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# American Railway Signaling Principles and Practices

## CHAPTER XIX
## Electric Interlocking

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# CHAPTER XIX

## ELECTRIC INTERLOCKING

*General.*

Electric interlocking is a type of power interlocking, and as the name implies, electricity is the operating agency. The first electric interlocking was installed in America in 1889. The essential elements for a complete electric interlocking system are a source of electrical energy, a machine with its levers and auxiliary apparatus for controlling switch and signal mechanisms, and apparatus for preventing the unauthorized movement of an operated unit.

In the electric interlocking field, two substantially different forms of interlocking are in present-day use, the difference relating principally to the type of control machine used to operate the plant. The older form employs machines with mechanical locking between levers to guarantee proper sequence in the operation of the levers and uses magnets on the machine levers to effect indication and detector locking, while the newer form employs control machines having miniature free levers or push-pull controllers and are without mechanical locking and indication magnets.

*Principles of interlocking systems using machines with mechanical locking.*

The design of the machines and the controlling circuits is such that the following features essential to safe operation are afforded:

1. No lever can be moved from a given position if another lever mechanically interlocked therewith is in such a position that its controlled unit will conflict with the unit to be operated. Furthermore, due to the mechanical locking being of the preliminary type, before a given lever can be moved from its position, all conflicting levers will be locked to prevent their movement until such time as conditions are proper for them to be released.
2. The movement of a switch lever cannot be completed either to the normal or reverse position until its controlled unit has moved to, and is locked in, the position corresponding with that of the lever. In some cases, equivalent protection is provided through the SS relay permitting lever movement from normal to reverse or vice versa without stopping at the indication point.
3. In the case of a signal lever, one of the following two methods may be employed: require correspondence of position when restoring lever to the normal position by preventing restoration until the signal has indicated that it has assumed its most restrictive position, or provide some means of preventing the initial movement of other levers affecting the route until such time as the signal has indicated that it has assumed its most restrictive position.
4. Each unit, when in a position of rest, is protected against unauthorized operation which might otherwise be accomplished through current being wrongfully applied to its controlling circuits.

*Principles of interlocking systems using free-lever machines or push-pull controller (route-type) machines without mechanical locking.*

The design of the machines and the controlling circuits is such that safe operation is afforded based on the following features:

1. Levers as well as push-pull controllers or buttons are free-working and can be moved at any time but improper manipulation or unauthorized operation of any lever or controller can in no way affect the safety of the system.
2. Generally, operative switch functions can be moved at any time that they are not electrically locked in an established route.
3. Operative signal functions can be moved only when there is an established route.
4. Electrical locking guarantees the integrity of the route and provides that no operative switch function in a route can be moved while locking is effective and no opposing or conflicting function can be operated until the route or sections of it are released.
5. Signals cannot be placed to stop by movement of any lever or controller other than their own respective control device.

Regarding electric interlocking systems employing control machines with mechanical locking, there are two schemes for supplying energy to the operative units in general use, one in which the electrical energy for operating the unit is carried through contacts on the lever and over wires to the unit; the same wires being generally used for the return of the indication current for operating the indication locking. This system, known as the electric dynamic indication system, employs what is commonly known as the dynamic indication principle in which the energy for indication purposes is furnished by a current generated by the momentum of the motor of the operated unit. In the other system, one arrangement of which is known as the Type F, the electrical energy for operating the unit is carried direct to the various units throughout the system by busses or feeders, and a separate alternating or direct current source is used for indication purposes. Each unit is controlled by a local relay or its equivalent constituting a part of the switch or signal, this relay being governed in position by two separate and independent wires leading direct from the control lever in the machine. One or two separate wires, depending on whether signal or switch, carry the indication current from the unit to either the interlocking machine or its associated group of relays, or both.

*Power supply.*

When the switch and signal units are operated by direct current, the supply is usually obtained from a storage battery of 110 volts, which may be charged by electric energy obtained from a commercial source, or by electric current generated at the interlocking system. An additional low-voltage storage battery of 10 or 12 volts is generally used for the control of relays, etc. If low-voltage signals are employed, their operating circuits may be energized from the same low-voltage storage battery. The details for charging storage batteries are described in Chapter IX—Rectifiers and Battery Chargers. When the units are operated by alternating current, the supply is transformed to the voltage required.

Signal lighting energy is usually supplied by transformed alternating current with means provided for transferring to a stand-by source in case of a power failure.

The storage battery with its charging apparatus, together with the switchboard in connection therewith, are usually located in the interlocking station, and are shown in Figs. 1 and 2.

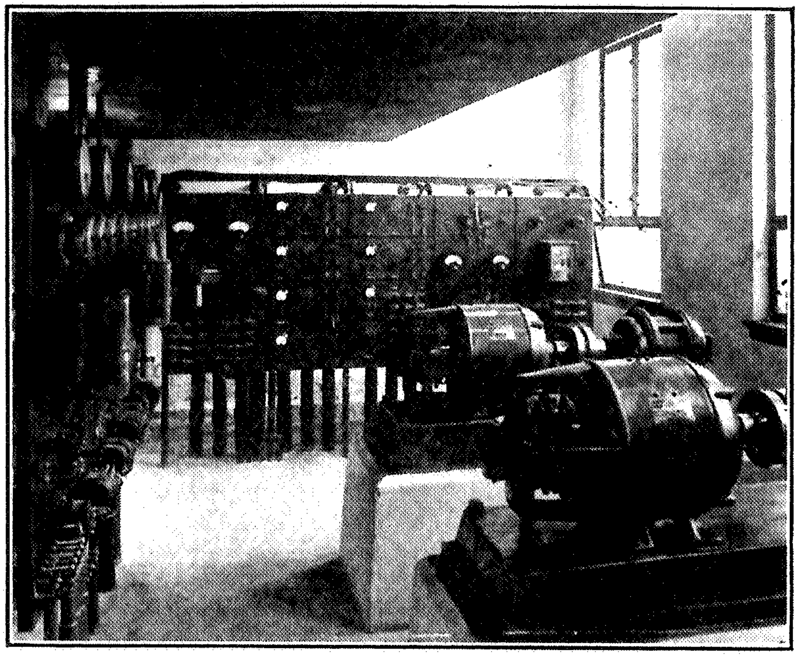


Fig. 1.
Power Switchboards and Motor-Generator Sets at Interlocking Station.

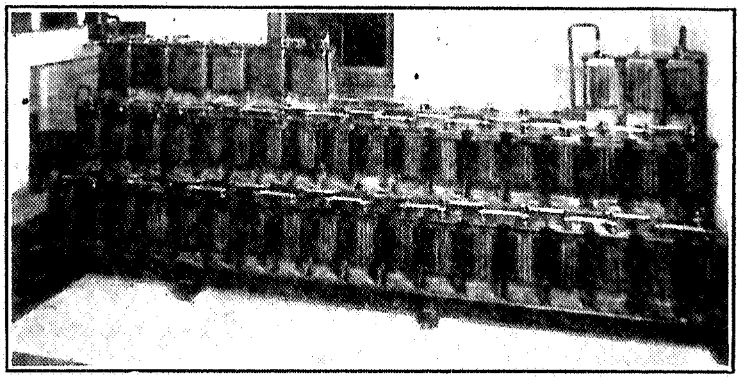


Fig. 2.
Storage Battery and Racks.

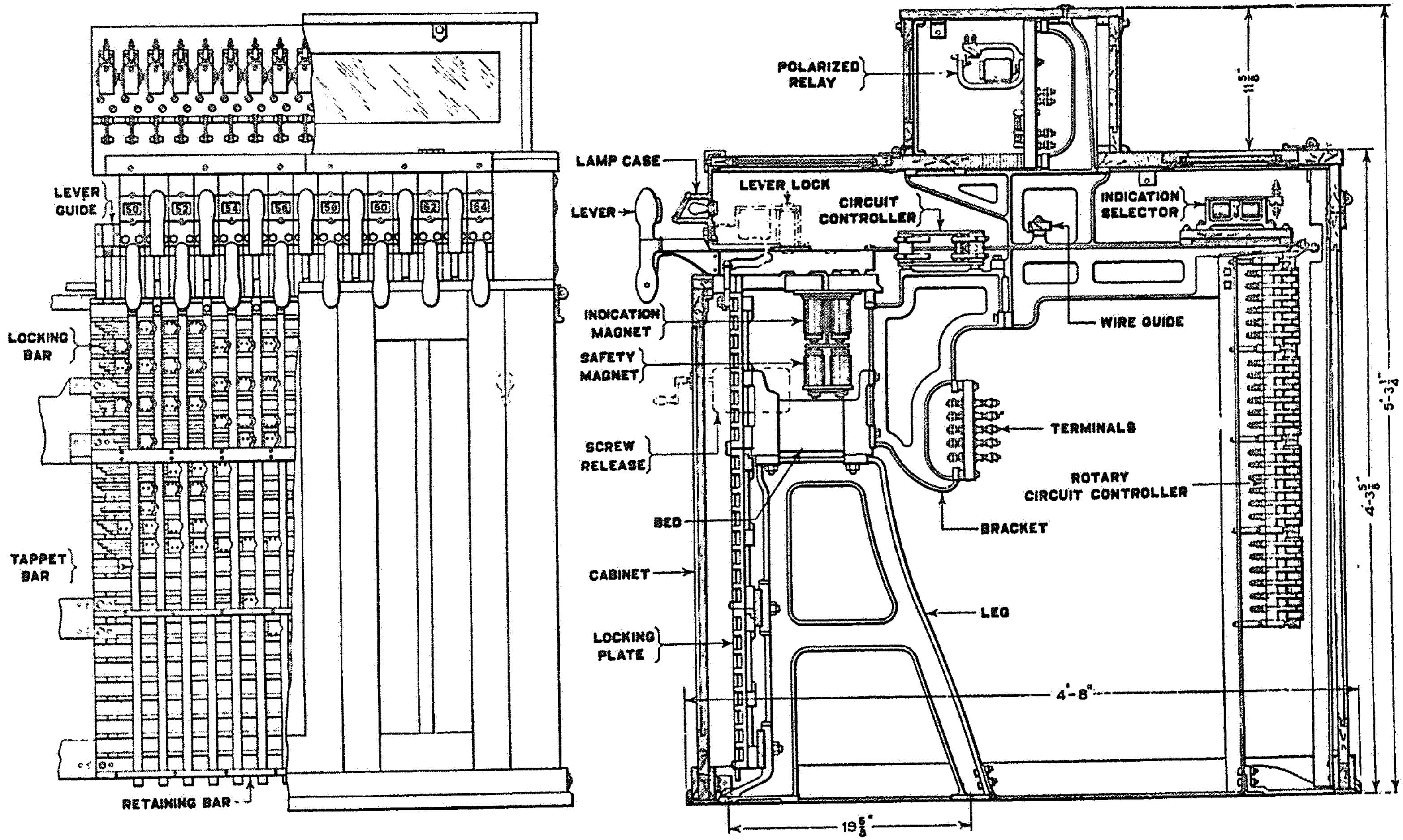
*Electric interlocking machine.*

The Signal Section, Association of American Railroads, defines Electric Interlocking Machine as: An assemblage of manually operated levers or equivalent for the control of power-operated signals, switches or other units.

*Electric Dynamic Indication System*

*Machine, using mechanical locking.*

One type of interlocking machine used in the electric dynamic system is shown in Fig. 3 and is known as the Model 2 unit lever type. Table interlocking machines are sometimes used to control units operated by this system and are described in another portion of this chapter.




(Front View) (Cross Section)

Fig. 3.

Model 2 Unit Lever Type Machine Equipped with Rotary Circuit Controllers.

The interlocked levers with their guides, indication magnets and circuit controllers are mounted in a common frame spaced 2 inch centers, the general practice being to furnish an individual lever for each signal and switch unit. Where two switches are operated together, such as a crossover, the levers are rigidly connected and operated as a single unit.

*Locking.*

The locking is described in Chapter XVI—Interlocking.

*Lever.*

Each lever with its guide, indication magnet, controller, etc., comprises a complete unit in the interlocking machine, the design being such that the unit may be removed from the machine without moving the lever tappet from the normal position or disturbing adjacent levers.

The circuit controller with which each lever is equipped can be provided with a maximum of five tiers of contacts, controlling five normal and five reverse independent circuits. Additional contacts are available on the auxiliary controller at the back of the machine as shown in Fig. 3.

*Lamp case and number plate.*

The combined lamp case and number plate is mounted above each lever as shown in Fig. 4. The number plate is designed to set at an angle which renders it readily visible to the operator when manipulating the levers. Lamps and sockets are furnished only for levers specified. They are generally used in conjunction with some type of electric locking to indicate whether the lever may or may not be moved. If desired, a double lamp case can be furnished to provide two separate indications.

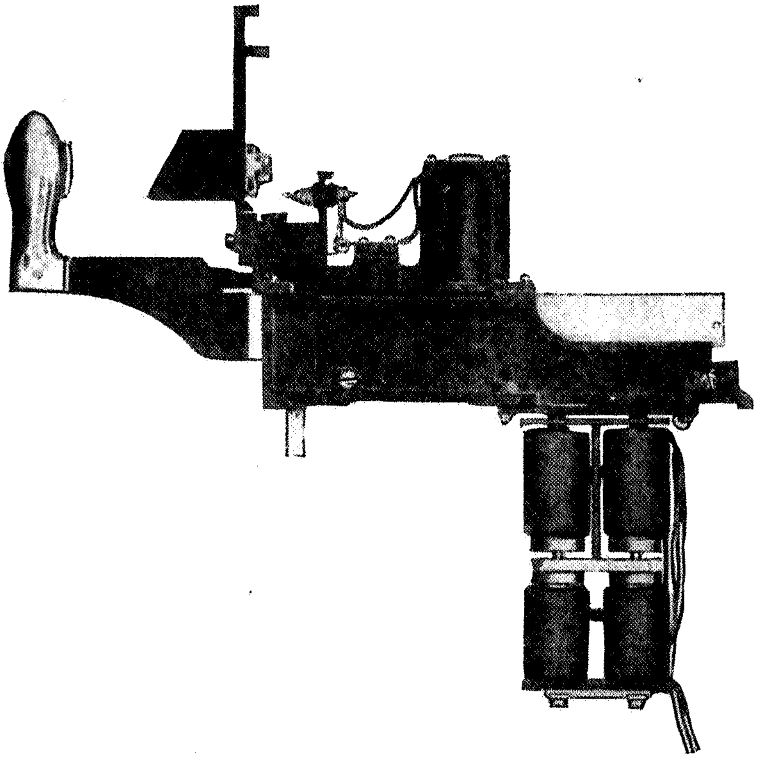


Fig. 4.
Switch Lever Equipped with Lever Lock and Lamp Case.

*Polar relay.*

The polar relay shown in Fig. 5 is provided with a soft iron core which sets lengthwise between the poles of a permanent magnet, the design being such that current passing in one direction through a winding on the soft iron core tends to hold the relay armature normal and the contact closed, while current in the opposite direction tends to "reverse" the armature and cause the contact to open.

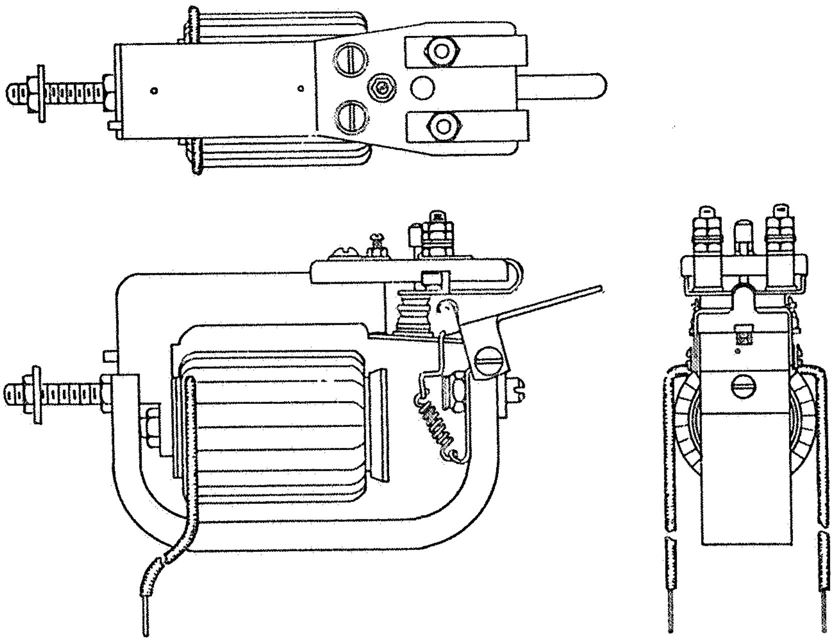


Fig. 5.
Polar Relay.

*Indication selector.*

The indication selector, one of which is used in connection with each switch lever, consists of two electromagnets and a contacting armature which moves in one direction when the lever is reversed, and in the other direction when the lever is normal.

*Lever lock.*

The electric lever lock shown in Fig. 4 may be applied to any lever in the machine and may be provided for operation by direct or alternating current. The lock is designed to be mounted on top of the lever guide, locking the lever in any required position by means of a solenoid plunger, which, when the magnet is de-energized, is forced into a notch cut in the top of the lever. To conserve battery the circuit for the lock is opened through a contact actuated by the lever latch.

*Operation of lever.*

In explaining the operation of the lever its movement may be considered as divided into three parts: preliminary, intermediate and final.

The operation of a switch lever is as follows: each switch lever is provided with a cam slot, by means of which intermittent motion is transmitted to its tappet bar and thence to the cross-locking. In Fig. 6, the dotted circles 1 to 5 in the cam slot indicate the positions assumed by the locking tappet roller.

Contact block Z moves to corresponding positions during lever movement. In the preliminary movement of a lever from position 1 to 2, the locking tappet is moved through one-half of its stroke which locks all levers which conflict

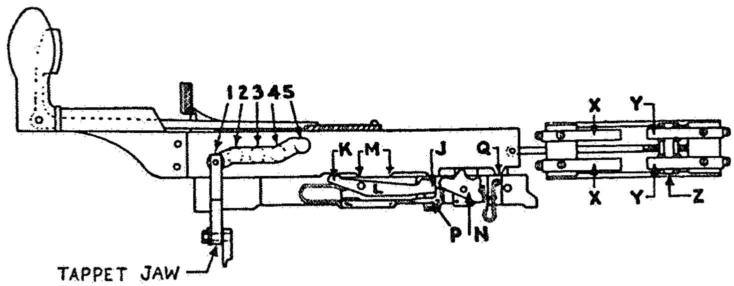



Fig. 6.
Switch Lever In Normal Position.

with the new position of the lever in question; in this movement no change is made in the switch operating circuits. During the intermediate part of the travel from position 2 to 4, the tappet bar remains stationary and contact block Z is moved out of contact with springs YY and into contact with springs XX as shown in Fig. 7, thus setting up the circuits for the operation of the switch. The lever is held at this point, through the mechanical design of the lever until such time as the switch, having moved to a corresponding position, makes it possible for the motor to generate the electric dynamic indication current which effects the release of the lever and permits its movement to position 5. During this final movement from position 4 to 5, the stroke of the locking tappet is completed, unlocking all levers which do not conflict with the position of the lever operated.

The method by which the lever is prevented from completing its stroke until the switch has moved to a corresponding position and has sent in its indication, is as follows: in moving from position 1 to 2, Fig. 6, projection M on the lever coming against projection K on latch L causes the latch to assume the position shown in Fig. 7. This brings projection J on latch L into the path of tooth Q on the lever. In moving from position 2 to 4, tooth Q engages with cam N, rotating it to the position shown in Fig. 7. As it passes the central position it

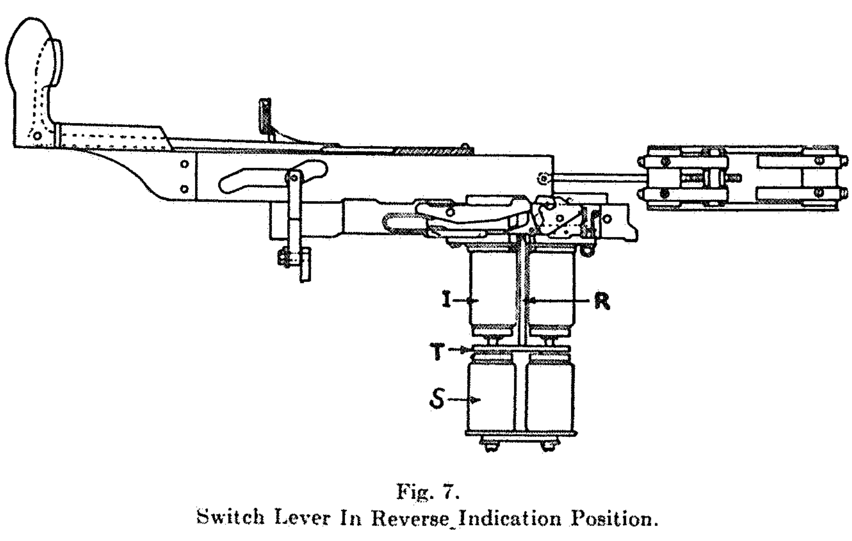



Fig. 7.
Switch Lever In Reverse Indication Position.

comes in contact with dog P which is forced under latch L, thereby locking latch L in the position assumed. The lever is stopped at position 4 by tooth Q coming against projection J on latch L as previously explained. The indication current, flowing through magnet I, Fig. 7, lifts armature T which causes plunger R to strike dog P, Fig. 6, and trip it out from under latch L. Latch L then drops to the position shown in Fig. 6, thereby releasing the lever and permitting its final movement. The movement of the lever from reverse to normal is performed in a similar manner. When the lever has been moved to or beyond position 3, it can neither be moved forward beyond position 4 nor backward beyond position 2 without the receipt of an indication.

The safety magnet S, Fig. 7, serves to prevent receiving premature indication due to a cross between the control and operating wires (NW and RW, Fig. 10), of the switch machine. The operating current through the safety magnet would prevent the operation of the indication magnet which, in the case of the cross, would be in series with the safety magnet.

The movement of the signal lever is identical with that of the switch lever except that no electrical indication is required during the reverse movement, the lever not being checked at position 4 because of a change in the design of dog P, which is mechanically tripped at this point from under latch L by cam N. The mechanical locking insures that before a signal lever can be reversed all levers controlling switches and derails in that route are in the proper position.

*Cross protection.*

The various signal and interlocking units are protected against unauthorized energy by means of the cross-protection system, the principal element of which is the polar relay. All lever contacts which form a part of this cross-protection system are used in the operation of the unit and hence are checked as to their integrity with every complete operation.

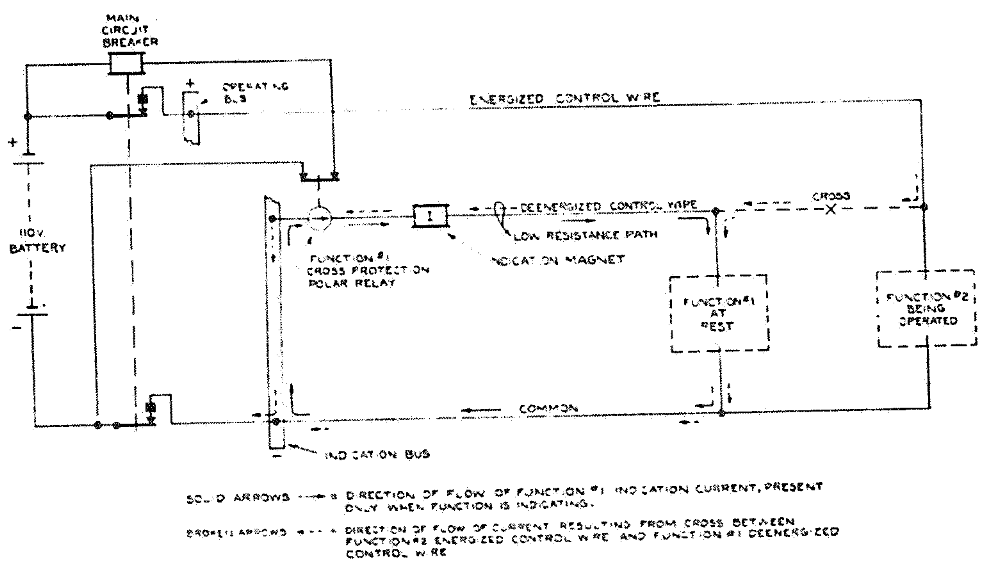



Fig. 8.

Simplified Circuit Showing the Principles of the Cross-Protection System.

All units when at rest are in closed circuits as shown by function #1, Fig. 8. All indication currents from function #1 will flow through the cross-protection polar relay in the direction indicated by the solid arrows. In event of a cross between the de-energized control wires of function #1 and an energized control wire belonging to some other function, as indicated by X, enough current will flow through the polar relay in the opposite direction, as indicated by the broken arrows, to actuate the polar relay to the open position, which will cause the main circuit breaker to open, cutting off operating current from the entire interlocking system or group of functions. Some of the current resulting from the cross will flow through function #1, but owing to the low resistance of the path through the cross-protection relay, plus the practically instantaneous action of the polar relay and main circuit breaker in removing current from the system, no movement will occur at function #1 and the current flow through that function may be considered as negligible.

Another design of interlocking machine using the electric dynamic indication system embodies latch type, mechanical locking (as shown in Fig. 9), two indication magnets mounted one over the other so that two switch machines may be operated from one lever; terminal boards, polar relays, circuit controllers, etc., arranged differently; and the frame so designed as to permit ease of inspection by means of a pit underneath the machine.

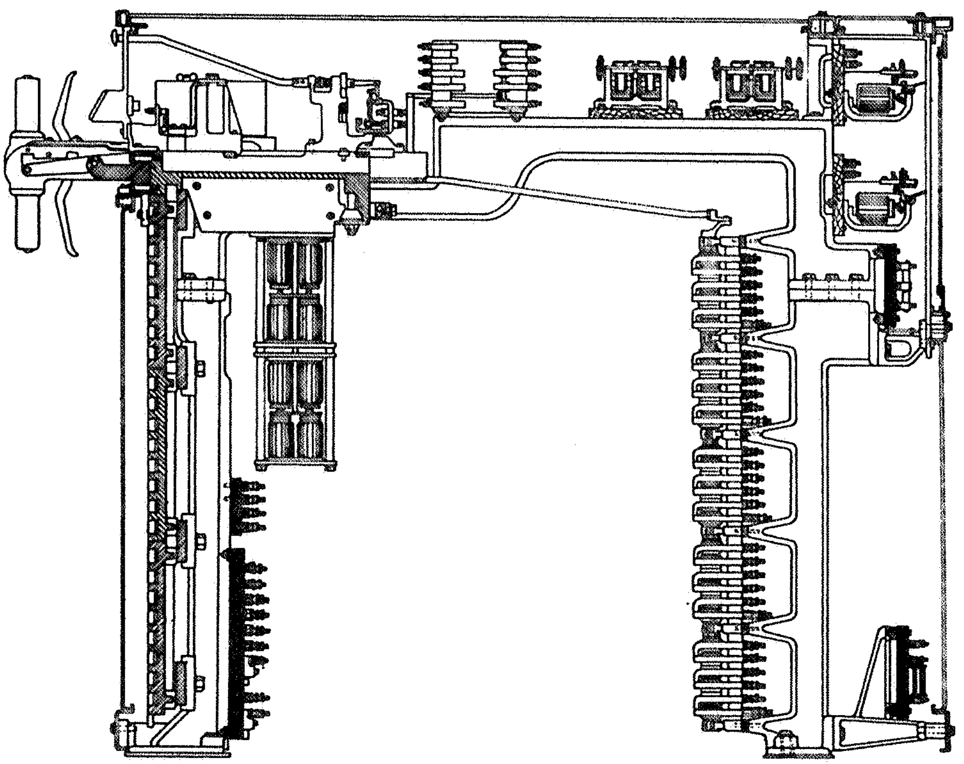


Fig. 9.
Model 5 Type Machine.

