Oil and gas engines

In steam engines, fuel burns outside the engine. The heat produced turns water into steam which, in turn, drives the engine. It is more efficient, however, to burn fuel inside an engine and let the expanding gases produce drive a piston or turbine.

The first such internal combustion engine was built by the German engineer Nikolaus August Otto (1832-91). His engine, which used a mixture of gas and air as fuel, was demonstrated in Paris in 1867 [Key]. Despite being large, noisy and inefficient, Otto's engine was the forerunner of the internal combustion engines used today.

The four-stroke cycle

Nine years after the invention of his first engine, Otto devised another design. It was based on the four-stroke cycle. The crucial advance with this engine was that it ignited gas which was compressed before it entered the combustion chamber. Not only did this modification produce more power, it also gave a marked reduction in fuel consumption.

Each of the four strokes that give this type of engine its name has a specific function. First, there is an induction stroke in which a downward movement of the piston sucks in the fuel-air mixture. Second, a compression stroke in which the upward movement of the piston compresses the gas. Third, a second downward piston movement, called the power stroke, caused by the explosion of fuel. Fourth, an exhaust stroke in which the upward-moving piston forces the exhaust gases out of the cylinder. The flow of the fuel-air mixture and exhaust gases in and out of the engine is controlled by valves opened and closed by a camshaft driven from the engine crankshaft.

Both of Otto's engines ran on coal gas. Most modern engines use liquid fuels, such as petrol (gasoline), which are refined from crude oil [1]. For petrol to burn effectively it has to be converted to vapour and mixed with air. In internal combustion engines, this takes place in the carburettor [2]. Air flowing through the carburettor sucks a fine mist of petrol drops out of a series of jets. The jets are calibrated to give the correct amount of fuel for the amount of air entering the carburettor. In other engine designs, measured amounts of petrol are sprayed into the incoming airflow by a petrol injection system.

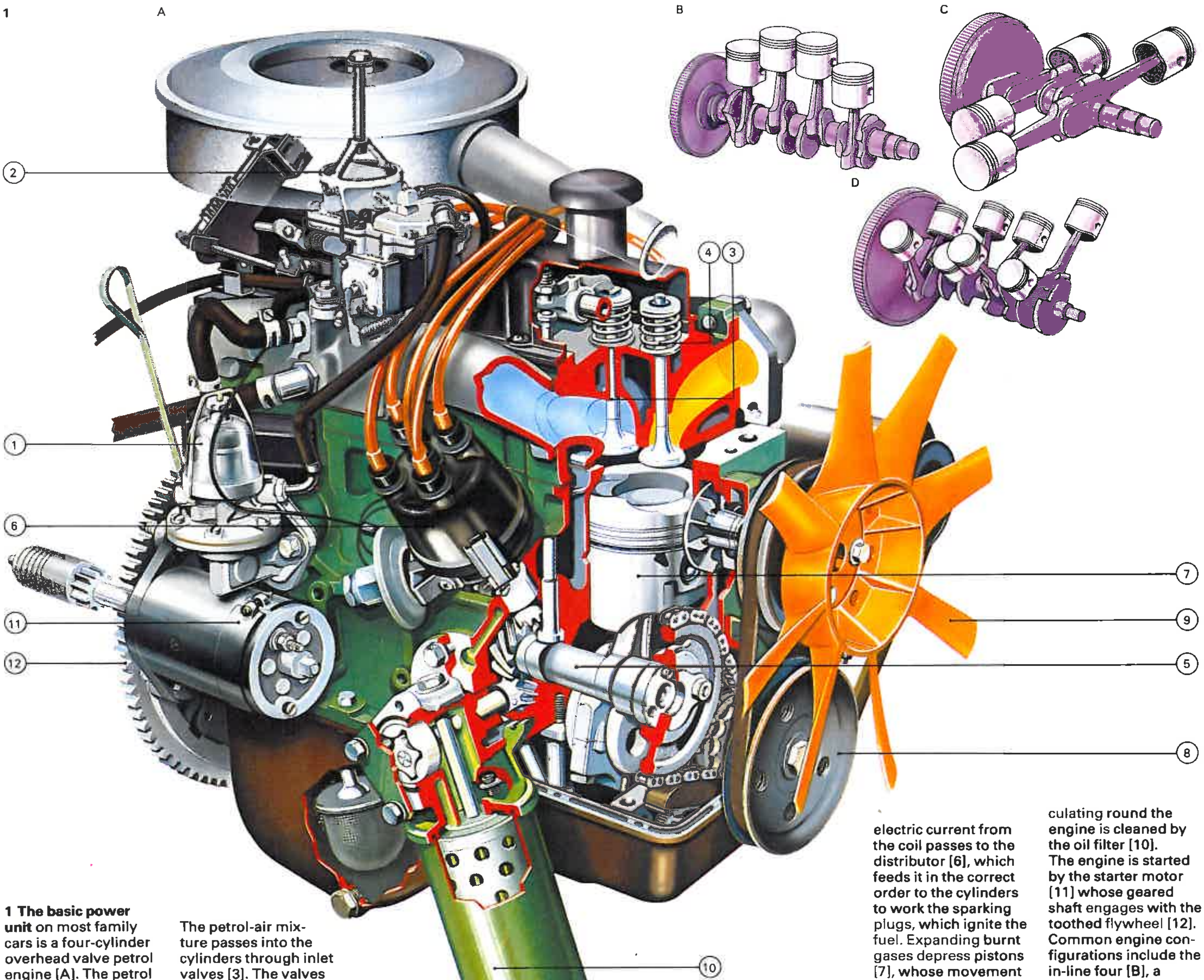
The fuel is ignited by a spark plug fitted into the cylinder's combustion chamber. An electrical induction system gives a high-voltage spark at the tip of the plug. The plugs are precisely timed to give a spark at the top of the compression stroke. This is achieved by an engine-driven distributor which initiates the sparks and directs them to each cylinder in turn. Modern engines are fitted with electronic ignition systems which time and produce the spark.

