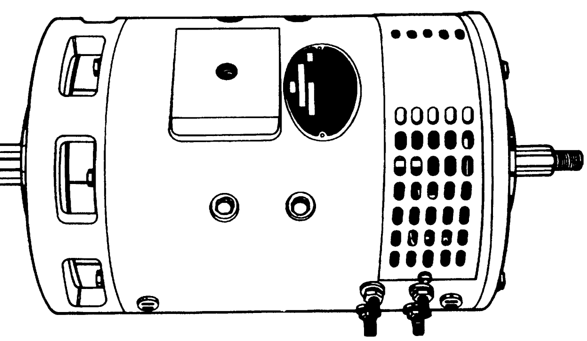
THE DC MOTOR



HYSTER

PART NO. 899769

620 SRM 145

CONTENTS

This section is for the following models:

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All Electric Lift Trucks Before The XL Series

INTRODUCTION

Electric lift trucks use Direct Current (DC) motors to convert electrical energy into mechanical energy. The DC motor usually will provide long periods of service with a minimum of maintenance. The motor's commutator and brush assembly are the first two areas that generally require maintenance. This section provides extra emphasis on these two areas along with the other normal maintenance items. A brief review of the basic principles of magnetism is included to provide an understanding of DC motor operation.

MAGNETISM

MAGNETISM AND PERMANENT MAGNETS

The space affected by a magnet is called a "field of force." The extent of this field is determined by the strength of the magnet and can be detected by the use of a compass. It is common practice to show the field by lines which are called "lines of force." When a compass is used as a pointer in exploring a field, it indicates that the lines have direction (leaving the north pole and returning to the south pole). The magnetic field of a permanent magnet can be concentrated by shortening the air gap between the north and south poles ("U" shaped or horsehoe magnet). The smaller the air gap between the poles, the greater the concentration of the lines.

When two magnets are placed so that the north pole of one and the south pole of the other are close together, they attract each other. If the magnets are placed with their like poles adjacent they will repel each other. These facts identify a fundamental law of magnetism – **Unlike poles attract each other and like poles repel each other.**

Materials differ in their behavior when placed in a magnetic field. Most materials have no effect on the magnitude or direction of the field. These are called "non–magnetic" materials. Other materials (such as iron) having the property of magnifying or concentrating a field are called "magnetic" materials. Magnetic lines seem to penetrate all substances and are deflected only by magnetic materials or by another magnetic field.

ELECTROMAGNETIC FIELDS

A magnetic field exists around a conductor carrying an electric current. The greater the current flow, the stronger the magnetic field. This field is at right angles to the conductor. These lines are concentric circles around the length of a straight conductor. The field differs from a permanent magnet because there are no magnetic poles at which the lines can enter or leave.

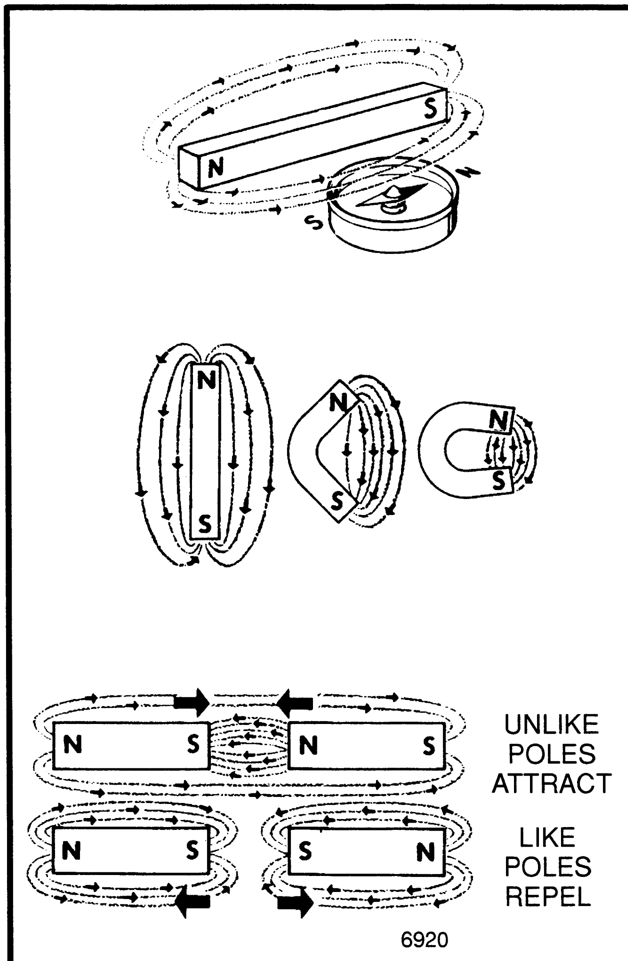


FIGURE 1. MAGNETISM AND PERMANENT MAGNETS

The direction of the lines around a conductor may be determined by the use of the compass. Also if the direction of current flow is known, use the "Right Hand Rule for Determining the Direction of Lines of Force Around a Straight Conductor." This rule is based on the Current Theory which assumes that current flows from positive to negative. To apply the rule imagine grasping the conductor with the right hand so that the thumb extends in the direction of current flow; then the fingers will point in the direction in which the lines surround the conductor.

The lines spread out as expanding circles into space. The number of lines per unit area is called density. The density is greatest at the surface of the conductor and decreases with the distance from the conductor. At a distance of 25.4 mm (1.0 inch) from the conductor there is one–half the density of force as at a distance of 12.7 mm (0.5 inch).

If a current–carrying conductor is formed into a single loop all of the lines around the conductor must pass through the inside of the loop. The lines on the outside spread out but the lines on the inside of the loop are confined and increase the density. This creates a much greater magnetic effect with the same amount of current flow.

ELECTROMAGNETS

When two or more loops of wire are wound around a common core the magnetic field of each turn is affected by the fields of adjacent turns. The field directly between adjacent turns of wire is neutralized. The external and internal lines join to make continuous loops creating an electromagnet. The internal lines are concentrated, which creates a strong magnet having a north and south pole.

