the stepping electronic tube L to step the glow from L^1_9 to L^1_0 and in so doing transmit an impulse to the trigger electrode T^1_2 of the valve T_2 causing the valve T_1 to be rendered nonconductive and the valve T_2 conductive. Upon the valve T_1 being rendered nonconductive a pulse is applied from the anode thereof to the trigger electrode T^1_6 of the valve T_6 which renders the valve T_6 conductive and the valve T_5 nonconductive.

When the valve T_5 is rendered nonconductive a zero potential is applied from the anode T^1_5 of the valve T_5 to the studs E^0 arranged in advance of the commutator segments Z_9, Y_9 and so on up to H and L. When the brush F^1 bridges the successive pairs of studs E^0—E^0, zero potential is applied from the anode T^1- of the valve T_5 to the normally negatively biased trigger electrode of the valve T_8 which is thereupon rendered conductive. When rendered conductive the valve T_8 applies a negative potential to the studs O_{12} to O_{21}, P_{12} to P_{21}, up to H_{12} to H_{21} and to the studs P_{22} to P_{30} and so on up to L_{22} to L_{30}.

The sequence of operations is that the shifting operation commences at the accumulator Z_{10}. The contents of Z_{10} are initially transferred into the control tube L without being complemented, leaving the accumulator Z_{10} clear. The contents of the accumulator Y_{10} are then shifted into the accumulator Z_{10} and complemented, the contents of the accumulator X_{10} complemented and shifted into the accumulator Y_{10} and so on until the contents of the accumulator O_{10} are complemented and shifted into the accumulator P_{10}. At this stage the contents of the accumulator H_{10} are complemented and shifted into the accumulator O_{10} which has become a clear stage. This leaves the accumulator H_{10} clear. The number which should have been complemented and shifted, at the commencement of the operations from the accumulator Z_{10} into the accumulator H_{10} can now be shifted and complemented from the accumulator L into the accumulator H_{10}. As the tube L is used to control "catching up," it is necessary that the number which was shifted, without complementing from Z_{10} into the tube L be preserved in the tube L. Accordingly, it is essential in the step of shifting and complementing the content of L into H_{10} to deliver ten pulses to the tube L and not to stop pulsing it when it reaches zero. The studs L_{12} to L_{21} are therefore supplied with a voltage from the anode of the valve T_6 which is conductive during the whole cycle of shifting and complementing.

It will therefore be observed that in order to effect division the dividend is firstly added into the register. The machine is set for division, whereupon the stepping electronic tube L is set to **9**. The divisor is entered on the keys of the main keyboard and the DIVIDE key is actuated once for every digit of the quotient that the operator desires. The actuation of the DIVIDE key merely effects the operation of the one shot device which causes the valve T_1 to become conductive. The valve T_1 applies a potential through the switch CS_4, the contacts K of the various batches of studs O_0 to O_8, P_0 to P_8 and so on up to Y_0 to Y_8 and Z_0 to Z_8 and depending upon which keys in the various orders of keys have been actuated so the various studs (viewing from the left-hand side of FIGURE 1) Z_8 to Z_0, Y_8 to Y_0 and so on down to P_8 to P_0 and O_8 to O_0, have a potential placed upon them and to complement of the divisor is added into the successive accumulators Z_{10}, Y_{10} and so on up to P_{10} and O_{10}. If upon the addition of the complement of the divisor to the dividend there is no transfer from the accumulator Z_{10} to H_1, the valve T_9, which is normally conductive, applies a potential through the studs **4—4** to the drive electrode L^{11} of the stepping electronic tube L and causes the glow on the electrode L^1_9 to move to the electrode L^1_0 with the result that a pulse is applied from the electrode L^1_0 to the trigger electrode T^1_2 of the valve T_2 causing the valve T_2 to be rendered conductive and the valve T_1 to be rendered nonconductive. Upon the valve T_1 being rendered nonconductive a pulse is sent to the trigger electrode T^1_6 of the valve T_6 which is rendered conductive causing the valve T_5 to be rendered nonconductive. Upon the valve T_5 being rendered non-conductive, zero potential from the anode T^2_5 of the valve T_5 is applied to the studs E^0 arranged in advance of the commutator segments Z_9, Y_9 and so on up to H and L and as the brush F^1 bridges and short circuits the associated studs E—E the zero potential from the anode T^2_5 of the valve T_5 is applied to the trigger electrode T^1_8 of the valve T_8 which thereupon becomes conductive and applies a potential to all of the studs of both sets of studs O_{12} to O_{21}, and P_{12} to P_{21} and so on up to H_{12} to H_{21}, as well as upon the studs P_{22} to P_{30} and so on up to H_{22} to H_{30} and L_{22} to L_{30}. The studs L_{12} to L_{21} are fed with −150 volts from T_6 whilst the studs O_{22} to O_{30} are energised from T_7.

As a result of this operation and the movement of the brushes F^1 and F^2 over the various studs and the commutators of the various accumulators, the numeral standing in any one accumulator is shifted to the next order and complemented. Thus the numeral standing in the accumulator Z_{10} is moved into the tube L without being complemented and is also moved into the accumulator H_1 and complemented, the numeral standing in the accumulator Y_{10} is shifted into the accumulator Z_{10} and complemented and so on until the numeral appearing in the H_1 accumulator is shifted into the O_{10} accumulator and complemented.

After this operation is completed the operator once again actuates the key marked DIVIDE on the control panel, whereupon the operation as hereinbefore described is repeated with the exception that if there is a transfer from the accumulator Z_{10} into the accumulator H_1 the valve T_9 will be rendered nonconductive and in consequence the studs **4** will have a zero potential applied to one of them which when applied through the brush F^1 to the drive electrode L_1 of the stepping electronic tube L will have no effect, and consequently the valve T_2 will not be rendered conductive and in consequence the valve T_1 will remain conductive and the valve T_6 will remain non-conductive and the operation of adding the complement of the divisor to the dividend will continue.

When, however, the numeral which is shifted from the accumulator Z_{10} into the stepping tube L is not nine, it will be observed that until the stepping electronic tube L has been moved so that the glow is on the electrode L_0 the shifting and complementing operation hereinbefore described will not take place and the machine under such circumstances performs automatically what is known as catching-up. The amount that has got to be caught up is determined by the stepping electronic tube L which is in turn controlled by the numeral which is transferred from the accumulator Z_{10} into the said stepping electronic tube L. The process carried out by the machine is best understood from the attached chart in which the operation of the machine is shown in the case in which the numeral 2555 is being divided by the numeral 35. As hereinbefore stated the dividend 2555 is first introduced with the machine set for addition and the numeral 2 in the twelfth order of keys. The machine is thereupon set for division and the keys **35** in the twelfth and eleventh order of keys are actuated. The stepping electronic tube L is set to L_9 with the result that the cycle of operations, which will be clearly appreciated from the following chart, is initiated. The operator depresses a key marked DIVIDE as many times as there are required digits of the quotient.

The following chart is set out with only the readings of the first three and the last five accumulators as the readings of the remaining five accumulators will only vary between 0 and 9.

