the No. 7 control plate in each group of plates 544. This couples to the racks 532 not only all the parts required for zeroizing upper 0X but also certain of the parts whereby the zeroized amount can be reentered in 0X with column-shift when so desired. The other parts necessary for effecting a column-shift are called into operation whenever a shift key 273 is used as well as the key 550/7. Thus, to zeroize upper 0X, control key 550/7 is latched down; to column-shift an amount in upper 0X, key 550/7 and one of the keys 273 are latched down together. Latching down any of the keys 273 without latching the key 550/7 produces no effect when the handle 595 is rotated. Also, when zeroizing upper 0X, the cam 331 is zeroized, so that when a new dividend entry is made in upper 0X, the cam may be set in accordance with the new number of "zeros" on the left of the new dividend in the manner already described in reference to Figure 36d.

The movements of the mechanism when using key 550/7 for zeroizing only and when using key 550/7 in conjunction with a key 273 for column-shifting will now be described.

(a) Shaft 114 in 0X is rotated to lift the yokes 186 in the upper portion to mesh the coupler gears 194 with their related gears 192 and 193.

Shafts 120 in 0X to 5X are positioned rightward. These movements of shaft 114 and shafts 120 together condition both upper and lower 0X for zeroizing.

The shaft 96 is rocked to couple shafts 81 to shafts 92 through clutches 93, 94.

Cam bar 635 is moved down three steps to mesh the 0X gear 481a with its related rack 466, and immediately afterwards shaft 480a is rocked to move rack 171 in 0X rightward to the subtracting position, thus coupling the wheel 107 with the wheel 101 by clutches 109, 110, in each denomination of 0X above the split.

Shaft 513 is rocked to couple each shaft 81 to its related gear train 206, 207, 208, through clutches 510, 511.

These movements directly connect each dial in upper 0X to the corresponding gear 208 in the keyboard section.

Shaft 360 is rocked to lift tooth 358 on gear 357 into the path of tooth 356 on the disc 335 in readiness to zeroize the shaft 327 and cam 331 in (b).

Shafts 259 and 258a are rocked to raise the racks 250, 251, but the movement is an idle one at this stage.

Shaft 335 is rocked to disengage the rockers 341 while cam 331 is zeroized, the diagonal row of gears 259 which was operative being moved to the inoperative position as shown in Figure 23.

Striking bar 716 is shifted to move the rockers 711 into engagement with the set of transfer cams used in dividing cycles.

(b) Wheel 750 is rotated to cause the tooth 358 to pick up the tooth 356 on the disc 335 and rotate the cam 331 until the zero stop pin 331a contacts the end of the stop lever 359a as shown in Figure 1a.

Bail 850 moves rightward idly.

Shafts 190 in 0X to 5X are rotated. This action zeroizes upper 0X but does not zeroize

upper IX to 5X because the IX to 5X shafts 114 were not rotated in (a) to lift their yokes 186. Since the dials in OX are coupled to their respective shafts 92, the latter receive the amount in OX and through the various connections described in (a) set the wheels 208 in accordance with the digits of the amount.

(c) The following are restored: wheel 750, shaft 114 in OX, shaft 96, shafts 120 in OX to 5X, shafts 258 and 258a, cam bar 635, and shafts 360, 480a, 484 and 513. Shaft 335 is also restored with the result that the "normal" row of gears 259 is moved to operative position, but the movement is an idle one.

Shaft 216 is rocked to cause the zeroized amount now on the wheels 208 to be registered on the lower slides 212.

(d) The following are restored: bail 850, shaft 216, and shafts 190 in OX to 5X.

Shaft 420 is rocked to ensure that arm 410 and special arm 413 are raised to negative position.

Cam bar 641 is moved two steps down to mesh the OX gear 481 with its related racks 466, 467.

(e) Shaft 235 is rocked to couple the column-shift shaft 230' to the shaft 81 through clutches 232, 233, and gears 236 and 90.

Shaft 245 is rocked to couple the column-shift shafts 231 to the shafts 92 through clutches 242, 243 on the vertical shafts 241.

Shaft 480 is rocked to move racks 171 and 172 leftward to the add position in both portions of OX.

Shafts 258 and 258a are rocked to raise the racks 250, 251.

Shaft 335 is again rocked to disengage the rockers 341 from cam 331, the "normal" row of gears 259 made operative in (c) being moved by this action to inoperative position.

Immediately following these movements, the bail 850 is moved rightward to free the racks 250, 251.

At the same time, the bar 47 is moved downwards to operate the racks 83, with the result that the shafts 81, the related clutches 232 and 233, shafts 230', and racks 250 and 251 are all driven through amounts proportional to the digits registered on the slides 212. But because all the rockers 341 are disengaged from the cam 331, all the diagonal rows of gears 259 are held in inoperative position, with the result that the movements of the racks 251 are not transmitted to the shafts 231 which are connected through the vertical shafts 241, clutches 242 and 243, shafts 92, and clutches 106 and 108 to the gear trains and dials of OX. If, however, one of the shift keys 273 had been latched down, then the movements of the racks 251 would have been transmitted to the shafts 231, and hence to the dials of OX, through whichever row of gears 259 is associated with the latched shift key 273. Thus, the zeroized amount may be reentered in OX with column-shift which in amount and direction depends upon which of the keys 273 is used.

(f) The following are restored: shafts 235, 245, 258 and 258a, 335, 420 and 480. The cam bar 641 is also restored. It will be noted that because the cam 331 was zeroized in (b), restoring the shaft 335 causes the "normal" row of gears 259 to be moved into operative position, but this is of no disadvantage as there is no further transmission through the shafts 231 during this cycle.

At the same time, shaft 221 is rocked to release the slides 212, and shaft 283 is rocked to release whichever of the shift keys has been used.

After the above movements the racks 250, 251

are restored leftward by the bail 850. Also, the rack 406 is operated to reset the gears 201, 208.

It will be appreciated from the foregoing description that an amount in upper OX may be column-shifted rightward to lower OX and, if there is already an amount standing in lower OX, then the amount in upper OX may be added to the amount in lower OX, provided that the shift is not greater than nine columns in the present embodiment and is such that it will bring like denominations in the two amounts together. Such operation may give rise to transfer calls in lower OX and it was for this reason that the bar 716 was moved in (a) so as to select the later transfer timing for the purpose. Cooperating with the transfer bars 133, 134, are the bars 138, 139, and bars 137 in the manner already explained.

Finally, the bar 716 is restored and the bail 578 is rocked to release the control key 550/7.

Should it be desired after this operation to use the amount now in lower OX as a dividend, the amount may be column-shifted manually as already described to align its highest digit with that of the divisor multiple, or a blank dividend entering cycle may be performed using the key 550/8 and no entry on the upper portion of the keyboard. This brings into operation the measuring device and automatically sets the cam 331 in the required position for the preparatory cycle of the dividing operation instead of setting it manually.

Zeroizing lower OX: Reentering amount with column-shift

In this operation (see Figure 37) the control key 550/10 is used, either alone for zeroizing or in conjunction with a key 273 for column-shifting. The No. 10 control plates are positioned, and the operation is in general the same as when using key 550/7. The only differences are as follows:

Shaft 114 is rotated to lift the yokes 186 in upper OX and 187 in lower OX.

Shafts 120 are positioned rightward. These movements of shaft 114 and shafts 120 together condition both upper and lower OX for zeroizing, but shafts 191 in OX to 5X are rotated to effect the actual zeroizing in (b) instead of shafts 190 with the result that lower OX is zeroized instead of upper OX.

Cam bar 635 is positioned one step down in (a) instead of three, thereby meshing gear 481a in OX with rack 467 instead of rack 466. Consequently, when shaft 480a is rocked, rack 172 in OX is moved rightward to the subtract position instead of rack 171, thus coupling the wheel 107 with the wheel 101 by clutches 109, 110 in each denomination of OX below the split.

