MODULE CONTENT

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| Unit of Competency | **DIAGNOSE AND REPAIR STARTING SYSTEM** |
| --- | --- |
| Module Title | **DIAGNOSING AND REPAIRING STARTING SYSTEM** |
| Module Descriptor | This unit covers the knowledge, skills and attitudes required to diagnose and repair starting system and its component. |
| Nominal Duration | **hours** |
| Summary of the Learning Outcomes: | |
| Upon completion of this module the student must be able to: | |
| LO1. Prepare to diagnose and repair starting system | |
| LO2. Diagnose starting system | |
| LO3. Repair starting system | |
| LO4. Complete work processes | |

**LEARNING EXPERIENCES**

**LEARNING OUTCOMES NO. 1**

**PREPARE TO DIAGNOSE AND REPAIR STARTING SYSTEM**

| **Learning Activities** | **Special Instructions** |
| --- | --- |
| Read Information Sheet 3.1-1 Prepare to diagnose and repair starting system | If you have some problem with the content of the information sheet don’t hesitate to approach your Trainer.  If you feel that you are now knowledgeable on the content of the information sheet, you can now answer the self-check provided in the module. |
| Answer Self-Check 3.1-1 on Prepare to diagnose and repair starting system | Try to answer the Self-check without looking at the Answer Key  Compare your answer to Answer Key 3.1-1 |
| Observe Trainer’s demonstration on Task Sheet 3.1-1 on Prepare to diagnose and repair starting system | Listen carefully and attentively so that you may be able to perform a task correctly  Ask questions if are in doubt for clarification |
| Perform the Task Sheet 3.1-1 on Prepare to diagnose and repair starting system | Remember the step-by-step procedure of the Prepare to diagnose and repair starting system |
| Evaluate the performance using the Performance Criteria Checklist 3.1-1 | Repeat the task in case fail to meet the criteria |

**INFORMATION SHEET 1.1-1**

**PREPARE TO DIAGNOSE AND REPAIR STARTING SYSTEM**

**Learning Objectives:**

After reading this **Information Sheet**, you must be able to:

1. Determined job requirements
2. Sourced and interpreted diagnostic information.
3. Verified symptoms.
4. Identified hazards associated with the work and managed risks.
5. Selected and checked tools, equipment, and materials.
6. Reported defective and damaged tools and equipment.
7. Checked and reported availability of materials.

**STARTING SYSTEM**

The starting system converts electrical energy from the batteries, hydraulic or pneumatic force from a cylinder into mechanical energy to turn the engine over.

The vehicle’s starting system is designed to turn or crank the engine over until it can operate under its own power. To do this, the starter motor receives electrical power to the battery. The starter motor then converts this energy into mechanical energy, which it transmits through the drive mechanism to the engine’s flywheel **(Figure 18-1).**

The only function of the starting system is to crank the engine fast enough to run. The vehicle’s ignition and fuel systems provide the spark and fuel engine operation, but they are not considered components of the basic starting system.

**Figure 18-1** A starter motor meshed with the engine’s flywheel.

**STARTING SYSTEM – DESIGN AND COMPONENTS**

A typical starting system has six basic components and two distinct electrical circuits. The components are the battery, ignition switch, battery cables, magnetic switch, (either electrical or solenoid), starter motor, and the starter safety switch.

The starter motor **(Figure 18-2)** draws a great deal of current from the battery. A large starter motor might require 250 or more ampere of current. This current flows through the large cable that connect the battery to the starter ground.

**Figure 18-2** A cutaway of a heavy-duty starter motor.

The driver controls the flow of this current using the ignition switch normally mounted on the steering column. The battery cables are not connected to the switch. Rather, the system has two separate circuits; the starter circuit and the control circuit **(Figure 18-3).** The starter circuit carries the heavy current from the battery to the starter motor through a magnetic switch in a relay or solenoid. The control circuit connects the battery power at the ignition switch, which controls the high current to the starter motor.

**Figure 18-3** A simple diagram showing the starter and starter control circuits.

**Starter Circuit**

The starter circuit carries the high current flow within the system and supplies power for the actual engine cranking. Components of the starter circuit are the battery, battery cables, magnetic switch or solenoid, and the starter motor.

**Battery and Cables** Many of the problems associated with the starting system can be resolved by troubleshooting the battery ‘and its related components.

