

Jan. 10, 1939.

W. W. CRAMER ET AL

2,143,000

TELEGRAPH SYSTEM

Filed April 14, 1937

8 Sheets-Sheet 1

FIG. 1

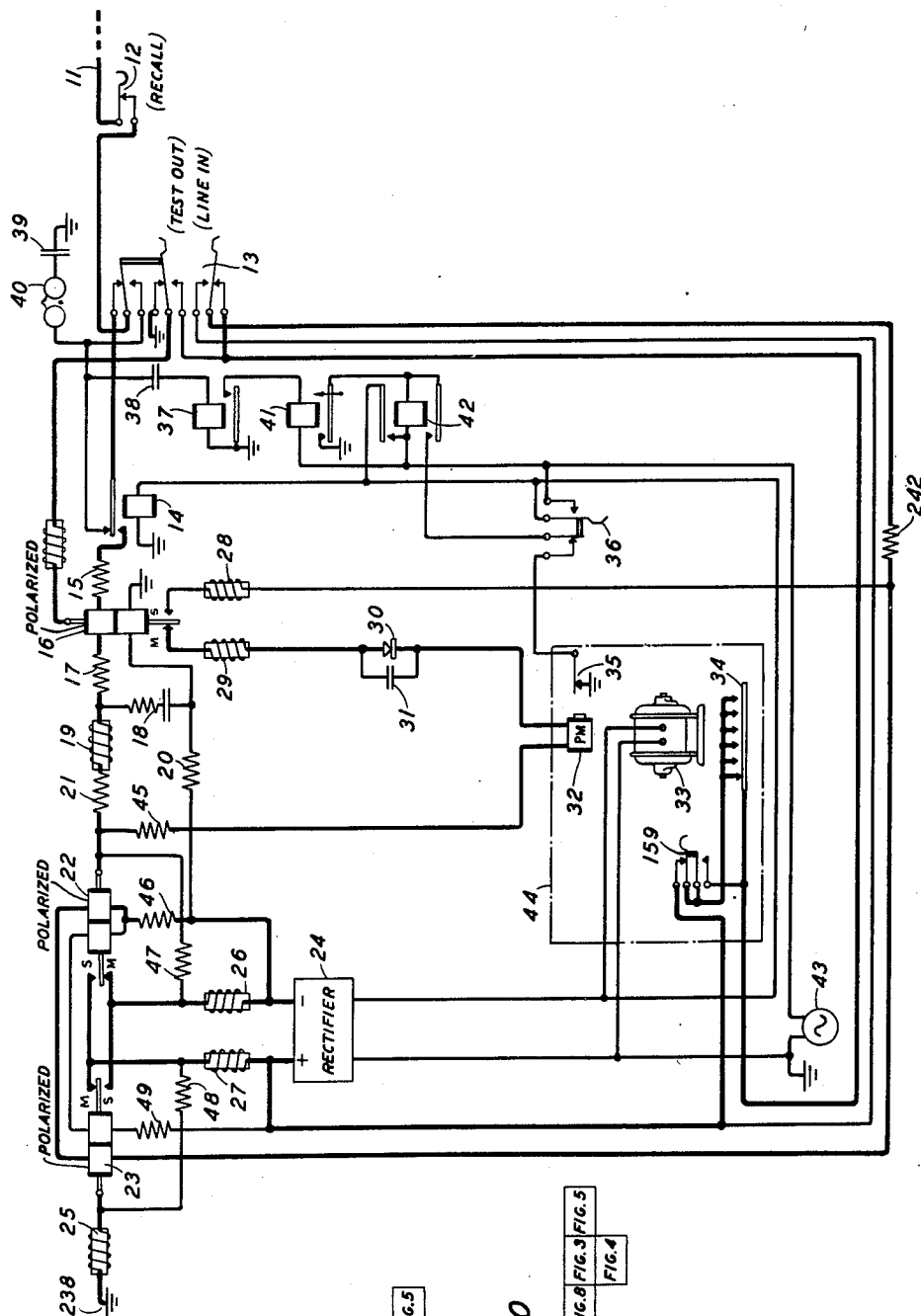


FIG. 9

FIG. 1 FIG. 2 FIG. 3 FIG. 5
FIG. 4

FIG. 10

FIG. 1 FIG. 6 FIG. 7 FIG. 8 FIG. 9 FIG. 5
FIG. 4

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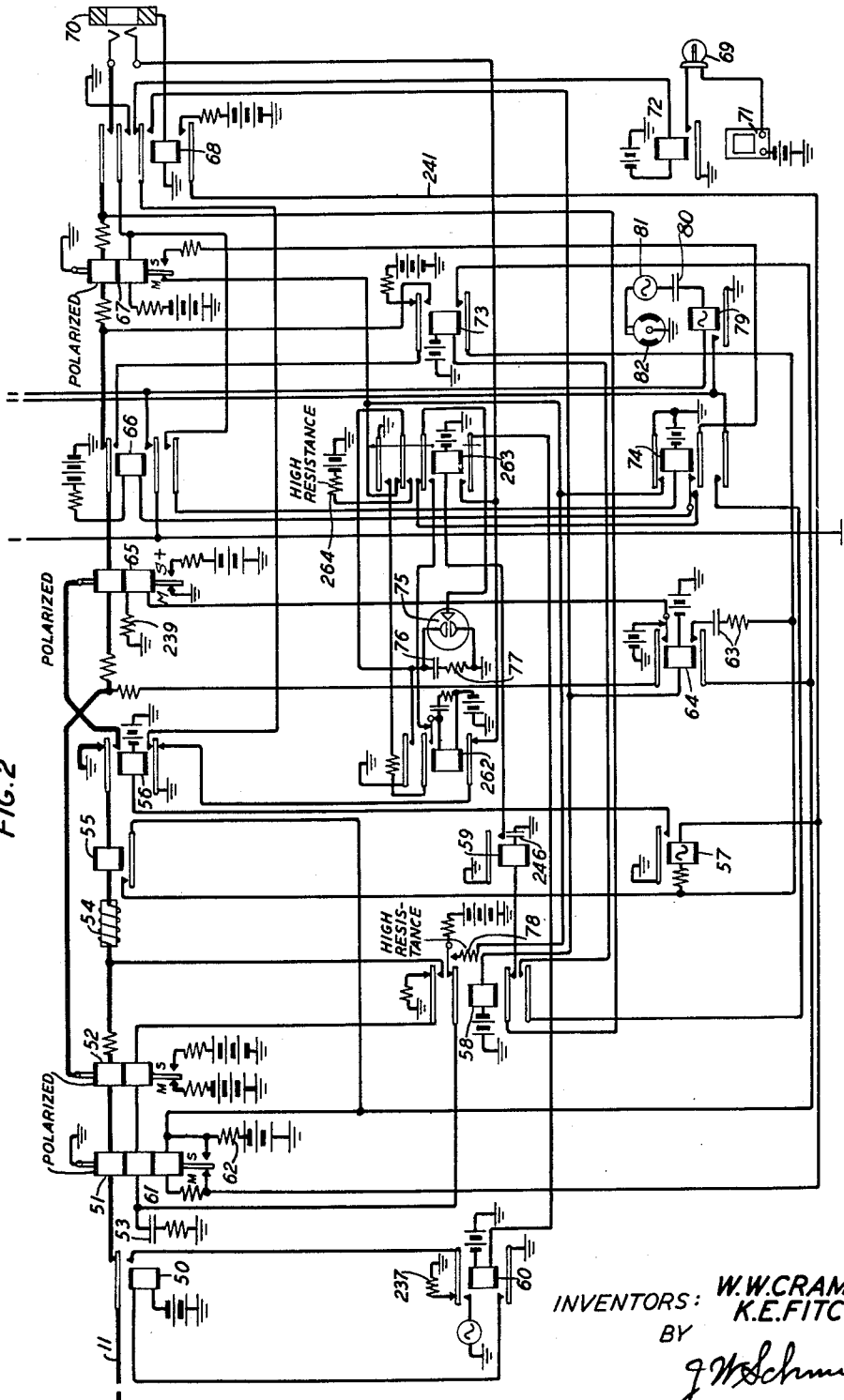
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TELEGRAPH SYSTEM

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FIG. 2



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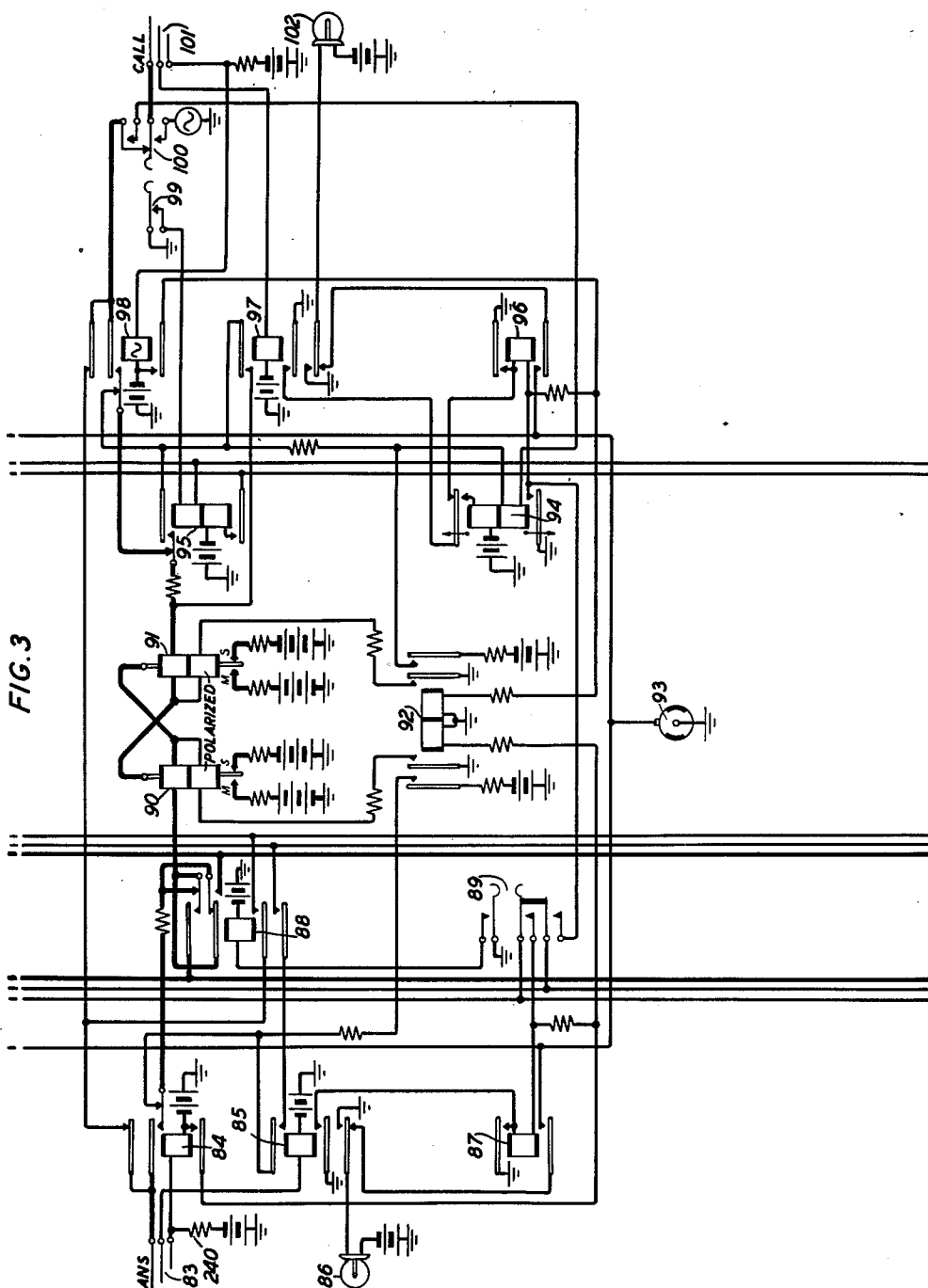
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TELEGRAPH SYSTEM

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TELEGRAPH SYSTEM

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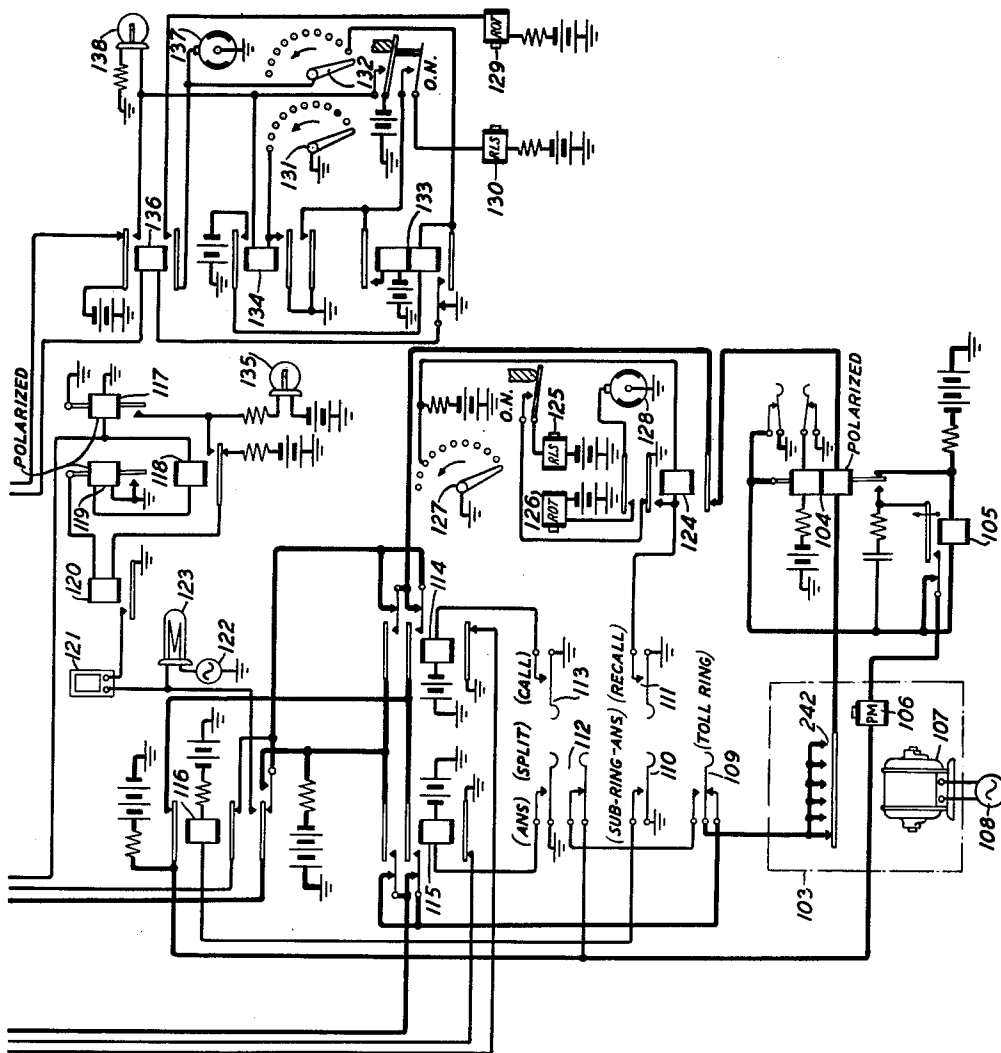


FIG. 4

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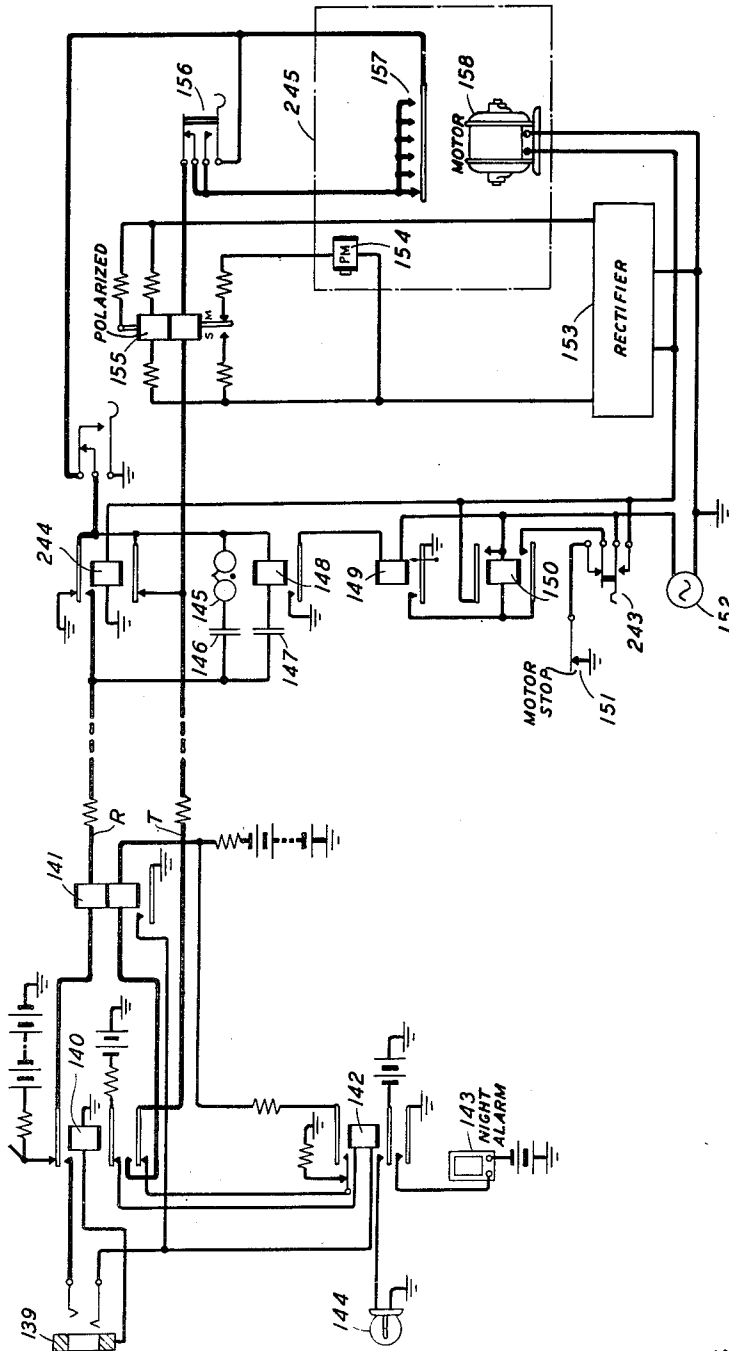
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TELEGRAPH SYSTEM