In the foregoing chart, the numbers in line 1 show the content of the register after the machine has been set up to divide 2555 by 35. The "add 65" operation described at the right of that line results from a first operation of the DIVIDE key of FIG. 3. Line 2 represents the

	H_1	L	Z_{10}	Y_{10}	X_{10}	W_{10}		Q_{10}	P_{10}	O_{10}	
1	0	9	2	5	5	5	0	0	0	0	Add 65 in Z_{10} and Y_{10}.
2	0	0	9	0	5	5	0	0	0	0	No carry from Z_{10} to H_1 but one pulse is added to L causing glow to reach L_0. Therefore shift and complement. (Note that contents of Z_{10} are shifted into L without complementing and into H_1 with complementing.)
3	0	9	9	4	4	9	9	9	9	9	Add 65 in Z_{10} and Y_{10}.
4	1	9	5	9	4	9	9	9	9	9	Carry from Z_{10} to H_1. Therefore add 65 again.
5	2	9	2	4	4	9	9	9	9	9	Carry from Z_{10} to H_1. Therefore add 65 again.
6	2	0	8	9	4	9	9	9	9	9	No carry from Z_{10} to H_1 but one pulse is added to L causing glow to reach L_0. Therefore shift and complement.
7	1	8	0	5	0	0	0	0	0	7	(Note that glow is now on L_8 indicating that there is "1" to catch up.) Add 65.
8	1	9	7	0	0	0	0	0	0	7	No carry from Z_{10} to H_1 but one pulse is added to L causing glow to reach L_9 which indicates that "1" has been caught up. Add 65.
9	2	9	3	5	0	0	0	0	0	7	Carry from Z_{10} to H_1. Therefore add 65 again.
10	3	9	0	0	0	0	0	0	0	7	Carry from Z_{10} to H_1. Therefore add 65 again.
11	3	0	6	5	0	0	0	0	0	7	No carry from Z_{10} to H_1 but one pulse is added to L causing glow to reach L_0. Therefore shift and complement.
12	3	6	4	9	9	9	9	9	2	6	(Note that the glow is now on L_6 indicating that there is "3" to catch up.) Add 65 in Z_{10} and Y_{10}.
13	4	6	1	4	9	9	9	9	2	6	Carry from Z_{10} to H_1. Therefore add 65 again.
14	4	7	7	9	9	9	9	9	2	6	No carry from Z_{10} to H_1 but one pulse is added to L causing glow to reach L_7 which indicates that there is still "2" to catch up. Therefore add 65 again.
15	5	7	4	4	9	9	9	9	2	6	Carry from Z_{10} tl H_1. Therefore add 65 agian.
16	6	7	0	9	9	9	9	9	2	6	Carry from Z_{10} to H_1. Therefore add 65 again.
17	6	8	7	4	9	9	9	9	2	6	No carry from Z_{10} to H_1 but one pulse is added to L causing glow to reach L_8 which indicates that there is still "1" to catch up. Therefore add 65 again.
18	7	8	3	9	9	9	9	9	2	6	Carry from Z_{10} to H_1. Therefore add 65 again.
19	8	8	0	4	9	9	9	9	2	6	Carry from Z_{10} to H_1. Therefore add 65 again.
20	8	9	6	9	9	9	9	9	2	6	No carry from Z_{10} to H_1 but one pulse as added to L causing glow to reach L_9 indicating that catching up is complete. Add 65 again.
21	9	9	3	4	9	9	9	9	2	6	Carry from Z_{10} to H_1. Therefore add 65 again.
22	9	0	9	9	9	9	9	9	2	6	No carry from Z_{10} to H_1 but one pulse is added to L causing glow to reach L_0. Therefore shift and complement.
23	0	9	0	0	0	0	0	7	3	0	Quotient appears in Q_{10} and P_{10}.

result of that operation, but it cannot be seen, in practice, by the observer since the shift and complement operation of line 2 follows automatically in a time which may readily be a small fraction of a second.

The result of this shift and complement operation is shown in line 3. The machine has now come to a stop, and O_{10} contains the nines complement of the first quotient digit.

The operator presses the DIVIDE key again, as a result of which the machine carries out the operations described at the right of lines 3 through 6. The machine comes to rest displaying the numbers shown in line 7, where the contents of P_{10} and O_{10} are the first two quotient digits in true form.

The operator now presses the DIVIDE key a third time, as a result of which the machine carries out the operations described at the right of lines 7 through 11, the machine coming to rest displaying the numbers shown in line 12. The contents of Q_{10}, P_{10} and O_{10} now represent the first three quotient digits in nines complemental form. Note that in this sequence of operation the first addition of the divisor complement represents catching up and not, in the narrow sense, extraction of a quotient digit.

The operator now punches the DIVIDE key a fourth time, initiating the operations described in lines 12 through 22 resulting in stopping of the machine with the register as indicated in line 23, where the four quotient digits appear in R_{10} (not shown, but displaying zero) Q_{10}, P_{10} and O_{10}.

On division operation of the DIVIDE key **400** of FIGS. 3 and 11 briefly closes a pair of normally open contacts temporarily to connect the L^1_9 cathode in tube L of FIG. 1 to the −150 volt bus shown beneath that tube in order to draw the glow in that tube to cathode L^1_9. The multiplier keys **1** through **9** effect respectively temporary closure, during multiplication, of similar normally open contacts between the −150 volt bus and the cathodes L^1_9 through L^1_1 respectively. For the multiplied digit 0, similar contacts are provided between the L^1_0 cathode and the −150 volt bus.

There has been hereinbefore described with reference to FIGURE 1 of the accompanying drawings a circuit diagram of a calculating machine capable of carrying into effect electronically operations which hitherto have been mainly, if not solely, effected by mechanical means. In FIGURES 3 to 10 there are illustrated a machine and the parts thereof showing one means whereby the essential mechanical operations of such a machine are carried into effect so as to ensure that the electrical result designed to be achieved by means of the circuit arrangements illustrated in connection with FIGURE 1 may be effected as a result of certain mechanical actuations on the part of an operator.

Thus, FIGURES 3 and 4 illustrate a calculating machine having a plurality of orders of keys **80**, an accumulator **70** associated with each order of keys, selecting means, in the form of a rotatable brush F and a commutator plate **12** operable upon the actuation of a key in any one order of keys to ensure the transmission of a selected number of electrical impulses to control the actuation of the accumulator **70** associated with the said orders of keys and ensure that the number registered by the said accumulator **70** is varied by an amount related to the numeral which the actuated key represents.

Further, means are provided for controlling adjacent pairs of accumulators **10** so that a transfer from one order of the machine may be recorded in the accumulator of the next adjacent higher order.

The machine illustrated in FIGURES 3 and 4 comprises a base frame **10** to which is fitted or secured a panel **11**, which may be made in a single piece or as a built up structure. The panel **11** is arranged to embody or carry a commutator plate **12** upon which are arranged either in the form of a printed circuit or as elements embedded in a suitable material or in any other desired manner, studs corresponding to the studs O_0 to O_8, P_0 to P_8, Q_0 to Q_8 and so on up to Y_0 to Y_8 and Z_0 to Z_8 of the circuit illustrated in FIGURE 1 and also commutator segments O_9, P_9, Q_9 and so on up to Y_9 and Z_9 corresponding to the commutator segments O_9 to Z_9 of the circuit illustrated in FIGURE 1. The commutator segments O_9 to Z_9 are arranged on the plate **12** so as to be respectively associated with the batches of studs O_0 to O_8, P_0 to P_8, Q_0 to Q_8 and so on up to Y_0 to Y_8 and Z_0 to Z_8. In addition to the studs hereinbefore referred to there are provided in advance of the batch of studs O_0 to O_8, the two studs C and B and the stud D. In advance of each of the remaining batches of studs P_0 to P_8, Q_0 to Q_8 and so on up to Y_0 to Y_8 and Z_0 to Z_8 are three studs C, B and A. Mounted in advance of each commutator segment corresponding to the various batches of studs are contacts C_1 and B_1. Each of the studs A are arranged in line with the leading end (that is the right-hand end when viewing FIGURE 1) of each commutator segment P_9, Q_9 and so on up to Z_9 and H. The commutator plate **12**, whether formed integral with or supported by the panel **11**, has in the example illustrated in FIGURES 3 and 4 the studs and the commutator segments thereof mounted on the under-side so as to face downwardly when viewing FIGURE 3. Secured upon the panel **11** which carries the commutator plate **12** are, if necessary, a series of additional commutator plates, for example the commutator plates **14** and **15**, which are employed in a calculating machine where functions such as automatic multiplication and division are desired. The commutator plates **14** and **15** are carried upon columns **16** and **17** and in the example illustrated carry their requisite studs and commutator segments upon the upwardly directed face thereof. Arranged to extend through the plates **12**, **14** and **15** and carried in suitable bearings on intervening panels **18** and **19** is a spindle **20** to which are attached suitable brushes F, F^1 and F^2 arranged to bridge the studs and the commutator segments and the pairs of studs hereinbefore referred to and in the manner described in connection with FIGURE 1. The brushes F, F^1 and F^2 are arranged to be rotated by means of a pulley-wheel **21** mounted at the upper end when viewed in FIGURE 3 of the spindle **20**, the pulley **21** being secured to the spindle and arranged to receive a belt **22** which engages with a pulley **23** driven by a vertical output spindle **25** of an electric motor **24**.

