TRIP RELAYS

AND

SUBSCRIBERS RINGING SYSTEMS

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PREFACE

This pamphlet is issued for the purpose of describing the general characteristics of trip relays, the particular part of the wave method of adjusting and testing these relays and the new AC-DC ringing system for the benefit of the Western Electric installers. The pamphlet contains brief explanations only and no attempt has been made to give the underlying theory.

This pamphlet will not be reissued to keep it up-to-date in accordance with changes in equipment. If there are changes of sufficient importance or general interest, a new pamphlet will be written.

The information contained in this pamphlet is based on various information issued by the American Telephone and Telegraph Company and the Bell Telephone Laboratories.

The contents are of a purely descriptive nature and in no way prescribe methods or give engineering information for the installation of Central Office Equipment.

CONTENTS

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GENERAL DESCRIPTION OF SUBSCRIBERS RINGING SYSTEMS

The purpose of this pamphlet is to discuss the characteristics of trip relays and their action on ringing currents, as well as explain the "particular part of the wave" method of adjusting and testing these relays, and the new AC-DC ringing system. As it is desirable, however, to have a basic knowledge of the fundamental problems involved in signalling a telephone subscriber, a brief description of the conditions encountered is given for preliminary information.

These conditions vary with the number and arrangement of subscribers placed on the line and are dependent primarily upon the class of service purchased by the subscriber. The type of equipment and kind of ringing current together with the circuit used for signalling the subscriber is called the "ringing system." There are a number of different ringing systems in use throughout the Bell System. For our purpose, however, the present day ringing systems will be classified into four groups as follows:

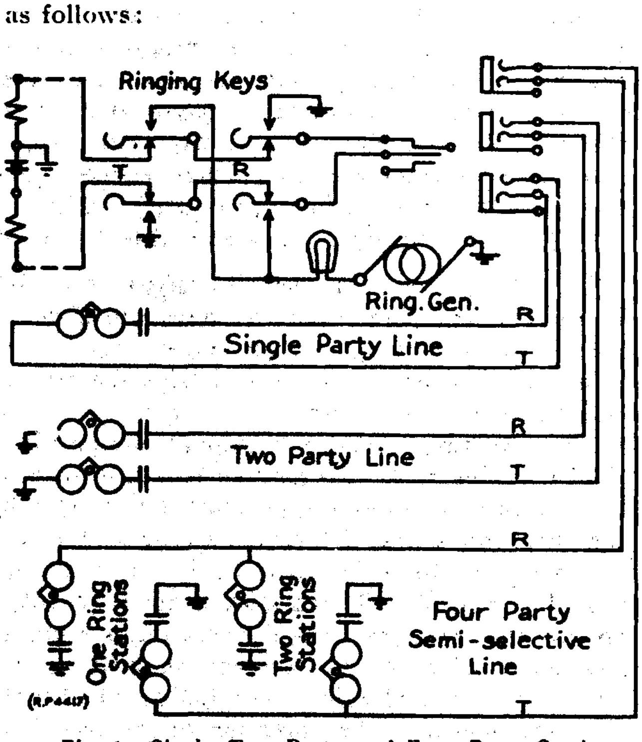

Fig. 1. Single, Two Party, and Four Party Semi-Selective Ringing Systems

Single Party
Two Party
Four Party, Semi-Selective
Four Party, Full Selective

As a general rule two party and four party semi-selective systems are broadly classified as single party systems, since the only difference is the number and arrangement of subscribers sets on the line. Any single party area may have two party and four party semi-selective subscribers on some lines. Figures 1 and 2 show the essential parts of the above systems.

On single party lines the ringer is connected directly across the line and in series with a condenser. The condenser prevents the leakage of battery current thru the windings of the line relay when the line is idle but allows alternating current for operating the bell to pass.

On two party lines the ringers are connected thru the condensers between ground and one side of the line instead of across the line. One party's ringer is connected to the tip side of the line, and the other party's to the ring side. Two keys or their equivalent are provided for determining which subscriber will be signalled.

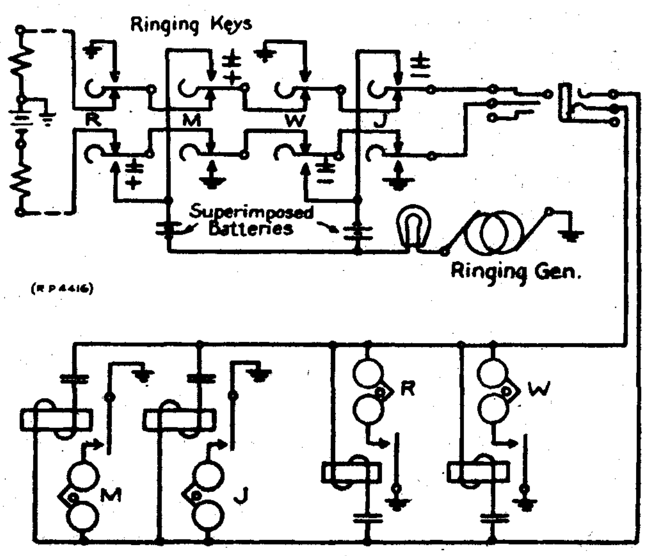

Fig. 2. Four Party Full Selective Ringing System

Four party semi-selective lines are the same as two party lines except that there are two subscribers on each side of the line. Both bells operate at the same time when ringing current is supplied to that side of the line. The subscriber being signalled is distinguished by code ringing, that is, one and two ring signals.

