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Chassis Unit – Course: Motor Vehicle Engineering 1. Textbook for Vocational Training

Table of Contents

Chassis Unit − Course: Motor Vehicle Engineering 1. Textbook for Vocational Training........................1
Preface..1
1. The frame..2
1.1. Functions of the frame..2
1.2. Frame types...2
1.3. Frame damage..5
1.4. Bodywork...6
2. Springing and suspension..8
2.1. Springs and their functions..8
2.2. Vibration dampers...18
2.3. Stabilizers and their construction...22
3. Wheel suspension..24
3.1. Front and rear wheel suspension of driven and non−driven wheels.........................28
3.2. Wheel positions..34
3.3. Removal and fitting of axles..36
3.4. Repair tools and auxiliaries..36
4. Steering..37
4.1. Types of steering...38
4.2. Construction and principle of steering systems..40
4.3. Power−assisted steering systems...44
4.4. Defects and wear of steering systems, and their elimination......................................46
5. Wheels and tyres...47
5.1. Wheels and rims..48
5.2. Tyres..52
5.3. Tyre damage and defects...55
5.4. Rim damage and defects..57
5.5. Influence of the condition of the tyre on road safety and petrol consumption..............57
6. Brakes...59
6.1. Functions of the brakes..59
6.2. Operating principle and types of brakes..59
6.3. Mechanical braking system..64
6.4. Hydraulic braking systems...65
6.5. Pneumatic braking system..67
6.6. Combined brake system...69
6.7. Brake system of the IFA W 50..71
7. Types, functions and uses of lifting gear..74

Chassis Unit – Course: Motor Vehicle Engineering 1. Textbook for Vocational Training

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Preface

This instruction manual is intended for all students of motor vehicle repair and maintenance.

It can be used as a basis for both theoretical lessons and practical training, and as such provides an essential link between theory and practice.

The manual is divided into three self–contained sections, each dealing with one of the main sub–assemblies of the vehicle: chassis, power transmission and combustion engine.

The instruction manual contains a clear and concise description of the design and function of each of the component parts of the motor vehicle, as well as information about the maintenance, servicing and repair of vehicles.

Numerous illustrations are intended to facilitate the student's understanding of the technical and engineering problems discussed. Test questions are included at the end of each chapter. These concentrate on points of particular importance to students of motor vehicle engineering and enable the individual student to assess his own progress.

1. The frame

1.1. Functions of the frame

The frame of a motor vehicle supports all the drive assemblies, i.e. the engine, gearbox and axles (front and rear).

In addition the suspension and steering systems and the shock absorbers are attached to it. The assembled components are collectively named the "chassis". The appropriate body is fixed to the chassis.

It is essential that the frame should not buckle on uneven road surfaces and that any distortions which may occur should not be transmitted to the body. The frame must therefore be torsion−resistant.

The frame of a motor vehicle is the load bearing part of the chassis which supports all forces (wheel forces) and weights. It should be as rigid as possible.

1.2. Frame types

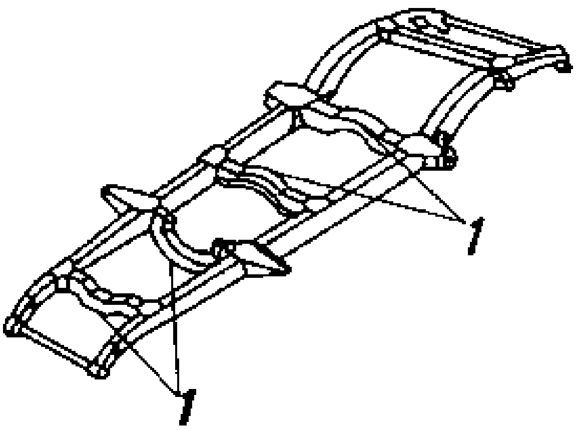
There are five different types of motor vehicle frame.

a) The box−type frame

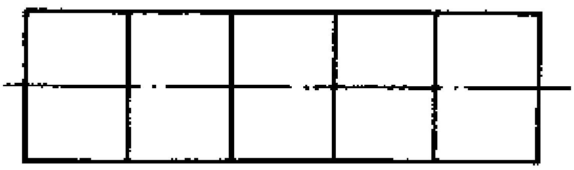
There are several types of box−frame which differ in the construction of their bracing. These can be seen in Figure 1/1. Cross bracing, diagonal bracing and triangular bracing can be used.

When deep−seated springs are used the frame is cranked in order to ensure correct axle freedom (see Figure 1/1).

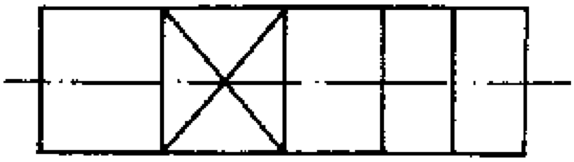
Figure 1/1 Box−type frame



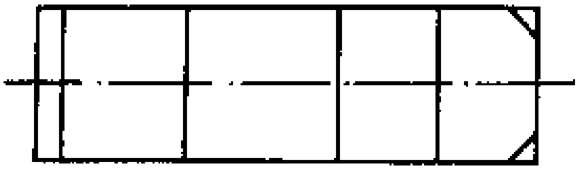
a) cranked box−type frame, 1 indicates cranked components,



b) box−type frame with cross bracing,



c) box–type frame with diagonal bracing,



d) box–type frame with triangular bracing

b) The trapezoidal frame

The trapezoidal frame is a symmetrical trapezoidal construction consisting of two side members with bracing. The frame is made from steel plate pressed into an open U profile. In order to ensure sufficient front wheel lock the frame tapers towards the front (Fig. 1/2).

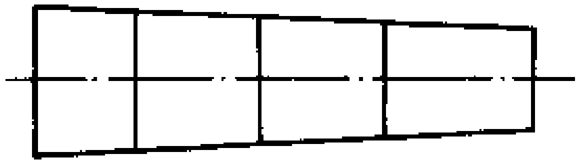


Figure 1/2 Trapezoidal frame

c) The central member frame

The central member frame (Fig. 1/3) has a single centrally positioned lengthwise member.

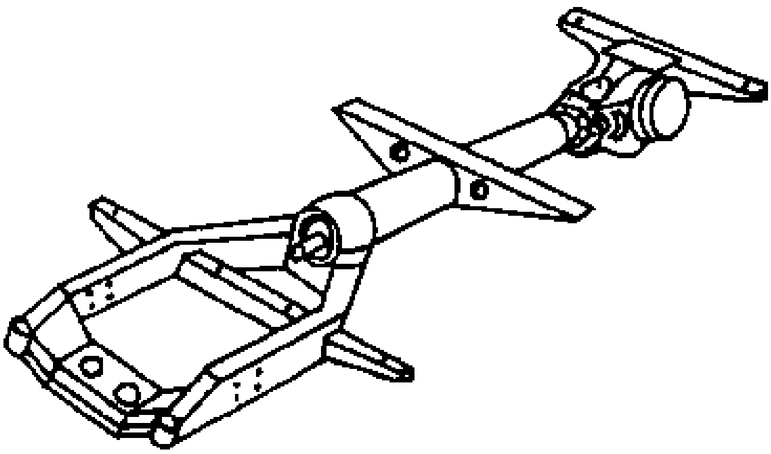


Figure 1/3 Central member frame

It is made from tubular or rectangular sections and is forked at the front end to take the motor and the gearbox. Attached to it are cross members of relatively small diameter which support the body. Due to its closed profile the frame is very torsion–resistant. The central member frame is used mainly in the manufacture of passenger vehicles. Pew lorries are fitted with this type of frame.

d) The X–frame

The X–frame consists of two side members made from tubular, oval or rectangular section. It is so designed, that the two side members curve towards each other and in the middle are only a few centimeters apart. When viewed from above the whole frame looks like an X. (Fig. 1/4) The closer the side members are to each other the stronger is the resistance against torsion. This type of frame is also typically very stable.

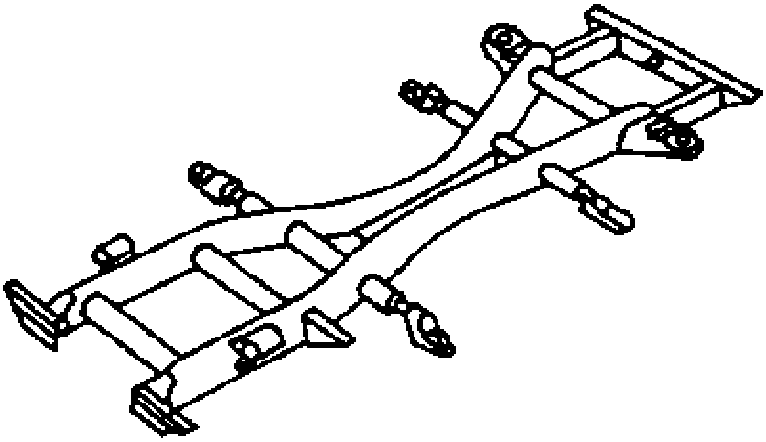


Figure 1/4 X–frame

e) The panel–type frame

The panel–type frame (Fig. 1/5) forms part of the car body and is considered a component thereof. During manufacture the frame and body are welded together, and this proves a disadvantage in comparison with other frame types because, if the frame has to be replaced the frame must cut away from the car body. An advantage of this frame type, however, is its light weight which means that it allows good fuel consumption.

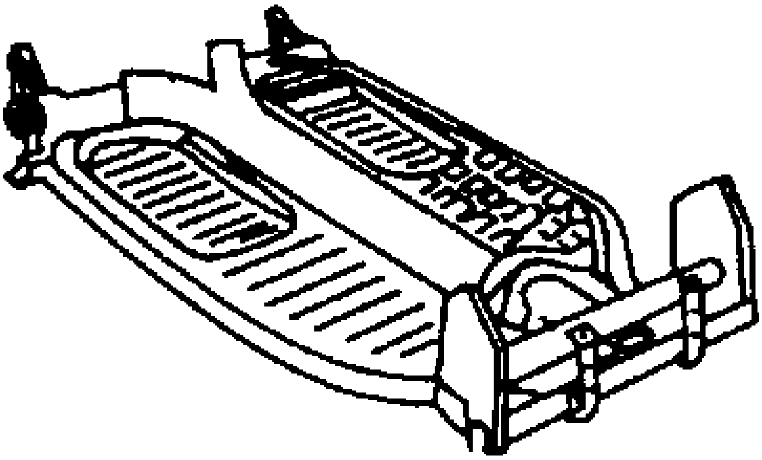


Figure 1/5 Panel–type frame

f) Integral body and frame

In the integral body and frame (Fig. 1/6) it is not an individual frame which supports the drive assemblies, but reinforced parts of the body itself. For this reason, this type of body can only properly fulfil its purpose if it is of light–weight construction. It must, however, also be buckle–, torsion– and vibration–resistant. Variations of this frame are the steel plate lattice–type and versions in which lengthwise, frame–like members, cross members and side members with bottom plates and side panels are integral parts of the body. Here small auxiliary frames can be used to support the engine and gearbox.

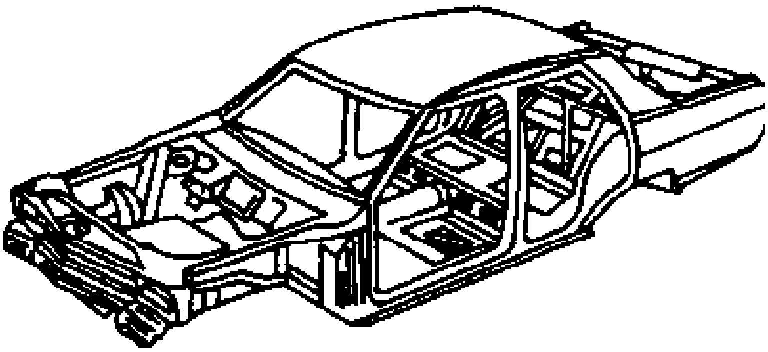


Figure 1/6 Integral body and frame

Motorcycle frames are not dealt with in this section as they represent a category of their own in frame construction.

1.3. Frame damage

Frame damage may be caused by wear or by accidents. The term wear covers both damage by environmental influences and by constant use.

Every motor vehicle frame is subject to wear, which can be accelerated by bad road and weather conditions.

Overloading is another cause of vehicle frame wear. It may be brought about by exceeding the maximum permissible payload and by driving too fast over bad road surfaces.

However frame damage is most frequently caused not by wear but by accidents. The frames are specifically designed to be strong enough to withstand the normal torsional strain.

Frame damage does not normally become noticable until it causes a change in roadholding or a deterioration in driving quality. If a frame is found to be buckled or broken it must be removed and measured. This measurement must be made with a special measuring device. The following are the commonest types of damage:

displaced front axle	distorted frame
displaced rear axle	displaced frame

Distorted and displaced frames can be straightened. Distortion, which may be caused by impact or buckling, will alter the structure of the frame. Displacement occurs when the two side members are shifted parallel to each other.

If a frame is broken it can be welded together, but the welded area must be reinforced with a gusset plate to prevent another break near the welded area. These repairs require a high level of technical knowledge and ability and must be carried out with great care.

Displacement of the front or rear axles can also be located by measuring, and thorough testing can ascertain whether or not they can be straightened. Before straightening, the leaf spring must be removed from the axle, and when the repair is complete the axle must be measured again.

If one of the axles is beyond repair the whole frame must be replaced.

In order to determine and eliminate frame deformations in time to repair them the frame must be measured periodically.

Measurements must be taken at the rearmost spring of the rear suspension and the foremost spring of the front suspension. Before measuring:

– The vehicle must be positioned on an even surface to obviate frame distortions which would distort the measuring results.

– The measuring points must be marked on the ground using a plummet.

– The marked points are to be measured diagonally by means of a string which must be taut throughout.

The lengths of the two diagonals are then compared to ensure that they are equal. If they are equal the frame is undamaged, however if they are not, the difference must be measured and the frame straightened. These measurements can only be taken on vehicles with frames.

The method for measuring frameless vehicles is different as they not have fixed measuring points as described above. When measuring integral frame and bodies and panel–type frames it is important to ensure that the wheels can run freely. Unbalanced wheels must be replaced with balanced ones. The vehicle should be driven onto a testing ramp and measured with the help of optical measuring equipment. A measuring rod can also be used. The front wheels must be aligned and a check made to see if the front and rear wheels on one side run on one track, or if toe−in and wheel camber show the same deviations. Then a perpendicular should be dropped at the middle of the steering stub and the diagonals measured.

1.4. Bodywork

The body of a vehicle is intended to accomodate persons or cargo. It can take many different forms with regard to both design and construction.

It is vital that the body should be of aerodynamic and lightweight design, and for this reason the principle of lightweight construction is followed in modern motor vehicle manufacture. Wind noise and boom should be obviated as far as possible.

Bodywork can be made from various materials: Wooden, lightweight metal, steel, composite (buses) and plastic−coated bodywork can be manufactured in varying styles. In contrast to the integral body or the panel−type frame it is of no significance whether or not the body is mounted to a frame, or forms a constructional unit with it. Today the motor vehicle industry is aiming to achieve a combination of minimum body weight and maximum pay load. The following section deals briefly with individual types of bodywork according to the materials used.

Wooden bodywork:

The term wooden bodywork includes all those components of the body which have a wooden skeleton, irrespective of the material used for the inner and outer panelling. Wooden bodywork is rarely used today because its manufacture is very complex and expensive.

Composite bodywork:

Composite bodies are those in which wood and metal are used for the skeleton (though not necessarily for the inner and outer panelling), and they occur in two different types, those made from steel sections and those with a framework construction.

The main characteristic of the first type is that hardwood elements are inserted into the steel sections of the skeleton onto which the inner panelling is mounted and which also serve to damp the vibrations which cause booming. The framework construction is used in particular for large bodies, e.g. for buses, and was adopted from the shipbuilding industry. In this design the number of joints subject to great stress and strain is reduced, but its most important advantage is the stability achieved by the use of bent frames.

All−steel bodywork:

This type of construction, in which the skeleton is made of thin−walled steel sections (from 2 mm thickness), produces rigid bodies. The are three types of all−steel bodywork, stressed−skin, cellular and sectional construction, all of which are lightweight.

In stressed−skin construction, rough−pressed components such as the front, side and rear panels are assembled and screwed or welded together to form a complete body.

In cellular construction, three cells are assembled to form a complete body. The advantage of this method of construction is that the individual cells − front, central and rear cells − can be economically replaced or repaired. The fact that the cells are manufactured separately makes it possible to produce a large number for different types of vehicles.

In sectional construction various pre−fabricated steel sections are welded together to form the skeleton. These can be removed and replaced with new ones after an accident, for example, or in case of corrosion. This method of construction also allows single section such as door sills and door posts to made and fitted manually. The outer panelling of the skeleton can be made of sheet steel or plastic.

Plastic−coated bodywork:

Plastic–coated bodies are substitutes for steel ones. Plastic materials have the following advantages over steel, they are:

1) thermally insulating
2) sound absorbing
3) non–booming
4) corrosion resistant
5) light weight

In this method of construction the skeleton consists of steel sections to which prefabricated plastic panels are mounted.

These panels can be replaced quickly and easily. The panels are sealed with weather strip putty and then the whole body is lacquered to protect it from the elements. The bodywork of lorry consists basically of the cab and a purpose designed rear body section. The main component of a passenger car or a bus is the passenger compartment. Lorries can also be manufactured with special purpose bodies.

The various types of bodywork are listed in Tab. 1.1. below.

Table 1.1.: List of the commonest forms of bodywork for lorries.

Platform truck with and without canvas cover	**box–type truck, open at top with collapsible side and rear walls**
Box–type truck	enclosed box with loading door
Tipper truck (two or three way)	enclosed platform, tippable on all sides
Estate car	body like saloon, space for transporting passengers and goods
Platform truck with hydraulic rear loading wall	rear loading wall, hydraulically raised
Tanker	for transporting liquids and powdered products
Crane or ladder truck	slewing lifting gear, mechanical ladders
Fire fighting vehicle	equipment: motor pump, hose reel, tools, seats for firemen
Road sweeper	equipment: spraying device, sweeping and suction devices
Workshop and repair	equipment: machine tools, welding equipment, hand tools, mobile workshop
Sales van	equipment: shop fittings, supply vehicle

In most cases frame and body are screwed together. Rubber spring packs (silent blocs) are located between the components of the body and the frame to prevent or suppress the transmission of vibrations to the frame. When components are in continuous use undamped vibrations can lead to structural fatigue and eventually to destruction of the component. Structural fatigue occurs when natural internal stress decreases.

Test questions:

1.1. What types of frames are you familiar with in motor vehicle engineering?

1.2. Name the main features which distinguish the various frame types.

1.3. Describe the design of a box–type frame.

1.4. Explain the difference between the terms 'panel–type frame' and 'integral frame and body'. Describe the design of these two types.

1.5. What do you understand by the term "wear"?

1.6. What causes "wear"?

1.7. What damage can be caused to the frame by wear and by accedints?

1.8. Outline the way in which a frame is measured.

1.9. What is the function of a vehicle frame?

1.10. What is the main demand made of the frame?

2. Springing and suspension

2.1. Springs and their functions

The purpose of spring components is achieved through their elasticity and therefore the materials and media used must be elastic, for example steel, rubber and air.

The principle of springing: If the equilibrium of an elastic body is disturbed, movements in different directions, called mechanical vibrations occur. The spring as an elastic system (mass and spring) is caused to vibrate by an impact and oscillates with ever decreasing amplitude of motion, until it returns to its original position. The period of vibration depends on the size of the swinging mass and the rigidity of the spring.

In a motor vehicle the springing is intended to damp the vibrations of the loosely coupled elastic system as quickly as possible after the impact.

This springing is required to vibrate slowly, and it is also regarded as favourable if the front and rear axle springing are of different rigidity. If a vehicle is to have good roadholding ability vibrations must be damped in order to prevent build–up. Vibrations are damped by the transformation of mechanical energy into thermal energy.

The most common types of spring are listed below:

– Steel springs

Leaf springs are simple and inexpensive to manufacture. A leaf spring pack is subjected to bending and can absorb thrust and lateral forces.

It is self–damping, but heavy and prone to spring friction. It is space consuming and must be serviced regularly. (Fig. 2/1)

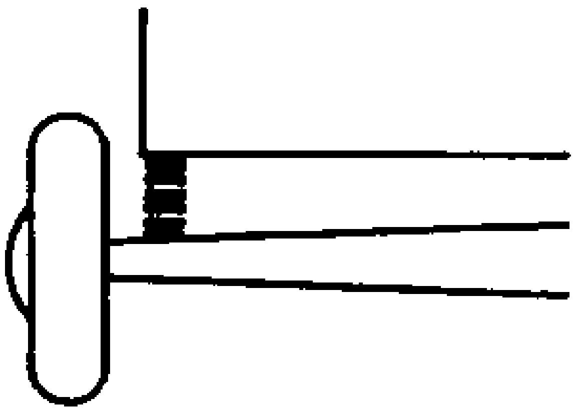


Figure 2/1 Leaf spring suspension

Use: cars; lorries; trailer vehicles; special purpose vehicles; rail–bound vehicles

Coil springs are simple to produce and allow a high performance whilst occupying a minimum of space. They are subjected to torsion, but cannot absorb thrust or lateral forces. Their self–damping is negligible but they do not require servicing. (Fig. 2/2)

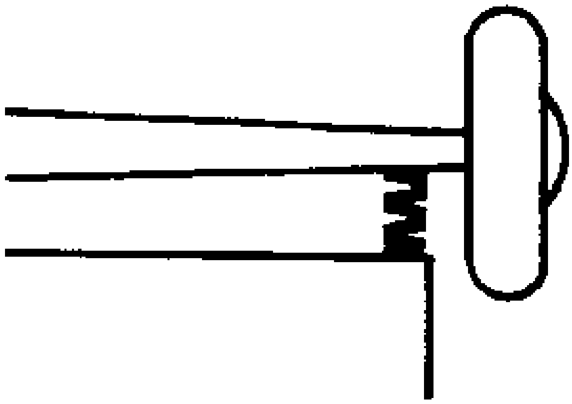


Figure 2/2Coil spring suspension

Use: cars; lorries; motor cycles; additional spring for trailers

Torsion bar springs are actuated by torsion and do not require servicing. They are lightweight and space−saving but made from high quality materials and expensive to produce. Damaging of the surface and overloading lead inevitably to the destruction of the torsion bar. With this type of spring damping is almost zero. (Fig. 2/3)

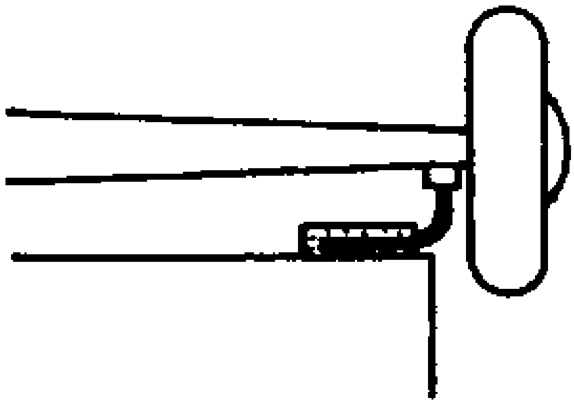


Figure 2/3 Torsion bar suspension

Use: cars; special purpose vehicles

− Rubber springs

Rubber springs have a progressive spring action and do not require servicing. There are three types of rubber springs: rubber torsion shear springs, rubber pack springs and hollow rubber springs. They are self−damping and relatively inexpensive to produce. Rubber springs do not perform well under changing loads and are sensitive to the sun, mechanical damage and lubricants.

Rubber torsion shear springs are actuated by torsion, rubber pack springs and hollow rubber springs to compression. (Fig. 2/4)

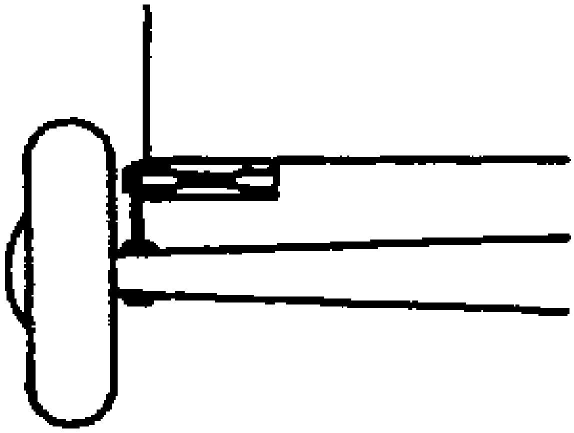


Figure 2/4 Rubber suspension

Use: cars; motor cycles as well as suspension of automotive units

– Air suspension

Air suspension is very efficient because it adjusts automatically to all load conditions, by means of a pneumatic control unit which is actuated by compression. In comparison with other types of suspension, the production of air suspension is very costly and it must be constantly serviced in order to avoid failure. Self–damping is negligible, it is spaceconsuming and very heavy. (Fig. 2/5)

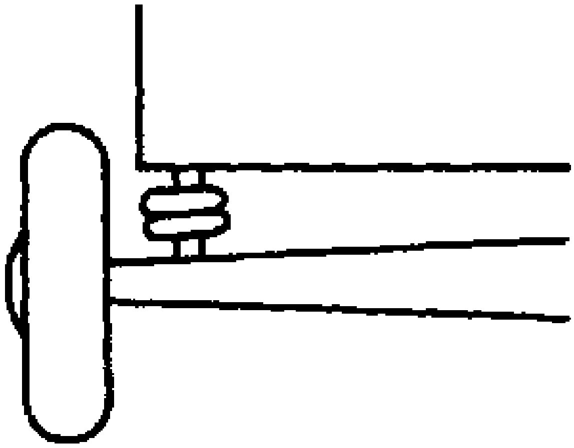


Figure 2/5 Air suspension

Use: predominantly in buses and heavy goods vehicles; cars

Design of leaf spring

A leaf spring pack consists of spring leaves of different lengths and different thicknesses. (Fig. 2/6)

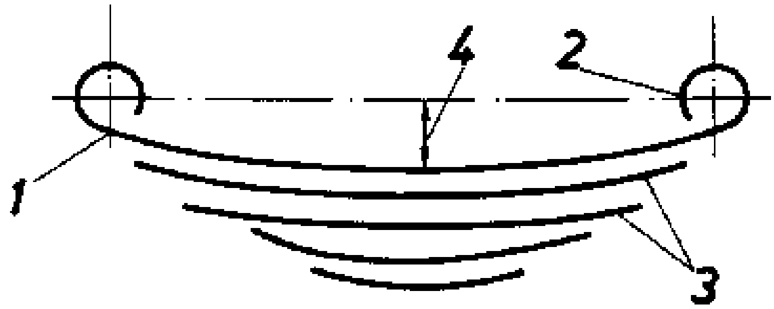


Figure 2/6 Construction of a leaf spring (cross section)

1 main leaf, 2 spring eye, 3 support leaves, 4 curvature of the spring leaves

If a leaf spring is loaded, sliding friction will occur between the leaves during springing, and this must be kept as low as possible. In order to achieve this, spring grease, a mixture of lubricating grease and graphite, is smeared between the individual leaves.

The leaf tips, which are subjected to the most friction, are further smoothed by longitudinal grinding.

Polyamide laminas can be inserted between the leaf tips so that they protrude beyond them, thus avoiding direct friction between them. (Fig. 2/7)

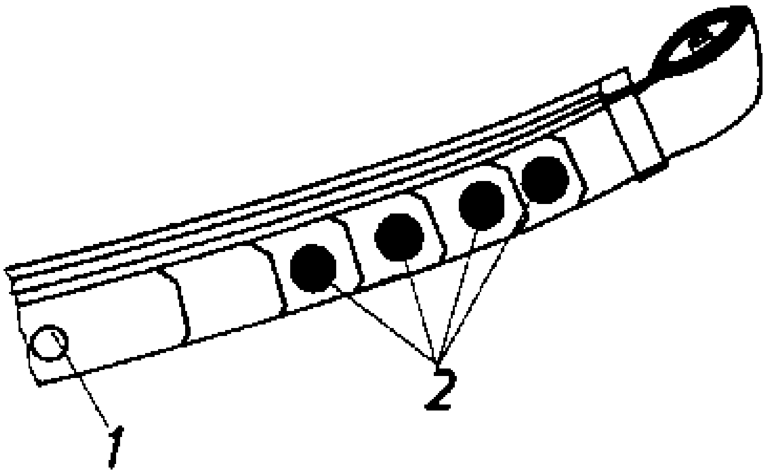


Figure 2/7 Construction of a leaf spring (leaf tips)

1 heart bolt, 2 polyamide laminas

This is intended to:

1. keep friction between the leaves constant, (this depends on the normal force and the friction coefficient)

2. keep the friction coefficient fairly constant irrespective of the lubrication of the leaves,

3. reduce spring noise,

4. protect the leaves from premature wear.

If a spring pack consists of single leaves of varying thicknesses, the thinner leaves must be curved more than the thicker ones, so that all leaves will be stressed equally under load.

If all the leaves are the same length, the thinner they are the smoother their effect, but the greater the number required for the same load capacity. This increases spring friction, which is favourable within certain limits, and improves damping.

All laminated leaf springs show spring friction. It is independant of the lubrication, the surface quality of the leaf springs, the curve of the leaves, the number of spring clamps, the thickness of the individual leaves and the thickness of the wear sections which develop at the leaf tips.

<u>Maintenance and repair of the leaf spring</u>

As we have already seen leaf springs require regular maintenance and servicing.

Wear sections on the leaves, loose spring clips and worn spring bolts, also called heart bolts, are often the causes of breaks in the leaves.

Regular inspection can:

1. prevent damage,
2. extend the service life of the spring,
3. increase the possible mileage of the vehicle,
4. protect the load.

Necessary maintenance work:

1. Spread a thin layer of graphite between the individual leaves to reduce sliding friction. This prevents water penetration which causes corrosion.

2. If a spring has to be lubricated, loosen the spring clamps and raise the vehicle so that the weight is taken off the axles and the springs. Then lubricate between the leaves with a grease gun.

3. At the same time check the wear sections and see if any of the spring leaves are broken.

4. Grease spring bushes and spring bolts regularly.

If a leaf spring shows fatigue it becomes weak and tensionless and must be removed. Such springs can be restored at a spring forge. There they are also examined for wear, and damaged spring leaves are replaced.

When repairing leaf springs ensure that the prescribed length and curve of the leaves are maintained.

When removing leaf springs ensure that the weight is taken off the axles and the springs. The frame must be supported by blocks.

Labour safety regulations must be followed at all times. The raised vehicle is to be secured by blocks to stop it rolling.

Helical springs

Helical springs are actuated by compression; they are used on rigid axles and independently suspended wheels. (Figs. 2/8, 2/9)

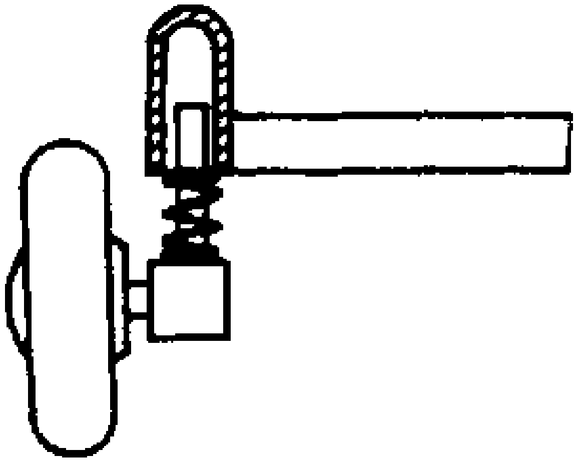


Figure 2/8 Coil spring suspension of a rigid axle

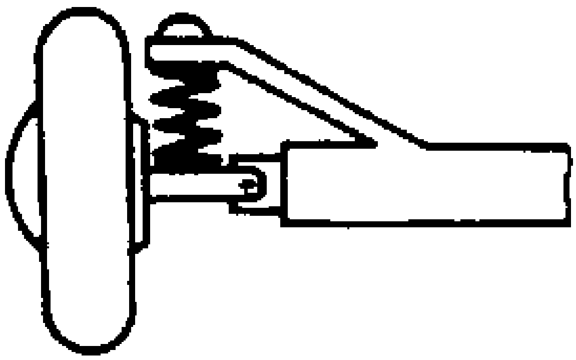


Figure 2/9 Independent coil spring suspension

Helical springs have the following advantages over leaf springs:

1. They require less room in the vehicle and are also considerably lighter.

2. As they have no external friction they do not need any special maintenance.
3. In comparison to leaf springs, helical springs have a smoother spring action and a better deflection.

Helical springs are not designed to take thrust forces and will buckle under them. These forces must be taken by other components such as the steering wheel and the drag links.

Long helical springs have only internal friction, i. a. friction occurs only within the material itself. For this reason, they cycle for longer than a leaf spring pack. Since these springs have negligible self–damping, they always have to be used with dampers.

As mentioned above, coil springs need no servicing. Damaged material surfaces and corrosion will lead to fatigue failure in the spring and must be avoided.

When a spring is mounted, care should be taken to ensure that it is at right angles to the axle.

Torsion bar springs

Torsion bar springs are actuated only by torsion (Fig. 2/10).

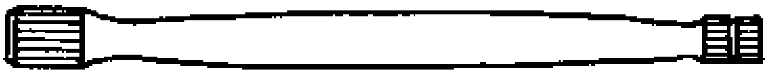


Figure 2/10 Torsion bar

Their main advantages are that they require little maintenance and are lightweight.

Torsion bar springs are made from high–quality special steel to give high fatigue strength and good cushioning properties. The surface of a torsion bar must be smooth; roughness or thost lines might cause fracture. The ends of the bar are upset and serrated. The torsion angle of a torsion bar is small and must be adjusted to the required deflection (Fig. 2/11).

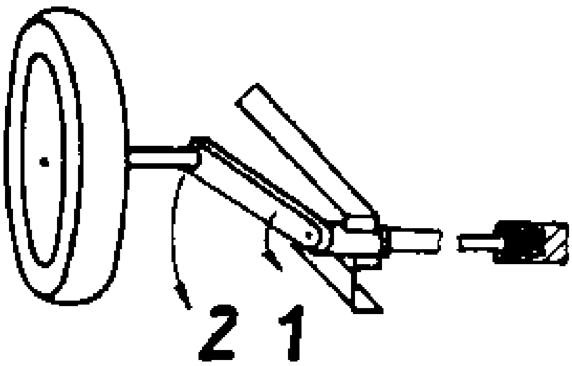


Figure 2/11 Lever action in torsion bar suspension

1 spring deflection, 2 spring deflection increased by lever action

Torsion bars have no external friction and the longer they are, the smoother their effect.

Torsion bars must not be subjected to bending. They are mounted in pipes which are fixed to the frame. When installed, torsion bars are fixed by means of a serration. They can be mounted at right angles or longitudinal to the direction of movement of the vehicle.

Torsion bars require no maintenance. During installation it is important to ensure that the torsion bars fit correctly into their mounts. Care must be taken to avoid damaging them during mounting and removal. They must be given a protective coating to protect them against corrosion. This coating must not be damaged or rust will form pits in the steel which will lead to the destruction of the torsion bar.

When replacing a torsion bar:

1. It should be marked 'left' or 'right'.

2. It must be removed from its mount with extreme care to avoid knocking it.

3. It should be laid on a wooden stand. It must not be put down vertically since there is the risk of it toppling over.

4. It is important that only acidless grease is used for assembly.

Rubber springs

The springs dealt with so far are based on the elasticity of the high quality steels used.

With rubber springs the elasticity of rubber is used as a means of suspension for motor vehicles and trailers. Rubber suspension is a progressive suspension, i.e. the spring becomes stiffer with increasing deflection.

Rubber suspension has one major advantage over steel, namely that due to internal friction a vibrating rubber spring returns to its initial position after only a few vibrations. For this reason, rubber is able to damp all types of vibration very well. The disadvantage of this system is that the deflection is minimal, and so a lever system must also be mounted to lengthen it. In this way, according to the principle of the lever, greater forces act on the rubber. Rubber springs require no maintenance and have a long service life, which is an advantage for the maintenance and upkeep of the car.

There are four different kinds of rubber springs used in motor vehicle engineering:

- rubber compression springs
- rubber torsion–shear springs
- rubber pack springs
- hollow rubber springs.

Rubber compression springs:

Rubber compression springs are used in lightweight motorcycles as frame–mounted rubber buffers for cushioning the front axle, and with steel springs for limiting spring deflection.

If spring deflection is too great, a rubber compression spring is used to take the load, thus preventing damage to the frame or the body (Fig. 2/12).

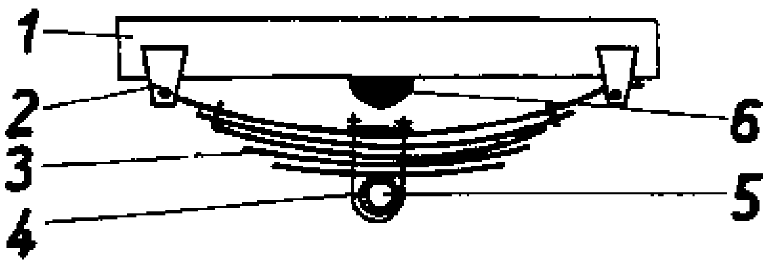


Figure 2/12 Use of a rubber compression spring

1 frame, 2 spring bracket, 3 leaf spring, 4 spring clamp, 5 axle, 6 rubber compression spring

Rubber torsion–shear springs:

A rubber torsion–shear spring consists of an inner and an outer metal bush. The space between these two bushes is filled with vulcanised rubber. The outer metal bush is pressed into a frame mount and thus firmly connected to the frame.

The control –arm which holds the wheel is fixed to the inner bush by means of a bolt. The wheel is cushioned by the elasticity of the rubber. This type of wheel suspension is ideal for light–weight constructions and does not require any maintenance (Fig. 2/13).

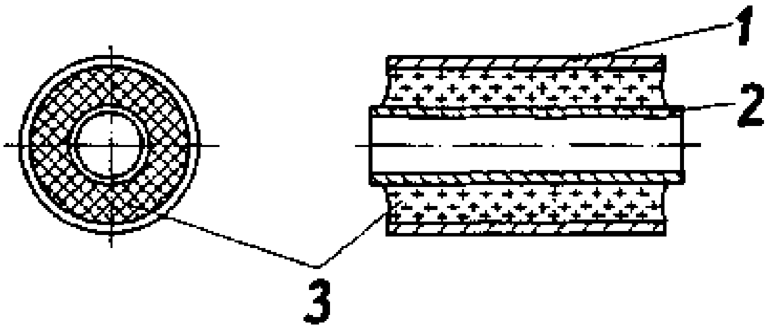


Figure 2/13 Rubber torsion–shear spring

1 outer metal bush, 2 inner metal bush, 3 layer of rubber

Rubber pack spring:

The rubber pack spring (silent bloc) is often used in heavy goods and rail vehicles and for suspending engines and gear boxes. It is an effective method of suspension as it can be subjected simultaneously to shear stress and compression (Fig. 2/14).

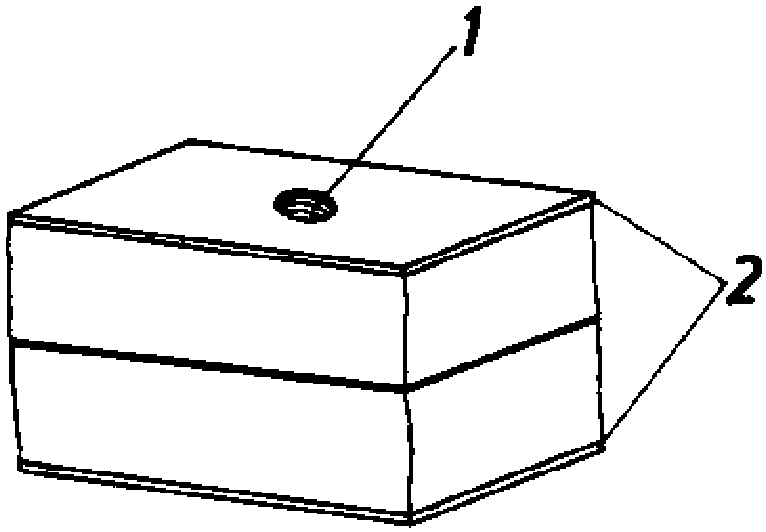


Figure 2/14 Rubber pack spring

1 internal thread, 2 bonded rubber pads

Hollow rubber springs:

Like the rubber compression spring, the hollow rubber spring is used as an additional spring. Its shape allows easy deformation and consequently a large deflection. (Fig. 2/15)

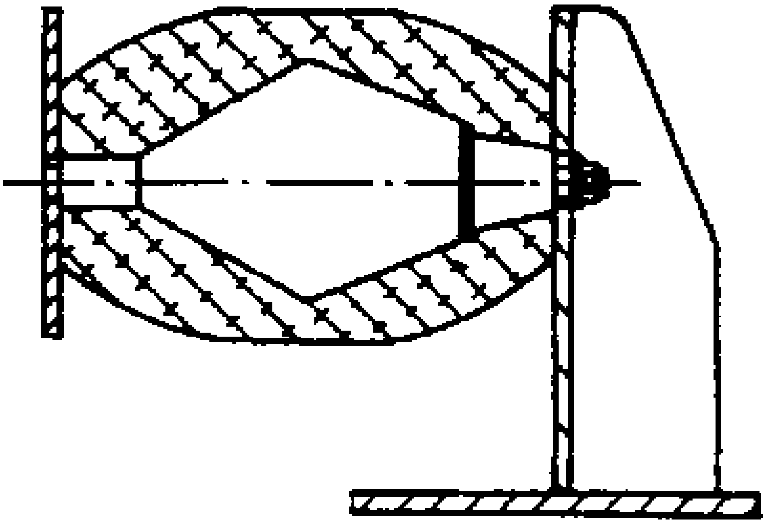


Figure 2/15 Hollow rubber spring

Rubber springs are used for damping low−amplitude vibrations which may occur, for example, at the engine supports, the leaf springs and spring bolts. The rubber is vulcanised to so−called vibration metal, and the springs produced in this way are called silent blocs.

Progressive rubber suspension requires no maintenance. If the spring is to be subjected to compression, sufficient clearance must be ensured. Rubber springs must be protected against constant heat as this will make the rubber brittle. Worn rubber components can easily be replaced according to the type of suspension.

Air suspension:

The fact that pneumatic tyres are used on vehicles shows that air is a good cushioning element. Air suspension is progressive. In this method of suspension the height of a vehicle can be kept constant by means of appropriate height controllers. There are two types of adjustable air suspension.

– pneumatically adjustable air suspension (Fig. 2/16)
– hydraulically adjustable air suspension (Fig. 2/17)

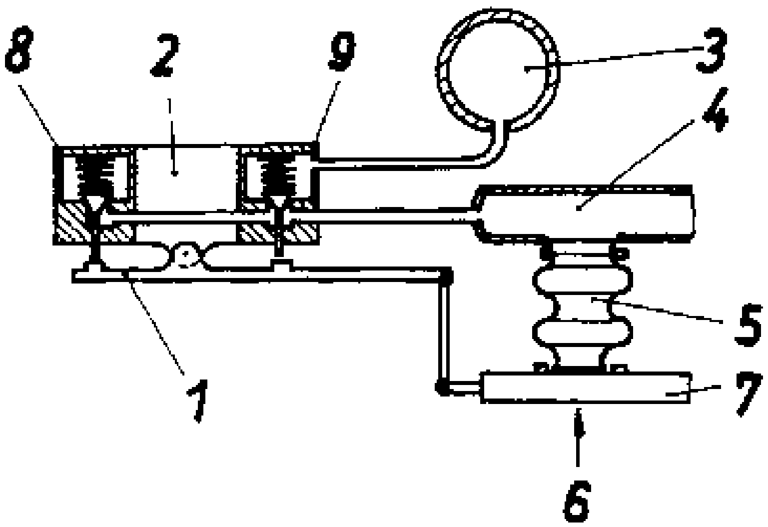


Figure 2/16 Pneumatically adjustable air suspension

1 control arm, 2 control valve, 3 compressed air cylinder, 4 air chamber (attached to the frame), 5 bellows, 6 wheel load, 7 component attached to the axle, 8 drain valve, 9 inlet valve

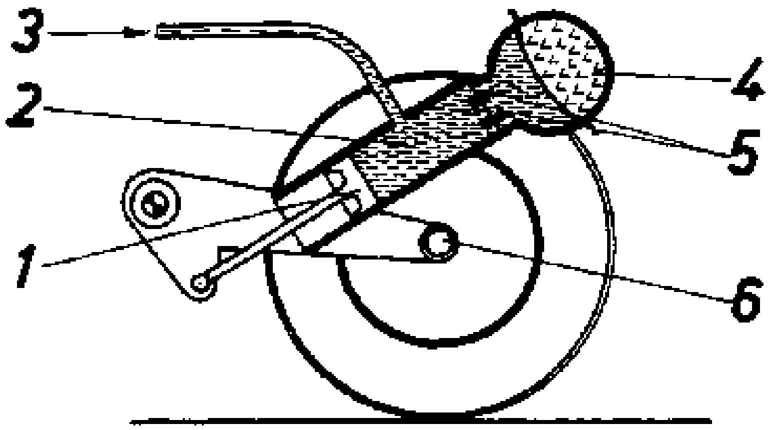


Figure 2/17 Hydraulically adjusted air suspension

1 control piston, 2 oil, 3 line from oil pump, 4 air cushion, 5 control valve, 6 wheel suspension

– Pneumatically adjustable air cushioning is used in vehicles where the ration of total utilised load−carrying capacity to the empty vehicles is large. The same height of the vehicle over the axle can be adjusted for different loads by controlling the air filling. Air chamber and rubber bellows form a storage volume. When the bellows expand, the control lever operates the drain valve. Normal height is reached by lowering. When the bellows are compressed, the control lever operates the admission valve, and the air flowing from the compressed−air reservoir returns the bellows to normal position.

There are three types of pneumatically adjustable air suspension which differ in the shape of the bellows. In lorries, semitrailer trucks and buses, cylindrical bellows are used (Fig. 2/18). In heavy trailers and semitrailers the so−called sandwich system, a ring bellows system, with long, oval rubber bellows, is used (Fig. 2/19).

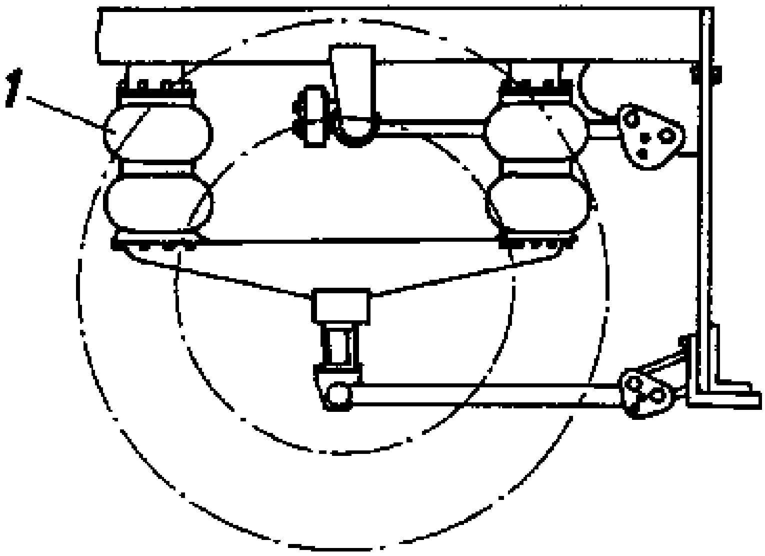


Figure 2/18 Pneumatically adjustable air suspension with cylindrical bellows

1 cylindrical bellows

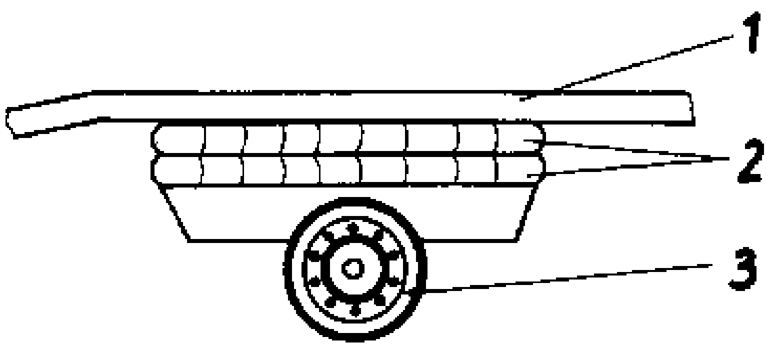


Figure 2/19 Pneumatically adjustable air suspension with ring bellows

1 frame, 2 ring bellows, 3 axle

Roller−type bellows have been developed for heavy passenger cars (Fig. 2/20).

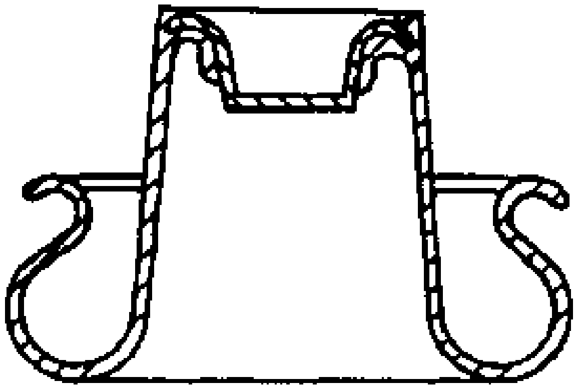


Figure 2/20 Pneumatically adjustable air suspension − roller−type bellows

− Vehicle in which the ratio of total utilised load capacity to empty vehicle weight is low, have hydraulically adjustable air suspension. Here the piston is held at the proper position not by controlling the air filling, but by controlling the oil volume between the piston and the air cushion. Oil foaming is prevented by a membrane between the oil volume and the air cushion. This method works on the principle that oil cannot be compressed.

2.2. Vibration dampers

Vibration dampers, also called shock absorbers, reduce vibrations and vibration times of spring elements and sprung masses in vehicles.

There are hydraulic single−action shock absorbers, double−action shock absorbers and telescopic shock absorbers.

The use of shock absorbers is determined by the vehicle's suspension system.

− Although they have a self−damping effect, leaf springs require shock absorbers.

In heavy lorries, leaf spring packs made of thick leaves are used so that a high self−damping effect is obtained, and shock absorbers are very seldom necessary.

− Since rubber springs are self−damping, they do not require shock absorbers. The damping effect results from rubber deformation. For this reason, rubber springs can themselves be used as shock absorbers.

− Torsion bar springs and coil springs have a very low self−damping effect. In order to reduce vibrations, single−action shock absorbers, double−action shock absorbers and telescopic shock absorbers are mounted in the vehicles.

− In case of oil hydraulic air suspension (Fig. 2/17), vibrations can be damped by a throttle in the pressure cylinder (control valves) of the spring element.

Hydraulic dampers are necessary for the other type of air cushioning.

Damping becomes stronger with progressive spring deflection and therefore shock absorbers can only be correctly built for specific loads. A shock absorber should meet the following requirements:

− They should always work correctly irrespective of variations in shock absorber oil temperatures, changing road conditions or changing vehicle loads.

− They should respond immediately to spring deflections to ensure fast damping of the vibrations.

– They should support progressive springing.

– The nearer they are to the wheel, the better they function. The principle of the lever is important here.

Below we deal with the shock absorbers already mentioned in more detail. Hydraulic dampers as described above are effective because liquids cannot be compressed. See Fig. 2/21.

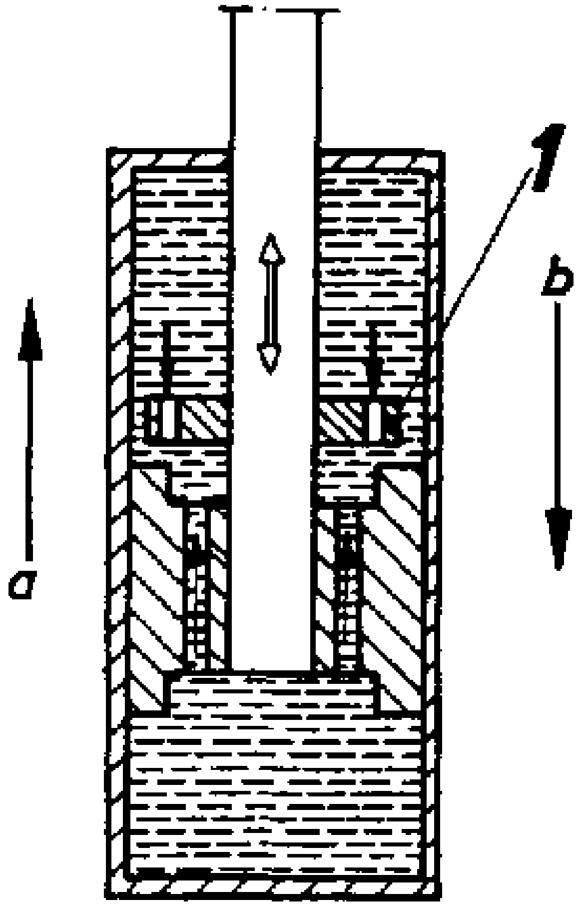


Figure 2/21 Hydraulic damper (principle)

1 compression disc (moveable on the rod) A compression, B expansion

A sealed casing is filled with oil which is pressed through a piston which divides the case into two chambers. The vibrations of the spring are transferred to the piston.

The piston has openings which can be enlarged and reduced by valves. Displacement causes fluid friction and thus vibrational energy is converted into heat energy.

All hydraulic shock absorbers use thin–bodies oils which must have special properties:

– Constant viscosity within the operating temperature range under normal conditions
– Sufficient and constant lubricating quality
– Free of acids and impurities
– Non–foaming

The damping force depends on the speed of the oil when pressed through the openings of the piston. The higher the speed the bigger the force, and therefore the damping, is required.

The driving speed, the vehicle load and the road conditions cause the springs to deflect. The vibrations have to be damped to given the vehicle good road holding qualities and, consequently, to guarantee safety on the road. Exact co–ordination of springs and shock absorbers prevent the driver and passengers from physical harm and protect the load and the vehicle.

Types of hydraulic shock absorbers

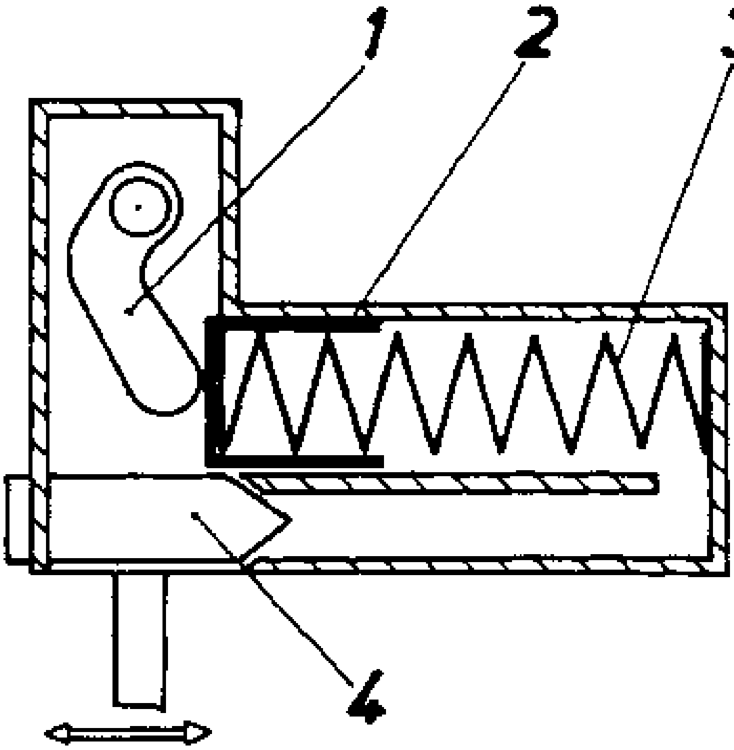


Figure 2/22 Single–action shock absorber

1 lever, 2 piston, 3 spring, 4 adjusting screw

Fig. 2/22 shows the single–action shock absorber. It only damps vibrations when the spring tension is released. The damping action can be adjusted by means of an adjusting screw. Piston and lever are held non–positively by the spring. The interaction of spring and oil causes damping. This shock absorber does require maintenance.

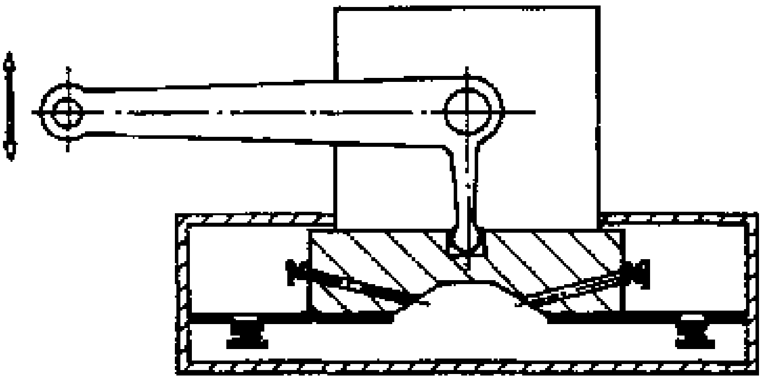


Figure 2/23 Double–action shock absorber

Fig. 2/23 shows how a double–action shock absorber works. As the name implies, it acts in two directions. When the spring deflects, the damping action is minimal; and when the tension reduces, the action increases. This shock absorber has high–pressure and low–pressure valves which can usually be adjusted. It requires maintenance. It is subjected to high pressures, and the damping path is short. It is subjected to intense heating. Damping losses are caused be the leverage.

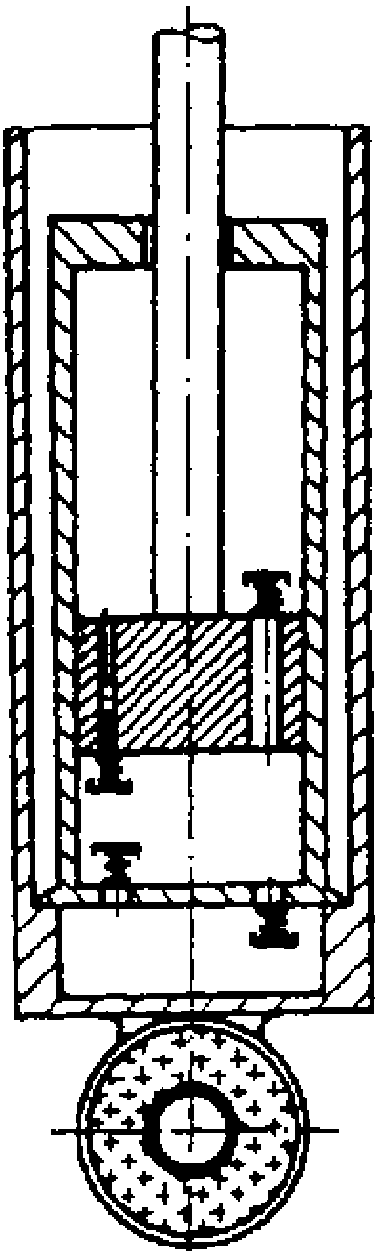


Figure 2/24 Telescopic shock absorber

Fig. 2/24 shows the telescopic shock absorber. It acts at right angles to the central axis and in two directions. The damping effect is minimal when the spring deflects, but it decreases considerably when it returns to its original position. During this time, the large boreholes in the piston are reduced in diameter by means of a diaphragm. This shock absorber requires little servicing and can be repaired very easily. It features long damping paths and low internal pressure. In this shock absorber, the oil is only moderately heated due to the low pressure. Wear is minimal. The design of the telescopic shock absorber permits easy installation.

Maintenance and repair of vibration dampers

Vibration dampers have to be checked regularly for correct mounting, oil content in the cylinder, and leaks at the screwing and the shock absorber shaft. These checks should be made after every 5,000 kilometres. In hydraulic single–action and double–action shock absorbers, the following operations are necessary in addition to topping up shock absorber oil:

– external cleaning of the shock absorber

– disconnecting of the leverage and inspection of the rubber torsion–shear springs (replace, if necessary)

– setting of the lever to its final position when filling with shock absorber oil and then moving it to and fro from one final position to the other to bleed the shock absorber

– draining of 3 to 10 mm^3 oil according to the manufacturer's instructions to enable the oil to expand when heated

– closing of the adjusting screw and reconnection of the leverage.

Fatigue in the high–pressure valve spring and wear of the shock absorber shaft are causes of decreased efficiency.

Wear of the shock absorber shaft increases the leverage play and seal play, causing oil losses which result in decreased efficiency.

In comparison to telescopic shock absorbers, the shock absorbers mentioned above have the following disadvantages:

– High pressures build up in them and accelerate wear.

– Due to ageing and the deposit of wear and abrasion particles, the shock absorber oil becomes viscous and should therefore be replaced after every 30.000 km. Before assembling the shock absorber, it should be cleaned with an oil–dissolving agent.

In case of oil leakage, the telescopic shock absorber should be removed and sent for repair to a workshop.

Telescopic shock absorbers may only be built in vertically or with a maximum angle of inclination of 45°.

2.3. Stabilizers and their construction

Stabilizers are necessary to reduce the tipping tendency and the lateral sway of vehicles. Hydraulic and torsion–bar stabilizers are used. The torsion–bar stabilizer (Fig. 2/25) is a mechanical lateral stabilizer mounted laterally or transversally to the vehicle axle; it connects the suspension of both wheels on one axle. If the body cants or an axle is lifted on one side, the stabilizer twists, raising the body by the force developing on the opposite side. Torsion–bar stabilizers are often used with coil springs. This stabilizer does not require any servicing, its production is inexpensive and its construction simple.

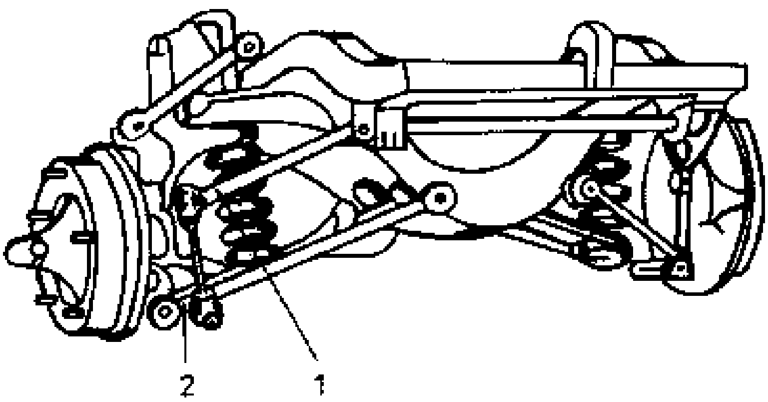


Figure 2/25 Torsion bar stabilizer

1 torsion bar stabilizer, 2 independent wheel suspension

Hydraulic stabilizers serve both for absorbing shocks and for lateral stabilization. Here double–action shock absorbers, connected to each other by pipes, are used. The pressure pipe of one shock absorber runs from its front pressure chamber to the rear pressure chamber of the other shock absorber, and vice versa, see Fig. 2/26.

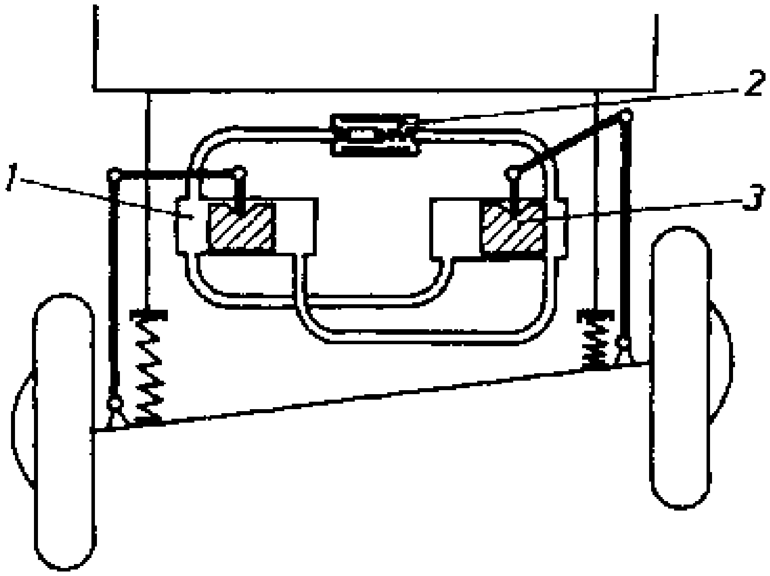


Figure 2/26 Hydraulic stabilizer

1 double–action shock absorber, left, 2 compensating valve, 3 double–action shock absorber, right

If both wheels of an axle are loaded simultaneously there is a pressure compensation in the pipe, i.e. the oil compensates at zero pressure. The tension reduction of the spring is damped. If only one side of the vehicle is loaded, the oil is pressed through the pipes to the other side and the body is raised.

The use of shock absorber oil in hydraulic stabilizer systems results in the following disadvantages:

– They require servicing.
– They are heavy.
– Due to the number of wear parts in the control valves they are particularly prone to wear.
– The construction of these systems is complex and expensive.

Hydraulic stabilizers are only used if the resulting improvement in the vehicle's road holding qualities are vitally necessary or economically justifiable.

Test questions:

2.1. What types of springs do you know?

2.2. Which materials and media may be used as springing elements?

2.3. What is a leaf spring pack subjected to?

2.4. Describe the terms 'coil spring' and 'torsion–bar spring'.

2.5. Where on a vehicle are rubber pack springs to be found?

2.6. What advantages has air suspension over other types of suspension?

2.7. Describe the design of a leaf spring pack.

2.8. What is the purpose of putting grease between the leaves of a leaf spring?

2.9. Why are polyamide laminas inserted in the tips of spring leaves?

2.10. Why must a leaf spring be regularly maintained?

2.11. Name the essential maintenance jobs on leaf springs.

2.12. What should be taken into consideration when repairing a leaf spring?

2.13. Describe the process of removing a leaf spring.

2.14. What is a coil spring subjected to?

2.15. What are the advantages of a coil spring over a leaf spring pack?

2.16. Why should coil springs always be fitted together with shock absorbers?

2.17. How is a coil spring maintained and repaired?

2.18. What are torsion−bar springs subjected to?

2.19. Why must the surface of a torsion bar be unmarked by machine tools?

2.20. What should be taken into consideration when mounting a torsion bar?

2.21. What spring material other than steel do you know?

2.22. What is understood by progressive springing?

2.23. What types of rubber springs do you know?

2.24. Describe the design of a rubber torsion shear spring.

2.25. What types of air suspension do you know?

2.26. Describe the construction of pneumatically adjustable air suspension.

2.27. What types of bellows are used in them?

2.28. Describe the design of hydraulically adjustable air suspension.

2.29. Explain the term 'vibration damper'.

2.30. What is the function of vibration dampers in vehicles?

2.31. Explain why rubber can also be used for vibration damping.

2.32. What is understood by a hydraulic shock absorber?

2.33. Describe the function of this type of vibration damper.

2.34. What requirements must be met by hydraulic shock absorbers?

2.35. Describe the design of a single−action shock absorber.

2.36. Describe the design and operating principle of a double−action shock absorber.

2.37. Describe the design and operating principle of a telescopic shock absorber.

3. Wheel suspension

This section deals with the various types of wheel suspension for vehicles. Wheel suspension is the connection of the wheels to the supporting vehicle frame and their guidance. The general function of a wheel suspension system is to connect the supporting vehicle frame to the wheels, to ensure wheel guidance and to transfer the weight of the vehicle onto the wheels.

The essential function of the wheel suspension is to properly transmit guiding forces acting on the wheel, such as thrust forces, brake forces and lateral forces, to the supporting vehicle frame. Each axle journal must be connected with the frame by a positive guidance during the up and down movements of the springs.

The wheel suspension of a vehicle is determined by three important factors:

– vehicle type
– intended purpose of the vehicle
– driving properties required for the specific vehicle type

Wheel suspension systems should meet the following requirements:

– Whatever the driving state – acceleration, constant speed, cornering or braking – and whatever the state of the road surface, all the wheels should always be in contact with the ground.

– They should allow only small transversal inclinations or vibrations, or none at all.

(Achieved by correct combination of front and rear wheel suspension)

– They should prevent changes of wheel camber and caster angle of the steered wheels during spring deflection.

– The wheel suspension system should not allow any change in the set wheel track as this will accelerate type wear and increase the danger of skidding, especially when the weight of the vehicle is distributed unevenly over the wheels.

– The wheel suspension system should be lightweight in order to keep the unsprung weight of the vehicle low.

– To increase road safety and the life of the suspension system, steering joints should not require maintenance.

The following parameters are dependent on wheel suspension:

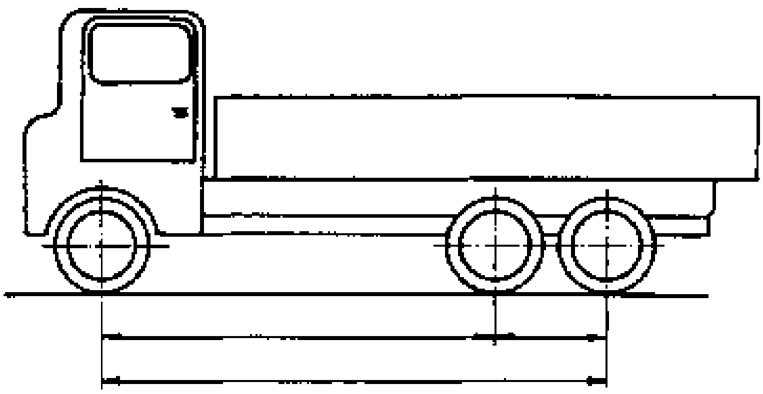


Figure 3/1 Wheel base

<u>Wheel base</u> (Fig. 3/1 – the distance between the mid–points of the front wheels and the rear wheels, measured in millimetres (mm).

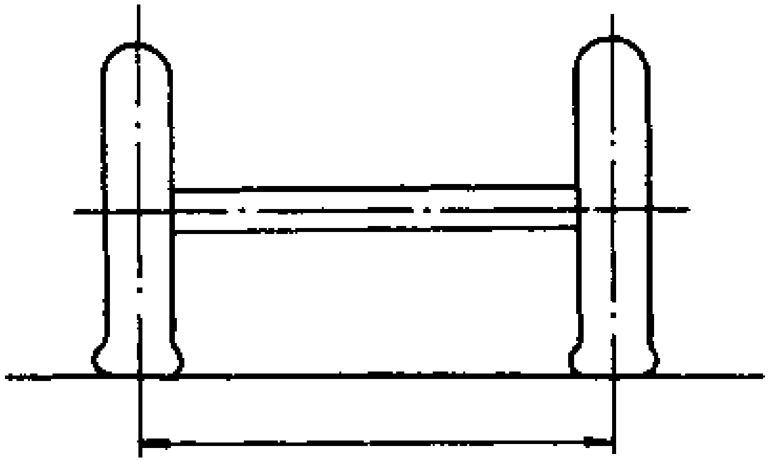


Figure 3/2 Track

Track (Fig. 3/2) – the distance between the mid–points of the two single wheels on one axle, measured in mm. In the case of twin wheels the distance is measured between the mid–points of twin wheels.

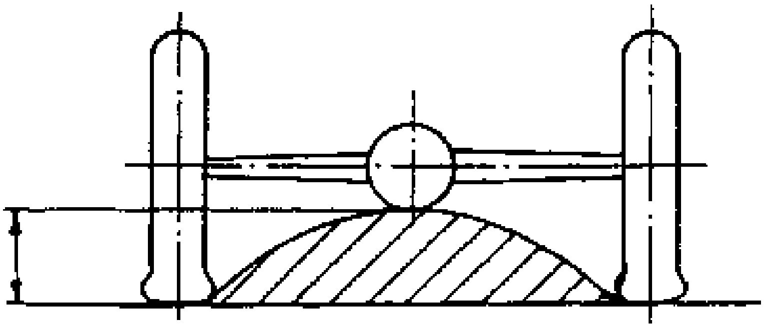


Figure 3/3 Ground clearance

Ground clearance (Fig. 3/3) – the shortest distance between the vehicle and the ground when the vehicle is fully loaded, measured in mm.

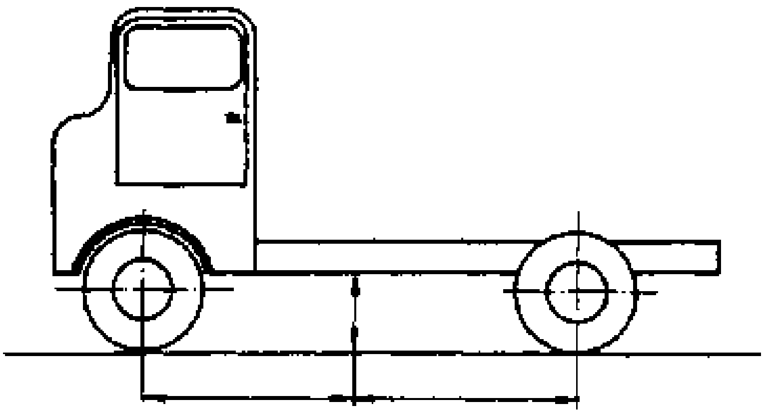


Figure 3/4 Height of the chassis above ground

Height of the chassis above ground (Fig. 3/4) –the distance between the upper edge of the chassis and the ground when the vehicle is fully loaded, measured in mm at the mid–point of the wheel base.

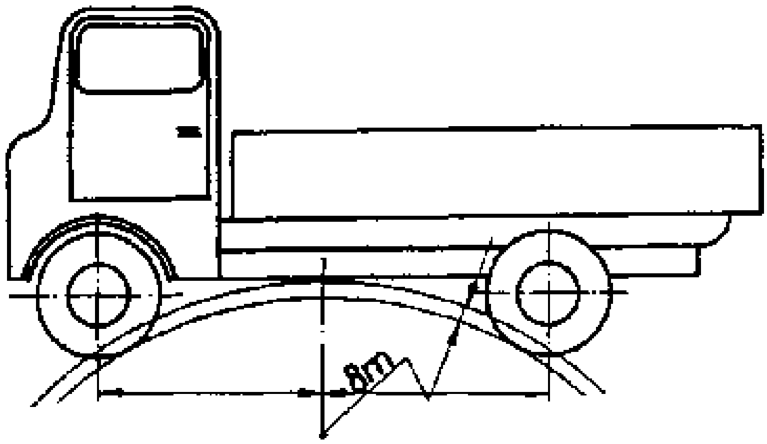


Figure 3/5 Ground clearance on a convex surface

Ground clearance on a convex surface (Fig. 3/5) – the shortest distance between the lower edge of the chassis of a fully loaded vehicle and the lateral surface or a cylinder, of 8 m radius for a lorry and 5 m radius for a car, whose axis is perpendicular to the longitudinal plane of symmetry of the vehicle, and on which the vehicle rests.

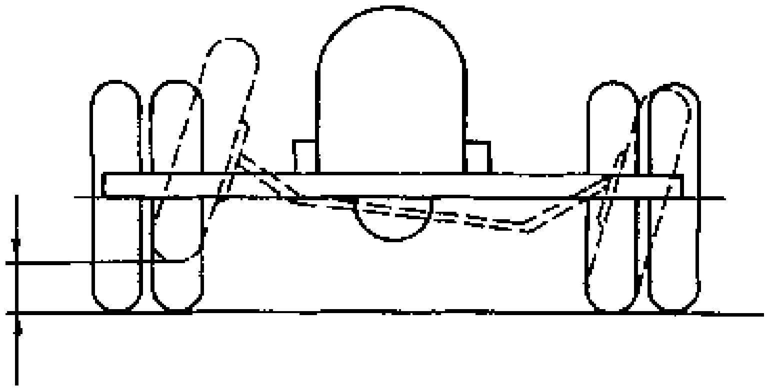


Figure 3/6 Lift

Lift (Fig. 3/6) – the height to which a front wheel may be lifted without the other wheels leaving their supporting surface, measured in mm.

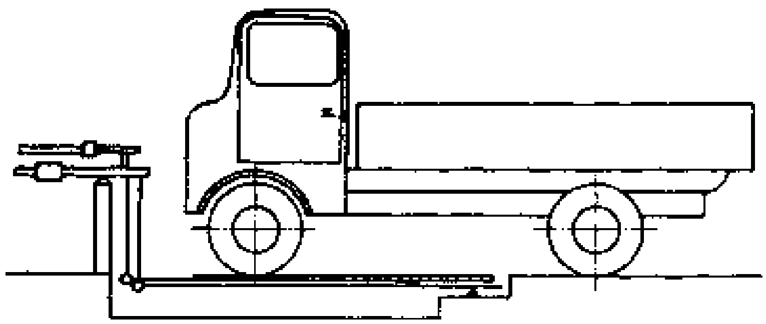


Figure 3/7 Maximum axle weight

Maximum axle weight (Fig. 3/7) – the total weight transferred from the wheels of one axle on to the road, measured in kilogrammes (kg). Two axles set between 1 metre and 2 metres apart are considered as a double axle.

The unsprung masses such as axles, brakes and wheels should be kept as small as possible. This can be favourably influenced by the type of wheel suspension.

The driving properties, especially steering stability, are influenced by the wheel suspension in connection with the springs of the vehicle and all other parts of the chassis.

3.1. Front and rear wheel suspension of driven and non–driven wheels

Vehicles can be driven the rear wheels or the front wheels or both, and so vehicle wheels can have different functions.

– They can be steered wheels. This applies to the front wheels in normal and rear–wheel drive vehicles. In vehicles with normal drive, the drive assembly is mounted in the front part of the vehicle and the force is transmitted to the rear axle by propeller shafts. In the case of rear–wheel drive vehicles, the drive assembly is mounted behind or directly on the rear axle.

– They can be driven wheels, as is the case with normal and rear–wheel drive vehicles.

– They can be both steered and driven wheels. This is the case with front–and four–wheel drive vehicles. In a front–wheel drive vehicle the drive assembly at the front or directly above the front axle. In a four–wheel drive vehicle all the wheels are driven be the drive assembly.

There are three different types of wheel suspension:

– rigid axle suspension
– independent suspension
– half–axle suspension

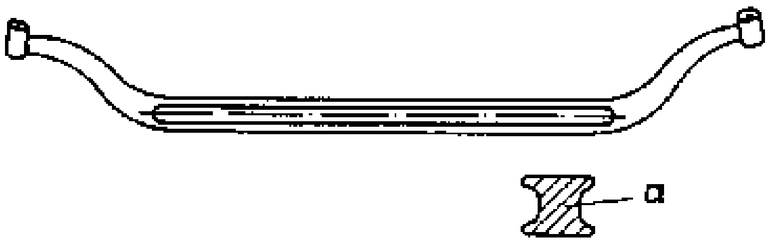


Figure 3/8 Rigid axle

A cross section of axle body

The term rigid axle suspension (Fig. 3/8) means that both the wheels on one axle have common suspension and common springing.

With this type of suspension the upward movement of one wheel is partially transmitted to the other. The track width cannot change but the wheel camber varies as the spring deflects.

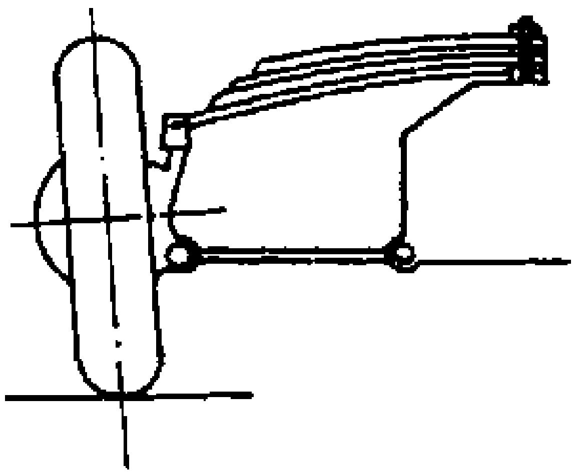


Figure 3/9 Independent suspension

With independent suspension (Fig. 3/9) the wheels are mounted independently, i.e. they are individually sprung, and spring deflections are restricted to one wheels only. Stabilizers are used, however, to achieve a balancing effect and thus the movement is transmitted to both wheels. Whether or not wheel track and camber change during deflection is dependent on the individual design of the suspension, especially on the design and arrangement of the guiding elements.

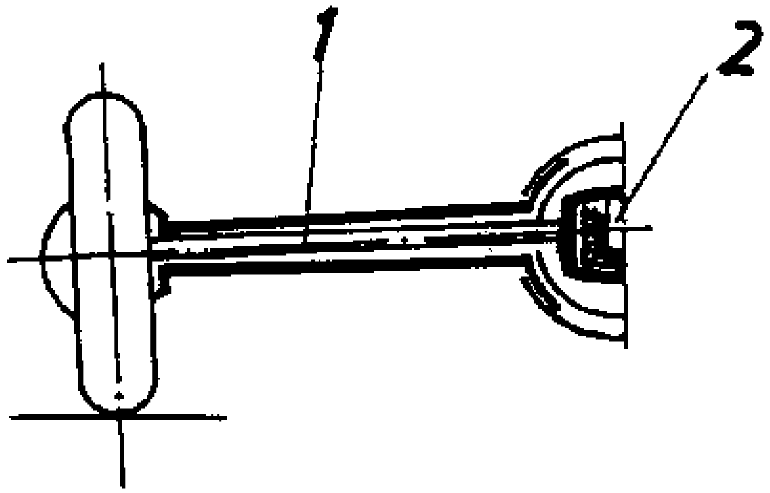


Figure 3/10 Half axle

1 Half axle, 2 differential

As the term half−axle (Fig. 3/10) suggests, the wheels are mounted separately to one half of the axle. The axle halves are connected to the differential unit in the centre of the chassis, and when the spring deflects they swing about this point. This type of wheel suspension is a combination of independent wheel and fixed wheel suspension.

Because of the wheel guiding forces, bending and torsional forces act on the wheel suspension elements. This means that these elements must be designed to withstand bending and torsion. Die−forged and rigid pressed sheet metal parts are used for this purpose.

Drop forgings and very rigidly designed pressure forged parts are used as these parts must be made of a tough and strong material. They are quenched and tempered.

There are quite different types of wheel suspension, and all kinds of springs can be used with them. The type of axle used depends on the purpose of the vehicle and the driving qualities required of it.

In modern vehicle construction, independent suspension is becoming ever more important, especially in the construction of passenger vehicles. In buses and lorries, however, rigid axles are still predominant. In some cars, independent suspension is used on the front wheels and a rigid axle for the rear wheels. Below the advantages of independent wheel suspension and half−axles over rigid axles are discussed:

– With independent suspension, the unsprung masses can be kept low.

– Road grip and, consequently, road safety are better.

– With this suspension, the centre of gravity is low and roadability is better which is especially important for racing cars.

– Different spring systems can be combined with these types of suspension in the vehicle.

– Wheel camber variations can be kept to a minimum during deflection.

– When the springs deflect, the wheel camber, toe−in and castor angle of the steered wheels do not change if the wheel guiding parts have been correctly designed (See section on steering).

Half axles have the following advantages over rigid axles:

– The unsprung masses are reduced as the drive mounted on the sprung chassis.

– The road grip of the wheels is better.

– They have a better stability on curves and a lower transversal inclination.

– Transmission of the wheel forces is better due to the greater distance between the swivel points (fixed points).

However, the rigid axle continues to prove its worth in motor engineering. It possesses some important advantages which should not go unmentioned.

– The rigid axle is simple in construction.
– It is simple and therefore fairly inexpensive to manufacture.
– This simplicity means that it is very reliable and requires little maintenance.

Rigid axles can be used for both front and rear axles, but these two types vary considerably.

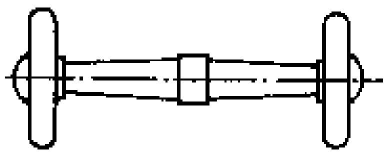
The rigid front axle is a continuous support with axle heads at either end which support the axle bolts for the steerable front wheels. The mounting surfaces for the springs are also found on this support. Fig. 3/11 shows the various types of axle.

Figure 3/11 Types of axle

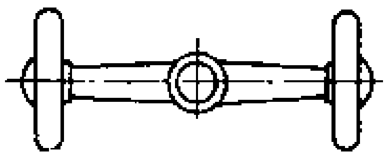
a...d rigid axles;

a) forked axle

b) stub axle

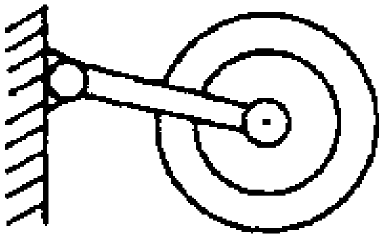


c) funnel axle

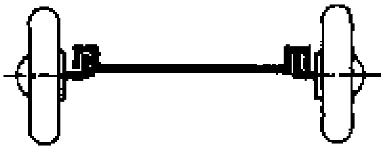


d) banjo axle

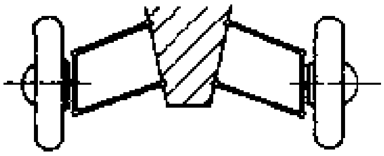
e) half axle as swing axle



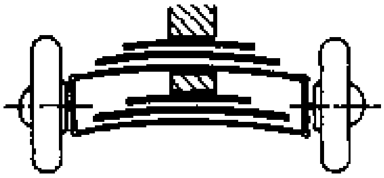
f) crank axle



g) guide axle (pivot axle)



h) wheel suspension by means of track control arms



i) wheel suspension by means of cross springs

In most cases the cross section of a rigid front axle is an I–beam section, but in smaller vehicles pipe–section axles are also common. They are manufactures from high–quality steel which must not be hot straightened after an accident because the heating process will cause the loss of the rigidity gained by quenching and tempering. The axle body is always cranked to ensure the lowest possible position of the frame.

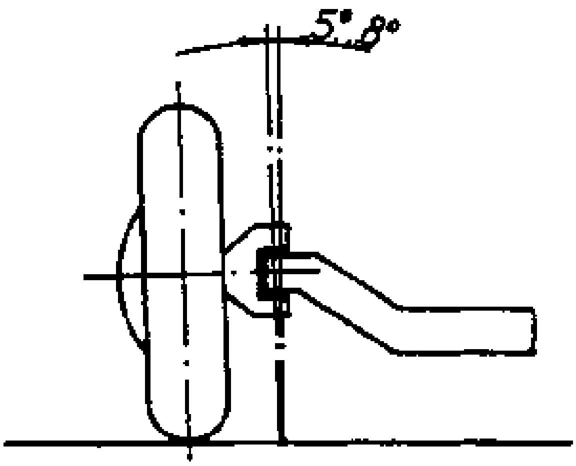


Figure 3/12 Position of the drive joint housing to the road

The axle heads are directed outwards in relation to the vertical to the road (Fig. 3/12) in such a way that an extension of the axle bolt in the axle head meets the ground (road) near to where the wheels touch the ground. This is to reduce the shocks to which the wheel is subjected while moving. The wheel position described here is called 'inclination'. Vehicles having no or minimum inclination only transmit each shock to which the front wheels are subjected, to the steering wheel. Such vehicles are difficult to drive and tend to 'drift', i.e. they are unstable, and the front wheels wobble. Rigid front axles are found nowadays only in lorries and buses.

To improve the driving comfort of a vehicle, more and more swing axles and independent wheel suspension systems are being used. Combinations of independent wheel suspension and rigid axles are also found. In this case, the front wheels are independently suspended while the rear axle is a rigid axle.

In independent wheel suspension systems a transversal leaf spring is often used to connect the two front wheels, and guidance is ensured by the steering arms. Coil springs and air suspension, shown in Figs. 2/17 and 2/25, are becoming increasingly more important. When using leaf springs track variations occur during spring deflection.

In the suspension shown in Fig. 3/9 even wheel camber may vary, this may, however, be kept within acceptable limits by constructional measures on the part of the manufacturer.

These variations do not occur with coil springs and air suspension.

With independent suspension, unsprung masses are kept low, i.e. they are restricted to the wheel drive, brake shoes, anchor plate and wheel.

Like front axles, the rear axles can be designed as rigid axles, swing axles and in the form of independently suspended wheels.

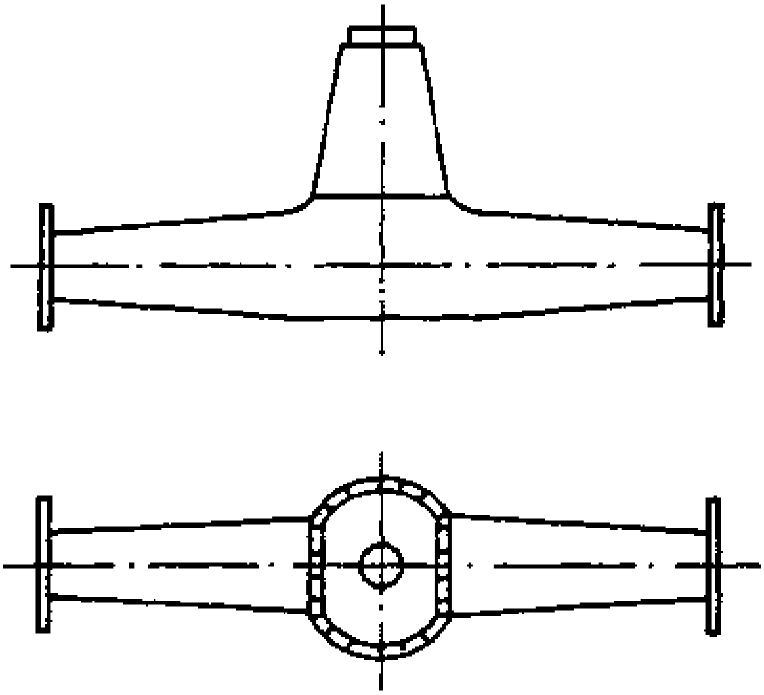


Figure 3/13 Funnel axle

The most common type of rear axle today is the rigid axle. It is used both in passenger cars and in lorries. Similar to the front axle, it is a continuous supporting axle body. Provided that the vehicle has rear axle drive, it serves to accomodate the power transmission components which are protected from outside damage by the construction of the axle body. It can be designed as a funnel axle or banjo axle (Figs. 3/13 and 3/14).

In case of a front wheel drive, the rear axle is a hollow body of square or pipe cross section. In rear wheel drive, the differential unit and the axle shafts, also called fully floating axles, are integrated in the axle body.

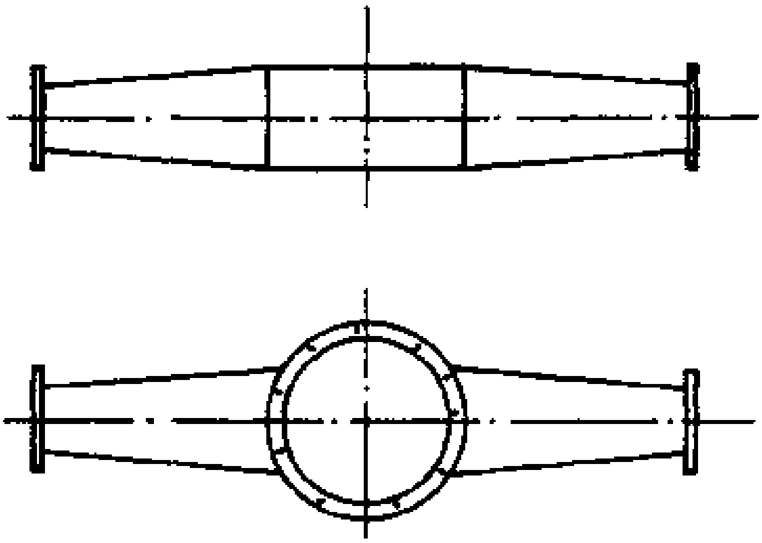


Figure 3/14 Banjo axle

The differential unit of a vehicle consists of the ring gear, bevel gear and planetary gears held by the differential housing. This differential gear unit has the function of compensating the rotation of the wheels on curves. On a curve, the inside wheel turns slower and covers a shorter distance than the outside wheel. The differential unit is used to compensate these different wheel speeds (Fig. 3/15).

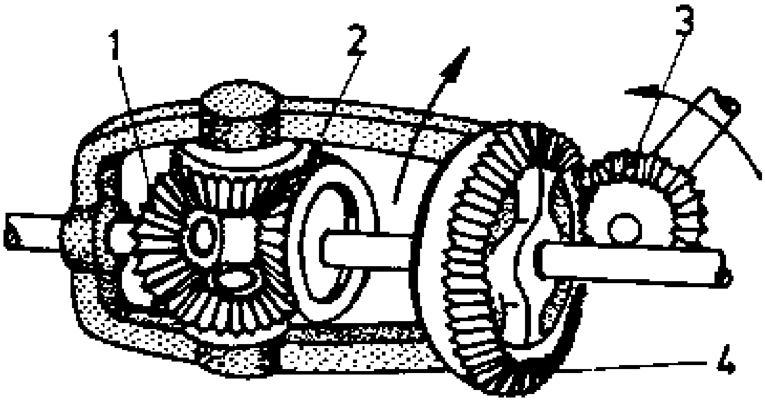


Figure 3/15 Differential gears

2 differential casing, 3 bevel gear, 4 crown wheel

Modern lorries have a second wheel drive transmission by means of spur gears (Fig. 3/16).

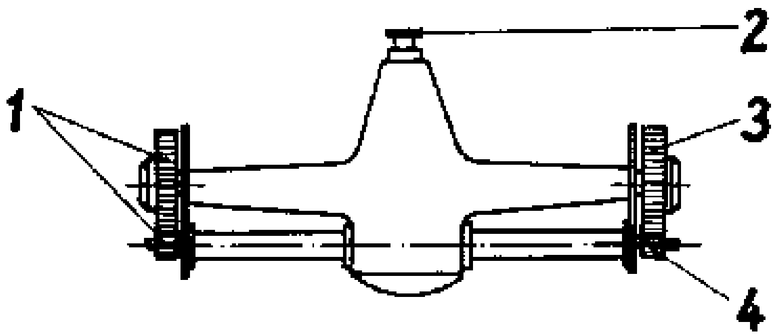


Figure 3/16 Second wheel drive transmission by spur gears

1 spur gears, 2 final drive, 3 driven gear, 4 driving gear

This additional transmission increases the force by which the wheels are driven, and keeps the driving power relatively low.

In lorries, axle bodies of cast steel are used for the rigid rear axle. In passenger cars light−metal or pressed sheet−steel parts are used. The axle bodies of rear−axle drives must be sealed as, after the assembly of all parts, they must be filled with oil for the drive to ensure lubrication of the rotating parts within the axle body. The amount and grade of oil to be used is specified by the manufacturer.

It is evident from the description of the rear axle that the unsprung masses are very heavy. This is due to the fact that the complete axle drive and the wheels are mounted onto the axle. To counteract this disadvantage, independent wheel suspension is made use of in vehicles with rigid rear−axle drive.

The purpose of independent wheel suspension in rear axle drives is to reduce the unsprung masses. The axle drive is fixed to the frame and the driving power is transmitted to the wheels by swing axles (see also Fig. 3/11) so that, besides the wheels, brakes, suspension elements and springs, the only shock−transmitting masses left are the swinging half−axles accomodated in the casing of the differential unit. They have to be supported on the frame for the transmission of the thrust. This design is used in vehicles with a central pipe frame. The two axle halves can be sprung by a transversal spring or by coil springs supported by the frame, and by lateral leaf springs in the case of double axles.

With front wheel drive, the rear axle has only a supporting function. The wheels can be held by wishbone suspensions or by simple suspension arms fixed to the frame. The rear axle is sprung by a transversal spring, a coil spring or a torsionbar spring.

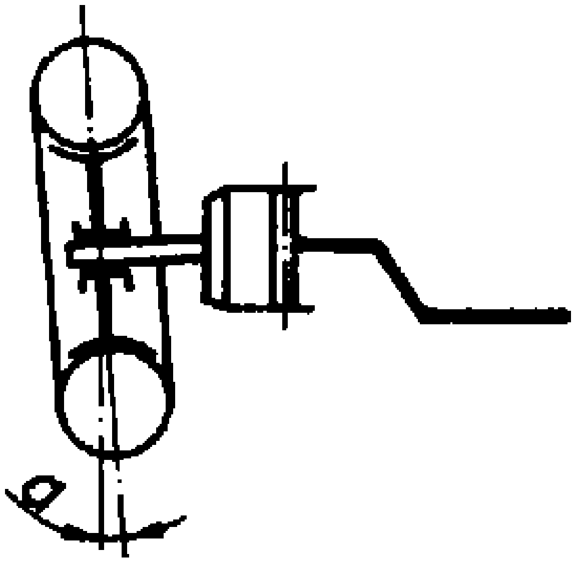
3.2. Wheel positions

This section deals with the position of the steered wheels of the front axle, which have to have specific relationships to the road. These are known as wheel camber, toe–in, castor angle and inclination.

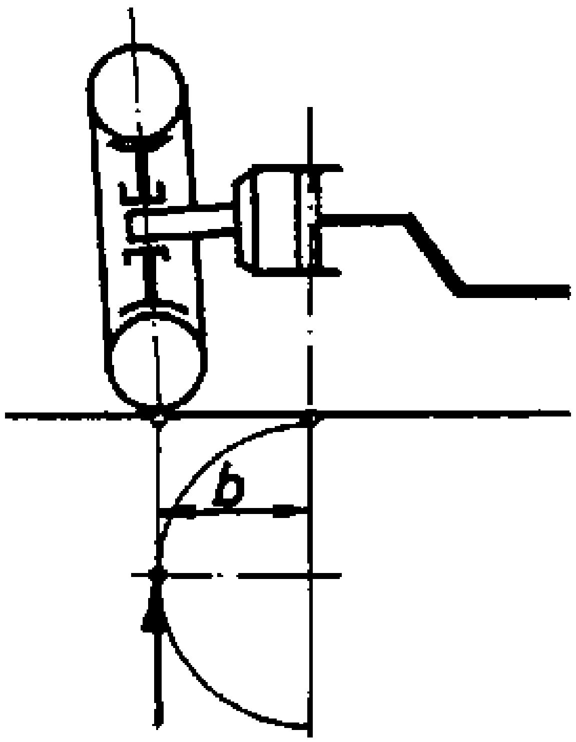
The various wheel positions serve to give the vehicle the following driving qualities:

– favourable driving properties
– perfect functioning of the steering system
– easy and safe steering under all conditions
– suppression of any steering vibrations

Figure 3/17 Wheel camber



a) camber angle 0,5° to 8°



b) steering roller radius

The wheel camber (Fig. 3/17a) is the inclination of the wheel plane in ° (degree) to the perpendicular raised from the point of wheel contact with the road.

The wheel camber prevents wobbling of the front steered wheels and causes the steering wheel to return automatically to the straight position after turning. If wheel camber is too great, tyre wear is accelerated, and wheel instability and torsional vibrations are caused, which lead in turn to wobbling of the steered wheels and unsafe driving. For this reason, the wheel camber should be as small as possible. However, a favourable steering roll radius should also be maintained. The purpose of a positive wheel camber is:

Because of the wheel camber the wheel tends to roll outwards like a cone but is forced to roll in a straight line by the wheel guidance. Wheel guidance means wheel suspension such as rigid axle or independent suspension. The wheels are positively guided, causing a force component which makes the wheels overrun the steering swivel pin. This results in an even loading of the wheel bearings, unloading of the axle stub nut and elimination of bearing play (Fig. 3/17b).

Toe−in is the distance by which the rear rim beads are farther away from each other than the front ones. This distance is measured on an even surface in the middle of the left and the right wheels of a vehicle with the wheels turned straight. The vehicle must be fully loaded (Fig. 3/18).

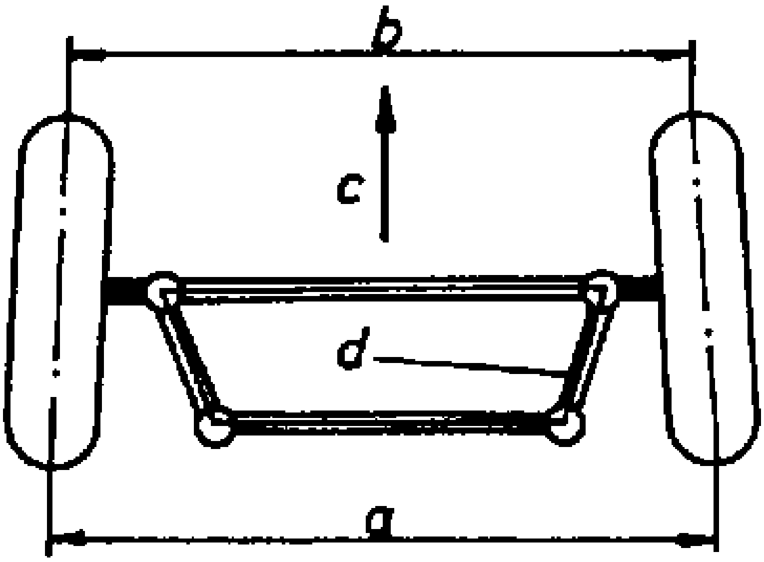


Figure 3/18 Toe−in

A rear track, B front track, C direction of travel, D steering trapezium

A graduated track meter is used for adjusting the toe−in at the tie rods connecting the left and the right part of the front axle.

The toe−in serves to reduce the tendency of the steered wheels to wobble, to reduce tyre wear and to make steering easier.

Another purpose of the toe−in is to set the wheels approximately parallel at high speeds by means of centrifugal force.

The inclination, as shown in Fig. 3/12, has an average value of between 5° and 8°. The inclination is measured with the vehicle fully loaded. Due to the inclination, shocks act on a short lever arm.

The castor angle is the extension of the perpendicular erected at the midpoint of the wheel compared to the midline of the steering swivel pin (Fig. 3/19).

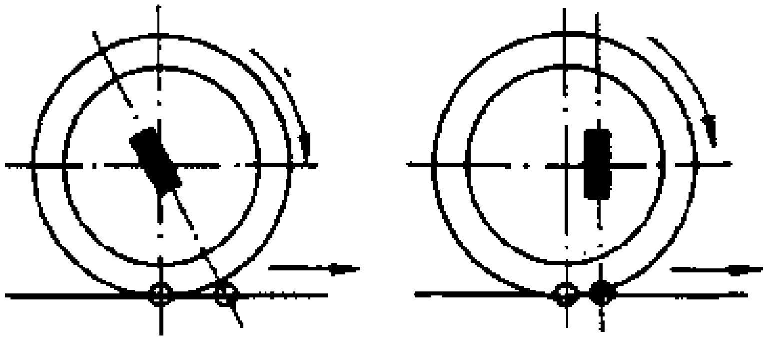


Figure 3/19 Castor angle

This distance is measured at the ground where the vehicle is positioned. It is intended to improve the steerability of the wheels, since pulled wheels are more stable compared to pushed wheels which are unsteady and tend to wobble. Because of the castor angle the wheels follow each steering movement well, do not wobble and straighten automatically.

3.3. Removal and fitting of axles

A vehicle is taken to a repair shop to have the front axle reconditioned.

In this example, a rigid front axle is to be completely reconditioned. In order to do this it is necessary to remove the axle from the vehicle. The vehicle is positioned in the repair bay, i.e. it has to be protected from rolling away by blocks. These blocks are placed at the wheels of the rear axle. How the wheel nuts are slackened. By means of an appropriate jack the vehicle can be lifted, the wheels can be unscrewed and removed. Supports are used to prevent the vehicle from tipping and to take the load off the jack.

Another jack is positioned under the axle in the middle of the axle body for support. After having finished these preparations the spring clips are loosened and the axle is separated from the springs. The steering track is loosened at the steering lever and has to be pressed out of the cone by means of a steering track remover. The shock absorbers also have to be removed from the axle body by loosening the screw connections. How the front axle is lying on the jack. Having lowered the jack, the axle can be removed from the vehicle and transported to the workshop where it is to be disassembled by means of a mobile jack. The individual parts then pass through a washing machine to be cleaned and are checked to see if they are re–usable.

Defective parts are discarded and are replaced by new or regerated ones during the assembly of the axle. The axle is re–fitted in reverse order. First the axle has to be fixed to the springs and straightened so that the vehicle does not move diagonally or break away from the track after repair. When removing the rear axle, the cardan shaft which transmits the power must also be removed. In order to avoid accidents care must be taken to ensure that the springs are always relieved during removal of the axles. When mounting the cardan shaft it is essential to ensure that it is put together in the same way as it was disassembled. The cardan shaft is balanced, and if two parts are incorrectly assembled an unbalance may occur and lead to the destruction of the transmission parts. When assembling the bevel gear at the rear axle, care must be taken to ensure that the clearance between the ring gear and the bevel gear is adjusted to guarantee effective and silent power transmission. The clearance can be adjusted by means of a dial gauge and is determined by the manufacturer. Since this clearance will increase in the course of time (due to wear) the distance can be corrected to a certain extent by the removal or insertion of thin spacer rings.

3.4. Repair tools and auxiliaries

Open ended wrenches, 12–point opening socket wrenches, wheel nut spanners and electrical and pneumatic tools with nut drivers of all wrench sizes are used for reconditioning axles.

Jacks, blocks and supports as well as transporters for handling components are used as auxiliary parts.

The axle testing gauge is used for measuring and checking inclination, wheel caber and castor.

The dial gauge is used for adjusting the clearance between the ring gear and the bevel gear as mentioned above.

The track meter, also mentioned above, is used for adjusting toe–in.

Test questions:

3.1. What do you understand by wheel suspension in a vehicle?

3.2. What is the main function of wheel suspension?

3.3. What factors determine the type of wheel suspension to be used on a vehicle?

3.4. What demands are made on the wheel suspension?

3.5. Explain the term wheel base.

3.6. What do you understand by wheel track and ground clearance?

3.7. What do you understand by the terms 'height of the chassis above ground' and 'ground clearance on a convex surface'?

3.8. Explain, with examples, the terms distortion and maximum weight.

3.9. What do you understand by a rigid axle?

3.10. Give a diagramatical explanation of independent suspension.

3.11. What do you understand by a half–axle?

3.12. What types of wheel suspension do you know?

3.13. Give the advantages of independent suspension.

3.14. Give the advantages of the half–axle.

3.15. What are the advantages of the rigid axle?

3.16. Describe the design of a rigid front axle.

3.17. What do you understand by resistance to rolling?

3.18. What different types of axle heads do you know?

3.19. Describe the construction of a differential unit.

3.20. What rear axle designs do you know?

3.21. What function does the differential unit fulfill in a driving axle?

3.22. Describe the structure of a differential unit.

3.23. What is the, function of the rear axle in front wheel drive? Give some examples of springing which could be used in such a case.

4. Steering

The steering system of a vehicle should, in every situation, cause the vehicle to travel in the direction required by the driver reliably and with the least possible effort. Along with wheel position and the brakes it is a very important component for ensuring road safety. Its design, and the load of the steered wheels, are determined according to the total weight and maximum speed of the vehicle, to give light and steady steering. In order to facilitate steering for drivers of heavy vehicles, power–assisted steering is fitted. This, however, also allows the driver to stop the vehicle by steering manually should the power–assisted system fail.

The steering system must be so designed that road surface and air currents do not cause the vehicle to change direction. The additional power–assisted steering can be operated hydraulically or pneumatically.

The joints of the steering system must not work loose due to gradual wear.

In order to ensure the vehicle's road safety, steering components must be replaced immediately wear or damage occurs.

4.1. Types of steering

Steering systems can be divided into two main groups:

- fifth–wheel steering
- axle pivot steering

Fifth–wheel steering is used in trailers, single track vehicles (motorcycles, mopeds and motor–assisted bicycles with kick starters) and special purpose vehicles. In this type of steering the whole axle is steered, and for this reason skidding is likely if bends are negotiated too quickly. Fifth–wheel steering allows the vehicle to negotiate tight bends or even to turn on the spot. The required sliding surfaces are provided by rings, discs bushes or ball bearings (Fig. 4/1).

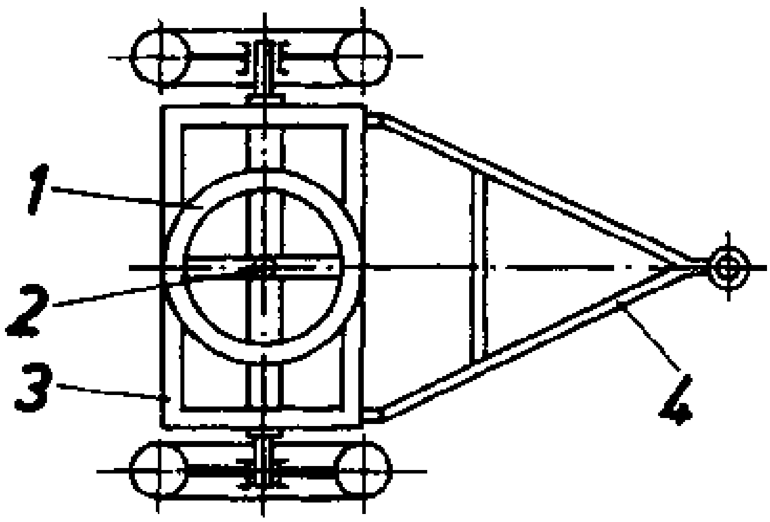


Figure 4/1 Fifth–wheel steering

1 slewing ring, 2 centre bolt, 3 swivelling bolster, 4 forked draw–bar

Axle pivot steering has a far more complicated structure. In this case an axle body (rigid axle, swing axle or independent suspension) is fixed to the frame via the springs. At the ends of the axle body there are swivelling steering stubs held by the steering swivel pin.

In contrast to fifth–wheel steering, a vehicle's ground clearance can be kept low with this type of steering design. The disadvantage is that a larger turning circle is required for this type of steering. The smallest turning circle can be determined when the steering angle of the wheels is as large as possible (Fig. 4/2).

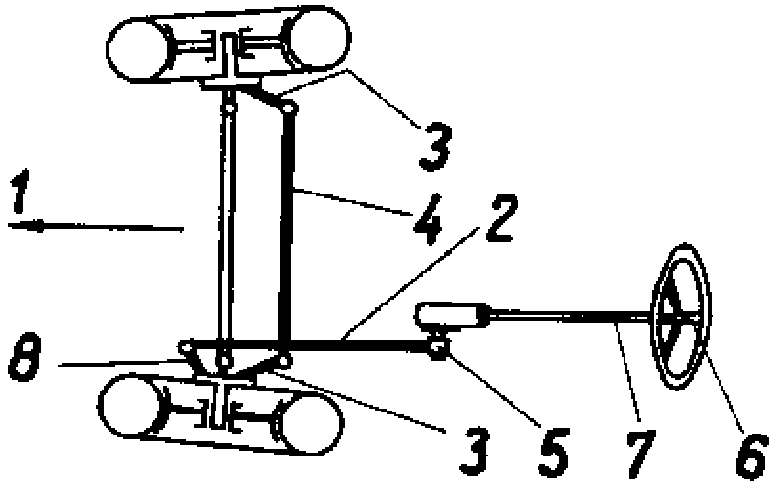


Figure 4/2 Axle−pivot steering

1 direction of travel, 2 drag link, 3 track rod arm, 4 track rod, 5 drop arm, 6 steering wheel, 7 steering column, 8 linkage lever

Axle pivot steering systems can be classified according to the structure of the steering gear. The most common types are listed below:

Peg−and−worm steering, worm steering, finger−type steering, cam and roller steering and rack−and−pinion steering.

It must be added that in fifth−wheel steering the whole axle, together with the swivelling holster, rotates around a pivot which is perpendicular to the axle. Thus good ground clearance is given for trailers and the tipping angle is increased.

For steering movement made by the driver, called the steering angle, is transmitted to the wheels in the following way:

The steering wheel is connected to the steering column by a cone with a disc spring or by toothed wheels, and is locked by a nut or a clamp.

At the lower end of the steering column is the steering worm (except in rack−and−pinion steering which has a gear wheel). The steering segment meshes with the steering worm or the gear wheel according to the design. The drop arm is mounted to the steering segment. These components are situated above the frame. The drag link beginning at the drop arm is connected with the steering stub, usually at the left−hand side of the vehicle (left−hand drive), by the connecting rod lever. There is another lever at the steering stub, which is called the track rod arm. Both steering stubs have a track rod arm which meshes with the track rod. In this way the steering trapezium is formed by the axle, the track rod arm and the track rod (Fig. 4/3).

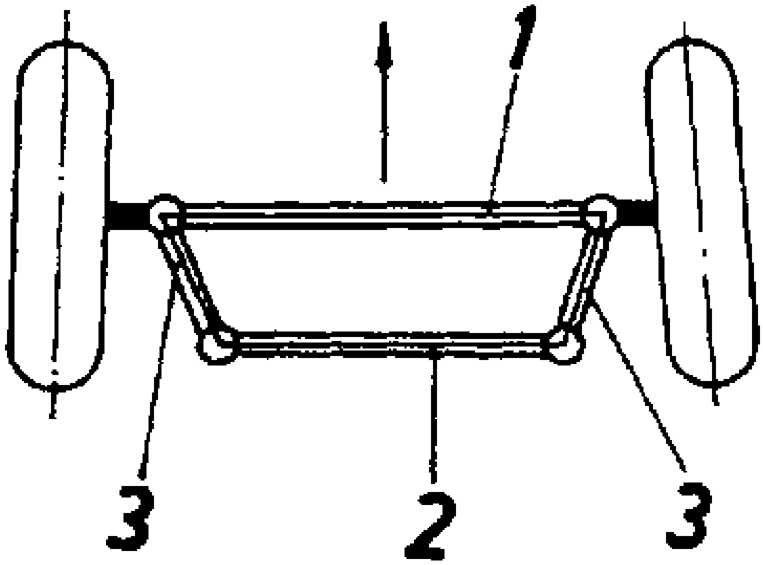


Figure 4/3 Steering trapezium

1 axle, 2 track rod, 3 track rod arm

As far as rack–and– pinion steering is concerned the track rods, which are split, are connected directly to the steering rack. All components of the steering system are secured by castle nuts and split pins. The following principle applies to the steering system and its components:

Screw connections have to be against loosening secured by castle nuts with split pins or by locking plates. Once removed, split pins and locking plates may not be used again. Welding of the steering system and of steering components is prohibited. Steering components may not be straightened by heating as this will cause them to loose the properties gained by their Initial heat treatment.

4.2. Construction and principle of steering systems

The most common type of steering is worm steering. It can be designed according to the special requirements of an individual vehicle to give almost self–retaining transmission of motion. The lesd angle of the worm is important for this self–retaining effect.

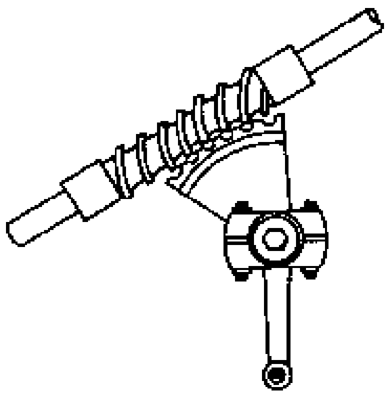


Figure 4/4 Worm steering system with gear segment

Worm steering (Fig. 4/4) has the advantage of being adjustable in three directions. The first is an axial direction at the thrust bearing of the steering shaft. This adjusts the height clearance. The second is the adjusting of the thrust bolt by means of which the centre of pressure can be changed.

The third possibility is the adjustment of the tooth play by means of an accentric cam.

In worm steering the straight direction of movement of the steering nut is transferred into the swivel motion of the steering shaft by means of slide rings or journal rings. The nut of the worm steering is babbitted. This steering system is not adjustable (Fig. 4/5).

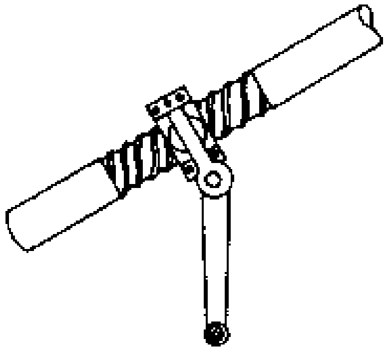


Figure 4/5 Worm steering system with slide rings and journal rings

In finger–type steering systems, a finger–type journal, in a ball and parallel–roller bearing, meshes with the worm. The ball and parallel–roller bearing is inside a lever which is firmly connected to the steering shaft. A rolling motion takes place between the worm and the finger. This gear is easy and the components wear only slightly. The worm threads are trapezoidal, and so the play between the worm and the finger can be adjusted. During adjustment the finger is pressed into the worm by means of an adjusting screw at the steering box. When adjusting the play, steering must always be in the centre position. If the steering is not centred the steering gear cannot be moved across the centre of the worm and it becomes jammed. The axial play is adjusted in the same way as for worm steering. With this steering system, lateral road shocks are hardly noticed and only a small force is required at the steering wheel. (Fig. 4/6) In the centre the lead angle of the worm is small, but it increases towards the ends. Therefore a bigger movement at the steering wheel is required for smaller steering locks, and smaller steering movement is required for bigger sheel locks.

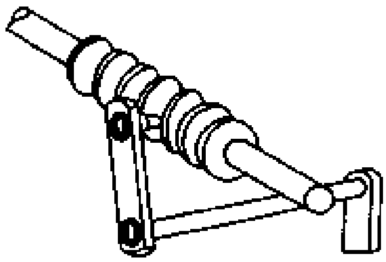


Figure 4/6 Finger–type steering system

In the cam–and–roller steering system a formed roller performs the task of the steering finger. The steering roller is in a ball bearing and has two roller teeth. When the steering wheel is turned these roller teeth describe an arc. Hence it follows that the worm is not cylindrical, but that its outer surface describes an arc.

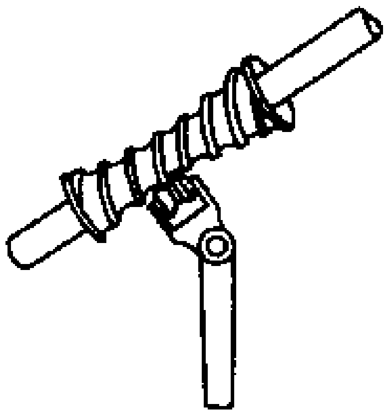
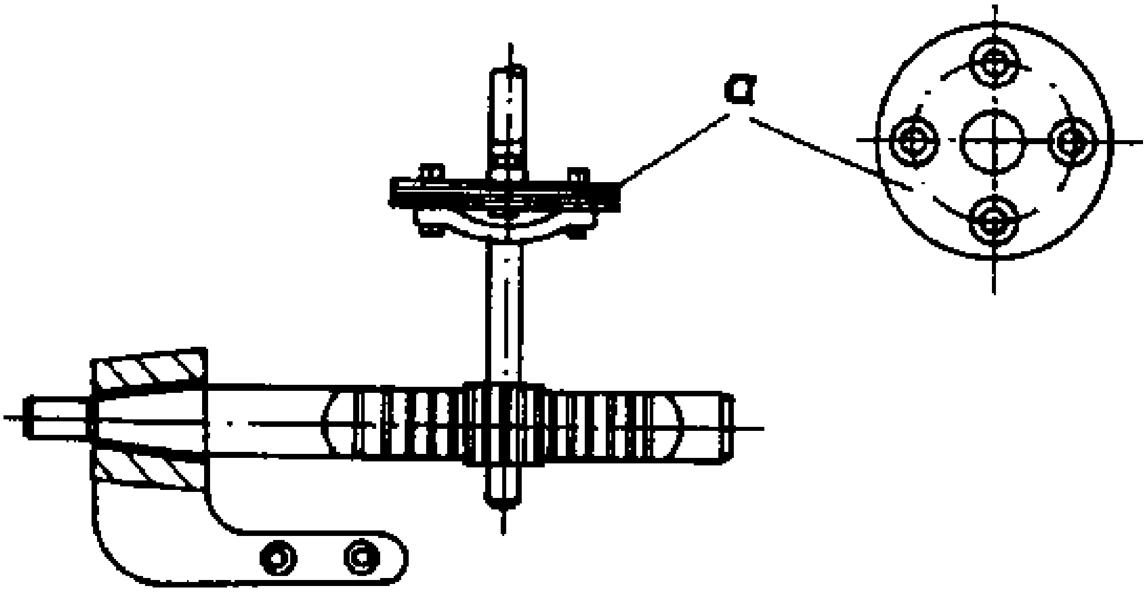


Figure 4/7 Cam–and–roller steering system

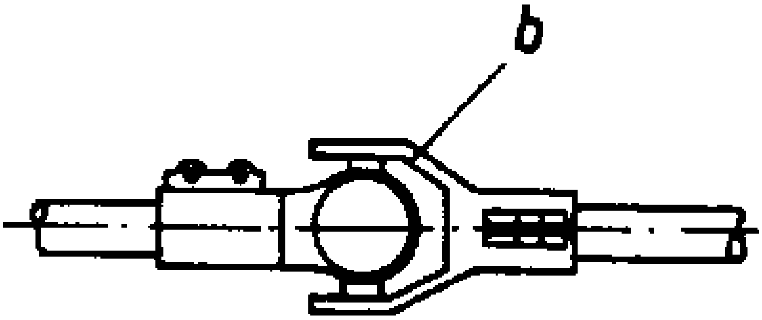
The diameter of the worm is smallest in the middle and it increases towards the ends. Due to the very large meshing surface between the steering worm and the steering roller efficient transmission is possible and wear on both parts is low. This type of steering is used particularly in heavy lorries. (Fig. 4/7)

Rack–and–pinion steering is simple in its structure. At the lower end of the steering shaft there is a pinion which meshes with a rack and moves it in two directions within the box. Rack–and–pinion steering is particularly suitable for vehicles with independent suspension since it is often used as a central component between split track rods. In this steering system the steering column is divided. It can be connected by fabric discs or by a universal coupling (Fig. 4/8). Such frame connections necessitate this divided support. Each steering gear has a play, determined at the steering wheel, which is normally the breadth of a hand. The play, which must be set exactly, is laid down by the steering gear manufacturer.

Figure 4/8 Rack–and–pinion steering system



a) connected by fabric disc



b) connected by universal joint

In modern motor vehicle engineering the safety of the driver is of ever increasing importance, and for this reason so–called safety elements are built into the steering system in case of accident. This safety element is an energy absorbing steering column which is either telescopic or constructed partly from wire mesh and which collapses on impact with an obstacle. Another possibility is to provide the steering column with folding elements which perform the same task. Another safety measure is the safety steering wheel which also distorts on impact.

All linking components in the steering system of a vehicle are rotatable. This is achieved by the use of ball heads and ball cups which require no maintenance. The ball heads have limited freedom of movement (Fig. 4/9).

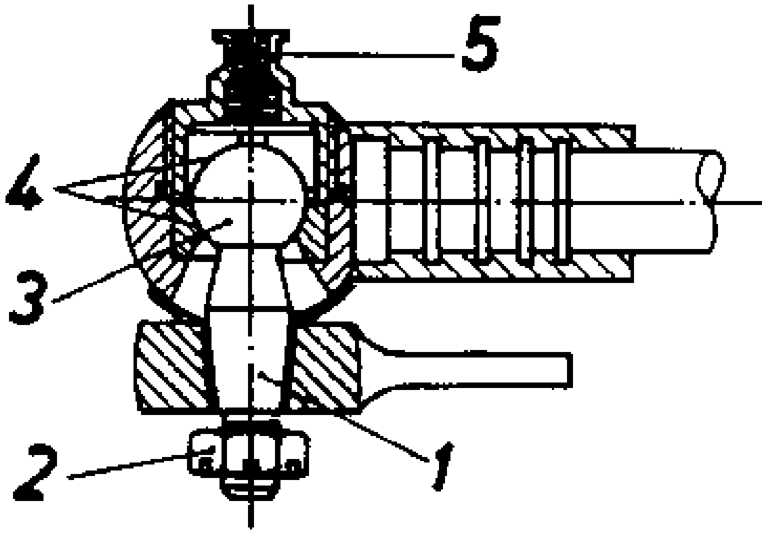


Figure 4/9 Ball head

1 cone, 2 castellated nut, 3 ball head, 4 ball socket, 5 lubricating nipple

At the ball heads there is a cone and a thread to connect the track rod and the rod arm at the steering stub.

Now we will deal with a type of steering gear, the principle of which is not new, but is which is widespread in the manufacture of commercial vehicles today. Fig. 4/10 illustrates the steering gear of the recirculating ball steering system. This recirculating ball steering system is used in the W 50 lorry and, compared with other mechanical steering gear systems, is very efficient. It can be more than 95 % effective. It is the most easy–running of all the steering systems described so far due to its rolling friction. This friction is caused by travelling in a closed circuit between the steering bolt and the steering unit.

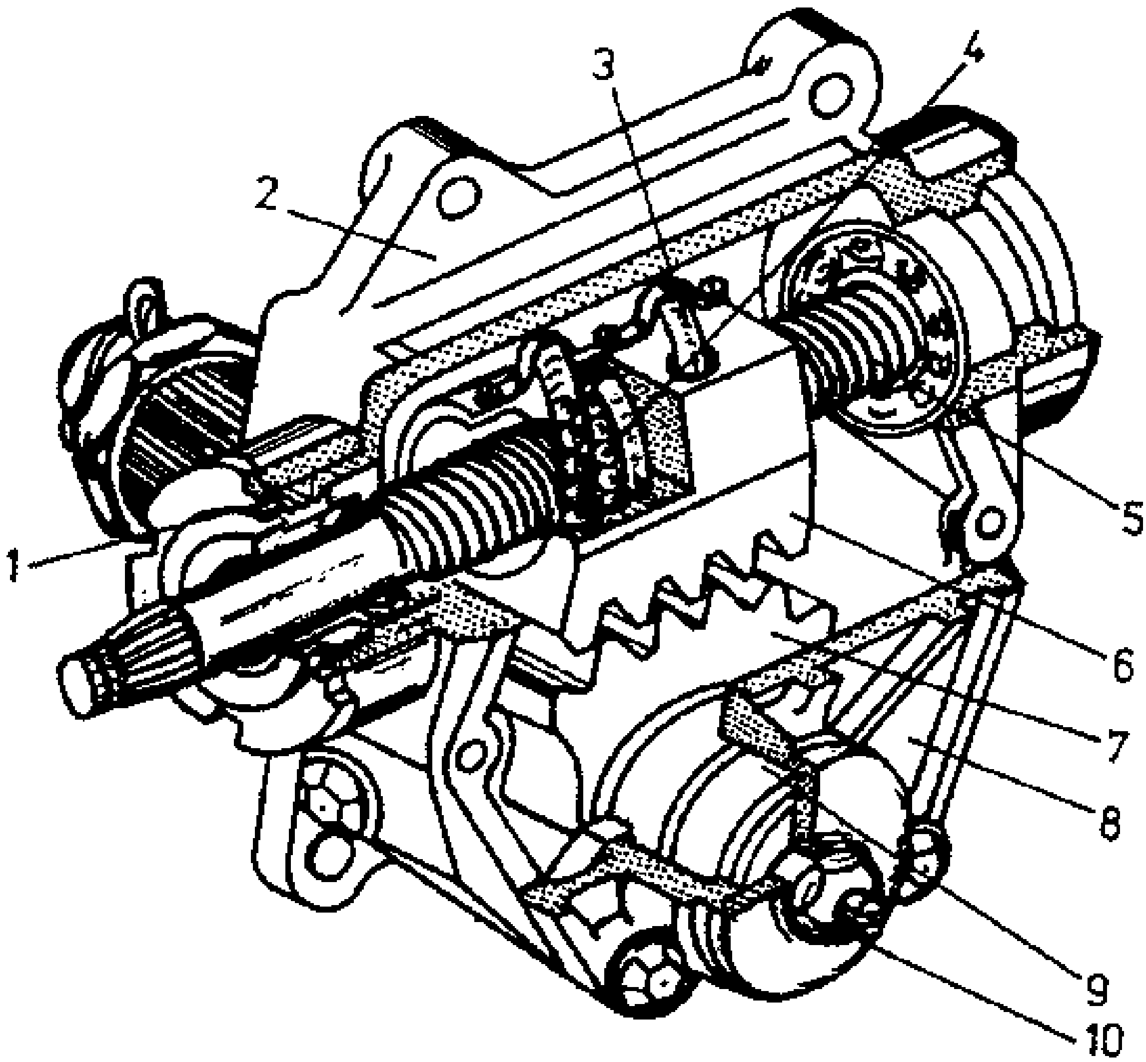


Figure 4/10 Recirculating ball steering system

1 threaded ring, 2 steering−gear housing, 3 small bulb tube, 4 balls, 5 steering bolt, 6 steering nut, 7 steering segment, 8 steering−gear case lid, 9 needle bearing, 10 adjusting screw

The balls travel through a small ball tube and form two endless ball chains. The practical value of this steering gear system is much greater than that of the finger−type steering system. The manufacturer gives, for example, 200.000 kilometres as the maximum service life for the type K 520 recirculating ball steering system. It requires no maintenance until, according to the maintenance schedule, the oil level must be checked.

4.3. Power−assisted steering systems

As already mentioned, power−assisted steering systems are used in heavy vehicles to facilitate steering for the driver. Power−assisted steering may be hydraulic, pneumatic or allhydraulic.

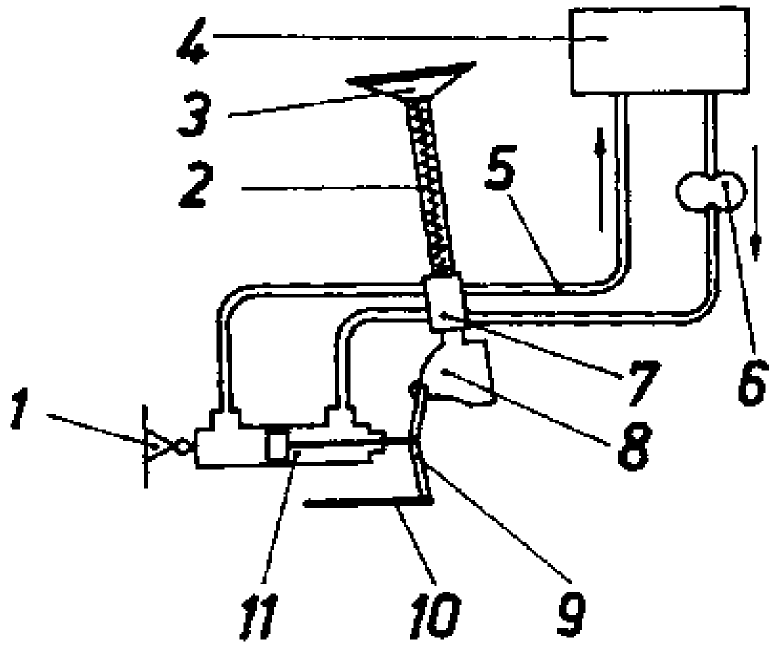


Figure 4/11 Hydromechanical steering system

1 frame, 2 steering spindle, 3 steering wheel, 4 oil tank, 5 return line, 6 gear pump, 7 control valve, 8 steering gear, 9 drop arm, 10 drag link, 11 double–action cylinder

Hydraulic power–assisted steering works by means of oil. This can be outside (hydromechanical steering Fig. 4/11), or inside, working directly on the steering worm (hydro–spindle steering system Fig. 4/12).

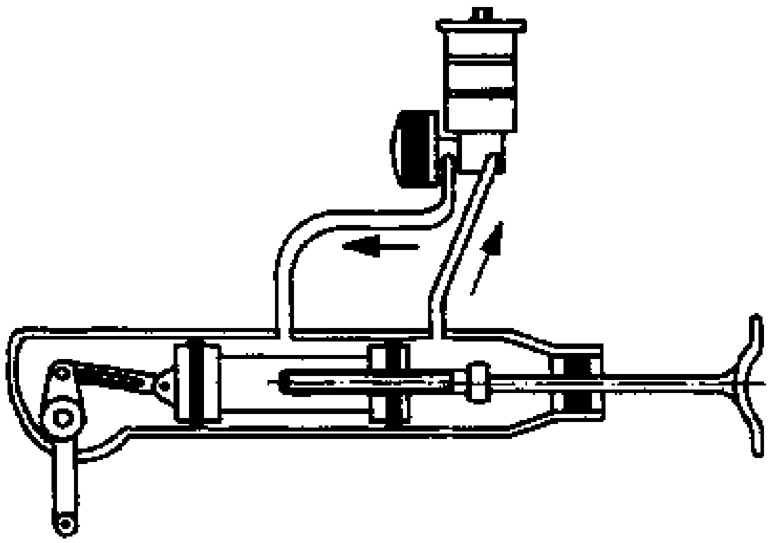


Figure 4/12 Hydro–spindle steering system

When the steering wheel is turned the additional force cuts in and facilitates steering.

Hydromechanical power–assisted steering works by means of a drag link on the drop arm. By means of a gear pump oil is forced through a system of lines and a control valve into a double action cylinder. The oil is forced into the appropriate chamber of the cylinder by the control valve which is connected to the steering column, and thus moves the piston in the same direction as the steering sheel. If the power–assisted steering system fails, it is possible to steer the vehicle mechanically like a normal steering system. Hydro–spindle and hydraulic cam–and–roller steering systems are very often combined.

Pneumatic power–assisted steering works on a similar principle to hydromechanical power–assisted steering. In this case when the drop arm is moved it operates a control valve which then opens the way to left or right side of the working piston.

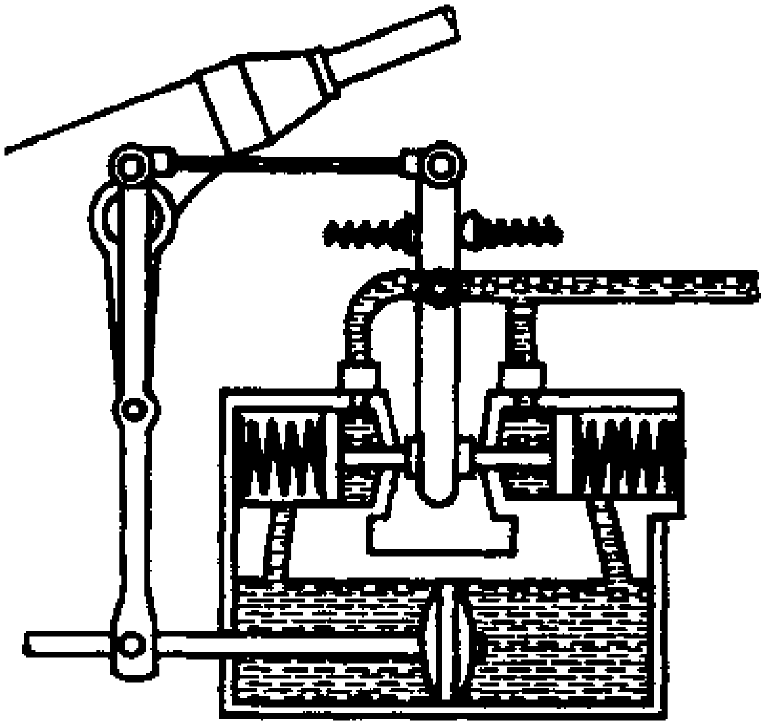


Figure 4/13 Pneumatic power–assisted steering system

The resulting force, which acts on the piston by means of compressed air, is transmitted by a linkage to the drop arm and facilitates steering. The compressed air is taken from the compressed air reservoirs in the vehicle's brake system (Fig. 4/13).

All–hydraulic power–assisted steering differs essentially from all the power–assisted steering systems mentioned above. It does not have a rigid connection between the drop arm and the steering wheel, i.e. there is no linkage in the form of a steering column.

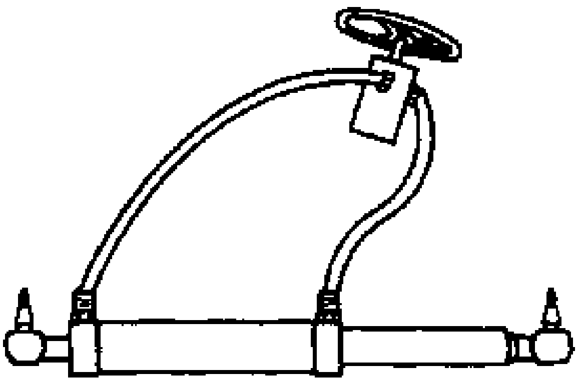


Figure 4/14 All–hydraulic power–assisted steering system

The steering wheel is coupled with a valve which transports the hydraulic oil in the same direction as the steering wheel. The oil is forced through the piping by means of a special hydro–pump. With this system very little effort is required, but should any part of the power–assisted system fail, the vehicle will be rendered unmanoeuvrable (Fig. 4/14).

4.4. Defects and wear of steering systems, and their elimination

As can be seen from the description of the individual steering gear types above, they are all subject to different degrees of wear. The surfaces of steering worms, and the moving parts which mesh with them, become hardened. Their supporting surfaces are formed of only a thin hard layer which is easily damaged by the application of force. Dents then develop causing irregular movement of the steering wheel. The roller bearing within the steering system may wear out, after which the steering motion can no longer be guaranteed. Due to wear, after a certain period of time it is no longer possible to readjust the steering. Then the components of the steering system have to be replaced to ensure safety again. Since different parts of the steering system are subject to different degrees of stress, they also wear at different rates. Wear is most obvious at the ball heads of the steering track rods, as these are subjected to the most stress due to the strain from the wheels. They wear out in the ball cup and track–keeping can no longer be guaranteed. The vehicle tries to break away. Wobbling and shocks at the steering wheel increase. The angle of play at the steering wheel should be about 15°. If it becomes too largy the steering system has to be readjusted. Prom time to time the toe–in has to be checked to keep wear of the front axle as low as possible.

Test questions:

4.1. Outline the purpose and the function of vehicle steering systems.

4.2. Describe the general structure of a steering system.

4.3. What do you understand by fifth–wheel steering?

4.4. Describe the structure of a stub axle steering system.

4.5. What types of steering gears do you know?

4.6. What measures must be taken while working on steering systems and their components?

4.7. Describe the structure and the mode of operation of a finger–type steering system.

4.8. Describe the structure of a rack–and–pinion steering system.

4.9. What are the functions of power–assisted steering systems?

4.10. Describe the structure and the mode of action of a pneumatic power–assisted steering system.

4.11. Describe the structure and the mode of action of a hydraulic power–assisted steering system.

4.12. What do you understand by an all–hydraulic power–assisted steering system and how does it work?

5. Wheels and tyres

Wheels and tyres are among the most stressed parts of the vehicle. They must absorb all the different forces which may occur between the road and the vehicle. Furthermore they must withstand the frictional heat which is generated by flexing of the tyres and friction between brake drum and brake lining during braking. The condition of the tyres ensures safe driving on all road and weather conditions.

The condition of the tyres and the fit of the wheels on the axles have a great influence on road safety.

Tyres are standardised and are marked uniformly throughout the world. Tyre dimensions are generally given in inches, but they may also be indicated in metric measurements. Normally, tyre sizes are given as two numbers, separated from by a dash or a letter.

Examples of tyre designations:

Designation	Explanation
4 1/2 J x 13	Wheel with well–base rim, tyre width 4 1/2 inches, J–type flange, rim diameter 13 inches
W 10 x 38	Wheel with wide base rim, tyre width 10 inches, rim diameter 38 inches
6.5 – 20	Wheel with tapered bead rim, tyre width 6.5 inches, rim diameter 20 inches
6.75 x 22.5	Wheel with 15° tapered rim, tyre width 6.75 inches, rim diameter 22.5 inches

5.1. Wheels and rims

Vehicle wheels have developed from wooden spoked wheels via cast wheels to the sheet metal disc wheel of today. This is the most commonly used wheel in motor vehicle engineering at the present time. The wheel must be able to resist and transmit all forces which act between the road and the vehicle. The following essential demands are made on the vehicle:

– adequate rim stability
– firm fit of the tyre on the rim
– firm and secure connection with the wheel hub
– good dissipation of frictional heat
– adequate space for accomodating the brake system

The following travelling comfort is demanded:

– vertical and lateral impact must be as small as possible
– unbalance at circumference must be kept low
– attractive design
– simple fitting of tyres to the rim and of wheel to the hub

Production should be based on the following:

– low production price
– long service life
– low weight of the rim and small mass moment of inertia

Wheels can be distinguished by the materials used for production and the design. Five of the most common types are listed below:

– wire–spoked wheels
– sheet metal wheels, double wall welded
– disc wheels
– cast light metal wheels
– cast steel wheels

The wheel of the vehicle consists of the wheel hub, spokes or disc and the rim, which can be of varying shapes. Rim shapes are shown in Fig. 5/1. Fig. 5/2. shows the most common types of rims used in lorries (commercial vehicles).

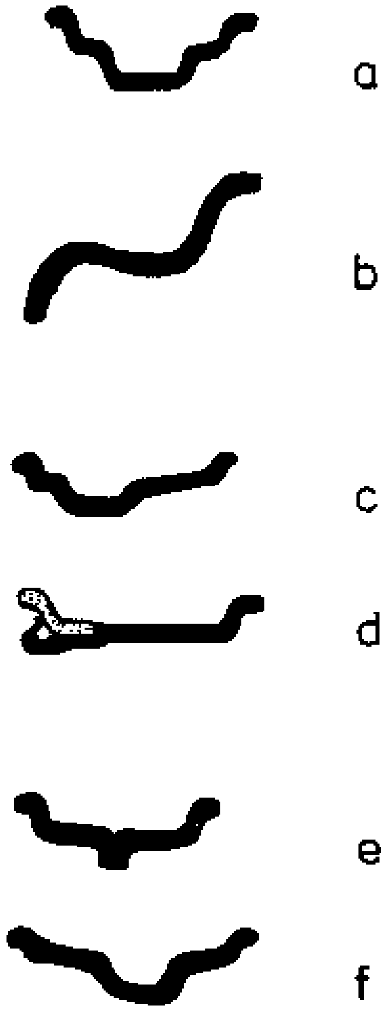


Figure 5/1 Wheel rim shapes

a) well–base rim, b) rump rim, c) asymmetrical rim, d) tapered bead seat rim, e) wide base rim, 15 tapered rim = f)

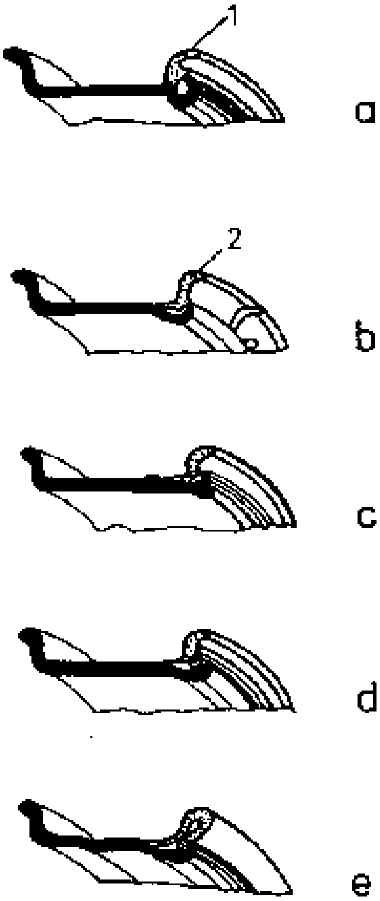


Figure 5/2 Rim types

a) flat base rim type 80 (with side ring 1), b) tapered bead seat rim type LS (with retaining ring 2), c) tapered bead seat rim type R 5 Firestone–Kronprinz system, d) tapered bead seat rim Lemmerz–system, e) tapered bead seat rim type AR

With regard to the rim base two types are distinguished:

– wide base rim
– well–base rim

The wide base rim is in sections to allow easy fitting and removal of the tyre. It can either be halved along its circumference, or divided by a detachable wheel ring with locking spring. If it is to be divided along the circumference the two rim halves are connected and held together by bolts. Tapered bead seat rims are similar to wide base rims. They are used for heavy lorries. Pitting the larger and stiffer tyres used for these vehicles makes the devision of the rim necessary, and so the rims are divided into two or three sections. There are different ways of dividing them. The centrally divided simples wheel and the triplex wheel are used. This triplex wheel is divided three times along its circumference, but each ring is a closed section.

The tapered bead seat rim has virtually replaced the wide base rim in motor vehicle engineering. Its advantage in comparison to the wide base is that the bead seat inclines 5° to the rim flange. The bead of the tyre is pressed onto the tapered bead seat rim by the tyre pressure. In this way the tapered bead seat rim and the flange prevent the bead from tipping. Fig. 5/3 shows a tyre fitted to a tapered bead seat rim.

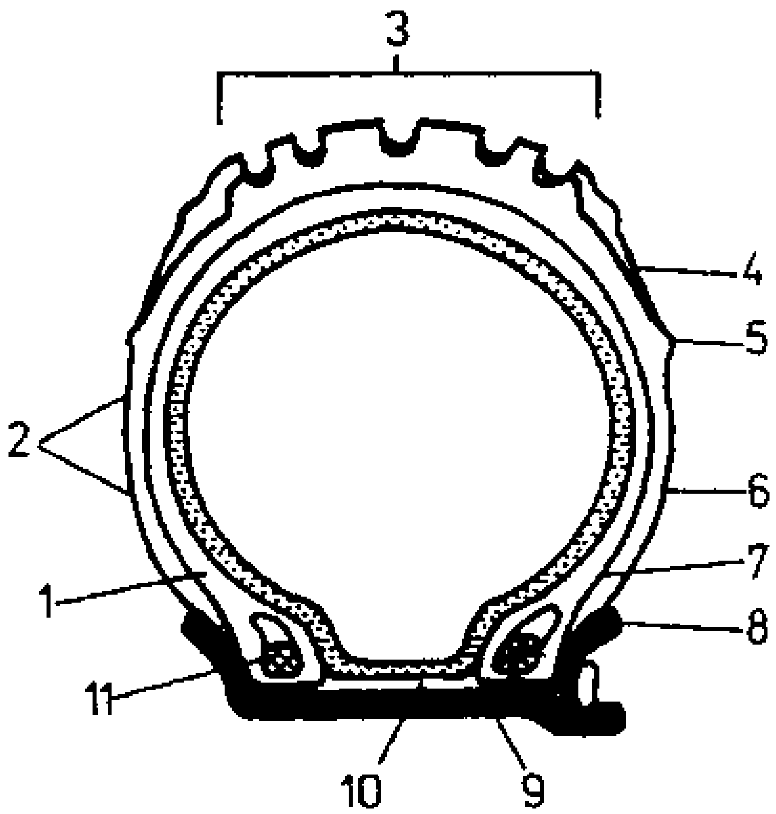


Figure 5/3 Tyre with tapered bead seat rim

1 fabric body, 2 flexing section, 3 tread, 4 shoulder, 5 tyre side wall, 6 side rubber, 7 bead, 8 rim flange, 9 tapered bead seat, 10 clincher, 11 bead core, 12 inner tube

For vehicles up to about 5 tonnes pay weight disc wheels are mainly used.

Steel wires, known as bead cores, run around the circumference of tyres. These steel wires are closed and not ductile. In the well–base rim this recess helps in fitting the tyre. The tyre and bead are pressed into the well–base at one side, and then pressed inwards or outwards across the rim flange on the opposite side. The tyre is always pressed into the well–base at the opposite side to the valve.

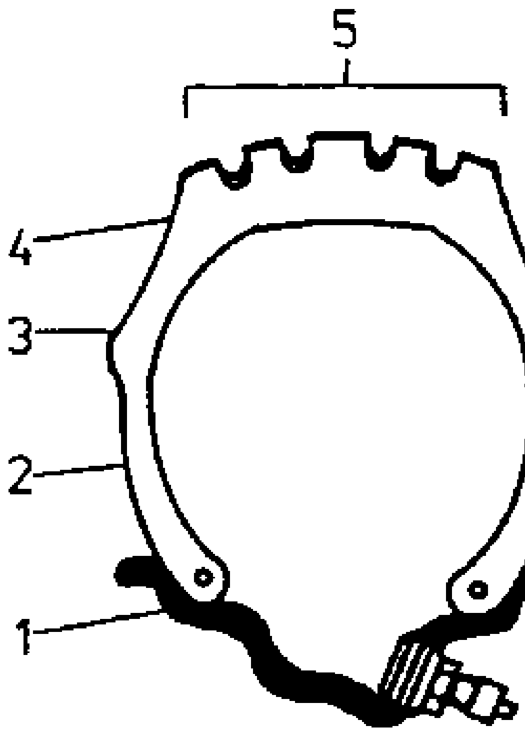


Figure 5/4 Tubeless tyre

1 rim flange, 2 side rubber, 3 tyre side wall, 4 shoulder, 5 tread

In passenger cars the wheel rim can have a 'hump' at the shoulder which prevents sudden air losses in tubeless tyres on tight bends and when air pressure is low. A tubeless tyre is shown in Fig. 5/4.

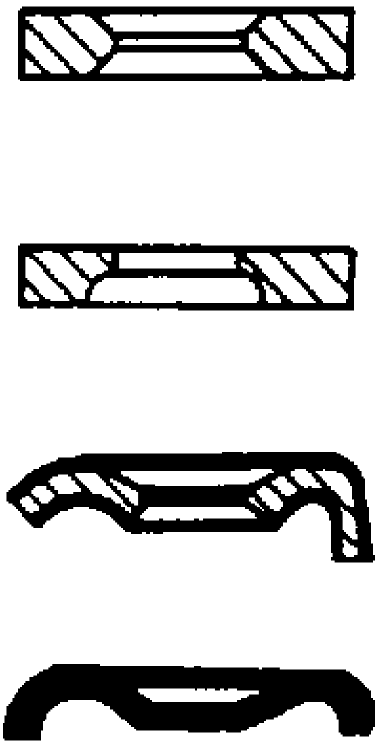


Figure 5/5 Types of rim mounting holes

Asymmetric rims are used in agricultural machines and construction machinery. These vehicles manly have rims with a broadened well–base. They are also called wide–base rims. In order to gain more space for the brakes the well–base is shifted asymmetrically to the outer rim flange. The 15 tapered rim is undivided, but has a particularly strongly inclined bead. The inclination is 15°. This type of rim is used in lorries. The rim is linked to the wheel hub by the wheel disc, but it is disconnectable. The rim diameter must always be larger than the wheel hub diameter. In the wheel disc there are clearance holes which are standardised. In Fig. 5/5 these clearance holes are shown.

When mounting the wheel at the wheel hub you must ensure that the wheel nuts correspond to the clearance holes so that the wheel fits firmly and safely.

Then wheel nuts can loosen when stressed and loaded. Centring of the wheel on the wheel hub can be done either by means of the wheel nuts or centring pins. Another method of centring is the use of a centre hole in the wheel disc. Holes and slots are made in the wheel disc to cool the brakes. The wheel nuts and the axle nuts can be covered by a hub cap.

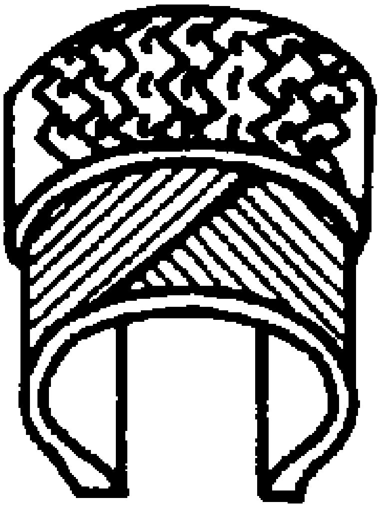
5.2. Tyres

The tyres of the vehicle are intended to moderate the effects of uneven road surfaces, to improve the driving qualities and to make high speeds possible by low ground friction. Today pneumatic types are used exclusively.

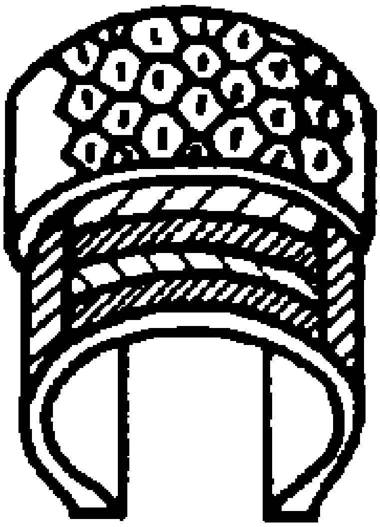
The rubber tyre tread is to guarantee that the tyres have a good road grip and protect the vehicle against skidding and side–slipping. To obtain a good road grip various tread patterns are available. The term 'tyre' includes the rim band, the tube and the tyre. The rim band is put between the rim and the tube to prevent friction between them. Such friction would lead to the premature destruction of the tube. The tyres used in modern vehicles are mostly low–pressure tyres. They are elastic and tend not to sink into the ground. The tread pattern should guarantee a good grip on the road. The lateral grooves on the tread help to prevent skidding, and the transversal grooves improve motion. Grip can be improved by narrow lateral and transversal grooves. Pneumatic tyres consist of several rubberised cord plies and the rubberised tread. These two section are connected by vulcanisation, i.e. heat treatment under pressure.

Figs. 5/6, 5/7 and 5/8 illustrate sections of the most common types of tyres. The plies in Fig. 5/7 are made of steel cord and lie on a textile cord radial carcass. By using steel cord in the belt the serviceability is further increased. Steel cord is also used in the belts of radial tyres.

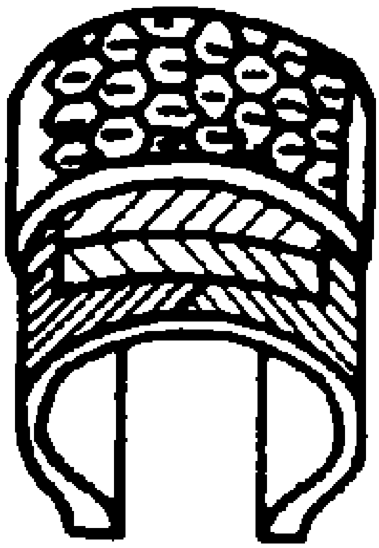
Figure 5/6 Types of tyres



a) conventional diagonal tyre with diagonal threads on the fabric body



b) radial tyre (braced–tread tyre) with radial threads



c) semi–radial tyre with diagonal threaded fabric body and surrounding belt

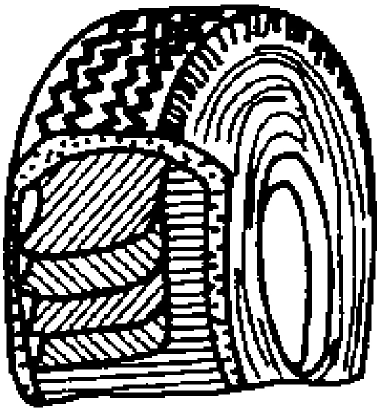


Figure 5/7 Radial tyre

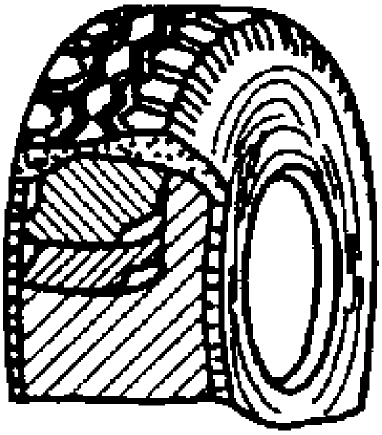


Figure 5/8 Semi–radial tyre

Designation of tyres

There are two types of tyres, high–pressure and low–pressure tyres. The difference is due to the different number of plies inside the carcass. In both types the tyre inflation pressure is between 0.07 and 0.28 p.s.i..

The inflation pressure necessary for the tyre is indicated by the manufacturer. The symbol between the two numbers (x for high–pressure, – for low–pressure) serve to make a distinction possible. The first number on the side wall of the type indicates its width, and the second number the rim diameter. Both dimensions are given in inches. The examples below illustrate these: 5.50 x 16; 6.50 – 19.

The table shows extracts from the technical data for various tyre sizes:

Designation	dia. mm	Tyre width mm	Inflation pressure p.s.i.	Load–carrying capacity kg	Required rim
Motorcyles					
2.50–19	625	65	0.13	160	2 x 19
3.25–19	667	85	0.13	210	2 1/2x 19
3.50–19	672	91	0.13	225	3 x 19
Cars					
4.50–16	645	118	0.14	300	3.00 Dx 16
5.50–16	695	147	0.14	450	3.50 Dx 16
6.00–l6e	720	158	0.15	550	4.00 Ex 16

Lorries					
7.25–20e	880	176	0.37	1200	6" – 20 L
6.00Tr–20	834	156	0.26	790	5" – 20 L
7.00Tr–20	874	174	0.30	1020	5" – 20 L

The above table serves as an example.

In addition to these two figures each tyre carries another figure which indicates type and use. As an example the identification letters of car tyres is given below. On lorries radial tyres are marked with an 'R' instead of a dash, for example: 8.25 R 20.

Designation	Example	Explanation
S or H instead of dash	5.90 S 13 5.90 H 13	Tyre suitable for high (S) or very high (H) speeds. Maximum speed depends on rim dia
SR instead of dash	165 SR 13	Radial tyre with maximum permissible speed of 180 km/h.
HR instead of dash	185 HR 13	Radial tyre suitable for more than 210 km/h.
VR instead of dash	165 VR 15	Radial tyre suitable for more than 210 km/h.

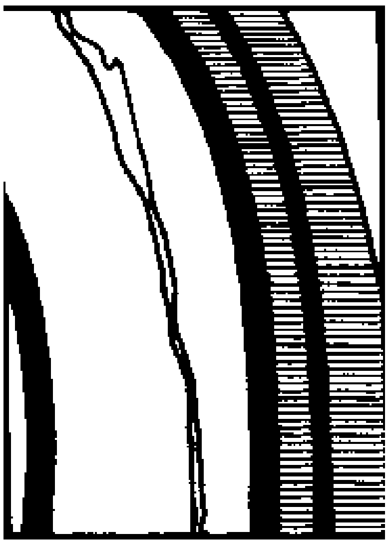
The permissible maximum speeds of other tyres cannot be seen from their designation. They are specified in the manufacturer's tyre catalogue. Further specifications found on tyres are:

4 PR = ply rating; this figure is not necessarily identical to the number of plies. It specifies the strength of the carcass. The word tubeless is self–explanatory.

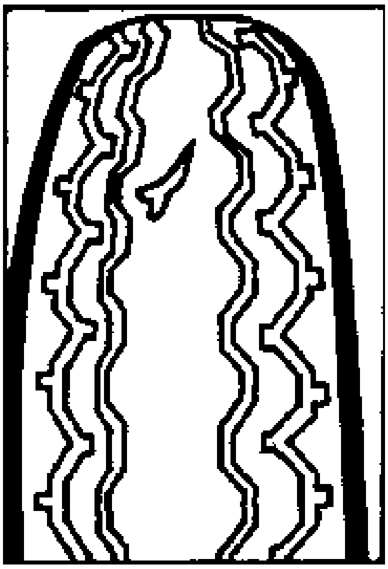
AS and AS–front are the specifications for tractoe tyres. AS for drive wheels and AS–front for non driven wheels; eg.

5.3. Tyre damage and defects

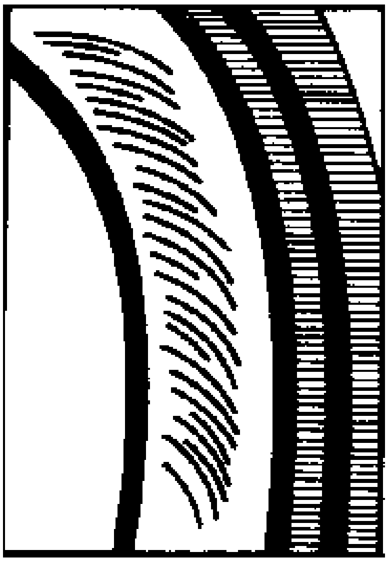
Figure 5/9 Tyre damage



a) due to overloading



b) due to excessive inflation pressure



c) due to insufficient inflation pressure

In Fig. 5/9 several types of tyre damage are shown. Tyre damage may develop due to non−compliance with the specifications given by the manufacturer, for example correct in inflation pressure or exceeding of the maximum permissible speed limit. Damage to a tyre side wall is shown in Fig. 5/9a. It develops due to overloading. This can be caused by overloading of the vehicle and exceeding the load−carrying capacity of the tyre.

The tyre damage in Fig 5/9b is due to excessive inflation pressure. The total weight of the vehicle and its load are supported by the tyres. For this reason, each tyre is given a specified inflation pressure, according to its size and intended load−carrying capacity, which must not be exceeded. If the inflation pressure is exceeded, the tread becomes damaged and the service life and mileage capacity are reduced.

In Fig. 5/9c the casing plies of the side walls have been damaged by insufficient inflation pressure. Due to the load, the tyre is compressed at the point where it comes into contact with the ground, and it starts to spring. If the inflation pressure is constantly too low, springing can lead to the destruction of the carcass. To increase the service life of the tyre it is necessary to check the inflation pressure regularly. If the vehicle is driven at a very high cruising speed, the tread becomes overheated. The rubber gets warm and peels away from the carcass. If a vehicle passes too quickly over sharp obstacles, punctures may occur, rendering the tyres unserviceable. If the wheel camber, toe−in and brakes are adjusted incorrectly, the tyres will rub and will wear quickly. Defective shock absorbers can be recognised by irregular wear of the tyre tread.

5.4. Rim damage and defects

The rim is subject to little wear. It occurs due to incorrect driving techniques and wheel nuts which are not correctly tightened after wheel changing. Incorrect driving techniques include the following:

Driving the vehicle at impermissible speed over raised edges, which can damage the rim edges.

Driving the vehicle at too great a speed over uneven road surfaces and potholes, which can damage the rims.

Incorrect fitting and removal of the tyre can damage the rim flanges and in turn also the tyres.

If the wheel nuts are not tightened correctly, the mounting holes in the wheel disc become deformed and the wheel no longer fits firmly to the wheel hub; this means that the road safety of the vehicle can no longer be ensured.

As the rims are constantly subjected to the influence of weather, corrosion may occur.

5.5. Influence of the condition of the tyre on road safety and petrol consumption

As explained above, the tyres of a vehicle are very important as improper maintenance and driving technique can have a considerable effect on their service life. The driver should consider the following points in order to increase the service life of the tyres:

– Lubricants and oils can damage rubber tyres, and must be removed from them immediately.

– It is possible that stones may become lodged between twin tyres – this will cause friction and so damage the tyres.

– The wheels of a vehicle must be examined regularly, as damage will lead to increasing tyre wear and petrol consumption.

The state of the tyres is of great importance for the road safety of the vehicle and for the service life of the tyres themselves. The depth of tread of a tyre should never be less than 1 mm. If this should occur, the grip of the tyre on the road will be insufficient, and an accident may result. If the road is wet, the grooves in the tread will not be able to carry off enough water, a film of water will develop between the tyres and the road surface, preventing the vehicle from gripping the road correctly. It will start to 'drift' and will no longer be safe. This state is also called aquaplaning because the vehicle will leave the intended direction at the slightest steering movement. This may cause accidents and personal injury. If the tread depth is too small, the vehicle stopping distance is also affected. Since static friction is no longer completely ensured, the vehicle stopping distance is increased.

The diagram in Fig. 5/10 again illustrates the service life of the tyre in relation to inflation pressure.

With increasing age and mileage, the crown of the tyre becomes smaller and so the speed decreases. In order to reach the same speed as could be reached with new tyres, the performance of the engine has to be increased, and this can only be achieved by higher petrol consumption. If tyre inflation pressure falls below the value specified, the result will be the same as the effect of wear. Both examples demonstrate the fact that tyres influence petrol consumption. To ensure the efficiency of the vehicle the tyres should be checked regularly.

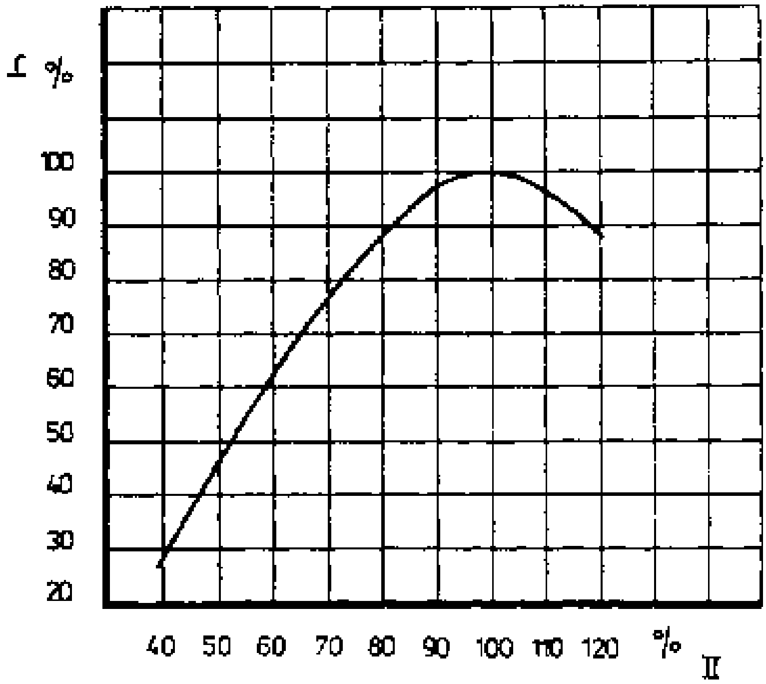


Figure 5/10 Importance of inflation pressure to tyre service life

I service life, II inflation pressure

A further increase in the service life of the tyres can be achieved by balancing the wheels. Due to their production, tyres and rims run unevenly. This unbalance has the following effects on road safety:

– Road grip is reduced by wheel wobble and vibrations.

– Steering of the front wheels is affected by wheel wobble.

– The centrifugal forces caused by the unbalance, which work outwards in constantly changing directions, cause excessive stress on the wheel bearings and steering components. Thus they shorten the service life of the components.

– Tyre wear is increased by improper run of the wheel.

<u>Test questions</u>:

5.1. Describe the design of a wheel.

5.2. What do you understand by a tubeless wheel and a wheel with a tube?

5.3. What rim forms do you know?

5.4. Describe a taperd bead seat rim.

5.5. Describe the fitting of a tyre to a well–base rim.

5.6. Explain the function of the wheels and the tyres.

5.7. What main demands are made on the wheels?

5.8. List the most common types of wheels.

5.9. What do you understand by a wide base rim? Give some examples.

5.10.What do you understand by a well–base rim?