The motor **24** with integral gear reduction is mounted on the base **10** and is connected, for example, by two belts from two pulleys **27** and **26** mounted upon the vertical output spindle **25** of the gear box or by any other conventional gears and shafts to a spindle **301** of the accumulator **70** and to the spindle **50** of the keyboard delay mechanism hereinafter described.

The keyboard delay mechanism is arranged to ensure that once a key of any order of keys has been actuated another key in the same order of keys cannot be actuated until the machine has cleared all the data which is carried upon the commutator plates **12**, **14** and **15**.

The machine illustrated in FIGURES 3 and 4 shows a machine having a plurality of orders of keys which are operable to vary the numeral displayed either upon a mechanically operated accumulator wheel **70** or any stepping electronic tubes arranged either to supplement or take the place of the said mechanically operated accumulator wheel **70**.

Referring to FIGURES 3 and 4, there will now be described how the motor **24** is switched on when any one key of the plurality of orders of keys **80** which comprises the main keyboard of the machine is actuated in a calculation involving addition and subtraction. Normally, the motor **24** is switched off and arranged to be brought into operation by permitting a yieldingly-controlled contact **34** to make contact with a contact **35**.

Dealing with a calculation involving addition, the mechanism for permitting the contact **34** to engage with the contact **35** comprises a switch stirrup **29** (FIGURE 3) which is arranged to span the main keyboard and is provided with an upwardly projecting arm **30** connected adjacent to the right-hand end thereof (when viewing FIGURE 3). The arm **30** is provided with a hole at the upper extremity thereof arranged to receive the end of a rod **31** which is guided between a pair of studs or pressed lugs **32** carried by or formed upon a fixed part of the machine. The free end of the rod **31** (FIGURE 4) is arranged to bear against the face of a flap **33** mounted upon a pivot **34***a*. The flap **33** is provided at the displaceable free end thereof with a rearwardly extending projection **33***a*, the free end of which abuts against an insulated button **36** fitted to the displaceable end of the spring contact **34**. It will be observed that when any one key of an order of keys is actuated the rod **31** moves with the associated key bar **37** towards the left-hand side of the drawing (when viewing FIGURE 4) and thereby permits the flap **33** to move to the left about its pivot **34***a* (when viewing FIGURE 4) and thereby permit the contact **34** to move into engagement with the contact **35**, and so close the circuit of the motor **24**. Upon the restoration of the actuated key to its normal position the rod **31** will push the flap **33** towards the right and thereby move the contact **34** out of engagement with the contact **35** and so open the circuit of the motor **24**.

It will be appreciated that in order to ensure that the overrun of the motor continues for a sufficient time to permit, for example, the accumulator **70** to follow any change in the stepping electronic tubes effected by the bridging of the studs and commutator segments described with reference to FIGURE 1, it may be necessary to provide either a mechanical delay device such as a dashpot or the electrical equivalent in the circuit between the contacts **34**, **35** and the motor **24**.

In order to effect multiplication upon a machine embodying the characteristics hereinbefore described it is first necessary to "make" switch CS_8 and to move the common terminal of the switch CS_9 to the left, thereby connecting a stepping electronic counter tube L in circuit with the stud **3** and also the trigger electrode T^1_2 of the valve T_2 in circuit with the zero cathode of the tube L. The above operation can be effected by the actuation of the multiplication key **39** in the control column **40** of FIGURE 3.

The stepping tube L is set by the actuation of one of a series of multiplier keys numbered **0** to **9** mounted in the multiplier key column **38** of FIGURE 3. Normally the tube L is clear and if it is desired to effect multiplication by any numeral the actuation of the corresponding multiplier key sets the stepping electronic tube L to the "tens" complement of that figure. Thus, if it is desired to multiply by six, the actuation of the No. 6 multiplier key will ensure that the stepping electronic tube L is set for 10—6, namely 4, thereby ensuring that the stepping electronic tube L is moved six steps in returning to zero or the clear position. At the clear or zero position a potential will be applied to the trigger electrode T^1_2 whereby the valve T_2 will be rendered conductive and in consequence render the valve T_1 nonconductive and so break the supply of potential to the studs of the various orders of keys.

The arrangement for carrying into effect automatic multiplication of a multiplicand by a digit of a multiplier necessitates the driving electrode L^{11} of the stepping electronic tube L being connected to one of the pair of studs **3**—**3** the other stud being connected to the anode T^3_1 of the valve T_1. The arrangement is such that when it is desired to multiply a number for example 851 by 97 the multiplication key **39** of the control column **40** is actuated and then the keys **1**, **5** and **8** of the first, second and third order of keys are depressed. The keys so representing the multiplicand are locked or held in their actuated position. Upon the actuation of the No. 7 key of the multiplier keys the motor operable to drive the machine is set in operation and thereafter the one shot device is actuated in a manner hereinafter described. The actuation of the multiplier key will set the stepping electronic tube L to 10–*n*, where *n* represents the numeral of the multiplier key which has been actuated and which in the example chosen will be **7**. Upon the actuation of the selected multiplier key the one shot device U is operated and an impulse is transmitted through the studs

E—E to the trigger electrode T^1_1 of the valve T_1 which is rendered conductive and the valve T_2 nonconductive. Upon the valve T_1 being rendered conductive a potential is applied, by way of the contacts CS^3_4 and CS^1_4 of the two-way switch CS_4, to the studs Q_0 to Q_7 of the third order of keys, to the studs P_0 to P_4 of the second order of keys and to the stud O_0 of the first order of keys.

The multiplier key No. 7 of the stepping electronic tube L has initially been actuated with the result that a glow will occur upon the cathode L^1_3. As the brush F sweeps over the various orders of keys it will transmit in its first revolution eight impulses to the accumulator Q_{10}, five impulses to the accumulator P_{10} and one impulse to the accumulator O_{10}. When the brush F has completed one revolution a circuit will be completed through the contacts 3—3, through the drive electrode L^{11} of the stepping electronic tube L whereupon the glow at the cathode L^1_3 of the stepping electronic tube L will be extinguished and a glow at the electrode L^1_4 will be formed. An impulse is not transmitted to the trigger electrode T^1_2 of the valve T_2 by the zero cathode and in consequence the valve T_2 remains nonconductive, and the valve T_1 remains conductive. In the conductive state of the valve T_1 it is connected through the two-way switch CS_4 to the studs of the first, second and third order of keys and the brush in commencing its second revolution will transmit one impulse to the accumulator O_{10}, five to the accumulator P_{10}, which will cause the accumulator P_{10} to read zero and transfer, in the manner hereinbefore described, an impulse by way of the stud A to the accumulator Q_{10}. In addition the accumulator Q_{10} will receive eight impulses from the studs associated therewith, bringing the total number of impulses transmitted to the accumulator Q_{10} up to 17. As a result of seventeen impulses having been transmitted to the accumulator Q_{10} one impulse will be transferred from the accumulator Q_{10} to the accumulator R_{10}, thus causing the accumulators O_{10}, P_{10}, Q_{10} and R_{10} to read 2, 0, 7 and 1 respectively. Upon the completion of the seventh revolution of the brush F the glow at the cathode L^1_9 of the stepping electronic tube L will be extinguished and the glow will pass from the cathode L^1_9 to the cathode L^1_0. Upon the glow passing from the cathode L^1_9 to the cathode L^1_0 a pulse will be transmitted to the trigger electrode T^1_2 of the valve T_2. The valve T_2 is thereupon rendered conductive and the valve T_1 nonconductive. At this point the keys **1**, **5**, **8** of the first, second and third orders of keys are released either by the operator so as to permit them to return to their initial positions or by depressing an appropriate control key.

When the machine hereinbefore described is set to effect a calculation involving multiplication it is first necessary for the multiplicand to be inserted into the main keyboard and for the actuated keys of the multiplicand to be held in their actuated condition, after which a multiplier is inserted into the machine by the actuation of a multiplier key of a set of multiplier keys ranging from **0** to **9** provided in column **38** (FIGURE 3).

