

Jan. 16, 1945.

K. W. PFLEGER

2,367,522

SIGNALING SYSTEM

Filed Oct. 2, 1942

5 Sheets-Sheet 1

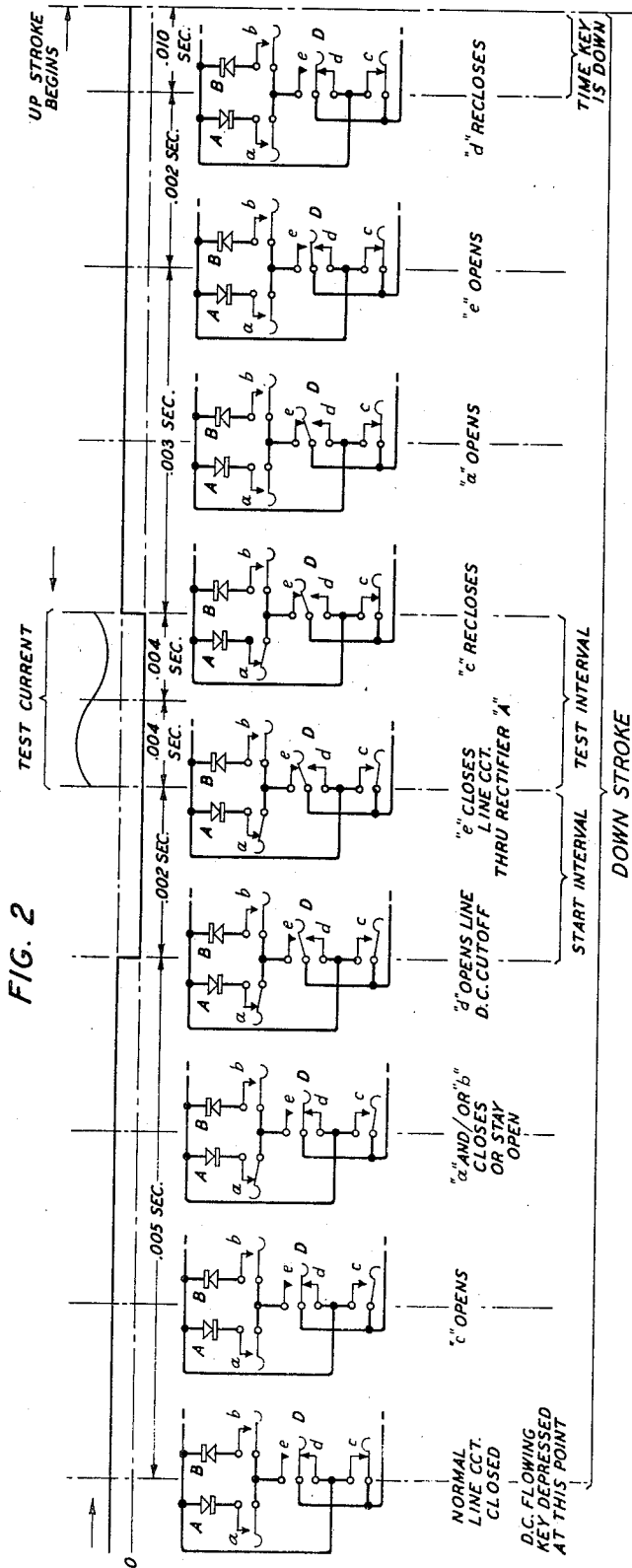


FIG. 1

FIG. 2	FIG. 3	FIG. 4	FIG. 5, or FIG. 6
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INVENTOR
K. W. PFLEGER
BY *John A. Hall*
ATTORNEY

Jan. 16, 1945.

