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<u>COUNTERS</u> In all computing machines there is a counter of some sort which represents or remembers numbers by virtue of the various states which its parts may assume. In this machine the role of counter is played by a set of electrical condensers, each of which corresponds to one place in a number to the binary or base-2 system. The term counter will be extended to include such a set of condensers.

The two digits, 1 and 0, of the base-2 system are represented respectively by negative and positive charges on the contacts connected to the condensers of a counter. Referring to Fig. 1, the condnesers 1 are mounted on the interior of a cylinder 2 made of insulating material, with their inner ends connected in common 3 and brought out to a slip ring 4, and their outer ends connected to individual contacts 5 which protude through the walls of the cylinder. The cylinder is arranged to be rotated at constant speed past a pair of brushes 6, 7 (Fig. 2) which are spaced half the distance between contacts. The first brush 6 to touch a given contact is called a "reading" brush, and the second 7 is called a "charging" brush. Fig. 6 gives an assembly view of the entire set of brushes for the computing counter and Fig. 5 gives the assembly view of the holder-shifter counter (defined later). A portion 8 (Fig. 1) of the periphery of a counter is left free of contacts in order that during the period of a complete revolution of a counter there will be a certain amount of time available for resetting various parts of the machine.

connected to

Counters are used for two main purposes in this machine--the first, merely to hold a number as long as desired so that it may be used over and over again in a computation; and the second, to retain instantaneous results of computation (this might be called an accumulator). For certain operations it is necessary to shift the number on the first type of counter along the condensers, i.e., shift the decimal point. Hence this counter will be ? called the holder-shifter counter (abbreviation HS counter) and the second type of counter will be called the computing counter.

When a number of counters are to be used in one machine, it is convenient to arrange them in one large cylinder (Fig. 3).

A simple type of counter (Fig. 7) using only one condenser 9 is used for "remembering" carryover from one place in a number to the next place. A carryover counter with two contacts such as the one shown is geared to make one-half a revolution during the time a counter rotates the distance between two adjacent contacts. Brush 10 is used for reading and brush 11 for charging.

<u>COMPUTER CIRCUIT</u> In order to add or subtract numbers which are on a pair of counters an electron-tube circuit, called a computer, is used. Only one computer is needed for any number of places on the counters since it computes for each place in turn as the counters rotate past their brushes.

The computer is a device which obeys the rules of addition and subtraction in the base-2 system. These rules are summarized in the following table. It will be observed that the only difference between addition and subtraction is in the carryover.

Table I

		Possible Combinations							
Number		0	0	0	0	1	1	1	1
Number added or subtracted		0	1	0	1	0	1	0	1
Carryover from previous place		0	0	1	1	0	0	1	1
Add	(Result in this place	0	1	1	0	1	0	0	1
	(Carryover to next place	0	0	0	1	0	1	1	1
Subt.	(Result in this place	0	1	1	0	1	0	0	1
	(Carryover to next place	0	1	1	1	0	0	0	1

Table II

Plate of tube	Possible Combinations							
A	L	L	L	L	H	H	H	H
B	H	H	H	H	L	L	L	L
C	L	H	L	H	L	H	L	H
D	L	L	H	H	L	L	H	H
E	H	H	H	L	H	L	L	L
F	H	L	L	L	H	H	H	L
G	L	H	H	H	L	L	L	H
H	H	L	L	H	L	H	H	L

Fig. 10 is a diagram of a circuit which mechanizes the above table. All of the tubes operate in either one of two possible states--with the grid so far negative that the tube is blocked, or with a zero or slightly positive potential on the grid so that a substantial plate current flows. Thus the plate potential of each tube is either high or low depending upon the potential of the grid; if the grid is high the plate is low, and if the grid is low the plate is high.

Tubes A, C, D are input tubes which connect to reading brushes, connecting respectively to the computing counter, the HS counter, and the carryover counter. These grids have small condensers 12 connected to ground so that charges placed on them are retained between reading periods. Tubes E, F, H are output or charging tubes the plates of which are connected to the charging brushes. A relay 13 connects E when adding or F when subtracting to the charging brush of the carryover counter. Tube H connects to the computing counter charging brush. Tube B inverts the output of tube A, and tube G inverts the output of tube F; i.e., when A passes current B is blocked, and when A is blocked B passes current.