A key **39** in a control column **40** is marked to indicate multiplication. When the key **39** is actuated, a motor switch rod **41** associated with the keys of the multiplier column **38** is brought into action. In the case of a calculation involving addition the end of the motor switch rod **41** (when viewing FIGURE 4) is held clear of the path of the free end of the flap **33** by a link **42** (FIGURE 3) connecting the switch rod **41** with a stirrup member **43** which is pivotal about the axes **44** and **45**.

The end **46** of the pivotal stirrup member **43** which is disposed towards the front of the machine is arranged to project under the stem of the multiplication key **39** so that upon the actuation of the multiplication key **39** the stirrup **43** is rocked about the pivotal axes **44** and **45** thereof and in consequence draws the switch rod **41** into the path of the flap **33**. As hereinbefore described the actuation of the keys of the main keyboard, for a calculation involving addition, will withdraw the rod **31** from engagement with the free end of the flap **33** but, in a calculation involving multiplication, the provision of the switch rod **41** will prevent the movement of the flap **33** and in consequence the contact **34** will be prevented from engaging with the contact **35**. However, after the insertion of a multiplicand into the main keyboard, the actuation of a multiplier key in column **38** will rock an individual motor switch bar **48** to withdraw the rod **41** from engagement with the flap **33** and thereby permit the contact **34** to engage with the contact **35**.

If the motor **24** were rotating whilst the above operation was being carried into effect the shaft **50** which is driven through a pulley **51** by the belt **52** from the pulley **26** mounted upon the vertical output spindle **25** of the motor **24** would be rotating. It will be readily appreciated, however, from the description of a key delay release mechanism hereinbefore set forth that upon the mere depression of a multiplier key in the column **38** all the keys of the multiplicand would be restored to normal and any further introduction, of the multiplicand into the accumulators would be prevented. It is therefore necessary to provide means whereby upon the depression of a single multiplication key **39**, the pulley **51** is unclutched from the shaft **50** and the shaft **50** is locked against rotation until either the multiplication key **39** is released or until a cancel or display key is actuated. If it is desired to effect a series of multiplications by actuating a succession of multiplier keys it is possible to latch the multiplication key **39** in a depressed condition in a manner hereinafter described.

To connect the pulley **51** to the dog clutch **53** fixed to the shaft **50** for the purpose of restoring the keys after multiplication, and yet to retain the key **39** in its latched condition, it is necessary for the actuation of either the cancel keys **89** and **90** or the display keys **91** and **92** (FIGURE 3) to override the connection between the key **39** and pulley **51**. In order to achieve this result the pulley **51** is positioned either free or in engagement with the dog clutch **53** by a forked member **54**. When force is applied to the forked member **54** to rock the same in a clockwise direction (when viewed in FIGURE 3) about a pivot **56** it slides the pulley out of engagement with the clutch **53** and by the same motion causes the spring tongue **55** fixed to the fork **54** to move into engagement with serrations **57** on the adjacent face of the dog **53** and thereby stop the rotation of the spindle **50**.

The member **54** is moved (clockwise when viewing FIGURE 3) to cause the pulley **51** to disengage the dog **53** when a downwardly extending arm **58** mounted on the stirrup member **43** is actuated to pull a connecting link **59** to the right (when viewing FIGURE 3) upon the actuation of the multiplication key **39**. Movement of the downwardly extending arm **58** is transmitted to the connecting link **59** through an adjustable compression spring **60**. A collar **61** is provided on the connecting link **59** to ensure that upward movement of the key stem of the multiplication key **39** releases the link **59** to allow the fork member **54** under the influence of a light torsion spring **62** to move in a counterclockwise direction and cause the pulley **51** to re-engage the dog **53**.

When the multiplication key **39** is latched down for a series of multiplications by the successive actuations of various multiplier keys, the actuation of the stems of the cancel keys or the stems **63** or **64** of the display keys rocks a stirrup **65** about the pivotal axes **66** and **67** thereof to cause a depending arm **68** mounted thereon to engage a collar **69** secured relatively to the connecting link **59**. The pressure exerted by the depending arm **68** on the collar **69** will compress the spring **60** still further and move the connecting link **59** to the left (when viewing FIGURE 3), so causing the fork member 54 to move the pulley 51 into engagement with the dog 53.

Should the teeth 53*a* of the dog 53 and 51*a* of the pulley 51 not freely engage with one another immediately, the arm 71 of the forked member 54 will yield slightly under the influence of a spring 72.

In the event of a calculation involving "division" or "subtraction" it is necessary to control the drive to shaft 50 in a similar fashion to that described above in connection with multiplication. It will be observed that the subtraction key is constructed in a manner similar to the division key and is released in the same way as the division key.

Referring to FIGURE 12 there is illustrated in side elevation the control key column 38 and stirruped parts 43 and 65 which control the disengagement and reengagement of the drive 50 to the delay device hereinbefore described. FIGURE 12 shows means of latching down the multiplication key 39 either in a manner sufficient to effect multiplication by a single digit (for example by any figure up to 9) or for a longer period where a succession of multiplications by a series of digits is to be effected (for example multiplication by a number in excess of 10).

The stems of the various control keys are arranged to extend through an upper guide plate 80 and a lower guide plate 81 of a switch unit. The key stems 82 carry contacts which correspond to the switch contacts of the circuit diagram illustrated in FIGURE 1 which are arranged to be moved into and out of engagement with contacts mounted on insulating panels 83 so as to make and break circuits required for the particular calculation to be undertaken. The key stems 82 are held in their inoperative or rest position by means of compression springs 84 arranged to extend between the upper guide plate 80 and a collar 85 secured relatively to the associated key stem 82. The upper portion of each key stem 82 is arranged to extend through a subsidiary guide frame 86 and the lower portion of each key stem 82 is arranged to extend to a position above, but just clear of parts of the stirrups 43 or 65 (FIGURE 3), as previously described.

The stems of the cancel keys 89 and 90, the plus key 87, and the display keys 91 and 92 slide freely in the guide frame 86, whereas the keystems of the multiplication key 39, the division key 93 and the minus key 88 are jointed at 94 and 98 respectively. Such a construction enables the upper part 95 of the stem 82 of the multiplication key 39 to be tilted forwardly or backwardly by the operator, whilst the joint 98 of the stem 82 of the division key 93 permits the upper part 97 of the keystem to be moved forwardly. Similarly the minus key 88 is permitted to be tilted forwardly. The depression and the tilting forwardly of the multiplication key 39 will cause a nib 94 on the upper part 95 of the keystem to engage the underside of the subsidiary guide frame 86 at 96. In this position multiplication can be effected by one digit or by a series of digits forming one multiplier in the case where automatic multiplication is involved and where after each multiplication by a digit of the multiplier the content of each accumulator is automatically moved into the next higher order. At the completion of multiplication, pressure on the plus key 87 will move a tongue 97 secured relatively to the keystem 82 of the plus key 87 downwardly against the influence of a spring 84, into contact with the horizontal arm 98 of a bell crank lever 99 mounted upon a pivot 100 and sprung upwardly by tension spring 105. The upper edge 101 of the upwardly extending arm 102 of the bell crank lever 98 will when the lever 98 is moved downwardly by the tongue 97, engage with the forwardly direct face of the upper part 95 of the keystem 82 of the multiplication key 39 and push the said upper part 95 rearwardly (that is to the right when viewing FIGURE 12) to release the nib 94 from engagement with the subsidiary frame 86 at 96. Similarly, the depression of the display keys 91 and 92 will cause the tongues 103 and 104 mounted on the respective keystems to effect the same result.

The depression of the cancel key 90 will move a ramped tongue 106 into contact with the upper edge 101 of the upwardly directed arm 102 of the bell crank lever 99 and rock the bell crank lever 99 about its pivot 100 to release the upper part 95 of the keystem 82 of the multiplication key 39. The provision of the ramped tongue 106 avoids the necessity of actuating the plus key after a single multiplication as either of the display keys 91 or 92 or the cancel keys 89 or 90 will restore the upper part 95 of the keystem 82 of the multiplication key 39.

The second cancel key 89, having a similar but larger ramped tongue 107, functions in the same manner.

When a considerable number of separate multiplication problems have to be performed it is a convenience if the operator is relieved from setting the multiplication key 39 for each problem. An alternative latched position for the multiplication key is provided.

