CHAPTER IX.

MOTORS, RELAYS, ETC.

SIGNAL motors are of small size, series wound, and for direct current only. As they are generally operated by battery current, the terminal voltage is of necessity low. It is not practicable to operate motors over line wires of any great length, owing to the great loss of energy in the latter, and the low starting torque of the motor.

The sizes of motors used vary from 65 to 150 watts, or one-twelfth to one-fifth of a horse-power. From 10 to 20 Edison or Gordon cells are used to operate these motors, so that, should the applied voltage vary from 7 to 14, the full-load current will vary from 9 to 5 amperes in the smallest motors to from 20 to 11 amperes in the one-fifth horse-power unit. The larger motors (as in all-electric systems of interlocking) are supplied with current from a storage battery having considerable potential, so that the above currents are much reduced. Derailing and switch movement motors are at a maximum of about one horse-power, although they operate normally at about 420 watts (7 amperes at 60 volts, or 4 amperes at 110 volts).

In Fig. 115 a standard form of signal motor is illustrated. *F* is the laminated field, which consists of a large number of stampings of soft iron held firmly between heavy end pieces of similar contour. The exciting coils, *W*, are connected in series with the armature, *A*, through the brushes *B*, and the commutator, *C*. *S* is a removable transparent glass end-shield, which effectually prevents dust and moisture from collecting on the moving surfaces, also allowing inspection from time to time. *P* is the brake pulley and *M* the brake mechanism, whose function is described in connection with Fig. 117.

The laminations of soft iron on both armature and field, having a high permeability, allow of a greater flux density than could be obtained from solid iron, at the same time reducing to a minimum the eddy-current loss. The armature shaft carries a pinion which engages with the gear train of the clearing mechanism. The motor is provided with a base by means of which it is bolted to the frame. Semaphore signals in general use motors that have become the standard for small sizes in electrical power application, with but slight modification.

There are a number of combined electrical and mechanical methods of applying a brake to a motor armature for the purpose of rapidly bringing it to rest; so that the semaphore movement will occur within a minimum time and at a uniform rate throughout the entire angle of motion. Obviously the most effective arrangement will operate immediately upon current cessation, and release upon the commencement of its flow. Two such schemes will now be considered.

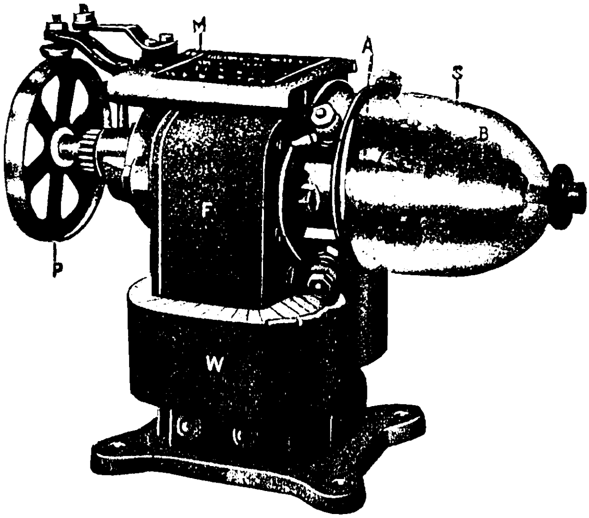

FIG. 115

In Fig. 116, *a* is a friction wheel keyed to the shaft, *i*, of the motor. In series or shunt with the motor or its field is an electromagnet, *g*, whose armature, *f*, pivoted at *d*, and weighted at *e*, carries a shoe or brake, *b*, pivoted at *c*, and conforming on its inside surface to the circumference of *a*. When the current passing through *g* (and consequently the motor) ceases, *b* will engage with *a* and bring the latter to a stop within a time proportional to the relative position of *c*. The disadvantage of this device is the multiplicity of parts and the waste of energy in exciting *g*.

