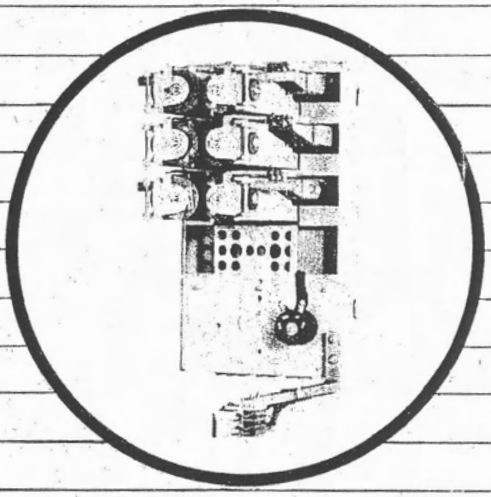
AUTOMATIC ELECTRIC TRAINING SERIES | Bulletin **810**

PULSE REPEATERS

STROWGER AUTOMATIC TELEPHONE SYSTEMS



AUTOMATIC ELECTRIC

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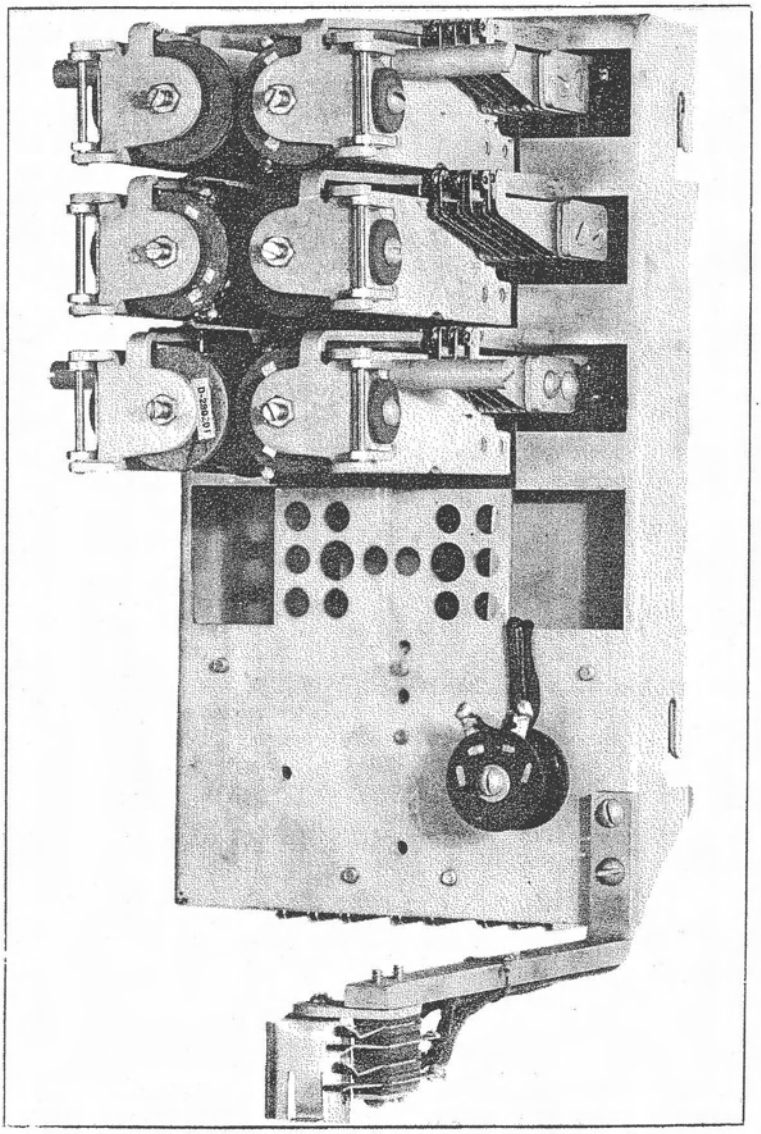

Typical One-Way Impulse Repeater

PULSE REPEATERS

1.0 INTRODUCTION

Impulse repeaters are devices consisting principally of relays, which relay (or repeat) dial pulses originating in one office to the switching equipment in another office. They are used in conjunction with Strowger automatic telephone systems and are employed as fixed components of inter-office trunks.

While the repeater derives its name from its repeating function, there are three principal reasons for employing repeaters on inter-office trunks. These are:

(A) ECONOMY - The need for a third (control) wire in the inter-office trunk is eliminated thereby reducing wire expense. The repeater accomplishes this (when engaged in a call) by placing a "holding" ground on the control circuit to all preceding switches in the train.

(B) TRANSMISSION EFFICIENCY - Since the performance of a telephone transmitter is dependent upon the amount of direct-current flow, it is desirable to restrict the distances over which transmission current is supplied. This is accomplished on inter-office trunk calls by having the repeater in the originating office (instead of the connector in the distant office) supply current to the calling telephone. The transmission efficiency of the calling station is therefore the same on inter-office calls as on local calls.

(C) REPEATING OF IMPULSES - The need to repeat impulses which arises primarily from the preceding two functions, provides still another important advantage. This advantage is an inherent characteristic of the relaying process in that a new source of impulsing current is introduced at each relaying (repeating) point. The impulsing current on the respective portions of the circuit is consequently maintained at a level, higher than if current were supplied from one source through the entire telephone circuit. This higher impulsing current assures better impulsing performance.

Impulse repeaters which can relay calls in an outgoing direction, are located in the offices which originate calls over inter-office trunks. Thus, if it is possible for calls to originate from both ends of a trunk (two-way trunk) then an impulse repeater is required in each office. Where calls originate from only one end of a trunk (one-way trunk) the other (terminating) end may be connected directly to an incoming selector, connector or "incoming repeater" in the terminating office. ("Incoming repeaters" relay only the calls received at offices to the incoming equipment in those offices. These are discussed in section 6. The sections preceding section 6 are concerned mainly with repeaters of the "outgoing" variety.)

Impulse repeaters can be classified generally into three categories. These are one-way repeaters, repeaters for two-way trunks and two-way repeaters. The one-way repeater relays calls in one direction only (outgoing) and is employed on one-way trunks. A repeater for two-way trunks is essentially a one-way repeater which has been properly adapted to allow two-way operation of inter-office trunks. When such repeaters are part of a trunk circuit, the repeater at one end is automatically "busied out" to prevent its seizure, if the repeater at the other end has been seized for a call.

The two-way impulse repeater relays impulses in two directions and is seized from either end of the trunk. However, the conditions involving the use of two-way repeaters, plus the general requirement of reducing 3-wire facilities to two-wire inter-office trunks, require that a two-way repeater be employed at each end of the trunk. Both repeaters are active on calls originating from either end of the trunk. Two-way impulse repeaters are employed where it is desirable to insert repeating coils in the transmission circuit (for the elimination of noise, matching of impedances) or where the requirement of using composite or simplex dialing makes the introduction of repeating coils compulsory.

1.1 D-C Pulse Repeating Methods

Impulse repeaters may employ one of several (d-c) methods for repeating dial impulses as follows: loop pulsing, battery pulsing, simplex (SX) dialing and composite (CX) dialing. The schematics accompanying the explanation of these methods below, are greatly simplified.

(A) Loop Pulsing - Figure 1 illustrates the loop-pulsing method. When the impulse repeater is seized at the local (originating) office the loop circuit is closed to the line relay (A-1) of an incoming switch in the distant office. When line relay A of the local repeater

responds to the dial pulses, the loop to the distant office is alternately opened and closed. This causes line relay A-1 of the incoming switch to correspondingly restore and operate and step the switch towards the desired line.

(B) Battery Pulsing - The battery-pulsing method is illustrated in figure 2. Line relay A of the impulse repeater in the local (originating) office, follows the dial pulses and alternately connects and disconnects resistance-battery and resistance-ground to each side of the trunk, respectively. At the distant end, the inter-office trunk is connected through each winding of line relay A-1, to ground and negative-battery respectively. Thus, the batteries at both the originating and terminating offices, are employed for impulsing, return for each side of the trunk being made through ground. The use of two batteries in this fashion permits dialing over longer trunks or trunks of higher resistance.

(C) Simplex Dialing - With this method, (illustrated in figure 3) repeating coils are employed at the ends of the inter-office trunk. The dial leg is derived from the mid-points of each repeating coil as shown; the operation of the line relay in the originating repeater, alternately connects and disconnects resistance-battery to the dial leg. At the terminating end, a relay (A-1) associated with the dial leg alternately opens and closes the loop to the incoming switch causing it to step. Return, as in all simplex systems, is made through ground or a ground lead. It should be noted that this dialing arrangement requires the use of a repeater at each end of the trunk.

