American Railway Signaling Principles and Practices

CHAPTER VI

Direct Current Relays

Published by the Signal Section, A. R. A.
30 Vesey Street, New York, N. Y.

American Railway Signaling Principles and Practices

CHAPTER VI

Direct Current Relays

CHAPTER VI

DIRECT CURRENT RELAYS

In practically every branch of the electrical field relays play a very prominent part in the operation of the system. Their principal function is to repeat the effects of an electric current in a second circuit. As an illustration: In a telegraphic line circuit the relay is energized by a comparatively weak current. This attracts an armature electromagnetically. Suitable contacts, which close other circuits, are connected to the armature.

In railway signaling there is no apparatus that is more essential to the successful operation of the system than the relay. In a track circuit the relay is arranged to close its contacts on the passage of a comparatively weak current in the rails. The closing of these contacts in turn completes a circuit in which a current flows to operate the signal or other apparatus as desired. The same principle applies, if necessary, to operate apparatus located at some distance from the controlling point. The relay, located at the outlying point, is energized by a comparatively weak current transmitted over wires from the controlling point. When the control circuit is closed it energizes the relay, closing its contacts, completing a circuit to the apparatus to be operated.

Relays are constructed quite differently, depending on the service in which used. This chapter will deal exclusively with relays, used in signal work, operated by direct current. The arrangement of circuits controlling relays, circuits controlled by them and relays operated by alternating current, will be treated in subsequent chapters.

Theory of an electromagnet as applied to the operation of direct current relays.

The following general principles of the operation of an electromagnet should be borne in mind throughout the study of this chapter.

As an electric current is transmitted through or along a wire it gives out magnetic lines of force in the form of circumferences of circles about the axis of the wire.

Any magnetic substance brought under the influence of these magnetic lines of force will collect them and become a magnet as long as the substance is under the influence of this circuit. As soon as the current stops flowing the lines of force collapse and there is no magnetism if a specially annealed iron, such as relay cores, is used.

If wire is formed into a coil of many turns the magnetic lines of force passing through the center of this coil become quite strong, and, with a given amount of current flowing in a circuit the magnetizing force increases in proportion to the number of turns of wire. For example, a coil of 100 turns of wire with 0.1 ampere of current flowing through it will have ten times the magnetizing force of a coil of 10 turns with the same current flowing through it. Likewise, any increase in current through a coil will increase the magnetizing force in proportion to the increase in current. Therefore, a coil of 10 turns of wire and 1 ampere of current flowing will have the same magnetizing force as a coil of 100 turns and 0.1 ampere of current.

The magnetizing force is determined by multiplying the number of turns of wire by the current as expressed in amperes and is known as ampere turns. This force produces magnetic flux or lines of force.

An iron core inserted in this coil will collect these magnetic lines of force as it offers a low-resistance path, but the amount is limited by the saturation of the magnetic circuits. This point varies with

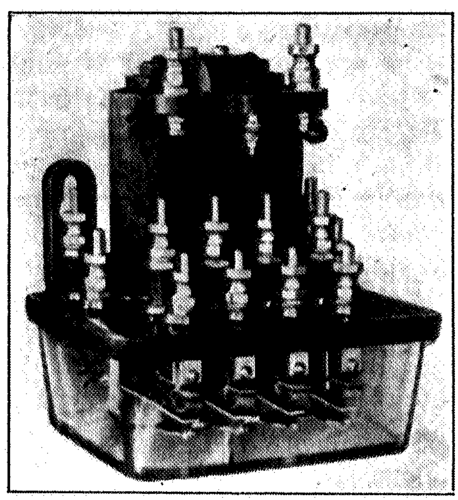


Fig. 1.
Neutral Relay, Wall Type.

quality of iron, cross-section and air gaps. The quantity of magnetism or magnetic flux, as it is called, is the total number of magnetic lines of force passing through the magnetic circuit.

Winding wire around a core in one direction will produce a north magnetic pole at one end of the core and a south magnetic pole at the other with current flowing through the wire in a given direction. By reversing the flow of current or the direction of winding around the core, the magnetic poles will be reversed.

The core used in the coils is of a specially selected iron susceptible to magnetism but just as easily demagnetized; otherwise, the core would become a permanent magnet. It is desired that the core be a magnet only when under the influence of an electric current; therefore, the name "electromagnet."

The most common form of electromagnet used in direct current relays is the horseshoe or U-shaped electromagnet consisting of four parts: namely, two cores over which are wound the magnetizing coils, a bar or plate of soft iron across the top of cores, known as the yoke, joining the cores together and a strap or piece of soft iron across the bottom of the cores, known as the armature, and which is the movable part of the electromagnet. This completes the magnetic circuit from one core to the other. It is necessary that the current in one coil should flow around its core in a direction opposite to that in the other coil; otherwise, the magnetic flux produced in the two cores would oppose each other and form like poles at the corresponding ends with the result that there would be no magnetic attraction of the armature.

For a complete theory of magnetism, consult standard text-books on electricity and magnetism.

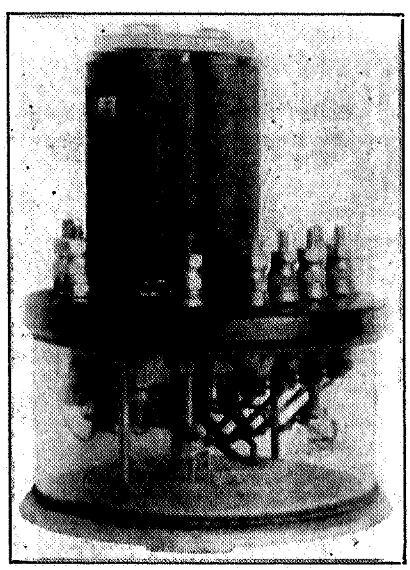


Fig. 2.
Neutral Round Base Relay.

General

Direct current relays are divided into two general groups, neutral and polarized. Under each group there are two general classes, track and line, which are further sub-divided into shelf and wall types. A track relay receives its operating energy through conductors of which the track rails are the essential part, while a line relay receives its operating energy through local or line circuits.

There is only a slight difference in the construction of the track and line relays; therefore, in describing the construction and method of their operation no distinction will be made between them.

In Fig. 3 there is shown a typical round and typical rectangular relay.

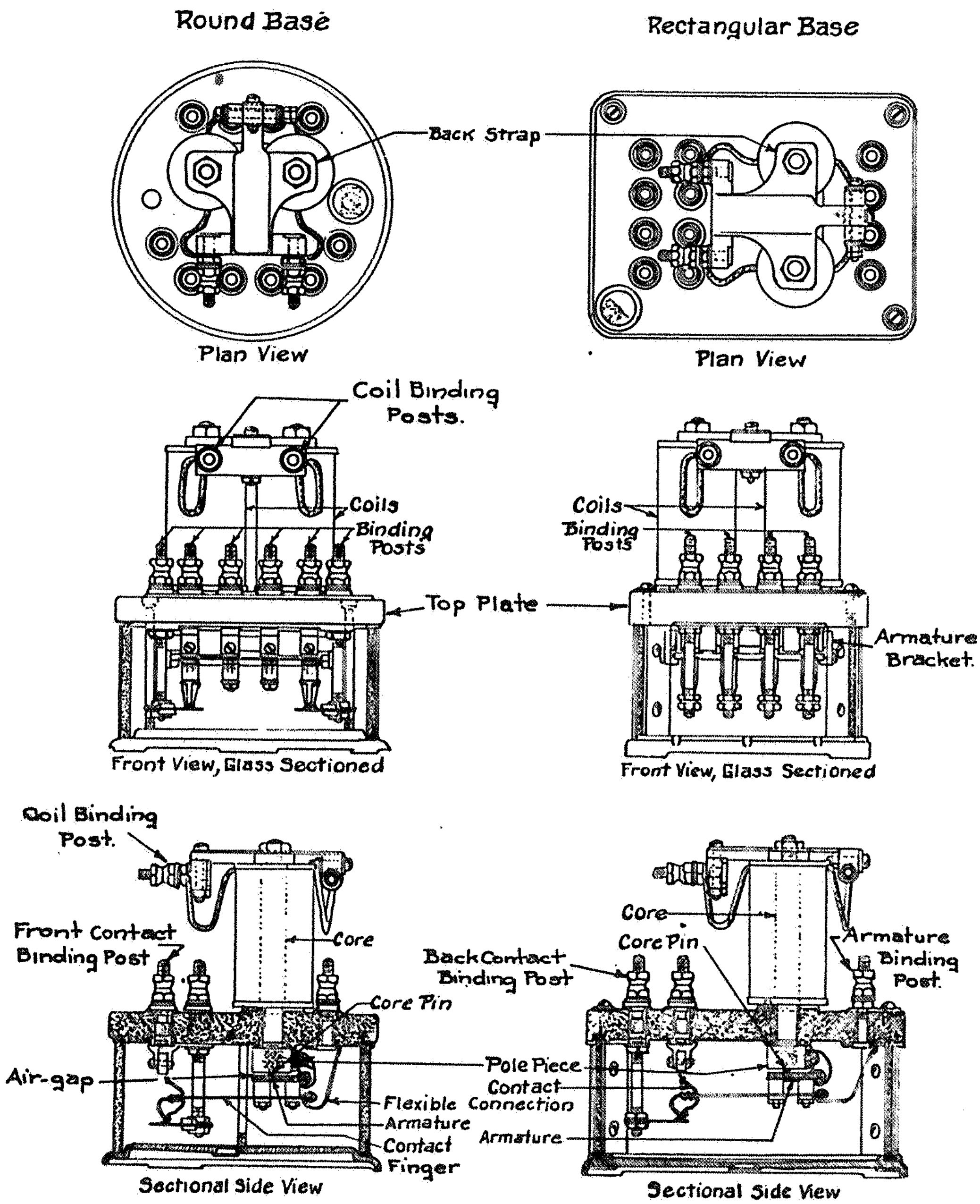


Fig. 3.