An amount in lower OX may be reentered in OX with column-shift in either direction. When an amount in lower OX is column-shifted so as to be added to an amount in upper OX, the operation affords a ready means of dealing with an expression of the form

$$\frac{A \times B}{C \times D}$$

which may be written

$$\frac{A \times B}{C} \times \frac{1}{D};$$

$$\frac{A \times B}{C}$$

may first be evaluated by a simultaneous dividing and multiplying operation as already described,

giving a product result in lower OX. This result may then be column-shifted to upper OX and divided by D in a "division only" operation, the final product appearing in lower OX. Alternatively, A may be divided by C; after that the quotient result may be set up in upper OX and divided by D while the quotient resulting from this second dividing operation is simultaneous multiplied by B.

Zeroizing whole of Q

For this operation (see Figure 37b) the control key 550/13 is used. It positions the No. 13 plate in each group of plates 544, and on rotating the handle 595 the action is as follows:

(a) Bar 137 in Q is positioned leftward to bring the tooth 123 on the transfer receiving wheel 122 into the path of the tooth 501 on the zeroizing sleeve 500.

Shaft 335 is rocked to disengage coupler gear 292 from gears 290, 291 in the denomination showing the quotient signal.

(b) Shaft 124 is rotated to zeroize the sleeve 500 as already described.

(c) Bar 137 is restored and also shaft 335.

(d) Shaft 124 is restored. Shaft 420 is rocked to raise arms 410 and special arm 413 to negative position in case the next operation of the machine is performed with key 550/16.

(e) Shaft 124 is operated idly.

(f) Shaft 420 is restored and also shaft 124. Ball 578 is rocked to release No. 13 control plates and key 550/13.

The machine may be used to perform division only by adjusting the split to a position below the lowest section of the machine. The operation during division will be exactly as described except that no multiplicand will be entered and no product formed. The machine may be adjusted to perform multiplication by setting the multiplier in the machine in the same way as the dividend was set in the machine. Unity is set on the highest section of the machine as a divisor and the machine is operated to divide the multiplier by unity and multiply the quotient, that is, the original multiplier, and the multiplicand together. It is essential that the dividend or the multiplier should be entered into the machine in sections to the left of the multiplicand and so as to leave at least one clear section between the lowest figure of the dividend or multiplier and the highest figure of the multiplicand to receive transfers during the calculations of the multiples of the multiplicand. The multiplier and dividend need only be entered above the split if the multiplicand is entered negatively and the machine should be split at such a point as to leave at least one clear section to its right above the highest significant figure of the largest multiplicand occurring in a series of calculations. A series of quotients can be summed by leaving them in the quotient register and the products may be summed by not clearing the right-hand part of the totalizer OX. The divisor and multiplicand can be cleared from the machine for reset independently and for this purpose the machine may be arranged to perform a zeroizing cycle in which the totalizers 1X to 5X are zeroized, the multiples are reset on them and then one or more of the totalizers is zeroized in part or as a whole depending upon which of a number of zeroizing keys has been depressed.

The keyboard is also split so that either the left-hand or right-hand part can be cleared separately by depressing one or other of two control keys, one of which is shown at 870 in

Figure 41b. The stem of one key has rack teeth meshing with a gear (not shown) on a shaft 804 (Figure 3), so that it rocks it when the key is depressed while the other drives a shaft 805 in the same way. The shaft 804 is thus rotated when the key for clearing the left-hand part of the keyboard is depressed, while the shaft 805 is rotated when the key for clearing the right-hand part of the keyboard is depressed. A number of gear sectors 806, one for each section of the machine, are splined on the shaft 804 and each sector has a gear wheel 807 associated with it. The gear wheels 807 are rotatable on the shaft 804 and each of them can be coupled to the associated sector 806 by means of a coupling gear 808, of which there is one in each section. In the position shown in Figure 3, the gear wheel 808 meshes with the sector 806 and the associated wheel 807. The shaft 805 carries, in the same way, gear sectors 809 splined on it and gear wheels 810 rotatable on it (see also Figure 42a). Each gear wheel 808 is rotatable on a slide 811 which can be shifted to the right so as to disengage the wheel 808 from the sector 806 and wheel 807 and mesh it with the sector 809 and wheel 810. Thus, if the shaft 804 is rotated it will drive gear wheel 807 in each section of the machine in which the slide 811 is in the position shown in Figure 3, but it will not drive the gear wheel 807 in each section in which the slide 811 is shifted to the right. In a similar way, the shaft 805 will not drive the gear wheel 810 in the sections in which the slide 811 is in the position shown in Figure 3, but will drive the gear wheel 810 in each section in which the slide 811 has been shifted to the right. The slides 811 have rack teeth 812 (Figure 4) meshing with a gear sector 813 which is connected by a link 814 to the bell-crank lever 163. As the shaft 160 is rotated it will rock the bell-crank levers 163 so that those in the sections to the left of the split will be in the position shown in Figure 4, and the corresponding slides 811 will be in the position shown in Figures 3 and 4. The levers 163 to the right of the split will be rocked from the position shown in Figure 4 so that the slides 811 are shifted to the right from the position shown. Thus, rotation of the shaft 804 by one control key will rotate the gear wheels 807 in the sections to the left of the split, while rotation of the shaft 805 by the other control key will rotate the gear wheels 810 in the sections to the right of the split. The gear wheel 807 and the gear wheel 809 in each section cooperate with teeth 815 and 816 on a slide 817 so that either of them, when rotated, moves the slide to the right. Each slide 817 is connected by a two-armed lever 818 (Figure 1a) pivoted at 819 to the locking slide 55 (Figure 1) so as to move the slide in the same way as it is moved by the depression of the zero key 50. This, as explained previously, gives the effect of unlocking any other slide 55 that may be latched by the pawl 64 (Figure 3) and thus releases any depressed key. It will thus be seen that each half of the keyboard can be cleared by depressing the corresponding control key.

Isolating, canvassing and quotient entering mechanism

As shown in Figures 14, 15 and 16, the highest section of each of the totalizers 1X to 5X is provided with a transfer mechanism operating on a dummy section comprising a wheel 111C connected to the highest section of the totalizer by

the transfer mechanism. An arm 410 is secured to each of these wheels 111C. If the totalizer contains zero or a positive amount the arm 410 will be in the position shown in Figures 33 and 34. If a negative amount is entered sufficient to leave the totalizer registering a negative difference, the highest section of the machine will borrow one unit from the dummy section and will rotate the wheel 111C to rock the arm 410 up as shown in Figure 34a. This latter figure is purely conventional and shows the relative positions of the canvassing mechanism before the preparatory cycle is commenced. If a positive amount is now added which is sufficient to leave the totalizer registering a positive amount, a unit will be transferred to the highest section of the machine and the wheel 111C will be rotated to rock the arm down again. The end of each arm 410 is connected to the end of the next arm by a link 411. The end of the arm 410 for the totalizer 1X is connected to the extreme right-hand link 411 which is pivoted at its other end on a fixed pin 412. A special arm 413 is provided which is not operated by one of the totalizers but serves to support the left-hand link 411. A pin 414 is carried at the centre of each link 411 and a separate canvassing slide 415 is supported on each pin. An operating link 416 is pivoted at 417 on each arm 410 and on the arm 413 so that, by pulling these links down, all the arms can be rocked upwardly. Each link 416 has a tooth 418 (Figure 35) co-operating with a tooth 419 on a shaft 420. Before each comparing operation the shaft 420 is rocked by a cam on the mainshaft and through the teeth 418 depresses all the links 416 so as to rock all the arms 410 and the arm 413 upwardly. Each of the links 411, except the extreme right-hand one, is thus raised parallel to itself but the right-hand one is tilted about its pivot 412. The right-hand canvassing slide, which is the one associated with the OX totalizer, will thus be raised one step while the other slides will be raised two steps. This is also the condition when the quotient result is "0", and the mechanism will now be described in reference to the entering of that particular quotient value. Each slide 415 is provided with a lug 421 co-operating with a canvassing bar 425 and a lug 423 co-operating with a canvassing bar 426. With the extreme right-hand slide 415 raised one step and all the other slides raised two steps, its lug 421 will be in the path of a lug 422 on the canvassing bar 425 and its lug 423 will be in the path of a lug 424 on the canvassing bar 426. The canvassing bars are employed as a differential means for entering each value in Q and they are driven in the same direction (i. e. leftward in Figures 33 and 34) by differential gearing shown in Figure 35 until they contact the lugs 421 and 423. The differential gearing comprises a gear wheel 427 meshing with a rack 428 secured to the bar 425. The wheel 427 is secured to a shaft 429 to which one sun wheel 430 of a differential gear is secured. The other sun wheel 431 of this gear is secured to a gear wheel 432 which meshes with a rack 433 secured to the bar 426. The sun wheels gear with planet wheels 434 carried by a planet carrier 440. This planet carrier is integral with a gear wheel 441 driven by a vertical rack 442 which is moved downward by a cam on the mainshaft when a quotient value is entered. The stroke of the rack is such that the sum of the movements of the two canvassing bars will be nine steps.

