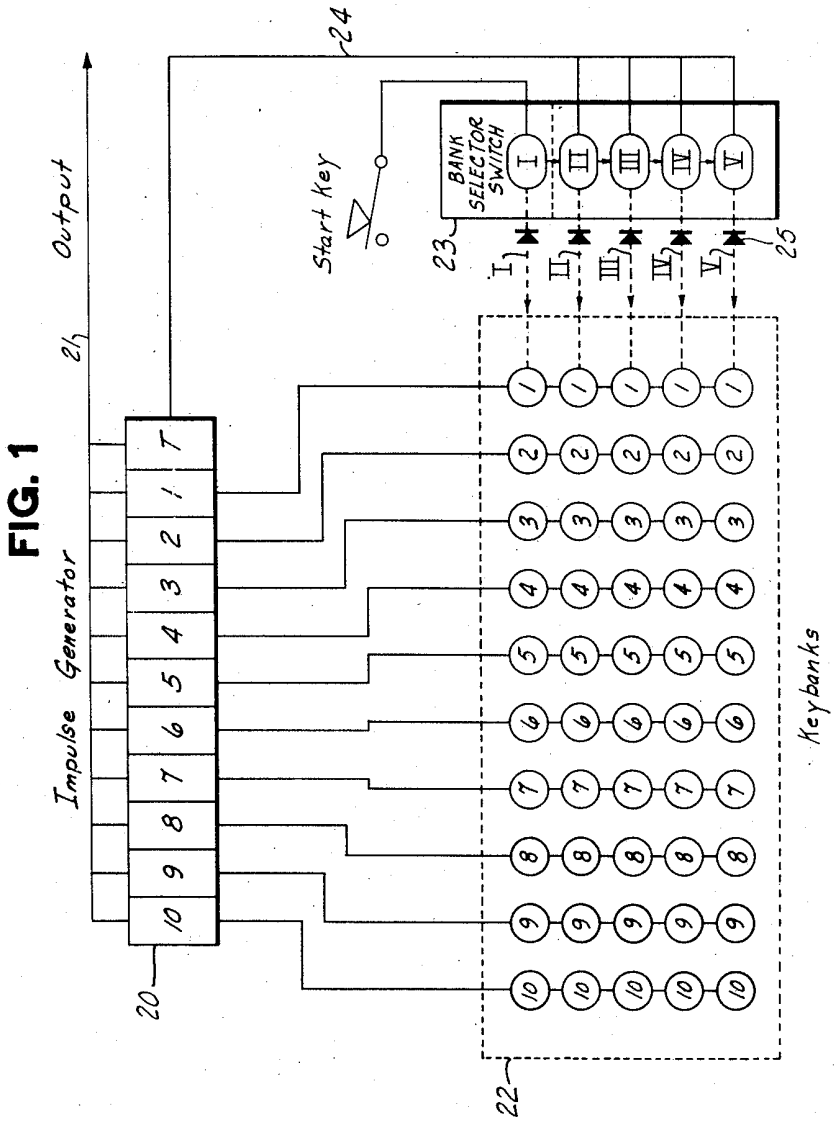
April 9, 1946. R. E. MUMMA ET AL 2,398,150

ELECTRONIC DEVICE

Filed March 3, 1943 5 Sheets-Sheet 1

FIG. 1



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April 9, 1946. R. E. MUMMA ET AL 2,398,150

ELECTRONIC DEVICE

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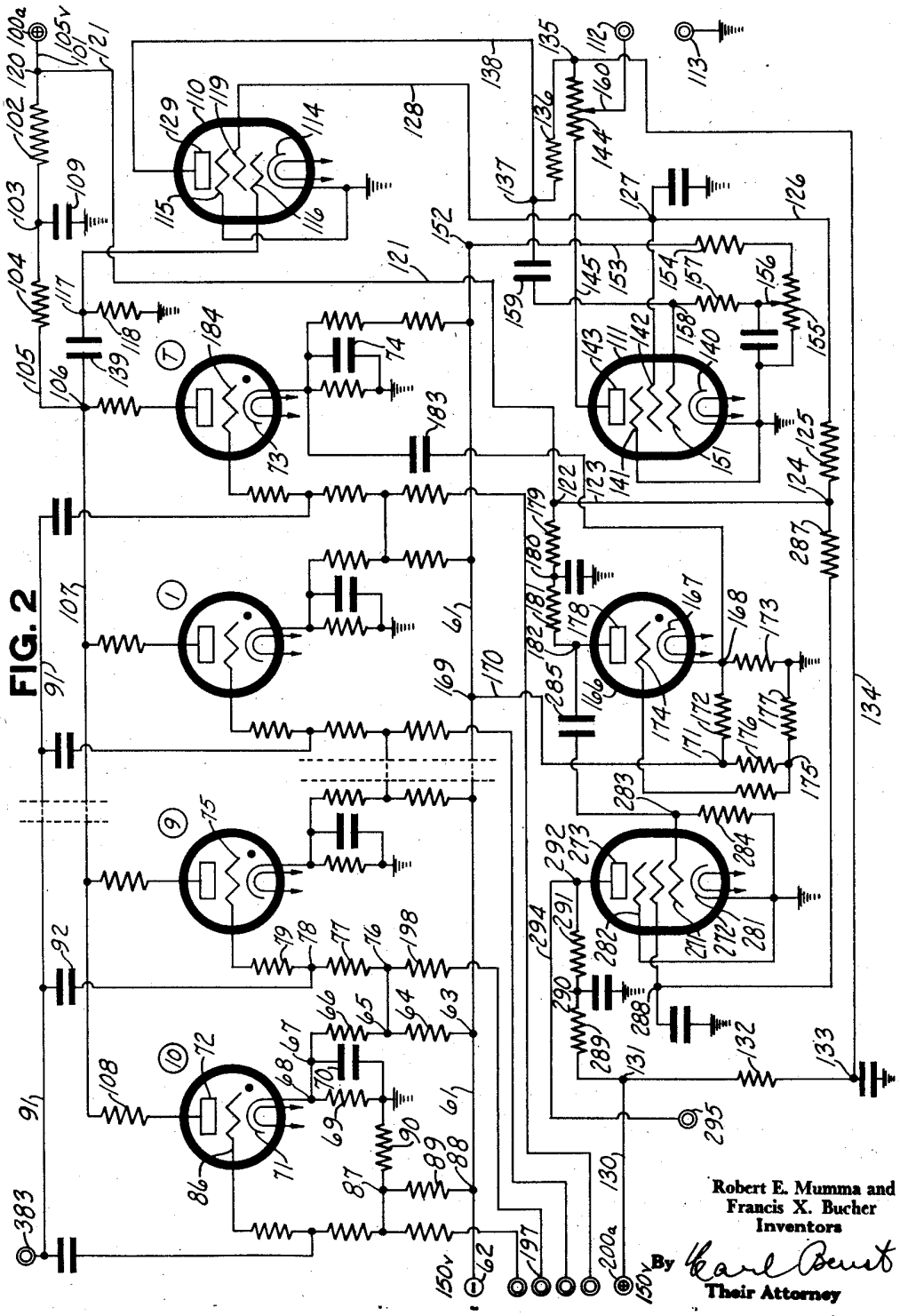

FIG. 2

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ELECTRONIC DEVICE

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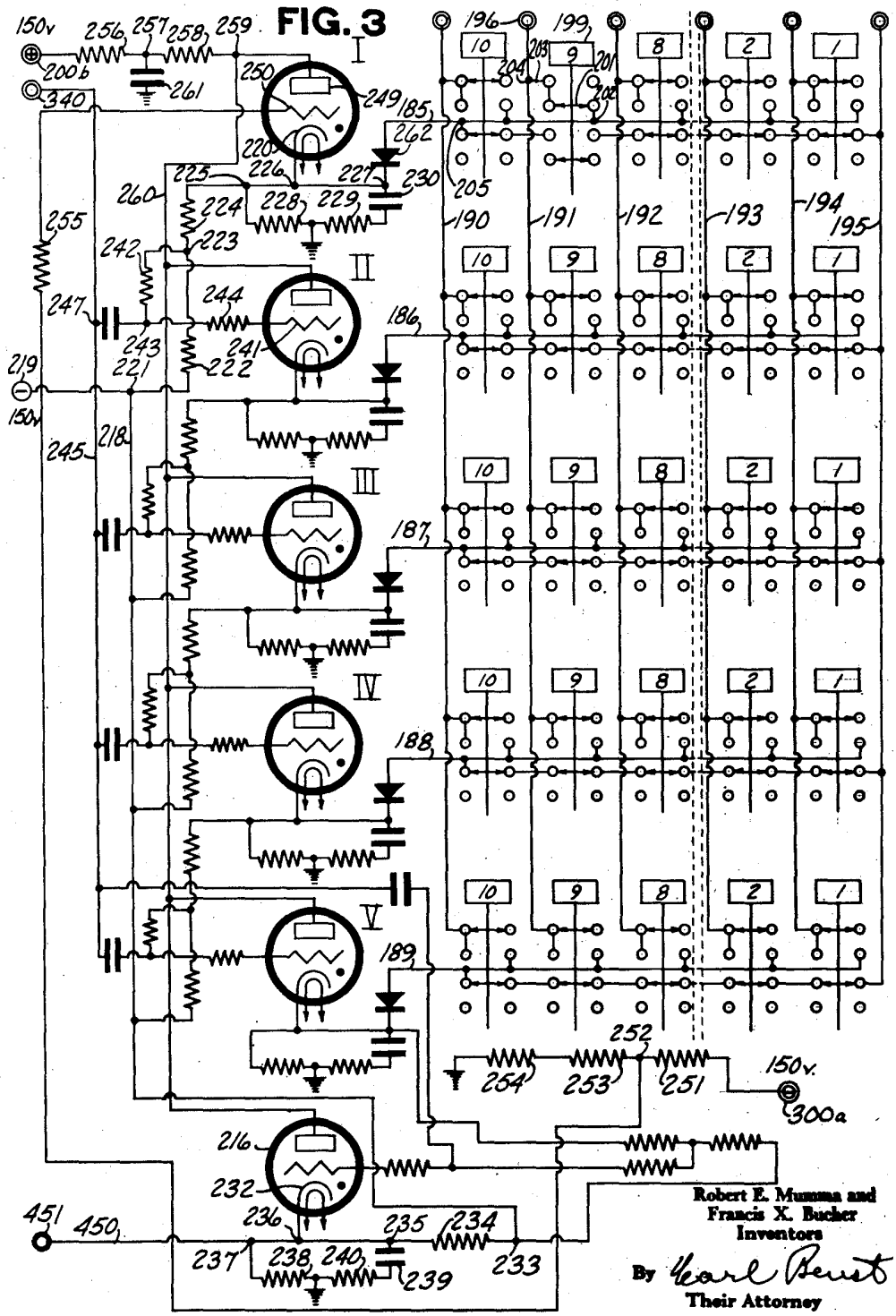
FIG. 3



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April 9, 1946. R. E. MUMMA ET AL. 2,398,150