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8 Sheets-Sheet 5

FIG. 5



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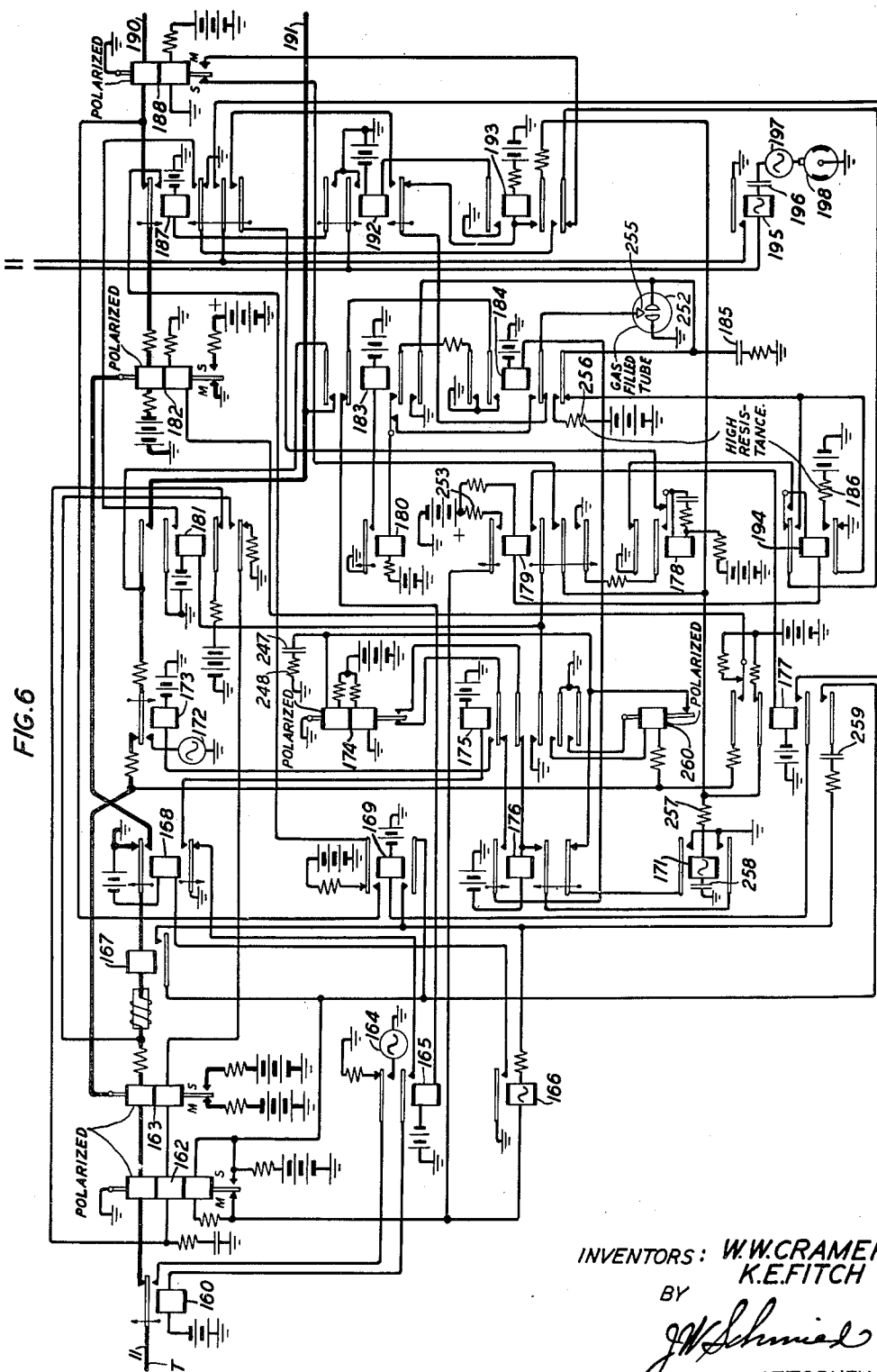
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TELEGRAPH SYSTEM

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8 Sheets-Sheet 6



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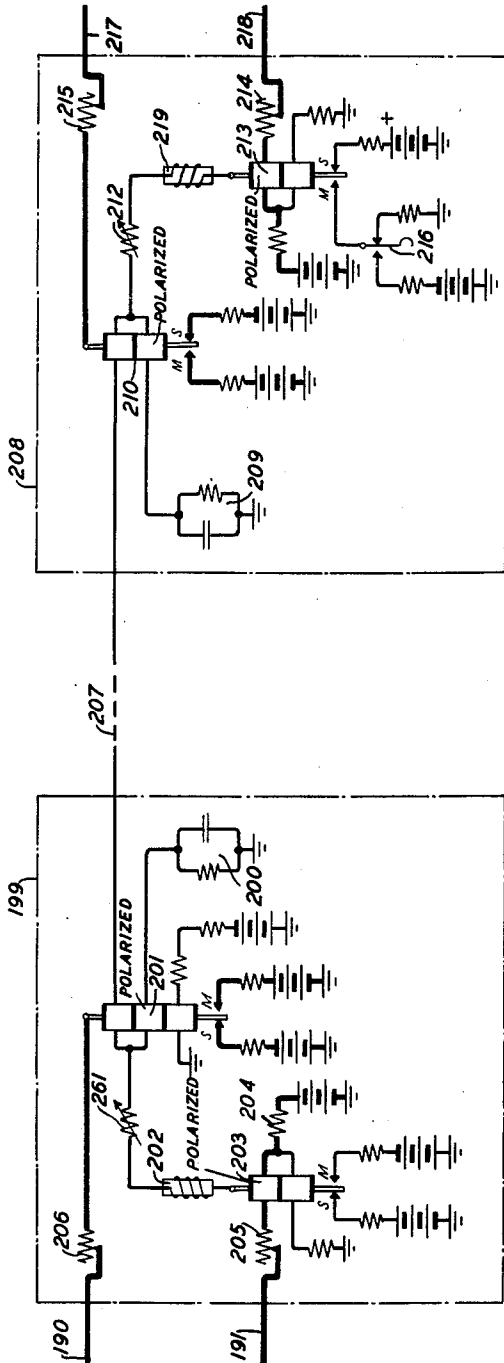
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TELEGRAPH SYSTEM

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FIG. 7



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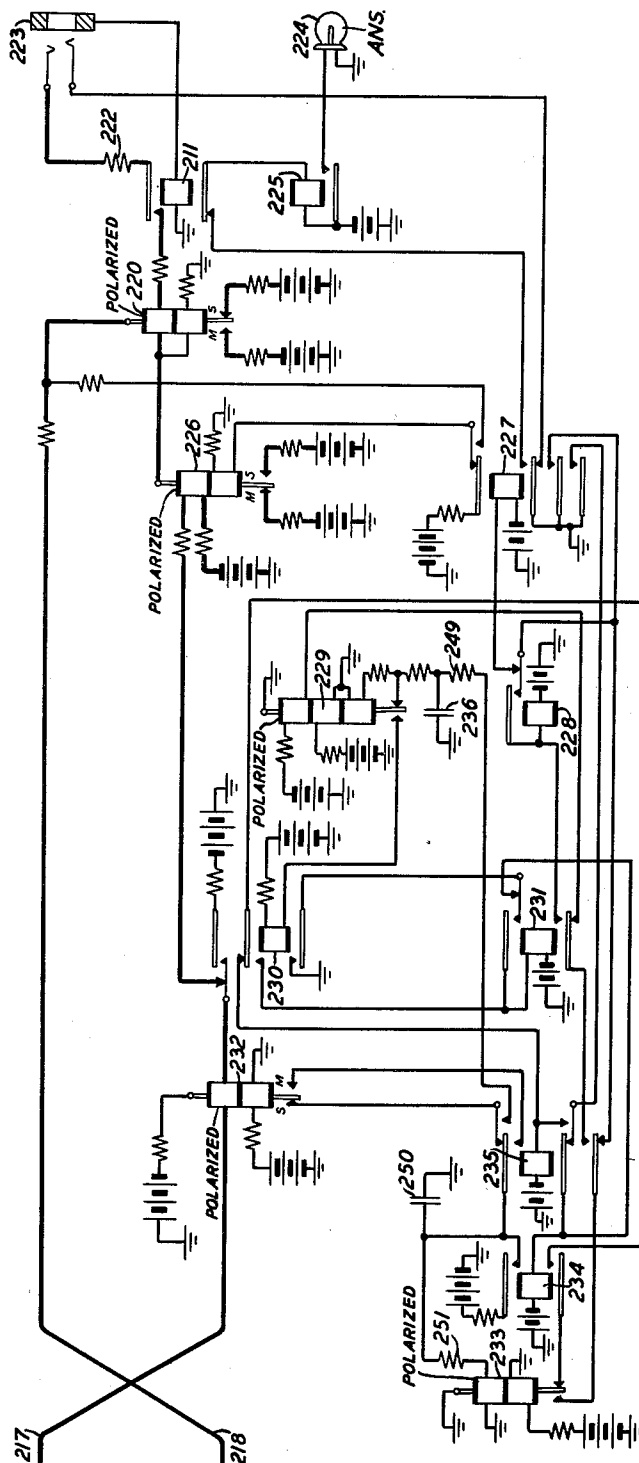
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TELEGRAPH SYSTEM.

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FIG. 8



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UNITED STATES PATENT OFFICE

2,143,000

TELEGRAPH SYSTEM

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Application April 14, 1937, Serial No. 136,734

16 Claims. (Cl. 178—2)

This invention relates to a communication system for transmitting signaling impulses over long telegraph lines or telegraph channels of composite toll lines and more particularly to a telegraph system for connecting an outlying telegraph subscriber's station to a central switching station over a long telegraph line or composite toll line.

The signaling, or telegraph impulses, are transmitted over an improved transmission circuit in which the bias of the impulses is unaffected by changes of the leakage resistance of the telegraph line. A transmission system of this type is described and the novel features thereof claimed in a copending patent application of W. W. Cramer, Serial No. 104,959, filed October 10, 1936, Patent No. 2,131,870, issued Oct. 4, 1938.

This improved transmission system permits the extension of the long telegraph lines and composite toll lines from a transmitting standpoint to such an extent that the existing supervisory signaling arrangements have been found to be inadequate.

It is an object of this invention to provide improved circuit arrangements for extending the supervisory range to take advantage of the extended transmission range provided by the transmitting system described in said copending application.

Another object of this invention is to provide means for transmitting all of the supervisory signals between an outlying subscriber and the central exchange over such long telegraph lines as are employed between the local subscribers and the central exchange.

A further object of this invention is to provide terminal apparatus for these long telegraph, or composite toll lines at the central exchange, which will cooperate with the same switching or cord circuits as employed for interconnecting local subscribers.

Another object of this invention is to provide supervisory circuit arrangements in which the supervisory signals at the ends of the line are positively and continuously controlled from the other end of the line.

Still another object of this invention is to provide supervisory circuit arrangements for long direct current or low frequency telegraph channels which require intermediate repeaters so that the same supervisory information may be transmitted between the subscribers' stations located at the ends of these long circuits and the central exchange as is transmitted between local subscribers' stations and the central exchange.

Another object of this invention is to adapt the telegraph transmitting system described in said copending application for use over sections by a multi-section subscriber's line circuit and at the same time provide means for transmitting supervisory signals over this same circuit by arranging the line section for full duplex operation.

Other objects and features of this invention relate to improved circuit arrangements at the subscriber's station, improved trouble indicating arrangements, as well as improved supervisory circuits.

The novel features of these improved circuit arrangements set forth in the claims appended hereto, may be more readily understood from the following description when read with reference to the attached drawings in which:

Fig. 1 shows the apparatus and circuit arrangements at the outlying subscriber's station;

Fig. 2 shows the terminal equipment of the long toll line at the central station;

Fig. 3 shows a typical cord circuit;

Fig. 4 shows an operator's circuit for cooperating with the cord circuit shown in Fig. 3;

Fig. 5 shows a local subscriber's line circuit and station equipment;

Figs. 6, 7 and 8 show equipment at an intermediate repeater point and the terminal equipment at the central exchange for a long multi-section subscriber's line circuit;

Fig. 9 shows, in block form, the manner in which Figs. 1, 2, 3, 4 and 5 may be arranged to illustrate a typical connection between a local subscriber and an outlying subscriber connected to the central exchange over the telegraph channel of a single-section toll line; and,

Fig. 10 shows, by means of a block diagram, the manner in which Figs. 1, 6, 7, 8, 3, 4 and 5 should be arranged to illustrate a typical connection between a local subscriber and an outlying subscriber connected to the central exchange over a telegraph channel of a long multi-section toll line.

GENERAL DESCRIPTION

In both the single-section toll line circuits in all the sections of the multi-section toll line, the intelligence or telegraph signaling impulses are transmitted by means of the improved transmitting circuit arrangements described in the above-identified copending application.

In brief, that copending application describes method of transmitting signaling impulses over telegraph channels of long communication lines in such a way that the bias of the signals is sub-

stantially independent of the leakage resistance, or changes in the leakage resistance, of the toll lines. This is accomplished by providing the proper transmitting potentials at the two ends of the long line and by employing the correct biasing current for the receiving relays at each end of the line. When these factors are correctly proportioned with respect to the distribution of the line resistance and leakage resistance, the sum of the marking and spacing current received at each end of the line remains constant and substantially independent of the leakage resistance of the line. The biasing current of the receiving relays is then adjusted to be one-half the magnitude of the sum of the received marking and spacing currents but in a direction to oppose the magnetic effect of the sum of these currents on the relay. Under these conditions, the bias of the telegraph signaling impulses is substantially independent of the leakage resistance of the line.

The term "bias" as applied to the signaling impulses in this specification indicates a lengthening of one of the signal impulses or conditions, and the shortening of another signaling impulse of condition. For example, marking bias means that the marking impulses or pulses are lengthened and that the spacing impulses or pulses are shortened, whereas spacing bias indicates that the spacing pulses are lengthened and the marking pulses are shortened. Thus, signals having greater bias are less satisfactory for operating receiving apparatus than are signals having less bias. Consequently, the biased signals are poor in quality.

A common cause of this lengthening and shortening of the various signal impulses is due to the fact that the magnitude of the two pulses of the current conditions are unequal, or differ by different amounts from a fixed reference or biasing current adjustment of the receiving apparatus. For a marking bias, the marking current is greater, or differs by a greater amount from a reference or fixed biasing current than a spacing current, whereas for spacing bias, the spacing current is greater or differs from a given reference current by a greater amount than the marking current.

However, in accordance with the transmission arrangement shown in this specification and claimed in the above-identified copending application, when the sum of the marking and spacing currents remains substantially constant and independent of variations of the leakage resistance of the line both currents will always be of substantially the same magnitude or differ from a given reference current by substantially the same amount.

The term "marking" and "spacing" as used in this specification, differentiate two line or signaling conditions transmitted from each end of the line to the other end of the line. These terms are also used to designate the positions of relays and other apparatus during these signaling conditions.

The term marking is used to designate the line or signaling condition employed during the time no intelligence or signaling impulses are being transmitted over the system but the transmission circuits of the system are fully established, connected and energized and properly connected to suitable circuits so that it is ready to transmit the signal impulses when the transmitting apparatus at either end of the line is operated. The

term "spacing" designates the other signal or line condition.

This improved transmission system permits extension of the telegraph lines beyond the limit of the supervisory arrangements heretofore employed for transmitting supervisory signals between the subscriber's station and the central switching or interconnecting station. In general, it is not desirable to distinguish between the marking or spacing conditions for supervisory purposes. One disadvantage of such a supervisory arrangement is that it is usually necessary to maintain a constant current flowing in the line at all times. Another disadvantage is that it is difficult, if not impossible, to distinguish between break signals and supervisory signals transmitted over the system.

The preferred method of supervising is to open the line circuit at the subscriber's station to indicate an idle line condition. However, as the line becomes long, the effect of earth potential, interference, cross-fire and leakage resistance becomes greater so that the usual methods employed at the central office for recognizing an open line condition at the subscriber station were found to be unsatisfactory.

In accordance with this invention the outlying subscriber's station is arranged to connect substantially equal positive and negative sources of potential to the subscriber's line in accordance with the impulses to be transmitted while at the central station ground and a source of potential are connected to the line extending to the subscriber's station. The ground is applied to the line at the central station for the marking condition and a source of potential which aids the marking potential at the subscriber's line is connected to the line at the central station during the spacing condition transmitted therefrom. By thus reversing the ends of the line from that described in the above-identified copending application it is possible to distinguish at the central office between both the marking and spacing signaling conditions and conditions applied at the subscriber's station and an open line or idle condition at the subscriber's station.