(D) Composite Dialing - Figure 4 shows the composite method of impulsing which is similar to the simplex method. The trunk is composited as shown and the line relay of the originating repeater responding to dial impulses, alternately connects and disconnects resistance-battery to a dial leg. At the distant (terminating) end, a relay (A-1) opens and closes the loop to the incoming switch. The dial leg return is made through ground. (For additional information regarding simplex and composite systems refer to A.E.Co. Bulletin 331 entitled, "Repeating Coils and Their Uses.")

2.0 FUNCTIONS OF IMPULSE REPEATERS

The repeater performs a variety of functions in order to accomplish the purposes enumerated in section 1. In general, these functions, listed in the order in which they occur, are:

(a) To ground the control lead at the originating exchange in order to hold all of the preceding switches in the train operated.

(b) To make itself busy against seizure by other calls.

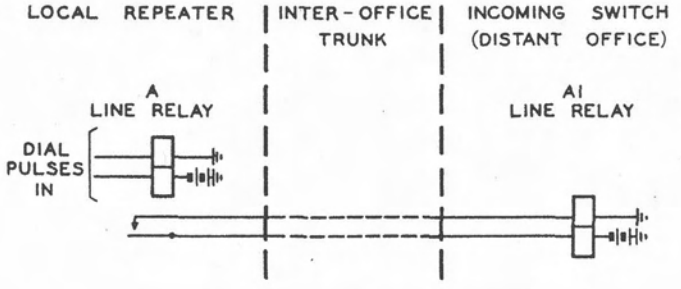

Fig. 1 Loop Pulsing

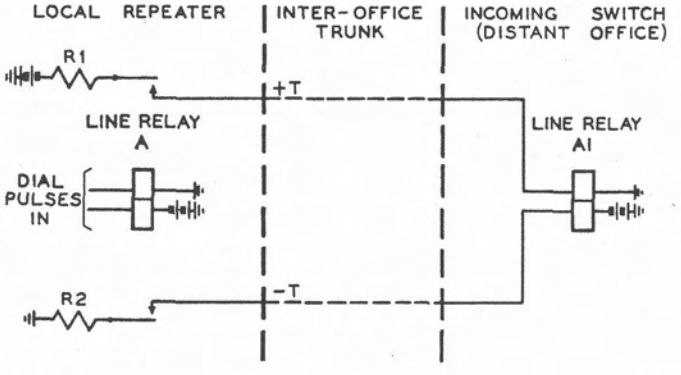

Fig. 2 Battery Pulsing

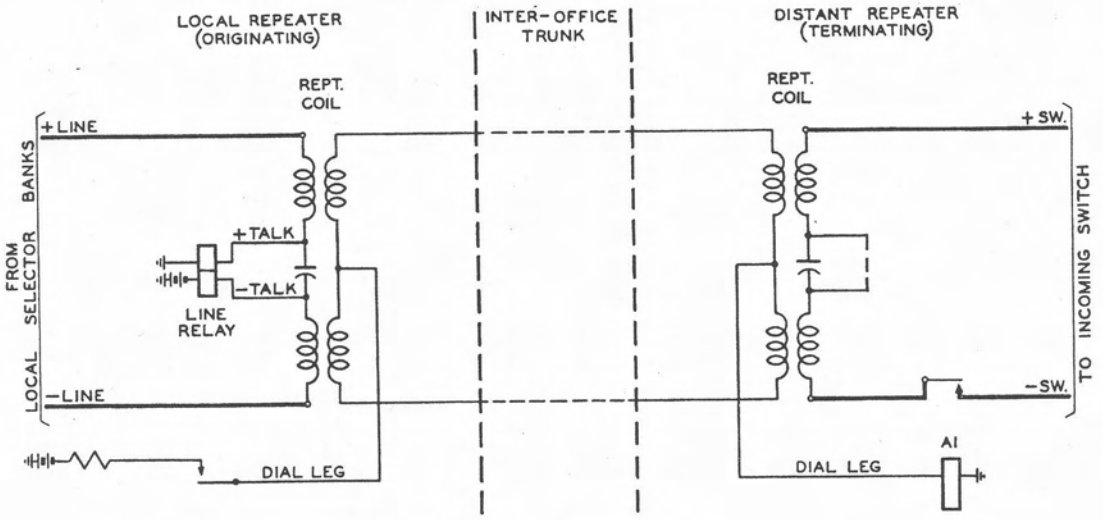

Fig. 3: Simplex Dialing

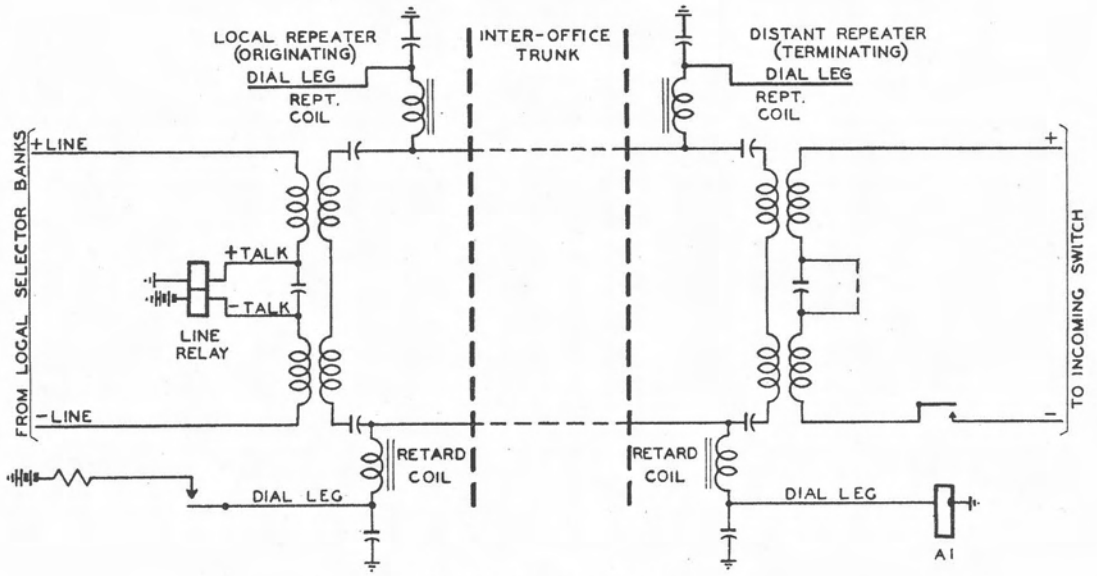

Fig. 4. Composite Dialing

(c) To close the loop to an incoming switch in the called office and to repeat impulses to the switches in that office.

(d) To reverse the current supply polarity to the calling telephone for answer supervision when the connector in the called office reverses battery polarity at the distant end.

(e) To supply transmission current to the calling telephone.

(f) To allow all the switches involved in establishing the connection, to release when the calling party's handset is replaced.

While the method of performing these functions may vary with repeaters of different design, the types described in the next three sections will afford an understanding of the techniques involved.

3.0 ONE-WAY IMPULSE REPEATER (Loop Pulsing Type)

The circuit of a typical one-way impulse repeater for use in conjunction with battery-searching selectors, is seen in figure 5. When the repeater is seized by a preceding switch (usually a local selector) a circuit is established between both windings of relay A over the calling loop. This circuit may be seen by tracing from ground on relay A, through the associated 200-ohm winding, a break contact on relay D, out over the + LINE, through the calling telephone, back over the - LINE, through another break contact on relay D, and the other 200-ohm winding of relay A to negative-battery.

Relay A operates, connects the + TRK lead with the + LINE and places ground on relay B. Relay B operates; (1) places ground on the top (polarizing) winding of shunt field relay E, (2) places ground on the C lead which holds the preceding switches operated and guards the repeater against seizure by other switches, (3)

prepares a circuit to relay C, (4) disconnects the - TRK lead from relay D and associates it with the - LINE thereby completing the transmission circuit. The latter action also closes the trunk loop to an incoming switch in the distant office, through the bottom winding of relay E. Relay E, a shunt field relay, does not operate at this time because of the opposing field polarities of its top and bottom windings.

3.1 Impulse Repeating

The impulses delivered by the dial of the calling telephone alternately restore and operate relay A of the repeater which opens and closes the trunk loop. Each time relay A restores, ground is extended to relay C (slow release) through a make contact on relay B (slow-release). Relay C operates and remains operated during each series of impulses (dialed digit of call number); relay B remains operated during the entire impulsing sequence.

