# Student Learning Guide & Record

| TASK | PAGE | TASK TITLE | DATE COMPLETED | INSTRUCTOR'S SIGNATURE |
|---|---|---|---|---|
| Assessment 1 | 15 | Starter motor drives – Over-running clutch | | |
| Assessment 2 | 17 | Starter motor drives – Bendix drive | | |
| Assessment 3 | 22 | Review questions – Starter motors | | |
| Assessment 4 | 24 | Research removal and replacement procedures | | |
| Assessment 5 | 25 | Research starter motor removal and replacement procedures | | |
| Assessment 6 | 27 | Remove and replace a starter motor | | |
| Assessment 7 | 27 | Starter motor specification | | |
| Assessment 8 | 28 | Inspect the starter motor drive and ring gear | | |
| Assessment 9 | 28 | Replace the starter motor | | |
| Assessment 10 | 29 | Carry out replacement inspection | | |
| Assessment 11 | 29 | Rectify any faults discovered | | |
| Assessment 12 | 29 | Start your engine | | |
| Assessment 13 | 30 | Write a condition report for the customer | | |

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# STARTER MOTOR DRIVES

## The Starter Motor

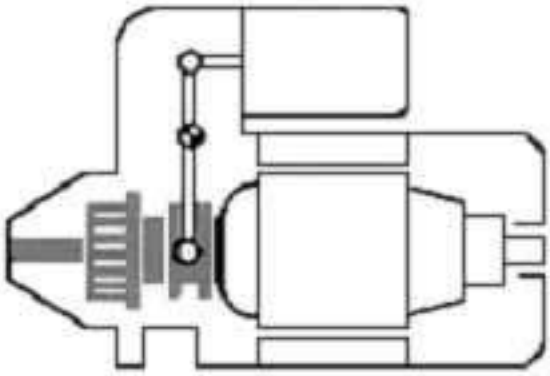
The starter motor is a DC motor which converts battery electrical energy to mechanical energy which is used to crank the engine for starting. Starter motors range in size from 746W to 30,000W (1 hp up to 40 hp) units which are used on heavy diesels which have displacements up to 147 litres (9,000 cubic inches). Starter motors are series wound because this type of winding provides maximum armature torque at zero speed, needed to start an engine moving. All starters are similar in design and operation, differing mainly in size and type of drive used.

## Pinion-Engaging Drive

The starter drive end shield contains the following main components; pinion-engaging drive with pinion, over-running clutch, engaging lever or engagement rod for the engaging stroke, and meshing spring. This starter subassembly is responsible for coordinating the thrust motion of the solenoid switch and the rotary motion of the electric starter motor and transferring them to the pinion.

## Pinion

The starter engages the ring gear on the engine flywheel by means of a small displaceable gear called the pinion. A high transmission ratio, **normally between 10:5 and 15:1** makes it possible to overcome the high cranking resistance of the internal combustion engine. The pinion gear teeth are specially designed in order to promote meshing of the starter pinion with the ring gear during starting, to transmit the starter torque and to demesh the starter pinion at the appropriate time:



Pinion – engaging drive assembly

- The pinion gear teeth have an involute shape to promote meshing
- The faces of the pinion gear teeth, and those of the ring gear depending upon starter design, are chamfered
- In contrast to gears which remain meshed all the time, the center distance between the pinion and ring gear is increased in order to ensure great enough backlash at the tooth flanks
- The outer face of the pinion in its rest position must be a certain minimum distance away from the face of the ring gear and
- In order to achieve long service life, pinion and ring gear materials and hardening methods are matched to each other.

As soon as the engine starts and accelerates past the cranking speed, the pinion must automatically demesh in order to protect the starter, i.e. the connection between the starter shaft and the engine flywheel must automatically be broken. For this reason, starters also incorporate an over-running clutch and a mechanism to mesh and demesh the pinion.

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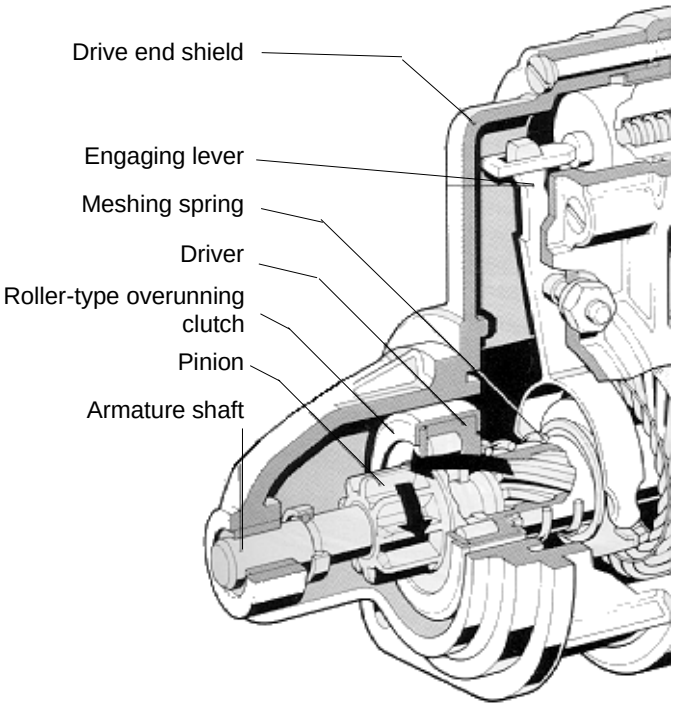
## Pinion-engaging Drive

The pinion-engaging drive must in all cases be designed such that the thrust movement of the solenoid switch and the rotary motion of the electrical starter motor can occur at the same time – but independently – under all meshing conditions. The various different sizes of starters, however, have differently designed pinion-engaging drives.