In four party full selective systems, selective ringing of the two subscribers on the same side of the line is accomplished by arranging the ringers to operate on different currents. Positively and negatively superimposed or pulsating ringing currents are used instead of alternating current, the ringers being biased to operate on one polarity of ringing current only. Superimposed or pulsating current takes the form of straight alternating current when sent thru a condenser, and for that reason the ringers must be connected directly between ground and the line. In order to prevent a useless drain on the central office battery while the line is idle, a relay is connected across the line in series with a condenser, the ringer being connected to the line thru the contacts of the relay. In four party manual ringing systems the subscribers are usually designated by a common number and the letters M, W, J, and R. The ringing keys are labeled with these letters and so connected that the operation of any key will cause the proper ringing current to be connected to the line.

In the above circuits the lamp shown in series with the ringing generator is provided to prevent an excessive flow of current when the subscriber answers and when the line becomes crossed or grounded.

Where manual ringing is used a considerable portion of the operator's work in completing a connection thru the local subscribers multiple is that incident to signalling the called station, especially in the case of slow answers. It is obviously desirable to reduce the operator's work as much as possible, and in the case of automatic or machine switching telephone systems it is necessary to provide some means of controlling ringing other than manual. For this reason nearly all ringing systems are applied on a machine ringing basis, that is, ringing is controlled by means of relays and interrupters, and the operator is relieved of this work.

However, when ringing systems are applied on a machine ringing basis a number of problems are encountered which are not found under manual ringing conditions. In machine ringing it is important that the subscriber be signalled without fail when his number is called, and that the ringing current be cut off as soon as he answers so that conversation can take place and so that the subscriber will not be disturbed by ringing in the receiver. Since signalling is done over the line and is stopped by a change in the line condition due to the subscriber having answered, it is apparent that line conditions must be taken into consideration, otherwise ringing may be stopped prematurely or may not stop when the subscriber answers. In either case no conversation can take place and the telephone would be useless. Therefore, when ringing current is applied on a machine basis reliable equipment must be provided for controlling it, and limits must be placed on the lines over which it is used.

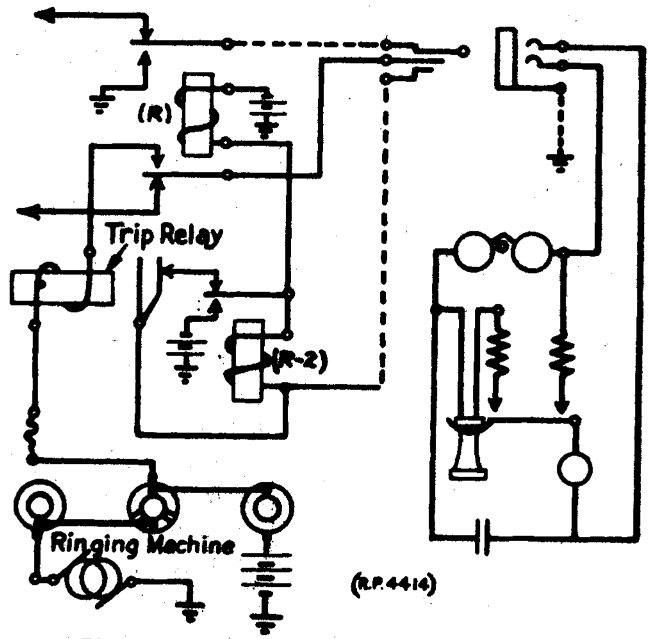

Fig. 3. Fundamental Machine Ringing Circuit

The arrangement in use throughout the Bell System for applying machine ringing consists essentially of supplying ringing current to the line thru a relay which operates and trips the ringing current when the subscriber answers. A typical machine ringing circuit for manual equipment is shown in Figure 3. Ringing current is placed on the line thru the interrupters and the trip relay by the operation of the "R" relay as soon as the cord is placed in the subscribers jack. The current passed by the subscribers station is not sufficient to operate the trip relay until the receiver is removed and the condenser and bell are shunted by the transmitter and induction coil winding which have a low resistance. The operation of the trip relay allows the R-2 relay to operate which, in turn, shunts out the R relay which releases. The release of the R relay cuts off the ringing current and establishes the talking circuit.