Tubes E, F, H each have three coupling resistors of equal size connected to their grids, and a fourth resistor connected to a source of negative bias. The other ends of the coupling resistors are connected to the plates of A, C, D; B, C, D; A, E, G respectively. The coupling resistors are high enough in resistance so that they have negligible effect upon the plate circuits to which they are connected. The bias resistors of E, F, H have such values that if any two or all of the controlling plates are at their low potential, the controlled tube will not pass current because it will be blocked. The operation of the circuit of Fig. 10 is summarized in tabel II, where H stands for high and L for low. Comparison with table I shows that the circuit responds properly to each of the possible input combinations.

<u>BOOSTER</u> Since the counter condensers must be charged either positively or negatively with respect to ground, it is necessary to connect their common point alternately to ground during a reading period, and to a fixed potential midway between the high and low potentials of the charging plates during a charging period. This is done with a commutator 61 in Fig. 11~~a~~b which is synchronized with the rotation of the counters. A counter is cleared by removing the boosting voltage for one revolution (switch 62 of Fig. 11~~a~~b). This places a positive charge, corresponding to a zero number, on each condenser.

<u>HOLDING AND SHIFTING CIRCUIT</u> An electron-tube circuit is used in conjunction with the HS counter to retain any number once it is put on the counter, that is, to prevent the condensers from losing their original polarity of charge. Fig. 21 is a circuit diagram. Two reading brushes 14, 15 (Fig. 4) are used on the HS counter, spaced one contact apart. The charging brush 16 is spaced half the distance between contacts from brush 15. The reading brushes 14, 15 connect respectively to the grids of tubes W, V (Fig. 21), which have small condensers connected to ground. Relay 17 connects the plate circuit of V to a supply voltage and that of W to ground, or vice versa. Tube U is the condenser-charging tube, and is controlled by tubes V, W through the coupling resistors 18. The bias resistor 19 has such a value that both control plates (V, W) must be at low potential before tube U is blocked.

The action of the circuit in holding a number is as follows. For holding, relay 17 supplies tube W with plate voltage. Suppose a counter condenser having the digit 1 appears at the first reading brush 14. This places a negative charge on the grid of tube V, but since this tube has no plate voltage, nothing happens. However, when the condenser appears at the second reading brush 15 a negative charge is placed on the grid of tube W, blocking the tube. This causes the potential at the grid of tube U to rise so that plate current flows and the plate of U is at a low potential. The circuit is held in this state even after the reading contact is broken, because of the retention of a negative charge by the grid condenser of W. When the counter condenser has moved to the charging brush the booster has acted to raise the potential of the other side of the condenser so that the plate of the U charges the condenser negatively. This is the charge that was originally on the condenser.

The action when a zero number (positive charge) is presented is similar. When the reading brush 15 is contacted the positive charge on the counter condenser is drained off through the grid of tube W until the grid is nearly at ground potential. Under this condition tube W passes current and its plate potential is low, causing tube U to be blocked and its plate to be high. This condition persists after the reading period and through the charging period, when the counter condenser receives a new positive charge.

For shifting a number, relay 17 is thrown so that tube V receives plate voltage and tube W none. Because of the spacing of brushes 14 and 16 the charge which is on the first counter condenser is not replaced on any condenser; in other words it is shifted past the end place in the counter. The charge which is on the second condenser is placed on the first, that on the third is placed on the second, etc.. Thus after one complete revolution of the counter, the number on it has been shifted back one place.

In this machine negative numbers are represented by their complements; for instance, -10 (negative two) is represented by $\overleftarrow{111110}$, where the arrow indicates that the "ones" continue out to the end place in the counter. In order that negative numbers may be shifted without shifting zeros on to the end places it is necessary to have an extra contact 20 (Fig. 4) on the HS counter, which is connected to the adjacent contact 21. Thus, in effect, the end place in the number is not shifted, but recharges itself. A positive number large enough to occupy the end place in the counter cannot be shifted properly, of course, but such numbers will be avoided in using the machine.

<u>INPUT DISCHARGING</u> Although the circuits will perform as described, tolerances can be increased by discharging all grid condensers during the time between the end of one charging period and the beginning of the next reading period. Fig. 22 shows the method of discharging, which discharges any number of input condensers with only one commutator 22. A neon tube 23 and series resistor 24 are connected between the grid condenser 12 and the commutator. When the commutator is closed the neon tube ionizes and passes current. This places a slightly positive charge on the condenser, which is quickly drained off by the grid of the input tube when the commutator opens. The input grid is thus left at approximately zero potential for the beginning of the next reading period.

