UNIT –II

Emission standards are the legal requirements governing air pollutants released into the atmosphere. Emission standards set quantitative limits on the permissible amount of specific air pollutants that may be released from specific sources over specific timeframes. They are generally designed to achieve air quality standards and to protect human health. Many emissions standards focus on regulating pollutants released by automobiles (motor cars) and other powered vehicles. Others regulate emissions from industry, power plants, small equipment such as lawn mowers and diesel generators, and other sources of air pollution

1. VEHICLE EMISSION PERFORMANCE STANDARD

An **emission performance standard** is a limit that sets thresholds above which a different type of emission control technology might be needed. While emission performance standards have been used to dictate limits for conventional pollutants such as oxides of nitrogen and oxides of sulfur (NOx and SOx), this regulatory technique may be used to regulate green house gasses, particularly carbondioxide (CO_2). In the US, this is given in pounds of carbon dioxide per megawatt-hour (lbs. CO_2/MWhr), and kilograms CO_2/MWhr elsewhere

1.1 INTERNATIONAL EMISSION STANDARDS

Canada

In Canada, the Canadian Environmental Protection Act, 1999 (CEPA 1999) transfers the legislative authority for regulating emissions from on-road vehicles and engines to Environment from Transport Canada's Motor Vehicle Safety Act. The Regulations align emission standards with the U.S. federal standards and apply to light-duty vehicles (e.g., passenger cars), light-duty trucks (e.g., vans, pickup trucks, sport utility vehicles), heavy-duty vehicles (e.g., trucks and buses), heavy-duty engines and motorcycles.

United States of America

In the United States, emissions standards are managed by the Environmental Protection Agency (EPA). Under federal law, the state of California is allowed to promulgate more stringent vehicle emissions standards (subject to EPA approval), and other states may choose to follow either the national or California standards. California had produced air quality standards prior to EPA, with severe air quality problems in the Los Angeles metropolitan area. LA is the country's second-largest city, and relies much more heavily on automobiles and has less favorable meteorological conditions than the largest and third-largest cities (New York and Chicago).

California's emissions standards are set by the California Air Resources Board, known locally by its acronym "CARB". By mid-2009, 16 other states had adopted CARB rules;[3]given the size of the California market plus these other states, many manufacturers choose to build to the CARB standard when selling in all 50 states. CARB's policies have also influenced EU emissions standardsCalifornia is attempting to regulate greenhouse gas emissions from automobiles, but faces a court challenge from the federal government. The states are also attempting to compel the federal EPA to regulate greenhouse gas emissions, which as of 2007 it has declined to do. On May 19, 2009 news reports indicate that the Federal EPA will largely adopt California's standards on greenhouse gas emissions.

California and several other western states have passed bills requiring performance-based regulation of greenhouse gases from electricity generation.

In an effort to decrease emissions from heavy-duty diesel engines faster, the California Air Resources Board's Carl Moyer Program funds upgrades that are in advance of regulations.

European Union

The European Union has its own set of emissions standards that all new vehicles must meet. Currently, standards are set for all road vehicles, trains, barges and 'nonroad mobile machinery' (such as tractors). No standards apply to seagoing ships or airplanes.

EU Regulation No 443/2009 sets an average CO_2 emissions target for new passenger cars of 130 grams per kilometre. The target is gradually being phased in between 2012 and 2015. A target of 95 grams per kilometre will apply from 2021.

For light commercial vehicle, an emissions target of 175 g/km applies from 2017, and 147 g/km from 2020 a reduction of 16%.

The EU introduced Euro 4 effective January 1, 2008, Euro 5 effective January 1, 2010 and Euro 6 effective January 1, 2014. These dates had been postponed for two years to give oil refineries the opportunity to modernize their plants.

UK

Several local authorities in the UK have introduced Euro 4 or Euro 5 emissions standards for taxis and licensed private hire vehicles to operate in their area.

Germany

According to the German federal automotive office 37.3% (15.4 million) cars in Germany (total car population 41.3 million) conform to the Euro 4 standard from Jan 2009.

Asia

China

Due to rapidly expanding wealth and prosperity, the number of coal power plants and cars on China's roads is rapidly growing, creating an ongoing pollution problem. China enacted its first emissions controls on automobiles in 2000, equivalent to Euro I standards. China's State Environmental Protection Administration (SEPA) upgraded emission controls again on July 1, 2004 to the Euro II standard.[8] More stringent emission standard, National Standard III, equivalent to Euro III standards, went into effect on July 1, 2007. Plans are for Euro IV standards to take effect in 2010. Beijing introduced the Euro IV standard in advance on January 1, 2008, became the first city in mainland China to adopt this standard.

Hong Kong

From Jan 1, 2006, all new passenger cars with spark-ignition engines in Hong Kong must meet either Euro IV petrol standard, Japanese Heisei 17 standard or US EPA Tier 2 Bin 5 standard. For new passenger cars with compression-ignition engines, they must meet US EPA Tier 2 Bin 5 standard.

Japan

Starting June 10, 1968, the Japanese Government passed the **(Japanese: Air Pollution Control Act)** which regulated all sources of air pollutants. As a result of the 1968 law, dispute resolutions were passed under the 1970 **(Japanese: Air Pollution Dispute Resolution Act)**. As a result of the 1970 law, in 1973 the first installment of four sets of new emissions standards were introduced. Interim standards were introduced on January 1, 1975 and again for 1976. The final set of standards were introduced for 1978.

Israel

Since January 2012 vehicles which do not comply with Euro 6 emission values are not allowed to be imported to Israel.

South Africa

South Africa's first clean fuels programme was implemented in 2006 with the banning of lead from petrol and the reduction of sulphur levels in diesel from 3 000 parts per million (ppm) to 500ppm, along with a niche grade of 50ppm.

The Clean Fuels 2 standard, expected to begin in 2017, includes the reduction of sulphur to 10ppm; the lowering of benzene from 5 percent to 1 percent of volume; the reduction of aromatics from 50 percent to 35 percent of volume; and the specification of olefins at 18 percent of volume.

1.2 NATIONAL EMISSION STANDARDS

India

Bharat stage emission standards are emission standards instituted by the Government of India to regulate the output of air pollutants from internal combustion engine equipment, including motor vehicles. The standards and the timeline for implementation are set by the Central Pollution Control Board under the Ministry of Environment & Forests.

The standards, based on European regulations were first introduced in 2000. Progressively stringent norms have been rolled out since then. All new vehicles manufactured after the implementation of the norms have to be compliant with the regulations. As of 2014, the country is under a combination of Euro 3 and Euro 4-based norms. Euro 6 norms are planned to be introduced across the country by the April 1, 2020.

2. EMISSION STANDARDS

The NOx and PM Law introduces emission standards for specified categories of in-use highway vehicles including commercial goods (cargo) vehicles such as trucks and vans, buses, and special purpose motor vehicles, irrespective of the fuel type. The regulation also applies to diesel powered passenger cars (but not to gasoline cars).

In-use vehicles in the specified categories must meet 1997/98 emission standards for the respective new vehicle type (in the case of heavy duty engines NOx = 4.5 g/kWh, PM = 0.25 g/kWh). In other words, the 1997/98 new vehicle standards are retroactively applied to older vehicles already on the road. Vehicle owners have two methods to comply:

1. Replace old vehicles with newer, cleaner models
2. Retrofit old vehicles with approved NOx and PM control devices

Vehicles have a grace period, between 8 and 12 years from the initial registration, to comply. The grace period depends on the vehicle type, as follows:

- Light commercial vehicles (GVW ≤ 2500 kg): 8 years
- Heavy commercial vehicles (GVW > 2500 kg): 9 years
- Micro buses (11-29 seats): 10 years
- Large buses (≥ 30 seats): 12 years
- Special vehicles (based on a cargo truck or bus): 10 years
- Diesel passenger cars: 9 years

Furthermore, the regulation allows fulfillment of its requirements to be postponed by an additional 0.5-2.5 years, depending on the age of the vehicle. This delay was introduced in part to harmonize the NOx and PM Law with the Tokyo diesel retrofit program.