In Fig. 117, which is a brake frequently applied to semaphore motors, *F* is the field pole of the motor, *S* the armature shaft, and *P* a pulley keyed to the latter. *B* is a rubber held normally against the face of *P*, by the adjustable spring, *H*. *B* is carried on the iron rocking pieces, and its position determined by the adjustment, *G*. When current passes through the motor, the iron prong or strip is attracted to the tips of *F*, and by overcoming the tension of *H* releases *B*. When current ceases, the cessation of the flux in *F* releases the prong, causing *B* to be forced against *P*, and rapidly overcoming the inertia of the armature.

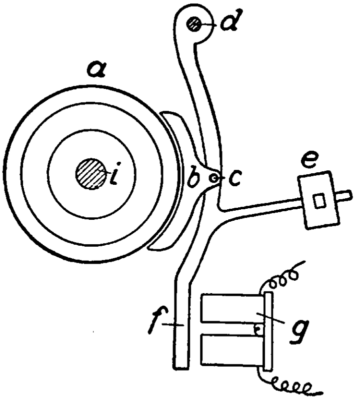

FIG. 116

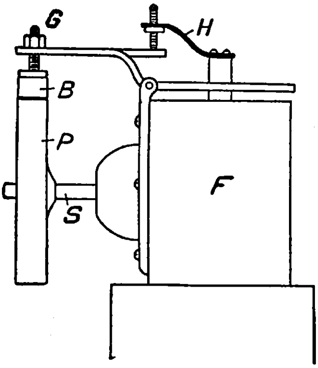

FIG. 117

Soft iron disks affixed to the armature shaft have also been used to retard the rotation of the latter. The disk moves between the poles of a strong electromagnet, and the reaction caused by the setting up of eddy currents in this disk effectually brings the armature to a stop.

A motor brake and the circuit arrangement thereto is shown in Fig. 118. *A* is the signal-control relay (normal danger) in series with the main battery, common, home line-wire, and track-relay armature. It has front and back armature contacts, *C* and *B*, having a common connection. *B* is in series with the motor, so that the latter is short-circuited upon itself. *H* is a circuit controller whose movable contact, *E*, travels in the direction of the arrow when the signal is clearing. When *A*, is energized, a current passes from *D* to *G*, *H*, motor, and *C*. When the semaphore is about cleared, *E* connects *G* and *I*, thus sending a current through the brake magnet, *J*, and bringing the motor armature to a stop, current being cut off simultaneously from the motor circuit. When the semaphore returns to danger by the deënergization of its slot and *A*, the current set up by the counter e.m.f. through the low resistance circuit, *H*-*E*-*F*-*B*, produces the desired retardation.

For a given output, the resistance of motors increases as the voltage of the circuits to which they are applied is increased.

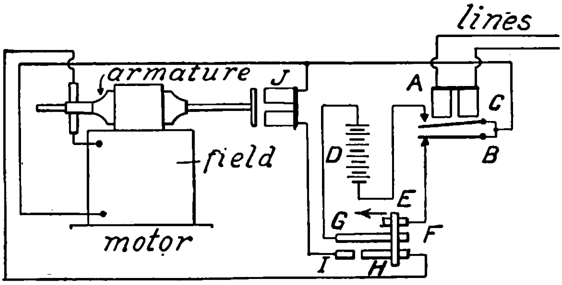

Fig. 118

In small motors, the higher the average voltage at which they operate, the more efficient do they become. It is not so much the actual resistance of the motor itself which gives the increased efficiency, but the relativity of this resistance to the total resistance, external to the motor terminals, such as that in the wiring, relay contacts, batteries, and connections. Hence, the greater the operating voltage, the less will be the percentage of loss in these subsidiary devices, and the greater the available energy manifested in motor torque.

A transmission gear for throwing one or more semaphores to clear is outlined in Fig. 119. The motor, *M*, drives the sheave, *S*, through the gearing, *G*. *B* is a brake magnet whose armature lever when deënergized bears against the wheel, *W*, keyed to the armature shaft, thus preventing rotation of the latter, the adjustable counterweight, *C*, providing a time limit.

