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EDUCATIONAL PAMPHLET
TECHNICAL ELECTRICITY 1/1

THE TELEPHONE RELAY

General Principles and Practical Applications

A relay may be defined as an electrically-operated ***switch*** for opening and closing circuits. In the operation of modern telephone and telegraph equipment, most of the many and often complex switching operations are performed by relays. In a large automatic exchange there may be as many as 120,000 relays, and the routing of a single call may be dependent upon the correct functioning of 200 or more relays.

THE ELECTROMAGNET

A simple form of electromagnet is shown in Fig. 1. A coil of insulated wire is wound around a soft-iron rod of horseshoe shape called the core. A small rectangular piece of soft iron, known as the armature, is located near to the ends of the core ; the armature is pivoted and a spring normally holds it against a stop. When an electric current is passed through the coil of wire the core becomes a magnet and attracts the armature ; When the current is switched off the armature returns to its normal position under the influence of the restoring spring.

THE ELECTROMAGNETIC RELAY

If two contacts are fitted to the electromagnet described in the last paragraph, one to the movable armature and the other in a fixed position, so that the contacts touch when the armature is attracted to the core, they can form part of another circuit (*see* Fig. 1) thus converting the electromagnet into a relay.

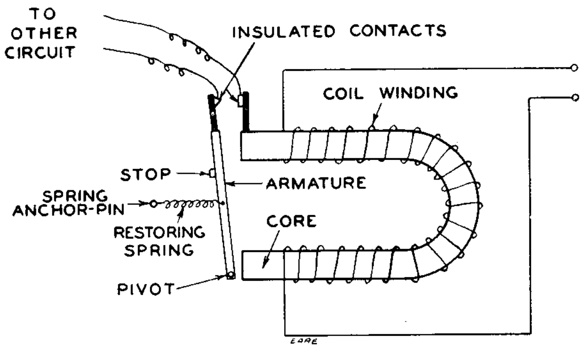


FIG. 1

The foregoing explains the broad principles of the electromagnetic relay. The specific case of the telephone relay will now be considered in detail.

THE TELEPHONE RELAY

If an examination is made of the relays that different manufacturers have favoured from time to time for use in telephone equipment it will be found that despite variations in appearance, the same principles of construction apply in practically all cases. These principles will be explained with the aid of Fig. 2, which depicts a skeleton relay of a popular form of construction. The component parts and the generally-accepted nomenclature are as follows :—

(a) *A Core*, consisting of a soft-iron rod with an enlarged end ; this enlarged end is called the *Pole Face*.

(b) *A Winding*, consisting of insulated wire wound round the core.

(*NOTE :—The complete assembly of core and winding is called the Coil.*)

(c) *A Yoke*, which is an 'L'-shaped piece of soft iron attached at one end to the coil.

(d) *An Armature*, which is an 'L'-shaped piece of soft iron pivoted at the front end of the yoke.

(e) *A Spring-set*, consisting of a number of flat springs carrying contacts and mounted on the yoke.

For convenience of construction and economy in space the core is made in the form of a straight bar but a magnetic circuit of horseshoe shape is obtained by means of the yoke.

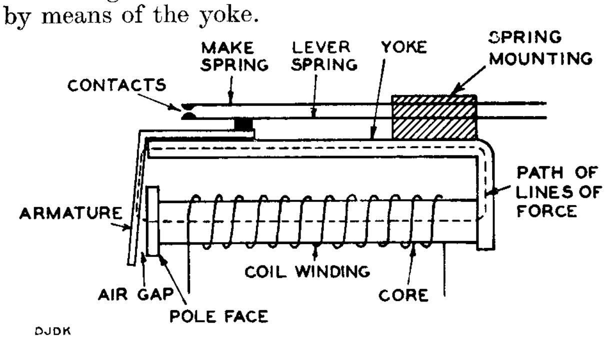


FIG. 2.—THE ELEMENTS OF A TELEPHONE RELAY

When a current flows through the winding a magnetic field is built up, most of the magnetic lines of force (or 'flux') following the dotted path shown in Fig. 2. The armature is therefore attracted to the core, thus operating the lever spring and closing the contacts. On cessation of the current, the magnetic field collapses and the mechanical pressure of the contact springs causes the armature and contacts to resume their normal positions.

THE ESSENTIAL FEATURES OF A TELEPHONE RELAY

Magnetic circuit

The magnetic circuit consists of the *core, yoke, and armature* and the space—known as the *air-gap*—between the armature and the pole-face.

To operate a relay, the current flowing in the coil must create sufficient lines of force in the magnetic circuit to produce an attraction between the armature and the pole-face which is strong enough to overcome the force exerted by the contact springs. The number of lines of force produced—up to the point where the iron is becoming saturated—is proportional to $\frac{I \times T}{S}$, where

I is the strength of the current,

T is the number of turns of wire in the coil winding, and

S is the reluctance of the magnetic circuit, *i.e.* the resistance of the magnetic circuit to the creation of lines of force.

In general the product of *I* and *T*—known as "*ampere-turns*"—should be kept low for economic and circuit reasons; therefore *S* must also be kept as low as possible.

To ensure a low reluctance the following steps are taken :—

(*a*) The core, yoke, and armature are made of Swedish iron and then annealed. These components, when made in this way, not only possess low reluctance but, under normal conditions, quickly lose practically all their flux when the magnetizing current ceases. This second point is important, as any flux that is retained when the current ceases (known as residual flux) will retard, if not altogether prevent, the release of the armature.

(*b*) The air-gap is kept short. This is important as, in the majority of relays, the air-gap, however short, forms by far the greatest portion of the total reluctance of the magnetic circuit. The point is illustrated in Fig. 3, which shows that the number of ampere-turns required to attract the armature increases with an increase of the armature movement, which is equivalent to an increase in the air-gap.

(*c*) A pole face is formed at the front end of the core. This enlarges the area of the air-gap and, since reluctance is inversely proportional to the area of the gap, the reluctance is reduced.

(*d*) The anti-corrosive finish of the core, yoke, and armature is applied thinly. Commercial anti-corrosive finishes all consist of materials having little or no magnetic property, and the thickness of the coating on the pole face or armature is, in effect, equivalent to an increase in the air-gap.

The distance through which the armature moves is known as the *stroke* or *travel* of the relay. This is always less than the air-gap, because if the iron armature were allowed to make metallic contact with the iron pole-face a magnetic circuit of very low reluctance and comprised entirely of magnetic material would be formed. Such a circuit is termed a *closed magnetic circuit* and has the property of retaining a considerable amount of residual magnetism after cessation of the magnetizing current. As this would prevent correct release of the armature, a stud or screw of non-magnetic material, known as the *residual stud or screw* [shown in Figs. 15 (*a*) and (*b*)], is used to keep the armature separated from the pole face when the relay is operated. The portion of the air-gap which remains when the relay is operated is known as the *residual air-gap*.

