American Railway Signaling Principles and Practices

CHAPTER X

Alternating Current Relays

Published by the Signal Section, A. A. R.

59 East Van Buren Street, Chicago 5, Ill.

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ALTERNATING CURRENT RELAYS

General.

The alternating current relay performs the same function as the direct current relay, *i.e.*, both types are provided with contacts to open or close circuits as desired, depending on whether these circuits are to be opened or closed when the relay is de-energized or energized as the case may be. In the alternating current relay, however, its motor mechanism or device which actuates the contacts is especially designed to operate on alternating current, while in the direct current relay this device, of course, is designed to operate on direct current. The entire mechanism of the alternating current relay, including windings, cores, armature and contact, is enclosed in a substantial case with exterior binding posts and glass sides to permit inspection. All cores of alternating current relays are laminated, being formed of thin painted sheets of steel stampings to prevent loss of power due to heating by eddy currents that would be generated to an undue extent by the alternating magnetic flux, if the core were solid as in direct current relays. The armature vane or rotor is the chief movable part of the relay, inasmuch as it furnishes the mechanical power to operate the contacts. A winding of a relay is the coiled conductor, which receives its energy from the outside source to make the relay function. A winding may be one coil or two or more coils wired in series or multiple. Nearly all relays are operated on the induction principle and are used either for track or line work, depending upon the source of control energy. The alternating current relay is either a single or two-element relay, depending upon the number of external control circuits. The two-element relay is sometimes called double-element relay or polyphase relay. It always has two windings and can be converted into a single-element relay by means of resistors or reactors used in connection with one of the windings. One of the windings in a two-element relay is connected to a constant local power source and called the "local" element; it is usually wound for 15, 57.5 or 115 volts. The other winding is connected either to the track or line control, and is called the "control" element; the control element is usually referred to as the track or line element.

Types.

The following principal types of alternating current relay are used on railroads at the present time:

Vane type—sector-shaped:
- Single-element, two-position.
- Two-element, two or three-position.

Vane type—disc-shaped:
- Single-element, two-position.
- Two-element, two or three-position.

Rotor type*:
- Single-element, two-position.
- Two-element, two or three-position.

Galvanometer type*:
- Single-element, two-position.
- Two-element, two or three-position.

Frequency type—sector-vane or rotor:
- Single-element, two-position.
- Two-element, two-position.

Tractive armature type:
- Single-element, two-position.

Rotating iron armature type:
- Single-element, two-position.

Tractive transformer type:
- Single-element, two-position.

Time element type:
- Single-element, two-position.
- Two-element, two-position.

Alternating current relays, known as time element relays, slow drop-away relays, flasher relays, indicator relays, interlocking relays, etc., are made from the types mentioned above, by adding to or altering the mechanism, but the general working principles are unaltered.

Binding posts and contacts.

The binding posts and contacts of alternating current relays are in accordance with A.A.R. recommended practice. The contacts are generally silver-impregnated carbon to silver, silver-impregnated carbon to silver-impregnated carbon, or silver to silver, being similar in general design to those used in direct current relays. Contacts illustrated in Fig. 1 are known as either front or back for two-position relays and normal or reverse or de-energized for three-position relays, and these are further classified in Chapter VI—Direct Current Relays. The contacts are usually carried on a bracket supporting member which is moved by the vane, armature or rotor.

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* Not furnished for new work, but a large number still being continued in service.

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Tractive armature type:
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Rotating iron armature type:
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Tractive transformer type:
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In the two-position relay the contact finger rests on the back contact when de-energized. In the three-position relay when de-energized, the normal or reverse contact finger rests midway between the normal and reverse contact posts and does not make contact. When a contact is desired in the de-energized position, a contact finger is sometimes used that spans the space between two stationary contacts when the relay is de-energized and closes the circuit between the two posts, but when the relay is energized, either normal or reverse, one of the contact springs is drawn away from one of the posts and the circuit between the posts is opened. There is, however, another type of contact made in the de-energized position of the relay and consisting of two separate contact springs resting on their respective back contact posts when the relay is de-energized, the binding posts of the two contact fingers being so connected that there is a continuous circuit formed through the two back contacts in series; the two contacts are independently connected to the driving mechanism of the relay, so that when the latter moves to the normal position, the back contact on that side is lifted or opened, and when the driving mechanism moves to the reverse position it lifts or opens the back contact on that side, the result being that both back contacts, connected in series, are closed only when the relay is de-energized.

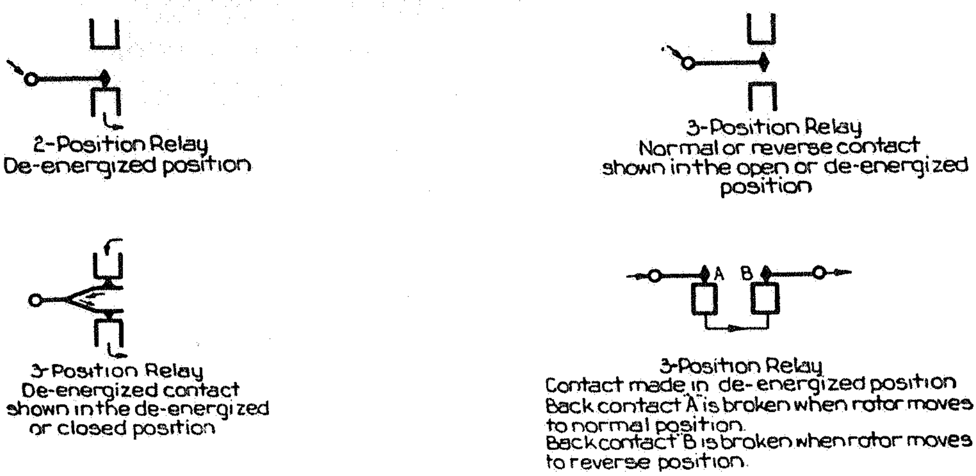

Fig. 1.
Various Types of Alternating Current Relay Contacts.

Detachable type (plug-in) relays require a somewhat different contact design. The contact posts are replaced by relatively stiff spring members with appropriate tips. The movable contact members are of a relatively light spring material with appropriate tips. These springs are extended to pass through the base of the relay which holds them in place rigidly. External contact is made to the extending members when the relay is plugged into its mounting base. The movable springs are driven by a bracket or brackets of insulating material connected to the armature.

Alternating current relays are manufactured in standard sizes for various types. The size is determined by the number of contact spaces and the type of mechanism.

Track relays.

Alternating current track relays are made to suit the characteristics of the track circuits. Some of the characteristics to be considered are the size and section of rail, nature of bonding, kind and physical condition of track ballast, the longest and shortest length of track circuit, the power used for propulsion; if alternating current propulsion, what frequency is used; the maximum and average alternating current or direct current return propulsion current per rail and duration of maximum current. For information on non-coded alternating current track circuits, see Chapter XI.

Vane Type

*Theory of the "rotating field" principle in vane relays using copper ferrules.**

When two circuits are placed near each other, a current sent through one will in general produce an appreciable magnetic flux through the other, some of the magnetic flux of the first circuit becoming linked with the second. The circuits are said to possess mutual inductance, and taking into account the principle known as Lenz' Law, it is easy to arrive at the general nature of the results produced by mutual inductance when the first circuit is supplied with an alternating current, and the second circuit, which contains no impressed electromotive force, is simply closed on itself. (According to Lenz' Law, the current induced in any circuit by a varying flux always opposes the changes in flux which give rise to it; and the circuit in which the current is induced is subject to mechanical forces tending to move the circuit, so as to reduce the extent of the flux variations.)

Let us now suppose that the first circuit is fixed and the second movable. If we assume the two circuits to be parallel to each other, the second circuit will be repelled by the first, since the result of such motion would be to reduce the amplitude of the flux variations. Thus, a ring of copper or aluminum slipped over a pole of an alternating current electromagnet will be projected upward as soon as a sufficiently strong current is sent through the coil of the electromagnet, and if provided with suitable guides, the ring may even be kept floating in the air above the electromagnet, gravity being neutralized by electromagnetic repulsion.

If the second circuit is prevented from having motion of translation, but is free to rotate about an axis, rotation will take place until the plane of the second circuit is parallel to the inducing field; for this is the position in which the flux fluctuations are completely suppressed. Since action and reaction are always equal and opposite, an equal and opposite couple will be experienced by the first circuit. For example, a coil of wire conveying an alternating current, when pivoted or suspended in front of a sheet of metal, will experience a couple, tending to turn it into a position at right angles to the conducting sheet.

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The principles just explained find a practical application in the vane relay, in which case an alternating current field magnet is made to act on two secondary short circuited circuits. Let us suppose that two rings of copper of the same size are suspended parallel to, and nearly in contact with each other, in the field of such a magnet. The currents induced in the rings by the alternating magnetic field will be nearly in phase with each other, the rings being nearly in the same region of the field, so that there will be attraction between them, since conductors conveying currents flowing in the same direction attract each other. Let us now suppose that the rings are displaced relative to each other, as in "A" of Fig. 2, in a direction parallel to their planes. In "A" of Fig. 2 the shaded portion represents the pole of the alternating current electromagnet, which, for the sake of simplicity is shown of circular shape. The attraction between the rings will tend to pull them into coincidence, and there will be a component of stress in a direction parallel to the planes of the rings. Next suppose one of the rings to be replaced by a conducting sheet of metal as in "B" of Fig. 2, in which the dotted circle shows the position of the pole, and let the ring be fixed, while the conducting sheet is free to move. If the ring were removed, then, by symmetry, it is clear that the currents induced in the conducting sheet by the alternating flux, from the magnet pole

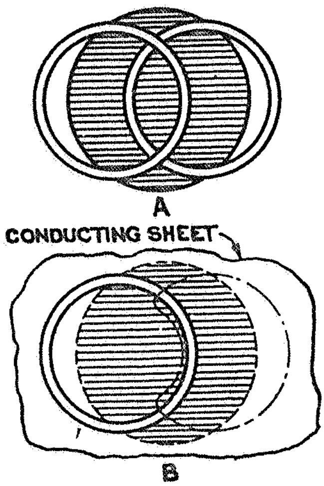


Fig. 2.
Illustrating Attraction Principle of Single-Element Vane Type Relay.

would (assuming the sheet to be of large extent, so as to project well beyond the polar edges) follow circular paths having their centers in the axis of the magnet. But, with the ring in place, according to Lenz' Law the currents induced in it give rise to a magnetic field in opposition to the main field, and the result of this is to cause a shifting of the main magnetic flux (whose distribution with the ring removed would be uniform) toward the right-hand unshaded crescent-shaped portion of the polar surface. But, with this shifting of the flux, the currents induced in the conducting sheet will also be shifted to the right, following the paths similar to that roughly indicated by the dot-and-dash line. Now, the portion of the conducting sheet forming the closed circuit indicated by the dot-and-dash line and the ring will behave relatively to each other in the manner of the two rings in "A" of Fig. 2 and, since the ring is fixed, the sheet will move from right to left, that is, from the unshaded to the shaded portion of the magnetic pole. Since, however, the conducting sheet is continuous, as it moves successive portions of it come into the position of the dot-and-dash line, and so the pull is maintained and the motion is continuous.

In the vane relay, whose operating elements are illustrated diagrammatically in Fig. 3, the vane is aluminum and is free to rotate and takes the place of the conducting sheet above mentioned in connection with "B" of Fig. 2. Around one-half of each pole face is placed a shading coil or ferrule consisting of a simple heavy band of copper, which takes the place of the fixed ring in "B" of Fig. 2. Coil "C" in Fig. 3 and its laminated iron field core constitute the alternating current electromagnet, and cause magnetic flux to induce currents in the aluminum vane, which by the continuous attraction action described above, swings upward in the direction of the shaded pole faces (those surrounded by the ferrules) when coil "C" is energized.

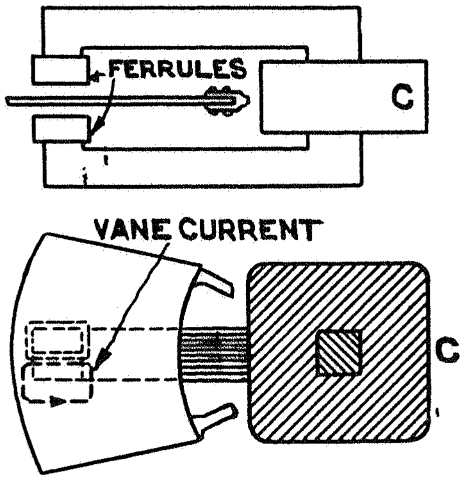
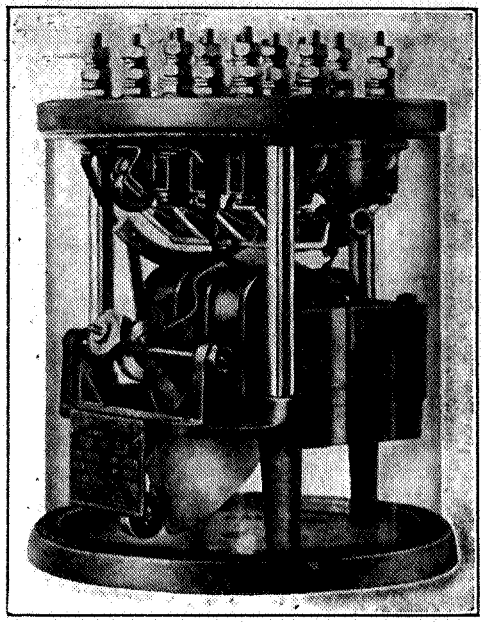
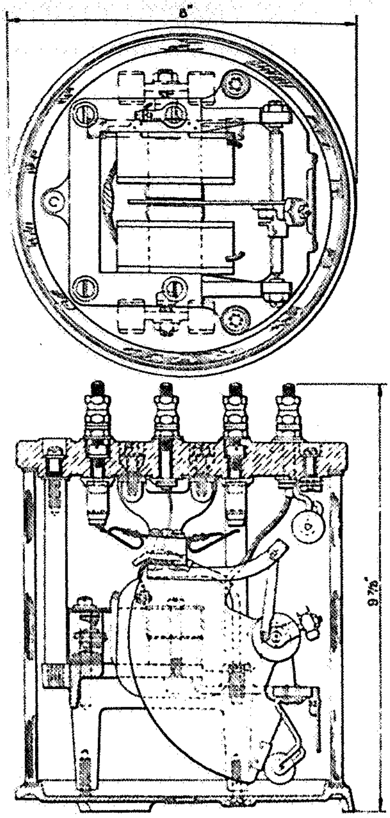


Fig. 3.
Operating Element of Single-Element Vane Type Relay.

Sector-shaped vane, single-element, two-position relay.

This relay, Figs. 4 and 5, consists of a horizontal laminated core having two coils wired in series. Between the coils is a narrow slot in the core in which the vane is free to move. The vane is fastened to a horizontal shaft outside the core. At the shaft end of the vane are adjustable counterweights used for regulating purposes.



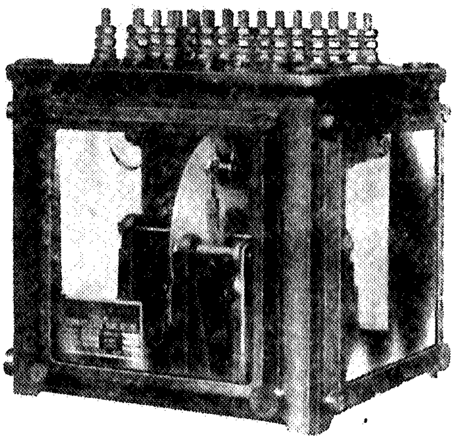


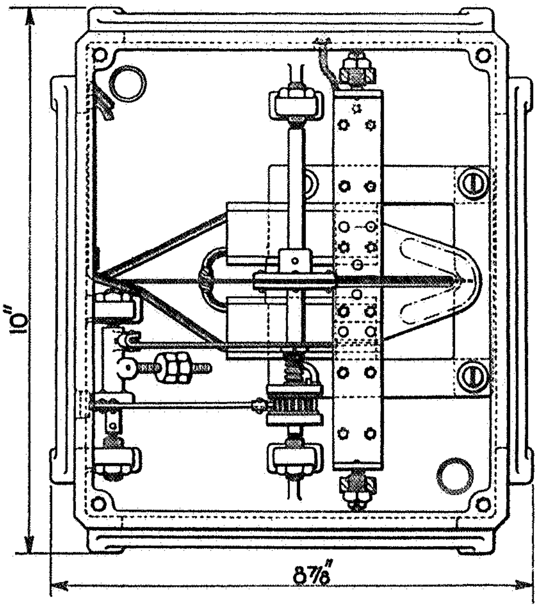
Figs. 4 and 5.
Sector-Shaped Vane, Single-Element, Two-Position Relay.

