training chart manual

SECTION C

CRANKING MOTORS

Delco Remy

Delco Remy

SECTION C

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introduction

A cranking motor has often been referred to as an "educated short circuit." This is a very good description, because the total internal resistance of a typical cranking motor may be less than .01 ohm.

Consisting essentially of an armature, a field frame, a drive mechanism, and in some cases a solenoid, the cranking motor is designed and built to provide long periods of service in gasoline, diesel and turbine engine applications. This manual covers the operating principles of cranking motors, and also includes a section devoted to the different types and designs of cranking motors.

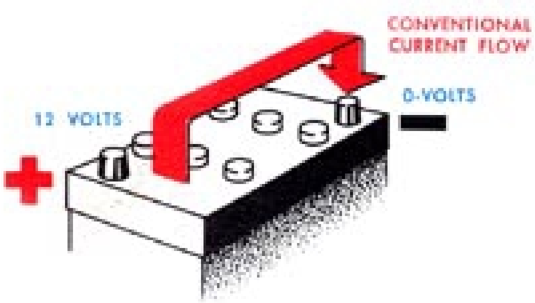
review of electrical fundamentals

A brief review of the fundamentals of electricity will be helpful in understanding the operating principles of cranking motors.

Ohm's law

Electric current is defined as a movement of electrons through a conductor such as a copper wire. Current flow is measured in amperes, and in cranking motor applications, the current flow provided by the battery often is several hundred amperes.

The force which causes current to flow is called voltage. The voltage is always measured between two points in a circuit. Using a 12-volt battery as an example, the voltage measured between the two battery posts is 12 volts. One post of the battery is said to have negative polarity, and the other positive, with the conventional direction of current flow being from positive to negative through the external circuit.

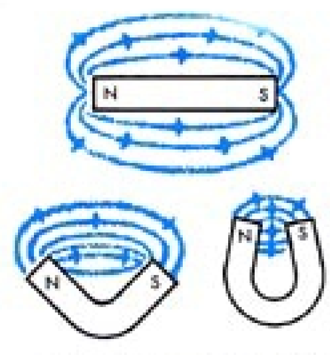


All conductors have a normal resistance to the flow of current. Resistance is measured in ohms, and when one volt is applied to a circuit having a resistance of one ohm, the current flow will be one ampere. This is an expression of Ohm's Law, which can be written as follows:

$$\text{AMPERES} = \frac{\text{VOLTS}}{\text{OHMS}}$$

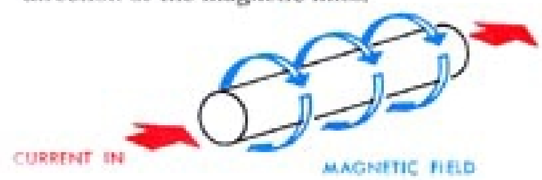
magnetism

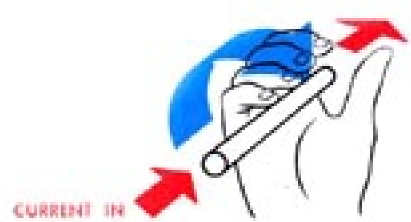
The effects of magnetism are well known, such as the attraction of a bar magnet for iron filings. A magnet has a North pole, designated as "N," and a South pole, designated as "S." The space around the magnet in which iron filings are attracted is called the field of force, or magnetic field, and is described as lines which come out of the "N" pole and enter the "S" pole.



electromagnetism

When an electric current is passed through a wire, a magnetic field consisting of concentric circles is created around the wire. The direction of the magnetic lines can be determined by grasping the conductor with the right hand with the thumb pointed in the direction of current flow; the fingers will then point in the direction of the magnetic lines.





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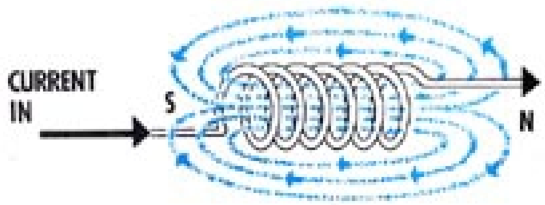
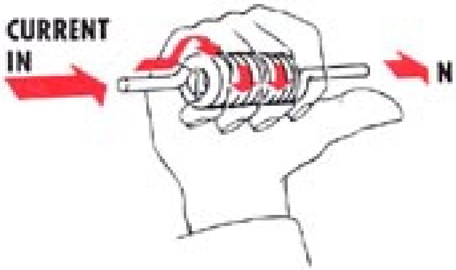
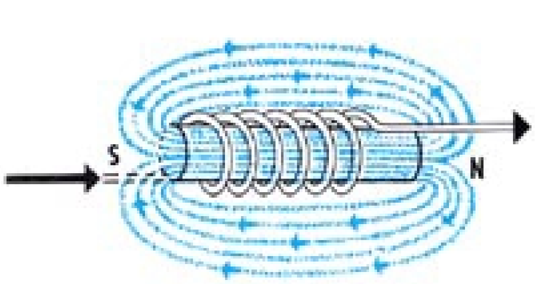
When the current-carrying wire is wound into a coil, a magnetic field with "N" and "S" poles is created just as in a bar magnet. The higher the current, and the greater the number of turns, the stronger will be the magnetic field. The location of the "N" and "S" poles can be determined by using the "Right Hand Rule"—wrapping the fingers around the coil in the direction of current flow, the thumb will then point towards the North or "N" pole.





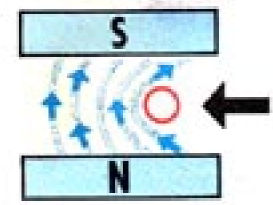
If an iron core is placed inside the coil, the magnetic field becomes much stronger, because iron conducts magnetic lines much easier than air. The iron frame and iron laminations in the armature of cranking motors not only provide a place onto which the windings can be assembled but also greatly increase the strength of the magnetic fields.



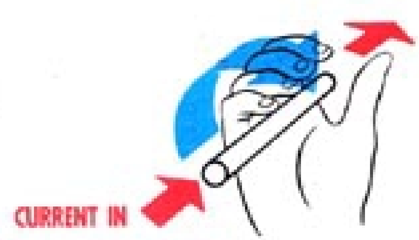
electromagnetic induction

If a conductor is moved so that it cuts across magnetic lines of force, a voltage will be induced in the conductor. The induced voltage will cause current to flow through the conductor when it is connected to an electrical load.

The direction of current flow is determined by the direction of the magnetic lines of force and the direction of motion of the conductor with respect to the magnetic field. With a conductor moving toward the left and cutting across a magnetic field as illustrated, the conductor will be striking the magnetic lines on its left side, which is called the leading side.



To determine the direction of current flow, grasp the conductor with the right hand with the fingers on the leading side and pointed in the direction of the magnetic lines of force. The thumb will then point in the direction of current flow.

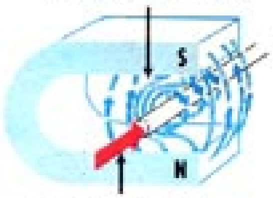


Electromagnetic induction is the principle whereby a voltage is produced which can cause current to flow in a generator; however, in the next section we will see that this same principle plays an important part in the operating principles of cranking motors.

Our coverage of electrical fundamentals has been limited and very brief, but it should serve as a useful background for the following sections covering the operating principles of cranking motors. For a more thorough treatment of electrical fundamentals, refer to the Delco-Remy Training Chart Manual DR-5133A, entitled "Fundamentals of Electricity and Magnetism."

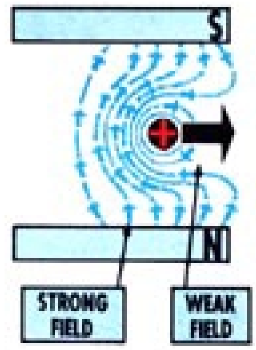
motor principles

To illustrate the electrical principle on which a cranking motor operates, consider a straight wire conductor located in the magnetic field of a horseshoe-shaped magnet with current flowing through the wire as shown by the red arrow. With this arrangement there will be two separate magnetic fields—the one produced by the horseshoe magnet, and the one produced by the current flow through the conductor.