The NOx and PM Law is enforced in connection with Japanese vehicle inspection program, where non-complying vehicles cannot undergo the inspection in the designated areas. This, in turn, may trigger an injunction on the vehicle operation under the Road Transport Vehicle Law.

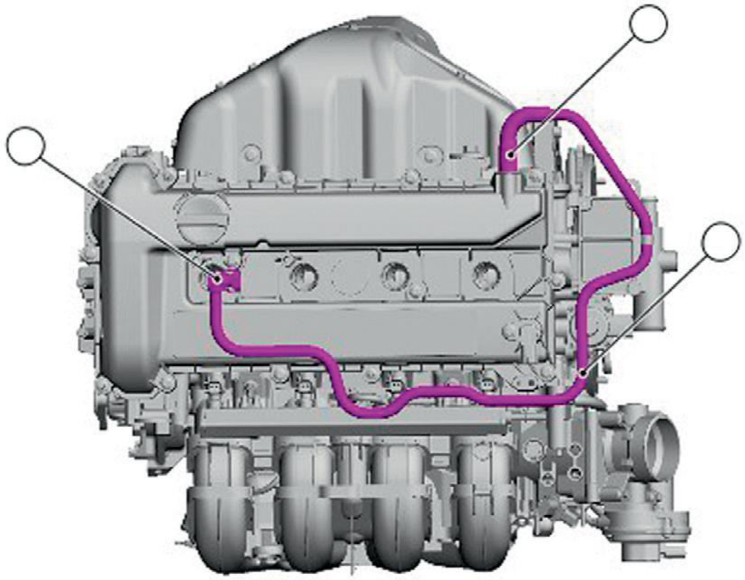
2.1 EMISSION CONTROL SYSTEMS

Crankcase ventilation

Oil vapour occurs in the engine crankcase because of heat, spray and the churning action of engine components as the engine is running. A fi ne mist of oil vapour is always present in a running engine. The engine crankcase pressure is never constant. Slight leakages into and from the combustion chambers, and the movement of the pistons, are responsible for most of the pressure variations. A vent to atmosphere system was once used for ventilating pressure variations in the engine. This simple vent allowed a large quantity of oil vapour to escape.

By fi tting an oil separator the quantity of oil was reduced but still unacceptable quantities of oil vapour were emitted. Developments since that time have seen the introduction of a positive crankcase ventilation (PCV) system. This takes any escaping oil vapour into the engine for combustion.

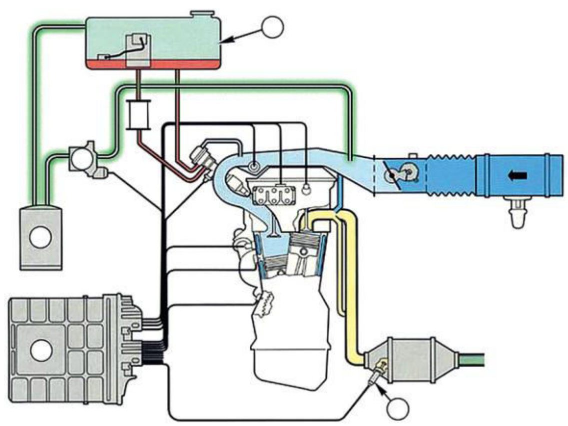
The PCV system shown in Figs 2.206 and 2.207 consists of a valve mounted in the crankcase vent oil separator (attached to the cylinder block) and two hoses. One PCV hose connects the PCV valve to the intake manifold; the other connects the valve cover to the air cleaner. Under idle and part throttle conditions, the crankcase vapour fl ows through the intake manifold into the combustion chambers where the vapour is burnt during combustion. Under full throttle conditions, the crankcase vapour fl ows from the valve cover into the air cleaner through the PCV hose.



Evaporative emission control

Fuel vapour and particularly petrol vapour is harmful. It is given off from petrol at quite low ambient temperatures. Fuel is stored in underground tanks to reduce vapour formation. However, during filling up and when fuel is in the tank, vapour can escape into the atmosphere. Modern vehicles are fitted with fuel systems that prevent vapour loss from the vehicle.

An evaporative emission control system (EVAP) has a sealed tank and fuel lines .It allows for expansion and reuse of the fuel through a charcoal canister .Air can pass through but the fuel vapour is trapped. To prevent the fi lter becoming saturated it is cleaned, or purged, by drawing air



through the filter in the opposite direction. The air collects the deposited fuel vapour and carries it through pipes into the inlet manifold and engine, where it is burnt. To prevent vapour loss through this route when the engine is not running, a canister purge control valve is fitted into the fuel vapour line. The valve is closed when the engine is stationary and during warm-up. When the engine is at normal running temperature the valve opens and the inlet manifold vacuum is able to cause air fl ow through the canister. This draws vapour out of the filter and into the inlet manifold.

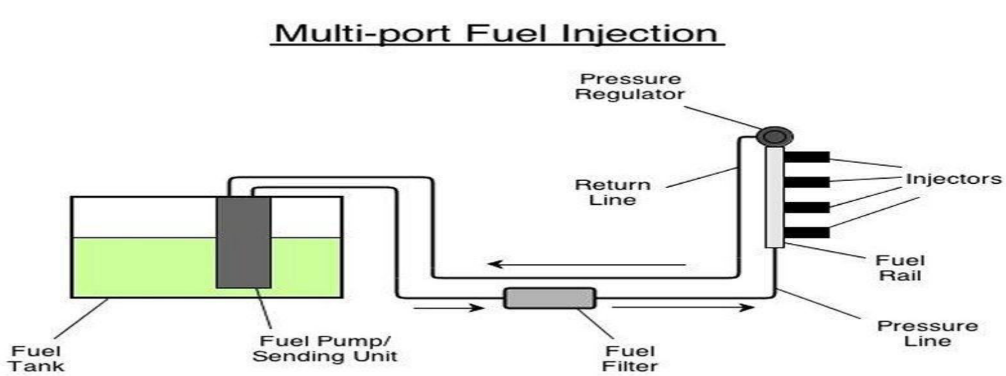
The evaporative canister can be fitted almost anywhere on the vehicle. It may be near to the fuel tank, in the engine compartment or under a body panel. Fuel traps, to prevent fuel loss if the vehicle turns over in an accident, are also fitted.

Exhaust gas recirculation

Exhaust gas recirculation (EGR) has become a common feature on petrol and diesel engines. The addition of exhaust gas to a fresh air and fuel charge lowers the combustion temperature and reduces the formation of NOx. EGR operates during normal engine temperature and high vacuum conditions. Exhaust gases are piped from the exhaust manifold to the inlet manifold through a vacuum or electrically operated valve. The amount of exhaust gas introduced into the air supply is usually less than 15% of the total charge. However, where closed-loop control is used, up to 50% can be used under some conditions on diesel engine systems. Some systems use a one-piece electrical solenoid valve, in place of the separate electronic vacuum regulator and valve. Some valves have a sensor fi tted above the valve so that the ECM can monitor the opening performance.

3. MULTI POINT FUEL INJECTION

MPFi is a fuel injection technique used in gasoline engines. Multi port fuel injection injects fuel into the intake ports of each cylinder's intake valve, rather than at a central point within an intake manifold like in spark plugs. It can be sequential, in which injection is timed to coincide with each cylinder's intake stroke.



separate injector supplies the correct quantity of fuel to each of the engine cylinders by a fuel-rail according to the firing order or in a ‘particular sequence’. This system provides further precision by varying the fuel quantity and injection timing by governing the each injector separately and thereby improving the performance and controlling the emissions. The return valve returns fuel in case the fuel is oversupplied. Also the pressure regulator regulates the pressure of the intake fuel.Fuel filter contains small sized membranes which filters and absorbs the undesirable matters of size 30 to 40 microns. The fuel and air are mixed in intake manifold and each manifold is controlled by an ECU(Electronic Control Unit). fuel pressure runs between 3 to 5 bars.

4. COMMON RAIL DIRECT FUEL INJECTION

It is a direct fuel injection system for petrol and diesel engines.

