Oct. 11, 1949. A. H. DICKINSON 2,484,081

ELECTRICAL ITEM COMPARING SYSTEM

Filed April 17, 1943 9 Sheets-Sheet 1

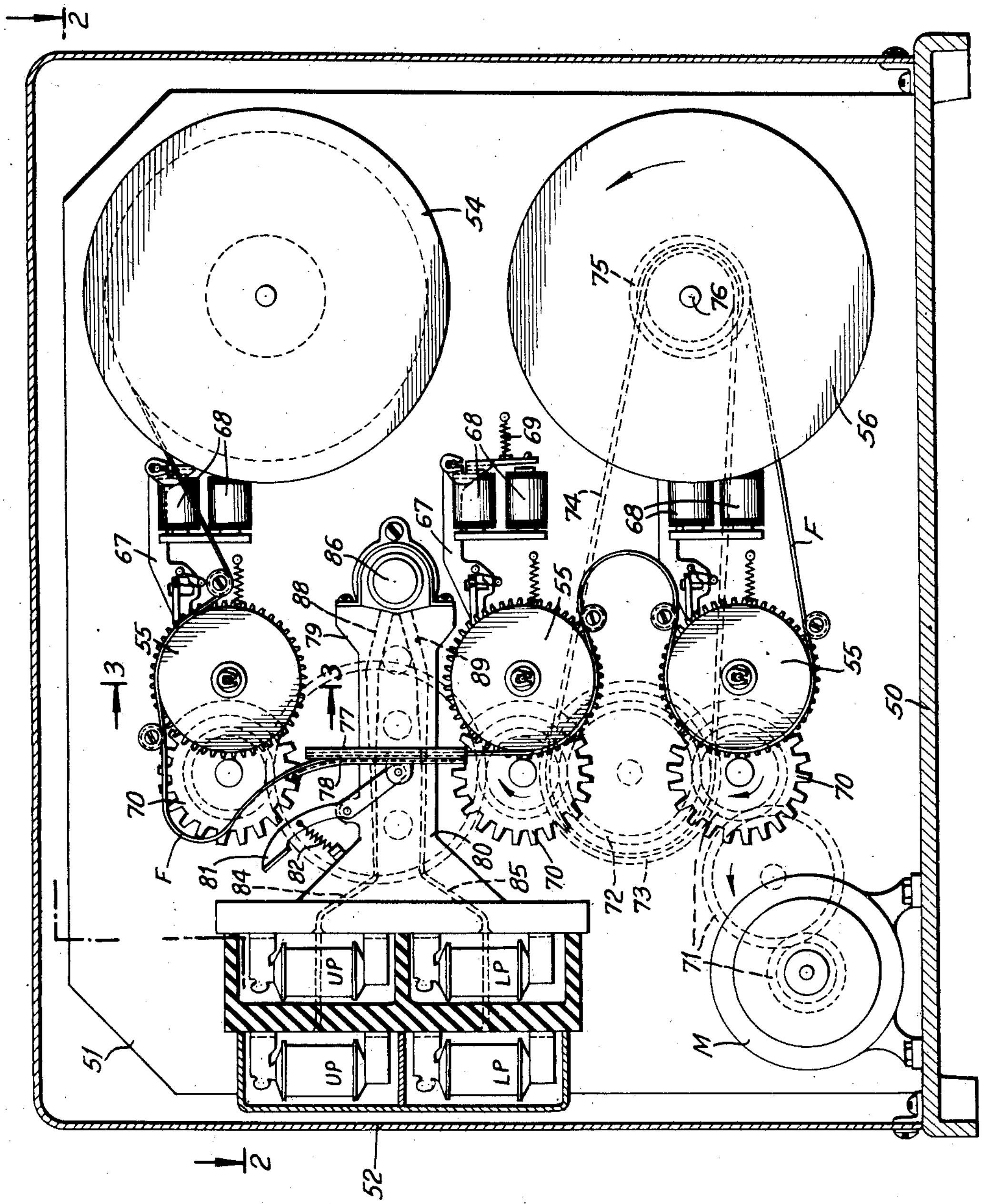

FIG.1.

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ELECTRICAL ITEM COMPARING SYSTEM

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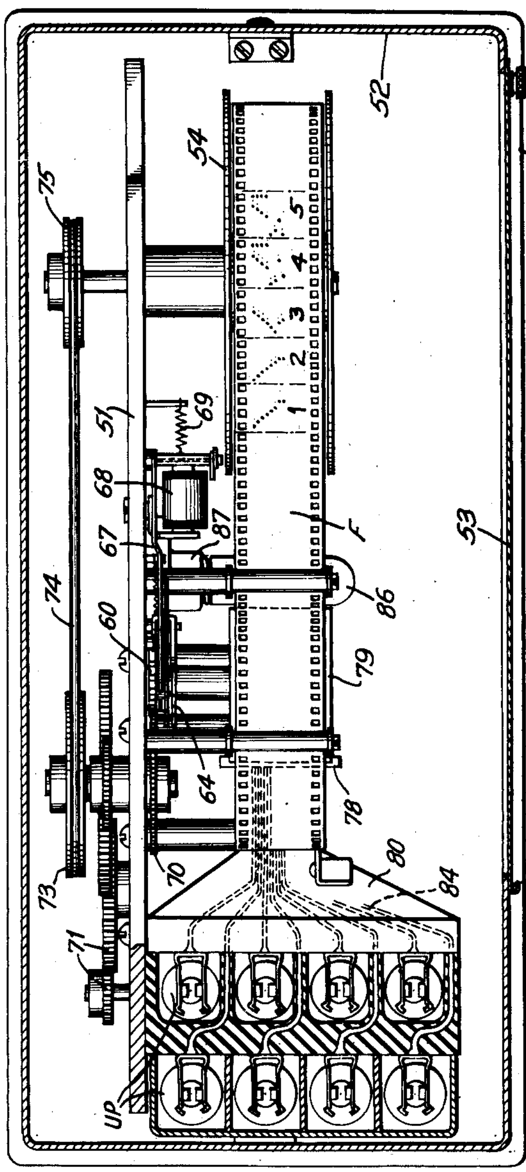

FIG. 2.

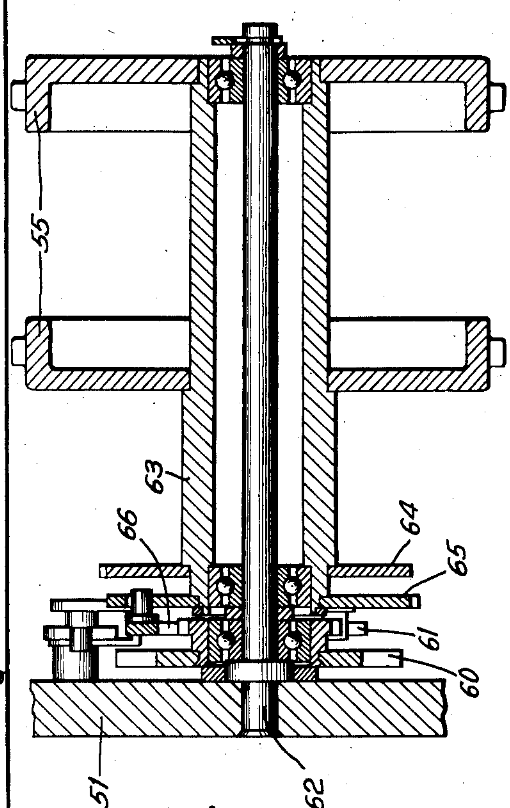

FIG. 3.

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FIG. 4.

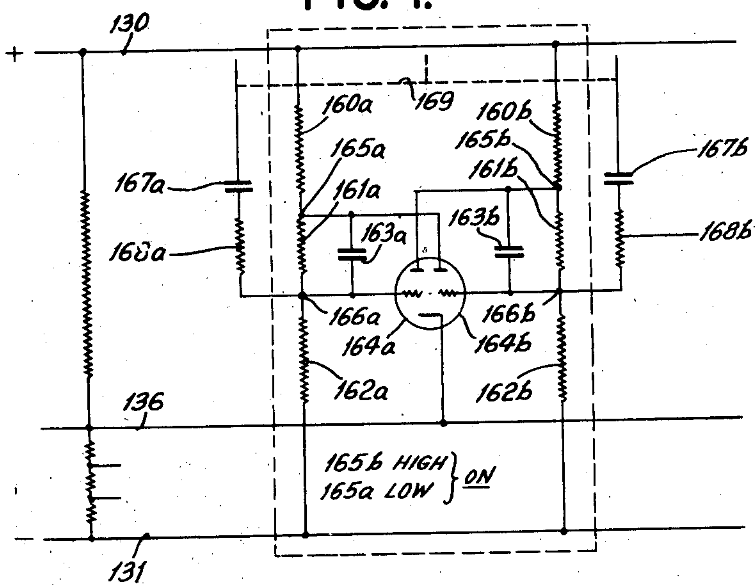
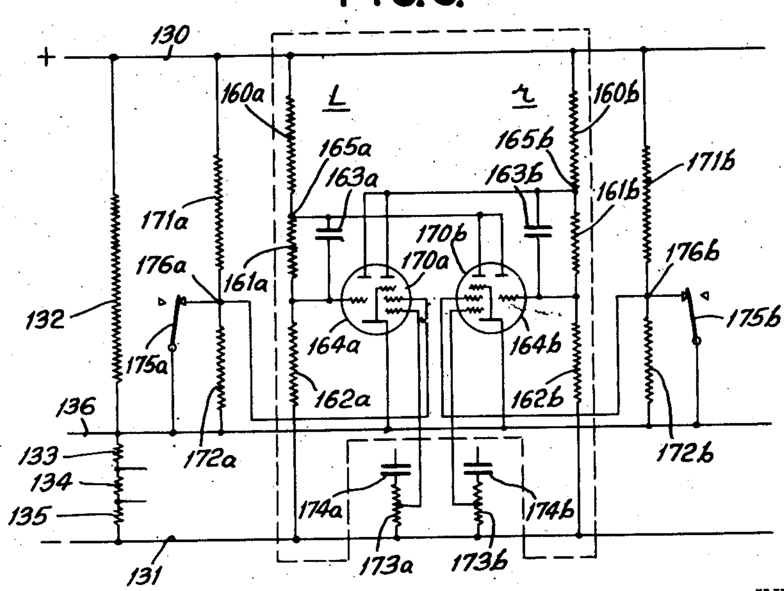


FIG. 5.



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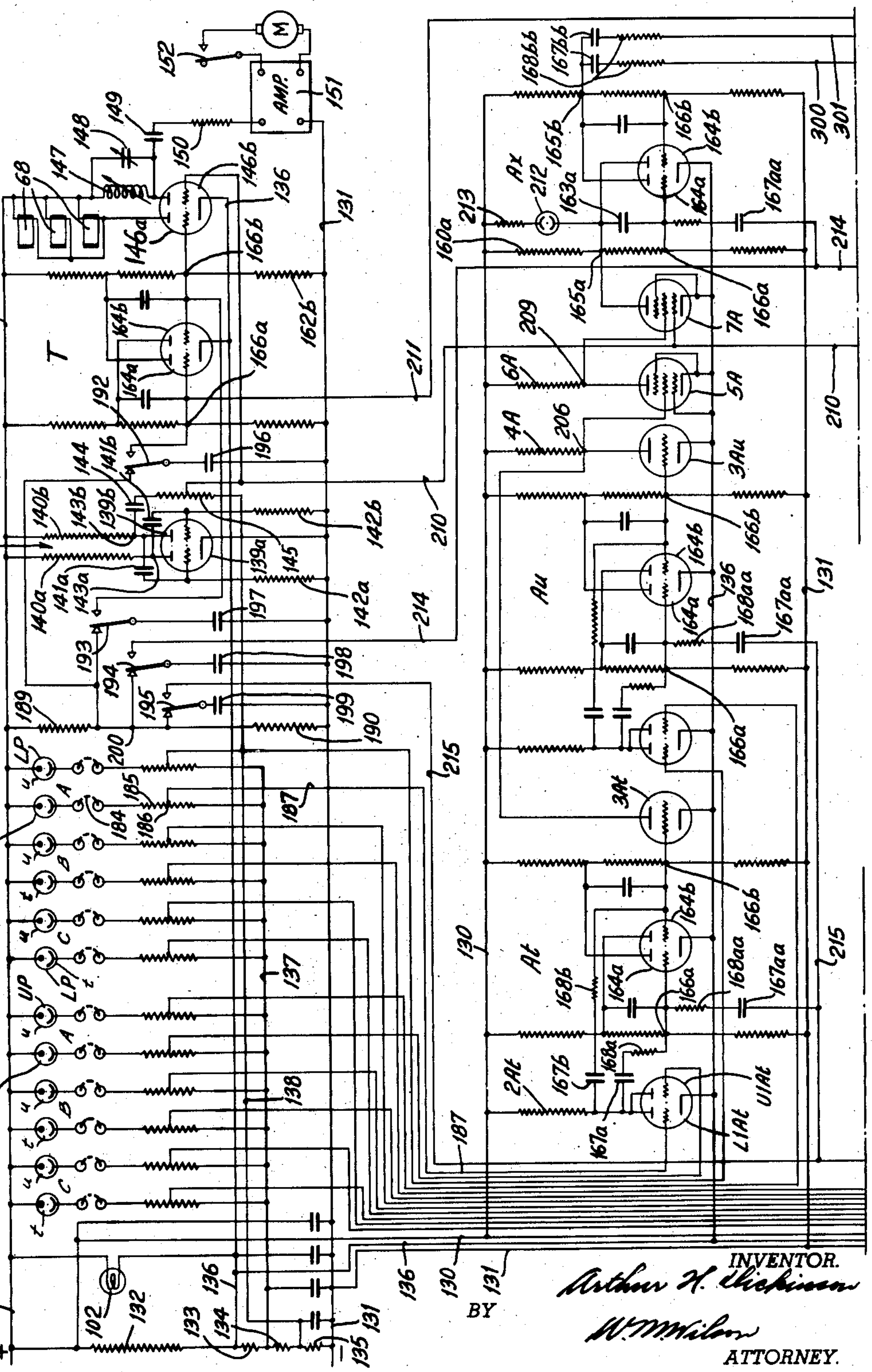

FIG.6a.

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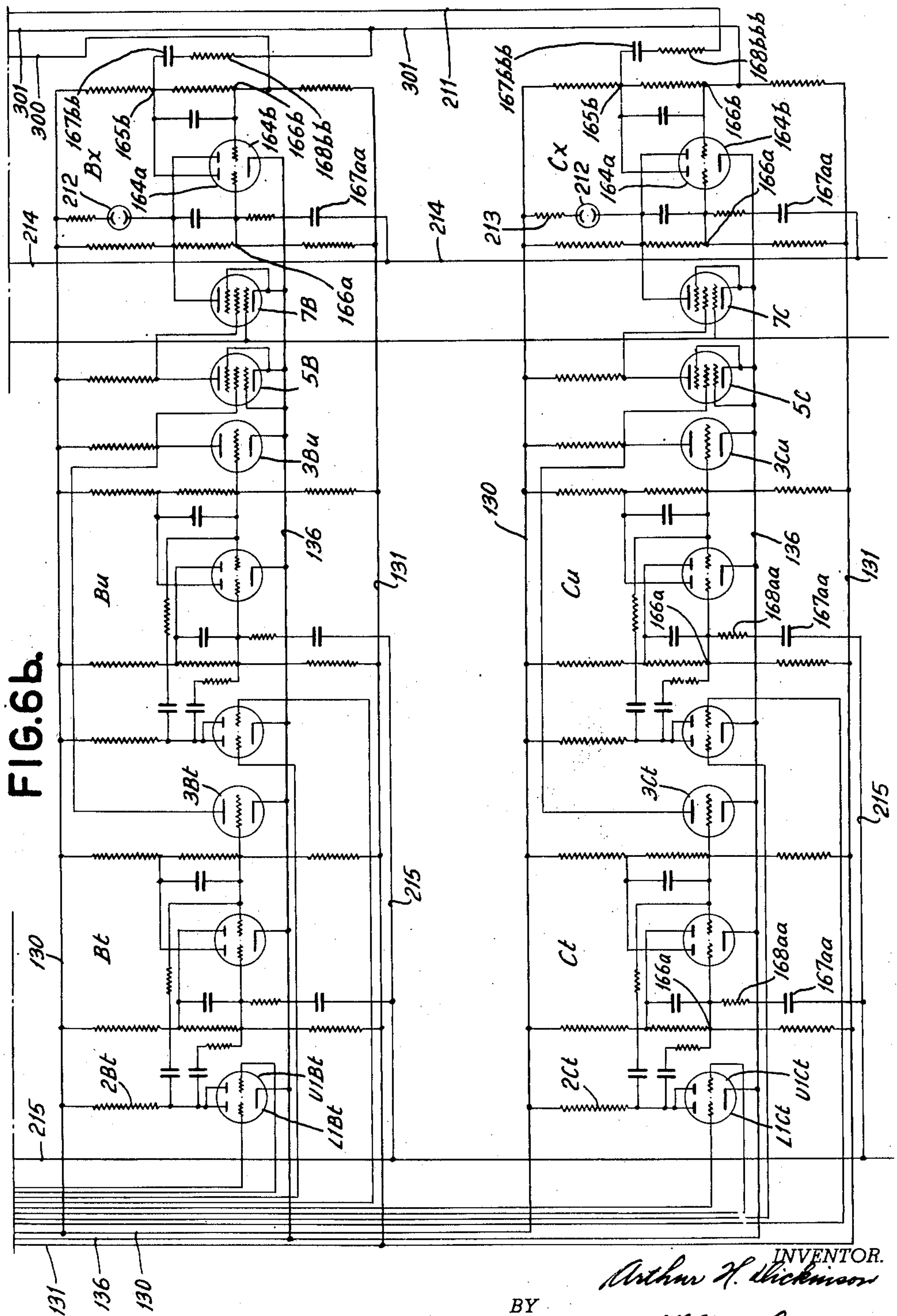

FIG.6b.

