counting device steps from 1 to 0. When the counting device 1R registers 0, a carry pulse is fed to the input of the counting device 2R which accordingly steps from 0 to 1. During the period T3 nine pulses are added into the counting device 2R through the gate 2GA so that this counting device steps from 1 to 0. A carry is thus fed to the counting device 3R which is subsequently stepped to 0 and supplies a carry to the counting device 4R. The process continues until the counting device 8R has been stepped round and back to 0. Moreover, during the period T4 a pulse from the output Z of the pulse generator is applied through the gate 13GE to the counting device 13R which steps from 0 to 1. During the period T9 a carry pulse is applied to the counting device 9R to step it from 6 to 7, and during the period T10 nine further pulses are added into the counting device 9R to step it from 7 to 6. As the counting device 9R passes through zero, it sends a carry pulse to the counting device 10R which is stepped from 4 to 5. During the period T11 seven (9—2) more pulses are applied to the counting device 10R which accordingly steps from 5 to 2. As the counting device 10R passes through 0, it applies a carry pulse to the counting device 11R which accordingly steps from 1 to 2. During the period T12 eight (9—1) further pulses are applied to the counting device 11R which accordingly steps from 2 to 0. As the counting device 11R passes through zero, it applies a carry pulse to the counting device 12R which is accordingly stepped from 0 to 1. During the period T13 nine pulses are applied through the gate 12GA to the counting device 12R which is accordingly stepped from 1 to 0. No operation takes place during the periods T14 and T15. Moreover, when the timing device T reaches T0, the pulse from the output Z of the pulse generator has no effect on the control device since the gate CGA is disabled as a result of the fact that the control device 13R has been stepped from 0 to 1, and the gate CGB is disabled since the counting device 12R is not registering 9. Accordingly the machine performs a further subtraction operation similar to that just described. At the end of this operation the machine reads 990600000000. Further the counting device 13R registers 2.

When the counting device 12R reaches 9, all the inputs of the gate circuit CGB are energised on the occurrence of the pulse at the output Z of the pulse generator during the period T0, and a pulse is applied to the input of the counting device C, stepping it from C0 to C1. As has been pointed out above, the output C1 is connected to the SP line and not to the AP line and accordingly the next operation is similar to the shift or multiplication by ten performed during multiplication. However, since the outputs S1 and S2 are now in parallel the machine operates to complement all the numbers registered in the machine at the same time as it shifts them. Throughout the period T1 both inputs of the gate 12GF are energised since the counting device 12R is registering 9. Accordingly the line SC is energised and the switch CS is disabled, so that no pulses are applied to the gate 12GB or to the gate 13GC. Similarly during the whole of the period T2 both inputs of the gate 11GF are energised and no pulses are applied to the gate 11GB or to the gate 12GC. During the period T3 nine pulses are applied through the gate 10GB (not shown) to step the counting device 10R from 0 to 9. These nine pulses are also applied through the gate 11GC to step the counting device 11R from 9 to 8. When the counting device 11R passes through 0, it applies a carry pulse to the counting device 12R which thus steps from 9 to 0. During the period T4 pulses are applied through the gate 9GB to step the counting device 9R on from 6. When the counting device 9R reaches 9, the two inputs to the gate circuit 9GF are energised and a voltage is applied to the SC line. As a result the switch CS is disabled and the outputs from S1 and S2 cease. Thus only three of the nine pulses occurring during the period T4 are effective at the outputs S1 and S2. Thus, three pulses are applied through the gate 10GC to the input of the counting device 10R which is stepped from 9 to 2. As the counting device 10R passes through 0, it applies a carry pulse to the counting device 11R which thus steps from 8 to 9. No pulse is applied during the period T4 from the output Z of the pulse generator to the counting device 13R since the line Y is not energised as the control device C is at C1.

During the period T5 nine pulses are applied to the counting devices 8R and 9R stepping the former to 9 and the latter to 8. As the counting device 9R passes through zero, it applies a carry pulse to the counting device 10R stepping that counting device from 2 to 3. During the period T6 nine pulses are applied to the counting devices 7R and 8R stepping the former to 9 and the latter to 8. As the counting device 8R passes through zero, it applies a carry pulse to the counting device 9R which thus steps from 8 to 9. Similar conditions apply during the periods T7 to T12 during which the counting devices 8R to 3R are stepped to 9, the counting device 2R to 8 and the counting device 1R to 9. During the period T13 eight pulses are applied to the counting devices 13R and 1R stepping the former to 0 and the latter to 7. As the counting device 1R passes through 0, it applies a carry pulse to the counting device 2R stepping that counting device to 9. The counting device 13R is stepped to 0 instead of to 9 as in the case of the other counting devices because the gate 13GF is connected to 13R0 and not 13R9.

During the period T14 one pulse is applied from the pulse generator output Z through the gate 1GD to the counting device 1R which accordingly steps from 7 to 8. During the period T15 nothing happens, but during the next period T0 the control device C is stepped from C1 to C2, by means of a pulse applied through the gate CGA which opens when the pulse from the Z output of the pulse generator arrives, since the counting device 13R is at 0. As a result the lines AP and Y are energised and the line SP is deenergised. Consequently the machine again commences to perform repeated complementary addition in the manner described above. The results of this operation are shown in Table 2. It will be seen that the machine performs eight complementary addition operations at the end of which the register reads 997999999998. The counting device 13R reads 8 and the control device C is stepped from 2 to 3 when the counting device 12R reaches 9. Thus the line SP is energised and the lines Y and AP are deenergised, with the result that the machine operates to shift and complement. As a result of this step the register reads 020000000012. The figures 1 and 2 in the counting devices 2R and 1R are the first two digits of the answer and the figure 2 in the counting device 11R is the remainder. The machine, however, repeats the process described above with the results shown in Table 2. The first four digits of the answer now appear in the counting devices 4R, 3R, 2R and 1R. If further digits are required, these counting devices can be cleared by means of a "CLEAR RIGHT" key and a further four digits may be produced in the same four counting devices by repressing the 0 key in the bank MK which will have been released when the control device was stepped to C7 at the end of the last shift and complement operation. Alternatively, since space is available in the counting devices 8R to 5R, the 0 key in the bank MK may be repressed without clearance of the counting devices 4R to 1R and in this case eight figures of the answer will appear in the counting devices 8R to 1R.

Thus on division, the machine of FIG. 13, once set into operation, automatically effects extraction of four quotient digits. Further quotient digits may be extracted, in groups of four each, one group for each operation of the 0 key in the column or bank of multiplier keys MK0 to MK9 in FIG. 25.

TABLE 2

C	13R	12R	11R	10R	9R	4R	3R	2R	1R	
0	0	0	1	4	6	0	0	0	0	146 is added into the orders 11R, 10R and 9R. Press DIVIDE key, enter 12 in keys of 11K and 10K and press 0 multiplier key.
0	1	0	0	2	6	0	0	0	0	12 is subtracted from 14 in 11R and 10R. 12R does not register 9, therefore C is not moved. Subtract again.
1	2	9	9	0	6	0	0	0	0	12R registers 9. Therefore C is stepped to 1 and a shift and complement operation initiated.
2	0	0	9	3	9	9	9	9	8	Note that the "tens" complement of the number in 13R is shifted into 1R. C is stepped to 2 at the end of the shift and further subtractions commence.
2	1	0	8	1	9	9	9	9	8	12R does not register 9. Therefore subtract again.
2	2	0	6	9	9	9	9	9	8	Do.
2	3	0	5	7	9	9	9	9	8	Do.
2	4	0	4	5	9	9	9	9	8	Do.
2	5	0	3	3	9	9	9	9	8	Do.
2	6	0	2	1	9	9	9	9	8	Do.
2	7	0	0	9	9	9	9	9	8	Do.
3	8	9	9	7	9	9	9	9	8	12R registers 9. Therefore shift and complement.
4	0	0	2	0	0	0	0	1	2	C is stepped to 4. Therefore subtract.
4	1	0	0	8	0	0	0	1	2	12R does not register 9. Therefore subtract again.
5	2	9	9	6	0	0	0	1	2	12R registers 9. Therefore shift and complement.
6	0	0	3	9	9	9	8	7	8	C is stepped to 6. Therefore subtract.
6	1	0	2	7	9	9	8	7	8	12R does not register 9. Therefore subtract again.
6	2	0	1	5	9	9	8	7	8	Do.
6	3	0	0	3	9	9	8	7	8	Do.
7	4	9	9	1	9	9	8	7	8	12R registers 9. Therefore shift and complement.
0	0	0	8	0	0	1	2	1	6	Answer is in 4R, 3R, 2R and 1R. Remainder in 11R.