Relay C operating; (1) places a low resistance (100 ohms) shunt across the bottom winding of relay E to reduce loop resistance during impulsing, (2) removes 500-ohm battery from the C lead. During the pause between successive digits, relay A remains operated and keeps ground from relay C while replacing it on relay B. Relay C restores and removes the 100-ohm shunt from the bottom winding of relay E. This prepares the circuit for transmission through condensers P and N. Each time the 100-ohm shunt is removed by the restoration of relay C, the bottom winding of relay E remains bridged across the trunk and thus, maintains a closed loop for holding the switches in the distant office. (This "holding bridge" is of a sufficiently high impedance, so as to limit or prevent the by-passing of voice currents during transmission.)

3.2 Talking Circuit

When the called party answers the current polarity over the trunk is reversed. This reverses the current through the bottom winding of relay E. The magnetic fields of the bottom and top windings now aid, and relay E operates.

Relay E operating, places ground on relay D. Relay D operates, places a second ground on the C lead and reverses the calling line connections to relay A. Relay A now supplies transmission current in reverse polarity to the calling telephone for supervisory purposes. The circuit is ready for transmission.

Figure 6 shows, in simplified form, the transmission circuit of the inter-office call through the repeatered trunk. It will be seen that transmission battery to the calling telephone is supplied through the windings of the repeater's line relay. The called telephone receives transmission current from the back-bridge relay of the connector in the distant office. The bottom winding of the shunt-field relay, bridging the trunk completes the trunk loop to the line relay of the connector. This holds the switch train in the terminating office and makes its release dependent upon the action of the repeater.

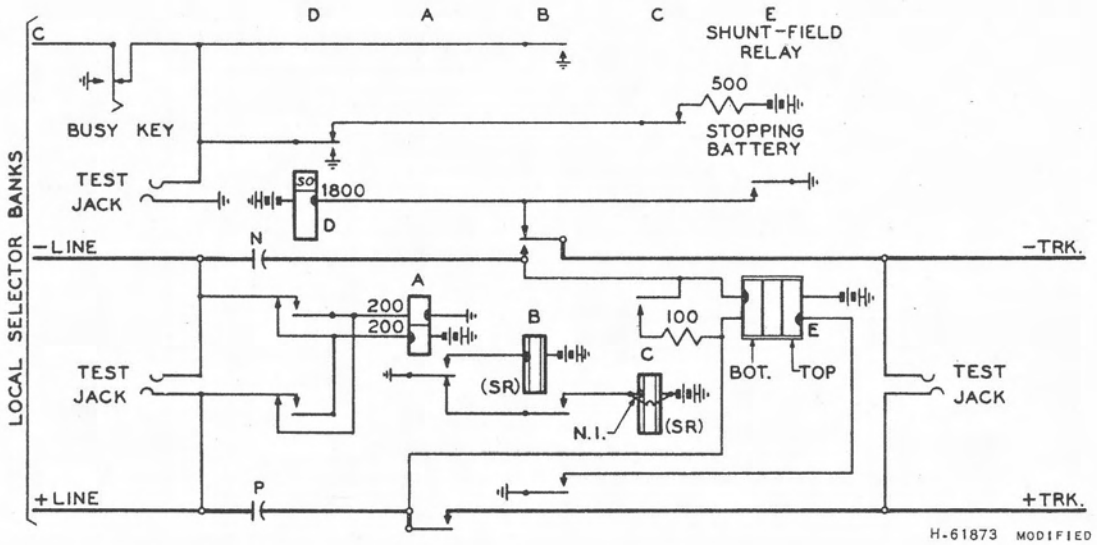

Fig. 5. One-Way (Outgoing) Impulse Repeater - Loop Pulsing

3.3 Releasing the Repeater

(A) Calling Party Disconnects First - Referring to figure 5 again, when the handset at the calling telephone is replaced, the circuit to line relay A is opened which allows relay A to restore.

Relay A restoring; (1) opens the trunk loop which releases the switch train in the distant office - this action also de-energizes the bottom winding of relay E, (2) opens the circuit to relay B. Relay B is slow to release so that the circuit to relay C is momentarily maintained.

Therefore, upon the restoration of relay A, relay C momentarily operates. The utility of this particular feature is made apparent in section 3.3B following. Relay B restores; (1) completely opens the transmission circuit by disconnecting the - TRK lead from condenser N, (2) removes ground from, and thereby de-energizes the top winding of relay E, (3) removes multiple ground from the C lead, (4) opens the circuit to relay C. Relay C restores and re-establishes the circuit to 500-ohm stopping battery. Relay E restores, removing ground from relay D. Relay D restores; (1) removes ground from the C lead (which releases the local switch train) and replaces it with 500-ohm stopping battery, (2) reverses the line connections to relay A to normal. The trunk circuit is now available for additional calls.

(B) Called Party Disconnects First - When the called party replaces the handset, battery polarity to the repeater over the trunk leads, is again reversed. This reverses the field polarity of the bottom winding of relay E which now opposes the field of the top (polarizing) winding. Relay E therefore restores and removes ground from relay D.

Relay D restores; (1) reverses the calling line connections to relay A to normal, (2) replaces multiple ground on the C lead with 500-ohm battery. The circuit remains in this condition and the switch trains in both offices are held, however, until the repeater is released by the calling party.

When the calling party finally disconnects, the circuit to relay A is opened. Relay A restores; (1) opens the trunk loop which de-energizes the bottom winding of relay E and releases the switch train in the distant (called) office, (2) removes ground from relay B and places it on a make contact of relay B. As relay B is slow to release, ground is extended through this make contact, to relay C which operates momentarily. Relay C disconnects 500-ohm battery from the C lead and thus provides a short interval (immediately after the release of relay B) during which the preceding switch train in this (originating) office, is given time to release and the repeater is guarded against seizure.

Relay B restoring; (1) de-energizes the top winding of relay E, (2) removes ground from the C lead, (3) opens the circuit to relay C. Relay C restores and replaces 500-ohm stopping battery on the C lead. The circuit is again at normal.

3.4 Busying Repeater From Distant End

If the circuit is in normal condition, the repeater can be busied from the distant end by grounding the - TRK lead. Ground on this lead operates relay D of the repeater. Relay D busies the switch by replacing 500-ohm battery on the C lead with ground. Relay D will remain operated until the trunk lead is ungrounded at the distant end.

4.0 REPEATERS FOR TWO-WAY TRUNKS

Two-way operation of inter-office trunks may be accomplished through the use of what are essentially one-way repeaters, properly adapted for the purpose. While these repeaters relay impulses in only one direction (outgoing) they allow two-way operation of trunks by incorporating an arrangement wherein the trunk leads are normally associated directly with an incoming selector (or connector). On an incoming call, the repeater is inactive insofar as the repeating of impulses or transmission of voice currents is concerned. When the same repeater is seized for an outgoing call, the trunk leads are automatically transferred from the incoming switches to the repeater.

A "repeater for two-way trunks" is to be distinguished from a "two-way" repeater which relays impulses in both directions - incoming and outgoing. Where two-way trunking is employed with either type, however, a repeater is required at each end of the inter-office trunk. Several typical examples of repeaters for two-way trunks are given below.

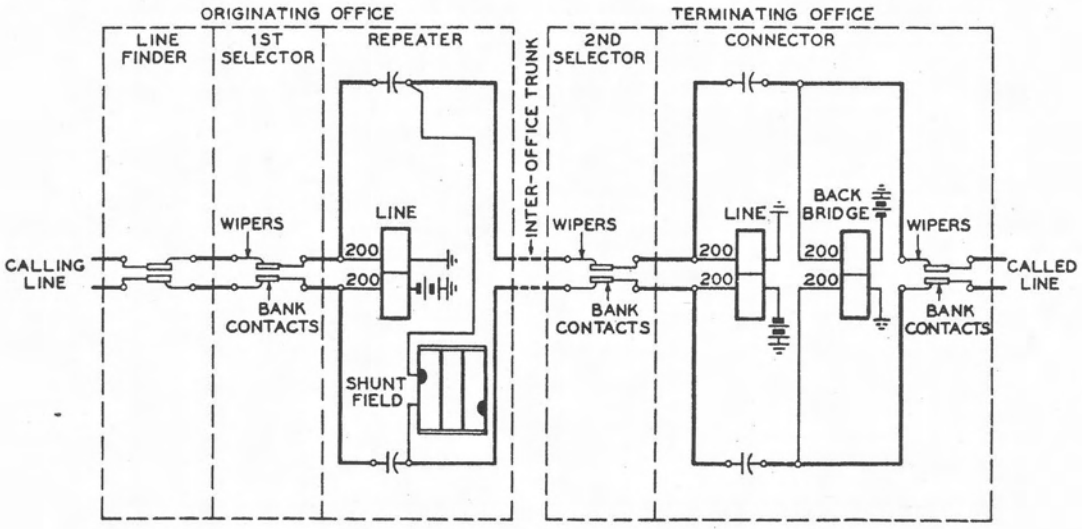

Fig. 6. Transmission Circuit of the Inter-Office Call

4.1 Repeater For Two-Way Trunk (Loop-Pulsing Type)

Figure 7 illustrates the circuit of a typical repeater (loop-pulsing type) for two-way trunks. This circuit is almost identical to that shown in figure 5 (one-way) but another relay, designated "H", is provided. The trunk