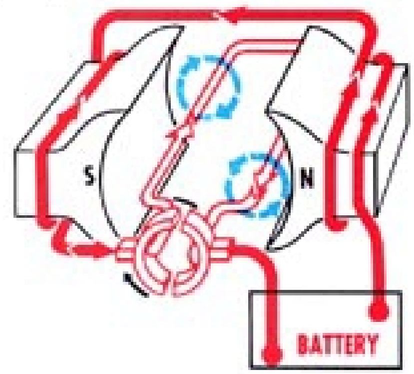


Since magnetic lines leave the "N" pole and enter the "S" pole, the direction of the magnetic lines between the two poles of the horseshoe magnet will be upward, as shown. The current-carrying conductor will produce a magnetic field consisting of concentric circles around the wire in the direction illustrated. The net result is a heavy concentration of magnetic lines on the left hand side of the wire, and a weak magnetic field on the right hand side of the wire. This condition occurs on the left side where the magnetic lines are in the same direction and add together, and on the right side where the magnetic lines are in the opposite direction and tend to cancel out each other.

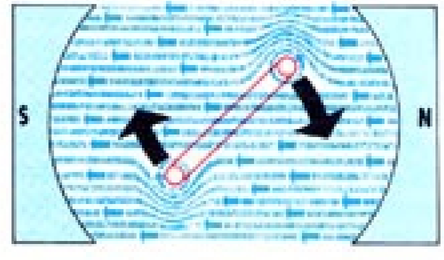
With a strong field on one side of the conductor and a weak field on the other side, the conductor will tend to move from the strong to the weak field, or from left to right as shown. The stronger the magnetic field produced by the horseshoe magnet, and the higher the current flow in the conductor, the greater will be the force tending to move the conductor from left to right. The resultant force illustrates the electrical principle on which a cranking motor operates.



A basic motor is illustrated. A loop of wire is located between two iron pole pieces, and is connected to two separate commutator segments, or bars. Riding on the commutator bars are two brushes, which are connected to the battery and to the windings located over the pole pieces.



With this arrangement, current flow can be traced from the battery through the pole piece windings to a brush and commutator bar, through the loop of wire to the other commutator bar and brush, and then back to the battery. The resulting magnetic fields impart a turning or rotational force on the loop of wire as illustrated.



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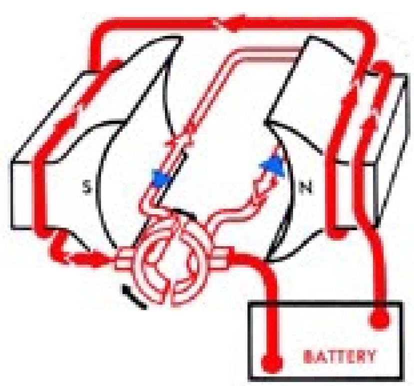
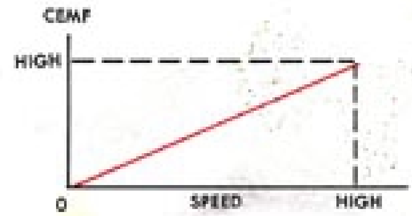
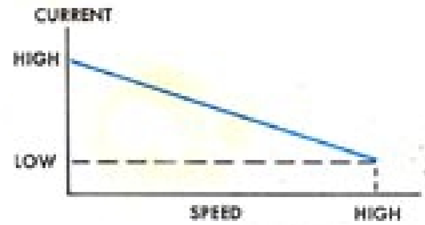
When the wire loop has turned one-half turn, the commutator bars will have interchanged positions with the two brushes, so the current through the wire loop will be in the opposite direction. But since the wire loop has interchanged positions with the pole pieces, the rotational effect will still be in the same clockwise direction as previously shown.

At this point in our discussion, it is important to note that with the wire loop rotating in the magnetic field created by the pole piece windings, all the conditions necessary for inducing a voltage in the wire loop are present, namely—a conductor, a magnetic field, and relative motion between the two. It is indeed true that a voltage will be induced in the wire loop, and the resulting direction of current flow, as explained in the previous section, would be as shown by the blue arrows in the illustration. However, an actual current will not flow as shown by the blue arrows, because the net effect of the induced voltage, called the counterelectromotive force, or CEMF, is to oppose the battery voltage and reduce the current supplied by the battery.

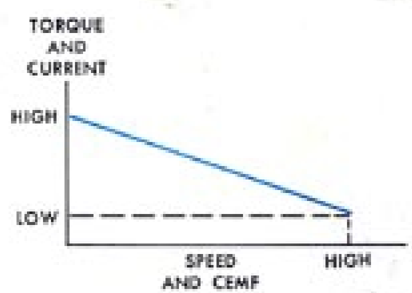


Since the voltage induced in a conductor is directly proportional to the speed at which the conductor is cutting across the magnetic lines of force, the value of the CEMF will be directly proportional to the speed at which the loop of wire is revolving. This means that as the speed of rotation increases, the CEMF increases, and the current supplied by the battery through the motor windings decreases. As the speed of rotation increases, the CEMF will approach in value but never completely reach the battery voltage.





The turning force, or torque, exerted by the wire loop is directly proportional to the current. This means that maximum torque occurs when the wire loop is not turning at all, because under this condition there is no CEMF and current flow is at a maximum. As the rotating speed of the wire loop increases, the CEMF increases, the current decreases, and the torque decreases.



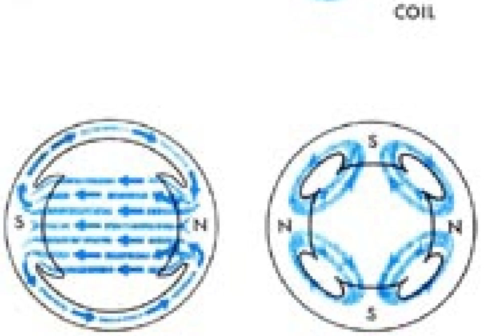
The basic motor we have used in our illustrations has no practical value, since it would produce very little torque to crank an engine. It has served, however, to show in simplified fashion the fundamental principles on which a cranking motor operates.

summary

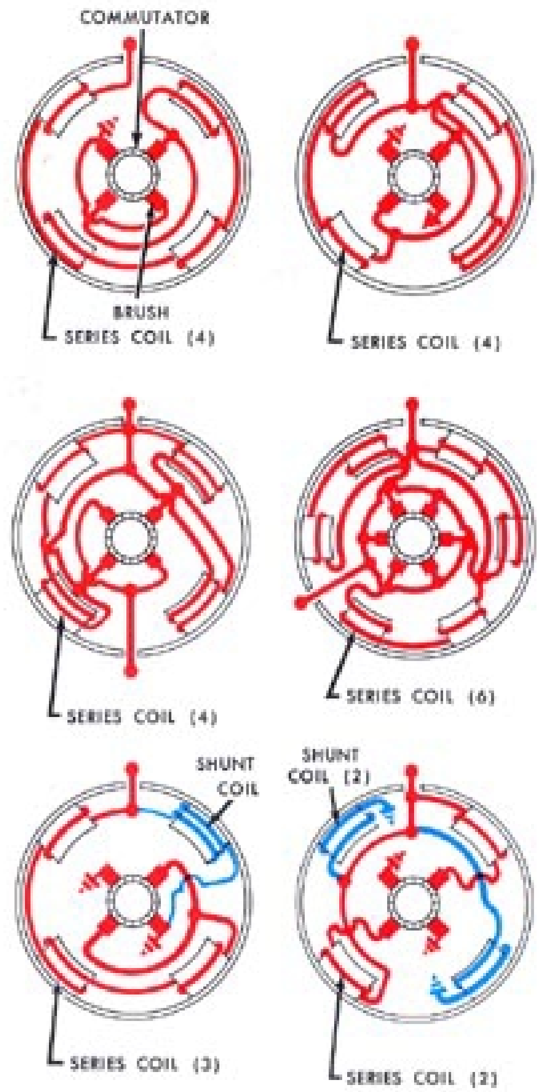
In this section we have covered the fundamental operating principles of a cranking motor. In simplest terms, a turning or rotational force is imparted to the armature by a concentration of magnetic lines on one side of the armature conductor, and a deficiency of magnetic lines on the other side of the armature conductor. Also, we have seen that a counter voltage, or CEMF, is generated in the rotating armature windings that increases with speed. Since this voltage opposes the battery voltage, the current flow to the motor decreases as the speed and CEMF increase. This means that at zero speed, the current flow and torque, or turning force, are at their highest values, and as the speed and CEMF increase, the current flow and torque decrease.

frame and field assembly

The frame and field assembly consists of field coil windings assembled over iron pole pieces which are attached to the inside of a heavy iron frame. The iron frame and pole shoes not only provide a place onto which the field coils can be assembled, but also provide a low reluctance, or low resistance path for the magnetic flux produced by the field coil windings.