The interrupters shown in Figure 3 are provided to apply the ringing current to the line intermittently, and to connect direct current battery to the line during the silent period. The silent period battery is provided so that the talking circuit will be established at once if the subscriber answers during the silent period, and insures the disconnection of the ringing current from the line before the subscriber places the receiver to his ear. The ringing and silent intervals are usually two and four seconds respectively for selective ringing systems.

CONSTRUCTION OF TRIP RELAYS

Since trip relays must function on alternating current and under marginal conditions, a relay of special design is required. The relays now supplied as trip relays are the No. 114 and No. 198 types. These relays are identical in design except that the No. 198 type is provided with two windings and is used in four party full selective systems where two different ringing currents are required. A cross section of a No. 114 type relay is shown in Figure 4. The following features of the design of these relays should be noted:

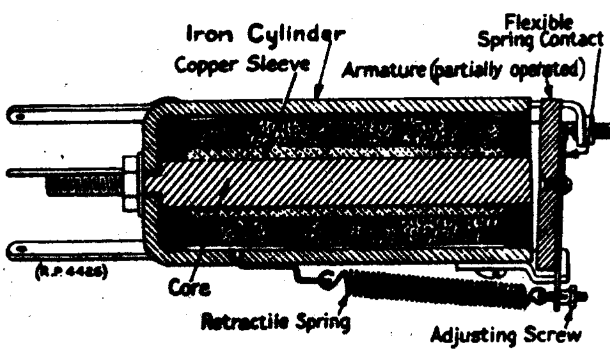

Fig. 4. Cross Section of Trip Relay

1. They have a much better magnetic circuit than is found in the average relay. This is accomplished by enclosing the core and winding in an iron cylinder which is closed at one end. The armature forms the other end of the cylinder.

2. They have copper sleeves over their cores.

3. The armatures are much heavier than are required for the magnetic circuit or the mechanical construction of the relay.

4. The contacts are arrranged so that the armature can move a considerable amount of its travel before breaking contact.

With a copper sleeve over the core the trip relay is in effect a transformer having a short circuited secondary winding, and since ringing currents are alternating (varying currents), the sleeve creates a demagnetizing effect which opposes the magnetizing action of the line winding. The action of the sleeve, together with the mechanical design of the armature and contacts, gives the relay considerably better operating characteristics than if these features were omitted. This sleeve also improves the operating characteristics of the trip relay when used with ringing currents having DC components.

The iron cylinder provides an excellent magnetic circuit which is necessary for the best action of the sleeve, and also prevents magnetic interference with adjacent apparatus.

METHODS OF MAINTAINING TRIP RELAYS

In maintaining any relay to meet service conditions it is necessary to set up testing requirements that indicate whether or not the relay will meet the worst service conditions. Since trip relays function in service on ringing current through the line loop and subscribers' set, it would seem satisfactory to test them on this basis by simulating the worst service conditions with resistance, inductance and capacity, but this method was found unsatisfactory due to the commercial variation in the inductance and capacity used in the test circuit itself. The AC current flow method was also found impractical due to the excessive cost and delicate construction of dependable meters for this purpose and if this method of testing had been adopted the same difficulty would no doubt have been encountered as was encountered with the test adopted, since the current flow would have been regulated with non-inductive resistances.

The trip relay or any relay having a similar design operates differently on alternating current than on direct current. A direct current test is, therefore, a poor test for maintaining these relays for service on alternating current. These conditions and the fact that resistance can easily be held to close limits led to the adoption of non-inductive resistance tests on ringing current as the routine test of the trip relay.

Non-inductive resistance tests did not prove entirely satisfactory, however, when applied in the field as there was some unknown factor in the test that caused inconsistent results. On consecutive tests the relay would fail and then meet the test for a considerable number of times or might fail after meeting the first test and under these conditions, the test was not an accurate indication of the adjustment of the relay.

An investigation made by the Bell Telephone Laboratories as a result of this condition showed that the inconsistent results obtained with non-inductive resistance tests were due to the varying operating characteristics of the trip relay when functioning in testing circuits. It was found that due to these characteristics, closing at the zero point on the wave constituted an operating condition approximately one and one half times the operating condition when the circuit was closed at the peak of the wave. This means that one and one half times as much current is required to operate the relay when the circuit is closed at the peak of the wave.

This action is explained briefly as follows: When the circuit is closed at the zero point the current in the active winding builds up along the sine wave with the result that the demagnetizing effect of the sleeve is minimum and there is the time of a full half cycle for operating the relay. On the other hand when the circuit is closed at the peak, the current increases from zero to a maximum value almost instantly, the demagnetizing action of the sleeve is much greater and, since the time until the end of the half cycle is less, a much higher current is required to cause operation of the relay than at zero closure.