FIGURE 16 is a simplified circuit diagram of the pulse generator PG and the changeover switch **1S**. The pulse generator includes a ten cathode electronic stepping tube PD and a double triode valve PV. The valve PV is connected in a conventional cathode coupled multivibrator circuit which normally oscillates at 5 kc./s. This frequency ensures that the speed of operation of the machine as a whole is such that it is impossible for an operator performing addition or subtraction to make successive key strokes at a faster speed than the machine can deal with them.

The two anodes of the valve PV are connected through respective resistors **PR15** and **PR16** to a potential of +300 volts and the two cathodes are connected through a common resistor **PR17** to a potential of −130 volts. The control grid of the left-hand half of the double-triode PV is connected to a gate circuit comprising two diode rectifiers **PW1** and **PW2**. This grid is connected to the terminal **T15** of the timing device TD through the diode PW1 and to the stop line through the diode **PW2**. This grid is also connected to a potential of +50 volts through a resistor **PR1**. Terminal **T15** is connected to a potential of −130 volts through a resistor (not shown in this figure) as also is the stop line. Unless the potentials of these terminals are lifted, the arrangement is such that the circuit will oscillate. If, however, the potentials of both the terminal **T15** and the stop line are lifted, the circuit will stop oscillating.

The output of the valve PV is taken from the anode of the right-hand triode and is applied to the drive electrodes of the stepping tube PD in a conventional manner. This anode is connected to the drive electrode **PDD1** through a differentiating circuit consisting of the capacitor **PC1** and the resistor PR2, and to the drive electrode **PDD2** through an integrating circuit consisting of the resistor PR3 and the capacitor PC2. The drive arrangement is such that each pulse from the anode of the right-hand triode of the valve PV steps the glow from one cathode of the tube PD to the next succeeding cathode.

The anode PDA of the tube PD is connected to a potential of +470 volts through a resistor **PR4**, and the cathodes **1** to **9** of this tube are connected through diode rectifiers and resistors PR6 to PR14 to a potential of −130 volts. The **0** cathode is connected through a resistor **PR5** to a potential of −15 volts. It is also connected to a terminal T which leads to the input amplifier of the timing device. As the glow is being stepped continuously along the cathodes of the tube PD during operation of the machine positive pulses are developed in succession across the cathode loads of the tube. Accordingly a positive pulse is applied to the terminal T each time a glow passes the **0** cathode of the tube.

The cathodes **2** to **9** of the tube PD are connected together in groups, the first group consisting of the cathodes **2** and **3**, the second group of the cathodes **4**, **5** and **6** and the third group of the cathodes **7**, **8** and **9**. These groups of cathodes and the cathode **1** are connected through switches **PS1**, **PS2**, **PS3**, **PS4** and **PS5** and rectifiers (which are unnumbered) to output terminals which are designated as **1/8**, **2/6** . . . **9/0**, **0/9**. Each switch is illustrated with one black contact and one white contact. The black contact in each case is closed when the machine is set for performing substraction or division and the white contact in each case is closed when the machine is set for performing addition or multiplication. Each output terminal is connected to a number of cathodes equal to the first figure in its designation when the machine is set for addition or multiplication, and is connected to a number of cathodes equal to the second figure in its designation when the machine is set for substraction or division. It will be seen, for example, that, when the machine is set for addition, one pulse is applied from cathode **1** through the white contact of switch **PS1** to the terminal **1/8** and that nine pulses are applied from the cathodes **1** to **9** through the white contact of the switch PS5 to the terminal **9/0**. On the other hand, when the machine is set for substraction eight pulses are applied to the terminal **1/8**. Two of these eight pulses are derived from the cathodes **2** and **3** through the black contact of the switch **PS2**, three from the cathodes **4**, **5** and **6** through the black contact of the switch **PS3**, and three from the cathodes **7**, **8** and **9** through the black contact of the switch **PS4**. The terminal **0/9** is disconnected from the cathodes of the tube PD when the switch **PS5** is set to the white contact and the terminal **9/0** is disconnected from the tube PD when the switch **PS5** is set to the black contact. The potential of either of these terminals, when it is disconnected from the tube PD, is maintained at a potential of substantially −25 volts by means of respective resistors PR17 and PR18. This arrangement ensures that the gate circuits to which these terminals are connected are closed except when the terminals are being supplied with pulses from the cathodes of the tube PD.

The terminals 1/8 to 8/1 are connected to a potential of −25 volts through resistors PR6 to PR13 respectively and the movable contact of the switch PS5 is connected to the potential of −25 volts through a resistor PR14.

The pulse wave forms on the terminals 1/8 to 9/0 when the machine is set for addition or multiplication are shown in FIGURE 17.

FIGURE 18 is a circuit diagram of the gate circuit CG and the electronic changeover switch CS. The principal elements of the arrangement illustrated are a valve CV1 operating as a cathode follower, valves CV2 and CV3 operating essentially as amplifiers, a first gate circuit comprising diode rectifiers CW1 and CW2, a second gate circuit comprising the diode rectifiers CW3 and CW4, and a changeover switch CS1.

The anode of the valve CV1 is connected to a potential of +300 volts and the cathode is connected to a potential of 0 volts through a resistor CR1. The grid of this valve is connected through a grid stopper resistor CR2 and a capacitor CC1 to a terminal CA. This terminal is connected to the terminal PA in the pulse generator illustrated in FIGURE 16 and accordingly nine positive-going pulses are applied to this terminal during each cycle of the pulse generator. The junction of the resistor CR2 and the capacitor CC1 is connected through a resistor CR3 to a potential of +160 volts. The output of the valve CV1 is taken from the cathode and is applied to one input of each of the two gates referred to above. If the first gate consisting of the rectifiers CW1 and CW2 is open, the nine pulses are applied through a capacitor CC2 to the terminal S1. Further, if the changeover switch CS1 is in the left-hand position (shown in black) the nine pulses are also applied to the output S2. This is the condition when the machine is set for division. When the switch CS1 is set to the right-hand position (shown in white) the nine pulses are applied to the output S2 only if the second gate consisting of the rectifiers CW3 and CW4 is open. This is the condition during multiplication.

The anode of the valve CV2 is connected to +300 volts through a resistor CR4 and the cathode is connected to a potential of 0 volts. The grid of this valve is connected through a grid stopper resistor CR5 to a terminal SC and through the grid stopper resistor, a diode rectifier CW5, and a resistor CR6 to a terminal AP. The grid of this valve is also connected through the grid stopper resistor and a further resistor CR7 to a potential of −25 volts. Therefore, when there is no input to either the terminal AP or the terminal SC, the valve CV2 is cut off so that the anode potential is above the +160 volts applied through a resistor CR8 to the junction of the two rectifiers CW1 and CW2. Accordingly, the gate comprising these two rectifiers is open and pulses are able to pass from the input terminal CA to the output terminal S1. When the AP line is energised, it raises the terminal AP to +15 volts with the result that the valve CV2 commences to conduct so that its anode potential drops below +160 volts. As a result the gate comprising the rectifiers CW1 and CW2 is closed and pulses are prevented from travelling from the terminal CA to the terminal S1. Similarly if the SC line is energised, it raises the potential of the terminal SC to +15 volts with the result that pulses are prevented from travelling from the terminal CA to the terminal S1.

