LECTURENOTESON

AUTOMOBILEELECTRICITY

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AutomobileElectricalSystem

- Electricalsystemisthemostvitalsystemofautomobile.
- Ithastwomainfunction. Thereare
  - Itmustbesupplyelectricalenergytostartandoperatetheengine.
  - Itmustbeprovidethepowertooperatelightinstrumentandotherelectrica laccessories.
- TheelectricalsystemofAutomobilemainlyconsistoffour maincircuitandanumberofbranchcircuits.
  - Generatingcircuit
  - Startingcircuit
  - Ignitioncircuit
  - Lightningcircuit
- Branchcircuitsaretherefor radio,wiperandlight.
- Different color code are given to various circuits for quick recognition when repair isnecessary.

CHAPTER–1

StorageBattery

Purpose

Thestoragebatteryistheheartofthechargingcircuit.Itisanelectrochemicaldeviceforproducingand storing electricity.Avehiclebatteryhasseveralimportantfunctions:

• Itmustoperatethestartingmotor,ignitionsystem,electronicfuelinjectionsystem,andotherelectricald evicesforthe engineduringengine crankingandstarting.

• Itmustsupplyalloftheelectricalpowerforthevehiclewhentheengineisnot running.

• It must help the charging system provide electricity when current demands are above the outputlimitofthechargingsystem.

• Itmustactasacapacitor(voltagestabilizer)thatsmoothescurrentflowthroughtheelectricalsystem.

• Itmuststoreenergy(electricity)forextendedperiods.

TypesOfBattery

- Lead-Acid Battery
- AlkalineBatteries(Nickel– CadmiumBatteryOr,Nickel– IronBattery)
- Aluminium–AirBatteryOr,Zinc–AirBattery
- Nickel–MetalHydrideBattery
- SodiumSulphurBattery

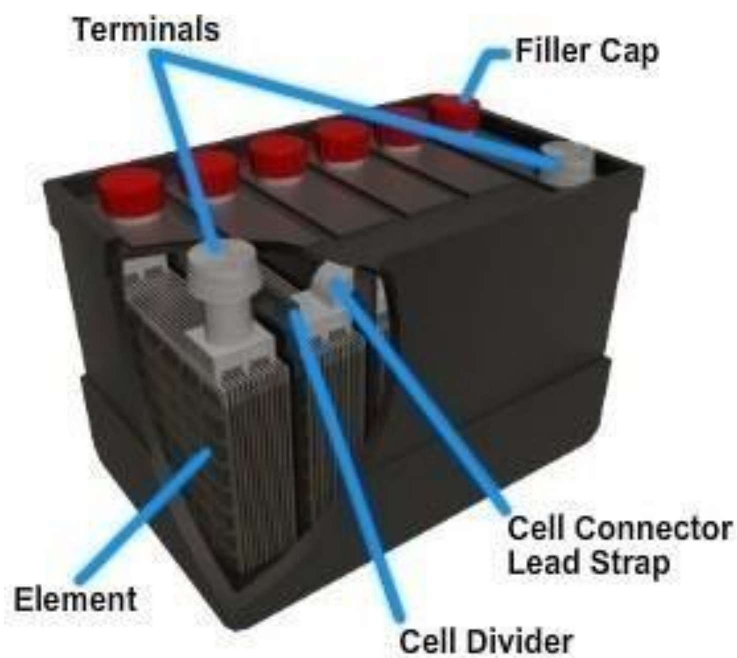
The type of battery used in automotive, construction, and weight-handling equipment is a lead-acid cell-type battery. This type of batter produces direct current (DC) electricity that flows inonly one direction. When the battery is discharging, it changes chemical energy into electricalenergy,thereby,releasingstoredenergy.Duringcharging(currentflowingintothebatteryfrom the charging system), electrical energy is converted into chemical energy. The battery can thenstoreenergyuntilthevehiclerequiresit.

BatteryConstruction

Lead-AcidBattery

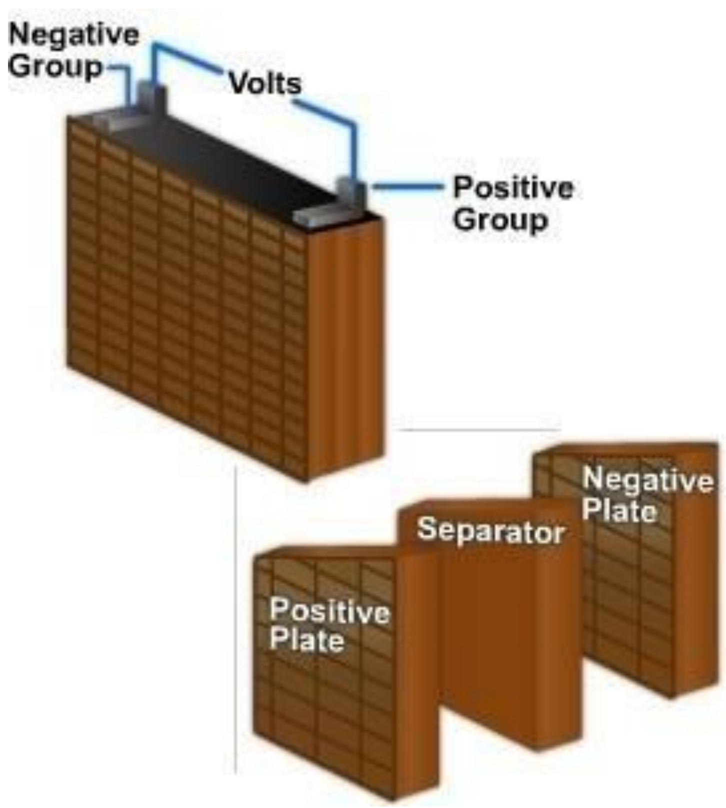
The lead-acid cell-type storage battery is builtto withstand severe vibration, coldweather,engine heat, corrosive chemicals, high current discharge, and prolonged periods without use. Totest and service batteries properly, you must understand battery construction. The construction ofa basiclead-acidcell-typebatteryis asfollows:

- Batteryelement
- Batterycase,cover,andcaps
- Batteryterminals
- Electrolyte



The battery element is made up of negative plates, positive plates, separators, and straps. Theelement fits into a cell compartment in the battery case. Most automotive batteries have sixelements.

Each cell compartmentcontains two kinds of chemically active lead plates, known as positiveand negative plates. The battery plates are made of a stiff mesh framework coated with porouslead. These plates are insulated from each other by suitable separators and are submerged in asulfuricacidsolution(electrolyte).



Charged negative plates contain spongy (porous) lead (Pb), which is gray in color. Chargedpositiveplatescontainleadperoxide(PbO_2),whichhasachocolatebrowncolor.Thesesubstances are known as the active materials of the plates. Calcium or antimony is normallyadded to the lead to increase battery performance and to decrease gassing. Since the lead on theplates is porous like a sponge, the battery acid easily penetrates into the material. This aids thechemicalreactionandtheproductionofelectricity.

Lead battery straps or connectors run along the upper portion of the case to connect the plates.Thebatteryterminals(postorsideterminals)areconstructedaspartofone endofeachstrap.

To prevent the plates from touching each other and causing a short circuit, sheets of insulatingmaterial (micro-porous rubber, fibrous glass, or plastic impregnated material), called separators,are inserted between the plates. These separators are thin and porous so the electrolyte will floweasily between the plates. The side of the separator that is placed against the positive plate isgrooved so the gas thatforms during charging will rise to the surface more readily. Thesegrooves also provide room for any material that flakes from the plates to drop to the sedimentspacebelow.

The battery case is made of hard rubber or a high-quality plastic. The case must withstandextreme vibration,temperature change,and the corrosive action of the electrolyte.The dividersinthecaseformindividualcontainers foreachelement. Acontainerwith itselementisonecell.

Stiff ridges or ribs are molded in the bottom of the case to form a support for the plates and asediment recess for the flakes of active material that drop off the plates during the life of thebattery. The sediment is thus kept clear of the plates so it will not cause a short circuit acrossthem.

The battery cover is made of the same material as the container and is bonded to and seals thecontainer.The coverprovidesopeningsforthetwobatterypostsand a cap foreachcell.

Battery caps either screw or snap into the openings in the battery cover. The battery caps (ventplugs) allow gas to escape and prevent the electrolyte from splashing outside the battery. Theyalso serve as spark arresters. The battery is filled through the vent plug openings. Maintenance-freebatterieshave alarge coverthat isnotremoved duringnormalservice.

Hydrogen gas can collect at the top of a battery. If this gas is exposed to a flame or spark, it canexplode.

Battery terminals provide a means of connecting the battery plates to the electrical system of thevehicle.Eithertworoundpostortwoside terminalscanbeused.

Battery terminals are round metal posts extending through the top of the battery cover.Theyserve as connections for battery cable ends. The positive post will be larger than the negativepost. It may be marked with red paint and a positive (+) symbol. The negative post is smaller,maybemarkedwithblackorgreenpaint,andhasanegative(-)symbolonornearit.

Side terminals are electrical connections located on the side of the battery. They have internalthreads that accept a special bolt on the battery cable end. Side terminal polarity is identified bypositiveandnegativesymbolsmarkedonthecase.

The electrolyte solution in a fully charged battery is a solution of concentrated sulfuric acid inwater.Thissolutionisabout60 percentwaterandabout40 percentsulfuricacid.

The electrolyte in the lead-acid storage battery has a specific gravity of 1.28, which means that itis 1.28 times as heavy as water. The amount of sulfuric acid in the electrolyte changes with theamount of electrical charge; the specific gravity of the electrolyte also changes with the amountof electrical charge. A fully charged battery will have a specific gravity of 1.28 at 80°F. Thefigurewillgohigherwithatemperature decrease,andlowerwithatemperatureincrease.

As a storage battery discharges, the sulfuric acid is depleted and the electrolyte is graduallyconverted into water. This action provides a guide in determining the state of discharge of thelead-acidcell.Theelectrolyte that isplacedinalead-acidbatteryhasaspecificgravityof1.280.

The specific gravity of an electrolyte is actually the measure of its density. The electrolytebecomes less dense as its temperature rises, and a low temperature means a high specific gravity.The hydrometer that you use is marked to read specific gravity at 80°F only. Under normalconditions, the temperature of your electrolyte will not vary much from thismark.However,largechangesintemperature requirea correctioninyourreading.

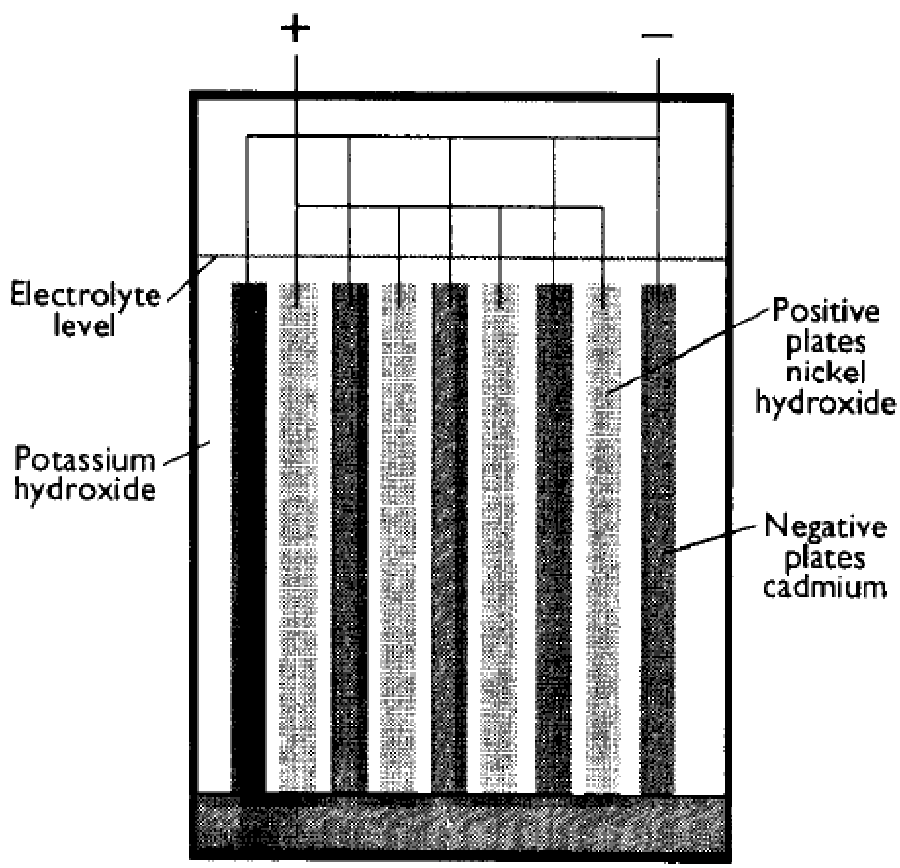
For every 10-degree change in temperature ABOVE 80°F, you must add 0.004 to your specificgravity reading. For every 10-degree change in temperature below 80°F, you must subtract 0.004from your specific gravity reading. Suppose you have just taken the gravity reading of a cell. Thehydrometer reads 1.280. A thermometer in the cell indicates an electrolyte temperature of 60°F.That is a normal difference of 20 degrees from the normal of 80°F. To get the true gravityreading,youmustsubtract0.008from1.280.Thusthespecificgravityofthecellisactually

1.272.Ahydrometerconversionchartisusuallyfoundonthehydrometer.Fromit,youcanobtainthe specificgravitycorrectionfortemperaturechangesaboveorbelow80°F.

AlkalineBatteries(Nickel–CadmiumBattery)

Lead-acid batteries traditionally required a considerable amount of servicing to keep them ingood condition, although this is not now the case with the advent of sealed and maintenance-freebatteries.

However, when a battery is required to withstand a high rate of charge and discharge on a regularbasis, or is left in a state of disuse for long periods, the lead-acid cell is not ideal. Alkaline cellson the other hand require minimum maintenance and are far better able to withstand electricalabusesuchas heavydischargeandover-charging.



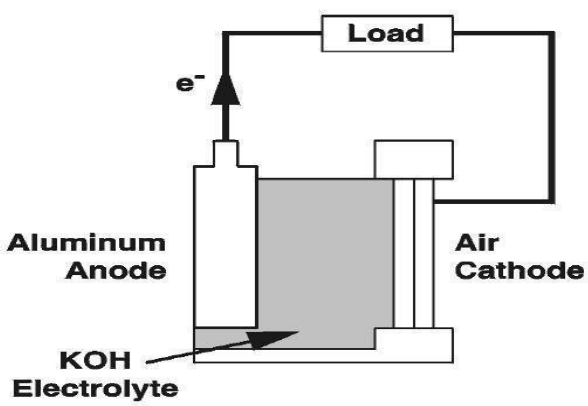
Thedisadvantagesofalkalinebatteriesarethattheyaremorebulky,havelowerenergyefficiency and are more expensive than a lead-acid equivalent. When the lifetime of the batteryand servicing requirements are considered, the extra initial cost is worth it for some applications.Busandcoachcompaniesandsomelargegoods-vehicleoperatorshaveusedalkaline batteries.

Alkaline batteries used for vehicle applications are generally the nickel-cadmium type, as theother main variety (nickel-iron) is less suited to vehicle use. The main components of the nickel-cadmium–orNicad–cellforvehicleuse areasfollows:

- Positiveplate–nickelhydrate(niooh);
- Negativeplate –cadmium(Cd);
- Electrolyte–potassiumhydroxide(KOH) andwater(H_2O).

Aluminium–AirBattery

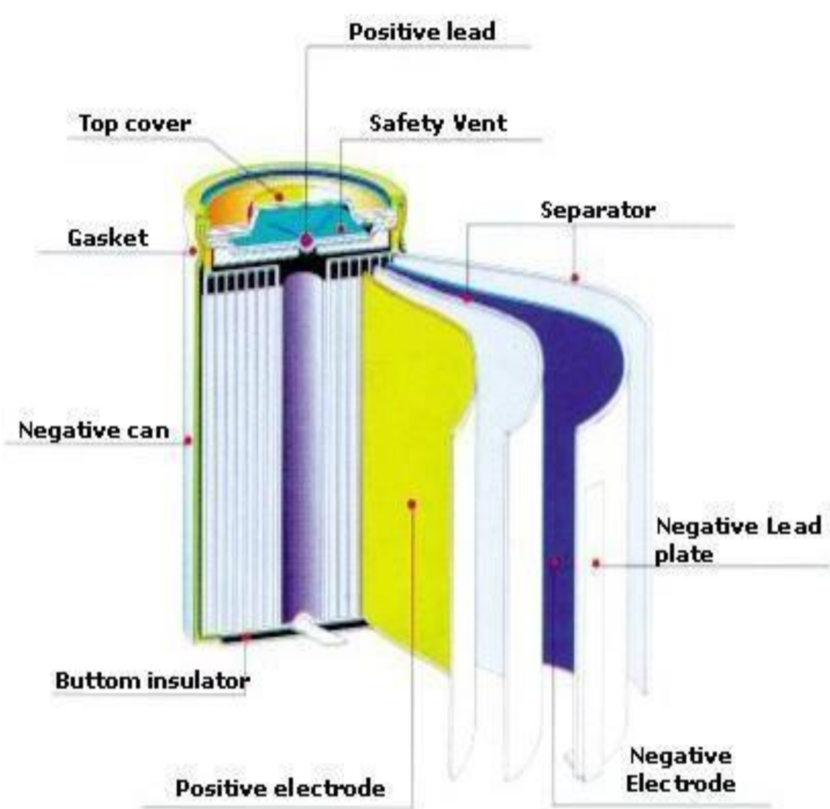
Aluminium–air batteries or Al–air batteries produce electricity from the reaction of oxygen in theair with aluminium.They have one of thehighestenergy densities of all batteries,but they arenot widely used because of problems with high anode cost and byproduct removal when usingtraditional electrolytes and this has restricted their use to mainly military applications. However,an electric vehicle with aluminium batteries has the potential for up to eight times the range of alithium-ionbatterywithasignificantlylowertotalweight.



Aluminium–air batteries are primary cells; i.e., non-rechargeable. Once the aluminium anode isconsumed by its reaction with atmospheric oxygen at a cathode immersed in a water-basedelectrolyte to form hydrated aluminium oxide, the battery will no longer produce electricity.However, it is possible to mechanically recharge the battery with new aluminium anodes madefrom recycling the hydrated aluminium oxide. Such recycling would be essential if aluminium–airbatteries aretobe widelyadopted.

Nickel–MetalHydrideBattery

A nickel–metal hydride battery, abbreviated NiMH or Ni–MH, is a type of rechargeable battery.Its chemical reactions are somewhat similar to the largely obsolete nickel–cadmium cell (NiCd).NiMH use positive electrodes of nickel oxyhydroxide (NiOOH), like the NiCd, but the negativeelectrodes use a hydrogen-absorbing alloy instead of cadmium, being in essence a practicalapplication of nickel–hydrogen battery chemistry. A NiMH battery can have two to three timesthe capacity of an equivalent size NiCd, and their energy density approaches that of a lithium-ioncell.



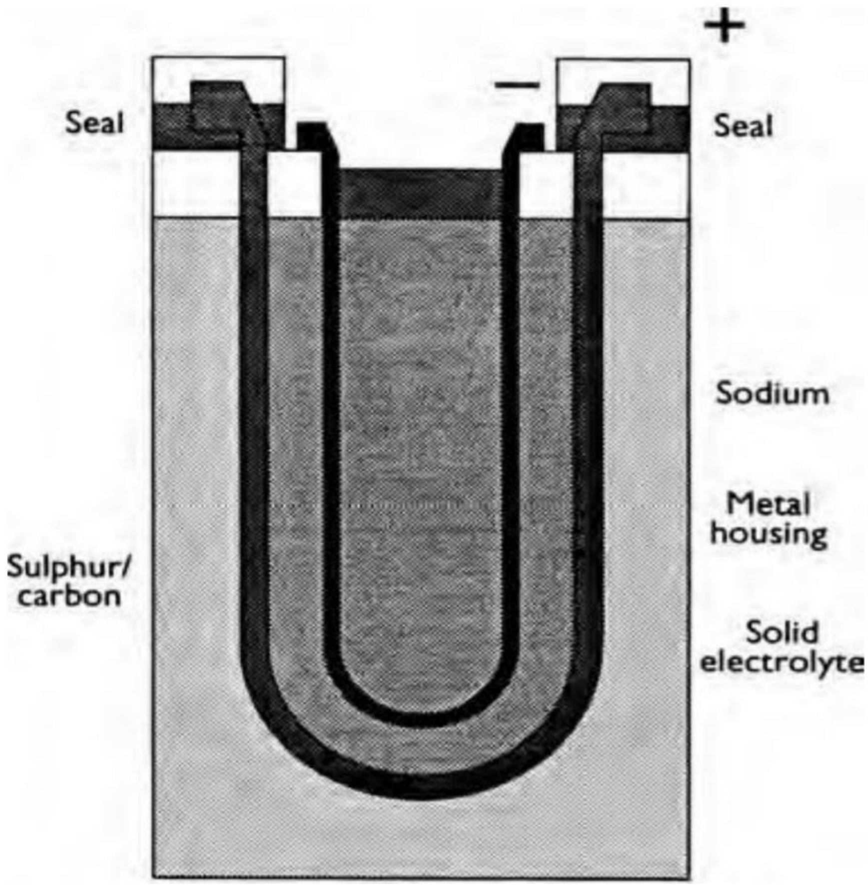
The typical specific energy for small NiMH cells is about 100 W·h/kg, and for larger NiMH cellsabout 75 W·h/kg (270 kJ/kg). This is significantly better than the typical 40– 60 W·h/kg forNiCd, and similar to the 100–160 W·h/kg for lithium-ion batteries. NiMH has a volumetricenergy density of about 300 W·h/L (1,080 MJ/m3), significantly better than NiCd at 50–150W·h/L,andaboutthe sameaslithium-ionat250–360W·h/L.

NiMH batteries have replaced NiCd for many roles, notably small rechargeable batteries. NiMHbatteriesareverycommonforAA(penlight-size)batteries,whichhavenominalchargecapacities (C) of 1.1–2.8 A·h at 1.2 V, measured at the rate that discharges the cell in five hours.Useful discharge capacity is a decreasingfunction of the discharge rate,butup to a rate ofaround1×C (full dischargein onehour),itdoesnotdiffersignificantlyfrom thenominalcapacity. NiMH batteries normally operate at 1.2 V per cell, somewhatlower than conventionalV cells,butwilloperate mostdevicesdesignedforthatvoltage.

SodiumSulphurBattery

Much research is underway toimprove on currentbattery technology in order toprovideagreater energy density for electric vehicles. A potential major step forwards however the sodiumsulphurbattery,whichhasnowreachedproductionstage.Sodium-sulphurbatterieshaverecently reached the production stage and, in common with the other types listed, have muchpotential;however,alltypeshavespecificdrawbacks.Forexample,storingandcarryinghydrogeni soneproblemoffuelcells.

The sodium-sulphur or NaS battery consists of a cathode of liquid sodium into which is placed acurrent collector. This is a solid electrode of β-alumina. A metal can that is in contact with theanode(asulphurelectrode)surroundsthewholeassembly.Themajorproblemwiththissystemis that the running temperature needs to be 300–350 ° C. A heater rated at a few hundred wattsforms part of the charging circuit. This maintains the battery temperature when the vehicle is notrunning.Batterytemperatureismaintained wheninusedueto I^2Rlossesinthebattery.



Each cell of this battery is very small, using only about 15 g of sodium. This is a safety featurebecause, if the cell is damaged, the sulphur on the outside will cause the potentially dangeroussodium to be converted into polysulphides – which are comparatively harmless. Small cells alsohave the advantage that they can be distributed around the car. The capacity of each cell is about10 Ah. These cells fail in an open circuit condition and hence this must be taken into account, asthe whole string of cells used to create the required voltage would be rendered inoperative. Theoutput voltage of each cell is about 2V. A problem still to be overcome is the casing material,which is prone to fail due to the very corrosive nature of the sodium. At present, an expensivechromizedcoatingisused.

This type of battery,supplying an electricmotor, is becoming a competitor to the internalcombustion engine. The whole service and charging infrastructure needs to develop but lookspromising.It is estimated that the cost of runningan electric vehicle will be as little as 15% ofthe petrolversion,whichleaves roomtoabsorbtheextracostofproduction.