Coil

The wire is generally wound directly on to the core, after the latter has been prepared by covering it with thin insulating material and fitting a coil cheek [illustrated in Figs. 15 and 16] at each end. The coil may consist of one or more separate windings depending on the function of the particular relay; the number of turns and the resistance of each winding are also variable according to requirements. The resistance and the code number of the coil are

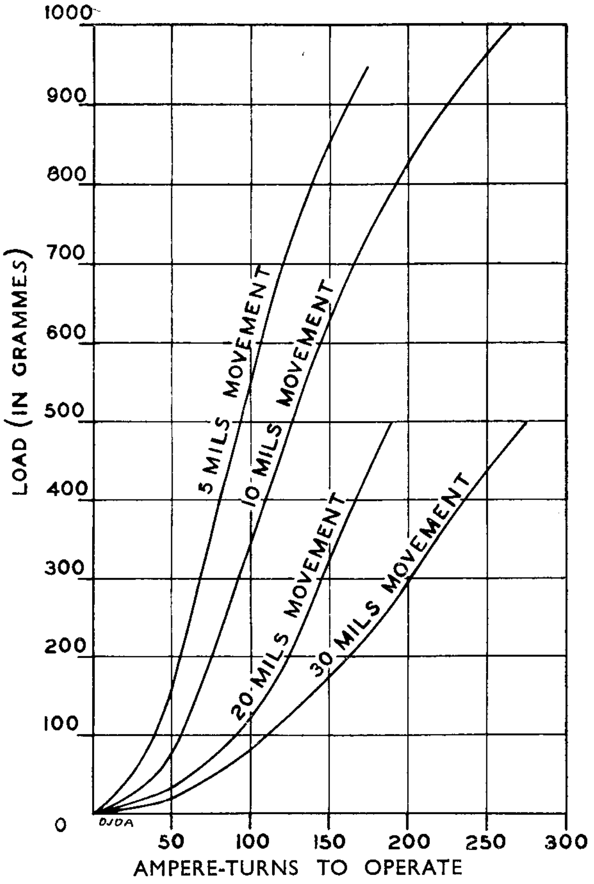


FIG. 3. AMPERE-TURN CURVES

generally stamped on the outside wrapping of the coil or on the coil cheek at the armature end. The end of the coil which is attached to the yoke is known as the "heel-end."

Contact springs

A *lever spring* is one which is actuated directly by the armature.

A *make spring* is one which makes an electrical connexion when the armature is operated.

A *break spring* is one which breaks an electrical connexion when the armature is operated.

A *contact unit* is a combination of springs in electrical association. Fig. 2 shows a contact unit of two springs, mounted so that the contacts *make* when the relay is operated. Other contact units can be arranged to give *break*, *change-over*, or *make-before-break change-over* actions.

A *spring-set* is a set of springs mechanically clamped together to comprise one or more contact units. Fig. 15 (*a*) shows a spring-set consisting of three contact units, viz. two change-over actions and one make-before-break change-over action. It will be seen in Figs. 15 (*a*) and 15 (*b*) that one relay can be made to operate more than one spring-set, but there is of course a limit to the number of springs that may safely be fitted, varying according to the circuit conditions and the mechanical restrictions of particular types of relay.

It is sometimes required that one contact unit should operate earlier than the remainder; this unit is said to have an *X action.* On the other hand it may be necessary for one unit to operate later than the rest; this is known as a *Y action.*

To reduce the risk of failure, contacts should bear firmly against each other when closed; the contact springs are therefore usually made of nickel-silver (an alloy of copper nickel and zinc) because this metal possesses the requisite flexibility and durability.

The value of the requisite magnetizing force (which is proportional to the ampere-turns) is determined by the load which the springs place on the armature. This load will depend on the number and pressure of the contact units. The relationship between the load of the springs and the ampere-turns required to operate the armature is illustrated, for a typical relay, in Fig. 3. Contact pressure is measured in grammes (1 lb. = 454 grammes), a typical pressure being 14 grammes, *i.e.* 0·5 oz. (approx.).

Contacts

As a reliable electrical connexion could not be assured between the nickel-silver springs themselves, domes of a special material are fitted to form the actual points of contact. Various pure metals and alloys have been used from time to time for contacts, the aim being to find a material of high electrical conductivity which, in addition to resisting atmospheric corrosion, is not burnt by the sparking which always occurs where an electrical circuit is broken. Platinum is a very good metal for contacts which are required to carry heavy currents or to operate very frequently. In other cases cheaper materials are satisfactory, and silver is used for the contacts on modern relays. A spring with platinum contacts is identified by a small notch cut in the tip of the spring.

THE OPERATE AND RELEASE LAGS OF RELAYS

The operate lag of a relay is the interval of time between the application of the voltage to the coil and the opening or closing of the last contact unit to operate. Similarly, the *release lag* is the interval of time between the disconnexion of the coil circuit and the opening or closing of the last contact unit to restore to normal. The operate and release lags are each made up of a *waiting* period and a *moving* period. In most relays the waiting period constitutes the greater portion of the lag and, in an elementary study of relays, the moving period may be considered negligible. Factors affecting the operate and release lags of relays are dealt with in the following paragraphs.

Self-induction in the coil winding

The coil winding of a relay possesses *inductance* and an interval will therefore elapse before the current (which rises gradually) attains its maximum steady value. Neglecting the effect of eddy currents (which is explained later), the strength of the magnetic field (or flux) set up is proportional to the current in the winding and some time will therefore elapse before

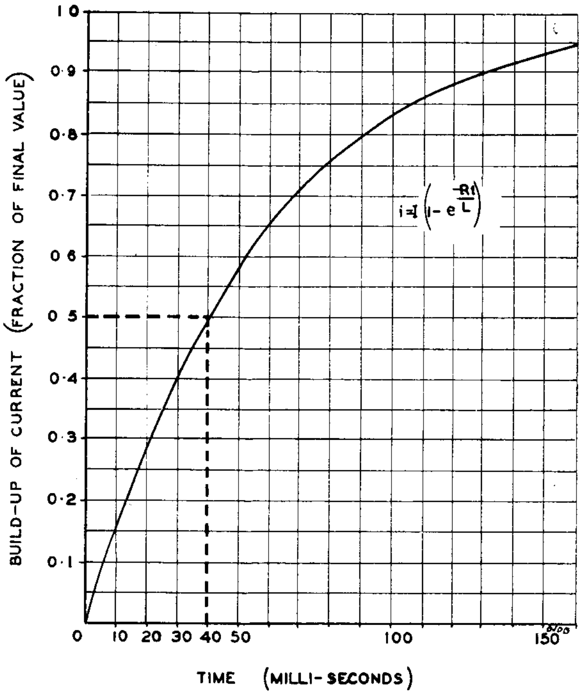


FIG. 4. RISE OF CURRENT IN INDUCTIVE CIRCUIT

the flux is of sufficient magnitude to overcome the spring pressure and operate the armature. Thus an operate lag results.

A typical curve showing the rise of current in an inductive circuit is given in Fig. 4. In most relays the armature operates at a current considerably less than the value finally attained, thus providing a factor of safety.

If the curve in Fig. 4 represents the rise of current in a particular relay, and assuming that the armature operates when the current reaches 0.5 of its final value, it will be seen that the operate lag is 40 milli-seconds (thousandths of a second).

