DIESEL MECHANIC

MINING QUALIFICATIONS AUTHORITY

CODE: MCS-2

MAINTAIN AUTO-ELECTRICAL SYSTEM

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TRG 9

INDEX

The following elements are contained in this learning guide:

OBJECTIVE

What you must do

- Set the gap of the contact breaker points and the spark plugs, and adjust the engine timing.
- Trace and repair faults which may occur in the starting circuit, the ignition circuit, the charging circuit or the lighting circuit.
- Start the diesel engine when cold and warm.

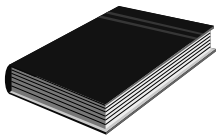
How well you must do it

- The spark plug gap, the contact breaker points gap and the timing must be set according to the specifications given in the workshop manual.
- The correct methods must be used when tracing a fault in the electrical circuits.
- Capacitors must be tested as explained in the notes.
- Any broken or blown globes must be replaced with the correct types and sizes.
- Blown fuses must be replaced with fuses of the correct size and current-carrying capacity.
- Any motors that are removed must be disassembled and assembled according to the workshop manual.
- No nuts, bolts, studs or screws must be damaged or stripped when being removed or replaced.
- Any faulty wires must be replaced with wires of the correct colour and size.
- All the connections must be clean and tight.
- The glow plugs of the diesel engine must be tested correctly, and the engine must start when cold and warm.

What you will be given

- A motor vehicle.
- The relative workshop manual.
- All the necessary tools and equipment.

Additional Resources



- The "Workshop Manual" or the "Owners Manual" of the vehicle under test.
- The instructions that accompany any new parts that has to be replaced.
- The instructor.

HAZARD IDENTIFICATION AND CONTROL (HIAC) FORM

MCS-2

MAINTAIN AUTO-ELECTRICAL SYSTEM

STEPS IN OPERATION / PROCESS	POTENTIAL ACCIDENT / INCIDENT	CONTROLS (BY RESPONSIBLE PERSON)
• Stored energy	• •	• • OEM requirements
• Use hand tools	• Using damaged tools or wrong tools for the job can cause injury and damage to equipment.	• Always use the correct tool for the job. • Ensure tools are in good condition. • Use tools correctly. • Wear appropriate PPE where necessary. • Always take good care of tools. Maintain, clean and store it properly.
• Work on vehicle	• Working on moving equipment can cause serious injury.	• Make sure that vehicle is stationary, switched off and locked out (if applicable). • Ensure vehicle stands level surface. • Install stop blocks behind and in front of wheels.

NOTE:Before doing the practical work contained in this module, the learnermust study the content of the above HIAC form again and then sign the statement below.

The above risks, which will be encountered in this module, are fully understood and will be controlled during the practical work.

Signature of Learner: _____

Signature of Training Officer: _____

Date: _____

1. INTRODUCTION

ITEM / TASK: Electrical System

DESCRIPTION:
A motor vehicle operates on two basic systems, namely, the electrical system and the mechanical system. These systems are dependent on each other. The engine is started by the battery which in turn must be charged by the generator or alternator which is driven by the engine.

The electrical system is divided into four parts which differ for the different makes of vehicles. Each part is explained in this module. They are:

- Starting circuit
- Ignition circuit
- Charging circuit
- Lighting circuit.

2. THE STARTING CIRCUIT

ITEM / TASK: Starting Circuit

DESCRIPTION:
The starting circuit converts electrical energy from the battery into mechanical energy on the starter drive which then turns the engine. See Figure 1 below.

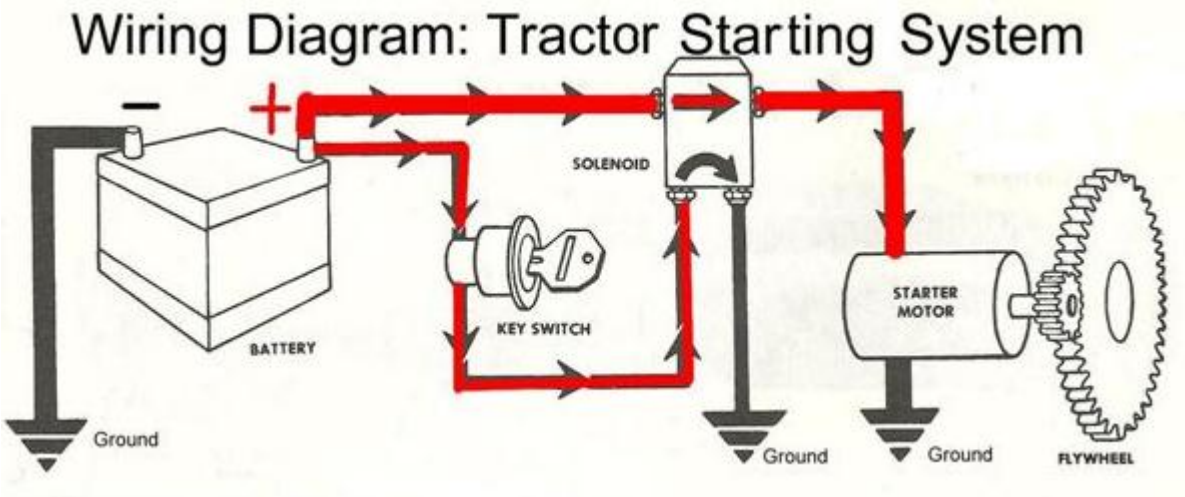


Fig. 1

The key is turned to activate the solenoid which supplies electric current and turns the starter motor. When electric current is supplied to the coil (windings) of the solenoid a magnetic field is formed. This field activates the plunger inside the solenoid which moves forward to close the contacts for electrical supply to the starter motor.

A heavier switch is needed to switch on the starter motor. That is why a solenoid is incorporated in the starting circuit to keep the ignition switch small and neat.

Some starters are equipped with bendix drives which work on centrifugal force. Once the engine has started and the ignition key is released, the speed of the ring gear will kick the pinion out of mesh while the engine is running (Fig. 2).

Fig. 2

On other starters, the solenoid is situated on the starter motor, and has a mechanism to engage the pinion of the starter into the ring gear. See Fig. 3.

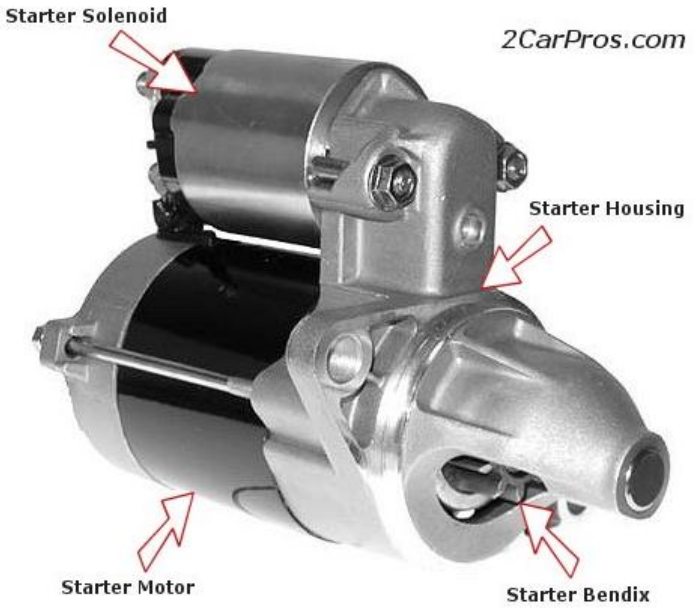


Fig. 3

When the engine starts, the key is released and the current is cut off from the solenoid. This causes the plunger of the solenoid to return to its original position and open the contacts of the supply to the motor, and the increased rotation speed of the flywheel, will spin the pinion out of mesh with the ringgear.

The starter motors used on motor cars are generally D.C. series-wound motors

3. TEST THE STARTING CIRCUIT AND DIAGNOSE FAULTS

ITEM / TASK: Test the Starting Circuit and Diagnose Faults

DESCRIPTION:
The battery is the source of energy and it must be at least 75% fully charged for accurate testing. A method of testing and diagnosing the five most common faults is given on the following page.

- **The ignition key is turned but nothing happens**

Diagnosis: Electrical supply does not reach the solenoid.

Test:

- Make sure that the vehicle is out of gear, i.e. in neutral.

- Connect an insulated wire (jumper lead) from the positive (+) terminal of the battery, and the other side of the lead to the "live wire" terminal of the solenoid (as shown in Fig. 4).

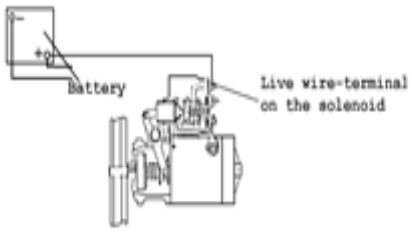


Fig. 4

The live wire is the wire which comes from the ignition switch.