A number of wiring diagrams showing the various types of field coil connections are illustrated. By tracing the current flow through the windings, and by using the "Right Hand Rule," it is seen that the polarity on the face of each pole shoe over which the coil is wound alternates around the field frame. That is, the polarities alternate North, South, North and South.



An inspection of the wiring diagrams shows various combinations of series, series-parallel, and parallel connections. The one selected for any particular application is dependent on many factors, such as engine speed and torque

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requirements, cable size, battery capacity, and the current carrying capacity of motor brushes and switches. In many cases an equalizer bar is connected across two or more brushes to equalize the voltage at the brushes. The equalizer bar reduces the amount of arcing and burning at the commutator bars. Also, it can be noted from the wiring diagrams that some motors are grounded internally, and others are insulated and have two motor terminals.

There are two types of field coils used in cranking motors—series and shunt. The current that flows through series coils also flows through the armature windings, but current through a shunt coil bypasses the armature and flows directly back to the battery. The shunt coil can be identified easily by its direct connection to ground. Series coils contain several turns of heavy copper ribbon conductor, and shunt coils contain comparatively more turns of smaller wire.

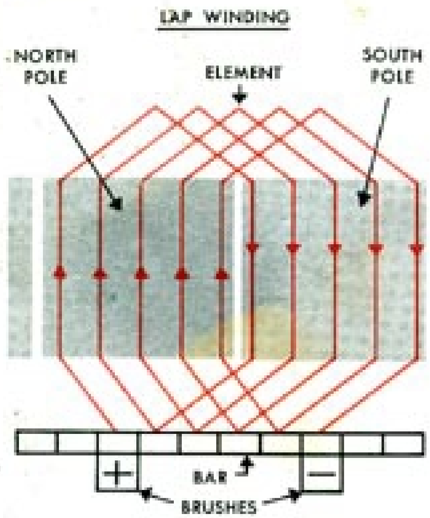
The reason for using a shunt coil can be explained as follows. In a motor without a shunt coil, that is, with all field coils in series with the armature, the speed of the motor armature is inversely proportional to the amount of field magnetic flux. In other words, the lower the magnetic flux, the higher the speed. We have already seen in the previous section that as the motor armature speed increases, the CEMF increases, the current decreases, and the magnetic flux decreases. This means that when a battery is connected to a series motor that is allowed to free speed (no load connected to the armature), the increasing speed of the armature causes the magnetic flux to decrease which in turn causes the armature speed to increase even further. Finally a maximum free speed is reached which on some applications may be high enough to cause objectionable noise or to cause the armature windings to be thrown from their slots. Since, as we shall see later on, the armature usually does free speed when the engine starts, some means of protecting the armature if it is subjected to high speed must be provided. By using a shunt coil that is connected from the battery directly to ground, and which therefore is not affected by armature CEMF, a constant value of magnetic flux as determined by battery voltage is always present in the motor, and the maximum free speed is accordingly limited.

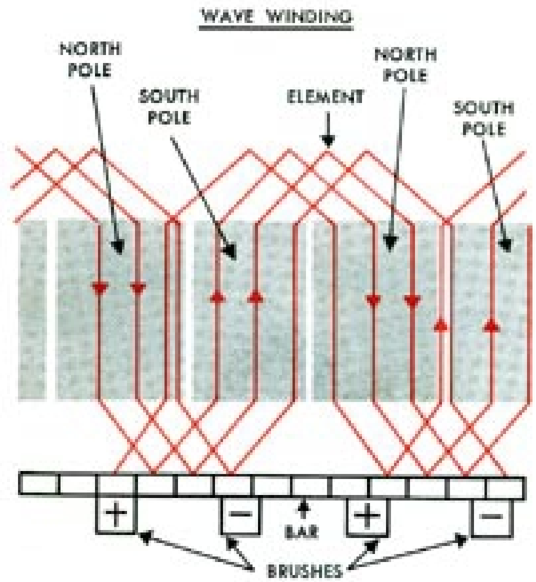
armature assembly

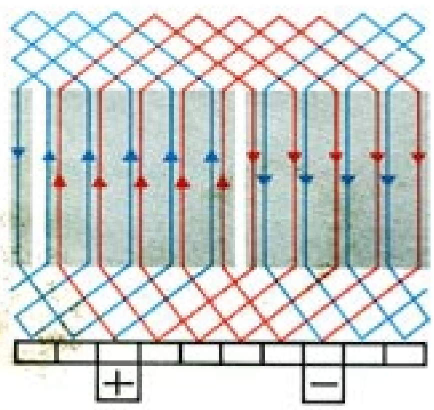
The armature assembly consists of a stack of iron laminations located over a steel shaft, a commutator assembly, and the armature windings. The windings are heavy copper ribbon that are assembled into slots in the iron laminations. The winding ends are soldered or welded to the commutator bars which are electrically insulated from each other and from the iron shaft.

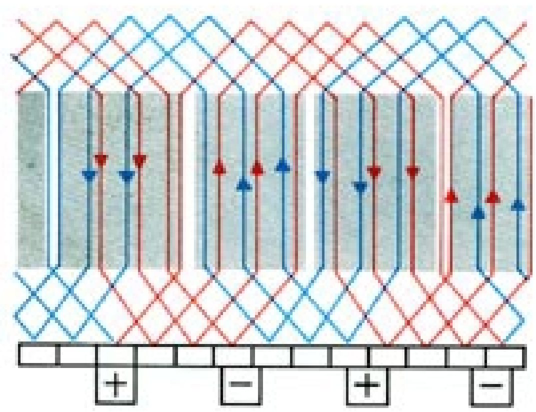
There are two major types of armature windings—lap and wave. Since the lap winding has as many paths as poles, and the wave winding always two paths, a lap winding is normally used where a low resistance armature is needed.

Two illustrations showing the assembly arrangement for a lap wound armature used in a two-pole motor are shown. The first illustration shows only one of the two electrical paths in the armature, and pictures only half of the normal number of conductors. Note that in the lap winding the lead ends of a winding element, or complete turn of conductor, are connected to adjacent commutator bars. The winding element enters and leaves a slot on the same side of the slot. With a battery connected to the brushes with polarities as shown, the direction of current flow under the North Pole is the same in all conductors, and the current flow under the South Pole is the same in all conductors. This arrangement provides maximum torque. When the other windings are assembled onto the armature, a completed lap wound armature is formed. The two circuit paths are shown in red and blue, with two conductors normally occupying the same slot.









The two illustrations of a typical wave winding used on a 4-pole motor show that a winding element has its ends connected to commutator bars that are approximately 180 degrees apart. The element enters a slot on one side and leaves on the other side. As in the lap winding, the current flow directions in conductors under the same pole are the same to provide maximum torque. Note that a winding element whose ends are connected to bars riding under brushes having the same polarity is effectively shorted and will not conduct current with the armature in this position. With the other windings assembled onto the armature, a wave wound assembly is formed with the two current paths shown in red and blue.

The armature is supported on the shaft ends by bushings in end frames that are assembled onto the frame and field assembly. With brushes that are supported on the frame and field assembly riding on the commutator bars, an operable cranking motor is formed. Many motors have a long pole shoe tip which is assembled in the direction of armature rotation. This feature permits in the manufacturing process the retention of the brushes in the same location for motors of clockwise or counterclockwise rotation.

The line between the pole shoes is called the static neutral point, and is the point where the direction of current in the armature winding must be changed to maintain a turning force in the same direction. Since the actual magnetic field is usually distorted, the brushes are located back of the static neutral point (against the direction of rotation) to prevent excessive arcing at the brushes and to obtain more efficient operation.

motor drives

The motor drive mechanism is assembled onto the armature shaft, and is the component part through which power is transmitted from the armature to the engine during the starting cycle. There are a number of different types of drive mechanisms used on cranking motors, and these are covered in the sections which follow.

All drives, regardless of type, contain a pinion which is made to move along the shaft and engage the engine ring gear for cranking purposes. A gear reduction is provided between the pinion and ring gear, with a typical value being 15 to one. The electrical design of the motor is selected to utilize this ratio to meet the cranking requirements of the engine. With the gear reduction feature, the motor operates to crank the engine at speeds sufficient for starting purposes.

When the engine has started, the ring gear would drive the armature at speeds which could cause the windings to be thrown from their slots. Accordingly, all drive mechanisms are designed to disengage the pinion from the ring gear or to provide an overrun feature when the engine begins to drive the pinion faster than the armature. This design feature protects the armature from being driven to damaging speeds.