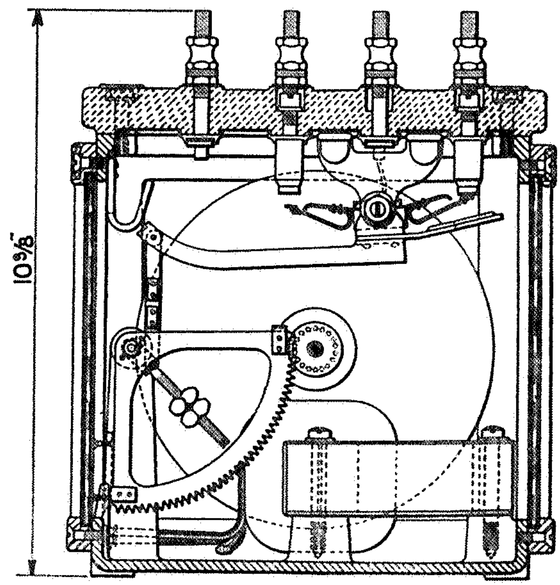
The upward movement of the vane closes the front contacts of the relay, but when the relay is de-energized the vane falls back by gravity to its de-energized position and opens the front contact. This relay is suitable for all line circuit work requiring a two-position relay, and is equally adapted to track circuit work, on both steam and electric roads with direct current propulsion. However, since it is a single-element relay and hence, when used as a track relay, receives all its power from the rail circuit, it is best adapted to track circuits of comparatively short length up to approximately 1,500 feet, depending on track conditions. It is inoperable by direct current, but proper arrangement should be made, as is the case with all alternating current track relays used on roads employing direct current propulsion, to prevent excessive amounts of direct current flowing through its coils, as this would cause chattering. To properly control the amount of direct current flowing through the coils of the relay, a resistance coil connected in series between the feeding transformer and the track, and another resistance coil connected in series between the relay and the track are generally all that is necessary, but in those cases where this is insufficient, further protection may be secured by shunting an impedance coil of low resistance across the terminals of the winding of the relay; practically all the direct current will then pass through the shunt impedance coil, which, due to its impedance, will choke out the alternating current so that it will flow through the relay winding.

Disc-shaped vane, single-element, two-position relay.

The vane type relay, Figs. 6 and 7, is a modified form of the sector-shaped vane relay. The vane being enlarged into the form of a disc, instead of making part of a revolution, continues to revolve until the relay contacts are made. The direction of rotation is controlled by the proper placing of the copper ferrules about a portion of the pole pieces. The disc revolves on a shaft passing through its center. The shaft carries a pinion that moves a counter weighted sector, which in turn operates the contacts. When the winding is energized the sector closes the front contacts; when the winding is de-energized the counterweight by gravity opens the contacts; when the sector is resuming its de-energized position the disc revolves backward. This relay is used when delayed opening and closing of contacts is desired.







Figs. 6 and 7.
Disc-Shaped Vane, Single-Element, Two-Position Relay.

Sector-shaped vane, two-element, two or three-position relay.

Relay with Separate Local and Control Air Gaps

The two-element vane relay, Figs. 8 and 9, consists of two separate windings; a radially slotted aluminum vane and three laminated cores: two for the local circuit and one for the control (track or line) circuit.

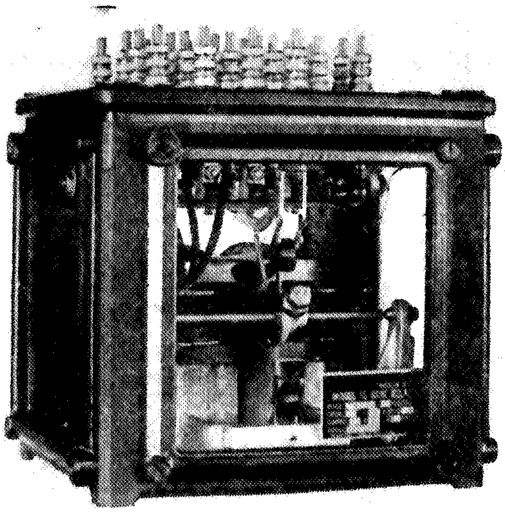


Fig. 8.
Sector-Shaped Vane, Two-Element, Two-Position Relay.

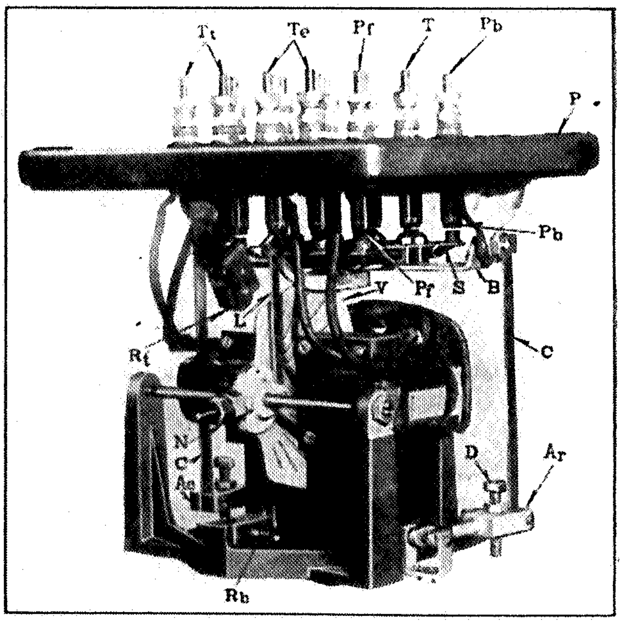


Fig. 9.
Mechanism of a Three-Position, Two-Element Vane Relay.

The operating member of this relay is a slotted aluminum vane enclosed by two separate magnetic circuits which act inductively on the vane and cause it to rotate when the windings of both magnetic circuits are energized by alternating current. The relative positions of these two magnetic circuits and the vane in its midstroke position will be seen from Figs. 10, 11 and 12. It will be noted from Figs. 10 and 11 that one of the magnetic circuits consists of two C-shaped laminated iron cores separated by an air gap in which the vane moves. This magnetic circuit has two sets of poles located near the center of the vane. These cores with their coils are called the "local" element since they are usually energized from a local source, receiving the larger part of the energy required for the operation of the relay.

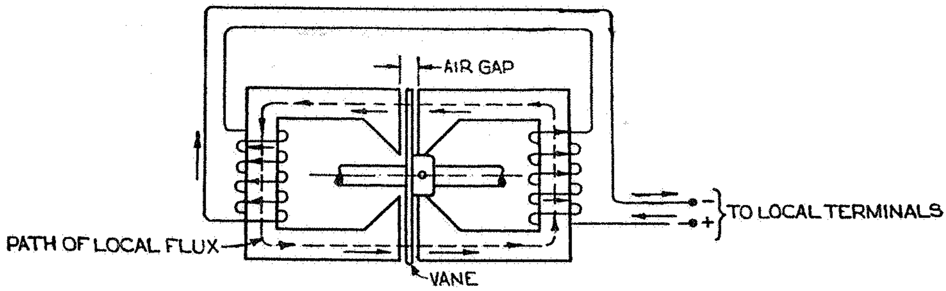


Fig. 10.

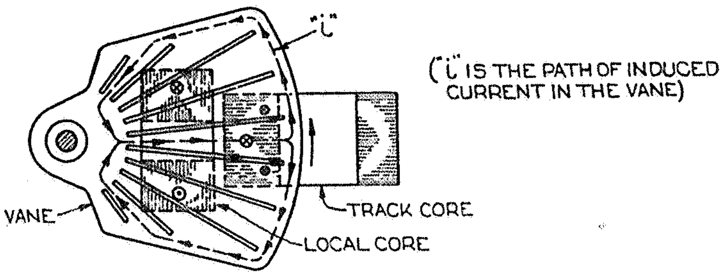


Fig. 11.

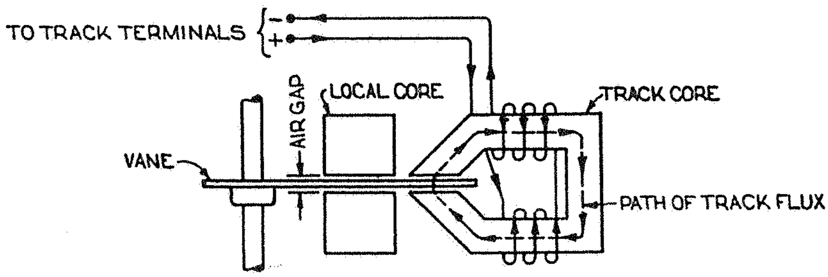


Fig. 12.
Diagrams of Windings, Currents and Fluxes of Sector-Shaped Vane, Two-Element Relay. (Union)

The second magnetic circuit consists of a single C-shaped core with but one pole located near the periphery of the vane on a line midway between the local poles as will be seen from Figs. 11 and 12. This magnetic circuit with its windings is called the "control" element. This is the element which receives power from the track circuit when the relay is used as a track relay, in which case it is known as the "track" element. The presence of current in this element when the local is also energized causes the vane to move from its de-energized position, the direction of the rotation being governed by the relative directions of the currents in the two elements of the relay, thus making it possible to use it as a three-position polarized relay.

To understand how the torque is produced on the vane, refer to Figs. 10, 11 and 12. If we consider the plus (+) and minus (−) signs to indicate the instantaneous polarities of the terminals of the windings at a given instant the arrows will show the directions of the currents in the two elements and of the fluxes produced by these currents. The dotted lines in Figs. 10 and 12 show the paths of the fluxes in the "local" and "track" (or line) cores, respectively. In Fig. 11 the circles with dots or crosses in them show how the

(⊙ OR ⊗)

fluxes are passing from the pole faces either out of the plane of the paper toward the reader or into it away from the reader.

The local flux passing across the air gaps and through the vane induces currents in the vane by transformer action, the instantaneous directions and paths of which are indicated by the arrows on the dotted lines "i" in Fig. 11. The local coils can be considered as the primary of a transformer, the local magnetic circuit as the transformer core and the vane as the secondary coil. The radial slots in the vane cause the induced currents to flow in a nearly horizontal direction in front of the pole faces of the "track" (or line) core. The action between these induced currents in the vane and the "track" (or line) flux produces a force on the vane which causes it to move up or down depending on the relative directions of the current and flux. If the directions are as shown in Fig. 11 the vane will move up. This can be seen from the elementary theory of a direct current or alternating current series motor, the operation of which depends on the fact that when a conductor carrying a current is placed in a magnetic field a force acts on the conductor in a direction at right angles to both the conductor and the flux. The direction of this force can be determined from Fleming's "left-hand rule" which states that: if the forefinger of the left hand extended horizontally represents the direction of the flux from the track core and the middle finger bent forward at right angles to the palm represents the direction of the current in the vane (see Fig. 11) it will be found that the thumb points upwards, indicating that the force tends to move the vane upwards. Reversal of the direction of the track flux by reversing the connections to the track terminals would cause the vane to move downwards.

It is also known from the elementary theory of the electric motor that the force acting on a conductor carrying current in a magnetic field is proportional to both the strength of the current and the strength of the field. From this it can be seen that if the current is small a stronger field will be required to obtain a given force on the conductor than will be needed if the current is large. In this way, by inducing heavy currents in the vane the required vane torque can be obtained with a relatively weak field in the air gap of the track element. This is useful in that it enables the greater part of the power required by the vane relay to be applied to the local element which induces large currents in the vane. A small amount of power applied to the track element supplies the necessary flux in the track core to operate the relay. This is important as a long alternating current track circuit is a very inefficient transmission line on account of its low ballast resistance in wet weather. Track circuits of the lengths ordinarily used may require from 200 to 700 times as much power at the secondary of the track transformer as the amount which reaches the track element of the relay. By using a two-element relay which requires a very small amount of power in its track element it is therefore possible to operate these long track circuits without the expenditure of too much power at the track transformer.

In this Chapter so far consideration has not been given to the phase relations of the a.c. currents in the two elements of the relay but it can be readily seen that the phase relations have an important bearing on the operation of the relay. The currents and fluxes in the two elements of the relay are continually fluctuating between maximum positive and maximum negative values through zero. The condition for the greatest torque on the vane is that the currents in the vane and the flux in track element reach their maximum values at the same instant, that is, that they be in phase. If the vane current is zero at the instant the track flux is maximum, that is, if they are 90 degrees apart in phase, no torque will be produced.

The local flux is in phase with the local current and this flux induces in the vane an electromotive force which lags the flux 90 degrees. This electromotive force causes a current to flow in the vane which is nearly in phase with the electromotive force or 90 degrees out of phase with the local current.

The track flux is in phase with the track current, therefore, if the vane current is to be in phase with the track flux it is necessary for the local flux and current to be 90 degrees out of phase (in quadrature) with the track flux and current, since it was shown in the foregoing that the vane current is 90 degrees out of phase with the local current. It is thus seen that the maximum torque is produced when the currents in the local and track element are in quadrature. This phase difference is approximated by track circuit adjustment, which is usually made by varying the amount of resistance between the transformer and track.

The windings have the proper relative phasing 90 degrees forward or 90 degrees backward to give the vane the direction of movement required to make the proper contacts when the control winding is energized. When the control winding is de-energized the vane resumes its de-energized position by gravity and the front contacts open. This type of relay is suitable for use as a line relay or as a track relay on either short or medium length track circuits and is inoperable by direct current.

For long track circuits or ones of medium length having very low ballast leakage resistance, to obtain proper phase relations it is necessary to use a reactor between the track transformer and track and to either raise the power factor of the local element by inserting a resistor in series with it or to connect a capacitor in parallel with the track element. The second method is used most commonly since it does not require the expenditure of extra watts in the local element and since it also effects a saving of at least 50 per cent in the volt-amperes required by the track element.

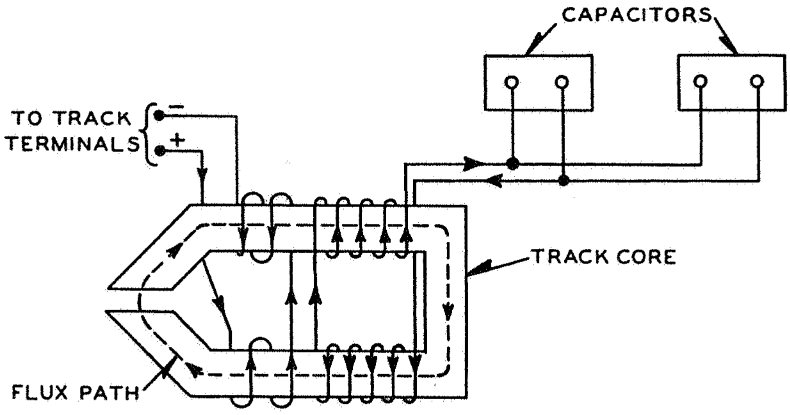


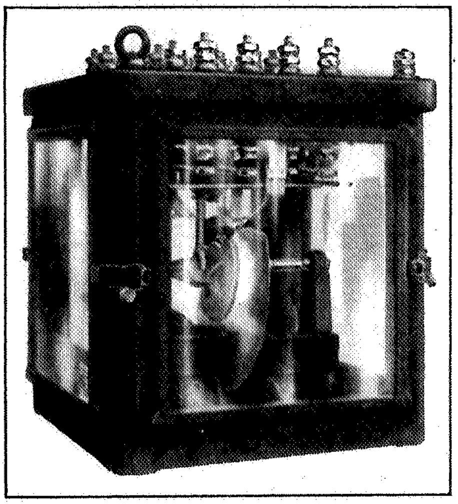
Fig. 13.
Diagram of Connecting Capacitors to the Secondary Winding on the Track Core.