K. W. PFLEGER

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FIG. 3

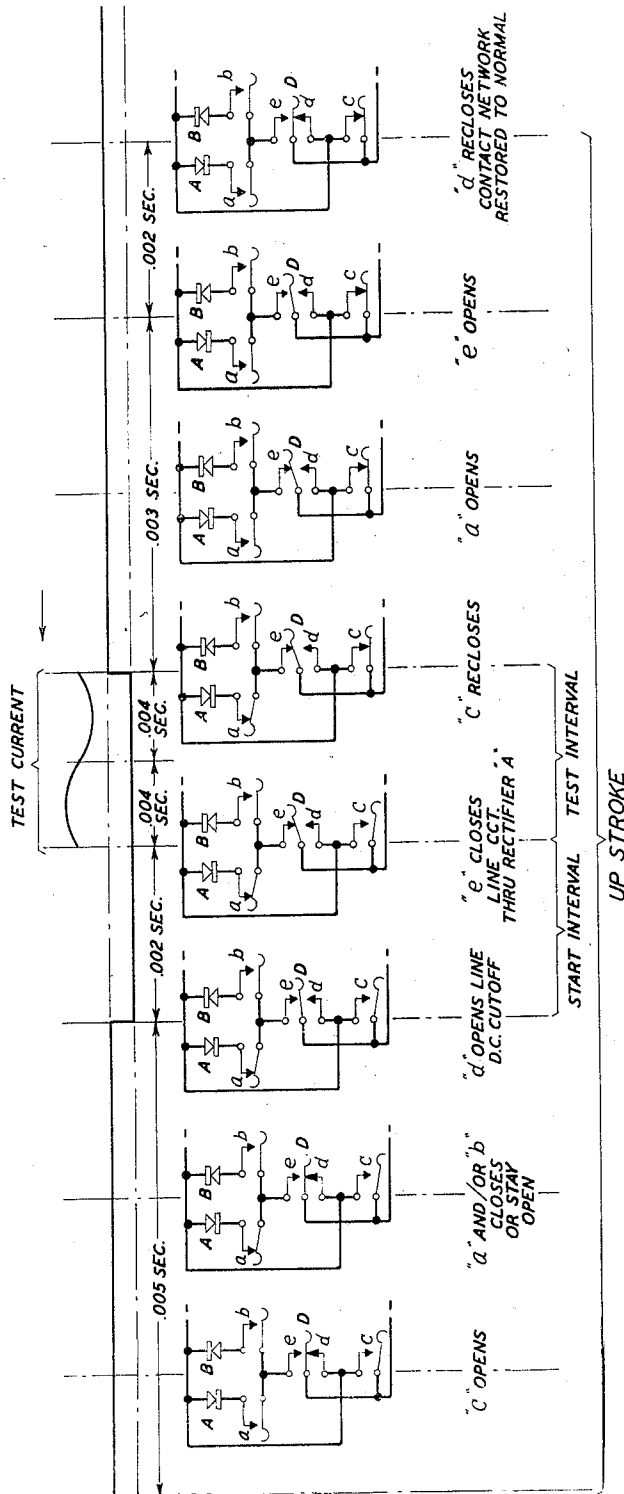
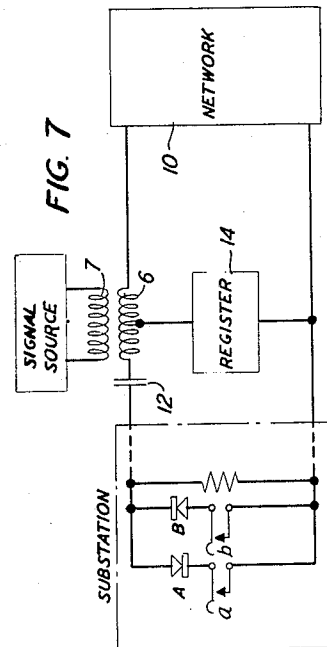


FIG. 7



INVENTOR
K. W. PFLEGER

BY

John A. Hall

ATTORNEY

Jan. 16, 1945.