Neutral Relays.

Neutral Relays

Relays of this type, Figs. 1, 2, 4 and 5, are constructed in two general shapes, round and rectangular. Generally speaking, all moving parts are enclosed in a sealed dust-proof case, the sides of which are of glass of such transparency that the parts within the case are visible and can be readily inspected. The principal parts are coils, cores, armature, contacts and binding posts with the necessary supports.

Coils.

Each relay usually has two coils with a hollow center to accommodate a core. The coils are made up of a large number of turns of small gauge, soft-drawn copper wire, the size and number of

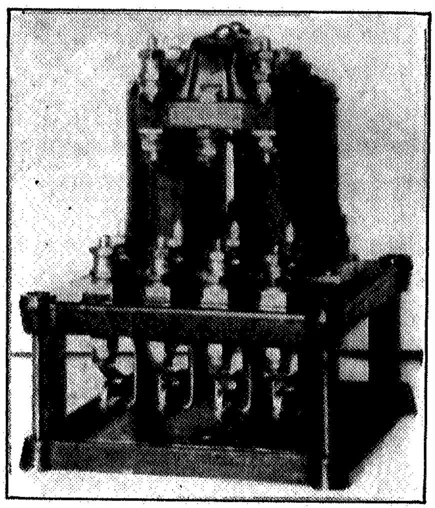


Fig. 4.
Rectangular Base Relay.

turns depending on the resistance of the relay in question. For example, a 4-ohm relay will have approximately 800 turns of No. 18 gauge wire while a 1000-ohm relay will have approximately 14,000 turns of No. 30 or 31 gauge wire. The insulation on the wire is silk, cotton, enamel or like insulation so that the coils will not be of an excessive size. The coils are generally connected in series, the ends of the wires terminating on binding posts to which the control wires may be attached. Each coil, therefore, contains one-half the specified resistance of the relay; that is, in a 4-ohm relay each coil has a resistance of 2 ohms, while in a 1000-ohm relay each coil has a resistance of 500 ohms. The recommended resistance for the various relays is as follows: 2, 4, 9, 16, 50, 500, 670 and 1000 ohms.

Each coil is constructed so that it may be removed and replaced, in kind, without changing the magnetic or mechanical adjustment of the relay, also they are securely fastened in place to prevent any movement by vibration. They are impregnated or otherwise treated so as to satisfactorily protect the wire from moisture under all service conditions and are protected in a suitable manner from mechanical injury.

Cores.

Each coil is placed around a cylindrical shaped core which is a piece of specially selected soft iron susceptible to magnetism, but just as easily demagnetized. The cores extend beyond the top and bottom of each coil. At the top of the two cores is a soft iron yoke, known as the back strap, securely fastened to each core by a nut. The bottom of each core is equipped with a large square soft iron block known as the pole piece or face.

From the study that has previously been made of magnetism, it will be seen that with this arrangement there are three sides of a magnetic circuit as the winding on the coils is arranged so that when a flow of current is sent through the wire it will produce a north magnetic pole in one pole piece and a south magnetic pole in the other pole piece. To complete this magnetic circuit, across the bottom of the pole pieces is the movable part of the relay, the armature.

Armature.

The armature is a flat piece of soft iron, easily magnetized, suspended in a bracket which is securely fastened to the pole pieces or to the top plate of the relay. This bracket is so constructed that it cannot exert pressure on the armature, but leaves it free to be moved when under the influence of a magnetic circuit. As the circuit through the coils of a relay is closed, it sets up a magnetic circuit from one core to the other through the back strap and armature. As the armature is free to move, it will be drawn to the pole pieces and remain there as long as the circuit through the coils is closed. When the circuit is opened, the magnetic flux collapses and the armature will drop away from the pole pieces, by gravity, to a stop provided for that purpose.

Air gap.

In order that a permanent air gap between the armature and pole pieces may be maintained, relays are provided with non-magnetic residual or core pins imbedded either in the pole face or in the armature. In addition, there is generally an independent adjustable armature stop located midway between the pole pieces toward the front of the armature and supported by the top plate or the extension of the armature bracket; this stop, after being properly adjusted to secure the requisite air gap, is sealed or otherwise secured in place.

It is essential to maintain this permanent air gap to prevent residual magnetism from keeping the armature attracted or "picked up." Without these core pins the armature could come in direct contact with the pole faces and a small amount of residual magnetism would be sufficient to hold the armature picked up. The amount of opening to be maintained in this magnetic air gap is dependent on the number of contacts with which the relay is equipped; the fewer contacts the larger the opening, while the greater the number of contacts the smaller the opening, not less, however, than a minimum value established for mechanical clearances.

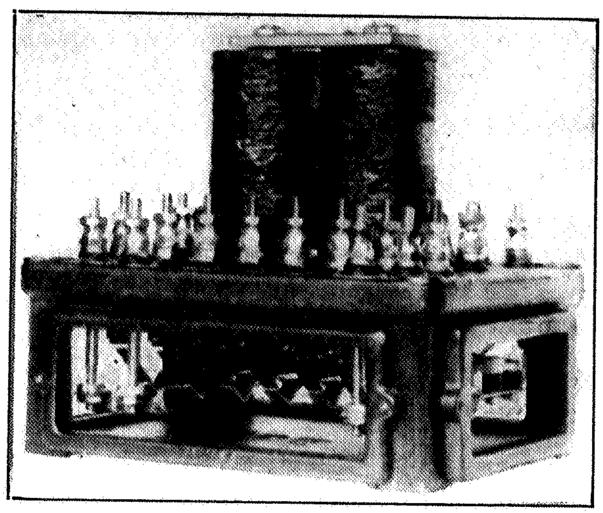


Fig. 5.
Neutral Rectangular Base Relay.

Contacts.

Securely fastened to the armature, but thoroughly insulated therefrom, are metallic springs or fingers, the fronts of which are equipped with contacting surfaces. These contacting surfaces are metal, carbon, or similar composition, depending on the type of relay or service in which they are to be used. Relay contacts are designed for low and high current; high current contacts are usually carbon to carbon.

Contacts are arranged so that circuits may be completed with the relay energized, de-energized or in either position. Those contacts arranged to close a circuit with the relay energized are called "independent front contacts"; with the relay de-energized "independent back contacts," while those arranged to complete a circuit in either position are called "dependent front and back contacts." Figure 6 illustrates the contact arrangement of a neutral relay.

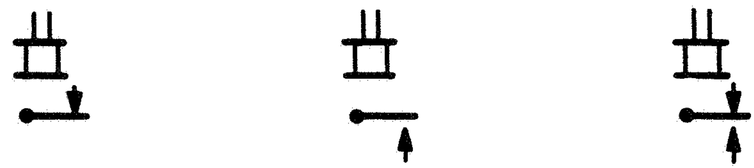


Fig. 6.

The contact finger is connected by a flexible connection to a binding post projecting through the top of relay. This flexible conductor or connection is formed and attached so that it will not affect the torque of the armature. It is also designed that in case of an excessive flow of current it will burn off before the front contacts will fuse and hold closed, when they should be open.

Binding posts.

Binding posts are made of brass and so constructed that they cannot be turned in the frame to which they are attached. Binding posts supporting the fixed parts of front and back contacts are fastened in their supports so that adjustments of any kind cannot be made without first breaking the seal of the relay. The end of the binding post that makes contact with the contact springs connected to the armature is also of metal, carbon or similar composition, while the other end is a brass terminal to which the outside wires or circuits are fastened by terminal nuts.

Circuits are controlled through these relays by attaching wires to the proper binding posts; the circuit is made or broken when the armature is picked up or dropped away as the case may be. These circuits are easily traced through the relay by following from the binding post on the front of relay to contact spring, to flexible connector, to armature binding post on rear of relay. The relays are constructed to accommodate different combinations of contacts.

Polarized Relays

The same general construction is followed in the polarized relay, Fig. 8, as in the neutral relay with the following additions: A permanent magnet similar in shape and appearance to the core of the neutral relay is installed between, but a little ahead of, the two relay coils. One end of this permanent magnet is attached to the back strap; the other end is equipped with a polar armature placed in front of the two neutral pole pieces. This permanent magnet and polar armature has the appearance of an inverted "T," the head being one pole and the bottom of the stem the other pole. The polar armature is free to move in a lateral direction or at right angles to the armature described under neutral relays. Contacts are connected to either end of this polar armature, which in turn connect to binding posts, closing or opening circuits depending on the position of the polar contacts. Figure 7 illustrates the contact arrangement of a polarized relay.

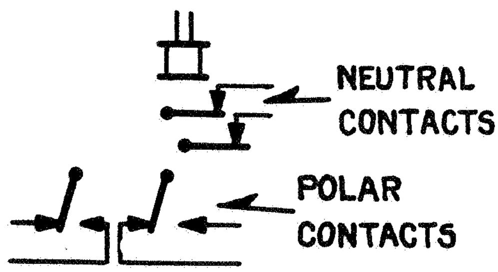


Fig. 7.
Contact Arrangement of Polarized Relay.