*Switch machine control.*

Switch and derail units in this system are operated by switch machines driven by electric motors.

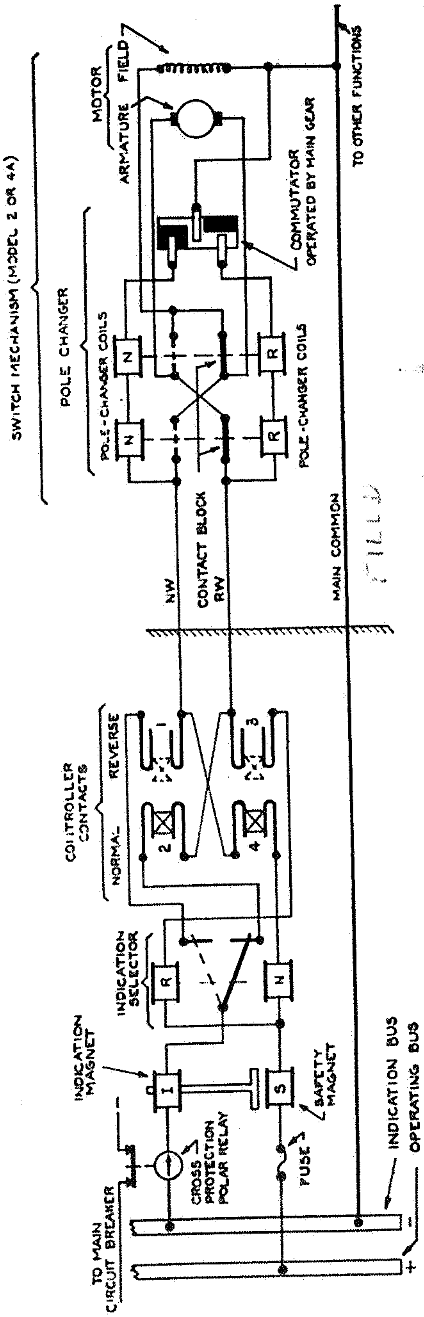



Fig. 10.
Circuit for Switch Machine Using Electric Dynamic Indication With Main Common and With Main Circuit Breaker Controlled by Cross-Protection Polar Relays.

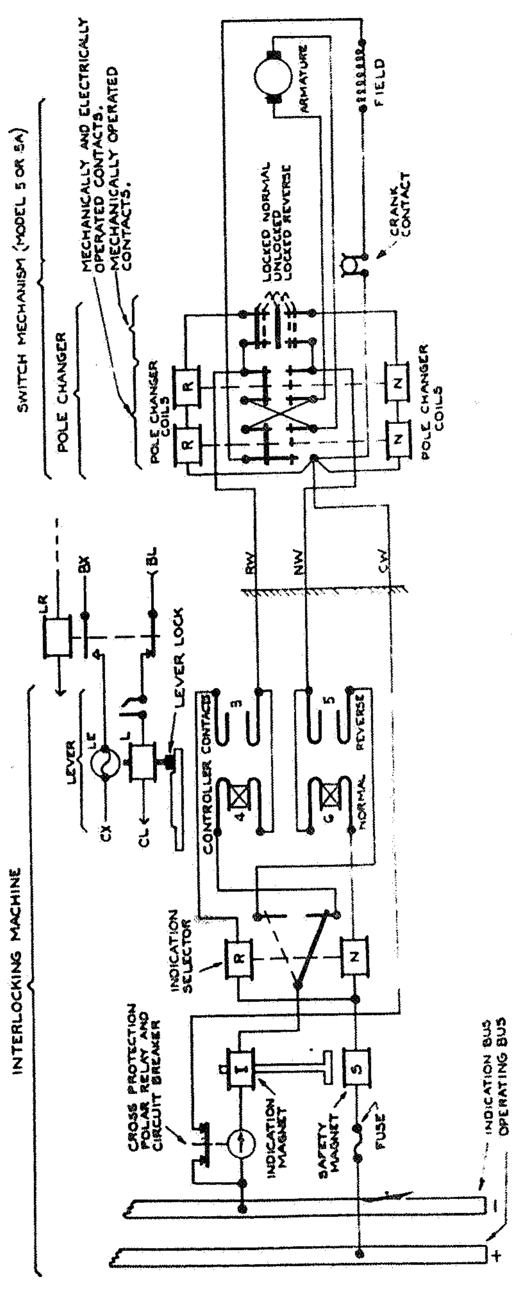



Fig. 11.
Circuit for Switch Machine Using Electric Dynamic Indication and Provided With Individual Return and Polar Relay Circuit Breakers for Cross Protection.

These switch machines require two operating and one common return wire for their operation, one of the operating wires being used for the normal and the other for reverse operation. These wires are also used for indication purposes, the normal control wire being used for the reverse indication and the reverse control wire for the normal indication. The circuit is connected to the common return wire at the switch location, per Fig. 10, or each function is provided with an individual return wire, Fig. 11. The latter circuit represents modern recommended practices.

Considering the earlier practice of using one main common for all functions, per Fig. 10, operation is as follows: when the lever is moved to a position to cause reverse operation of the switch machine (see dotted lever contacts), current is taken from the positive bus bar, through the safety magnet, the reverse coil of the indication selector, lever contact 3, control wire RW, and R contact on the pole changer, the motor armature, through the other R contact on the pole changer, the motor field, and to the common return wire. This causes the desired movement of the switch machine, which performs the following functions in the order given:

1. Switch is unlocked.
2. Switch points thrown.
3. Switch points locked.
4. Current is cut off the motor, the connections to the motor armature reversed for indication purposes and the pole changer coil connections are changed, leaving the machine properly connected for the next movement.

The motor is now on a closed circuit which includes the indication magnet. Because of the momentum acquired during the switch operation, the motor armature continues for several revolutions thus providing means for the generation of the current which energizes the indication magnet and permits the final movement of the lever to be completed. The operation of the switch machine in the opposite direction is accomplished in the same manner.

Changing of the motor operating connections at the end of the switch operation is effected by mechanical shifting of the contact block in the pole changer. The mechanical shift is accomplished by means of a mechanical pole changer movement which checks the position and integrity of the lock rod and locking plunger. In addition to being mechanically operated, this contact block is under the control of two sets of solenoid magnets, so that should the switch not complete its movement the controlling lever may be shifted and, through the energizing of one set of the magnets, cause the pole changer to set up the circuit for the operation of the switch in the opposite direction. This places the machine under the control of the leverman so that should the switch points be blocked with snow, ice, etc., the points may be moved back and forth, frequently dislodging the obstruction, thereby permitting the desired movement of the switch to be completed.

Changing of the pole changer coil connections at the commutator occurs at the approximate end of the stroke and after the locking plunger is engaged. The commutator is driven by the main gear shaft and is so arranged that a snap action occurs as it changes from the one position to the other.

The switch machine is, at all times, safeguarded from improper operation and its lever from improperly indicating as follows: with the switch lever in either its normal or reverse position and the switch machine at rest, the unauthorized movement of such switch machine, because of currents wrongfully applied to its circuit, is prevented by the cross-protection system as previously described. While the lever is being moved to a position to cause operation of the switch it is guarded against premature indication by the mechanical design of the lever.

During the time current is flowing through the lever contacts for the operation of the switch machine, the safety magnet insures against the possible receipt of an improper indication because of an accidental cross between the control wires. The safety magnet is mounted beneath the indication magnet and so arranged that the same armature is actuated by both the safety and indication magnets in opposite directions. The safety magnet coils are connected into the operating circuit in such manner that the operating current flows through them, hence any current flowing through the indication magnet because of a cross between the control wires of the switch machine cannot exceed the current through the safety magnet. The winding of the safety magnet is so proportioned that in conjunction with the above two features, the indication magnet armature will not be lifted by current resulting from a cross.

From the time the lever is moved to the other operating position until the operation of the switch machine is completed, the indication selector further insures against the possible receipt of an improper indication, being so connected that the operating current will attract its armature and close the contact for the reverse indication only when the lever is moved reverse, and close the contact for the normal indication when the lever is moved normal. It should be noted that both the indication selector and safety magnet coils are connected in series with the control circuit, therefore if the circuit through them is not intact, operation of the switch machine will be prevented.

When the motor operating circuit is opened by the action of the pole changer, after the switch has been locked in position, current ceases to flow through the safety magnet. Therefore, the armature of the indication magnet is no longer held down, thus permitting the indication to be effected upon receipt of the dynamic current generated by the motor. The mechanism is now at rest protected against an unauthorized movement in the same manner as before the controlling lever was reversed.

Because of the design of the operating circuits, the magnetic control of the pole changer prevents the switch from being moved by the use of a hand crank from the position occupied, except by opening the operating circuits by some such means as lifting the brushes from the motor. If this is done and the switch machine is operated to a position out of correspondence with its controlling lever, upon replacement of the brushes the switch will immediately assume its proper position. Manipulation of the pole changer by hand will not cause movement of the switch out of correspondence with its lever.

Considering modern recommended practice of providing a separate return wire for each function (CW in Fig. 11), the circuit operation is found to be fundamentally the same as that just described. The main difference lies in the fact that the individual cross-protection polar relays act as circuit breakers, breaking the return path (CW) of any function whose operating circuits may become energized as a result of a cross or some other abnormal condition.

The operation of the pole changer in the switch mechanism (Model 5A) shown in Fig. 11 is basically the same as that previously described, performing the following functions:

1. Opens the motor circuit when the switch points are closed and locked.
2. Establishes the circuit for dynamic indication, permitting the motor to "snub," thereby bringing the machine to rest without shock.

3. Permits the machine, when unlocked, to follow the movement of the control lever (facilitates reversing the movement of the machine from the midstroke position).

The Model 5A switch machine may be provided with a point detector mechanism for the control of a switch repeater relay (or relays) as shown by circuit, Fig. 12.

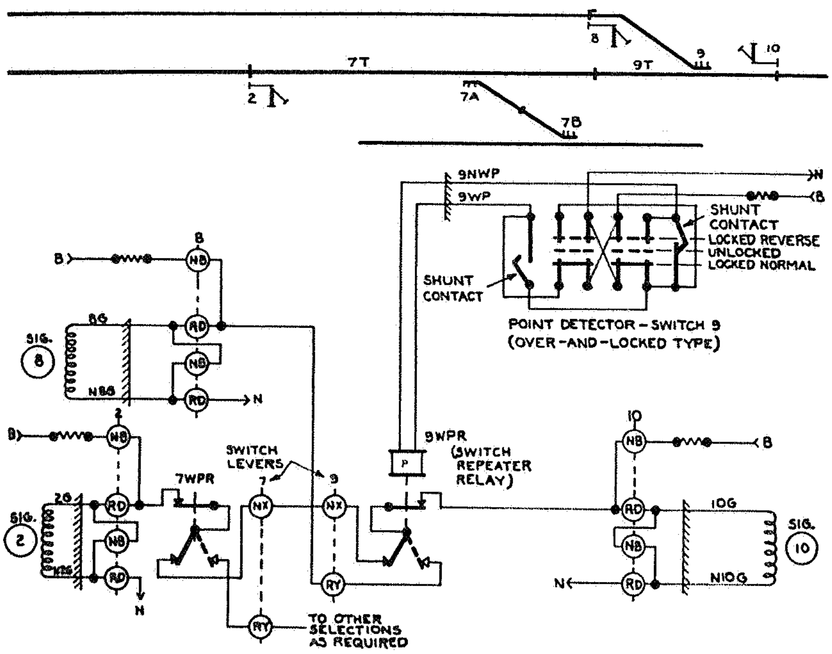



Fig. 12.
Typical Circuit for SS Protection.
Typical switch repeater relay circuit and signal selection network as used with electric interlocking. Note optional circuit using two biased-neutral relays instead of one polarized switch repeater relay. (For accompanying switch control and operating circuit, see Fig. 11.)

*SS protection. (Sometimes called WP protection).*

SS protection is an arrangement of circuits whereby proceed indications of a signal cannot be displayed unless the position of all switches and their controlling levers or equivalent control devices are in correspondence.

This scheme of control is now generally used with power switches where provision is required for the continuous checking of both switch point position and the locked condition of the switch points.

A direct check of the position of a switch may be secured in either of two ways: by breaking the signal controls through circuit controller contacts at the switches or by breaking the controls through contacts on switch repeater relays (WPR, Fig. 12).

For maximum protection, the signal controls are usually taken through opposing signal control levers or equivalent devices, through proper contacts on the switch repeater relays and corresponding levers or control devices for the switches involved, then through the signal lever or equivalent device and outward to the signal. Track, pole-changing and other breaks may be introduced as required. In this way, signal selection is made in the tower and a continuous check is provided as to correspondence of the switch position and its controlling lever or equivalent control device.

SS protection is usually secured by taking the control of the switch repeater relay through indication contacts operated by a point detector mechanism in the switch machine, thereby continuously insuring that the switch points are in proper position and locked. The typical circuit, Fig. 12, shows such a circuit arrangement. Note that this circuit may use either one polarized switch repeater relay or two biased-neutral relays.

In the SS scheme of control, the signal control wires extend unbroken from the interlocking station to the signal. A ground or cross is then a remote possibility, and even if one should occur there would be but slight chance of its being detrimental. Circuit trouble can be quickly located and corrected. The SS scheme of control allows a concentration of parts vital to this reliable control of signals in the interlocking station where they are protected from the weather and other possible damage and where proper maintenance is encouraged by facilitated inspection.

It will also be noted that, with the SS scheme of control, should a switch not respond to a lever movement and through some fault or series of faults the lever movement or equivalent control circuit be completed, subsequent operation of any signal lever cannot cause a signal to display a Proceed indication.

Also, should a switch be accidentally or maliciously changed in position, any signal cleared for train movement over the switch will display its most restrictive indication.

*Signal control.*

Motor-driven signals are operated by mechanisms in which a series-wound motor is directly connected to the semaphore shaft through the medium of low reduction gearing.

The signal mechanisms used are of two types:

1. The non-automatic type, which is entirely under the control of a lever in the interlocking machine. Generally speaking, this type is furnished for dwarf signals and for such high signals that will not require track circuit control.
2. The semi-automatic type, which is operated under the joint control of a lever in the interlocking machine and the track circuits in such sections of track as are governed by the signal. The semi-automatic mechanism is also furnished for non-automatic high signals when there is a possibility of the signal being controlled by track circuits at some future time, or in case it is desired to have uniformity in the type of mechanisms throughout the installation.

Each two-position non-automatic signal requires only one control wire (and a common return wire) for its operation, this wire being used both for operating and indication purposes. When the signal is to operate in three positions, two control wires are required. In the case of semi-automatic control, three wires are required.

*Non-automatic signal control.*

The following description of the operation is based on the circuit shown in Fig. 13 which is for the control of the two-position non-automatic signal mechanism.

Upon reversing the controlling lever, current is taken from the positive bus bar through the lever contacts, the control wire, the operating field and armature of the signal motor, and thence to common return wire through the various

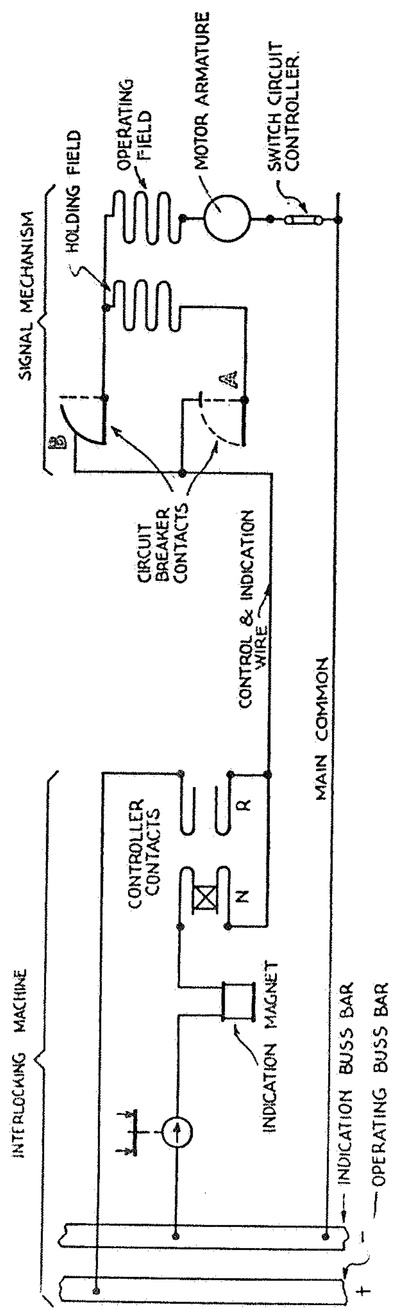



Fig. 13.
Circuits for Control of Non-Automatic Motor-Driven Signal.

switch circuit controllers, as required. This causes the movement of the semaphore arm from the stop to the desired position, upon the completion of which movement circuit breaker contact B opens and A closes, thus connecting the holding field of the motor in series with the operating field and armature. The design of the pole pieces on which the holding field windings are mounted is such that the magnetic flux, thrown across the air gap between the motor armature and the pole pieces, magnetically holds the armature against rotation and thereby retains the signal in the desired position as long as the circuit is intact. Since the holding field windings have a high resistance the current used to hold the signal in this position is reduced to a minimum.

The signal lever is not indicated in the reverse position since no safety features are sacrificed should the signal not assume the proceed position upon reversing the controlling lever.

When the lever is placed in the normal indication position, current is cut off the motor and the signal returns by gravity to the stop position, thus causing the gearing and motor armature to revolve backward to their original position. Contact A opens at the beginning of the movement and contact B closes just before the signal reaches the stop position, thus connecting the motor armature and operating field in their original closed circuit in which is included the indication magnet. Because of the acquired momentum of its armature, the motor (now a generator) produces a dynamic current in this circuit, which effects the release of the controlling lever and permits it to be restored to the normal position. The generation of the indication current effectually checks the speed of the returning mechanism and brings it to rest without shock.

In the case of the three-position signal, operation from the zero to the 45 degree position is the same as for a two-position signal. Operation from this point to the 90 degree position is ordinarily dependent upon the signal in advance. The signal is held in the 90 degree position through the medium of the holding fields in the same manner as in the 45 degree position. When the signal is returning from the 90 degree position and is to be held at the 45 degree position, its movement is arrested at that point by short circuiting a "snubbing" winding on the motor described in Chapter XII—Semaphore Signals, which causes current to flow in this winding, thereby bringing the mechanism to rest. The signal is retained in this position by current flowing through the retaining fields of the motor, as previously explained.

*Semi-automatic signal control.*

When it is desired to have the signal controlled semi-automatically, the operation differs from that previously described in that the first 40 degree movement of the mechanism from the normal position does not effect the position of the semaphore arm, but puts under tension a set of coil springs which are strong enough to rotate the motor on the return movement with sufficient speed to generate the current for energizing the indication magnet on the lever. This preliminary movement of the mechanism is always under the control of the operating lever irrespective of whether the track circuit is occupied or not, the receipt of the indication therefore not requiring the restoration of the lever to the normal position simultaneously with the entrance of a train into the controlling track section. Any movement of the mechanism beyond this point, however, is dependent upon the track circuit or circuits being unoccupied.

Referring to the circuit for a two-position semi-automatic signal, shown in Fig. 14, it will be seen that upon reversing the controlling lever current is taken from the positive bus bar through the lever contacts, the control wire, the signal motor operating field and armature, to common return wire. This causes the operation of the mechanism through its preliminary 40 degree movement to the zero degree position at which point the mechanism will be held against the tension of the coil springs in the event of the track circuit being occupied; this is accomplished by circuit breaker contact $B_1$ opening and $A_1$ closing which connects the holding fields in series with the operating fields and armature of the signal motor. Should the track circuit be unoccupied, the mechanism will not stop at this point but will continue its movement, current being taken through the track relay contact and circuit breaker contact $B_2$; the

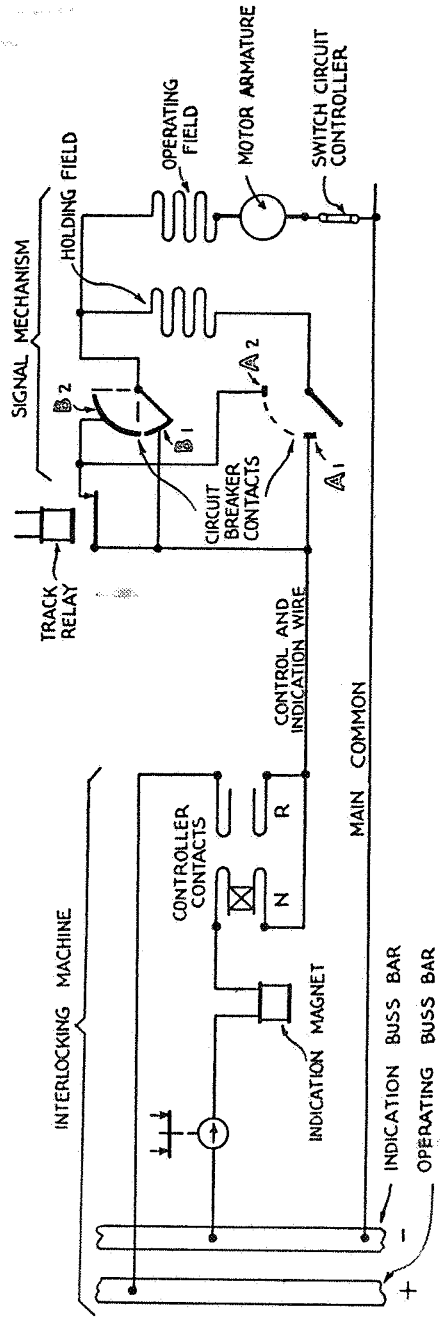



Fig. 14.
Circuits for Control of Semi-Automatic Motor-Driven Signal.

movement of the mechanism from the zero degree position on, carries the semaphore arm with it to the proceed position. Just before reaching the proceed position, circuit breaker contact $B_2$ opens and $A_2$ closes, again connecting the holding field in series with the operating field and armature, thereby retaining the signal mechanism and semaphore arm in that position.

Upon the entrance of a train into the track section controlling the signal, the track relay is de-energized, cutting current off the motor which causes the semaphore arm and mechanism to return to the zero degree position. The speed of the returning mechanism is checked at this point by "snubbing" the motor in the same manner as at the 45 degree position of the non-automatic mechanism. Circuit breaker contact $A_1$ closes, thereby retaining the mechanism in the zero degree position during such time as its lever may be reversed. Sometimes the control is so arranged that a second clearing of the semaphore arm can be secured only after the mechanism has been returned to its minus (−) 40 degree position. When the lever is moved to the normal indication position current is cut off the motor, and the mechanism, because of the tension of the coil springs, is driven to its minus (−) 40 degree position; just before reaching this position circuit breaker contact $B_1$ closes, thus connecting the motor armature and operating field into a closed circuit in which is included the indication magnet. Because of the momentum of the motor armature acquired during this movement, the motor (now a generator) builds up the dynamic current necessary to energize the indication magnet and release the lever, permitting it to be restored to its normal position.

Should the controlling lever be placed in the normal indication position before the entrance of a train into the controlling track section, the semaphore arm and mechanism return to the zero degree or stop position, and the mechanism continues its rotation to the minus (−) 40 degree position because of the action of the indication springs. When within a few degrees of the end of its travel, the dynamic indication for the release of the controlling lever is generated as previously described.

It will be seen that the operation of the signal mechanism, from the time the semaphore arm begins its movement to the stop position until it returns to that position, is the same as that of the non-automatic signal, the indication springs being in no way depended upon to bring the semaphore arm to the stop position.

Where light type signals are used, other means of indication are provided. There are various schemes employed for equivalent control and indication of such signals. Some require no indication or lock magnets on the signal levers and incorporate the desired electric locking in the switch lever lock circuits. Others provide an electric lock on each signal lever, so arranged that the lever is prevented going full normal until the lock is energized, which is possible only when the signal is displaying the stop indication. For different methods used for indicating the stop position of light signals, see Chapter XX—Interlocking Circuits.

### *Type F System*

*Machine, using mechanical locking.*

The interlocking machine used in this system is known as the Model 14 and is described in Chapter XVIII—Electro-Pneumatic Interlocking. A cross-section of this type of machine is shown in Fig. 15.

*Type F switch circuit controller.*

As previously stated, the electrical energy for operating the switch machines of this system is carried direct to these units by means of a pair of bus mains which extend throughout the interlocking area. Each switch machine is controlled by a Type F controller, or, in later installations, by a DP-25 polarized relay referred to later. Type F controllers are operated by current flowing over two wires controlled by suitable circuit controllers operated by an interlocking lever; the wires are used for the exclusive control of switches. A Type F direct current switch circuit controller is shown in Fig. 16. It is housed in a cast-iron box mounted on a foundation adjacent to the switch machine, but independent of the track. Therefore, it is not integral with the switch machine

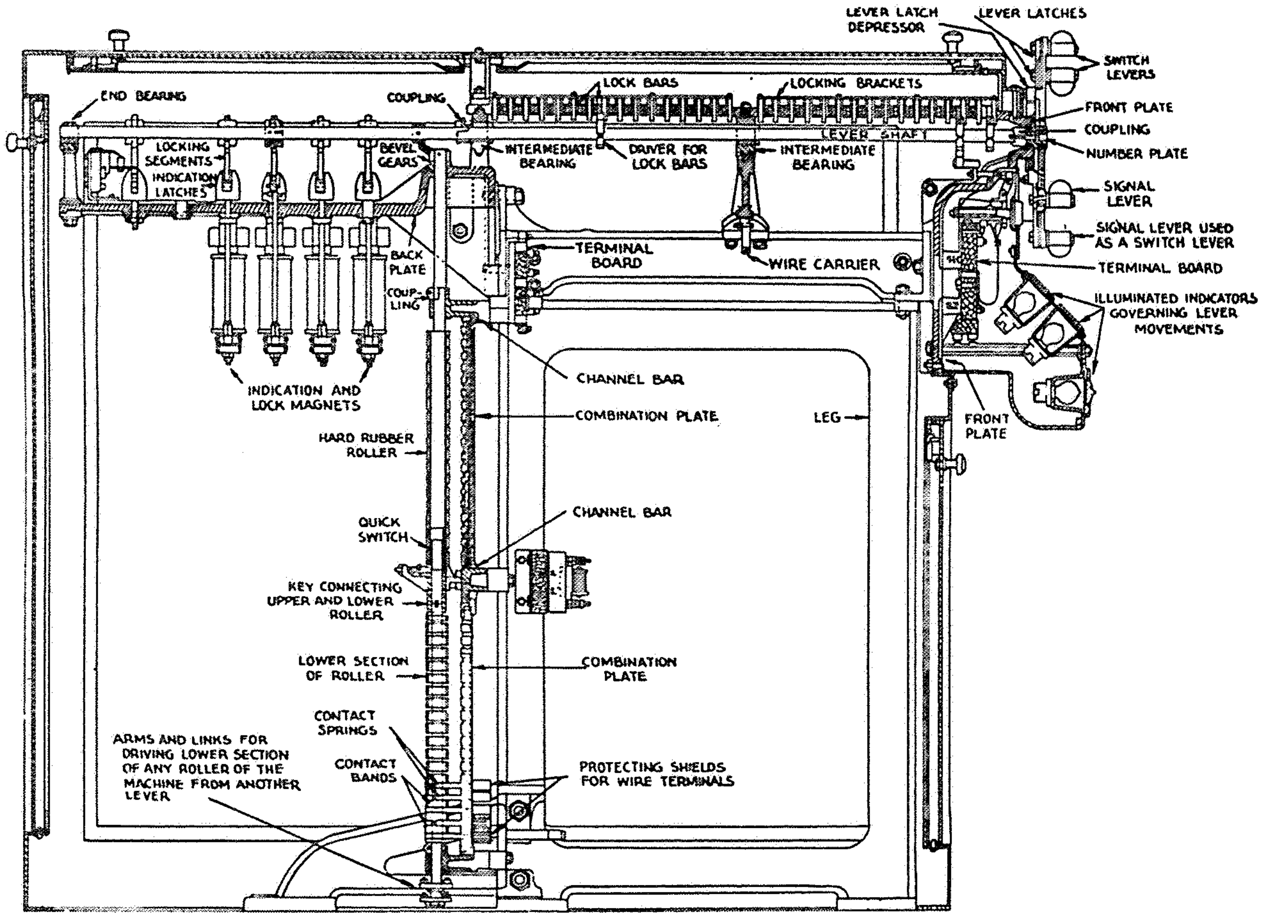



Fig. 15.
Cross-Section of Machine Used in Type F System.