This arrangement is fastened near the base of the signal pole and provided with a weatherproof cover.

Numerous types of relays are used in signal practice, all of which embody certain generic features. Great variations exist, however, in the resistance to which they are wound, in one case a four-ohm winding being standard, and in another a 3000-ohm winding is applied.

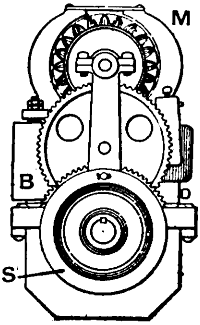

FIG. 119

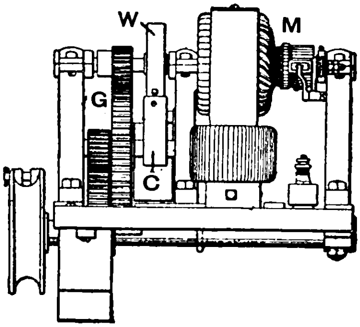

FIG. 119*a*

In Fig. 120 a Taylor neutral-track or control relay is shown. The magnets, *M*, are carried on the cast brass base, between which and the sub-base are the armature and contacts, the latter being protected by a cylindrical glass ring, *G*. The contact fingers, *H*, are fastened to the armature, *A*, by lavite bushings, *L*, and make scraping connection with the front contact, *F*, and back contacts, *B* ; these being introduced in the external circuit by the binding posts, *C*. The coils of *M* are connected to posts, *P*.

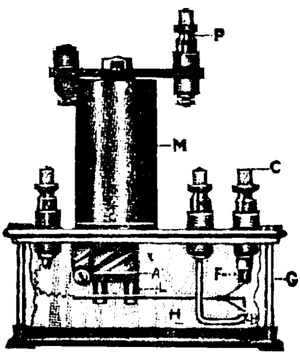

FIG. 120

Fig. 121 shows in section and elevation a polarized type glass-enclosed relay having a neutral armature, *C*, and a polarized armature, *G*. The latter swings about a pivot, *B*, the direction of motion depending upon the polarity of the poles of magnets, *M*. *A* is a permanently magnetized rod of steel, one end of which is fastened in the yoke, *H*, the other projecting to the level of the pole tips of *M*. The neutral armature is given a vertical movement, and has front carbon contacts at *D* and back contacts at *E*, through the flexible strip, *F*.

The operation will be evident from the plan of the contact parts in Fig. 122. When current in either direction passes through the magnets, the neutral armature, *G*, is raised, closing the front contacts, *D*. On cessation of current, the back contact only is closed. If the pole tip on the right hand side be of north polarity, and the same end of the polarized armature, *G*, be magnetized inductively from the permanent magnet so that it becomes a south pole, attraction will result and the armature will turn in this direction. The opposite end of the armature will be repelled from the other magnet pole, as the latter is of south polarity, the armature end also being south. This causes the contact fingers, *L*, to be forced against the carbon contact-buttons, *K*. A reversal of current will reverse these conditions.

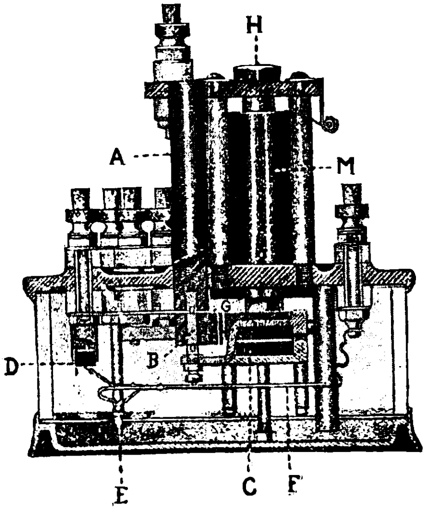

FIG. 121

Both armatures are pivoted close to the field poles, so that the required motion is slight, hence they are continually in a strong field when energization occurs, due allowance being made for eliminating the effects of residual magnetism. Adjustment is not required, as the pivots are fastened to the pole tips, overcoming the variations due to expansion. The alternate polar contacts are in multiple, and contact made with a scraping motion, for self-cleaning. With a short armature motion, a wide break results, flexible copper strips connecting the binding posts of the armature fingers.