The starting circuit requires two-or-more heavy-gauge cables. One of these connects between the battery’s negative terminal and the engine block or transmission case. The other cable connects the battery’s positive terminal with the solenoid. On vehicles equipped with a **starter relay,** two positive cables are needed. One runs from the positive battery terminal to the relay and the second from the relay to the starter motor terminal. In any case, these cables carry the required heavy current from the battery to the starter and the from the starter back to the battery.

Cables must be heavy enough to comfortably carry the required current load. Cranking problems can be created when undersized cables are installed. With undersized cables, the starter motor does not develop its greatest turning effort and even a fully charged battery might be unable to start the engine.

**Magnetic Switches** Every starting system contains some type of magnetic switch that enables the control circuit to open and close the starter circuit. This magnetic switch can be of several designs.

*Solenoid* The solenoid-actuated starter is by far the most common starter system used. A solenoid is an electromechanical device that uses the movement of a plunger to exert a pulling or holding force. As shown in **Figure 18-4,** the solenoid mounts directly on top of the starter motor.

**Figure 18-4** An example of a solenoid-actuated starter where the solenoid mounts directly to the starter motor.

In this type of starting system, the solenoid uses the electromagnetic field generated by its coil to perform two distinct jobs.

The first to push the drive pinion of the starter motor into the mesh with the engine’s flywheel. This is the solenoid’s mechanical function. The second job is to act as a n electrical relay switch to energize the motor once the drive the pinion is engaged. Once the contact points of the solenoid are closed, full battery current floes to the starter motor.

The solenoid assembly has two separate windings: **a pull-in winding** and a **hold-in winding.** The two windings have approximately the same number of turns but are wound from the different size wire. Together with these winding procedures the electromagnetic force needed to pull the plunger into the solenoid coil. The heavier pull-in windings draw the plunger into the solenoid, while the lighter-gauge winding produce enough force to hold the plunger in this position.

Both windings are energized when the ignition switch id turned to the start position. when the plunger disc makes contact with this solenoid terminal, the pull-in winding is deactivated. At the same time, the plunger contact disc makes the motor feed connection between the battery and the starting motor, directing current to the field coils and starter motor armature for cranking power.

As the solenoid plunger moves, the shift fork also pivots on the pivot pin and pushes the starter drive pinion into mesh with the flywheel ring gear. When the starter motor received current, its armature starts to turn. This motion is transferred through an overrunning clutch and pinion gear to the engine flywheel and the engine is cranked.

With this type of solenoid-actuated direct drive starting system, teeth on the **pinion gear** may not immediately located behind the pinion compresses so the solenoid plunger can complete its stroke. When the starter motor armature begins to turn, the pinion teeth quickly line up with the flywheel teeth and the spring pressure forces them to mesh.

*Starter Relay.* Relays are the second major type of magnetic switch used. All **positive engagement starters** (describe later in this chapter) use a relay series with the battery cables to deliver the high current necessary through the shortest possible battery cables. **Figure 18-5** shows a typical starter relay. It is very similar to the solenoid. However, it is not used to move the drive pinion into mesh. It is strictly an electrical relay or switch. When current from the ignition switch arrives at the ignition switch terminal of the relay, a strong magnetic field is generated in the coil of the relay. This magnetic force pulls the plunger contact disc up against the battery terminal and the starter terminal of the relay, allowing full current flow to the starter.

**Figure 18-5** A starter relay/solenoid mounted on a vehicle.

A secondary function of the starter relay is to provide an alternate electrical path to the ignition coil during cranking. This current flow bypass the resistance wire (or ballast resistor) in the ignition bypass terminal on the relay. Not all systems have ignition bypass setup.

Some vehicles use both a starter relay and a starter motor mounted solenoid. The relay controls current flow to the solenoid, which in turn controls currents flow to the starter motor. This reduces the amount of current flowing through the ignition switch.

Basically, all the different starting systems in use today fit into in of three categories: the solenoid shift, solenoid shift with relay, or the positive engagement with relay. Typical writing diagrams for these systems are shown in **Figure 18-6** and **18-7.**

**Figure 18-6** (A) A solenoid shift and (B) a solenoid shift with starter relay starting system.

**Figure 18-7** A schematic of a positive engagement starter.

**Starter Motor**  The starter motor **(Figure 18-8)** converts the electrical energy from the battery into mechanical energy for cranking the engine. The starter is a special type of electric motor designed to operate under great electrical overloads and to produce very high horsepower.