In order to effect such more permanent latching of multiplication key 39 the operator must depress the key 39 and tilt the upper part 95 thereof rearwardly (that is to the right when viewing FIGURE 12) so that a nib 108 secured relatively to the stem 82 is trapped under the frame 86 at 109.

The depression of the display keys 91 and 92 or the cancel keys 89 and 90, whilst performing the appropriate electrical functions by means of contacts carried by the stems 82 and the associated panels 83, hereinbefore referred to, will also rock the bell crank lever 99 and the edge 101 of the upwardly extending arm 102 of the bell crank lever 98 as hereinbefore described, but this action will be ineffective with respect to the upper part 95 of the keystem 82 of the key 39 in the rearwardly directed position thereof in view of the fact that the said upper part 95 is latched away from and clear of the arc of movement of edge 101 of the upwardly extending arm 102 of the bell crank lever 98.

The multiplication key 39 is restored to normal at the conclusion of a succession of multiplications by a series of separate multipliers by the operator depressing the plus key 87, whereupon the ramped tongue 110 will push a stud 111, mounted on the rear face of the upper part 97 of the keystem 82 of the key 39 forwardly until nib 108 is free of engagement with the frame 86, at 109. In the case of division the division key 93 is provided with a joint at 98 so that the upper part 120 thereof can be tilted towards the front of the machine (that is to the left when viewing FIGURE 12). Thus, when an operator wants to effect a calculation in division he depresses key 93 and moves the same forwardly so as to cause a nib 121 secured relatively to the upper part 97 of the stem 82 to engage with the under side of the subframe 86 at 122. Mounted upon the subframe 86 is a slotted link 123 arranged to engage with screws or studs 124 permitting the link 123 to move in a longitudinal direction. The link 123 is designed so that the ends thereof engage with the forwardly directed face of the upper part 97 of the stem 82 of the division key 93. The length of the link 123 is such that the ends thereof are just clear of the upper edge 121 of the upwardly extending portion 102 of the bell crank lever 99 and just clear of the forwardly directed face of the upper part 97 of the keystem 82 of the key 93, when the key 93 is latched in a forward direction. It will thus be seen that rearward movement of the upper edge 101 of the bell crank lever 99 will push the upper part 97 of the key stem 82 of the division key 93 rearwardly and move the nib 121 out of engagement with the portion 122 of the subframe 86.

The minus key 88 is similarly provided with a hinged stem capable of being latched forwardly under subframe 86 and released by the rearward movement of an upturned tab 123*a* forming part of link 123.

Referring to FIGURE 11 there is illustrated in side elevation the multiplier key column provided with a key **400** designated DIVIDE.

The construction of the above line of keys is similar to that of an order of keys of the main keyboard with the exception that there is not any mechanism operable to delay the return of a key, after it has been actuated, until the machine has completed the operation intended by the actuation of the key.

In addition to the keys designated **1** to **9** inclusive a naught key **401** is provided for use when a naught occurs in the multiplier figures.

The 10 keys **401** to **410** are provided at the lower extremities thereof with bifurcated contacts **411**, which in the nonactuated condition of a key do not bridge, so as to short-circuit, two fixed contacts **412** and **413**.

At the rear end of the keybar **437** there is provided an extension **414** arranged, in the normal position thereof with none of the keys **0** to **9** depressed to engage with an insulated pad **415** mounted on a spring contact blade **416** holding a contact pip **418**, mounted on the blade **416**, out of contact with a contact pip **417** mounted on a blade **420**, and in contact with **424** mounted on a blade **419**.

Upon the depression of any one of the keys **0** to **9** inclusive, for example No. **4** key, the keybar **437** will move the extension **414** forwardly (that is to the left when viewing FIGURE 11) and thereby permit the contact blade **416** to move away from the blade **419** and cause the contact **418** to make contact with the contact **417** carried by the blade **420**. Further, the depression of the No. **4** key will cause bifurcated contact **411** to move downwardly and bridge so as to short-circuit the contacts **412** and **413**.

The operator maintains pressure on the No. **4** key until a signal from the accumulator indicates the completion of that stage of the multiplication.

The keybar **437** is extended forwardly to provide an inclined slot **421** in which is arranged to slide a nib **422** secured relatively to the stem **423** of the divide key **400**. The divide key **400** is employed during stages of division and its action only effects the changeover switch contacts **417, 418, 424** and **425**.

The DIVIDE key **400** does not constitute the key the operation of which sets the switch contacts of the machine in their respective positions in order to effect division, electronically. The key which controls the switch contacts that ensure that division is effected is mounted in the control column **40** and is designated **93**.

The invention may also be embodied in a machine which dispenses with the studs and movable scanning brushes F, F^1 and F^2 of FIGS. 1 and 13, substituting therefor an electronic pulse generator. This pulse generator goes through a cycle for each order of the main keyboard keys and during each such cycle develops at separate outputs groups of pulses in the numbers one to nine. Each order of keys is arranged to select, by operation of an appropriate key therein, any one of these outputs. A timing device, representing in some sense an electronic analogue to the structure in FIGS. 1 and 13 whereby the studs O_0 to Z_8, O_{22} to L_{30} and O_{12} to L_{21} are scanned successively, then defines a machine cycle including a separate phase or period for each order. The pulse generator goes through a complete cycle during each of these periods, and during successive such periods the output of the pulse generator, as selected by the keys of the various orders, is gated into the accumulators of those orders successively. Actuation of any of the main keyboard keys initiates a cycle of operation of the timing device, and the machine of FIGS. 14 to 26 performs addition in essentially this way. For subtraction, a switching device is disposed between the output of the pulse generator and the pulse output selection switches operated by the main keyboard keys. This switching device in effect transposes the pulse generator outputs so that the pulses are selected by the main keyboard keys

in numbers equal to the nines complements of the value of the operated ones of those keys.

Additional electron tube circuits provide for performance, on multiplication, of the shift operation already described herein with reference to FIG. 1 and of iterative addition of a multiplicand a number of times selected by operation of a multiplier key in a series of multiplier keys. Likewise, additional electron tube circuits provide for performance, on division, of the complemental addition operation and of the shift and complement operation.

The calculating machine illustrated in FIGURE 14 includes eleven orders of keys, of which only the first two orders (**1K** and **2K**) and the last order (**11K**) are shown in the drawing. The register of the machine comprises eleven counting devices associated with the eleven orders of keys and of these only the first two counting devices (**1R** and **2R**) and the eleventh counting device (**11R**) are shown in the drawing. The register also includes a twelfth counting device **12R** which is provided to receive carry pulses from the counting device **11R**, but there is no order of keys associated with this counting device. It will be appreciated that there is no limit to the number of orders of keys and counting devices which can be employed in order to obtain any desired capacity for the machine, but it will normally be desirable to make the number of counting devices one greater than the number of orders of keys in order to accommodate carry-over from the counting device associated with the highest order of keys.

Each counting device has associated therewith an input amplifier and in the drawing there are illustrated amplifiers **1A** and **2A** for the first two counting devices **1R** and **2R**, and amplifiers **11A** and **12A** for the eleventh and twelfth counting devices **11R** and **12R**. The counting devices **3R** to **10R** (not illustrated) are respectively provided with input amplifiers **3A** to **10A** (also not illustrated). The counting devices will normally be in the form of multicathode electronic stepping tubes and in this case each amplifier includes the necessary drive circuit for such a stepping tube. Thus, if the stepping tubes have two drive electrodes each, the amplifiers will have two outputs each, and if the stepping tubes have three drive electrodes each, the amplifiers will be provided with three outputs each. The phase relationship between the outputs of each amplifier will be such as to step the glow in the associated tube from the **0** cathode step-by-step to the **9** cathode and thence on again to the **0** cathode.

Each amplifier has a number of inputs connected to the outputs of a number of gate circuits or AND logical elements. Each amplifier includes means for decoupling its various inputs so that the output of any one gate does not interfere with the operation of the remaining gates associated with the same input amplifier. In the drawing gates **1GA, 1GB, 1GC, 1GD** and **1GE** are shown supplying the amplifier **1A**; gates **2GA, 2GB** and **2GC** are shown supplying the amplifier **2A**; gates **11GA, 11GB** and **11GC** are shown supplying the amplifier **11A**; and gates **12GA, 12GB** and **12GC** are shown supplying the amplifier **12A**. Each of the counting devices **3R** to **10R** (not shown) is provided with three gate circuits —GA, —GB and —GC (also not shown). In addition to the inputs from the various gate circuits each amplifier, except amplifier **1A**, is provided with a further input from the **0** output of the preceding counting device so that the number registered in each counting device is increased by one each time the counting device of the next lower order registers zero.