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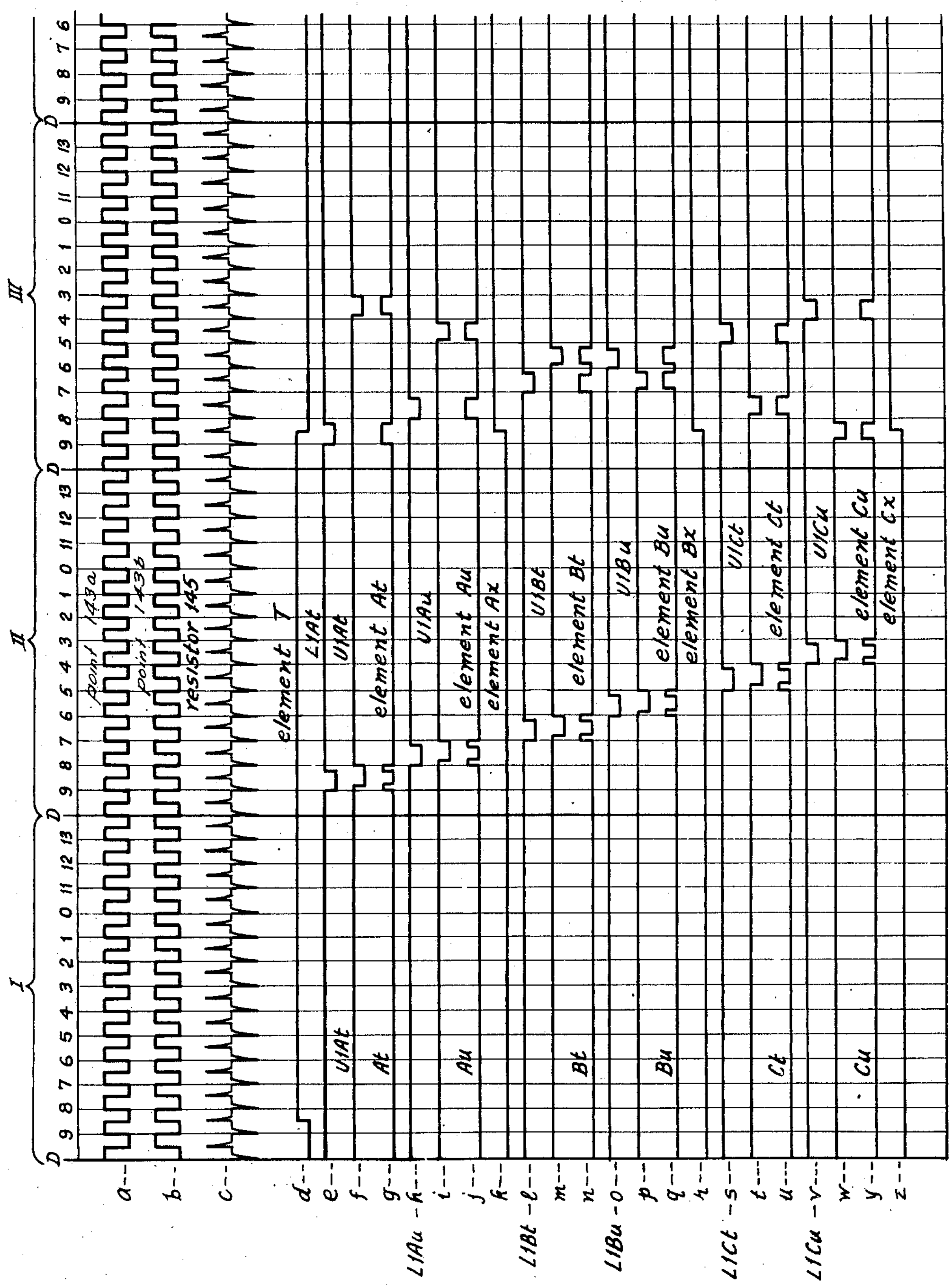

FIG.7.

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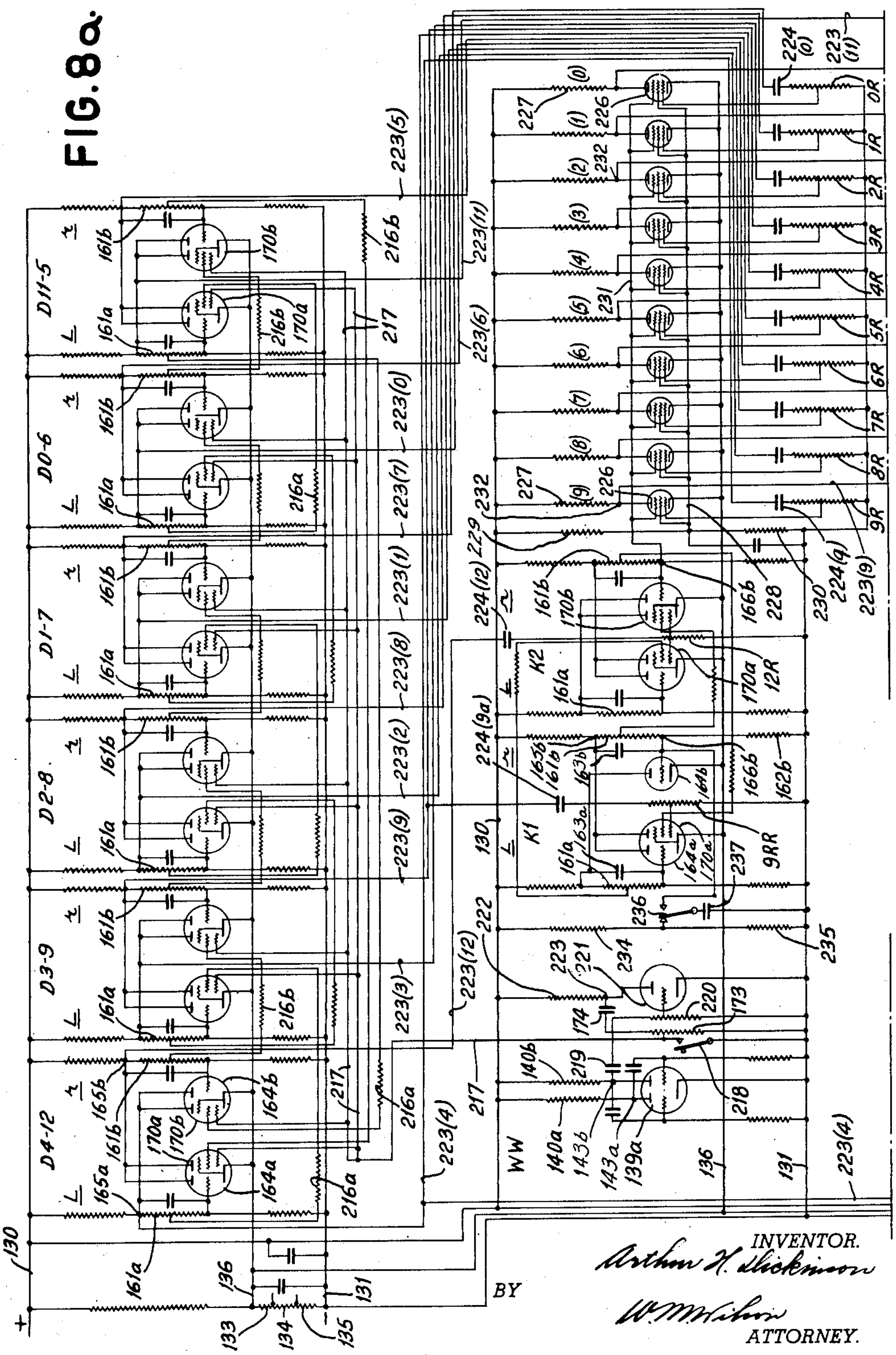
FIG. 8a.



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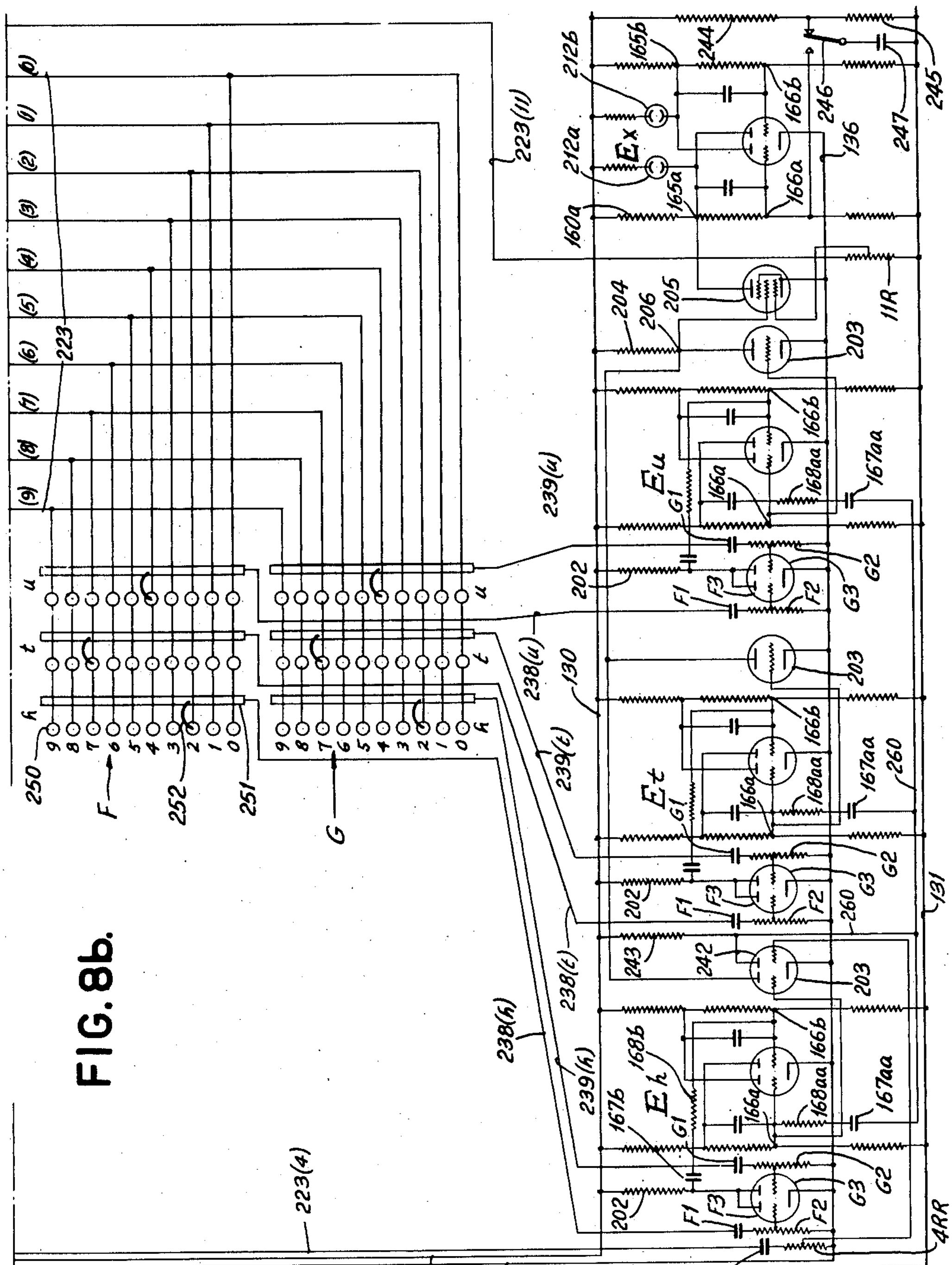

FIG. 8b.

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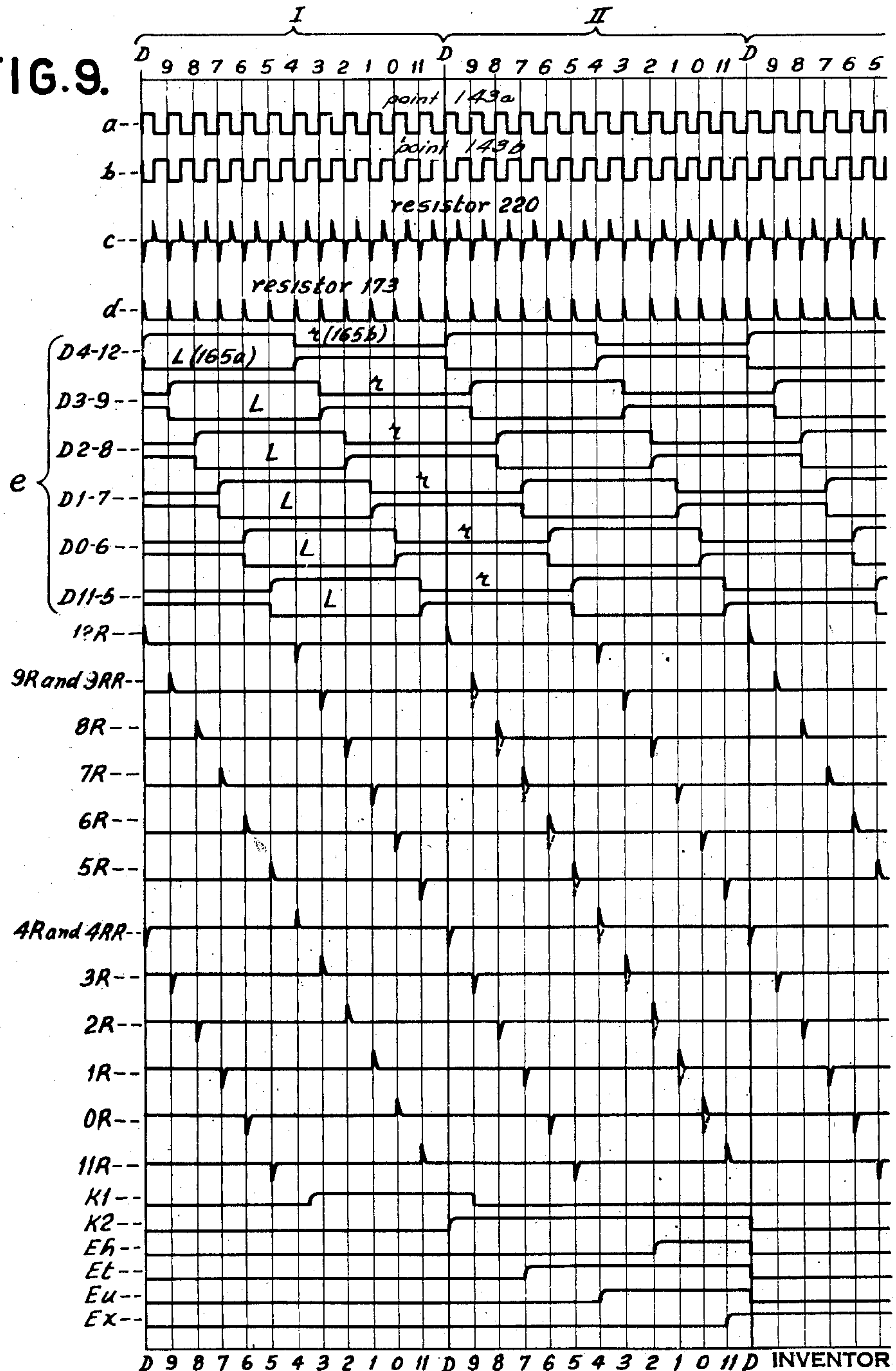
FIG. 9.



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UNITED STATES PATENT OFFICE

2,484,081

ELECTRICAL ITEM COMPARING SYSTEM

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Application April 17, 1943, Serial No. 483,506

19 Claims. (Cl. 235—61.7)

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This invention relates to an electrical system for determining the relative magnitude of values represented by electrical signals. The values may be digits or alphabetic characters or other symbols to which value significance may be applied. The values may be represented on suitable value sources such as settable value registers or record material on which the values may be represented by a suitable code.

Means heretofore utilized for comparing values and determining their relative magnitude have utilized moving parts whose mass necessarily produced inertia and momentum effects which limited the operating speed of these devices. Further, because of the existence of such mass; noise, wear, and other undesirable effects were produced which could be reduced by careful design but not eliminated.

The general object of the present invention is to provide such comparing means as will be practically inertialess and will embody solely electronic means having negligible inertia which may be disregarded completely in practice.

Another object is to provide electronic machine control means controlled by electronic comparison of values.

Another object is to provide electronic means for electronically, selectively manifesting comparison conditions.

Another object is to provide electronic means for comparing multicolumnar data.

Another object is to provide a plurality of electronic comparing means so related that a manifestation by one will supersede a manifestation by another of the comparing means.

Another object is to provide electronic means capable of comparing alphabetic data, as well as numerical data.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of example, the principle of the invention and the best mode, which has been contemplated, of applying that principle.

In the drawings:

Fig. 1 is a cross-sectional view of the record controlled mechanism.

Fig. 2 is a sectional view taken along line 2—2 of Fig. 1.

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Fig. 3 is an enlarged sectional view taken along line 3—3 of Fig. 1.

Fig. 4 is a wiring diagram of one of the electronic trigger circuits employed in the invention.

Fig. 5 is a wiring diagram of another electronic trigger circuit utilized in the invention.

Figs. 6*a* and 6*b* comprise the wiring diagram of the record controlled embodiment of the invention.

Fig. 7 is a timing chart for the latter embodiment.

Figs. 8*a* and 8*b* comprise the wiring diagram of a modification of the invention.

Fig. 9 is a timing diagram for the modification.

The invention is disclosed in connection with a main embodiment and a modification. The main embodiment is a record-controlled machine and includes means to compare data designated on records and to control the machine accordingly. The modification comprises means to compare data entered in or represented by data representing means. Such data representing means may be considered, for illustration, as manually settable, but it will be evident that automatically settable data representing means may be used.

In both forms of the invention, electronic means are provided to respond to data from corresponding columns of two data sources and to control an electronic comparison manifesting device for the columnar order. The columnar comparison manifesting devices control a common comparison manifesting device according to comparison conditions in all the columns; that is, the common manifesting means manifests the comparison relation of the data in all orders.

In the record-controlled embodiment, the common comparison manifesting means will control continuation of operation of the machine or may control another desired operation automatically and selectively according to a comparison result. Further, a plurality of such control devices are embodied in the record-controlled machine, each relating to a different class of data. These control devices are so related that one will dominate another.

In the modification, the control device will be disclosed as manifesting by visible signals the different comparison conditions. It will be evident that other suitable manifestations may be effected.

The record-controlled embodiment will now be described.

1. *General—record controlled machine*

Before proceeding to a detailed description of the completely novel control device, a more general description is set forth. Each of the plurality of control devices comprises a number of electronic tubes and related circuits for comparing data and for manifesting the agreement or non-agreement of data. The manifesting means comprises discrete electronic units, also termed elements, each element including electronic tubes. A number of such elements, termed denominational elements, equal to the number of columns of data to be compared are provided. A common element, termed a class element, is provided, for effecting an all-column manifestation under control of the elements which relate to the separate columns. Each element may have either an on or an off status. When an element is in off status following comparing operation, it indicates a condition of data agreement. When an element is in on status following a comparing operation, it indicates a condition of data disagreement. The status of the denominational elements is regulated under control of record controlled entry means producing differentially timed impulses, each indicative of a determined entry.