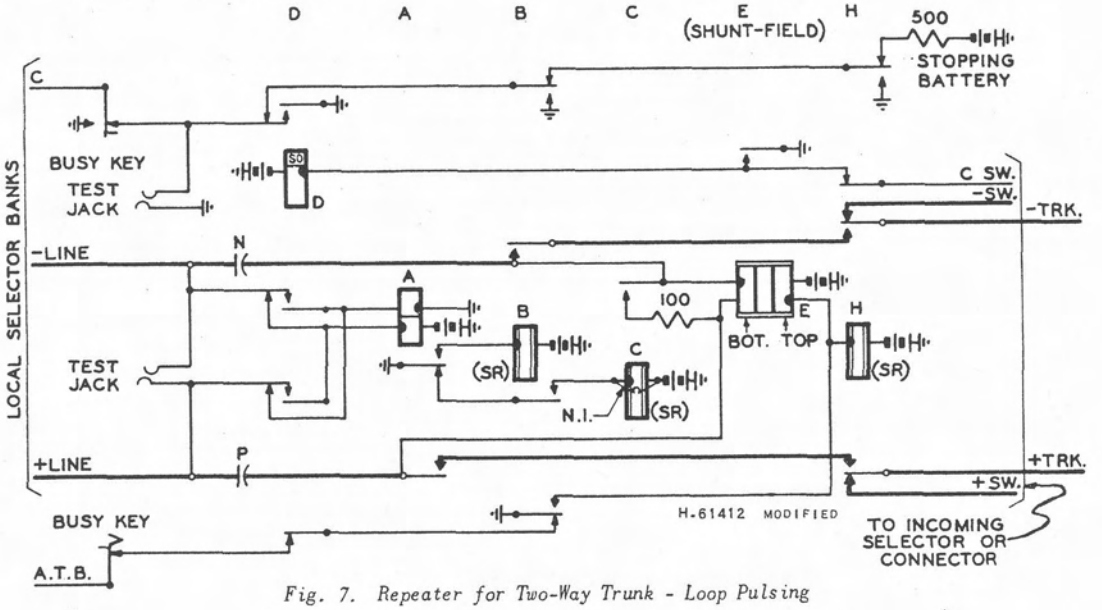

Fig. 7. Repeater for Two-Way Trunk - Loop Pulsing

leads are normally connected to an incoming selector or connector through a pair of break contacts on relay H. When the repeater is seized from the local selector banks with subsequent operation of relay B, ground is extended to relay H which disconnects the trunk from the incoming switch and connects it to the repeater.

On an incoming call when the repeater at the distant end has been seized, the loop to the incoming switch at this end is closed through the break contacts of relay H. The incoming switch (selector or connector) upon being seized, places ground on the CSW lead. Relay D receives this ground through a break contact on relay H, and operates. Relay D operating, removes 500-ohm stopping battery from the local selector C lead and replaces it with ground. The repeater at this (terminating) end is therefore, busied and safeguarded against seizure by the local selectors during an incoming call.

4.11 Release - Release of this repeater is accomplished in virtually the same manner as that of the one-way type described in section 3, the relays restoring in the same sequence. The additional relay H is de-energized upon the restoration of relay B. Relay H is slow to release so that on outgoing calls, the switch train in the called office has time to release before the incoming switch in this (originating) office is reconnected to the trunk. This prevents the incoming switch in this office from "locking up" to the switch train in the called office should the called party disconnect last. If the restoration of relay H were not delayed, in this instance, reverse battery polarity from the connector in the terminating office, would remain on the trunk at the time when the incoming switch in the originating office was reconnected to the trunk (Figure 8).

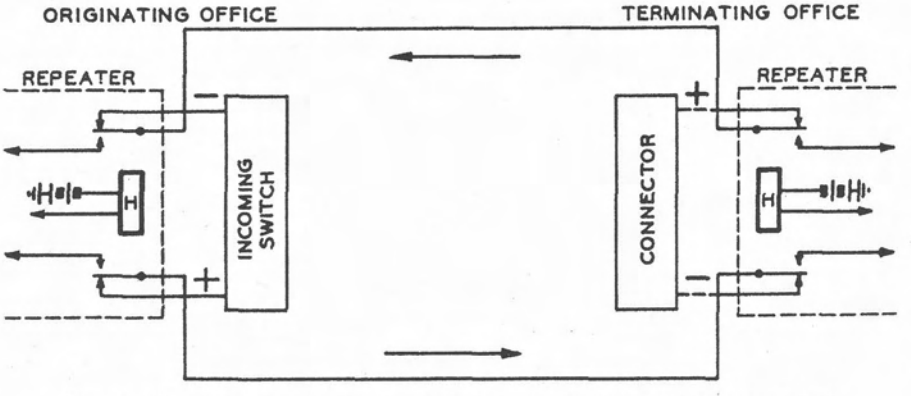

Fig. 8. Demonstrating Manner in which Incoming Switch at Originating End might "Lock Up" to Switches at Terminating End if Relay H were Fast Releasing

4.12 All Trunks Busy (A.T.B.) Feature - The "All Trunks Busy" (A.T.B.) feature seen in the circuit of figure 7 (omitted from figure 5 for simplicity) provides an indication of, and supervision over an all-trunks-busy condition. This feature or a similar feature is widely employed in impulse repeaters. It will be seen from figure 7, that upon seizure and the subsequent operation of relay B, ground is removed from the A.T.B. lead. If this trunk circuit were the last available, all grounds would then have been removed from the A.T.B. lead. Absence of ground on this lead can be made to operate an A.T.B. meter or other supervisory equipment by releasing a normally operated relay. The ground is restored to the A.T.B. lead when the repeater is released and the trunk is again available for use.

When the trunk is seized from the distant end, the incoming switch at this end, places ground on the CSW lead.

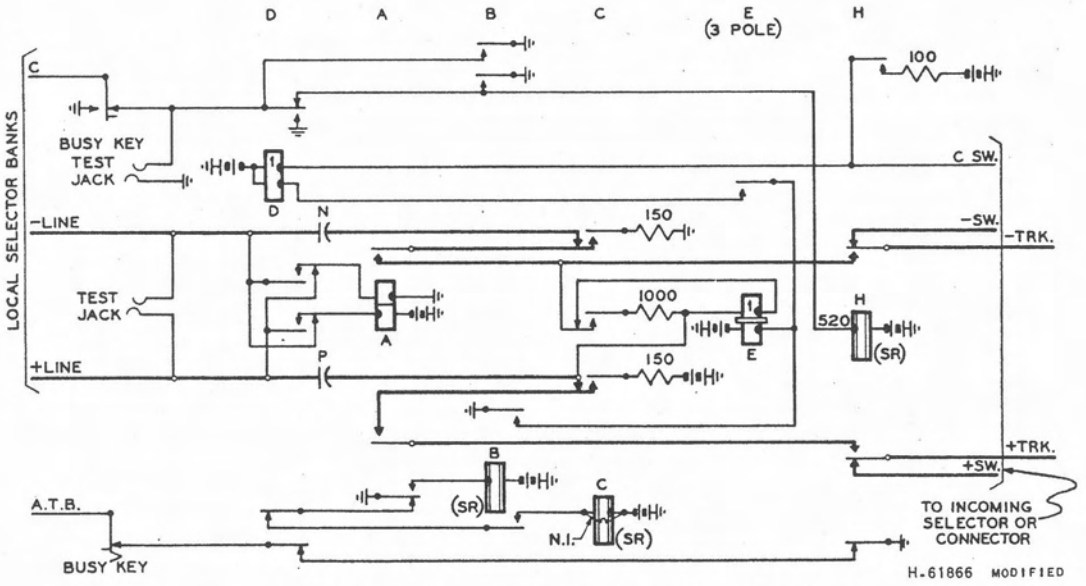

Fig. 9. Repeater for Two-Way Trunk - Battery Pulsing

This operates relay D to busy the repeater (See Sec. 4.1). Relay D operating, removes ground from the A.T.B. lead until the trunk is released at the distant end.