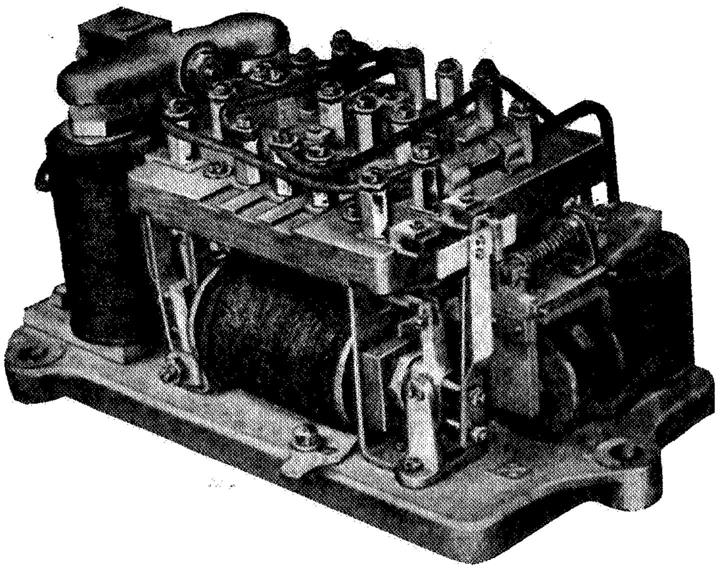


Fig. 16.
Type F Direct Current Switch Circuit Controller.

which, of necessity, is directly connected to the rails and ties. The Type F controller for direct current interlocking is normally de-energized, that is, it requires current only when changing from one position to the other.

In Fig. 17 the various parts of the direct current Type F controller are shown in diagrammatic form. N represents a neutral magnet operating front contacts directly and a contact closed when the magnet is de-energized, by means of a link connection S. Magnet N also actuates a lock on the armature of polar magnet P. This armature determines the position of three sets of contacts used in circuit selection of neutral magnet N and the switch motor. R represents an automatic circuit breaker. The switch motor armature and field are shown by means of standard symbols.

Pole changing contacts actuated by a lever in the interlocking machine are shown as L. Negative battery is connected through a closed contact on pole changer L to wire 1RW, through magnet N, to negative CH. Both terminals of the coils are therefore connected to the same side of battery, that is, there is no drop in potential across the magnet normally and the armature is not attracted.

The operation of the controller will be more clearly understood by following a description of what happens when the interlocking switch lever is moved from normal to reverse, and returned to its normal position. When lever L is moved to the reverse indication position, positive battery from the machine bus will be connected to wire 1RW and current will flow through wire 1RW, contact X, wire W5, to neutral magnet N. Magnet N is permanently connected to negative bus wire CH. The energization of magnet N causes its armature to be attracted, closing contact between wires 1RW and W6, W7 and BH, and opening the connection between wires 1W8 and BH.

Current will then flow from wire 1RW through front contact operated by magnet N, wire W6, polar magnet coils P1 and P2, wire 1NW, lever contact L, to negative machine bus. It will be noted that the rectifier-resistance circuit in multiple with the polar magnet coils P1 and P2 reduces the current in coil P1 but increases the current in coil P2 of the magnet which attracts the polar armature on this operation. This results in a stronger torque on the armature

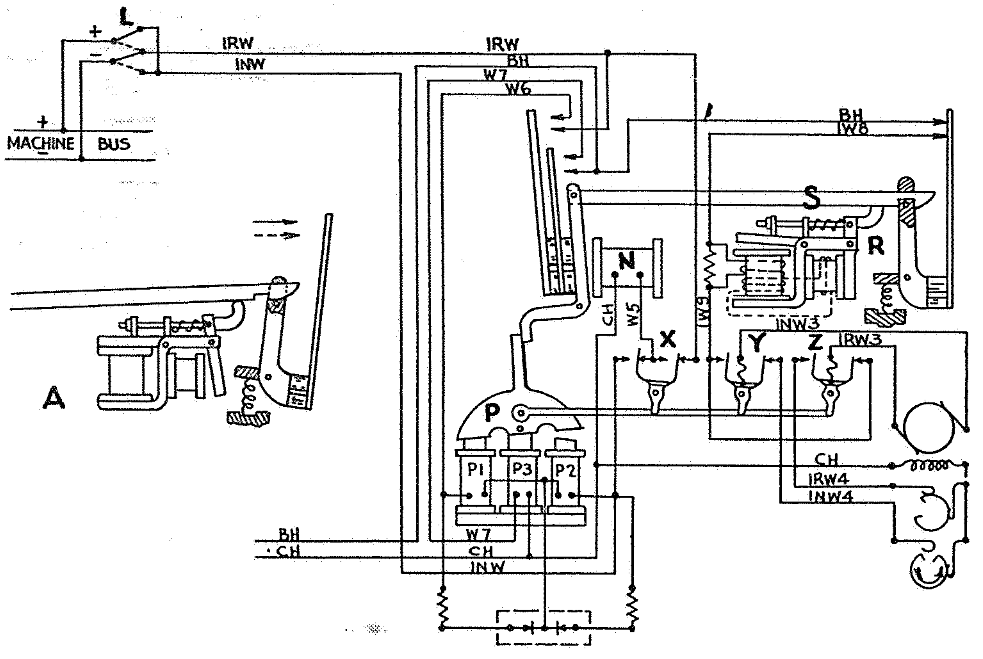



Fig. 17.
Diagram of Circuits for Direct Current, Type F Controller for a Single Switch.

and provides for positive operation over a wider voltage range than obtainable without the rectifier. It will thus be seen that the operating circuit for the Type F controller does not include a common return wire but is a separate metallic circuit going out over lever contacts on one wire and returning over the lever contacts over another wire. A local circuit through the other front contact operated by magnet N is also closed for the purpose of energizing magnet P3, the function of which is similar to that of the permanent magnet used in a polar relay. By electrically energizing this magnet during operation, a much higher energization can be obtained than would be possible with a plain permanent magnet. There is, however, a permanent magnet core in this coil which acts to hold the polar armature in its extreme operated position to allow it to be locked when the armature of magnet N drops. Current flowing in the direction stated will cause the polar magnet to be energized and shift polar armature P which causes contact X to change over the connection for neutral magnet N from wire 1RW to wire 1NW. Magnet N will then be connected to negative machine bus through lever contact L, and to negative bus CH at the magnet. This will result in its de-energization, and when the armature drops, polar armature P will be locked mechanically in its reverse position with its magnet de-energized. The other two sets of contacts actuated by polar armature P will be so connected to the switch motor armature and field that current will flow through the following path: positive bus BH, back contact of neutral magnet N, wire 1W8, primary coil of motor circuit breaker R, wire 1W9, circuit controller contact Y, wire 1NW3, motor armature, wire 1RW3, circuit controller contact Z, wire 1RW4, motor cut-out circuit controller contact, motor field, to negative bus CH. The switch motor, in revolving, will cause the switch points to be unlocked, thrown and locked in the reverse position, the final movement also resulting in the motor circuit being opened at the motor cut-out circuit controller.

It will be noted that before current can pass through the switch motor and cause reversal of the switch movement, the neutral magnet N must be de-energized, this in turn causing polar magnet P to be de-energized. Thus the energization of these magnets is momentary and the amount of power consumed is negligible. When the switch has completed its movement and is locked mechanically it completes the reverse indication circuit allowing the switch control lever to be moved to the reverse position.

The movement of the switch from reverse to normal is accomplished by moving the lever to the normal indication position, thus completing the circuit shown in full lines at L. The current will pass through contact L, wire 1NW, circuit controller X, wire W5, neutral magnet N, to negative bus CH. While magnet N is energized the circuit for polar magnet P will again be completed, but in such a way that current will pass through coils P1 and P2 in a reverse direction to that previously described. This will cause the polar armature to be reversed in position, which in turn will actuate circuit controller springs X, causing neutral magnet N to be de-energized, since it will again have both sides connected to negative bus, because wire 1RW is connected to negative at the interlocking machine.

Contacts Y and Z, actuated by polar armature P, will cause current to flow through the motor armature in a direction opposite to that when the switch movement traveled from normal to reverse. Contact will again be opened at the motor cut-out circuit controller when the switch points have moved normal and locked. The controller springs will then be in the same position as shown in Fig. 17.

As soon as the motor starts to unlock the switch, the motor cut-out circuit controller contacts are shifted to the middle position and remain there until the switch is reversed and locked when the contacts are moved to the reverse position. The reason for the motor cut-out circuit controller maintaining both circuits closed in the middle position during the entire movement of the switch is to allow for reversal of the switch by the lever at any time during its movement, if desirable, so as to repeatedly attempt to crush snow or ice which might prevent the switch point being moved against the stock rail and locked in that position.

The automatic overload circuit breaker R is worked on very much the same principle as the overload circuit breakers on power switchboards, except that it is made with a slow pick-up, and a resistor is permanently connected across the terminals of the primary magnet to provide an inverse time delay characteristic, that is, the time required for the circuit breaker to open on overload is inversely proportional to the value of the current in the switch motor circuit. This circuit breaker consists of two magnets with armatures which are pivoted separately, but are jointly connected to a detent or tripping arm which, when raised, releases the hook, connected to the neutral magnet armature, from the back contact member of that magnet, allowing this contact to be forced open by a coil spring. When the motor circuit is first closed, there is a heavy surge of current through it, because of the low resistance of the motor and the fact that the counter electromotive force has not had an opportunity to build up, but as soon as the motor speeds up the counter electromotive force approaches the value of the impressed electromotive force and therefore the current is reduced to what is usually known as the motor operating current.

If an ordinary overload circuit breaker were employed, adjusted to open for a heavy current, the momentary current previously mentioned would trip the breaker every time the motor started. To prevent this, the circuit breaker magnet to the left, which is called the "primary" magnet, has a double winding and functions like a transformer. When the first strong surge of current passes through this coil, there is induced in the other winding on the same coil an electromotive force generally proportionate to the rapidity of the rise of the current in the motor circuit. This electromotive force is impressed on the magnet coil to the right, called the "secondary," sending a current through it which assists in holding the armature against the pole face. As soon as the current ceases to change in value, there will be no more current induced in the secondary coil of the primary magnet, and hence no magnetic attraction of the armature by the secondary magnet, so that if the current in the primary coil continues at too great a magnitude the primary magnet is then unopposed by the secondary magnet and the armature lifts the detent which releases the back contact of the neutral magnet N. However, if the surge is reduced to normal within a reasonable time, the attraction of the armature by the primary magnet will not be sufficient to overcome the spring and the motor circuit will not be opened.

If the breaker opens due to high current for an excessive length of time it can be restored by throwing the interlocking machine lever to its opposite indication position. In doing this, the neutral armature is again attracted, the hook engages the back contact member and upon subsequent de-energization of the neutral magnet the circuit breaker is reset for another movement of the switch.

In recent installations, the Type F controller generally has been replaced by the DP-25 polarized relay (typical circuits are shown in Fig. 18), and the overload protection is provided by means of an OR-11 relay for all direct current electric switch movements. The DP-25 relay and the OR-11 relay are mounted in a cast-iron box at the switch similar to the box used for the Type F controller. There is also a similar arrangement using the DP-25 relay and the OR-20 overload relay to provide low-voltage direct current control and alternating current operation for 25 or 60 cycles a.c. switch movements. For 110 volts, 100 cycle alternating current movements, the alternating current Type F controller is used and a rectifier is supplied to convert the alternating current power to direct current for operation of a direct current switch motor. Overload protection is provided by an OR-20 relay.

### *Switch Indication Circuits*

The switch indication circuits are somewhat similar to the polarized switch indication circuits described in Chapter XVIII—Electro-Pneumatic Interlocking. Two types of indication circuit are used, one employing the "quick switch," also explained in Chapter XVIII, and one in which the quick switch is not used. The indication segments used on the switch levers are also the same as those used on the electro-pneumatic machine. The elimination of the quick switch affords a certain increase in flexibility of plant operation in that if a switch in moving to a new position fails to indicate, the switch lever can be moved back to the indication point of the original position and if the switch movement follows and indicates the lever can be restored to its original position. With the quick switch the switch lever would be held between the indication points if a switch failed to indicate in going to the new position. By restoring a switch to its original position it is often possible to develop a route over the switch in this position and thereby not unnecessarily delay traffic. When eliminating the quick switch, the main change in the indication circuit outside the interlocking station is the inclusion of checking contacts in the

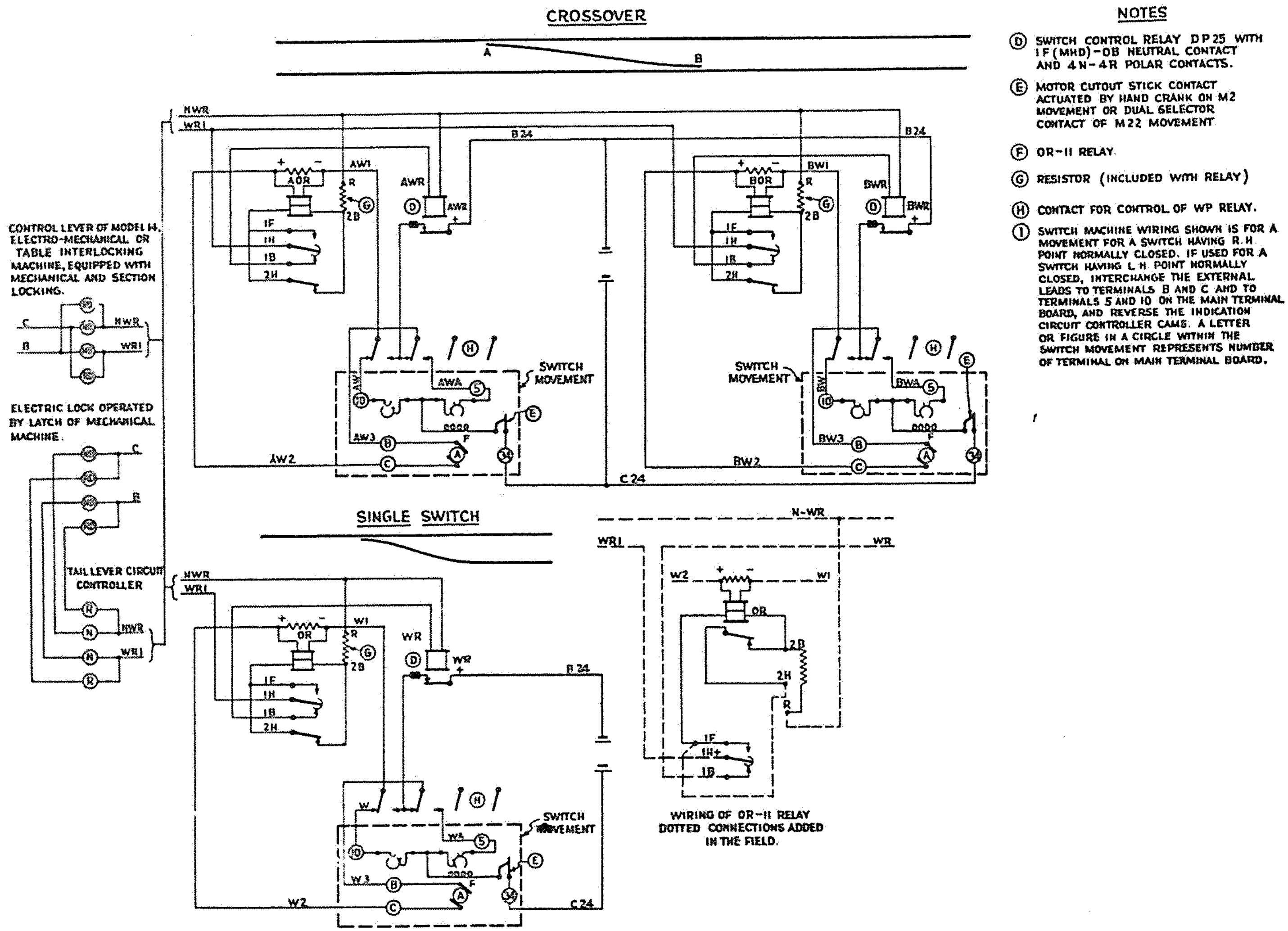



Fig. 18.
Switch Control Circuit for Single Switch Using DP-25 Relay.

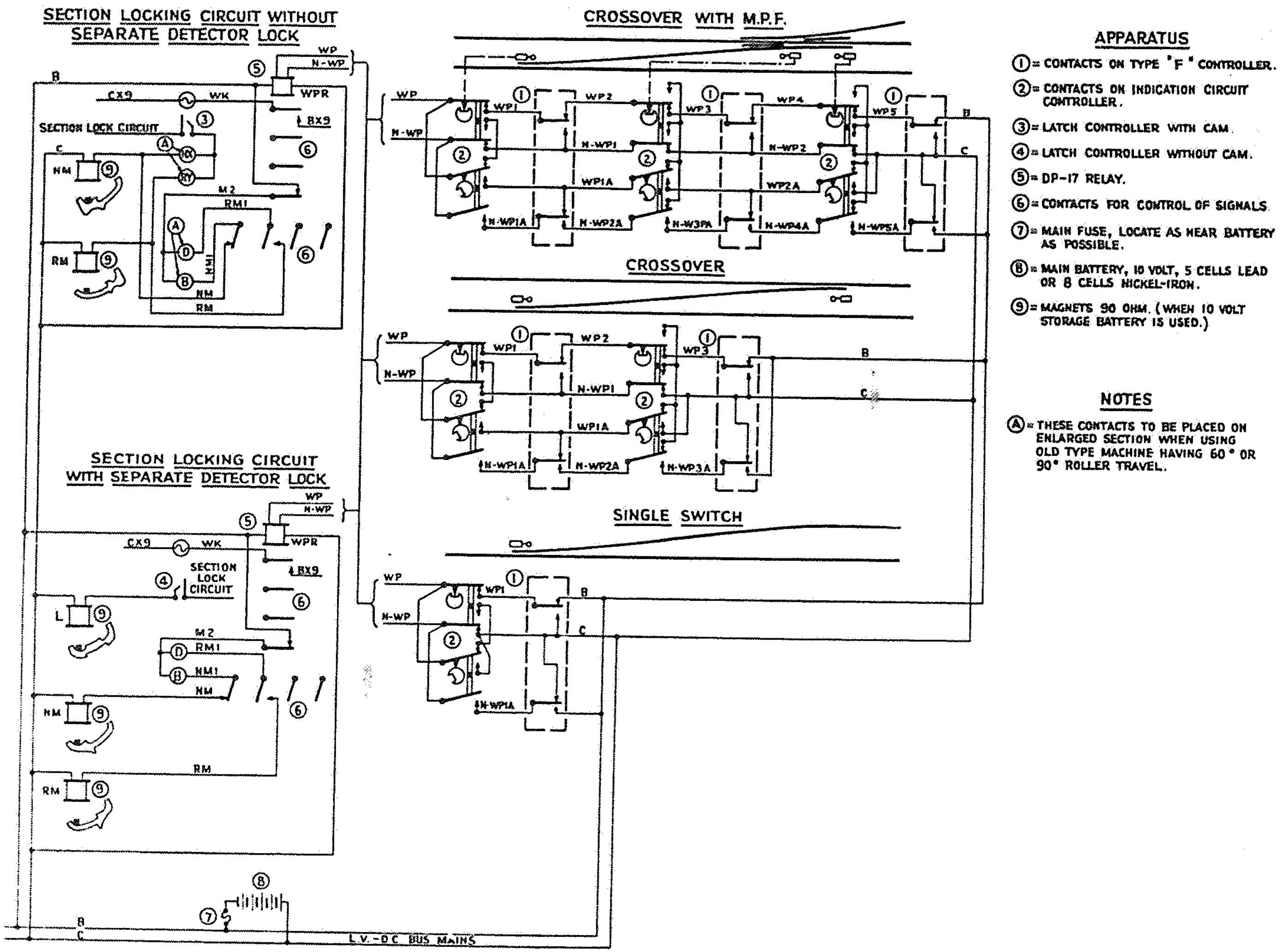



Fig. 19.
Switch Indication Circuit for Crossover Without Quick Switch.

Type "F" controller, which insures that the controlling device and the switch machine are in corresponding position before the indication can be received. A polar contact on the DP-25 relay is used to give the same check when that relay is used.

The circuit as illustrated in Fig. 19 shows the Type F controller contacts closed in normal position. The contacts shown open are closed when the controller is in the reverse position.

The indication circuit in the interlocking station is somewhat different from that using a quick switch. The normal indication takes battery through a front neutral contact of the WP relay, wire M2, through a B contact on the switch lever, wire NM1 through normal polar contact on relay WP, wire NM to normal indication magnet to common return wire. The reverse indication takes battery through the same neutral front contact of the WP relay, wire M2 to D contact on the switch lever, wire RM1, through reversed polar contact of relay WP, wire RM to reverse indication magnet to common return wire.

A single switch is wired similar to the near end of the crossover, except positive battery is applied to the terminals as shown in place of wires WP2 and N-WP2A, and common is applied in place of wires N-WP1 and WP1A. The remainder of the circuit is the same as for the crossover.

By eliminating the quick switch and installing the checking contacts in the Type F controller, it is not necessary to complete the stroke of the lever to normal or reverse position before returning it to its original position. In other words, if the lever is moved from normal to reverse indication position and the switch does not indicate, the lever can be returned to the normal indication position and if the switch locks in the normal position the lever can be returned to normal position, whereas with the quick switch it would be necessary to place the lever in reverse position so that the quick switch could operate and close the normal indication circuit ready for the next operation of the lever, as explained in Chapter XVIII—Electro-Pneumatic Interlocking.

*Cross protection.*

The separation of the indication circuit of each switch from electrical contact with any part of any other circuit between the switch and the interlocking machine is the first step in providing cross protection; the use of individual polarized control circuits for each switch or set of switches operated by a single lever is the second step; the use of a current of one polarity for indicating one position of the switch and a current of the opposite polarity for indicating the other position of the switch is a third safeguard; means for short circuiting the two indication wires at the switch until it is properly locked in one or the other of its extreme positions constitutes the fourth protection; the fifth step embraces the use of a polarized indication relay at the interlocking machine so adapted as to control jointly the current supply to both the indication magnets of a switch lever and all signals governing traffic over the switch or switches operated by the lever. Cross-protection is inherent in the circuits employed and does not require the use of cross-protection devices.

*SS protection.*

SS protection as described earlier in this chapter is, of course, an inherent feature of Type F interlocking.

A Type F alternating current switch circuit controller is shown in Fig. 20. It is similar to the direct current type except that it is normally energized and does not have an automatic circuit breaker. Any overload on the switch

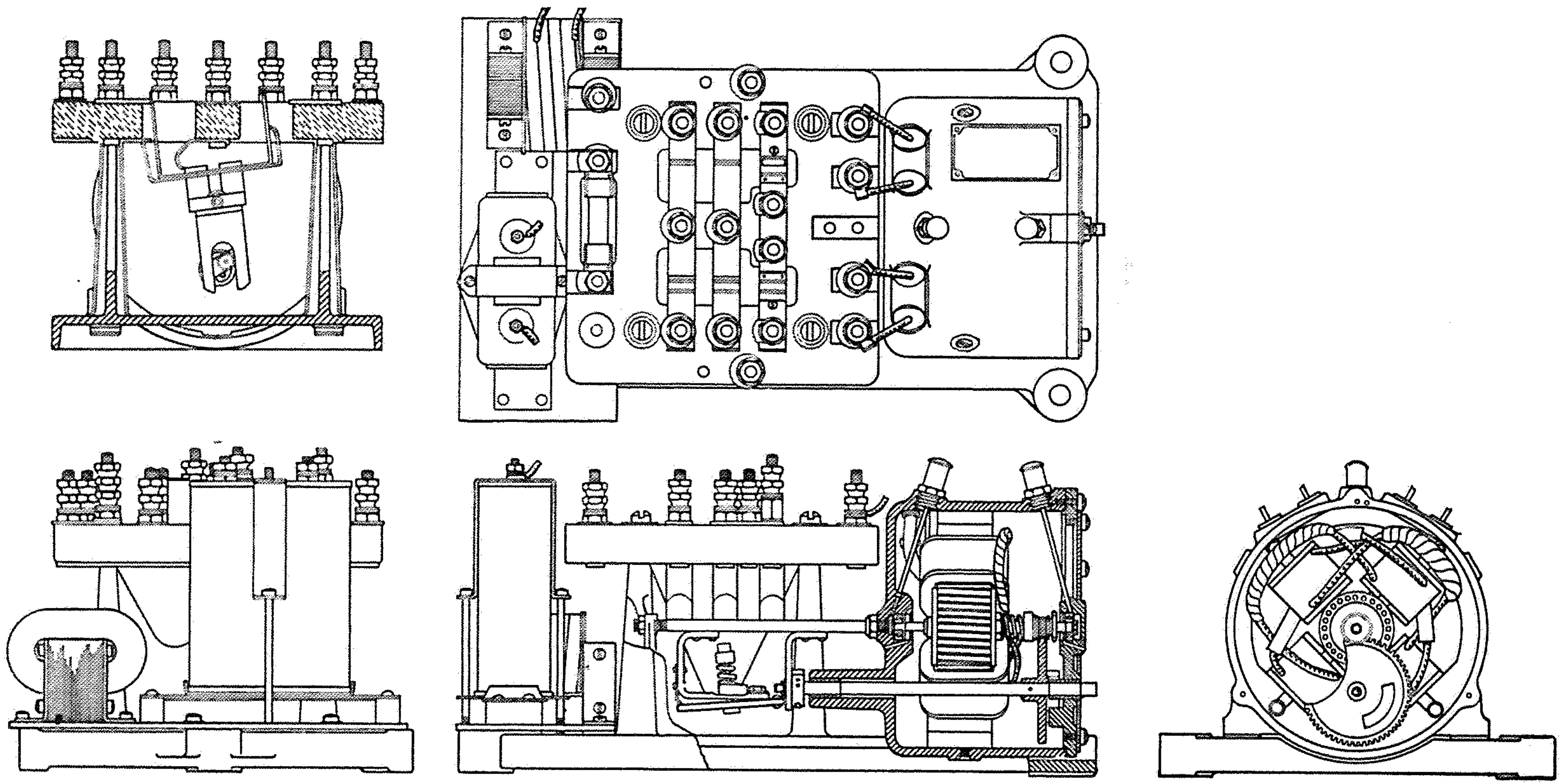


Fig. 20.
Type F Alternating Current Switch Circuit Controller.

machine was taken care of in earlier installations by a fusible link cut-out in the motor circuit. In recent years the OR-20 overload relay has been supplied, which provides an automatic reset feature. The contacts of this controller are operated by a salient pole induction motor, the stator of which has four coils, each pair of opposite coils being connected in series. One pair of coils constitutes the local element and is connected to local alternating current energy at the switch through a series reactor and with a capacitor in multiple. The other pair of coils constitutes the control element and is energized from the pole changing contacts on the switch lever in the interlocking machine through a series resistor. When the switch lever in the interlocking machine is moved to the opposite position, it causes a change in the relative polarity of the two windings on the stator and causes the rotor to rotate and thereby moves the contacts of the controller to the opposite position and operates the motor of the switch machine. The torque of the rotor is great enough to insure sufficient contact pressure on the controller contacts. The controller is so designed that once it has been moved to either energized position, a toggle action in conjunction with the contact spring pressure will hold the contacts closed without depending on the energization of the controller windings. In this way a switch restoring circuit is maintained even though the control circuit or the local circuit of the controller should become open. A buffer is provided on the contact bar to prevent reversal in case control circuit becomes open under the abnormal condition of the preceding operation not being complete due to low voltage so that the contacts were not locked by the toggle action.