These differences are indicated by the names of the starters.




Pinion-engaging drive of a pre-engaged drive starter

## Pre-engaged drive

In pre-engaged drive starters, the thrust movement of the integral solenoid switch is transferred to the driver (with pinion) which rides in a helical spline in the armature shaft. This design results in combined axial and rotary motion which greatly facilitates the meshing of the pinion.

## Sliding-gear drive, electromotive pinion rotation

In sliding-gear starters with engagement solenoids as an extension of the armature axis, the pinion is pushed straight forward by an engagement rod which passes through the hollow shaft. As this is happening the armature begins to rotate slowly in an initial actuation stage in order to facilitate meshing. After the pinion has meshed with the ring gear, the main starter current is applied in the second stage in order to crank the engine.

## Sliding-gear drive, mechanical pinion rotation

In sliding-gear starters with integral solenoid switches the entire drive with pinion is moved straight forward in the first stage. If direct meshing is not possible, the second mechanical stage takes over, and rotates the pinion.

Starter pinion (small gear) fully meshed with the ring gear of engine flywheel (large gear).

The pinion gear teeth are chamfered to facilitate meshing.

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As a result, the meshing spring is compressed via the engaging lever and guide rings until the moving contact meets the solenoids. The starter motor is now switched on and begins to turn. This spins the pinion against the ring gear until the pinion teeth are aligned with gaps in the ring gear. The pressure exerted by the coil spring and the pressure applied by the helical spline cause the pinion gear to mesh fully with the ring gear.

**Helical travel**
At the end of the solenoid travel the solenoid switch contacts close – independent of the pinion position – and switch on the starter current. The starter armature now begins to rotate, and the helical spline forces the pinion held by the ring gear even farther into the ring gear until it contracts the stop ring of the armature shaft.

When the starter circuit is closed, the pull-in winding is simultaneously shorted. Now only the hold-in winding is in effect, however its magnetic force is sufficient to hold the solenoid armature in its pulled-in position until the engine is started.

**Demeshing**
After the engine starts and the speed of the starter pinion surpasses the no-load speed of the starter motor, the roller-type over-running clutch described earlier breaks the connection between the pinion and the armature shaft. This keeps the armature from being rotated too fast and damaged. The pinion remains meshed as long as the engaging lever is held in the engaged position. The engaging lever, driver and pinion are returned to their initial positions by the return spring only when the starter is switched off. The return spring also ensures that the pinion remains in its rest position in spite of engine vibration until the starter is again operated.

## ASSESSMENT 1: STARTER MOTOR DRIVES – OVER-RUNNING CLUTCH

Complete the following questions to display to your instructor your understanding of the over-running clutch.

1. State typical starter motor current draw and voltage. (Refer maker's specification)

   Car or light commercial .....

   Heavy commercial vehicle .....

2. If the engine backfires whilst the pinion is in mesh; how does this affect the pinion and starter armature?

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5. An over-running clutch pinion is moved in and out of mesh by a lever which can be either mechanically or electrically operated.

6. The Bendix drive depends on the inertia of the pinion to bring it into mesh with the flywheel.

7. With a Bendix drive the starter is turning before the pinion meshes with the flywheel.

8. A Bendix drive pinion is thrown out of mesh by the flywheel driving the pinion when the engine starts.

9. Axial starters are used mainly on large engines.

10. The armature shaft is capable of axial movement and when extended the pinion meshes with the flywheel gear.

11. Movement of the armature shaft closes the main switch after the pinion is in mesh with the flywheel gear.

12. During axial shaft movement a shunt field causes the shaft to turn slowly enabling the gears to mesh easily.

13. An overload clutch device prevents damage to the motor in the event of engine back-fire.

14. The pinion is made of phosphor bronze so that any wear occurs on the pinion rather than on the flywheel gear.

15. Bendix starters are operated by either a manually operated switch or by a magnetic switch.

16. An over-running clutch starter circuit incorporates four circuits, the relay, the pull-in coil, the hold-in coil and the main field and armature circuit.

## ASSESSMENT 3: REVIEW QUESTIONS – STARTER MOTORS

Answer the following questions to display to your instructor your understanding of starter motor drives.

1. What can happen if a starter motor is run for long periods unloaded?

   .....

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   a) What is the maximum time a starter motor can be safely used under load?

      .....

      .....

   b) Why?

      .....

      .....

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2. What is the average pinion to ring **gear** ratio (no. of teeth)?

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3. Describe the operation of the over-running clutch?

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4. Where are Axial starters used?

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# REMOVAL AND REPLACEMENT OF A STARTER MOTOR

## INTRODUCTION

Removing the starter motor enables a more efficient repair to be carried out and at the same time, allows a more thorough inspection of the associated starter motor parts. The starter motors are removed and replaced from an engine, in a set procedure, laid down by the vehicle manufacturer.


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