4.2 Repeater For Two-Way Trunk (Battery-Pulsing-Type)

A simplified schematic of a battery-pulsing type of repeater for two-way trunks, is shown in figure 9. This circuit is broadly similar to the loop-pulsing type shown in figure 7 except that each side of the trunk is pulsed with resistance-ground and resistance-battery, respectively. A three-pole relay performs approximately the same functions in this repeater that the shunt field relay performs in the previously described types. Relay H in series with negative-battery provides stopping battery for the local (battery-searching type) selectors.

The operation of this repeater otherwise closely parallels that given in section 4.1 for the loop-pulsing type. There are, however, a few notable points of variance: For example, on an outgoing call, when relay A restores on the first pulse, relay C (slow release) is energized. Relay C operates make-before-break contacts which; (1) prepare resistance-ground and resistance-battery to the - TRK and + TRK leads respectively, through pairs of make contacts on relay A, and (2) remove the original seizing bridge (number 1 winding of relay E) from the trunk. (Relay C operating, also shunts the number-1 winding of relay E momentarily with a resistance - 1000 ohms - in order to absorb inductive kicks.)

Therefore, whenever relay A operates during the succeeding pulses of the series, it connects resistance-ground and resistance-battery to the + and - trunk leads. This aids the rapid reoperation of the distant pulsing relay between pulses (open periods) and assures reliable pulse repetition (See Sec. 1.1B). At the end of each series, relay C restores, removes resistance-ground and resistance-battery and replaces the original seizing bridge.

4.21 Answer (Reverse Battery) Supervision - Reverse battery supervision in this repeater occurs in a manner similar to that stated for the one-way repeater in section 3.2; in this case, however, the operation of relay D also breaks the circuit to relay C and disconnects the C lead from relay H. Relay H, however, is held by a multiple ground on relay B.

The circuit to relay C is broken so that jiggling of the hookswitch or inadvertant movement of the dial at the calling end, will not result in the loss of the switch train at the called end. This could occur (assuming a continuous circuit to relay C) when relay A restores upon the first (accidental) pulse. Ground would then be extended to relay C through a make contact on relay B. Relay C operating, would remove the holding bridge and

close resistance-ground and resistance-battery to the trunk. Since this ground and battery would appear on the trunk in the same polarity as the reverse battery being sent back by the distant office connector, no current would flow over the trunk and the switches in the distant office would consequently release. This condition is not encountered in the loop-pulsing repeater described previously, as the holding bridge is replaced immediately after each impulse (break interval).

4.22 Release - Release for the repeater is similar to that given for the loop-pulsing types in sections 4.11 and 3.3 with minor variances. For example, when the calling party restores first; (1) relay A upon restoring, disconnects both sides of the trunk from condensers N and P, (2) relay C is prevented from momentarily operating upon the release of A because of a break contact on relay D in its circuit.

5.0 TWO-WAY IMPULSE REPEATER (SX Dialing)

The two-way impulse repeater relays impulses in two directions and performs essentially the same functions as the repeaters previously described except that these functions are performed whether the circuit is seized for an outgoing or an incoming call. As a two-way repeater is required at each end of the trunk, the repeating of dial pulses during a given call takes place at both the originating and terminating ends.

Simplex or composite dialing is often employed with two-way repeaters. The circuit shown in figure 10 illustrates a typical two-way repeater for SX whose operation is explained below.

The pull-out drawing (Fig. 13) at rear of bulletin shows a two-way trunk circuit equipped with these repeaters. Portions of the originating and terminating repeaters, respectively, have been eliminated to show only the active components for a call in the direction indicated.

The following circuit conditions should be noted in examining this SX repeater:

(a) The dial leg is connected to ground at both ends when the circuit is idle.

(b) When the circuit is seized, battery is connected to the dial leg at the originating end; dial pulses are transmitted in the form of battery pulses.

(c) Answer supervision is given at the terminating end by transferring the dial leg from ground to battery.

(d) Battery is connected to both ends of the dial leg during conversation.

(e) Release supervision is given when one end of the dial leg is transferred from battery to ground.

These conditions for pulsing and supervision are referred to as "battery-ground" or "positive-negative" pulsing and supervision. (The same conditions would apply if this repeater were used on a composited, CX, circuit.)

5.1 Outgoing Call (Refer to "originating" repeater of figure 13)

5.11 Seizure - The repeater is marked "idle" to the local (battery searching) selectors by the presence of resistance-battery on the C lead. (Resistance-battery is provided by the number-2 winding (500 ohms) of relay G in series with negative-battery.) When the control wiper of a local selector encounters stopping battery on the C lead of the repeater, a circuit is established to ground causing relay G to operate. (The operation of relay G at this point is inconsequential.)

At the same time the loop from the calling party to relay A, is established and relay A operates. This circuit may be seen by tracing the leads from relay A to break contacts on H, through the - TALK and + TALK leads and the windings of the repeating coil, over the - LINE and + LINE leads, to the calling party. Relay A operates and places ground on relay B. Relay B operates and; (1) closes ground to the number-1 winding of relay K, (2) connects together the CH IN and CH OUT leads to close this repeater's portion of the all-trunks-busy (A.T.B.) chain circuit, (3) disconnects the dial leg from relay A-1 and connects it to relay E through a make contact on A.

Relay K operates, grounds the C lead to hold the preceding switches and, at the same time, opens the circuit to relay G which now restores. At the terminating end of the trunk the dial leg is connected to ground (in a similar repeater) through the windings of relay A-1 of that repeater. The resistance-ground on the distant end of the dial leg causes relay E of the originating repeater to operate. (Relay A-1 of the distant repeater also operates to inaugurate the seizure of that repeater - See Sec. 5.21). Relay E operating, keeps ground from relay D. The circuit is now ready to repeat the dial pulses to the terminating office.

5.12 Repeating Impulses (Relays now operated: A, B, E, K) - Relay A alternately restores and operates in response to the dial impulses from the calling telephone. Each time relay A restores, negative-battery (through the windings of relay E) is removed from the dial leg. Pulsing the dial leg in this fashion, causes the terminating repeater to relay the dial impulses to the incoming selector or connector at that end (See Sec. 5.22).

Whenever relay A restores during the impulsing, ground is removed from relay B and extended to relay C through a break contact on D and a make contact on K. Relay C (slow release) operates on the first pulse of each series (digit of the call number) and remains operated during each series. (Relay B remains operated throughout the entire impulsing sequence.) Relay C operating, places 100-ohms, through a make contact on K, in multiple with relay E to improve impulsing over the dial leg. (When relay E is shunted by this 100-ohms, it may restore and remain so during impulsing.) At the end of each series of impulses, relay A remains operated, removing ground from relay C. The interval before the impulsing of the