5.11. What do you understand by the term 'tyres'?

5.12. What is the function of tyres on a vehicle?

5.13. What types of tyres do you know?

5.14. What types of tyre damage do you know? Give the reasons for them.

5.15. Name the factors which affect the service life of tyres.

5.16. What effect does the condition of the tyre have on the road safety and petrol consumption of a vehicle?

5.17. Give reasons for the necessity of balancing the wheels.

6. Brakes

6.1. Functions of the brakes

The brakes are an essential safety element of the vehicle. They are intended to reduce the speed of the vehicle (if necessary to bring it to a standstill) or to prevent the vehicle from rolling away.

The following brake systems are distinguished according to their function in the vehicle:

Service brake system	– to reduce the speed, if necessary to a standstill.
Auxiliary brake system	– an emergency brake in case of failure of the service brake system.
Parping brake system	– to prevent a parked vehicle from rolling away.
Retarder system	– to keep the speed of vehicles of more than 5 tonnes constant on long gradients. Also called the engine brake system.

6.2. Operating principle and types of brakes

Friction brakes are used exclusively in vehicles. A friction body is pressed axially or radially by a mechanism against a drum or disc. These are firmly connected to the wheels. The speed of the vehicle is reduced, if necessary to a standstill, by the developing friction. Kinetic energy is converted into heat energy, which depends on the speed to be reduced, the period of braking and the weight of the vehicle. In modern vehicles two types of braking systems are distinguished:

– drum brakes
– disc brakes

For a long time, drum brake systems were used on almost all vehicles. However, for some time disc brakes, which can also be combined with drum brakes, have been used more often. Both types of brakes can be operated mechanically, hydraulically–pneumatically. The brake is operated by the driver by foot or by hand. Manual brakes are used mostly in vehicles for disabled persons. These vehicles must be specially equipped for the purpose.

The following demands are made on the service brake:

– The shortest braking distance shall be achieved in the shortest possible time between actuating the brake and stopping the vehicle.

– To avoid premature blocking of one of the two axles, it is necessary to distribute the braking force according to the axle load displacement.

– The forces which have to be applied to operate the brake should be as low as possible. This can be achieved air pressure brake servo systems, vacuum brake servo systems, hydraulic pumps etc..

– In case of successive stop braking or continuous braking on long gradients, maximum deceleration should be maintained if possible.

The following demands are made on the brake system of a vehicle:

1. Vehicle must have two braking systems acting independently of each other, e.g. the service brake and the parking brake, or a braking system with two operating devices which work independently of each other, i.e. a main brake and another one which can be operated if the first fails.

2. The independent operating devices must have separate transmission systems on different braking surfaces, these can however be in or on the same drum.

3. If more than two wheels can be braked, common braking surfaces and common transmission systems (total or partial) can be used.

They must be constructed in such a way that if one component breaks at least two wheels, which are not on the same side, can be braked.

4. All braking surfaces must act on parts which are not disconnectable and which are connected positively with the wheels.

Brake linings

Materials such as asbestos and cotton combined with steel, aluminium or brass chips, are used predominantly as brake linings. These materials are impregnated with a binding agent and then dried out. The brake linings produced in this way are then glued or rivetted to the brake shoes. The rivets used for this purpose must be corrosion– and heat–proof to ensure full efficiency. These requirements also apply for the glue and the brake lining itself.

The brake lining should meet the following requirements:

– it must be able to withstand a contact pressure of about 1.2 N/mm^2
– the ends of the brake lining must be bevelled to avoid rattling and blocking of the brake shoe
– while operating the brake, the brake lining should lie completely on the brake shoe
– it must withstand temperatures of up to 400°C and wear little under normal service conditions.

As already mentioned, drum brakes are still one of the most common types of brakes used today. They are also called internal shoe brakes. Here the brake shoes are pressed against the drum, which is the most important component of the drum brake. There are different brake shoe arrangements in this brake type.

Simplex brake

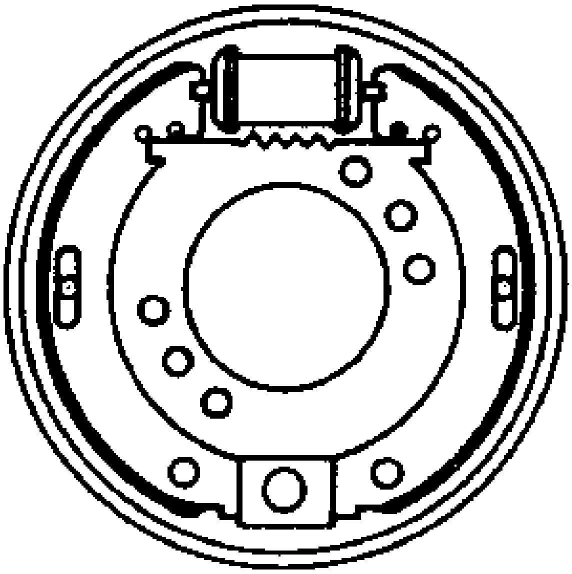


Figure 6/1 Simplex brake

The simplex brake is the most simple design among the drum brakes.

Two brake shoes work a brake anchor pin. They are pivoted on a shoe cap bolt. While braking, the front brake shoe (in direction of movement) is driven by the rotating drum and overruns the shoe cap bolt. This is also termed the leading or primary shoe, and the process is known as self–energisation. The second brake shoe is called the second or trailing shoe and is self–attenuating. The simplex brake (Fig. 6/1) is used mostly on rear wheels. When a vehicle is reversed, the functions of the primary and secondary shoes are reversed.

Duplex brake

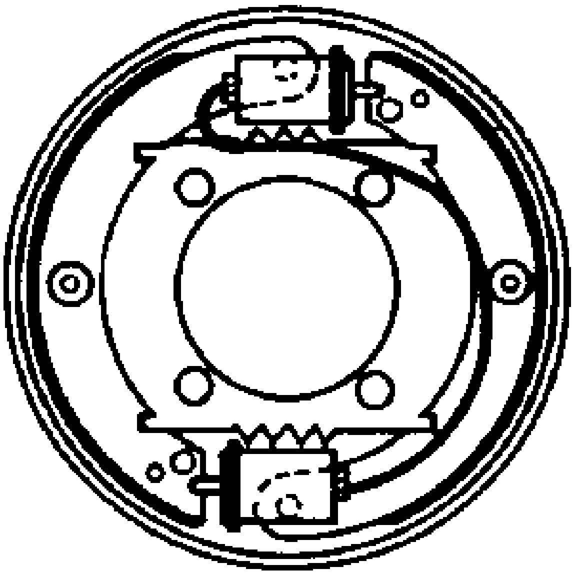


Figure 6/2 Duplex brake

The main characteristics of the duplex brake (Fig. 6/2) are its two wheel mounted brake cylinders. Each brake shoe is combined with such a wheel mounted brake cylinder. In this kind of brake, both brake shoes become primary shoes, and so self–energisation is increased. This type of brake is equipped with automatic adjustment.

Servo brake

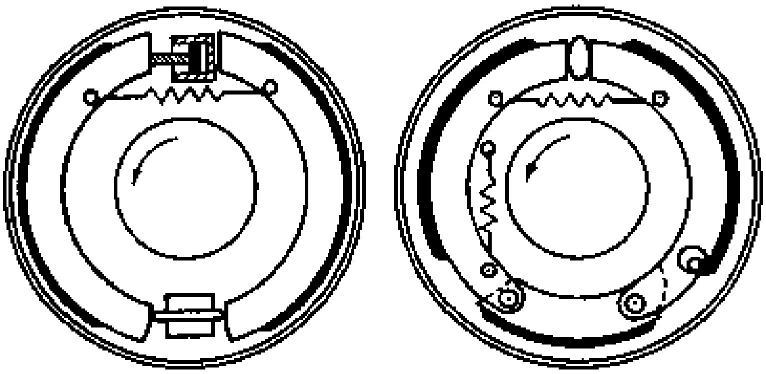


Figure 6/3 Servo brake

The servo brake (Fig. 6/3) consists of two or three brake shoes connected to one another at one pivoting point. When the brake is operated, the primary shoe puts the secondary shoe into operation via a spanner or a joint, and so the secondary shoe also becomes a leading shoe. This type of brake is also manufactured as a twin servo brake. This differs from the servo brake in that the brake cylinder operates bilaterally, i.e. both brake shoes spread at the same time. The disc brake is a more modern type of vehicle brake with a larger braking surface and therefore a better braking effect. Like drum brakes, the disc brake is a friction brake. Two types of disc brakes are distinguished, caliper–type disc brakes and internal–expanding clutch–type disc brakes.

Caliper–type disc brake

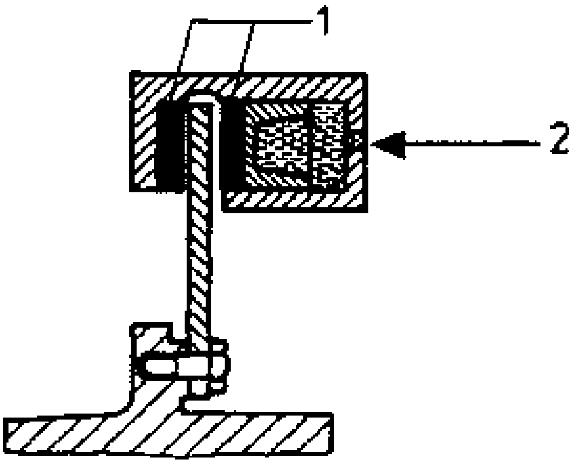


Figure 6/4 Floating caliper disc brake

1 friction lining
2 contact force

The brake anchor plate has two brake segments with brake linings. They act on both sides of the brake disc like tongs. They are set into motion by a brake cylinder which is operated by the brake fluid. There are two types of caliper–type disc brakes (Fig. 6/4) which can be distinguished by the form of the brake cylinder body. There are floating caliper disc brakes. In the floating caliper disc brake the brake cylinder anchor plate is movable. The hand brake system can be incorporated in the hydraulic actuator.

The fixed caliper disc brake has a fixed brake cylinder anchor plate and two pressure cylinders per caliper. For the hand brake either a special caliper or a drum brake can be used. (Fig. 6/5)

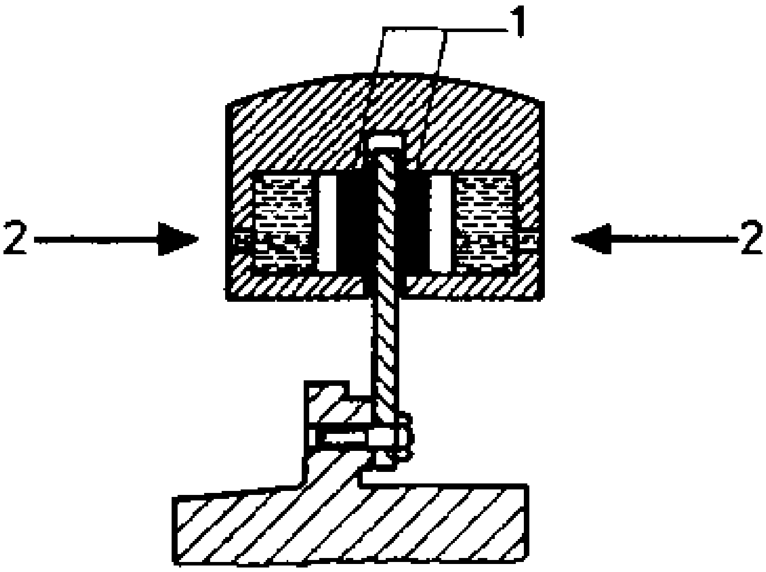


Figure 6/5 Fixed caliper disc brake

1 friction lining, 2 contact force

Internal–expanding clutch–type disc brake

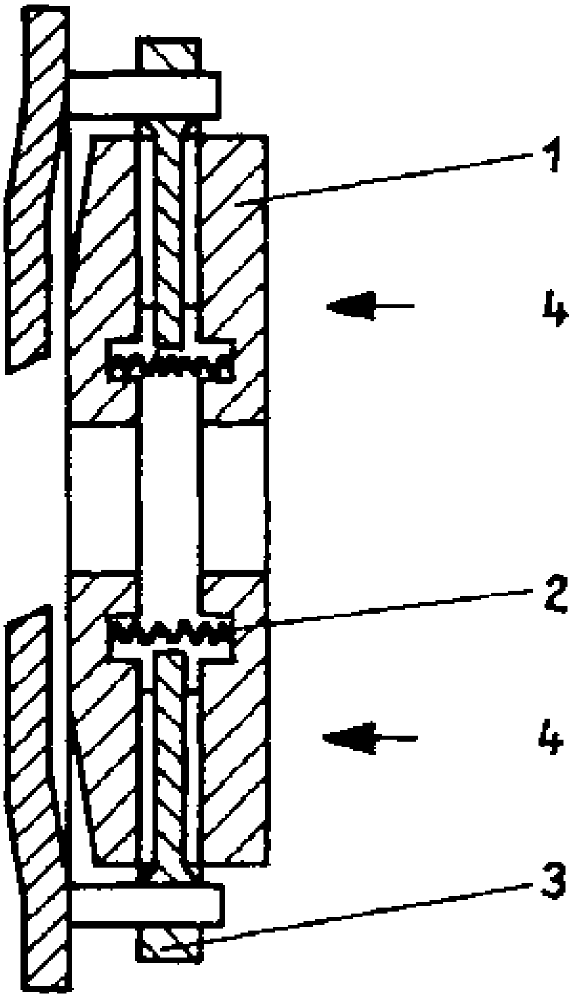


Figure 6/6 Internal expanding clutch–type disc brake

1 friction ring, 2 compression spring, 3 ring disc, 4 contact pressure

The internal–expanding clutch–type disc brake (Fig. 6/6) is used for lorries and tractors. Brake discs are pressed against a ring disc with a brake lining. With this type of brake, both pneumatic and hydraulic systems can be used. The lining is pressed by the pressure cylinder against the whole disc.

6.3. Mechanical braking system

Mechanical brakes are the oldest type of brakes. The force generated by foot or hand is transmitted to the brake shoes by means of a brake rods (Fig. 6/7) or a cable (Fig. 6/8).

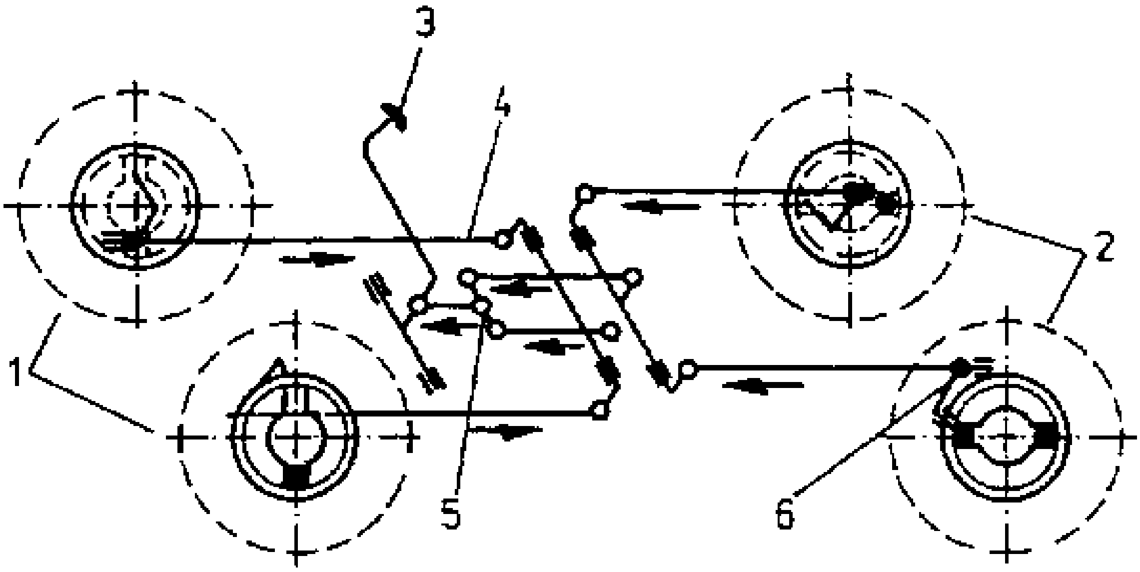


Figure 6/7 Mechanical brake with brake rods

1 front wheels, 2 rear wheels, 3 brake pedal, 4 brake rods, 5 brake compensator, 6 brake toggle lever

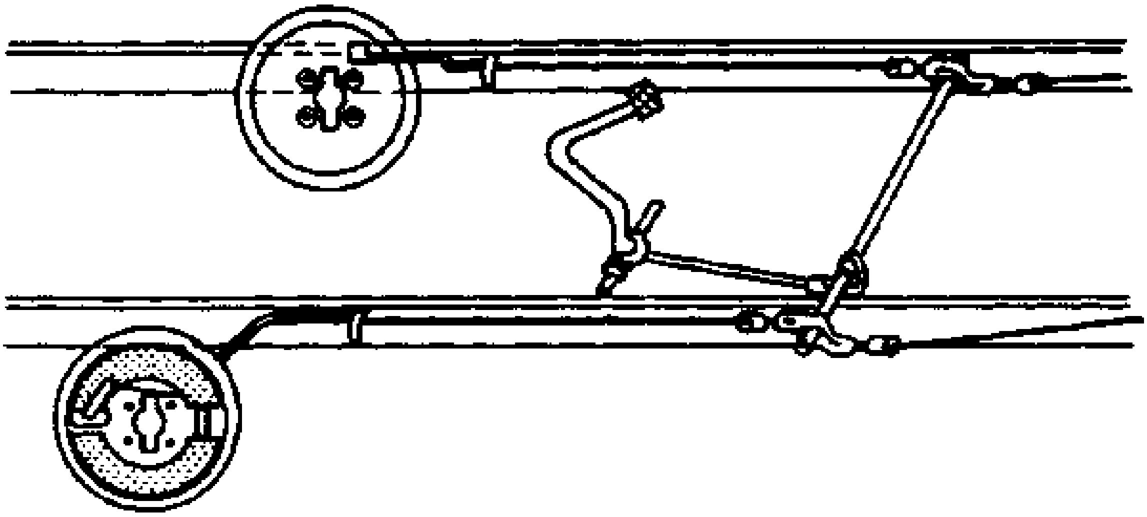


Figure 6/8 Mechanical brake with cable control

In modern vehicles the hand brake as a parking brake is a typical representative of the mechanical brake. The braking force is transmitted by a cable to the brake shoes. A skid sensor serves to distribute the braking force evenly on the front and rear axles. This sensor is also called a balance arm.

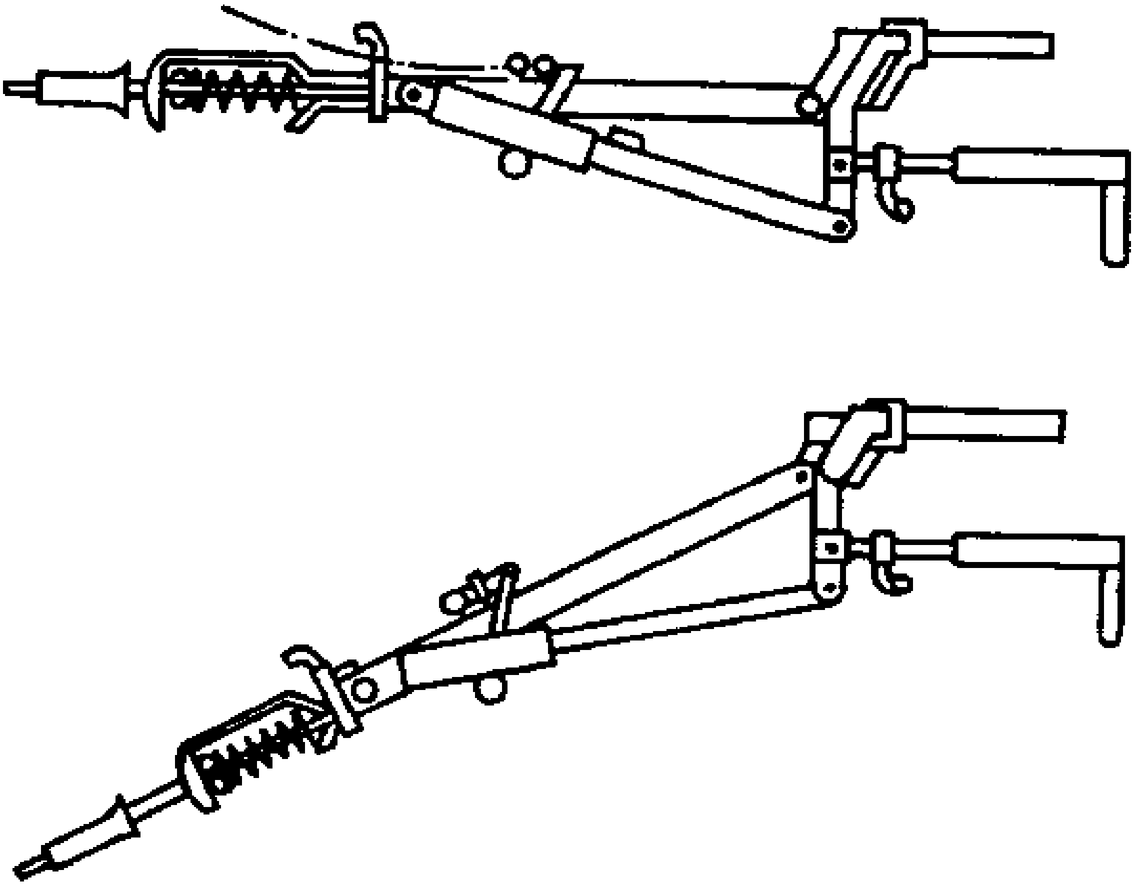


Figure 6/9 Over−run brake

The overrunning trailer brake shown in Fig. 6/9 is no longer widely used. When the brakes on a tractor unit are applied, the trailer runs up to it, the braking effect is transmitted to the brake shoes of the trailer wheels by a linkage in the tow bar and deceleration starts. This means that during emergency braking the trailer will move out of line with the tractor unit, causing a hazard to other traffic. Today this type of brake is only used in slow−moving vehicles. When the tow bar is lowered, this brake serves as a parking brake for the trailer.

6.4. Hydraulic braking systems

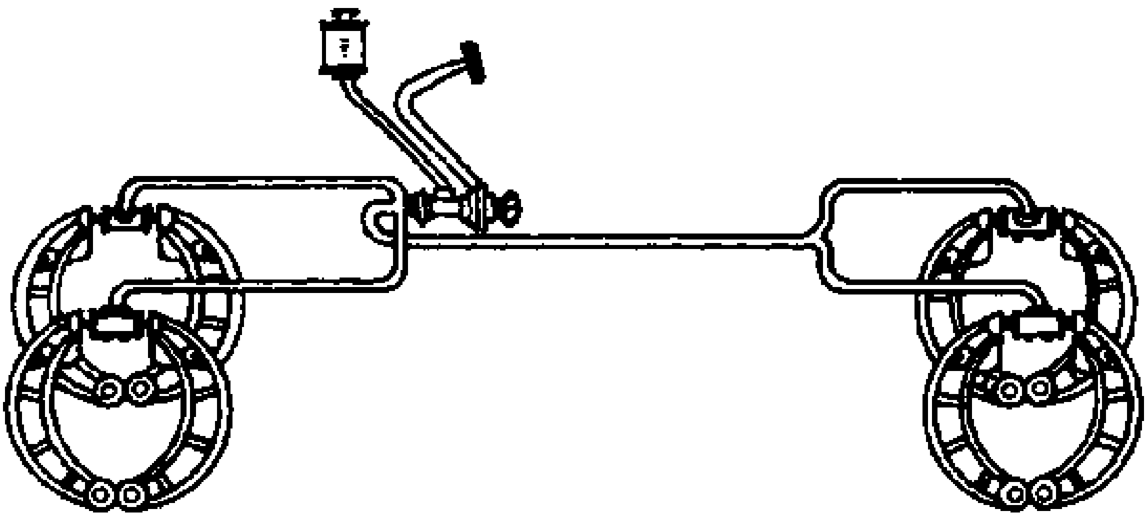


Figure 6/10 Hydraulic brake

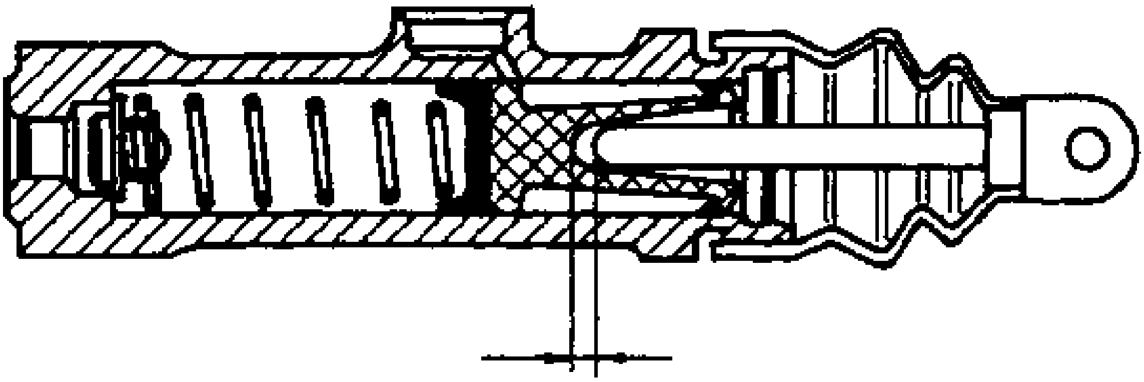


Figure 6/11 Main brake cylinder

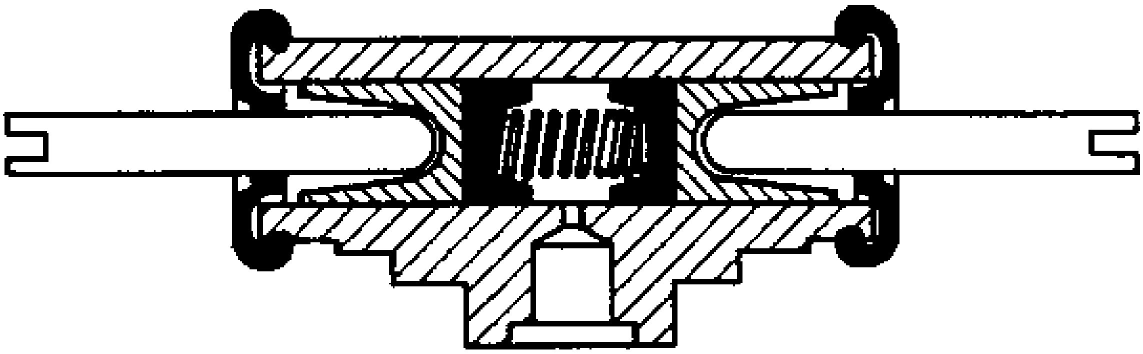


Figure 6/12 Wheel brake cylinder

With hydraulic brakes (Fig. 6/10) the braking force is transmitted by means of brake fluid. Joints, power–consuming sliding surfaces and balancing parts are not required. When operating the brake pedal, the brake fluid which is in the main brake cylinder with compensating reservoir (Fig. 6/11) is pressed into the brake lines. At the other end of the brake line are the wheel brake cylinders (Fig. 6/12) which produce the braking effect. Pascal's principle applies here. The principle states that when pressure is applied to any fluid, it is transmitted equally to all other parts of the fluid.

Hence it follows that the brake fluid ensures complete brake compensation. The brake lines are secured in rubber gaiters to prevent them being damaged by the frame. Where the brake lines pass the axle and the driven wheels, they are protected by rubber pressure hoses.

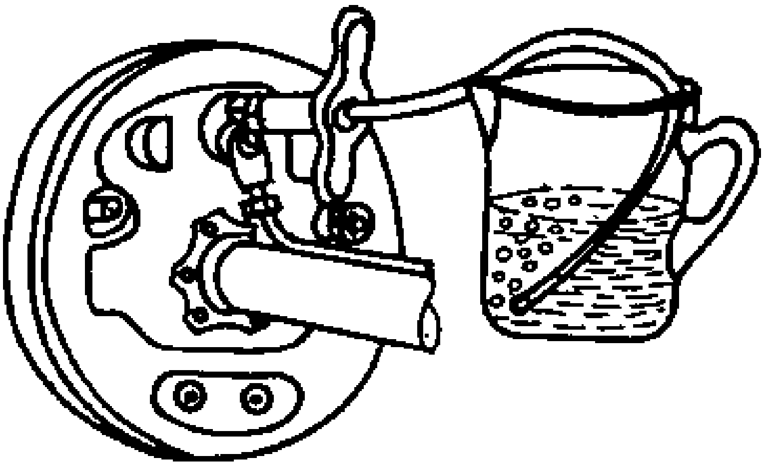


Figure 6/13 Bleeding the brake wheel cylinder

To ensure proper functioning, the brake system has to be bled. The process of bleeding a wheel brake cylinder is shown in Fig. 6/13.

Before bleeding, the fluid level in the compensating reservoir is to be checked, and during bleeding it must be constantly topped up. Bleeding is started at the point furthest from the main brake cylinder. The highest point should be bled last. The presence of air in the brake system becomes evident if the brakes need to be pumped in order to make them function correctly. Only after this pumping, which compresses the hydraulic brake system, the response time will be reduced. In extreme situations this may have grave consequences.

There are several bleeder screws at the brake calipers of the disc brake which have to be opened and closed according to the manufacturer's instructions while bleeding the system. To prevent any air from penetrating the bleeder screws during bleeding, a pipe is connected to them and put into a container filled with brake fluid. Then the brakes are pumped and the pressure is maintained. The bleeder screws are opened with a brake wrench and brake fluid and air may escape. This procedure has to be repeated at each bleeder screw until the brake can no longer be pumped. The brake pedal must be depressed until the bleeder screw has been closed. Having bled the whole system, the brakes must be tested to check that the individual wheels brake evenly. If necessary the brake shoes must be adjusted to ensure that the vehicle stays on track during braking. The vehicle will leave the track if the brakes on one side respond faster than those on the other side, or if a wheel locks.

Hydraulic brakes have to be flushed first with spirit and then with brake fluid to clean them. When repairing components of the brake system, the brake piston cups and brake cylinders are to be lubricated with brake grease before fitting. The wheel brake cylinders and the main brake cylinder as well as the brake lines have to be tested for leaks.

Brake fluid

Brake fluid is a synthetic fluid which transmits pressure during braking. It consists of a mixture of high−boiling alcohols, synthetic components such as glycols and their derivatives. This fluid is chemically indifferent to rubber and metal, and its properties change only slightly under temperature variations. This is vital since the brakes of a vehicle must work perfectly in the most varied temperature conditions. The brake fluid is non−ageing and non−corrosive. Its freezing point is approximately −65°C and its boiling point approximately 240°C to 290°C. Its disadvantage is that the brake fluid is hygroscopic, i.e. it tends to absorb water. This property makes it necessary for the fluid to be completely renewed after about two years, since the water will cause corrosion. High temperatures occur during braking and are transmitted to the brake fluid by the brake cylinders. If the water content is too high, bubbles will develop which have a negative effect on braking.

If a loss of brake fluid is noticed in the brake system, it is important to ensure that brake fluid of the appropriate classification is used for refilling. Not all brake fluids may be mixed.

If brake fluid comes into contact with paintwork of the vehicle, it must be removed immediately with water to avoid damage to the paintwork. The brake fluid causes the paint to become soft and flake off, thus allowing corrosion to occur.

6.5. Pneumatic braking system

With pneumatic brake systems, air at different pressures serves as the means of transmission of the braking force. Vacuum servo brakes, compressed air brakes and combined brake systems are all pneumatic brakes.

With vacuum servo brakes an additional force is generated by the vacuum in the engine induction line. This is used to support the action of the mechanical or hydraulic brakes. A vacuum brake booster is connected to the mechanical transmission elements in this system.

The compressed air brake system (Figs. 6/14 and 6/15) is fed by means of a piston compressor. It is driven by the engine of the vehicle and generates the operating pressure for the brake system. This operating pressure is limited to between 71 and114 p.s.i. by a pressure regulator incorporated in the system. If this pressure is reached the piston compressor is switched to idle running. This means that air pressure produced thereafter is blown off into the open air via a relief valve, if maximum pressure has been reached in the reservoirs. These reservoirs have a capacity of between 40 and 80 litres. There are two reservoirs to ensure that sufficient air is available for the brake to be operated frequently, and so that the engine does not have to idle for a long time in order to reach the operating pressure. When a pressure of 43 p.s.i. is reached, the vehicle is ready to drive. The pressure can be read at a pressure gauge in the driver's cab. This gauge shows the air pressure in the system and the brake pressure. The brake system of a vehicle consists of the piston compressor, the tyre inflator, the pressure regulator upstream of the first reservoir, the relief valve of the main reservoir, the brake pedal, the engine brake valve and the trailer brake valve as well as the wheel brake cylinders and the transmission lines which are connected to a double pressure gauge. There is another valve at the reservoirs to remove the condensed water from the system. The relief valve of the main reservoir does not open until the operating pressure is reached in the first reservoir. Both reservoirs are connected with the tractor unit brake valve. When operating the brake pedal, the feed line to the wheel brake cylinders is opened, the compressed air flows in and the braking effect is produced. At the same time the trailer brake valve is operated by a linkage and the trailer brakes are actuated by means of a feed line. The tractor unit and the trailer are connected by a coupling head and a pressure hose. When operating the brake, a vacuum develops in the trailer control valve which is coupled with a load sensitive brake pressure regulator. This causes the air to flow from the reservoir into the brake lines, and so braking is effected via the brake lines. After braking, the air used is discharges to atmosphere. The brake pressure regulator has to be set to the load of the trailer before starting. This must be done so that the trailer brakes before the tractor unit in order to avoid overrunning.

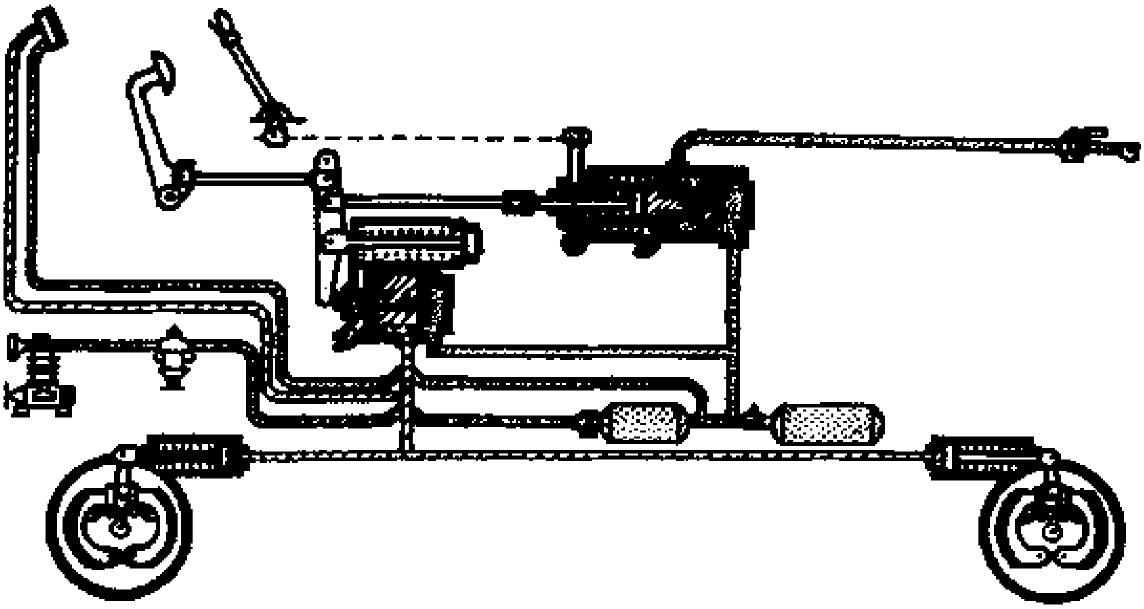


Figure 6/14 Pneumatic brake for motorised vehicles

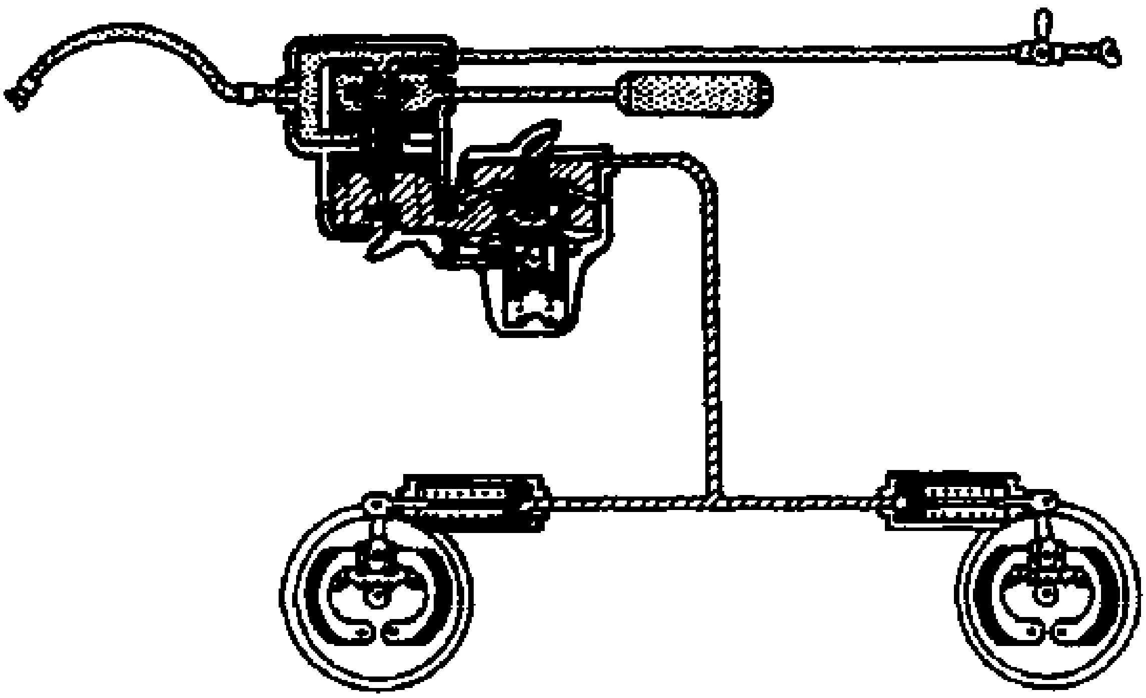


Figure 6/15 Pneumatic brake for trailers

The brake valves and the pressure regulators must not be adjusted or repaired by unauthorised persons if safety and service−ability are to be guaranteed.

Valves and pressure regulators have technical data determined by the manufacturer which must be adhered to. Repairs must be carried out in special workshops. Only the mechanical transmission components of the brake system may be adjusted. The pipes are made of seamless drawn tubular steel and are screwed together. They are cold bent with a bending tool. After repair the brake system is checked for leaks. This is done by putting the system under pressure and by covering the joints with a mixture of water and foaming agent. The presence of air bubbles shows the location of any leaks, and these can then be eliminated by retightening the joint concerned or by replacing the whole component. After repair the system must be checked for leaks again.

To avoid accidents it is important to ensure that any air pressure is released before starting work on the brake system.

If the tractor unit is moved or driven without the trailer, the shut−off valve has to be closed before the brake hose is removed from the coupling so that the compressed air cannot escape. The coupling line must also be at zero pressure. The trailer will brake automatically after uncoupling, and in order to move it the shut−off valve has to be set to release. Damage due to dirt is one of the main causes of defects in pneumatic brake systems. It is therefore necessary to periodically check and clean the air filter in the air compressor. After cleaning with a cleaning fluid (Not petrol!) and blowing out, the filter is slightly moistened with oil to bind most of the dirt particles together.

If the required operating pressure is not reached, the valves and the piston rings in the air compressor have to be checked, and replaced if necessary.

Other defects, which can be located by the escape of air when the compressor is at a standstill, can be traced back to leaking joints, valves, diaphragms or power pistons. These defects can be eliminated by cleaning the components, by tightening screws or by replacing defective parts.

6.6. Combined brake system

Combined brake systems are used when mechanical or hydraulic brakes are not strong enough but when the use of pneumatic brakes is not warranted. The have a pneumatic actuating system but their operating principle is hydraulic. The actuating system comprises, as shown in Fig. 6/16, a piston compressor, a pressure regulator, an anti−freeze pump, an air reservoir, a brake booster valve, an engine brake valve, a spring accumulator, a shut−off valve and the coupling head for the trailer. The brake booster is coupled to the hydraulic main brake cylinder. It is a dual−circuit brake cylinder which works on brake fluid which transmits the braking force to the wheel brake cylinders. In motor vehicle engineering, single− and dual−circuit brake systems are used. With the single−circuit system power transmission to all four wheel brake cylinders is via a single−chamber main brake cylinder. If one link in this chain fails, the brake system ceases to be serviceable. As it is not possible to drive without brakes, the vehicle cannot be used in traffic until it has been repaired. Due to the malfunction the brake fluid escapes and the system is no longer closed. Due to this disadvantage of the single−circuit brake system, modern motor vehicle engineering is turning increasingly to the dual−circuit system.

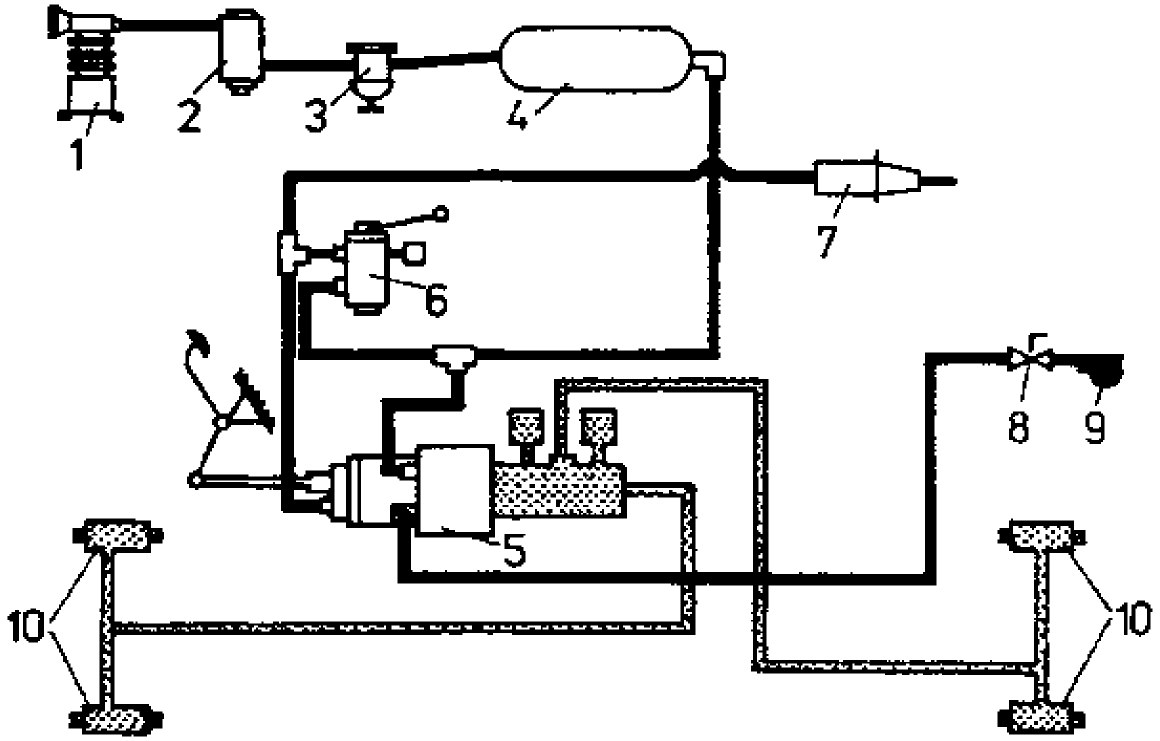


Figure 6/16 Combination brake

1 reciprocating compressor, 2 pressure regulator, 3 antifreeze pump, 4 air brake reservoir, 5 servo brake valve, 6 engine brake valve, 7 spring accumulator, 8 shut–off valve, 9 coupling head for trailer brake unit, 10 hydraulic wheel brake cylinder

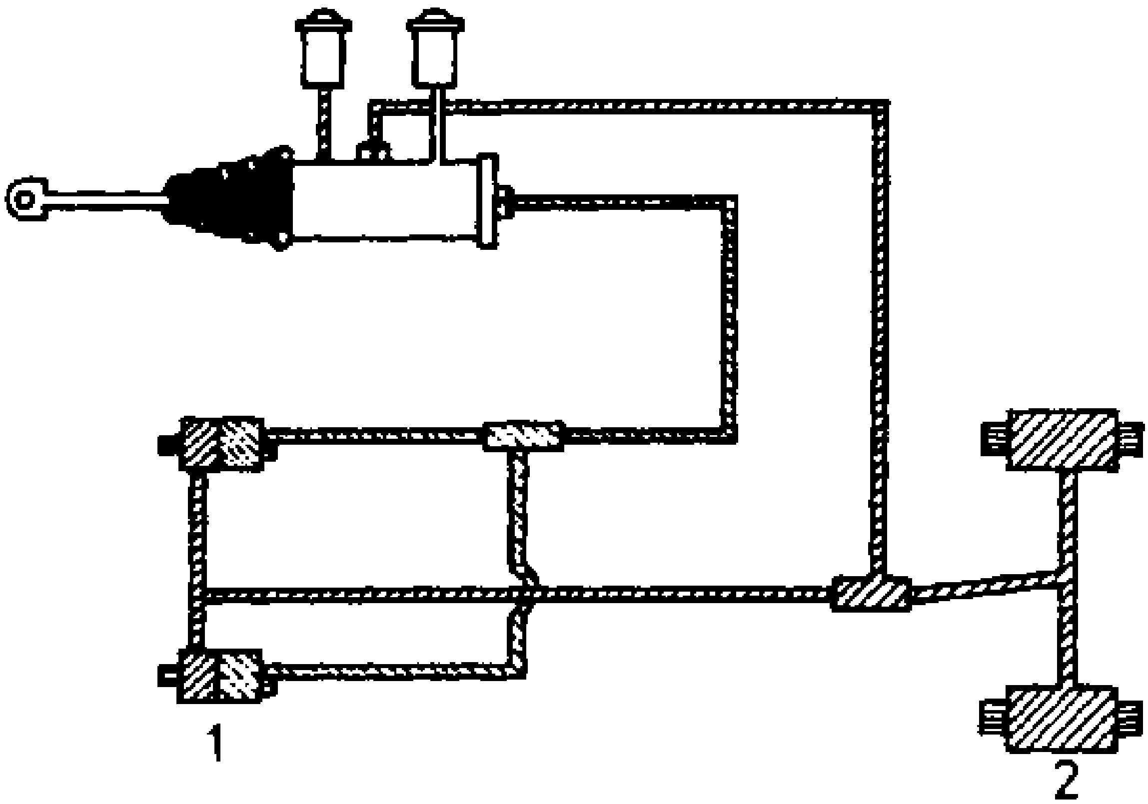


Figure 6/17 'Non–genuine' dual–circuit braking system

1 twin–chamber brake cylinder, 2 single–chamber brake cylinder

There are genuine and non–genuine dual–circuit brake systems. A 'non–genuine' dual–circuit brake system is one in which the front and rear axles are separately connected in two individual brake circuits. A genuine dual–circuit brake system is one in which all the wheel brake cylinders are dual–chamber drake cylinders. In Fig. 6/17 the wheel brake cylinders of a front axle are illustrated as dual–chamber brake cylinders. In a genuine dual−circuit brake system, if one of the brake circuits fails, the vehicle is still completely serviceable as the second brake circuit then comes into action.

6.7. Brake system of the IFA W 50

The W 50 lorry has a pneumatically−assisted hydraulic brake system. The drum brakes, which have a bilaterally acting wheel brake cylinder, produce a duo−servo−effect. This system, shown in Fig. 6/16, is a dual−circuit brake system. It requires some additional components in its structure, such as the brake booster and the spring accumulator. The piston compressor is the vital component for effective breaking, it produces the air pressure required for braking which is accumulated in the reservoir. When the foot pedal is operated, the linkage works directly on the brake booster which is in turn linked to the main brake cylinder. The main brake cylinder is a hydraulic dual−circuit brake system. The wheel brake cylinders are actuated by means of the brake fluid and so the braking begins. If the pneumatically assisted system fails, braking of the vehicle is still possible but more difficult, and the vehicle must be driven very slowly.

The individual components of the brake system:

Brake booster

When operating the brake pedal a piston is moved by a linkage in such away that the compressed air assists the function of the piston itself. This increased force is transmitted to the main brake cylinder via the piston rod. In this way the brake booster serves to assist the force of the driver's foot, and the energy expended is reduced.

Main brake cylinder

In the IFA W 50 lorry the main brake cylinder is divided into two independent brake circuits. Each brake cylinder has a brake cylinder element and a compensating reservoir. The piston rod coming from the brake booster operated the piston in the first brake circuit, which in turn transmits pressure to the brake fluid. Due to this, the second cylinder is moved and transmits pressure to the brake fluid of the second brake circuit. Both cylinders are kept at a distance determined by the manufacturer by a compression spring.

If one of the two brake circuits fails due to a defect, the other will continue working. The compensating reservoir and the main brake cylinder, shown in Fig. 6/11 as a single−circuit brake cylinder, are connected by a feed line. There must be a play of one millimetre between the piston in the brake cylinder and the piston rod. The foot valve in the main brake cylinder produces a slight overpressure which keeps lost motion to a minimum. If it becomes too high, adjustment is necessary. The level of the brake fluid in the compensating reservoirs must be checked regularly to prevent failure of the whole brake system. The pressure of the brake fluid is transmitted to the wheel brake cylinders by the brake line.

Wheel brake cylinder

In the wheel brake cylinders there are two pistons (Fig. 6/12) which are sealed by rubber gaiters. The space between the two pistons is occupied by a compression spring and the brake fluid. The compression spring maintains the distance between the two pistons. It also ensures that the inlet opening is not closed by the pistons. In the pistons there are push rods which operate the brake shoes. The wheel brake cylinders are protected against dirt penetration by a rubber gaiter, which also holds the push rods horizontal. When the brake is released, the push rods are pressed back into the wheel brake cylinders by the brake shoes which are tensioned by a spring.

Hand brake valve

Each vehicle must be fitted with a parking brake. It can be a mechanical, or as is the case with the IFA W 50 lorry, a compressed air brake. This type of parking brake is shown in Fig. 6/18. When operating the hand brake lever the push rod is shifted so that the outlet is opened, and there is a gradual pressure drop in the spring. This type of parking brake is also called a spring brake. The pressure drop in the brake lines causes the brake to be fully applied. In comparison to all mechanically operated parking brakes, this type has the advantage that it comes into effect immediately on operation. With most ratchet brakes, the wheel brake lever must be operated several times before it is locked. Therefore in emergencies this brake can be used immediately, even if both brake circuits fail. A compression spring and a release mechanism return the brake to the release position.

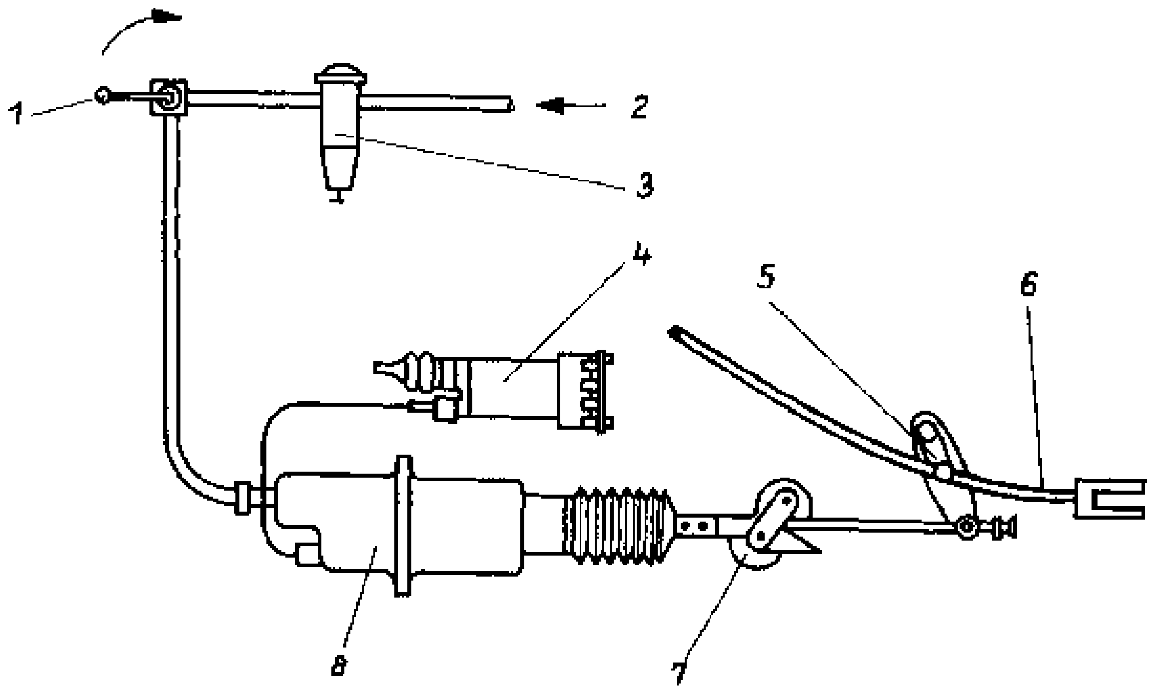


Figure 6/18 Parking brake

1 hand brake valve, 2 air supply, 3 pressure regulator, 4 servo brake valve, 5 frace compensator, 6 hand brake cable, 7 release, 8 spring accumulator

Engine brake

Vehicles over 5.5 tonnes total weight must have an engine brake system. It is fitted in the exhaust manifold of the engine as is shown in Fig. 6/15. The engine brake can be actuated either hydraulically or mechanically.

The engine brake is actuated by operating a bleed valve or by retracting the accelerator pedal. The compressed air flows via the engine brake valve into the clutch release cylinder, thus closing a flap in the exhaust system. At the same time the fuel feed is reduced. The burnt exhaust gases accumulate is this chamber and the vehicle is decelerated by the compressor effect of the engine. The vehicle can also be brought to a standstill. The purpose of the engine brake is to avoid overloading of the brake system on long gradients.

Trailers with compressed air brake systems are coupled to the IFA W 50 lorry.

Faults and rectifications

From time to time every brake system is subject to faults, some of which are dealt with below.

The most common fault found in the IFA W 50 lorry is that it pulls either to the left or the right during braking. The cause of this fault can lie in the presence of oil or grease on the brake shoes, in uneven wear of the brake linings or misshapen brake drums. In most cases it is advisable to replace the faulty or unserviceable parts. If the brake shoes need to be fitted with new linings, both wheels on one axle must be repaired at the same time to prevent the brakes from pulling to the side.

Defective wheel brake cylinders or hand brake cables which have been greased too much can be the cause of oil or grease on the brake shoes. Worn brake linings and connections may cause the foot pedal travel to be too great. When the brake linings have been worn down to 50 % of their original thickness, they must be replaced. If re–adjustment of the brakes is possible, proceed as follows:

Lift the axle so that the wheels can be moved freely by hand, i.e. so that they no longer have any road grip. Then remove the locking pins. Using a large screwdriver, turn the eccentric wheel to the right to lock the brake, so turning the gear back by three teeth.

Move the wheel in the direction of travel, and if the brake has been adjusted correctly a slight rubbing noise should be heard. When the work is completed, the locking pin can be replaced. Proceed in the same way for the other wheel. Ensure that the wheels are running in parallel.

When work on one axle is complete, lower the vehicle and adjust the other axle in the same way. As the hand brake cannot be used, ensure that brake blocks are placed in front of the wheels on the ground to stop the vehicle from rolling away.

Air in the brake system can cause the brake pedal travel to be too great. With the IFA W 50 lorry bleeding is started at the main brake cylinder. The reservoir must be topped up. Place a ring spanner on the bleeder screw and then attach a tightly fitting hose to it. Put the end of the hose into a half−filled bottle of brake fluid, to stop air from re−entering the brake system. Two people are required for bleeding a hydraulic brake system, one to open and close the bleeder screw and the other to operate the brake pedal. They must communicate orally. As mentioned above, the brake system is to be pumped, i.e. the air in the brake system is compressed. When the person pumping the brakes feels some resistance, pressure has built up and the bleeder screw should be opened. As soon as the foot pedal reaches the floor, the bleeder valve must be closed. Then release the brake and repeat the process until bubbles no longer appear in the bottle. When the main brake cylinder has been bled at both its bleeder screws, the same process is carried out at the wheel brake cylinders. During bleeding the level of the brake fluid in the bottle must be constantly checked and topped up. Before bleeding, the brake system must be visually checked for leaks, and the connecting hose to the wheels must be examined for cracks and fractures.

If the play between the piston rod and the piston in the main brake cylinder is too small, the brakes will become warm. This can be rectified by adjusting the play.

If the brake rattles, it means that the brake lining is worn out and must be replaced. Rattling can also occur if the brake linings are not sufficiently bevelled, in which case the ends of the linings must be rebevelled. If the lateral play is very great, or if the brake pedal sticks, this is a sign that the bush is worn and must be replaced. When the return spring becomes slack it must be replaced.

A fast pressure drop in the brake system means that the connections or the units are defective. When a defective part is located, for example the brake booster or the spring accumulator, it must be replaced. It must not be repaired, because after repair its serviceability has to be checked on special machines. Whilst they are fitted to the vehicle this is not possible and so their correct functioning cannot be guaranteed.

Test questions:

6.1. What types of drum brakes do you know?

6.2. What are the tasks of brakes on a vehicle?

6.3. Describe the design of a simplex brake.

6.4. What do you understand by a duplex brake?

6.5. Describe the design and the operating principle of a servo brake.

6.6. Describe the design and the operating principle of a disc brake.

6.7. What types of disc brakes do you know?

6.8. What do you understand by mechanical brakes and for what purpose are they used in modern vehicles?

6.9. Describe the design of a hydraulic brake system.

6.10. What advantages does the hydraulic brake system have over the mechanical brake system?

6.11. Describe the basic principle of bleeding a hydraulic brake system.

6.12. Why must brake systems be bled?

6.13. What is brake fluid and of what does it consist?

6.14. What properties does brake fluid have and how must it be handled?

6.15. Why must only brake fluids of the same classification be used for topping up?

6.16. Describe the design of a compressed air brake system by means of an example.

6.17. What can be adjusted in such a system?

6.18. What functions do the pressure controller and the relief valve perform?

6.19. How can a brake system be checked for leaks?

6.20. Why can the piping of a brake system only be bent when cold?

6.20. What failures do you know and how can they be rectified?

6.21. Describe the design of a combined brake system.

6.22. What do you understand by a single–circuit brake system and what is its disadvantage?

6.23. What do you understand by a genuine and a 'non–genuine' dual–circuit brake system? Give examples of their advantages and disadvantages.

6.24. Describe the design of the brake system of the IFA W 50.

6.25. Explain the operating principle of the spring accumulator brake.

6.26. Describe the bleeding of a hydraulic brake.

6.27. What can be the causes of unserviceable brakes?

6.28. How can a worn bush be detected?

6.29. Why can the pneumatic units of the brake system be repaired only in authorised workshops?

7. Types, functions and uses of lifting gear

Two types of lifting gear are used for vehicle repairs:

1. mechanical lifting gear
2. hydraulic lifting gear

Mechanical lifting gear can be manual or mechanised. They are suitable only for certain load capacities. Before using a lifting unit, check whether it is suitable for load concerned. The following lifting units are used for vehicle repairs:

block and pulley	(manual)
scissor–type jack	(manual)
autohoists	(mechanised)
column–type car lift	(mechanised)
pit hoist	(mechanised)
assembly hoist	(manual and mechanised)

The block and tackle (Fig. 7/1) has a wide variety of uses. It can for example be used for dismantling, lifting and fitting bodies. It is seldom fixed in one place, but usually mobile. It works on the basis of an endless chain which must be operated manually. By means of this chain it can be moved up and down. The transmission ratio of the block and tackle facilitates the lifting of large loads. The transmission ratio is the transmission of a force or motion from a small to a large wheel or vice versa. With transmission from a small sheel to a large wheel, the speed is reduced or the lifting force is kept small. The part to be lifted is fixed to the hook of the block and tackle by steel cables or special assessories (balance beam, crane hook).

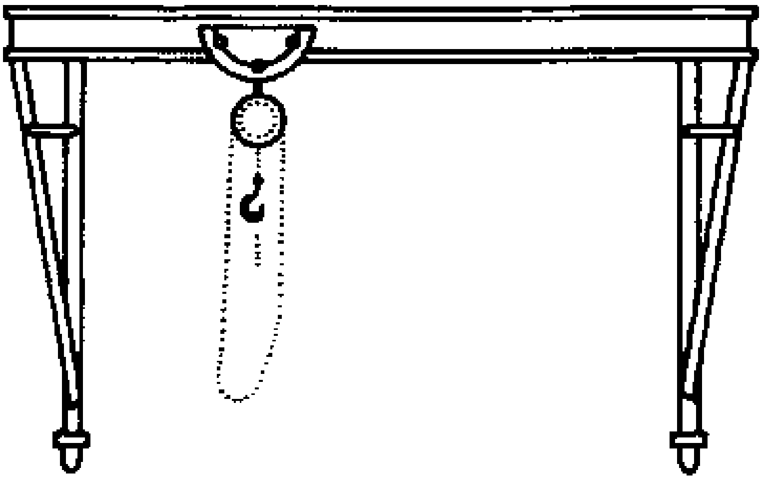


Figure 7/1 Block and tackle (mobile)

When working with this lifting device it is important to ensure that the part to be lifted is safely secured and correctly suspended, in order to avoid accidents.

The block and tackle is mobile even when loaded.

The scissor−type jack (Fig. 7/2) is raised or lowered by a spindle which is moved by a crank. It is generally used for changing wheels on cars or as a support for facilitating the fitting of screws. The scissor−type jack has a relatively low load capacity and therefore is rarely used in repairs to lorries.

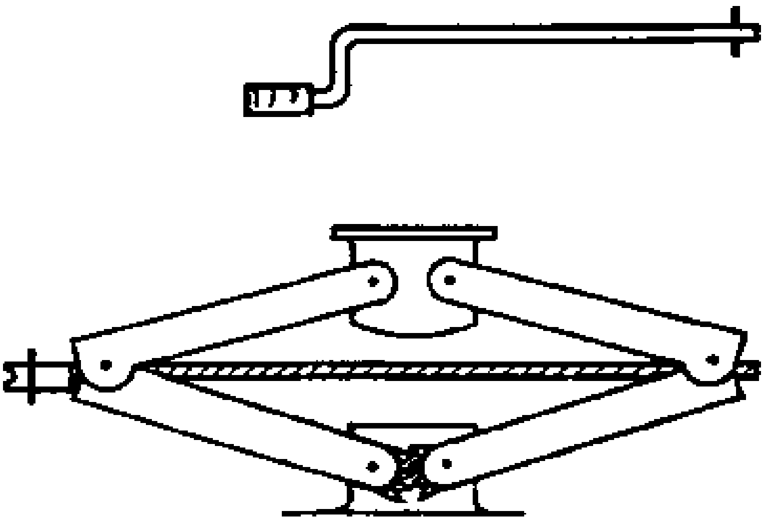


Figure 7/2 Scissor−type jack

The autohoists (Figs. 7/6 and 7/7) and the column−type car lifts (Fig. 7/8) are used to lift the vehicle from ground level to working height. They are motorised. Once they have reached the desired working height, they must be secured to stop them falling down. The difference between the autohoist and the column−type car lift is that on the autohoist the vehicle stands on its wheels, and when work is being carried out on the brakes it must be raised further. With the column−type car lift the vehicle rests on small areas of the frame and no parts of the lifting gear hinder repair work.

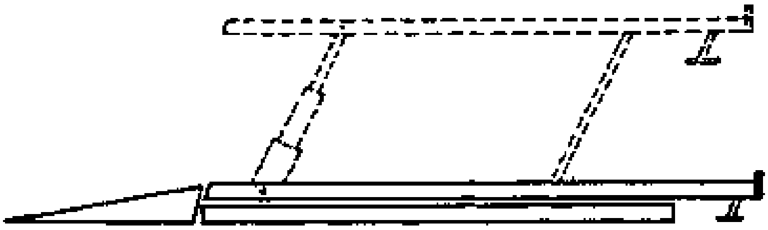


Figure 7/6 Auto−hoist for lorries

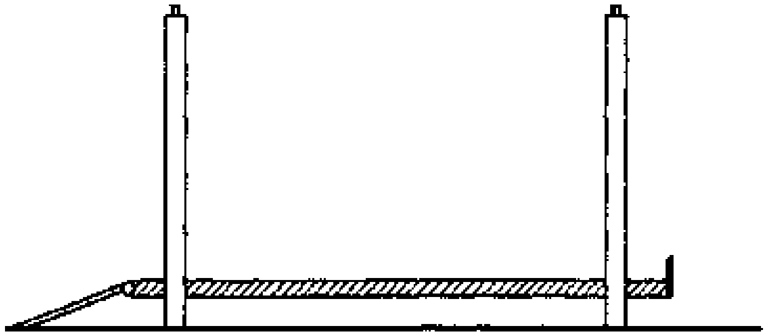


Figure 7/7 Auto−hoist for cars

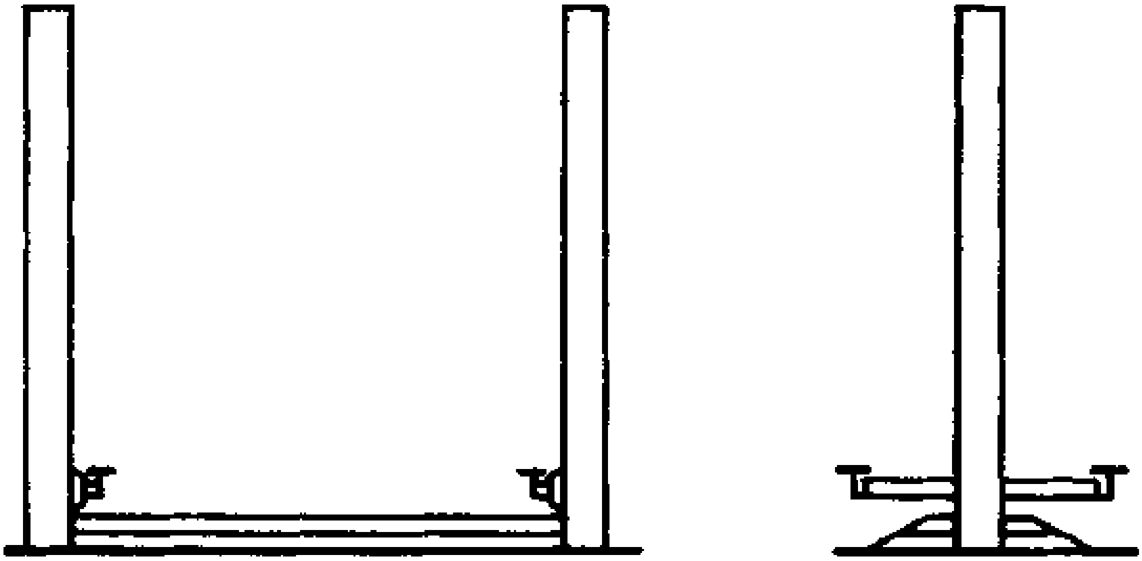
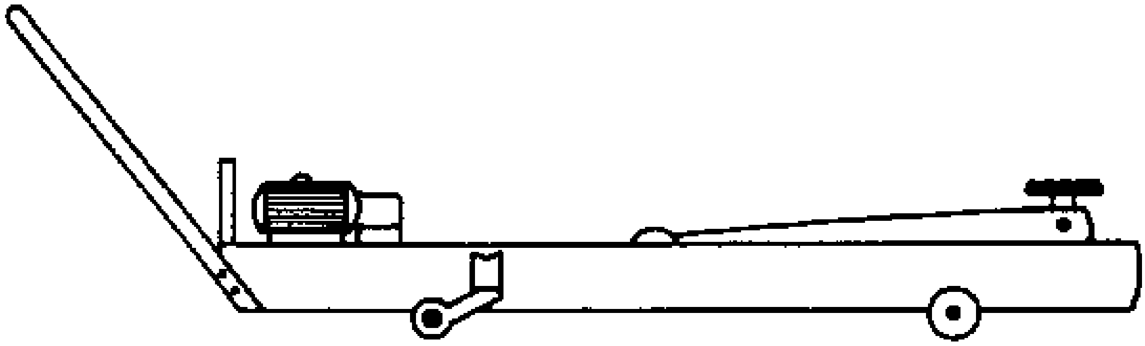


Figure 7/8 Column−typ car lift

In this way the mechanic's work is made easier. There are autohoists for both cars and lorries; column−type car lifts, however, are made only for cars because they have a limited load capacity. Both of these lifting devices are stationary. Autohoists can be operated hydraulically.

Assembly hoists (Fig. 7/3) can be found in every workshops and are used to remove individual parts from the vehicle, for example axles or gear boxes. Electrically driven assembly hoists are driven by a spindle and the hydraulic hoists by a pump piston and brake fluid. They have a limited load capacity. Pit hoists (Fig. 7/4) are installed in inspection pits. The assembly trestle (Fig. 7/5) is used to secure raised vehicles.

Figure 7/3 Assembly hoist



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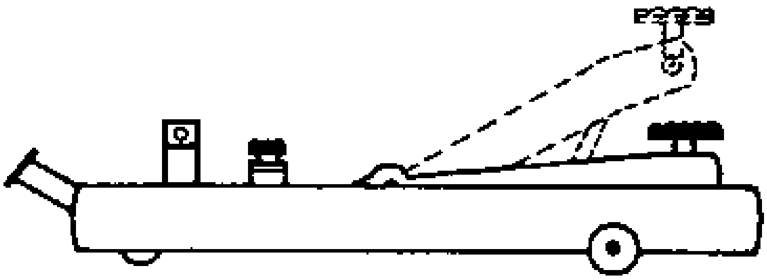


b) hydraulic

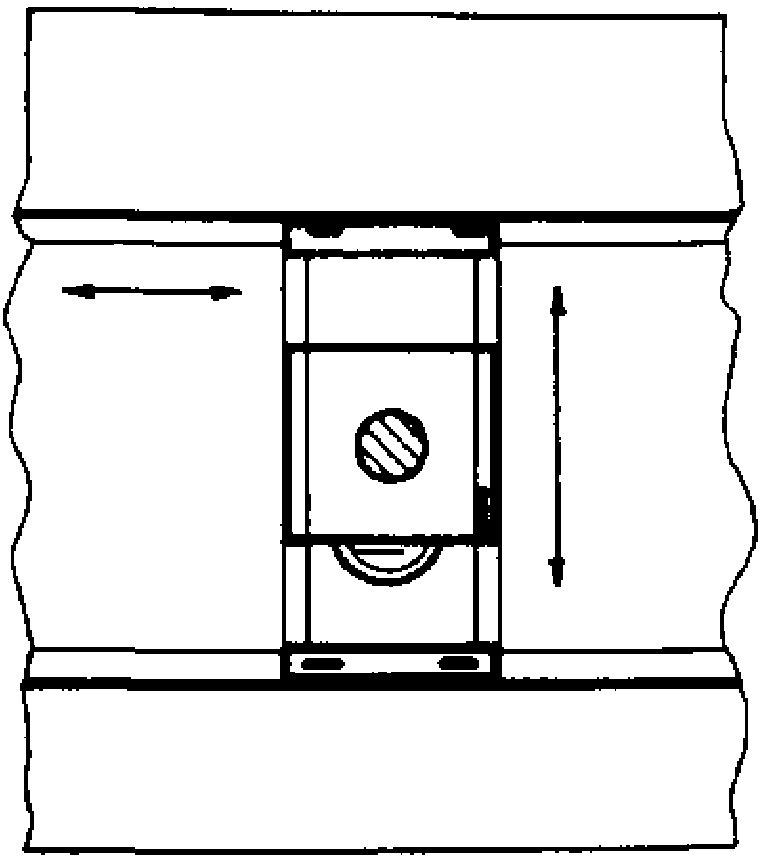


Figure 7/4 Pit hoist

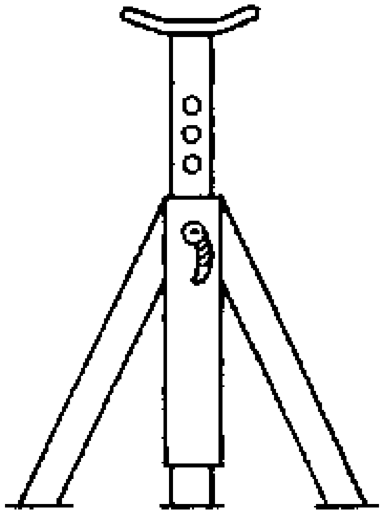


Figure 7/5 Assembly trestle

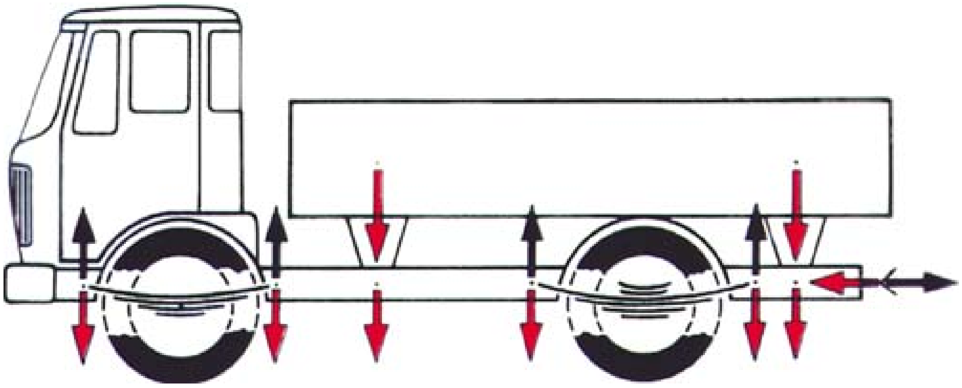
Chassis System – Automotive Transparencies

Table of Contents

Chassis System – Automotive Transparencies 1

Chassis System – Automotive Transparencies

1



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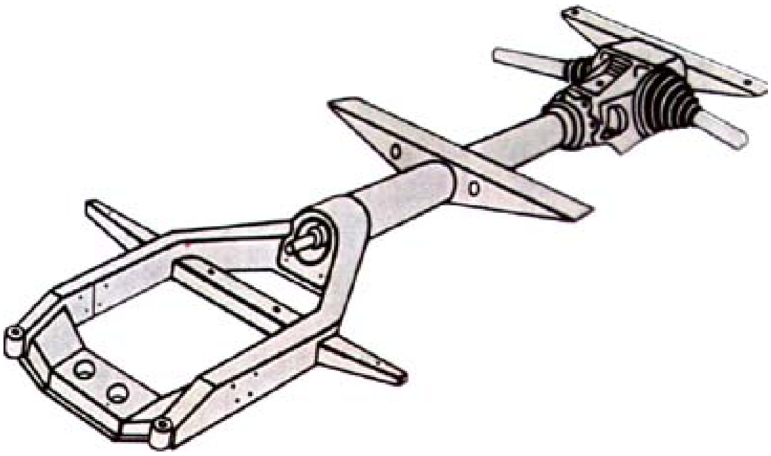

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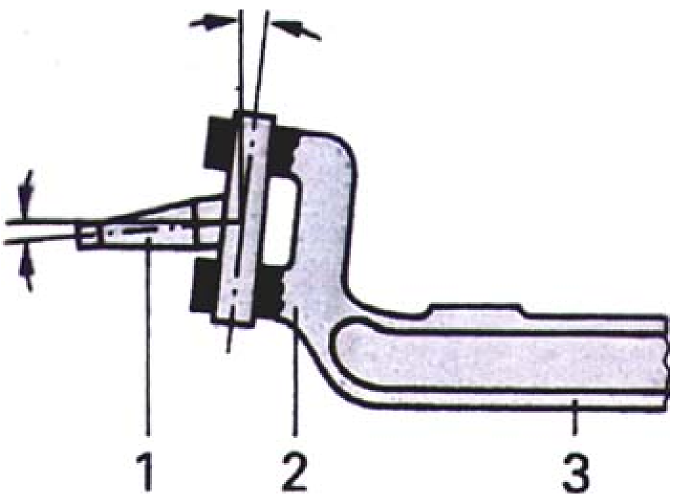

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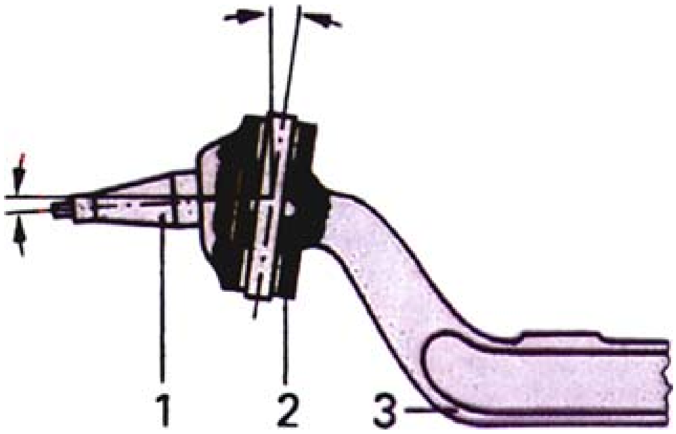

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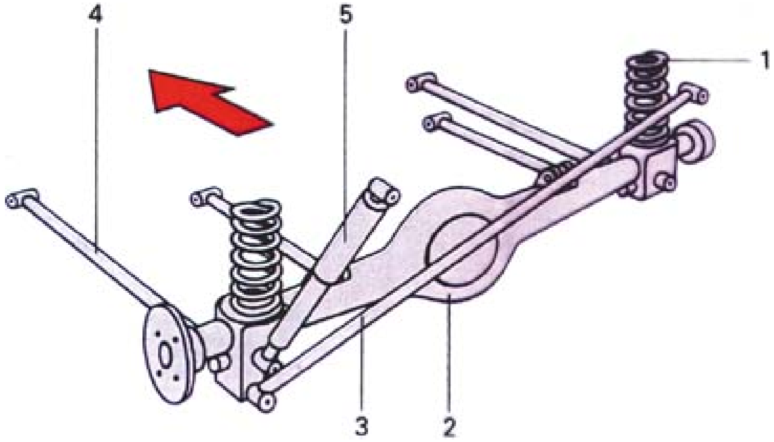

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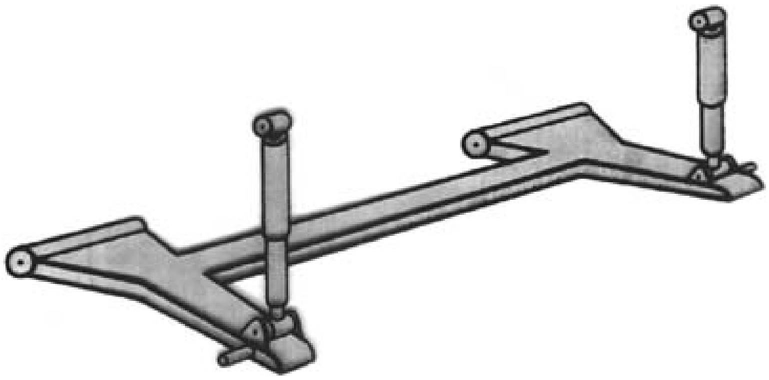

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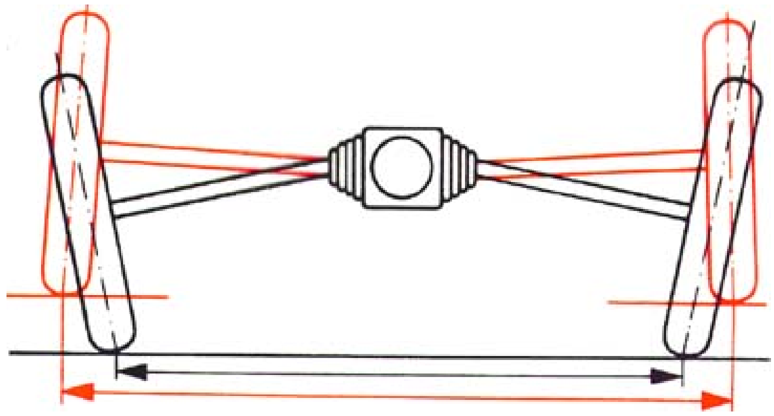

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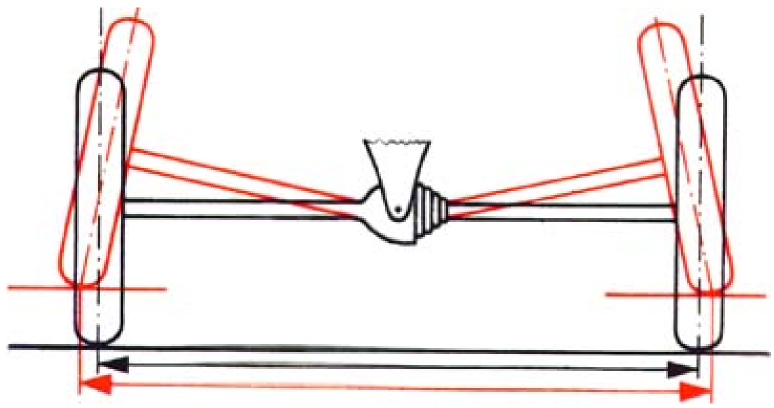

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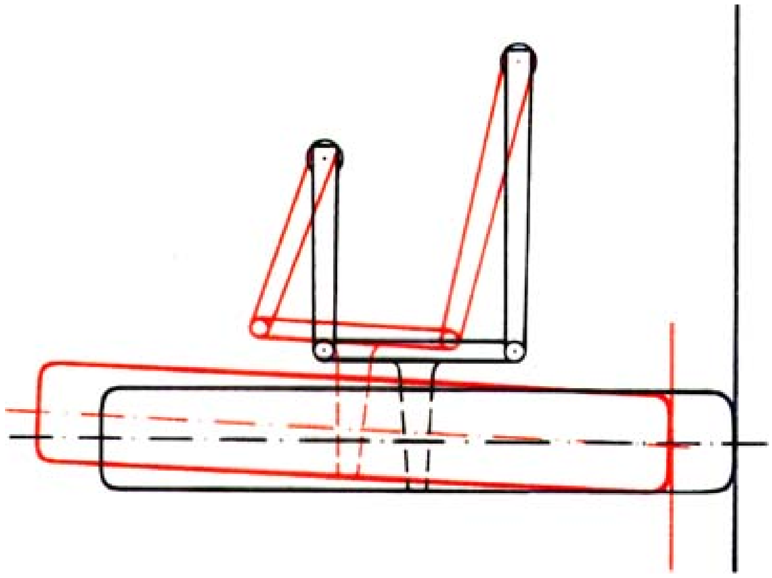

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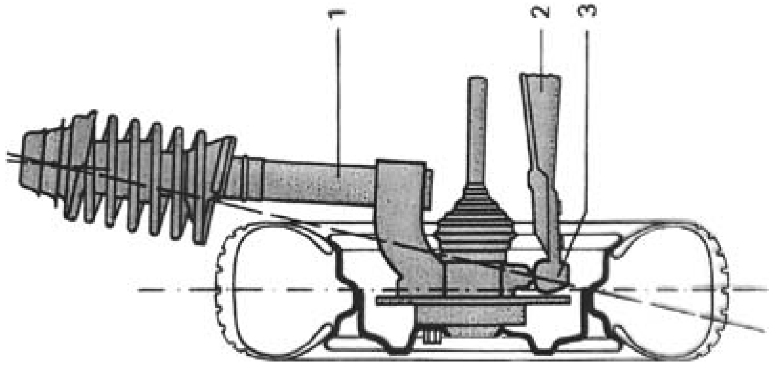

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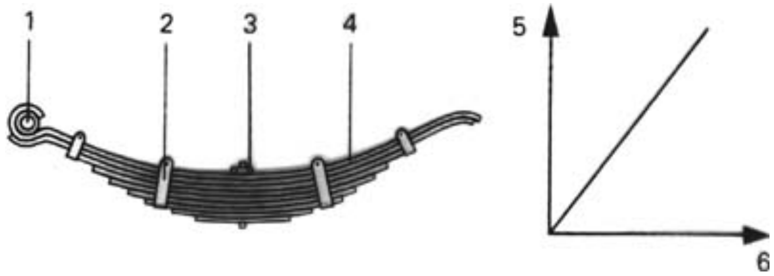

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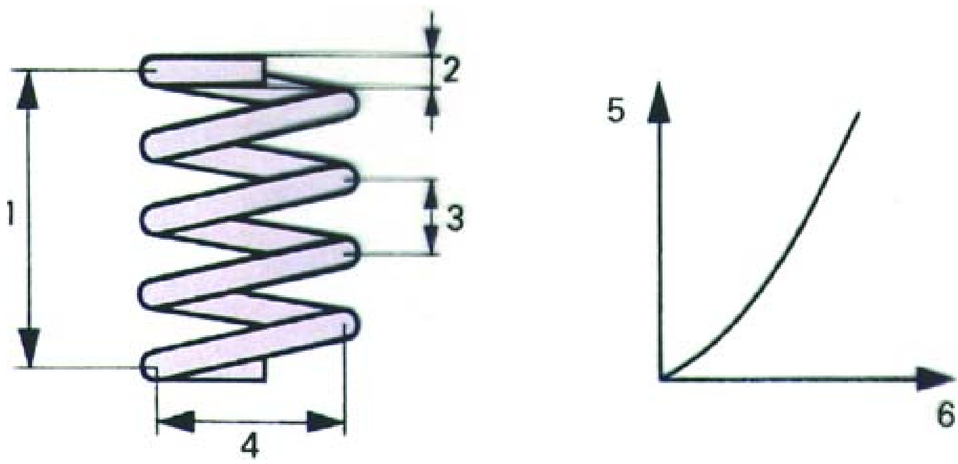

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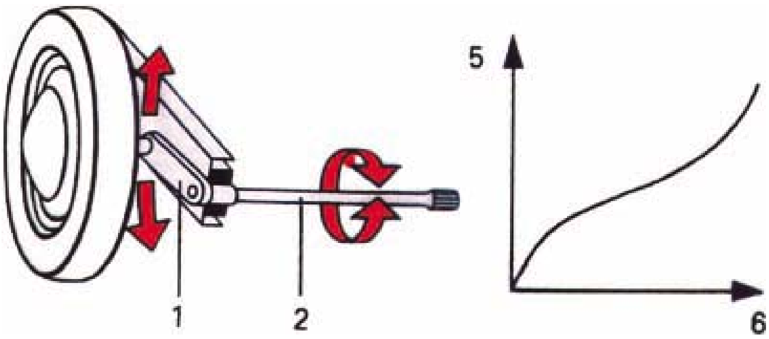

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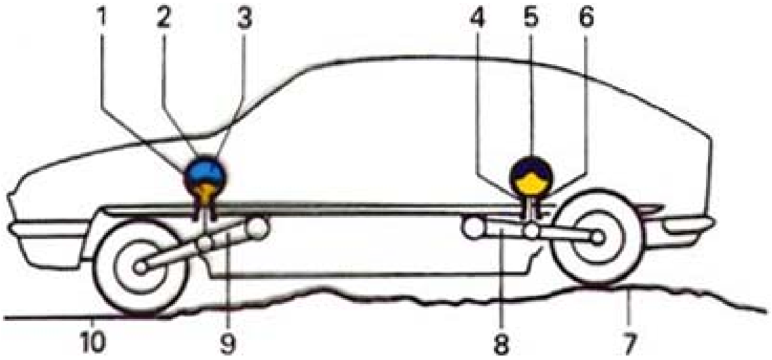

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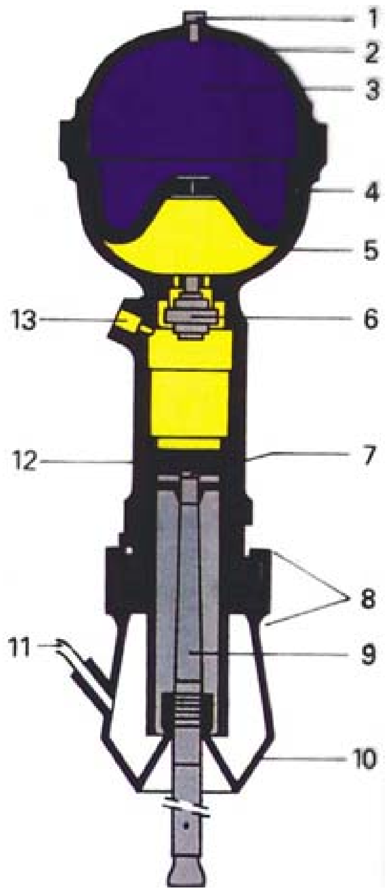

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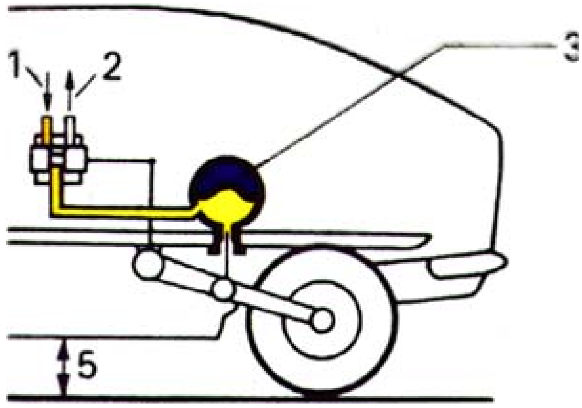

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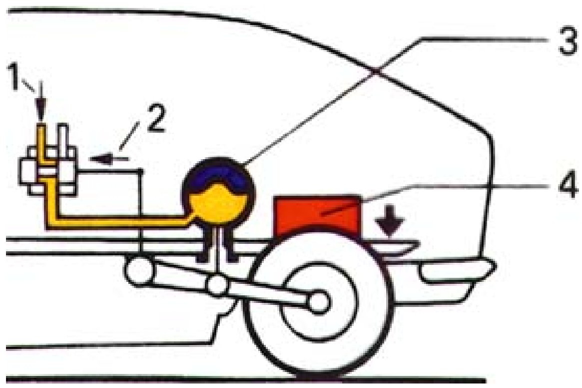

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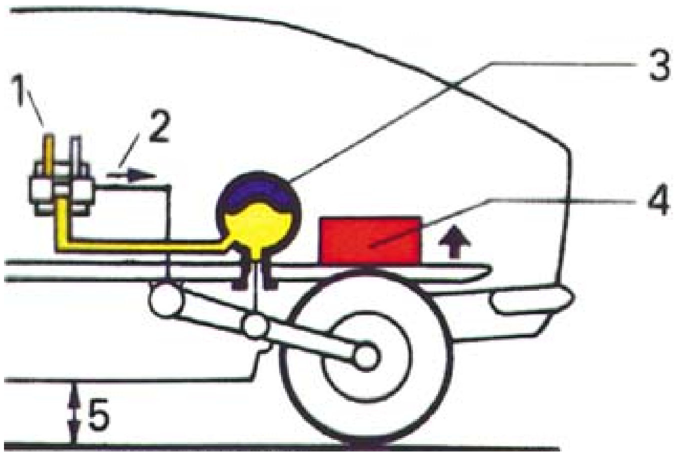

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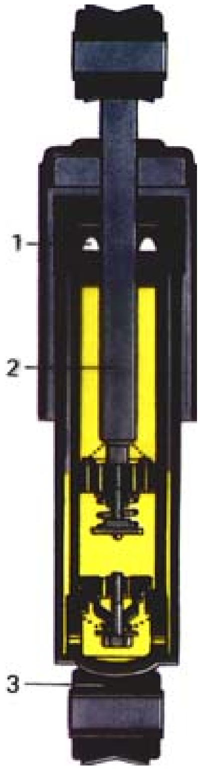

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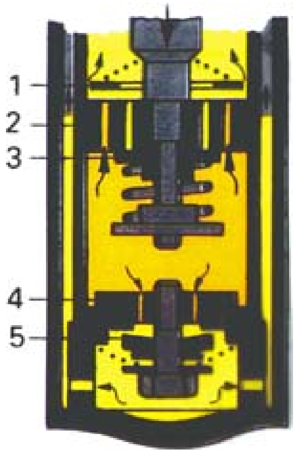

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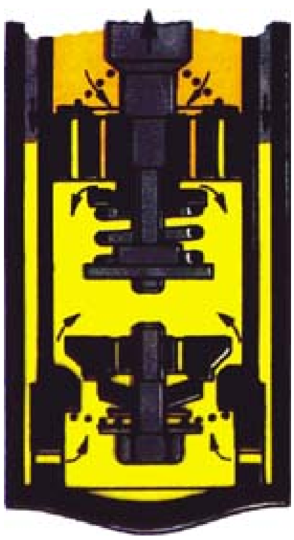

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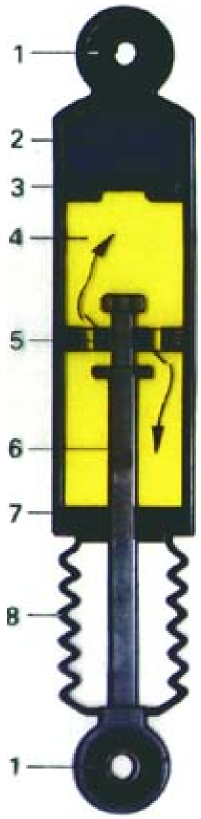

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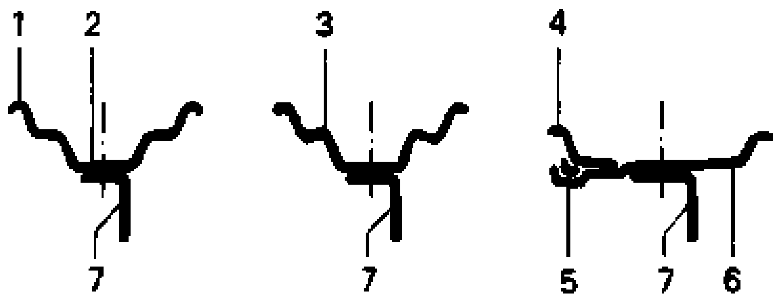

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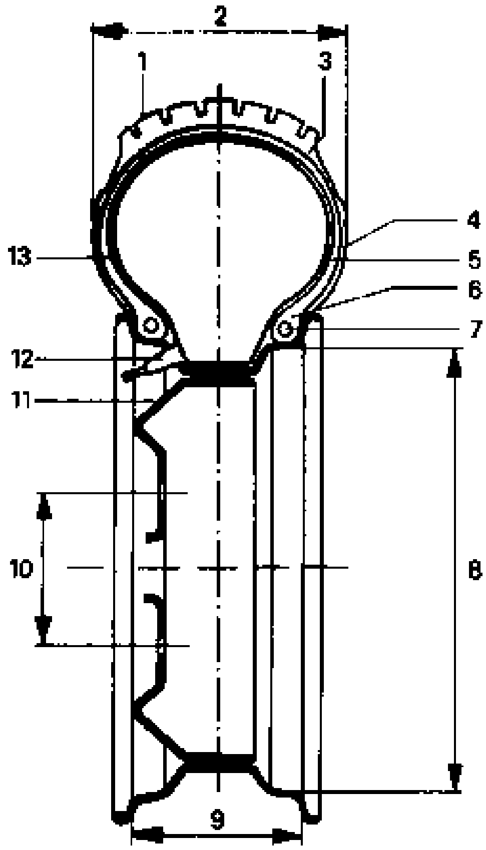

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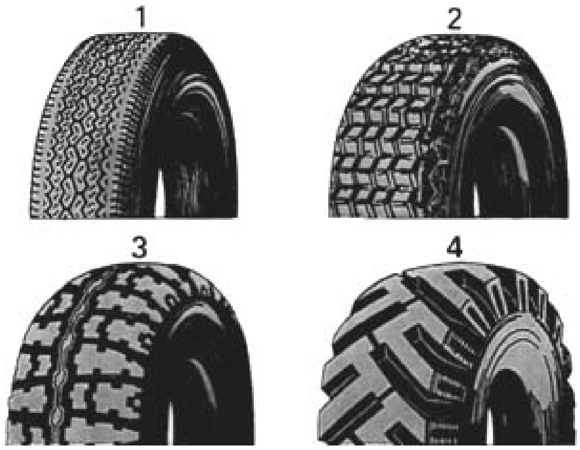

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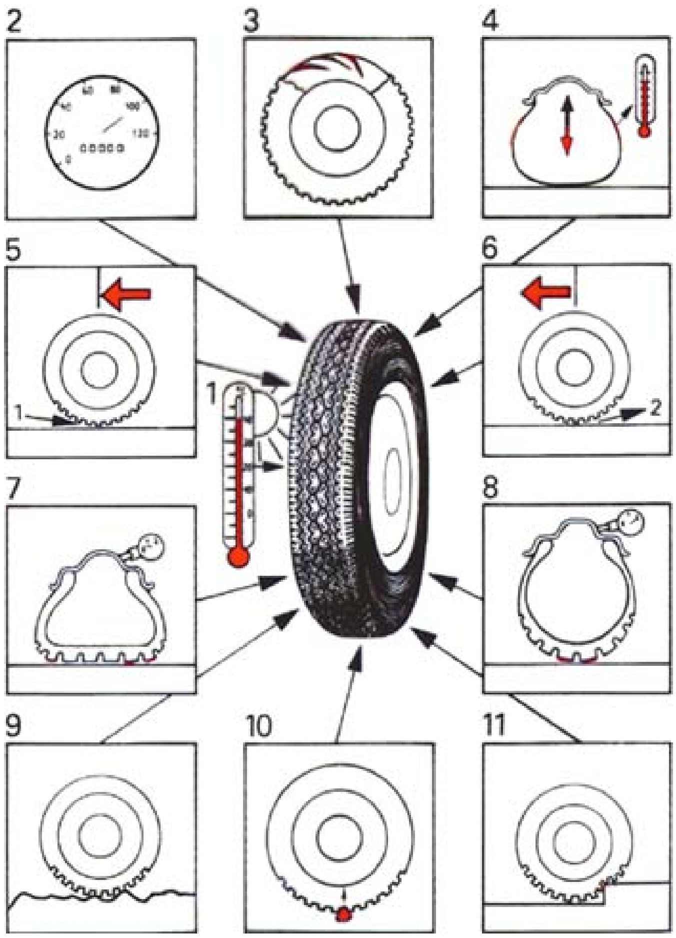

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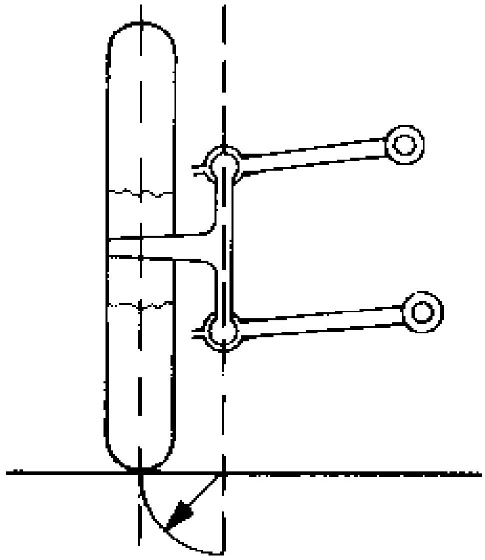

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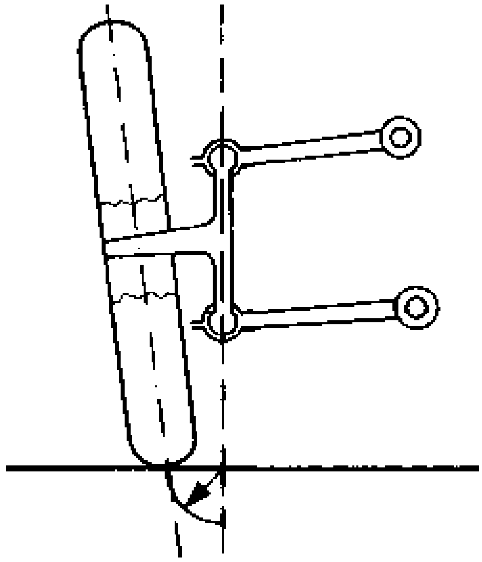

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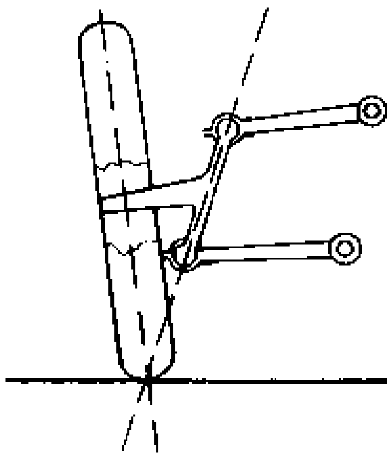

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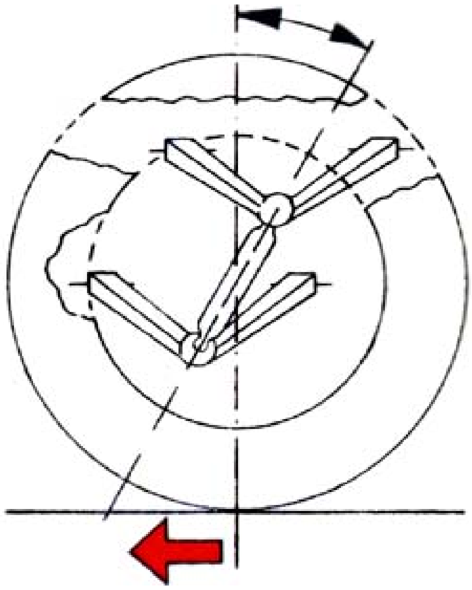

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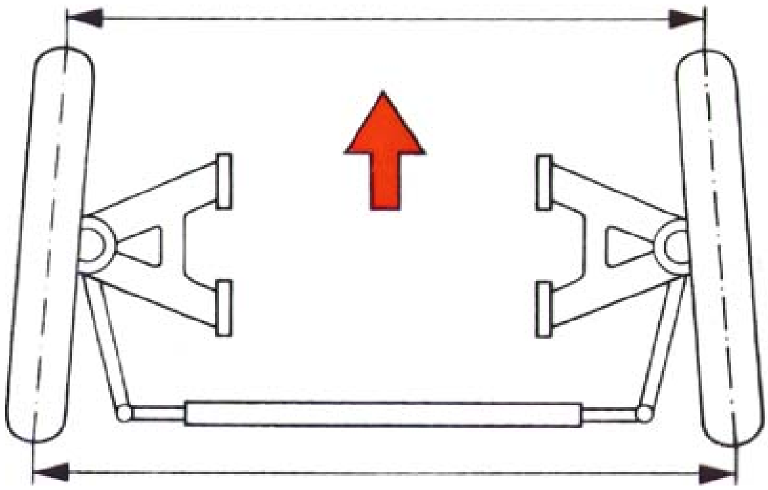

Brake System – Automotive Transparencies

Table of Contents

Brake System − Automotive Transparencies..1

Brake System – Automotive Transparencies

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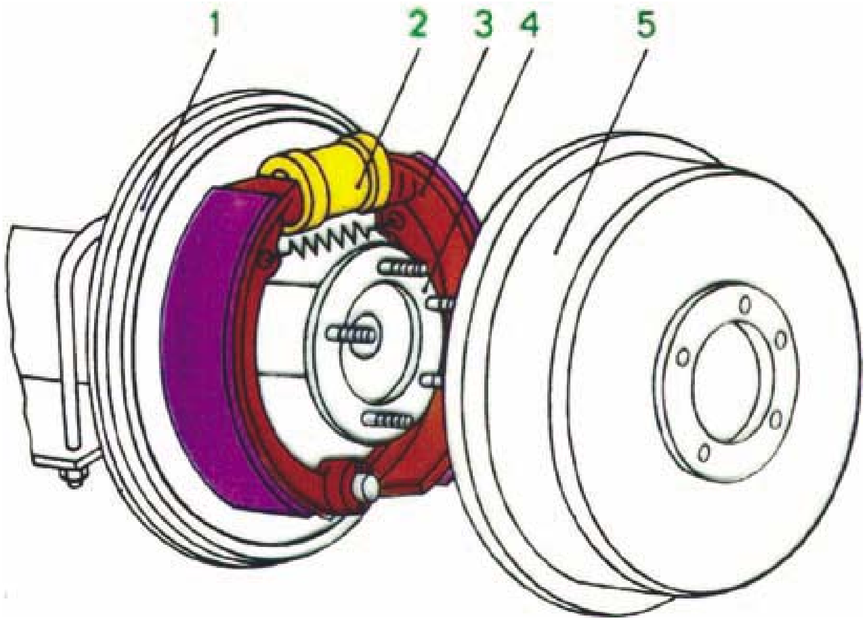

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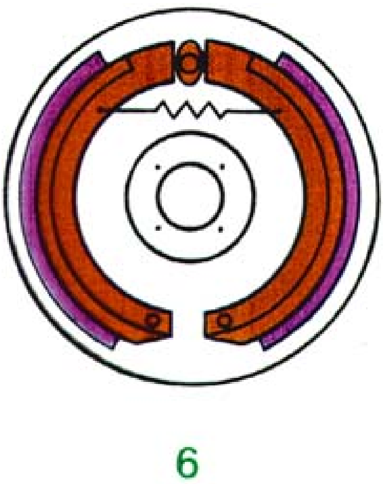

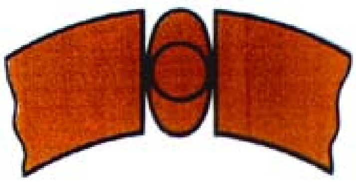

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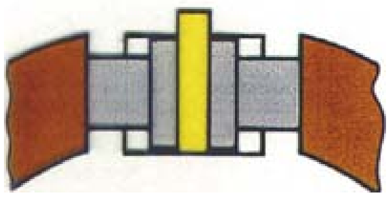

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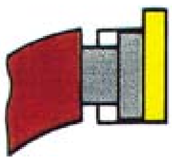

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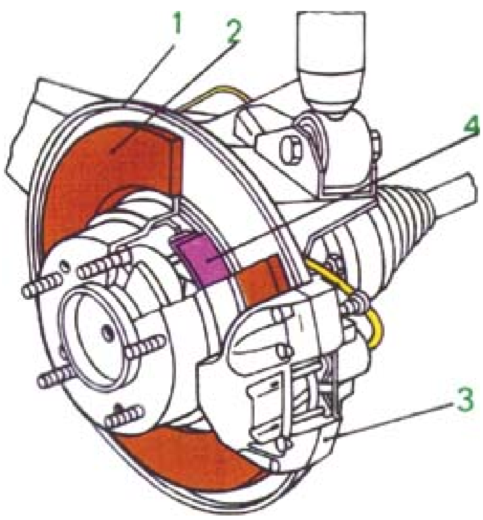

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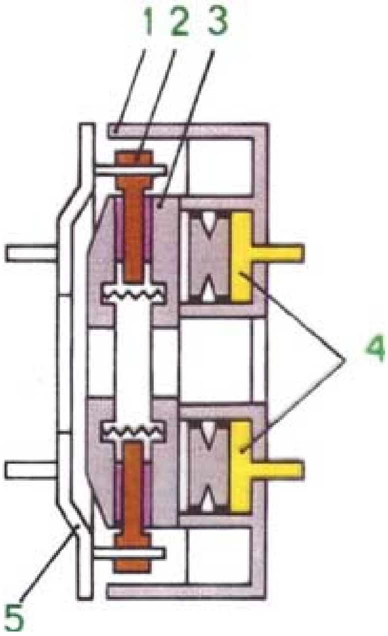

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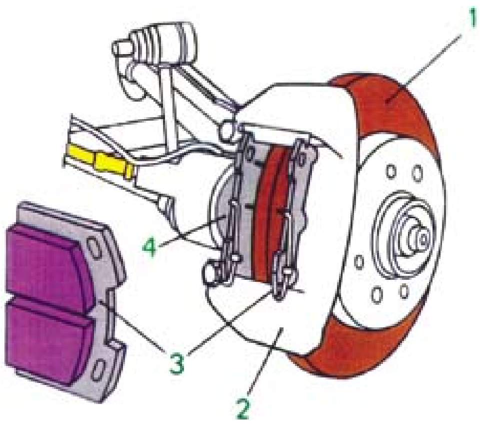

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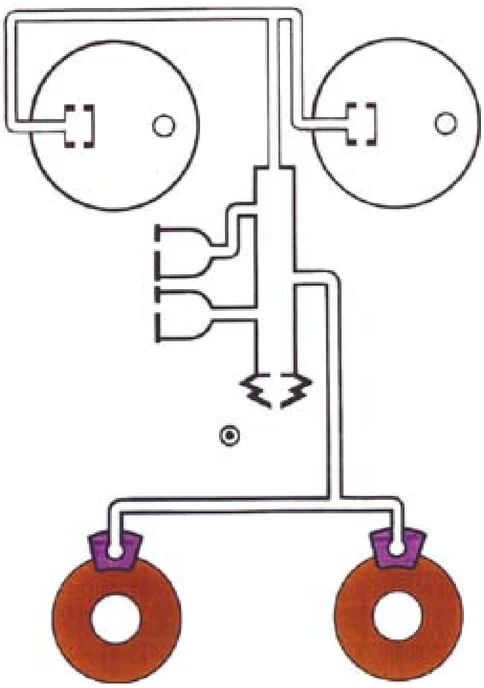

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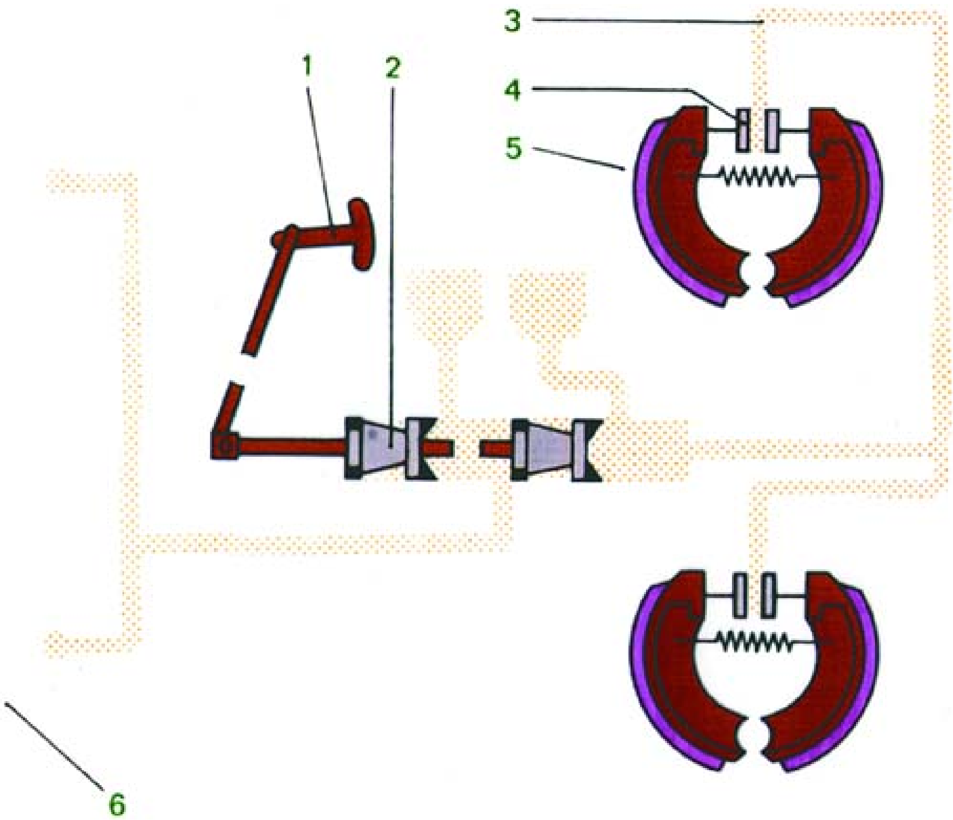

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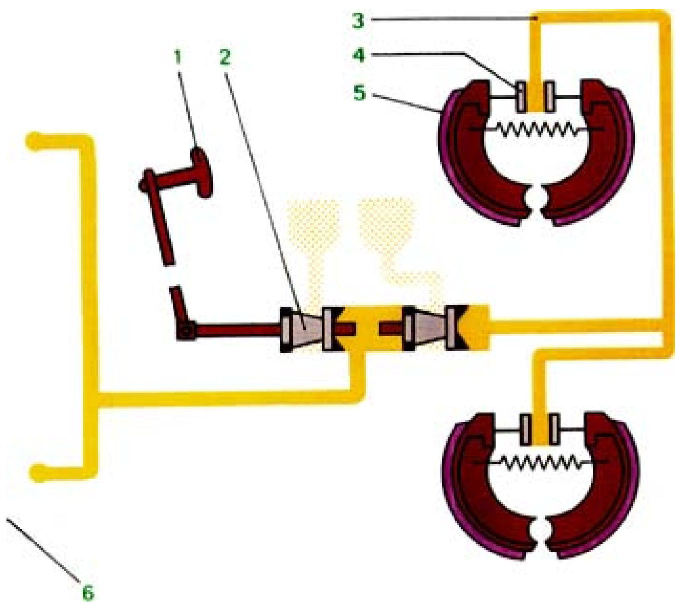

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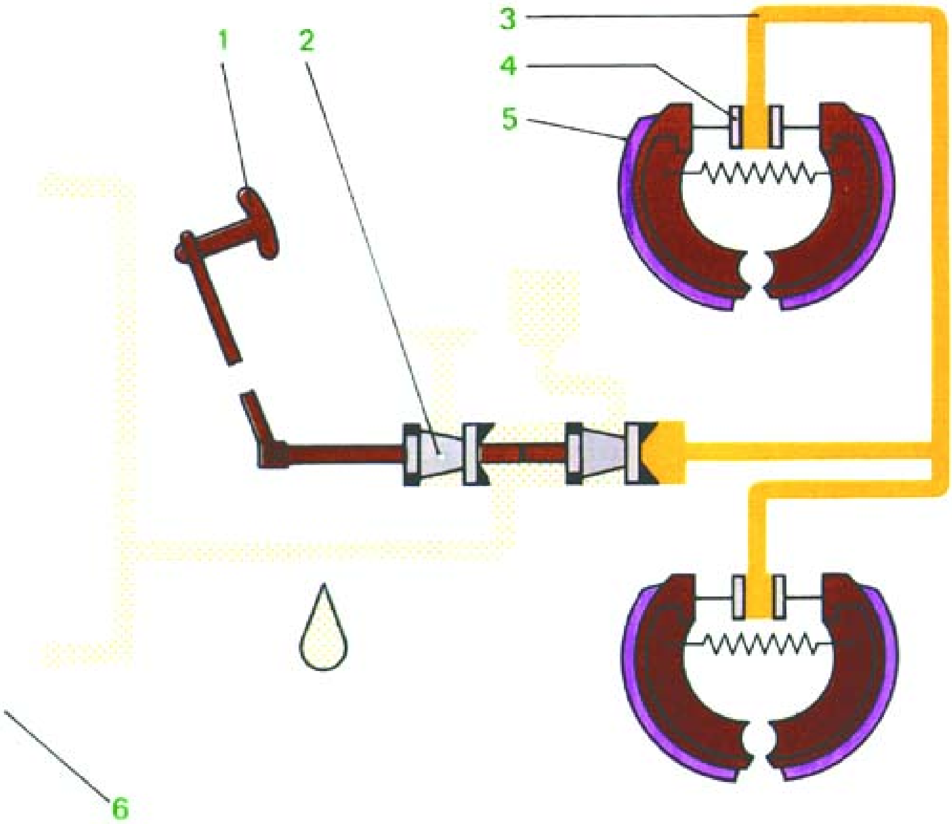

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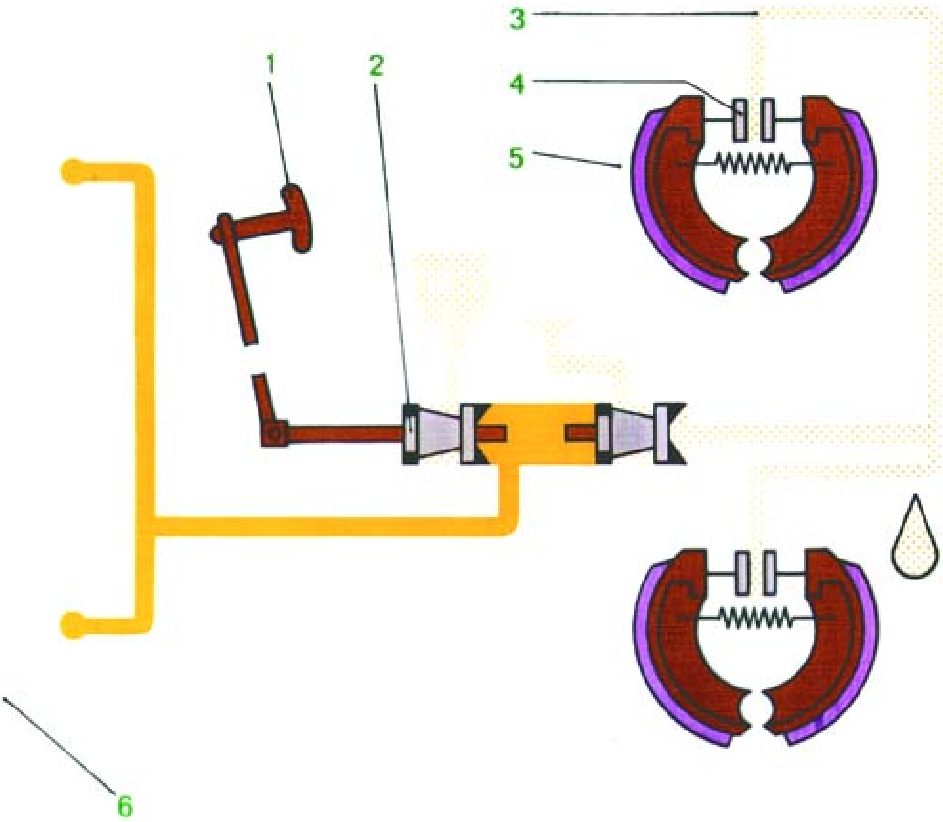

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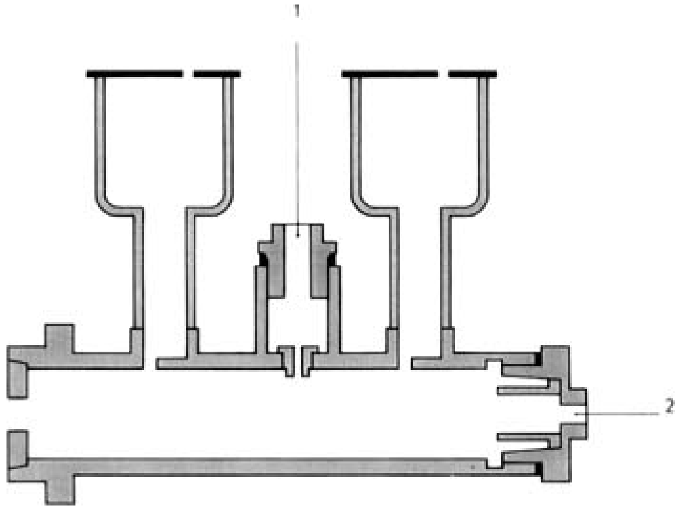

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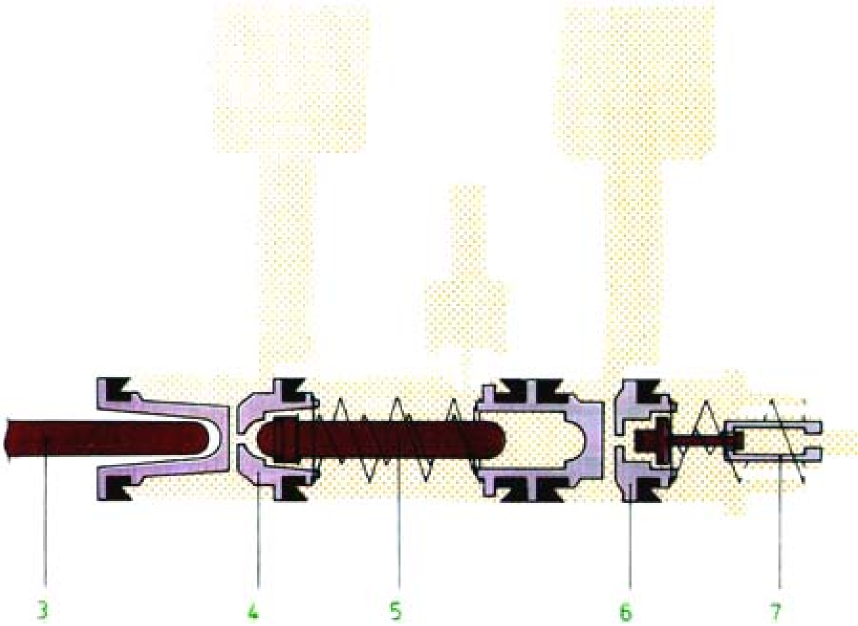

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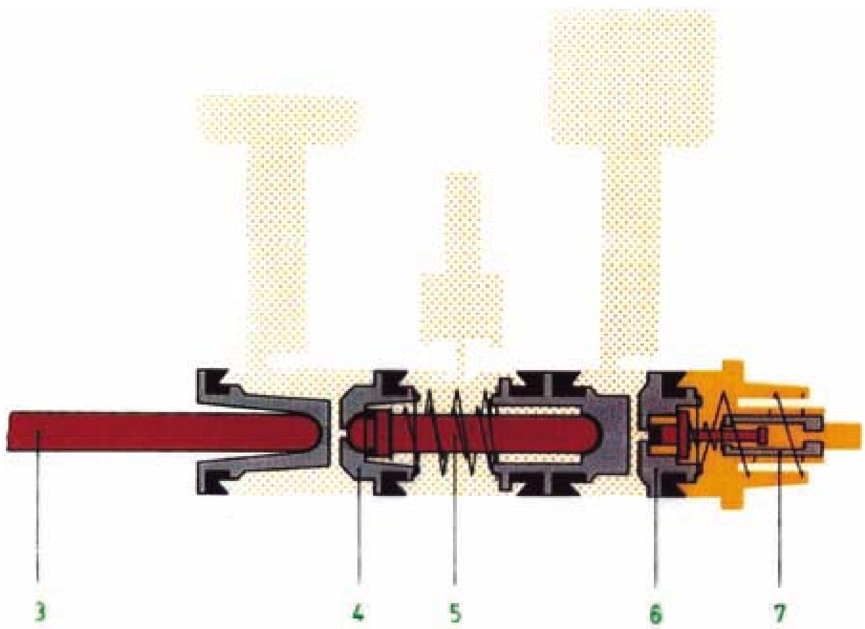

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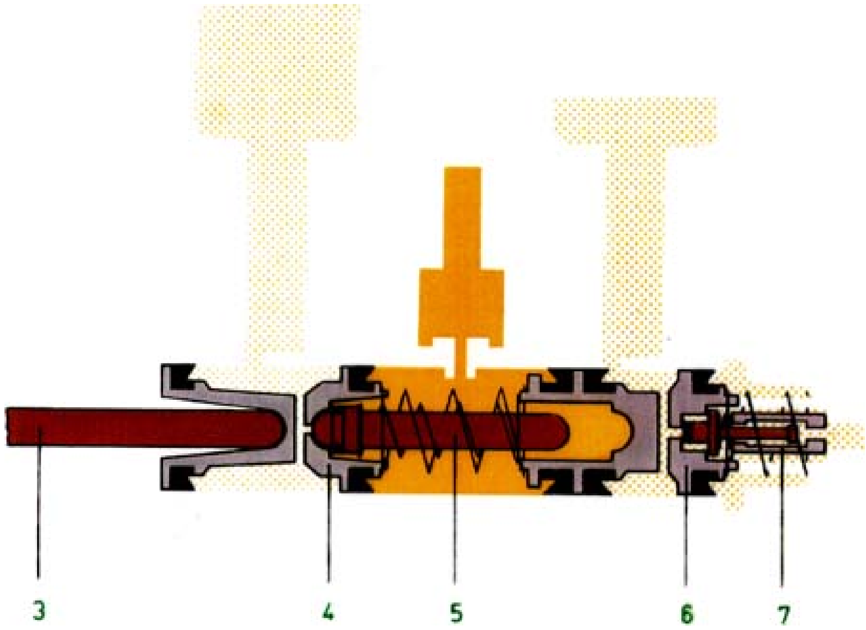

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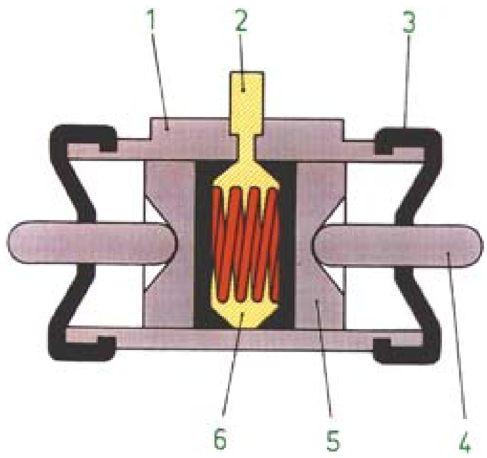

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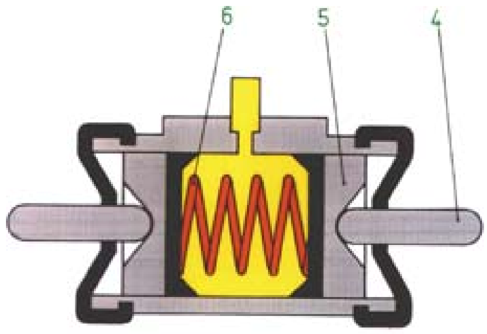

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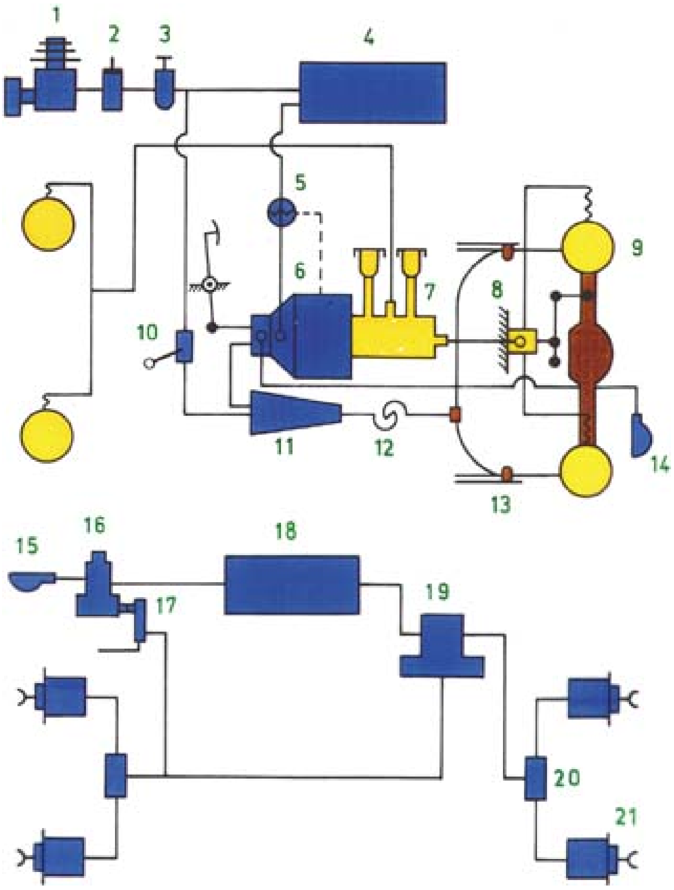

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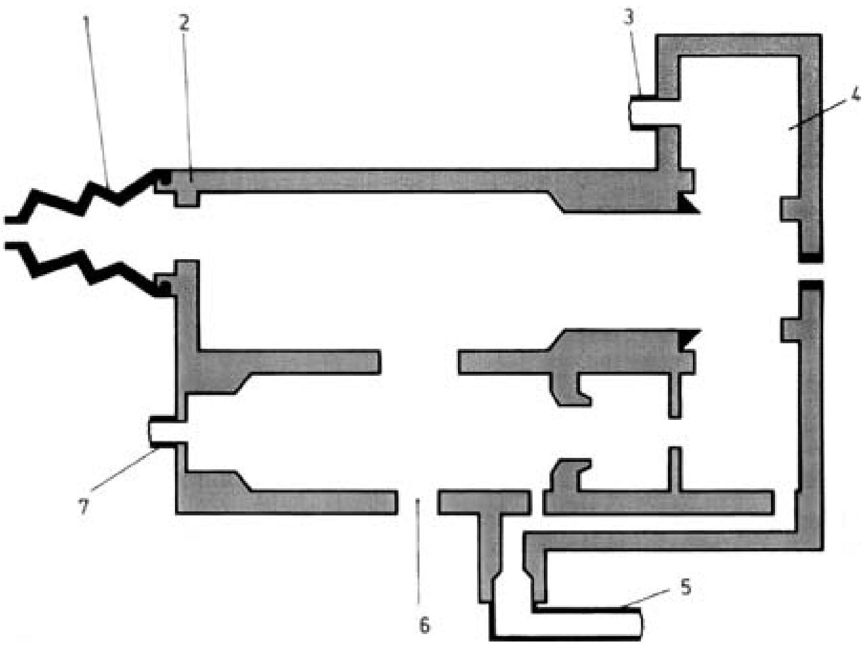

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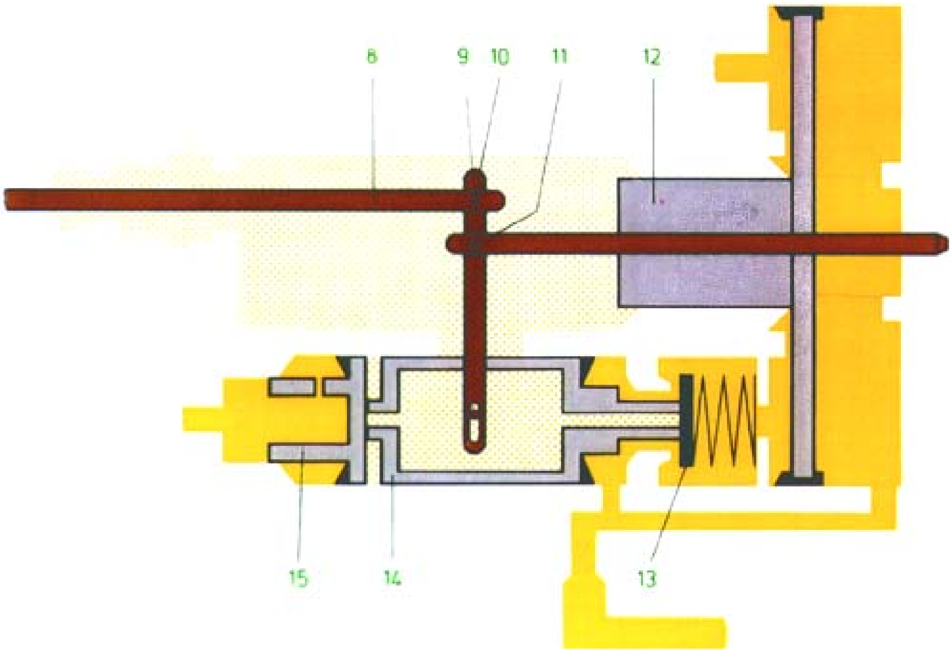

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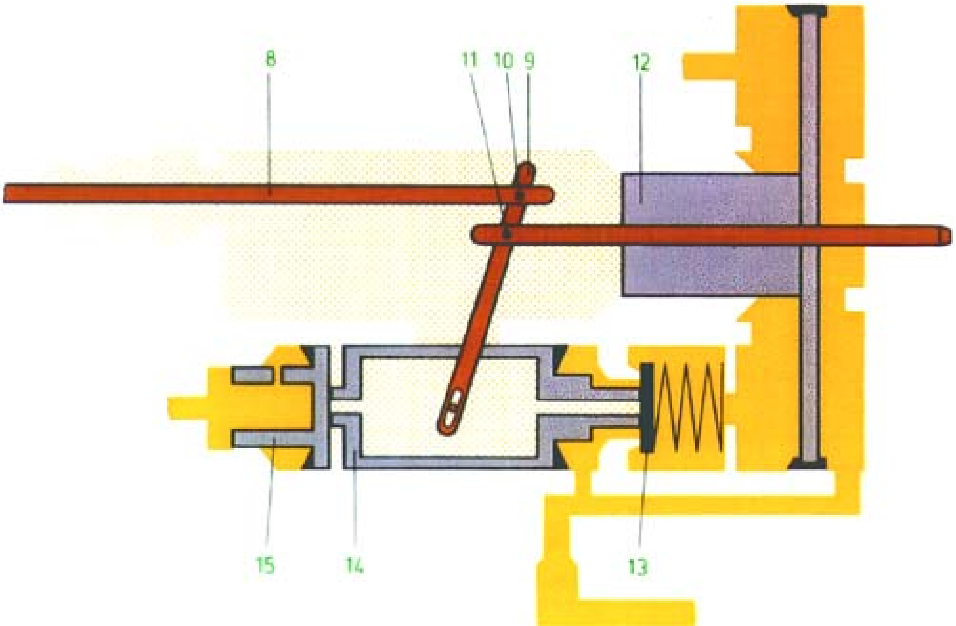

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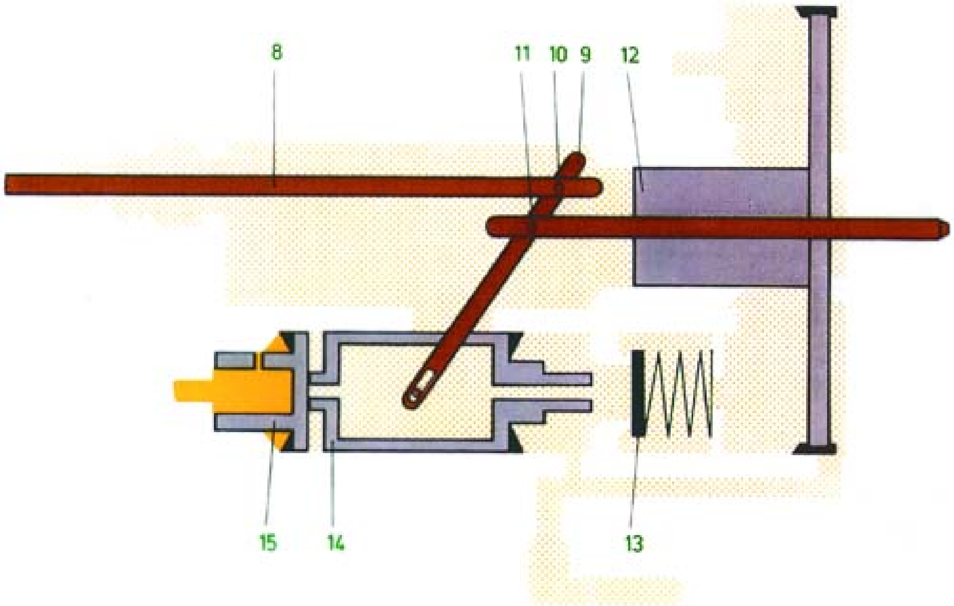

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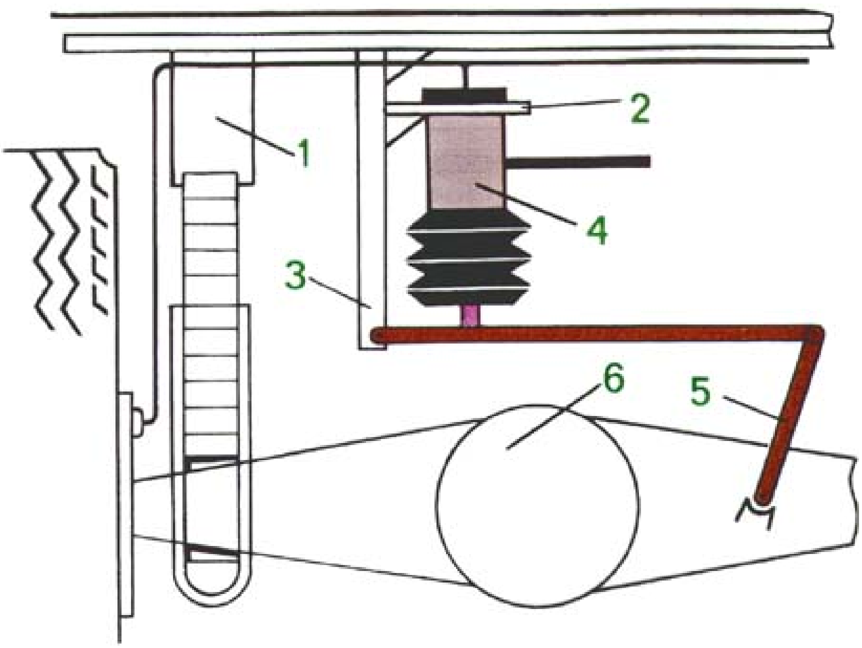

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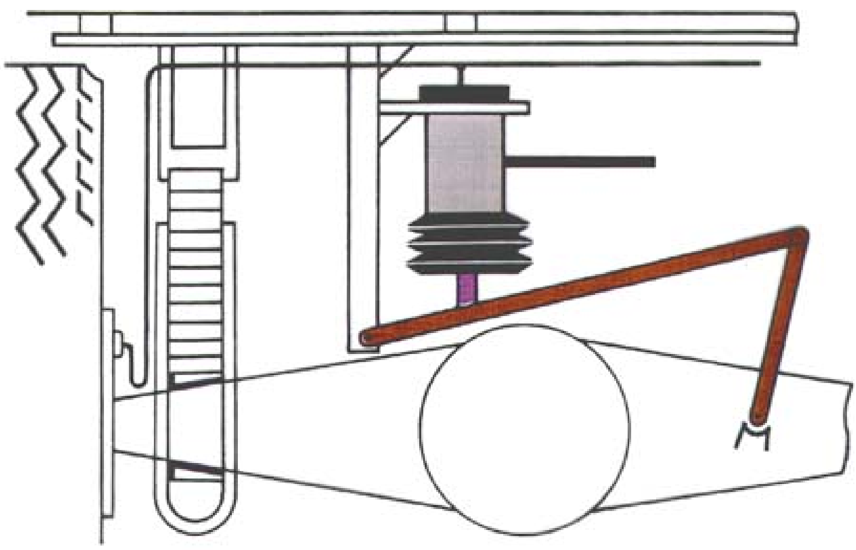

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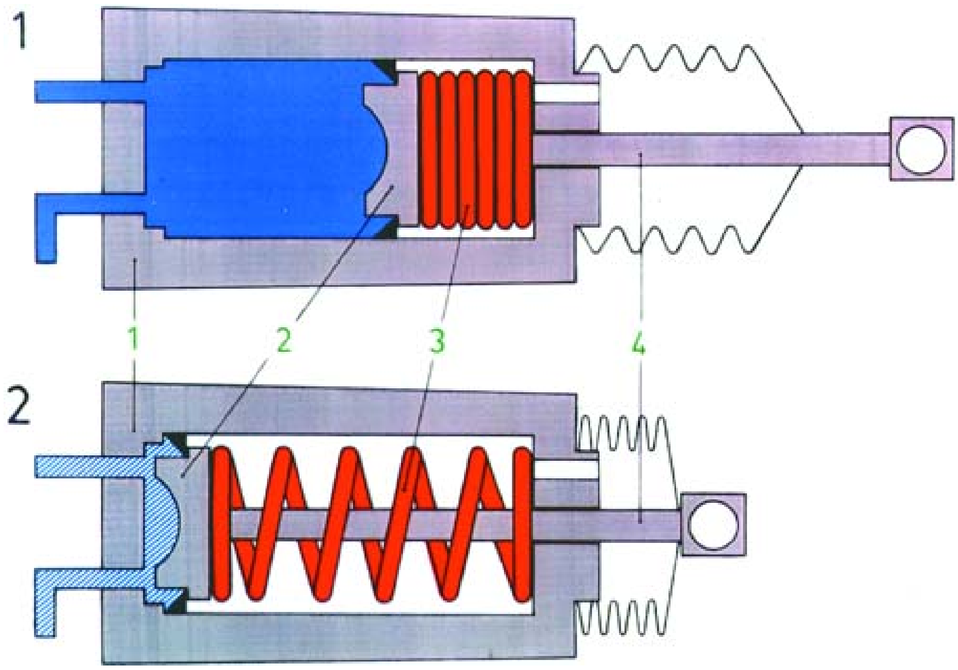

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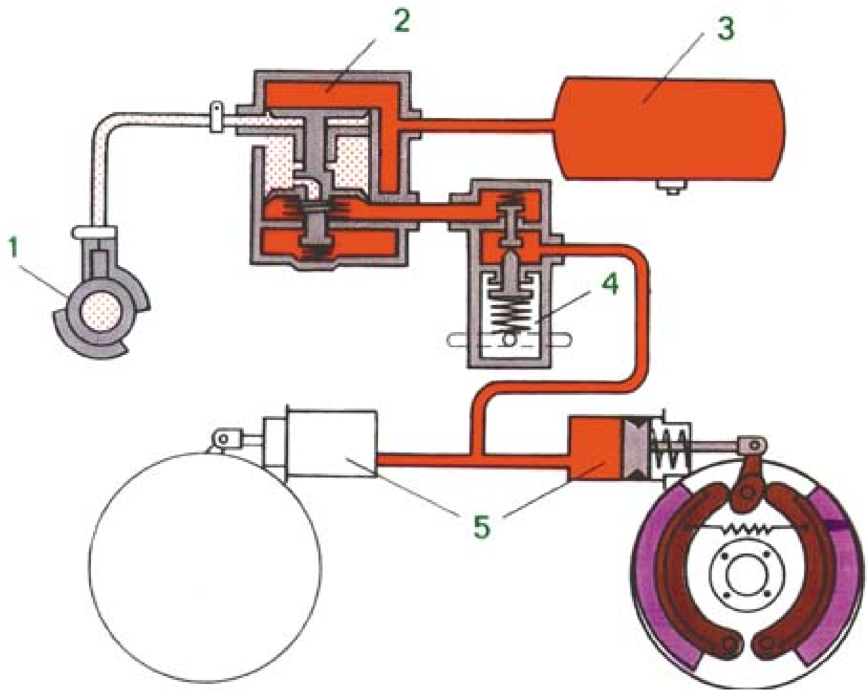

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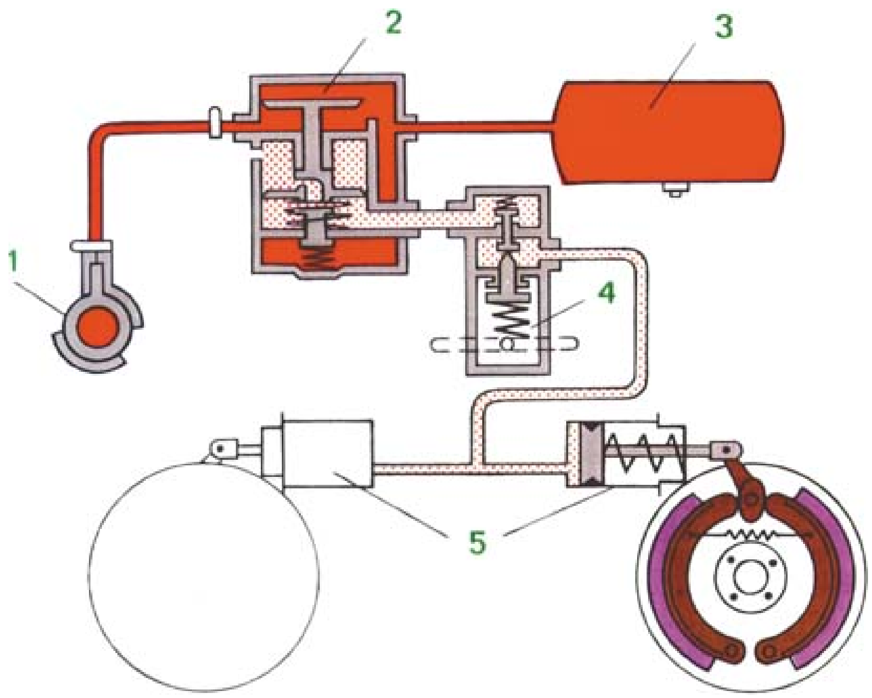
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Steering System – Automotive Transparencies

Table of Contents

Steering System – Automotive Transparencies....1

Steering System – Automotive Transparencies

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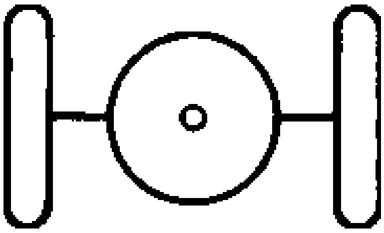

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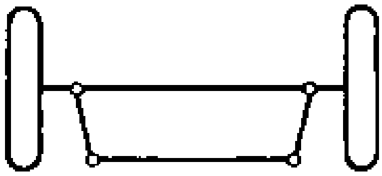

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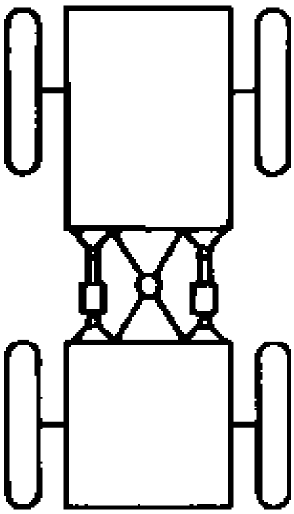

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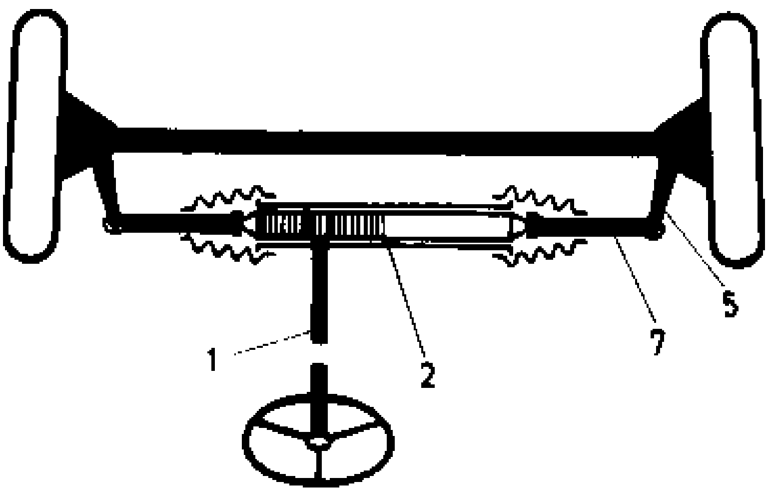

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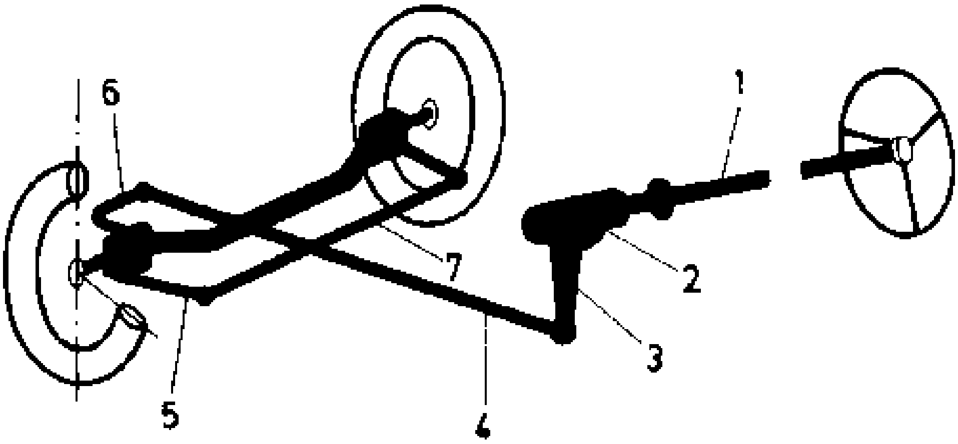

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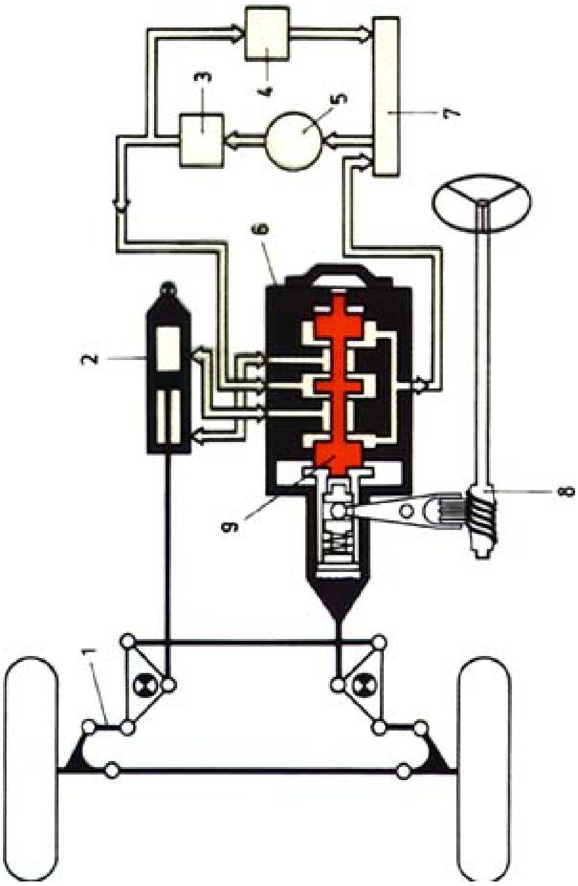

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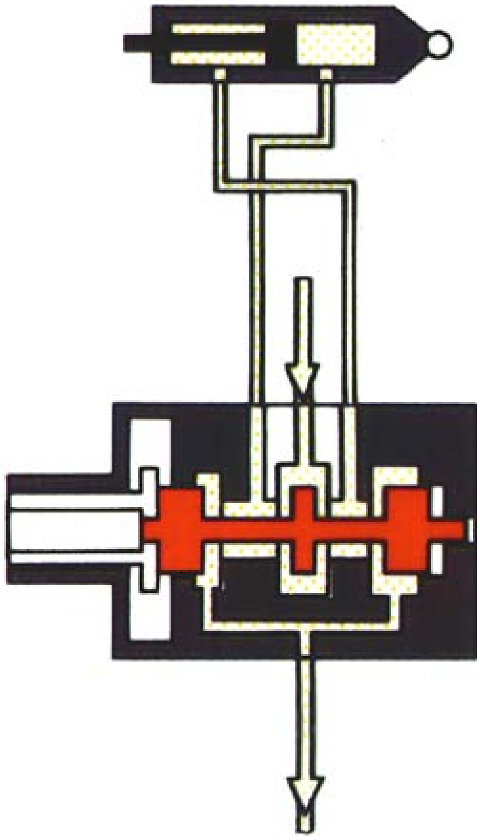

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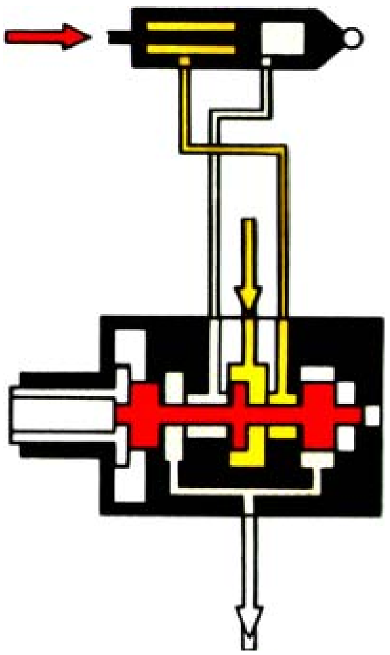

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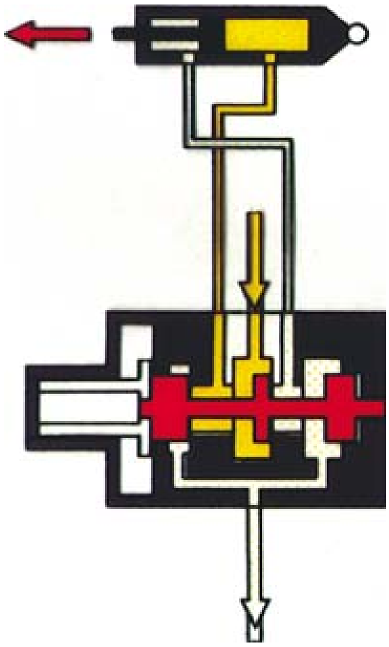

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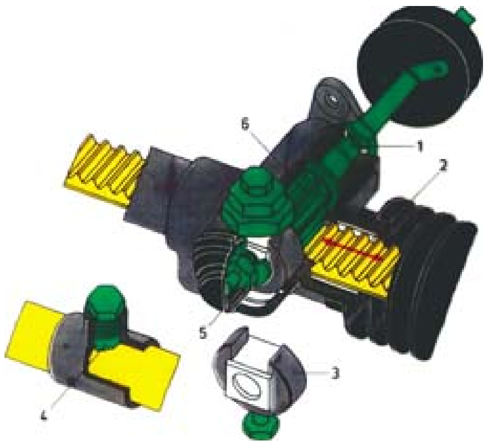

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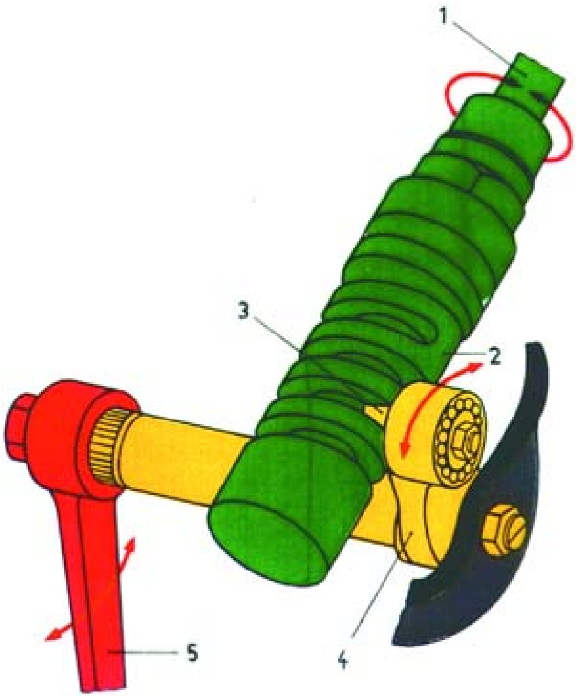

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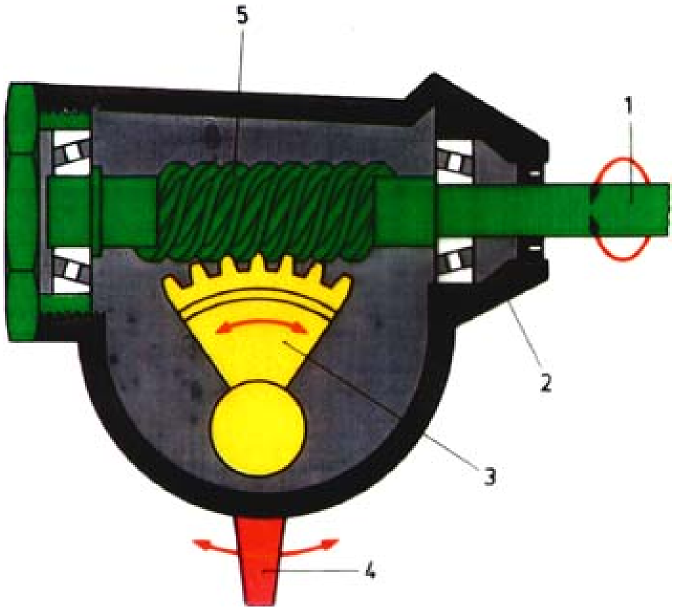

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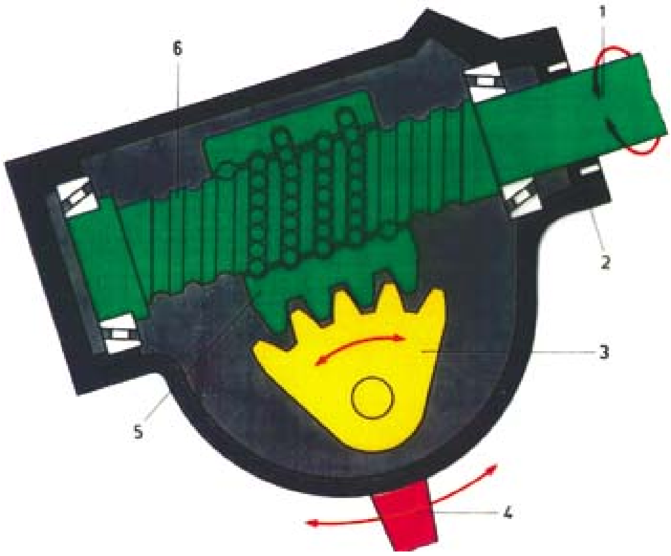

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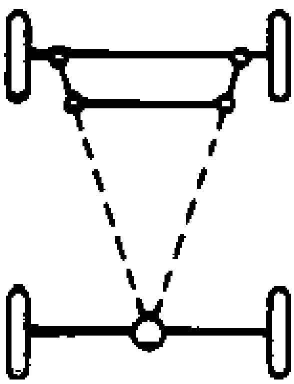

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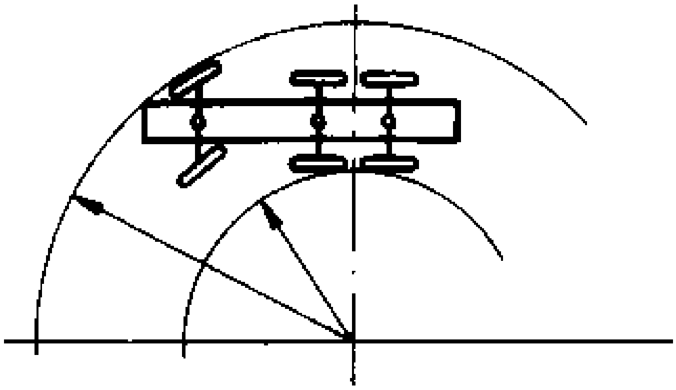

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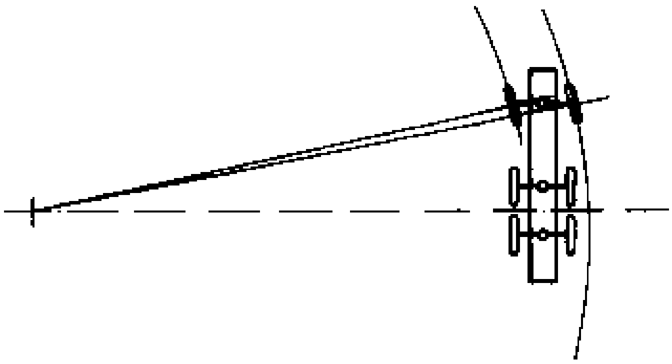

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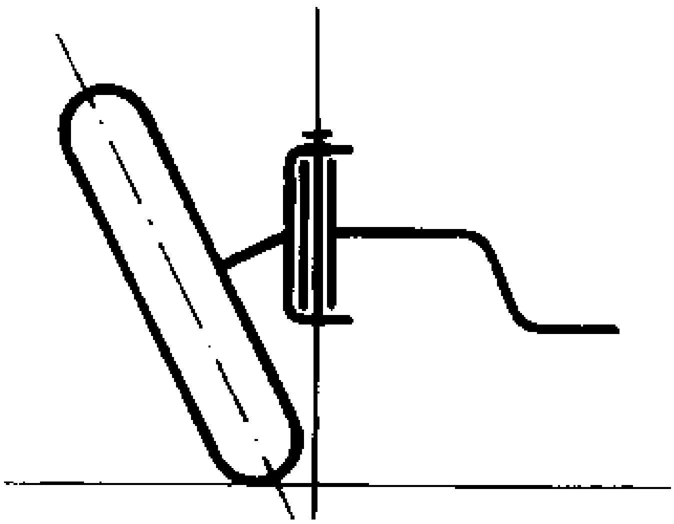

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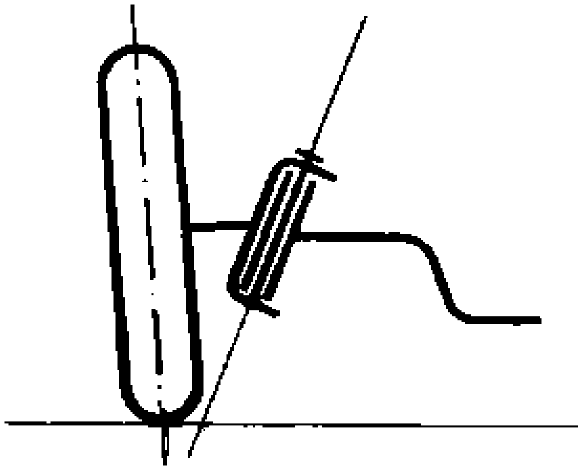

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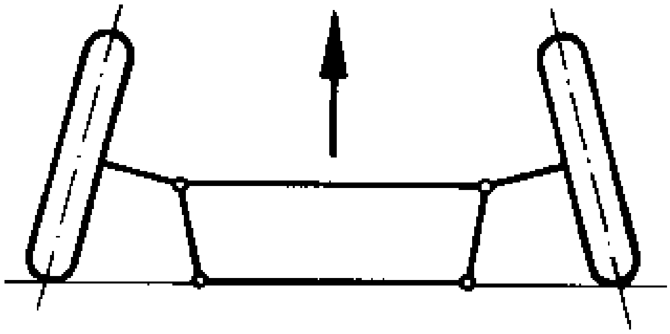

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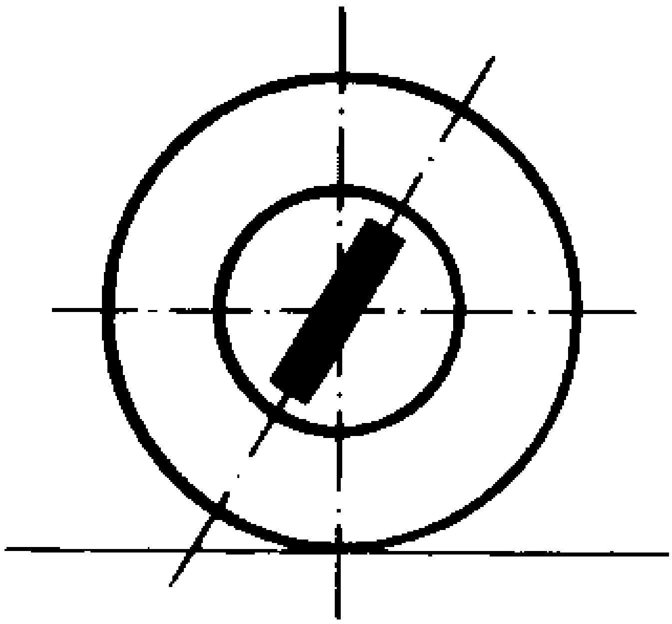

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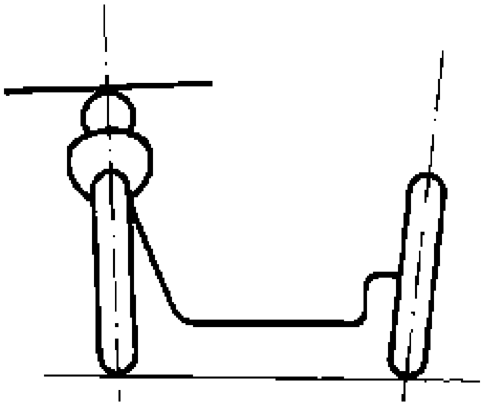

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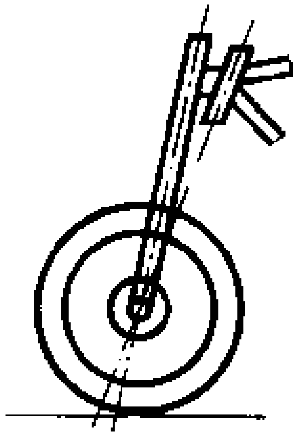

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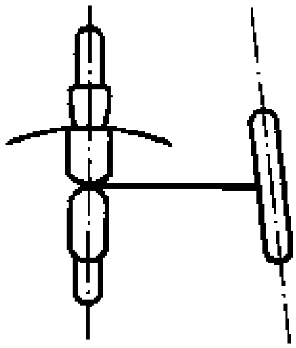

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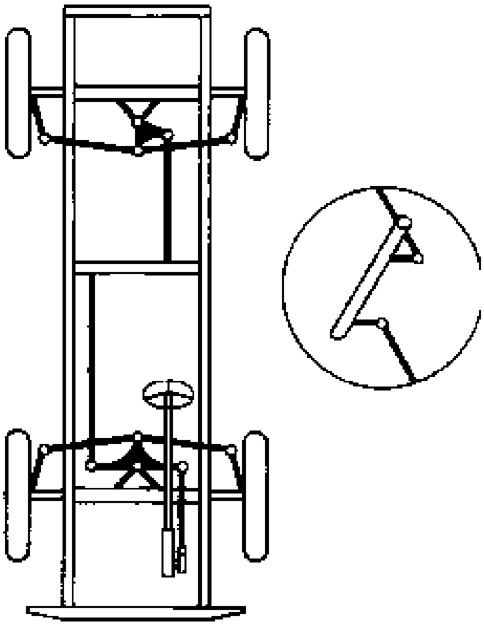

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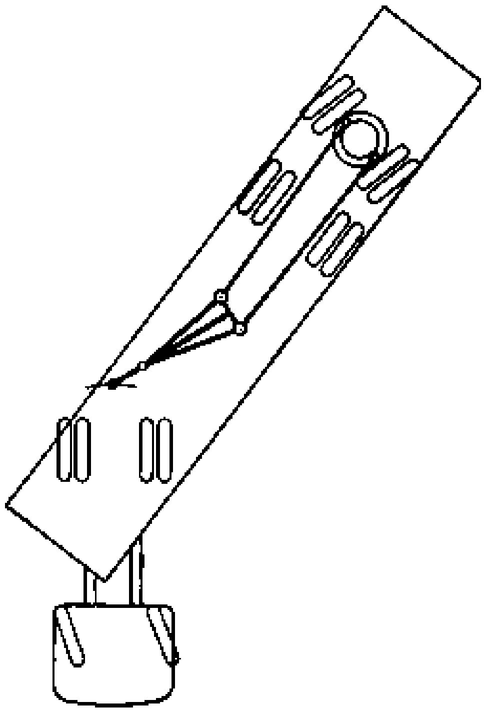

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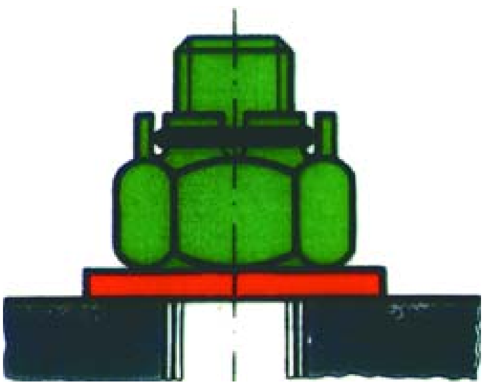

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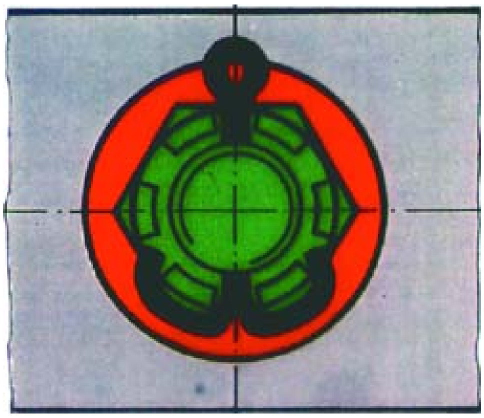

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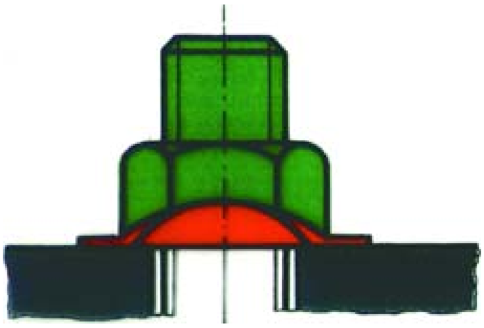

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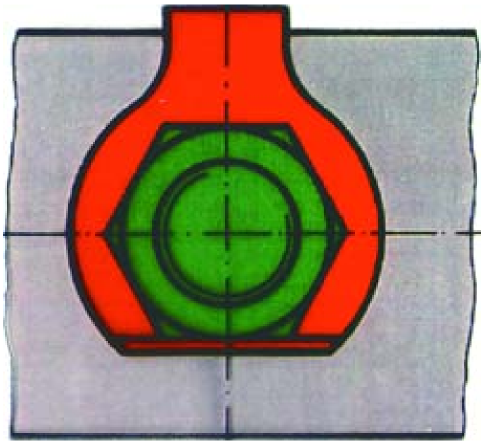

Power Transmission – Course: Motor Vehicle Engineering 2. Textbook for Vocational Training

Table of Contents

Power Transmission − Course: Motor Vehicle Engineering 2. Textbook for Vocational Training............1
Preface......1
1. The clutch......1
1.1. Purpose and operating principle of the clutch......2
1.2. The mechanical clutch......3
1.3. The hydraulic clutch......7
2. Gear change boxes......8
2.1. Mechanical gearboxes......8
2.2. The freewheel......14
2.3. The transfer box......15
2.4. Fluid gear units......16
3. Change of gears......17
3.1. Steering−column gear shift......18
3.2. Floor−type gear shift......18
4. Propeller shafts......18
4.1. The universal joint......19
4.2. The longitudinal propeller shaft......20
4.3. The transverse propeller shaft......20
4.4. Maintenance and repair of propeller shafts......22
5. Final drives......23
5.1. The bevel−gear drive......24
5.2. The worm−gear drive......26
5.3. Other types of drive......27
6. The differential unit......28
7. Lubrication......29
8. General instructions for repairing pear units:......31

Power Transmission – Course: Motor Vehicle Engineering 2. Textbook for Vocational Training

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Textbook for Vocational Training

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Preface

This instruction manual is intended for all students of motor vehicle repair and maintenance.