In addition to the twelve counting devices which constitute the register of the machine two further counting devices are provided. The first of these further counting devices, designated as **13R** in the drawing, is a buffer counting device. This counting device is used, during shift or multiplication by ten, to store the digit registered in the counting device **12R** until space is made for it in the counting device **1R**. It is also used in division to count the number of subtraction cycles performed by the machine. The counting device **13R** is provided with an input amplifier **13A** and four gate circuits **13GB**, **13GC**, **13GD** and **13GE**. The second of the two further counting devices is designated in the drawing as C and functions as a control device. The primary function of this control device is to count the number of addition cycles performed during multiplication and to control the changes between subtraction and complementary shift cycles during division. This control device is associated with a set of keys MK which are used to set the multiplier when the machine is being used for multiplication. The control device C is also provided with an input amplifier CA which is controlled by two gate circuits CGA and CGB. The inputs to the gate CGA are constituted by the Z line, the output **T0** of a timing device and, when the switch **4S** is closed, the output **13R0** of the counting device **13R**. The switch **4S** is open during addition and multiplication and closed during subtraction and division. Thus, the third input to the gate CGA is ineffective during addition and multiplication so that one pulse is applied to the amplifier CA during multiplication whenever the output **T0** is energised. This causes the control device to move one step forward for each complete cycle of the timing device. During division, however, the control device is only stepped forward by a pulse through the gate CGA when the counting device **13R** registers 0. The inputs to the gate CGB are constituted by the Z line, the ouput **T0** of the timing device and the output **12R9** of the counting device **12R**.

As in the case of the counting devices **1R** to **12R** the counting devices **13R** and C may be multicathode electronic stepping tubes and the input amplifiers must then include suitable phase-displaced drive circuits.

The pulses required for operating the counting devices referred to above are produced by a pulse generator PG which is illustrated as having separate outputs numbered **1** to **9**. During one cycle of the generator the output **1** produces one pulse, the output **2** produces two pulses and so on up to the output **9** which produces nine pulses. The pulses produced by the output **4** are shown by way of example in line **1** of FIGURE 15 of the drawings. It will be seen that in this case one pulse is produced during the first pulse period of each cycle of the generator and that three pulses are produced during the fourth, fifth and sixth pulse periods of each cycle. However, the actual position of the pulses within a cycle is irrelevant to the operation of the machine and they could equally well all occupy consecutive pulse periods, for example. The outputs from the pulse generator are applied to the various orders of keys through a changeover switch **1S**. This switch is in a first position when the machine is being used for addition and multiplication and in a second position when the machine is being used for subtraction and division. In the first position of the switch **1S**, output **1** is connected to the number one key in each order; output **2** is connected to the number two key in each order; and so on up to the output number **9** which is connected to the number nine key in each order. When the switch **1S** is in the second position, output **1** of the pulse generator is connected to the number eight key in each order of keys; output **2** is connected to the number seven key in each order; and so on up to output **8** which is connected to the number one key in each order. Further, with the switch **1S** in the second position, output **9** is connected to the GA gate circuit of each counting device associated with an order of keys in which no key is operated, and also to the GA gate of **12R**.

The output designated by the letter Z produces one pulse during each cycle of the generator.

To control the operation of the machine a timing device T is provided. This device has sixteen outputs which are designated **T0** to **T15**. The wave forms of the outputs **T1**, **T2**, **T3** and **T4** are illustrated in lines **5**, **6**, **7** and **8** of FIGURE 15. A switch SS is connected to the **T0** output to ensure that at the start of a calculation the first pulse appears at **T1** output. The timing device is provided with an input amplifier TA which is fed by one pulse from the pulse generator during each cycle of the pulse generator. Thus, during a calculation the timing device is moved forward one step for each cycle of the pulse generator and the output voltage moves forward sequentially from output **T1** to **T15** and thence back to **T0**. The timing device makes an additional step during which none of its output terminals is energised as it moves from **T15** to **T0**. Thus, the timing device completes one cycle while the pulse generator performs seventeen cycles.

The various outputs of the timing device are connected to the gate circuits as indicated by the references **T1** to **T15** shown at the inputs of the gates. Thus, for example, the output **T2** is connected to one input of the gate **1GA**, to one input of the gate **11GB**, to one input of the gate **11GF**, to one input of the gate **12GC**, and to one input of the gate **13GD**. The output **T15** is connected to one input of a gate SG the other input to which is constituted by a stop signal. The output of this gate is applied to the pulse generator and serves to stop the generator during the fifteen cycle of the timing device if the stop line is energised.

The components so far described would enable the machine to perform addition and subtraction, but when the machine is required to perform multiplication or division it is necessary for the timing device to carry out more than one cycle and, to control the number of cycles of operation of the timing device, the control device C is provided. The control device has ten outputs which are illustrated as **C0** to **C9**. Each of these outputs is associated with a corresponding key in a bank of multiplier keys MK. Each multiplier key, when operated, selects the corresponding output of the control device and when no multiplier key is operated the output **C0** is selected. The various outputs are supplied to a switching arrangement CM which enables the outputs to be correctly routed when the machine is being used for any of its four arithmetical operations. Thus, during multiplication the selected output is connected to the stop line so that the operation of the pulse generator is stopped when the timing device has performed the number of cycles corresponding to the operated key in the bank of multiplier keys. Other outputs of the switching arrangement include an AP line, an SP line and a Y line. When the AP line is energised the machine operates to perform addition or subtraction and when the SP line is energised the machine operates to shift or multiply by ten.

In order to control the shift operation of the machine, a gate CG and an electronic changeover switch CS are provided. Nine pulses per cycle of the pulse generator are supplied to one input of the gate CG, the other input of which is constituted by the AP line. Provided the AP line is not energised, nine pulses per cycle of the pulse generator are passed to the changeover switch CS. Normally these pulses are passed through to the output **S1** of the changeover switch, but when the line SC is energised during multiplication the nine pulses are passed to the output **S2** instead of to the output **S1**. During division the pulses are normally passed through to both the outputs **S1** and **S2**, but when the line SC is during division the pulses are prevented from reaching either of these outputs.

Additional inputs to certain of the gate circuits are provided by the switches **2S**, **3S** and **4S**. The switch **2S** is open during subtraction and division, but is closed during addition and multiplication. The switches **3S** and **4S** are closed during subtraction and division, but are open during addition and multipilcation.

Operation

When the machine is set to perform addition, the output C0 of the control device C is connected through the switching arrangement CM to the stop line and also to the AP line. Before any keys are depressed, the switch SS is in the closed position so that the output of the timing device T is held at the output T0 and the output of the control device C is held at the output C0.

It will be assumed that the number **34** is to be added to the number **57**. Before the start of the calculation all the counting devices will register zero. To insert **34** into the machine, the number three key is depressed in the order 2K and the number **4** key is depressed in the order **1K**. It is assumed in the following description that the two keys have been depressed together so that the **3** and the **4** are both added into the register during the same cycle of operation of the timing device T. However, this is not the normal method of operating the machine, since the operator will normally depress one key and then the other. In this case the insertion of each digit into the register will occupy a separate cycle of operation of the timing device T. It is irrelevant whether the higher order or the lower order key is depressed first.