**Figure 18-8** A typical starter motor assembly.

All starting motors are generally the same in design and operation. Basically, the starter motor consists of a housing, field coils, an armature, a commutator and brushes, and end frames.

The **starter housing** or **starter frame** encloses the internal starter components and protects them from damage, moisture, and foreign material. The housing supports the field coils.

The **field coils** and their **pole shoes (Figure 18-9)** are securely attached to the inside of the iron housing. The field coils are insulated from the housing but are connected to a terminal that protrudes through the outer surface of the housing.

**Figure 18-9** An example of a field coil and pole shoe.

The field coils and poles shoes are desired to produce strong stationary electromagnetic fields within the study as current is passed through the starter. These magnetic fields are concentrated at the pole shoe. Fields have an N or S magnetic polarity depending on the direction of current flow. The coils are wound around respective pole shoes in opposite directions to generate opposing magnetic fields.

The field coils connect in series with the armature winding through the starter **brushes.** This design permits all current passing through the field coil circuit to also pass through the armature windings.

The **armature** is the only rotating component of the starter. It is located between the drive and accumulator end frames and the field windings. When the starter operates, the current passing through the armature produces a magnetic field in each of its conductors. The reaction between the armature’s magnetic field and the magnetic fields produced by the field coils causes the armature to rotate. This mechanical energy is then used to crank the engine.

The armature has two main components: the armature windings and the **commutator.** Both mount to the armature shaft. The windings are made of several coils of a single loop each. The side of these loops fit into slots in the armature core or shaft, but they are insulated from it.

The coils connect to each other to the commutator so current from the field coils flows through all of the armature windings at the same time. This action generates magnetic field around each armature winding, resulting in a repulsion force all around the conductor. This repulsion force causes the armature to turn.

The commutator assembly is made up of heavy copper segments separated from each other and the armature shaft by insulation. The commutator segments connect to the ends of the armature windings.

Most starter motors have two to six brushes that ride on the commutator segments and carry the heavy current flow from the stationary fields coils to the rotating armature windings via the commutator segments.

The brushes mount on and operate in some type of holder, which may be pivoting arm design inside the starter housing or frame **(Figure 18-10).** However, in many starters the brush holders are secured to the starter’s end frame. Springs hold the brushes against the commutator with the correct pressure. Finally, alternate brush holders are insulated from the housing or end frame. Those in between the insulated holders are grounded.

The end frame is a metal plate that bolts to the commutator end of the starter housing. It supports the commutator end of the armature with a bushing and often contains the brush holders that support the brush.

**Figure 18-10** The location of the starter motor brushes and commutator.

*Operating Principle*. The starter motor converts electric current into torque or twisting force through the interaction of magnetic fields. It has a stationary magnetic field, the field windings, and a current-carrying conductor, the armature windings **(Figure 18-11).** When the armature windings are placed in this stationary magnetic field and current is passed through the windings, a second magnetic field is generated with its line of force in the stationary magnetic field flow in one direction across the winding they combine on one side of the wire, increasing the field strength, but are opposed on the other side, weakening the filed strength. This creates an unbalanced magnetic force, pushing the wire in the direction of the weak field **(Figure 18-12).**

**Figure 18-11** A simple DC motor.

**Figure 18-12** Rotation of the conductor is in the direction of the weaker magnetic field.

Since the armature windings are formed in loops or coils, current flows outward in one direction and returns in the opposite direction. Because of this, the magnetic lines of force are oriented in opposite directions in each of the two segments of the loop. When places in the stationary magnetic field of the field coils, one part of the armature coil is pushed in one direction. The other part is pushed in the opposite direction, causing the coil and the shaft to which it is mounted to rotate.

Each end of the armature winding is connected to one segment of the commutator **(Figure 18-13).** Carbon brushes are connected to the terminal of the power supply. The brushes contact the commutator contact conducting current to and from the armature coil.

As the armature coil turns through a half revolution, the contact of the brushes on the commutator causes the current flow to reverse in the coil. The commutator segment attached to each coil end has traveled past one brush and is now in contact with the other. In this way, current flow is maintains constantly in one direction, while allowing the segment of the rotating armature coils to reverse polarity as they rotate.