It can be used as a basis for both theoretical lessons and practical training, and as such provides an essential link between theory and practice.

The manual is divided into three self–contained sections, each dealing with one of the main sub–assemblies of the vehicle: chassis, power transmission and combustion engine.

The instruction manual contains a clear and concise description of the design and function of each of the component parts of the motor vehicle, as well as information about the maintenance, servicing and repair of vehicles.

Numerous illustrations are intended to facilitate the student’s understanding of the technical and engineering problems discussed. Test questions are included at the end of each chapter. These concentrate on points of particular importance to students of motor vehicle engineering and enable the individual student to assess his own progress.

1. The clutch

1.1. Purpose and operating principle of the clutch

To drive a motor car, the output power of the combustion engine must be transmitted to the driving wheels. We distinguish four different kinds of drive:

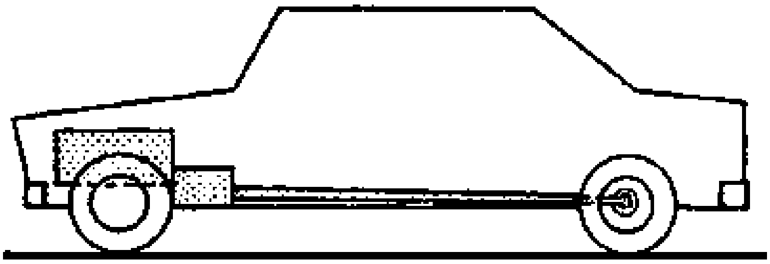


Figure 1/1 Rear–axle drive (front–mounted engine)

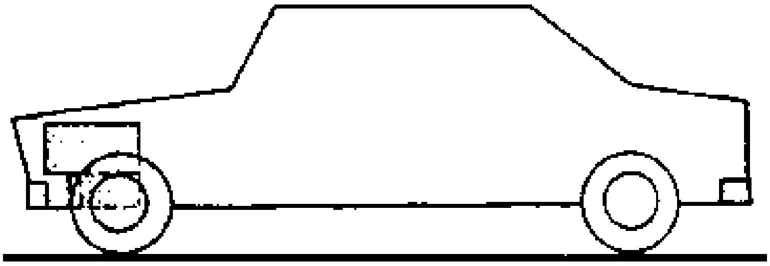


Figure 1/2 Front–axle drive (front–mounted engine)

The most common kind of drive is the rear–axle drive with the engine being front–mounted (Fig. 1/1). Fig. 1/2 shows a frontdriven car. Here, the engine is located in the front of the car, and the front wheels are driven.

Another kind of drive is the rear–axle drive with the engine being rear–mounted (Fig. 1/3).

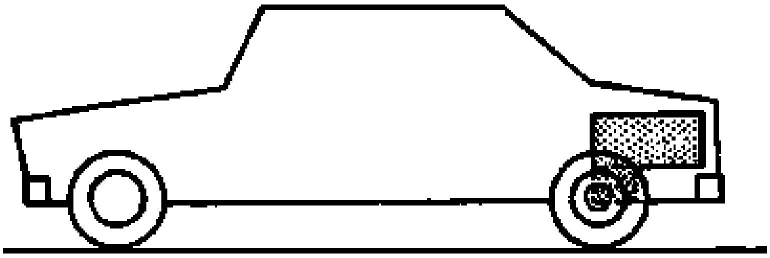


Figure 1/3 Rear–axle drive (rear–mounted engine)

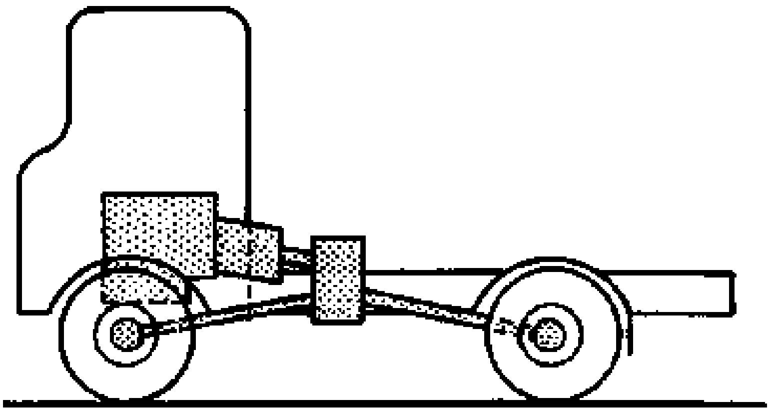


Figure 1/4 Four–wheel drive

The fourth kind of drive is the four–wheel drive (Fig. 1/4). It is used for cross–country vehicles, e.g. agricultural and military vehicles and those used in the building industry. With the four–wheel drive, all axles of the vehicle are driven by an additional transfer box. This increases the driving force and makes it easier for the vehicle to surmount obstacles and cope with heavy soils.

The power is transmitted from the engine through clutch – box – cardan shaft – final drive with differential gear to the wheels (Fig. 1/5).

The power of the engine is first transmitted through the clutch to the gearbox. Usually, the clutch is engaged. It can be disengaged by depressing a pedal, actuating a hand lever, or by electromagnetic operating elements. Disengaging the clutch interrupts the power transmission from the engine to the gearbox, permitting an easy shifting of the different gears.

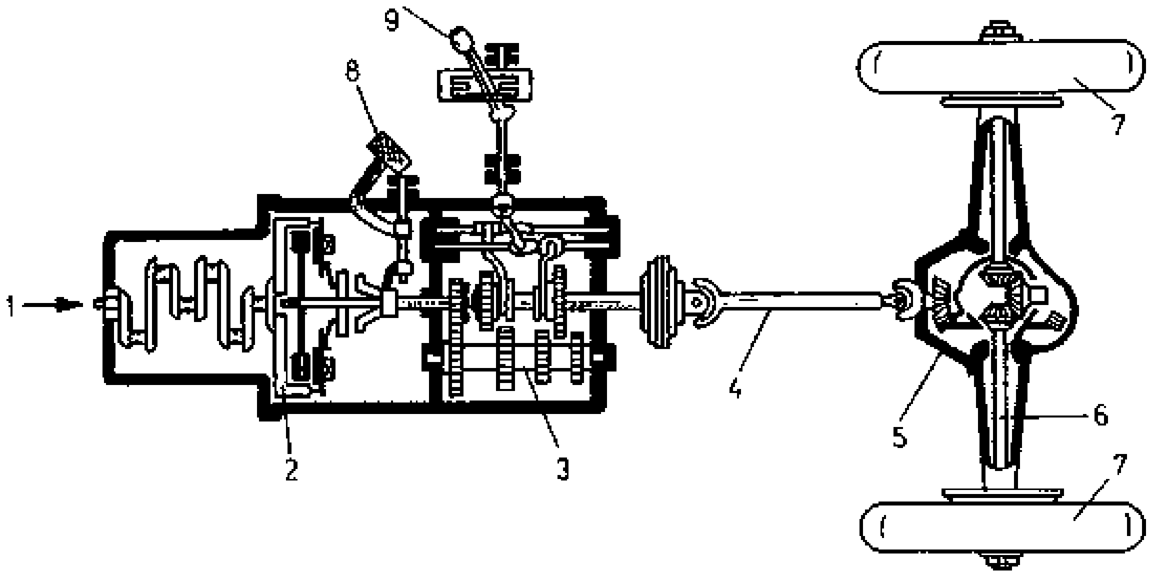


Figure 1/5 Power transmission

1 engine; 2 clutch; 3 gear–change; 4 cardan or propeller shaft; 5 differential unit; 6 axle; 7 wheels; 8 clutch pedal; 9 gear shifting lever

When starting the stationary vehicle, the clutch ensures that the speed of the gearbox is gradually adapted to that of the engine.

The clutch is attached to the engine's flywheel. The clutch bell, which is secured to the gearbox and connects it to the engine block, protects the clutch from damage and dirt.

Basically, there are three types of clutches:

1. Mechanical clutches
2. Hydraulic clutches
3. Electric clutches

1.2. The mechanical clutch

The mechanical friction clutch has remained the most common type of clutch until this day. The torque is transmitted by friction. As to their design, friction clutches are classified into cone clutches, single dry plate clutches, multiple dry disk clutches and multiple–disk clutches running in oil.

Because of their importance only dry clutches shall be dealt with in detail in this manual. Dry clutches are used in most vehicles. Fig. 1/6 is a cross section of a single dry plate clutch.

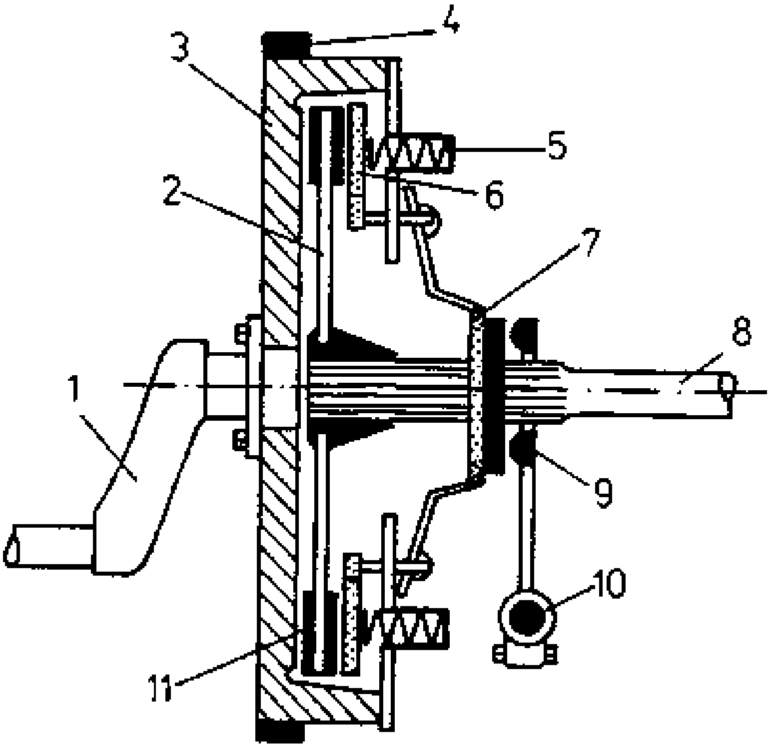


Figure 1/6 Single dry plate clutch

1 crankshaft; 2 catch plate; 3 flywheel; 4 starter rim gear; 5 pressure spring; 6 thrust plate; 7 thrust collar; 8 drive shaft; 9 release claw; 10 release shaft; 11 clutch facing

The principle underlying this design is that two disks are used to connect the engine to the drive. One of them is the engine's flywheel. The other is positioned on the drive shaft of the gear unit and can be shifted.

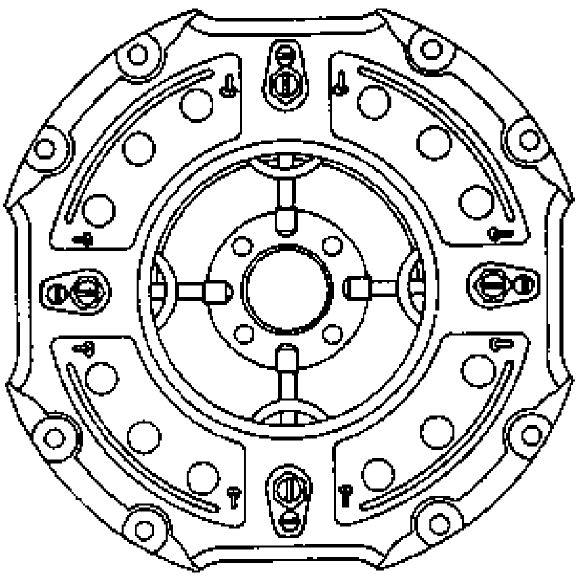


Figure 1/7 Ring spring clutch

The two disks are forced against each other by an automatic clutch fixed to the flywheel. A non–positive connection is made. The contact pressure is produced by ring springs, a central unit pressure spring in the central of the automatic clutch or by a plate spring (Figs. 1/7 and 1/8). Throwing in the clutch compresses the springs causing the contact pressure to be relieved. The catch plate is released, and the transmission of power is interrupted.

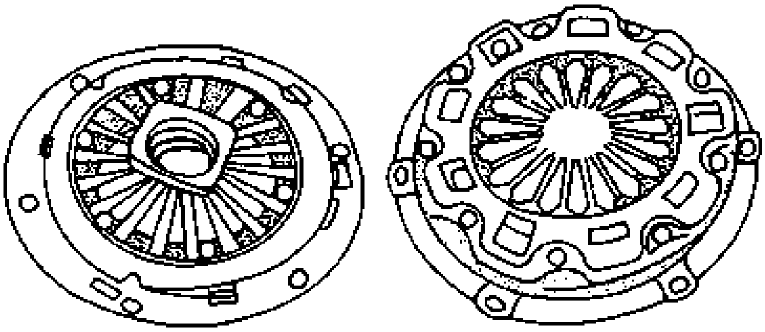


Figure 1/8 Belleville spring clutches

The clutch disk has slots dividing it into 12 to 16 sectors. Every other sector protrudes from the disk plane by some tenth of a mm parallel to it. This causes the disk to be compressed evenly, even if a moderate pressure is applied, ensuring an even wear of the friction facing.

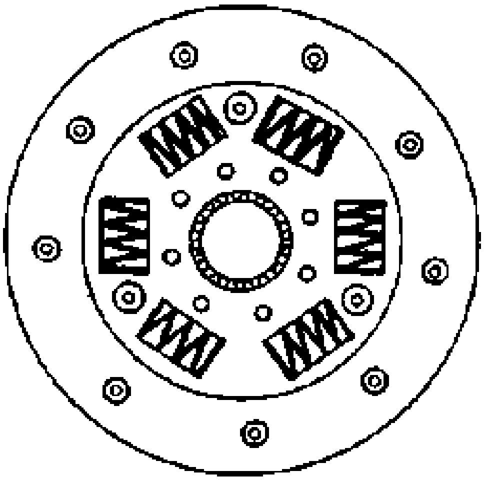


Figure 1/9 Torsional vibration damper with damping springs

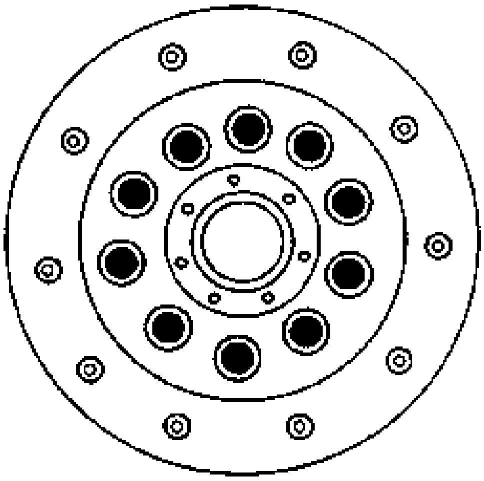


Figure 1/10 Torsional vibration damper with rubber elements

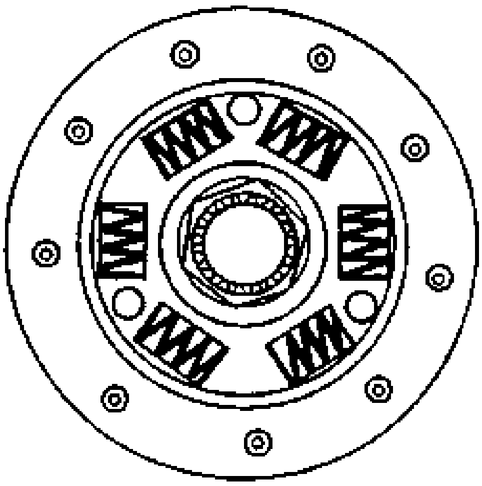


Figure 1/11 Torsional vibration damper with damping springs and adjustable internal friction

The clutch may be provided with dampers ensuring a smooth power transmission and preventing the friction facing from being subjected to excessive load during starting (Figs. 1/9 to 1/11). There are, however, also clutch disks without dampers. In this case, the friction facing is simply riveted to a flat steel plate. Friction facings are riveted to both sides of the clutch disk.

Like the brake lining, the friction facing consists of asbestos fibre cloth reinforced with brass wire, cotton fabric and compressed asbestos fibre compound. From this material, annular facings are made which are then fastened to the clutch disk by means of hollow aluminium or copper rivets, in the centre of the clutch disk there is the star member provided with internal toothing. It is riveted to the steel plate.

The internal toothing and the toothing of the gearbox drive shaft form a positive connection. The ring spring clutch is fitted with between 6 and 9 or more helical compression springs arranged annularly on the thrust plate. This enables a uniform pressure to be applied. In most cases, the springs are protected by sleeves. Central spring clutches have a strong helical spring positioned in the centre of the clutch cover. It produces the contact pressure and is provided with a thrust roller bearing.

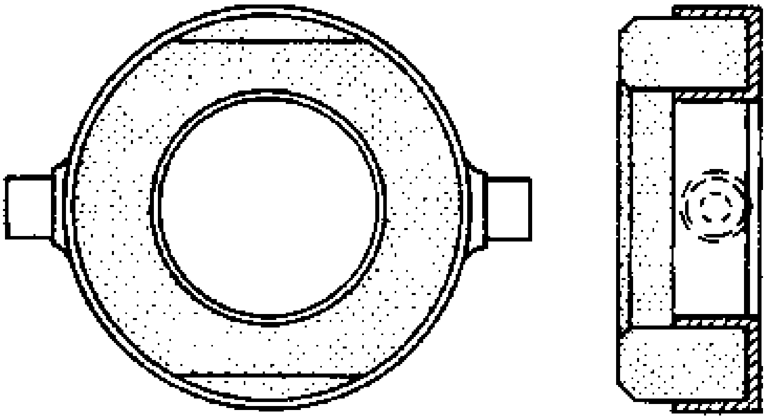


Figure 1/12 Clutch release bearing with graphite ring

With Belleville spring clutches (Fig. 1/8) the contact pressure is produced by the Belleville spring.

The clutch release bearing enables the clutch disk to move when throwing out the clutch.

Fig. 1/12 shows a clutch release bearing with graphite ring, whereas Fig. 1/13 illustrates a clutch release bearing with thrust roller bearing. They are fitted into the clutch release yoke (Fig. 1/14) and secured with clips. The bearings can be tilted in their seat. The release yoke is connected to the clutch shaft. The clutch shaft may be operated either by a hydraulic cylinder (similar to a wheel–braking cylinder) with brake fluid or by a linkage. The clutch thrust bearing exerts pressure on the release bearing. This compresses the springs thus interrupting the flow of power.

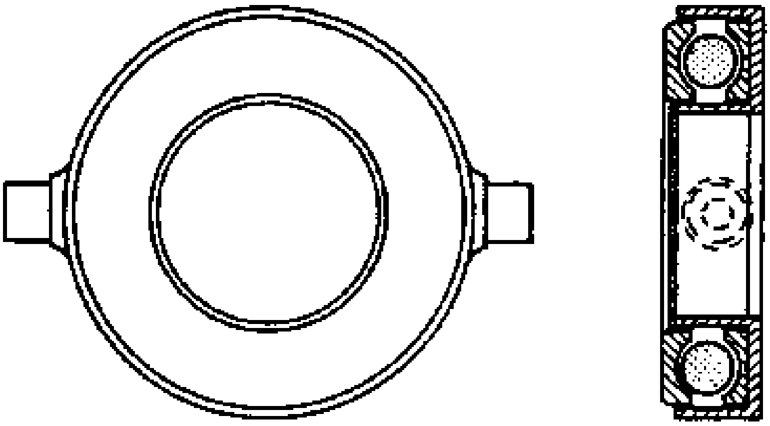


Figure 1/13 Clutch release bearing with thrust roller bearing

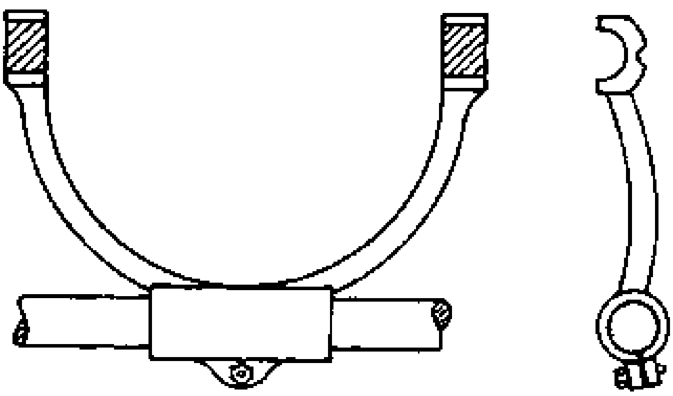


Figure 1/14 Clutch release yoke with clutch shaft

The release bearings are maintenance–free. The multiple dry disk clutch aims at enlarging the friction area. It is mainly used for heavy motor lorries. The operating principle is the same as that of the single dry plate clutch, however, several clutch disks faced on both sides and axially sliding on the drive shaft are used. A driving plate of cast steel is inserted between the clutch disks. It rotates positively with the flywheel as it is connected to it by grooves or bolts, but can be displaced in axial direction. The thrust springs force the thrust plate, the clutch disks and the driving disk as a whole package against the flywheel.

As already mentioned, the clutch remains engaged in its normal state. To prevent it from slipping, i.e. from being constantly under full spring pressure, there must always be a clearance of 2 to 3 mm between the release bearing and the slip ring. If there is a clearance, the clutch pedal moves easily the first 20 to 30 mm max. If there is no clearance, the clutch slips and gets hot resulting in excessive wear of the facing. If extreme heat develops the facing burns up. This is indicated by the smell. Another problem arises if the clutch clearance is too large. The pedal travel is then insufficient for the complete disengagement of the clutch, resulting in an overloading of the shifting mechanism, the gear–change box and the toothed gears. A noise can be heard when engaging a gear, or gears cannot be engaged at all. The clutch is readjusted by turning the adjustment screws located at the linkage or the clutch cylinder. If the clutch cannot be readjusted, the facing is to heavily worn. The clutch disk has to be replaced. When doing such a repair work, the condition of the flywheel and the thrust plate should be checked as well. If there is oil on the facing, the clutch may also tend to slip. If this occurs, the gaskets of the gearbox or the engine must be checked and replaced, if necessary, in order to ensure the proper functioning of the clutch.

1.3. The hydraulic clutch

The term “hydraulic clutch” denotes a clutch which utilizes the forces of gravity of a liquid for the transmission of power. The primary wheel is the driving part. The forces of gravity are produced here by acceleration, while in the secondary wheel, which is the driven part, they are generated by deceleration.

These clutches consist of two parts provided with radial ribs, i.e. the pump wheel and the turbine wheel. The pump wheel is connected to the crankshaft of the engine and takes the function of the flywheel. The two wheels face each other, forming a cavity which is divided into small chambers filled with a thinbodied oil. When the engine drives the pump wheel the centrifugal force causes the oil to flow towards the outer circumference thus making a circular motion in the cavity. The motion exerts a lateral pressure on the ribs of the turbine wheel (secondary wheel). As soon as the liquid pressure exceeds the resistance of the turbine wheel (which occurs at a certain engine speed), the turbine wheel is forced to rotate by the pump wheel (primary wheel).

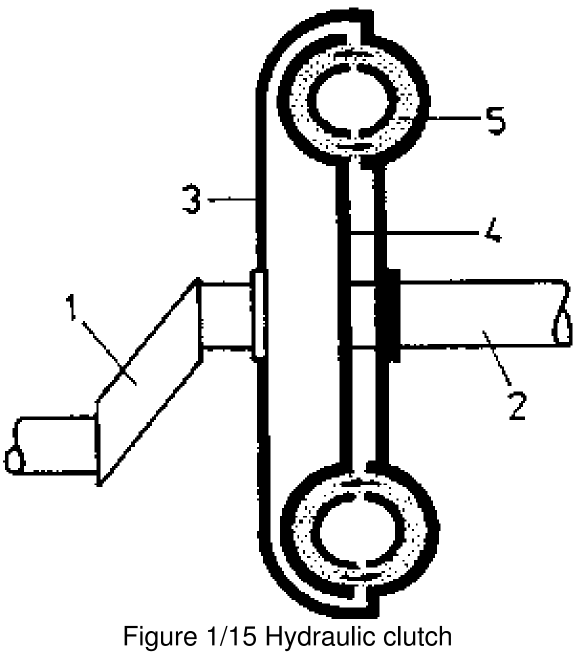


Figure 1/15 Hydraulic clutch

1 crankshaft; 2 gear shaft; 3 pump impeller; 4 turbine wheel; 5 radial ribs

Fig. 1/15 shows a hydraulic clutch. The power generated by the engine, i.e. the torque, is thus transmitted to the gearchange box. The output torque of the turbine wheel is always equal to the input torque of the pump wheel. This means that the efficiency of the output power is proportional to the input power. Power, in this case, means speed. The hydraulic clutch is particularly suitable as a starting clutch.

What is additionally needed is a separating clutch for changing the gears. In an automatic gear unit the separating clutch can be dispensed with.

Note:

Shift the lever to “idling” when working on mechanical gear unit, and to the zero position when working on automatic units.

Test questions:

1.1. What do you understand by “transmission of power”?

1.2. Which kinds of drives do you know?

1.3. Explain the power train.

1.4. What is the function of a clutch?

1.5. What do you understand by “mechanical clutch”?

1.6. Describe the construction of a single dry plate clutch.

1.7. What is an automatic clutch?

1.8. What is a torsinal vibration damper? What is its function?

1.9. Describe the construction of a clutch disk.

1.10. What do you have to check when a clutch slips?

1.11. Describe the construction of a hydraulic clutch.

1.12. Describe the operating principle of a hydraulic clutch.

1.13. What do you have to bear in mind when doing repair work on a motor vehicle with a hydraulic clutch?

2. Gear change boxes

2.1. Mechanical gearboxes

The engine of a motor vehicle generates sufficient power within a particular speed range only. Therefore, it should always run in the proper speed range for the different driving speeds or load conditions to prevent it from being overloaded. From this we can conclude that, while the engine power remains the same, a greater force should be available for the driving wheels. A motor vehicle may move the faster the less force is required for rotating the wheels. This is the reason why motor vehicles are equipped with gear−change boxes. Earlier these had three gears but today they are ever more stepped in order to allow engines of a low power to be used. Large and heavy vehicles today have as many as 8 to 10 gear steps. The gear unit is housed in a casing and generally forms an assembly including the clutch bell and the engine. The individual parts are screwed to each other. The gear unit can be operated either from a steering−column or floor−type gear shift. Steering−column gear change is mainly used in passenger cars. The power train is illustrated in Fig. 1/5.

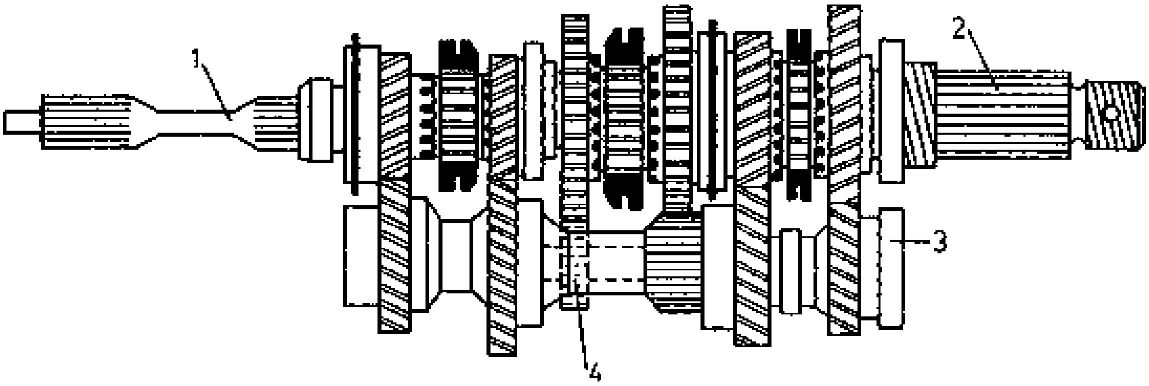


Figure 2/1 Gear box (for rear–axle drive)

1 drive shaft; 2 mainshaft; 3 countershaft; 4 reversing gears

In rear–axle driven vehicles the power is transmitted from the crankshaft via the clutch to the drive shaft, the countershaft and the main shaft (Fig. 2/1) from where it is transmitted via the propeller shaft to the final drive with the differential gear and on to the wheels by full–floating axle shafts. Fig. 2/2 shows a gearbox for a front–driven vehicle.

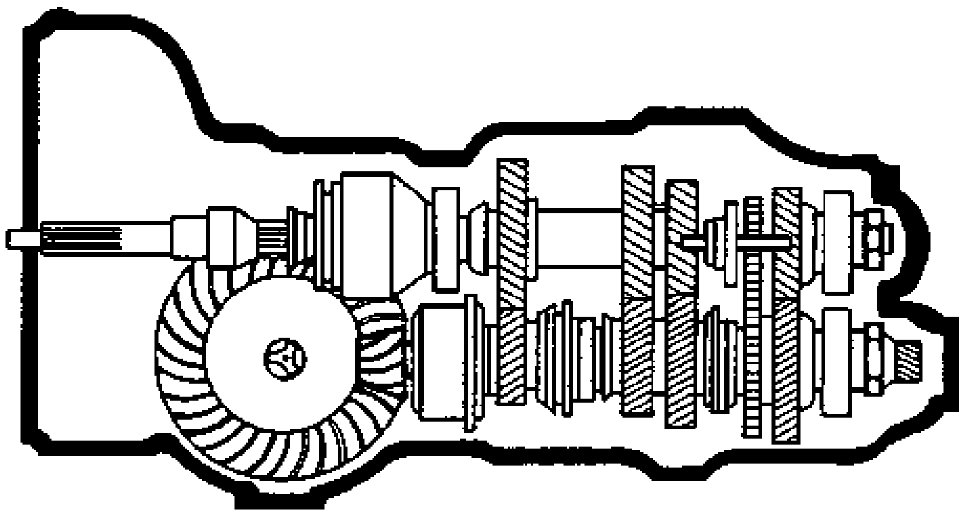
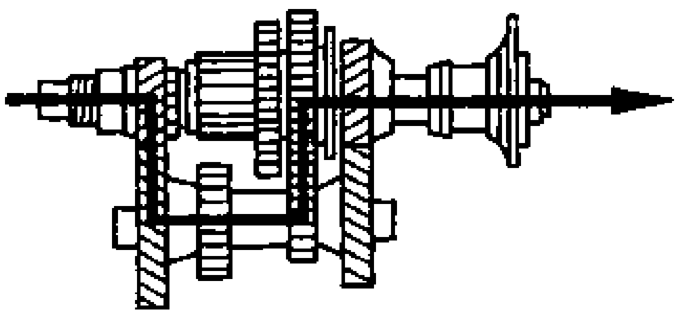


Figure 2/2 Gear–change box (for front–axle drive)

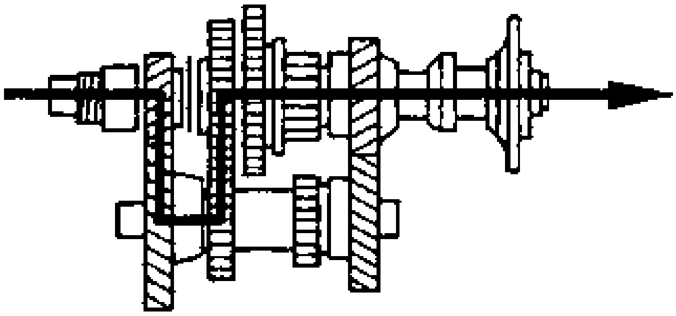
Intermediate gears permit the backward driving of the car. The gear unit should have a high wear resistance, run very smooth and be easily shiftable. The automatative industry still uses mainly the mechanical toothed gear unit. Its construction is simple and sturdy, and it features a high efficiency. Fig. 2/3 shows the power train in a mechanical four–speed gearbox for the individual gears. It is a two–shaft gear unit. The unit shown in Fig. 2/1 is a three–shaft unit with additional shaft and reversing gears.

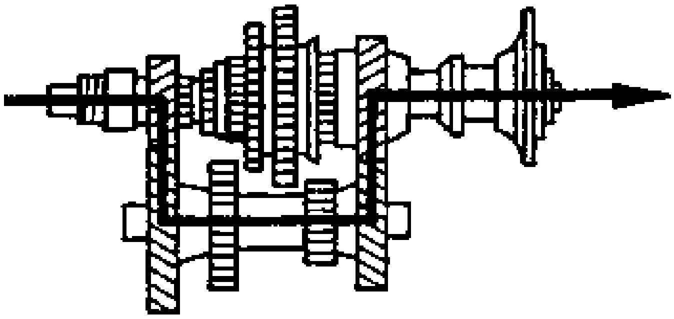
The two–shaft gearbox is a sliding–mesh gear box. The driving gear of the countershaft and the third gear have helical teeth contributing essentially to the low noise of the gear unit.

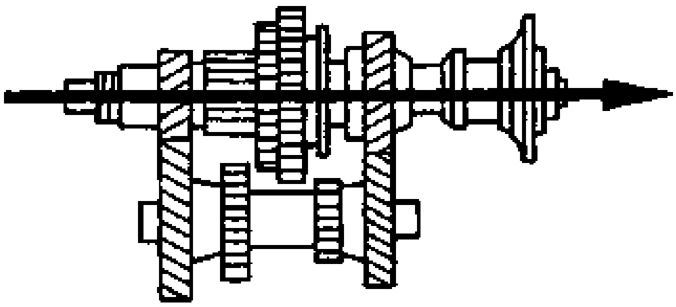
Figure 2/3 Power transmission in a four–speed gear–change box



I. first gear;


II. second gear;


III. third gear;


IV. fourth gear

With straight–toothed gears a clicking noise is heard due to the clearance between the gears. For selecting the different gears the sliding gears are positioned axially on the grooved main shaft, the grooves causing them to rotate positively. The toothed gears of the countershaft are fixed on it (incorporated or pressed on). The gear shafts are held by antifriction bearings in the gearbox casing and run in oil.

Gears are changed (Fig. 2/4) in mechanical toothed gear units by shifting a lever connected to a ball–shaped assembly.

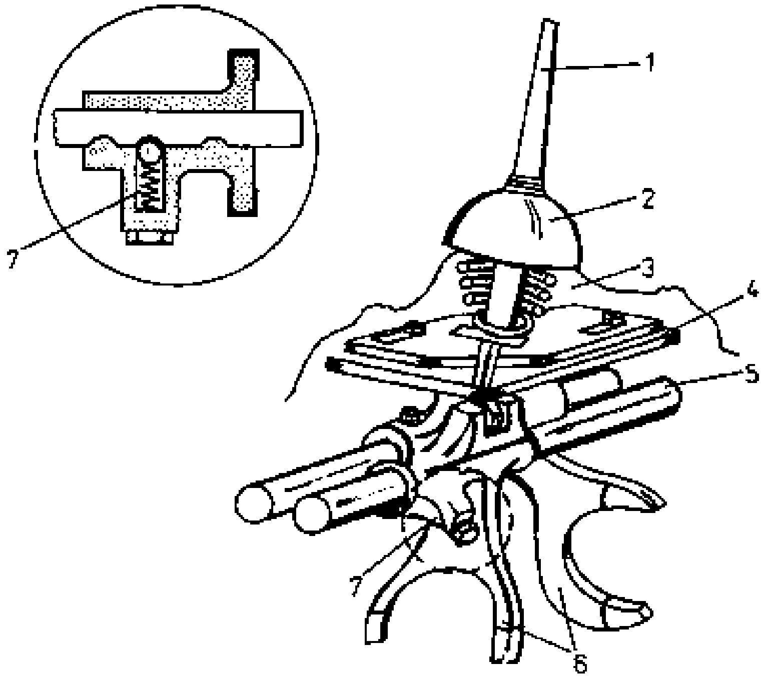


Figure 2/4 Gear changing mechanism

1 gear shifting lever; 2 joint; 3 shift arbor; 4 shift plate; 5 main shaft; 6 shifting fork; 7 shifting fork detent

The shift forks displace the gears as required for the desired speed. In most cases the shift forks are guided by shifter shafts. An interlock prevents the shifter shafts from moving uncontrolled. In addition, interlocks are incorporated to prevent simultaneous engaging of two gears.

The interlock consists of small balls which are forced against the shifter shaft by springs. The shifter shaft is provided with several despressions. The centre depression is for idling. To engage the reserve gear of a vehicle, another detent has to be overcome.

2.1.1. The sliding−mesh claw−clutch gearbox

The sliding−mesh claw−clutch gearbox (Fig, 2/1) provides for even greater noise reduction and easier gear shifting. All toothed gears, except the first and reserve gear, are helicaltoothed and in constant mesh. The gear shafts are carried in several roller bearings positioned in the casing. Rotary shaft seals are used to seal off the gear box casing. With this type of gear unit the gears are shifted by displaceable claw clutches which couple the gears to the main shaft. The claws are rugged and have a low circumferential speed as a result of their small diameter. They are also moved by shift forks.

The claws are of a robust design and not easily damaged even by wrong shifting.

2.1.2. The synchromesh gear unit

The shiftability of the sliding−mesh claw−clutch gearbox may be improved by synchronisation (synchronous = running at the same speed). It facilitates shifting and eliminates the shifting noise. This increases the life of the individual gears and the unit as a whole. A locking ring is provided to enable gear selection only after full synchronism between shaft and gear has been obtained.

The gears of a gearbox are mainly subjected to surface wear and flexural stress. They are made of alloyed case hardened steel. The tooth profiles are hardened and ground. The following parts of the gear unit are particularly liable to wear:

− tooth profiles of the gears
− shift forks and claws of the sliding sleeves

– gear shaft bearings
– gear casing seals

Wear of the listed parts may give rise to various troubles in the gear unit:

Roaring of a gear unit is mainly due to gear errors or excessive wear of the teeth.

Toothed gears wear heavily when they are only partly in mesh. The surface load is then too high and teeth are broken. If the main shaft and the countershaft are not positioned parallel to each other in the gearbox casing, the gears will mesh only insufficiently, increasing wear and resulting in damage of the gear unit. Other errors include pitch errors, helix errors and profile errors. They have their cause in the manufacture of the toothed gears and cannot be eliminated by reworking the gears. Toothed gears showing such flaws have to be replaced.

If a gear unit runs with a knocking noise this is mostly due to broken or heavily damaged teeth or to distorted gear shafts. This fault can only be eliminated by replacing the defective parts. Other problems are poor shiftability of gears and the uncontrolled, the disengagement of gears. The causes may be found even in the clutch. If it is not properly thrown out, i.e. if the play is too large or the facing heavily worn, it is difficult to change gears. The seat of the sliding gears or the sliding claw may be too tight, The gears may not be in line. The play of the antifriction bearings may be too large, or the profiles of the shift forks may be worn down by continuous rubbing along the shift claw. The shift forks may also be distorted which may be caused by engaging a gear forcibly. Other gear troubles may be due to improper synchronisation, the causes being weak pressure springs, excessive clutch segment play or excessive wear of the keys and lock pins. The defective parts should be replaced to eliminate such faults.

Another source of trouble may be excessive wear of the sliding grooves, with the following causes being possible:

– The car is always started too quickly or is subject to heavy load by jerks and jolts. If worn gears have to be replaced, this should also be done with the grooved shaft,

– The gear unit blocks because the synchron segments are jammed. The film of oil between the segments is broken causing their surfaces to rub on each other until they get stuck. They can no longer be used and have to be replaced with new ones.

– With synchromesh gear units, care should be taken when shifting that the working point is not passed too quickly as this would increase wear of the toothed gears.

The working point is the point where the synchronizing clutch (Fig. 2/5) becomes effective and the detent springs are forced out of the sliding claw. This is seen in section A – A.

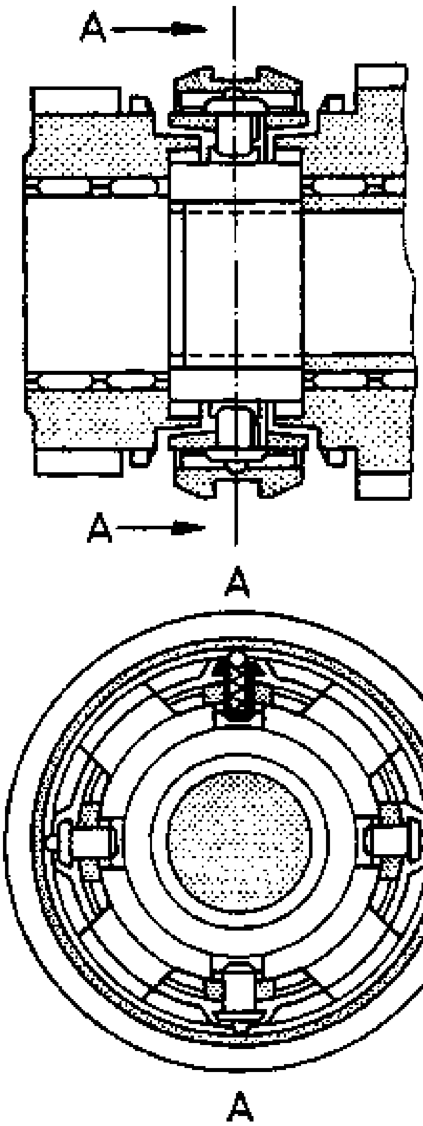


Figure 2/5 Synchronizing clutch A–A: section

The seals of mechanical gear–change boxes must be constantly checked for leakage to prevent gear oil from leaking. If, a leakage occurs, the oil level drops which leads to sticking of the gears, overheating of the antifriction bearings or burning of the rotary seals. A technical inspection should, there force, include not only the oil level of the engine but also that of the gearbox and the other gear units such as the transfer box and differential unit.

2.1.3. The planetary gear unit

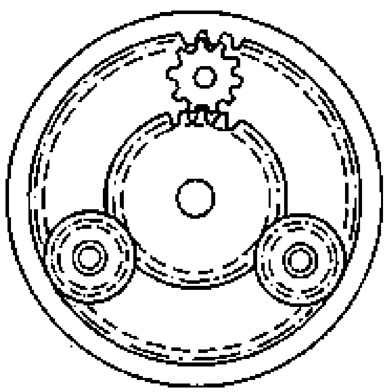
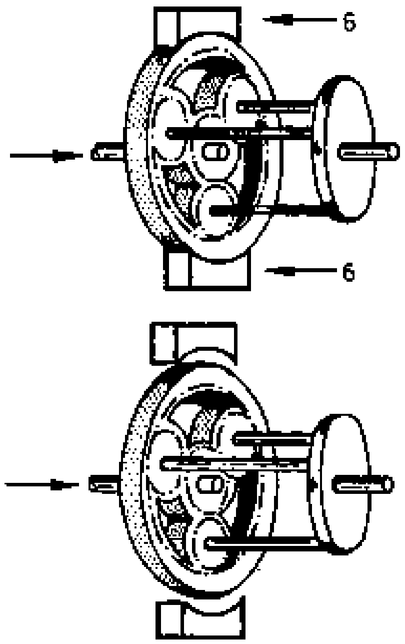


Figure 2/6 Planetary gear unit (cross section)

Another type of gearbox is the planetary gear unit, also called epicyclic gear (Fig. 2/6). The name has been derived from the planet pinions rotating around a sun gear. The planet pinions are fixed on a common holder and rotate in a ring gear. The planetary gear unit permits the selection of two speeds. For the first speed, the holder is moved and the ring gear remains stationary, the sun gear thus being turned at a particular speed.

For the second speed, the holder is moved and the sun gear remains stationary so that the planet pinions have to rotate around the sun gear. As a result, the ring gear rotates at another particular speed.

The planetary gear unit is often used for semi–automatic or automatic gear units. In this case, several gear units are usually mounted one after the other. The Wilson gear is an example of that.



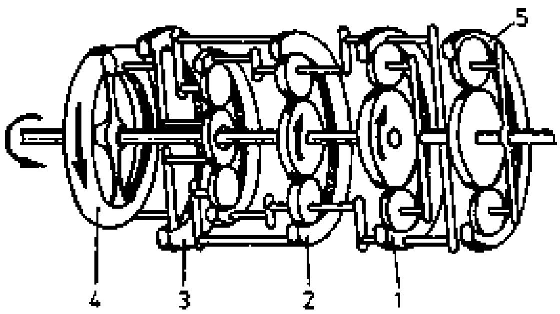


Figure 2/7 Planetary gear unit (longitudinal section)

1 first gear; 2 second gear; 3 third gear; 4 fourth gear; 5 reverse gear; 6 braked

As shown in Fig. 2/7, the Wilson (planetary) gear unit consists of several epicyclic units. The gears are preselected with a small lever in the driver’s cabin and engaged by depressing a pedal. This pedal is used instead of the clutch pedal. The preselected gear is engaged by blocking the ring gear through a brake which is operated mechanically or electromagnetically. Only the ring gear of the selected gear is blocked.

2.2. The freewheel

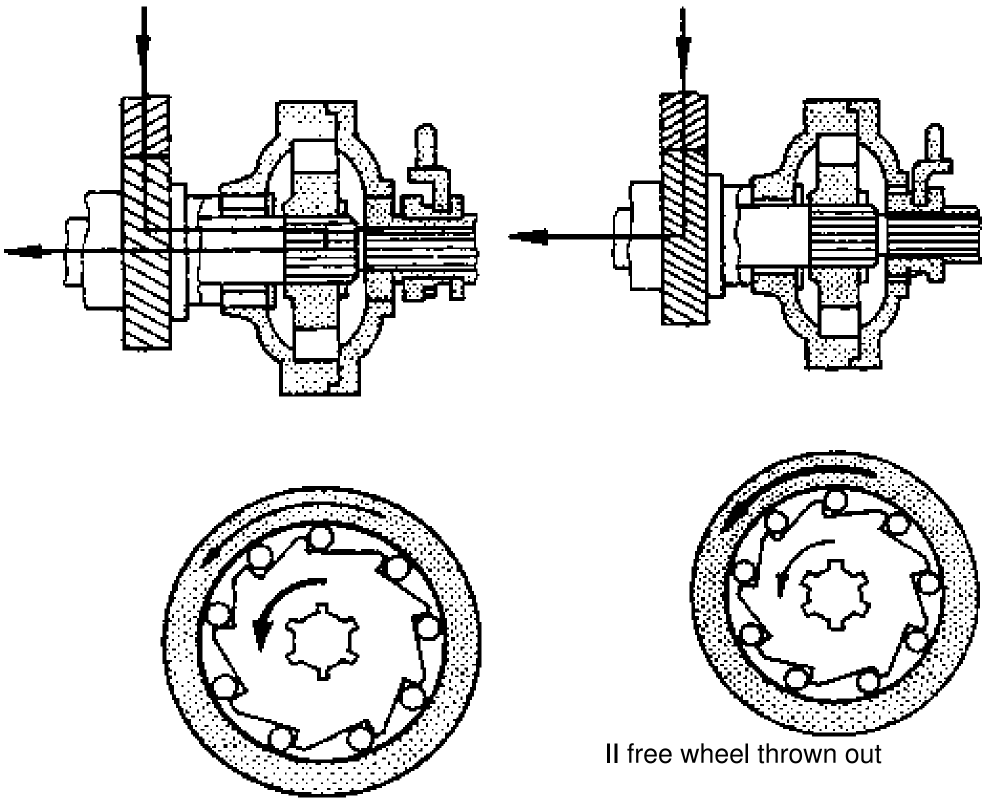
This paragraph deals once more with the mechanical gear–change box but with regard to the freewheel provided in some cases.

The freewheel (Fig. 2/8) is positioned between the drive shaft and the main shaft of the mechanical gear unit. Its function is to separate the drive from the driven wheels should they be forced to rotate faster than is possible by the power of the engine. This occurs when driving down hills. The car can thus utilize the natural drive. This saves fuel and spares the engine.

Operation of the freewheel:

The drive shaft of the gear unit is provided with a toothed star member. Loose rollers between the teeth in their bottom position when the vehicle is at rest or the star member rotates slowly. If the drive shaft is rotated, the rollers shift to their top position carrying the casing with them. The power is transmitted to the gear unit. If the freewheel is now blocked by a lever the rollers cannot return to the bottom position when the driven wheels rotate faster: the engine is made use of as an additional brake (the braking force is, however, very small with two–stroke engines).

Figure 2/8 Free wheel of a gearbox



II free wheel thrown out

I Free wheel trown in;

2.3. The transfer box

Another mechanical gear unit shall be deal with in this paragraph: the auxiliary gearbox or transfer box.

Normally, it is only used for special vehicles that are driven on difficult terrain or have to climb steer gradients. This gear unit often incorporates an additional low range of gears with a respective speed ratio. Gears are changed by levers located in the driver's cabin. Some designs of this gear unit feature a power take–off shaft for additional units such as a hydraulic pump for tilting the floor or the side wall of a truck or for driving agricultural machines. The transfer box is designed so that either all axles of a vehicle can be driven or only the rear axle. Generally, the transfer box is driven by a propeller shaft mounted behind the gearbox.

Fig. 2/9 shows the gears of a transfer box. It serves for an additional speed reduction.

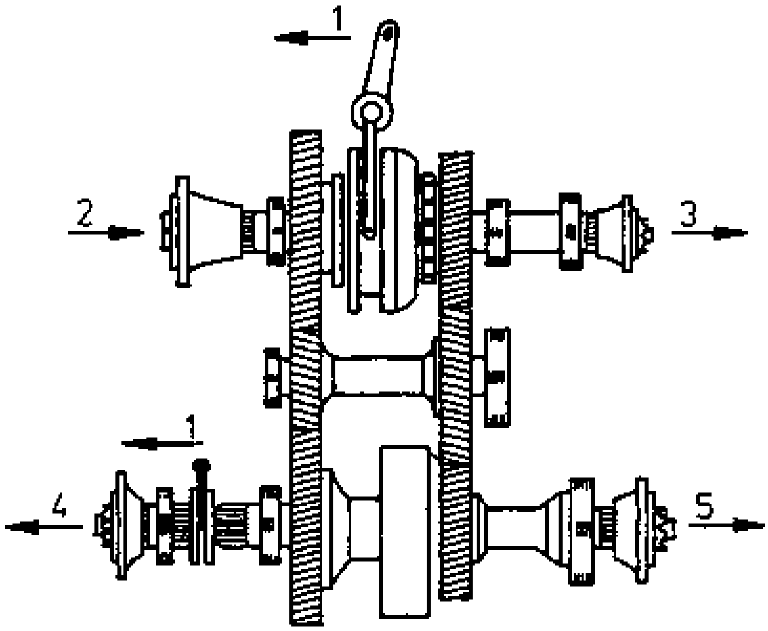


Figure 2/9 Transfer box

1 to shifting lever; 2 power from gear–change box; 3 driven side for accessory units; 4 drive for front axle; 5 drive for rear axle

The force of the driven wheels is increased but the speed reduced.

Any gear of the gearbox can be selected even–if the transfer box is engaged. If the engine is needed for operating an additional unit, the transmission of power to the axles of the vehicle may be interrupted by a shift claw. Only the additional unit is then driven by the engine, the vehicle remains stationary. The transfer box is equipped with helical gears to keep the noise within limits. It is used for derrick wagons and as drive unit for hydraulic pumps.

2.4. Fluid gear units

From the gear units described so far it was obvious that they were not infinitely variable. In this paragraph, the infinitely variable gear units shall be dealt with briefly.

According to their principle of operation they are classified into:

– infinitely variable mechanical gear units,
– hydraulic gear units,
– infinitely variable electric gear units.

In the following, especially the hydraulic gear unit shall be dealt with. As the name denotes, a hydraulic fluid is used, The hydraulic gear unit has been developed on the basis of the hydraulic clutch. It is used to drive heavy vehicles such as rail buses and heavy lorries but also larger passenger cars.

A turbine wheel incorporating three different blade rims is fitted on the drive shaft of the gear unit. Two other blade rims are positioned on the inside of the casing. They are used as fluid reciprocating blades. When the pump impeller begins to rotate, the centrifugal forces carry the fluid to the first system of the turbine wheel. The stationary blade rim in the casing reverses it, and it flows into the next blade rim. After the next change in the flow direction by the next stationary rim blade the fluid reaches the third system of the turbine wheel and is again in the centre. The process begins anew. With this system the clutch and be used to adjust the speed steplessly within a wide range.

Test questions:

2.1. What are the function of a gear–change box in a vehicle?

2.2. What is meant by “gear−change box”?

2.3. Describe the different power trains in a gear − change box.

2.4. What is the advantage of helical−toothed gears as compared to straight−toothed gears?

2.5. How are gears changed in mechanical gear−change boxes? Describe the construction and operating principle of the gear changing mechanism.

2.6. Describe the operating principle of a sliding−mesh gearbox.

2.7. Describe the construction and operating principle of a sliding−mesh claw−clutch gearbox.

2.8. What do you understand by “synchronisation” of a gear unit?

2.9. What is the advantage of synchronisation in mechanical gear−change boxes?

2.10. What types of werar in a gearbox do you know?

2.11. What is meant by “roaring” of a gearbox and how is it caused?

2.12. What do you understand by “knocking” of a gearbox? What are the causes?

2.13. What are the possible faults causing poor shiftability of a gearbox and disengaging of gears? How can they be eliminated?

2.14. Which causes for excessive wear of the sliding grooves do you know?

2.15. What is meant by “gearbox blocking”? How can you eliminate this fault?

2.16. What should be borne in mind when driving a car with a synchromesh gearbox?

2.17. Describe the construction and operating principle of a planetary gear unit.

2.18. Describe the construction and operation of a Wilson (planetary) gear.

2.19. Describe the construction and operating principle of the freewheel in a gear−change box.

2.20. What do you understand by a “transfer box”?

2.21. Give examples of the application of transfer boxes and describe the operation of such units.

2.22. Describe the construction and operating principle of a hydraulic gearbox.

3. Change of gears

As has been shown by the previous explanations mutli−step gear units are operated by shift levers located in the driver’s cabin. They may be operated either via a linkage connected to the gearbox or by direct connection to the gearbox. In today’s vehicles two types of gear changing mechanisms predominate:

− steering−column gear shift
− floor−type gear shift

3.1. Steering–column gear shift

Steering–column gear shift is an indirect gear change. The shift lever is mounted on the steering column. It is connected to the short shift lever of the gearbox by reversing and slide members.

This type of gear changing mechanism has some negative aspects. The shifting path is long and therefore liable to trouble. Reversing members are required which are subject to constant wear. Exact shifting is then no longer ensured. The linkages are liable to corrosion. Screw joints and other securing elements are required.

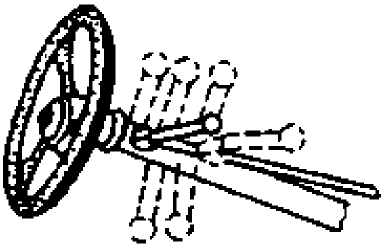


Figure 3/1 Steering–column gear shift

This gear changing mechanism can, however, not be completely eliminated from the automotive industry, since floor– type gear shifts cannot be used, for instance, in some front–driven vehicles.

Fig. 3/1 shows the steering–column gear changing mechanism.

3.2. Floor–type gear shift

Another common type of gear shift is the floor–type gear changing mechanism. In most cases it acts directly on the gearbox which is housed in a tunnel at the bottom of the vehicle. Larger vehicles with a centre–mounted or rear–mounted engine are provided with floor–type gear changing mechanisms. The shifting action is transmitted to the gearbox by reversing members and shift linkages (Fig. 3/2).

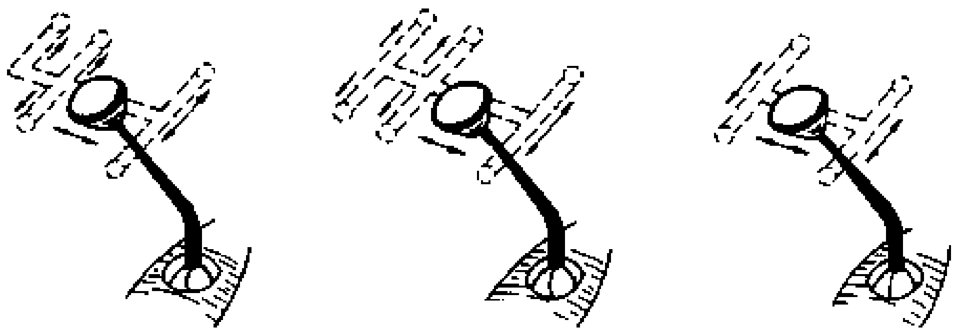


Figure 3/2 Floor–type gear shift

If there are shift linkages and reversing members, care should be taken to maintain them regularly to ensure proper gear shifting.

Test questions:

3.1. Describe the construction and operating principle of a steering–column gear change mechanism.

3.2. What do you understand by “floor–type gear shift”? How can it be designed?

4. Propeller shafts

The propeller shafts transmit the power of the engine from the gearbox to the driven axles. They are subject to heavy torsinal stress since the force of the engine acts on one end, and on the other end the stationary masses or masses tending to come to a rest have to be moved. This stress increases gradually while starting or accelerating the car. The propeller shaft have to satisfy the following requirements: minimum weight, maximum rigidity, high torsional strength and exact balance. If a propeller shaft is improperly balanced, it will generally vibrate during driving. The vibrations may damage the shaft and the adjacent parts. Fig. 4/1 shows the operating principle of a propeller shaft.

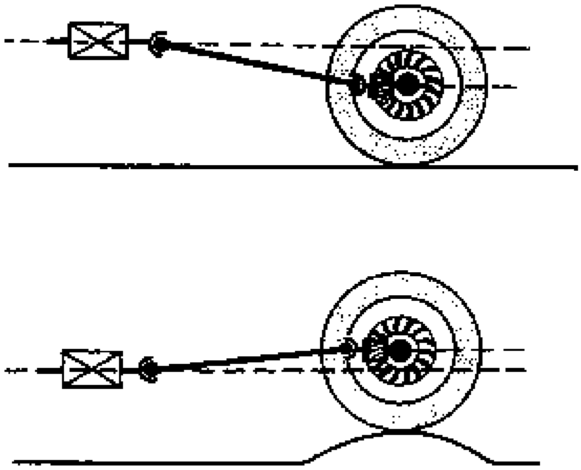


Figure 4/1 Operating principle of the cardan shaft

Propeller shafts are normally made of tubing to achieve high rigidity combined with low weight.

The tube tapers on both ends. Welded to one end is a universal joint and to the other end an internally and longitudinally toothed member.

Fig. 4/2 shows a propeller shaft of this type.

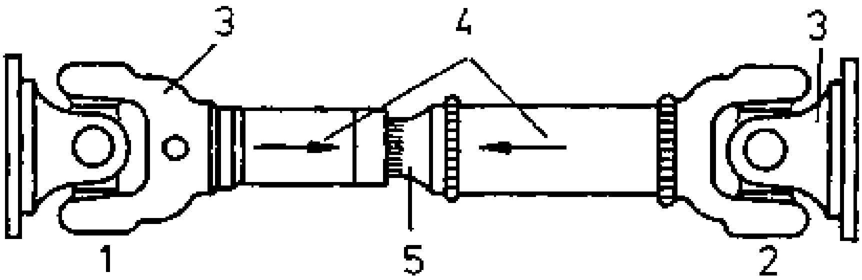


Figure 4/2 Cardan shaft or propeller shaft

1 first joint; 2 second joint; 3 fork positions; 4 marking arrows; 5 spline

4.1. The universal joint

The universal joints serve to balance chassis deflections and spring deflections of the driven axle. Each end of the shaft is there fore provided with universal joint (Fig. 4/3). Each universal joint consists of two yokes and a journal spider. The journals are ground because they rest in needle bearings which form end support bearings positioned in the yokes.

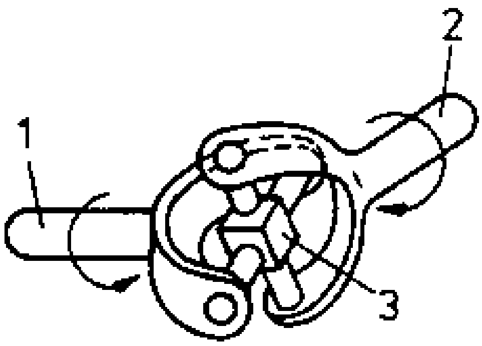


Figure 4/3 Universal joint

1 shaft I; 2 shaft II; 3 journal spider

All metallic bearing surfaces have to be protected against the ingress of dust. They must also be protected against moisture as it may cause the bearings to stick impairing proper functioning.

4.2. The longitudinal propeller shaft

The propeller shaft must have a length−changing means. Longitudinal propeller shafts are provided with a spline. Often, this is protected against moisture and dust by a rubber sleeve. It must always be lubricated when making inspections. The lubricant is forced into a grease nipple in the short part of the spline using a grease gun (caution: excessive lubricant may hamper the movement of the spline). Fig. 4/2 shows a longitudinal propeller shaft with spline. The arrows on the shaft must be in line as the shaft is balanced in this position.

When assembling propeller shafts care should be taken that the universal joints coincide in position. If the shafts are improperly installed, heavy vibrations will occur which may destroy the shaft.

The non−enclosed longitudinal propeller shafts are mounted in the direction of the vehicle. If the distance between gearbox and rear axle is too long, the shaft should be supported by centre bearings to limit vibrations. Propeller shafts running at high speeds (mainly in passenger cars) should not be interrupted, if possible. In modern vehicles with rear−axle drive the gearbox is displaced or extended so that a short propeller shaft can be used and vibrations are reduced. Vibrations are also reduced by incorporating the spline into the gearbox.

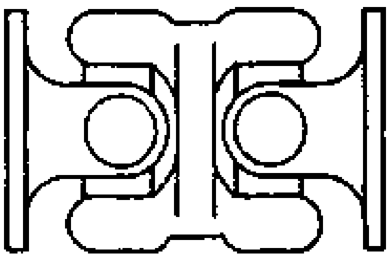


Figure 4/4 Double universal joint

If the transfer box is connected by a flange, a double universal joint (Fig. 4/4) may be incorporated between the gearbox and the transfer box. It is used to connect the two gear units and to balance the movements of the Silentbloc type rubber−metal connections.

4.3. The transverse propeller shaft

Besides the longitudinal shafts, transverse propeller shafts are know. They are designed to be installed at right angles to the longitudinal axis of the vehicle. Like the longitudinal propeller shafts, they are used to drive the wheels. They are found in front−driven vehicles and vehicles with single−wheel suspension. The propeller shafts of a frontdriven vehicle must be suitable for a deflection angle 45 to compensate for the steering angle and the resulting spring angle. Here the uniform circumferential speed of the wheels with a large steering angle is important. Generally, constant velocity joints are used for drives of this type. If a constant velocity joint is a universal joint, then it must be a double joint (Fig. 4/5).

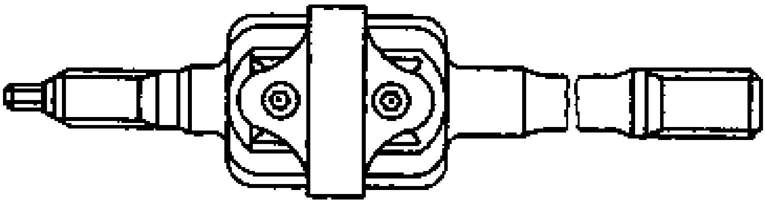


Figure 4/5 Constant velocity joint

The double universal joint incorporates a pilot device. If the bearings of the joint are near to the gearbox, the pilot device can be dispensed with. If the driven wheels are suspended singly, an additional joint is necessary.

This joint can operate with two slide members or one tripod member (Fig. 4/6) which are (is) carried in slide bearings in the gearbox and can compensate the movements of the single–wheel suspensions.

Transverse propeller shafts belong to the springless masses of a vehicle. Therefore, they should be of low weight. Transverse propeller shafts normally have two joints. The connection between them may be loose or rigid. If the joints or the connection pieces are equipped with flexible members then torsionally elastic connection is obtained which permits a shock–absorbing power transmission.

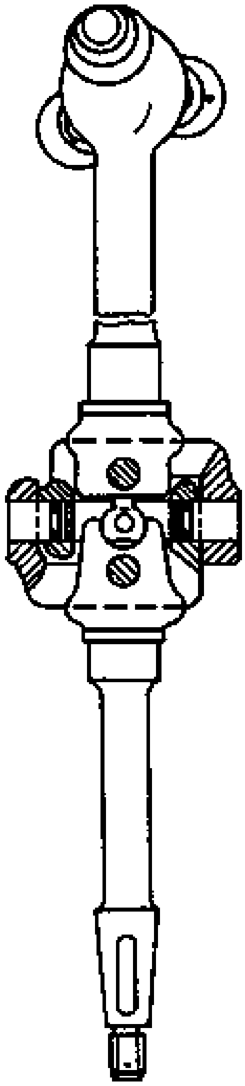


Figure 4/6 Double universal joint with 2 slide members and tripod member

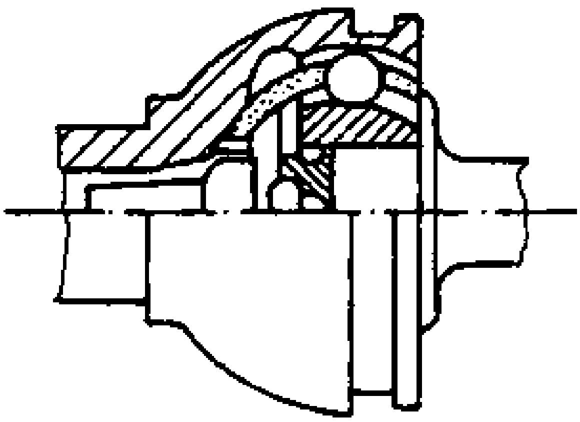


Figure 4/7 Ball joint

Transverse propeller shafts may not only be provided with universal joints but also with ball joints. They enable a high mobility to be obtained (Fig. 4/7). They consist of hardened steel balls rolling on a circular surface. Since the relative movements are balanced by the balls in any position, no non–uniform rotation may occur. Therefore, these joints are also referred to as “ideal” constant velocity joints.

These joints permit large deflection angles (about 38°). Since they are very small they are often used in front–driven vehicles. As compared to other joints their manufacture is difficult.

One of the most simple types of joints is the flexible disk joint (Fig. 4/8). It transmits torques elastically and accommodates vibrations. The angular mobility of this joint is ensured by flexible fabric disks or rope sheaves. Such joints have only a very small deflection angel of approximately 3°.

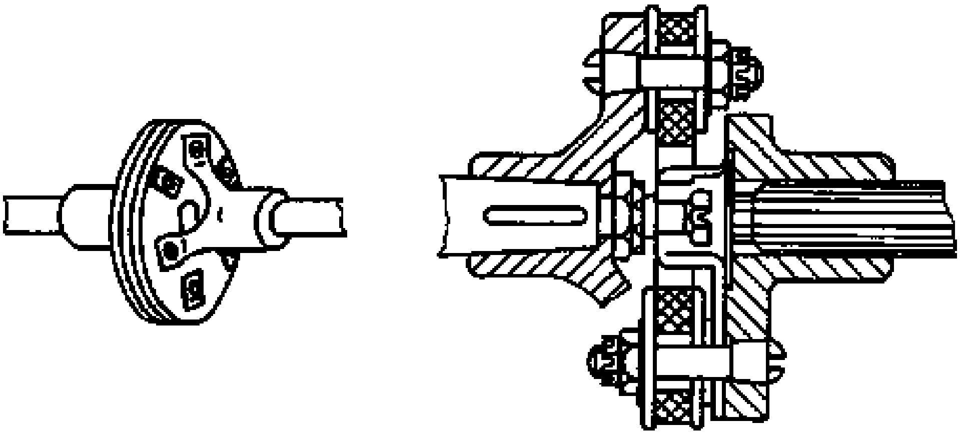


Figure 4/8 Flexible disk joint

Fig. 4/8 shows how the two shafts are connected to the joint. The shafts have “flange arms” positioned at angles of 120° to each other. These arms are connected to the disk joint by fit bolts which are also used to centre the disk. With this type of joint the countershaft is offset by 60°.

The following table shows a comparison of the advantages and disadvantages of metal joints and rubber fabric joints:

	Metal joints	Rubber fabric joints
Power transmission	for maximum loads	used for minor and medium loads
Permissible angle variation	30° (special joint 50°)	limited to about 8°
Maintenance	routine lubrication required	no lubrication required

If the favourable properties of both types of joints were to be made use of, the two types would have to be incorporated in one propeller shaft train.

4.4. Maintenance and repair of propeller shafts

Despite its important function in the transmission of power, the propeller shaft is still frequently considered to be of minor importance. As a result, maintenance and care is neglected. The propeller shafts can, however, only withstand their high loads when they are regularly maintained. Otherwise, the bearing play will increase prematurely resulting in early wear of the driving parts. If the propeller shaft breaks, the braking effect of the engine is no longer present so that the road safety of the vehicle is impaired.

The flange connections should be regularly checked for tightness. This includes that no flange bolts are missing. The bolts must comply with the hole diameter since they are not only stressed in tension but also in shear during movement.

The universal joints should be regularly checked for proper lubrication. The check may be made with a grease gun. If grease emerges from a bearing, then it is sufficiently greased.

With enclosed universal joints it should be seen to that the rubber sleeves protecting the joint from dirt, water and moisture are leakproof.

Flexible disk joints should be protected from oil and grease since these destroy the rubber member, thus making the joint inoperative.

Wear of the catches or the grooved members causes vibration of the propeller shaft, resulting in drumming.

The engaging splines must be mounted carefully so as not to damage the seals on the profiled ends of the propeller shaft. Before installing propeller shafts or splines remember to grease them, since the grease film ensures easy movement. Furthermore, propeller shafts may only be stressed within their angle of deflection.

When installing propeller shafts it is important that the yokes on the shaft ends be at the same level. They must be fully aligned as misalignment causes unbalance. If there are so−called propeller shaft trains in a vehicle, i.e. several propeller shafts are installed one after the other, the specified claw position must be maintained. When installing the shafts it should be seen to easily and do not jam that the splines move. Forces are generated by heavily moving splines that may result in an overloading of the gear unit bearings and even destroy them in case of extended service.

Test questions:

4.1. What are the functions of propeller shafts in a vehicle?

4.2. To what stresses are propeller shafts exposed?

4.3. Why must propeller shafts be balanced? What should be borne in mind when reinstalling them?

4.4. Describe the construction of a longitudinal propeller shaft.

4.5. What is the function of universal joints of a propeller shaft?

4.6. Why are propeller shafts mounted in centre bearings in some types of vehicles?

4.7. Which types of propeller shafts do you know besides the longitudinal propeller shaft?

4.8. Describe the construction of the trans− verse propeller shaft with double joint.

4.9. Describe the construction of a ball joint.

4.10. Describe the construction of a flexible disk joint.

4.11. Why is it necessary to maintain the propeller shafts of a vehicle regularly?

4.12. What should be borne in mind when installing propeller shafts?

4.13. Why is it necessary to protect flexible disk joints from oil and grease?

4.14. Describe the installation of a propeller shaft in a vehicle with rear−axle drive.

5. Final drives

The final drive forms the connection between the propeller shaft and the differential unit.

Normally, final drive and differential unit are housed in one casing and screwed to each other. They run in an oil bath.

Principally, two types of final drive are distinguished:

− bevel−gear drive and
− worm−gear drive

In most cases the propeller shaft is positioned in the direction of travel and the driving gears are positioned at right angles to it. From this can be concluded that the direction of force action has to be turned by 90. This is implemented by the final drive. To increase the torque, the final drive is provided with a transmission gear. For passenger cars, the gear ratio is between 4 to 1 and 6 to 1 and for lorries between 5 to 1 and 10 to 1. The gear ratio of a vehicle is composed of that of the gearbox and that of the final drive.

5.1. The bevel−gear drive

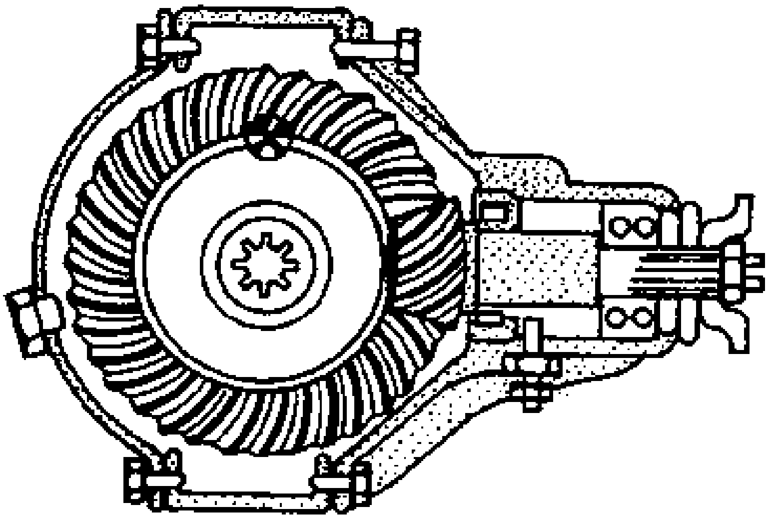


Figure 5/1 Bevel−gear drive

In the bevel−gear drive (Fig. 5/1) the driving pinion engages with a ring gear. There are two types of bevel gear drive. In the standard design, the central axis of the driving bevel gear connected to the propeller shaft is exactly at the same level as the central axis of the driven ring gear (as shown in Fig. 5/1). The bevel gears of the final drive are provided with a special toothing.

This type of toothing ensures a quieter running of the final drive to be achieved in comparison with straight toothing.

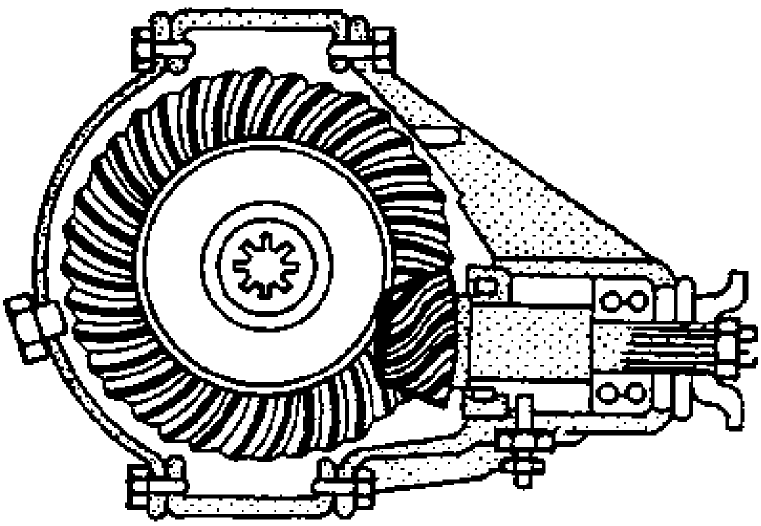


Figure 5/2 Hypoid−gear drive

They hypoid−gear drive (Fig. 5/2) is the second type of bevel−gear drive.

The bevel gear and the ring gear have a hypoidtooth system where the angle of the teeth differs from that of a normal bevel gear drive.

This permits the driving pinion to be mounted off the ring gear centre. Owing to this, the body of the vehicle or the propeller shaft tunnel in the body may be of a lower design.

The hypoid–gear drive is subjected to considerable lateral pressures. This calls for a special lubricant. The hypoid oil used is very viscous, and unlike other lubricants it accommodates the high lateral forces acting on the tooth profiles and prevents the grease film from being broken.

For quiet running it is necessary for the bevel gears of the final drive to mesh properly. This means that the reference circles of the tooth profiles of the two bevel gears must come into contact. This can be seen from the tooth bearings (Fig. 5/3). To obtain a tooth bearing, marking ink is to be applied on both gears. Then the gears are rolled in mesh in two directions since you can reserve a car. Through this procedure the bearing faces are marked. The gears can then be adjusted. Note that the teeth may not contact each other at the smallest diameter.

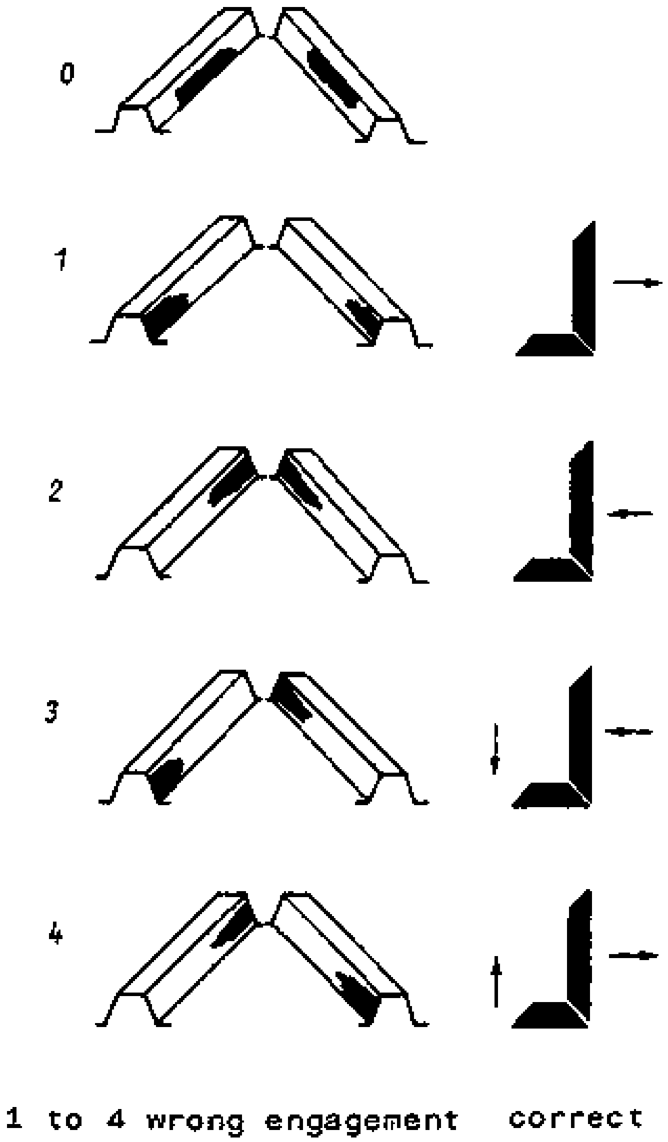


Figure 5/3 Tooth bearings, 0 engagement

Explanation of the tooth bearings illustrated in Fig. 5/3:

0 This bearing shows the proper mesh of the bevel gears.

1 Wrong mesh: The ring gear must be moved slightly out of mesh.

2 Wrong mesh: The ring gear must be moved slightly into mesh.

3 Wrong mesh: The ring gear must be moved slightly into mesh, and the driving pinion must be moved slightly out of mesh.

4 Wrong mesh: The driving pinion must be moved slightly into mesh, and the ring gear must be moved slightly out of mesh.

A readjustment of the two bevel gears can be made as follows:

– Adjusting washers may be inserted between the shaft flanges and bearing bushes or fitted to the front faces of the bevel gears.

– Shims are inserted between the fitting surfaces of bearing faces and casing parts.

– The whole bearing assembly can be shifted by a thread.

The shims and adjusting washers are very thin and sensitive.

Fig. 5/4 shows the support of the ring gear. This support counteracts sudden shocks resulting from wrong gear changing, blocking of the engine and other external forces. In such situations enormous forces occur causing the ring gear to deflect considerably, resulting in the teeth of the ring gear and the bevel gear to be subjected to considerable stress

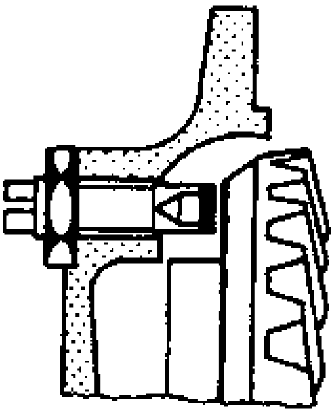


Figure 5/4 Crown wheel support

The ring gear is supported by an adjustable thrust bolt. The gap between the support and the rear face of the ring gear must be adjusted to 0.1 mm. To prevent the drive pinion from being distorted, the ring gear in lorries is in most cases carried in bearings on two sides.

5.2. The worm–gear drive

Final drive by means of a worm and a worm gear is mainly used for heavy lorries. The advantage is that high gear ratios can be implemented in a comparatively small space. Another advantage is the low noise level. The unit can drive two rear axles without a transfer box being required.

Figs. 5/5 and 5/6 show two possible types of worm–gear units. The construction depends on the intended use of the vehicle.

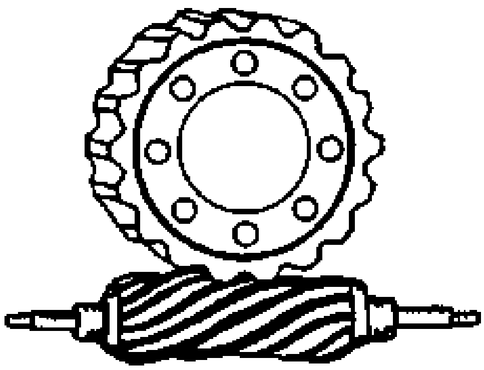


Figure 5/5 Worm drive with bottom–mounted worm

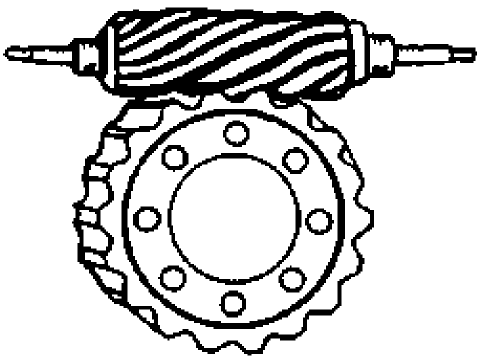


Figure 5/6 Worm drive – with overhead worm

If the worm is bottom–mounted, the vehicle's centre of gravity is low. If the worm is mounted overhead, a higher ground clearance is obtained. Such a worm–gear unit is also used for driving the tachometer shaft.

5.3. Other types of drive

In order to achieve for the bevel–gear drive the gear ratios possible for the worm–gear drive, bevel–gear unit and spur gear pair are combined. Fig. 5/7 shows such a combination. The IFA W 50 lorry is provided with such an assembly. The ring gear is connected to a spur pinion which drives a spur gear. This, in turn, is connected to the axle shafts and drives the wheels.

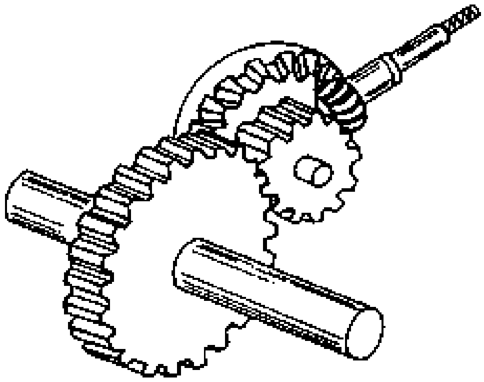


Figure 5/7 Combination of bevel–gear drive and spur gear pair

Another type of final drive is by the spicyclic spur gear unit. Here, differential spur gears are connected to the ring gear and positioned so that they mesh with it in pairs.

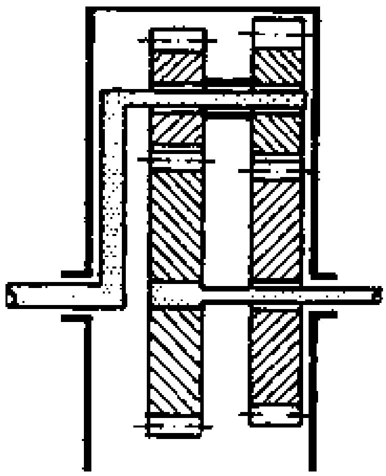


Figure 5/8 Epicyclic spur gears on parallel axes

Fig. 5/8 shows an epicyclic spur gear unit. The differential | pinions rotate in the stationary casing. Epicyclic spur gear units of this type are often used for automatic gear units.

Test questions:

5.1. Which types of drives do you know?

5.2. Describe the construction of a bevel–gear drive.

5.3. What do you understand by “hypoid–gear drive”?

5.4. Explain the proper adjustment of the bevel gears by using the tooth bearing diagrams.

5.5. What is the function of the ring gear support?

5.6. What do you understand by “worm–gear drive”?

5.7. Why are worm–gear drives with bottom–mounted and overhead worm used?

5.8. What is an epicyclic spur gear unit?

6. The differential unit

The differential unit is firmly connected to a ring gear. On both sides of the differential casing, drive shafts for the wheels are introduced. In the casing they are connected to bevel gears either by internal toothing of the bevel gears or a tulip–shaped drive member in mesh with a tripod member or slide members. (Only rarely are the bevel gears fastened to the drive shaft.) A differential "star" comprising two or four pivoted bevel gears is seated between these two bevel gears (Fig. 6/1).

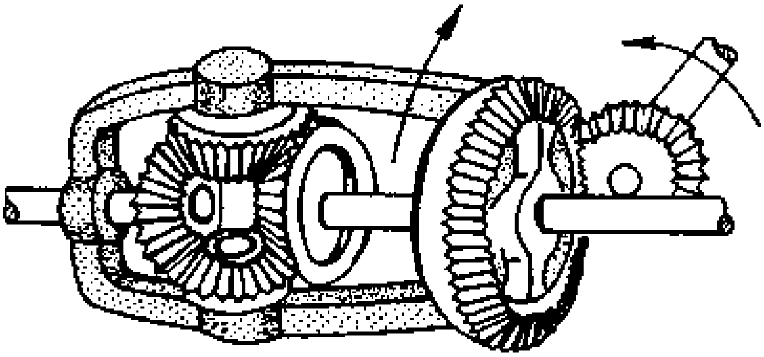


Figure 6/1 Differential gear unit

Operating principle of the differential unit:

The propeller shaft causes the drive pinion to rotate which, in turn, drives the ring gear carrying along the differential casing fixed to it. This causes the two drive shafts to rotate which, in turn, drive the wheels.

When the vehicle goes straight ahead, the driven wheels turn at equal speed. The differential gears do not rotate but serve only as a coupling between the rotating differential casing which makes a circular movement, i.e. they rotate together with the differential casing. When the vehicle goes through a corner, the differential casing continues to rotate at the same speed. Since the inner wheel has to travel a shorter distance than the outer wheel, its speed is reduced as compared to the differential casing, with the differential gears rotating around their axes rolling on the bevel gear lagging behind. Through this, the shaft of the outer wheel is driven, increasing the wheel's speed as compared to the differential casing.

We can draw the following conclusion from this: The slower the inner wheel rotates the faster the outer wheel must rotate.

If one of the two driving wheels encounters a stationary obstacle and, therefore, can no longer rotate, the other wheel must take over its speed. This means that the latter rotates at double speed while the former remains stationary. This can be observed when one wheel sinks into soft ground and has no adhesion. It is then held up, while the other is still able to move freely. In this situation the vehicle cannot be driven away under its own power.

These problems are excluded in modern lorries moving mainly over difficult terrain in that they are provided with a differential lock.

The purpose of the differential lock is to establish a rigid connection between the two axle halves. The differential lock is generally operated by the driver from his cabin. It eliminates the disadvantages of a differential unit.

In the following, the function of the differential lock is described briefly: A claw clutch is attached to a drive shaft which can be positively connected to the differential casing by actuating a lever. If the clutch is engaged, the shaft and the associated drive shaft pinion are no longer capable of turning relative to the final drive casing.

The differential gears can no longer rotate. Like the propeller shaft toothing they act as a catch for the bevel gear of the other drive shaft. Thus, the vehicle can be driven away under its own power.

It is important to release the differential lock as soon as the vehicle reaches solid ground once again. Otherwise the gearbox components would be excessively stressed on a nonskid road and in bends, the tyres would wear quickly and steering would be impeded.

Differential locks may be designed similar to previously described freewheel. The differential units are then selflocking. As soon as the speed of one of the driving wheels becomes excessive, this unit is locked automatically as a result of the centrifigual forces and returns automatically to its normal "unlocked" position when the driving wheels run at equal speed.

Test questions:

6.1. What do you understand by "differential unit"?

6.2. Describe the construction of a differential unit.

6.3. Describe the operating principle of the differential unit when the vehicle goes straight ahead.

6.4. Describe the operating principle of the differential unit when the vehicle goes through corners.

6.5. Why are differential locks used in vehicles?

6.6. Describe the operating principle of the differential lock.

6.7. What do you understand by a "self−locking differential unit"?

7. Lubrication

Each gear unit in a vehicle must be lubricated in order to run properly. Additive−treated and non−additive−treated oils are used for lubrication. The additives improve the lubricating quality, resistance to ageing and corrosion, the foaming behaviour and the viscosity−temperature relation. They are used to reduce mechanical wear. They form a film with a low shear resistance on the tooth profiles that is continuously worn and renewed thus preventing seizing of the tooth profiles. The viscosity of additive−treated oils is lower than that of non−treated oils. This is of great advantage during the running of the vehicle since it reduces mechanical losses in the power train, facilitates changing of gears and results in an improved heat removal. Additive−treated gear oils have a wide operating temperature range. They can be employed at temperatures between − 20°C and + 100°C.

Gear oils are used for all types of gear units found in vehicles and for antifriction bearings exposed to high stresses. They are employed to lubricate gearboxes, transfer boxes, differential gear units, steering gear units and final drives.

An oil renewal should generally be carried out between 20,000 km and 30,000 km (max.). After a repair of a gear unit fresh gear oil should always be used, since abraded metal particles settle in the oil during operation.

As mentioned above, hypoid oil is a gear oil with a very high additive content; it is used for highly stressed gear units.

Application of oil

Viscosity plays a decisive role for the application of a gear oil. It influences the oil flow, the thickness of the oil film to be built up on the components to be lubricated, the mechanical efficiency of the gear unit, the thermal behaviour and the power losses due to friction. Furthermore, it depends on the viscosity whether a gear oil can be used for full fluid−film lubrication. For proper running of the gear units it is necessary that operation conditions, design and viscosity be matches to each other. This increase also the service life of the gear unit components.

If a gear unit features a low circumferential speed and a high ambient temperature, the lubricating oil should have a high viscosity. If, however, a high circumferential speed and a low ambient temperature occur, the viscosity of the gear oil may be low.

If a gear unit is exposed to alternating or discontinuous loads, a high–viscosity oil should be used. If low–viscosity gear oil is used, special care should be taken that the connections to the gearbox are leakproof since proper lubrication is no longer ensured when the thin oil escapes. Therefore, the oil level should be checked regularly in gear units with low–viscosity oil. This is done with a dip–stick or by opening an inspection plug where the oil flows out when the filling is sufficient.

Gear oils are divided into SAE viscosity clases.

Because of the convenient identification of lubricating oils – gear oils or engine oils –viscosity grades are indicated worldwide in SAE.

The tabel below lists the viscosity classes: The most common viscosity classes are between 75 and 250 and are specified for –17.8°C and +98,9°C in the table. Viscosity is given in sq.mm/s.

	Viscosity in sq.mm/s (cSt)			
SAE viscosity class	at –17,8 °C		at +98,9 °C	
	minimum	maximum	minimum	maximum
75	–	3,257	4,18	–
80	8,257	21,716	4,18	–
90	–	–	14,24	25,0
140	–	–	25,0	42,7
250	–	–	42,7	–

Advantages of additive–treated gear oils

Additive–treated gear oils provide an outstanding protection against seizing of gear unit parts and wear due to friction. They have a high thermal and ageing stability. Gear oils have a good viscosity–temperature behaviour, protect against corrosion and feature a favourable foaming behaviour.

Disadvantages of additive–treates gear oils

Since high–viscosity oils are also additive–treated oils, only their disadvantages shall be listed.

They are generally used for full fluid–film lubrication. This means that the respective gear unit component dips into the oil–bath during its rotation. This type of lubrication is also called oil–bath lubrication or dip–feed lubrication. It re– suits in a considerable loss of power, leading to high temperatures accelerating the ageing of the oil.

At low outdoor temperatures the oil is very hard and the teeth have to free themselves at first. Thus full lubrication is not ensured from the start. This results in increased wear of the tooth profiles. In the case of dip–feed lubrication gear parts which do not run directly in the oil–bath and do not dip into it may wear prematurely because the oil is not sufficiently whirled around since it–is cold. At low outdoor temperatures the delivery rate of the oil pump in a forced lubrication system may be insufficient, also resulting in increased wear.

In gearboxes, mechanical troubles may occur which even make it impossible to move the vehicle. In such a case, the gearbox should be warmed up using a suitable heat source to thin the oil.

Gear grease

Another type of lubrication is by gear greases. They are used wherever lubrication with gear oil is impossible or does not seem appropriate (for example, when the gear oil drips down or is spun off thus being not available for lubrication).

Greases are oils thickened by additives. They are used for the following applications:

– for antifriction bearings and stuffing boxes that come into contact with water (pump greases);

– for lubrication points which have to be protected against foreign matter (foreign matter being dust or dirt particles or water; the grease film protects the adjacent parts)

– for lubrication points requiring very little grease (these lubrication points are understood as being permanently lubricated, e.g. universal joints, springs, pedal shafts, etc.)

– for slowly rotating bearings and those with high surface pressures.

As applies to the lubrication with gear oil, some aspects are of major importance to the selection of greases.

The design of the bearings – plain bearings or antifriction bearings – must be taken into account. Furthermore, speed, bearing load and bearing temperature have to be considered.

Test questions:

7.1. What do you understand by “lubrication”?

7.2. What should be the properties of a lubricant intended for use in vehicles?

7.3. What do you understand by “additive–treated oils”?

7.4. What are the advantages of additive–treated oils in comparison with non–treated ones?

7.5. When should the gear oil be renewed?

7.6. Why may only fresh gear oil be used after gear units have been repaired?

7.7. What do you have to take into account when using oils?

7.8. What do you understand by “viscosity” of an oil?

7.9. Name the disadvantages of high–viscosity oils?

7.10. Which other lubricants, except oils, do you know?

7.11. What are the functions of these lubricants? Give some examples.

7.12. Where are these lubricants used in a vehicle?

8. General instructions for repairing pear units:

After the gear unit to be repaired has been removed, its outer surface should be cleaned. The unit is then disassembled. The individual components must also be thoroughly cleaned so that they can be checked for reusability. Reusable parts are laid aside for reassembly. Non–reusable parts are checked to find out whether reconditioning is possible or whether they have to be scrapped.

Parts to be scrapped have to be replaced with new ones. Before reassembly the sealing faces of the gearbox casing should be checked for smoothness, because they may have been damaged by careless disassembly. When disassembling a casing, wedges such as screw drivers should never be forced between sealing faces as this would damage them.

All abrades particle must be removed from the casing. Then the sealing faces are smoothened on a surface planing plate covered with abrasive fabric. At the same time, the casing can be checked for distorsion of the sealing faces. After smoothing the casing must be cleaned again since abraded material will have deposited on it.

Now assembly can be started. An oil film should be applied to the gear shafts, especially the bearings. The lips of the rotary shaft seals must be coated with oil to prevent them from running dry and being burned. An oil film should also be applied to the toothed gears so that the gear shafts rotate more easily and do not abrade due to dry running while they are being checked for serviceability.

When gaskets are placed on the sealing faces between the casing halves these faces must also be coated with oil before applying the gaskets so as to achieve leakproofness. If no gaskets are used, the seal faces are coated with sealing compound which has the same effect as a paper seal.

After the casing halves have been assembled, the screws are put in place and screwed in finger−tight. When all screws are inserted, they are tightened crosswise so as to prevent the casing halves from being distorted, which would again result in leakages or seizing of gear shafts. For tightening the screws, dynamometric keys with a plug−on cocket should be used so as not to stress the screws beyond their tensile strength. If this occurs considerable efforts are required to reestablish the initial condition of the casing.

The repaired gear unit is then checked for proper functioning. The gears are engaged and the gear shaft rotated simultaneously. If the gear unit functions properly, the specified amount of gear oil can be filled in. The gear unit is then reinstalled into the power train.

The basis concept of disassembling and reassembling gear units remains the same even if units are concerned the casings of which cannot be dismantled into halves.

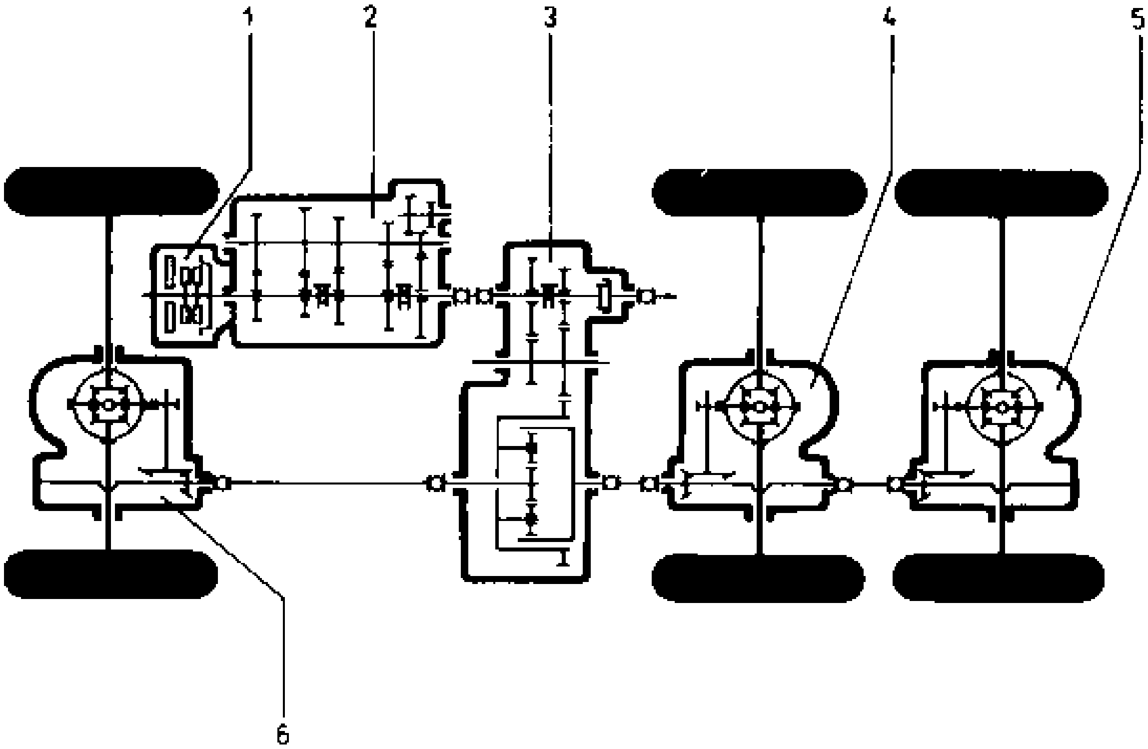
Power Transmission – Automotive Transparencies

Table of Contents

Power Transmission – Automotive Transparencies..1

Power Transmission – Automotive Transparencies

1



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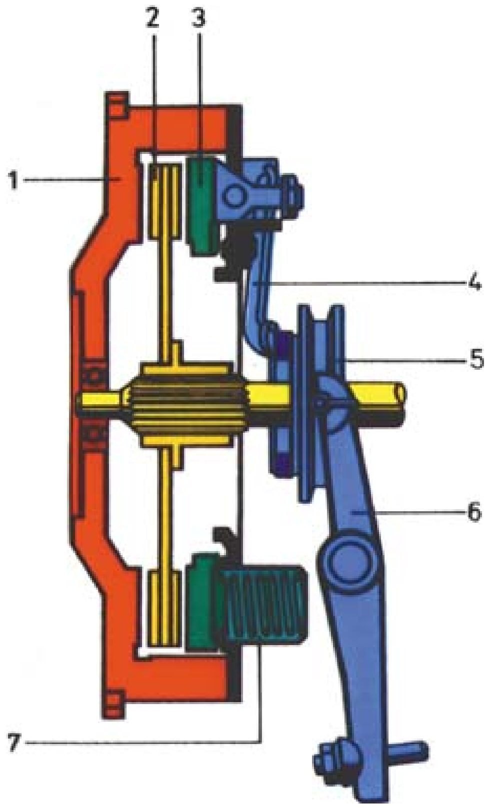

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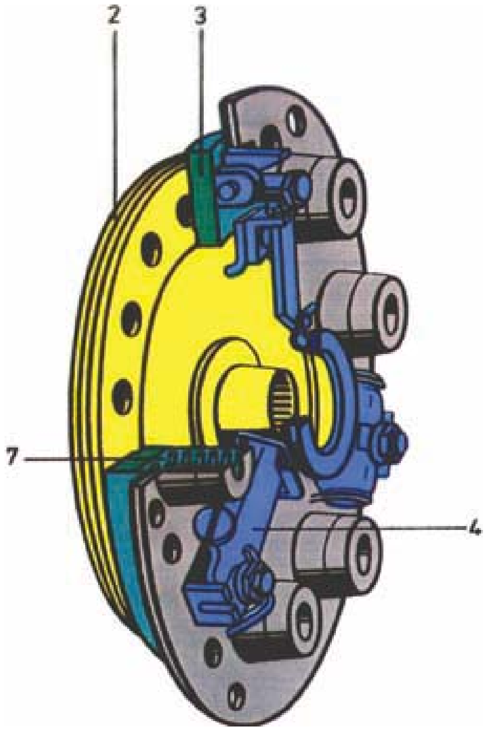

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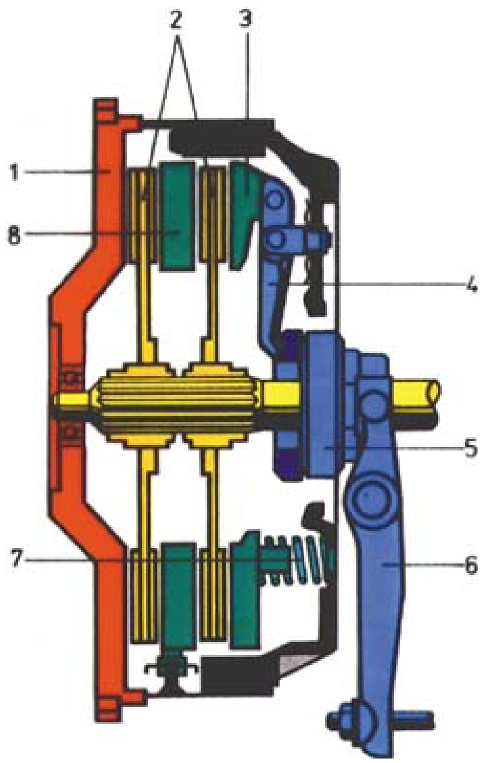

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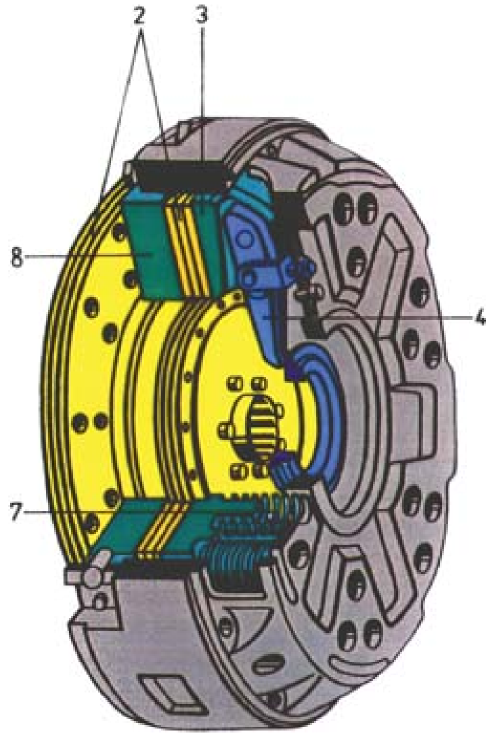

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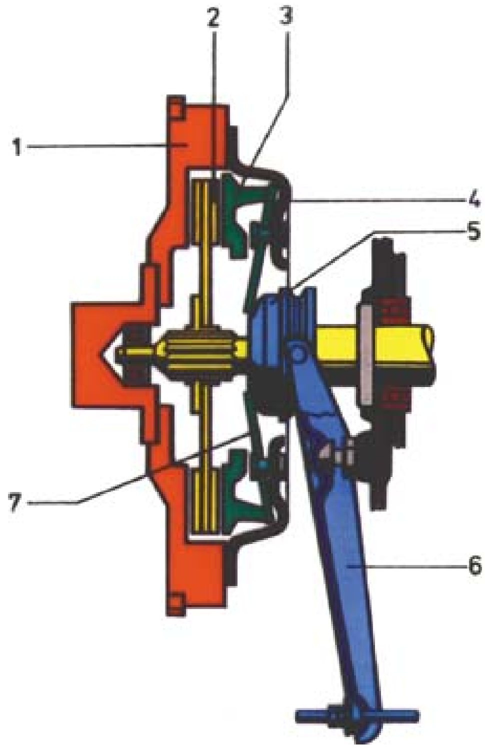

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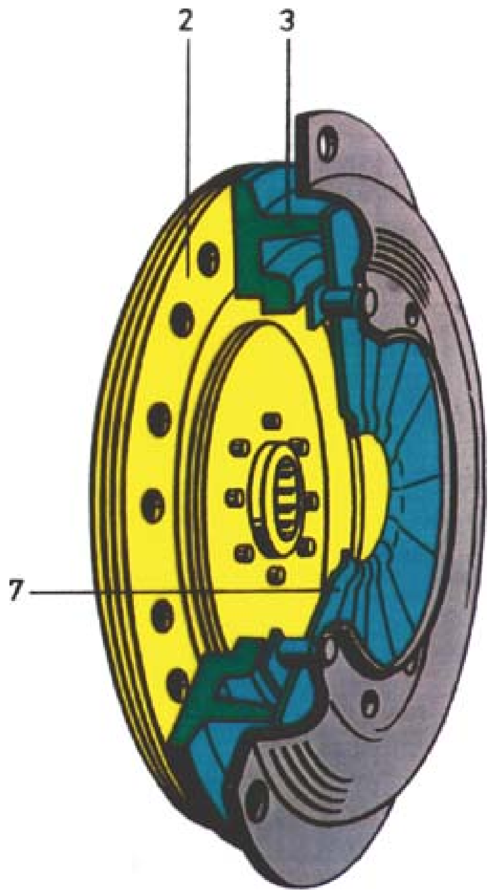

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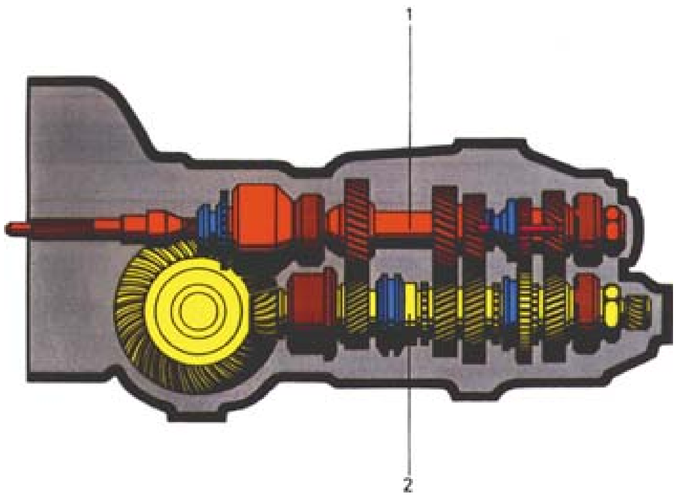

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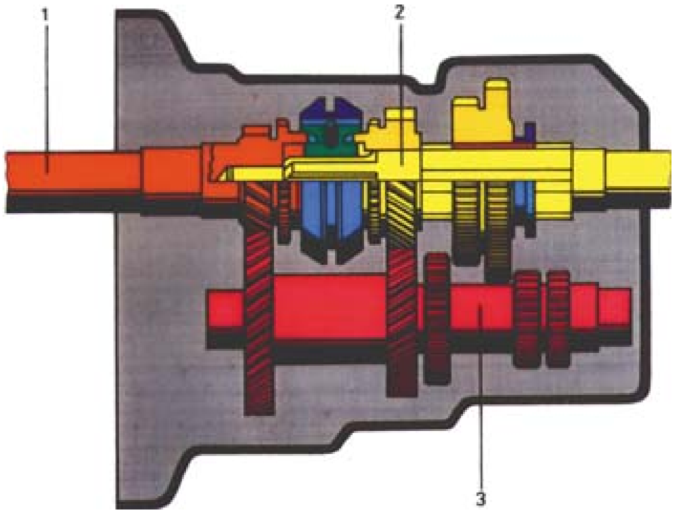

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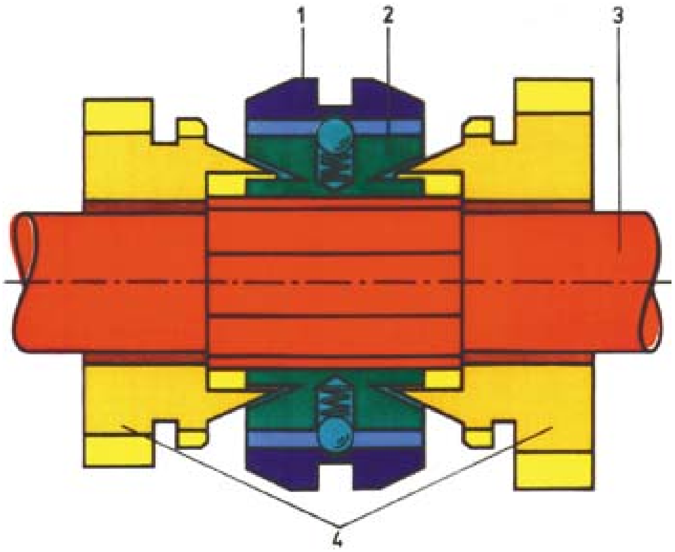

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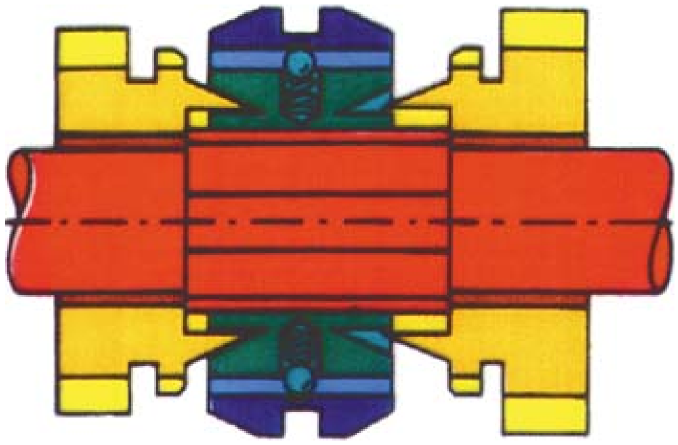

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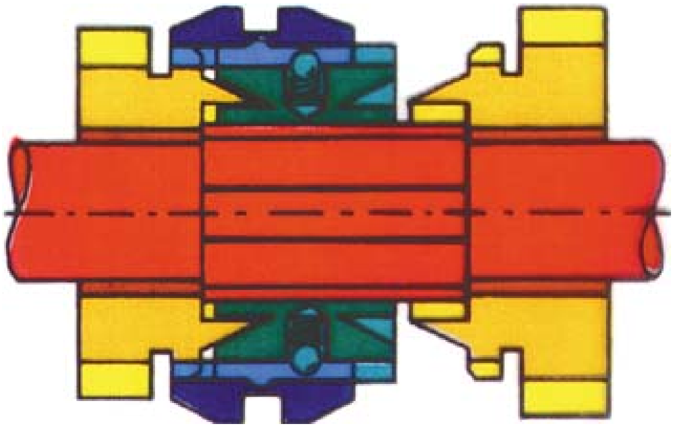

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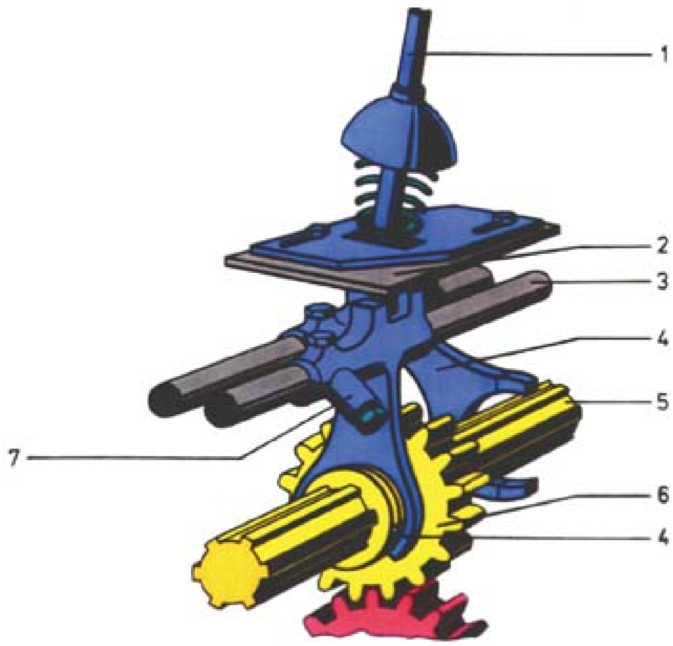

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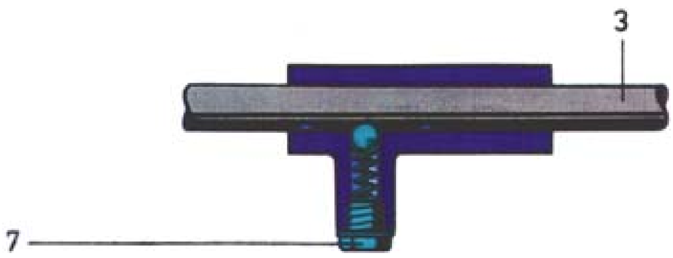

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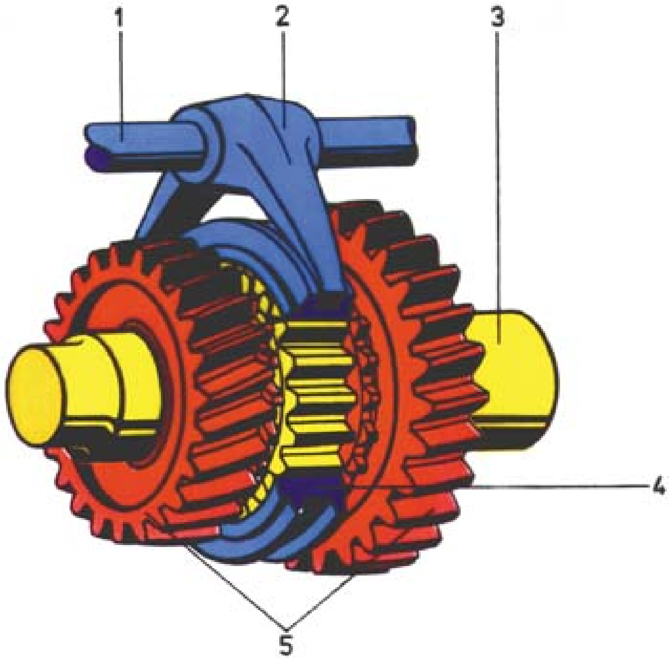

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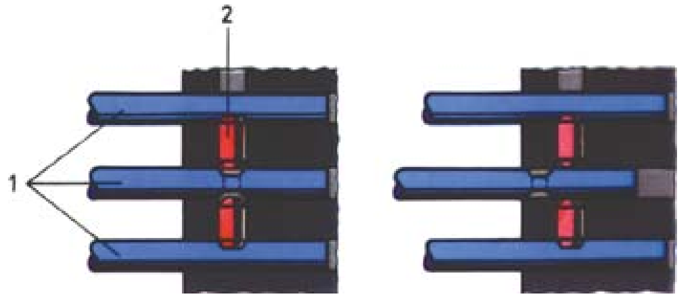

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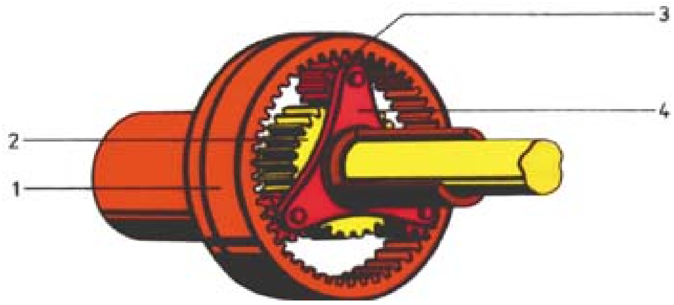

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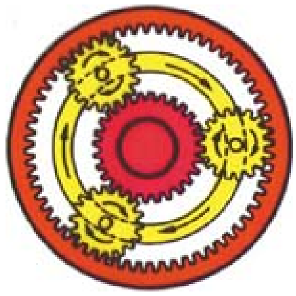

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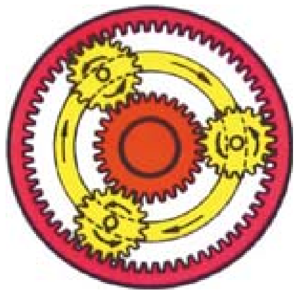

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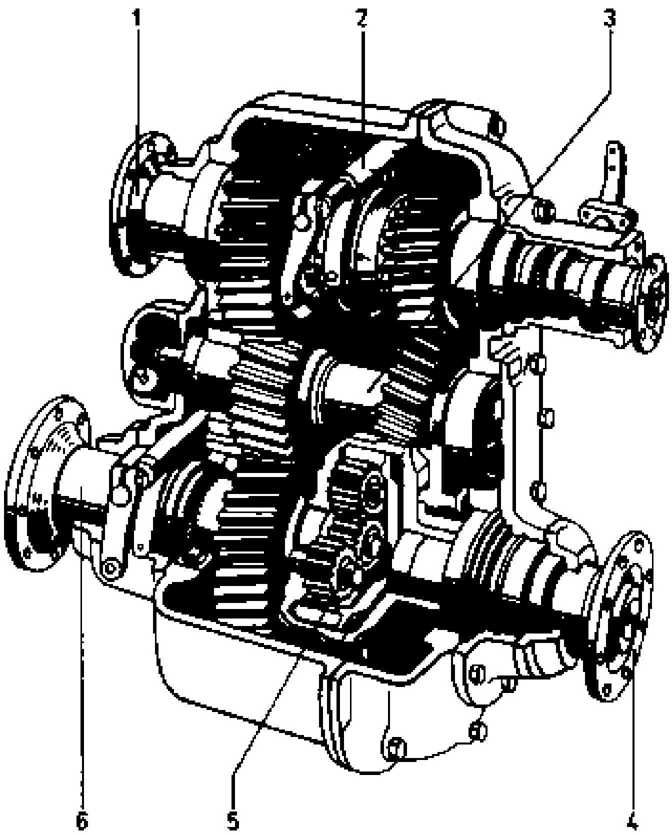

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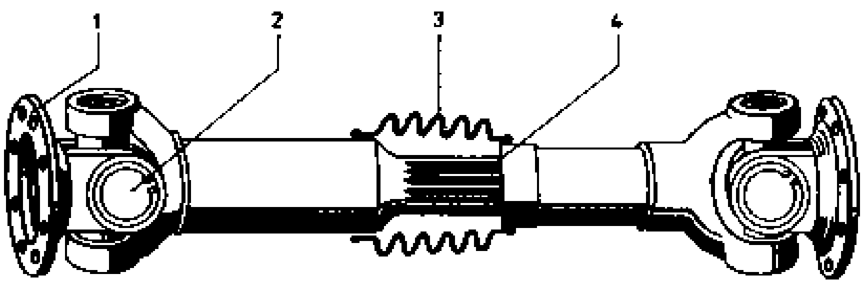

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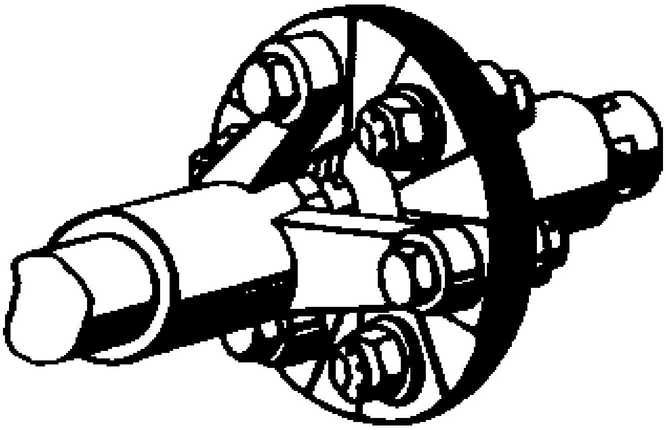

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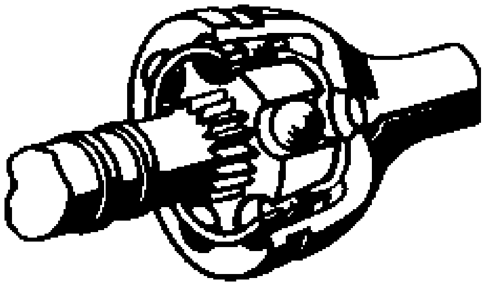

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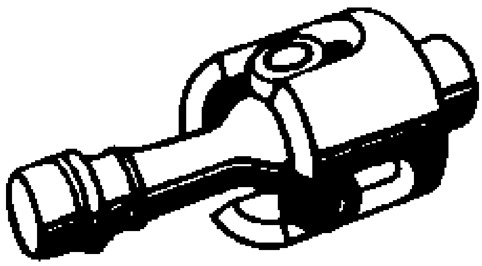

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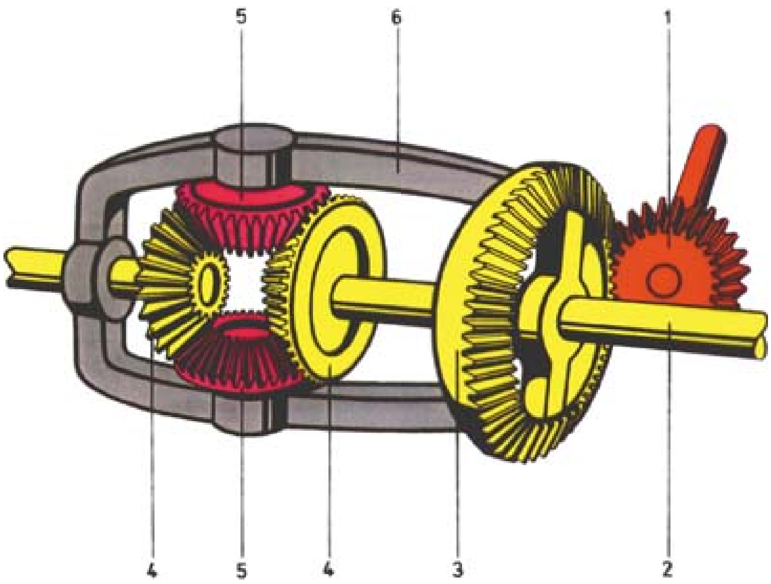

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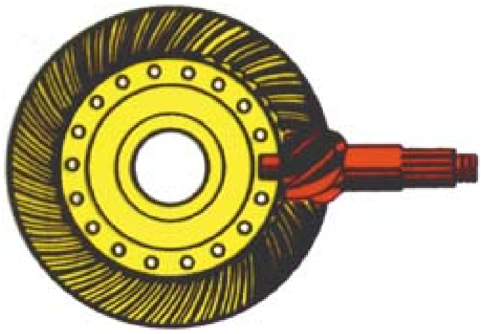

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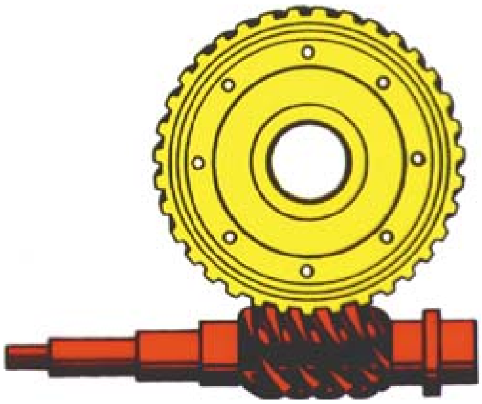

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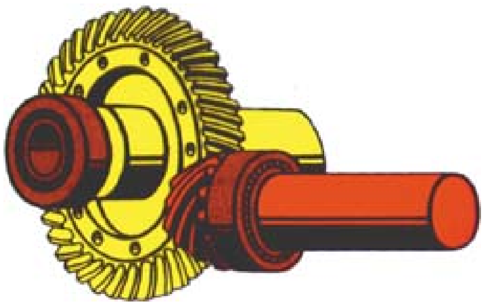

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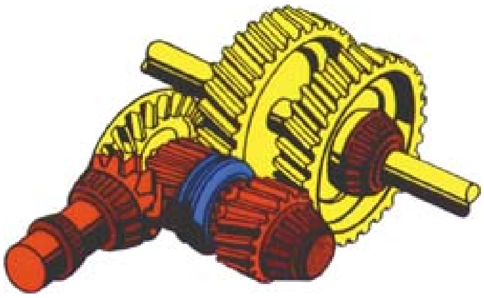

Combustion Engine – Course: Motor Vehicle Engineering 3. Textbook for Vocational Training

Table of Contents

Combustion Engine − Course: Motor Vehicle Engineering 3. Textbook for Vocational Training.............1
Preface...1
1. Types of combustion engines..2
2. Design of the reciprocating−piston engine...4
2.1. The cylinder..6
2.2. The crankcase...8
2.3. The crank mechanism...9
2.4. The engine timing system..14
3. Mode of operation of the Otto engine...20
3.1. The four−stroke engine..21
3.2. The two−stroke engine..22
3.3. The fuel system of the Otto engine..23
4. Mode of operation of the diesel engine...31
4.1. Feed pump and filter..31
4.2. The injection pump...34
4.3. The injection nozzle...35
5. Engine lubrication..39
6. The cooling system...43
6.1. Water−cooling system..44
6.2. Air−cooling system...46
7. The air filter...47
8. Mode of operation of the gas turbine...47
9. Mode of operation of the rotary piston engine..49

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Preface

This instruction manual is intended for all students of motor vehicle repair and maintenance.

It can be used as a basis for both theoretical lessons and practical training, and as such provides an essential link between theory and practice.

The manual is divided into three self–contained sections, each dealing with one of the main sub–assemblies of the vehicle: chassis, power transmission and combustion engine.

The instruction manual contains a clear and concise description of the design and function of each of the component parts of the motor vehicle, as well as information about the maintenance, servicing and repair of vehicles.

Numerous illustrations are intended to facilitate the student's understanding of the technical and engineering problems discussed. Test questions are included at the end of each chapter. These concentrate on points of particular importance to students of motor vehicle engineering and enable the individual student to assess his own progress.

1. Types of combustion engines

Almost all types of prime movers have already been tested as drive units in motor vehicles. Next to the conventional combustion engines, gas turbines and electric motors are most frequently used.

So far, however, the combustion engine operated on petrol or diesel fuel has proved to be the most successful of them all.

Combustion engines can be divided as follows:

1. According to the type of ignition:

In this category the Otto engine is distinguished from the diesel engine.

– The Otto engine, named after its inventor Otto operates on the principle of spark ignition.

A fuel–air mixture or only fuel and air is drawn injected, compressed and ignited by an electric high–voltage spark.

– The diesel engine, named after its inventor Diesel operates on the principle of compression ignition.

Diesel fuel is injected into very highly compresses air, and ignites on its own due to the high compression temperature.

2. According to the type of carburation:

A distinction is made between engines with external mixture formation and those with internal mixture formation.

– In combustion engines with external mixture formation the fuel air mixture is prepared in an intake pipe outside the combustion chamber.

– In the case of internal mixture formation this mixture is not prepared until it reaches the combustion chamber. This mixture formation is made by injecting the fuel into the air.

3. According to the mode of operation:

There are two different modes of operation.

– With the two–stroke mode of operation the piston works at every second stroke (piston stroke).
– In case of four–stroke engines, the piston works at every fourth stroke.

4. According to the number of cylinders:

– Single–cylinder engines
– Multi–cylinder engines
– Planetary piston engines

5. According to the cylinder arrangement: (Fig. 1/1)

– The in–line engine: here the cylinders are arranged in a line.
– The V engine: here the cylinder are arranged in V form.
– The opposed cylinder engine: here the cylinders are arranged opposite each other.

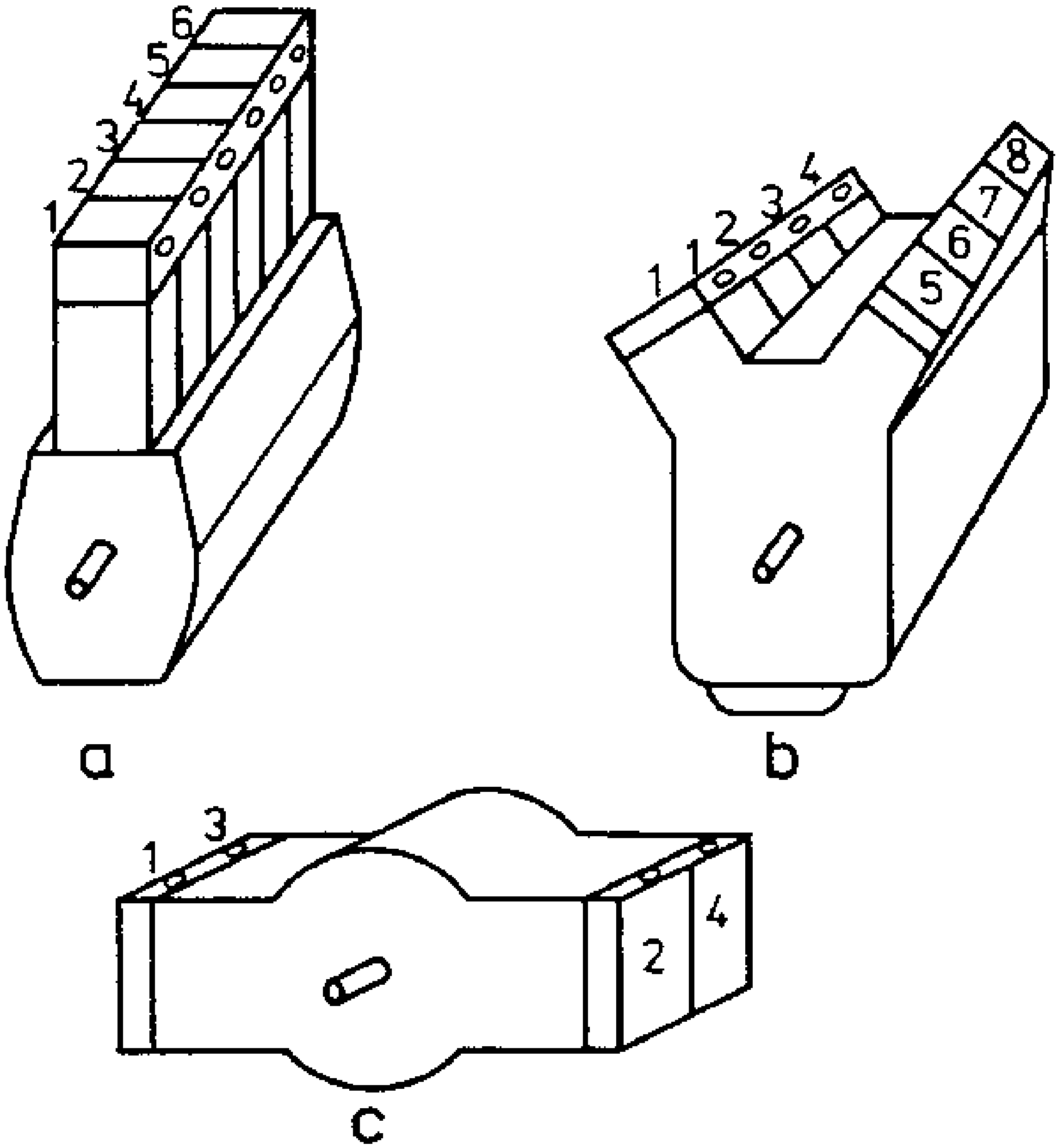

Figure 1/1 Types of engines according to the arrangement of the cylinders

a in−line engine (vertical); b V engine; c opposed cylinder engine; 1, 2, 3... number of cylinders

6. According to the type of timing:

− Valve timing engines. Intake and discharge of gases are controlled by valves. These are four−stroke engines.

− Engines with slide valve timing. Intake and discharge of gases are controlled by slide valves.

− Valveless engines. Intake and discharge of gases are controlled by the piston.

7. According to the type of cooling:

We distinguish between liquid cooling and air cooling.

− In the case of liquid−cooled engines, the combustion chamber is surrounded by a cooling shell. There are cylinders with dry liners and with wet liners. The coolant (distilled water with antifreeze additives, if required) is circulated between the combustion chamber and the cooler.

– In the case of air–cooled combustion engines, the cylinder is directly cooled by the air stream or by a blower. The cylinder is furnished with cooling ribs for better heat discharge.

Test questions

1.1. What is understood by the term 'combustion engine'?

1.2. What other kinds of drives for motor vehicles do you know?

1.3. What are the criteria for classifying combustion engines?

2. Design of the reciprocating–piston engine

Since the engines used in motor vehicles are almost exclusively reciprocating engines, we are concentrating entirely on this type.

The reciprocating engine consists of the following main subassemblies:

- Crankshaft
- Connecting rod
- Piston with gudgeon pin
- Cylinder liner
- Cylinder head with combustion chamber

All reciprocating engines are of the same design. The term reciprocating engine is derived from the straight up and down movement of the piston in the liner. The connecting rod is connected to the piston by the gudgeon pin and transforms the straight movement of the piston into a rotational one via the crankshaft. The crankshaft is supported in the crankcase and secured to prevent axial shifting. A flywheel is flanged to the PTO side of the engine. Here the power generated is transferred to the clutch.

In the Otto engine, the fuel–air mixture is produced by a carburettor. It is connected to the combustion chamber of the engine by an intake manifold. The exhaust duct is also in the combustion chamber. The burnt gases are discharged into the open through this duct passing the exhaust manifold, the pre–silencer, the main silencer and the exhaust pipe. The mixture is ignited by the spark plug which is screwed into the combustion chamber.

The position in which the piston is closest to the cylinder head is called top dead centre.

The largest distance of the piston from the cylinder head is called bottom dead centre.

The path to be covered by the piston between top and bottom dead centre is called the piston stroke (or simply stroke). Every piston engine is supplied with a particular amount of thermal energy by the fuel; this heat is transformed by the engine into power, however, the process is connected with very high energy losses. Only a portion of the energy supplied can be utilized as brake power for the engine. The ratio between energy supplied and energy losses and effective engine power is shown in the Fig. 2/1.

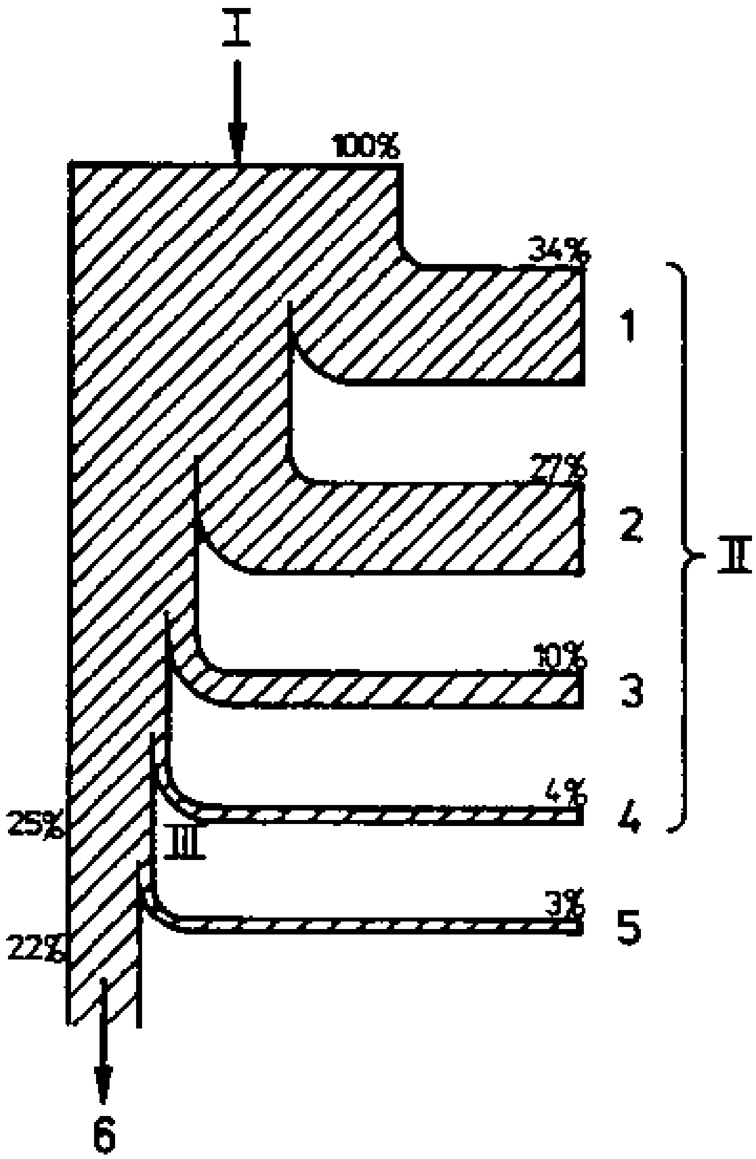

Figure 2/1 Ratio of energy fed into the engine vs. energy losses and efficiency of the engine.

I Thermal energy of the fuel supplied, II Energy losses of the engine composed of the following shares: 1 Losses due to exhaust gases; 2 Losses due to cooling; 3 Losses due to friction and radiation; 4 Losses due to dynamo, fan or blower; III Effective power of the engine from which losses in the gearbox due to friction (5) must be deducted; 6 reflects the output that can be converted into the travelling performance proper.

The energy supplied to the engine can be subdivided as follows:

– the brake power which will be transformed into mechanical power;

– the cooling heat which will be discharged into the cooling water or the cooling air;

– the exhaust heat which is energy carried off in the exhaust gases;

– the residual heat which is carried off by radiation and conductivity;

– the engine friction which is the energy lost by friction of the moving parts of the transmission system of the engine.

In the diagram the losses are given in percentages. The values given can only be mean values because the power range will vary depending on the type of the engine.

2.1. The cylinder

Every combustion engine which is designed as a reciprocating engine has a combustion chamber in the cylinder head. Note the following types (Fig. 2/2):

- the Ricardo head
- cylindrical combustion chamber
- hemispherical combustion chamber.

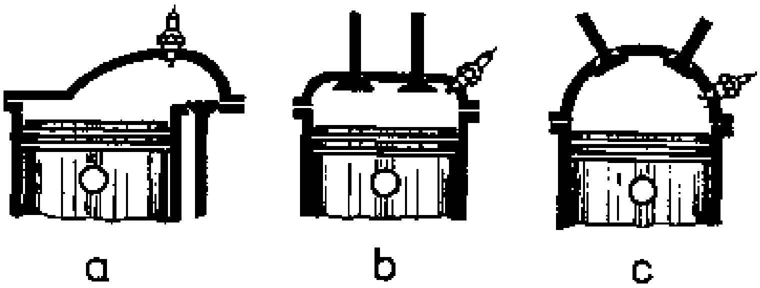

Figure 2/2 Shapes of cylinder heads

1 Ricardo head; 2 Cylindrical combustion chamber; 3 Hemispherical combustion chamber

The design of the combustion chamber is of special importance. It is not only the diesel engine that requires intensive mixing of the air for rapid combustion. In the Otto–engine, proper mixing of the fuel–air mixture ensures fast progress of the flame front, i.e. proper and rapid combustion of the mixture, resulting in high output and efficiency.

Due to the design of the Ricardo head, there its compression ratio has an upper limit. The fuel–air mixture is started to be mixed before top dead centre is reached, thus ensuring quicker ignition. This type of head is mainly used for combustion engines with side valves.

The cylindrical and the hemispherical combustion chambers are used for overhead–valve engines because the valves are suspended in the combustion chamber. Here the position of the valves is of great importance.

The cylinder head seals the top end of the cylinder (liner). The liner is shaped like a hollow cylinder (Fig. 2/3). The bottom end of the cylinder is open. Here in the cylinder, the piston moves between top and bottom dead centre. The bottom dead centre forms the lower limit of the cylinder chamber while the top dead centre is the lower limit of the combustion chamber. The path covered by the piston between the two dead centres is called the stroke.

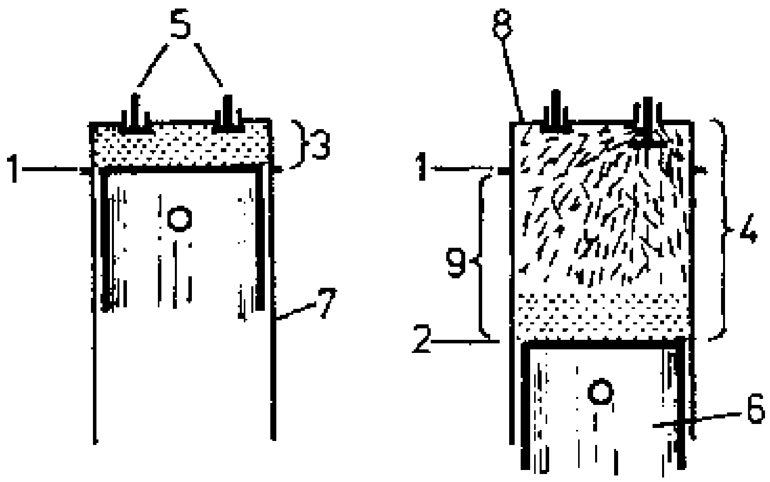

Figure 2/3 The cylinder

1 Top dead centre; 2 Bottom dead centre; 3 Combustion chamber; 4 Cylinder chamber; 5 Valves; 6 Piston; 7 Liner; 8 Cylinder head; 9 Swept volume

Here the ratio between the cylinder chamber and the combustion chamber corresponds with the compression ratio. In Fig. 2/4 the combustion chamber is 1/8 the size of the cylinder chamber. The fuel–air mixture is compressed to 1/8 in the space between the bottom and the top dead centre. This process is called compression. In this case the compression ratio is 8:1.

The higher the compression ratio, the higher the output of the combustion engine.

An important property of the fuel is its knocking resistance.

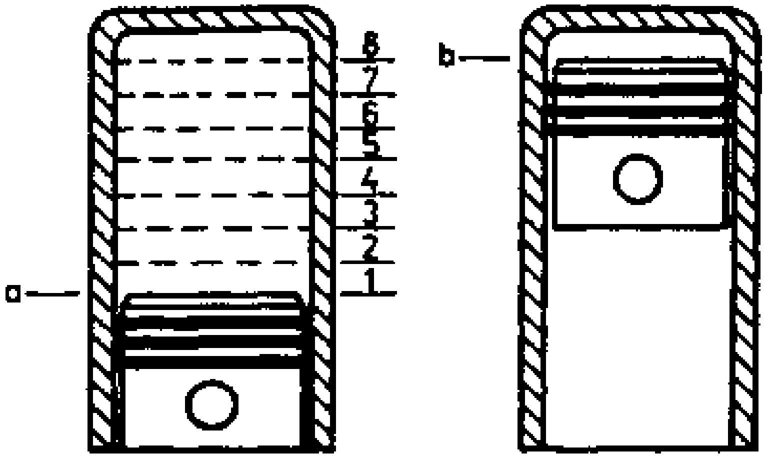

Figure 2/4 Compression ratio 8:1

a Bottom dead centre; b Top dead centre

The knocking resistance of a fuel is clear from the octane number. Fuels with an octane number between 76 and 98 octane are used for the current combustion engines. If fuels with too low an octane number are used with combustion engines with high compression, knocking of the fuel will have a negative effect on the transmission system.

The cylinder must be very strong to withstand the entire combustion pressure. It is made of a special grey cast iron which must be hard, dense and fine grained. In special cases it is also possible to use steel liners. The liner can either be fixed in the cylinder block or be replaceable.

The liners fixed in the cylinder block are called dry liners.

Another type of liner is the wet liner. It is inserted into the cylinder block and sealed with rubber gaskets. Wet liners can also be individually replaced because they are not rigidly connected with the cylinder block (Fig. 2/5).

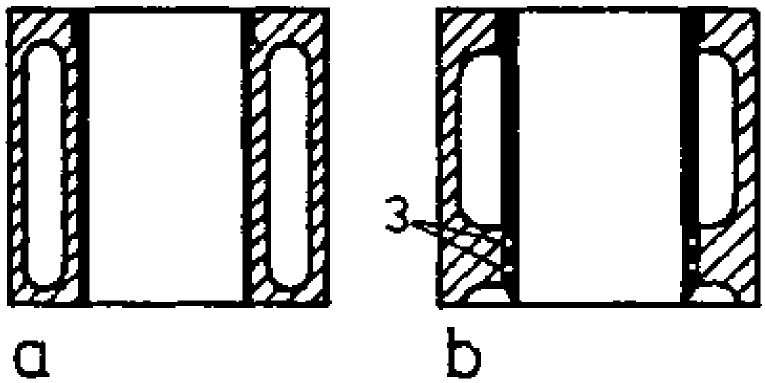

Figure 2/5 Cylinder liners

1 Dry liner; 2 Wet liner; 3 Sealing rings

As already mentioned, the top end of the cylinder is sealed with the cylinder head. In most cases the valve seats are located where the cylinder head is connected to the cylinder block. Cylinder block and cylinder head are connected by a screwed joint. A cylinder head gasket is inserted between cylinder block and cylinder head to prevent the combustion gases from escaping (Fig. 2/6).

The cylinder head gasket is made of metal–asbestos–fabric, aluminium or copper. Head gaskets made of the metal–asbestos–fabric are reinforced with metal at their openings. The profile section is also shown in Fig. 2/6. The thickness of the cylinder head gasket has an effect on the compression.

The movement of the piston between top and bottom dead centre causes wear on the cylinder.

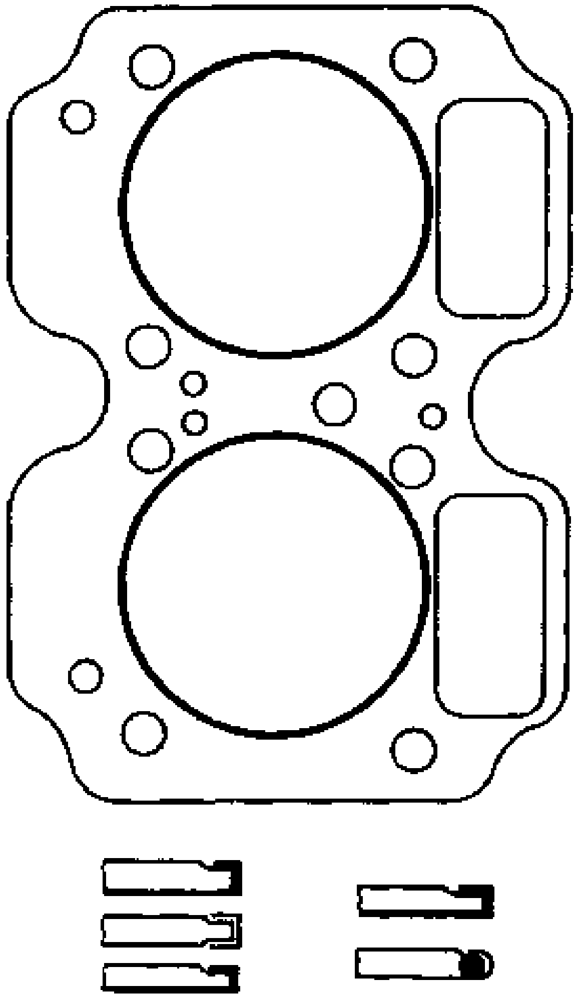

Figure 2/6 Cylinder head gasket

This wear is greatest at the point where the top piston ring is at the top dead centre. This is the point where temperatures and pressures are highest and lubrication is worst.

Moreover, the liner wall is exposed to acids which develop during combustion.

Premature wear of the liner can be combatted by using correct engine oils, by correct actuation of the choke (the engine must not be choked for too long), by maintaining the correct service temperature of the engine and by replacement of the air filter at regular intervals. Liners can be reworked.

This rework is called honing. The inner running surface of the cylinder wall is re–faced with abrasive slips mounted on a honing tool. This honing requires accurate work. Liners can only be honed to a particular wall thickness after which the wall cannot resist the pressure. If excessive wear is noted on a liner, it must be replaced by a new one. In the case of dry liners, rework can only be carried out after forcing the liner into the cylinder block.

2.2. The crankcase

The cylinders are either bolted individually or as blocks to the crankcase or they form an integral part of it. The crankshaft is supported in the crankcase. The camshaft can also be supported here. The oil pan is bolted to the bottom of the crankcase. The brackets for the lugs are located on the crankcase; they serve for mounting the engine on the chassis. The engine is mounted on the chassis with bounded–rubber blocks to protect the chassis from vibrations generated during engine operation.

2.3. The crank mechanism

The crank mechanism of a combustion engine consists of piston, connecting rod and crankshaft with flywheel. The crankshaft serves to transform the straight up and down movement of the piston into a rotational movement. It is supported in several places in the crank–case; the bearing in the centre is designed as the main bearing.

2.3.1 The piston

This section deals in detail with the piston of a combustion engine. Various types of pistons are used. The piston serves to transfer the combustion pressure via the connecting rod, crankshaft and power transmission components to the driving wheels. Moreover, the piston must perform the suction stroke to let the fuel–air mixture, in, it must compress this mixture and then discharge the burnt gases. It is clear that the piston is the part of a motor vehicle which is subjected to the greatest load. The combustion pressure is dependent on the calorific value of the fuel, the compression ratio and the shape of the combustion chamber. For Otto–engines and diesel engines the value is 30 to 40 kg/cm^2 and 60 to 90 kg/cm^2, respectively.

The combustion temperature ranges between 2000 – 2500° C. The piston consists of the following parts: piston top, piston shaft, piston pin bosses and annular grooves (Fig. 2/7). In addition to all the demands made on a piston, it must properly seal the combustion chamber and move in the cylinder so that noise and wear are kept to a minimum. It must neither stick nor rub against the cylinder wall. The weight of the piston should be kept as low as possible, and ensure good heat conductivity.

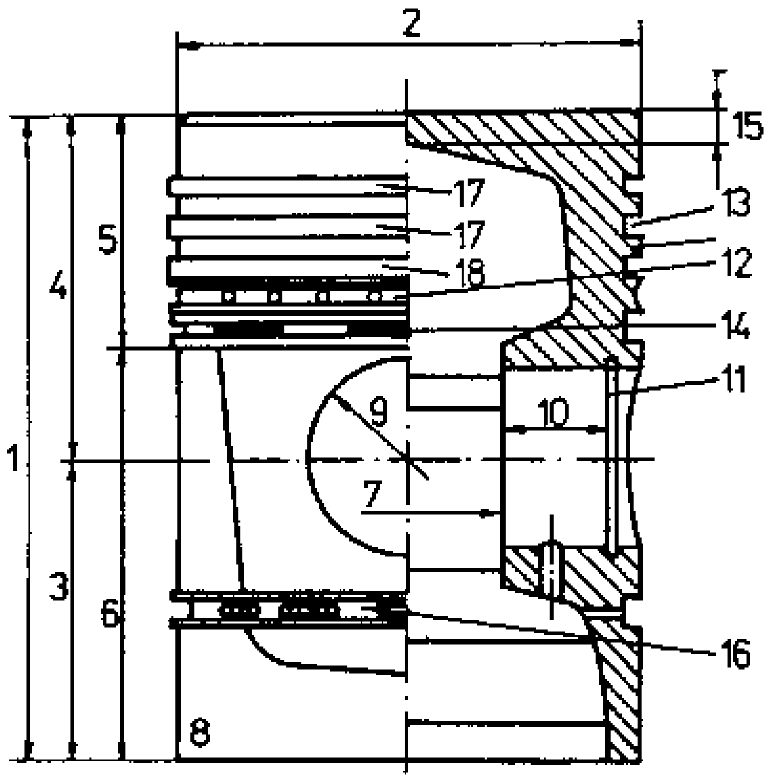

Figure 2/7 The piston

1 Total length; 2 Diameter; 3 Shaft length; 4 Height of compression; 5 Annular section; 6 Piston shaft; 7 Distance between eyes; 8 Running surface; 9 Gudgeon bore; 10 Carrying bolt length; 11 Securing groove; 12 Oil groove; 13 Annular groove; 14 Upper oil scraper ring; 15 Thickness of piston crown; 16 Lower oil scraper ring; 17 Compression rings; 18 Lower compression ring

Due to the heat generated during combustion the piston extends. This extension can result in seizure in the cylinder liner and for this reason the diameter of the piston is smaller than the diameter of the cylinder liner. This difference is called mounting clearance. When the engine is running correctly, this mounting clearance is filled by the oil film which develops on the wall of the liner. The oil film is an extremely thin layer of oil which eliminates friction between two metals and minimizes wear. Depending on the type of engine, the mounting clearance is between 0.03 and 0.08 mm. Too small a clearance can result in piston seizure, while too large a clearance can cause noisy engine run or piston chatter. The piston clearance for air–cooled engines is always somewhat larger than for water–cooled engines.

Pistons are mainly made of aluminium – silicon alloys. They can have a smooth or a curved crown as well as reinforcements in the piston crown. They can have a smooth shaft or a shaft with openings. The various types are used according to engine design.

2.3.2. The piston rings

The piston rings are used in the top part of the piston in the ring grooves. They serve to compensate the varying clearance between the piston and the cylinder wall and diameter variations of the cylinder. Since they are constantly in contact with the cylinder wall, there is constant sliding motion between piston rings and cylinder wall (Fig. 2/8).

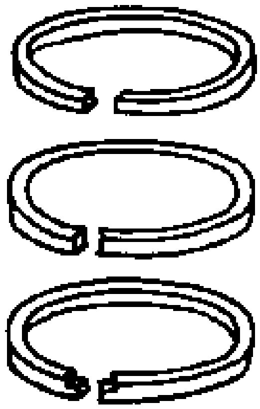

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Figure 2/8 Piston rings – I Compression rings

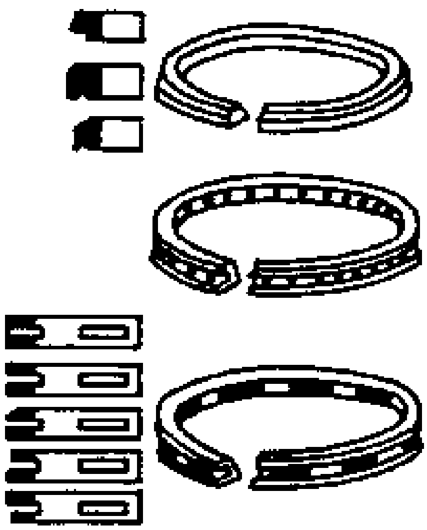

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Figure 2/8 Piston rings – II Oil scraper rings

The piston rings must also seal the combustion chamber from the crankcase so that the correct compression pressure can be reached. The piston rings lay against the cylinder wall and the groove flanks. In the case of four−stroke engines, the piston rings fit loosely in the grooves. In the case of two−stroke engines, the piston rings must be secured at the joint by pins. This is to prevent the piston rings turning in the grooves and to stop the slits in the rings moving round to the inlet or exhaust ports. In the case of four−stroke engines, the bottom−most ring is usually designed as an oil scraper ring. It has several openings around its circumference which have a direct connection with the bores in the piston ring groove. Excessive oil is removed by the piston rings and carried back to the oil pan.

The piston rings are usually of rectangular cross section and their working surfaces can be chromium−plated. They are made of a fine−grained grey cast iron.

Otto engines normally have 2 to 3 piston rings. Because of the higher compression, diesel engines have 4 to 5 piston rings.

2.3.3 The gudgeon pin

The pressure exerted by the piston is transferred by the gudgeon pin to the connecting rod. The gudgeon pin is supported by the gudgeon pin bosses. The gudgeon pin moves through the small end of the connecting rod.

There it may be supported in bushings or needle bearings so that it is free to slide. The gudgeon pin is loaded by high and constantly varying pressures.

It is made of high−quality carbonized steel. The surface of the gudgeon pin is glasshard and ground. Since it should be as light as possible, it is hollow.

Since the gudgeon pin must not touch the cylinder liner, it must be secured by the gudgeon pin boss. The gudgeon pin is shorter than the diameter of the piston; it can be secured against shifting in the gudgeon pin boss by retaining rings. The gudgeon pin can be supported in various ways:

- pivotably supported in the gudgeon pin boss and the connecting −rod small end (this is also known as 'floating support').

- rigidly supported in the gudgeon pin boss and pivotably in the connecting rod small end. (This is the most frequent type of support.)

- pivotable supported in the gudgeon pin boss and rigidly in the connecting rod small end.

For rigid support of the gudgeon pin in the bosses, the piston is heated in an oil bath or on a heating plate (approx. 60° C) to allow it to expand. Then the gudgeon pin will be slightly oiled and inserted. The piston is allowed to cool and rigidly supported and secured in the boss and then it is ready for installation.

2.3.4 The connecting rod

The connecting rod transfers the power of the piston from the piston to the crankshaft. It consists of the small end, the shaft and the big end. The connecting rod big end can be solid or split. It is subjected to tension, pressure and axial compression. It is made of high−quality material (steel). The shaft is a double−T design. The small end accomodates a bronze bushing or a needle bearing for gudgeon pin support. There is a lateral clearance of some 2 to 3 mm between the gudgeon pin bosses. The connecting rod big end connects the rod with the crankshaft. It can be split in the middle and bolted together. Bearing shells or roller bearings can be accommodated in the connecting rod big end. They ensure easy slide on the crank−pin. The bearing shells consist of two halves which are lined with bronze or light metal. To prevent distortion the bearing shells are secured in the connecting rod big end by pins. For light−metal bearing shells, white metal is used as bearing metal. Connecting rod wear is low.

Normally the connecting rod is only damaged by rupture or bending because the bearings themselves can be replaced. Prior to installation the connecting rods must be squared to ensure proper operation of the piston. If the connecting rods do not form a right angle (90 deg.), it is possible to straighten them by to 1 per cent.

A torque wrench is used to bolt the connecting rod big ends because after tightening the screws, the connecting rod must be able to move slightly on the crank−pin due to its weight, but is must not have any height clearance.

2.3.5 The crankshaft

As already mentioned, the crankshaft transforms the straight movement of the piston into a rotational movement. A strong and well−balanced crankshaft will produce smooth and vibration−free operation of the engine. There are built−up crankshafts and solid ones. The individual parts of the crank−haft can be either connected by bolts or pressed into one another. The crankshaft is cranked according to the number of cylinders an engine has. The points of impact on the connecting rods are called the crank−pins. They are situated outside the shaft axle. The crankshaft bearings are parallel to the shaft axle. The main bearing is usually situated in the middle of the shaft. It protects the crankshaft from displacement in axial direction. The crank−pins are connected with the axial bearings by angular crank arms. The crankpins are staggered to provide balanced loading of the crankshaft.

<u>Four−stroke engines</u>

Single cylinder engine:

In the case of the four−stroke engine, each working stroke is followed by three idle strokes. This must be overcome by a large flywheel.

Two−cylinder engine:

The crank−pins are staggered through 180 degrees. Each working stroke is followed by an idle stroke.

Four−cylinder engine:

The crank−pins are staggered through 180 degrees. Here the working strokes follow one after another. Therefore, the dominating firing order is either 1−2−3−4 or more frequently 1−3−4−2.

The figures listed above designate the cylinders. In this respect it is assumed that the first cylinder is positioned on the P.T.O.−side.

Six−cylinder engines:

In these engines the crank−pins are staggered through 120 degrees and the working strokes overlap resulting in the following firing order: 1−5−3−6−2−4.

Eight−cylinder engines:

In this engine, the crank−pins are staggered through 90 degrees. Due to the number of cylinders, the one working stroke starts before the previous one is completed. The firing order is 1−6−2−5−8−3−7− 4.

<u>Two−stroke engines</u>

Two−stroke engines have a similar mode of operation to four−stroke ones, but they have twice as many working strokes. Here the three−cylinder engine has the same crankshaft shape as the six cylinder engine. However, the shaft is only half the length. The working strokes are produced as with the six−cylinder four−stroke engine.

The crankshafts almost always turn clockwise, beginning at the front face of the engine. Here the crank−pins describe an arc around the shaft axis. When describing the downward arc, the piston moves towards bottom dead centre and during the upward arc towards top dead centre. Hence two piston paths equal one full crankshaft rotation.

Single−cylinder engines and two−cylinder engines are normally double supported. In the case of engines with four cylinders, two cranks are supported by two bearings, i.e. this crankshaft is supported three times. However, there are also crankshafts in which every crank is supported by two bearings. Here a crankshaft for a six cylinder engine has seven bearings while an eight−cylinder engine has nine. The bearings of a crankshaft can be designed as slide bearings or antifriction bearings. If slide bearings are to be used for crankshaft support, the bearing blocks must be split. This means that half a bearing is rigidly fixed to the engine block or cast into it and the other half is screwed on like a bridge. The bearing shells are made of bronze of antifriction bearing metal. They are secured by pins to prevent distortion. The advantage of using antifriction bearings lies in a lower friction. However, splitting of the shaft must be possible. In the majority of cases, these crankshafts are built from individual parts which are pressed into each other. Crankshafts must be well balanced by balancing machines. Balance weights are used to oppose the centrifugal forces. They can either be bolted to the crankshaft or may be an integral part of it.

In the case of slide bearings, lube oil is supplied through the oil gallery. The barings must be exactly circular.

If wear is not excessive bearing journals and crank pins can be reworked on a crankshaft grinding machine.

Prior to fitting a crankshaft in the crank−case, the crankshaft bearings must be bored in true alignment. To do this all bearings are inserted and tightened. Boring is carried out in true alignment with borer with bits which correspond to the numbers of the bearings.

2.3.6 The flywheel

The flywheel helps produce smooth engine operation. Size and weight of the flywheel depend on the number of cylinders. The more cylinders an engine has, the smoother the impacts of the power pulses on the shaft are and so the lighter the flywheel can be. The flywheel is centred on the crankshaft and kept in position by a bolted connection. The starter rim is shrunk onto the flywheel in the direction of the crankcase. The starter rim is a geared ring which serves to start the engine. Setting marks for engine ignition and timing can be marked on the flywheel.