It is appreciated, in view of the foregoing, that, if two multicolumnar items are compared and agree, all elements are in off status, and that, if the items disagree, one or more elements are in on status. The class or common element becomes turned on, when one or more of the denominational elements are in on status. The common element, therefore, when off, manifests a condition of agreement between the two items of data, and when on, manifests a condition of disagreement. The status of the common element controls the entry means whereby the latter is maintained in operation as long as the common element remains in off status and is interrupted in its operation when the common element is in on status.

In many instances it is desirable to effect control of a record controlled entry means by more than one class of classifying data and generally similar data. For this reason, therefore, a control device is provided in connection with each class of data. Each device is capable of manifesting the agreement or non-agreement of its related class of data and is also capable of maintaining or interrupting the operation of the entry means.

Since classifying data and generally similar data may be divided into main and subordinate classes, provision is made in this invention whereby the manifestation of the control device related to the main class of control data supersedes the manifestations of the control devices related to the subordinate classes of control data and whereby the manifestation of the control device related to the first subordinate class of control data supersedes the manifestation of the control device related to the second class of control data.

The record medium for controlling the record controlled entry means comprises a film upon which multidenominational control or classifying data and other data are recorded by means of code designations such as spots located at different positions. The spot representations are scanned by light to control photoelectric cells in electrical circuits whereby differentially timed electrical impulses are produced, indicative of the control data to be entered into the control devices.

The film, upon which the differential spots are located is controlled by a feeding mechanism whose operation is manually initiated but is automatically terminated. This mechanism includes two analyzing stations separated by a distance which is slightly less than the length of one film frame. From both of the first and second analyzing stations, classifying data are entered into the control devices. In this manner the items comprising classifying data upon two adjacent film frames are compared simultaneously for agreement or non-agreement. As long as all classifying data on successive film frames agree, film feeding continues. When there is a disagreement between either the main or any of the subordinate classes of control data on adjacent film frames, film feeding is interrupted so that the type of "control break," main or subordinate, may be observed. Film feeding is then resumed after one manual operation. This conditions the extra elements of the control devices which manifest a "break" in classifying data and initiates film feeding operations, which automatically continue until another disagreement in the classifying data on adjacent film frames is manifested.

2. *Structure—record controlled machine*
(*Figs. 1 to 3*)

This structure includes means to feed records and analyze them for data. The record medium is a film F of which successive frames constitute successive records. Fig. 2 shows five such frames designated **1**, **2**, **3**, **4**, and **5**. The feed means is driven, through clutch means, by a motor M mounted on a base **50**. An upright frame member **51** is carried by the base and supports the feeding and analyzing means. All of the structure is enclosed by a casing **52** having a door **53**.

The film is wound on a supply reel **54** and fed by three similar pairs of feed sprockets **55** to a take-up reel **56**. The film is suitably guided and formed with loops as shown in Fig. 1. A single clutch may be used to drive all three sprocket pairs. However, to reduce stress and inertia, a separate clutch is used for each sprocket pair. This clutch may be of any suitable construction and one such as disclosed in Patent 2,150,227 has been chosen. Since the details of the clutch do not enter into the invention, it will be briefly explained only in so far as necessary to understand its present function. It may be mentioned that while the clutch is used in said patent as an accumulator actuator, its function here simply is to releasably connect a sprocket pair to the motor M for drive. Briefly, the drive part of the clutch is a rigid assembly of gear **60** and ratchet **61** journaled on a rod **62**. Both the gear and ratchet have ten teeth. The driven part of the clutch includes a sleeve **63** journaled on rod **62** and to which one sprocket pair is fixed. A detent disk **64** is fast on the sleeve while a toothed disk **65** is freely mounted on the sleeve. Carried, in a manner not shown here, by disk **64** is a clutch dog **66**. A clutch lever **67** engages a tooth of disk **65** to prevent rotation of the driven part of the clutch. When the clutch lever is rocked clockwise (Fig. 1) by energization of a clutch magnet **68**, it releases disk **65**. The disk thereupon permits clutch dog **66** to engage ratchet **61** which then drives the sleeve **63** and the parts carried thereby. Upon deenergization of the magnet, a spring **69** returns the clutch lever into arresting engagement with disk 65 and, as the disk 64 with clutch dog 66 move slightly further, the clutch dog is forced to disengage ratchet 61. The driven part of the clutch is thereby uncoupled from the drive part. Gears 60 of the clutches are meshed with gears 70. The lowest gear 70 is driven by gearing 71 from motor M. One-to-one gearing, including a gear 72 (see Fig. 1), transmits drive from the lowest gear 70 to the other two gears 70. Rigid with gear 72 is a pulley 73 connected by a coil spring belt 74 to a pulley 75 on shaft 76 of the take-up reel 56. The reel is thereby urged constantly in take-up direction.

Feed sprockets 55 are of such size that in one tenth of a revolution they feed the film through one frame length. Since feed sprockets 55 are clutch-driven by ratchets 61, it follows that one-tenth of a revolution of the ratchets 61 effects one frame advance of the film. As stated before, each ratchet 61 has ten teeth, so that one-tenth of a revolution thereof is its travel through one tooth distance. Thus, one tooth travel of the ratchet will cause a single frame advance of the film. This single frame advance is taken here as the measure of a machine cycle (see Fig. 7). When the clutch dog 66 is permitted to engage the ratchet 61, a tooth of the ratchet will pick up the clutch dog at the beginning of such machine cycle, and in one machine cycle, the ratchet will move through one tooth distance and cause advance of the film for one frame length.

As the film feeds from the upper pair of sprockets 55 to the next pair, it moves through a film gate. The film gate comprises a channeled guide plate 77 and a coacting pressure plate 78. The plate 77 is fixed to one end of a block 79, while the plate 78 is slidably carried by a confronting end of a block 80. Both blocks are of molded material and attached to frame member 51. The gate may be opened by retracting the pressure plate 78. This is effected by manually rocking a lever 81 clockwise. The lever is connected to the pressure plate and is acted on by a spring 82 which normally maintains the pressure plate in closed position. In its passage through the film gate, the film is scanned for data designations. Such designations are in the form of spots disposed in differential positions of a film frame and represent numerical data by the single point Hollerith code and alphabetic data by a known combinational code. The analyzing means includes upper and lower designation sensing means. These are spaced apart slightly less than a frame length. Each sensing means is of the light responsive type including photocells and a light source. The cells of the upper sensing means are designated UP and those of the lower sensing means, LP. Upper and lower groups of quartz rods 84 and 85 are molded in the block 80. The upper group pertains to the upper analyzing means and the lower group to the lower analyzing means. Each rod terminates at its front end (right end) in alinement with a column of the film. The rods 84 thus terminate in a single transverse line at one side of the upper sensing station, while rods 85 are similarly alined at their front ends at one side of the lower sensing station. Each rod 84 conducts light passing through a designation position in one column of the film, at the upper sensing station, to one cell UP. Similarly, each rod 85 conducts light passing through a designation position in a column of the film, at the lower sensing station, to one cell LP. The quartz rods 84 and 85 constitute one side of the upper and lower sensing means, respectively. The other, coacting side of the sensing means includes a common light source consisting of an elongated lamp 86 carried by a socket 87 which is attached to frame member 51. Molded into the block 79 are two wide quartz pieces 88 and 89. Piece 88 conducts light from the lamp to the right side of the upper sensing station while piece 89 conducts light to the lower sensing station. Each piece forms a thin line of light at its related sensing station. This line of light at a sensing station is such as to cross all the columns of the film and to illuminate only a single row of the designation positions when the row is at the sensing station. In this manner, at each sensing station, light is commonly supplied to all the designation positions of a single row, while light passing through a position in any particular column is conducted by one quartz rod to the related photocell. When a designation position in a column bears a data representing spot, light to the related column cell is obscured. In a manner described later, the reaction of the cell to the change in light manifests the significance of the spot.

It will be clear that while one record or film frame is being sensed by the upper scanning means, the preceding record or frame is being scanned by the lower sensing means. Further, each frame will be scanned successively by the upper and lower sensing means.

It will be recalled that in one cycle, the film is advanced through one record or frame length. This cycle has fourteen cycle points (see Fig. 7). Thus, a record will pass a sensing station in one cycle of fourteen cycle points. Further, the designation positions of a column of a record will pass a sensing station in successive portions of the cycle, each such cycle portion being equal to the cyclic spacing between successive cycle points.

3. *Oscillators—record controlled machine*

Pulses are utilized in this invention for various purposes. One pulse may be required in any of the fourteen cycle portions which are defined by the cycle points of a cycle. Accordingly, pulses must be supplied at the same rate as the frequency of the cycle points. The source of these pulses is preferably a main oscillator of the type known as a multivibrator. The duration of time corresponding to one cycle determines the base frequency of this oscillator, as will be clear from the previous explanation. Essentially, the multivibrator consists of a two-stage, resistance coupled amplifier in which the output of the second stage is fed back to the input of the first stage. Such an oscillator is capable of producing either square-topped or saw-toothed waves, depending upon the portion of the oscillator from which the waves are derived. The square-topped waves are employed herein because they are easily changed into pulses of extremely sharp wave front and short duration. The circuit diagram of the multivibrator and its principle of operation will now be described in detail.

Referring to Fig. 6*a*, a voltage is supplied to lines 130 and 131, and to a voltage divider consisting of resistances 132, 133, 134, and 135. Potential is also supplied by means of this divider to lines 136, 137, and 138, their potentials being positive with respect to each other in the order given and with respect to line 131. The oscillator, generally designated W, comprises a duplex tube containing triodes 139*a* and 139*b* and associated resistances and condensers. The anodes of the respective triodes are connected to line 136 through load resistors 140a and 140b and the common cathode is directly connected to line 131.

The anode of triode 139a is coupled back to the grid of triode 139b by means of coupling condenser 141b which is also connected to line 131 through the grid leak resistance 142b. The anode of triode 139b is coupled back to the grid of triode 139a by means of coupling condenser 141a, which is also connected to line 131 through the grid leak resistance 142a. With this circuit connection, the normal bias of the grids of triodes 139a and 139b is zero. Such an arrangement is unstable and oscillations are initiated by a minute change of emission of either triode. Assuming that the current through 139a momentarily increases, there is produced across resistance 140a an increased voltage drop and a decrease in potential across 139a. The resulting negative pulse is fed through coupling condenser 141b to the grid of triode 139b, making it more negative. Current through 139b is decreased, decreasing the voltage drop across resistance 140b and an increase in potential across 139b. This increase is equal to the original decrease across 139a multiplied by this tube's amplification factor and is thus much higher. Coupling condenser 141a conveys this potential change to the grid of 139a making said grid much less negative with a resulting rapid increase in the current through 139a. The voltage drop due to this increased current is in turn fed to 139b with cumulative results. Actually, the current flow through 139a is increased to a high value substantially instantaneously, which flow reaches a maximum when the grid of 139b has a negative potential great enough to reduce the current flow through 139b to zero. When this condition is reached, the charge on condenser 141b commences to leak off through resistance 142b, the time consumed being determined by the time constant of the condenser 141b and resistance 142b. When this leakage is completed, current flow in 139b begins and the operation described above reverses, that is, the grid of 139a will instantaneously become negative, shutting off flow through 139a and the grid of 139b will instantaneously become slightly positive and heavy flow will occur in 139b.

It will now be understood that a heavy current flows alternately and for a given period of time through each of the triodes 139a and 139b. When triode 139a is conducting, the other triode, 139b, is shut off; this situation then instantaneously reverses and 139a is shut off and tube 139b conducts. This produces alternate and sustained voltage drops across resistors 140a and 140b, these voltages being 180 degrees out of phase with each other. These voltages are in the form of square-topped waves, easily converted into pulses that possess a steep wave-front and are extremely short in duration.

Fig. 7, line *a*, diagrammatically illustrates the voltage oscillations (with respect to line 131) which occur at point 143a (Fig. 6a) and shows that they are square-topped in form and occur fourteen times per machine cycle. Fig. 7, line *b* illustrates the voltage oscillations (with respect to line 131) which occur at point 143b (Fig. 6a) and also shows that they are square-topped in form and also occur fourteen times per cycle. Since as stated above these voltages are 180 degrees out of phase the potential of point 143a rises at each of the fourteen cycle points and drops midway between cycle points while the potential of point 143b rises midway between cycle points and falls at each cycle point. One cycle of oscillator operation is that period between successive potential rises of point 143a, for example, and its time duration in seconds is proportional to the sum of the time constants of condenser 141a and resistor 142a and of condenser 141b and resistor 142b, respectively, i. e., $1/f$ is proportional to $R_{142a}C_{141a}+R_{142b}C_{141b}$. It is understood that while the frequency is determined primarily by the grid-leak resistance and grid-condenser capacity, it is also influenced by the remaining circuit constants, the tube characteristics and the electrode voltages.

A rise in potential of point 143b causes charging of condenser 144 and current flow through resistor 145 to line 138. By suitably choosing the values of resistor 145 and of condenser 144 so that their R. C. product is relatively small, the rise in potential of 143b produces on 145 a positive pulse of extremely short duration having a steep wave front. A decrease in the potential of 143b causes 144 to discharge and a negative pulse of the character just noted is thereby produced on 145. Since the rise and fall of 143b is constantly recurring, positive and negative pulses are continually produced on resistor 145, of the form shown in Fig. 7, line *c*.

The foregoing has described the manner in which an oscillator of the multivibrator type is employed to produce square-topped waves, which are converted into pulses of extremely sharp character, suitable for use in various portions of the circuit of the control device. The manner in which pulses are employed for control purposes is described subsequently in Section 5. The synchronization of an auxiliary oscillator by means of pulses generated by the main oscillator is now considered.

Attention is again directed to the fact that whenever film feeding operations occur, a film frame completely traverses a sensing station in one machine cycle. It is sufficient to state here that each differential position on the film must be at a sensing station at the time a control pulse is generated. Accordingly, the film feeding mechanism, when it is operating, must be synchronized in operation with regard to the generation of pulses by the main oscillator. That is to say, during one machine cycle in which one film frame traverses a sensing station, it is required that the rate of presentation of the differentially disposed designation positions to the sensing station be equal to the rate at which the main oscillator generates control pulses.

It has already been pointed out in Section 2 that a movement equal to one tooth movement of ratchet 61 (Figs. 2 and 3) advances the film one frame length. It is therefore apparent that the time during which ratchet 61 is advanced one tooth must be equal to that of a machine cycle. Accordingly, the motor M (Fig. 1) is driven at the proper speed to cause ratchet 61 to advance one tooth each machine cycle. Synchronism between the film feeding mechanism and the generation of control pulses by the main oscillator is accomplished by supplying motor M (Figs. 1 and 6a) from a power source which is controlled from said main oscillator.

It has been explained above that positive and negative pulses appear on resistor 145. The grid of triode 146b is connected to resistor 145. The cathode of 146b is connected to line 136 and resistor 145 terminates at line 138. The difference in potential between lines 136 and 138 is the grid bias for triode 146b and is sufficient to maintain the triode at shut-off when no pulses appear on resistor 145. It is therefore apparent that negative pulses appearing on 145 momentarily serve to increase further the grid bias of 146b without affecting the shut-off condition. A positive pulse, however, on resistor 145 reduces the grid bias of triode 146b, permitting current to flow therethrough momentarily. A resonant circuit, comprising inductance 147 and condenser 148, in series with triode 146b, between lines 130 and 136, is momentarily excited upon current flow in the triode, and oscillations are initiated in the resonant circuit. The inductance 147 and condenser 148 are adjusted so that the period of oscillation is either equal to, or is a multiple or submultiple of the frequency with which 146b passes current. The output of this resonant circuit is coupled by means of condenser 149 and resistor 150 to an amplifier 151. The output of this amplifier is of sinusoidal character and of sufficient power to drive motor M, when switch 152 is closed. In this manner, a power supply of correct frequency is afforded the motor so that when the film feed means is subsequently clutched to the motor drive, the feed of film is such that the rate of presentation of differentially disposed designation positions to a sensing station equals the rate of generation of control pulses by the main oscillator.

Having described the main oscillator which produces control and synchronizing pulses and the auxiliary oscillator for supplying power to the motor of the film feeding mechanism, a fundamental circuit employed in the control device is now discussed.

4. *Trigger circuit*

A basic circuit, which is employed in this invention comprises electronic discharge means, illustrated in Fig. 4 as a plurality of triodes in one envelope, these triodes being associated with resistances and condensers as shown. These triodes are so interconnected in a circuit and operate in such a manner that the circuit assumes two conditions of stability. When one of the triodes is conducting, a large amount of current flows through it and the other triode is at shut-off. In other words, in one condition of stability, one of the triodes has a relatively low impedance and the other has a relatively high impedance. In the other condition of stability, the respective conditions of the two triodes is reversed. Controlling impulses are applied to resistances and condensers associated with the circuit to cause the shift from one condition of stability to the other. Every other impulse brings the circuit to the original condition of stability. Such an arrangement of vacuum tubes and associated circuits is herein termed a trigger circuit, and voltage variations therein, which are determined by the conditions of stability, may be employed for various controlling purposes.

Referring to Fig. 4, voltage of the polarity indicated is supplied to lines 130, 131 and 136 in the manner described in Section 3 in connection with Fig. 6a.

The trigger circuit (Fig. 4) comprises two impedance networks. One network includes resistances 160a, 161a, and 162a, resistance 161a being shunted by coupling condenser 163a. Triode 164b is connected in parallel between the junction of resistances 160a and 161a and line 136. The second impedance network consists of resistances 160b, 161b and 162b, resistance 161b being shunted by coupling condenser 163b. The triode 164a is connected in parallel between the junction of resistances 160b and 161b and 136. Resistances 160a and 160b are equal in value as are resistances 161a and 161b, and resistances 162a and 162b. The capacities of condensers 163a and 163b are also equal. In actual practice an efficient combination was found when the values of resistances 160a and 162a were each approximately one-third the value of 161a. A suitable value for the capacity of 163b is of the order of a few hundred micromicrofarads.

Assuming that the grid of 164a is substantially at the potential of cathode line 136, its grid bias will be substantially zero. With resistance 160b properly chosen, 164a has an impedance relatively low as compared to that of 160b, and its anode and point 165b to which the anode is connected will have a voltage which is not much greater than that of cathode line 136 with large current flow through 164a. With resistances 161b and 162b properly chosen, the potential drop across 161b is great enough to maintain point 166b and hence the grid of tube 164b, negative with respect to cathode line 136. With 164b negatively biased, it has an impedance greater than that of 160a. Hence the anode of 164b and point 165a to which the anode is connected are at a high enough potential so that the voltage drop across resistance 161a will not force the potential of point 166a below that of line 136. The foregoing describes one condition of stability of the circuit in which 164a has a large current flow therethrough and 164b is at shut-off; hence, with no current flow therethrough, and point 165a is at a higher potential, with respect to lines 136 and 131, than is point 165b. The manner of switching the trigger circuit to the other condition of stability, is as follows.