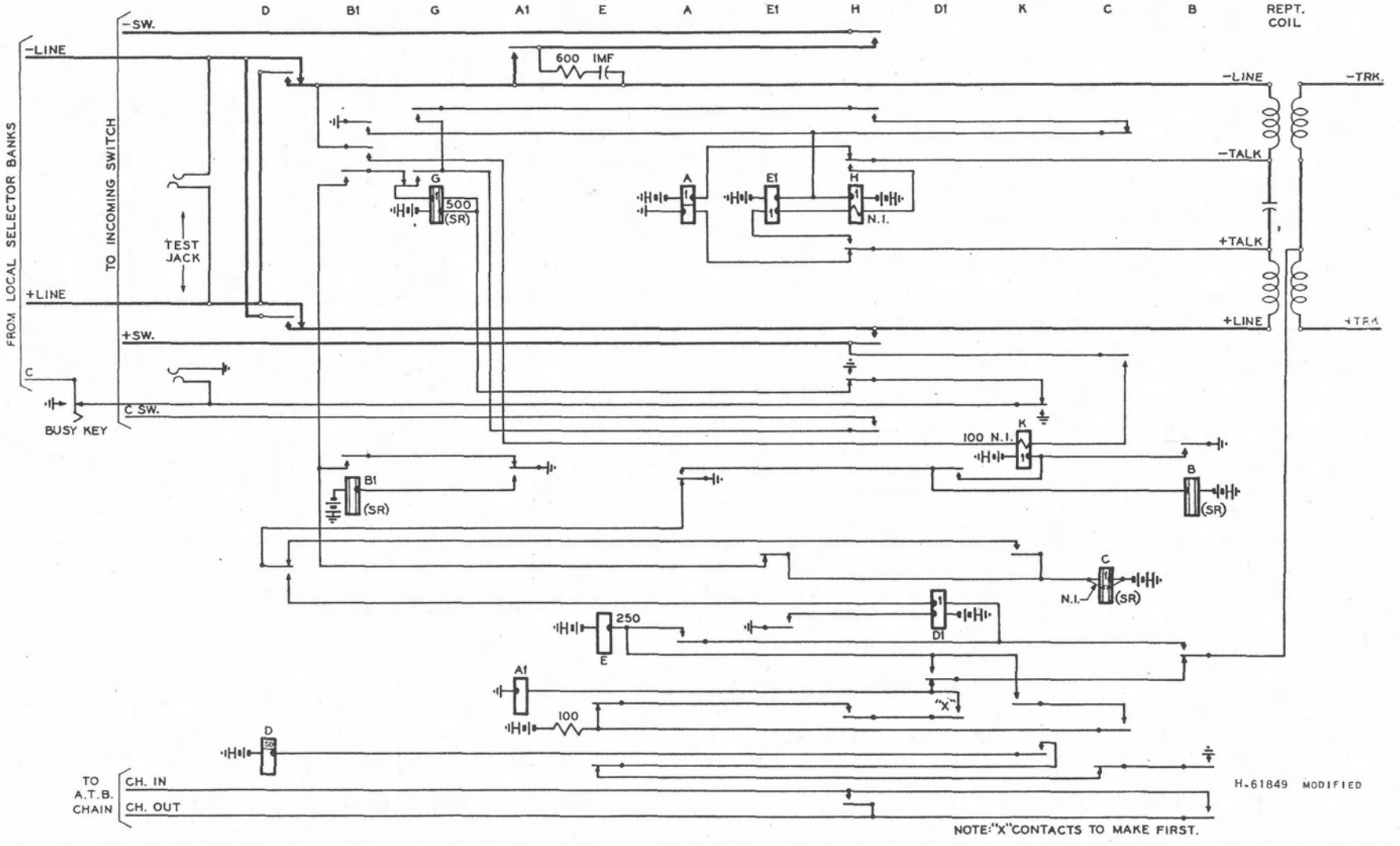

Fig. 10. Two-Way Repeater - SX Dialing

next series is now sufficient to allow relay C to restore. Relay C restoring, removes the 100-ohm shunt from relay E. Relay E will again operate if it has meanwhile restored as explained above.

At the end of the entire impulsing sequence, the switches in the terminating office have extended the call to the desired party and now automatically ring the called line.

5.13 Called Party Answers (Relays now operated: A, B, E, K) - When the called party answers, the dial leg at the terminating office, is transferred from ground to battery (See Sec. 5.23). As this battery is in the same polarity as the battery furnished through relay E at this end, relay E restores and completes a circuit from ground (on a relay B contact) to relay D. Relay D operates and reverses battery polarity (for supervision) to the calling party. The circuit is ready for transmission.

5.14 Release (Relays now operated: A, B, D, K)

(A) Calling Party Disconnects First - When the calling party disconnects, the loop circuit to relay A is opened. Relay A restores, removes ground from relay B and removes battery (through E) from the dial leg. Relay B restores; (1) opens relay K, (2) opens relay D, (3) transfers the dial leg to ground through relay A-1 and (4) opens the A.T.B. chain circuit. Relay K restores and removes ground from the C lead which permits the preceding switch train to restore. Relay D restores and reverses the calling line connections to normal. (The terminating repeater releases when ground is placed on the dial leg and the trunk circuit is again at normal - See Sec. 5.24A. The dial leg is in the idle or normal condition when ground has been applied at both ends.)

(B) Called Party Disconnects First - When the called party disconnects first, ground appears on the dial leg as the result of the partial restoration of the terminating repeater. (See Sec. 5.24B).

The originating repeater then operates as follows: Relay E operates from ground on the dial leg and opens the circuit to relay D. Relay D restores and reverses battery over the calling loop for supervisory purposes. The repeater will be held in this condition until the calling party disconnects.

When the calling party disconnects, relay A restores and opens the circuits to relays E and B. Relay B restoring, opens the circuit to relay K and removes battery (through E) from the dial leg, replacing it with ground from relay A-1. In the interval after relay A releases, but before B and K release, ground from a contact on relay A, operates relay C. Relay C operating, opens the circuit to relay D to prevent its re-operation from ground on a relay B contact. When relay K restores, it opens the circuit to relay C and removes ground from the local selector C lead to release the preceding switch train.

Note that the restoration of relay B removes battery from the dial leg and replaces it with ground. This action releases relay A-1 in the terminating repeater which results in the complete release of that repeater and the associated incoming switch train (See Sec. 5.24B). The circuit is now at normal.

5.2 Incoming Call (Refer to "terminating" repeater of figure 13)

5.21 Seizure - The terminating repeater is seized from the originating end when resistance-battery is placed on the dial leg by the originating repeater (See Sec. 5.11). Resistance-battery on the dial leg operates relay A-1 in the terminating repeater. Relay A-1 completes part of a circuit from the - LINE to the - SW lead of the incoming switch (selector or connector) and closes ground to relay B-1. Relay B-1 grounds the number-1 winding of relay H and the number-2 winding of relay E-1. Relay E-1 is merely polarized by this action but relay H operates. Relay H operating; (1) connects the - SW lead to the - LINE lead, (2) completes the loop to the incoming switch. This loop may be more clearly seen by tracing the + SW lead to a make contact on relay H, out on the + LINE lead, through a winding of the repeating coil, over the + TALK lead through the number-1 winding of relay E-1 and the number-2 (non-inductive) winding of H, back over the - TALK lead through another winding of the repeating coil over the - LINE lead to a make contact on relay A-1 to the - SW lead.

Relay H also grounds the C lead to make the repeater busy to the local selectors and in addition, connects the CH leads together to close this repeater's part of the A.T.B. chain circuit. Relay E-1 does not operate at this time because of the opposing field polarities of its windings. This repeater is now ready to receive the dial pulses from the originating repeater.

5.22 Impulsing - (Relays now operated: A-1, B-1, H) - Relay A-1 follows the pulses coming over the dial leg from the originating office and alternately opens and closes the line loop to the incoming switch causing it to step. When relay A-1 restores on the first pulse: (1) ground is extended to relay C (slow release) from a contact on A-1 through a make contact on B-1 and a break contact on E-1, (2) the same ground is also extended to relay G through its 1 and 2 windings.

Relay C operates and remains operated during each series of impulses. Operation of relay C places the 100-ohm, non-inductive winding of relay K across the SW leads thereby shunting out the number-1 winding of relay E-1, the number-2 winding of relay H and the windings of the repeating coil. This improves the impulsing to the incoming switch. Relay H does not restore as a result of this shunting action. Relay G operates and is now held by ground on the CSW lead.

5.23 Called Party Answers (Relays now operated: A-1, B-1, G, H) - When the called party answers, reverse battery is returned over the - SW and + SW leads. This reverses the current through the loop to the incoming switch (See Sec. 5.21) and consequently through the number-1 winding of relay E-1. As the field of this

winding now aids the polarizing (#2) winding, relay E-1 operates and places ground on the number-2 winding of relay D-1. Relay D-1 extends 100-ohm battery to relay A-1 to hold it operated and connects relay E to the dial leg. This causes relay E in the distant (originating) repeater, to release and thereby provide "off-hook" (answer) supervision (See Sec. 5.13). The circuit is ready for transmission.

5.24 Release (Relays now operated: A-1, B-1, D-1, E-1, G, H)

(A) Calling Party Disconnects First - When the calling party disconnects, the originating repeater releases and places ground on the dial leg (See Sec. 5.14A). Ground appearing on the dial leg as a result of the release of the originating repeater, operates relay E in the terminating repeater. Relay E removes 100-ohm battery from A-1. Relay A-1 restores; (1) opens the loop to the incoming switches which now restore, (2) removes ground from B-1. Opening the loop as described above, de-energizes the number-1 winding of E-1. Release of the incoming switches also removes ground from the CSW lead and consequently from the holding circuit to relay G, the 2 winding of E-1 and the 1 winding of H. Relays E-1 and H are momentarily held by relay B-1 (slow release) but relay G releases. When B-1 releases, E-1 and H also release. Relay E-1 restoring opens D-1. Relay D-1 restoring, transfers the dial leg from relay E to ground (through A-1). Relay E restores and the circuit is at normal.

(B) Called Party Disconnects First - When the called party restores, polarity over the SW leads is again reversed which reverses the polarity of #1 winding of relay E-1. Relay E-1 restores and removes ground from relay D-1. Relay D-1 restores and removes battery (through E) from the dial leg. Relay D-1 restoring, allows ground (through relay A-1) to be applied to the dial leg. Relay A-1 operates over the dial leg in series with relay E in the originating repeater to give release supervision. Relay A-1 holds this repeater and its train operated until the calling party disconnects.