An earlier type of this alternating current switch circuit controller, known as the shuttle type, was operated by a motor consisting of a bi-polar laminated field magnet with a coil and wire wound shuttle type rotor. The winding of the rotor was permanently connected to the alternating current mains and the coil on the field was connected to the pole changing contacts of the switch lever.

*Switch and signal levers.*

Figure 21 shows a perspective diagram of a complete switch lever, and Fig. 22 shows a signal lever. Both of these, as well as their operation, are described in detail in Chapter XVIII—Electro-Pneumatic Interlocking.

### *Table Machine, Using Mechanical Locking*

The table interlocking machine is used for the control and operation of electric interlockings. It generally is used for controlling a small number of units at locations where the space available for the control machine is limited. As the name implies, it is a small interlocking machine that may be placed on a desk or table and is composed of one or more assemblies approximately 6½ inches wide, mounted side by side and the levers interlocked, if required.

Generally, each assembly comprises the following apparatus in addition to the lever: one circuit controller usually with 10 or 12 contacts, 1 forced drop electric lock, and 4 indicators.

When more than one assembly is used, they are mounted on sub-bases and the bases bolted together.

Table machines of the type shown in Fig. 23 have been supplied with a track model front as illustrated in Fig. 24. As shown, the track model includes track circuit section, approach, and "signal clear" indication lights; also push buttons for auxiliary controls.

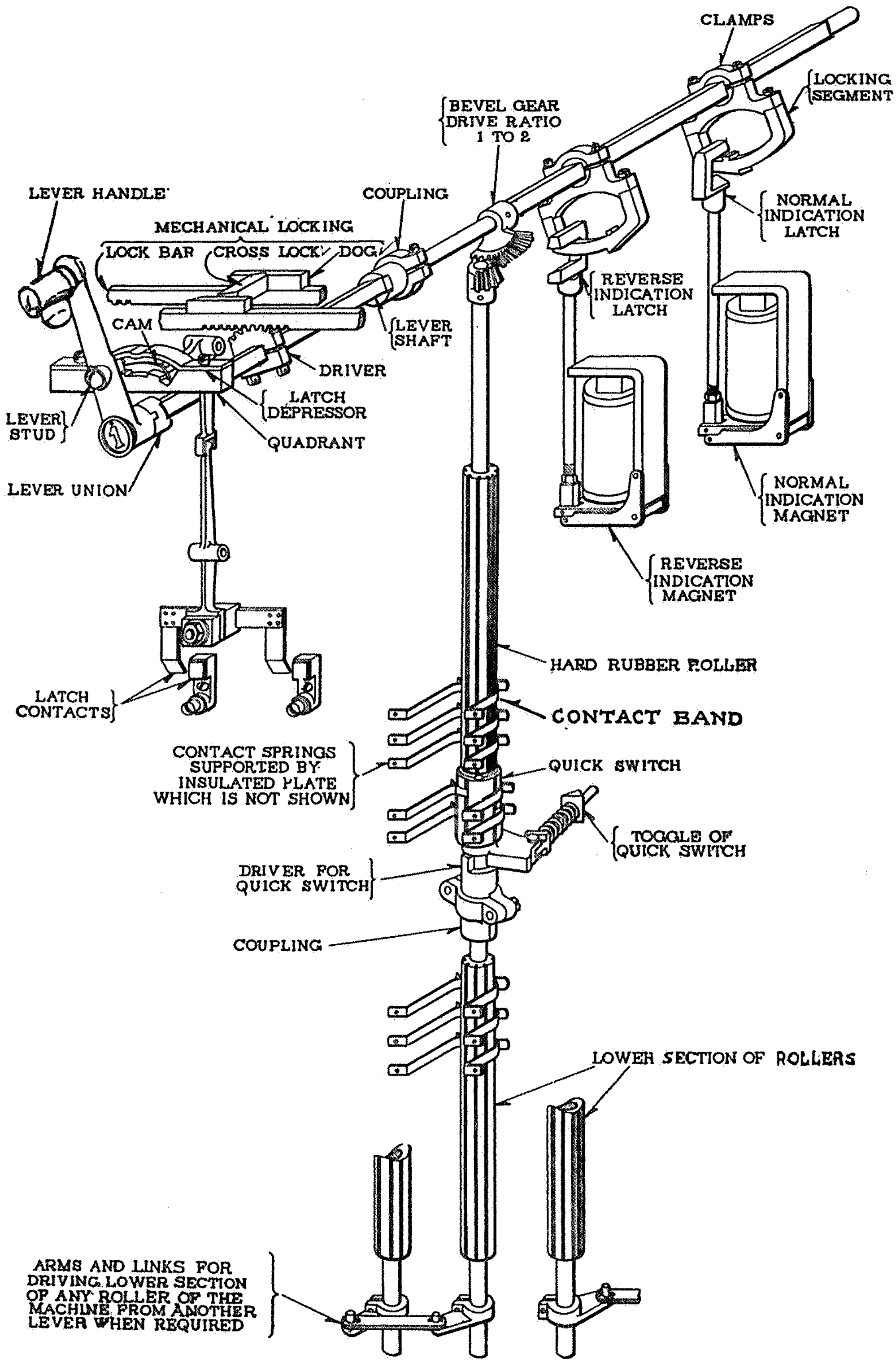



Fig. 21.
Perspective Diagram of Switch Lever, Complete.

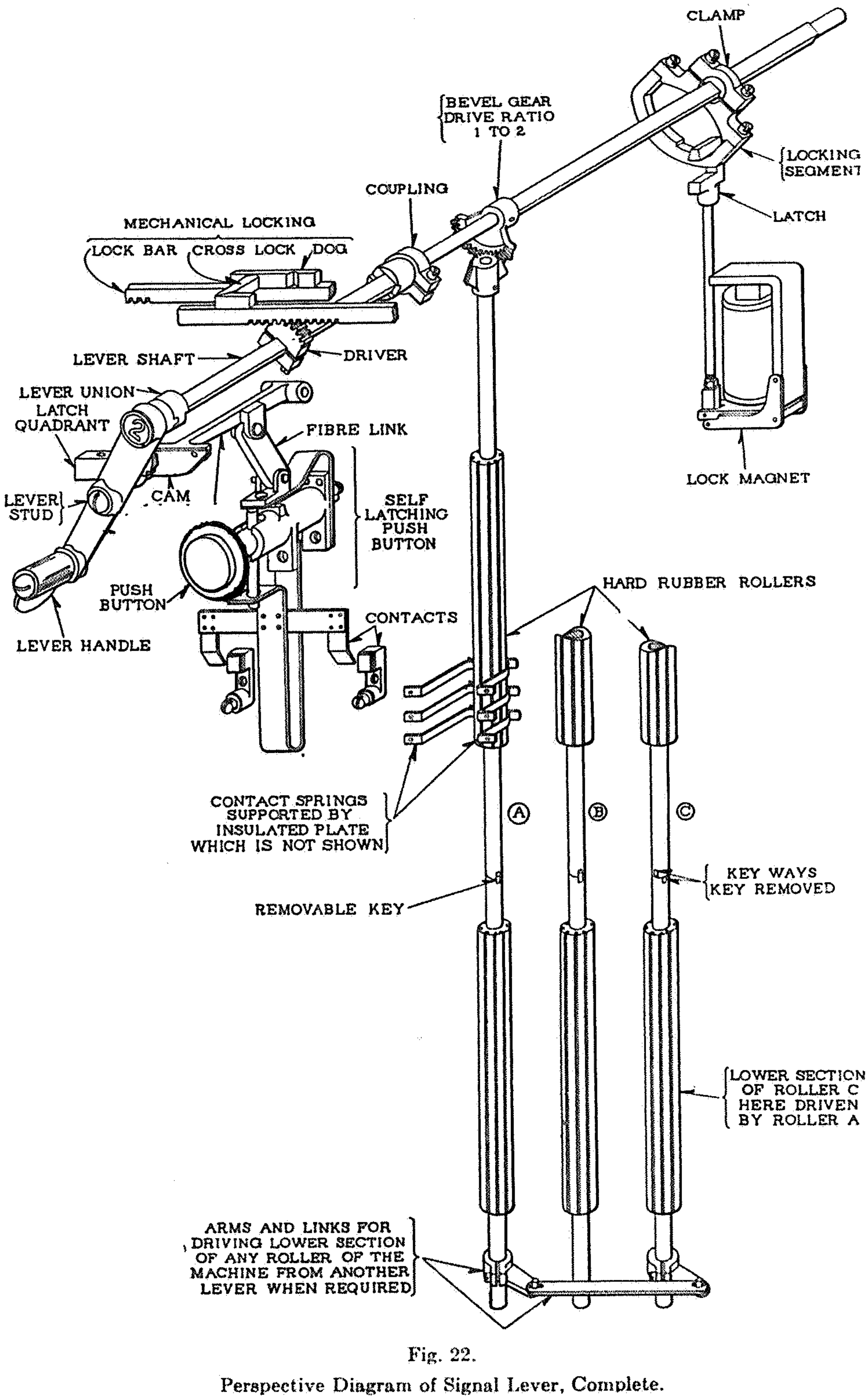



Fig. 22.
Perspective Diagram of Signal Lever, Complete.

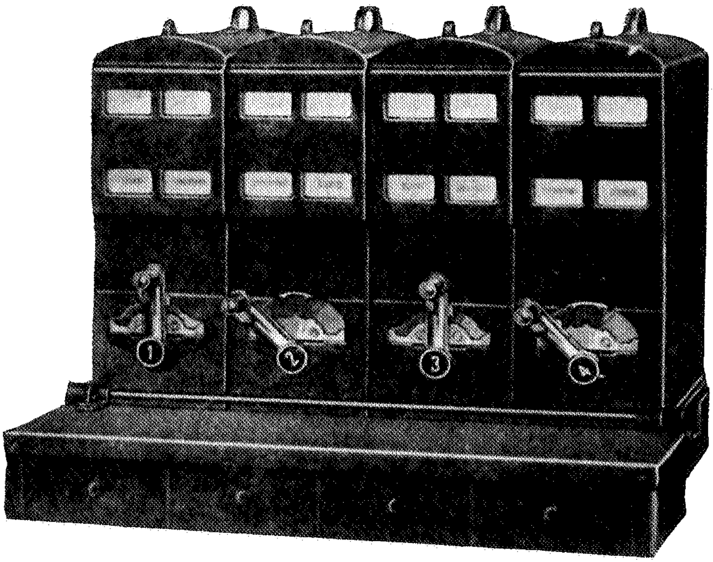


Fig. 23.
Table Machine with Four Units, Magnetic Type Indicator and Extended Locking Bed.

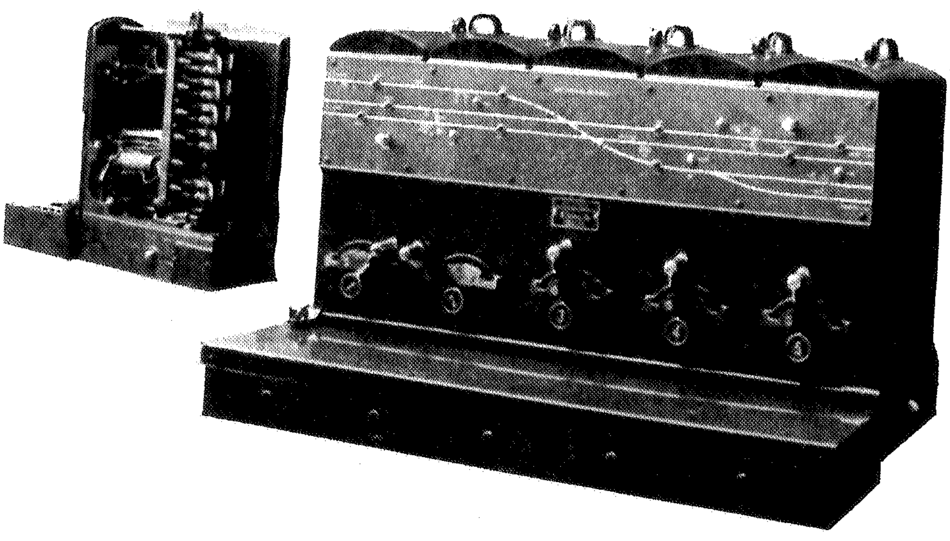


Fig. 24.
Table Machine with Five Units, Track Model Type Indicators and Extended Locking Bed.

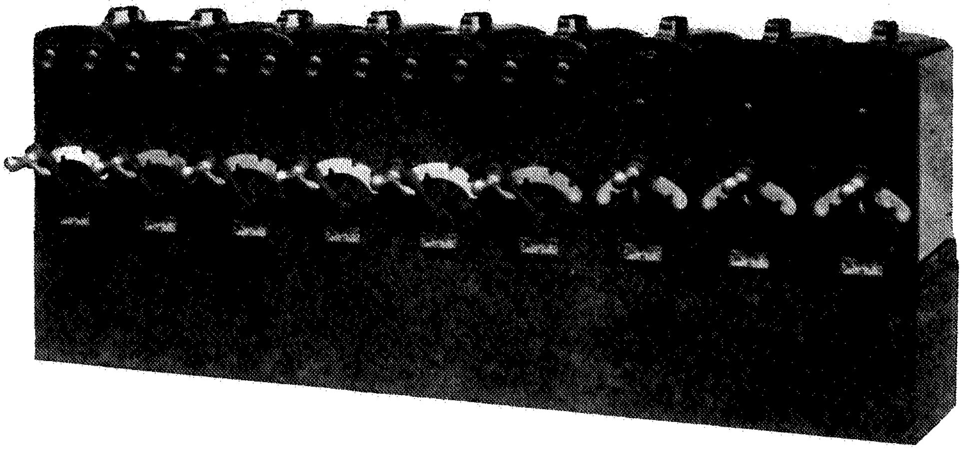


Fig. 25.
Table Machine with Nine Units, Light Type Indicators and Vertical Locking Bed.

*Locking.*

The locking is miniature Saxby and Farmer, which is described in Chapter XVI—Interlocking. In the earlier types, the locking was placed in the sub-bases. In later types, the locking is in an extension of the sub-bases located in front of the machine, as shown in Figs. 23 and 24, or in a vertical position, as shown in Fig. 25.

*Lever.*

The switch and signal levers operate in practically the same manner as those of the electro-pneumatic interlocking machine described in Chapter XVIII—Electro-Pneumatic Interlocking.

As shown in Fig. 26, a locking segment 32 is attached to the lever handle. These segments may be so provided that latch 41 of the electric lock may lock either switch or signal levers in any position desired. Locking shaft 3 is driven from the segment by a connecting link 7.

The circuit controllers are equipped with contacts which may be adjusted to open or close at any desired position of the lever stroke. An auxiliary circuit controller may be added to any assembly when required to increase the number of contacts, and is mounted below the unit as shown in Fig. 26. Each assembly may be equipped with four indicators for conveying information to the operator, as shown in Fig. 23. When these are of the magnetic type they are usually lettered to convey the information desired, such as "normal" and "reverse" on switch lever assemblies and the other two spaces sometimes used to show track occupied or unoccupied to indicate that the switch lever is free to be moved. On signal levers, indicators are usually lettered "stop" and "clear." Other spaces are used for annunciators, etc.

Indicators are sometimes operated mechanically from the armature of the electric lock and marked "locked" and "unlocked." Lamps are sometimes used instead of the magnetic type indicators as shown on the machine in Fig. 25.

As previously mentioned, units of the electric dynamic indication system are sometimes controlled from table interlocking machines. Figure 27 shows a machine of this type.

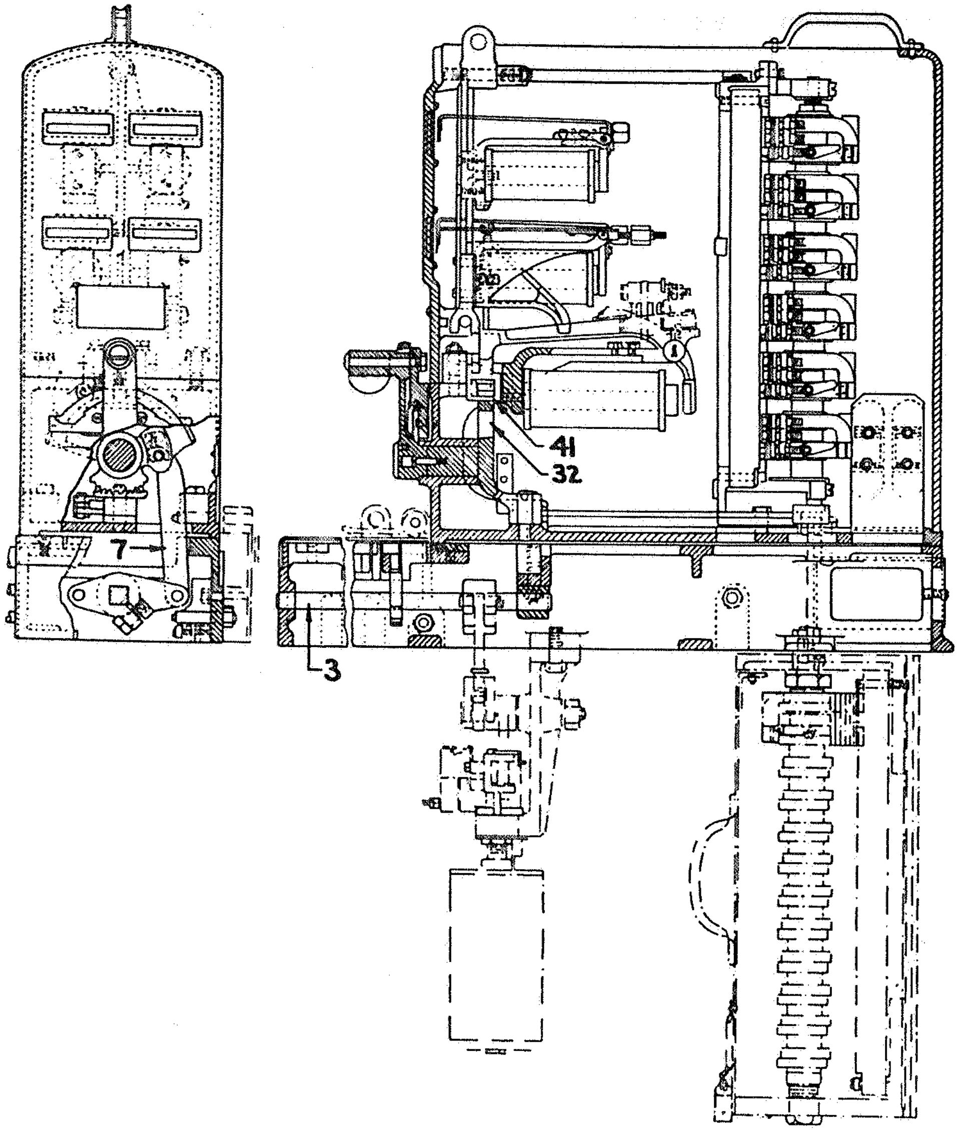



Fig. 26.
Cross-Section of Table Machine.

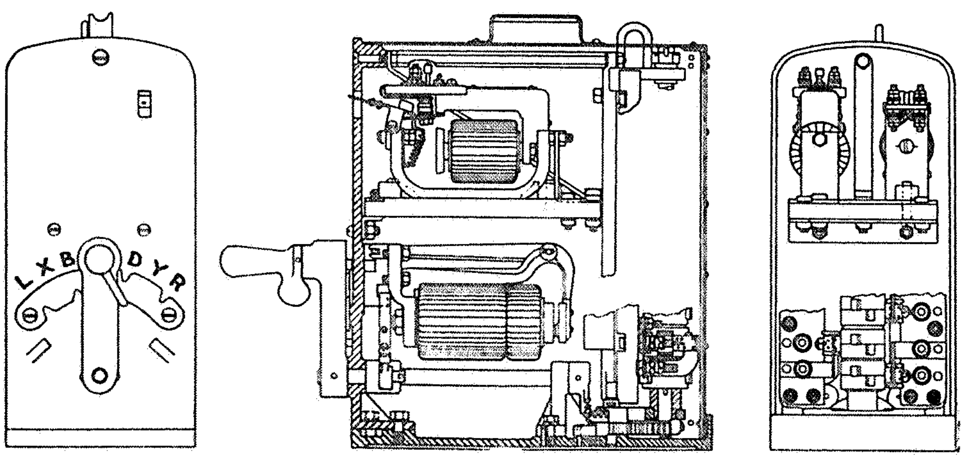



Fig. 27.
Table Machine Equipped with Polar Relay and Indication Selector for Controlling Units Employing Dynamic Indication.

*Interlocking systems using free-lever control machines.*

The interlocking systems hereinbefore described and all their predecessors have employed control machines with mechanical locking. However, about the time that centralized traffic control came into use in the late twenties, a form of interlocking was introduced in which control machines were used that employed miniature levers like those on centralized traffic control machines, and were without mechanical locking. Being without mechanical locking and also without lever electric locking, these miniature levers were free and any or all could be moved at will by the operator. In this new system the vital safety features inherent in the mechanical locking and the lever electric locking were transferred to relays and their controlling circuits, and because relays assumed these additional vital functions, the new system became known as the "all-relay" system of interlocking or later, simply, "relay-type interlocking."

In relay type interlocking, the free levers control the switches directly through relays or other control devices and the switch position is indicated into the tower or other central housing by the usual switch repeater relay arrangements. The signals are usually controlled first by a system of selecting network circuits that check correspondence of switch position and control lever and which network in a way substitutes for the switch indication magnets and the mechanical locking in the older systems and then finally the signals are controlled over the selecting network which guarantees and continuously checks proper routing. The final network once established for a routing maintains its integrity irrespective of the interim positioning of any or all involved free levers, except the governing signal lever for the route. This type of circuiting is necessary to meet the fundamental requirement of this type of interlocking in that no signal should be put to stop by other than its own controlling lever. With the selecting networks, as described, SS protection becomes an integral part of this type of interlocking system.

Equivalent electrical locking features to those used with the mechanically locked machines are employed in relay interlocking and provide equivalent and equal protection. In the earlier systems, these locking features were applied through the medium of the lock magnets on the levers, thus there was detector and route locking applied to the switch levers and approach or time locking to the signal levers. In relay interlocking, all of these features are usually applied directly in the circuits that operate the switch control relays or other switch control devices rather than being effected through the medium of interlocking levers with magnets.

Indication lights on the free-lever control machines take different forms. Separate normal and reverse switch indicating lights mounted immediately above the respective levers are used on some machines to indicate respective position of the switches in the field, while a single disagreement light above each lever is used on others. In the latter case, a dark light indicates agreement between lever position and switch position. Generally, a "Hands Off" light is used with each switch lever, indicating, when lighted, that the particular switch is electrically locked in the field.

Left and right signal indicating lights are sometimes mounted directly above the signal levers to indicate a respective left or right signal "clear." In other cases, a single disagreement light is employed and again when not lighted indicates agreement between lever position and signal position. Sometimes the signal "clear" indicating lights are placed directly in their respective signal symbols on the track diagram. A "red" signal indicating light is usually associated with each signal lever indicating, when lighted, that all signals controlled by that lever are at Stop.

Track indication lights are placed in the track diagram in the usual manner to show track occupancy, when lighted.

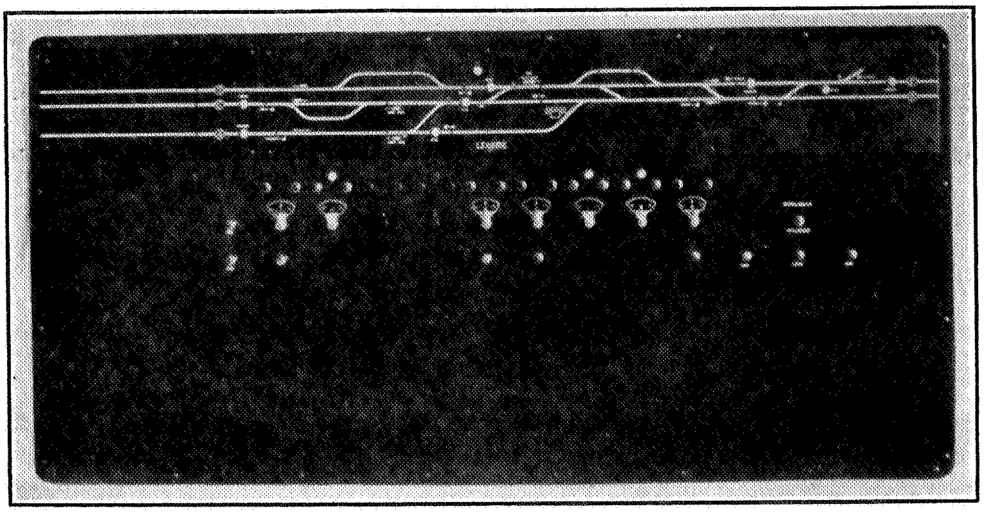


Fig. 28.
Relay Type Machine, Table Model.

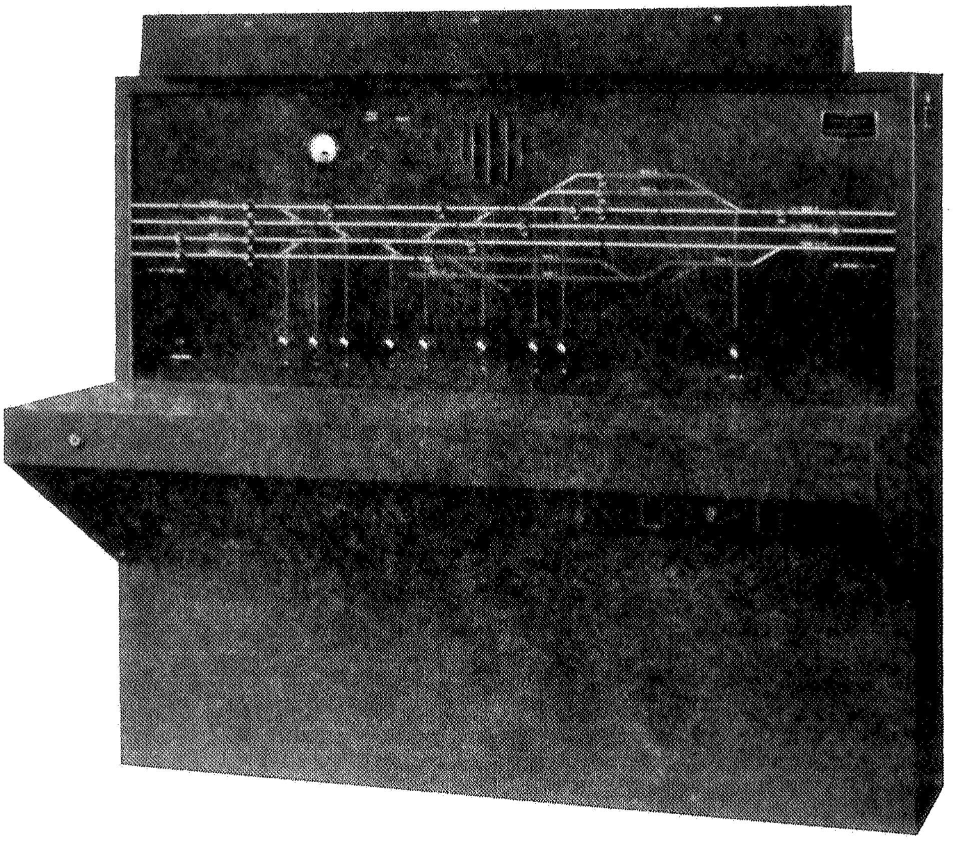


Fig. 29.
Relay Type Machine, Floor Model.

