American Railway Signaling Principles and Practices

CHAPTER X

Alternating Current Relays

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CHAPTER X

ALTERNATING CURRENT RELAYS

General

The alternating current relay performs the same function as the direct current relay, *i.e.*, both types are provided with certain 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, 55 or 110 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 railways 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:
- Single-element, two-position.
- Two-element, two-position.

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

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

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

The alternating current relays, known as time element relays, slow-acting 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 of alternating current relays are in accordance with A.R.A. recommended practice and the contacts are generally graphite to silver, graphite to graphite, 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.

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 broken, 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.

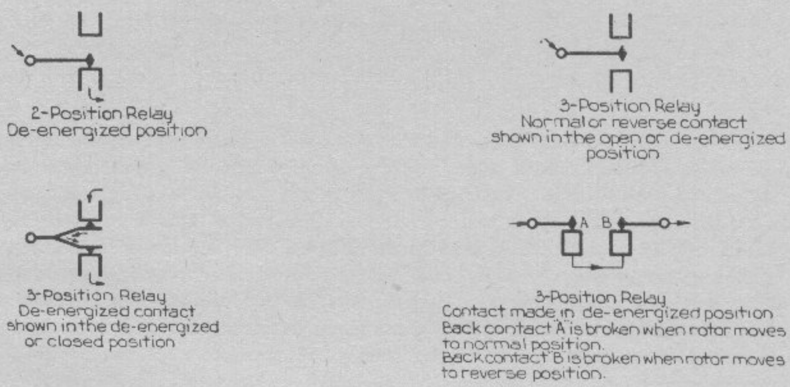

Fig. 1.
Various Types of Alternating Current Relay Contacts.

Alternating current relays are manufactured according to standard sizes for various types. The size is based on the number of ways or contact spaces. The number of ways limits the number of contacts that can be used.

Track relays.

Alternating current track relays are made to suit the physical and electrical conditions of railroads. Some of the operating features to be considered in the application of alternating current relays 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.

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. A coil of wire, for example, conveying an alternating current will, when pivoted or suspended in front of a sheet of metal, experience a couple, tending to turn it into a position at right angles to the conducting sheet.

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.

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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,

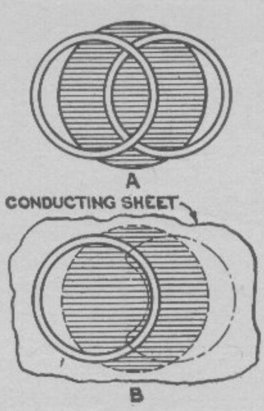


Fig. 2
Illustrating Attraction Principle of Single-Element Vane Type Relay.

by symmetry, it is clear that the currents induced in the conducting sheet by the alternating flux, from the magnet pole 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 diametrically in Fig. 3, the aluminum vane is free to rotate and takes

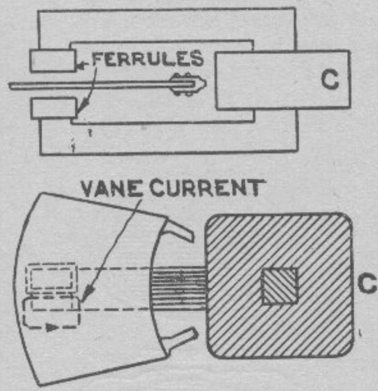


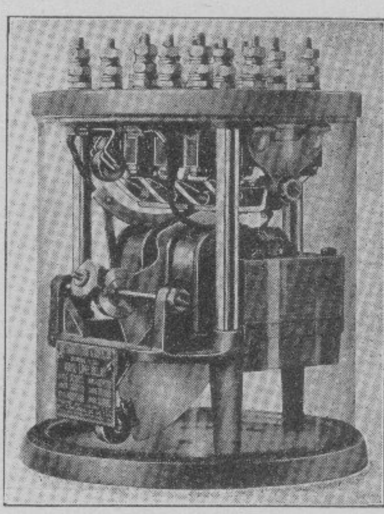
Fig. 3.
Operating Element of Single-Element Vane Type Relay.

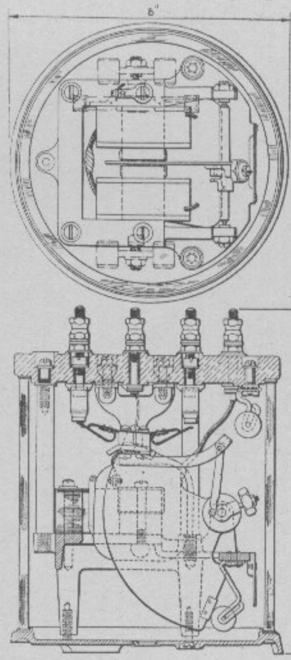
the place of the conducting sheet above mentioned in connection with "B" of Fig. 2. Around one-half of each pole face is placed a shading coil or ferrule consisting of a simple heavy band of copper, which takes the place of the fixed ring in "B" of Fig. 2. Coil "C" in Fig. 3 and its laminated iron field 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.

Sector-shaped, 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.

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



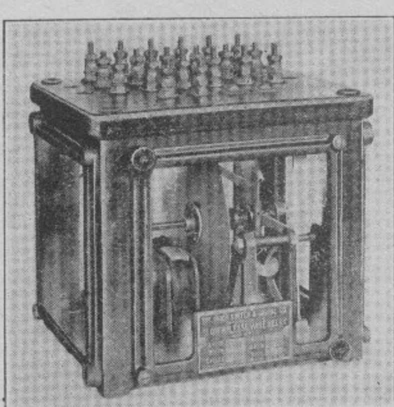


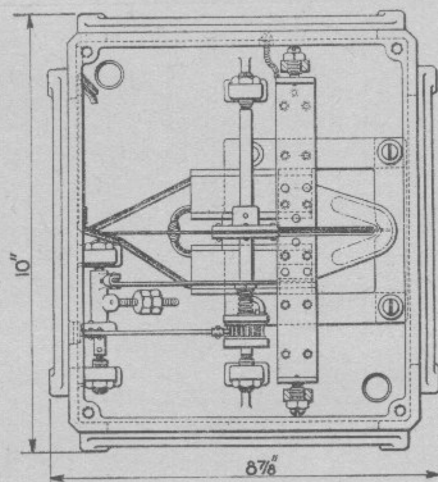
Figs. 4 and 5.
Vane Type, Sector-Shaped, Single-Element, Two-Position Relay.

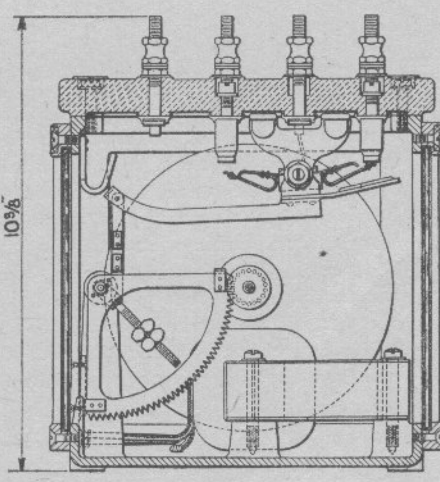
control the amount of direct current flowing through the coils of the relay, a resistance coil connected in series between the feeding transformer and the track, and another resistance coil connected in series between the relay and the track are generally all that is necessary, but in those cases where 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, slow-acting, single-element, two-position relay.

The slow-acting 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 turn, continues to revolve until the relay contacts are made. The direction of rotation is controlled by the proper placing of the copper ferrules in the slot of the laminated core. The disc revolves on a shaft passing through its center. The shaft carries a pinion that moves a counterweighted 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 making of contacts is desired.







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

Flasher relay.