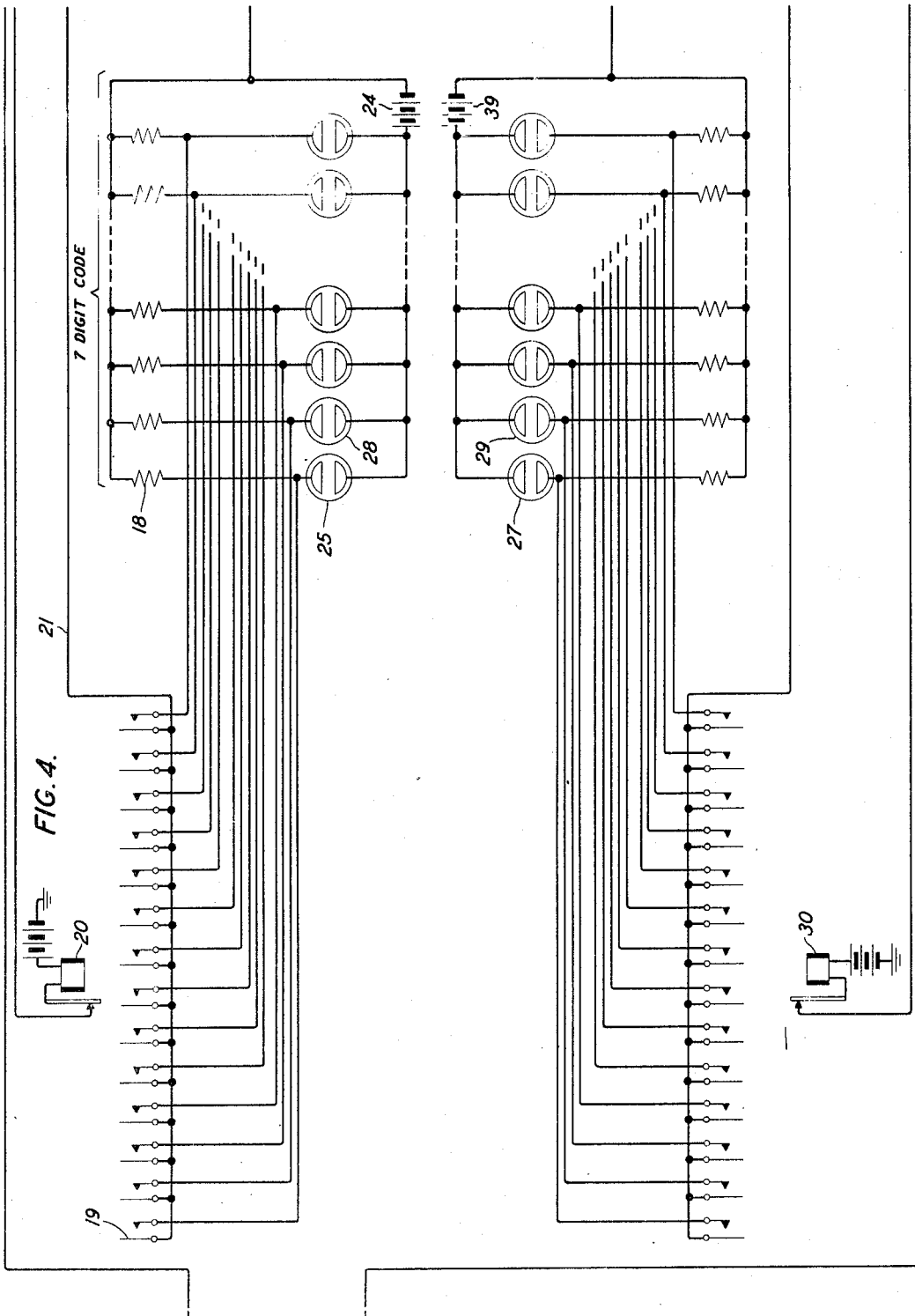
K. W. PFLEGER

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SIGNALING SYSTEM

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5 Sheets-Sheet 3



INVENTOR

K.W. PFLEGER

BY:

Sam Attall

ATTORNEY

Jan. 16, 1945.

K. W. PFLEGER

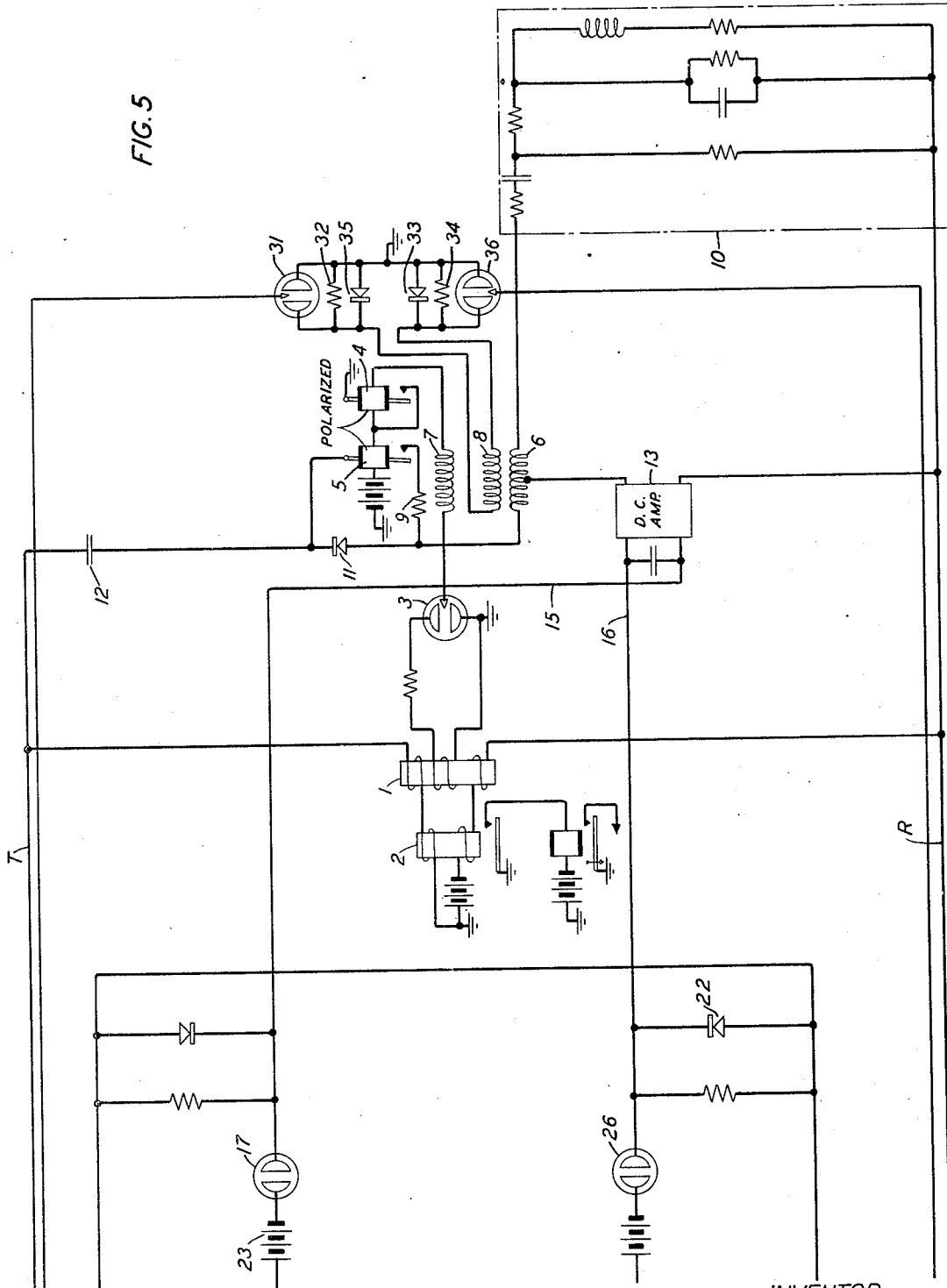
2,367,522

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FIG. 5



INVENTOR

K. W. PFLEGER

BY

John A. Hall

ATTORNEY

Jan. 16, 1945.