ELECTRONIC DEVICE

Filed March 3, 1943 5 Sheets-Sheet 4

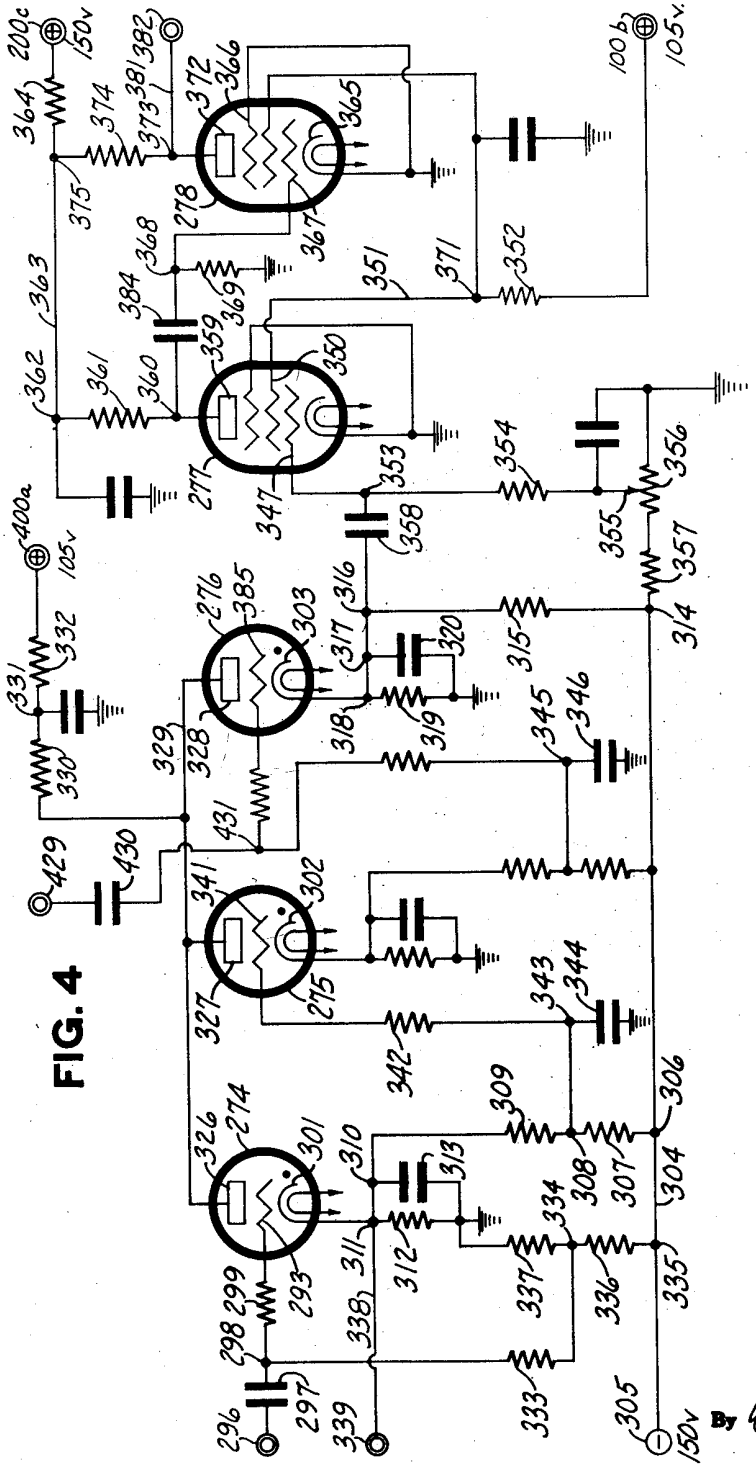

FIG. 4

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ELECTRONIC DEVICE

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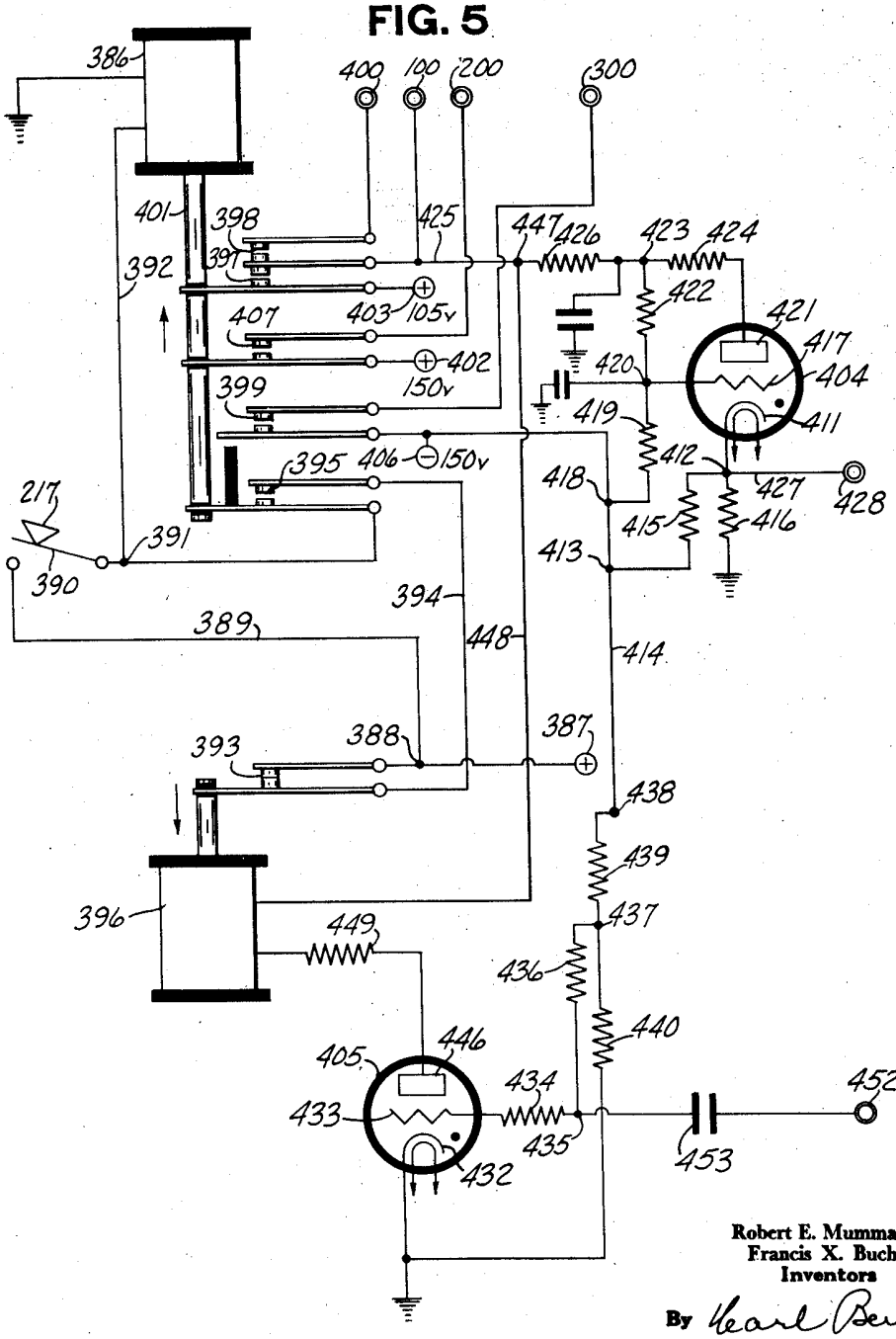
FIG. 5



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UNITED STATES PATENT OFFICE

2,398,150

ELECTRONIC DEVICE

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Application March 3, 1943, Serial No. 477,786

19 Claims. (Cl. 315—323)

This invention relates to an impulse-generating means and is directed particularly to one in which a single differentially operable impulse-generating means can be differentially controlled by a plurality of control means, one after another automatically in succession, to produce different numbers of impulses.

In applicants' novel device, a plurality of control means are provided to control the number of impulses which are to be produced in each of a plurality of groups of impulses. A single generating means is provided to produce the plurality of groups of impulses, and a selector switching means enables the plurality of control means to be effective one after another to exert a control on the generating means. The selector switching means is operated at the completion of each differential operation, which is controlled by a control means and renders the next control means effective to control the number of impulses which will be generated. The single generating means, therefore, is differentially operated repeatedly to produce a group of impulses for each of the plurality of control means.

Prior to the instant novel construction, it was usual, in impulse-generating means for producing a plurality of groups of impulses, to provide a separate generating means and a separate control means for each group of impulses. By utilizing the same generating means repeatedly with a plurality of control means, applicants have provided a simplified means for producing a plurality of groups of impulses, and one in which the capacity to produce a larger number of groups of impulses may be increased merely by adding additional control means and expanding the selector switching means to accommodate the additional control means. The capacity of the generating means can accordingly be increased without a corresponding proportional increase in the mechanism required, as was the case in impulse-generating means prior to this one.

It is an object of this invention, therefore, to provide a simplified impulse-generating means for producing a plurality of groups of impulses under control of a plurality of control means.

Another object of this invention is to provide novel controls for an impulse-generating means, whereby a single generating means can be controlled by a plurality of groups of differential control means, one group after another automatically in succession.

Another object of the invention is to provide a selector switching means to render a plurality of banks of control means effective, one bank at a time in automatic succession, to control a single impulse-generating means.

Another object of the invention is to provide a plurality of banks of control means for controlling a single bank of impulse-generating means and to provide switching means controlled by the generating means, each time a differential operation of the generating means under control of one bank of control means is terminated, to render another bank of control means effective to control the generating means.

A further object of the invention is to provide novel controls for an impulse-generating means, in which a selector switching means can render a plurality of banks of control devices successively effective to control the differential operation of the generating means and in which the generating means, at the completion of a differential operation under control of one bank of control devices, causes an operation of a bank selector switching means to render another bank of control devices effective and causes the automatic initiation of another operation of the generating means under control of said other bank of devices.

With these and incidental objects in view, the invention includes certain novel features of construction and combinations of parts, the essential elements of which are set forth in the appended claims and a preferred form or embodiment of which is hereinafter described with reference to the drawings which accompany and form a part of this specification.

In the drawings:

Fig. 1 is a schematic showing of the impulse-generating means, the banks of control keys, and the bank selector switching means, and illustrates the operative relation between these elements.

Fig. 2 shows a portion of the impulse-generating means and certain control tubes associated therewith.

Fig. 3 shows a portion of the several banks of keys which control the number of impulses in the groups of impulses, and also shows the bank selector switching means.

Fig. 4 shows a group of tubes which are used to coordinate the operation of the bank selector switching means and the impulse-generating means.

Fig. 5 illustrates a start and a stop control means by which the initiation and termination of an operation of the impulse-generating means are effected.

General Description

The novel impulse-generating means is operable to produce a plurality of groups of rapidly-recurring impulses, which impulses may have any desired significance and may be used in many ways to actuate or control the actuation of other mechanism.

In the disclosed embodiment, the impulse-generating means is capable of emitting five groups of impulses under control of five banks of control means. The control means is shown as consisting of depressible digit keys, of which there are ten to a bank.

However, the invention is not limited to the use of banks of keys as control means, because other forms of control means which can selectively render circuits effective may be used in place of the depressible keys. The automatic generation of five groups of impulses and the use of ten digit keys in each bank have been chosen arbitrarily in order to explain the invention, but it will be obvious from the following description that the number of groups of impulses which the generating means can produce in automatic succession, and the number of keys in each bank and their significance, can be varied without departing from the substance of the invention.

The essential elements of applicants' novel impulse-generating means are shown schematically in Fig. 1.

The impulse-generating means, shown generally at **20**, consists of a single bank of gaseous electron tubes, and in this bank there are a tube corresponding to each of the keys of a bank, and a terminal tube, which tubes are connected in a chain sequence to be fired and rendered conducting automatically one after another beginning with any selected tube in the chain and ending with the terminal tube. The firing of the tubes in the bank is initiated by a firing impulse which is impressed on the bank but which is effective to fire only that tube in the bank which has been selected by the depressed key. Once a tube in the bank is fired, the remaining tubes in the sequence fire automatically one after another until the terminal tube is fired to indicate the completion of the operation of the bank of tubes under control of a bank of keys. When each tube is fired, it impresses an impulse on a common conductor, as conductor **21**, so that, as the selected number of tubes in the bank is fired, a group of impulses containing a corresponding number of impulses is produced. By operation of the bank of tubes over and over, a plurality of groups of impulses can be generated.