2.3.7 The vibration damper

Torsional vibrations occur at the crankshaft. In order to dampen these vibrations, larger engines are often equipped with a torsional vibration damper.

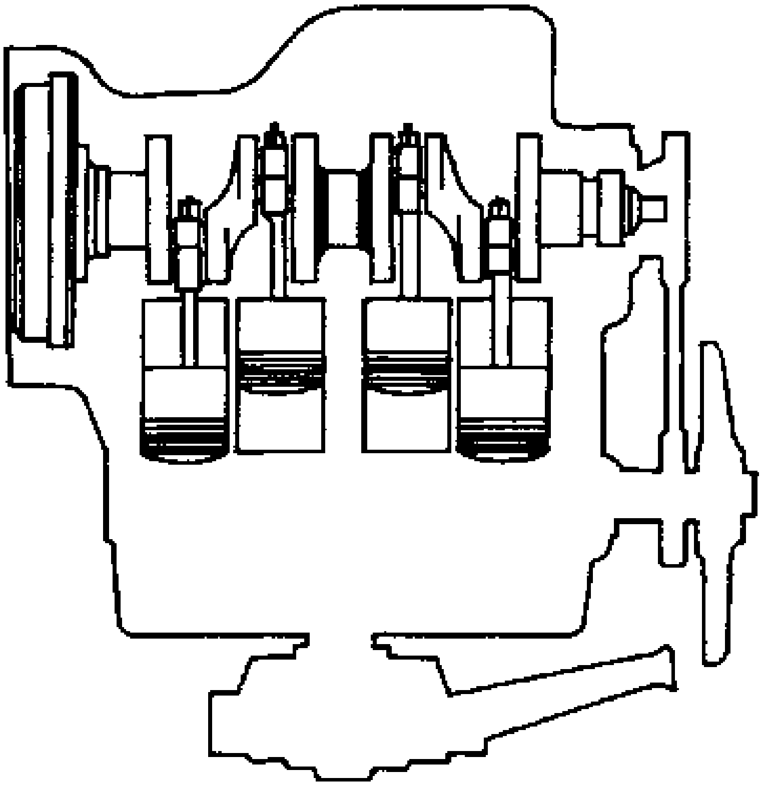


Figure 2/9 Crank mechanism of a four−cylinder engine

This is mounted opposite the flywheel and consists of a two−part balance weight in which the two halves are pressed apart by small springs and pressed against the flanks of their support. Often the vibration damper is connected with V−belt pulleys which drive the water pump and the generator as well as the compressor for the pneumatic brake system.

Fig. 2/9 shows the complete crank drive system of a four−cylinder engine.

2.4. The engine timing system

The timing system of the engine controls the gas exchange in a combustion engine.

Fig. 2/10 shows the timing system of a four−stroke engine with valves. This type of motor timing is the valve timing system. The valve timing system consists of the following components:

− Valves with valve springs
− Transmission components
− Camshaft.

In engine production conical valves are used. The valve disc is connected with a valve stem in the top of which there is a circular groove. It protects the spring plate from displacement. The spring plate is keyed. The springs are required for pressing the valve disc into its seat and to seal the oil gallery and the combustion chamber. Valve stems must be aligned accurately. Since they are prone to wear, which prevents accurate timing, they can be replaced. The valves are not only exposed to mechanical wear, but also to high thermal load as they extend into the combustion chamber.

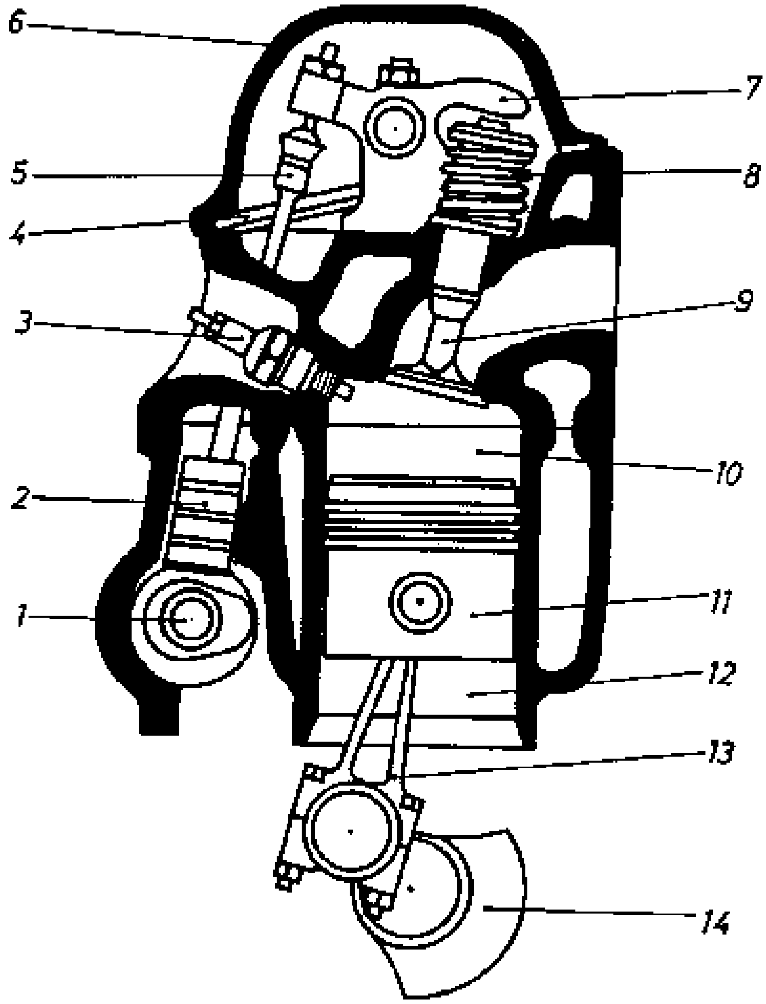


Figure 2/10 Engine timing

1 Camshaft; 2 Tappet; 3 Spark plug; 4 Cover seal; 5 Push rod; 6 Valve cover; 7 Rocker arm; 8 Valve spring; 9 Valve; 10 Combustion chamber; 11 Piston, 12 Liner; 13 Connecting rod; 14 Crankshaft

This is especially true of the outlet valves because they are surrounded by the hot gases during opening, whereas the inlet valve is constantly cooled by new gases during the inlet process. Helical springs are often used as valve springs.

Another type of motor timing is roller–type slide valve timing. By turning the roller–type slide valve, the intake and outlet passages are opened.

The transmission components of the engine timing system include:

– camshaft located near the crankshaft:

• valve tappet
• push rod
• rocker arm;

– overhead camshaft:

• rocker arm (Fig. 2/11)

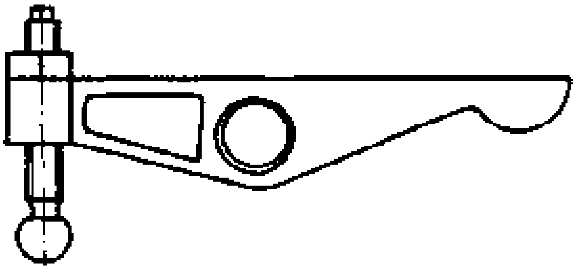


Figure 2/11 Rocker arm

The camshaft can be driven by the crankshaft in various ways. Fig. 2/12 shows the drive of an overhead camshaft by means of a timing chain.

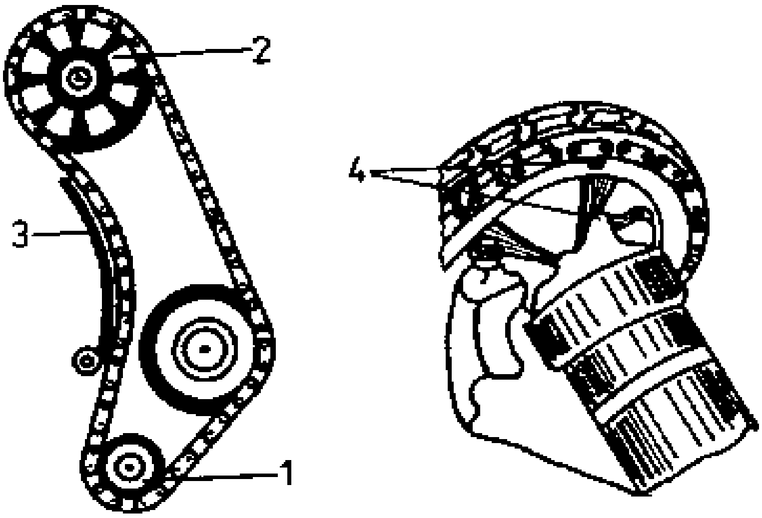


Figure 2/12 Drive of an overhead camshaft by means of a timing chain

1 Crankshaft; 2 Camshaft sprocket wheel; 3 Timing chain tensioner; 4 Timing chain marks for adjusting the camshaft

The figure also shows the marking for correct setting of the camshaft. Fig. 2/13 shows the drive of the camshaft located near crankshaft by a toothed belt. There is also a mark on the cylinder head for correct setting of the camshaft. In the case of large engines, the camshaft is driven by means of spur gears. They are also marked. If the markings do not agree, the timing is wrongly set and the engine will not run. Fig. 2/14 shows a diagram of the timing gears.

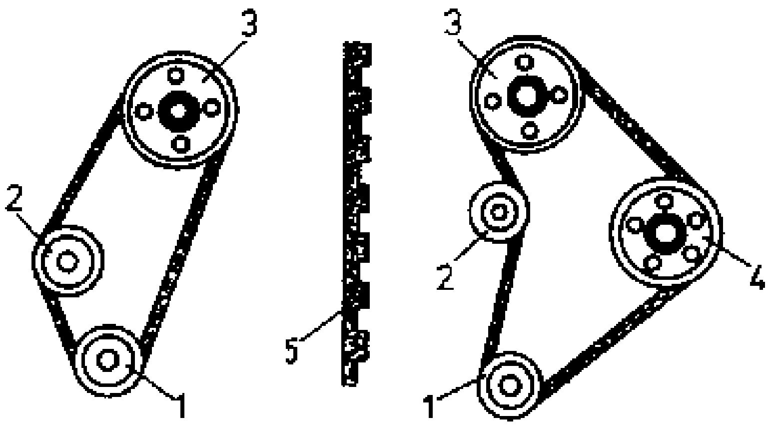


Figure 2/13 Drive of an overhead camshaft by means of a toothed belt

1 Crankshaft; 2 Tightening idler; 3 Camshaft sprocket; 4 Injection pump; 5 Profile of the toothed belt

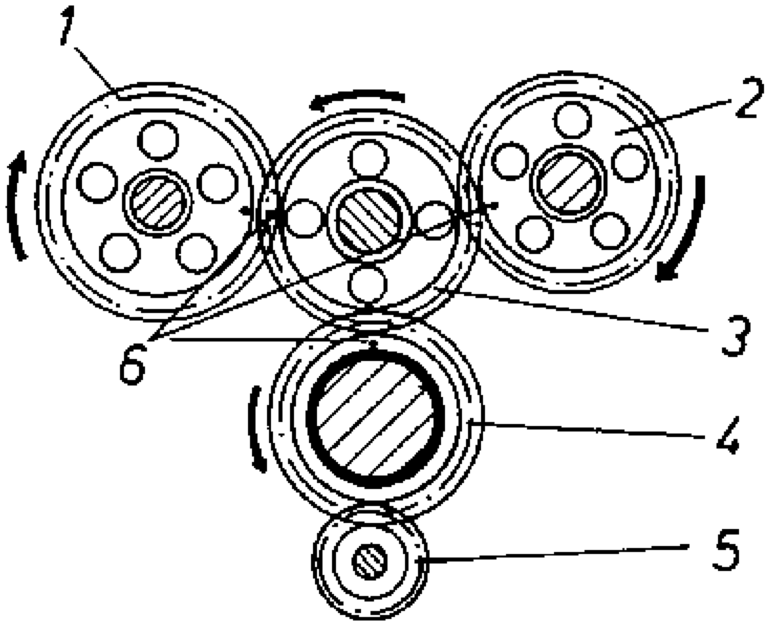


Figure 2/14 Layout of timing gear

1 Camshaft sprocket; 2 Injection pump gear; 3 Intermediate gear; 4 Crankshaft; 5 Drive of oil pump; 6 Timing chain marks for adjustment

The engine timing system with valves uses either vertical valves or overhead valves.

Fig. 2/15 shows the engine timing system with vertical valves. Here the valve stem is seated on a setting screw which extends into a valve tappet. There are two types of vertical valves: vertical valves and side valves. An engine with side valves is also called an sv engine.

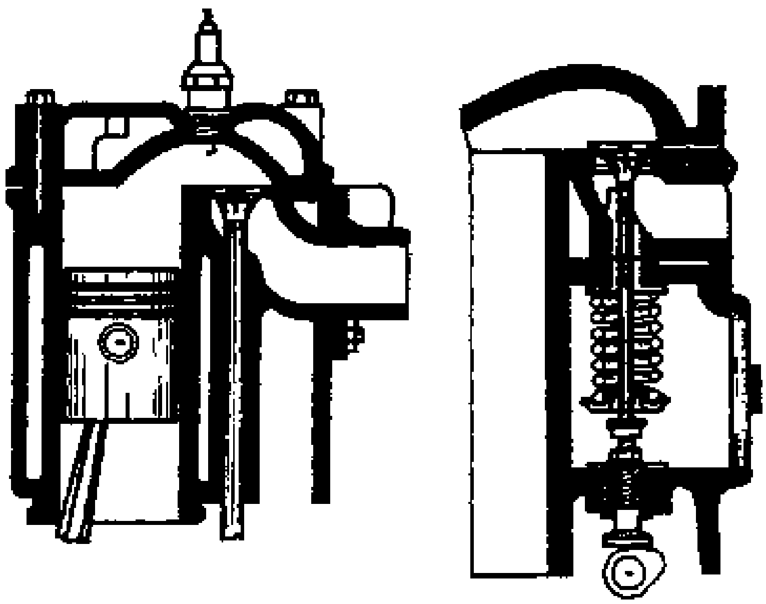


Figure 2/15 Engine timing by means of vertical valves

Another type of engine timing is the timing system with overhead valves. Fig. 2/16 shows the arrangement of overhead valves with an overhead camshaft and with a camshaft located near crankshaft. The latter is known as ohv (overhead valve) timing. However, overhead valves can also be controlled by an overhead camshaft. This can be done in two ways: by transmission of the movement to the valve by the rocker arm, and by transmission of the movement by direct impact of the cams on the valve stem. When the valves are driven directly by the cams, it is called ohc (overhead camshaft) timing.

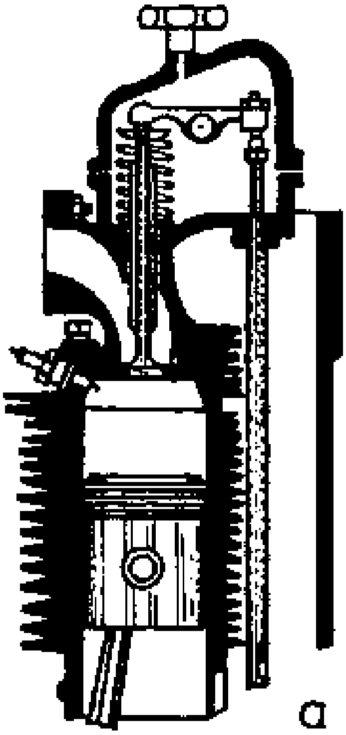


Figure 2/16 Engine timing by means of overhead valves – with camshaft located near the crankshaft

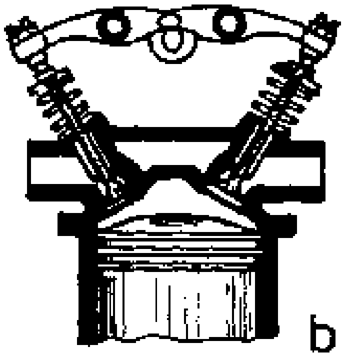


Figure 2/16 Engine timing by means of overhead valves – with overhead camshaft

The correct valve clearance is set by means of the setting screw provided on the rocker arm (Fig. 2/17).

The camshaft allows valve movement. Around the circumference there are curved raised sections called "cams'. Their number is always equal to the number of valves. The valves can be lifted abruptly of smoothly. This is also true of the closing procedure. Valves which are lifted abruptly have a higher efficiency, but wear much more quickly. However, abrupt lifting and closing will always depend on the shape of the cam.

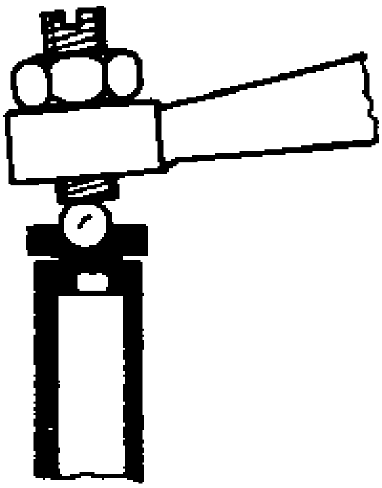


Figure 2/17 Setting screw for valve clearance

The relative position of the cams on the camshaft depends on the working sequence of the individual cylinders.

The camshaft is driven by the crankshaft. It is supported in slide bearings or antifriction bearings to prevent bending during operation. The camshaft is lubricated in connection with engine lubrication.

There must always be a clearance between the transmission parts and the valve stem, i.e. valve clearance. This clearance is specified by the manufacturer.

Fig. 2/18 shows these valve clearances. They can by set in various ways.

The most common of these is the setting of the clearance by means of a screw. Another method is the use of adaptors. The valve clearance is necessary both to compensate for thermal expansion and to ensure proper and safe closing of the valves.

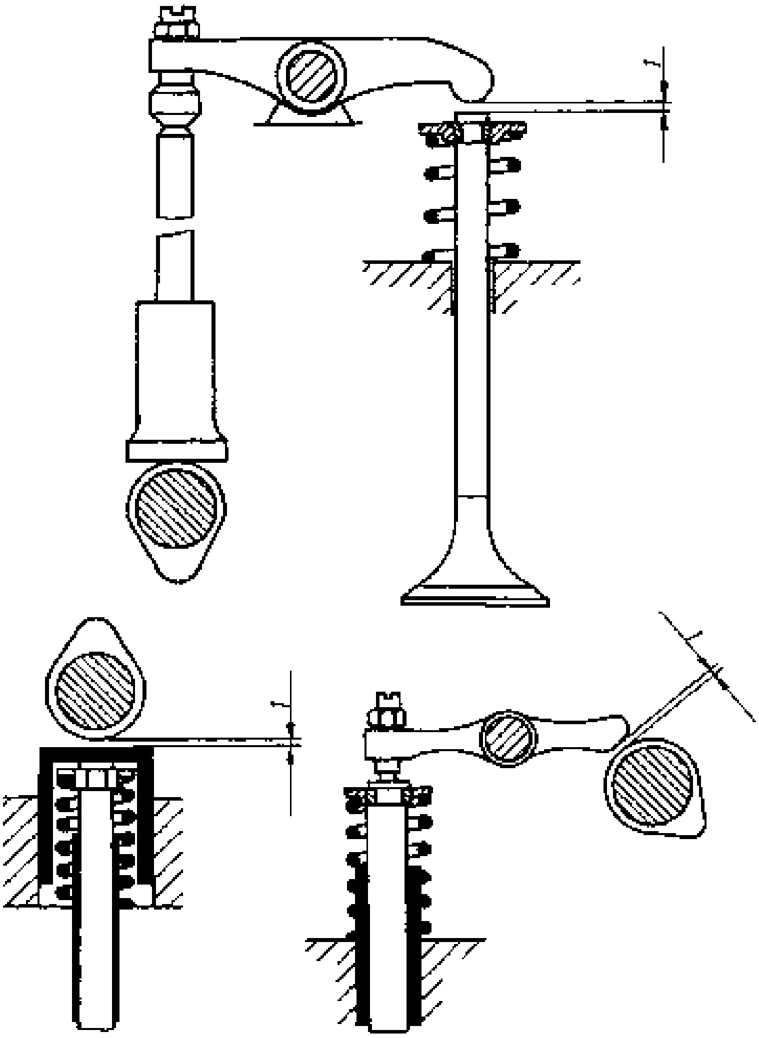


Figure 2/18 Valve clearances for various valves

1 Amount of clearance

If there is no clearance, signs of burning may appear on the valves, engine output will decrease and blow/back into the carburettor may occur. The valve clearance can either be the same for both the intake and the outlet valve, or it can be larger for the outlet valve than for the intake valve.

<u>Test questions</u>

2.1. Describe the design of a reciprocating– piston engine.

2.2. What do you understand by a reciprocating–piston engine?

2.3. What does the crank mechanism consist of?

2.4. What do you understand by top and bottom dead centre?

2.5. What do you understand by the term combustion chamber?

2.6. Describe the design of a cylinder.

2.7. What do you understand by the stroke volume?

2.8. What do you understand by the terms wet and dry liner?

2.9. Why is a gasket inserted between cylinder head and cylinder block?

2.10. Why does the thickness of the cylinder head gasket effect the compression ratio of the engine?

2.11. What is the cause of cylinder wear?

2.12. What are the functions of the crankcase?

2.13. What are the functions of a piston in an engine?

2.14. What demands are made of a piston?

2.15. Explain the design of a piston.

2.16. What are the functions of the piston rings and the oil scraper rings?

2.17. What is the function of the gudgeon pin?

2.18. What types of gudgeon pin support do you know?

2.19. What is the function of the connecting rod in a combustion engine?

2.20. Why is it necessary to square the connecting rod?

2.21. What types of bearings for connecting rods do you know?

2.22. Describe the design of a crankshaft.

2.23. What do you understand by the terms crankshaft bearing and connecting rod big end and small end bearing?

2.24. What is the function of the main bearing?

2.25. What do you understand by the term four–stroke engine?

2.26. What do you understand by the term two– stroke engine?

2.27. Why is it necessary to balance crank shafts?

2.28. What is the function of a flywheel?

2.29. Why are torsional vibration dampers used in large engines?

3. Mode of operation of the Otto engine

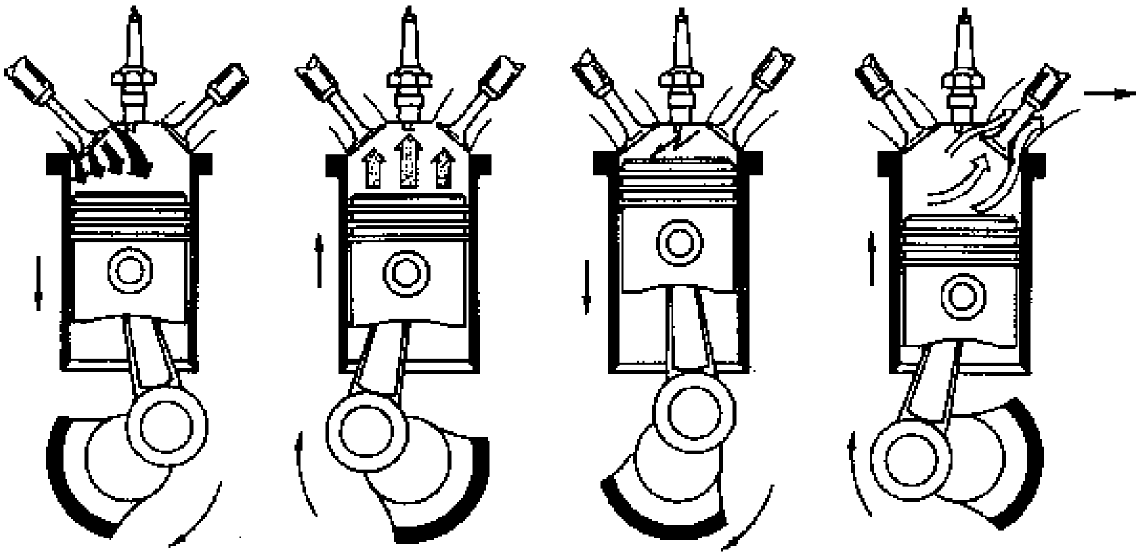
The following section deals with the mode of operation of the Otto engine.

There are two types of Otto engines: four–stroke and two–stroke engines. With regard to their combustion the two engine types have the same mode of operation, however, in the case of the two–stroke engine, the combustion process is condensed to two rotations of the crankshaft. The outer shape of the engines is also similar.

Their main difference is the charging and discharging process. In the case of the four–stroke engine, these processes are controlled by valves while in the two–stroke engine they are controlled by the power piston.

3.1. The four–stroke engine

The four–stroke engine works in 4 working strokes. These strokes are shown in Fig. 3/1.



1 2 3 4

Figure 3/1 Working cycles of the four stroke engine

1 Induction stroke; 2 Compression stroke; 3 Power stroke; 4 Exhaust stroke

The individual working strokes have the following functions:

– Suction = The intake valve is open. The piston moves towards bottom dead centre.

During this process the fuelair mixture is let in from the carburettor through the intake passage. When this process is finished, the intake valve closes again.

– Compression = Both valves of the cylinder are closed. The piston moves towards top dead centre. The fuel–air mixture will be compressed. When the piston reaches top dead centre, the degree of compression is highest. The connecting rod passes the top dead centre and enters into the downward arch.

– Ignition = Having reached its highest degree of compression, the mixture is ignited by an electric spark generated by the spark plug. The piston is pressed in the direction of the bottom dead centry be the released energy.

– Exhaust = When the piston moves back in the direction of top dead centre, the exhaust valve opens and the burnt gases are discharged.

In the Otto engine, the fuel–air mixture is ignited by an electric high–tension spark (approx. 13 000 to 15 000 Volts). This is called 'externally supplied ignition'. Therefore, this engine requires an ignition system.

The processes mentioned above last for only a fraction of a second in which short period of time, the charging and discharging process in the cylinder must have finished. In order to achieve proper charging and discharge, the valves are set so that they do not open or close directly in the dead centres. There is an overlapping of valve times.

When the inlet valve begins to open, the exhaust valve is still not fully closed. These timing cycles differ for individual combustion engines and are fixed by the manufacturer.

The timing cycles are in close relation to the crank circle and are marked in angular degrees on the flywheel or the V−belt pulley. This is to ensure that when the engine is overhauled the camshaft can be re−set. The timing cycle fixed for every engine ensures the highest output and efficiency possible. However, this requires that the valve clearance specified by the manufacturer be maintained exactly. The manufacturer also specifies whether this clearance is to be set when the engine is cold or when it is warm. A feeler gauge is used for setting the valve clearance. The feeler gauge should be inserted between valve stem and rocker arm or cam so that it can still be moved slightly.

3.2. The two−stroke engine

In the case of the two−stroke engine, the relatively complicated timing mechanism of the valves is not required. However, for this type of engine the crankcase must be well sealed as intake and precompression occur in it. In principle, there are two types of timing used today?

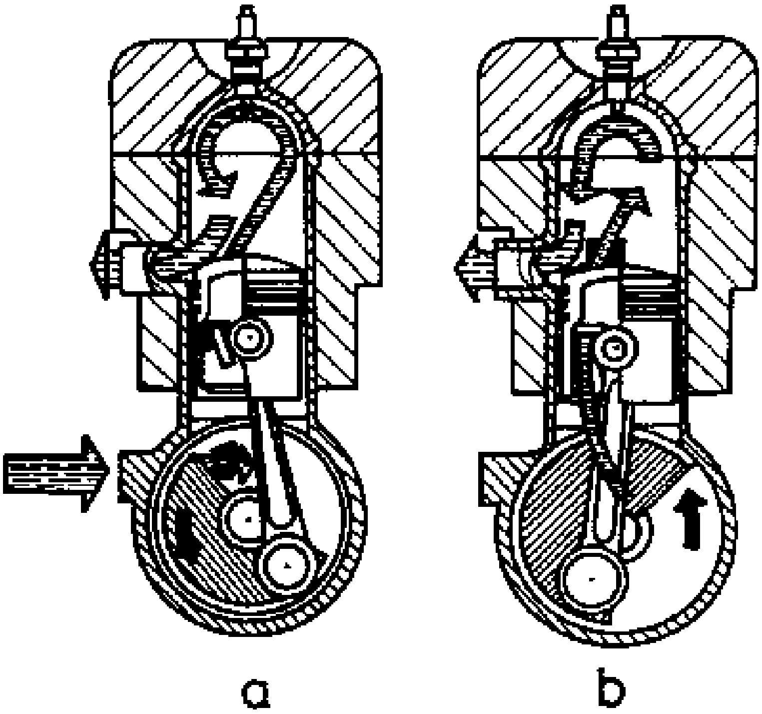


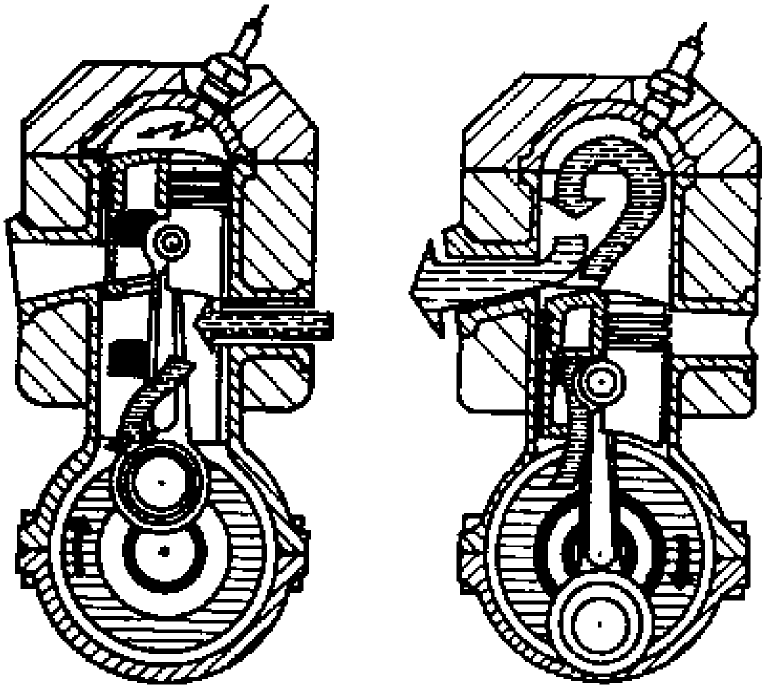
Figure 3/2 Timing by rotary slide valve

1 Inlet, overflow and outlet ducts uncovered
2 Inlet duct covered by rotary slide valve

− Rotary slide valve control
− Loop scavenging.

Fig. 3/2 shows the principle of rotary slide valve control.

When the fuel−air mixture has been ignited, the piston approaches bottom dead centre. The intake port is still closed by the rotary slide. When the piston has passed this point and the upward movement has begin, the exhaust port, the transfer port and the intake port are uncovered. When the piston moves upward, the fresh air mixture is taken into the crankcase and compressed. As a result the piston is pressed down and the mixture flows through the transfer port into the combustion chamber. Since transfer port and exhaust port are open at the same time, some of the fresh gases are discharged again. Due to the scavanging effect, the burnt gas is pressed out of the combustion chamber again and at the same time the intake port is covered by the rotary slide. When the loop scavanging principle is used there is no rotary slide (see Fig. 3/3). The fuel−air mixture is not taken in directly by the crankcase. During the ignition process, the lower control edge uncovers the intake port. The suction developing there takes the mixture into the crank–case and precompresses it. Then the intake port is covered by the piston while the exhaust port and the transfer port are uncovered by the upper control edge. The transfer port connects the crankcase with the combustion chamber.



a b

Figure 3/3 Loop scavenging

1 Ignition procedure, inlet duct opened;
2 Inlet duct closed; out let duct and overflow duct opened

Acavanging starts again. The burnt gases are pressed out of the engine.

In order to combat the scavanging losses, which are relatively high, and to ensure better charging of the two–stroke engines, a charging pump can be used. It operates in a special cylinder and can be driven directly or indirectly by the crankshaft. Such a charging pump operates on the principle that its piston does the intake timing. It is used, for example, in racing engines in order to increase the output of the engine.

3.3. The fuel system of the Otto engine

It is the function of the fuel system to produce the fuelmixture and to supply it to the cylinder in the quantities required.

3.3.1 The carburettor

The carburettor mixes the liquid fuel with the required quantity of air and converts it into a flammable fuel–air mixture. The air flowing through the carburettor is atomized and is not converted into the gaseous state until it is in the cylinder. The oxygen required for combustion is present in the air taken in Fig. 3/4 shows the design of a carburettor. In the intake duct there is a nozzle which is connected to the float chamber. Due to the accelerated intake of air, the fuel is drawn from the nozzle and flows into the combustion chamber in a atomized state. The intake duct can be in various positions. Fig. 3/4 shows the principle of the updraught carburettor.

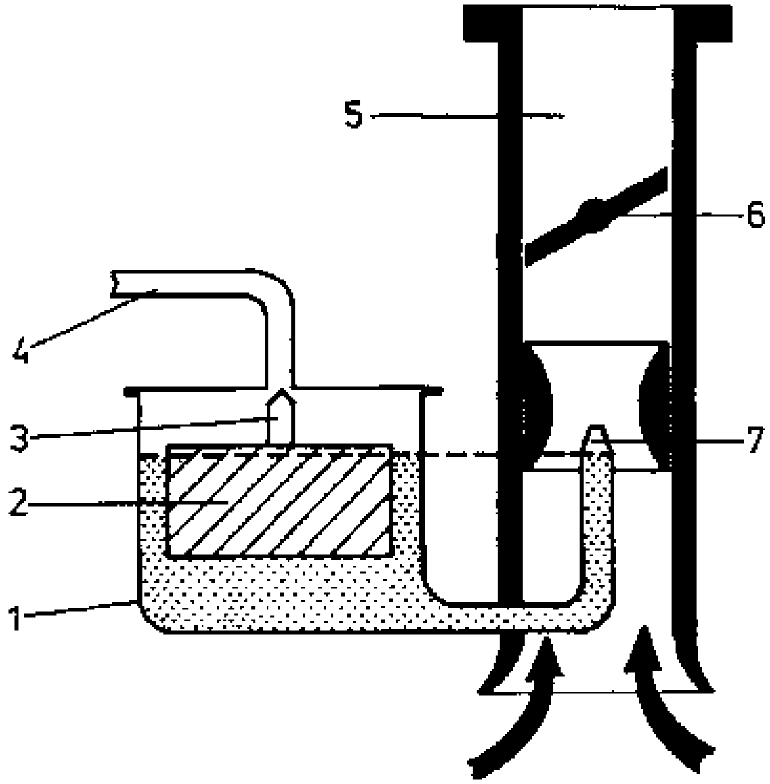


Figure 3/4 Design of the carburettor (updraught carburettor)

1 Float chamber; 2 Float; 3 Float needle valve; 4 Fuel inlet; 5 Intake port; 6 Throttle valve; 7 Jet; 8 Intake air

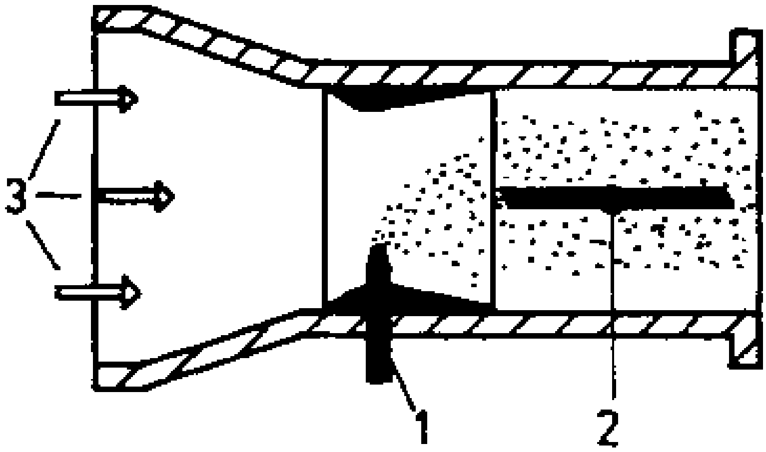


Figure 3/5 Horizontal carburettor

1 Jet; 2 Throttle valve; 3 Intake air

Fig. 3/5 shows a cross–draught carburettor. In the case of an updraught carburettor, the intake pipe is arranged in a vertical position, while in the cross–draught carburettor it is arranged horizontally.

Every carburettor has a reservoir, called the float chamber. This chamber houses the float with the float needle valve. The float is a very light hollow body through which the fuel is carried. This flow actuates a float needle valve which controls the fuel intake. If the fuel level in the float chamber decreases, the valve opens and the fuel flows in until it reaches level at which the valve closes. The float must always be tight so that no fuel can get into it. Otherwise it will sink in the petrol, the float needle valve could no longer operate and the float chamber would overflow.

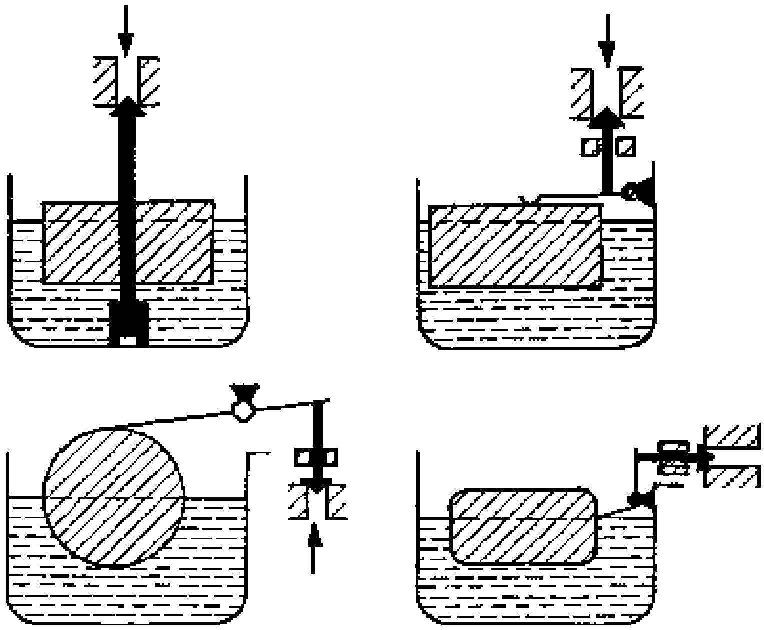


Figure 3/6 Methods of actuating the needle valves

Fig. 3/6 shows various possibilities of actuating float meedle valves.

In order to increase the flow rate of the air taken in, the suction pipe is narrowed at the height of the nozzle by a venturi tube. Above the venturi tube in the suction pipe a butterfly valve is mounted. In its home position, the butterfly valve covers the venturi tube. By means of the accelerator pedal, the butterfly valve can be adjusted infinitely as far as the fully opened position.

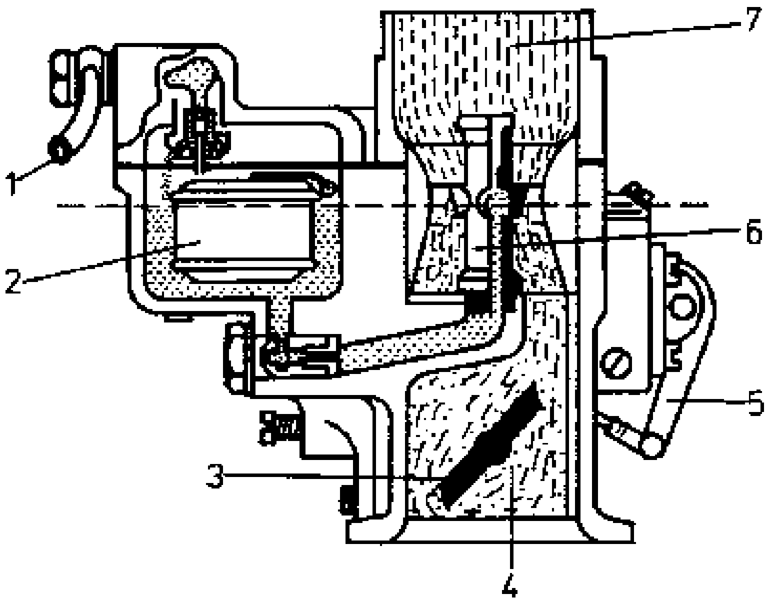


Figure 3/7 The carburettor

1 Fuel inlet; 2 Float; 3 Throttle valve; 4 Carburation; 5 Throttle linkage; 6 Jet; 7 Intake air

Fig. 3/7 shows a diagram of a complete carburettor system. To supply the engine with sufficient fuel in all speed ranges compensating equipment is required.

The compensating equipment is to ensure that the engine is supplied a mixture low in fuel when the speed is low and a mixture high in fuel when the speed is high. This compensating equipment differs from carburettor to carburettor. However, all compensating equipment should ensure the right coordination between the compensating jet, the main jet and the venturi tube. The aim is to achieve low fuel consumption, good acceleration and high performance.

Every carburettor has an idling system to allow the engine to run even when the butterfly valve is almost closed. If an engine is idling, a high air speed will only occur at the butterfly valve, which is almost fully closed, and the suction tube wall. This causes a strong air current. There is a small bore at this point which controls the throughput of the fuel by an idling jet. A special duct connects the float chamber with the idling jet. If the engine is accelerated and the butterfly valve opened, the effect of the idling system decreases to a complete standstill. This state is reached when the speed of the air in the venturi tube is higher than that at the butterfly valve.

In order to ensure good acceleration, i.e. trouble−free transition from idling to full load, the carburettors are equipped with an accelerator pump. A small amount of the fuel is injected into the venturi tube through a special passage. The accelerator pump is actuated by the shaft of the butterfly valve.

If the engine is cold, the fuel from the idling system is not sufficient to ensure the safe start of the engine. Due to the low speed during starting, the underpressure in the carburettor systems is too low.

When the outside temperatures are low, the relatively low speed is further decreased as the friction losses in the combustion engine are also increased by the viscous oil. The fuel then fed in small quantities is deposited on the walls of the suction tube and the combustion chambers are not filled. This means that the air in the individual combustion chambers contains insufficient fuel to obtain a flammable fuel−air mixture. To overcome this problem, every carburettor was an auxiliary starting carburettor system.

An air choke, usually located upstream of the carburettor, throttles the intake air during the starting process, thus generating an underpressure which produces an oversaturated mixture.

When the choke is closed the auxiliary equipment, which is called the auxiliary starting carburettor, supplies the mixture which is free of fuel upon actuation of a lever. When actuated, air chock or auxiliary starting carburettor consume a great amount of fuel. When they are actuated for too long, the oil will be diluted, resulting in decreased lubricity. Therefore it is necessary to close the starting carburettor or the air choke again as soon as the engine is running.

Today there is a growing tendency to use automatic starting systems in motor vehicles. They are the equivalent of chokes or auxiliary starting carburettors, however, they are automatically actuated by in−built components which are heatsensitive. These can be bimetal fibres or thermostatic elements. They can be heated by switching on the ignition, by the cooling water or by the exhaust gases. When the system is sufficiently heated, the starting carburettor will be closed after a particular period of time.

3.3.2 The fuel supply system

The explanation above is based on the presumption that sufficient fuel is present in the carburettor. This section explains the way in which the fuel reaches the carburettor. There are two systems:

- gravity petrol system
- fuel feed system

The gravity petrol system is the easiest way of feeding fuel to the carburettor. The tank is located above the carburettor and due to the forces of gravity, the fuel runs down into the carburettor. This type of fuel supply is mainly used in twowheeled vehicles or motorcycles. The disadvantage is that the tank must be as close to the engine as possible. Another disadvantage is that the carburettor will overflow if the float needle valves do not close exactly. To prevent serious damage in case of such mal−functions, overflow bores are provided on the housing.

If the carburettor is located higher than the tank, the fuel must be supplied by a fuel supply pump. The fuel supplied in this way is called 'pump−fed petrol'. The fuel supply pumps can be driven either mechanically or pneumatically. Most frequently a diaphragm pump is used, serving at the same time for sealing the supply chamber from the drive casing.

Fuel pumps are driven from the crankcase of the combustion engine. Fig. 3/8 shows a fuel pump with lever drive. This type of fuel pumps in only used in the Otto engine. The diaphragm is moved by a drive pin via a pump lever. The pump lever is moved from the pump shaft by a separate cam on the camshaft. When the diaphragm moves downwards the spring of the diaphragm is tensioned. This process is known as the suction stroke. By releasing the diaphragm spring, the delivery stroke is initiated. During the suction stroke the fuel is let into the pump through a sieve. Here the intake valve is open. When the delivery stroke begins, this valve is closed and the discharge valve opened. Then the fuel is supplied to the float chamber of the carburettor. The injected quantity corresponds with the load range of the engine.

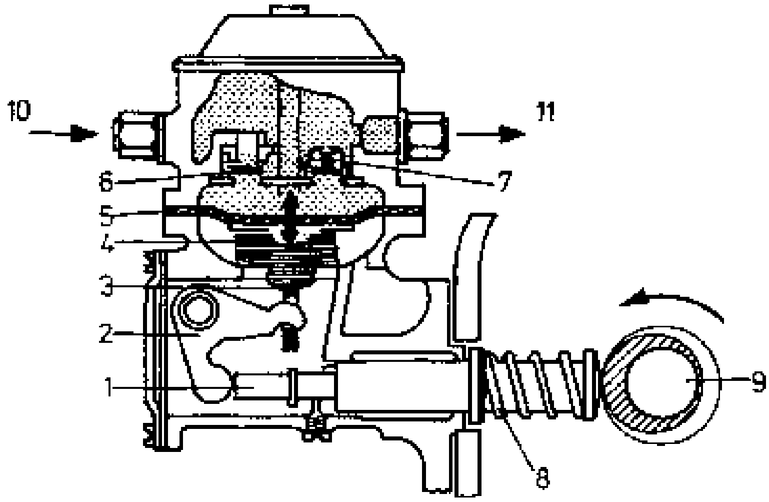


Figure 3/8 Mechanical fuel feed pump

1 Pump shaft; 2 Pump lever; 3 Driving tappet; 4 Diaphragm spring; 5 Diaphragm; 6 Inlet valve; 7 Outlet valve; 8 Return spring; 9 Camshaft; 10 Fuel from tank; 11 Fuel to carburettor

Since two−stroke engines do not have a camshaft, and some of the fuel must still be supplied to the carburettor, a pneumatically driven fuel supply pump is required (Fig. 3/9). On the supply side, it is equipped with the same components as a mechanically driven fuel supply pump. However, this type of pump can cause problems with the injected quantities required, because the driving vibrations are very low. This results in very short diaphragm movements in comparison to mechanically driven fuel pumps. The pneumatically driven fuel pump is driven by the underpressure generated in the crank−case during the suction stroke of the piston. This means that not only is the fuel air mixture taken in, the diaphragm is also moved.

Another type is the electrically driven fuel pump. The advantage of this fuel pump is that the fuel supply starts as soon as the ignition is switched on. The difficulties which might arise with mechanical or pneumatic pumps due to low batteries or the effect of cold do not occur here. Centrifugal pumps, diaphragm pumps or piston pumps can be driven electrically. As is the case in other pumps, the fuel is filtered by an upstream sieve, thus opposing any disturbance in the pumping operation.

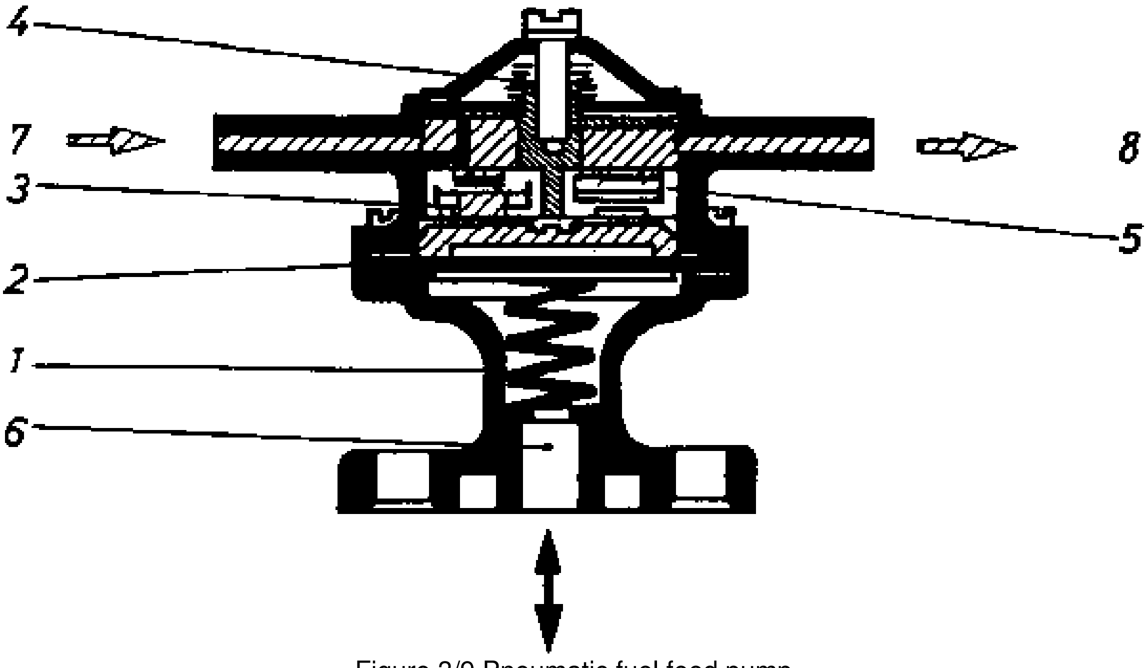


Figure 3/9 Pneumatic fuel feed pump

1 Diaphragm spring; 2 Diaphragm; 3 Inlet valve; 4 Holding spring for screen; 5 Outlet valve; 6 Connection to crankcase; 7 Fuel from tank; 8 Fuel to carburettor

3.3.3 Petrol injection

Besides the formation of the fuel−air mixture in the carburettor, there is also the possibility of petrol injection. In the case of petrol injection, the fuel−air mixture can be produced through internal or external mixing. In the case of internal mixing the fuel is injected into the combustion chamber, while in the case of external mixing it is injected into the suction duct. Petrol injection gives the following functional advantages:

– The suction tube may have a large cross section.

– All cylinders contain almost the same amount of fuel and the composition of the mixture is almost the same.

– Since the composition of the mixture in the cylinders is the same, the compression ratio can be increased and the fuel content of the mixture lowered. This lowering of the fuel content in the mixture is possible for the entire load range of the combustion engine.

– Thus the mixing process becomes in dependent of the flow in the suction tube which results in an immediate response of the engine upon actuation of the accelerator, and smooth acceleration.

– In two−stroke engines this advantage is manifested by the fact the scavanging losses do not cause any fuel losses.

– Also during fuel injection, the crank transmission does not come in contact with the fuel.

3.3.4 Supercharging of combustion engines

In an attempt to further increase the output and the efficiency of the engine, the supercharging of engines is becoming more and more important. Supercharging gives the following advantages: decrease in fuel consumption, improvement of torque characteristics and favourable exhaust emission.

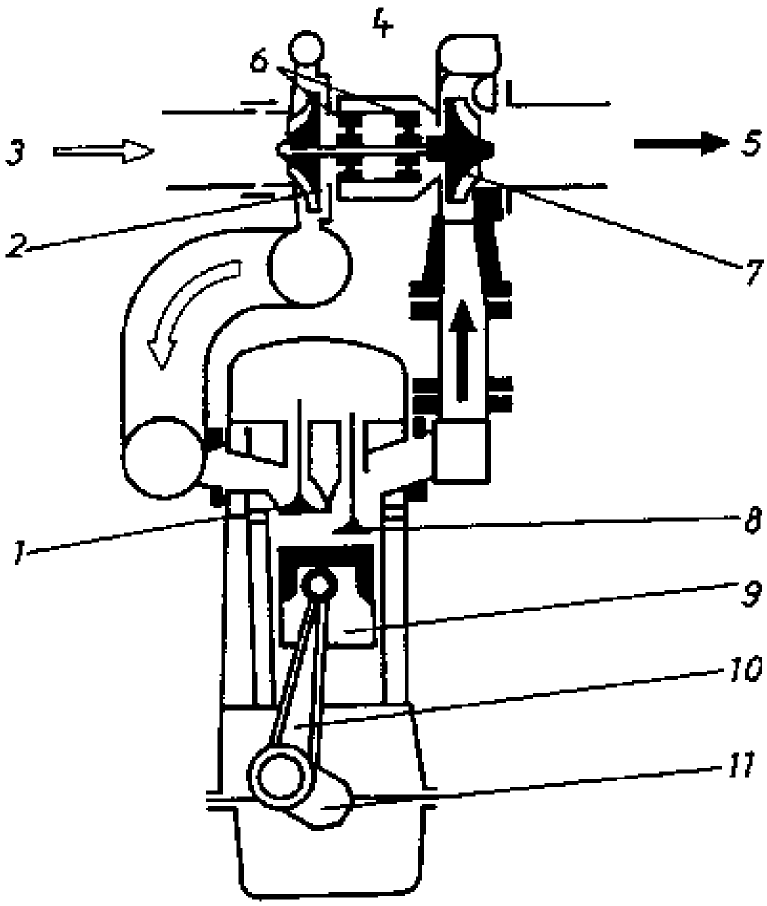


Figure 3/10 The exhaust gas turbo−supercharger

1 Inlet valve; 2 Turbocharger; 3 Fresh−air charge; 4 Turbine; 5 Removal of exhaust gas to silencer; 6 Pillow block; 7 Rotor; 8 Outlet valve; 9 Piston; 10 Connecting rod; 11 Crankshaft

Fig. 3/10 shows the diagram of an exhaust gas turbo−supercharger. The exhaust turbo−charger consists of an exhaust gas turbine and a compressor. The exhaust gas turbine is driven by the discharged burnt gases. This turbine is connected with the compressor by a shaft and causes the latter to rotate. This rotation allows fresh air to be sucked in and accelerated. This process causes pre−compression and thus a greater fresh charge is obtained. The exhaust turbo−charger is not only used in Otto engines, but also in diesel engines.

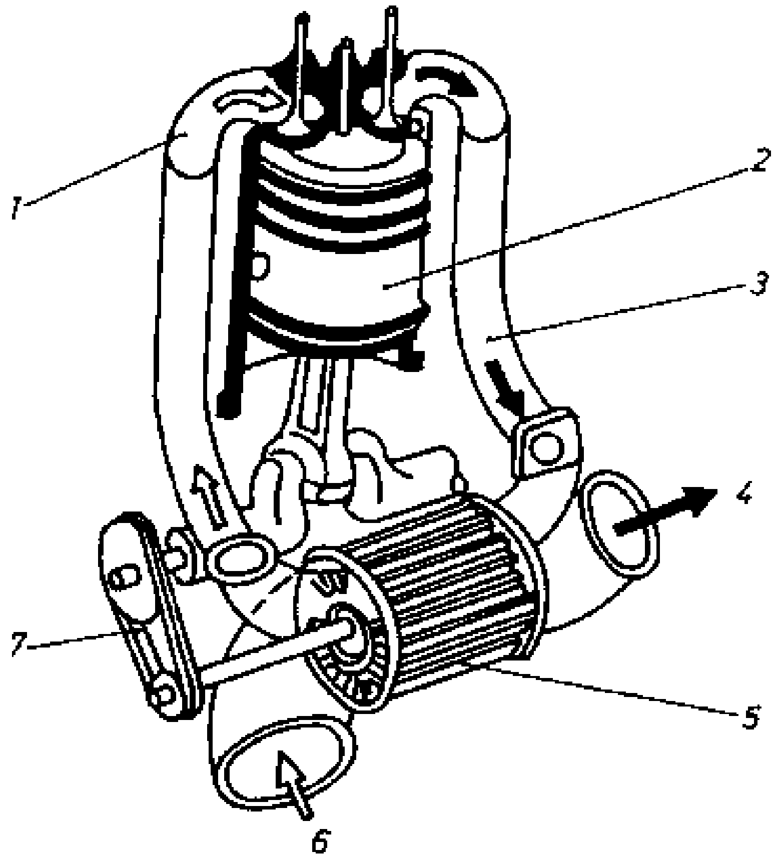


Figure 3/11 The Comprex shock wave supercharger

1 Infeed of charge air; 2 Engine piston; 3 Exhaust gas of engine; 4 Discharge of the relieved exhaust gas; 5 Cellular wheel; 6 Fresh–air inlet; 7 Belt drive

Another type of supercharger is the Comprex–pressure wave charger. Here the turbine is replaced by a cell wheel which is driven by the crankshaft via a vee–belt. In some respects this system of supercharging produces better results than even the turbo–charger. These advantages include improvements in the duration of acceleration and the smoke integral. However, the Comprex–pressure wave charger is used only in some types of diesel engine.

Test questions

3.1. Describe the mode of operation of a four–stroke Otto–engine.

3.2. Describe how the valve clearance is to be set.

3.3. Explain the mode of operation of a two– stroke engine.

3.4. What do you understand by the term timing by rotary slide valve?

3.5. What do you understand by loop scavanging?

3.6. What is the function of the carburettor of an Otto engine?

3.7. What do you understand by a down– draught carburettor and a cross– draught carburettor?

3.8. What is the function of the float? Describe the design and the various possibilities of actuating float needle valves.

3.9. Describe the function of a idling system.

3.10. What do you understand by the terms 'gravity–fed petrol' and 'pump–fed petrol'?

3.11. What is the function of a fuel pump? Describe the design of such a pump.

3.12. What are the advantageous of fuel injection in Otto engines?

4. Mode of operation of the diesel engine

The diesel engine, like the Otto engine, is a reciprocating piston engine. The basic design of the two engines is very similar. The following describes the differences between the Otto engine and the diesel engine.

In contrast to the Otto engine, the diesel engine only takes in air which will be highly compressed. The compression heat generated during this process is enough to ignite the fuel injected. Therefore, in the case of diesel engines we speak of self−ignition. The mixture is formed inside the engine. The diesel engine has no carburettor, it is equipped with an injection pump. Due to the self−ignition, there is no electric ignition system required. In Otto engines light oils (petrol) are used for forming the mixture. The diesel engine, however, can use heavy oils (diesel fuel, crude oil and others). In the Otto engine, the formation of the mixture is completed before combustion begins whereas in the case of the diesel engine it can still continue when combustion has begun. The average rated speed of the diesel engine is must lower than the speed of the Otto engine: Otto−engine: 3000 – 6500 min^{-1}; diesel engine: 1500 – 3600 min^{-1}.

In the diesel engine gears need not to be changed as often as in the Otto engine because the have different torque behaviour. As compared to the Otto engine, the fuel consumption of the diesel engine is relatively low.

4.1. Feed pump and filter

Both diesel engines and Otto engines are built in two−stroke and four−stroke models. The following deals with the fourstroke diesel engine. Fig. 4/1 shows the entire fuel system of a diesel engine.

It consists of a tank with level indicator, feed pump, filter combination, injection pump, injection nozzles and lines.

Fig. 4/2 shows the function of the feed pump. Normally it is flanged to the injection pump. and is driven by the camshaft. The piston of the feed pump can be actuated by a lever. The pumping piston is pressed up to top dead centre by a pushrod which is not rigidly connected with it. The fuel is supplied in the direction of the injection pump. This process is called the delivery stroke. Now the piston is moved back towards bottom dead centre by a built−in spring. This is the suction stroke.

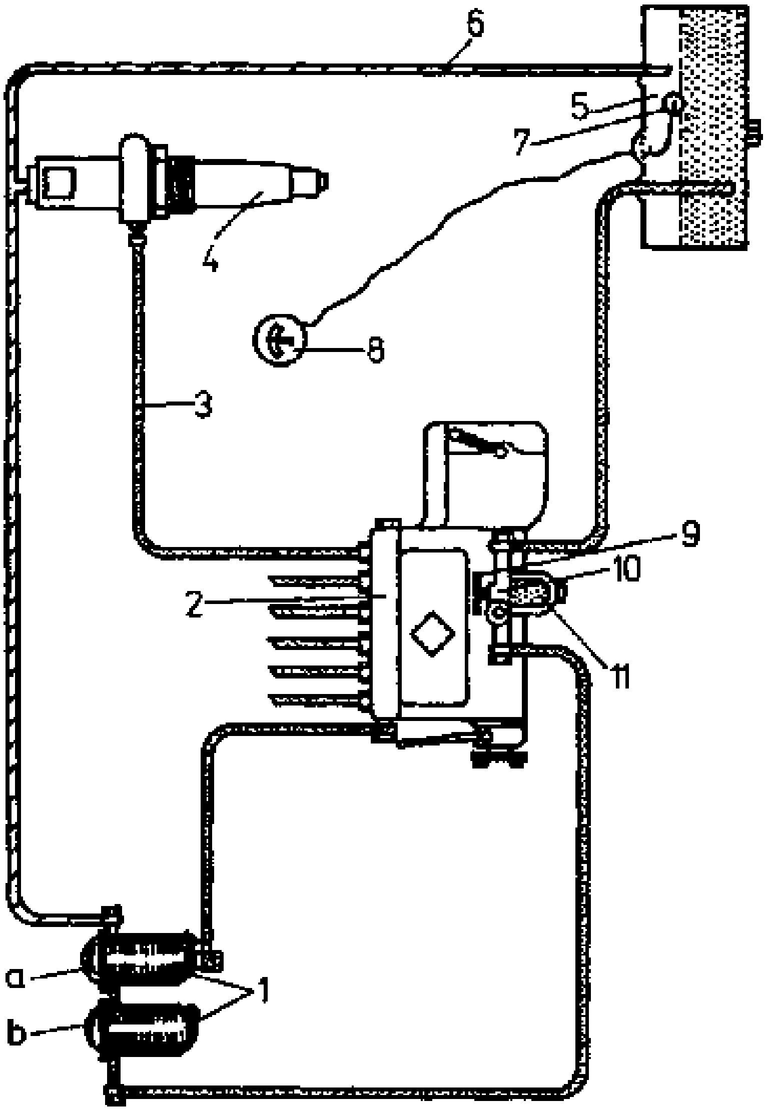


Figure 4/1 Fuel system of the diesel engine

1 Filter combination (a fine filter, b coarse filter); 2 Inject ion pump; 3 Pressure line; 4 Injection nozzle; 5 Tank; 6 Return line; 7 Level indicator; 8 Tank dial; 9 Manual pump; 10 Fuel feed pump; 11 Precleaner with sight glass

The fuel is taken in form the tank. During the delivery stroke, the fuel is circulated in the pump casing. When the counterpressure of the fuel exerted on the bottom side of the piston becomes too high, the pushrod will run free until the counterpressure reduces again.

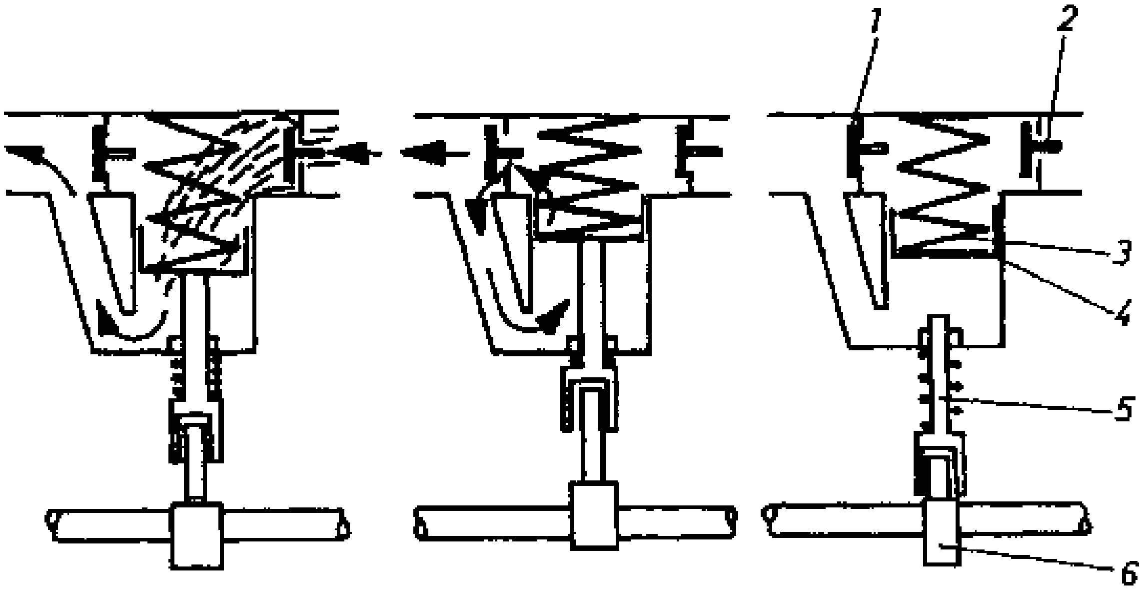


Figure 4/2 Function of the fuel feed pump

1 Pressure valve; 2 Suction valve; 3 Spring; 4 Piston; 5 Tappet; 6 Cam

Thus the injected quantity will always automatically match the consumption and there oversupply is impossible. On the feed pump is a sight glass which contains asieve for impurities.

Now the fuel is pressed through the piping into the filter combination. The fuel filter is located upstream of the injection pump so that no impurities will enter the pump. The filter combination (Fig. 4/3) consists of a pre−filter and a fine−mesh filter. Both are rigidly connected by a channel in the crank−case cover.

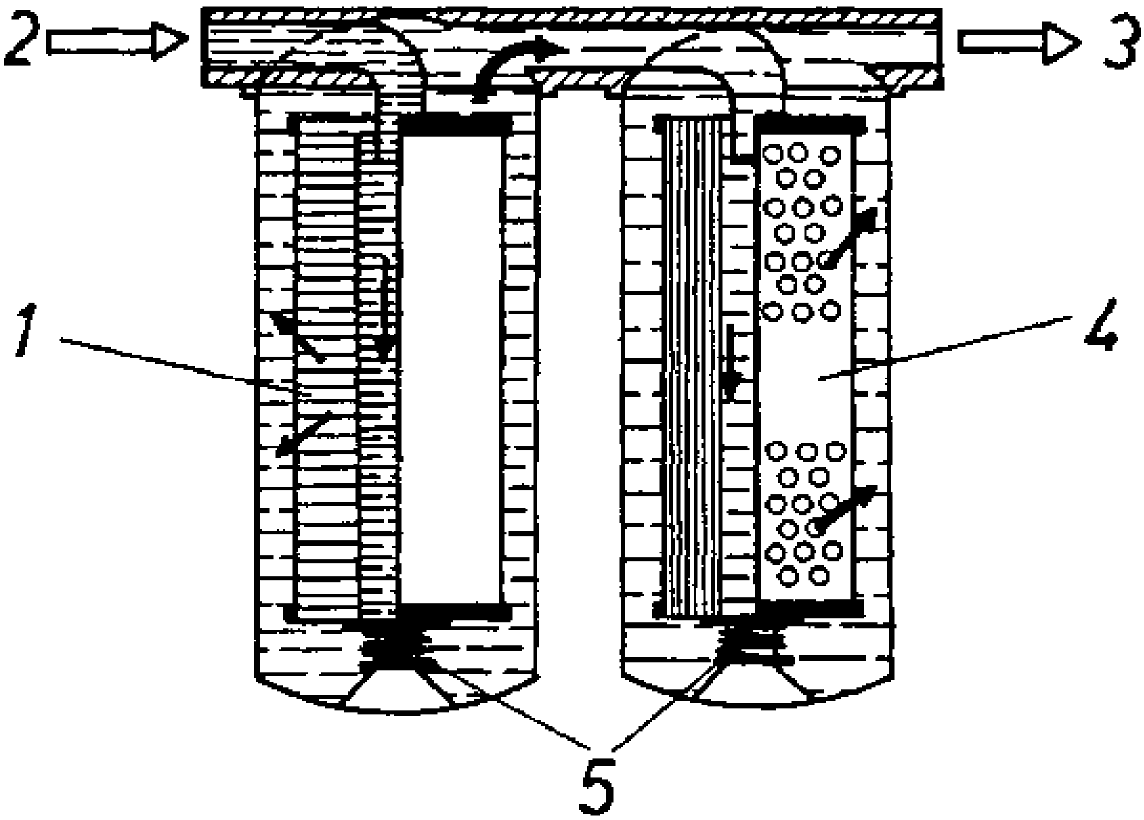


Figure 4/3 Filter combination

1 Prefilter cartridge; 2 Fuel from feed pump; 3 Fuel cleaned to injection pump; 4 Filter cartridge; 5 Compression spring

Moreover, there is an air vent screw and a safety valve in the cover. The safety valve is coupled with a return pipe to the tank. If there is an overpressure in the filter combination, the valve will be opened and the excess fuel will flow back into the tank.

The filter housing and the cover are bolted together. The filter inserts are located in the filter housing. A felt insert is provided in the rough or pre−filter while a paper insert is placed in the fine−mesh filter. The fuel is pressed from inside through the filter insert into the housing and then flows through a channel into the fine−mesh filter insert. Here again it is pressed from the inside outwards and flows through a pipe to the injection pump. To ensure correct functioning of the injection pump and the injection nozzles, the mechanical purity of the fuel must be guaranteed. Therefore, the filter inserts must be replaced at particular intervals. The lifetime of a filter insert is specified by the manufacturer of the combustion engine. Filter inserts can be washed in fuel. However, filter inserts made of paper must be replaced by new ones.

4.2. The injection pump

From the filter combination, the fuel flows into the injection pump and is fed from here under high pressure through the injection nozzles into the combustion chamber. The injection pump contains pump elements, the number of which depends on the number of cylinders, which are accommodated in a light metal housing.

Each individual pump element consists of a plunger and a cylinder. The plunger is moved up and down by a camshaft in the injection pump. To force the plunger back into its home position, a thrust spring is provided. The plunger fits the cylinder exactly so that no special sealing against the cylinder is required, even in the case of very high pressures. The fit ranges from 0.001 to 0.002 mm.

The most commonly used injection pumps are rotary injection pumps.

These pumps have ajoint inlet chamber for all pump elements. Each pump element is connected with the inlet chamber by an inlet hole and a back flow hole.

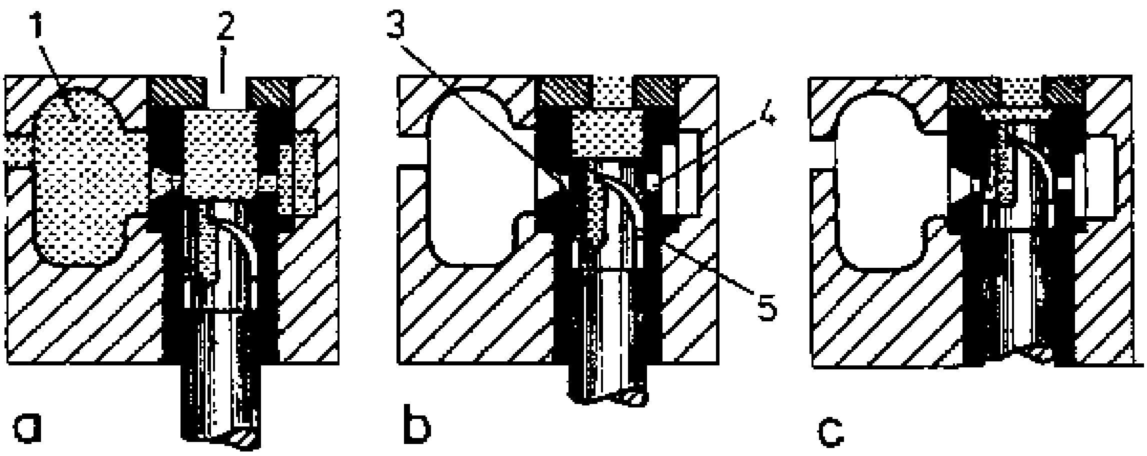


Figure 4/4 Mode of operation of the injection pump

A End of suction stroke; B Beginning of delivery; C End of delivery
1 Suction space;
2 Pressure line;
3 Suction port;
4 Return port;
5 Helix

Fig. 4/4 shows the mode of operation of the rotary piston injection pump. When the plunger is moved downward, fuel is let in through the inlet hole. This process is called the suction stroke. When the plunger is pressed upward by the cam, the inlet hole and the back−flow are covered.

Now the fuel can be supplied under high pressure through the pressure line to the injection nozzle. A pressure valve is provided upstream of the cylinder so that the fuel cannot flow back into the pump element. The plunger has a helix control edge with a vertical groove to allow the volume injected to be changed in accordance with the engine speed. The vertical groove connects the plunger chamber and the room beneath the helix control edge. The fuel is only supplied for as long as the inlet hole and the backflow hole are covered by the plunger.

As the helix control edge passes over the backflow hole, the pressure in the plunger chamber falls. The fuel flows through the vertical groove into the pressure compensating chamber which is connected with the backflow line. The injection time depends on the time the two cylinder holes are covered. The plunger of the pump is connected with a toothed gear which can be turned by a rack, also called the control rod. The further to the right the control rod turns the plunger, the earlier the backflow hole is uncovered by the helix control edge. When the vertical groove reaches the backflow hole, the delivery is zero. (See Fig. 4/5). The delivery always begins at the same time, but finishes at different times, depending on the position of the plunger, so producing the various injection–pump deliveries. The control rod turns all the plungers at the same time, thus setting the effective stroke. The control rod is moved by the accelerator, through in some cases manual control is possible.

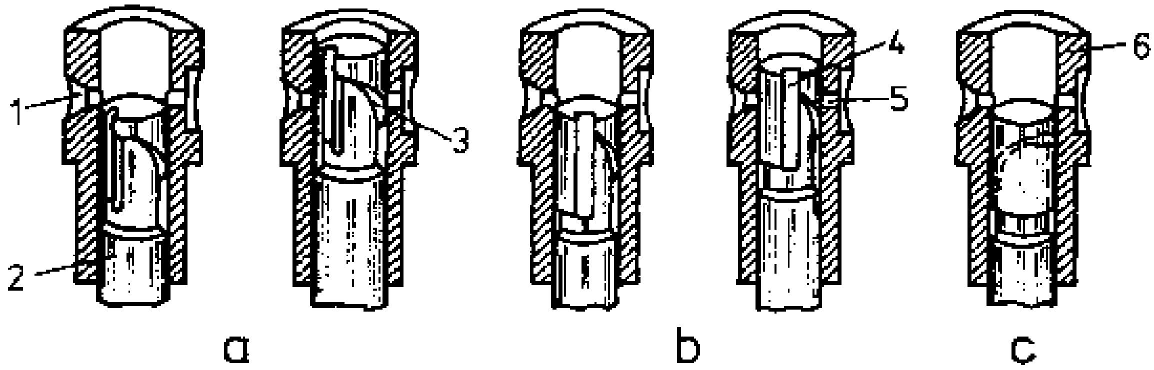


Figure 4/5 Changing the rate of delivery of the injection pump

A Maximum delivery; 3 Half–delivery; C Zero delivery 1 Suction port; 2 Piston; 3 Helix; 4 Longitudinal groove; 5 Return port; 6 Cylinder

Mechanical speed governors are mounted to the injection pump. They can either be mounted upstream of the injection pump or be integrated with it. They are designed as mechanical governors and limit the maximum speed and the idle run of the engine. They consists mainly of two flyweights which are spring loaded. They cause the control rod to be pushed towards stop direction when the speed limit is exceeded. If the speed in idle run falls too much, the control rod is moved towards full load. In the speed range between idle run and maximum speed the governor does not work because the volume injected is controlled here by the accelerator pedal. However, if the maximum speed is exceeded, the governor begins to function again.

The injection pump is driven by the crankshaft, either by timing gears or a toothed belt. Here the power can be transmitted either by a flange or a cross–head coupling. The coupling has a device for setting early or late injection. This corresponds with the ignition control in Otto engines.

4.3. The injection nozzle

The fuel is supplied to the injection nozzles by the pumping elements. Their function is to inject the fuel under high pressure in atomized state into the combustion chamber. The nozzle consists of the nozzle body and the nozzle needle. The nozzle needle is pressed onto the valve seat of the nozzle body by a strong spring. On the nozzle needle there is a conical section which fits into the ring–groove. The fuel flows through the bore in the nozzle holder into the ring–groove. When the pressure is high enough to overcome the spring tension, the nozzle needle is lifted and the fuel is fed into the combustion chamber in atomized state. When the delivery stroke is finished, the nozzle needle is pressed into the valve seat by the spring tension. The injection pressure is between 100 and 180 kg/cm^2. Various types of injection nozzles are used in diesel engines. The most important ones are shown in Fig. 4/6.

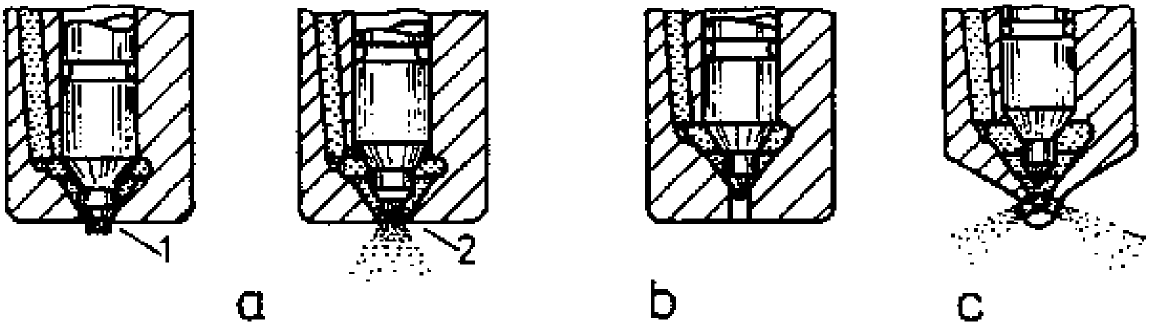


Figure 4/6 Injection nozzles

A Pintle nozzle; 1 opened; 2 closed
B Single–orifice nozzle closed,
C Multi–orifice nozzle opened

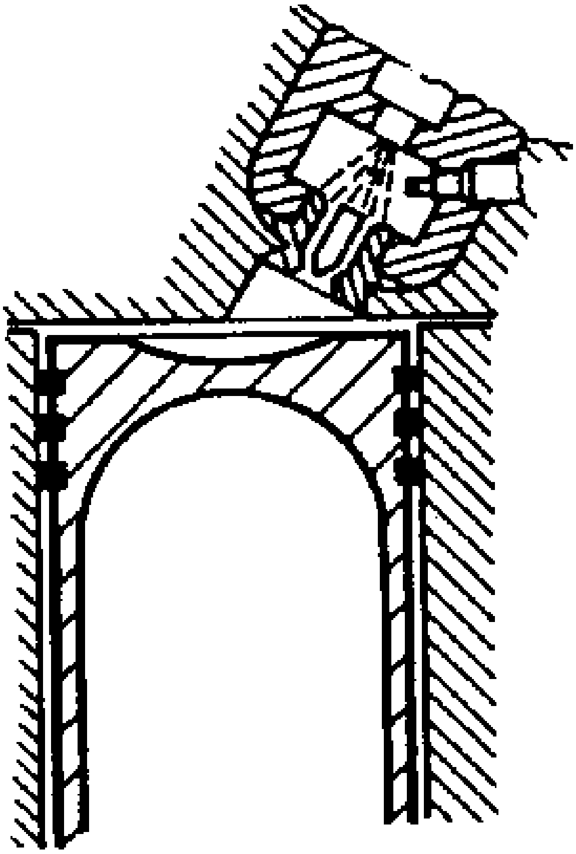


Figure 4/7 Pre–chamber process (182/3)

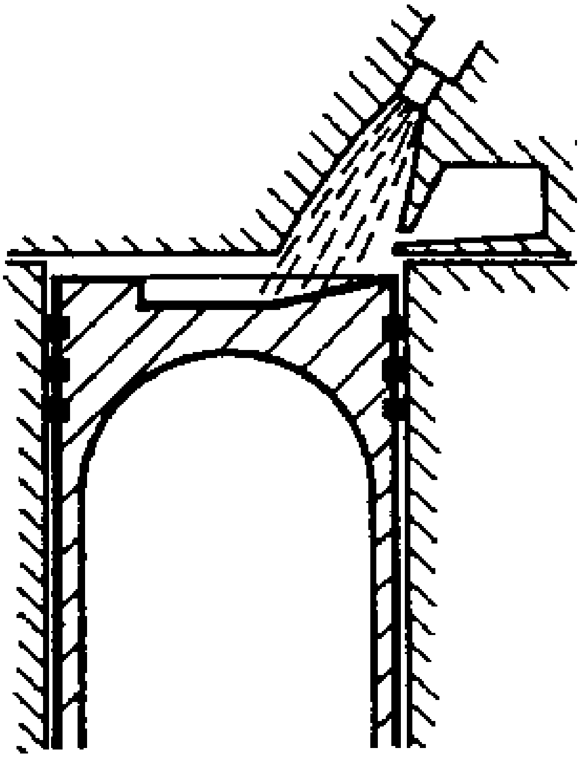


Figure 4/8 Air−chamber process (182/4)

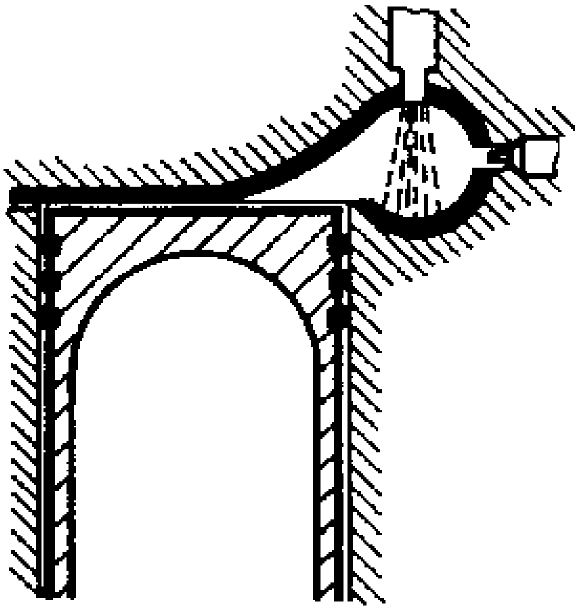


Figure 4/9 Whirl−chamber process (182/2)

The pintle nozzle and the single hole nozzle are used in combustion engines for the pre−chamber procedure (Fig. 4/7), the air−chamber procedure (Fig. 4/8) and the whirl−chamber procedure (Fig. 4/9) as they produce a good turbulence effect. For combustion engines in which the turbulence effect is not so good, multi−hole nozzles are used in order to improve it.

Direct−injection, a special type of fuel injection, has lead to the development of new methods of mixing. A spiral−type intake duct forces the incoming charge to rotate around the cylinder axis. This turbulence flow is continued by the spherical piston recess. In the case of this process, the fuel is injected at top dead centre. Approximately 95 % of the volume injected is deposited as a film at the wall of the combustion chamber and only 5 % is atomized in the air thus starting combustion. Due to the effect of the combustion heat and the turbulence in the combustion chamber, the fuel is evaporated.

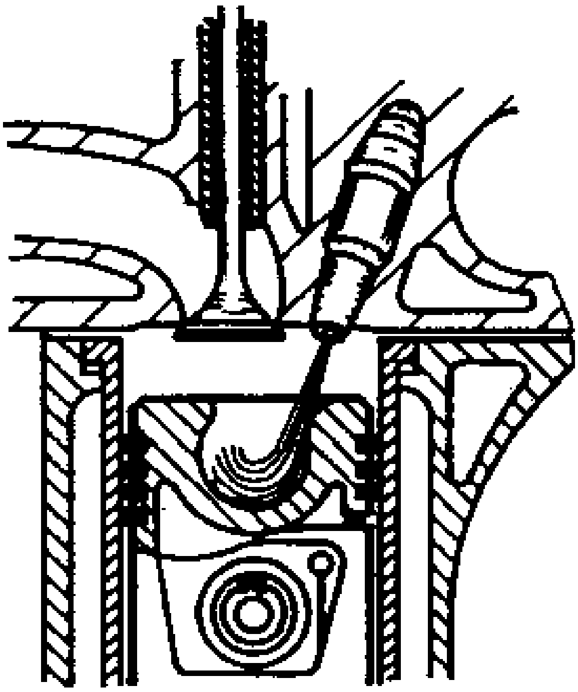


Figure 4/10 Direct injection process, (182/5)

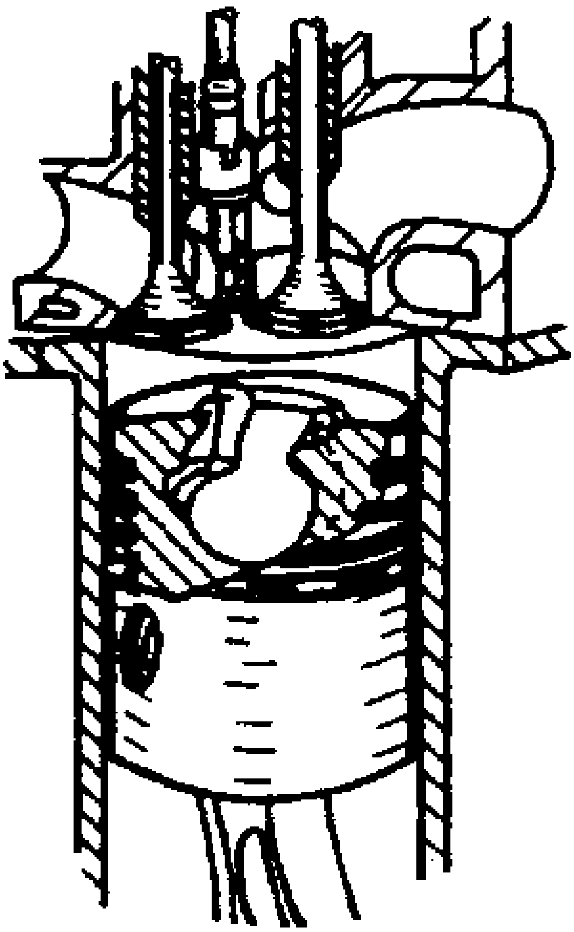


Figure 4/11 Direct injection process with externally supplied ignition (182/6)

Thus a homogeneous mixture is formed which, controlled by the charging current, is supplied to the flame front (Fig. 4/10). A further development is shown in Fig. 4/11. It meets the requirements of multi−fuel engine. The mixing process is the same as above. However, ignition is not caused by the great compression heat, but by a spark plug which protrudes into the combustion chamber. This engine combines the advantages of both Otto and diesel engines. Due to the use of external ignition, the compression can be kept within the range of self−ignition. Further merits include:

– All types of petrol can be burnt at high compression without causing knocking.

– Efficient operation of the diesel engine is ensured.

– In comparison to the Otto engine, the exhaust gases contain only small amounts of carbon monoxide throughout the entire service range.

The injection nozzles are inserted into a nozzle holder and can be replaced. The thrust spring required to produce the injection pressure is also located in the nozzle holder. The thrust spring can be adjusted. The nozzle holder is connected with the injection pump by a pressure line. The ends of the pressure lines are sealed with sealing cones. There are two ducts in the nozzle holder. One is used to supply the fuel to the nozzle, the other is coupled with the flowback line, and returns excess fuel.

Test questions

4.1. Explain the differences between diesel engine and Otto engine.

4.2. Describe the fuel system of the diesel engine.

4.3. Describe design and function of the fuel pump.

4.4. Explain function and structure of the injection pump.

4.5. Describe the mode of operation of a rotary injection pump.

4.6. What is the function of the centrifugal governor of an injection pump?

4.7. Describe the design and the function of injection nozzles.

4.8. What types of injection procedures do you know? Give some examples.

4.9. What are the merits of the MAN – M – process in comparison with other injection processes?

5. Engine lubrication

The combustion engine has a great number of metal surfaces sliding on one another. If metal surfaces slide directly on one another, strong friction occurs, causing excessive heating and high wear. In order to prevent friction a lubricant is used. The lubricant is to form a film on the sliding metal surfaces, thus preventing friction between them (since liquid friction is lower than dry friction) and reducing metal abrasion. The lubricant used in the combustion engine is engine oil which can be of various viscosities. However, the engine oil not only lubricates it also cools and seals the sliding surfaces, e.g. sealing of combustion chamber (piston rings – cylinder wall).

High demands are made of the engine oil. It must always maintain its properties whatever the conditions prevailing in the engine. In the case of high pressures and temperatures, the oil must cool, seal and lubricate. In addition to constant supervision, it is imperative to observe the periodical oil changes specified by the engine manufacturer in order to prevent damage to the engine. Always use the oil specified. In order to. ensure that all moving parts of the combustion engine are constantly supplied with oil it is circulated, and having been cooled and filtered, is supplied to the individual lubricating points. There are three main types of engine lubrication:

– Forced feed lubrication
– Dry sump lubrication
– Petrol lubrication.

Forces feed lubrication

The forced feed lubrication (see Fig. 5/1) is the type of lubrication used most frequently in modern motor vehicle engineering, and is mainly used in four–stroke engines. The oil pump (see Fig. 5/2) which is mainly designed as a gear pump and driven by the crankshaft, supplies the oil through lubricating channels to the individual lube points of the engine. The oil pan forms the lower end of the engine block. There is a recess in the oil pan which is called the oil sump. The oil screen which is connected to the oil pump extends into the oil sump. The oil passes through the screen to a rotating filter in which, due to its great speed, all floating and abrasive particles are thrown out and deposited on the filter walls. Therefore, the filter must be cleaned at regular intervals.

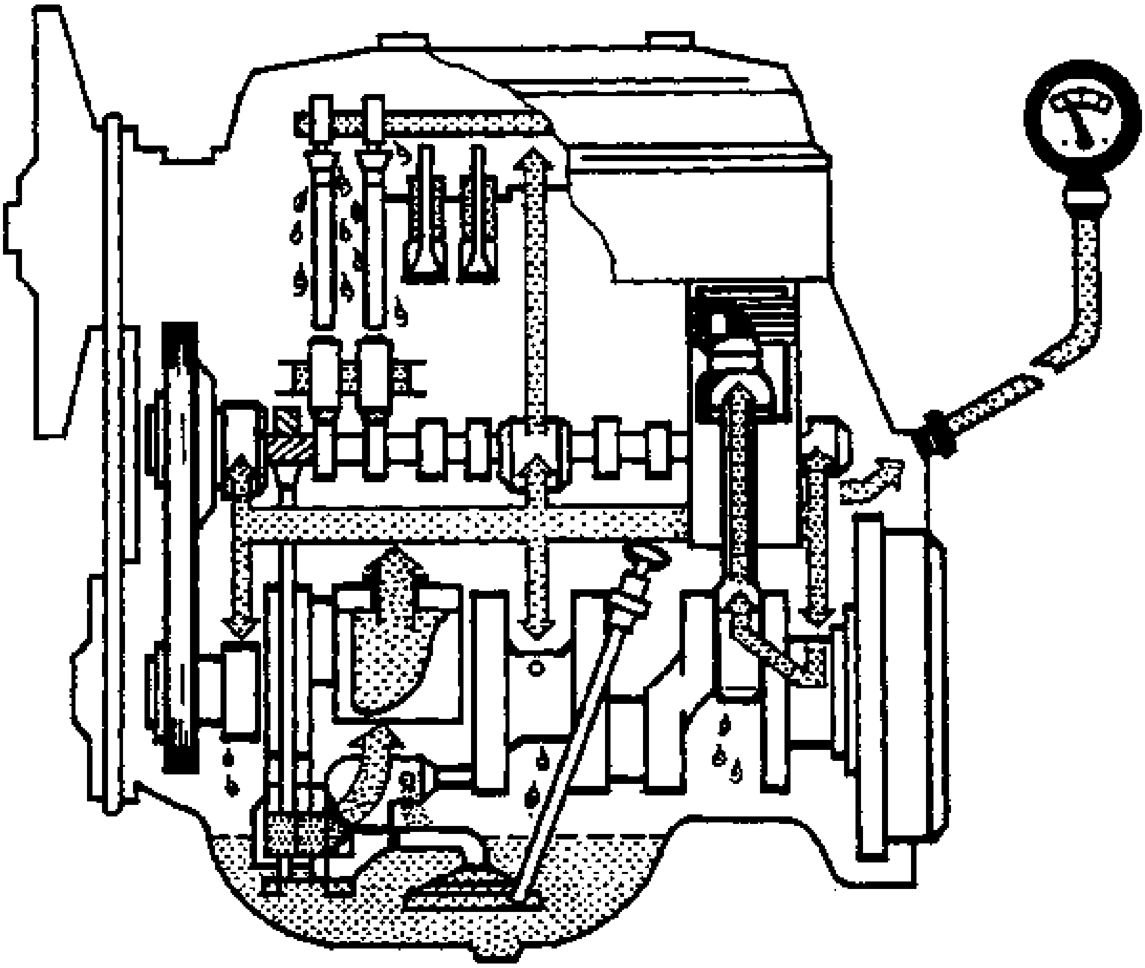


Figure 5/1 Force−feed circulation oiling (183)

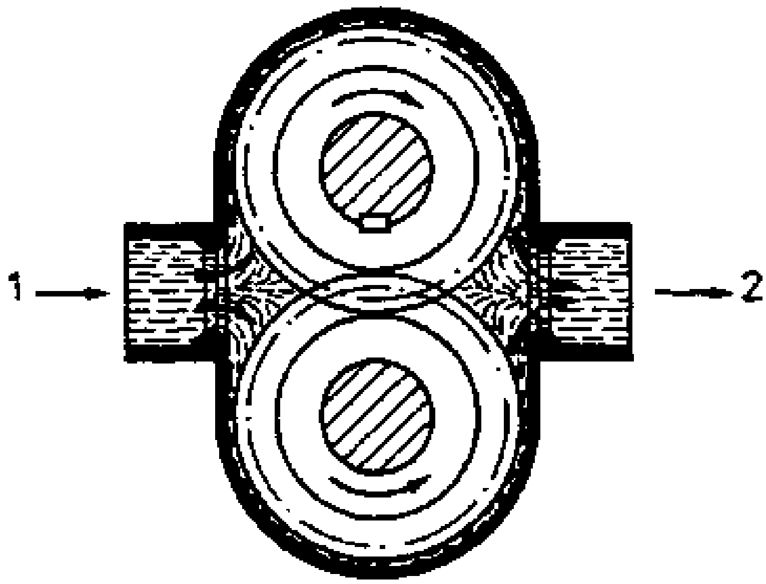


Figure 5/2 Oil pump

1 Oil coming from oil screen 2 Oil to lubricating points

When the oil has passed through the filter, the pressure carries it to the individual lubricating points through channel systems and oil bores. Modern types of combustion engines have oil coolers in which the oil is cooled by the air stream and then returned into the oil pan. The oil is cooled so that it maintains its lubricating properties even if temperatures are high.

There is an oil level dipstick at the engine. When the engine is at standstill, it can be used to check the oil level in the oil pan. The oil level dipstick has a minimum and a maximum level mark. If the oil level falls below the minimum mark, it could result in excessive wear and seizure. If the oil level exceeds the maximum mark, however, there will either be severe carbon deposits or the oil will be pressed out of the engine. Therefore, in order to prevent such damage, the checking of the oil level in the engine should be a routine before starting the vehicle. Inside the motor vehicle there are instruments which indicate the oil pressure when the engine is running. These instruments can be either an oil pressure gauge or an oil pressure light.

Dry sump lubrication

Dry sump lubrication (see Fig. 5/3) is another type of forced feed lubrication. Here two oil pumps are used, one of which constantly empties the oil sump and supplies oil to the oil reservoir. The oil reservoir is connected to a second pump which pumps the oil to the individual lubricating points as described above. Both pumps can be accommodated in the same housing and driven by the same shaft. Even if the motor is in a tilted position, dry sump lubrication ensures good oil supply because the oil is not only present in the oil pan. The oil pan can have cooling fins to give better dissipation of heat.

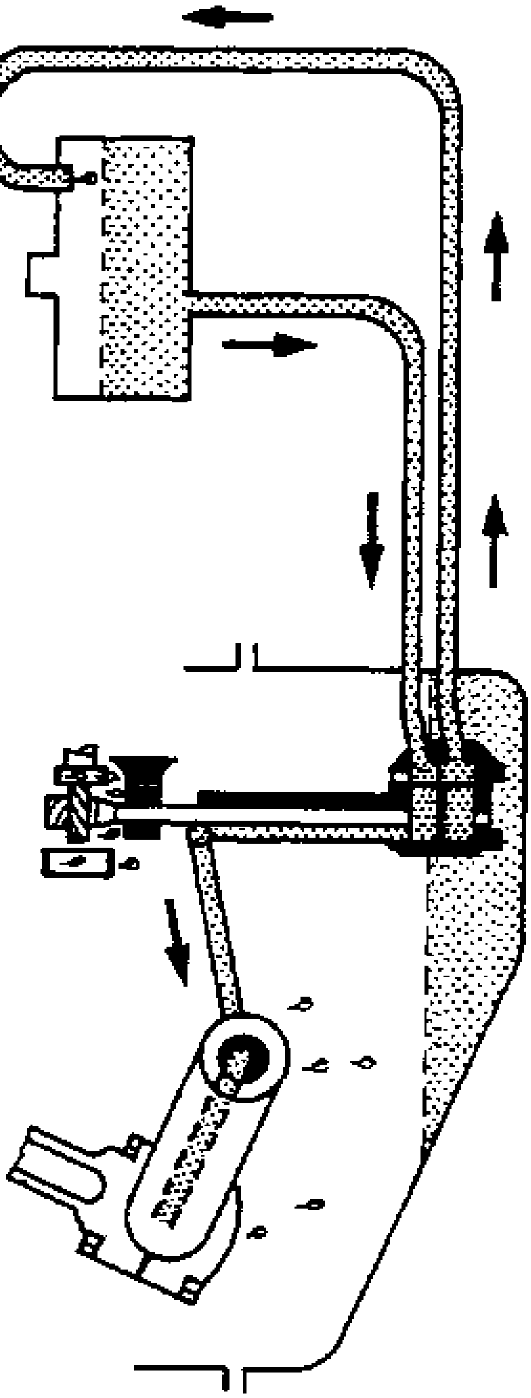


Figure 5/3 Dry sump lubrication (184)

Petrol lubrication

Petrol lubrication (see Fig. 5/4) is the simplest type of engine lubrication. It is only used in two−stroke Otto engines. In this kind of engine lubrication oil and petrol are mixed in a particular ratio. Modern two− stroke engines work with a mixing ratio of 1: 33 or 1: 50.

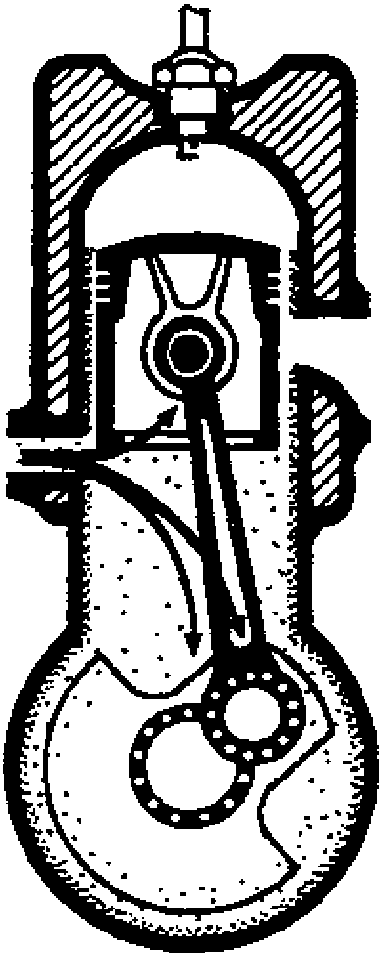


Figure 5/4 Petrol lubrication

1 litre of oil is mixed with 33 litres of petrol. Here, once again, only one particular grade of oil should be used. The oil enters the crank−case with the fuel air mixture, during pre−compression, it is forced out and carried to the individual bearing points such as crankshaft, piston and cylinder liners.

Fresh oil lubrication

Another form of lubrication of two−stroke engines in the fresh oil lubrication. Here the oil is stored in a separate reservoir. The volume of oil is dependent on the speed and the throttle valve position of the carburettor. The volume, which can be varied, is added to the fuel through a feeding point behind the compensating jet in the carburettor.

Test questions

5.1. What is the function of the engine lubrication system?

5.2. Describe forced feed lubrication.

5.3. Explain the mode of operation of dry sump lubrication.

5.4. Explain the petrol lubrication principle.

6. The cooling system

In the combustion engine heat is generated during operation and must be dissipated. This requires intensive cooling. If an engine is not cool enough, the components could be overloaded. If the fuel−air mixture is heated excessively, performance will drop, the oil film will evaporate, and dry friction will occur, causing damage to the sliding surfaces.

There are two types of cooling used in motor vehicles:

– Water cooling
– Air cooling.

6.1. Water−cooling system

A water−cooling system is designed to dissipate the combustion heat generated by an engine. Every combustion engine must have a certain service temperature so that components of performance agree. There are two important types of liquid cooling:

– Thermosiphon cooling
– Pump circulated cooling.

The principle of liquid cooling is based on the fact that the cylinder is surrounded by cooling water. Since the temperature of the coolant is lower than the service temperature, the heat is transferred to the coolant. This process is utilized in thermosiphon cooling as the heated water rises because it is lighter than the cold water. The engine block is connected with a heat exchanger, called a radiator. The radiator dissipates much of the ' heat of the cooling water into the atmosphere. The water cooled down in this way sinks to the bottom again. Then the circulation starts again. However, since not all of the heat has been dissipated, the engine reaches its service temperature once more. Fig. 6/1 shows the diagram of the thermosiphon cooling system. It is based on the simple physical principle that the specific weight of the heated water is relatively lighter than that of cold water. To ensure better cooling in warm conditions, a fan is located behind the radiator which is driven from the crankshaft by a vee−belt to accelerate the air flow. When this type of cooling system is used it is necessary to ensure that there is always sufficient coolant in the cooling system to protect the circuit from interruption. The cooling surface required here is normally larger than that required for pump cooling.

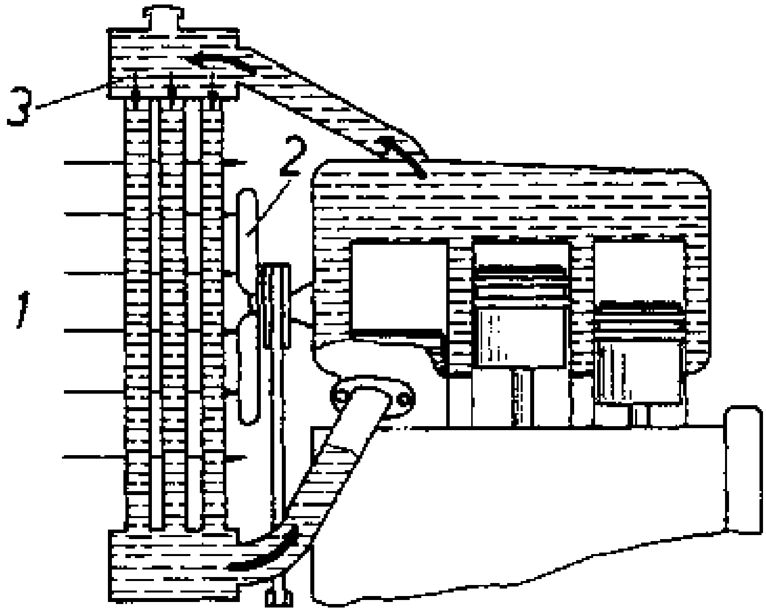


Figure 6/1 Thermosyphon cooling

1 Air;
2 Fan;
3 Radiator

Another type of liquid cooling is pump circulated cooling. In principle it is the same as the thermosiphon cooling, the only difference is that there is an additional pump to circulate the coolant (see Fig. 6/2).

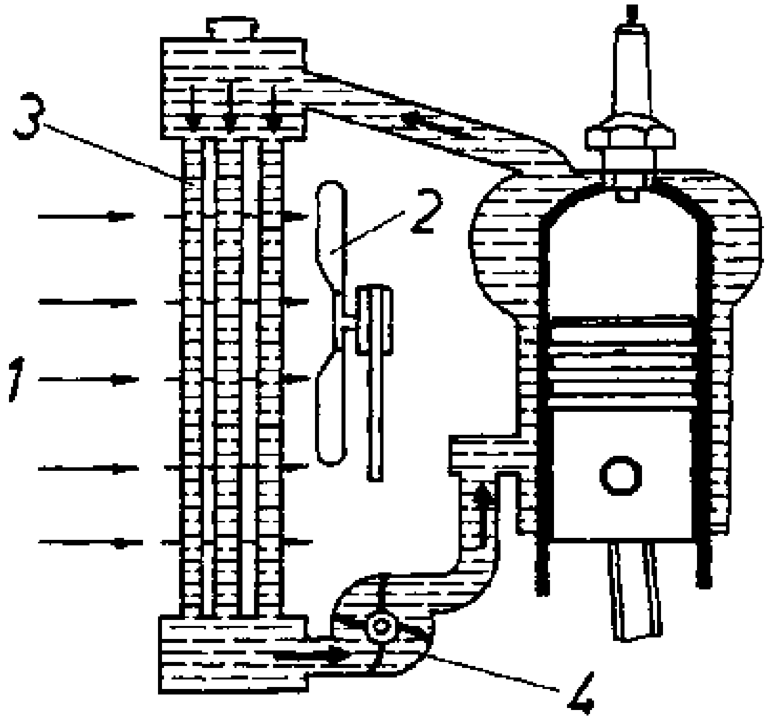


Figure 6/2 Pump circulation cooling

1 Air; 2 Fan; 3 Radiator; 4 Water pump

In comparison with thermosiphon cooling, this type of liquid cooling is much more effective, The volume of water required for this type of cooling is smaller, and the general dimensions of the radiator can be smaller. Due to the relatively high water flow rates, the pipe cross sections can be smaller. The speed of the water pump is 1 to 1.5 times that of the crankshaft. In the case of pump cooling, a fan is also provided.

In most engines the water pump is flanged to the front face and is driven by the Vee−belt. In the pump bowl there is an impeller which causes the water to circulate. The pump shaft is sealed in the pump housing by radial sealing rings or stuffing boxes. Water pump grease is used for lubrication because it is not sensitive to water.

The radiator serves to decrease the water temperature by means of the air passed through it. It is used as a heat exchanger in which the largest possible exchange area is accommodated in the smallest possible space. These radiators are made of a metal which is light weight but ensures good conductivity. It consists of the upper and the lower header tank with intermediate small tubes. The filler stud with safety valve and the supply pipe are mounted to the upper header tank. The radiator mounting, drain plug and drain pipe are mounted to the lower header tank.

The radiator is connected with the water circulation system by flexible connections (e.g. rubber hoses). It is also mounted on flexible shims in the motor vehicle. In modern motor vehicle engineering closed cooling systems are also still in use. In these systems the coolant which consists of distilled water and anti−freeze is circulated in a closed circuit which is connected to the compensating tank.

The merit of the system is that no coolant is lost as it is always collected by the compensating tank and returned into the circuit. To ensure that the combustion engine reaches service temperature as quickly as possible, the cooling circuit is divided into a large and a small circuit by a thermostat. The large circuit includes the radiator. When the service temperature, which ranges between 80 and 85 C depending on the type of engine, is reached, the large circuit is opened by the thermostat and when the temperature falls again, it is closed.

The fan can be directly connected with the water pump, or alternatively it may be coupled with an electromagnetic coupling. If it is directly connected, it is runs constantly. To further increases the effect of the thermostat the fan is integrated into the cooling system by means of an electromagnetic coupling. Until the service temperature is reached the fan is at a standstill and only when this temperature is exceeded is it started by a thermostat. Another merit is that the service temperature is reached earlier and so the engine is preserved because wear is essentially greater when the engine is cold.

6.2. Air−cooling system

There are some external features which make it easy to distinguish the air−cooling system from the water−cooling system; the air−cooling system does not require a radiator or a water pump and it has a different cylinder form. In the case of air−cooling, the surface of the cylinder block must be greatly extended in order to dissipate excessive heat.

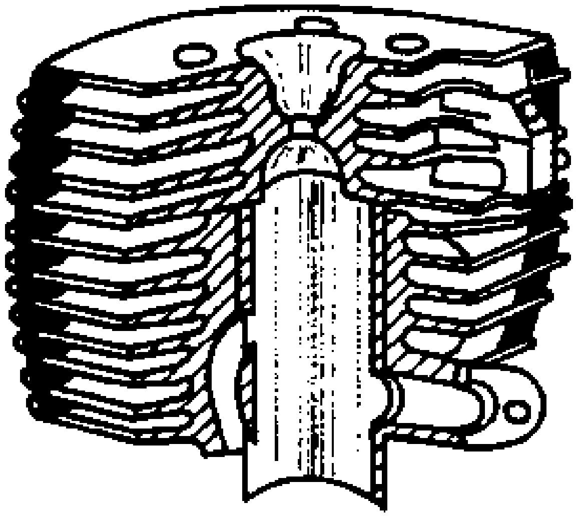


Figure 5/3 Air−stream cooling

This extension is achieved by additional radiating fins (see Fig. 6/3 and 6/4) which are arranged parallel to the air stream. In general, they are made of a light metal which is a good heat conductor. There are two types of air cooling: air stream cooling and fan−type air cooling. Air stream cooling is used in motorcycles, and uses air taken from the air stream. Cylinders with large radiating fins are required. In order to protect these large fins against excessive vibrations, rubber stabilizers are used for damping. The radiating fins must have a rough top surface in order to trap the air stream or the fan air stream and to dissipate the heat.

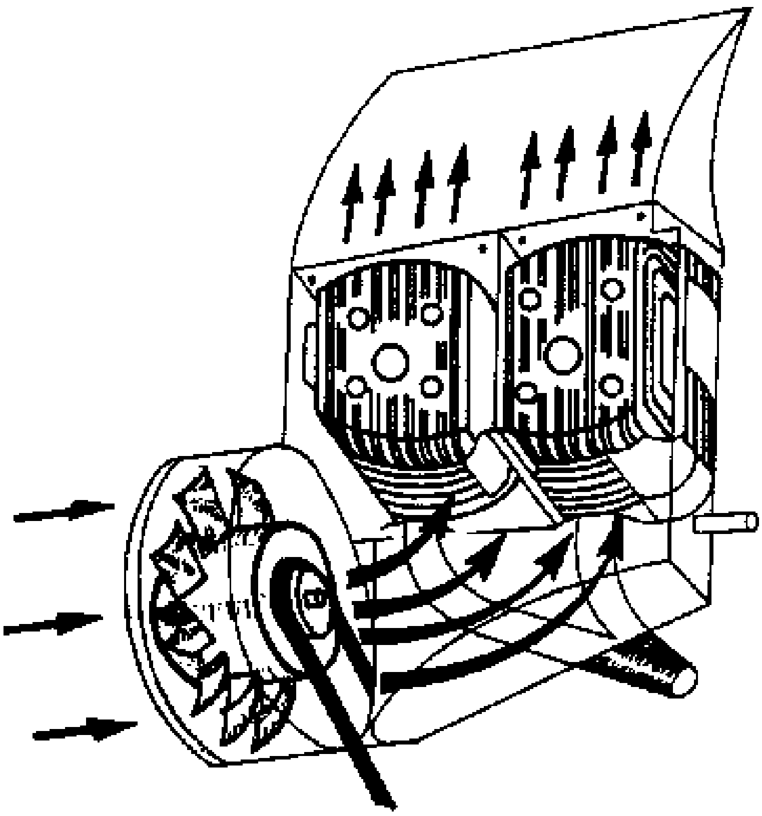


Figure 6/4 Fan cooling

Fig. 6/4 shows the fan−type air−cooling system. The impeller, which is driven directly by the crankshaft via a vee−belt, intensifies the air stream still further. However, this means that the engine must be clead with air guide plates. Air cooling is noisier because of the air turbine.

Test questions

6.1. What is the function of the engine cooling system?

6.2. Describe the thermosiphon cooling system.

6.3. Explain the principle of pump circulation cooling system.

6.4. Describe the design and the function of the water pump.

6.5. What is the function of the cooler? Describe its design.

6.6. What do you understand by air cooling, and what types of air cooling do you know?

7. The air filter

The air required by the engine for combustion in the fuel−air mixture must be cleaned before it reaches the combustion chamber. To do this an air filter is required to remove any airborne dust particles from the air, which would otherwise act like abrasive powder in the engine components and cause excessive wear. There are two types of filter: wet−type air filters and dry filters.

The wet−type filters have a metal fabric insert which is oilwetted in order to bind the dust. Another type is the turbulence oil filter. Here a certain amount of oil is circulated by the air stream and binds over which it passes.

The dry air filter is equipped with a filter cartridge made of filter paper which is similar to the oil filter. It is inserted into an intake silencer which is made of steel sheet and can be mounted directly to the carburettor or the intake pipe. All air filters also serve as intake silencers.

Air filters must be cleaned at regular intervals. This means that the filter cartridge must either be replaced or the oil must be changed in order to ensure correct operation.

The lifetime of an air filter is specified by the manufacturer. Lifetime is specified either as mileage, or in the case of marine engines, number of service hours. If the air filters are clogged with dust, engine output will be impaired as insufficient air can pass through them.

8. Mode of operation of the gas turbine

Apart from the combustion engines described above there are other types of engines used in modern vehicle engineering, for example the gas turbine and the rotary piston engine, also called the Wankel engine after its inventor Felix Wankel. Fig. 8/1 compares the sizes of a diesel engine and a gas turbine of the same output. Since the output of today's combustion engine can only be slightly improved, new methods of powering motor vehicles must be found. Combustion engine speeds cannot be constantly increased because the forces which are generated by the moving masses increase as the square of the speeds and therefore can only be controlled up to a certain value. This however is not the case with the gas turbine.

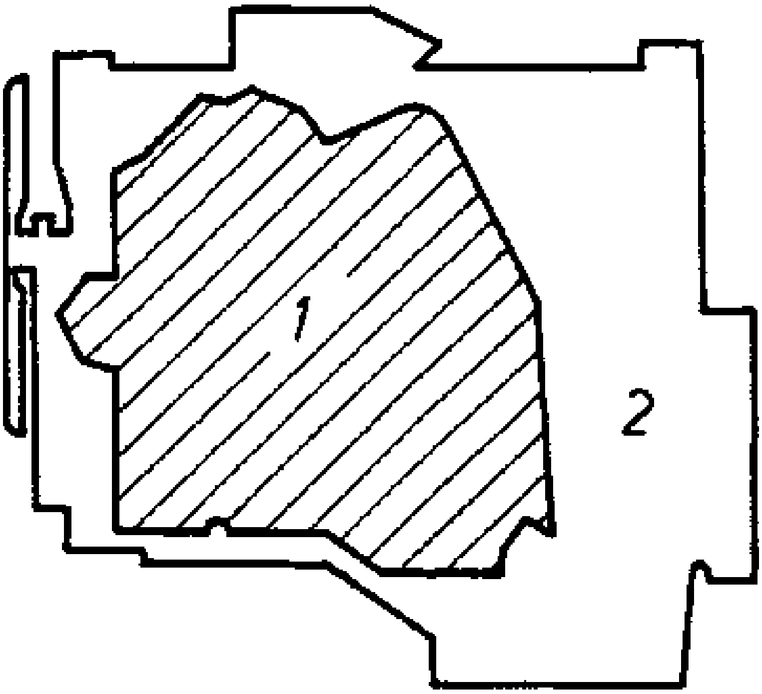


Figure 8/1 Difference in size between a gas turbine and a diesel engine

1 Outline of a gas turbine
2 Outline of a diesel engine (of same performance)

Gas turbines are thermal engines. The rotational movement is produced by gases flowing against the turbine blades. Like the combustion engines, gas turbines are started by a starter which must produce very high speeds in order to start the turbine. Gas turbines have a large amount of excess air and therefore their exhaust gases are free of carbon monoxide and not dangerous. There are four types of gas turbines: single−shaft gas turbines, twin−shaft gas turbines, tripple−shaft gas turbines and free−piston gas turbines.

In the single−shaft gas turbine, all the thermal energy is converted in the turbine by extension, i.e. some of the power generated is used for driving the compressor and only the remainder of the effective output can be used for driving the engine. This type of gas turbine is not suitable for driving motor vehicles because the output rapidly decreases as speed falls.

In the twin−shaft gas turbine, however, a completely different torque characteristic is produced. Extension takes place in two turbines which are mechanically separated.

A compressor is driven by a high−pressure valve while the effective output is generated through a low−pressure valve. This type of turbine is very useful for powering motor vehicles because its torque characteristic is more favourable than that of the reciprocating piston engine. Moreover, it ensures a good starting torque, and the effective power turbine can be matched to the speed at any time, independent of the gas producer, the compressor and its driving turbine, by changing the amount of fuel injected. Fig. 3/2 shows the diagram of a triple−shaft gas turbine. This turbine has three shafts and two combustion chambers.

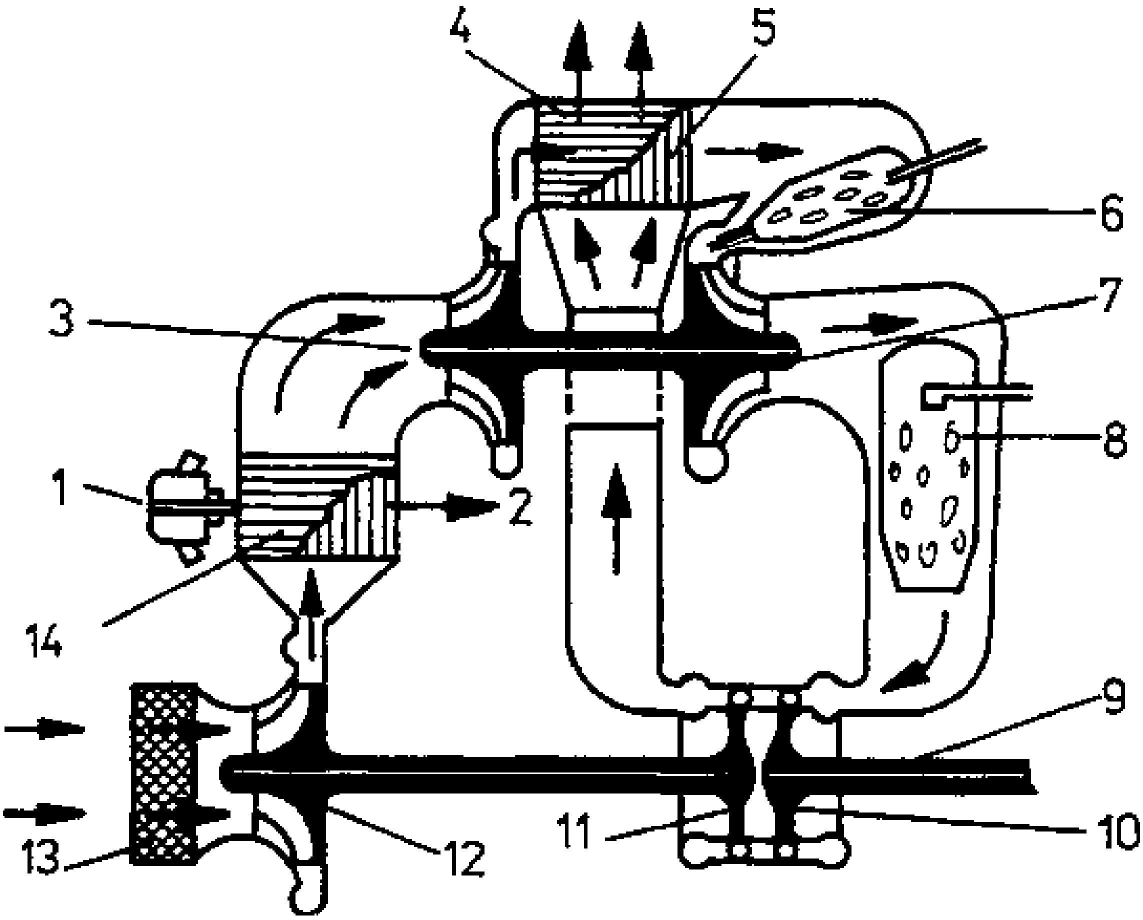


Figure 3/2 Three–shaft gas turbine

1 Cooling fan; 2 Fan air; 3 High–pressure compressor; 4 Exhaust; 5 Recuperator; 6 First combustion chamber; 7 High–pressure turbine; 8 Second combustion chamber; 9 Drive shaft; 10 Operating turbine; 11 Low–pressure turbine; 12 Low–pressure compressor; 13 Air filter; 14 Intermediate cooler

9. Mode of operation of the rotary piston engine

Another type of engine is the rotary piston engine. In the case of this engine, the compression pressure is not transferred to a cylindrical, piston, as is the case with the reciprocating piston engine, but to a triangular rotor which is directly connected to the drive shaft. Fig. 9/1 shows the main components of the Wankel engine, the drive shaft with the flywheel mass, the rotor shaft with external toothing and compensating mass and the rotor with internal toothing. While the engine is working, all these components are moving. In contrast to the reciprocating piston engine, they only describe a circle. The rotor and the housing always form three different chambers the volume of which changes constantly. This is necessary in order to allow gas exchange and compression.

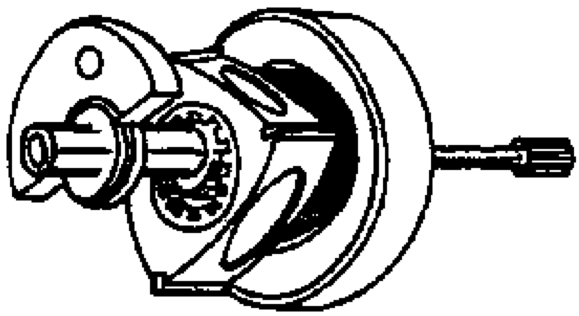


Figure 9/1 Shaft and piston of a rotary piston engine

As in the reciprocating piston engine, ignition occurs at maximum compression. This engine requires a fuel–air mixture and has external ignition. The mode of operation of the rotary piston engine is shown in Fig. 9/2. The combustion pressure causes the piston area to be rotated in clockwise direction and due to the geometry of the rotor, this operation continues of its own accord. In order to seal the rotor from the housing, it revolves both around the drive shaft and on its own axis. The mode of operation of the rotary piston engine can be compared with that of the four–stroke engine, although it has no valves. In the case of this engine, sealing the rotor from the housing is of particular importance as not only the edges must be sealed, but also the surfaces.

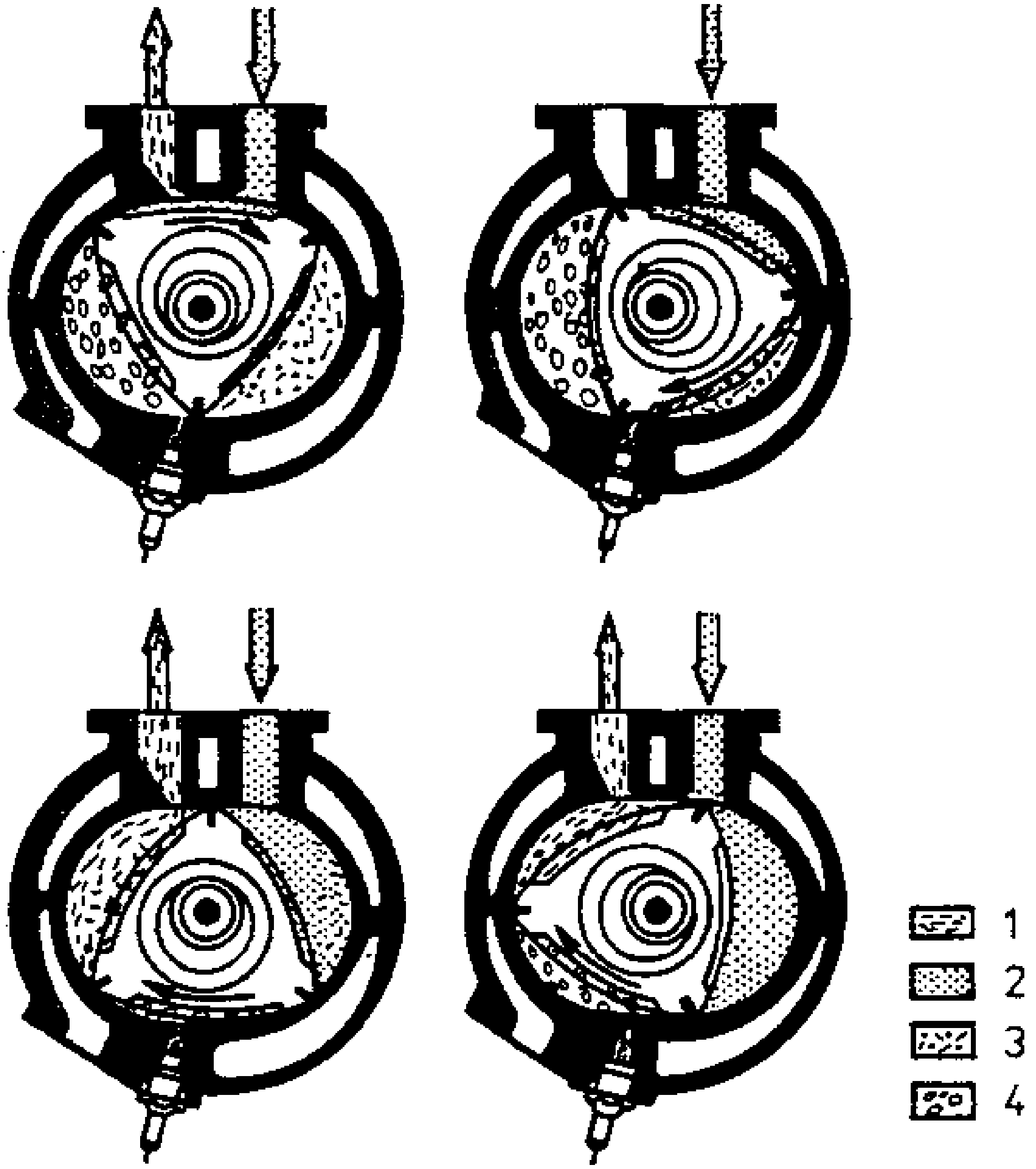


Figure 9/2 Node of operation of a rotary piston engine

1 Exhaust; 2 Intake; 3 Compression (ignition); 4 Power stroke (combustion)

Another problem is the spark plug. To ensure proper sealing, it must not extend into the combustion chamber. Hitherto rotary piston engines have been used exclusively in cars, marine engines and as stationary engines.

Small Engine Technology

Table of Contents

Small Engine Technology 1
Introduction 1
Objectives 2
1. Fuel system 6
1.1 Components of fuel system 6
1.2 Fuel tank 7
1.3 Fuel filter 7
1.4 Air filter 7
Task sheet 9
1.5 Carburetter 10
Task sheets 14
1.6 Repair and maintenance 19
Job Sheets 25
2. Ignition system 28
2.1 Basic principle 28
2.2 Contact point ignition system 29
Task sheet 31
2.3 Transistor ignition system 32
2.4 Capacitive discharge ignition system (CDI) 34
2.5 Advantages and disadvantages of CDI and transistor ignition systems 35
Task sheets 36
2.6 Maintenance and repair 39
Job sheets 49
3. Speed control system 50
3.1 Task of governor 50
3.2 Types and function of governor 50
Task sheet 52
3.3 Repair and maintenance 53
Job Sheet 55
4. Valve mechanism 56
4.1 Task of valve mechanism 56
4.2 Types and function 56
Task sheet 58
4.3 Compression reduction mechanism 59
Task sheet 61
4.4 Repair and maintenance 63
Job sheets 74
5. Crankshaft mechanism 76
5.1 Components and functions of crankshaft mechanism 76
Task sheet 78
5.2 Repair and maintenance 80
6. Lubrication system 92
6.1 Tasks of the lubrication system 92
6.2 Splash–type lubrication 92
Task sheet 93
6.3 Repair and maintenance 94
Job sheet 95
7. Cooling system 95
Task sheet 96
7.1 Repair and maintenance 97
Job sheet 97
8. Starting system 98
8.1 Types of starting systems 98
8.2 Repair and maintenance 99
Job sheet 102
9. Exhaust system 102
9.1 Purposes of exhaust system 103
9.2 Components and their function 103
Task sheet 104

Small Engine Technology

CRYSTAL

Lehr– und Lernmittel,
Informationen, Beratung

Educational Aids
Literature, Consulting

Moyens didactiques,
Informations, Service–conseil

Material didáctico,
Informaciones, Asesoría

Feedback: Thai–German Teaching Aid Centre
in cooperation with the
Technical College Nongkhai

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

Introduction

What this Instruction Material wants:	What this Instruction Material does not want:
– to be easy understadable	– to replace a book
– to be job related	– to substitute the teacher
– to support the teacher in his work	– to teach unnecessary subject matter
– to create student activity	
Help to teach and learn efficiently	

• This instructional material is developed by the Thai–German Teaching Aid Centre in cooperation with the Technical College Nongkhai.

• The student should have preknowledge about the principle of 4–stroke internal combustion engine.

• The Information, specially about maintenance and repair–is based mainly on the Honda engines G 150 – G 200 and GX 120 – GX 160.

• The teaching method, which should be used, is the "questioning technique". Please do not only lecture!

The Instructional Material Package (IMP) contents the following elements:

1. List of objectives
2. Information sheets
3. Task sheets
4. Job sheets
5. Teaching aids (Transparencies, models, e.g.)
6. Solutions

1. A list of objectives shows the teacher what the student should know after the lesson.

2. Information sheets show pictures with short explanations of the subject matter. These information sheets should be given to the student after the lesson as a summary. Information about repair and maintenance should be given briefly before starting the work prescribed in the Job sheets.

3. Task sheets help the teacher to check the learning progress. They should be used at the end of one period. It is necessary to discuss the solutions with the students. Please do not use them as a test.

4. The Job sheets are showing the student the right sequence of working steps. The Information sheets about maintenance and repair can be used like a manual during work.

5. Teaching aids make the subject matter better understandable and motivate the students.

6. Solutions for the task sheets

Objectives

The student should be able to ...

1. Fuel system

1.1 Components of fuel system

1. Name various components and their functions of fuel system
2. Describe about fuel delivery from fuel tank to carburetter

1.2 Fuel tank

3. Tell components of fuel tank
4. Tell function of fuel tank

1.3 Fuel filter

5. Tell components of fuel filter
6. Tell functions of fuel filter

1.4 Air filter

7. Tell various types of air filter
8. Tell features and characteristics of the wet−type air filter
9. Explain principle of the wet−type air filter
10. Tell advantages and disadvantages of the wet−type air filter
11. Tell features and characteristics of the dry−type air filter
12. Explain principle of the dry−type air filter
13. Tell advantages and disadvantages of the dry−type air filter

1.5 Carburetter

14. Explain principle of carburetter
15. Tell various types of carburetter
16. Tell internal construction of the side draft carburetter
17. Tell functions and components of the floating circuit
18. Explain principle of the floating circuit
19. Tell functions and components of the idle circuit

20. Explain principle of idle circuit
21. Tell functions and components of full throttle circuit
22. Explain principle of full throttle circuit
23. Tell functions and components of choke unit
24. Explain principle of choke unit

1.6 Repair and maintenance

25. Inspect any leakage of the fuel tube
26. Clean fuel tank correctly
27. Clean air filter correctly
28. Dismantle and reassemble carburetter correctly
29. Inspect components of carburetter for wear
30. Set the float correctly
31. Adjust the idle mixture correctly
32. Adjust the idle speed correctly

2. Ignition system

2.1 Basic principle

1. Explain basic principle of ignition system used in small engines.
2. Tell various types of ignition system used in small engines

2.2 Contact breaker ignition system

3. Tell name and function of various parts of the contact breaker ignition system.
4. Explain principle of the contact breaker ignition system.

2.3 Capacitor discharge ignition system (CDI)

5. Tell name and function of various parts of the CDI system
6. Explain principle of the CDI system.
7. Tell advantages and disadvantages of the CDI system

2.4 Transistor ignition system

8. Tell name and function of various parts of the transistor ignition system.
9. Explain principle of transistor ignition system.
10. Tell advantages and disadvantages of the transistor ignition system.

2.5 Repair and maintenance

11. Remove and reassemble various parts of ignition system.
12. Check conditions of spark plug.
13. Clean and set electrode gap of spark plug correctly.
14. Check ignition coil correctly.
15. Check CDI and transistor ignition module correctly.
16. Check condenser correctly.
17. Set contacting point gap correctly.
18. Adjust ignition timing correctly.
19. Adjust clearance between ignition coil and magnetic flywheel correctly.

3. Speed control system

3.1 Governor

1. Tell the task of a governer

3.2 Types and function of governers

2. Tell various types of speed control systems.
3. Explain principle of pneumatic governor.
4. Explain principle of mechanical governor.

3.3 Repair and maintenace

5. Remove/refitting pneumatical and mechanical governer
6. Adjust pneumatical and mechanical governer

4. Valve mechanism

4.1 Functions of valve mechanism

1. Tell functions of valve mechanism.

4.2 Types and principle of valve mechanism

2. Tell various arrangements of valve.
3. Explain principle of overhead valve engine.
4. Tell advantages and disadvantages of the overhead valve engine.
5. Explain principle of side valve engine.
6. Tell advantages and disadvantages of side valve engine.

4.3 Compression–reduction mechanism

7. Tell purpose of compression–reduction mechanism
8. Tell various parts of compression–reduction mechanism.
9. Tell function of various parts of compression–reduction mechanism.
10. Explain principle of compression–reduction mechanism.

4.4 Repair and maintenance

11. Remove–reassemble cylinder head.
12. Remove–reassemble valves.
13. Measure length of valve spring.
14. Check squareness of valve spring.
15. Check strength of valve spring.
16. Measure diameter of valve stem.
17. Check straightness of valve stem.
18. Check valve face, margin and valve stem.
19. Measure width of valve seat.
20. Use valve seat cutter correctly.
21. Grind valve correctly.
22. Measure bore of the valve guide.
23. Remove and refit valve guide.
24. Adjust valve clearance correctly.

5. Crankshaft mechanism

5.1 Components and functions

1. Tell various parts of crankshaft mechanism
2. Tell various types of piston rings.
3. Tell functions of piston rings.
4. Tell functions and components of piston, connecting rod and crankshaft.

5.2 Repair and maintenance

5. Test compression, and tell their specification.
6. Remove and reassemble crankshaft mechanism.
7. Inspect piston, crankshaft and cylinder.
8. Inspect thickness and clearances of piston rings.
9. Arrange piston ring ends.
10. Measure sizes of gudgeon pin, hole and small−end connecting rod.

6. Lubrication system

6.1 Tasks of the lubrication system

1. Tell the Tasks of the lubrication system
2. Tell various parts that need lubrication.

6.2 Splash−type lubrication

3. Tell various parts of the splash−type lubrication.
4. Explain principle of the splash−type lubrication.
5. Tell advantages and disadvantages of the splash−type lubrication.

6.4 Repair and maintenance

6. Check and change oil.

7. Cooling system

1. Tell tasks of the cooling system.
2. Explain principle of air cooling system.
3. Tell components of air cooling system

7.1 Repair and maintenance

4. To remove−reassemble various components of cooling system.
5. To clean blower blade and its cover.

8. Starting system

8.1 Types of starting system

1. Tell types of starting systems.

8.2 Components of starting system

2. Tell components of starting unit.
3. Tell functions of components of starting unit.

8.3 Repair and maintenance

4. To remove/reassemble components of the starting unit.
5. To repair the starting unit.

9. Exhaust system

9.1 Purpose of exhaust system

1. Tell purposes of the exhaust system.

9.2 Components of exhaust system

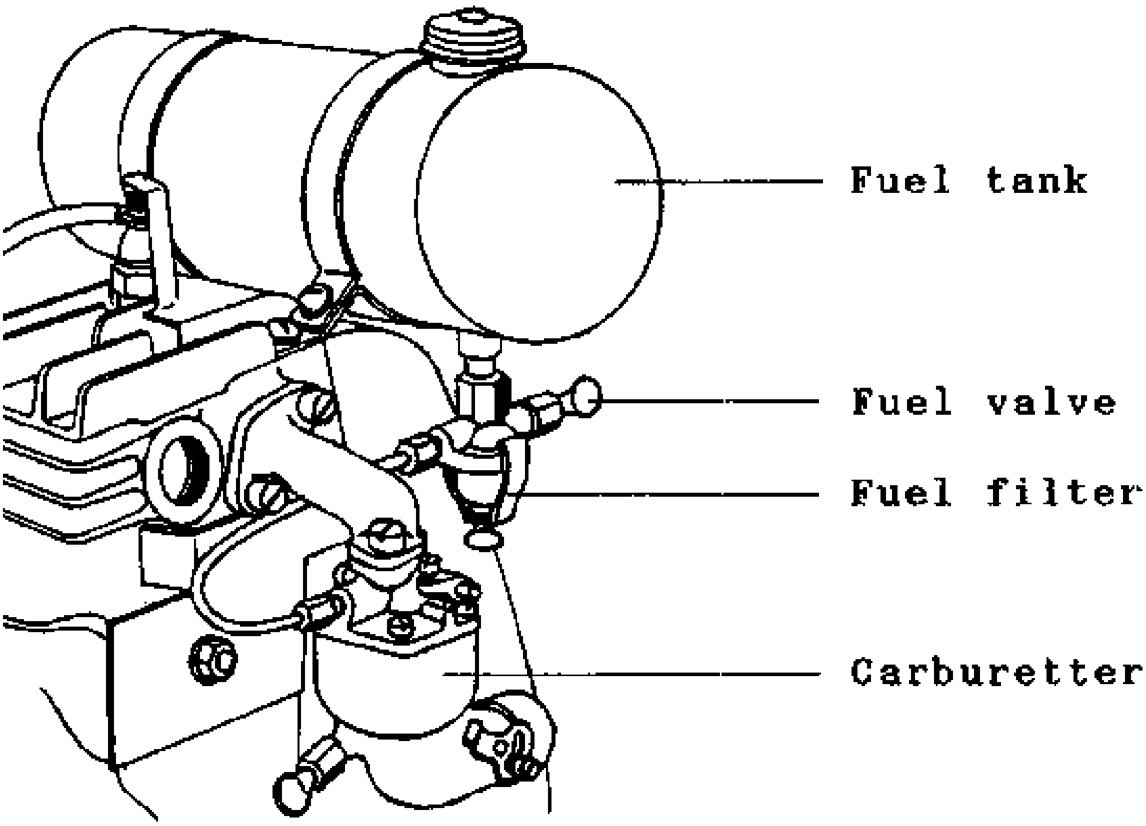
2. Tell components of the exhaust system.
3. Tell functions of the components of the exhaust system.

Information

1. Fuel system

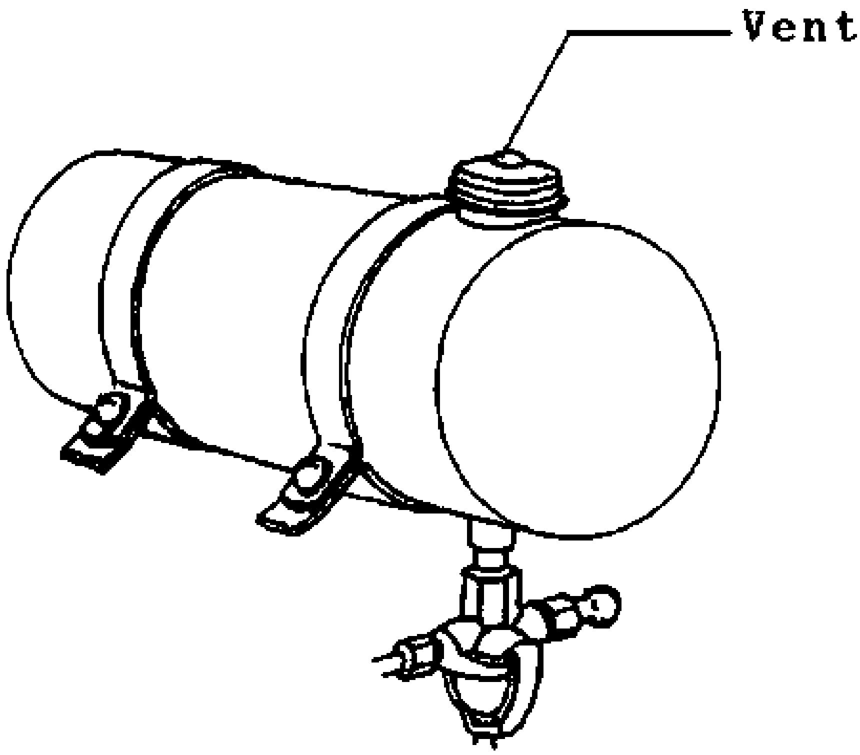
Information

1.1 Components of fuel system



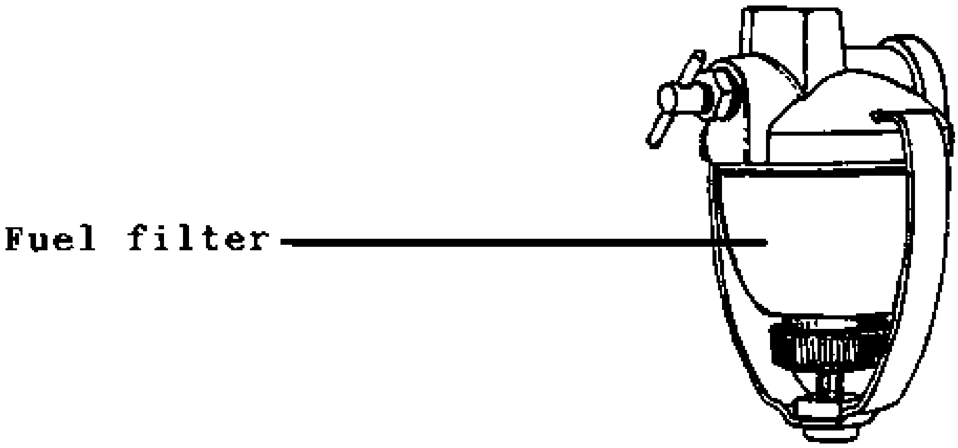
Fuel is delivered from the fuel tank into the carburetter by means of its gravity

1.2 Fuel tank



Vent: When fuel level decreases, air can enter into the fuel tank via the vent and fills up the decreased space of fuel.

1.3 Fuel filter

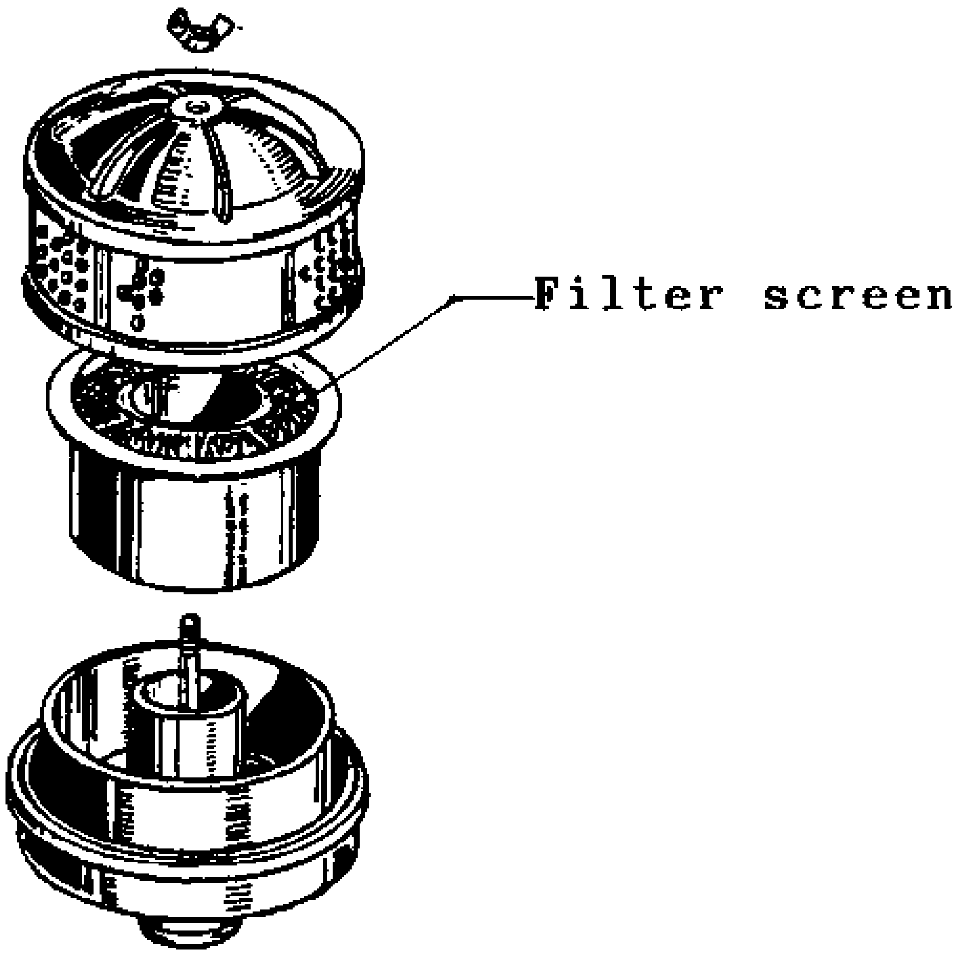


Fuel filter will trap impurities as contained in the fuel before the fuel is delivered into the carburetter.

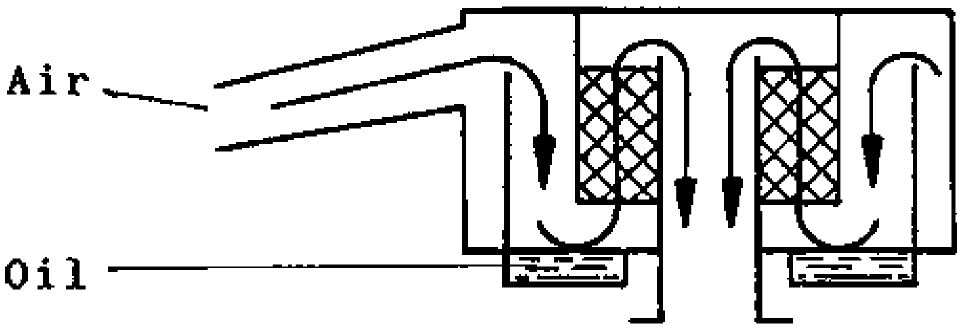
1.4 Air filter

If unfiltered air is entering the combustion cambre, then both, cylinder and piston will be worn rapidly.

1.4.1 Oil bath– or wet–type



Oil will trap dust in the air.

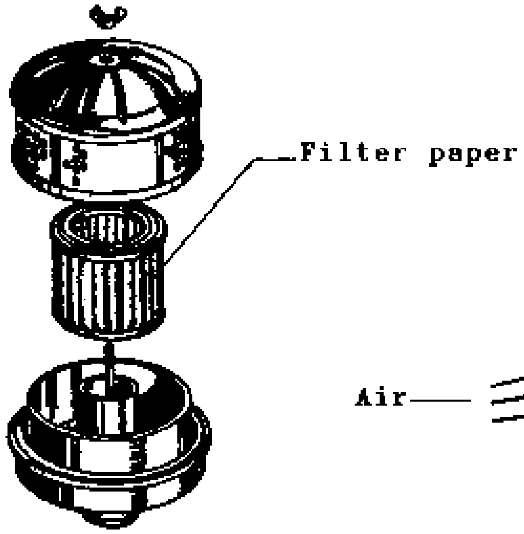


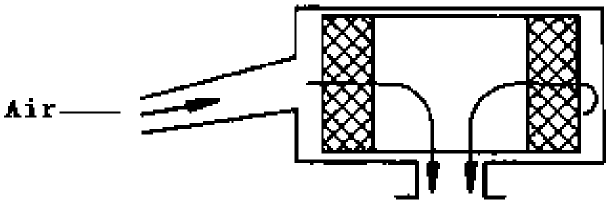
Filtered air to carburetter

Advantage: Filter screen can be washed by benzene

Disadvantage: dirty

1.4.2 Paper element type or dry type





Filtered air to carburetter

Advantage: Easy to use and maintain, most use nowaday

Disadvantage: If the filter gets too dirty, it most be replaced.

Task sheet

1.1 to 1.4 Tank and Filters

Cross the correct statements!

1. Fuel from the fuel tank enters into the carburetter by means of its gravity.

..... 2. In small engines, the fuel tank is mounted below the carburetter.

..... 3. If the fuel tank vent is clogged, then the fuel cannot enter into the carburetter.

..... 4. Fuel filter can trap water as contained in the fuel.

..... 5. Engine without fuel filter will shorten life of its piston and piston rings.

..... 6. Air filter can be classified, according to usage, into 2 types: wet and dry.

..... 7. Wet type air filter uses oil to trap dust from intake air.

..... 8. Clogged air filter will cause high fuel consumption.

..... 9. Wet type air filter can be cleaned by benzene.

..... 10. Nowaday, small engines employ the dry type air filter.

Task (Solution)

1.1 to 1.4 Tank and Filters

Cross the correct statements!

..X.. 1. Fuel from the fuel tank enters into the carburetter by means of its gravity.

..... 2. In small engines, the fuel tank is mounted below the carburetter.

..X.. 3. If the fuel tank vent is clogged, then the fuel cannot enter into the carburetter.

..... 4. Fuel filter can trap water as contained in the fuel.

..... 5. Engine without fuel filter will shorten life of its piston and piston rings.

..X.. 6. Air filter can be classified, according to usage, into 2 types: wet and dry.

..X.. 7. Wet type air filter uses oil to trap dust from intake air.

..X.. 8. Clogged air filter will cause high fuel consumption.

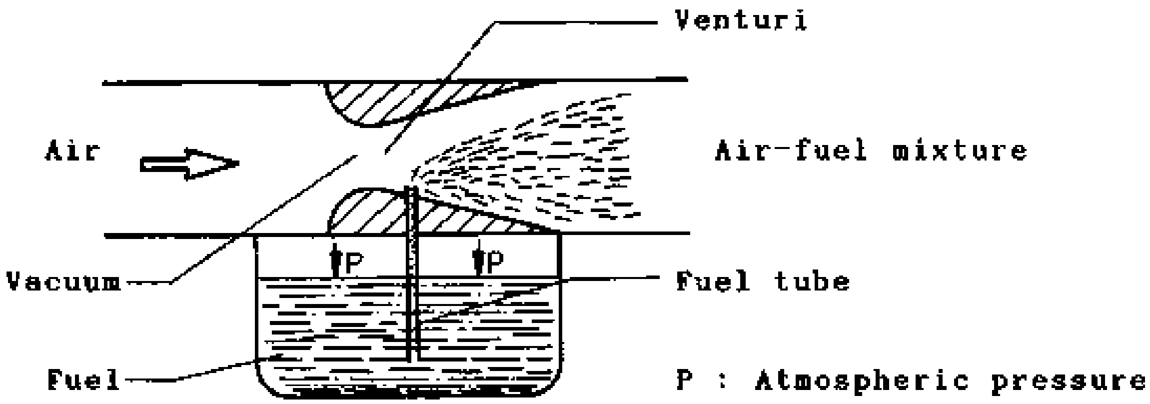
..X.. 9. Wet type air filter can be cleaned by benzene.

..X.. 10. Nowaday, small engines employ the dry type air filter.

1.5 Carburetter

Information

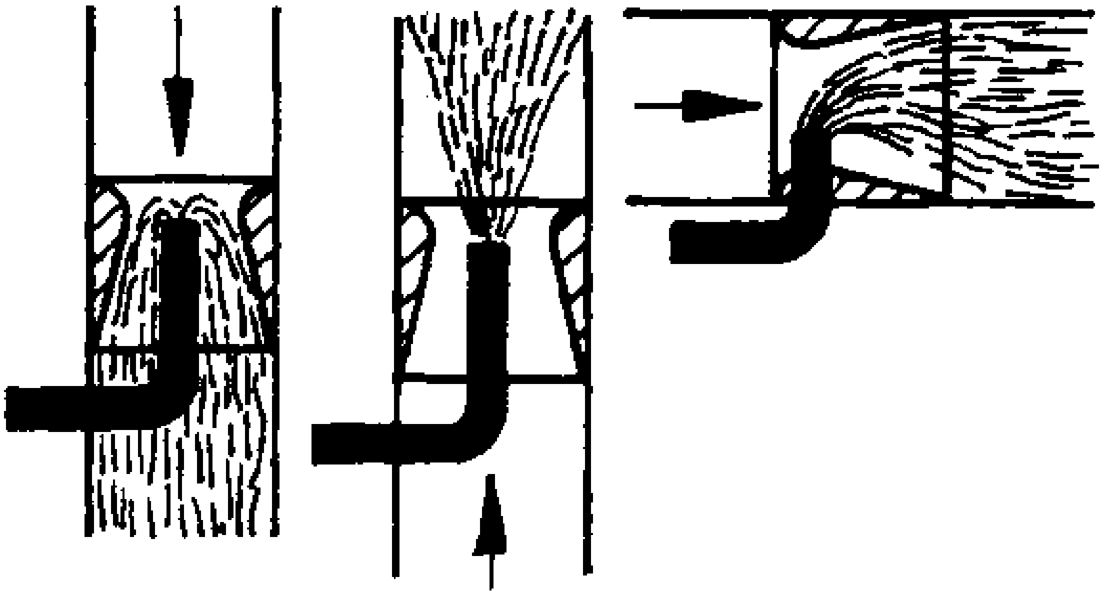
1.5.1 Principle of carburetter



As air rushes through the venturi, it will develop partial vacuum in that area. At the same time, atmospheric pressure will push fuel up by the fuel tube to mix with the rushing air.

1.5.2 Types of carburetter

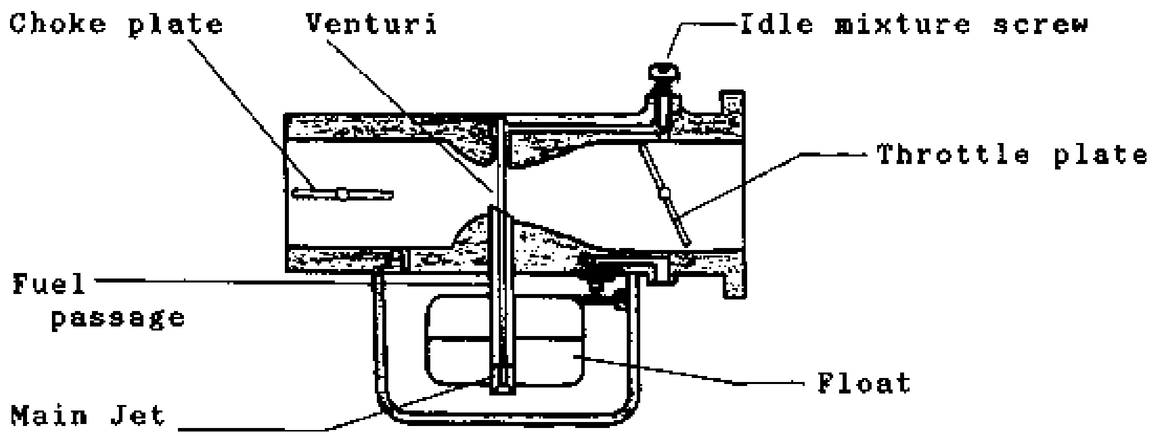
They can be classified into three types according to suction methods:



a) Down draft b) Up draft c) Side draft

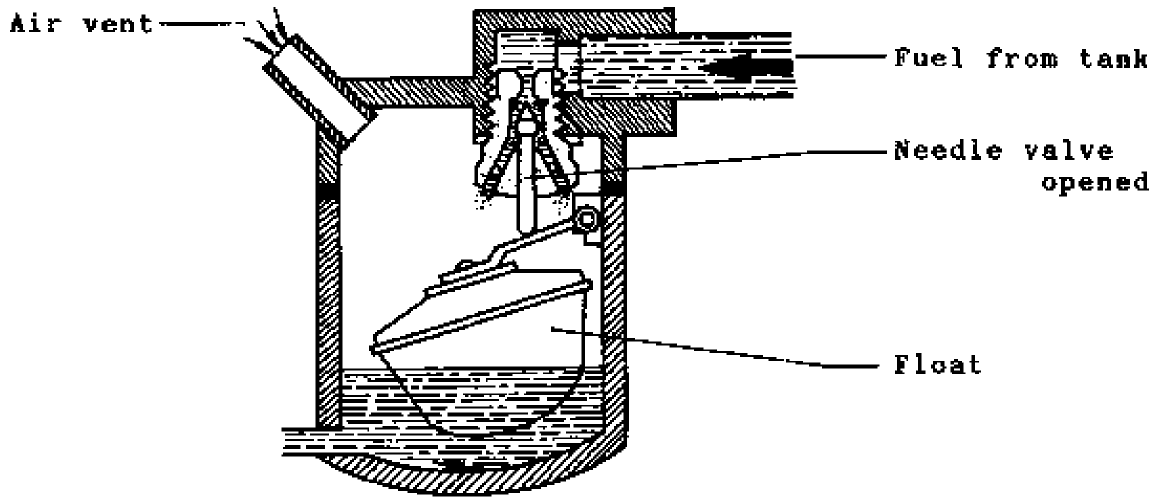
Remark: Most small engines use the side draft carburetters, and next the up draft ones.

1.5.3 Side draft carburetter

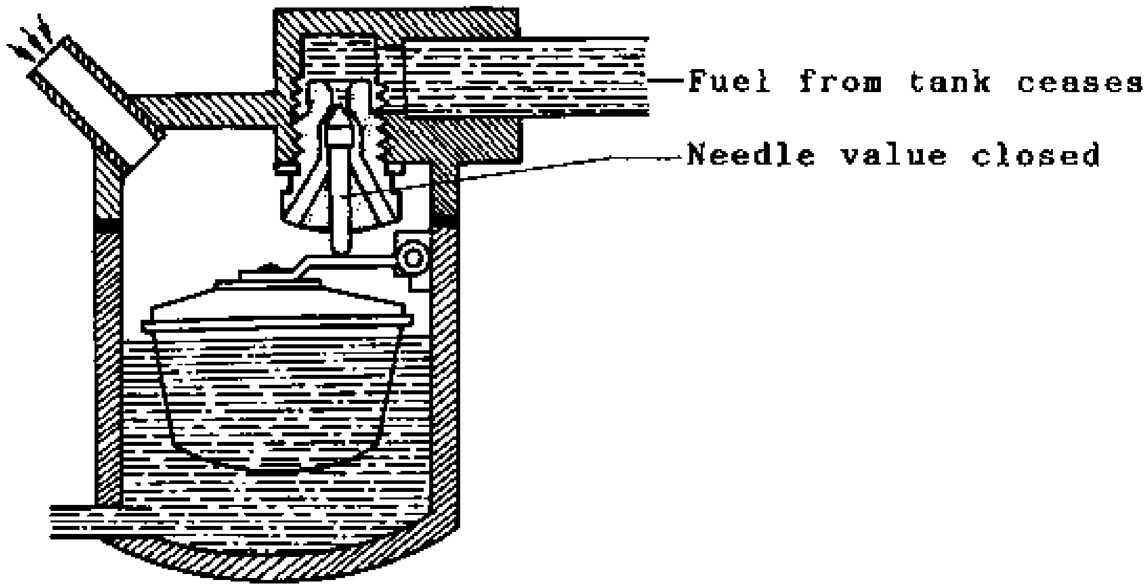


1.5.4 Floating circuit

Floating circuit is to control the amount of fuel entering the float chamber and maintain the fuel level in it.

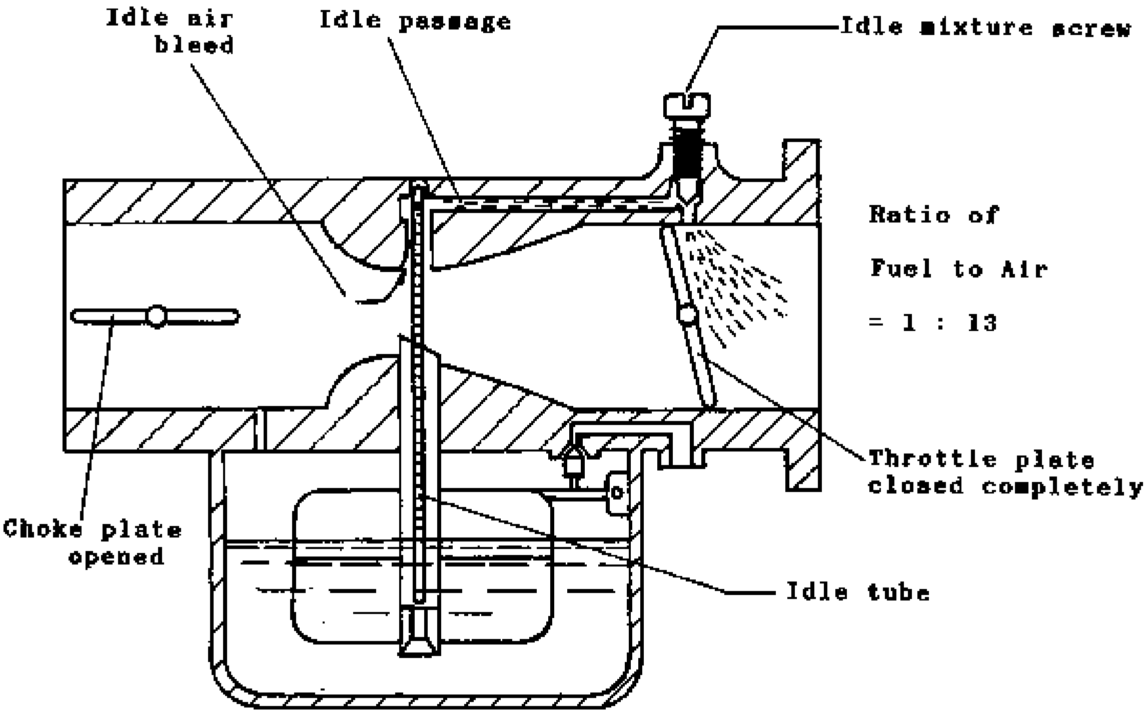


As the engine is running, a certain amount of fuel is used up causing the fuel level to decrease and thereby lowering the float which activates the needle value to allow additional fuel to enter into the float chamber.



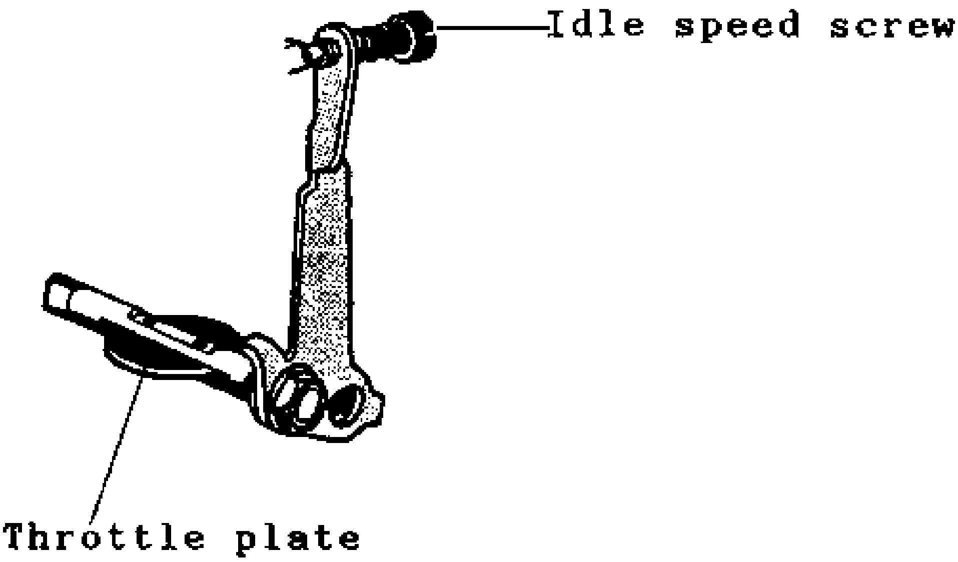
As additional fuel is entering into the float chamber, the float rises until a certain level the needle value closes and fuel flow ceases. In this circumstance, the fuel level is maintained constantly.

1.5.5 Idle circuit



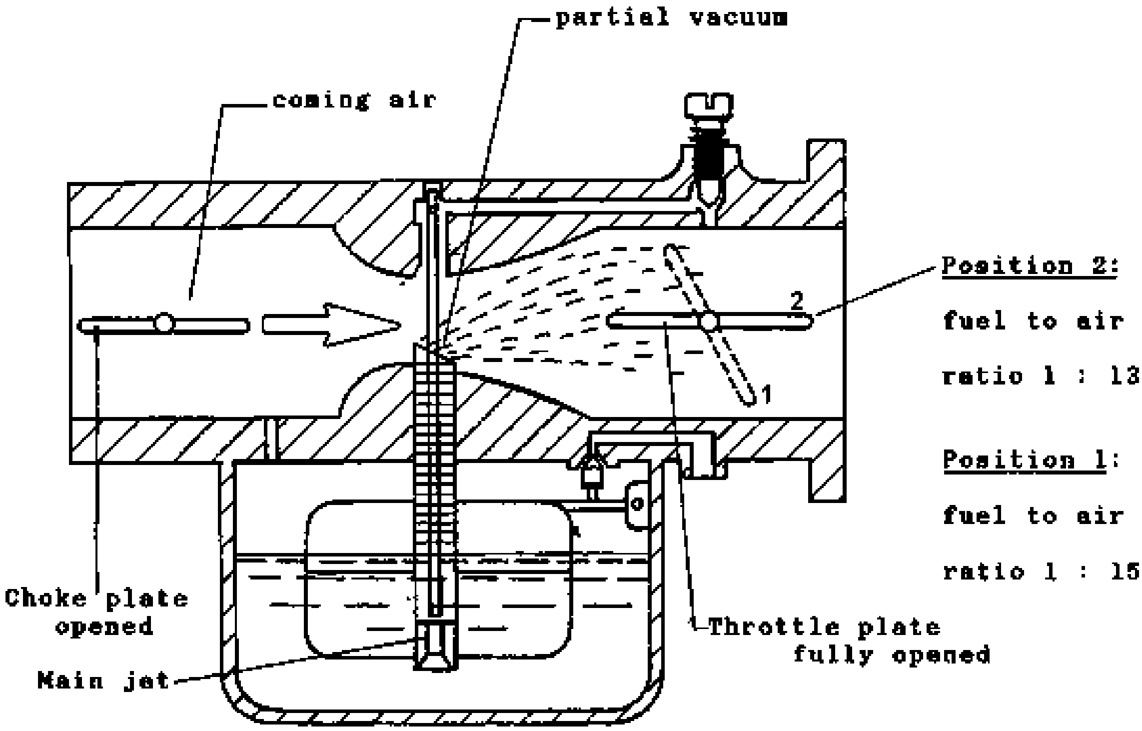
When the throttle plate closes completely, air is sucked via the idle air bleed and thereby sucks fuel from the float blow to mix with it in the idle passage and comes out by the idle port.