<u>CONVERTER AND BASE-10 CARD READER</u> In order to utilize data cards punched on a standard card-punching device a mechanism for automatic conversion from base-10 to base-2 within the machine is used. The mechanized conversion table (Fig. 8) is a metal cylinder 25 with insulating supports 26, carrying

contacts 27 each row of which represents the base-2 equivalent of a base-10 number. The contacts have the same angular spacing as the counter contacts, and the conversion drum is rotated on the same shaft as the counters. The numbers represented on the converter are 1, 2, 3, ... 10, 20, 30, ... 100, 200, 300, ... etc. up to 9×10^{14} (for a machine with 50 base-2 places).

Since multiplication by 2 in the base-2 system merely shifts the decimal point one place to the right, considerable saving in the size of the converter is accomplished by using the same set of contacts for numbers which are mutiples of two of the same number. This is done by using several sets of brushes 28, spaced angularly the same amount as the contacts, on certain rows. Thus 1, 2, 4, 8 are all represented by one row, and the same for 5, 10, 20, 40, 80 etc.. Likewise 3 and 6, 30 and 60, etc. require only one row per pair. The sevens and nines, however, require individual rows.

The card reader, Fig. 9, consists of an insulating plate 29 which contains electrical contacts 30 spaced the same as the holes in a card. These contacts are each connected to the corresponding brushes which bear on the converter, i.e., 1 to 1, 2 to 2, etc.. A carriage 31 above this plate carries a row of ten brushes 32. Nine of these are used for the digits 1 through 9, and the tenth for sensing a special punching in the zero column which indicates the sign of the number. The carriage is equipped with a magnetically operated ratchet that it may be moved ahead one place during the resetting period of the machine. During a reading period the brushes remain over one row, and if there is a hole in that row the corresponding brush drops through and touches the contact below.

The nine brushes used for sensing numbers are connected together electrically, and when a number is being read into the machine they are connected to the grid of tube C of a computer. A brush 33 and slip ring 34 (Fig. 8) maintain the converter contacts at negative potential with respect to ground, so that the grid of tube C receives a sequence of negative impulses corresponding to the number punched in the place being read on the card.

The operation in reading a number is as follows. Suppose the number 952 is punched on a card. The carriage moves along one step per revolution of the machine, taking the steps during the resetting period. When the hundreds row is reached the nine brush drops through. This allows the converter to put the series of impulses representing 900 on the computing counter through the computing circuit. After one revolution, the carriage drops back to the tens row and the number five brush contacts. A 50 is added to the 900 already on the counter, through the action of the computer. During the next revolution the brushes are over the units row, and a 2 is added to the 950 on the counter.

Negative numbers are read in by subtracting from zero. On the card, the zero spot in the first place read is punched to indicate the number is negative. Brush 35 touches contact 36, closing relay 37 (Fig. 11a). Once this relay is closed, it holds itself closed by means of contacts 38, and also closed contacts 39 which control the add-subtract relay 13 in the computer, throwing this relay to subtract. Relay 37 remains closed until the carriage has moved to the end of its travel, when it opens contacts 40.

<u>BASE-2 Cards</u> Means for high-speed punching and reading of cards in the base-2 system are included in the machine. Fig. 12 shows the type of mechanism used for both punching and reading. A set of rolls 41 geared to the main shaft pulls cards at constant speed through electrodes 42 which punch or read the cards with electrical discharges. A card pusher 43 feeds the cards into

the rolls; this pusher is actuated by a cam 44 which moves a lever system 45. A latch 46 on the cam follower prevents the pusher from operating until the latch has been released by electromagnet 47, and after one cycle of operation the latch automatically locks.

Fig. 13 is a circuit for securing high-voltage punching impulses. Tube M is a control tube for tube N, which is a gas-filled triode. The low-voltage winding of a step-up transformer 48 is connected in the plate circuit fo tube N. The alternating supply voltage applied to terminals 49 has the same frequency as the computing frequency, that is, the frequency of contact of the counter brushes. The grid of tube M receives impulses from the plate of tube H in a computer, such that when a "one" is on a counter condenser tube M is blocked and tube N passes current. The phase of the alternating supply voltage is such that at this instant the plate potential of tube M is starting its positive swing. A high induced voltage thus appears at the secondary of the transformer, and this is applied to the punching electrodes 42, producing a hole in the card. The punching electrodes are preferrably pointed. Synchronization of the machine shafts and the alternating supply voltage is best obtained by driving the machine by a synchronous motor through suitable gear reduction.