If the engine starts:

- use a continuity tester (Fig. 5) to check for a broken wire (open circuit), or

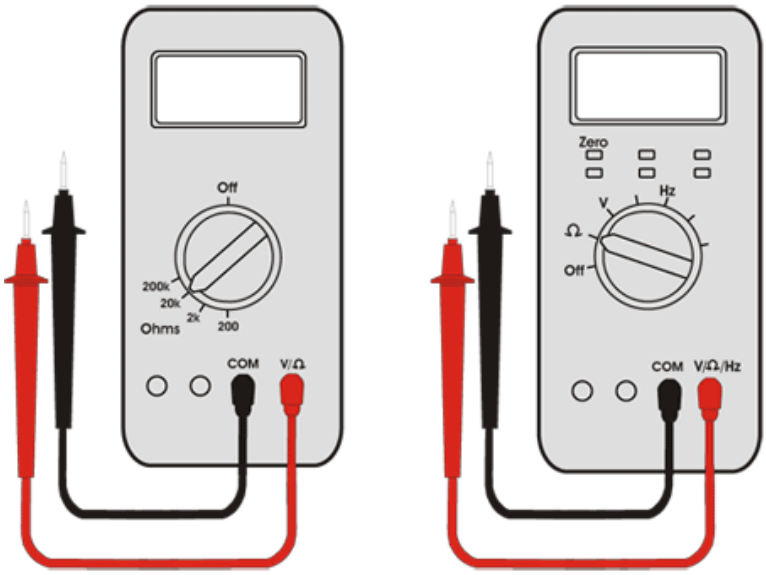


Fig. 5

- Check for loose connections, or
- Check for faulty ignition switch.

➢ **If the engine does not start**:

- Check for loose solenoid connections,
- Have the solenoid windings tested by an auto electrician.

➢ **The solenoid "clicks" but the starter motor does not turn**

Diagnosis: There is a fault in the starter motor circuit.

Test

Make sure that the vehicle is out of gear, i.e. in neutral.

- Connect a thick jumper lead (preferable a battery "slave cable") to the positive side of the battery, and the other side of the jumper lead to the "live wire" terminal of the starter motor. Refer to Fig. 6.

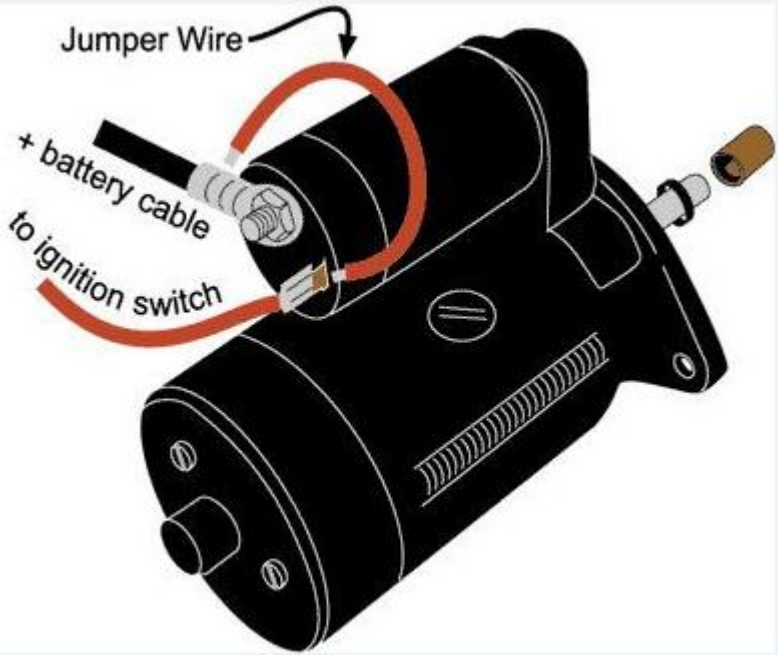


Fig. 6

- **If the engine starts**:
    - Check the solenoid connections, or
    - Check for any other loose connections.

  If the engine does not start, the starter motor must be removed and disassembled. The motor must be checked for the following:
    - Sticky or worn brushes and brush spring tension,
    - Worn bushes or bearings on the shaft.

  In addition the armature and field windings must be tested by an auto electrician.

- **The starter motor turns but the engine does not turn**

  Diagnosis: There is nothing wrong with the electrical circuit. The fault is either in the bendix drive or in the mechanical parts of the solenoid.

  Test

  The starter motor must be removed to check for mechanical breaks or faults.
    - Check the ring gear on the flywheel for worn or broken teeth.

- **The starter motor operates erratically or turns the engine over very slowly**

  Diagnosis: The fault is either in the starter motor or in the drive assembly.

Test

- Carry out a volt drop test on the battery before the starter motor is removed. This is done as follows :

Volt drop test

Connect a voltmeter across the battery terminals.

Check the voltmeter whilst the starter is turning the engine. The voltage should not drop below 8,5V for a 12V battery or 17V for a 24V battery. A voltage reading lower than 8,5V or 17V indicates that the battery is faulty.

Connect the voltmeter across the positive (+) terminal of the battery and the "live wire" terminal of the starter motor.

Turn the key to start the engine. The volt drop should not be more than 0,3V.

Connect the voltmeter across the negative earth (-) terminal of the battery and the casing of the starter motor.

Turn the key to start the engine. The volt drop should not be more than 0,1V.

The latter two tests will indicate loose connections. If the starter still does not operate, the starter motor must be removed and checked.

- **The engine starts but the motor drive does not disengage from the flywheel**

Diagnosis: The bendix gear is jammed or the return spring is broken, the solenoid-plunger is sticking in the on position or the solenoid contacts are welded together due to flashing.

Test

- Check the solenoid contacts and the ignition switch first. If the solenoid is a sealed unit, test it with a bell tester or have it tested by an auto electrician.
- Connect the bell tester across the terminals of the solenoid. If the bell rings it will indicate that the contacts are welded together.

NB: Sections of 1 and 2 of this module applies to both petrol and diesel engines.

GO ON TO THE NEXT PAGE FOR THE SELF TEST

SELF TEST 1

Answer the following questions without referring to references:

1. Draw a simple wiring diagram of a typical motor car starting circuit.

2. Why is a solenoid switch employed on the starter motor of a motor car?

   _____

   _____

3. What type of motors is used as starter motors on motor cars?

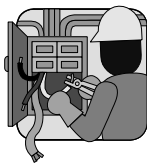
   _____

Compare your diagram and answers with the notes and do the practice if they are correct.

If they are not all correct, read the notes again and repeat the self test, then go on to the practice on the next page.

LEARNER	TRAINING OFFICER
DATE :	DATE :
SIGNATURE :	SIGNATURE :

PRACTICE



Practice diagnosing the five faults listed below:

a) The ignition key is turned but nothing happens.

b) The solenoid "clicks" but the starter motor does not turn.

c) The starter motor turns but the engine does not turn.

d) The starter motor operates erratically or turns the engine very slowly.

e) The engine starts but the motor does not disengage from the flywheel.

Ask your instructor to check your work and to sign below when you have achieved the required standards. Then go on to the next section.

LEARNER	TRAINING OFFICER
DATE :	DATE :
SIGNATURE :	SIGNATURE :

4. THE IGNITION CIRCUIT - PETROL ENGINE

ITEM / TASK: Petrol Engine-Ignition Circuit

DESCRIPTION:

When the engine is turned by the starter, the ignition systems takes over and creates the spark which ignites the air-fuel mixture in the combustion chambers of the engine cylinders.

The ignition circuit converts a low voltage, usually 12V, to a high voltage of between 8000V and 28000V.

At predetermined timing, the high voltage sparks across the gap of the spark plug and ignites the air-fuel mixture.

When the contact breaker points are closed, current will flow through the coil and a magnetic field will start building up in the coil. If the timing of the ignition system is set correctly the cam in the distributor will open the points when the piston reaches the correct position in the cylinder.

Refer to Figure 7 **on the following page** whilst reading the text.

As the contact breaker points open, supply is cut off from the low voltage winding in the coil. The magnetic field collapses, thus inducing a current in the high voltage winding. The rotor is now opposite a contact in the distributor cap and the current flows into the spark plug and causes it to spark across the gap of the plug. This ignites the air-fuel mixture. The capacitor (condenser) is put in the circuit to absorb the voltage, due to the collapsing field, through the low voltage windings.

This cycle of combustion and breaking and closing of the points takes place between 100 and 300 times per second, depending on the engine speed.