Ratio of fuel to air can be adjusted by means of the idle mixture screw. Whereas the idle speed is adjusted by the idle speed screw.



1.5.6 Full throttle circuit

Full throttle circuit is for distributing sufficient amount of air–fuel mixture to the required increasing engine speed.

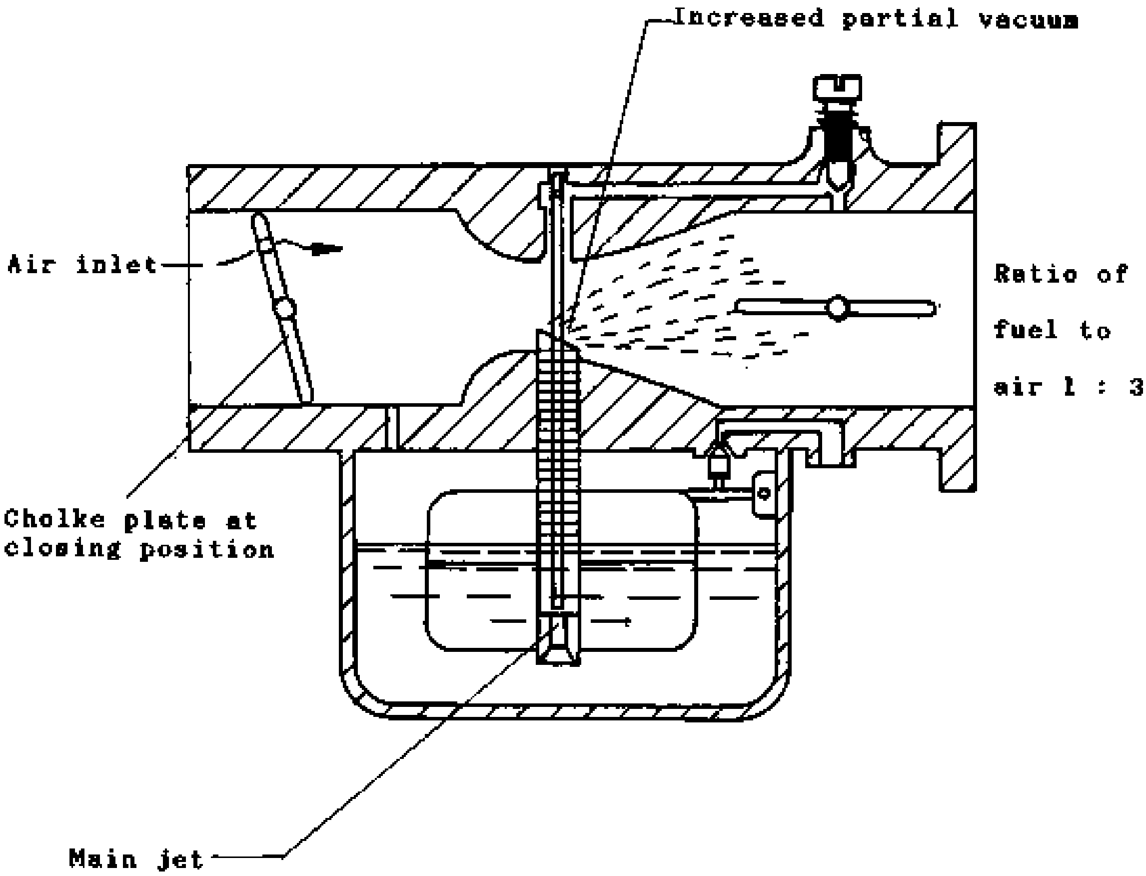


Pos. 1: When the throttle plate opens, air rushes over the venturi increasing the partial vacuum in that aerea and thereby sucks fuel via the main jet – Engine speed is thus increasing.

Pos. 2: When the throttle plate opens fully, more air rushes over the venturi, thus higher partial vacuum is developed. The fuel is sucked more than in the previous position, thus the engine is running at maximum speed.

1.5.7 Choke Circuit

Choke circuit provides richer fuel mixture than normal especially, during the start of the engine.

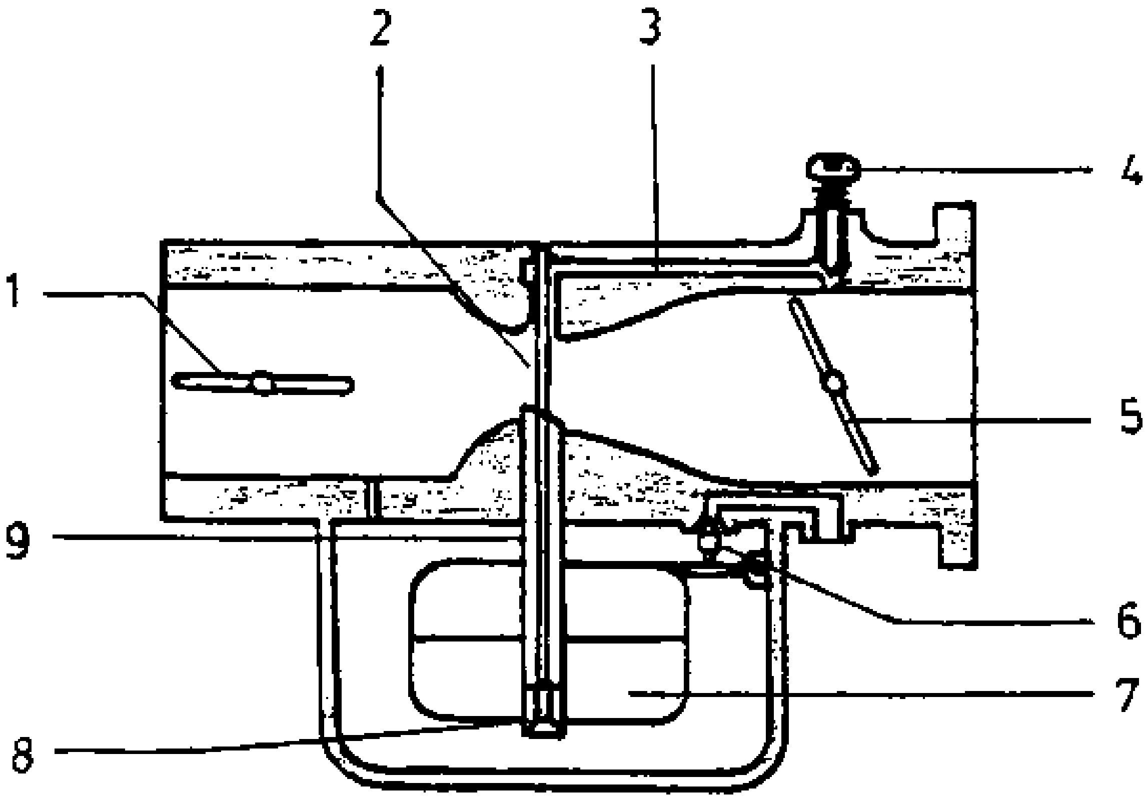


When the engine is started, its speed is still low. A small amount of air flows through the venturi and suck very limited amount of fuel. Increasing fuel is needed in this case by closing the choke plate which in turn increasing the partial vacuum over the venturi.

Task sheets

1.5 Caburetter (I)

1. Name the parts of the carburetter!



1. ________________________________
2. ________________________________
3. ________________________________
4. ________________________________
5. ________________________________
6. ________________________________
7. ________________________________
8. ________________________________
9. ________________________________

2. As air is flowing through the venturi, the pressure at the venturi is –higher/lower– than the atmospheric pressure.

3. The pressure over the float chamber is –higher/lower– than the pressure at the main jet when air is flowing through the venturi.

4. Carburetters used in small engines can be classified, according to types of drafts, into __ types; i.e. ______________________.

5. The most used carburetter for small engines is ________________.

6. The float circuit is for ______________________________________.

7. If the fuel level in the float chamber is dropped, the needle valve will –close/open–.

8. The fuel to air ratio of the idle circuit is about ___: ___.

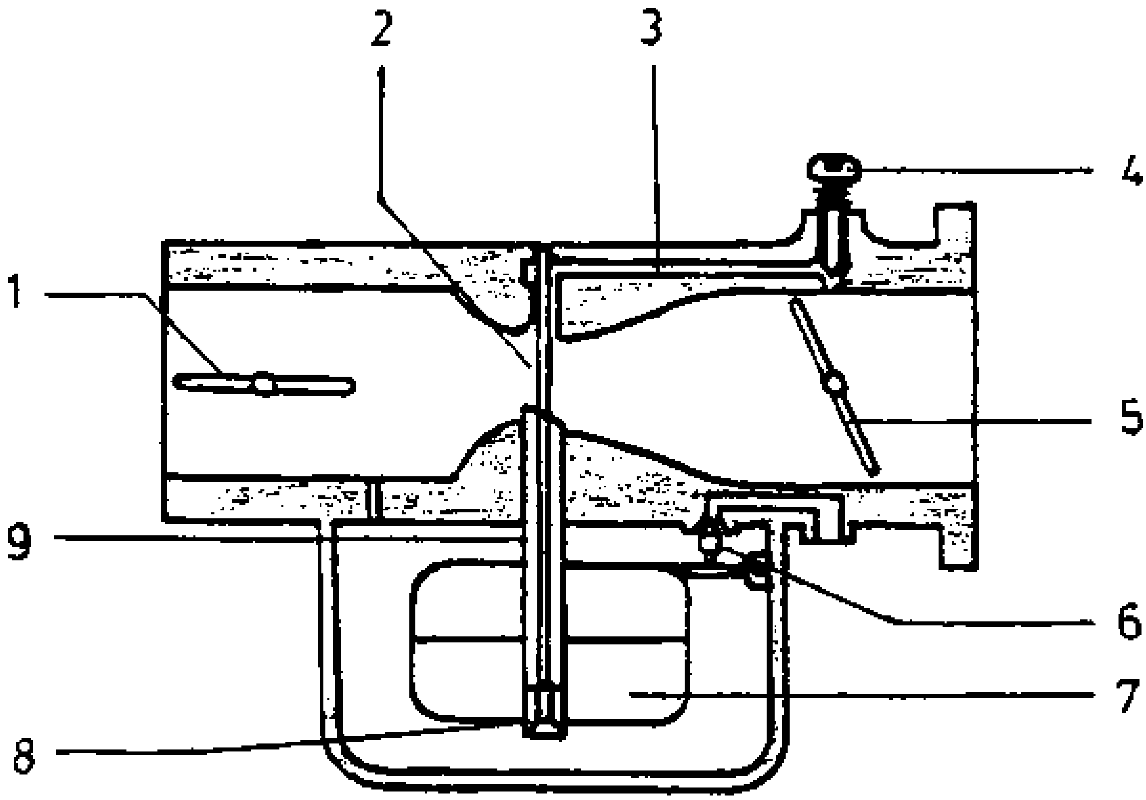
9. While the engine is idling, the throttle plate will be at –fully closing/fully opening– position.

10. The fuel to air ratio of the idle circuit can be adjusted by ________________________.

Task (Solution)

1.5 Caburetter (I)

1. Name the parts of the carburetter!



1. Choke plate
2. Venturi
3. Idle passage
4. Idle mixture screw
5. Throttle plate
6. Needle valve
7. Float
8. Main jet
9. Fuel passage

2. As air is flowing through the venturi, the pressure at the venturi is –~~higher~~/lower– than the atmospheric pressure.

3. The pressure over the float chamber is –higher/~~lower~~– than the pressure at the main jet when air is flowing through the venturi.

4. Carburetters used in small engines can be classified, according to types of drafts, into 3 types; i.e. down, up side.

5. The most used carburetter for small engines is side draft.

6. The float circuit is for control the amount of fuel in the carboretter.

7. If the fuel level in the float chamber is dropped, the needle valve will –~~close~~/open–.

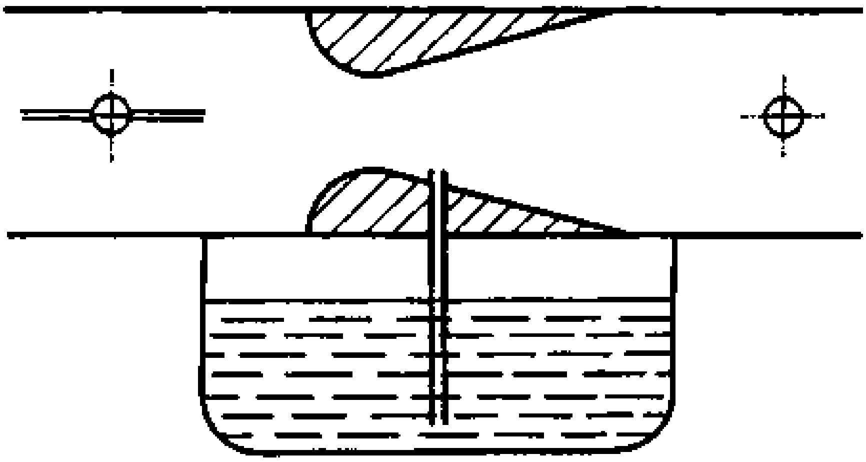
8. The fuel to air ratio of the idle circuit is about 1:13.

9. While the engine is idling, the throttle plate will be at –fully closing/~~fully opening~~– position.

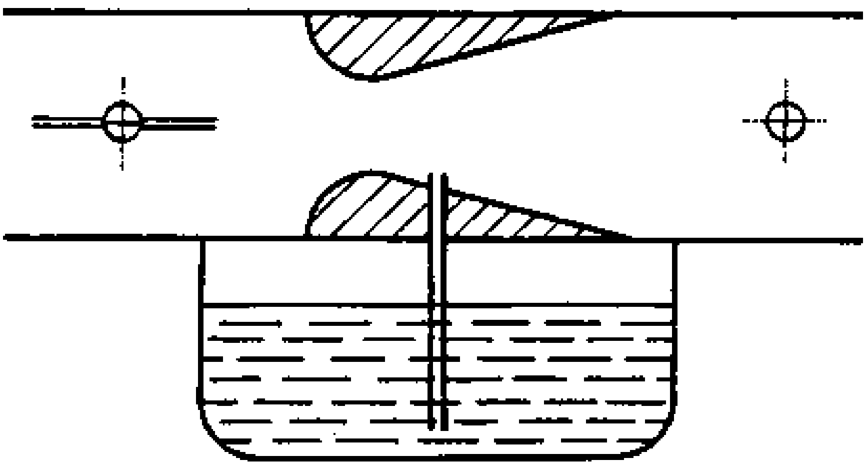
10. The fuel to air ratio of the idle circuit can be adjusted by the idle mixture screws.

1.5 Carburetter (II)

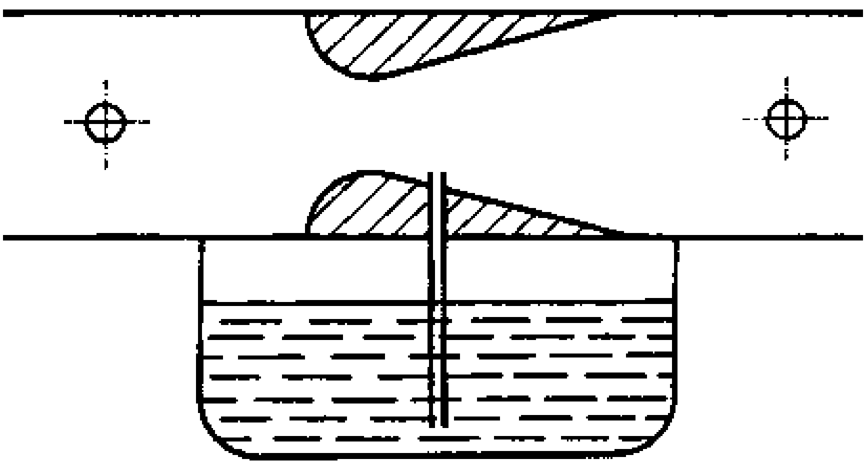
Picture 1: If little fuel is needed by the cylinder, (idle run) what will be the position of the throttle plate? (make a sketch!)



Picture 2: If more fuel is required by the cylinder, what will be the position of the throttle plate? (make a sketch!)



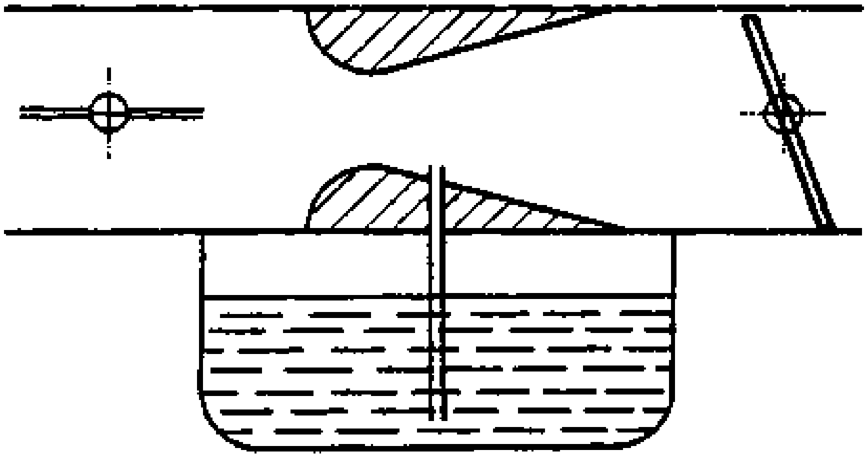
Picture 3: If maximum fuel is needed by the cylinder, what will be the positions of both, the choke plate and the throttle plate? (make a sketch!)



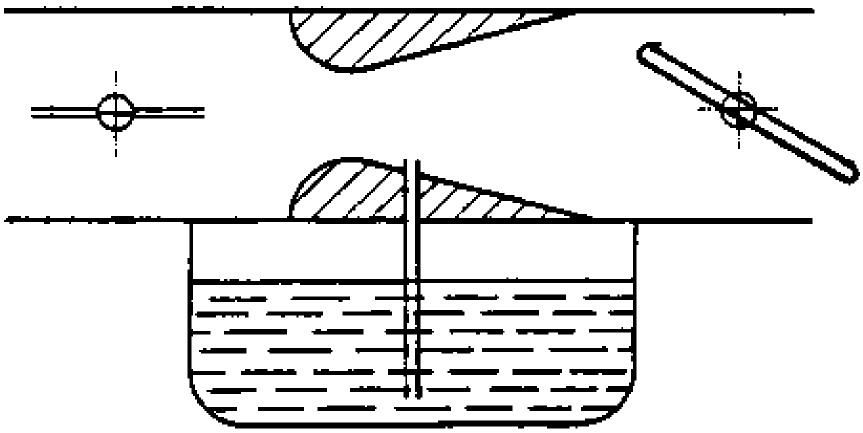
Task (Solution)

1.5 <u>Carburetter (II)</u>

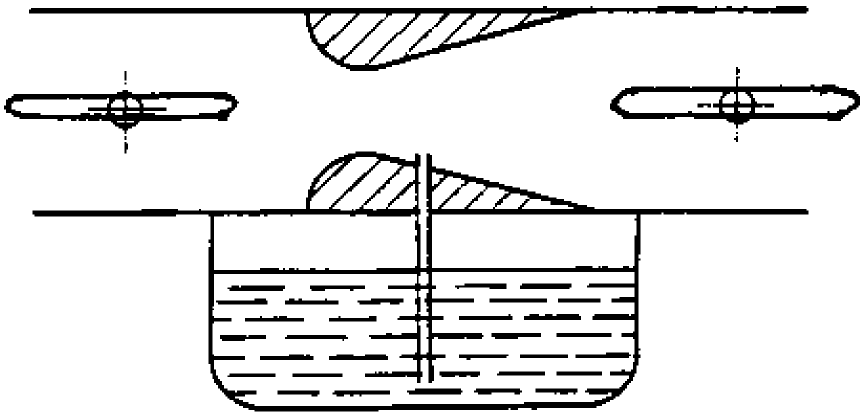
Picture 1: If little fuel is needed by the cylinder, (idle run) what will be the position of the throttle plate? (make a sketch!)



Picture 2: If more fuel is required by the cylinder, what will be the position of the throttle plate? (make a sketch!)



Picture 3: If maximum fuel is needed by the cylinder, what will be the positions of both, the choke plate and the throttle plate? (make a sketch!)



1.5 <u>Carburetter (III)</u>

Answer the following questions correctly!

1. In float setting, what will happen if the float is not set to the specified value?

    1.1 In case the float is too low: ______________________________
    1.2 In case the float is too high ______________________________

2. What will happen if the idle mixture screw is not adjusted to the specified value?

2.1 In case it is higher than the given standard: ____________
2.2 In case it is lower than the given standard: _____________

3. How can the size of the main jet effect the fuel consumption rate?

____
____
____

4. What will happen if the needle valve is worn?

____
____
____

1.5 Carburetter (III)

Task (Solution)

Answer the following questions correctly!

1. In float setting, what will happen if the float is not set to the specified value?

1.1 In case the float is too low: Fuel is overflowing
1.2 In case the float is too high Insufficient fuel

2. What will happen if the idle mixture screw is not adjusted to the specified value?

2.1 In case it is higher than the given standard: idle speed is to high

2.2 In case it is lower than the given standard: idle speed is to low

3. How can the size of the main jet effect the fuel consumption rate?

Big bore ? high fuel consumption
Small bore ? low fuel consumption

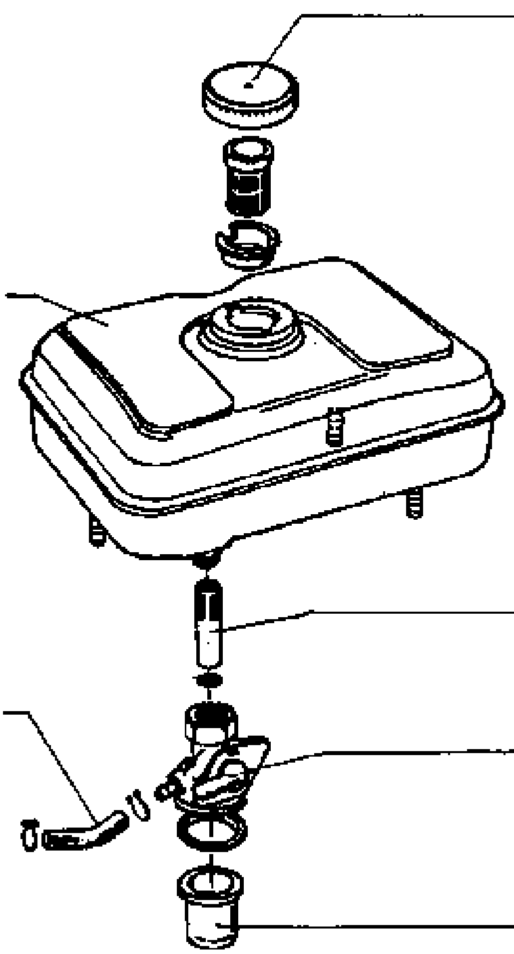
4. What will happen if the needle valve is worn?

The carboretter will leak

1.6 Repair and maintenance

Information

1.6.1 Servicing fuel tank

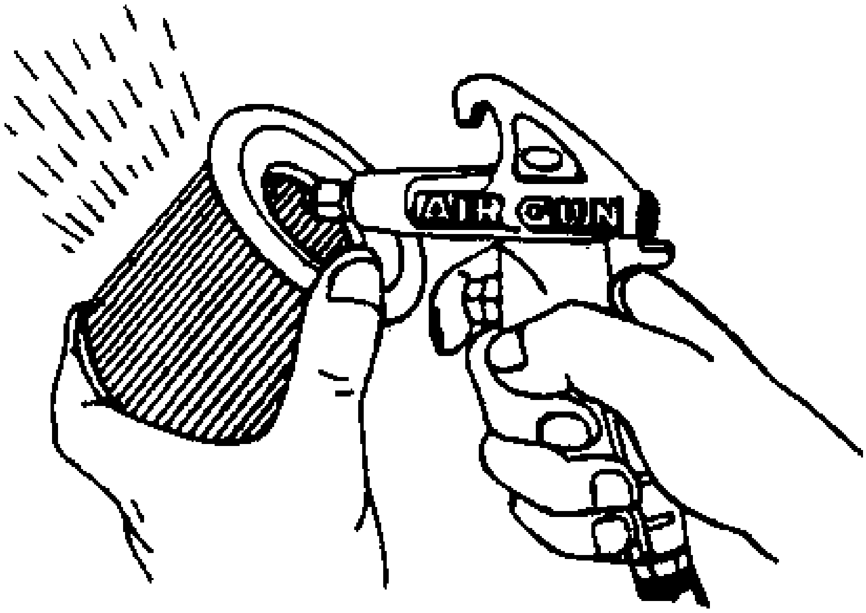


Caution: Fuel must be drained out completely prior removing the fuel tank.

Components	Services
1. Fuel cap	– Inspect the vent, it must be clean and clear. Use air gun to clean it.
2. Fuel tank	– Inspect for any puncture of the fuel tank. Clean inside of the tank.
3. Fuel screen	– Inspect for any blockage or wreckage.
4. Valve	– Clean it.
5. Fuel tube	– Inspect conditions like cracks.
6. Filter case	Clean the filter case in benzene.

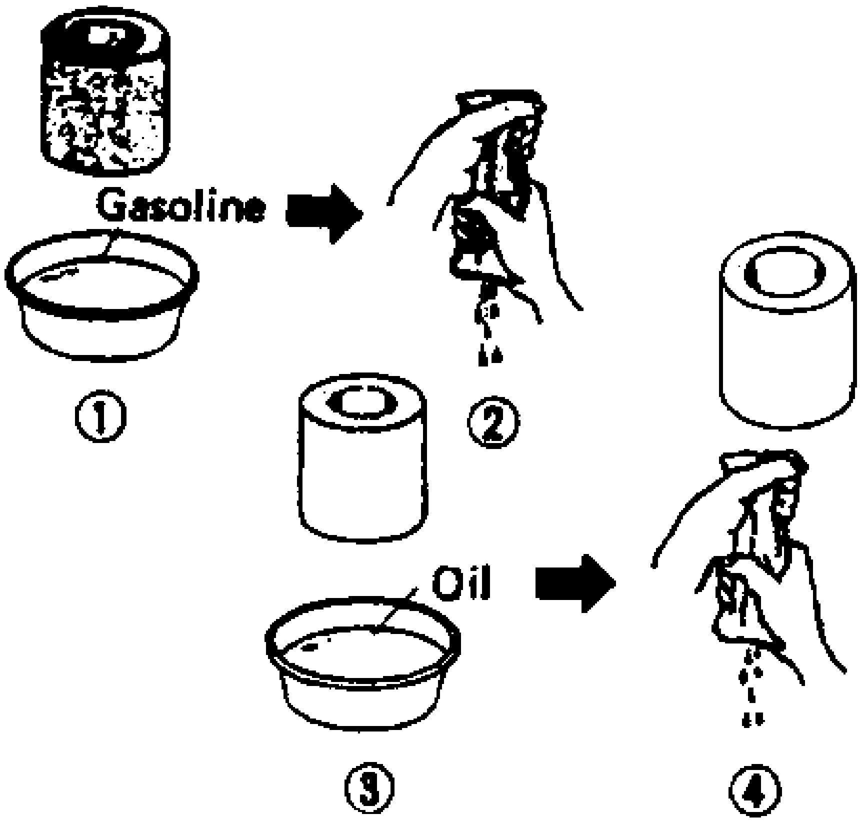
Caution: Be sure that no fuel leakage after reassemble.

1.6.2 Servicing dry–type air filter



Filter paper type

- Tap the filter rim gently or brush the paper.
- Blow out dirt from inside the filter with an air gun.

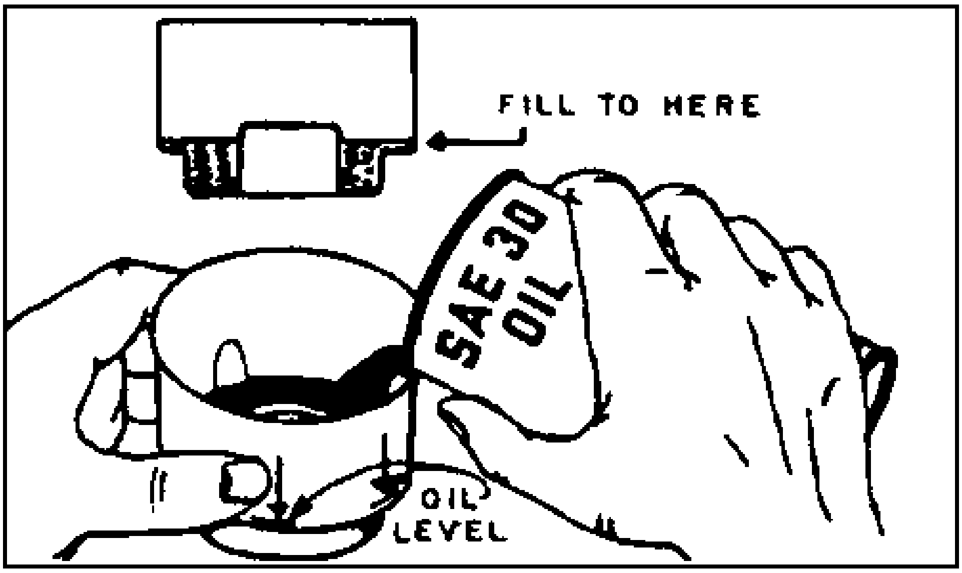


Filter sponge

- Clean the filter sponge in benzene, squeeze out dirt.
- Dry the filter sponge by squeezing and waving it.
- Dip the filter sponge into the pan of oil and benzene mixture of 1 to 10 ratio.
- Squeeze the sponge until wet dry.

Precaution: Do not twist the filter sponge, otherwise it will be torn off. Replace the damaged or ruin sponge.

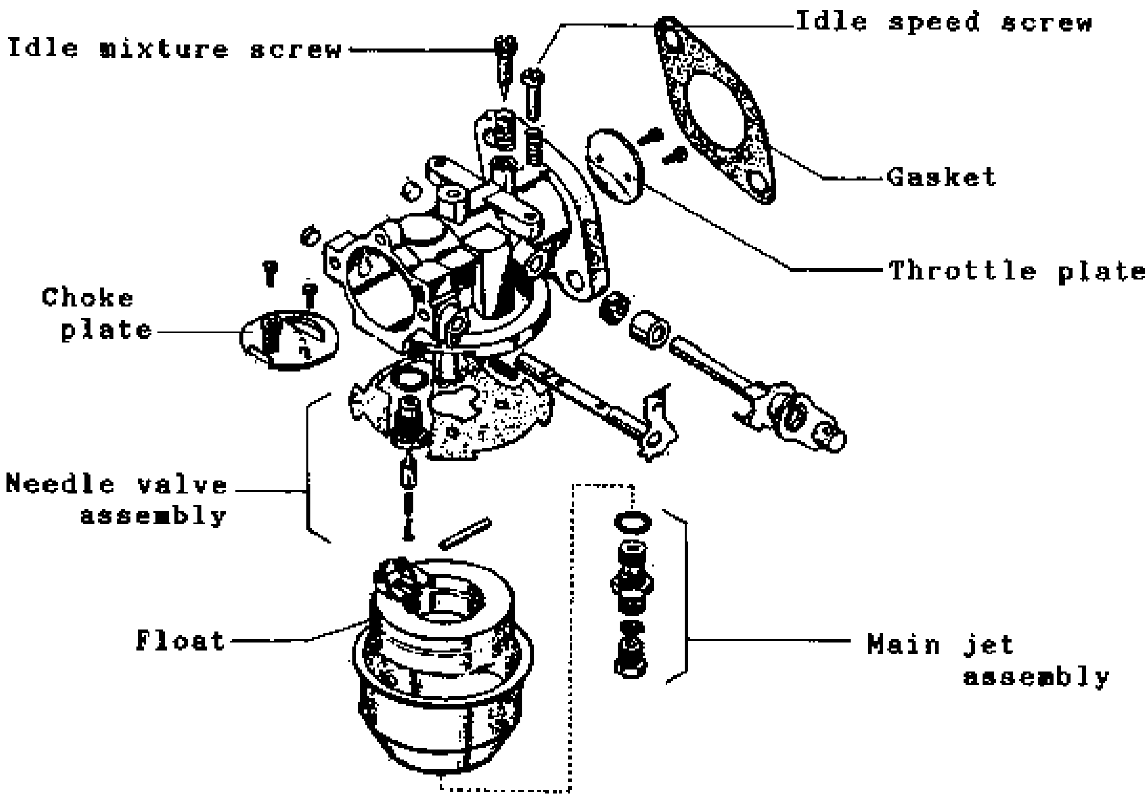
1.6.3 Servicing wet–type filter



– Remove the filter and stir it in a fuel pan.
– Clean the filter inside and outside.
– Refil the oil upto the marked level.

Precaution: Use the correct oil and refil according to the manufacturer's manual.

1.6.4 Dismantling Reassembling carburetter



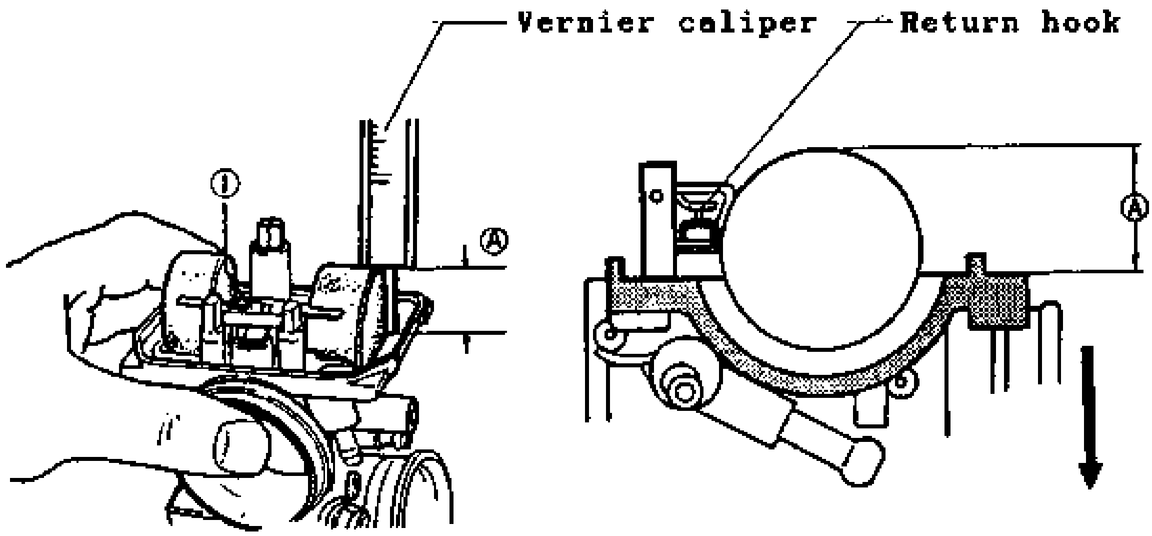
Components	Services
1. Float chamber	– Clean and blow with air gun
2. Float	

3. Main jet	– Blow with air gun
4. Needle	– Inspect for wear
5. Idle mixture screw	– Inspect for wear or damage on cone and thread
6. Carburetter body	– Clean and blow with air gun.

Remarks: – In removing the carburetter assembly, unscrew and remove the float chamber, and drain out fuel residual.

– Before Inspection, clean all parts with benzene and brush, and blow until dry with air gun.

1.6.5 Float Setting



Measuring and setting:

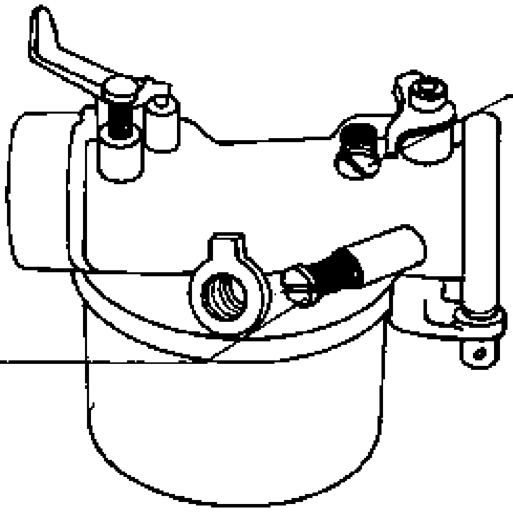
With the float cover placed horizontally, lift the float slowly with a finger (until the return hook is just lifting the float). Measure the height of the float at this position and compare the obtained value with that given in the manual.

If the obtained value is outside the manual value, then resetting is needed.

Example:

Standard value for height of float:	HONDA	G 150	8.2 mm
		G 200	8.0 mm
		GX 120	13.7 mm
		GX 160	13 mm

1.6.6 Idle mixture adjustment



Screw in the idle mixture screw completely and then unscrew it for the specified number of turns as given in the manual.

The specified number of turns of idle mixture screw:	HONDA	G 150	1 3/8 Turns
		G 200	3 1/4 Turns
		G x 120	2 5/8 Turns
		G x 160	2 1/8 Turns

Remark: If the specified number of turns is not known, then assumes for 1 1/2 to 2 turns or observe for the smoothest idling of the engine.

1.6.7 Idle speed setting

– Start the engine and allow it to idle.

– Adjust the idle speed screw inward or outward until the specified number of revolutions is obtained.

Standard idling speed	1,400 rev/min

1.6.8 Fault diagnosis oil engine as due to carburetter failure.

Symptom	Causes	Remedy
1. Wet spark plug	– Fuel flooded	– adjust float level
	– Worn float needle or dirty	– Clean, replace
2. Idle speed too high	– Incorrect idle speed	– Readjust idle mixture screw
	– Clogged idle circuit	– Clean, blow with air gun
	– Clogged fuel tube of idle circuit	
3. Poor acceleration	– Clogged fast idle main jet	– Clean, blow with air gun
	– Fuel level is too low in the float chamber	– Readjust the float level

	– Choke unit sticking	– Dismantle, clean
4. Engine will not start	– Float sticking, no fuelentering	– Clean
	– Choke unit sticking	– Dismantle, clean
	– Fuel flooded	– Readjust the float level

Job Sheets

1.2 to 1.4 <u>Tank and Filters</u> (I)

Tools: A set of wrenches, air gun with hose

Equipement: Benzen, Oil, Soft brush, cleaning pan, cloth

Manufacturer .... Model...........
Type of air cleaner ....

Sequence of operations	Inspection	
1. Prepare tools and equipment		
2. Close fuel valve and disconnect hoses.	– Condition of	fuel valve
	☐ Normal	☐ Damaged
	– Condition of hose	
	☐ Normal	☐ Damaged
3. Remove fuel tank		
4. Empty the fuel tank	– Condition of fuel	
	☐ Normal	☐ Deposited
	☐ Water contained	
	☐ Others	
5. Remove fuel valve and fuel cap	– Condition of fuel cap	
	☐ Normal	☐ Blocked vent
6. Clean fuel valve and fuel filter	– Condition of fuel filter	
	☐ Normal	☐ Clogged
	☐ Damaged	
7. Clean fuel tank with benzene	– Condition of fuel tank	
	☐ Normal	☐ Rusty
	☐ Leaked	
8. Reassemble those components in reverse order.	Remarks:	....

1.2 to 1.4 <u>Tank and Filters</u> (II)

Sequence of operations	Inspection

Paper type air cleaner:	
1. Remove the air cleaner unit from the carburetter.	
2. Remove the filter for inspection	– Condition of the filter
	☐ Normal
	☐ Dirty, clogged
	☐ Damaged
	☐ Others
3. Blow the filter from inside	
4. Clean the air cleaner body with benzene	
5. Reassemble the air cleaner	Remarks: ....
Sponge type air cleaner:	
1. Remove the air cleaner unit from carburetter.	
2. Remove the filter for inspecting.	– Condition of filter
	☐ Normal
	☐ Dirty, clogged
	☐ Damaged
	☐ Others
3. Clean the filter with benzene	
4. Squeeze and wave the filter.	
5. Dip the filter in the fuel oil mixture (1: 10 ratio)	
6. Reassemble the air cleaner	Remarks: ....

1.2 to 1.4 <u>Tank and Filters (III)</u>

Sequence of operations	Inspection
Wet type air cleaner:	
1. Remove the air cleaner unit.	
2. Remove the filter for inspecting	– Condition of the filter
	☐ Normal
	☐ Dirty, clogged
	☐ Damaged
	☐ Others
3. Clean the filter and the air cleaner body.	
4. Refil oil into the air cleaner body upto the marked level.	– Amount of refil oil
	...... ccm
	Oil number ....
5. Reassemble the filter and the air cleaner.	
6. Clean and store tools and equipment used.	Remarks ....

1.5 Carburetter (I)

Tools: A set of wrenches, air gun with hose

Equipement: Benzen, soft brush, cleaning pan, cloth

Manufacturer.................... Model ....

Type of carburetter .... Model ....

Standard float height ..... mm

Standard number of turns of idle mixture screw ....

Standard idling speed........ rev/min

Standard number of main jet ....

Sequence of operation	Inspection	
1. Prepare tools and equipment.		
2. Remove air cleaner.	– Type of filter	
3. Close fuel valve and disconnect hose.		
4. Remove carburetter and related linkage and spring.		
Remark: Memorize linkages before removing.		
5. Clean outside of carburetter.	– Condition of leakage	
	☐ Nil	☐ leaked
6. Remove carburetter cover and empty fuel residual.	– Condition of float chamber	
	☐ Normal	☐ Dirty
Caution: Gasket may be torn off	– Condition of fuel	
	☐ Normal	☐ Dirty
	☐ Water contained	
	☐ Others	

1.5 Carburetter (II)

Sequence of operations	Inspection	
7. Remove float and needle for	– Condition of float	
inspection.	☐ Normal	
	☐ Damaged	
	– Condition of needle	
	☐ Normal	☐ Dirty
	☐ Worn	☐ Others
	....	
8. Remove main jet assembly	– Condition of main jet bore	

	☐ Normal	☐ Blocked
	☐ Worn	
	Number of main jet	
	☐ Original main jet	
	☐ New main jet	
9. Remove idle mixture screw	– Condition of idle mixture screw	
	☐ Normal	☐ Dirty
	☐ Worn	☐ Others
	....	
10. Clean all components with benzene and dry with air gun.		
11. Set the height of float according to the manual.	– Height of float	
	Obtained value .... mm	
	☐ Normal	
	☐ Resetting	
12. Reassemble the carburetter in reverse order.		

1.5 <u>Carburetter</u> (III)

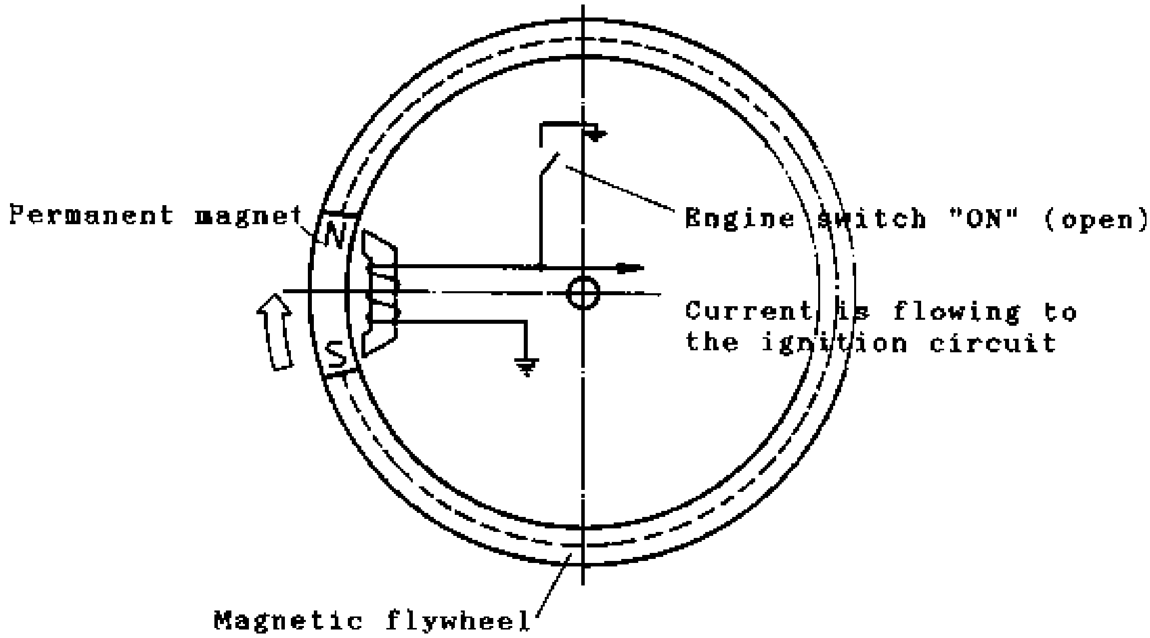
Sequence of operations	Inspection	
13. Adjust the idle mixture screw according to the manual as specified.	– Number of turns	
14. Start the engine and allow to idle.	– Performance of the engine	
	☐ Normal	☐ Abnormal
15. Adjust the idle speed screw according to manual.	– Idling speed as specified .... rev/min	
16. Stop the engine		
17. clean tools and equipement and store it.		
Remarks:	....	
	....	

2. Ignition system

Information

2.1 Basic principle

For small gasoline engines, <u>magneto ignition system</u> is generally used.



– The magnetic field of the permanent magnet, which rotates over the coil will generate current in the coil circuit.

– If the engine switch is at "OFF" position (closed), the generated current flows to the ground and cause no current flows in the ignition circuit.

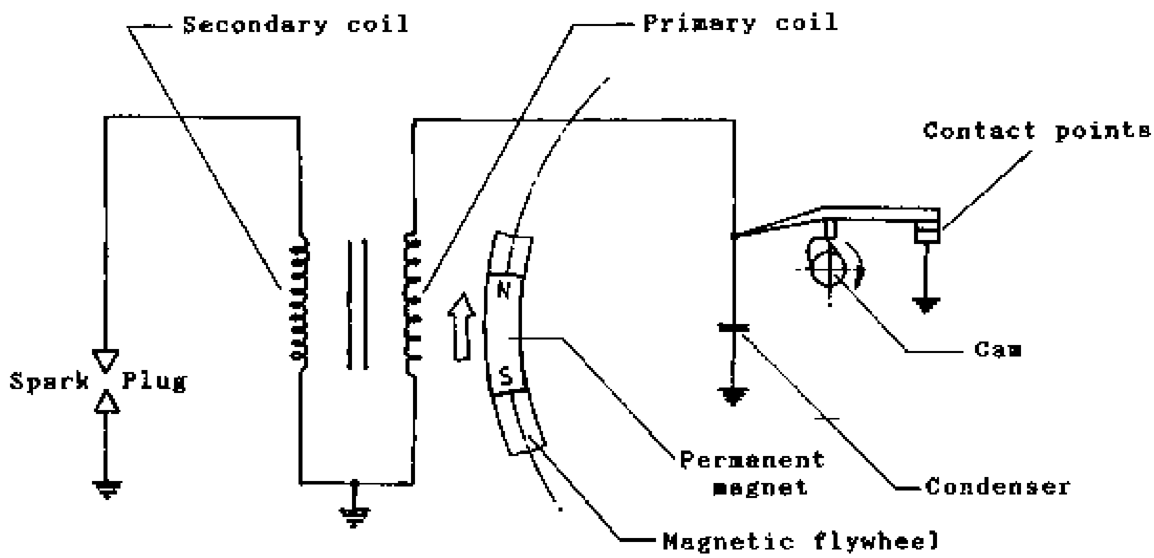
Magneto ignition system can be classified into 3 types:

1. Contact point ignition system.
2. Transistor ignition system
3. Capacitive discharge ignition system.

On the following pages the function of these systems is shown.

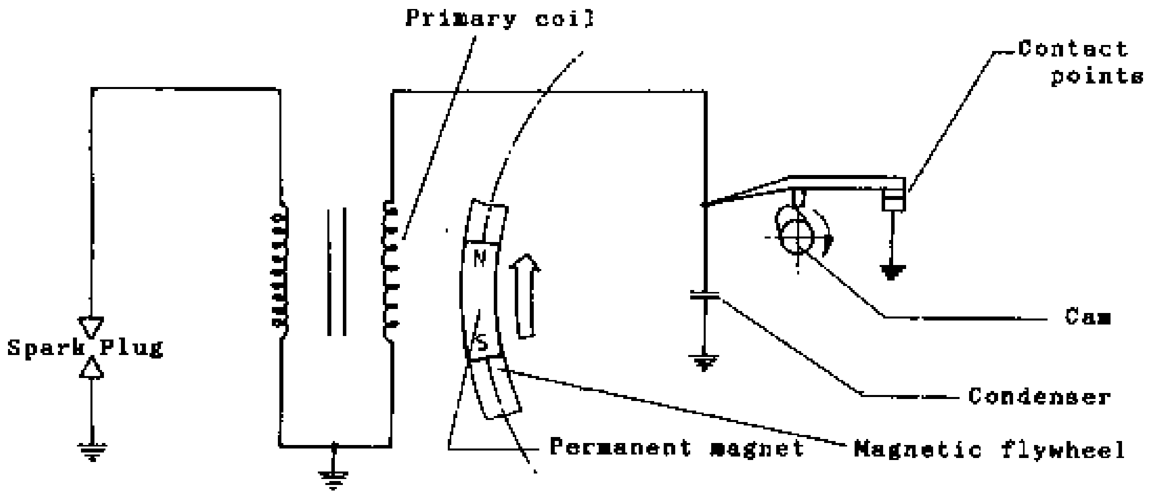
2.2 Contact point ignition system

2.2.1 Components of contact point ignition system and their function



Components	Functions
1. Magnetic fly wheel	– makes the permanent magnet rotates around the coil and thereby produces the current in the ignition circuit
2. Contact point	– switches on and off the current flowing from the primary coil
3. Cam	– open/closes the contact point at correct timing.
4. Condenser	– charges/discharges the current and to prevent arcing between the two contact points.
5. Ignition coil	– converts low current voltage to high current voltage, sufficient for arcing the spark plug.
6. Spark plug	– produces arcing and ignite the fuel mixture in cylinder.

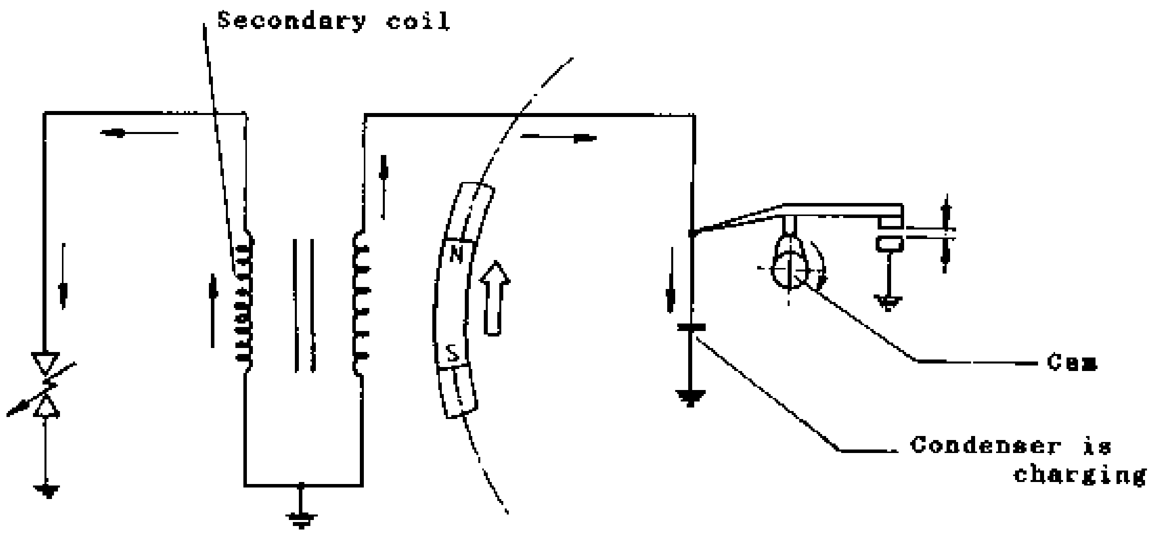
2.2.2 Function of contact point ignition system



– When the engine is starting, the magnetic flywheel rotates causing the magnetic field of permanent magnet to cut the primary coil, and thereby generates current flowing in the primary coil.

As the gap of contact point is closed, the generated current is flowing to the ground by the contact points.

At the ignition stroke, the gap is opened.



– At the ignition stroke, the cam mounted on the magnetic flywheel opens the gap of contact points. The current flowing to ground is impossible. The condenser is charging by the time the gap is opening. This will prevent arcing between contact points.

– A sudden interruption of current flowing in the primary coil causes the magnetic field to collapse and cut the secondary coil.

– Thus, the high current voltage is generated in the secondary coil and enable arcing between the electrodes of the spark plug.

Task sheet

2.2 Contact point ignition system

Complete the sentences or underline the correct options.

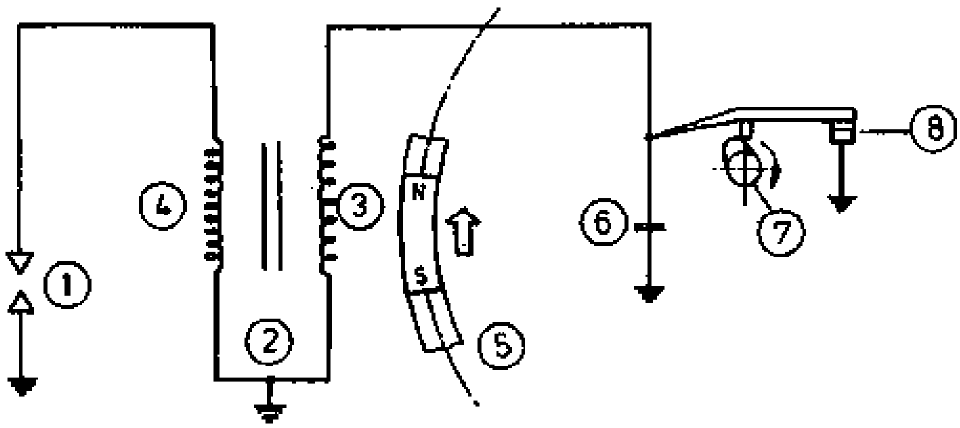
1. Ignition system generally used in small gasoline engine is

– battery/magneto type.

2. Current which flows in the ignition circuit is generated by _________________.

3. Magneto ignition system is classified into _____ types, they are
____

4. Please name all parts of the ignition system.



1.................... 5....................

2.................... 6....................

3.................... 7....................

4.................... 8....................

5. Contact point is for ____.

6. The device that opens/closes the contact point is ___________.

7. Condenser/Ignition coil is for converting low current voltage to high current voltage.

8. The primary coil will be induced when the gap of contact point is closed/opened.

9. When the current flowing in the primary coil is interrupted suddenly, the magnetic field will
_________________________.

10. The secondary coil shall generate high current voltage for the spark plug when the gap of contact is beginning to open/close.

Task (Solution)

2.2 Contact point ignition system

Complete the sentences or underline the correct options.

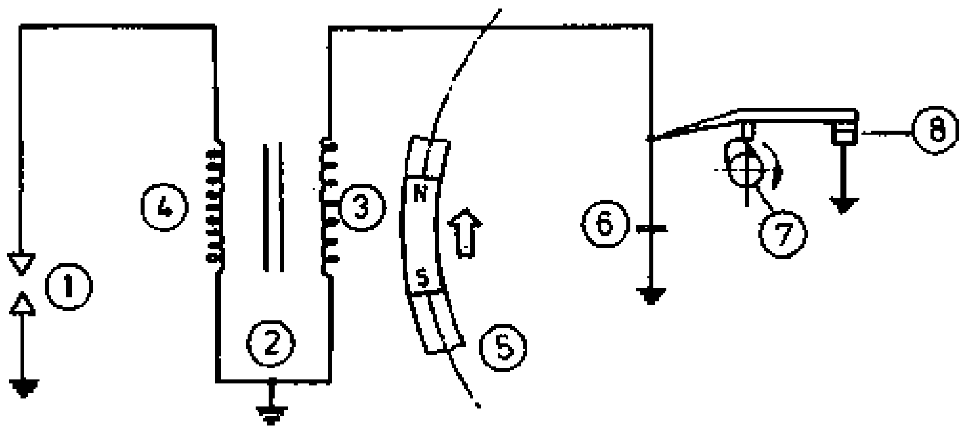
1. Ignition system generally used in small gasoline engine is

   – ~~battery~~/magneto type.

2. Current which flows in the ignition circuit is generated by magnetic flywheel.

3. Magneto ignition system is classified into 3 types, they are Contact point, Transistor and CDI.

4. Please name all parts of the ignition system.



1 Spark plug	5 Magnetic flywheel
2 Ignition coils	6 Condenser
3 Primary coil	7 Cam
4 Secondary coil	8 Contact points

5. Contact point is for interrupting current flows in primary coil.

6. The device that opens/closes the contact point is the cam.

7. ~~Condenser~~/Ignition coil is for converting low current voltage to high current voltage.

8. The primary coil will be induced when the gap of contact point is closed/~~opened~~.

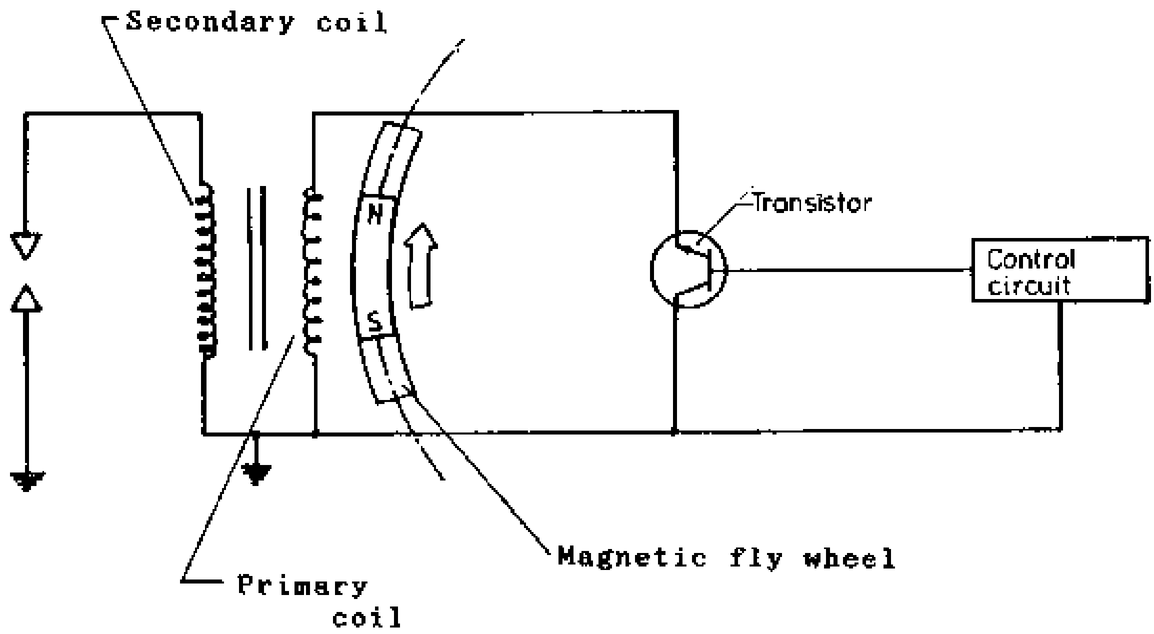
9. When the current flowing in the primary coil is interrupted suddenly, the magnetic field will collapse.

10. The secondary coil shall generate high current voltage for the spark plug when the gap of contact is beginning to open/~~close~~.

2.3 Transistor ignition system

Information

2.3.1 Components of transistor ignition system and their function



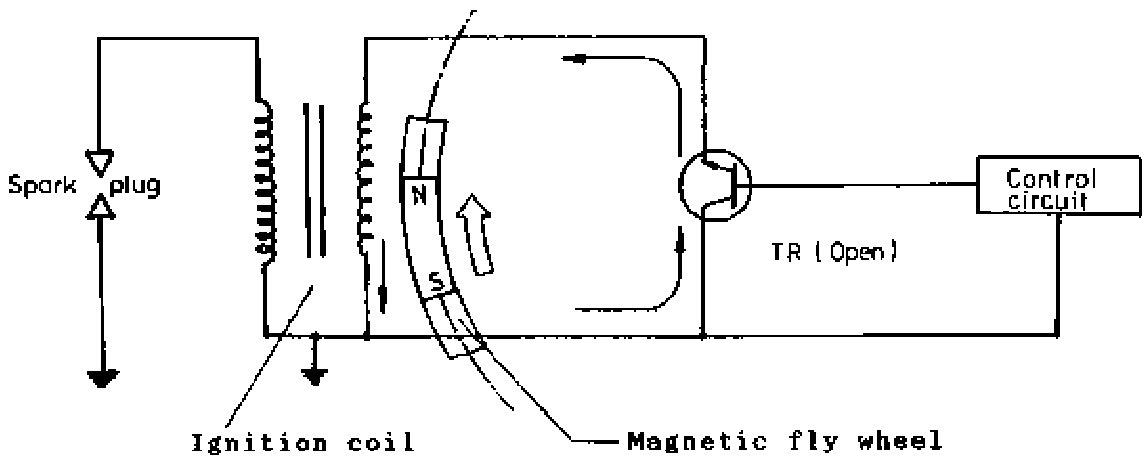
Transistor (TR)

– acts as on/off switch, like the contact points. But, a transistor can do the task contact–free.

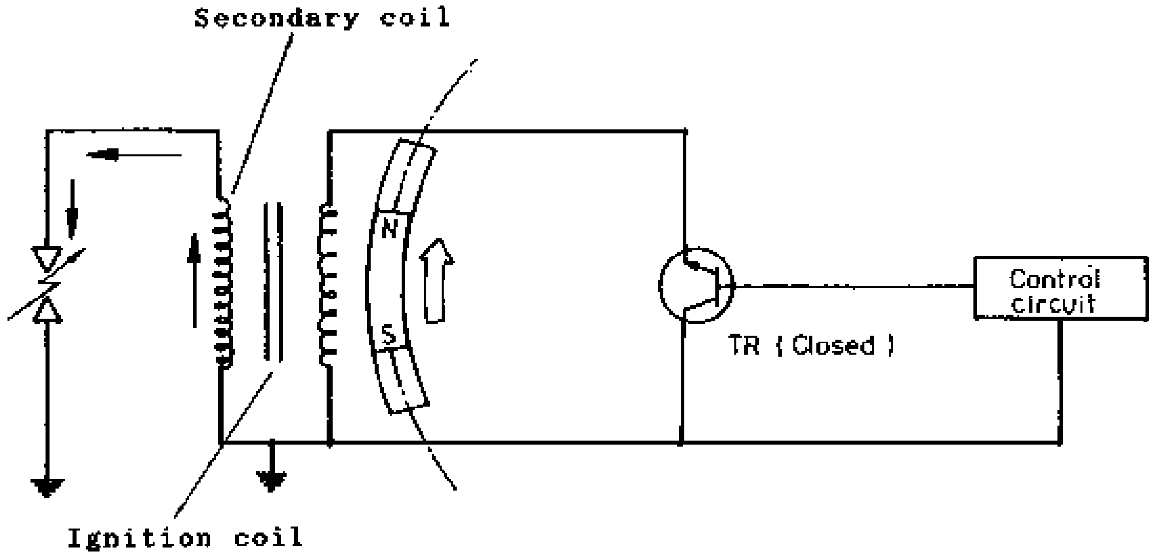
Control circuit

– acts like the cam in opening–closing the contact points, it controls the opening/closing of the transistor.

2.3.2 Function of transistor ignition system



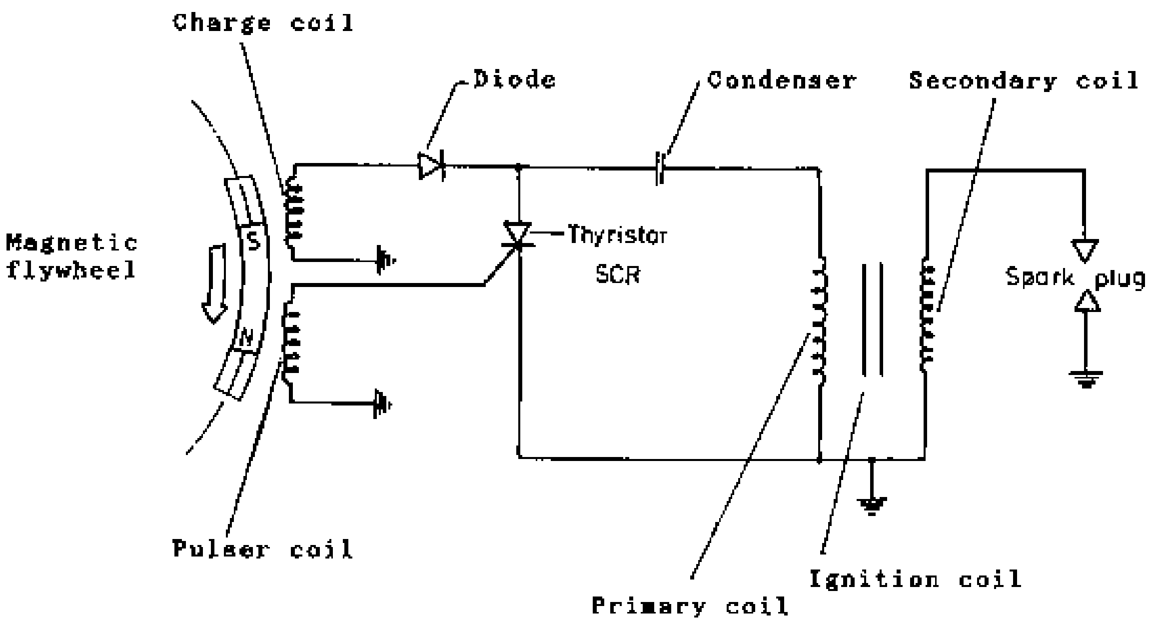
When starting the engine, magnetic fly wheel will rotate. As the magnetic field of permanent magnet is approaching the primary coil, current is induced and flowing through the transistor and thereby coming back to the primary coil, generating a magnetic field.



As the magnetic fly wheel turns until the ignition stroke, the induced voltage is increasing sufficiently for the control circuit to activate the Transistor to cut the flow of current to the primary coil. The magnetic field in the coil is, thus, collapsing and thereby inducing the high voltage current in the secondary coil, to flow to the spark plug.

2.4 Capacitive discharge ignition system (CDI)

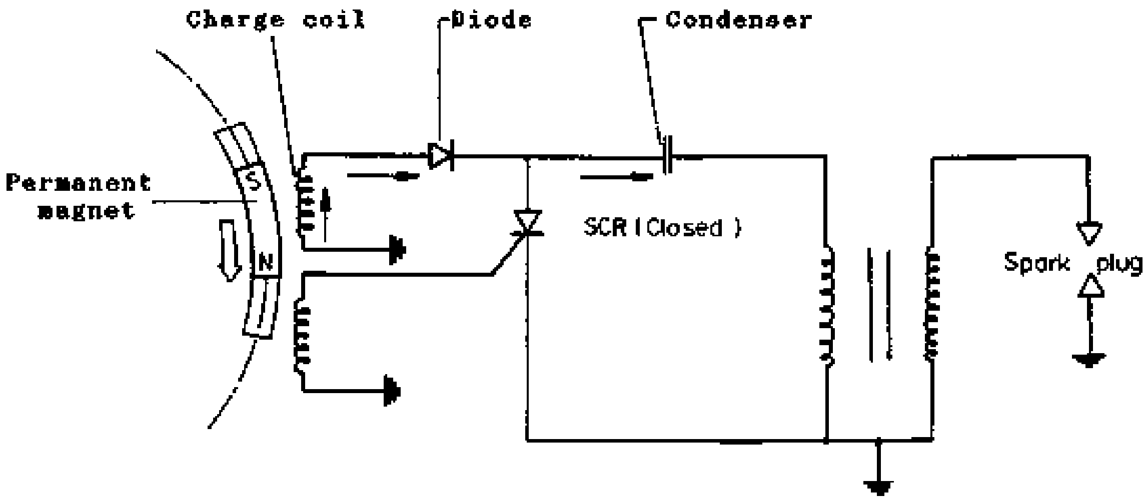
2.4.1 Components of capacitive discharge ignition system and their function



Components	Functions
1. Primary coil	– generates alternating current
2. Diode	– converts alternating current to direct current
3. Condenser	– charges and discharges current
4. Thyristor or SCR SCR = Silicon Control Rectifier	– closes/opens the circuit, acts like the contact points of the contact point ignition system. The current can flow from A to K only when G is activated.

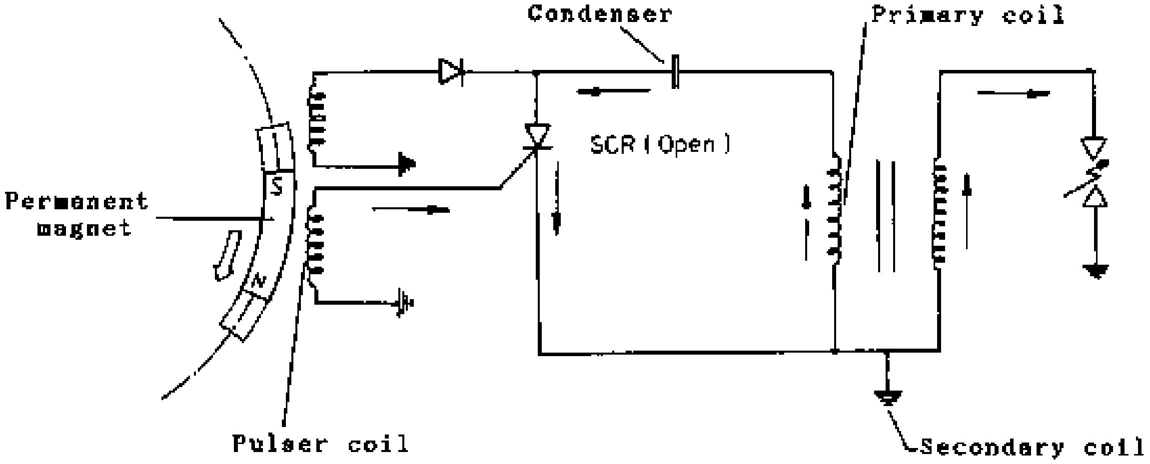
5. Pulser coil	– generates a current to activate the SCR to open the circuit.

2.4.2 Function of CDI ignition system



When starting the engine, the magnetic flywheel will rotate.

As the magnetic field of the permanent magnet cuts the charge coil, alternating current is induced and flows to the diode. The diode will rectify it into direct current and the condenser will store it.



As the magnetic flywheel turns until the ignition stroke, its magnetic field cuts the pulser coil and current is generated.

The generated current will trig the SCR, causing the condenser to discharge its stored current to flow through SCR and through the primary coil to ground. This will induce the high current voltage in the secondary coil which flows to the spark plug causing arcing between the electrodes of the spark plug.

2.5 Advantages and disadvantages of CDI and transistor ignition systems

Advantages:

1. Reduced maintenance, no need of adjustment
2. Prolong life of a spark plug
3. No wearing of contact points
4. Easy starting, because higher ignition voltage
7. Constant high performance over the working life.

Disadvantages:

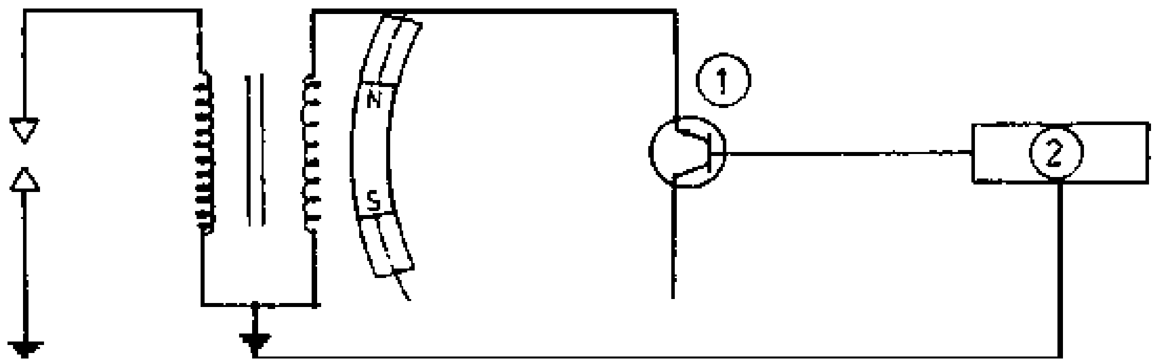
1. Expensive.
2. Electronic devices are not repairable.

Task sheets

2.3 and 2.4 Transistor and CDI ignition systems

Fill in the blanks and underline the correct answers.

1. Name various parts and complete the circuit diagramme of the transistor ignition system.



1. ....
2. ....

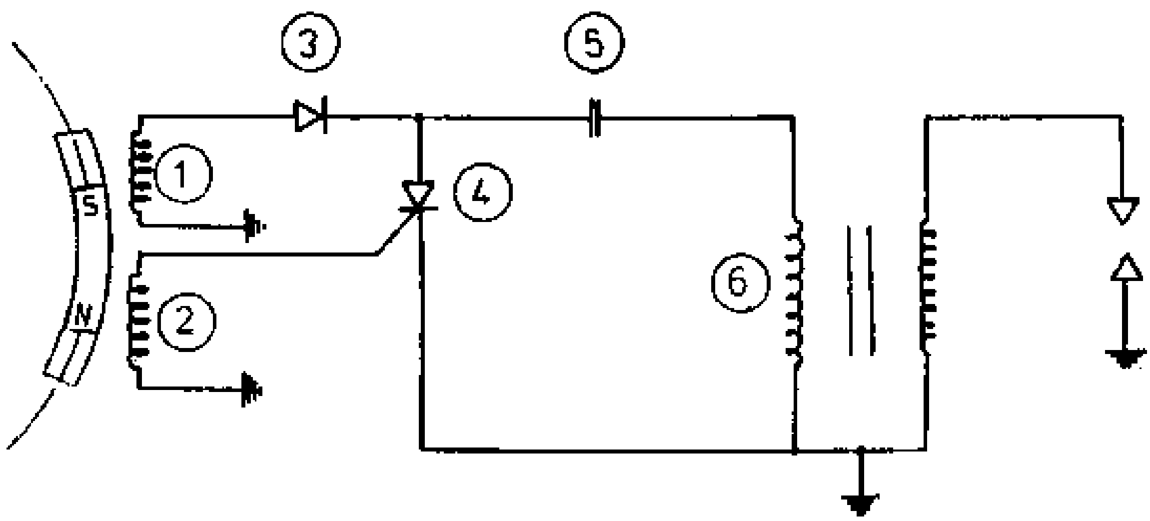
2. The Transistor is for ....

3. In a Transistor ignition system, the device which is equivalent to the cam is ....

4. The Control circuit will activate the Transistor to cut the current flow when the voltage is increasing/decreasing.

5. What happens, when the Transistor cuts the current flow to the primary coil?
....

6. Name the parts of the CDI system.



1 .... 4 ....

2 .... 5 ....

3..................... 6 ....

7. The device in the CDI system, which performs the same function as the contact points is ....

8. The Pulser coil/Charge coil is producing the current that triggers the SCR to open the circuit.

9. From the circuit of item 6:

As the permanent magnet is moving past the coil 1,

–alternating/direct– current will be generated and flowing through the diode by which it is changed into –alternating/ direct– current and storing in ....

10. When the SCR opens the circuit, the current as released by the condenser will flow through ....

11. High voltage current will flow to the spark plug when the magnetic wheel is cutting– the charge coil/the pulser coil.

12. Advantages of both the CDI and transistor ignition systems are:

1. .... 3...........................
2 .... 4...........................

13. Disadvantages of both the CDI and transistor ignition systems are:

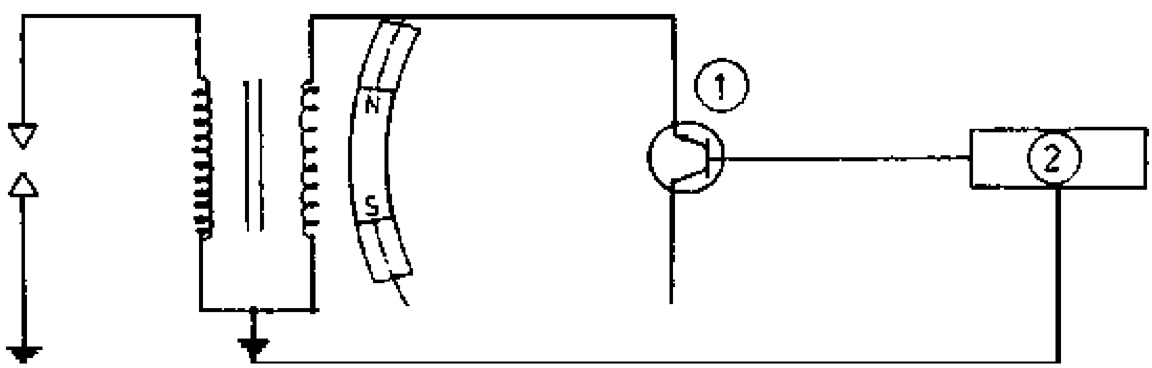
1...
2...

Task (Solution)

2.3 and 2.4 Transistor and CDI ignition systems

Fill in the blanks and underline the correct answers.

1. Name various parts and complete the circuit diagramme of the transistor ignition system.



1. Transistor
2. Control unit

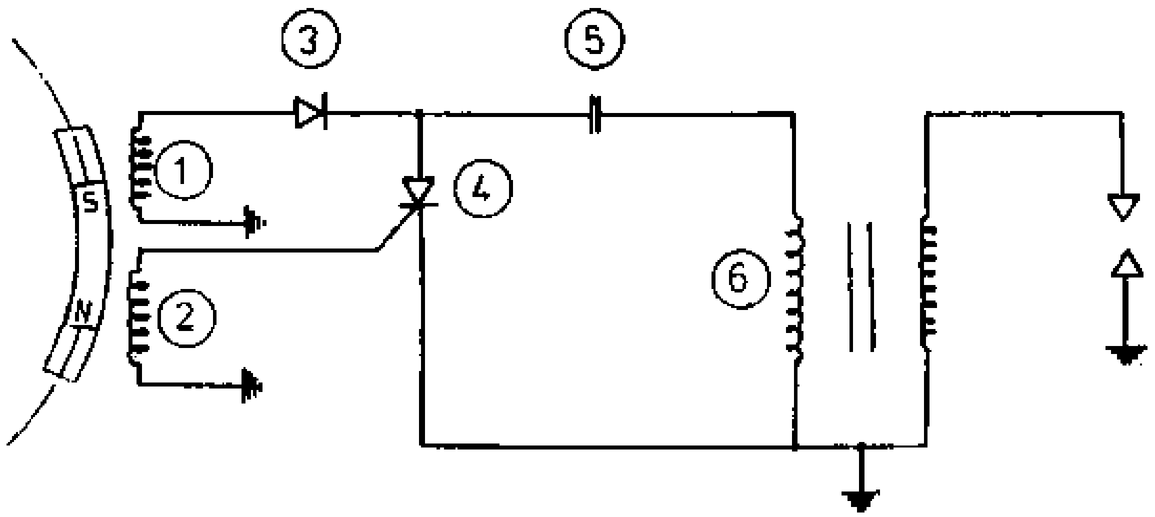
2. The Transistor is for opening/closing the current flow of primary coil

3. In a Transistor ignition system, the device which is equivalent to the cam is the Control unit

4. The Control circuit will activate the Transistor to cut the current flow when the voltage is increasing/~~decreasing~~.

5. What happens, when the Transistor cuts the current flow to the primary coil? The magnetic field is collapsing and generating high voltage in the secondary coil.

6. Name the parts of the CDI system.



1 Charge coil	4 Thyristor (SRC)
2 Pulser coil	5 Condenser
3 Diode	6 Primary coil

7. The device in the CDI system, which performs the same function as the contact points is the Transistor.

8. The Pulser coil/~~Charge coil~~ is producing the current that triggers the SCR to open the circuit.

9. From the circuit of item 6:

As the permanent magnet is moving past the coil 1,

–alternating/~~direct~~– current will be generated and flowing through the diode by which it is changed into –~~alternating~~/direct– current and storing in the condenser.

10. When the SCR opens the circuit, the current as released by the condenser will flow through the primary coil.

11. High voltage current will flow to the spark plug when the magnetic wheel is cutting– ~~the charge coil~~/the pulser coil.

12. Advantages of both the CDI and transistor ignition systems are:

1. Reduced maintenance	3 No wearing of contact points
2 Longer live of spark plug	4 Easy starting

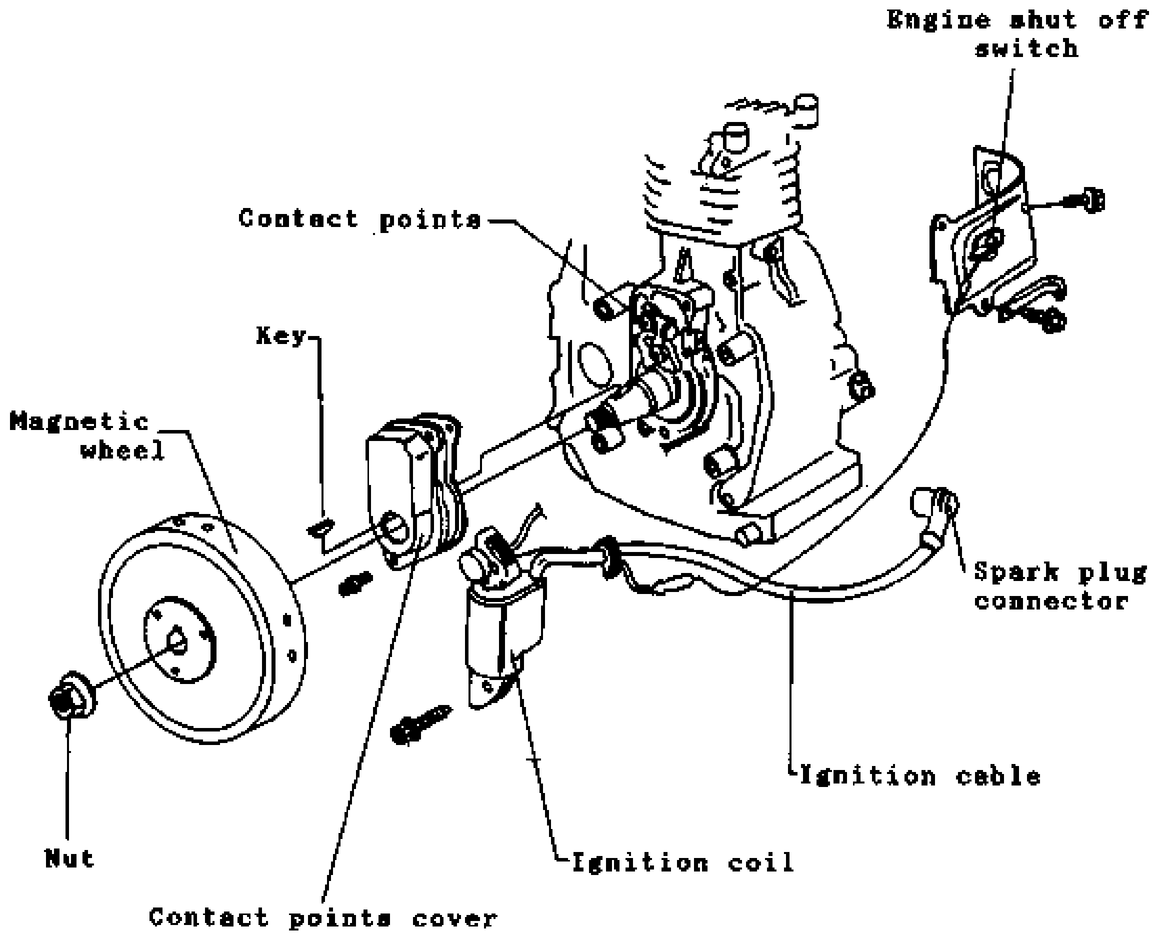
13. Disadvantages of both the CDI and transistor ignition systems are:

1 Expencive
2 Electronic devices not repairable

2.6 Maintenance and repair

Information

2.6.1 Assemble and disassemble the ignition system



Removing: – Special tool should be used to remove the magnetic wheel.

– Do not hammer the magnetic wheel, otherwise it will be damaged or spoiled.

Refitting: – Clean the magnetic wheel completely before refitting.

Remark: – The magnetic wheel nut must be tighten with a torque wrench at the correct torque according to the manufacture's manual.

– The specified torque = 6.0 – 7.0 kgm

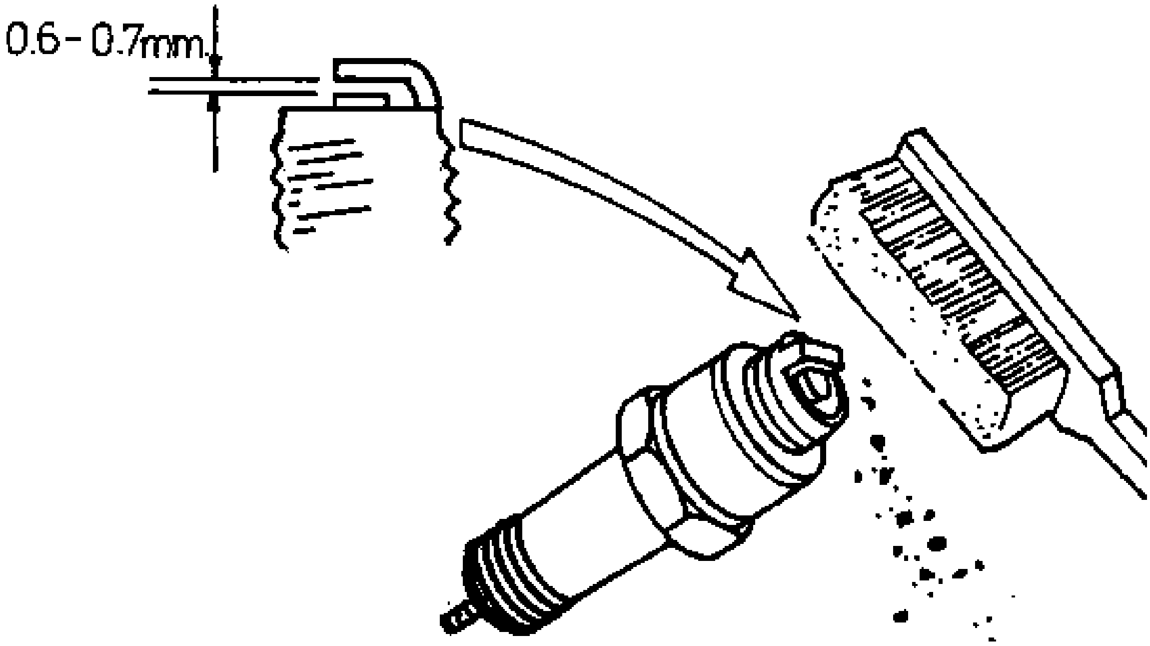
2.6.2 Inspect, clean and adjust spark plugs

Inspecting conditions of a spark plug:

Conditions of electrodes	Cause	Remedy
dry and light brown	– normal engine operation	
dry and black	– fuel mixture too rich	– readjust the idle mixture screw
		– inspect choke and air filter

	– wrong heat range	– switch to hotter plug, e.g. from BP 7 ES to BP 6 ES
wet and black	– Oil leaking into the combustion chamber may be caused by worn piston rings or others	– inspect and repair piston rings, piston and cylinder
burned and eroded	– wrong heat range	– switch to colder plug, e.g. from BP 6 ES to BP 7 ES
white spot deposit	– aditive deposits from leaded fuel	– switch to hotter plug

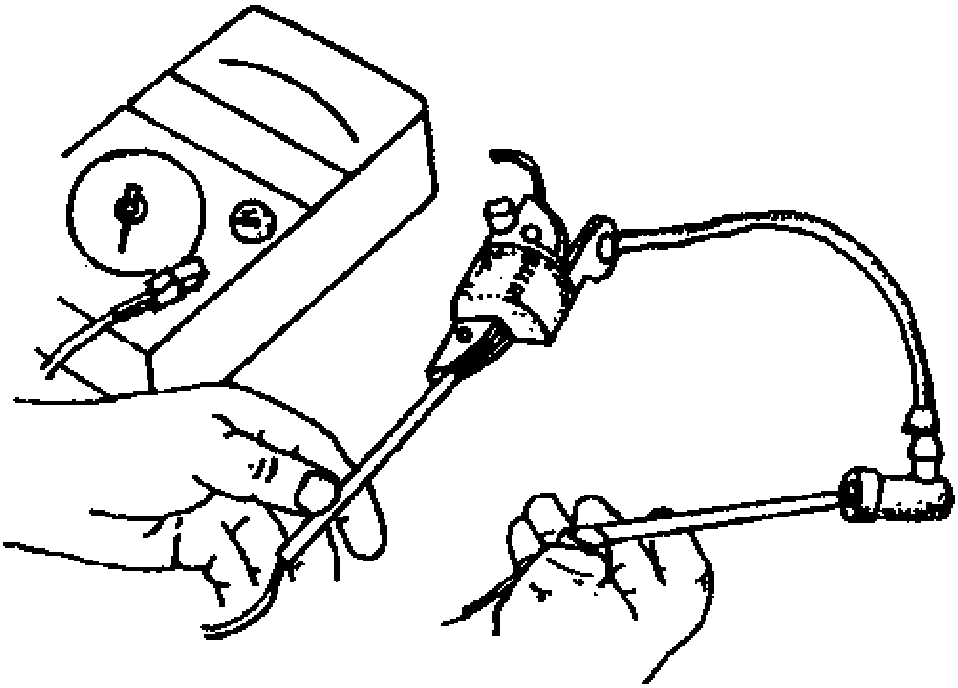
Cleaning and adjusting a spark plug:



– clean the electrodes with a steel brush.
– adjust the spark plug gap according to manual

(Standard spark plug gap = 0.6 – 0.7 mm)

2.6.3 Inspect the ignition coil

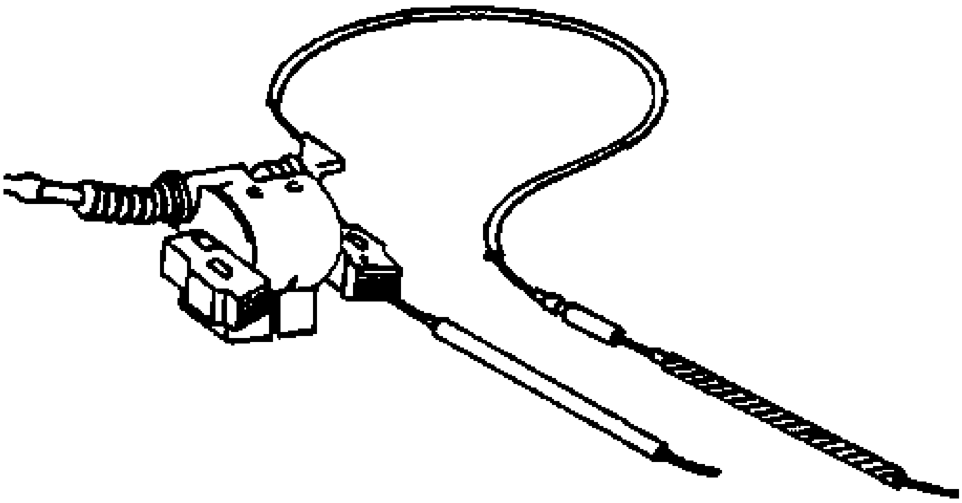


– disconnect the spark plug connector
– measure between the spark plug connector and the ignition coil base with an ohmmeter standard resistance = 6.6 K?

Condition of ignition coil	Causes
Resistance of the primary coil is too low	– short circuit in coil 1
Resistance of the primary coil is too high	– dirty coil
Resistance of the secondary coil is too low	– short circuit in coil
Resistance of the secondary coil is too high	– dirty terminal

2.6.4 Inspect CDI and transistor ignition system

Primary coil:

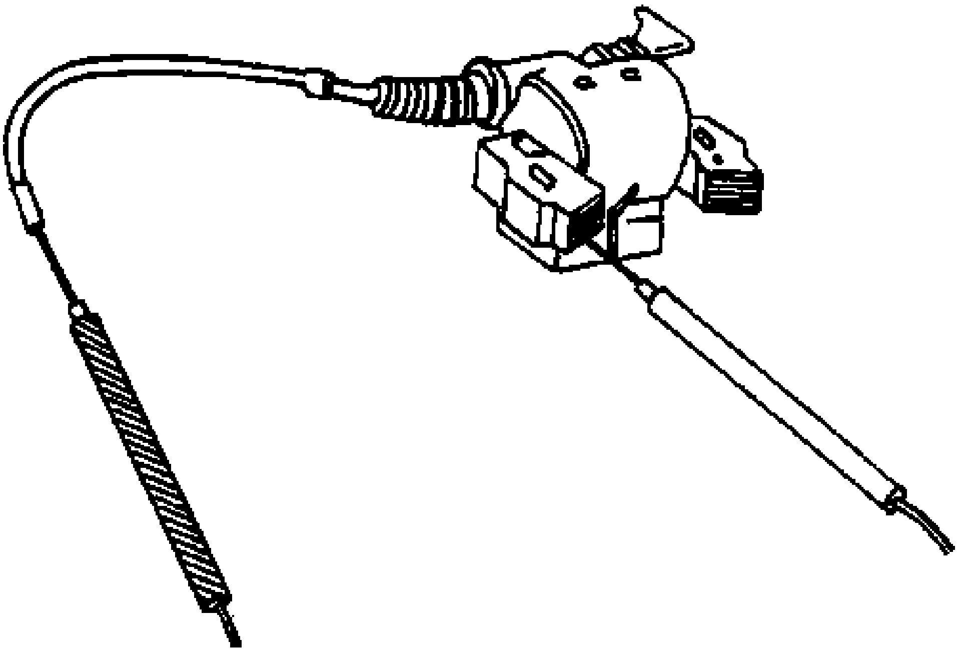


Use ohmmeter to check between the black cable (engine stop) and the core.

Standard resistance of primary coil:

for HONDA Model GX 110, 120, 140, 160	=	1.2 – 0.2 ?
For HONDA Model GX 240, 340	=	0.7 – 0.9 ?

Secondary coil:



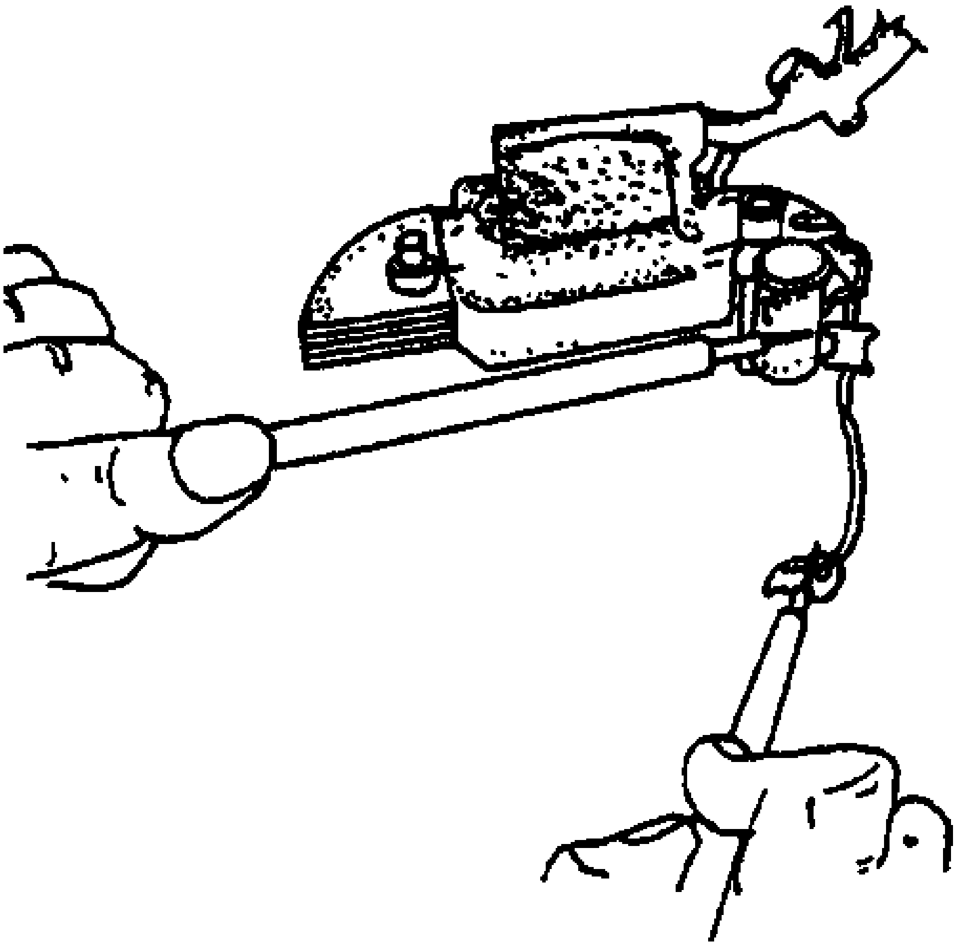
– Remove the spark plug lead.

– Use ohmmeter to check between the spark plug lead and the core.

Standard resistance of secondary coil:

for HONDA Model GX 110, 140	=	12 – 2 K?
for HONDA Model GX 120, 160	=	6.5 – 8 K?
for HONDA Model GX 240, 340	=	6.3 – 7.7 K?

2.6.5 Inspect condenser



– measure the resistance of the condenser between positive and negative terminals
– if the indicater rises a little and falls back, the condenser is alright
– if the indicater does not rise or fall, it is damaged

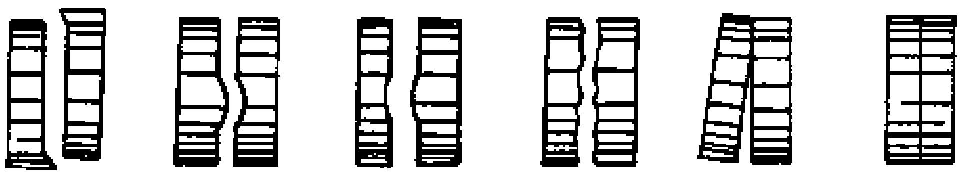
Standard capacitive = 0.24 µF

Remark: If the contact points wear abnormally, then the condenser must be replaced.

Conditions of condenser	Faults
Too large capacitive	– Contact points are eroded
Too small capacitiv	– Contact points are eroded

2.6.6 Inspect: and adjust contact points

<u>Conditions of contact points</u>:

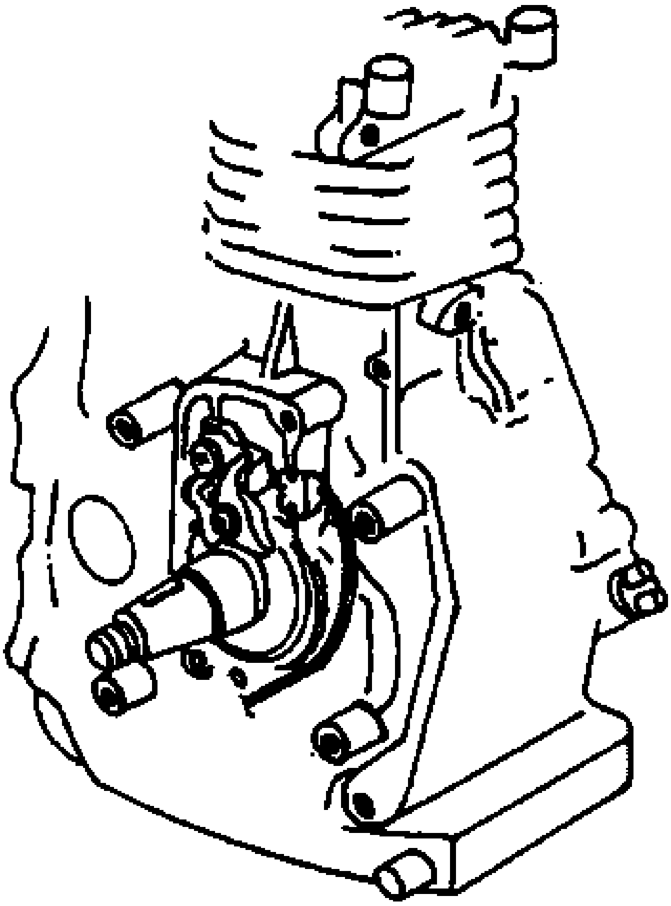


– Light gray contact points are normal.
– If burned, eroded or pitted, contact points must be replaced.
– If colour is normal and worn a little, then file them smooth.

Adjusting the contact points:

– Insufficient gap will cause contact points arcing and burning.

– Excessive gap will reduce the dwell angle of the contact points and thereby ceasing the ignition at high–speed.



Operating steps:

– Turn the crank shaft until the cam opens the contact points fully.
– Measure the gap by using feeler gauge.
– Readjust the gap if it is not correct according to the manual.
(Standard contact point gap = 0.4 – 0.5 mm)

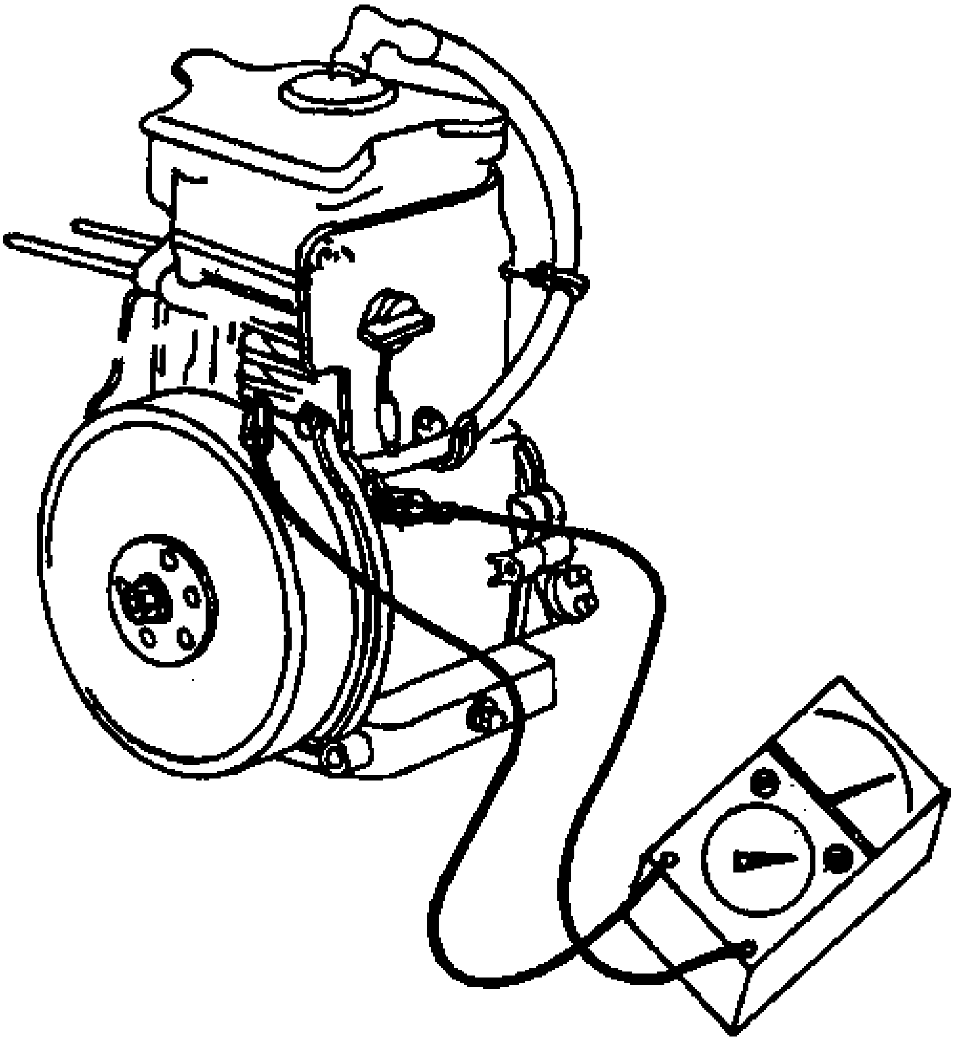
2.6.7 Adjust the ignition timing

Ignition timing	Faults
1. Advanced ignition	– Engine is knocking
	– Engine runs back
2. Retarded ignition	– Difficult to start
	– Engine lacks power
	– Engine is

	overheated

Adjusting the ignition timing:

a) by using timing tester



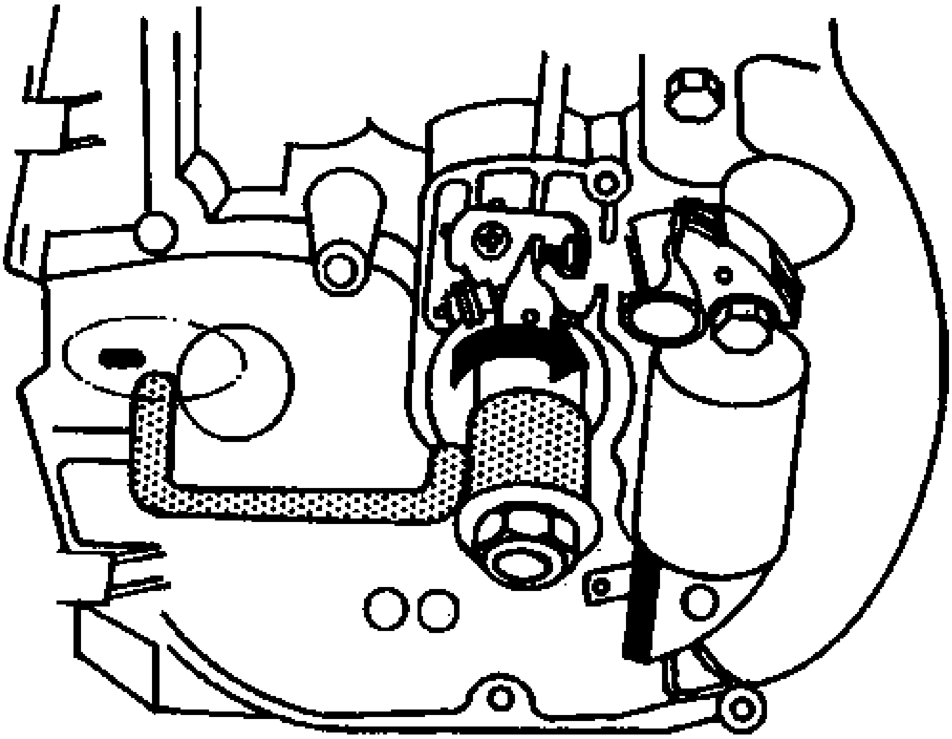
– Connect one lead of the timing tester to ground.

– Connect another lead of the timing tester to contact point terminal (ignition terminal of switch key)

– When the timing tester is switched on, sound should be heard if the contact points open, or vice versa.

– The position at which the contact points open, must be inlined with F, otherwise readjusting the ignition timing is needed.

b) by using special tool to identify the "F" mark



– Remove the magnetic wheel and the cover of contact points.

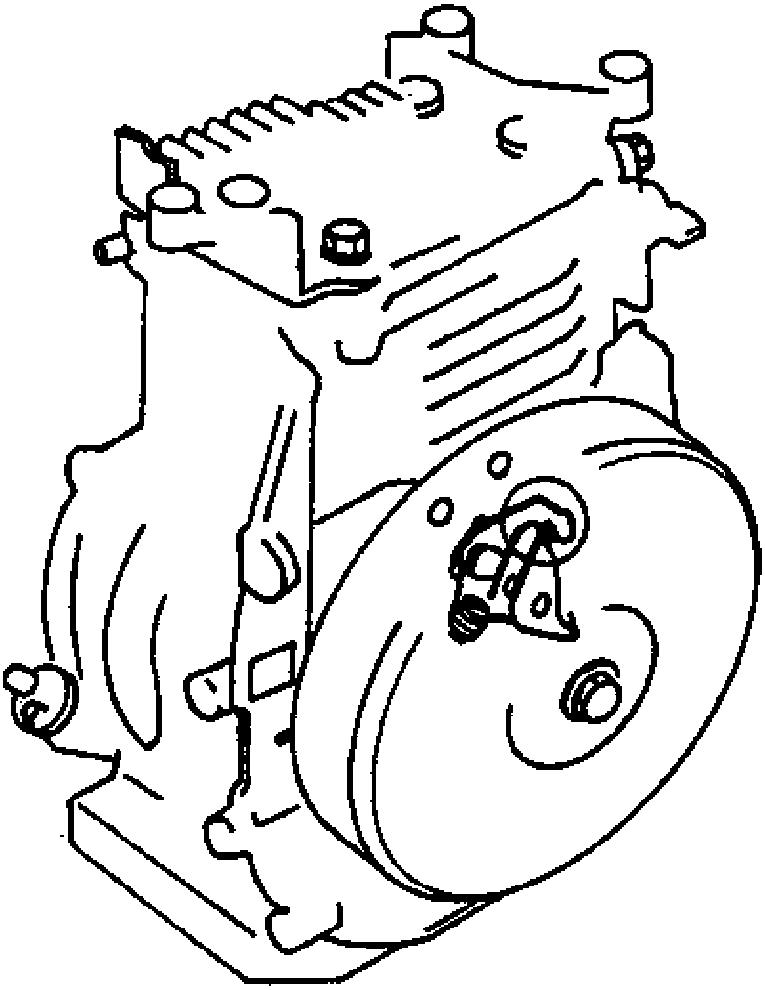
– Install the special tools to the crank shaft and tighten the nut.

– Turn the engine clockwise.

– At the position where the contact points open, the mark on the special tool must be inlined with the F mark.

– If it is out of inlined, then loosen the screw of the contact point base, and readjust it according to the mark.

c) Without using a special tool

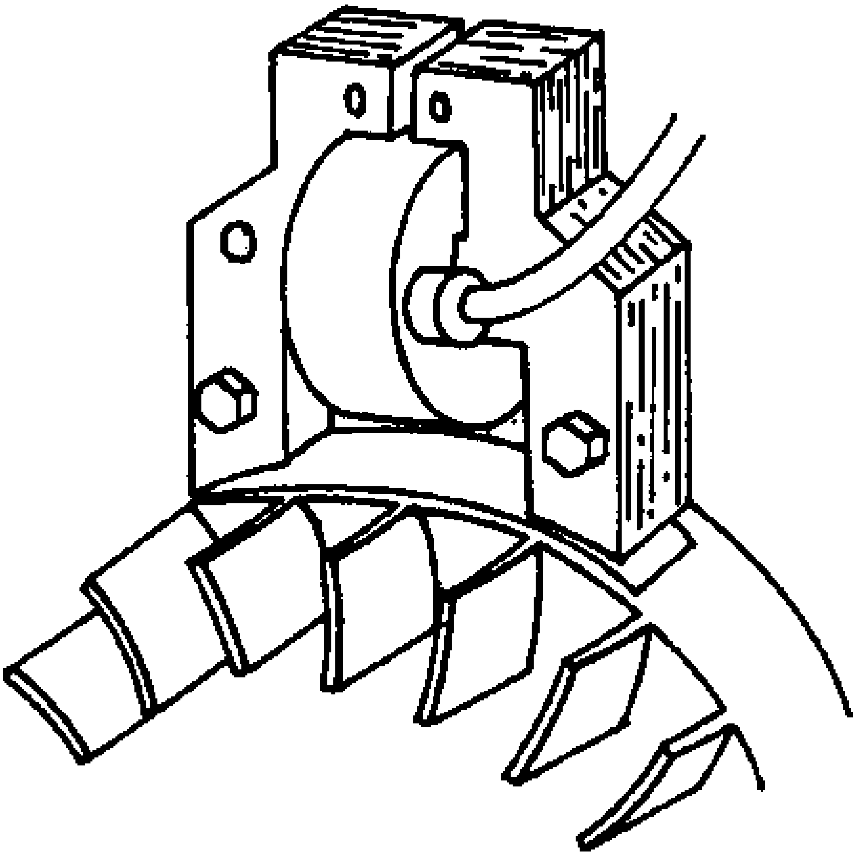


– Remove the magnetic wheel and the contact point cover, then reassemble the magnetic wheel temporarily to its position.

– Now the opening – closing of the contact points can be seen.

– Turn the magnetic wheel clockwise, at the point where the contact points are opening, the F mark on the magnetic wheel must be inlined with the mark of the engine.

2.6.8 Adjust gap between ignition coil and magnetic wheel



– Turn the engine until the permanent magnet is underneath the ignition coil.
– Measure the gap by feeler gauge.

Standard gap = 0.4 – 0.2 mm.

If it is outside the standard value, then loosen the screw of the ignition coil and readjust the ignition coil up or down until the required gap is obtained.

2.6.9 Trouble shooting

Fault	Possible causes	Remedy
Engine cranks normally, but will not start	1. Low voltage circuit is broken.	– Inspect connections of ignition coil and contact points.
	2. Contact points sticking.	– Readjust.
	3. Burned contact points.	– Clean or replace.
	4. Incorrect ignition timing.	– Inspect and readjust the ignition timing.
	5. Damaged condenser.	– Replace the condenser.
	6. Damaged ignition coil	– Replace the ignition coil.
	7.	– Inspect ignition coil and spark plug cable.
	8. Foulded spark plug	– Clean and readjust or replace.
Engine lacks power	1. Incorrect ignition timing	– Inspect and readjust the ignition timing.
Engine is overheated	1. Retarded ignition timing	– Readjust the ignition timing.
Engine is back fired	1. Incorrect ignition timing	– Readjust the ignition timing.

	2. Wrong heat range of spark plug	– Use correct heat range.
Engine is knocking or pinging	1. Incorrect ignition timing	– Readjust the ignition timing.
	2. Incorrect contact point gap	– Readjust the contact points gap.

Job sheets

Tools: A set of wrenches, special tool for removing magnetic flywheel, Torque wrench, Filler gauge, Ohmmeter, Smooth file, Timing tester, a special tool for setting the position F, Air gun with hose

Equipement: Steel brush, Brass brush, Cleaning pan, Cloth

Manufacturer: .... Model......................................

Type of ignition system:...

Standard torque for magnetic flywheel: .... Nm

Standard resistance of ignition coil:...

Standard inspection for C.D.I and transistor module:

– Primary coil:...
– Secondary coil: ....

Standard capacitive of condenser: ....µF

Standard gap between ignition coil and magnetic flywheel .... mm

Standard gap between contact points....................................... mm

Sequence of operations	Inspection	
1. Prepare tools and equipment	Condition of spark plug.	
2. Remove spark plug.	☐ Normal	☐ Damaged
3. Clean spark plug.	☐ Use steel brush	
4. Check and adjust electrode.	Obtained electrode gap	
5. Remove starting unit.	☐ Normal	
6. Remove blower cover and other obstruction.	☐ To be readjusted	
7. Remove magnetic flywheel.	Use of tools.	
	☐ Use special tools	
	☐ Others	
8. Remove all parts of ignition system.	Conditions of general parts.	
	☐ Perfect	☐ Imperfect
9. Check ignition coil.	Obtained reading	
	☐ Normal	☐ Damaged

10. Check CDI and transistor module.	Obtained reading	
	☐ Primary coil	
	☐ Secondary coil	
	☐ Normal	☐ Damaged
11. Check condenser	Condition of condenser	
	☐ Normal	☐ Damaged
12. Check contact points	Condition of contact points	
	☐ Normal	☐ Damaged
13. Reassemble those parts in their reverse order.	Reassemble	
	☐ Complete	☐ Incomplete
14. Adjust clearance between ignition coil and magnetic flywheel.	Standard clearance ...... mm.	
15. Adjust gap of contact point.	Standard gap of contact points ...... mm.	
16. Adjust ignition timing.	Ignition timing adjustment	
	☐ Use timing tester	
	☐ Others	
17. Reassemble all parts.	Reassemble of all parts.	
	☐ Complete	☐ Incomplete
18. Clean and store tools–equipment.	☐ Complete	☐ Incomplete
Note:	....	
	....	

3. Speed control system

Information

3.1 Task of governor

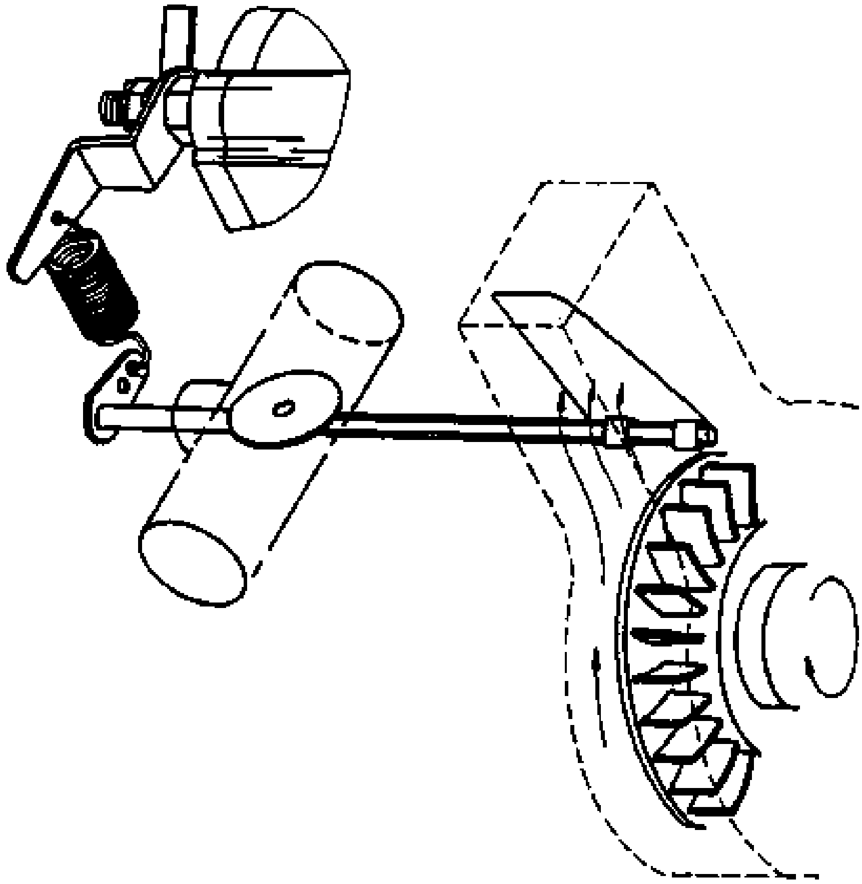
– to maintain constant engine speeds during running under varying loads.

3.2 Types and function of governor

Governors can be classified into 2 types:

3.2.1 Pneumatic governor

Constant engine speed is controlled by means of air flowing from the blower upon the blade of governor, which is connected to throttle plate mechanism.

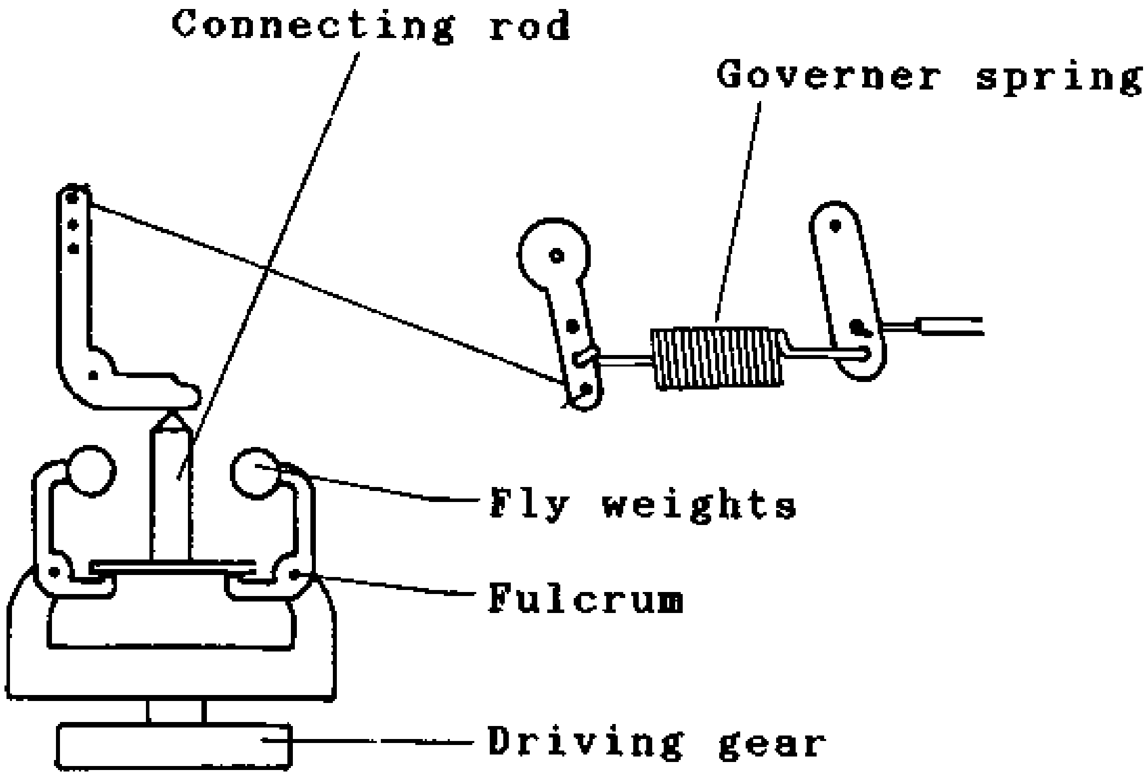


− As the engine speed increases, the flow of air is also increasing accordingly, and thereby turning the governor blade to turn the throttle plate in the direction to which the engine speed decreases until the throttle plate spring balances the force on the governor blade.

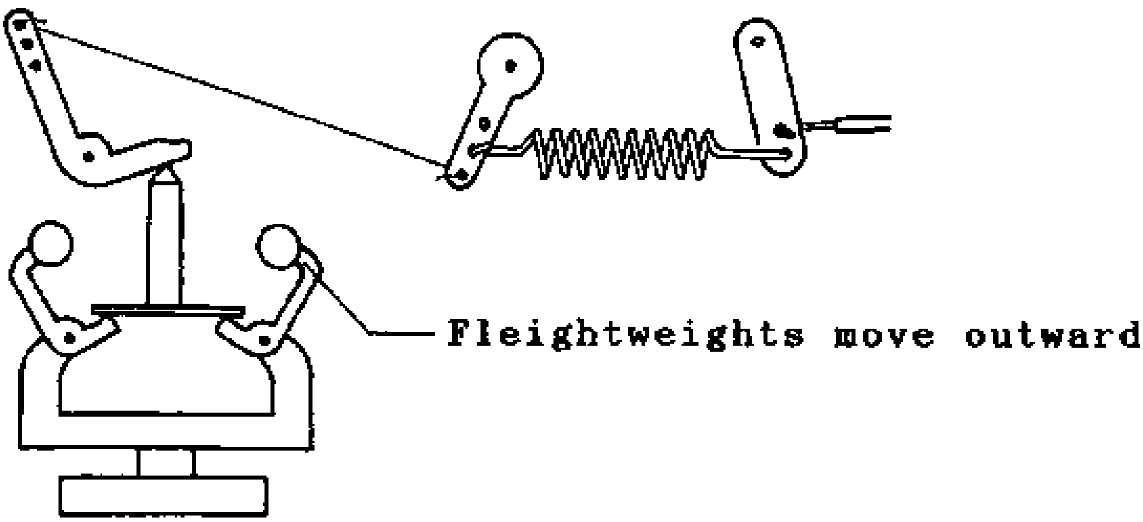
− When the engine is subjected to increasing load its speed will be decreasing. Thus, the air−force on the governor blade is also decreasing relatively, and surrendering to the force of throttle plate spring.
Therefore, the engine speed will be maintained constantly at every changing load.

3.2.2 Mechanical governor

This type of governor is operated by means of centrifugal force of the fly weights.



– As the engine speed decreases, the centrifugal forces of the flyweights are also decreasing, and thereby opens the linkgage of the throttle plate further. Thus, the engine speed increases to match a particular load.



– As the engine speed increases, the fly weights move away further and thereby reducing the opening of the throttle plate. Thus, the engine speed is coming down. Therefore, the engine speed will be maintained constantly at every changing load.

Task sheet

Fill in the blanks and underline the correct answer.

1. Governor is for ....

2. Governor is classified into ..... types, i.e...

3. At the engine stops, the position of the throttle plate will be –fully opened/ fully closed–.

4. The tensioning force of spring will tend to –increase/decrease–the engine speed.

5. Governor that has fly weights is of the .... type.

6. As the engine speed is on the increase, the flyweights will be –retracted/expanded–.

7. When the centrifugal forces of the flyweights are reducing, the throttle plate will be progressively –opened/closed–.

Task (Solution)

Fill in the blanks and underline the correct answer.

1. Governor is for maintaining constant engine speed

2. Governor is classified into 2 types, i.e Pneumatic governor a Mechanical governor

3. At the engine stops, the position of the throttle plate will be –~~fully opened~~/ fully closed–.

4. The tensioning force of spring will tend to –increase/~~decrease~~–the engine speed.

5. Governor that has fly weights is of the mechanical type.

6. As the engine speed is on the increase, the flyweights will be –~~retracted~~/expanded–.

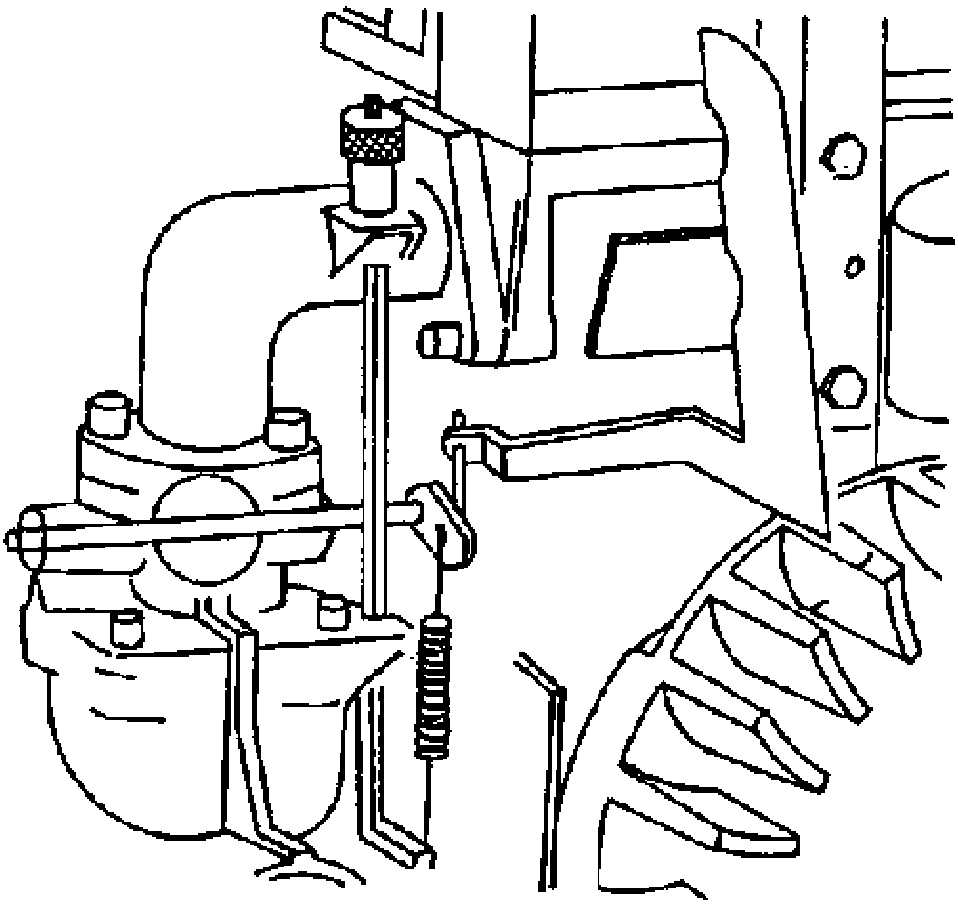
7. When the centrifugal forces of the flyweights are reducing, the throttle plate will be progressively –opened/~~closed~~–.

3.3 Repair and maintenance

3.3.1 Adjusting the pneumatic governor

Sequence of operations:

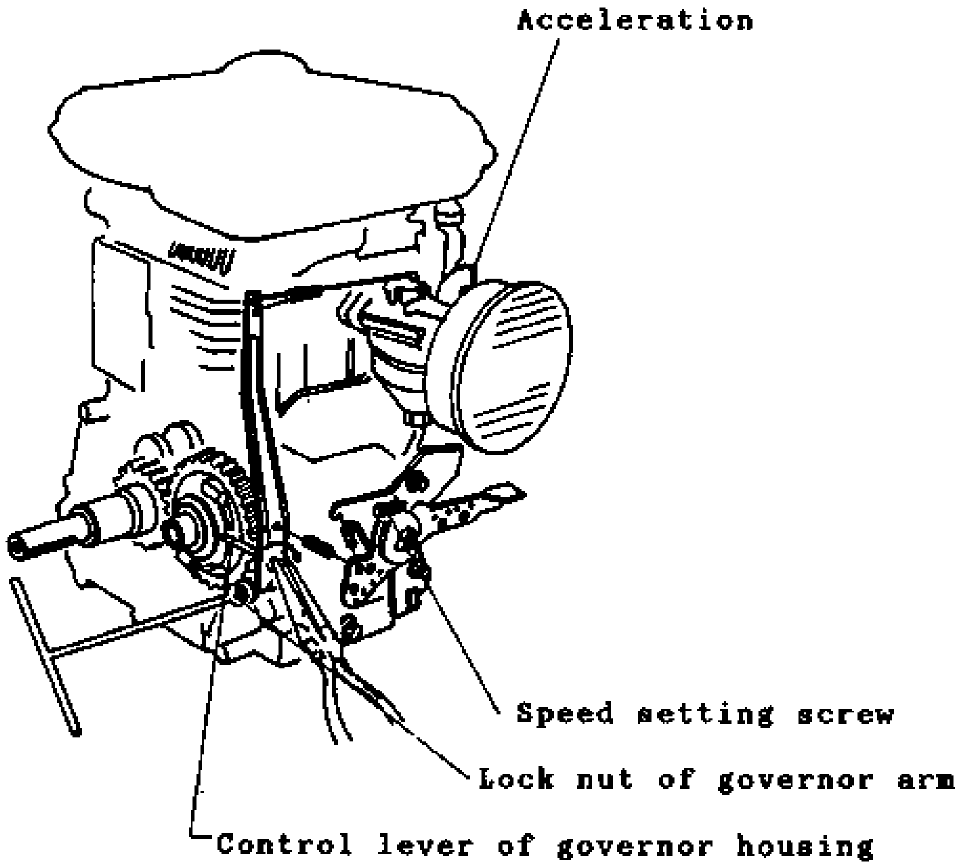
1. Screw on the governor spring fully.
2. Start the engine.
3. Unscrew the governor spring gradually until the required engine speed is obtained.



Remark: – The further the screw is tightened the lower the engine speed.

– The further the screw is loosened the higher the engine speed.

3.3.2 Adjusting the mechanical governor



– Push the governor arm to the maximum speed position and loosen the lock nut of the governor arm.

– Turn the control lever of the governor housing clockwise until stop (shut off position), then tighten the lock nut of the governor arm.

– Start the engine; adjust the speed setting screw until the maximum engine speed is obtained.

Standard maximum speed 4000 rev/min.

Job Sheet

Tools:	a set of wrenches, air gun with hose
Equipement:	Benzene, oil can, cleaning tray, cloth

a) Pneumatic governer

Manufacturer .... Model ....

Sequence of operations	Inspection	
1. Remove the blower cover.	– Condition of blower cover	
2. Remove the governor unit.	– Condition of governor spring	
Caution: Be aware of mixing up positions of governor mechanism	Normal	Weakened

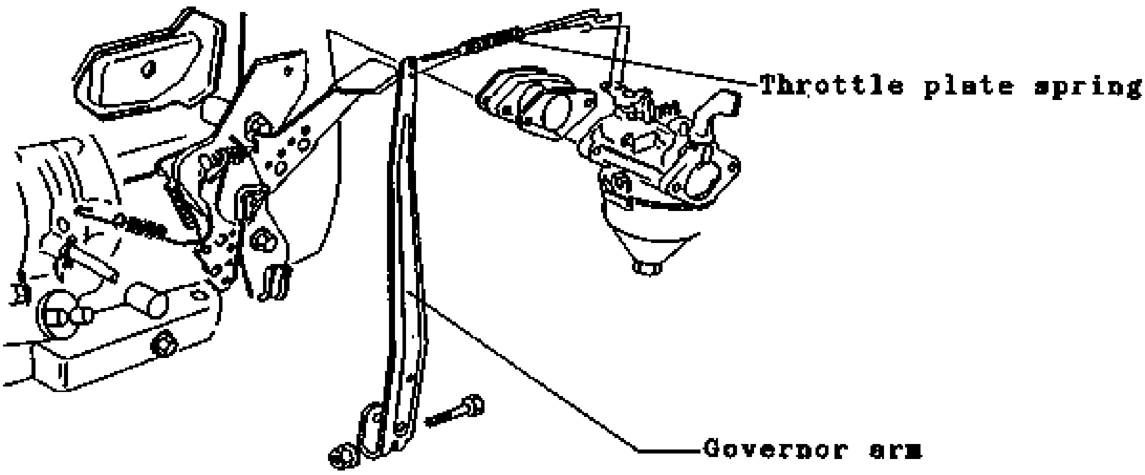
	Others ....
3. Reassemble in reverse order.	

b) Mechanical governer

Manufacturer .... Model ....

Sequence of operations	Inspect ion	
	– Tension of the throttle plate spring.	
Caution beware of benzene	Normal	Weakened
2. Remove governor unit from the carburetter.	– Straighteness of the governor arm	
	Normal	Bent
3. Reassemble in reverse order		

Remember: The short end of the throttle plate spring is on the carburetter side.



4. Valve mechanism

Information

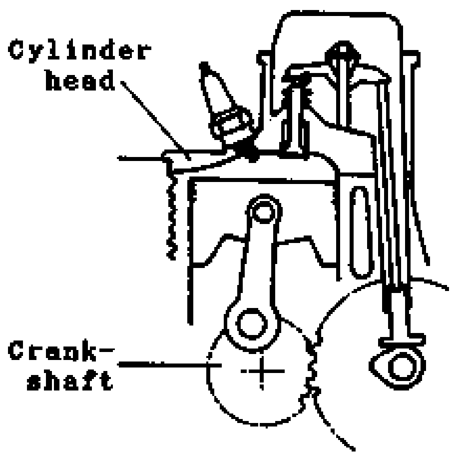
4.1 Task of valve mechanism

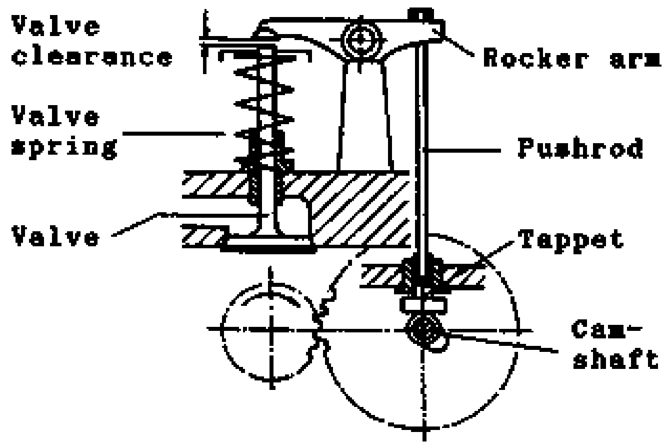
to open/close intake air–fuel mixture and exhaust gas in and out the cylinder, according to various strokes of engine.

4.2 Types and function

Valve mechanism is classified into 2 types:

4.2.1 Overhead valve





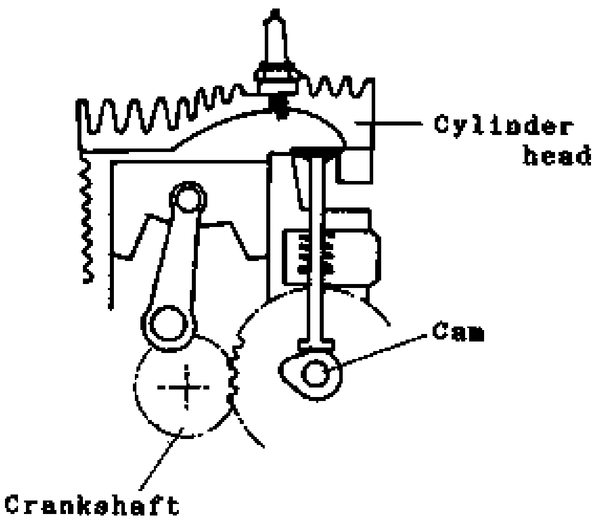
Crankshaft speed: Camshaft speed =2:1

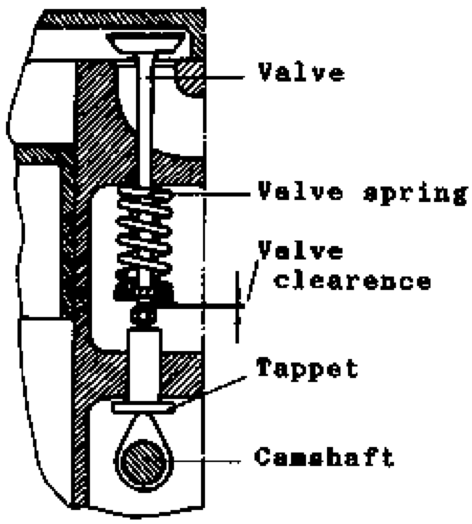
As the camshaft is driven by the crankshaft gear, the tappet is left and thereby the push rod pushes the rocker arm. The valve is, thus, opened as the pushing force of the rocker arm prevails that of the spring. When the cam turns beyond its lift the valve is closed under the force of valve spring.

Opening/Closing of valves is timed according to various strokes of the engine.

Advantages	Disadvantages
1. Low intake flow resistance.	– Complicated cylinder head.
2. Improved engine power.	– Engine is tall.
3. Valve servicing is easy.	– High number of parts of valve mechanism.

4.2.2 Side Valve





– As the camshaft is driven by the crankshaft gear, the valve is pushed to open by the cam via the tappet.

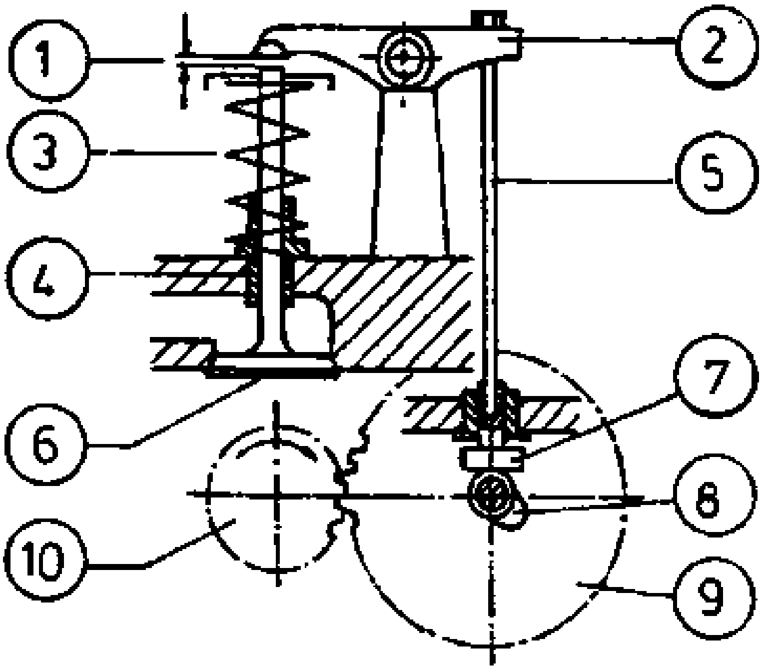
Advantages	Disadvantages
1. Valve arrangement is easy.	– High intake and exhaust flow resistance.
2. Small number of parts of valve mechanism.	– Combustion chamber is not compact.
	– Inefficient engine power.

Task sheet

Complete the statements.

1. Valve arrangement for 4 stroke small engines can be accomplished in ..... ways, that is.......................................

2. Name various parts of the valve mechanism.



1	6.................
2	7 ....
3	8 ....
4..................	9 ....
5..................	10 ....

3. Crankshaft speed: camshaft speed = ...: .....

4. As the engine makes 1 complete turn, the intake valve will open and close for ..... time whereas the exhaust valve does the same for ..... time.

5. Both intake and exhaust valves can be opened or closed by means of...

6. The advantages of the overhead valve engine are:

1...
2...
3...

7. The advantages of the side valve engine are:

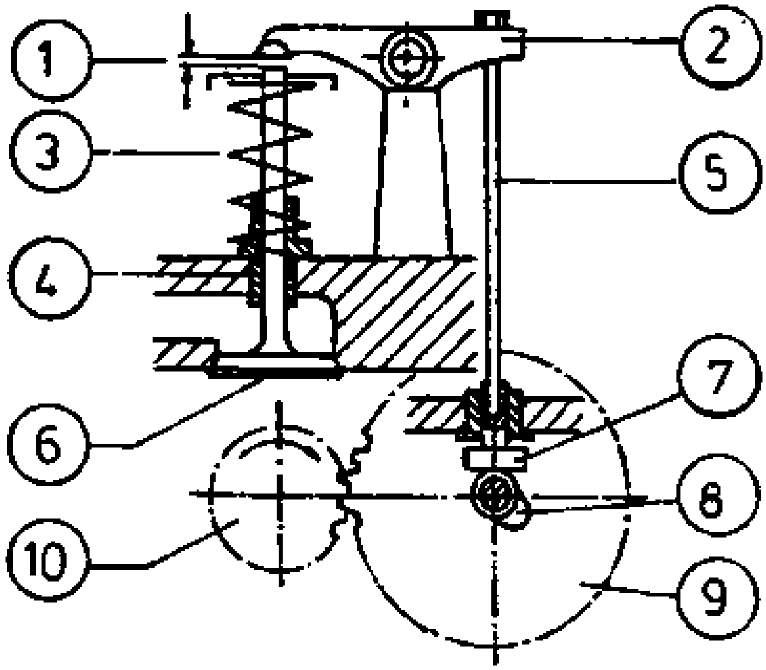
1...
2...

Task (Solution)

Complete the statements.

1. Valve arrangement for 4 stroke small engines can be accomplished in 2 ways, that is Side valve and overhead valve

2. Name various parts of the valve mechanism.



1 Valve clearance	6 Valve
2 Rocker arm	7 Tappet
3 Valve spring	8 Cam
4 Valve guidance	9 Timing gear (cam)
5 Pushrod	10 Timing gear (crankshaft)

3. Crankshaft speed: camshaft speed = 2:1

4. As the engine makes 1 complete turn, the intake valve will open and close for 1 time whereas the exhaust valve does the same for 1 time.

5. Both intake and exhaust valves can be opened or closed by means of Cam, Tappet, Pushrod and Rocker arm

6. The advantages of the overhead valve engine are:

1 Low intake flow resistance
2 Improved engine power
3 Valve service is easy

7. The advantages of the side valve engine are:

1 Valve arrangements is easy
2 Small number of parts

4.3 Compression reduction mechanism

Information

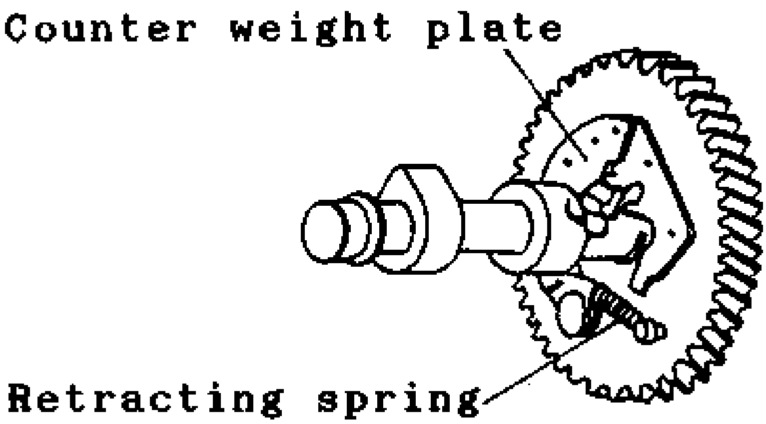
4.3.1 Purpose of compression reduction mechanism

To reduce compression in the cylinder during engine starting, thus, the power to start the engine is at minimum..

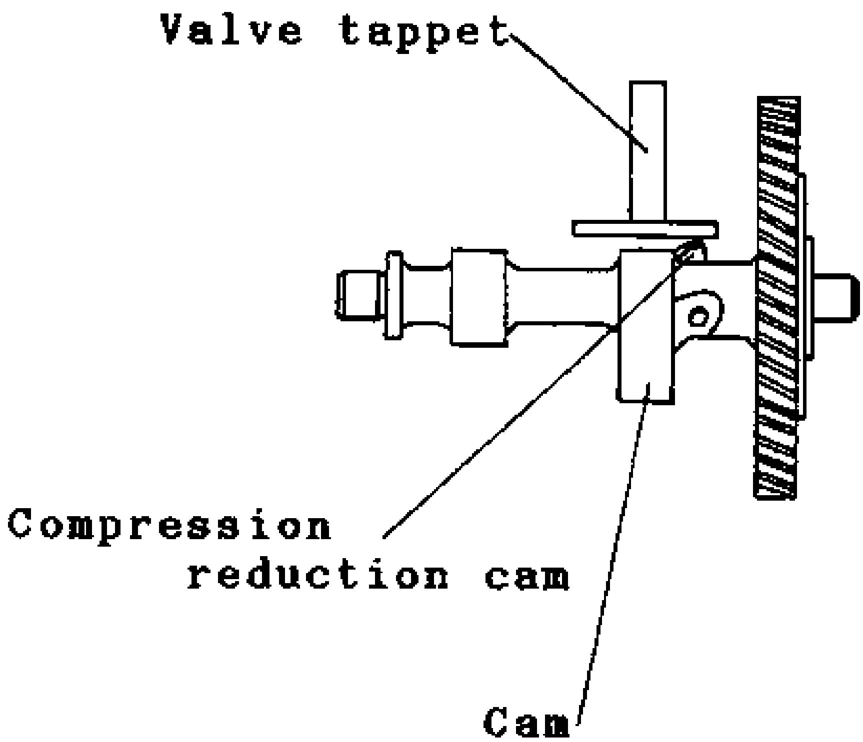
4.3.2 Components and function

This mechanism will open the exhaust valve during the starting string is pulled out.

a) When starting the engine



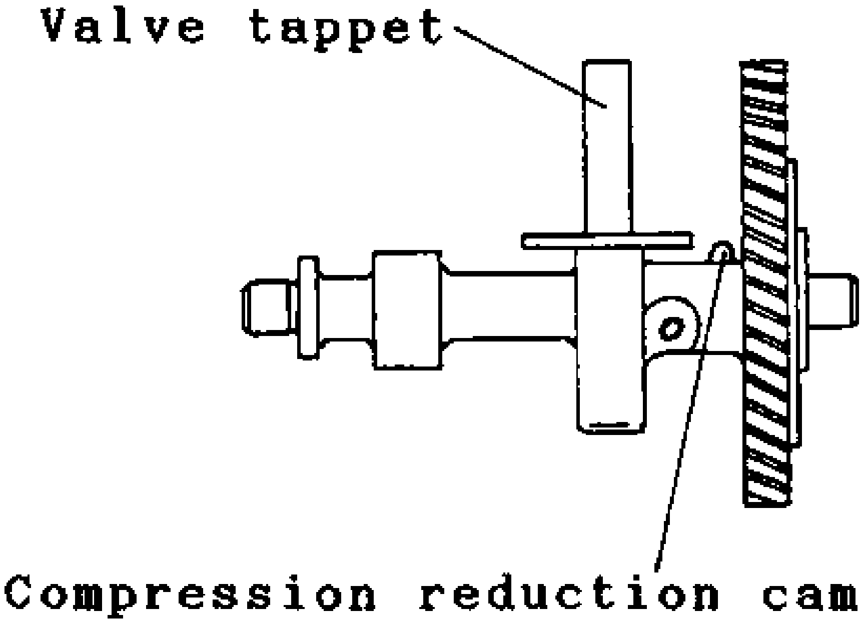
When the engine is at rest, the counter weight plate is kept in its original position by means of the retracting spring.



The compression reduction cam is on its peak which is above the heel of the cam.

When the starting string is pulled out, the compression reduction cam will slightly raise the valve tappet to reduce compression. This arrangement will ease the stert of the engine due to the engine can run fast.

b) During engine running



When the engine is running at the speed of 800 rev/min, the counterweight plate is forced outward by the centrifugal force.

The compression reduction cam is thereby pulled down and away from the valve tappet.

Task sheet

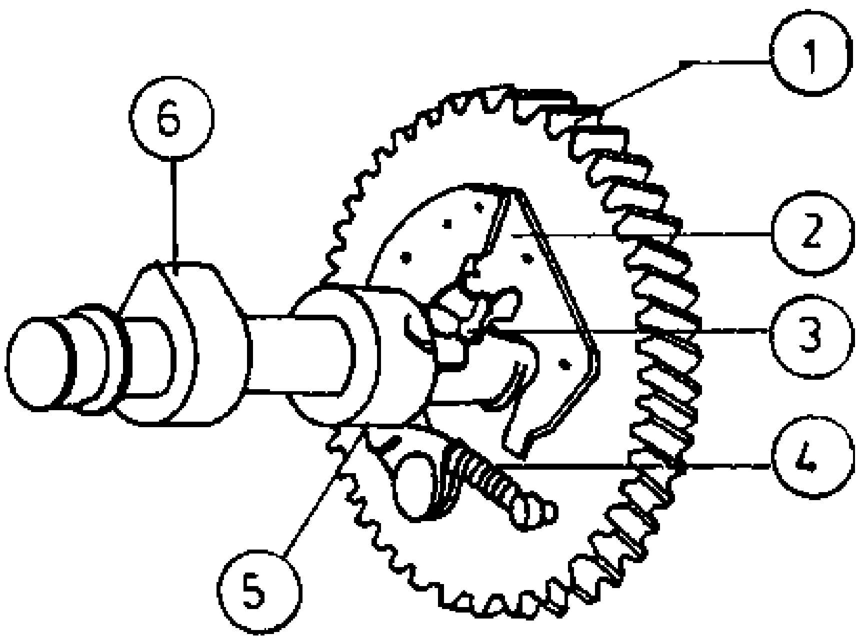
4.3 Compression reduction mechanism

Complete the statements or underline the correct answers.

1. The purpose of compression–reduction is ....

2. Compression –reduction can be accomplished by –opening/closing–the .... valve.

3. Name various parts of the compression–reduction mechanism.



1..............................
2..............................

3..............................
4..............................
5..............................
6..............................

4. When the starting string is pulled, the .... will lift the tappet and the .... is opened to allow the exhaust gas to escape.

5. As the engine is running, the centrifugal force of the counterweights will be –increasing/decreasing– and causing them to –expand/retract.

Task (Solution)

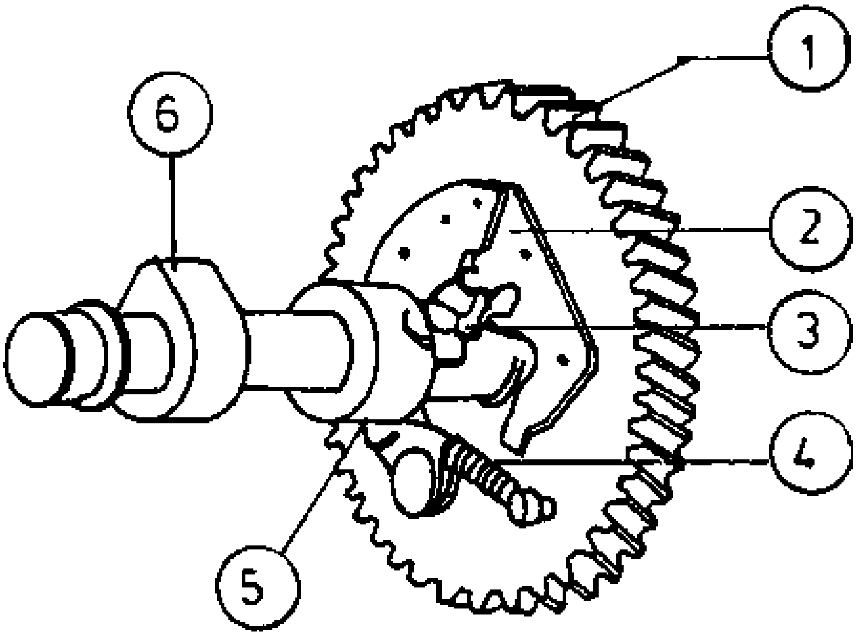
4.3 Compression reduction mechanism

Complete the statements or underline the correct answers.

1. The purpose of compression–reduction is to reduce compression in the cylinder during engine start.

2. Compression –reduction can be accomplished by –opening/closing–the exhaust valve.

3. Name various parts of the compression–reduction mechanism.



1 Timing gear
2 Counter weight plate
3 Compression reduction cam
4 Retracting spring
5 Cam for exhaust valve
6 Cam for intake valve

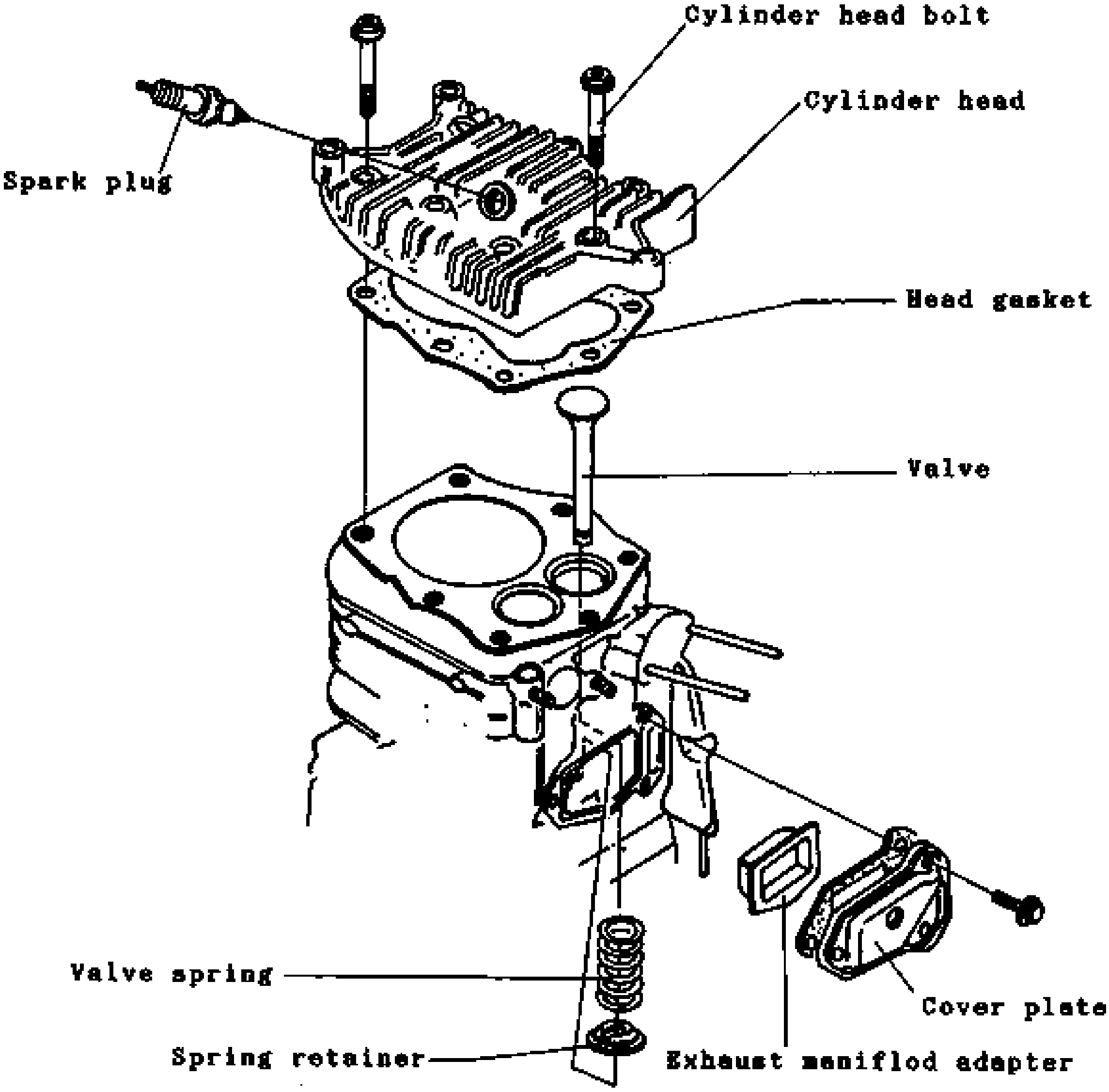
4. When the starting string is pulled, the compression redc. will lift the tappet and the exhaust valve is opened to allow the exhaust gas to escape.

5. As the engine is running, the centrifugal force of the counterweights will be –increasing/~~decreasing~~– and causing them to ~~–expand~~/retract.

4.4 Repair and maintenance

Information

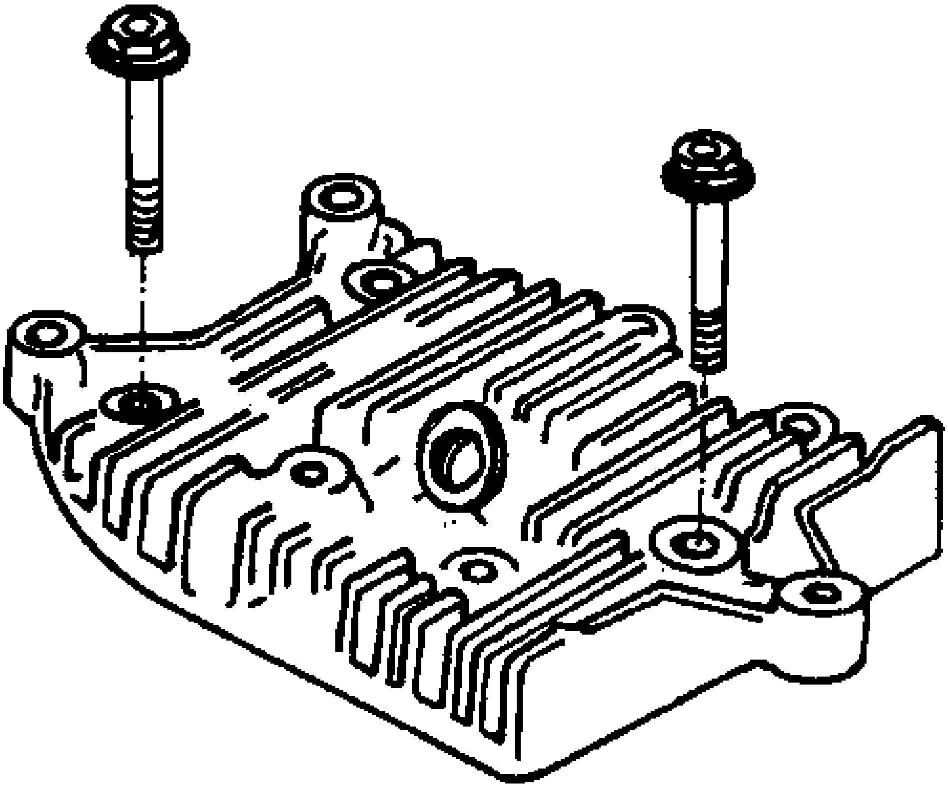
4.4.1 Removal and refitting of valve mechanism



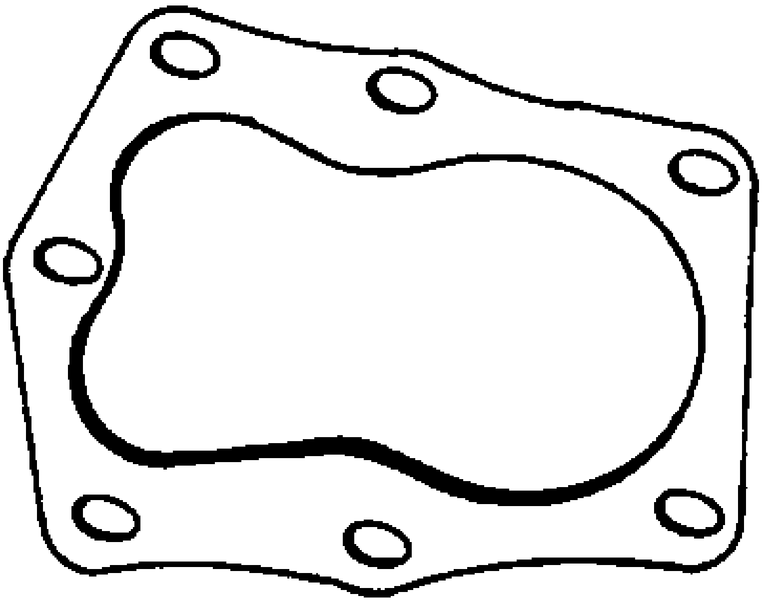
Remark: For valve mechanism removal, cylinder head and valves must be removed accordingly to the specified numbers and reassembled in their reverse order.

4.4.2 Removal/Reassemble of the cylinder head

a) Removing cylinder head

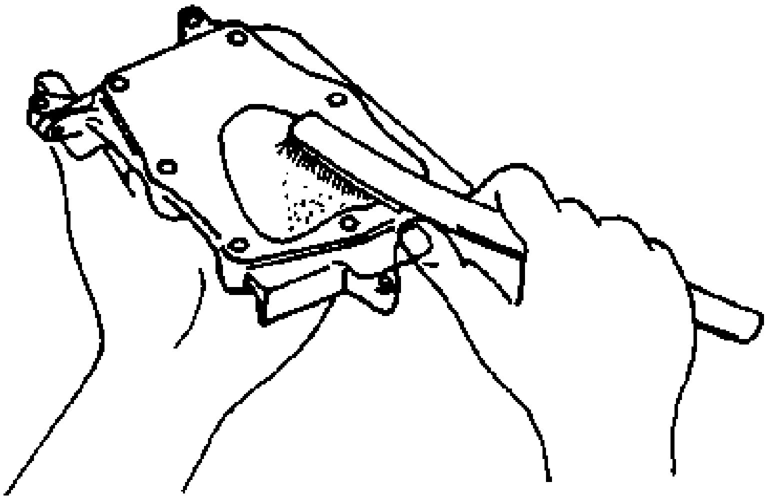


– Loosen all bolts in reverse order
– During loosening, gradual torque settings must be distributed over each bolt.



– Mating surface of the gasket, between the cylinder head and the cylinder block, must be cleaned and of no traces.

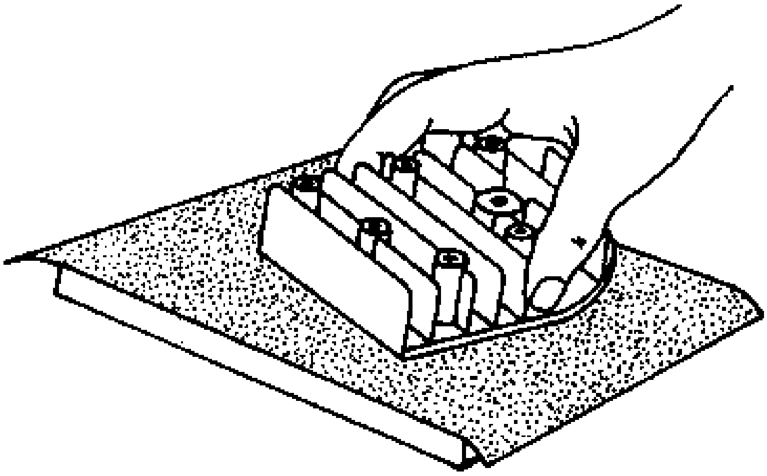
b) Cleaning cylinder head



– Decarbonize the combustion chamber and clean with benzene and dry with air gun.

Remark:

In removing carbon deposits, a broken piece of saw blade which is ground unsharp may be used.

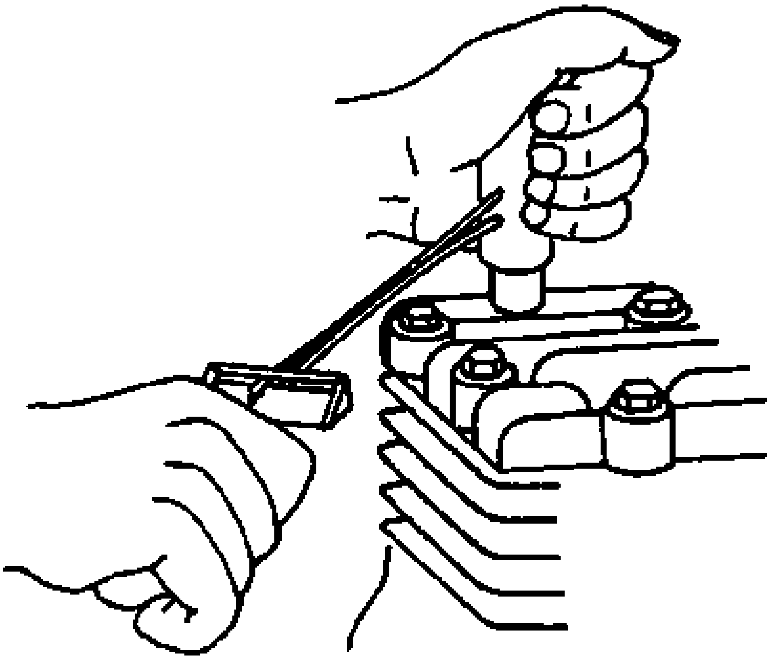


– In case, the cylinder head is distorted or bent, then grind its mating surface with fine grain sand paper (No. 400), which places on a smooth, flat surface level.