The more turns of wire on the coil the stronger the magnetic field will be. The strength of the magnetic field also depends upon the amount of current flowing through the coil.

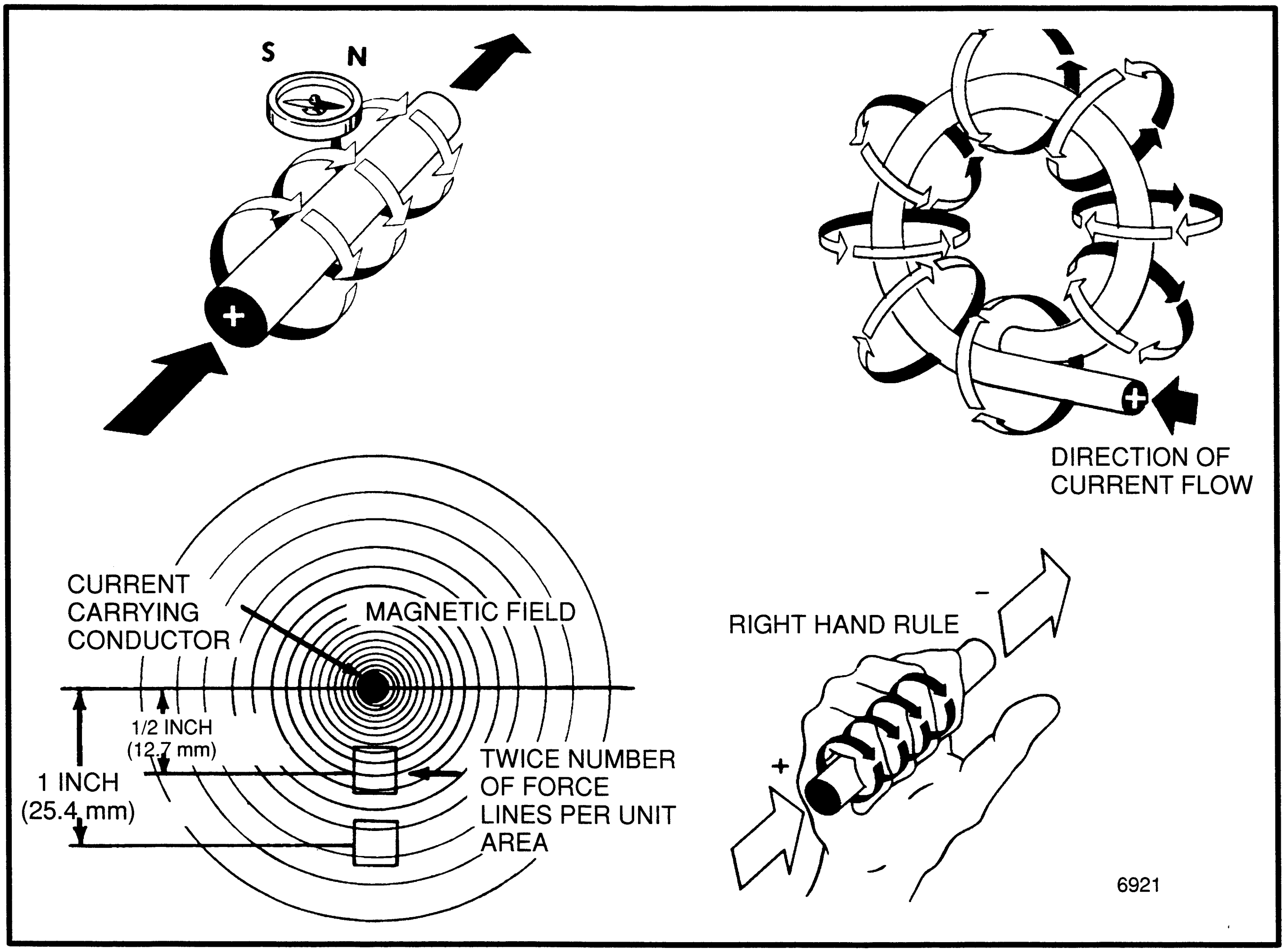


FIGURE 2. ELECTROMAGNETIC FIELD

The magnetic polarity of a coil may be determined by the "Right Hand Rule for COILS" if the direction of current flow is known. To apply this rule, imagine grasping the coil with the right hand so the fingers are pointed in the direction of current flow; then the thumb will point toward the north pole of the coil.

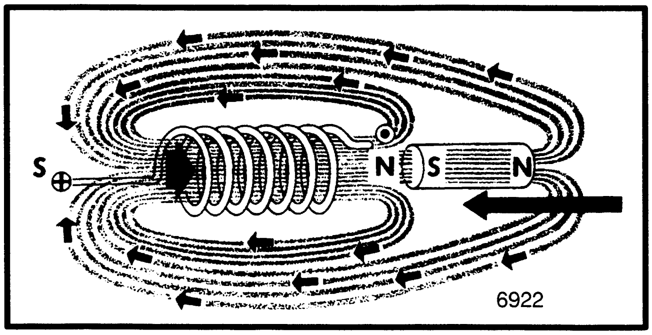


FIGURE 3. ELECTROMAGNETS

Some electromagnets have an iron core or armature which moves when the coil of wire is energized. The movable component has a south pole generated adjacent to the north pole of the coil because of the magnetic lines from the coil. Since iron is a better conductor of magnetic lines than air, the lines enter the movable component and return through air to the pole at the opposite end of the coil. The magnetic attraction pulls the movable component towards the coil when current flows. This type of electromagnet is often called a "Solenoid."

ELECTROMAGNETIC INDUCTION

The principle of electromagnetic induction is to produce a voltage by a change in the magnetic field. Any change (increase or decrease) in the current flow in the primary will create (induce) a voltage in the secondary. A change in voltage in a closed circuit is also accompanied by a corresponding change in current. The most common application of this principle is the transformer. Two stationary windings are placed over a common laminated steel coil. The primary winding is excited by a fluctuating current source. A change in magnetism by the primary winding will induce a voltage in the secondary because both windings are linked together magnetically. The ignition coil and SCR pulse transformer operate on this principle.