Eddy currents

When the circuit of the coil winding is either closed or broken, the growth or decay respectively of the magnetic field will induce E.M.F.s in any conducting materials which are near enough to be within its influence, *e.g.* the core, yoke, or armature, and as the metals of which these components are made constitute closed electrical circuits the E.M.F.s will cause currents to circulate. These currents are called *Eddy currents* and they themselves produce ampere-turns, the effects of which are to retard the growth of the rising main magnetic field or to oppose its decay when collapsing. This is in agreement with Lenz's Law according to which induced currents always flow in such a direction that the magnetic effects they produce oppose the change to which they owe their origin (which in this case is the changing ampere-turns due to the main current). The magnitude of the eddy currents is proportional to the rate at which the flux increases or decreases, and inversely proportional to the resistance of the closed circuit in which they flow.

The effect of eddy currents on a relay is twofold. In the first place the operating flux which, as has been seen, already builds up slowly due to the inductance of the coil is further retarded : in other words, the operate lag is lengthened. Secondly, on cessation of the coil current, the flux, instead of collapsing practically instantly, takes some time to fall to zero : a release lag is therefore introduced. The decay of flux in a typical relay is illustrated in Fig. 5.

It will be explained later how the eddy-current effect is turned to great advantage in the design of relays which are required to be slow acting.

Air-gap

A variation of air-gap affects the operate lag. An increase in the air-gap will increase the reluctance of the magnetic circuit when the armature is in the unoperated position. When the coil circuit is closed, the current will have to rise to a higher value before the flux will reach the point at which the load of the springs on the armature is overcome. An increase in the air-gap, therefore, results in an increased operate lag.

Residual air-gap

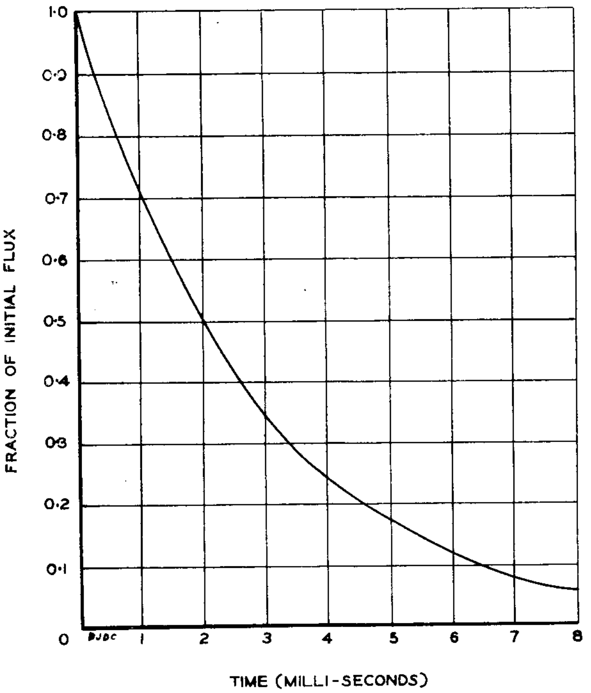
A variation of the residual air-gap affects the release lag. A decreased residual air-gap reduces the reluctance of the magnetic circuit when the relay is operated. In consequence, the number of ampere-turns required to maintain a flux sufficient to retain the armature is reduced and further, the larger flux produced by the current in the coil produces on disconnexion eddy currents of greater magnitude. Thus a longer time is taken to reach the point in the decay of the eddy current flux at which the armature is released. The release lag of a relay can therefore be increased by shortening the residual air-gap. It is not advisable however to reduce the residual air-gap to too small a value as subsequent wear on the relay parts may cause the gap to disappear altogether, with the consequent danger that owing to the presence of residual flux the relay may fail to release.

Contact pressure

It will be obvious that an increase of contact pressure will, by its effect on the armature, increase the operate lag and decrease the release lag.

FAST RELAYS

Most general purpose relays are known as fast relays but the terms fast or slow as applied to relays



NOTE :—The values in the above curve would be true for the impulsing type of relay described on page 9.

FIG. 5—EXAMPLE OF DECAY OF FLUX AFTER DISCONNEXION OF CURRENT

are purely relative. A relay in which no special features have been introduced to affect its natural speed of operation and release may be regarded as a fast relay.

The paths of flux in the magnetic circuit are shown diagrammatically in Fig. 6. When the circuit of the coil is completed the inductance will cause the current to rise in the manner illustrated in Fig. 4; a short operate lag will result. The eddy-current effect is not felt to a great extent as the currents generated in the core, yoke, and armature by the slowly-rising main current are comparatively small, and therefore the rise of flux will follow the same type of curve as that of the rise of the current in the coil. After the armature has been attracted there is a further increase in flux, owing to the reduction of the air-gap between the core and armature. The path of the leakage flux—which is always present to some degree—is shown in Fig. 6. The amount of this flux depends on the magnetic circuit, and the better the magnetic circuit the less will be the leakage flux.

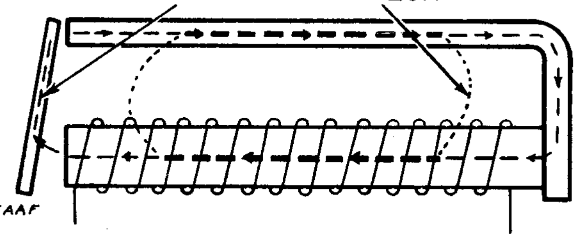


FIG. 6—FAST RELAY–OPERATING

On disconnexion of the coil the current drops to zero immediately but, as previously explained, the decay of the flux is slightly retarded by the eddy currents.

The release may be assisted considerably by the use of a large residual air-gap which, by increasing the reluctance, prevents a large increase of flux when the armature is attracted to the core and increases the number of ampere-turns required to hold the armature in an operated position.

In practice the operate and release lags of ordinary fast relays lie between 10 and 30 milli-seconds.

SLOW RELAYS

For certain functions relays slower in action than the fast relay described in the foregoing paragraphs are required.

It has already been shown that the phenomenon of eddy currents has an effect on the operate and release lags of relays, and it is by deliberately making conditions favourable to the formation of eddy currents that a slow-acting effect is principally obtained. The eddy-current effect can be considerably increased by providing a closed path, of low electrical resistance, around the core. The device may be an additional winding (this winding being short-circuited) or a thin copper sleeve fitted over the core, but more frequently it consists of a thick copper ring, known as a *slug*, placed over one end of the core.

The magnetic effects produced by the eddy currents

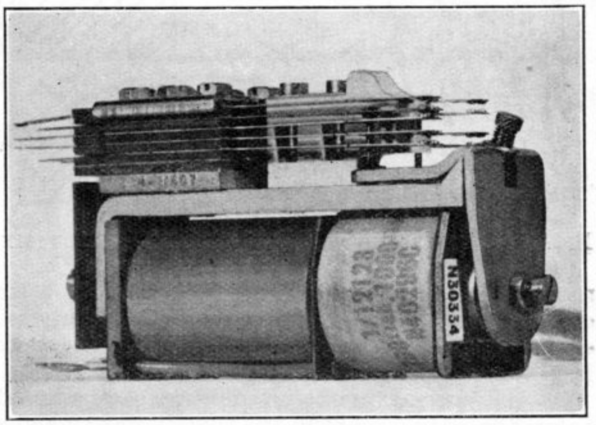


FIG. 7(*a*).—RELAY WITH HEEL-END SLUG

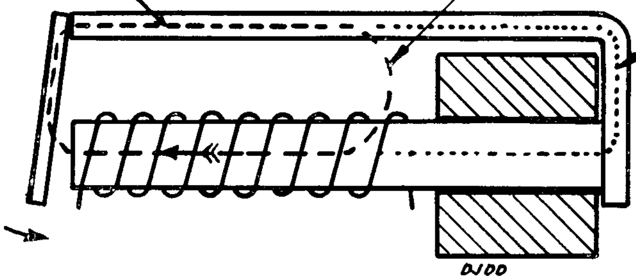


FIG. 7 (*b*).—RELAY WITH HEEL-END SLUG—OPERATING depend on the position of the slug on the core. These effects are discussed in detail in later paragraphs.