K. W. PFLEGER

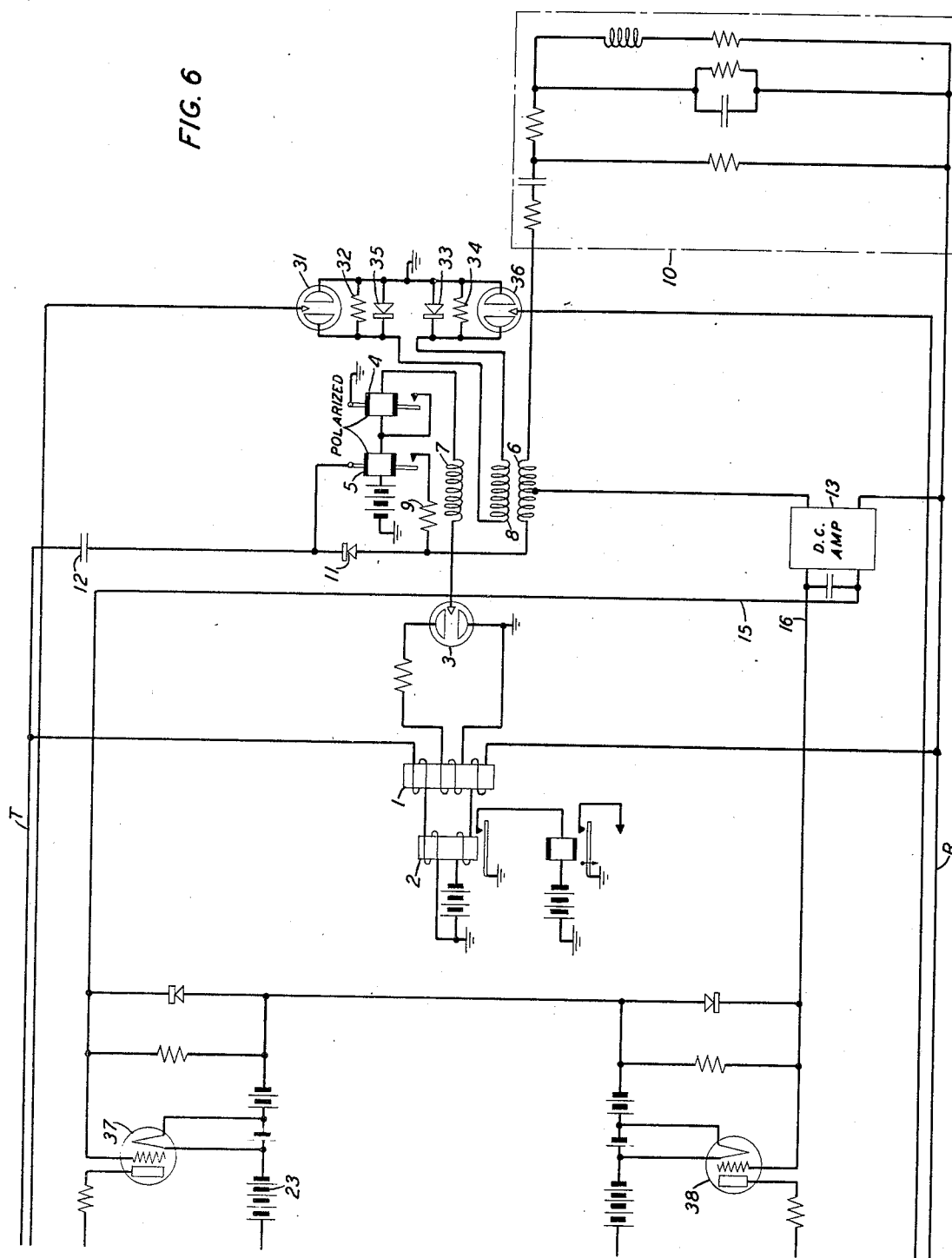
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FIG. 6



INVENTOR
K. W. PFLEGER
BY *John A. Hall*
ATTORNEY

UNITED STATES PATENT OFFICE

2,367,522

SIGNALING SYSTEM

Kenneth W. Pfeiffer, Arlington, N. J., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application October 2, 1942, Serial No. 460,521

4 Claims. (Cl. 177—353)

This invention relates to signaling systems and particularly to means for transmitting number designations by setting up differing circuit conditions at one end of a line and testing for such conditions at the other end of the line and is an improvement on the system disclosed in the application of W. P. Albert, Serial No. 449,257, filed July 1, 1942, now Patent Number 2,349,129, issued May 16, 1944.

The object of the invention is to magnify or enlarge the reaction of a test current so that the margin of error will be brought well within commercial limits. In a telephone system it is desirable to have a substation transmitter which will operate reliably under many adverse conditions so that the central office apparatus will respond correctly even where the substation lines are in bad condition or are near the limits of allowable variations in resistance, leakage and so forth. Where the difference between a full strength signal and a weak signal approaches the difference between a signal and no signal, then the central office apparatus must be very sensitive in order to correctly report the condition which is set-up at the signaling end of a line. Accordingly, the present invention provides means to magnify or increase the difference between a signal and the absence of a signal.