Unlike steam engines, most internal combustion engines do not produce great power at slow speeds. The cylinders are small and each individual ignition produces comparatively little power. To obtain a useful amount of power from such an engine it must run fast, giving the maximum amount of ignition strokes per second. Motor car engines usually produce maximum power at engine speeds of about 5,000rpm (revolutions per minute) or more. The upper speed limit is restricted by wear and tear on the engine caused by the oscillating pistons and valve gear. High-

CONNECTIONS

See also
Basic types of engine
How an automobile works
How an aircraft works
Modern ships

In other volumes
Technology of the Industrial Revolution (9)
Steam engines (9)
History of motorcycles (9)
History of automobiles (9)
Locomotives (9)



1 The basic power unit on most family cars is a four-cylinder overhead valve petrol engine [A]. The petrol pump [1] draws fuel from the petrol tank and in the carburettor [2] it is vaporized and mixed with air. The petrol-air mixture passes into the cylinders through inlet valves [3]. The valves are closed by springs [4] and opened by tappets controlled by push rods via the camshaft [5]. High-tension electric current from the coil passes to the distributor [6], which feeds it in the correct order to the cylinders to work the sparking plugs, which ignite the fuel. Expanding burnt gases depress pistons [7], whose movement rotates the crankshaft. A pulley [8] drives a cooling fan [9] by means of the fan belt. Lubricating oil circulating round the engine is cleaned by the oil filter [10]. The engine is started by the starter motor [11] whose geared shaft engages with the toothed flywheel [12]. Common engine configurations include the in-line four [B], a horizontally opposed or flat four [C] and a V-8 [D], with two sets of four cylinders inclined at an angle.

performance engines are built with great attention to balance and smoothness.

The diesel engine

The compression-ignition engine, designed by the German engineer Rudolf Diesel (1858-1913) in 1896, dispenses with the carburettor and spark plugs of the petrol engine [3]. During the compression stroke, pure air is compressed to between 1/14 and 1/20 of its initial volume in the cylinder. This is a much higher compression ratio than in the petrol engine. At the top of the compression stroke a fine spray of fuel oil is injected into the cylinder. As a gas is compressed, its temperature increases. Therefore, as the oil is injected into the cylinder the heat of the compressed air causes it to ignite spontaneously. The hot gases produced as a by-product of the ignition expand and drive the pistons through a four-stroke cycle, as in a petrol engine.