BatteryCapacity

The capacity of a battery is measured in ampere hours. The ampere-hour capacity is equal to theproduct of the current in amperes and the time in hours during which the battery is supplyingcurrent. The ampere-hour capacity varies inversely with the discharge current. The size of a cellis determined generally by its ampere-hour capacity. The capacity of a cell depends upon manyfactors,themostimportantofwhichare asfollows:

- Areaoftheplatesincontactwiththeelectrolyte
- Quantityandspecificgravityoftheelectrolyte
- Typeofseparators
- Generalconditionofthebattery(degreeofsulfating,platesbuckled,separatorswarped,sediment inbottomofcells,etc.)
- Finallimitingvoltage

BatteryRatings

Battery ratings were developed by the Society of Automotive Engineers (SAE) and the BatteryCouncilInternational(BCI).Theyaresetaccordingtonationaltestsstandardsforbatteryperformance. They let the mechanic compare the cranking power of one battery to another. Thetwo methods of rating lead-acid storage batteries are the cold-cranking rating and the reservecapacityrating.

The cold cranking rating determines how much current in amperes the battery can deliver forthirty seconds at 0°F while maintaining terminal voltage of 7.2 volts or 1.2 volts per cell. Thisrating indicates the ability of the battery to crank a specific engine (based on starter current draw)ataspecifiedtemperature.

For example, one manufacturer recommends a battery with 305 cold-cranking amps for a smallfour-cylinder engine buta 450 cold-cranking amp battery for a larger V-8 engine.A morepowerfulbatteryisneeded to handlethe heavierstartercurrentdrawofthelargerengine.

The reserve capacity ratingis the timeneeded tolowerbattery terminalvoltage below 10.2 V(1.7 V per cell) at a discharge rate of 25 amps. This is with the battery fully charged and at 80°F.Reservecapacitywillappearonthe batteryas atimeintervalinminutes.

For example, if a battery is rated at 90 minutes and the charging system fails, the operator hasapproximately 90 minutes (1 1/2 hours) of driving time under minimum electrical load before thebatterygoes completelydead.

ChargingOfBattery

Undernormal conditions,ahydrometerreadingbelow1.265specificgravity at80°Fisawarningsignalthatthe batteryneeds chargingorisdefective.

When testing shows that a battery requires charging, a battery charger is required to re-energizeit. The battery charger will restore the charge on the plates by forcing current back into thebattery.Thebattery charger usesAC (Alternating Current)currentfrom a wall outlet,usually120 volts, and steps it down to a voltage slightly above that of a battery, usually 14-15 volts.There arebasicallytwotypesofchargers,theslowchargerand thefast(quick)charger.

The slow charger is also known as the trickle charger. It feeds a small amount current back intothe battery over a long period of time. When using a trickle charger, it takes about 12 hours at 10amps to fully charge a dead battery. However, the chemical action inside the battery is improved.During a slow charge, the active materials are put back onto the battery plates stronger than theyare during a fast charge. It is always better for the battery to use a trickle charge when timeallows.

The fast charger, or quick charger and sometimes called the boost charger, forces a high amountof current flow back into the battery. A fast charger is commonly used in shops to start an engineor get the vehicle out of the shop quickly because there is no time to wait for a slow charge. Fastchargingisbeneficialifyoujustneedtostarttheengine;iftimeallows,usetheslow charge.

When using a fast charger, do not exceed a charge rate in excess of 35 amps. Also, ensure thebattery temperature does not exceed 125ºF. Exceeding either one could cause damage to thebattery.

If there is a possibility that the battery is frozen, do not charge the battery. Charging a frozencircuitcan rupture the battery case and cause an explosion.Always allow the battery time tothaw beforechargingit.

ChargingMethod	**Notes**
Constant voltage	Willrechargeanybatteryin7hoursorlesswithoutanyriskofovercharging(14.4Vmaximum).
Constantcurrent	Idealcharge rate canbeestimatedas:1/10ofAhcapacity,1/16of reservecapacityor1/40ofcoldstartcurrent(charge timeof10–12hoursorprorataoriginalstate).
Boostcharging	Atnomorethanfivetimestheidealrate,abatterycanbebrought uptoabout70%ofchargeinaboutonehour.

It is easy to connect the battery to the charger, turn the charging current on, and, after a normalchargingperiod, turn thechargingcurrentoff andremovethebattery.Certain precautions,however,are necessary both before and during the charging period.These practices are asfollows:

- Clean and inspect the battery thoroughly before placing it on charge. Use a solution ofbaking soda and water for cleaning, and inspectit for cracks or breaks in the container.Do not permit the baking soda and water solution to enter the cells. To do so wouldneutralizetheacidwithin theelectrolyte.
- Connect the battery to the charger. Be sure the battery terminals are connected properly;connect the positive post to the positive (+) terminal and the negative post to the negative(-)terminal.Thepositiveterminalsofbothbatteryandchargeraremarked;thoseunmarked are negative. The positive post of the battery is, in most cases, slightly largerthanthenegativepost.Ensureallconnections aretight.
- See that the vent holes are clear and open. Do NOT remove battery caps during charging.This prevents acidfrom spraying onto the top of the battery and keeps dirt out of thecells.

- Check the electrolyte level before charging begins and during charging. Add distilledwateriftheleveloelectrolyteisbelowthetopoftheplate.
- Keep the charging room well ventilated. Do NOT smoke near batteries being charged.Batteriesonchargerelease hydrogengas.Asmallsparkmaycause anexplosion.
- Take frequent hydrometer readings of each cell and record them. You can expect thespecific gravity to rise during the charge. If it does not rise, remove the battery anddispose ofitas perlocalhazardousmaterialdisposalinstruction.
- Keep close watch for excessive gassing, especially at the very beginning of the charge,whenusingtheconstantvoltagemethod.Reducethechargingcurrentifexcessivegassing occurs.Somegassingisnormalandaidsinremixing theelectrolyte.
- Donotremoveabatteryuntilithasbeencompletelycharged.

BatteryTesting

Asamechanicyouwillbeexpectedtotestbatteries

forproperoperationandcondition.Thesetests areasfollows:

A battery leakage test will determine if currentis discharging across the top of the battery. Adirty battery can discharge when not in use. This condition shortens battery life and causesstarting problems. To perform a battery leakage test, set a voltmeter on a low setting. Touch theprobes on the battery. If any current is registered on the voltmeter, the top of the battery needs tobe cleaned.

The battery terminal test quickly checks for poor electrical connection between the terminals andthebatterycables.Avoltmeter isusedtomeasurevoltagedropacrossterminalsandcables.

To perform a battery terminal test, connect the negative voltmeter lead to the battery cable end.Touch the positive lead to the battery terminal. With the ignition or injection system disabled sothattheenginewillnotstart,crankthe engine whilewatchingthe voltmeterreading.

If thevoltmeterreadingis.5voltsorabove,thereishighresistanceatthebattery cableconnection. This indicates that the battery connections need to be cleaned. A good, clean batterywillhaveless thana .5voltdrop.

Thebatteryvoltagetestisdonebymeasuringtotalbatteryvoltagewithanaccuratevoltmeterora special battery tester. This test determines the general state of charge and battery conditionquickly.

The battery voltage test is used on maintenance-free batteries because these batteries do not havecaps thatcan be removedfor testing with a hydrometer. To perform this test, connectthevoltmeter or battery tester across the battery terminals. Turn on the vehicle headlights or heaterblower to provide a light load. Now read the meter or tester. A well-charged battery should haveover 12 volts. If the meter reads approximately 11.5 volts, the battery is not charged adequately,oritmaybedefective.

Thecellvoltagetestwillletyouknowifthebatteryisdischargedordefective.Likeahydrometer cell test, if the voltage reading on one or more cells is .2 volts or more lower than theothercells,the batterymustbe replaced.

To perform a cell voltage test, use a low voltage reading voltmeter with special cadmium (acid-resistant metal) tips. Insert the tips into each cell, starting at one end of the battery and workingyour way to the other. Test each cell carefully. If the cells are low but equal, recharging usuallywillrestorethebattery.Ifcellvoltagereadingsvarymore than.2 volts,thebatteryisBAD.

A battery drain test checks for abnormal current draw with the ignition off. If a battery goes deadwithoutbeingused,youneedtocheckfora currentdrain.

To perform a battery drain test, set up an ammeter. Pull the fuse if the vehicle has a dash clock.Close all doors and the trunk (if applicable). Then read the ammeter. If everything is off, thereshouldbeazeroreading.Anyreadingindicatesaproblem.Tohelppinpointtheproblem,pull fuses one at a time until there is a zero reading on the ammeter. This action isolates the circuitthathas theproblem.

A battery load test, also termed a battery capacity test, is the best method to check batterycondition. The battery load test measures the current output and performance of the battery underfullcurrentload.Itisoneofthemostcommonandinformative batterytestsusedtoday.

Before load testing a battery, you must calculate how much current draw should be applied to thebattery. If the ampere-hour rating of the battery is given, load the battery to three times its amp-hourrating.Forexample,ifthebatteryisratedat60amphours,testthebatteryat180amps(60x 3 = 180). The majority of the batteries are now rated in SAE cold cranking amps, instead ofamp-hours. To determine the load testfor these batteries, divide the cold-crank ratingby two.Forexample,abatterywith 400coldcrankingampsratingshouldbeloadedto200amps(400÷2 = 200). Connect the battery load tester. Turn the control knob until the ammeter reads thecorrectloadforyourbattery.

After checking the battery charge and finding the amp load value, you are ready to test batteryoutput. Make sure that the tester is connected properly. Turn the load control knob until theammeter reads the correct load for your battery. Hold the load for 15 seconds. Next, read thevoltmeter while the load is applied. Then turn the load control completely off so the battery willnot be discharged. If the voltmeter reads 9.5 volts or more at room temperature, the battery isgood. If the battery reads below 9.5 volts at room temperature, battery performance is poor. Thiscondition indicates that the battery is not producing enough current to run the starting motorproperly.

Familiarize yourself with proper operating procedures for the type of tester you have available.Improperoperationofelectricaltestequipmentmayresultinseriousdamagetothetestequipmentortheunitbeingtested.

The quick charge test, also known as 3-minute charge test, determines if the battery is sulfated. Iftheresultsofthebatteryloadtestarepoor,fastchargethebattery.Chargethebatteryfor3 minutes at30 to 40 amps. Test the voltage while charging. If the voltage goes ABOVE 15.5volts, the batteryplatesaresulfatedandthe batteryneedstobereplaced.

BatteryServicing

PlacingNewBatteriesinService

New batteries may come to you full of electrolyte and fully charged. In this case, all that isnecessary is to install the batteries properly in the piece of equipment. Most batteries shipped toNCFunits arereceivedchargedanddry.

Charged and dry batteries will retain their state of full charge indefinitely so long as moisture isnot allowed to enter the cells. Therefore, batteries should be stored in a dry place. Moisture andair entering the cells will allow the negative plates to oxidize. The oxidation causes the battery toloseits charge.

To activate a dry battery, remove the restrictors from the vents and remove the vent caps. Thenfill all the cells to the proper level with electrolyte. The best results are obtained when thetemperatureofthebatteryandelectrolyteis withintherangeof60°Fto80°F.

Some gassing will occur while you are filling the battery due to the release of carbon dioxide thatis aproduct of the dryingprocess of the hydrogen sulfide producedby the presence of freesulfur.Therefore, thefilling operations shouldbein a well-ventilated area.These gases andodorsarenormalandare nocauseforalarm.

Approximately 5 minutes after adding electrolyte, check the battery for voltage and electrolytestrength. More than 6volts or more than 12volts, depending upon the rated voltage of thebattery, indicates the battery is ready for service. From 5 to 6 volts or from 10 to 12 voltsindicates oxidized negative plates, and the battery should be charged before use. Less than 5 orless than 10 volts, depending upon the rated voltage, indicates a bad battery, which should not beplacedinservice.

If, before the battery is placed in service, the specific gravity, when corrected to 80°F, is morethan.030pointslowerthanitwasatthetimeofinitial fillingor ifoneormorecellsgasviolently after adding the electrolyte, the battery should be fully charged before use. If the electrolytereadingfailstorise duringcharging,discardthebattery.

Most shops receive ready-mixed electrolyte. Some units may still get concentrated sulfuric acidthat mustbemixedwithdistilledwatertogettheproperspecificgravityforelectrolyte.

Mixing electrolyte is a dangerous job. You have probably seen holes appear in a uniform for noapparentreason.Lateryourememberedreplacingastoragebatteryandhavingcarelesslybrushedagainstthebattery.

When mixing electrolyte, you are handling pure sulfuric acid, which can burn clothing quicklyand severely bum your hands and face. Always wear rubber gloves, an apron, goggles, and a faceshieldforprotectionagainstsplashes oraccidentalspilling.

When you are mixing electrolyte, NEVER pour water into the acid. Always pour acid into water.If water is added to concentrated sulfuric acid, the mixture may explode or splatter and causesevere burns. Pour the acid into the water slowly, stirring gently but thoroughly all the time.Largequantities ofacidmayrequirehoursofsafedilution.

Let the mixed electrolyte cool down to room temperature before addingit to the battery cells.Hotelectrolytewill eatup thecell plates rapidly.Tobe on thesafeside,donotadd theelectrolyte if its temperature is above 90°F. After filling the battery cells, let the electrolyte coolagainbecausemoreheatisgeneratedbyitscontactwiththebatteryplates.Next,takehydrometer readings. The specific gravity of the electrolyte will correspond quite closely to thevalues onthemixingchartifthepartsofwater andacidaremixedcorrectly.

MaintenanceOfBattery

If abattery isnotproperlymaintained,its servicelifewillbedrastically reduced.Batterymaintenanceshouldbedoneduringevery vehicleservicing.Completebattery maintenanceincludes thefollowing:

Visually checking the battery. Battery maintenance should always begin with a thorough visualinspection. Look for signs of corrosion on or around the battery, signs of leakage, a cracked caseortop,missingcaps,andlooseormissinghold-downclamps.

Checking the electrolyte level in cells on batteries with caps, and adding water if the electrolytelevel is low. On vent cap batteries, you can check the electrolyte level by removing the caps.Some batteries have a fill ring which indicates the electrolyte level. The electrolyte should beeven with the fill ring. If there is no fill ring, the electrolyte should be high enough to cover thetops of the plates. Some batteries have an electrolyte-level indicator (Delco Eye). This gives acolor code visual indication of the electrolyte level, with black indicating that the level is okayandwhitemeaningalowlevel.

If the electrolyte level in the battery is low, fill the cells to the correct level with distilled water(purified water). Distilled water should be used because it does not contain the impurities foundintapwater.Tapwatercontainsmanychemicalsthatreducebatterylife.Thechemicalscontaminat e the electrolyte and collect in the bottom of the battery case. If enough contaminatescollectinthebottomofthe case,thecellplates shortout,ruiningthebattery.

If water must be added at frequent intervals, the charging system may be overcharging thebattery. A faulty charging system can force excessive currentinto the battery. Battery gassingcanthenremovewaterfromthebattery.

Maintenance-free batteries do NOT need periodic electrolyte service under normal conditions.Theyare designedtooperate forlongperiodswithoutlossofelectrolyte.

Cleaning off corrosion around the battery and battery terminals. If the top of the battery is dirty,using a stiff bristle brush, wash it down with a mixture of baking soda and water. This action willneutralize and remove the acid-dirt mixture. Be careful not to allow cleaning solution to enter thebattery.

Do NOT use a scraper or knife to clean battery terminals. This action removes too much metalandcanruintheterminalconnection.

To clean the terminals, remove the cables and inspect the terminal posts to see if they aredeformed or broken. Clean the terminal posts and the inside surfaces of the cable clamps with acleaningtoolbeforereplacingthemontheterminalposts.

When reinstalling the cables, tighten the terminals just enough to secure the connection, over-tightening will strip the cable bolt threads. Coat the terminals with petroleum or white grease.Thiswillkeepacidfumesofftheconnectionsandkeepthem fromcorrodingagain.

Checking the condition of the battery by testing there state of charge. When measuring batterycharge, you check the condition of the electrolyte and the battery plates. As a battery becomesdischarged, its electrolyte has a larger percentage of water. Thus the electrolyte of a dischargedbattery will have a lower specific gravity number than a fully charged battery. This rise and dropin specific gravity can be used to check the charge in a battery. There are several ways to checkthestateofchargeofabattery.

Non maintenance-free batteries can have the state of charge checked with a hydrometer. Thehydrometertestsspecificgravityoftheelectrolyte.Itisfastandsimpletouse.

A fully charged battery should have a hydrometer reading of at least 1.265 or higher. If below1.265,thebatteryneeds toberecharged,oritmaybedefective.

A defective battery can be discovered by using a hydrometer to check each cell. If the specificgravity in any cell varies excessively from other cells (25 to 50 points), the battery is bad. Cellswith low readings may be shorted. When all of the cells have equal specific gravity, even if theyare low, the battery can usually be recharged. On maintenance-free batteries a charge indicatoreye shows the battery charge. The charge indicator changes color with levels of battery charge.For example, the indicator may be green with the battery fully charged. It may turn black whendischarged or yellow when the battery needs to be replaced. If there is no charge indicator eye orwhenindoubtof itsreliability,youcan useavoltmeterandammeteroraloadtester todeterminebatteryconditionquickly.

CHAPTER–2

StartingSystem

The starting system of an automobile is used to start the internal combustion engine. Both SI andCI engines cannot start by itself. These engines need to be cranked by a starting motor. Thismotor is also called a starter or cranking motor. Cranking of any engine means rotating its crankshaft. Rotation of crank shaft causes the piston to reciprocate. When piston reciprocates, suction,compression, expansion and exhaust strokes of engine are completed. Thus, engine completes itsworkingcycleanditstartsrunning.

Starting motor produces necessary torque to rotate the engine wheel (crank shaft) through asuitable gear(one piniononmotorandotherringgeararoundenginewheel).

ComponentsofStartingSystem

Starting systemconsistsofthefollowing:

- StartingMotor:Starting motortoproducerotationofcrankshaft.
- DriveMechanism:Drivemechanismtotransferrotarymotionofstartertothecrankshaftoftheengine.
- The ignitionswitchtostartmotor.

StarterMotor

The starting motor converts electrical energy from the battery into mechanical or rotating energyto crank the engine. The main difference between an electric starting motor and an electricgenerator is that in a generator, rotation of the armature in a magnetic field produces voltage. In amotor, current is sent through the armature and the field; the attraction and repulsion between themagnetic poles of the field and armature coil alternately push and pull the armature around. Thisrotation (mechanical energy), when properly connected to the flywheel of an engine, causes theenginecrankshafttoturn.

It is also known as starting motor or cranking motor. It is used to start heavy engines whichcannotbestartedbyhandcranking.

FunctionOfStarter

IC engines are required to be rotated at some minimum speed after which the engines startsrunning by fuel supply. This initial rotation is given by the starting motor and this is the functionofastarter.

WorkingPrinciple

A motor converts electrical energy into mechanical energy. Mechanical energy is obtained in theformofrotationofa wheel.ThisrotationofawheelisusedtostarttheICengine.

The motor works on the principle that “when a current carrying conductor is put in a magneticfield, it experiences a mechanical force”. The direction of force is determined by the Flemming"slefthandrule.

Flemming’sLeftHandRule

If we stretch the thumb, forefinger and middle finger such that they are mutually perpendicular,thenaccordingtothis rule:

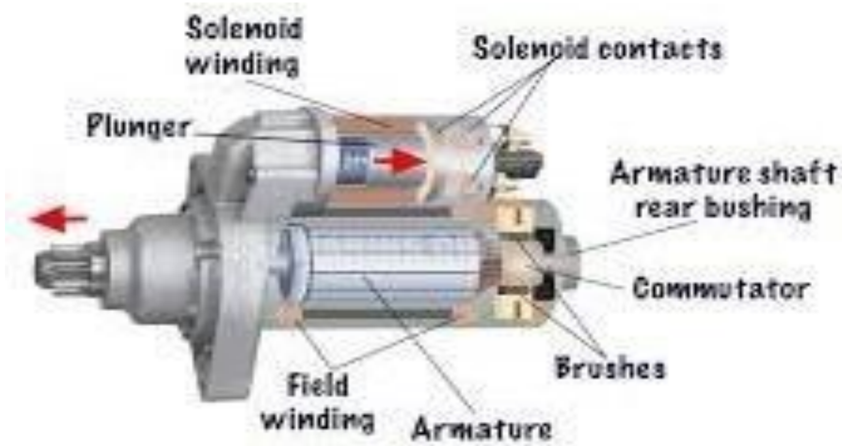
“If the first finger points in the direction of magnetic field and the second (middle) finger in thedirection of current then the thumb will give the direction of force acting on conductor or thedirectionofitsmotion”.

WorkingOfStarter

When the starter switch is put on position, the current from battery flows to starting motor, themotor starts rotating. The motor is connected to the drive unit, which is used to rotate the enginecrank shaft. A small pinion (small gear) is fitted on the armature shaft of the starting motor. Thispinion meshes with the ring gear when starter rotates. Thus, the fly wheel which is attached toring gear also starts revolving. Thus, engine crank shaft starts revolving. With the revolution ofcrank shaft, the engine strokes viz. suction, compression, power and exhaust are completed.Therefore, engine starts running. The starter is engaged to the engine ring gear (attached to flywheel) till the engine starts running. As soon as engine starts running, the starter is disengaged.The startingmotorisalow voltage DCserieswoundedmotor.

ConstructionOfStarterMotor

Theconstructionofallstartingmotorsisverysimilar.Thereare,however,slightdesignvariations.Themainpartsofa startingmotorareasfollows:



The armature assembly consists of an armature shaft, armature core, commutator, and armaturewindings.

The armature shaft supports the armature assembly as it spins inside the starter housing. Thearmature core is made of iron and holds the armature windings in place. The iron increases themagneticfieldstrengthofthe windings.

The commutator serves as a sliding electrical connection between the motor windings and thebrushes and is mounted on one end of the armature shaft. The commutator has many segmentsthat are insulated from each other. As the windings rotate away from the pole shoe (piece), thecommutator segments change the electrical connection between the brushes and the windings.This action reverses the magnetic field around the windings. The constant changing electricalconnectionatthe windings keeps themotorspinning.

Thecommutatorendframehousesthebrushes,thebrush springs,andthearmatureshaftbushing.

Thebrushesrideon top of thecommutator.They slideon thecommutatortocarry batterycurrent to the spinning windings. The springs force the brushes to maintain contact with thecommutator as itspins, thereby nopower interruptions occurs. The armature shaftbushingsupportsthecommutatorendofthearmatureshaft.

The pinion drive assembly includes the pinion gear, the pinion drive mechanism, and solenoid.There are two ways that a starting motor can engage the pinion assembly: first with a movablepole shoe that engages the pinion gear, and second with a solenoid and shift fork that engages thepiniongear.

The pinion gear is a small gear on the armature shaft that engages the ring gear on the flywheel.Moststarter pinion gears aremade as partof a pinion drivemechanism. The pinion drivemechanism slides over one end of the starter armature shaft. The pinion drive mechanism foundon starting motors that you will encounter is of three designs: the bendix drive, the overrunningclutch,andthedyerdrive.

The field frame is the center housing that holds the field coils and pole shoes. It is a stationary setof windings that creates a strong magnetic field around the motor armature. When current flowsthrough the winding, the magnetic field between the pole shoes becomes very large. Actingagainst the magnetic field created by the armature, this action spins the motor with extra power.Fieldwindingsvaryaccordingtotheapplicationofthestartermotor.Themostpopularconfigurati onsareas follows:

The two windings, parallel (the wiring of the two field coils in parallel) increases their strengthbecause they receivefullvoltage.Note thattwo additional poleshoesare used.Though theyhavenowindings,theirpresencewillfurtherstrengthenthemagneticfield.

The four windings, series-parallel (the wiring of four field coils in a series-parallel combination)creates a strongermagneticfieldthanthetwo fieldcoilconfiguration.

The four windings, series (the wiring of four field coils in series) provides a large amount of lowspeed torque, which is desirable for automotive starting motors. However, series wound motorscanbuildupexcessivespeedif allowedtorunfree,tothepointwherethey will destroythemselves.

The six windings, series-parallel (three pairs of series-wound field coils) provides the magneticfieldforaheavy-dutystartermotor.Thisconfigurationusessixbrushes.

The three windings, two series, one shunt (the use of one field coil that is shunted to ground witha series-wound motor) controls motor speed. Because the shunt coil is not affected by speed, itwilldrawasteadyheavycurrent,effectivelylimitingspeed.

The drive end frame is designed to protect the drive pinion from damage and to support thearmature shaft. The drive end frame of the starter contains a bushing to prevent wear between thearmatureshaftanddriveendframe.