Bendix drive

Although there are a variety of different types of Bendix Drives which may differ considerably in appearance, each drive operates on the principles of inertia to cause the pinion to engage the engine ring gear when the motor is energized. A partially exploded view of a typical inertia drive consisting primarily of a pinion and sleeve assembly, a drive spring, and a drive head is illustrated.

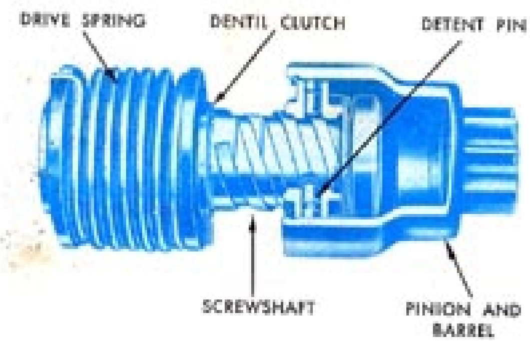
The drive pinion is normally unbalanced by a counterweight on one side, and has screw threads or splines cut on its inner bore. These screw threads match the screw threads cut on the outer surface of the Bendix sleeve. The pinion and sleeve assembly fits loosely over the armature shaft, and is connected through the drive spring to the drive head, which is keyed to the shaft. Thus, the pinion and sleeve assembly is free to turn on the armature shaft to the extent permitted by the flexing of the drive spring.

When the starting switch is closed and the motor windings are energized by the battery, the armature starts to revolve. This rotation is transmitted through the drive head and drive spring to the sleeve, and these parts increase in speed with the armature. The pinion, however, being unbalanced and having a loose fit on the sleeve, does not increase in speed with the armature due to its inertia. The net result is that the spiral splined sleeve rotates within the pinion, and the pinion moves endwise along the shaft to engage the ring gear. When the pinion reaches its stop on the sleeve, cranking takes place, with the initial shock being taken up by the spring.

When the engine begins to operate, the pinion is driven by the ring gear at a higher speed than the armature. This causes the pinion to rotate in the same direction as the sleeve but at a higher speed, and the pinion is driven back out of mesh with the ring gear teeth. For as long as the operator keeps the motor energized with the engine running, the motor free speeds. The motor start switch, therefore, should be released immediately after the engine has started.

From the foregoing discussion it is seen that the Bendix Drive operates on the principle of inertia to automatically engage the pinion with the ring gear to provide cranking, and to automatically de-mesh the pinion from the ring gear when the engine starts to operate. If a tooth abutment should occur during engagement, the spring compresses to allow the sleeve to move until the pinion engages.

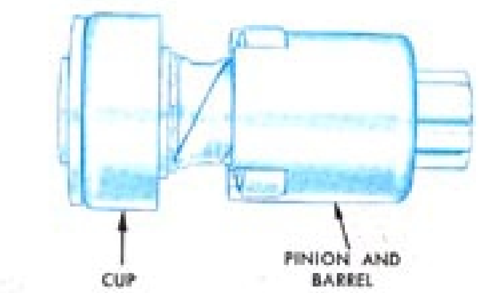
A Folo-Thru Bendix Drive is illustrated, with the pinion and barrel assembly in the cranking position and partially cut away to show the internal construction. This drive operates in the same manner as the type previously discussed, and has two additional features.



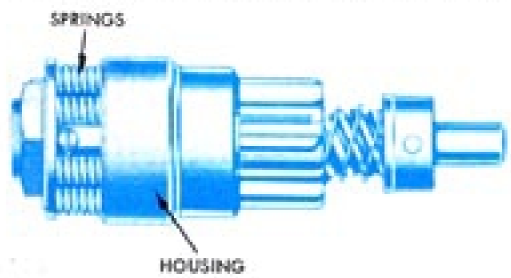
A spring-loaded detent pin that moves into a notch cut in the spiral spline serves to lock the pinion in the crank position. This feature prevents unwanted disengagement during false starts. When the engine starts and reaches sufficient speed, centrifugal force causes the detent pin to move out of the notch, and the pinion then is driven out of mesh with the ring gear. A second pin rides on the spiral spline and acts as an anti-drift device during engine operation.

The second feature of the Folo-Thru drive is a sleeve or screwshaft having two pieces that are connected by a Dentil Clutch, or mating ratchet teeth. This feature prevents the armature from being driven to excessive speeds by the engine by allowing the pinion and mating sleeve to overrun the ratchet teeth until the detent pin has disengaged the notch.

A drive that is used on some of the smaller motors is the rubber compression type. This drive has the mating ratchet teeth feature, but uses a rubber cushion located inside the cup to take up the shock of initial cranking. A small spring located over the screwshaft inside the pinion and barrel assembly prevents the pinion from drifting into the ring gear during engine operation.



Another Bendix drive is the friction-clutch type that is used on some of the larger cranking motors. This type of drive uses, instead of a drive spring or rubber cushion, a series of flat spring-loaded clutch plates inside the housing that slip momentarily during engage-

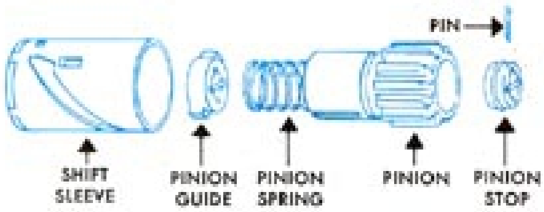


ment to relieve shock. A meshing spring is located inside the drive to allow the pinion to clear a tooth abutment condition. An anti-drift spring is located over the spiral splined sleeve. Otherwise this drive operates in much the same manner as the drives just discussed.

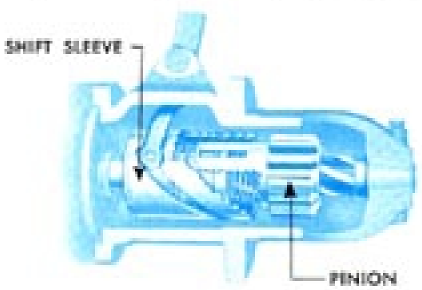
Dyer drive

The Dyer drive pinion is moved into mesh with the ring gear by a shift lever that is either manually operated or operated by a solenoid. This type of drive is used on large motors and features positive engagement of the pinion with the ring gear before the switch can be closed between the battery and motor. This feature avoids spinning meshes which are damaging on high horsepower motors with rapid armature acceleration.

The Dyer drive mechanism consists essentially of a shift sleeve, pinion guide, pinion spring, pinion, pinion stop and cotter pin. The pinion guide is a close fit on the spiral splines of the armature shaft, while the pinion (which has internal splines matching the armature splines) fits loosely on the armature shaft splines. An exploded view showing the major components is illustrated.



A cutaway view of a Dyer drive in a partial view of the motor assembly is illustrated. The drive mechanism is shown in the "at-rest" position. The spring located between the guide and pinion holds the internal teeth of the pinion and guide against the spiral splines on the shaft. In this position, the pinion guide teeth are located in milled notches in the spiral splines which holds the pinion and guide assembly at the at-rest position. The only way the assembly can be released from this position is by movement of the shift lever.



Movement of the shift lever causes the shift sleeve, pinion guide, pinion spring and pinion to be moved endwise along the shaft so that the pinion meshes with the ring gear teeth. Since the guide and pinion have internal splines matching the shaft splines, these parts rotate as they are moved endwise along the shaft by the shift sleeve. If a tooth abutment should occur, the pinion spring allows further movement of the pinion guide which continues to rotate the pinion until the abutment is cleared. The spring then causes the pinion to mesh with the ring gear. Continued movement of the shift lever closes the switch and cranking takes place, with the pinion held in place by the pinion stop.

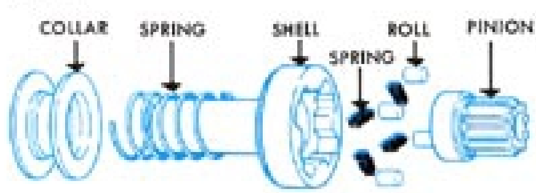
When the armature begins to rotate, friction between the pinion guide and shift sleeve causes the sleeve to move back to its original position on the shaft, with the shift lever button following the groove in the shift sleeve. As the engine starts, the ring gear drives the pinion faster than the speed of the armature, and the pinion, spring and guide are moved back to the at-rest position with the guide held in place by the notches in the shaft splines. Another cranking cycle cannot be started without first moving the shift lever back to the at-rest position.