Operate lag of a slugged relay

Consideration will now be given to relays carrying slugs at either the heel or armature ends of the core, and the sleeved or short-circuited coil types will be neglected for the moment.

The first case to be considered is that of a relay fitted with a heel-end slug illustrated in Fig. 7 (*a*), schematic drawings of which appear in Figs. 7 (*b*) and 7 (*c*).

When the circuit of the winding is closed, the rising flux induces a heavy eddy current in the slug which in turn sets up a magnetizing force in opposition to that of the main current. The tendency will be for the lines of force of the winding to avoid entering the slug in any appreciable quantity until the current in the latter has subsided. The winding flux will therefore leak across to the yoke and complete a

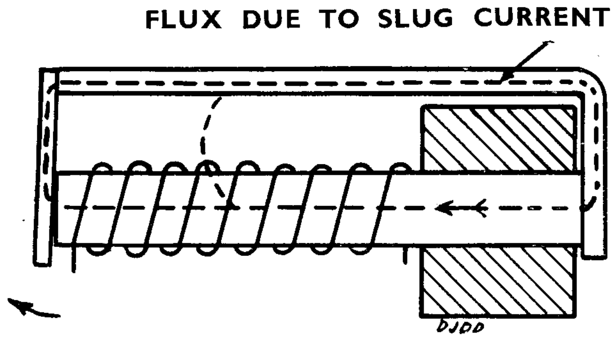


FIG. 7(*c*). RELAY WITH HEEL-END SLUG—RELEASING

magnetic circuit, as shown in Fig. 7 (*b*). By means of this leakage action the flux through the air-gap is enabled to rise fairly rapidly. A heel-end slug has little effect therefore on the *operate* lag of a relay.

As the current in the winding reaches a steady value, the eddy current in the slug dies away and so allows the winding flux to extend gradually throughout the whole of the magnetic circuit.

Consider now the relay with an armature-end slug illustrated in Fig. 8 (*a*), schematic drawings of which appear in Figs. 8 (*b*) and 8 (*c*).

When the winding circuit is closed, flux will commence to build up through the core but, owing to the rising flux in the portion of the core enclosed by the slug, eddy currents will flow round the slug. The effect of this is to cause a large proportion of the winding flux to leak from the core to the yoke without traversing the armature gap. As the rate of change of the flux in the slugged portion of the core dies down,

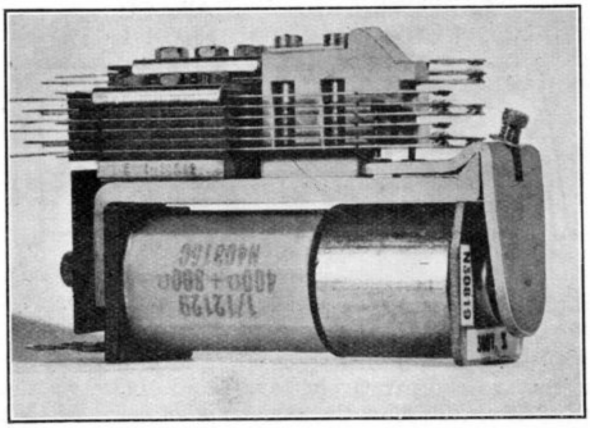


FIG. 8 (*a*). RELAY WITH ARMATURE-END SLUG

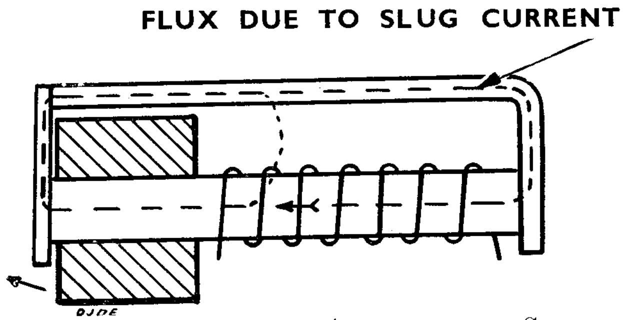


FIG. 8 (*b*). RELAY WITH ARMATURE-END SLUG—RELEASING

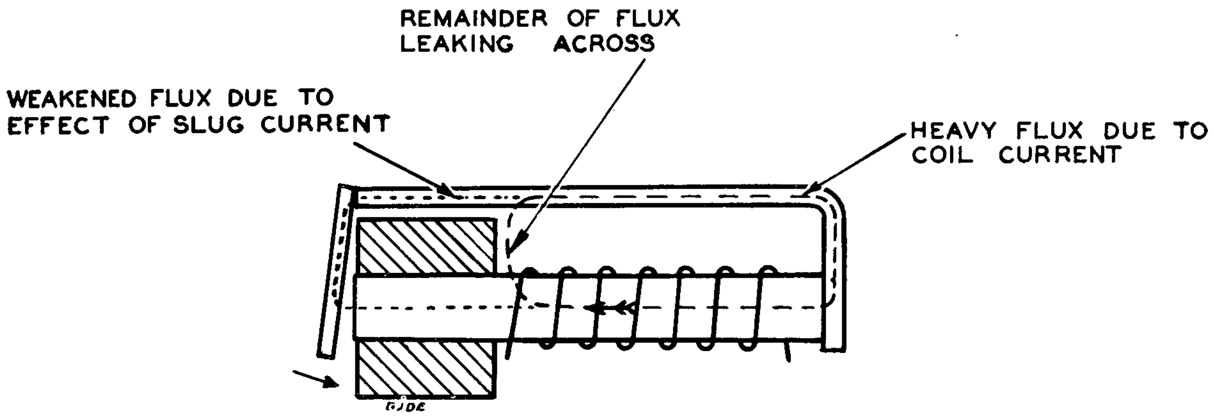


FIG. 8 (*c*). RELAY WITH ARMATURE-END SLUG—OPERATING the eddy currents in the slug subside and a greater proportion of the winding flux can then pass through the slug and armature circuit. When this flux reaches a sufficiently high value the armature will operate, and it will be clear that the time required to reach this point depends on the tension of the relay springs. If this tension is small the operating value of flux in the armature air-gap is reached fairly quickly, a longer time being taken to overcome a greater tension. Fig. 9 illustrates the variation of currents and flux in a relay during the operating period.

Thus it will be seen that, whilst a heel-end slug has little effect on operation, the operate lag of a relay provided with an armature-end slug is greater than that of a relay without a slug and that the greater the spring tension on the relay the greater will be the operate lag.