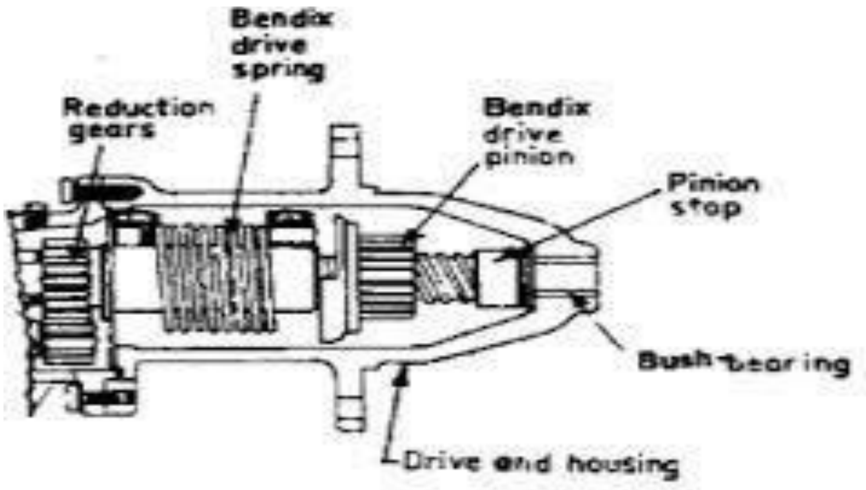
There are two types of starting motors that you will encounter on equipment: the direct drivestarter and the double reduction starter. All starters require the use of gear reduction to providethe mechanicaladvantage requiredtoturntheengineflywheelandcrankshaft.
Direct drive starters make use of a pinion gear on the armature shaft of the starting motor. Thisgear meshes with teeth on the ring gear. There are between 10 to 16 teeth on the ring gear forevery one tooth on the pinion gear. Therefore, the startingmotor revolves 10 to 16 times forevery revolution of the ring gear. In operation, the starting motor armature revolves at a rate of2,000to3,000revolutionsperminute,thusturningtheenginecrankshaftatspeedsupto200rpm.

The double reduction starter makes use of gear reduction within the starter and the reductionbetween the drive pinion and the ring gear. The gear reduction drive head is used on heavy-dutyequipment.
The gear on the armature shaft does not mesh directly with the teeth on the ring gear, but with anintermediate gear which drives the driving pinion. This action provides additional breakaway, orstartingtorque,andgreatercrankingpower.Thearmatureof astartingmotorwith agearreduction drive head may rotate as many as 40 revolutions for every revolution of the engineflywheel.

DriveArrangementAndControl

A starter motor's operation is dependent upon the type of drive it contains. Below are the threedrivesystems,alongwithanexplanationof the operationofeach.

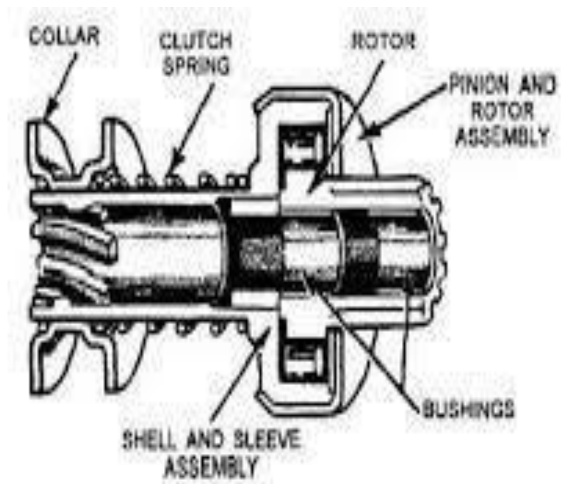
The Bendix drive relies on the principle of inertia to cause the pinion gear to mesh with the ringgear. When the starting motor is not operating, the pinion gear is out of mesh and entirely awayfrom the ring gear. When the ignition switch is engaged, the total battery voltage is applied to thestartingmotor,andthe armatureimmediatelystartstorotateathighspeed.

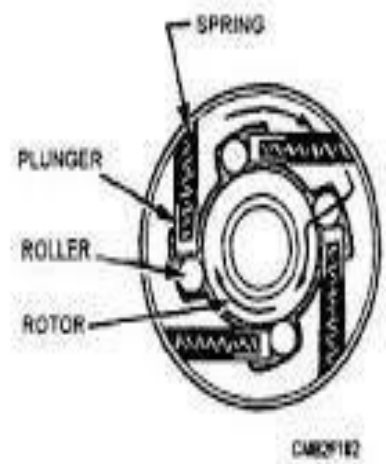


Bendix Drive

The pinion, being weighted on one side andhavinginternal screw threads, does notrotateimmediately with the shaft but because of inertia, runs forward on the revolving threaded sleeveuntil itengages with the ring gear.If the teeth of the pinion and ring gear donot engage,thedrive spring allows the pinion to revolve and forces the pinion to mesh with the ring gear. Whenthe pinion gearis engagedfully with the ring gear, the pinion is then driven by the starterthrough the compressed drive spring and cranks the engine. The drive spring acts as a cushionwhile the engine is being cranked against compression. It also breaks the severity of the shock onthe teeth when the gears engage and when the engine kicks back due to ignition.When theengine starts and runs on its own power, the ring gear drives the pinion at a higher speed thandoes the starter. This action causes the pinion to turn in the opposite direction on the threadedsleeve and automatically disengagesfrom the ring gear.This prevents the enginefrom drivingthe starter.

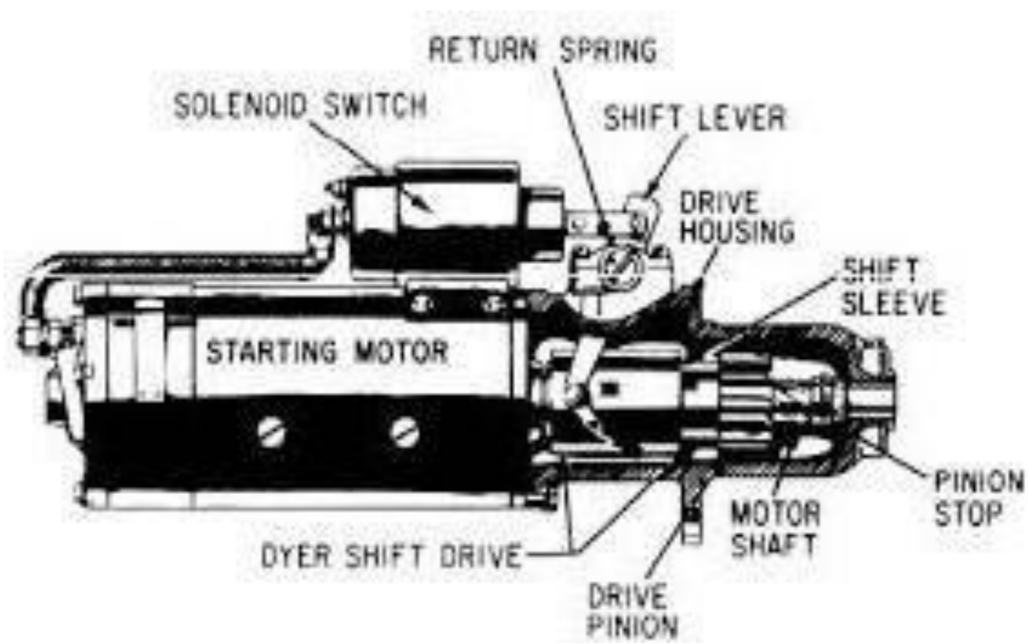
The overrunning clutch provides positivemeshing and demeshing of the starter motor piniongear and the ring gear. The starting motor armature shaft drives the shell and sleeve assembly ofthe clutch.The rotorassembly is connected to the pinion gear, which meshes with the enginering gear. Spring-loaded steel rollers are located in tapered notches between the shell and therotor. The springs and plungers hold the rollers in position in the tapered notches. When thearmature shaft turns, the rollers are jammed between the notched surfaces, forcing the inner andoutermembers oftheassemblytorotateas aunitandcrankthe engine.





After the engine is started, the ring gear rotates faster than the pinion gear, thus tending to workthe rollers back against the plungers, and thereby causing an overrunning action. This actionprevents excessive speed of the startingmotor. When the starting motor is released, the collarandspringassemblypulls thepinionoutofmeshwiththe ringgear.

The Dyer drive provides complete and positive meshing of the drive pinion and ring gear beforethe starting motor is energized. It combines principles of both the Bendix and overrunning clutchdrives andis commonlyusedonheavy-dutyengines.



A starter solenoid is used to make the electrical connection between the battery and the startingmotor. The starter solenoid is an electromagnetic switch; it is similar to other relaysbut iscapable of handling higher current levels. A starter solenoid, depending on the design of thestartingmotor,hasthefollowingfunctions:

- Closesbattery-to-startercircuit.
- Pushesthe starterpiniongearintomeshwiththeringgear.
- Actsasanelectro-magnetic switchto engagethestarter.

The starter solenoid may be located away from or on the starting motor. When mounted awayfrom the starter, the solenoid only makes and breaks electrical connection. When mounted on thestarter, it also slides the pinion gear into the flywheel. In operation, the solenoid is actuated whenthe ignition switch is turned or when the starter button is depressed. The action causes current toflowthroughthesolenoid(causingamagneticattractionoftheplunger)toground.Themovement of the plunger causes the shift lever to engage the pinion with the ring gear. After thepinion is engaged,further travel of the plunger causes the contactsinside the solenoid to closeanddirectlyconnects thebatterytothestarter.

MaintenanceOfStarterMotor

If cranking continues after the control circuit is broken, it is most likely to be caused by eithershorted solenoid windings or by binding of the plunger in the solenoid. Low voltage from thebattery is often the cause of the starter making a clicking sound. When this occurs, check allstartingcircuitconnectionsforcleanliness andtightness.

The condition of the starting motor should be carefully checked at each PM service. This permitsyou to take appropriate action, where needed, so equipment failures caused by a faulty starter canbe reduced,ifnoteliminated.

A visual inspection for clean, tight electrical connections and secure mounting at the flywheelhousing is the extent of the maintenance check. Then operate the starter and observe the speed ofrotationandthesteadiness ofoperation.

Do NOT crank the engine for more than 30 seconds or starter damage can result. If the starter iscranked too long, it will overheat. Allow the starter to cool for a few minutes if more crankingtimeisneeded.

Ifthestarterisnotoperatingproperly,removethestarter,disassembleit,andcheckthecommutator and brushes. If the commutator is dirty, you may clean it with a piece of No. 00sandpaper. However, if the commutator is rough, pitted, or out-of-round or if the insulationbetweenthecommutatorbarsishigh,itmustbe reconditioned usinganarmaturelathe.

Brushes should be at least half of their original size. If not, replace them. The brushes shouldhavefreemovementinthebrushholdersandmakegood,cleancontactwiththecommutator.

Once you have checked the starter and repaired it as needed, you should reassemble it, makingsure that the starter brushes are seated. Align the housings and install the bolts securely. Installthe starter in the opening in the flywheel housing and tighten the attaching bolts to the specifiedtorque.Connectthe cable andwireleadfirmlytocleanterminals.

ServicingOfStarterMotor

Step1:StuffYou WillNeed.

First thing to is to check out the price of a new starter motor. There is no point repairing the oldone,ifitisgoingtocostyoumorethananew one.

Step2:Diagnosis

A faulty starter motor can sound like a flat battery, the engine turns over slowly or not at all,sometimes you can see the battery terminals and leads smoke or get hot due to the high currentsbeen drawn by the faulty starter. First thing, check for other faults. The best way to check thebattery is with aload tester but these are expensive,and there are ways aroundit.Puta voltmeter on the battery,itshouldread, around12.6 volts. If itis as low as 12.2 volts then chargethe battery. Check battery cables are clean and tight and in good condition. If all is good then thebest way to check the battery and starter motor is to remove the battery and put it into anothervehicle. If the fault moved to the other vehicle, then you have a problem with your battery,Charge it or replace it . If you have eliminated everything else chances are that the starter isfaulty.

Step3:StarterRemoval

First thing to do when doing any repair thatinvolves the high currentcables on a motor vehicle**is** DISCONNECT THE BATTERY, if you skip this step you could end up injuring yourself orsettingthecaronfire.

Step4:StrippingtheStarter

Now that you have it out find a clean work area and a container to put all the bits into. Nowwould be a good time to clean the outside of the starter, just wiped it over with a petrol soakedrag,soitis notallthatclean

Make sure you mark the case and solenoid the so it makes it easy to resemble as some parts canbe assembledaroundthewrongway.

- Removethe2screwsthatholdthebackcover andbrushesinplace
- Removetheclipandspring
- Removetheheatshield
- Disconnectthemotorcablefromthesolenoid
- Removethelongblotsthatholdthemotortogether
- Removethebrushcover
- Carefully unclipthe2brushesthatareattachedtothefieldwindingsby pullingbackthespringandremovingthebrush
- Removethebrushholder
- Removethefieldwindings
- Unboltthesolenoidandremovethearmatureandsolenoidtogether.

Step5:AssesstheDamage

Thoroughly do a visual inspection of the field windings, and armature for any burnt or brokeninsulation, broken wires corrosion or other damage. Also check the commutator on the armaturefor broken or missing segments If these parts are damageditmay be cheaper to replace thewholestartermotor.Thepiniongearandsolenoid canalsobecheckedforwearordamage.

This starter was quite corroded in places due to the recent flood we have had here, the brushesandbushesare worn,butthe restappearstobeinreasonable condition.

Step6:RepairingtheArmatureandFieldWindings

Remove any corrosion with wet and dry sand paper, and the commutator can be sanded and thebackofaboxcutterknifecanbeusedtocleanoutbetweenthesegments. Theinsulation between thesegmentsshouldbeundercuttoworkcorrectly.Thananoilyragisusedtowipeeverythingtohelppreve ntanyfuturecorrosion.

After inspecting and cleaning up everything it was decided to only replace the brushes andbushes. The bushes can be removed with socket and a hammer.The bush in the nose of thestarter has a cap which can be carefully knocked out with a 1/4" drive extension. A little heat onthe alloy nose will help remove the bush. 2 of the bushes are crimped on and can be carefullyuncrimpedandthebrushremoved.

Step7:PurchasetheParts

After inspecting and cleaning up everything it was decided to only replace the brushes andbushes. The bushes can be removed with socket and a hammer.The bush in the nose of thestarter has a cap which can be carefully knocked out with a 1/4" drive extension. A little heat onthe alloy nose will help remove the bush. 2 of the bushes are crimped on and can be carefullyuncrimpedandthebrushremoved.

Step 8:Lubricating theNewBushes

The bushes are made from phosphor bronze which is porous and has to be pre-oiled or they willnot last very long. This is not to difficult just put it on your finger and fill with engine oil thenplace your thumb on top and squeeze. Do this 2 or 3 times until you can see the oil coming outthe sidesofthebush.

Step9:FittingtheNewBushes

This step can be tricky, and if you have access to a press then use it, as you a much less likely todamage the bushes. Firstmake sure that the housing where the bushes fit into is clean, then fitthe bush to the end of the armature and gently tap it in to the housing with hammer. Make surethat the armature is straight and you tap the end of the armature flat with the hammer or it couldbe damaged. Again a little heat on the alloy end will help fit the bush. Once you have got thebush in about 1/2 way you can use a drift or large punch to drive it into its final position. Again ifyou useahammertodothisstep,begentleandgeteverythingstraightandflat.

Step10:CheckingtheBushesandPinion

I like to make sure the bushes are not damaged by fitting the armature without the field windingsand checking it all spins without binding. If the pinion needs to be replace simply slide the sleevedown and remove the wire clip. The pinion will slide off. Don't remove it unless you plan toreplaceitasthewireclipitdifficulttoremovewithoutdamagingit.Somepeoplewilltellyounot to lubricate the pinion as clutch dust can get into the starter motor and combine with the oiland make the pinion sticky. This may be true of some older vehicles, I find a small amount of oilhelpkeeps corrosionawayandkeeps everythingworking.

Step 11:FittingtheBrushes

Lookcarefullyatthebrusheshowtheyarefittedandthereorientation.2brushesarecrimpedon, they could be carefully uncrimped with side cutters and new brushes crimped back on. 2brushes are spot welded on. these 2 were carefully pulled off and a little solder melted on thebraid on the end of the brush and on the copper where it was spot welded. The brush is thensweated into position.Iuseasmallgastorchbutalargesolderingironwouldalsowork.

Step12:AssemblingtheStarter

Assembling is straight forward if you know a trick with the brush plate. Don't put the brushes inproperly have them half hanging out with the spring jammed against the side of the brush, that it,that's the trick! you can now assemble everything without having to fight with springs. Thearmature and the solenoid need to go in together and make sure you get the fork in the right spot.If you have been paying attention you will see I've put the solenoid in upside-down, whoops! thebench test will pick that up. The field windings can be fitted and the mark on the side of themotorcanbelineduptomakeiteasiertoassemble.

Step13:Assembling theStarterPart 2

The brush plate can now be fitted, and the bushes on the field windings areinserted into thebrush holders. Make sure the bolts all line up and then the brushes can be pushed in properly sothe springs are pushing down on them. The back plate or brush cover can go on next and the longbolts inserted and done up fingertight. Put one screw into the brush holdertomake sureeverything is lined up and tighten it all up. Make sure the armature turns freely. The spring andclipcangoonnextandalittleoilontheshaftbeforescrewingtheendcapon.Thenoseofthe starter can also have a little oil on the shaft before refitting the cap which is carefully put intoposition and punched on. The motor cable can be connected to the solenoid and all the bolts andscrewsre-tightenedandrechecked

Step14:Testing

The starter motor can be tested without fitting to the car, and this will find problems like meputting the solenoid in upside-down. You will need a battery and some jumper leads. Firstconnect the leadstoyourbattery,andthenthenegativeleadtothecaseofthestarter.Test1CheckingTheMotor.

Connect the positive lead to the bottom terminal on the solenoid this should make the motor spin,athighspeed.

Test2CheckingTheSolenoid.

Connect the positive lead to the small terminal on the solenoid this should make the pinion slideout and engage the ring gear. (this is when I noticed the solenoid upside down as it failed to dothis)

Test3CheckingBothMotorAndSolenoid.

Connectthe positiveleadto thetop terminal on the solenoid.Thestartermotorshoulddonothing it shouldn't spark or click. Connect another positive lead to the small terminal on thesolenoid the starter should fire up throwing the pinion out and spinning the motor. If all is wellrefitthe heatshieldanditreadytogobackonthecar.

Step15:ReductionBoxStarterMotor

Reduction box starter motors are becoming more common and have a few differences. They a setofgearsinside andusebearingratherthanbushes.

Just a quick note on solenoids. The type that is fitted to is fitted to our 4AGEstarter in therebuild is not repairable, it doesn't come apart, thankfully they are very reliable. There is anotherstyleof solenoidfittedtoreductionbox startersthatis repairablebutseem togivemoreproblems,Iwoulddefinitelybe replacingthestartercontactsandplunger.

CHAPTER–3

GeneratingSystem

Generatingsystem is requiredtorecharge the battery whichis animportantcomponentofelectrical system of an automobile. Charging is required as the capacity of a battery to supplycurrent is limited to the energy stored in it in the form of chemical energy. Battery supplies thecurrenttorunthe startingmotor,variouslightsandhorn,etc.

Thegeneratingsystem generateselectricity torechargethebattery andrun otherelectricalcomponents.

ComponentsOfAGeneratingSystem

Generatingsystemconsists of:

- GeneratororDynamo:Itconvertsmechanicalenergyintoelectricalenergy.
- Regulator:Itcontrolsthegeneratoroutputaccordingtotheneed.Itcontrolsthecurrentorvoltage.
- Relay : Itis used tocontrol the flow of currentbetween generator and battery. Itacts ascircuitbreaker.

Generator

A generator is a machine used to convert mechanical used to convert mechanical energy intoelectrical energy. When it is driven by the engine it produces electricity for runningall theelectrical circuits of the automobile and keeps the battery in charged condition. This is thefunctionofgenerator.

Flemming’sRightHandRule

If thumb, fore finger and middle finger of right hand are stretched so that they are mutuallyperpendicular then the direction of induced currentin the conductor can be found outby thisrule.

“If the fore finger indicates the direction of magnetic field and the thumb shows the direction ofmotion of the conductor, then middle finger will indicate the direction induced current”. This iscalledFlemming‟srighthandrule.

Lenz'sLaw

Lenz's law, named after the physicist Emil Lenz whoformulated itin 1834, states that thedirection of the electric current which is induced in a conductor by a changing magnetic field issuch that the magnetic field created by the induced current opposes the initial changing magneticfield.

It is a qualitative law that specifies the direction of induced current, but states nothing about itsmagnitude. Lenz's law explains the direction of many effects in electromagnetism, such as thedirection of voltage induced in an inductor or wire loop by a changing current, or the drag forceofeddycurrentsexertedonmovingobjects inamagneticfield.

The current induced in a circuit due to a change in a magnetic field is directed to oppose thechangeinfluxandtoexertamechanicalforcewhichopposesthemotion.

Lenz's law is contained in the rigorous treatment of Faraday's law of induction, where it findsexpressionbythenegativesign:

which indicatesthattheinduced electromotiveforceandtherateofchangein magneticfluxhaveoppositesigns.

PrincipleOfGenerator

“When a conductor moves in a magnetic field, current is produced in it. The direction of currentisdeterminedbyFlemming‟srighthandrule”.

A magnetic field acts between north and south poles of magnets. There are lines of forcesbetween two poles. When the conductor moves such that lines of force are cut, current is inducedin the conductor. This current can be used to run any electrical components, e.g. lights andchargingsystem,etc.

The current induced in the conductor depends upon the rate at which force lines are cut andstrengthofmagneticfield,etc.

When the conductor (armature of dynamo) is rotated (by engine) in the magnetic field, a currentis induced in the conductor. The direction of flow of current in the two legs of conductor isopposite because their direction of motion is also opposite. The two ends of conductor connectedto the commutator (two split copper rings) and these are connected to external circuit throughcarbon brushes. Thus, rotation of the armature generates current which can be used for runningelectrical systems of an automobile. The magnets used are electromagnets which are suppliedenergyfromthegeneratoritself.Thearmatureconsistsofacore,windingsand anarmature shaft.

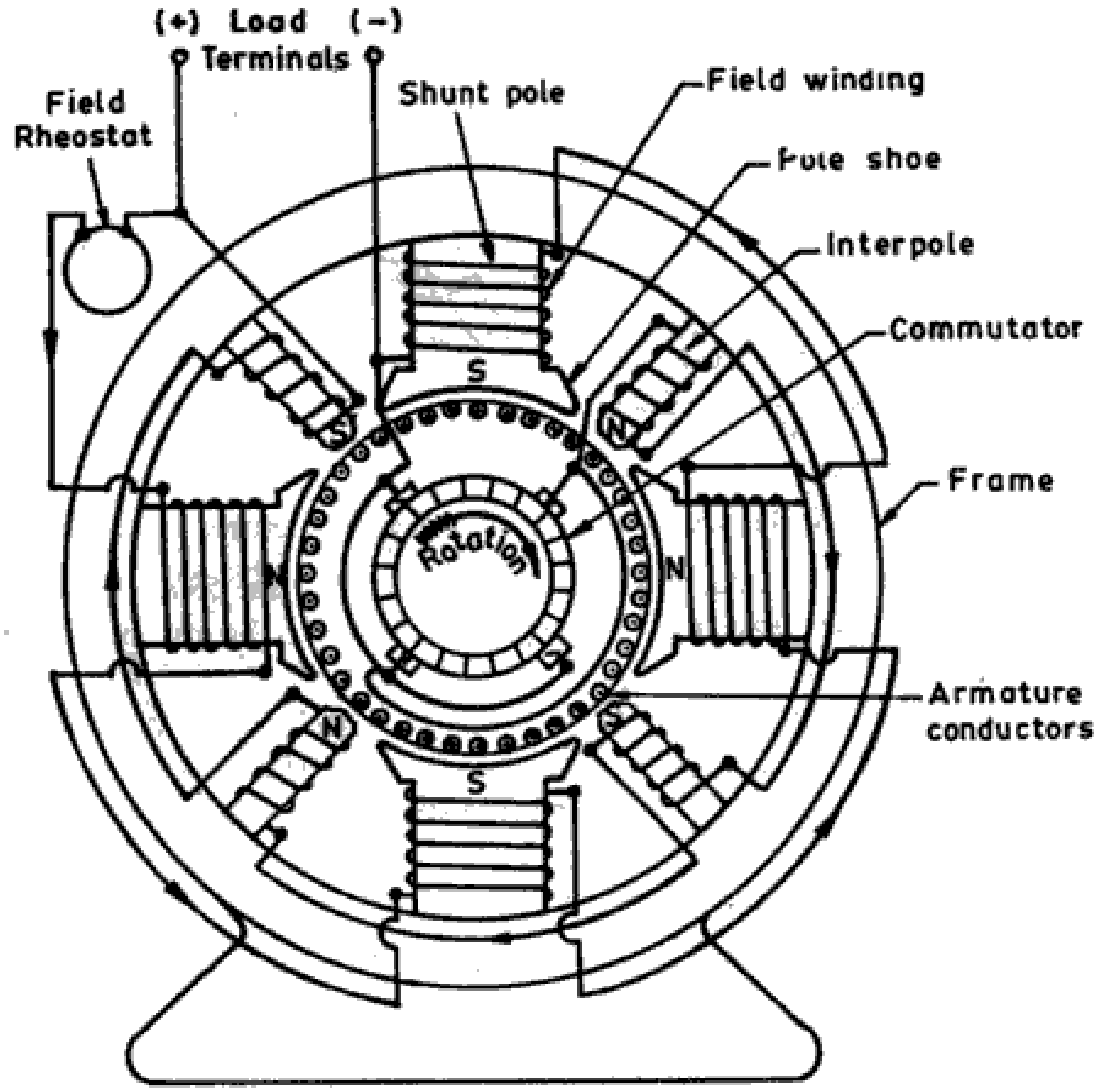
According to Faraday's law of electromagnetic induction, when a conductor moves in a magneticfield (thereby cutting the magnetic flux lines), a dynamically induced emf is produced in theconductor. The magnitude of generated emf can be given by emf equation of DC generator. If aclosed path is provided to the moving conductor then generated emf causes a current to flow inthe circuit.