With the right-hand slide 415 moved one step,

its lug 423 will engage the lug 424 on the bar 426 and prevent it moving. The bar 425 will move nine steps when its lug 422 will engage the lug 421 on the OX slide 415. The other slides 415 will remain raised two steps so that their lugs 421 and 423 are above the level of the lugs 422 and 424 respectively. These slides will thus have no effect on the movement of the canvassing bars. The canvassing bar 426 is provided with rack teeth 443 meshing with a gear wheel 444. This gear wheel is secured to a gear wheel 445 (Figure 35) which meshes with a vertical rack 446. A second rack 447 is pivoted on the rack 446 at 448 and is guided for vertical movement by a pin 449 carried by a slide 450. The rack 447 (Figure 34) has two sets of teeth 451 and 452. The slide 450 can be shifted by a cam on the mainshaft so as to swing the rack about its pivot 448 and mesh either the teeth 451 or the teeth 452 with a gear wheel 453 secured on the quotient entering shaft 151 (see also Figures 13 and 20). Thus movement of the rack 426 is communicated to the shaft 151 either additively or subtractively depending upon the position of the slide 450. With the setting of the parts assumed, the shaft 151 is not rotated so that no quotient digit is entered. This condition is that existing during the preparatory cycle and in all subsequent cycles when the quotient entry will be "0".

As shown in Figure 35, each slide 415 is provided with a control portion having projections 455, 456 and 457. When the slide is in its lowest position, the projection 455 engages a pin 458 at the upper end of a floating lever 459. The lever 459 is pivoted at 460 on an eccentric strap 461. This strap is mounted on an eccentric on a shaft 462 which can be rotated through half a turn by means of a cam on the mainshaft. When the shaft 462 is rotated, the lower end of the lever 459 will move to the right idly while its upper end will be held by the projection 455. In the same way the upper end of the lever 459 will be held by the projection 456 if the slide is in its highest position and the lever 459 will rock idly. On the other hand, if the slide is in its intermediate position, a pin 463 on its lower end will be obstructed by the projection 457 while the pin 458 will be free to move between the projections 455 and 456. Thus rotation of the shaft 462 will rock the lever 459 and the upper end of this lever will move to the right. The lower ends of two levers 464 and 465 (Figures 33 and 35) are pivoted on the pin 458 while their upper ends are pivoted on racks 466 and 467 which are stationary at this time. The levers 464 and 465 are pivotally connected at their centres to the racks 171 and 172 respectively of an associated totalizer. Thus, when the OX slide 415 is in its intermediate position, the corresponding lever 459 will be rocked on the rotation of the shaft 462 and will rock the levers 464 and 465 to move the racks 171 and 172 to the subtracting position so that the totalizer is coupled to the shafts 92 which will receive amount in the OX totalizer on the latter being zeroized.

Each slide 415 controls the racks 171 and 172 for a different one of the totalizers OX to 5X and the designation of the totalizer controlled by each slide is shown against it in Figures 33 and 34. It will be understood that, with the setting of the parts previously described, the slides 415 associated with the totalizers 1X to 5X are in their highest position so that the racks 171 and 172 in these totalizers do not move from

their neutral position. The slide 415 for the totalizer 0X is in its intermediate position so that the racks 171 and 172 for this totalizer will be operated when the shaft 462 is rotated. This shaft is rotated at the very commencement of the cycle and the operation of selecting one pair of racks 171 and 172 and operating them is the operation previously referred to as isolating a totalizer. After the 0X totalizer has thus been isolated, the amount in it may be transmitted to the keyboard section. The canvassing racks 425 and 426 may be operated concurrently to enter the quotient digit into the quotient totalizer. In the preparatory cycle, however, the canvassing racks need not be operated as the quotient value in that cycle is always "0" because the 0X totalizer is always the one to be isolated. But in each subsequent cycle the canvassing racks are operated and, after the quotient digit has been entered. The shaft 335 (Figure 1a) is rocked to disengage the rockers 341 from the cam 331 and at the same time disengage the coupler gear 292 in the column in which the quotient signal is showing so that the shaft 151 is not coupled to any section of the quotient totalizer. At this time the canvassing racks and connected parts are restored in readiness for the next operation.

While the canvassing racks are being restored, a part 470 operated by a cam on the mainshaft in each dividing cycle is moved to the left in Figure 33. This part is hung on a link 471 from the canvassing slide 415 for the totalizer 5X. The link 471 carries a pin 472 projecting into an opening 473 in the slide 352 which carries the pawl 351 (Figure 1a) for stepping round the column shift cam 331. If the slide 415 for the totalizer 5X is in its upper position, as it will be whether the 0X totalizer is the one to be isolated, the link 471 will be raised and the pin 472 will enter a portion 474 of the opening 473 so that the movement of the part 470 will be communicated to the slide 352 and the latter will move to the left in Figure 33, that is to the right in Figure 1a, to step the wheel 350 and with it the column-shift cam 331 round one step. This latter movement corresponds to the superimposing of "minus one" on the differencing device and it only occurs when the quotient entry is less than "5" as already explained. In this manner the column-shift cam is stepped in each dividing cycle when necessary, except in the preparatory cycle when the part 470 is not operated. A spring 475 serves to hold the slide 352 to the right in Figure 33, unless it is positively actuated.

In Figure 34b, which is also purely conventional, the relative movements of the canvassing, isolating and quotient entering mechanisms are shown for the case where the totalizer 1X contains the smallest positive difference. It will be observed that the 0X and 1X arms 410 are in the down positions because their totalizers each contain a positive difference, but the 2X, 3X, 4X and 5X arms are up because their totalizers each contain a negative difference. Consequently, the links 411 will be so positioned that the 0X slide 415 is moved to its lowest position, the 1X slide 415 is moved downwards one step to its intermediate position, and the slides 415 for the totalizers 2X to 5X remain in their highest position. Thus, the 1X slide being the only one in the intermediate position it will control the rocking of the 1X lever 459 so as to isolate the totalizer 1X in exactly the same way as the isolating of the totalizer 0X.

The lowering of the 1X slide 415 one step places its lug 421 in the path of one of the lugs 422 on the rack 425 so as to permit the latter to move eight steps when the rack 442 is operated. Its lug 423 will also be in the path of a lug 424 on the canvassing rack 426 so as to permit the latter to move one step. This movement of the rack 426 is communicated to the rack 447 and hence to the quotient entering shaft 151 as described.

While the quotient value is being entered, the totalizers are cleared with the result that the difference and partial product sum in 1X are transmitted to the keyboard section and the amounts in each of the other totalizers are discarded as described.

The 5X slide 415 being in its highest position, the pin 472 on the link 471 will engage the slide 352 and step the column-shift cam 331 round one step to effect a column-shift change.

The 2X, 3X 4X and 5X totalizers are isolated in exactly the same way as the 0X and 1X, except that in the case of the 5X its slide 415 being in its intermediate position the pin 472 will still be in the wide part of the opening 473 and the slide 352 will not be moved by the part 470, for in that case the machine will be required to perform the next cycle without a change in the column-shift adjustment so as to ascertain whether the quotient result "5" is a partial quotient or a true quotient.

In a complete set of operations in a dividing cycle, the isolating of one of the multiple totalizers forms the first stage; the entering of the quotient amount and the transmitting of the difference and partial product sum therein to the keyboard section by zeroizing all the multiple totalizers forms the second stage; and registering the transmitted amounts in the keyboard section while at the same time changing the setting of the differencing device when necessary forms the third stage. The fourth stage mainly comprises the resetting of the multiples and the readjustment of the column-shift setting, also the rocking of the shaft 420 to raise the arm 413 and the arms 410. The fifth stage comprises the comparing operation; and the sixth the transfer action and the resulting movement of the slides 415. It will be noted that these stages correspond to the six parts into which each cycle in the example of a calculation is divided.