When either of the keys is depressed, the switch SS is opened and accordingly the next pulse from the pulse generator is enabled to step the timing device from **T0** to **T1**. This has no effect since, at this stage, there is no other input to any gate circuit to which the output **T1** is connected. When the timing device steps from **T1** to **T2**, two of the inputs of the gate **1GA** are energised, since the AP line is energised by the output **C0** from the control device. Since the number **4** key is depressed in the order of keys **1K**, four pulses will be applied during each cycle of the pulse generator to the gate **1GA**. During the period **T2** these pulses pass through the gate **1GA** to the input of the amplifier **1A** and thence to the input of the counting device **1R**. These four pulses serve to step the counting device **1R** from 0 to 4. Similarly during the period **T3** three pulses will be applied through the gate **2GA** to the amplifier **2A** and thence to the counting device **2R**. During the periods **T4** to **T14** nothing further will happen, since none of the gates will have all its inputs energised. During the period **T15** both the inputs of the gate SG will be energised, since the stop line is connected to the output **C0** of the control device through the switching arrangement CM. Accordingly the pulse generator will be stopped and this stage of the calculation is completed. As soon as the keys **3** and **4** in the orders **2K** and **1K** are released by the operator, the contacts SS will close again and the control device T will be returned from **T15** direct to **T0**. As a result one of the inputs to the gate SG will be removed and the pulse generator will restart.

To perform the second stage of the calculation, the number **5** key in the order **2K** is depressed and the number **7** key in the order **1K** is depressed. Again the switch SS is opened by the operation of either of these keys and the timing device T is allowed to step forward to **T1** when it receives a pulse through the amplifier TA from the pulse generator PG. Again nothing happens during period **T1**, but during period **T2** seven pulses are passed through the gate **1GA** to the amplifier **1A** and thence to the input of the counting device **1R**. Accordingly the counting device steps from 4 to 9 and thence to 0 and 1. When the counting device **1R** registers 0, a pulse is applied to the input of the amplifier **2A** and thence to the input of the counting device **2R** so that this counting device steps from 3 to 4. During the period **T3** five pulses are passed through the gate **2GA** to the amplifier **2A** and thence to the input of the counting device **2R** so that this counting device steps from 4 to 9.

During the periods T4 to **T14** none of the gate circuits is opened, but during the period **T15** both the inputs of the gate SG are energised and the pulse generator PG is stopped. When the keys **5** and **7** in the orders **2K** and **1K** are released, the switch SS is closed and the counting device T returns to **T0**. The register of the machine now reads 000000000091 which is the result of the addition of 34 to 57.

When the machine is to be used for subtraction, the switch **1S** is changed over so that, when a key in any order of keys is depressed, the corresponding GA gate input is supplied with a number of pulses equal to the nines complement of the value of the depressed key.

As an example the subtraction of 17 from 34 will be described.

Initially the number 34 is entered into the machine with the switch **1S** set for addition in the same manner as in the example described above. The switch **1S** is then changed over to subtraction and the number 17 is inserted in the orders **2K** and **1K**. Once again it will be assumed that the two keys are depressed together, but it is to be understood that normally the operator will first depress the number one key in the order **2K** and then the number seven key in the order **1K**, or vice versa.

Changing the switch **1S** over to subtraction has the effect of opening the switch **2S** and thus removing the negative potential from the fourth input to the gate **1GE**. Consequently during the period **T1** the gate **1GE** is opened when the pulse appears on the Z line. As a result one pulse is fed into the counting device **1R** during this period so that it steps from 4 to 5.

During the period **T2** two (9—7) pulses are added into the counting device **1R** so that it steps from 5 to 7. During the period T3 eight (9—1) pulses are added into the counting device **2R** so that it steps from 3 to 1. As it steps to zero a pulse is applied to the amplifier **3A** which causes one carry pulse to be entered into the register **3R** (not shown) so that this counting device steps from 0 to 1. During the period **T4** nine pulses are applied to the counting device **3R** so that this counting device is stepped from 1 to 0. As this counting device reaches 0, a carry pulse is applied to the counting device of the next higher order which is subsequently stepped to 0 by nine pulses from the pulse generator. This process continues until the counting device **11R** has been stepped from 0 to 1 by the carry pulse and thence back to 0 by the nine pulses from the generator PG through the unoperated keys of the order **11K**. As a result of the return of the counting device **11R** to 0 a carry pulse is fed into the counting device **12R** which is subsequently stepped during the period **T13** by nine pulses applied directly to one input of the gate **12GA** from the switch **1S**. Thus, the register of the machine now reads 000000000017, which is the result of subtracting 17 from 34.

When the machine is to be used for multiplication, the switch **1S** is in the same position as for addition, but contacts in the switching arrangement CM are changed over so that the stop line, instead of being connected directly to the output **C0** of the control device C, is connected to whichever of the outputs of the control device is selected by the depression of a key in the bank of multiplier keys MK. In addition the line SP is connected to the output **C0** and the line AP is connected to all of the outputs **C1** to **C9**. During multiplication the switches **3S** and **4S** open, but the switch **2S** is closed, with the result that the gate circuit **1GE** is prevented from opening, but the gate circuits **13GC**, **13GD** and **CGA** are allowed to open when their other inputs are energised. In addition to performing the various switching operations described above, setting the machine for multiplication converts it from a key-responsive machine to a key-set machine. In other words, when a key in any of the orders of keys **1K** to **11K** is depressed, it will remain down until the calculation is completed. Finally, setting the machine to multiplication places the contact SS under the control of the multiplier keys in the bank

MK instead of the keys in the orders 1K to 11K. Thus, when the machine is set for multiplication, the contact SS is opened when any one of the multiplier keys is depressed.

As an example the multiplication of 34 by 17 will be described.

Initially the multiplicand 34 is set on the keys of the machine by the depression of the number three key in the order 2K and the number four key in the order 1K. The orders 2K and 1K are only given by way of example, since the multiplicand could be set on any two consecutive orders of keys. However, it will normally be set in the lowest possible orders since, if it is set in too far up the machine, the first one or more digits of the answer may be lost. The two keys will lock down as the machine is set for multiplication, but the machine will not start to operate since these keys no longer control the contact SS. The first digit of the multiplier 17 is now entered into the multiplier keys by the depression of key 1 in the bank MK. This key locks down and opens the contact SS. The next pulse from the pulse generator that is applied to the amplifier TA causes the timing device to step from T0 to T1. As the output C0 of the control device is still energised, the line AP is deenergised and the line SP is energised. Accordingly, during the period T1 nine pulses are applied from the pulse generator through the gate circuit CG and the switch CS over the line S1 to one input of the gate 12GB, to the other input of which the output T1 is applied As a result nine pulses are applied through the amplifier 12A to the input of the counting device 12R which accordingly steps from 0 to 9. When nine is registered in the counting device 12R, both inputs of the gate circuit 12GF are energised and a voltage is applied through the SC line to change over switch CS. As a result the input from the date circuit CG is switched from the output S1 to the output S2. However, no further pulses are received by the gate circuit CG from the pulse generator during the period T1 and accordingly no pulses are passed through the output S2. It is to be noted that, if the number registered in the counting device 12R had been other than 0, a corresponding number of pulses would have been applied during the period T1 from the output S2 through the gate circuit 13GC to the counting device 13R. At the end of the period T1 the line SC is deenergised and the changover switch CS reverts to its normal state in which its input is coupled to its output S1.

During the period T2 nine pulses are applied from the line S1 through the gate 11GB and the amplifier 11A to the counting device 11R which is stepped from 0 to 9. Again the changeover switch CS is changed over on the ninth pulse and reverts to its normal state at the end of the period T2 without passing any pulses to its output S2.

Also during the period T2 the gate circuit 13GD is opened to allow one pulse to be applied from the Z terminal of the pulse generator through the amplifier 13A to the input of the counting device 13R. As a result the counting device 13R is stepped from 0 to 1. It is to be noted that no pulses are passed through the gate 1GA during the period T2 since the AP line is deenergized.

During the period T3 nine pulses are applied from S1 to the counting device 10R (not illustrated) and the operation of the machine continues in the same manner until at the end of the period T12 each of the counting devices 12R to 1R register 9. During the period T13 nine pulses are applied to the counting device 13R through the gate circuit 13GB. As a result the counting device 13R is stepped from 1 to 0. When the counting device 13R reaches 0, both inputs of the gate circuit 13GF are energised so that the SC line is energized. However, once again, no further pulses are received by the gate circuit CG from the pulse generator during the period T13 and accordingly no pulses are passed through the output S2.