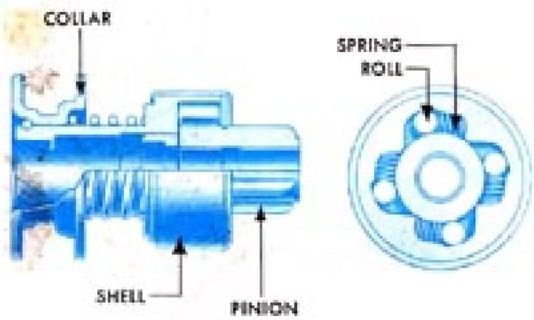
An important adjustment on Dyer drive motors involves the amount of pinion travel against the pinion spring with the shift lever in the cranking position. This measurement is made by energizing the solenoid or moving the shift lever by hand to the crank position with the motor windings de-energized, and then pushing the pinion back by hand against the spring and noting the full extent of its travel.

Complete details on the method for checking pinion travel are covered in the applicable Delco-Remy Service Bulletin.

roll clutch drive

The Roll Clutch Drive pinion is moved into and out of mesh with the ring gear by a shift lever which is either manually operated or operated by a solenoid switch. The Roll Clutch Drive has a shell and sleeve assembly which is splined internally to match either straight or spiral splines on the armature shaft. The pinion is located inside the shell along with spring-loaded rollers that are wedged against the pinion and a taper cut inside the shell. The springs may be either the helical or accordion type, and four rolls are used. A collar and spring located over the sleeve are the other major clutch components. An exploded view and a cutaway view are shown.





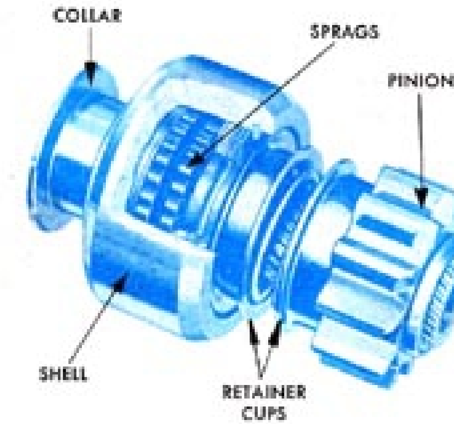
When the shift lever is operated, the shift lever buttons located inside the collar move the collar endwise along the shaft, and the spring pushes the pinion into mesh with the ring gear. If a tooth abutment should occur, the spring compresses with lever movement until the switch is closed, at which time the armature starts to rotate and the tooth abutment is cleared. The compressed spring then pushes the pinion into mesh, and cranking begins with torque being transmitted from the shell to the pinion by the rolls which are wedged tightly between the pinion and taper cut into the shell.

When the engine starts, the ring gear drives the pinion faster than the armature rotation, and the rolls are moved away from the taper allowing the pinion to overrun the shell. The start switch should be opened immediately when the engine starts to avoid prolonged overrun. When the shift lever moves back by return spring or manual action, the pinion is moved out of mesh and the cranking cycle is completed.

An important service check on roll clutches involves the clearance in the crank position between the pinion and housing or retainer with the pinion pushed back toward the shift lever. Proper clearance is needed to prevent rubbing of the collar against the shift lever during motor operation and to insure proper engagement before cranking begins. Complete checking procedures are covered in the applicable Delco-Remy Service Bulletin.

sprag clutch drive

The Sprag Clutch Drive is constructed and operates in a manner somewhat similar to the Roll Clutch Drive, except that a series of sprags, usually 30 in number, replace the rolls between the shell and sleeve. The sprags are held against the shell and sleeve surfaces by a garter spring. The shell and collar assembly is splined to the armature shaft, and the pinion is spiral splined to the sleeve with a stop collar on the end of the sleeve. A cutaway view is shown.



Movement of the shift lever against the collar either manually or by a solenoid causes the entire clutch assembly to move endwise along the splined shaft, and the pinion teeth to engage the ring gear. If a tooth abutment should occur, continued movement of the shell and spiral splined sleeve causes the pinion to rotate and clear the tooth abutment. The compressed meshing spring then forces the pinion into mesh with the ring gear. If sufficient rotational movement is not imparted to the pinion to clear the abutment before the two retainer cups meet, the shift lever movement is stopped by the retainer cups and the operator must start the engagement cycle over again. This feature prevents closure of the switch contacts to the motor with the pinion not engaged and resulting damage caused by spinning meshes. On the second attempt the pinion will engage in a normal manner.

With the pinion engaged and the switch closed to energize the motor windings, the cranking cycle begins. Torque is transmitted from the shell to the sleeve and pinion through the sprags which tilt slightly and are wedged between the shell and sleeve. When the engine starts, the ring gear drives the pinion and sleeve faster than the armature, and the sprags tilt in the opposite direction to allow the pinion and sleeve to overrun the shell and armature. To avoid prolonged overrun, the operator should immediately open the start switch as soon as the engine starts.

This sprag clutch drive is used primarily on larger cranking motors, and is designed to carry the high torque transmitted by the armature. Like the roll clutch drive, an important service procedure is the proper adjustment of pinion clearance in the crank position, and this adjustment is accomplished as covered in the appropriate service bulletin.

magnetic switches and solenoids

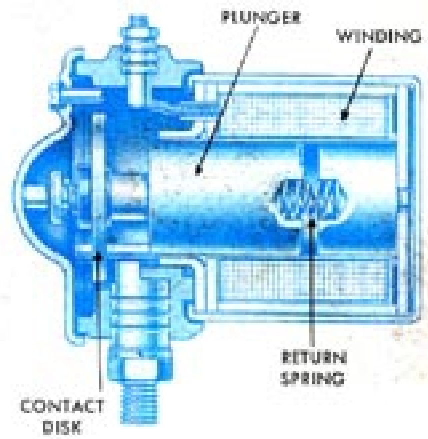
A magnetic switch as used in many cranking motor applications operates electromagnetically to open and close the circuit between the battery and the motor. This is the only function that the magnetic switch performs in the cranking circuit.

A solenoid performs two functions in the cranking circuit—like the magnetic switch, it closes the circuit between the battery and the motor, and in addition, the solenoid plunger shifts the motor drive mechanism into mesh with the ring gear.

magnetic switches

A magnetic switch consists basically of a winding mounted around a hollow cylinder containing a moveable core or plunger, with a contact disk assembled into the plunger. When the winding is energized, plunger movement causes the contact disk to be held tightly against the two main switch terminals, thereby closing the circuit between the two terminals. When the winding is de-energized, a return spring causes the plunger to return to its original position, and the circuit is opened. The magnetic switch, therefore, is a mechanical switch that is operated electromagnetically.

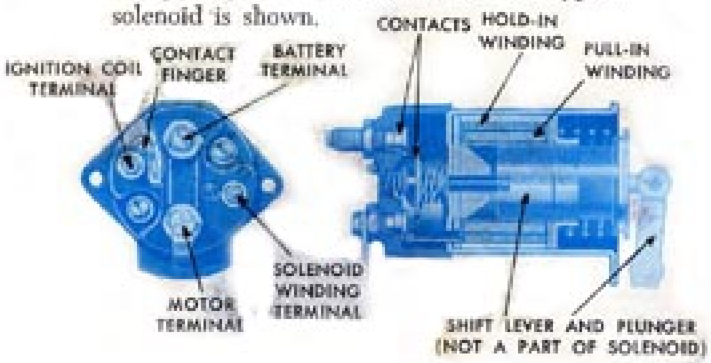
Magnetic switches are manufactured in a wide variety of designs, but each operates on the principle just outlined. A typical switch is shown, along with a cross-sectional view of one of the larger models. Some models have one switch terminal with the other winding end grounded internally to the switch case, and others have two switch terminals to which the winding ends are connected.



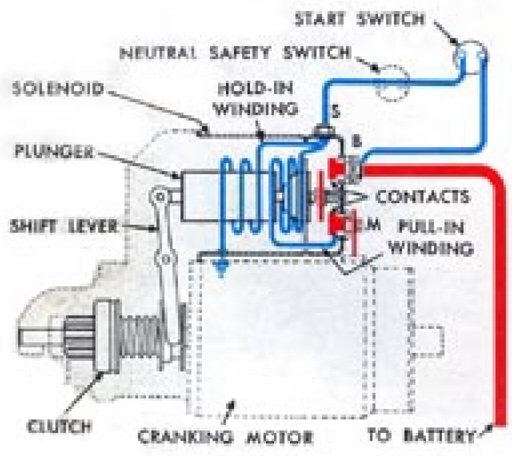
In the next section entitled "Basic Circuits" the reason for the use of a magnetic switch will be given.

solenoid switches

The solenoid switch consists basically of two windings mounted around a hollow cylinder containing a moveable core or plunger. A shift lever is connected to the plunger, and a push rod and contact disk are assembled in line with the plunger. When the windings are energized, the plunger pulls the shift lever and moves the motor drive into mesh with the ring gear. The contact disk is pushed into firm contact with the solenoid battery and motor terminals. With the motor windings connected directly to the battery, cranking takes place. A cross-sectional view of a typical solenoid is shown.