It will thus be seen that after the zeroizing of the totalizers in the second stage and the registering of the isolated amounts in the keyboard section in the third stage, the next operation in a dividing cycle is resetting the multiples and the shaft 420 is again rocked to raise the arm 413 and the arms 410 if they are not already raised. The amount in the keyboard section of the machine is then entered into each of the totalizers 0X to 5X. If this amount is sufficient to leave any one of the totalizers 1X to 5X registering a positive amount, the corresponding arm 410 will be rocked down so that all the links 411 to its right will be moved down into the position shown in Figures 33 and 34. It will be appreciated from Figure 34b that the totalizers to the left of that containing the smallest positive difference necessarily contain negative amounts while those to the right necessarily contain positive amounts. Also the arm 410 for the totalizer containing the smallest positive difference and the arms 410 to the right are down while the arms 410 to the left and the arm 413 are up. Consequently the

links 411 between the arms 410, which are down, are in their lowered position as shown, while the link between the extreme left-hand arm which is down and the adjacent arm which is up will be inclined and will hold its slide 415 in the intermediate position in which it serves to isolate the totalizer containing the smallest positive difference. The remaining links on the left will hold their slides in the highest position. It will be seen that the slide corresponding to the required totalizer is in its operative intermediate position, those on the left are raised and so are not operative to isolate their totalizers, while those on the right are in the lowermost position and also do not isolate their totalizers. This completes the action of the isolating mechanism during a comparing operation.

The lugs 424 are so pitched on the canvassing bar 426 that the movement of the bar before one of the lugs 424 engages the lug 423 on the slide 415 which is in its intermediate position is proportional to the digit by which the divisor and multiplicand were multiplied to form the multiple registered in the totalizer which is associated with that slide. The lugs 422 are so pitched that the movement of the bar 425 is complementary to that of the bar 426 so that the bar 426 is forced to move the maximum distance possible. As explained previously the movement of the bar 426 is transmitted to the quotient digit entering shaft 151, so that the appropriate quotient digit can be entered.

Mechanism is provided by which either part of each of the totalizers 0X to 5X may be coupled individually to the totalizer drive shafts 92, either to add or to subtract. Splined on a shaft 480 (Figures 33 and 35) are a number of gear sectors 481, one for each totalizer. Each gear is embraced by ears depending from a separate striking bar 482 so that each gear can be moved independently into one of four positions. It will be noted from Figure 33 that each gear has two sets of teeth, separated by a gap. In the position shown it meshes with neither of the racks 466 and 467. If it is moved one step, it meshes with the rack 467 but not the rack 466 and, if it is moved two steps it meshes with both racks, while if it is moved three steps it meshes with the rack 466 but not with the rack 467. Thus the shaft 480 can operate one or the other or both or neither of the racks to set the related part of the totalizer to add. The rack 466, when operated, moves the bar 171 to set the related totalizer to add by rocking the lever 465 about the pin 458 and the rack 467 operates the rack 172 in a similar manner. A similar shaft 480a and set of gear wheels 481a and striking bars 482a are provided for setting the racks 171 and 172 individually in their subtracting position. Thus, any desired combination of adjustments of the totalizers to add and subtract can be obtained by properly shifting the bars 482 and 482a. Locking members 483 are provided for locking the racks 466 and 467, except when they are to be moved, and these members are positively actuated by a rock shaft 484 on which they are splined. Both the shafts 480 and 480a are rocked by cams on the main shaft when required, and either may be used individually or they may be used together, depending upon the operation being performed. Table 5 shows a summary of the adjustments of the bars 171 and 172 made possible by the above arrangement in each of the totalizers 0X to 5X.

Table 5

	When gear—	Is moved—	It meshes with rack—	Then rocking shaft—	Sets bar—
5	481.....	1 step....	467 only....	480.....	172 left to add in lower portion.
	481.....	2 steps....	466, 467....	480.....	171 leftward to add in upper portion, and 172 leftward to add in lower portion.
10	481.....	3 steps....	466 only....	480.....	171 leftward to add in upper portion.
	481a....	1 step....	467 only....	480a....	172 rightward to subtract in lower portion.
	481a....	2 steps....	466, 467....	480a....	171 rightward to subtract in upper portion, and 172 rightward to subtract in lower portion.
15	481a....	3 steps....	466 only....	480a....	171 rightward to subtract in upper portion.

The method of calculating the multiples of the divisor and multiplicand described previously requires five cycles. One cycle may be saved by entering the factor into all five totalizers 1X, 2X, 3X and 5X in the first cycle and then into the totalizer 2X only in the second cycle. In the third and fourth cycles, the totalizer 2X is zeroized, the amount in it set on the keyboard section and is entered into the totalizers 2X, 4X and 5X. The three different kinds of cycle will require three different control plates in the driving section of the machine and these may be operated in succession by separate control keys or automatically under the control of one key.

Other series of multiples may be used. For example the totalizer 5X may be omitted and the stepping of the column shift cam 331 (Figure 1a) controlled by the totalizer 4X. The totalizer 4X may also be omitted in the same way. The speed of the machine is, however, reduced by omitting totalizers since the average number of dividing cycles per quotient digit is increased but this is partly off-set by the fact that only three cycles are needed to calculate three times a factor and three or four to calculate four times a factor. A discontinuous series, such as once, twice, three times and six times the factor, may be used. The multiple six times the factor is formed in the same way as the multiple five times as explained in the preceding paragraph except that an extra entry is made in the second cycle. This series is so selected that any digit 4, 5, 7, 8 and 9 can be formed as the sum of two of the digits 1, 2, 3 and 6 so that the number of cycles giving a significant quotient digit is a minimum for four multiples. It is necessary, however, to step the column shift cam 331 when the quotient digit is 0, 1 or 2 but not when it is 3 or 6. This increases the number of cycles giving 0 as the quotient digit so that there is no saving over the use of the series once to four times. More totalizers may be provided for registering higher multiples, the maximum speed is reached if all the multiples from once to nine times the factors are used. In this case the column shift cam 331 is stepped in every cycle. The multiples are calculated by first forming the multiples once to five times, as explained in the preceding paragraph, in the totalizers 1X to 5X and in five additional totalizers 6X to 9X. The totalizer 4X is then zeroized and the amount in it set on the keyboard section and entered from that section into the totalizers 4X and 6X to 9X.

When using all nine multiples, multiplication may be performed directly, instead of dividing by one, in the manner explained in prior British Patent No. 502,958. This can be effected by ze-

roizing the quotient totalizer in which a multiplier is set up and transmitting the zeroizing movement from one section of the totalizer through the quotient-entering means to set the canvassing racks in a position corresponding to the digit in that section. The canvassing racks adjust a set of gears in such a manner that, by rocking the gear, the arms 410 are set in the same position they would have been if the multiplier digit had been a quotient digit. The re-setting gear in the quotient totalizer permits the multiplier to be reset in the quotient totalizer ready for the next step of the calculation. This method may be used in the present machine by providing two such sets of gear wheels one of which controls multiplication by digits up to 5 or by 5 for higher digits while the other controls multiplication by the remainder over 5 for the higher digits. Means must be provided for operating the proper set of wheels in each cycle, the two sets operating alternatively. The method involving division by unity as described above does not require these extra parts and is thus preferred.

It will be appreciated that the present machine compares the multiples of the divisor with the highest figures of the dividend by subtracting the multiples from the dividend so as to find the largest multiple that is not greater than the dividend. The difference between the dividend and this multiple is the amount which the machine requires for the next stage of the calculation and the remaining differences are merely calculated as part of the comparing operation. The machine thus, in effect, combines a comparing and a subtracting operation, but the invention is applicable to machines in which the multiples of the divisor are first compared with the highest figures of the dividend and afterwards the appropriate multiple only is subtracted from the dividend as a separate operation, as described in United States application Serial No. 89,570. In such a case, each time a multiple of the divisor was subtracted, the corresponding multiple of the multiplicand would be added in a suitable totalizer. In the machine described in the prior specification, the multiples of the divisor are entered subtractively into a dividend totalizer with an appropriate column shift, and this totalizer could be enlarged so as to have a number of empty denominations below the dividend into which the multiples of the multiplicand would be entered additively each with the same column shift as the corresponding multiple of the divisor. The two corresponding multiples would thus be treated as one amount, except that one would be subtracted and the other added, as is, in fact, the case with the present machine.