The flasher relay is the foregoing type of relay, Figs. 6 and 7, equipped with a flasher attachment for use at railway highway crossings for controlling flashing light highway crossing signals.

Sector-shaped, two-element, two and three-position relay.

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.

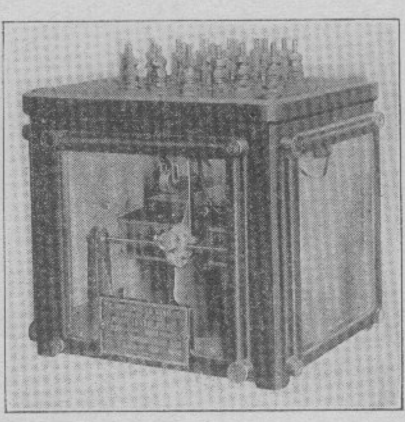


Fig. 8.
Vane Type, Sector-Shaped, Two-Element, Two and Three-Position Relay.

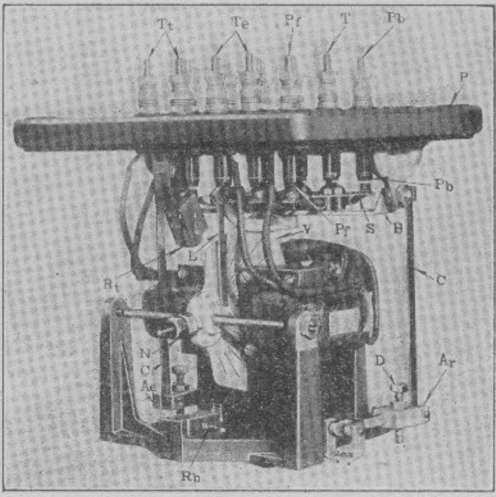


Fig. 9.
Mechanism of a Three-Position, Two-Element, Vane Type Relay.

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 moves the vane. 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.

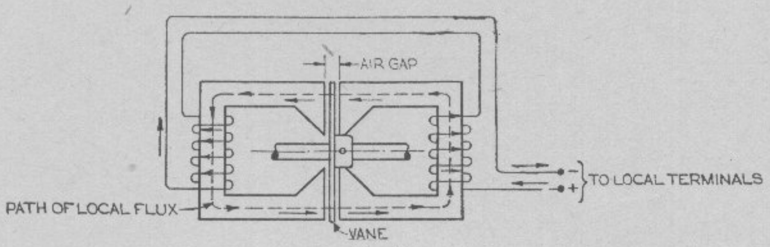


Fig. 10.

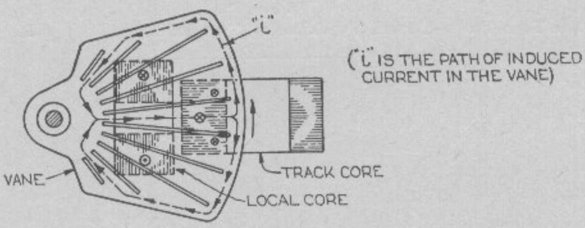


Fig. 11.

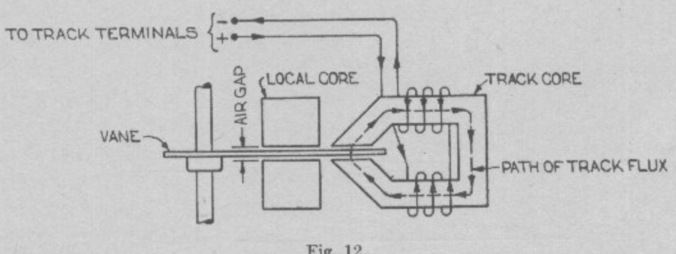


Fig. 12.
Diagrams of Windings, Currents and Fluxes of Vane Type, Sector-Shaped, Two-Element Relay. (Union)

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

(⊙ OR ⊗)

show how the 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.

We also know 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 inducting 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.

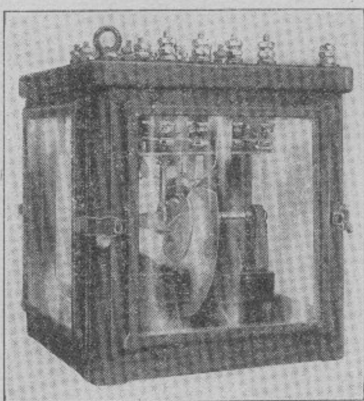
In our discussion so far we have not considered the phase relations of the a.c. currents in the two elements of the relay but it can be readily seen that the phase relations have an important bearing on the operation of the relay. The currents and fluxes in the two elements of the relay are continually 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.

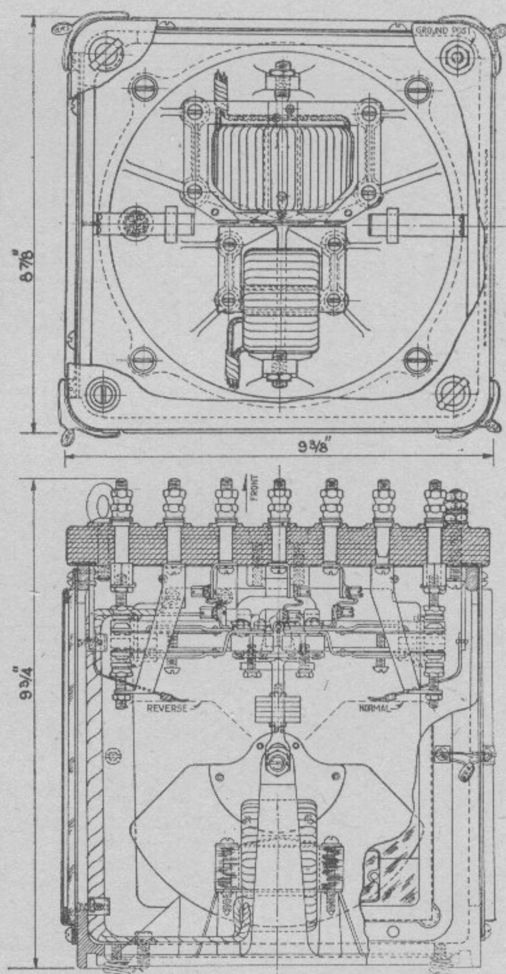
The local flux is in phase with the local current and this flux induces in the vane an electromotive force which lags the flux 90 degrees. This electromotive force causes a current to flow in the vane which is nearly in phase with the electromotive force or 90 degrees out of phase with the local current.

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 above that the vane current is 90 degrees out of phase with the local current.

We thus see 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 reactance or resistance between the transformer and the 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





Figs. 13 and 14.
Vane Type, Sector-Shaped, Two-Element, Three-Position Relay.

track relay on either long or short track circuits and is inoperable by direct current.

The relay, Figs. 13 and 14, operates on the same general principle as the relay illustrated in Fig. 8.

This relay is for long or short track circuits and is inoperable by direct current.

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

Figures 15 to 19, inclusive, illustrate the magnetic structure of another vane type, sector-shaped, two-element relay and illustrate the instantaneous directions of currents and fluxes.

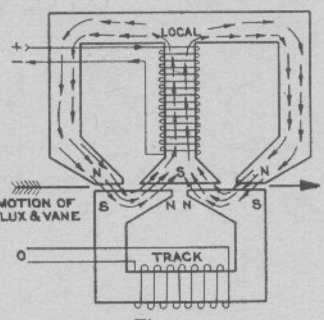


Fig. 15.

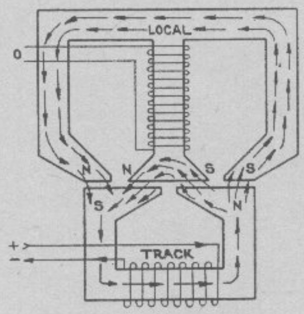


Fig. 16.