In addition a neutral relay and a polarized relay are connected in series with the line at the central station in addition to the usual receiving relay employed to receive the signaling or telegraph current impulses. The neutral relay is adjusted to release when the line circuit at the subscriber's station is open for any appreciable period of time. This relay, however, is designed to remain operated as long as either the marking or the spacing current conditions are transmitted from the subscriber's station. It has been found impossible, however, to design a relay to meet these conditions and also remain operated during the time the marking and spacing signal conditions are transmitted in rapid succession from the subscriber's station. It has also been found impractical to maintain a slow release relay operated from the contacts of this relay during the time signaling impulses are being transmitted to or from the subscriber's station. Consequently, a second, or polar relay, is also connected in series with the line at the central exchange. This relay is arranged to alternately charge and discharge the condenser through the windings of a third or alternating current relay. This alternating current relay will thus be maintained operated as long as signaling impulse are transmitted over the system because the polar relay follows the signaling impulses and alternately

charges and discharges or reverses the charge on the condenser through the windings of the third relay. During the time no signals are being transmitted to or from the subscriber's station but the line circuit is closed or potential applied to the line at the subscriber's station, the polar relay will be maintained on one of its contacts so that the alternating current relay will release. To prevent this, the neutral relay which operates at these times is arranged to close a direct current circuit through the windings of the alternating current relay and thus maintain it operated at this time. It has been found necessary to make the polar relay somewhat less sensitive than the receiving relay so that it will not respond to interference and cross-fire received from other circuits during the time the circuit in question is idle. This prevents a false operation of the supervisory apparatus at the central station.

In the case of multi-section subscribers' lines, the line section between the subscriber and the first repeater point is substantially the same as the single-section line. The line section between repeater points and between a repeater point and the central station is arranged for full duplex operation. As pointed out in the above-identified compending application, the improved transmission circuit described therein was not arranged for full duplex operation because the self-compositing feature which renders the bias of the transmitted signal substantially independent of the leakage resistance or changes of the leakage resistance of the line cannot be obtained for full duplex operation. However, a circuit arrangement, shown in Fig. 7, provides full duplex operation as required over the intermediate sections and the section nearest the central exchange. During the normal transmission of signal impulses over the line, the signal impulses are transmitted in only one direction at a time. During these times the circuit is arranged to be self-compensated. However, when it is desired to transmit supervisory or break signals over the line in the reverse direction at a time when signaling impulses are being transmitted in one direction, the system will not be fully self-compensated. At these times it is usually desired to interrupt the transmission for some reason or other, hence the reduced quality of the transmission circuit is of small importance.

In addition, it is to be understood that the long toll, or telegraph line may include open wire sections, entrance cable sections, cable sections, as well as terminal and intermediate composite sets. These lines may also include suitable noise suppression and shaping coils and networks, as well as other circuit elements usually employed in long telegraph lines or composite toll lines.

In order that the invention can be more readily understood, the operation of the single-section line when the toll subscriber originates a call will be described first. The operation of a single-section line when the central exchange operator calls the subscriber will next be described, and then the operation of the multi-section line under these respective conditions will be described. It is to be understood, however, that the following description with reference to the attached drawings illustrate only a typical circuit arrangement in which this invention may be employed. In addition to the particular switchboard and circuits described, this invention may be used equally well with other types of switchboard, as, for example, single-section switchboards which do not have any multiple jacks, switchboards which have

simple cord circuits which do not include repeaters, automatic switching systems, as well as small private branch exchange systems.

SINGLE LINE SECTION

Idle condition

Reference will now be made to Figs. 1, 2, 3, 4, and 5 arranged as shown in Fig. 9. With the exception of sending relays 22 and 23 and the receiving relay 16 at the subscriber's station, the relays of the single line section are shown in Figs. 1, 2, 3, 4, and 5 in their normal positions. These relays remain in these positions during the time the circuit is idle. Relays 16, 22, and 23 at the subscriber's station may, however, be on their spacing contacts during the idle condition.

Key 13 is normally in the position shown in Fig. 1. Key 13 is provided to enable the printing equipment 44 at the subscriber's station to be testing locally. When key 13 is operated to the opposite position from the position shown, line 11 is connected directly to ringer 40 and relay 37 through condensers 39 and 38, respectively. This permits the central exchange operator to call the subscriber during the time his equipment is being tested or adjusted. In the opposite position key 13 also connects the right-hand winding of relay 22 and left-hand winding of relay 23 directly across a rectifier 24, thus maintaining these relays in their marking position. Key 13 in its opposite position also connects transmitting contacts 34 of the printer equipment 44 directly in series with printer magnet 32 of printer equipment 44, thus permitting the local operation of this equipment for test purposes.

However, as stated above, test key 13 is normally maintained in the position shown and permits the operation of the system as will be described hereinafter.

At the central office the relays of the terminal equipment are shown in their normal positions. The term "normal position" or "normal" is used to indicate the position assumed by the relays when the circuit is idle. Relays 51 and 52 are maintained on their marking contacts by current flowing in a circuit from ground connected to the upper break contacts of relay 58 through the lower winding of relay 52, middle winding of relay 51 to battery connected to the upper inner break contact of relay 58. Relay 65 is also maintained on its marking contact by current flowing in a circuit from ground through resistance 239, lower winding of relay 65 to battery connected through the upper break contacts of relay 64. Relay 67 usually remains on its marking contact as shown in Fig. 2 during idle intervals but need not be so positioned during this time.

Subscriber originates a call

The subscriber originates a call by operating the power switch 36 at the subscriber's station. The operation of switch 36 completes a path from the source of power 43 through its right-hand make contacts for energizing the printer motor 33, rectifier 24 and relay 14. Relay 14 in operating closes the circuit from line 11 extending from the central station through recall key 12, test key 13, contacts of relay 14, resistance 15, upper winding of relay 16, resistances 17 and 21 and noise suppressing choke coil 19 through the armature and contact of relay 22, rectifier 24, armature and contacts of relay 23, through choke coil 25 to ground 238. The energized rectifier 24 supplies a source of potential between its ter-

minals and thus in series between ground 238 and line 11 extending to the central exchange. Rectifier 24 on becoming energized also causes current to flow through the lower biasing winding of receiving relay 16 and the biasing and operating windings of relays 22 and 23. The biasing winding of relay 22 is the left-hand winding while the biasing winding of relay 23 is the right-hand winding. The operating windings are the other windings of these relays. Resistances 20 and 49 as well as 46 control the value of the biasing currents.

Line 11 which extends to the central exchange may include the various types of lines and equipment mentioned above which are usually employed or associated with telegraph lines or telegraph channels or composite toll lines.

At the central station the line 11 extends through the break contacts of relay 50, the upper windings of relays 51 and 52, noise suppression choke coil 54, winding of relay 55 to ground through the armature and break contact of relay 56. Current flowing over this line circuit due to the source of potential applied to the line by rectifier 24 will cause relay 55 to operate. Relay 55 in operating completes a path from battery through resistance 62, through its contacts, winding of relay 57 to ground connected through the armature and marking contact of relay 51. As pointed out above, relay 51 is maintained upon its marking contact at this time by current flowing through its middle winding. This causes relay 57 to operate, which in turn operates relay 56. Relay 56 in operating transfers the circuit of line 11 from its back contacts to its front contacts and thence through the armature and marking contact of relay 65 to ground. As pointed out above relay 65 is maintained on its marking contact by current flowing through its lower winding at this time. Relay 56 in operating also connects ground through its lower make contacts and innermost top break contacts of relay 68 to the winding of relay 72. Current flowing in this path from the battery connected to the other terminal of the winding of relay 72 causes relay 72 to operate, which in turn lights the call lamp 69 and indicating or alarm device 71. Device 71 may include either or both supervisory and alarm circuits and apparatus.

Operator answers

The operator answers the call by inserting the answering plug 83 in the answering jack 70 associated with the terminal equipment connected to line 11. Jack 70 is shown as a single jack. However, it is to be understood that it as well as lamp 69 may be multiplied at various positions of a multi-section switchboard or it may be only a single jack of a single section switchboard, depending upon the type of switchboard at the central station.

When the operator inserts plug 83 in jack 70 a circuit is completed from ground through the winding of relay 68, sleeve of jack 70, sleeve of plug 83 and winding of relay 84 to battery. Current flowing in this circuit causes the operation of relays 68 and 84. Resistance 240 provides a shunt for the winding of relay 84 to properly control the potential of sleeve of jack 70 and the currents flowing through the windings of relays 68 and 84. The operation of relay 68 extends the transmission circuit from the tip of plug 83 through the tip of jack 70, the uppermost make contacts of relay 68, the upper winding of relay 67, the upper break contacts of

relay 66, upper winding of relay 65 to the armature and contacts of relay 52. This transmission circuit is completed in the cord circuit shown in Fig. 3 through the upper make contacts of relay 84, the contacts of relay 88 through the transmission circuit of the operator's position and teletypewriter circuit to the upper winding of the repeater relay 90 and thence to the armature and contacts of repeater relay 91. The operator usually has key 89 operated at the time she inserts plug 83 in jack 70 so that this transmission circuit is extended through her position equipment. However, if she does not have this key operated at this time the transmission circuit extends directly to the upper winding of the repeating relay 90 and is completed through the armature and contacts of relay 91. Relay 68 in operating completes an obvious circuit through the lower or biasing winding of relay 67. Relay 68 also transfers the ground from the lower make contacts of relay 56 from its innermost upper break contacts to its innermost upper make contacts and the windings of relays 58 and 64. This interrupts the circuit through the winding of relay 72 which releases and in turn extinguishes light 69. Relays 58 and 64 are operated by current flowing in the above circuit through their windings. Relay 58 in operating disconnects the above traced circuit through the lower winding of relay 52 and middle winding of relay 51 and connects these windings to the transmission circuit of line 11. These windings are now connected between the transmission circuit line 11 and the artificial line 53. It should be noted that the artificial line 53 does not provide any direct current path. No biasing current is required for the receiving relays 51 and 52 because they receive positive and negative signal impulse currents of substantially the same magnitude from the subscriber's station.

The operation of relay 58 also interrupts the operating circuit of ringing relay 59 and prepares a circuit for the operation of relay 73 and also connects battery to the upper terminal of condenser 76 through high resistance 78 and the upper break contacts of relay 263. However, ground is connected to the upper terminal of condenser 76 through the marking contact and armature of relay 67 the upper break contacts of relay 263 so that the battery connected through resistance 78 performs no useful function at this time.

The operation of the relay 64 connects the lower winding of relay 65 to the transmission circuit through jack 70. This relay also completes a circuit in parallel with the contacts of relay 55 through its lower make contacts, condenser and resistance 63.

Transmission circuit

Assuming now that the central exchange operator has operated key 89, the transmission path as above traced is now complete between the operator's printer equipment 103 (Fig. 4), and the printer equipment 44 at the subscriber's station. Communication signaling impulses may now be transmitted from the operator to the subscriber. The operator in operating the transmitting contacts 242 of her teletypewriter equipment 103 interrupts the transmission circuit through jack 70. This causes the line relay 104 of the operator's position equipment to repeat the signals to the receiving equipment of the operator's printer to produce an operator's copy. The relay 65 of the terminal equipment shown in Fig. 2 also

follows these signal impulses and repeats them to line 11 through the transmission circuit above described. It should be noted that relay 65 transmits by connecting ground to line 11 for marking signal impulses and connects positive battery to line 11 for spacing signal impulses. The positive battery connected through the spacing contacts of relay 65 to line 11 aids the source of negative potential connected to line 11 at the subscriber's station. As described in the above identified copending application the preferred ratio of the two currents for marking and spacing conditions respectively is of the order of 1 to 3. To obtain this ratio of currents the potential developed by rectifier 24 is substantially one-half the potential of the source connected to the spacing contact of relay 65. The current flowing through the lower or biasing winding of the receiving relay 16 is adjusted to produce substantially one-half the magnetic effect upon relay 16 as is produced by the sum of the two currents flowing through the upper winding of relay 16. However, the magnetic effect produced by the current flowing through the lower winding of relay 16 opposes the magnetic effect of the algebraic sum of two currents flowing through the upper winding of relay 16. When these conditions are substantially satisfied as described in said copending application, relay 16 responds substantially equally well to both the marking and the spacing signaling condition independently of the changes of leakage resistance of line 11. Relay 16 in responding to the signaling impulses transmitted by the operator repeats them to the printer magnet 32 of the receiving teletypewriter equipment 44 and causes it to record the information transmitted by the operator at the central station. The operating circuit of the printer magnet 32 may be traced from ground through test key 13, armature and marking contact of relay 16, unilateral conducting device or rectifier 30 in parallel with condenser 31, winding of printer magnet 32, resistance 45, armature and marking contact of relay 22, rectifier 24, marking contact and armature of relay 23 to ground 238. Rectifier 24 supplies the current for this path causing the operation of printer magnet 32 in accordance with the signals repeated by relay 16.

In the spacing position, receiving relay 16 short-circuits the transmitting contacts 34 and resistance 242. In short-circuiting resistance 242, relay 16 increases the current through the left-hand winding of relay 23 and the right-hand winding of relay 22 and thus provides an additional load for rectifier 24 during the time relay 16 is on its spacing contact. This extra load compensates for the load on the rectifier during the time relay 16 is on its marking contact causing current to flow through the printer magnet 32.

In short-circuiting the transmitting contacts 34 in its spacing position, relay 16 insures the proper reception of a break signal by a transmitting operator at the subscriber's station. With the transmitting contact short-circuited it is impossible to transmit signals to line 11 which might interfere with the reception of the break signal, or to cause signals to be recorded by the receiving printer as home copy.

In response to the information transmitted from the central operator, the subscriber will transmit information regarding the party with which the subscriber wishes to communicate by operating the transmitting contacts 34 of the teletypewriter equipment 44. The operation of

the transmitting contacts 34 opens and closes the circuit through the right-hand winding of relay 22 and left-hand winding of relay 23. Current flowing through these windings is in such a direction as to maintain these relays on their marking contacts. The current flowing through the other windings of these relays is in such a direction as to cause these relays to be operated and remain upon the spacing contacts. However, the current flowing through the right-hand winding of relay 22 and the left-hand winding of relay 23 overpowers the current flowing through the other windings so that so long as this current flows these relays remain on their marking contacts. However, when the circuit of these windings is interrupted by the transmitting contacts 34 this current is interrupted and the biasing windings of these relays cause the armatures to move to their spacing contacts. In moving to the spacing contacts the armatures of relays 22 and 23 reverse the connections of the rectifier 24 to line 11 whereby a positive potential is now connected between line 11 and ground 238 instead of negative potential. This causes a spacing impulse to be transmitted over the line 11.

The armatures of relays 22 and 23 in moving to their spacing contacts also tend to reverse the current flowing through the printer magnet 32 at the subscriber's station over a circuit traced from ground 238, armature and contacts of relay 23, rectifier 24, contacts and armature of relay 22, resistance 45, printer magnet 32, unilateral conducting device or rectifier 30, choke coil 28, armature and marking contacts of receiving relay 16 to ground through the contacts of test key 13. The direction of current which would flow through this circuit is opposed by the device or rectifier 30 so that substantially no current flows through printer magnet 32 at this time, thus causing printer magnet 32 to follow the signal impulses transmitted by transmitting contacts 34 to record a home copy of the information transmitted by the subscriber. However, inasmuch as substantially no current flows through the printer magnet 32 it is necessary to provide a compensating load comprising resistances 47 and 48 across the terminals of rectifier 24 in order to insure substantially constant voltage under both marking and spacing current conditions. The path of this compensating load may be traced from the negative terminal of rectifier 24 through choke coil 26, resistance 47, armature and spacing contact of relay 22 to the positive terminal of rectifier 24 through coil 27. A similar path may be traced from the positive terminal of rectifier 24 through choke coil 27, resistance 48, armature and spacing contact of relay 23 to the negative terminal of rectifier 24 through choke coil 26.

As pointed out and described in detail in the above identified copending application of Cramer, receiving relay 16 at the subscriber's station would not normally follow the signaling impulses transmitted from the transmitting relays 22 and 23. In the arrangement shown in Fig. 1 this is also true. However, it should be noted that the current through the biasing winding of relay 16 is reduced to substantially zero when the transmitting relays 22 and 23 move to their spacing contacts. Normally the current through the biasing winding of relay 16 tends to cause this relay to move to and remain upon its marking contact. The current normally flowing through the upper or line winding of relay 16, which is the marking current, tends to operate

the armature of relay 16 to its spacing contact and maintain it on the spacing contact. However, this current under marking conditions is insufficient to overpower the biasing current which, therefore, maintains the relay on its marking contact. When signal impulses are transmitted from the distant station current through the upper or line winding of relay 16 becomes substantially three times as great as the normal current and thus overpowers and overcomes the magnetic effect of the biasing current and causes this relay to move to its spacing contacts. When spacing impulses are transmitted from the subscriber's station the line current reverses so that the current through the upper or line winding of relay 16 will tend to hold the relay upon its marking contacts. Hence, the reduction of current through the lower or biasing winding at this time does not permit the relay to leave its marking contact so relay 16 does not follow the signal impulses transmitted from the subscriber's station.

The path for the current through the lower winding of relay 16 may be traced from ground through the lower winding of relay 16 and resistance 20 to the negative terminal of rectifier 24. During the transmission of spacing current from the subscriber's station this terminal of the rectifier is grounded through spacing and armature contacts of relay 23 to ground 230, thus preventing any current flow through the lower winding of relay 16. However, during the transmission of marking current from the subscriber's station the positive terminal of rectifier 24 is grounded through the marking and armature contacts of relay 23 to ground 230, thus including the source of potential of rectifier 24 in the circuit of this biasing winding and causing biasing current to flow through the lower or biasing winding of relay 16.