There is only one transfer actuating bar in the dummy section of the totalizers, namely, that which effects positive transfers or carries, the bar which effects negative transfers or borrowing being omitted. If this were not done, negative transfers would occur in each multiple forming cycle owing to the negative entries made so that the arm 410 (Figure 33) of the totalizer 5X (for example) would move through five steps and become disengaged from its link 411. The correct positioning of the arms is taken care of by the shaft 420 and the positive transfers occurring during dividing cycles.

Driving connections

The connections by which the various parts of the machine are driven by the shafts 520 in the

control and driving section are shown in Figures 18a, 18b and 18c and Figures 19a, 19b and 19c. The connection for the bar 47 has already been described with reference to Figure 18b. The remaining connections are as follows:

Canvassing mechanism.—The shaft 462 (see also Figure 35) is connected by bevel gearing 602 (Figure 18b) to a vertical shaft 603 which is connected by bevel gearing 604 to one of the lower shafts 520. The shaft 420 is connected by bevel gearing 605 to a vertical shaft 606 which is connected by bevel gearing 607 to one of the upper shafts 520. The shaft 480a is connected by bevel gearing 608 to a vertical shaft 609 which is connected by bevel gearing 610 to one of the lower shafts 520. The shaft 480 behind the shaft 480a (Figure 35) is connected by bevel gearing, a vertical shaft and gearing 611 to one of the upper shafts 520. The slide 450 (see Figure 34) carries a pin 612 (Figure 18b) which enters a cam-slot 613 in a bar 614. The bar is guided at its upper end for vertical movement and is also guided at its lower end by one of the lower shafts 520. The bar 614 is formed with rack teeth 616 meshing with a gear wheel 617 on one of the lower shafts 520. The rack 442 which drives the canvassing bars has rack teeth 618 meshing with a gear wheel 619 on one of the upper shafts 520. The part 470 which steps the column shift is connected to a bell-crank lever 620 (Figure 18a). This lever is connected by a link 621 to an arm 622 fixed on one of the lower shafts 520. The lowermost striking bar 482a (see also Figure 35) embracing the 5X gear sector 481a carries a pin 623 entering a slot 624 in a bar 625 which is mounted to slide vertically. For this purpose the bar is supported at its upper end in a comb 629 and is formed with a slot 626 to receive a collar on one of the upper shafts 520 so that its lower end is supported by the shaft. This method of mounting the vertically sliding bars is used wherever possible. The bar 625 is formed with teeth 627 meshing with a gear wheel 628 on one of the upper shafts 520. The remaining striking bars 482a embracing the 4X, 3X, 2X, 1X and 0X gear sectors 481a are operated in the same way by bars 630 to 635 respectively, these bars being operated by separate upper shafts 520. The slot 624 is shaped to move the bar 482a into one of four positions (as explained before) depending on how far the bar 625 is moved down. The slot is provided with a dwell corresponding to each position to ensure that the bar 482a is properly positioned in each of its settings. The striking bars 482 (see Figure 35) are operated in the same way by vertically sliding bars 636 to 641 respectively and these latter bars are operated by gear wheels on separate lower shafts 520. The bars 636 to 641 are arranged behind the bars 482 and are concealed by the bars 625 and 630 to 635 except for their lower ends. The shaft 484 (Figure 18b) is driven by bevel gearing 642, a vertical shaft 643 and bevel gearing 644 from one of the upper shafts 520.

The shafts 520 shown in Figures 18a, 18b and 18c only extend partly across the machine as shown diagrammatically on Figures 26 and 27, and are in axial alignment with other shafts 520 which extend towards the opposite side of the machine and are shown in Figures 19a, 19b and 19c. The latter shafts drive the remaining parts of the machine as will now be explained.

Column-shift mechanism.—The column shift racks are raised by rocking the shafts 258 and 258a (Figures 20 and 22). These shafts have

each an arm 650 (Figures 19b and 19c) fixed to it and each arm is connected by a link 651 to an arm 652 fixed on one of the lower shafts 520. These two shafts 520 are rocked at the same time so as to rock the shafts 258 and 258a in opposite directions.

Zeroizing mechanism.—Each of the shafts 191 (see also Fig. 11) has a gear wheel 653 (Figs. 19b and 19c) secured on it and all these wheels mesh with a common rack 654. The rack 654 has teeth 654a which mesh with a gear wheel 657 secured on a shaft 658 which is driven through bevel gearing 658a from one of the upper shafts 520. Gear wheels 655 are secured on the shafts 190 and mesh with a common rack 656. The rack 656 is formed with teeth 655a which mesh with a gear wheel 659 secured on a shaft 660 which is driven through bevel gearing 660a by another upper shaft 520. Thus the shafts 190 are driven by one shaft 520 and the shafts 191 by another shaft 520. This allows of either or both parts of the totalizers being zeroized. The totalizers can be selected for zeroizing individually by means of the shafts 114 (see Figure 11). A gear wheel 661 (Figures 19b and 19c) is secured on each of the shafts 114 and meshes with a separate rack 662. Each of these racks meshes with a gear wheel 663 on a separate one of the upper shafts 520. It is necessary to shift the sleeves 197 (Figure 12) axially and they are confined on the shafts 120 by collars one at each end of each shaft so as to move axially with the shafts. Each shaft 120 is formed with a slot into which extends an arm 664 (Figures 19b and 19c) secured on a shaft 665. The shaft 665 is rocked by an arm 666 which is secured on it. This arm is rocked to rock the shaft by moving down a bar 667 which is pivoted to it. The bar 667 pivoted at its lower end on an arm 668 secured on one of the upper shafts 520. The shaft 124 in the totalizer Q is rotated to zeroize that totalizer and has a gear wheel 680 secured to it. This wheel meshes with a rack 681 which also meshes with a gear wheel 682' on one of the upper shafts 520. The striking bar 137 relating to the totalizer Q must also be moved and is formed with rack teeth meshing with a gear wheel 682 which is secured to an arm 683. This arm is rocked about a shaft 674 to shift the bar 137 by moving a bar 685 down. The bar 685 is formed with a cam slot in which a roller 684 on the arm is engaged. The bar is also formed with rack teeth meshing with a gear wheel 686 on one of the lower shafts 520. The slot is shaped in the same way as slots in other bars described later.

Resetting gear.—In order to reset the multiples, the shafts 142 must be rotated. A gear wheel 669 is secured to each of them and these wheels all mesh with a common rack 670 which has rack teeth 670a meshing with a gear wheel 671 secured on a shaft 672. This shaft is driven by one of the upper shafts 520 through bevel gearing 672a. The striking bars 149 must also be shifted and they are formed with rack teeth meshing with gear wheels 673 secured on the shaft 674. An arm 675 is secured on the shaft 674 and carries a roller 676 entering a cam slot in a bar 677 which has rack teeth meshing with a gear wheel 678 on one of the lower shafts 520. The driving connections are similar to those described previously for the striking bar 137 of the totalizer Q.