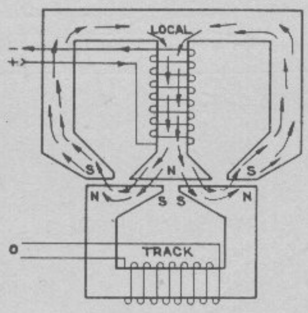


Fig. 17.

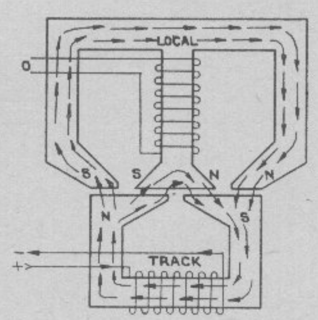


Fig. 18.

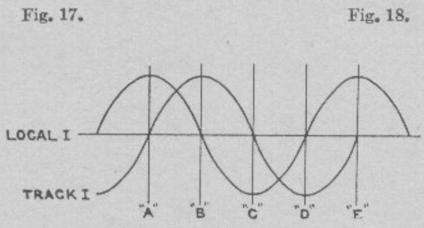


Fig. 19.

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

Figure 19 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. 15, showing direction of currents and fluxes at that instant. At "B" in Fig. 19, the current in the local element is zero, while that in the control is at positive maximum, which condition is duplicated in Fig. 16, illustrating the corresponding direction of currents and fluxes at that instant. At "C" in Fig. 19 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. 17. At "D" in Fig. 19 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. 18.

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.

Rotor Type

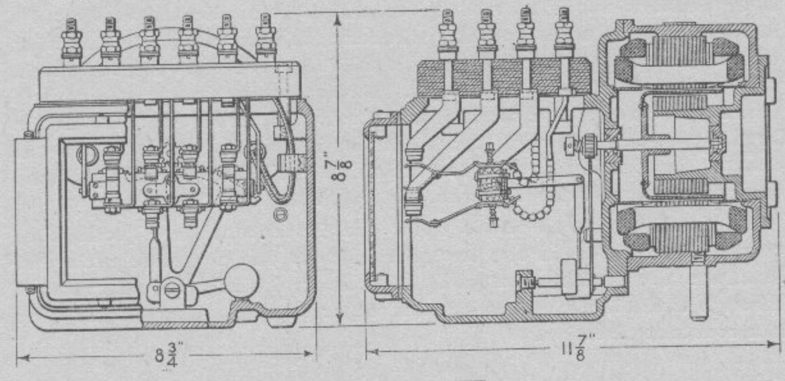
Rotor type induction or polyphase non-magnetic, single-element, two-position, two-element, two and three-position relay.

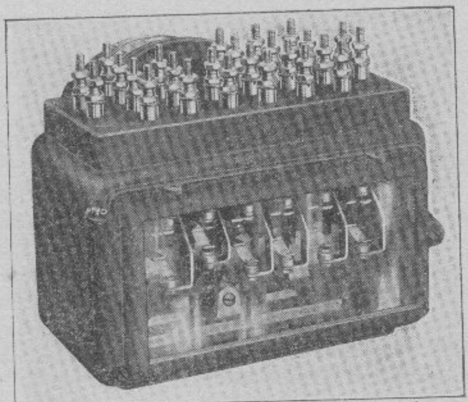
The rotor type relay is a two-phase alternating current induction motor made adaptable for signal relay purposes. The motor-operating mechanism of these relays is enclosed at the rear in a cylindrical case and consists of a stator and a rotor. The stator is a cylindrical, ring-shaped, laminated core, and separated from the inside face of the stator core by an air gap is a second 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 interior cylindrical laminated core and free to turn without touching the core is the rotor, a drum-shaped shell of metal 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.

A permanent magnet placed over the outer rim of a metallic disc, able to revolve, produces small rotary currents in the disc at the magnet, when the magnet is moved. These currents in the disc produce a magnetic field in the disc 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. 20 and 21.
Rotor Type Induction
Non-Magnetic 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 reversed contacts of relay as desired—this, of course, applies to a three-position relay. Where 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 and three-position relay.

This type of relay 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.

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

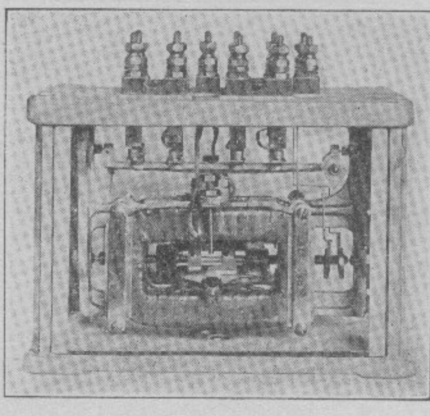


Fig. 22.
Galvanometer Type, Ironless, Two-Element, Two or Three-Position Relay.

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 and three-position relay.

The galvanometer iron core relay 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.

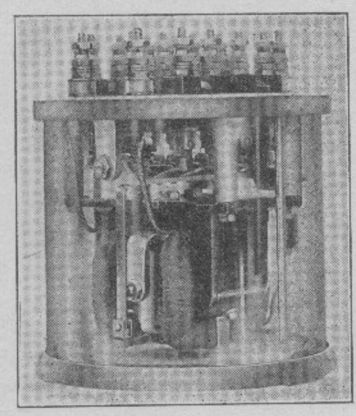


Fig. 23.
Galvanometer Type, Iron Core, Two-Element, Two and Three-Position Relay.

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, 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:

$$\text{Speed of motor (r. p. sec.)} = \frac{\text{2 times frequency}}{\text{Number of poles in motor}}$$

The centrifugal frequency relay 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

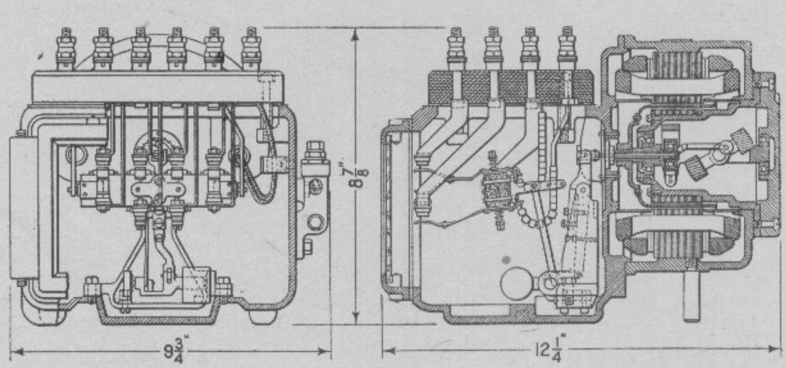
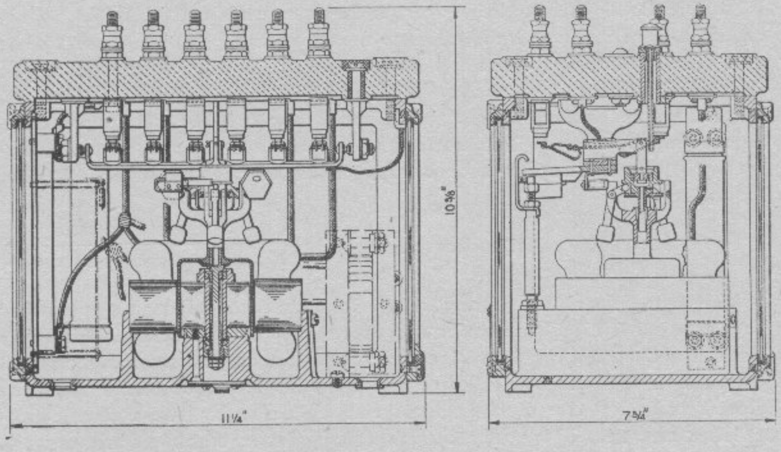
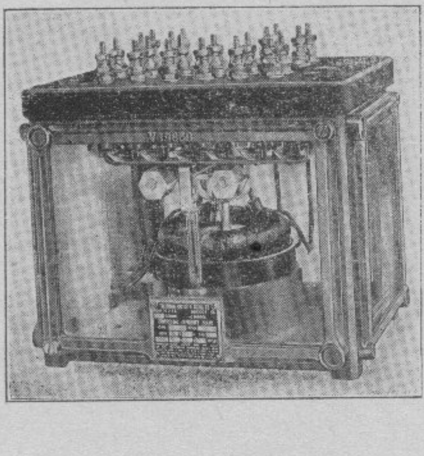