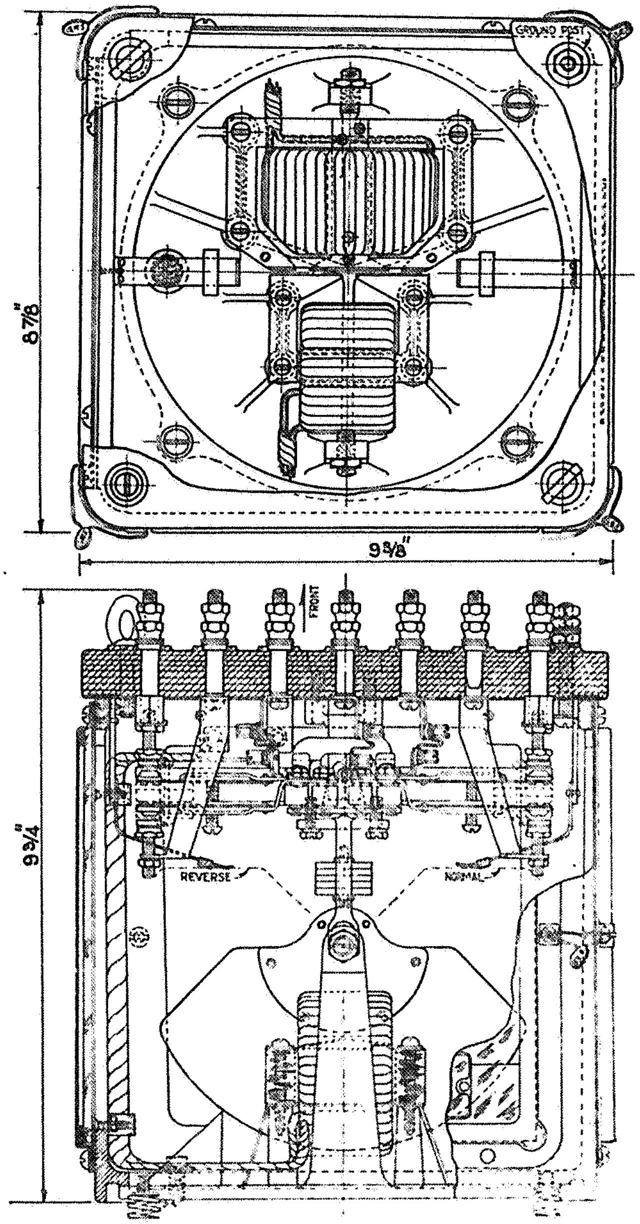
When the capacitor is used it is connected to a secondary winding on the track core as shown in Fig. 13. Each of the track coils has two windings, one of a few turns connected to the track terminals of the relay, the other of many turns and connected to the capacitor. This makes the track element a "step-up" transformer and allows the use of a relatively small capacitor to produce the same effect as if a large capacitor, having about 3,000 times the capacity for a steam road relay, were connected directly to the track terminals. For double rail electric road circuits, the turn ratio is increased so that the secondary capacitor is equivalent to one of about 6,000 times the capacity connected directly to the track terminals.

The use of capacitance as just explained is an application of parallel resonance, a more complete explanation of which may be found in any alternating current text book. The track element flux maintains approximately the same phase relation with respect to the track element voltage. The current, however, is brought nearly in phase with the track voltage—it may actually lead the voltage for electric road use—and therefore the track flux will lag the track current by 55 degrees or more instead of being nearly in phase with it.

Relay with Common Local and Control Air Gap

The relay shown in Figs. 14 and 15 is another type of two-element, sector-shaped vane relay in which the local and control elements have a common air gap. This relay may be used on long or short track circuits and is inoperable by direct current.





Figs. 14 and 15.
Sector-Shaped Vane, Two-Element, Three-Position Relay.

Figures 16 to 20, inclusive, illustrate the magnetic structure of this relay and indicate the instantaneous directions of currents and fluxes.

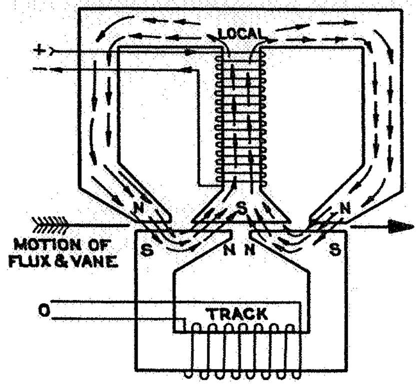


Fig. 16.

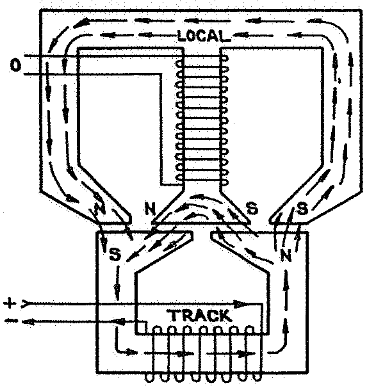


Fig. 17.

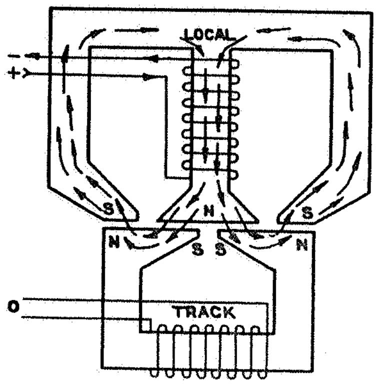


Fig. 18.

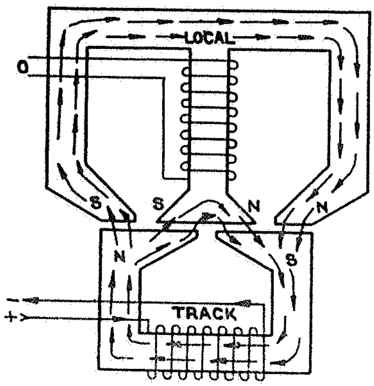


Fig. 19.

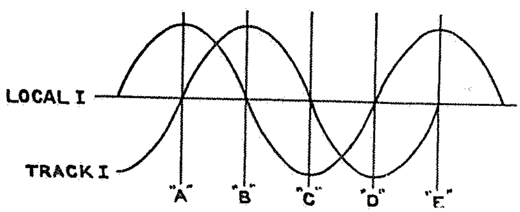


Fig. 20.
Diagrams of Instantaneous Currents and Fluxes in Sector-Shaped Vane, Two-Element, Three-Position Relay. (General)

Figure 20 is a graph showing the phase relation of the currents in the local and control elements for one complete cycle. At "A" current in the control element is zero, while the local element is maximum positive, which condition is illustrated fully in Fig. 16, showing direction of currents and fluxes at that instant. At "B" in Fig. 20, the current in the local element is zero, while that in the control is at positive maximum, which condition is duplicated in Fig. 17, illustrating the corresponding direction of currents and fluxes at that instant.

At "C" in Fig. 20 it will be noted that the current in the local element is at negative maximum, while that of the control element is zero, which condition is illustrated in Fig. 18. At "D" in Fig. 20 the current in the local element is at zero, while that in the control element is at negative maximum, the corresponding flux and current relations being illustrated in Fig. 19.

These diagrams therefore show the instantaneous directions of currents and fluxes in the two windings for one complete cycle and illustrate the fact that although the control and local currents go through sinusoidal changes, the torque or twisting effect on the vane is a constant direction.

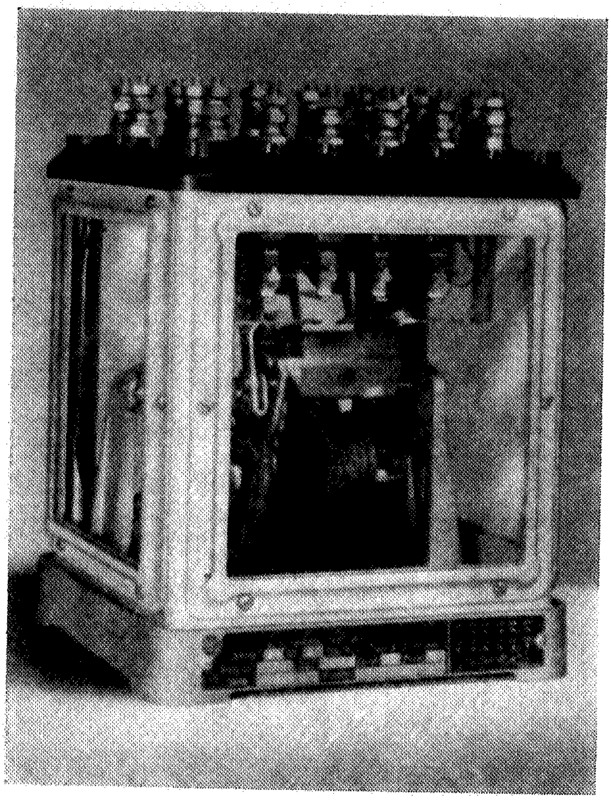


Fig. 21.
Sector-Shaped Vane, Two-Element, Two-Position Relay.

Another type of two-element, two-position vane relay, illustrated in Fig. 21, is designed primarily for use as a track relay, although it may be used as a line relay by employing coils to fit the application. It is equipped with four dependent front and back articulated contact fingers and hardened knife-edge shaft bearings instead of jewel bearings usually used.

A copper vane, especially treated to prevent warping, is clamped between the two halves of the vane shaft which is supported at each end by bearings made of non-corroding hardened alloy steel. These knife-edge bearings are practically frictionless, require no lubrication, and withstand severe vibration.

A link drive transmits the movement of the vane shaft to the moulded contact block which is supported by bronze trunnions in brass bearings. The contact finger consists of two parts flexibly connected. The one part is mounted on the bakelite contact block. The other part, pivoted on a ball and socket joint and held in place by a spiral bronze spring, carries the contact. The articulated feature provides a means for easily adjusting to a uniform pressure, between 1⅝ and 1⅞ ounces, on the contact surfaces. The contacts are the standard combination of silver on the fingers to silver-impregnated stationary fronts and silver stationary back contacts.

Both local and track coils are double-wound so that either set may be connected in series or multiple as required by the particular application. They can be connected externally to operate on half voltage which provides, in the case of the local, for the connection of a phase shifting device should adverse track circuit conditions make this desirable. The coils are wound on bakelite spools which provide additional insulation against breakdown to ground in case the coils are subjected to lightning surges.

Detachable Type Relays

The relays shown in Figs. 22 and 23 are quick detachable (plug-in) type and have a field structure similar to that shown in Figs. 16–19. They may be adapted to two-element or single-element (split phase) operation for single or double-rail track circuits, line of power transfer service.

They can be plugged onto and removed from a plugboard without disturbing the wiring. They have a sector-shaped vane that moves to two positions only. The vane is attached to a horizontal shaft and moves in a vertical plane in the air gap between the pole faces of the local and track elements. Pushers of insulating material transfer the rotary motion of the shaft to an up-and-down motion of the contact fingers. These fingers are molded in bakelite blocks and extend through the blocks and out of the back of the relay to form jacks or prongs. Line and track winding connections are brought out to similar prongs. The fields and vane structure are mounted on a cast frame, which may also form the base for the whole structure including the contact blocks, or may be attached to a molded bakelite relay base. A transparent cover protects the working parts against dust and mechanical injury.

Means are provided for guiding the relay into its proper position on the plugboard and for securing in place. Registration means are provided between the relay and mating plugboard to prevent applying a relay to the wrong plugboard. Circuit wires behind the plugboard are permanently soldered to terminals and are not disturbed when a relay is to be removed and replaced. Means are provided for making current and voltage measurements. The plugboard is bolted to a steel framework or rack for installation in tower relay rooms and instrument cases and housings.

These terminals, when of the removable type, are automatically locked in place when inserted in the proper slots on the plugboard. They can be removed from the locked-in position only by using a special tool which disengages the locking tongues. If field changes in wiring are required, the new wires are soldered and clamped to the terminals which can then be inserted in the proper slots.

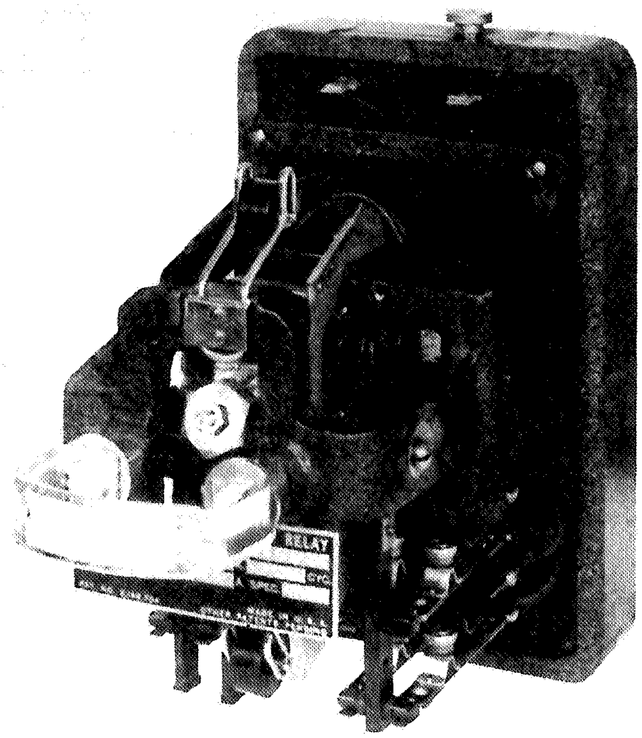
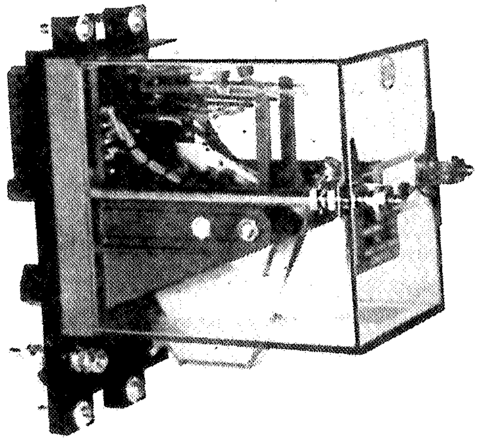


Fig. 22.
Sector-Shaped Vane, Two-Element, Two-Position Detachable Relay.



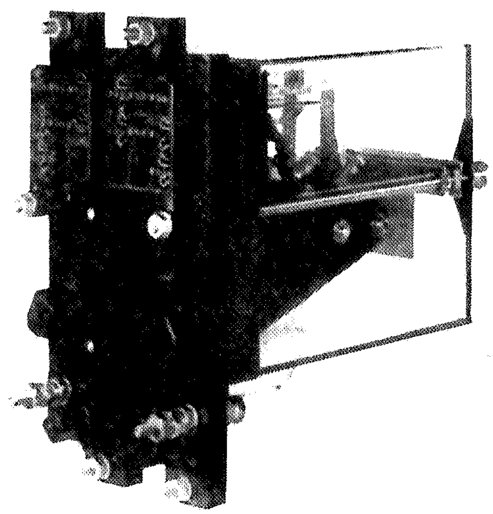


Fig. 23.
Two-Element, Two-Position Vane Relay on Plugboard.

Disc-shaped vane, two-element, three-position relay with common air gap.

A relay with a circular disc vane and using a field structure similar to that shown in Figs. 16–19 is used for line and indication service. This relay is shown in Fig. 24.

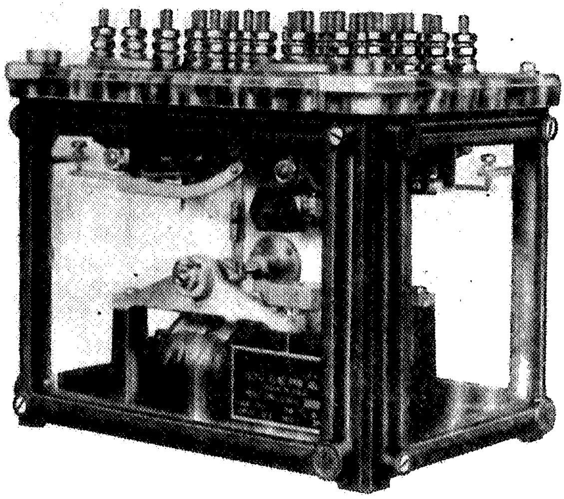


Fig. 24.
Disc-Shaped Vane, Two-Element, Three-Position Relay.

A feature of this relay is the use of a separate contact spring support for each of the two energized positions. A de-energized contact of each position in series provides a de-energized position circuit. In addition, these de-energized contacts may be used independently.

The relay is also provided with a mechanical buffer for stopping the vane in the de-energized position without the damping of the local field. This is a particularly valuable feature for an indication relay.

Due to its inherent phase relations, this relay is especially adaptable to indication circuits. The phase-shifting resistor used with the control winding is located at the device whose position is being indicated, and a direct local cross on the control circuit between the resistor and the relay will not hold the relay energized. The resistor is commonly wound into the secondary of the indication (insulating) transformer. The relay may be used as a line relay with a built-in resistor.