When the calling party finally disconnects, the originating repeater releases and places ground on the dial leg (See Sec. 5.14B). Relay A-1 in this (terminating) repeater then restores; (1) opens the loop to the incoming switches which restore (2) removes ground from relay B-1. When the incoming switches release, ground is removed from the CSW lead and consequently from the holding circuit to G and H. Relay G releases but H is momentarily held by B-1 (slow release). When B-1 releases, H also releases. The circuit is now at normal.

5.3 Recording-Completing ("C.L.R.") Holding

In early toll practice a "recording operator" merely took the order for a desired long-distance call, and a separate "line operator" set up the actual connection. To speed things up, some 30 years ago the girls became "combined line and recording [C.L.R.] operators", and now perform both functions. The modern term is "recording-completing operator", and names the functions in their logical order.

Although on a local call the switchtrain releases a fraction of a second after the caller hangs up (§5.14), on a toll call the operator's plug in the jack must hold the linefinder, selector, pulse repeater(s), etc., so that if the caller "recalls" (slowly flashes) the operator, or hangs up while she works on the call or figures charges, the path from operator to caller will not be broken. The operator's plug in the jack causes the recording-completing trunk circuit to ground lead C.SW. (figure 13, right-hand end). Now the caller can hang up or can signal the operator without releasing the trunk.

For example, the calling party by jiggling the hookswitch will pulse relay A in the originating repeater (relays operated: A, B, D, K). Relay A during restorations, places ground on the dial leg through a make contact on relay D and the number-1 winding of relay D-1. Relay D-1 thus operates on each hookswitch pulse and closes a holding ground from a contact on relay B to relay B. This prevents the restoration of relay B and the consequent release of the switch train during the operation of the hookswitch. Relay A pulsing ground to the dial leg (as a result of hookswitch operation) pulses relay E in the terminating repeater which, in turn, arranges to flash a light to the operator by interrupting the circuit of A-1.

To elaborate, the conditions at the terminating office (relays operated: A-1, B-1, D-1, E-1, G, H) are as follows:

Relays G, H and E-1 are held by ground returned (by the operator) on the CSW lead. Relay E-1 holds relay D-1 operated but opens the circuit to relay C. When the calling party in the originating office signals the operator at this office by operating the hookswitch, relay E in the terminating repeater follows the pulsing over the dial leg and pulses A-1 which opens and closes the loop to the incoming switch. This flashes a supervisory lamp at the operator's position. Relay A-1 following the hookswitch motion, may remove ground from relay B-1 for an interval, sufficiently long to enable relay B-1 (slow release) to restore. This "fluttering" of relay B-1, however, will not restore relays E-1 and H because they are held by the ground on the CSW lead mentioned above.

Relay E-1 by holding D-1 keeps battery (through E) on the terminating end of the dial leg and thus forestalls operation of relay E at the originating end. Relay E (originating repeater) by not operating, maintains the circuit to D which maintains the circuit to D-1. Relay D-1 prevents B (release relay) from restoring on the hookswitch pulses as explained previously. Thus, by holding the terminating repeater, the operator can prevent the originating repeater from releasing even though the calling party has momentarily depressed the hookswitch or completely disconnected. The circuit can be released only when the operator releases the call (and removes ground from the CSW lead).

When the call has been made through an operator's position at the originating end, the called party in the terminating office may signal this operator. Each time the called party jiggles the hookswitch, battery is reversed over the SW leads of the terminating repeater. Relay E-1 pulses on each reversal and pulses D-1. Relay D-1 pulses the dial leg from battery to ground and thereby pulses relay E in the originating repeater to flash a light to the operator at that end. The terminating repeater does not release during signaling as relay A-1 of that repeater is held operated by battery over the dial leg from E of the originating repeater (See Sec. 5.23). The originating repeater will not release until the operator at that end disconnects (calling-party-release - see section 5.14B). The operator thus holds the trunk circuit by taking advantage of the calling-party-release feature.

5.4 Arrangements for Composite Dialing

The two-way repeater of figure 10 may also be employed for repeating impulses over a composited dial leg as shown in figure 11. Connection to the dial leg is the

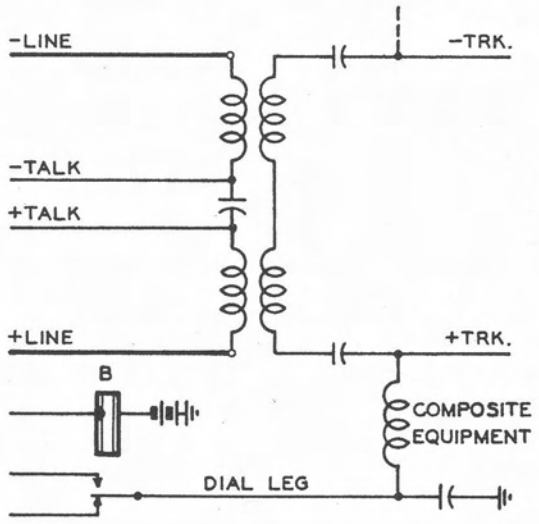

Fig. 11. Arrangements for Composite Dialing

same except that the dial leg is now derived from a composited trunk lead. Repeater operation remains the same as previously described.

6. PULSE CORRECTING REPEATERS

Repeaters employing pulse-correcting features are employed on inter-office trunks where distortion of dial pulses prevents satisfactory operation of the automatic switches. This distortion may become apparent at the terminating end of a trunk (assuming satisfactory operation at the originating end) because of such conditions as high trunk loop resistance, excessive leakage (low shunt resistance) or because of "repeated pulse repetition". For example, ordinary repeaters without pulse correcting features, introduce a nominal pulse distortion. If the impulses have been relayed by several repeaters in tandem this distortion may become excessive. At the originating end, the dial pulses may be distorted before they are transmitted to the distant end. This situation may occur as the result of excessive resistance, leakage, or because of excessive equipment on the subscriber's line.

Pulse distortion causes the line (pulsing) relay in the incoming switch or repeater at the terminating end, to deliver, in turn, pulses which are "longer" or "shorter" than the standard pulses required for satisfactory switch operation; that is, the ratio of the make interval to the break interval of one impulsing period (make interval plus break interval) is altered, and a longer or shorter pulse (break interval) is consequently delivered. If the length of the pulse varies sufficiently far from the desirable length, improper switch operation may result.

Pulse correction in repeaters involves the re-establishment of the pulse length within the nominal limits required for satisfactory switch operation even though the pulses delivered to the repeater have been distorted by the preceding equipment or intervening trunk facilities. If pulse distortion at the originating end of a trunk is sufficiently great, then an outgoing type of repeater embodying pulse correcting features may be employed. The repeaters previously described or similar repeaters, can be arranged to incorporate pulse correction on outgoing calls. If pulse distortion occurs as a result of trunk line conditions, then a pulse correcting incoming repeater may be employed at the terminating end of the trunk; or, if two-way repeaters are employed, they may be designed to incorporate facilities for correcting pulses on incoming calls.

The one-way incoming repeater seen in figure 12 whose operation is explained below, illustrates one method of impulse correction. An incoming repeater is placed ahead of the incoming switches (selector or connector). Where repeaters similar to those shown in figures 7 and 9 are employed on the trunk, the incoming repeater (if required) is connected to the trunk through the break contacts of relay H of those repeaters. Incoming repeaters are also available without the pulse correcting feature as they serve other important functions such as introducing repeating coils into the transmission circuit for the reduction of noise, or matching of the trunk impedance to the exchange impedance, etc.

6.1 One-Way Incoming, Pulse Correcting Repeater

6.11 Functions - The pulse correcting repeater seen in figure 12 is required to perform the following functions:

(a) Correct dial pulses which have been received from the distant (calling) office and repeat them to the incoming switch train.

(b) Reverse battery to the calling office for answer supervision.

(c) Project ground forward to hold the succeeding switch train. (Optional-used primarily in toll applications.)

6.12 Seizure - When the trunk is seized from the distant end, the loop is closed to relay A. Relay A operates, closes ground to relay B and connects the ungrounded side of condenser S to relay J through a break contact on relay D. Condenser S is charged from battery through relay J. Relay J operates momentarily and releases when the condenser becomes charged (the size of condenser S determines the operated time of relay J). Relay B on operating closes ground to relay K, grounds the C lead and the number-2 winding of relay E and connects the + SW lead to the repeating coil. Relay K operates, locks to ground through a break contact on J, grounds relay H and connects the - SW lead to the repeating coil to complete the loop through the number-1 winding of relay E for seizing an incoming switch. Relay H operates. Relay E does not operate as the field polarities of its windings, oppose.