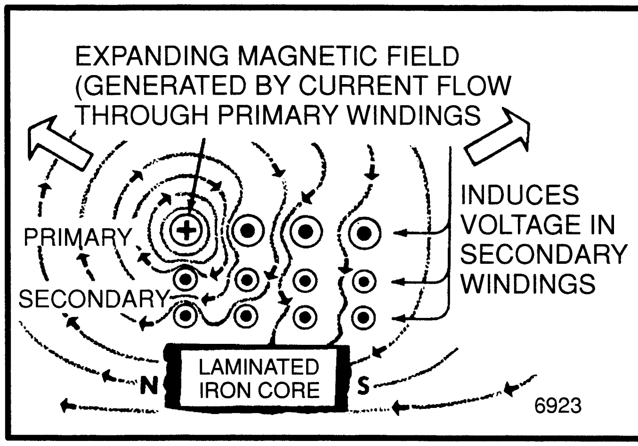
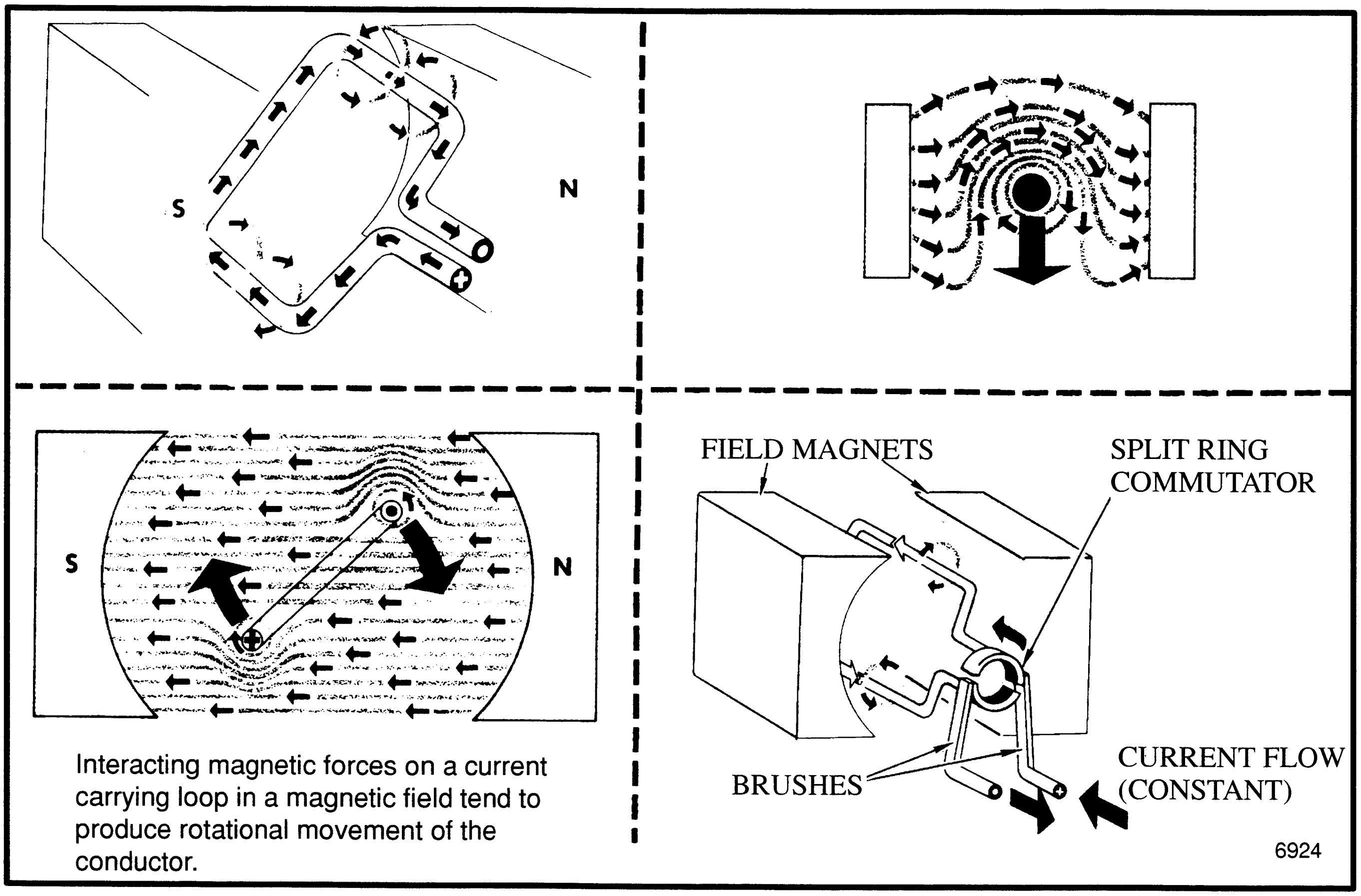


FIGURE 4. ELECTROMAGNETIC INDUCTION

MAGNETIC FORCE ON A CONDUCTOR

When a current–carrying conductor is positioned in a magnetic field there is a distortion of the normal lines of force between the poles. Magnetic lines of force in the same direction join together to make a stronger field. Lines of force in the opposite direction tend to cancel out which creates a weaker field. Under these conditions the conductor moves toward the weaker field.

The upper LH quarter of FIGURE 5. shows the current flowing into the left–hand side and out of the right–hand side. There will be a tendency for the conductor to turn in a clockwise direction. Current flow through the left–hand conductor creates a clockwise field around the conductor. The lines of force below the conductor join with the lines of force from the permanent magnet and a strong field is produced. The lines of force above the conductor oppose the lines of force from the permanent magnet and a weak field is produced. The result is an upward movement of the left–hand conductor. Since the current flow through the right–hand conductor is in the opposite direction, a counterclockwise field is created around the conductor. This causes the right–hand conductor to move downward. The commutator will change the direction of current when the conductors travel past the neutral point.



Interacting magnetic forces on a current carrying loop in a magnetic field tend to produce rotational movement of the conductor.