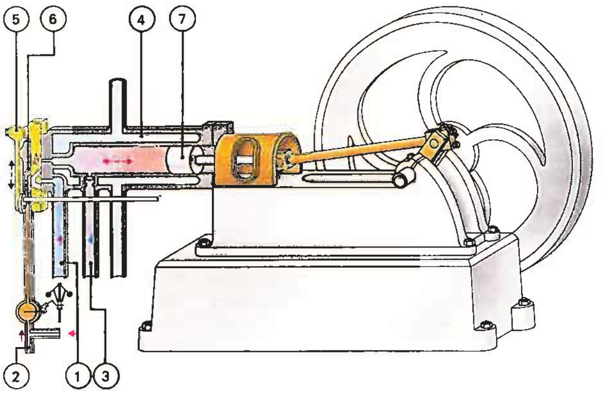
The compression-ignition, or diesel, engine is more efficient than the petrol engine because of its high compression ratio. But for the same reason it must be more solidly built, offsetting some of the advantage. Diesel engines use fuel more economically at the expense of a loss in performance. They are particularly suited to vehicles that start and stop frequently, such as buses.

The gas turbine

The gas turbine engine [4] is completely different from the petrol and diesel engines. It has a single shaft that carries a series of propeller-like fans. The fans are divided into two groups: the compressor (at the front of the shaft) and the turbine.

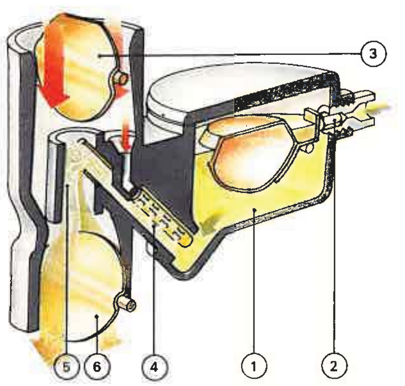
Air is drawn into the engine by the compressor. The compressor increases the pressure of the air. The compressed air is mixed with fuel and ignites, further increasing temperature and pressure in the combustion chamber. The exhaust gases are expelled from the engine through the turbine, driving the blades round to produce power. Some of the power is diverted to drive the compressor, but the net power output is high enough to give the gas turbine engine a good power-to-weight ratio. Gas turbine engines are particularly suited to aircraft. The power produced is used within the engine to drive a fan that produces thrust.

KEY



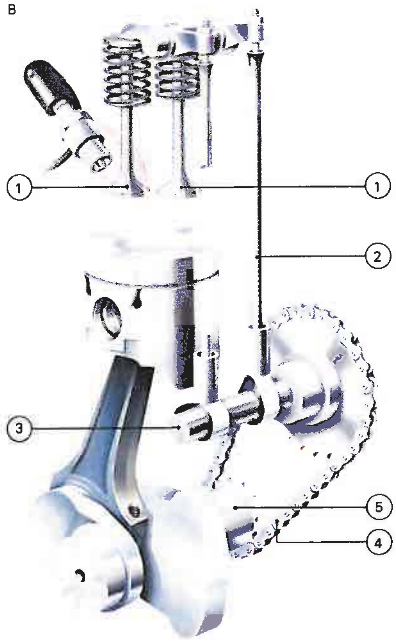
Otto's engine of 1876 was the first successful internal combustion engine. A four-stroke horizontal engine, it used a mixture of gas and air as fuel. The charging stroke drew in air [1] and gas [2] through a slide valve [5] into the cylinder, pulled in by movement of the piston [7]. On the return stroke, the fuel mixture was ignited by a flame carried through a narrow opening in the slide valve from a continuously burning gas jet [6] outside the engine. The expanding products of combustion produced the working stroke. On the fourth and last stroke the exhaust gases were forced out of the engine [3]. A jacket of cold water [4] surrounded the cylinder and kept the engine cool.

2A



2 In a carburettor [A], petrol enters the float chamber [1] controlled by a needle valve [2]. Part of the air passing the choke valve [3] mixes with the petrol [4]. The mixture passes into the main air stream [5] and past the throttle valve [6]. In an overhead valve engine [B] the valves [7] are worked by push rods [8] moved by cams on the camshaft [9], which is rotated by a chain [10] from the crankshaft [11].