The two windings in the solenoid are called the hold-in winding and the pull-in winding. The hold-in winding contains many turns of fine wire, and the pull-in winding the same number of turns of larger wire. When the start switch is closed, current flows from the battery to the solenoid "S" terminal, through the hold-in winding to ground, and then back to the battery. Current also flows through the pull-in winding to the solenoid "M" terminal and then through the motor windings to ground. The magnetism created by each winding adds together to form a strong magnetic field that attracts the plunger into the core. Plunger movement shifts the pinion into mesh with the ring gear, and also moves the contact disk to close the circuit between the solenoid battery (B) and motor (M) terminals. With the motor windings connected directly to the battery through the contact disk, cranking takes place.



The pull-in winding operates to assist the hold-in winding in pulling the plunger into the core. Once the plunger movement has been completed, much less magnetism is needed to hold the plunger in the cranking position. With the contact disk contacting the solenoid battery and motor terminals, the pull-in winding is shorted and no current flows through the pull-in winding. This design feature reduces current draw on the battery and also reduces the amount of heat created in the solenoid.

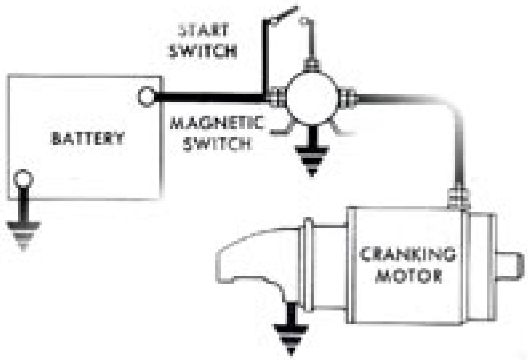
When the start switch is opened, current for a very brief instant flows through the contact disk to the solenoid motor (M) terminal, through the pull-in winding in a reverse direction to the solenoid "S" terminal, and then through the hold-in winding in a normal direction back to the battery. The magnetisms created by each winding oppose and cancel out each other, and the return spring moves the entire shifting mechanism to the at-rest position to complete the cranking cycle.

Solenoid switches are manufactured in a variety of types and designs, but each operates on the basic principles just outlined. An added feature on some models is a contact finger which touches the contact disk when the solenoid is in the cranking mode of operation. The contact finger is connected to the ignition coil terminal or "R" terminal on the solenoid which in turn is connected directly to the ignition coil. This feature bypasses the ignition resistor and provides more available ignition voltage during cranking.

basic circuits

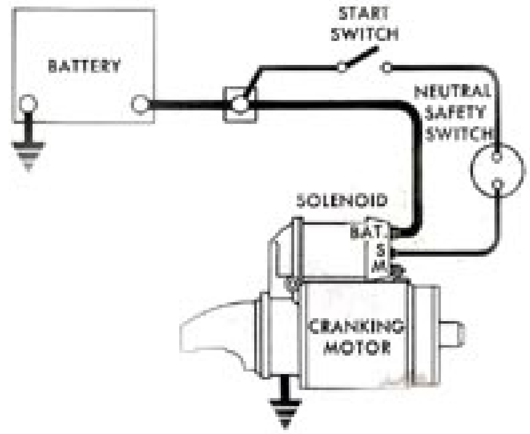
There are two basic types of cranking motor circuits. The first type involves a motor with a Bendix drive that relies upon inertia for moving the pinion into mesh with the ring gear. The second type utilizes motors with drive mechanisms that require a shift lever either manually or solenoid operated to move the pinion into mesh with the ring rear.

A basic circuit is shown in which a Bendix drive motor and a magnetic switch are used. When the start switch is closed, the magnetic switch winding is energized and the contact disk closes the circuit between the battery and motor. The cranking cycle then begins and continues until the operator opens the start switch.



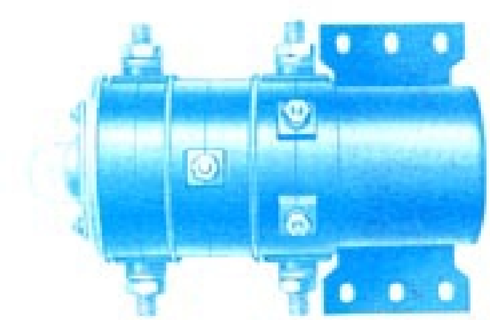
A magnetic switch is used to provide a circuit of short length and low resistance between the battery and motor. Since the motor may draw over one hundred amperes during operation, heavy cables of short length are needed to reduce the voltage drop in the circuit. The magnetic switch in the actual installation is normally located in close proximity to the battery and motor to reduce cable length. If a magnetic switch were not used, and the high motor currents were carried directly through the start switch mounted on the vehicle dash, cables of excessive size would be required to limit the voltage drop to an acceptable value. Since the start switch on the dash is usually some distance from the battery and magnetic switch, the long leads connected to the switch can be of reasonable size since they conduct only the small current drawn by the magnetic switch winding.

A basic circuit with a motor and solenoid used to close the circuit to the motor and shift the pinion into mesh with the ring gear is shown. In this type of circuit the solenoid switch performs the same function as the magnetic switch as just described, Additionally, when the start switch is closed, the solenoid moves the pinion into mesh, and the cranking cycle begins. When the start switch is opened, the cranking cycle ends as described in the previous section covering solenoids. The neutral safety switch in this type of circuit is closed only when the transmission shift lever is in the proper position, thereby preventing cranking of the engine with the transmission in gear.

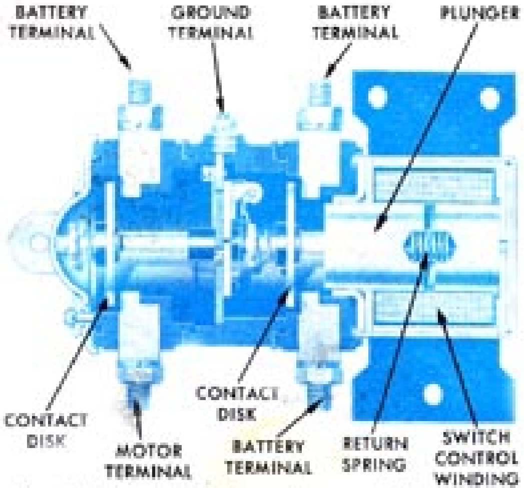


series-parallel circuits

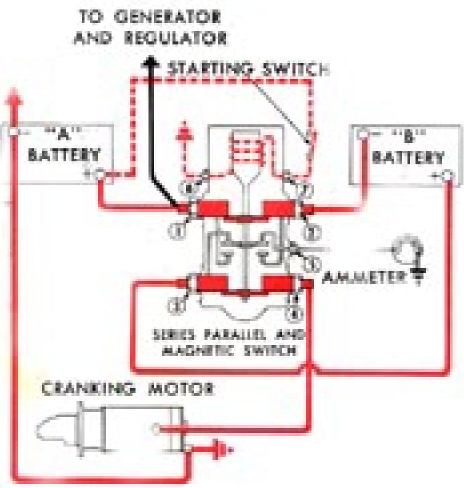
The function of the series-parallel switch is to connect two 12-volt batteries in series for 24-volt cranking, and to connect the same 12-volt batteries in parallel where it is desirable to have 12-volt charging and lighting circuits. Series-parallel switches are manufactured in a variety of types and designs, and are used in systems having different types of circuit connections. A typical series-parallel switch that also incorporates a magnetic switch for Bendix Drive motors is illustrated, along with a cross-sectional view of the same switch.



COMBINED SERIES-PARALLEL

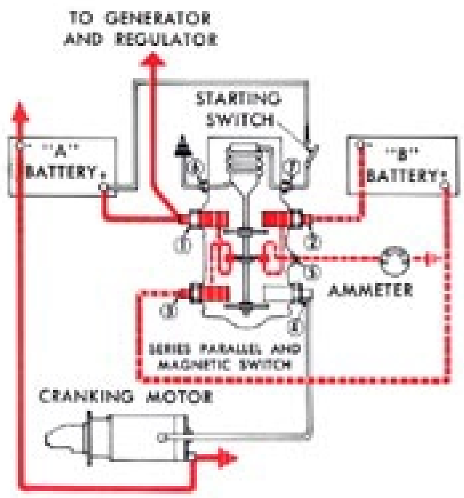


Also illustrated is the series-parallel magnetic switch connected to two batteries and a cranking motor using an inertia type of drive. The cranking circuit is shown, and the operation is explained as follows.