Fig. 24.
Centrifugal Frequency Type, Single-Element, Two-Position Relay.

propulsion current should enter the relay to operate it. Up to the present time electric roads using alternating current propulsion employ 25-cycle current for propulsion and the frequency relays are designed to operate selectively on 60 cycles, 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 60-cycle 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



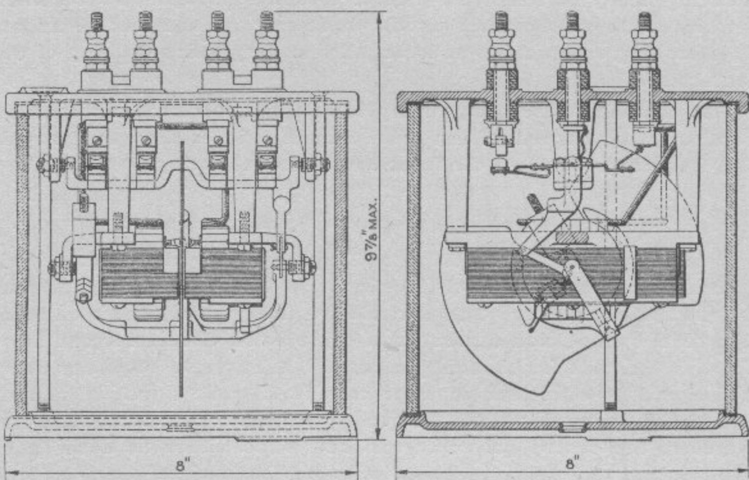


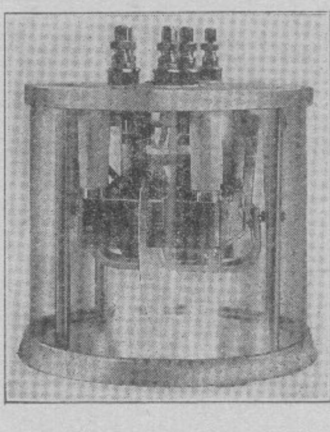
Figs. 25 and 26. Centrifugal Frequency Relay, Single-Element and Two-Element, Two-Position.

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.

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.





Figs. 27 and 28.
Vane Frequency, Single-Element, Two-Position Relay.

Centrifugal, two-element and single-element, 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.

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

This relay, 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-cycle track circuit current flows through the rails for signaling purposes. The vane frequency relay is designed to selectively operate on the 60-cycle 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.

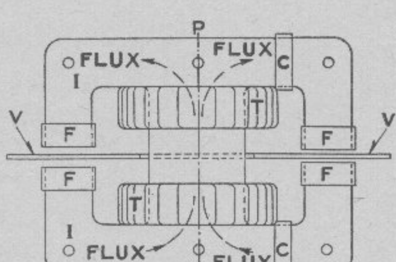


Fig. 29.
Operating Element, Vane Frequency Relay.

Its operating element is illustrated in Fig. 29, 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 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.

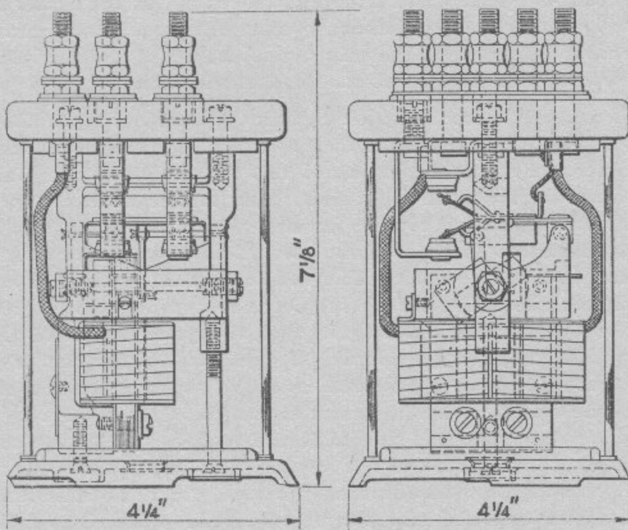
The ends of the core legs at the air gap are each provided with copper ferrules "FF" (just as in the case of the single-element vane relay described at the beginning of this chapter), but the main part of the core legs at the right-hand half of the core are provided with an extra pair of copper ferrules "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 60-cycle 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 cycles, so that the relay therefore acts selectively on the 60-cycle signaling current to close its contacts.

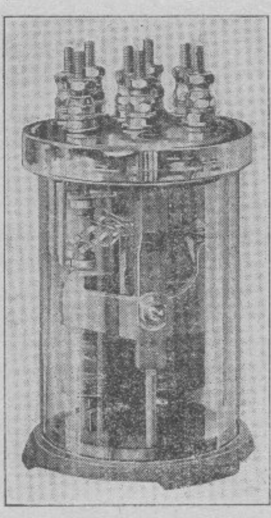
The vane frequency relay is therefore immune to direct current and also to alternating propulsion current.

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





Figs. 30 and 31.
Tractive Armature, Single-Element, Two-Position Relay.

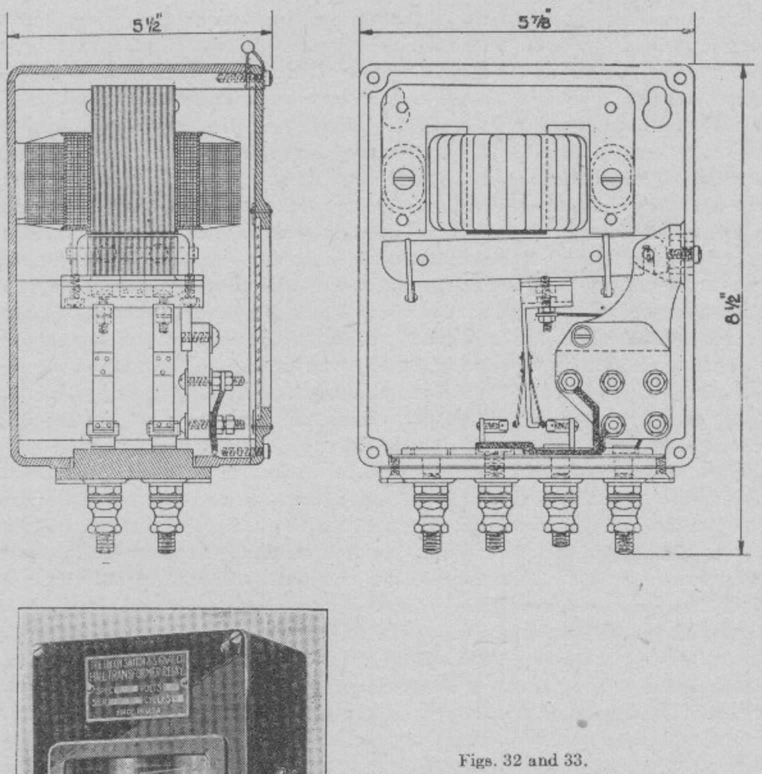
both laminated and the pole pieces of the horseshoe core were fitted with copper ferrules or shading bands, so as to secure a more or less constant magnetic flux to draw the armature up and keep it in that position; as described in connection with the single-element vane relay at the beginning of this 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.