FIGURE 5. MAGNFTIC FORCE ON A CONDUCTOR

BASIC MOTORS

MOTOR OPERATION

Current flows from the battery through the armature conductor when the brushes contact the two commutator bars. This creates magnetic fields around the conductor. Current also flows through the field windings creating a powerful magnetic field. In FIGURE 6. current from the battery flows first around the right–hand field coil and then crosses over to flow around the left–hand field coil. Current then flows through the left–hand brush, the armature winding and current returns through the right–hand brush to the battery. The magnetic fields around the conductor will be in the directions shown by the circular arrows. The left–hand side of the armature winding will be pushed upward and the right–hand side downward producing clockwise rotation.

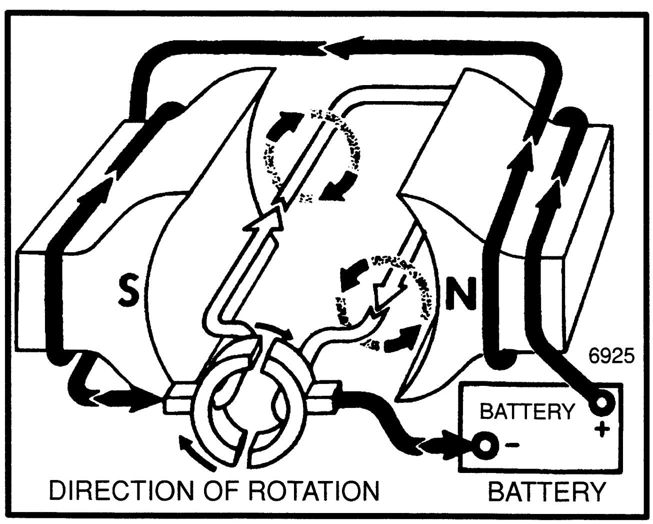


FIGURE 6. MOTOR OPERATION

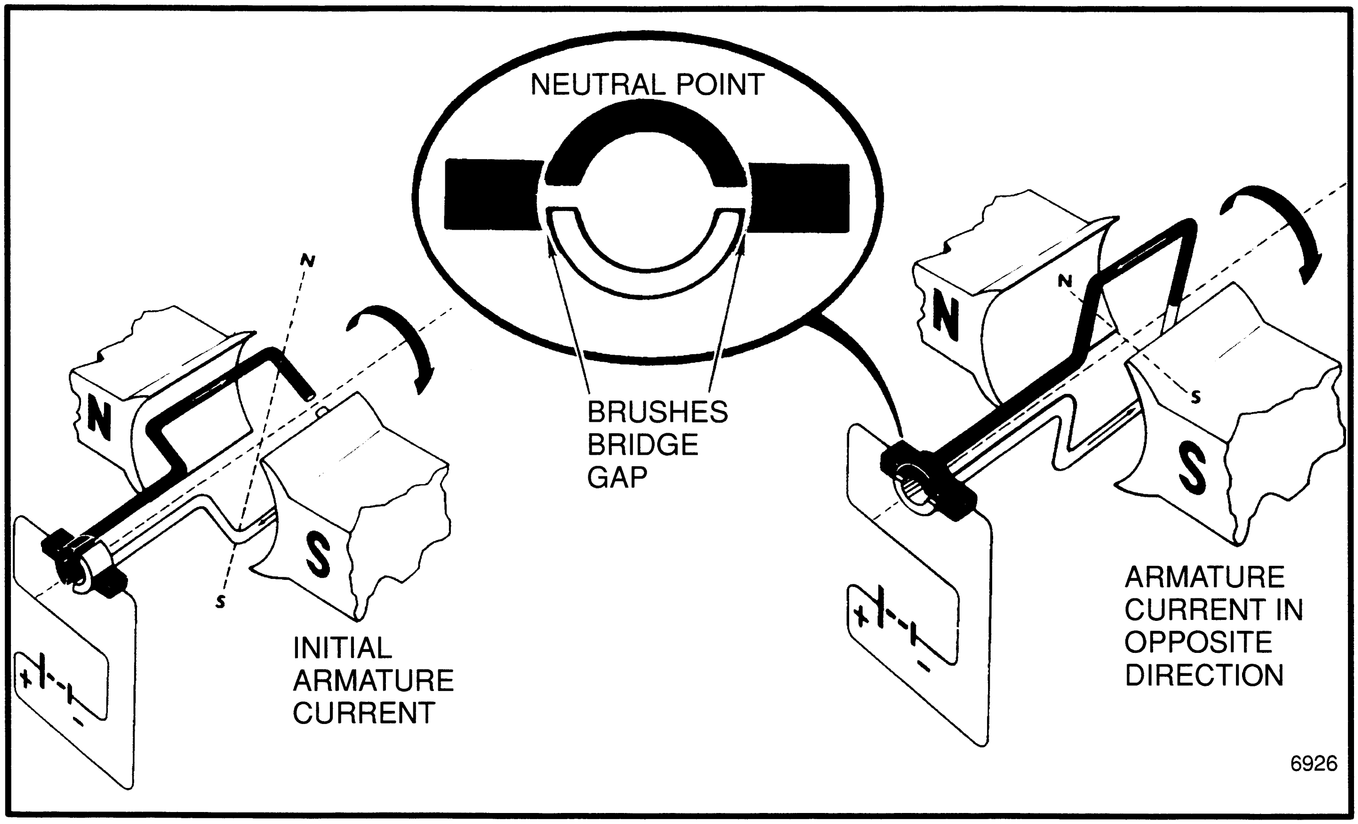


FIGURE 7. COMMUTATION PRINCIPLE

COMMUTATION PRINCIPLE

Commutation is the reversal of current in the armature conductor at the proper time. In the left–hand side of FIGURE 7., the armature current flows first through the darkened portion of the conductor and then returns to the negative brush through the lighter portion. The brushes will then "short circuit" the conductor when it has rotated to the neutral point half way between the poles. Current flow stops at the neutral point because each brush bridges the adjacent commutator bars for an instant. Then when the commutator bars rotate enough to reverse connections with respect to the brushes the current will flow in the opposite direction in the conductor. The direction of current flow in the conductor changes direction every 180° at the neutral point, that is commutation.