As mentioned under neutral relays, current flowing through the coils of the relay made one of the pole pieces a south and the other a north magnetic pole. The polar armature being part of the permanent polar magnet does not change its magnetic pole; therefore, the top of the permanent magnet remains one pole and the bottom the opposite pole. According to the law of magnetism like poles repel and unlike poles attract; therefore, the polar armature

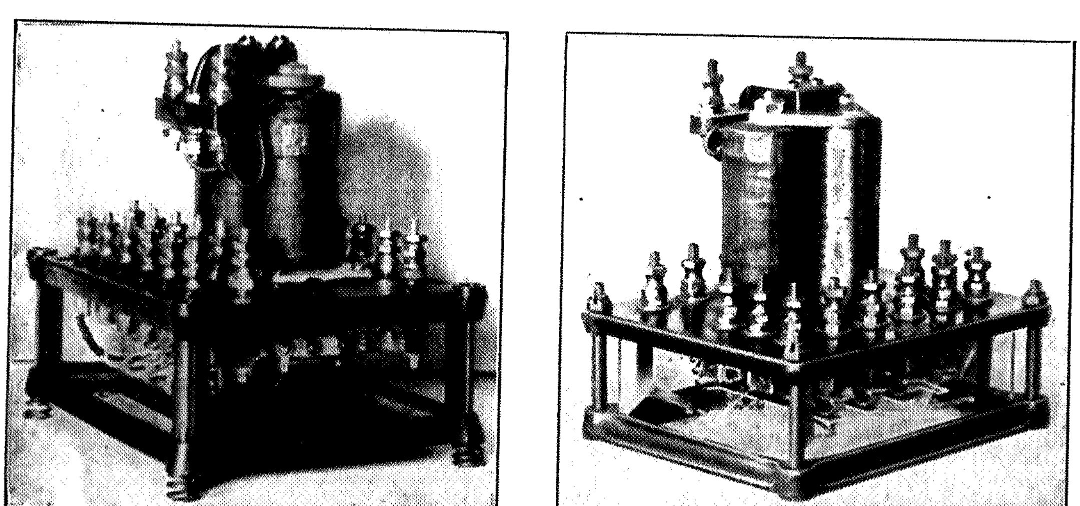


Fig. 8.
Polarized Relays.
The relay to the left is equipped with vibration springs.

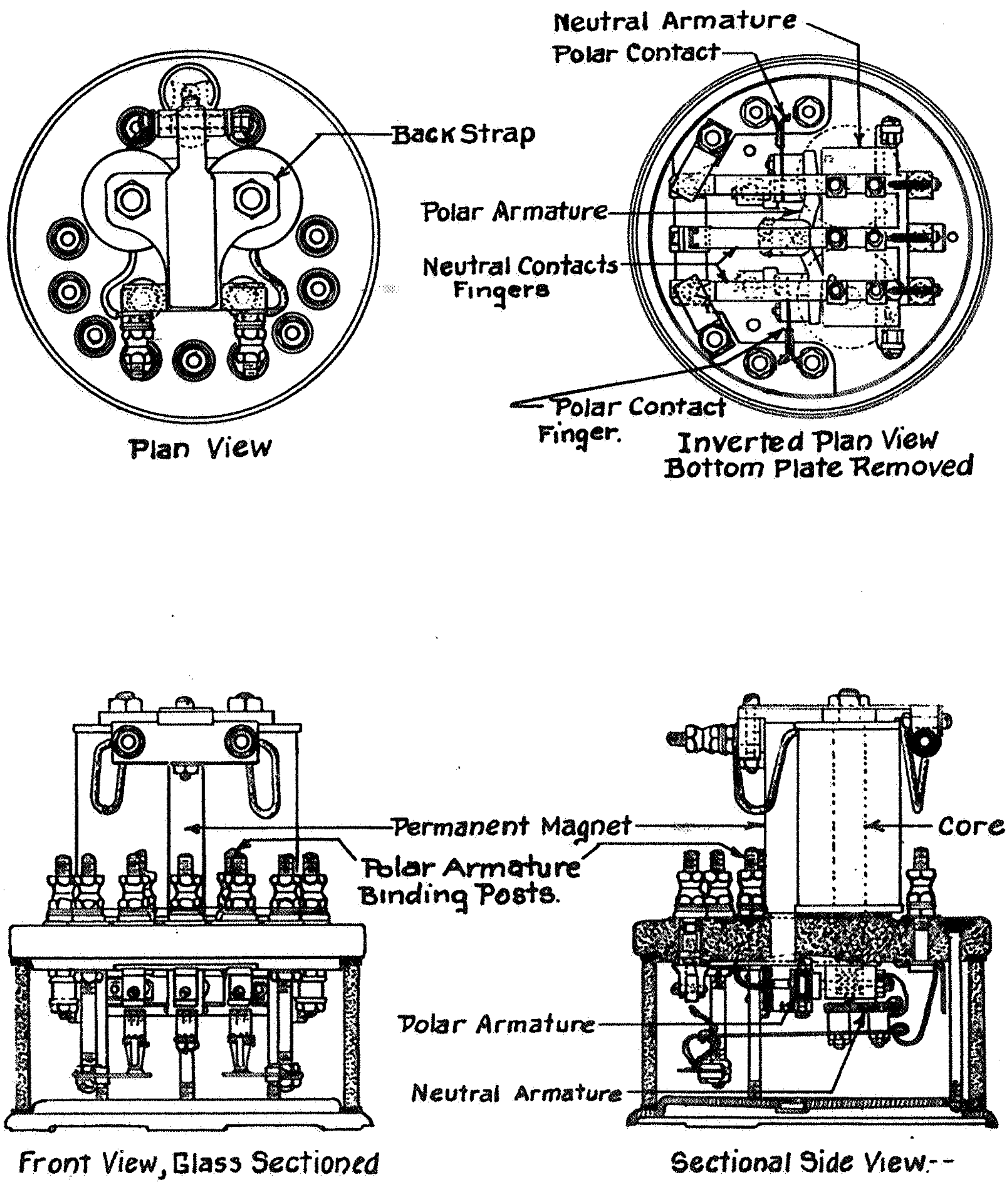


Fig. 9.
Polarized Relays.

will be repelled by the like neutral pole piece and attracted by the unlike neutral pole piece. This polar armature being pivoted in the center will cause the polar contacts to move and make contact with one set of binding posts keeping the contacts on the opposite side open.

By reversing the flow of current through the coils of relay, the neutral pole pieces will change to the opposite magnetic poles. As the polar armature still retains the same pole there will be attraction where previously there was repulsion and repulsion where there was attraction, causing the polar contacts to move in the opposite direction closing the polar contacts that were opened and opening those that were closed.

Special mention is made of the fact that a circuit controlled through a polar contact should also be controlled through a neutral contact to insure the circuit opening when the relay is de-energized, as ordinarily the polar contact will retain its contact in the last position it was in and a circuit controlled through this contact alone would not necessarily open with the relay de-energized.

Figure 9 represents a typical polarized relay.

Quick-Acting Relays

For certain conditions it is desirable to use a relay that will release somewhat more quickly than the regular type of direct current relay and for this purpose certain modifications are made in the relays previously described.

The quick-acting relay is practically the same in all mechanical features as the ordinary relay except that the back strap is insulated magnetically from the cores by means of copper ferrules and very thin washers. These washers, by introducing an additional air gap in the magnetic circuit, increase the pick-up and drop-away values approximately 15 and 30 per cent respectively. This characteristic provides a quicker shunt or drop-away than the ordinary relay; in other words, when used on track circuits the quick-acting relay will release in about 0.3 second after the shunt is applied, while with the ordinary relay this interval is about 0.5 second.

Slow-Acting Relays

For certain conditions it is desirable to use relays that will not release as quickly as the ordinary relay and for this purpose slow-acting relays are used.

These relays likewise have the same general mechanical characteristics as the ordinary relays, except that the coils are wound over a heavy section copper tubing to provide an inductive means to retard the dying down of the flux in the magnetic circuit. The air gap between the armature and the pole pieces is also materially reduced, the idea being to decrease the reluctance of the magnetic circuit and provide sufficient flux for retardation purposes. The main