Thus in DC generators, as we have studied earlier, when armature is rotated with the help of aprime mover and field windings are excited (there may be permanent field magnets also), emf isinducedinarmatureconductors.Thisinducedemfistakenoutviacommutator-brusharrangement.

ConstructionOfDCGenerator

Inconstructiondcmachineconsistsoffourparts.

1. Fieldmagnets
2. Armature
3. Commutator
4. Brushandbrushgear



FieldSystem:

The object of the field system is to create a uniform magnetic field within with the armaturerotates. Electromagnets are preferred on the account of their magnetic effects and field strengthregulation which can be achieved by controlling the magnetizing current. Field magnets consistofthefollowingparts:

- YokeorFrame
- Polecores
- Poleshoes
- Magnetizingcoils

Cylindrical yoke is usually used which acts as a frame of the machine and carries the magneticflux produced by the poles. Since the fieldis stationary thereis noneed to use laminated yokefor normal machine. In small machines, cast iron yokes are used because of its cheapness butyoke oflargemachinesaremade offabricatedsteeldue toits highpermeability.

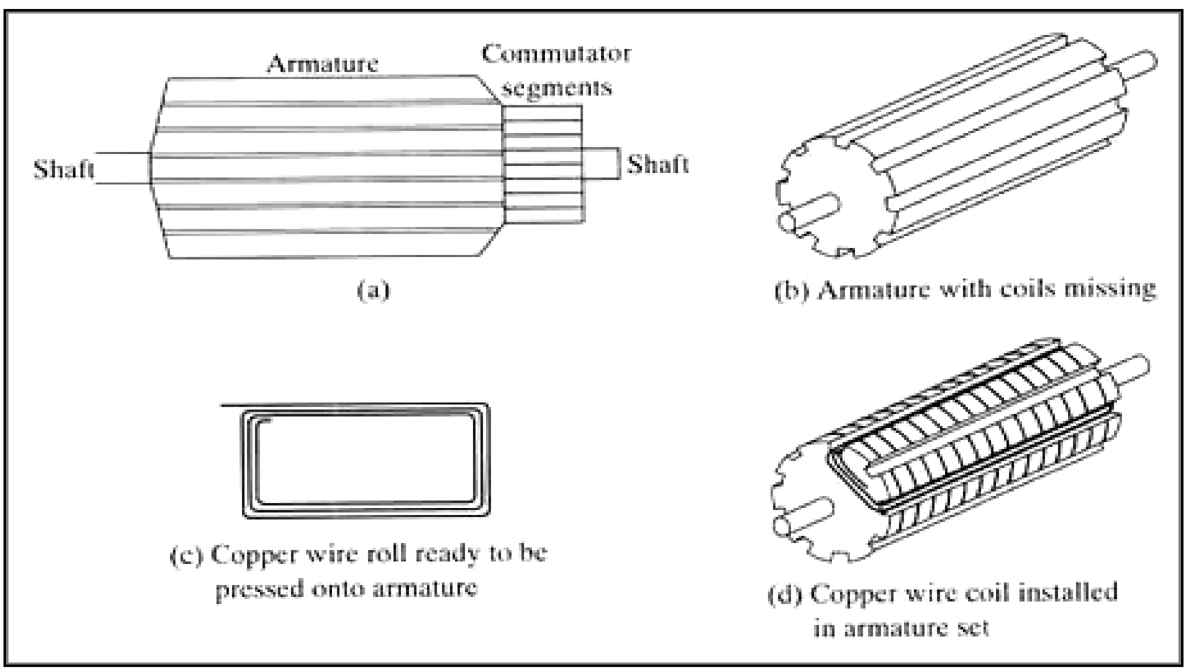
Pole core is usually of circular section and is used to carry the coils of insulated wires carryingtheexcitingcurrent.Polecoresareusuallynotlaminated andmadeofcaststeel.

Each pole core has a pole shoe serves having a curved surface. The pole shoe serves twopurposes:

- Itsupportsthefieldcoils
- Itincreases thecross-sectionalareaofthe magnetic circuitand reducesitsreluctance.

Each pole core has one or more field coils or magnetizing coils placed over it to produce amagneticfield.Thefield coils are connected in series with one anothersuch that when thecurrent flows through the coils, alternate north and south poles are produced in the direction ofrotation.

Armature:



ItisarotatingpartofaDCmachineandisbuiltupinacylindricalordrumshape.Thepurposeof armature is to rotate the conductors in the uniform magnetic field. It consists of coils ofinsulated wires wound around an iron and so arranged that electric currents are induced in thesewires when the armature is rotated in a magnetic field. Its most important function is to provide apath of low reluctance to the magnetic flux. The armature core is made of high permeabilitysilicon-steelstampings.

Commutator:

It is a form of rotating switch. They are placed between armatureand external circuit. Thecommutator will reverse the connections to the external circuit at the instant each reversal ofcircuitinthearmature coil.

Brushes&Bearings:

Brushes are made of carbon or graphite. It collects current from the commutator and convey it toexternal load resistance. It is rectangular in shape. Brushes are housed in brush holders andmounted over brush holder studs. Ball bearings are used as they are reliable for light machines.Forheavymachines rollerbearings areused.

TypesOfGenerators

Generators are usually classified according to the way in which their fields are excited. The fieldwindings provide the excitation necessary to set up the magnetic fields in the machine. There arevarious types of field windings that can be used in the generator or motor circuit. In addition tothefollowingfieldwindingtypes,permanentmagnetfieldsare usedon somesmallerDCproducts.

Generatorsmaybedividedinto

- Separately-excitedgenerators
- Self-excitedgenerators

Separately-excited generators are those whose field magnets are energised from an independentexternalsourceofDCcurrent.

Self-excited generators are those whose field magnets are energised by the current produced bythe generators themselves. Due to residual magnetism, there is always present some flux in thepoles. When the armature is rotated, some e.m.f and hence some induced current is producedwhich is partly or fully passed through the fieldcoils thereby strengthening the residual poleflux.

Self-excited generators are classed according to the type of field connection they use. There arethreegeneraltypes offieldconnections—

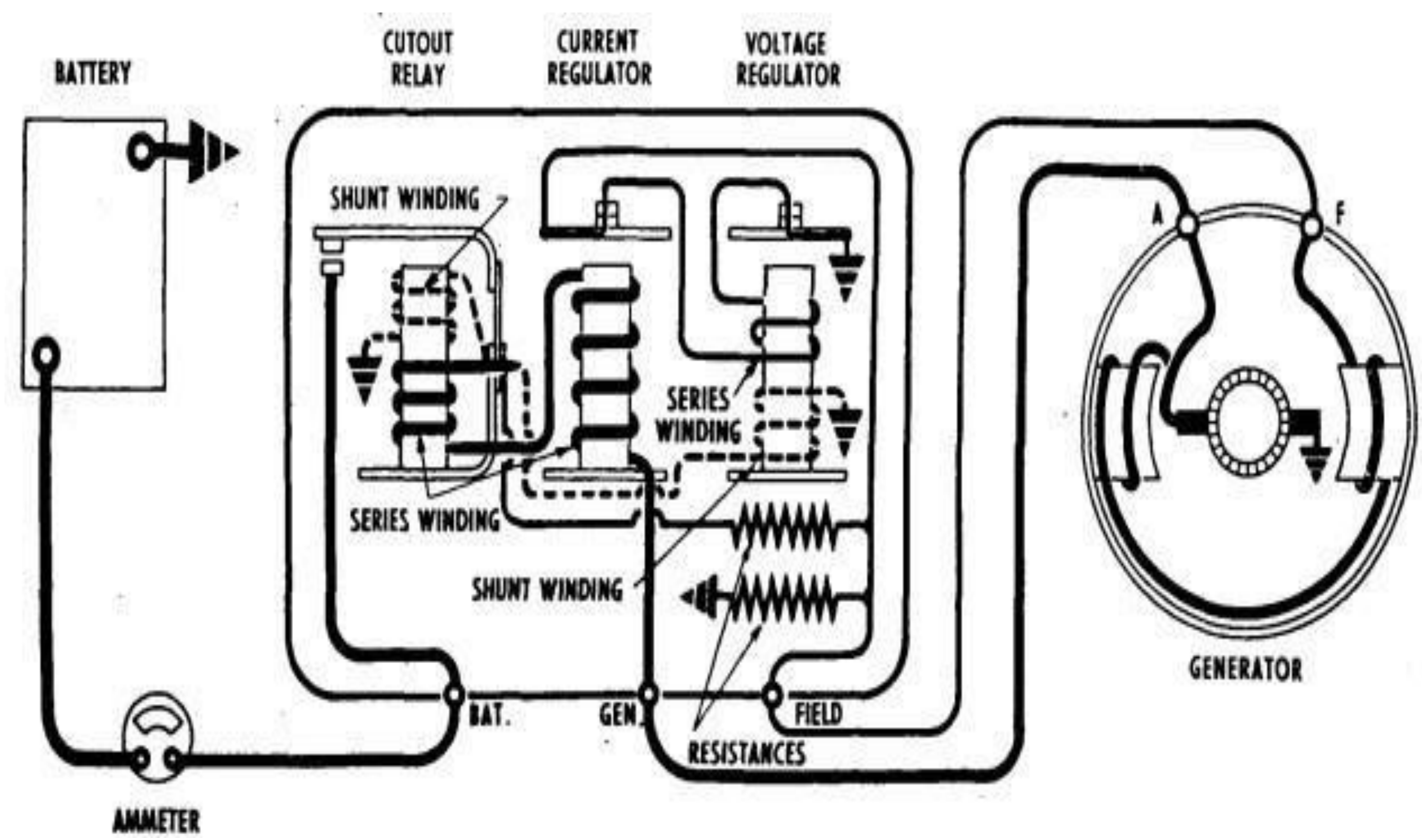
- Series-wound
- Shunt-wound(parallel)
- Compound-wound

Compound-woundgeneratorsarefurtherclassifiedas

- Cumulativecompound
- Differentialcompound

RegulatorsForGenerator

The voltage and current of a generator are controlled by providing an external resistance. Theregulation is required to prevent generator to generate excessive voltage and current. In onemethod, a resistance is connected in the field circuit. It is connected between the field windingsand insulated brush. The field circuit is grounded through the brush inside the generator. Theswitch remains closed till the voltage output is not excessive. The switch connects the outer endof the field circuit to the ground. In case, voltage increases beyond a given limit, the switchopens. This brings the resistance in the field circuit. Because of this, the current flowing in thefieldwindingsdecreases.The voltageisalsoreduced.



VoltageRegulator

The voltage regulator has two windings assembled on a single core, a shuntwinding consistingof many turns of fine wire which is shunted across the generator, and a series winding of a fewturns of relatively heavy wire which is connected in series with the generator field circuit whenthe regulatorcontactpoints are closed.

The windings and core are assembled into a frame. A flat steel armature is attached to the frameby a flexible hinge so that it is just above the end of the core. The armature contains a contactpointwhichisjustbeneathastationarycontactpoint.Whenthevoltageregulatorisnotoperating, the tension of a spiral spring holds the armature away from the core so that the pointsareincontactandthe generatorfieldcircuitiscompleted togroundthroughthem.

VoltageRegulatorAction

When the generator voltage reaches the value for which the voltage regulator is adjusted, themagnetic field produced by the two windings (shunt and series) overcomes the armature springtension and pulls the armature down so that the contact points separate. This inserts resistanceintothe generatorfieldcircuitsothatthe generatorfieldcurrentandvoltage are reduced.Reduction of the generator voltage reduces the magnetic field of the regulator shunt winding.Also, opening the regulator points opens the regulator series winding circuit so that its magneticfield collapses completely. The consequence is that the magnetic field is reduced sufficiently toallow the spiral spring to pull the armature away from the core so that the contact points againclose. This directly grounds the generator field circuit so that generator voltage and outputincrease. The above cycle of action again takes place and the cycle continues at a rate of 50 to200 times a second, regulating the voltage toa predeterminedvalue. With the voltage thuslimited the generator supplies varying amounts of current to meet the varying states of batterychargeandelectricalload.

CutoutRelay

Cutoutrelayactsascircuitbreakerbetweengeneratorandbatterywhendynamoisnotgenerating any current. It prevents the discharging of battery in case generator is not working orrunningatverylowspeeds.

This relay is nothing but a magnetic switch which closes to connect battery and generator whengenerator is running. When generator does not running, a spring breaks the circuit between thebatteryandgenerator.

The cutout relay has two windings, a series winding of a few turns of heavy wire and a shuntwinding of many turns of fine wire. The shunt winding is connected across the generator so thatgeneratorvoltageisimpresseduponitatalltimes.

The series winding is connected in series with the charging circuit so that all generator outputpassesthroughit.Therelaycoreandwindingsareassembledintoaframe.Aflatsteel armatureis attached to the frame by a flexible hinge so that it is centered just above the end of the core.Thearmaturecontactpointsarelocatedjustabovethestationarycontactpoints.Whenthe generator is not operating, the armature contact points are held a wax from the stationary pointsbythetensionofaflatspringrivetedonthesideofthe armature.

CutoutRelayAction

When the generator voltage builds up a value great enough to charge the battery, the magnetisminduced by the relay windings is sufficient to pull the armature toward the core sothat thecontactpoints close.The currentwhich flowsfrom the generator to the battery passes throughthe series winding in a direction to add to the magnetism holding the armature down and thecontactpointsclosed.

Whenthe'generatorslowsdown orstops,currentbeginstoflowfrom thebattery tothegenerator. This reverse flow of current through the series winding causes a reversal of the serieswinding magnetic field. The magnetic field of the shunt winding does not reverse. Therefore,instead of helping each other, the two windings now magnetically oppose so that the resultantmagnetic field becomes insufficient to hold the armature down. The flat spring pulls the armatureaway from the core so that the points separate; this opens the circuit between the generator andbattery.

Maintenance

The generator generates energy. A broken belt – one of the most common issues related togenerator failures. Itcan be fixed by using a long sock. However, such fixing will notlastforlong – more reliable work is being performed at car service and repair center were specialgenerator belts and tensioning mechanisms or bearings are to be installed. When the belt isbroken,youwillonlybeable totravelfewkilometersusingthe remaining batterypower.

Thismayendupinaworsesituation–thegeneratorcouldbecompletelydamagedandshouldbe replaced. In such case, the car won’t run, an engine will completely malfunction and smokemayappear.The carwillneedtobeurgentlytakentothegarage.

In order to guarantee a safe and more economical operation of your generator, you must proceedwith its continuedmaintenance. If care mustbe taken with the essential components, so itmustbe withalltheotherelements,whichmustbe checkedfrequently.

Most of the failures in starting the generator are related to the battery. The misuse of thiscomponentandthelackofmaintenanceleadtoitsdeteriorationand,consequently,toitsimproperfunctioning,renderingitincapable ofturningthestartermotor.

In addition, the battery is especially susceptible to damage, since it is prone to the accumulationofleadsulfatesonitsplates,eventuallybreakingdownandbecomingobsolete.

It is therefore very important to pay attention to this element, checking it carefully and regularly,andtakingthe necessarymaintenanceprecautions,asdescribedbelow.

CHAPTER–4

Alternator

AC generators are usually called alternators. They are also called synchronous generators. Asynchronous generator is a machine for converting mechanical power from a prime mover to acelectricpowerata specificvoltageandfrequency.

“An alternator generates alternating current (AC) unlike a dynamo which generates direct current(DC)”.

Modern automobiles which require more electric loads are fitted with alternators insteadofdynamos. These vehicles require more electrical power because they have power steering, powerwindows,electricalsystemforautomobiletransmission,etc.

ArectifierisrequiredtoconvertACtoDCasallelectricalequipmentsuseDC.

PrincipleOfAlternator

Theoperationofasynchronousgeneratorisbasedon Faraday'slawofelectromagneticinduction, and in an ac synchronous generator the generation of emf's is by relative motion ofconductors and magnetic flux. The rotating magnetic field induces an AC voltage in the statorwindings. Since the currents in the stator windings vary in step with the position of the rotor, analternator is asynchronous generator.

The principle of working of alternator differs from that of dynamo in the manner in which theconductor and magnetic field move relative to each other. In an alternator the conductor remainsstationary butthe magneticfieldisrotated. However, conductor rotates and magneticfieldremains stationaryincaseofadynamo.

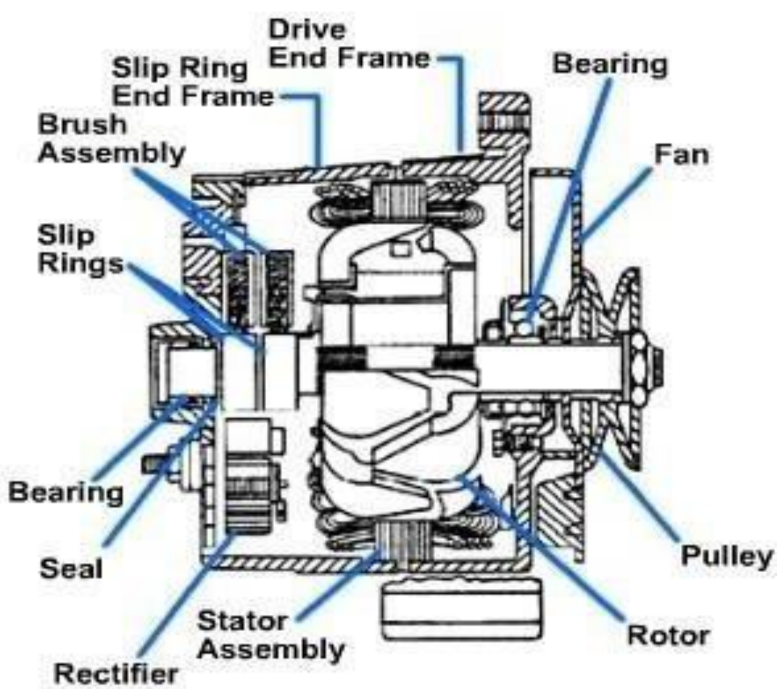
In an alternator, a rotating bar magnet produces magnetic field which is cut by a stationaryconductor.Thenorthpoleofrotatingmagnetisattopandsouthpoleatthebottom.Ifthis magnet is rotated by half revolution such that north pole comes down and south pole takes upperposition. During this the current in the upper leg of conductor flows in one direction. The northpole of magnet at bottom and south pole at top. When the magnet is now rotated by another halfrevolution, the direction of current in the wire is reversed. Therefore, with the revolution ofmagnet, the current reverses its direction after each half revolution. Thus, an alternating currentflows.Thisis theprincipleofworkingofanalternator.

The alternator has replaced the DC (Direct Current) generator because of its improved efficiency.It is smaller, lighter, and more dependable than the DC generator. The alternator also producesmore output during idle, which makes it ideal for late model vehicles. The alternator has aspinningmagneticfield.The outputwindings (stator) are stationary.As themagneticfieldrotates, itinducescurrentintheoutputstatorwindings.

In constructing a synchronous machine a point to note is that the stator is fixed and the polesrotate.

TherearetwocategoriesofSynchronousmachines:

- Thosewithsalientorprojectingpoles
- Those withcylindricalrotors



AlternatorConstruction

Knowledgeoftheconstructionofanalternatorisrequiredbeforeyoucanunderstandtheproperoperation, testingprocedures, andrepairproceduresapplicable toanalternator.

Theprimarycomponentsofanalternatorare asfollows:

- The rotor assembly (rotor shaft, slip rings, claw poles, and field windings)consists offield windings (wire wound into a coil placed over an iron core) mounted on the rotorshaft . Two claw-shaped pole pieces surround the field windings to increase the magneticfield. The fingers on one of the claw-shaped pole pieces produce south (S) poles and the otherproduces north (N) poles. As the rotor rotates inside the alternator, alternating N-S-N-Spolarity andAC currentare produced. An external source of electricity (DC)is requiredtoexcitethemagneticfieldofthe alternator.
  Slip rings are mounted on the rotor shaft to provide current to the rotor windings. Eachendofthefieldcoilconnectstothesliprings.

- Stator assembly (three stator windings or coils, output wires, and stator core). The statorassembly produces the electrical output of the alternator . The stator, which is part of thealternator frame when assembled, consists of three groups of windings or coils whichproduce three separate AC currents. This is known as three-phase output. One end of thewindings is connected to the stator assembly and the other is connected to a rectifierassembly. The windings are wrapped around a soft laminated iron core that concentratesandstrengthenthemagneticfieldaroundthestatorwindings.

  Therearetwotypes ofstators.

  - Ytypestator
  - Delta-typestator

The Y-type stator has the wire ends from the stator windings connected to aneutral junction . The circuit looks like the letter Y. The Y type stator providesgoodcurrentoutputatlowenginespeeds.

The delta-type stator has the stator wires connected end to- end. With no neutraljunction, two circuit paths are formed between the diodes. A delta-type stator isusedinhighoutputalternators.

- The rectifier assembly, also known as a diode assembly, contains the heat sink, diodes,diode plate, and electrical terminals. It consists of six diodes used to convert stator ACoutput into DC current. The current flowing from the stator winding is allowed to passthrough an insulated diode. As the current reverses direction, it flows to ground through agrounded diode. The insulated and grounded diodes prevent the reversal of current fromthe rest of the charging system. By this switching action and the number of pulses createdby motion between the windings of the stator and rotor, a fairly even flow of current issuppliedtothebatteryterminalofthealternator.

  The rectifier diodes are mounted in a heat sink or diode bridge. Three positive diodes arepress fit in an insulated frame. Three negative diodes are mounted into an uninsulated orgroundedframe.

  When an alternatorisproducingcurrent,theinsulateddiodespassonlyoutflowingcurrent to the battery. The diodes provide a block, preventing reverse current flow fromthe alternator.

AlternatorOperation

The operation of an alternator is somewhat different than the DC generator. An alternator has arotating magnet (rotor) which causes the magnetic lines of force to rotate with it. These lines offorce are cut by the stationary (stator) windings in the alternator frame as the rotor turns with themagnetrotatingtheNandSpolestokeepchangingpositions.WhenSisupandNisdown, current flows in one direction, but when N is up and S is down, current flows in the oppositedirection. Thisis calledalternating currentas it changes direction twicefor each completerevolution. If the rotor speed were increased to 60 revolutions per second, it would produce 60-cycleAC.

Since the engine speed varies in a vehicle, the frequency also varies with the change of speed.Likewise, increasing the number of pairs of magnetic north and south poles will increase thefrequency by the number pair of poles. A four-pole generator can generate twice the frequencyperrevolutionofatwo-polerotor.

AlternatorOutputControl

A voltage regulator controls alternator output by changing the amount of current flowthroughthe rotor windings. Any change in rotor winding current changes the strength of the magneticfield acting on the stator windings. In this way, the voltage regulator can maintain a presetchargingvoltage.Thethreebasic typesofvoltageregulatorsareasfollows:

- Contactpointvoltageregulator,mountedawayfromthealternatorintheenginecompartment.
  The contact point voltage regulator uses a coil, set of points, and resistors that limitsystem voltage. The electronic or solid-state regulators have replaced this older type. Foroperation,refertothe "RegulationofGeneratorOutput"section ofthischapter.

- Electronicvoltageregulator,mountedawayfromthealternatorintheenginecompartment.
  The electronic voltage regulators use an electronic circuit to control rotor field strengthand alternator output. It is a sealed unit and is not repairable. The electronic circuit mustbe sealed to prevent damage from moisture, excessive heat, and vibration. A rubberlikegelsurrounds thecircuitforprotection.
  An integral voltage regulator is mounted inside or on the rear of the alternator. This is themostcommon type usedon modern vehicles.Itis small,efficient,dependable,andcomposedofintegratedcircuits.