B



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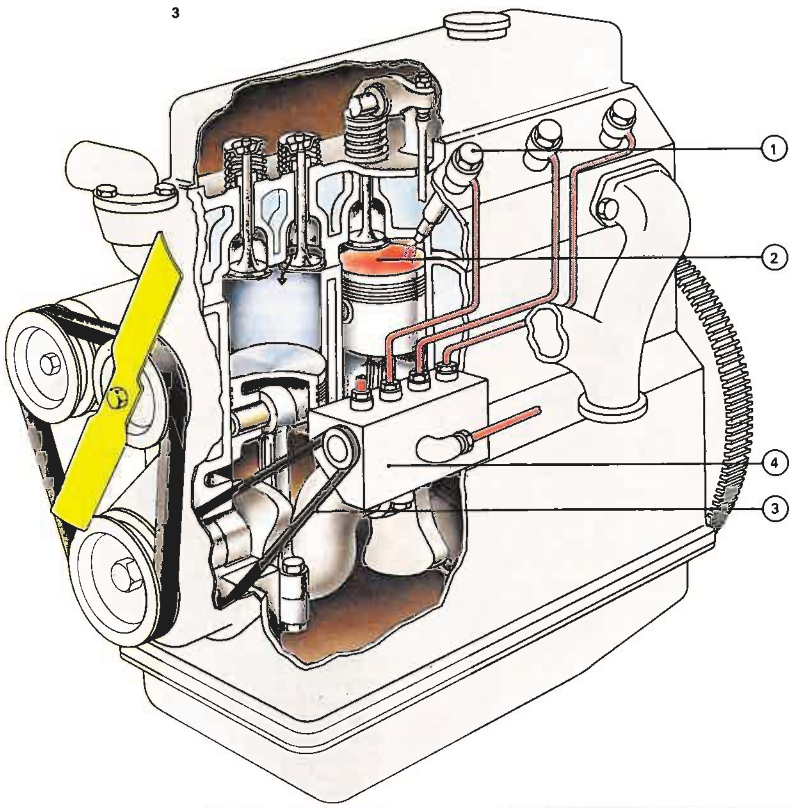
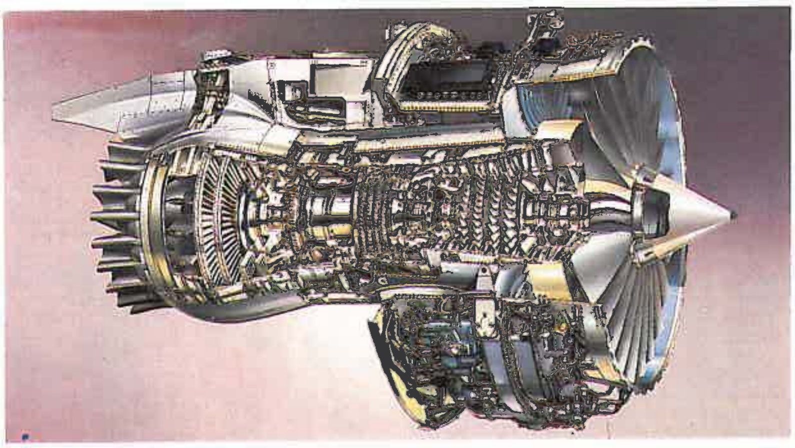


3 A diesel engine has no sparking plugs and works on the principle of compression-ignition. An injector [1] squirts fuel into the cylinder [2] where the upwards stroke of the piston compresses the air. In these conditions the fuel ignites spontaneously and the expansion of the combustion products forces the piston downwards. A drive taken from the crankshaft [3] works the fuel pump [4]. As in a petrol engine there is a pair of valves on each cylinder, but in a diesel one controls the admission of air only and the other lets exhaust gases out of the cylinder. The power of the engine depends on the amount of fuel delivered by the pump and this, in turn, is controlled by the vehicle's accelerator pedal. A fan belt round a pulley at the end of the crankshaft drives a cooling fan and a dynamo or alternator to work the electrical accessories.

4



4 A gas turbine engine, such as this Rolls-Royce RB211 aircraft engine, has a compressor situated at the front of the engine. This supplies air to a central combustion chamber. The burning fuel produces hot gases for driving the turbine blades. These gases then power both the compressor and a fan. Air from the fan passes around the engine core where it is mixed in with the combustion gases. This gives rise to a rapidly moving exhaust stream, which provides the thrust.

How an automobile works

A typical modern car can be divided into four main component systems: the engine, the source of power; the transmission, which feeds the power to the road wheels; the electrical system; and the body (chassis), including steering, brakes and suspension [Key]. Wherever the engine is placed – at the rear, driving the rear wheels, or in front, driving the front or rear wheels – the working principle is basically the same. In the conventional front-engined, rear-drive car, the engine feeds rotary power via the clutch, gearbox, transmission shaft and differential to the back axle and road wheels.