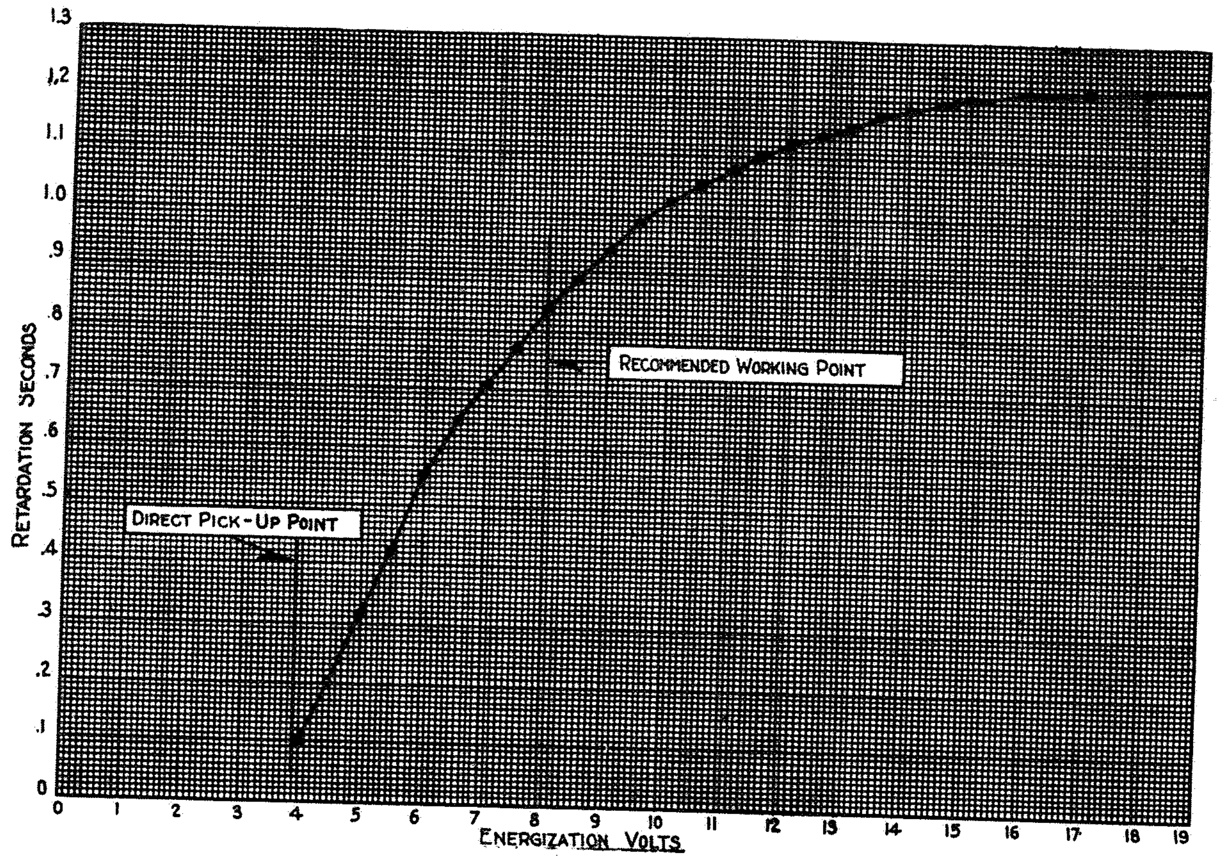


Fig. 10.

Typical Curve Showing Relationship Between Retardation and Energization of a 500-ohm, 2 point, Slow-Acting Relay.

purpose of this relay is to permit of a circuit being controlled through its contacts during the open circuit periods of the neutral contacts on polarized relays due to change in polarity. This retardation period is the time interval from the opening of the relay circuit to the opening of the front contacts and is approximately six times longer than with the ordinary relay.

The resistance of these slow-acting relays is generally about one-half that of the ordinary relay for a given voltage operation in order that twice the amount of current will flow through the coils, thereby increasing the flux in the magnetic circuit to more nearly the saturation point and also on account of the limited winding space on the coils due to the use of copper tubing.

To still further increase the retardation of these relays the coils are sometimes short circuited through the back contact of the controlling relay.

In order that proper retardation may be obtained, it is essential that the working voltage be maintained at normal or above, as a slight decrease in voltage causes a material reduction in the retarding effect of the relay.

Figure 10 illustrates by a curve the decrease in retardation if operated under normal voltage.

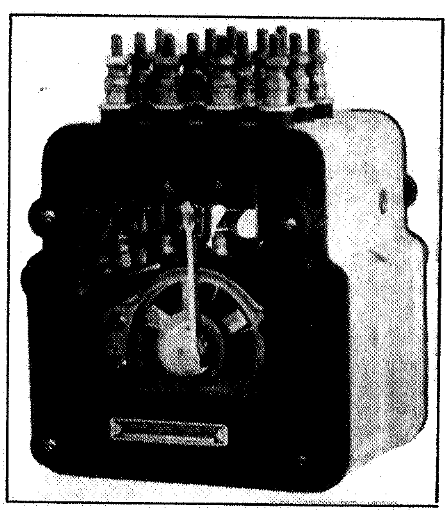


Fig. 11.
Motor Relay.

Direct Current Motor Relays

The direct current motor relay, Fig. 11, was originally designed for a three-position track relay to be used in place of the polarized relay previously described. Since then, however, it has been used to very good advantage as an "SS" relay in connection with electric switch lever locking circuits.

The operating mechanism consists of a small direct current motor having strong magnetic fields with ample air gap between the armature and pole pieces. The contacts are moved from the de-energized or open position to either of the energized or closed positions by the rotary motion of the motor armature, the movement of which is transmitted to the contacts by suitable link connections. The closing of one or the other sets of contacts is accomplished by a partial rotation of the armature, the direction being dependent on the polarity of the operating current.

The contacts have the same opening and pressure and are quite similar in design to those described in the neutral relay. The usual arrangement of contacts is four normal and four reverse. Figure 12 illustrates the contact arrangement of a motor relay.

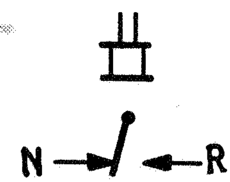


Fig. 12.
Contact Arrangement of Motor Relay.

Flasher Relays

The flasher relay is generally used where the flashing type of highway crossing signals are installed. There are two principal types of flasher relays. One type, Fig. 13, consists essentially of two ordinary neutral relays mounted on the same base. Each set of coils

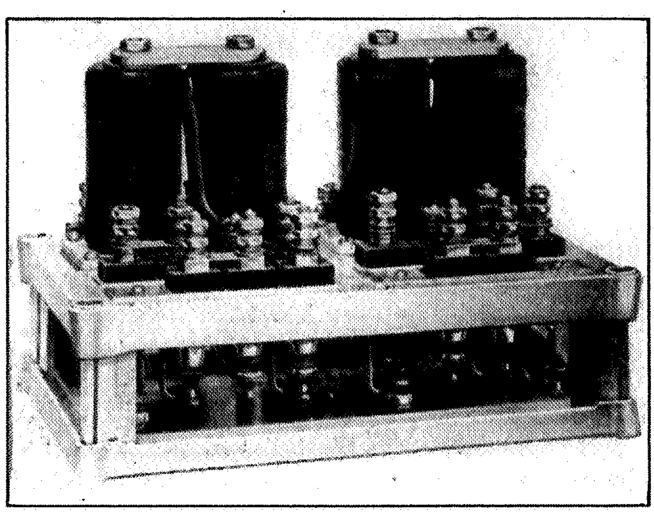


Fig. 13.
Flasher Relay.

is controlled through the back contacts of the other relay so that as one set of contacts closes it opens the control circuit of the other coils and vice versa. The coils are designed to give proper slow action to insure from 30 to 45 operations per minute, which requires that the coils be wound to a certain resistance for a given operating voltage. The front contacts generally used on this type of relay are intended for the opening of circuits to low-voltage lamps, or voltages not in excess of 30 volts. Two contacts are connected in multiple for each lamp circuit, one contact being graphite to graphite which makes first and breaks last, taking the arc; the other contacts being silver to silver to insure low contact resistance for the lamp circuit. If contacts are required to open a circuit of 110 volts then a contact combination of tungsten to tungsten is used.

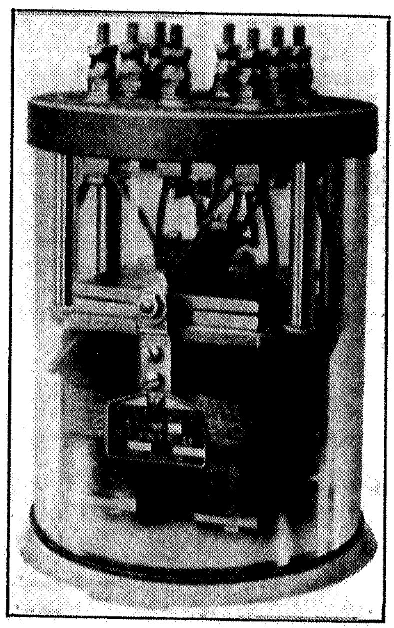


Fig. 14.
Flasher Relay.

Another type of flasher relay, Fig. 14, has the appearance of a single relay, although it functions the same as the type just described. The actuating member consists of two pairs of electromagnets mounted upon a brass supporting plate. These magnets attract, alternately, a single armature which is pivoted on a center line above and between the two pairs of magnets. The action of the magnets tends to oscillate or move the armature in opposite directions. The fixed contact members are mounted on terminal posts assembled with the top plate of relay, while the movable contact members are mounted upon an insulated member secured to the armature.

The contacts in the lamp control circuit consist of a graphite block supported on the armature and connected to the positive terminal post on the top plate, and two springs, each attached to one of the lamp terminal binding posts. The lamp contact springs have silver tips in order to provide low contact resistance and to minimize wear. The graphite block is specially treated in order to minimize contact resistance.

The operation of the relay is about as follows: Two of the coils are so located that when they attract the armature, which is pivoted on a line between the pair of magnets, the half of the armature above the other pair of coils will be lifted. All four coils forming the two magnets are permanently connected in series. The control wires from the controlling relays are to be brought to the terminal binding posts marked "Coil +" and "Coil —." These posts also support two graphite contact elements which are located directly under the center of the top plate. A vertical spring is mounted on the relay armature and moves between the two graphite contacts as the armature oscillates.

This spring is permanently connected to the wire leading from one magnet to the other. When one of the magnets is energized the armature will be attracted toward it and will move the vertical spring until it makes contact with the graphite tip on the side of the magnet energized. The completion of this contact short circuits the magnet which has just been energized. As soon as the flux in the shunted magnet decreases to the point where the attraction of this magnet for the armature is less than that of the other magnet, the armature will snap over to the opposite position. The reversal of the armature position will cause the vertical spring to disengage one graphite block and engage the other located above the magnet which has just been energized. This short circuits that magnet and in turn with the decreasing of its flux will allow the other magnet to attract the armature and another cycle of operation to be started.