The anode of the valve CV3 is connected to a potential of +300 volts through a resistor CR9 and the cathode is connected to a potential of 0 volts. The grid is connected through a grid stopper resistor CR10, a diode rectifier CW6 and a resistor CR11 to the terminal AP and also to the junction between two resistors CR12 and CR13 which are connected in series between the anode of the valve CV2 and a potential of −130 volts. The grid of this valve is also connected through the grid stopper resistor CR10 and a further resistor CR14 to a potential of 0 volts. When the AP line is not energised, the valve CV2 is nonconducting, as mentioned above, and its mean anode potential is approximately +170 volts. As a result the potential at the junction of the resistors CR12 and CR13 (the resistances of which are equal) is sufficient to ensure that the valve CV3 conducts. Accordingly, the anode potential of this valve drops below +160 volts which is applied through a resistor CR15 to the junction of the two rectifiers CW3 and CW4. As a result the gate comprising the two rectifiers CW3 and CW4 is closed and pulses are prevented from travelling from the cathode of the valve CV1 through the capacitor CC3 to the right-hand contact of the switch CS1.

When the AP line is energised and raises the potential of the terminal AP to +15 volts, it causes the valve CV2 to conduct as mentioned above. This causes the anode potential of this valve to drop and accordingly the potential of the junction of the resistors CR12 and CR13 would also drop if it were not held up by the connection between terminal AP and this point through the resistor CR11 and the reactifier CW6. This connection holds the grid of the valve CV3 sufficiently positive under these conditions for it to remain conducting and for the gate comprising the rectifiers CW3 and CW4 to remain closed.

If the AP line is not energised, but the SC line is energised, so that the terminal AP is at −25 volts, whereas the terminal SC is at +15 volts, the valve CV2 conducts, but the valve CV3 ceases to conduct since the potential of its grid is no longer held up by the potential from the terminal AP. Accordingly, the gate comprising the rectifiers CW1 and CW2 is closed, but the gate comprising the rectifiers CW3 and CW4 is open so that the pulses cannot pass from the terminal CA to the terminal S1, but can pass to the right-hand contact of the switch CS1. Accordingly, when the machine is being used for multiplication pulses pass from the terminal CA to the terminal S2 when the SC line is energised and the AP line is not energised.

In addition to the components already mentioned FIGURE 5 also shows a rectifier CW7 and a resistor CR16 connected to the right-hand contact of the switch CS1 and a rectifier CW8 and a resistor CR17 connected to the terminal S1. These components serve to ensure that the terminals S1 and S2 are at a potential substantially −15 volts when they are not receiving pulses from the terminal CA so that at these times they serve to close the gate circuits to which they are connected.

FIGURE 19 is a circuit diagram of the timing device T and its input amplifier TA. The principal components of the timing device are two ten-cathode electronic stepping tubes TD1 and TD2 together with their drive circuits which include triode valves TV1 and TV2. The anode of the tube TD1 is connected through a resistor TR1 to a potential of +470 volts. The cathode 0 of the tube TD1 is connected through a resistor TR2 to a start terminal which is maintained at a potential of −130 volts until a key in any one of the orders of keys 1K to 11K is depressed during addition or subtraction, and until one of the keys in the bank of keys MK is depressed during multiplication or division. As a result the glow in this tube is maintained on the cathode 0 until one of the said keys is actuated. The cathode 0 is also connected to a terminal T0 which constitutes one of the inputs to each of the gate circuits CGA and CGB. The cathodes 1 to 7 of the tube TD1 are connected through resistive and capacitative loads to a potential of −50 volts and also to terminals T1 to T7 respectively. The cathodes 7, 8 and 9 of this tube are connected through isolating rectifiers TW1 and TW2 to the input of a gate circuit consisting of diode rectifiers TW3 and TW4 at the input of the valve TV2. The particular stepping tubes illustrated in this figure have three drive electrodes and accordingly the drive circuits are designed to provide three phase displaced outputs. The anode of the valve TV1 is connected through a resistor TR3 to a potential of +300 volts and is also connected through a differentiating circuit comprising a capacitor TC1 and a resistor TR4 to the drive electrode TDD1, through a differentiating circuit comprising a capacitor TC2 and the resistor TR5 to the drive electrode TDD2, and through a coupling capacitor TC3 and an integrating circuit comprising a resistor TR6 and the capacitor TC4 to the drive electrode TDD3. In addition the drive electrode TDD1 is connected through the resistor TR4 to a potential of −25 volts, the drive electrode TDD2 is connected through the resistor TR5 to a potential of 0 volts and the drive electrode TDD3 is connected through a resistor TR7 to a potential of +50 volts. This arrangement ensures that when a pulse is applied to the grid of the valve TV1 the glow in the tube TD1 is stepped from one cathode to the next.

The grid of the valve TV1 is connected through a grid stopper resistor TR8 to the output of a gate circuit consisting of the diode rectifiers TW5 and TW6. This grid is also connected through the grid stopper resistor and a resistor TR9 to a potential of +50 volts. The rectifier TW5 is connected to a terminal PG0 which is the cathode 0 of the pulse generator. The rectifier TW6 is connected through rectifiers TW7 and TW8 to the cathode 0 of the tube TD2. It is also connected through a resistor TR14 to a potential of −50 volts.

The anode of the tube TD2 is connected through a resistor TR10 to a potential of +470 volts. The cathode 0 of this tube is connected through a resistor TR11 to the start terminal and is also connected through the rectifier TW8 and a resistor TR12 to a potential of −25 volts. The junction of the rectifier TW8 and the resistor TR12 is connected through the rectifier TW7 to one input of the gate circuit associated with the grid of the valve TV1 as described above. The cathodes 8 and 9 of the tube TD2 are connected through rectifiers TW9 and TW10 respectively to the said input of the gate circuit associated with the grid of the valve TV1. The cathodes 1 to 7 of the tube TD2 are connected through resistive and capacitive loads to a potential of −50 volts. The cathodes 8 and 9 are similarly connected through resistive loads to the same potential. However, the cathodes T1 to T8 are connected respectively to terminals T8 to T15.

The drive circuit for the tube TD2 is identical with that for the tube TD1 and accordingly will not be described in detail.

Before a key is depressed the glow in each of the tubes TD1 and TD2 is called to the cathode 0 by the negative potential on the start terminal. After this negative potential has been removed by the depression of a key the next pulse applied to the terminal PG0 is able to step the glow in the tube TD1 from the cathode 0 to the cathode 1. It is able to do this because the glow in the tube TD2 is still on the cathode 0 so that the gate circuit at the input of the valve TV1 is open. As a result of the glow passing to the cathode 1 the potential of the terminal T1 is raised. Subsequent pulses applied to the terminal PG0 step the glow in the tube TD1 successively along the cathodes to the cathode 6. These pulses are also applied to one input of the gate circuit at the input of the valve TV2 but they are unable to drive the tube TD2 since this gate is closed by the negative potential applied to the other input of this gate circuit through a resistor TR13. However, the next pulse applied to the terminal PG0 steps the glow on to the cathode 7 of the tube TD1 and accordingly the potential of the second input to the gate circuit associated with the valve TV2 is raised. This allows the gate circuit to open and the next pulse applied to the terminal PG0 is able to drive both the tubes TD1 and TD2. Accordingly the glow in the tube TD1 steps to the cathode 8 and the glow in the tube TD2 steps to the cathode 1 thus raising the potential of the terminal T8. In order to prevent the gate at the input of the valve TV2 from closing while the glow is passing between the cathode 7 and the cathode 8 of the tube TD1, a capacitor TC5 is provided to store the positive potential previously on the cathode 7 until the potential of the cathode is raised. Similarly a capacitor TC6 is provided to keep open the gate at the input of the valve TV1 long enough to ensure that the glow reaches the cathode 8 of the tube TD1. After this step the gate circuit at the input of the valve TV2 is maintained open through the rectifier TW1 since the glow is resting on the cathode 8 of the tube TD1. However, as the glow has left the cathode 0 of the tube TD2, one input of the gate circuit associated with the valve TV1 is de-energised and accordingly pulses from the terminal PG0 are now unable to step the tube TD1. Accordingly the subsequent pulses at the terminal PG0 step the glow in the tube TD2 successively along the cathodes to the cathode 7 thus energizing the terminals T9 to T14 successively. When the glow is stepped on to the cathode 8 of the tube TD2 a potential is applied through the rectifier TW9 to the input of the gate circuit associated with the valve TV1 so that the next following pulse is able to step the glow in the tube TD1 on to the cathode 9 at the same time as the glow in the tube TD2 is stepped on to its cathode 9. Under these conditions the gate circuits at the inputs of both valves TV1 and TV2 remain open and accordingly the next pulse steps the glow in both tubes back to the cathode 0. It will thus be seen that a cycle of the timing device is completed in 17 steps corresponding to 17 cycles of the pulse generator.