During the transmission of the telegraph signal impulses between the subscriber's station and the operator, and also during the transmission of signaling impulses to or from the subscriber's station at any other time, relay 57 (see Fig. 2) is maintained operated either from the contacts of relay 55 or by polar relay 51 reversing the charge on condenser 63 through resistance 63 and the winding of relay 57. Due to the extended range available with the improved transmission circuit employed and described in the above identified copending application as well as the lower leakage resistance permissible and the higher earth potentials encountered over the extended range, it has been found impossible to provide a relay similar to relay 55 which will remain operated during the time signal impulses are being transmitted over line 11 and at the same time release against the low value of leakage resistance, earth potential, cross-fire, and other interference usually encountered on long telegraph lines or telegraph channels of composited toll lines. In accordance with this invention relay 55 is arranged to release against the low value of leakage resistance, cross-fire and a reasonable value of earth potential when the subscriber removes potential from line 11. Relay 55 when so adjusted will also operate on the longer signal impulses and the steady state marking and spacing currents received over line 11 but may not remain operated during the transmission of telegraph signal impulses. In the specific embodiment of this invention shown in the drawings, marking current or impulses transmitted from the subscriber's station is of

one polarity and spacing current or impulses transmitted from the subscriber's station is of the opposite polarity. Consequently relay 55 is required to close a contact when current of either polarity flows over the line and through its winding but is required to open its contacts when substantially no current or a very small current is flowing through its winding. Relays of this type are frequently called neutral relays. Consequently relay 55 is referred to in this application as a neutral relay. Relay 51 is arranged to follow the telegraph signal impulses. Inasmuch as the telegraph signaling impulses or currents are of opposite polarity in the embodiment of the invention shown in the drawings relay 51 is a polar relay since it must close one contact on marking impulses and another contact on spacing impulses. This relay has therefore been called a polar relay in this application to clearly distinguish it from relay 55. The essential characteristics, however, of these relays are that relay 51 follow the signaling impulses and that relay 55 close a contact when long impulses of either character are received and these terms "neutral" and "polar" are intended to distinguish these two types of relays but include any relay which function in these respective manners. Relay 51 on its marking position connects ground to the right-hand terminal of the winding of relay 57. When relays 55 and 73 are released the other winding terminal of relay 57 is connected through condenser 63 and lower contacts of relay 64 to battery connected to the spacing contact of relay 51. At this time relay 73 is released as it performs other functions. Condenser 63 is charged in the circuit above traced through the winding of relay 57. When relay 51 moves to its spacing position it connects ground to the upper terminal of condenser 63 through the lower make contacts of relay 64 and disconnects ground from the right-hand terminal of the winding of relay 57. Condenser 63 now charges in the reverse direction from battery through the lower contacts of relay 63 over lead 241, the winding of relay 57, condenser and resistance 63 to ground through the spacing contacts of relay 51. When relay 51 again closes its marking contact the charge on condenser 63 will be again reversed through the winding of relay 57 as described above. This reversing of the charge of condenser 63 provides in effect an alternating current for maintaining relay 57 in its operated position during this time. Relay 57 is accordingly arranged to operate and hold operated on alternating current and is some times called an "alternating current" relay. Relay 57 is arranged to hold operated on direct current as are most alternating current relays so that during the time no signal impulses are received over line 11, during which time relay 51 will remain on one or the other contact and thus cause no alternating current to flow through the winding of relay 57, relay 55 will operate to provide a direct current path through relay 57 and thus maintain it operated. It should be noted that the direct current flowing through the winding of relay 57 when relay 55 is operated is in one direction when relay 51 is in its marking position and in the opposite direction when relay 51 is in its spacing position. Relay 57 however, operates and remains operated by current flowing through its winding in either direction so relay 55 will maintain relay 57 operated independently of the position of relay 51 and thus

during the transmission of both long marking and long spacing impulses.

Relay 56 which is operated by relay 57, is a slow release relay which further serves to protect the circuit arrangement from false supervisory signal indications at the central switchboard, due to any momentary releases of relay 57 which might occur between the time either relay 51 or relay 55 is holding relay 57 operated and the time the other of said relays operates and maintains relay 57 operated.

Relay 51 is provided with a third winding in addition to the two windings similar to the windings of the receiving relay 52. The third or lower winding is connected to the contacts of relay 51 in such a manner that an additional or biasing current flows through this winding in such a direction as to maintain relay 51 on the contact on which it is resting. In other words this winding tends to make relay 51 less sensitive than relay 52. This is desirable in order to prevent false operation of relay 51 on cross-fire currents and other interference received during the time the line 11 is open-circuited at the subscriber's station or has no potential connected to it at the subscriber's station.

Thus by jointly controlling relay 57 from the neutral relay 55 connected in series with line 11 and the polar relay 51 also connected in series with line 11 it is possible to differentiate between an open line condition at the subscriber's station and signaling impulses transmitted over the line during the time the line is closed or potential applied to it at the subscriber's station. In this manner it is possible to provide reliable supervisory signals at the central exchange.

After the operator at the central station has received all the necessary information she can connect the subscriber to the desired station by inserting the calling plug 101 into the proper jack 139. She will then operate ringing key 100 to call the subscriber and after the called subscriber has answered, the operator may disconnect her circuit by releasing key 89. At this time the outlying subscriber may transmit from the equipment shown in Fig. 1 over line 11 to a local or other outlying subscriber. A local subscriber is shown in Fig. 5.

The operation of other features of the cord circuit, operator's position circuit and local subscriber's line and station equipment circuits and apparatus need not be described in detail since they operate in their usual manner.

Briefly the busy test circuit shown in the operator's position circuit of Fig. 4 includes relays 117, 118, 119, and 120 and lamps 135 and 123 and indicator 121 and is connected to the tips of both plugs 83 and 101 through the inner lower make contacts of relay 88 and the upper break contacts of relays 84 and 98 to enable the operator to determine if the lines are idle.

Splitting keys 112 and 113 and relays 115 and 114 are provided to enable the operator to communicate with either subscriber connected to the cord circuit without communicating with the other subscriber connected to the cord circuit.

A recall circuit including recall key 111, relay 124, selector switch 127 having rotary magnet 126 and release magnet 125 is provided to enable the operator to send a recall signal over a toll line to an operator at a distant central exchange.

Disconnect key 99, relays 95, 133, 134 and 136, selector switch having contact arms 131 and 132, rotary magnet 129 and release magnet 130 are

provided to transmit a disconnect signal over a toll line to a distant central station operator. Ringing key 100 is likewise provided to ring a distant operator.

It is to be understood, that these features may or may not be provided and that other features can be provided when desired. These circuits and features cooperate with the circuits to the outlying subscribers' stations in substantially the same manner that they cooperate with local subscriber station circuits and equipment.

Recall

If at any time during the transmission the outlying subscriber wishes to recall the central exchange operator he may do so either by turning on and off the power momentarily by release and reoperation of key 36 or by momentarily operating recall key 12. Generally, if the central exchange is equipped with a flashing recall feature, recall key 12 is not furnished. However, recall key 12 may or may not be furnished when the flashing recall key is or is not provided at the central exchange. The operation of the recall key or the power switch disconnects the source of potential from line 11 at its subscriber's station. This will cause the receiving relay 52 as well as polar relay 51 to remain on the contact to which they were last operated and will allow relay 55 to release provided relay 65 is in its marking position. If relay 65 is not in its marking position other circuits described hereinafter function after a given time interval to periodically operate relay 65 to its marking position after which the operation of the circuits is as described below.

With relays 51 and 52 remaining on a given contact and relay 55 released, relay 57 will release and release relay 56 which in turn releases relays 58 and 64. When relay 56 releases it connects ground to the ring of jack 70 through its lower break contacts and the lower break contacts of relay 262. This ground causes the operation of relay 85 in the cord circuit over the ring of the plug 83 (see Fig. 3). Relay 85 in operating lights the supervisory lamp 86 of the cord circuit. Relay 85 in operating also operates relay 87 which locks operated through its upper make contacts. Then when the subscriber recloses the line either by releasing recall key 12 or by reoperating the power switch 36, potential is again applied to line 11 which in turn causes relays 55, 57, 56, 58 and 64 to operate. Relay 56 in operating removes the ground from the ring of jack 70 and allows relay 85 of the cord circuit to release. The release of relay 85 completes a path from interrupter 93 through the lower make contacts of relay 87 through the lower break contacts of relay 85 to lamp 86, which will cause this lamp to flash. Lamp 86 continues to flash until the operator operates key 89 at which time ground from the contacts of the splitting relay 114 (Fig. 4) is connected to the other side of the winding of relay 87 and causes this relay to release and disconnect the interrupter 93 from lamp 86. In the event that this flashing recall circuit is not provided lamp 86 is controlled directly from the contacts of relay 85. In this case it is necessary for the attendant at the subscriber's station to operate and release the recall key 12 or the power switch 36 as often as it is desired to flash the supervisory lamp 86.

Break signals

At any time during the transmission break signals may be transmitted either by the outlying

subscriber to the central exchange or from the central exchange to the outlying subscriber. The outlying subscriber transmits a break signal to the central exchange by operating switch or key 159.

5 This interrupts the circuit including the right-hand winding of relay 22 and the left-hand winding of relay 23 and permits the other windings of these relays to operate their armatures to their spacing positions. In their spacing positions relays 22 and 23 connect spacing potential to line 11 at the subscriber's station and causes relays 51 and 52 at the central station to move to their spacing positions during the transmission of the next marking impulse to the subscriber's station by relay 65. Relay 52 repeats the spacing or break signal over the tip of jack 70 to the operator or the other subscriber connected to the associated cord circuit and prevents the operation of relay 65 to its spacing position by spacing impulses transmitted over the tip of jack 70 from the cord circuit.

When break signals are transmitted from the central exchange to the outlying subscriber's station relay 65 is operated to its spacing position and repeats the break signal to line 11. At the subscriber's station relay 16 responds to the break signal and moves to its spacing position. In its spacing position relay 16 short-circuits resistance 242 and also the transmitting contacts 34 in addition to interrupting the circuit of printer magnet 32. This indicates to the subscriber that a distant operator or subscriber wishes to interrupt transmission and also prevents the transmission of impulses by the subscriber which might interfere with the reception of the break signal.

At the central station relay 67 also responds to the break signals by moving to its spacing position. In moving to its spacing position relay 67 removes the ground connected to the upper terminal of condenser 76 and permits this condenser to start to charge from battery through the high resistance 78. After an interval of time determined by the constants of condenser 76 and resistance 78, the potential of the upper terminal of condenser 76 will reach the potential required to initiate a discharge between the control elements of tube 75. In the preferred embodiment of this invention the constants of condenser 76 and resistance 78 are so chosen that it requires approximately 6 seconds to initiate a discharge through tube 75.

When a discharge is initiated between the control elements of tube 75, a discharge also takes place between the main anode of tube 75 and the cathode, which causes relay 66 to operate in a circuit from battery through its winding, the inner lower break contacts of relay 74, the inner upper break contacts of relay 263 to the main anode of tube 75. Relay 66, in operating, connects the transmission circuit of relay 65 to marking battery through the upper make contacts of relay 66 and the upper break contacts of relay 73. Relay 66, in operating, also completes a circuit for the operation of relay 74 from ground through the center set of upper make contacts of relay 66, lower make contacts of relay 66 to battery through the winding of relay 74. Relay 74, in operating, completes a holding circuit for maintaining relay 66 operated from battery through the winding of relay 66, inner lower make contacts of relay 74 to ground through the spacing contacts of relay 67 and interrupts the circuit of the main discharge through tube 75, thus extinguishing this discharge. Relay 74 also connects ground to the upper terminal of condenser 76 through its upper

make contacts and the upper break contacts of relay 263 to discharge condenser 76 and extinguish any remaining discharges between the elements of tube 75.

Relay 66 in operating also completes a circuit for the operation of relay 79 from ground through the lower inner make contacts of relay 66, winding of relay 79, source of alternating current 81 and interrupter 82. Relay 79 then follows the interruptions of interrupter 82. Relay 79, in operating, completes a circuit for the operation of relay 73 from ground through its contacts, the lower make contacts of relay 74, lower make contacts of relay 58 to battery through the winding of relay 73. Relay 73, in operating, completes a circuit from the spacing contact of relay 51 to the left-hand winding terminal of relay 57 for holding this relay operated. Relay 73, in operating, also transfers the transmission circuit from the front contact of relay 66 from marking battery to the upper winding of relay 67.

If the break or spacing impulse is no longer being transmitted over the system at this time, relay 67 operates to its marking contact and releases relay 66 which in turn causes the release of relays 74, 79 and 73. This restores the circuit to its normal transmitting condition.

If the spacing or break signal is still being transmitted over the system, relay 73 will transmit long marking impulses to the outlying subscriber at regular periodic intervals and indicate that there is some trouble in the system.

Tube 75 and relays 66, 74, 79 and 73 and their associated circuits by sending long marking impulses over line 11 permit an outlying subscriber to transmit recall or disconnect signals to the central exchange in case a long break signal due to trouble or other conditions is transmitted to the subscriber's station. Under extreme conditions of line leakage the spacing potential connected to the spacing contact of relay 65 will cause a sufficient current to flow through relay 55 and the leakage resistance of line 11 to maintain relay 55 operated independently of the removal of potential from line 11 by the subscriber in attempting to transmit a recall or disconnect signal to the central exchange as described herein. Consequently, it is necessary to remove the spacing potential applied by relay 65 to line 11 by operating this relay to its marking position and connecting ground to line 11 at periodic intervals during the long break or spacing signal to permit the subscriber to signal the operator at the central exchange at these times. In the preferred embodiment of this invention the marking interval transmitted to the subscriber's station is sufficiently long to permit the subscriber to cause the supervisory lamp to flash several times in case the central exchange equipment is not provided with a flashing recall circuit.

Disconnect

At the termination of transmission between the subscribers connected together through the central exchange the outlying subscriber will stop his machine by releasing the power switch 36. This disconnects power from the teletypewriter motor 33, rectifier 24 and relay 14. Relay 14 will release and connect line 11 to ground through ringer 40 and condenser 39 in parallel with condenser 38 and relay 37. This removes all sources of potential from line 11 at the subscriber's station. At the central station, this will permit relay 55 to release provided the transmission circuit through jack 70 is maintained

in a marking condition. With this transmission circuit in the marking condition relay 65 is maintained on its marking contact, and thus connects ground to line 11. Consequently the only sources of potential effective in line 11 are earth potential connected to line 11 through the leakage resistance of line 11 and cross-fire and interference. Relay 55 is arranged to release under these conditions. As pointed out above, relay 51 is made insensitive to any cross-fire and other interference which may be received by line 11 at this time so that it will remain upon whichever contact it was resting when line 11 was opened at the subscriber's station. With relay 55 released and relay 51 remaining on either one of its contacts for a short interval of time relay 57 will release and in turn release relay 56. Relay 56 in releasing connects ground to line 11 through its upper break contacts. Relay 56 in releasing also connects ground to the ring of jack 70 and causes relay 85 in the cord circuit to operate, which lights lamp 86 as described above under "Recall". However, in this case light 86 remains lighted and does not flash. This indicates to the operator that the subscriber has completed the call and turned off his equipment. The operator will then remove plug 83 from jack 70. This will allow relay 88 of the terminal equipment shown in Fig. 2 to release which in turn restores the circuit to its normal condition. Relays 58 and 64 previously released when relay 56 released. These relays in releasing cause relays 51, 52 and 65 to remain upon their marking contacts or move to these contacts and remain upon them.

If at the time the subscriber at the outlying station removes the source of potential from line 11 or opens line 11 relay 65 at the central station is on its spacing contact, potential will be applied to line 11 at the central exchange. Under extreme conditions of line leakage the current flowing from this source of potential on the spacing contact of relay 65 through the winding of relay 55 and the leakage resistance may be sufficient to maintain relay 55 operated. This will prevent a disconnect signal from appearing before the operator. At the time the spacing or break signal was applied to or received by the system due to any condition, trouble or otherwise, relay 67 which follows the signal impulses transmitted over the transmission circuit of jack 70 moves to its spacing contact. In moving to its spacing contact this relay removes ground from the upper terminal of condenser 76. This permits condenser 76 to start to charge from battery through the upper inner make contacts of relay 58 and resistance 78. Resistance 78 is of the order of several megohms and is related to the capacity of condenser 56 in such a way that the potential across condenser 76 rises very slowly.

A gaseous conduction tube 75 is provided with three elements comprising a control discharge path and a main discharge path. The electrodes of the control discharge path are connected across condenser 76 and resistance 77. When a potential across condenser 76 reaches the breakdown potential of tube 75 a discharge starts between the control elements of this tube and causes a discharge to flow between the main discharge elements of this tube. The main discharge then continues substantially independently of the potential across the control discharge elements.

The time constants of the condenser 76 and

resistances 78 and 77 are designed to give the desired time delay. In the preferred embodiment of this invention these elements are designed to give a time delay of approximately six seconds. This is the time required after relay 67 moves to its spacing position for the potential across condenser 76 reaches the breakdown potential of tube 75. If, during this time relay 67 should be operated by a marking signal to its marking contacts, it will connect ground to the upper terminal of condenser 76 and discharge it so that the charging process will have to start over again when relay 67 again moves to its spacing contact. If relay 67 is so operated, relay 65 will also be operated to its marking position and connect ground to line 11 which will permit relay 55 to release and light the disconnect lamp as described above.

If, however, relay 67 remains on its spacing contact for over the entire time interval required to initiate a discharge through tube 75, tube 75 in discharging will cause the relay 66 to operate. Relay 66 in operating operates relay 74 in a circuit traced from ground through the central upper make contacts of relay 68, the lower make contacts of relay 66 to battery through the winding of relay 74. Relay 66, in operating, transfers the circuit through the upper winding of relay 65 from the upper winding of relay 67 to the contacts of relay 73. It also connects ground to the winding of interrupter relay 79 which is operated from ringing current through condenser 80 supplied by generator or source 81. This ringing current is periodically interrupted by interrupter 82.