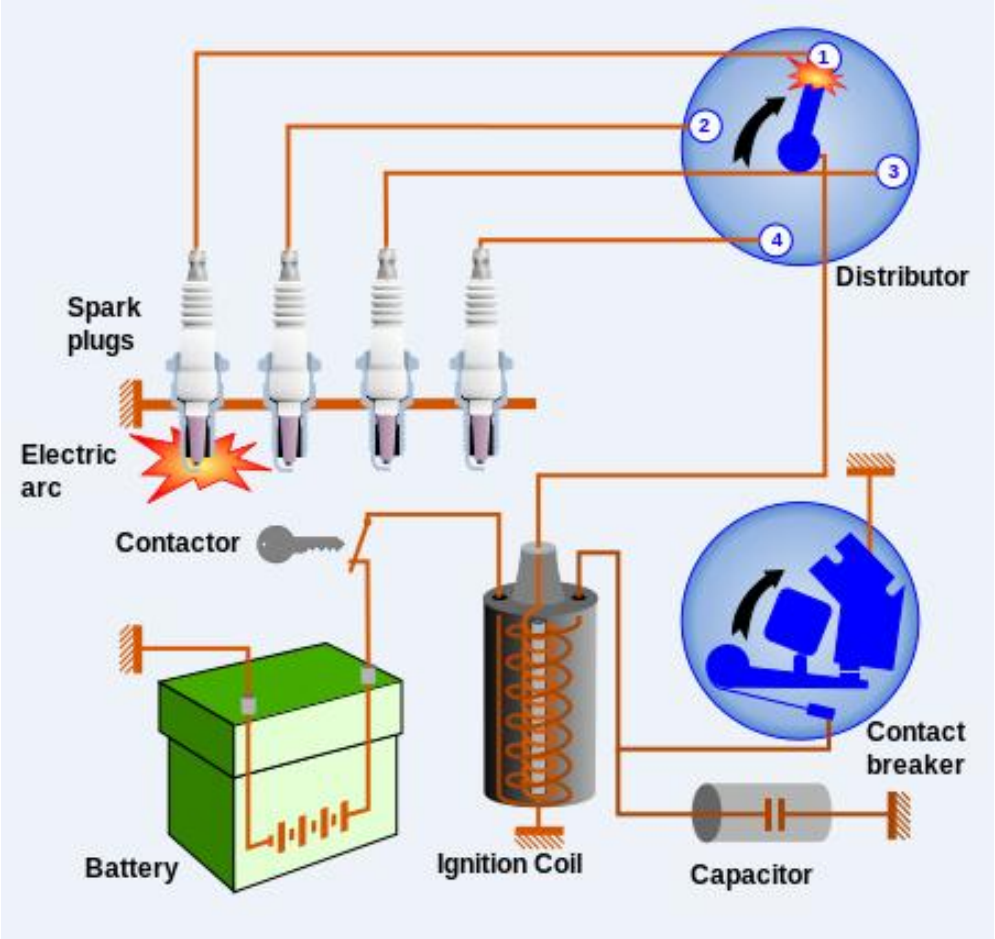


Fig. 7

5. TEST THE DIFFERENT COMPONENTS OF THE IGNITION SYSTEM

ITEM / TASK: The coil

DESCRIPTION:

The low and high voltage windings are both wound around the laminated core. The leads of the windings are brought out to their individual contacts as shown in Figure 8

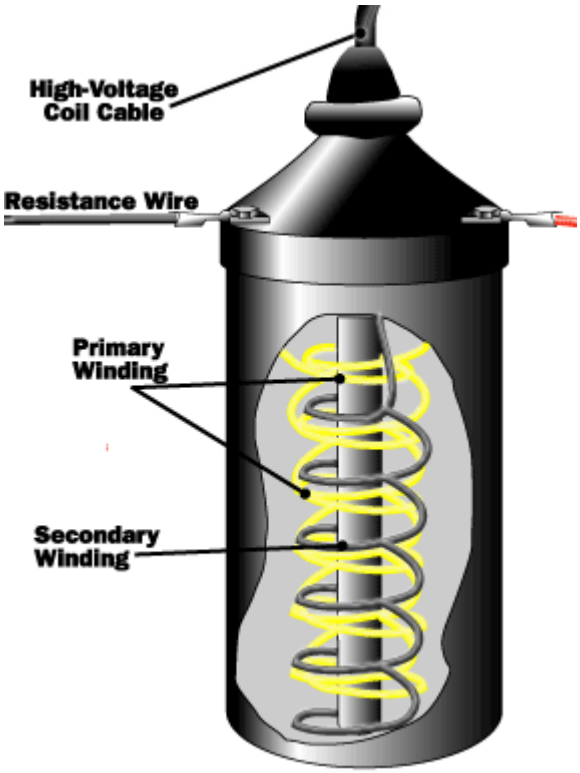


Fig. 8

A faulty coil will result in the following:

- The engine is difficult to start or will not start at all.
- The engine misfires on a warm humid day.
- The engine stops suddenly.

If any of the above faults occur, a visual check should be made of the coil for loose connections or broken or cracked insulation.

ITEM / TASK: Testing for earth fault and open windings

DESCRIPTION:

A 12V test lamp must be used in these earth fault and open winding tests. Refer to Fig. 9**.**

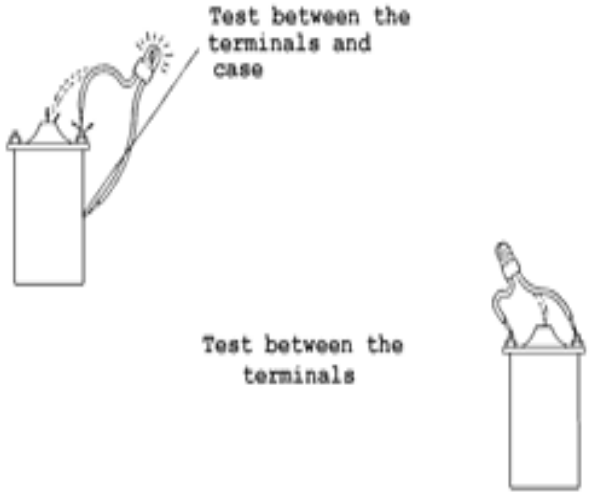


Fig. 9

- **Earth fault test**

✓ Open the distributor cap and place an insulator, e.g. a match stick, between the points.
✓ Connect the one lead of the test lamp to any earthing screw or bolt on the vehicle's body, e.g. the coil mounting screw.
✓ Switch on the ignition.
✓ Connect the other lead of the test lamp to any of the two low voltage terminals or to the high voltage terminal of the coil. When a spark is observed or the lamp burns, there is an earth fault.

- **Open windings test**

✓ Remove the insulator, the one that was put in for the earth fault test.
✓ Make sure that the points close properly. The engine must be rotated slowly until the points are closed.
✓ Connect the test lamp across the earth and the negative (-) terminal of the ignition coil, i.e. the terminal that is connected to the distributor. If the lamp burns, the low voltage winding is satisfactory. When the lamp does not burn, the winding is in an open circuit.
✓ Connect the lead of the test lamp to the positive (+) side of the coil.
✓ If the high voltage winding is continuous, a spark will occur when the lead of test lamp touches the terminal. If there is no sparking an open circuit in the secondary winding is indicated.

ITEM / TASK: The capacitor (condenser)

DESCRIPTION:

Fig.10

The correct method of testing the capacitor is by using a capacitor tester. In practice this is seldom done because it is much cheaper to buy a new capacitor.

A simple test is to connect the capacitor across the terminals of the car battery and to keep it there for about 20 seconds before taking it off. A spark should occur when the lead of the capacitor is scratched along the metal casing.

ITEM / TASK: The distributor

DESCRIPTION:

This part distributes the high voltage to the individual plugs at the specified times. It also opens and closes the contact breaker points by means of a cam situated on the shaft of the distributor. See Fig. 11**.**

Fig.11

ITEM / TASK: Checking the distributor

DESCRIPTION:

The following checks should be made periodically, and any broken, worn and damaged parts must be replaced.

Checking the distributor cap

Remove the cap, clean it with a dry cloth and check for the following :

- ✓ Cracks and chips on the inside or outside of the cap.
- ✓ Carbon tracks on the inside or outside of the cap. They may occur because of a crack which, at some stage, started to conduct the high voltage and formed a carbon path (Fig. 12 on the next page).

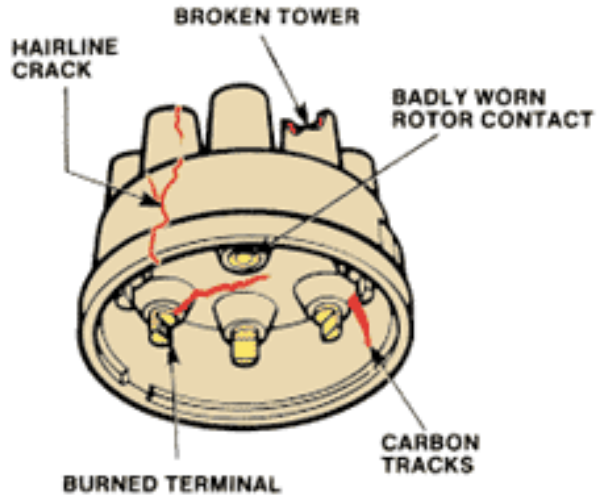


Fig.12

- ✓ Corroded or burnt plug lead-contacts on the inside of the distributor cap. See Fig.11.
- ✓ A worn or broken centre terminal button. This is situated in the centre on the inside of the cap. See Fig. 11.

If any of the above faults appear on or in the cap, it must be replaced.

ITEM / TASK: The rotor

DESCRIPTION:

Fig.13

The rotor is situated on the inside of the distributor. It is rotated by the shaft which also rotates the cam for opening and closing the contact breaker points. The rotor conducts the high voltage from the centre of the terminal button to the plug lead-contacts at specified times.