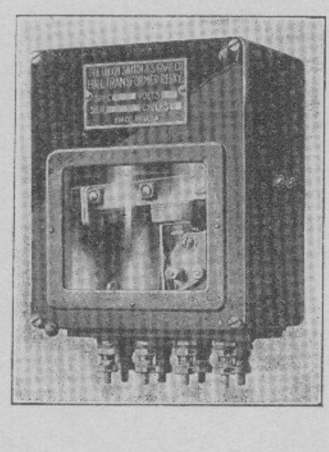
The more modern tractive armature relays, however, are built on what is known as the "Z" armature principle, the moving element consisting of a laminated Z-shaped armature, rotating in a cylindrical air gap between the poles of a horseshoe-shaped magnet, somewhat of the same character as used in an ordinary bi-polar motor. The Z-shaped armature rotates on a shaft passing through the center of the vertical leg of the "Z" and this shaft actuates the contact mechanism through a crank and link. The arrangement of parts is such that when the energizing coils on the legs of the horseshoe-shaped core are on open circuit, the center leg of the "Z" is in approximately a vertical position, the upper and lower wings of the "Z" projecting towards the pole faces of the core and overlapping them slightly; thus, the magnetic flux passes from one of the pole pieces through the air gap to one of the wings of the "Z," down through the center leg of the "Z" then through the lower wing of the "Z" and finally, across the air gap into the other pole piece. However, the magnetic flux lines always tend to shorten themselves wherever possible, *i.e.*, they follow the path of least reluctance and therefore when the winding on the core is energized, the "Z" is turned around to a position where its center leg is in approximately a horizontal position, under which circumstances, of course, the magnetic lines cannot shorten themselves, without increasing the reluctance of their path. With the armature in this position, the front contacts of the relay are, of course, closed and a counterweight is attached to the shaft of the "Z" armature to return it to its vertical position, to make the back contacts of the relay when the energizing coils are open circuited. Due to the mechanical inertia of the "Z" armature, the front contacts of the relay are kept closed without the use of shading bands.

"Z" armature relays, as well as other tractive type relays, have but one winding and are hence single-element relays fitted only for line circuits. They are not immune to direct current and are not intended for track circuit work.

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

This relay has an inverted E-shaped laminated iron core with the legs of the "E" projecting downward. The middle leg of the "E" carries two separate coils, the outer coil being the main energizing winding and acting inductively on the second coil, so that in reality the main energizing coil forms the primary of the transformer and the second coil constitutes the secondary of the transformer. A laminated armature supported at one end is carried beneath the legs of the E-shaped main core and two bronze ferrules





Figs. 32 and 33.
Tractive Transformer, Single-Element, Two-Position Relay.

surround this armature, one under each outer leg of the core, the ferrules serving as air gap spacers and to split the magnetic flux. When the main (or primary) coil of the relay is energized, magnetic flux flows from the center leg of the E-shaped core through the air gap to the armature in either direction, back to the two outside legs of the main core and with proper energization, the armature is picked up to close the front contacts of the relay. The bronze ferrules carried at each end of the armature just below the center line of their respective core legs, act simply as phase splinters, so as to maintain a relatively constant flux flowing through the armature at all times when the relay is energized.

As thus far described, the relay is simply a tractive armature instrument with front and back contacts, but, as previously stated, the center leg of the E-shaped main core carries a secondary coil, in which voltage is induced through the medium of the main energizing primary winding. With this construction, the relay is adapted for use, for example, in connection with light signals, using low-voltage lamp bulbs, which are to be normally lighted from an alternating current power line; in this case, the lamp bulbs are normally fed by alternating current over the front contacts of the transformer relay and from its low-voltage secondary coil, but when the alternating current power source fails, the main winding of the relay is de-energized, the armature drops on its back contacts and this closes a circuit to feed the light signal lamp bulbs from a reserve power source, such, for example, as a set of batteries. In this service, the transformer relay is really a power shifting relay inasmuch as it automatically connects the load to the reserve power source when the main power source fails.

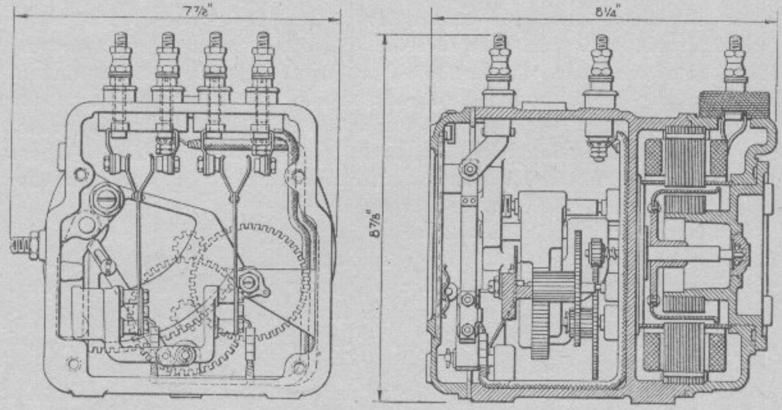
Time Element Type

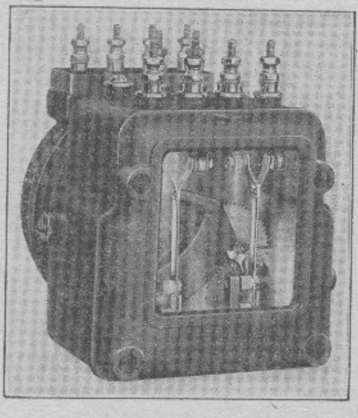
Time element, single-element and double-element, two-position relay.

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 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. 34 and 35 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 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.



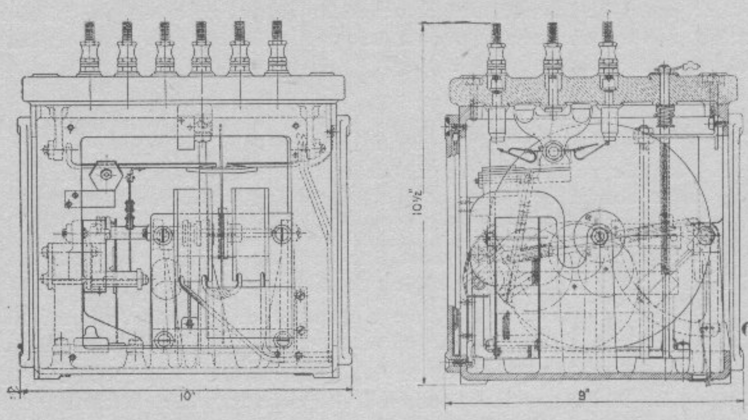


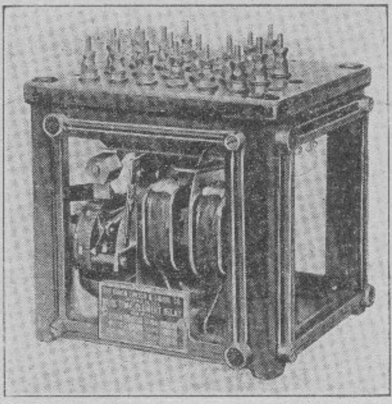
Figs. 34 and 35.
Time Element, Single-Element and Double-Element, Two-Position Relay.

Time element disc relay.

This relay 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, this 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. 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.