A condenser 167a is connected in series with a resistance 168a and the latter terminates at point 166a. A condenser 167b is connected in series with a resistance 168b and the latter terminates at point 166b. Condensers 167a and 167b serve to couple resistors 168a and 168b respectively to sources of steep pulses, not shown in Fig. 4. In the absence of any pulses on resistors 168a and 168b, the potentials of points 166a and 166b remain at the values determined by the condition of stability described above.

When a positive pulse is applied through condenser 167b to resistance 168b, it is also applied to resistor 162b, since these two resistors are connected in series. Accordingly, point 166b rises in potential with respect to line 131. Also, the difference in potential between cathode line 136 and 166b, the grid bias of triode 164b is reduced. If the pulse applied to 168b and 167b is of sufficient value, the grid bias voltage of 164b is reduced to less than the shut-off value. Such operation permits 164b to pass current, causing point 165a to suddenly drop in potential, producing a negative pulse. This pulse is fed through condenser 163a to the grid of 164a, effecting a sudden increase in the negative grid bias thereof, and reducing current flow through 164a and resistance 160b. Point 165b, accordingly, rises in potential, with respect to line 136 to produce a positive pulse which is fed through condenser 163b to the grid of 164b, changing its grid bias to substantially zero. Since, as just described, the potential of 165b has now risen and that of 165a has now dropped, triodes 164a and 164b assume a condition of stability which is the reverse of that originally described; namely, 164a is now at shut-off while 164b passes a large amount of current. The new status of the trigger circuit is maintained until a positive pulse is applied to resistances 168a and 162a. When this occurs, the resulting negative grid bias reduction of 164a causes increased current flow therethrough, and the trigger circuit is returned to the former condition of stability.

In the foregoing description, it was assumed that positive pulses are not applied concurrently to resistances 168b and 162b, and to resistors 168a and 162a. If, on the other hand, either positive pulses from two sources are concurrently applied through condensers 167a and 167b to associated resistors or positive pulses from a single source are applied with 167a and 167b connected in parallel as indicated by the dash line wiring 169, such pulses are effective alternately only, in two branches of the circuit and cause it to shift back and forth from one condition of stability to another.

Assume now that pulses are simultaneously applied to two points of the trigger circuit by either of the two methods given in the paragraph above and that the trigger circuit is in the condition of stability where points 165a and 165b are respectively high and low in potential. When a positive pulse is applied through condenser 167a to resistances 168a and 162a, point 166a rises somewhat in potential with respect to line 131. Since 166a is already substantially at the potential of line 136, the bias of triode 164a is at or near zero and it is passing substantially maximum current. Therefore, a further rise of 166a in potential may cause the bias of 164a to go slightly positive without affecting current flow therethrough. Thus a positive pulse applied to this branch of the trigger circuit, when it is in the condition of stability specified, has no effect thereon. The simultaneous application of a positive pulse through condenser 167b to resistors 168b and 162b, however, does cause the trigger circuit to shift its condition of stability in the manner described above. In further explanation, the positive pulse applied through condenser 167a and resistor 168a to the grid of triode 164a is extremely sharp whereas the negative pulse applied through condenser 163a is exponential in character. The positive pulse will, therefore, have substantially lost its effect when the negative pulse applied via condenser 163a is still effective. It requires only a minute change in conductivity of triode 164b to start the triggering action which continues in a regenerative manner until the circuit is fully triggered in the same way as when a positive pulse is applied only to the grid of triode 164b. Just as the circuit is triggered, when positive pulses are applied concurrently, from the status in which point 165b is at low potential to the status in which this point is at high potential, the circuit may be triggered back to its former status when the positive pulses are next applied concurrently to the grids of the triodes.

So far in this description of the trigger circuit, positive pulses have been employed to cause a shift in the condition of the circuit's stability. It is to be noted that negative pulses are equally effective in causing a shift in the condition of stability. Assume that the condition of the trigger circuit is such that points 165b and 165a are respectively high and low in potential. When a negative pulse is applied through condenser 167b to resistor 168b, it is also applied to resistor 162b. Accordingly, point 166b falls in potential with respect to line 131, and the grid bias of triode 164b is increased. Such operation reduces current flow through triode 164b, causing point 165a to suddenly rise in potential, producing a positive pulse. This pulse is fed through condenser 163a to the grid of 164a, effecting a sudden decrease in the grid bias thereof, and causing increased current flow through 164a and resistance 160b. Point 165b, accordingly, drops in potential, with respect to line 136, to produce a negative pulse which is fed through condenser 163b to the grid of 164b, increasing its grid bias to shut-off value. Since, as just described, the potential of 165b, has now dropped and that of 165a has now risen, 164a and 164b assume a conjoint condition of stability which is the reverse of that originally described, namely, 164a passes a large amount of current while 164b is shut off. The new status of the trigger circuit is maintained until another negative pulse is applied to 168a and 162a. When this occurs, the resulting grid bias increase of 164a causes decreased current flow therethrough, and the trigger circuit is returned to first condition of stability.

In the description just concluded, it was assumed that negative pulses are not applied concurrently to resistances 168b and 162b, and the resistors 168a and 162a. If, on the other hand, either negative pulses from two sources are concurrently applied through condensers 167a and 167b to associated resistors or negative pulses from a single source are applied to 167a and 167b, connected in parallel as indicated by the dash line wiring 169, such pulses are effective alternately only, in two branches of the circuit and cause it to shift back and forth from one condition of stability to another.

Assume now that negative pulses are simultaneously applied to two points of the trigger circuit by either of the two methods given in the previous paragraph and that the trigger circuit is in the condition of stability where points 165b and 165a are respectively high and low in potential. When a negative pulse is applied through condenser 167a to resistances 168a and 162a, point 166a drops somewhat in potential with respect to line 131. Since 166a is at the lower of its two possible values, the bias of tube 164a is equal to or greater than that required for shut-off, when 164a passes no current. Therefore, a further drop in potential of 166a merely causes an increase in the grid bias of 164a without affecting the shut-off condition. Thus a negative pulse applied to this branch of the trigger circuit, when it is in the condition of stability specified, has no effect thereon. The similar application of a negative pulse through condenser 167b to resistors 168b and 162b, however, does cause the trigger circuit to shift its condition of stability in the manner described above. In further explanation, the negative pulse applied directly to the grid of triode 164a is extremely sharp whereas the positive pulse applied through condenser 163a is exponential in character. Accordingly, the negative pulse will have been substantially dissipated when said positive pulse is still effective. The triggering action thus continues and is completed in the same way as though a negative pulse were applied directly only to the grid of triode 164b.

That portion of the circuit in Fig. 4, within the broken line enclosure is a trigger circuit which is used in various portions of both the main embodiment and the modification. For purposes of simplification, this enclosed portion also may be termed an element which may be considered to be "on" when points 165b and 165a are at high and low potentials, respectively, and to be "off" when the potentials of 165b and 165a are low and high, respectively. The voltages which exist at points, such as 165a and 165b, of the triggering circuit, and which vary in accordance with the conditions of stability are employed for many control purposes as subsequently explained. Several such elements are utilized in the invention. To aid in identifying the purpose of parts of these elements, these parts will be designated the same as in Fig. 4. Pulses are applied to some of the elements via condensers and resistors such as 167a and 167b and 168a and 168b of Fig. 4. Ready identification of the purpose of these parts will be afforded by designating the similar parts wherever they appear by the general reference numbers 167 and 168 followed by one or more letters *a* or *b*.

It may be noted that to successfully achieve the operations as described above, the pulses applied to the points 166a and 166b of an element should be of steep wave form. Preferably the R. C. product of the value of resistances such as 168a and 162a and the value of the capacity of an associated condenser such as 167a should not exceed one-fifth the R. C. product of resistance 161a and condenser 163a. The effect of these relative time constants is to prevent a single pulse from causing more than one change on the state of the element or trigger circuit.

The foregoing has described an element comprising a trigger circuit in which vacuum tubes and electrical parts are so interconnected and operated as to produce alternate conditions of stability. Either positive or negative pulses may be employed, and these may be derived from either a common source or a plurality of sources and applied to two points of the circuit. Pulses simultaneously applied are effective alternately only in two branches of the circuit and cause it to shift back and forth from one condition of stability to another.

5. *Control device—record controlled machine*

A general explanation of the operation of the control device as applied to a record controlled machine is given in Section 1 and, therefore, need not be repeated here. Accordingly, the specific details of the construction and operation of the control device are now set forth.

Prior to placing the machine in operation the operator closes a switch (not shown) which supplies a voltage to lines 130 and 131 (Fig. 6*a*) and also to lamp 102. Certain conditioning operations are next performed and these are described in detail subsequently (Section 6). For purposes of facilitating the description it is assumed that the conditioning operations have been performed, as a result of which elements T, A*t*, A*u*, A*x*, B*t* (Fig. 6*b*), B*u*, B*x*, C*t*, C*u* and C*x*, each of the same nature as the trigger circuit element described in Section 4, are in off status. Accordingly, the point 166b in each of the aforesaid elements is at low potential with respect to 131. Since the main and intermediate oscillators (Section 3) now function, the operator closes switch 152, placing motor M in operation.

Referring to Figs. 1 and 2, the film F is inserted in the record feeding mechanism (Section 2) so that the leading edge of frame 1 is about to pass the lower sensing station. With such adjustment, it is seen that frame 2 is about to pass the upper sensing station 110.

Referring now to Fig. 6*a*, a voltage divider comprising resistors 189 and 190 is connected between lines 130 and 131. Normally, switches 192, 193, 194, and 195 are in the position shown, thus affording circuit connections for condensers 196, 197, 198, and 199 between a point 200 on the aforementioned voltage divided and 131. With this circuit arrangement and with the switches positioned as shown, the condensers 196 to 199 are each charged to a potential equal to that across resistor 190.

To initiate film feeding operations, the operator throws switch 193 to reverse position from that shown. The discharge of condenser 197 through resistance 162b causes point 166b of element T to rise in potential, thus shifting element T to an on status. This rise of potential of point 166b occurs, by happenstance, shortly after "9" of cycle I (Fig. 7, line *d*). The grid of a triode 146a is connected to point 166b of element T, the anode of the triode is connected to line 130 by parallel clutch magnets 68 (also see Figs. 1 and 2), and the cathode of this triode is connected to line 136. The rise in potential of point 166b of element T reduces the grid bias of triode 146a causing current flow therethrough and through the clutch magnets 68. The energization of these clutch magnets releases the several clutch dogs 66 for engagement with ratchets 61 (Fig. 3) of the clutch mechanism (Section 2). Since rotation of the ratchets through one tooth distance requires a complete cycle, dogs 66 will not be picked up by the ratchets until "D" following the switching of element T to an on status and regardless of the time at which, by happenstance, this element is switched on. Since element T is a trigger circuit such as described in Section 4, when it is switched on its point 166b remains at relatively high potential and triode 146a remains conductive and clutch magnets 68 remain continuously energized, until element T is switched to off status.

It will be assumed that automatic control is to be effected according to comparison of major, minor, and intermediate classification data recorded in six columns of the film.

Fig. 6*a* shows the six cells LP and six cells UP to sense the classification data at the lower and upper sensing stations. Each cell is similarly connected into a control circuit which determines the current flow through an electronic unit. The units relating to the two cells LP and UP which sense corresponding columns are in parallel with each other and connected to a common load resistor. Impulses are produced on this resistor upon changes in current flow through the connected tubes. These impulses control the switching of a demoninational control element from one status to another. There may be a plurality of denominational control elements for each class of data. Thus, if the major class has two columns of orders, there will be two denominational control elements for such class. The denominational control elements relating to the same class each control a common class control element. The condition of the class element determines whether an agreement has been found in all the orders of the class of data. Thus, there will be one class control element for the major class, one for the intermediate class, and one for the minor class. The major class control element dominates the intermediate and minor class control elements, and the intermediate element also dominates the minor class element.

As stated in Section 2, the lower and upper sensing stations are slightly less than a frame length apart. It follows that with respect to two like designation spots on successive frames, the spot on the leading frame will be sensed slightly before the spot on the following frame. In other words, since one cycle is required for travel of each frame across a sensing station, the spot on the leading frame will be sensed at a time of the cycle which is just previous to the time at which the spot on the following frame will be sensed. With the film adjusted in the manner previously described in this section, a spot on the leading frame will be sensed substantially at an exact cycle point while a corresponding spot on the following frame will be sensed a slight fraction of a cycle portion later.

For convenience, in the further description, parts may be distinguished as follows: The letters U and L denote relation of the parts to upper and lower sensing means; letters A, B, C denote major, intermediate, and minor class relations; and letters *t* and *u* denote tens and units orders.

In Figs 6*a* and 6*b*, the major, intermediate, and minor class control elements are designated, respectively, A*x*, B*x*, and C*x*. The denominational control elements associated with element A*x* are designated A*t* and A*u*. Similarly, the denominational elements associated with the intermediate class element B*x* are designated B*t* and B*u*, and those associated with element C*x* are designated C*t* and C*u*. The control triodes for the denominational element A*t* are designated L1A*t* and U1A*t*. The common load resistor connected to these triodes is designated 2A*t*. The similar intermediate class parts are designated L1B*t*, U1B*t*, and 2B*t*, and the similar minor class parts are designated L1C*t*, U1C*t*, and 2C*t*.

The manner in which each photocell shown in Fig. 6*a* controls a related triode is the same and will be explained in detail only in connection with the cell LP*t* (major) which senses the tens order of the major field of the leading film frame.

The cell is connected by a plugwire 184 to a resistance 185. This resistance is tapped at a chosen point 186 by a wire 187 leading to the grid of triode L1A*t*. The cathode of the triode is connected to line 136 while resistance 185 terminates at line 137. The cell is of the type whose impedance is lowered by light falling thereon. When the cell is illuminated, its impedance is low and the potential at point 186 is substantially the same as that of line 136. The grid bias of triode L1A*t* is then approximately zero, and there is substantially maximum current flow through the triode. When light to the cell is obscured, the cell impedance is high, and the potential at point 186 is approximately the same as that of line 137. The grid bias of triode L1A*t* is then high, and current flow in the triode is rapidly curtailed. It should be understood that the cell reacts extremely rapidly to a change in light falling thereon and causes a correspondingly rapid change in the current flow through the related tube and, hence, of its impedance.

As the impedance of triode L1A*t* rapidly rises, the potential across the load resistor 2A*t* sharply drops. The load resistor is connected to condensers 167*a* and 167*b* which lead through resistors 168*a* and 168*b* to points 166*a* and 166*b* of denominational control element A*t*. It should be noted that condensers 167*a* and 167*b* and resistors 168*a* and 168*b* correspond to the similarly designated parts of the circuit shown in Fig. 4 and explained in Section 4. Hence, upon the occurrence of the drop in voltage across the load resistance 2A*t*, the condensers apply steep positive pulses to both branches of element A*t*, shifting it from assumed off state to an on state. The above explains the action of a control element in response to the sensing of a designation at the lower sensing station. Subsequent to this action, a matching designation may be sensed at the upper station. In a manner now clear, the related triode U1A*t* will increase rapidly in impedance, and a second further sharp drop in voltage across the load resistance 2A*t* will occur. Positive pulses are again produced by condensers 167*a* and 167*b* and element A*t* thereupon shifts back to off state.

Attention is directed to the fact that because of the triodes L1A*t* and U1A*t* being in parallel with each other, the voltage across the load resistor 2A*t* will depend on the impedance of both triodes. Thus, when one triode rises in impedance while the other triode remains at low impedance, a first drop in voltage across the load resistor occurs. When the impedance of the other triode also rises, a second, further drop of voltage across the resistor occurs. Likewise, a decrease in impedance of one triode, while the other triode remains at high impedance, causes the potential across the resistor to increase to a first extent, and a decrease in impedance of both triodes produces a further rise in potential across the resistor.

It has been explained that when a designation on the leading frame was sensed, element A*t* was turned on and that the element was turned off upon the sensing of a matching designation on the following frame. The operation of turning an element to one status and then back to the original status may be referred to as a switching sequence. Thus, the sensing of the matching points jointly controls one switching sequence (off to on and back to off) of a related denominational control element. A second, similar switching sequence of the element, under joint control of the matching designations as they successively leave the lower and upper sensing stations, is effected as follows. When the spot in the leading frame leaves the lower station, light again falls on the related cell LP and the grid bias of triode L1A*t* decreases rapidly, causing the impedance of the triode to drop abruptly. The result of this is a first rapid rise in potential across the load resistor, causing negative pulses to be applied by condensers 167*a* and 167*b* to element A*t*. In the manner described in Section 4, such pulses also shift the status of the element. Since the element, at the end of the first switching sequence, was off, it is now shifted to on status again. Subsequently, the spot on the following frame leaves the upper sensing station and the cell UP is again illuminated. The impedance of the related tube U1A*t* drops rapidly, and there is a second, further rise in potential across resistor 2A*t*. Consequently, negative pulses are again applied to element A*t*, returning it to off status. This completes the second switching sequence of the denominational control element under joint control of matching spots.

It may be mentioned at this time that lines *d, g, j, k, n, q, r, u, y,* and *z* of Fig. 7 graphically represent high and low potential states of points 166*b* or points 165*b* or on and off states of the trigger circuits or elements, the on state being indicated by the high part and the off state by the low part of the graph relating to an element. Lines *e, f, i,* and other lines of Fig. 7 relating to electronic discharge units, such at L1A*t*, graphically represent high and low current.

The operations will be explained further with reference to the illustrative data tabulated below. The general (accounting) data are included merely to indicate other data which may be recorded on the film.

Frame	Classification Data			General Data
	Major	Intermediate	Minor	
1	98	76	54	22
2	98	76	54	33
3	45	67	89	76
4	AF	CG	89	27
5	AF	CG	89	59

While the 9 spot in the tens order of the major field of frame 1 is traversing the lower station, it interrupts light to the related cell LP, sharply reducing current flow through the triode L1*At*. This action occurs at the "9" time of the cycle II, as indicated by line *e* of Fig. 7. The increased impedance of triode L1*At* causes substantially immediate switching of element At from off to on state (see line *g* of Fig. 7, cycle II), in the manner explained before.