FIGURE 20 is a circuit diagram of the control device C, its input amplifier CA, the gate circuits CGA and CGB, the bank of multiplier keys MK and the switching arrangement CM. The control device consists essentially of a ten-cathode electronic stepping tube MD; the input amplifier consists of a triode valve MV together with its associated components; the gate CGA consists of three diode rectifiers MW1, MW2 and MW3; the gate CGB consists of diode rectifiers MW4, MW5 and MW6; the bank of multiplier keys consists of nine change-over switches MK1 to MK9; and the switching arrangement CM consists of the switches MS1 to MS6. The switches are normally in the position indicated by the black contact, but the switches MS1, MS3, and MS5 are changed over when the machine is set for multiplication, the switches MS4 and MS6 are changed over when the machine is set for division and the switch MS2 is changed over when the machine is set for subtraction or division.

The anode of the tube MD is connected through a resistor MR1 to a potential of +470 volts. The 0 cathode of this tube is connected through a rectifier MW7 and a resistor MR2 to a potential of −25 volts. The cathodes 1, 3, 5, 7 and 9 are connected through individual rectifiers such as MW8 to the right-hand (black) contacts of the switches MS2 and MS3. They are also connected through the individual rectifiers and a common resistor MR3 to a potential of −25 volts. The cathodes 2, 4, 6 and 8 are connected to the centre (movable) contact of the switch MS2 and to the left-hand (white) contact of the switch MS4. When the switch MS2 is in the right-hand (black) position, these cathodes are connected through their individual rectifiers and the resistor MR3 to a potential of −25 volts. When the switch MS2 is in the left-hand (white) position, these cathodes are connected to a potential of −25 volts through their individual rectifiers and the resistor MR2. Each of the cathodes 1 to 9 is connected to the upper (white) contact of a respective one of the keys MK1 to MK9. These contacts are normally open, but each is closed when the respective key is depressed.

The glow in the stepping tube MD is moved from cathode to cathode by means of the drive circuit including the valve MV. The particular stepping tube illustrated is shown with three drive electrodes and these are connected to the anode of the valve MV through two differentiating circuits and an integrating circuit. The three drive electrodes are connected through resistors to potentials of −25 volts, 0 volts and +50 volts respectively. The anode of the valve MV is connected through a resistor MR4 to a potential of +300 volts. The grid of the valve MV is connected through a grid stopper resistor MR5 and isolating rectifiers MW9 and MW10 to the outputs of the two gate circuits previously referred to. The anodes of the rectifiers MW1, MW2 and MW3 are connected through a resistor MR6 to a source of varying positive potential +GD referred to hereinafter. Similarly the anodes of the diodes MW4, MW5 and MW6 are connected through a resistor MR7 to the same source +GD. The cathode of the rectifier MW1 is connected to the centre contact of a changeover switch MS7 which is in the right-hand (black) position when the machine is being used for addition or multiplication and in the left-hand (white) position when the machine is being used for subtraction or division. The right-hand contact is connected to a potential of +15 volts and the left-hand contact is connected to the **0** cathode of the stepping tube 13R. This switch is therefore equivalent to the switch 4S shown in FIGURE 14. The cathode of the rectifier MW4 is connected to the ninth cathode of the stepping tube 12R (FIGURE 14), the cathodes of the rectifiers MW2 and MW5 are connected to the **0** cathode of the stepping tube TD1 (FIGURE 19) and the cathodes of the rectifiers MW3 and MW6 are connected to the terminal Z shown in FIGURE 16. The grid of the valve MV is also connected through the grid stopper resistor MR5 and a resistor MR8 to a varying negative potential −GD which will be referred to hereinafter.

The **0** cathode of the tube MD is connected through a resistor MR9 to the start line and accordingly, when the machine is switched on, but before a key is depressed, a potential of −130 volts is applied to this resistor MR9. Under these conditions the glow resides on the **0** cathode. Pulses may be applied to step the glow to the succeeding cathodes either through the gate consisting of the rectifiers MW1, MW2, and MW3 or through the gate consisting of the rectifiers MW4, MW5 and MW6. When the machine is being used for addition or subtraction the glow normally remains throughout on the **0** cathode.

When the machine is being used for multiplication or division the glow also starts on the **0** cathode. As a result of the current through the tube the potential of the **0** cathode is raised and this potential rise is applied through the rectifier MW7 and the operated switch MS3 to the terminal SP. It is to be noted that during multiplication the terminal AP is connected through the operated switch MS1 to the cathodes **2**, **4**, **6** and **8** of the tube MD and also through the unoperated switch MS2 to the cathodes **1**, **3**, **5**, **7** and **9** of the tube MD. However, since at this time the glow is not residing on any of the cathodes **1** to **9** of the tube MD, the potential of the terminal AP is negative and accordingly the machine operates to perform a shift operation. The glow is stepped forward once for each cycle of the timing device by means of the pulses applied through the rectifiers MW2 and MW3. As soon as the glow is stepped from the **0** cathode to the **1** cathode, the positive potential is removed from the terminal SP and is applied to the terminal AP so that the machine operates to perform addition. Assuming that the key MK4 has been depressed, this process will continue until the glow reaches cathode **4** in the tube MD, when a positive potential will be applied from this cathode through the operated key MK4 and the unoperated switch MS6, to the stop line.

When the machine is being used for division, a key MK0 (not shown) is depressed and this has the effect of opening the start contact without changing over any of the keys MK1 to MK9. Once again the glow is on the **0** cathode at the start of calculation and with the machine set for division the **0** cathode is connected through the rectifier MW7 and the unoperated switch MS1 to the AP terminal so that the potential of this terminal is raised. The potential on the AP line is also applied to the terminal Y through the operated switches MS2 and MS4. Accordingly the machine performs complementary addition and also allows the "odd one" to be applied to the counting device 13R during the period T4. The switch MS7 is changed over when the machine is set for division and accordingly pulses are not applied through the gate CGA to the drive valve unless the counting device 13R (FIGURE 14) is at 0. A pulse, however, is applied to the drive valve through the gate CGB when the counting device 12R is at 9. When the glow in the tube MD is stepped on to the cathode **1**, the potential of the AP line drops and the potential of the SP line is raised through the unoperated switch MS3. Accordingly the machine operates to perform a complementary shift operation. When the glow in the tube MD is stepped on to the cathode **2**, conditions are again as when it was on the cathode **0** and, when the glow is stepped on to the cathode **3**, conditions are the same as when it was on the cathode **1**. When the glow reaches cathode **7**, the potential of the stop terminal is raised through the operated switch MS6 and the pulse generator is disabled.

FIGURE 21 is a circuit diagram of the counting device 11R together with its input amplifier 11A, the gate circuits 11GA, 11GB, 11GC and 11GF, and the bank of keys 11K.

The counting device consists essentially of a ten-cathode electronic stepping tube 11RD and a display tube 11RE; the amplifier 11A consists essentially of a valve 11RV and its associated components which are arranged to provide phase-displaced drive potentials for the tube 11RD similar to those described for the tube TD1 illustrated in FIGURE 19. The gate circuit 11GA consists of rectifiers 11RW1, 11RW2, and 11RW3; the gate circuit 11GB consists of rectifiers 11RW4 and 11RW5; the gate circuit 11GC consists of rectifiers 11RW6 and 11RW7; and the gate circuit 11GF consists of rectifiers 11RW8 and 11RW10. Pulses are applied to the grid of the valve 11RV whenever both, or all, of the inputs of any one of the gate circuits 11GA, 11GB or 11GC are energised. The output of the gate 11GF is applied to the terminal SC through a rectifier 11RW9 and the potential of this terminal will be raised if the glow in the stepping tube 11RD is on the cathode **9** during the period T2.

The connections between the stepping tube 11RD and the display tube 11RE are as shown in FIGURE 5 of U.S. Patent No. 2,954,507 of N. Kitz et al. for "Indicating Devices," which issued September 27, 1960 and is assigned to the same assignee as the present invention and the circuit operates in the manner described with reference to that figure. The cathode **0** of tube 11RD in addition to being connected to the associated trigger tube is also connected to a terminal 11R0, which leads to the input amplifier 12A.