The slow action of this relay, which is desirable in order that the flashes of light from the signal it controls may be distinctive, is obtained because of the self-induction of the magnets made effective by the alternate short circuiting of their coils. The time period is obtained by means of properly proportioning the magnets and the short circuiting of their windings in the regular operation of the relay as described.

The lamp control contacts are arranged so they open only in each extreme position of the armature. The open pair of contacts close during the stroke of the armature, before it reaches its center position; thus, an overlap of the two pairs of lamp control contacts is obtained. For this reason at least one pair of lamps in the crossing signal will be lighted at all times when the other control relay contacts are closed. As a matter of fact, the armature assumes such a position when the coils are de-enegrized that all lamp contacts are closed, thus providing maximum protection at the crossing should there be a failure in the flasher control circuit. Figure 15 illustrates the arrangement of the contacts of this type of relay.

This relay is designed to give from 30 to 45 operations per minute, or about the same as the first flasher relay described.

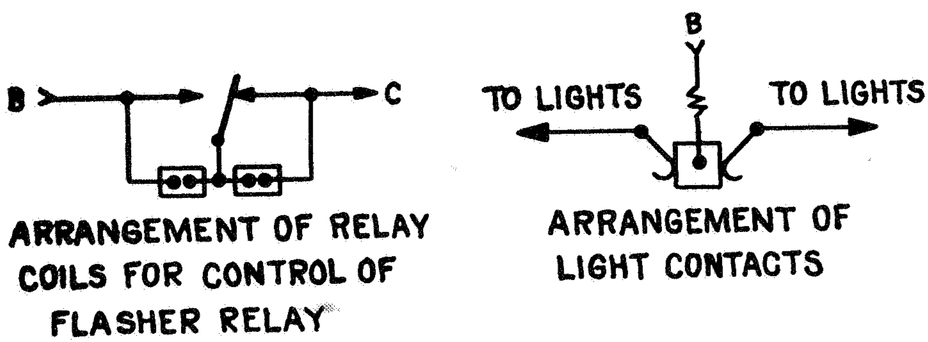


Fig. 15.

Interlocking Relays

In the case of an interlocking relay, Fig. 16, it is the same as two neutral relays enclosed in the same case or base with an interlocking device between the two sets of contacts arranged so that when one set of coils is de-energized it will lock the other set of contacts away from the back contacts. These relays are generally used on single track for the control of highway crossing signals; also on double, three or more tracks when the crossing signals are controlled in both directions on such tracks.

Miscellaneous

Other special types of relays are in service to accommodate some special or local requirement, but the method of operation is practically the same as mentioned in this chapter.

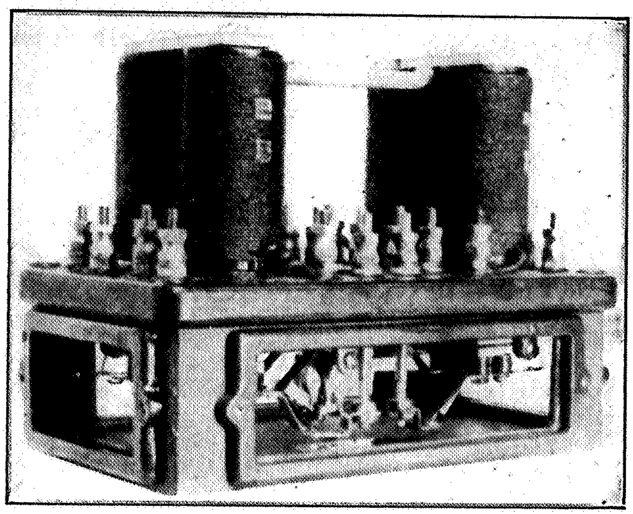
Instructions.

Relays should be inspected and tested in accordance with the following instructions:

Shop Tests and Inspections

Coils.

1. At 68 degrees Fahrenheit, the percentage variation in the resistance of individual coils must not exceed:
   - (a) For 5 ohms or less, plus or minus 5 per cent.
   - (b) Above 5 ohms, plus or minus 10 per cent.
2. Coils must be rigidly fastened in place to prevent vibration.



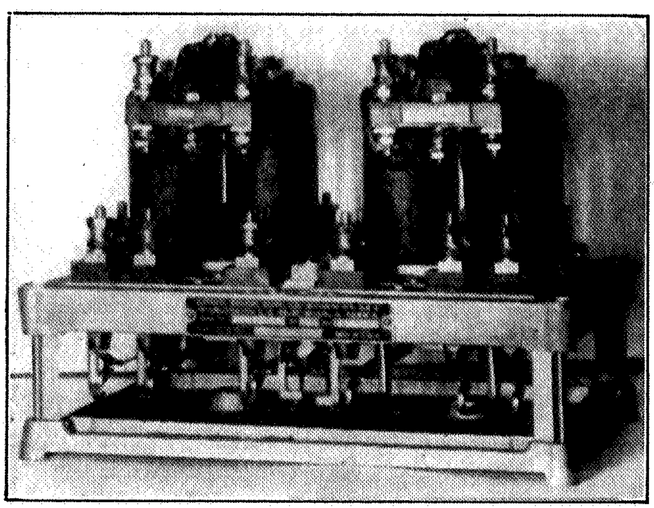


Fig. 16.
Interlocking Relays.

Binding posts.

3. Right or left-hand coil terminal, as specified, must be marked plus (+) at binding post and must be used for positive connection.

Flexible connections.

4. Flexible conductor which connects binding post and contact finger, must be formed and attached so as not to affect the pick-up or drop-away of the relay, and must be of sufficient conductivity to carry 10 amperes without over-heating.

Contacts.

5. Flexible part of finger contacts must be of sufficient resilience to exert a contact pressure of not less than 1 ounce when armature is against stop pin.

6. Finger contacts must meet contact surfaces squarely and simultaneously.

7. Finger contacts must have horizontal contact slide movement of not less than 0.010 inch against contact surfaces.

8. Metal support of the non-fusible contact element must be not less than 1/16 inch from the contact surface.

9. Opening between finger contact and back contact surface, with front contact just closed, must be not less than 0.020 inch.

10. Front and polar contact openings for first range voltage must be not less than 0.050 inch.

11. Front contact opening for second range voltage must be not less than 0.090 inch.

12. Back contact opening for first range voltage with working current or voltage applied must be not less than 0.040 inch.

13. The initial cleaned contact resistance when relay is energized at working current or voltage must not exceed the following:

(a) Metal to metal, 0.03 ohm per contact.
(b) Metal to carbon, 0.18 ohm per contact.
(c) Carbon to carbon, 0.40 ohm per contact.

Armature end play.

14. Armature end play must be not less than 0.010 inch and not more than 0.020 inch.

Air gap.

15. A minimum working magnetic air gap for the neutral armature of both neutral and polar relays, with adjustable stop pins, of 0.020 inch for a relay with two neutral contacts, and of 0.015 inch for a re-

lay with three or four neutral contacts must be maintained by an adjustable hard-drawn phosphor bronze stop pin so placed that its position relative to the cores will be fixed and so that when armature is picked up it will strike against the stop near the edge farthest from the bearings and midway between the cores. The physical working air gap must be not less than 0.018 inch for a relay with two neutral contacts and 0.013 inch for a relay with three or four neutral contacts. A minimum working magnetic air gap for polar armature of 0.025 inch for a relay with two normal and two reverse polar contacts, and of 0.008 inch for a relay with four normal and four reverse polar contacts must be similarly maintained. A non-adjustable stop pin of phosphor bronze must be placed under each core near the edge farthest from the bearings protruding 0.010 inch from the under side of the core or the upper side of the relay armature for safety purposes.

16. A minimum working magnetic air gap for the neutral armature of both neutral and polar relays, without adjustable stop pins, of 0.020 inch for a relay with two neutral contacts, and of 0.015 inch for a relay with three or four neutral contacts must be maintained by two non-adjustable hard-drawn phosphor bronze stop pins. The physical working air gap must be not less than 0.018 inch for a relay with two neutral contacts and 0.013 inch for a relay with three or four neutral contacts. A minimum working magnetic air gap for polar armature of 0.025 inch for a relay with two normal and two reverse polar contacts, and of 0.008 inch for a relay with four normal and four reverse polar contacts must be similarly maintained.

Gaskets.

17. Defective gaskets must be replaced.

Case.

18. Case must be so arranged as to insure a minimum clearance of 1/8 inch between it and movable parts.

Meter calibration.

19. Meters for shop use must be calibrated monthly.

Repairing.

20. Relays must be tested for defects. Special attention must be given to the defects noted on repair tag, A.R.A. Signal Section Form 14.

21. Repairs and adjustments made must be recorded on A.R.A. Signal Section Form 10.

Testing.

22. Pick-up, drop-away and working current or voltage of relays must be determined as follows:

(a) Initial charge as specified in Table 1 must be applied to coils.

(b) The value of the drop-away with contact pressure must be obtained by applying the initial charge to coils, then gradually reducing to the value at which front contact opens.

(c) The value of the direct pick-up must be obtained by applying initial charge and taking drop-away readings, the circuit must then be opened and current again applied in same direction to coils and gradually increased until front contact just closes.