Remarks: – Contaminated dirt on fins of the cylinder head causes poor heat dissipation.

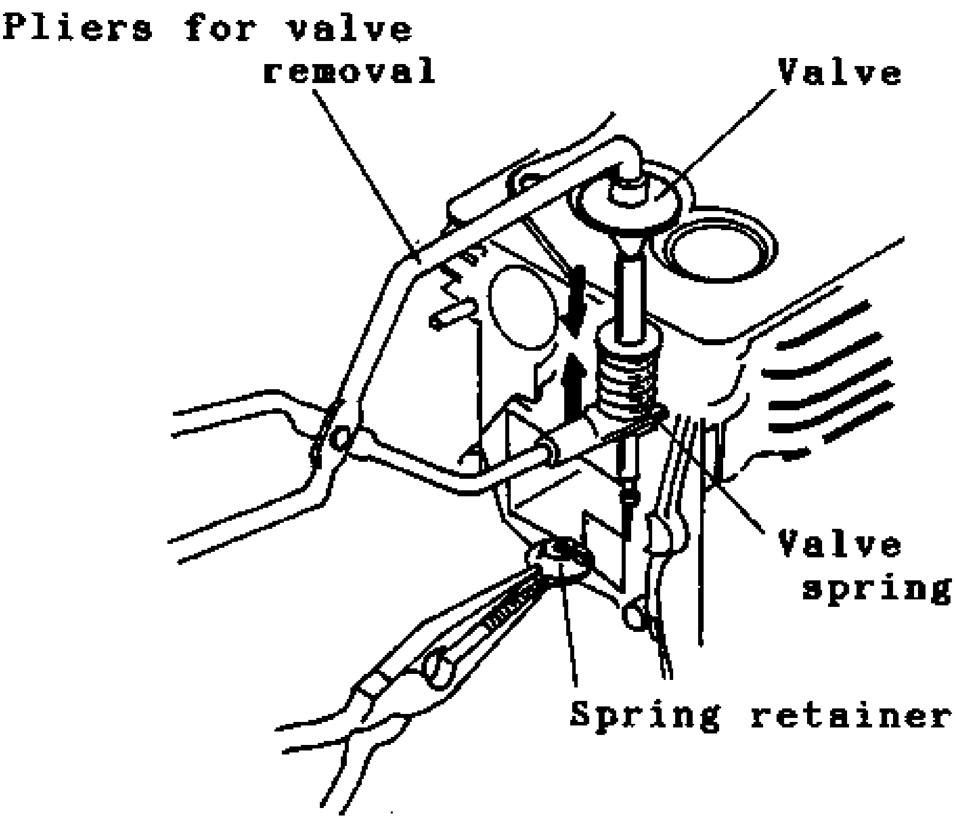
– After scraping and cleaning the fins, the cylinder head must be cleaned with benzene and dried with air gun.

c) Refitting the cylinder head



– Tighten the cylinder head bolts in their reverse sequence by using the torque wrench.
– The required tightening torque must be distributed gradually over successive settings.
Remark: Required tightening torque 24 – 26 Nm

4.4.3 Removal/Reassemble of the valves



Removal:

Press the valve spring with pliers and remove the spring retainer, then release the pliers and remove valve and valve spring.

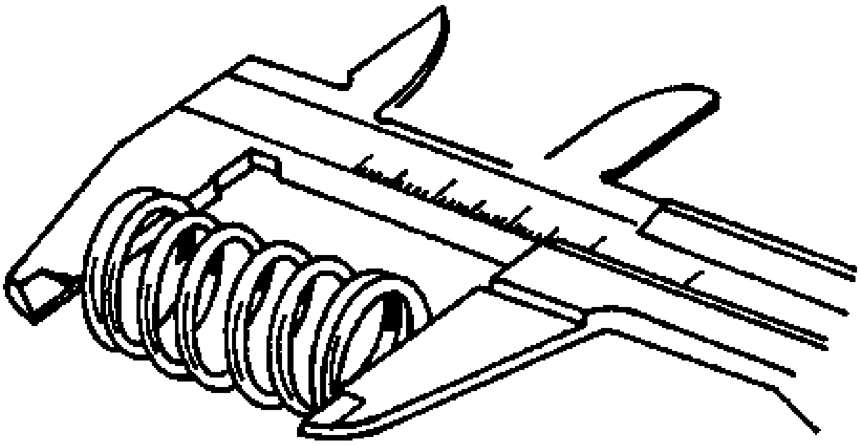
Reassemble:

Insert valve and valve spring, press the spring with pliers and insert the valve retainer.

Caution: Check, if the spring retainer is in the right position!

4.4.4 Valve spring

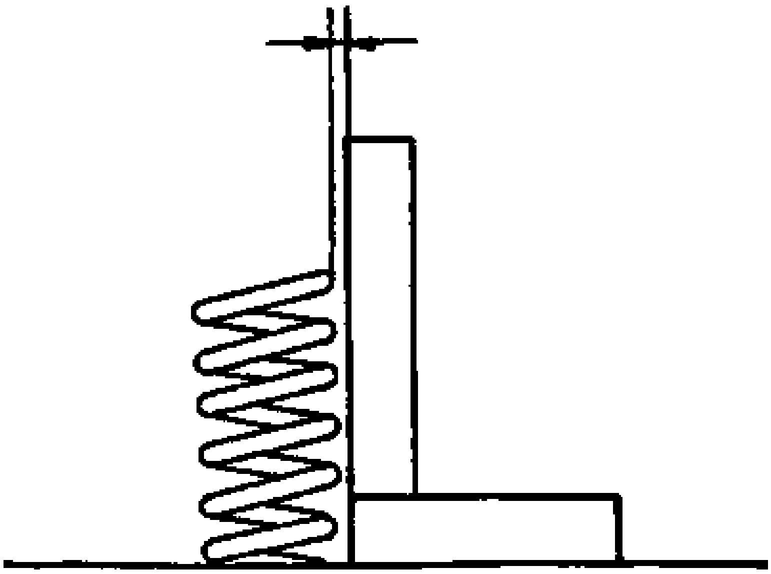
a) Measuring length of valve spring



– If the length of spring is shorter than the specification, then the spring is weakened.

Standard length	36.7 mm
Minimum length	35.2 mm

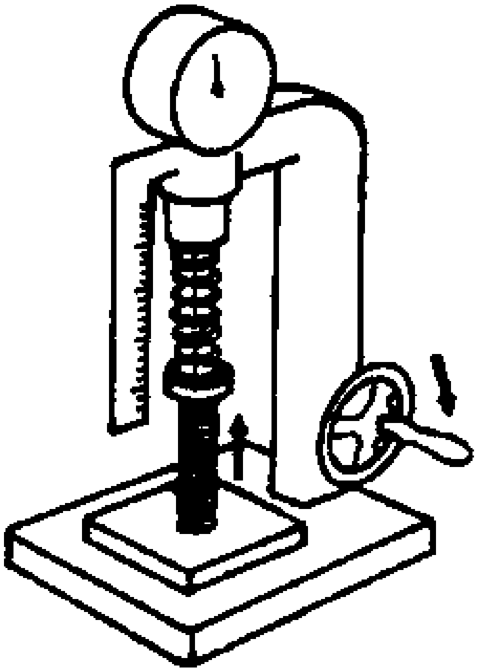
a) Checking squareness



– Turn the spring around itself against the square and observe any diviation.

Remark: Deviation should not exceed 2 mm

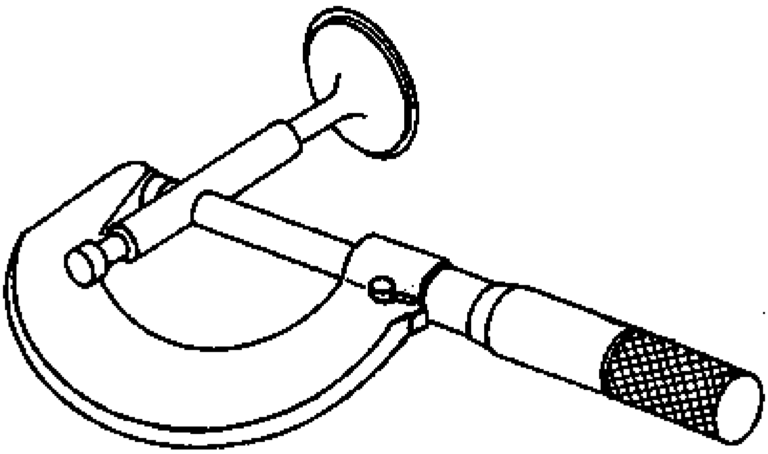
c) Checking strength of spring



– Set the height of the tester to the specification and read the obtained valve on the dial.

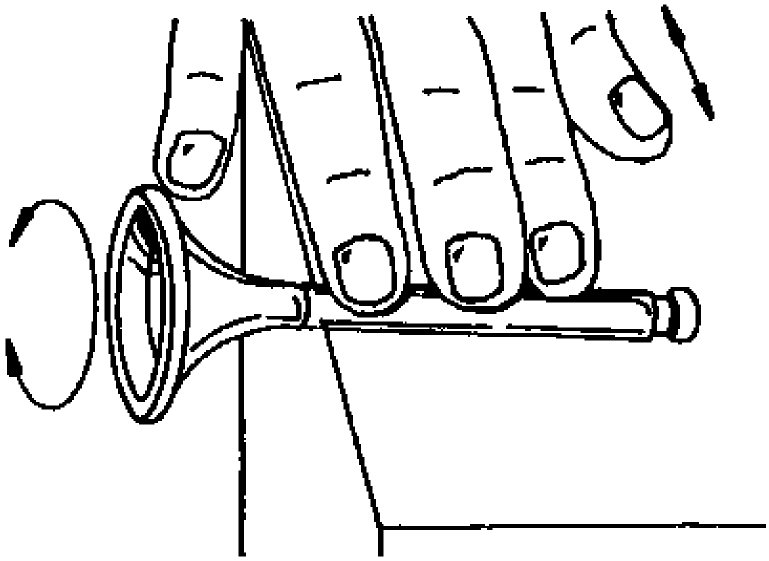
4.4.5 Valve

a) Measuring diameter of valve stem



– Compare the obtained reading with that of the manual.

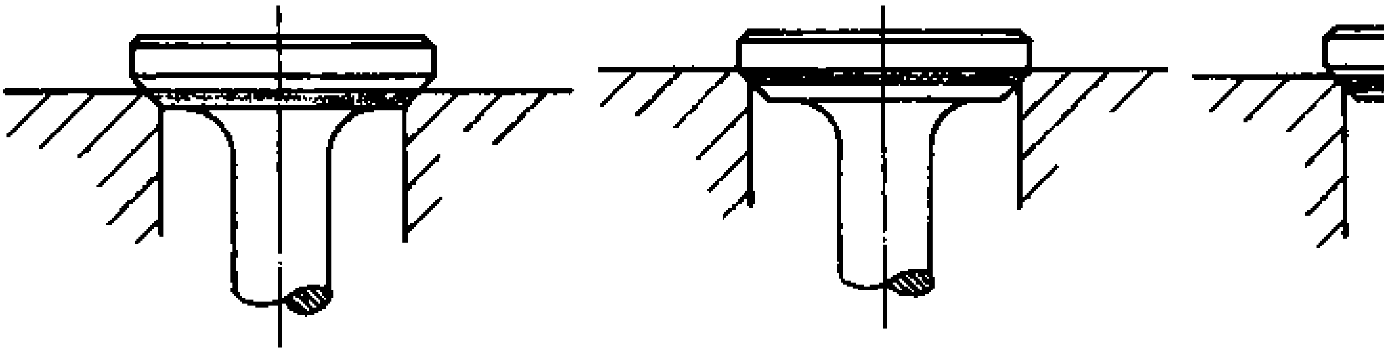
b) Checking straightness of the valve stem



– Roll the valve stem over the surface level, notice for any bending. Replace if it is bented.

c) Checking valve face, margin, and valve stem

Valve margin ...



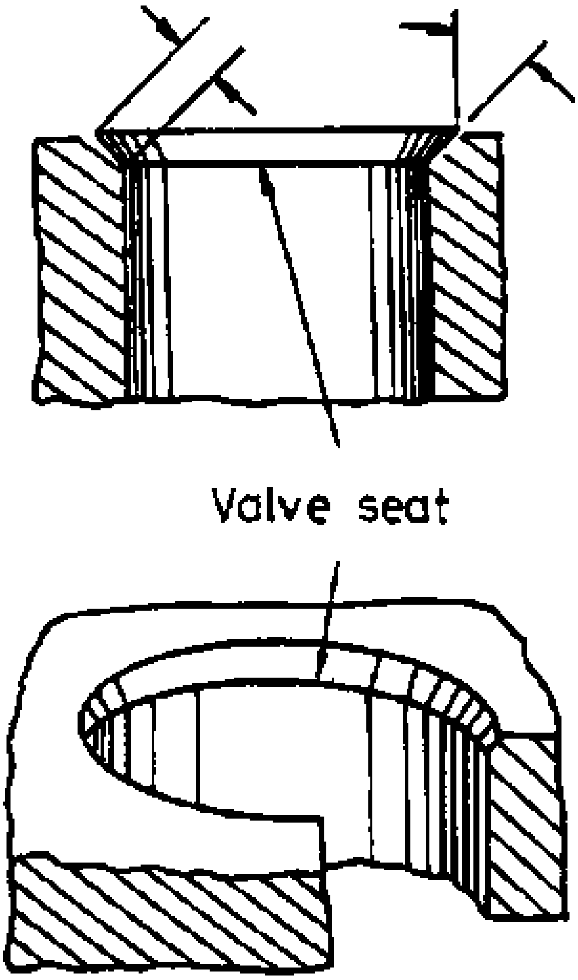
–to high

–to low

If valve foot is not smooth, then grind it with oil stone.

4.4.6 Valve seat

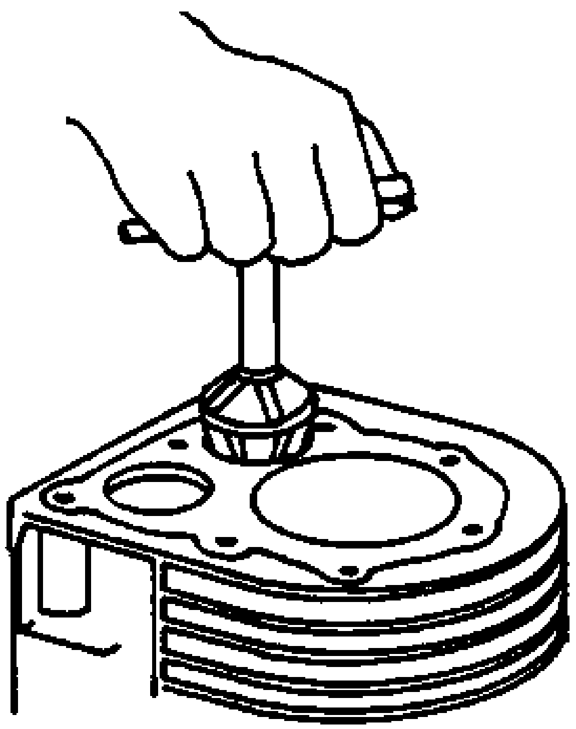
a) Measuring width of valve seat



– Measure width of valve seat with vernier caliper.

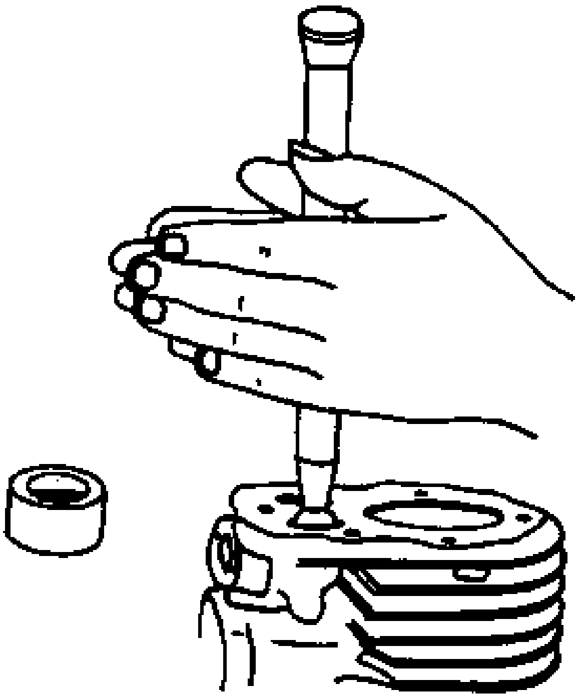
– Recut the valve seat with the valve seat cutter, if its width is less than that of the specification.

a) Valve cutting



– cut the valve seat with 90 valve seat cutter.
– Recut the valve seat with the smooth cutter.
– Final cut with the 90 valve seat cutter.

b) Valve grinding



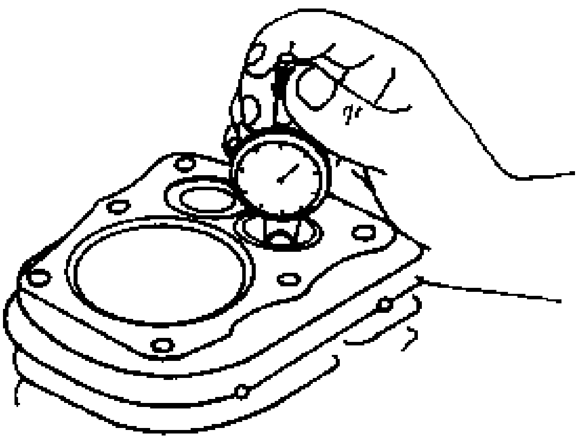
– Smear the valve seat lightly with carborundum paste.

– Hold the valve by the rubber of the grinding tool. Turn the grinding tool to tub the valve face against valve seat.

– Clean the ground valve seat ant valve face.

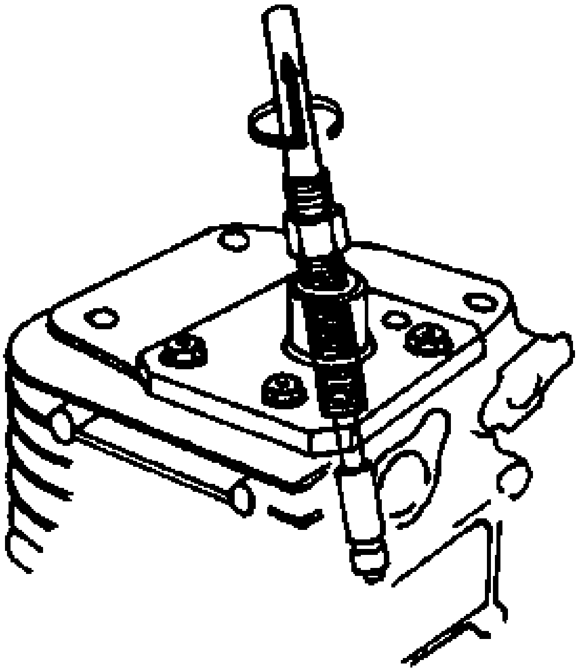
4.4.7 Valve guide

a) Measuring bore of the valve guide



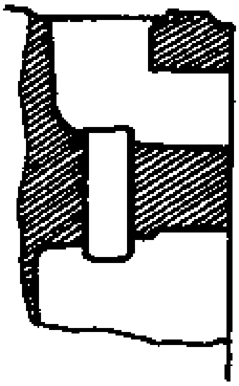
– Measure the bore with the dial indicator.
– Replace the valve guide if the obtained reading is beyond that of the specification.

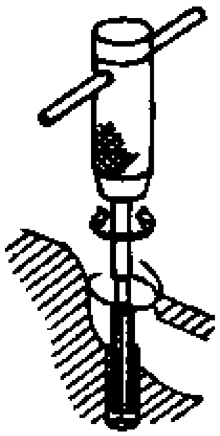
b) Removing valve guide



- Mount the special tool to the cylinder head by tightening 3 nuts.
- Screw in the valve guide extractor and screw on the nut underneath the valve guide.
- Unscrew the valve guide extractor until the valve guide is out.

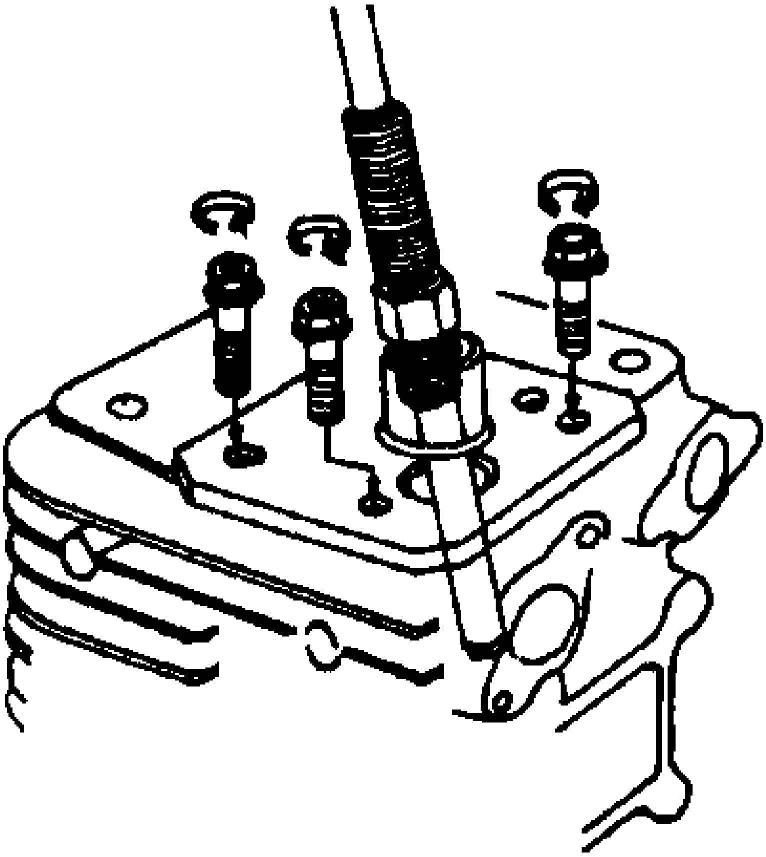
c) Guide and its bore





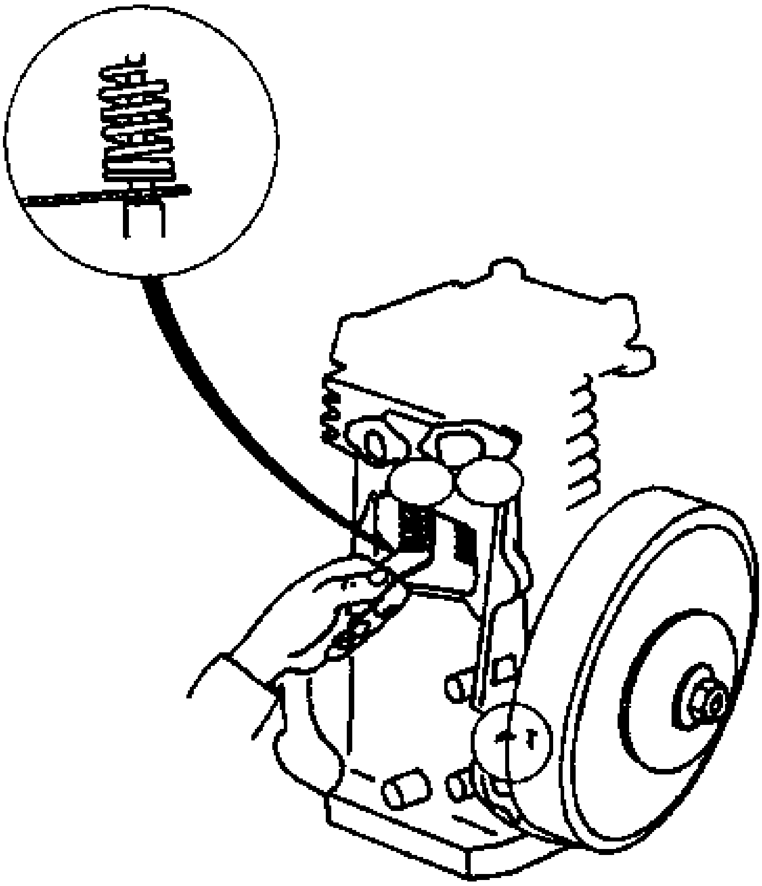
- Screw in the extractor to pull the valve guide.
- The valve guide must be pulled in and positioned correctly.
- Remove the nut and the extractor.

d) Reassembling valve guide



– Reverse the valve guide extractor.
– Fix the flange to the cylinder head and screw on the nut tightly.
– Insert the valve guide onto the extractor and hold it with the nut •
– Oil must be applied to the valve guide and its bore before reassembling.

4.4.8 Valve adjustment



– Turn the engine until the piston is at the top of compression stroke.
– Measure the valve clearance by the feeler gauge.
– Adjust the valve clearance to the specification.

Valve clearance specification 0.04–0.12 mm

– Excessive valve clearance:	change valve or tappet
– Insufficient valve clearance:	grind valve stem with oil stone.

Job sheets

Tools:	a set of wrenches, Spark plug wrench, Torque wrench, Socket wrench and handle, Feeler gauge, Vernier caliper, Spring strength tester, dial indicater
Equipement:	Benzene, Oil caan, Cleaning pan, Cloth, Brass brush, Sand paper (400), broken saw blade, Oil stone

Manufacturer .... Model ....

Type of valve arrangement...

Compression–reduction mechanism ☐ Yes ☐ No

Torque for cylinder head hold–down screw ....Nm

Standard lenght of valve spring...................................... mm

Limited deviation of valve spring squareness .... mm

Standard strength of valve spring ....

Standard diameter of valve stem .... mm

Standard width of valve seat... mm

Standard bore of valve guide .... mm

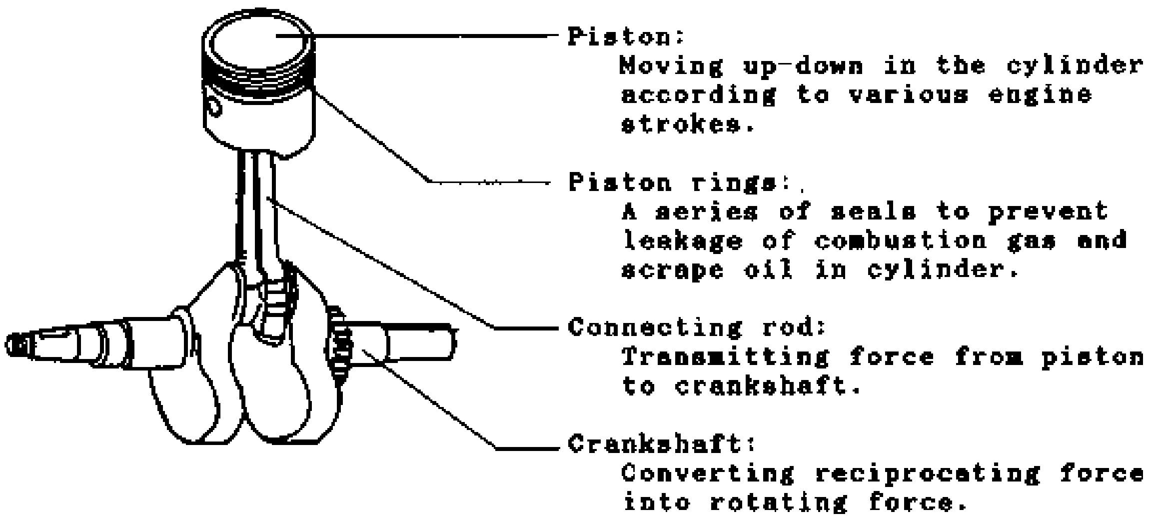
Standard valve clearance .... mm

Sequence of operations	Inspection	
1. Prepare tools and equipment.		
2. Close fuel valve and disconnect fuel hose.		
3. Remove fuel tank.		
4. Remove blower cover and any obstruction.		
5. Remove cylinder head by loosening from the outmost screw toward center.		
6. Remove head gasket.	– Condition of head gasket	
	☐ Normal	☐ Damaged
7. Clean cylinder head.	– Condition of cylinder head	
Remark:	☐ Normal	☐ Dirty
If the cylinder head is bent or distorted, grind it with sand paper over the surface level.	☐ Craked	☐ Bent, disorted
8. Remove carburetter.		
9. Remove side cover plate.		
10. Remove valve springs.		
11. Remove valves.		
12. Clean valve unit and valve seats and arrange them in good order.		
13. Check length of valve spring.	– Obtained reading .... mm.	
	☐ Normal	☐ Damaged
14. Check squareness of valve spring.	– Obtained reading .... mm.	
	☐ Normal	☐ Damaged
15. Check strength of valve spring.	– Correct to specification	
16. Measure diameter of valve	– Obtained reading .... mm.	
	☐ Normal	☐ Worn
17. Check straightness of valve	☐ Normal	☐ Distorted, bent
18. Check valve face.	☐ Normal	☐ Worn
19. Check margin of valve seat.	– Obtained reading .... mm.	
	☐ Normal	☐ Worn

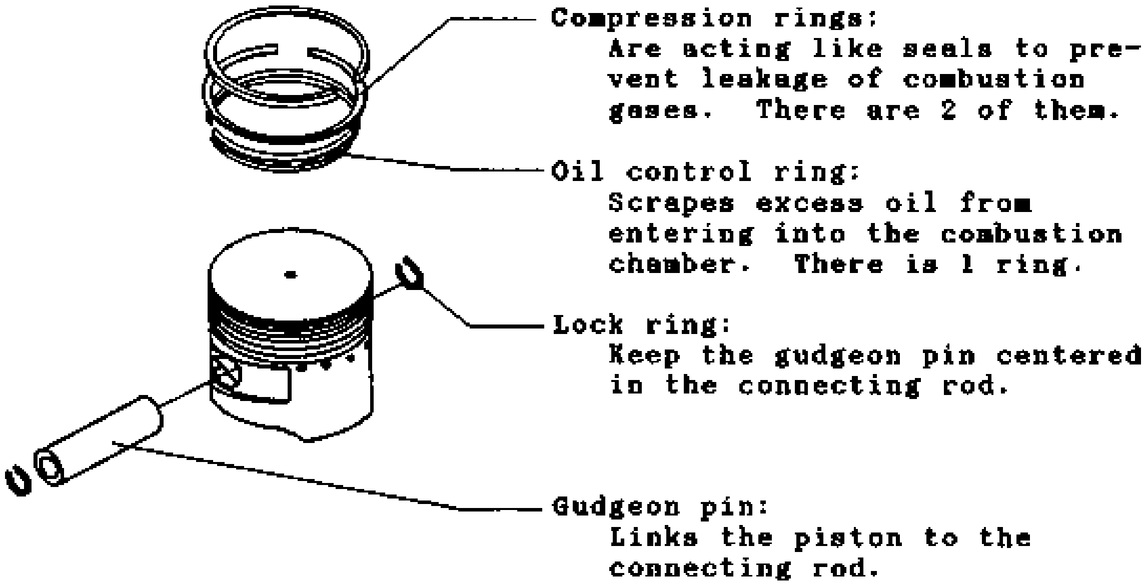
20. Check width of valve seat.	– Obtained reading .... mm.	
	☐ Normal	☐ Worn
Remark: If excessive wear on valve seats, then recut the valve seats and regrind it.		
21. Check bore of valve guide.	– Obtained reading .... mm.	
	☐ Normal	☐ Worn
Remark: If excessive wear on valve guides then remove and replace the valve guides by using the special tool.		
22. Reassemble all components in their reverse order.	Reassembling	
	☐ Complete	☐ Incomplete
23. Adjust valve clearance.	– Standard valve clearance .... mm	
24. Clean and store all tools and equipment.	Note:.....................	

5. Crankshaft mechanism

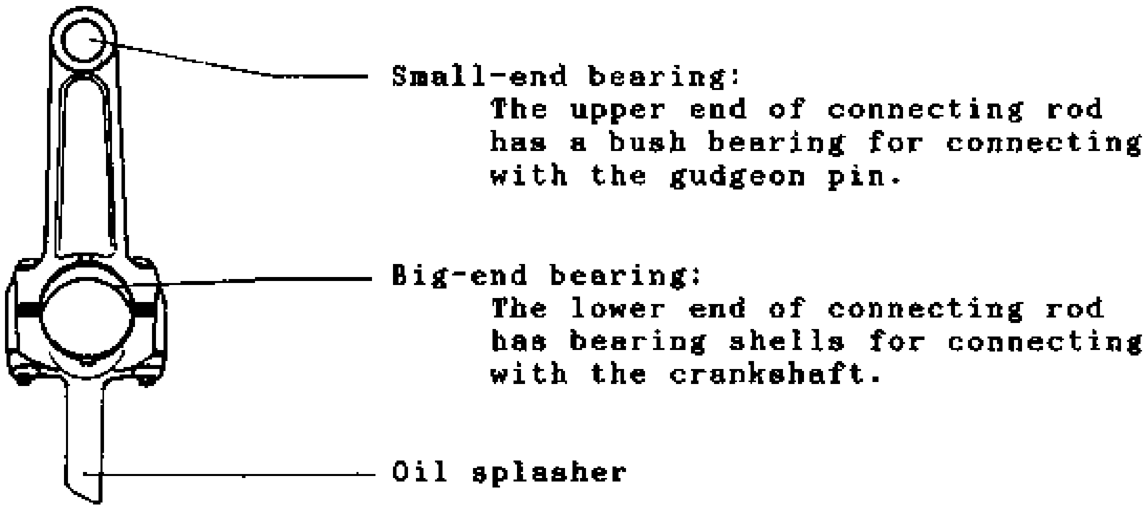
5.1 Components and functions of crankshaft mechanism

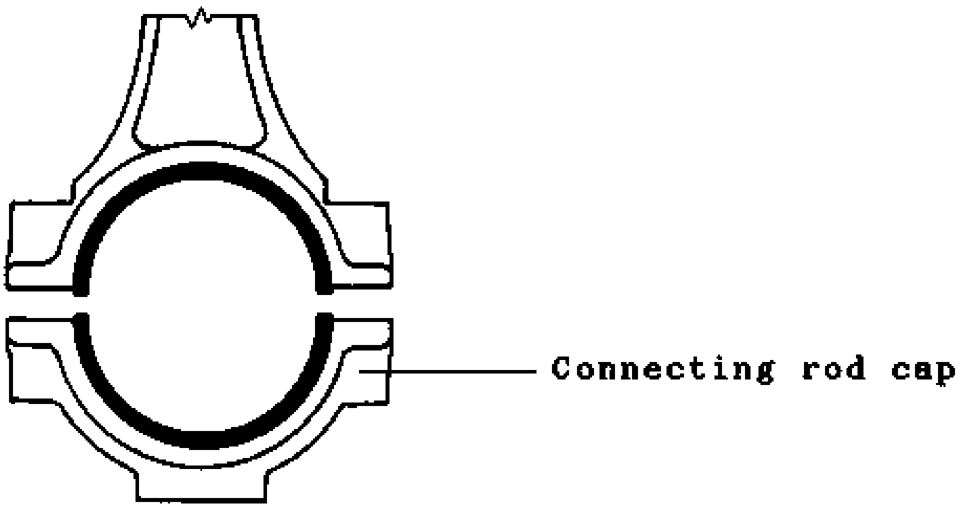


5.1.1 Piston and piston rings

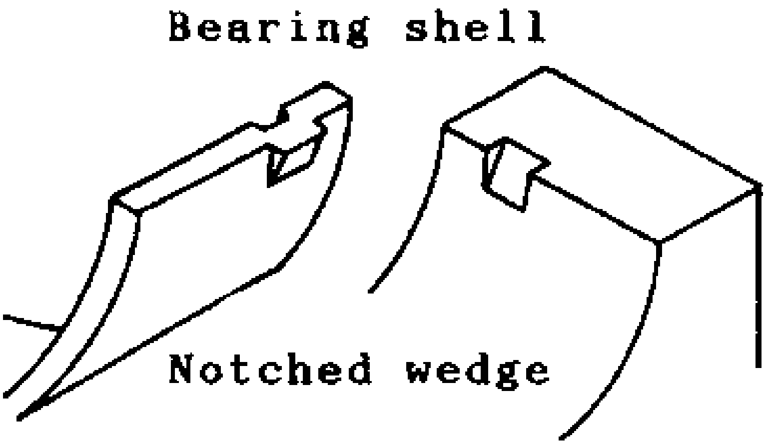


5.1.2 Connecting rod and connecting rod bearings



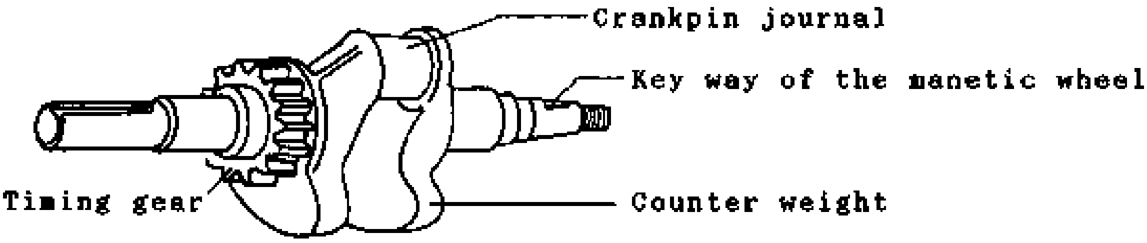


The big−end bearing shells split in two halves. The upper shell fixes with the connecting rod, the lower one with the connecting rod cap.



The bearing shells are positioned by the notched wedges and grooves on the connecting rod and connecting rod cap.

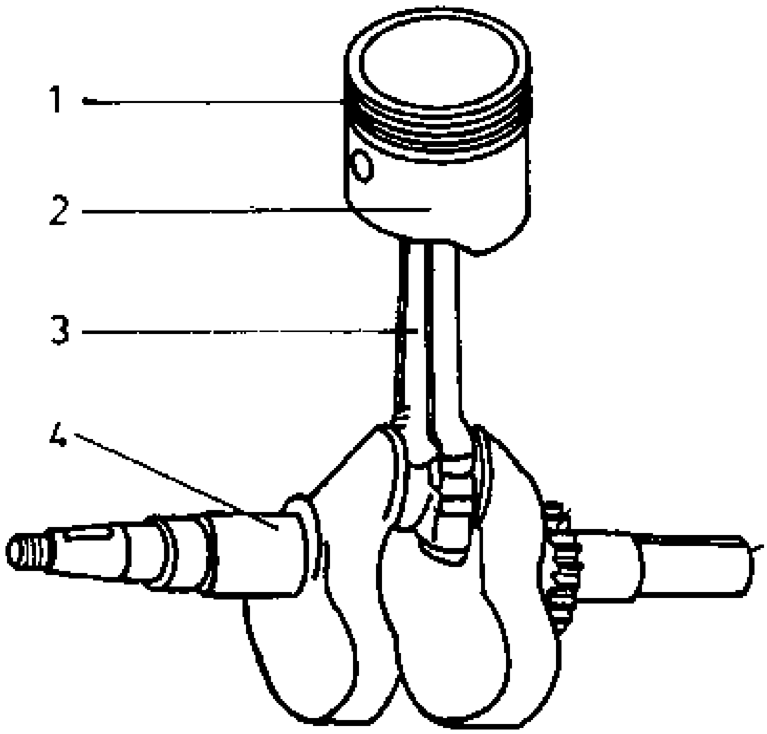
5.1.3 Crankshaft



- Crankpin journal is for connecting with the connecting rod.
- Timing gear is for driving the camshaft.
- Key way is for connecting with the magnetic wheel.
- Counterweight is for damping the engine vibration.

Task sheet

1. Name the parts of the crankshaft mechanism.



1. ....
2. ....
3. ....
4. ....

2. Make a cross in front of the correct statements

... 1. The part of the piston that bears the impact force mostly is the piston skirt.

... 2. Piston rings act as a series of seals to prevent leakage of combustion gases.

... 3. Compression rings and oil control ring are exchangeable.

... 4. Connecting rod transfers the force from piston to crankshaft.

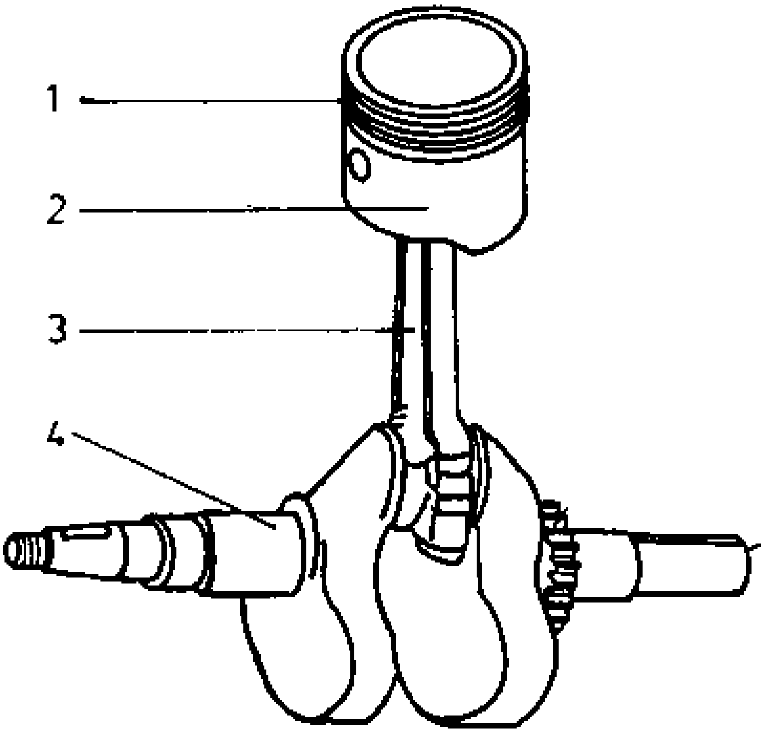
... 5. Big−end bearing shells can be inserted to connecting rod with regardless of their pisitions.

... 6. Crankshaft converts reciprocating motion into rotary motion.

... 7. Timing gear of the crankshaft is for setting the ignition timing.

Task (Solution)

1. Name the parts of the crankshaft mechanism.



1 Piston rings
2 Piston
3 Connecting rod
4 Crankshaft

2. Make a cross in front of the correct statements

... 1. The part of the piston that bears the impact force mostly is the piston skirt.

X 2. Piston rings act as a series of seals to prevent leakage of combustion gases.

... 3. Compression rings and oil control ring are exchangeable.

X 4. Connecting rod transfers the force from piston to crankshaft.

... 5. Big−end bearing shells can be inserted to connecting rod with regardless of their pisitions.

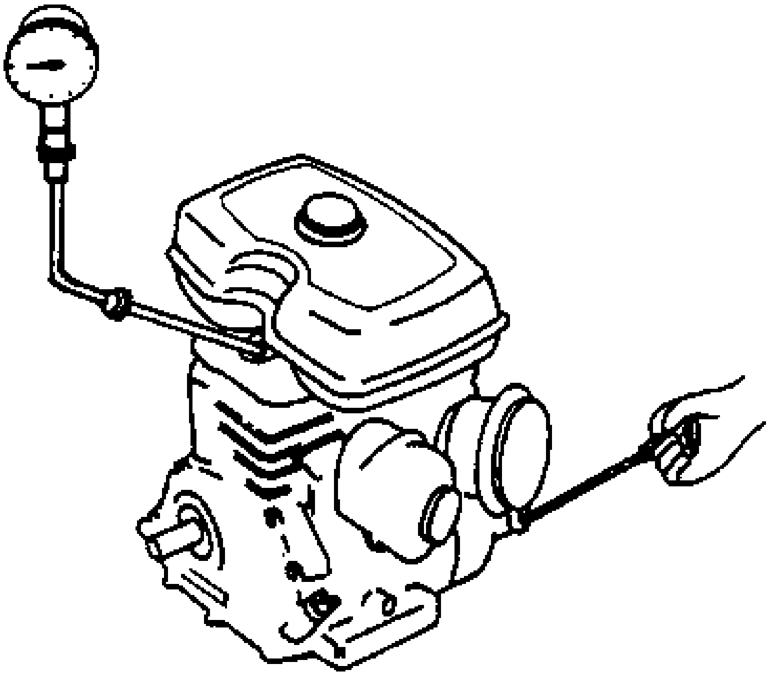
X 6. Crankshaft converts reciprocating motion into rotary motion.

... 7. Timing gear of the crankshaft is for setting the ignition timing.

5.2 Repair and maintenance

Information

5.2.1 Testing the compression



Sequence of operations:

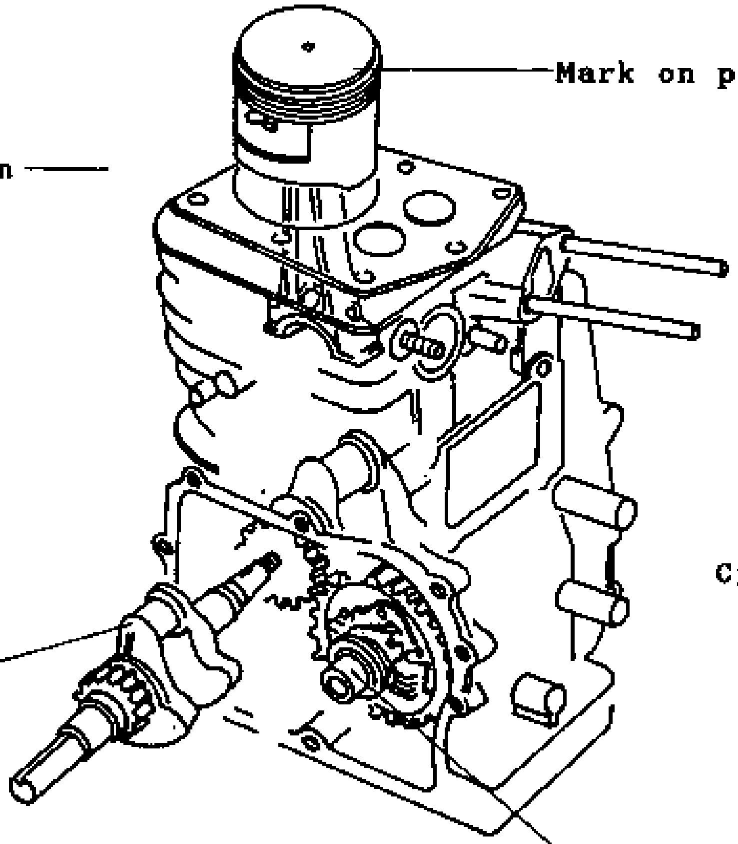
- Remove the spark plug.
- Install the pressure gauge in the spark plug hole.
- Pull the string to crank the engine hardly for several times, and read the pressure.

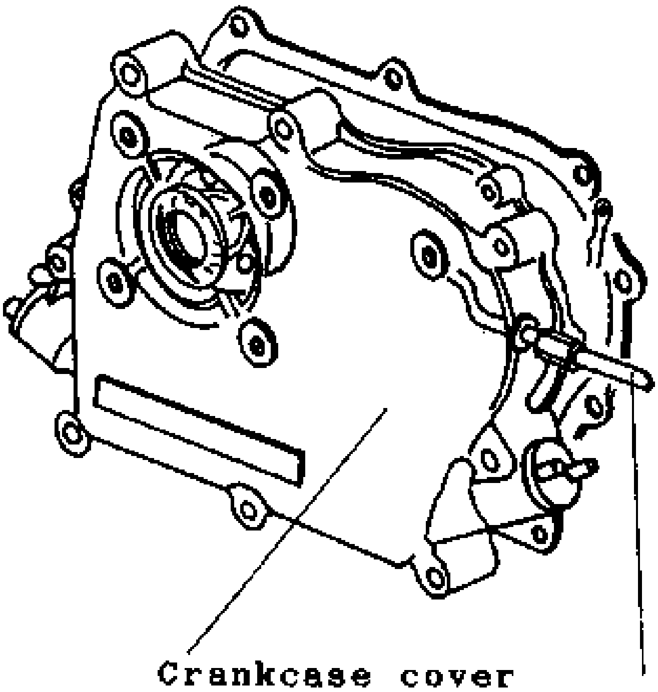
Standard minimum compression = 6 bar

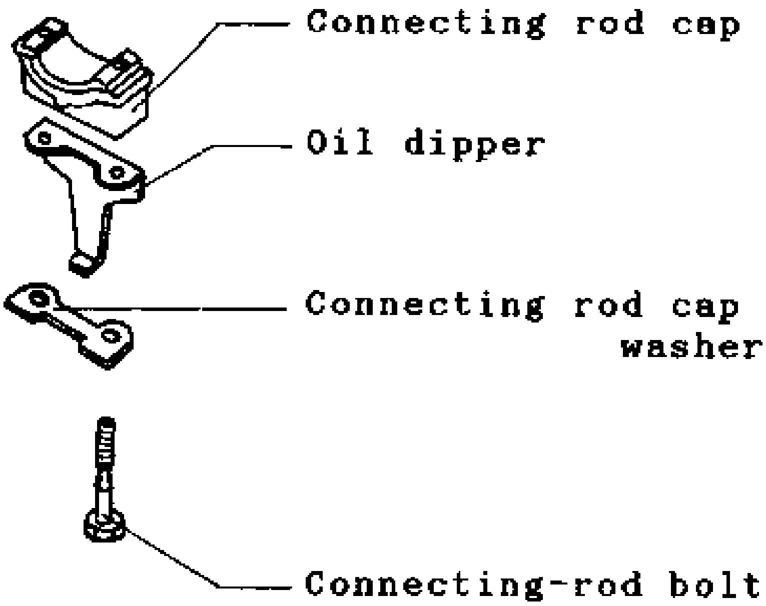
Caution:

- During spark plug removal, be aware of dust falling into the cylinder.
- Pressure gauge should be cleaned before installing.

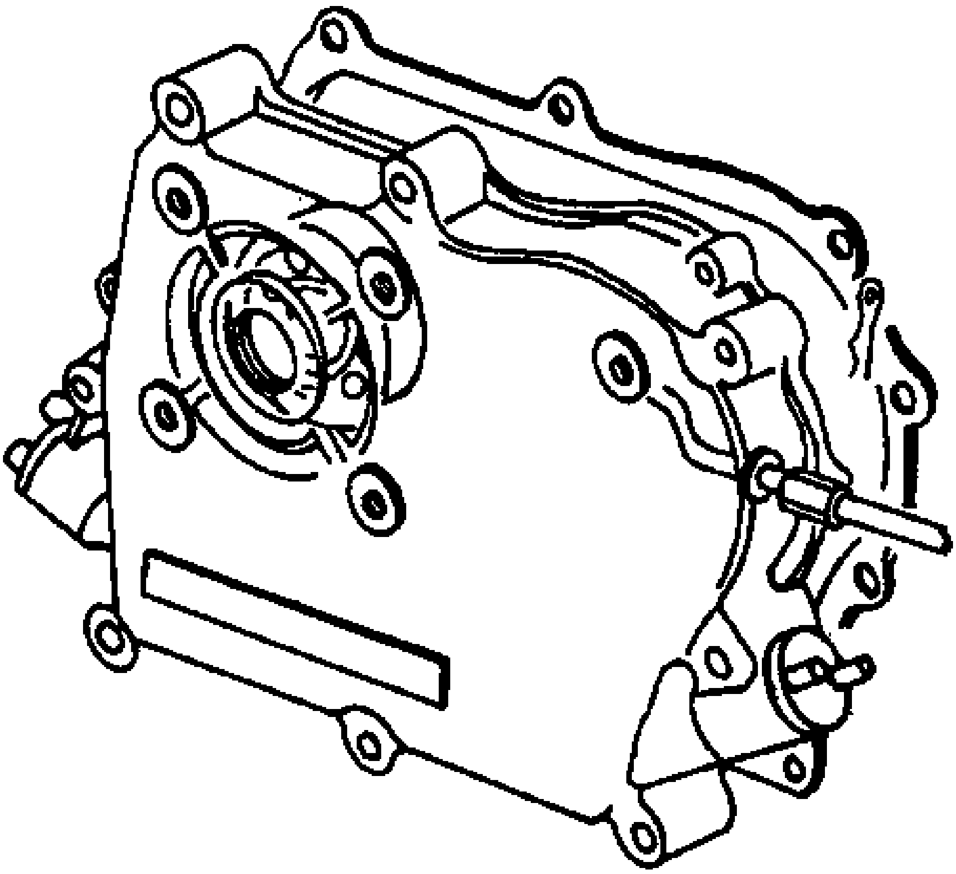
5.2.2 Dismantling–Reassembling components of engine


Mark on piston crown
Piston
Cylinder block
Crankshaft
Lock pin
Camshaft


Crankcase cover
Governor control rod



a) <u>Crankcase cover</u>

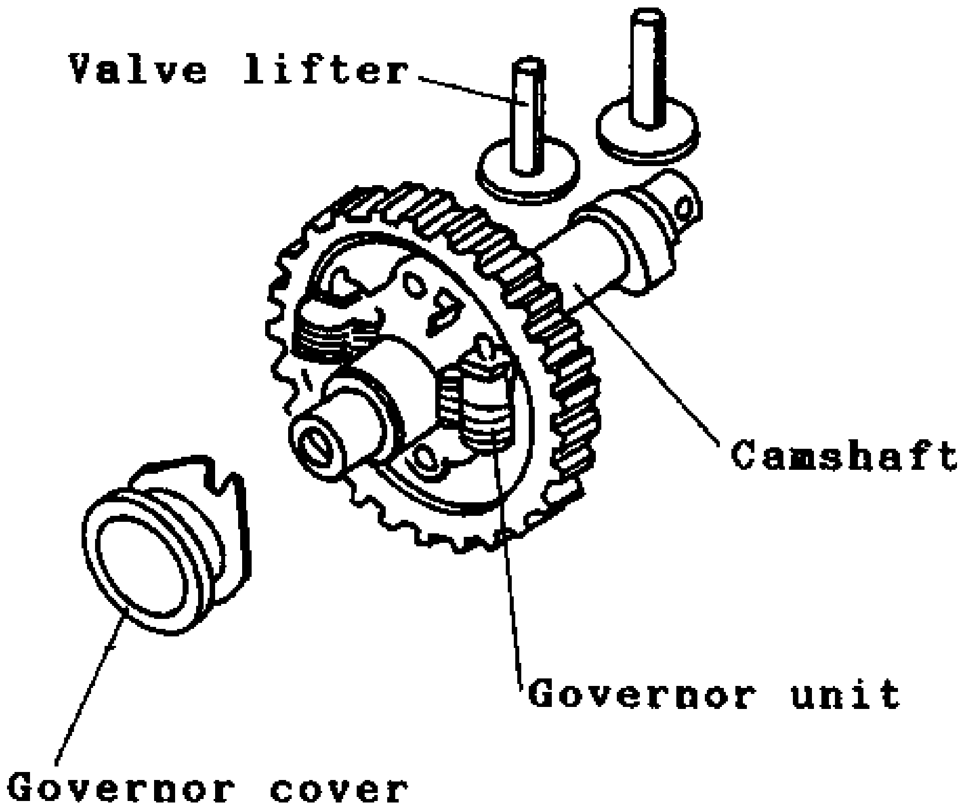


<u>Removal</u>:

1. Remove key on crankshaft if any.
2. Remove all screws of crankcase cover.
3. Tap the crankcase cover around gently with a plastic head hamer.
4. Remove the crankcase cover slowly.

<u>Caution</u>: Gasket may tear off and seal be damaged.

b) <u>Camshaft</u>

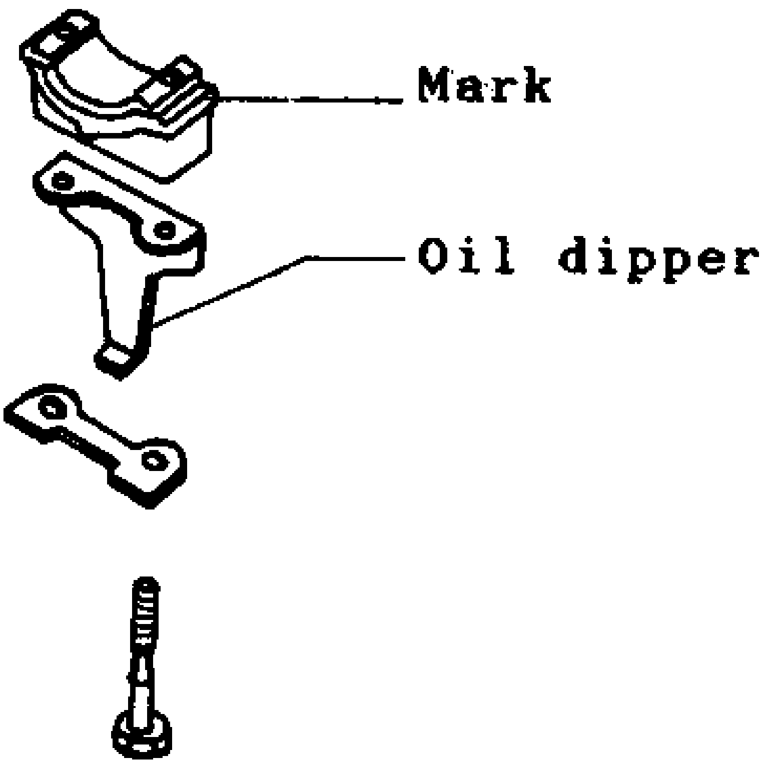


Removal:

1. Turn the crankshaft until the piston is at the top of the compression stroke.
2. Pull the camshaft assembly out.
3. Remove the valve lifters.

Remark: Governor unit is fixed to the camshaft assembly.

c) Connecting–rod cap



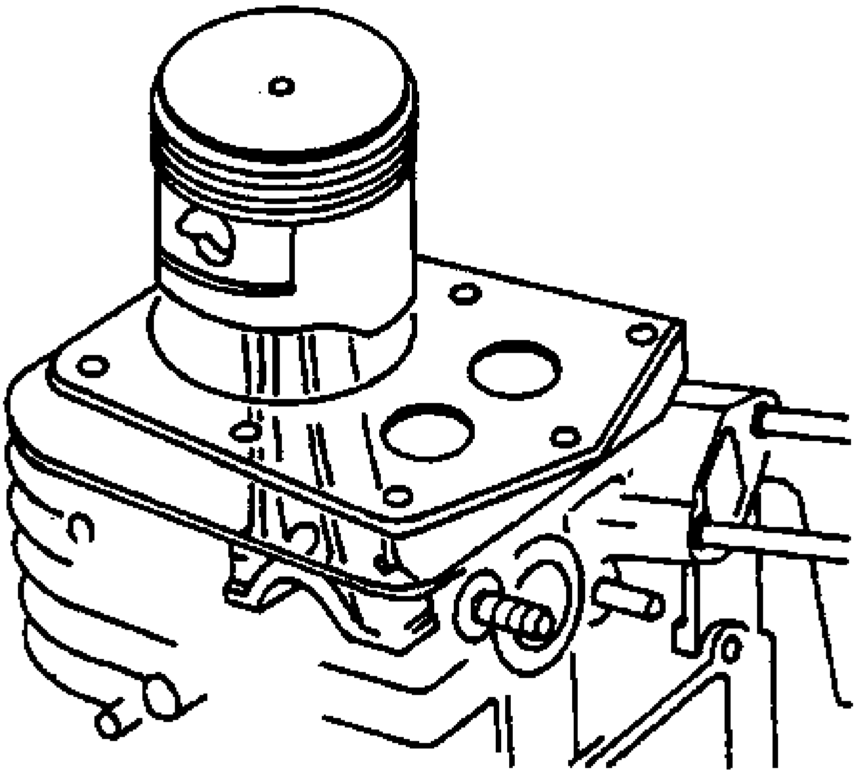
1. Make a mark onto the connecting−rod cap to prevent mixing up.
2. Unscrew the connecting rod bolts after flatten the cap washer.

Caution: position of oil dipper

3. Remove the connecting rod and cap.

Standard torque 9−11 Nm

d) Piston unit



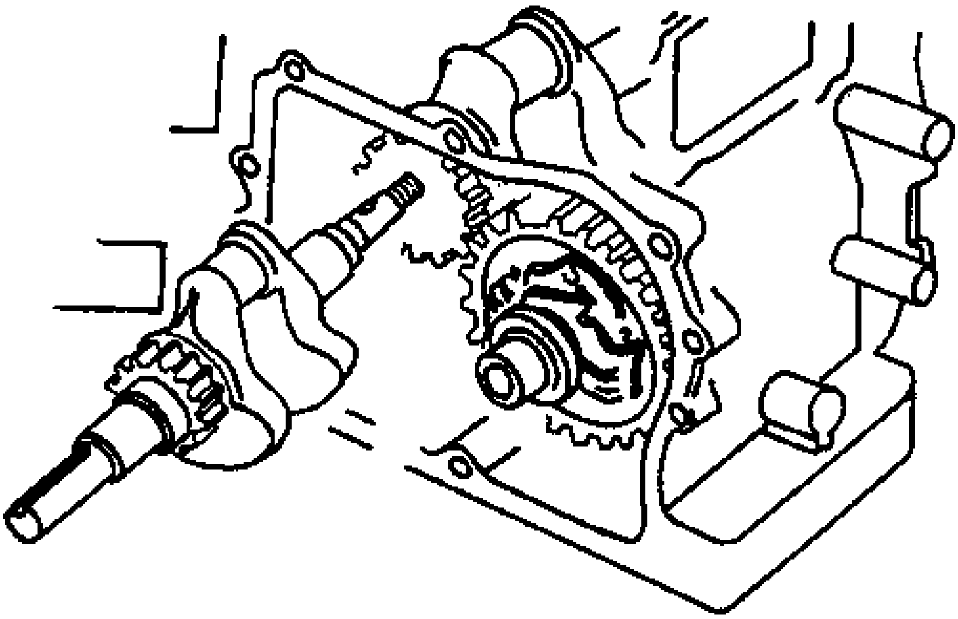
Removal:

Push the piston assembly upward

Reassemble:

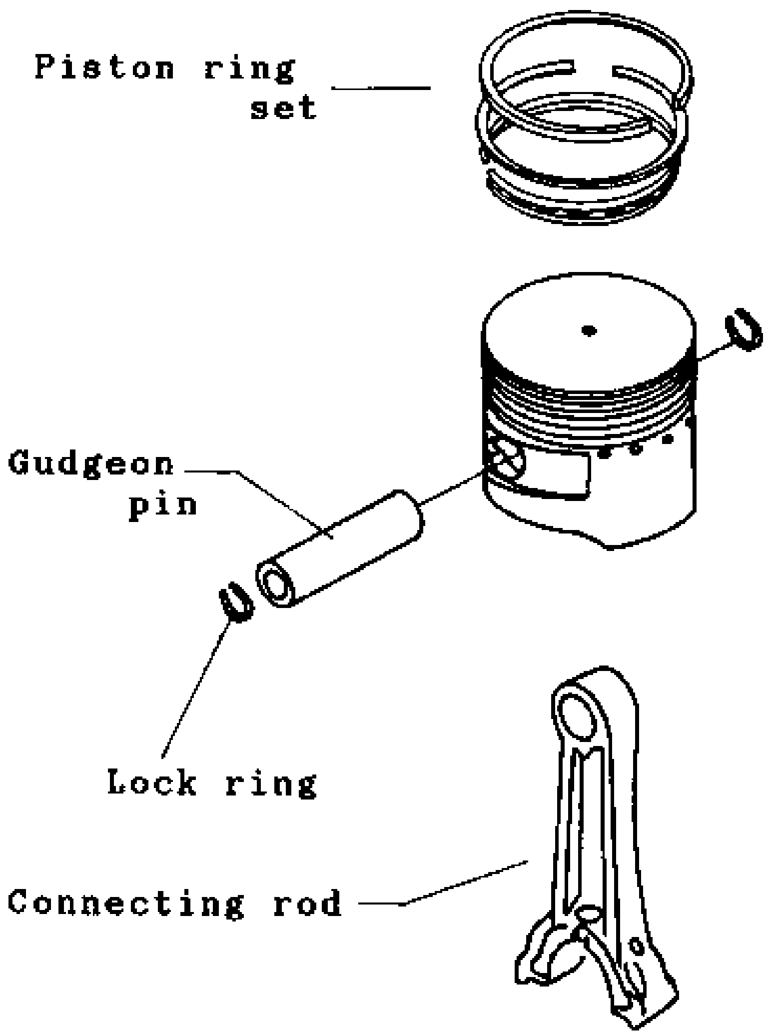
The arrow mark must be directed toward the valves.

e) Crankshaft unit



Caution: Do not drop the crankshaft.

f) Piston rings and gudgeon pin



Removal:

1. Remove piston rings with a special tool.
2. Take out one of the loc ring.
3. Push out the gudgeon pin by hand or with hammer.

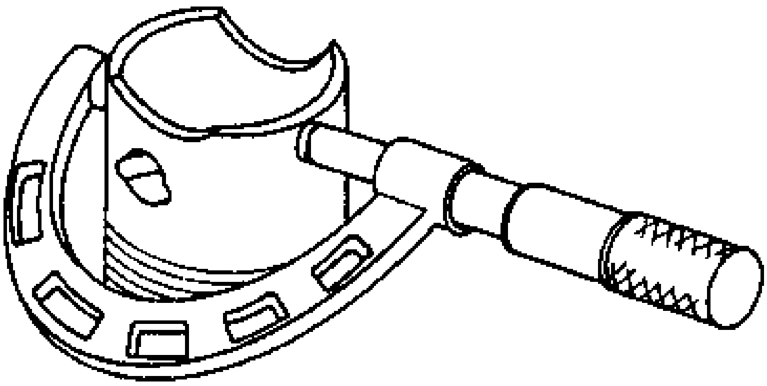
Remark: Remove piston rings before the gudgeon pin, otherwise, piston ring may brake

Reassembling: Install piston Gudgeon pin rings in correct order and arrange their ends at 120 offset.

Mark

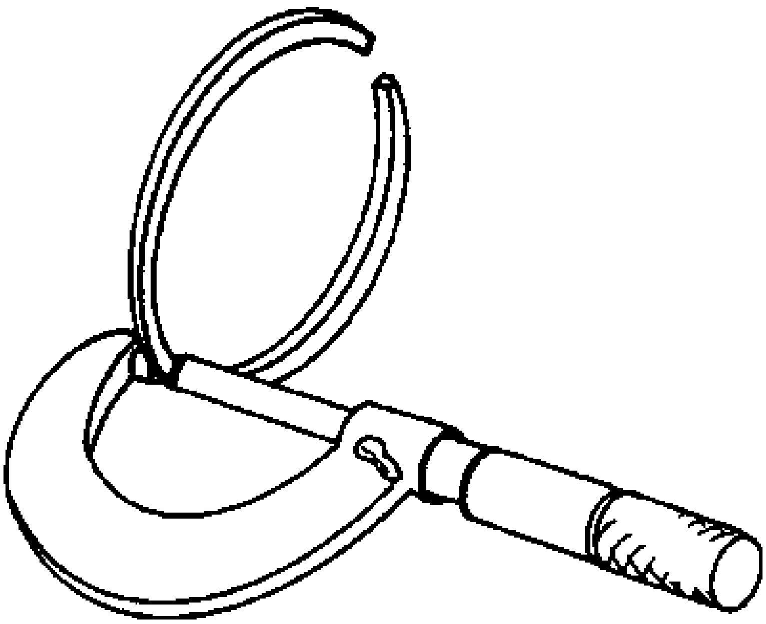
5.2.3 Inspecting the piston and piston rings

a) Measure diameter of the piston skirt



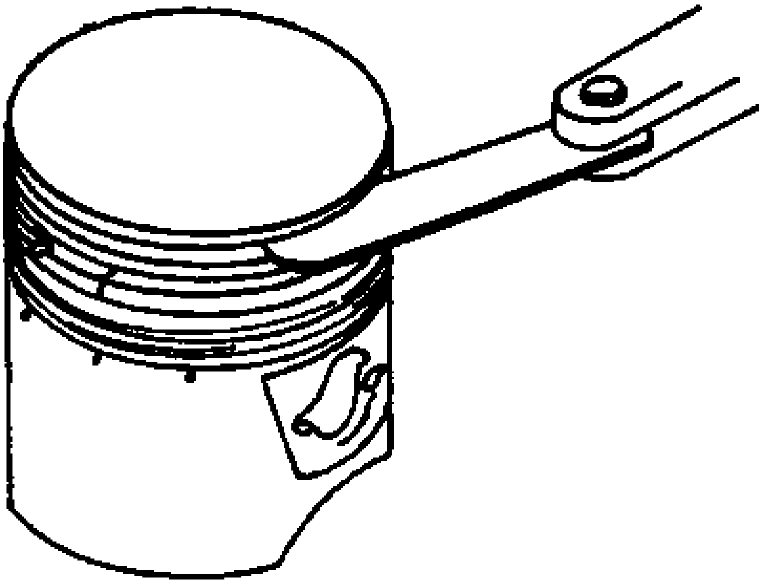
Model	Nom. size	Limited size
G150	64 mm	68.88 mm
G200	67 mm	66.88 mm

b) Measure thickness of compression rings and oil control ring



Nominal size	Limited size
Top compression ring 2 mm	1.87 mm
Second compr. ring 2 mm	1.87 mm
Oil control ring 2 mm	2.87 mm

c) Measure side clearance of piston ring

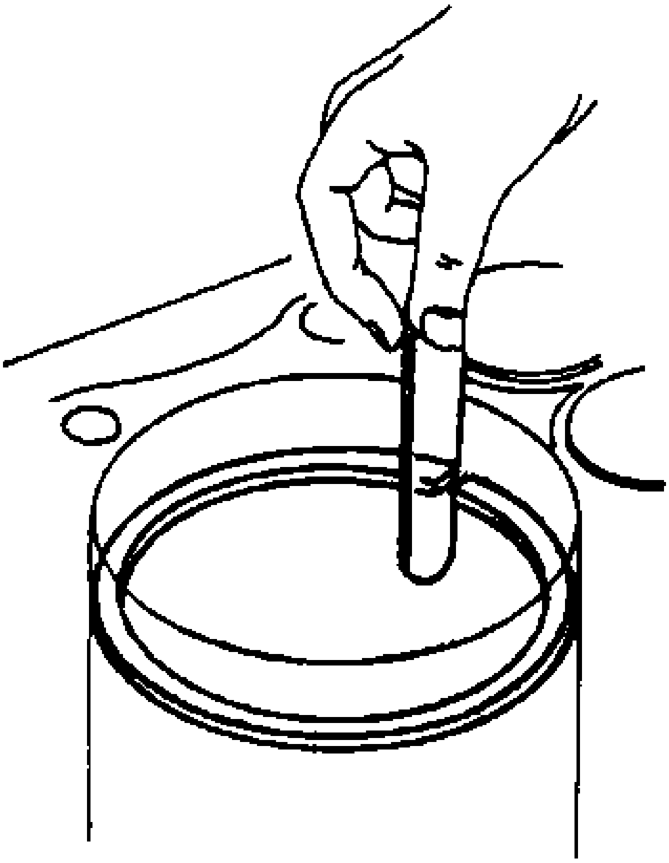


All piston rings must be installed correctly before measuring.

Nominal size	Limited size
all rings	
0.01–0.05 mm	0.15 mm

d) Check piston ring end gaps with feeler gauge

Insert all piston rings into the cylinder before measuring.



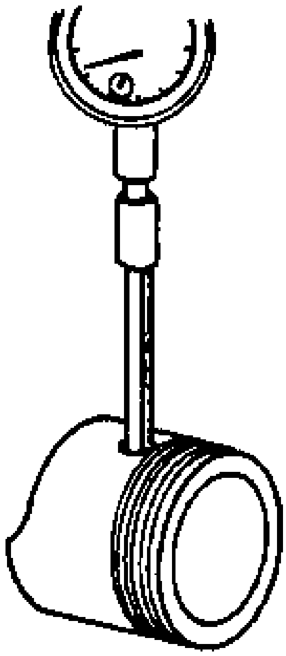
Nominal size	Limited size

all rings	
0.2–0.4 mm	1 mm

5.2.4 Checking gudgeon pin and gudgeon–pin hole

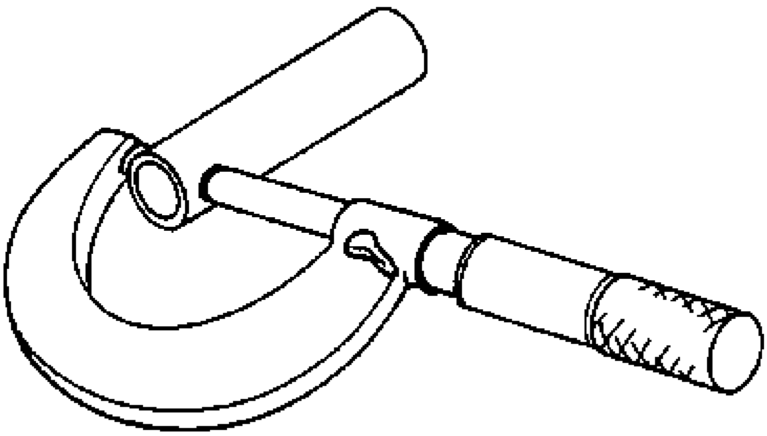
a) Check gudgeon–pin hole

Inside micrometer



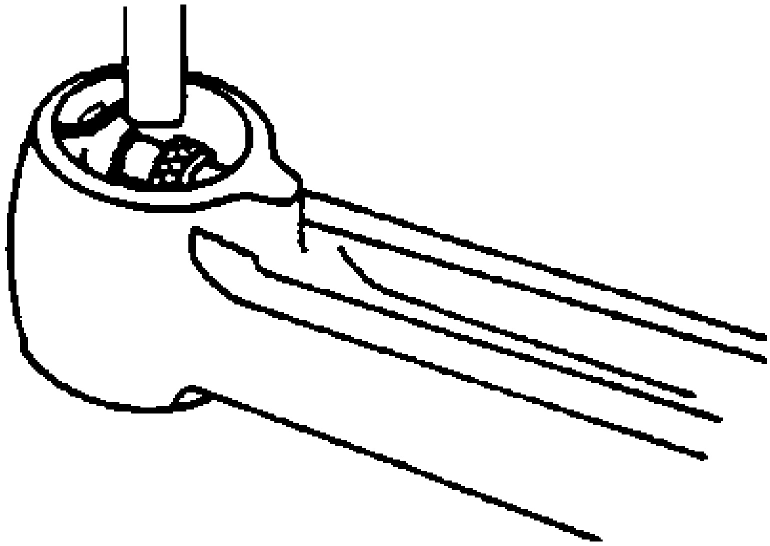
Nominal size	Limited size
15 mm	15.04 mm

b) Measure diameter of the gudgeon pin



Nominal size	Limited size
15 mm	14.954 mm

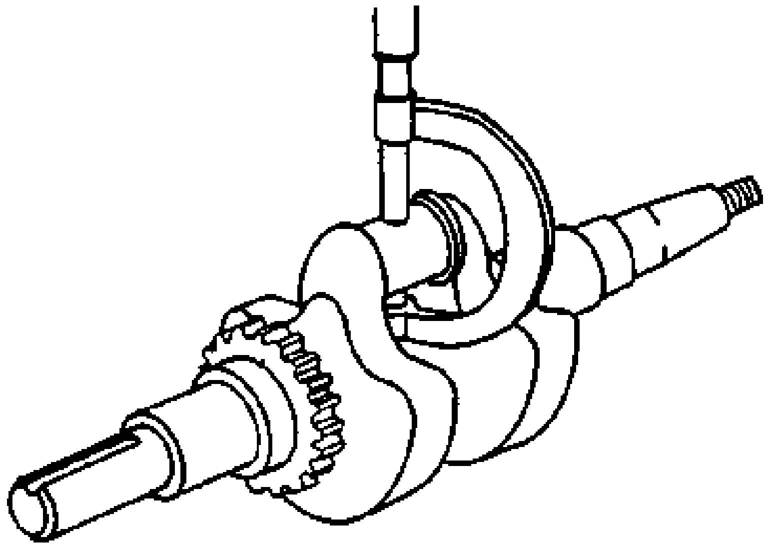
c) Measure bore of the small–end connecting rod



Nominal size	Limited size
15 mm	15.07 mm

5.2.5 Checking crankshaft and crankshaft bearings

a) <u>Measure diameter of crankpin journal</u>

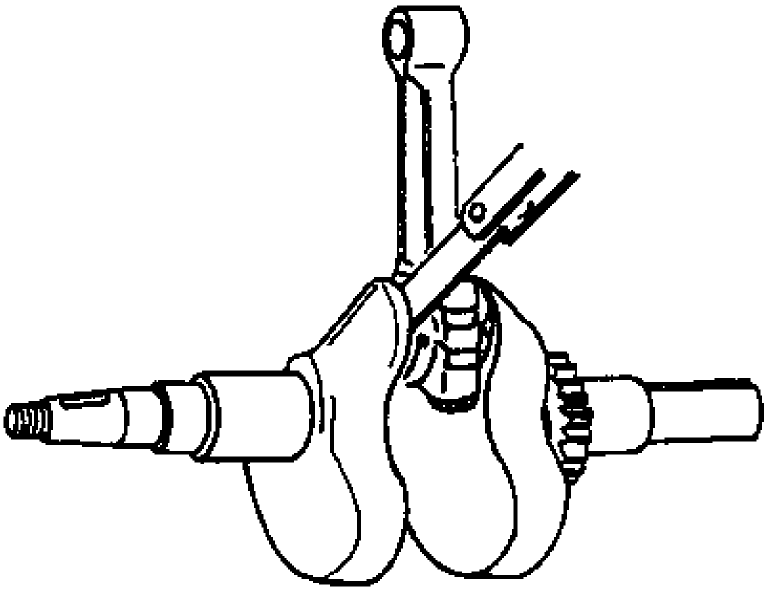


Nominal size	Limited size
26 mm	25.917 mm

b) Inspect surface conditions of both, crankshaft and seals with eyes.

c) Inspect condition of the big−end bearing shells with eyes for any sign of wear.

d) Measure connecting rod side clearence with feeler gauge.

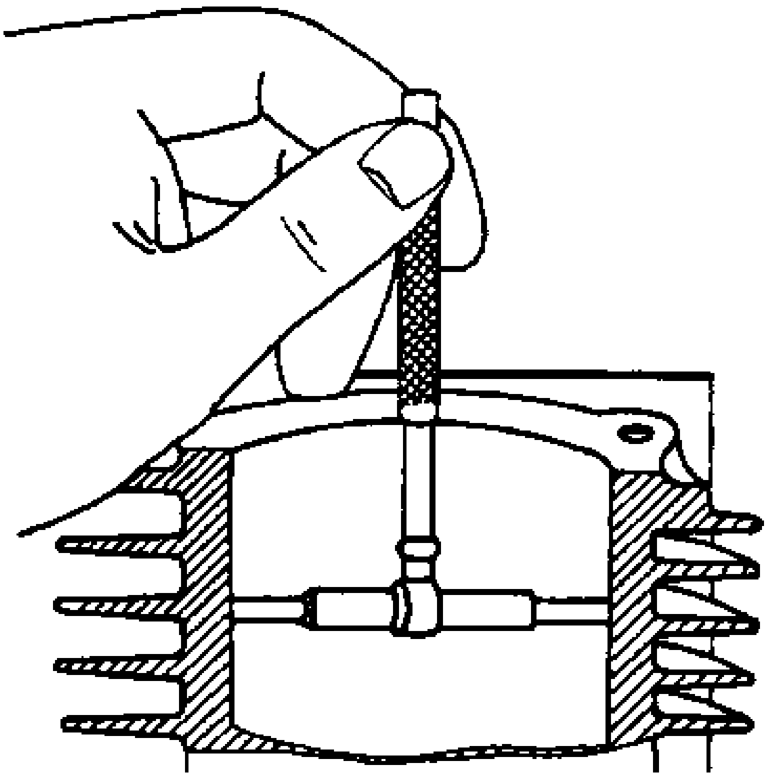


Nominal size	Limited size
0.1–0.8 mm	1.2 mm

Remark: Any parts of beyond the limited size it must be replaced.

5.2.6 Checking the cylinder

Measure diameter of cylinder with inside micrometer.



Nominal size	Limited size
G150 64.0 mm	64.165 mm

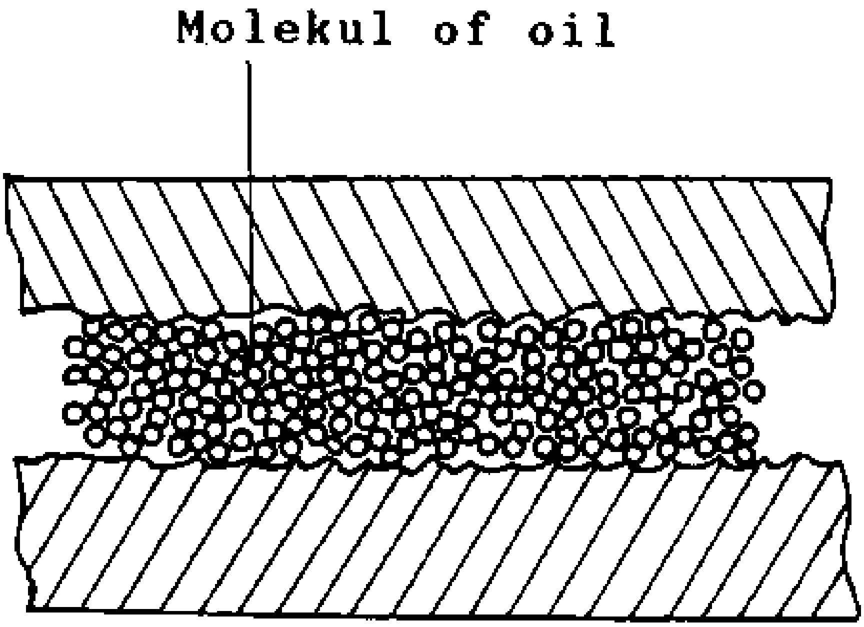
G200 67.0 mm	67.165 mm

Remark: Measuring should be carried out in several locations.

6. Lubrication system

Information

6.1 Tasks of the lubrication system



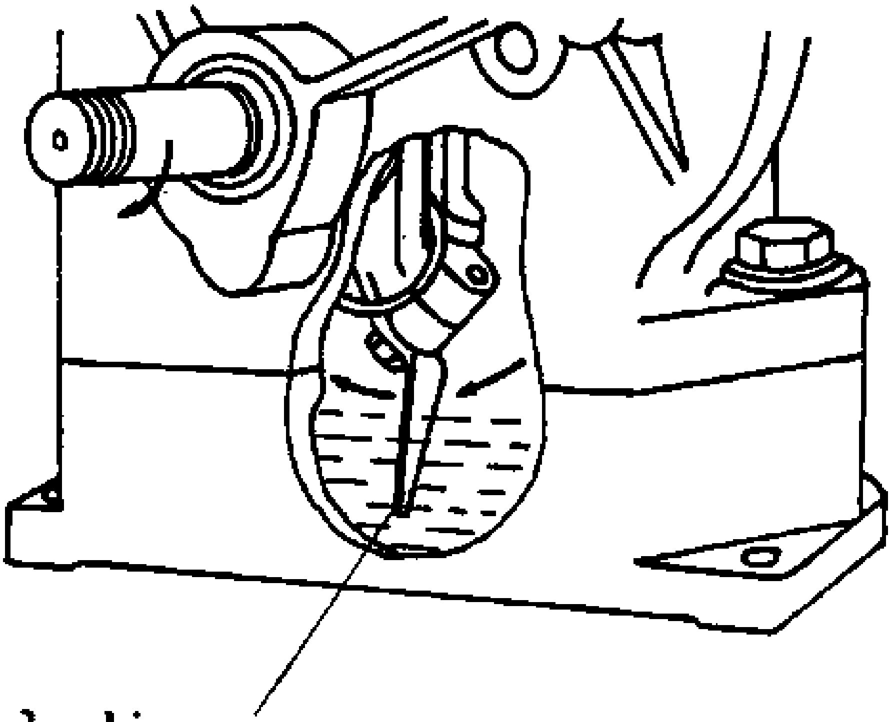
Lubrication system will supply oil to various moving parts of an engine, in order to ...

- reduce friction between moving parts,
- dissipate heat from various parts,
- absorb shock load between shaft and bush bearing,
- act like a sealing between piston rings and cylinder,
- act as cleaning agent.

6.2 Splash−type lubrication

This type of lubrication is mostly used in small engines, due to its simple construction and the simplest lubricating method.

6.2.1 Components and their function



– Oil dipper will splash oil from the sump during the downward rotation of the crankshaft, to the cylinder wall and other parts.

Advantage:

– Small number of parts and simple construction

Disadvantage:

– Insufficient lubrication may occur to various part in case there is inadequate amount of oil in the sump.

Task sheet

Complete the statements!

1. Lubrication means...

2. The tasks of the lubrication systems are:

1. ....
2. ....
3. ....
4. ....
5. ....

3. Parts of small engine which need lubrication are...............

4. Most used lubrication system in small engines is the ..... type, because...

5. Disadvantage of the lubrication system used in small engines:

....
....

Task (Solution)

Complete the statements!

1. Lubrication means Supply oil to the moving parts of the engine.

2. The tasks of the lubrication systems are:

1 reduce friction between moving parts
2 dissipate heat from various parts
3 absorb shock load between shaft and bush bearings
4 act like a sealing between piston rings and cylinder
5 act as cleaning agent

3. Parts of small engine which need lubrication are crankshaft, mechanism, valve mechanism and cylinder

4. Most used lubrication system in small engines is the splash type, because due simple construction

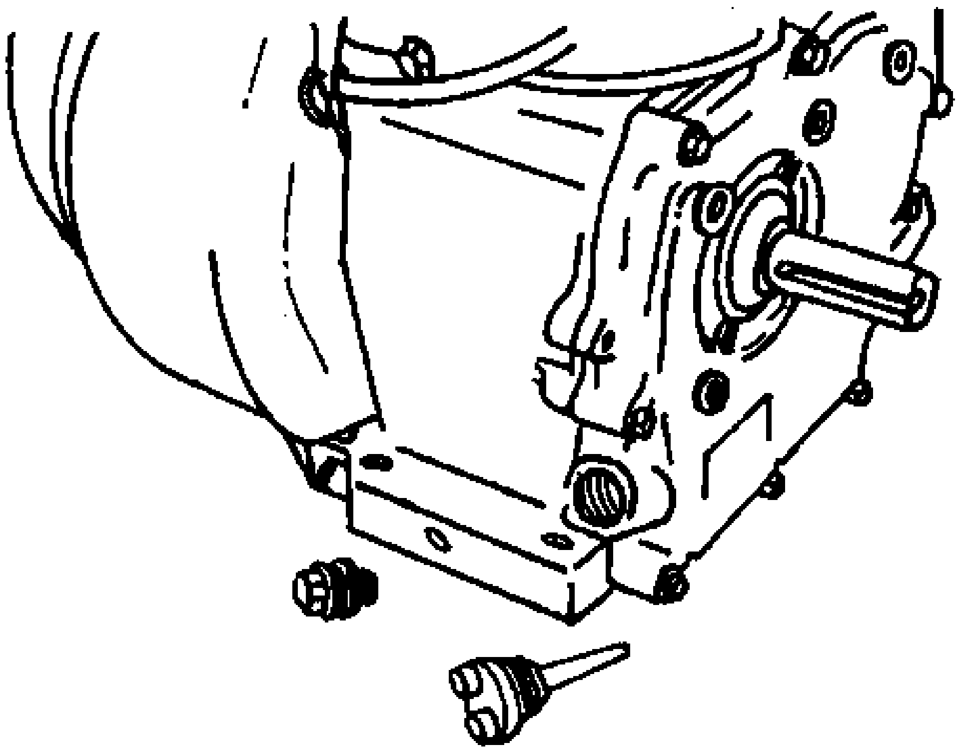
5. Disadvantage of the lubrication system used in small engines:

Insufficient lubrication when there is inadequate amount of oil in the sump

6.3 Repair and maintenance

Information

Inspecting/changing oil:

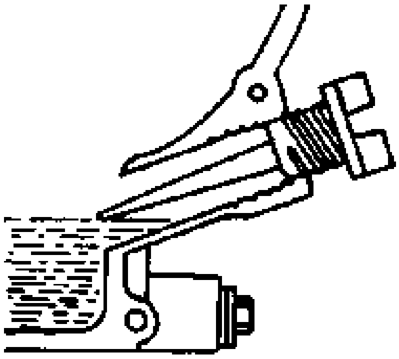


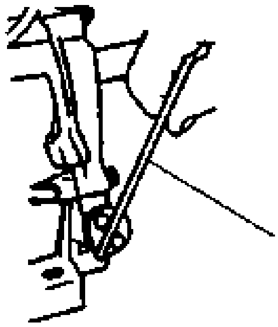
– Unscrew both the drain plug and oil refil screw plug to drain out old oil.
– Screw in the drain plug and refil with new oil upto the specified level.

Capacity of oil sump 0.7 litre

Recommended oil: SAE 2100 W–30

– The engine must be in horizontal position when checking oil level.
– Close the screw plug tightly with the aid of screw driver.





Job sheet

Tools: A set of wrenches

Equipement: Equipment tray, Cloth, Oil, Oil pan

Manufacturer .... Model ....
Oil grade ....
Capacity .... litre

Sequence of operation	Inspection	
1. Prepare tools and equipment.		
2. Run the engine for 5 minutes.		
3. Stop the engine and drain oil.	– Condition of oil	
4. Refil new oil upto the specified level.	– Capacity of oil .... litre	
	– Grade	
5. Start the engine and observe for oil leakage.	☐ Leakage	☐ No leakage
6. Stop the engine and recheck oil level.	– Oil level	
	☐ Correct	☐ Incorrect
7. Clean and store tools and equipment.	– Tools	
	☐ Complete	☐ Incomplete

Note:..

7. Cooling system

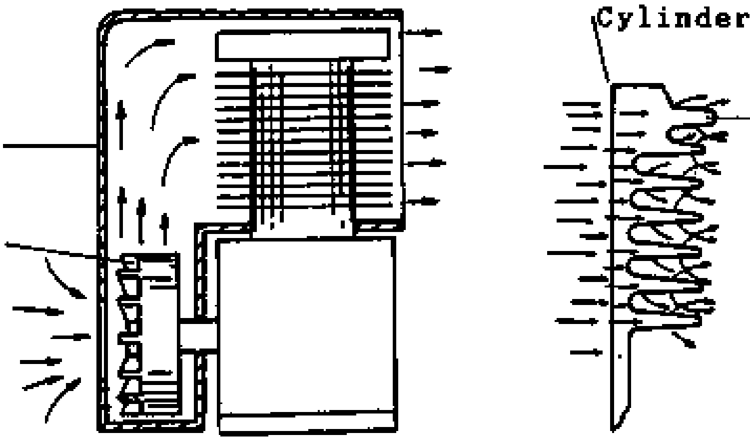
Information

Air cooling system....

is the most used system in small engines because it is easy to place, light in weight, has a small number of parts and low production costs. Its tasks are:

– to dissipate heat as generated by friction

– to control dissipating heat within certain range of working temperature for efficient engine performance



– The system uses air as a cooling medium to transfer heat from engine to surrounding air which has lower temperature.

– For engine with air cooling system, the exterior of cylinder will be in forms of fins and spaces which increases area of air contact.

– To be of efficient the blower cover is used to direct air blowing.

– As the engine runs, the blower blade attached on the flywheel will suck in cool air and blow it along the cover to cool down the cylinder wall.

Task sheet

Complete the statements!

1. The tasks of the cooling system are:

1 ....
2 ....

2. Small gasoline engines generally use .... cooling system, because ....

3. Small gasoline engines generally have their cylinder head and cylinder block made in the forms of ....

This is for ....

4. Components of cooling system of most small gasoline engines consist of ....

5. Blower cover is used for ....

Task (Solution)

Complete the statements!

1. The tasks of the cooling system are:

1 To dissipate heat as generated by friction
2 To control temperature within a certain range

2. Small gasoline engines generally use air cooling system, because it is easy to place, light in weight, has a small number of parts and low production costs.

3. Small gasoline engines generally have their cylinder head and cylinder block made in the forms of fins and spaces.

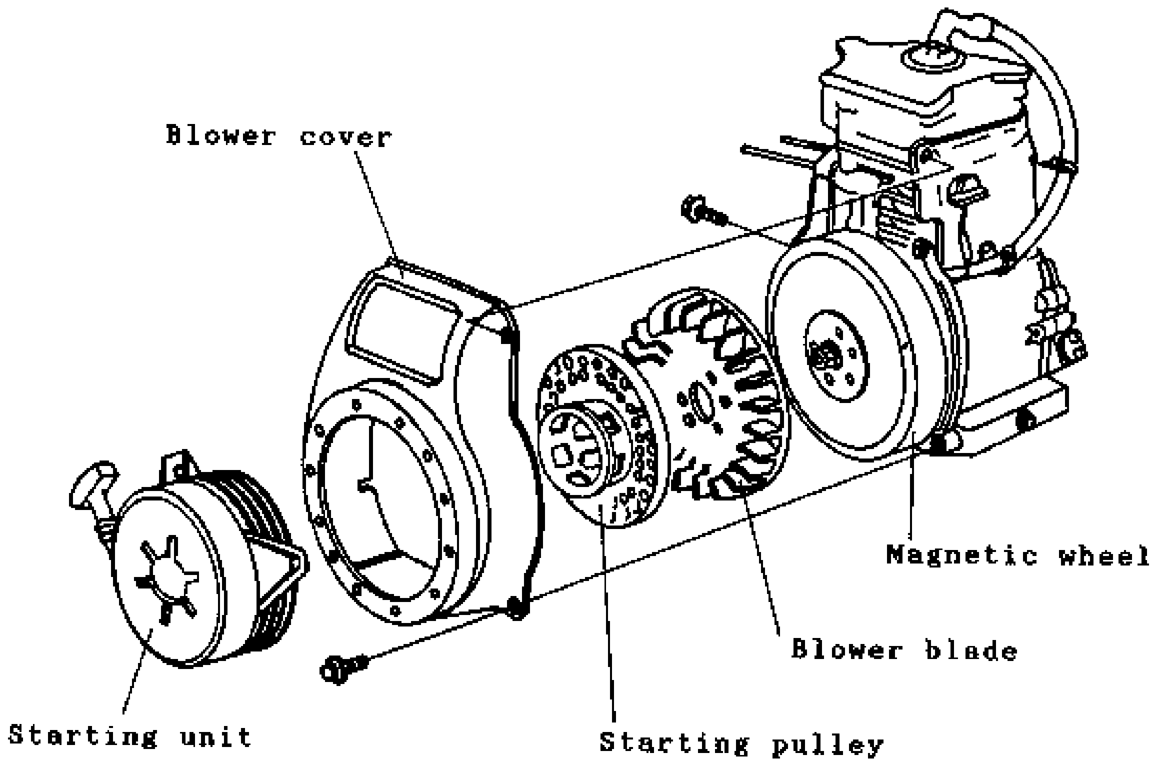
This is for increasing the area of air contact

4. Components of cooling system of most small gasoline engines consist of lower, lower–cover and fins

5. Blower cover is used to guide the air.

7.1 Repair and maintenance

Information



– The starting unit must be cleaned before assembling the blower cover.

– The blower blade must be fixed to the magnetic wheel at the correct position which is guided by the pilot pin of the magnetic wheel. Be aware of cracking the blower blade.

Job sheet

Tools: A set of wrenches

Equipement: Tray, cloth, benzene

Manufacturer........................... Model ....
Type of cooling system.....................................

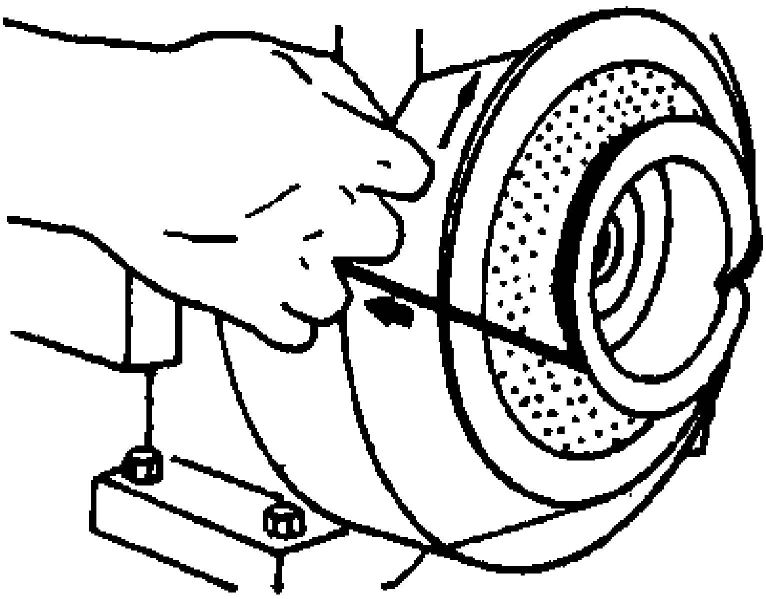
Sequence of operations	Inspection	
1. Prepare tools and equipment.		
2. Close fuel valve, disconnect fuel hose and remove fuel tank.		
3. Remove starting unit.		
Remark: Notice the position of starting unit.		
4. Remove blower cover.	– Condition of blower cover	
	☐ Normal	☐ Damaged
5. Remove starting pulley.		
Remark: Notice the position of starting pulley.		
6. Remove blower blade.	– Condition of blower blade	
	☐ Normal	☐ Damaged
7. Clean blower blade, fins of cylinder head and cylinder block, and blower cover.		
8. Reassemble those components		
9. Clean and store tools and equipment.	– Tools–equipment	
	☐ Complete	☐ Incomplete

Note: ....

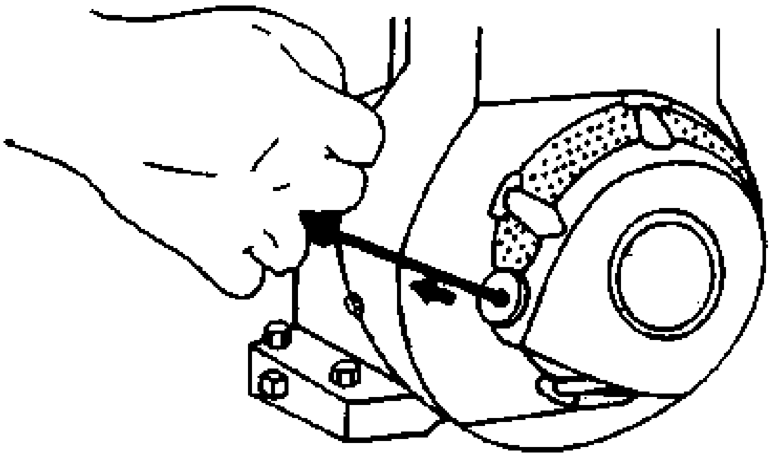
8. Starting system

Information

8.1 Types of starting systems



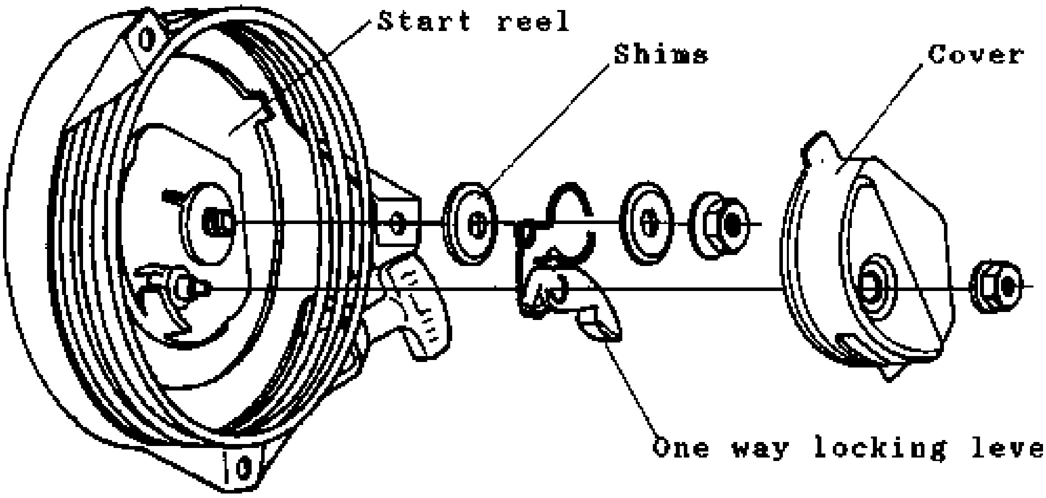
Conventional type



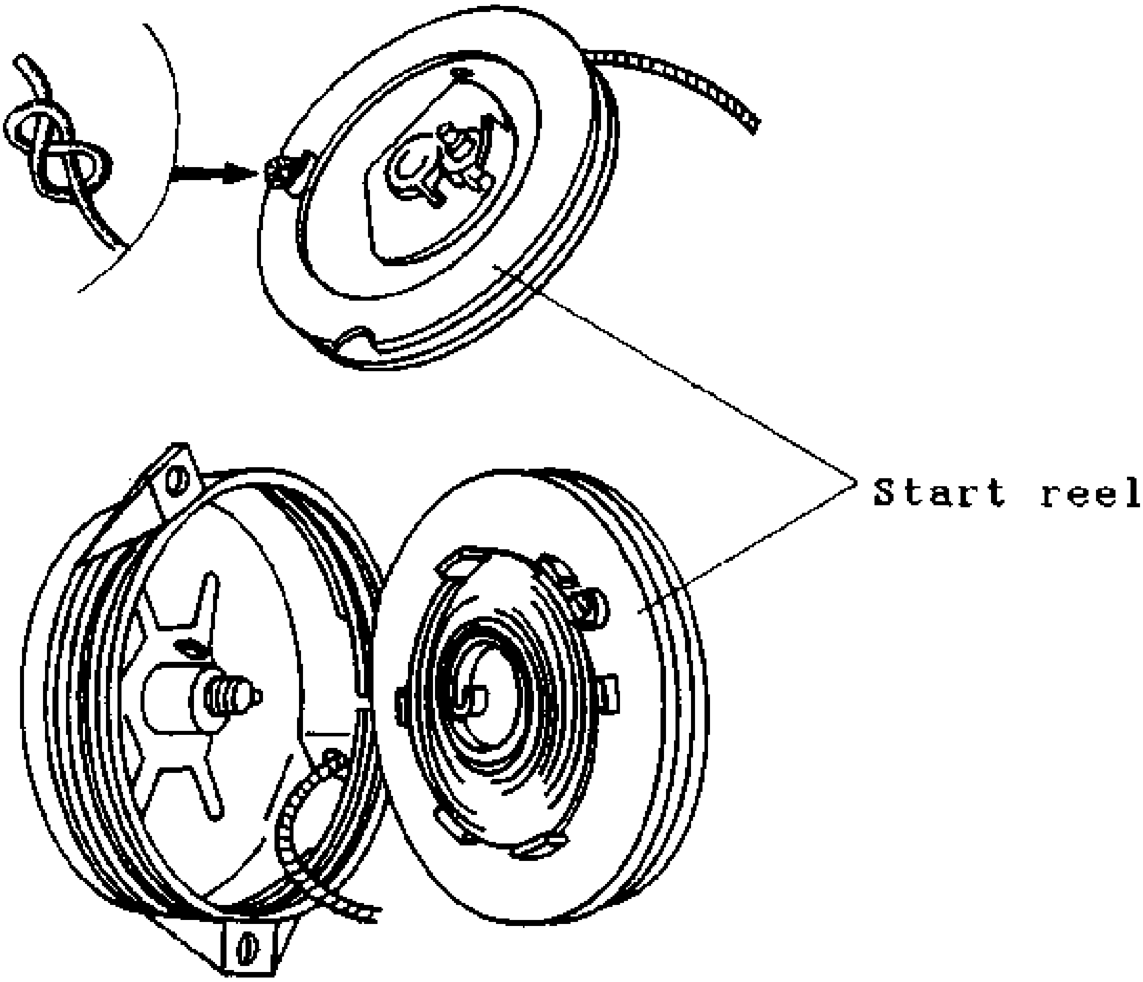
Built in starting unit

8.2 Repair and maintenance

a) Removal and reassemble starting unit



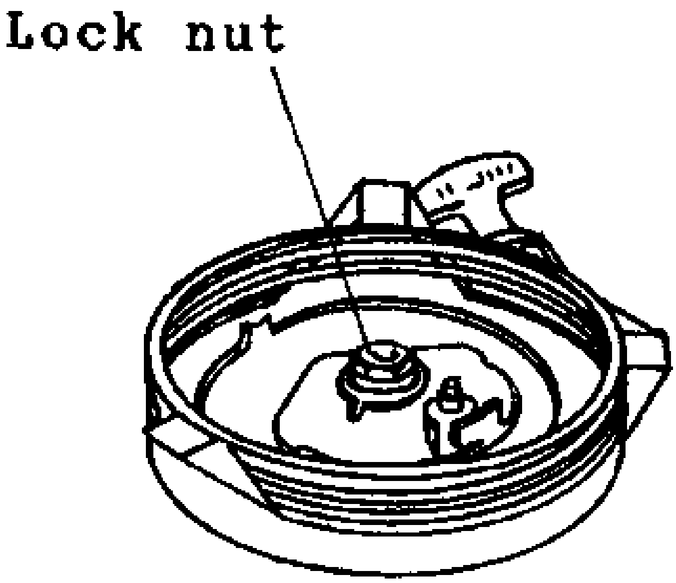
b) Assembling starting string



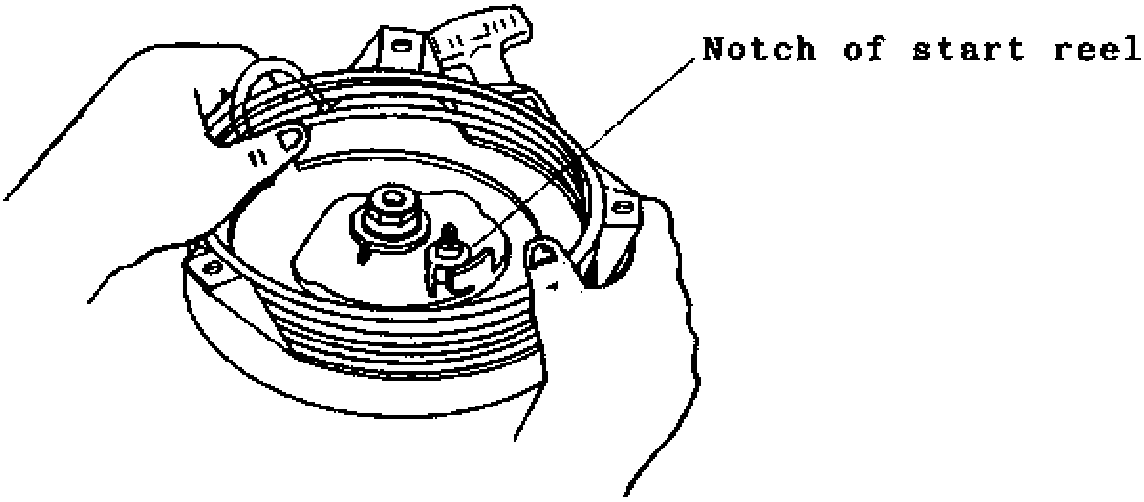
Starting spring housing

– Thread one end of the string through the hole of the start reel and make a knot.

– Wind the string on the start reel (in the direction of spring). Thread the other end of string through the spring housing. Refit the start reel to the spring housing.

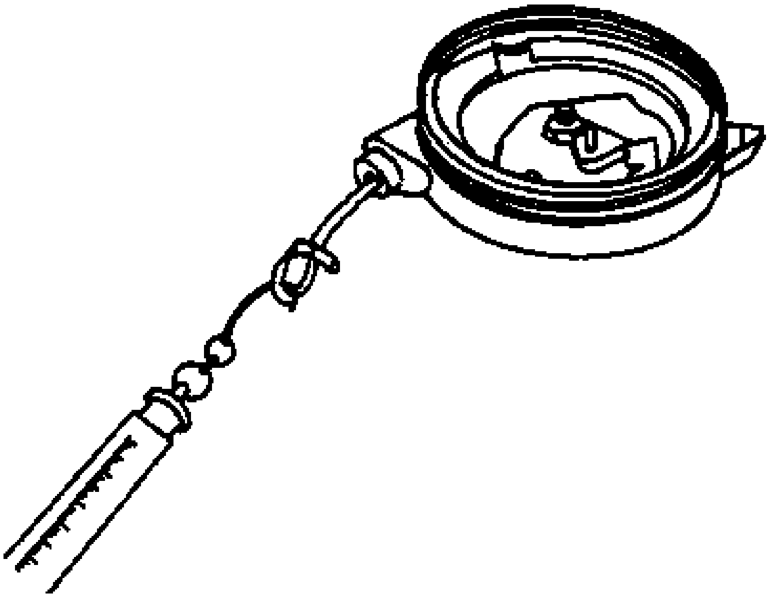


– Reassemble the spring plate and screw on the lack nut. Tighten it to the specified torque–

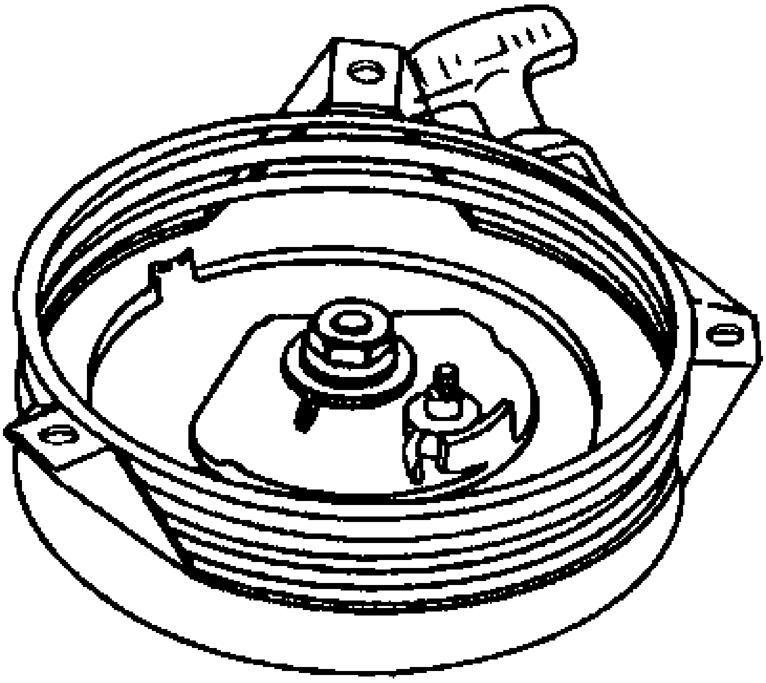


Spring plate

– Turn the start reel for about 1 1/2 turns to wind up the rest of string from the notch of the start reel.



– Check tensioning of the starting string by using a spring scale. The reading should be about 0.6–1.4 kg. Adjustment of tension can be accomplished by tightening or loosening the start reel.



– Refit the handle to the starting string and tie it. Assemble the spring to the ratchet of the start reel. Inspect function of the ratchet.

– Reinstall the start reel cover.

Job sheet

Tools: A set of wrenches

Equipement: Tray, cloth, grease

Manufacturer .... Model ....
Type of starting system ....

Sequence of operations	Inspection
1. Prepare tools and equipment.	
2. Remove starting unit from blower cover.	
3. Dismantle components of starting unit.	– check/replace parts
4. Clean all parts of the starting unit.	– grease moving parts
5. Reassemble components of the starting unit.	
6. Refit the starting unit	– check performance
7. Inspect its function	
8. Clean and store tools and equipment.	

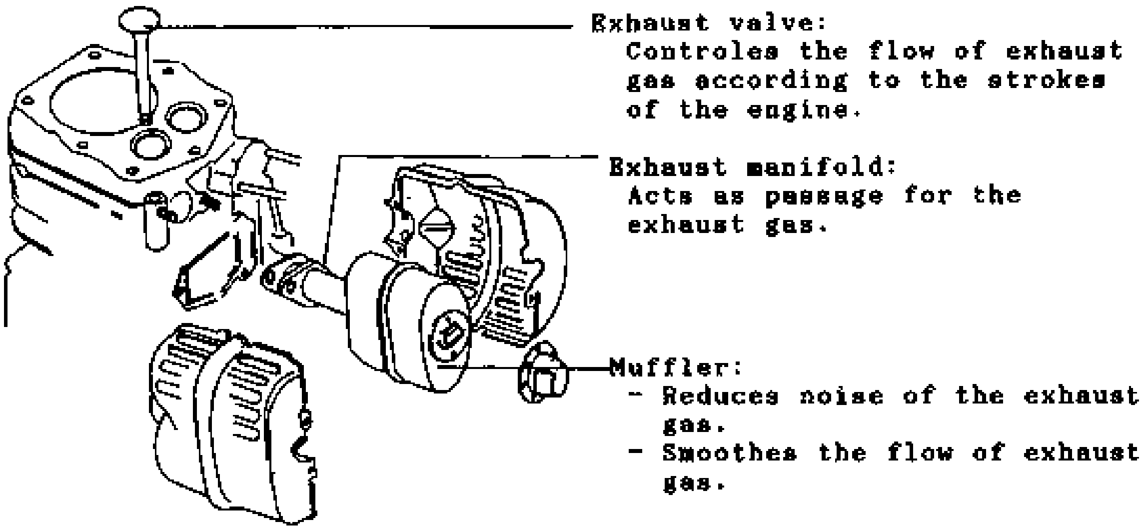
Note: ....

9. Exhaust system

9.1 Purposes of exhaust system

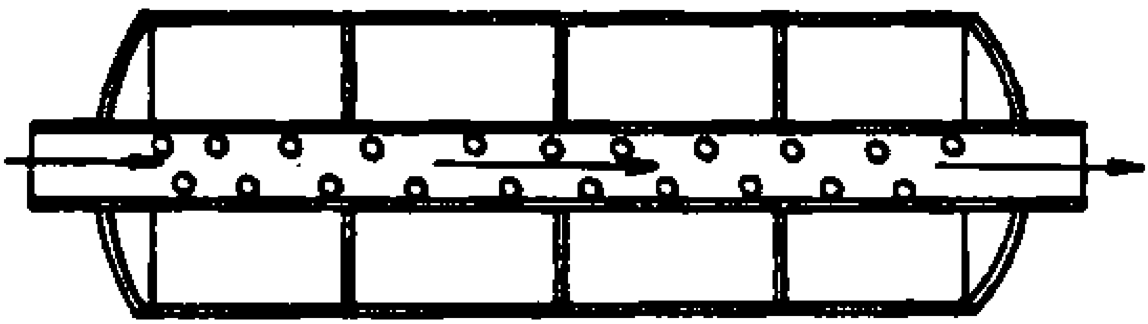
a) To relief exhaust gas from the combustion chamber.
b) To improve engine power.
c) To reduce expanding noise of exhaust gas.

9.2 Components and their function



There are two kinds of mufflers:

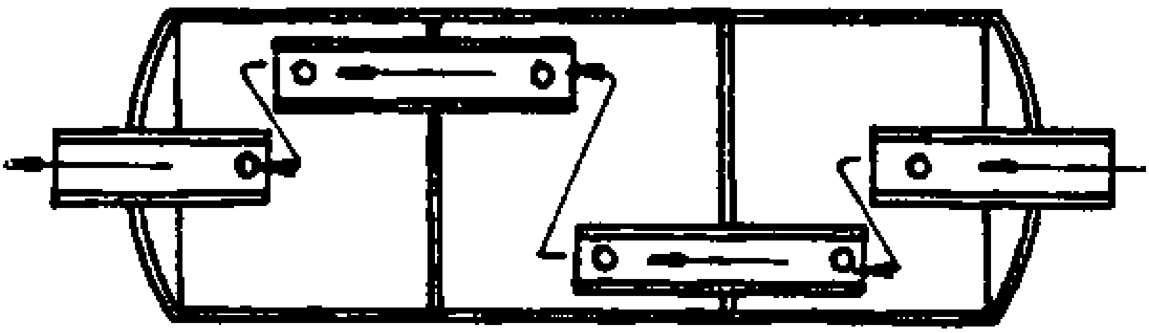
a) Straight–through muffler



The exhaust gas flows like a stream both inside and outside the muffler, causing turbulence.

Hard flow of exhaust gas will reduce engine power.

b) Reverse–flow muffler



The exhaust gas will expand inside each compartment of the muffler as it flows. This will minimize the level of noise considerably when it comes out to the atmosphere.

Turbulence of exhaust gas is reduced, thus, noise is also reduced.

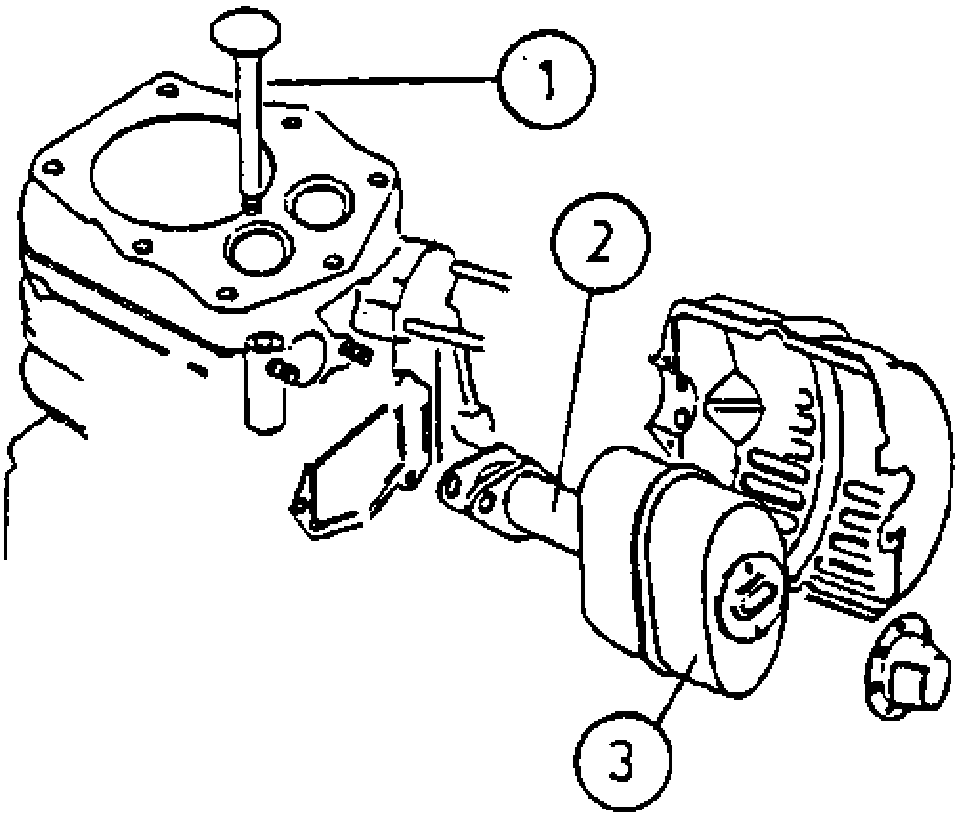
Task sheet

Complete the statements!

1. Purposes of exhaust system are:

a) ....
b) ....
c) ....

2. Name various parts of the exhaust system.



1...........................
2...........................
3...........................

3. The muffler can reduce noise of exhaust gas, due to ....

4. There are .... muffler–designs, which are ....

5. Small gasoline engines generally use the .... muffler–type, because
....

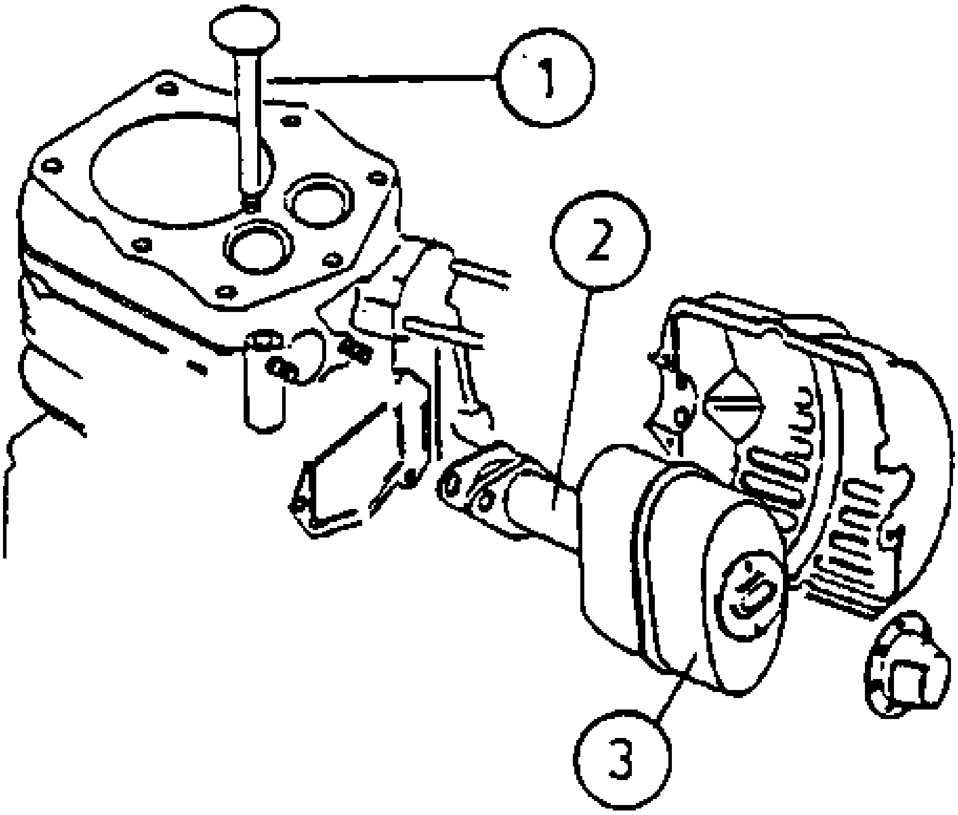
Task (Solution)

Complete the statements!

1. Purposes of exhaust system are:

a) To relief exhaust gas from the combustion chambre
b) To improve engine power
c) To reduce expanding noise of exhaust gas

2. Name various parts of the exhaust system.



1 Exhaust valve
2 Exhaust manifold
3 Muffler

3. The muffler can reduce noise of exhaust gas, due to turbulence and expansion

4. There are 2 muffler−designs, which are Straight−through and Reverse−flow muffler

5. Small gasoline engines generally use the Reverse muffler−type, because noise is reduced and engine power improved.

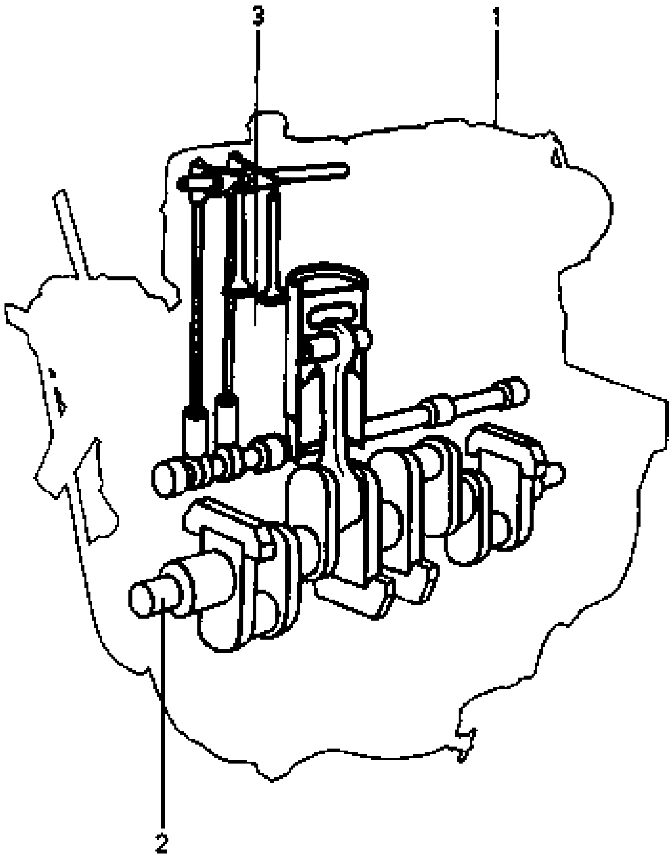
Motor/Engine – Automotive Transparencies

Table of Contents

Motor/Engine – Automotive Transparencies.....1

Motor/Engine – Automotive Transparencies

1



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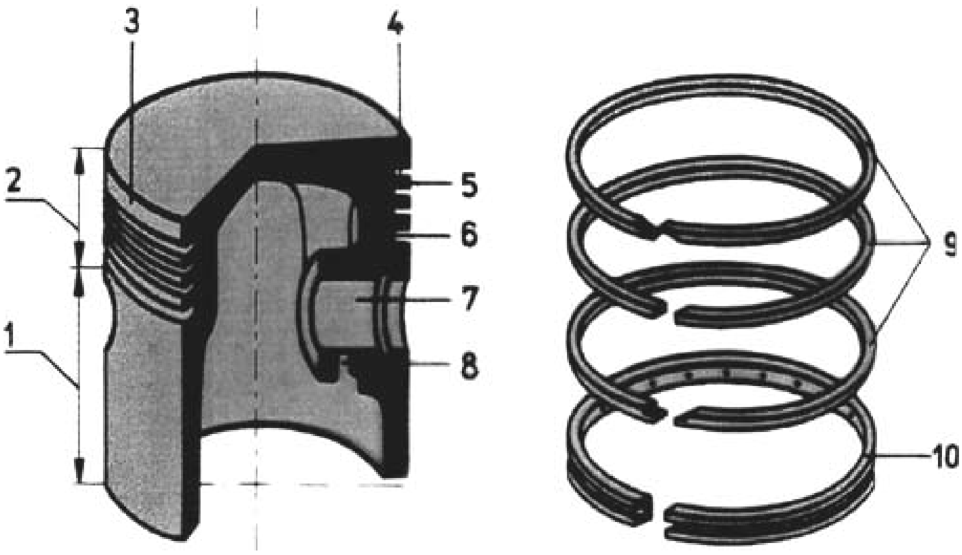

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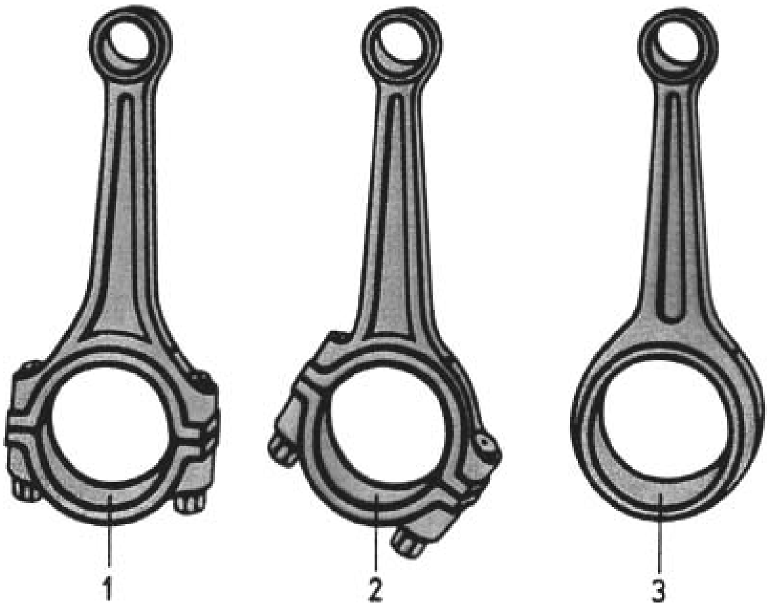

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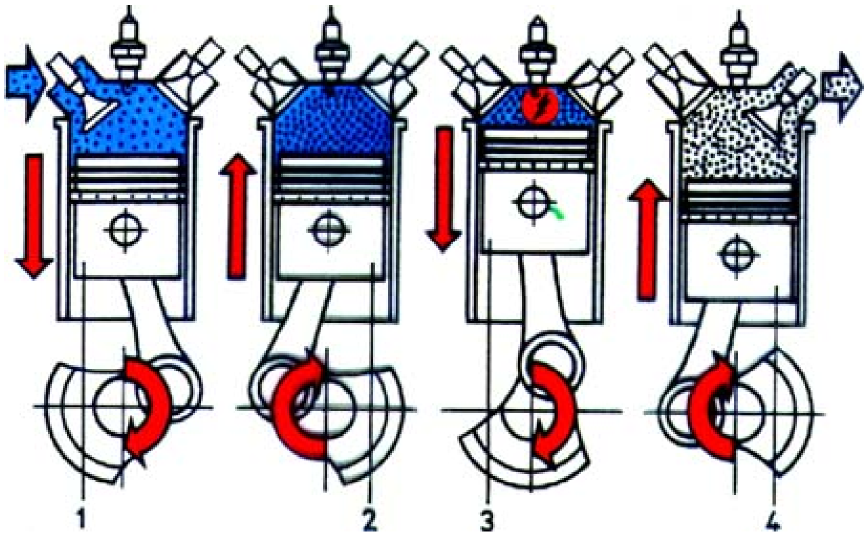

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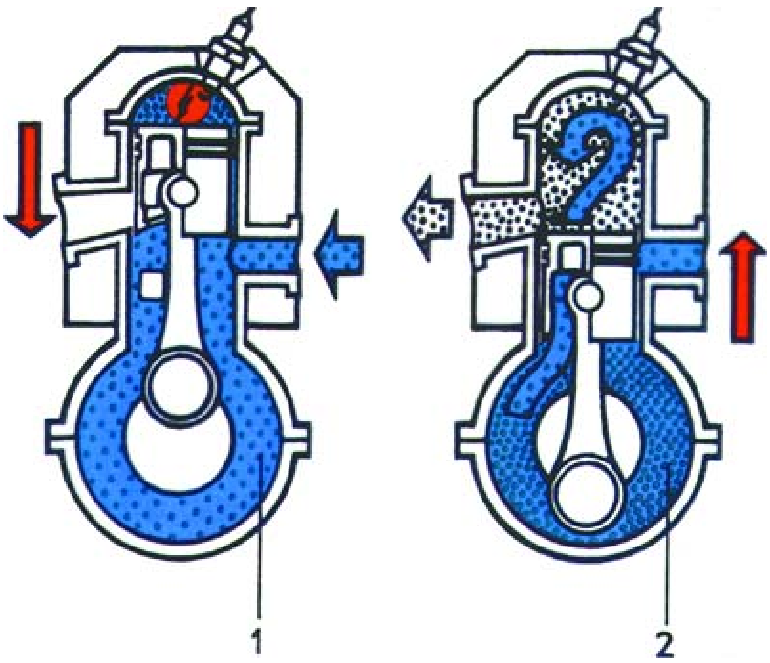

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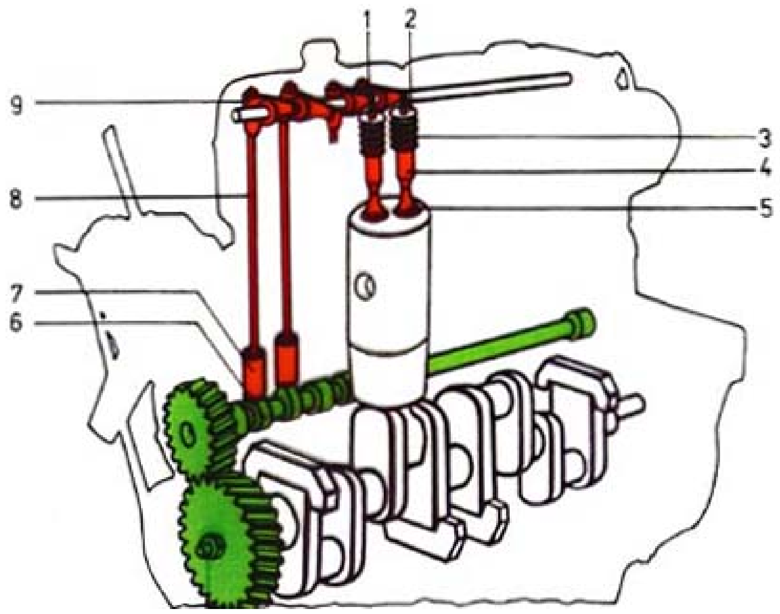

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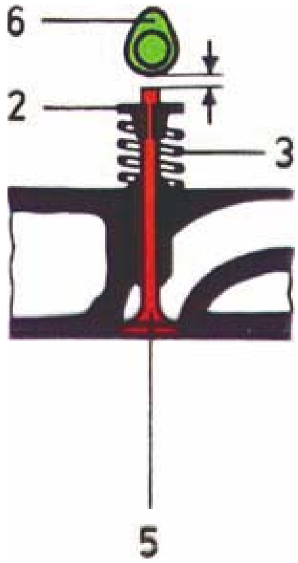

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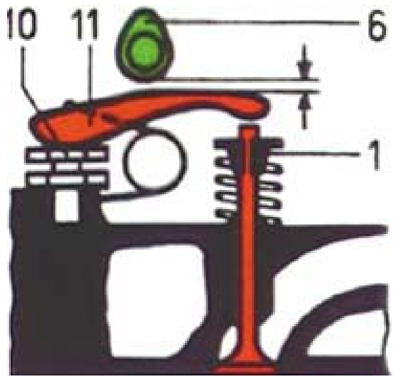

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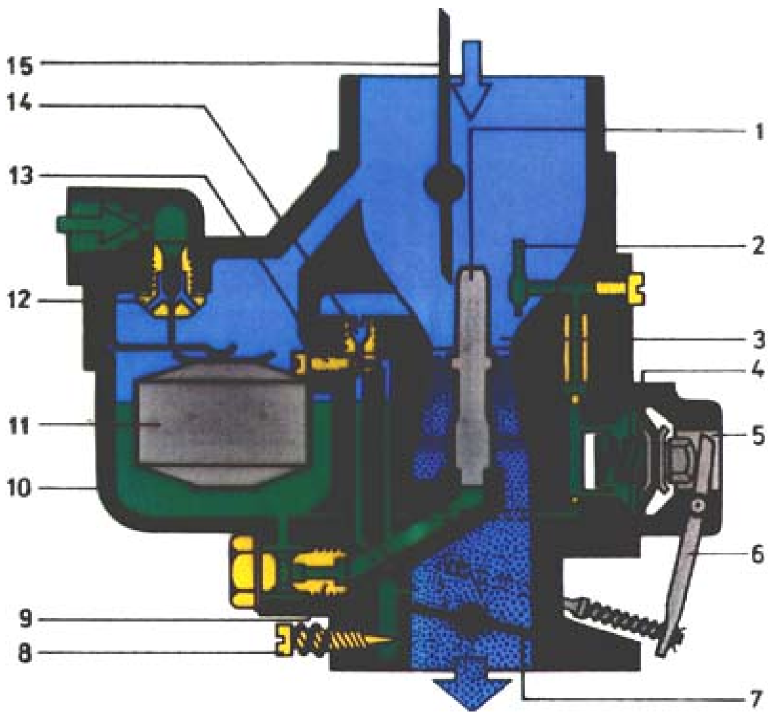

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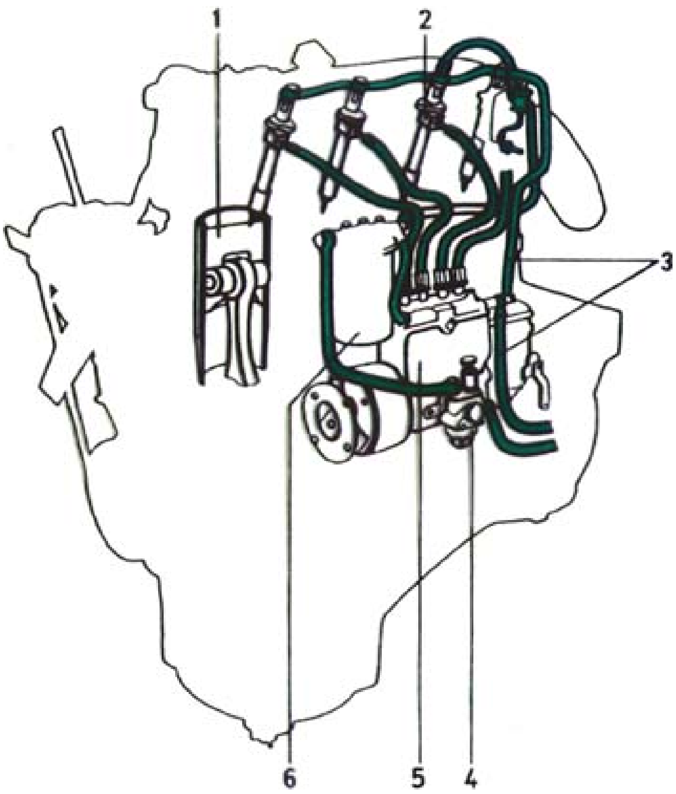

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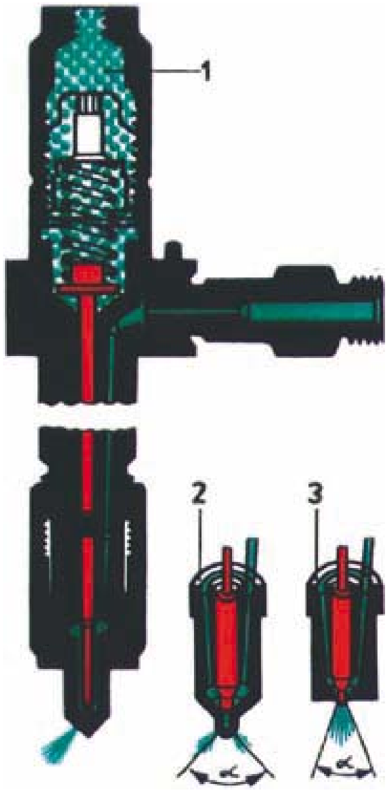

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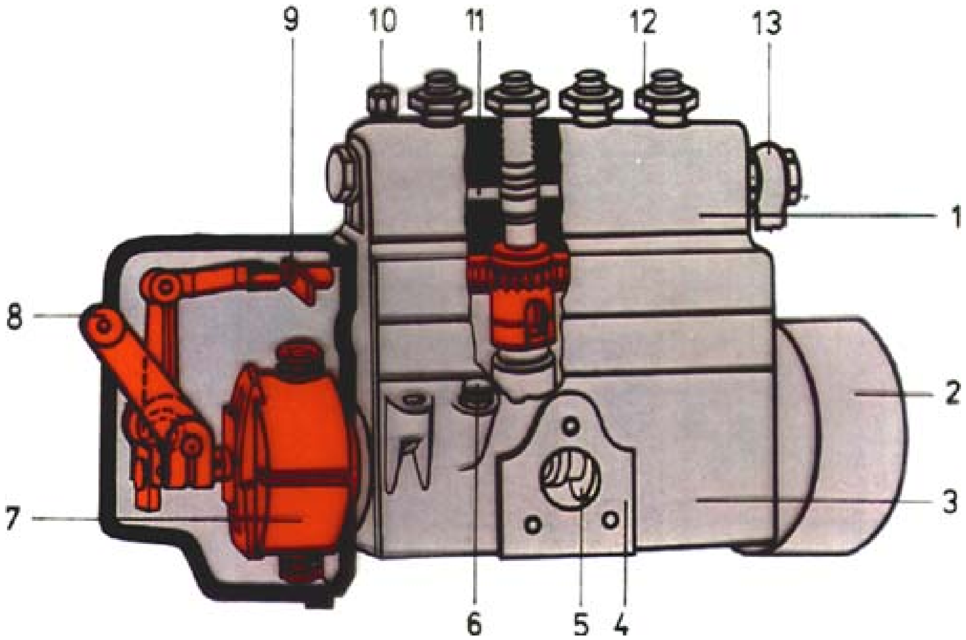

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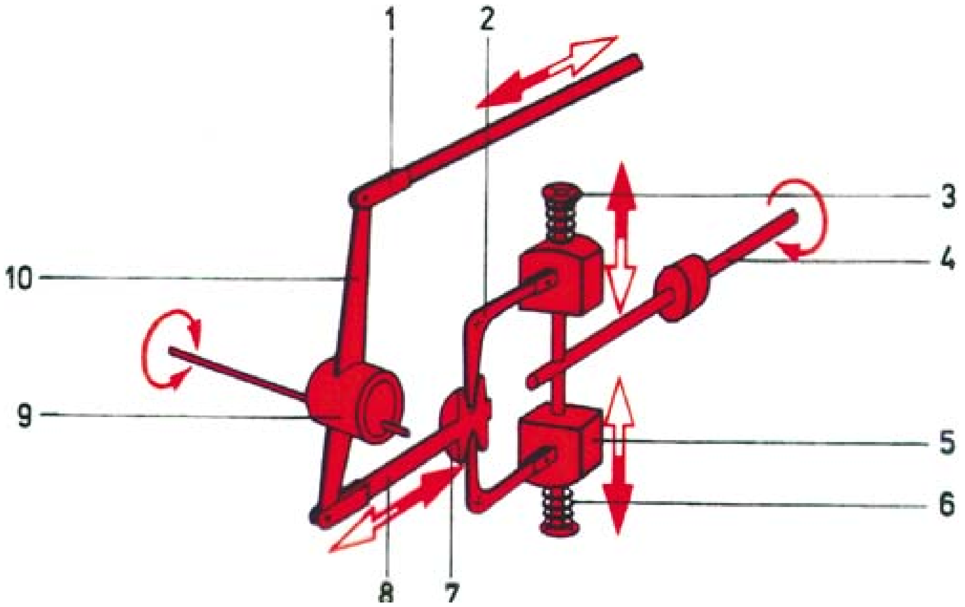

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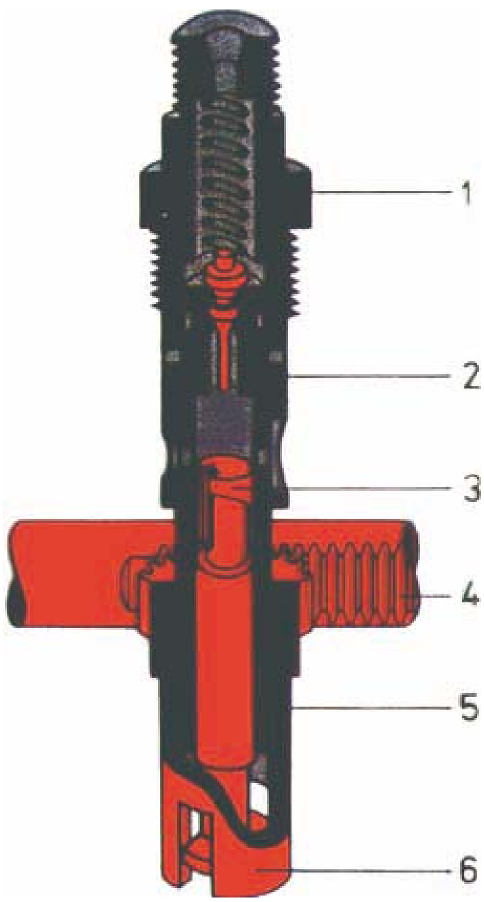

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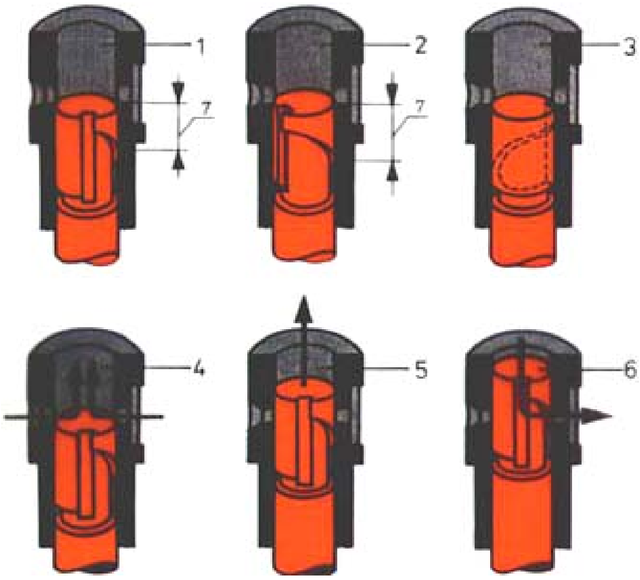

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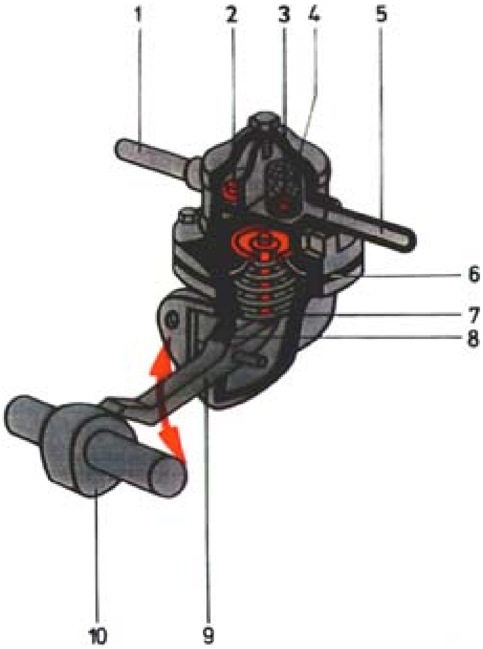

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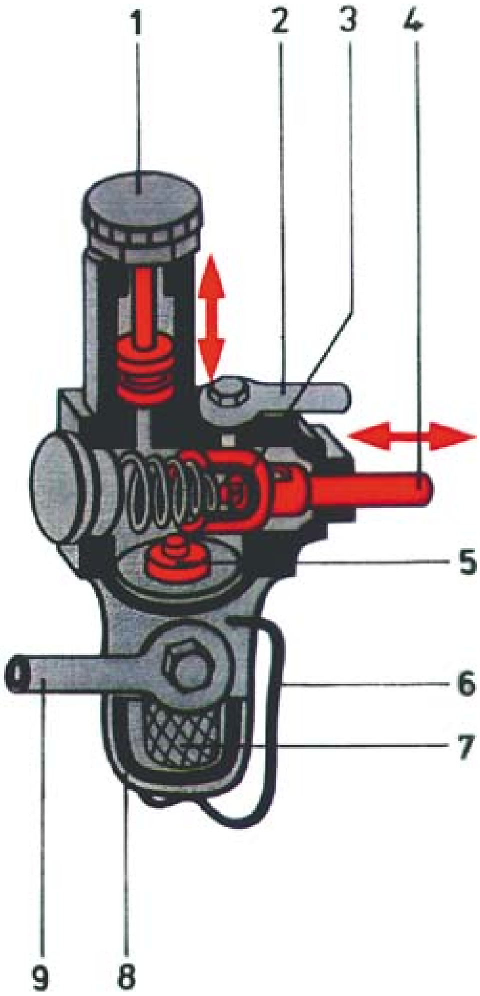

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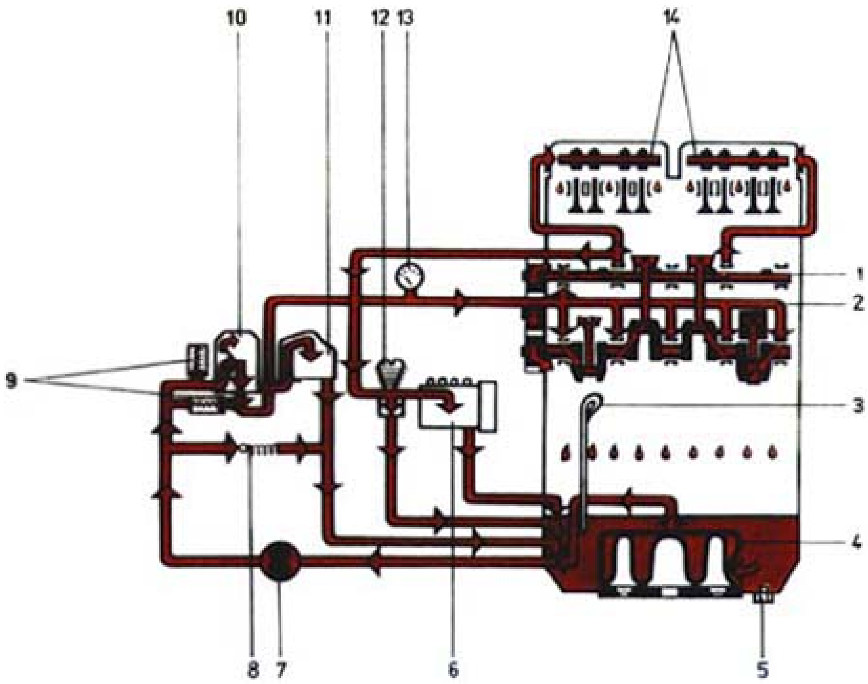

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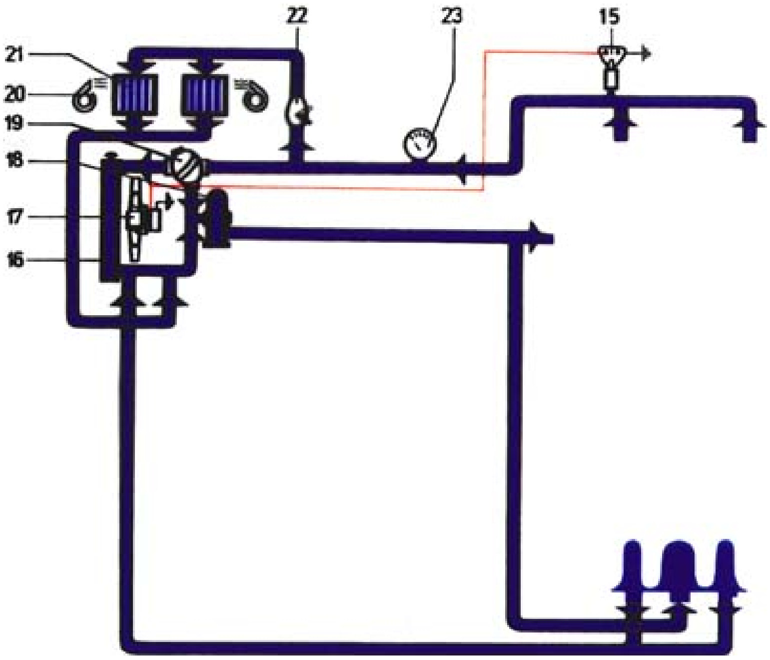

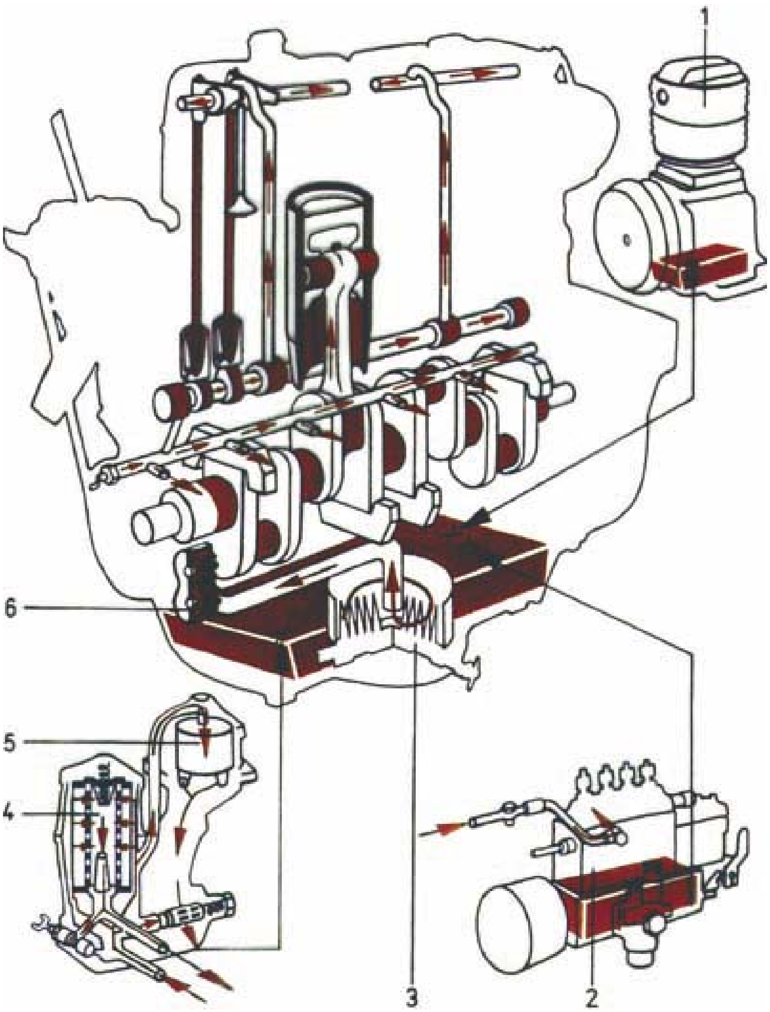

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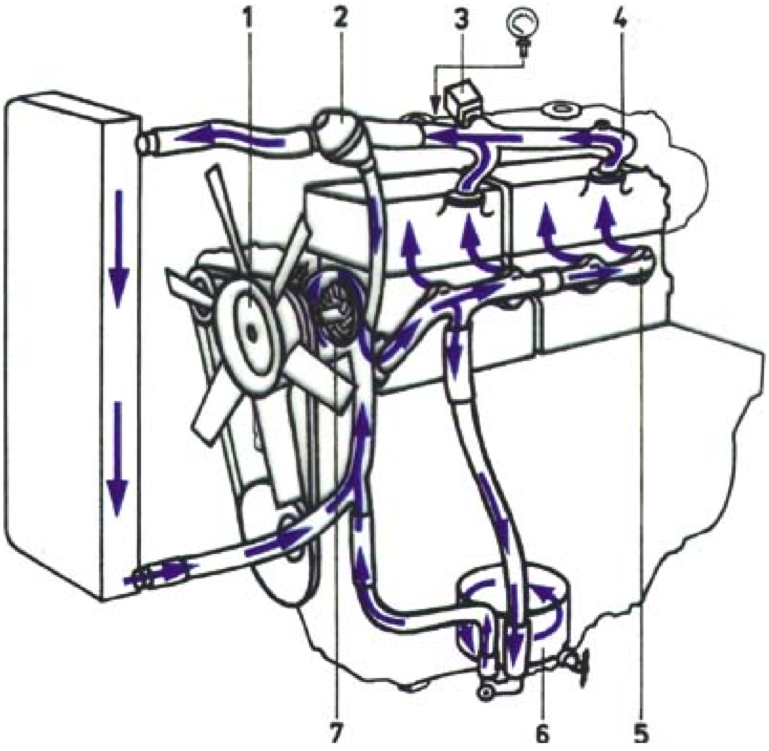

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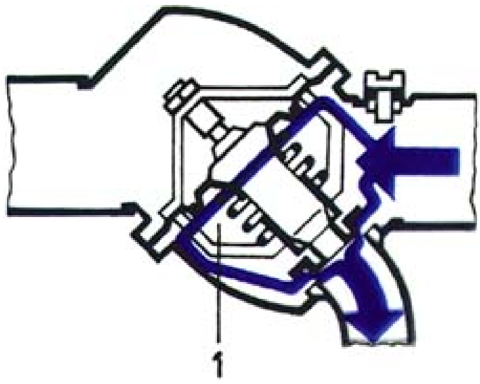

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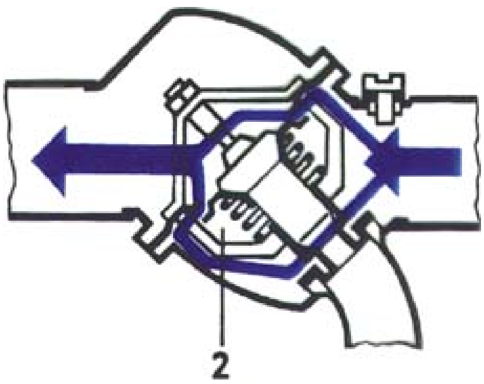

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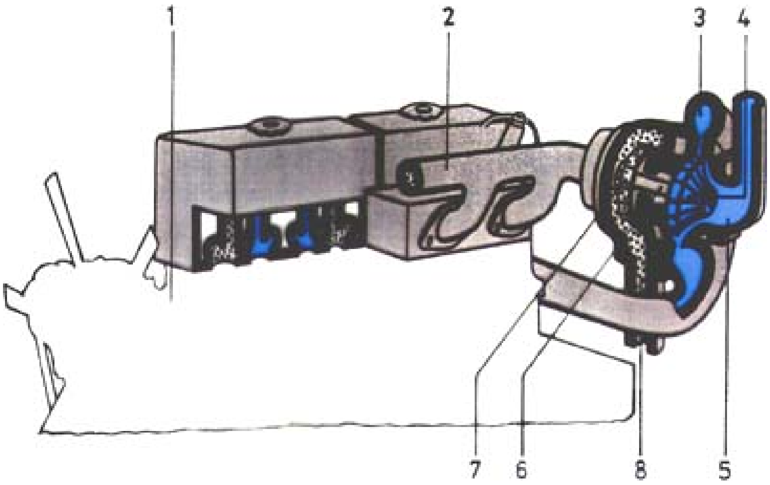

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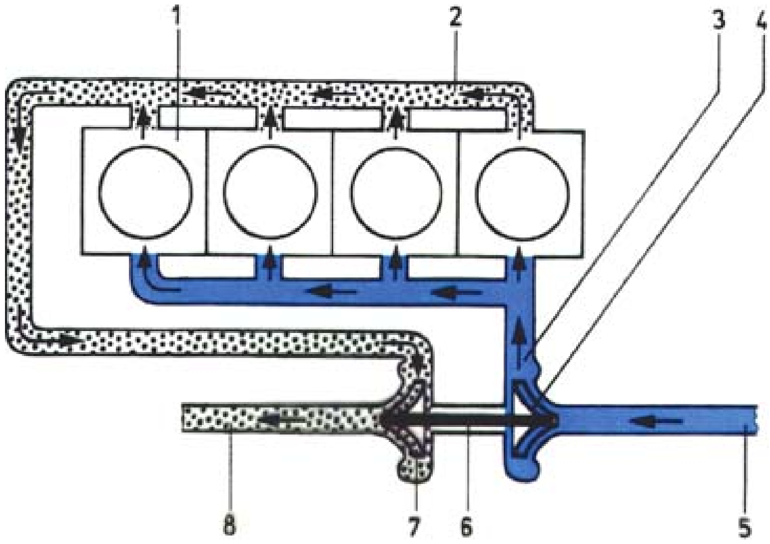

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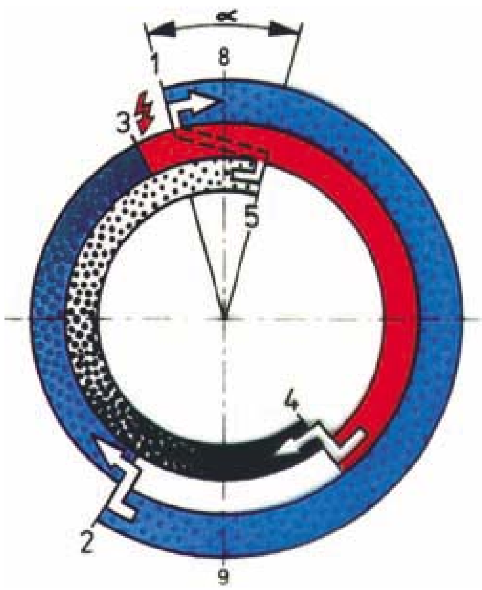

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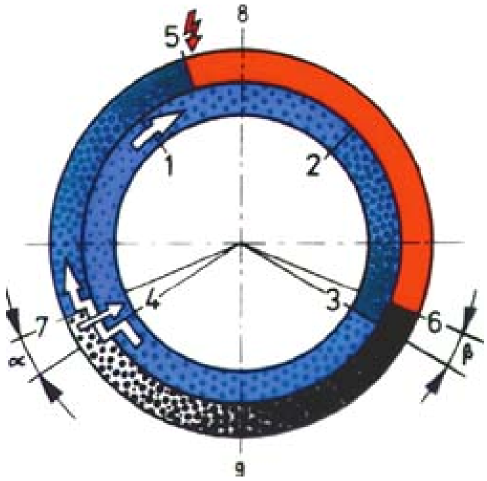
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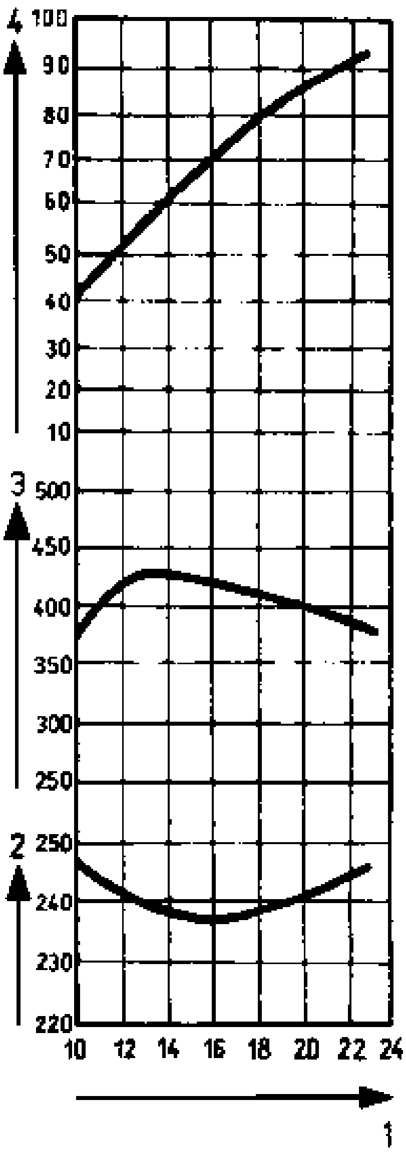
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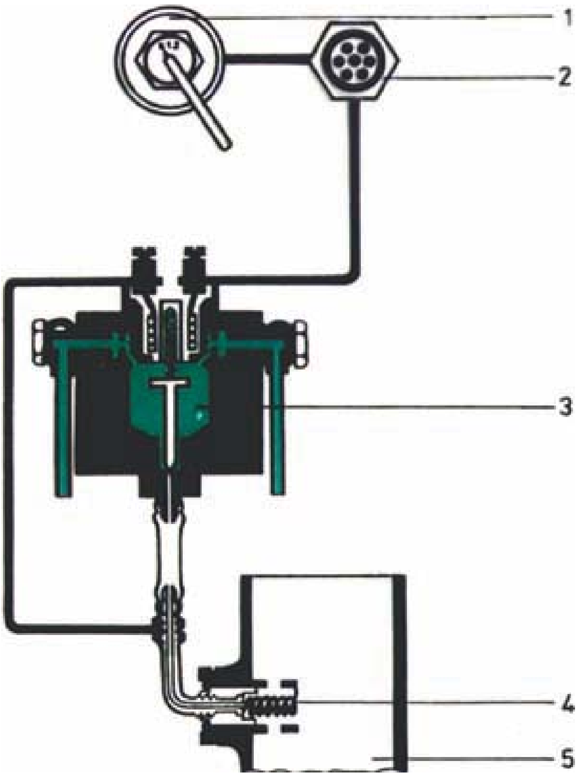

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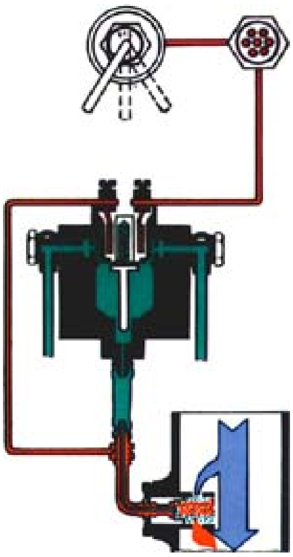

Mechanic Motor Vehicle 1st Year – Transparencies

Table of Contents

Mechanic Motor Vehicle 1st Year – Transparencies 1
Vernier Caliper parts and principle 1
Reading of Vernier Caliper 2
Micrometer parts and graduations 3
Micrometer reading 4
Wheel alignment 5
Tyre wear Patterns and causes 7
Clutch actuation (Hydraulic) 7
Types of gears 8
Function of Universal joint and slip joint 9
Hydraulic brakes 10
Relationship between piston and flywheel movement 12
Four Stroke cycle operation (petrol) 12
Four Stroke cycle operation (Diesel) 13
Two stroke cycle operation (Petrol) 14
Bore dial gauge–checking ovality and taper 15
Overhead valve operating mechanism 17
Cooling system 18
Fuel pump operation 19
Carburettor Function 20
Float and starting circuit 21
Idling and main circuit 22
Pump and Econostat circuit 23
Lubrication system (Engine oil circulation) 24
Lubrication system (full flow and by pass flow oil filter) 25
Ignition system 26