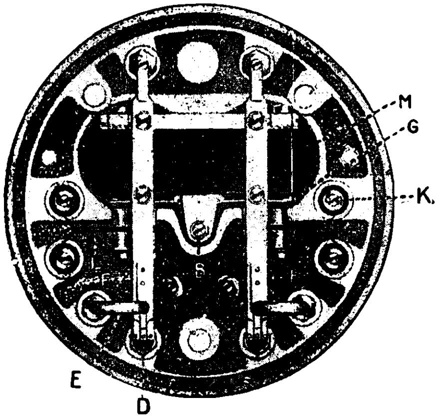

FIG. 122

Fig. 123 shows a relay designed for breaking circuits carrying heavy current at comparatively high potential (for signal circuits). The magnet coils, *M*, are connected to the track, or other control circuit; the working current being carried by the resilient strip, *E*, and carbon contacts, *C*. When the armature falls, a wide and rapid break is introduced, the back contact at *D* being then closed. *B* is a series magnetic blow-out coil, the poles of its magnetic circuit causing a powerful flux to pass across the arc, thus rapidly disrupting it; a slight movement of the armature, *F*, also produces a wide break at *C*. The mechanism is enclosed in a glass case, as the presence of dust or insects is inimical to its proper operation.

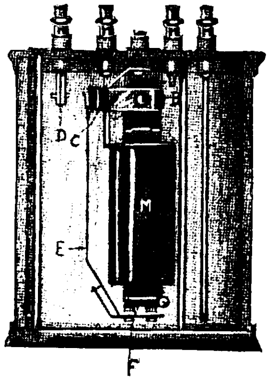

FIG. 123

The G. E. neutral relay, with the glass cover removed, is shown in Fig. 124. *M* are the electromagnets, which actuate the armature, *A*. The latter carries brass lugs to which the carbon contacts *C*, are clamped, these making and breaking contact with the flexibly mounted fingers, *F*, carrying ends of silver. The posts, *P*, are in connection with the terminals, *D–D*. A quadruple break is effected by this device, which is very satisfactory. The contacts cannot be fused by lightning, as carbon and a metal will not fuse together in such cases.

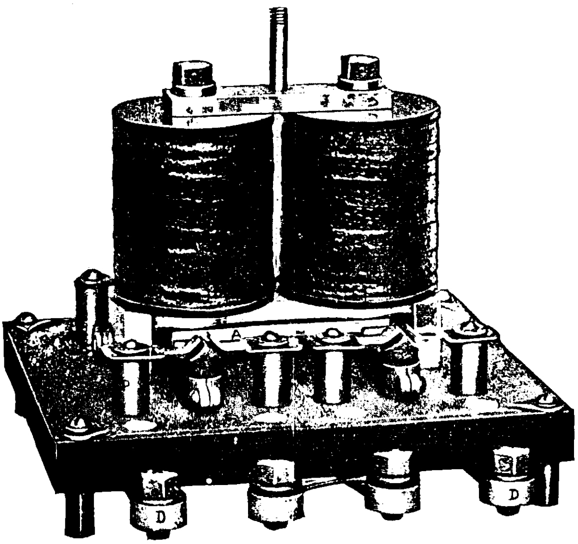

FIG. 124

The advantage of using carbon is that its oxide is a gas; thus it continually presents a clean surface, while the oxide of silver itself is a good conductor.