Where the signal is produced at the substation by inert apparatus and is tested at the central office end of the line by an impulse sent therefrom, the variation in the strength of the impulse due to the manipulation of the said inert apparatus, particularly where the line has approached the commercial limits of allowable conditions, cannot be very great. Accordingly, the principle of the hybrid coil and balancing network circuit is employed to substantially eliminate the effect of such impulse when the condition for no signal is established. A differential circuit is employed so that when the impulse is transmitted toward the substation where such no signal condition is established, the reaction at the central office will be practically nil. For this purpose a network is employed to balance such a condition so that substantially no part of the testing impulse will be diverted into a responsive circuit.

In the specific embodiment of the invention herein described, a transformer is employed hav-

ing a primary winding and a secondary winding divided into two equal sections and provided with a mid-tap. A testing impulse is applied to the primary winding and is thus reproduced in the secondary winding. One section of the secondary winding is connected to the line wherein the condition to be tested is established and the other section is connected to a network arranged to balance the line when no signal is to be sent. The mid-tap leads to a responsive device such as a register so that upon the transmission of the impulse practically no current will flow in the mid-tap circuit if the no signal condition is established. When a signal condition is established, however, a considerable current will flow into the mid-tap circuit so that the difference as viewed by the mid-tap circuit is greatly magnified over the difference produced by the simple prior art arrangements.

A feature of the invention is a hybrid coil and balancing network circuit arrangement for increasing the difference in the effect of a unidirectional current impulse transmitted to a circuit under different conditions established at the distant end of a line.

Other features will appear hereinafter.

The drawings consist of five sheets which may be combined as shown in Fig. 1. Figs. 2, 3, 4 and 5 in combination serve to explain one embodiment of the invention and Figs. 2, 3, 4 and 6 in combination show an alternative arrangement. Figs. 2 and 3 are schematic circuit diagrams showing the sequential operations of a dialing key, Fig. 2 representing the down stroke and Fig. 3 representing the return or up stroke of the key. Each of these figures consists of a plurality of circuit diagrams of the key contacts placed in order from the left to the right with an indication of the timing and the creation of a start signal sent from the substation and the test current returned from the other end of the line. Fig. 7 is a schematic circuit diagram. The remainder of the figures are circuit diagrams.

The key arrangement is such that a particular key will set up two independent circuit conditions, one on the down stroke and another on the up stroke. These circuit conditions may be alike or they may be different. The mechanical arrangement of the spring contacts may be simi-

lar to the arrangement shown and described in the application, Serial No. 444,772, filed May 28, 1942, by Bascom and Hubbard.

Each of the separate circuit diagrams of Figs. 2 and 3 shows a path through the key contacts from one line wire to another and each at the time of its consideration is to be connected to the line wires at the extreme left in Fig. 4. The first diagram of Fig. 2 is the normal condition before the key is depressed and the last is the normal condition at the extreme end of the down stroke. This diagram may also be considered the normal condition before the start of the up stroke since the subscriber may hold the key in this condition for an indefinite period. The last diagram in Fig. 3 is also a duplicate of the first diagram in Fig. 2 and represents the normal condition attained at the extreme end of the up stroke. The intermediate diagrams represent various stages in the sequential operation of the springs, and it is believed that with the help of the notations the operation will be abundantly clear.

At the top of these diagrams there is a line which represents the direct current flowing in the line circuit. This flows at a value fixed by the various circuit factors and remains at a fixed point until the fourth stage is reached when it drops to zero as the circuit is effectively opened at this point. This condition exists through the fifth stage and until the sixth stage is reached whereupon the circuit for the direct line current is again closed. During this interval a test current consisting of a single cycle of alternating current is sent from the distant end to detect the circuit condition established at the substation. Similar operations take place on the up stroke of the key.

The essential operation is to selectively connect a pair of varistors in the circuit and to then test from and record at the other end of the line which of these varistors has been introduced into the circuit. The two varistors in the circuit diagrams of Figs. 2 and 3 are marked A and B respectively. If the A varistor has been included in the circuit, then the positive impulse or the positive half wave of the single cycle of alternating current will find a path of low resistance at the substation and consequently the current flow will rise to the point where it will act as a signal. Similarly, if the B varistor is included in the circuit the negative impulse or negative half wave will find a path of low resistance at the substation and the resulting current will act as a signal. By the selective connection of these varistors the transmission of the single cycle of alternating current from the other end of the line will result in the recording of four different conditions: first, no response showing that neither varistor has been connected in the circuit; second, a positive signal showing that the A varistor has been connected in the circuit; third, a negative signal showing that the B varistor has been connected in the circuit, and fourth, both a positive and a negative signal showing that both varistors have been connected in the circuit. Since one selective connection may be made from the down stroke and a different one for the up stroke of the key, it follows that there are, theoretically, sixteen different available combinations which may be used for signals. Since that one where there is no response in either the down stroke or the up stroke could not be used for certain practical reasons it follows that there are

fifteen codes which may be used for digital designations. Ten of these may be used in regular service and the other five may be used for certain special service features, such as for calling long distance or for making certain emergency calls, such as to the police or the fire services. The following table shows the combinations which may be used.