Mechanic Motor Vehicle 1st Year – Transparencies

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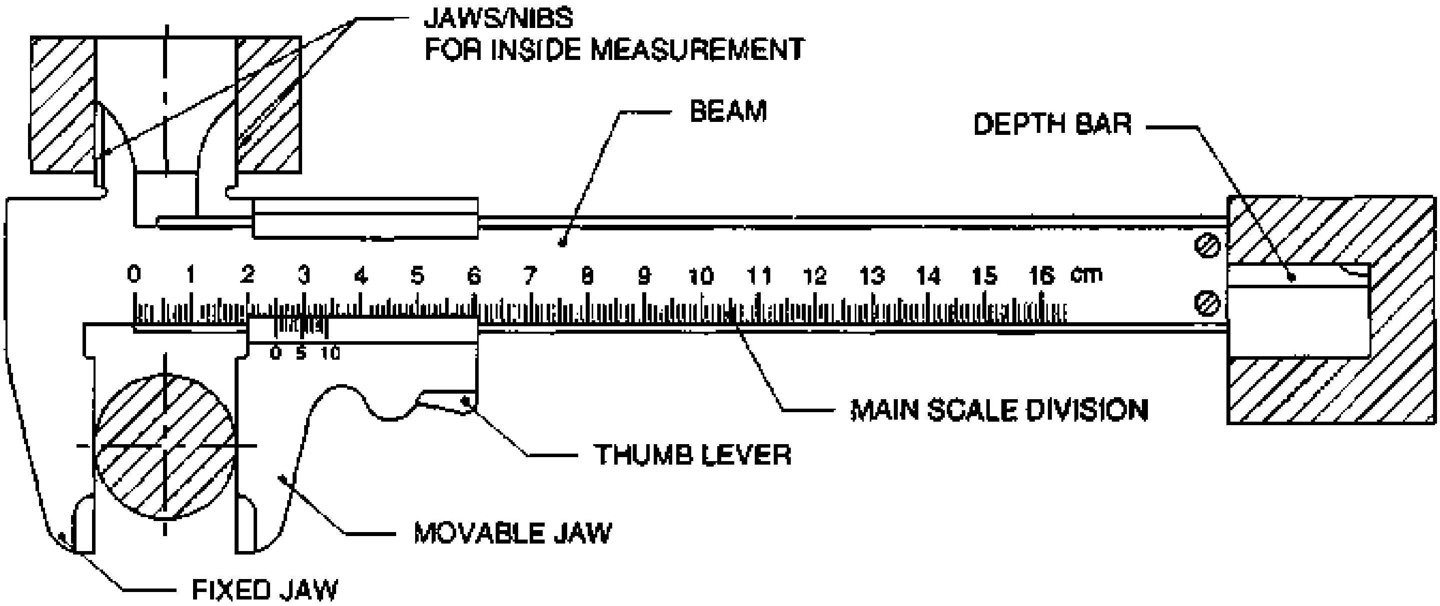
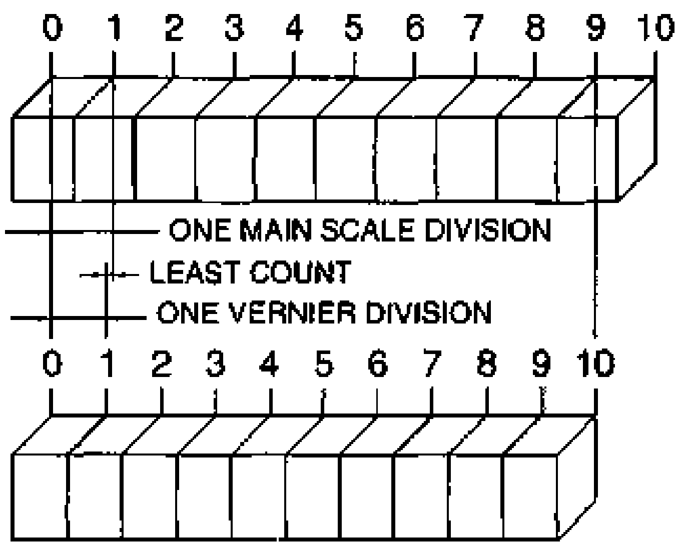
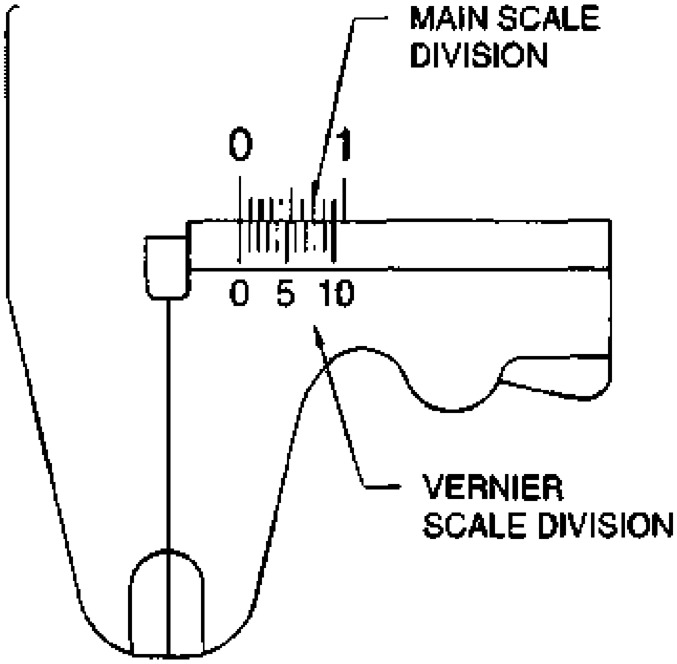
Vernier Caliper parts and principle

TR 01 02 01 01 95







Reading of Vernier Caliper

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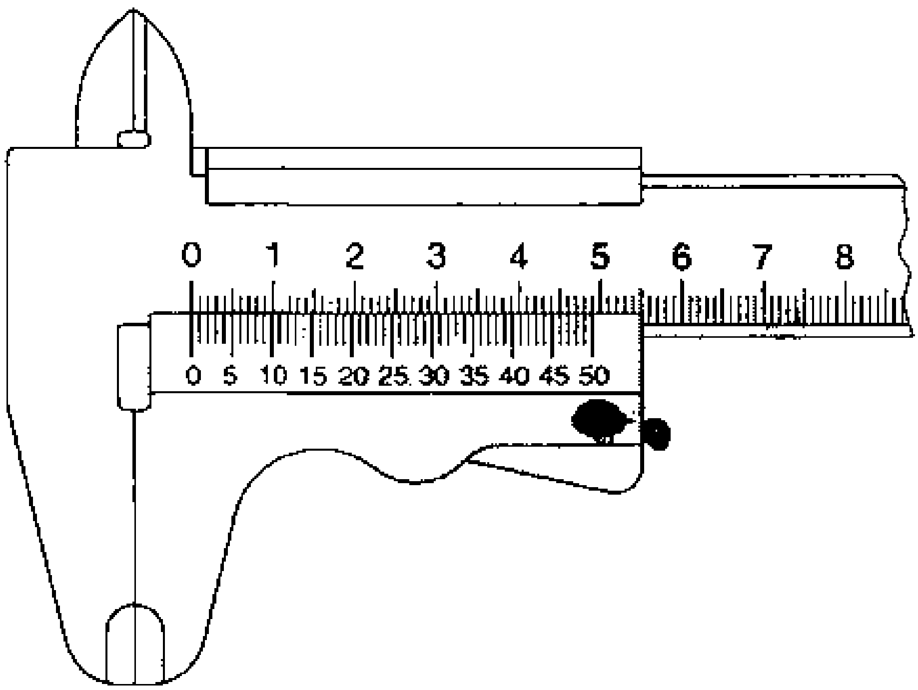


49 Main scale divisions are divided into 50 vernier scale divisions

$$\text{VALUE OF 1 VSD} = \frac{49}{50}\,\text{mm}$$

$$\text{LEAST COUNT} = 1\text{MD} - 1\text{VSD}$$

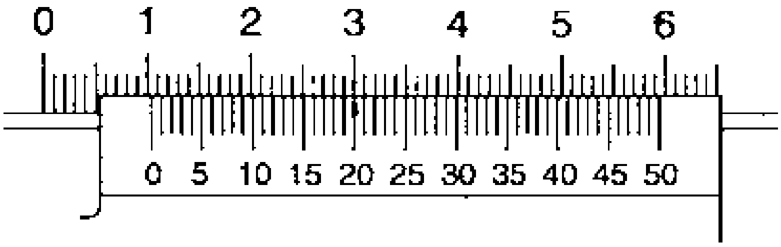
$$= 1 - \frac{49}{50}$$

$$= \frac{1}{50} = 0.02\,\text{mm}$$

MAIN SCALE READING = 10.00mm

VALUE OF COINCIDING VERNIER DIVISION = 00.40mm

READING = 10.40mm



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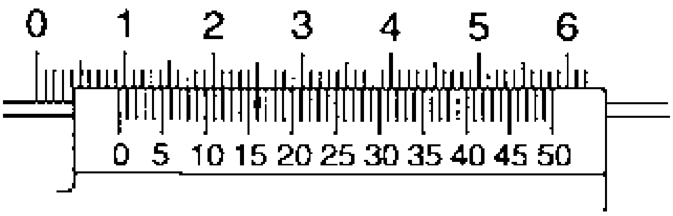
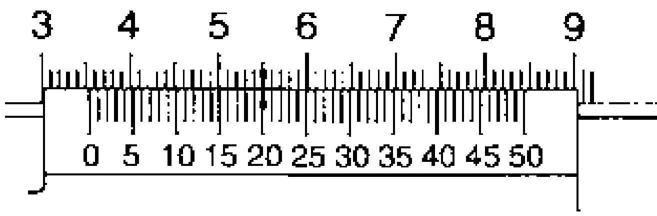
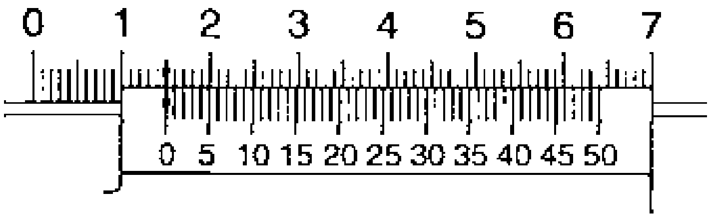


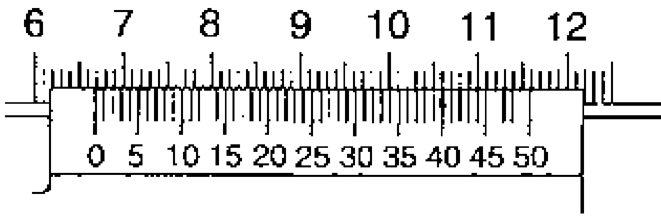
A READING 9.32 mm



B READING 35.40 mm



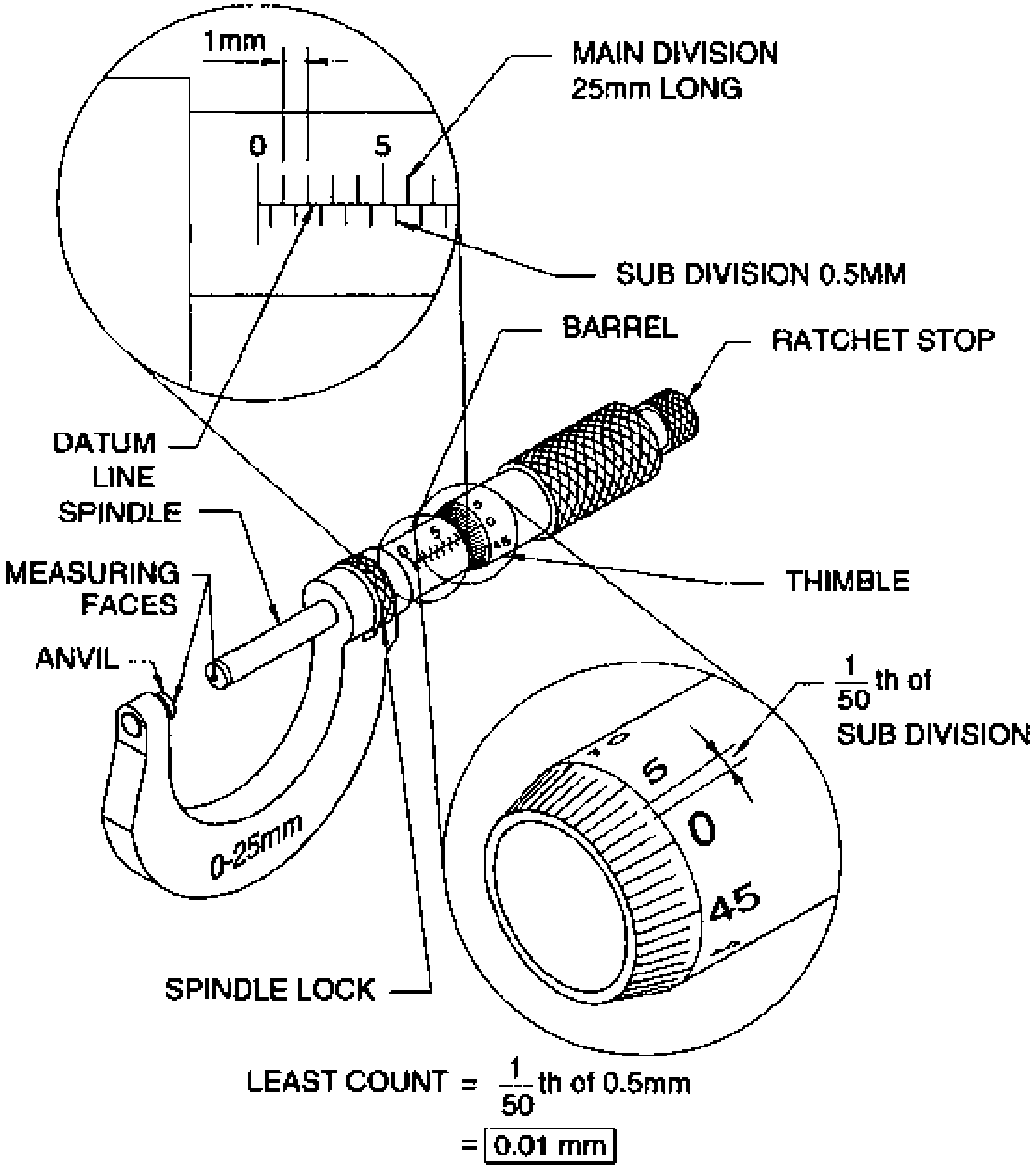
C READING 15.00 mm



D READING 66.80 mm

Micrometer parts and graduations

TR 01 02 02 01 95



Micrometer reading

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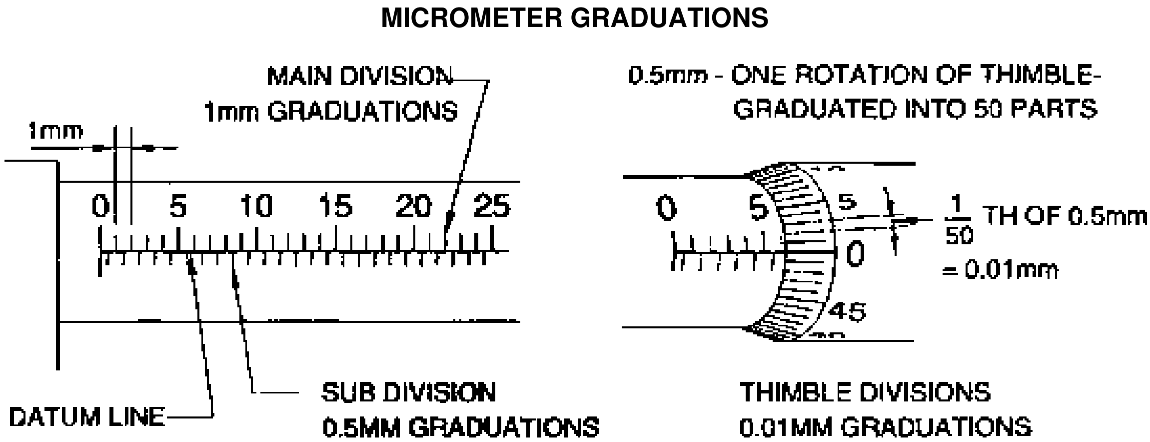

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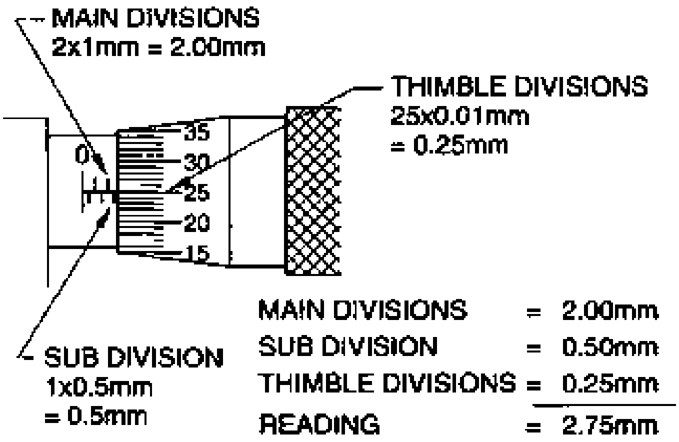
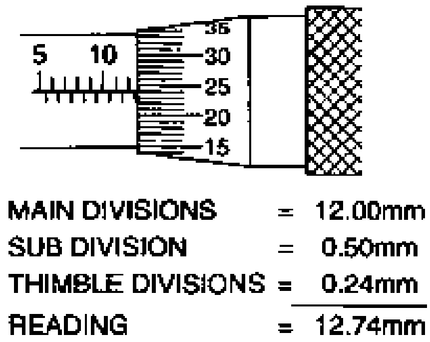


Example



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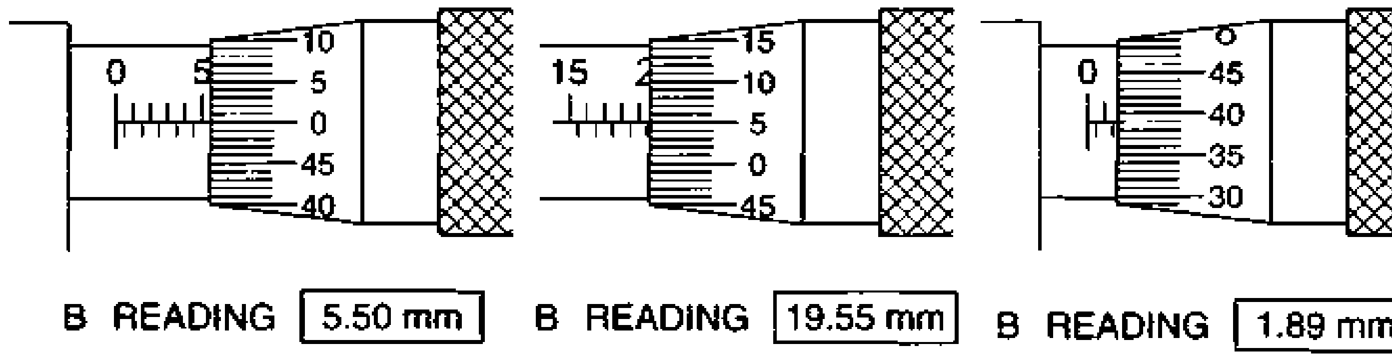
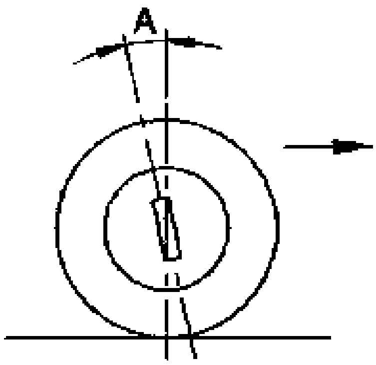
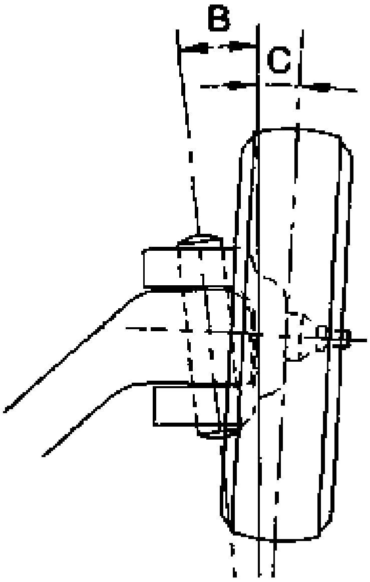


Wheel alignment

TR 10 09 04 01 95



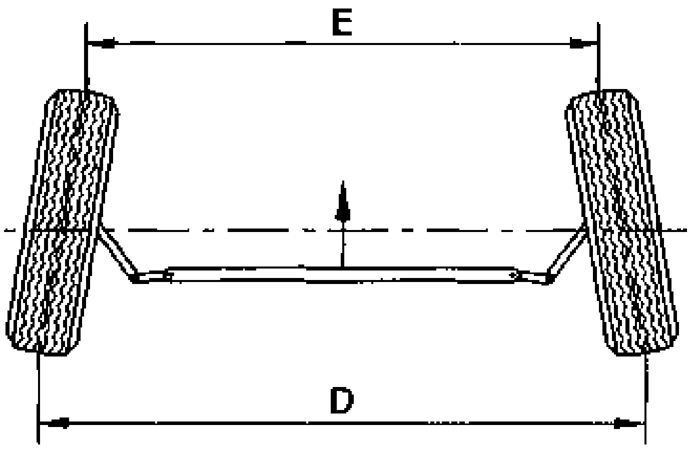
A = Caster angle



B King pin inclination

C Camber angle

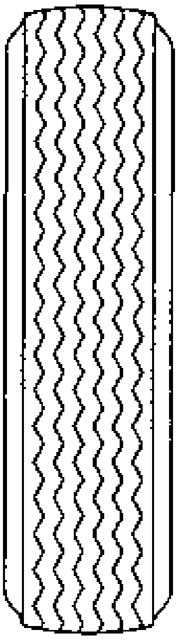
B+C= Included angle



D-E = Toe-in

Tyre wear Patterns and causes

TR 10 09 03 01 95



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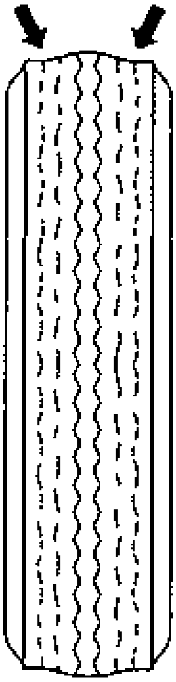

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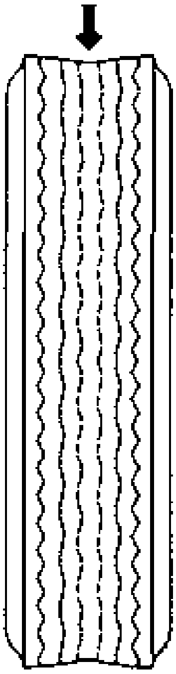

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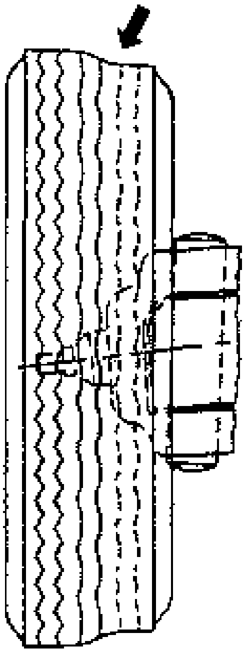

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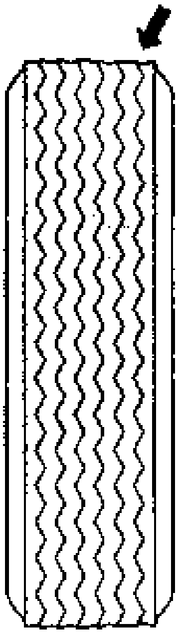

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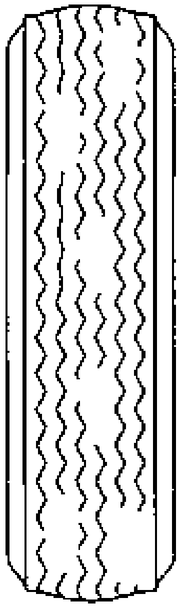
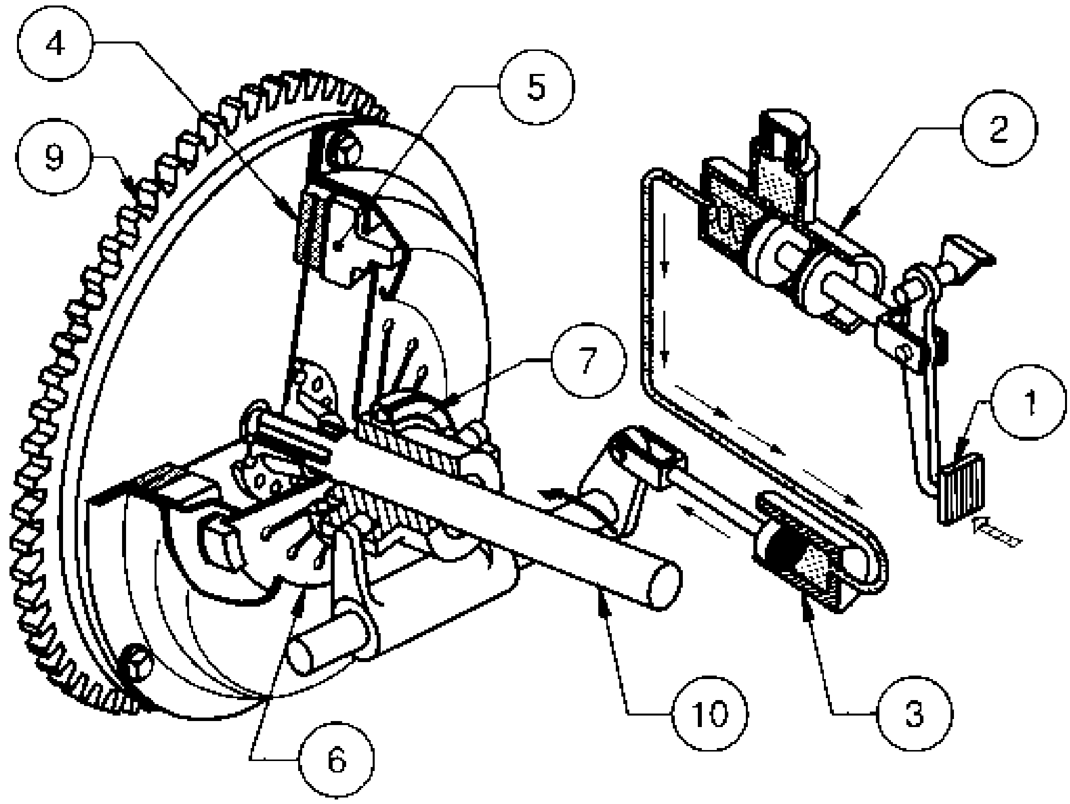


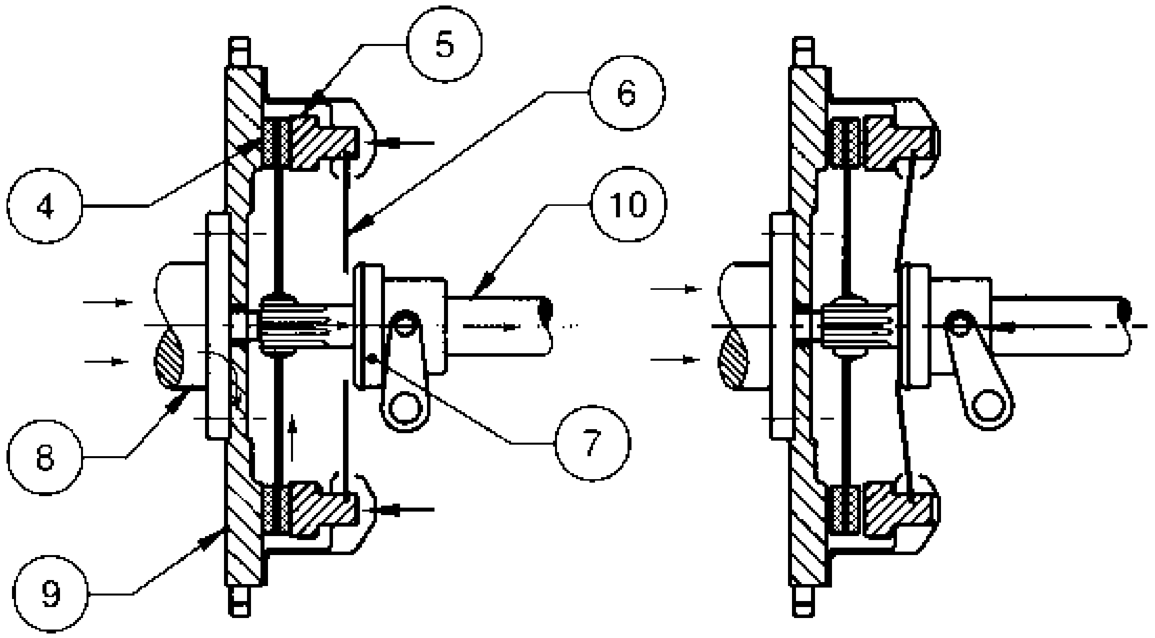
figure

WEAR PATTERN	IDEAL	At shoulders	At center	On one side	Feathered edge	Bald spots
CAUSE	PERFECT CONDITION	Under inflation	Over inflation	Excessive camber	Incorrect toe	Unbalanced wheel

Clutch actuation (Hydraulic)

TR 10 02 06 01 95



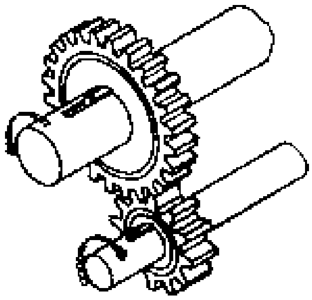


Action: The diaphragm spring **(6)** pushes the pressure plate **(5)** against the clutch plate **(4)**. Power flows from crankshaft **(8)** ' flywheel **(9)** ' pressure plate **(5)** ' clutch plate **(4)** ' and to primary shaft **(10)**

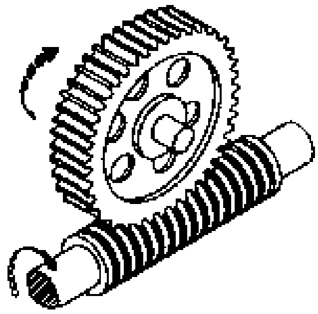
Action: The downward movement of the clutch pedal **(1)** pumps fluid from the master cylinder **(2)** to the slave cylinder **(3)** and pushes the release bearing **(7)** and the diaphragm **(6)** inwards. The pressure plate **(5)** and the clutch plate **(4)** move away from the flywheel **(9)**. No power flows from the crankshaft **(8)** to the primary shaft **(10)**

Types of gears

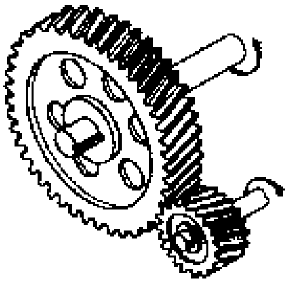
TR 10 03 07 01 95



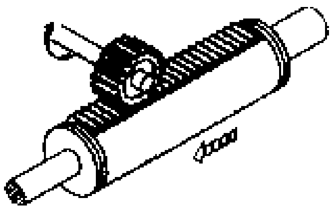
Spur Gears
Teeth are straight and parallel
Only one tooth is in contact at a time.
There is no axial thrust
APPLICATION – Gear box



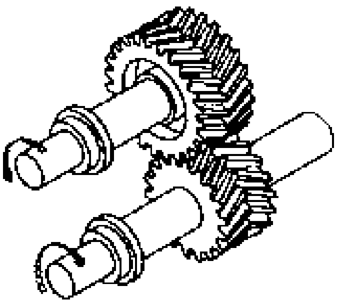
Worm Gears
Teeth are at an angle and curved
More teeth are in contact at a time
There is axial thrust
APPLICATION – Gear box.



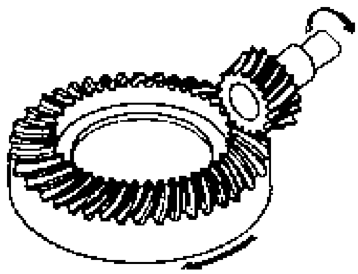
Helical gears
Teeth are at an angle
More teeth are in contact at a time
There is axial thrust
APPLICATION – Gear box.



Rack and Pinion
Teeth are parallel
Only one tooth is in contact at a time
There is no axial trust.
Converts rotary motion into linear motion.
APPLICATION – Steering



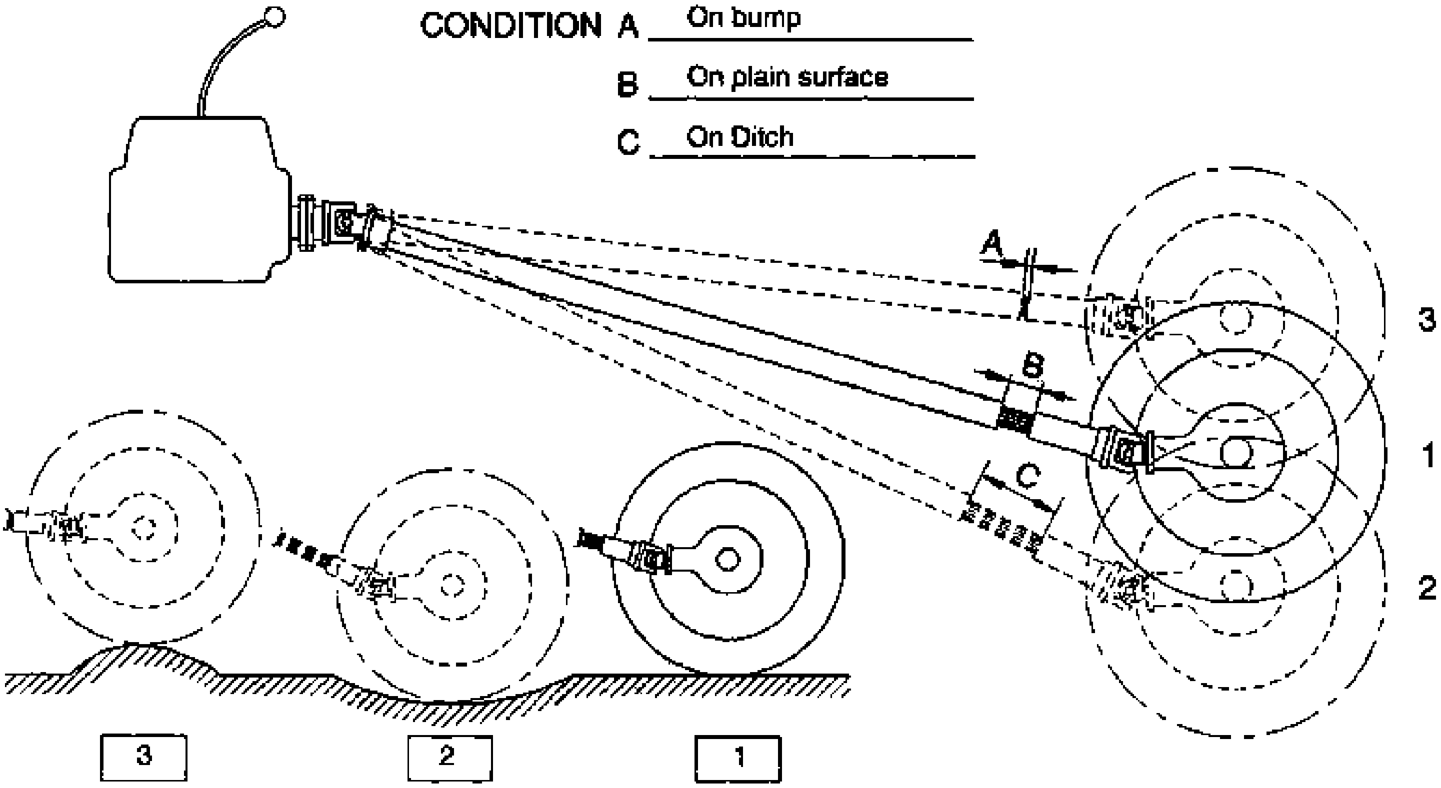
Herring Bone Gears
Teeth are straight at an angle
More teeth are in contact at a time
Axial thrust is neutralized
APPLICATION – Gear box



Spiral Bevel Gears
Teeth are curved
More teeth are in contact at a time
Produces axial thrust
Transmits torque at 90°
APPLICATION – Final drive differential

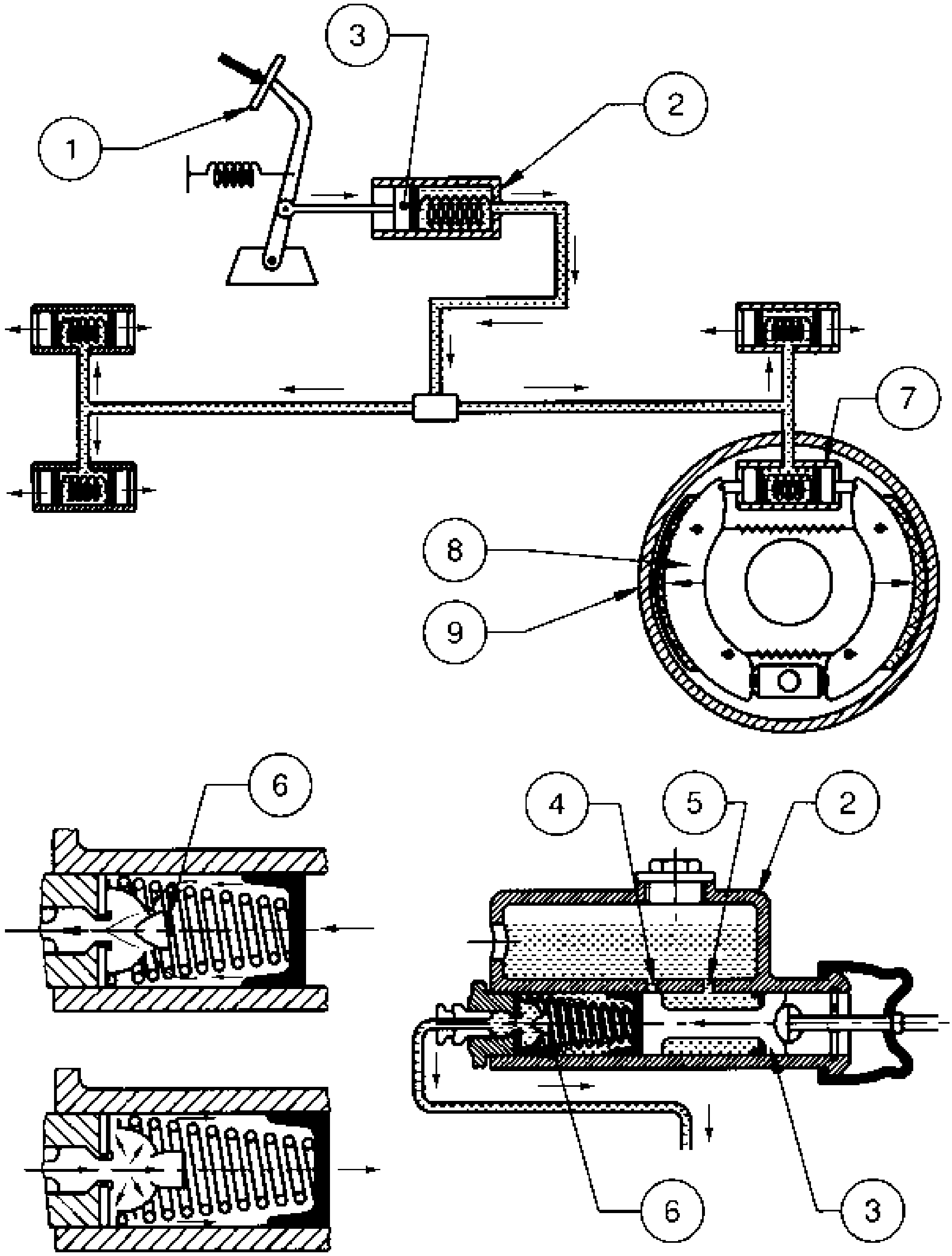
Function of Universal joint and slip joint

TR 10 05 02 01 95



Hydraulic brakes

TR 10 11 02 01 95



When the brake pedal **(1)** is pressed, the push rod forces the piston **(3)** of the Master Cylinder **(2)** forward against the spring tension. The primary cup covers compensating port **(4)**. The pressurised fluid is supplied to the wheel cylinders **(7)** through the non return check valve **(6)**. The wheel cylinder piston pushes the brake shoes **(8)** towards the brake drum **(9)** and stops the rotation of the brake drum.

When the brake pedal **(1)** is released, the pedal comes to its original position with the help of the pedal return spring and shoes by the retracting springs. Wheel cylinder pistons are pushed inside and the fluid is sent back to master cylinder **(2)** by lifting the check valve **(6)** from its seat through the compensating port **(4)** and the transfer port **(5)**.

Relationship between piston and flywheel movement

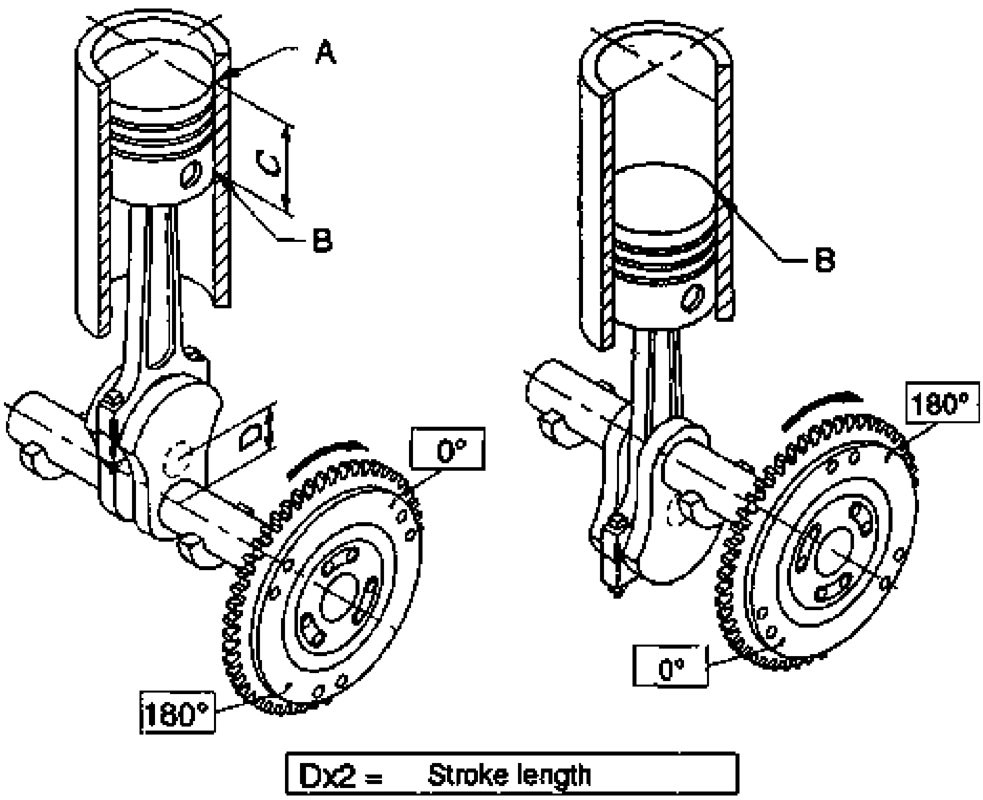
TR 10 01 01 01 95

A Top Dead center (T.D.C)

B Bottom Dead Center (B.D.C.)

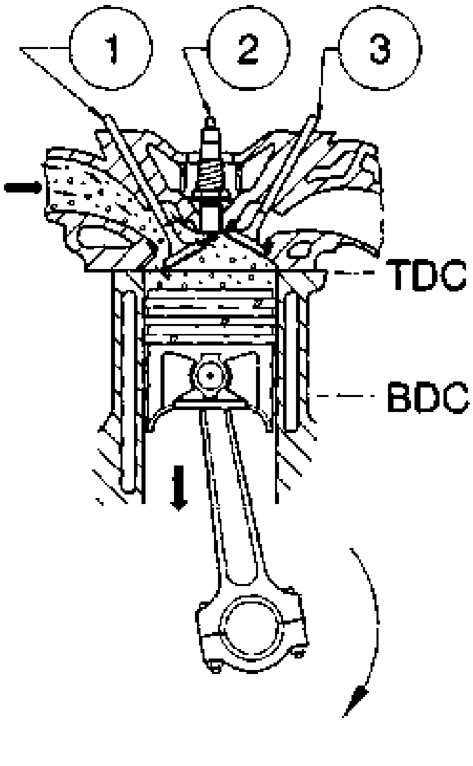
C Stroke length

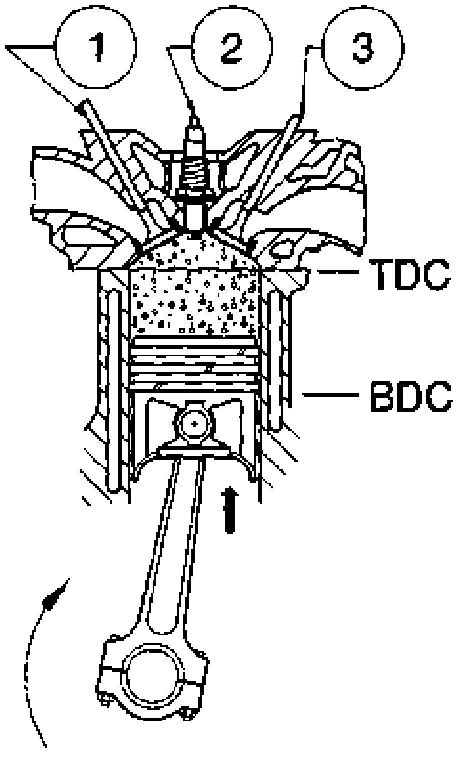
D Crank throw

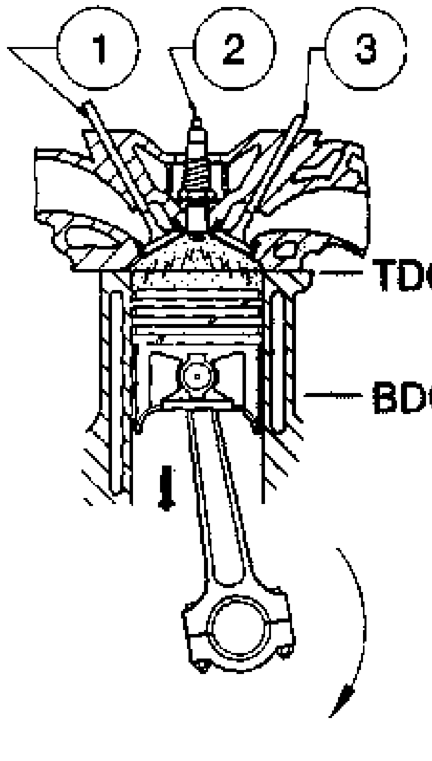


Four Stroke cycle operation (petrol)

TR 10 01 01 02 95



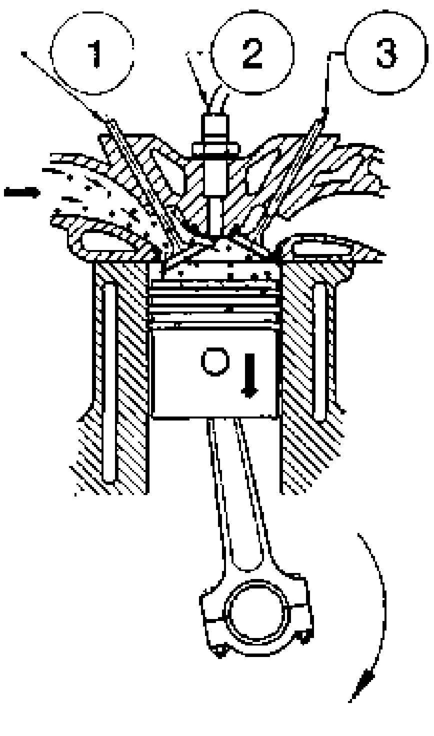


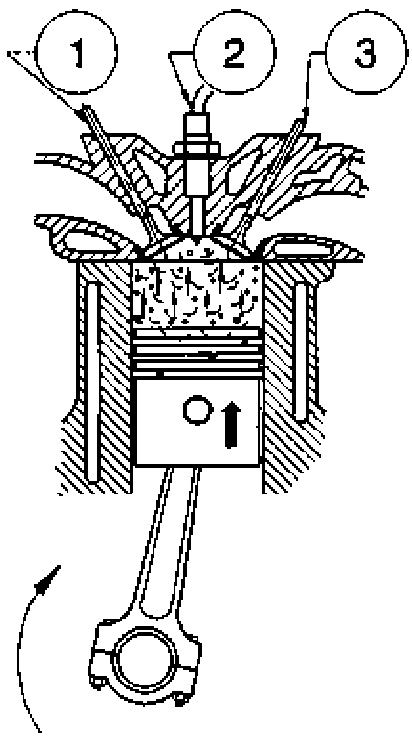


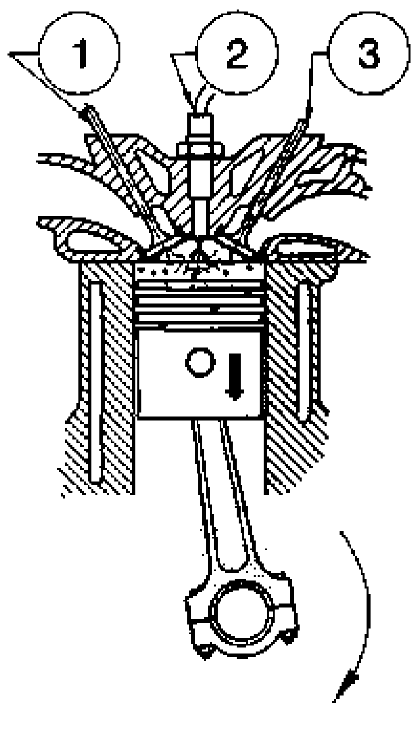
A – Suction Stroke	B – Compression Stroke	C – Power Stroke
Action: Inlet valve **(1)** opens and air fuel mixture enters inside the cylinder.	**Action**: Inlet valve **(1)** and exhaust valve **(3)** are closed. Air fuel mixture is compressed.	**Action**: Valves **(1)** and **(3)** are closed. Spark from the spark plug **(2)** ignites the mixture. Piston is forced down by th burnt gases.

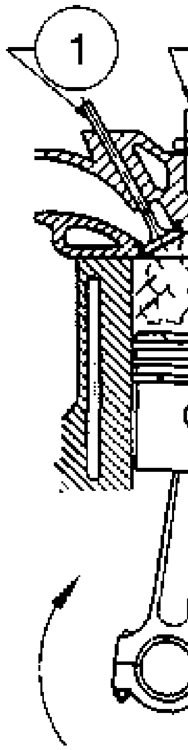
Four Stroke cycle operation (Diesel)

TR 10 01 01 03 95



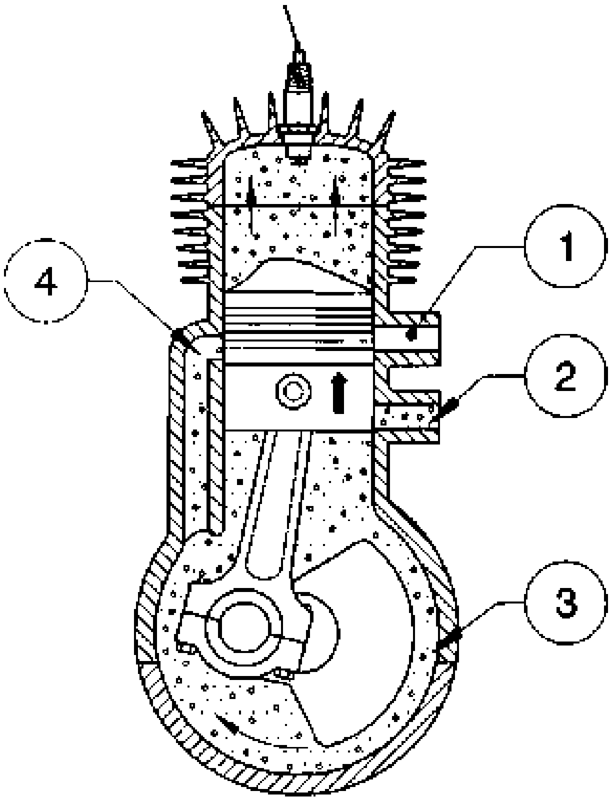
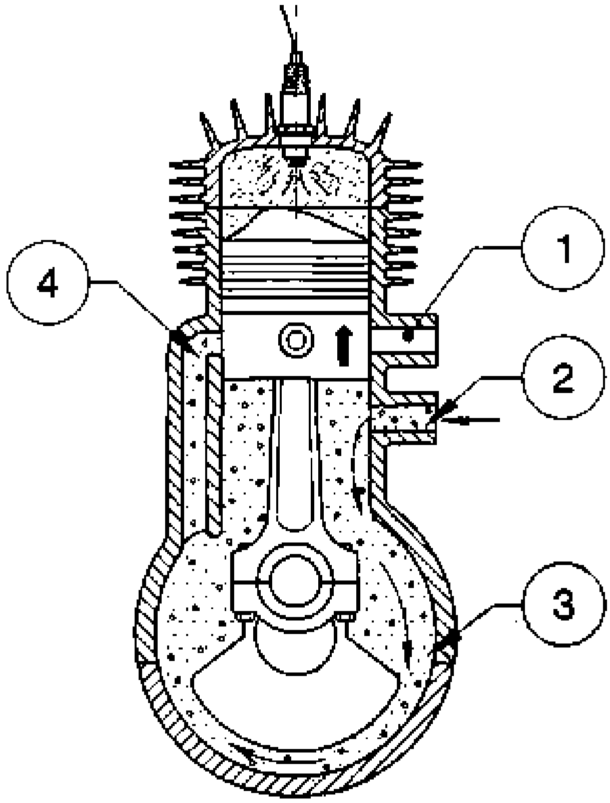
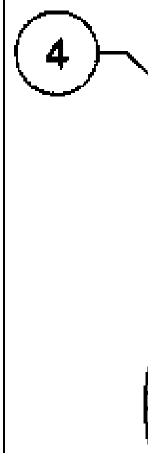




			
A – Suction Stroke	**B – Compression Stroke**	**C – Power Stroke**	**D – Exhaust St**
Action: Inlet valve **(1)** opens and only air enters inside the cylinder.	**Action**: Inlet valve **(1)** and exhaust valve **(3)** are closed. Air is compressed.	**Action**: Valves **(1)** & **(3)** are closed and Injector **(2)** sprays diesel. Diesel is ignited by hot compressed air. Piston is forced down by burnt gases.	**Action**: Exhaust valve (gases are force cylinder.

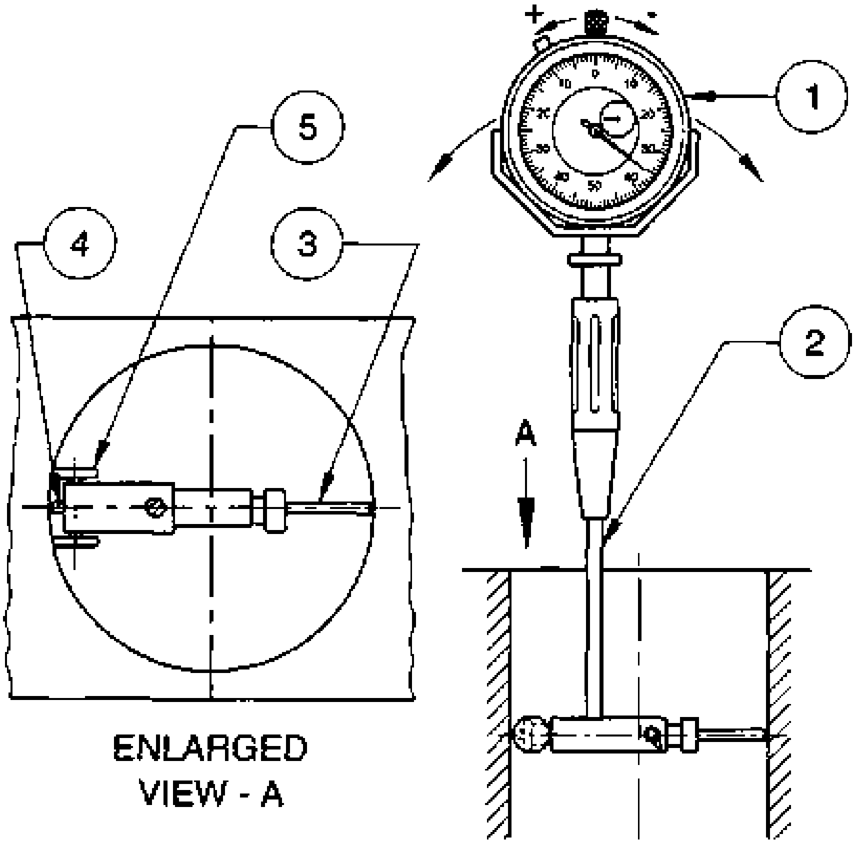
Two stroke cycle operation (Petrol)

TR 10 01 01 04 95

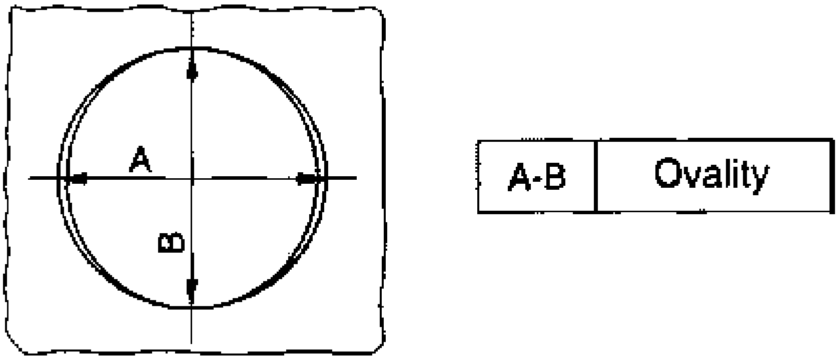
		
A – Begining of Compression Stroke	**B – Suction and Compression Stroke**	**C – Power**
Action: All the ports **1**,**2** & **4** are closed. Air fuel mixture is compressed above the piston.	**Action**: Inlet port **(2)** opens and the charge goes inside crank case **(3)**. Charge above the piston is compressed and ignited.	**Action**: Piston is for port **(1)** ope the charge

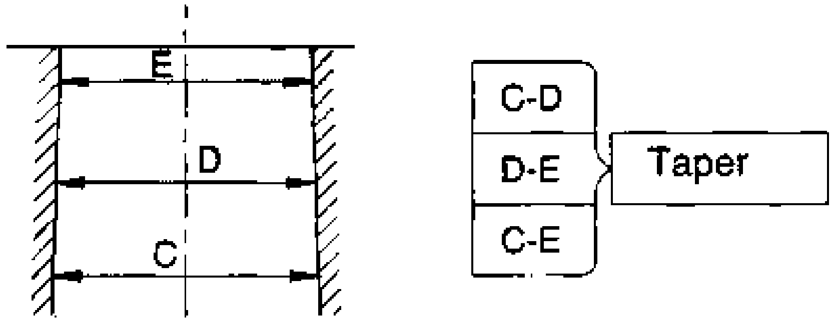
Bore dial gauge–checking ovality and taper

TR 10 01 08 01 95



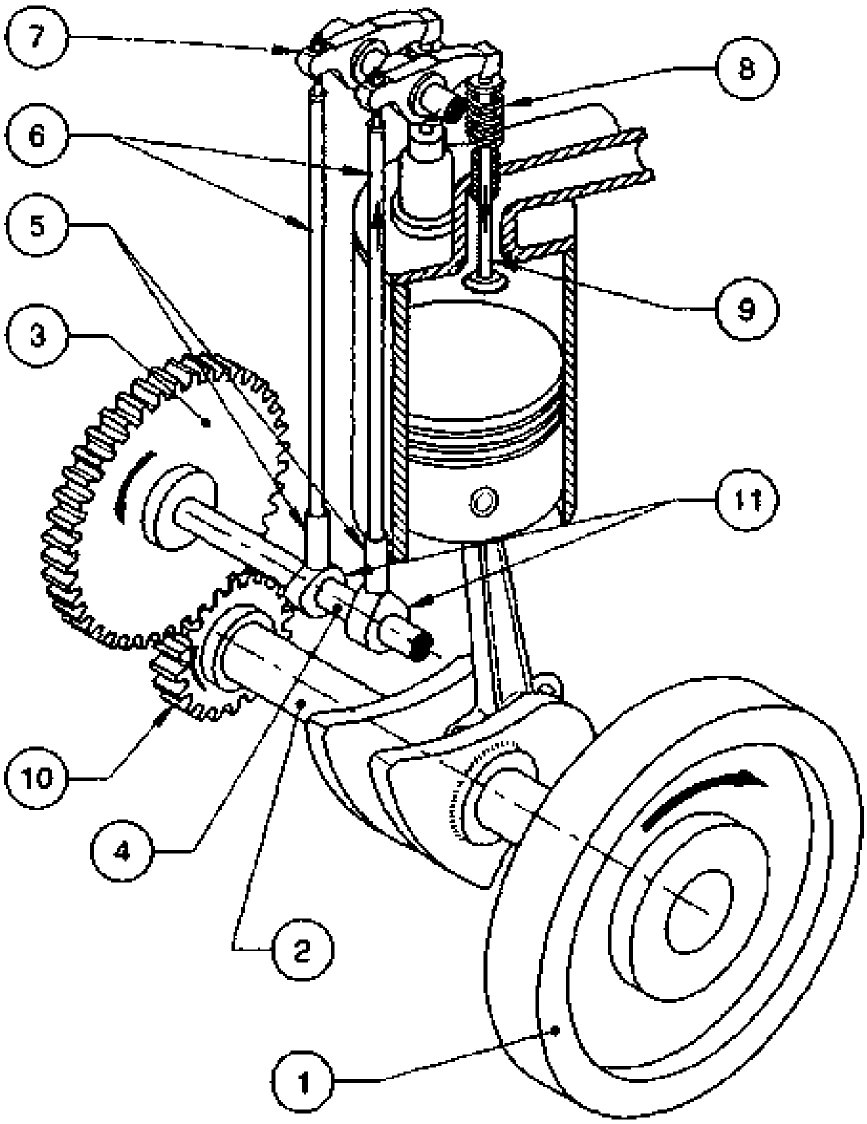
1. Dial
2. Stem
3. Extension Rod
4. Plunger
5. Guide shoe





Overhead valve operating mechanism

TR 10 01 01 05 95



Crankshaft Gear (10)	21 teeth
Camshaft Gear (3)	42 teeth

The flywheel **(1)** rotates in clock–wise direction.

The crankshaft **(2)** and the gear **(10)** also rotate in clockwise direction.

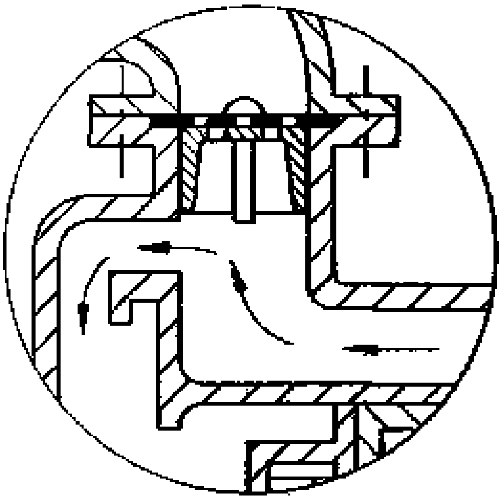
The camshaft gear **(3)** and the camshaft **(4)** rotate in the anti–clockwise direction at half of the crankshaft speed.

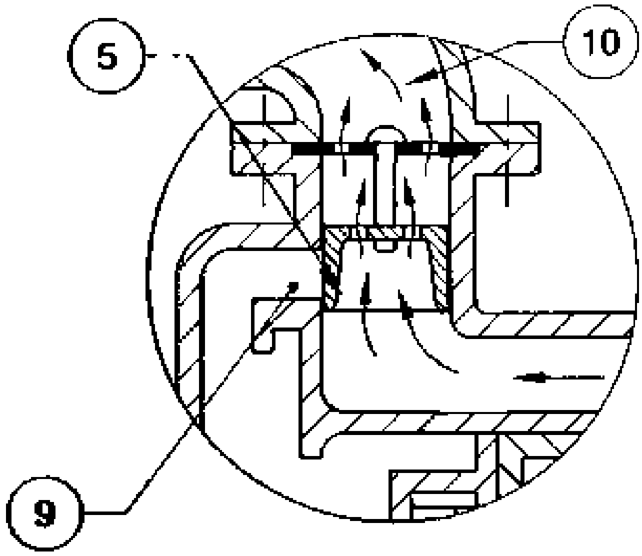
The eccentricity of the cam lobe **(11)** pushes the tappet **(5)** and the push rod **(6)** in upward direction. The push rod **(6)** pushes the rocker lever **(7)**.

The rocker lever **(7)** swivels and the valve **(9)** is opened against the pressure of the spring **(8)**.

Cooling system

TR 10 01 07 01 95



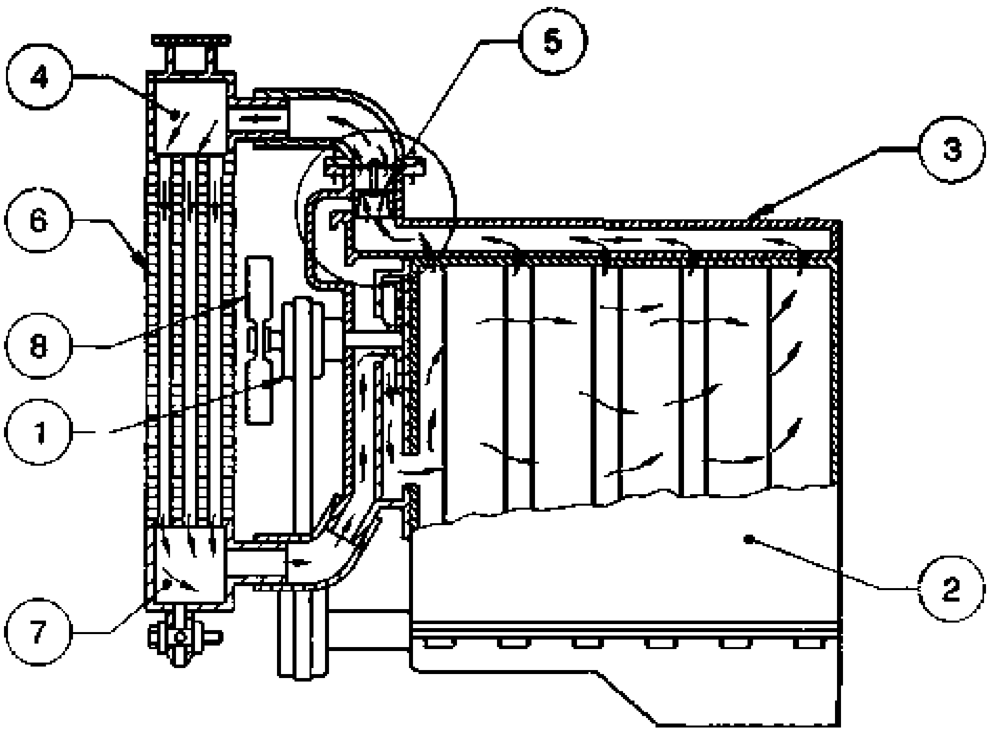


Engine cold

When the thermostat **(5)** is closed the by–pass port **(9)** opens and water circulates in the engine itself and warms up quickly.

Engine hot

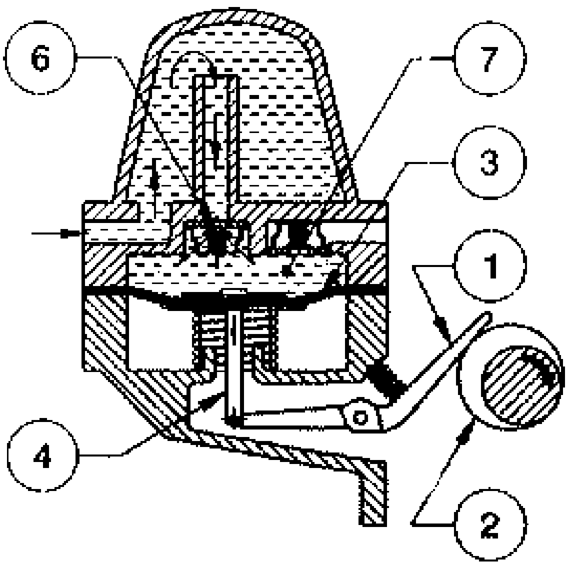
When the thermostat **(5)** is opened, the by–pass port **(9)** closes. Water is circulated to the radiator through outlet **(10)**



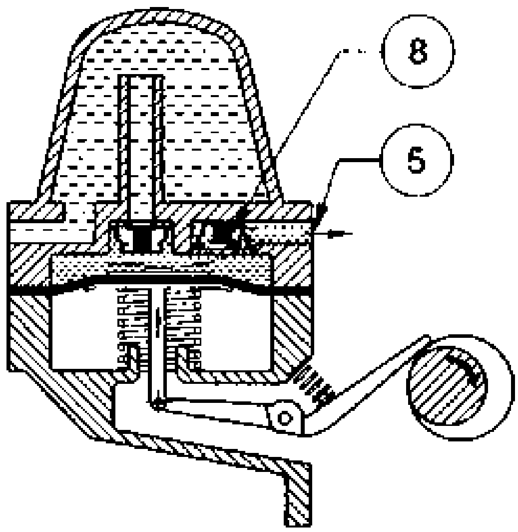
Water flows from pump **(1)** ' Engine block **(2)** ' Cylinder head **(3)** ' radiator uppertank **(4)** through thermostat **(5)** ' Radiator core **(6)** ' Lower tank **(7)** ' and to water pump **(1)**. Air passes through the radiator cores with the help of a fan **(8)**

Fuel pump operation

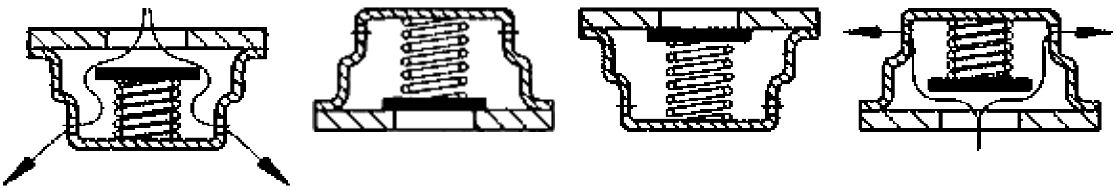
TR 10 01 02 01 95



Suction



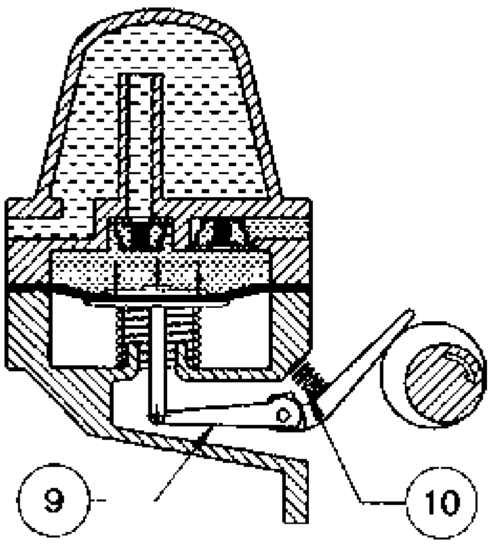
Delivery



DETAILS: 6 8 6 8

When the rocker arm **(1)** is actuated by a cam lobe **(2)**, diaphragm **(3)** is pulled down. The inlet valve **(6)** opens and the fuel is sucked in chamber **(7).**

When the diaphragm is pushed up by the spindle **(4)**, the outlet valve **(8)** opens and the fuel is sent to carburetor via outlet **(5).**

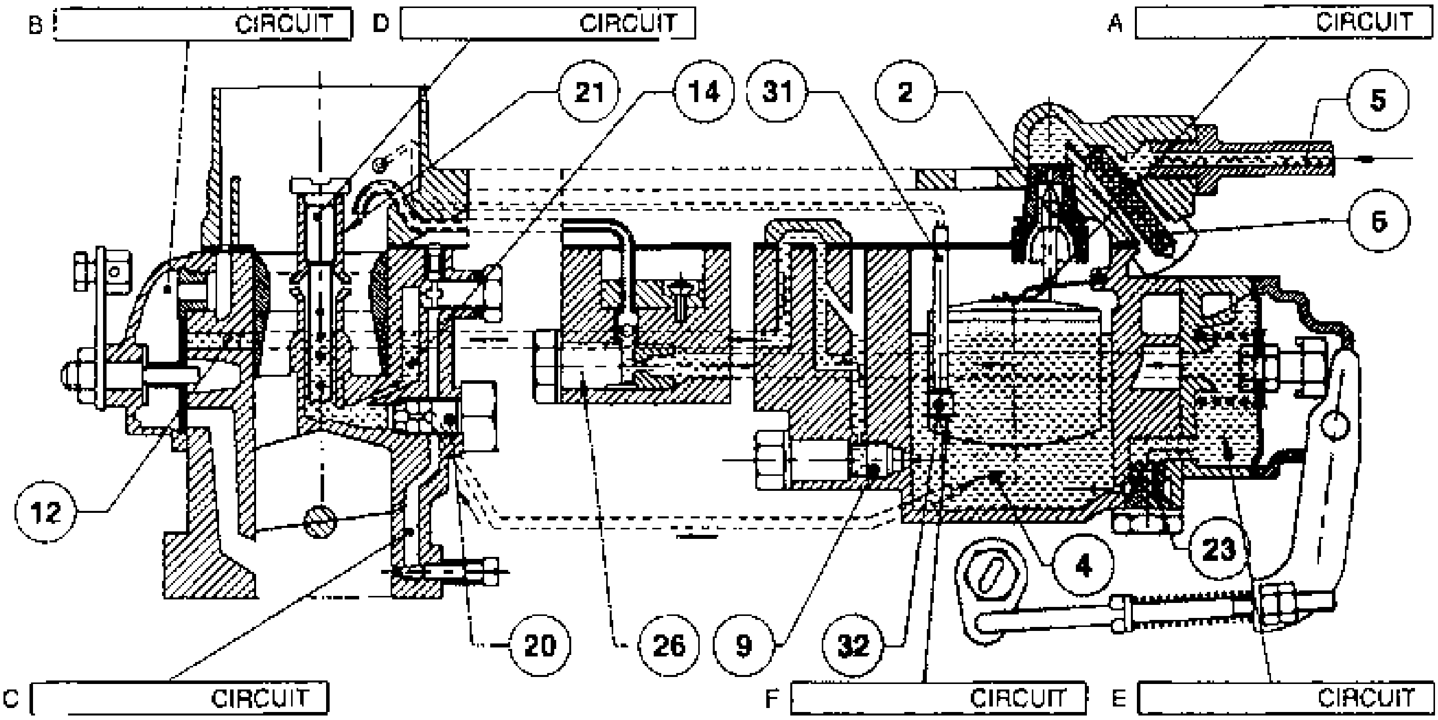


Idling

When the float chamber is full, back pressure keeps the diaphragm **(3)** down and the connecting link **(9)** does not move, only the rocker arm **(1)** moves. The spring **(10)** reduces the rattling noise.

Carburettor Function

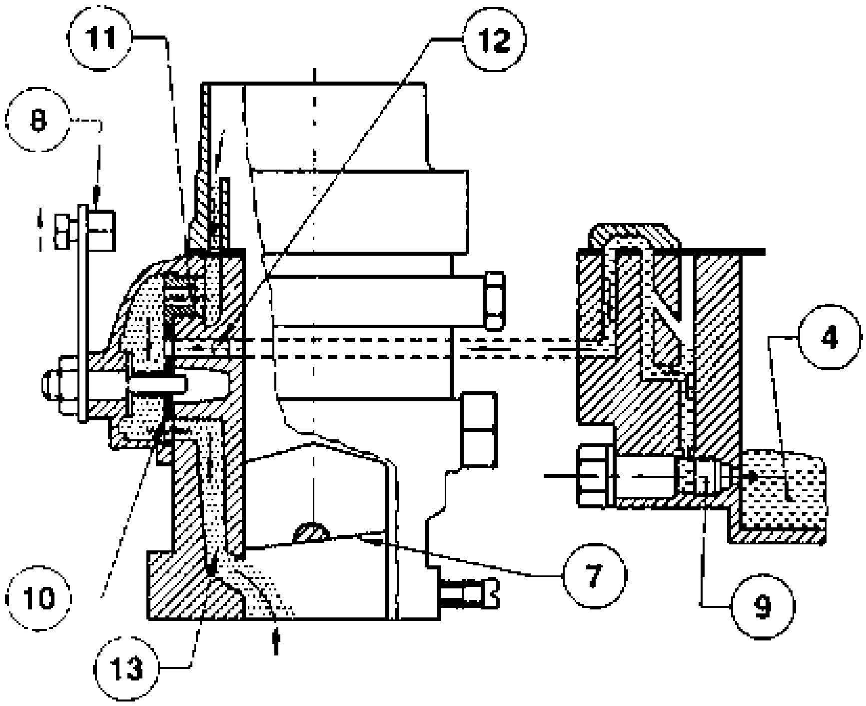
TR 10 01 02 02 95



A	**Float circuit:**	When the needle valve **(2)** opens, fuel flows to the float chamber **(4)** through the inlet **(5)** and filter **(6)**.
B	**Starting circuit:**	Petrol is drawn from the float chamber **(4)** through the starter jet **(9)** to the passage **(12)**.
C	**Idling circuit:**	Petrol is drawn to the well **(14)** from the float chamber **(4)** through the main jet **(20)**
D	**Main circuit:**	Petrol is drawn from the float chamber **(4)** to the emulsion tube **(21)** through the main jet **(20)**
E	**Pump circuit:**	Petrol is drawn from the float chamber **(4)** to the pump chamber through the pump inlet valve **(23)** and to the pump jet **(26)**
F	**Econostat circuit**:	Petrol is drawn from the float chamber **(4)** to the econostat tube **(31)** through the jet **(32)**

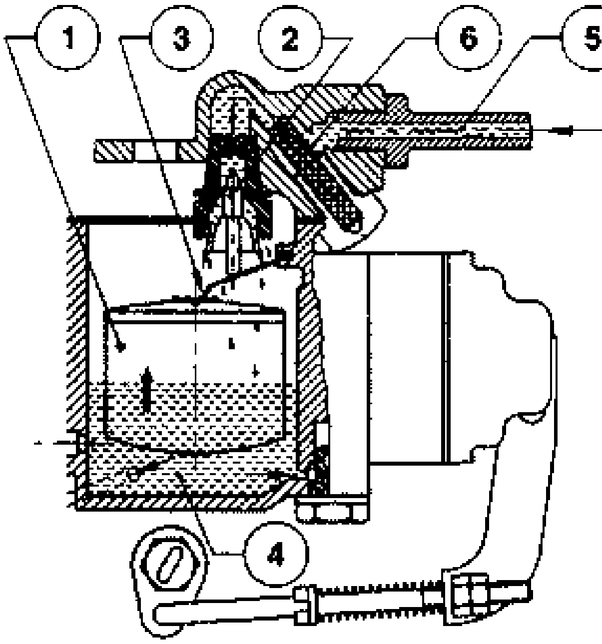
Float and starting circuit

TR 10 01 02 03 95



B Starting circuit

When the dash board knob is pulled out, the starter valve lever **(8)** rotates the starter disc valve **(10)** and opens the fuel passage **(12)**. Petrol is drawn from the float chamber **(4)** through the starter jet **(9)** to the fuel passage **(12)**. Air is drawn from the air jet **(11)**. Air fuel mixture passes through the passage **(13)** below the throttle **(7).**

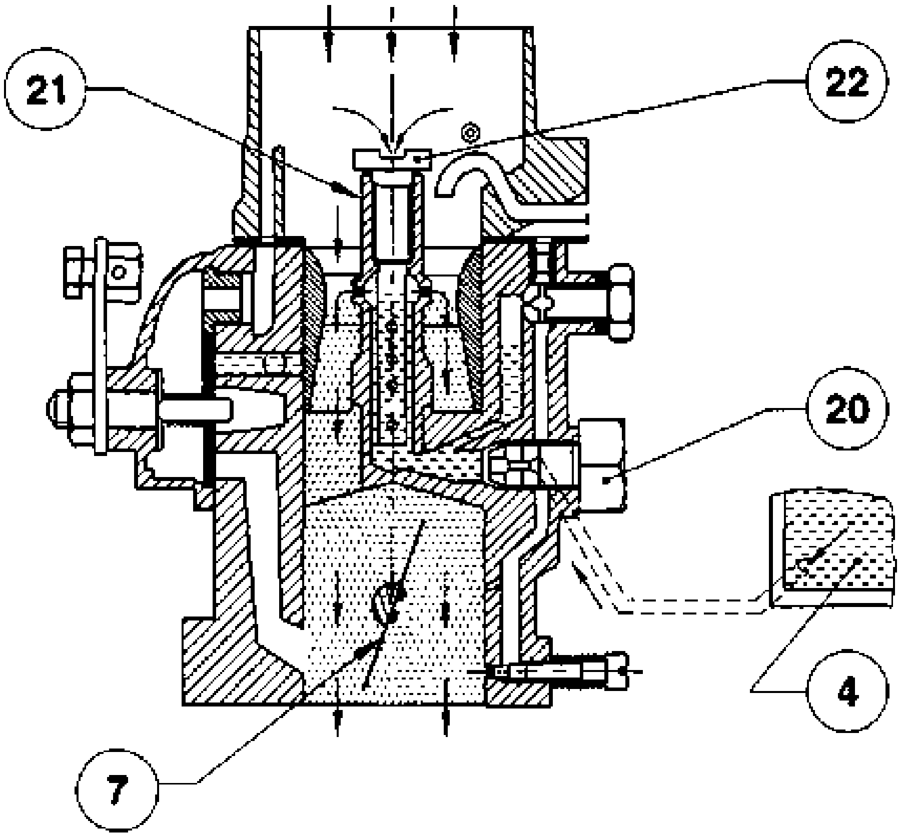


A Float circuit

When the fuel flows to various circuits, fuel level in the float chamber **(4)** drops. The float **(1)** move dow and the needle valve **(2)** opens. Fuel flows through the inlet **(5)** and the filter **(6)** to the float chamber **(4** When the fuel level rises in the float chamber **(4)** th float **(1)** moves up and closes the needle valve **(2)** by the toggle **(3)**.

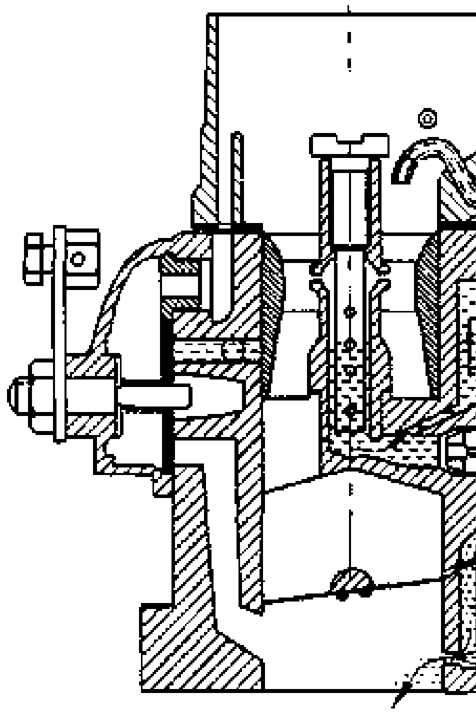
Idling and main circuit

TR 10 01 02 04 95



D Main circuit

On further wide opening of the throttle valve **(7)**, air velocity increases across the narrow passage and creates more vacuum. Petrol is drawn from the float chamber **(4)** through the main jet **(20)** to the emulsion tube **(21)**. Vacuum draws petrol through the emulsion tube orifices and air through choke tube and the air correction jet **(22).**

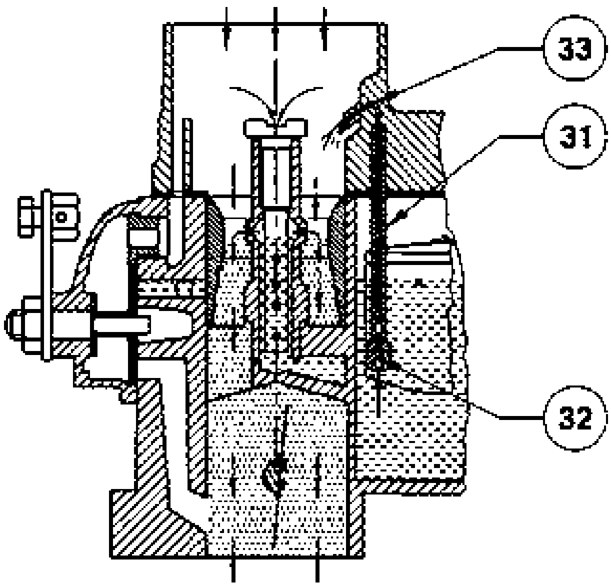


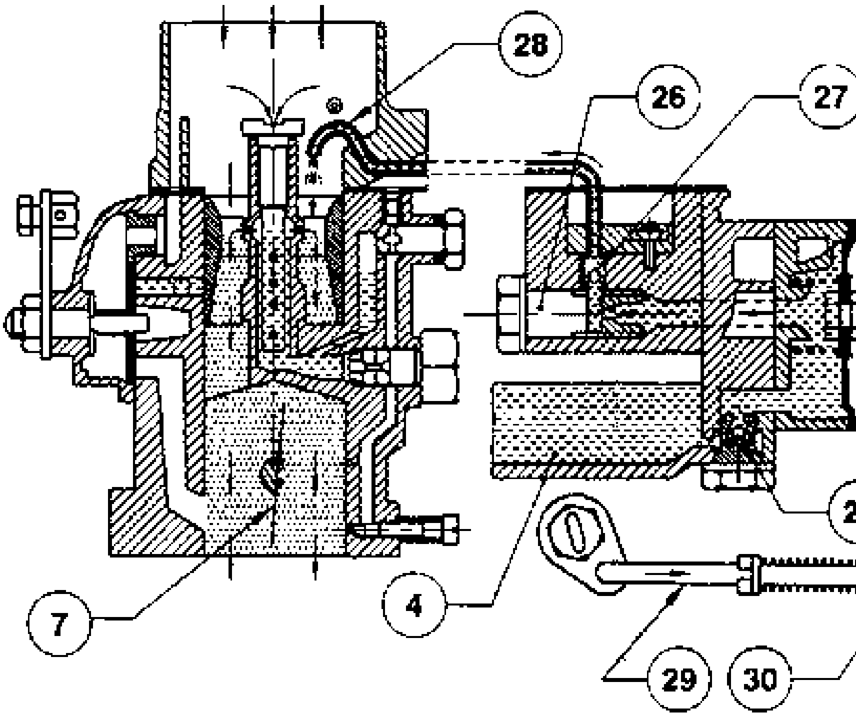
C Idling cir

When the throttle valve **(7)** is closed, the
petrol to flow from the well **(14)** to the pi
air bleeder **(16)**. Both air and fuel mixtur
to run the engine at idling speed. Volum
the screw **(19)**. When the throttle **(7)** is c
orifice **(18)** discharges extra mixture req

Pump and Econostat circuit

TR 10 01 02 05 95





F Econostat circuit

Under full load and full throttle opening at cruising speed, petrol is sucked from the float chamber **(4)** to the econostat tube **(31)** through the jet **(32)** and injected by an injector **(33)** which provides maximum fuel economy.

E Pump circuit

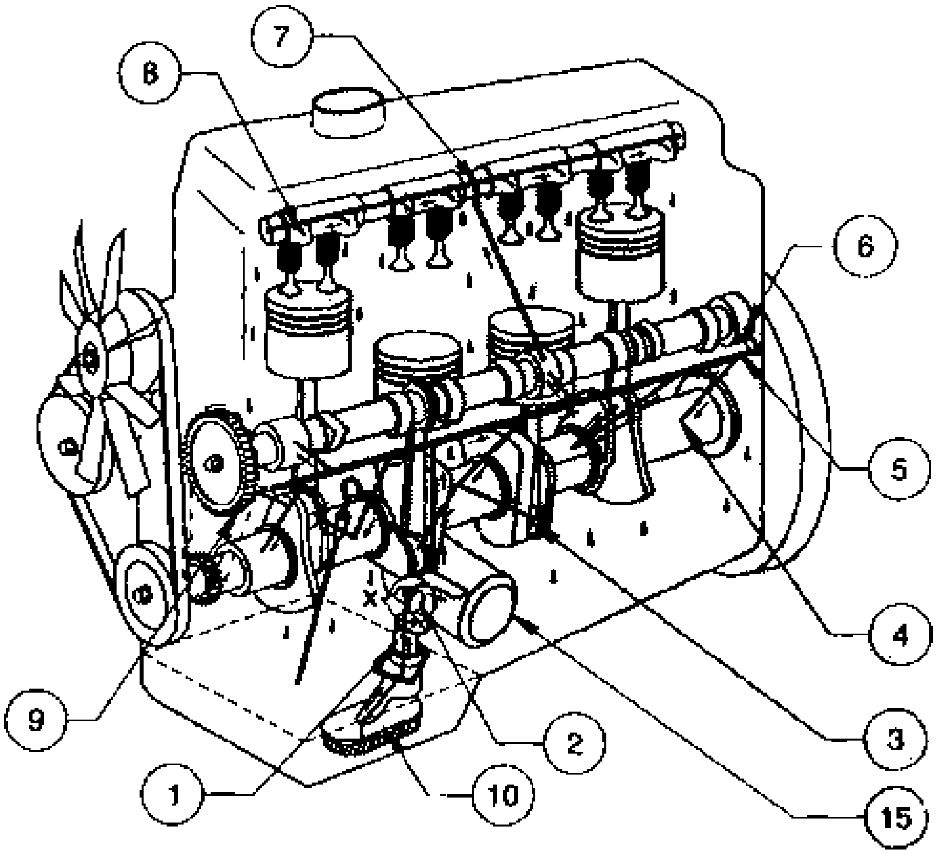
When the throttle **(7)** is closed, the diaphragm **(25)** is pushed back. Petro from the float chamber **(4)** to the pump chamber through the non return i valve **(23)**.
Due to sudden wide opening of the throttle **(7)**, the lever **(24)** pushes the **(25)** forward. Petrol passes through the pump jet **(26)** and opens the non outlet ball valve **(27)**. The petrol is injected to the choke tube by the injec **(28)**. This action supplies extra amount of fuel required for avoiding flat s spring loaded rod **(29)** is adjusted by a nut **(30)** for effective travel of the

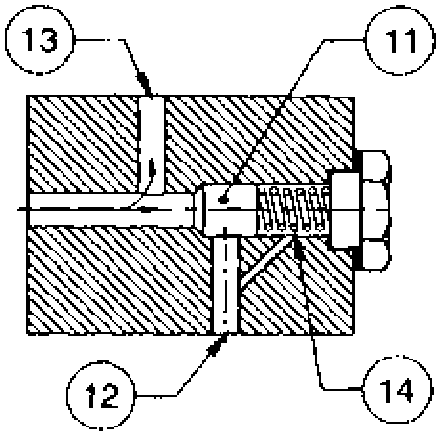
Lubrication system (Engine oil circulation)

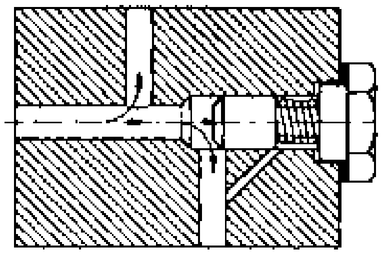
TR 10 01 06 01 95

Oil circulation

Oil flows from stainer **(10)** ' Oil pump **(1)** ' Filter **(15)** ' Oil gallery **(5)** ' Main bearings **(4)** ' Connecting rod bearings **(3)** ' and finally to sump.
From main gallery **(5)** to ' Camshaft bearings **(6)** ' rocker shaft **(7)** ' rocker arms **(8)** ' and to sump.
From main gallery to timing gear/chain **(9)** ' and to sump.
Excess pressure from pump **(1)** is relieved by the oil pressure relief valve **(2)**







Detail X–A: oil under normal pressure

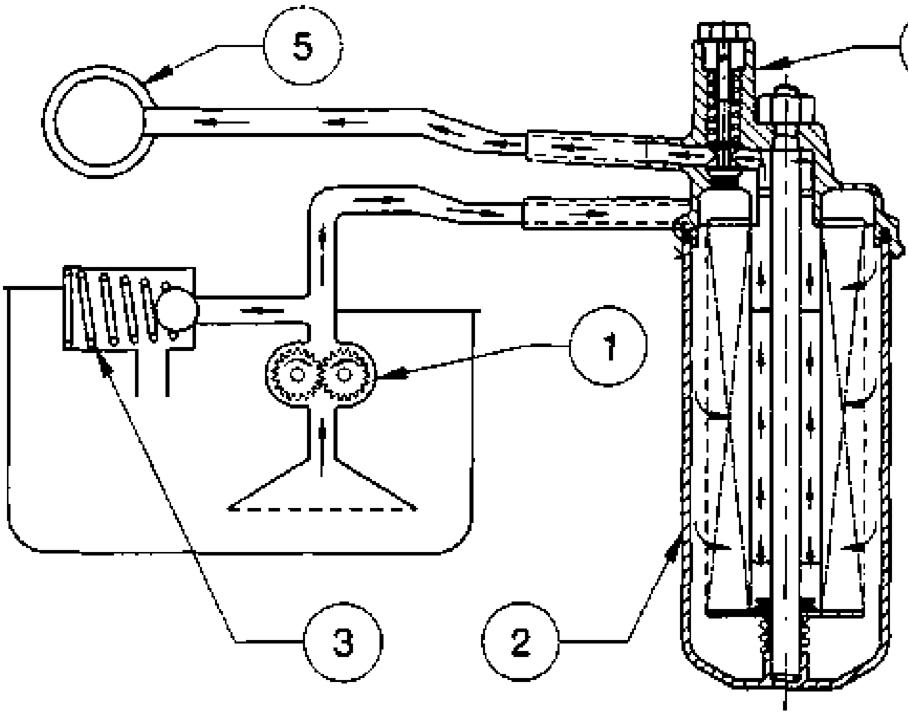
Relief valve plunger **(11)** closes the by–pass port **(12)** and oil passes through outlet port **(13)** and to the oil filter **(15)**

Detail X–B – Oil pressure more than specified limit

The relief valve plunger **(11)** moves against the spring pressure **(14)** and opens the by–pass port **(12)**. Excess of pressurised oil escapes through by–pass port **(12)** and to the oil sump.

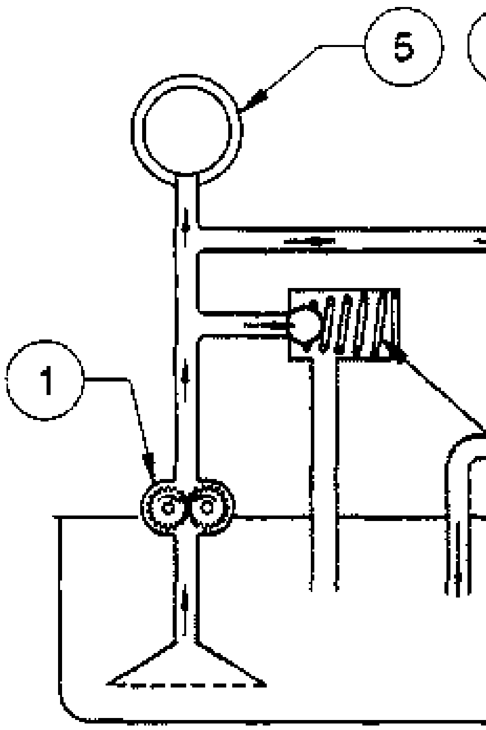
Lubrication system (full flow and by pass flow oil filter)

TR 10 01 06 02 95



Type – Full flow oil filter

Function: From the oil pump **(1)** all the oil passes through the filter **(2)** to the main oil gallery **(5)**. By pass valve **(4)** provided in the filter allows oil to reach main oil gallery directly when the filter is chocked. Excess oil pressure is relieved by oil pressure relief valve **(3).**

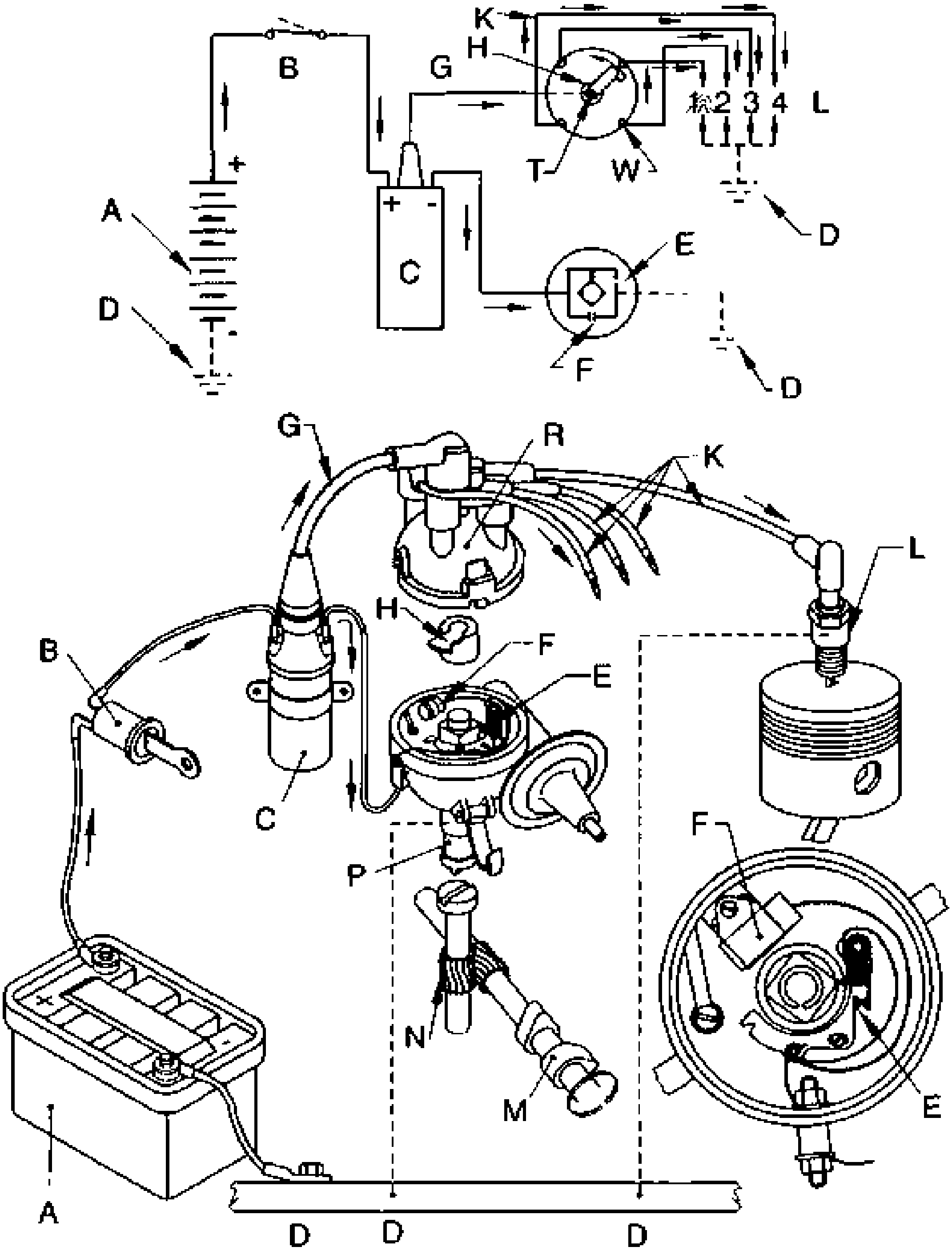


Type – By pass flow oil filter

Function: From the oil pump **(1)** only par
goes to the oil sump **(6)**. The remaining c
gallery **(5)**. Excess oil pressure is relieved

Ignition system

TR 10 10 04 01 95



FIRING ORDER: 1–3–4–2

Function: Current flows from battery **(A)** ' Ignition switch **(B)** ' the primary windings of the Ignition coil **(C)** ' CB points **(E)** ' earth **(D)**. Condenser **(F)** is fitted parallel to CB points **(E)**. High tension current from coil **(C)** ' High tension wire **(G)** ' Carbon rod **(T)** at the centre of the distributtor cap **(R)** ' rotor **(H)** ' distributor cap segments **(W)** ' HT wires **(K)** ' spark plug **(L)**. The battery **(A)** the distributor **(P)** and the spark plug **(L)** are earthed at points **(D)** on the vehicle frame. Distributor **(P)** gets drive from the engine camshaft **(M)** through the screw gear **(N)** and rotates at half of the engine speed.

Mechanic Motor Vehicle 2nd Year – Transparencies

Table of Contents

Mechanic Motor Vehicle 2nd Year − Transparencies 1
Magneto Ignition System (4 Cylinder Engine) 1
Magneto Ignition System (Single Cylinder Engine) 2
Anti−dazzling arrangement 2
Flasher unit and its circuit 3
Wiring Diagram of relay type horn 4
Self starter wiring circuit (Petrol Engine) 5
Self starter wiring circuit (Diesel Engine) 6
Wiring Diagram of a charging circuit (Vehicle) 7
Circuit Diagram of Alternator Testing 8
Synchroniser unit and its action 8
Layout of 4 Wheel Drive 9
Four wheel drive transfer case (High Range) 10
Independent front wheel suspension (Macpherson & Coil spring) 11
Valve Timing Diagram (4 Stroke Cycle Diesel Engine) 12
Crankcase Ventilation 13
Comparison of function Multi hole and Pintle nozzles 13
Fuel feed system (Diesel Inline Jerk Pump) 15
Fuel Injection Pump 16
Diesel Engine Fuel Filter 17
Types of Stub Axle mountings on front Axle 18
Steering linkages Light Motor Vehicle 19
Steering Gear Box Rack & Pinion Steering 20
Tandem Master Cylinder and its function 20
Differential and its action 21
Wheel Cylinder and its action 22

Mechanic Motor Vehicle 2nd Year – Transparencies

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MEDIA INSTITUTE, CHENNAI

AN INDO – GERMAN PROJECT

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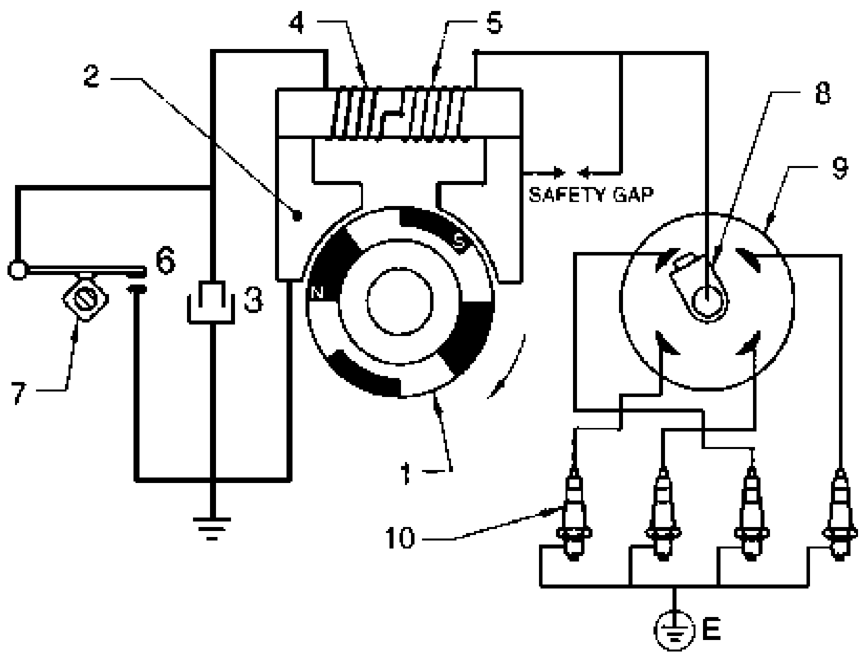
Phone: 234 5256, 234 5257, Fax: (0091–44) 234 2791

Magneto Ignition System (4 Cylinder Engine)



ROTATING MAGNET TYPE (4 CYLINDER ENGINE)

Function

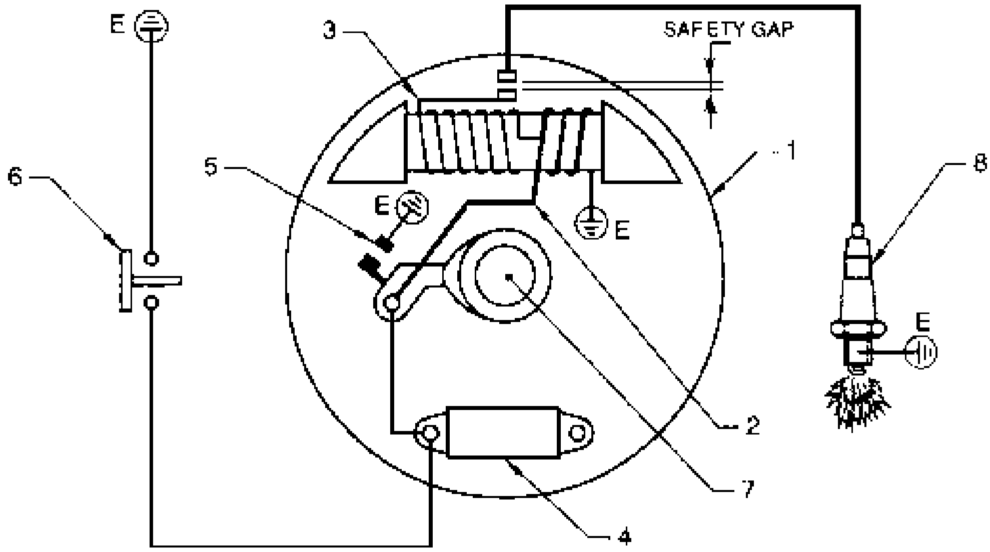
The magnet (1) revolves whereas the Armature and pole pieces (2) remain stationary. In a base plate condenser (3) and Primary and Secondary coils (4 & 5) are mounted, The CB points (6) are also kept stationary. The Ignition cam (7) is attached to distributor shaft and it only rotates.

When the flywheel revolves, the magnet (1) also revolves. It generates current in the coil as its magnetic field cuts across the Ignition coil windings (4 & 5). This current flows through the primary coil (4) and gets earthed. When CB points (6) are separated by an Ignition cam (7) a h.t. current is generated in the secondary coil (5). The condenser (3) absorbs surge of primary current when CB points (6) open and prevents arcing also across the points. The h.t. current then passes on to the distributor Rotor Arm (8) and from the arm the current is delivered to spark plug (10) through segments in distributor cap (9) and discharged as a spark with high intensity across plug gap and finally earthed to complete its circuit. As the distributor shaft rotates at 1/2 speed of crankshaft rpm, one spark will be delivered at 180° of its revolution.

NOTE

Some tractors with 4 cylinder engine work with the rotating magnet type Magneto ignition System

Magneto Ignition System (Single Cylinder Engine)



FLYWHEEL MAGNET MAGNETO (SINGLE CYLINDER ENGINE)

Function

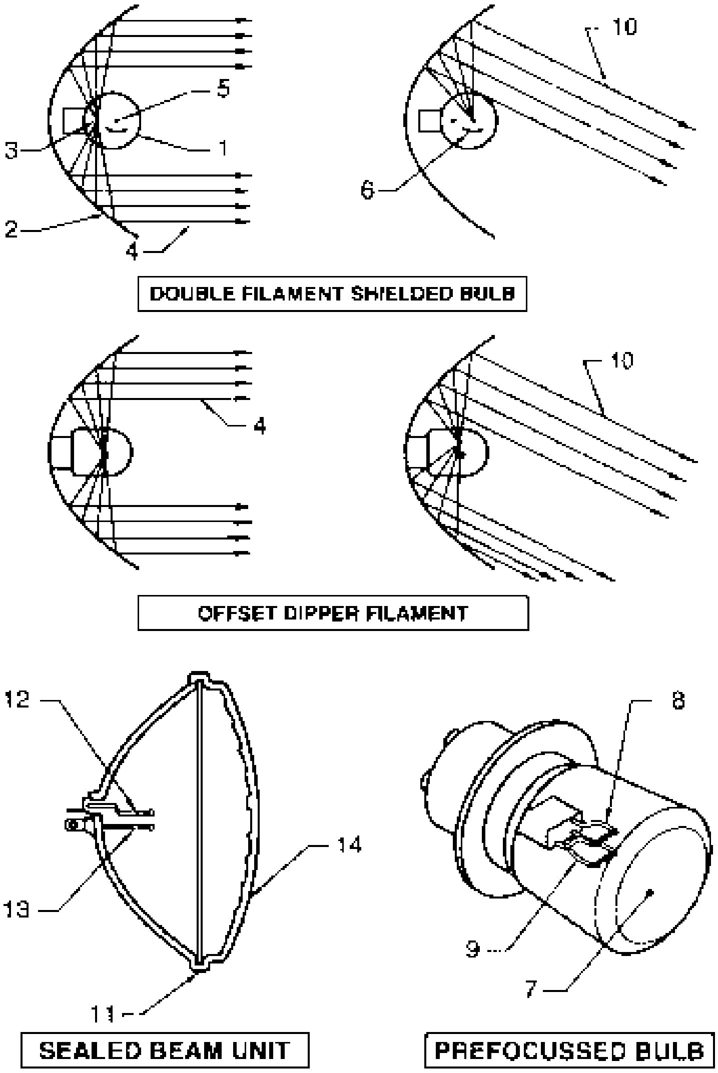
This system is used in Motor cycles & Scooters. In this design flywheel (1) is attached with magnetic pole pieces and revolving as one unit with crank shaft. The primary winding (2). Secondary winding (3), condenser (4), CB points (5) are all fixed on a base plate on the engine housing. The Ignition cam (6) is attached to one end of the crankshaft and revolves with it.

When the flywheel revolves, magnetic pole pieces also revolve. The magnetic lines set up between N & S poles, cut the primary winding (2) generate LT current. The LT current flows then to condenser (4) and contact breaker points (5). When the points remain closed a magnetic field is set up around the primary winding (2). A switch (6) is provided in the primary circuit in series with CB points to earth the primary circuit. When the Ignition cam (7) opens the CB points (5) the surging current is absorbed by the condenser and thus prevents arcing. Due to break up of primary circuit, the magnetic field collapses and a heavy current (h.t) is induced at secondary winding (3) and it is delivered to the spark plug (8) and the h.t current jumps across plug points and finally earthed through engine block.

This cycle of operation is repeated and one spark per crank shaft revolution will be delivered in a Single cylinder 2 stroke engine.

The L.T current thus generated passes on through rectifiers for change of AC to DC and is supplied to lights, Battery, Horn and other circuits.

Anti–dazzling arrangement



Function

In a car the effect of head light dozzle is being prevented by re−direction of light rays towards the ground. A double filament shielded bulb (1) is used. The Bulb (1) is fitted on the parabolic reflector (2) at the focal point (3) and the reflected rays (4) are indicated by straight line arrows. If another filament (5) is placed away from focal point (3) the light rays (10) are deflected towards the ground surface. The shield assists deflection of rays to wards ground. This beam is called dipped beam and operated by a dipper switch provided in instrument panel of the vehicle or at foot of drivers seat.

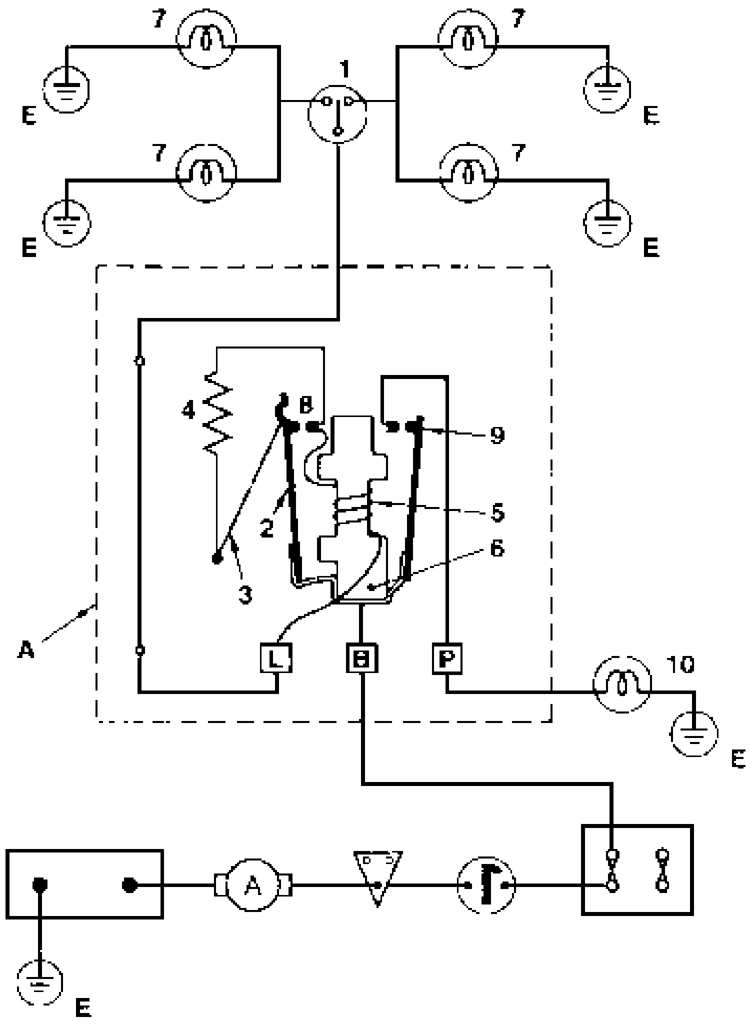
(A) By use of pre−focussed bulb (7) with dip and main beam (8 & 9) filaments

It can be fitted in the reflector to give a main beam (4) and also a dip beam to deflect the rays in a deflected path (10), when dazzling of head light rays come from opposite vehicles.

(B) By use of a Sealed Beam Unit (11)

There are two filaments (12) and (13) accurately positioned in the unit. A special type of lense (14) is provided which redirect the light rays in the deflected path (10).

Flasher unit and its circuit



Function

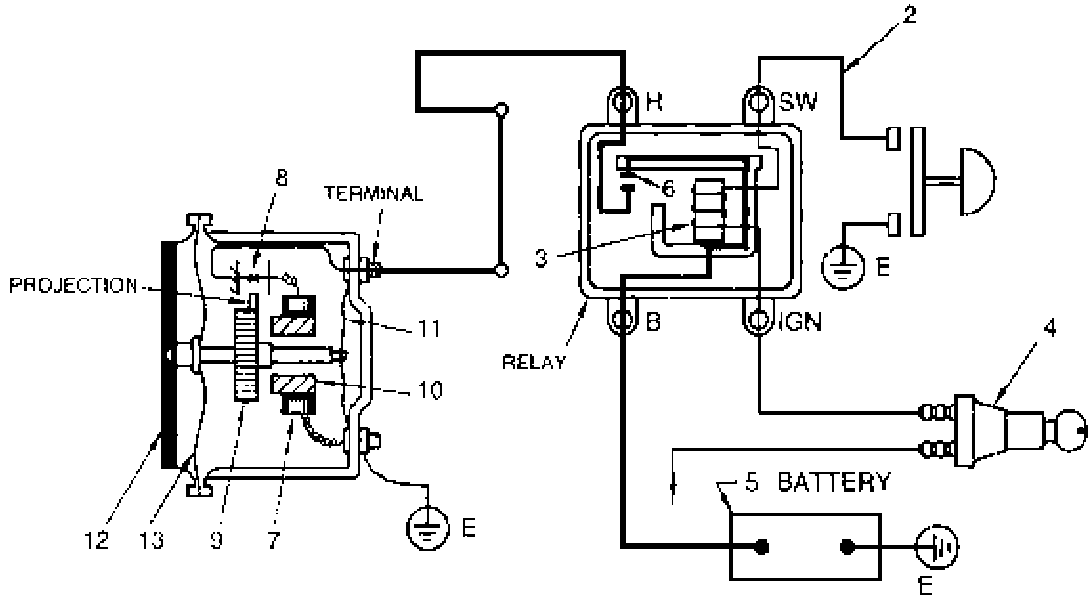
The flasher unit (A) is provided between Battery and lamps. This is a sealed unit and mounted vertically in a place below the Bonnet of the car.

When the flasher switch (1) is operated to the right or left the battery current flows from terminal (B) through the main armature (2) actuating wire (3), Ballast resistor (4), Coil winding (5) on the Iron core (6) and to the flasher lamp filaments (7) and get earthed. The lamps (7) do not illuminate but ready to flash due to pre−heating of filaments.

Due to current flow, the actuating wire (3) is heated up and expands in its length. This action causes the lamp contacts (8) to close in the supply circuit of flasher lamps (7) and at the same time to keep the actuating wire (3) and Ballast resistor (4) out of circuit. Now full current flows, from terminal (B) to Terminal (L) along the closed contacts (8) and round the coil windings (5). The lamps (7) get now illuminated. At the same time, the pilot contacts (9) also close due to Electro−Magnetic action of the coil winding (5) and pilot lamps (10) are now lit. Now the current flows to the two lamps (7) of the same side through the main points (8) and they begin to flash at a regulation of 70−100 flashes per minute.

When the actuating wire (3) cools down, it breaks the contact; the current flow is cut out from the lamps (7) and points (8) reopen. Now reduced current flows to the coil (5) through Ballast resistor (4). The current is not sufficient enough to illuminate the lamps (7). Thus lighting signals are extinguished off. The pilot lamps also go off. The sequence of operation is repeated till indicator switch is returned to its off position.

Wiring Diagram of relay type horn

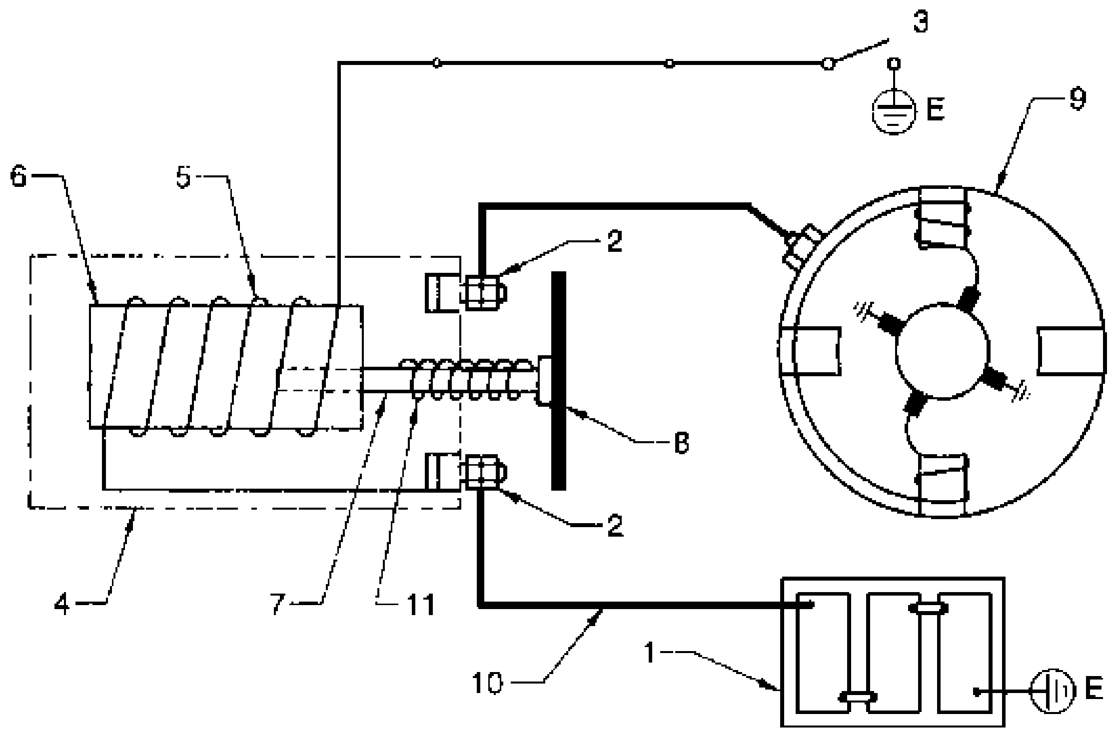


Function

Most horn circuits employ a horn relay to operate double horns. The relays help to avoid pitting of horn contacts.

When the horn button (1) is pressed it completes the circuit denoted by fine lines (2) in which a Solenoid energising coil (3) (provided in the relay), Ignition switch (4) battery (5) with earth returns (E) are provided. The current passing through the Solenoid coil (3) creates a magnetic field around it, thus exerting a pull on the movable contact of the relay which makes relay contacts (6) to close. The circuit thus completed is shown in thicker lines. It carries a heavy current from the battery (5) to the horn coil (7) via the horn contacts (8). Now the armature (9) is set into vibration. When the armature (9) is attracted by the magnet (10), the contact points (8) get separated, thus disconnecting the circuit. The guide spring (11) moves the Armature (9) back to its original position, thereby horn circuit is connected once again. As the armature (9) strikes the magnet (10) the tone disc (12) is made to produce over tone notes. The tone disc and diaphragm (13) produces vibration which produce pleasant sound.

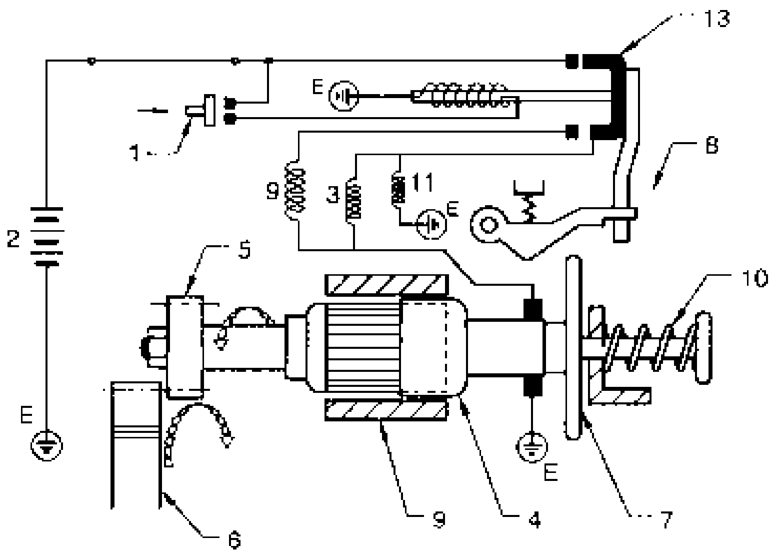
Self starter wiring circuit (Petrol Engine)

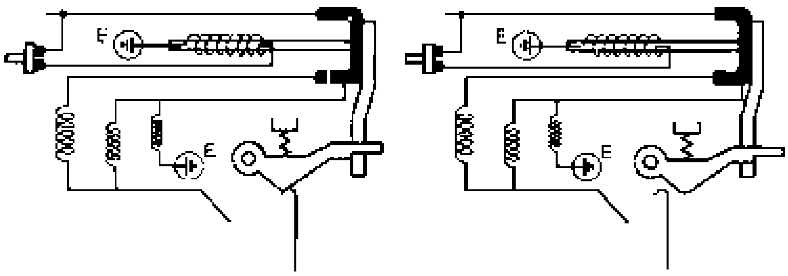


A. Function

In the starter wiring circuit, Battery (1) supplies current to solenoid switch terminals marked (2) through a starter button switch (3). The solenoid switch (4) is placed between the battery (1) and starter motor (9). When the current passes through a winding (5) in the solenoid switch, it gets a magnetic field around it and the soft Iron Core (6) becomes an Electro Magnet. This electro Magnet attracts the plunger (7) to force the contact disc (8) on one end to make contact with terminals (2) of the switch thus completing the circuit. Now a heavy current passes to the starting motor (9) through battery cables (10) from battery and the starter begins to revolve. When the switch is released the electro magnetic field collapses and the spring (11) moves plunger (7) and the contact disc (8) away from the terminals (2) thus electrical connection is open between the battery (1) and the starter motor (9). Now the self starter stops revolving.

Self starter wiring circuit (Diesel Engine)





Function

In these type of axial starters, the pinion engagement is done by axial movement of complete armature assembly. The starter wiring circuit indicates two stages of operation.

A. First stage

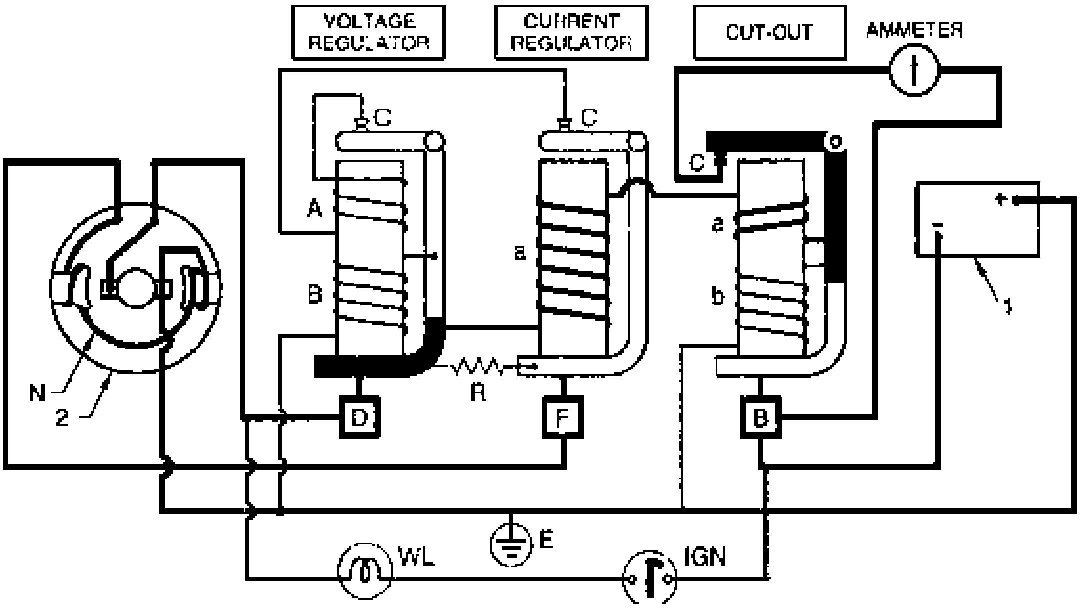
When starter push contact (1) is pressed, the first set of contact on the solenoid close and a small current passes from Battery (2) through Auxiliary field windings (3) causing armature (4) to rotate slowly. Due to magnetic field set up in the windings, the armature (4) is drawn towards driving end of the machine and pinion (5) engages with the engine flywheel ring gear (6).

B. Second stage

As the armature nears the end, in its axial movement, a tripping plate (7) operates the Trigger (8) on the solenoid switch resulting on the second stage contacts to close and complete the circuit with main series winding (9).

Now the starter exerts its full torque to the engine. When the starter button (1) is released, the armature (4) is returned to its disengaged position by the coiled spring (10) on the armature plunger. The auxiliary shunt windings (11) in the circuit try to hold the pinion in mesh until the starter push button (1) is released.

Wiring Diagram of a charging circuit (Vehicle)



General

The vehicle charging circuit consists of a battery 12V (1) and a two brush dynamo (2) and a regulator unit and connecting wires,

The regulator unit contains a voltage regulator (I) current regulator (II) and a cutout relay III, all being mounted on a single base, with markings B–D–F for wire connections.

Function

A. At Slow speeds

The dynamo (2) produces less voltage and hence less current so it does not charge the battery (1).

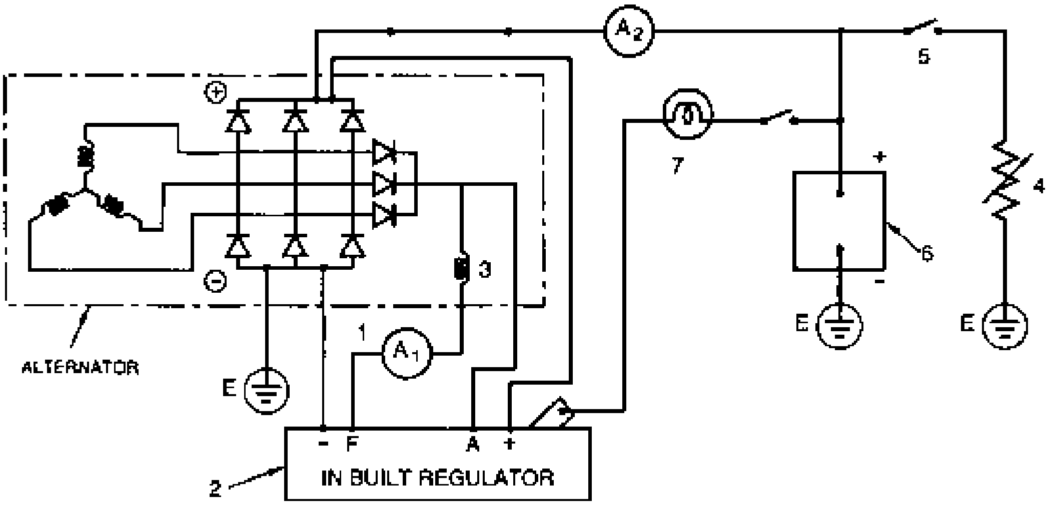
B. At High speeds

The current produced is sufficiently of high value and flows into the series and shunt coils of voltage regulator, current regulator and cutout (A, a, b). The shunt coil in the cutout (b) produces a magnetic field which attracts the contacts (C) and when they are closed, current passes into the battery (1) via Ammeter and series coil (a). The cutout (III) does not allow reverse current from battery (1) to dynamo (2) when Battery is fully charged. Hence it is called Reverse current relay.

Dynamo output regulation

The function of regulator is to limit the output voltage/current of the dynamo. The current and voltage regulator contacts open when the current/voltage reaches a pre-set value causing a resistance (R) to be inserted to reduce the value of the current/voltage and contacts are closed again by spring action. With a Low Battery Voltage the current regulator (II) will

Circuit Diagram of Alternator Testing



Bench Testing Method

The Bench Testing of an Alternator is described below.

Preliminaries

1 Mount alternator on test rig with cowl removed.
2 Connect the Test circuit wires as shown in the chart.
3 Use recommended size of wires. (Refer Vehicle Service Manual)

Test connections

1 Connect field ammeter (A_1)(1) between Field Terminal of regulator box (2) and field winding (3).

2 Connect a variable load of 60 Amps (4) in series with switch (5) and across the battery (6),

Alternator output test with an Voltmeter

1 Run alternator upto 6000 rpm

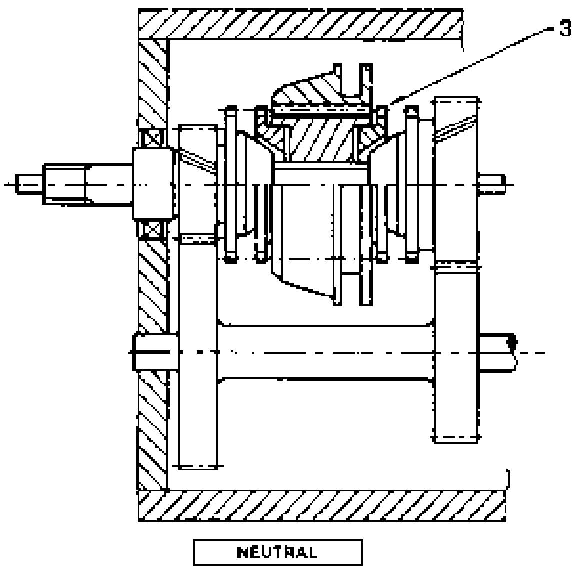
2 Adjust variable load (4) so that voltmeter will show 13.5 volts for 12V and 26.75 V for 24 V systems.

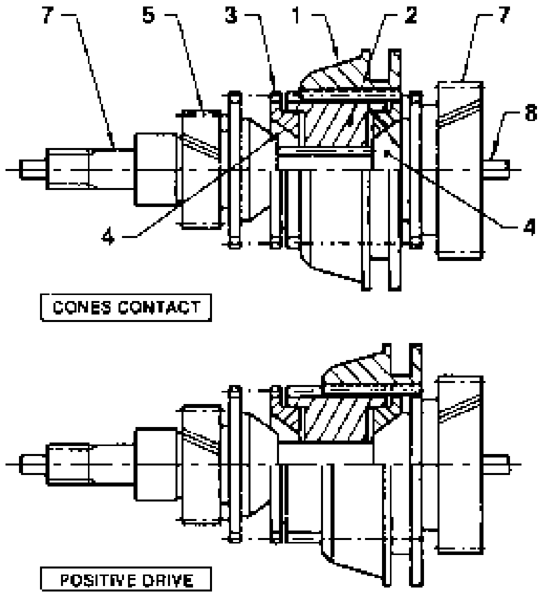
3 Ammeter (A_1)(1) should also record field current as below.

a) 3 to 4 amps for 12 volt system
b) 2 to 2.5 amps for 24 volt system

4 Test warning lamp (7) for its working or not. (Refer to fault finding chart for remedial action in the Vehicle Service Manual)

Synchroniser unit and its action





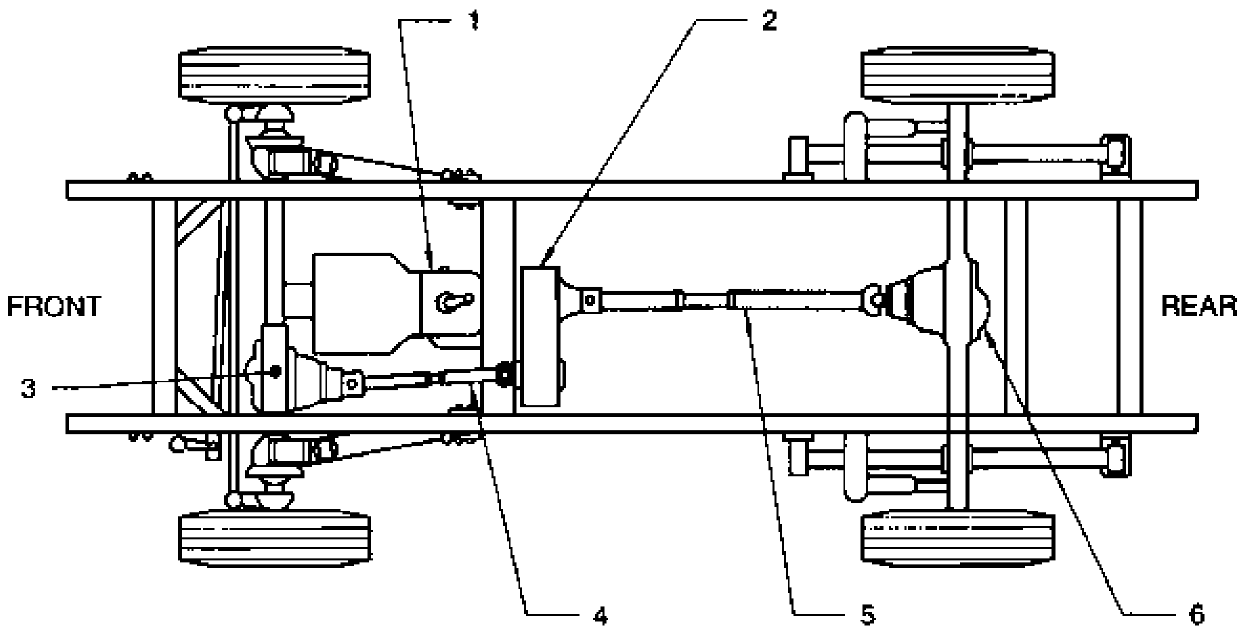
(A) Description of the unit

The synchroniser unit has a synchroniser sleeve (1), a centre hub (2), a set of blocking rays (3) with inside conical surfaces (4). The corresponding conical surfaces (4) are also made on the gear wheels (5) and (6) which are driven by clutch primary shaft (7) and gear box main shaft (8). These conical surfaces match with each other. Gears (5) & (6) rotate in mesh with gear box counter shaft gears in the gear box. But the hub (2) rotates at the main shaft speed, as it is splined to it. The synchroniser sleeve (1) can slide back and forth along the splines provided on the synchroniser hub.

(B) Working

The synchroniser unit is provided between top gear and second gear drive in the gear box when a gear change is made for the second gear the synchronising unit moves as a unit until the conical surfaces of blocking ring (3) and gear wheel (6) engage with each other. Now the speeds of gear box mainshaft and clutch primary shaft become equal. Further movement of the sleeve 1 engages the dog teeth of blocking ring (3) and gear wheel (6). At this stage both shafts are rotating at the same speed. Thus II gear drive is obtained without clashing of gears and double declutching. All the three stages of operation are shown in the figures.

Layout of 4 Wheel Drive

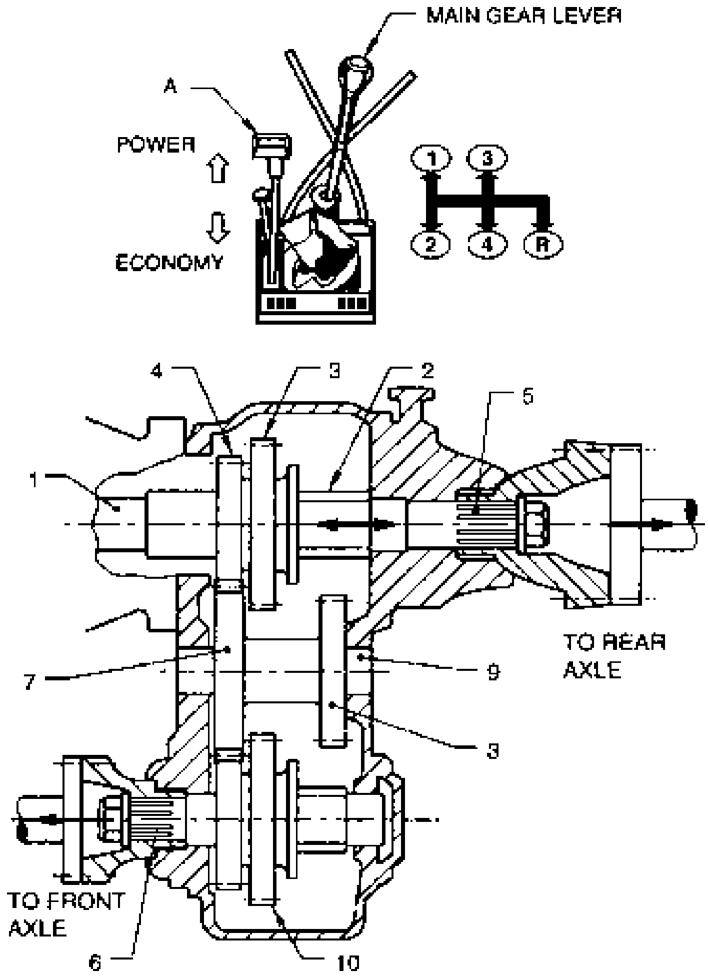


Power flow

The main transmission (1) is fitted with a transfer case (2) at its back. The transfer case (2) is an auxiliary transmission, connected to front differential (3) through a front drive (propeller) shaft (4) and to rear differential (6) through a rear drive shaft (5). By shifting to gears in the transfer case by a selector lever (A) the engine power is divided and transmitted to both front and rear differentials. High speed in transfer case provides a direct drive i.e. 1:1 ratio and low speed provides a ratio of 2:1.

These ratios help to drive the vehicle on rugged terrain, upgradients muddy and sandy roads without spinning of wheels.

Four wheel drive transfer case (High Range)



General

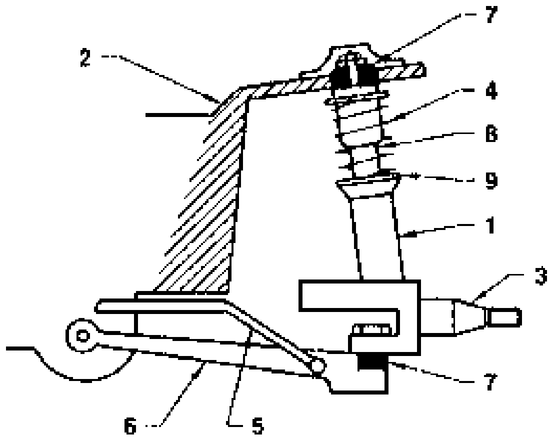
A gear lever is provided with 4 positions shaft for gear shift. In addition a transfer case selector (A) is provided on the left or right of drivers seat. The selector lever (A) can be placed either in high range (for economy) or Low range (for power). The figure shows high range drive through transfer case mechanism.

Power flow

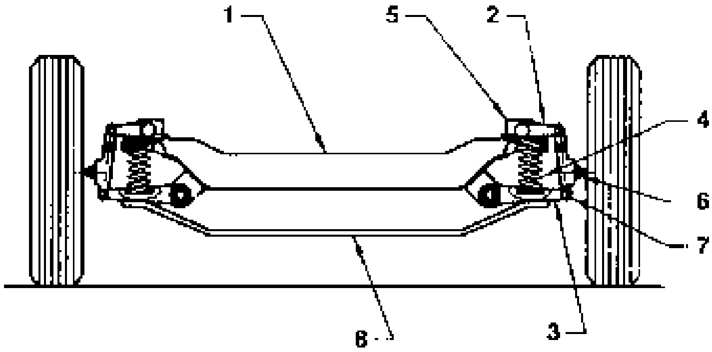
When the selector lever (A) is shifted to engage high range drive position, the drive from the primary gear box shaft (1) goes to the main shaft (2). The main shaft sliding gear (3) engages with high range gear (4) and the power is transmitted to the rear wheels drive output shaft (5) directly and to the front wheel drive output shaft (6) through idler gear (7).

The four wheel drive mechanism provides necessary gear ratios to avoid spinning of road wheels on slippery surfaces.

Independent front wheel suspension (Macpherson & Coil spring)



MACPHERSON STURT TYPE SUSPENSION



COIL SPRING SUSPENSION

A. Macpherson strut type suspension

This system is largely used for independent springing action of front wheels of a car. The working of it is described below.

Working

This type of suspension has no upper control arm. A strut (1) is mounted between the frame (2) and Stub axle (3). The road shocks (while driving a vehicle) received by front strut (1) is distributed through stub axle (3) and coil spring (4) and then to front suspension Arm (7) and finally are absorbed. A rubber pad (7) is provided to prevent road wheel shocks being transferred to the frame (2). The coil spring (4) reduces the effects of Road shocks due to bumps and Pot holes and a shock absorber (8) distributes it evenly to all members. A stabiliser bar (6) connects the two lower transverse members and prevent body rules on cornering.

B. Coil spring suspension

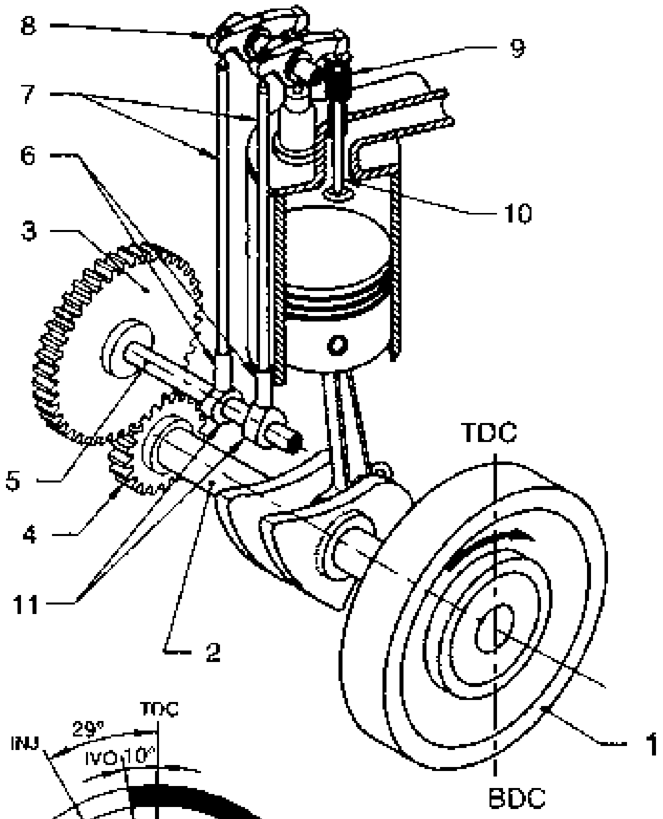
This system uses coil springs for spring action of front wheels and keeps the car stable on road during driving due to low centre gravity of the vehicle.

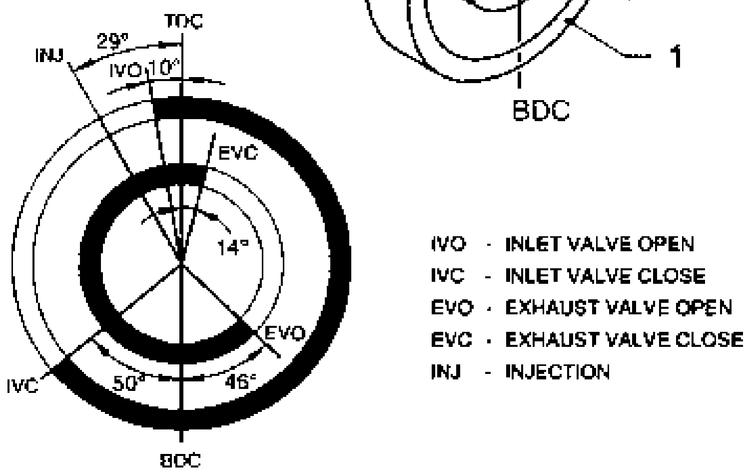
Working

A frame (1) is provided with two control arms (upper and lower) (2&3) with suitable swinging arrangement. A coil spring (4) and shock absorber (5) are placed between them. A steering knuckle (6) is pivoted at each end of the upper and lower control arms through Ball joints (7). These joints allow angular movement of steering knuckle and its linkages. When the vehicle is driven on pumps and pot holes, the wheel and tyre moves upward and also inwards. The inward movement drags the tyre sideways and causes rapid tyre wear. This tyre wear could be reduced by use of shorter and longer arms in the system. Shims are provided on the upper control arm for chamber adjustments.

A stabiliser bar (8) (called also Anti−Roll Bar) connecting both Lower Control Arms prevents the tendency of car body to roll outwards during vehicle cornering by offering resistance to twisting action.

Valve Timing Diagram (4 Stroke Cycle Diesel Engine)





Valve timing

Valve timing is set and checked with reference to TDC and BDC marked on flywheel (1).

Checking Inlet valve opening

The valve timing angles are marked on the face of the flywheel (1). Hence rotate flywheel (1). The crankshaft (2) Timing gears (3 & 4) camshaft (5). Tappet (6) pushrod (7) and Rocker arm (8) and springs (9) will operate. Observe position of pushrod (7) and compression of springs (9). Feel the push rod for tightness and ensure the valve opening. Now the Inlet valve (10) is fully opened.

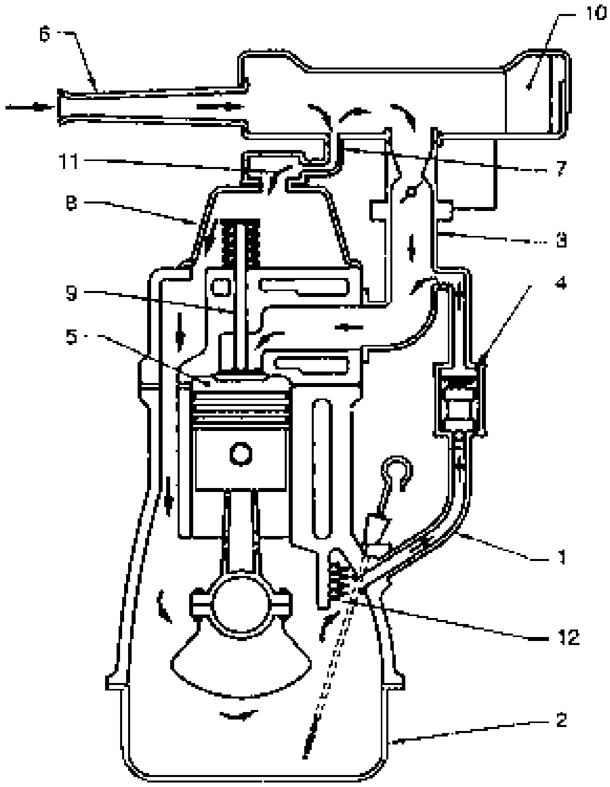
Now measure the distance on the flywheel (1) from TDC to the point of opening Inlet valve (9) by using a measuring tape. Convert, this flywheel distance into degrees of crankshaft revolution by using the formula

D = 2 ? 360 × A × R [Where A = Timing angle, R = Radius of flywheel]

Result

If in the conversion you get 10° as the degrees marked on the flywheel, the Inlet valve opening is correct. Also check the timing gear marks for alignment. If they align, the timing is correct.

Crankcase Ventilation



Function

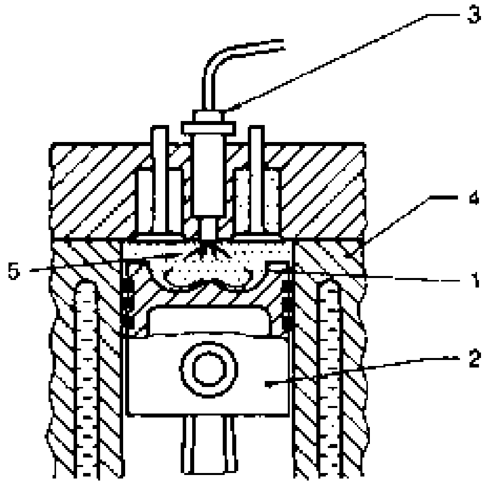
In IC engines, products of combustion leak past the rings into the crankcase. These products are to be removed to reduce oil contamination, dilution, corrosion and other undesirable chemical effects. For removal of these products positive crankcase ventilation is used in engines.

As per MV Act all Motor Vehicle Engines are to be provided with P.C. Ventilation system and this is compulsory.

Working

Generally a Tube or Hose (1) connects the crankcase (2) to the Intake manifold (3) via a PCV valve (4). The crankcase gases are drawn into the Inlet manifold (3) by engine vacuum, then goes into the combustion chamber (5) with air fuel mixture and gets burnt up as a fuel. Clean Air is delivered to the engine through air entry tube (6) and also through a Breather pipe provided on the oil filler or A Tube or Hose (7) connecting the engine air filter to the crankcase or rocker cover (8). The PCV Valve (4) controls the flow of air through the crankcase (2) and prevents excess air admission during suction and acceleration of the vehicle. Also it protects engine against damage due to back firing.

Comparison of function Multi hole and Pintle nozzles



A. Multi−Hozzle Nozzle

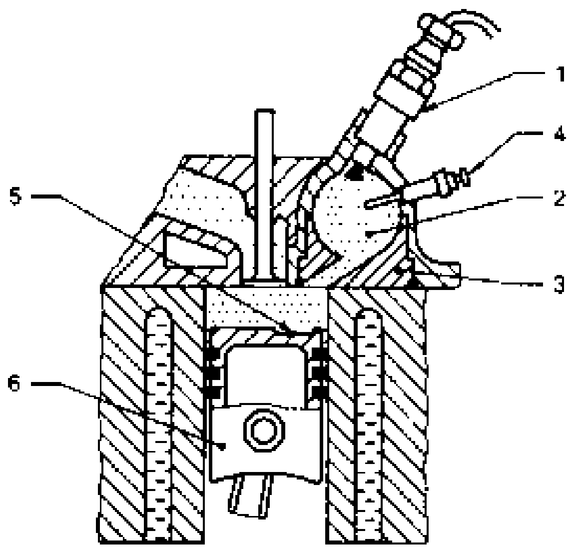
Functional aspect

This nozzle works in conjunction with a Torroidal chamber.

The provision of torroidal chamber (1) on the top of the piston (2) provides a squish turbulence of air to enable fuel to mix with air fully.

The air in the cylinder (4) is compressed to a very high pressure. The fuel nozzle (3) has 4 spray (5) holes and fuel is sprayed at a very high pressure to penetrate into the highly compressed air. The fuel is ignited very quickly and combustion proceeds in the cylinder (4).

No heater or glow plug is necessary. Hence starting of engine is easy. The method is called direct injection in diesel engines. (D.I. Engines)



B. Pintle Nozzle Functional aspect

The pintle nozzle (1) works in conjunction with Pre−chamber (2) provided in the cylinder head (3).

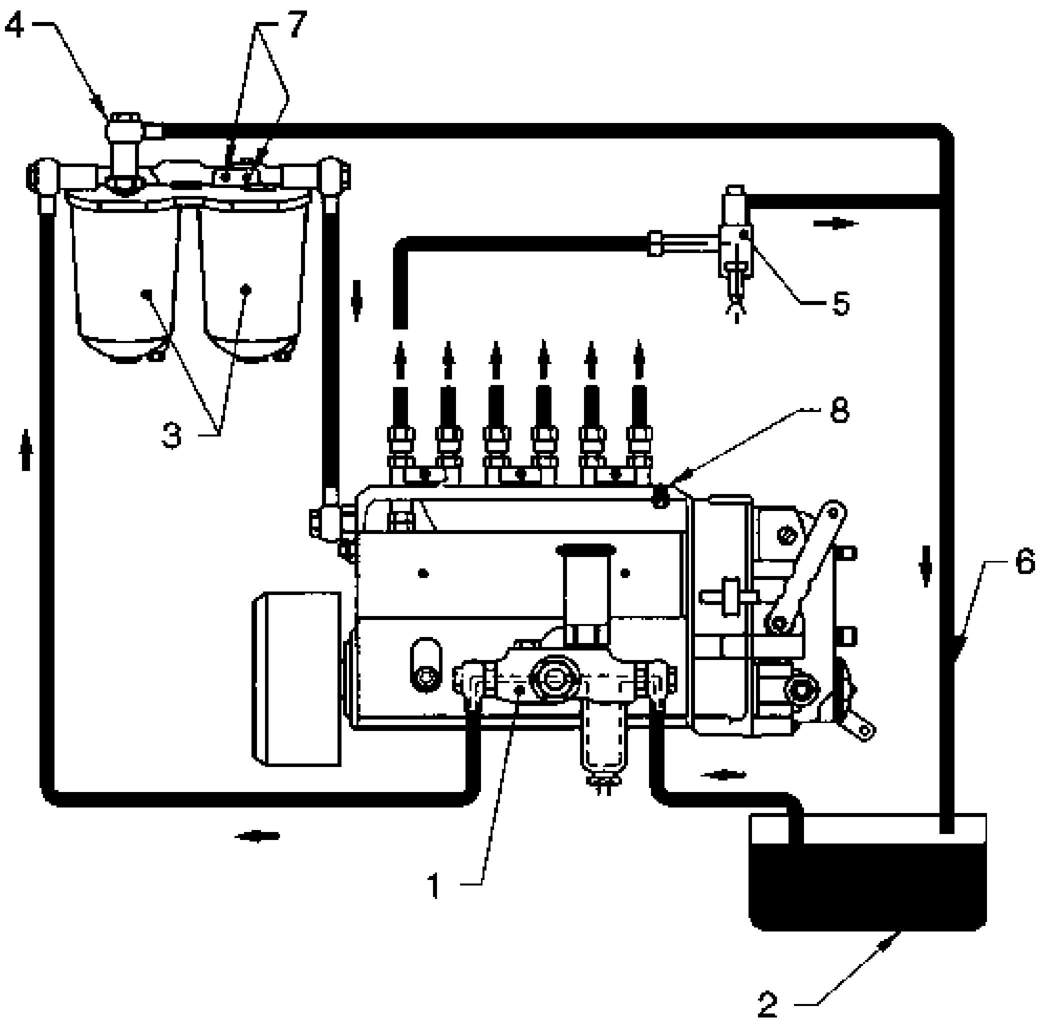
The pintle nozzle (1) provides a conical spray of fuel at a low pressure on the compressed air in the pre−combustion chamber (2).

The pre−chamber provides good turbulence of air for mixing with fuel spray. Since the air in the pre−chamber (2) is not compressed to high pressure enough heat is not available for igniting the fuel. Hence a glow plug (4) to preheat the air is provided.

The combustion of fuel takes place in two stages, i.e first in the pre−combustion chamber (2) and it is continued in the spherical chamber (5) on the top of the piston. The burnt gas and unburnt fuel particles pass to the main chamber through passage in the pre−chamber (2). During this process further atomisation of fuel takes place and all fuel is burnt out. The combustion process is continued on the top of the piston (6).

This method is called Indirect Injection in diesel engine.

Fuel feed system (Diesel Inline Jerk Pump)



Fuel circulation

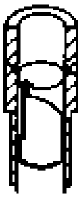
In a Motor Vehicle fitted with diesel engine, diesel fuel is drawn by the fuel feed pump (1) from the fuel tank (2). The fuel from the feed pump (1) is supplied to the fuel filters (3) under low pressure. From fuel filters (3) the fuel flows into the fuel Injection pump gallery. The excess fuel is sent back to the fuel tank through the overflow valve (4). From the fuel injection pump the fuel is supplied to the injectors (5) under high pressure. The excess fuel from the Injector Nozzle is delivered back to the fuel tank (2) through overflow pipe line (6).

For removing the air trapped in the pipe lines, bleeder screws (7) on the filter and Bleeder screws (8) on the F.I. Pump are provided and they are to be opened up and then closed tightly after exit of air from the fuel lines.

The system of removing air from the pipe lines is called bleeding or air venting.

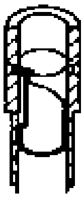
Fuel Injection Pump

Fuel Delivery position

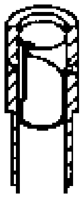


Position 1: The Plunger (2) is now at BDC – Fuel enters the Top of Plunger (2) from gallery (6).

No fuel is delivered now.

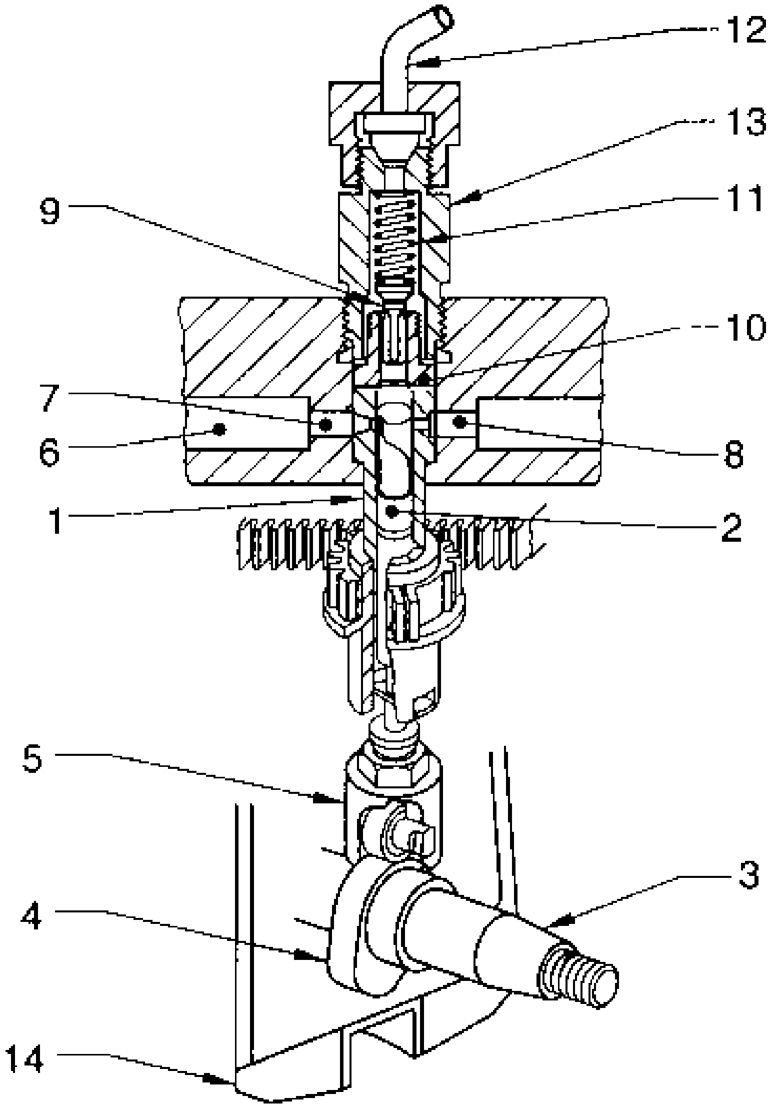


Position 2: Plunger (2) moves up in the Barrel, closing both the ports (7 & 8). The fuel is being pressurised by the moving plunger (2) during the movement to TDC.



Position 3: When the helix of the plunger uncovers the spill ports fuel delivery is complete. The pressure drops in the fuel line. But the plunger will continue to move upto TDC to complete its stroke.

NOTE: The height of helix determines the quantity of fuel delivered to the engine.



(B) ARRANGEMENT OF PLUNGER & BARREL

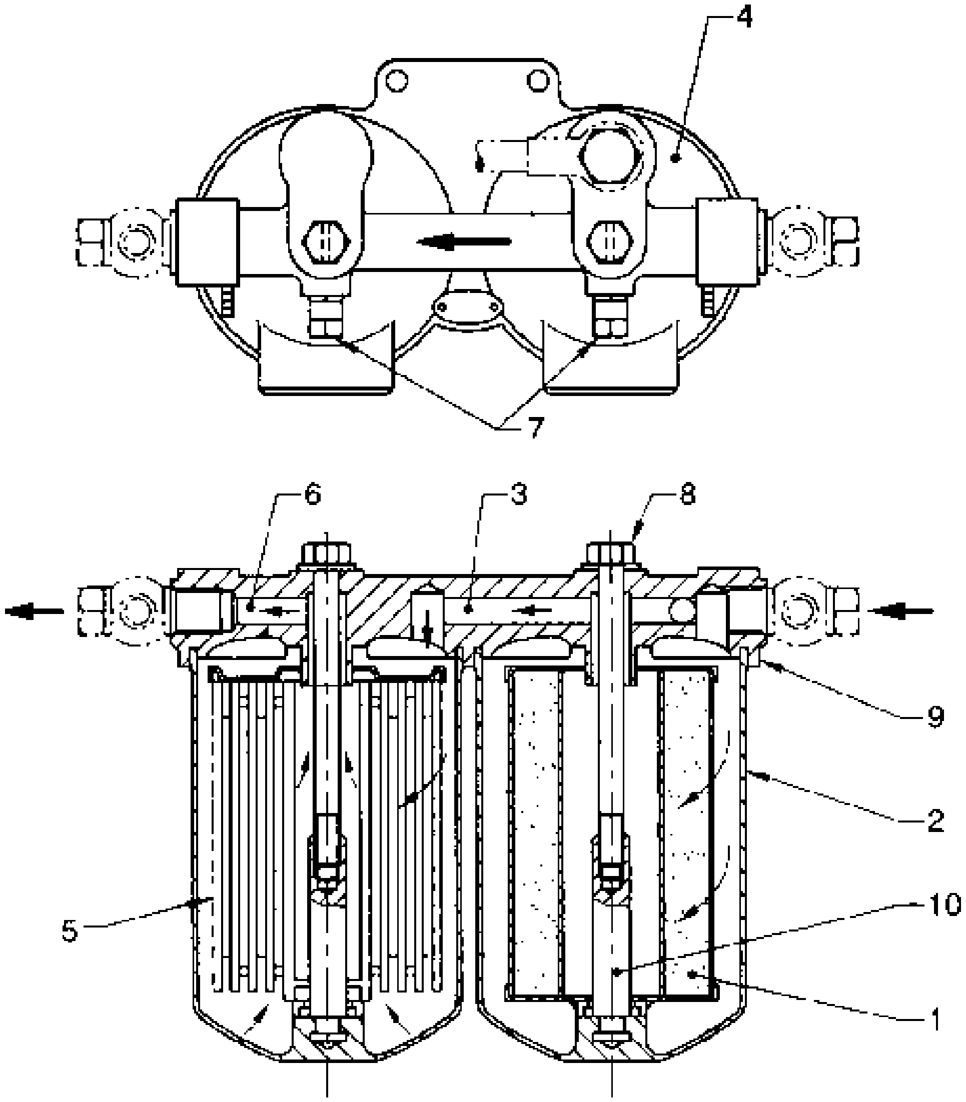
Working of F.I. Pump (Fig B)

The figure (B) indicates assembly of components of a Fuel Injection Pump.

This pump has a Barrel (1) and plunger (2) for each Engine Cylinder in a Multi–cylinder engine. The camshaft (3) is driven by the engine and a cam lobe (4) operates each plunger. When a lobe of a cam (4) comes up with roller tappet (5) under a plunger (2), the plunger (2) is lifted and its movement pressurises the Diesel entered from the gallery (6) through feed port (7). The pressure of fuel is raised to a high value when both ports Feed Port (7) and spill port (8) closed. This pressurised fuel lifts the delivery valve (9) off its seat (10) compressing the spring (11) and passes into the fuel out let pipe (12) and then delivered to the Injector nozzle by opening it. The Injection of fuel is stopped, when bottom of helix on the plunger uncovers the spill port (8). The fuel pressure in the pipe line drops. Due to this the delivery valve is seated first on its seat increasing the drop in the fuel pressure. The Injector Nozzle is closed abruptly without dribbling of fuel.

NOTE: The quantity of fuel delivered can be altered by rotating the plunger in the barrel. As plunger is rotated the effective stroke of the plunger is varied and the quantity of fuel delivered to the engine also varies.

Diesel Engine Fuel Filter



Function

In a Diesel Engine a number of fuel filters are used to clean the fuel free of contaminants to enable the fuel to pass through clearances of very highly precision finished parts like Elements and Nozzles.

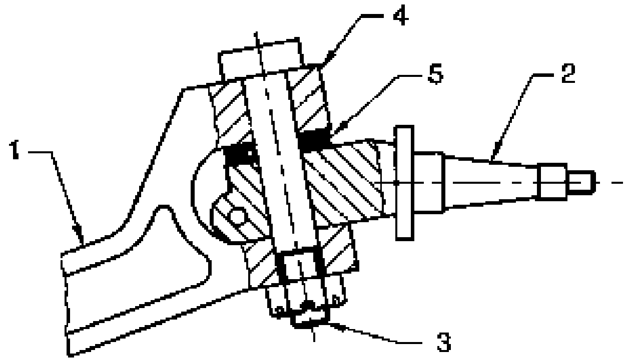
Fuel flow

The fuel passes through cloth insert (1) in the Bowl (2) of the pre−filter. Then it passes through the drilled passage (3) in the top cover (4) and enters into Bowl of Micro filter. Then the fuel passes through paper insert (5) and comes out fully cleaned off impurities, dust and dirt and enters the outlet passage (6) provided in the top cover (4) and reaches the F.I. pump. Bleeding screws (7) are provided to remove air from the system (fuel lines). At the Inlet and outlet, Banjos, Banjo bolts with copper washers are provided for connection of fuel lines from lift pump and F.I. pump. The copper washers prevent leakage of fuel through Banjos.