Transmission

By using the clutch [6], the driver is able to connect or disconnect the engine's power from the transmission. This makes it possible to engage and disengage gears and stop the vehicle without stopping the engine. Gradual clutch engagement allows a power flow for smooth starting.

The gearbox is generally positioned immediately after the clutch and is designed to vary the ratio of speed between engine and road wheels. The normal petrol engine works best at between 2,000 and 5,000 revolutions a minute (the rate at which the crankshaft turns). To permit this while the car is moving at anything from 15 to 150 km/h, the usual manual gearbox has a selection of four or five different forward gear ratios [5]. Selecting low (first) gear allows the engine to turn at its working speed while driving the road wheels slowly, resulting in a greater torque, or turning effort, needed to overcome inertia, heavy loads or a gradient. When the car gathers speed and less effort is needed to power it, successively higher gears are engaged until top may be used.

Electrical system and brakes

Automatic gearboxes are connected to the engine by a torque converter and have a control system that uses internal clutches to engage the gears according to the car's speed and the driving conditions. Output from the gearbox is transmitted to the final drive differential, which may be in the same housing. The differential allows the driven wheels to turn at different speeds – when the car is turning a corner the outer wheel has to travel faster than the inner one.

A major function of the electrical system in modern cars is to operate the ignition and produce a spark to ignite the petrol-air mixture in the engine cylinders. However it also performs many other functions to make the car easier to use, such as the lights and starter motor, together with the horn, heater, windscreen wipers and radio. Power is produced by an alternator or dynamo, which is driven from the engine by a belt (which may also drive a fan), and stored in a battery, with the system in most cars working at 12 volts.

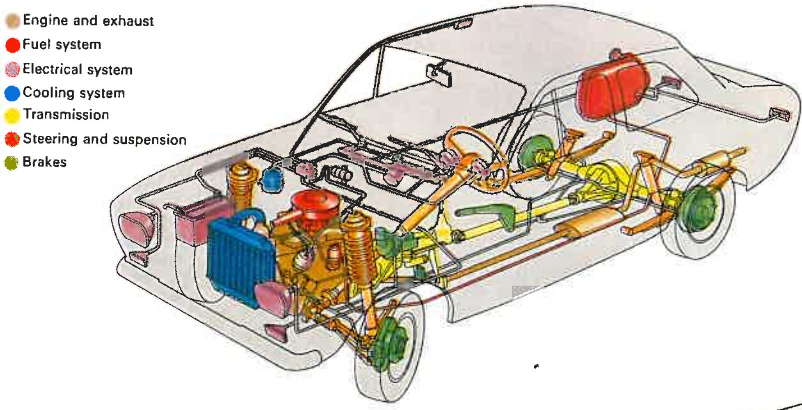
Many of the features of modern cars were originally developed for motor racing applications. For example disc brakes are now in general use with a common arrangement being front disc and rear drum brakes, although some cars have discs all round. These brakes consist of metal discs which rotate with the wheels. When the brakes are applied the disc is gripped by friction pads in a fixed brake caliper. This design minimizes the effects of heat build-up and so helps to avoid the loss of brake action known as brake

CONNECTIONS

See also
Basic types of engine
Oil and gas engines

In other volumes
History of transport (9)
History of automobiles (9)

1



2

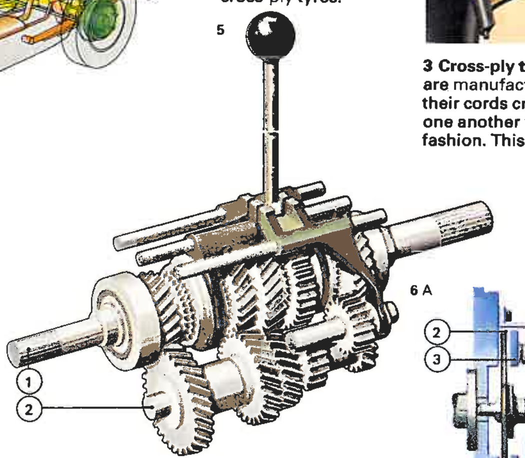
2 Radial-ply tyres have the cords of the inner case braced and running directly from one side to the other without criss-crossing. They hold the road better and last longer than cross-ply tyres.

3

3 Cross-ply tyres are manufactured with their cords crossing one another trellis fashion. This provides equal stiffness to both the walls and the tread. It is highly dangerous to use cross-ply and radial-ply tyres together, and in many countries this practice is illegal.