Since frame 2 contains a matching 9 spot in the tens column of the major field, the light to the related cell is interrupted and the current flow through triode U1*At* reduced rapidly. This action occurs after the element *At* has shifted to on state, as indicated by comparison of lines *f* and *g* of Fig. 7, cycle II. The increased impedance of triode U1*At* causes a second shift of the element *At*, so that the element returns to off state. This completes one switching sequence of the element. Reference to line *g* of Fig. 7, cycle II, shows that element *At*, after completion of the first switching sequence, remains in off status mid-way of the cycle portion between cycle points 9 and 8. Such attained status is a manifestation of matching data in corresponding columns of two successive film frames.

The configuration of a designation spot is such that in its passage through a sensing station, it interrupts the light to the related photocell for slightly more than half the cycle portion between two successive cycle points. Thus, the 9 spot in the tens order of the major field of frame 1 leaves the lower station shortly after the midway point between the cycle points 9 and 8. The related cell LP is again illuminated at this time and the impedance of triode L1*At* rapidly drops, causing the voltage drop across resistor 2At to increase rapidly. As a result, condensers 167*a* and 167*b* apply steep negative pulses to element *At*, shifting it again to on state at the time indicated in line *g* of Fig. 7, cycle II.

With regard to frame 2, the matching 9 spot leaves the upper sensing station shortly before "8," permitting light to fall again on related cell UP. A sharp drop in impedance of triode U1*At* results, and the voltage drop across resistor 2*At* rapidly increases to a further extent. Steep negative pulses are again applied to points 166*a* and 166*b* of element *At*, shifting it back to off status. This completes the second switching sequence of element *At* and the element remains in off status until designations on frames 2 and 3 are compared. It is seen that following a point midway between cycle points, a second complete switching sequence occurs when there is an agreement of data in corresponding columns of two successive film frames.

The switching of a control element to off status prior to a mid-index point time is a manifestation of the agreement of data in corresponding

columns of successive frames. A subsequent switching of the element to on and then to off status, prior to the end of the cycle portion, occurs as the matching spots successively leave the lower and upper sensing stations. The net result is that the element is off at the end of the cycle portion and is ready for operation in accordance with the next comparison of data in the related columns. When the designations on the frames being compared do not agree, these designations will be sensed in different cycle portions. The first designation sensed will be the one corresponding to a higher value. Each designation, when sensed, will turn on the denominational element which will then stay on until this same designation leaves the sensing station. The designation spot is of such length as to require more than half a cycle portion to cross the sensing station. Hence, the element will remain on at the mid-index point time. In a manner explained later, this condition of the element at such mid-index point time causes a disagreement of data to be manifested. This manifestation will be effected as the higher value representing spot of the two non-matching spots crosses a sensing station. Such spot may be either on the leading or the following frame. When the spot leaves the station after the mid-index point time, the element is again turned off. Thus, a switching sequence will be completed under individual control of each spot during each of the separate cycle portions in which such non-matching spots are scanned. Each such switching sequence requires a longer time than the switching sequence effected under control of matching designations. Before the first of the individually controlled switching sequences is completed, the element is on at a mid-point and a condition of non-agreement will be manifested. The subsequent completion of the switching sequence brings the element to off state, in condition to operate under control of the next spot or spots in the related columns of the successive frames.

The manner in which the on state of a denominational control element causes a condition of non-agreement; i. e., a "break" in classification data, to be manifested will be explained shortly hereafter.

Reference to the above table of illustrative classifying data indicates that the remaining classifying data on frames 1 and 2 agree; i. e., —87654— and —87654—. In view of the detailed explanation given regarding operation of element *At* under a condition of agreement in designation spots, a detailed description of the operation of the other control elements under conditions of agreement is believed unnecessary. It is sufficient to state that the two switching sequences are effected for each of the other control elements at the times indicated by lines *j*, *n*, *q*, *u*, and *y*. It is clear now that all the control elements *At*, *Au*, B*t*, B*u*, C*t*, and C*u* are in off status at midpoints of indicated cycle portions, manifesting agreement of major, intermediate, and minor data in frames 1 and 2.

Point 166*b* of element *At* is connected to the grid of a tube 3*At*. When element *At* is off, point 166*b* is at low potential and the grid bias of the tube 3*At* is high. Under this condition, there is substantially no current flow through the tube. In a similar manner, points 166*b* of the other control elements are connected to the grids of related tubes. As will be explained later in this section, when current flow does exist in one or more of these tubes at mid-points of cycle portions, conditions of non-agreement in classifying data are manifested and one or more of the elements A*x*, B*x*, and C*x* are shifted to on status. It is sufficient to state here that since all classifying data on frames 1 and 2 agree, elements A*x*, B*x*, and C*x* remain in off state during the machine cycle in which these frames are compared. When these elements thus remain in off state, feed of the film continues and a third cycle will be performed.

During the third cycle, frames 2 and 3 will be compared. Since frame 2 contains a 9 spot in the tens order of the major field, element A*t* is first shifted to on state, such shift occurring at the 9 point of cycle III, as shown by line *g* of Fig. 7. Frame 3, however, contains a —4— instead of a —9— in the tens order (major field) and there is no interruption of the light falling on its related photocell UP (Fig. 6*a*) at shortly after "9." Accordingly, element A*t* remains in on status at midway between "9" and "8" of cycle 3, as indicated by Fig. 7, line *g* (III). With element A*t* on at this time, its point 166*b* is at high potential, and therefore, a low bias voltage is applied to the grid of its associated tube 3A*t*, causing current flow through said tube and a common load resistor 4A. The screen grid (hereinafter termed screen) of a pentode 5A is connected to a point 206 of a resistor 4A. The current flow through tube 3A*t* and resistor 4A brings about an increase in the potential drop across the resistor and, accordingly, the screen voltage of tube 5A is reduced.

The control grid (hereinafter termed grid) of tube 5A is connected to line 136, as is the cathode of this tube. With this circuit arrangement, tube 5A is always maintained at zero bias, and variations in current flow therethrough are controlled solely by changes in its screen voltage. Since this screen voltage is now low, current flow through tube 5A and its load resistance 6A is relatively small and, therefore, the drop in potential across the latter resistance is small. The screen of a tube 7A is connected to point 209 of resistor 6A. The grid of tube 7A is connected to wire 210 which extends to a point on resistance 145 on which, as explained before in Section 3, is continually produced the steep pulses, as shown in line *c* of Fig. 7. The cathode of tube 7A is connected to line 136 and resistance 145 terminates at line 138. The difference in potential between lines 136 and 138 is the normal grid bias of tube 7A. This grid bias is sufficient to maintain this tube at shutoff for the values of screen potential which are utilized. It is only when both the screen voltage of tube 7A is at high value and the grid bias of said tube is reduced by a positive pulse appearing on resistance 145 that there is current flow through the tube.

When the drop in potential across resistance 6A is small, as is now the case, the point 209 and, hence, the screen voltage of tube 7A, is at a high potential. The appearance of a positive pulse on resistance 145 at midway between "9" and "8" (Fig. 7, line *c* III) reduces the grid bias of tube 7A (Fig. 6*a*), causing current flow therethrough. The anode of this tube is connected to point 165*a* of resistance 160*a* of element A*x*. The current flow through tube 7A is in the form of a sharp pulse, and causes an extremely rapid increase in potential across resistance 160*a* of element A*x*. Accordingly, a negative pulse is applied by the condenser 163*a* of the element to the grid of triode 164*a* of the element. The current flow in triode 164*a* falls rapidly, point 165*b* rises in potential, and the grid bias of triode 164*b* is reduced sharply. Consequently, current flow in triode 164*b* rises, maintaining point 165*a* at low potential. Since point 165*b* is now at high potential and point 165*a* at low potential, the element A*x* has been switched to on status. The time at which this action occurs under the stated disagreement condition is indicated in line *k*, cycle III of Fig. 7. As has been mentioned previously (Section 1), the manifestation of the control device related to the major class of data supersedes the manifestation of the devices related to the intermediate and minor classes of data. Also, the manifestation of the intermediate control device supersedes that of the minor control device. The means whereby such superseding control is effected is now set forth.

It has been explained above that element A*x* has been shifted to on state as a result of a disagreement found in the tens order of major class data on frames 2 and 3. As is now understood, point 165*b* of element A*x* is high in potential when the element is turned on. Point 165*b* of element A*x* is coupled by pairs of condensers 167*bb* (Fig. 6*a*) and resistors 168*bb* and wires 300 and 301 (also see Fig. 6*b*) to points 166*b* of elements B*x* and C*x*, respectively. Point 165*b* of element B*x* (Fig. 6*b*) is also coupled to point 166*b* of C*x* by means of a condenser 167*bb* and a resistance 168*bb* and the wire 301. The recovery time of the condenser-resistor circuit is relatively small and, therefore, the rise in potential of point 165*b* of element A*x* at midway between "9" and "8" of cycle 3 causes steep positive pulses to be applied concurrently to points 166*b* (Fig. 6*b*) of elements B*x* and C*x*, thus shifting both of them simultaneously to on status at the time indicated in lines *r* and *z* of Fig. 7 (III).

To recapitulate, when frames 2 and 3 were compared, a disagreement was found in the tens orders of the major classification data designated on these frames. This condition was manifested by the retention of an on status by element A*t* (Fig. 6*a*) during a mid-point between two cycle points. With element A*t* in on state at such time, the result was that element A*x* was turned on. As element A*x* was switched on, it brought elements B*x* (Fig. 6*b*) and C*x* to a like status. Accordingly, whenever there is a manifestation of a "break" in the major classifying data, such manifestation produces "break" manifestations for the intermediate and minor classes of data, even though there should be no disagreement in either of the latter classes of data. It will be appreciated that, by virtue of the point 165*b* of element B*x* and point 166*b* of element C*x* being coupled by a condenser 167*bb* and resistor 168*bb*, when there is a "break" in the intermediate classifying data, such manifestation produces a like manifestation for the minor class of data. The "break" in the intermediate data, however, has no effect on the manifestation of the major control device. Further, when there is a "break" solely in the minor classifying data, the manifestations of the major and intermediate control devices are unaffected.

As the —9— spot, recorded in the tens order (major field) of frame 2, leaves the lower sensing station shortly after midway between "9" and "8" of cycle 3, light again falls on its related photocell LPt (Fig. 6*a*) and the current flow in triode L1A*t* is increased. Hence, element A*t*, previously in on state because of the discussed disagreement condition, shifts to an off status in a manner now understood. The resulting increase in current flow through triode L1A*t* and the shift of element A*t* to an off status occur slightly after midway between "9" and "8," as indicated by lines *e* and *g*, Fig. 7, cycle III. Thus, only a single switching sequence is effected during one cycle portion (between successive cycle points) when there is a disagreement of data in corresponding columns of successive film frames. It is clear that a denominational control element is switched to an on status and remains in said status midway of a cycle portion to indicate a condition of non-agreement, and is automatically switched off prior to the termination of the cycle portion, under control of the non-matched data spot of one only of the successive film frames being compared. By thus automatically returning said control element to off state after it has manifested a condition of non-agreement of data, the element is placed in proper status for operation in following cycle portions.

The operations resulting from a condition of non-matching data in the tens orders of the major data of frames 1 and 2 have been described. It has been shown that when the data in corresponding columns of two successive film frames disagree, a denominational control element A*t* undergoes one complete switching operation only, thereby resulting in its being in on status at a mid point of a cycle portion. Further, it has been shown that it is the on status of the denominational element at the mid point of the cycle portion which is a manifestation of the non-agreement of the entered data. It is seen, further, that when a denominational control element, such as A*t* (Fig. 6*a*), is on at a mid-index point time, it causes a related class control element, such as A*x*, to shift also to on status. Finally, it has been shown that element A*x*, when turned on, shifts elements B*x* and C*x* to on state and element B*x*, when on, regardless of the status of element A*x*, also shifts element C*x* to on state.

Reference to the table of illustrative data indicates that the remaining classification data of frames 2 and 3 also disagree; i. e., —87654— and —56739—. In the manner described for element A*t*, the other denomination elements A*u*, B*t*, B*u*, C*t*, and C*u* are similarly operated upon a condition of disagreement in the related orders. It is sufficient to state that such operation of each element is a turning on and off of the element during a cycle portion under control of only one of the non-matching designations of the related order. This cycle portion is the one which is indicated by the higher of the two non-matching values which may be either on the leading frame or the following frame. At the mid point of such cycle portions, the several denomination control elements will still be in on state, manifesting non-agreeing designations. The times at which such action of these elements occurs are indicated in Fig. 7, cycle III, lines *g*, *j*, *n*, *q*, *u*, and *y*. At the indicated mid-cycle point times, the points 166*b* of the denomination elements will be at high potential, thereby reducing the grid bias of related tubes 3A*t*, 3A*u*, 3B*t*, 3B*u*, 3C*t*, and 3C*u*. Each such tube, as has already been explained for tube 3A*t*, causes the related class element A*x*, B*x*, or C*x* to be turned on. If the class element has been turned on previously in the same cycle under control of one such tube related thereto, the action of the other related tube has no effect, the class element simply remaining in on state. For instance, since element A*x* is turned on under control of tube 3A*t* between "9" and "8" of cycle 3, the subsequent action of tube 3A*u* between the "8" and "7" times of the same cycle has no effect on element A*x*. However, if the element A*x* had been off at the time the tube 3A*u* was rendered conductive, this tube would then have caused element A*x* to turn on. Further, in the assumed example of data compared on frames 2 and 3, the element A*x* was the first one turned on of all the class elements. In the manner explained before, as class element A*x* is turned on, it causes class elements B*x* and C*x* to be turned on, so that the control of the latter elements by the related denomination control tubes thereby is superseded. When one or more of the class elements are turned on, they cause an interruption of record feeding operations in the following manner.

The point 165*b* of element C*x* (Fig. 6*b*) is coupled by means of a condenser 167*bbb*, resistance 168*bbb*, and line 211 (see also Fig. 6*a*) to point 166*a* of element T. Element T has been turned on, in the manner described before in this section so as to energize the clutch magnets 68. Condensers 167*bbb* and resistance 168*bbb* correspond to condenser 167*b* and resistance 168*b* of Fig. 4. Hence, when the class element C*x* is turned on, and its point 165*b* rises in potential, a steep positive pulse is applied to point 166*a* of element T (Fig. 6*a*), shifting it to off status. It is recalled that element C*x* (Fig. 6*b*) became on at midway between "9" and "8" of cycle III. Accordingly, element T (Fig. 6*a*) is turned off at this time, as shown in Fig. 7, line *d* (III).

When element T is turned off, its point 166*b* falls to a low potential, thereby increasing the grid bias of tube 146*a*, interrupting current flow therethrough, and through the clutch magnets 68, causing their deenergization. Such deenergization of magnets 68 (see also Figs. 1 and 2) allows the clutches to latch up at "D" at the end of the cycle. Thus, the feed of film F is terminated with frames 3 and 4 about to pass the lower and upper sensing stations, respectively.

When a class control element, such as A*x* (Fig. 6*a*), is on, its point 165*a* is at low potential. A neon or like gaseous discharge lamp 212, in series with a current limiting resistor 213 is connected between line 130 and point 165*a*. When this point is at said low potential, the voltage difference between the point and line is sufficient to ignite lamp 212, thus affording a visual manifestation that class element A*x* is on; i. e., that there is a "break" in the major classifying data. The class elements B*x* (Fig. 6*b*) and C*x* are also provided with neon lamps 212 which become ignited when said elements are on. In the example set forth in detail above, all of the class elements are on, and all the lamps 212 are ignited, visually manifesting "breaks" in the major, intermediate and minor classifying data.

As long as element T is off, clutch magnets 68 are deenergized and film feed suspended. At the same time, one or more of elements A*x*, B*x*, and C*x* remains on, indicating the disagreement of control data. To restart film feed and turn off elements A*x*, B*x*, and C*x*, the operator reverses the position of switch 194 (Fig. 6*a*), causing condenser 198 to discharge a steep positive pulse on wire 214. This pulse is applied via coupling condensers 167*aa* and related resistors to points 166*a* of elements A*x*, B*x*, and C*x*, turning them off. When element C*x* turns off, its point 165*b* falls in potential, so that a steep negative pulse is applied via condenser 167*bbb* and resistor 168*bbb* and wire 211 to point 166*a* of element T. Element T, consequently, turns on and causes clutch magnets 68 to be energized. At the following D point, film feed resumes and frames 3 and 4 are fed past the lower and upper sensing stations, respectively.

The foregoing has described automatic machine control means comprising electronic devices for comparing and manifesting conditions of agreement and non-agreement of classes of data recorded on successive record bodies. It has been explained that a "break" or non-agreement in a class of data is manifested by the lighting of an associated "class" lamp, and further is manifested by interruption of record feed. While, in this illustrative case, the control of the machine by the class control devices is applied to the common feed means, it is evident that the separate class control devices are capable of individually controlling separate machine control means, just as they control lamps 212 individually. It will now be understood that the electronic auto-control means is capable of (a) detecting non-agreement of data among different groups of record bodies constituted by successive sections of the film, of which each section may contain one or more frames or record bodies (b) detecting unwanted, extra classifying data on records (c) detecting missing classifying data on either of the compared records. Either numeric or alphabetic control data may be compared for agreement or for non-agreement. This follows from the fact that the control devices effect position by position comparison of successive records in each and every one of the cycle portions between points "9" to "13" of a cycle as the designation positions 9 to 0, 11, and 12 of the successive records traverse the lower and upper sensing stations. If comparison of any pair of corresponding positions on the successive records shows that one is marked and the other is not marked, a condition of non-agreement will be manifested. Such manifestation will be effected at the midpoint of the first cycle portion in which such disagreement of marks in corresponding positions has been detected. Numeric data are represented by marking designation positions of the columns according to the Hollerith single-point code; that is, a digit is denoted by marking one position of a column of the record. Alphabetic data are designated here in accordance with the code shown in Patent 2,224,771. By such code, a letter is designated by marking a combination of two positions in a column, one marked position being in the zone of positions 9 to 1 and the other marked position being in the zone of positions 0, 11, and 12. Thus, letters A to I are designated respectively by marks in positions 1 to 9 paired with a mark in position 12; letters J to R by marks 1 to 9 paired with marked position 11, and letters S to Z by marks in positions 2 to 9 paired with a —0— mark. Referring to the illustrative table of data, it will be found that frame 3 bears classifying data —456789— and frame 4 bears classifying data —AFCG89—. When these two frames are compared by the auto-control devices during a cycle, no disagreement will be found during cycle portions "9" to "8" and "8" to "7" since, in these cycle portions, agreeing minor data are sensed. During the "7" to "6" cycle portion, mark —7— in the units order of the intermediate class field of frame 3 is sensed and, at the same time corresponding position 7 of frame 4 is found to contain a mark. Thus, at this time, there will be no manifestation of disagreement between number 7 designation and letter G designation since the designation of letter G includes a mark in position 7. Subsequently, in the cycle portion "6" to "5", a mark is sensed in position 6 of the tens order of the intermediate field of frame 3, whereas no corresponding mark is sensed on frame 4. Accordingly, denominational control device B*t* will be on mid-way between "6" and "5" and will cause class control device B*x* to be turned on, manifesting disagreement of intermediate data on frames 3 and 4. Similarly, disagreement will be found at the "12" to "13" time by element B*u* since position 12 of the tens order of the intermediate field of frame 4 is marked and the corresponding position of frame 3 is not marked. Element B*x*, having been turned on previously, is not affected by the on condition of element B*u*. In a similar manner, comparison of the tens order of the major field will detect non-agreement between "4" and "3" and element A*x* will be turned on. The later disagreement found between "12" and "13" in the tens and units orders of the major field will have no effect because A*x* is already on.