An important point to be brought out here is that, when the demagnetizing effect of the sleeve is greater during the first half cycle than during normal half cycles, as it will be for peak closure, a relay which will not operate on the first half cycle may still operate under normal conditions (succeeding half cycles). The current required to operate the relay under normal conditions, that is after the transient conditions due to circuit closure have subsided, is known as the fundamental operating current. For this reason the peak closure operating current and the normal condition operating current are considered equivalent since the normal condition always exists in the circuit as soon as the first half cycle has passed.

It is apparent that under the above conditions the actual test applied varies with the point of circuit closure, and if non-inductive resistance tests are to be an accurate indication of the adjustment of the relay, it is necessary to apply every test at a definite point on the wave.

As a result the Bell Telephone Laboratories developed a reliable method of applying tests uniformly which is known as the "Particular Part of the Wave" (PPW) method. With it the testing circuit is always closed at or near the peak of the wave. It would be equally satisfactory to make the test at the zero point or at other points on the wave providing it was applied uniformly at the same point. However, since the rate of change in an alternating current is least at the peak, it is most satisfactory to use that point so that variations in the operation of testing equipment will have a minimum effect on the uniformity of the test. At the peak of a sine wave there is a period of time of about 30° of the wave (see Figure 5) in which the current variation is less than 5%. From an equipment standpoint it is also more satisfactory to apply the test at the peak as additional equipment is required to apply the test at zero closure.

An additional point concerning the application of PPW tests should be noted again at this time. When a DC component is added to a ringing current it stabilizes the operating characteristics of the trip relay. When this component is sufficiently high it eliminates the necessity of PPW tests, and since the standard four party ringing currents have high DC components, these tests are not required on these ringing currents.

A question that is frequently raised concerning the application of PPW tests should be mentioned here in order to give a clearer understanding of the purpose of these tests. It is pointed out that machine ringing is not applied at a particular part of the wave, in view of which the value of a uniform test is questioned. The answer to this is that the zero closure condition occurs only in testing circuits, and therefore no preventative action is necessary in Subscribers ringing circuits. Standard ringing currents which do not have high DC components have condensers in series with the ringers, and the combined reactions of the condensers and ringers are always sufficient to eliminate the zero closure condition. As was mentioned previously, it is not practical to test trip relays with inductance and capacity due to the commercial variation in ringers and condensers and the excessive cost of accurate testing equipment of this type.

EQUIPMENT USED IN APPLYING PPW TESTS

Tests are applied at the peak of the wave thru the use of polarized relays, which are polarized by means of a winding connected to local battery. A second winding of the relay is then connected in circuit with the generator and trip relay and when the half cycle of ringing current, which acts differentially with the local battery winding, reaches the peak of the wave the flux produced by the ringing current neutralizes the flux produced by the local battery winding and causes the relay to release and apply the test at that point. Since the action of these relays is due to the differential action they are known as differential relays.

The essential circuit for applying tests at the peak of the wave on straight AC ringing current