NOTE: Some 78–80V motors require interpole windings which reduce arcing at the neutral point. The interpole windings provide this feature by reducing the magnetic field across the armature conductor at the neutral point.

DIRECTION OF MOTOR ROTATION

The direction of armature rotation depends upon the direction of the field and the direction of current flow in the armature. If either the direction of the field or the direction of current flow through the armature is reversed, the rotation of the motor will reverse. However if both of the above two factors are reversed at the same time, the motor will continue rotating in the same direction. The traction motor direction of rotation is changed by reversing the field with the F/R contactors. (See FIGURE 7.). The hoist and steering motors have a fixed direction of rotation.

MOTOR SPEED

The speed of the motor depends on the voltage applied and the load. In a lift truck the voltage to the traction motor is controlled by either a resistor or SCR controlled circuit. The pump and power steering motors have full battery voltage applied and change speed with a change in the load.

MOTOR TORQUE

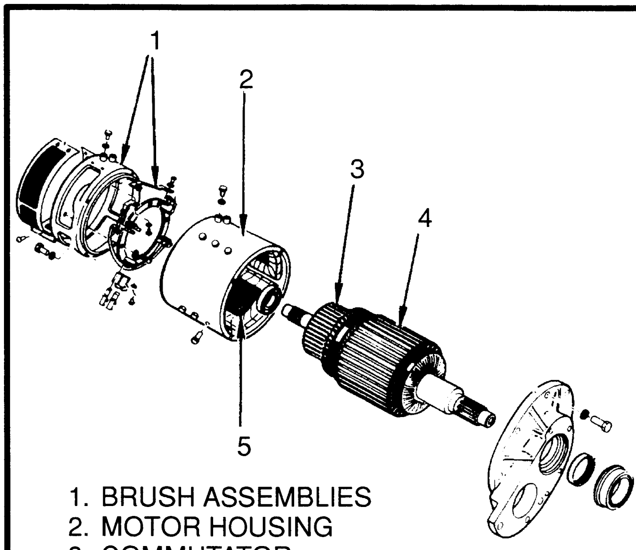
The torque a motor develops to turn a certain load depends on the amount of current drawn from the battery. The greater the load the more torque required and the greater the current flow will be. The lighter the load, the less torque required and the smaller the current will be.

COUNTER ELECTROMOTIVE FORCE

When the armature rotates the coil windings "cut" the magnetic field, inducing a voltage or electromotive force in these coils. Since this induced voltage opposes the applied terminal voltage, it is called the "counter electromotive force," or "counter–emf." This counter–emf depends on the speed, direction of rotation and the field strength. The stronger the field and the faster the rotating speed, the larger will be the counter–emf. However, the counter–emf will always be less than the applied voltage because of the internal voltage drop due to the resistance of the armature coils. The internal resistance of the armature is very low, (less than one ohm). If the armature coil resistance was all that limited the armature current, the current would be very high. For example, if the armature resistance is 0.01 ohm and the applied voltage is 50 volts, the resulting current, according to Ohm's law, would be 5000 amps. This excessive current would completely burn out the motor. However, the counter–emf is in opposition to the applied voltage and limits the value of armature current that can flow. If the counter–emf is 48 volts, then the effective voltage acting on the armature is the difference between the terminal voltage and the counter–emf (2 volts). The armature current is then only 200 amps.

TYPICAL MOTOR

Typical motors basically include a housing, armature, brush assemblies and field windings. The housing is the main structure of the motor which provides protection for motor components and a magnetic path for the field. The armature is the rotating part which has coils of wire wrapped around an iron core connected to a commutator. The brushes ride against the commutator which allows battery current to reach the armature windings. The field windings mounted on iron pole pieces within the housing form electromagnets which provide the magnetic field necessary for motor operation.



1. BRUSH ASSEMBLIES
2. MOTOR HOUSING
3. COMMUTATOR
4. ARMATURE
5. FIELD WINDINGS

FIGURE 8. TYPICAL MOTOR

TYPES OF MOTORS

There are four basic types of DC motors:

a. Permanent–Magnet

b. Series Wound

c. Parallel or Shunt Wound

d. Compound Wound

Each has characteristics that are advantageous under given load conditions. The permanent–magnet, series wound, and compound wound motors are the most commonly used in lift truck systems.

Permanent–Magnet

Permanent–magnet motors have no field windings because the field is provided by permanent magnets. All the current flows through the armature windings. Permanent–magnet motors are normally physically smaller and less expensive than comparable field wound motors. They are sometimes used in the lift truck power steering system.

NOTE: The field on Series, Parallel, and Compound motors is provided by an electromagnet (See Page 2).