All the gate circuits illustrated have two or more diodes with a common anode connection, from which a signal output is taken. The anodes of the diodes 11RW1, 11RW2 and 11RW3 are connected through a resistor 11RR2 to a source of potential +GD; the diodes 11RW4 and 11RW5 are connected to the same source through a resistor 11RR4, and the diodes 11RW6 and 11RW7 are connected to the same source through a resistor 11RR3. The input cathodes carry a normal closed gate potential of −15 volts to −25 volts.

Each gate output circuit is shown connected through a further diode to a load resistor 11RR1. In the case of each gate circuit a resistor, for example, resistor 11RR2, a diode, for example diode 11RW11, and the resistor 11RR1, form a potential divider between +GD and −GD. The further diodes such as 11RW11 are included in order to allow all the gates to feed the same output load.

The output potential when the gate is closed may be about −12 volts, allowing for three volts dropped across only one diode holding the gate closed. In the gate open condition all the input cathodes may rise to +15 volts. Now if +GD be taken as +50 volts and −GD as −25 volts, and allowing three volts drop in the series diode, for example diode 11RW11, the output potential rises to +11 volts.

Unfortunately a nonconducting diode behaves like a small capacitor, and one output may be loaded by several diodes in this condition. For example, the diodes 11RW2 and 11RW3 may have their cathodes at a potential of +15 volts. Then the diode 11RW1 may be pulsed with pulses through the keys 11K which drive its cathode from −15 volts to +15 volts. The time of rise of the pulses at the output will be controlled by the shunt capacitance of the output circuit, which will include the diodes 11RW2 and 11RW3, together with the available charging current for this stray capacitance.

If each of the resistors 11RR1 to 11RR4 has a resistance of 1 megohm, the charging resistance comprises two parallel 1-megohm resistors and is therefore 0.5 megohm. The potential rises from −12 volts to +11 volts on an exponential curve. If, therefore, the capacitance is 100 picofarads, the rise time will be 50 microseconds approximately.

The back of the pulse, or fall time, is also affected by some of the stray capacitance. Although the gate may close quickly as one of the input potentials drops, this may leave the coupling diode 11RW11 between this part of the circuit and the output in a non-conducting state. At the start of the rise of a pulse there was 23 volts across 0.5 megohm. Now at the start of the fall there is 25 volts across 1 megohm. The stray capacitance should therefore be about halved, which is in fact the case.

The forward impedance of the diodes makes the use of lower gate load resistance values impracticable. The source impedance of the input circuits to the gates also adds to the diode impedance and imposes a more severe limitation.

The capacitance losses are, therefore, partially neutralised, according to one aspect of the invention, by the use of variable potentials on the terminals +GD and −GD. The waveforms of these potentials are illustrated in FIGURE 22, which shows that +GD is the +50 volt supply added to a differentiated oscillator pulse. −GD is part of an A.C. waveform, gated, and referred to the −25 volt line. The +GD waveform may be derived, for example, from the secondary of a transformer the primary of which is connected in the anode circuit of the right-hand triode of the valve PV illustrated in FIGURE 16. The −GD waveform may be derived from the guide electrode PDD1 through a rectifier and a resistor, the junction of said rectifier and resistor being connected through a further rectifier to the −25 volt line.

+GD rises sharply to a maximum of +80 volts at the same time as the front of the pulses from the pulse generator PG. This assists the gate to open both by the increased current flowing in the 1 megohm resistors coupling into the gates, and by current in the stray capacitance across these resistors and elsewhere in the wiring.

−GD serves a similar function at the end of these pulses, so helping to restore the cutoff bias to the drive valves.

As would be expected, these additional sources of pulses supplied to the gates and drive valve grids, can give rise to errors; but present in the right amount they can make poor pulses into good ones.

A gate which is held closed by the negative potential from a TD cathode will "leak" a small amount of +GD waveform. The amount of this will depend upon the impedance of this cathode circuit, and on the series diode impedance. The leak of "spikes" from +GD is minimised by the shunt capacitors on the TD cathode loads.

Turning again to FIGURE 21 we find four possible signal inputs to the grid of the drive valve 11RV. Each is isolated from the others by a diode. The first signal input is that provided for the carry from the 0 cathode of the preceding counting device 10R. As the glow may rest on this cathode, it is necessary to differentiate the voltage on it in order to produce the required carry pulse. The differentiating circuit provided consists of a capacitor 11RC1 and a resistor 11RR5. The second input is that provided for pulses from the pulse generator PG when one of the nine keys 11K is depressed.

The add gate 11GA has three input diodes; one to the number line keys; one to the AP line; and one to T12 which is connected to the cathode 5 of the tube TD2. The cathode 5 potential, when there is no glow on this cathode, is adjusted to take the +GD1 load off the other two diodes. This condition holds for all other gates controlled by TD cathodes. During the period of the T12 positive pulse the +GD load falls on the AP line, which is strong enough (has enough tail current) to hold down a limited number only of GD loads. (This condition is met in multiplication and division for the shift cycles.)

When no key in the order 11K is depressed and the add gate finds its AP line diode and its T12 line diode cathode potential positive, the remaining diode to the 0/9 output of the switch 1S holds the gate closed, unless the machine is set for subtraction, when the gate will open to admit nine pulses.

The shift line S1 connects to the drive valve 11RV when a T2 pulse occurs, whereas the shift line S2 connects at T3 time, to take the spill over from the counting device 10R if the shift change line SC so directs.

The input to the diode 11RW1 of the gate 11GA is taken from the centre contact of the key 11K1. When none of the keys 11K1 to 11K9 is depressed, this diode is connected through the closed contacts of all the keys 11K1 to 11K9 to the 0/9 output of the switch 1S as mentioned above. When any one of the keys is depressed, this diode is disconnected from the 0/9 output and connected to the output appropriate to the value of the depressed key in its order. Thus, for example, when the key 11K3 is depressed the diode is connected to the 3/6 output of the switch 1S. Thus, when the machine is set for addition, three pulses are applied to this diode during each cycle of the pulse generator and, when the machine is set for subtraction, 6 pulses are applied to this diode during each cycle of the pulse generator.

All stages of the register have three sets of gates like the 11R stage.

The units counting device 1R finds itself with no carry input from the counting device 13R, but with two additional gates for "odd one" pulses. The gate 1GE allows an "odd one" for a subtraction cycle only, at T1 time; while the 1GD allows an "odd one" pulse at T14 time for each shift cycle.

The counting device 13R has four input gates; numbers are shifted out at T13 time of a shift cycle, when pulses up to nine if required appear at S1.

Numbers are shifted in a T1 time, from the counting device 12R via the S2 line. This is stopped on a division setting by the switch 3S holding a diode of the gate 13GC to −15 volts.

The gate 13GD has this same control for an "odd one" pulse, added at T2 time for a shift cycle, in order to distinguish between the normal (multiplication) and the complementary (division) shift.

The gate 13GE, with three diodes, is also an "odd one" adder, now at T4 time. Switch MS4 ensures that "odd ones" are only added when the machine is set to division, and then are admitted for every subtraction cycle.

The cathodes 1 to 9 of the stepping tube 11RD are connected to a potential of −25 volts through individual desistors while the cathode 0 is connected through a resistor to a terminal F. The 0 cathodes of the counting device stepping tubes 12R and 7R to 10R are all connected to the terminal B. Further the 0 cathodes of the counting device stepping tubes 5R and 6R are connected to the terminal F when the machine is set for division, otherwise the 0 cathodes of these tubes are connected to the terminal B. The terminal F is connected to a potential of —132 volts through a "CLEAR LEFT" key and the terminal B is connected to a potential of 130 volts through a "CLEAR RIGHT" key. Thus operation of the "CLEAR RIGHT" key, for example, causes the glow to return to the 0 cathode in the counting devices 1R to 4R when the machine is set for division and in the counting devices 1R to 6R when the machine is not set for division.

The cathodes of all the trigger tubes associated with the display tube 11RE are connected to the start terminal so that the tube is extinguished while a calculation is being performed.