Transfer operations require that the striking bars 137 be shifted (see also Figures 13 to 16). The drive for the bar 137 in the totalizer Q has already been described. Each of the other bars

is formed with rack teeth meshing with gear wheels 695 secured on a shaft 696. An arm 697 is secured on this shaft and is rocked by a cam slot in a bar 698 which is operated by a gear wheel 699a meshing with teeth in the bar, the drive being similar to that for the bar 137 in the totalizer Q. The slides 380 (see also Figure 8) are locked by detents 699a which are splined on a shaft 700. This shaft is rocked at the beginning of each cycle into the position shown to lock the slides and is restored at the end of the cycle. The shaft has an arm 701 secured on it and this arm carries rollers 702 engaging cam rises 703 on a bar 704. This bar is mounted to slide horizontally and is connected by a bell-crank lever 705 pivoted at 706 and connected to a link 707 which is connected to an arm 708 on one of the lower shafts 520. Each of the racks 370 is connected to a separate rocker 711 through a pin 711a (Figure 39c) which is slidable in the end of 370. Each rocker is pivoted on a shaft 712 and is operated by a pair of complementary cams 713 and 713a on the shaft 714 which carries the main operating handle 595. It will be recalled that the transfer operations may occur at two different times in the cycle and to permit this another pair of cams 713b and 713c is provided on the shaft 714 and are arranged alternately (see Figures 39a, 39b, and 39c). The rockers can be slid along the shaft 712 by a striking bar 716 to co-operate with either set of cams as illustrated in Figure 6 of British Patent Specification No. 502,958. The striking bar 716 is shifted by a gear sector 717 meshing with teeth in the bar and secured on a shaft 718. The shaft is rocked by an arm 719 engaged with a cam slot in a bar 720 which has teeth meshing with a gear sector 721 on one of the upper shafts 520.

There is a pair of cams for each timing arranged in each of the sections Nos. 1 to 17. Each pair of No. 1, through its related rack 370, operates the transfer bars 133 and 134 in No. 2, and, similarly, each pair in No. 17 operates the transfer bars in No. 18. The pair of cams for each timing arranged in No. 18 section, through its related rack 370, operates the transfer bars in the dummy section. In the dummy section there is a pair of cams 713d and 713e for the earlier timing shown in Figure 36a and another pair 713f and 713g for the later timing shown in Figure 37d, also another rocker 711 and a rack 370a associated with them, for simultaneously operating all the bars 138 and 139 which restore the transfer lock bars 128.

Thus, for the earlier timing when a dividend or multiplier is entered in OX, or when an amount is manually column-shifted or when an amount is cleared from either portion, the striking bar 716 is not moved, and in that position it holds the rockers 711 in operative engagement with the cams 713 and 713a in each section and 713d and 713e in the dummy section. For this timing, the cams in the No. 18 section which relate to the bars 133 and 134 in the dummy section comprise a pair of plain discs with no cam rise on one or a complementary depression in the other, so that the bars in that section are not operated. For the later timing in a preparatory cycle and in all subsequent cycles, the striking bar 716 is moved so that the rockers 711 are held in operative engagement with the other set of cams 713b and 713c in each section and 713f and 713g in the dummy section. For this timing the cams in the No. 18 section relating to the

transfer bars in the dummy section are provided with a rise on one and a complementary depression in the other, so that the bars in that section are operated for the comparing operation when the difference in one or more of the multiple totalizers may become positive. Negative transfer bars 133 for the dummy section may be omitted, however, as the correct positioning of the arms 410 and the special arm 413 are dealt with by the rocking of the shaft 420 in the manner already described. Thus, all the racks 370 relating to the transfer bars in sections 2 to 18 are operated during the earlier timing, but not the bars in the dummy section; while all are operated during the later timing including those in the dummy section. On reference to Figures 19c and 39c, it will be observed that, when the striking bar 716 is shifted for the later timing, each rocker can slide to engage either pair of cams in its section without laterally moving its rack 370. It has already been explained under "splitting transfer action" that there is a rack 369 associated with each rack 370, and that each rack 369 meshes with a gear 367 through which the racks 133 and 134 are operated. Reference to Figures 50 and 50a will show that each rack 369 is bent over to the left to mesh with the gear 367 and that each of the latter is clutched to a sleeve 367a integral with the gear 367b in the next higher section. This arrangement for transferring the drive from the racks 369 and 370 in one section to the transfer bars 133 and 134 in the next higher section is provided in each section of the machine.

The bars 138 and 139 (Figures 4 to 8, 45, 50 and 50a) which restore the transfer lock bars 128 are formed with rack teeth meshing with gear wheels 709a and 710a respectively. Each gear wheel 709a is pinned on the shaft 709, but each wheel 710a is loosely mounted on the sleeve 367a between the gears 367 and 367b. Therefore, when the shaft 709 is rocked, all the gears 710a will be rocked at the same time with the result that the bars 138 and 139 will be operated simultaneously to restore the lock bars 128. To rock the shaft 709 there is provided in the dummy section, in addition to the pair of cams 713d and 713e, the other pair 713f and 713g and the rocker 711 already mentioned, a rack 370a and a rack 369a which are similar to the racks 370 and 369 respectively, except that they are fastened together and need not be provided with teeth 362. The rack 369a meshes with a gear 710b mounted loosely on the shaft 710. This gear meshes with another gear 709b pinned on the shaft 709. Thus, when the bar 370a is actuated by one or other pair of cams, the shaft 709 will be rocked to operate the bars 138 and 139 as described.

The clutches must be operated individually to connect the differential mechanism, the totalizers and the column shift mechanism in the required manner. This involves rocking the shafts 513 (Figure 3) 96, 235 (Figure 4) and 245 (Figure 8) individually. The shaft 513 (Figure 19b), shown in the clutched position, carries an arm 722 carrying rollers 723 cooperating with cam rises 724 on a bar 725 which has rack teeth meshing with a gear wheel 726 (Figure 19a) on one of the lower shafts 520. The shaft 96 (Figure 19b) has an arm 727 secured to it and this arm carries a roller 728 entering a slot 729 in a bar 730 which has teeth 731 meshing with a gear wheel 732 on one of the upper shafts 520. The slot 729 is similar to the slots referred to previously and is shaped with a dwell at each end so as ac-

curately to position the shaft and compensate for lost motion in the connections. The shaft 235 is operated in a similar manner by means of an arm 733, a bar 734 and a gear wheel 735. The shaft 245 (Figure 19c) has an arm 760 secured on it and this arm carries two rollers 761 cooperating with cam rises 762 on a bar 763. This bar is operated to rock the arm 760 and the shaft 245 by a bell crank lever 764, a link 765 and an arm 766 secured on one of the lower shafts 520.

The keyboard and differential mechanism.

The shafts 65 and 216 (see Figure 3) are rocked when setting an amount on the keyboard and the differential mechanism respectively. These shafts are rocked in a similar manner to the shaft 96 by arms 736 and 737 (Figure 19b), bars 738 and 739 and gear wheels 740 and 741. The shaft 87 is rocked when entering an amount set on the keys by means of an arm 742 and a bar 743. This bar has teeth meshing with a gear wheel 745 rotatable on the shaft 65 and meshing with a rack 746 which also meshes with a gear wheel 747 on one of the upper shafts 520. The shaft 221 (Figures 2 and 19a) is rocked to clear the differential mechanism. The shaft 221 has an arm 767 secured on it and this arm is connected by a link 768 to an arm 769 on one of the lower shafts 520. The rack 406 (see also Figure 4) is reciprocated to restore the wheels 201 and 208 (Figure 3). It is formed with rack teeth 770 meshing with a gear wheel 771 which is secured on a vertical shaft 772. This shaft is driven by bevel gearing 773 from one of the upper shafts 520.

Measuring apparatus.—The shafts 314 and 314a (see also Figure 21) must be rocked to measure the factors. For this purpose an arm 774 (Figure 19b) is secured to the shaft 314a and is pivoted to a link 775. An arm 776 is secured on the shaft 314 and has an open slot embracing the pivot pin on the link 775. The link 775 is pivoted on an arm 777 on one of the lower shafts 520. The shaft 321 (Figure 19a) carries a gear wheel 779 which meshes with a rack 780. This rack meshes with a gear wheel 781 which also meshes with a rack 782 which is driven by a gear wheel 783 on one of the upper shafts 520. A gear wheel 784 rotatable on the shaft 321 and disposed on the leftward side of the gear 779 is driven in the same manner from a wheel 783a on a lower shaft 520 which meshes with a vertical rack 782a which in turn operates a gear 781a and rack 780a (which are identical with the gear 781 and rack 780). The gear 784 drives a gear wheel 785 through an idler 786. The gear wheel 785 is secured on the shaft 321a. The clutch-operating shaft 330 (see Figure 1a) carries an arm 787 which is connected by a link 788 to a bell crank lever 789 and this lever is connected by a link 790 to an arm 791 on one of the lower shafts 520. An arm 792 secured on the column-shift restoring shaft 278 is also connected to the link 789 and rocked thereby. The shaft 283 is rocked to unlatch the column shift keys by an arm 793, a link 794 and an arm 795 on one of the upper shafts 520. The shaft 335 is rocked to render the column shift mechanism inoperative by an arm 796 secured on it, a link 797 and an arm 798 on one of the upper shafts. In order to reset the column shift control cam, the shaft 360 must be rocked. This is effected by an arm 799 secured on it, a link 800, a bell crank lever 801, a link 802 and an arm 803 on an upper shaft 520. It is also necessary to rotate the gear

wheel 357 (Figure 1a). This gear wheel is driven by a gear wheel 750 (Figure 18c) which is secured on a shaft 751. This shaft is driven through bevel gearing 752 from a shaft 753 which is driven by one of the lower shafts 520 through bevel gearing 754.