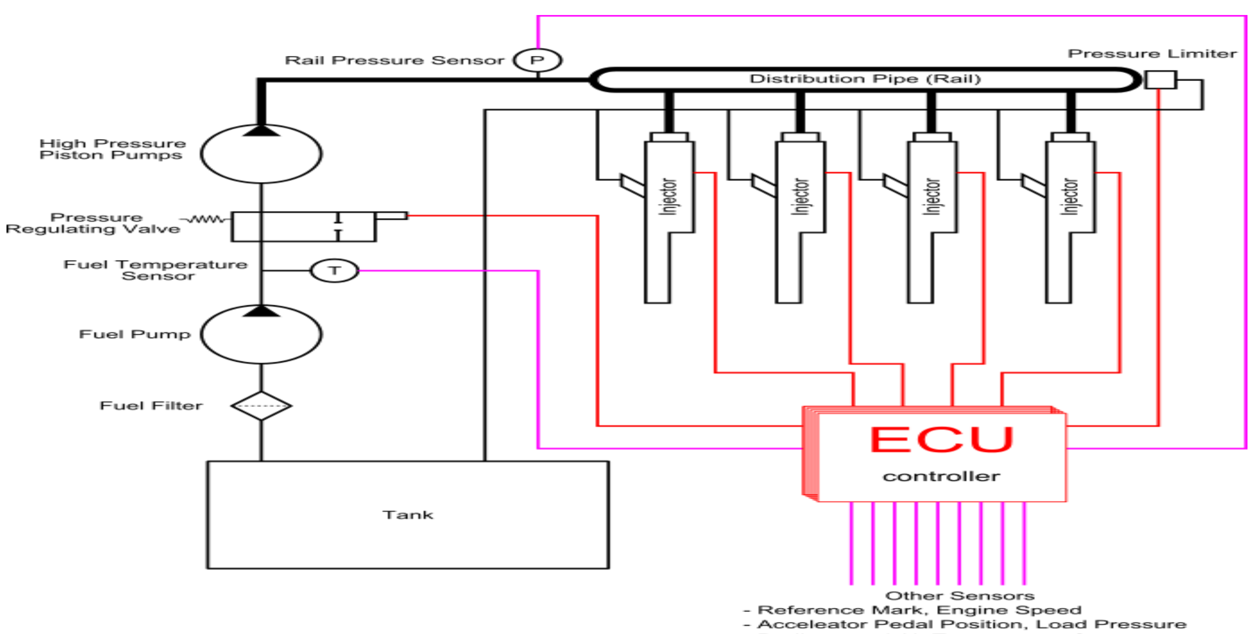
On diesel engines, it features a high-pressure (over 1,000 bar or 100 M Pa or 15,000 psi) fuel rail feeding individual lsolenoid valves, as opposed to a low-pressure fuel pump feeding unit injectors (or pump nozzles). Third-generation common rail diesels now feature piezoelectric injectors for increased precision, with fuel pressures up to 3,000 bar (300 MPa; 44,000 psi).In petrol engines, it is used in Gasoline direct injection (GDI) engine technology.

Solenoid or piezoelectric valves make possible fine electronic control over the fuel injection time and quantity, and the higher pressure that the common rail technology makes available provides better fuel atomisation. To lower engine noise, the engine's electronic control unit can inject a small amount of diesel just before the main injection event ("pilot" injection), thus reducing its explosiveness and vibration, as well as optimising injection timing and quantity for variations in fuel quality, cold starting and so on. Some advanced common rail fuel systems perform as many as five injections per stroke. Common rail engines require a very short to no heating-up time, depending on the ambient temperature, and produce lower engine noise and emissions than older systems. Diesel engines have historically used various forms of fuel injection. Two common types include the unit injection system and the distributor/inline pump systems. While these older systems provided accurate fuel quantity and injection timing control, they were limited by several factors:

- They were cam driven, and injection pressure was proportional to engine speed. This typically meant that the highest injection pressure could only be achieved at the highest engine speed and the maximum achievable injection pressure decreased as engine speed decreased. This relationship is true with all pumps, even those used on common rail systems. With unit or distributor systems, the injection pressure is tied to the instantaneous pressure of a single pumping event with no accumulator, and thus the relationship is more prominent and troublesome.

- They were limited in the number and timing of injection events that could be commanded during a single combustion event. While multiple injection events are possible with these older systems, it is much more difficult and costly to achieve.
- For the typical distributor/inline system, the start of injection occurred at a pre-determined pressure (often referred to as: pop pressure) and ended at a pre-determined pressure. This characteristic resulted from "dummy" injectors in the cylinder head which opened and closed at pressures determined by the spring preload applied to the plunger in the injector. Once the pressure in the injector reached a pre-determined level, the plunger would lift and injection would start.

In common rail systems, a high-pressure pump stores a reservoir of fuel at high pressure up to and above 2,000 bars (200 MPa; 29,000 psi). The term "common rail" refers to the fact that all of the fuel injectors are supplied by a common fuel rail which is nothing more than a pressure accumulator where the fuel is stored at high pressure. This accumulator supplies multiple fuel injectors with high-pressure fuel. This simplifies the purpose of the high-pressure pump in that it only needs to maintain a commanded pressure at a target (either mechanically or electronically controlled). The fuel injectors are typically ECU-controlled. When the fuel injectors are electrically activated, a hydraulic valve (consisting of a nozzle and plunger) is mechanically or hydraulically opened and fuel is sprayed into the cylinders at the desired pressure. Since the fuel pressure energy is stored remotely and the injectors are electrically actuated, the injection pressure at the start and end of injection is very near the pressure in the accumulator (rail), thus producing a square injection rate. If the accumulator, pump and plumbing are sized properly, the injection pressure and rate will be the same for each of the multiple injection events.



5. ALTERNATIVE FUELS

The use of an alternative fuel can lessen dependence upon oil and reduce greenhouse gas emissions. There are several alternative fuels and each of these is outlined briefl y in this section.

ETHANOL

Ethanol is an alcohol-based fuel made by fermenting and distilling starch crops, such as corn. It can also be made from plants such as trees and grasses. E10 is a blend of 10% ethanol and 90% petrol (gasoline). Almost all manufacturers approve the use of E10 in their vehicles. E85 is a blend of 85% ethanol and 15% petrol and can be used in fl exible fuel vehicles (FFVs). FFVs are specially designed to run on petrol, E85, or any mixture of the two. These vehicles are offered by several manufacturers. There is no noticeable difference in vehicle performance when E85 is used. However, FFVs operating on E85 usually experience a 20–30% drop in miles per gallon owing to the lower energy content of ethanol.

There are some advantages and disadvantages of using ethanol:

Advantages:

- lower emissions of air pollutants
- more resistant to engine knock
- added vehicle cost is very small

Disadvantages:

- can only be used in fl exible fuel vehicles
- lower energy content, resulting in fewer miles per gallon
- limited availability.

BIODIESEL

Biodiesel is a form of diesel fuel manufactured from vegetable oils, animal fats or recycled restaurant oils. It is safe and biodegradable, and produces fewer air pollutants than petroleum-based diesel. It can be used in its pure form (B100) or blended with petroleum diesel. Common blends include B2 (2% biodiesel), B5 and B20. B2 and B5 can be used safely in most diesel engines. However, most vehicle manufacturers do not recommend using blends greater than B5, and engine damage caused by higher blends is not covered by some manufacturer warranties.

Advantages:

- can be used in most diesel engines, especially newer ones
- produces fewer air pollutants (other than NO_x) and greenhouse gases
- biodegradable
- non-toxic
- safer to handle.

Disadvantages:

- use of blends above B5 may not yet be approved by manufacturers
- lower fuel economy and power (10% lower for B100, 2% for B20)
- more NO_x emissions
- B100 generally not suitable for use in low temperatures
- concerns about B100's impact on engine durability.