(d) The value of the reverse pick-up must be obtained by applying initial charge to coils in normal direction and decreasing to zero. The polarity must then be reversed, gradually increasing the energy to value at which front contact closes.

(e) The value of the direct working current or voltage must be obtained by applying initial charge to coils in normal direction and decreasing to zero. The energy must then be gradually increased in same direction to value required to bring armature against stop pin.

(f) The value of the reverse working current or voltage must be obtained by applying initial charge to coils in normal direction and decreasing to zero. The polarity must then be reversed, gradually increasing the energy to value required to bring armature against the stop pin.

(g) The value of the polar pick-up must be obtained by applying current or voltage to the coils, the current or voltage being gradually increased until polarized armature reverses its position. Without current in either direction, polarized armature with or without contact pressure should not move to the position opposite the last position operated.

(h) The value of the polar working current or voltage must be obtained by applying current or voltage to the coils, the current or voltage being gradually increased to the value required to bring polar armature against stop pin in either operating position.

23. Relay operating requirements must be in accordance with shop requirements of Table 1.

24. When taking current readings, voltmeter must be disconnected. When taking voltage readings, the voltmeter must be across the coils of the relay.

25. Tests as required by A.R.A. Signal Section Forms 11, 12 and 13 must be made and recorded at time relay is tested.

26. Front, back and polar contacts of relay must be tested for contact resistance after case is in place and before relay is sealed.

27. Insulation resistance test must be made between binding posts and relay top. The resistance must be not less than 1 megohm.

Inspection.

28. It must be determined by actual operation that relay has a positive drop-away and relay contacts open without retardation of movement due to friction or external force.

29. Before case is placed, relay and case must be subjected to air blast to remove any foreign matter, then checked to see that all parts are in proper position and in good condition. Particular attention should be given to the removal of metal particles from the relay and case.

Sealing.

30. Relay case must be sealed.

Final test.

31. Final drop-away, pick-up and working current tests must be made after relay is sealed. The values obtained must not vary more than 2 per cent from those of the previous tests.

Shipping.

32. Relay must be tested and must meet shop requirements before shipment.

33. Each relay must be put in a separate carton or suitably wrapped before being placed in packing boxes. Not more than two relays must be placed in same packing box.

Field Tests and Inspections

Meter calibration.

34. Meter for field use must be calibrated before each cycle of tests and as often as necessary.

Testing.

35. Tests required by Instructions 22 to 28, inclusive, and A.R.A. Signal Section Form 11 must be made at least annually.

Inspection.

36. Relay must meet shop requirements when placed in service, except in emergency, when relays meeting field requirements may be used.

37. It must be determined by observation that sufficient front, back and polar contact openings exist.

38. It must be determined by observing operation of relay that sufficient clearance exists between case and movable parts.

39. Parts enclosed must be free from foreign matter, and all parts in proper position and in good condition.

40. Relays not fulfilling field requirement must be taken out of service.

Repairing.

41. Emergency repairs and adjustment to insure positive operation of relay, for temporary use in emergency, may be made in the field only by an authorized relay inspector.

Recording.

42. Relays must be identified by serial number, which must be recorded. Manufacturer's serial number must be used if available.

43. Inspector must re-mark indistinct serial number.

44. Relays having illegible or no serial number must be assigned a serial number, preceded by a letter. The letter to be used will be assigned by ....

45. Inspector must immediately record field readings on A.R.A. Signal Section Form 11, which, when filled, must be forwarded to ....

46. Field readings must be transferred weekly from A.R.A. Signal Section Form 11 to A.R.A. Signal Section Form 10. One A.R.A. Signal Section Form 10 must be used for each relay.

TABLE 1—DIRECT CURRENT RELAY AND INDICATOR REQUIREMENTS

	SHOP REQUIREMENTS			FIELD REQUIREMENTS		
	NEUTRAL	POLAR	MOTOR	NEUTRAL	POLAR	MOTOR
Initial charge	Four times direct pick-up	Four times direct pick-up		Direct working current or voltage	Reverse working current or voltage	
Drop-away	Not less than 90% of original marking nor less than 43% of direct pick-up	Not less than 90% of original marking nor less than 43% of direct pick-up	Not less than 90% of original marking	Not less than 70% of original marking nor less than 33% of direct pick-up and in no case less than: (a) 35 milli-amperes for 2-ohm relay. (b) 25 milli-amperes for 4-ohm relay.	Not less than 70% of original marking nor less than 33% of direct pick-up and in no case less than: (a) 35 milli-amperes for 2-ohm relay. (b) 25 milli-amperes for 4-ohm relay.	Not less than 40% of original marking
Direct pick-up	Not more than 10% greater than original marking	Not more than 10% greater than original marking	Not more than 10% greater than original marking	Not more than 10% greater than original marking	Not more than 10% greater than original marking	Not more than 10% greater than original marking
Reverse pick-up	Not more than 25% greater than direct pick-up	Not more than 25% greater than direct pick-up	Not more than 10% greater than original marking		Not more than 30% greater than direct pick-up	Not more than 10% greater than original marking
Direct working current or voltage	Not more than 10% greater than original marking	Not more than 10% greater than original marking	Not more than 10% greater than original marking	Not more than 10% greater than original marking	Not more than 10% greater than original marking	Not more than 10% greater than original marking
Reverse working current or voltage	Not more than 10% greater than original marking	Not more than 10% greater than original marking	Not more than 10% greater than original marking		Not more than 10% greater than original marking	Not more than 10% greater than original marking
Polar pick-up		Not more than 85% of direct pick-up of neutral armature			Not more than 85% of direct pick-up of neutral armature	
Polar working current or voltage		Not more than 83.5% of direct working current of neutral armature			Not more than 83.5% of direct working current of neutral armature	

8"

5"

A.R.A. SIGNAL SECTION __10____

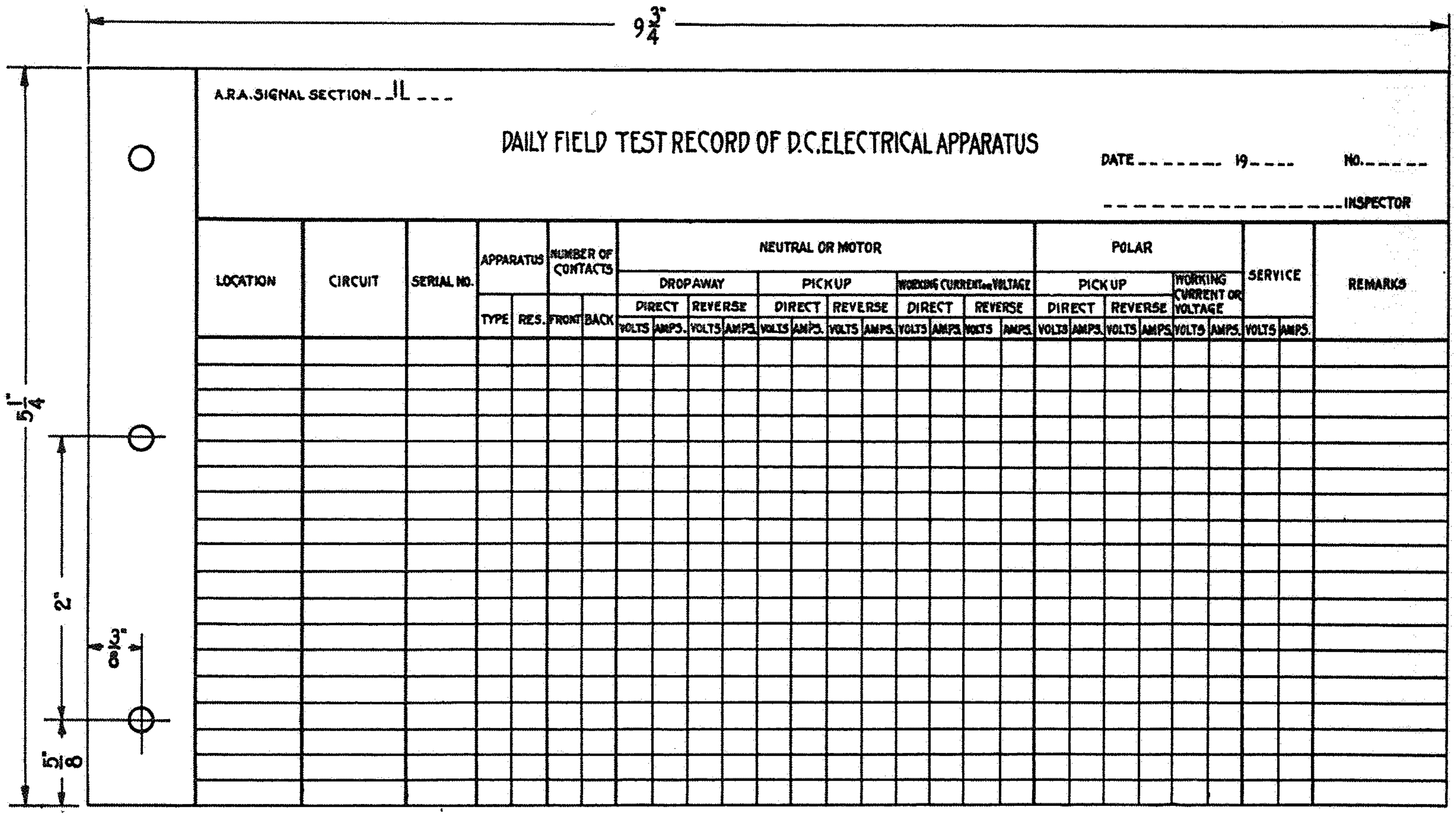
OFFICE TEST RECORD OF D.C. ELECTRICAL APPARATUS