- The integral voltage regulator is mounted on the back of orinside the alternator.Itperforms the same operation as a contact point or electronic regulator, except that it usestransistors, diodes, resistors, and capacitors to regulate voltage in the system. To increasealternatoroutput,thevoltageregulatorallowsmorecurrent intotherotorwindings,thereby strengthening the magnetic field around the rotor. More current is then inducedintothestatorwindings andoutofthealternator.

  To reduce alternator output, the voltage regulator increases the resistance between thebattery and the rotor windings. The magnetic field decreases, and less current is inducedintothestatorwindings.

  Alternatorspeedandloaddetermineswhethertheregulatorincreasesordecreasescharging output. If the load is high or rotor speed is low (engine at idle), the regulatorsenses a drop in system voltage. The regulator then increases the rotor's magnetic fieldcurrent until a preset output voltage is obtained. If the load drops or rotor speed increases,theoppositeoccurs.

EMFEquationOfAnAlternator

Let,

P=No.ofpoles

Z=No.ofConductorsorCoilsidesinseries/phasei.e.Z=2TwhereTisthe

numberofcoilsorturns perphase

f=frequencyofinduced e.m.finHzϕ=

Fluxperpole (Weber)

N=rotorspeed (RPM)

Ifinducede.m.fisassumed sinusoidalthen,Kf= Formfactor=1.11

Inone revolutionoftherotori.e.in60/N seconds,eachconductoriscutbyafluxofPϕWebers.

dϕ=ϕPandalsodt=seconds60/N

then induced e.m.f per conductor (average) = dϕ/ dt= Pϕ/(60/N) =P N ϕ/60

…..(a)ButWeknowthatf=PN/120orN=120f/P

PuttingthevalueofNinEquation(a)...

Weget

theaveragevalueofe.m.fperconductoris**Eav**=

Pϕ/60 x 120 f/P **= 2f ϕ Volts.** {N=

120f/P}Ifthereare Zconductors inseries perphase,

thenaverage e.m.fperphase=2fϕZVolts**=*4fϕTVolts* ....** {Z=2T}

AlsoweknowthatFormfactor=RMSValue/AverageValue...

=>**RMSvalue**=FormfactorxAverageValue,

=1.11x4fϕT=4.44fϕTVolts.

AlternatorMaintenance

Alternator testing and service call for special precautions since the alternator output terminal isconnected to the battery at all times. Use care to avoid reversing polaritywhen performingbattery service of any kind. A surge of current in the opposite direction could burn the alternatordiodes.

Do not purposely or accidentally "short" or "ground" the system when disconnecting wires orconnecting test leads to terminals of the alternator or regulator. For example, grounding of thefieldterminal ateitheralternator or regulatorwill damagetheregulator.Groundingof thealternator output terminal will damage the alternator and possibly other portions of the chargingsystem.

Never operate an alternator on an open circuit. With no battery or electrical load in the circuit,alternators are capable of building high voltage (50 to over 110 volts) which may damage diodesandendangeranyonewhotouches the alternatoroutputterminal.

Alternator maintenance is minimized by the use of prelubricated bearings and longerlastingbrushes. If a problem exists in the charging circuit, check for a complete field circuit by placing alarge screwdriver on the alternator rear-bearing surface. If the field circuit is complete, there willbe a strong magnetic pull on the blade of the screwdriver, which indicates that the field isenergized. If there is no field current, the alternator willnot charge because it is excited bybatteryvoltage.

Should you suspect troubles within the charging system after checking the wiring connectionsand battery, connect a voltmeter across the battery terminals. If the voltage reading, with theengine speed increased, is within the manufacturer’s recommended specification, the chargingsystem is functioning properly. Should the alternator tests fail, the alternator should be removedfor repairs or replacement. Do NOT forget, you must ALWAYS disconnect the cables from thebatteryfirst.

CHAPTER–5

IgnitionSystem

IgnitionSystem

In spark ignition engines, a device is required to ignite the compressed air-fuel mixture at theend of compression stroke. Ignition system fulfills this requirement. It is a part of electricalsystem which carries the electric current at required voltage to the spark plug which generatesspark at correct time. It consists of a battery, switch, distributor ignition coil, spark plugs andnecessarywiring.

Acompressionignitionengine,i.e.adieselenginedoesnotrequireanyignitionsystem.Because, self ignition of fuel air mixture takes place when diesel is injected in the compressedairathightemperatureatthe endofcompressionstroke.

RequirementsOfAnIgnitionSystem

a) Theignitionsystemshouldbecapableofproducinghighvoltagecurrent,ashighas25000volts,so thatsparkplugcanproducesparkacross itselectrodegap.
b) Itshouldproducesparkforsufficientdurationsothatmixturecanbeignitedatalloperatingspeeds ofautomobile.
c) Ignitionsystemshouldfunctionsatisfactoryatallenginespeeds.
d) Longerlifeofcontactpointsandsparkplug.
e) Sparkmustgenerateatcorrecttimeattheendofcompressionstrokeineverycycleofengine operation.
f) Thesystemmustbeeasytomaintain,lightinweightandcompactinsize.
g) Thereshouldbeprovisionofsparkadvancewithspeed andload.
h) Itshouldbeabletofunctionsmoothly evenwhenthesparkplugelectrodesaredepositedwithcarbonleadoroil.

FUNCTIONSOF COMPONENTSUSEDINCIRCUITS

Functionsofvariouscomponentsused insparkignitionarediscussedhereinbrief.

Battery

It is an important component of electrical system. The battery supplies the necessary current tothe primary winding of ignition coil which is converted into high voltage current to producespark. It also supplied current to run the starting motor when engine is cranked for starting. Abattery stores energy in the form of chemical energy and supplies it for running lights and otheraccessoriesofanautomobile.Lead-acidbatteryiscommonlyusedin mostoftheautomobiles.

Ignition orInduction Coil

The ignition coil is step up transformer to increase the voltage form 12 volt or 6 volt to 20000-30000 volts.Itconsists of a primary winding and a secondary winding wound on a laminatedsoft iron core. Primary winding contains about 300 turns made of thick wire. Secondary consistsof about 20000 turns of thin wire. In a can type coil, secondary is wound on the soft core overwhich primary is wound. This assembly is housed in a steel casing fitted with a cap. The cap ismade of insulating material. The terminals for electrical connections are provided in cap. To savethewindingsfrommoistureandtoimproveinsulation,windingsaredippedinoil.

ContactBreakers

Contact breaker is required to make contact and break contact of the primary circuit of ignitionsystem. It consists of two contact breaker points as shown in Figures. One point remains fixedwhile the other can move. A cam is used to move the movable point. As cam moves, the contactis made and broken alternately. Primary circuit breaks when the breaker points open. Magneticfield collapses due to this. This produces high voltage current in the secondary winding which issupplied to the distributor. This current is distributor to proper spark plug where itproducessparkforignitionof fuel-airmixture.

Condenser

The function of the condenser in the ignition system is to absorb and store the inductive currentgenerated in the coil. If condenser is not provided, the induced current will cause arcing at thebreakerpoints.Thiswillcauseburningofthebreakerpoints.

Distributor

The distributor sends the high voltage current, generated in the secondary winding, to the properspark plug at proper time. If the automobile is having a four cylinder engine, it will have foursparkplugs.

The cap of the distributor is connected to the secondary winding of coil. It has a rotor whichrotates and comes in contact with the terminals (4 in number for 4 spark plugs) placed around therotor. As the rotor comes in contact with the terminals (numbered 1, 2, 3 and 4 in Figures), thecurrentispassed totherespective spark plugatpropertimewhensparkis needed.

IgnitionSwitch

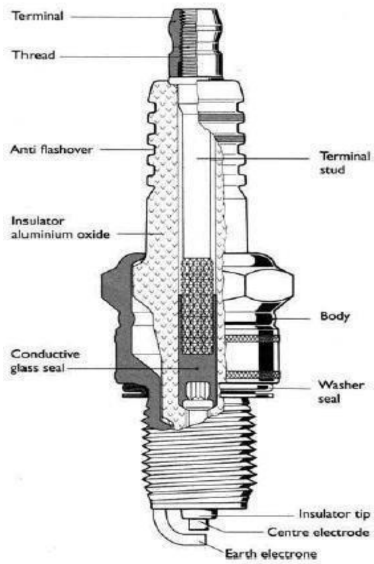
Thefunctionoftheignitionswitchistoconnectthebatteryandstartingmotorintheautomobileshavingsel fstartingsystem.

Example: Incar, jeep, etc.

Itsfunctionistoconnectbatterytoinductioncoilinthebatteryignitionsystem.

SparkPlugs

Thefunctionofthesparkplugistoproducesparkbetweenitselectrodes.Thissparkisusedtoignitethe fuel-airmixtureinthesparkignition(SI)engines.



IgnitionTimingDevices

Ignition timing refers to how early or late the spark plugs fire in relation to the position of theengine pistons.Ignitiontimingmustvarywithengine speed,load,and temperature.

Timing advance happens when the spark plugs fire sooner than the compression strokes of theengine.The timingissetseveraldegrees beforetopdeadcenter(TDC).

More time advance is required at higher speeds to give combustion enough time to developpressureonthepowerstroke.

Timing retard happens when the spark plugs fire later on the compression strokes. This is theoppositeof timingadvance.Sparkretardisrequiredatlowerspeedsandunderhighloadconditions. Timing retard prevents the fuel from burning too much on the compression stroke,whichwouldcausesparkknockorping.

Thebasicmethodstocontrolignitionsystemtimingareasfollows:

- Centrifugaladvance(controlled byenginespeed)
- Vacuumadvance(controlledbyintakemanifoldvacuumandengineload)
- Computerizedadvance(controlledbyvarioussensors—speed,temperature,intake,vacuum,throttleposition,etc.)

ComputerizedAdvance

The computerized advance, also known as an electronic spark advance system, uses variousengine sensors and a computer to control ignition timing. The engine sensors check variousoperating conditions and sends electrical data to the computer. The computer can change ignitiontimingformaximumengineefficiency.

Ignitionsystemenginesensorsincludethefollowing:

- Enginespeedsensor (reportsenginespeed tothecomputer)
- Crankshaftpositionsensor(reportspistonposition)
- Throttlepositionswitch(notesthe positionofthethrottle)
- Inletair temperaturesensor(checksthetemperatureoftheair entering theengine)
- Enginecoolanttemperaturesensor(measurestheoperating temperatureoftheengine)
- Detonationsensor(allowsthecomputertoretardtimingwhentheengineknocksorpings)
- Intakevacuumsensor (measuresenginevacuum,anindicatorofload)
- The computerreceives differentcurrentorvoltagelevels (inputsignals)from thesesensors. It is programmed to adjust ignition timing based on engine conditions. Thecomputermaybemountedontheaircleaner,underthedash,onafenderpanel,orundera seat.

The following is an example of the operation of a computerized advance. A vehicle is travelingdowntheroadat50mph;thespeedsensordetectsmoderateenginespeed.

The throttle position sensor detects part throttle, and the air inlet and coolant temperature sensorsreport normal operating temperatures. The intake vacuum sensor sends high vacuum signals tothe computer.

The computerreceivesall the data andcalculates that the engine requiresmaximum sparkadvance. The timing would occur several degrees before TDC on the compression stroke. Thisactionassures thathighfueleconomyisattainedontheroad.

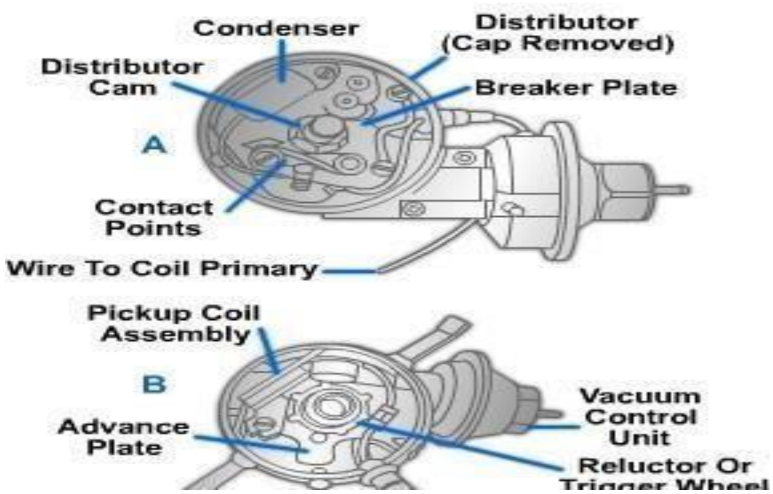
If the operator begins to pass another vehicle, intake vacuum sensor detects a vacuum drop tonear zero and a signal is sent to the computer. The throttle position sensor detects a wide openthrottle and other sensor outputs say the same. The computer receives and calculates the data,then,ifrequired,retardsignitiontimingtopreventsparkknockorping.

IgnitionDistributor

Anignitiondistributorcanbeacontactpoint.Acontactpointdistributoriscommonlyfoundinoldervehicles,whereasthepickup coiltypedistributorisusedonmanymodernvehicles.

Theignitiondistributorhasseveralfunctions:

- It actuatestheon/offcyclesofcurrentflowthroughtheprimarywindingsofthecoil.
- Itdistributesthe highvoltagesurgesofthecoiltothesparkplugs.
- It causes the spark to occur at each spark plug earlier in the compression stroke as speedincreases.
- It changes spark timing with the changes in engine load. As more load is placed on theengine, the spark timing must occur later in the compression stroke to prevent sparkknock.
- Insomecases,the bottomofthedistributorshaftpowerstheengineoilpump.
- In some electronic distributors, the distributors house the ignition coil and the electronicswitchingunit.



The distributor cap is an insulating plastic component that covers the top of thedistributorhousing. Its center terminal transfers voltage from the coil wire to the rotor. The distributor capalso has outer terminals that send electric arcs to the spark plugs. Metal terminals are moldedintotheplasticcaptoprovideelectricalconnections.

The distributor rotor transfers voltage from the coil wire to the spark plug wires. The rotor ismounted on top of the distributor shaft. It is an electrical switch that feeds voltage to each sparkplugwireinturn.

A metal terminal on the rotor touches the distributor cap center terminal. The outer end of therotor almost touches the outer cap terminals. Voltage is high enough that it canjump the airspace between the rotor and cap. Approximately 4,000 volts are required for the spark to jumpthisrotor-to-capgap.

SolidStateIgnition(ReplacesIgnition Coil)

Anelectronicignition, alsocalledsolidstateignition, usesanelectroniccontrolcircuitanddistributorpickupcoiltooperatetheignitioncoil.

Anelectronicignition ismoredependablethanasystemofcontactpointsbecausethereare no mechanical breakers to burn out or wear down. This avoids trouble with ignitiontiming.

An electronic ignition is capable of producing a significantly higher secondary voltageoverapointssystem. Thisallows forawidersparkpluggapandhighervoltagetoburnlean air-fuel mixtures. Leaner mixtures are now used to reduce emissions and improvefueleconomy.

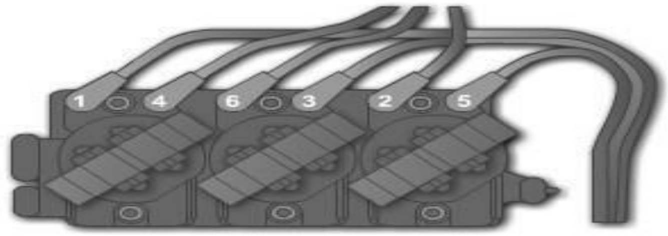
DistributorlessIgnition

A distributorless ignition uses multiple ignition coils, a coil control unit, engine sensors, and acomputertooperatethesparkplugs.

The electronic coil module consists of more than one coil and a coil control unit that operates thecoils.Themodule’s control unitperforms about the samefunction as the IgnitionControlModule (ICM) in an electronic ignition. It will analyze data from different engine sensors and thesystemcomputer.

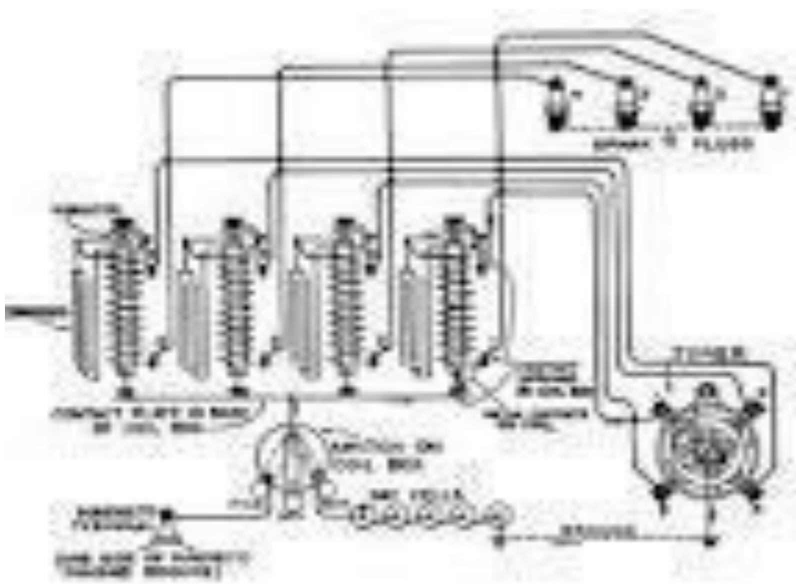
The coils are wired so they fire two spark plugs at the same time. One plug will fire on the powerstroke and the other will fire on the exhaust stroke (there is no effect on engine operation). Thissystem reduces the number of ignition coils required to operate the engine. For instance, a fourcylinderwouldhave onlytwocoils,asixcylinderwould haveonlythreecoils andso on.

A camshaft position sensor is installed in place of the ignition distributor. It sends an electricalpulsetothe coilcontrolunitprovidingdataoncamshaftandvalve position.



BatteryorCoilIgnitionSystem

Battery ignition system consists of a battery of 6 or 12 volts, ignition switch, induction coil,contact breaker, condenser, distributor and spark plugs. A typical battery ignition system for fourcylinderSIenginehasbeenshowninFigure



The primary circuit consists of battery, switch, primary winding and contact breaker point whichis grounded. A condenser is also connected in parallel to the contact breaker points. One end ofthe condenser is grounded and other connected to the contact breaker arm. It is provided to avoidsparkingatcontactbreakerpointssoastoincreasetheirlife.

The secondary ignition circuit consists of secondary winding distributors and spark plugs. Allsparkplugs aregrounded.

Theignitioncoilstepsup12volts(or6volt)supplytoaveryhighvoltagewhichmayrangefrom 20,000 to30,000 volts.A high voltageis requiredfor the spark tojumpacross the sparkpluggas.Thissparkignitestheair-fuelmixtureastheendofcompressionstroke.Therotorofthedistributorrevolvesanddistributorsthecurrenttothefoursegmentswhichsendthecurrenttodifferentsparkplugs.Fora4-cylinderenginethecamofthecontactbreakerhasfourlobes.Therefore,itmakesandbreaksthecontactoftheprimarycircuitfourtimesineveryrevolutionof cam. Because of which current is distributed to all the spark plugs in some definite sequence.Theprimarywindingofignitioncoilhaslessnumberofturns(e.g.200turns)ofthickwire.Thesecondarywindinghasrelativelylargenumberofturns(e.g.20,000turns)ofthinwire.Whenignitionswitchinturnedon,thecurrentflowsfrombatterytotheprimarywinding.Thisproducesmagneticfieldinthecoil. Whenthecontactpointisopen,themagneticfieldcollapsesand themovementof themagneticfieldinduces currentin the secondary windingof ignitioncoil.Asthenumbersofturnsinsecondarywindingaremore,averyhighvoltageisproducedacross theterminals ofsecondary.

The distributor sends this high voltage to the proper spark plug which generates spark forignition of fuel-air mixture. In this way, high voltage current is passed to all spark in a definiteordersothatcombustionoffuel-airmixturetakesplaceinallcylindersoftheengine.

A ballast register is connected in series in primary circuit to regulate the current. At the time ofstarting this register is bypassed so that more current can flow in this circuit. The breaker pointsareheldbyaspringexceptwhentheyareforcedapartbylobes ofthecam.

Advantages

a) Lowinitialcost.
b) Bettersparkatlowspeedsandbetterstartingthanmagnetosystem.
c) Reliablesystem.
d) Noproblemsduetoadjustmentofsparktimings.
e) Simplerthanmagnetosystem.

Disadvantages

a) Batteryrequiresperiodicalmaintenance.
b) Incaseofbatterymalfunction,enginecannotbestarted.

Magneto-ignitionSystem

This system consists of a magneto in place of a battery. So, the magneto produces and suppliescurrent in primary winding. Rest of the system is same as that in battery ignition system. AmagnetoignitionsystemforafourcylinderSIenginehasbeenshowninFigure.

The magneto consists of a fixed armature having primary and secondary windings and a rotatingmagneticassembly.Thisrotatingassemblyis drivenbytheengine.

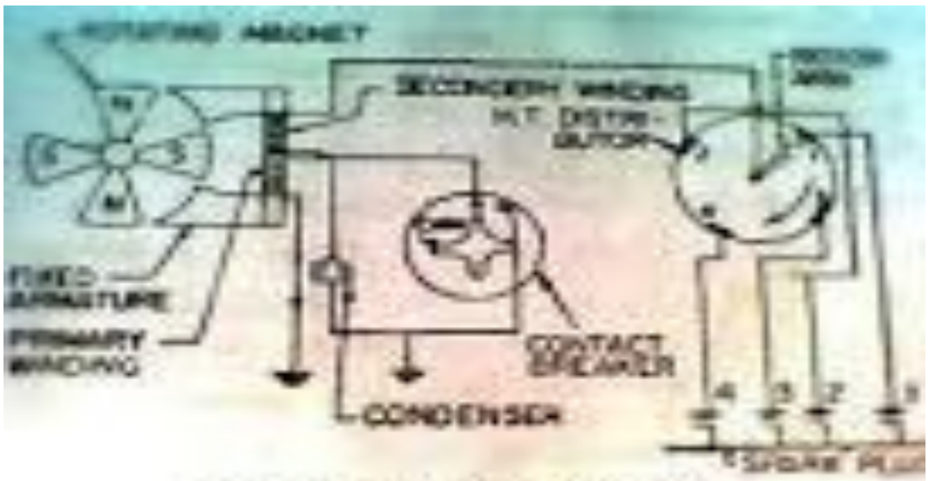


Fig. Magneto ignition system

Rotationofmagnetogeneratescurrentinprimarywindinghavingsmallnumberofturns.Secondary windinghavinglargenumberof turnsgenerateshighvoltagecurrentwhichissupplied to distributor. The distributor sends this current to respective spark plugs. The magnetomay be of rotating armature type or rotating magnet type. In rotating armature type magneto, thearmature having primary and secondary windings and the condenser rotates between the poles ofastationaryhorseshoemagnet.Inmagneto, themagneticfieldisproducedby permanentmagnets.

Advantages

a) Betterreliabilityduetoabsenceofbatteryandlowmaintenance.
b) Bettersuitedformediumandhighspeedengines.
c) Modernmagnetosystemsaremorecompact,thereforerequirelessspace.

Disadvantages

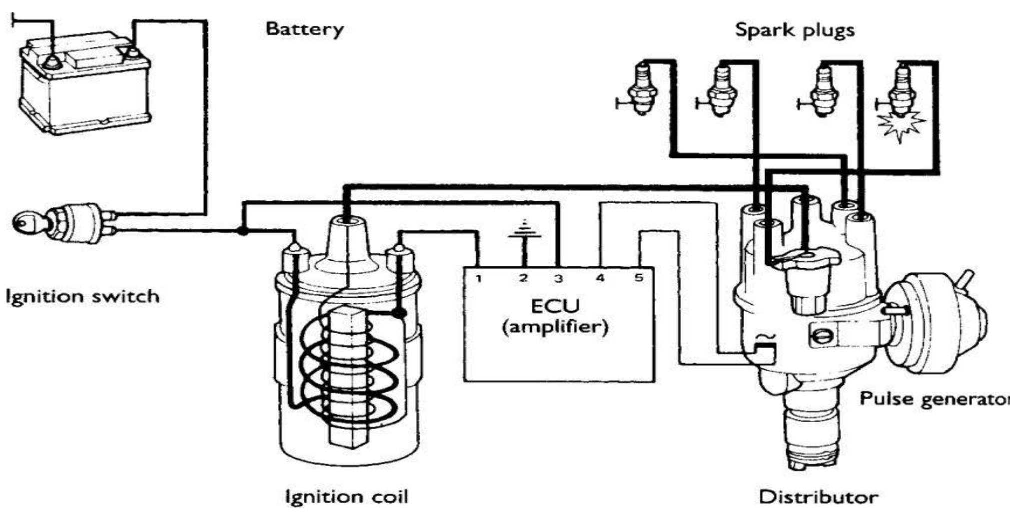
a) Adjustmentofsparktimingsadverselyaffectsthevoltage.

b) Burningofelectrodesispossibleathighenginespeedsduetohighvoltage.
c) Costismorethanthatofmagnetoignitionsystems.