Disc-shaped vane, two-element, two or three-position relay with common air gap and strap-wound local.

A relay particularly suited for longer track circuits without the use of capacitors uses a circular disc vane, a common local and control air gap, and a heavy strap copper local winding wound into the pole faces. The heavy local winding is energized from a self-contained transformer in the relay. The relay is shown in Fig. 25.

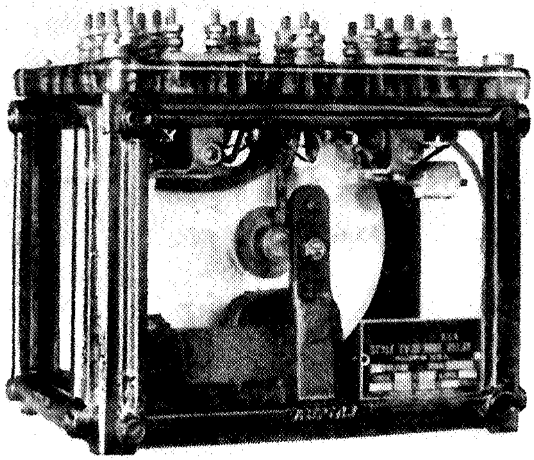


Fig. 25.
Disc-Shaped Vane, Two-Element, Three-Position Relay.

This relay also uses two separate contact spring supports for three-position relays. Since these supports move independently for each energized position, the de-energized contact springs are compressed sufficiently by the normal counterweight and the relay does not require extra power for a de-energized contact. For two-position relays, the contact supports operate together and provide nearly double the number of front contacts.

Rotor Type

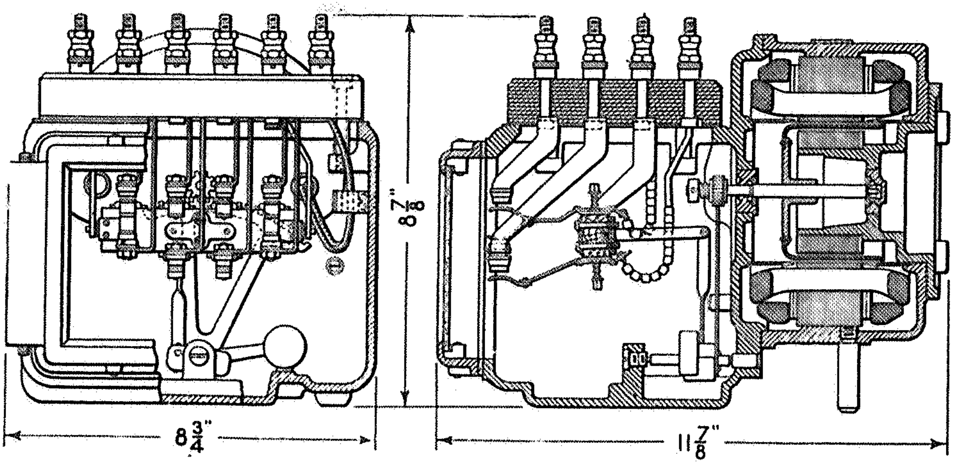
Induction or polyphase type, non-magnetic rotor, single-element, split-phase, two-position, and two-element, two or three-position relay.

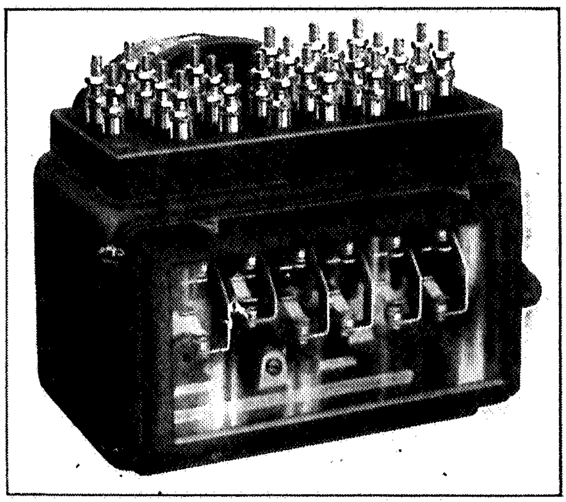
The rotor type relay illustrated in Figs. 26 and 27 has a two-phase alternating current induction motor operating mechanism. The operating mechanism is enclosed at the rear in a cylindrical case and consists of a stator, a cup rotor and an inner core. The stator is a cylindrical, ring-shaped, laminated core, and separated from the inside face of the stator core by an air gap is an inner cylindrical laminated core which provides a path for the magnetic flux from the stator ring through the air gap. On the inside face of the stator core are two separate and distinct windings, spaced in alternate positions. These two windings constitute the local and control element windings.

In the annular gap between the stator core and the inner core, and free to turn without touching the core, is the rotor, a drum-shaped shell of non-magnetic metal (such as aluminum or copper) attached to and supported on a shaft at the center and parallel to the sides of the drum. On the shaft is a pinion which engages in a segmental gear which operates the contacts.

The operation of an induction motor may be compared to a permanent magnet which, when placed over the outer rim of a metallic disc and rotated around the disc, produces small rotary currents in the disc. If the disc is free to rotate on a shaft the induced currents produce a magnetic field which reacts on the field of the permanent magnet and causes the disc to revolve.

Likewise, when both windings of the rotor relay are energized there is produced the effect of a revolving field of a permanent magnet around the concentric gap with the shaft of the rotor as its center. The drum of the rotor in the gap is equivalent to the disc described, and the action of the revolving magnetic field on the drum causes it to revolve closing the proper contacts of the relay. The torque of the rotor holds the contacts closed while both windings are energized.





Figs. 26 and 27.
Induction Type Non-Magnetic Rotor Relay.

When the control winding is de-energized, a counterweight causes the rotor to turn backward, thus opening the contacts previously closed. The currents in the two windings of the rotor relay should be adjusted as nearly as possible by track circuit adjustment, so that there will be as closely as possible a 90 degree phase difference either forward or backward, in order that when both windings are energized, the direction of movement of the rotor will close the normal or reverse contacts of relay as desired—this, of course, applies to a three-position relay. Where a two-position relay is involved, the direction of current in the control element is, of course, never changed, so that the relay is picked up to close its front contacts or de-energized to close its back contacts as the case may be.

If the rotor turns clockwise while the phase difference is 90 degrees forward it will turn counter-clockwise when the phase difference is 90 degrees backward. This reverse movement is necessary for the three-position relays. The phase adjustments are made by resistors or reactors and the alternation of phase difference is caused by a pole changer.

Such relays having two separate windings are, of course, two-element relays, but in certain cases the two windings on the stator element may be connected in multiple and phase difference between the current in the two windings can be secured by the use of a resistor or reactor in series with one winding or the other; thus, but one power source such as the current from a track or line circuit is necessary to operate the relay and the phase difference or phase split is artificially produced in the relay itself, rather than by track circuit adjustment, in order to produce motion of the rotor. Relays with the two windings thus connected together, but in which artificial phase splitting devices have been included inside the relay, are known as split-phase, single-element relays.

Galvanometer Type

Ironless, two-element, two or three-position relay.

This type of relay, illustrated in Fig. 28, is based on the principle of the electro-dynamometer consisting of an outer stationary coil and inner movable coil. The stationary coil is the local coil; the inner coil is the control coil fastened by means of a brass frame with adjustable balancing nuts to a horizontal shaft, which makes a part turn when both coils are energized.

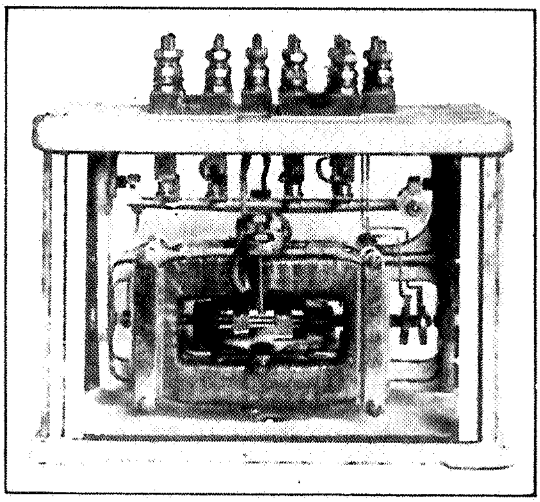


Fig. 28.
Galvanometer Type, Ironless, Two-Element, Two or Three-Position Relay.

The movement of the inner coil is caused by the attraction produced by the magnetic flux which surrounds the coils when they are energized. A torque is produced on the shaft by a pulling up force on one side of the control coil and a pushing down force on the opposite side.

The currents in the coils are in phase in a two-position relay and the inner coil has but one direction of movement.

In a three-position relay, the coil is balanced in the horizontal position and its direction of movement depends upon whether the two coils are in phase or 180 degrees out of phase. The difference in phase is produced by means of a pole changer. The changing of the phase 180 degrees by changing the polarity of the track circuit reverses the attraction and repulsion forces, thus changing direction of movement of armature. The normal contacts of the relay are closed when the track coil is energized and opened by a counterweight when de-energized. Likewise, when the direction of current is reversed in the control element the armature swings in the other direction to close the reverse contacts. This relay is immune to direct current if such current is in one winding only. It is not, however, immune to direct current in both windings.

Iron core, two-element, two or three-position relay.

The galvanometer iron core relay, illustrated in Fig. 29, employs windings of the same type as used in the ironless galvanometer relay. The local coils wired in series are carried on the lower arms of an inverted U-shaped laminated core, one on each side of a tubular shaped gap. Within the gap is a suspended cylindrical iron core. In the tubular air gap between the outer main field core and the inner cylindrical core, rotates a hollow formed armature coil, properly pivoted. The laminated core is suspended from the top of relay case. The galvanometer iron core relay operates on the same principle as the ironless galvanometer relay.

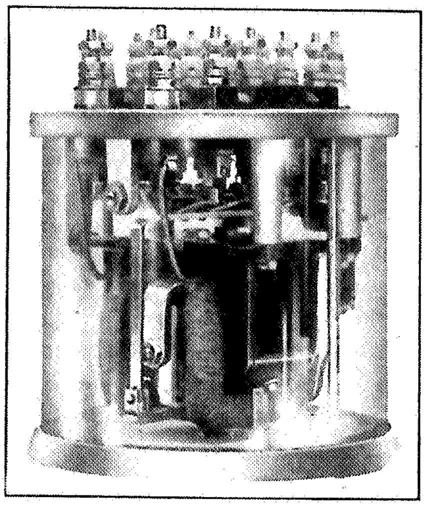


Fig. 29.
Galvanometer Type, Iron Core, Two-Element, Two or Three-Position Relay.

As more magnetic flux is produced by a coil with an iron core than produced with the same current by a coil without an iron core, it is possible to produce equal torque in the iron core relay with less current than in the ironless relay. This relay is not immune to heavy direct currents in the track windings. It is adapted for long track circuits on steam roads.

Frequency Type

Centrifugal, single-element, split-phase, two-position relay.

The contact operating member of the centrifugal frequency relay consists of a small induction motor, exactly similar to that used in the induction motor relay previously described but continuously rotating a ball centrifuge, like the fly ball governor on a steam engine, the rotating member being carried on ball bearings to minimize friction. When the motor is de-energized and there is no rotation the centrifuge balls assume a stationary position close to the axis of rotation, but when the motor is energized and rotation begins the balls are forced outward from the axis by centrifugal action and advantage is taken of this movement to close the relay contacts. The speed developed depends on the frequency of the power delivered to the induction motor and is indicated by the following formula:

$$\text{Speed of motor (revolutions per second)} = \frac{\text{2 times frequency}}{\text{Number of poles in motor}}$$

The centrifugal frequency relay (illustrated in Figs. 30, 31 and 32) is therefore a rotor type relay provided with a ball governor for operating the contacts. This relay is designed to be used on electric railways using alternating current propulsion and its chief feature is that its front contacts must be closed only by the signaling current and not by the railway propulsion current, if by any unbalancing of the track circuit enough propulsion current should enter the relay to operate it. Up to the present time electric roads using alternating

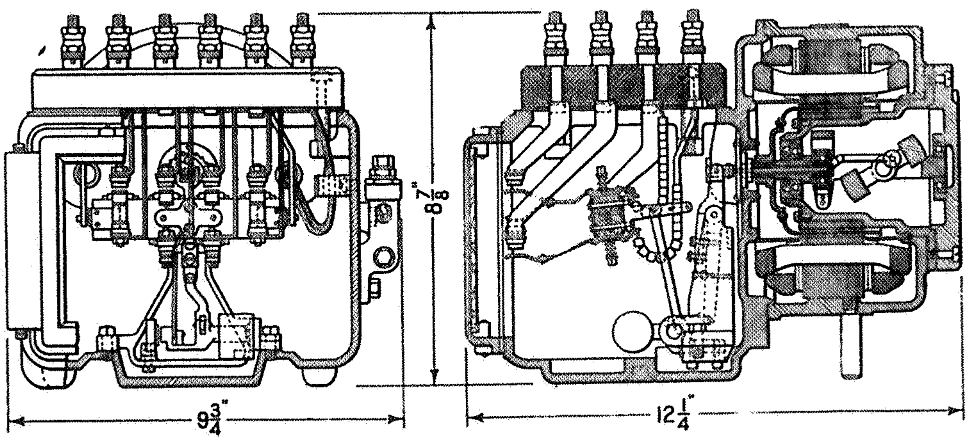
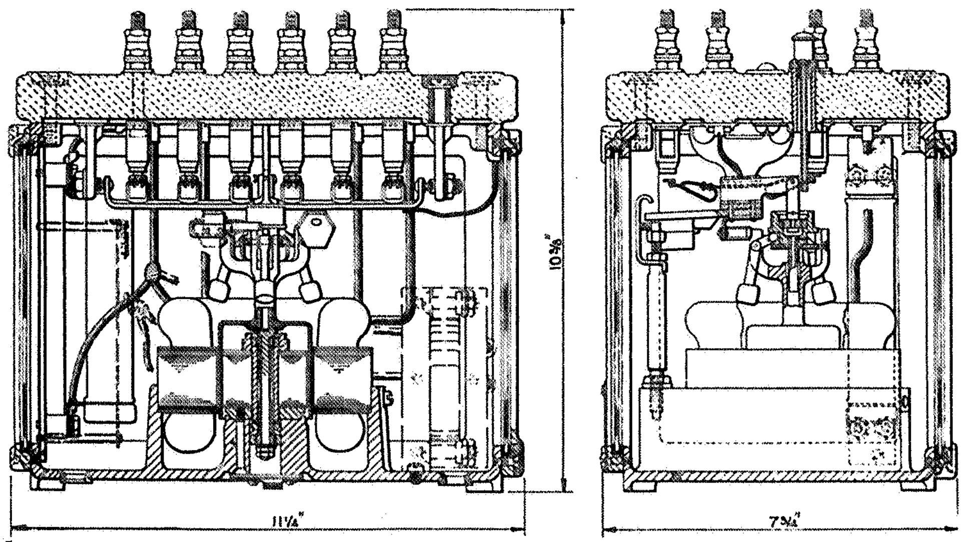
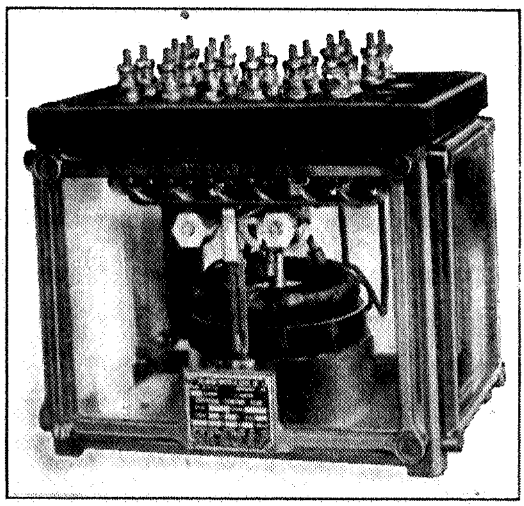


Fig. 30.
Centrifugal Frequency Type, Single-Element, Two-Position Relay.

current propulsion employ 25-cycle current for propulsion and the frequency relays are designed to operate selectively on 60 cycles or a higher frequency, this latter frequency being used for energizing the track circuits for signal purposes. The speed of the rotor with the 60-cycle signal frequency is more than double that which could be attained by the propulsion current. As the rotor accelerates to its 60-cycle speed, the ball governors are so designed that they close the front contacts of the relay just before the 60-cycle speed limit is reached. The rotor will only accelerate to the 60-cycle speed, when the windings are energized by the signaling frequency track circuit current; 25-cycle propulsion current flowing through the relay will not develop sufficient speed to raise the ball governor far enough to close the contacts. When the track circuit is shunted and the relay is de-energized, the induction motor stops and the ball governor collapses by gravity, opening the front contacts.