The five banks of keys, shown schematically at **22**, are normally ineffective to control the generating means but are rendered effective one bank after another by the bank selector switching means and, when effective, control the number of impulses which will be included in the group of impulses being generated. The keys having the same digit value in each of the banks are operable to complete a control circuit from the various banks to their corresponding tube, so that, when the banks become effective one after another, the tube corresponding to the depressed key in the effective bank will be selected as the one with which the automatic firing of the tubes of the bank will begin. If no key is depressed in a bank, a control circuit is closed to the terminal tube to cause that tube to be fired when this bank of keys is in control.

The bank selector switching means, shown schematically at **23**, consists of a bank of gaseous electron selector tubes, numbered I, II, III, IV, and V, which are connected to be fired and rendered conducting one at a time in a chain sequence in response to impressed impulses. The selector tubes of the bank selector switching means are related to the various banks of keys, and the act of conduction occurring in any one of these tubes will render that tube effective to apply a sufficient potential to its related bank of keys to enable the keys to select the tube of the generating means which will respond to the firing impulse. The numerals I, II, III, IV, and V applied to the connections between the tubes and the banks of keys indicate the order in which the banks of keys are effective.

The selector tube corresponding to the first bank of keys is fired by the starting means, which initiates the generation of the plurality of groups of impulses, and renders this bank effective to control the impulse-generating means. When the terminal tube of the bank of generating tubes is fired after the first operation of the bank of generating tubes, it causes an impulse to be sent over a conductor, shown at **24**, to the bank selector and switching control tubes to cause the tube related to the second bank of keys to be fired and the previously conducting selector tube to be extinguished. This places the second bank of keys in control of the generating means. In this manner, the termination of the operation of the impulse-generating means under control of one bank of keys causes the selector switching means to be operated to restore said one bank to its ineffective condition and render another bank of keys effective to control the impulse-generating means.

Rectifiers, as shown generally at **25**, are included between the banks of keys and their related switching control tubes to prevent back-up circuits, which might otherwise occur and render the switching control means inoperative.

The firing of the terminal tube in the bank of generating tubes also causes a firing impulse to be impressed on the bank of impulse generating tubes after the bank selector switching means has operated, and this impulse will fire the selected tube and recycle or start another operation of the impulse-generating means.

A detailed description of these essential elements and the means whereby their operation is coordinated will now be given.

Detailed Description

It is not intended that the invention be limited to the use of the particular potentials and values of resistance and capacitance given in the following description, because the potentials applied to the various elements of the tubes are merely selected as convenient potentials for the disclosure, and the circuit elements of resistance and capacitance correspond in relative value to the potentials chosen. It is obvious that other potentials may be used and the values of the circuit elements adjusted accordingly to maintain the proper relation between the various parts of the circuit. Throughout the drawings, the cathode heater elements are shown conventionally.

The impulse-generating means

The impulse-generating means is shown in Fig. 2 and consists of a single bank of gaseous electron tubes of the type having an internal potential drop of fifteen volts, when conducting, and having an anode, a cathode, and a control grid

which is given a negative bias with respect to the cathode and will prevent the tube from firing and becoming conducting until this bias is reduced to less than fifteen volts negative with respect to the cathode.

The bank will include as many tubes as the maximum number of impulses possible in any group. In the present embodiment, this will mean that there is a tube for each of the keys "1" to "10" and a terminal tube T for indicating the completion of an operation of the generating means under control of a bank of keys. In Fig. 2, only the "10", "9", "1", and T tubes are shown, the tubes for the keys "2" to "8" inclusive having been omitted to simplify the showing of the bank, because the circuits for these tubes are identical with those for the other tubes and the operation of the impulse-generating means can be readily understood without their inclusion.

The tubes of the bank are connected to be fired automatically one after another in a sequence extending from the "10" tube and continuing through the "1" tube to the T tube. The automatic firing of the tubes may begin with any selected tube in the sequence and, when once begun, will continue through the remaining tubes of the sequence until the terminal tube T has been fired and rendered conducting.

The anodes of the tubes are supplied with positive potential by being connected to a source of positive potential over a common resistor, so that, as each tube is fired and becomes conducting, a potential drop or impulse occurs across the common resistor in the anode potential supply connections. These impulses are used to extinguish any previously conducting tubes and are also used to furnish the impulses which are generated by the bank.

A firing impulse conductor which is common to all the tubes in the bank enables firing impulses to be impressed on the tubes to fire any selected tube and initiate the automatic firing of the remaining tubes in the sequence.

Amplifying means is provided to amplify the generated impulses before they are impressed on an output terminal.

The circuits for supplying the potential to the elements of the impulse-generating tubes and the amplifying tubes and for interconnecting the tubes for operation will be clear from those shown in Fig. 2.

Negative potential is supplied to the cathodes of the impulse-generating tubes by means of parallel circuits, one for each tube, extending to ground from a negative potential supply conductor **61**, to which a negative potential of 150 volts is applied at terminal **62**. The circuit for the "10" tube is representative of the circuits for the "1" to "10" tubes and extends from point **63** on the negative potential supply conductor **61**, over resistor **64** of 150,000 ohms, point **65**, resistor **66** of 75,000 ohms, points **67** and **68** and to ground over resistor **69** of 15,000 ohms and capacitor **70** of .002 microfarad in parallel. The cathode **71** for the "10" tube is connected to this circuit at point **68** and is given a negative potential of about 9 volts when the tube is not conducting. When the tube becomes conducting, however, its cathode **71** is conductively coupled to the anode **72** by the discharge path through the tube, so that the positive potential applied to the anode will be impressed on the cathode potential supply circuit and will cause the potential of the cathode to rise from a negative potential of 9 volts to a positive potential of about 70 volts.

The potential supply circuit for the cathode **73** of the terminal tube T is similar to those for the other circuits, except that the capacitor **74** in this circuit has a value of 500 micro-microfarads instead of .002 microfarad. This particular value for the capacitor **74** is used because of other capacitance associated with this cathode.

Negative biasing potential is supplied to the control grids of the impulse-generating tubes by means of the circuits which connect the tubes of the bank for sequential operation. Each cathode potential supply circuit is connected to the control grid of the tube next in sequence and supplies this grid normally with a negative biasing potential sufficient to prevent conduction. As an example, the cathode potential supply circuit for the "10" tube supplies the control grid **75** of the "9" tube with a normal negative biasing potential of 56 volts by means of a circuit extending from point **65** in the cathode potential supply circuit, over point **76**, resistor **77** of 500,000 ohms, point **78**, and resistor **79** of 50,000 ohms. However, when the potential of the cathode **71** of the "10" tube rises from a negative potential of 9 volts to a positive potential of about 70 volts when the "10" tube is fired and becomes conducting, this potential rise is reflected on the control grid **75** of the "9" tube and reduces the bias below the critical point and causes that tube to be fired and rendered conducting.

Since the "10" tube is the first tube in the sequence, its control grid **86** is given a negative bias of 56 volts from point **87** in a circuit which is equivalent to the cathode potential supply circuits and extends from point **88** on the negative potential supply conductor **61**, over resistor **89** of 150,000 ohms, point **87**, and resistor **90** of 90,000 ohms to ground.

Each control grid of the impulse- generating tubes is electrostatically coupled to a firing impulse conductor **91**, the coupling for the grid **75** of the "9" tube extending from point **78** in this grid circuit, over a capacitor **92** of 10 micro-microfarads to the firing impulse conductor **91**. The firing impulses, which are positive potential impulses impressed on conductor **91**, tend to reduce the negative bias of the control grids below their critical value but are not sufficient to overcome this normal negative bias. The firing impulses will be effective to fire a tube and start the automatic firing of the impulse-generating means only if that tube has been "primed" or has had its grid bias reduced to near the critical point, so that a firing impulse can reduce the bias below the critical point and cause that tube to fire and become conducting. The manner in which the tubes are "primed" will be explained hereinafter.

Positive potential is supplied to the anodes of the impulse-generating tubes from the terminal **100***a*, upon which is impressed a positive potential of 105 volts whenever the generating means is operative, as will be explained later herein. From terminal **100***a*, the circuit extends over conductor **101**, resistor **102** of 250 ohms, point **103**, resistor **104** of 3,000 ohms, conductor **105**, point **106**, and conductor **107**, to which the anodes are connected over 1,000-ohm resistors, as the resistor **108** for the "10" tube. Point **103** in this circuit is connected to ground over a capacitor **109** of 4 microfarads, which absorbs the shock of any abrupt application or change of potential in the circuit.

When none of the impulse-generating tubes is conducting, the anodes will have a positive poten-

tial of 105 volts, but when any tube is conducting, the resistance in the circuit will cause the potential of the anode of the conducting tube to drop to +85 volts and the potential of the conductor 107 and the anodes of the other tubes to drop to +90 volts.

At the instant a tube is fired, the capacitor, as 70 in the cathode potential supply circuit, will cause the cathode to retain its negative potential of 9 volts, and, since the tubes are of a type having an internal drop of 15 volts, the potential of the anode will drop to 6 volts positive, which drop will be reflected throughout the anode potential supply circuit. After the capacitor, as 70, has been charged, the potential of the cathode and the anode of the conducting tube will rise to 70 and 85 volts positive, respectively.

This impulse, which occurs in the potential of the anode supply circuit as a tube is fired, is used to extinguish any previously conducting tube, because it will reduce the anode potential of a previously conducting tube below the potential of its cathode, which, at this time, is at a positive potential of 70 volts due to conduction within that tube.

The impulses, which occur on the conductor 107 as the tubes are fired, are amplified by a pair of vacuum tubes 110 and 111 (Fig. 2), by which the impulses are sharpened and amplified before they are impressed on the terminal 112, which, with terminal 113, constitutes the means from which the impulses may be taken from the impulse-generating means.

Tube 110 has a zero bias and is normally conducting. The cathode 114 and the suppressor grid 115 are connected directly to ground, and the control grid 116 is connected to ground over point 117 and resistor 118 of 10,000 ohms. Screen grid 119 has a positive potential of 105 volts supplied from point 120 on conductor 101 and over conductor 121, point 122, conductor 123, point 124, resistor 125 of 250 ohms, conductor 126, point 127, and conductor 128. The anode 129 of this tube is supplied with positive potential from terminal 200*a*, which has a positive potential of 150 volts applied thereto, in a manner to be explained hereinafter, whenever the generating means is operating. From the terminal 200*a*, the circuit continues over conductor 130, point 131, resistor 132 of 250 ohms, point 133, conductor 134, point 135, resistor 136 of 3,000 ohms, point 137, and conductor 138 to anode 129.

The control grid 116 is electrostatically connected from point 117 to the conductor 107 in the anode potential supply means for the impulse-generating tubes, by means of a capacitor 139 of 10 micro-microfarads, so that, as each impulse-generating tube is fired, the impulse generated thereby can be impressed on the grid and can reduce conduction in tube 110.

Since tube 110 is normally conducting, the potential of its anode 129 will normally be reduced to about +20 volts due to the resistors in its anode potential supply circuit. As conduction is reduced in tube 110 by the impulses impressed on the grid 116, the potential of the anode 129 will rise toward 150 volts. This rise in potential is used to cause tube 111 to become conducting.

Tube 111 is normally non-conducting but may be rendered conducting by the impulses formed by the tube 110. The cathode 140 and the suppressor grid 141 of tube 111 are connected directly to ground. The screen grid 142 has positive potential applied thereto by being connected to point 127 in the circuit traced above for the screen grid 119 of tube 110.

Anode 143 of tube 111 has 150 volts positive potential applied thereto over the circuit traced above for the anode 129 of tube 110 to the point 135 and from this point over resistor 144 of 5,000 ohms and conductor 145 to the anode 143. The control grid 151 of tube 111 obtains a negative bias from a circuit which starts at point 152 on the negative potential supply conductor 61 and continues over conductor 153, resistor 154 of 100,000 ohms, and resistor 155 of 50,000 ohms to ground. The control grid 151 obtains a negative biasing potential by means of a potential-tapping member 156, which cooperates with the resistor 155 and is connected to the grid 151 over resistor 157 of 50,000 ohms and point 158 and may be adjusted to give the desired negative bias to the control grid.