Special control levers or push buttons may be provided as desired on these machines for such purposes as call-on control and maintainer's call. Special indication lights may also be provided for power-off and other purposes.

This type of control machine is now being used very extensively and is most desirable when it is to be operated by a person who has other duties to perform and where speedy operation is essential, also where machine space is limited. Machines of this type are illustrated in Figs. 28 and 29.

A machine of this type may be operated by a person seated and the complete route set up without waiting for the units to operate. Circuits covering this type of interlocking are described in Chapter XXVI—All-Relay Interlocking. A detailed description of the control machine will be found in Chapter IV—Centralized Traffic Control.

*Interlocking systems using route type control machines.*

Following the introduction of the free-lever type machine, another design of control machine came into use in which the route principle of function control was provided, thereby giving rise to the later system known as route type interlocking. Route type interlocking was developed upon the same fundamental principles as relay type interlocking, differing therefrom essentially in the means provided on the control machine for route setting. Route type interlocking is generally regarded simply as another form of relay type interlocking. In this type of machine push-pull route buttons or controllers are located on the track diagram at points representing wayside signal locations which points also correspond to route entrances. Buttons are also located on the track diagram at points representing exits to routes. Complete routes may be established through a plant with this type of machine by the manipulation of a control button at the entering end of a route and another button at the leaving end. By this action the complete route is automatically established, including the throwing of the required switches and the clearing of the desired signal. The proper sequence of operation of the interlocking units is obtained by the use of relays employed in selective circuit networks in similar fashion to relay type interlocking.

Upon the pushing of the entrance and exit buttons to establish a route, route selector relays in a selective network operate to establish the desired controls of the switches, thus in an automatic way accomplishing the same results as manipulating the individual switch levers in other types of interlocking. As in relay type interlocking, the position of switches is indicated into the central housing by the usual switch repeater relay arrangements, also the signals are controlled by selecting networks in essentially the same manner as described for relay type interlocking differing principally in that the entrance route buttons control the signals instead of miniature signal levers. SS protection is likewise an integral part of route type interlocking.

Electrical locking features are the same as described for relay type interlocking.

Route type machines are characterized by the outlining of the established route or routes on the track diagram by movable switch points or by lights whereby the machine operator, at a glance, can see before him on the machine, the route that has been set up in the field. Upon the signal clearing, following the completion of the route in the field, a signal "clear" indication appears in or adjacent to the signal control button on the machine. A red indication appears at this same point between the time the entrance button is pushed and the time the signal clears, indicating an activated route.

Track indication lights are placed in the track diagram in the usual manner to show track occupancy, when lighted.

Individual auxiliary switch levers are usually included on the track diagram to provide means for the individual operation of the switches in the interlocking. Individual operation may be found necessary for testing purposes, for pre-selection of a route or for use in an emergency.

The signal control buttons employed on route type machines are usually of the type that include push, pull and turn characteristics. Generally the push action is used in establishing a route, the pull action for cancelling a route and the turn action or actions for a special purpose such as non-stick control for use in fleeting trains. Call-on controls are handled by the turn action of the signal control buttons or by separate push buttons. One form of this type of interlocking designated "entrance-exit" (NX), makes use of separate entrance and exit controllers. At each entrance there is a knob controller and at each exit a button controller and the aligning of the route is effected by first actuating the entrance knob and then pushing the exit button. Another form, designated UR, utilizes a single push-pull-turn controller for entrance and exit purposes, the first controller actuated functions to establish an entrance while the second one determines the exit.

Special controllers may be provided as desired on these machines for maintainer's call and such purposes. Likewise, special indication lights may be provided for power-off and other uses.

This type of interlocking provides for selecting alternate routes, when there is more than one route from a given entrance to a given exit. If the preferred route is occupied or inoperative, an alternate route will be automatically selected by the machine. Pre-selection of an alternate route by operating a certain switch or switches individually is possible in route interlocking.

A feature termed "through-routing" can also be provided in the route system, whereby it is unnecessary to use intermediate control buttons for a complete route through the interlocking. Controls are usually provided so that upon actuating a given entrance, an exit can be taken at any intermediate exit or only at the last exit, if desired.

Line lighting of the track diagram has been provided on many route type control machines. This is a scheme of lighting whereby an established route is outlined from end to end by light sections that are lighted white to form a continuous line of light. Upon a train entering the route, light sections representing respective track circuits in the plant, change from white to red, denoting occupancy. These same sections go dark behind a train as the route or sections of it are released. If the route has not been accepted, the line sections continue lighted white while the route is approach or time locked. In line lighting, the track diagram is normally dark and lighting appears only when the machine is activitated by the aligning of a route, by an approach becoming occupied, or by manipulation of individual switch levers. Switch positions are indicated by normal or reverse light sections being lighted steadily for agreement or flashing for disagreement between the switch and its control.

A spotlighting scheme of track diagram lighting may be used wherein the routes are outlined by spotlights or a combination of spotlights and light sections. In the latter combination, light sections are used on the diagram at the switch locations to outline the routing at these points only, with spotlights used for the remainder of the route. Track indication spotlights are used in the track diagram in the usual manner to show track occupancy when lighted.

The advantages of this type of machine, illustrated in Figs. 30 and 31, are its ease and speed of manipulation and accuracy in routing.

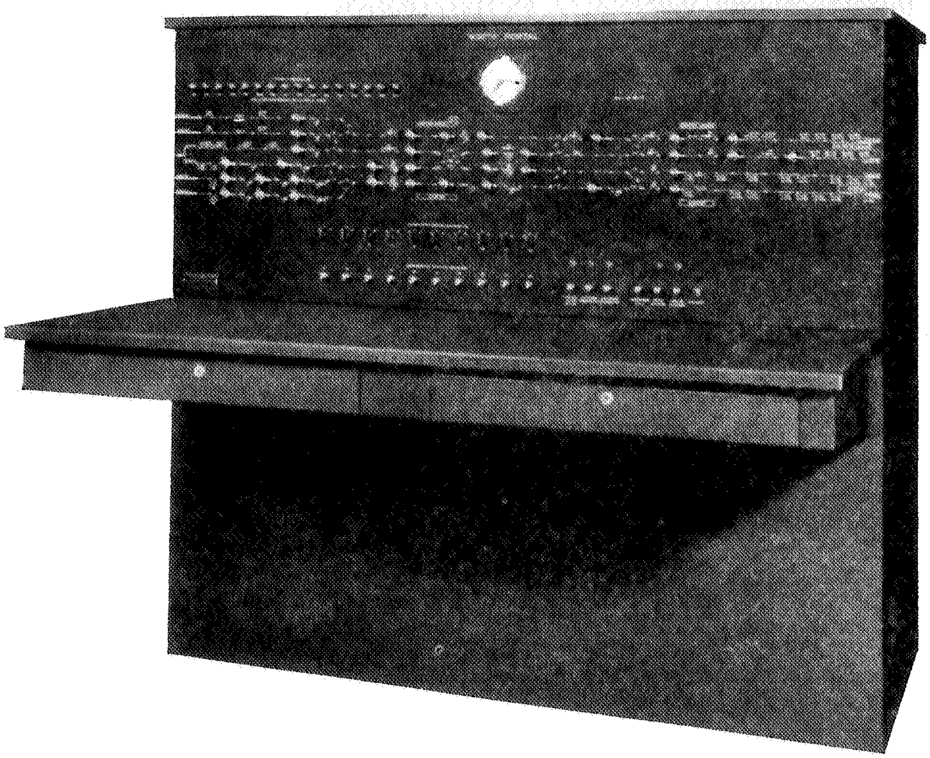


Fig. 30.
Route Type Interlocking Machine Using Line-Lighting.

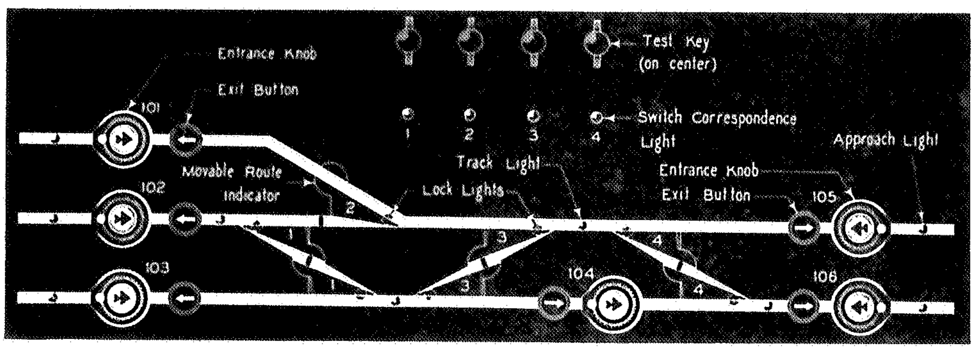



Fig. 31.
Typical Layout of Control Panel on Entrance-Exit or Route Type Interlocking Control Machine.

## *Automatic Interlocking*

An automatic interlocking is operated through the medium of track circuits upon the approach of a train. Referring to Fig. 32, and assuming that no trains are within the limits of the interlocking on either road, a train entering upon track circuit E will automatically clear the route for movement of this train over the crossing, and home signal 3 and approach signal 4 will indicate "proceed." Before these two signals display the proceed indication, home signals 6 and 7 on the crossing line must be in the stop position and approach signals 5 and 8 in the approach position. Therefore, should a train approach on the crossing line at this time, it will not receive signals to proceed over the

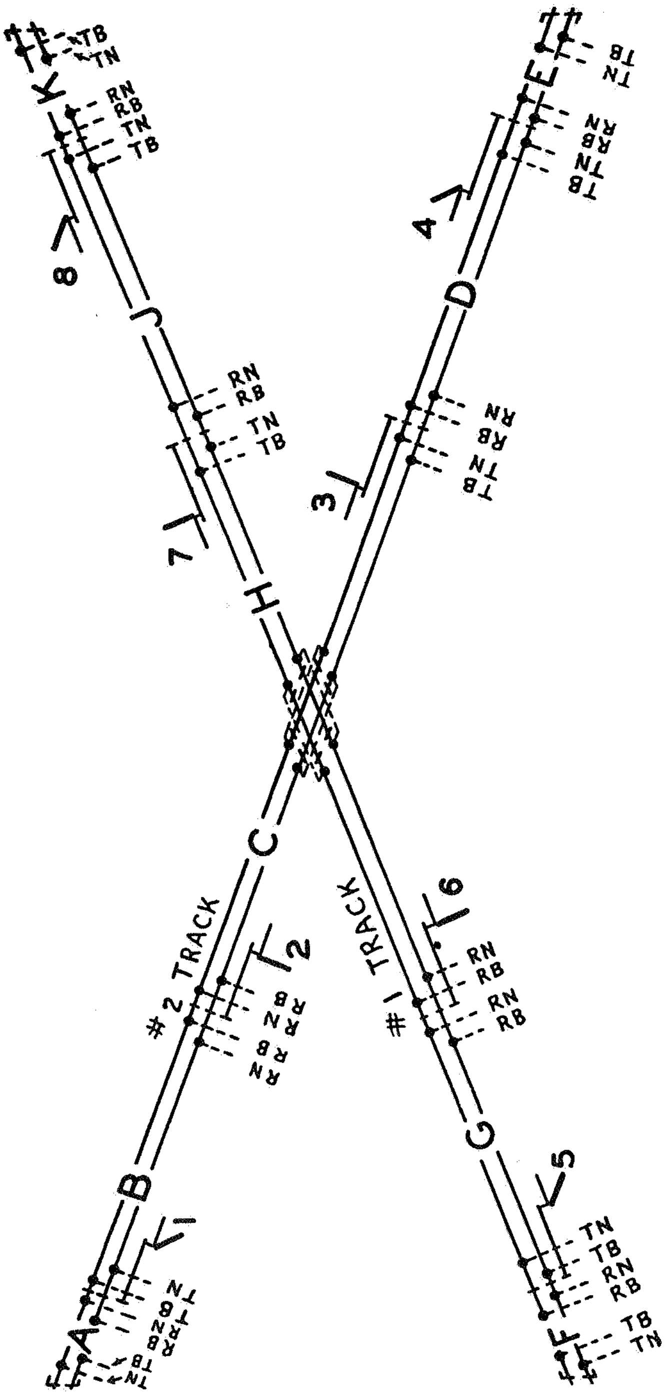
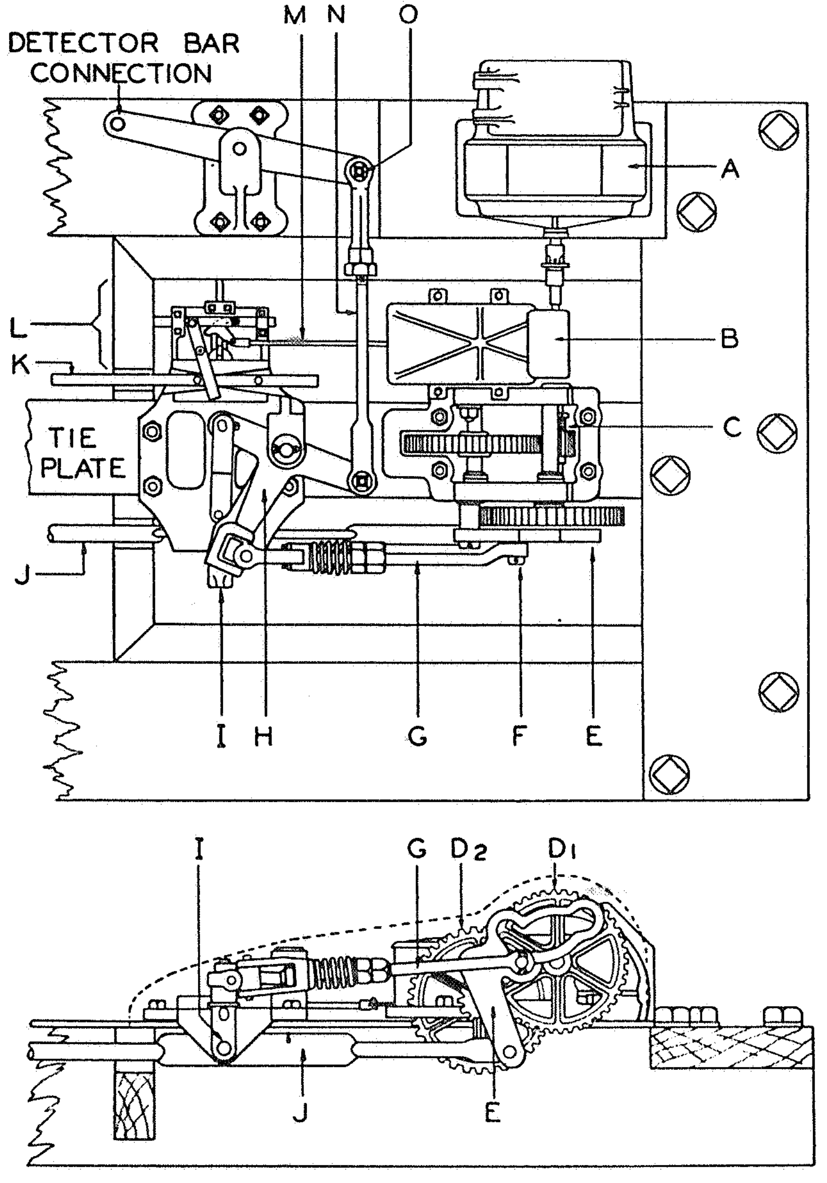



Fig. 32.
Diagram of Automatic Interlocking Layout.

crossing until the train which has entered track circuit E has passed over the crossing and cleared track circuit C, or in other words, has passed beyond the opposing home signal 2 on that line.

Provision is generally made at automatic interlockings whereby a train which may be stopped at a home signal on one line due to a train standing on the approach circuit of the crossing line and not ready to proceed over the crossing, may send a trainman to the crossing and by operating a device, cause the signals already cleared for the standing train to assume the stop position and thereby allow those for the second train to assume a proceed position. A time interval is sometimes imposed in the circuits of the signals. In other cases, a trainman proceeds to the crossing and opens a switch which disconnects all energy from the system and then by the use of hand signals advances the train over the crossing. Many other devices are used at automatic interlockings to suit the track layout involved. Detail circuits for an automatic interlocking are described in Chapter XX—Interlocking Circuits.




A—Motor.
B—Pole changer.
C—Friction clutch.
$D_1$—Main gear.
$D_2$—Intermediate gear.
E—Cam crank.
F—Stud on main gear.
G—Driving rod.
H—Lock crank.
I—Lock plunger.
J—Throw rod.
K—Lock rod.
L—Pole changer movement.
M—Pole changer connecting rod.
N—Detector bar driving link.
O—Pin.

Fig. 33.
Model 2 Switch Machine.

### *Switch-and-Lock Movements*

There are many types of switch-and-lock movements used in electric interlocking.

The Signal Section, A.A.R. defines Switch-and-Lock Movement as: A device, the complete movement of which performs the three operations of unlocking, operating and locking a switch, movable point frog or derail.

#### *Model 2 switch machine.*

This is one of the earliest types of electric switch-and-lock movements and is illustrated in Fig. 33. It operates on 110 volts direct current.

The gear frame and locking movement are bolted to the tie plate as shown. Movement is transmitted to the switch by the motor through a train of gears. The switch points are moved by rod J and cam crank E due to stud F on main gear $D_1$ engaging with the cam crank.

Locking plunger I and detector bar (if used) are actuated through crank H and driving rod G, the latter directly connected to stud F on main gear $D_1$. Where detector bars are not used a buffer spring is sometimes connected to rod N. The movement of pole changer B is effected through the medium of pole changer movement L, which is operated by the last 1/8 inch movement of lock plunger I after it has passed through lock rod K. The design of the mechanism is such as to allow switch motor A, because of its acquired momentum, to continue its rotation for the generation of the indication current, which checks the speed of the motor and brings it to rest without shock.

A friction clutch C is introduced into the connection between the motor and main gear $D_2$ to relieve the switch mechanism from any injurious strain should it suddenly be brought to stop by an obstruction in the switch points. Provision is made for operating the movement by hand by inserting a crank in a socket attached to the motor armature shaft.

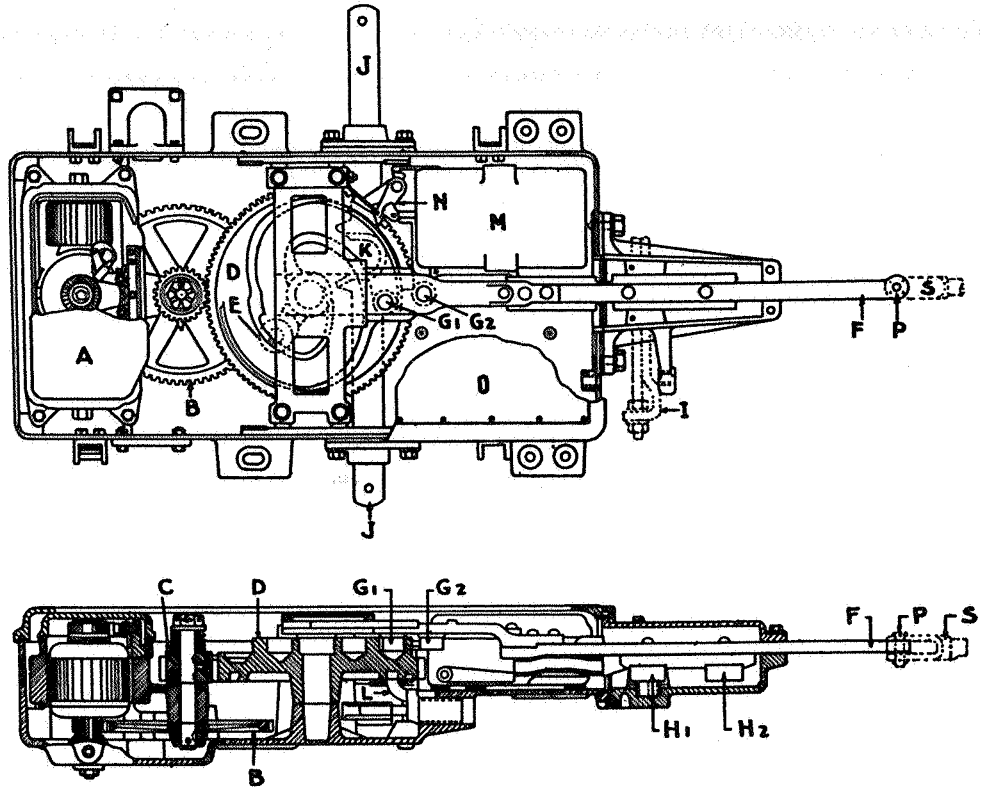
#### *Model 4A switch machine.*

The Model 4A switch machine, shown in Fig. 34, is designed with all operating parts within one case, which besides affording protection against the weather, also provides a base plate for the mechanism. It operates on 110 volts direct current.

The operating parts consist of motor A, a train of spur gears, the main or cam gear D, pole changer M, throw rod J and locking bar F. The motor through the medium of the train of gears drives the cam gear, from which gear the various parts of the switch machine are operated.

The intermittent movement of the locking bar and detector bar is accomplished by the engagement of rollers on the locking bar with the cam slot on the upper side of the main gear. Staggered locking is provided by the arrangement of the dogs on the locking bar, these dogs being so placed that after one dog has been withdrawn to release the lock rod, the switch must be moved to the opposite position before the other dog can enter its slot in the lock rod. The throw rod is locked in both extreme positions of the switch by a bolt operated from the cam movement. The switch points are thrown at the proper time by a roller on the lower side of the main gear engaging a jaw in the throw rod.

The principles of the pole changer movement, shown in Fig. 35, are essentially the same as in the Model 2 switch machine, although the mechanical method of effecting this action is accomplished through the main gear movement and locking bar, instead of through the pole changer movement and




A—Motor.
B—Intermediate gear.
C—Friction clutch.
D—Main or cam gear.
E—Roller on main gear.
F—Locking bar.
$G_1$, $G_2$ } Rollers on locking bar.
$H_1$, $H_2$ } Locking dogs.

I—Lock rod.
J—Throw rod.
K—Jaw in throw rod.
L—Locking bolt.
M—Pole changer.
N—Tripper arm.
O—Switch circuit controller location.
P—Pin.
S—Detector bar connection.

Fig. 34.
Model 4A Switch Machine.

locking plunger as in the Model 2. Contact blocks $S_1$ and $S_2$ are operated from tripper arm N which engages at the proper time with a cam either on the upper or lower surface of main gear D, depending on the direction of travel of the mechanism. The tripper arm is placed in a position to engage with the proper cam only after the switch has been locked in position at the end of its movement. This is accomplished through the medium of cranks $T_1$ and $T_2$, a roller U on the latter working in a cam slot on locking rod F shown in Fig. 34. Contact arm V (which corresponds with commutator T on the Model 2 pole changer, Fig. 33), is operated by this same crank movement.

The cam gear is designed to permit a free run of the motor at the end of the operation of the mechanism for the purpose of generating the indication current. A friction clutch is provided to protect the mechanism from shock should its movements be obstructed.

A circuit controller as shown in Fig. 36, when furnished, is located within the mechanism case at the point indicated by letter O shown in Fig. 34. The operating part consists of a frame carrying contact fingers and a cylindrical commutator W upon which are mounted contact segments. As the switch is unlocked, a disengaging arm X with roller Y working in a cam slot on locking bar F shown in Fig. 34 lowers the commutator out of engagement with the contacts. During the movement of the switch the commutator is rotated on its axis through motion transmitted from the switch points by means of a crank connection, a sector (not shown) and pinions $Z_1$ and $Z_2$. After the switch points are locked in position the commutator is raised into engagement with the contacts by the engaging arm and cam slot movement. It will be seen that this control insures that the switch points are in position and locked before the contacts of the circuit controller can close. The maximum capacity of the controller is ten independent contacts, these being adjustable in pairs to close as desired at the normal or reverse position of the switch.

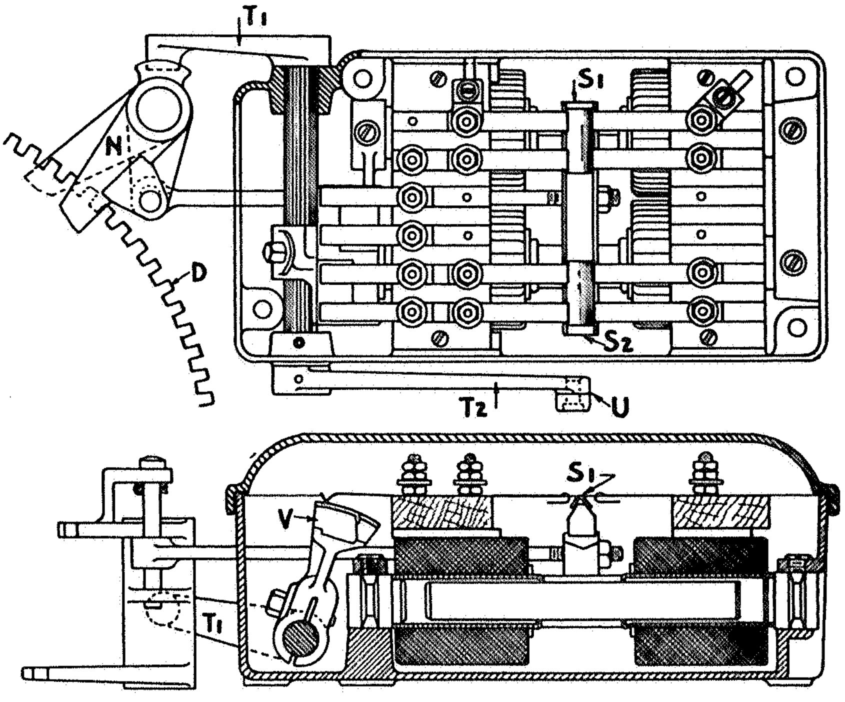



Fig. 35.
Pole Changer for Model 4A Switch Machine.