Figs. 31 and 32.
Centrifugal Frequency Relay, Single-Element and Two-Element, Two-Position.

One type of centrifugal frequency relay has the ball governor inside the motor and revolves about a horizontal axis. As the motor is accelerating the centrifuge produces a horizontal thrust along the shaft of the rotor that closes the contact just before the rotor reaches its highest speed.

This relay has two sets of windings as in the rotor relay, but is operated by one circuit. The phase difference is produced by adjustments between the windings. As a single-element relay the rotor will not run backward.

Centrifugal, two-element and single-element, split-phase, two-position relay.

This type of relay has its ball governor outside the rotor and revolves about a vertical axis, the rotor and stator being in a horizontal position in the relay case. As the rotor accelerates, the centrifuge pulls down a collar on the axis to close the front contacts of the relay when the speed nears its 60-cycle limit.

This relay has two windings so that it can be operated either as a single-element or as a two-element relay, as desired. When used as a single-element relay it is connected and operated like the previous relay. It is, however, almost always used as a two-element relay in which the "local" element is generally energized considerably in excess of what would be required for rotation, the excess local flux inducing heavy currents in the rotor to exert a braking action when a train enters on the track circuit to de-energize the track element. This braking or snubbing action results in very quick opening of the contacts.

The centrifugal frequency relay is immune to direct current and no alternating current of less than 5 cycles higher than the propulsion frequency will close the front contacts of the relay.

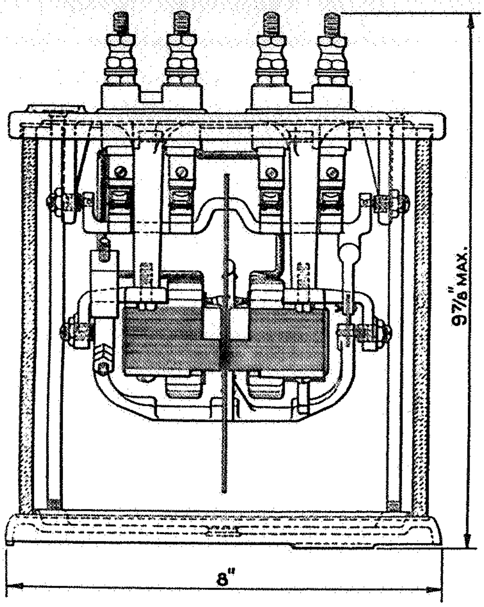
While 60 cycles has been mentioned as the signaling frequency in the foregoing description, the relay may be operated on any signaling frequency greater than 50 cycles. One hundred cycles is used quite commonly in cab signal territory.

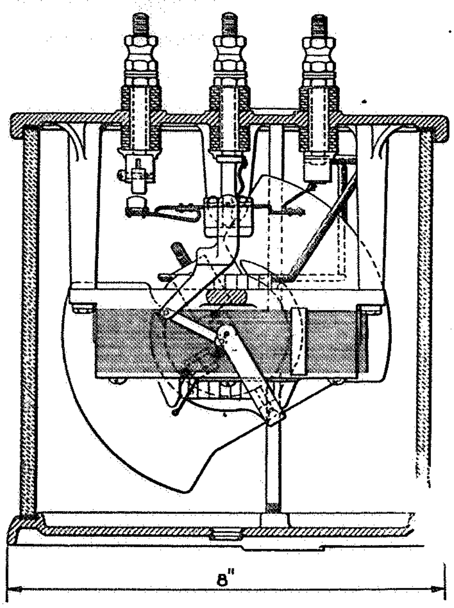
A ratchet is provided to prevent the rotor from running in the reverse direction. By this means, broken-down insulated joints may be guarded against by staggered track polarities.

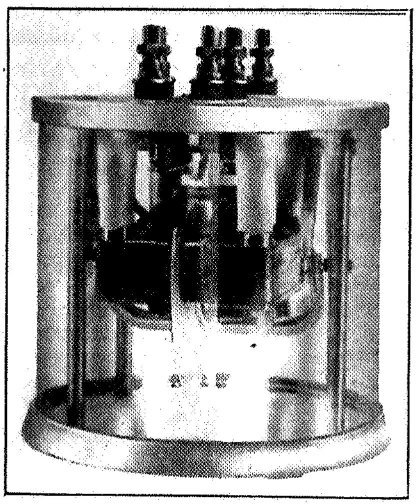
Vane frequency, single-element, two-position relay.

This relay, illustrated in Figs. 33 and 34, like the centrifugal frequency relay above described, is used as a track relay on electric roads using alternating current for propulsion, generally of 25-cycle frequency, and where in addition to the propulsion current a 60 or 100-cycle track circuit current flows through the rails for signaling purposes. The vane frequency relay is designed to selectively operate on the signaling current and to be immune to the 25-cycle propulsion current. Whereas, however, the centrifugal relay can be wound either as a single or two-element relay and is hence adapted for use on short or long track circuits as desired, the vane frequency relay is a single-element instrument and is therefore used only on track circuits of comparatively short length.

Its operating element is illustrated in Fig. 35, from which it will be noted that the horizontal H-shaped laminated iron core "I" forms two separate paths for two independent magnetic circuits, the crossbar of the "H," carrying the two energizing coils "T" wired in series, being common to both magnetic







Figs. 33 and 34.
Vane Frequency, Single-Element, Two-Position Relay.

circuits. As the illustration shows, the legs of the core are formed so as to enclose a vertical air gap at either end of the "H" and in these air gaps a vertical butterfly-shaped aluminum vane "V" is suspended; this vane is pivoted on jeweled bearings whose axis "PP" passes through the center leg or crossbar of the H-shaped core and the vane is cut out at the center so as to clear the center leg or crossbar, so that the vane really consists of two separate wings mechanically connected together, each swinging in its own separate air gap at each end of the core.

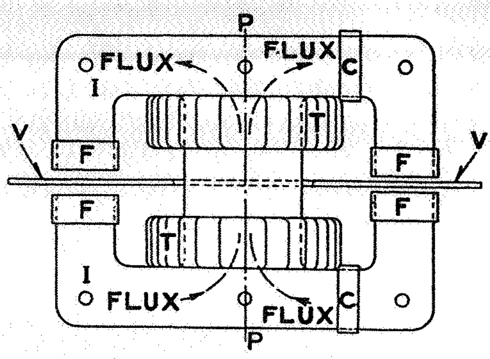


Fig. 35.
Operating Element, Vane Frequency Relay.

The ends of the core legs at the air gap are each provided with copper ferrules "FF" (just as in the case of the single-element vane relay described at the beginning of this Chapter), but the main part of the core legs at the right-hand half of the core are provided with an extra pair of copper ferrules "CC." The air gap at the right-hand half of the core is, however, less than the air gap at the left-hand end of the core. The result is, that when the winding "TT" is energized, the vane is subjected to two opposing forces, *i.e.*, both the right and left-hand wings of the vane are lifted upward. However, since the air gap at the left-hand end of the core is greater than the air gap at the right-hand end, the upward lift on the left wing of the vane would be less than the lift on the right-hand wing of the vane, were it not for the fact that the ferrules "CC" on the right-hand legs of the core exert a choking action, which reduces the amount of magnetic flux flowing through the right-hand magnetic circuit, this in turn reducing the upward pull on the right-hand wing of the vane. The air gap at the left end of the core and the ferrules "CC" on the right half of the core are so proportioned that when 25-cycle propulsion current flows in the coils "TT," the upward pulls on the opposite wings of the vanes will just be equal and, of course, opposite, so that the resultant torque exerted on the vane is zero. The vane is counterweighted, however, to rest on a back stop, keeping the front contacts open. Now, when signaling current flows through the coils "TT," the above balance is destroyed, for, whereas the reluctance of the left-hand air gap remains unchanged, the choking effect of the ferrules "CC" is greatly increased, so that the greater part of the flux flows through the left-hand half of the core, when, of course, the upward pull on the left wing of the vane is greater than the pull on the right-hand wing, so that the vane is pulled upward on the left-hand end to close the relay contacts. Thus, the torque effects in the two ends of the vane on the 25-cycle propulsion current are always balanced, the balance being destroyed on 60 or 100 cycles, so that the relay therefore acts selectively on the signaling current to close its contacts.

The vane frequency relay is therefore immune to direct current and also to alternating propulsion current.

Tractive Type

Tractive armature, single-element, two-position relay.

The first tractive armature relays were, in general, of very much the same construction as ordinary direct current relays, except that in order to adapt the tractive armature relay for operation on alternating current, the horseshoe-shaped iron core and armature were both laminated and the pole pieces of the horseshoe core were fitted with copper ferrules or shading bands, so as to secure a more or less constant magnetic flux to draw the armature up and keep it in that position; as described in connection with the single-element vane relay at the beginning of this Chapter, the shading bands or ferrules on the pole faces of the horseshoe core caused the armature to be acted on by two separate magnetic fluxes, one of which, resulting from the currents induced in the copper shading bands, lags the main flux flowing through that part of the pole face not surrounded by the copper shading band. Thus, when the main flux flowing in the unshaded portion of the pole piece is approaching the minimum, the supplementary flux flowing in the shaded portion of the pole piece is at the maximum, with the result that there is always flux available to lift the armature and keep it in its closed position as long as the energizing coils on the horseshoe core are sufficiently energized. Relays of this type are illustrated in Figs. 36 and 37.

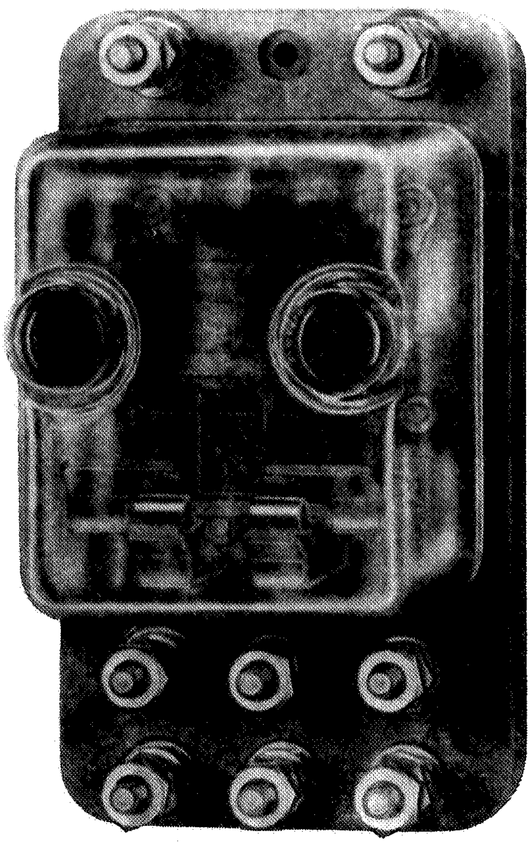


Fig. 36.
Tractive Armature Single-Element, Two-Position Relay.

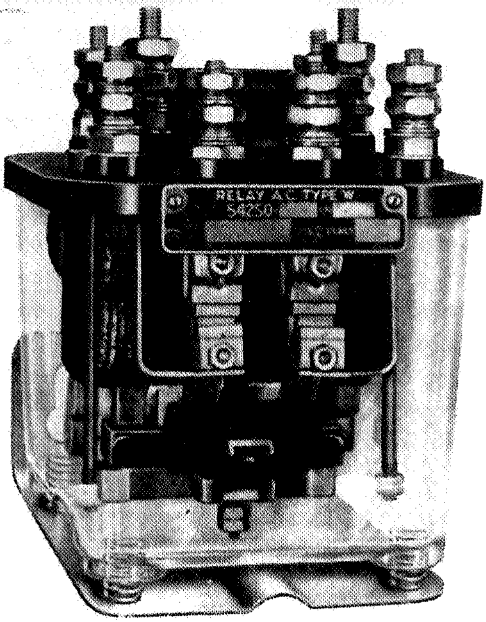


Fig. 37.
Tractive Armature Single-Element, Two-Position Relay.

A current example of this type of construction is the alternating current relay similar to the direct current relays used in centralized traffic control, as shown by Fig. 38. It uses the conventional solid U-shaped backstrap and solid armature but a laminated center core which carries the copper ferrule and winding. The relay may be used for light out service or as a line relay in non-vital circuits. It may be enclosed in a case and furnished with a terminal board, or it may be of the plug-in type.

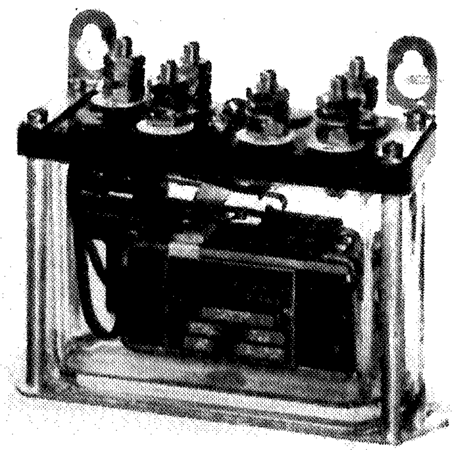


Fig. 38.
Tractive Armature A.C.-D.C. Relay.

Other small size relays having both the field and armature laminated are used for power-off or line relays. None of these relays is immune to direct current. They are not usually considered to be suitable for use in vital circuits.

The conventional type of direct current relay equipped with a rectifier for alternating current operation has been used in vital circuits. Two such relays have characteristics which make them particularly adaptable to alternating current circuits. A standard two or four-point relay having a low resistance winding and with a half-wave rectifier shunted across the coils provides a very satisfactory light out relay. Due to its low impedance on alternating current, the relay will pick up on the small current of the minor filament of a lamp having major and minor filaments and not require too much transformer voltage for normal operation. The second one has a half-wave rectifier across each of the two coils. These rectifiers are connected in opposing directions so that one half-wave goes through one coil while the other half-wave goes through the other coil. The relay is used for power transfer service and has a relatively high release with respect to the normal alternating current voltage applied to it.

Rotating iron armature, single-element, two-position relay.

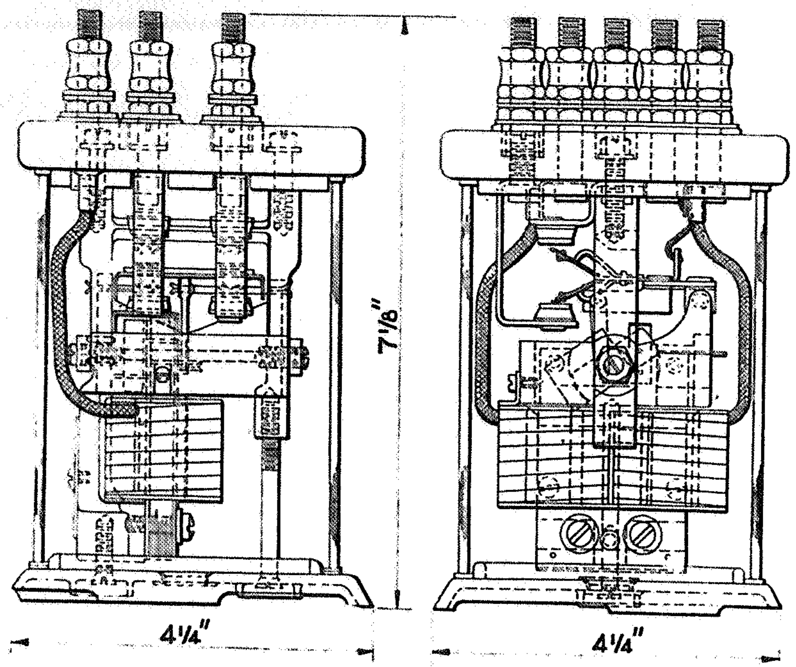
An example of the rotating iron armature type is illustrated in Figs. 39 and 40. The armature consists of a bar built up of laminations which rotates about a centrally positioned shaft in an air gap between two pole faces. The axis of the shaft is at right angles to the plane of the field and armature. The field is a U-shaped laminated structure with the outer ends facing each other machined to form symmetrical pole faces lying in a cylindrical surface. The contact bracket is actuated by a crank and link connection with the armature.