Point 137 in the circuit for the anode 129 of tube 110 is electrostatically connected to point 158 in the control grid circuit of tube 111 by means of a capacitor 159 of 10 micro-microfarads, and the impulses produced by reducing the conduction in tube 110 will cause the bias on tube 111 to be reduced and allow conduction to take place therein. When conduction occurs in tube 111, the potential of its anode will drop due to resistor 144 in its anode potential supply circuit. A potential-tapping member 160, cooperating with resistor 144, is connected with the output terminal 112 and enables a negative impulse of the desired amplitude to be impressed on the output terminal each time one of the impulse-generating tubes is fired.

The terminal tube T, being the last tube to fire in the sequence of operation of the impulse-generating tubes, remains conducting at the end of a differential operation of the generating means, and, since it may be necessary to fire this tube as the first tube in the next differential operation of the generating means, as is the case when no digit key is depressed in the next bank of keys to be used to control the generating means, means must be provided to extinguish the terminal tube.

The means used to extinguish the terminal tube T is a gaseous electron tube 166 (Fig. 2) of the same type as the impulse-generating tubes. Tube 166 is normally conducting but is extinguished momentarily when the terminal tube T is fired. After the tube 166 has been extinguished for a short time, it automatically refires and becomes conducting, and its refiring extinguishes the terminal tube T.

The cathode 167 of tube 166 is given a negative potential of 9 volts by being connected at point 168 in a circuit extending from point 169 on the negative potential supply conductor 61 and continuing over conductor 170, point 171, resistor 172 of 225,000 ohms, point 168, and resistor 173 of 15,000 ohms to ground. The control grid 174 of tube 166 is given a negative potential of about 10 volts by being connected at point 175 in a circuit which extends from point 171 in the circuit traced above and continues over resistor 176 of 200,000 ohms, point 175, and resistor 177 of 150,000 ohms to ground. Positive potential is supplied to the anode 178 of tube 166 from the terminal 100*a*, which, as noted earlier herein, has a positive potential of 105 volts impressed thereon when the generating means is operating. The circuit extends from point 120 on conductor 101 and over conductor 121, point 122, resistor 179 of 250 ohms, point 180, resistor

181 of 3,000 ohms, and point 182 to the anode 178. A capacitor of 4 microfarads is connected between point 180 and ground to absorb shocks due to abrupt application of or change in potential in this circuit.

Inasmuch as the potential of the control grid 174 of tube 166 is less than 15 volts negative with respect to the potential of its cathode 167, this tube will be fired and become conducting when positive potential is applied to its anode. Due to the conduction in the tube, the potential of its cathode 167 will rise to about 70 volts positive, and the potential of its anode 178 will be about 85 volts positive. The cathodes of the terminal tube T and tube 166 are electrostatically coupled over a capacitor 183 of .002 microfarad to enable the mutual extinguishing action to take place. The operative relation between these tubes is as follows:

When the operation of the impulse-generating means is initiated by a start key, in a manner to be explained later, positive potential is applied to the anode 178 of tube 166, and, since the potential of the control grid 174 is less than 15 volts negative with respect to the cathode 167, the tube will immediately be fired and become conducting. The conduction in tube 166 will cause the potential of cathode 167 to rise from a negative potential of 9 volts to a positive potential of 70 volts. This potential rise is impressed as an impulse on the electrostatic coupling between the cathode 167 of tube 166 and the cathode 73 of the terminal tube T, but at this time the terminal tube T is non-conducting and its cathode 73 has a negative potential of 9 volts, so that the impressed potential rise will not affect the condition of the terminal tube T.

When the terminal tube T is fired at the end of a sequential operation of the impulse-generating tubes, the potential of its cathode 73 will rise to a positive potential of 70 volts, and this rise is applied to the electrostatic coupling between the cathode 73 and the cathode 167 of tube 166. The cathode 167 of tube 166 is already at a positive potential of 70 volts due to conduction in that tube, and, when the potential rise of the cathode 73 of the terminal tube T is impressed thereon by the electrostatic coupling, it will cause a momentary rise of the potential of the cathode 167 above the potential of the anode 178 and will extinguish conduction in tube 166.

As soon as tube 166 is extinguished, its cathode potential will drop to a negative potential of 9 volts, but, as the control grid 174 does not have a sufficient bias to prevent conduction, tube 166 will refire and become conducting again as soon as the potential of cathode 167 drops to within 15 volts of the potential of grid 174. The firing of tube 166 will cause the potential of its cathode 167 to rise, and this rise is impressed on the cathode of the terminal tube T by means of the electrostatic coupling. At this time, the terminal tube T is conducting, and its cathode 73 has a positive potential of 70 volts, so that the potential rise of the cathode 167 of tube 166, which is impressed thereon, will cause the potential of the cathode 73 of the terminal tube T to rise above its anode potential and extinguish conduction in the terminal tube T. The control grid 184 of the terminal tube T has a sufficient negative bias and will retain that tube in its extinguished condition.

In this manner, the terminal tube T can momentarily extinguish the tube 166 at the end of each sequential operation of the impulse-generating tubes, and the refiring of the tube 166 will extinguish the terminal tube T and prepare the impulse-generating tubes for further operation.

Tube 166, when it is refired after it has been momentarily extinguished, is effective to cause an operation of the bank selector switching means and to cause another operation of the impulse-generating means. These additional functions of tube 166 will be explained more fully hereinafter.

The keyboard

The means for controlling the number of impulses that will be generated in each of the five groups of impulses may take any desired form. In the disclosed embodiment, this controlling means is in the form of a keyboard made up of five banks of keys which can selectively cause the closing and opening of circuits by which the operation of the impulse-generating means can be controlled. It will be obvious from the following description that the number of banks of keys and the number of keys in a bank may be varied, and that other forms of circuit controllers may be used instead of banks of keys without departing from the substance of the invention.

As stated before, the impulse which is impressed on the firing impulse conductor 91 (Fig. 2) in the impulse-generating means is effective to fire only that impulse-generating tube which has been "primed" by having its grid bias reduced almost to the critical or firing point. This condition has been used to enable the various banks of control means to select the tubes of the generating means with which the automatic firing of the tubes is to begin in the five differential operations of the impulse-generating means. The manner in which the keys can selectively "prime" the tubes to control the operation of the generating means will now be explained.

Fig. 3 shows diagrammatically portions of the five banks of keys for controlling the operation of the impulse-generating means. Each bank of keys contains ten keys, numbered "1" to "10" inclusive, but only the keys numbered "1", "2", "8", "9", and "10" are shown in this figure, the keys for the numbers "3" to "7" inclusive having been omitted to simplify the showing of the banks, inasmuch as the circuits controlled by the omitted keys are similar to the circuits shown and the operation of the keys to control the impulse-generating means can be understood from the circuits shown.

Each key carries a pair of contacts, one for selectively closing a circuit from a potential supply conductor to a priming conductor extending to the tube corresponding to the key, and the other for interrupting a normally closed circuit connecting the potential supply conductor to the terminal tube T. Potential supply conductors 185, 186, 187, 188, and 189, respectively, are associated with various ones of the five banks of keys and have priming potential applied thereto one after another in the order given, to render their associated banks of keys effective to control the impulse-generating means. Priming conductors 190, 191, 192, 193, and 194 are associated with the "10", "9", "8", "2", and "1" keys, respectively, in all the banks and enable the keys of the various banks to select and prime the tubes of the generating means as the banks of keys are rendered effective. Priming conductor 195 for the terminal tube T is normally connected to all the potential supply conductors over the second contact carried by the keys; however, the connection to the potential supply conductor for any bank

of keys will be broken if any key in that bank has been depressed.

The various priming conductors are connected to the grid circuits of the impulse-generating tubes; for instance, the priming conductor 191 associated with the "9" keys (Fig. 3) extends to terminal 196, which is connected to terminal 197 (Fig. 2). From terminal 197, the circuit extends over resistor 198 of 300,000 ohms to point 76 in the grid circuit for the "9" tube. Similar connections extend from the other priming conductors to the other tubes of the bank.

The operation of the bank of keys which controls the impulse-generating means during the formation of the first group of impulses is representative of the operation of all the banks, and their operation will be clear from a description of this bank. Referring to Fig. 3, it is seen that the "9" key 199 in the first bank of keys is depressed. The upper contact 201 carried by the key closes a circuit from point 202 on the potential supply conductor 185, over contact 201 and conductor 203 to point 204 on the priming conductor 191, which, as described above, is connected to the control grid circuit for the "9" tube. The depression of the "9" key has caused its lower contact to be moved to interrupt the connection which starts at point 205 on the potential supply conductor 185 and continues to the priming conductor 195 for the terminal tube T over the lower contacts of all the keys as long as no key is depressed.

When priming potential is applied to the potential supply conductor 185 in a manner to be described later, this potential will, through the priming conductor 191, cause the biasing potential of the control grid of the "9" tube to be reduced to nearly its critical value, so that an impulse on the firing impulse conductor can fire the "9" tube and initiate the automatic sequential firing of the remaining tubes of the sequence. Similarly, if any other key in the bank were depressed, it would "prime" its related tube for firing by the impulse on the firing impulse conductor 91 (Fig. 2). If none of the keys in the bank is depressed, the connection between point 205 on the potential supply conductor 185 and the terminal tube priming conductor 195 is not interrupted, so that the terminal tube T will be "primed" and will be fired in response to the firing impulse on conductor 91.

The bank selector switching means which provides priming potential to the potential supply conductors 185, 186, 187, 188, and 189, one after another in succession, will now be described.

The bank selector switching means

The bank selector switching means may be composed of any means which can apply "priming" potential to the various banks of keys one after another in succession.

In the embodiment of the bank selector switching means which is shown in Fig. 3, this means is made up of a bank of gaseous electron tubes of the type used in the impulse-generating means. In this bank of tubes, there is provided a selector tube for each bank of keys, which tubes are numbered "I," "II," "III," "IV," and "V" to indicate the order in which they operate, and an auxiliary control tube 216 for setting up conditions which are necessary to bring about a termination of the operation of the impulse-generating means after the last bank of keys has been effective to exert its control. The tubes in this bank are connected in a chain sequence to be fired and rendered conducting one at a time beginning with the "I" tube and ending with the auxiliary control tube 216. As each tube is fired, it will extinguish any previously conducting tube in the bank, and, while it is conducting, it will supply biasing potential to its related bank of keys and will prepare the next tube in the sequence for operation in response to a firing impulse impressed on the bank. A firing impulse is impressed on the tubes of the bank, in a manner to be explained hereinafter, each time the impulse-generating means has completed a differential operation under control of a bank of keys, and causes an operation of the bank selector switching means to render the previous controlling bank of keys ineffective and a new bank of keys effective. The "II," "III," "IV," and "V" selector tubes and the auxiliary control tube 216 can be fired by these firing impulses, since these tubes are fired after one or more operations of the impulse-generating means have taken place.

However, the first selector tube, the "I" tube, cannot be fired by these firing impulses, because it must be fired and rendered conducting before the first differential operation of the impulse-generating means in order to render the first bank of keys effective to control the impulse-generating means during its first differential operation. When an operation of the generating means is initiated by a start key 217 (Fig. 5), the "I" tube is caused to fire immediately, which firing is accomplished by momentarily withholding the biasing potential from the control grid of this tube until after potential has been applied to the anode and to the cathode.

Thus it is seen that, by the operation of the bank selector switching means, the various banks of keys can be selected and rendered effective one after another to control the same impulse-generating means, the operation being such that, as soon as the operation-initiating or start key 217 is depressed, the first selector tube is fired automatically and renders the first bank of control keys effective to control the first differential operation of the tubes of the impulse-generating means, and thereafter, upon the termination of each differential operation of the impulse-generating means, a different one of the other selector tubes is operated, and these tubes in turn cause the remaining banks of keys to be rendered effective seriatim. At the end of the differential operation of the impulse-generating means under control of the fifth or last bank of control keys, the auxiliary control tube 216 is fired, this extinguishing the "V" selector tube to render the fifth bank of keys ineffective and setting into operation the means for terminating the operation of the impulse-generating means.