NATURAL GAS

Natural gas is a fossil fuel made up mostly of methane. It is one of the cleanest burning alternative fuels. It can be used in the form of compressed natural gas (CNG) or liquefi ed natural gas (LNG) to fuel cars and trucks. Dedicated natural gas vehicles are designed to run on natural gas only, while dual-fuel or bi-fuel vehicles can also run on petrol (gasoline) or diesel . Dual-fuel vehicles take advantage of the widespread availability of conventional fuels but use a cleaner, more economical alternative when natural gas is available. Natural gas is stored in high-pressure fuel tanks so dual-fuel vehicles require two separate fuelling systems, which take up extra space. Natural gas vehicles are not produced commercially in large numbers. However, conventional vehicles can be retrofi tted for CNG.

Advantages:

● 60–90% less smog-producing pollutants

● 30–40% less greenhouse gas emissions

● less expensive than petroleum fuels.

Disadvantages:

● limited vehicle availability

● less readily available

● fewer miles on a tank of fuel

LIQUEFIED PETROLEUM GAS

Propane or liquefi ed petroleum gas (LPG) is a clean-burning fossil fuel that can be used to power internal combustion engines. LPG-fuelled vehicles produce fewer toxic and smog-forming air pollutants. Petrol (gasoline) and diesel vehicles can be retrofi tted to run on LPG in addition to conventional fuel. The LPG is stored in high-pressure fuel tanks , so separate fuel systems are needed in vehicles powered by both LPG and a conventional fuel.

Advantages:

● fewer toxic and smog-forming air pollutants

● less expensive than petrol

Disadvantages:

● no new passenger cars or trucks commercially available, but vehicles can be

retrofi tted for LPG

● less readily available than conventional fuels

● fewer miles on a tank of fuel.

HYDROGEN

Hydrogen (H_2) can be produced from fossil fuels (such as coal), nuclear power or renewable resources, such as hydropower. Fuel cell vehicles powered by pure hydrogen emit no harmful air pollutants. Hydrogen is being aggressively explored as a fuel for passenger vehicles. It can be used in fuel cells. to power electric motors or burned in internal combustion engines. Hydrogen is an environmentally friendly fuel that has the potential to dramatically reduce dependence on oil, but several significant challenges must be overcome before it can be widely used.

Advantages:

● can be produced from several sources, reducing dependence on petroleum

● no air pollutants or greenhouse gases when used in fuel cells

● it produces only NO_x when burned in internal combustion engines.

Disadvantages:

● expensive to produce and is only available at a few locations

● fuel cell vehicles are currently too expensive for most consumers

● hydrogen has a lower energy density than conventional petroleum fuels, so

ELECTRICAL SYSTEMS

To understand electricity properly we must start by fi nding out what it really is. This means we must think very small. The molecule is the smallest part of matter that can be recognized as that particular matter. Subdivision of the molecule results in atoms. The atom is a basic unit of matter and consists of a central nucleus made up of protons and neutrons. Around this nucleus electrons are in orbit, like planets around the sun .The neutron is a very small part of the nucleus. It has an equal positive and negative charge. It is therefore neutral and has no polarity. The proton is another small part of the nucleus. It is positively charged. As the neutron is neutral and the proton is positively charged, this means the nucleus of the atom is positively charged. The electron is an even smaller part of the atom, and is negatively charged.

1. BATTERIES

A good supply of electric power is necessary for modern vehicles. The engines require a large current to operate the starter motor and many other systems are electrically powered. All modern cars use a 12 V system. The majority of vehicle batteries are of conventional design, using lead plates in a dilute sulphuric acid electrolyte (Fig. 3.37). This feature leads to the common description of ‘lead-acid’ batteries. The output from a lead-acid battery is direct current (d.c.). A rechargeable battery is an electrochemical unit that converts an electric current into a modified chemical compound. This chemical reaction can be reversed to release an electric current. The modified chemical compound in the battery stores energy, which is available as electricity when connected to a circuit.A few batteries have open cells that require routine maintenance to the electrolyte level. This usually consists of adding distilled water at regular intervals. Most modern lead-acid battery designs have improved plate construction and case design, which with precise alternator charge control allows maintenance-free types to be used. A vehicle 12 V battery is made up from six cells. Each lead-acid cell has a nominal voltage of 2.1 V, which gives a value of 12.6 V for a fully charged battery under noload conditions. The six cells are connected in series, internally in the battery, with lead bars. The cells are formed in the battery case and are completely separate from each other.

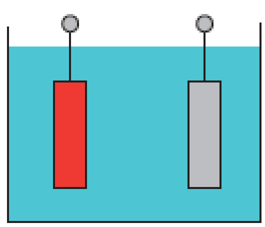


Figure 3.39 Charged state (see text)

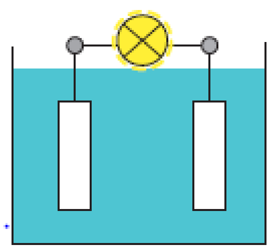


Figure 3.40 Discharged state (see text)

Each cell has a set of interleaved positive and negative plates kept apart by porous separators. The separators prevent contact of the plates, which would give an internal short-circuit and affect the chemical reaction in the battery cell. The cell plates are supported above the bottom of the case. This leaves a sediment trap below the plates so that any loose material that falls to the bottom does not cause a short-circuit between the plates. The cell plates are formed in a lattice grid of lead–antimony or lead–calcium alloy. The grid carries the active material and acts as the electrical conductor. The active materials are lead peroxide for the positive plate and spongy lead for the negative plate. When a battery is in a charged state the positive plates of lead peroxide (PbO_2) are reddish brown in colour, and the negative plates of spongy lead (Pb) are grey in colour .When the battery is discharging, a chemical reaction with the electrolyte changes both plates to lead sulphate ($PbSO_4$) .

Applying an electric current to the battery reverses the process. The charged battery stores chemical energy. This can be released as electrical energy when the battery is connected into a circuit. The electrolyte is dilute sulphuric acid, which reacts with the cell plate material during charging and discharging of the battery. Sulphuric acid (H_2SO_4) consists of hydrogen, sulphur and oxygen. These chemicals separate during the charge and discharge process and attach to the cell plate active material or return to the electrolyte.

During discharge, the sulphate (SO_4) combines with the lead to form lead sulphate ($PbSO_4$). The oxygen in the positive plate is released to the electrolyte and combines with the hydrogen that is left, to form water (H_2O). During charging, the reverse process occurs with the sulphate (SO_4), leaving the cell plates to reform with the hydrogen in the electrolyte to produce sulphuric acid (H_2SO_4). Oxygen in the electrolyte is released to reform with the positive cell plate material as lead peroxide (PbO_2).

Near the fully charged state some hydrogen (H_2) and oxygen (O_2) may be lost as gas from the battery vent (Fig. 3.42). Some water (H_2O) can also be lost by vaporization in hot weather. With older batteries, this meant that the battery electrolyte needed regular inspection and topping up. Only water is lost from the battery and therefore only water should be used for topping up. Any contaminants will affect the chemical reactions in the battery and, therefore, the performance.

2. CHARGING SYSTEM

The electrolyte chemical composition changes with the state of charge. It is possible to measure this change using a hydrometer. Sulphuric acid is denser and provides greater buoyancy than water. This property is called specific gravity or relative density. Water, which is used as the base for measurement of all liquids, is given a value of 1 for readings at 15°C (60°F).

The dilute sulphuric acid of the electrolyte of a fully charged battery cell has a reading of 1.280. The reading for a half-charged battery cell is 1.200 and for a fully discharged battery is 1.150. A reading below 1.140 may indicate a cell that can no longer be recharged. It is common to write these values with three decimal places but to just say the significant digits (e.g. twelve eighty). A hydrometer consists of a calibrated fl oat in a glass cylinder (Fig. 3.43). A bulb on the top of the cylinder is depressed so that it acts as a vacuum pump when it is released. A small rubber tube is attached to the bottom of the cylinder and is inserted into the electrolyte in the battery cell. A sample of the electrolyte can, therefore, be drawn into the cylinder.

There are two ways of charging batteries in the workshop; one is a slow or trickle charge and the other a fast charge. These require two different types of charger. Most batteries can be fast charged, but this should only be carried out infrequently. If a high charge is used this can cause some deterioration of the battery's active materials.