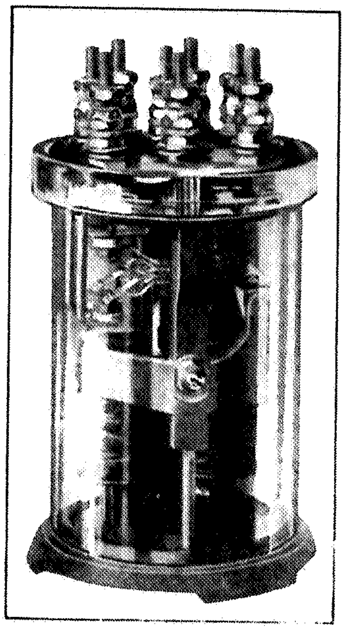
In the de-energized position a stop holds the armature so that an edge of each end is just within the pole face area. When energy is applied the flux passes from one pole face, across the air gaps, through the armature, and into the other pole face. Since the greater part of the armature ends is outside of the pole face area, considerable reluctance is introduced by the large air gap. The flux in tending to reduce the reluctance of the magnetic circuit applies a torque to the armature causing it to rotate into the air gap. This closes the front contacts. Since the armature is symmetrical about the shaft, it is necessary to provide a weight to return the armature to the de-energized position. Due to the mechanical inertia of the armature, no shading bands are required to maintain a steady force to hold the front contacts closed.

The armature may take other form, such as the Z-armature as used in alternating current switch valve magnets. This type of structure gives greater angular motion of the armature. These relays are single-element and may be used as line, light out or series relays. They will operate just as readily on direct current.

Transformer relay.

The transformer relay is a combination of a lighting transformer and a tractive armature type power transfer relay. In its latest form the transformer is





Figs. 39 and 40.
Rotating Iron Armature, Single-Element, Two-Position Relay.

of the shell type with a closed magnetic circuit. The relay core is an E-shaped structure built up of transformer laminations. The relay coil is around the middle leg, and a ferrule is placed around a portion of this middle leg pole face. The transformer coil is extended to surround the relay coil. The relay core structure is separated magnetically from the transformer core structure. The relay armature is a laminated bar with a core pin in each end to rest against the pole faces of the outer legs when energized. The armature is fastened to a hinged bracket which also carries the movable contacts.

The transformer primary is wound for the required primary voltage and frequency. The secondary is a normal lighting secondary with an adjusting winding for obtaining fine adjustments. Additional secondary taps are provided for energizing the relay coil. A tapped relay winding with an external link connection provides for operation on 60 or 100 cycles. Bringing the relay coil leads to the terminal board also allows for an external control circuit. The terminal board carries the terminals for the relay contacts as well as the transformer windings and a name plate showing the voltages which might be expected.

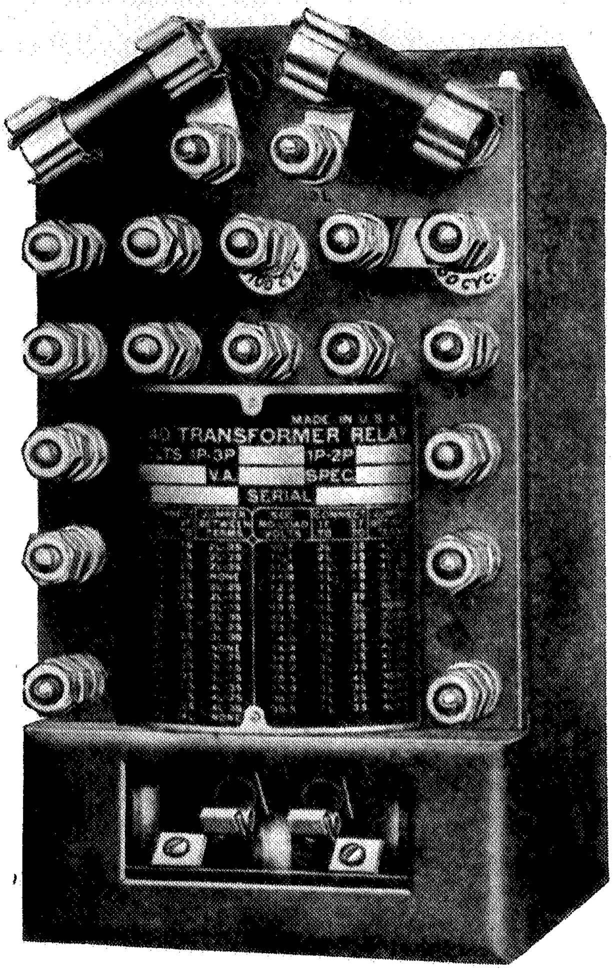


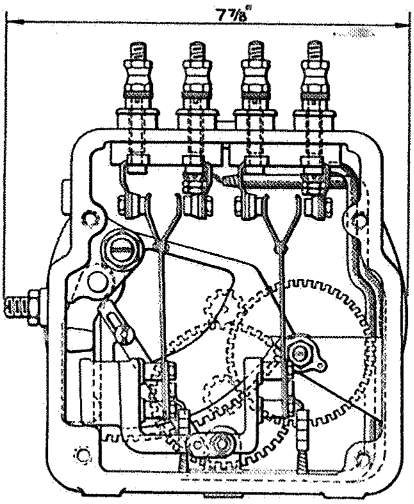
Fig. 41.
Tractive Transformer, Single-Element, Two-Position Relay.

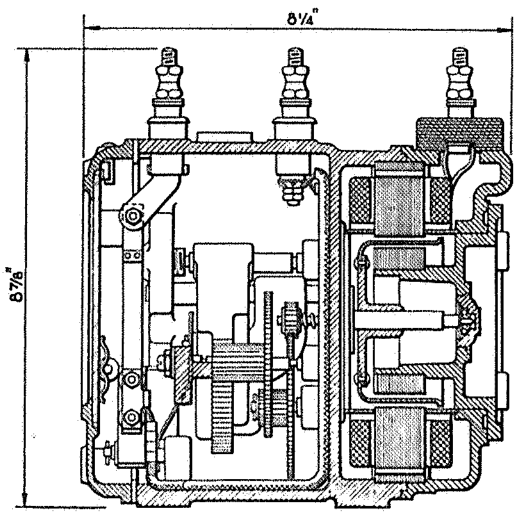
The transformer relay shown in Fig. 41 is designed specifically for alternating current lighting with direct current stand-by and with self-contained transfer. The secondary fuses are so connected as to release the relay if they blow. The failure of the primary voltage will also cause the relay to release. One of the major features of the transformer relay is the saving in space over separate transformer and relay.

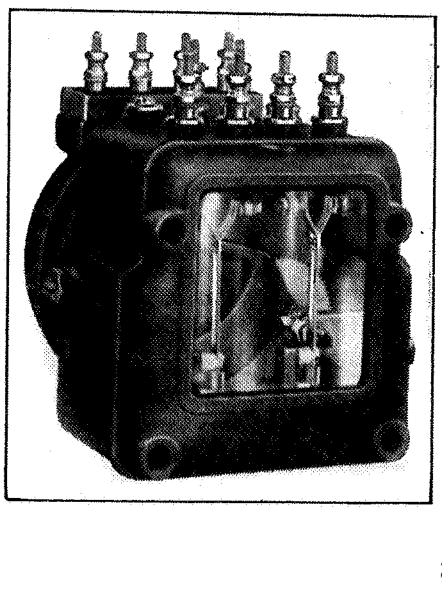
Time element, single-element and double-element, two-position relay.

Time element relays are provided with contacting mechanisms to close or open contacts a predetermined time after the relay has been energized or de-energized, as the case may be. The time element desired can be selected by a proper adjustment of the mechanism, generally through the use of a graduated scale and pointer, adjustable from the exterior. The outside means of adjustment is sealed.

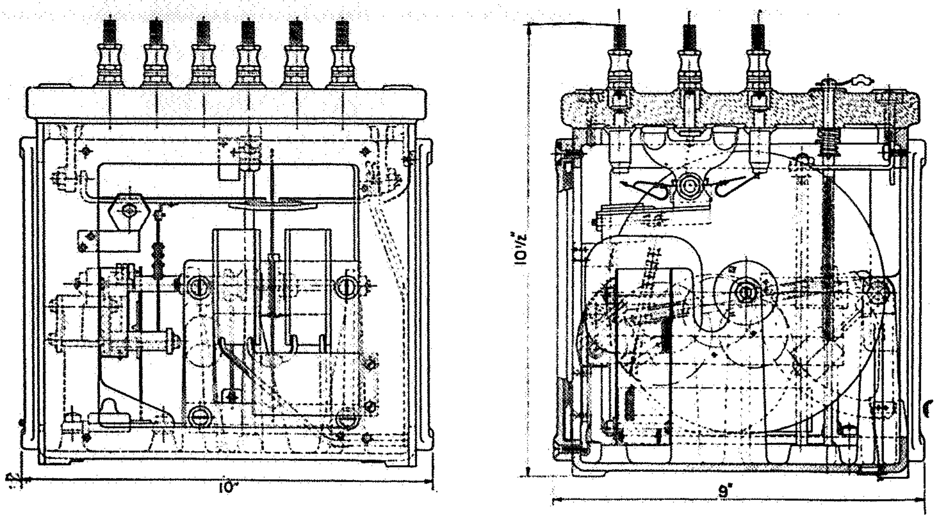
The relay illustrated in Figs. 42 and 43 is an inductive, non-magnetic rotor relay, in which the usual pinion and sector has been replaced by a gear train, to produce the desired time element by retardation. This relay uses one circuit when designed to close its front contacts in a predetermined time after the relay is energized and open its front contacts immediately after the relay is de-energized. This relay uses two circuits when designed to close its front

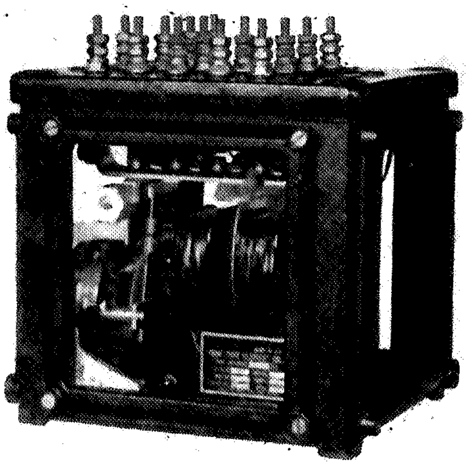






Figs. 42 and 43.
Time Element, Single-Element and Double-Element, Two-Position Relay.





Figs. 44 and 45.
Time Element Disc Relay.

contacts immediately after the relay is energized and open its front contacts in a predetermined time after the relay is de-energized. Properly placed counterweights restore the relay to its de-energized position. The relay is adjustable between zero and 120 seconds.

Time element disc relay.

This relay, illustrated in Figs. 44 and 45, is simply a single-element vane relay in which the vane is a continuous disc, driving the usual pinion and segmental gear. When the relay is properly energized, the vane at once rotates until the segmental gear is driven against a stop, thereby extending a long spiral spring connected to the time element device, through a gear train and pawl and ratchet arrangement. The tension of this spring serves to drive a retarding vane at a uniform rate, thus providing a time element independent of applied voltage; the rotating retarding vane is, in reality, a complete disc rotating in the air gap between the poles of a powerful permanent magnet, the currents induced in the disc, when rotating, causing the desired retarding action. These magnets are provided with temperature compensating shunts to make the relay practically independent of temperature. No movement of the relay contacts occurs until nearing the completion of the time element. When the relay is de-energized, the gear segment falls by gravity, due to a counterweight, carrying with it the contacts and all connected parts. The pawl and ratchet device mentioned above allows the relay to release without rotating the train of gears so that the front contacts of the instrument are opened and the back contacts are closed immediately after the relay is de-energized. A contact is closed when the segmental gear strikes its back stop to check that the relay will give its full time interval on its next operation.

Time elements (time to pick up and close the front contacts) of from 3 to 15, 5 to 25, or 10 to 45 seconds may be secured, as desired. Some relays are provided with an adjustable magnetic shunt by use of which the time range may be reduced approximately one-half. These adjustments are made without opening the case. The release time to close the back contacts is practically instantaneous.

INSTRUCTIONS

Alternating current relays should be maintained, tested and inspected in accordance with Signal Section, A.A.R. instructions, as follows:

Shop Tests and Inspections

Meters.

1. Meters must be in calibration.

Repairing.

2. Test and inspect relay for defects, giving special attention to those noted on repair tag, Form 7018. (See Fig. 66.)

Coils.

3. Coils must be secured in place to prevent their being damaged due to vibration.

Flexible connections.

4. Flexible connection from binding post to contact finger must be formed and attached so as not to affect the operating characteristics of the relay.

Contacts.

5. Inspect and clean contacts, replacing any which are defective.
6. Finger contacts must meet fixed contact surfaces squarely and practically simultaneously.
7. All parts of the contact fingers (other than contact point), including its flexible connections and the post to which it is attached, must be separated by at least 0.1 inch from any other metal or conducting part of the relay.

8. Metal support of the non-fusible contact element must not come within $\frac{1}{32}$ inch of the contact surface.

9. On two-position relays the opening between finger contact and back contact surface, with front contact just closed, must be not less than 0.020 inch for contacts of the first and second voltage ranges.

10. Contacts must be so adjusted that in their open position there will be not less than 0.031 inch space between the fixed post and the contacting point for the first and second voltage ranges, and not less than 0.060 inch for the third voltage range.

11. On three-position relays with normal or reverse contacts just closed, contacts which are closed with relay de-energized must be open not less than 0.015 inch.

12. The contact resistance must not exceed the following values, per contact:

(a) For front, normal or reverse contacts, when relay is energized at working current or voltage:

1. Metal to metal, 0.03 ohm.
2. Metal to carbon, 0.18 ohm.
3. Metal to metal impregnated carbon, 0.09 ohm.
4. Carbon to carbon, 0.40 ohm.
5. Metal impregnated carbon to metal impregnated carbon, 0.20 ohm.

(b) For back or de-energized contacts, when relay is de-energized:

1. Metal to metal, 0.06 ohm.
2. Metal to carbon, 0.36 ohm.
3. Metal to metal impregnated carbon, 0.18 ohm.
4. Carbon to carbon, 0.80 ohm.
5. Metal impregnated carbon to metal impregnated carbon, 0.4 ohm.

End play.

13. End play of the moving element supported by bearings must be not less than 0.010 inch nor more than 0.020 inch.

Clearance.

14. In the assembled relay, under the most unfavorable conditions of play and relative position of parts, all moving parts except bearings and contacts, must be separated by not less than the following minimum clearances:

(a) Radial 0.020 inch.

(b) Longitudinal 0.017 inch.

General.

15. Inspect and clean shaft and pivot bearings replacing any which are worn or defective.

16. Determine by actual operation that relay has a positive drop-away and contacts open without retardation of movement due to friction or external force.

17. Defective gaskets must be replaced.

18. Insulation test must be made between windings and between binding posts and relay frames. The insulation resistance must be not less than 1 megohm. If high potential tests are made, the voltage employed should be 80 per cent of the value specified for a new relay.

19. Inspect all nuts to determine that they are tight and then bend lock washers, where used, into place.

20. Before case is closed, relay and case must be cleaned to remove any foreign matter, then checked to see that all parts are in proper position and in good condition.

21. Make test specified in Instruction 26 and record values on Form 7051. (See Fig. 67.)

22. Relay operating characteristics must be in accordance with shop requirements of Table I corresponding to the type and specification number of relay under test.

23. Values obtained in accordance with Instruction 26, together with serial number, type, frequency in cycles, method of test, date and inspector's initials must be marked on a tag fastened inside the relay case where it can be read and in such a manner that it will not obscure or obstruct moving parts. Form 7053 to be used for this purpose. (See Fig. 69.)

24. Contacts of relay must be tested for contact resistance after case is closed and before relay is sealed.

25. Determine by observing operation of relay that at least 1/8 inch clearance exists between case and moving parts.

Operating characteristics.

26. Pick-up, working, and drop-away values of relays must be determined as follows:

(a) Pick-up.

1. Apply a reduced current and gradually increase same until the front contacts just close. This value is the pick-up. For a three-position relay this test must be made in both normal and reverse positions.

(b) Working.

1. After pick-up, continue gradually increasing the current until the moving element strikes its normal or front stop, or gives the contacts a compression of 0.031 inch. This is the normal working value. With three-position relay, this test must be made in both normal and reverse positions.

(c) Drop-away.

1. After determining normal working value, gradually reduce the current to the value at which contacts open. This is the drop-away.