While the bank selector switching means disclosed is particularly suited to the desired operation of the device, the invention is not limited to this particular form, as any other equivalent arrangement by which priming potential can be supplied to the banks one after another, such as a rotary switch which could be operated step by step to apply potential to the banks in succession, could be used.

The circuits for supplying potential to the elements of the bank of tubes making up the disclosed embodiment of the bank selector switching means and for connecting the tubes for sequential operation will now be explained.

Negative potential is supplied to the cathodes of the "I," "II," "III," "IV," and "V" selector

tubes (Fig. 3) by means of parallel circuits, one for each tube, extending to ground from a negative potential supply conductor 218, to which a negative potential of 150 volts is applied at terminal 219. The circuit for the cathode 220 of the "I" tube is representative of these circuits and extends from point 221 on the potential supply conductor 218, over resistor 222 of 13,000 ohms, point 223, resistor 224 of 39,000 ohms, points 225, 226, and 227 and to ground over resistor 228 of 30,000 ohms in parallel with resistor 229 of 2,500 ohms and capacitor 230 of .005 microfarad in series. Cathode 220 for the "I" tube is connected to this circuit at point 226 and is given a negative potential of about 55 volts whenever the tube is not conducting. When the tube is conducting, however, its cathode 220 is conductively coupled to the anode 231 by the discharge path through the tube, so that the positive potential applied to the anode will be impressed on the cathode potential supply circuit and will cause the potential of the cathode to rise from a negative potential of 55 volts to a positive potential of 110 volts.

The potential supply circuit for the cathode 232 of the auxiliary control tube 216 is substantially the same as the ones for the other tubes, and extends from the negative potential supply conductor 218 at point 233, over resistor 234 of 50,000 ohms, points 235, 236, and 237, and to ground over resistor 238 of 30,000 ohms in parallel with capacitor 239 of .005 microfarad and resistor 240 of 2,500 ohms in series. Cathode 232 of the auxiliary control tube 216 is connected to point 236 and has a negative potential of about 56 volts when the tube is not conducting, which potential will rise to a positive potential of 110 volts whenever the tube is conducting.

Negative biasing potential is supplied to the control grids of the tubes in this bank by means of the circuits which connect the tubes for sequential operation. These circuits connect the control grids of the "II," "III," "IV," and "V" tubes and the auxiliary control tube 216 to the cathode potential supply circuits of the "I," "II," "III," "IV," and "V" tubes, respectively, so that the normal negative bias on any of these grids can be reduced by the potential rise of the cathode connected thereto. The circuit to the control grid 241 of the "I" tube is representative and extends from point 223 in the cathode potential supply circuit for the "I" tube, over resistor 242 of 500,000 ohms, point 243, and resistor 244 of 50,000 ohms to the control grid 241 and supplies this grid with a normal negative biasing potential of 127 volts, which potential is sufficient to prevent the firing impulses from firing the tubes. This normal potential bias is reduced almost to its critical value when the potential of the cathode 220 of the "I" tube rises due to conduction in that tube, thus enabling the firing impulse to be effective to reduce the potential of the control grid 241 below its critical value and cause the tube to fire and become conducting.

The control grids for the "II," "III," "IV," and "V" selector tubes and the auxiliary control tube 216 are electrostatically connected to a firing impulse conductor 245, upon which an impulse is impressed each time the generating means has completed a differential operation under control of one of the banks of keys. The connection for the control grid 241 of the "II" tube is representative and extends from point 243 in the control grid circuit, over capacitor 246 of 50 micro-microfarads to point 247 on the firing impulse conductor 245.

The control grid 250 of the "I" tube is also given a negative potential bias of 127 volts, but the circuit for this grid is different from those of the other tubes in order that the biasing potential of the grid may be momentarily withheld at the beginning of an impulse-generating operation. The circuit from which the biasing potential is derived extends from terminal 300a, upon which a negative potential is impressed during an impulse-generating operation but after a momentary delay at the beginning of such an operation, and continues over resistor 251 of 13,000 ohms, point 252, resistor 253 of 39,000 ohms, and resistor 254 of 30,000 ohms to ground. Control grid 250 is connected to point 252 in this circuit over resistor 255 of 500,000 ohms. While this bias is not applied in time to prevent the tube from being fired at the beginning of an operation, it does enable the "I" tube to remain in its non-conducting condition after it has been extinguished by the firing of the "II" tube.

Positive potential is applied to the anodes of the tubes of this bank from terminal 200b, to which a positive potential of 150 volts is applied while the generating means is operating to produce the five groups of impulses. From terminal 200b, the circuit extends over resistor 256 of 250 ohms, point 257, resistor 258 of 3,000 ohms, and point 259 to conductor 260, to which the various anodes are connected. Point 257 is connected to ground over capacitor 261 of 4 microfarads to absorb any shock which might result from an abrupt application or change of potential in this circuit. The anodes are supplied with a normal potential of 150 volts when none of the tubes is conducting, but, when any one tube is conducting, the potential of all the anodes will drop due to resistors 256 and 258. At the moment any tube is fired, the capacitor, as 230, in its cathode potential supply circuit will hold the potential of its cathode at a negative potential of 55 volts, and the potential of the anode of that tube will drop to within 15 volts of the cathode. Since all the anodes are connected to the same supply conductor, this will cause the potential of the anode of a previously conducting tube to become more negative than the potential of its related cathode, the potential of which has risen due to conduction in the tube. When the potential of the anode of the previously conducting tube becomes more negative than that of its related cathode, it will cause that tube to cease conducting and allow its control grid to regain control. After the capacitor in the cathode circuit of the fired tube has been charged, the potentials of the anode and cathode of this tube rise to positive potentials of 125 and 110 volts, respectively, and remain at these potentials as long as the tube remains conducting. This rise in potential of the cathodes of the "I," "II," "III," "IV," and "V" selector tubes in this bank is used to render the banks of keys effective by supplying the "priming" potential thereto, the various potential supply conductors for the several banks of keys being connected over unidirectional devices, such as rectifiers, to the cathodes of their related selector tubes. The connection to the potential supply conductor 185 for the first bank of keys is representative and extends from point 227 in the cathode potential supply circuit for the "I" tube, and over rectifier 262 to the potential supply conductor 185.

If several keys of the same value are depressed in different banks of keys, or if there are no keys depressed in several banks, the potential supply conductors of these banks will be connected to-

gether, so that, when "priming" potential is applied to the conductor of a bank which is to be rendered effective, it will be applied to all the potential supply conductors connected thereto.

The unidirectional devices between the various cathode potential supply circuits and their related potential supply conductors enable the potential rise in these circuits, as the tubes become conducting one after another, to be impressed on their related potential supply conductors to render the banks successively effective, but prevent any potential supply conductors which are connected to the potential supply conductor of the bank which is effective from applying this potential rise to the cathode potential supply circuits of tubes which are not conducting. These unidirectional devices, therefore, prevent improper application of potential to the cathode potential supply circuits of the tubes of the selector switching means which would prevent these tubes from being operated properly one after another in succession to render the various banks of keys successively effective.

The potential rise of the cathode **232** of the auxiliary control tube **216** is used to fire a stop tube **405** (Fig. 5), which terminates an impulse-generating operation. The manner in which this is carried out will be explained later herein.

Thus it is seen that the tubes of the bank selector switching means apply potential to the banks of keys one after another in succession to selectively enable these banks of keys to be effective to control a single bank of impulse-generating tubes by selectively "priming" tubes therein to determine with which tubes in the sequence the automatic firing of the impulse-generating tubes will begin and consequently determining the number of impulses in each of the generated groups of impulses.

Other forms of selector switching means may be used, and in any selector switching means in which there are no connections between the several potential supply conductors for the various banks of keys or in which the "priming" potential is applied to the various potential supply conductors one at a time in succession, as by a commutator or a sequence switch, the unidirectional devices can be eliminated.

Recycling control means

Means are provided to recycle the impulse-generating means to cause the successive operations thereof to take place and thereby to produce the different groups of impulses. The recycling control means also causes the bank selector switching means to be operable at each recycling of the impulse-generating means to enable the different banks of keys to control the number of impulses in the groups.

Referring to Fig. 2, it will be recalled that the tube **166** was extinguished by the terminal tube T each time the terminal tube was fired at the end of a sequential operation of the tubes of the bank of impulse-generating tubes, and that the tube **166** immediately refired and extinguished the terminal tube T.

The refiring of the tube **166** is used to cause the recycling of the impulse-generating tubes and the operation of the bank selector switching means in the following manner. As tube **166** is refired, the potential of its anode **178** will drop, and this drop is impressed on a control grid **271** (Fig. 2) of a normally conducting vacuum tube **272** and will reduce the current flow in this tube, which reduction of the current flow in tube **272** will cause the potential of its anode **273** to rise. This rise is utilized as a positive potential impulse to cause the firing of the first of three gaseous electron tubes **274**, **275**, and **276** (Fig. 4) of the type used in the impulse-generating means, said three tubes being connected for automatic sequential operation.

The first tube **274** of the sequence, when it is fired, sends a firing impulse to the firing impulse conductor **245** of the bank selector switching means to cause the operation of a selector tube therein, which tube, when operated, applies "priming" potential to another bank of keys to enable this bank of keys to control the "priming" of the tubes in the impulse-generating means. Tube **274** is also effective to fire the second tube **275** of the sequence after a slight delay, and the second tube **275**, when it fires and becomes conducting, causes the third tube **276** of the sequence to be fired after a slight delay. The firing of the third tube **276** provides a positive potential impulse, which is amplified and sharpened by a pair of vacuum tubes **277** and **278** and is impressed on the firing impulse conductor **91** for the bank of impulse-generating tubes to cause the "primed" tube of the bank to be fired and initiate the automatic step-by-step operation of the remaining tubes of the sequence through the terminal tube T. The operation of tubes **275** and **276** of the three gaseous electron tubes provides a spacing between the various groups of impulses and also provides an interval between the time when a firing impulse is sent to the bank selector switching means and the time when a firing impulse is impressed on the firing impulse conductor **91** for the bank of impulse-generating tubes, to insure that sufficient time will have been provided to enable the bank of keys to selectively "prime" one of the tubes of the bank before the firing impulse is impressed thereon.

The operation of the bank selector switching means and the recycling of the impulse-generating tubes will take place after each operation of the terminal tube T in the sequence until all the banks of keys have been effective to control the bank of impulse-generating tubes, at which time the operation of the generating means will be terminated.

The circuits for supplying potential to the various elements of these control tubes and for connecting these tubes to perform their functions will now be described.

Tube **272** (Fig. 2), which is a normally conducting vacuum tube, has its cathode **281** and suppressor grid **282** directly connected to ground and its control grid **271** connected to ground over point **283** and resistor **284** of 10,000 ohms. An electrostatic coupling including capacitor **285** of 10 micro-microfarads extends between point **283** in the control grid circuit and point **182** in the circuit to the anode **178** of tube **166** and enables the potential drop of anode **178** of tube **166**, as that tube refires, to be impressed on the control grid **271** as a negative impulse which is effective to reduce conduction in tube **272**.

Screen grid **286** is connected to terminal **100***a* over conductor **101**, point **120**, conductor **121**, point **122**, conductor **123**, point **124**, resistor **287** of 250 ohms, and point **288**. A positive potential of 105 volts is applied to terminal **100***a*, in a manner to be described later herein, whenever the generating means is operating.