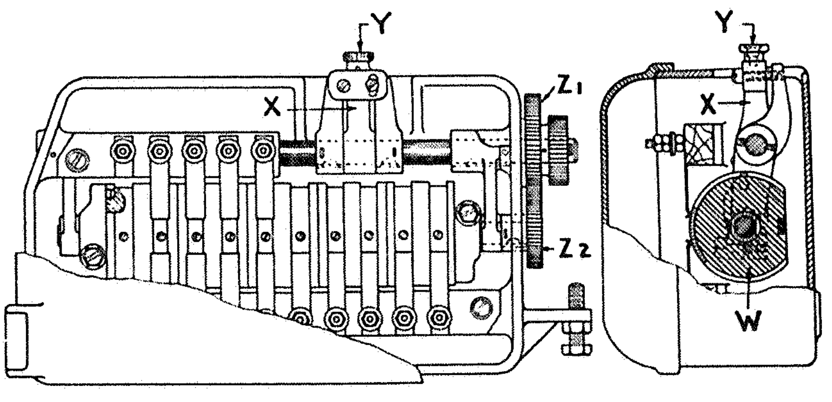



Fig. 36.
Switch Circuit Controller for Model 4A Switch Machine.

Electromagnetic brakes may be provided on the Model 4A switch machine. If desired, this brake may be applied in the field to machines not so equipped.

The switch machine may be used for a right or left-hand layout, without change, as the lock and throw rods may be connected from either side. A

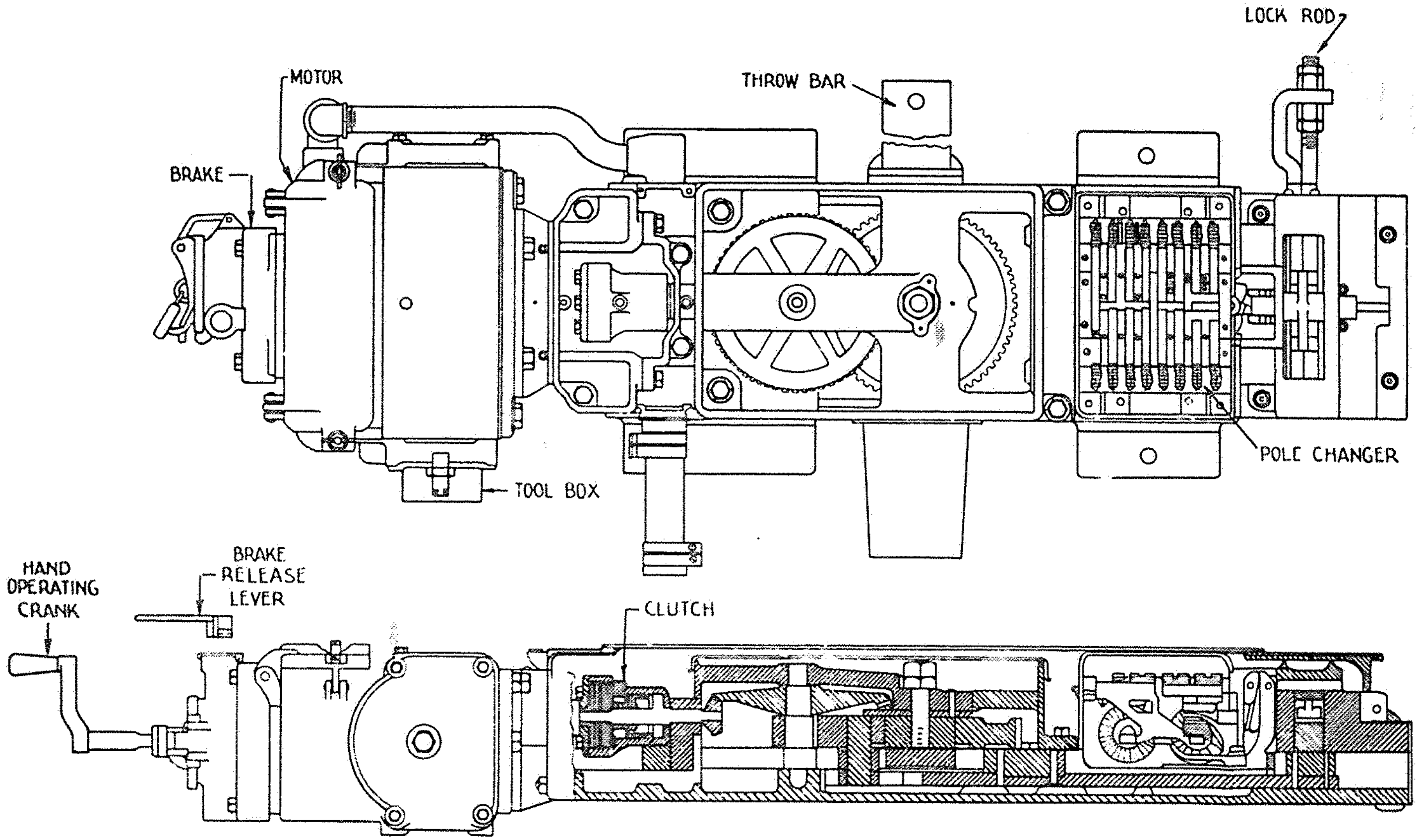



**Fig. 37.**
**Model 5 Switch Machine.**

double locking cage is furnished when the machine is to operate a movable point frog.

Provision is made for operating the machine by hand by inserting a crank in a socket on the motor armature shaft.

*Model 5 switch machine.*

The Model 5 switch machine consists of a motor train of gears, operating and locking members, a pole changer, clutch and magnetic brake. Except for the magnetic brake, its operation is practically the same as the Model 4A switch machine.

The motor is bolted direct to the end of the machine frame in such manner that it can be readily detached. The magnetic brake is mounted on the motor frame and provides a front bearing for the motor armature thereby making the motor and brake a complete unit. Provision is made for operating the movement by hand by inserting a crank in an opening in the end of the motor frame, as shown in Fig. 37. Before this crank can be inserted, a motor cut-out contact arm must be moved to one side which opens the switch repeater relay circuit and thereby prevents current being applied to the motor while crank is inserted.

The magnetic brake is provided primarily to prevent the switch machine from operating due to vibration of a passing train should the switch be unlocked. It consists of a friction disc which rotates with the motor shaft and which is normally held against the brake housing by spring tension. A coil connected in series with the motor field causes this friction disc to be released whenever current is applied to the motor. The brake magnet is made "slow release" so that the brake will not set immediately after the motor circuit is opened, to allow the motor a free run for the generation of the dynamic indication. The brake is adjustable so that wear on the friction disc can be taken up.

When operating the machine by hand, the magnetic brake must be released mechanically and an opening on top of the brake housing is provided for this purpose; the brake release lever shown in Fig. 37 is inserted in this opening and pushed in a clockwise direction and held there while cranking the machine by hand.

The Model 5 switch machine is narrower than the Model 4A and may be mounted in locations where the clearances are restricted, such as in subways, etc. It may be provided with one or two lock rods by changing the locking bar and locking frame; it is regularly furnished for operation on 110 volts direct current although there are a number of these machines furnished for operation on 20 volts direct current, which machines are not equipped with a magnetic brake. Early designs of these machines for operation on 110 volts direct current were furnished with the motor detached and separately mounted.

*Model 5A switch machine.*

The Model 5A switch machine is similar in appearance to the Model 5, the principal difference being that it is equipped with a point detector. It may also be equipped with a magnetic brake, if required. It is regularly furnished for operation on high (110 volts) or low (24-32 volts) voltage direct current, or high (110 volts) voltage alternating 25 or 60-cycle current. Direct current machines may be high, medium, or low-speed types. Only high-speed types are available for operation on alternating current. Indication may be dynamic or relayed battery. A friction clutch of the multiple dry-plate type is regularly supplied on all Model 5A switch machines.

The motor is housed in a separate waterproof case which is bolted direct to the end of the machine frame, no change of the frame being necessary in changing from one type of motor to another. Different gear ratios are required for the various motors and no change in the machine frame is necessary in changing these gears.

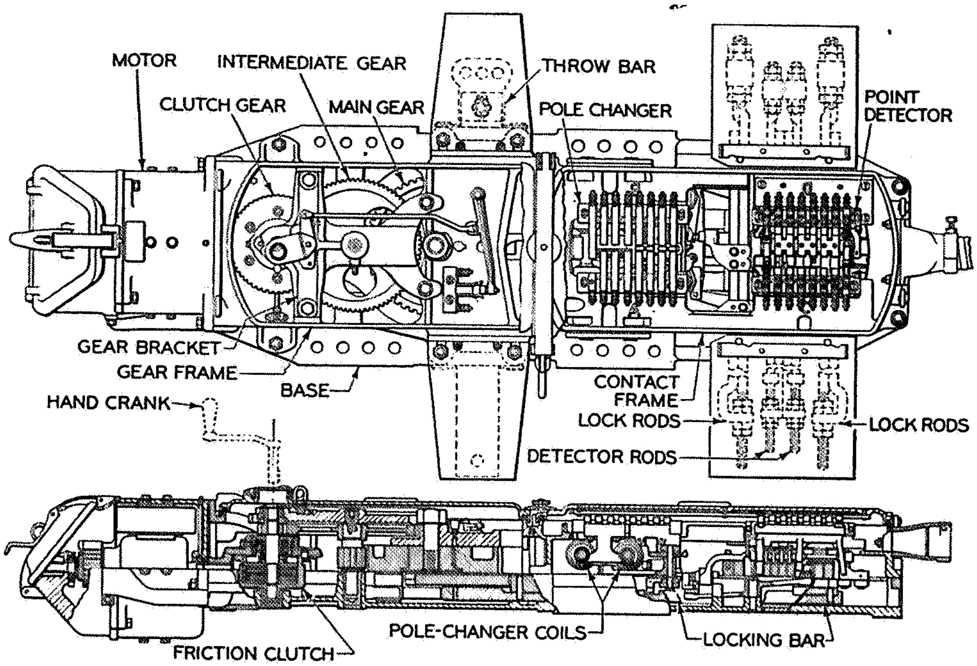
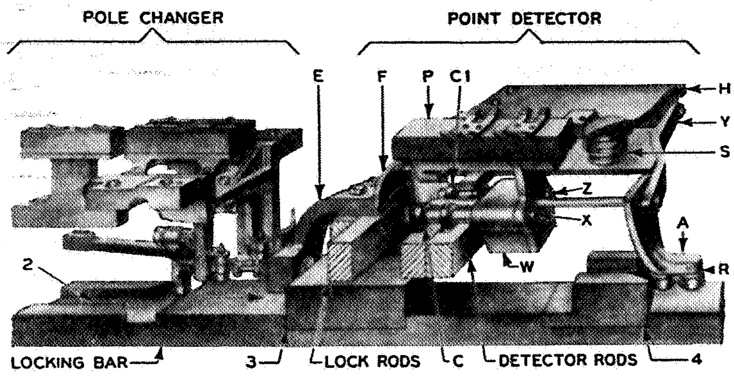



Fig. 38.
Model 5A Switch Machine with Two Sets of Lock and Detector Rods as for a Double Slip Switch.

Its application is universal as it is suitable to operate a single switch, derail, double-slip switch or movable point frog with only a few changes in parts required.

Figure 38 shows the assembly of the Model 5A switch machine. Its operation is practically the same as the Model 4A, except that it has an enclosed switch circuit controller or point detector of the so-called "over and locked type," which means that the switch must be over and locked before the point detector contacts are closed. The point detector may be operated independently from each of four switch points or less, or from each of two pair of switch points or less and its movement is checked against the movement of the lock rods so that all point detector rods must be in place and operative either normal or reverse before the moving contact member can operate to close or open the proper contacts.

Figure 39 shows the point detector movement and the principal parts in positions occupied when the switch is locked normal. The line drawings show the various positions assumed by these parts during operation from normal to reverse. The fixed support H is rigidly fastened to the machine frame and carries the pivot end of yoke Y. The other end of yoke Y is mechanically connected to the center contact bar assembly P which, by reason of pressure exerted by spring S, exerts a downward pressure on rollers C and C1. Contact bar assembly P is also pivoted to tip to the right or left, as viewed from the end, thus opening or closing the normal or reverse contacts, as the case may be.



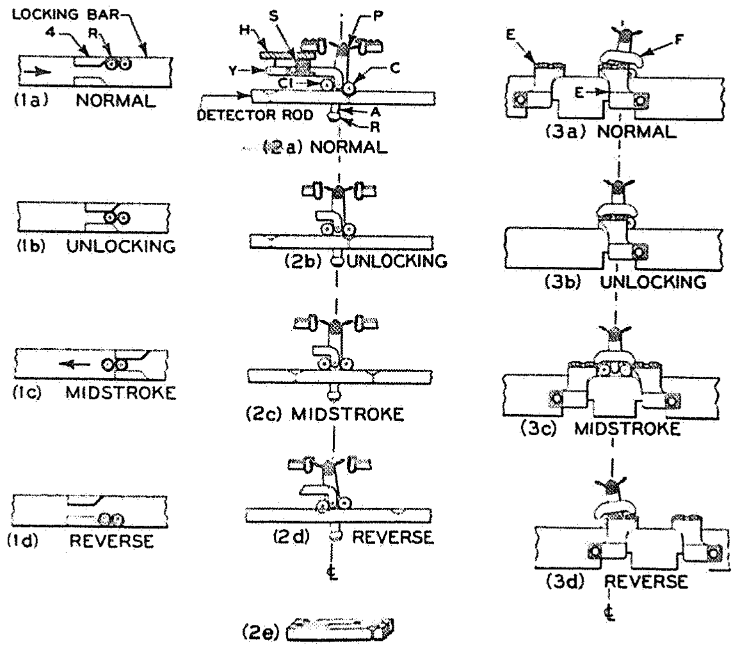




Fig. 39.
Pole Changer and Point Detector Movement, Model 5A Switch Machine.

Referring to drawings 1a through 3d, operation is as follows: when the locking bar is moved in the direction of the arrow, crank arm A of the point detector is caused to move to the central position as rollers R are forced into the slot in dog 4. This opens the reverse or normal contacts, as the case may be, and closes the shunt contacts. As the locking bar continues its travel (during unlocking) it removes dog 3 from its notch in the lock rods and frees these rods to move with the second or switch-operating movement. As this movement occurs, the switch points move and carry with them the detector and lock rods (2c and 3c). This in no way affects the point-detector contacts as contact bar P remains in the central position. After the switch points have reached their extreme opposite position, the third or locking movement begins. In the meantime, one set of slots in the detector rods have been positioned under rollers C or C1, depending on whether the switch movement was reverse or normal, and, correspondingly, brackets E carried by the lock rods have been repositioned to permit contact bar to tip only in the desired direction. As the third or locking movement is completed, dog 3 is restored to its former position but in the other slot in the lock rods, and rollers R on crank arm A are freed from the slot in dog 4. This then permits contact bar assembly P to tip to the opposite position and close the opposite set of point detector contacts and also open the shunt contacts. If, however, the switch had not completed its stroke because of some abnormality, this third or locking movement could not have been completed; dog 3 would have prevented final movement of the locking bar because the notch it engages in the lock rods would not have been properly aligned, and the proper slots in the detector rods (2e) would not have been aligned underneath rollers C or C1. Had the lock rods been entirely disengaged from the switch points and had never moved, one of the brackets E in conjunction with rocker F would have prevented final movement of contact bar P. If at any time the adjustment of the point detector rods is improper or if they are moved with the switch locked, rollers C or C1 will be forced out of their respective notches and the corresponding point detector contacts opened, causing the repeater relay to drop and, in turn, causing stop indications to be displayed by all signals governing movements over the switch. (For point detector wiring, see Fig. 12.)

A crank is provided for hand operation which is inserted into the friction clutch mechanism through a small opening in the gear case cover, as shown in Fig. 38. Before the crank can be inserted, it is necessary to open a contact which prevents current being applied to the motor while crank is inserted.

Figure 40 illustrates the gearing arrangement used in Models 5A and 5C switch machines.

*Model 5B switch machine.*

The Model 5B switch machine is equipped for dual control, that is, it can be operated either by power or hand. The purpose of dual control is explained in Chapter IV—Centralized Traffic Control. It is essentially the same as the Model 5A machine, except for the introduction of the parts required for hand operation.

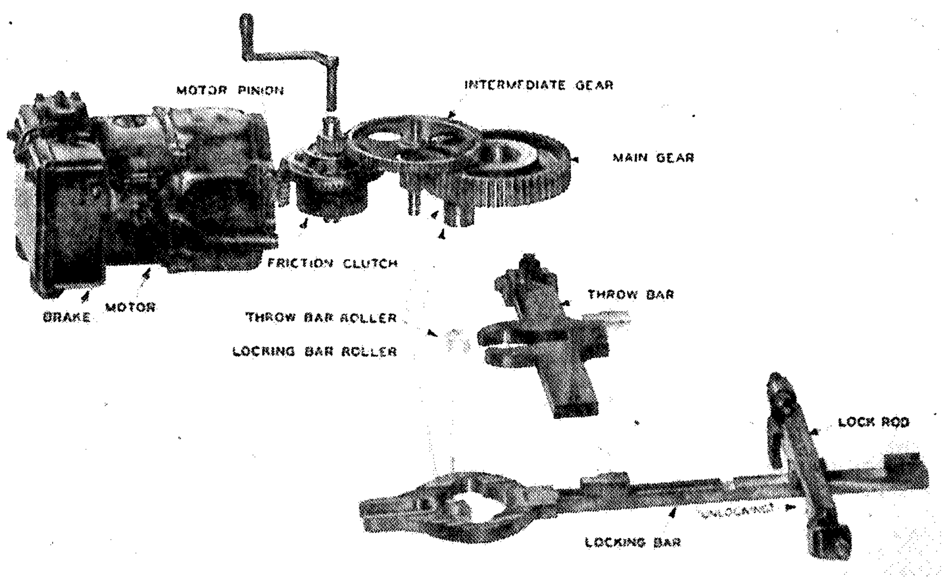



Fig. 40.
Arrangement of Gearing Used in Models 5A and 5C Machines.

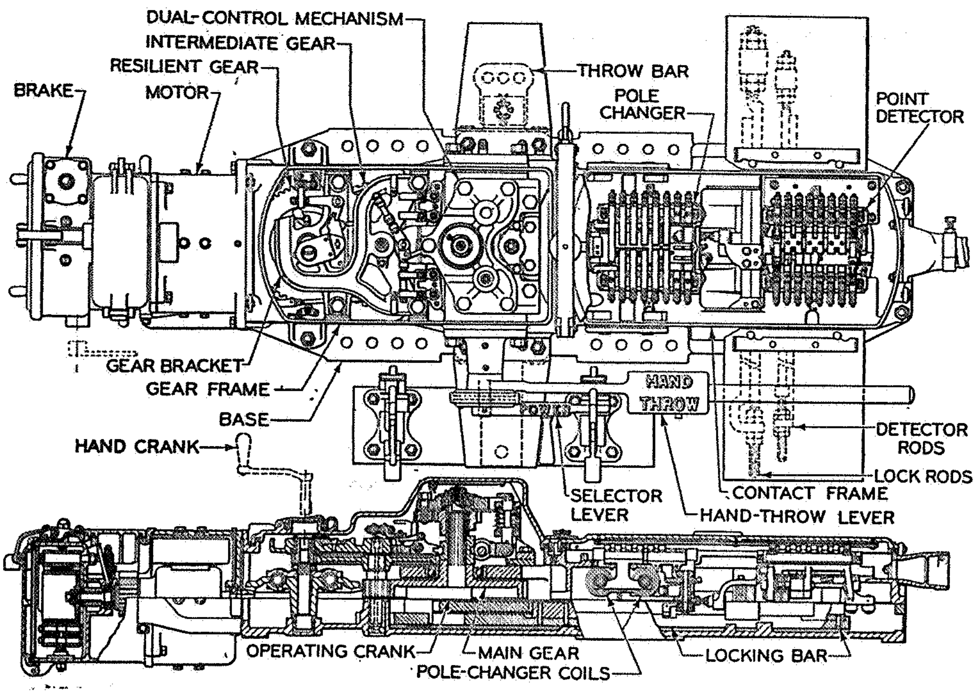



Fig. 41.
Model 5B Switch Machine. (Shown Arranged for Left-Hand Operation.)

Externally, these parts consist of two levers: one for selecting the method of operation, *i.e.*, power or manual, and one for the manual operation of the switch. These levers are referred to as hand-throw levers and both are marked as shown in Fig. 41, the selector lever being marked "power" on one side and "hand" on the opposite side, while the hand-throw lever is marked "hand throw" on each side.

The position of the selector lever determines whether the switch machine is in condition for hand or power operation. An interlocking feature between these levers makes it necessary that the selector lever be reversed before the hand-throw lever can be moved. The reversal of the selector lever opens the motor operating circuit, mechanically disconnects the motor-operated gear train and connects the throw and operating members to the hand-throw lever.

The reversal of the hand-throw lever unlocks and throws the switch points and leaves the switch operating rod locked in the reverse position. Both the normal and reverse contacts in the point detector are opened and the shunt contacts are closed.

Figure 42 illustrates the gearing arrangement and hand-throw mechanism used in Models 5B and 5D switch machines. In operation, power is transmitted from the motor to the throw bar and locking bar via the regular gear train and then from the main gear via the clutch sleeve (which must be in lowered position), to the splined shaft of the operating crank and thence to the throw bar and locking bar.

When the selector lever is manipulated to select hand operation, the clutch shifter raises the clutch sleeve on the operating crank's splined shaft, disengaging it (clutch sleeve) from the main gear and engaging it with the clutch gear. Hand-operation power is then transmitted from the hand-throw lever to the hand-throw pinion, hand-throw idler gear, clutch gear and clutch sleeve to the splined shaft of the operating crank and thence to the throw bar and locking bar.

If, when the selector lever is moved to the hand position, the position of the hand-throw lever does not correspond to that of the switch points, the clutch gear and clutch sleeve will not immediately engage because the raised surface on top of the clutch sleeve adjacent to its beveled face will strike against a similar surface on the lower end of the clutch gear. In this position, the clutch-shifter spring will take up and, in effect, store the movement of the selector lever. Then, when the hand-throw lever is moved to the position corresponding to that of the switch points, the clutch gear will be rotated to where the clutch shifter spring can drive the clutch sleeve up into engagement with the clutch gear.

The clutch shifter spring functions in the same manner when the movement of the selector lever is from the "hand" to the "power" position.

Under power operation, both the throw bar and lock rods are locked in the usual manner. In this way, if the point detector rods are properly positioned, the point detector contacts will be closed and the switch repeater circuit energized.

Under hand operation, the points are not locked in position as when power operated, but are held in position by the roller on the operating crank resting against the concave cam face of the throw bar. Under these conditions, the point detector contacts are open and the switch repeater circuit de-energized. Thus, if some abnormal condition prevents the switch throw bar and lock rods from being locked in the usual manner by power, the switch may be operated by hand and train moves made over it by use of hand signals.

When the selector lever is returned to the "power" position, the motor will, if conditions permit, automatically operate to lock the throw bar and lock rods and thus close the point detector contacts. If the machine is out of correspondence with the control, the motor will operate it to that position and complete its stroke in the usual manner, provided, of course, control circuit conditions permit.

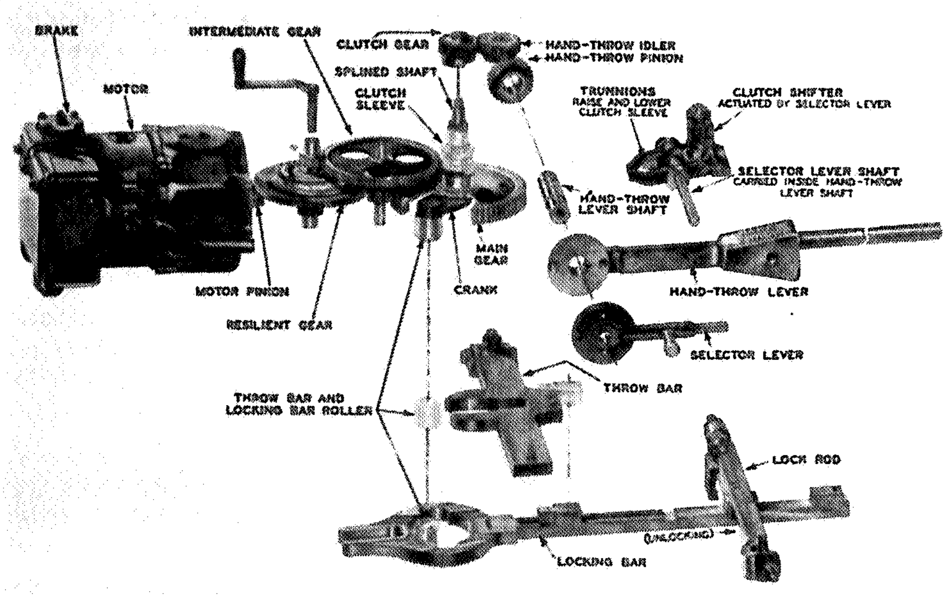



Fig. 42.
Arrangement of Gearing and Hand-Throw Mechanism Used in Models 5B and 5D Machines.

The hand-throw lever may be left in either position when the selector lever is returned to the "power" position, and the selector lever when so moved will lock the hand-throw lever.

The Model 5B switch machine is regularly furnished for operation on high (110 volts) or low (24-32 volts) voltage direct current, or high (110 volts) voltage alternating 25 or 60-cycle current. Direct current machines may be high, medium or low-speed types. Only high-speed types are available for operation on alternating current. Resilient gears are ordinarily supplied on all Model 5B machines except high-voltage, high-speed types. Multiple dry-plate type friction clutches are supplied on the latter.

Electromagnetic outboard shoe-type brakes are regularly furnished on the Model 5B switch machine.

*Models 5C and 5D switch machines.*

The Models 5C and 5D switch machines are much the same as the Models 5A and 5B switch machines, respectively, except they provide relayed battery indication only and have a switch machine controller resiliently supported in a metal case in the contact compartment in place of the pole changer used in the Models 5C and 5D switch machines.

A friction clutch of the multiple dry-plate type is regularly furnished on all Model 5C switch machines and on high-voltage high-speed Model 5D machines. Resilient gears are regularly furnished on low-voltage machines.

These machines are regularly furnished for operation on high (110 volts), or low (24-32 volts) voltage direct current. When equipped with biased-neutral controllers their control may be 20 to 24 or 10 to 12 volt direct current. When equipped with controllers with master relays, their control may be 110, 24 to 32 or 10 to 12 volt direct current. Machines may be high, medium or low-speed types.

The Model 5C switch machine is shown in Fig. 43 and the Model 5D in Fig. 44.

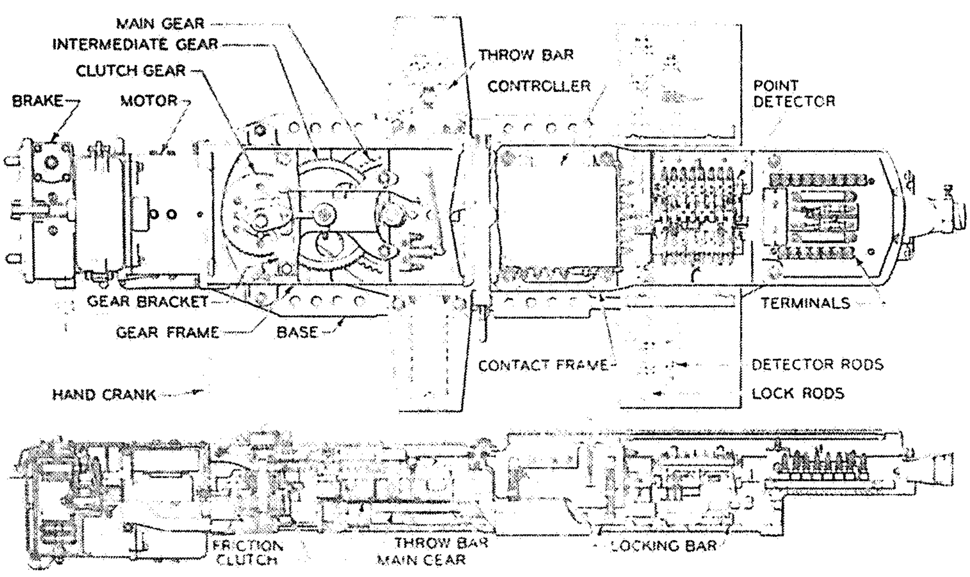



Fig. 43.
Model 5C Switch Machine. (Shown Arranged for Left-Hand Operation.)