(d) Method of varying current.

1. In making the test for pick-up, working and drop-away values, the variation in energy must be made very slowly in order to secure accurate results.

(e) Phase displacement.

1. With two-element relay, tests enumerated in Instructions 26-a to d, inclusive, must be made with sufficient phase displacement

between the currents in the two windings to insure satisfactory relay operation on a reasonable amount of current in the controlled element. The phase relations obtained by the different test methods will frequently vary considerably from ideal values. The necessary increase, because of phase relations, over calibrated operating values is taken account of in the percentages given in Table I for the particular test method recommended.

Recording.

27. Relays must be identified by serial number, which must be recorded. Manufacturer's serial number must be used if available; otherwise, a number must be assigned by proper authority.

Sealing.

28. Relay case must be sealed.

Final test.

29. Final pick-up, working and drop-away value 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.

30. Each relay must be put in a separate carton or suitably wrapped before being placed in packing box. Not more than two relays should be placed in one box.

Field Tests and Inspections

Meters.

31. Meters must be checked frequently and calibrated when necessary.

General.

32. Tests required by Instruction 26 must be made as instructed, and it must be known that no unsafe conditions are set up by the application of testing equipment.

33. Relay operating characteristics must be in accordance with field requirements of Table I corresponding to the type and specification number of relay under test.

34. Determine by actual operation that relay has positive drop-away and contacts open, without retardation of movement due to friction or external force.

35. Inspect all screws, nuts and binding posts to determine that they are tight.

36. Determine by observation that sufficient contact opening exists.

37. Determine by observing operation of relay that sufficient clearance exists between case and moving parts.

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

TABLE I—OPERATING CHARACTERISTICS OF ALTERNATING CURRENT RELAYS

Type.. Specification No...

	Shop Requirements			Field Requirements		
	Single-element	Two-element		Single-element	Two-element	
		Two-position	Three-position		Two-position	Three-position
Pick-up (normal direction)	Not more than ....% of original marking	Not more than ....% of original marking	Not more than ....% of original marking	Not more than ....% of original marking	Not more than ....% of original marking	Not more than ....% of original marking
Pick-up (reverse direction)			Not more than ....% of original marking			Not more than ....% of original marking
Working current or voltage (normal direction)	Not more than ....% of original marking	Not more than ....% of original marking	Not more than ....% of original marking	Not more than ....% of original marking	Not more than ..% of original marking	Not more than ....% of original marking
Working current or voltage (reverse direction)			Not more than ....% of original marking			Not more than ....% of original marking
Drop-away (normal direction)	Not less than ....% of pick-up	Not less than ....% of pick-up	Not less than ....% of pick-up	Not less than ....% of pick-up	Not less than ....% of pick-up	Not less than ....% of pick-up
Drop-away (reverse direction)			Not less than ....% of pick-up			Not less than ....% of pick-up
Testing diagrams recommended						

Contact opening Instruction 8.. 9.. 10..
For ideal phase relations in two-element track relays:
Track volts should lag local volts .... degrees or lead .... degrees.
Track amperes should lag local volts .... degrees or lead .... degrees.
Data as to contact openings, recommended test figure number, percentages, and phase angles required to fill in blanks on this Table should be obtained from the manufacturer to cover the types and specification numbers of relays used.

39. Relays not meeting field requirements must be removed from service as promptly as possible and defects noted on repair tag, Form 7018. (See Fig. 66.)

40. Relays must meet shop requirements specified in Table I, when placed in service, except in emergency when relay meeting field requirements may be used.

Emergency repairs.

41. Repairs and adjustments to insure positive operation of relay, for temporary use in emergency, may be made in the field by authorized person and should be followed as promptly as practicable by removing from service, and conditions noted on repair tag, Form 7018. (See Fig. 66.)

Recording.

42. Inspector must record field readings on Form 7052, which, when complete, must be forwarded as instructed. (See Fig. 68.)

43. Field readings should be transferred from Form 7052 (Fig. 68) to Form 7051 (Fig. 67) as instructed. One Form 7051 to be used for each relay.

Method of Testing (Shop and Field)

Shop testing of single-element track relays.

44. Connect relay as shown in Fig. 46 or 47, open circuit, then close circuit with all resistance in series with relay. Make tests for pick-up, working and drop-away values as outlined in Instructions 26-a to e, inclusive.

Field testing of single-element track relays.

45. Connect relay as shown in Fig. 48 or 49 and proceed as outlined in Instruction 44.

Shop testing of single-element line relays.

46. Connect relay as shown in Fig. 50 or 51, open circuit, then close circuit gradually reducing resistance in the relay circuit. Make test for pick-up, working and drop-away values as outlined in Instructions 26-a to e, inclusive.

Field testing of single-element line relays.

47. Connect relay as shown in Fig. 52 or 53 and proceed as outlined in Instruction 46.

Shop and field testing of two-element track relays.

48. The following outlines the various methods of testing two-element relays dependent upon the type of phase shifting device used. Manufacturer's recommendation (as furnished for Table I) must be consulted as to the method of testing.

(a) In reactive testing transformer method, adjust leakage block to give zero air gap before energy is applied to the primary of the testing transformer. Connect relay as shown in Fig. 54 or 55, then gradually increase the leakage block air gap, making test for pick-up, working and drop-away values as outlined in Instructions 26-a to e, inclusive. This method gives the effect of an adjustable reactor in series with the relay track element, the reactance being varied by adjustment of the transformer leakage block.

(b) In adjustable resistor method, connect relay as shown in Fig. 56, 57, 58 or 59, open circuit, then close with all resistance in series with relay track element. Make tests for pick-up, working and drop-away values as outlined in Instructions 26-a to e, inclusive.

(c) In using Fig. 56 or 57, the transformer secondary voltage must be not less than ten times the test working voltage. Where practicable, testing per Fig. 57 is to be preferred to Fig. 56.

(d) In using Fig. 58 or 59, the voltage for the track element circuit must be not less than 55 or 110 volts, depending on the line (or local) voltage of the relay.

Shop and field testing of two-element line relays.

49. Connect relay as shown in Fig. 60 or 61, open circuit, then close circuit, gradually increasing voltage on relay control circuit. Make tests for pick-up, working and drop-away values as outlined in Instructions 26-a to e, inclusive.

Phase relation measurements and corrections.

50. It is advisable to determine the phase displacement so that the operating values obtained for the relay can be corrected to the ideal phase relation. This will permit checking the manufacturer's test values given on the relay.

51. To determine exactly the phase relations existing under a given test condition, find the angle between the relay track element voltage or current and the line (or local) voltage, by one of the methods described in Instructions 52 and 53. By comparing this angle with the ideal angle given in Table I, the angular difference from the ideal position is determined. Reference to Fig. 62 will give the factor by which the calibrated values must be multiplied to obtain the operating values which apply for the test phase relations.

Method of measuring phase angles.

52. Phasemeter method:

(a) Connected as shown in Fig. 63. The reading obtained is the angle between the line (or local) voltage and the track voltage.

(b) Connected as shown in Fig. 64. The reading obtained is the angle between the line (or local) voltage and the track current.

53. Watt-meter method.

(a) Connected as shown in Fig. 65. Divide the watt-meter reading by the product of the relay track current and line voltage. Result will be the cosine of the angle between line voltage and track current, which angle can be found by reference to a trigometric table of cosines.

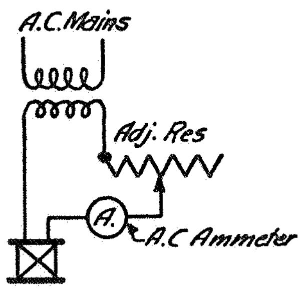


Fig. 46.

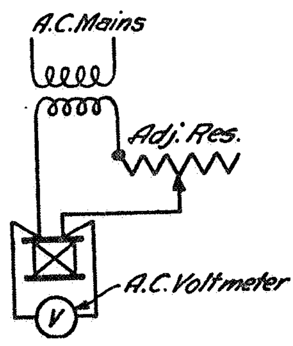


Fig. 47.

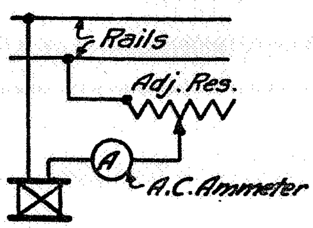


Fig. 48.

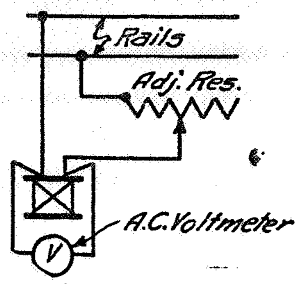


Fig. 49.

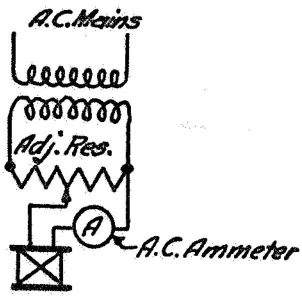


Fig. 50.

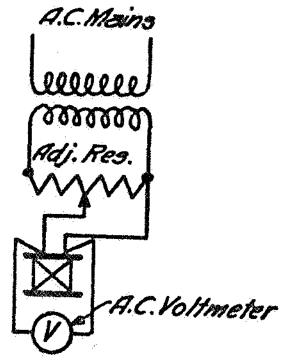


Fig. 51.

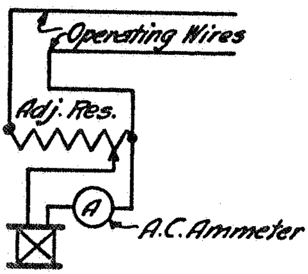


Fig. 52.

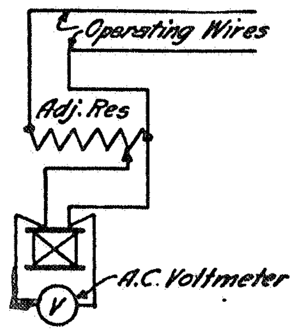


Fig. 53.

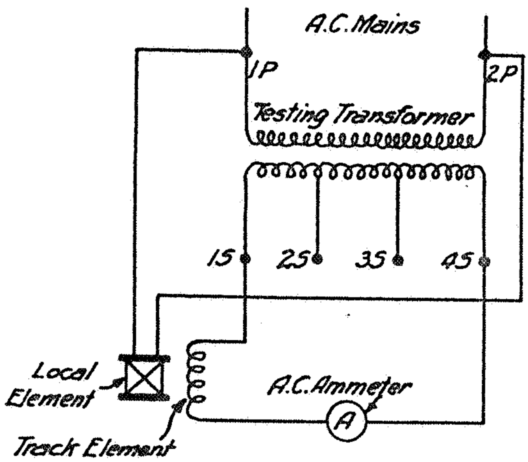


Fig. 54.

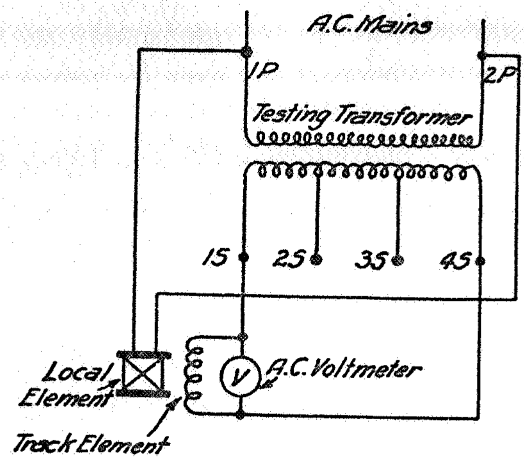


Fig. 55.

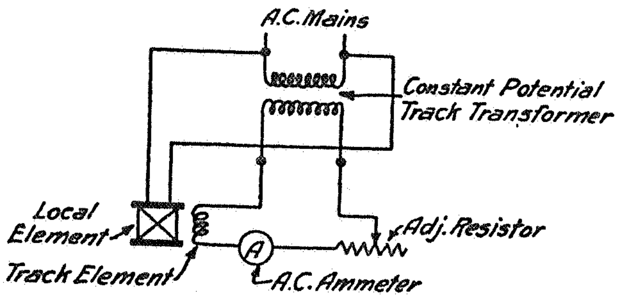


Fig. 56.

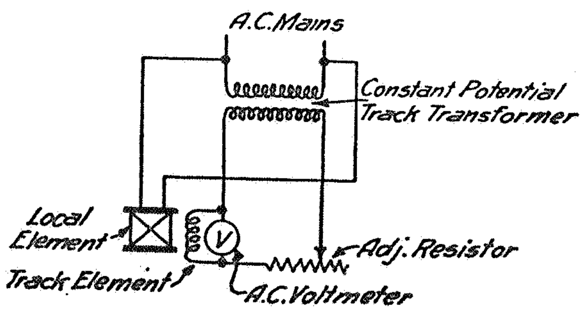


Fig. 57.

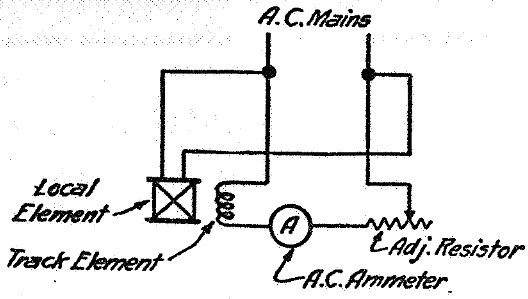


Fig. 58.

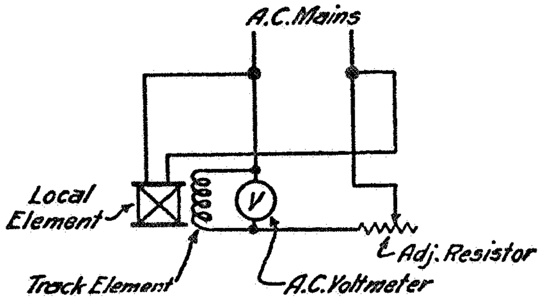


Fig. 59.

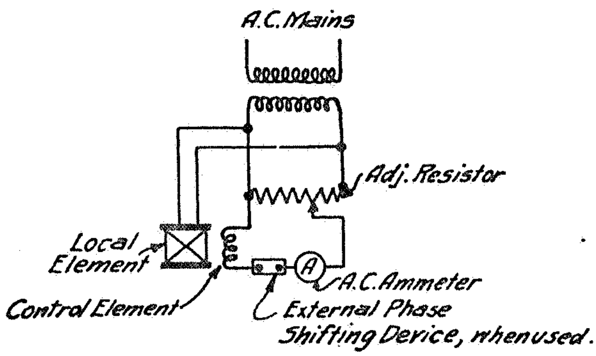


Fig. 60.