When the starting switch is closed, current supplied by the "A" battery flows through the series-parallel switch winding, and the switch plunger is attracted into the core. As a result, the switch No. 1 and No. 2 terminals are connected together, and the No. 3 and No. 4 terminals are connected together by the contact disks located on the plunger rod. With this arrangement, the two batteries are connected in series to the 24-volt motor to provide 24-volt cranking. The cranking circuit is shown in red in the diagram.

After the cranking cycle has been completed, and the starting switch is opened, the return spring in the series-parallel switch causes the contact disks to move away from the Nos. 1, 2, 3 and 4 terminals. At the same time, spring-loaded contacts in the switch close to connect the No. 1 and No. 3 terminals together, and the No. 2 and No. 5 terminals together. With the switch plunger and contacts in this position, the batteries are connected in parallel for 12-volt charging. The charging circuit is shown in red, with current from the generator being supplied to the No. 1 terminal on the series-parallel switch. Half of the current then flows through the "A" battery to ground, with the other half flowing through the switch No. 1 and No. 3 terminals, through the "B" battery, and then through the switch No. 2 and No. 5 terminals to ground.



Since the charging circuit through the "B" battery is more lengthy and contains more connections than the "A" battery, it is especially important to maintain the "B" battery connections and wiring, along with all others, in good condition to prevent an unbalanced state of charge condition in the batteries. If the "B" battery tends to remain in a lower state of charge than the "A" battery with satisfactory lead connections, the two batteries should be interchanged periodically for maximum life.

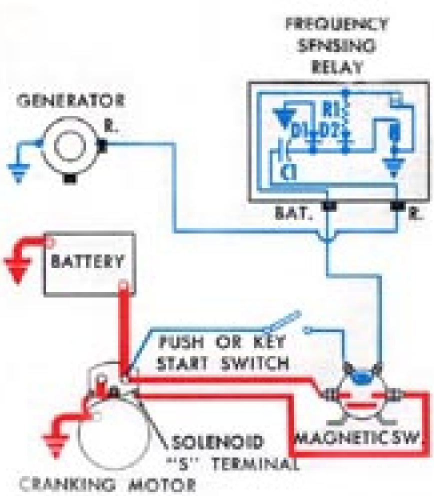
Although the series-parallel system has been in widespread usage, it is being replaced by 12-volt motors having essentially the same performance as 24-volt motors when the same total battery capacity is used with the 12-volt system.

"ADLO" circuits

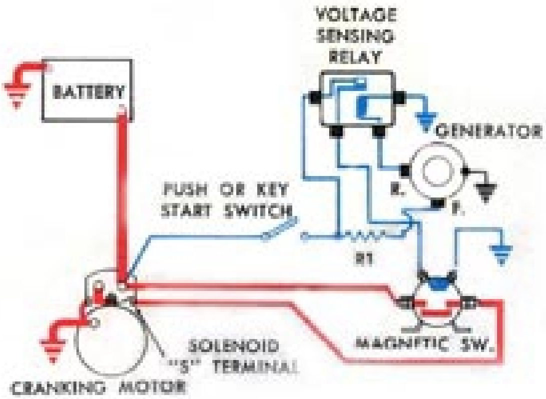
A relay can be connected to provide automatic disengagement and lockout action for solenoid operated cranking motors in electrical systems which use a Delcotron® generator in the charging circuit. When the engine starts the relay contacts open to disconnect the control winding, thus causing the cranking motor pinion to disengage even though the start switch is held closed. Lockout action is also provided for as long as the engine is running. This type of protection promotes longer cranking motor life by eliminating the wear on brushes, bearings, and other component parts that otherwise would occur during overrun, and prevents milled teeth caused by attempted engagements while the engine is running.

The two major types of relays are frequency sensing relays and voltage sensing relays.

frequency sensing relay



A typical circuit using a frequency sensing relay is illustrated. When the start switch is closed, the magnetic switch winding circuit is completed to ground through the normally closed frequency sensing relay contacts, the cranking motor solenoid is energized through the magnetic switch, and cranking takes place. When the engine starts, voltage from the generator "R" or "AC" terminal energizes the frequency sensing relay winding through capacitor C1, and the relay contacts open, thereby de-energizing the magnetic switch and disconnecting the cranking motor from the circuit. When the relay contacts open, an induced voltage in the magnetic switch winding causes current to flow through resistor R1, diode D2 and the relay winding, thus causing the contacts to open quickly and lessen contact arcing. Induced voltages in the relay winding flow through ground and diode D1 back to the winding. This type of action, therefore, instantly disconnects the motor from the circuit when the engine starts even though the start switch is held closed.



voltage sensing relay

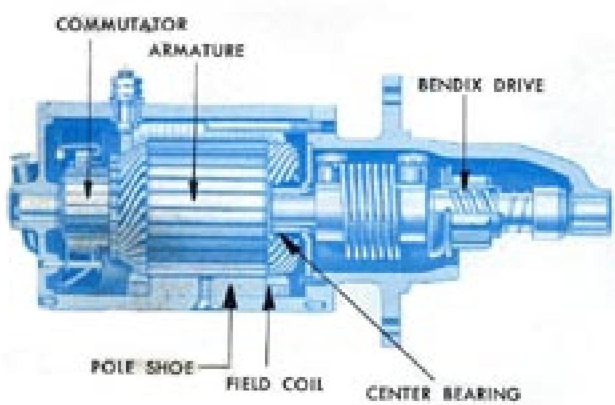
A typical circuit using a voltage sensing relay is illustrated. This circuit operates in much the same way as the frequency sensing relay circuit, except the relay winding is connected directly to the generator "R" or "AC" terminal. The proper amount of "R" or "AC" terminal voltage with the start switch closed is provided by resistor R1 connected between the switch and the generator field winding. This arrangement assures prompt opening of the relay contacts as soon as the engine starts.

cranking motor types and designs

The cranking motor has only one function to perform—to crank the engine at a speed sufficient for starting purposes. Since there are many different types and designs of engines, there are an equal number of different cranking motors designed to meet the requirements of each engine. Some of the engine factors that determine cranking motor design are cubic inch displacement, number of cylinders, size of ring gear, compression ratio, oil viscosity, minimum speed required for starting at the lowest cranking temperature, and mounting space limitations as imposed by the engine application.

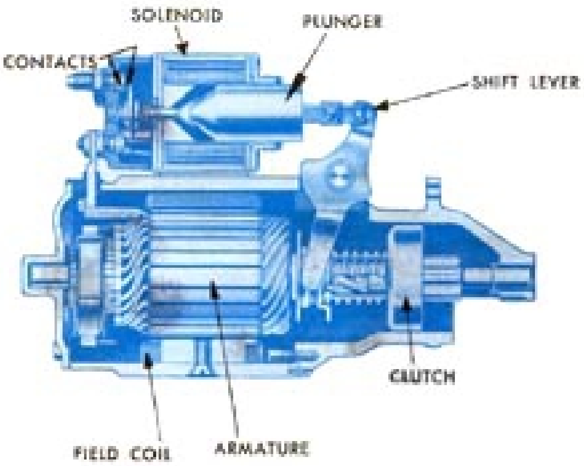
All designs of cranking motors support the shaft on the ends with bushings. Lubrication is provided by wicks and hinge cap oilers, oil plugs, or oil reservoirs, and in some cases by grease cups. Some models use oilless bushings. Many models feature a center bearing that supports the armature shaft during cranking.

The following illustrations show some of the basic types and designs of cranking motors.