Relay 74 in operating locks relay 66 operated to the ground connected to spacing contacts of relay 67 and interrupts the main discharge path through tube 75 and thus extinguishes the main discharge through tube 75. Relay 74 in operating also connects ground to the upper terminal of condenser 76 and thus discharges it and extinguishes any and all remaining discharges between the elements of tube 75. Relay 74 in operating completes the circuit from the contacts of interrupter relay 79 through the lower make contacts of relay 74, lower make contacts of relay 58 to the winding of relay 73. This relay then follows the operations of relay 79 caused by interrupter 82. When relay 79 operates, relay 73 in turn operates. Relay 73 in operating connects the spacing contact of relay 51 to the left-hand terminal of the winding of relay 57 to hold relay 57 operated during this time. Relay 73 in operating also removes battery from the upper front contacts of relay 66 and thus transmits the spacing impulses to the subscriber's station if the transmission path through jack 70 is still open, that is, in a spacing condition. During the time relay 79 is released relay 73 will also be released. This will remove the holding circuit connected to the left-hand winding of relay 57. Relay 73 in releasing at this time also connects marking battery to the front make contacts of relay 66 which will cause relay 65 to be operated to its marking contacts. When relay 65 is in its marking position ground is connected to line 11 which will permit relay 55 to release if the subscriber has attempted to disconnect. Relay 55 in releasing will allow relay 56 to release as described above and light a cord supervisory light 86 in the cord circuit as described above. Relay 56 in releasing connects ground to line 11 so that if or when relay 73 again operates and causes relay 65 to move to its spacing contacts, relay 55 will not

be operated to extinguish the supervisory lamp 86 in the cord circuit. When the operator disconnects, relay 68 will be released as described above and in turn releases the other relays so the circuit is restored to its normal condition.

Calling outlying subscriber

In case another subscriber wishes to call an outlying subscriber over a single line section of a long telegraph channel or composited toll line that subscriber will signal the operator and the operator will insert answering plug 83 in the line jack of that subscriber. For purpose of illustration assume that the subscriber located at the station shown in Fig. 5 wishes to call the subscriber whose station equipment is shown in Fig. 1. Under these conditions the operator at the central exchange will insert plug 83 in jack 139 connected to the local subscriber's line. The operator can communicate to the subscriber shown in Fig. 3 in the usual manner for local calls. Briefly, the local subscriber shown in Fig. 5 will operate the power switch 243 which energizes rectifier 153, motor 158, and relay 244. Relay 244 closes the subscriber's line circuit and causes relay 141 to operate. Relay 141 in operating operates relay 142 which in turn causes lamp 144 to operate. In answering the calling subscriber the operator will insert plug 83 in jack 139. This operates relay 140 and permits relay 141 of the subscriber's line circuit shown in Fig. 5 to release. Relay 84 of the cord circuit is operated in series with relay 140. The release of relay 141 releases relay 142 which in turn extinguishes light 144.

With the key 89 of the cord circuit operated as before, the transmission path is completed from the operator's teletypewriter equipment 103 to the subscriber's teletypewriter equipment 245 located at the subscriber's station. If the operator at the central station has received the information from the subscriber located at the station shown in Fig. 5 directing the central station operator to connect the subscriber's station shown in Fig. 5 with the subscriber's station shown in Fig. 1, the operator will insert the calling plug 101 in jack 70. This will cause relays 98 of cord circuit (Fig. 3) and 68 of the terminal circuit shown in Fig. 2 to operate. Relay 68 in operating completes the transmission path from the tip of the jack 70 through the upper winding of relay 67, the upper break contacts of relay 66 and winding of relay 65 to the contacts of relay 52. Relay 68 in operating also closes the biasing circuit of the lower winding of relay 67. A circuit is also completed from ground through condenser 246 and winding of relay 59, inner bottom break contacts of relay 58 to the armature of the upper make contacts of relay 68 to the tip of jack 70.

When the operator operates ringing key 100 of the cord circuit ringing current is connected to the tip of plug 101 which in turn is connected to the tip of jack 70. Relays 65 and 67 may respond to this ringing current but perform no useful function at this time. It should be noted that relay 67 in following the ringing current is in its marking position each cycle long enough to completely discharge condenser 76 and thus prevents a discharge through tube 75. Relay 59, however, will respond to the ringing current from the contacts of key 100. Relay 59 in responding completes an obvious circuit for the operation of relay 263. Relay 263 in operating completes a circuit from ground through the lower break contacts of relay 56, the lower break contacts of

relay 262 the lower make contacts of relay 263 to the winding of relay 60. Relay 60 in operating operates relay 50 which is slow release and also connects ringing current to the make contacts of relay 50 which in turn connects the ringing current to line 11. Ringing current is transmitted over line 11 to the subscriber's station and causes ringer 40 to respond to it over a path from line 11 through ringer 40, and condenser 39 to ground.

When the operator inserted plug 101 in jack 70 ground is also connected to the ring of jack 70 from the lower break contacts of relay 56 through the lower break contacts of relay 262. Relay 97 in operating in this circuit over the ring of plug 101 connects ground to the circuit of lamp 102, and causes this lamp to light.

When the subscriber answers, the subscriber will operate power switch 36 which will energize rectifier 24, teletypewriter motor 33 and operate relay 14. Relay 14 will close the subscriber's line circuit as described above and cause relay 55 at the central station to operate which in turn operates relay 57. Relay 57 operates relay 56 which removes ground from the ring of jack 70 and thus allows relay 97 to release and extinguish light 102.

It should be noted that relay 50 in operating interrupts the circuit of relay 55 so that relay 55 can only be operated during time intervals when no ringing current is being transmitted to the subscriber's station. In order to prevent false operations of relay 55 as well as relays 51 and 52, relay 50 is made slow in releasing so that when the operator releases ringing key 100 in cord circuit relay 59 will release which in turn releases relays 263 and 60. Relay 60 in turn releases relay 50. However, relay 50 does not release immediately so that relay 60 connects line 11 to ground through resistance 237 during the release time of relay 50. The release time of relay 50 is sufficiently long to discharge the cable capacity of line 11 so that relay 55 will not be falsely operated when relay 50 releases.

When the subscriber answers, the operation of the system is substantially as described above except that the supervisory lamp 102 of the cord circuit now responds to recall and disconnect signals transmitted from the outlying subscriber's station shown in Fig. 1 instead of lamp 86.

Unattended service

In cases where it is desired to furnish unattended service to the outlying subscriber and the outlying subscriber does not answer after several short rings, the operator at the central station will depress the ringing key 100 for a long interval of time.

At the central exchange relays 59, 263, 60 and 50 operate as described above for attended service and transmit ringing current over line 11 to the subscriber's station. However, it should be noted that when relay 263 operates it also connects battery to the upper terminal of condenser 76 through the center set of its upper make contacts and high resistance 264 and permits this condenser to start to charge. Relay 263 also transfers the main anode circuit of tube 75 to battery through the winding of relay 262, the inner upper make contacts of relay 262 and the inner upper make contacts of relay 263. At the end of the interval of time determined by the constants of condenser 76 and resistance 264, a discharge is initiated between the control elements of tube 75 which causes a discharge be-

tween the cathode and main anode of tube 75. In the preferred embodiment of this invention these constants are so chosen that it requires approximately 9 seconds for the potential of condenser 76 to reach the value required to initiate a discharge through tube 75.

If at any time during this interval the operator releases the ringing key, relays 59, 263, 60 and 50 will release. Relay 263, in releasing, will again complete a circuit from the upper terminal of condenser 76 to ground through the upper break contact of relay 263 and the marking contact of relay 67. Condenser 76 is discharged in this circuit but will again start to charge after the operator again operates ringing key 100.

If, however, the operator maintains the ringing key 100 in the cord circuit operated during this entire time interval so that relays 59, 263, 60 and 50 remain operated, tube 75 in discharging causes the operation of relay 262. Relay 262, in operating, completes a locking circuit from battery through its windings and upper make contacts to ground through the upper make contacts of relay 263 and interrupts the main discharge circuit of tube 75. Relay 262, in operating, also connects ground to the upper terminal of condenser 76 to discharge this condenser and extinguish any remaining discharges between the elements of tube 75. Relay 262 in operating interrupts the operating circuit of relay 60 from ground through the lower break contacts of relay 56 and lower break contacts of relay 262 and the lower break contacts of relay 263 to battery through the winding of relay 60. Relay 60 releases and in turn interrupts the operating circuit of relay 50 and causes this relay to release. As pointed out above, the charge stored in the capacity of line 11 is discharged through resistance 237 during the release time of relay 50. The release of relay 50 connects line 11 to the upper windings of relays 51 and 52 and to the winding of relay 55. If the subscriber's apparatus has responded as described hereinafter, relay 55 will operate at this time. Relay 262, in operating, also interrupts the circuit from ground through the lower break contacts of relay 56, lower break contacts of relay 262 to the ring of jack 70. This permits the release of relay 97 in the cord circuit shown in Fig. 3, which in turn extinguishes the supervisory lamp 102 to indicate to the operator that the called subscriber has answered. The operator will then release ringing key 100. This releases relays 59, 263 and 262 as described above.

At the subscriber's station the ringing current received over line 11 from the central station will operate ringer 40 and will also operate relay 37 through condenser 38 for this entire interval of time. Relay 37 in operating operates relay 41. Relay 41 is arranged to be very slow in operating and in the preferred embodiment of this invention requires about 8 seconds to operate. If the ringing current remains on line 11 for at least 8 seconds so that relay 37 maintains the circuit of relay 41 closed for this entire interval, relay 41 will operate and in turn operate relay 42. Relay 42 in operating locks operated through its lower make contacts, break contacts of power switch 36 and teletypewriter stop contacts 35. Relay 42 in operating also connects power to the subscriber's station apparatus in the same manner as power switch 36; i. e., energizes rectifier 24, starts the printer motor 33 and operates relay 14. The subscriber's station is then ready

to record any messages that may be transmitted to it.

When potential is applied to line 11 from rectifier 24 by operation of relay 14 at the subscriber's station and relay 50 at the central station is released as described above, relay 55 will be operated and in turn cause relays 57, 56, 58 and 64 to operate as described when the subscriber originates a call. The operation of relay 56 will prevent reoperation of relay 97 of the cord circuit at this time and thus indicate to the operator that the subscriber's equipment has been started and is ready to receive messages.

If the equipment at the subscriber's station does not start as described above no potential will be applied to line 11 at the subscriber's station and relay 55 at the central exchange will not operate when relay 50 releases after the operator has released ringing key 100. Under these conditions, relay 97 will again operate when relay 262 releases and thus indicates to the operator that the subscriber's equipment did not start whereupon the central exchange operator can again attempt to start the equipment by again operating ringing key 100 for the prolonged interval of time during which the circuits operate as described above.

The operation of an unattended subscriber's station is similar to that described above except that when the transmission of the message is complete a motor stop signal is transmitted to the teletypewriter equipment which causes the operation of contacts 35. The contacts 35 in operating open a locking circuit of relay 42 which in turn disconnects the station equipment from the source of power 43 and transmits a disconnect signal to the operator at the central switchboard, thus indicating that the subscriber's equipment has returned to normal.

The above-described circuits permit the operator at the central exchange to both call and start the subscriber's equipment over a long toll line in the same manner that she calls and starts the motor equipment at local subscriber's stations. In addition, the outlying subscriber continuously and positively controls the supervisory signals at the central station. The outlying subscriber can transmit calling, recall and disconnect signals to the central exchange station at all times and these signals are continuously under the direct control of the outlying subscriber. These circuits provide the above features and at the same time permit the loop and leakage resistance to be extended to the full capabilities of the self-compensating transmitting circuits described in the above identified copending application.

If the outlying subscriber wishes to abandon a call at any time he may do so by releasing power switch 36 which will cause the calling lamp to be extinguished if the call has not been answered by the central station operator; change the flashing recall signal to a disconnect signal; or transmit a disconnect signal to the central station operator in the same manner as a local subscriber transmits and controls these supervisory signals at the central exchange. Thus it is unnecessary for the operator to do anything merely to restore a circuit to normal or restore any signal to normal.

It is to be understood that the invention is not limited to the particular type of switchboard circuits shown and described. The terminal circuits may be arranged to cooperate with any suitable type of switchboard or other switching

equipment including automatic or machine switching circuits. In addition, the invention is not limited to the particular circuit arrangements for operating the various relays and tubes or for securing the necessary or desired time delays, it being understood that other suitable circuits and apparatus may be employed for performing these functions without affecting the scope of this invention as defined in the claims appended hereto.

MULTI-LINE SECTION

General description

When the outlying subscriber is beyond the limits of a single-section line, it is necessary to provide intermediate stations or repeater points along the line. Generally, the length of a single-section line over which the single-line section may operate depends upon the type of line employed. For open wire composite lines the maximum length is around 300 miles, provided the resistance does not exceed 2100 ohms. For simplex open wire lines the maximum length is about 200 miles. For cable lines the maximum length is of the order of 125 miles.

When the subscriber's station is located at a greater distance from the central switching point than the maximum limit of the particular type of line connected to the subscriber's station, one or more intermediate sections is connected between the subscriber's station and the central exchange.

The subscriber's station circuit is exactly the same as for the single-section line and the line circuit between the subscriber's station and the first repeater point is similar to the single-section line. At the repeater point, however, slightly different terminal apparatus is provided.

Between this intermediate or repeater point and each succeeding intermediate or repeater points, and between the last intermediate or repeater point and the central office, a single full duplex telegraph circuit or channel is required.

At the central office an additional terminal circuit arrangement is provided to relay both the supervisory and telegraph signal impulses received over the full duplex line to the operator.

The full duplex channel between the intermediate repeater points and between the central exchange and the last intermediate repeater point may be of any suitable type including a grounded open wire full duplex circuit, full metallic full duplex cable or open wire circuits, a full duplex voice frequency carrier telegraph channel or carrier current full duplex telegraph channel. These telegraph channels may be channels of telegraph wires or of composited toll line wires which transmit telephone currents in addition to the telegraph channel currents. The carrier current channels may include carrier current amplifiers, filters, gain regulators and other equipment usually associated with carrier current lines and channels. As described in this application, a long open wire grounded full duplex telegraph circuit is shown in the intermediate section.

This intermediate section, shown in Fig. 7, is arranged to provide the self-compensating feature described in the above-identified copending application.

In said above-identified application a half duplex telegraph system was described, in which signals could be transmitted in either direction, one direction at a time, but not in both direc-

tions at the same time. In the intermediate section shown in the multi-section line, the circuit has been arranged to provide full duplex operation between the two stations and at the same time provide for the self-compensating feature described in said copending application, so long as the circuit is operated on a half duplex basis. This is the way the circuit is operated to transmit telegraph signaling impulses to and from the subscriber's station. Telegraph impulses are transmitted over the long line either to or from a subscriber's station only in one direction at a time. However, it is necessary for supervisory purposes to provide a full duplex channel over these intermediate sections. When it is desired to transmit the supervisory signals over the intermediate sections, it is usually not desirable or necessary to transmit telegraph signaling impulses, so that slight distortion introduced by variation of the leakage resistance of the intermediate line section at these times is of small importance. The essential requirement is that the line operate substantially independent of the leakage resistance of the line during the time the circuit is arranged for transmitting telegraph signal impulses either to or from the subscriber's station.

Idle condition

Reference will now be made to Figs. 1, 6, 7, 8, 3, 4 and 5, arranged as shown in Fig. 10 of the drawings. The operation of Fig. 1 was described in detail with reference to the single line section and need not be repeated. It should be noted, however, in this case line 11 connected to the subscriber's station, shown in Fig. 1, terminates in an intermediate circuit arrangement, shown in Fig. 6. The repeater equipment 199, shown in Fig. 7, as well as the equipment shown in Fig. 6, is located at the intermediate repeater point. This intermediate equipment is connected over line 207 to the central exchange station. The line 207 may be similar to line 11 and include both terminal and intermediate composite sets and other equipment usually associated with long telegraph or toll lines.

The terminal equipment at the central station includes repeater equipment 208, shown in Fig. 7, as well as the equipment shown in Fig. 8.

Equipment is shown in Figs. 6, 7 and 8 in their normal or idle condition with the subscriber's station equipment idle and unenergized, and the equipment at the central station in its normal condition and not connected to any cord circuit. At the intermediate station relays 162 and 163 are maintained on their marking contacts by current flowing from battery through the inner lower contacts of relay 181, middle winding of relay 162, lower winding of relay 163, to ground connected through the lower break contacts of relay 181. Relay 182 is maintained in its marking position by current flowing from battery through the uppermost break contacts of relay 177, through the lower winding of relay 182 to ground. Relay 188 is maintained in its spacing position by current flowing through its lower winding in an obvious circuit. Relay 203 of repeater equipment 199 is maintained in its spacing position by current flowing through its lower winding in an obvious circuit. The circuit through the upper winding of relay 203 is interrupted by the uppermost make contacts of relays 181 and 183. Relay 201 of repeater equipment 199 is maintained in its spacing position by current received over line 207 from the central sta-

tion. Relay 174 (see Fig. 6) is maintained in the position shown by an obvious circuit through its lower winding.

At the central station, relay 210 of repeater 208 is maintained in its spacing position by current received from relay 203 over line 207. Relay 213 is also maintained in its spacing position by relay 220, and relay 220 is maintained in its spacing position by current flowing through its lower windings from the marking contact of relay 226 to ground. It should be noted that the circuit of the upper winding of relay 220 is open at the upper contacts of relay 211. Relay 226 is maintained in its marking condition by current flowing through the upper break contacts of relay 227 and the lower winding of relay 226 to ground. Relay 232 is maintained on its spacing contacts by an obvious circuit through its lower winding. Relay 233 is maintained in the position shown by current flowing through its upper windings, through the armature and spacing contact of relay 232, upper break contact of relay 235 to ground, through the upper winding of relay 233. Current through an obvious circuit flowing through the lower winding of relay 233 tends to operate relay 233 to its opposite contact but is prevented from doing so by the current flowing through the upper winding. Relay 229 is also maintained in the position shown by an obvious circuit through its middle winding. The remaining relays remain in the position shown until energized by currents flowing through their windings.