- Check the rotor for cracks or chips and for a burnt or corroded fixed contact point or rotor tip.
- Replace the rotor if it is faulty.

ITEM / TASK: The drive shaft

DESCRIPTION:

- Check for a worn shaft or worn bushes.
- Check for uneven wear on the cam lobes.

ITEM / TASK: Contact breaker points

DESCRIPTION:

Fig.14

These points make and break contact at predetermined times and intervals. They differ with each model and make of vehicle. All points work on the same principle.

✓ Checking the contact breaker points

Before removing the points, the following checks should be carried out.

Pitted and burnt points - it is always advisable to replace the points if this occurs.

However, if they are not badly damaged they could be repaired with a points file. They should then last for another 2 000 to 5 000 km.

- ✓ Worn rubbing (fibre) block - The rubbing block is fixed to the moving contact and it slides on the cam. When properly lubricated, the points will burn away long before the block wears off.

- ✓ Misaligned points - When properly aligned, the pitting or spark will appear in the centre of the 2 point seats.

- ✓ Size of contact gap - Set the gap according to the specifications laid down by the manufacturer.

NOTE: Never use sandpaper to clean the points.

Adjusting the contact point gap

The adjustment is made with a feeler gauge (Fig. 15).

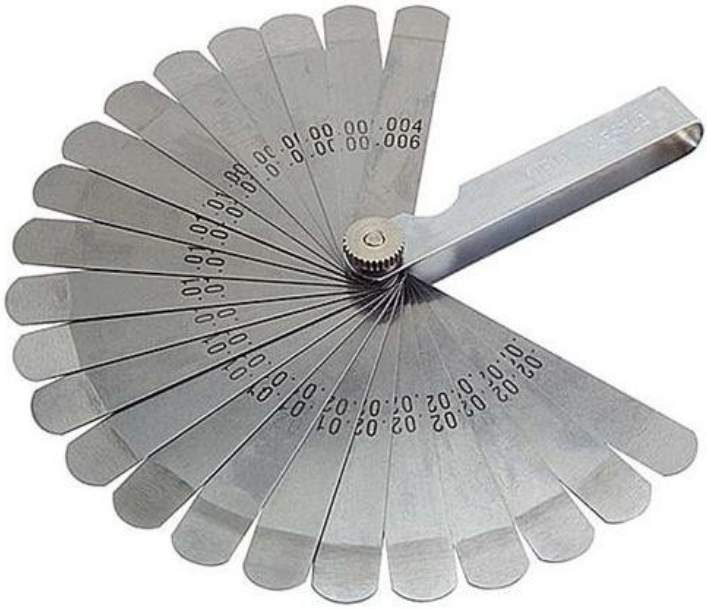


Fig.15

The following method should be used when installing contact points and adjusting the gap between them:

- Place the points in the correct position on the plate inside the distributor.
- Replace the screw that holds the points in position.
- Only "nip" the screw so that the points can be moved with only a small amount of pressure.
- Remove the spark plugs from the engine with a plug spanner (Fig. 16). Turn the engine by hand, pulling on the fan belt, until the rubbing block on the points is directly on the top of the cam on the rotor shaft.

Fig.16

- Select the correct size of blade of the feeler gauge. The correct size is obtained from either the "Owners Manual" or the "Workshop Manual" for the car.
- Slide the blade in between the points. If it is too loose, close the points, and if it is too tight or will not fit, the points must be opened.
- The contact breaker points gap is correctly adjusted when the correct feeler blade just fits in between the points, i.e. the blade must no open the points and there must not be the slightest gap between the blade and the points.
- Lock the securing screws so that the points cannot move.

NOTE: Only practice will give the "feel" of setting gaps with a feeler gauge.

ITEM / TASK: The spark plug

DESCRIPTION:

The function of a spark plug is to ignite the compressed fuel/air mixture inside the combustion chamber of the engine.

The spark plug is screwed into the cylinder head so that the electrodes enter the combustion chamber. When the engine is started a spark is created between the two electrodes which in turn ignites the fuel/air mixture above the piston in the combustion chamber. During the ignition the temperature in the combustion chamber increases, by a few thousand degrees, and the plug has to withstand a pressure as high as 6 200kPa and a voltage as high as 20 000 volts.

Types of spark plugs

Spark plugs are classified according to their heat range, i.e. a "hot" or "cold" plug. This classification is made according to the length and diameter of the insulator. Refer to Fig. 17 on the following page.

- "Cold" spark plug

A "cold" spark plug will dissipate the heat into the surrounding cylinder head much quicker than a "hot" spark plug.

- "Hot" spark plug

When a spark plug has a long insulator the heat has a longer path to get to the cylinder heard, thus it will absorb more heat and work at a higher temperature than the "cold" plug. Refer to Fig. 17 on the next page.

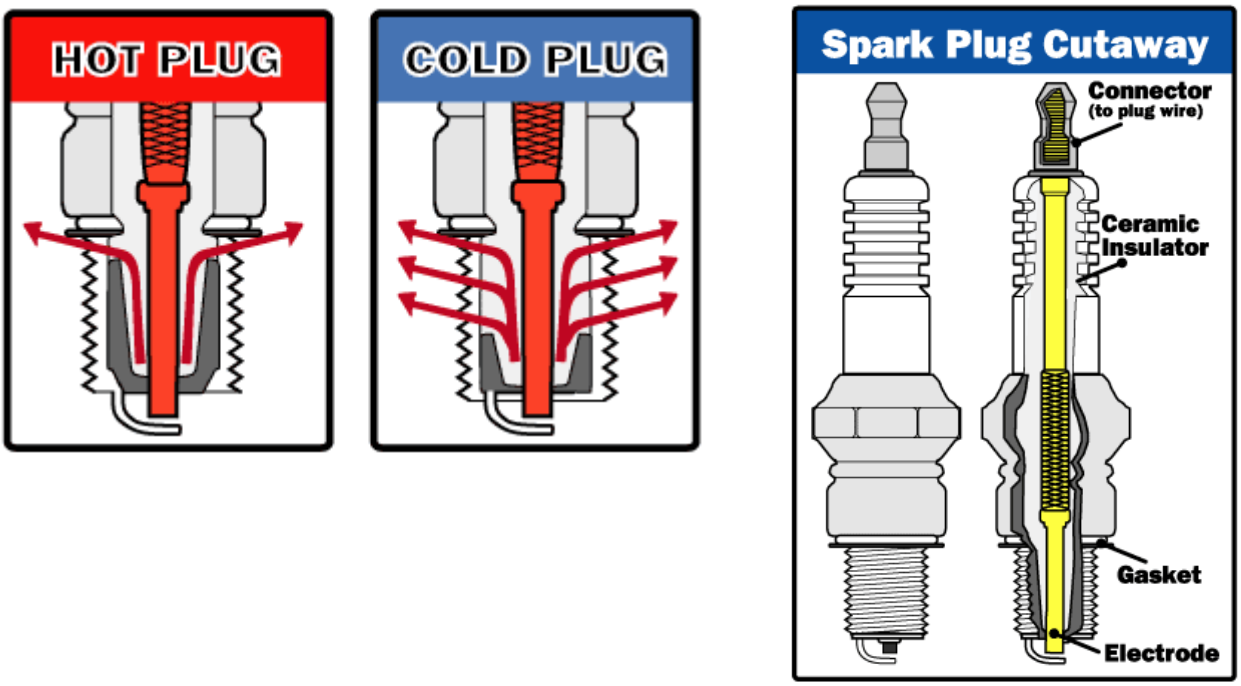


Fig.17

The heat range of spark plugs differ, therefore it is essential to refer to the manufacturer's manual for the specific vehicle before installing new plugs.

Another aspect of the types of spark plugs available is the length of the screw thread.

The difference in these lengths is basically only due to the thickness of the cylinder heads of different engines. See Fig. 18 on the next page.

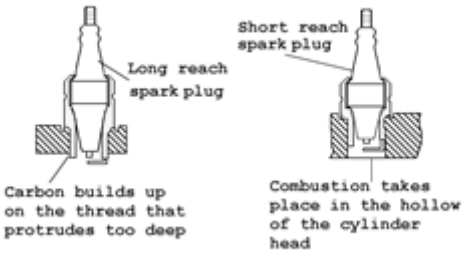


Fig.18

Important: A long reach plug must never be used in the place of a short reach plug because:

- The piston will hit it when the piston is at top dead centre.
- The screw thread protruding into the combustion chamber will become clogged with carbon and removal will become difficult.
- The protruding part of the screw thread and electrodes will absorb the excessive heat from the combustion chamber, resulting in a higher working temperature of the plug which can lead to a lower plug efficiency.

Important: A short reach plug must never be used in place of a long reach plug because:

- The spark between the two electrodes will occur in the hollow of the cylinder head, thus affecting the efficient combustion of the fuel/air mixture.
- Under certain conditions the engine will "ping".