During the period T14 one pulse is applied from the output Z of the pulse generator through the gate circuit 1GD to the counting device 1R. As a result the counting device 1R is stepped from 9 to 0 and a carry is passed through the amplifier 2A to the counting device 2R. The counting device 2R is thus also stepped from 9 to 0 and the carry passes up through all the orders of the machine until all the counting devices up to 12R are registering 0. There is no carry from the counting device 12R to the counting device 13R and therefore the latter counting device remains at 0.

During the period T15 one input of the gate circuit SG is energized, but the stop circuit is not energized and accordingly the pulse generator PG continues to run. As a result the timing device is stepped on to the ouput T0. During the period T0 a pulse is applied from the output Z of the pulse generator through the gate circuit CGA to the amplifier CA and thence to the input of the control device C. The gate CGA is allowed to open since the switch 4S is open during multiplication. Accordingly the cotrol device is stepped from C0 to C1. This causes the SP line to be deenergized and the AP line to be energized.

During the period T1 nothing happens since the other inputs of the gate circuits 12GB, 12GF, and 13GC are not energized at this time.

During the period T2 four pulses are supplied from the generator PG through the depressed number 4 key in the order 1K and thence through the gate circuit 1GA and the amplifier 1A to the input of the counting device 1R. As a result the counting device 1R is stepped from 0 to 4. Similarly, during the period T3 three pulses are fed into the counting device 2R which is stepped from 0 to 3. Nothing further happens during the periods T4 to T14, but during the period T15 both inputs to the gate circuit SG are energized since the stop circuit is connected through the depressed number 1 key in the bank MK to the energised output C1 of the control device. Accordingly the pulse generator is stopped and the first part of the calculation is completed. When the pulse generator stops, the depressed number 1 key in the bank MK is released by means to be described hereinafter, and the switch SS is reclosed so that the timing device returns to T0 and the control device returns to C0.

Key number 7 in the bank of multiplier keys is now depressed and a shift operation similar to that described above commences while the control device is at C0. The operations performed by the machine during the periods T1 to T10 are precisely the same as those which occurred at the commencement of the calculation. However, during the period T11 the sixth pulse from the pulse generator causes the counting device 2R to register 9. Accordingly both inputs of the gate circuit 2GF are energized and a voltage is applied from the SC line to the changeover switch CS. As a result the input from the gate circuit CG is switched from the output S1 to the output S2 and the remaining three pulses from the pulse generator occurring during the period T11 are passed to the output S2 instead of to the output S1. The inputs to a gate circuit 3GC (not shown) associated with the counting device 3R (not shown) are constituted by the S2 line and the output T11 from the timing device. Accordingly this gate is opened during the period T11 and the three pulses from the S2 line are applied to the counting device 3R. This counting device was previously registering 9 and accordingly it is now stepped to 2. As it passes through 0, it causes a carry to be passed to the counting device 4R, which is accordingly stepped from 9 to 0. This carry is then passed up through all the orders until all the counting devices 4R to 12R are registering 0.

During the period T12 the counting device 1R is stepped to 9 by the first five pulses from the pulse generator over the S1 line. When the counting device 1R reaches 9, both inputs of the gate circuit 1GF are energised and a voltage is applied through the SC line to change over the changeover switch CS from S1 to S2. Accordingly the remaining four puses which occur during the period T12 are passed through the S2 line, the gate 2GC and the amplifier 2A to the input of the counting device 2R. Accordingly the counting device 2R is stepped from 9 to 3, the resulting carry causing counting device 3R to step from 2 to 3.

During the period T13 nine pulses are applied over the S1 line through the gate 13GB to the counting device 13R. As a result the counting device 13R is stepped from 1 to 0. When the counting device 13R reaches 0, both inputs of the gate circuit 13GF are energised so that the SC line is energised. However, no further pulses are received by the gate circuit CG from the pulse generator during the period T13 and accordingly no pulses are passed through to the output S2.

During the period T14 one pulse is applied from the output Z of the pulse generator through the gate circuit 1GD to the counting device 1R. As a result the counting device 1R is stepped from 9 to 0 and a carry is passed through the amplifier 2A to the counting device 2R. The counting device 2R is thus stepped from 3 to 4. The machine therefore now registers 000000000340.

During the period T15 one input of the gate circuit SG is energised, but the stop circuit is not energized and accordingly the pulse generator PG continues to run. As a result the timing device T is stepped on to the output T0. During the period T0 a pulse is applied from the output Z of the pulse generator through the gate circuit CGA to the input of the control device C. Accordingy the control device is stepped from C0 to C1. This causes the SP line to be denergised and the AP line to be energised.

During the period T1 nothing happens, but during the period T2 four pulses are supplied from the generator PG through the depressed number 4 key in the order 1K to the input of the counting device 1R. As a result the counting device 1R is stepped from 0 to 4. Similarly during the period T3 three pulses are fed into the counting device 2R which is stepped from 4 to 7. Nothing further happens during the periods T4 to T15 but during the next period T0 the control device C is stepped from C1 to C2. The SP line is still deenergised and the AP line is still energised so that the machine performs another addition and the counting device 1R is stepped from 4 to 8 and the counting device 2R from 7 to 0. When the counting device 2R reaches 0, it sends a carry pulse to the counting device 3R which is accordingly stepped from 3 to 4.

The machine continues to perform repeated addition while the control device is stepped up to C7. When the control device reaches C7, the stop line is energised and the pulse generator is stopped during the period T15. The machine now registers 000000000578. The various steps in the calculation are shown in the following Table 1.

TABLE 1

C	13R	12R	11R	4R	3R	2R	1R	
0	0	0	0	0	0	0	0	34 entered on keyboard, but not in register.
0	0	0	0	0	0	0	0	Multiplier key 1 depressed and machine starts. Shift, as C is at 0.
1/0	0	0	0	0	0	3	4	As C is not at 0, add 34. At T15 machine stops and C returns to 0.
0	0	0	0	0	3	4	0	Multiplier key 7 depressed and machine starts. Shift as C is at 0.
1	0	0	0	0	3	7	4	As C is not at 0, add 34.
2	0	0	0	0	4	0	8	As C is not at 0, add 34.
3	0	0	0	0	4	4	2	Add 34.
4	0	0	0	0	4	7	6	Add 34.
5	0	0	0	0	5	1	0	Add 34.
6	0	0	0	0	5	4	4	Add 34.
7/0	0	0	0	0	5	7	8	Add 34. Add T15 machine stops and C returns to 0.

When the machine is to be used for division the switch 1S is in the same position as for subtraction, but contacts in the switching arrangement CM are changed over so that the stop line is connected to the output C7 of the control device C, so that the line SP is connected to the outputs C1, C3, C5, C7 and C9 of the control device and so that the line AP and the line Y are connected to the outputs C0, C2, C4, C6 and C8 of the control device. During division the switch 3S is closed with the result that the gates 13GC and 13GD are prevented from opening but the switch 2S is opened with the result that the gate circuit 1GE is allowed to open when its other inputs are energised. Further the switch 4S is closed so that the gate CGA is prevented from opening except when the counting device 13R is at 0. As in the case of multiplication, setting the machine to division converts it from a key-responsive machine to a key-set machine, and places the contact SS under the control of the multiplier keys in the bank MK. Further, setting the machine for division affects the operation of the change-over switch CS, so that the outputs S1 and S2 are in parallel and are connected to the input so long as the SC line is not energised, but are disconnected from the input when the SC line is energised.

As an example, the division of 146 by 12 will be described.

Initially the machine is set for addition and the number 146 is entered into the highest orders of the machine by the depression of the key 1 in the order 11K, the key 4 in the order 10K and the key 6 in the order 9K. As a result the number 146 is registered in the counting devices 11R, 10R and 9R in the same manner as described above for addition. The machine is now set for division and the divisor 12 is entered into the keys of the orders 11K and 10K. It is not essential that the dividend be inserted in the highest orders of the machine. Further, it is preferred that the divisor be entered in the highest orders of the machine.

The 0 key in the bank MK is now depressed to open the contact SS. As a result the next impulse from the pulse generator to the timing device steps the timing device from T0 to T1. Since the control device C is at C0, the line AP is energised and during the period T1 one pulse is fed into the counting device 1R through the gate circuit 1GE so that this counting device steps from 0 to 1.

During the period T2 nine pulses are added into the counting device 1R through the gate 1GA so that this