Subscriber initiates a call

As before, the outlying subscriber operates power switch 36 to initiate a call. This causes a negative potential to be applied to line 11 at the subscriber's station. This negative potential causes relay 167 at the intermediate point, shown in Fig. 6, to operate.

Relay 167, in operating, completes a circuit from battery connected to the spacing contacts of relay 162 through its lower contacts and winding of relay 166 to ground through the marking contacts of relay 162 for operating relay 166. Relay 166, in operating, causes relay 168 to operate, which in turn causes relay 175 to operate and transfers the circuit of line 11 from ground through its upper break contacts to the armature of relay 182. Relay 175, in operating, causes relay 181 to operate. Relay 175 also connects the winding of relay 260 to ground but this relay remains in the position shown at this time because the current flowing through the winding from the marking contact of relay 163 to ground on the contacts of relay 175 is in such a direction as to maintain this polarized relay 260 in the position shown. With relay 260 in the position shown, the operation of relay 175 completes a circuit from ground through its lowermost contacts, armature contacts of relay 260, through the upper winding of relay 174, causing relay 174 to operate to its right-hand position. This operation of relay 174 performs no useful function at this time.

The operation of relay 181 transfers the circuit through the lower winding of relay 163 and the middle winding of relay 162 to line 11 and thus prepares these relays for the reception and transmission telegraph signal impulses from and to the subscriber's station. Relay 181 also completes a circuit from negative battery through the marking contacts of relay 163, upper break contacts of relay 173, upper make contacts of

relay 181, through the upper winding of relay 203 to positive battery. This causes relay 203 to operate to its marking position and transmit marking current over line 207 to the central exchange where relay 210 responds to this marking current and connects positive battery to a circuit extending through its marking contacts, resistance 215, line 217, thence through the upper winding of relay 232, upper back contacts of relay 230, and the upper winding of relay 226 to negative battery. This causes relay 232 to move to its marking position. The operation of relay 232 interrupts the circuit through the upper winding of relay 233. As soon as this circuit is interrupted, condenser 250 starts to discharge through the upper winding of relay 233. After about two-tenths of a second the discharge current from condenser 250, flowing through the upper winding of relay 233, falls to such a value that the current flowing through the lower winding of this relay overpowers it and causes the armature of relay 233 to move to its other position. This completes a circuit from ground through the armature and left-hand contacts of relay 233, lowermost break contacts of relay 235, break contacts of relay 228, and the winding of relay 227 to battery. Current flowing in this path causes relay 227 to operate. Relay 227 then locks operated in a circuit from battery through its winding, the break contacts of relay 228, to ground through the center set of lower make contacts. Relay 227, in operating, connects the lower winding of relay 226 to the armature of relay 220 and thus prepares the bias circuit of relay 226 for the transmission of signal impulses through the circuit. The operation of relay 227 also completes a circuit from ground through its lower innermost make contacts, lower break contacts of relay 211 to battery through the winding of relay 225. This causes relay 225 to operate, which in turn completes an obvious circuit for lighting the answering light associated with the jack 223 of the terminal equipment. Relay 227 also completes a circuit for operating relay 234 from ground through its lowermost make contacts, lower inner break contacts of relay 235 to battery through the winding of relay 234. The operation of relay 234 again connects battery to the upper winding of relay 233, causing this relay to move to its right-hand position and also causing condenser 250 to become fully charged. Relay 233, in operating, completes a circuit for the operation of relay 235 from ground through its armature and right-hand contacts, lower make contacts of relay 234, upper break contacts of relay 230 to battery through the winding of relay 235. In operating, relay 235 locks on a circuit from ground through the lowermost contacts of relay 227 and the inner make lower contacts of relay 235. Relay 235 also connects the marking contact of relay 232 through its innermost upper make contacts to condenser 250 and the upper winding of relay 233 for maintaining this relay in its right-hand position so long as relay 232 remains on its marking contact. The operation of relay 235 interrupts the operating circuit of relay 234 through the innermost break contacts of relay 235, thus permitting relay 234 to release.

Operator answers

The operator observing the lamp 224, answers the call by inserting plug 83 in jack 223. This completes a circuit for operating relay 211 from ground through its winding, the sleeve of jack 223, sleeve of plug 83 to battery through the winding of relay 84 and resistance 240. Relay 211, in

operating, interrupts the operating circuit of relay 225, which thereupon releases and extinguishes a lamp 224. Relay 211, in operating, also completes a transmission circuit from the tip of the plug 83 of the cord circuit, shown in Fig. 3, through the upper winding of relay 220. This causes relay 220 to be operated to its left-hand or marking position, which in turn causes relay 213 to move to its marking position and transmit marking current over line 207 to the repeater 199 at the intermediate station. Relay 201 responds to this marking current by moving to its marking position and in turn causes relay 188 to move to its marking position by causing current to flow through its upper winding.

Relay 188 in operating to its marking position completes a circuit for operating relays 194 and 179 in series from ground through the armature and marking contacts of relay 188, the lower break contacts of relay 193, the upper break contacts of relay 194 through the windings of relays 194 and 179 to battery. Relay 194 in operating closes a locking circuit for locking relays 194 and 179 operated from ground through the upper break contacts of relay 178, the upper make contacts of relay 194 through the windings of relays 194 and 179 to battery. Relay 194 in operating also disconnects ground through its lower break contacts, lowermost contacts of relay 184 from a control element of tube 252 and upper terminal of condenser 185, and connects battery through high resistance 186 to this condenser. The innermost upper make contacts of relay 194 connect the marking contact of relay 188 to this condenser so that when relay 188 is on its marking contact it will discharge the upper terminal of condenser 185.

Relay 179 in operating connects battery through resistance 253 and its upper make contacts to the left-hand winding terminal of alternating current relay 166 and also to the marking contact of relay 162. Relay 179 in operating also connects the spacing contact of relay 188 through the middle set of make contacts of the lower set of contacts of relay 179 to the right-hand terminal of the winding of alternating current relay 171. Through the innermost lower make contacts of relay 179 a circuit is completed for operating relay 177 from ground through the lower contacts of relay 175, innermost lower contacts of relay 179 through the winding of relay 177 to battery.

Relay 177 in operating connects the lower or biasing winding of relay 182 to the armature of relay 163 and prepares this relay for repeating signals through the circuit. Relay 177 in operating disconnects battery through its innermost upper contacts from the right-hand winding terminal of relay 171 thus preventing this relay from operating. Relay 177 also completes a circuit from battery connected to the spacing contact of relay 162 through its lowermost contacts, condenser 259 to the right-hand winding of relay 166.

Transmission between the central exchange and the subscriber

The circuits are now in condition for transmitting signaling impulses between the subscriber's station and the central office. During the time signal impulses are being transmitted by the subscriber's station by the operation of transmitting contacts 34, impulses of positive and negative current in accordance with the signals to be transmitted are applied to line 11 from rectifier 24 by relays 22 and 23. These signal impulses

cause receiving relay 163 and relay 162 to follow these signals. Relay 167 which is similar to relay 55 of Fig. 2 may not follow these signals or remain operated during the time they are transmitted. If this relay releases, relay 162 in moving between its marking and spacing contacts reverses the charge on condenser 259 through the winding of the alternating current relay 166, thus maintaining this relay on its marking contact. During pauses between the transmission of signaling impulses over line 11 a long marking signal condition is transmitted over line 11 and relay 167 will operate and complete a direct current circuit from battery connected to the spacing contact of relay 162 through the lower make contacts of relay 167 and winding of relay 166 to ground connected to the armature of relay 162. It is to be noted that during long spacing impulses relay 167 is operated and completes the same direct current circuit but the direct current flows through the winding of relay 166 in the opposite direction. Relay 166 is maintained operated by both currents so it remains operated as long as relay 167 is operated.

Relay 163 repeats the signal impulses to relay 203 over a circuit from its armature through the upper break contacts of relay 173, uppermost make contacts of relay 181 through resistance 205 and the upper winding of relay 203, resistance 204 to positive battery. Relay 203 follows the signaling impulses and repeats them to line 207 by connecting alternate positive and negative potential to this line through noise suppression choke 202 and the upper winding of relay 201.

As pointed out above the transmission over line 202 is arranged so that the bias of the signals will not be appreciably affected by the leakage resistance or changes of the leakage resistance of line 207 in accordance with the description in the above-identified copending application. However, as pointed out above, in the arrangement shown in Fig. 7 the circuit is arranged for full duplex operation. This necessitates a direct current path through the balancing network 200 and the balancing winding as described in said copending application.

The signal impulses transmitted from relay 203 over line 207 cause the receiving relay 210 of repeater 208 at the central station to repeat the received signal impulses over line 217 to relays 232 and 226. In order to secure full duplex operation it is necessary to provide a direct current path in the balancing network connected to the biasing winding of relay 210. However, during the reception of signals from the intermediate station with relay 213 in its marking position ground is connected to both terminals of this winding so that it will apply no bias to receiving relay 210. This relay will therefore respond equally to positive and negative signals or impulses transmitted by relay 203.

Relay 226 responds to the signals and repeats them to the tip of the cord circuit through the upper winding of the sending relay 220, upper make contacts of relay 211, to the tip of jack 223. From the tip of jack 223 the signals are transmitted over tip of plug 83 to the cord circuit shown in Fig. 3. The signals are either transmitted through this cord circuit to another subscriber connected thereto over the calling plug 101 and the subscriber's line, or to the operator when key 89 is operated.

Relay 232 also follows the signals received over line 217. However, these signals are sufficiently rapid to prevent relay 233 from being operated

to its left-hand contact. When relay 232 is in its marking position it fully charges condenser 250 in a very short interval of time and relay 232 is not on the spacing contact long enough to permit condenser 250 to become sufficiently discharged to allow relay 233 to operate to its left-hand contact since it requires approximately .2-second for this relay to operate.

Relay 260 at the intermediate station also follows the signal impulses transmitted from the subscriber's station but does not remain with its contacts open for a sufficiently long interval to allow the slow-acting relay 174 to respond to the operation of relay 260 at this time.

Signals transmitted from the cord circuit shown in Fig. 3 cause relay 220 of Fig. 8 to repeat them over line 218 to sending relay 213 of repeater 208 at the central station. This relay repeats the signals to line 207 through the noise filter 219, resistance 212 and upper winding of receiving relay 210. Relay 213 connects ground and positive potential to line 207 in accordance with the signals to be transmitted.

The potential connected to the spacing contact of sending relay 213 is related to the potential connected to the marking and spacing contacts of relay 203 and to the distribution of both the leakage resistance and line resistance of line 207 and the bias current flowing through the lower winding of relay 201 so that relay 201 responds equally well to both the marking and spacing impulses transmitted over line 207 from relay 213 substantially independent of the leakage resistance or changes in leakage resistance of line 207.

In the preferred embodiment of this invention the potential connected to the spacing contact of relay 213 is twice the magnitude of the potentials connected to the marking and spacing contacts of relay 203 of repeater 199 and is of the same plurality as the potential connected to the spacing contact of relay 203. Thus during the transmission of signal impulses over line 207 from repeater 208 at the central exchange to repeater 199 at the intermediate repeater point, the spacing current impulse is substantially three times the magnitude of the marking impulse.

As pointed out in the above-identified copending application, the values of these potentials may be obtained by connecting suitable sources of potentials to the contacts of these relays or they may be obtained by adjusting the resistances 212 and 261 in the two repeaters. As pointed out in the above-identified copending application, resistance 212, the lower or balancing winding of relay 210 and the resistance of the balancing or artificial line 209 form a potentiometer with the line winding of relay 210 connected to its center point. By varying the value of resistance 212 the effective transmitting potentials applied to line 207 may be varied so as to secure the proper transmitting potentials and currents whereby the receiving relay 201 of repeater 199 respond equally well to both marking and spacing signal impulses transmitted from repeater 208 substantially independently of the leakage resistance or changes of the leakage resistance of line 208. In a similar manner resistance 261 may be varied to control the effective transmitting potentials applied to line 207 by repeater 199 so as to secure the proper transmitting potentials and currents necessary to provide self-compensating operation in the reverse direction.

Key 216 of repeater 208 is provided to change the transmission over line 207 so that it will be substantially the same as for the usual or nor-

mal differential polar full duplex operation. In this case it is necessary to interrupt the biasing or lower winding of the receiving relay 201 of repeater 199 at the intermediate repeater station.

Relay 201 responds to the signals transmitted over line 207 by relay 213 and repeats them over line 190 to relay 182. Relay 188 also follows these signals but does not cause or permit the operation of any other apparatus or relays at this time. Relay 188 does not remain off its marking contact sufficiently long to allow condenser 185 to acquire the charge required to cause a discharge through tube 252. Since no battery is connected to the right-hand winding terminal of relay 171 at this time the alternate completing and interrupting the circuit through the spacing contact of relay 188 to ground is unable to operate ringing relay 171.

Relay 182 repeats the signal impulses to line 11 in the same manner that relay 65 of Fig. 2 repeats the impulses to line 11. The impulses are transmitted over line 11 as described above and operate the subscriber's teletypewriter equipment 44 as described above. The potential connected to the spacing contact of relay 182 is related to the potentials developed by the rectifier 24 at the subscriber's station and to the constants of line 11 in the same manner as is the potential connected to the spacing contact of relay 65 as described above.

Recall

The subscriber may recall the central station operator at any time during the time this line is connected to a cord circuit either by momentarily releasing and reoperating power switch 36 or operating and releasing recall key 12. The operation of either of these switches removes potential from line 11 at the subscriber's station. This permits relay 167 to release during marking intervals and causes relays 162 and 163 to remain upon one of their contacts sufficiently long to permit relay 166 to release which in turn release relays 168, 175, 181 and 177. The release of relay 181 interrupts the transmission circuit over line 191 to relay 203 which is operated to its spacing position by current flowing through its lower winding and transmits a spacing impulse over line 207. Relay 210 of repeater 208 at the central station responds by moving to its spacing position and repeats the spacing impulse to relays 232 and 226. Relay 226 repeats the spacing impulse over the tip of jack 223 to the cord circuit shown in Fig. 3, and thence to the other subscriber's line circuit or the operator's circuit connected thereto.

Relay 232 in moving to its spacing contacts, interrupts the circuit of the upper winding of relay 233 and permits condenser 250 to discharge through it. After approximately the .2-second required for condenser 250 to sufficiently discharge, relay 233 is operated to its left-hand position by current flowing through its lower winding. In its left-hand position, relay 233 completes a circuit for the operation of relay 229 from ground through the left-hand contacts of relay 233, lower outer make contacts of relay 235, lower break contacts of relay 231 to battery through the upper winding of relay 229. Relay 229, in operating, locks operated in a circuit from ground through its lower winding, the uppermost make contacts of relay 235 to battery through the spacing contacts of relay 232. It is assumed that relay 232 will remain in its spacing position sufficiently long to light the supervisory cord circuit light as will be described. If relay 232 does

not remain in this position the required time it will release relay 229 and restore the circuits to the transmitting condition.

Relay 229, in operating, completes an obvious circuit for operating relay 230. Relay 230, in operating, completes a circuit for operating relay 234 from ground through its lower make contacts, the upper break contacts of relay 231 to battery through the winding of relay 234. Relay 234, in operating, again connects battery to condenser 250 and the upper winding of relay 233, causing this relay to operate to its right-hand position. In its right-hand position relay 233 now completes a path for the operation of relay 231 from ground through its right-hand contacts, the lower make contacts of relay 234, the upper make contacts of relay 231 to battery through the winding of relay 231. Relay 231, in operating, locks operated in a circuit from ground through the lower make contacts of relay 230, the upper make contacts of relay 231 to battery through the winding of relay 231. Relay 231, in operating, also interrupts operating circuit of relay 234 which in turn releases. Relay 234, in releasing, again removes battery from the upper winding of relay 233 which after the .2-second delay interval again operates to its left-hand position. In its left-hand position relay 233 now completes a circuit for the operation of relay 228 from ground through the left-hand contacts of relay 233, the lowermost make contacts of relay 235, lower make contacts of relay 231 to battery through the winding of relay 228. Relay 228, in operating, interrupts the locking circuit of relay 227 which in turn releases. Relay 227, in releasing, connects ground to the ring of jack 223 which causes relay 85 of the cord circuit, shown in Fig. 3, to operate and relight the supervisory lamp 86 provided answering plug 83 is inserted in jack 223. If calling plug 101 is inserted in jack 223, then relay 97 will be operated by ground from the innermost lower break contacts of relay 227 and in turn light the supervisory lamp 102. Relay 227, in releasing, causes the interruption of the circuit holding relays 228 and 235 operated. Relay 235, in releasing, interrupts the locking circuit of relay 229 and in turn releases and permits the release of relays 230 and 231.

When the subscriber again applies power to line 11 by reoperating power switch 36 or releasing recall key 12, relays 167, 166, 168, 175, 181 and 177 are again operated as described when the subscriber initiates a call. This causes relays 203, 210, 232 and 226 to be moved to their marking positions as described above. Relay 232, in moving to its marking position, causes relay 233 to move to its left-hand position which in turn operates relay 227. The operation of relay 227 removes ground from the ring of jack 223 and permits either relay 85 or 97 to release. Relay 227, in operating, causes relay 234 to operate which in turn operates relay 233 to its right-hand position. In its right-hand position relay 233 now completes the operating circuit of relay 235 which locks operated under control of relay 227. Thus the transmitting circuits are again restored.