In order to eliminate the false conditions set up from relay contacts being fused together by lightning, the relay armature arrangement shown in Fig. 125 is used. The armature, *H*, of the electromagnet, *M*, having pole tips, *P*, is pivoted at *F*, and carries a depending member, *K*, at the pivot, *G*. Fastened to *K* is the spring contact strip, *B–E*, which normally is in contact with the connection *A*. When *B*, however, becomes fused to the contact button, *C*, this latter point acts as the pivot, so that when M is demagnetized the weight of H and K causes E to come into contact with D. The signal magnet relay or battery is connected to D and C, so that when E comes into contact with D, it will be short-circuited, as this shunt has practically no resistance. This causes the signal arm to move to the stop position, thereby apprising the maintainer that something is wrong. Otherwise, the presence of a train in the section would not affect the clear position of the signal, since the release of the armature cannot open the circuit at C–B.

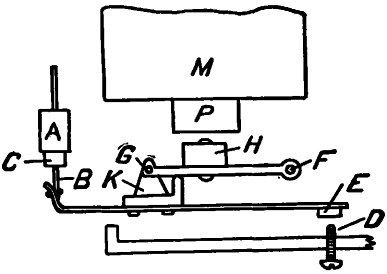

FIG. 125

Great care should be exercised in selecting the proper resistance value to which relays are to be wound, as upon this factor depends in a large measure the life of the batteries to which they are connected. Thus a 700-ohm relay will take but one-tenth of the current that one wound to 70 ohms would. Too high a resistance is not advisable, as the wire then must be of very small diameter, so that the proper number of ampere-turns can be put into the necessarily limited space between the cores. Fine wire is very costly and difficult to wind, while the slightest corrosion or mechanical injury results in an open circuit. Too large a size or wire, on the other hand, involves too great a current input for the production of the proper ampere-turns.

Individual cases require special determination of resistance; so that no fixed rule can be followed. It is sometimes advisable to introduce a German silver resistance spool, having a predetermined ohmic factor, in series with a relay connected to a battery of too high voltage, which is primarily intended for other purposes. Such a procedure should be avoided whenever possible, however, as the energy thus lost in the resistance is wasted. Relays in series must have resistances proportional to the work which they perform. For instance, a relay in series with a disk magnet must have a low resistance relative to that of the latter, otherwise too great a proportion of the available energy would be taken. Relays in parallel must have high resistance so that the changed drop in potential resulting on one or more being thrown in circuit cannot materially affect the others.

Fig. 126 is a plotted curve showing the voltages required to operate standard track-relays of from 2 to 10 ohms resistance. Curve *V* shows the least voltage that should be applied to a given relay of a certain resistance in practice. This curve allows for operation under favorable conditions; with allowance for an average amount of leakage, due to the effects of wet weather, and rail proximity to stone ballast.

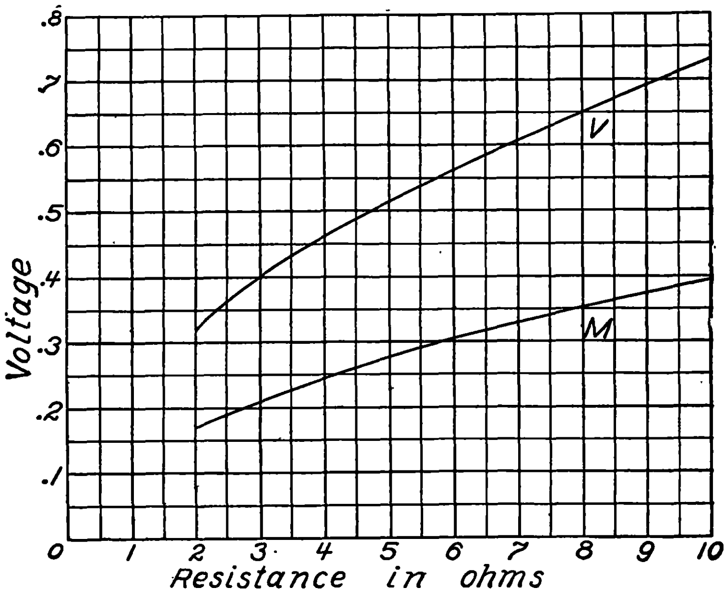

FIG. 126

The curve, *M*, shows the minimum voltage that will lift the armature of the relay and produce contact with the fingers. This voltage curve allows only for a moderate amount of resistance of motion due to friction of the pivots, and will not lift the armature with cobwebs, interference by insects, or other deleterious opposition. On the other hand, the presence of residual magnetism will require a lower voltage for energizing the magnetic circuit; this, however, being an undesirable condition.