Digit	Down stroke		Up stroke	
	Positive	Negative	Positive	Negative
1.....				
2.....	✓			
3.....		✓		
4.....			✓	
5.....	✓			✓
6.....	✓	✓	✓	
7.....		✓	✓	
8.....	✓	✓		✓
9.....	✓	✓		✓
0.....	✓	✓	✓	✓
10.....	✓	✓	✓	✓
11.....	✓	✓	✓	✓
12.....	✓	✓	✓	✓
13.....	✓	✓	✓	✓
14.....	✓	✓	✓	✓
15.....	✓	✓	✓	✓

By way of example the diagrams of Figs. 2 and 3 show the key contact operations for the sending of digit 5 according to the above table.

The essential operations of a key are then to select the varistor to be used, to open the line as a start signal to the apparatus at the other end of the line and then to connect in the selected varistor to expose it to the single cycle of alternating current which will be sent from the other end of the line in response to the said start signal. These operations both for the down stroke and for the up stroke are shown in step-by-step detail in Figs. 2 and 3. The time values indicated are by way of example and are not necessarily controlling.

The various contacts of the keys at the substation are designated *a*, *b*, *c*, *d* and *e*. The two varistors A and B are cut into the loop circuit by closure of key contacts *a* and *b*, respectively, followed by the transfer of the key from contact *d* to *e*. All key contacts are common to all keys but contacts *a* and *b* are controlled by mechanical cams on the individual keys so that various combinations may be obtained on the down stroke and different combinations on the up stroke of the keys. Contacts *c*, *d* and *e* function on each down stroke and again on each up stroke of any key. The order of operation of contacts on the down stroke is: *c* opens, *a* and/or *b* close if required, *d* transfers to *e* with a definite open interval, then near the end of the down stroke, *c* recloses, *a* and *b* open followed by transfer from *e* to *d*. On the up stroke the same order is required, namely, *c* opens, *a* and/or *b* close, *d* transfers to *e* and near the end of the up stroke *c* recloses, *a* and *b* open and *e* transfers back to *d*. The transfer from contact *d* to *e* on both strokes of any key may be arranged to open the loop by a toggle switch arrangement for a definite interval independent of the speed of operation of the key.

The momentary opening of the loop caused by the transfer from contact *d* to contact *e* in the subset is the signal for the sender to send out a pulse of positive and negative current to determine the polarity condition existing by virtue of the closed or opened *a* and *b* contacts. When the line has been taken for use a circuit is established from ground through the upper windings

of relays 1 and 2, and the tip of the line T through the loop closed at the substation, the ring of the line R and thence through the lower windings of relays 1 and 2 to battery. The momentary opening of the loop induces in the middle coil of relay 1 a potential which is sufficient to energize the tube 3 which thereupon locks in its anode circuit to positive battery through the windings of relays 4 and 5 and in series with the primary winding of a transformer having the windings 6, 7 and 8. The build up of flux in the transformer due to current flowing in its primary winding induces a potential in its secondary winding 6 and this is connected so that the terminal which is positive on the build up of flux is connected to the tip of the line through the varistor 11 and condenser 12 which will transmit the pulse. This positive potential is therefore applied to the tip of the line and finds a path over the loop through varistors A or B, over the ring of the line through the network 10, back to the other terminal of the secondary winding 6. Since varistors A and B are designed with very low resistance in one direction and very high resistance in the opposite direction, there will be a very great difference in the amount of current which will flow in the resistance 9.

It will be noted that upon the firing of tube 3 a circuit is established in series through relays 4 and 5. Thus relay 5 will operate as tube 3 fires and on the build up of current through the transformer winding 6. This will cause the resistance 9 to be shunted about the varistor 11 so that the negative pulse which follows can pass by the varistor 11. The condenser 12 is opaque to direct current but will pass the single cycle of alternating current now being generated by the action of the transformer having windings 6, 7 and 8. After the current builds up in the transformer winding 7, the relay 4 becomes energized. This results in locking relay 5 in so that the resistance 9 remains shunted about varistor 11 during the negative half wave now being generated. Relay 4 also short-circuits tube 3 so that this tube becomes extinguished and this short circuit is maintained until the current in transformer winding 7 has fallen below the holding value of relay 4 and until the voltage acting in winding 7 is below the firing potential of tube 3. During the falling value of the current in transformer winding 7, the negative half wave of the single cycle of alternating current is generated in the winding 6 and transmitted to the substation. Relays 4 and 5 are polarized so that they break contact immediately after the negative pulse has been transmitted.

It will be noted that an amplifier 13 is connected between the line wire R and the mid-point of transformer 6 so that the single cycle of alternating current generated by this transformer winding is transmitted to two paths in parallel, one including the substation circuit and the other including the network 10. Considering the schematic circuit diagram of Fig. 7, it will be noted that the network 10 is in the form of a balancing network as used in a hybrid coil circuit. This network is designed and adjusted to balance the circuit conditions at the substation when both contacts a and b are open and hence at this time substantially no current will flow in the register 14 (which includes the amplifier 13). When, however, either or both of the contacts a and b are closed, the circuit as a whole is unbalanced and current will flow through the register 14. Thus the difference between the response in the register when neither contacts a nor b is

closed and when one or the other is closed is magnified over similar response in the said Albert arrangement. In the present arrangement the undesired response may be reduced to zero with careful adjustment of the network 10.