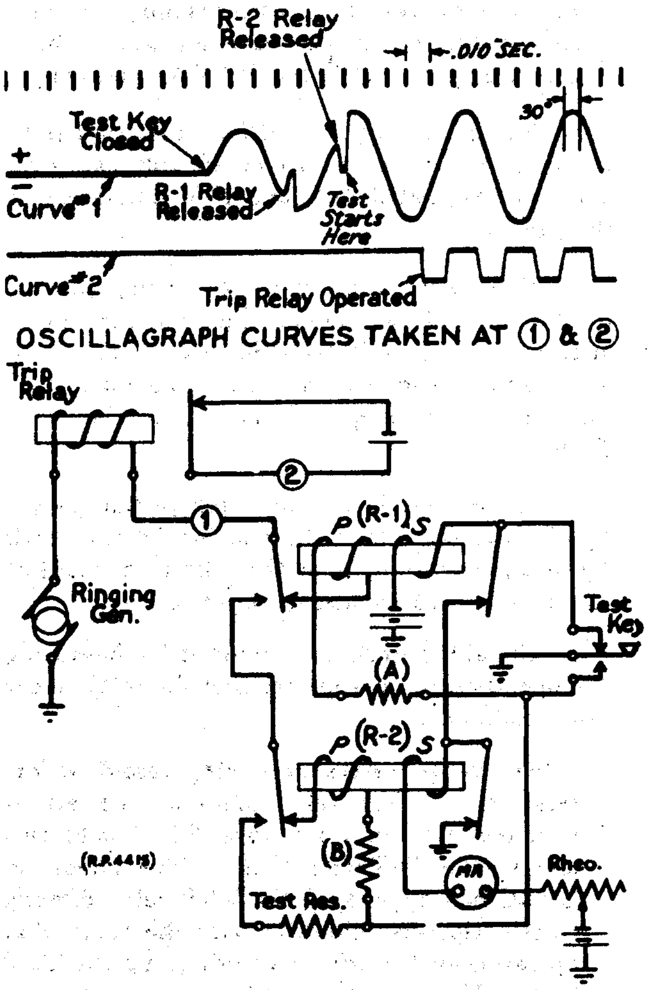

Fig. 5. Fundamental Circuit for Applying PPW Test on AC Ringing Current

is shown in Figure 5 together with oscillograph curves of its operation. The detail operation of this circuit is as follows: The differential relays, R-1 and R-2, are operated and locked thru their secondary windings (S). When the test key is operated: it (1) removes the operating ground from the secondary winding of the relays which do not release but remain operated from the ground on the front contact of the R-2 relay, and (2) completes the generator circuit traced from generator thru the winding of the trip relay, contacts and P winding of the R-1 relay, resistance "A" to ground thru the test key. The resistance "A" is sufficiently high to prevent operation of the trip relay. The two windings of the R-1 relay are connected so as to act differentially when the AC current flows thru the circuit from generator to ground (negative direction), which causes this relay to release at or near the peak of the negative wave. The release of the R-1 relay transfers the ringing current circuit from the P winding of the R-1 relay to the P winding of the R-2 relay. Resistance "B" has the same value as "A" and prevents operation of the trip relay over this circuit.

The two windings of the R-2 relay are connected so as to act differentially when the current is flowing thru the circuit from ground to the generator, (positive direction) which causes this relay to release at or near the peak of the positive wave. The release of the R-2 relay connects the trip relay to ground thru the test resistances and the test key. After the R-1 and R-2 relays have functioned, a few cycles of ringing current is sufficient to test the trip relay. A study of the oscillograph curves accompanying the circuit will help to make the condition in the above test clear. It may be noted that the relay does not operate in synchronism with the peaks of the waves but lags behind. This is due to the phase relations in the relay circuits.

It is not necessary to apply the test at the peak of the positive wave as might be inferred from the fact that two relays are provided, since both waves of an AC current are identical. The second relay is necessary to insure that closure will occur before the peak and not after, as would be possible with a single relay. In this latter case the test key might happen to be closed just after the peak of the wave on which the single relay was poled to release, and by the time the armature had reached the back contact the AC wave would be near the zero point.

Another condition which it is necessary to guard against is the release of the R-2 relay so low on the increasing part of the wave as to materially reduce the rate of build up of current at circuit closure. This condition might be brought about by a low central office battery voltage which would decrease the holding power of the differential relay. In order to prevent this condition the ammeter and rheostat are placed in circuit with the polarizing winding of the R-2 relay and the current is adjusted to a definite value before tests are applied.

The circuit shown in Figure 5 is obviously an arrangement for applying PPW tests on AC ringing current in the laboratory, and the circuit for applying the test on a commercial basis must necessarily be more complicated. In addition the Installation Department is confronted with the problem of adjusting and testing trip relays under varying conditions of ringing current, central office voltage, and code of relay, and it is desirable, from a standpoint of convenience and economy, to combine the several different circuits. This has been accomplished in the Installation Department's Universal Tripping Relay Adjusting Set, ITE-2030. The schematic circuit of this set is shown in Figure 6 and the panel in Figure 7. No detailed explanation of the operation of this circuit will be given here. This information is given in Section 7 of Handbook No. 6. It is, however, desirable to give here the conditions which make necessary the somewhat complicated circuit shown in Figure 6.

In this set the following provisions are made to cover the various conditions encountered when adjusting and checking trip relays.

1. Equipment is provided for making tests on all standard ringing currents as follows:

(a) **Straight AC Ringing Currents.** PPW tests using both differential relays are applied on these ringing currents. Operation of the PPW key sets up the circuit for these tests. Provision is also made for testing at five sets of voltage bands; 75-87, 80-92.5, 85-98.4, 90-104.2 and 95-110 volts. *The voltage band used is determined by cross-connecting the terminals of a small panel mounted inside the set. For maintaining a constant current in the polarizing winding of the second differential relay, regardless of the central office battery voltage, a rheostat and meter are provided. This current is adjusted under control of the AMM key.

(b) **AC-DC Ringing Current.** This is a new and recently developed single party ringing current described later in this pamphlet. PPW tests using only one differential relay are applied on this ringing current. The circuit for these tests is set up by means of the PPW and 95-103 V.A.C. 16-19 V.D.C. keys. No adjustment of the differential relay current to cover variations in central office voltage is required on this ringing current.

(c) **Standard Four Party Selective Superimposed Ringing Currents, all Voltages and Frequencies.** As was previously explained PPW tests are not required for these ringing currents and the differential relays are not used. These tests are applied with the PPW key normal.

2. Equipment is provided for making all tests in offices having either 24 or 48 volt batteries. The key designated 24-V and 48-V takes care of this feature.

3. Equipment is provided for setting up any combination of operate and non-operate resistance values. This is accomplished by means of a variable resistance unit which contains 1995 ohms in 5 ohm steps. This unit is shown in Figure 7.