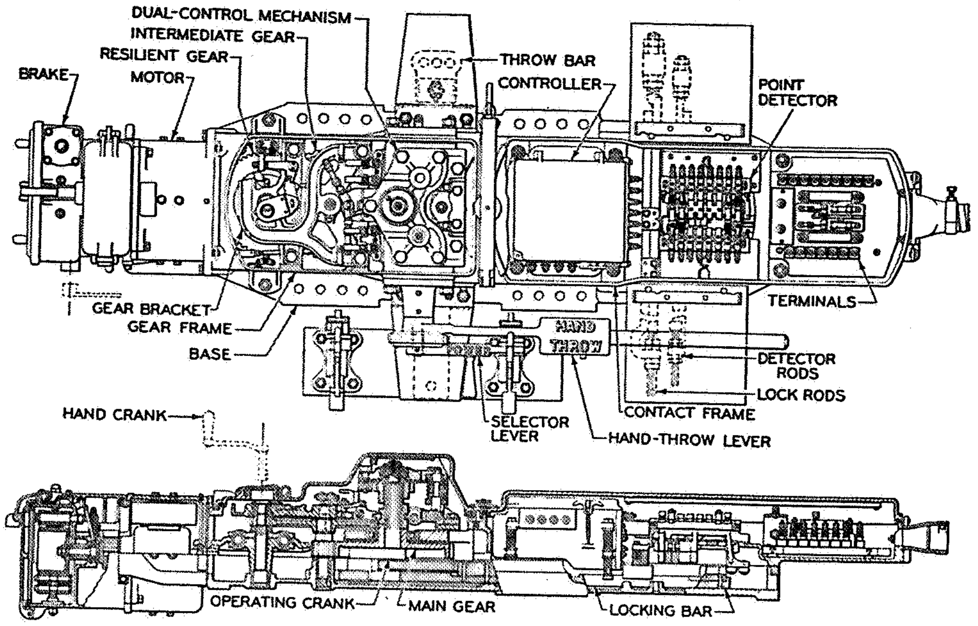



Fig. 44.
Model 5D Switch Machine. (Shown Arranged for Left-Hand Operation.)

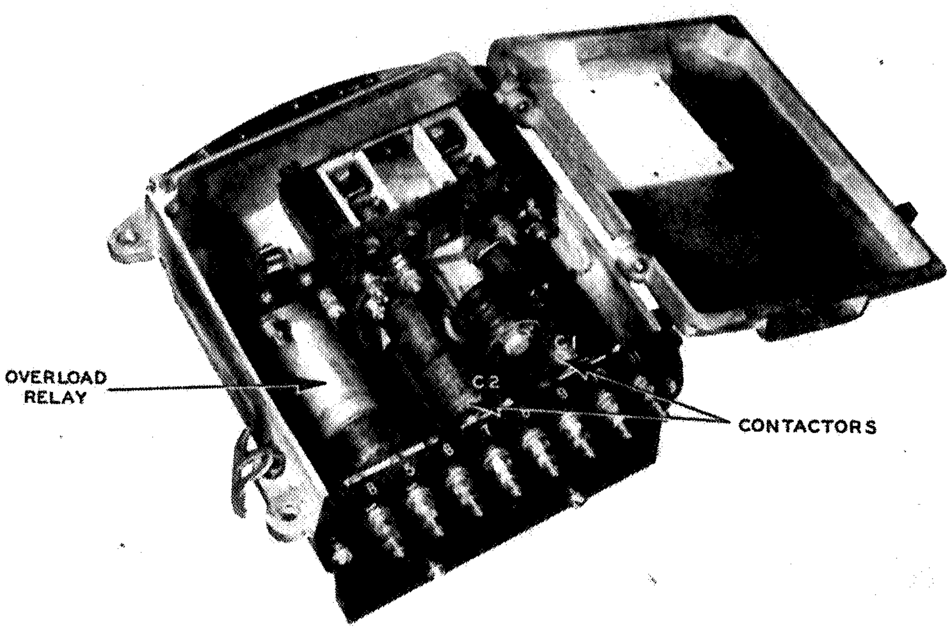



Fig. 45.
Biased-Neutral Switch Machine Controller Used on Models 5C and 5D Switch Machines.

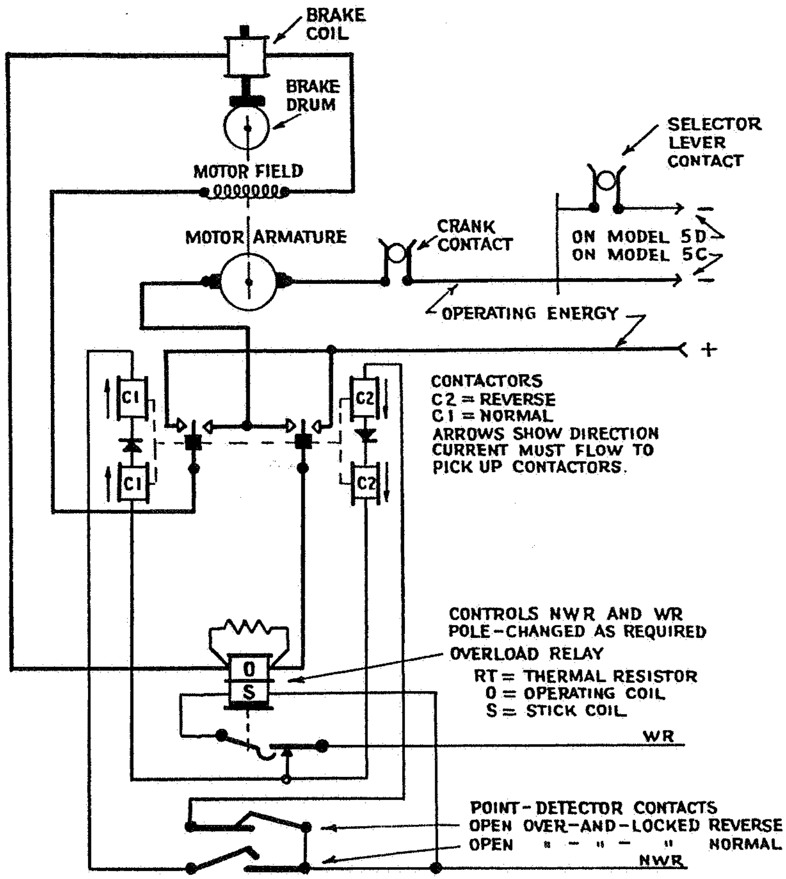



Fig. 46.
Simplified Circuit Showing Control and Operating Circuits for Models 5C and 5D Switch Machines Equipped with Biased-Neutral Controller.
(Note: Normal as used in Fig. 46 is for a switch whose right-hand point is normally closed.)

Models 5C and 5D switch machines may be equipped with either of two types of controllers. These controllers differ principally in the means used to secure integrity of response to two-wire polarized control. The biased-neutral controller, a more recent development, has two biased-neutral operating contactors (one normal and one reverse) and an overload relay. The biased-neutral contactors respond only to control current of a specific polarity. The normal contactor responds only to one polarity, and the reverse controller responds to the opposite polarity.

The older controller has two neutral contactors (one normal and one reverse) and an overload relay. Discrimination of control polarity is accomplished either by a built-in polar master relay or by external local means of control when a master relay is not required.

Figure 45 shows the biased-neutral controller, and Fig. 46 shows a simplified circuit for the use of the biased-neutral controller for Models 5C and 5D switch machines.

Referring to Fig. 46, operating contactors C1 and C2 open and close the motor and brake circuit. These contactors are equipped with magnetic blowouts to suppress arcs that may occur in ordinary operation or when the machine is stalled. The magnetic structure of each biased-neutral contactor is such that the contactor will not pick up its armature unless current is flowing through the contactor coils in one specified direction.

The overload relay acts to open the circuit to the operating contactors (and hold it open) only when the machine is stalled. Reversing the polarity of the control current automatically resets the contact of the overload relay and permits the machine to be restored to its former position. Then the machine can again be operated in the direction in which it was stalled. The overload relay is usually adjusted to pick up in 15 seconds or less at 10 amperes, but may be adjusted to fit particular operating requirements. Adjustment may be made by means of an easily accessible square-head nut.

As shown in Fig. 46, the normal and reverse operating contactors are controlled through the motor control contacts (part of the point detector contacts). The motor control contacts are both closed during the unlocking of the machine, and they both remain closed until the machine is fully locked, at which time the appropriate contact (normal or reverse) opens. The motor control contacts thus act to de-energize the proper contactor at the end of a movement and to provide a circuit for reversing in midstroke when desired.

The motor operating circuit (heavy lines) is controlled through the contacts of the normal and reverse contactors in series with the thermal resistor and operating winding O of the overload relay. The contact fingers of the contactors are held in the positions shown by a centering device when both contactors are de-energized, thus completely isolating the motor circuit and protecting against possible crosses on the motor wires. Also, when one contactor picks up its armature to close its front contact, the back contact of the other contactor will be made, and vice versa.

A half-wave rectifier is connected between the coils of each biased-neutral contactor. Connecting the rectifier between the coils provides considerable protection against the effects of lightning, as the coils act as chokes.

The rectifier is used for the following reasons:

1. It permits a relatively high energy input to the contactor. As soon as the switch machine has operated in response to the energization of the control circuit, the current to the contactor is cut down to the amount permitted by the low back-leak (approximately 0.007 ampere at 10 volts) of the blocking rectifier. This makes normally energized control practical and economical, although not essential to operation of controller.
2. Both contactors are in multiple when the switch machine is unlocked, but only one is taking current. The only current through the other contactor is that permitted by the back-leak of the rectifier. This permits the use of control wires with higher resistance than is practicable with older controllers.
3. Since only one contactor is energized when the machine is unlocked, and since both contactors are connected in multiple, there is a tendency for the de-energized contactor to absorb the inductive surge produced by the other contactor when the control energy is interrupted in midstroke.

The overload relay has two coils: an operating coil with a thermal resistor connected in multiple and a stick or holding coil. Normally, the major part of the current to operate the motor flows through the resistor, but heavy current, such as the motor would draw when the movement of the switch is obstructed, heats the resistor and increases its resistance. This will cause sufficient current to pass through the operating coil of the overload relay to pick up its armature. Once the armature is picked up, it will be held up by the stick

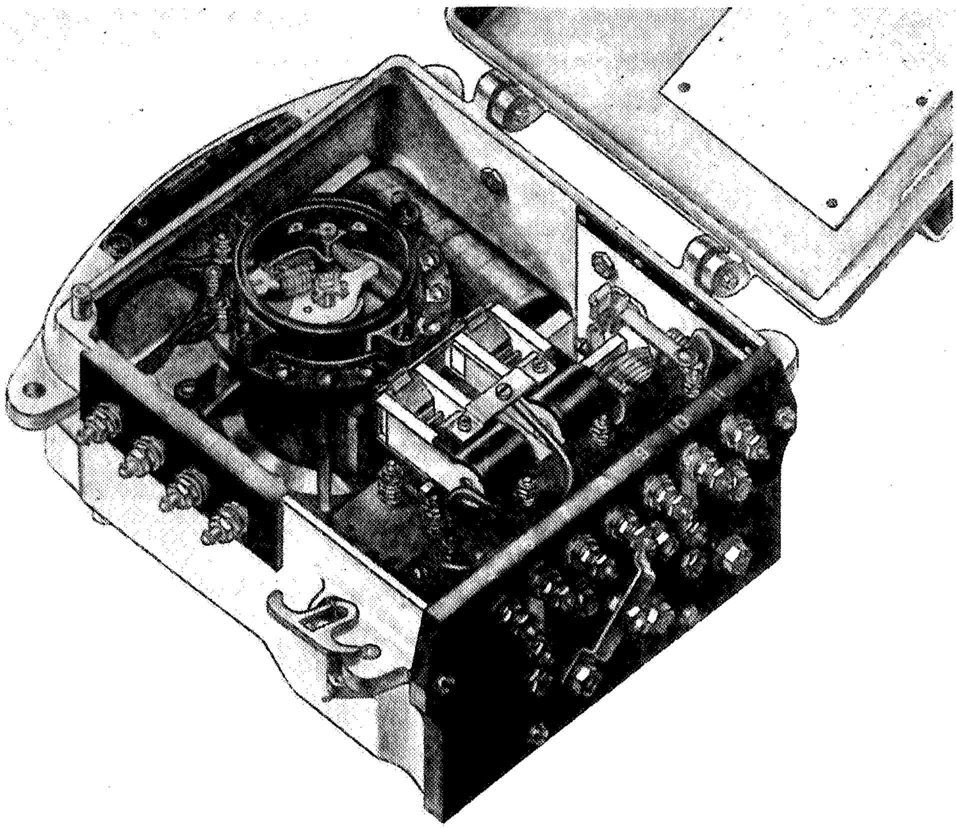


Fig. 47.
Switch Machine Controller with Master Relay Used on Models 5C and 5D Switch Machines.

coil, and the contactor, and in turn the motor circuit, will be de-energized until the control circuit is de-energized or changed to call for the switch machine to be operated in the opposite direction. The action of the relay is retarded by copper rings to prevent its picking up and opening the motor circuit because of surges in current when starting or reversing.

Figure 47 shows the switch machine controller with two neutral operating contactors (one normal and one reverse), an overload relay, and a master relay. The master relay may be omitted when local means of control are provided.

The operating contactors open and close the motor and brake circuit. For 110-volt operation, these contactors are equipped with magnetic blow-outs. Earlier type machines were equipped with electromagnetic blow-outs, but present-day models are equipped with permanent-magnet blow-outs.

The overload relay is the same in principle as used with the biased-neutral controller.

The master relay is a two-position polar device, strongly biased in either normal or reverse position by means of its permanent-magnet rotor, which is strongly attracted to one position or the other whether the coil is energized or not, and also by a contact toggle spring. Present-day master relays are regularly furnished with one dependent normal-reverse contact. In some former applications they were furnished with up to four dependent normal-reverse contacts.

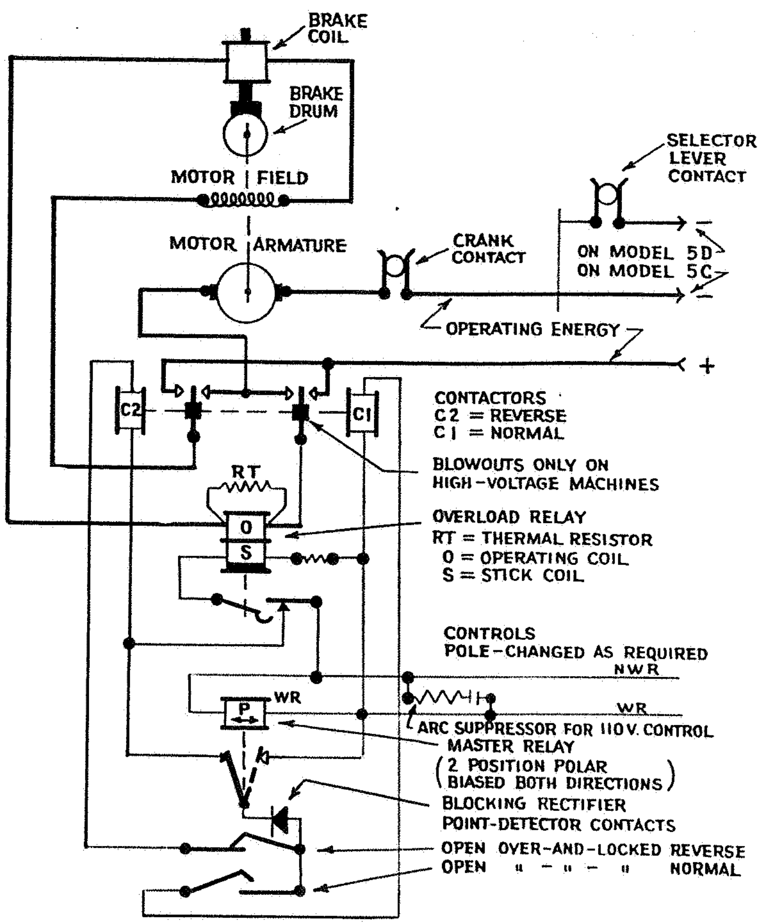



Fig. 48.

Simplified Circuit Showing Control and Operating Circuits for Models 5C and 5D Switch Machines Equipped with Master Relay.

(Note: Normal as used in Fig. 48 is for a switch whose right-hand point is normally closed.)

Figure 48 shows a simplified circuit for the use of the controller with neutral contactors and master relay for Models 5C and 5D switch machines. The motor operating circuit (heavy lines) is controlled through the contacts of the normal and reverse contactors in series with the thermal resistor and operating winding of the overload relay. The armatures of the contactors are equipped with a centering device so constructed that when both contactor coils are de-energized the contact fingers of both are held midway between their front and back contacts, thus completely isolating the motor circuit and protecting against possible crosses on the motor wires. Also, when one contactor is energized and its front contact made, the back contact of the de-energized contactor will be made, and vice versa.

The half-wave blocking rectifier, shown in series with the master relay contact, prevents the momentary pick-up of the last operated contactor, which otherwise sometimes occurs after an overload has been encountered or when reversal in midstroke is made.

The magnetic brake (solenoid coil) is connected in series with the motor and releases the brake when current is applied to the motor. The purpose of the brake is to stop the motor at the end of the stroke, or any time the motor circuit is de-energized, without shock, and hold it stopped against creeping due to vibration. In this way the machine is protected against possible unlocking if it should stand unused for long periods.

*Style M switch machine.*

A Style **M** switch machine with covers removed is shown in Fig. 49.

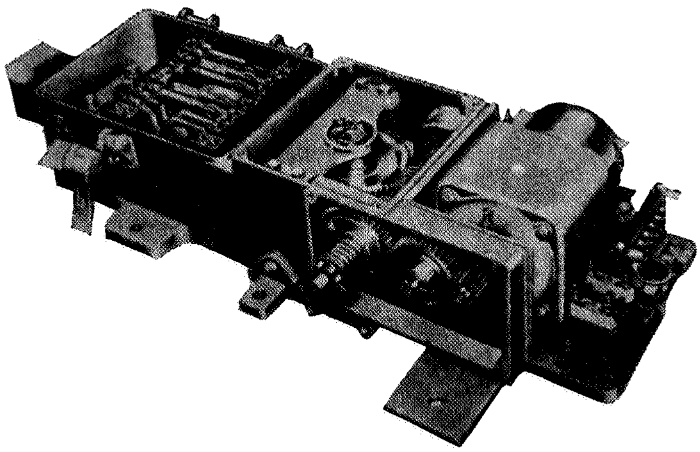


Fig. 49.
Style M Switch Machine with Covers Removed.

This machine consists of a motor, a clutch, gear train, a cam arrangement, a locking device and a circuit controller. These units are housed in a cast-iron case, separate compartments house the motor, the gear train and the circuit controller, with separate covers for each compartment.

Power from the motor is transmitted by means of the gear train which includes a worm gear to a combined crank shaft and arm X as shown in Fig. 50, which drives the switch operating bar Y and the locking bar Z.

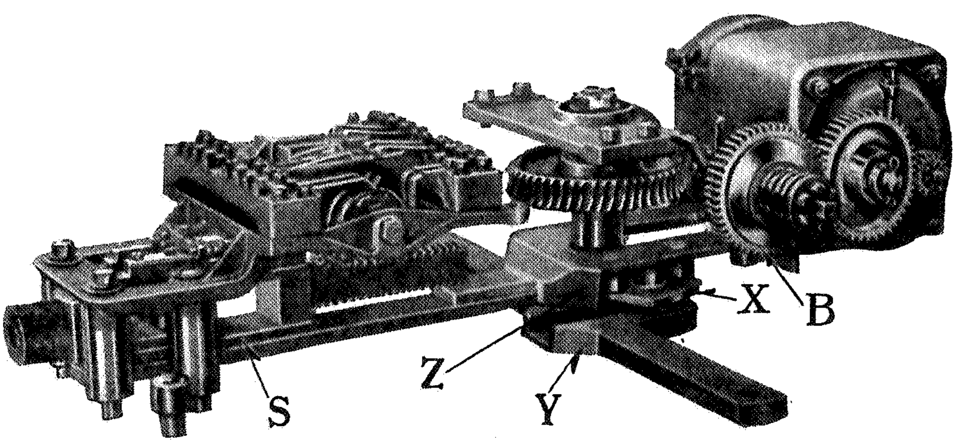



Fig. 50.
Gear Arrangement for Style M Switch Machine.

Connection to the switch points can be made at either end of the operating bar Y. The position of the switch points is checked and secured by the action of the lock box S which forms a part of the locking bar. The circuit controller is mounted over and operated by a rack fastened to lock box S.

Motors for direct or alternating current are interchangeable. A friction clutch is provided to protect the motor against overload or shock and is a part of gear wheel B, Fig. 50.

The operation of the parts for throwing and locking the switch is shown in Figs. 51, 52 and 53. Figure 51 shows the normal position. Starting from this position a reverse movement is started by a clockwise rotation of combined shaft and crank arm X. Lug $x^1$ on the top of crank X acting against roller $z^1$ on locking bar Z effects the unlocking of the lock rod by causing motion plate Z to move to the left one-half of its stroke. Meanwhile, roller x on the underside of crank X has moved through an arc of 40 degrees in groove y in switch operating bar Y, thus freeing the bar for the reverse stroke. During the next 140 degree revolution of crank X roller x engages the reverse operating face of groove y and throws the switch operating bar Y to the reverse position.

Figure 52 shows the relative midstroke positions of switch operating bar Y and locking bar Z, crank X is still rotating clockwise, but is not transmitting motion to locking bar Z, as lug $x^1$ has become disengaged from roller $z^1$ and the arcs of contact at v and $v^1$ between crank X and locking bar Z are radial to the center of the shaft.

The complete reverse position is shown in Fig. 53. Roller x on crank X acting in groove y has moved operating bar Y to the reverse position and secured it; lug $x^2$ has come into contact with roller z thus driving locking bar Z to the reverse position.

In Fig. 50 it will be noted that lock box S rests on top of locking bar Z, two holes in the lock box fitting over two studs on the locking bar. The lock box S is inverted when changing from right to left-hand movement, or vice versa. This feature allows the same lock rod to be used for both right and left-hand movements.

Provision is made for operating the machine by a hand crank. The machine is also furnished with double lock box for two lock rods for movable point frogs.

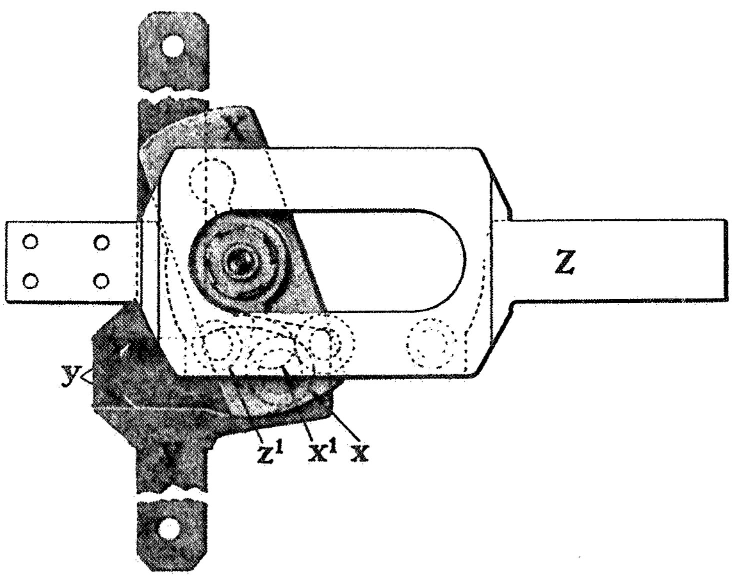



Fig. 51.
Driving Parts in Normal Position, Style M Switch Machine.

A point detector may be applied and since it is similar in operation to that on the Style M-22 switch machine, its operation will not be described here. Style M switch machines are made for operation on 220, 110 or 20 volts direct current and 110 volts alternating current.

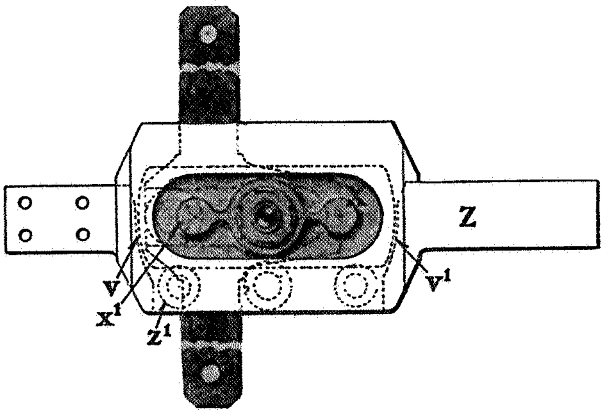



Fig. 52.
Driving Parts in Mid-Position, Style M Switch Machine.

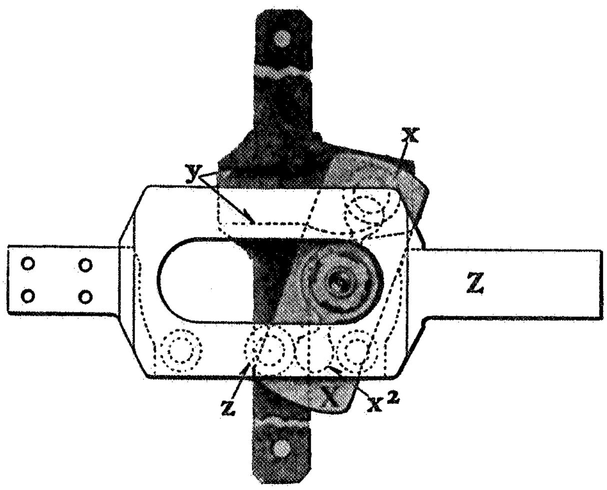



Fig. 53.
Driving Parts in Reverse Position, Style M Switch Machine.

*Style M-2 switch machine.*

The Style M-2 switch machine is the same as the Style M except the motor and train of gears have been rearranged, also a crank contact has been added which opens the motor field circuit when the crank is inserted for hand operation.

*Style M-22 switch machine.*

The Style M-22 switch machine shown in Fig. 54 is equipped for dual control, that is, it can be operated either by power or hand. It is similar to the Style M-2 machine except for the addition of the selector and hand-operation levers and change in the main gear case. This description will be confined to the operation of the gear case. This gear case permits the operation of the machine by means of the motor, or by means of the hand-throw lever.