A slow charger or bench charger uses mains electricity. Inside is fitted a transformer to reduce the voltage to 6, 12 or 24 V, to suit the battery or batteries on charge. Also fitted is a rectifier to change the a.c. volts of the mains supply to the d.c. volts needed for charging batteries. The charger is connected to the battery terminals with the correct polarity. After setting the control switches, the charger is then turned on at the main switch.

There are several different types of charger and these should be used in accordance with the manufacturers' instructions. The recommended charge rate for a battery is one-tenth of the ampere-hour capacity. A 40 Ah battery should be charged at 4 A. If the ampere-hour capacity is not known, set the rate to one sixteenth of the reserve capacity. Where the charge current can be adjusted, this facility should be used to set the rate.

A fast charger can be connected to a battery on a vehicle, to give a quick boost when a battery has a low charge. Some of these chargers have an engine start facility. Always follow the equipment manufacturer's instructions when using this type of charger. Some batteries are not suitable for fast charging; therefore, always refer to the vehicle or battery manufacturer's data for recommendations.

Fast chargers have a time clock for setting the charger for a fIxed charge period . Some have a temperature probe included, to switch off the charger if the battery becomes overheated. Keep a close watch on the battery temperature if a fast charger does not have a temperature probe. The maximum setting for a fast charge should not exceed one hour at fi ve times the normal charge rate.

3. GENERATOR

Alternators are used in modern automobiles to charge the battery and to power the electrical system when its engine is running.

Until the 1960s, automobiles used DC dynamo generators with commutators. With the availability of affordable silicon diode rectifiers, alternators were used instead. This was encouraged by the increasing electrical power required for cars in this period, with increasing loads from larger headlamps, electric wipers, heated rear windows and other accessories.

Advantages over dynamos

Alternators have several advantages over direct-current generators. They are lighter, cheaper and more rugged. They use slip rings providing greatly extended brush life over acommutator. The brushes in an alternator carry only excitation current, a small fraction of the current carried by the brushes of a DC generator, which carry the generator's entire output. A set of rectifiers (diode bridge) is required to convert AC to DC. To provide direct current with low ripple, a three-phase winding is used and the pole-pieces of the rotor are shaped (claw-pole) to produce a waveform similar to a square wave instead of a sinusoid. Automotive alternators are usually belt driven at 2-3 times crankshaft speed. The alternator runs at various RPM (which varies the frequency) since it is driven by the engine. This is not a problem because the alternating current is rectified to direct current.

OPERATION

Despite their names, both 'DC generators' (or 'dynamos') and 'alternators' initially produce alternating current. In a so-called 'DC generator', this AC current is generated in the rotating armature, and then converted to DC by the commutator and brushes. In an 'alternator', the AC current is generated in the stationary stator, and then is converted to DC by the rectifiers (diodes).

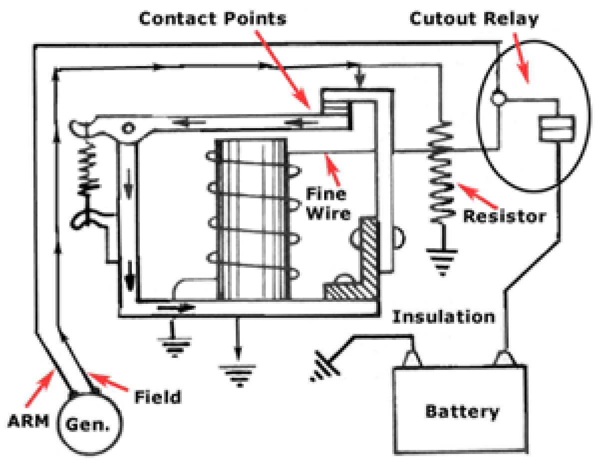
Typical passenger vehicle and light truck alternators use Lundell or 'claw-pole' field construction. This uses a shaped iron core on the rotor to produce a multi-pole field from a single coil winding. The poles of the rotor look like fingers of two hands interlocked with each other. The coil is mounted axially inside this and field current is supplied by slip rings and carbon brushes. These alternators have their field and stator windings cooled by axial airflow, produced by an external fan attached to the drive belt pulley.

Modern vehicles now use the compact alternator layout. This is electrically and magnetically similar, but has improved air cooling. Better cooling permits more power from a smaller machine. The casing has distinctive radial vent slots at each end and now encloses the fan. Two fans are used, one at each end, and the airflow is semi-radial, entering axially and leaving radially outwards The stator windings now consist of a dense central band where the iron core and copper windings are tightly packed, and end bands where the windings are more exposed for better heat transfer. The closer core spacing from the rotor improves magnetic efficiency. The smaller, enclosed fans produce less noise, particularly at higher machine speeds.

Larger vehicles may have salient pole alternators similar to larger machines. The windings of a 3 phase alternator may be connected using either the Delta or Wye connection regime.

Voltage Regulators

As you may recall from last month's article on the function of generators, there is no means of internally controlling the output of one. In other words, the faster it spins the more voltage goes into the car's electrical system. If this weren't controlled the generator would damage the battery and burn out the car's lights. Also, if the generator weren't cut out from the car's circuitry when not running, the battery would discharge through its case.



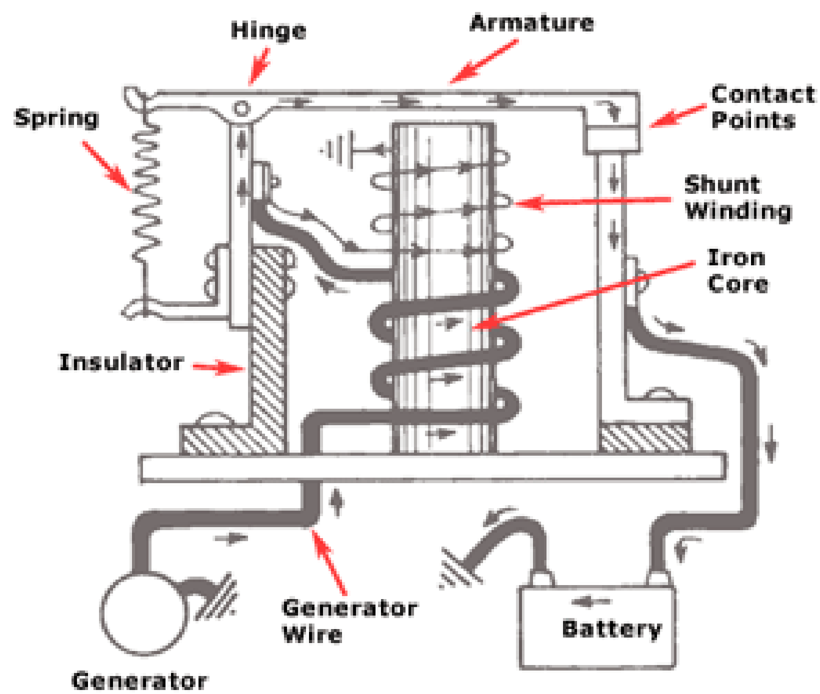
Typical Voltage Regulator

That's where the REGULATOR (commonly called the Voltage Regulator, but that's only one component of the system) comes in. Regulators have seen many design improvements over the decades, but the most commonly used electro-mechanical regulator is the three-control units in one box type. Let's look at how these things work.

Cutout Relay

Sometimes called the circuit breaker, this device is a magnetic "make-and-break" switch. It connects the generator to the battery (and therefore the rest of the car) circuit when the generator's voltage builds up to the desired value. It disconnects the generator when it slows down or stops.

The relay has an iron core that is magnetized to pull down a hinged armature. When the armature is pulled down a set of contact points closes and the circuit is completed. When the magnetic field is broken (like when the generator slows down or stops) a spring pulls the armature up, breaking the contact points.



A Schematic of the cutout relay. Trace the flow of current through its components.