ITEM / TASK: Adjusting the spark plug gap

DESCRIPTION:

The following method is recommended:

- Select the correct size blade on the feeler gauge. For the correct gap setting consult either the "Owners Manual" or the manufacturers "Workshop Manual".
- Fit the blade in between the two electrodes of the spark plug.

If the blade slides in very loosely, then the outer electrodes must be closed towards the inner electrode. This is done either with the proper bending tool or by tapping the outer electrode lightly to close it.

If the blade does not fit between the electrodes at all, then the outer electrode must be bent open and away from the centre electrode.

This is also done either with a proper bending tool or with the blade of a knife. Slide the sharp edge of the knife in between the two electrodes and lever the top one open slightly.

NOTE: When the outer electrode of the spark plug has to be opened or closed, it must be done carefully and slowly.

- The correct gap setting is obtained when the blade of the feeler gauge just fits in between the two electrodes.
- Make sure that the gasket is against the shoulder of the plug.
- Replace the plug wires. Make sure that they are connected in the correct order.
- Start the engine to check its performance.

ITEM / TASK: Replacing the spark plugs

DESCRIPTION:

When replacing spark plugs it is essential that it is done properly because over-tightening will cause damage to the plug, especially when it heats up, and under tightening will cause a leak, thus dropping the temperature and pressure inside the combustion chamber.

A table for tightening of different size plugs in cylinder heads of different materials is given below.

The last column on the right hand side is only used if a torque wrench is not available.

Tighten the plug as tightly as possible by hand, then give it the further required amount of turns with an ordinary plug spanner.

Plug Size	Aluminium Heads	Cast Iron Heads	Finger tight plugs
10mm	12 - 15 Nm	18 - 20 Nm	3/4 to 1 turn
14mm	31 - 37 Nm	35 - 41 Nm	3/4 turn
18mm	38 - 46 Nm	43 - 52 Nm	½ to 3/4 turn
18mm without a packing ring		20 - 27 Nm	

6. SET THE IGNITION TIMING

ITEM / TASK: Setting the Ignition Timing

DESCRIPTION:
The time of the spark occurring at the spark plug is most important. The spark must occur at the time when it will burn the air-fuel mixture most efficiently in the combustion chamber of the pistons.

Disadvantages of incorrect timing

Late timing:

- The vehicle will not start easily
- There will be overheating and a loss of power.

Early timing:

- Early timing causes combustion while the piston is still moving upwards in the cylinder.

The timing must always be adjusted after the points have been set. If the point`s gap is adjusted, the timing is also automatically altered.

The best method of adjusting the distributor timing is to use a stroboscope (timing light).

The timing is adjusted as follows:

- Locate the fixed timing mark pointer situated against the engine.
- Locate the timing mark on the flywheel or fanbelt pulley.
- Use white chalk or paint to mark the timing mark on the pulley.
- Connect the timing light on the number one plug wire and plug.
- Consult the "Workshop Manual" or "Owners Manual" of the vehicle to see the idling speed and position of the timing mark.
- Start the engine. Keep the leads of the light clear from the radiator fan.
- Adjust the idling of the engine by turning the idling screw on the carburettor.

- Point the stroboscope to the timing mark pointer on the engine. The light will flash when number one plug fires.

NB: The timing will be correct if the pointer and mark on the pulley is in line when the stroboscope flashes.

- If the timing is incorrect, the clamp screw of the distributor should be loosened and the distributor should be rotated slowly until the marks correspond.

- Tighten the clamp screw of the distributor.

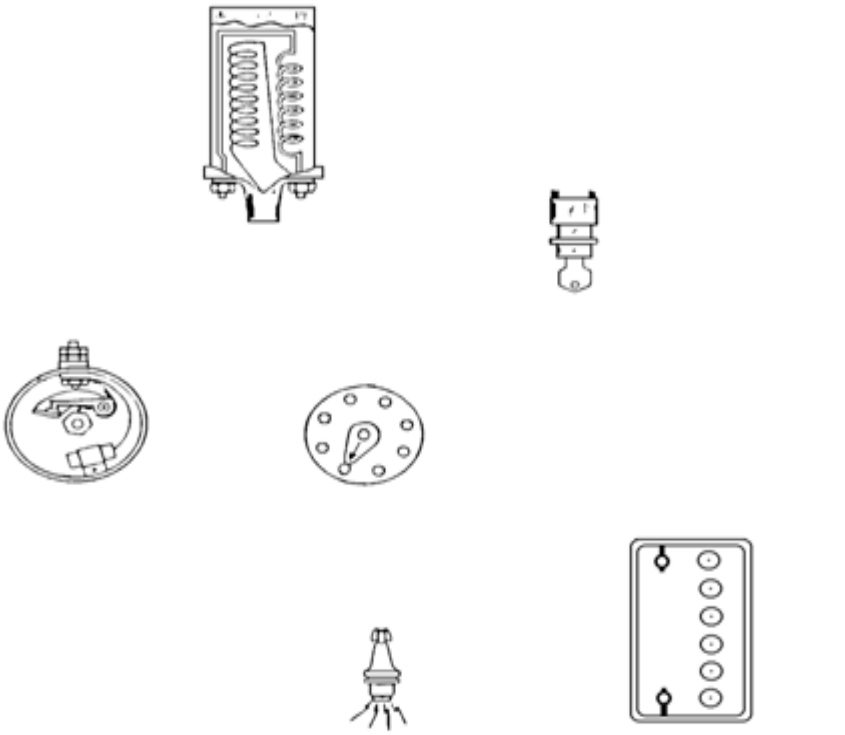
- Re-check the timing.

GO ON TO THE NEXT PAGE TO DO THE SELF TEST.

SELF TEST 2

Answer the following questions without referring to references:

1. Complete the typical diagram of an ignition circuit used in a four cylinder motor car, shown below.



2. What is the function of the capacitor in the ignition circuit?

_____

_____

3. What **four** defects should be looked for when checking the distributor cap?

_____

_____

_____

_____

4. What defects should be looked for before changing the contact breaker points?

_____

_____

_____

_____

5. What **three** effects does a spark plug have on an engine when the spark gap is set too small?

_____

_____

_____

6. What **five** faults must be looked for when checking spark plugs?

_____

_____

_____

_____

_____

7. What are the disadvantages of incorrect timing in the following?

a) Late timing?

_____

_____

b) Early timing?

_____

_____

_____

Check your answers. If they are not all correct, study the notes again. If they are all correct, ask your training officer to sign below and do the practice on the following page.

LEARNER	TRAINING OFFICER
DATE :	DATE :
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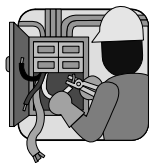
PRACTICE



Practice the following tasks:

1. Test the different capacitors and coils and note their conditions.

2. Install and adjust the contact breaker point gap.

3. Adjust the spark plug gaps and install them in the engine.

4. Set the timing of an engine.

Ask your training officer to check your work and to sign below when you have achieved the required standards. Then go on to the next section.

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7. IGNITION SYSTEM - DIESEL VEHICLES

ITEM / TASK: Diesel Engine-Ignition System

DESCRIPTION:

The ignition system for a diesel engine is much simpler than that of a petrol engine. It does not make use of a coil, distributor points, condenser or spark plugs. The engine of a diesel vehicle is, however, equipped with cold starting devices known as "glow plugs", their purpose and operation is explained in the following notes.

NB: It must be however pointed out that not all diesel engines are fitted with these devices.

Starting the diesel engine

a) Hot or warm start

- Turn the ignition key to the "on" position.

If the indication lamp does not glow, it shows that the engine is warm enough for direct starting.

- Turn the ignition key to the "start" position to start the engine.
- Release the key to return to the normal "on" position once the engine has started.

b) Cold start

- Turn the ignition key to the "on" position.

If the indication lamp glows, it shows that the engine is too cold for direct starting.

- Turn the ignition key to the "pre-heat" position.

In the "pre-heat" position the "glow plugs" are switched on and pre-heats the fuel and air mixture.

- Turn the ignition key to the "start" position as soon as the indication light goes out showing that the pre-heating has been completed.

The starter motor will now crank the engine to start it, and the "glow plugs" will ignite the mixture to complete the cold start procedure.