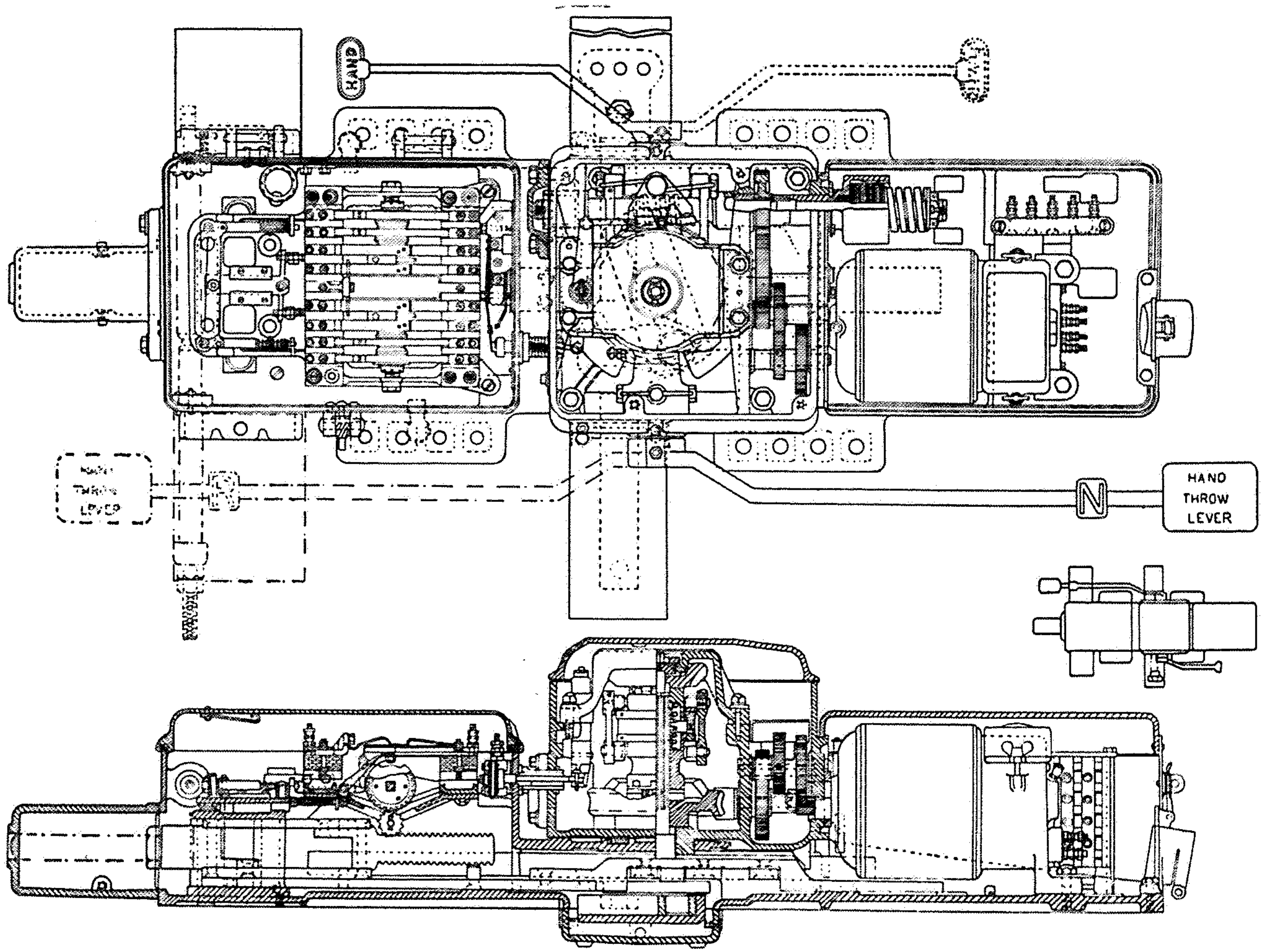



Fig. 54.
Sectional View of Style M-22 Switch Machine.
(Mechanism in hand-operation position.)

Figure 55 shows that the shaft of the main driving crank is mounted vertically and supported by two bearings. The top bushing, which is secured against the shoulder at the top of the shaft by a castellated nut and cotter, rides in a recess in the top bearing plate, thus obtaining both horizontal and vertical support. The worm gear is fitted to turn freely on the main shaft and its hub is supported on the bottom of the gear case. On the upper surface of the worm gear is a ring of symmetrically spaced teeth of uniform size. Immediately above this gear is the selector clutch which consists of two members forced apart by a coil spring and limited in their vertical travel by a coupler which holds the clutch together as a complete unit. The clutch is splined to the shaft, being free to move up or down, but rotates with the shaft as a unit. The lower member of the clutch has a similar set of teeth to that on the upper face of the worm gear, and Fig. 55 shows them in mesh. The teeth of the upper clutch member are similar to those on the worm gear, except that one tooth is left out for a reason explained later.

Hand-throw pinion B rotating on a bushing around the top of the main shaft is driven by hand-throw bevel gear C and teeth on its lower hub engage with selector clutch A when the latter is forced to the "up" position by throwing the selector lever to the hand-operation position. However, the engagement be-

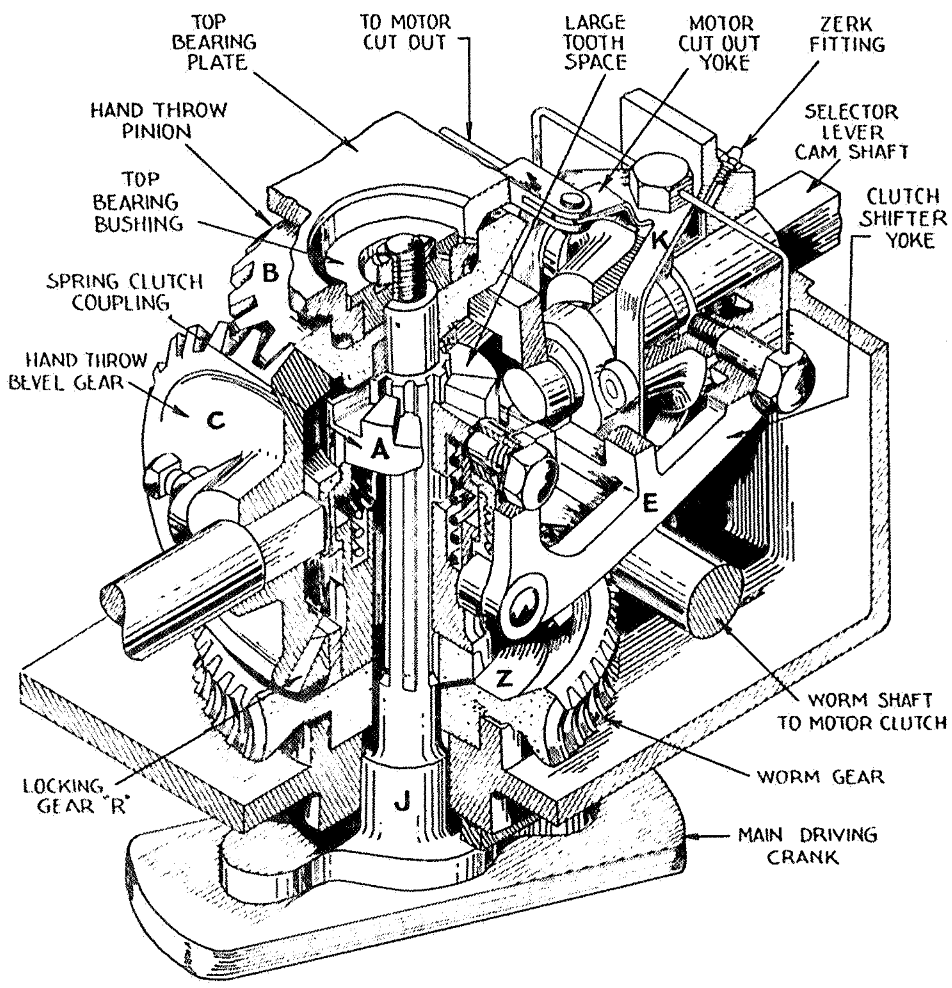



Fig. 55.
Perspective View of Gear Case for Style M-22 Switch Machine.

tween these two members cannot be made until the hand-throw lever and the switch mechanism agree in position, as one large tooth and one large space, respectively, in otherwise symmetrical sets of teeth, are provided to prevent this.

Since neither the motor-driven worm gear Z nor the manually actuated hand throw pinion B are directly connected to the main shaft, it is necessary to transmit motion to the main driving crank through the selector clutch which is splined to the main shaft. Selection between these two sources of power is obtained, through the operation of the selector lever, by throwing it to either the "hand" or the "motor" operation position. The selector lever cam shaft has two cams: one operates clutch shifter yoke E and the other operates motor cut-out yoke K which opens the motor circuit the instant the selector lever is moved from the motor operation position. Both yokes in effect are cam followers and are positive in action.

The clutch shifter yoke has two pairs of rollers straddling the selector clutch housing at 180 degrees and raises the clutch to engage with the hand-throw pinion for "hand" operation, or lowers the clutch for engagement with the worm gear to allow "motor" operation. As shown in Fig. 56, there is also a locking arm on the lower end of the clutch shifter yoke which engages in a notch cut in a bevel locking gear located just above the worm gear, but meshing with the hand-throw bevel gear. When the selector lever is thrown to the hand-operation position, the locking arm is disengaged from the locking gear, and, what is more vital, the complete movement of the selector lever to the motor position is contingent upon the switch mechanism being in either the full normal or reverse position. The design of the selector clutch allows the selector lever (except when locked out, as explained in the description of Fig. 56) to be moved from one extreme position to the other regardless of the positions of the sets of teeth which must mesh to permit either "hand" or "motor" operation. Should these teeth not mesh when the selector lever is thrown, the spring inside the selector clutch is compressed and as soon as the teeth on the adjacent gear, against which the clutch has been forced, are moved to a meshing position the teeth on the clutch will automatically snap into engagement.

The Style M-22 machine is furnished to operate on 110 volts direct or alternating current and 20 volts direct current.

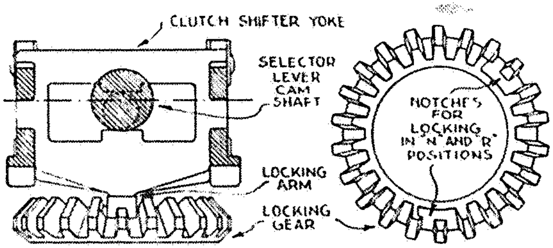



Fig. 56.
Illustrating Locking between Clutch Shifter Yoke and Locking Gear to Insure That Hand-Throw Lever is Left in One or the Other Extreme Positions.

*Styles M-22A and M-22B switch machines.*

The Style M-22A switch machine differs from the Style M-22 in that the selector lever and hand-throw lever are both located on the field side of the movement and the interlocking between levers is accomplished by means of interlocking discs mounted on the lever shafts on the outside of the movement.

The interlocking discs being visible aids the trainmen in understanding the manipulation of the levers.

The M-22A movement retains the feature of the M-22 in that full lock rod protection is provided for both motor and hand-throw operation.

The M-22B movement is identical with the M-22A except it is so arranged that it does not provide switch point locking when under hand-throw operation. This permits the train crew, in case of lock rod failure, to throw the movement by hand and allow the train to pass over the switch, using hand signals.

Mechanically, the only difference between the M-22A and M-22B movement is in the design of the hand-throw pinion. All other parts are interchangeable and one movement can be changed to the other by substituting the proper hand-throw pinion.

*Style M-25 switch machine.*

The Style M-25 switch machine is the same as the Style M-22 machine except that its control device is housed within the switch machine case.

*Gear Ratios.*

The Styles M, M-2, M-22, M-22A and M-22B machines, furnished for operation on 20 volts direct current, may be obtained with three different gear ratios as follows: one for 30 seconds operation with current of 3.7 amperes, one for 14 seconds operation with current of 5.4 amperes, and one for 7.5 seconds operation with current of 10 amperes, these values being considered as average.

Machines equipped with the first two gear ratios may be controlled by standard polarized relays but the 7.5 seconds ratio on account of its high current is usually controlled by a DP-25 polarized switch control relay.

*Contactor type controller.*

The contactor type controller used in earlier installations for the control of the 7.5 second switch movement has been superseded by the DP-25 switch control relay and OR-11 overload relay.

*DP-25 switch control relay.*

The DP-25 is a polarized relay designed specifically to provide a universal direct current control device for low-voltage direct current electric switch movements, or for 110-volt direct current or alternating current movements (except 100 cycles). This relay replaces the direct current Type F controller, the contactor controller, and the alternating current Type F controller, except for alternating current 100-cycle applications. For 110-volt 100-cycle alternating current switch movements, the alternating current Type F controller is recommended.

The DP-25 relay is designed to operate on low-voltage direct current control energy, but can also be operated on high-voltage direct current energy with suitable series resistor in the control circuit.

The standard DP-25 relay includes one heavy-duty magnetic blow-out neutral front contact and 4N-4R polar contacts. The magnetic blow-out contact is designed to handle the closing and opening of the motor circuit. Two silver-to-silver polar contacts are used to reverse the motor current, and two silver-to-silver impregnated carbon polar contacts are used in the WP relay circuit for checking purposes.

An overload relay is necessary to protect switch operating circuits against overload should a switch movement become stalled, and therefore an overload relay is used as a complementary protective device with every DP-25 relay. The OR-11 relay provides the desired protection for low-voltage and high-voltage direct current circuits and the OR-20 relay provides the same protection for 25 and 60-cycle alternating current circuits. The overload relays are circuited in such a manner that they are self-restoring, which means that should the relay function to open the switch operating circuit when the switch is moving in a given direction, when the control circuit for the DP-25 relay is

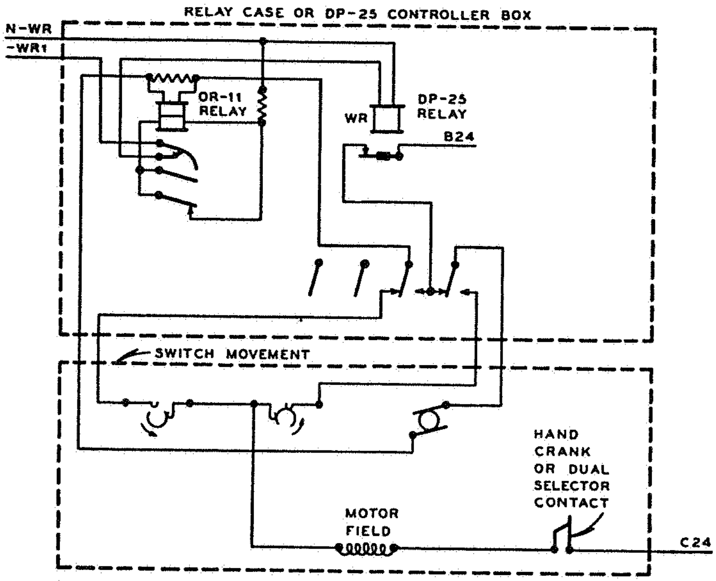



Fig. 57.
Typical L. V., D. C. Switch Movement Circuits Using DP-25 Control Relay.

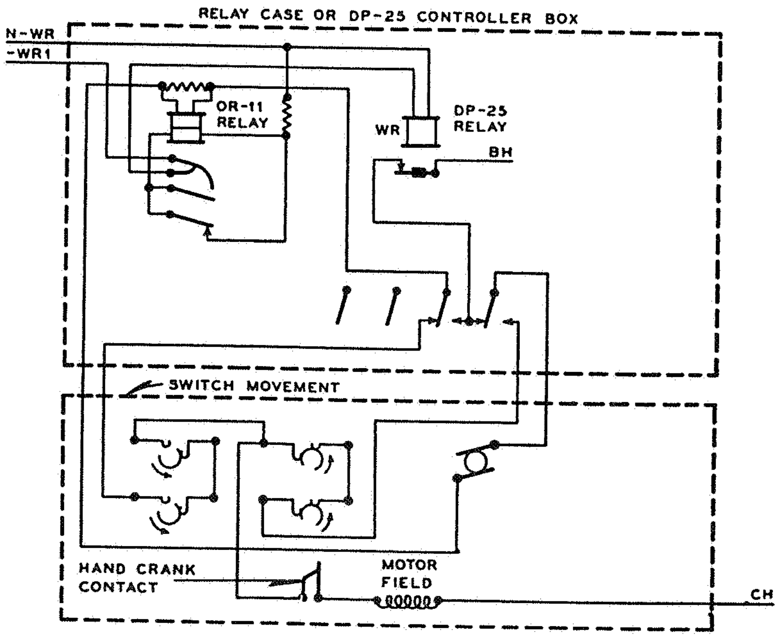



Fig. 58.
Typical H. V., D. C. Switch Movement Circuits Using DP-25 Control Relay.

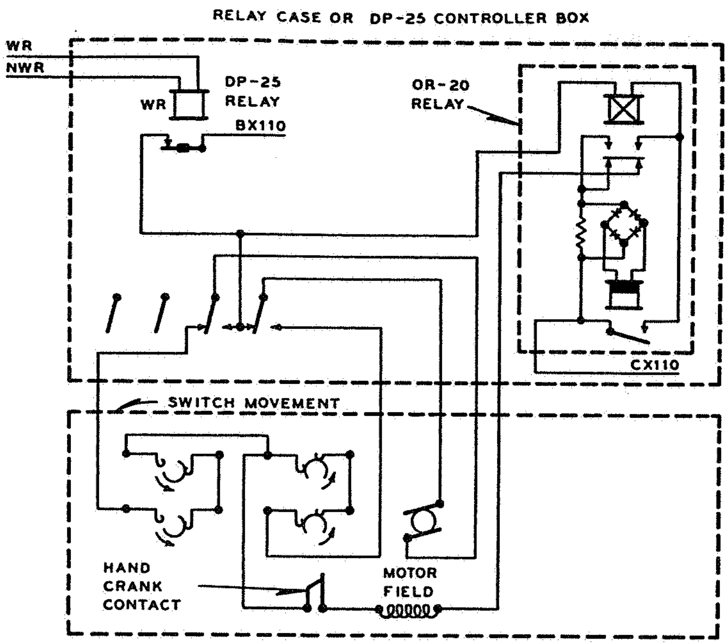



Fig. 59.
Typical H. V., A. C. (25 or 60 Cycle) Switch Movement Circuits Using DP-25 Control Relay.

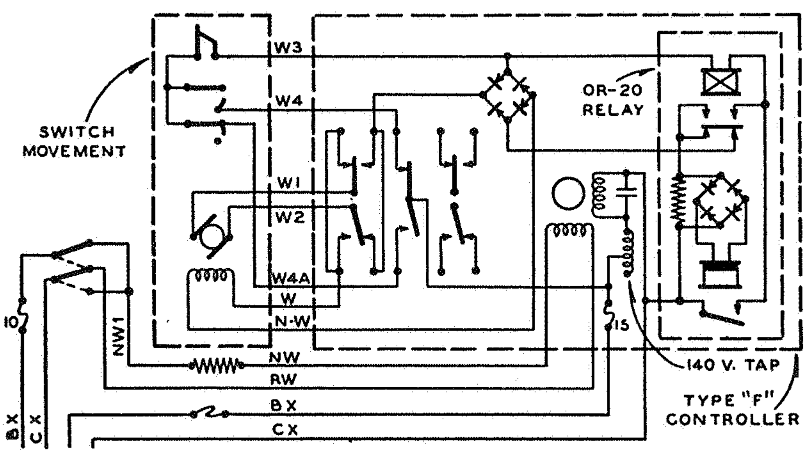



Fig. 60.
Typical Switch Movement Circuits Using A. C. Type F Controller.

pole-changed to move the switch to the opposite position, the overload relay releases and is immediately in position to function for the new position.

In electric interlockings, the DP-25 relay and its related overload relay are placed in a combined relay housing and junction box and this unit is located immediately adjacent to the switch movement that it controls. A control unit of this type is used for every switch function in the interlocking.

Typical switch movement circuits using the DP-25 relay are shown in Figs. 57, 58 and 59. Typical switch movement circuits using the alternating current Type F controller and OR-20 relay in a 110-volt 100-cycle application are shown in Fig. 60.

*General.*

1. Maintenance and repair work which may interfere with safe operation of trains or engines must not be started until such operation has been fully protected.

2. Before removing rails, points or frogs, protecting signals must be arranged to display their most restrictive indication. Signals must not be restored to normal operation until it is known that track is safe and inspection and tests have been made to determine that the signals function as operated.

3. When mechanical locking of interlocking machine is to be changed or removed from machine, or locking becomes disarranged or broken, proper measures must be taken to protect train movements until interlocking is restored to normal operation.

4. Circuits must not be opened or shunted, contacts of controlling devices bridged, or any other action taken which may affect safety of train operation.

5. Machine must be kept in good condition, free from dust, grease, dirt and excessive lost motion. Levers and locking must be kept clean, all bearing parts properly lubricated, dowel pins tight, and sufficient tension in latch springs. Contacts must be kept clean and in proper adjustment.

6. During snow and sleet storms, switches and pipe lines must be kept clean. Where snow melting open flame methods are used, care must be exercised to prevent damage to apparatus.

7. Seals and padlocks, where provided, must be maintained and handled in accordance with instructions issued by proper authority.

8. Clearances must be maintained as required.

9. Paint must be applied as often as required to prevent deterioration. Rusty surfaces must be cleaned before painting. Paint must not be applied to threads or screw jaws, adjustable screws, cotters or gaskets.

10. Threads of rods, jaws and bolts, and bearings of all movable parts must be kept clean and properly lubricated.

11. Bolts must be kept tight. Cotter pins of the proper size must be in place in holes provided for that purpose, must be in good condition and properly spread.

12. Gaskets for housings must be in place, in good condition, of proper size, resistant to water, and provide a weatherproof and dustproof seal.

13. When movable parts are worn to such an extent as to create excessive lost motion, they must be replaced.

14. Batteries must be maintained and tested in accordance with Instructions for Batteries and Cells.

15. Electric lamps must be maintained and tested in accordance with Instructions for Incandescent Electric Lamps.

16. Insulated rail joints must be maintained and tested in accordance with Instructions for Insulated Rail Joints.

17. Rectifiers and motor-generators must be maintained and tested in accordance with Instructions for Rectifiers and Motor-Generators.

18. Relays must be maintained and tested in accordance with Instructions for Relays.

19. Setting of time releases must be in accordance with Instructions for Time Releases Applied to Signal Apparatus.

20. Electric locks must be maintained in accordance with Instructions for Electric Locks for Interlocking Machines.

21. Signals must be maintained and tested in accordance with Instructions for Light and Motor Semaphore Signals.

22. Switch circuit controllers must be maintained and tested in accordance with Instructions for Switch Circuit Controllers.

23. Track circuits must be maintained and tested in accordance with Instructions for Track Circuits.

24. Wire and cable must be maintained and handled in accordance with Instructions for Wire and Cable.

25. Switches, movable point frogs and split point derails must be so maintained that they cannot be locked when ¼ inch obstruction is placed between stock rail and switch point 6 inches from point of switch.

26. Holes or notches in lock rods must have square edges and must not be more than 3/16 inch larger than the locking bar or plunger.

27. Edges of locking dogs and rods of switch-and-lock movement or facing point lock must be maintained with not more than 1/16 inch wear.

28. Point detector circuit controller must be so maintained that the contacts will not assume the positions indicating point closure if the switch point is closed with a ¼ inch obstruction placed between the stock rail and switch point 6 inches from point of switch.

29. Wires must be so arranged as not to interfere with operating parts of apparatus.

30. Circuits must be kept free of grounds which may interfere with proper operation.

31. Lightning arresters must be properly connected and maintained.

*Tests.*

32. When making tests of apparatus, proper instruments must be used and it must be known that no unsafe conditions are set up by the application of testing equipment.

33. When repair, adjustment, change or replacement is made in any part which may affect the operation of the interlocking, tests must be made immediately to determine that proper operation is assured.

34. Insulation resistance tests must be made in accordance with Instructions for Insulation Resistance.

35. Tests must be made periodically, as instructed, to determine that the various safety features are effective.

36. Electric locking must be tested in accordance with Instructions for Electric Locking.

37. Cross protection must be tested to insure that protective devices operate properly to prevent movement of switches, signals and other units when current is improperly applied to the circuits.

38. Restoring feature on power switches must be tested to insure that power will be applied and will restore switch movements to normal or reverse position.

39. Movable bridge locking must be tested to insure that rail locks, bridge locks, bolt locks, circuit controllers, and electric locks are in good condition and are functioning properly.

40. Ground resistance test must be made in accordance with Instructions for Resistance of Made Grounds.

*Mechanical locking.*

41. The various parts of the locking bed, locking bed supports and tappet stop rail must be kept rigidly secured and properly aligned to insure free and effective operation.

42. Driving pieces, dogs, stops and trunnions must be kept properly secured to locking bars. Swing dogs must have full and free movement. Top plates must be in place and tight. Splices in longitudinal locking bars must be straight and properly made.

43. Locking faces must fit squarely against each other.

44. Locking bars in new locking must have full stroke as follows:

(a) Power interlocking machine, S.& F. miniature locking ...... $1\frac{1}{16}$ inches

(b) Power interlocking machine (Style A miniature locking).

1. Vertical locking ............ $\frac{1}{4}$ inch
2. Horizontal locking ............ $\frac{11}{32}$ inch

(c) Table interlocking machines.

1. Type A.
   - (a) Vertical locking ............ $\frac{7}{32}$ inch
   - (b) Horizontal locking ............ $1\frac{1}{2}$ inches
2. Type TC ............ $1\frac{1}{16}$ inches

45. When lever or latch which should be locked can be moved more than shown below, it must be considered as having too much lost motion and lost motion must be removed.

(a) Power machine.

1. Latch operated locking. When lever latch block can be raised to within $\frac{7}{32}$ inch of top of quadrant.

2. Lever moving in horizontal plane. When lever can be moved more than $\frac{5}{16}$ inch when in normal position or $\frac{9}{16}$ inch when in reversed position.

3. Lever moving in an arc. When lever can be moved more than 3 degrees, equivalent to $\frac{7}{64}$ inch movement of the lever latch on quadrant.

46. When new locking is to be placed in service or a change in locking is made, a complete check and test must be made of the locking as follows:

(a) With all levers normal see that locking agrees with the dog chart.

(b) Levers must be tested to see that each lever when reversed and latch down, locks all other levers in the position as required by the locking sheet.

(c) Complete test of the locking from a signal layout or interlocking plan must be made as follows:

1. Test locking between switch, derail and movable point frog levers.

2. Set up each route and endeavor to reverse each signal lever that should be locked by that route; then reverse signal lever, governing movements over route and endeavor to operate each lever that should be locked by the signal lever; then restore lever to normal position and make similar test with lever for the opposing signal.

3. Parallel routes or other routes must be set up and signal levers operated for movements in both directions on each route to insure that the locking of one route does not interfere with other routes.

4. These tests require that the lever latch must be fully down with lever in proper position.

*Electric.*

47. While adjusting and operating mechanism, energy must be cut off the motor. Where facilities are not provided to open motor circuit, motor brushes must be lifted and fuse at interlocking machine removed until the work on operating mechanism is completed.

48. Operating mechanism must be operated by hand after making adjustments to see that they operate properly and without undue strain on any part before being operated by power and then by power from the control point for checking operation after making adjustments.

49. Contactors must not be operated manually, except when out of service.

50. Commutator must be smooth, clean and have a glossy appearance. To clean, lift brushes from commutator and use chamois or cloth free from lint and abrasives, moistened, if necessary, with Specification 102 or 103 oil, and then wipe commutator dry with dry chamois or cloth. Abrasives or files must not be used on commutators.

51. Brushes must be kept clean, fitted to commutator, free in brush holder, or brush holder free on stud. Springs must be in place and so maintained that brushes will have proper bearing and pressure. When installing new brushes they should be placed in position and carefully seated on the commutator by placing No. 000 or finer sandpaper under the brush with smooth side against the commutator, and while pressing brush oscillate sandpaper with commutator. Burrs must be removed from the brush. When finished, all sand and dust must be removed.

52. Friction clutch in operating mechanism must be adjusted in accordance with manufacturer's instructions.

53. Magnetic brake and overload relays must be checked periodically for proper operation.

54. Operating mechanism must be lubricated in accordance with manufacturer's instructions.