An obvious failure mode is the contact points. As they open and close, a slight spark is generated, eventually eroding the material on the points until they either "weld" themselves together or become so high in resistance that they won't conduct current when closed. In the first case the battery would discharge through the generator overnight and in the second there would be no charging to the system.

Voltage Regulator

Another iron core-operated set of contact points is utilized to regulate maximum and minimum voltage at all times. This circuit also has a shunt circuit (a shunt re-directs electrical flow) going to ground through a resistor and placed just ahead (electrically) of the points. When the points are closed the field circuit takes the "easy" route to ground but when the points are open the field circuit must pass through the resistor to get to ground.

The field coil on the generator is connected to one of the voltage regulator contact points. The other point leads directly to ground.

When the generator is operating (battery low or a number of devices running) its voltage may stay below that for which the control is set. Since the flow of current will be too weak to pull the armature down the generator field will go to ground through the points. However, if the system is fully charged the generator voltage will increase until it reaches the maximum limit and current flow through the shunt coil will be high enough to pull the armature down and separate the points.

This cycle is repeated over and over in real time. The points open and close about 50 to 200 times per second, maintaining a constant voltage in the system.

Current Regulator

Even though the generator's voltage is controlled it is possible for its current to run too high. This would overheat the generator, so a current regulator is incorporated to prevent premature failure.

Similar in appearance to the voltage regulator's iron core, the current regulator's core is wound with a few turns of heavy wire and connected in series with the generator's armature.

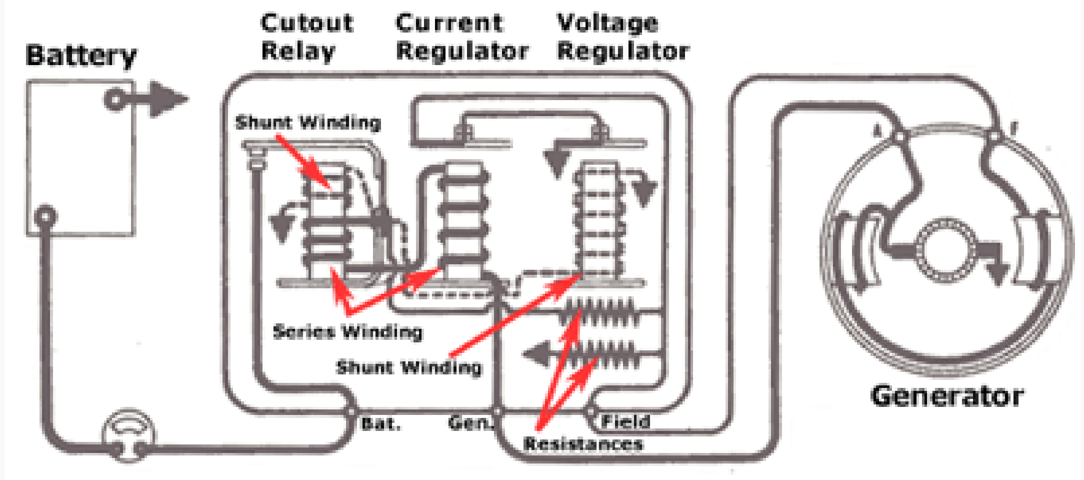


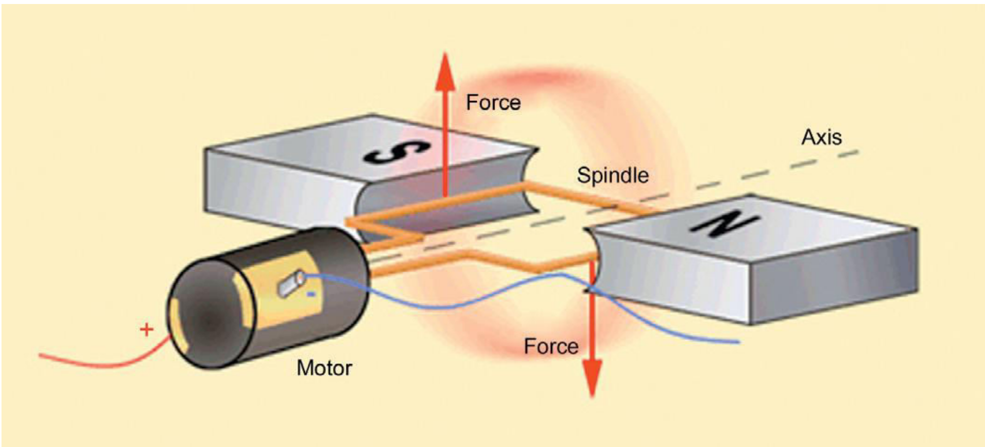
Diagram of a typical three-unit regulator. Trace all circuits a few times and you will understand how it functions.

In operation, current flow increases to the predetermined setting of the unit. At this time, current flow through the heavy wire windings will cause the core to draw the armature down, opening the current regulator points. In order to complete the circuit the field circuit must pass through a resistor. This lowers current output, points close, output increases, points open, output down, points close, and so on. The points, therefore, vibrate open and closed much as the voltage regulator's points do, many times every second.

4. STARTING SYSTEM

The engine starting system consists of a heavy-duty motor, with a drive pinion that engages with a gear on the engine flywheel, and an electrical control circuit to operate the motor (Figs 3.53 and 3.54). The starter motor power output has to be able to crank a cold engine at

suffi cient speed to start it. A 2 litre petrol engine will have a starter motor of about 1 kW, which will spin the engine at about 150 rpm. A similarly sized diesel engine will require double the power and possibly twice the cranking speed to start. The main components of the starter motor are the magnetic fi elds, armature, drive pinion and solenoid. The circuit consists of a battery supply, earth cables and the starter switch. The starter motor is a direct current (d.c.) electromagnetic unit that usually has two pairs of magnetic pole shoes arranged at opposite positions inside the motor casing. The casing acts as the yoke for the magnetic poles. The magnetic pole shoes can be strong permanent magnets or electromagnets using a winding.



The armature, which consists of a series of wire conductor loops wound around a laminated iron core, is mounted on the motor spindle. The conductor loops are terminated into segments of a commutator. Carbon or composite brushes conduct the motor electrical supply through the commutator segments to the individual conductor loops. The construction of a simple d.c. motor is shown in Fig. The magnetic force between the poles is from north to south. A loop conductor inside the magnetic field is provided with a d.c. electrical supply through a split slip ring, which forms a simple commutator. When an electrical current is passed through a conductor a magnetic field is formed around that conductor. The magnetic field direction depends on the direction of the current fl ow. When the conductor is placed inside a fixed magnet, the magnetic field distorts to produce a repelling magnetic force, which pushes on the conductor.

A starter motor requires strong magnetic forces to produce the speed and torque to crank an engine at sufficient speed for starting. For this, the armature is made with soft iron cores to make strong electromagnets, which are able to change polarity with the direction of current fl ow in the loop conductors. Laminations of soft iron are used for the cores to reduce magnetization losses. They are insulated from each other and assembled as a single unit on the armature.

The magnetic strength of the field magnetic poles is usually determined by using an electrical winding around the pole shoe. The wire coil is wound around one pole shoe and then the other in the opposite direction, so that the opposing field poles are produced opposite each other in the casing.

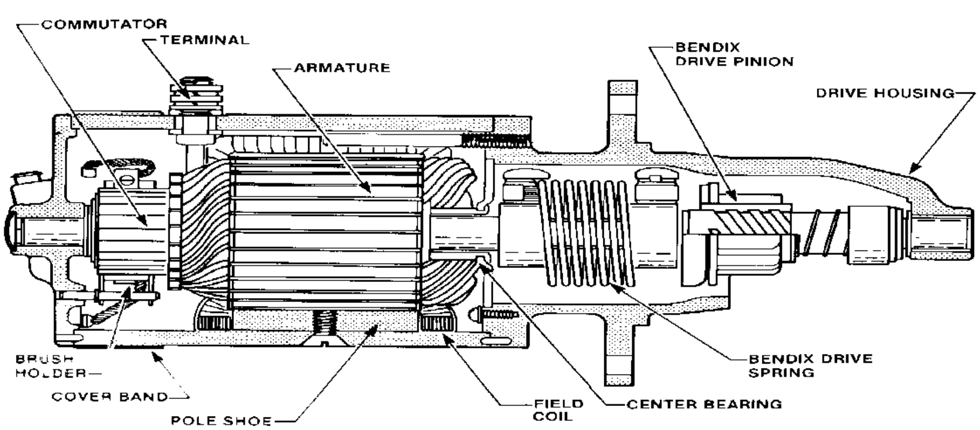
The drive from the motor is taken from a pinion gear on the spindle to the large diameter starter ring gear on the engine. The starter ring gear is fitted to the outside of the fl ywheel on manual transmission vehicles, or the torque converter drive plate on automatic transmission vehicles. The pinion meshes with the ring gear only during starting and is made to slide axially on or with the spindle to engage the drive when operated (Fig. 3.58).