It will be clear from the foregoing that alphabetic as well as numeric data may be compared for conditions of agreement and non-agreement to control machine operation and to manifest the result of the comparison.

Film feed will be interrupted as a result of the disagreement found between the classifying data of frames 3 and 4, after which manual re-initiation of film feed will be effected, in the manner now clear. Frames 4 and 5 will then be compared. As shown by the table of illustrative data, the classification designations on these two frames agree, so that film feed will continue for another cycle. It is assumed that frame 6 is blank. Hence, during the cycle following the cycle of comparison of frames 4 and 5, frame 5 will traverse the lower station and blank frame 6 will traverse the upper station. Since the blank frame does not have data agreeing with the classifying data on frame 5, the film feed will be interrupted at the end of the cycle in which frames 5 and 6 are compared.

Having described the operation of the control devices for the various conditions of agreement and non-agreement when alphabetic and numerical data are being compared, a description will now be given of various conditioning operations which take place prior to placing the machine in operation.

6. *Conditioning—record controlled machine*

When the operator closes a switch (not shown) to supply a voltage to lines 130 and 131 (Fig. 6*a*), elements T, A*t*, A*u*, A*x*, B*t* (Fig. 6*b*), B*u*, B*x*, C*t*, C*u*, and C*x* assume either an on or off status which is governed solely by chance. Prior to placing the machine in operation upon a run of film, it is necessary, therefore, for the operator to adjust the several elements to a given status by the following conditioning operations.

The operator first throws switch 195 (Fig. 6*a*) to a reverse position from that shown, permitting condenser 199 to discharge over line 215. Condensers 167*aa* and 168*aa* couple line 215 to the points 166*a* of elements A*t*, A*u*, B*t* (Fig. 6*b*), B*u*, C*t*, and C*u*. The discharge of condenser 199 (Fig. 6*a*) causes a steep positive pulse to be applied through condensers 167*aa* and 168*aa* to each of the points 166*a* of the above mentioned elements, thereby shifting any of said elements which happen to be in on status to an off status. The operator then throws switch 194 to a reverse position from that shown to shift any of the elements Ax, Bx (Fig. 6b) and Cx which happen to be on to an off status, in a manner described above (Section 5). Following this conditioning operation, the operator throws switch 192 (Fig. 6a) to a reverse position from that shown, thus allowing condenser 196 to discharge and apply a positive pulse to a point 166a of element T, thereby shifting said element to an off status should it be on, perchance, at this time. Since in each such conditioning operation, positive pulses have been applied only to the points 166a of the elements, it follows that if any such element happened to be off, the application of the positive pulse to its point 166a will have no effect, and the element will remain off.

The foregoing has described the conditioning operations which are performed when starting up the machine. The result of such conditioning operations is to place all of the elements T, At, etc., in an off status. Following said conditioning operations the film may be inserted in the record handling mechanism and feeding operations initiated as described previously (Section 5).

7. *General—modification*

This modification applies the principles of the invention to the comparison of settable data by the electronic comparing means. The electronic comparing means of the modification is essentially of the same nature as the comparing means of the record-controlled embodiment. However, the modification, instead of comparing data designated on successive records, compares data entered in and represented by settable entry receiving and representing means. Instead of manifesting agreement of data by continuing record feed, the modification manifests agreement by lighting a signal lamp. Whereas the record-controlled embodiment continues automatically to compare data on one record after another during successive cycles until a disagreement is detected, the modification compares one set of data in one cycle and must then be restarted to compare data in another cycle, and so on. While the record-controlled embodiment provides for cyclically timed emission of control impulses for the comparing means under control of and in accordance with the sensing of recorded designation spots differentially related to a cycle, the modification provides a commutator for supplying differentially timed impulses which are converted by means including the data representing devices into control impulses for controlling the comparing means according to the data standing on the data representing means.

As in the record-controlled embodiment, the modification provides a plurality of denominational control elements, each to compare, electronically, the data in corresponding orders, and a common data comparing means jointly controlled by the denomination comparing means to manifest agreement or non-agreement of the compared data as a whole.

8. *Trigger circuit—modification*

In addition to utilizing the trigger circuit shown in Fig. 4 and described in Section 4, the modified embodiment of this invention also employs another trigger circuit. This circuit is shown in Fig. 5, and, except for certain features, is substantially similar to the Fig. 4 circuit. Portions of the Fig. 5 circuit, which correspond in character and function to portions of the circuit of Fig. 4, are given the same reference characters.

The trigger circuit shown in Fig. 5 may also have two conditions of stability. Whereas the Fig. 4 circuit has only one vacuum tube unit in each branch and to which the controlling pulses are applied to effect switching action, the Fig. 5 circuit includes in each branch an additional vacuum tube unit to which the control pulses are applied to effect switching action. The additional vacuum tube units are pentodes 170a and 170b. The screen of 170a is connected to a point 176a on a voltage divider consisting of resistors 171a and 172a. The potential of point 176a is positive with respect to line 136 when switch 175a is in reverse position from that shown, and, hence, the screen voltage of 170a is positive with respect to its cathode. The screen of 170b is connected to a point 176b on a voltage divider consisting of resistors 171b and 172b. The voltage of this point is likewise positive with respect to line 136 when switch 175b is in reverse position from that shown, so that the screen potential of 170b is positive with respect to its cathode. The grid of 170a is connected to a resistance 173a and the grid of 170b is connected to a resistance 173b. Positive pulses are applied to resistances 173a and 173b through condensers 174a and 174b, respectively, from a source or sources not shown in Fig. 5. In the absence of any pulses on the resistors 173a and 173b, the grid bias of each of units 170a and 170b is the potential difference between lines 136 and 131 and is great enough to maintain these units at shutoff. It is also assumed that switches 175a and 175b are each in reverse positions from that shown and that the trigger circuit has attained a state of stability such that points 165a and 165b are respectively at high and low potentials.

When a positive pulse is applied through condenser 174b to resistance 173b, the grid bias of tube unit 170b is reduced. The anode of tube unit 170b is connected to point 165a, the potential of which with respect to line 136, is relatively high. Hence, the bias reduction of tube 170b causes a current flow as follows: from line 130, via resistor 160a, tube unit 170b, line 136, resistances 133, 134, and 135, to line 131. As a result of such current flow, point 165a, suddenly drops in potential, producing a negative pulse which increases the grid bias of tube unit 164a, shutting off this tube unit. Accordingly, point 165b rises in potential, decreasing the grid bias of tube unit 164b so that current flow therethrough increases. Since the anode of this tube unit is connected to point 165a, current flow through the tube unit maintains this point at low potential. Thus, as a result of the positive pulse applied to resistance 173b and which rendered tube unit 170b conductive, points 165b and 165a are at high and low potentials, respectively. Thus, the trigger circuit has been shifted to a condition of stability which is the reverse of that originally described. The new status of the trigger circuit is maintained until a positive pulse is applied to resistance 173a through condenser 174a. When this occurs the resulting grid bias reduction of tube unit 170a is effective to increase current flow therethrough and the trigger circuit is returned, in a manner now clear, to the first condition of stability. It is to be noted that negative pulses applied to the grids of units 170a and 170b are ineffective to cause the shifting action explained above.

In the foregoing description, it was assumed that switches 175a and 175b are each in reverse position from that shown. Assume now that switch 175a is closed; hence, it shunts out resistance 172a, reducing the screen potential of 170a to substantially that of line 136. Assuming that the condition of stability is such that point 165b is at a high potential, such screen voltage reduction prevents any grid bias reduction of 170a from being effective in bringing about increased current flow therethrough. Therefore, until switch 175a is opened, applications of pulses to resistance 173a are ineffective to change the status of the trigger circuit from a condition in which points 165b and 165a are at high and low potentials respectively.

Similarly, switch 175b, in the position shown, shunts out resistance 172b, thus reducing the screen potential of 170b to that of line 136. Such screen voltage reduction, when point 165a is at high potential, prevents any grid bias reduction of 170b from being effective in bringing about increased current flow therethrough. Therefore, until switch 175b is placed in reverse position from that shown, pulses appearing on resistance 173b are ineffective to change the status of the trigger circuit from a condition in which points 165a and 165b are at high and low potentials respectively. Switches 175a and 175b, therefore, comprise parts of selection means whereby selectivity in operation of the trigger circuit is obtained.

That portion of the Fig. 5 circuit within the broken line enclosure is also hereinafter termed an element, utilized in various parts of the embodiment under discussion. One such part is the electronic commutator which is described in the following section.

The foregoing has described a trigger circuit in which controlling impulses are applied to vaccum tube units of the circuit to cause the shift from one condition of stability to the other. The manner in which the screen grids of pentodes are employed to permit triggering impulses to be selectively effective for controlling sequential operation was also described. It will be seen that 170a, when it responds to a pulse, causes triode 164a to pass increased current and that a pulse applied to 170b causes triode 164b to become more conductive. The portion of the element in which 164a and 170a are shown as located may be referred to as one element portion L. Similarly, the other portion in which 164b and 170b are shown as located may be called element portion *r*. For convenience, an element portion will be referred to as on when its triode is highly conductive.

9. *Electronic commutator*

The purpose of this commutator is to provide means whereby various results may be obtained with negligible inertia and at high speeds. The commutator has a number of elements such as described in the preceding section. The number of steps in a commutator cycle determines the number of elements required. Specifically, there are half as many elements as steps; hence, as many element portions as steps. Stated generally, advancing pulses will be applied to the commutator elements. Each element portion when on will condition a succeeding element portion to be turned on in response to an advancing pulse. Thus, in a commutator cycle, the element portions will be turned on successively in response to a series of pulses. When one portion of an element is turned on, the companion portion of the same element thereby automatically is turned off. Briefly, then, a commutator cycle of twelve steps will require six elements. Assume portion *r* of a first element to be on and all other element portions *r* to be off. Portion *r* of the first element, being on, conditions corresponding portion (*r*) of a second element to be turned. The first advancing pulse after such conditioning will turn on portion *r* of the second element. Both portions *r*, of the first and second elements, will remain on. In such manner, the portions *r* of the six elements will be turned on successively. When portion *r* of the sixth element is on, it conditions the non-corresponding portion (L) of the first element to be turned on by the next advancing pulse. Portion L of the first element upon being turned on will turn off portion *r* of the same element and will condition the portion L of the second element to be turned on. The L portions will be turned on in this way successively, coincidentally turning off companion elements *r* until the L portion of the sixth element has been turned on. This L portion conditions portion *r* of the first element to be turned on, and the next pulse will start a repeat cycle of the commutator.

Fig. 8a shows such a commutator circuit having six elements, designated D4—12, D3—9, D2—8, etc. Assume portion *r* of element D4—12 to be on and the other element portions *r* to be off and further, that switch 218 is in the position shown, and that pulses are being applied to resistance 173 of the character indicated in Fig. 9, line *d*.

The screen of pentode 170b of each portion *r* of elements D3—9 to D11—5 is connected, via a current limiting resistor 216b, to the midpoint of the resistor 161b of the preceding element. The screen of pentode 170b of element D4—12, however, is connected via a resistor 216a to the midpoint of resistor 161a of the sixth element D11—5, which may be considered as preceding the first element. The screen of pentode 170a of each of elements D3—9 to D11—5 is connected via a resistor 216a to the midpoint of resistor 161a of the preceding element. The screen of pentode 170a of element D4—12 is connected, however, via a resistor 216b to the midpoint of resistor 161b of of element D11—5. When portion *r* of an elementis on, the potential of the midpoint of the resistor 161b of the element is high. When portion L of the element is on, the potential at the midpoint of resistor 161a of the element is high. Thus, the screen potential of pentode 170b of each of elements D3—9 to D11—5 will be high when the portion *r* of the preceding element is on, while the screen potential of pentode 170b of element D4—12 will be high when portion L of element D11—5 is on. Similarly, pentodes 170a of elements D3—9 to D11—5 will have high or low screen voltage according to whether the preceding element portions L are on or off, while pentode 170a of element D4—12 will have high or low screen voltage depending on whether portion *r* of element D11—5 is on or off. The grids of the pentodes of elements D4—12 to D11—5 are connected to a common line 217 which taps resistor 173, terminating at line 131. The cathodes of these pentodes are connected to line 136. Hence, the normal grid bias of each of pentodes 170a and 170b is the potential difference between lines 131 and 136. At such normal grid bias of a pentode, a rise in its screen voltage has no effect. Moreover, a reduction in grid bias of the pentode has no effect while the screen voltage is low. The screen voltage must be high and, in addition, the grid bias reduced to render a pentode conductive. When a pentode is made conductive, it shifts the related portion to on status, as explained in Section 8. The grid bias is reduced by application of an advancing pulse thereto. Such pulses are taken off resistor 173 and applied to the grids of the pentodes of all the elements simultaneously via wire 217. Only the pentode at high screen voltage will be made conductive by the application of the pulse to its grid. The manner in which the advancing pulses are produced is described later on in this section of the specification.

This modification operates on a twelve-point cycle basis, a fact which follows from the utilization of the commutator described above, having six elements, each with two cross-tied element portions. It will be assumed that at the beginning, "D" or "12" point, of a cycle, the right hand portion *r* of element D4—12 is on and all other portions *r* are off. The cycle (Fig. 9) may be considered arbitrarily as at the "D" point when portion *r* of the first element begins to be turned on. In the manner explained above, portion *r* of element D3—9 is now conditioned to be switched on. The first effective advancing pulse (line *d*, Fig. 9) occurs at "9" of the cycle and, therefore, conditioned portion *r* of element D3—9 is turned on substantially at "9." Similarly, portions *r* of elements D2—8, D1—7, D0—6, and D11—5 will be turned on by advancing pulses produced at successive cycle points 8, 7, 6, and 5. Since portion *r* of element D11—5 is turned on, it conditions portion L of element D4—12 to be turned on by the next pulse, as is clear from the previous description. Accordingly, the advancing pulse at "4" turns on portion L of D4—12, coincidentally turning off portion *r*. Similarly, portions L of elements D3—9, D2—8, D1—7, D0—6, and D11—5 will be turned on successively at cycle points 3, 2, 1, 0, and 11 (see Fig. 9) and the companion portions *r* turned off. When portion L of element D11—5 is turned on, it conditions portion *r* of element D4—12 to be turned on. The next pulse at the "D" point will turn on portion *r* of the element D4—12, thus initiating a new cycle.

At any point of the cycle when advancing pulses cease to be applied, the element portions will remain in the states they assumed before pulse application was interrupted. The circuit is so devised that when a pulse turns an element portion on, rise in potential of the midpoint of resistor 161*a* or 161*b* of the element is exponential; that is, does not take place instantaneously. Accordingly, voltage of the connected screen of the pentode of the next element does not rise to required high value while an effective portion of the same advancing pulse is being applied. Thus, each advancing pulse may turn on only those portions conditioned for such action previous to the application of the pulse. Further explanation of this phenomenon will be found in my copending application, Serial No. 394,383 which has matured into Patent No. 2,402,989.

It has now been shown that as long as advancing pulses are applied to the commutator circuit the element portions D4—12*r*, D3—9*r*, . . . D11—5*r*, D4—12L, etc., are tripped on (and off) sequentially. There have also been explained circuits which interrelate the various element portions and provide for positive sequential operations, and it should be clear that the turning on (or off) of an element portion is not dependent upon inductive or capacitative coupling. It has been shown that a given element portion cannot be switched on until its predecessor element portion is on. With this circuit arrangement step-by-step progression from one element portion to the next is positive in character. This electronic commutator is utilized in this invention as a means for producing sequentially timed control and entry pulses, both of said functions being described in detail later in this section.

As described above, the commutator is operated by positive pulses (Fig. 9, line *d*) which appear on resistance 173 (Fig. 8*a*) and are transmitted therefrom by wire 217. Such transmission of pulses by line 217 occurs only while switch 218 is in the position shown. When switch 218 is in reverse position, it connects wire 217 directly to line 131, shunting out the portion of the resistance extending from the tap point of wire 217 to the line 131. Accordingly, with switch 218 in said reverse position, wire 217 is at the potential of line 131 and is not effective to transmit pulses to the commutator. In the absence of such pulses on the control grids of pentodes 170*a* and 170*b* of the commutator, the pentodes are at cut-off. Thus, by shifting switch 218 to a position reverse to the shown position, the operation of the commutator is interrupted. Conversely, to place the commutator in operation, switch 218 is set to the position shown.

In this modification, an oscillator WW (Fig. 8*a*) of the same structure as oscillator W (Fig. 6*a*) of the record controlled machine is employed for generating square-topped wave forms which are converted into steep pulses. To aid in identifying the character and function of portions of oscillator WW without further explanation, such portions are given the same reference characters as corresponding portions of oscillator W (Fig. 6*a*). Fig. 9, line *a* diagrammatically illustrates the voltages (with respect to line 131) which are produced on the lower end 143*a* of resistance 140*a* of oscillator WW (Fig. 8*a*) and Fig. 9, line *b* illustrates the voltages (with respect to 131) which are produced on the lower end 143*b* of resistance 140*b* (Fig. 8*a*). It is seen that these voltages are square-topped in form and occur twelve times per machine cycle, the respective voltages being 180 degrees out of phase.

A fall in potential of point 143*b* causes a discharge of condenser 219 and reverse current to flow through resistance 220. By suitably choosing the value of condenser 219 and resistor 220 so that its discharge time is relatively short, the drop in potential of point 143*b* produces a negative pulse of extremely short duration having a steep-wave front on resistance 220. A rise in the potential of point 143*b* causes charging of condenser 219 and circuit flow through resistance 220 to line 131. Such current flow is in the form of a steep positive pulse. Since the fall and rise in potential of point 143*b* is continually recurring, negative and positive pulses are continually produced on resistance 220 of the form shown in Fig. 9, line *c*.