In reading base-2 cards the card is fed through a set of flattened electrodes. Because of the gearing and cam arrangement, the holes on the card are presented to the electrodes in phase with the counter contacts. The circuit for obtaining reading impulses is shown in Fig. 14; in this the output of a high-voltage transformer 50 is rectified by a tube 51 and the resulting voltage appears across resistor 52. The frequency of this voltage is the same as that of the punching voltage. One electrode 53 is connected through resistors 55 and 56 to the lower end of resistor 52. The voltage developed across resistor 52 is low enough so that it cannot puncture the card. However, at a point where a hole has been made by the punching device the reading voltage forces a current flow. The resulting voltage drop across resistor 56 causes the neon tube 57 to ionize and transmit a negative charge to the grid of the input tube C.

COMBINATION OF ELEMENTS FOR EQUATION SOLVING The devices just described from the basis of a machine for solving linear simultaneous algebraic equations. For solving n equations in n unknowns, there are required n + 1 computer circuits, n + 1 computing counters, and n + 1 HS counters. The base-2 card mechanisms have n + 1 sets of electrodes and there are n + 1 punching circuits. The machine being described is designed for 29 equations in 29 unknowns, thus requiring 30 complete computing circuits.

The method of solution employed is that of successive elimination between pairs of equations. Eliminations are accomplished by a combination of linear operations---term-by-term addition, term-by-term subtraction, and division of the coefficients of one equation by two (shifting). The method is somewhat like synthetic division and strict accuracy is not obtained because of the digits shifted off the end of the counter, but if the original coefficients are made large by multiplying the equations by some large number, results as accurate as the original data can be obtained. The equations must be adjusted before each elimination so that the coefficients of the terms to be eliminated are positive. The mathematics of the method will be described first, then the machine details.

The coefficients of one equation are put on the HS counters and those of the other are put on the computing counters. The machine begins by subtracting each number on the HS counters from the corresponding one on the computing counters. It continues subtractions until the number on the first computing counter becomes negative (assuming the first coefficient is the one being eleiminated). The machine then shifts the numbers on the HS counters one place and begins adding. Addition continues until the number on the first computing counter becomes positive, whereupon the shift again operates and the machine changes to subtract. After a sufficient number of such operations the number on the first computing counter becomes zero. The remainder of the numbers on the computing counters are the coefficients of a new equation with one less unknown than the original. These coefficients are punched on a base-2 card and retained for further use in a subsequent elimination. By continuing eliminations in the usual manner an equation with only one unknown is obtained. Then, working backwards, all other unknowns are found.

A simple example shows the sequence of operations more clearly. Suppose X is to be eliminated from these two equations:

$$6X - 10Y + 22 = 0$$

$$4X + 6Y - 36 = 0$$

The coefficients are punched on base-10 cards and converted by the machine to base-2 numbers, the first three computing counters receiving 6, -10, +22 respectively, and the first three HS counters receiving 4, +6, -36. The following table shows the operations performed by the machine.

	X	Y	Z
Original numbers - comp.	110	← 1110110	10100
Original numbers - HS	(-) 100	110	← 111011100
Result on comp.	10	← 1110000	000111000
HS	(-) 100	110	← 111011100
Result on comp.	← 11110	← 1111010	← 1111011100
HS shifts	(+) 10	11	← 11101110
	000000	← 1111101	0011001010

The action of the shift and the change from add to subtract and vice versa take place whenever the X coefficient on the computing counter changes sign. When this happens there is a carryover from the last place on the X counter, and this impulse is taken off through a commutator and used to control the shifting circuit and add-subtract relays.

Figs. 11a, 11b, 11c together are a schematic diagram of the machine set up for solving equations in the manner described above. The square boxes marked a, b, c--h, i are respectively a computer, an HS circuit, a base-2 circuit, a base-2 punching circuit, the automatic add-subtract control, the negative-number indicator, the shift control, one-cycle relays, and the division control. These diagrams merely show the interconnection of these units; their details are shown in other diagrams. Units a, b, c, d are duplicated 30 times; the other units serve for the whole machine. The numbered terminals correspond to the numbers on the detail diagrams.