ElectronicIgnitionSystem

Electronic ignition is now fitted to almost all spark ignition vehicles. This is because theconventionalmechanicalsystemhassomemajordisadvantages.

- Mechanicalproblemswiththecontactbreakers, nottheleastofwhichisthelimitedlifetime.
- Currentflowintheprimarycircuitislimitedtoabout4Aordamagewilloccurtothecontacts – oratleastthelifetimewillbeseriouslyreduced.
- Legislationrequiresstringentemissionlimits,whichmeanstheignitiontimingmuststayintunef oralongperiodoftime.



- Weaker mixtures require more energy from the spark to ensure successful ignition, evenatveryhighenginespeed.

These problems can be overcome by using a power transistor to carry out the switching functionand a pulse generator to provide the timing signal. Very early forms of electronic ignition usedthe existing contact breakers as the signal provider. This was a step in the right direction but didnot overcome all the mechanical limitations, such as contact bounce and timing slip. Most (all?)systems nowadays are constant energy, ensuring high performance ignition even at high enginespeed.Figure the circuitofastandardelectronicignitionsystem.

DistributorlessIgnition

Distributorless ignition systems (DIS) have been around for almost a decade now, and haveeliminated much of the maintenance that used to be associated with the ignition system. Nodistributor means there's no distributor cap or rotor to replace, and no troublesome vacuum ormechanical advance mechanisms to cause timing problems. Consequently, DIS ignition systemsareprettyreliable.

Even so, that doesn't mean they are trouble-free. Failures can and do occur for a variety ofreasons. So knowing how to identify and diagnose common DIS problems can save you a lot ofguesswork the next time you encounter an engine that cranks but refuses to start, or one that runsbutismissingor misfiringononeormorecylinders.

If an engine cranks but won't start, is it fuel, ignition or compression? Ignition is usually theeasiest of the three to check because on most engines, all you have to do is pull off a plug wireand checkfor spark when the engineis cranked.On coil-over-plug DIS systems, there are noplug wiressoyouhaveto removeacoiland use aplugwire oradaptertocheckfora spark.

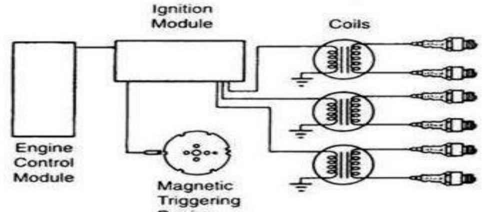
If there's no spark in one cylinder, try another. No spark in any cylinder would most likelyindicate a failed DIS module or crankshaft position sensor. Many engines that are equipped withelectronic fuel injection also use the crankshaft position sensor signal to trigger the fuel injectors.So, if there's no spark and no injector activity, the problem is likely in the crank position sensor.Nospark in only one cylinder or twocylinders thatshare a coil would tell you a coil hasprobablyfailed.

PrincipleofOperation

DistributorlessignitionsystemusedextensivelybyFordincorporatesallthefeaturesofelectronic spark advance systems, except a special type of ignition coil is used in place of HTdistributor. The system is generally used only on four- or six-cylinder engines, because thecontrol system becomes highly complex for higher number of cylinders. It works on the principleof the lost spark. The spark distribution is achieved by the help of two double ended coils, firedalternately by the ECU. The ignition timing is obtained from a crankshaft speed and positionsensor as well as through load and other corrections. When one of the coils is fired, a spark isdeliveredtotwoenginecylinders,either1and4,or2and3.Thesparkdeliveredtothecylinder on the compression stroke ignites the mixture as normal. Whereas the spark in other cylindercausenoeffect,as thiscylinderisjustcompletingits exhauststroke.Because of thelowcompression and the exhaust gases in the lost spark cylinder, the voltage only of about 3 kV isneededfor the spark tojump the gap. This is similar to cap voltage of themore conventionalrotor arm. The spark produced in the compression cylinder is therefore not affected. It may benoted that the spark on one of the cylinders jumps from the earth electrode to the spark plugcentre, whereas in others it jumps from the centre electrode. This is because the energy availablefrom modern constant energy systems produces a spark of suitable quality in either direction.However,thedisadvantageisthat thespark plugsmaywearmore quicklywiththissystem.

SystemComponents

Thedistributorlessignitionsystemcontainsthreemaincomponentssuchastheelectronicmodule, a crankshaft position sensor and the distributorless ignition coil. Many systems use amanifold absolute pressure sensor, integrated in the module. The module functions almost in thesame way as the electronic spark advance system. The crankshaft position sensor operates in thesimilar way to the one described in the previous section. It is also a reluctance sensor positionedagainst the front of the flywheel or against a reluctor wheel just behind the front crankshaftpulley. The tooth pattern uses 36-1 teeth, which are spaced at 10 degree intervals, with a gap forthe 36th tooth. The missing tooth is located at 90 degrees before TDC for numbers 1 and 4cylinders.ThisreferencepositionislocatedafixednumberofdegreesbeforeTDCforcalculatingthetimingorignitionpointasafixedangleafterthereferencemark.Thedistributorless ignition coil has a low tension winding, which is supplied with battery voltage to acentre terminal.The appropriate half of the windingis then connected to earth in themodule.Thehightensionwindingsareseparateandarespecifictocylinders1and4,or2and3.Figure 16.57 shows a typical Ford distributorless ignition coil. The Citroen 2 CV has been using adouble endedignitioncoiltogetherwithcontactbreakersformanyyears.



FaultDiagnosis

The distributorless ignition system is highly reliable, specifically because it does not have anymovingparts.Thenormalmanufacturersservicingscheduleshouldbeadheredtoforthereplacement of spark plugs (often after 19,200km operation). Some problems may be facedwhen trying to examine HT oscilloscope patterns, due to the lack of a king lead. This can beovercome by using a special adapter and shifting the sensing clip to each lead in turn. Anohmmeter can be used to test the distributorless ignition coil. The resistance of each primarywinding should be 0.5 Q and the secondary windings between 11 and 16 kQ. The coil producesopen circuit voltage in excess of 37 kV. The plug leads have integral retaining clips to preventwater ingress and vibration problems. The maximum resistance for the HT leads is 30 kQ perlead. Except for the octane adjustment on some models no service adjustments are possible withthis system. This adjustment involves connecting two pins together on the module for normaloperation, or earthing one pin or the other to change to a different fuel. The actual procedure asspecifiedbythemanufacturerforeachparticularmodelshould befollowed.

DIGITALIGNITIONSYTEM

ElectronicIgnitionSystemisasfollow:

a) CapacitanceDischargeIgnitionsystem
b) Transistorizedsystem
c) Piezo-electricIgnitionsystem
d) TheTexacoIgnitionsystem

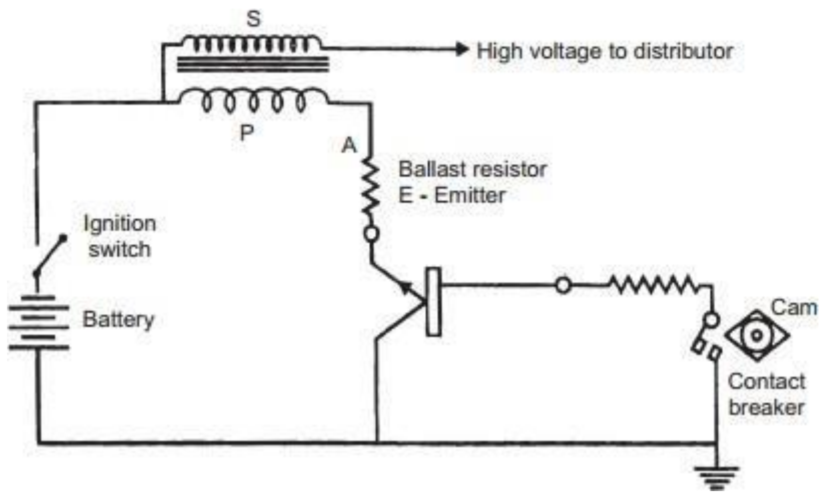
TransistorizedAssistedContact(TAC)IgnitionSystem

Advantages

a) Thelowbreaker-current ensureslongerlife.
b) Thesmallergapandlighterpointassemblyincreasedwelltimeminimizecontactbouncingandimproverepeatabilityofsecondaryvoltage.
c) The low primary inductance reduces primary inductance reduces primary current drop-offathighspeeds.

Disadvantages

a) Asintheconventionalsystem,mechanicalbreakerpointsarenecessaryfortimingthespark.
b) Thecostoftheignitionsystemisincreased.
c) Thevoltagerise-timeatthesparkplugisaboutthesameasbefore.



IgnitionSystemMaintenance

Ignition troubles can result from a myriad of problems, from faulty components to loose ordamaged wiring. Unless the vehicle stops on the job, the operator will report trouble indications,andtheequipmentis turnedintotheshopforrepairs.

Unless the trouble is known, a systematic procedure should be followed to locate the cause.Remember, electric current will follow the path of least resistance. Trace ignition wiring whilechecking for grounds, shorts, and open circuits. Bare wires, loose connections, and corrosion arefoundthroughvisualinspection.

After checking the system, you must evaluate the symptoms and narrow down the possiblecauses. Use your knowledge of system operation, a service manual troubleshooting chart, basictestingmethods,andcommonsensetolocatethetrouble.

Many shops have specialized equipment that provides the mechanic a quick and easy means ofdiagnosingignitionsystemmalfunctions.

SparkPlugsandSparkPlugWires

Bad spark plugs cause a wide range of problems such as misfiring, lack of power, poor fueleconomy, and hard starting. After prolonged use, the spark plug tip can become coated with ash,oil, and other residue. The spark plug electrodes can also burn and widen the gap. This makes itmoredifficultfor the ignitionsystemtoproduceanelectricarcbetweenthe electrodes.

Toreadspark plugs closely,inspectandanalyze the condition of each spark plugtipandinsulator. This will give you information on the condition of the engine, the fuel system, and theignitionsystem.Theconditionscommonlyencounteredwithspark plugsareasfollows:

- Normal operation condition appears as brown to grayish-tan deposit with slight electrodewear. This indicates the correct spark plug heat range and mixed periods of high- andlow-speed operation. Spark plugs having this appearance may be cleaned, regapped, andreinstalled.
- Carbon-fouled condition appears as dry,fluffy black carbon.This results from slowoperating speeds, wrong heat range (too cold), weak ignition (weak coil, worn ignitioncables, etc.), faulty automatic choke, sticking manifold control valve, or rich air-fuelmixture. Sparkplugshavingthisappearancemaybecleaned,regapped,andreinstalled.
- Oil-fouled condition appears as wet, oily deposits with very little electrode wear. Thisresults from worn rings, scored cylinder, or leaking valve seals. Spark plugs having thisappearancemaybedegreased,cleaned,regapped,andreinstalled.
- Ash-fouled condition appears as red, brown, yellow, or white colored deposits whichaccumulateon theinsulator.Thisresultsfrompoorfuel quality oroilenteringthecylinder. Most ash deposits have no adverse effect on the operation of the spark plug aslong as they remain in a powdery state. However, under certain conditions these depositsmelt and form a shiny glaze on the insulator which, when hot, acts as a good electricalconductor,allowingcurrenttofollowthedepositinsteadofjumpingthegap,thusshorting out the spark plug. Spark plugs having a powdery condition may be cleaned,regapped,and replaced.Thosehaving aglazeddepositmustbereplaced.
- Preignitondamageappearsasburnedorblisteredinsulatortipsandbadlywornelectrodes. This results from over-advanced timing, low octane fuel, wrong spark plugheat range (too high), or a lean air-fuel mixture. Spark plugs having thiscondition mustbe replacedwithoneshavingtherecommendedheatrange.

When a spark plug is removed for cleaning or inspection, it should be regapped to the enginemanufacturer’s specifications. New spark plugs must also be regapped before installation, as theymayhave beendroppedormishandledandmaynotbewithinspecifications.

Use a wire type feeler gauge to measure spark plug gap. Slide the feeler gauge between theelectrodes. If needed, bend the side electrode until the feeler gauge fits snugly. The gauge shoulddrag slightly as it is pulled in and out of the gap. Spark pluggaps vary from 0.030 inch oncontactpointignitionstoover0.060inchonelectronicignitionsystems.

When you are reinstalling spark plugs, tighten them to the manufacturer’s recommendation.Some manufacturers give spark plug torque, while others recommend bottoming the plugs on theseat and then turning an additional one-quarter to one-half turn. Refer to the manufacturer’sservicemanualforexactprocedures.

A faulty spark wire can either have a burned or broken conductor, or it could have deterioratedinsulation. Most spark plugs wires have a resistance conductor that can be easily separated. If theconductor is broken, voltage and current cannot reach the spark plug. If the insulation is faulty,sparks may leak through to ground or to another wire instead of reaching the spark plugs. To testthe wiresforproperoperation,youcan performthefollowing:

- Asparkplugwireresistancetestwillcheckthesparkplugconductor orcoil wireconductor. To perform a wire resistance test, connect an ohmmeter across each end of thewire. The meter will read internal wire resistance in ohms. Typically resistance shouldNOT be over 5,000 ohms per inch or 100,000 ohms total. Since specifications vary,compareyourreadingstothemanufacturer’s specifications.
- A spark plug wireinsulation testchecksfor sparks arcing through the insulationtoground. To perform an insulation test with the hood up, block out as much light aspossible, start the engine, and move a grounded screwdriver next to the insulation. If aspark jumps through the insulation to the screwdriver, the wire is bad. Spark plug leakageisa conditioninwhichelectricarcs passthroughthewireinsulation.

Installing new spark plug wire is a simply task, especially when you replace one wire at a time.Wire replacement is more complicated if all of the wires have been removed. Then you must useengine firing order and cylinder numbers to route each wire correctly. You can use servicemanuals totracethewiresfromeachdistributorcaptowertothecorrectsparkplug.

DistributorService

The distributor is critical to the proper operation of the ignition system. The distributor sensesengine speed, alters ignition timing, and distributes high voltage to the spark plugs. If any part ofthe distributorisfaulty,engine performancesuffers.

When problems point to possible distributor cap or rotor troubles, remove and inspect them. Thedistributor cap should be carefully checked to see that sparks have not been arcing from point topoint. Both interior and exterior must be clean. The firing points should not be eroded, and theinterior of the towers must be clean. The rotor tip, from which the high-tension spark jumps toeach distributor cap terminal,should not be worn.It alsoshould be checkedfor excessiveburning,carbontrace,looseness,orotherdamage.Anywearorirregularitywillresultinexcessiveresistancetothehigh-tensionspark.Makesurethattherotorfitssnugly onthedistributorshaft.

A common problem arises when a ***carbon trace*** forms on the inside of the distributorcap orouter edge of the rotor. The carbon trace will short coil voltage to ground or to a wrong terminallug in the distributor cap. A carbon trace will cause the spark plugs to either fire poorly or not atall.

Using a droplight, check the inside of the distributor cap for cracks and carbon trace. Carbontrace is black, which makes it hard to see on a black colored distributor cap. If you find carbontraceoracrack,replacethedistributorcaporrotor.

Inacontactpointdistributor,therearetwoareasof concern:thecontactpointsandthecondenser.

Bad contact points cause a variety of engine performance problems. These problems include highspeedmissing,no-startproblems,andmanyotherignitiontroubles.

Visually inspect the surfaces of the contact points to determine their condition. Pointswithburnedandpittedcontactsorwithawornrubbingblockmustbereplaced.

However,ifthepointslookgood,pointresistanceshouldbemeasured.Turntheengineoveruntilthepointsareclosedandthenuseanohmmetertoconnectthemetertotheprimarypointlead and to ground. If resistance reading is too high, the points are burned and must be replaced.Afaultycondensermayleak(allowsomeDCcurrenttoflowtoground),beshorted(directelectricalconnectiontoground),orbeopened(brokenleadwiretothecondenserfoils).Ifthecondenserisleakingoropen,itwillcausepointarcingandburning.If thecondenserisshorted, primary current will flow to ground and the engine will not start. To test a condenser using anohmmeter, connect the meter to the condenser and to ground. The meter should register slightlyand then return to infinity (maximum resistance). Any continuous reading other than infinityindicates thatthecondenserisleakingandmustbereplaced.

Installing contactpointsis a relatively simpleprocedure butmustbe done with precision andcare in order to achieve good engine performance and economy. Make sure the points are cleanandfreeofanyforeignmaterial.

Proper alignment of the contact points isextremely important. If the faces of the contact pointsdo not touch each other fully, heat generated by the primary current cannot be dissipated andrapid burning takes place. The contacts are aligned by bending the stationary contact bracketonly. Never bend the movable contact arm. Ensure the contact arm-rubbing block rests flushagainst the distributor cam. Place a small amount of an approved lubricant on the distributor camtoreducefrictionbetweenthecamandrubbingblock.

Once you have installed the points, you can adjust them using either a feeler gauge or dwellmeter.

To use a feeler gauge to set the contact points, turn the engine over until the points arefullyopen. The rubbing block should be on top of a distributor cam lobe. With the points open, slidethe specified thickness feeler gauge between them. Adjust the points so that there is a slight dragon the blade of the feeler gauge. Depending upon point design,use a screwdriver or Allenwrench to open and close the points. Tighten the hold-down screws and recheck the point gap.Typically point gap settings average around .015inch for eight-cylinder engines and .025 inchfor six- and four-cylinder engines. For the gap set of the engine you are working on, consult themanufacturer's servicemanual.

Ensure the feeler gauge is clean before inserting it between the points. Oil and grease will reducethe servicelifeofthepoints.

To use a dwell meter for adjusting contact points, connect the red lead of the dwell meter to thedistributorside oftheignitioncoil(wiregoingtothecontactpoints).

Connecttheblack leadtoground.

If the distributor cap has an adjustment window, the points should be set with the engine running.With themetercontrolssetproperly,adjustthepointsthroughthewindowofthedistributorcap using an Allen wrench or a special screwdriver. Turn the point adjustment screw until the dwellmeterreads withinmanufacturer’sspecification.

However, if the distributor cap does not have an adjustment window, remove the distributor capandgroundtheignition coil wire.Then cranktheengine; thisaction will simulateengineoperationandallowpointadjustmentwiththedwellmeter.

Dwell specifications vary with the number of cylinders. An eight-cylinder engine requires 30degrees of dwell. An engine with few cylinders requires more dwell time. Always consult themanufacturer’s servicemanualforexactdwellvalues.

Dwell should remain constant as engine speed increases or decreases. However, if the distributoris worn, you can have a change in the dwell meter reading. This is known as dwell variation. Ifdwell varies more than 3 degrees, the distributor should either be replaced or rebuilt. Also, achangeinthepointgapordwellwillchangeignitiontiming.

Forthisreason,thepointsshouldalwaysbeadjustedbeforeignitiontiming.

Most electronic ignition distributors use a pickup coil to sense trigger wheel rotation and speed.The pickup coil sends small electrical impulses to the ECU. If the distributor fails to producetheseelectricalimpulsesproperly,theignitionsystemcanquitfunctioning.

A faulty pickup coil will produce a wide range of engine troubles, such as stalling, loss of power,or failure to start at all. If the small windings in the pickup coil break, they will cause problemsonly under certain conditions. It is important to know how to test a pickup coil for properoperation.

Thepickupcoilohmmetertestcomparesactualpickupresistancewiththemanufacturer’sspecifications. If the resistance is too high or low, the pickup coil is faulty. To perform this test,connect the ohmmeter across the output leads of the pickup coil. Wiggle the wire to the pickupcoil and observe the meter reading. This will assist in locating any breaks in the wires to thepickup. Also, using a screwdriver, lightly tap the coil. This action will uncover any break in thecoilwindings.

Pickup coil resistance varies between 250 and 1,500 ohms, and you should refer to the servicemanual for exact specifications. Any change in the readings during the pickup coil resistance testindicates the coil should be replaced. Refer to the manufacturer’s service manual for instructionsfortheremovalandreplacementofthepickupcoil.

Once you have replaced the pickup coil, you need to set the pickup coil air gap. The air gap is thespace between the pickup coil and the trigger wheel tooth. To obtain an accurate reading, use anonmagneticfeelergauge (plasticorbrass).

With one tooth of the trigger wheel pointing at the pickup coil, slide the correct thickness non-magnetic feeler gauge between the trigger wheel and the pickup coil. Move the pickup coil in orout until the correct air gap is set. Tighten the pickup coil screws and double check the air gapsetting.

IgnitionTiming

The ignition system must be timed so the sparks jump across the spark plug gaps at exactly theright time. Adjusting the distributor on the engine so that the spark occurs at this correct time iscalled setting the ignition timing. The ignition timing is normally set at idle or a speed specifiedby the engine manufacturer. Before measuring engine timing, disconnect and plug the vacuumadvance hose going to the distributor. This action prevents the vacuum advance from functioningandupsettingthereadings.

Make the adjustment by loosening the distributor hold-down screw and turning the distributor initsmounting.

Turningthedistributorhousingagainstthedistributorshaftrotationadvancesthetiming.Turningthe distributorhousingwithshaftrotationretardsthe timing.

When the ignition timing is too advanced,the engine may suffer from spark knock orping.When ignition timing is too retarded, the engine will have poor fuel economy and power and willbe very sluggish during acceleration. If extremely retarded,combustion flames blowing out ofthe open exhaust valve can overheat the engine and crack the exhaust manifolds.A timing lightis used to measure ignition timing. It normally has three leads—two small leads that connect tothe battery, and one larger lead that connects to the number one spark plug wire. Depending onthe type of timing light, the large lead may clip around the plug wire (inductive type), or it mayneedtobe connecteddirectlytothemetalterminaloftheplugwire(conventionaltype).

Draw a chalk line over the correct timing mark. This will make it easier to see. The timing marksmay be either on the front cover in harmonic balance of the engine, or they may be on the engineflywheel.

With the engine running, aim the flashing timing light at the timing mark and reference pointer.The flashing timing light will make the mark appear to stand still. If the timing mark and thepointer do not line up, turn the distributor in its mounting until the timing mark and pointer arealigned.Tightenthedistributorhold-downscrew.

Keepyourhandsandthetiminglightleadsfromtheenginefanandbelts.Thespinningfanandbelts candamagethelightorcauseseriouspersonalinjury.
Aftertheinitialignitiontiming,youshouldchecktoseeiftheautomaticadvancemechanismisworking.This canbedonebykeepingthetiminglightflashesaimedatthetimingmarkandgradually increasing speed. If the advance mechanism is operating, the timing mark should moveawayfromthepointer.Ifthetimingmarkfailstomoveasthespeedincreasesorithesitatesandthen suddenly jumps, the advance mechanism is faulty and should either be repaired or replaced.Replacethedistributorvacuumlineandseeiftimingstill conformstothemanufacturer’sspecifications.IfthetimingisNOTadvancedwhenthevacuumlineisconnectedandthethrottleisopenedslightly,thevacuumadvanceunitortubingisdefective.
Mostcomputer-controlledignitionsystemshavenoprovisionfortimingadjustment.Afew,however,have atinyscreworleveronthecomputerforsmallignitiontimingchanges.
A computer-controlled ignition system has what is known as base timing. Base timing is theignition timing without computer-controlled advance. Base timing is checked by disconnecting awire connector in the computer wiring harness. This wire connector may be found on or near theengine or sometimes next to the distributor. When in thebase timing mode, a conventionaltiming light can be used to measure ignition timing. If ignition timing is not correct, you canrotate the distributor, in some cases, or move the mounting for the engine speed or crank positionsensor. If base timing cannot be adjusted, the electronic control unit or other components willhavetobereplaced.
Always refer to the manufacturer’s service manual when timing a computer-controlled ignitionsystem.

CHAPTER–6

Light

LIGHTING

The lighting circuit includes the battery, vehicle frame, all the lights, and various switches thatcontrol their use. The lighting circuit is known as a single-wire system since it uses the vehicleframeforthereturn.

The complete lighting circuit of a vehicle can be broken down into individual circuits, eachhaving one or more lights and switches. In each separate circuit, the lights are connected inparallel,and thecontrollingswitch isinseriesbetweenthegroupoflightsand the battery.

The marker lights, for example, are connected in parallel and are controlled by a single switch. Insome installations, one switch controls the connections to the battery, while a selector switchdetermines which of two circuits is energized. The headlights, with their high and low beams, areanexampleofthis typeofcircuit.

In some instances, such as the courtesy lights, several switches may be connected in parallel sothat any switch may be used to turn on the light. When awiring diagram is being studied, alllightcircuits can be traced from thebattery through the ammeter to the switch (or switches)tothe individuallight.