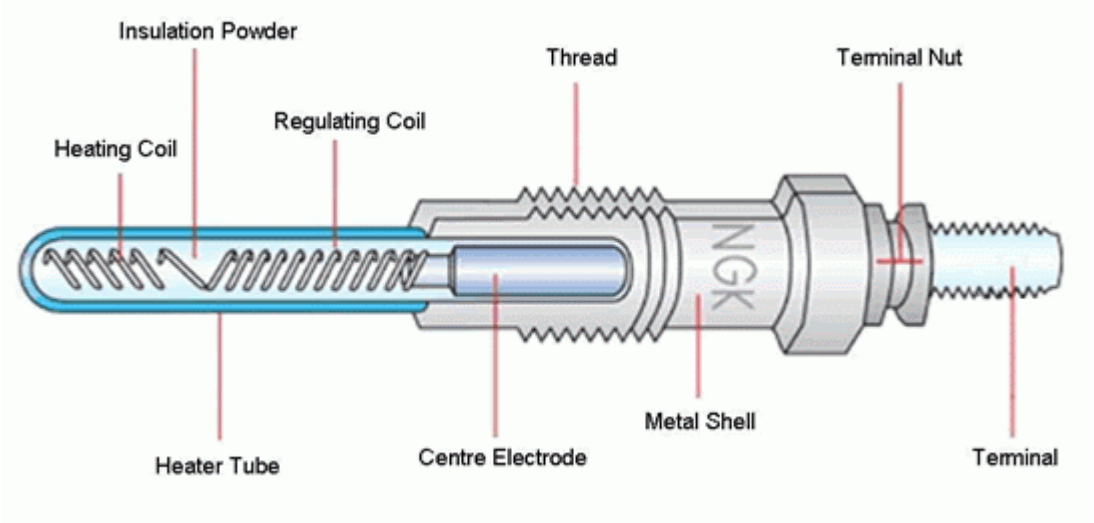
- Release the key to return to the normal "on" position once the engine has started.

1. The purpose of glow plugs:

The purpose of the glow plug is to pre-heat, vaporize and ignite the inlet air and fuel mixture.

2. The operation of glow plugs:

The construction and operation of glow plugs are as follows. Refer to Fig. 19.



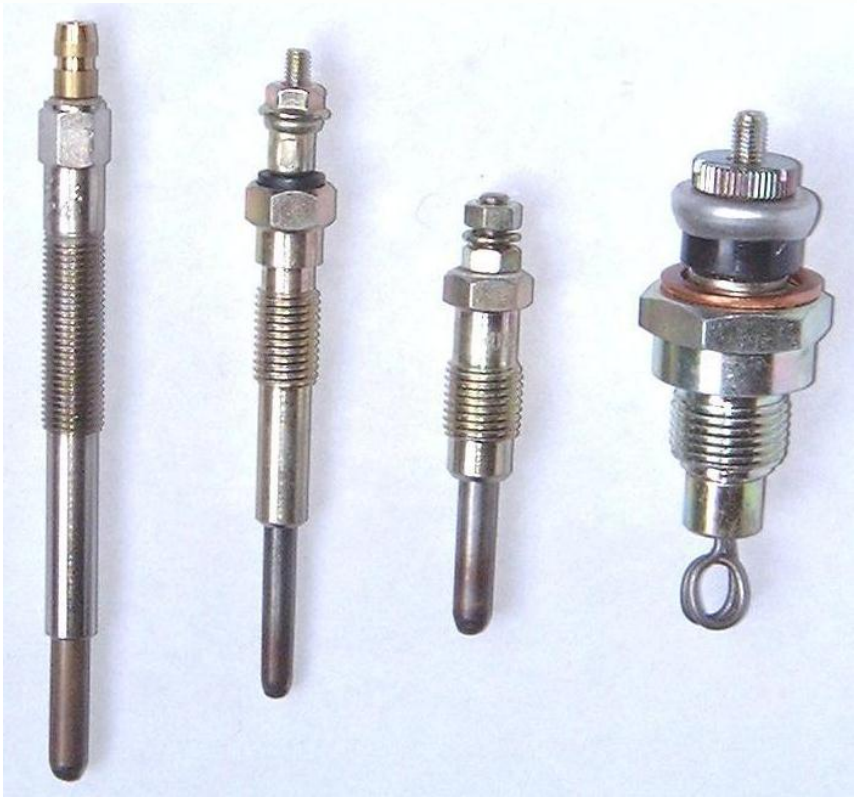


Fig.19

The "glow plug" comprises a tubular valve body carried in a holder which screws into the inlet manifold. The valve body is surrounded by a heater coil, an extension of which forms an igniter coil. The valve body houses a needle, the stem of which holds a ball valve in position against its seating. The unit is surrounded by an open perforated shield. Fuel oil from the container enters through an adaptor.

When the unit is cold, the ball valve is held closed. When the coil is switched on the valve body is heated and expands, opening the ball valve and permitting the fuel to enter. The fuel is vaporized by the heat of the valve body and, when the engine is cranked and air is drawn into the manifold, the vapour is ignited by the coil extension and continues to burn, thus heating the inlet air. When the coil is switched off, the flow of air in the manifold cools the valve body rapidly and the valve closes.

3. The engine fails to start

- Test the battery - refer to Module MCS-1.
- Check the starting circuit (section 1 of this module.
- Check the glow plugs as follows :

✓ Remove all the glow plugs from the engine.

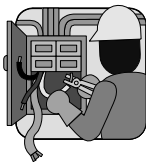
✓ Connect each one in turn to a fully charged battery.

Positive (+) to Positive (+) and
Negative (-) to Negative (-)

- Discard those glow plugs that do not heat up.

GO ON TO THE NEXT PAGE FOR THE PRACTICE.

PRACTICE



Practice testing all the glow plugs on the engine for correct functioning and start the engine when it is cold and warm.

Ask your training officer to check your work and to sign below when you have achieved the required standards. Then go on to the next section.

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8. THE CHARGING CIRCUIT

ITEM / TASK: The Charging Circuit

DESCRIPTION:
This circuit basically consists of two types, the operation of which is similar. They are:

a) The DC charging circuit using a generator, and
b) The AC charging circuit using an alternator.

ITEM / TASK: Operation of the DC charging circuit

DESCRIPTION:

This circuit consists of the generator, the regulator, the ignition switch, the ammeter and the battery. Refer to Fig. 20.

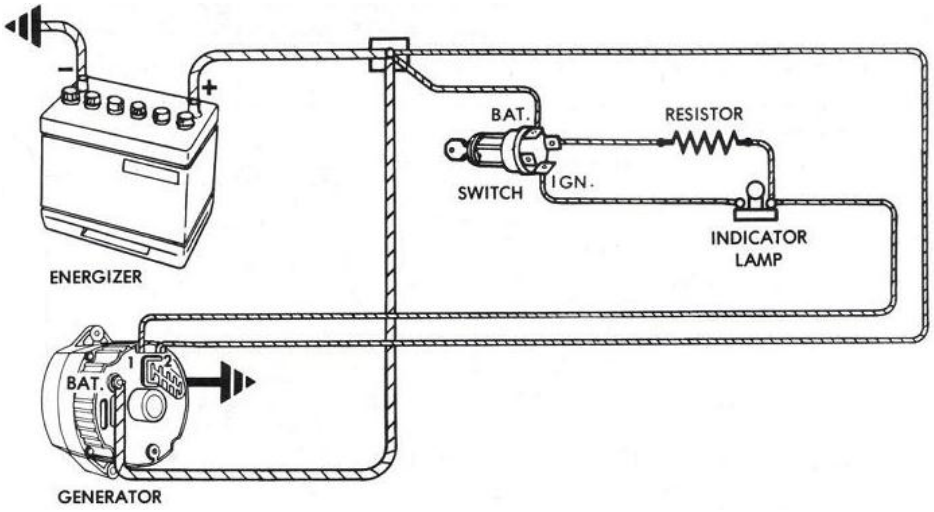


Fig. 20

The generator supplies the electrical power.
The charging circuit operates in three stages:

- Starting.
- Normal operation.
- Peak operation.

ITEM / TASK: Starting

DESCRIPTION:
The battery supplies the entire load current. See Fig. 21.
The battery starts the circuit by supplying the spark to start the engine and giving power back to the starter.

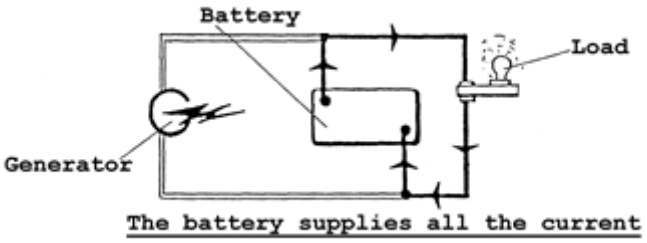


Fig. 21

ITEM / TASK: Normal Operation

DESCRIPTION:
The generator supplies all the current and recharges the battery. See Fig. 22.

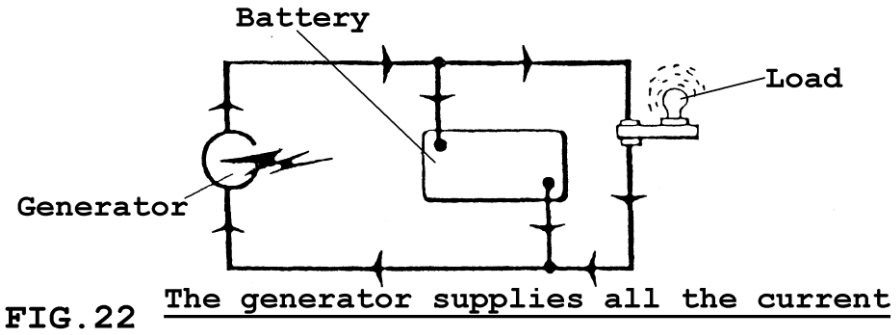


Fig. 22

Once the engine has been started, the generator is the work horse of the electrical circuit. It is driven by the engine by means of a vee belt and supplies current to the charging, ignition ,lighting and accessories circuit.