Time elements (time to pick up and close front contacts) of from either 3 to 15 or from 5 to 25 seconds may be secured, as desired, or between 1½ and 15 seconds without opening the case of the relay; the release time to close back contacts is practically instantaneous.





Figs. 36 and 37.
Time Element Disc Relay.

Maintenance of Relays

Instructions.

Alternating current relays should be inspected and tested according to the following instructions:

Shop Tests and Inspections

Coils.

1. Coils must be rigidly fastened in place to prevent their being injured by vibration.

Flexible connections.

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

Contacts.

3. Flexible part of finger contacts must be of sufficient resilience to exert a contact pressure of not less than 0.5 ounce when working current or voltage is applied to relay.

4. Finger contacts must meet fixed contact surfaces squarely and simultaneously and make a wiping contact.

5. Finger contacts must have a contact compression of not less than 0.031 inch when working current or voltage is applied to relay.

6. All parts of the contact fingers (other than contact point), including its flexible connections and the post to which the ribbon is attached, must be separated by at least 0.1 inch from any other metal or conducting part of the relay.

7. On two-position relays opening between finger contact and back contact surface, with front contact just closed, must be in accordance with opening specified in the Table of Alternating Current Relay and Indicator Requirements.

8. Contacts on three-position relays, normal and reverse, must be so adjusted that in their de-energized position they shall have at least the opening specified in the Table of Alternating Current Relay and Indicator Requirements between the fixed post and contacting point.

9. The openings of de-energized contacts on three-position relays with normal or reverse contacts just closed must be in accordance with opening specified in Table of Alternating Current Relay and Indicator Requirements.

10. When relay is energized at working current or voltage, the initial cleaned contact resistance must not exceed 0.5 ohm.

End play.

11. The end play of the moving element supported by bearings must be not less than 0.010 inch and not more than 0.015 inch.

Clearance.

12. 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.

Gaskets.

13. Defective gaskets must be replaced.

Meters.

14. Ammeters and voltmeters for testing relays must be in accordance with A.R.A. Signal Section Specifications 11221 and 11521.

15. Meters for shop use must be calibrated monthly.

Repairing.

16. Test and inspect relay for defects, giving special attention to those noted on repair tag A.R.A. Signal Section Form 14.

17. Make repairs and adjustments.

18. Make and record test, A.R.A. Signal Section Forms 12, 13 and 16.

Testing.

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

(a) Pick-up.

Apply a reduced current and gradually increase until the front or energized contacts just close. This value is the pick-up. For a three-position relay, this test should be made in both normal and reversed directions.

(b) Working current or voltage.

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 value is the working current or voltage. With three-position relay, this should be made in both normal and reversed directions.

(c) Drop-away.

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

(d) Method of varying current.

In making the test for pick-up, working current or voltage and drop-away, the variation in current must be made very slowly when approaching the observed point in order to secure accurate results.

(e) Phase displacement.

With two-element relay, tests enumerated in Instructions 19-a, b, c and d 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 the Table of Alternating Current Relay and Indicator Requirements for the particular test method recommended.

20. Relay operating values must be in accordance with shop requirements of Table of Alternating Current Relay and Indicator Requirements corresponding to the type and specification number of relay under test.

21. Test relay for electrical defects such as open circuits or short circuits in windings, resistors, reactors, or condensers by impressing the working voltage on each element and reading current. With working voltage applied, current should agree with manufacturer's marking for working current.

22. Test as required by A.R.A. Signal Section Form 16 must be made and recorded at the time relay is tested.

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

24. Insulation tests 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 in A.R.A. Signal Division Specifications 7819 and 9720.

Inspection.

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

26. Inspect and clean shaft and pivot bearings.

27. Inspect and clean contacts, replacing any which are badly burned or pitted.

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

29. Before the case is closed, subject relay to air blast to remove any foreign matter, then check to see that all parts are in proper position and in good condition.

Sealing.

30. Relay case must be sealed.

Final test.

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

Shipment.

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

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

Shopping.

34. Relays must be shopped at least once every three years for shop tests, inspection and repairs.

Field Tests and Inspections

Meters.

35. Ammeters and voltmeters for testing relays must be in accordance with A.R.A. Signal Section Specifications.

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

Testing.

37. Test required by Instructions 21 and 24 and A.R.A. Signal Section Form 16 should be made annually.

38. Relay operating values must be in accordance with field requirements of Table of Alternating Current Relay and Indicator Requirements, corresponding to the type and specification number of relay under test.

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

Inspection.

40. It must be determined by observation that sufficient contact opening exists.

41. Determine by observing operation of relay that at least ⅛ inch clearance exists between case and moving parts.

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

43. Relay not meeting field requirements must be taken from service as promptly as possible.

44. Relays located near points where lightning discharge has taken place should be inspected to determine if they have been damaged.

Repairing.

45. Repairs and adjustments to insure positive operation of relay for temporary use in emergency, may be made in the field by authorized inspector.

Recording.

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

47. Inspectors must re-mark indistinct serial numbers.

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

49. Inspector must immediately record field readings on A.R.A. Signal Section Form 16 which, when complete, must be forwarded to......................

50. Field readings must be transferred weekly from A.R.A. Signal Section Form 16 to A.R.A. Signal Section Form 15. One A.R.A. Signal Section Form 15 must be used for each relay.

Method of Testing

Single-element track relays.

51. When testing single-element track relays in the shop connect relay as shown in Fig. 38 or 39, open circuit, then close circuit with all resistance in series with relay. Make tests for pick-up, working current or voltage and drop-away as outlined in Instructions 19-a to e, inclusive.

52. When testing single-element track relays in the field connect relay as shown in Fig. 40 or 41 and proceed as outlined in Instruction 51.

Single-element line relays.

53. When testing single-element line relays in the shop connect relay as shown in Fig. 42 or 43, open circuit, then close circuit, gradually reducing resistance in the relay circuit. Make test for pick-up, working current or voltage and drop-away as outlined in Instructions 19-a to e, inclusive.

54. When testing single-element line relays in the field connect relay as shown in Fig. 44 or 45 and proceed as outlined in Instruction 53.

Two-element track relays.

55. 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. 46 or 47, then gradually increase the leakage block air gap, making test for pick-up, working current or voltage and drop-away as outlined in Instructions 19-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.

56. In adjustable resistor method, connect relay as shown in Figs. 48, 49, 50 or 51, open circuit, then close with all resistance in series with relay track element. Make tests for pick-up, working current or voltage and drop-away as outlined in Instructions 19-a to e, inclusive.

57. In using Fig. 48 or 49 the transformer secondary voltage should be not less than ten times the test working voltage and more if possible. Where practicable, testing per Fig. 49 is to be preferred to Fig. 48.

58. In using Fig. 50 or 51 the voltage for the track element circuit should be not less than 55 or 110 volts, depending on the line (or local) voltage of the relay.

Two-element line relays.

59. Connect relay as shown in Fig. 52 or 53, open circuit, then close circuit, gradually increasing voltage on relay control circuit. Make tests for pick-up, working current or voltage and drop-away, as outlined in Instructions 19-a to e, inclusive.

Phase relation measurements and corrections.

60. 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, if desired. This will permit checking the manufacturer's test values given on the sticker in the relay.

61. If it is desired to determine exactly the phase relations existing under a given test condition, it is only necessary to 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 62, 63 and 64. By comparing this angle with the ideal angle given in Table of Alternating Current Relay and Indicator Requirements, the angular difference from the ideal position may be determined. Reference to Fig. 54 will give the factor by which the calibrated values should be multiplied to obtain the operating values which should hold for the test phase relations.

Measurement of phase angles.

62. Using Union phase meter, connect as shown in Fig. 55. The reading obtained will be the angle between the line (or local) voltage and the relay track voltage.