Assuming that varistor A is connected in the substation network, then a relatively large current will flow during the positive half wave. This will manifest itself by a difference of potential between conductors 15 and 16 leading from the amplifier 13 sufficient to fire the tube 17. The circuit of tube 17 may be traced from conductor 15, tube 17, resistance 18, contacts 19 of the upper progress switch controlled by magnet 20, conductor 21, varistor 22, to conductor 16. Tube 17 fired adds the potential of battery 23 to that of battery 24 to cause tube 25 to fire. Tube 25 is then maintained in a local circuit with battery 24 and resistance 18 until a subsequent registering operation extinguishes it. Tube 17, however, is operated only while the current is flowing from the amplifier 13.

The progress switch which is under control of the magnet 20 may be of the type shown in the application of Frank H. Hibbard, Serial No. 411,105, filed September 17, 1941, now Patent Number 2,339,404, issued January 18, 1944.

As previously noted, the positive half of the test cycle is induced in the secondary winding 6 of the transformer by the build up of flux due to current flowing in the primary winding of the transformer by the firing of tube 3. The value of the voltage induced is dependent upon the time rate of change of flux acting upon the total turns of the secondary winding. The length of the positive pulse is largely dependent upon the design of the transformer but is also influenced by the load on the secondary and tertiary windings as well as the external inductive elements in series with the primary winding, namely, relays 4 and 5. It may be assumed that the flux in this transformer is almost fully built up and that relays 4 and 5 will operate in approximately .004 second. Relay 4 in operating closes its contact and short-circuits itself in series with the primary winding of the transformer and tube 3. This causes the flux in the transformer to decrease at a rate dependent upon the design of the transformer and loads on all three windings. During the collapse of the flux a negative voltage is produced at the terminal of the secondary winding 6 which is connected at the tip side of the line and a positive potential at the terminal which is connected to the ring side of the line. This negative half wave of the cycle of test current will be designed to be approximately the same value in potential and of about the same duration as the positive half cycle. If the B varistor at the substation is closed across the loop by contact b then a relatively large positive current will flow from the secondary winding 6 of the transformer over the ring of the line through varistor B, thence over the tip of the line back to the other terminal of the secondary winding 6 of the transformer. This produces a difference in potential across the conductors 16 and 15 in a direction to fire tube 26. This, in turn, increases the potential across tube 27 sufficient to fire it. This latter tube is sustained in an operated condition by the battery 39. As soon as the voltage of the anode of tube 26 drops below the sustaining value it will become extinguished. The key at the subset will now reach the end of the down stroke and contact c will reclose the loop circuit. The key may be kept depressed for as long or as short a time as desired.

The return stroke of the digit key at the subscriber's station will repeat the same order of operation of key contacts but the contacts *a* and *b* are now actuated by different mechanical cams from those on the down stroke. The opening of the loop on the return stroke again fires tube 3 and repeats the generation of the test current as described for the down stroke. This test current is always positive at the tip first followed by positive at the ring, resulting in the generation of a simulated full cycle of alternating current. On the up stroke tube 28 will be fired if contact *a* is closed and tube 29 will be fired if contact *b* is closed. When the varistors at the subset are connected so they oppose the flow of the positive or negative current, then the drop of potential across the conductors 15 and 16 is of low value and tubes 17 or 26 will not fire. Hence tubes 25, 27, 28 or 29 will not fire.

In the example given in the drawings of Figs. 2 and 3, tube 25 will fire on the down stroke of the key and tube 27 will fail to fire. On the up stroke, tube 28 will fire but tube 29 will fail to fire.

The means for progressing the registration from down stroke to up stroke of the same digit and for progressing from digit to digit is shown in Fig. 5. Four tubes are required to register a digit, although with the ten digit code used, not more than two out of the four will be energized for any given digit. The contacts of the progress switches are normally set to render the circuit for tubes 25 and 27 effective when the sender is seized for an incoming call. When the first digit key is operated, it opens the loop on the down stroke and causes the transformer to induce a cycle of alternating test current in its secondary winding 6, as previously described. At the same time a corresponding cycle of alternating current is induced in the tertiary winding 8 of this transformer for the purpose of advancing the progress switches controlled by the magnets 20 and 30. These switches are arranged to have the required number of positions for the total number of digits to be keyed and are capable of high-speed operation. When the positive half cycle of the line test current is about at its maximum and ready to fire tubes 17 and 25 (assuming they are to be actuated) the voltage across the tertiary winding 8 of the transformer has reached a point where tube 31 will fire on its cathode circuit from the potential drop across resistance 32. The tertiary winding 8 is connected so that the terminal which is positive when the flux is building up is connected to tube 31. Varistor 33 short-circuits resistance 34 for this positive current but varistor 35 compels the current to flow through resistance 32, causing tube 31 to operate. Tube 31 being fired, locks in its anode circuit from positive battery through magnet 20 and its self-interrupting contact. The magnet of this selector, therefore, starts to energize at almost the same instant that the record of the test current is being taken by tube 25. By the time the selector magnet 20 has energized to the point of breaking its contact with the terminal connected to tube 25, the register tube will have been actuated and the test with the negative half cycle will be in progress. When the selector magnet 20 is fully energized, it breaks its interrupter contact thus opening the circuit for tube 31 which is extinguished and selector magnet 20 releases to render the circuit for tube 28 now effective. Since this tube is not actuated until the positive test on the up stroke of the key, there is ample time for the operation of the se-