**Figure 18-13** The armature of a starter motor.

In a starter motor, many armature segments must be used, as one segment rotates past the secondary magnetic field pole, another segment immediately takes its place. The turning motion is made uniform and the torque coils **(series motor);** the field coils may be wired parallel or shunted across the armature (**shunt motors);** or a combination of series and shunt wiring may be used **(compound motors) (Figure 18-14).**

**Figure 18-14** Starter motors are grouped according to how they are wired: (A) in series, (B) in parallel (shunt), or (C) as a compound motor using both series and shunt coils.

The amount of turning torque from a starter motor depends on a number of factors is current draw. The slower the motor turns, the more current it will draw. This is why a starter motor will draw excessive amounts of current when the engine is very difficult to turn over or crank. A motor needs more torque to crank a difficult-to-turn engine. The relationship between the current draw and motor speed is explained by the principles of **counter EMF (CEMF).**

When the armature rotates within the field windings of a motor, conditions exist to exist to induce a voltage in the armature. Voltage is induced any time a wire is passed through a magnetic field. When the armature, which is a structure with many loops of wire, rotates past the field windings, a small amount of voltage is induced. This voltage opposes the voltage supplied by the battery to energize the armature. As a result, less current is able to flow through the armature.

The faster the armature spins, the more induced voltage is present in the armature. The more voltage in the armature, the more opposition there is to normal current flow to the armature. The induced voltage in the armature opposes or is counter to the battery’s voltage. This is why the induced voltage is called CEMF.

The effects of CEMF are quite predictable. When the armature of the motor turns slowly, low amounts of voltage are induced and, therefore, low amounts of CEMF are present. The low amount of CEMF allows a high amount of current draw. In fact, the only time a starter motor draws its maximum amount of current is when the armature is not rotating.

A series-wound motor develops its maximum torque at start-up and develops less torque as speed increases. It is ideal for applications involving heavy starting loads.

Shunt or parallel-wound motors a constant speed at all operating loads. Compound motors combine the characteristics of good starting torque with constant speed. The compound design is particularly useful for applications in which heavy loads are suddenly applied. In a starter motor, a shunt coil is frequently used to limit the maximum free speed at which the starter can operate.

**Starter Motor Drive Mechanisms** The area in which starters differ most is in their drive mechanisms used to crank the engine. The solenoid-actuated direct drive system has been explained earlier in this chapter.

Some starters are planetary gear set to increase the torque of a starter motor. Planetary gear sets offer the advantage of quite operation and compactness.

*Positive Engagement Movable Pole Shoe Drive.* Positive engagement movable pole shoe dive starters are found mostly on older Ford products. In this design, the drive mechanism is an integral part of the motor, and the drive pinion is engage with the flywheel before the motor is energized.

When the ignition switch is moved to the start position, the system’s starter relay closes, and full battery current is delivered to the starter. This current runs through the winding of a movable pole shoe and through a set of contacts to ground. This generates magnetic force that pulls down the movable pole shoe. It also forces the drive pinion to engage the flywheel ring gear using a lever action and opens the contacts. A small holding coil helps keep the movable shoe and lever assembly engaged during cranking. When the engine starts, an overrunning clutch prevents the engine’s flywheel from spinning the position, both the pole shoe and lever return to their original positions.

*Solenoid-Actuated Gear Reduction Drive.* Solenoid-actuated **gear reduction-drive starters** use a solenoid to engage the pinion with the flywheel and to close the motor circuit. The starter armature does not drive the pinion directly. Instead a gear set is used to reduce speed and increase the turning torque of the pinion gear. The gear set may be as simple as a small gear meshed with a larger one, or the reduction may take place through the use of a planetary gear set. This design allows a small, high-speed motor to develop increased turning torque at a satisfactory cranking rpm. The solenoid and starter drive operation is basically the same as in solenoid-actuated direct drive systems.

**Permanent Magnet Starter Motors** The most recent change in starter motors has been in the use of permanent magnets rather than electromagnets as field coils. Electrically, this starter motor is simpler. It does not require current for field coils. Current is delivered directly to the armature through the commutator and brushes. **Figure 18-15** shows this type of starter motor. This unit functions exactly as the other styles considered. Increased use of this style is expected in the future as production costs are greatly reduced. Maintenance and testing procedures are the same as for the other designs. Notice the use of a planetary gear reduction assembly on the front of the armature. This assembly allows the armature to spin with increased torque, resulting in improved starter cold-cranking performance.