4. Equipment is provided for testing relays by direct connection to the relay at the relay rack by means of terminals or thru the trunk cord at the switchboard by means of jacks.

5. Suitable signals are provided for indicating the operation or non-operation of the relay under two conditions.

(a) **When relays are being tested at the relay rack.** For this condition the set is equipped with a relay (the TRP) and two lamps (the TST and TRP). The indication is obtained by locking the TRP relay directly to the trip relay contacts with the result that operation of the trip relay brings up the TRP lamp. Non-operation and the completion of the test is indicated by the TST lamp.

*** At the time this pamphlet is issued, all ITE-2030 sets have not been equipped with these panels and sets without these panels may be encountered in the field for a short time.**

(b) **When relays are tested from the switchboard in manual offices.** For this condition a meter is used as an indicating device, since the contacts of the trip relay are not available. Operation of the TRK key causes the trip relay circuit to be connected to the meter as soon as the test is completed. Non-operation of the relay is indicated by an intermittent vibration of the needle and operation is indicated by a steady condition.

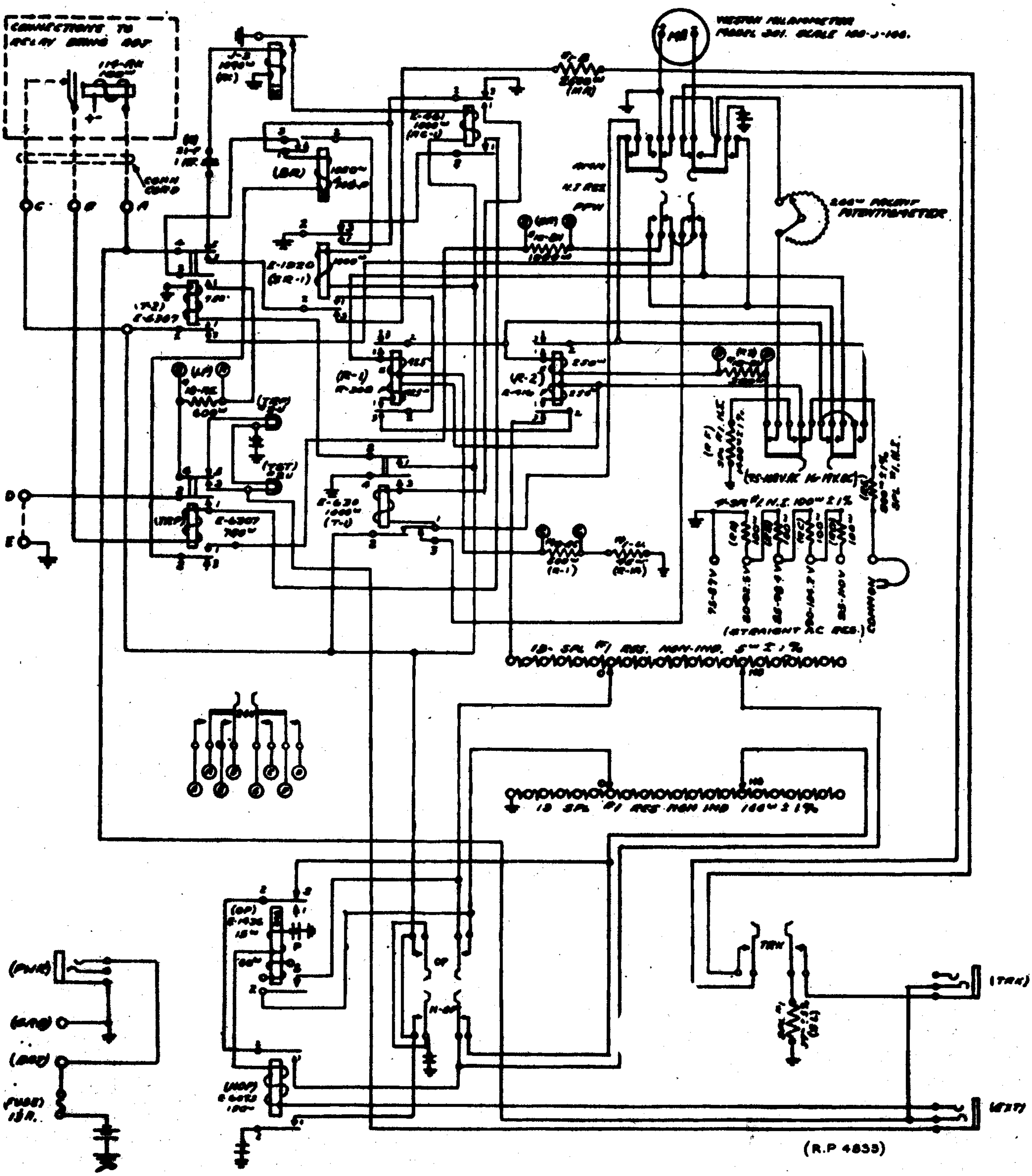

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Fig. 6. Schematic Circuit Trip Relay Adjusting Set ITB-2030