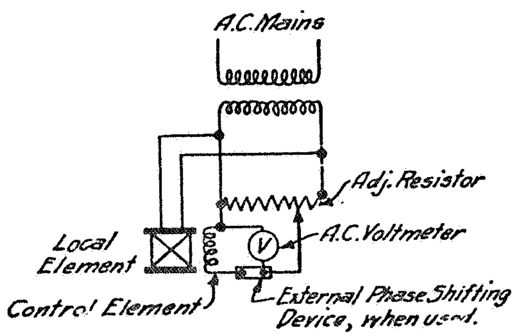
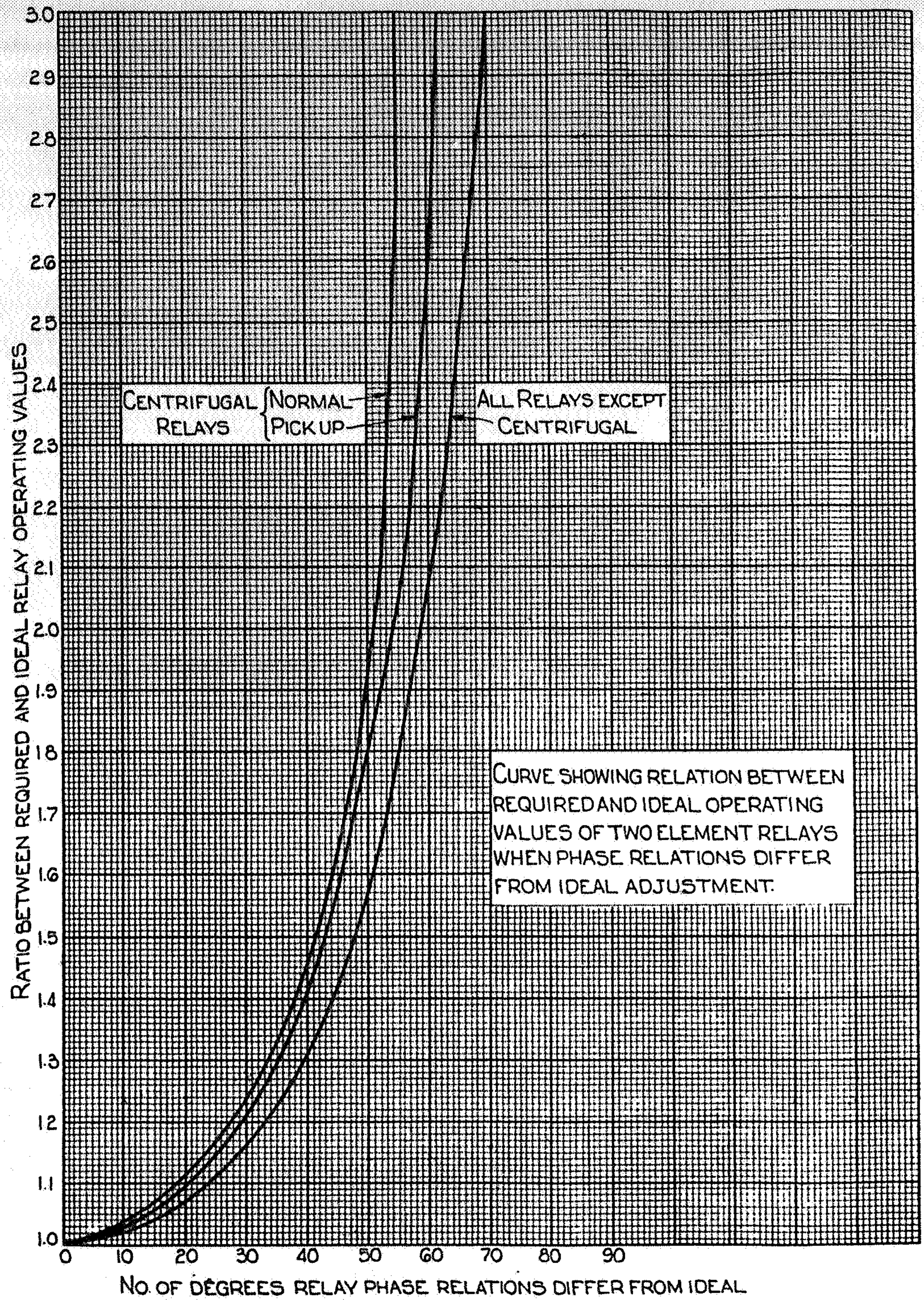


Fig. 61.



3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
RATIO BETWEEN REQUIRED AND IDEAL RELAY OPERATING VALUES
CENTRIFUGAL RELAYS
NORMAL
PICK UP
ALL RELAYS EXCEPT CENTRIFUGAL
CURVE SHOWING RELATION BETWEEN REQUIRED AND IDEAL OPERATING VALUES OF TWO ELEMENT RELAYS WHEN PHASE RELATIONS DIFFER FROM IDEAL ADJUSTMENT.
0
10
20
30
40
50
60
70
80
90
NO. OF DEGREES RELAY PHASE RELATIONS DIFFER FROM IDEAL

Fig. 62.

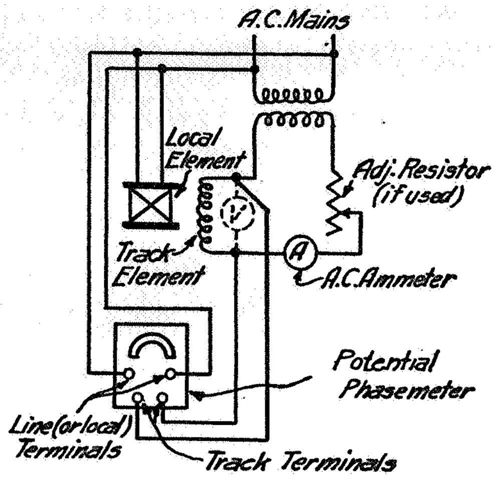


Fig. 63.

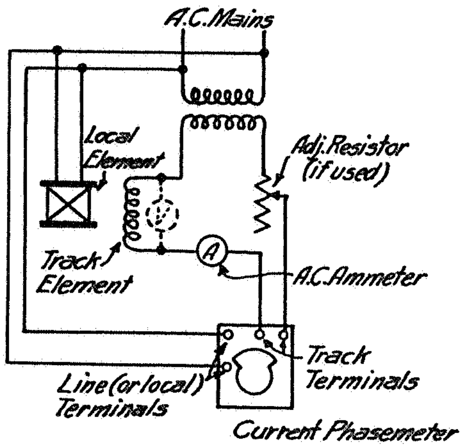


Fig. 64.

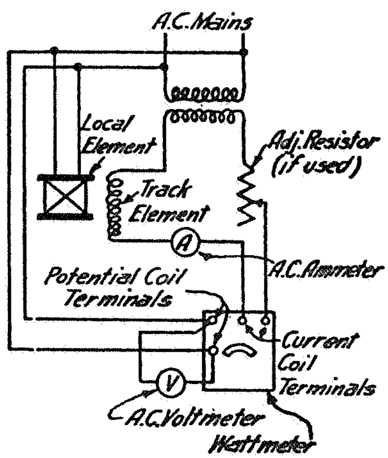


Fig. 65.

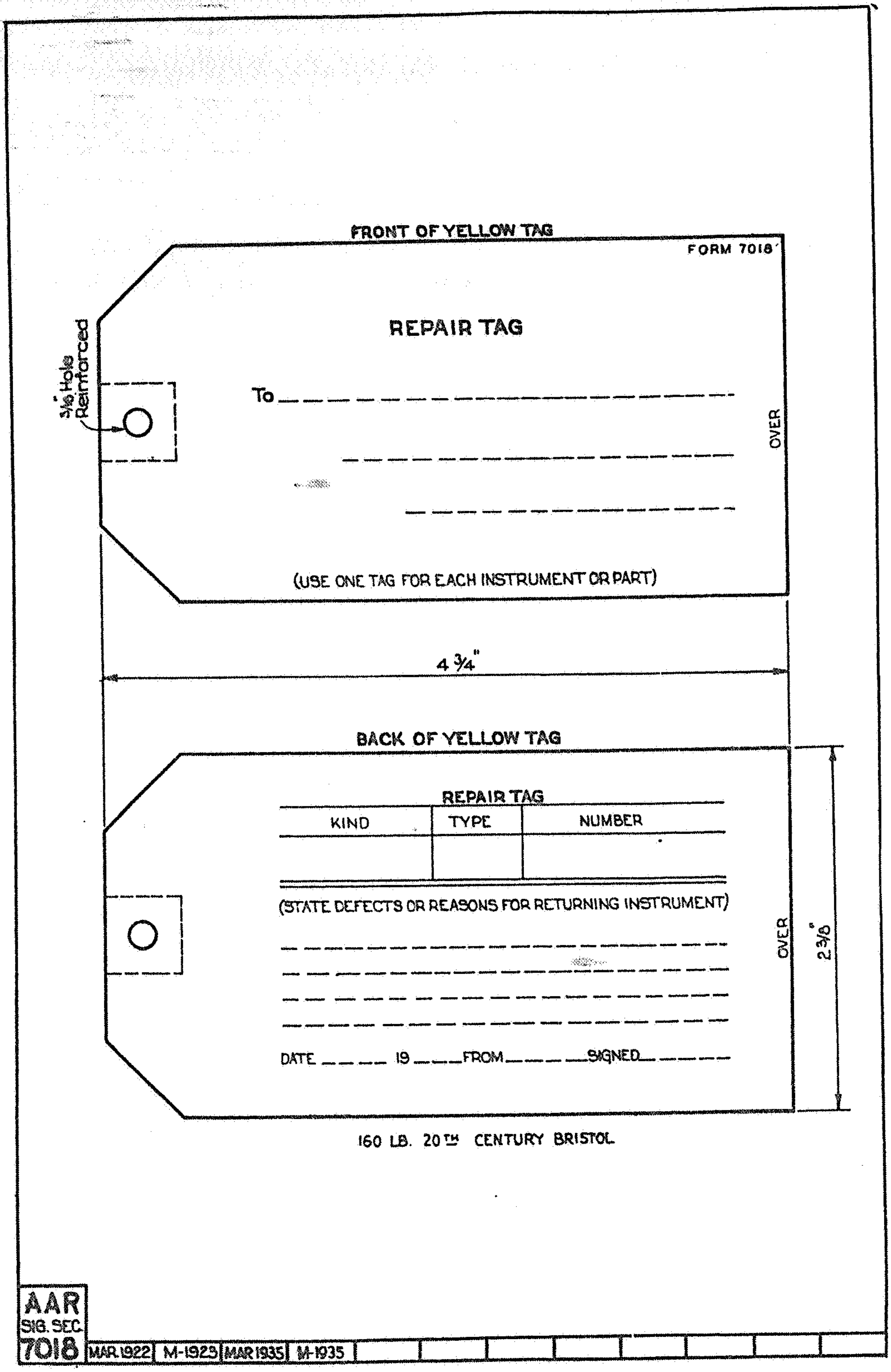

FRONT OF YELLOW TAG
FORM 7018
REPAIR TAG
To
OVER
3/16" Hole Reinforced
(USE ONE TAG FOR EACH INSTRUMENT OR PART)
4 3/4"
BACK OF YELLOW TAG
REPAIR TAG
KIND
TYPE
NUMBER
(STATE DEFECTS OR REASONS FOR RETURNING INSTRUMENT)
DATE 19 FROM SIGNED
OVER
2 3/8"
160 LB. 20TH CENTURY BRISTOL
AAR
SIG. SEC.
7018
MAR 1922
M-1923
MAR 1935
M-1935

Fig. 66.

A A R SIG. SEC. 7051

MAR. 1923 | M-1923 | MAR. 1935 | M-1935 | OCT. 1940 | M-1940

8"

5"

FORM 7051

OFFICE RECORD OF TEST OF A.C. ELECTRICAL APPARATUS

SERIAL NO ________ SPEC NO ______

APPARATUS________, TYPE_____, _____ ELEMENT, _____ POSITION

NO OF CONTACTS { 3 POSITION-NORMAL _____ REVERSE _____ DE-ENERGIZED _____
2 POSITION-FRONT _____ BACK ______

LOCATION	DATE
________________	19 _____
________________	19 _____
________________	19 _____
________________	19 _____

CIRCUIT	PICK-UP				WORKING				DROP-AWAY				SERVICE			DATE AND INSPECTOR	REMARKS
	NORMAL		REVERSE		NORMAL		REVERSE		NORMAL		REVERSE		CONTROL		LOCAL		
	VOLTS	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS		
ORIGINAL VALUES																	

72 LB WHITE SULPHITE INDEX

Fig. 67.

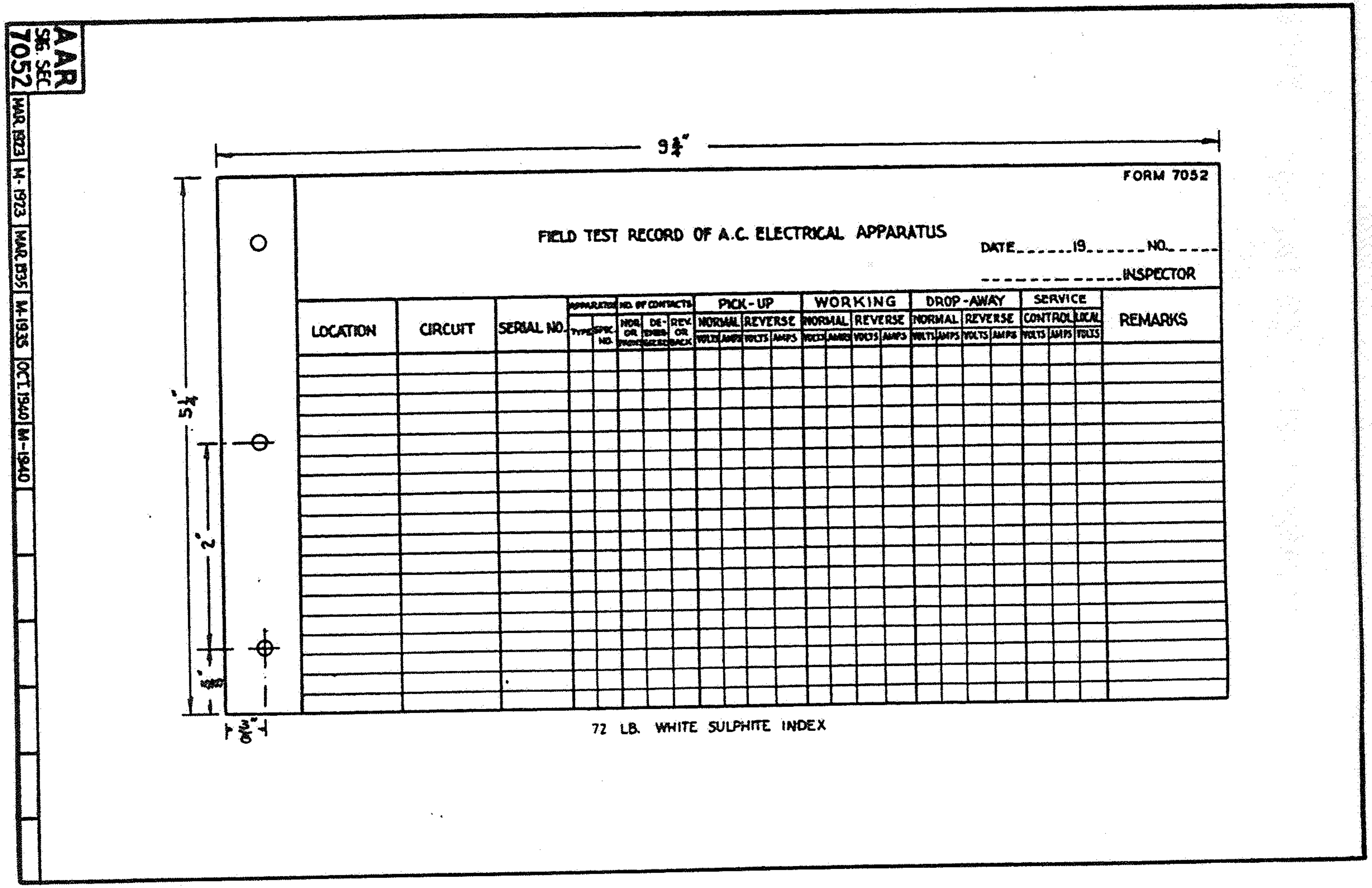

AAR
SIG. SEC.
7052
MAR. 1923
M-1923
MAR. 1935
M-1935
OCT. 1940
M-1940
9 3/4"
5 1/4"
2"
FORM 7052
FIELD TEST RECORD OF A.C. ELECTRICAL APPARATUS
DATE______19______NO.______
____________INSPECTOR
LOCATION
CIRCUIT
SERIAL NO.
APPARATUS
TYPE
SPEC. NO.
NO. OF CONTACTS
NOR. OR REVERSE
DE-ENERGIZED
REV. OR BACK
PICK-UP
WORKING
DROP-AWAY
NORMAL
REVERSE
VOLTS
AMPS
SERVICE
CONTROL
LOCAL
REMARKS
72 LB. WHITE SULPHITE INDEX

Fig. 68.

AAR
SIG. SEC.
7053

MAR.1935 | M-1935 | OCT.1940 | M-1940

A.C. RELAY RECORD TAG

4"

3/16"

1 1/2"

FORM 7053

SERIAL NO.________ SPEC.NO. _________ DWG. NO.__________ POS.__________ CYCLES________

TESTED AS PER FIG.___ OF AAR SIGNAL SECTION INSTRUCTIONS FOR A.C. RELAYS

	PICK-UP		WORKING		DROP-AWAY		DROP-AWAY PICK-UP PER CENT	INSPECTED
	VOLTS	AMPS.	VOLTS	AMPS.	VOLTS	AMPS.		BY: ___________
NORMAL								
REVERSE								DATE_______ 19___

LOCAL ELEMENT SERIES CONNECTED VOLTS_____ AMPS.______ WATTS______

FOR IDEAL PHASE RELATIONS:

TRACK VOLTS SHOULD LAG LOCAL VOLTS____ DEG. OR LEAD____ DEG.

TRACK AMPS. " " " " ____ DEG. " " ____ DEG.

16 LB. WHITE SULPHITE BOND

Fig. 69.