Reference has hereinbefore been made to the fact that, when a multiplier key is depressed, it will be held down. This is achieved by virtue of the fact that an output from the valve PV (FIG. 16) is applied to the control electrode of a thyratron valve (not illustrated) to energise a solenoid (also not illustrated) located in the anode circuit of the thyratron. The key depressed is held depressed by a locking mechanism which is kept locked by the solenoid as long as the solenoid is energised, and the solenoid will remain energised as long as the multivibrator circuit (which includes the valve PV) oscillates. When the circuit stops oscillating the lock is released and the key returns to its unoperated position.

Referring to FIGURES 23 and 24, the calculating machine is provided with a set of four control keys 1, 2, 3, 4, the key 1 being depressed when it is desired to condition the machine for addition, the key 2 for multiplication, the key 3 for subtraction and the key 4 for division. The stem of each of keys 1 and 3 is provided with a rearwardly extending arm 5 and the stem of key 1 is also illustrated in FIGURE 23 as being associated with a pair of switch contacts 10 and 11, each of which is illustrated as bridging the lower two contacts of a set of three contacts. The two sets of three contacts correspond to two of the five sets of three contacts which constitute the switches PS1 to PS5 (FIGURE 16) and it will therefore be appreciated that the key 1 is associated with three further sets of contacts (not illustrated) which are identical with or similar to those illustrated in FIGURE 23. In each set of three contacts in FIGURE 23, the uppermost contact corresponds to the white contact, and the lowermost contact to the black contact, in FIGURE 16.

Referring now particularly to FIGURE 23, there are illustrated the keys 11K1, 11K2 and 11K3 of the 11K order of keys, the stem 20 of each key having a laterally directed lug 21 which is in contact with a key bar 22 which is mounted for forward and rearward movement in the machine and in the upper edge of which there is a plurality of inclined slots 23. A boss 24 on each key stem 20 acts as the anchorage for one end of a light spring 25, the other end of which is anchored to a part of the machine framework.

A bail 30 is mounted for rocking motion about the axis of a pair of studs or spindles 31 (of which only one is visible in the drawings) through the intermediary of a pair of arms 32 (of which only one is visible in the drawings). The bail 30 extends across all of the orders of the machine and is so arranged that the upper edge thereof is located in the path of travel of the arm 5 secured to the stem of each of the keys 1 and 3. A further bail 33 is mounted upon the upper edge of each of the arm 32 and extends across all of the orders of the machine parallel to the bail 30.

A plate 34 is mounted in the machine for pivotal movement about the axis of a spindle 35. The plate 34 is provided with a series of rearwardly extending bosses 36 which are held against the front end 37 of the key bar 22 by a spring (not illustrated). Also mounted for pivotal movement about the axis of the spindle 35 and independently of the plate 34 is a plurality of blocking members 38, there being a member 38 associated with each order of the machine and a spring 39 extends between the plate 34 and the member 38 so as to urge the said member in a clockwise direction about its pivotal axis.

A key bar locking device 40, associated with each order of the machine, is provided with an horizontally disposed lug 41 and is mounted for pivotal movement about the axis of a spindle 42 and is urged at all times in a clockwise direction about the axis of the spindle 42 under the influence of a spring 43, one end of which is anchored to the forward end of the key bar locking device 40 and the other end of which is anchored in any convenient manner on the framework of the machine.

The operation of the mechanism hereinbefore described is as follows:

When either of the keys 1 and 3 is depressed, the arm 5 thereof makes contact with and presses downwardly the bail 30. The lower edge of the bail 30 is depressed into contact with the upper edge of each of the key bar locking devices 40, thereby moving the lugs 41 thereof out of contact with the undersides of the various key bars 22. At the same time as the bail 30 is moved downwardly so also is the bail 33. Upon depression of, for example, key 11K3 the lug 21 on the key stem 20 engages the associated slot 3 in the key bar 22 and causes forward movement thereof. The front end 37 of the key bar 22 causes the plate 34 to be rotated about its axis of rotation in a clockwise direction thereby causing the blocking member 38 in each of the orders in which an amount key has not been depressed to move into the path which the key bars in those orders would move if a key in those orders were to be depressed. The blocking member 38 in the order of the actuated key makes contact with the upper edge of the key bar which has moved into the path of travel of the blocking member 38. Thus, as long as the key 11K3 is held depressed, it is impossible for the machine operator to depress a key in any of the other ten orders of the machine. When the key 11K3 is released, it is restored to its rest condition by means of its spring 25 and such restoration ensures that the key bar 22 is moved rearwardly to its rest position. Rearward movement of the key bar 22 allows the plate 34 and each of the members 38 to rotate the axis of the spindle 35 in an anticlockwise direction under the influence of the associated spring.

When either of the two keys 2 and 4 are depressed, both the keys 1 and 3 are returned to their position of rest if they have been depressed. When either of the keys 1 and 3 return to its position of rest the arm 5 on the stem thereof moved upwardly and consequently the bail 30 and the bail 33 became displaced upwardly from the position illustrated in FIGURE 10 under the influence of the spring 43 because the lowermost edge of the bail 30 is, at all times, in contact with the upper edge of the key bar locking device 40. When the bails 30 and 33 are in this upper position, the lug 41 on the key bar locking device 40 is in contact with the underside of the key bar 22. Upon depression of, for example, the key 11K3, the key bar moves forwardly, as hereinbefore explained, until the lug 41 registers with a notch 44 formed in the underside of the key bar 22. As soon as these two parts are in register, the lug 41 is moved upwardly into the notch 44 thereby arresting the key bar in its forward position. Once again, forward movement of the key bar causes clockwise rotation of the plate 34 but, by virtue of the fact that the bail 33 is in its upper position, the blocking member 38 is held stationary in space and clockwise rotation of the plate 34 will, therefore, merely stretch the spring 39. It will be appreciated, therefore, that when setting the machine for either multiplication or division, it is possible to depress in succession, the keys representing the digits of a multiplicand to be set up in the machine either simultaneously or in succession.

Release of the keys of a multiplicand thus set up is achieved by depression of either of the keys 1 and 3 where-upon, as hereinbefore explained, the arm **5** on the stem of the key depressed moves the bail **30** downwardly about its axis of rotation in order to rotate the key bar locking device **40** in an anticlockwise direction about the axis of the spindle **42** and thereby stretch the spring **43**.

Clockwise rotation of the spindle **35**, which is effected by forward movement of any of the key bars **22** in the machine during either addition or subtraction breaks a pair of "start" contacts (not illustrated) equivalent to the contact SS. However, when either key **2** or **4** is depressed to set the machine for multiplication or division, respectively, these "start" contacts are shorted and the contact SS is opened upon depression of a multiplier key.

In addition to the facilities provided by the machine hereinbefore described it may sometimes be required that the machine should be capable of dealing with numbers including a decimal point and of indicating where the decimal point is in the answer. A further facility that may be required is the possibility of moving numbers from one part of the register to another. If these additional facilities are required the equipment illustrated in FIGURE 26 may be incorporated in a machine as hereinbefore described.

The equipment illustrated in FIGURE 26 includes an electronic stepping tube DD having twelve cathodes and driven by a valve DV, a bank of tubulator keys TK**0** to TK11 a bank of decimal keys DK1 to DK11 and a bank of decimal point indicating tubes DL1 to DL11.

The anode of the stepping tube DD is connected to a potential of +470 volts through a resistor DR1. The **0** cathode of the tube DD is connected through a resistor DR2 to a terminal F and the cathodes **1** to **11** are connected through respective resistors to a potential of —25 volts. Each of the cathodes **1** to **11** is also connected to the anode of a respective one of the neon indicating tubes DL1 to DL11. The cathodes of these indicating tubes are connected in common to the junction of a pair of resistors DR3 and DR4, the ends of which are connected between a potential of 0 volts and a potential of —130 volts. The potential of the junction of these resistors is such that each indicating tube will light when the glow in the stepping tube DD is resting on the cathode connected to the anode of that indicating tube but not at any other time. As can be seen from FIGURE 25, the indicating tubes DL1 to DL11 are arranged between the display tubes **1**RE to **12**RE which display the number stored in the register of the machine. Thus, the indicating tube DL1 is located between the display tubes **2**RE and **1**RE and indicates that the decimal point exists be tween the digits indicated by these two display tubes.