6. Equipment is provided for insuring the application of tests during the ringing period only. This operational feature is necessary to prevent two conditions that would be possible were the tests under manual control. These conditions are, application of the test during the silent period and application of the test so late during the ringing period as to cause the test to be bridged over into the silent period. In a large number of cases the silent period battery voltage is high enough to cause operation of the relay thru the ringing period testing resistance and this would result in false trip indications. The set applies the test at the beginning of the second ringing period occurring after the testing key is operated and a slow release relay stops the test after about one-half of a second.

the AC components to the limits of 95-103 volts instead of 95-110 volts in order that the maximum instantaneous voltage used in the past (165 V.) will not be exceeded. This system is, therefore, in effect a superimposed ringing system and to distinguish it from the present superimposed ringing systems used for four party selective service the term AC-DC is used. The new system offers the following advantages over the AC system.

1. A material improvement is effected in the maintenance of the relay due to the fact that greater margins are provided.

2. Improvement in service, particularly regarding pre-trips is obtained, due to providing margins between the worst circuit conditions and the test values for the trip relay.

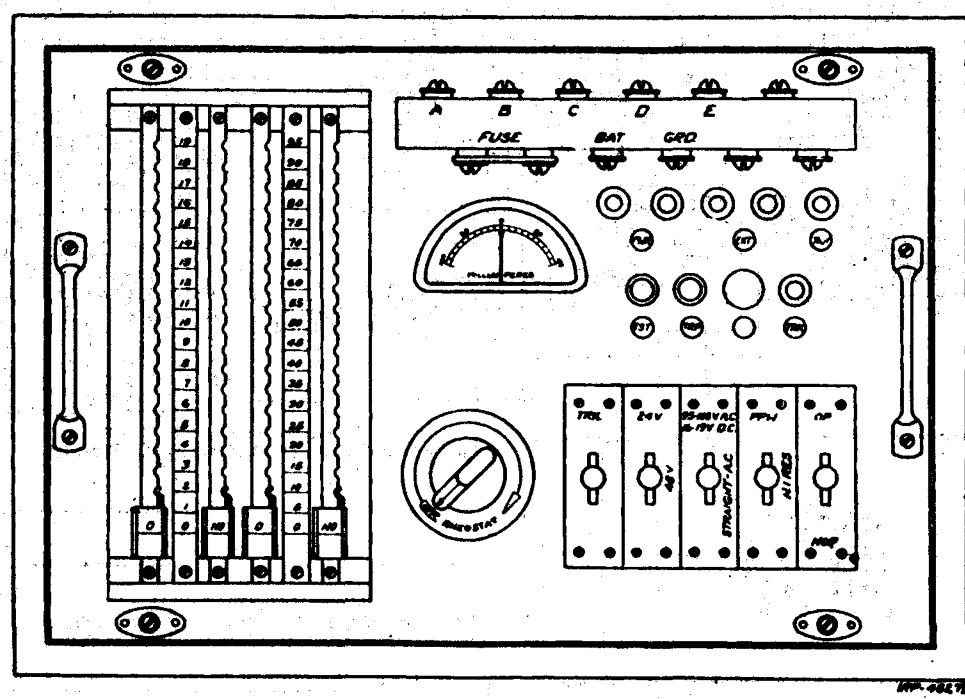

Fig. 7. Panel of Universal Tripping Relay Adjusting Set ITE-2030

THE AC-DC RINGING SYSTEM

Coincident with the introduction of the improved particular part of the wave testing and adjusting methods, a new ringing system has been developed for use in individual line, two-party selective and four-party semi-selective panel machine switching and manual machine ringing offices, which will be known as the "A.C.-D.C. Ringing System."

The new system consists of adding in series with the AC generator, a storage battery of nine cells with a voltage variation of 16-19 volts. With the addition of this battery, it is necessary to restrict

3. The tripping range is increased for the ringing period.

In single, two-party and four-party semi-selective lines condensers are placed in series with the ringers, and in four-party semi-selective lines this reduces the impedance of the line to such an extent that the current passed by the shortest ringing circuit is nearly as great as the current passed by the longest tripping circuit. In other words, the margin between the worst non-operate and worst operate circuit conditions is very small. For this reason entirely satisfactory adjustment of the trip relays cannot be obtained in straight AC ringing systems and it is necessary to disregard the operate condition as the non-operate is the most important since a pre-trip would prevent completion of the call. Under these conditions the trip relay operates during the silent period when the loop is too long to allow operation during the ringing period.

It is obviously desirable to have the circuit conditions such that the relay can be adjusted to meet both worst circuit conditions so as to provide better service and, further, so there will be sufficient margin available to allow economical adjustment of the relays. This is the function of the AC-DC ringing system.