Release lag of a slugged relay

When the circuit of the winding is disconnected, the previously steady current drops to zero immediately but the rate of decay of the flux is determined by the eddy currents produced in the slug by the flux change, and the armature is held operated so long as the flux produces an attractive force sufficient to withstand the pressure of the springs.

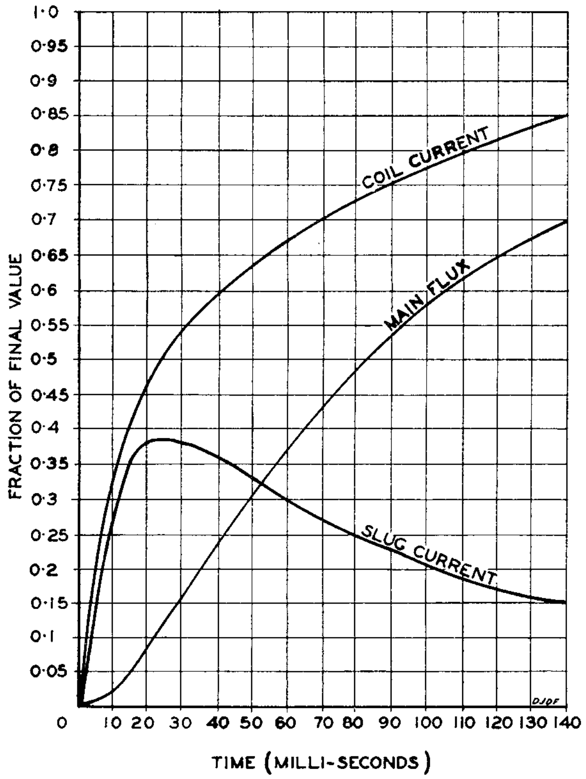


FIG. 9.—RISE OF CURRENT AND FLUX IN A SLOW-OPERATING RELAY

Owing to the flux leaking between the core and the yoke, the flux caused by the eddy currents in the slug will tend to be confined to the portion of core near the slug. In the case of an armature-end slug this portion contains the armature, and flux in the armature air-gap will be maintained for the maximum amount of time.

On the other hand, in a relay equipped with a heel-end slug the flux will tend to circulate round the heel end of the relay, and the leakage path is in effect acting as a shunt on the armature circuit and, in consequence, the flux value at which the relay releases will be reached slightly more rapidly.

In relays which have been designed for slow releasing this shunting effect is very small, owing to the low reluctance of the short residual air-gap. The release lag of these relays is therefore very little less than that of similar relays which are equipped with armature-end slugs.

The actual release lag of a slugged relay depends also on the spring tension, and it will be appreciated that the lighter the spring tension on the relay the smaller will be the flux required to retain the armature in the operated position and the greater will be the time required for the flux to die down to that value.

With light but reasonably safe spring pressures, a safe residual air-gap, and a large copper slug, release lags up to 350 milli-seconds can be obtained.

Relays with copper sleeves

Although the present practice is to fit a slug when slow operation is required, in the past some relays have been provided with a thin copper sleeve. The sleeve extends over the whole length of the core and the coil is wound over it. When operating, the effect of the eddy current in the sleeve opposes that of the winding current and the flux due to the combined effects therefore rises slowly; similarly, on release, the decay of flux is retarded.

The required condition as regards slow operation or release can however be obtained by the use of a slug in the appropriate position and, to keep the number of different relay parts to a minimum, sleeves are not now fitted to new relays.

Relays with separate closed windings

A relay can be provided with the equivalent of a copper sleeve in the form of a second winding, this extra winding being short-circuited. A winding is less efficient than a slug, as the amount of copper per cubic inch of winding space is less, and the resistance is greater. The separate closed winding however affords flexibility, as it enables the relay to be made either fast or slow as circumstances demand. This is achieved by connecting the ends of the extra coil to control contacts which may be opened or closed at will. A variety of conditions can then be set up and the relay can be made :—

(*a*) Slow to operate and release,
(*b*) Fast to operate and release,
(*c*) Slow to operate but quick to release, or
(*d*) Quick to operate and slow to release.

An example of this facility is described later, in connexion with relays which are insensitive to alternating currents.

Relays with shunted windings

Sometimes a slow-releasing effect is obtained on single-coil relays by shunting the coil with a non-inductive resistance or the winding of another relay. When the main circuit is opened the flux in the relay commences to die away, thereby inducing an E.M.F. across the relay coil. Owing to the presence of a closed circuit the induced E.M.F. causes current to circulate through the relay coil, and this retards the rate of decay of the flux.

Summary of considerations governing slow operation and release

Owing to the number of variable factors, *e.g.* spring load and armature air-gap, it is difficult to give definite data for slow relay design, but the following general rules apply in practice :—

(*a*) Relays which are required to be slow releasing and quick operating are usually equipped with heel-end slugs, lightly loaded spring-sets and small residual air-gaps. When, however, the speed of operation is not important but the maximum amount of release lag is required, an armature-end slug may be used.

(*b*) Relays which are required to be slow operating are equipped with armature-end slugs and heavy spring loads are used.

USE OF SLUGGING EFFECTS TO MAKE RELAYS INSENSITIVE TO ALTERNATING CURRENTS

In connexion with the application of ringing currents to subscribers' lines a relay is required which will

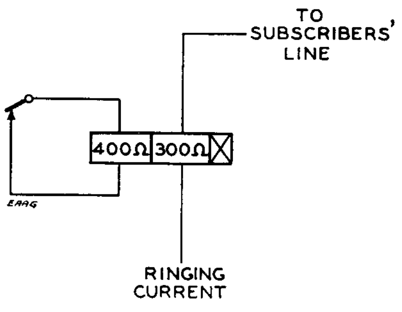


FIG. 10

not operate, or even chatter, when ringing (alternating) current flows through its coil to ring the subscriber's bell, but which will operate when the subscriber answers and thereby causes direct current to flow. At the same time a fairly fast release is required. The desired effect can be obtained by fitting a slow-operating relay, *i.e.* a relay with an armature-end slug, and at the same time applying the principle of the separate closed winding. The circuit of the relay is shown in Fig. 10. Normally the 400 ohms winding of the relay is closed by one of its own contacts. When ringing current is applied to the subscriber's line through the 300 ohms winding, the combined effect of the armature-end slug and the closed winding prevents operation. When the subscriber answers, direct current flows through the 300 ohms winding, the relay operates and its contact removes the short-circuit from the 400 ohms winding and so prepares for a fairly fast release.

Effect of Slugs, etc., on the Impedance of Relays

The presence of a slug, sleeve or separate closed winding, by slowing down the rate of flux change, reduces the inductance and therefore the impedance of the relay. Such a relay may be regarded as a transformer with one of its windings short-circuited.

It has been shown how in the fast relay the inductance of the coil causes the current to rise slowly and therefore introduces an operate lag. Since the presence of a slug—or its equivalent—reduces the inductance of a relay, the current will rise to its maximum value in a shorter interval of time than in the case of a fast, *i.e.* un-slugged, relay. It follows therefore that the inductance of the winding does not play a large part in creating the operate lag of a *slugged* relay. In effect, one slowing factor is destroyed but another is introduced.