1 Terms used in cars: *Alternator*: charges the battery, often instead of a dynamo. *Anti-roll bar*: tough steel bar attached to the suspension which minimizes roll when cornering. *BHP*: brake horse power, measure of engine power. *Brake shoes and pads*: Shoes are curved steel segments covered with lining which press on the brake drums. Pads grip exposed discs. *Dampers*: Shock absorbers fitted to cushion bounce from springs. *Half-shafts*: The two parts of the rear axle, taking drive from the differential.

5



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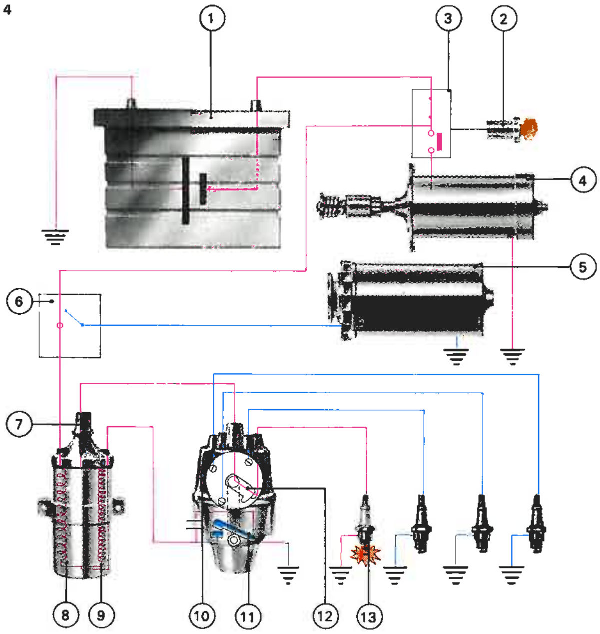
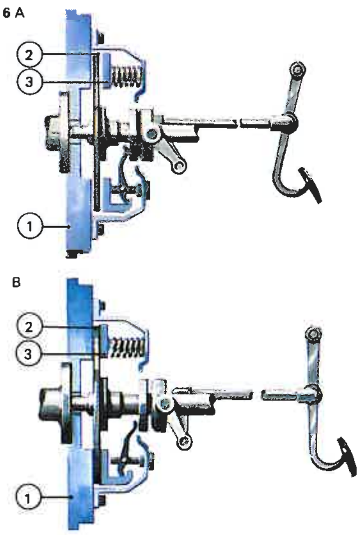


4 The 6- or 12-volt car battery must, through the coil, deliver 10,000 volts at up to 300 times a second to the plugs, and must also provide current for starting, heating, lighting and electrical accessories. The diagram shows only the starting, ignition and recharging electrical systems.

1 Battery
2 Ignition key
3 Electromagnetic relay, activated by the key when starting, connecting the battery to the starter motor
4 Starter motor
5 Dynamo or alternator, driven by the engine to recharge the battery
6 Control box
7 Ignition coil
8 Primary coil
9 Secondary coil
10 Distributor
11 Contact breaker
12 Rotor arm
13 Spark plug

5 The gearwheels of the gearbox (except reverse) are always in mesh. Those on the output shaft [1] revolve around it and those on the layshaft [2] are fixed. When a gear is selected, the appropriate gearwheel is locked to the output shaft. In first gear, the widest ratio is used for low-speed driving; second and third gears use progressively narrower ratios, and top gear is obtained by coupling the input shaft directly to the output shaft. Overdrive is a separate and higher top gear fitted to some cars to reduce wear and tear and petrol consumption and give easier high speed cruising with lower engine speeds.

6 A



6 The clutch is basically made up of three plates: the flywheel [1], which is fixed to the engine shaft and rotates with it; the driven plate [2], which is connected to the gearbox shaft; and the pressure plate [3], which clamps the driven plate to the flywheel when the clutch is engaged by releasing the clutch pedal [B]. Disengaging the clutch by depressing the pedal [A] separates the plates so that the flywheel and driven plates rotate independently.

fade, which is a serious problem with heavily worked brake drums. The brakes are operated from the brake pedal by a hydraulic system with the hydraulic lines often being split into two separate circuits for safety.