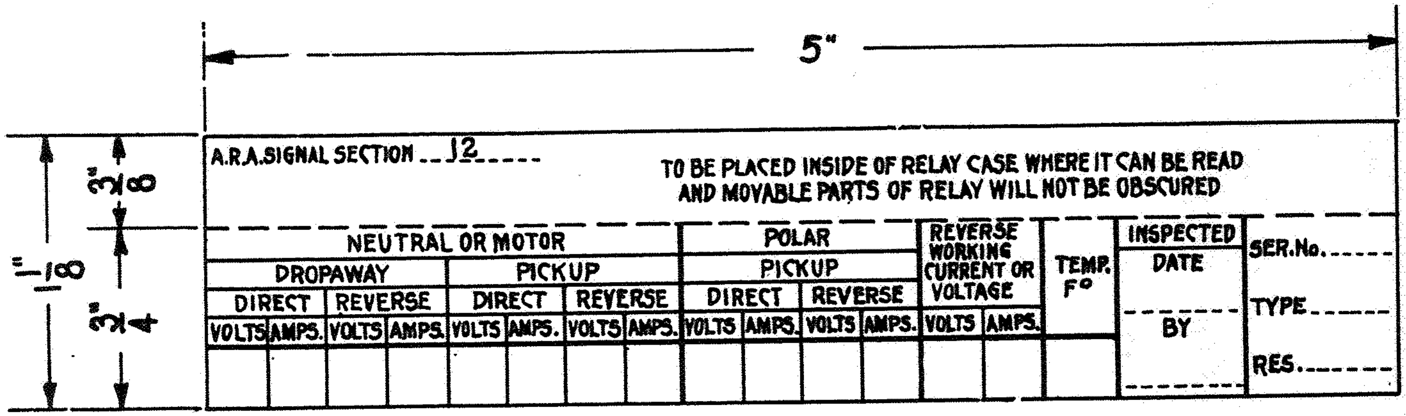
LOCATION	DATE
__________	19_____
__________	19_____
__________	19_____
__________	19_____

SERIAL NO.______ RESISTANCE______

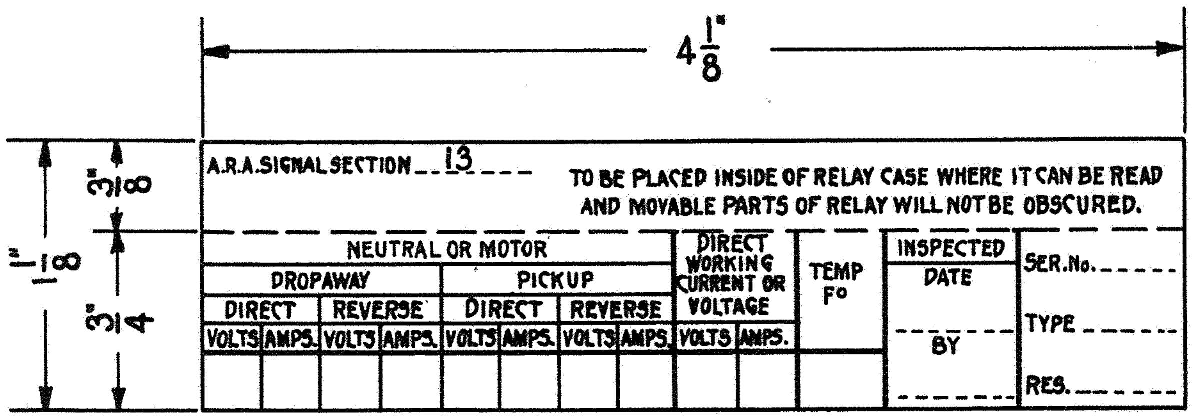
APPARATUS______ TYPE______ NUMBER OF CONTACTS: FRONT____ BACK_____

CIRCUIT	NEUTRAL OR MOTOR												POLAR						SERVICE		DATE AND INSPECTOR	REMARKS
	DROPAWAY				PICKUP				WORKING CURRENT or VOLTAGE				PICKUP				WORKING CURRENT OR VOLTAGE					
	DIRECT		REVERSE		DIRECT		REVERSE		DIRECT		REVERSE		DIRECT		REVERSE							
	VOLTS	AMPS.	VOLTS	AMPS.	VOLTS	AMPS.	VOLTS	AMPS.	VOLTS	AMPS.	VOLTS	AMPS.	VOLTS	AMPS.	VOLTS	AMPS.	VOLTS	AMPS.	VOLTS	AMPS.		
ORIGINAL MARKING																						

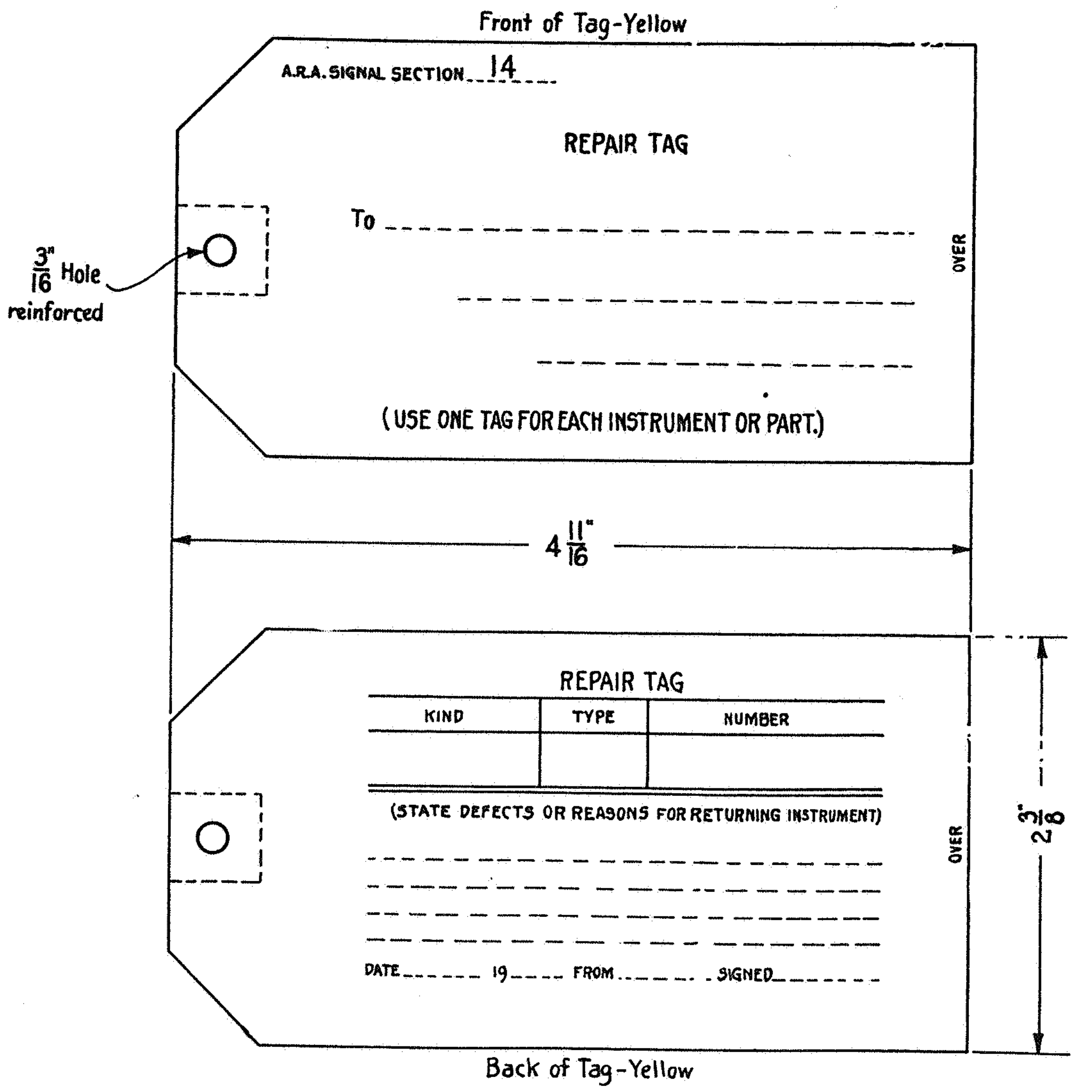

9 3/4"
5 1/4"
2"
3/8"
5/8"
A.R.A. SIGNAL SECTION — 1L —
DAILY FIELD TEST RECORD OF D.C. ELECTRICAL APPARATUS
DATE ______ 19___
NO. _____
____________ INSPECTOR
LOCATION
CIRCUIT
SERIAL NO.
APPARATUS
TYPE
RES.
NUMBER OF CONTACTS
FRONT
BACK
NEUTRAL OR MOTOR
DROPAWAY
PICKUP
WORKING CURRENT OR VOLTAGE
DIRECT
REVERSE
VOLTS
AMPS.
POLAR
PICK UP
WORKING CURRENT OR VOLTAGE
SERVICE
REMARKS



RELAY RECORD TAG



RELAY RECORD TAG


Front of Tag-Yellow
A.R.A. SIGNAL SECTION 14
REPAIR TAG
To
(USE ONE TAG FOR EACH INSTRUMENT OR PART.)
OVER
3/16" Hole reinforced
4 11/16"
REPAIR TAG
KIND
TYPE
NUMBER
(STATE DEFECTS OR REASONS FOR RETURNING INSTRUMENT)
DATE 19 FROM SIGNED
OVER
2 3/8"
Back of Tag-Yellow

American Railway Signaling Principles and Practices

QUESTIONS ON

CHAPTER VI

Direct Current Relays

QUESTIONS ON CHAPTER VI

DIRECT CURRENT RELAYS

1. In what field do relays play a prominent part?
2. What is the principal function of a relay?
3. How do relays compare with other apparatus in railway signaling in the successful operation of a railroad?
4. Describe the application of a relay to a track circuit.
5. Describe the application of a relay to other circuits.