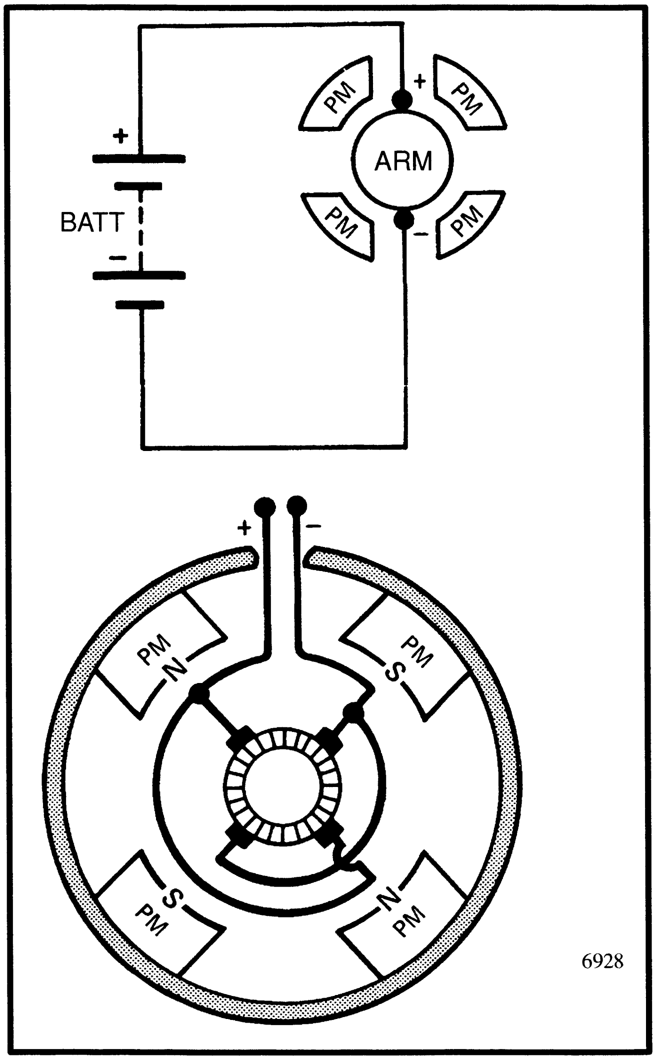


FIGURE 9. PERMANENT–MAGNET STEERING

Series Wound

Series wound motors have the field coils connected in series with the armature circuit. The same current flows through the armature windings and the field windings. In a series motor, the torque varies inversely with the speed. Under conditions of light load, there is high speed and low torque. Under conditions of heavy load, there is low speed and high torque. Series motors are desirable in some hydraulic systems where a light load can be raised fast and a heavy load at a slower speed. This gives the effect of a two speed hoist system. The series motor has high starting torque and quick acceleration. This characteristic makes it ideal for lift truck traction systems.

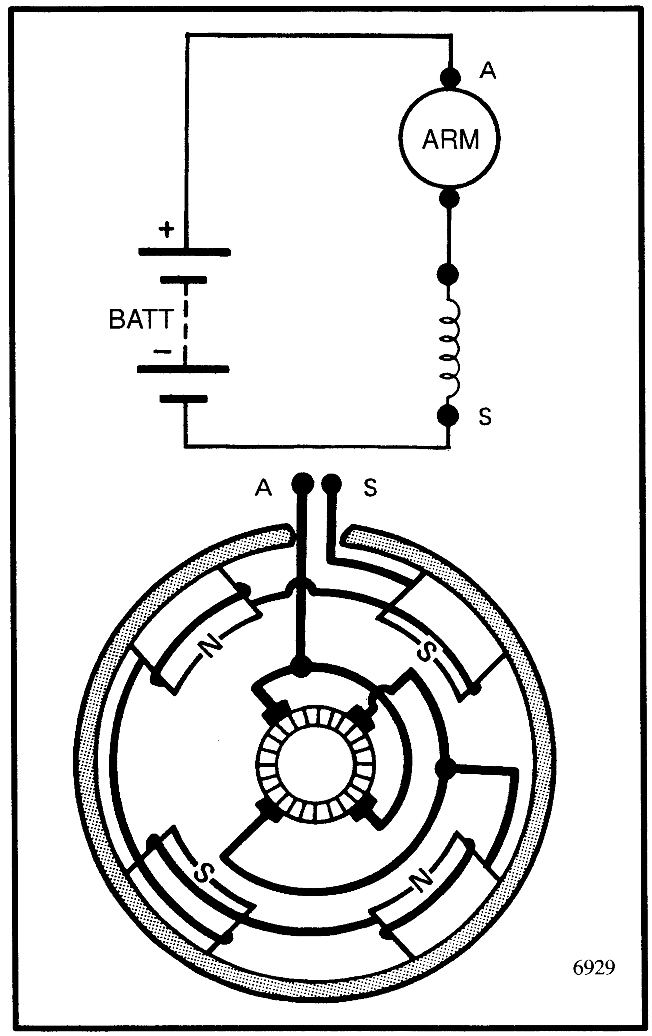


FIGURE 10. SERIES HOIST MOTOR DIAGRAM

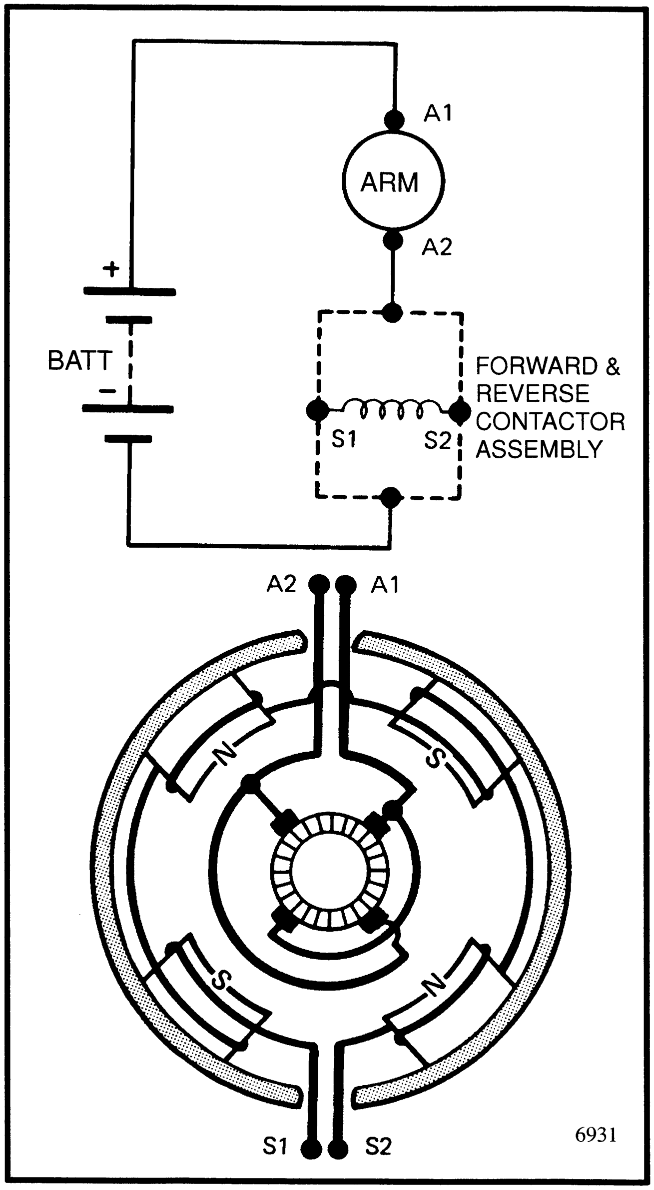


FIGURE 11. SERIES TRACTION MOTOR DIAGRAM

Parallel or Shunt Wound

In the parallel or shunt wound motor, the current divides. Most of the current flows through the armature windings and the remaining current flows through the field windings. This motor tends to keep a constant speed under varying load conditions, but has very little starting torque. A pure shunt motor is not used in Hyster lift truck systems.