Suspension and construction

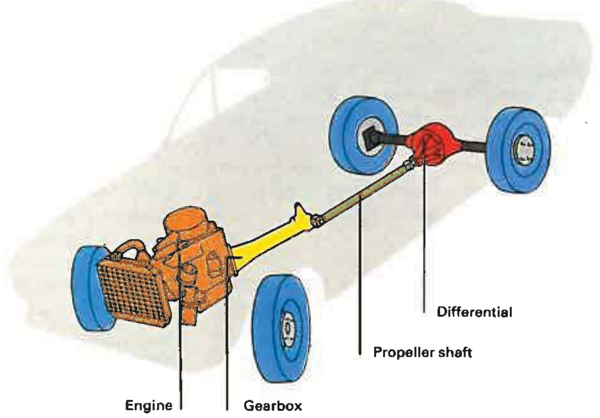
Suspension is designed to give the passengers a comfortable, smooth ride, and to protect the body and parts of the car by reducing the shocks from the uneven surface of the road [10]. However, springs alone would give a bouncing ride and dampers – or shock absorbers – are fitted to "damp" down the oscillation that the springs themselves produce. Traditional elliptical or semi-elliptical leaf springs have been replaced in many types of cars by helical or coil springs, torsion bar springs (in which a twisting action is used as springing), gas-and-fluid (combined springs and shock absorbers) or rubber springs. Some cars have more than one type of spring.

The front wheels of a car are each mounted on separate short axles, so that when the steering wheel is turned and the movement passed to them, each wheel turns on its own axis (the inner one describing a slightly tighter arc than the outer). Rack-and-pinion steering [9], the most popular of several systems, has a pinion on the end of the steering column that engages a transverse toothed rack. The rack, connected at its ends to track-rods attached to each wheel axle, is moved right or left by the action of the steering wheel, steering the wheels in the required direction. Power-assisted steering makes this easier.

Until the 1930s, the traditional way of building a car was by making a rigid chassis (the wheels, machinery and frame). Everything else was bolted on to the chassis. Now many manufacturers use the body itself as the frame. Pressed steel sections are welded together to give a body structure that consists of a series of interlinked box sections, frames and bulkheads. Each of the sections contributes to the overall strength giving a rigid body that is economical to manufacture. However, some specialized cars, particularly those with fibreglass bodies, still require a separate chassis – often a tubular "spaceframe" – on which to build the car.

KEY

Most modern cars have a front-mounted engine and gearbox which can drive the rear wheels through a propeller shaft and differential, or be arranged to drive the front wheels. The engine, suspension and steering are mounted in the main body of the car which is generally built-up from a series of pressed steel panels, welded together to give a rigid structure that accommodates the applied loads and also provides protection for the occupants.



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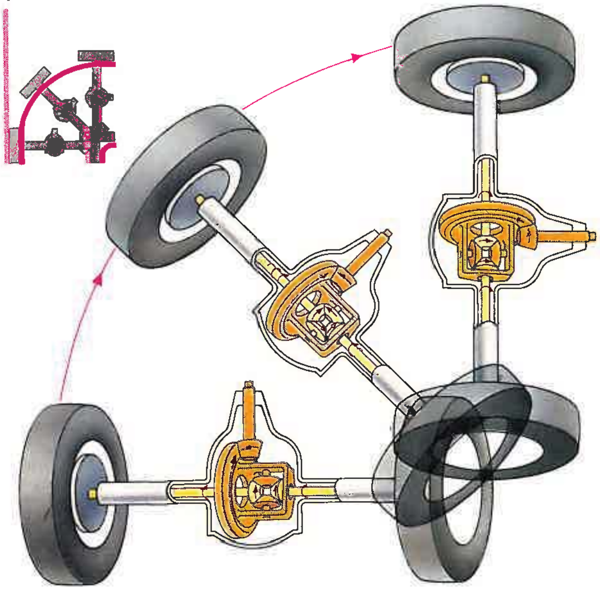
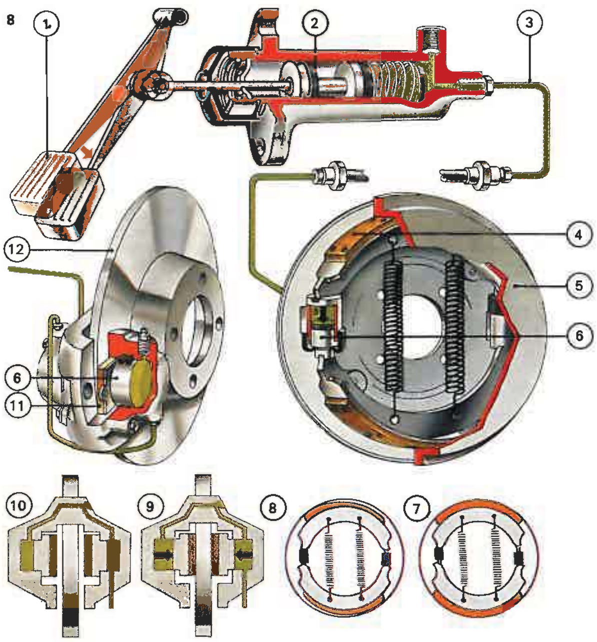