Theory of an electromagnet as applied to the operation of direct current relays.

6. What occurs when an electric current is transmitted through or along a wire?
7. Explain how a magnetic substance may become a magnet.
8. What occurs when a current is passed through a wire formed into a coil of many turns?
9. In what ways may the magnetizing force be increased?
10. Give an example.
11. How is magnetizing force determined and by what term is it known?
12. What happens when an iron core is inserted in a coil?
13. What limits the magnetic lines of force and how do they vary?
14. What is magnetic flux?
15. What is produced at the ends of a core with current flowing through the coil in a given direction?
16. How may the magnetic poles be reversed?
17. What is an electromagnet?
18. Of what material is the core made and why?
19. What is the most common form of electromagnet used in direct current relays?
20. Of what four parts does it consist?
21. Why is it necessary that the current in one coil should flow around its core in a direction opposite to that in the other coil?

General

22. Into what two general groups are direct current relays divided?
23. Into what classes and types are these general groups divided?
24. What is the difference between track and line relays?

Neutral Relays

25. In what two general shapes are neutral relays constructed?
26. How are all moving parts generally enclosed?
27. What are the principal parts of a neutral relay?

Coils.

28. How many coils does a relay usually have and how are they made up?

29. Of what insulation is the material on the wire and why?

30. How are the coils generally connected?

31. Will the magnetic or mechanical adjustment of the relay be changed when a relay coil is removed?

32. How are the coils treated to protect them against moisture and mechanical injury?

Cores.

33. What is a back strap and how is it connected?

34. What is the pole piece or face and where is it connected?

35. What do the cores and back strap form?

36. What is required to complete this magnetic circuit?

Armature.

37. What is the armature and how is it suspended?

38. How is the armature bracket constructed?

39. Describe the magnetic circuit and action of the armature when the circuit through the coils is closed.

40. What happens when the circuit is opened?

Air gap.

41. How is a permanent air gap between the armature and pole pieces maintained?

42. Where an independent adjustable armature stop is used, how is it applied?

43. Why is it essential to maintain a permanent air gap?

44. Upon what is the amount of opening in this permanent air gap dependent?

45. Regardless of the number of contacts, what is the minimum allowable air gap?

Contacts.

46. How are the metallic springs or fingers applied to the armature?

47. Where are the contacting surfaces applied and of what are they composed?

48. Are relay contacts designed differently for low and high current?

49. How are contacts arranged?

50. What are independent front contacts?

51. What are independent back contacts?

52. What are dependent front and back contacts?

53. How is the contact finger connected to a binding post?
54. How is this flexible connection formed and attached?
55. What other feature is taken care of by this flexible connection?

Binding posts.

56. Of what are binding posts made and how are they constructed?
57. Why is it necessary to break seal of relay to make adjustments?
58. How are circuits controlled through relays?
59. How may circuits be traced through relays?

Polarized Relays

60. What additional parts are required in the polarized relay?
61. How are circuits controlled by the polar armature?
62. Describe the operation of the polar armature.
63. In addition to controlling a circuit through a polar contact, through what other contact is it controlled?

Quick-Acting Relays

64. What is a quick-acting relay?
65. How is this quick action obtained?
66. Does the quick action affect the pick-up and drop-away values? If so, approximately how much?
67. How does the shunting time of a quick-acting relay compare with that of an ordinary relay?

Slow-Acting Relays

68. What is a slow-acting relay?
69. How is the slow action obtained?
70. What is the main purpose of this relay?
71. What is the retardation period?
72. How much longer is the retardation of a slow-acting relay than of an ordinary relay?
73. How does the resistance of the slow-acting relay generally compare with the ordinary relay and why?
74. How may the retardation of these relays be increased?
75. Why is it essential that the working voltage be maintained as nearly normal as possible?

Direct Current Motor Relays

76. Describe the operating mechanism and operation of the motor relay.
77. How does the design, opening and pressure of contacts compare with the neutral relay?

Flasher Relays

78. Where is the flasher relay generally used?

79. Describe the type which consists essentially of two ordinary neutral relays mounted on the same base.

80. How many operations per minute is this type of relay designed to provide?

81. For what purpose are the front contacts generally used in this type of relay?

82. Describe the front contacts and their operation.

83. What contact combination is used for opening circuit of 110 volts?

84. Describe the type which has the appearance of a single relay although it functions the same as the relay just described.

85. Describe the contacts and their operation.

86. Describe the operation of this type of flasher relay.

87. How is the slow action of this relay obtained?

88. How are the lamp control contacts arranged?

89. What position does the armature assume when the coils are de-energized?

90. How many operations per minute is this type of relay designed to provide?

Interlocking Relays

91. What is an interlocking relay?

92. Where are interlocking relays generally used?

Miscellaneous

93. How should relays be inspected and tested?

Shop Tests and Inspections

Coils

94. What percentage variation in the resistance of individual coils is permissible?

95. Must coils be fixed when in place to prevent vibrations?

Binding posts.

96. How must right or left-hand coil terminal, as specified, be marked?

Flexible connections.

97. How must the flexible conductor connecting the binding post and contact finger be formed and attached and what conductivity is required?

Contacts.

98. What contact pressure must be exerted by flexible part of finger when armature is against the stop pin?

99. How must a finger contact meet a contact surface?

100. What horizontal contact slide must finger contact have when against contact surface?

101. How far must the metal support of the non-fusible contact element be from the contact surface?

102. How far must the finger contact be from the back contact surface with the front contact just closed?

103. What is the minimum front and polar contact opening for first range voltage?

104. What is the minimum front contact opening for second range voltage?

105. What is the minimum back contact opening for first range voltage with working current or voltage applied?

106. What is the maximum allowable cleaned contact resistance when relay is energized at working current or voltage for the following contact combinations:

(a) Metal to metal?
(b) Metal to carbon?
(c) Carbon to carbon?

Armature end play.

107. What is the allowable armature end play?

Air gap.

Relays with adjustable stop pins.

108. What is the minimum working magnetic air gap for a relay with two neutral contacts?

109. What is the minimum working magnetic air gap for a relay with three or four neutral contacts?

110. How are these air gaps maintained?

111. What is the physical working air gap for a relay with two neutral contacts?

112. What is the physical working air gap for a relay with three or four neutral contacts?

113. Give composition, length and purpose of non-adjustable stop pins.

Relays without adjustable stop pins.

114. What is the minimum working magnetic air gap for a relay with two neutral contacts?

115. What is the minimum working magnetic air gap for a relay with three or four neutral contacts?

116. How is the air gap maintained?

117. What is the physical working air gap for a relay with two neutral contacts?

118. What is the physical working air gap for a relay with three or four neutral contacts?

Gaskets.

119. What must be done with defective gaskets?

Case.

120. What minimum clearance must be insured between the case and movable parts?

Meter calibration.

121. How often must meters for shop use be calibrated?

Repairing.

122. In testing for defects what special attention must be given?

123. On what form must repairs and adjustments be recorded?

Testing.

124. In testing relays for pick-up and drop-away, how must the following be determined:

(a) Initial charge?
(b) Drop-away?
(c) Direct pick-up?
(d) Reverse pick-up?
(e) Direct working current or voltage?
(f) Reverse working current or voltage?
(g) Polar pick-up?
(h) Polar working current or voltage?

125. What table determines the relay operating requirements?

126. When taking current readings, what must be done in regard to voltmeter?

127. How must voltage readings be taken?

128. What tests must be made?

129. When tests are made, what forms must be followed and what record made?

130. When must contacts be tested for resistance?

131. Where must insulation tests be made and what must be the minimum resistance?

Inspection.

132. How must it be determined that relay has a positive drop-away and relay contacts open without retardation of movement due to friction or external force?

133. What must be done to remove foreign matter before relay case is placed?

134. Following the removal of foreign matter, what must be done?

Sealing.

135. Must relay case be sealed?

Final test.

136. After relay case is sealed, what tests must be made?

137. What variation from previous tests is permissible?

Shipping.

138. What requirements must be met before relay is shipped?

139. How must each relay be packed?

140. How many relays is it permissible to put in the same packing box?

Field Tests and Inspections

Meter calibration.

141. How often must meters for field use be calibrated?

Testing.

142. What field tests are required and how often?

Inspection.

143. What requirements must be met when relay is placed in service and is there any exception?

144. How must it be determined that sufficient contact opening exists?

145. How must it be determined that sufficient clearance exists between case and movable parts?

146. What must be the condition of all enclosed parts?

147. What must be done with relays not fulfilling field requirements?

Repairing.

148. When and by whom may emergency repairs be made in the field?

Recording.

149. How must relay be identified?

150. What must the inspector do if a serial number is indistinct?

151. What must be done when relays are found with illegible or no serial number?

152. How must inspector handle field readings?

153. How often are field readings transferred and what forms are used?