63. Using Weston phase meter, connect as shown in Fig. 56. The reading obtained will be the angle between the line (or local) voltage and the relay track current.

64. Using watt-meter method, connect as shown in Fig. 57. Divide the watt-meter reading by the product of relay track current and line voltage. Result will be the cosine of the angle between line voltage and relay track current, which angle can be found by reference to a table of cosines.

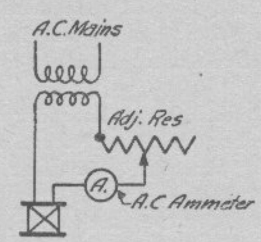


Fig. 38.

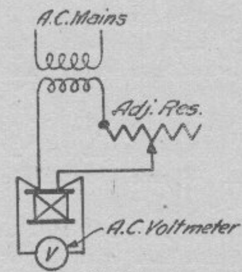


Fig. 39.

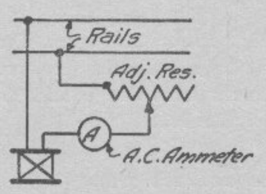


Fig. 40.

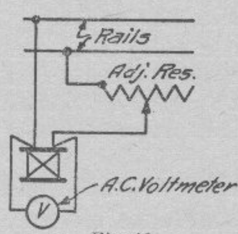


Fig. 41.

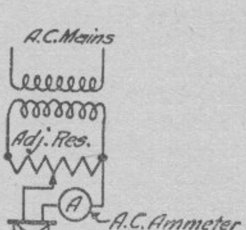


Fig. 42.

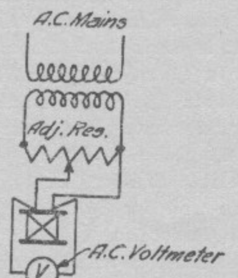


Fig. 43.

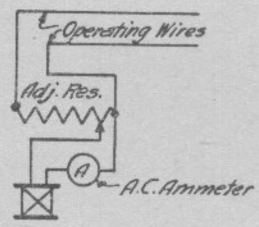


Fig. 44.

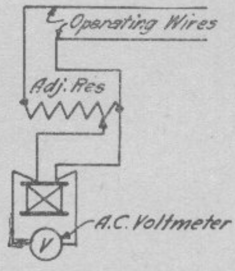


Fig. 45.

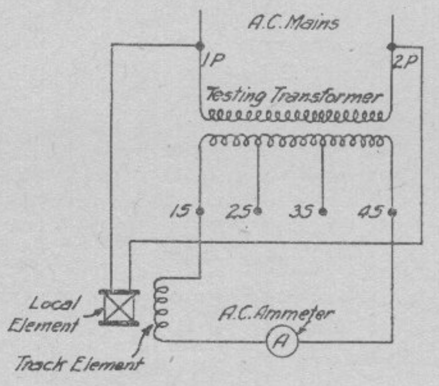


Fig. 46.

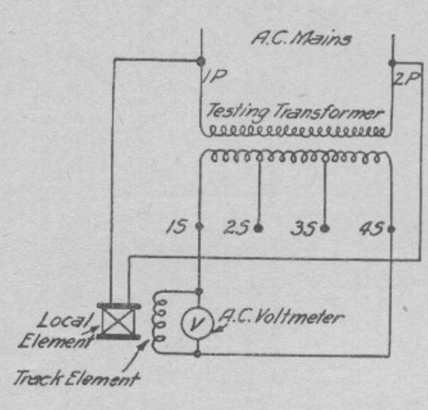


Fig. 47.

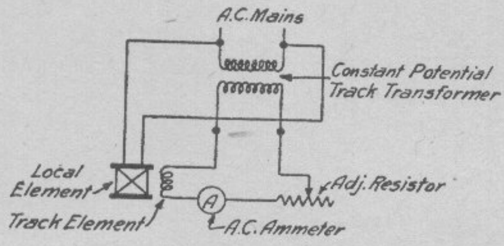


Fig. 48.

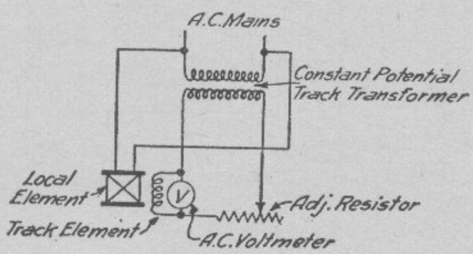


Fig. 49.

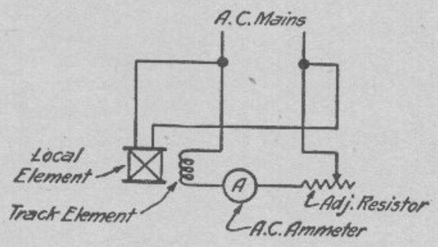


Fig. 50.

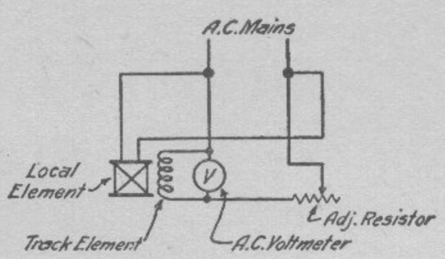


Fig. 51.

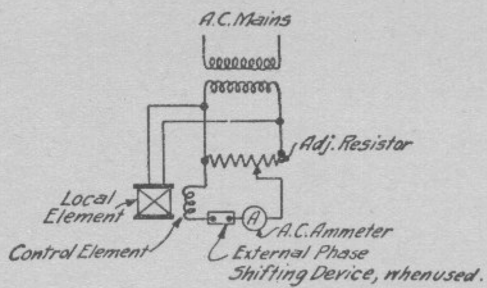


Fig. 52.

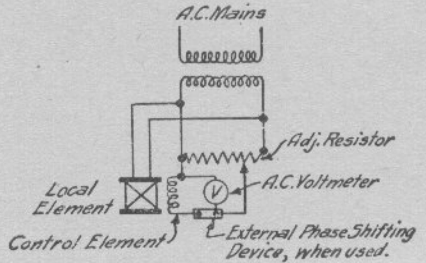
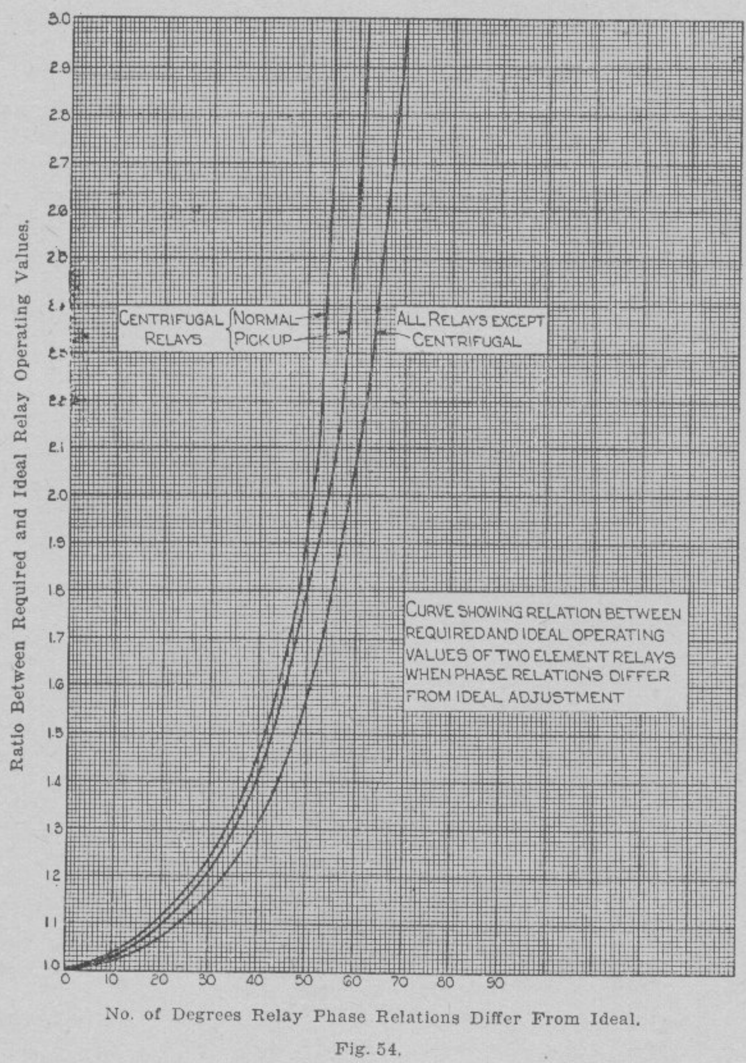


Fig. 53.