In Fig. 11b, 58 and 59 are respectively the computing counter and the HS counter, and 62 and 63 are the clearing switches for these counters. The booster commutator 61 connects to the counter slip rings through the clearing switches, and also directly to the carryover counters 60. Switch 68 is a 30-pole double-throw switch (only one pole is shown) which enables the C inputs of the computing units to be switched to the card devices or to the output of the HS units. Switch 90 is a single-pole double-throw switch which connects the add-subtract relays of all the computer units to relay 39 for reading base-10 cards or to terminal 37 of the add-subtract control device for computing. Switch 70 is a selector which determines into which counter a base-10 card will be read.

A commutator 65 provides discharging impulses for all the input discharging circuits 64. Switch 69 is a 30-pole double-throw switch which connects the charging brushes of the HS counters to the charging brushes of the computing counters in order to transfer numbers, or to the charging output of the HS circuits when numbers are to be retained or shifted on the HS counters. Contactors 74 through 83 are used to provide control impulses during the blank part of the cycle. Fig. 20 is a timing diagram for the machine showing the interrelation of these contactors.

Jacks 66 and 67 are connected respectively to the carryover charging and the condenser charging outputs of the computer units. One plug 72 goes with the set of 30 jacks 66 and another plug 73 goes with the set of jacks 67. Plug 72 selects on which computer the coefficient is going to be reduced to zero. Contactor 74 connects plug 72 to the add-subtract control e during the last carryover charging period in a cycle of operation, and contactor 77 connects plug 72 to the shift control at the same time. Plug 73 is used in conjunction with contactor 76 and negative-number indicator f for determing the sign of the number on any computing counter.

Units a, b, c, d have already been considered in detail in the foregoing. The control units will now be described fully.

ADD-SUBTRACT CONTROL Unit e is the device for automatically controlling addition and subtraction during the elimination of a coefficient. Fig. 15 is a circuit diagram of this device. The grid of tube 91 receives impulses through contactor 74; the impulses are negative when there is a carryover past the end of the computing counter and positive when there is no carryover. Condenser 96 holds the charge for a short itme, but resistor 97 causes the charge to leak away in less than one cycle of the machine. These impulses are amplified by tube 91 and applied through coupling condensers to the grids of gaseous triodes 92 and 93. These tubes are arranged in a trigger circuit such that only one can fire at a time. Condenser 98 is a commutating condenser. Relay 99 is closed by tube 92, and controls the add-subtract relays in the computers. The operation of the circuit is as follows: A positive impulse on the grid of tube 91 has no effect, since it is transformed to a negative impulse on the output of tube 91. A negative impulse, however, which occurs when a carryover past the end place in the counter takes place, is transmitted to the grids of 92 and 93 as a positive impulse. One of these tubes is normally conducting, and the positive impulse has no effect upon it. However, the other tube is fired by the impulse, and the sudden drop in potential at its plate is transferred to the plate of the other tube by the commutating condenser 98, extinguishing that tube. The circuit thus triggers back and forth with every negative impulse, the tubes conducting alternately and thus opening and closing relay 99 alternately. Contacts e_4 and e_5 of this relay go to indicating lights, and e_7 controls the add-subtract relays in the computer circuits when switch 90 is down.

Manual selection of add or subtract is accomplished by push-button switch

84, (Fig. 11b) which throws a positive impulse into the plate of tube 91.

Tube 94 of Fig. 15 is used to actuate the tripping magnet for the base-10 card reader. In reading a card into the machine, push button switch 85 is pressed. This closes relay 100, which holds itself closed through contacts 101 and contacts 42 on the card reader until the carriage of the reader reaches the end of its travel. Contactor 75 fires tube 94 for a short length of time each revolution, moving the carriage ahead one step at a time. The grid of tube 94 also receives impulses from tube 91 in conjunction with the reading out of numbers; this will be described later.

NEGATIVE NUMBER INDICATOR In some uses of the machine it is necessary to determine the sign of a number which is on one of the counters. Unit f (Fig. 16) is used for this purpose. In this, the grid of tube 105 receives through contactor 76 the charging impulse of the last condenser in a cycle. The counter being tested is chosen by placing plug 73 in the proper jack 67. Condenser 103 is kept negatively charged, blocking tube 105 and thus causing relay 104 to be open. A positive number maintains a positive charge on condenser 103, causing plate current to flow in the tube and closing relay 104. This relay controls indicator lights 106.

SHIFT CONTROL Fig. 17 is a circuit of the shift control g which causes all the numbers on the HS counters to be shifted one place each time there is a carryover past the end place on the counter carrying the coefficient to be eliminated. The grid of tube 108 receives the last carryover impulse (from the same source as the add-subtract control) through commutator 77. Condenser 107 holds the charge on this grid for one revolution of the counters. The plate current of tube 108 controls relay 109, which in turn controls the plate voltage of the V and W tubes in the HS circuits. Tube 108 blocks when there is to be a shift, opening the relay and applying plate voltage through contact G_3 to the V tubes.