There is a sufficient interim of current cessation at the reversal of polarity in a wireless system to throw the signal at danger unless a slow releasing of the control armatures or slots be provided for. The slow-releasing slot is obviously the best solution of this difficulty, as external control fixtures are then not required. The home-slot magnets are therefore constructed with a soft copper tube interposed between the core and the winding, and equal in length to the core. Any change of current in the latter sets up strong momentary eddy currents in the tube, which oppose any change in flux through the magnetic circuit. The magnet is also wound to sufficient ampere-turns to produce a much greater flux than is actually required, so this flux must die down a considerable amount before the armature is released. Should the circuit remain open after the mechanical pull of the armature becomes less than the opposition of gravity or the slot arm, the home semaphore will return to danger.

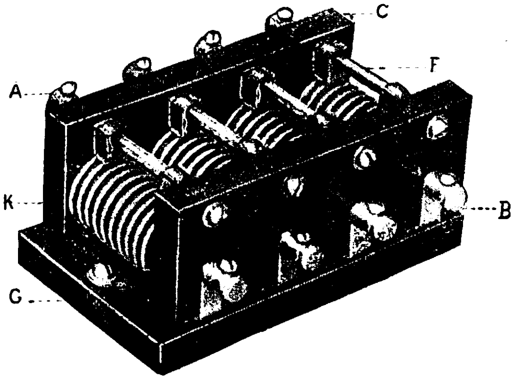

FIG. 127

Important adjuncts in a line-wire system are devices to secure adequate lightning protection. They are particularly required to prevent relay points from fusing together by affording the discharge a shunt circuit to ground of lower impedance than by way of the former. A lightning or other static discharge is in reality a surging alternating current of enormous frequency and short duration. Such a discharge will overcome the high resistance of an air-gap rather than pass around a few turns of coiled conductor, as the latter, at this frequency, offers an extremely high inductance.

A bank of four G. E. lightning arresters is shown in Fig. 127. The lines are connected to the posts, *A*, the instruments to the connectors, *B*, and ground to the plate, *G*. The choke coils, *K*, consisting of a few turns of heavy wire in an insulating form, are in series with the glass tube enclosed fuses, *F*, these latter being removable, and held between clips *C*. A discharge will pass from the points beneath the slate end pieces to the ground plate rather than around the coil. Jumping areas also occur between the lower parts of the convolutions and *G*, thereby increasing the factor of safety.

Another common form of arrester is illustrated in Fig. 128.

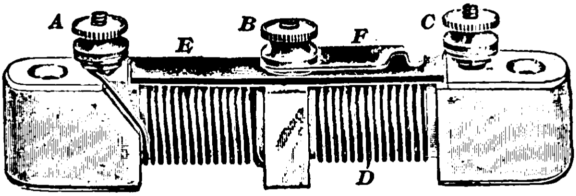

Fig. 128

Upon a porcelain form are wound two connected helices of bare wire, *D*, one end of which is connected to post *A*, and the other end to *C*. *B* is grounded, *A* connected to the line or track wire, and *C* to the instrument or wire desired to be protected. When a discharge enters at *A*, *D* offers such a high impedance that the air-gap between *E* and *D* is bridged before many turns have carried the current, thus conveying it to the ground. When a bank of such arresters is employed the ground plates are connected by the strips, *F*, but one ground wire being used. No provision is necessary to prevent grounding of the battery currents, since they are of too low potential to bridge this gap, as would be the case on a commercial lighting or power circuit.