**Figure 18-15** A permanent magnet-type starter assembly.

**Starter Drive** A **starter drive** a pinion gear set that meshes with the flywheel on the engine’s crankshaft **(Figure 18-16).** to prevent damage to the pinion gear or the flywheel’s ring gear, the pinion gear must mesh with the ring gear before the starter motor rotates. To help ensure smooth engagement, the end of the pinion gear is tapered **(Figure 18-17).** Also, the movement of the armature must always be caused by the action of the motor, not the engine. For this reason, starter drive assemblies include an overrunning clutch.

**Figure 18-16** A starter drive pinion gear is used to turn the engine’s flywheel.

**Figure 18-17** The pinion gear teeth are tapered to allow for smooth engagement.

*Overrunning Clutch.* The ove**rrunning clutch** performs a very important job in protecting the starter motor. When engine starts and runs, its speed increases. If the starter motor remained connected to the engine through the flywheel, the starter motor would spin at very high speed, destroying the armature winding.

To prevent this, the armature must disengage from the engine as soon as the engine turns more rapidly than the starter has cranked it. However, with most starter designs the pinion remains engaged until electricity stops flowing to the starter. In these cases, an overrunning clutch is used to disengage the starter.

The clutch housing is internally splined to the starting motor armature shaft. The drive pinion turns freely on the armature shaft. The drive pinion turns freely on the armature shaft within the clutch housing. When the clutch housing is driven by the armature, the spring-loaded rollers are forced into the small ends of their tapered slots and wedge tightly against the pinion barrel. This locks the pinion and clutch housing solidly together, permitting the pinion to turn the flywheel and thus, crank the engine.

When the engine starts **(Figure 18-18),** the flywheel spins the pinion faster than the armature. This releases the rollers, unlocking the pinion gear the armature shaft. The pinion then overruns the armature shaft freely until being pulled out of the mesh without stressing the starter motor. The overrunning clutch is moved in and out of mesh by the starter drive linkage.

**Figure 18-18** When the engine starts, the flywheel spins the pinion gear faster, which releases the rollers from the wedge.

**CONTROL CIRCUIT**

The control circuit allows the driver to use a small amount of battery current to control the flow of a large amount of current in the starting circuit.

The entire circuit usually consists of an ignition switch connected though normal-gauge wire to the battery and the magnetic switch (solenoid or relay). When the ignition switch is turned to the start position, a small amount of current flows through the coil of the magnetic switch, closing it and allowing full current to flow directly to the starter motor. The ignition switch performs other jobs beside controlling the starting circuit. It normally has at least four positions: accessory, off, on (run), and start.

**Starting Safety Switch**

The **starting safety switch,** often called the **neutral safety switch**, is normally open switch that prevents the starting system from operating when the transmission is in gear. This eliminates the possibility of a situation that could make the vehicle lurch unexpectedly forward or backward. Safety switches are more commonly used with automatic transmissions but are also used on manual transmissions.

Starting safety switches can be located in either of two places within the control circuit. One location is between the ignition switch and the relay or solenoid. In this position, the safety switch must be closed before the current can flow to the relay or solenoid. A second location for the safety switch is between the relay and ground. The switch must be closed before current can flow from the relay to ground.

The safety switch used with an automatic transmission can be either an electrical switch or mechanical device. Contact points on the electrical switch are closed only when the shift selector is in park or neutral. The switch can be mounter near the shift selector or on the transmission housing **(Figure 18-19).** The switch contact are wires in series with the control so that no current can flow through the relay or solenoid unless the transmission is neutral or park.

Mechanical safety switches for automatic transmissions are simply device that physically block the movement of the ignition key when the transmission is in a gear **(Figure 18-20).** The ignition key can only be turns when the shift selector is in park or neutral.

**Figure 18-19** A neutral safety switch attached to a transmission.

**Figure 18-20** A mechanical linkage used to prevent starting the engine while the transmission is in gear.

The safety switches used with manual transmissions are usually electrical switched mounted near the gear-shift lever or on the transmission housing. A clutch switch is a second type of safety switch used with the manual transmissions. This electrical switch mounts on the floor or firewall. Its contacts are closed only when the clutch pedal is fully depressed **(Figure 18-21)**.

**Figure 18-21** The clutch pedal must be fully depressed to close the clutch switch and complete the control circuit.