HIGH-IMPEDANCE RELAYS

When relays are connected directly across the speaking wires of a telephone circuit or provide the transmission bridge through which current is fed to the subscribers' transmitters, it is essential that they should offer a high impedance to currents of speech frequency in order to avoid shunting the path that these currents should take, but they should at the same time have a low direct-current resistance.

The inductance of a relay can be increased by the use of a highly permeable material in the core. Care has to be exercised however, as in most materials of this type permeability is very high at low values of magnetizing force but falls off rapidly as the magnetizing force is increased. In a transmission-bridge relay which is subjected to a current of an undulatory nature, the flux consists of a rapidly-varying portion superimposed on a steady portion. The extent to which the rapidly varying flux penetrates the core is very small however, as a phenomenon known as skin effect is experienced and this flux is restricted to the surface. The necessary increase in inductance and, consequently, in impedance can therefore be obtained by providing a highly-permeable material in which the voice-frequency flux can circulate near the surface.

Nickel-iron is used for this purpose as this metal—in addition to being of high permeability—possesses high specific resistance and thus reduces eddy currents, with a consequent further increase of inductance. The necessary thickness of nickel-iron is usually applied in the form of three sleeves, as this facilitates manufacturing operations.

A typical sleeve is shown in Fig. 11 (*a*), and the method of fitting three sleeves to a core is illustrated in Fig. 11 (*b*). To reduce eddy currents still further a longitudinal gap is left in each sleeve.

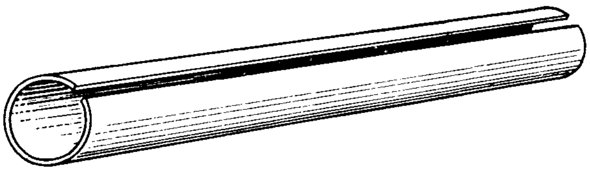


FIG. 11 (*a*) NICKEL-IRON SLEEVE

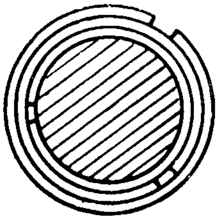


FIG. 11 (*b*).—SECTION OF CORE WITH N.I. SLEEVES

IMPULSING RELAYS

In automatic telephony the operation of selector electromagnets is controlled by the subscriber by means of a piece of mechanism called a dial, which is connected across the subscriber's end of the line. When the dial is operated, the continuity of the line is rapidly broken and re-made a number of times in succession, the number of ' breaks ' being the same as the digit dialled. At the exchange a relay coil is joined across the line, and the contacts of this relay are employed to repeat the dialled impulses to the selector electromagnet. Such a relay is called an *impulsing relay.*

To ensure correct functioning of the selector electromagnet it is important that the interval of time for which the line circuit is opened by the dial shall be repeated without distortion by the relay contact, and this necessitates a relay with equal operate and release lags. When a relay is connected to a line however, the operate and release lags are both influenced by line conditions, but not necessarily to an equal extent. Lines differ widely in characteristics and the problem is to design an impulsing relay which will have equal operate and release lags when joined to any line. This ideal cannot be achieved in practice as, in general, a variation in line conditions which gives an increase in the operate lag will reduce the release lag, and vice versa ; therefore a relay with short operate and release lags is the best compromise.

Generally speaking, an impulsing relay need not differ greatly from an ordinary fast relay except in the matter of adjustments. Thus, for quick operation the armature load is kept to a minimum, while to ensure quick release a large residual air-gap is provided.

One method of ensuring the early release of a relay is to limit the maximum flux in the air-gap so that on cessation of the main current the point at which the flux permits release will be reached at an earlier stage. This can be done by fitting an armature shaped as shown in Fig 12, so that the flux passes through a narrow neck or isthmus. Magnetic saturation of this restricted portion of the armature is reached with a comparatively low magnetizing force, and further increase in the relay current does not materially increase the flux in the air-gap. In this way the release lag is reduced and to some extent stabilized. An isthmus armature is also lighter and therefore more suitable for quick action.

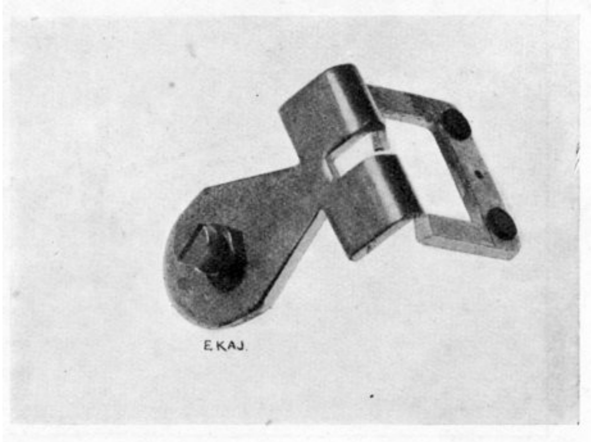


FIG. 12.—ISTHMUS ARMATURE

DIFFERENTIAL RELAYS

This relay is provided with two windings on a simple core which are arranged so that when both are energized the magnetic effect of one winding is neutralized by that of the other, with the result that effective flux is not produced. Any disturbance of this condition of balance resulting from an increase, decrease or reversal of current in either winding will, if the unbalance is sufficient, cause the relay to operate. This unbalanced condition can be produced in various ways, *e.g.* by shunting one winding or placing resistance in series with it.

SHUNT-FIELD RELAYS

A shunt-field relay is illustrated in Fig. 13 (*a*) and shown diagrammatically in Figs. 13 (*b*) and 13 (*c*). It differs from an ordinary relay in that it has two separate coils, each wound upon its own separate core. The cores are placed side by side and joined together by links of magnetic material at both ends. This relay operates when both coils are energized in in the same direction, but will not operate when only one coil is energized or when the two coils are energized in opposite directions.

In Fig. 13 (*b*) current is shown flowing through both coils in opposite directions. The links will be magnetized as indicated and the flux will circulate round the closed magnetic path formed by the two cores and links. Owing to the higher reluctance, only a very small portion of the flux will follow the path provided by the yoke, armature and air-gap, and the armature will not be attracted. The same applies when current flows through one of the coils only.

When current flows through both coils in the same direction [Fig. 13 (*c*)], each link has consequent poles produced in it and the flux of each coil is diverted to the alternative path provided by the yoke, armature, and air-gap. The relay therefore operates.

Another type of shunt-field relay operates on the same magnetic principle except that one of the coils of the relay is replaced by a permanent magnet and the operation is therefore controlled entirely by the strength and direction of the current in the remaining coil.