Anode **273** of tube **272** derives its potential from terminal **200***a*, upon which a positive potential of 150 volts is applied whenever the impulse-gen-

erating means is operating, the circuit extending from terminal 200a, over conductor 130, point 131, resistor 289 of 250 ohms, point 290, resistor 291 of 5,000 ohms, and point 292. Since the tube is normally conducting, its anode 273 will normally have a positive potential of 20 volts due to the drop across resistors 289 and 291, but, as conduction is reduced in the tube, the potential of the anode will rise toward 150 volts. Point 292 in the circuit to the anode 273 is electrostatically coupled to the control grid 293 of the first tube 274 of the three sequentially operable tubes, by means of conductor 294, terminal 295, which is connected to terminal 296 (Fig. 4), capacitor 297 of 50 micro-microfarads, point 298, and resistor 299 of 50,000 ohms, and, when the potential rise occurs on the anode 273, it will be impressed on the control grid 293 and cause the tube 274 to be fired and initiate the sequential firing of tubes 274, 275, and 276.

Cathodes 301, 302, and 303 (Fig. 4) for the tubes 274, 275, and 276, respectively, have a negative potential of approximately 9 volts applied thereto by means of individual parallel circuits extending to ground from a common negative potential supply conductor 304, to which is applied a negative potential of 150 volts at terminal 305. The circuit for the cathode 301 of tube 274 extends from point 306 on the potential supply conductor 304, over resistor 307 of 150,000 ohms, point 308, resistor 309 of 75,000 ohms, points 310 and 311, and to ground over resistor 312 of 15,000 ohms in parallel with capacitor 313 of .002 microfarad. The circuit for the cathode 302 of tube 275 is identical with this one, and the circuit for the cathode 303 of tube 276 is equivalent to this circuit, extending from point 314 on the potential supply conductor 304 over resistor 315 of 225,000 ohms, points 316, 317, and 318, and to ground over resistor 319 of 15,000 ohms in parallel with capacitor 320 of .002 microfarad. The cathode potential of any of these cathodes will rise to a positive potential of 70 volts when conduction occurs in its tube.

The anodes 326, 327, and 328 of tubes 274, 275, and 276, respectively, are connected to a common potential supply conductor 329, which is connected over resistor 330 of 4,000 ohms, point 331, and resistor 332 of 250 ohms to terminal 400a, to which a positive potential of 105 volts is applied shortly after positive potential has been applied to other terminals in the apparatus. The manner in which this application of potential is made will be explained later herein. The anodes of these tubes, being connected together and to a source of potential over a common resistor, will enable the firing of any of these tubes to extinguish any previously conducting tube of this group.

Control grid 293 of tube 274 has a normal negative potential of 45 volts applied thereto by being connected over resistor 299 of 50,000 ohms, point 298, and resistor 333 of 500,000 ohms to point 334 in a potential supply circuit which extends to ground from the negative potential supply conductor 304 at point 335, over resistor 336 of 250,000 ohms, point 334, and resistor 337 of 100,000 ohms. As explained earlier herein, point 298 in this circuit is connected, over capacitor 297 of 50 micro-microfarads, to terminal 296, which is connected to terminal 295 (Fig. 2), to which is connected the conductor 294 extending from point 292 in the anode circuit for tube 272. By means of this electrostatic connection, the potential rise of the anode 273 will be impressed on control grid 293 to reduce its potential below its critical value and cause tube 274 to be fired and rendered conducting.

When tube 274 fires and becomes conducting, the potential rise of its cathode 301 is impressed on the firing impulse conductor 245 (Fig. 3) for the bank selector switching means by means of a circuit extending from the cathode 301 at point 311 and continuing over conductor 338 and terminal 339, which is connected to terminal 340 (Fig. 3), to which the firing impulse conductor 245 is connected.

The potential rise of the cathode 301 of tube 274 is also used to cause the second tube in the sequence to be fired. Control grid 341 of tube 275 obtains a normal negative potential of 56 volts by being connected over resistor 342 of 500,000 ohms and point 343 to point 308 in the cathode potential supply circuit for tube 274, and, when the potential of cathode 301 rises due to conduction in tube 274, this rise will be reflected in the potential of control grid 341 and reduce its negative potential below the critical value and cause tube 275 to fire and become conducting. Capacitor 344 of 500 micro-microfarads is connected between point 343 and ground and delays the effect of the potential rise of cathode 301 on the control grid 341.

When tube 275 is fired and becomes conducting, it will cause tube 274 to be extinguished. The potential rise of cathode 302, as tube 275 is fired, is used to fire tube 276, the circuit for firing tube 276 being similar to the one by which tube 275 was fired; however, point 345 in this circuit is connected to ground over a capacitor 346 of 2,500 micro-microfarads to delay the firing of the third tube. The capacitance used in the connection between the first and second tubes and the second and third tubes to delay the firing of one tube by another may be varied to obtain any desired delaying action.

When tube 276 is fired and becomes conducting, it causes tube 275 to be extinguished, and the potential rise of cathode 303 is impressed as a positive potential impulse on the control grid 347 of tube 277, which is one of the vacuum tubes 277 and 278 used to amplify and sharpen the impulse and impress it on the firing impulse conductor 91 for the bank of impulse-generating tubes.

Tube 277 has its cathode 348 and suppressor grid 349 connected directly to ground. The screen grid 350 of this tube is connected over conductor 351 and resistor 352 of 250 ohms to terminal 100b, upon which a positive potential of 105 volts is applied when the impulse-generating means is operating. Control grid 347 of this tube is given a negative bias by being connected over point 353 and resistor 354 of 50,000 ohms to a potential-tapping member 355, which coacts with a resistor 356 of 50,000 ohms connected in series with resistor 357 of 100,000 ohms between point 314 on negative potential supply conductor 304 and ground. The relation between the potential-tapping member 355 and the resistor 356 can be adjusted to provide the desired bias on the control grid 347. The negative bias on the control grid 347 will prevent conduction in the tube. Point 316 in the cathode potential supply circuit for tube 276 is electrostatically connected over capacitor 358 of 10 micro-microfarads to point 353 in the control grid circuit for tube 277 and enables the cathode potential rise in tube 276 to reduce the negative bias on the control grid 347 and render the tube 277 conducting.

Anode 359 of tube 277 is connected over point

360, resistor 361 of 5,000 ohms, point 362, conductor 363, and resistor 364 of 250 ohms to terminal 200c, to which a positive potential of 150 volts is applied when the impulse-generating means is operating. As tube 277 becomes more conductive, the potential of its anode 359 will drop due to resistor 361, which drop is used to reduce the conduction in tube 278.

Tube 278 has its cathode 365 and suppressor grid 366 directly connected to ground and its control grid 367 connected to ground over point 368 and resistor 369 of 10,000 ohms. Screen grid 370 has positive potential applied thereto by being connected to conductor 351 at point 371, and anode 372 of this tube has positive potential applied thereto by being connected over point 373 and resistor 374 of 5,000 ohms to point 375 on conductor 363. When conduction is reduced in tube 278, the potential of the anode 372 will rise, and this potential rise is impressed on conductor 381 and terminal 382, which is connected to terminal 383 (Fig. 2), to which the firing impulse conductor 91 for the bank of impulse-generating tubes is connected.

Point 360 (Fig. 4) in the control grid circuit for tube 278 is connected over capacitor 384 of 100 micro-microfarads to point 360 in the potential supply circuit for anode 359 of tube 277 and enables the potential drop of the anode 359 of tube 277 to reduce conduction in tube 278, which, as explained above, provides the positive firing impulse for the impulse-generating tubes.

The above control means, which recycles the generating means after a previous operation thereof, is also used to cause the first operation of the generating means to take place after a start key is operated; however, the operation is slightly different. It will be recalled that the "I" selector tube (Fig. 3) for the first bank of keys is fired immediately after the start key is operated, and, accordingly, the first tube 274 of the three sequentially operable gaseous electron tubes must not be operated to send a firing impulse to the bank of selector tubes before the first firing impulse is sent to the bank of impulse-generating tubes. If the firing impulse were sent to the bank of selector tubes by tube 274 before the first firing impulse was impressed on the impulse-generating means, the next selector tube, the "II" tube, would be operated and render the first bank of keys ineffective before they exerted their control.

Therefore, in the first cycle of operation of the generating means after the start key is depressed, an impulse is impressed directly on the control grid 385 of the third tube 276 of the sequence to cause that tube to fire and become conducting and thereby cause the first firing impulse to be impressed on the bank of impulse-generating tubes. The manner in which tube 276 is fired at the start of the impulse-generating operation will now be explained.

Start and stop control means

After keys in the various control banks have been depressed, the impulse-generating operation is initiated by momentarily depressing the start key 217 (Fig. 5), which closes the energizing circuit for a starting relay 386. The circuit extends from terminal 387, upon which may be impressed any desirable potential, to the point 388, and thence over conductor 389, contacts 390 closed by key 217, point 391, conductor 392, and over the winding of relay 386 to ground. When the starting relay 386 is energized by the operation of the start key, it closes a holding circuit for itself from terminal 387, point 388, normally closed contacts 393, conductor 394, contacts 395 closed by the starting relay, point 391, and over the winding of the starting relay 386 to ground. This circuit will maintain the starting relay in energized condition after the start key 217 has been released and until the normally closed contacts 393 are opened by the energization of the stop relay 396, in a manner to be explained hereinafter, to terminate the impulse-generating operation.

Starting relay 386 also closes contacts 397, 398, and 399 to apply potential to the various tubes of the apparatus. Upon the initial operation of the armature 401 of the starting relay, contacts 397 and 407 are closed. Contact 397 closes a circuit from the source 403 of 105-volt positive potential to the anodes of a pair of gaseous electron tubes 404 and 405, used, respectively, as a start tube and a stop tube, and also to terminal 100, which is connected to terminals 100a (Fig. 2) and 100b (Fig. 4) to supply the elements of the tubes connected to these various terminals with a positive potential of 105 volts as long as the impulse-generating means is operating. Contact 407 closes a circuit to terminal 200 from source 402 of positive potential of 150 volts. Terminal 200 (Fig. 5) is connected to terminals 200a (Fig. 2), 200b (Fig. 3), and 200c (Fig. 4) and supplies these terminals with a positive potential of 150 volts whenever the impulse-generating means is operating.

Further operation of armature 401 causes contact 398 to close after contact 397 and apply the positive potential of 105 volts to terminal 400, which is connected to terminal 400a (Fig. 4) and delays the application of potential to the anodes of the sequentially operable tubes 274, 275, and 276 (Fig. 4) until after tube 166 (Fig. 2) has been fired, this delay preventing the initial firing of tube 166, which occurs when the contact 397 is closed, from causing tube 274 to be fired improperly before the first operation of the generating means.

Contact 399 also closes after contacts 397 and 407 and connects the source 406 of 150-volt negative potential to terminal 300, which is connected to terminal 300a (Fig. 3). Contact 399 delays the application of negative potential to the control grid 250 (Fig. 3) of the first selector tube, the "I" tube, until after contact 407 (Fig. 5) has closed and applied a positive potential of 150 volts to the anode 249 of this tube, thus causing the tube to be fired immediately.

The application of 105-volt positive potential to the anode of the start tube 404 (Fig. 5) by the closure of contact 397 causes the start tube 404 to be fired after a slight delay and rendered conducting. The circuits for accomplishing this are as follows.

Cathode 411 of the start tube is given a negative potential of 19.5 volts by being connected at point 412 in a cathode potential supply circuit which extends from point 413 on a negative potential supply conductor 414, upon which a negative potential is applied at source 406, and continues over resistor 415 of 100,000 ohms, point 412, and to ground over resistor 416 of 15,000 ohms.

Before the start relay 386 is energized, the control grid 417 of the start tube is given a negative potential of 150 volts by means of a circuit which extends from point 418 on the negative potential supply conductor 414, over resistor 419 of 500,000

ohms, and point 420. The anode 421 of the start tube 404 is also given a negative potentian of 150 volts before the start relay is energized, which potential is obtained from the point 420 in the grid circuit, over resistor 422 of 500,000 ohms, point 423, and resistor 424 of 2,000 ohms.