Since it is not at once apparent how the addition of the DC component provides these advantages, this is explained below. The DC component of the ringing current has no effect upon the subscriber's bell or upon the worst non-operate circuit condition as there is a condenser in series with the bell which absorbs the additional 18 volts on the negative half cycles and discharges it on the positive half cycles. The ringing current which operates the bell is a straight alternating current and the worst non-operate circuit condition is identical with that of the AC ringing system. However, when the subscriber removes the receiver the condenser and bell are shunted out of the circuit and the operating effort of the DC component is then added to the operating effort of the alternating current and causes operation of the relay over loops through which the alternating current alone cannot cause operation. In view of this, it may be stated that adding the DC component widens the margins between the worst operate and non-operate circuit conditions by shifting the operate condition without affecting the non-operate condition.

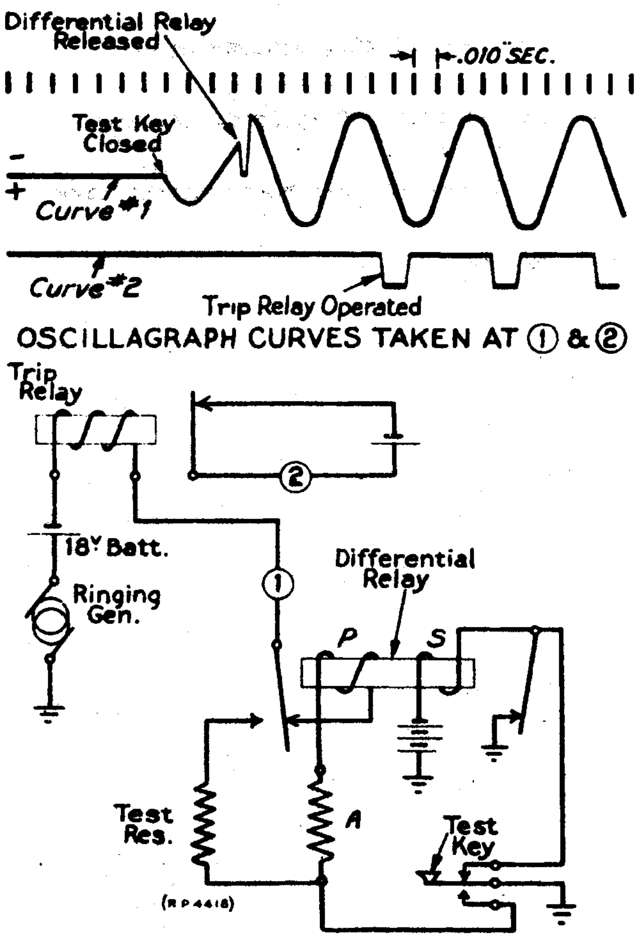

Fig. 8. Fundamental Circuit for Applying PPW Tests in AC-DC Ringing System

Trip relays used in AC-DC ringing systems are adjusted by the PPW method as the DC component is not sufficiently high to eliminate the value of this test. The circuit for applying these tests is shown in Figure 8 together with oscillograph curves of its operation. This circuit functions exactly the same as the two relay circuit described for AC ringing systems except that only one differential relay is provided. This relay functions at or near the peak of the negative wave. It may be noted that the relay does not operate in synchronism with the peaks of the negative waves but lags behind. This is due to the phase relations in the relay circuits.

It is not necessary to use two differential relays as the positive half cycle will not cause operation of the trip relay due to the superimposed negative battery which reduces the voltage on the positive half cycles. Also variations in office voltage can be disregarded as under any condition of central office battery voltage, the differential relay releases near enough to the peak of the wave to prevent the zero closure condition.

From the foregoing, it will be seen that testing and adjusting is done entirely during the ringing period. The condition of the trip relays resulting from the new testing and adjusting method is such that the relay will function properly during the silent period.

QUESTIONS

1. What is the function of a subscribers ringing system and what are the four commonly used systems.

2. What are the advantages of machine ringing over manual ringing.

3. Describe briefly the purposes of the ringing interrupter, trip relay and silent period battery of a machine ringing system.

4. What special conditions do trip relays operate under and what familiar piece of AC apparatus may they be compared to.

5. Why is it unsatisfactory to test trip relays with direct current or by simulating the operating conditions and what method of testing was finally adopted.

6. State briefly why trip relays must be tested at a particular part of the AC wave.

7. At what part of the AC wave is the testing circuit closed by PPW tests and why was this part of the wave chosen.

8. Why is it unnecessary to test trip relays in superimposed ringing systems at a particular part of the AC wave.

9. What conditions on subscribers' lines eliminate the necessity of applying machine ringing at a particular part of the wave.

10. What is the new ringing current adopted by the Bell System called; what current does it replace and what are the component voltages.

11. What are the advantages of the new AC-DC ringing system.