ITEM / TASK: Peak operation

DESCRIPTION:
The battery helps the generator to supply power. See Fig. 23.

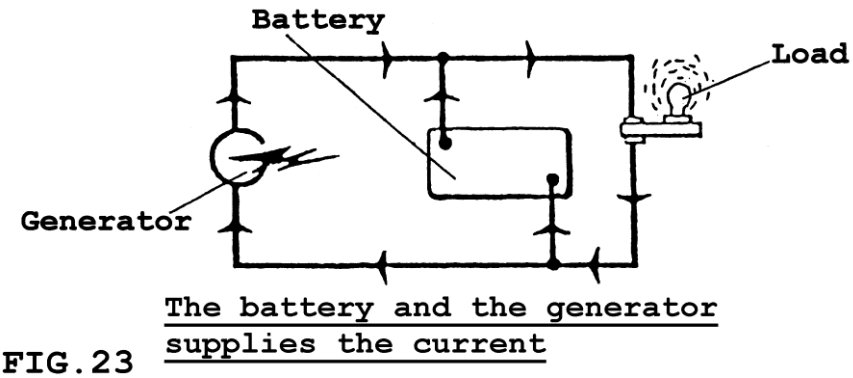


Fig. 23

The battery assists the generator during peak operation when the loads are too great for the generator. Peak operations occur at night when all the car's lights are on.

The engine supplies current only as long as the engine is running. When the engine slows down or stops, the battery takes over all or part of the load.

ITEM / TASK: To test the generator and diagnose faults

DESCRIPTION:

- The generator has no output voltage

This will be indicated by the charging light or volt meter.

Check for the following:

- ✓ sticking brushes,
- ✓ dirty or corroded commutator,
- ✓ earthed terminals or connections, or
- ✓ loose connections.

Have the generator tested for the following by an auto electrician:

- ✓ earthed, shorted or open armature windings,
- ✓ earthed, shorted or open field coils.

- The generator has a variable or low output voltage

This will be indicated by the voltmeter or light and by a consistently flat battery.

Check for the following:

- ✓ loose or worn drive belts,
- ✓ weak brush spring tension,
- ✓ dirty or burned commutator,
- ✓ eccentric or worn commutator.

An auto electrician must check for:

- ✓ partially earthed, shorted or
- ✓ open armature windings, and
- ✓ partially earthed, shorted or
- ✓ open field coils.

- The electrical output of the generator is normal but the generator is very noisy

Check for the following:

- ✓ loose mounting bolts or screws,
- ✓ loose pulley
- ✓ worn or dirty bearings and
- ✓ improperly seated brushes.

NB: Before stripping the complete charging circuit or removing and stripping the generator, a visual check should be carried out for:

- ✓ loose or broken wires and connections
- ✓ corroded or earthed connections
- ✓ loose pulley or v-belt
- ✓ dirty, worn or broken brushes
- ✓ broken brush springs, and
- ✓ improper seated brushes.

If none of these faults are visible or if they cannot be repaired, then the generator must be removed, disassembled and tested.

ITEM / TASK: Generator regulators

DESCRIPTION:

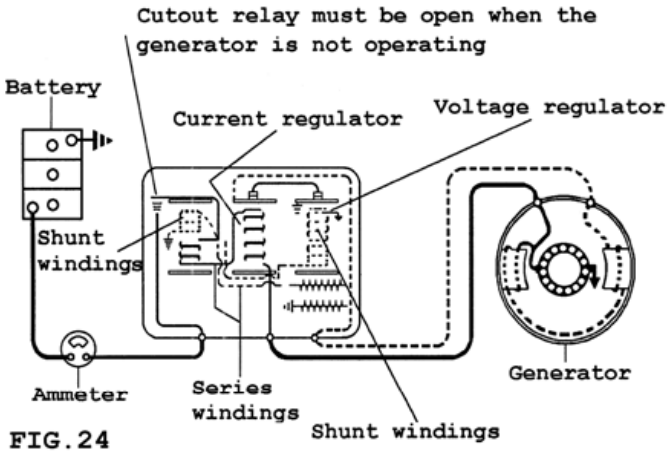


Fig. 24

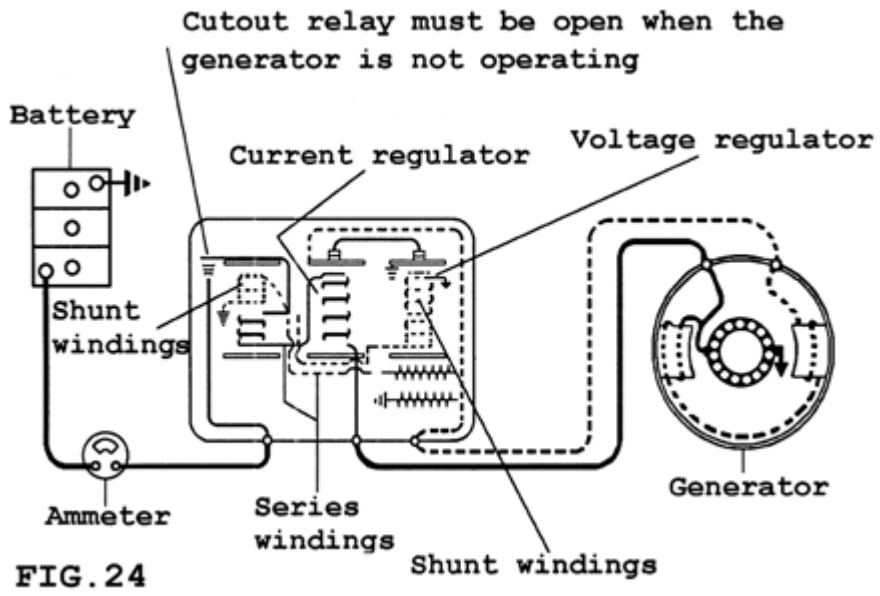


Fig. 24

The regulator consists of three coils which control the output of the generator. The regulator prevents the generator from producing too much voltage and current when it is turning at high speeds. It also prevents the battery from discharging back through the generator at low speeds.

The regulator performs four functions:

- As a cut out relay

The generator recharges the battery as well as supplying current to the rest of the electrical system. To recharge the battery, a circuit must run from the generator to the battery. If this circuit was closed when the generator was not operating, the battery would discharge through the generator.

To prevent this, an automatic switch, called a cut out relay, is installed in the circuit. While the generator is turning the cut out relay is closed and the circuit is complete. When the generator is stopped, the cut out relay opens the circuit.

- As a voltage regulator

The voltage generated by the generator will go as high as necessary to overcome any resistance in the circuit. If the voltage goes too high, the field and load circuits may be damaged. The generator cannot control the amount of voltage that it generates, therefore an external unit called a voltage regulator, which has a shunt coil, i.e. a coil, connected parallel across the generator and contact points, to control the strength of the magnetic field, thus limiting the voltage generated.

- As a current regulator

The amount of current drawn by the different circuits is controlled by the current regulator.

The current regulator looks very similar to the single-winding voltage regulator. The current regulator winding is a series coil of heavy wire which connected to the generator armature of the load circuit and which carries the entire generator current output.

During a heavy load, such as a discharged battery and the use of the electrical accessories, voltage may not increase enough to actuate the voltage regulator. In these cases, the generator output will continue to increase to meet the demand. To limit this output to a safe value, the current regulator is used.

- As three regulators working together

The thick line in Fig. 24 shows the series winding of the cut out relay and the current regulator. The dotted lines are the shunt windings in the cut out relay and the voltage regulator. The other lines show the field circuit and the resistors.

When the generator begins to operate it must recharge the battery. Two of the three units, i.e. the cut out relay and the current regulator, are used in this operation.

The current flows from the generator armature into the series coil of the regulator. From there it flows into the relay series coil, through the closed relay contact points and into the battery. When the battery is charged or the load has been reduced, less current flows and the voltage rises. The voltage regulator is now used to control the generator field current and voltage.

- Regulator problems

Before opening the regulator unit make sure that the generator, battery, wiring and connections are operating correctly. The following are problems that could occur in the regulator:

ITEM / TASK: Low or no charging rate - flat battery

DESCRIPTION:

Could be caused by:

Low regulator setting. Burned or oxidised contact points, or open series circuit in the regulator.

ITEM / TASK: High charging rate - fully charged battery

DESCRIPTION:

Incorrect voltage regulator setting. Defective voltage regulator unit or earthed generator field circuit in the regulator.

- ✓ Check for all the faults listed under (b) "to test the generator and diagnose faults".
- ✓ Check the regular units in the following order :

- The voltage regulator
- The cut out relay
- The current regulator.

ITEM / TASK: The AC charging circuit

DESCRIPTION:

The alternator and generator are basically the same and both convert mechanical energy into electrical energy. The difference lies in the manner in which AC output is changed or rectified to DC.