When the starting relay 396 closes contact 397, positive potential of 105 volts is applied to the anode 421 from source 403, over contact 397, conductor 425, resistor 426 of 250 ohms, point 423, and resistor 424. The positive potential which is applied to the anode by the closing of contact 397 will also be effective, over the circuit from point 423 in the anode potential supply circuit to point 420 in the control grid circuit, to raise the potential of the control grid 417 above its critical value and cause the start tube to fire and become conducting. A capacitor of 1 microfarad is connected between point 420 and ground to provide a slight delay in the firing of tube 404 after contact 397 is closed.

As the start tube fires and becomes conducting, the potential of its cathode 411 will rise from a negative potential of 19.5 volts to a positive potential of 75 volts. An electrostatic coupling, extending from the cathode 411 of the start tube 404 at point 412 and continuing over conductor 427, terminal 428, which is connected to terminal 429 (Fig. 4), and over capacitor 430 of 10 micro-microfarads to point 431 in the circuit to the control grid 385 of tube 276, enables the potential rise of the cathode 411 of the start tube 404 to fire tube 276 and cause a firing impulse to be impressed on the firing impulse conductor 91 of the bank of impulse-generating tubes to initiate the first sequential firing of these tubes.

After the first sequential firing of the impulse-generating tubes, the recycling control means described earlier herein will cause the various banks of keys to be rendered effective one after another and will cause the recycling of the bank of impulse-generating tubes for each bank of keys. After the operation in which the last bank of keys has been in control, the recycling control means will cause the auxiliary control tube 216 (Fig. 3) of the bank selector switching means to be fired to render the last bank of keys ineffective and to cause the firing of the stop tube 405 (Fig. 5), which terminates the operation of the impulse-generating means by energizing the stop relay 398 and thereby opening the holding circuit for the start relay.

Cathode 432 of the stop tube is at ground potential, being connected directly to ground. Control grid 433 of the stop tube has a negative potential of 19.5 volts applied thereto by being connected over resistor 434 of 50,000 ohms, point 435, and resistor 436 of 500,000 ohms to point 437 in a negative potential supply circuit which begins at point 438 on the negative potential supply conductor 414 and extends over resistor 439 of 200,000 ohms, point 437, and to ground over resistor 440 of 30,000 ohms. This potential will prevent the stop tube from firing until an impulse is impressed thereon.

Anode 446 of the stop tube 405 has a positive potential of 105 volts applied thereto when contact 397 is closed by the starting relay. The circuit extends from point 447 on conductor 425, over conductor 448, winding of stop relay 396, and resistor 449 of 5,000 ohms to anode 446. Until the stop tube fires and becomes conducting, there will be no current in the circuit which includes the winding of the stop relay; however, as soon as the stop tube is fired and becomes conducting, the stop relay 398 will be energized and cause the contact 393 to open and interrupt the holding circuit for the start relay.

Control grid 433 of the stop tube 405 is electrostatically coupled to the cathode 232 (Fig. 3) of the auxiliary control tube 216, the coupling extending from point 237 (Fig. 3) in the cathode potential supply circuit for the auxiliary control tube 216, over conductor 450, terminal 451, which is connected to terminal 452 (Fig. 5), and thence over capacitor 453 of 10 micro-microfarads to point 435 in the control grid circuit for the stop tube. The potential rise of the cathode 232 of the auxiliary control tube 216 is effective through this coupling to fire the stop tube 405 and cause the stop relay 396 to be energized and open the holding circuit for the start relay 396.

The opening of the holding circuit for the start relay 396 will cause it to be deenergized and open the contacts 397, 398, and 407, which remove positive potential from all the tubes and cause them to cease conducting and open contacts 399 to remove potential from the control grid 250 of the first selector tube of the selector switching means. In this condition, the apparatus has been cleared and made ready for another operation.

Operation

In the operation of the novel apparatus, the control keys of the various banks are depressed according to the number of impulses desired in each of the five groups of impulses which are to be generated in automatic succession.

The start key is operated to render the first bank of keys effective to control the impulse-generating means and to initiate its first differential operation to generate a number of impulses as determined by the key which was depressed in the first bank of keys. The same impulse-generating means is operated over and over to produce the different groups of impulses, and, at the end of the first and subsequent differential operations, recycling means are operable to control the bank selector switching means to render a previously effective bank of keys ineffective to control the generating means and to render another bank of keys effective to control a further differential operation of the same generating means. The recycling control means is also effective to initiate a differential operation of the impulse-generating means each time a new bank of keys has been rendered effective. After the last differential operation of the impulse-generating means, which is the fifth operation in the disclosed embodiment, an auxiliary control tube in the bank selector switching means is operated to render the fifth bank of keys ineffective and also to set in motion the means for terminating the operation of the impulse-generating means.

Applicants' novel impulse-generating means, therefore, provides a simplified means for generating a plurality of groups of impulses by enabling a single differentially operable impulse-generating means to be operated repeatedly and enabling different banks of control means to be rendered effective one after another to control different ones of said operations.

While the form of the invention herein shown and described is admirably adapted to fulfill the objects primarily stated, it is to be understood that it is not intended to confine the invention to the one form or embodiment herein disclosed, for it is susceptible of embodiment in various

forms all coming within the scope of the claims which follow.

What is claimed is:

1. In a device of the class described, the combination of an impulse-generating means differentially operable to produce selected different numbers of impulses; a plurality of normally ineffective control means common to the impulse-generating means for controlling the differential operation of the impulse-generating means in each of a corresponding plurality of operations thereof; and means for rendering the various control means effective one at a time in succession to control the operation of the impulse-generating means in the several operations thereof to determine the number of impulses to be produced by successive operations of the impulse-generating means.

2. In an apparatus of the class described, the combination of an impulse-generating means including a plurality of sequentially operable electronic devices, each of which devices produces an impulse when operated; a plurality of settable control means for controlling the impulse-generating means, each control means, when rendered effective, being operable according to its setting to select the number of devices that will be operated in sequence in an operation of the impulse-generating means, whereby to control the number of impulses which will be produced; and means for rendering the various control means effective one after another to control the impulse-generating means to determine the number of devices which will operate in sequence in each of the successive operations of said impulse-generating means.

3. In an apparatus of the class described, the combination of an impulse-generating means including a plurality of sequentialy operable electronic devices, each of which devices produces an impulse when operated; a plurality of normally ineffective selectively settable control means for controlling the impulse-generating means, each control means, when rendered effective, being operable, according to its setting, to select the number of devices that will be operated in sequence in an operation of the impulse-generating means, whereby to control the number of impulses which will be produced; means for rendering the various ones of the plurality of control means effective, one after another, to control the impulse-generating means to select the number of devices which will operate in a sequence in each of a corresponding plurality of successive operations of said impulse-generating means; and means to initiate a sequential operation of the devices each time a control means has been rendered effective.

4. In an apparatus of the class described, the combination of an impulse-generating means including a plurality of gaseous electron tubes interconnected to be fired and rendered conducting one at a time in an automatic sequential operation, each of which tubes produces an impulse when it is fired and becomes conducting, and also including common output means upon which the impulses are impressed by all the tubes; a plurality of control means, each control means, when rendered effective, being operable to select with which of the plurality of tubes in the sequence the automatic operation will begin whereby to control the number of tubes that will be operated in sequence in an operation of the impulse-generating means, and the number of impulses which will be produced; and means for rendering the various control means effective one after another to select the tubes with which the automatic sequential operation of the tubes will begin in successive operations of said impulse-generating means.

5. In an apparatus of the class described, the combination of an impulse-generating means including a plurality of sequentially operable electronic devices, each of which devices produces an impulse when operated; a plurality of banks of depressible keys; circuits selectively closable by the depressed keys in the various banks and, when rendered effective, operable to select the number of electronic devices that will be operated in sequence in an operation of the impulse-generating means, whereby to control the number of impulses which will be produced; means for rendering the circuits closed by the keys in the various banks effective one after another to control the number of devices which will operate in sequence in successive operations of said impulse-generating means; and means to initiate the successive operations of the impulse-generating means.

6. In an apparatus of the class described, the combination of an impulse-generating means including a plurality of sequentially operable electronic devices, each of which devices produces an impulse when operated; a plurality of control means, each control means, when rendered effective, being operable to select the number of devices that will be operated in sequence in an operation of the impulse-generating means, whereby to control the number of impulses which will be produced; means to initiate each sequential operation of the electronic devices of the impulse-generating means; selector means operable to render the control means effective, one at a time, to control successive operations of the impulse-generating means; and means to control the selector means to render the control means effective one after another in automatic succession and to render the initiating means effective to initiate a sequential operation of the impulse-generaing means each time another control means has been rendered effective.

7. In an apparatus of the class described, the combination of an impulse-generating means repeatedly operable to produce a plurality of groups of impulses, said generating means including a plurality of sequentially operable electronic devices, each of which devices produces an impulse when operated; a plurality of groups of manipulative devices, each group of manipulative devices being normally ineffective but, when rendered effective, being operable to select the number of electronic devices that will be operated in sequence in an operation of the impulse-generating means, whereby to control the number of impulses which will be produced in each group of impulses; means to initiate each sequential operation of the impulse-generating means; selector means operable to render the groups of manipulative devices effective, one at a time, to control successive operations of the impulse-generating means; and means automatically operable at the end of each operation of the generating means to control the selector means to render another group of manipulative devices effective and to control the initiating means to initiate another sequential operation of the impulse-generating means.

8. In an apparatus of the class described, the

combination of an impulse-generating means including a plurality of sequentially operable electronic devices, each of which devices produces an impulse when operated; a plurality of control means, each control means, when rendered effective, being operable to select the number of devices that will be operated in sequence in an operation of the impulse-generating means, whereby to control the number of impulses which will be produced; means to initiate each sequential operation of the impulse-generating means; selector means including a bank of gaseous electron tubes operable one after another in sequence in response to impressed impulses to render the control means effective, one at a time, to control successive operations of the impulse-generating means; and means set in operation by the operation of the last device of the impulse-generating means to impress an impulse on the tubes of the selector means to cause an operation thereof to render another control means effective and to cause an operation of the initiating means to initiate a further operation of the impulse-generating means.

9. In an apparatus of the class described, the combination of an impulse-generating means including a plurality of gaseous electron tubes interconnected to be fired and rendered conducting one at a time in sequence, each of which tubes produces an impulse when it is fired and rendered conducting; a plurality of banks of depressible keys; circuit selectively closable by the depressed keys in the various banks, and, when rendered effective, being operable to select the number of tubes that will be fired and rendered conducting in sequence in an operation of the impulse-generating means, whereby to control the number of impulses which will be produced; means to initiate each sequential firing of the tubes of the impulse-generating means; selector means operable to render the circuits closed by the keys in the various banks effective, one at a time, to select the number of tubes to be fired in sequence in successive operations of the impulse-generating means; and means to control the selector means to render the circuits closed by the keys in the different banks of keys effective one after another in automatic succession and to control the initiating means to initiate a sequential firing of the tubes of the impulse-generating means each time a circuit controlled by another bank of keys has been rendered effective.

10. In an apparatus of the class described, the combination of an impulse-generating means including a plurality of sequentially operable electronic devices, each of which devices produces an impulse when operated; a plurality of control means, each control means, when rendered effective, being operable to select the number of devices that will be operated in sequence in an operation of the impulse-generating means, whereby to control the number of impulses which will be produced; means to initiate each sequential operation of the impulse-generating means; selector means including a bank of gaseous electron tubes operable one after another in sequence in response to impressed impulses to render the control means effective, one at a time, to control successive operations of the impulse-generating means; and means to impress impulses on the tubes of the selector means to cause their sequential operation to render the control means effective one after another in automatic sucession, and to control the initiating means to initiate a sequential operation of the impulse-generating means each time another control means has been rendered effective.