BENDIX DRIVE

A **Bendix drive** is a type of engagement mechanism used in starter motors of internal combustion engines. The device allows the pinion gear of the starter motor to engage or disengage the flywheel of the engine automatically when the starter is powered or when the engine fires, respectively. It is named after its inventor, Vincent Hugo Bendix.

The Bendix system places the starter drive pinion on a helical drive spring. When the starter motor begins turning, the inertia of the drive pinion assembly causes it to wind the spring forcing the length of the spring to change and engage with the ring gear. When the engine starts, back drive from the ring gear causes the drive pinion to exceed the rotative speed of the starter, at which point the drive pinion is forced back and out of mesh with the ring gear.

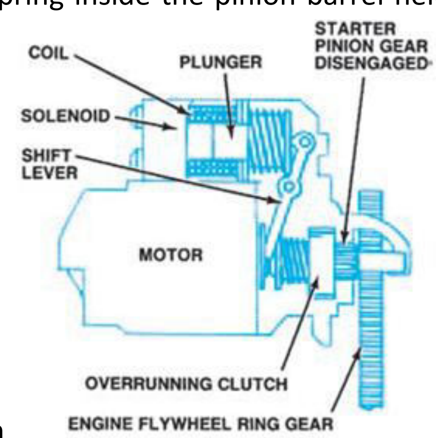
The main drawback to the Bendix drive is that it relies on a certain amount of "clash" between the teeth of the pinion and the ring gears before they slip into place and mate completely; the teeth of the pinion are already spinning when they come into contact with the static ring gear, and unless they happen to align perfectly at the moment they engage, the pinion teeth will strike the teeth of the ring gear side-to-side rather than face-to-face, and continue to rotate until both align. This increases wear on both sets of teeth. For this reason the Bendix drive has been largely superseded in starter motor design by the pre-engagement system using a solenoid.



SOLENOID SWITCH

In a pre-engaged starter motor, the drive pinion is brought into mesh by the action of an electromagnetic solenoid mounted on the starter motor casing. The solenoid has a soft iron plunger, which is drawn into the magnetic fi eld that is produced inside the solenoid when an electrical current is passed through the solenoid windings. Connected to the plunger is a lever, which is pivoted so that, as one end is pulled into the solenoid, the opposite end pushes the pinion into mesh with the starter ring gear. The pinion is mounted on a unidirectional clutch, which is fi tted to a sleeve with an internal spline to take the drive from the starter spindle. On the outside of the sleeve is a radial groove to take the fork of the engagement lever.

At the other end of the solenoid are the electrical contacts that form the switchto pass the electrical current to the motor. The solenoid on many pre-engaged starter motors has two windings. These are the 'closing' and 'holding' windings. The closing winding or pull-in coil operates as soon as the solenoid is energized. This winding has an earth, or ground, return through the motor windings. This passes a current into the motor so that it rotates slowly during the engagement phase. Once the switch contacts are fully engaged, the holding winding holds the switch in place. The closing winding does not conduct once the motor current has been switched on. A holding coil is wound around the solenoid. This creates the magnetic field required to hold the solenoid in the engaged position during starting. When the starter switch is released, a spring returns the solenoid plunger to its 'off' position. If the engine were to start under these conditions, it would drive the motor spindle at an excessive speed. To prevent this occurring in pre-engaged drive starter motors, a unidirectional overrun clutch is fitted on the pinion. This allows the motor to drive the engine but stops the engine driving the motor. A roller-type overrun clutch is a popular method, although a few other types are used. These clutch units are sealed for life and require replacement if they fail in service. Clutch operation is summarized in Fig. On early inertia-type starter motors, a spiral or helical sleeve carried the pinion, which slid into mesh because of the forward drive from the motor spindle, and out of esh by the engine spinning.A spring inside the pinion barrel held the gears out of mesh when



the starter was not in operation

6. LIGHTING SYSTEMS

Vehicle lighting systems are very important, particularly where road safety is concerned. If headlights were suddenly to fail at night and at high speed, the result could be serious. Remember that lights are to see with and to be seen by. Lights are arranged on a vehicle to meet legal requirements and to look good. Headlights, sidelights and indicators are often combined on the front . Taillights, stoplights, reverse lights and indicators are often combined at the rear.

The number, shape and size of bulbs used on vehicles are increasing all the time. Most bulbs used for vehicle lighting are generally either conventional tungsten fi lament bulbs or tungsten halogen. In the conventional bulb, the tungsten fi lament is heated to incandescence by an electric current. The temperature reaches about 2300°C. Tungsten, or an alloy of tungsten, is ideal for use as fi laments for electric light bulbs. The fi lament is normally wound into a 'spiralled spiral' to allow a suitable length of thin wire in a small space, and to provide some mechanical strength.

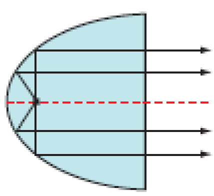


Figure 3.82 Concave reflector (light source at the focal point)

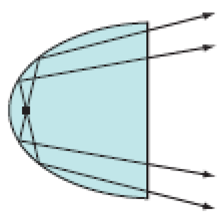


Figure 3.83 Light source behind the focal point

HEADLIGHT

A good headlight should have a powerful, far-reaching central beam, around which the light is distributed both horizontally and vertically to illuminate as great an area of the road surface as possible. The beam formation can be considerably improved by passing the reflected light rays through a transparent block of lenses. It is the function of the lenses to partially redistribute the reflected light beam and any stray light rays. This gives better overall road illumination.

Many headlights are now made with clear lenses, such that all the redirection of the light is achieved by the reflector .A clear lens does not restrict the light in any way. This makes the headlights more efficient as well as attractive. Sidelights, taillights, brake lights and others are relatively straightforward.

Headlights present the most problems. This is because on dipped beam they must provide adequate light for the driver, but not dazzle other road users. The conflict between seeing and dazzling is very difficult to overcome. The main requirement is that headlight alignment must be set correctly. Some cars have a headlight adjuster that the driver can control. The adjuster is connected to levelling actuators. The function of levelling actuators is to adjust the dipped or low beam in accordance with the load carried by the car. This will avoid dazzling oncoming traffic

STOPLIGHTS AND REVERSE LIGHTS

Stoplights, or brake lights, are used to warn drivers behind that you are slowing down or stopping. Reverse lights warn other drivers or pedestrians that you are reversing, or intend to reverse. The circuits are quite simple; one switch in each case operates two or three bulbs via a relay.

The circuits for these two systems are similar. Most incorporate a relay to switch on the lights, which in turn is operated by a spring-loaded switch on the brake pedal or gearbox. Links from the stoplight circuit to the cruise control system may be found. This is to cause the cruise control to switch off as the brakes are operated. A link may also be made to the antilock brake system.

INTERIOR LIGHTING

Interior lighting consists of several systems, the main ones being courtesy lights, map lights and panel illumination lights. Features such as delay and fade-out are now common. This requires some electronic control. Map lights are an extra feature to assist with reading a map in the dark. Many types are available: some are small spotlights, which form part of the interior light assembly, while others are positioned on the centre console of the vehicle.