Figure 38 shows the positions of the various sections of the machine in plan. The seven totalizers are shown by dotted rectangles Q to 5X and the windows through which the index dials are visible are shown at 596. The keyboard section is shown at KBS and the gearing and clutches connecting this section to the totalizers is designated G&C. The measuring apparatus and the column shift control mechanism is contained in the section MA&CS. The canvassing mechanism and part of the driving connections are in the section CM&DC while the rest of the driving connections are in the section DC. The transfer cams and the main driving cams are located in a section TC.

I claim:

1. A calculating machine comprising a plurality of totalizers, means for calculating predetermined multiples of a divisor and the corresponding multiples of a multiplicand and for entering each multiple of the divisor into a portion of a separate totalizer and the corresponding multiple of the multiplicand into a different portion of the same totalizer, the two multiples in each totalizer being one positive and the other negative, an additional totalizer for receiving the dividend, means for thereafter entering a dividend into each of the first named totalizers in such manner as to obtain in said first named portion of that totalizer the difference between the dividend and the multiple of the divisor, initially in that totalizer, with an appropriate denominational allocation, means for selecting the totalizer containing the smallest difference that is of a predetermined sign, a settable means controlled by the selected totalizer for registering the amounts in the selected totalizer, means for zeroizing all the totalizers, means for re-entering the multiples in the respective totalizers after the amount in the selected totalizer is registered in said settable means, means for entering the amounts registered, in the same way as the dividend, means for causing the recited means to operate in order and then repeated, means for column shifting the said amounts one denomination to the left, before they are entered into the totalizers, a product totalizer and means controlled by the selected totalizer for causing the related multiplicand multiple to be transferred to said product totalizer when the remainder therein is registered in the settable means.

2. A calculating machine according to claim 1, in which each of the plurality of totalizers has a separate device for setting each of its denominations to add or to subtract and two actuators for said devices, one of which actuators is connected to operate the devices for one portion of the totalizer and the other is connected to operate the remaining devices for the other portion, whereby the two portions of the totalizer can be set independently to add or subtract.

3. A calculating machine according to claim 1, comprising two zeroizing devices for each totalizer and two coupling devices in each section of each totalizer, each coupling device in one section of a totalizer being arranged to couple that section to a different zeroizing device and arranged to be adjusted so that all the sections in one portion

of a totalizer can be connected to one zeroizing device and the remaining sections to the other zeroizing device.

4. A calculating machine according to claim 1, wherein the column-shifting means is adjustable to produce a column-shift of an amount transmitted from the registering means to the totalizer of an adjustable extent and direction and, with the same adjustment, a column-shift of an amount transmitted from the totalizer to the registering means of the same extent but with the direction reversed, and wherein means is provided for adjusting the column-shift means, after an amount has been transmitted from the totalizer to the registering means in a dividing cycle, but before the amount is transmitted in the reverse direction, so as to vary the column-shift by one denomination to the left.

5. A calculating machine for effecting division, comprising a plurality of totalizers, means for calculating predetermined multiples of a divisor and registering them each in a separate one of the totalizers, means for entering a dividend into each totalizer concurrently in such manner as to obtain in each the difference between the dividend and the multiple originally in that totalizer, selecting means jointly controlled by the totalizers to select the totalizer containing the smallest difference of a predetermined sign, means for registering the said difference as the dividend for the next step of the calculating and means for registering the digit corresponding to the multiple related to the selected totalizer as a quotient digit.

6. A calculating machine for performing division and multiplication comprising a plurality of totalizers, means for calculating predetermined multiples of a divisor and registering them each in a separate one of the totalizers, a dividend totalizer, means for initially entering a dividend into the latter totalizer, means for transferring the amount in the dividend totalizer to each of the totalizers containing multiples of the divisor and vice versa, mechanism arranged to cause the transferring means to transfer the amount in the dividend totalizer to each totalizer containing multiples of the divisor in such manner as to obtain in it the difference between the transferred amount and the multiple originally in that totalizer, means operative to select the totalizer containing the smallest difference that is of a predetermined sign, means controlled thereby to cause the transferring means to transfer the difference in the selected totalizer to the dividend totalizer, and to register the digit corresponding to the multiple related to the selected totalizer as a digit of a multiplier and means to cause the transferring means to concurrently transfer the multiple in the selected totalizer to the dividend totalizer.

7. In a cyclically operable dividing machine, an entry receiving device settable to represent an amount, five accumulators, transferring mechanism between said entry receiving device and each accumulator for transferring amounts directly or in the form of a complement, five sets of control mechanism, one for each accumulator, for rendering the related transferring mechanism effective to transfer said amount to the accumulators in the form of a complement, driving mechanism operable through five cycles, means for selecting the first set of control mechanism for operation by the driving mechanism during each of the five cycles, means controlled by said first set of control mechanism for rendering the second set of control mechanism effective during

each of the second to fifth cycles, means controlled by the second set for rendering the third set effective during each of the third to fifth cycles, means controlled by the third set for rendering the fourth set effective during the fourth and fifth cycles, and means controlled by the fourth set for rendering the fifth set effective during the fifth cycle, whereby upon completion of the five cycles the five accumulators will respectively contain the complement, two times, three times, four times and five times the complement of the amount standing in the entry receiving device.

8. In a cyclically operable dividing machine, an entry receiving device settable to represent an amount, a series of accumulators, transferring mechanism between said entry receiving device and each accumulator for transferring the amount directly or in the form of a complement, a plurality of sets of control mechanisms, one for each accumulator, each for causing the transferring mechanism of its related accumulator to be effective to transfer the amount in the form of a complement into the accumulator, driving mechanism for the sets of control mechanisms, means for initiating and effecting repeated operation of the first set of control mechanisms, means controlled by the first set of control mechanisms for causing the second set to be effective during the second and subsequent repeated operations of the first set, means controlled by the second and subsequent sets for causing the next set to be effective during the second and subsequent operations of each previously operated set, whereby each accumulator after the first will receive the complement of said amount one time less than the preceding accumulator and the first accumulator will receive the complement of said amount as many times as its control mechanism is operated, and means controlled by the last set of control mechanisms for terminating the transferring operations.

9. In a dividing machine, a pair of accumulators, each having a predetermined number of denominational order elements, means for setting one accumulator to represent a dividend amount, means for setting the other to represent the complement of a divisor amount, a first testing means for testing the elements of the dividend accumulator for the presence of zeros to the left of the highest significant figure, a second testing means for testing the elements of the divisor accumulator for the presence of consecutive nines at the left of the divisor complement, a differentially positionable wheel, one for each testing means, means controlled by each testing means for controlling its related wheel to cause it to take a differential position representative of the consecutive number of zeros and nines in the accumulators, respectively, said wheels being rotated in opposite directions and forming part of an epicyclic gear group having a planet gear displaceable by the wheels in accordance with the difference between the number of zeros and nines tested, column shift mechanism, transferring mechanism including said column shift mechanism between said accumulators, and means controlled by said planet gear for adjusting said column shift mechanism.