11. In an apparatus of the class described, the combination of a bank of gaseous electron tubes; means connecting the electron tubes in a chain sequence so that they will be fired and become conducting automatically one after another in sequence toward one end of the chain after any electron tube in the bank has been fired and rendered conducting; a plurality of settable control means, each control means, when rendered effective, being operable to select any one of the electron tubes with which the sequential operation is to begin, so that the firing of the tubes may begin at any point in the chain, thus enabling different numbers of tubes in the bank to be selected for sequential operation; means to cause the selected electron tube to be fired and become conducting to initiate the automatic sequential firing of the selected number of electron tubes which follow the selected tube in the chain sequence; and means to render the control means operable one after another in automatic succession to control successive operations of the bank of tubes.

12. In an apparatus of the class described, the combination of a bank of gaseous electron tubes; means connecting the electron tubes in a chain sequence so that they will be fired and become conducting automatically one after another in sequence toward one end of the chain after any electron tube in the bank has been fired and rendered conducting; a plurality of settable control means, each control means, when rendered effective, being operable to select any one of the electron tubes with which the sequential operation is to begin, so that the firing of the tubes may begin at any point in the chain, thus enabling different numbers of tubes in the bank to be selected for sequential operation; means to cause the selected electron tube to be fired and become conducting to initiate the automatic sequential firing of the selected number of electron tubes which follow the selected tube in the chain sequence; selector means to render the control means operable one after another in automatic succession to control successive operations of the bank of tubes; and means set into operation by the firing of the last tube of the chain sequence for causing an operation of the selector means to render another control means operable to control the bank of tubes and to cause the initiating means to operate to recycle the bank of tubes.

13. In an apparatus of the class described, the combination of a bank of gaseous electron tubes, said bank of tubes being operable repeatedly to produce a plurality of groups of impulses; means connecting the electron tubes in a chain sequence so that, for each operation of the bank of tubes, they will be fired and become conducting automatically one after another sequence toward one end of the chain after any electron tube in the bank has been fired and rendered conducting; a plurality of groups of normally ineffective manipulative devices; means controlled by the groups of manipulative devices, and operable when the groups of devices are rendered effective, to select those electron tubes with which the sequential operation is to begin in the repeated operations of the bank of tubes, so that the firing of the tubes in the several operations of the bank may begin at any point in the chain, thus enabling different numbers of tubes in the bank to be selected for sequential operation to produce different numbers of impulses; means to cause

the electron tubes selected to initiate the several operations to be fired and become conducting to initiate in each operation the automatic sequential firing of the selected number of electron tubes which follow the selected tube in the chain sequence; and means to render different groups of manipulative devices effective for controlling, respectively, the different operations of the bank of tubes, whereby a single bank of tubes can be operated repeatedly under control of different groups of manipulative devices to produce a plurality of groups of impulses containing selected numbers of impulses as determined by the manipulative devices.

14. In a device of the class described, the combination of a plurality of gaseous electron tubes, each tube containing an anode, a cathode, and a control grid; means to supply positive potential to the anodes of the tubes; separate negative potential supply means for the cathode of each tube, said separate supply means including resistors to cause the potential of the cathode of a tube to rise when that tube becomes conducting; means for supplying negative potential bias to the control grids and for connecting the tubes for automatic operation on after another in sequence, said last-mentioned means consisting of circuits extending from the cathode potential supply means for any of the various tubes to the control grid of the next tube to be operated in the sequence, said circuits supplying normal negative bias to the control grids and enabling the potential rise of the cathode of a tube in the sequence to reduce the bias of the control grid of the next tube in the sequence to cause the automatic sequential firing of the tubes in the bank after any tube in the bank has been fired and rendered conducting; means to impress a firing impulse on the control grids of the tubes, said firing impulse being ineffective to overcome the normal negative bias on the control grids but effective to fire any tube which has been "primed" or had "priming" potential applied to its control grid to reduce the bias to a value where the firing impulse can cause that tube to fire and become conducting to initiate the sequential operation of the remaining tubes of the sequence; a plurality of control means; a potential supply conductor for each control means; a "priming" circuit extending from the control grid of each of said tubes; contacts closable by said control means for selectively connecting the "priming" circuits to the potential supply conductors; selector means for applying "priming" potential to the potential supply conductors one at a time in succession to enable the various control means to be effective one after another to select the tubes with which the sequential firing will begin in successive operations of the bank of tubes; and means to control the selector means to cause "priming" potential to be applied to a different potential supply conductor after each operation of the bank of tubes and to control the firing impulse means to impress a firing impulse on the bank of tubes each time "priming" potential has been applied to another potential supply conductor.

15. In a device of the class described, the combination of a plurality of gaseous electron tubes, each tube containing an anode, a cathode, and a control grid; means to supply positive potential to the anodes of the tubes; separate negative potential supply means for the cathode of each tube, said separate supply means including resistors to cause the potential of the cathode of a tube to rise when that tube becomes conducting; means for supplying negative potential bias to the control grids and for connecting the tubes for automatic operation one after another in sequence, said last-mentioned means consisting of circuits extending from the cathode potential supply means for any of the various tubes to the control grid of the next tube to be operated in the sequence, said circuits supplying normal negative bias to the control grids and enabling the potential rise of the cathode of a tube in the sequence to reduce the bias of the control grid of the next tube in the sequence to cause the automatic sequential firing of the tubes in the bank after any tube in the bank has been fired and rendered conducting; means to impress a firing impulse on the control grids of the tubes, said firing impulse being ineffective to overcome the normal negative bias on the control grids but effective to fire any tube which has been "primed" or had "priming" potential applied to its control grid to reduce the bias to a value where the firing impulse can cause that tube to fire and become conducting to initiate the sequential operation of the remaining tubes of the sequence; a plurality of banks of keys; a potential supply conductor for each bank of keys; a "priming" circuit extending from the control grid of each of said tubes; contacts closable by said keys for selectively connecting the "priming" circuits to the potential supply conductors; selector means for applying "priming" potential to the potential supply conductors one at a time in succession to enable the banks of keys to be effective one after another to select the tubes with which the sequential firing will begin in successive operations of the bank of tubes; and means to control the selector means to cause "priming" potential to be applied to a different potential supply conductor after each operation of the bank of tubes and to control the firing impulse means to impress a firing impulse on the bank of tubes each time "priming" potential has been applied to another potential supply conductor.

16. In a device of the class described, the combination of a plurality of gaseous electron tubes, each tube being an impulse-generating tube and containing an anode, a cathode, and a control grid; means to supply positive potential to the anodes of the tubes; separate negative potential supply means for the cathode of each tube, said separate supply means including resistors to cause the potential of the cathode of a tube to rise when that tube becomes conducting; means for supplying negative potential bias to the control grids and for connecting the tubes for automatic operation one after another in sequence, said last-mentioned means consisting of circuits extending from the cathode potential supply means for any of the various tubes to the control grid of the next tube to be operated in the sequence, said circuits supplying normal negative bias to the control grids and enabling the potential rise of the cathode of a tube in the sequence to reduce the bias of the control grid of the next tube in the sequence to cause the automatic sequential firing of the tubes in the bank after any tube in the bank has been fired and rendered conducting; means to impress a firing impulse on the control grids of the tubes, said firing impulse being ineffective to overcome the normal negative bias on the control grids but effective to fire any tube which has been "primed" or had "priming" potential applied to its control grid to reduce the bias to a value where the firing impulse can cause that tube to

fire and become conducting to initiate the sequential operation of the remaining tubes of the sequence; a plurality of banks of keys; a potential supply conductor for each bank of keys; a "priming" circuit extending from the control grid of each of said tubes; contacts closable by said keys for selectively connecting the "priming" circuits to the potential supply conductors; selector means including a bank of gaseous electron tubes, operable in a chain sequence in response to impressed impulses, for applying "priming" potential to the potential supply conductors one at a time in succession to enable the banks of keys to be effective one after another to select the impulse-generating tubes with which the sequential firing will begin in successive operations of the plurality of impulse-generating tubes; and means to impress an impulse on the selector means to cause the selector tubes therein to operate and apply "priming" potential to a different potential supply conductor after each operation of the plurality of impulse-generating tubes and to control the firing impulse means to impress a firing impulse on the plurality of impulse-generating tubes each time "priming" potential has been applied to another potential supply conductor.

17. In an apparatus of the class described, the combination of an impulse-generating means including a plurality of sequentially operable electronic devices, each of which devices produces an impulse when operated; a plurality of control means, each control means, when rendered effective, being operable to select the number of devices that will be operated in sequence in an operation of the impulse-generating means, whereby to control the number of impulses which will be produced; means to initiate each sequential operation of the impulse-generating means; selector means including a bank of gaseous electron tubes operable one after another in sequence in response to impressed impulses; unidirectional means connecting the tubes to the various control means to enable the tubes when operated to render the control means effective, one at a time, to control successive operations of the impulse-generating means; and means set in operation by the operation of the last device of the impulse-generating means to impress an impulse on the tubes of the selector means to cause an operation thereof to render another control means effective and to cause an operation of the initiating means to initiate a further operation of the impulse-generating means.

18. In an apparatus of the class described, the combination of an impulse-generating means including a plurality of sequentially operable electronic devices, each of which devices produces an impulse when operated: a plurality of control means, each control means, when rendered effective, being operable to select the number of devices that will be operated in sequence in an operation of the impulse-generating means, whereby to control the number of impulses which will be produced; means to initiate each sequential operation of the impulse-generating means; selector means including a bank of gaseous electron tubes operable one after another in sequence in response to impressed impulses; means, including unidirectional devices, for connecting the tubes to the several control means to enable the tubes to render the control means effective, one at a time, to control successive operations of the impulse-generating means; and means to impress impulses on the tubes of the selector means to cause their sequential operation to render the control means effective one after another in automatic succession, and to control the initiating means to initiate a sequential operation of the impulse-generating means each time another control means has been rendered effective.

19. In a device of the class described, the combination of a plurality of gaseous electron tubes, each tube being an impulse-generating tube and containing an anode, a cathode, and a control grid; means to supply positive potential to the anodes of the tubes; separate negative potential supply means for the cathode of each tube, said separate supply means including resistors to cause the potential of the cathode of a tube to rise when that tube becomes conducting; means for supplying negative potential bias to the control grids and for connecting the tubes for automatic operation one after another in sequence, said last-mentioned means consisting of circuits extending from the cathode potential supply means for any of the various tubes to the control grid of the next tube to be operated in the sequence, said circuits supplying normal negative bias to the control grids and enabling the potential rise of the cathode of a tube in the sequence to reduce the bias of the control grid of the next tube in the sequence to cause the automatic sequential firing of the tubes in the bank after any tube in the bank has been fired and rendered conducting; means to impress a firing impulse on the control grids of the tubes, said firing impulse being ineffective to overcome the normal negative bias on the control grids but effective to fire any tube which has been "primed" or had "priming" potential applied to its control grid to reduce the bias to a value where the firing impulse can cause that tube to fire and become conducting to initiate the sequential operation of the remaining tubes of the sequence; a plurality of banks of keys; a potential supply conductor for each bank of keys; a "priming" circuit extending from the control grid of each of said tubes; contacts closable by said keys for selectively connecting the "priming" circuits to the potential supply conductors; selector means consisting of a bank of gaseous electron tubes, operable in a chain sequence in response to impressed impulses; means, including unidirectional devices, for connecting the various potential supply conductors to the tubes of the selector means to enable these tubes to apply "priming" potential to the potential supply conductors one at a time in succession to enable the banks of keys to be effective one after another to select the impulse-generating tubes with which the sequential firing will begin in successive operations of the plurality of impulse-generating tubes; and means to impress an impulse on the selector means to cause the selector tubes therein to operate and apply "priming" potential to a different potential supply conductor after each operation of the plurality of impulse-generating tubes and to control the firing impulse means to impress a firing impulse on the plurality of impulse-generating tubes each time "priming" potential has been applied to another potential supply conductor.

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