Lights are designed to illuminate the vehicle interior when the doors are opened. Most cars have one central interior light above the rear-view mirror, or two lights, on the sides above the driver's and passenger's shoulders. Door switches are simple spring-loaded contacts that are made as the door opens. The contacts are broken again as the door closes. Rubber seals are sometimes used to keep water out. The same switches may also be used for the alarm system.

INDICATORS AND HAZARD LIGHTS

Direction indicators (turn signals) have a number of statutory requirements. The light produced must be amber (or red on the rear of some American cars), but they may be grouped with other lamps. The fl ashing rate must be between one and two per second with a relative 'on' time of between 30% and 57%. If a fault develops this must be apparent to the driver by the operation of a warning light on the dash. The fault can be indicated by a distinct change in frequency of operation or by the warning light remaining on. If one of the main bulbs fails then the remaining lights should continue to fl ash perceptibly. Legislation exists as to the mounting position of the exterior lamps. The rear indicator lights must be within a set distance of the rear lights and within a set height. The wattage (power) of indicator bulbs is normally 21 W These lights often come under the heading of auxiliaries or signalling.

7.WIPERS

The requirements of the wiper system are simple. The windscreen must be clean enough to provide suitable visibility at all times. To do this, it must:

● achieve effi cient removal of water and snow

● achieve effi cient removal of dirt

● operate at temperatures from _30 to 80°C

● pass the stall and snow load test

● have a service life in the region of 1.5 million wipe cycles

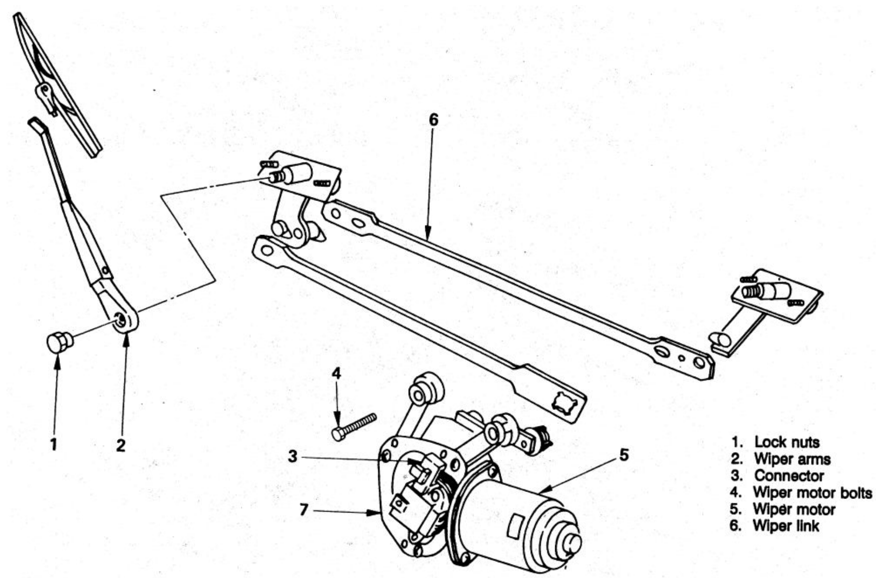
● be resistant to corrosion from acid, alkali and ozone.

Wiper blades are made of a rubber compound and are held on to the screen by a spring in the wiper arm. The aerodynamic property of the wiper blades has become increasingly important. The strip on top of the rubber element is often perforated to reduce air drag. A good quality blade will have a contact width of about 0.1 mm. The lip wipes the surface of the screen at an

angle of about 45°. The pressure of the blade on the screen is also important. Most wiper linkages consist of a series or parallel mechanism. Some older types use a fl exible rack and wheel boxes similar to the operating mechanism of many sunroofs. One of the main considerations for the design of a wiper linkage is the point at which the blades must reverse. This is because of the high forces on the motor and linkage at this time. If the reverse point is set so that the linkage is at its maximum force transmission angle, then the reverse action of the blades puts less strain on the system. This also ensures smoother operation.

All modern wiper motors are permanent magnet types. The drive is taken via a worm gear to increase torque and reduce speed. Three brushes may be used, such that when the washers are operated, the wipers start automatically and will continue, for several more sweeps, after the washers have stopped.

switches are shown in the off position and the motor is stopped and in its park position. Note that the two main brushes of the motor are connected together via the limit switch, delay unit contacts and the wiper switch. This causes regenerative braking because of the current, generated by the motor due to its momentum, after the power is switched off. Being connected to a very low resistance loads up the ‘motor/generator’ and, when the park limit switch closes, it stops instantly. When either the delay contacts or the main switch contacts are operated, the motor will run at slow speed. When fast speed is selected, the third brush on the motor is used. On switching off, the motor will continue to run until the park limit switch changes over to the position shown in. This switch is only in the position shown when the blades are in the parked position. Many vehicles use a system with more enhanced facilities. This is regulated by what may be known as a central control unit (CCU), a multifunction unit (MFU) or a general electronic module (GE)These units often control other systems as well as the wipers, thus allowing reduced wiring bulk under the dash area. Electric windows, headlights and heated rear window, to name just a few, are now often controlled by a central unit.



8. HORNS

Regulations in most countries state that the horn (or audible warning device) should produce a uniform sound. This makes sirens and melody-type fanfare horns illegal. Most horns draw a large current so are switched by a relay.

The standard horn operates by simple electromagnetic switching. Current flow causes an armature, which is attached to a tone disc, to be attracted to a stop. A set of contacts is then opened. This disconnects the current, allowing the armature and disc to return under spring tension. The whole process keeps repeating when the horn switch is on. The frequency of movement, and hence the tone, is arranged to lie between 1.8 and 3.5 kHz. This note gives good penetration through traffic noise. Twin horn systems, which have a high and low tone horn, are often used. This produces a more pleasing sound, but is still very audible in both town and higher speed conditions.

9. FUEL GAUGE

The main reason for stretching a vehicles mileage is the fuel gauge present on the dashboard of the car which makes the driver think that they are running low on fuel while there is plenty of fuel still left. Therefore the traditional system used is notoriously inaccurate; however some embedded systems were incorporated into the traditional systems in order to obtain better accuracy. Presently the most common and traditional fuel indicator system makes use of the resistive float type sensors to measure the level of fuel in the tank and this system consists of two units i.e. 1) The ―sender unit‖ responsible to measure the level of fuel in the tank,

2) The ―gauge unit‖ responsible to display the measured fuel level to the driver.

Another technique is known as the Smart fuel gauge system, which is similar to the traditional technique but also makes use of embedded systems such as microcontrollers or microprocessors for providing better accuracy

OPERATING PRINCIPLES OF THE EXISTING TECHNIQUES

The traditional fuel indicator consists of two units i.e. the sending unit and the gauge. The

Fig (1) shows the commonly used traditional fuel measurement system. The sending unit is located in the fuel tank of the car and it consists of afloat, usually made of foam, connected to a thin, metal rod. The end of the metal rod is mounted on a variable resister or potentiometer. The variable resistor consists of a strip of resistive material over it which moves across the variable resistor changing the resistance and flow of current depending on the movement of the float with respect to the level of fuel present in the fuel tank. The Fig (1) shows that the fuel in the in the fuel tank is almost empty and the float has moved to the bottom of the tank moving the strip on the resistor thus increasing the resistance to maximum and current flow through the resistor becomes minimum thus displaying fuel empty on the gauge[1]. The gauge consists of a bimetallic strip i.e. a strip made of different kinds of metal and whose thermal co-efficient of expansion differs from each other. When resistance is decreases, current increases and thus the strip is heated during which one metal expands less than the other, so the strip curves, and this bending action is what moves the needle move on the fuel gauge. As resistance increases, less current passes through the heating coil, so the bimetallic strip cools. As the strip cools, it straightens out, pulling the gauge from full to empty. The smart fuel gauge system techniques has been implemented in some newer cars in which, instead of sending the current directly to the gauge, an intermediate microprocessor is used to read the output of the resistor and then communicate with the dashboard for displaying the fuel on the gauge corresponding to the read output voltage from the sending unit and these systems actually help improve the accuracy of the gauge.