lector magnet 20. Likewise, while tube 27 is taking the record of the negative half wave of the test current, the corresponding negative voltage across the tertiary winding 8 of the transformer will fire tube 36 which locks in its anode circuit through selector magnet 30. Selector magnet 30 operates and releases in a manner similar to the selector magnet 20 and advances its contact to the terminal associated with tube 29. It should be noted that with the proper design of the transformer there can be practically no variation between the tube registration resulting from voltage induced in the secondary winding and the energizing of the selectors for advancing, resulting from a corresponding voltage induced in the tertiary winding of the same transformer. Because of this close timing it is possible to start energizing the selector magnet while the registration is still in progress. This cycle of operation is completed for the down and up stroke of each digit key. For a seven digit number there must be fourteen steps of each selector.

The means for utilizing the registration set up on the tubes 25, 27, 28 and 29 is not shown herein as it is the same as that fully shown and described in the aforementioned application of W. P. Albert.

It may be noted that the balancing network 10 comprises a number of condensers and resistances interconnected in conventional manner. This network is arranged and adjusted to render the output of the amplifier of insufficient effect to fire the tubes 17 and 26 when the contacts *a* or *b* at the substation are open or when the varistors A or B thereat are pointed in the direction opposing the pulse.

The circuit diagram of Fig. 6 is similar to that of Fig. 5 except that the tubes 17 and 26 are now replaced by the triodes 37 and 38 respectively. The operation will be practically similar except that there will be substantially no current flow from the amplifier 13, the rise of positive potential on the grids of these triodes being sufficient to bring the potential of the tubes 25, 27, 28 and 29 up to the firing point.

What is claimed is:

1. In a signaling system, a line, a plurality of differently poled varistors at one end of said line, means thereat to transiently open said line circuit and to then selectively insert therein said varistors, means at the other end of said line responsive to said transiently opened line circuit to produce a simulated single full cycle of alternating current, transmission means including a hybrid coil arrangement for transmitting said single cycle of alternating current to said one end of said line, said hybrid coil having means proportioned to match a substantially open circuit at said one end of said line whereby an augmented difference is produced in the half cycles of said full cycle of alternating current responsive to the poled insertion of said varistors at said one end of said line, and registering means responsive to the said augmented response of said alternating current.

2. In a signaling system, a line, means at one end of said line for producing a timed selective circuit change consisting of a transiently established open circuit followed by a transiently established connection through a circuit element which presents a low resistance to current flowing in one direction and a high resistance to current flowing in the opposite direction, means at the other end of said line responsive to said transiently opened line circuit to produce a test cur-

rent consisting of a positive impulse followed by a negative impulse simultaneously with the establishment of said poled high or low resistance connection at the said one end of said line to differentiate between the high and the low resistance connection established thereat, means including a hybrid coil for transmitting said test current to said one end of said line, said hybrid coil having means proportioned to match the circuit constants of said line when said high resistance connection is established whereby an augmented difference in the said test current between its response to the said high resistance connection and its response to the said low resistance connection is produced, and registering means responsive to the said augmented response of said test current.

3. In a signaling system, a line, means at one end of said line for producing a timed selective circuit change consisting of a transiently established open circuit followed by a transiently established connection through a circuit element which presents a low resistance to current flowing in one direction and a high resistance to current flowing in the opposite direction, means at the other end of said line responsive to said transiently opened line circuit to produce a test current consisting of a positive impulse followed by a negative impulse simultaneously with the establishment of said poled high or low resistance connection at the said one end of said line to differentiate between the high and the low resistance connection established thereat, a hybrid coil arrangement at the said other end of said line in the transmission path of said test current having a balancing network for rendering the response of said test current to one of said dif-

ferent resistance connections substantially different from the response of said test current to another of said different resistance connections and a register responsive to the different responses of said test current.

4. In a signaling system, a line, means at one end of said line for producing a timed selective circuit change consisting of a transiently established open circuit followed by a transiently established connection through a circuit element which presents a low resistance to current flowing in one direction and a high resistance to current flowing in the opposite direction, means at the other end of said line responsive to said transiently opened line circuit to produce a test current consisting of a positive impulse followed by a negative impulse simultaneously with the establishment of said poled high or low resistance connection at the said one end of said line to differentiate between the high and the low resistance connection established thereat, a transformer having a primary winding and a secondary winding, said secondary winding being divided into two equal sections and having a mid-tap, said primary winding being connected to said means for producing said test current, said line being connected to one of said sections of said secondary winding, a network connected to the other section of said secondary winding to balance said line for one of said resistance connections whereby the difference in the response of said test current to said different resistance connections is magnified, and registering means connected to said mid-tap operated by said test current responsive to said other of said resistance connections.

KENNETH W. PFLEGER.