Compound Wound

The compound wound motor uses a combination of series and shunt windings. The field consists of two separate sets of windings. One set, whose coils are wound with a few turns of heavv wire is connected in series with the armature as a series field. The other set, whose coil(s) are wound with many turns of fine wire, is connected across the armature as a shunt or parallel field. The result is a motor that combines the features of the series and shunt motors. This motor has good starting characteristics like the series motor, and reasonably constant speed between a loaded and no–load condition like the shunt motor. This type motor is used for power steering and the hydraulic system.

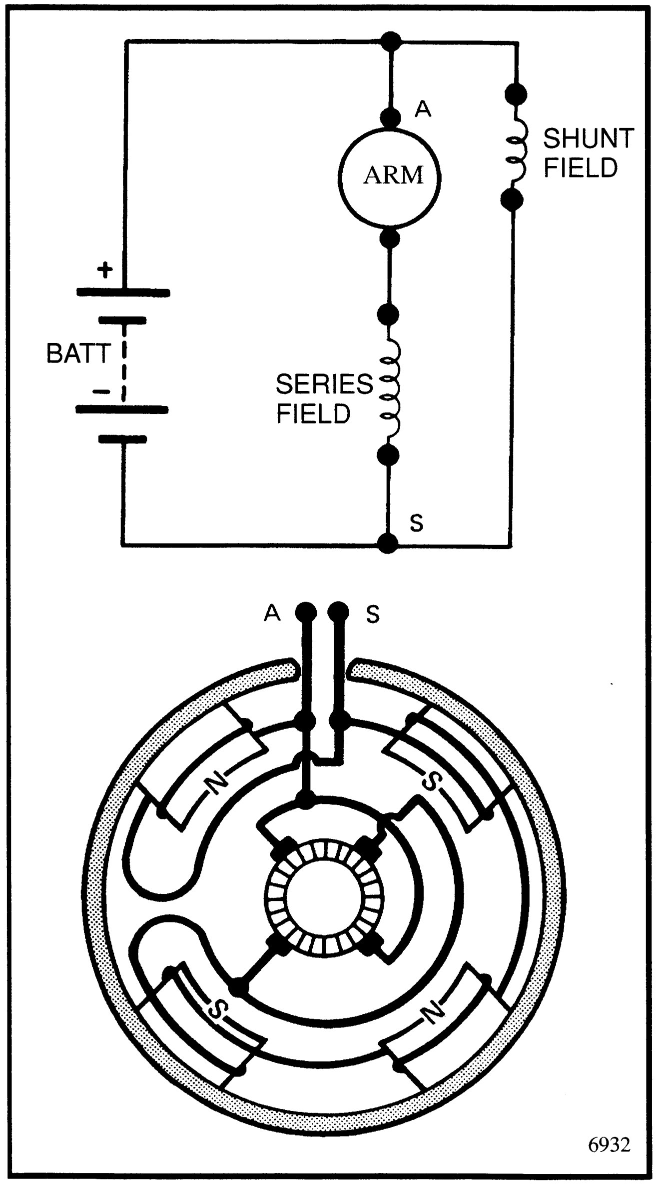


FIGURE 12. COMPOUND MOTOR DIAGRAM (HOIST AND STEERING)