10. The invention set forth in claim 9 in which the denominational order elements of the accumulators comprise toothed wheels, the dividend wheels having a single tooth for the digit zero and the divisor wheels having a single tooth for the digit nine, positionable along an axial test-

ing line when the wheels register zero or nine, respectively, the means for testing comprising slides, one for each wheel, positioned along the axial testing line, and means for moving the slides axially toward the wheels, the slides related to wheels registering zeros or nines being intercepted by the single teeth in such positions.

11. In a cyclically operable dividing machine, a dividend accumulator settable to represent a dividend amount, five multiple accumulators, settable to each represent a different one of the complements of one times to five times a divisor amount, entering mechanism for each accumulator, a denominationally ordered entry receiving device, entering means therefor controlled by the dividend accumulator to cause transfer of the dividend to said device, adjustable column shift connections between said device and the entering means of each of the accumulators, means controlled jointly by the dividend accumulator and the times one multiple accumulator for adjusting said column shift connections so that the element of the entry receiving device containing the highest order digit of the dividend is connected to control entry into the order of the times one multiple accumulator containing the complement of the highest order digit of the divisor, and corresponding orders of the other accumulators, means for initiating and effecting a cycle of operations of the machine, and control means effective during said cycle for causing an operation of said first named entering means to transfer the dividend to the entry receiving device and resetting said dividend accumulator, part of said control means thereafter causing the entering means of all the accumulators to be controlled by said entry receiving device through the adjusted column shift connections, whereby each multiple accumulator will contain the difference between its initial entry and the column shifted dividend amount and the dividend accumulator will contain the dividend in displaced relationship with respect to the initial entry.

12. In a cyclically operable dividing machine, a dividend accumulator settable to represent a dividend amount additively, a divisor accumulator settable to represent a divisor amount subtractively, entering mechanism for each accumulator capable of additive or subtractive operation, a denominationally ordered entry receiving device, means for transferring the amount in the dividend accumulator to said device and for concurrently resetting the dividend accumulator, adjustable column shift connections between said device and the entering means of both accumulators, means controlled jointly by both accumulators for adjusting said column shift connections so that the elements of the entry receiving device containing the highest ordered digit of the dividend is connected to control the element of the divisor accumulator containing the highest ordered digit of the divisor and also the corresponding element of the dividend accumulator, transferring means including said column shift connections and the said entering means for additively transferring the amount in the entry receiving device to both accumulators concurrently, means for initiating and effecting a cycle of operation of the machine, and control means effective during said cycle for causing successive operation of said first and second named transferring means.

13. In a cyclically operable dividing machine, a series of six accumulators, entering means for each arranged to effect additive or subtractive

entries therein, means for controlling the entering means for said accumulators except the first to enter in order the complements of one, two, three, four and five times a divisor amount, means for controlling the entering means for all six accumulators to enter the same dividend amount additively in each, whereupon one or more accumulators in order will contain a positive amount, means for each complement receiving accumulator settable thereby to indicate whether the related accumulator contains a negative or a positive amount, means jointly controlled by all of said last named means for selecting the highest order accumulator containing a positive amount, an entry receiving device, and means controlled by said selecting means for transferring the amount in said selected accumulator to said entry receiving device.

14. In a dividing machine, a plurality of accumulators, entering means for each arranged to effect additive or subtractive entries therein, an entry receiving device, transferring mechanism for each accumulator for transferring the amount therein to said entry receiving device, means for initially controlling the entering means of said accumulators to enter the complement of a divisor amount and complements of predetermined multiples of said divisor amount each into a different accumulator, means for controlling the entering means of the accumulators to add to the complement in each a dividend amount, whereby one or more accumulators will contain a positive remainder, means jointly controlled by all the accumulators for determining which accumulator contains the lowest positive remainder, and means controlled thereby for rendering effective the transferring mechanism between that accumulator and said entry receiving device, and means for causing the selected transferring mechanism to transfer the selected remainder.

15. The invention set forth in claim 14 in which a quotient accumulator is provided, means for selectively entering therein digits corresponding to the multiples of the divisor initially entered into said plurality of accumulators, and further means controlled by said determining means for causing the entry into said quotient accumulator of the digit corresponding to the accumulator containing the lowest positive remainder.

16. The invention set forth in claim 14 in which a second plurality of accumulators is provided, one for each of the first plurality of accumulators, each settable in accordance with a multiple of a multiplicand amount, a product accumulator, transferring mechanism for each of said second plurality of accumulators for transferring the amount therein to said product accumulator, and means controlled by said determining means for rendering effective the transferring means between the accumulator of said second plurality containing the multiplicand multiple corresponding to the selected divisor multiple and said product accumulator.

17. In a dividing machine, a plurality of accumulators, entering means for each, arranged to effect additive or subtractive entries therein, an entry receiving device, transferring mechanism for each accumulator for transferring the amount therein to said entry receiving device, means for initially controlling the entering means of said accumulators to enter the complement of a divisor amount and complements of predetermined multiples of said divisor amount each into

a different accumulator, means for controlling the entering means of the accumulators to add to the complement in each a dividend amount, whereby one or more accumulators will contain a positive remainder, means jointly controlled by all the accumulators for determining which accumulator contains the lowest positive remainder, a second plurality of accumulators, one for each of the first plurality, each settable in accordance with a multiple of a multiplicand amount, a product accumulator, transferring mechanism for each of said second plurality of accumulators for transferring the amount therein to said product accumulator, and means controlled by said determining means for rendering effective the transferring means between the accumulator of said second plurality containing the multiplicand multiple corresponding to the selected divisor multiple and said product accumulator.

18. In a calculating machine, two sets of accumulators, entering means for each accumulator capable of additive or subtractive entry, means for causing the entering means of one set to subtractively enter predetermined multiples of a divisor amount in the accumulators of said one set, means for causing the entering means of the second set to additively enter corresponding multiples of a multiplicand amount, an entry receiving device settable to represent a dividend amount, means controlled by said entry receiving device for causing the entering means of the first set to additively enter the dividend amount in each accumulator, means operative thereafter for determining which accumulator of the first set contains the lowest positive remainder, means controlled by said determining means for transferring the selected remainder to said entry receiving device, a product accumulator, and further means controlled by said determining means for transferring the multiplicand multiple from the accumulator corresponding to the one containing the said remainder to said product accumulator.

19. In a calculating machine, two sets of accumulators, entering means for each accumulator capable of additive or subtractive entry, means for causing the entering means of one set to subtractively enter predetermined multiples of a divisor amount in the accumulators of said one set, means operative concurrently with the last named means for causing the entering means of the second set to additively enter corresponding multiples of a multiplicand amount, an entry receiving device settable to represent a dividend amount, means controlled by said entry receiving device for causing the entering means of the first set to additively enter the dividend amount in each accumulator concurrently, means operative thereafter for determining which accumulator of the first set contains the lowest positive remainder, means controlled by said determining means for transferring the selected remainder to said entry receiving device, a product accumulator, and further means controlled by said determining means concurrently with the operation of the first named transferring means for transferring the multiplicand multiple from the accumulator corresponding to the one containing the said remainder to said product accumulator.

20. In a calculating machine, a set of devices settable to represent predetermined multiples of a divisor amount, a second set of devices settable to represent the same predetermined multiples of a multiplicand amount, a quotient receiving

device, means for selectively entering therein the factors determining said predetermined multiples, a product accumulator, column shift mechanism between said second set of devices and said product accumulator, transferring mechanism including said column shift mechanism for transferring any multiple of the multiplicand amount from said second set of devices to said product accumulator, means settable to represent a dividend, dividing mechanism controlled by said first set of devices and said dividend settable means for determining the largest multiple represented in the first set of devices that is not greater than the said dividend amount, means controlled thereby for causing said selective entering means to enter the related factor of such largest multiple into said quotient receiving device and for concurrently causing the transfer-

ring means to transfer the corresponding multiplicand multiple to the product accumulator, whereby the quotient and product of said quotient times the multiplicand will be concurrently obtained.

21. The invention set forth in claim 20 in which said dividing means includes devices for obtaining and setting up the remainder in said dividend settable means for a subsequent dividing operation, means for repeating said dividing operation to determine the largest multiple represented in the first set of devices that is not greater than the remainder, said determining means causing the concurrent entry of the appropriate quotient amount and multiplicand multiple to obtain the complete quotient and product concurrently.

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