ONE-CYCLE RELAYS In Fig. 18 the details of unit h are shown. The purpose of this set of relays is to provide an interlocked control system so that the operator can push certain control switches at any part of the cycle, yet the machine will not respond until the proper point in the cycle is reached.

Relay 113 is normally held closed by its own contacts 117 and push-button switch 88. This switch is pushed when it is desired to punch a base-2 card, opening relay 113, and closing contacts 116; however, nothing happens until that part of the cycle when contactor 78 closes, at which time relay 110 closes. This relay holds itself closed through its own contacts 120, and also closes 121, 122, 123. Of these, 122 supplies bias through h8 to the punching circuits, making them operative, and 123 operates the electromagnetic latch, 46 and 47, which allows a card to be fed in. A circuit for reclosing 113 is set up by contacts 121. After one revolution contactor 79 closes, and this through contacts 121 of relay 110 causes relay 113 to close and hold itself closed. The closing of relay 113 opens relay 110 and the system is in its original state.

The operation of relay pairs 114, 111 and 115, 112 is exactly the same. Relay 111 controls through contacts 125 the electromagnetic latch, 46 and 47, and through contacts 124 makes the source of base-2 reading voltage operative.

Relay 112 is used to control the beginning of a computation, in conjunction with the division control device i, which will be described next.

DIVISION CONTROL The circuit of the division control device i is shown in Fig. 19. The grid of tube 127 is connected to plug 73 and receives impulses from the plate circuit of the computer handling the coefficient which is being eliminated. The purpose of the division control is to supply a bias voltage once a complete cycle of the machine has occured without an impulse having been received by tube 127, since this means that the number has been reduced to zero.

The details of operation are as follows: to begin computation, switch 86 is opened for an instant. This causes relay 112 to be closed for one cycle of the machine as explained previously. Contacts 134 supply a voltage to i^6 causing relay 131 to close. This relay holds itself closed through contacts 132 and also closes contacts 133 which supply bias to b7, starting the computation.

Contactors 80 and 81 close in sequence during the resetting period, 81 closing first and 80 closing after 81 has opened. If during the preceding cycle at least one negative impulse has come into the grid of tube 127 relay 128 will be open at the end of the cycle. Thus when 81 closes contacts 130 will be open and relay 131 will remain closed, allowing computation during the next cycle. Contactor 80 closes after 81, reclosing relay 128.

At the end of a cycle during which no negative impulses have entered the grid of tube 127 relay 128 will be holding contacts 130 closed, and the closing of contactor 81 short-circuits relay 131 through contacts 130 causing relay 131 to open, thus stopping computation.

Fig. 20 is a timing diagram of the entire machine, showing the relative closing times of all contactors.

MISCELLANEOUS DETAILS Contactor 82 is used for disabling the input discharging circuits of the HS units during the last discharging period of a cycle in order that the shift may take place properly.

Contactor 83 is used for discharging the carryover counters by removing their booster voltage during one charging period in the resetting period. This prevents the possibility of a carryover from the last place in the number back to the first.

READING OUT BASE-10 NUMBERS Means for converting any base-2 number in the machine to a base-10 number on a set of dials are included. The process merely consists in using the converter and the powers-of-ten row on the base-10 card mechanism, and dividing out powers of 10. The number to be read is selected by means of plug 72. Switch 71 is opened, disconnecting all but the powers-of-ten brush on the card reader. Switch 86 is used to start computation, the machine having first been set to subtract (assuming a positive number is being read out) by means of switch 84. The base-10 number 10^{14} is subtracted until the number on the counter goes negative, whereupon the machine automatically changes to add and the carriage of the card mechanism is moved one step. The machine adds 10^{13} until the n number on the counter becomes positive, when the carriages drops back to 10^{12} and the machine begins to subtract again. This process continues automatically until all powers of ten have been used. A set of dial counters corresponding to the powers of ten record the number of revolutions of the machine made between each step of the carriage. The counters which count during subtractions record one less than the number of subtractions, and the counters which count during additions record 10 minus the number of additions in each place. The resulting number on the base-10 dials is the base-10 equivalent of the base number on the computing counter.

In case a negative number is to be read out the procedure is exactly the same, except that the machine is set to add initially.