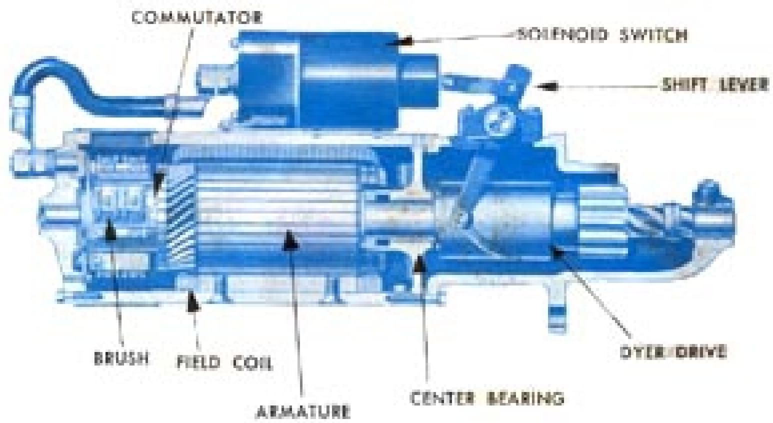


A 10MT Series Type 65 motor with a Bendix Drive is used on a great variety of applications involving small to medium size gasoline engines. This motor is used in many cases where space limitations prevent the application of a solenoid-equipped motor on the engine.

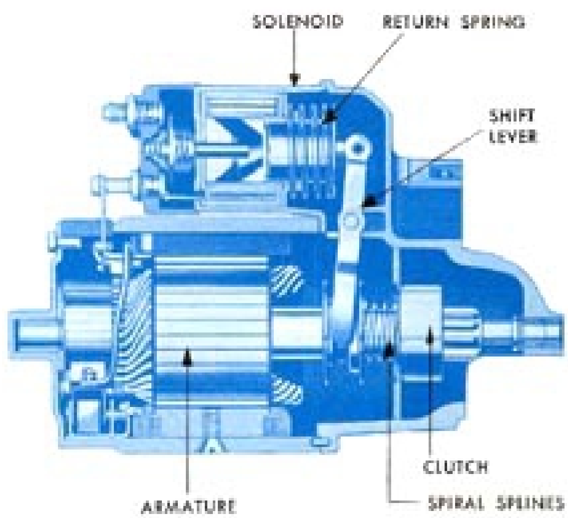
Also to be found in a large variety of applications is a 10MT Series Type 100 cranking motor that is solenoid-equipped with an exposed shift lever. This motor is being replaced by an improved design with a totally enclosed shift lever arrangement.

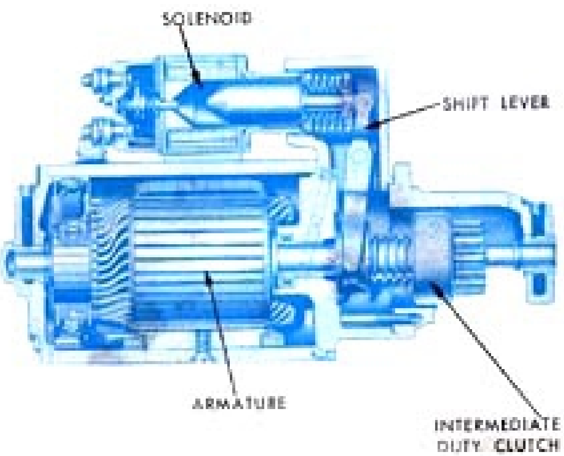


The Dyer Drive motor also is being replaced by a totally enclosed design. However, many Dyer Drive motors are still in usage, and have the pinion block feature that prevents closing of the circuit to the motor unless the pinion is engaged with the ring gear. This feature prevents damage resulting from spinning meshes. This type of design is to be found on large gasoline and diesel engines.

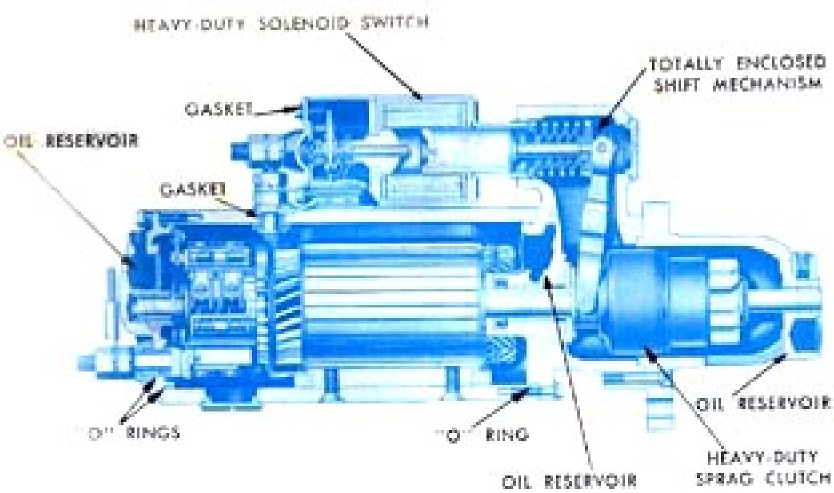


The 10MT Series Type 125 motor is a high production assembly that is totally enclosed for protection against environmental factors such as dirt, icing conditions and road splash. This motor is used on many applications including cars, trucks, farm tractors, and industrial and marine engines of small to intermediate displacement. Motors in the 20MT Series are similar to this assembly except the frame size is slightly larger for higher motor output.





A cranking motor designed to meet the requirements of intermediate displacement gasoline and diesel engines primarily in truck and farm tractor applications is the 30MT Series Type 150 assembly. The solenoid shifting mechanism is completely enclosed to insure freedom of operation during engagement and the nose housing can be rotated to obtain a number of different solenoid mounting positions where mounting interference is a factor. The four-roll or small sprag clutch remains positively engaged during false starts. Design variations in this series of motors include added solenoid sealing features to prevent entry of moisture and foreign material, and also a 35MT Series of motors having a slightly larger frame size for greater cranking ability.



The 40MT Series Type 250 motor is widely used on large displacement gasoline and diesel engine applications. The pinion block feature prevents closing of the solenoid contacts unless the large sprag clutch pinion is engaged with the ring gear, thereby preventing damage due to spinning meshes. The shift mechanism is completely enclosed to insure freedom of operation during engagement, and the nose housing can be rotated to obtain different solenoid mounting locations to avoid interference. The brushes are extra long for extended life, and sealing rings at each end of the frame and field assembly keep out moisture and other foreign materials. Some motors in this series have all four field coils connected in parallel to provide 12-volt motor performance comparable to 24-volt motor performance. These 12-volt high performance motors can be used to replace 24-volt motors in series-parallel systems, thereby eliminating the series-parallel switch and simplifying the wiring circuitry. Cranking motors in the 50MT Series are similar to the 40MT Series of motors, except the frame size is larger and six field coils are used to provide the cranking ability needed for very large gasoline and diesel engines.

circuit tests

The cranking motor is a special type of motor that is designed for intermittent duty only. It should never be operated for more than 30 seconds at a time without pausing for at least two minutes to allow it to cool. On some applications 30 seconds may be excessive. Because the cranking motor is designed to operate under great overload for short periods of time, it provides a high horsepower output for its small size.

The cranking motor does not produce power; it merely converts electrical energy from the battery into mechanical energy. The cranking output that is obtained from the motor is therefore dependent not only on the condition of the motor itself, but also on the condition of the battery, the wiring circuit, and the engine cranking requirements.

The importance of maintaining the battery in a fully charged and otherwise good condition for proper cranking performance cannot be overemphasized. If poor cranking is encountered, the condition of the battery should be thoroughly checked in accordance with the appropriate Delco-Remy Service Bulletin, and corrections made as required. The size and performance of the battery should be equal to or greater than that specified by the engine or vehicle manufacturer. The voltage rating of the battery must be the same as the voltage rating of the motor.

Of equal importance for maximum cranking output is the maintenance of all circuit connections in a clean and tight condition. Since the solenoid initially may draw as many as one hundred amperes, and the motor several hundred amperes throughout its cranking cycle, clean, tight connections become all-important to avoid excessive voltage drop or loss in the lines. Also, wiring of the type that is equal to or greater than the size recommended by the engine or vehicle manufacturer must be used.

As operating conditions indicate, the battery and wiring should be checked and serviced periodically in order to obtain continued optimum performance from the cranking circuit. The cranking motor, of course, cannot make up for deficiencies in the battery and wiring circuits.

Besides the battery and wiring, one other factor of major importance to good cranking performance is the use of the proper weight oil in the crankcase as recommended by the engine manufacturer. An oil heavier than specified lowers cranking speed drastically at low temperatures, and can cause complete failure of the engine to start.

If the battery, wiring and engine are in good condition, the cranking motor should be removed for testing if it fails to crank properly. Turning the armature by hand if practical before disassembly will reveal any mechanical restrictions to freedom of operation. Some motors with leather brake washers to reduce free speed time can not be turned easily by hand. Complete checking procedures covering switches, solenoids and motors are contained in Delco-Remy Service Bulletins.