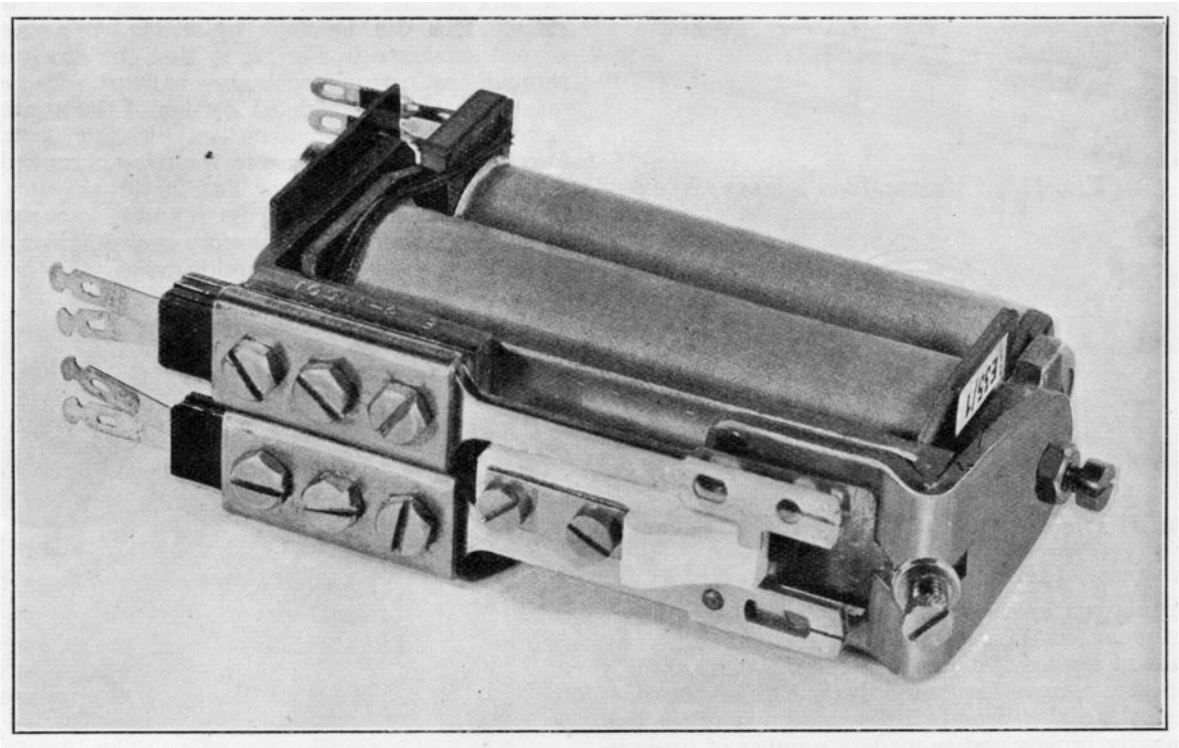


FIG. 13 (*a*).—SHUNT-FIELD RELAY 3,000-TYPE

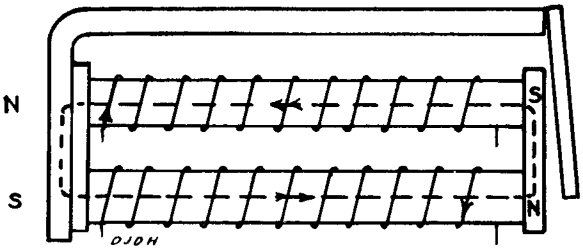


FIG. 13 (*b*).—SHUNT-FIELD RELAY—UNOPERATED

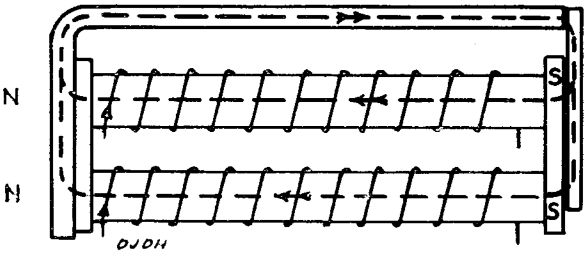


FIG. 13 (*c*).—SHUNT-FIELD RELAY—OPERATED

POLARIZED RELAYS

The operation of a polarized relay depends upon the direction as well as the magnitude of the current in the coil.

The principle usually employed is to polarize the core by means of a permanent magnet so that the core exerts a permanent pull on the armature. This pull, however, is not sufficient to overcome the force exerted by the contact springs. A current passing through the winding will, according to its direction, weaken or strengthen this pull and in the latter case if of sufficient magnitude cause operation of the relay. In certain polarized relays the polarizing magnet replaces most of the normal soft-iron core, and the coil winding is confined to a soft-iron extension of the magnet. It will be appreciated that there is a limit to the amount of current which may be permitted in the non-operate direction, since current in excess of the limit will reverse the polarity of the relay and may result in operation.

USE OF RECTIFIERS WITH RELAYS

In telephony an alternating current of 17 c./sec. is employed for ringing subscribers' bells. If a current of this nature were applied to the coil of an ordinary relay the armature would merely chatter. Reliable operation without vibration can however be achieved by the use of a metal rectifier connected across the relay winding, as illustrated in Fig. 14 (*a*).

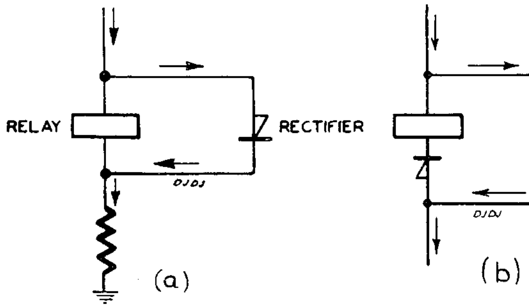


FIG. 14.—RECTIFIER AND RELAY COMBINATIONS

When the current flows in the direction indicated by the arrows, the rectifier will act as a short-circuit across the relay and current will not flow through the relay coil. The resistance of the rectifier is very high to current in the opposite direction, and when the reversal takes place current will flow through the coil and operate the relay ; the pulse of current which is received by the coil in this direction takes a comparatively long time to decay to zero as it is provided with a circulating path by the rectifier. The shunting effect of the rectifier therefore makes the relay slow to release. In practice, the relay is so slow to release that the armature remains held continuously by the pulses of current in one direction.

The connexion of a rectifier across the coil of a relay as in the preceding case is sometimes employed, as an alternative to the use of shunt-field or polarized relays, in order to render a relay operative to a current in one direction only. When current is applied in the 'go' direction of the rectifier, operation of the relay is prevented because the rectifier forms a low-resistance shunt across the coil of the relay. In the case of low-resistance relays the resistance of the rectifier in the 'go' direction may be too high to form an effective shunt, and the action may be made certain by connecting a further rectifier in series with the relay coil but in the opposite direction to that of the shunting rectifier [*see* Fig. 14 (*b*)].

POST OFFICE STANDARD TELEPHONE RELAYS

It has been mentioned previously that there is a great variety of relays in existence. Recently the Department decided to standardize relay construction and, based on a study of all the different types, a relay was designed in collaboration with the manufacturers which embodied principles which had been proved to be sound by years of experience and possessed certain novel features making for ease of maintenance. Two sizes of this standard relay are made, the 3,000-type for heavy duty and more rigorous operating requirements and the 600-type for light duty. A 3,000-type relay is shown in Figs. 15 (*a*) and 15 (*b*). The features of the standard relay are described in the following paragraphs.