The stepping tube DD has two drive electrodes and the anode of the valve DV is connected to these drive electrodes through a circuit similar to that described with reference to the drive of the tube PD illustrated in FIGURE 16. The grid of the drive valve DV is connected to the output of a gate circuit consisting of a resistor DR5 connected to the terminal +GD and three rectifiers DW1, DW2 and DW3. The cathode of the rectifier DW1 is connected through a changeover switch DKM to a potential of —15 volts and to a terminal SP. Normally the cathode of this rectifier is connected to a potential of —15 volts, but when the switch DKM is operated this cathode is connected to the terminal SP (FIGURES 14 and 20). The cathode of the rectifier DW2 is connected to the terminal T3 (FIGURES 14 and 19) and the cathode of the rectifier DW3 is connected to the terminal Z (FIGURES 14 and 16).

Each of the cathodes **0** to **11** of the stepping tube DD is connected to the normally open contact (white contact) of a respective one of the tabulator keys TK**0** to TK11. The moving contact of the key TK**0** is connected through a resistor DR6 to the normally open (white contact) of a switch TKM. The moving contact of this key is connected to a terminal T and the normally made (black contact) of this switch is connected to a potential of +15 volts. The white contact of this switch is also connected through a capacitor DC to a potential of 0 volts and through a rectifier DW4 to a potential of —25 volts. The black contact of the key TK11 is connected through a resistor DR7 to a potential of +15 volts. The black contact of each of the remaining keys TK**0** to TK10 is connected to the moving contact of the next higher key.

Besides being connected to the white contacts of the keys TK1 to TK11, the cathodes **1** to **11** of the stepping tube DD are also connected to the white contacts of the keys DK1 to DK11. The moving contacts of the keys DK1 to DK11 are connected to a potential of —130 volts. The black contacts of the keys DK1 to DK11 are unconnected.

Normally the glow in the stepping tube DD is resting on the cathode **0**. It is attracted to this cathode when the terminal F is connected to a potential of —130 volts by the operation of a CLEAR LEFT key (FIGURE 25). If, however, one of the keys DK1 to DK11 is actuated, the glow will be attracted to the corresponding cathode of the tube DD and the corresponding indicating tube will light. Thus, for example, if the key DK1 is operated, the glow will be attracted to the cathode **1** of the stepping tube DD and the indicating tube DL1 will light. As a result a decimal point will appear between the ultimate and penultimate display tubes on the right-hand side of the register. The keys DK1 to DK11 do not remain in the operated position after they have been actuated but return to their normal position. However, once the glow in the tube DD has been attracted to a particular cathode it remains there and accordingly the corresponding indicating tube will remain alight. As can be seen from FIGURE 25, the decimal point will also be situated between the ultimate and penultimate banks of keys on the right-hand side of the keyboard and accordingly this must be taken into consideration when entering numbers into the machine. Thus, for example, if the indicating tube DL1 is illuminated, the number 123 must be inserted with the 1 in the bank **4**K, the 2 in the bank **3**K and the 3 in the bank **2**K. Similarly the number 1.4 must be inserted with the 1 in the bank **2**K and the 4 in the bank **1**K. During addition and subtraction, providing the numbers are correctly inserted as indicated above, the answer will remain correct without movement of the decimal point. During multiplication, however, there may be a decimal point in the multiplier as well as, or instead of, in the multiplicand. In this case, the switch DKM is closed before the first digit on the right of the decimal point is inserted into the multiplier keys and remains closed while any further digits to the right of the decimal point are being entered. Thus, for example, if 1.5 is to be multiplied by 1.5, the 1 is inserted in the order of keys **2**K, the 5 is inserted in the order **1**K and the key DK1 is depressed. The multiplier key MK1 is then actuated and the machine performs the first step in the calculation, as a result of which the last two indicating tubes of the register read 1.5. The switch DKM is then actuated and the multiplier key MK5 is depressed. As a result the machine shifts the digits 1 and 5 from the counting devices **2**R and **1**R into the counting devices **3**R and **2**R respectively. At the same time, during the shift cycle the gate at the input of the valve DV will open once when a pulse appears on the Z line during the period T3 and the glow in the tube DD will be stepped from cathode **1** to the cathode **2**. Accordingly, the indicating tube DL1 will be extinguished and the indicating tube DL2 will be illuminated. The machine then adds 5 five times into the counting device **1**R and 1 five times into the counting device **2**R so that the counting device **1**R reads 5, the counting device **2**R reads 2 and the counting device **3**R reads 2. Further, the decimal point is now situated between the display device of the counting devices **2**R and **3**R so that the result of the calculation is 2.25.

The terminal T connected to the moving contact of the switch TKM is used to provide an additional input to the gate circuits associated with the valve MV (FIGURE 20), and the valve PV (FIGURE 16). Normally this terminal is connected to a potential of +15 volts through the black contact of the switch TKM so that neither of these additional inputs affects the operation of the respective gate circuits. However, when the switch TKM is operated this terminal is connected to a potential of −25 volts through the rectifier DW4. As a result input pulses are prevented from reaching the grid of the valve MV so that the glow in the stepping tube MD (FIGURE 20) cannot be moved. Further, the stop potential cannot reach the grid of the left-hand triode of the valve PV with the result that this valve cannot be prevented from oscillating. However, when one of the keys TK0 to TK11 is actuated, the potential of the terminal will be raised when the glow in the stepping tube DD is resting on the cathode connected to the white contact of that key. Thus, if the key TK3, for example, is operated, the potential of the terminal T will be raised when the glow reaches the cathode 3 in the stepping tube DD.

The switch TKM is controlled by a TAB key (FIGURE 25) which is effectively a multiplier key, in the sense that, when the machine is set to perform multiplication, depression of this key opens the start contact SS, and that the key is locked in its operated position until the oscillator PV is stopped, when the key is automatically returned to its normal position.

When the tabulator keys are being used, the switch DKM is also operated so that the glow in the stepping tube DD is stepped forward one cathode each time a shift operation is performed by the machine. Thus, it will be assumed that the number 12.34 has been inserted at the right-hand end of the register, that the machine is switched to perform multiplication, that the switch DKM has been operated and that the tabulator key TK4 is depressed. If now the switch TKM is operated to start the machine, the machine will perform two shift cycles during the first of which the glow in the stepping tube DD will be stepped from the cathode 2 to the cathode 3 and during the second of which the glow will be stepped from the cathode 3 to the cathode 4. The numbers in the counting devices will also be shifted during these two shift cycles so that the number 12.34 will now be displayed in the display tubes of the counting devices 6R, 5R, 4R and 3R instead of in the display tubes of the counting devices 4R, 3R, 2R and 1R. The indicator tube DL4 situated between the display tubes and the counting devices 5R and 4R will be illuminated.

FIGURE 25 of the accompanying drawings is a plan view of the exterior of the machine hereinbefore described. This figure shows the physical arrangement of those parts of the machine which are required to be actuated or viewed by the operator.

It will be seen that the banks of keys 1K to 11K are arranged centrally on the top surface of the machine and that the bank of multiplier keys MK0 to MK9 is arranged on the right-hand side of the order of keys 1K and the bank of tabulator keys TK0 to TK11 is arranged on the left-hand side of the order of keys 11K. The cold-cathode display tubes 1RE to 12RE are arranged vertically in a housing above the general level of the top surface of the machine so that they are conveniently visible to the operator. The anodes of the display tubes 5RE to 12RE are connected to the supply through a contact which is opened when the machine is set to perform division, so that only the tubes 1RE to 4RE, which display the quotient, are illuminated. Between each pair of adjacent display tubes is one of the decimal-point-indicating tubes DL1 to DL11, and immediately in front of each of the indicating tubes DL1 to DL11 is a corresponding one of the keys DK1 to DK11.

Between the bank of multiplier keys and the order of keys 1K are two large keys 12 and 13. The former of these is the TAB key which operates the switch TKM (FIGURE 26). The key 13 is a multiplier decimal key which operates the switch DKM (FIGURE 26).