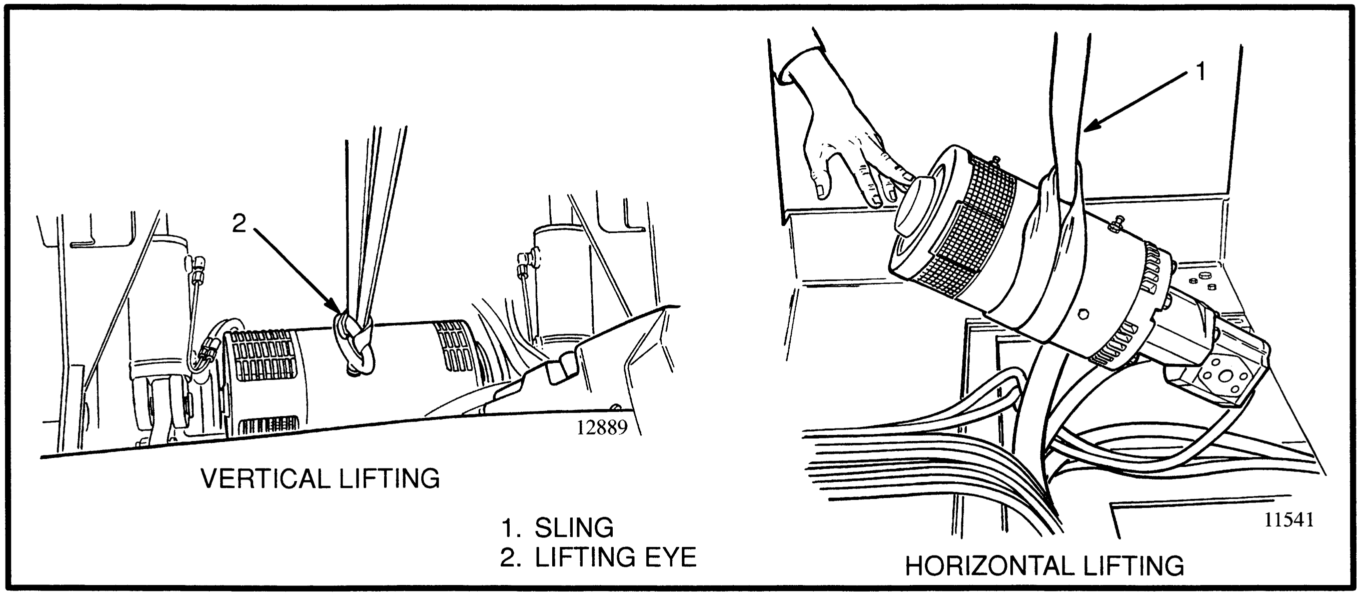


FIGURE 13. HANDLING MOTORS

MOTOR INSULATION CLASS

Motor windings must be electrically insulated from each other to prevent a short circuit. Insulation materials include glass cord, mica, silicone glass, and varnish glass. This insulation is subject to the aging effects of heat. A class rating has been set up based on a motor's ability to withstand a specific temperature over a specific period of operation. The insulation type is a significant factor in determining the class rating. Most of the motors used in Hyster Electric Trucks are class "H". The class "H" motor must withstand an armature temperature of 177°C (350°F). The motor's frame temperature is normally 10 to 37°C (50 to 100°F) lower than the armature temperature which is measured internally. The operating temperature of the motor's frame is generally too hot to touch. The permanent magnet motor used for power steering is not given an insulation class rating because the magnets have a low maximum operating temperature (about 93°C or 200°F).

STORAGE

The motor should be stored in a clean dry place if it is not to be installed immediately. Protect it from low temperatures and sudden changes in temperature or humidity. The brushes should be lifted off the commutator during extended storage periods otherwise corrosion may occur and later result in flat spots on the commutator.

HANDLING

Heavy motors with vertical drive should be lifted with a lifting eye screwed onto the shaft. Motors that mount horizontally may be lifted and handled with a sling around the frame. Care should be exercised to protect terminals, shaft extension(s) and accessories from damage during handling.

⚠ CAUTION

Permanent magnet motors have Ceramic magnets that are brittle. Do not strike or drop a PM motor.

BREAK–IN OPERATION

Break–in is a very critical time for the commutator and the brushes. With a little care the brushes will wear–in and provide reasonable service life, however, with abuse they can rapidly wear–out. A new or reconditioned commutator is bright and shiny indicating that the brushes have not yet completely conformed to the commutator. After a short operating period (40 to 100 hours) a protective film builds up on the commutator and the brushes exactly conform to the commutator. When the brushes are properly seated–in, the commutator will have a dull, thin, dark chocolate coating which is relatively uniform. NEVER break–in any motor with an inadequate battery charge (1.240 or lower).

No special procedure is required to break–in the traction motor(s); however, any traction motor will benefit if the truck is not put in a harsh cycle until a few hours of light duty operation has been accumulated. Avoid ramps and high speed plugging if possible (DO NOT REDUCE PLUGGING DISTANCE ADJUSTMENT). Stalling the motor is very detrimental during the break–in period.

Little can be done during hoist motor break–in to reduce in–rush currents, but the frequency of starts can be reduced. A common practice called jogging can be very detrimental to the brushes during break–in. Jogging is commonly done to fine position a load. Rather than throttle the lift speed with the valve spool, drivers often rapidly turn the hoist motor on and off in steps to position the load. This practice has the effect of destroying the newly developed film on the commutator that smooths commutation. If jogging is not abused during the break–in period, an adequate film can be established. It is critical to curtail jogging for the first 40 to 100 hours of operation. The jogging practice will reduce brush life and contactor life any time it is done. Encourage operators to lift the load high enough the first time to allow positioning the load by careful lowering. The "stoning" procedure will significantly improve the brush life of motors which must be put into heavy duty service immediately (Refer to Page 18).

CLEANING

Periodic cleaning of the motor is essential to prevent overheating and/or electrical grounds.

Motor Exterior. The exterior should be wiped with a solvent–moistened cloth to remove any dirt or grease deposits.

⚠ WARNING

Many solvents are highly inflammable and toxic. Be sure the area is well ventilated and free of flame or sparks.

Carbon Dust. Remove brush inspection cover. Using clean, dry compressed air [less than 3.52 kg/cm^2 (50 psi)], blow dust from motor housing, brush holders and commutator area.

Disassembled Motor Interior. The interior should preferably be cleaned by suction first to avoid blowing dirt or metal particles into the insulation. Dust should then be brushed out of the windings and blown clear using clean, dry, compressed air. Any grease or oil present, especially on the commutator, should be removed by wiping with a clean cloth dampened slightly with Perchloroethylene.

⚠ CAUTION

The cloth should not be wet because liquid solvent may carry electrical conducting dirt deep into cracks and voids in the insulation system.

⚠ CAUTION

Sealed bearings should never be submerged in solvent because internal lubricant will deteriorate.

BASIC REPAIR GUIDELINES

The following is a guide to observe when disassembling a typical motor. (Refer to the electric motor repair section for specific detail).

1. Match mark the motor fleld case and the two end housings before separating the components to aid in reassembly.

⚠ CAUTION

Before lifting off the brush–end housing, make sure that all tension is removed from the brushes (disengage the brush springs). Keep the brushes clear of the commutator during installation to prevent damage to these parts.

2. Carefully lift out or install the armature assembly with the drive–end (DE) frame attached. Do not lose the wave washer behind the commutator–end (CE) bearing on some motors.

3. Do not remove the field windings unless replacement is necessary. Be sure they are securely mounted to the frame.

4. The brush holder assembly must be match marked if removed from end housing. Align marks during reassembly.

⚠ CAUTION

The following Prestolite motors have a maximum torque value of 3.4 to 4.0 N.m (30 to 35 lb in) for the terminal nuts and bolts that fasten the end frames. Prestolite P/N letter codes: MDV, MFD, MMW, MUD, and MHG.

(More Content includes: Brake system, Capacities, and specifications, Frame, Hydraulic, System, Industrial battery, Main control, Valve, Mast repair, Fasteners, Schematics diagrams, Steering axle, Steering system, Wire harness repair And more)