The grid of a triode 221 is connected to resistance 220 (Fig. 8*a*). Resistance 220 and the cathode of triode 221 terminate at line 131. With this circuit arrangement, the normal bias of triode 221 is zero, and the current flow through triode 221 is unaffected by positive pulses appearing on resistance 220. A negative pulse on resistance 220, however, increases the grid bias of triode 221, decreasing the current flow through the triode and through its load resistance 222. A condenser 174 couples point 223 of resistance 222 to resistance 173. Since switch 218 now is in the position shown resistance 173 is completely in circuit. Accordingly, a reduction in current flow through resistor **222** and triode **221** causes point **223** to rise in potential with respect to line **131**, thereby producing on resistance **173** an advancing pulse of the form shown in Fig. 9, line *d*. Such pulse is effective to advance the commutator one step in the manner described before.

As has been mentioned previously in this section, the commutator is utilized as a means for producing sequentially timed entry and control pulses. The manner in which this is effected is now described. Fig. 9, part *e* indicates that substantially square-topped waves are sequentially produced at points **165***b* and **165***a* (Fig. 8*a*) of the several element portions. For entry and control purposes, these square-topped waves are converted into pulses having a sharp wave-front of short duration. Each pulse has a definite differentially timed relationship within a machine cycle.

For instance, a rise in potential of point **165***b* of element D4—**12***r* determines the "12" or "D" point of the cycle (see part *e* of Fig. 9), and is effective via wire **223(12)** to cause charging of condenser **224(12)** and current flow through resistance **12**R, connected at one end to the condenser and at the other end to line **131**. The R. C. product of the resistance **12**R and of condenser **224(12)** is so small that this current flow through resistance **12**R is in the form of a sharp positive pulse, occurring at "12."

A fall in potential of point **165***b* of element D4—**12***r* occurs at "4" (Fig. 9, part *e*) and causes discharge of condenser **224(12)** and reverse current flow through resistance **12**R. This current flow is in the form of a sharp negative pulse occurring at "4" in the cycle.

In a similar manner, as the potentials of points **165***b* of the other elements D3—**9**, D2—**8**, D1—**7**, D0—**6**, and D11—**5** rise, there are produced positive pulses on resistances 9R, 8R, 7R, 6R, and 5R at cycle points 9, 8, 7, 6, and 5, respectively. On the other hand, as the potentials of points **165***b* of these elements fall, negative pulses are produced on resistances 9R to 5R at cycle points 3, 2, 1, 0, and 11. Wire **223(9)** is connected not only to condenser **224(9)** but also to a condenser **224(9***a***)** which is in series with a resistance **9**RR terminating at line **131**. Thus, positive and negative pulses having timing similar to those produced on resistance 9R are also produced on resistance 9RR. The successive rises in potential of the points **165***a* of the six elements D4—**12**, D3—**9**, D2—**8**, D1—**7**, D0—**6**, and D11—**5** produce successive positive pulses on resistance **4**R, 3R, 2R, 1R, 0R, and **11**R at cycle points 4, 3, 2, 1, 0, and 11, respectively. The successive decreases in potential of these points **165***a* produce successive negative pulses on resistances 4R to 11R at cycle points 12, 9, 8, 7, 6, and 5, respectively. Wire **223 (4)** also is connected to condenser 224(4*a*) which is in series with a resistance **4**RR which terminates at **131**. Accordingly, positive and negative pulses having timing similar to those produced on resistance **4**R are also produced on resistance **4**RR.

The pulses thus produced on resistors 9R . . . 0R, 11R are shown by full lines in Fig. 9.

As explained above, both negative and positive pulses are produced on the resistances **12**R, 9R . . . 11R. The negative pulse appearing at "D" on resistor 4RR is used to reset the denominational comparing elements of the comparing means, as will be described in subsequent Section 10.

The positive "11" pulse on resistor **11**R is effective to control operation of the common comparing element; i. e., the element which manifests a combined comparison condition for all the denominations. This, too, will be explained in Section 10.

The positive "D" pulse on resistance **12**R is effective to initiate and terminate operation of a single entry cycle limiting means; namely an element **K2** (Fig. 8*a*), in a manner described in Section 10.

Element **K2** is brought into action under control of a related element **K1**, operation of which is manually initiated, as will be described in Section 10. The positive "9" pulse appearing on resistor **9RR** is used to terminate operation of this initiating element **K1** (Section 10).

Only the positive pulses appearing on resistances **9**R, **8**R . . . **5**R, **4**R . . . **0**R are utilized, and the effect of the negative pulses is eliminated. The positive pulses appearing on resistors 9R to 0R are converted into negative entry transmitting pulses by electronic means which are under additional control of the single entry cycle limiting element **K2** (Fig. 8*a*). The electronic means referred to are shown in Fig. 8*a* and comprise ten pentodes **226(9)** to **226(0)**, each having its anode connected to line **130** by one of the related load resistors **227(9)** to **227(0)**. From points 232(9) to 232(0) of these load resistors the negative entry transmitting pulses are derived. The pentodes have their cathodes connected to line **136**. The screens of these tubes are connected to a common wire **228** which terminates at a point between resistances **229** and **230**, comprising a voltage divider between lines **130** and **131**. The drop in potential across resistance 230 exceeds the drop between lines **131** and **136**. Hence, the screen potentials are kept constantly positive with respect to the cathode potential. The suppressor grids (suppressors) of the pentodes are connected via a common wire **231** to point **166***b* of element K2. When this element is off, point **166***b* is negative with respect to line **136**. Hence, the suppressor potentials, when element K2 is off, are negative with respect to the cathode potentials. The pentodes **226** are of the type which are at cut-off when either the suppressor or the control grid potential is negative with respect to cathode potential. The grid of each pentode taps a separate one of the resistances **9**R to 0R which terminate at line **131**. Normally, therefore, the grid potential is below the cathode potential and the tubes are at shut-off. The tubes are also at shut-off when the suppressor potential is negative with respect to the cathode potential. Only when both the suppressor potential and the grid potential are concurrently high will the pentode be rendered conductive. Thus, to prepare a pentode for a conductive condition, element K2 must first be placed on so that the suppressor potentials will be increased. Thereafter, during a cycle, as positive pulses appear at successive cycle points "9," "8" . . . "0" on resistances **9**R, **8**R . . . **0**R and reduce the grid bias of the pentodes, one pentode at each cycle point, the pentodes become successively conductive. Since a negative pulse on any one of the said resistances will merely increase the grid bias of the related pentode, the latter will remain at shut-off. Thus, only positive pulses on the resistances render the pentodes conductive when their suppressor potentials have been raised by the on condition of element **K2**, and the effect of the negative pulses is eliminated.

As a pentode **226(9)** to **226(0)** becomes conductive, a surge of current flows therethrough and through the connected load resistor **227(9)** to **227(0)**. Accordingly, the potential of point **232(9)** to **232(0)** drops sharply and a negative pulse appears thereat. The timing of these negative pulses is the same as the timing of the causative positive pulses appearing on resistors **9R** to **0R**, and such negative pulses are indicated in Fig. 9 by dotted lines adjacent the full lines denoting the positive pulses on the resistors 9R to **0R**.

The foregoing has described a continuously operating electronic commutator which produces pulses grouped in separate cycles, each pulse of a group having a differentially timed sequence in a cycle.

The data comparing device will now be described.

10. *Comparing device—modification*

To place the comparing device in operation, the operator closes a switch (not shown) to supply a voltage to lines **130** and **131** (Fig. 8*a*). Since the oscillator WW (Fig. 8*a*) is thereby brought into operation, the operator may now open switch **218** (Fig. 8*a*) to place the electronic commutator in operation. Certain conditioning operations are next performed, which will be explained in subsequent Section 11, and as a result of which all the elements are adjusted to a starting status.

Two amounts to be compared are entered in electrical amount representing devices F and G (Fig. 8*b*). Essentially, these devices are required to provide differential, electrical value representations of amounts. Such value representations are in the form of a set of contacts, one set for each denominational order, and each contact in each set corresponding to a different digital value. Such amount representing device may be of the kind set under control of a keyboard as in my copending application, Serial No. 314,767 or may be of the readout commutator kind. The readout commutator is usually associated with a value register or accumulator which may be operated in a known manner. For purposes of the present invention, the readout commutator may be considered as of the kind in which each order may be set individually by the operator, as disclosed in Patent No. 2,113,229 to J. W. Bryce. Fig. 8*b* diagrammatically shows such readout commutators as the amount representing devices F and G. For illustration, each device is shown with three orders, hundreds (*h*), tens (*t*), and units (*u*). Each order has ten contact segments **250** corresponding to values 0 to 9. There is a common segment **251** for each order and a commutator brush **252** which is settable to bridge any desired one of the value segments **250** and the common segment **251**. It may be mentioned that the operator can set the devices F and G to desired amounts before the switch **218** (Fig. 8*a*) is thrown to the position shown to initiate electronic commutator operation or after the switch **218** is in the position shown but before a comparing cycle is initated by throwing a switch **236** (Fig. 8*a*) to a position reverse to the position shown.

The switch **236**, when in the position shown in Fig. 8*a*, is connected to a point between resistances **234** and **235** which form a voltage divider across lines **130** and **131**. The switch blade is connected to one side of a condenser **237** whose opposite side is wired to line **131**. With switch

236 in the shown position, the condenser **237** is charged to the potential across resistor **235**. After the electronic commutator has been brought into action and after desired amounts have been entered in the devices F and G, the operator reverses the position of switch **236** to initiate a comparing operation. Condenser **237** thereupon discharges through the resistor **162***b* of element **K1**, raising the potential of its point **166***b*. Element **K1** and element **K2** comprise a single cycle control device. Element **K2** is of the same type as the element shown in Fig. 5. Element **K1** combines features of the circuits shown in Figs. 4 and 5; that is, its right hand portion *r* contains a triode **164***b* and its left hand portion L contains a triode-pentode tube. The right hand portion contains only a triode because preconditioning is not required in order to turn on element **K1**. The element **K1** is to be turned off only after element **K2** has been turned on. Accordingly, preconditioning is required to prepare the element **K1** to be turned off and, therefore, the triode-pentode is used in the left hand portion of element **K1**. When switch **236** is reversed from the position shown in Fig. 8*a*, condenser **237** discharges through resistor **162***b* of element **K1**, raising the potential of its point **166***b*. The increased potential at point **166***b* of element **K1** acts on the grid of triode **164***b* of this element, as a result of which the triode starts to conduct and a negative pulse is transmitted through condenser **163***a* of element **K1** to triode **164***a* of the element. Accordingly, in the manner fully described in Section 4, element **K1** is triggered to on status; i. e., to the status where its point **165***b* (also point **169***b*) stays at relatively high potential. Subsequently, as will be fully described later, element **K2** is turned on and increases the screen potential of pentode **170***a* of element **K1**. Thereafter, a pulse appearing on resistor **9RR** is fed to the grid of this pentode and in the manner fully described in Section 8, causes element **K1** to be turned off. The shift to on status of element **K1** which occurs when switch **236** is reversed from shown position may occur at any chance time depending on when the operator chooses to reverse the position of switch **236**. As illustrative, the element **K1** is assumed to be switched on shortly after "4" of cycle I (Fig. 9). The screen of pentode **170***b* of element **K2** is connected to the midpoint of resistor **161***b* of element **K1**. Since, with element **K1** on, the midpoint of its resistor **161***b* is at high potential, the screen of tube **170***b* of element **K2** now is at high potential. A reduction in the grid bias of the pentode will now be effective to render the pentode conductive. Such grid bias reduction occurs at "D" following the shift of element **K1** to on status and is effected by a positive pulse appearing at "D" on resistance **12R** which is tapped by the grid of the pentode (see Figs. 8*a* and 9). When tube **170***b* of element **K2** is thus tripped to a conductive condition, it causes the element to shift to on status, in a manner previously described (Section 8). Cycle II (Fig. 9), starting with the shift of element **K2** to on status, may be referred to as the comparing cycle.

The element **K2** is in on status and, hence, the suppressor grids of tubes **226(9)** to **226(0)** are at high potential, conditioning these tubes to be rendered conductive upon reduction of grid bias. The electronic commutator has been placed in operation and positive pulses are being produced on resistances **9R** to **0R** at the times indicated in Fig. 9. In the manner previously explained, the application of these positive pulses to the tubes while the suppressor potentials are high causes the tubes to become conductive, each tube becoming momentarily conductive as the positive pulse is applied thereto. As each tube becomes conductive, the potential across the related load resistor 227 increases and a negative pulse appears at its point 232. Points 232(9) to 232(0) are connected by wires 223(9) to 223(0) with the rows of value segments 250(9) to 250(0) of both amount representing devices F and G (Fig. 8b). Accordingly, negative pulses are impressed on the value segments 9 to 0 of each device at the differential times of the comparing cycle corresponding to the values of the segments. Such negative pulses on points 232(9) to 232(0) and on the value segments are indicated in Fig. 9 as dotted lines in relation to the timing lines of the causative positive pulses produced on resistances 9R to 0R.

The value segments 250 are the inputs of the devices F and G. The outputs of these devices are the common segments 251. The value for which an order of either device has been set selects the time at which the output of this order to receive a negative pulse. This is because only that negative pulse which is impressed on the value segment connected by brush 252 to the common segment 251 will be passed through by the brush to the common segment. Thus, the outputs of the devices F and G will be negatively pulsed at differential times of the comparing cycle selected by the amount settings of the devices.

Common segment 251(*h*) of device F is connected to line 136 by a wire 238(*h*), condenser F1(*h*) and resistor F2(*h*). Similarly, common segments 251(*t*) and 251(*u*) of device F are connected via wires 238(*t*) and 238(*u*) to condensers F1(*t*) and F1(*u*) which lead through resistors F2(*t*) and F2(*u*) to line 136. Common segment 251(*h*) of device G is connected to line 136 via a wire 239(*h*), condenser G1(*h*) and resistor G2(*h*). Likewise, wires 239(*t*) and 239(*u*) and condensers G1(*t*) and G1(*u*) and resistors G2(*t*) and G2(*u*), respectively connect the common segments 251(*t*) and 251(*u*) of device G to line 136. The resistances G2(*h*), G2(*t*), and G2(*u*) are tapped by the grids of triodes G3(*h*), G3(*t*), and G3(u), respectively. Resistances F2(*h*), F2(*t*), and F2(*u*) are tapped by the grids of triodes F3(*h*), F3(*t*), and F3(*u*), respectively. Since the several resistances F2 and G2 terminate at line 136, as do also the cathodes of triodes F3 and G3, the normal grid bias of these triodes is zero, and the triodes are normally conductive. The pair of tubes associated with the corresponding orders of devices F and G are connected, in parallel with each other, to a common load resistor 202. The load resistor of each order is connected by a condenser 167*b* and resistor 168*b* (also see Fig. 4) to point 166*b* of a comparison manifesting element E for the order. When both triodes G3 and F3 of corresponding orders are conductive, there is a maximum drop of voltage across the connected load resistor 202. When only one latter triode is conductive, the potential at the lower terminus of the load resistor rises to a certain extent and a positive pulse is applied via resistor 168*b* and condenser 167*b* to the point 166*b* of the related E element. Such pulse, however, is not of sufficient amplitude to shift element E to on status. When both triodes F3 and G3 of corresponding orders are shut off, the voltage across the connected load resistor 202 decreases to a greater degree, causing condenser 167*b* to apply a positive pulse at the instant both triodes are shut off, to point 166*b* of the related element E, which pulse is of sufficient amplitude to shift the element to on status. Both triodes F3 and G3 of corresponding orders of devices F and G will be shut off only when the values registered by these orders are equal. When all the orders of the devices F and G contain equal values, all the elements E(*h*), E(*t*), and E(*u*) will be shifted to on status, affording a manifestation of the fact that the amounts set in their devices are equal.

As an example, assume each of devices F and G has been set to the amount 274. Accordingly, at "2" of cycle II (Fig. 9), a negative pulse impressed on segment 250—2 of the hundreds order of device F will be passed through to common segment 251(*h*) of the device. The negative pulse will be transmitted therefrom via wire 238(*h*) and condenser F1(*h*) and resistance F2(*h*) to the grid of triode F3(*h*). The grid bias of this triode will increase and the tube will be shut off at "2" of cycle II. At the same time, a negative pulse has been passed through value segment 2 in the hundreds order of device G to the common segment of this order. The pulse is applied via wire 239(*h*), condenser G1(*h*) and resistance G2(*h*) to the grid of triode G3(*h*), shutting of this tube at "2" of cycle II. With both triodes F3(*h*) and G3(*h*) concurrently shut off at "2" (cycle II), the voltage drop across load resistor 202(*h*) decreases materially, and a positive pulse is applied via connected condenser 167*b* and resistance 168*b* to point 166*b* of element E(*h*). The element E(*h*) thereby is turned on at "2" of cycle II (see Fig. 9).

In a similar manner, element E(*t*) is switched on at "7" and element E(*u*) at "4" of cycle II (see Fig. 9).

Each of the elements E(*h*), E(*t*), and E(*u*) has its point 166*a* connected to the grid of an associated one of the tubes 203(*h*), 203(*t*), and 203(*u*). The cathode of each tube connects to line 136 and the anodes of the tubes are connected to a common load resistance 204. When element E*h*, E*t*, or E*u* is turned on, the potential of its point 166*a* drops, increasing the grid bias of the associated tube 203, thereby reducing current flow through the tube to the point of virtual cut-off. The screen of a tube 205 is connected to point 206 of resistance 204. The grid of this tube is connected to the resistance 11R which provides a positive pulse at "11." Such pulse decreases the grid bias of the tube 205 at "11." If the screen potential of this tube is low, the reduction in grid bias is ineffective to cause current flow through the tube. Only when the screen potential of the tube is high does the reduction in its grid bias at "11" render the tube sufficiently conductive. The screen potential of tube 205 is the potential of point 206 of load resistor 204. When any one or more of tubes 203(*h*), 203(*t*), or 203(*u*) is conducting current, the voltage drop across load resistor 204 is high and the potential of point 206 is not appreciably higher than that of line 136. Under this condition, the tube 205 will not become conductive when its grid bias is reduced at "11" of the cycle. When all the tubes 203 are shut off, the current flow through common load resistor 204 is negligible and point 206 is at high potential. The potential of the screen of tube 205 is then high enough to cause the tube to become conductive when its grid bias is reduced at "11" by the positive pulse appearing on resistance 11R. All the tubes **203**(*u*), **203**(*t*), and **203**(*h*) will be shut off only when all the elements E(*u*), E(*t*), and E(*u*) are on. The digital positions of devices F and G are all sensed by the comparing tubes F3 and G3 before the "11" time of a comparing cycle, and when an equality condition is ascertained to exist, then all the elements E will be on before "11." In the assumed example, the amounts in devices F and G are equal; hence, all the elements E are on before "11" (cycle II). Accordingly, all the tubes **203** are shut off, and the screen potential of tube **205** is high. When the grid bias of this tube is decreased at "11" (cycle II), the tube becomes conductive.