In front of the orders of keys are arranged a first bank of control keys 1 to 4 and a second bank of control keys 6 to 9. The control key 1 is pressed when the machine is required to perform addition, the control key 2 is pressed when the machine is required to perform multiplication, the control key 3 is pressed when the machine is required to perform subtraction and the control key 4 is pressed when the machine is required to perform division. The control key 6 is pressed when it is desired to return the counting devices at the left-hand side of the register to zero and the control key 7 is pressed when it is desired to return the counting devices at the right-hand side of the register to zero. Arrangements are provided for causing the key 6 to control the counting devices 7R to 12R and for the key 7 to control the counting devices 1R to 6R except when the machine is set for division, when the key 6 controls the counting devices 5R to 12R and the key 7 controls only the counting devices 1R to 4R. The switching arrangements for achieving this have not been particularly described since they will be obvious to anyone skilled in the art. The key 8 is used when it is desired to release keys in the orders of keys 1K to 11K which have been dpressed with the machine set to multiplication or division. This key is provided with an arm 5 similar to that illustrated in FIGURE 24 on the keys 1 and 3, which arm presses down the bail 30 when the key is depressed. The key 9 is used to clear any multiplier key which may not have been released as a result of interference with the normal operation of the machine during multiplication.

I claim:

1. A calculating machine including a plurality of orders of keys, a corresponding plurality of counting devices, a counting device being uniquely associated with each order of keys, one plurality of energisable electrodes arranged in a circular path and associated with said counting devices and with said orders of keys, means resulting from the actuation of a key of any one order of keys for energising a predetermined number of electrodes of the electrodes associated with said order of keys, the number of energised electrodes being related to the value of the actuated key, means for transmitting from the energised electrodes to the associated counting device a number of electrical impulses equal to the number of energised electrodes to effect a change, related to the value of the actuated key, in the registration of the said counting device, means operatively connected to the counting device of the lower order of two adjacent orders of counting devices and operable upon the counting device of the lower order registering a predetermined maximum value to feed an impulse to the counting device of the higher order and so cause the registration thereof to be increased by one, and means operable upon the actuation of a key to register a number in an associated counting device to ensure that any key of the order of keys including the actuated key is inoperable to register an additional number upon the said counting device until the number which the initially actuated key represents has been registered in the associated counting device.

2. A calculating machine comprising a plurality of pulse-operated counting devices, carry means effective between adjacent ones of said counting devices, a plurality of electrodes, a plurality of orders of keys coupled to said electrodes, each order being uniquely associated with one of said counting devices, means responsive to the actuation of any of said keys for establishing an electrical connection substantially simultaneously to a number of the electrodes equal to the value of the actuated key in its order, means for scanning all of the electrodes, and means responsive to the actuation of any of said keys for initiating a cycle of operation of the machine during which the orders of keys are successively coupled to their respective associated counting devices to cause a number of pulses equal to the value of any actuated key to be fed from the

connected electrodes to the counting device associated with the order of that key.

3. A calculating machine including a plurality of orders of keys, a corresponding plurality of counting devices each counting device comprising a multi-cathode stepping electronic tube, a batch of electrodes uniquely associated with each counting device and each order of keys, means resulting from the actuation of a key of an order of keys for selecting a predetermined number of electrodes of a batch of electrodes, the selected number of electrodes being related to the value of the actuated key, means for energising the selected electrodes, means for transmitting sequentially from the energised selected electrodes of the batches of electrodes to the counting devices associated with said batches of electrodes a number of electrical impulses to each counting device equal to the number of selected electrodes associated with said counting device to effect a change, related to the value of the actuated key, in the registration of the said counting device, a valve common to the counting devices of the different orders operatively connected to the counting devices of adjacent orders in such a manner that as a result of a counting device registering a predetermined maximum value the said valve feeds an impulse to the counting device of the next higher order to increase the registration thereof by one, and a display device operatively connected to the cathodes of each counting device in such a manner that when the glow is arrested upon a cathode of the counting device the outline of a numeral corresponding to the numeral registered by the cathode of the counting device is displayed by the display device associated therewith.

4. A calculating machine comprising a plurality of impulse counting devices, one for each of a plurality of denominational orders, a plurality of sets of switches, one set uniquely associated with each of said counting devices, pulse delivery means to deliver impulses to said counting devices successively during separate phases allocated to said counting devices individually within a machine cycle and in response to the operation of a switch in each of the switch sets of said one or more counting devices, said impulses being determined in number for each of said one or more counting devices by the operated switch in the corresponding one of said sets, a single two-state carry storage device input-connected to all of said counting devices and settable to one state upon the appearance in any of said counting devices of a pulse count of predetermined value, and means responsive to the setting of said carry storage device to said one state to deliver an additional impulse to said pulse delivery means for delivery thereby to the counting device of phase succeeding that of the counting device in which said predetermined pulse count appeared.

5. A calculating machine according to claim 4 wherein said means to deliver an additional impulse comprises a second two-state device settable to a state effective for pulse delivery only upon restoration of said first two-state device to its other state, and means operative at the beginning of each of said phases to reset said first two-state device to its other state if and only if it has been set to its said one state.

6. A key controlled electronic calculating machine which comprises in combination a plurality of orders of keys, an accumulator controlled by electrical impulses uniquely associated with each order of keys, impulse distributing means operable, as a result of the actuation of any one key of an order of keys, to introduce into the accumulator associated with said order of keys an impulse or a series of impulses related to the value of the actuated key so as to increase the value registered in the accumulator by an amount equal to the complement of the value of the actuated key, an electronic stepping tube, means for shifting the contents of the accumulator associated with the highest order of keys into the said tube, means for complementing and shifting the contents of each accumulator into the accumulator associated with the next higher order of keys, means for increasing the number registered by said tube by unity each time a cycle of operation of the machine does not result in a carry from the accumulator associated with the highest order of keys, and means for initiating a number of cycles of operation of the machine equal to the number required to produce a carry from said tube.

7. A calculator comprising a plurality of accumulators, one for each of a plurality of numerical orders, a carry accumulator, separate carry means coupled between each accumulator of said plurality and the accumulator of adjacent higher order in said plurality and between the accumulator of highest order in said plurality and said carry accumulator, and means to change the count in each accumulator of said plurality except the lowest to a complement of the count in the accumulator of adjacent lower order, to change the count in said carry accumulator to a complement of the count in the accumulator of highest order in said plurality, and to change the count in the accumulator of lowest order in said plurality to a complement of the count in said carry accumulator.

8. A decimal calculator comprising a plurality of orders of keys, a plurality of accumulators, one for each of said orders, means operable, in response to the actuation of any one key in each of one or more of said orders, to introduce into the accumulators of corresponding order pulses in number equal to the nines complement of the actuated key of such order, a carry accumulator, separate impulse carry means between each accumulator of said plurality and the accumulator of adjacent higher order and between the accumulator of highest order in said plurality and said carry accumulator, and means responsive to such introduction without the occurrence of an impulse carry into said carry accumulator to shift the impulse count in each accumulator of said plurality to the nines complement of the count in the accumulator of next lower order in said plurality, to shift the count in the accumulator of lowest order in said plurality to the nines complement of the count in said carry accumulator, and to shift the count in said carry accumulator to the nines complement of the count in the accumulator of highest order in said plurality.

9. A key controlled calculating machine which comprises in combination a plurality of keys, a plurality of counting devices, each counting device being associated with a single denominational order, a plurality of circumferentially arranged stationary energisable electrodes associated with said counting devices, means resulting from the actuation of a key of said plurality of keys for selecting a predetermined number of the electrodes of the said plurality of electrodes, the selected number of electrodes being related to the value of the actuated key, means for applying a potential to each of the preselected electrodes and for transmitting in succession from said electrodes to the counting device associated with said actuated key a number of electrical impulses equal to the selected number of electrodes to effect a change, related to the value of the actuated key, in the registration of the said counting device, a multicathode stepping electronic tube, a series of multiplier keys each associated with a cathode of the multicathode stepping electronic tube, said stepping electronic tube being operable, as a result of the actuation of a multiplier key of the series of multiplier keys and after the impulse or the plurality of impulses related to the value of the actuated key of the plurality of keys have been transmitted to the associated counting device, to cause the glow on a cathode of the stepping electronic tube to be moved to the next adjacent cathode and cause the transmission means for transmitting the impulses to transmit a further impulse or a further plurality of impulses to the associated counting device, means operable, after the glow on the cathode of the stepping electronic tube has been moved sequential-