LAMPS

Smallgas-filledincandescentlampswithtungstenfilamentsareusedonautomotiveandconstructionequipment.The filamentssupplythelightwhensufficientcurrentisflowingthrough them. They are designed to operate on a low voltage current of 12 or 24 volts, dependinguponthevoltageofthevehiclewillbeofthesingle-ordouble-contactsmallone-half-candlepower bulbs to large 50- candlepower bulbs. The greater the candlepower of the lamp, themore current it requires when lighted. Lamps are identified by a number on the base. When youreplace a lamp in a vehicle, be sure the new lamp is of the properrating. The lamps withinLampsareratedastosizebythecandlepower(luminousintensity)theyproduce.Theyrange from types with nibs to fit bayonet sockets, as shown in lamp is also whiter than a conventionallamp,whichincreaseslightingability.

HEADLIGHTS

Theheadlightsaresealedbeamlampsthatilluminate theroadduringnighttimeoperation.Headlights consist of a lens, one or two elements, and a integral reflector. When current flowsthrough the element, the element gets white hot and glows. The reflector and lens direct the lightforward.

Many modern passenger vehicles use halogen headlights. A halogen headlight contains a small,inner halogen lamp surrounded by a conventional sealed housing. A halogen headlamp increaseslight output by 25 percent with no increase in current. The halogen The headlight switch is anON/ OFF switch and rheostat(variable resistor) in the dash panel) or on the steering column.The headlight switch controls current flow to the lamps of the headlight system. The rheostat isforadjustingthebrightnessoftheinstrumentpanellights.

Military vehicles that are used in tactical situations are equipped with a headlight switch that isintegrated with the blackout lighting switch. An important feature of this switch is that it reducesthe possibilityofaccidentallyturningonthelightsinablackout.

With no lights on, the main switch can be turned to the left without operating the mechanicalswitch to get blackout marker lights (including blackout taillights and stoplights) and blackoutdriving lights. But for stoplights for daylight driving or headlights for ordinary night driving, youmustfirstliftthe mechanical switch lever andthen turn the main switch to the right. Theauxiliaryswitch givespanellightswhenthemainswitchisinanyofitsONpositions.Butitwill giveparkinglightsonlywhenthemainswitchis inservicedrive(totheextremeright).Whenthemainswitch

isoff,theauxiliaryswitchshouldnotbemovedfromtheOFFposition.

DIMMERSWITCH

The dimmer switch controls the high and low headlamp beam function and is normally mountedon the floorboard or steering column. When the operator activates the dimmer switch, it changesthe electricalconnectiontotheheadlights.

In one position, the high beams are turned on, and, in the other position, the dimmer changesthemtolowbeam.

AimingHeadlights

The headlights can be aimed using a mechanical aimer or a wall screen. Either method assuresthat the headlight beams point in the direction specified by the vehicle manufacturer. Headlightsthat are aimed too high can blind oncoming vehicles. Headlights that are aimed too low or to oneside willreducetheoperator'svisibility.

Halogen

Mostvehicles madetodayuseahalogenheadlampbulbinsert.

These are small heat-resistant quartz bulbs filled with halogen gas to protect the filament fromdamage. They are inserted to a headlight lens assembly. This assembly will protect the light bulbanddispersethelightgivenfromthehalogenbulb.

Never touch the glass surface of a halogen or HID light. The oil in your skin and the highoperatingtemperature canshortenthe lifeofthebulborcausethe glasstoshatter.

The white halogen bulb increases visibility and increases output by about 25% while drawing thesameamountofcurrent.Atypicallowbeambulbis45 wattsand ahighbeambulbis65watts.

HighIntensityDischarge(HID)

A high intensity discharge lamp does not use a filament. Instead, a high voltage electric arc flowsbetweentwoelectrodesinthebulb.Thisarcexcitesxenonvaporcontainedinthebulb,producing a bright blue-white light. An external ballast is used to convert battery voltage intohigh-voltage AC to create and maintain the arc. When it is first turned on, an igniter works withthe ballast to provide several thousand volts to establish the arc. The ballast then provides asmany as 450 volts to maintain the arc. As the bulb warms up, the voltage needed to maintain thelampcanbeaslowas 50volts.

HID lights produce more light than a standard halogen bulb while consuming less power, andtheylastlonger.

HID bulbs require a large amount of voltage for startup: beware of a shock hazard. Also, HIDbulbsare underpressurewhenhotandmayleadtoanexplosionhazard.

LightEmittingDiode(LED)

Alightemittingdiodeisasemiconductorthatwillemitlightwhenelectricallyenergized.

TheLEDconvertselectricitydirectlyintolight;

thismakesitmuchmoreefficientthananormalfilamentbulb.

TheLEDisanN-

Pjunctionwithspecialdopedsemiconductors.Whenenergized,photons(electrons)areemittedfromthe semiconductorsubstance.Wethensee thesephotonsaslight.

BackupLightSystem

The backup light system provides visibility to the rear of the vehicle at night and a warning to thepedestrians, whenever the vehicle is shifted into reverse. The backup light system has a fuse,gearshiftortransmission-

mountedswitch,twobackuplights,andwiringtoconnectthesecomponents.

Thebackuplightswitchcloses thelightcircuitwhenthetransmissionisshiftedintoreverse.Themostcommonbackuplightswitchconfigurationsareasfollows:

- Thebackuplightswitchmountedonthetransmissionandoperatedbytheshiftlever.
- Thebackuplightswitchmountedonthesteeringcolumnandoperatedbythegearshiftlinkage.
- Thetransmission-orgearshift-mountedbackuplightswitchonmanyautomatictransmissionequippedvehiclesiscombinedwiththeneutralsafetyswitch.

Stop-LightSystem

Allvehiclesthatareusedonpublichighways mustbeequippedwithastoplightsystem. Thestoplightsystemconsistsofafuse,brakelightswitch,tworearwarninglights,andrelatedwiring.
The brake light switch on most automotive equipment is mounted on the brake pedal.Whenthebrakepedalispressed,itclosesthe switchandturnsontherearbrakelights.
On construction and tactical equipment, you may find a pressure light switch. This type of switchuses either air or hydraulic pressure, depending on the equipment. It is mounted on the mastercylinder of the hydraulic brake system or is attached to the brake valve onan air brake system.As the brakes are depressed, either air or hydraulic pressure builds on a diaphragm inside theswitch.Thediaphragmcloses,allowing electricalcurrenttoturnonthe rearbrakelights.

EmergencyLightSystem

The emergency light system, also termed hazard warning system, is designed to signal oncomingtraffic that a vehicle has stopped, stalled, or pulled over to the side of the road. The systemconsists of a switch,flasher unit,four turn-signal lights,and related wiring.The switch isnormallyapush-pullswitchmountedonthesteeringcolumn.
When the switch is closed, current flows through the emergency flasher. Like a turn signalflasher, the emergency flasher opens and closes the circuit to the lights. Thiscauses all four turnsignals toflash.

DimmerSwitchBlackoutLights(MilitaryApplication)

Military vehicles used in tactical situations are equipped with a headlight switch that is integratedwith the blackout lighting switch. The blackout select is operated by a 2-way rocker switch. Thisswitch allows an operator to select between normal or blackout mode. To select normal mode,press the smaller bottom switch up and hold, while pressing the main switch down. To selectblackoutmode,insteadofpressingthemainswitchdown,pressitup.

Thepurposesofblackoutlightingareasfollows:

- Toprovidethevehicleoperatorwithsufficientlighttooperatethevehicleintotaldarkness.
- To provide minimum lighting to show vehicle position to a leading or trailing vehiclewhenillumination mustberestrictedtoalevelnotvisibletoadistantenemy.

Thethreetypesofblackoutlightingareasfollows:

- The blackout driving light is designed to provide a white light of 25 to 50 candlepower ata distance of 10 feet directly in front of the light. The light is shielded so that the top ofthe low beam is directed not less than 2 degrees below the horizon. The beam distributionona levelroadat100feetfromthelightis30feetwide.
- The blackout stop/taillight and marker light are designed to be visible at a horizontaldistance of 800 feet and not visible beyond 1,200 feet. The lights also must be invisiblefrom the air above 400 feet with the vehicle on upgrades and downgrades of 20 percent.The horizontal beam cutoff for the lights is 60 degrees right and left of the beams centerline at100feet.
- The composite light is currently the standard light unit that is used on the rear of tacticalmilitary vehicles. The composite light combines service, stop, tail, and turn signals withblackout stop and tail. Blackout lighting control switches are designed to prevent theservicelightingfrombeingturnedonaccidentally.

Turn-SignalSystems

Vehicles that operate on any public road must be equipped with turn signals. These signalsindicatealeftorright turnbyprovidingaflashinglightsignalattherear andfrontofthevehicle.

The turn-signal switch is located on the steering column. It is designed to shut off automaticallyaftertheturnis completedbytheaction ofthecancelingcam.

A common design for a turn signal system is to use the same rear light for both the stop and turnsignals. This somewhat complicates the design of the switch in that the stoplight circuitmustpass through the turn-signal switch. When the turn signal switch is turned off, it must passstoplight current to the rear lights. As a left or right turn signal is selected, the stoplight circuit isopenandthe turnsignalcircuitisclosedtothe respectiverearlight.

The turn signal flasher unit creates the flashing of the turn signal lights. It consists basically of abimetallic (two dissimilar metals bonded together) strip wrapped in a wire coil. The bimetallicstripserves as oneofthecontactpoints.

When the turn signals are actuated, currentflows into the flasher—first through the heating coilto the bimetallic strip, then through the contact points, then out of the flasher, where the circuit iscompleted through the turn-signal light. This sequence of events will repeat a few times a secondcausingasteadyflashingoftheturnsignals.

CHAPTER–7

Accessories&Control

HORN

Thehorn currently usedon automotivevehiclesis theelectricvibratingtype.Theelectricvibrating horn system typically consists of a fuse, horn button switch, relay, horn assembly, andrelated wiring. When the operator presses the horn button, it closes the horn switch and activatesthe horn relay. This completes the circuit, and current is allowed through the relay circuit and tothe horn.

Most horns have a diaphragm that vibrates by means of an electromagnetic. When the horn isenergized, the electromagnet pulls on the horn diaphragm. This movement opens a set of contactpoints inside the horn. This action allows the diaphragm to flex back towards its normal position.This cycle is repeated rapidly. The vibrations of the diaphragm within the air column produce thenoteofthehorn.

Tone and volume adjustments are made by loosening the adjusting locknut and turning theadjustingnut.Thisverysensitive adjustmentcontrolsthecurrentconsumedbythehorn.

Increasing the current increases the volume. However, too much current will make the hornsputterandmaylockthediaphragm.

When an electric horn will not produce sound, check the fuse, the connections, and test forvoltage at the horn terminal. If the horn sounds continuously, a faulty horn switch is the mostprobable cause. A faulty horn relay is another cause of horn problems. The contacts inside therelaymaybeburnedorstucktogether.

WINDSHIELDWIPERS

Thewindshieldwipersystemisoneof themostimportantsafety factors on any pieceofequipment. A typical electric windshield wiper system consists of a switch, motor assembly,wiperlinkageand arms,andwiperblades.Thedescriptionofthe componentsisasfollows:

TheWINDSHIELDWIPERSWITCHisamultipositionswitch,whichmaycontainarheostat.Eachswitchpositionprovidesfordifferentwipingspeeds.Therheostat,ifprovided,operatesthe delay mode for a slow wiping action. This permits the operator to select a delayed wipe fromevery 3 to 20 seconds. A relay is frequently used to complete the circuit between the batteryvoltageandthewipermotor.

The WIPER MOTOR ASSEMBLY operates on one, two, or three speeds. The motor has a wormgear on the armature shaft that drives one or two gears, and, in turn, operates the linkage to thewiper arms. The motor is a small, shunt wound dc motor. Resistors are placed in the controlcircuitfromthe switchto reducethe current andprovidedifferentoperatingspeeds.

The WIPER LINKAGE and ARMS transfer motion from the wiper motor transmission to thewiperblades.Therubberwiperbladesfitonthewiperarms.

The WIPER BLADE is a flexible rubber squeegee-type device. It may be steel or plastic backedand is designed to maintain total contact with the windshield throughout the stroke. Wiper bladesshould be inspected periodically. If they are hardened, cut, or split, they are to be replaced. Whenelectrical problems occur in the windshield wiper system, use the service manual and its wiringdiagram of the circuit.Firstcheck thefuses,electrical connections,and all grounds.Thenproceedwithcheckingthecomponents.

FuelGauge

Most fuel gauges are operated electrically and are composed of two units—the gauge, mountedon the instrument panel; and the sending unit, mounted in the fuel tank. The ignition switch isincluded in the fuel gauge circuit, so the gauge operates only when the ignition switch is in theON position. The basic fuel gauge circuit uses a variable resistor to operate either a bimetal ormagnetictypeindicatorassembly.

Located in the trunk, the sending unit consists of a float and arm that operate a variable resistor.When the fuel tank is empty, the float is down so the variable resistance will be high. This allowsonly a little amount of current to flow through the fuel gauge. The bimetal arm stays cool and theneedleshowsthatthetankislow.

When the tank is filled, the float rises to the top of the tank. This slides the wiper to the lowresistance position on the variable resistor. More current then flows through the fuel gaugecircuit.Thebimetalarmheatsupand warpstomove theneedle tothefullsideofthe gauge.

The THERMOSTATIC FUEL GAUGE, SELF-REGULATING contains an electrically heatedbimetallic strip thatis linked to a pointer. A bimetallic strip consists of two dissimilar metalsthat, when heated, expand at different rates, causing it to deflect or bend. In the case of thisgauge, the deflection of the bimetallic strip results in the movement of the pointer, causing thegauge to give a reading. The sending unit consists of a hinged arm with a float on the end. Themovement of the arm controls a grounded point that makes contact with another point which isattached to an electrically heated bimetallic strip. The heating coils in the tank and the gauge areconnectedtoeachotherinseries.

TheTHERMOSTATICFUELGAUGE,EXTERNALLYREGULATEDdiffersfromaself-regulating system in the use of a variable resistance fuel tank sending unit and an externalvoltage-limiting device. The sending unit controls the gauge through the use of a rheostat (wirewound resistance unit whose value varies with its effective length). The effective length of therheostat is controlled in the sending unit by a sliding brush that is operated by the float arm. Thepower supply to the gauge is kept constant through the use of a voltage limiter. The voltagelimiter consists of a set of contact points that are controlled by an electrically heated bimetallicarm.

The THERMOSTATIC FUEL GAUGE, DIFFERENTIAL TYPE is similar to the other type ofthermostatic fuel gauges, except that it uses two electrically heated bimetallic strips that shareequallyin operatingandsupportingthe gaugepointer. The pointerpositionis obtainedbydividing the available voltage between the two strips (differential). The tank unitis a rheostattypesimilartothatalreadydescribed;however,itcontainsawire-woundresistorthatisconnected between external terminals of one of the gauges of the bimetallic strip. The float armmoves a grounded brush that raises resistance progressively to one terminal, while loweringresistance to the other. This action causes thevoltage division and resultingheatdifferential tothe gauge strips formulating the gauge reading. The MAGNETIC FUEL GAUGE consists of apointer mounted on an armature. Depending upon the design, the armature may contain one ortwo poles. The gauge is motivated by a magnetic field that is created by two separate magneticcoilsthatarecontainedinthegauge.Oneofthesecoilsisconnecteddirectlytothebattery, producing a constant magnetic field. The other coil produces a variable field, whose strength isdeterminedbya rheostat-type tankunit.The coilsareplaced90degreesapart.

PressureGauge

A pressure gauge is used widely in automotive and construction applications to keep trackofsuch things as oil pressure, fuel line pressure, air brake system pressure, and the pressure in thehydraulic systems. Depending on the equipment, a mechanical gauge, an electrical gauge, or anindicatorlampmaybeused.

OilPressureGauge

A pressure gauge is used widely in automotive and construction applications to keeptrack ofsuch things as oil pressure, fuel line pressure, air brake system pressure, and the pressure in thehydraulicsystems.

Depending on the equipment, a mechanical gauge, an electrical gauge, or an indicator lamp maybe used.

The mechanical gauge uses a thin tube to carry an actual pressure sample directly to the gauge.The gauge basically consists of a hollow, flexible C shaped tube called a bourbon tube. As air orfluid pressure is applied to the bourbon tube, it tends to straighten out. As it straightens, theattachedpointermoves,givingareading.

The electric gauge may be of the thermostatic or magnetic type as previous discussed. Thesendingunitthatisusedwitheachgaugetype variesasfollows:

- The sending unit used with the thermostatic pressure gauge uses a flexible diaphragm thatmoves a grounded contact. The contact thatmates with the grounded contactis attachedto a bimetallic strip. The flexing of the diaphragm, which is done with pressure changes,variesthepointtension.Thedifferentpositionsofthediaphragmproducegaugereadings.
- The sending unit used with the magnetic-type gauge also translates pressure into theflexing of a diaphragm. In the case of the magnetic gauge sending unit, however, thediaphragmoperates arheostat.

The indicator lamp (warning light) is used in place of a gauge on many vehicles. The warninglight,althoughnotanaccurateindicator,isvaluablebecause ofitshighvisibilityin theeventofa low-pressure condition. The warning light receives battery power through the ignition switch.Thecircuittogroundis completedthroughasendingunit.

The sending unit consists of a pressure-sensitive diaphragm that operates a set of contact pointsthat arecalibratedtoturnonthe warninglightwheneverpressuredropsbelowasetpressure.

TEMPERATUREGAUGE

The temperature gauge is a very important indicator in construction and automotive equipment.Themostcommonusesaretoindicateenginecoolant,transmission,differentialoil,andhydraulicsystemtemperature.Dependingonthetypeofequipment,thegaugemaybemechanical,electric,or awarninglight.

The ELECTRIC GAUGEmay be the thermostatic or magnetic type, as described previously.Thesending unit(fig.2-83)thatis usedvaries,dependinguponapplication.

- The sending unit that is used with the thermostatic gauge consists of two bimetallic strips,each having a contact point. One bimetallic strip is heated electrically. The other stripbendstoincreasethetensionofthecontactpoints.Thedifferentpositionsofthebimetallicstripcreatethegaugereadings.
- Thesendingunitthatisusedwiththemagneticgaugecontainsadevicecalledathermistor. A thermistor is an electronic device whose resistance decreases proportionallywithanincreaseintemperature.
- The magnetic gauge contains a bourbon tube and operates by the same principles as themechanicalpressuregauge.
- The indicator lamp (warning light) operates by the same principle as the indicator lightpreviouslydiscussed.

CHAPTER–8

Wiringsystem

AUTOMOTIVEWIRING

Electrical power and control signals must be delivered to electrical devices reliably and safely sothat the electrical system functions are not impaired or converted to hazards. To fulfill powerdistribution military vehicles,use one-and two-wire circuits,wiring harnesses,and terminalconnections.

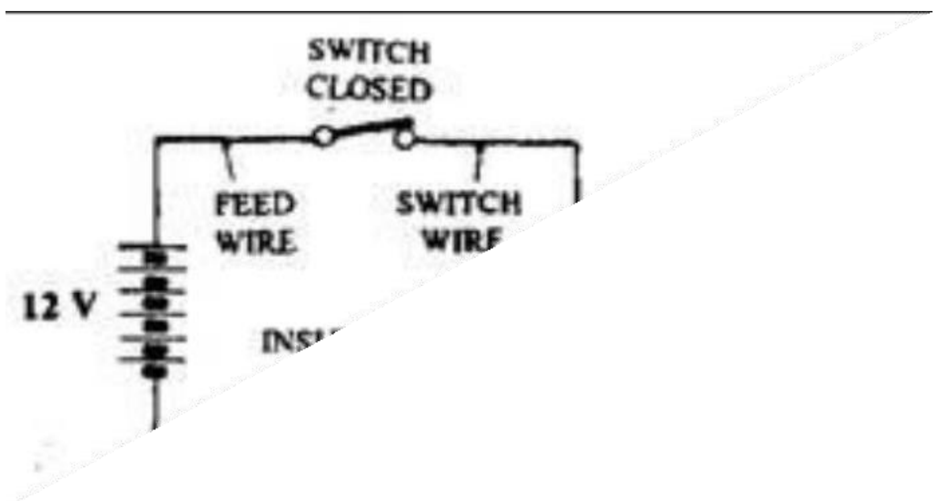
Among your many duties will be the job of maintaining and repairing automotive electricalsystems. All vehicles are not wired in exactly the same manner; however, once you understandthe circuit of one vehicle, you should be able to trace an electrical circuit of any vehicle usingwiringdiagramsandcolorcodes.

ONE-ANDTWO-WIRECIRCUITS

Tracing wiring circuits, particularly those connecting lights or warning and signal devices, is nosimple task. The branch circuits making up the individual systems have one wire to conductelectricity from the battery to the unit requiring it and ground connections at the battery and theunit to complete the circuit. These are called ONE-WIRE CIRCUITS or branches of a GROUNDRETURNSYSTEM.Inautomotiveelectricalsystemswithbranchcircuitsthatleadtoallparts of the equipment, the ground return system saves installation time and eliminates the need for anadditional wiring to complete the circuit. The all-metal construction of the automotive equipmentmakes it possible to use this system. The TWO-WIRE CIRCUIT requires two wires to completethe electrical circuit- one wire from the source of electrical energy to the unit it will operate, andanother wire to complete the circuit from the unit back to the source of the electrical power.Two-wirecircuitsprovidepositiveconnectionforlightandelectricalbrakesonsometrailers.The coupling between the trailer and the equipment, although made of metal and a conductor ofelectricity, has to be jointed to move freely. The rather loose joint or coupling does not providethe positive and continuous connection required to use a ground return system between twovehicles.Thetwo-wirecircuitiscommonlyusedonequipmentsubjecttofrequentorheavy vibrations.Trackedequipment,off-roadvehicles(tactical),andmany typesof constructionequipmentarewiredinthismanner.

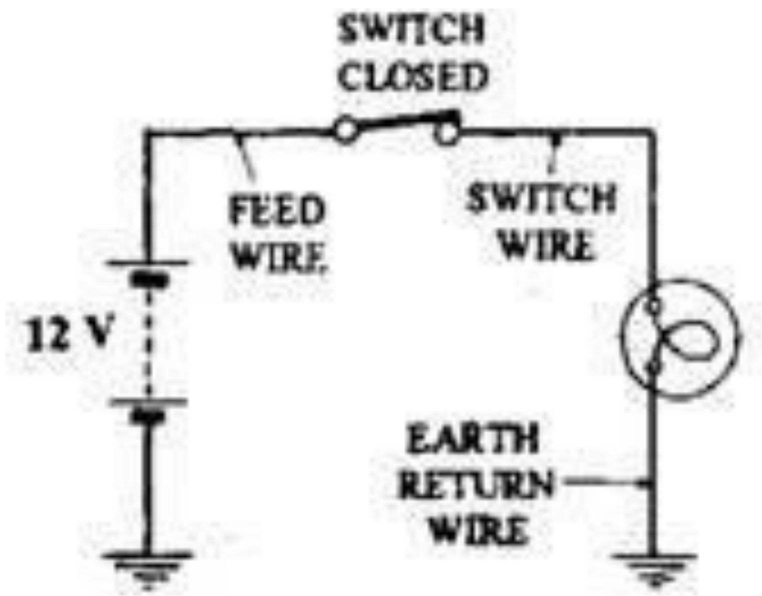
InsulatedReturn

Some vehicle application requires a separate insulated-cable system for both the feed and thereturn conductors. It is also safer because with separate feed and return cables, it is practicallyimpossiblefor the cableconductors toshorteven if chafed and touching any of themetalbodywork, as the body is not live since it is not a part of the electrical circuits. From the safetyreasons, an insulated return is essential for vehicles transporting highly flammable liquids andgases, where a spark could very easily set off an explosion or a fire. The vehicles, suchascoaches and double-decker buses use large quantity of plastic panelling. For these vehicles aninsulated return is more reliable and safer. The insulated return off course uses extra cable thatmakes the overall wiring harness heavier, less flexible, and bulky, consequentlyincreases thecosttosomeextent.



EarthReturn

All electrical circuits incorporate both a feed and a return conductor between the battery and thecomponent requiring supply of electrical energy. The vehicle with a metal structure can be usedas one of the twoconducting paths.Thisis called as the earth return (Fig.13.51). A livefeedwire cable forms the other conductor. To complete the earth-return path, one end of a short thickcableisboltedtothechassisstructurewhiletheotherendisattachedtooneofthebattery terminal posts. The electrical component is also required to be earthed in a similar way. Only onebattery-to-chassis conductor is necessary for a complete vehicle's wiring system and similarlyany number of separate earth-return circuits can be wired. An earth-return system, therefore,reducesand simplifiestheamountofwiringsothat itiseasytotrace electricalfaults.



PositiveandNegativeearthing

In the beginning, it was the general practice of earthing the negative terminal of the battery,whereas the positive current was supplied to the electrical units. The negative earthing system isstillusedinthecars ofAmericanmake.