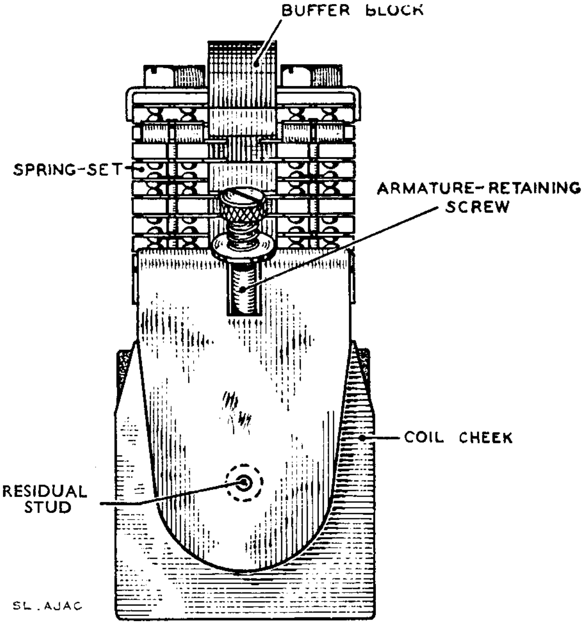


FIG. 15 (*a*).—FRONT VIEW OF 3,000-TYPE RELAY

Magnetic Circuit

The magnetic circuit is of very low reluctance. The armature end of the yoke is enlarged and machined to a knife-edge. The bend of the armature is V-shaped and fits snugly over the knife-edge. With this arrangement a good magnetic continuity is ensured at the pivot. The coupling of the yoke to the core is such as to minimize the reluctance at this point, but at the same time to permit the withdrawal of the core and winding without removing the relay from the mounting plate. Corrosion of the components is prevented by nickel plating and, as this material is slightly magnetic, the effect of the plating on the reluctance of the magnetic circuit is kept to a minimum.

For slow-operating or slow-releasing relays three lengths of slug are employed—½ in., 1 in. and 1½ in.—according to the spring-set load and the required lag.

To minimize the number of contact faults due to dust the standard relay is mounted with the springs at the side, *i.e.* on edge, so that dust will tend to fall clear of the contacts. This necessitates the fitting of an armature-retaining screw to hold the armature in position when the relay is not energized [*see* Figs. 15 (*a*) and 15 (*b*)].

Contact Springs

The nickel-silver contact springs are 14 mils (thousandths of an inch) thick for normal use, but 12-mil springs are used if it is necessary to reduce the armature load. Exceptionally, springs exceeding 14 mils in thickness are employed.

A block, moulded from synthetic material, is mounted on the yoke of the relay (*see* Figs. 15 and 16). This is known as the buffer block and is grooved so that it engages with lugs formed on the sides of the make or break springs to limit their 'follow' when the associated moving spring moves out of contact with them. Thus a make spring rests on the buffer block when the relay is normal, and is lifted off by the moving spring when the relay operates. A break spring, with the relay normal, is held away from the buffer block by the pressure of the moving spring, but when this pressure is removed by the operation of the relay the break spring is checked by the buffer block after a limited amount of 'follow.'

The make and break springs can be readily adjusted to bear against the block with any desired pressure, break springs being adjusted with the armature operated. The subsequent adjustment of the moving springs to ensure that the make and break springs are lifted clear of the block when the armature is operated or unoperated respectively, will then guarantee that the contact pressures are slightly above the block pressures to which the make and break springs have been adjusted. To lift a break spring it is of course necessary to tension the moving spring sufficiently to overcome the pressure of the break spring against the block, and it should also be

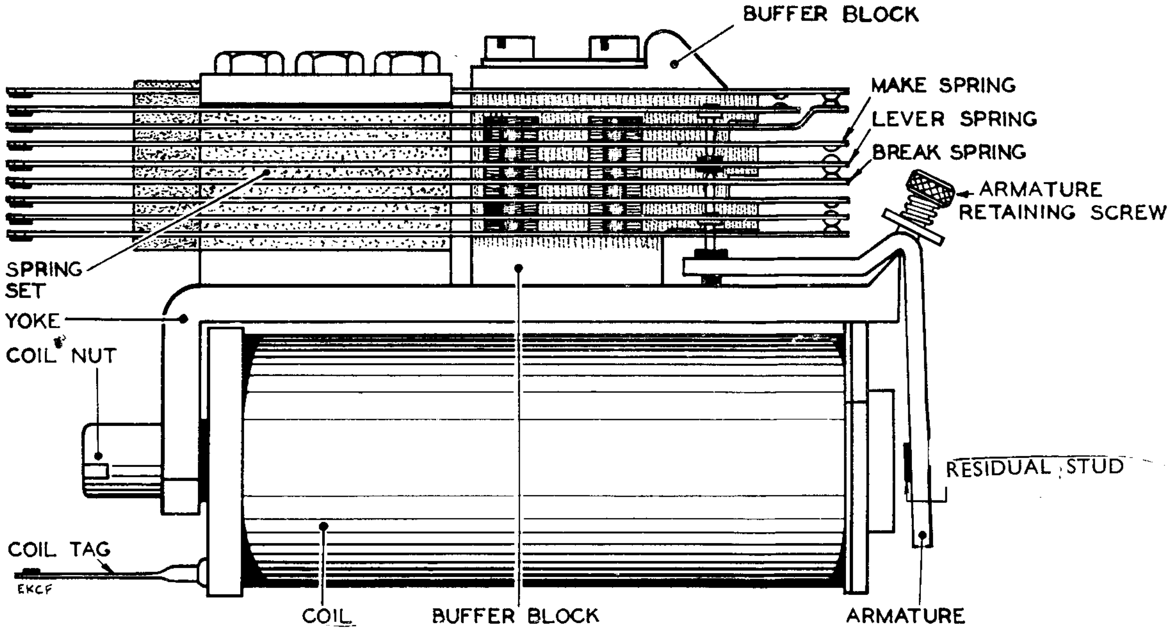


FIG. 15 (*b*).—SIDE VIEW OF 3,000-TYPE RELAY

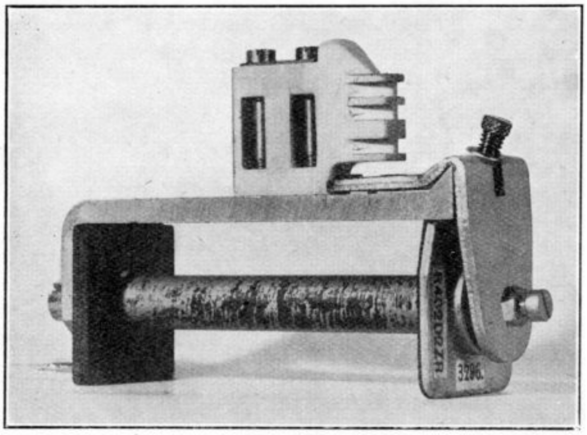


FIG. 16.—SKELETON OF RELAY

given sufficient additional tension to enable it to exert a slight pressure against the armature in its unoperated position.

This method of adjustment ensures a definite standard of contact pressure, a point of considerable importance as it has been proved that where low pressures are used fault liability is greatly increased.

Contacts

Twin contacts are employed, the end of each spring being centrally slotted for about half an inch and a dome-shaped contact fitted to the tip of each prong so formed. The prongs permit of a slight amount of independent flexing so that a double contacting action normally occurs. The liability to contact failure due to dirt etc. is thus considerably reduced because one contact can maintain the circuit if its 'twin' be rendered temporarily ineffective by a particle of dust.

END

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