6.13 Impulse Repeating and Correcting - Relay A alternately opening and closing, follows the dial impulses from the distant office. Relay A restoring at each impulse, opens relay B and discharges condenser S through resistance T. When relay A operates at the end of each impulse, it reconnects condenser S to relay J to operate it momentarily as before (see above). Relay J therefore follows the pulsing of relay A. Relay J operating, removes ground from relay K which restores. Relay K restoring, removes ground from H, places ground on C and opens the line loop to the incoming selector. Relay H restores and connects ground (from B) to relay K which locks up. (Relay J operating only momentarily, has meanwhile restored.) Relay K operating, closes the loop to the incoming selector (or connector) and closes H. Relay K therefore repeats the pulses to the incoming selector. The length of the repeated impulse (break interval) thus becomes a function of the release time of H and K plus the operate time of K. Its length has no direct relation to the pulse (open period) of A. Relay A following the impulses from the distant office, acts basically as a "triggering" mechanism for setting the pulse correcting and repeating relays into action.

It should be noted that the pulse to the incoming switch is out of step with the pulse received from the distant end; i.e., K opens the pulsing loop only after A has reoperated.

Relay C (slow release) operates on the first pulse of each digit and shorts the drop side of the repeating coil with resistor Y to improve impulsing. It restores at the end of each digit.

6.14 Called Party Answers - When the called party answers, battery is reversed over the SW leads from the connector. This reverses the current through the number-1 winding of relay E. As the field polarities of the windings of E now aid, E operates and closes the circuit to relay D. Relay D operating, reverses battery back over the trunk to the calling party and opens the incomplete circuit to J so that further inadvertant pulsing of A will not affect J.

6.15 Release - When the called party disconnects, battery is again reversed over the SW leads through the number-1 winding of relay E. Relay E restores as its fields again oppose, and opens the circuit of D. Relay D restores and again reverses the battery polarity over the trunk to normal for "disconnect supervision".

When the calling party disconnects, the trunk loop circuit is opened and relay A restores opening the circuit to B. Relay B restores, opens relay K, removes

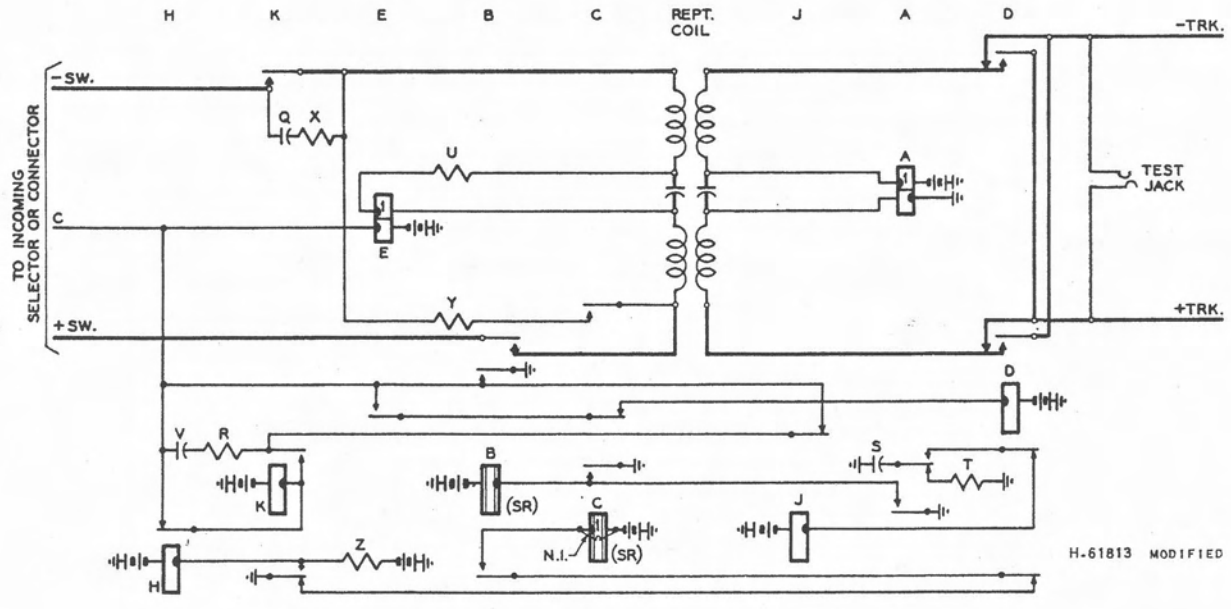

Fig. 12. One-Way Incoming, Pulse Correcting Repeater

ground from the C lead and opens the loop to the incoming switch train which now restores. Relay K restores and opens H. Relay H restores.

6.16 Additional Notes - The resistance-capacitance combinations Q-X and R-V and the non-inductive winding of relay C, serve to reduce sparking at the contacts which open their respective circuits.

7.0 OTHER REPEATERS AND IMPULSING METHODS

The foregoing material has dealt with some basic repeater types and impulsing methods. Other types of repeaters and methods of impulsing are also available to fill needed field requirements. A few of these are briefly described below.

Repeaters for Two-Way Automatic to Manual Trunks - Used on trunks between manual offices and automatic offices, for example CAX. Repeaters employed at the automatic end are classified as "automatic-to-manual" - those used at the manual end, "manual-to-automatic". The manual operator may dial into the automatic exchange and the pulses will be repeated. Pulse repeating is not required in the other direction - automatic to manual. The subscriber, to reach the operator at the manual end, dials the proper code (for example, "0") and is connected to the automatic-to-manual repeater, which sends a signal to the manual end. This signal may consist of a "splash" of alternating ringing current or a change of polarity on a dial leg, etc. In any case, the operator is signaled by means of a lamp or drop. C.L.R. holding is usually provided so that the manual operator may hold the circuit during recall signals by calling subscriber.

Switching-Selector-Repeater - Combines the functions of both the selector and the repeater into one mechanism; and contains the means for discriminating between local and outgoing calls. It serves as a loop pulsing repeater on calls from one office to other offices and as a selector on calls within the office. Its use results in the reduction of the number of trunks required between a sub-office and a central office in a multi-office exchange area (See A.E.Co. Bulletin 817 for detail description).

Selector-Repeater - Essentially a selector with a built-in repeater. In addition to extending a given call, the selector-repeater usually corrects and repeats the impulses to the succeeding switches. The selector-repeater may also distinguish between calls which require the repeating feature and those which do not, and automatically operate to accomplish the desired service. Similar to switching-selector-repeater but without the discriminating feature mentioned above.

High-Low Supervision - A means of supervision employed on SX or CX circuits. As contrasted with the battery-ground supervision described in section 5, high-low supervision functions on the amount of resistance in the dial leg and uses interrupted ground for pulsing. The current on the dial leg can be varied to effect changes in relay operation, and provide supervisory indications. Thus, before the called party answers, an "on hook" indication is provided by low resistance in the dial leg. When the called party answers, an additional resistance is automatically placed in the dial leg to provide an "off hook" indication. This system is frequently employed on automatic-to-manual circuits; its major advantage is that it does not require pulsing battery at the manual end.

Duplex Signaling - A system employed with composited trunks which is fundamentally the same as that used in differential duplex telegraph operation. The system derives two independent two-way signaling channels from a two-wire trunk, and employs a sensitive "polar duplex relay" at each end of each wire. It permits signals or impulses to be transmitted simultaneously from both ends of one channel without interfering with each other (which is sometimes desirable for toll operator's supervision). The sensitive relay employed, allows dialing over impulsing circuits of substantially higher resistance.

A-C Dialing - D-C pulses are converted to pulses of 50 or 60-cycle alternating current which are sent directly over the trunk. At the terminating end the a-c pulses are converted again to d-c pulses. This system is used on a limited scale where ground potentials prohibit effective use of composited d-c circuits.

Voice Frequency Dialing (VFD) - A system of dialing which converts d-c dial pulses to pulses of alternating current in the voice frequency range, such as 1000 cycles. This is the preferred method of a-c dialing because voice frequency signals pass through the same equipment (voice frequency repeaters or carrier circuits etc.,) as speech currents without requiring special equipment. As the VF signals will be amplified by voice frequency repeaters, this system may be employed on very long circuits. It is the most expensive, however, and is used only where d-c methods are not suitable.

Carrier Frequency Dialing - Another method of a-c dialing using frequencies above the normal voice frequency range. This system is incorporated into several types of carrier systems and is as flexible and dependable as VFD.

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