In some countries, the negative earth system has been replaced by the positive earth system. Thisis because the positive earth system possesses certain advantages over the negative earth system.These advantagesconcern the temperature of the central spark plug electrode and the corrosionof some parts, it is well known fact that the positive terminal of the lead acid battery is attackedby the liberated gases. If this is the live terminal and the negative terminal earthed, the exposedpartofthepositivewillbecomecorroded.

Further it is also a well known fact that the positive point of the spark plug wears away morequickly than the negative point. In view of this fact, the central electrode of the plug will wearawayquicklyifmadeelectrodeoftheplugwillwearawayquicklyifmadepositivewhen compared with the metal electrode of the shell. Alternatively, the central electrode of the plugwillhavemuchlongerlifeifmadenegativebyearthing thepositiveterminalofthe battery.

Another factor which plays an important role in the voltage requirements of a spark plug is thetemperature of the negative electrode. The hotter this electrode is, the lower will be the voltagerequired for producing the spark, It has also been observed that more uniform voltages at thesparking points have been obtained with the central electrode being negative. Further, the metalrotor arm of the distributor, if made negative, will wear at a slower rate than if it were madepositive.

There is an additional advantage of the positive earth method in the ignition coil elements theprimarycircuitvoltageisaddedtothesecondarycircuitvoltage, makingitmoreeconomical.

Recently, with the adoption of alternators in place of generators, ithas been observed thatemploying negative earth method is advantageous along with an ac currentrectifier havingtransistors and diodes. This has meant shifting back to the negative earth method. However it isworth mentioning that the important advantages of the positive earth for the ignition system stillholdgood.

VariousVehicleWiringDiagrams

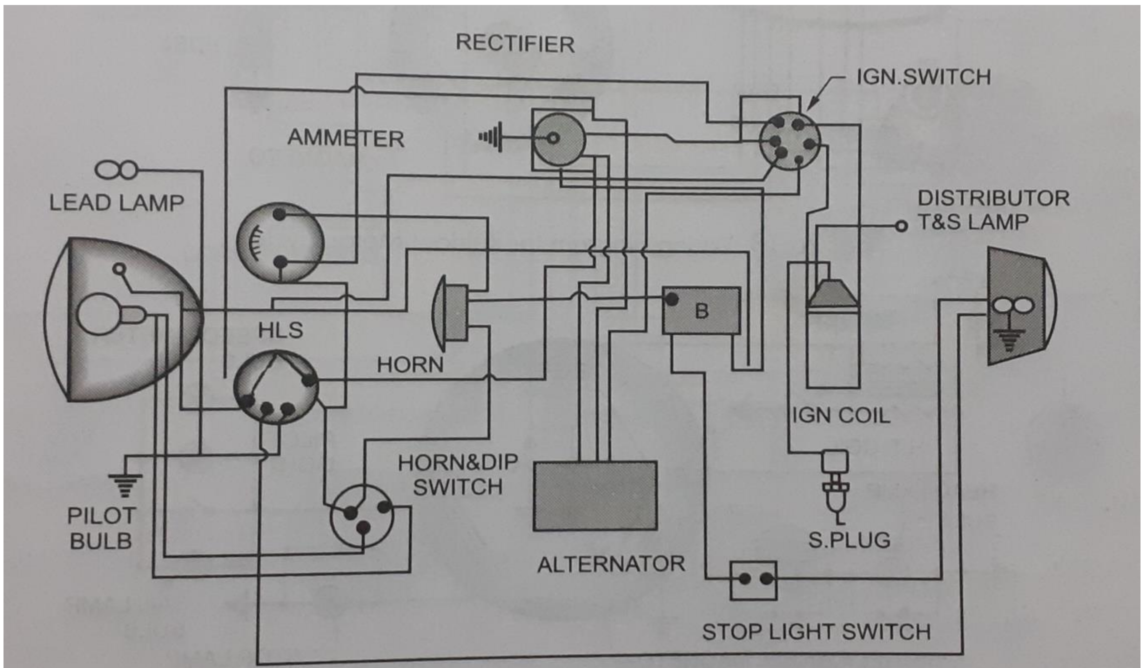


Fig. 26.11. Wiring diagram for enfield India 350 c.c. bullet motor cycle.

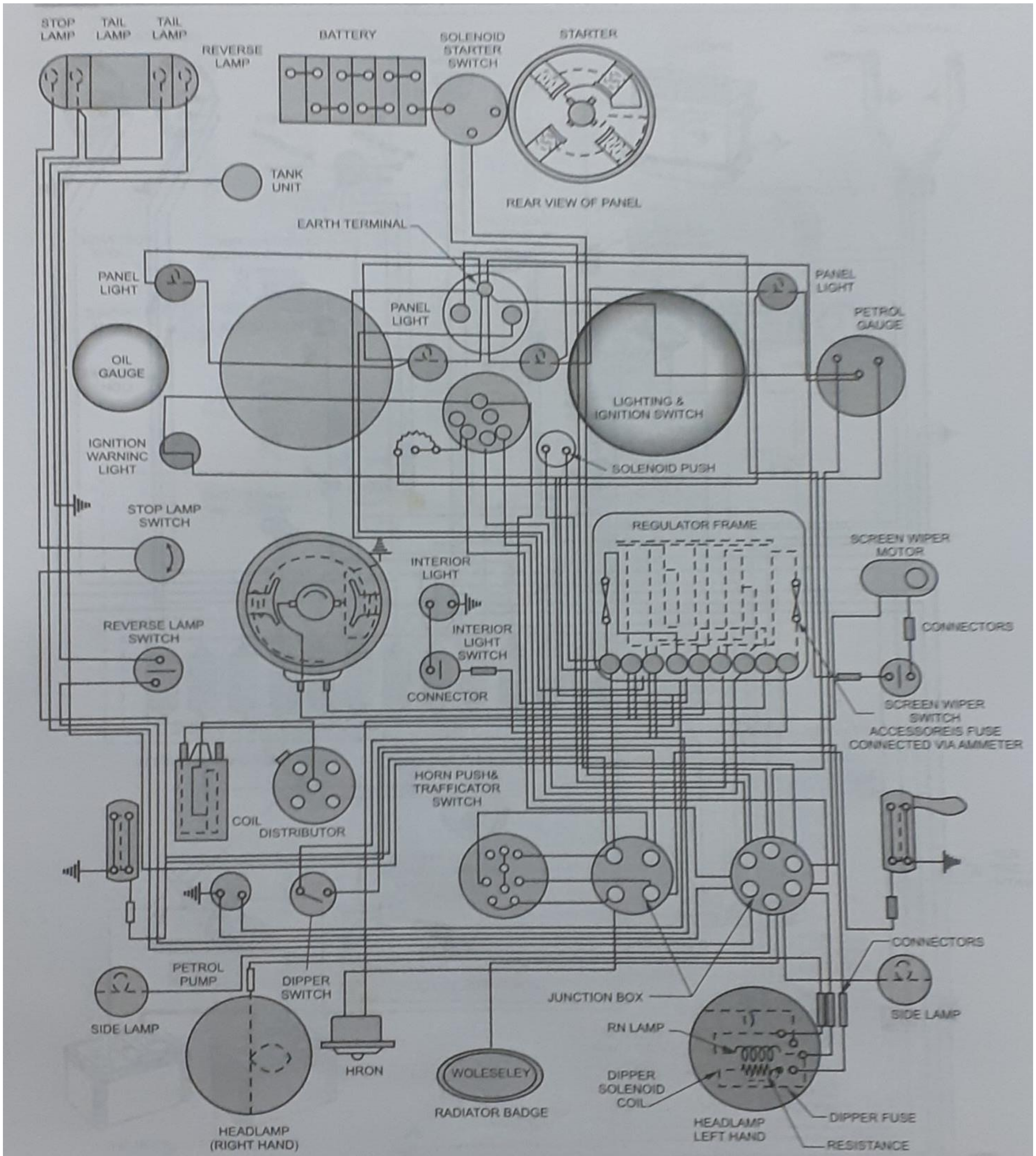


Fig. 26.18. Wiring diagram of Wolseley model "Ten" (1939).

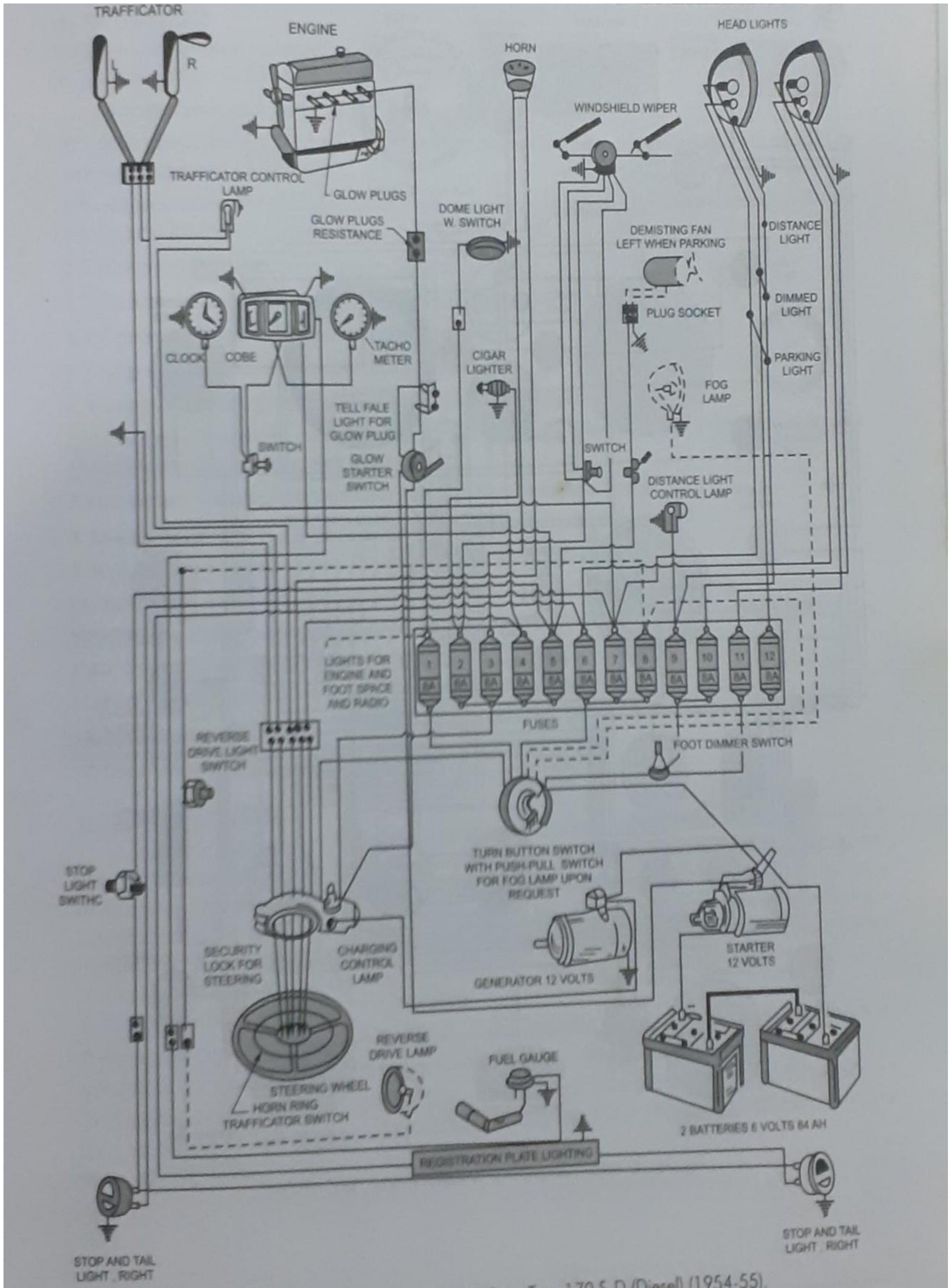


Fig. 26.17. Wiring diagram of Mercedes-Benz Type 170 S-D (Diesel) (1954-55).

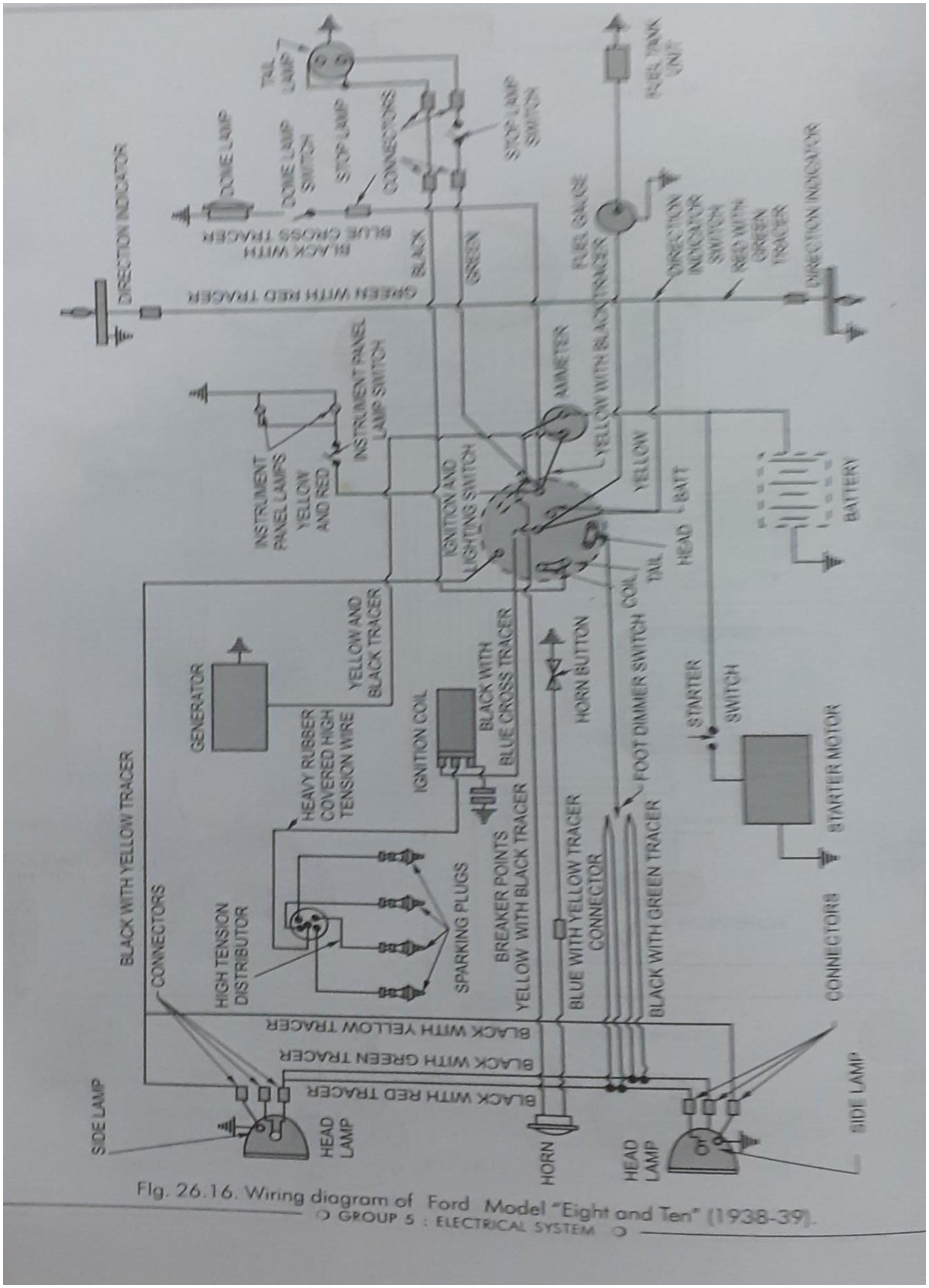


Fig. 26.16. Wiring diagram of Ford Model "Eight and Ten" (1938-39).

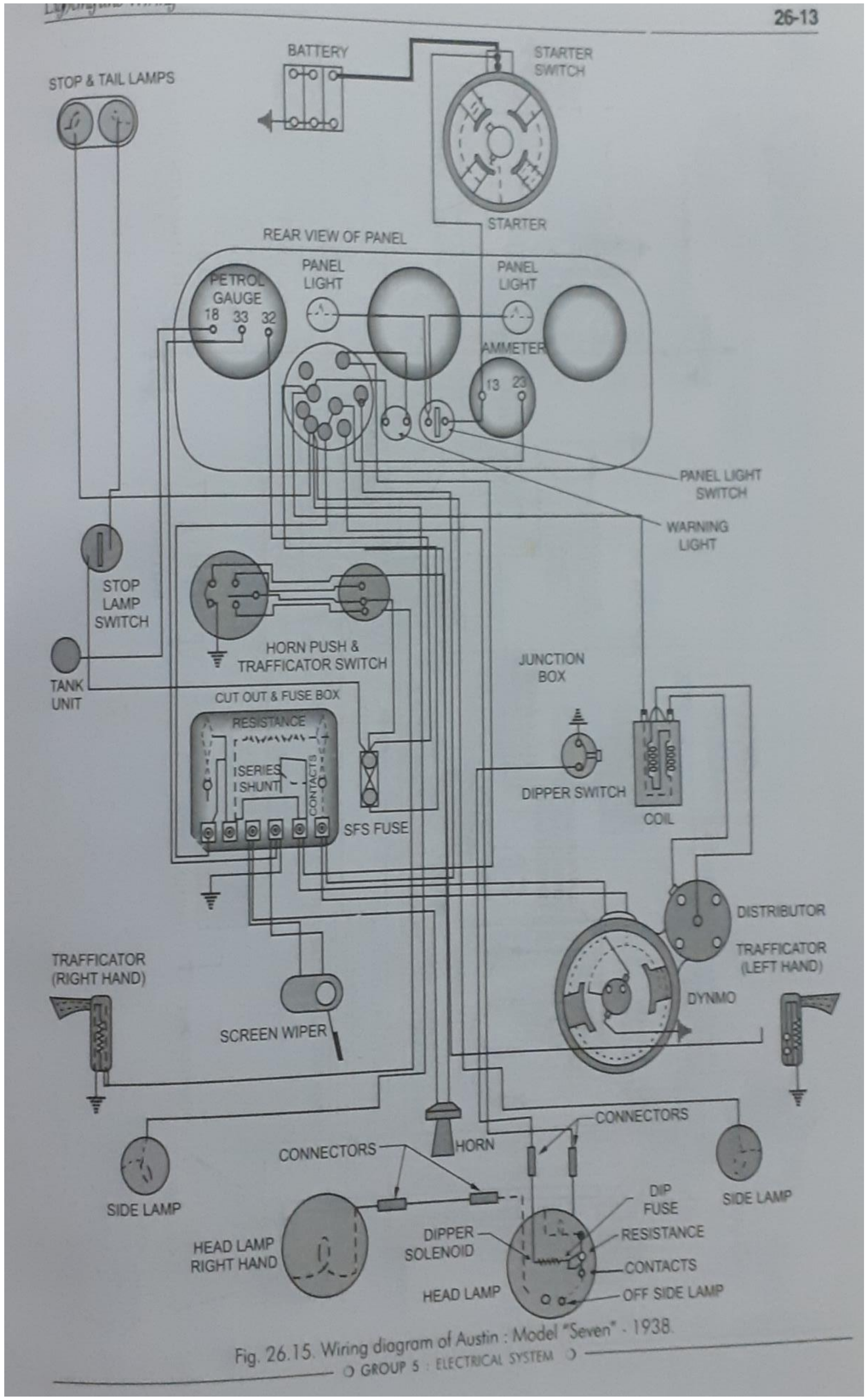


Fig. 26.15. Wiring diagram of Austin : Model "Seven" - 1938.

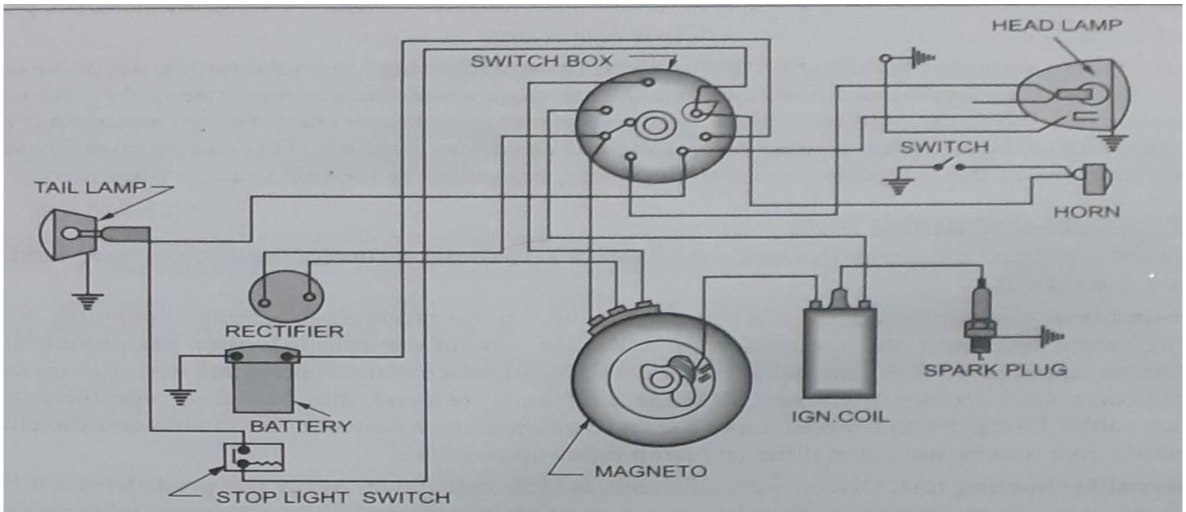


Fig. 26.12. Wiring diagram for Jawa/Yezdi 250 c.c. Motor Cycle.

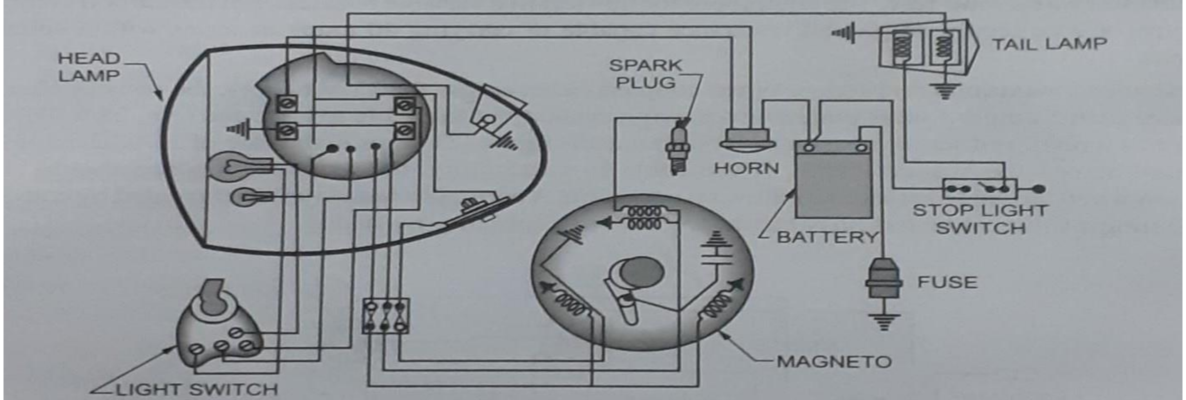


Fig. 26.13. Wiring diagram for Rajdoot Motor Cycle.

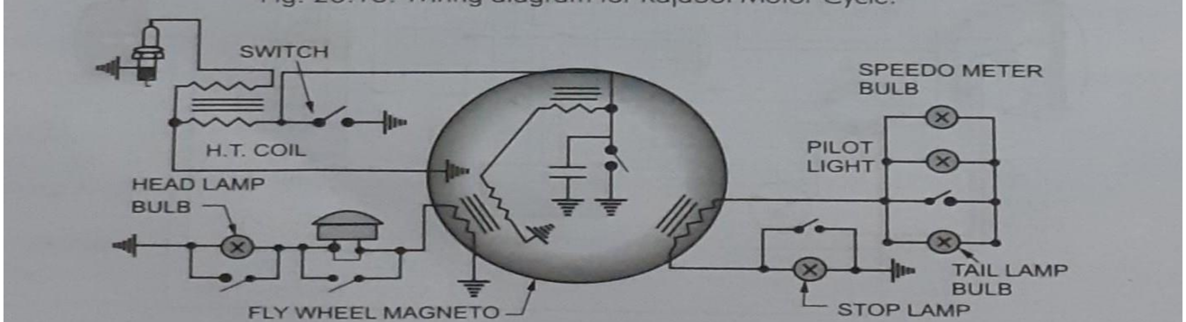


Fig. 26.14. Wiring diagram for Bajaj Chetak.