If the associated cord circuit is not provided with flashing recall circuits the supervisory lamp follows the operation of the recall key 12 or power switch 36 at the subscriber's station, as described above. If, however, the cord circuit is provided with flashing recall circuits the supervisory lamp will flash until the operator operates the transmitting key associated with that cord

circuit. This will extinguish the supervisory lamp as described above. The operator will then communicate with the subscriber to determine the additional service requested by the subscriber.

Break signal

The subscriber may transmit the break signal by operating a break key 159 of his teletypewriter equipment 44. This causes relays 22 and 23 to apply positive battery to line 11 which operates relays 162 and 163 at the intermediate point to their spacing positions. Relay 167 operates or remains operated and holds relay 166 operated. Relay 166 in remaining operated holds the remaining relays in their transmitting positions. Relay 163 repeats the break signal to relay 203 which in turn repeats it to line 207. Relay 260 which follows relay 163 opens the circuit from ground through the lowermost contacts of relay 175, armature and contacts of relay 260, to battery through the upper winding of relay 174, in response to a break signal received and repeated by relay 163. When relay 260 breaks the circuit through its contacts, condenser 247 starts to charge from battery through the upper winding of relay 174, condenser 247 and resistance 248 to ground. The charging current of condenser 247 flowing through the upper winding of relay 174 is sufficient to maintain this relay operated for an interval of time. In the preferred embodiment of this invention this current will maintain relay 174 operated in its right-hand position for approximately .3 second after the relay 260 has operated. At the end of this time interval the charging current of condenser 247 falls to such a value that the current flowing through the lower winding of relay 174 is sufficient to overpower it and cause relay 174 to be operated to its left-hand position. In this position relay 174 connects ground through its left-hand contact, innermost lower make contact of relay 175 to the winding of relay 173. This causes relay 173 to operate and connect source of ringing current 172 to the upper winding of relay 203 through the upper make contact of relay 181.

It should be noted that due to the delay of .3 second in the operation of relay 174 by the charging current of condenser 247, the momentary opening of the contacts of relay 260 during transmission of signal impulses is ineffective to operate relay 174 so that the application of ringing current to relay 203 is dependent upon a long break signal of more than .3 second duration.

Relay 203 thereupon follows 20 cycle ringing current and transmits impulses at this rate over line 207 to the central station.

At the central station when the break signal from relay 203 is first received it causes relays 232 and 226 to move to their spacing positions. Relay 226 repeats the break signal to the teletypewriter apparatus connected to the cord circuit shown in Fig. 3. Relay 232 in operating to its spacing position disconnects battery from condenser 250 and the upper winding of relay 233. Substantially .2 of a second later, relay 233 operates to its left-hand position and connects ground through its left-hand contacts, lowermost make contacts of relay 235, lower break contact of relay 231 to battery through the upper winding of relay 229. Current flowing through the upper winding of this relay overpowers the current flowing through the middle winding of relay 229 and causes this relay to operate to its left-hand position. In this position relay 229 completes an obvious circuit for the operation of

relay 230. Relay 230 in operating completes a circuit for operating relay 234 from ground through the lower make contacts of relay 230, the upper break contacts of relay 231 through the winding of relay 234 to battery. Relay 234 in operating again connects battery to the upper winding of relay 233 which causes relay 233 to be operated to its right-hand contact. Relay 233 in operating to its right-hand position completes a circuit for operating relay 231 from ground through its right-hand contacts, lower make contact of relay 234, upper make contact of relay 230 through the winding of relay 231 to battery. Relay 231 in operating locks operated in a circuit from ground through the lower contacts of relay 230 and upper make contacts of relay 231 to battery through the winding of relay 231. Relay 229 in operating removes a short circuit from its lower or locking winding. The locking circuit for this relay may be traced from battery through the spacing contacts of relay 232, uppermost make contacts of relay 235 through the lower winding of relay 229 to ground. So long as relay 232 remains on its spacing contact relay 229 will, therefore, remain in its left-hand position. As soon as relay 231 operates, it reopens the operating circuit of relay 234 through its upper break contacts and allows this relay to release. Relay 234 in releasing disconnects battery from the upper winding of relay 233 and condenser 250 which thereupon starts to discharge through relay 233. If ringing current is received by relay 232 before the end of the .2 second operating time of relay 233 relay 232 in following this ringing current will connect battery to the upper winding of relay 233 and condenser 250 on alternate half cycles of the ringing current and thus maintain relay 232 in its right-hand position. Relay 233 on the opposite half cycles of the ringing current connects battery through resistance 249 to condenser 236 and to the lower locking winding of relay 229. Battery connected to this condenser and lower winding of relay 229 on these alternate half cycles of the ringing current is sufficient to maintain relay 229 in its left-hand position. Relay 230 in operating also connects negative battery to the winding of relay 232 and opens the upper winding of relay 226 so that this relay will continue to repeat a break signal to the teletypewriter equipment connected to the cord circuit shown in Fig. 2.

The circuits just traced in Figs. 6, 7 and 8 remain in this condition so long as a break signal is transmitted from the subscriber's station shown in Fig. 1. When the subscriber releases the break key 159, negative potential is again applied to line 11 which causes relay 163 to move to its marking contact. This causes relay 260 to close the circuit through its contacts by operating to its right-hand position and operates relay 174 to its right-hand position. Relay 174 in operating to its right-hand position interrupts the operating circuit of relay 173 which thereupon releases and connects the armature of relay 163 to the winding of relay 203. At the central station relay 232 then ceases to vibrate between its marking and spacing contacts and remains upon its marking contacts. This interrupts the current flowing through the lower locking winding of relay 229 and allows this relay to move to its right-hand position under influence of current flowing through its middle winding. Relay 229 in moving to this right-hand position interrupts the operating circuit of relay 230 which releases and in turn releases relay 231.

The circuits at both the intermediate repeater point and the central exchange are thus returned to their transmitting condition and signal impulses may be transmitted from the subscriber's station to the central exchange to explain the reason for the break signal.

Break signals are transmitted from the central office to the subscriber's station as spacing impulses. These impulses are repeated by the equipment shown in Figs. 6, 7 and 8 to the subscriber's line 11. The break impulse is received by relay 16 at the subscriber's station and repeated by it to the teletypewriter equipment 44 at the subscriber's station. The break impulse causes the receiving relay 16 to move to its spacing position. In the spacing position this relay short-circuits the resistance 242 and also the transmitting contacts 34 and thus prevents the transmission of signal impulses to line 11 which might interfere with the reception of the break signal. Relay 20 16 also interrupts the circuit of the current magnet 32 and thus indicates to the subscriber that the distant subscriber or operator wishes to interrupt the transmission for some reason.

When the break signal is transmitted from the central office to the subscriber's station relay 188 of Fig. 6 at the intermediate station is operated to its spacing position in response to the break signal. Relay 188, in operating to its spacing position, interrupts a circuit from the upper terminal of condenser 185 through the lowermost break contacts of relay 184, upper inner make contacts of relay 194, lower break contacts of relay 193 to ground through the marking contact of relay 188. In interrupting this circuit, relay 188 permits condenser 185 to start to receive a charge from battery through high resistance 186, lower make contacts of relay 194 and lowermost break contacts of relay 184.

If the break signal is of short duration relay 188 in moving to its marking position at its termination will discharge condenser 185 in the above circuit and prevent the operation of other apparatus.

If the break signal continues uninterrupted for approximately 6 seconds in the preferred embodiment of this invention the potential on the upper terminal of condenser 185 will rise to the value required to initiate a discharge between the control element and the cathode of gaseous conduction tube 252. The initiation of a discharge between the control element and the cathode of gaseous conduction tube 252 initiates a discharge between the cathode and the main anode 255 of gaseous conduction tube 252. The current of the main discharge flows in a circuit from battery through the winding of relay 193, lower break contacts of relay 192, lower inner break contacts of relay 184 to the main anode 255 of tube 252. This discharge current causes the operation of relay 193. Relay 193, in operating, locks in a circuit from battery through its winding, lower inner make contact, the lower center make contacts of relay 179 to ground through the spacing contacts of relay 188. This locking ground is also connected to the main anode 255 of tube 252 and terminates the discharge to this electrode.

Relay 193, in operating, also completes an obvious circuit for the operation of relay 192 which in turn completes an obvious circuit for the operation of relay 187. During the operating times of relays 192 and 187 ground is connected to the upper terminal of condenser 185 through a circuit including the lower outer break contacts

of relay 184, the upper inner make contacts of relay 194, lower outer make contacts of relay 193 to ground through the lower inner break contacts of relay 187. This circuit discharges the upper terminal of condenser 185 during this time and thus terminates any discharge between the cathode and control electrode of tube 252.

Relay 192 also completes a circuit for the operation of relay 195 in series with interrupter 198.

Relay 187, in operating, connects marking battery through its upper make contacts to the upper winding of relay 182 which in turn connects ground to line 11 and transmits a marking impulse to the subscriber's station. Relay 187 also transfers the upper terminal of condenser 185 from ground through its lower inner break contacts to ground through its lower inner make contacts and the upper inner make contacts of relay 181. This maintains the upper terminal of condenser 185 at ground potential and prevents the initiation of a discharge through tube 252. Relay 187 also completes a circuit for the operation of relay 169 from ground through the make contacts of relay 195, center set of lower make contacts of relay 187, lower inner make contacts of relay 177 to battery through the winding of relay 169. Relay 169 follows the operation of relay 195 which in turn follows the operation of interrupter 198. During the time relay 169 is operated it disconnects a marking battery from the upper winding of relay 182 and connects this winding to lead 190 through the upper winding of relay 188. This again transmits a break signal to the subscriber's station if it is still being transmitted from the central exchange. If the break signal is no longer being transmitted from the central exchange relay 188 will be operated to its marking contact at this time and interrupt the locking circuit of relay 193 which releases and in turn causes the release of relays 192, 187, 195 and 169 and restores the circuit to its former transmitting condition.

Thus, if a long break signal, existing for example, 6 seconds, is transmitted from the central station, long marking signal impulses are periodically transmitted to the subscriber's station. During these long marking signal impulses the subscriber may transmit recall signals to the operator as described above or he may transmit disconnect signals to the operator as will be described hereinafter after which he can again initiate another call in the usual manner.

It is necessary to send the marking signals to the subscriber to insure that relay 167 will release when the subscriber removes potential from line 11 at his station. During the transmission of spacing signal impulses to a subscriber's station current from the spacing battery connected to the spacing contact of relay 182, flowing through the winding of relay 167 and the leakage resistance of line 11 may be sufficient to maintain relay 167 operated even when the subscriber has removed potential from line 11 at his station. Consequently, to permit the subscriber to transmit a recall or disconnect signal to the central station at these times it is necessary to transmit marking signal impulses to the subscriber's station by connecting ground to line 11 through the marking contacts of relay 182, thus removing all sources of transmitting potential from line 11 and insuring the release of relay 167.

Subscriber disconnects

At the completion of transmission the sub-

scriber may send a disconnect signal by releasing the power switch 36. This removes all sources of potential from line 11 at the subscriber's station as described above and permits relay 167 to release, and relays 162 and 163 to remain in the position to which they were operated. This permits relay 166 to release which in turn releases relays 168, 175, 181 and 177. Relay 181 in releasing interrupts the circuit of the upper winding of relay 203. Relay 203 thereupon transmits a spacing signal over line 207. Relay 210 responds to this spacing signal and repeats it to relays 226 and 232. Relay 232 in moving its spacing contact interrupts the circuit of the upper winding of relay 233, permitting this relay to operate to its left-hand contact after about .2 second whereupon a circuit is completed for the operation of relay 229 which locks in a circuit including the spacing contact of relay 232 and the lower winding of relay 229. Relay 229 in operating operates relay 230 which in turn causes relay 234 to operate. Relay 234 in operating causes relay 233 to be operated to its right-hand position. When relay 233 is operated to its right-hand position the circuit is completed for the operation of relay 231, and relay 231 in operating interrupts the operating circuit of relay 234 which in turn releases, disconnecting battery from the upper winding of relay 233 and permitting condenser 250 to start to discharge through the upper winding of relay 233. The circuits for the above described operation are the same as for the reception of a break signal previously described.

However, in the case of a disconnect signal no ringing current will be received by relay 232 within the .2 second time delay of relay 233. At the end of this .2 second time interval after relay 234 has released, relay 233 will again be operated to its left-hand position. Relay 233 in its left-hand position now closes a circuit for operating relay 228 from ground through its left-hand contacts, lowermost make contacts of relay 235, lower make contacts of relay 231 to battery through the winding of relay 228. Relay 228 locks operated in a circuit from ground connected to the center make contacts of the lower set of contacts of relay 227 and make contacts of relay 228. Relay 228 in operating interrupts the locking circuit of relay 227 and allows this relay to release. Relay 227 in releasing causes relays 228 and 235 to release. Relay 235 in releasing interrupts the locking circuit of relay 229 through the spacing contacts of relay 232 and completes a circuit for operating relay 233 to its left-hand position by connecting battery from the spacing contacts of relay 232 to the upper winding of relay 233. Relay 229 in releasing releases relay 230 which in turn releases relay 231 and thus restores the circuit to normal. Relay 227 in releasing connects ground through its innermost lower break contacts to the ring of jack 223. As described with reference to the single section line this causes the supervisory lamp 86 in a cord circuit to be lighted whereupon when the operator removes plug 83 from jack 223 relay 211 will release. Relay 211 in releasing interrupts the circuit including the upper winding of relay 220 whereupon relay 220 is operated to its spacing position by current flowing through its lower winding as hereinbefore described. This causes relay 213 to be operated to its spacing position and repeats a spacing signal over line 207 to the intermediate point. Here relay 201 again repeats the spacing signal to relay 188.

When relay 188 releases it disconnects ground

from the upper terminal of condenser 185 and permits condenser 185 to charge through high resistance 186. After an interval of time determined by the constants of condensers 185 and resistance 186, the potential of condenser 185 rises to the value required to initiate a discharge through gaseous conduction tube 252. In the preferred embodiment of this invention this time interval is of the order of 6 seconds. When a discharge is initiated through tube 252 by the control electrodes a discharge is also initiated between the main electrodes and causes the operation of relay 193 in a circuit traced from battery through the winding of relay 193, lower contacts of relay 192, the lower inner contacts of relay 184 to the main anode 255 of tube 252. Relay 193 in operating completes an obvious circuit for operating relay 192 and locks operated in a circuit from battery through its winding, its inner lower contacts, middle set of lower make contacts of relay 179 to ground through the spacing contacts of relay 183. This locking ground also extinguishes any discharge between the main anode 255 and the other elements of tube 252. Relay 193 in operating also connects ground to the upper terminal of condenser 185 in a circuit traced from ground through the innermost lower break contacts of relay 187 and lowermost make contact of relay 193, innermost upper make contacts of relay 194, lowermost break contacts of relay 184 to the upper terminal of condenser 185. This ground discharges condenser 185 during the time interval during which relays 192 and 187 are operating and extinguishes any discharge between the control element and the cathode.

Relay 192 in operating completes an obvious circuit for operating relay 187 and transfers the anode circuit of tube 252 from the winding of relay 193 to the winding of relay 178 in a circuit traced from the lower make contacts of relay 192, lowermost make contacts of relay 187 and break contacts of relay 178 to battery through the winding of relay 178. Relay 192 also connects ground to the left-hand winding of relay 195. When relay 187 operates it removes ground from the upper terminal of condenser 185 connected to its innermost lower break contact and thereupon condenser 185 starts to charge through high resistance 186. At the end of the time interval tube 252 again discharges and this time causes relay 178 to operate over the circuit previously traced. Relay 178 locks operated to ground connected to the lowermost make contacts of relay 179 and interrupts the discharge through tube 252. Relay 178 also interrupts the locking circuit of relays 194 and 179 thereby permitting these relays to release. Relays 179 and 194 in releasing release relays 178, 187, 192 and 193, and thus restore the circuit to its normal condition.

In case the operator at the switchboard disconnects first, before the subscriber operates power key 36, or if the subscriber operates power key 36 during the time a break signal is being transmitted from the central station, leakage resistance of line 11 may be sufficient to prevent relay 167 from releasing due to the fact that spacing current from the spacing battery flowing through the spacing contacts of relay 182 is connected to the line and may hold relay 167 operated. In this case, relays 167, 166, 168, 175, 181 and 177 will be prevented from releasing at this time.

However, relay 188 will operate to its spacing position in response to the spacing signal caused either by transmission of a spacing or break sig-

nal or by the operator removing plug 83 from jack 223 to disconnect the circuit. As before, this will cause condenser 185 to charge and initiate a discharge through tube 252 which causes relay 193 to operate. Relay 193 in turn causes relays 192 and 187 to operate. During the operating time of these relays ground is connected to the upper terminal of condenser 185 to discharge it. In this case, however, when relay 187 operates ground from the upper inner make contacts of relay 181 through the lower innermost make contact of relay 187, the lower make contacts of relay 193, innermost upper make contacts of relay 194, lower break contacts of relay 184 prevents the upper terminal of condenser 185 connected thereto from receiving a charge sufficient to operate it to initiate a discharge through tube 252 a second time. Relay 192 in operating completes a circuit from ground through its innermost upper make contacts through the winding of alternating current relay 195, condenser 196, source of alternating current 197 and interrupter 198 to ground. Relay 195 will follow the interruptions of interrupter 198, and connect ground through its contacts, the lower make contacts of relay 187, inner lower make contacts of relay 177, to battery through the winding of relay 169. Relay 169 will follow the interruptions of relay 195. Relay 187 in operating connects marking battery from the upper break contacts of relay 169 through the upper make contacts of relay 187 to the upper winding of relay 182, causing relay 182 to operate to its marking condition. Then when relay 169 operates in response to the operation of relay 195 it will remove this marking battery and short-circuit the upper break contacts of relay 187. If an idle signal is still being received over line 207 the idle signal will be transmitted to the subscriber's station circuit shown in Fig. 1. Thus alternate marking and spacing signals are transmitted to the subscriber to indicate either trouble condition on the line or that the communication is completed whereupon he will release power switch 36. During the time interval that marking battery is connected to the upper winding of relay 182 and a marking impulse transmitted over line 11 to station 1, relay 167 will release in response to the removal of potential from the subscriber's line at the subscriber's station circuit. Relay 167 will then release relay 166 which in turn releases relays 168, 175, 177 and 181. Relay 181 in releasing removes ground from the circuit above traced connected to the upper terminal of condenser 185 and permits this condenser to charge through resistance 186. After the time interval determined by the constants of this circuit a discharge is initiated through tube 252 which operates relay 178 as described above. Relay 178 in turn releases relays 179, 194, 192, 193, 187 and 178 and restores the circuit to its normal condition.