7 The differential enables one of the half-shafts and its road wheel to rotate at a slower rate than the other while the car is turning, even though both sides are being driven. This is necessary when cornering since the outside wheel has to cover more distance than the inside one. Without a differential, turning a corner would result in tyre wear and poor road-holding ability. In a rear-wheel drive car, the propeller shaft drives the differential input of the rear axle, which turns the differential crown wheel. This carries a set of intermeshed bevel wheels which can rotate to give different output speeds for the two sides. Two half-shafts take the drive from the differential to the rear wheels. A similar arrangement is used with independent rear suspension and front wheel drive, the half-shafts being replaced with exposed shafts.

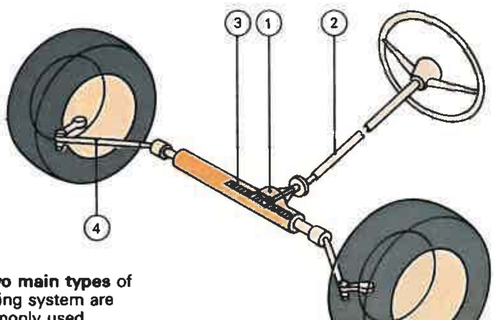
8



8 When the brake pedal is depressed, a piston in the master cylinder forces fluid along hydraulic pipes to slave cylinders on each wheel, pushing shoes or pads into contact with drums or discs. (Brake-shoe pads are curved steel platforms covered with tough fibrous shoes which act on the inside of the brake drums. Pads act on exposed discs holding them in a vice-like grip.)

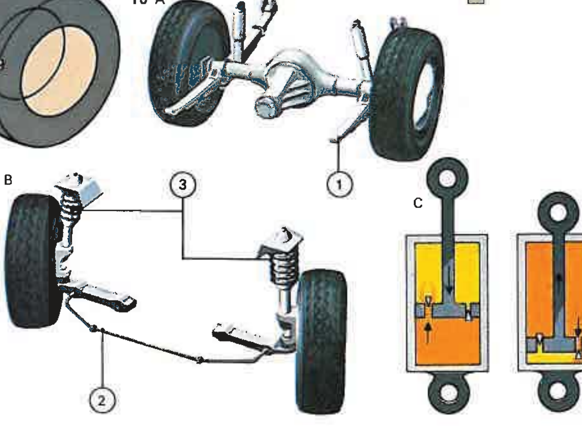
1 Brake pedal
2 Master cylinder
3 Hydraulic pipe
4 Brake shoe and lining
5 Brake drum
6 Slave cylinder
7 Drum brakes on
8 Drum brakes off
9 Disc brakes on
10 Disc brakes off
11 Brake pad
12 Disc

9



9 Two main types of steering system are commonly used. Rack-and-pinion steering has a toothed pinion [1] at the end of the steering column [2], which engages with a transverse rack [3] moving it right or left as necessary. Track rods [4] at each end transmit the movement to the wheels. The steering box system (not shown) has a box which houses a worm reduction gear. The gear drives a drop arm, and, via a transverse link, a slave arm. The power-assisted system is a modern refinement of steering, which uses hydraulic power from an engine-driven pump to reduce the effort needed from the driver.

10 A



10 Without suspension every irregularity of the road surface would be transmitted to the occupants of the car. Springing avoids this problem, but to avoid over-springiness, damping must be introduced. [A] shows a rear suspension layout with leaf springs [1] mounted on the axle. The front-wheel suspension [B] shown uses suspension struts [3], which combine coil spring and damper in a single unit, together with pivoted control arms at the bottom of the strut and an anti-roll bar [2], all these elements being mounted on the car body structure. Telescopic dampers [C], also called shock absorbers, are fitted to the suspension to prevent excessive bouncing due to the spring action. They consist of a piston sliding in an oil-filled cylinder. As the piston moves, oil is forced through valves, giving a resistance that slows movement.