The anode of tube **205** is connected to line **130** via resistor **160***a* of element E*x*. Thus, current flow through the tube at "11" (cycle II) produces a sharp negative pulsation at point **165***a* of resistance **160***a*. In the manner described before, this causes element E*x* to switch on. With point **165***a* of element E*x* now at low potential, there is sufficient voltage difference across neon lamp **212***a* to ignite the lamp, thus visibly manifesting the quality condition.

If the amounts on devices F and G do not agree, at least one of the E order elements will remain off. Correspondingly, at least one of the tubes **203** will remain conductive, and the point **206** of common load resistance will be at low potential, and the screen of tube **205** also will be at low potential. Accordingly, the grid bias reduction of this tube **205** will be ineffective, and the tube will remain shut off, element E*x* will not be turned on, and lamp **212***a* will not be lit. With element E*x* off, its point **165***b* is at low potential and neon lamp **212***b* is ignited. When lamp **212***b* is lit after a comparing cycle has been initiated, it visibly manifests non-agreement of data standing on devices F and G.

It will be recalled that element **K1** was switched on before the comparing cycle began, and that the comparing cycle began with the switching on of element **K2**, under control of element **K1** and a pulse on resistor **12R** at "D." Element **K1** may be turned off after element **K2** has been turned on. For this purpose, the midpoint of resistor **161***b* of element **K2** is connected to the screen of tube **170***a* of element **K1**. The grid of this tube is connected to resistance 9RR on which a positive pulse appears at "9" to reduce the grid bias. With element **K2** on, the midpoint of its resistor **161***b* and, hence the screen voltage of tube **170***a* of element **K1**, is high. The subsequent grid bias reduction of this tube, at "9" of the comparing cycle, renders the tube conductive, causing element **K1** to return to off state. As soon as element **K1** returns to off state, it, in turn, conditions element **K2** to be switched off. Such conditioning is brought about by the connection between the midpoint of resistance **161***a* of **K1** and the screen of tube **170***a* of **K2**. When **K1** is off, the midpoint of its resistor **161***a* is at high potential and the screen of the latter tube **170***a* also is at high potential. The grid of this tube is connected to resistance **12R**. When the positive pulse appears at "D" at the end of the comparing cycle on resistance **12R**, it reduces the grid bias of tube **170***a* of element **K2**. The screen potential of this tube was increased since "9" of the comparing cycle, when element **K1** was turned off. Hence, with high screen potential and reduced grid bias at "D" at the end of the comparing cycle, tube **170***a* of element **K2** is rendered conductive, causing the element to switch to off state.

It is seen from the above that elements **K1** and **K2** are interrelated to provide a single entry cycle limiting means, affording only a single comparing cycle for each reversal of switch **236** (Fig. 8*a*) from the position shown. During this single comparing cycle, element **K2** will enable the amounts on devices F and G to be entered only once in the comparing means.

Provision is made to switch off automatically, at the end of a comparing cycle, any of the elements E(*h*), E(*t*), and E(*u*) which may have been placed in on condition during the comparing cycle. For this purpose, resistance **4RR** is connected to the grid of a tube **242** (Fig. 8*b*). Both this resistance and the cathode of tube **242** connect to line **136**, so that the normal grid bias of the tube is zero, and the tube is normally conductive. The anode of tube **242** is connected to line **130** through a load resistor **243**. The lower end of the resistor **243** is connected to a wire **260** which is coupled by condensers **167***aa* and resistors **168***aa* to the points **166***a* of the elements E(*h*), E(*t*), and E(*u*). A negative pulse on resistance **4RR** appears at "D" (see Fig. 9) and increases the bias of tube **242**, decreasing current flow therethrough and through its load resistor **243**. Accordingly, a positive pulse is applied via wire **260** and condensers **167***aa* and resistors **168***aa* to points **166***a* of the elements E. Such pulse is effective, in the manner described before, to turn off any of the denominational elements E which may have been switched on during the comparing cycle.

Following determination of the agreement or non-agreement of data standing on the amount representing devices F and G, and prior to making a new data comparison, element E*x*, if on, must be switched off. This is done by the following means. A voltage divider comprising resistances **244** and **245** is connected between lines **130** and **131** (see Fig. 8*b*). One pole of a hand switch **246** is connected to a point intermediate these resistances. The blade of the switch is connected to line **131** by a condenser **247**. With this arrangement, when switch **246** is in shown position, condenser **247** is charged to the voltage across resistance **245**. After a comparing operation has been completed, the operator throws switch **246** to reverse position, causing the condenser **247** to discharge a positive pulse which is applied to point **166***a* of element E*x*. Such pulse turns off element E*x*, if the element had been turned on during the comparing cycle.

Having described the operation of the comparing device when equal and unequal amounts are set up in the amount receiving devices, an explanation is now given of the conditioning operations which are required upon starting up the machine.

11. *Conditioning*

When the operator closes a main switch (not shown) to supply a voltage to lines **130** and **131** (Figs. 8*a* and 8*b*), elements E(*h*), E(*t*), E(*u*), E*x*, **K1**, **K2**, D4—**12**, D3—**9**, etc., assume either an on or an off status which is governed solely by chance. Thereupon the operator opens switch **218**, which should be in reverse position from that shown up to this time. The opening of the switch **218** permits advancing pulses to be applied, via wire **217**, to the commutator elements. Regardless of the chance status which the elements assumed when the main line switch was closed, the circuit relationship and organization of the elements are such that the element portions will be compelled by advancing pulses to assume the orderly cyclical status shown in Fig. 9. The number of pulses so required depends on the initial chance status of the elements. Assume, for instance, that the initial chance status of the elements is as follows, on portions only being noted:

D4-12	D3-9	D2-8	D1-7	D0-6	D11-5
r	L	r	L	L	L

The next four pulses will cause the status of the elements to shift as follows:

	D4-12	D3-9	D2-8	D1-7	D0-6	D11-5
1	r	r	L	r	L	L
2	r	r	r	L	r	L
3	r	r	r	r	L	r
4	r	r	r	r	r	L

It will be noted that the fourth pulse has brought the element portions to the status they should have at "6" of a cycle (see Fig. 9). Thereafter, succeeding pulses will shift the status of the element portions in the cyclical sequence indicated in Fig. 9.

If either one of the elements K1 and K2 should chance to turn on when the main line switch is closed, such on element will automatically shift to an off status in one or two cycles in a manner described before in Section 10. This is because control pulses at "D" and "9" appear on resistances 12R and 9RR respectively. Once a pulse appears at "D" on resistance 4RR (Fig. 8b) any of the elements E*h*, E*t* and E*u* which may have been initially on, by happenstance, are automatically switched off as described previously in Section 10. The operator throws switch **246** to a reverse position from that shown in order to switch element E*x* to an off status in a manner set forth above in Section 10. Having performed the foregoing conditioning operations when starting up the machine, the operator may thereupon condition the machine to perform comparing operations on desired data.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to a preferred embodiment, and to a modification it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated and in their operation may be made by those skilled in the art, without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. An electrical system comprising circuits producing signals representative of values from different sources, means to manifest the comparative relation of the values from the different sources and including selectively conditionable electronic discharge means having alternative self-sustained electronic discharge conditions, electron discharge devices respectively varied in impedance by the signals from the different sources, and circuit means coupled to all said electron discharge devices to be commonly controlled by the devices according to variations in their impedance for selectively electronically conditioning the conditionable electronic discharge means according to matching or nonmatching relation of the values represented by the signals.

2. An electrical system comprising circuits producing signals representative of values from different sources, means selectively to manifest equal and unequal comparative relations of the values from the different sources and including an electronic trigger circuit having two alternative states of stability and shiftable in response to a tripping pulse from one state to the other, a circuit network operable to produce the tripping pulse, a plurality of electronic discharge devices respectively varied in impedance by the signals from the different sources, and a circuit commonly coupling the plurality of electronic discharge devices to said circuit network and rendered effective, in response to variations in impedance of the electronic discharge devices produced by signals representative of values having one of the aforementioned comparative relations, for rendering said network operable to produce a pulse to trip the trigger circuit to a state manifesting said one of the aforesaid comparative relations.

3. An electrical system comprising circuits producing signals representative of values from different sources, means to compare the values and including a switchable element performing a switching sequence in which it shifts from one state to a reverse state in response to one pulse and back to the first state in response to a succeeding pulse, and electrical means responsive to the signals produced by said circuits and representing values from the different sources for producing successive pulses and transmitting them along partially common paths to the switchable element to cause a switching sequence to be performed.

4. An electrical system comprising circuits producing signals representative of values from different sources, means to compare the values from the different sources and including an electronic trigger element having alternative conditions of equilibrium and shiftable from one condition to the reverse condition and back to the first condition in response to successively applied pulses, an electron discharge device varied in operation by signals from one source, another electronic discharge device varied in operation by signals from another said source, and common means controlled by said devices upon their being varied in operation for applying a pair of pulses in succession to the trigger element to shift it from and then back to said first condition.

5. An electrical system comprising circuits producing signals at differential times of a cycle and representative according to their timing of values from different sources, an electronic element having alternative self-sustained states of equilibrium and performing a switching sequence in which it shifts from one state to the other and back to the first state in response to a succession of applied pulses, means responsive to the signal circuits for controlling application of pulses to the electronic element to cause a switching sequence thereof to be completed by a predetermined point of the cycle when the values represented by the signals from the different sources are equal and to remain uncompleted at said

predetermined cycle point when the values are unequal, and means coacting with the electronic element at said predetermined cycle point to manifest the equal or unequal relation of the values selectively according to whether the switching sequence has been completed or is incomplete at said predetermined cycle point.

6. An electrical system comprising circuits producing signals at differential times of a cycle and representative according to their timing of values from different sources, electronic means having alternative self-sustained conditions of equilibrium and shiftable in condition in response to an applied pulse, means responsive to the signal circuits for generating and applying pulses to the electronic means to establish one condition thereof at any of predetermined points of the cycle when the values from the different sources are equal and to establish a different condition thereof when said values are unequal, means producing testing pulses at such predetermined points of the cycle to test for the condition of the electronic means, and means controlled by the electronic means according to its condition at a said cycle point and by the testing pulse produced at said point for manifesting equal or unequal comparative relation of the values from the different sources.

7. An electrical system comprising a circuit capable of producing a signal at any of differential times of a cycle according to a value represented on one value source, another circuit capable of producing a signal at any of differential times, off timed with respect to the first mentioned times, according to a value represented on another value source, means producing testing pulses at recurrent points of the cycle off timed with respect to the differential times at which signals may be produced by the said circuits, means converting the signals produced by each circuit to control pulses, whereby when the values on both sources agree a control pulse derived from one source, a control pulse derived from the other source, and a testing pulse follow each other in the order stated, and electronic means controlled by the pulses when produced in the stated order for manifesting agreement of values from the sources and controlled by the pulses when produced out of the stated order for manifesting disagreement of values from the sources.

8. An electrical system comprising circuits producing signals representative of multicolumn values represented on a pair of value sources, a plurality of denominational electronic elements, means controlled by the signals representative of values in corresponding columns of the sources for separately conditioning each denominational electronic element to one condition when values in corresponding columns are in matching relation and to another condition when values in corresponding columns are in non-matching relation, a common, electronic trigger element having self-sustained alternative conditions of equilibrium and shiftable from a normal state to a reverse state in response to an applied pulse, electronic discharge means conditionable to pass an applied pulse to the trigger element, and means controlled by the denominational electronic elements when in condition manifesting one said relation of values in corresponding columns for conditioning the electronic-discharge means to pass a pulse to said common element to shift it to said reverse state so as to manifest the latter relation of the values as a whole.

9. An electrical system for comparing values of different classes represented upon a plurality of value sources, and comprising circuits producing signals representative of the values, electronic class comparing organizations, each for comparing the values of one said class for equal and unequal comparative relations and including an electronic element having alternative self-sustained conditions of equilibrium and shiftable from a normal state to a reverse state in response to an applied pulse, means controlled by said signal circuits for controlling application of a pulse to the electronic element of each said organization to shift the element to said reverse state when the values of the related class have one of said comparative relations, and a circuit controlled by the element of one said organization when shifted to said reverse condition for applying a pulse to the element of another said organization for shifting it to the reverse state independently of the relation of the values of the class to which said another organization pertains.

10. An electrical system comprising circuits producing signals representative of values from different sources, an electronic trigger element having alternative states of equilibrium and composed of cross-tied tubes, one of which is conducting and the other non-conducting to determine one state of equilibrium and the conductive conditions of which are reversed to establish a reverse state of equilibrium of the element, means for applying a pulse to the element to reverse its state of equilibrium, and electrical means commonly controlled by the signals from the different sources for controlling application of such pulse to the element in accordance with the matching or non-matching comparative relation of the values from the different sources.

11. An electrical system comprising circuits producing signals representative of values from different sources, a trigger circuit having alternative self-sustained conditions of equilibrium and shiftable from one condition to a reverse condition in response to an applied pulse, means for applying a pulse to the trigger circuit to effect such reversal in condition, and an electronic tube circuit having its output commonly controlled by the signals from the different sources for controlling the application of the pulse to the trigger circuit according to matching or non-matching comparative relation of the values from the different sources.

12. An electrical system comprising circuits producing signals representative of values from different sources, a pair of electron emitting tube units, each varied in impedance by signals from a different one of the sources, an electronic trigger circuit capable of being reversed from one electrical status to a reverse status in response to a pulse applied thereto, and means commonly controlled by the pair of electron emitting tube units upon concurrent variation in impedance thereof in response to signals representing equal values for producing and applying a pulse to the trigger circuit to reverse its status.

13. An electrical system comprising a pair of electron emitting devices, means producing a succession of differentially timed pulses, a plurality of sources of value representations, circuits controlled by value representations on the plurality of sources for applying those of the pulses selected by and corresponding to the value representations to said devices, the pulses selected by representations from one source being applied to one said device and those selected by representa-

tions from another source being applied to another said device, said devices being varied in flow condition in response to the applied pulses, a common load impedance across which a desired change in potential is produced upon concurrent variation in flow condition in both devices in response to correspondingly timed pulses selected by equal value representations on the pair of sources, electronic means for manifesting the equality of the values represented on the pair of sources, and means coupled to said impedance for operating the electronic means to manifest said equality upon the occurrence of the desired change in potential across said impedance.

14. An electrical system comprising circuits producing signals at differential times of a cycle and representative according to their timing of data from different sources, an electrical trigger circuit having alternative self-sustained conditions of electrical stability and shiftable from either condition to the other in response to an applied pulse, electrical means responsive to the signal circuits for selectively pulsing the trigger circuit to establish one condition thereof at any one of given times of the cycle if the data from the different sources have a matching comparative relation and to establish the alternative condition if said data have non-matching comparative relation, means producing testing pulses at said given times of the cycle, means selectively controlled by said trigger circuit at a said given time according to its condition and by the testing pulse produced at this time for manifesting one said comparative relation of the data from the different sources.

15. In combination, an electronic trigger circuit capable of performing a switching sequence in which it is tripped by one pulse from one electrical status to a reverse status and back to the first status by a following pulse, a circuit capable of producing a signal at any of differential times of a cycle according to a value represented on one value source, another circuit capable of producing a signal at any of differential times off-timed with respect to the first mentioned times, according to a value represented on another value source, electrical means responsive to a value representing signal from one source for applying a pair of successive pulses a given interval apart to the trigger circuit and responsive to a matching value representing signal from another source for applying to the trigger circuit a pair of successive pulses staggered with respect to the pulses derived from the first mentioned signal, whereby the trigger circuit completes a switching sequence before the end of said interval if the signals match and at the end of the interval if the first mentioned signal is unmatched by a corresponding signal from the other source, and means for manifesting the relation of the signals from the different sources including means to test the status of the trigger circuit before the end of said interval.

16. In combination, an electronic trigger circuit having cross-coupled impedance networks to sustain the circuit in either of alternative states of electrical stability and arranged upon simultaneously receiving pulses of either positive or negative polarity to bring about the tripping of the circuit from either prevailing status to the alternative status, a circuit capable of producing a signal at any of differential times of a cycle according to a value represented on one value source, another circuit capable of producing a signal at any of differential times off-timed with respect to the first mentioned times, according to a value represented on another value source, electrical means responsive to a signal from one source for producing a pair of pulses of relatively opposite polarity and applying them to the trigger circuit at a given interval apart and responsive to a matching signal from another source for producing and applying to the trigger circuit a similar pair of pulses staggered with respect to the first mentioned pulses, whereby the circuit performs a switching sequence within said interval in consequence of a pair of pulses of like polarity derived from matching signals and performs a switching sequence completed at the end of said interval in consequence of a pair of pulses of opposite polarity derived from a single signal unaccompanied by a matching signal, and means for manifesting the relation of the signals including means for testing the status of the trigger circuit before the end of said interval.

17. In combination, an electronic trigger circuit to perform a switching sequence in which it trips from one electrical status to a reverse status and back to the first status in response to a pair of successive pulses, means to sense data designations on one record portion, means to sense such data designations on another record portion at times offset with respect to times at which the first mentioned designations may be sensed, electrical means controlled by each sensing means upon sensing a designation for applying a pair of pulses to the circuit an interval apart greater than the period between the sensing of corresponding designation on the two record portions, whereby the circuit completes a switching sequence in response to pulses relating to such corresponding data designations before the end of said interval but completes a switching sequence at the end of said interval in response to pulses relating to a data designation on one record portion which is unaccompanied by a corresponding data designation on the other record portion, and means for manifesting the relation of the data designations on the two portions including means for testing the status of the circuit within said interval.

18. An electrical system for concurrently comparing data of different classes represented upon a plurality of data sources, comprising circuits producing signals representative of the data, an electrical comparing organization for comparing values in each class of data for matching and non-matching comparative value relationships and including an electronic trigger circuit and electrical means controlled by signals representing data from the different sources and having a given one of said comparative relations for tripping the trigger circuit from one electrical status to a reverse electrical status, and means controlled by the trigger circuit of one class upon being tripped to said reverse status for applying a pulse to the trigger circuit of a different one of the classes to trip it to the reverse status.

19. An electrical system for concurrently comparing data of different classes represented upon a plurality of data sources, comprising circuits producing signals representative of the data, an electrical comparing organization for each class of data and including an electronic trigger cirsuit and electrical means controlled by signals representing non-agreeing data for applying a pulse to the trigger circuit to trip it from one electrical status to a reverse electrical status, and means controlled by the trigger circuit of one

class upon being tripped to the reverse status for applying a pulse to the trigger circuit of another of the classes to reverse its status.

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