Ratio Between Required and Ideal Relay Operating Values.
3.0
2.9
2.8
2.7
2.6
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0
10
20
30
40
50
60
70
80
90
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
No. of Degrees Relay Phase Relations Differ From Ideal.

Fig. 54.

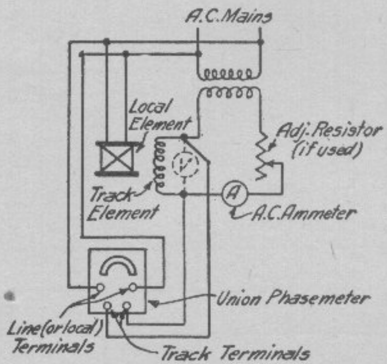


Fig. 55.

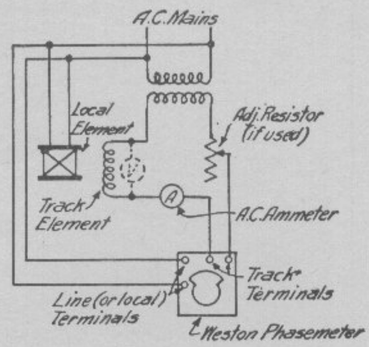


Fig. 56.

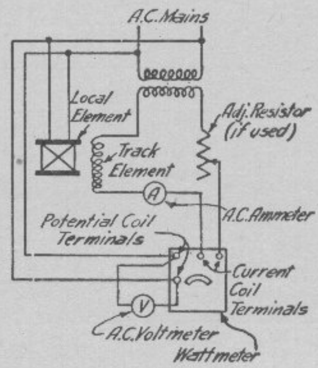


Fig. 57.

8"

5"

A.R.A. SIGNAL SECTION FORM·15

OFFICETEST RECORD 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	PICKUP				WORK. CURRENT OR VOLT.				DROPAWAY				SERVICE			DATE AND INSPECTOR	REMARKS
	NORMAL		REVERSED		NORMAL		REVERSED		NORMAL		REVERSED		CONTROL		LOCAL		
	VOLTS	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS		
ORIGINAL MARKING																	

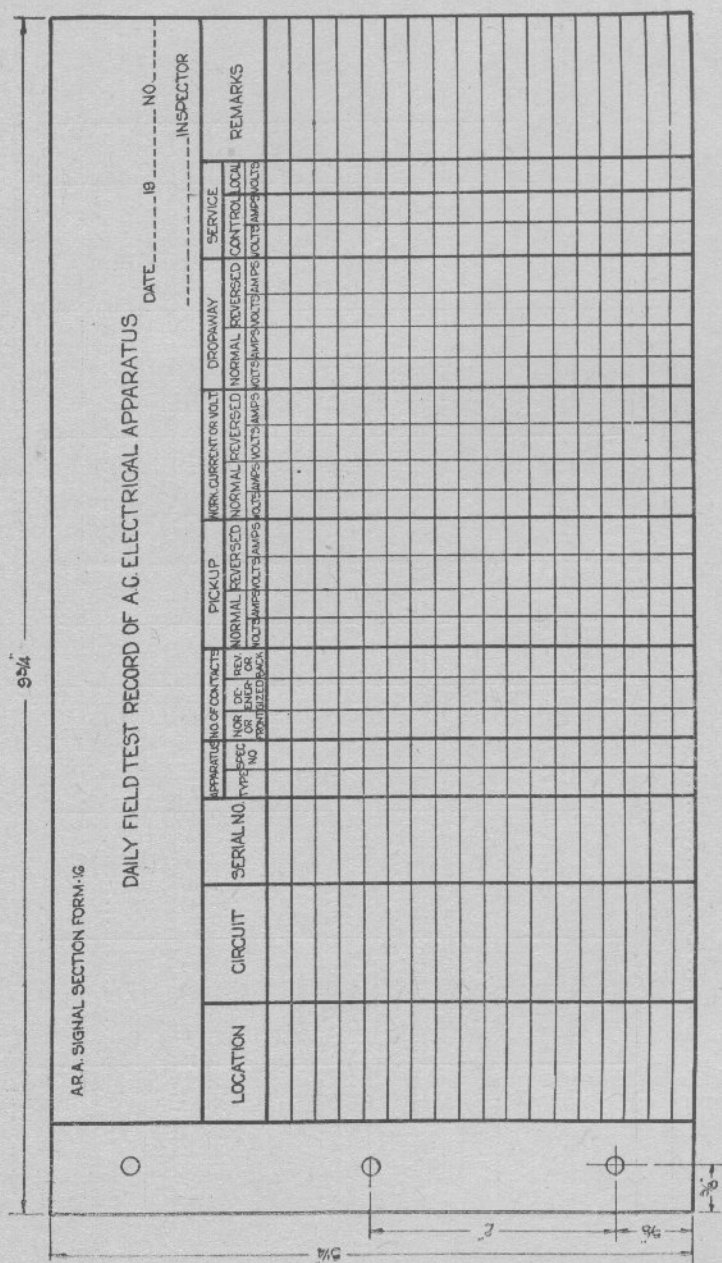

A.R.A. SIGNAL SECTION FORM-16
DAILY FIELD TEST RECORD OF A.C. ELECTRICAL APPARATUS
DATE 19 NO.
INSPECTOR
LOCATION
CIRCUIT
SERIAL NO.
APPARATUS
TYPE
SPEC NO
NO. OF CONTACTS
NOR OR FRONT
DE-ENERGIZED
REV. OR BACK
PICKUP
WORK. CURRENT OR VOLT
DROPAWAY
NORMAL
REVERSED
VOLTS
AMPS
SERVICE
CONTROL
LOCAL
REMARKS
9¼"

TABLE OF ALTERNATING CURRENT RELAY AND INDICATOR REQUIREMENTS

Type............................ Specification No............

	SHOP REQUIREMENTS					FIELD REQUIREMENTS				
		Two Element					Two Element			
	Single Element	Two Position	Three Position	Ideal Phase Displacement*		Single Element	Two Position	Three Position	Ideal Phase Displacement*	
				Voltage	Current				Voltage	Current
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 ....% greater than original marking	Not more than ....% greater than original marking	Not more than ....% greater than original marking			Not more than ....% greater than original marking	Not more than ....% greater than original marking	Not more than ....% greater than original marking		
Working Current or Voltage (Reverse Direction)	....	....	Not more than ....% greater than original marking			....	....	Not more than ....% greater than 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 Section 7.............................., 8.............................., 9..............................

* In these columns are given the phase angles of the relay track voltage or current with respect to local voltage for ideal phase relations. Angles which lag line (or local) voltage are preceded by a minus sign, those which lead by a plus sign.