- Precautions during alternator testing

Before connecting the battery or the alternator, make sure that the correct polarity is observed, i.e. the negative (-) of the battery to the negative (-) of the alternator and the positive (+) of the battery to the positive (+) of the alternator.

Disconnect the earth strap of the battery before connecting a battery charger to the battery if you are not sure whether the charger is safe for an alternator charging circuit.

NEVER operate the alternator on an open circuit.

NEVER short or earth the alternator terminals.

Make sure that the battery is fully charged before doing any of the alternator tests.

NEVER attempt to polarise an alternator. This action will damage the rectifying part of the unit.

- Testing the alternator and diagnosing the faults

The alternator has no output voltage

Check for the following:

- ✓ Loose v-belt
- ✓ Worn, defective or sticking brushes.

Have an auto electrician check for:

- Open or high resistance in charging circuit
- Faulty regulator
- Open isolation diode
- Open rotor field coil.
- Low or unsteady charging rate

Check for the following:

- ✓ Loose v-belt
- ✓ Worn, defective or sticking brushes.

Have an auto electrician check for:

- ✓ Open or high resistance in charging circuit
- ✓ Faulty regulator
- ✓ Shorted or open rectifier diode

- ✓ Earthed or shorted rotor field coil
- ✓ Open, earthed or shorted stator windings.

- Excessive charging rate

Check for the following:

- ✓ Loose alternator or regulator connections

Let an auto electrician check for:

- ✓ Faulty regulator.

- Noisy alternator

Check for the following:

- ✓ Worn or damaged v-belt
- ✓ Misaligned belt and pulley
- ✓ Loose pulley
- ✓ Worn bearings.

- Alternator regulators

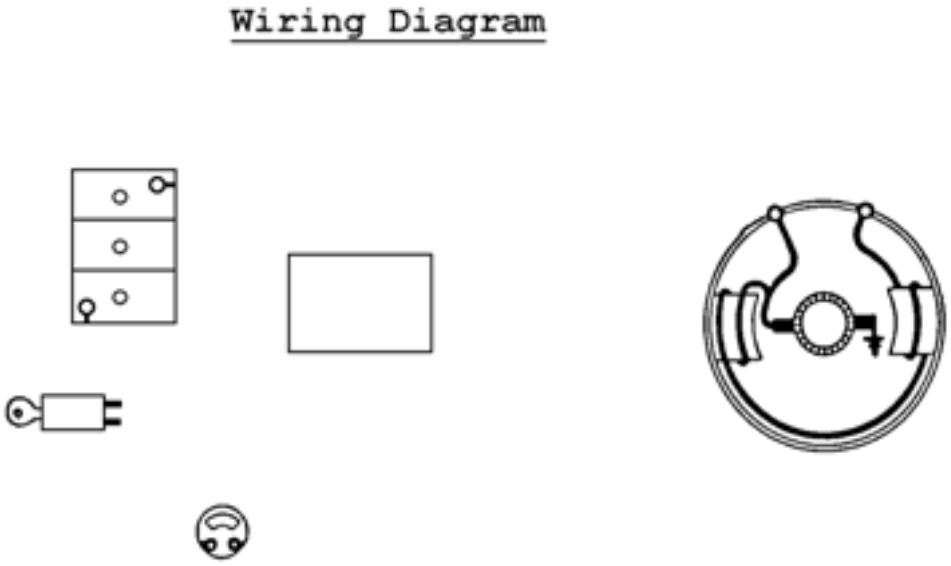
The alternator regulator, like the generator regulator, is used to control the electrical output of the alternator.

GO ON TO THE NEXT PAGE TO DO THE SELF TEST.

SELF TEST 3

Answer the following questions without referring to references:

1. Complete the typical wiring diagram shown below of a charging circuit used in a motor car.



2. Name the three stages of operation of the charging circuit and briefly describe each one.

_____

_____

_____

3. What tests should be carried out under the following conditions?

a) The generator has no output voltage.

_____

_____

b) The generator has an excessive output voltage.

_____

_____

c) The electrical output of the generator is normal but the generator is very noisy.

_____

_____

4. What function is performed by the regulator?

_____

5. What tests should be carried out under the following conditions?

a) The alternator has no output voltage.

_____

_____

b) The alternator has a low or unsteady charging rate.

_____

_____

c) The alternator has an excessive charging rate.

_____

_____

d) The alternator is noisy when running.

_____

_____

Check your answers. If they are not all correct, study the notes again. If they are all correct, ask your training officer to sign below and do the practice on the following page.

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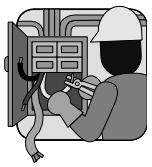
GO ON TO THE NEXT PAGE FOR THE PRACTICE

PRACTICE



You must practice testing a generator for sound operation.

Ask your instructor to check your work and to sign below when you have achieved the required standards. Then go on to the next section.

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SIGNATURE :	SIGNATURE :

9. THE LIGHTING CIRCUIT

ITEM / TASK: Lighting Circuits

DESCRIPTION:
This section will cover some of the extra electrical equipment that is used in a motor vehicle.
Lights are used on all types of motor vehicles that are driven on the national roads.

The lighting circuit is normally a part of the complete electrical system. It operates on power supplied from the battery with help from the charging circuit.

The lighting circuit in modern motor vehicles consistsIof :

- **Headlights**

There are either two or four headlights. When two or four lights are used they are fixed in equal numbers on either side of the front of the vehicle.

- **Tail lights**

The number of tail lights depends on the design and make of the vehicle. Two, four or six lights are used. They are fixed in equal numbers on either side of the back of the vehicle.

- **Brake lights**

Sometimes double filament globes are used so that the tail lights and brake lights are the same lights or sometimes the two lights are completely separated.

- **Parking lights**

These are separate lights situated at the front and back of the vehicle. They are used when the vehicle is parked next to the road at night.

It is illegal to drive at night with only parking lights switched on, even when it is not dark enough yet. You should switch the headlights on in the dimmed position.

- **Flicker lights (indicator lights)**

These lights are situated at the back and the front of the vehicle and are used to indicate the direction in which the driver intends to turn. If it is a left turn, then both the front and back left hand side flickers will operate; if it is a right turn, then the back and front right hand flickers will work. They can be separated from or incorporated in the tail lights and the front parking lights.

- **Panel lights**

These are used to illuminate the dashboard and the instruments inside the vehicle. There may be as many as four separate lamps used on this circuit. The switch that controls them usually contains a resistance that can be used to dim the dashboard lights.

- **Inside lights**

These vary with the different makes of vehicles. The interior roof lights come on when the car doors are opened, or they can switch on via individual switches when the doors are closed.

Other lights are used to illuminate the glove compartment, cigarette lighters, door steps, map trays, luggage and engine compartments, etc.

ITEM / TASK: Changing globes

DESCRIPTION:
There is such a variety of sizes, types and shapes of globes that when one has to be changed, care must be taken that it is replaced exactly according to its wattage, number of contact pins and filaments, and part number.

ITEM / TASK: Failure of lights

DESCRIPTION:

- **Causes**

Failure of lights can be caused by one of the following:

A broken filament in the globe which can be caused by an excessive voltage due to an earth fault or short circuit, by using the wrong globe or merely by corrosion of the contacts or deterioration of the filament after a long period of use.

- A blown fuse which is caused by an earth fault or short-circuit.
- A switch failure which is caused by a loose or burnt connection.
- A loose or broken wire in the circuit.
- A dirty or corroded connection or connections.

- **Testing for faults**

✓ Inspect and test the circuit and lamps in the order set out in (I) above.

✓ Check the globe visually for a broken filament or for discolouration.

✓ Check the fuse for a melted wire or fusible plate.

✓ Look for loose, dirty or corroded connections, if the lamp only glows dimly.

✓ Check for a broken wire, a broken connection or a faulty light switch.

- **Causes of blown fuses**

- A short circuit in the electrical circuit caused by defective wiring or a defective component.
- An overload in the circuit caused by a surge of power passing through the wires.
- Bad contacts or loose connections in the circuit or in the components.
- Using the wrong size fuses to protect the circuit.

NOTE: Blown fuses must always be replaced with fuses of the correct size and rating. The correct sizes and ratings can be obtained from the "Workshop Manual".

GO ON TO THE NEXT PAGE TO DO THE SELF TEST.

SELF TEST 4

Answer the following questions without referring to references:

1. What precautions must be taken when changing globes in a motor vehicle?

_____

_____

_____

2. What five reasons are there for the failure of lights in the lights in the lighting circuit of motor vehicles?

_____

_____

_____

_____

_____

3. What three electrical faults are usually found in the electrical wiring of a motor vehicle?

_____

_____

_____

4. What are three possible causes of a blown fuse in an electrical circuit of a motor vehicle?

_____

_____

_____

5. What precautions must be taken when replacing a blown fuse?

_____

_____

_____

Check your answers. If they are not all correct, study the notes again. If they are all correct, ask your training officer to sign you off.

LEARNER	TRAINING OFFICER
DATE :	DATE :
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REMEMBER ALWAYS WORK SAFE

Once you have passed all the self test and entire practices, you are now at liberty to request a Formative Assessment from your Assessor.