Calling the outlying subscriber

When it is desired to call an outlying subscriber connected over the multi-section toll line the operator will insert calling plug 101 in jack 223 or a jack in multiple therewith. This completes a circuit for operating relay 211 from ground through its winding to sleeve of jack 223 and plug 101, to battery through the winding of relay 98. Relay 211 in operating completes a transmission circuit from the tip of the cord to the upper winding of relay 220 and causes relay 220 to be operated to its marking position. Relay 220 in operating to its marking position repeats a marking

impulse to relay 213 which in turn repeats it over line 207 to receiving relay 201 at the intermediate station. Receiving relay 201 repeats the marking impulse to relays 182 and 188. In response thereto relay 188 moves to its marking position and completes a circuit hereinbefore traced for operating relays 194 and 179, which relays lock operated to the uppermost break contact of relay 178. The operator then operates ringing key 100 when she desires to ring and call the outlying subscriber. Relays 220 and 213 follow the ringing current and transmit 20 cycle impulses over line 207 to the intermediate station. At the intermediate station relays 201 and 188 follow these impulses. During alternate half cycles relay 188 connects ground through its spacing contact, the middle set of the lower make contacts of relay 179 to the winding of relay 171 and discharges condenser 258 through winding of relay 171. During the other half cycles of the ringing current or impulses the spacing contact of relay 188 is disconnected. During these intervals of time condenser 258 is charged from battery connected to the innermost upper break contacts of relay 177 through resistance 257 and winding of relay 171. The alternate charging and discharging of condenser 258 is equivalent to an alternating current flowing through the winding of alternating current relay 171. This causes relay 171 to operate. Relay 171 in operating causes relay 174 to operate in a circuit from battery through its upper winding, lower break contact of relay 176 to ground connected to the upper make contact of relay 171. Relay 174 in operating completes a circuit for operating relay 176 from ground through its right-hand contacts, lowermost break contacts of relay 175 through the winding of relay 176 to battery. Relay 176 operates in this circuit and locks operated in a circuit from battery through its winding, lower make contact and lower make contact of relay 171 to ground. Relay 176 in operating interrupts the operating circuit of relay 174 and after approximately .3 second during which condenser 247 is being charged, relay 174 is again operated to its left-hand position. In its left-hand position relay 174 completes a circuit for operating relay 184, from ground through the left-hand contacts of relay 174, innermost lower contacts of relay 175, upper make contacts of relay 176, through the winding of relay 184 to battery. Relay 184 in operating transfers the anode 255 of tube 252 to battery through the winding of relay 180 and the lower break contacts of relay 183. Relay 184 also transfers the control electrode of tube 252 and upper terminals of condenser 185 to battery through high resistance 256. In case the station shown in Fig. 1 is attended, the operation of the circuits relating to tube 252 performs no useful function.

Relay 184 also completes a circuit for the operation of relay 165 from ground through the innermost make contacts of relay 184, innermost upper break contacts of relay 183 through the winding of relay 165 to battery. Relay 165 in operating completes the operating circuit for relay 160 from ground through the lower break contacts of relay 168, innermost upper make contacts of relay 165, through the winding of relay 160 to battery. Relays 160 and 165 in operating complete a circuit from a source of alternating ringing current 164 through the upper make contacts of these two relays to line 11, to ring the subscriber's bell 40.

When the subscriber's station is attended, the

operator rings for short intervals of time by operating ringing key 100. Relays 171, 174, 176, 184, 165 and 160 follow the operations of the ringing key 100 after a slight delay and connect ringing current to line 11. When relay 165 is released in response to the release of the ringing key 100 at the central station relays 171, 176, 184, 165 and 160 release. During the release time of relay 160 which is a slow release relay ground is momentarily applied to line 11 over a circuit traced through upper make contacts of relay 160 and the upper break contacts of relay 165. This ground discharges the capacity of cable 11 and thus prevents false operation of relay 167 at this time due to discharging cable capacity through its winding.

When the subscriber answers by operating power switch 38, ringer 40 and relay 39 are disconnected from line 11 and potential is applied thereto as above described when the subscriber initiates a call. During periods when the operator has released the ringing key 100, the upper windings of relays 162 and 163 and winding of relay 167 are connected to line 11 at the intermediate station, as described above, so that relay 167 will operate in response to the potential connected by the subscriber to line 11 at this time. Relay 167, in operating, completes a circuit for the operation of relay 166 which in turn causes the operation of relays 168, 178, 181 and 177. Relay 181, in operating, completes a circuit from the marking contacts of relay 163 to the upper winding of relay 203 over lead 191 and causes relay 203 to move to its marking position. Relay 203 repeats the marking impulse to the central station and causes the supervisory lamp 102 to be extinguished as described elsewhere herein. This indicates to the operator that the called subscriber has answered and is ready to transmit or receive messages. The circuits then function as described above.

Unattended service

In case the subscriber's station circuit shown in Fig. 1 is unattended the operator at the central station may start the subscriber's station motor by transmitting a prolonged ringing signal. When relay 184 operates in response to the operation of the ringing key 100 at the central office as described hereinbefore condenser 185 starts to charge through resistance 256. The constants of resistance 256 and condenser 185 are such as to require, in a preferred embodiment of this invention, approximately 9 seconds for the potential of condenser 185 to reach the potential required to initiate a discharge through tube 252. When the discharge is initiated through tube 252 by the control elements a discharge takes place between the main anode 255 and the cathode. This discharge causes the operation of relay 180 in a circuit from ground connected to the cathode of tube 252, the anode 255 of tube 252, the innermost lower make contacts of relay 184, the lower break contacts of relay 183 through the winding of relay 180 to battery. Relay 180, therefore, operates and, in turn, operates relay 183. Relay 183 in operating interrupts the discharges through tube 252 and completes a locking circuit for relay 180 from ground connected to the uppermost make contact of relay 184 and inner lower make contact of relay 183 through the winding of relay 180 to battery. Relay 183 in operating interrupts the circuit of relay 165 and thus interrupts the ringing current supplied to the subscriber's station.

Relay 183 also closes the circuit of the upper winding of relay 203 and causes a marking signal to be transmitted to the central station over line 207 to indicate that the subscriber's equipment has been started. If the subscriber's station apparatus has not been started when the operator releases her ringing key and relays 171, 176, 180, 183, and 184 release in response thereto. Relay 183 in releasing will interrupt the circuit of the upper winding of relay 203 unless relay 181 has in the meantime operated in response to a potential applied to line 11 by the subscriber's station equipment becoming energized. The opening of the upper winding of relay 203 will transmit the spacing signal to the central station and cause the supervisory lamp 102 in the cord circuit to operate and indicate to the operator that the subscriber's equipment did not start, whereupon the operator may again try to start the equipment, by transmitting a long ringing signal.

At the subscriber's station relays 37, 41 and 42 respond to the long ringing signal received over line 11 as described for the unattended service over a single line section.

In addition, the subscriber's equipment is shut down in a similar manner after the message has been completed by transmitting to the teletypewriter a motor stop signal which operates contacts 35 in the subscriber's teletypewriter and returns the circuits to their normal condition as previously described.

Thus the above-described multi-section line circuits provide apparatus and circuit arrangements for permitting the central station operator to call an outlying subscriber and to automatically start his printer motor over the long multi-section toll line in the same manner as a local subscriber is called and furnished unattended service.

In addition, the outlying subscriber continuously and positively controls supervisory signals at the central station. The outlying subscriber can transmit calling, recall and disconnect signals to the central station at all times and these signals are continuously under the direct control of the subscriber.

If the subscriber wishes to abandon a call at any time he may do so by releasing power switch 36 which will extinguish the calling lamp, change the flashing recall signal to a disconnect signal or transmit a disconnect signal to the central station in the same manner as a local subscriber transmits these signals to the central station. Thus it is not necessary for the operator to do anything merely to restore a signal to its normal condition. The operator's services are only required to perform some desired switching or to supply some desired information. It should be noted that the above-described circuits also permit the values of line and leakage resistance to be extended to the limit of the self-compensating circuits described in the above identified copending application.

It is to be understood that the invention is not limited to the specific details of the terminal circuit arrangements. For example, any suitable method of securing the desired time delay may be employed in place of the specific methods described. In addition, other types of switchboards and switching circuits may be employed to interconnect the outlying subscriber with other subscribers. The outlying subscriber may also be connected to long interoffice trunks to other cen-

tral exchanges in the same manner that local subscribers are connected to distant exchanges.

Features of the multi-section subscribers' line circuits described but not claimed herein are claimed in a copending application of K. E. Fitch, Serial No. 180,075, filed December 16, 1937.

What is claimed is:

1. In a communication system a first station, a second station, an impulse signaling channel connected between said stations, transmitting and receiving means for transmitting two signaling conditions in each direction over said channel so related to said channel that the bias of said signaling conditions is substantially independent of the leakage resistance of said channel, and means at one of said stations responsive to long impulses of both of said signaling conditions, additional means at said station responsive to changes of said signaling conditions and a retarded relay jointly controlled by said two responsive means and supervisory signals at said station controlled by said retarded relay.

2. In a telegraph system a supervisory circuit arrangement comprising an incoming telegraph line, a neutral relay connected in series therewith for responding to long impulses of two different signaling conditions, a polar relay also connected in series of said line responsive to the signaling impulses transmitted thereover, a third relay, an operative connection between said neutral relay and said third relay for maintaining said third relay operated during long impulses and an operative connection between said third relay and said polar relay for maintaining said third relay operated during changes of said impulses.

3. In a communication system, a first station, a second station, a direct current impulse signaling channel connected between said stations, means for transmitting in each direction over said channel two different currents in accordance with the information to be transmitted, and means at one of said stations responsive to both of said currents comprising a neutral relay connected in series with said channel, a polar relay connected in series with said channel and an alternating current relay jointly controlled by said neutral and polar relays and a slow-release relay controlled by said alternating current relay whereby said slow-release relay is maintained operated in response to either of said signaling currents or signaling impulses of said currents.

4. A teletypewriter exchange system comprising a plurality of subscribers' lines, means for interconnecting said subscribers' lines, a plurality of additional subscribers' stations, long toll lines connecting said additional subscribers' stations to said teletypewriter exchange, means for transmitting signaling impulses of two signaling currents over said long toll line the bias of which is substantially independent of the leakage resistance thereof, a calling signal at said central station responsive to either of said signaling currents comprising the neutral relay and the polar relay connected in series with said line, an alternating current relay jointly controlled by said neutral and polar relays for controlling said calling signal and a disconnect signal at said central station also controlled by said neutral, polar and alternating current relays in response to the cessation of said signalling currents.

5. In a communication system a first station, a second station, a direct current impulse signaling channel connected between said stations, transmitting and receiving apparatus at each of said stations connected to said channel for trans-

mitting and receiving two different impulse conditions over said channel, the bias of which is substantially independent of the leakage resistance of said channel, a neutral relay at one of said stations responsive to both of said impulse conditions, a polar relay connected in series with a channel, a third relay, an operative connection between said neutral relay and said third relay for causing a direct current to flow through the winding of said relay in response to the operation of said neutral relay, an operative connection including a condenser for causing an alternating current impulse to flow through a winding of said third relay in response to changes of said impulse conditions transmitted over said channel.

6. In a teletypewriter system a central exchange station and an outlying subscriber's station, a long direct current telegraph channel connecting said subscriber's station to said central exchange, telegraph transmitting and receiving apparatus at each of said stations connected to said telegraph channel for transmitting and receiving impulses over said channel, a supervisory circuit arrangement at said central station including a neutral relay and a polar relay connected in series with said channel during the operation of said transmitting and receiving apparatus, and a third relay jointly controlled by said neutral and polar relays, means for disconnecting said supervisory circuit from said channel and for connecting ringing current to said channel to call the outlying subscriber's station and means for discharging the cable capacity of said telegraph channel after the application of the ringing current but before reconnecting said supervisory circuit to said channel.

7. In a communication system a first station, a second station, a long impulse transmission channel extending between said stations, impulse transmitting and receiving apparatus at each of said stations connected to said channel, means for transmitting ringing current from said second station to said first station to call said first station, means for transmitting supervisory signals from said first station to said second station including a supervisory circuit comprising a neutral relay and a polar relay connected in said channel during the operation of said transmitting and receiving apparatus, and a third relay jointly controlled by said neutral and polar relays for continuously responding to supervisory signals transmitted from said first station.

8. In a teletypewriter exchange system a central exchange station, a distant subscriber's station, an intermediate repeater station, a low frequency telegraph channel connected between said subscriber's station and said intermediate station, a full duplex telegraph system connected between said intermediate station and central station, telegraph signal impulse transmitting and receiving apparatus at said subscriber's station and said central station for transmitting marking and spacing impulses, repeating apparatus at said intermediate station for repeating said impulses between said stations, means for transmitting calling and supervisory signals between said central station and said distant subscriber's station including circuit arrangements at said intermediate station having a neutral relay and a polar relay connected in series with the channel to the subscriber's station, a third relay jointly controlled by said neutral and polar relay and translating apparatus controlled by said third relay for transmitting corresponding supervisory

signals over said full duplex channel to the central exchange.

9. A teletypewriter exchange system in accordance with claim 8 characterized in that the full duplex telegraph channel extending between the intermediate station and the central station is a full duplex low frequency direct current telegraph system comprising a low frequency telegraph channel, transmitting and receiving apparatus at said intermediate station and at said central station for simultaneously transmitting in both directions two signaling conditions over said channel, means for controlling said apparatus and signaling conditions transmitted thereby relative to the distribution of the line resistance and leakage resistance of said telegraph channel whereby the bias of the signaling conditions received at both of said stations is substantially independent of the leakage resistance of said channel.

10. In combination, a first telegraph station, a second telegraph station, an impulse transmitting channel connected between said stations, impulse transmitting and receiving apparatus at each of said stations connected to said channel, a calling and supervisory system for transmitting supervisory signals over said channel and between said stations including a neutral relay and a polar relay connected in series with the channel extending to said first station, and a third relay jointly controlled by said polar and neutral relays, and means responsive to a long spacing break signal transmitted over said channel for periodically transmitting long marking impulses over said channel.

11. In a telegraph exchange system a central exchange, an outlying subscriber's station, a telegraph line connecting said outlying subscriber's station and said central exchange, means for connecting potential sources of opposite polarity to said line at the subscriber's station, means for connecting ground and a source of potential to said line at the central station, relay connected in series with said line at the central station and means responsive during long impulses of potential applied to said line at the central station for intermittently connecting ground to said line thereat to permit said relay to release when the subscriber disconnects both of said sources of potential from said line.

12. In combination, a first telegraph station, a second telegraph station, a full duplex telegraph channel extending between said stations for simultaneously transmitting signaling impulses in both directions between said stations, means for connecting potentials to the ends of said channels which are so related to each other and the line resistance and leakage resistance of said channel that the algebraic sum of the signaling currents received at either station from the other station during the time a particular potential is connected to the line at the station which is then receiving is substantially independent of the leakage resistance of the line.

13. A telegraph system comprising a first station, a second station, a full duplex telegraph line connected between said stations for simultaneously transmitting message currents in both directions over said line, means at one of said stations for connecting potentials of substantially the same magnitude and of opposite polarity to said channels in accordance with the message signaling impulses to be transmitted, and means for connecting ground and a potential which is substantially twice the magnitude of the potential

connected to the line at said first station and which aids the potential normally connected to the line at said first station, in accordance with the message currents to be transmitted from said second station.

14. A telegraph exchange system comprising a central station, an outlying subscriber's station, a telegraph line connected between said stations, means at said subscriber's station for connecting potentials of opposite polarity to said line in accordance with the message currents to be transmitted, means at the central office for connecting to said line ground and a potential of substantially twice the magnitude of the potentials at the subscriber's station, a polar relay connected in the line at the central station responsive to the signaling currents transmitted over said line, a neutral relay also connected in series with said line for responding to long impulses transmitted over said line, and a third relay, and an operative connection between said neutral relay and said third relay for maintaining said third relay operated during long impulses and an operative connection between said polar relay and said third relay for maintaining said third relay operated during changes of said impulses.

15. A telegraph exchange system comprising a central station, a subscriber's station, a telegraph line extending between said stations, means for connecting potentials of substantially

equal magnitude but of opposite polarity to said line at said subscriber's station, a circuit connected to said line at said subscriber's station comprising a neutral relay in series with a unidirectionally conducting device for securing a copy of the message currents transmitted therefrom, a neutral relay connected in series with said line at said central station for responding to long impulses, a polar relay also connected in series with said line at said central station responsive to signaling impulses transmitted thereover, and a third relay, an operative connection between said third relay and both said neutral relay and said polar relay for maintaining said third relay operated during the time message currents are transmitted from subscriber's station and also during the time either of said sources of potential are connected to the line at said subscriber's station.

16. A telegraph exchange system comprising a central station, a subscriber's station, a telegraph line extending between said stations, means for connecting potentials of substantially equal magnitude but of opposite polarity to said line at said subscriber's station, a circuit connected to said line at said subscriber's station comprising a neutral relay and a unidirectionally conducting device for securing a copy of the message currents transmitted thereover.

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