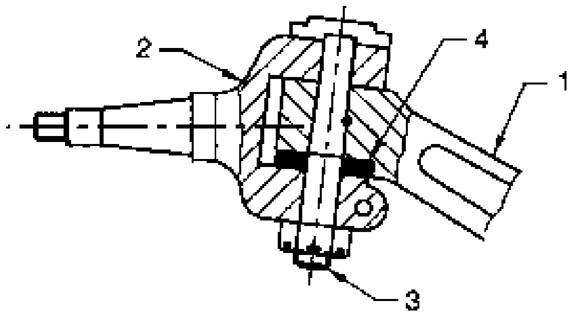
Types of Stub Axle mountings on front Axle

Stub Axle mounting

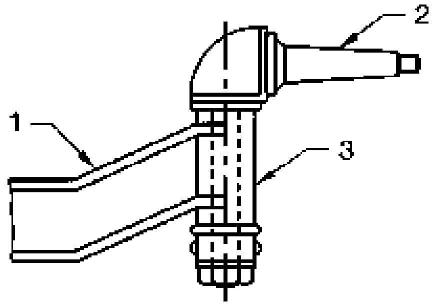
The stub axle mountings on the Beam front axle conventional type are of 3 types. They are illustrated in the figures.



1. Elliot type



2. Reversed Elliot type



3. Lemoin type

Out of the 3 types, Reversed Elliot type stub axle is largely used on commercial vehicle like Trucks and buses.

Elliot type

In this type the axle (1) is a single rigid 'I' shaped beam with a provision to fit the stub axle (2) at its two ends with king pins (3). The end of the axle (1) is Elliot shaped (forked with two eyes) (4). The stub axle (2) is mounted in between the two eyes with a thrust bearing (5) at the top end of the stub axle.

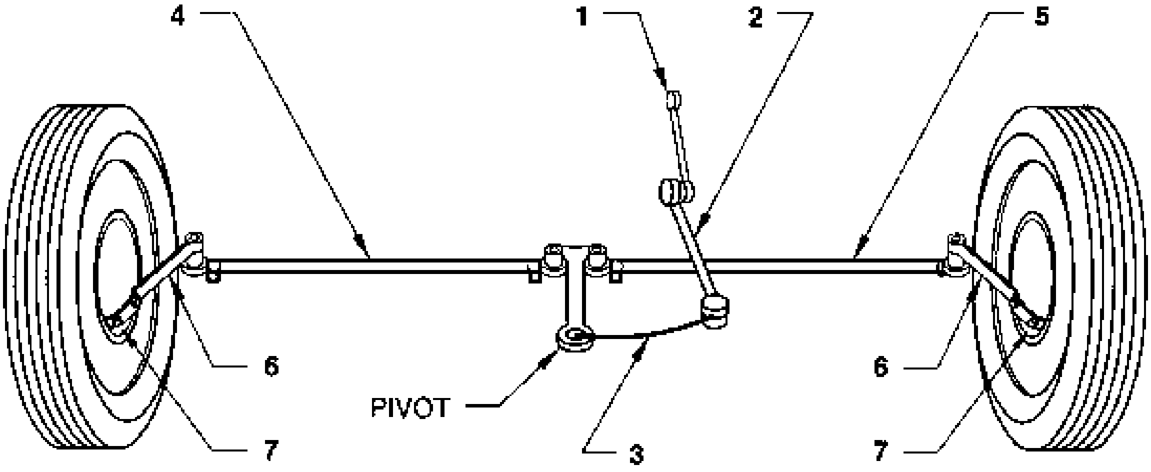
Reversed Elliot type

In this type Elliot shape is provided in the stub axle (2) The solid and of axle beam (1) is mounted in between the two eyes of the stub axle (2) with king Pins (3) with a thrust washer/bearing (4) at the bottom of the axle. It is commonly used in commercial vehicles.

Lemoin type

In this type the stub axle (2) is mounted on the top of the axle beam (1) with king pins (3).

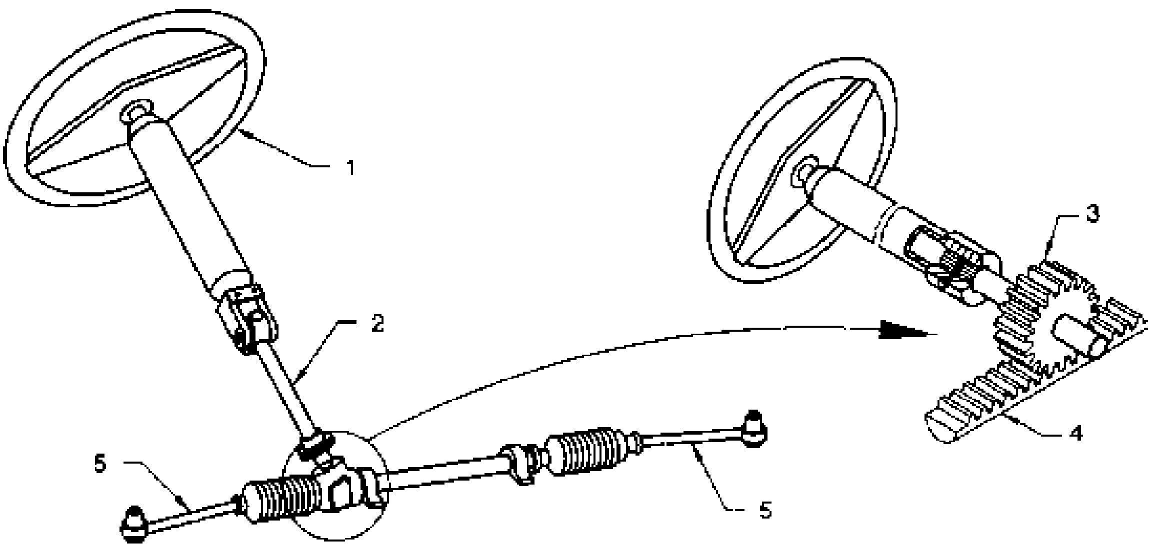
Steering linkages Light Motor Vehicle



Working

The type of Steering Linkages used in LMVs is different from the Heavy Motor Vehicle Linkages. In the system shown in figure, one Bell Crank Lever and two tie Rods are used for steering operation in addition to other components. When Pitman Arm or Drop Arm (1) is turned by steering wheel it operates the Drag link (2). The Drag link moves the Bell crank (3) on its pivot. When Bell crank (3) moves, it actuates the Right and left Tie rods (4) and (5), which in turn operates the spindle steering arm (6) to turn the wheels. Sockets (7) are provided at all moving points so that turning of these Tie rods will be easy. These Sockets or Joints are to be lubricated with grease periodically.

Steering Gear Box Rack & Pinion Steering

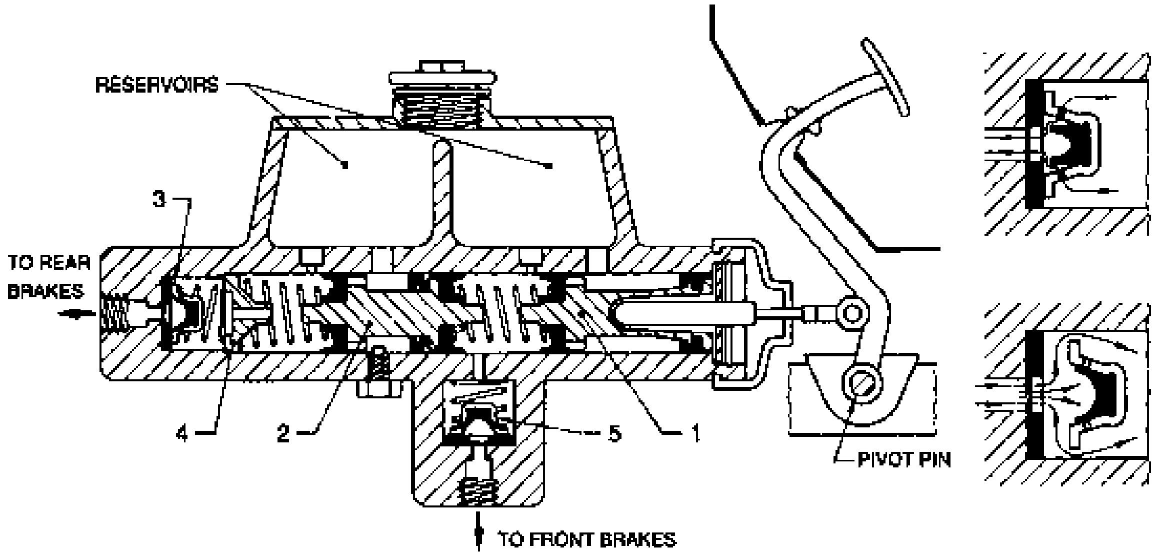


In some of the lighter cars, a Rack and Pinion steering mechanism is provided.

Function

When the steering wheel (1) is rotated the steering column (2) attached with a pinion (3) is also rotated. The pinion (3) is always in mesh with the Rack Teeth (4). This action makes the rack (4) to move either left or right. The Rack (4) is connected to tie rods which cause the wheels to turn for steering the vehicle on road. The steering adjustments are very simple and easy to carry out. The maintenance cost is also less.

Tandem Master Cylinder and its function



(a) Special points

The operation of this type of master cylinder is similar to that of ordinary master cylinder used in cars and other vehicles.

In this type two separate cylinders and reservoirs are provided in the same body there are two check–valves and two pistons for operation, one each for the front and rear brakes.

In this type, in the event of failure of one brake line (front or rear), the other continues to work and stops the vehicle.

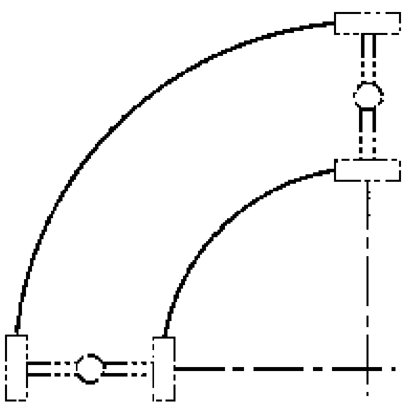
(b) Failure of brakes

When the front brake fails, the primary piston (1) is forced forward till it contacts the secondary piston (2) Now, both the pistons move together in TANDEM.

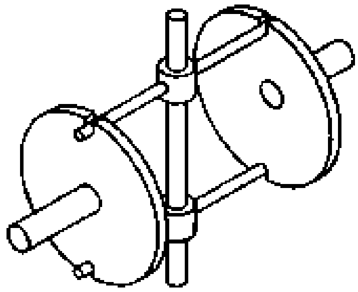
Pressure is created on the secondary side and this forces the fluid through the check–value (3) to the rear brakes and the vehicle is stopped.

When the rear brake fails there is no pressure on the secondary side. The pedal effort pushes the primary position (1) which forces the secondary piston (2) to stop point (4). Further movement of the piston (1) builds up the fluid pressure which is transmitted to the front wheel cylinders through the check–valve (5) and the vehicle is stopped.

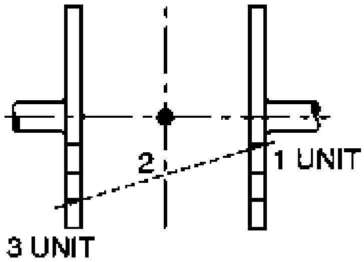
Differential and its action



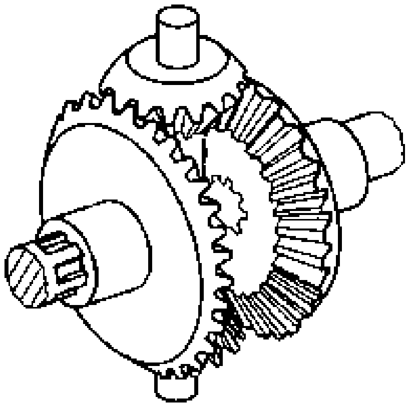
(a)



(b)



(c)

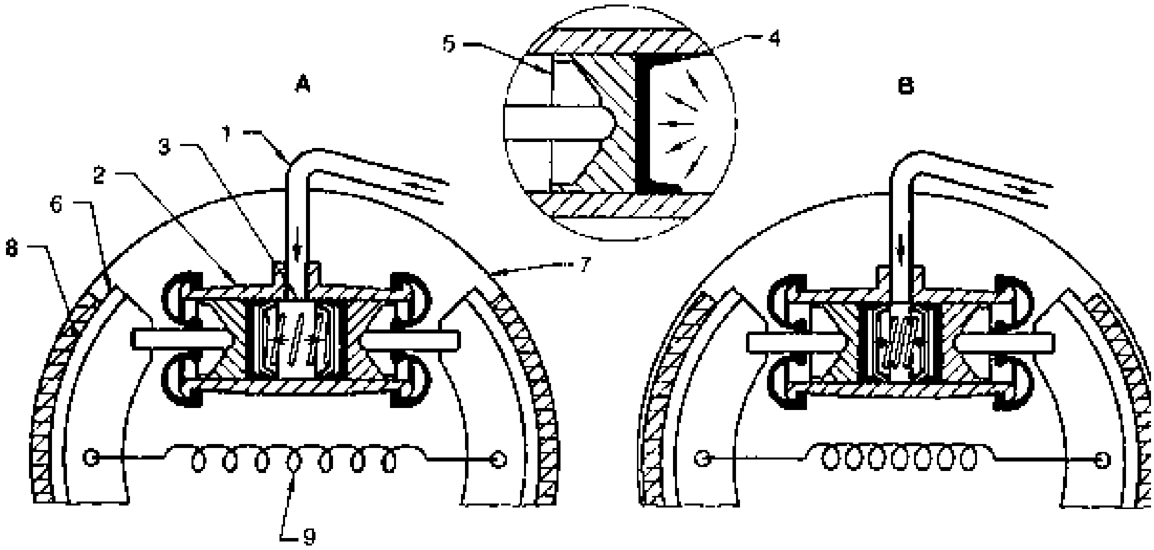


(d)

When the vehicle is moving straight, the power is transmitted from the pinion to the crown wheel and to the cage. The differential mechanism is mounted with in the cage and it also moves. When the spider cage is rotating the cross pin or (1) also rotates along with the star gears (2). The sun gears are pushed by the star gears, and power is transmitted to the axle shafts (4) During a straight line run the star gear (3) do not rotate on their axis.

When the vehicle makes a turn, the inner wheel has more grip on the road than the outer wheel. So the respective inner sun gear (3) offers more resistance. At that time, the star gears (2) rotate on their own axis and move the inner sun gear slowly and allow the outer sun gear to rotate faster. So the outer wheel travels more distance in the same time. This is also shown in the Figure (d).

Wheel Cylinder and its action



a) Brake application

The pressurized brake fluid coming from mater cylinder pipeline (1) enters the wheel cylinder (2) through the entry port (3). This fluid exerts pressure on rubber cups (4) in the direction shown. Now the flanged edges of the cups are pressed tight against wheel cylinder bore. This action prevents leakage of fluid and also entry of air in the system. The pistons (5) move outwards and forces the brakeake shoes (6) against the brake drum (7). The friction between the brake shoe lining (8) and the brake drum (7), stops the rotation of brake drum (7). Now the vehicle is stopped.

b) Brake release

When brakes are released, the brake shoes (6) come to original position with the help of retracting spring (9). this action pushes the wheel cylinder pistons (5) inside the cylinder and the pressurized fluid returns back to master cylinder by lifting the check valve off its seat.

Mechanic Diesel – Transparencies

Table of Contents

Mechanic Diesel – Transparencies 1
Diesel Fuel Feed Pump 1
Valve Timing Diagram (4 Stroke Cycle Diesel Engine) 2
Valve Timing Diagram (2 Stroke Cycle Diesel Engine) 3
Diesel Engine Lubrication with oil cooler 5
Diesel Engine Lubrication oil filter (full flow) 6
Glow Plug Electrical Circuit 7
Crank Case Ventilation 8
Sparking Plug 10
Chemical action in Lead Acid Battery 12
Reading of Micrometer (Outside) 13
Micrometer parts and graduations 14
Reading of Vernier Caliper 15
Vernier Caliper Parts and Principle 16
Combustion chambers 17
TURBO Charged Engine (Two stroke diesel) 19
Uniflow Scavenge 20
Scavenging system (Diesel) Loop Scavenge 21
Pneumatic governor function 22
Mechanical governor Principle (A) 24
Mechanical governor Principle (B) 24
Fuel Feed System (Diesel Inline Jerk Pump) 26
Diesel Engine fuel filter 27
Comparison of Function multi hole and Pintle Nozzles 29
Fuel Injection Pump 30
Piston rings assembly 33

Mechanic Diesel – Transparencies

CENTRAL INSTRUCTIONAL
MEDIA INSTITUTE, MADRAS

ANINDO – GERMAN PROJECT

Directorate General of Employment & Training, Ministry of Labour, Govt. of India.

Developed by
CENTRAL INSTRUCTIONAL MEDIA INSTITUTE
in collaboration with DEUTSCHE GESELLSCHAFT FUER TECHNISCHE ZUSAMMENARBEIT (GTZ)
Germany

P.O. Box 3142, 76, GST Road, Guindy, Madras – 600 032. Phone: 234 5256, 234 5257, Fax (0091 44) 234 2791

Diesel Fuel Feed Pump

TR 10 01 03 05 99

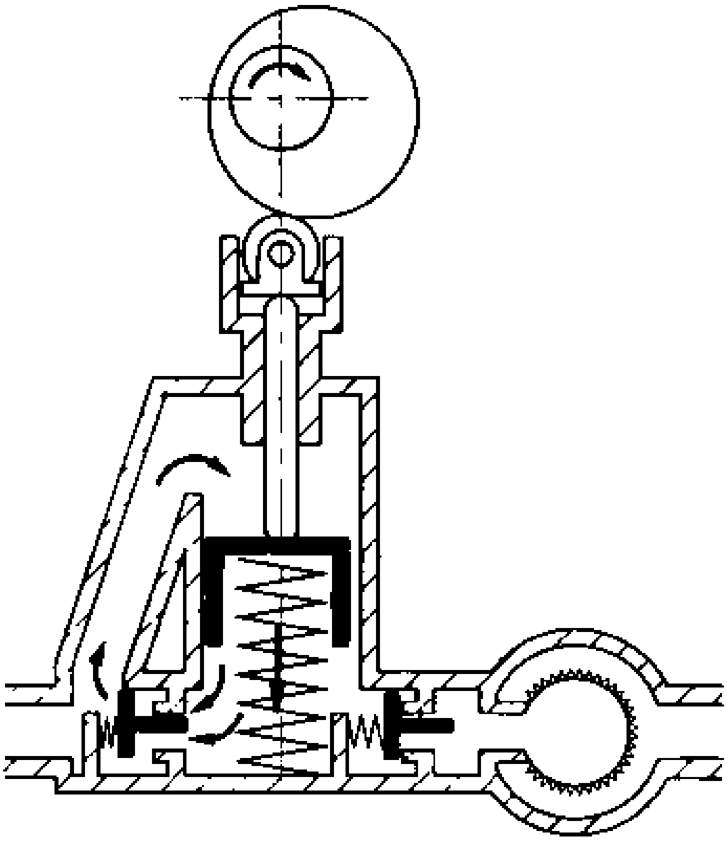
Function

Fig A: Delivery and Suction

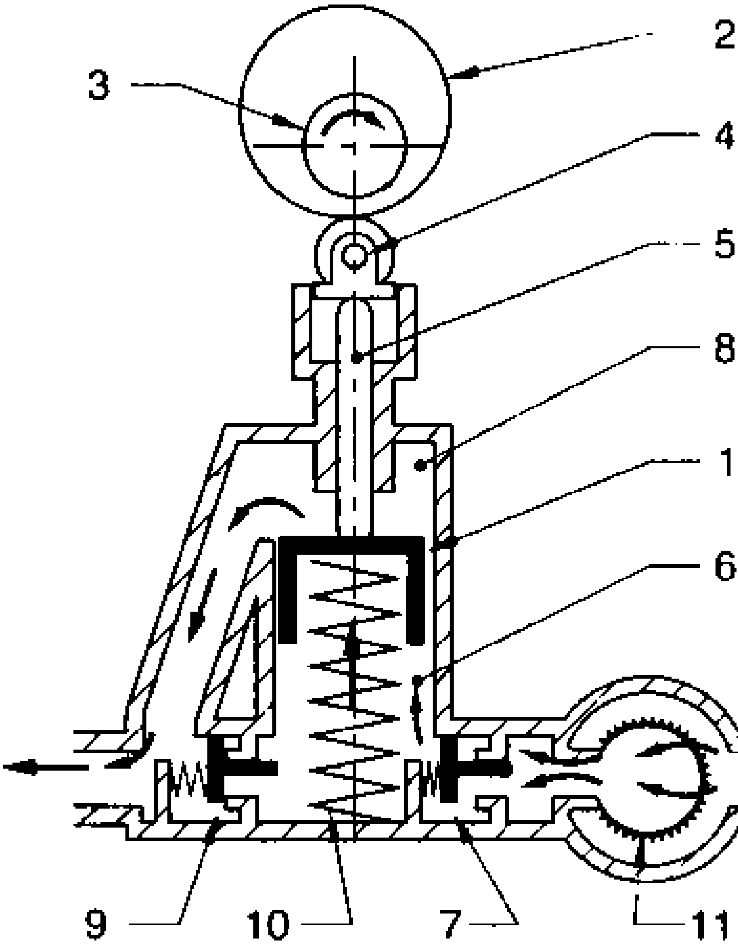
The feed pump piston (1) is operated by an eccentric (2) on the camshaft (3) through a roller tappet (4) and a thrust pin (5). This action creates suction in the suction chamber (6), to which place, fuel is drawn through Inlet marked with arrow via suction valve (7). When the suction valve (7) is closed, fuel is delivered to pressure chamber (8) through pressure valve (9). The piston spring (10) is compressed at the same time and the spring loaded valve (9) closes at the end of the stroke. As soon as the eccentric (2) has passed the point of maximum lift, piston (1), thrust pin (5), roller tappet (4) move upwards due to the pressure exerted by piston spring (10). This action forces part of the fuel out of the pressure chamber (8) and through the filter to the Injection pump. This is called delivery stroke. During this time, fuel is sucked simultaneously from the fuel tank to suction chamber (6).

Idling Action

Fig B: When the fuel pipe line is full the F.I.P does not need any fuel and the pressure in the pressure chamber (8) holds the piston (1) in the top position, putting the feed pump out of action. No fuel will be delivered to the F.I.Pump.



A INTERMEDIATE STROKE / IDLING ACTION



B DELIVERY AND SUCTION STROKE

Valve Timing Diagram (4 Stroke Cycle Diesel Engine)

TR 10 01 01 06 99

Valve timing

Valve timing is set and checked with reference to TDC and BDC marked on flywheel (1).

Checking Inlet valve opening

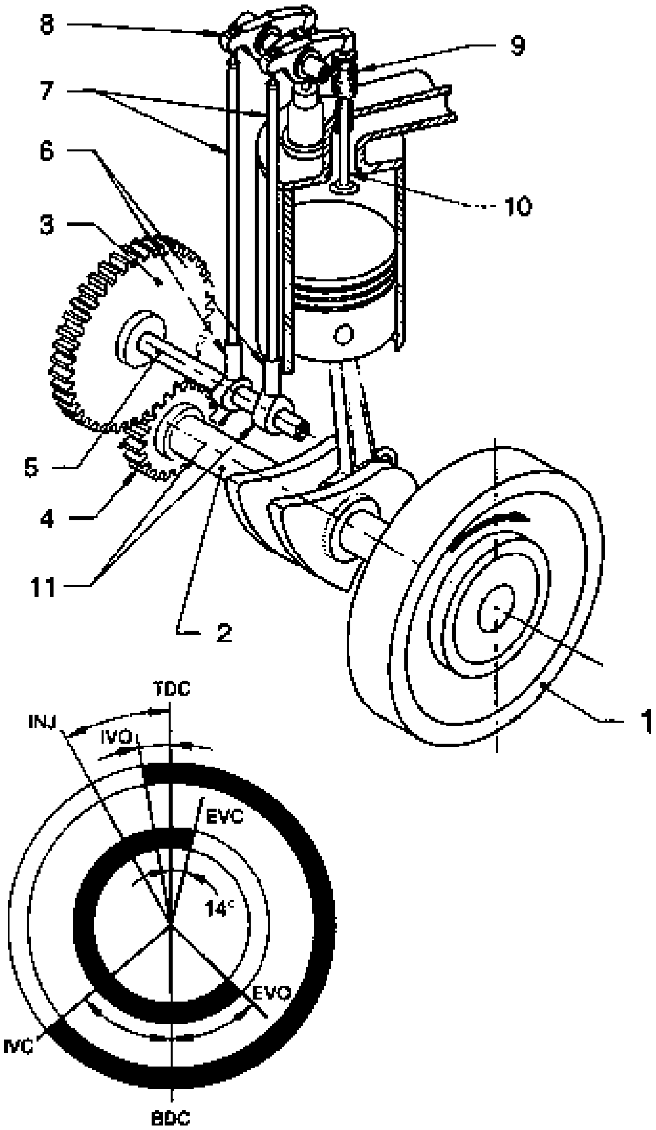
The valve timing angles are marked on the face of the flywheel (1). Hence rotate flywheel (1). The crankshaft (2) Timing gears (3 & 4) camshaft (5). Tappet (6) pushrod (7) and Rocker arm (8) and springs (9) will operate. Observe position of pushrod (7) and compression of springs (9). Feel the push rod for tightness and ensure the valve opening. Now the Inlet valve (10) is fully opened.

Now measure the distance on the flywheel (1) from TDC to the point of opening Inlet valve (9) by using a measuring tape.. Convert, this flywheel distance into degrees of crankshaft revolution by using the formula

D = 2? 360 × A × R [Where A =,Timing angle, R = Radius of flywheel]

Result

If in the conversion you get 10° as the degrees marked on the flywheel, the Inlet valve opening is correct. Also check the timing gear marks for alignment. If they align, the timing is correct.



IVO – INET VALVE OPEN
IVC – INLET VALVE CLOSE
EVO – EXHAUST VALVE OPEN
EVC – EXHAUST VALVE CLOSE
INJ – INJECTION

Valve Timing Diagram (2 Stroke Cycle Diesel Engine)

TR 10 01 01 07 99

Function

In this engine inlet ports (1) and exhaust valves (2) are used. The Inlet ports (1) are opened and closed by the movement of the piston (4) in the cylinder (5) from TDC to BDC and vice versa. The ports could be seen when the piston (4) is at BDC. The exhaust valves (2) are opened by camshaft gear & Rocker mechanism.

Port and valve timing

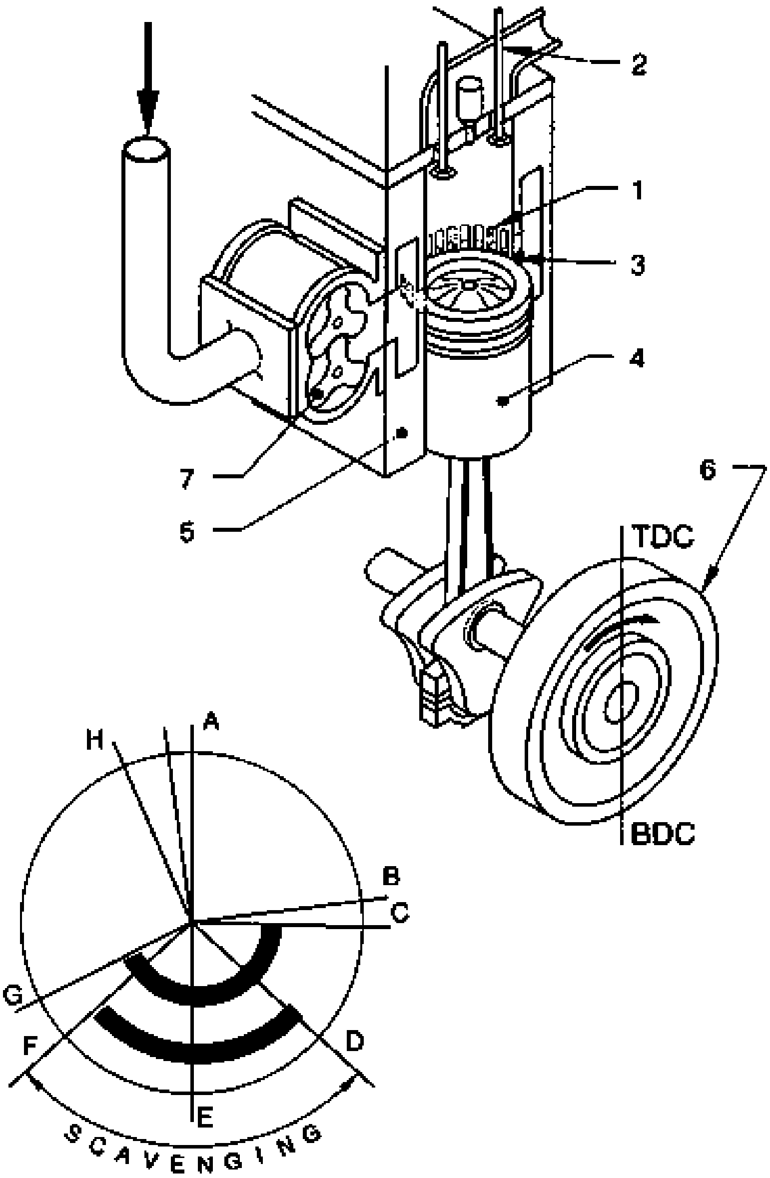
Port and Valve timing are set and checked with reference to TDC and BDC marked on the flywheel (1). During overhauling an engine this timing is checked and reset.

Checking Exhaust Valve Opening

Port and valve timing angles are marked on the face of flywheel (6). By rotating flywheel (6). Timing gear and crankshaft, the push rod will lift the exhaust valve compressing the springs. In this figure Exhaust Valve (2) is shown in the open position. Now measure the distance on flywheel (6) from TDC point to the point of opening the valve. Convert this flywheel distance into degrees by using the formula D = 2? 360 × A × R

Where

A = Angle
R = Radius of flywheel



A – TDC
B – Ex. VALVES START TO OPEN 82.5° ATDC
C – Ex. VALVES OPEN – 91.5° ATDC
D – In. TAKE PORTS OPEN – 132° ATDC
E – BDC
F – In. TAKE PORTS CLOSE – 48° ABDC
G – Ex. VALVES CLOSE – 117° BTDC
H – INJECTION – 23.5° BTDC

Result: If in the conversion you get 82 1/2° as the degree marked on the flywheel (6) the exhaust valve (2) opening is correct. Also check for Alignment of timing marks. If the marks align timing is correct.

Checking Inlet ports Opening

Follow the same procedure. These Inlet ports (1) open at 132° ATDC. Here also bring the flywheel (6) to TDC position and from there rotate it to the opening point of ports (1). This could be felt by the suction on the blower (7) side, as free air will enter through ports from outside. Measure the flywheel distance from TDC and calculate the degrees and compare markings.

Checking closing of ports and valve

Similar procedure could be followed for Inlet port (1) closing from BDC and Exhaust Valve (2) closing from TDC.

Refer to markings on the flywheel (6)

Diesel Engine Lubrication with oil cooler

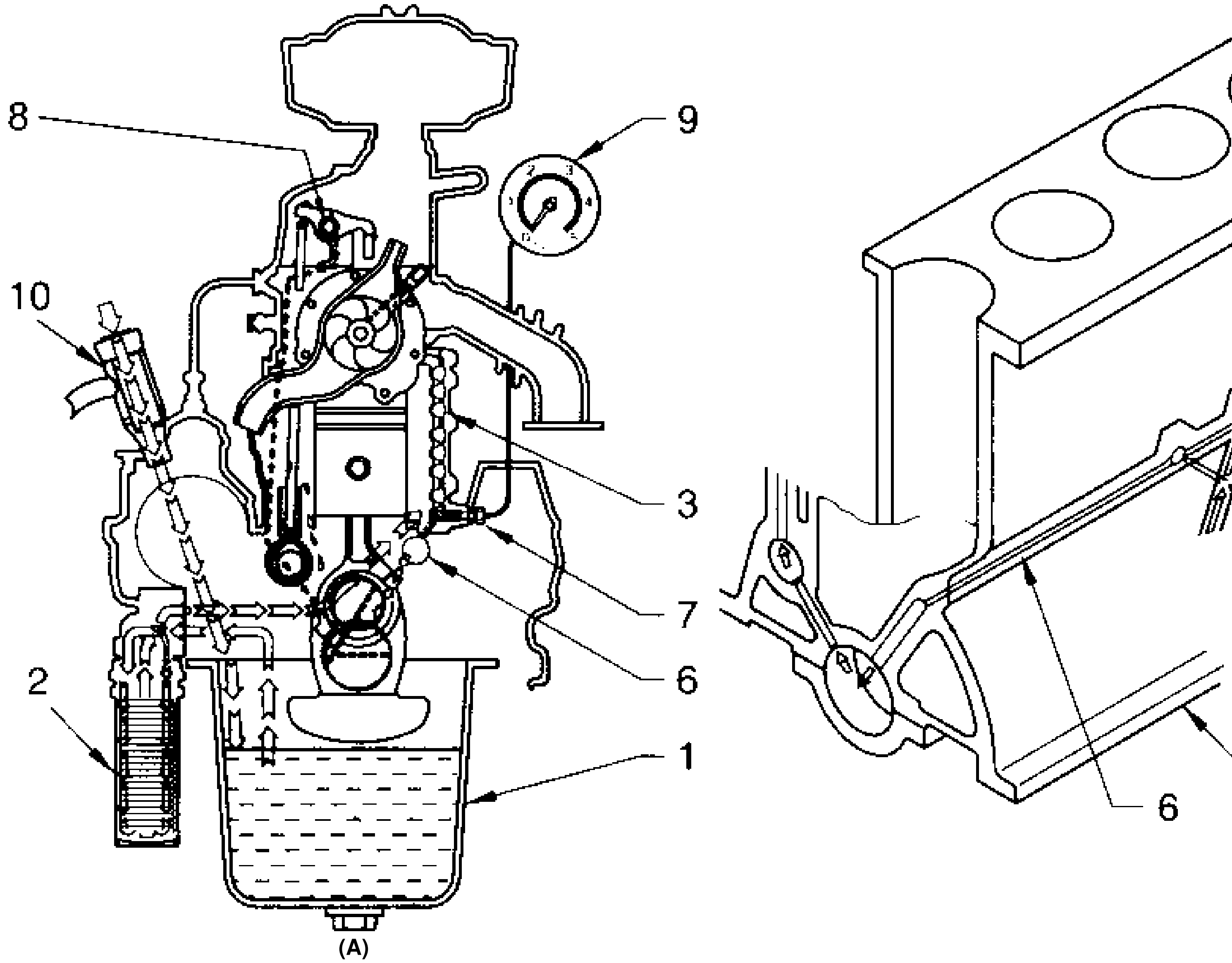
TR 10 01 06 02 99

Function

An oil cooler is provided in the lubrication system of the engine, to cool the engine oil, which becomes hot during working.

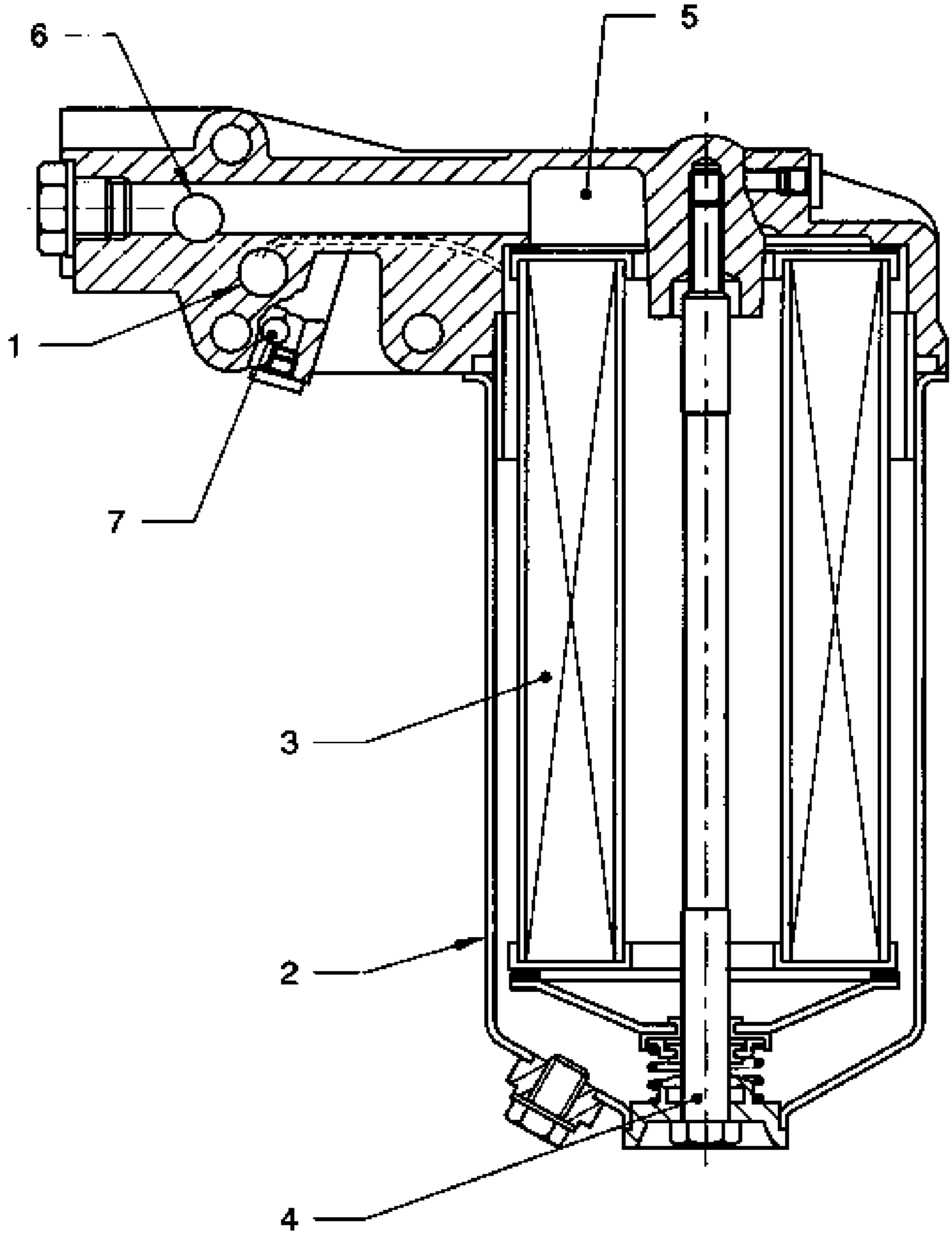
Flow of Lubrication oil

The engine oil in the oil sump/pan (1) is delivered under pressure created by the oil pump. The oil passes into the full flow filter element (2). (Filter located outside the engine cylinder) and gets fully filtered. After filtration the oil passes into the channels of the oil cooler (Heat exchanger) (3). The oil cooler (Heat exchanger) (3) channel plates and cover (4) are bolted to cylinder block (5) with gaskets. The inner plate is in contact with water in the water jacket of engine. The hot oil passing through heat exchanger (3) channels, transfer its heat to the cooling water. The cooled oil, passes on to oil main gallery (6) in the cylinder block (via the by pass valve (7)) and from there it is delivered to main bearings, cam shaft bearings and then to Rocker Arm shaft (8) and finally it returns to the oil sump (1). A tube from by pass valve (7) is connected to oil pressure gauge (9) and the gauge records the working pressure of lubricating oil. The engine oil may be filled through oil filler pipe (10) to the recommended level. The drain plug is used for draining the oil during service.



Diesel Engine Lubrication oil filter (full flow)

TR 10 01 06 03 99



Introduction

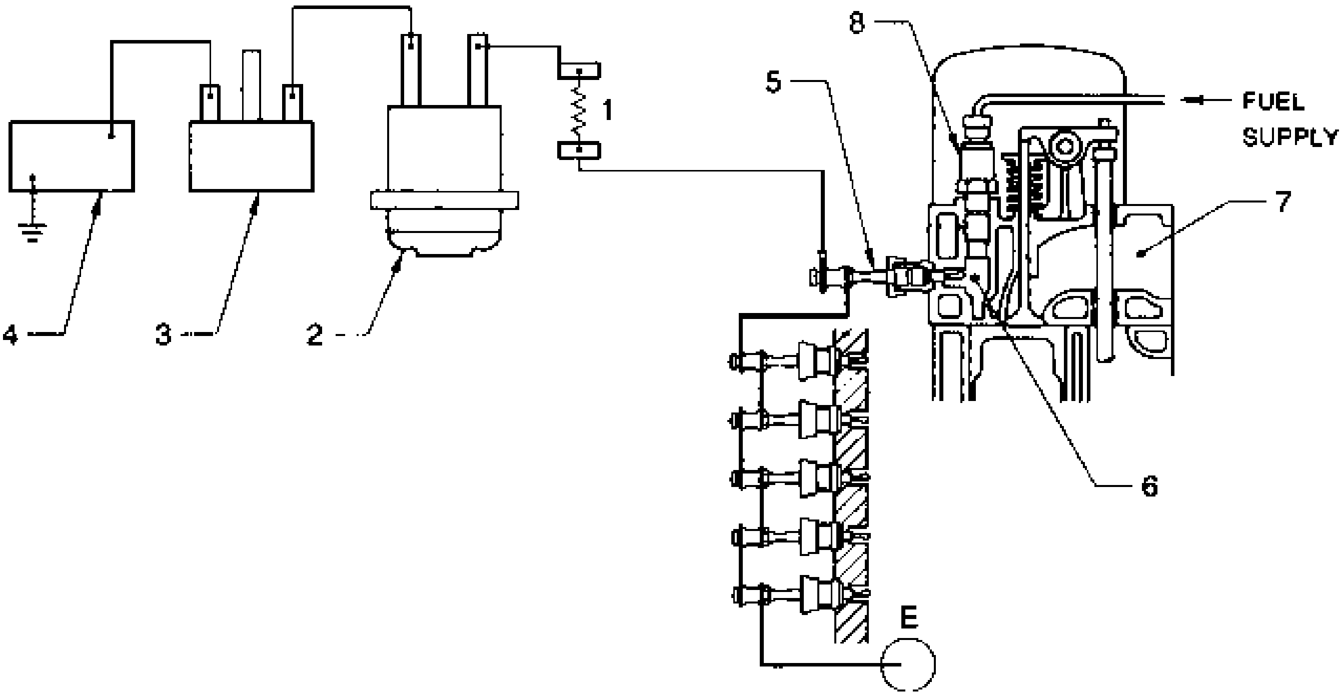
The oil filter is a full flow type, which means that 100% of oil passes across the filter element out of which 94% of oil is passed on to the engine bearings after filteration.

The oil circulation

The Lubricating oil from oil pump under pressure enters the Inlet port (1) of the filter and passes on to the housing (2) (or Bowl) through a drilled passage (shown in dotted lines). After circulating through the filter element (3) (cartridge paper type) it gets fully filtered and then the filtered oil enters the drilled passage in tension bolt (4) and reaches oil outlet passage (5) in the filter assembly. From this passage, oil flows into outlet port (6) and from there it flows into oil cooler, main bearings and finally reaches oil sump.

A by pass to sump (7) is provided to allow excess oil to reach oil sump from the filter.

Glow Plug Electrical Circuit



Function

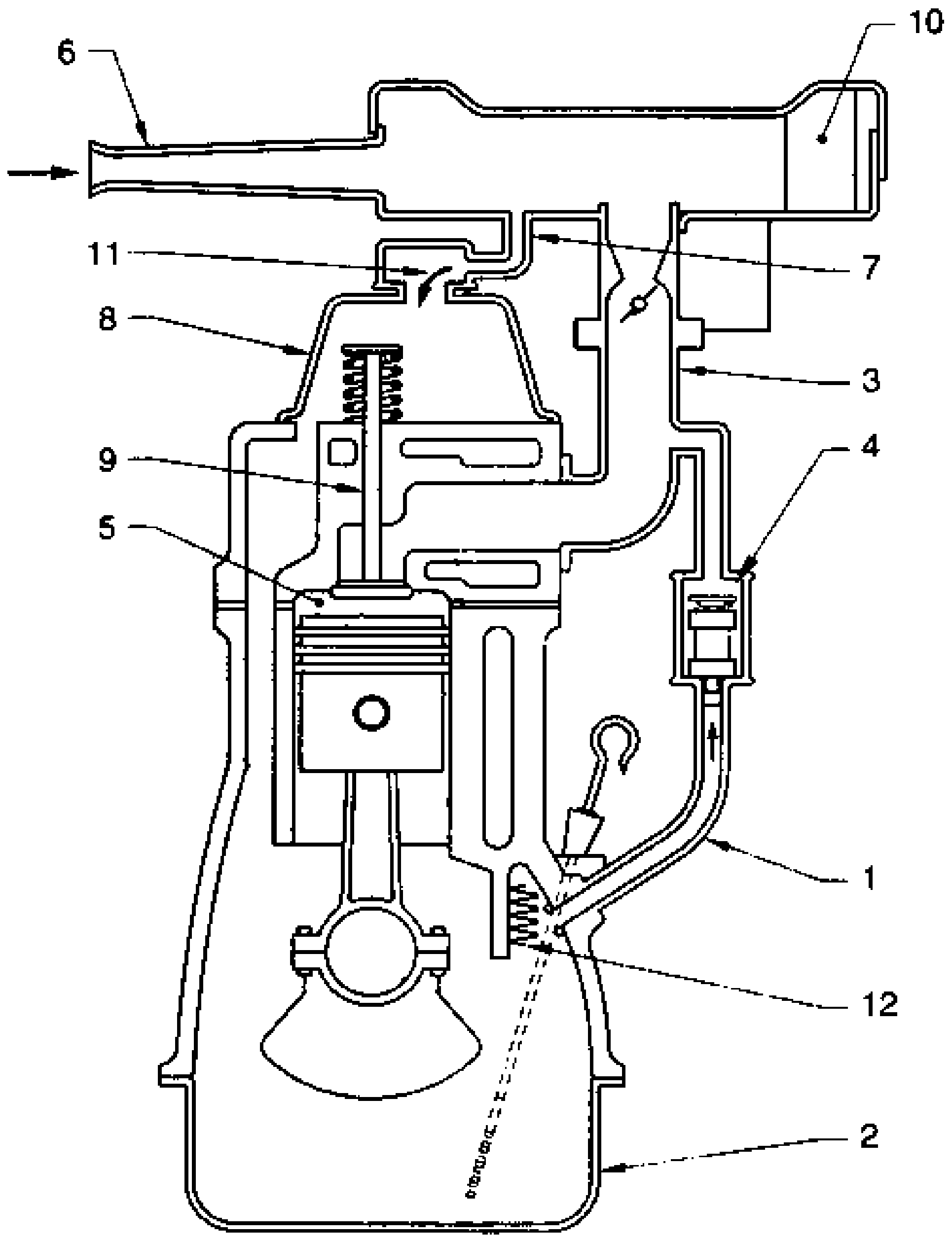
In this system Glow Plug resistor (1) and pre−heating monitor (2) are connected in series. The line resistor (1) and the preheating monitor (2) provide for the over all electrical resistance of the pre−heating system to match with battery voltage.

The pre−heating control switch (3) has two positions. In the first position all the electrical resistors are in the battery (4) current circuit. When the glow plugs (5) reach the correct temperature the yellow monitor light comes on and the second stage is switched on. In this position the glow control circuit (3) (Monitor) is short circuited because the battery voltage will drop due to high rate of current discharge. After the engine is started the glow system is switched off. The battery (4) supplies all the current to this glow system. The glow plugs (5) are located in the pre−chamber (6) provided on the cylinder head (7) in all diesel engines. The operation time is only for few seconds.

Each cylinder will have one glow plug and in a six cylinder engine, these glow plugs are connected in series with the battery.

Crank Case Ventilation

TR 10 01 06 01 99



Function

In IC engines, products of combustion leak past the rings into the crankcase. These products are to be removed to reduce oil contamination, dilution, corrosion and other undesirable chemical effects. For removal of these products positive crankcase ventilation is used in engines.

As per MV Act all Motor Vehicle Engines are to be provided with P.C.Ventilation system and this is compulsory.

Working

Generally a Tube or Hose (1) connects the crankcase (2) to the Intake manifold (3) via a PCV valve (4). The crankcase gases are drawn into the Inlet manifold (3) by engine vacuum, then goes into the combustion chamber (5) with air fuel mixture and gets burnt up as a fuel. Clean Air is delivered to the engine through air entry tube (6) and also through a Breather pipe provided on the oil filler or A Tube or Hose (7) connecting the engine air filter to the crankcase or rocker cover (8). The PCV Valve (4) controls the flow of air through the crankcase (2) and prevents excess air admission during suction and acceleration of the vehicle. Also it protects engine against damage due to back firing.

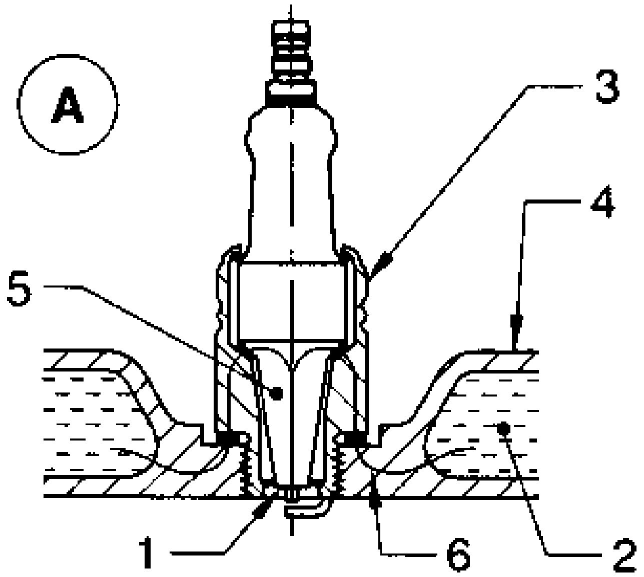
Sparking Plug

TR 10 10 04 01 99

Function

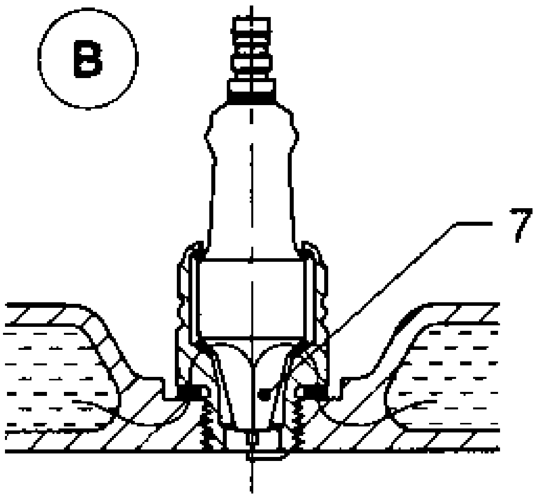
Sparking plugs are classified as Hot plug and Cold plug.

I. Hot plug (Fig A)



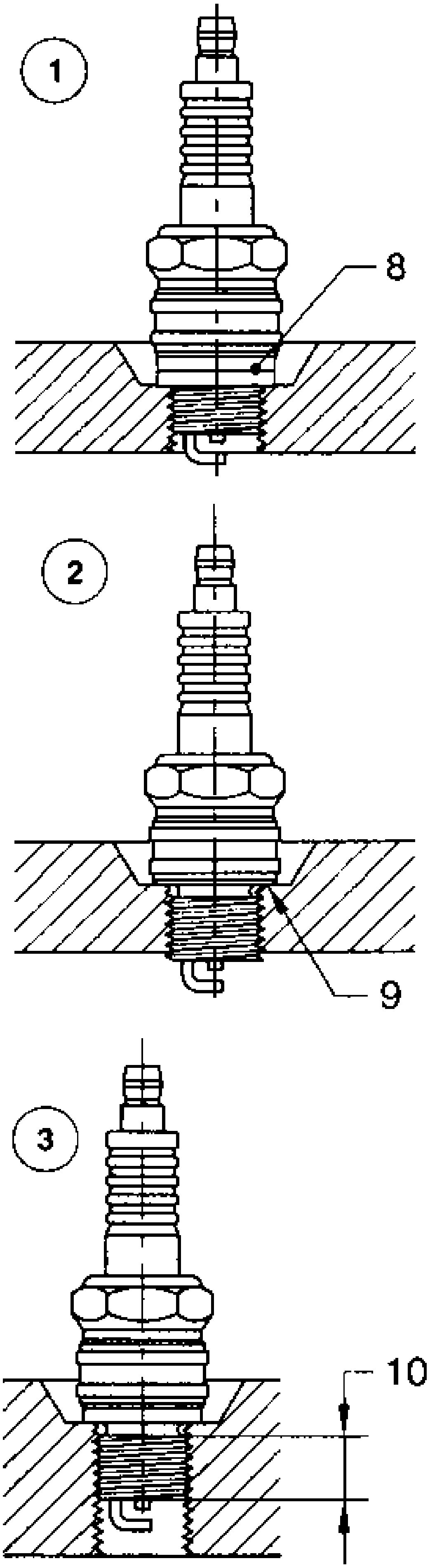
The travel of heat in a Hot plug (A) is shown. The heat travels from Insulator nose (1) and reaches the cooling water (2) through shell (3) and cylinder head (2). The Insulator Base (5) is long and so heat travel path (6) is also long. Hence it is called as Hot Plug (A). The Insulator Nose (1) is the hottest part of a plug, which determines the "Heat Range". The Nose of Insulator Projects into combustion chamber. The Hot Plug vaporises carbon deposits quickly.

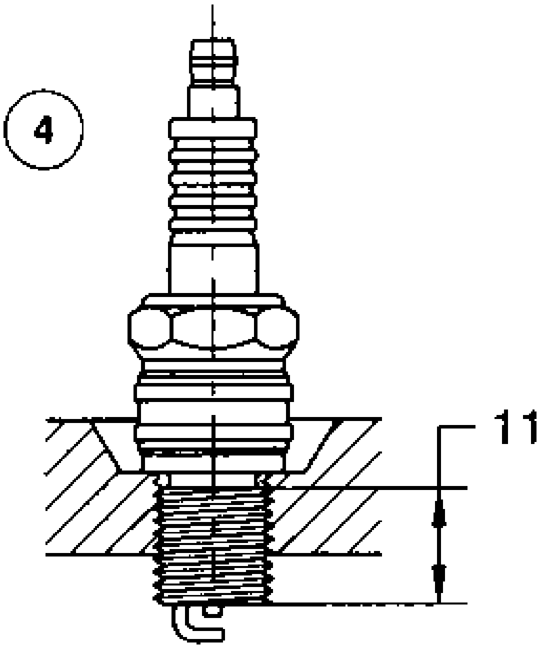
II. Cold Plug (Fig B)



In this plug, the heat travel path/Insulator base (7) is shorter. Hence plug is cooled quicker by cooling water in the jacket (2). It works comparatively cooler. Hence it is called as "Cold Plug" (B).

III. Installation


1
8
2
9
3
10



Plug No. 1: This is fitted with 2 gaskets (8). Hence danger of misfiring and difficulty in removal are present. This is not the correct way.

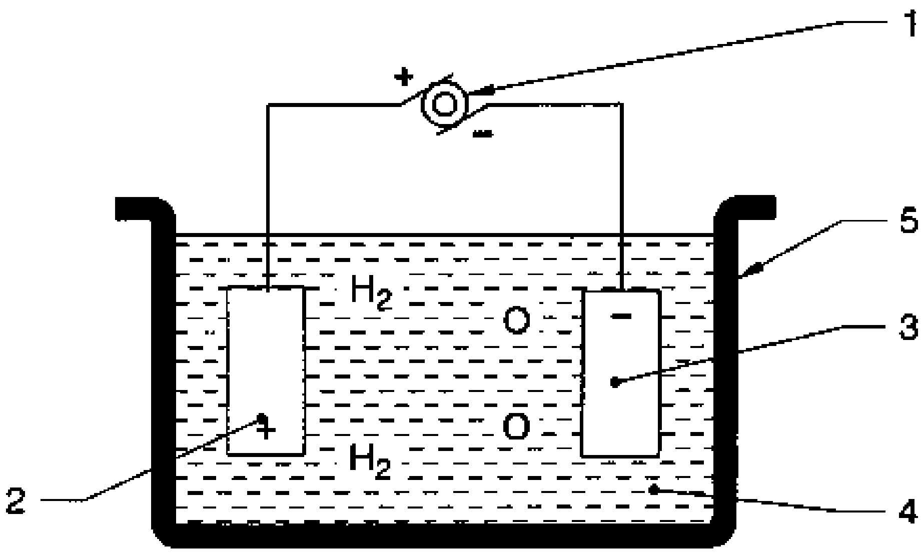
Plug No. 2: No gasket (9) is shown between the plug shell and cylinder head. Danger of preheating and overheating will result. This is also not the correct way.

Fig 3: Spark plug with short reach of thread (10) in the cylinder meant for long reach. Combustion action will be delayed.

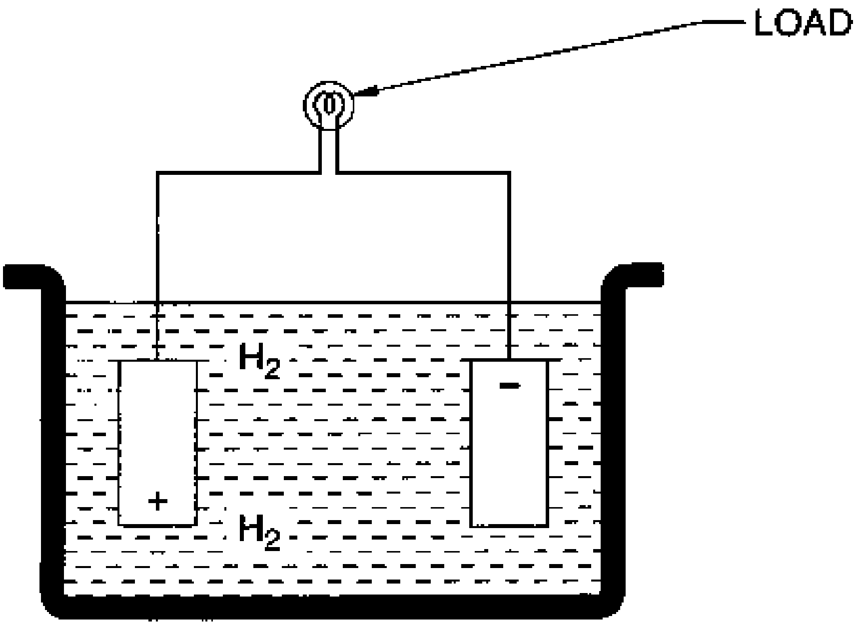
Fig 4: This long reach (11) plug is fitted in a cylinder head meant for short reach. The plug projects into the combustion chamber and may hit piston head and damage it. The combustion also will be affected.

Chemical action in Lead Acid Battery

TR 10 10 01 01 99



CHARGING



DISCHARGING

Function

Chemical Action between Plates and Acid

A. Charging

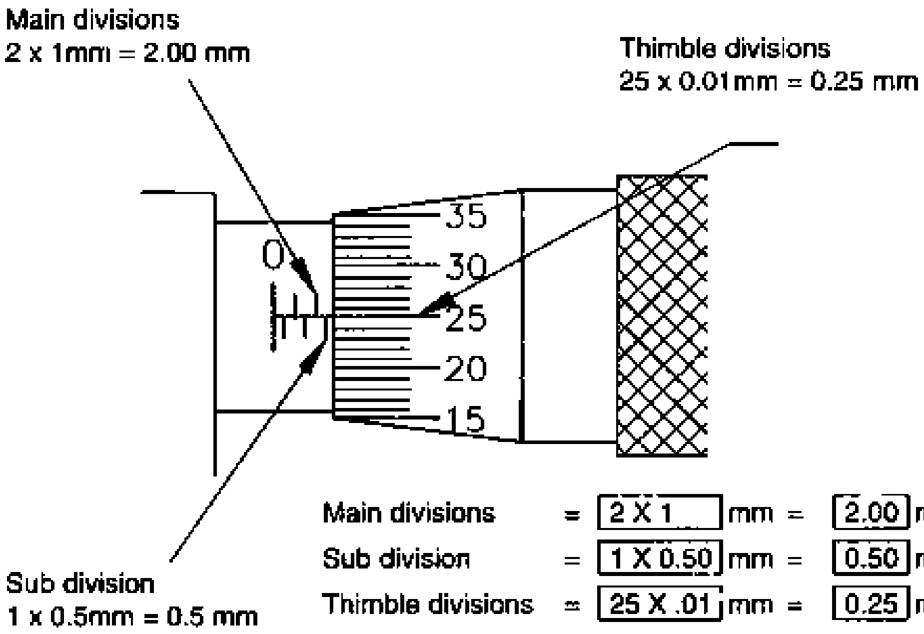
For charging a battery it is connected to a generator (1). Both the plates (+ve (2) and –ve (3) are Lead Sulphate (Pbs04). The current from Generator (1) enters the Battery terminals (+ve) and (–ve) (2 & 3) and passes through the water. The water content in the Acid (4) is broken into (H_2) Hydrogen and Oxygen (0). The So_4 sulphate ions moves back to the Electrolyte from plates and gets united with Hydrogen to form Sulphuric Acid. The oxygen atoms are driven back into positive plate (2), thus forming into Lead peroxide. Lead sulphate disappears in both the plates leaving lead on the negative plate (3) called spongy lead. The specific gravity of electrolyte increases. Positive plate (2) becomes chemically lead peroxide and negative plate (3) becomes spongy lead. Now battery is fully charged, specific gravity of Electrolyte increases and voltage also increases. The container (5) holds the Sulphuric Acid (4) and plates.

B. Discharging

During discharging the current is supplied to a lamp (1) from Battery. The Sulphuric Acid (4) is split up into H2 and So4. One S04 unites with P.b (Spongy Lead Pb) of negative plate (3) and other units with pb of the positive plate. (2) This action makes both plates lead sulphate. (Pbs04). The uniting of hydrogen and oxygen (b) becomes water. Now Sulphuric Acid (4) becomes water. Both plates converted into Pbs04. Specific gravity of electrolyte becomes less and voltage is also less.

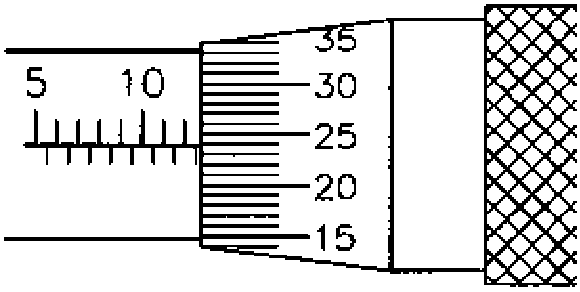
Reading of Micrometer (Outside)

TR 01 02 02 02 98



Main divisions	=	2 X 1 mm	=	2.00 mm
Sub division	=	1 X 0.50 mm	=	0.50 mm
Thimble divisions	=	25 X .01 mm	=	0.25 mm
Reading	=			2.75 mm

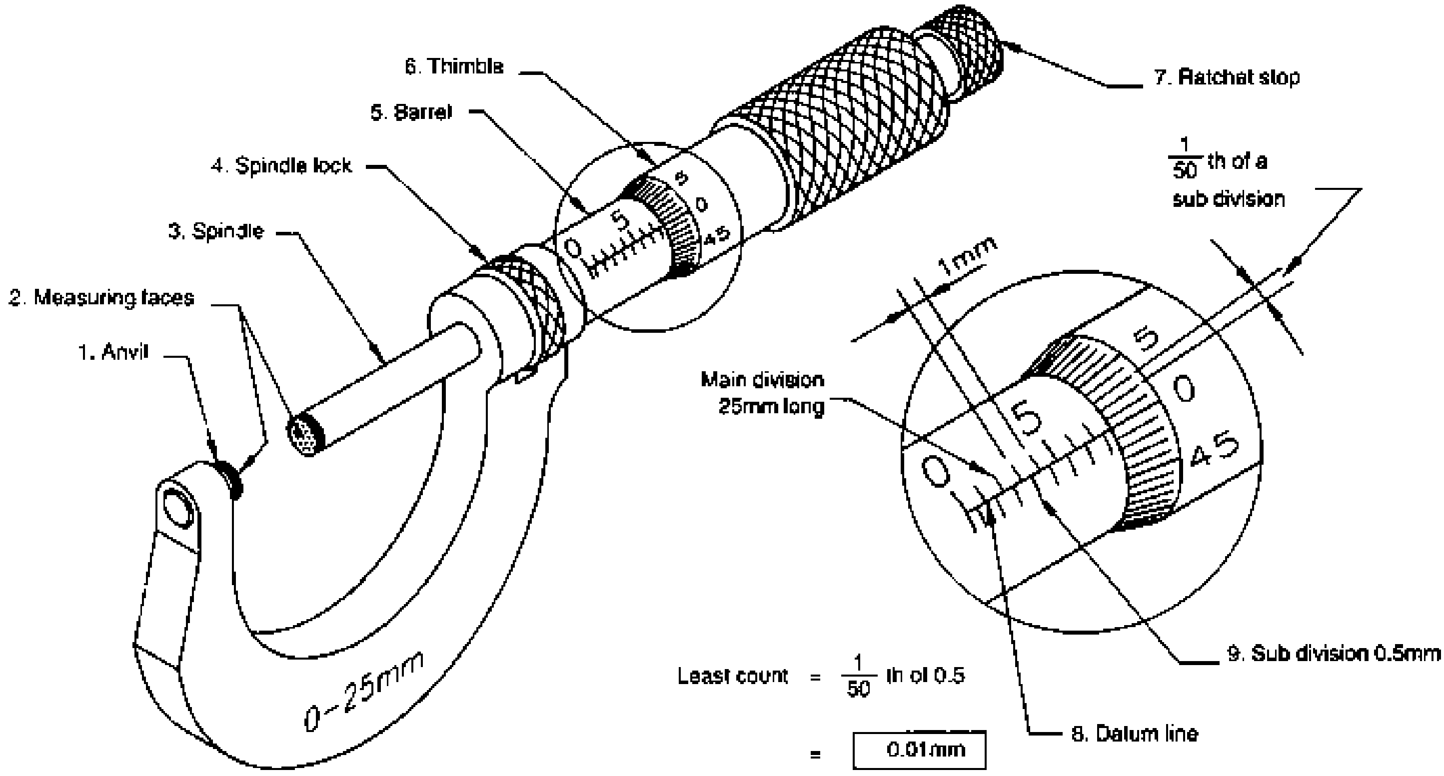
EXAMPLE



Main divisions	=	12 X 1 mm	=	12.00 mm
Sub division	=	1 X 0.50 mm	=	0.50 mm
Thimble divisions	=	24 X .01 mm	=	0.24 mm
Reading	=			12.74 mm

Micrometer parts and graduations

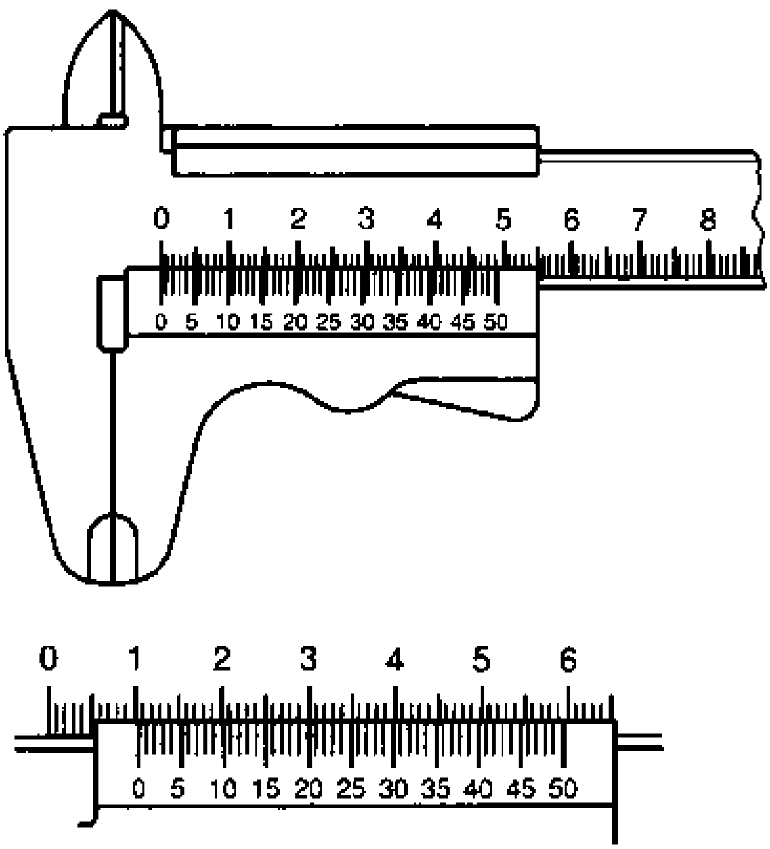
TR 01 02 02 01 98



The range of the Micrometer is 0 – 25 mm.

Reading of Vernier Caliper

TR 01 02 01 02 98

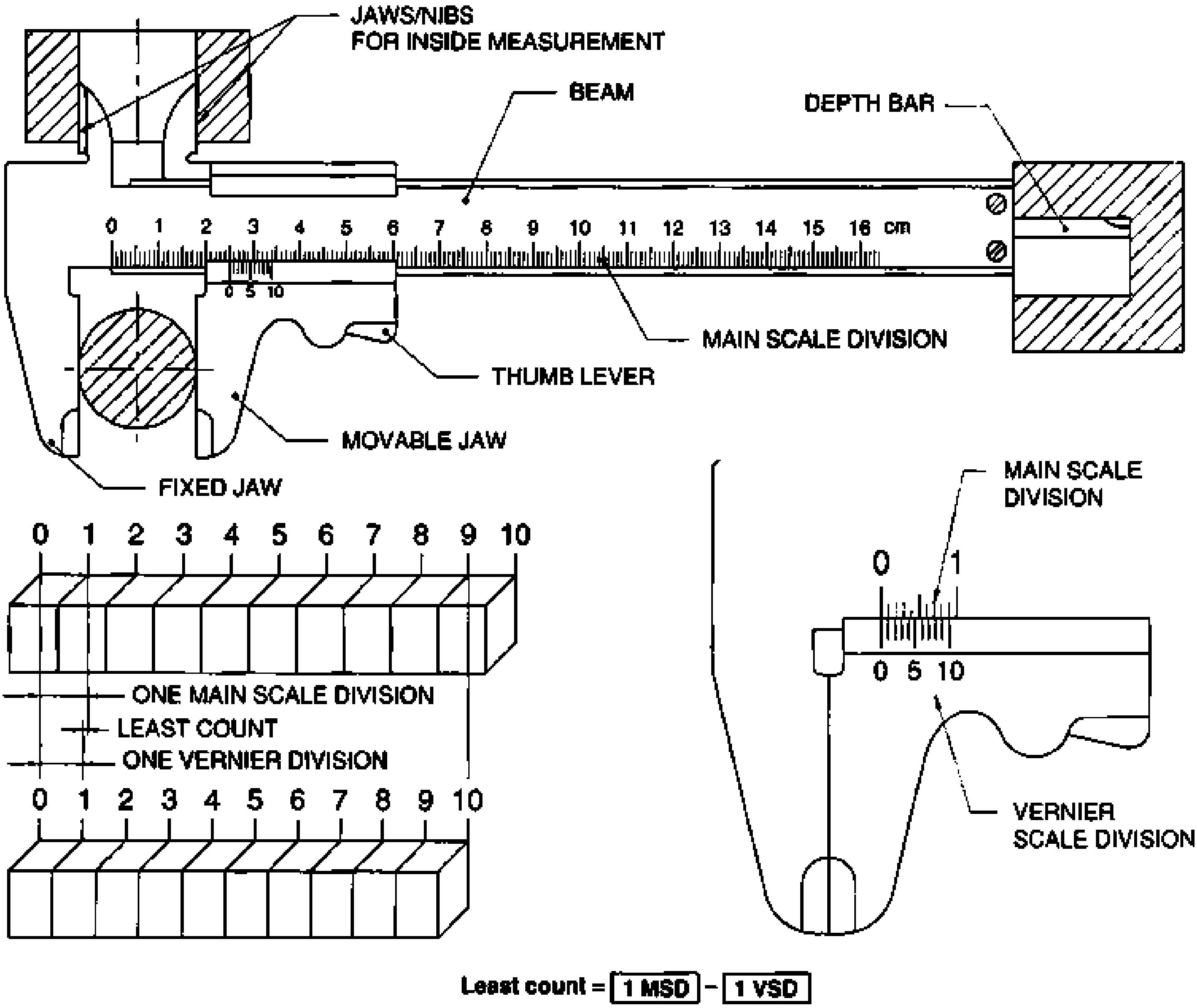


49 Main scale divisions are divided into 50 vernier scale divisions

Value of 1 VSD	$= \frac{49}{50} mm$
Least count	= 1 MSD – 1 VSD $= 1 - \frac{49}{50}$ $= \frac{1}{50} = 0.02$ mm
Main scale reading	= 10.00 mm
No of VSD coinciding with MSD	= 20
Value of coinciding vernier division	= 00.40 mm
Reading	= MS Reading + VS Reading = 10.00 + 0.40 mm = 10.40 mm

Vernier Caliper Parts and Principle

TR 01 02 01 01 98



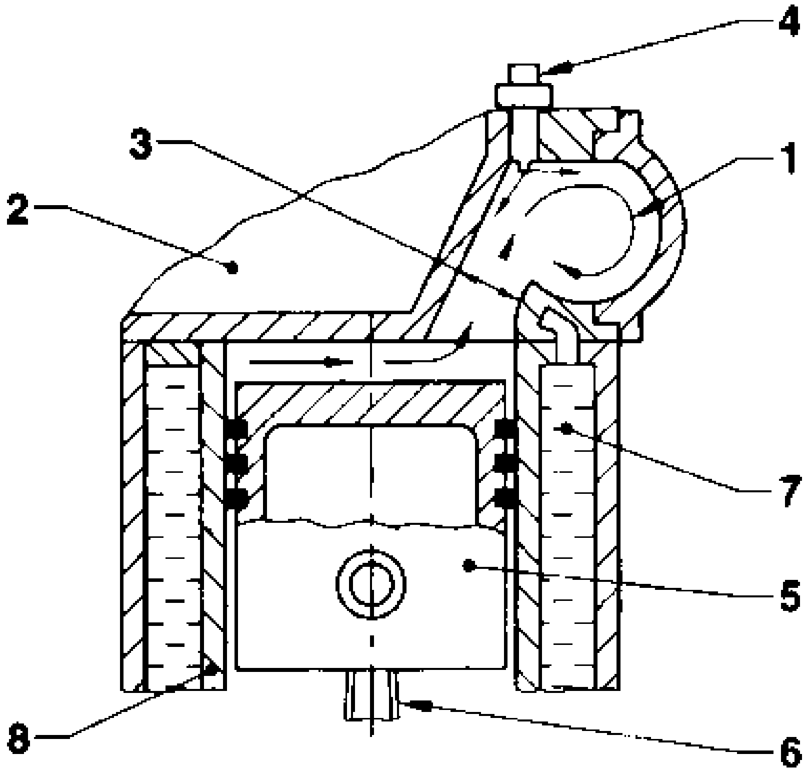
Combustion chambers

TR 10 01 04 01 99

Function

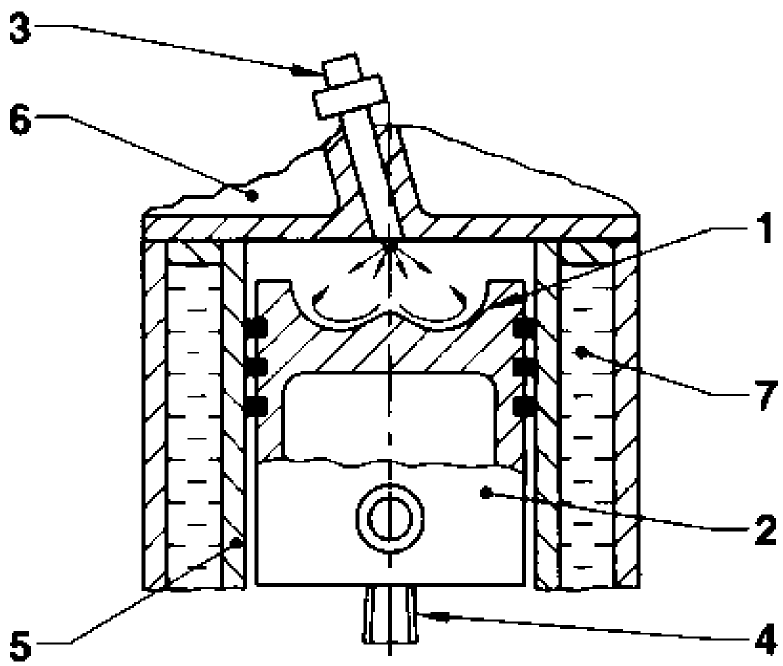
Diesel Engine combustion chambers are of special designs.

A. Indirect Injection – Aero flow chamber



This combustion chamber (1) is used in Perkins engines which is also known as AERO FLOW CHAMBER, The shape of the chamber is spherical and formed in the cylinder head (2). The outer portion can be unbolted, for cleaning purposes. Air enters with great velocity into the combustion chamber (1) through tapered passage (3). The turbulence of air is good and it mixes well with fuel sprayed from 2nd hole of the Injector Nozzle (4). This is called Indirect injection. (Air seeks the fuel). A second spray is injected directly on the surface of the air and this is called direct injection of fuel. (Fuel seeking the air). Fuel gets ignited quickly without the heater plug. The combustion of fuel takes place in the chamber and as well as on the top of piston. (5) The force on the piston (5) is carried to crankshaft through connecting rod (6). The engine runs continuously under the piston force and produces the required power. The injection pressure can be low. i.e 1800 LBS/Sq. Inch.

B. Direction Injection OR Open Combustion Chamber



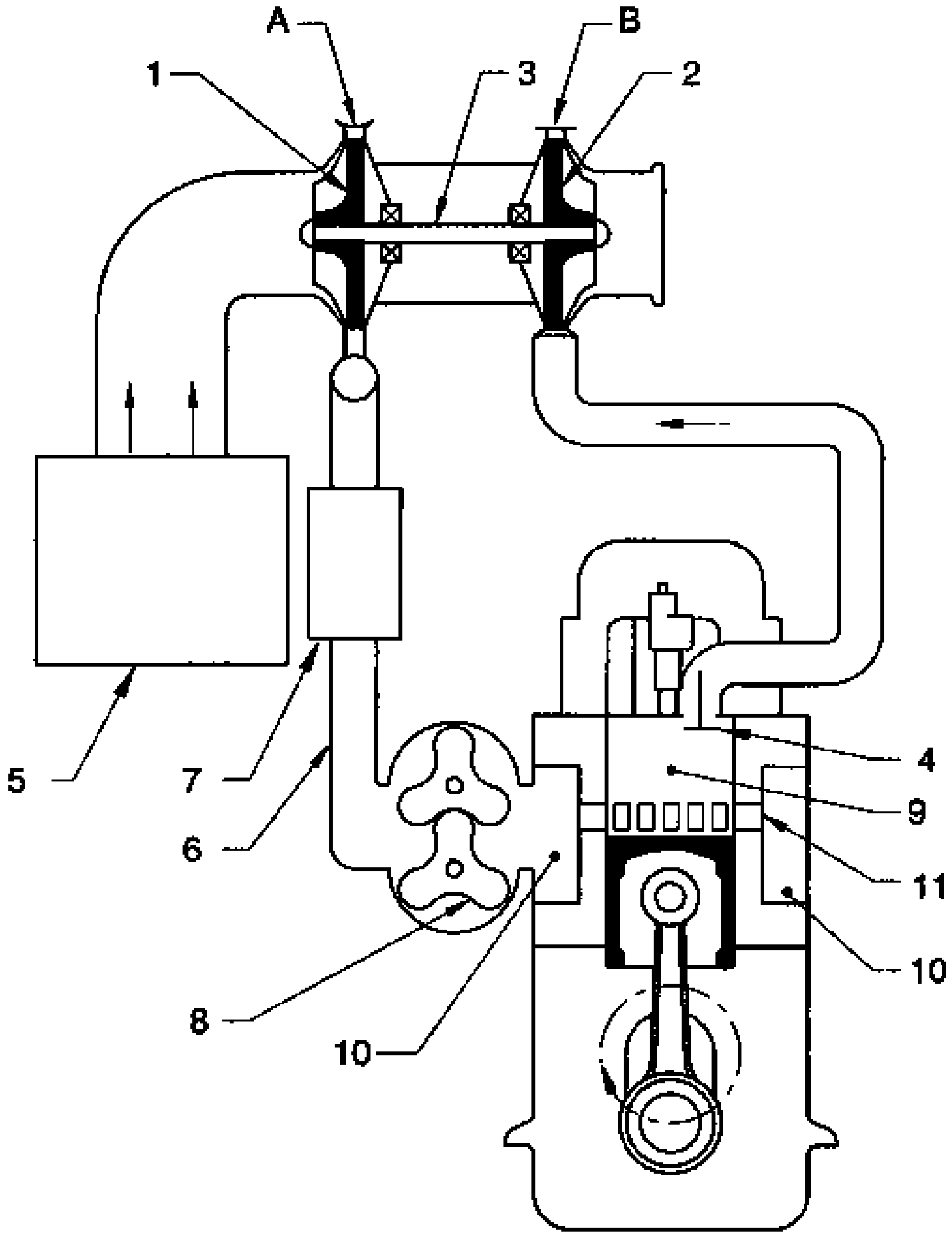
This combustion chamber (1) is provided on the top of piston (Crown) (2) in the form of cup shaped recess called “TORRIDAL”. A swirling motion with squish is provided by the air when it passes into the Torridal chamber. The mixing of fuel and air is good and quick.

Since the Air is very hot due to high compression, the engine starts quickly without a heater plug. A 4 spray hole nozzle (3) is used for injecting the fuel into all direction of air. Here “FUEL SEEKS THE AIR”. Hence the Injector pressure is very high (ie 2400 LBS/Sq. Inch) as air depth is more in the chamber.

The force on the piston (2) is transferred to crankshaft through Connecting rod (4). The engine runs continuously under piston force and produces the required power.

TURBO Charged Engine (Two stroke diesel)

TR 10 01 04 02 99



Function

The Turbo charger increases the amount of air delivered to the engine, thereby more fuel can be burnt. More engine power is produced due to increased volumetric efficiency. It also improves high altitude operation of the engine by making up the decreased atmospheric pressure of air.

Operation

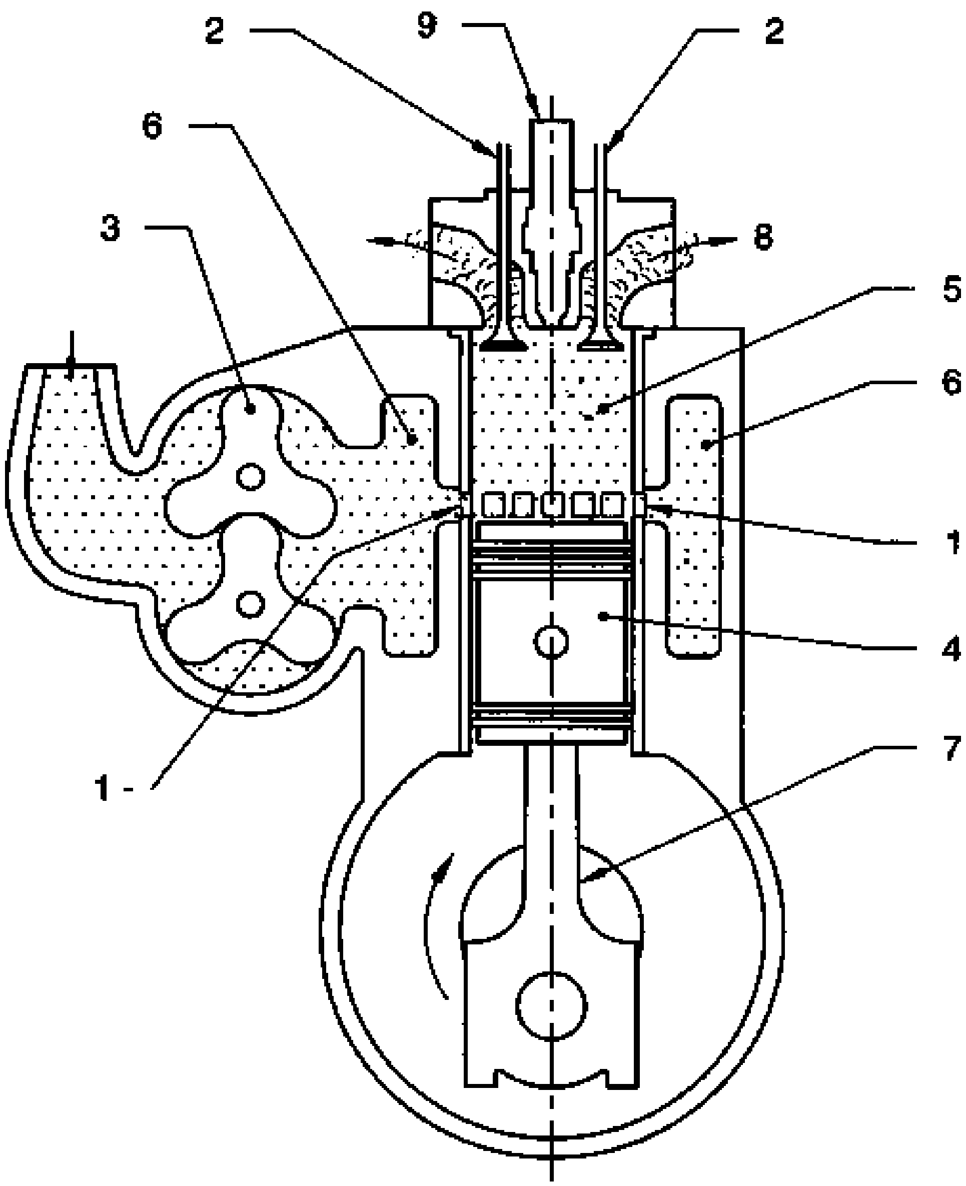
The Turbo charger is an exhaust driven compresser. The turbo charger is fitted on the exhaust manifold. It has a compressor wheel (1) and a Turbine wheel (2) both mounted on the same shaft (3). The exhaust gases enter the Turbine Housing (B) through the exhaust valves (4) and rotate the turbine wheel (2) which in turn causes the compressor wheel (1) to rotate as it is connected on a common shaft (3).

The Compressor Housing Inlet (A) is connected to the Air cleaner (5). The Compressed Air is discharged into the Inlet manifold (6) through the after cooler (7). This air enters the Blower housing where it is further pressurised by the rotation of the Blower (9) to a higher pressure than atmospheric, and flows into the main cylinder (9) via Air Box (10) and Inlet Ports (11) drilled on the periphery of cylinder wall. The Exhaust gases pass through the Exhaust valves (4) and reaches the exhaust pipe and finally reaches the Turbine Housing (B). After driving the Turbine wheel (2), the remaining exhaust gases passes into the exhaust pipe and then into the atmosphere.

Thus the cycle of Air entry is repeated and power is developed during its working. An engine may have one or two Turbo chargers to increase Torque and B.h.p.

Uniflow Scavenge

TR 10 01 05 01 99



Function

Introduction

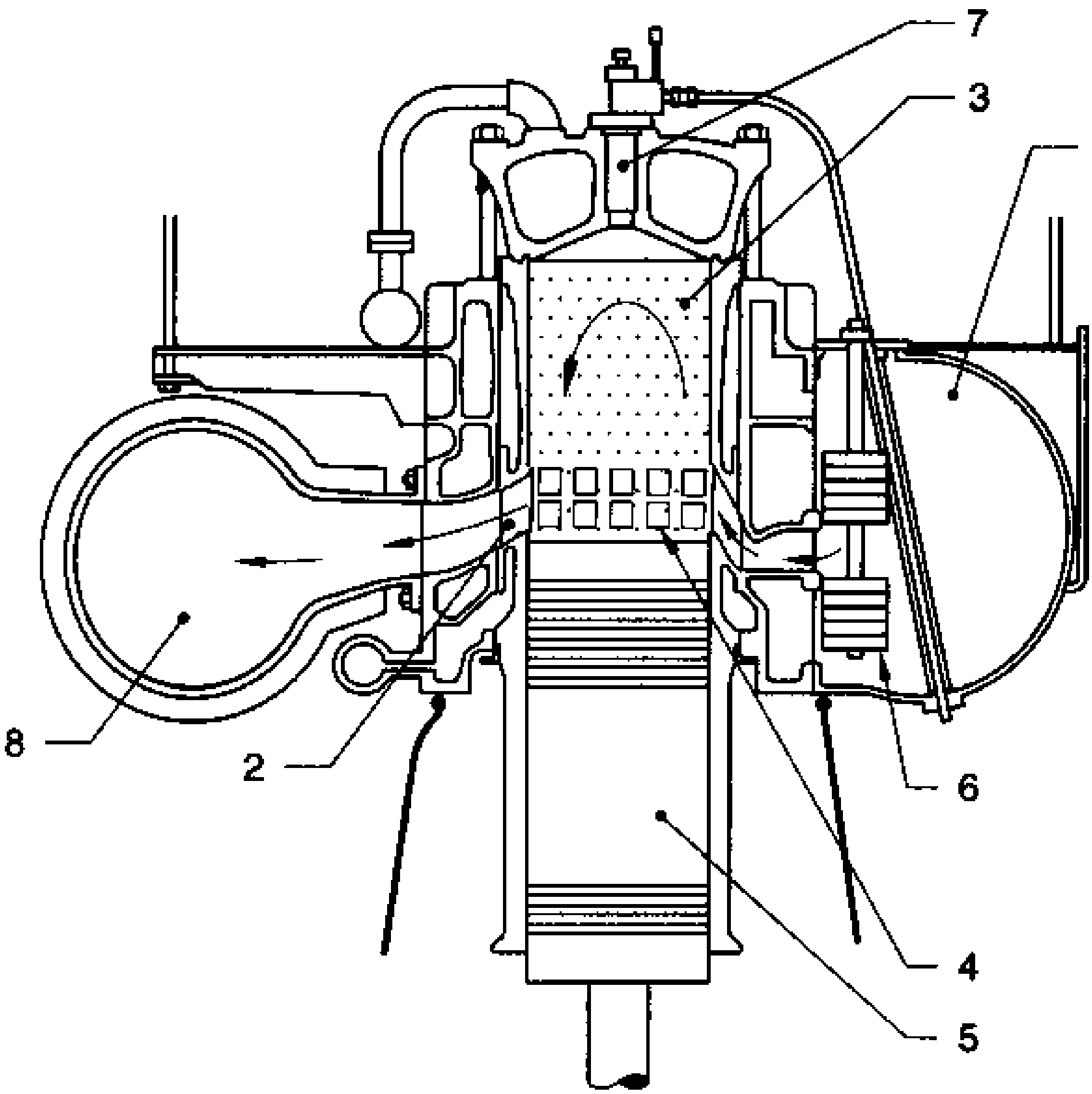
The two stroke engines are classified according to the flow of air into the cylinder and drives out exhaust gases. In the Uniflow scavenge the scavenge air goes in an Unidirectional path in driving out exhaust gases into atmosphere.

Working

In this engine, Inlet ports (1) are used for admitting air and exhaust valves (2) are used in the cylinder head to allow the flow of scavenge air with burnt exhaust gases into the atmosphere. A Roots type blower (3) is used in all these engines. The Inlet ports (1) are covered by the movement of the piston (4) and the exhaust valves (2) are opened by camshaft drive arrangement. In the figure shown both intake ports (1) and exhaust valves (3) are in open position when the piston (4) is at the bottom of its stroke. The blower (3) supplies air at a certain pressure above atmospheric and air goes into the main cylinder (5) through the air manifold or air chamber (6) and Inlet ports (1) cut on the periphery of cylinder wall. THE AIR FLOW PATH IS UNDIRECTIONAL. Hence it is called Uniflow Scavenge. This system is largely used in GM Diesel Engines.

Scavenging system (Diesel) Loop Scavenge

TR 10 01 05 02 99



Introduction

Two stroke cycle diesel engines are classified according to the flow of air into the cylinder to drive out exhaust gases. The most common arrangement shown in the chart is called “Loop Scavenge System” as Air goes in the form of Loop.

Working

In this engine the scavenging air is supplied by a Blower (1) attached to the engine cylinder.(3)

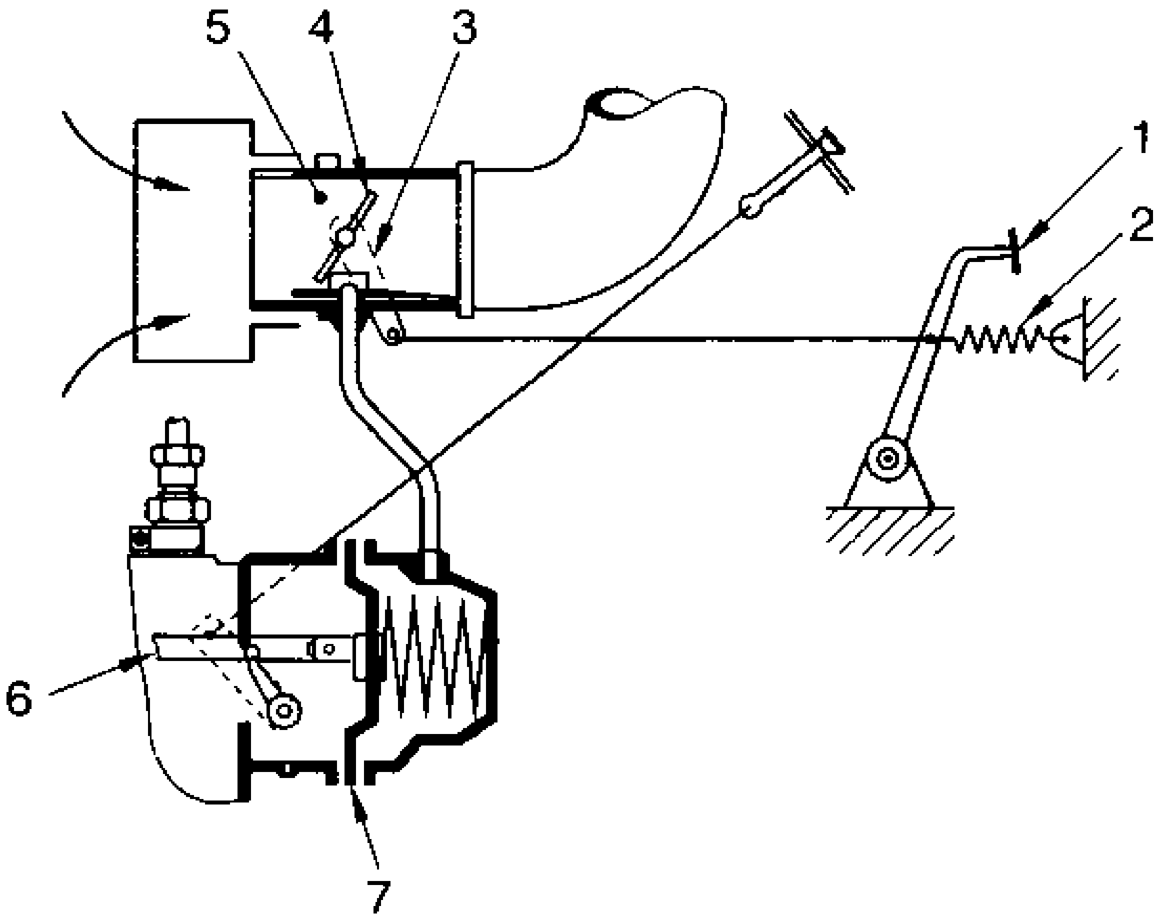
In the design of this engine, the exhaust ports (2) are placed as close as possible to the bottom of the main cylinder (3). The upper edges of the port are at the same level as the upper edges of the Inlet Air Port (4). The descending piston (5) starts to uncover both sets of ports simultaneously.

The Automatic Air Valves (6) keep the burnt gases from flowing out through Air Ports (4).

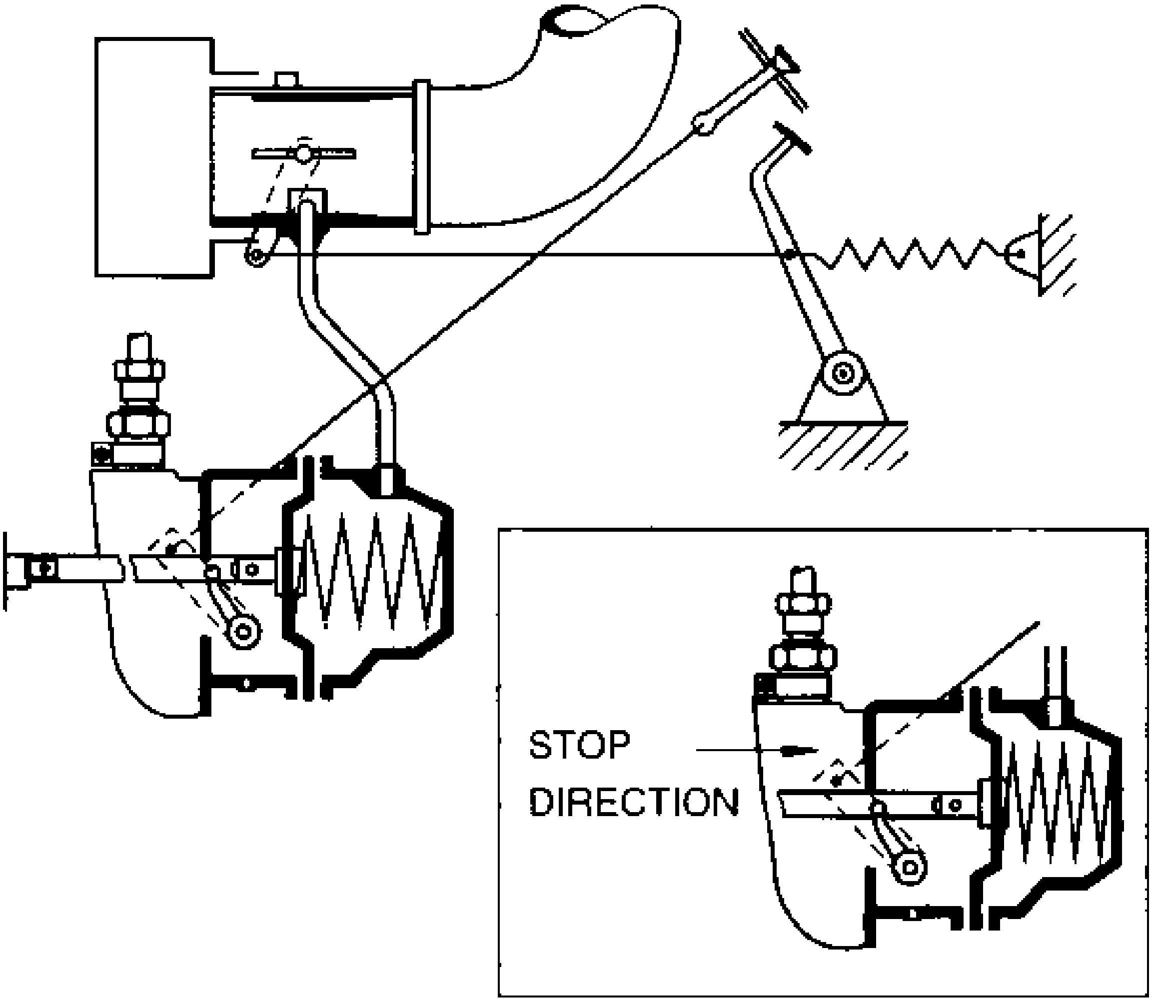
The scavenging Air from Blower (1) enters the main cylinder (3) and drives out the exhaust gases and it goes in the form of Loop. Hence called “Loop Scavenge”.

Pneumatic governor function

TR 10 01 03 08 99



IDLING



MAXIMUM RATED SPEED

Function

Idling of the engine

The Accelerator Pedal (1) is in the rest position, The return spring (2) on the accelerator Pedal (1) pulls the control lever (3) of the venturi butterfly valve (4) towards the adjustable Idling stop so that the venturi (5) Is practically closed. As a result a vacuum Is created which Is sufficient to pull the control rod (6) to Idling position.

Load decrease

The engine speed Increases but the diaphragm (7) moves the control rod (6) towards stop position due to increased vacuum – thus engine speed decreases.

Load increase

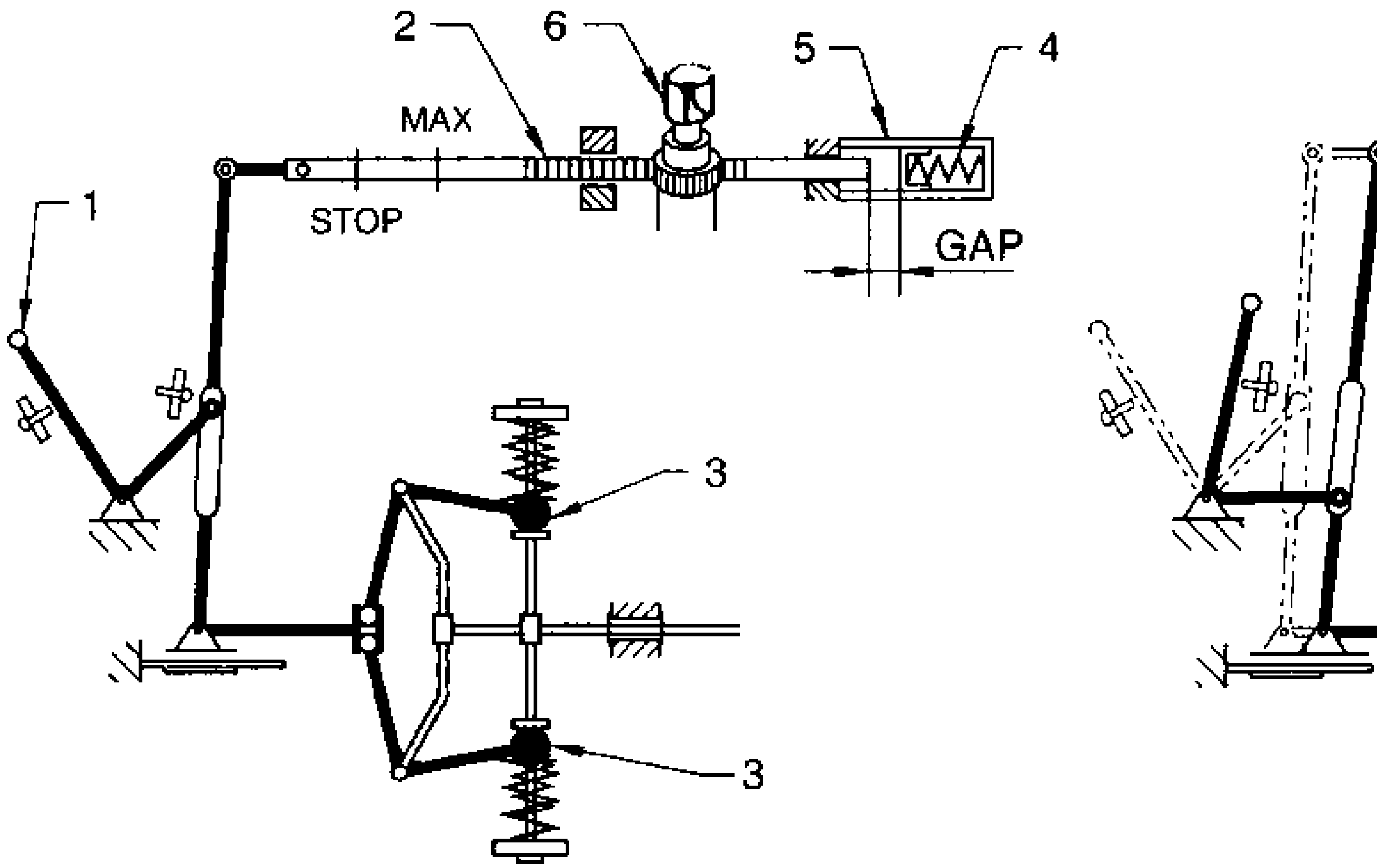
The engine slows down, vacuum decreases – the diaphragm (7) moves the control rod (6) to full load position.

Maximum speed and Rated speed

The Accelerator Pedal (1) Is fully depressed and the venturi valve control lever (3) rests against its full load stop. The butterfly valve (4) Is fully opened and the vacuum available Is very less. The engine now reached rated speed. The governing of maximum speed starts at this stage by moving control rod (6) away from full load stop.

Mechanical governor Principle (A)

TR 10 01 03 01 99



Function

Mechanical governor

A. Rest Position

The control lever (1) and control rack (2) are in the stop position.

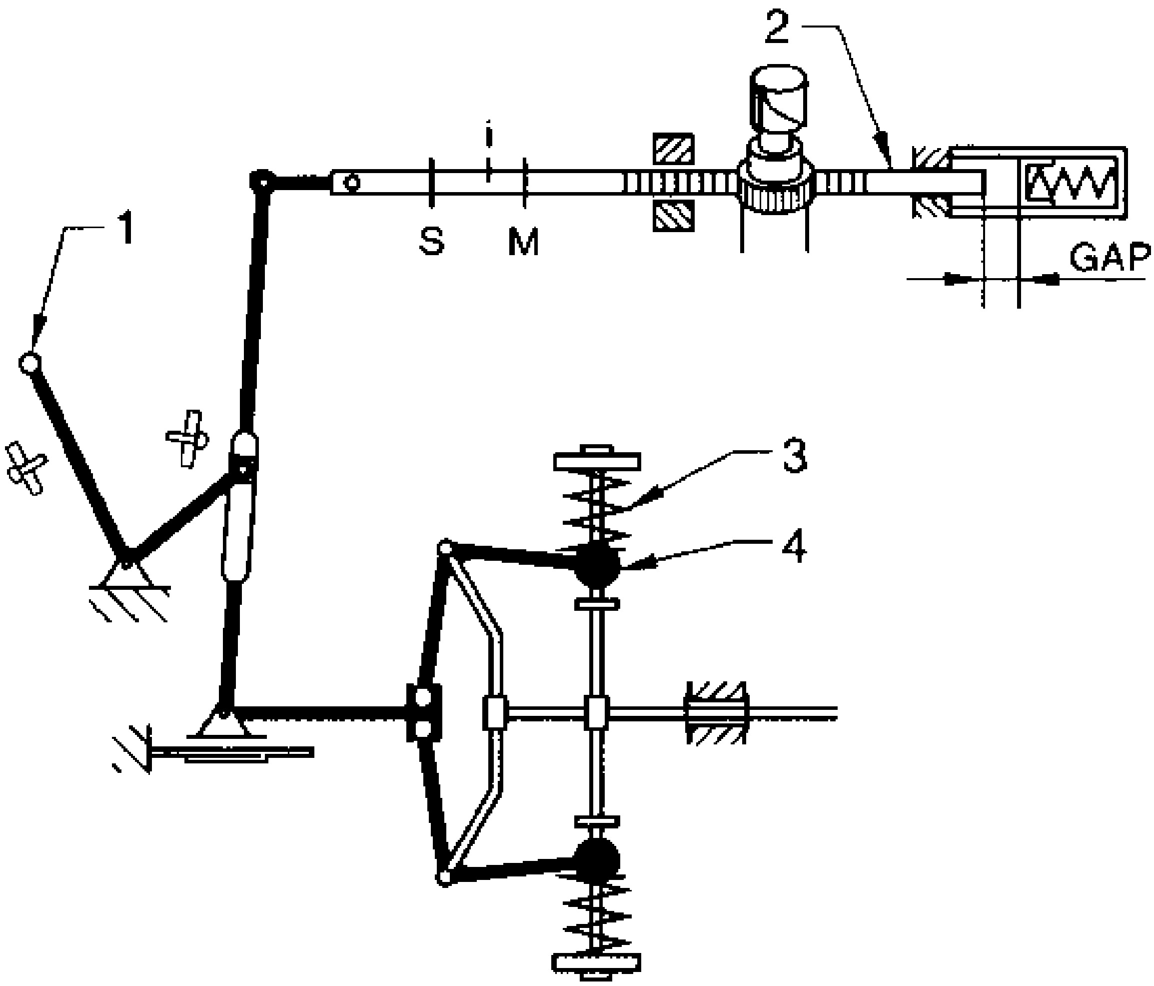
Fly weights (3) are at their Inner most position.

B. Starting position

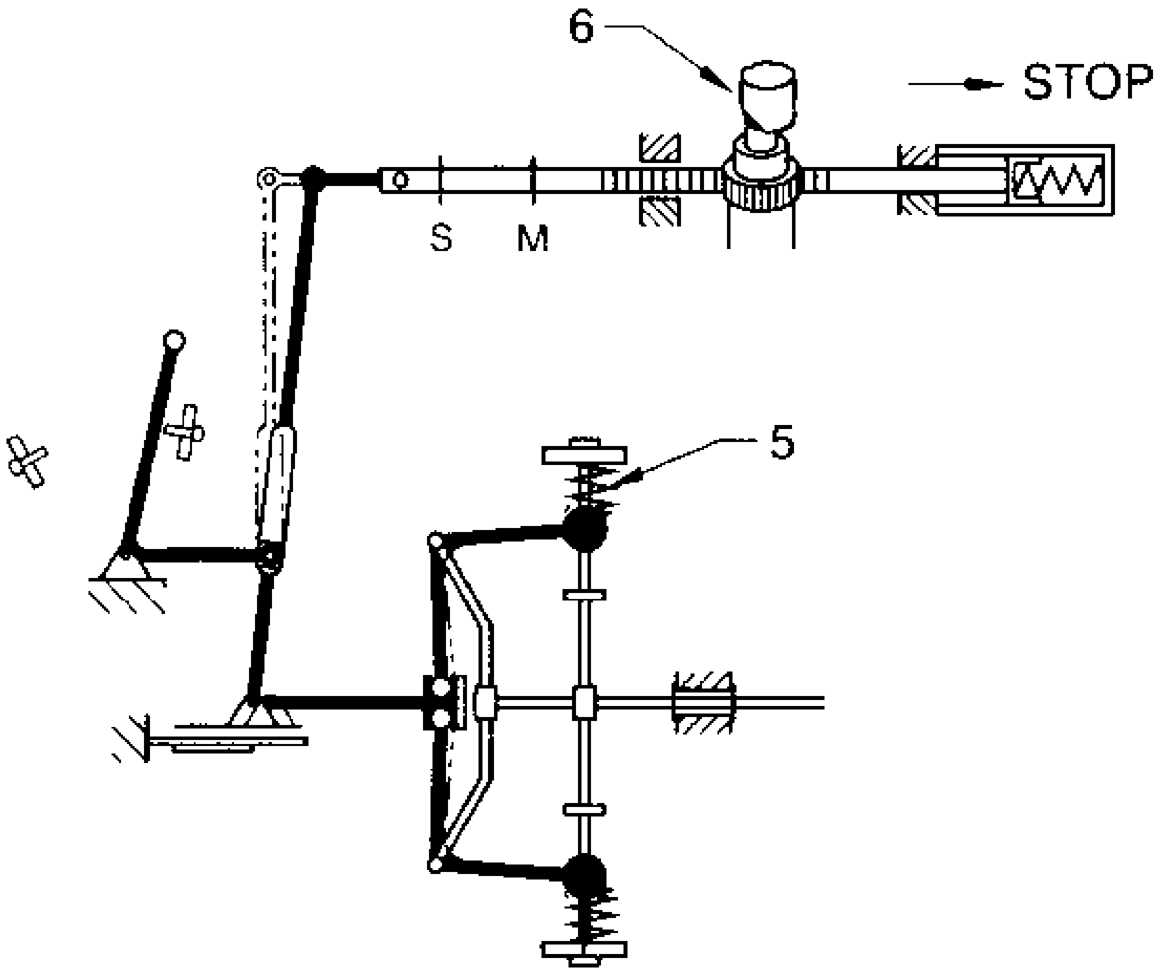
The control lever (1) is pressed to maximum position after over coming the force of return spring (4) in the Automatic control rack stop (5). The control rack (2) move to its starting fuel delivery position. (Plunger (6) turned). Fly weights (3) has moved outwards. Engine starts now.

Mechanical governor Principle (B)

TR 10 01 03 02 99



IDLING SPEED



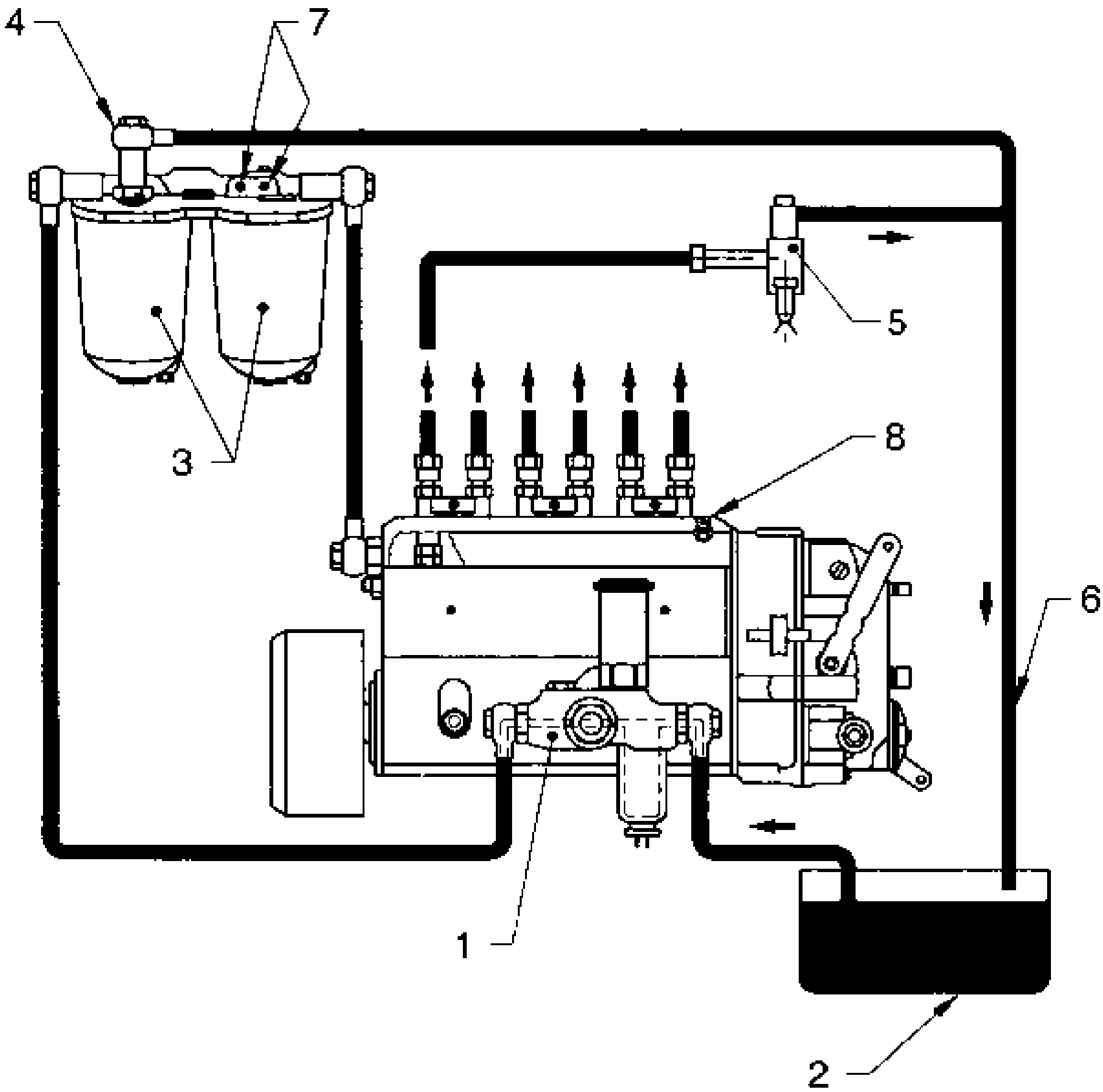
MAXIMUM SPEED

A. Idling speed position

The engine has now started – the control lever (1) (connecting accelerator pedal)is released and it returns to Idling position. The control rack (2) also returns to its corresponding position determined by governor. The Idle speed is governed by the outer springs (3). The fuel quantity delivered to the engine during idling is less than starting fuel quantity – Observe position of control lever (1) and fly weights (4).

B. Maximum speed regulation (at full load)

Maximum speed may occur when the engine exceed normal speed. When this happens the maximum speed control springs (5) get compressed and fly weight (4) move outwards. Now the control rack (2) begins to move towards stop position. The fuel quantity is thus reduced and the maximum speed is regulated by the action of governor spring (5).



Fuel circulation

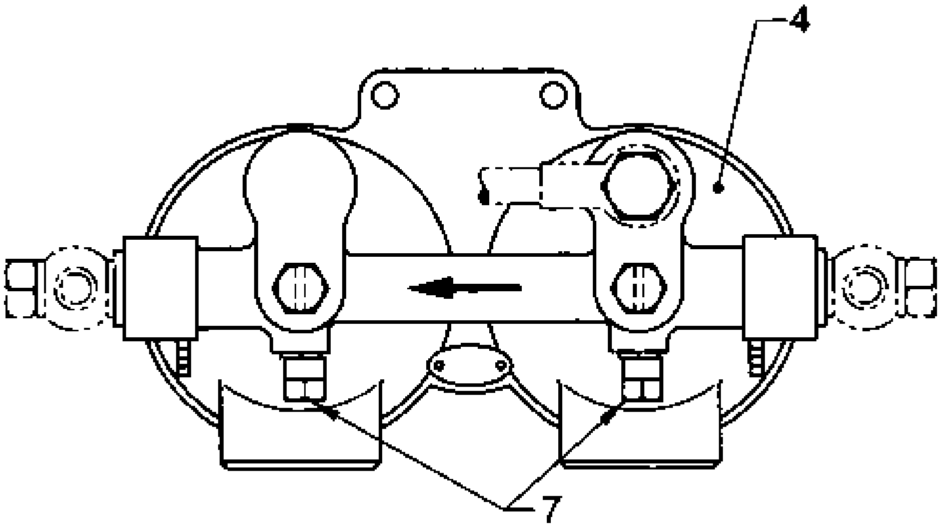
In a Motor Vehicle fitted with diesel engine, diesel fuel is drawn by the fuel feed pump (1) from the fuel tank (2). The fuel from the feed pump (1) is supplied to the fuel filters (3) under low pressure. From fuel filters (3) the fuel flows into the fuel Injection pump gallery. The excess fuel is sent back to the fuel tank through the overflow valve (4). From the fuel injection pump the fuel is supplied to the injectors (5) under high pressure. The excess fuel from the Injector Nozzle is delivered back to the fuel tank (2) through overflow pipe line (6).

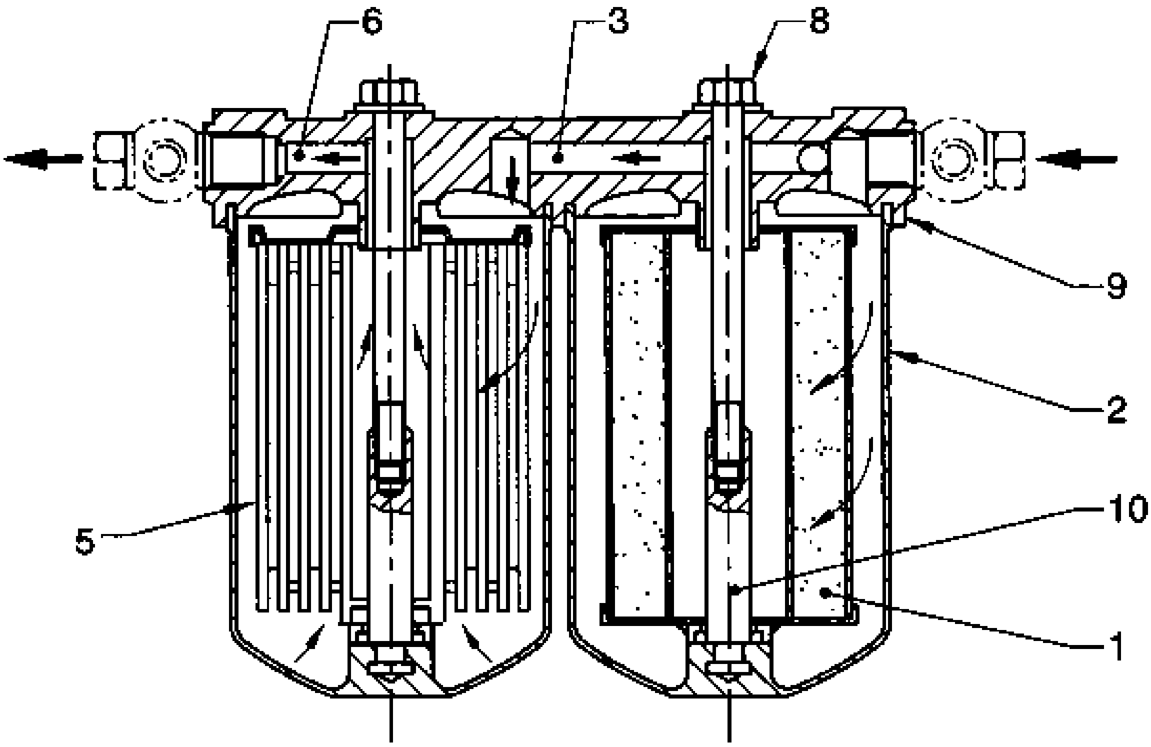
For removing the air trapped in the pipe lines, bleeder screws (7) on the filter and Bleeder screws (8) on the F.I.Pump are provided and they are to be opened up and then closed tightly after exit of air from the fuel lines.

The system of removing air from the pipe lines is called bleeding or air venting.

Diesel Engine fuel filter

TR 10 01 03 06 99





Function

In a Diesel Engine a number of fuel filters are used to clean the fuel free of contaminants to enable the fuel to pass through clearances of very highly precision finished parts like Elements and Nozzles.

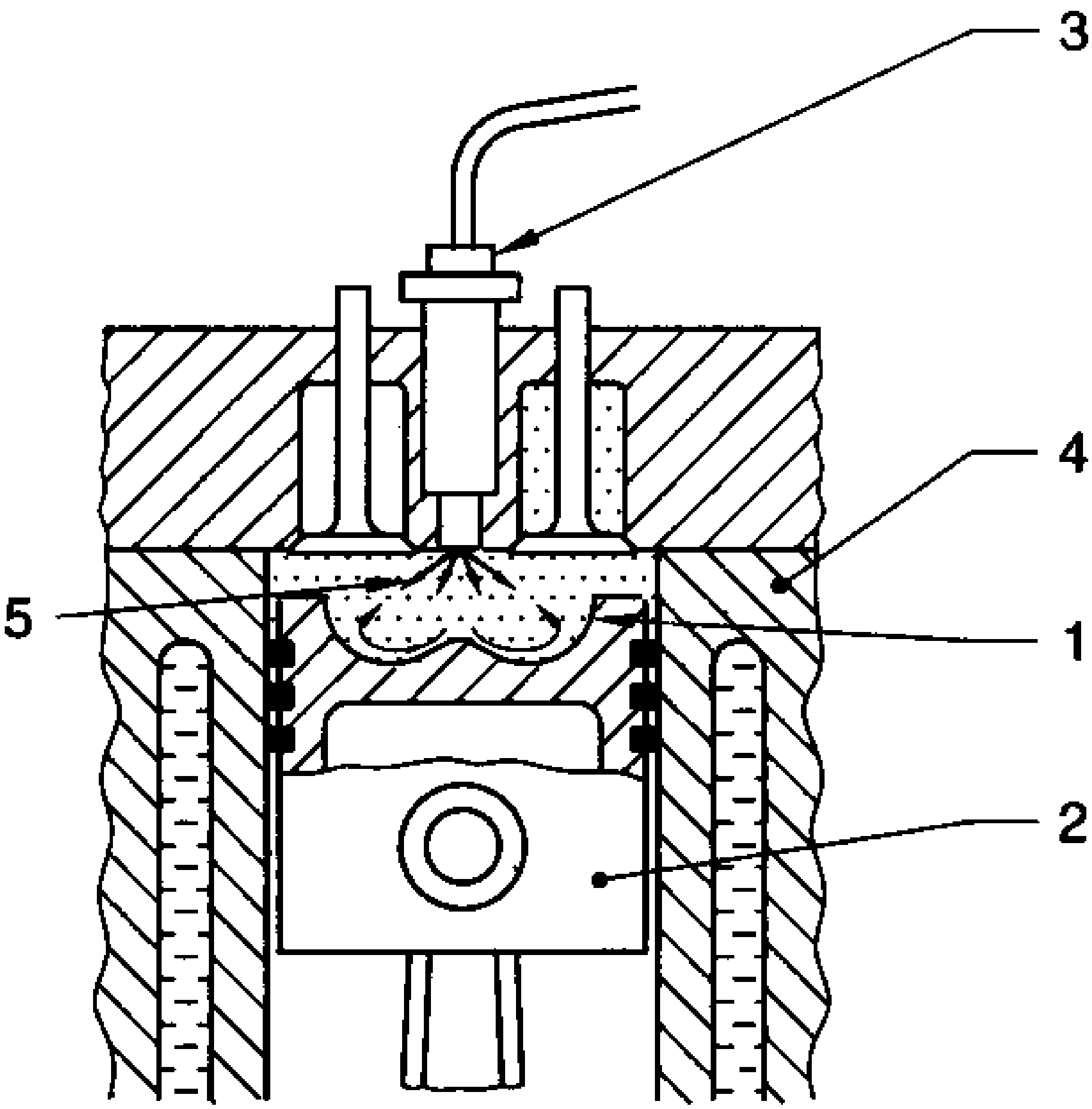
Fuel flow

The fuel passes through cloth insert (1) in the Bowl (2) of the pre−filter. Then it passes through the drilled passage (3) in the top cover (4) and enters into Bowl of Micro filter. Then the fuel passes through paper insert (5) and comes out fully cleaned off impurities, dust and dirt and enters the outlet passage (6) provided in the top cover (4) and reaches the F.I.pump. Bleeding screws (7) are provided to remove air from the system (fuel lines). At the Inlet and outlet, Banjos, Banjo bolts with copper washers are provided for connection of fuel lines from lift pump and F.I.pump. The copper washers prevent leakage of fuel through Banjos.

Comparison of Function multi hole and Pintle Nozzles

TR 10 01 03 07 99

A. Multi–Hozzle Nozzle



Functional aspect

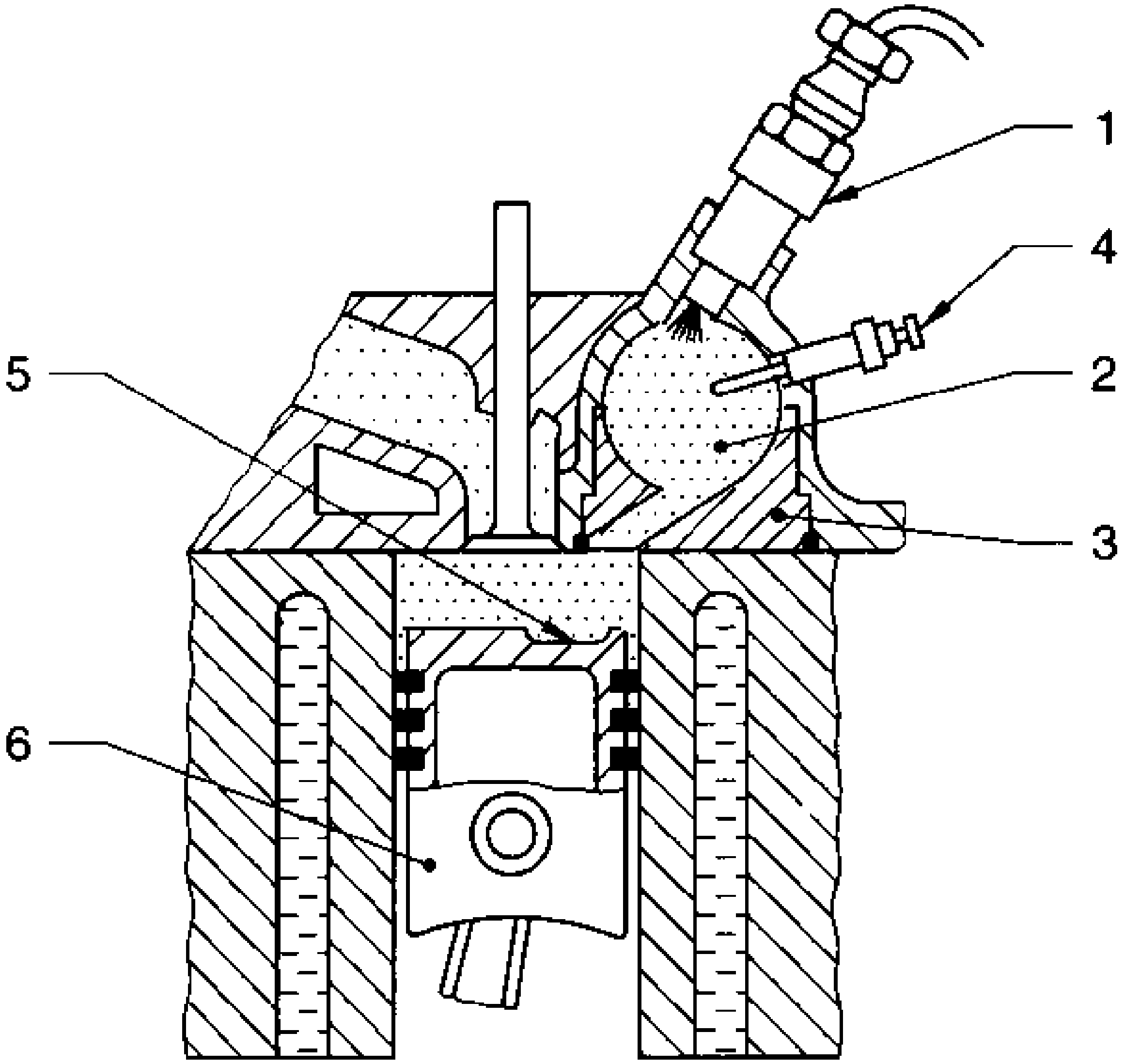
This nozzle works in conjunction with a Torroidal chamber.

The provision of torroidal chamber (1) on the top of the piston (2) provides a squish turbulence of air to enable fuel to mix with air fully.

The air in the cylinder (4) is compressed to a very high pressure. The fuel nozzle (3) has 4 spray (5) holes and fuel is sprayed at a very high pressure to penetrate into the highly compressed air. The fuel is ignited very quickly and combustion proceeds in the cylinder (4).

No heater or glow plug is necessary. Hence starting of engine is easy. The method is called direct injection in diesel engines. (D.I.Engines)

B. Pintle Nozzle



Functional aspect

The pintle nozzle (1) works in conjunction with Pre−chamber (2) provided in the cylinder head (3).

The pintle nozzle (1) provides a conical spray of fuel at a low pressure on the compressed air in the pre−combustion chamber (2).

The pre−chamber provides good turbulence of air for mixing with fuel spray. Since the air in the pre−chamber (2) is not compressed to high pressure enough heat is not available for igniting the fuel. Hence a glow plug (4) to preheat the air is provided.

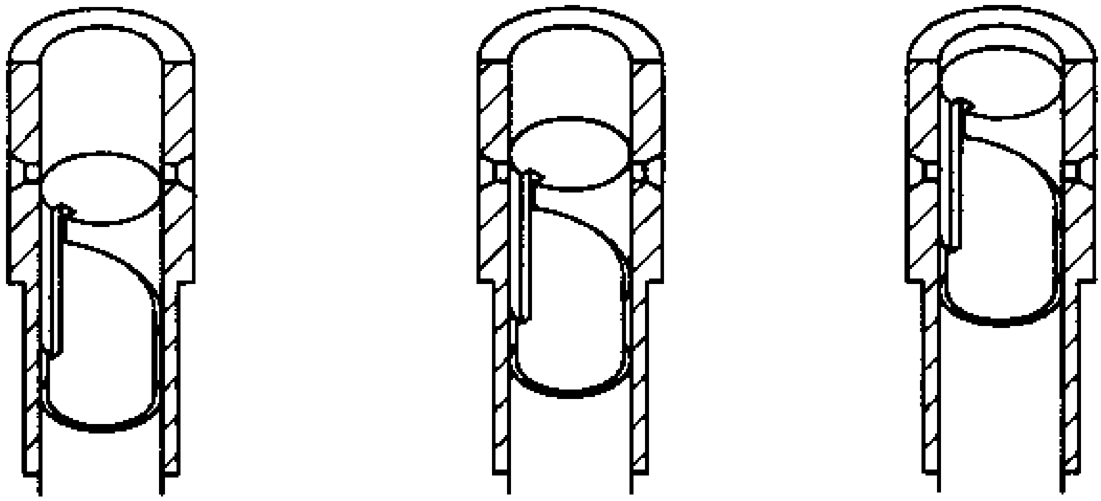
The combustion of fuel takes place in two stages, i.e first in the pre−combustion chamber (2) and it is continued in the spherical chamber (5) on the top of the piston. The burnt gas and unburnt fuel particles pass to the main chamber through passage in the pre−chamber (2). During this process further atomisation of fuel takes place and all fuel is burnt out. The combustion process is continued on the top of the piston (6).

This method is called Indirect Injection in diesel engine.

Fuel Injection Pump

TR 10 01 03 03 99

Fuel Delivery position



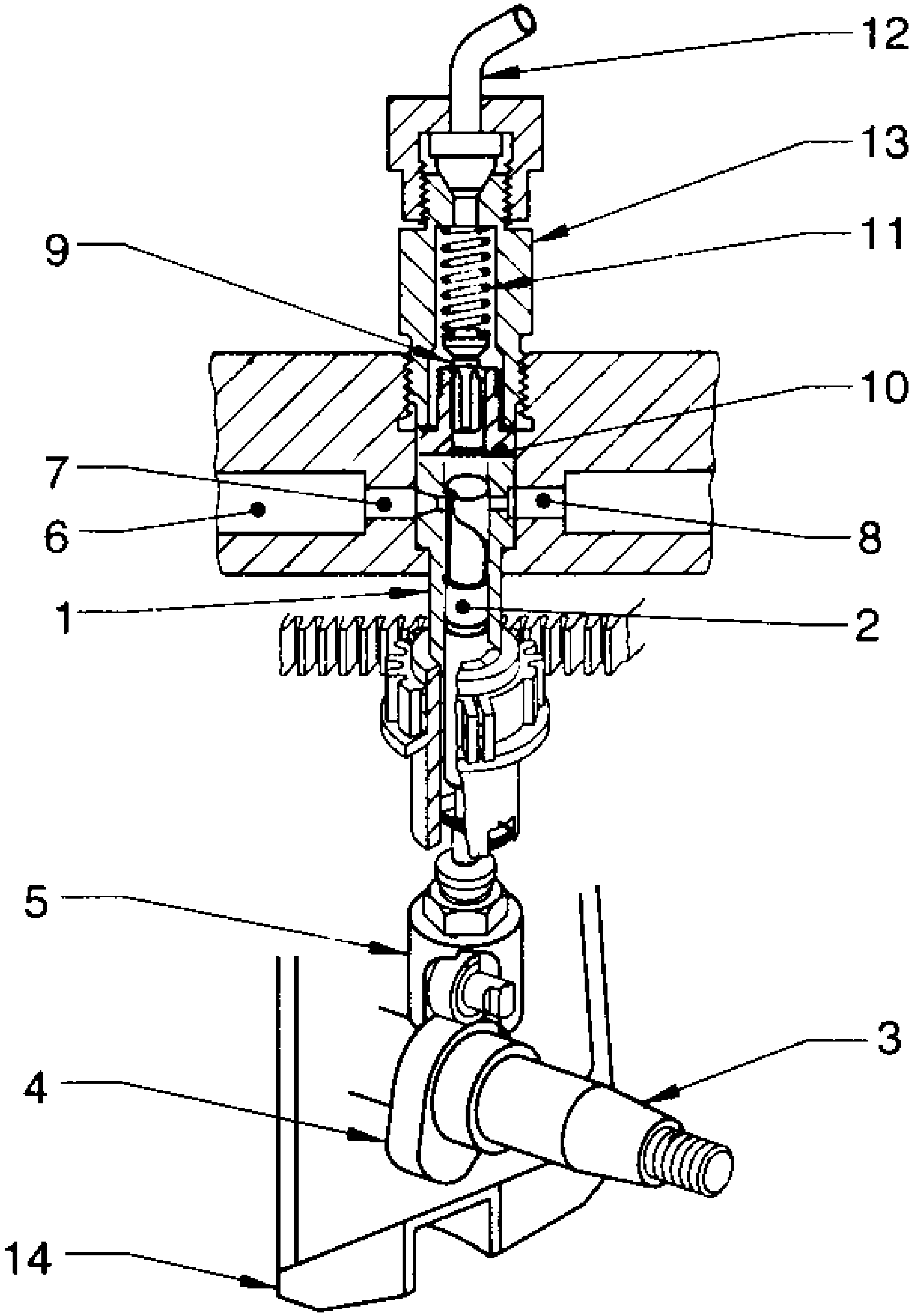
1 2 3

Position 1: The Plunger (2) is now at BDC – Fuel enters the Top of Plunger (2) from gallery (6). No fuel is delivered now.

Position 2: Plunger (2) moves up in the Barrel, closing both the ports (7 & 8). The fuel is being pressurised by the moving plunger (2) during the movement to TDC.

Position 3: When the helix of the plunger uncovers the spill ports fuel delivery is complete. The pressure drops in the fuel line. But the plunger will continue to move upto TDC to complete its stroke.

NOTE: The height of helix determines the quantity of fuel delivered to the engine.



(B) ARRANGEMENT OF PLUNGER & BARREL

Working of F.I.Pump (Fig B)

The figure (B) indicates assembly of components of a Fuel Injection Pump.

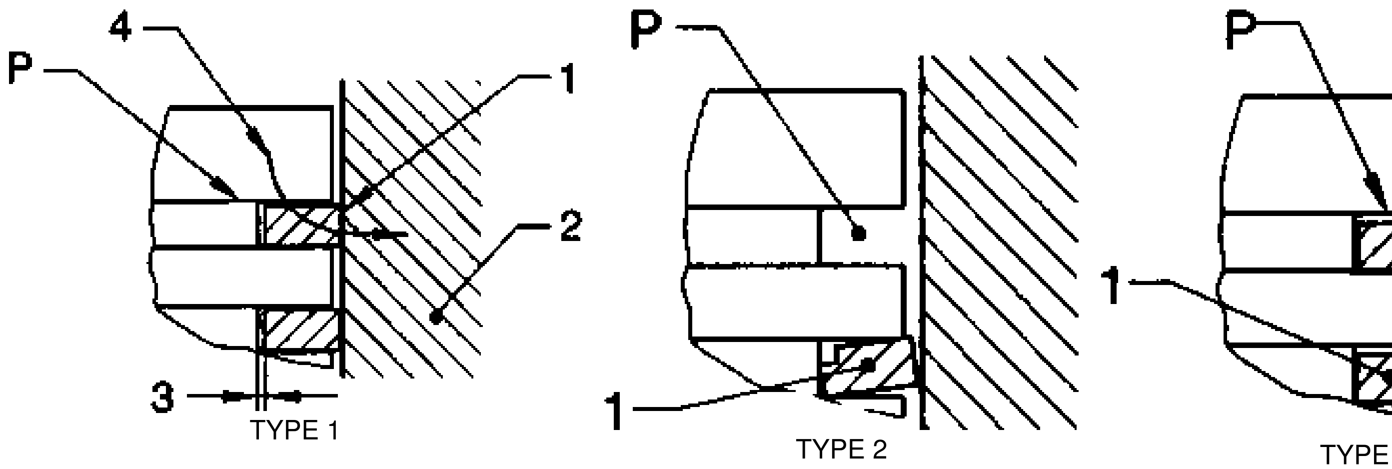
This pump has a Barrel (1) and plunger (2) for each Engine Cylinder in a Multi−cylinder engine. The camshaft (3) is driven by the engine and a cam lobe (4) operates each plunger. When a lobe of a cam (4) comes up with roller tappet (5) under a plunger (2), the plunger (2) is lifted and its movement pressurises the Diesel entered from the gallery (6) through feed port (7). The pressure of fuel is raised to a high value when both ports Feed Port (7) and spill port (8) closed. This pressurised fuel lifts the delivery valve (9) off its seat (10) compressing the spring (11) and passes into the fuel out let pipe (12) and then delivered to the Injector nozzle by opening it. The Injection of fuel is stopped, when bottom of helix on the plunger uncovers the spill port (8). The fuel pressure in the pipe line drops. Due to this the delivery valve is seated first on its seat increasing the drop in the fuel pressure. The Injector Nozzle is closed abruptly without dribbling of fuel.

NOTE: The quantity of fuel delivered can be altered by rotating the plunger in the barrel. As plunger is rotated the effective stroke of the plunger is varied and the quantity of fuel delivered to the engine also varies.

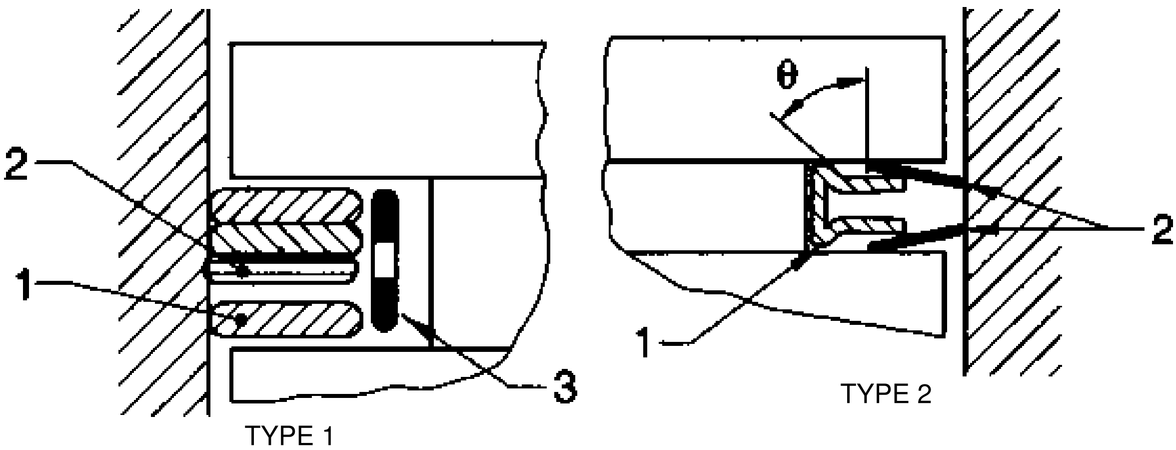
Piston rings assembly

TR 10 01 11 01 99

(A) COMPRESSION RINGS



(B) OIL CONTROL RINGS



Function

Piston Rings

A Compression Rings

3 Types are normally used in engines.

Type I: Rectangular rings

These have rectangular faces (1). These faces contact cylinder wall (2). These are mounted on Piston Top grooves (P) with some back clearances (3). These rings seal the compression pressure and leakage of combustion gases. Also they transfer heat to cylinder wall (2). Heat flow path (4) from piston (P) to cylinder wall (2) is shown in the figure.

Type II: Inside Bevel Rings

A step is cut on **the** top surface at the inner diameter of ring (1). These are used in second grooves. These prevent blow by gas into oil sump.

Type III: Taper Faced Rings

The face of the ring (1) is tapered on both sides. The lower edge of the ring 3s in touch with cylinder wall (2). These rings (1) scrapes all the oil from the cylinder wall. **Function**

B Oil Control Rings Type I: Oil Scraper Rings

They are also called Duaflex Rings.

These rings have greater force against cylinder wall because they are made of steel. They scrape oil well and reduce oil consumption. Hence they are used for re−ringing jobs. They are made in three parts.

One set of Ring has a rail, a crimped spring and expander. The rail (1) is made of good steel and number of rails vary in accordance with width of groove. It wipes oil from the cylinder wall.

The crimped spring (2) keeps the rail space apart and seals against Top & Bottom of the groove. The expander (3) exerts correct amount of pressure against the rail and provides a good sealing on the cylinder wall. Irrespective of cylinder bore wear, these rings provide effective sealing.

Type II: ‘T’ Flex Rings

In this type T shaped expander (1) is used with two scraper rails (2). The expander (1) forces the rail (2) against cylinder wall. This enables ring to scrape excess oil.

Auto−Electric Basic Technology − Part 1

Table of Contents

Auto–Electric Basic Technology – Part 1......1
1. Fundamentals of electricity......2
Electricity......2
Electron Theory of Electricity......2
Size of atoms......3
Insulators and Conductors......4
Speed of electricity......4
Types of electrical circuits......6
Measuring resistance......7
Direction of current......9
2. Batteries and service of them......10
Battery functions......10
Battery construction......10
Elements......12
Battery inspection......14
Battery problems......16
Change of a battery......18
Automotive battery/TV–battery......18
3. Lighting and signal circuits – Accessories and wiring......20
Lighting and signal circuits......20
Switches......23
Electrical circuits......25
Connections......27
Bulbs......28
Fault finding......29
Technical drawing of circuit diagrams......30

Auto–Electric Basic Technology – Part 1

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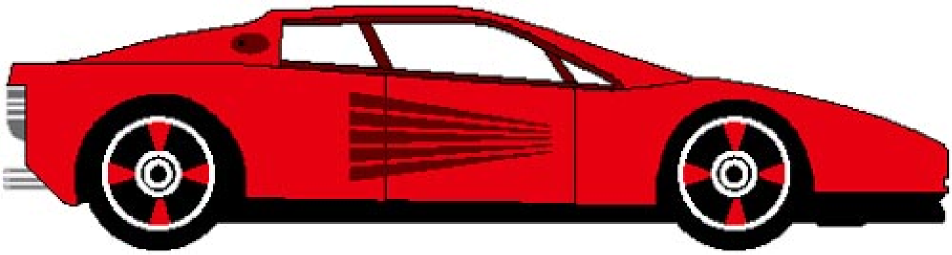

WRITTEN BY:

HARTMUT ARLITT/GERMAN DEVELOPMENT SERVICE IN NAMIBIA INSTRUCTOR AT THE RUNDU VOCATIONAL TRAINING CENTRE

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2. Different information material of the BOSCH company Germany

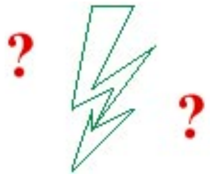
3. Different teaching material from the Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) GmbH

4. Own material, scripts and circuit diagrams

November 1997

1. Fundamentals of electricity

Electricity



Electricity has a vital role in the safe and reliable operation of modern automotive vehicles.

In such cases we do speak about a simple circuit by using only one consumer (i.e. a bulb) and one switch as well as about complete electrically systems (i.e. starting systems, recharging systems, ignition systems, lighting and signal systems).

If someone wants to be successfully as an auto–electrician concerning maintenance, troubleshooting or reparation he or she will have to have a clear knowledge to the following basics.

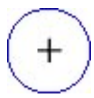
Electron Theory of Electricity

Many different theories have been advanced regarding the nature of electricity but no one can just explain what electricity really is. Today is generally accepted the **electron theory**.

This theory proposes that all matter (earth, rocks, minerals, elements, etc.) consist of tiny particles called ***molecules***. These molecules are made of two or smaller particles called ***atoms***. The atoms are divided further into smaller particles called ***protons, neutrons and electrons***.

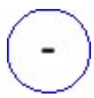
Protons, neutrons and electrons are the same in all matter like gases liquids or solids. The different properties or characteristics of all these matters are to see according to the ***arrangement and number of protons, neutrons and electrons*** to build in the end a specific atom.

Proton



The ***proton*** **has a** ***positive charge*** **of electricity** naturally.

Electron



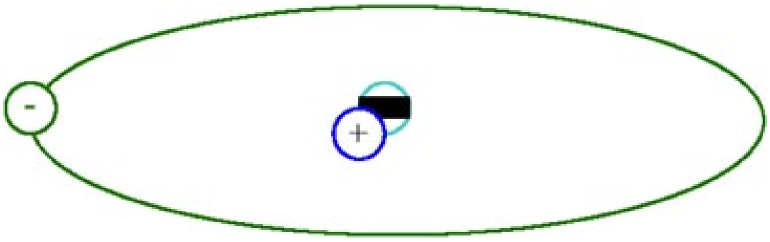
The ***electron*** **has a** ***negative charge*** **of electricity** naturally.

Neutron

The ***neutron*** **has** ***no charge*** at all, but ***adds the weight*** to the matter.

Central core of an atom

Protons and neutrons form the *nucleus* (central core) of the atoms. The electrons revolve around the nucleus.



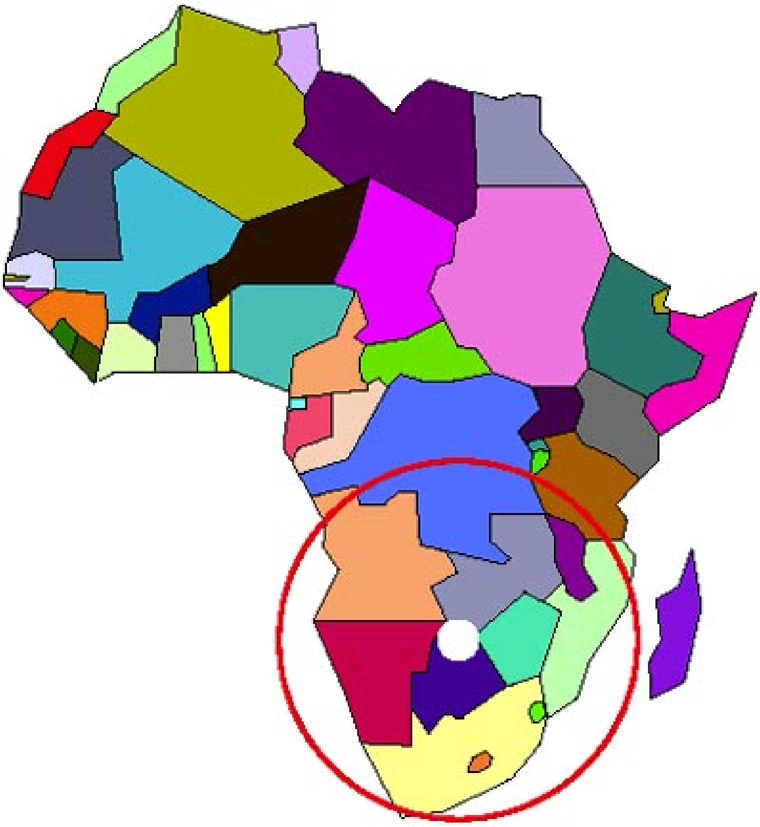
The **simplest atom is the hydrogen atom** (see above). It consists of one positive charged proton and one negative charged electron.

Other atoms are much more complicated. For example a copper atom has 29 electrons revolving around the nucleus in four different orbits.

Size of atoms

0,000 000 000 000 000 000 000 000 000 911

To understand the size of an atom is really difficult.
For example the mass of an electron in gram (like physicists established it) contains behind the comma first after 27 zeros the numbers 911.



And for an atom let's use another example.

If we would think the size of a proton from a hydrogen atom could has the size like a football and could be located in Victoria Falls then its orbit would reach from the Atlantic coast of West Africa to the Pacific coast of East Africa. Now think about a piece of copper: 10 mm thick, 10 mm long and 10 mm wide. Such small pieces mean, **atoms and also electrons and protons are extremely small and relatively vast distances separate them**. There should be a clear understanding when we speak about the flow of electrons!

Insulators and Conductors

Insulators

In most of the elements the nucleus is surrounded by closely held electrons that never leave the atom. These are called ***bound electrons***.

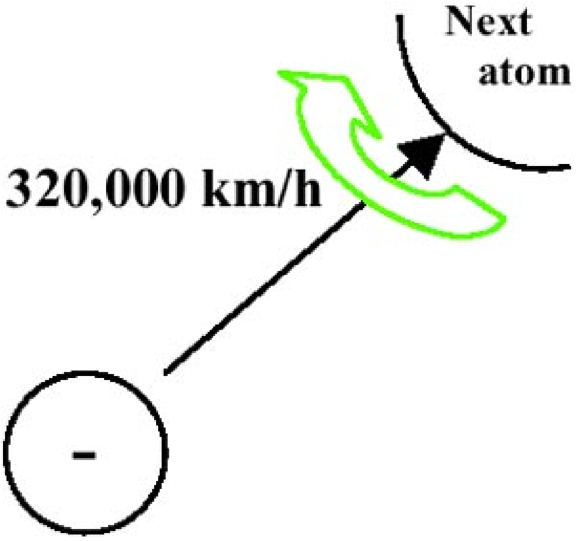
If these **bound electrons are in the majority** in an element or compounded material **then the material is called an *insulator*** (non−conductor of electricity).

Conductors

In other types of material the nucleus is surrounded by electrons that can move freely from one atom to another one if they are forced by applied electricity.

These electrons are known as ***free electrons*. Materials made with these atoms** are called ***conductors*** of electricity.

Speed of electricity



Free electrons in a conductor material are pulled from one atom to another one and so on. By moving that extremely short distances in the case of being forced through electricity, the electricity it self develops a speed of around 320,000 km/h.

As the electrons are moving they temporarily rotate around each new centre. We already know an electron carries a negative charge of electricity and so the ***electron flow (current flow)* is assumed to be from negative to positive**.

Electron drift

The rate of drifting of the free electrons from atom to atom determines the amount of current. To create a drift of electrons through a circuit we must have an ***electrical pressure, the voltage***.

The more electrons the stronger the current.

That means i.e. **in the case of a starter battery**, the greater the concentration of electrons at a battery, **the higher the pressure between the electrons and the greater that pressure is, the greater is the flow of electrons**.

Volts, Amperes, Ohms, Watts

The ***pressure between the electrons***, namely **voltage,** is **measured in *volts (V)*.**

One unit of *volt is the Potential Difference (P. D.)* between two points of a conductor by a constant current flow of one ampere ***(1 A)*** when **the power dissipated** between these points **is equal to one watt *(1 W)***.

The ***flow of electrons, the current***, is **measured in *ampere (A)***.

One unit of ampere is that constant current (I) that (if maintained in two parallel rectilinear conductors of infinite length of negligible cross section and placed at a distance of one meter apart in vacuum) **would produce between the (these) conductors a force equal to 2 × 10^{-7} Newton per meter length.**

Opposing the flow of electrons is ***the resistance*** of the conductors **measured in *ohms (?)***.

One unit of electrical resistance (R) is the resistance between two points of a conductor **if a constant Potential Difference of one volt (1 V) applied** between these points **produces a current of one ampere (1 A)** and the conductor isn't the source of an electromotive force.

Some materials offer a bigger resistance to the electron flow than others. For example the **resistance of iron is higher than the resistance of copper**, but the **resistance of silver is less than the one of copper**. Also the ***length and the size of a wire are important facts to look for*** in that case.

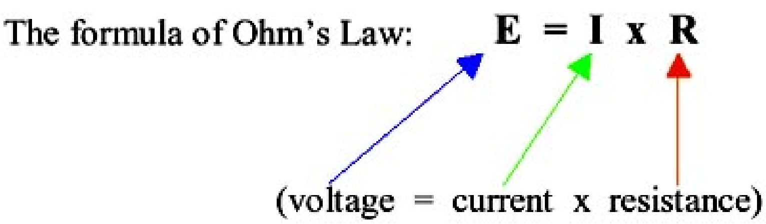
The ***electric power (P) is the product of voltage (E) and current (I)*** and is **measured in *watt (W)***.

P = E × I; (P = U × I)

Electrical loads such as i. e. electric motors, coils and bulbs **will consume power**.

Ohm's Law

The ***Ohm's Law* is the understanding of the mathematical relationship between voltage (E), current (I) and resistance (R) in an electrical circuit**. Each and every one affects the other one.



Sometimes you will find the formula is written in another way:

$$\frac{V}{IR}$$

or so:

All that is the same and that means:

The *Potential Difference (PD = voltage)* in a conductor *is* under constant conditions *equal to the current flow multiplied with resistance* (oppose directed to the current) of the conductor.

The *current through a conductor* under constant conditions ***is proportional to the difference of potential***

across the conductor.

$$I=\frac{E}{R};\left(I=\frac{V}{R};I=\frac{U}{R}\right)$$

By using Ohm's Law is it possible to calculate

– voltage: **V = I × R**;
– current: **I = V/R**;
– resistance: **R = V/I**.

Types of electrical circuits

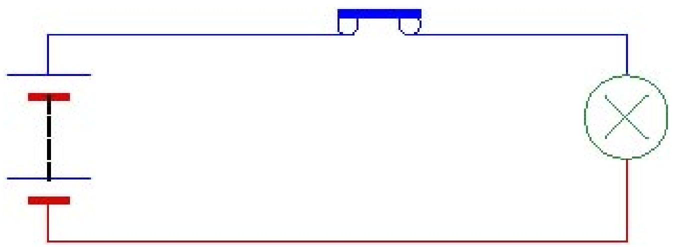
We do know three general types of electrical circuits:

Series circuit; ***Parallel*** circuit; ***Series–parallel*** circuit. For all circuits there are a need for an electricity source (battery), electrical equipment (switch, bulb, etc.) and electrical conductors (wires) to connect the equipment with the source.

Series circuit: The current passes from the power source to each device in turn and then flows back to the other terminal of the source ***(only one path has the current)***. The amount of current will be the same in all parts of the circuit.

Parts of a simple electrical circuit:

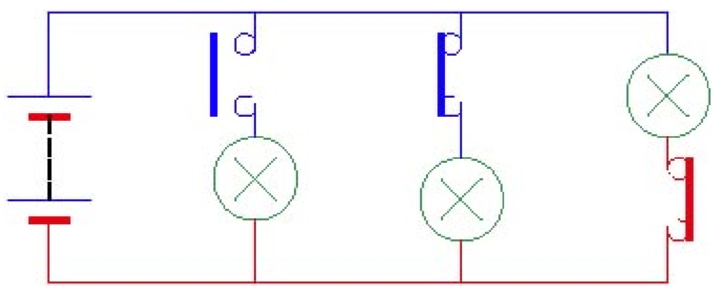
– source of electricity
– switch
– cable
– consumer



Parallel circuit: One terminal of each device is connected to a common conductor, which leads to one terminal of the source. There is ***more than one path for the current to flow*** and therefore each and every path has a separate amount of current flow depending on the equipment by forcing a weaker current flow or stronger one.

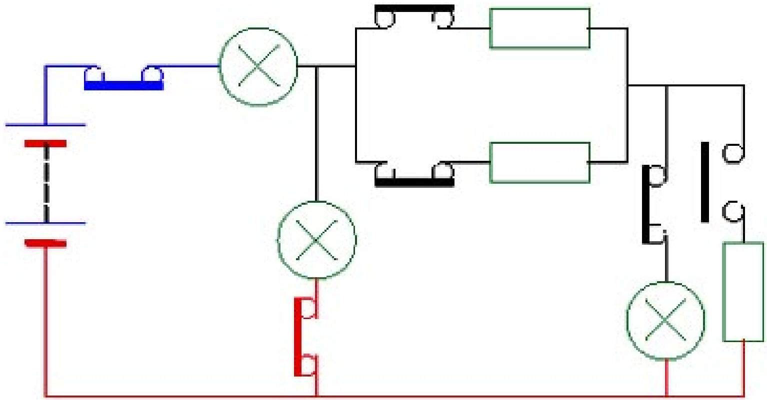
Parts of a circuit:

– one source of electricity
– cable and eventually cable connectors
– the quantity and kind of switches and consumer depends on the kind of the circuit



Series–parallel circuit: Such kinds of circuits have electrical devices connected in series and others connected in parallel. That means we do have ***more than one path for the current to flow***.

Make sure what parts of the circuit are connected in series and/or in parallel.



Measuring resistance

To find the total resistance (RT) of a *series circuit* is to add the resistance of each device.

This means as well, **when a number of resistance's are connected together in series the *current* is the same in every part of the circuit.**

In series **the *P. D. (Potential Difference)* across each resistance is in general different. The overall P. D. is equal to the sum of all P. D. across the individual resistances.**

Remember: There is only one path for the current flow.

$R_T = R_1 + R_2 + R_3$ $R_1 = 2?$

$R_2 = 5?$

$R_3 = 4?$

$R_T = 2 + 5 + 4 + 1 = 12?$ $R_4 = 1?$

The flowing current in this circuit can be found by applying Ohm's Law:

$V = I \times R$  $I = V/R$ $V = 12\ V$

$I = 12\ V/12?$

$I = 1\ A$

In a *parallel circuit* we do have more than one path for the current flow. **Therefore the total resistance of all the devices will be less than the resistance of any single device**.

Resistance is the ability of any wire or electrical component to oppose the flow of current.

Conductance is the reciprocal (opposite) of resistance.

To find the total resistance in a parallel circuit the easiest way is to use the conductance formula:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

R_1=3?
R_2=6?
R_3=4?

R_4=4?

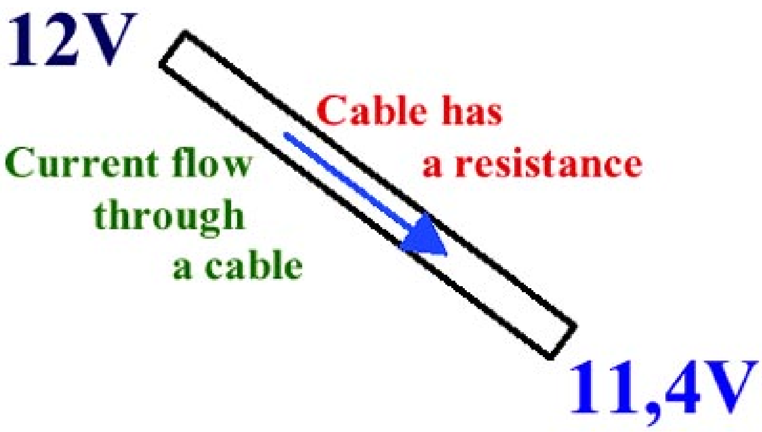
$$\frac{1}{R_T} = \frac{1}{3} + \frac{1}{6} + \frac{1}{4} + \frac{1}{4}$$

Invert both sides of the equation (equal factors).

$$\frac{1}{R_T} = \frac{4}{12} + \frac{2}{12} + \frac{3}{12} + \frac{3}{12} = \frac{12}{12} = 1\Omega$$

The total current flow trough the circuit will be:

I_T = V/RT
I_T = 12 V/1 ?
I_T = 12 A



Voltage drop

The ***decrease in voltage*** as current passes through a resistance **is known as *voltage drop***. The sum of individual voltage drops is equal to the total voltage on For **calculation of the voltage** drop in all the different parts of the circuit can be used Ohm's Law.

Let's use the examples we had already (R_1 = 2?; R_2 = 3?; R_3 = 5?):

Series circuit: Current = 1 A (all over)

Voltage drop ⇨ V = I × R

1. part 1 A × 2 ? = 2 V
2. part 1 A × 5 ? = 5 V
3. part 1 A × 4 ? = 4 V
4. part 1 A × 1 ? = 1 V

= 2 + 5 + 4 + 1 = 12 V

Parallel circuit: Voltage drop ⇨ V = I × R

1. part 4 A × 3 ? = 12 V
2. part 2 A × 6 ? = 12 V
3. part 3 A × 4 ? = 12 V
4. part 3 A × 4 ? = 12 V

Direction of current

The ***positive ions in liquids move from the positive to the negative pole*** **(technical direction of current flow)**.

The **electrons in a liquid flow** in the opposite direction, **from negative to positive**. ***Electric current can flow only in a closed circuit***.

Loads and conductors close a circuit and a switch will control the circuit. The ***current flow in a circuit goes on from positive to negative***.

Alternating current (AC)

The **current changes its strength and direction periodically**.

The free electrons oscillate to and from along the conductor axis**.**

One complete oscillation is a period or a cycle and the **amount of complete periods per second is called** ***frequency, measured by using the unit Hertz (Hz).***

Direct current (DC)

Direct current flows always in the same direction and at a constant current strength as long as the circuit resistance doesn't change.

The free electrons move continuously at the same speed as well.

This kind of current flow we do have in all the motor vehicles by connecting the different consumers.

There is one difference only.

The **recharging system** in motor vehicles is in modern cars **equipped with an** ***alternator***.

This ***alternator generates*** for the recharging process an ***alternating current***. For getting useable that current in a motor vehicle is it ***therefore*** necessary to ***rectify the current as a direct current*** what is done by a diode assembly as rectifier unit.

On each and every consumer **in a motor vehicle** ***the amount of voltage is 12 V.***

It is important to understand why we will find that most of the consumers in motor vehicles are connected in parallel to the power source.

Electrical work and power

The **electrical unit for work** is called ***joule.***

One joule **is equal to one ampere flowing for one second under the pressure of one volt.**

1 J = 1 A/s * 1 V

Work is done when energy is expended.

Work **is the** ***product of force multiplied by the distance through which it acts in overcoming resistance.***

An ***electrical force*** **may exist without work being done.** This is the **condition** that exists **between the terminals of a battery when no equipment is connected** to them.

When a piece of ***equipment is connected*** **to the terminals of a battery then** ***current will flow*** **and** ***work will be done*****.**

Power is the ***rate of doing work*****:**

$$\text{Power} = \frac{\text{work}}{\text{time}}; \text{electrical power} = \frac{\text{electrical work}}{\text{time}} = \text{W}$$

The ***electrical unit of power*** is ***Watt***.

One watt = to one joule of electrical work per second

$$\text{Watt} = \frac{\text{Joules}}{\text{Seconds}} = \frac{\text{Volts} \times \text{Amperes} \times \text{Seconds}}{\text{Seconds}}$$

P (W) = E (V) * I (A)

Watt = Volts × Amperes

That means, if in an electrical circuit by using 12 V one bulb is connected and a current of 1,75 A is flowing than the number of watt is 21 W.

P = E × I; P = 12 × 1,75; P = 21 W

2. Batteries and service of them

Batteries in motor vehicles

The battery is an electrochemical device that ***converts chemical energy into electrical energy***. When the battery is connected to an external load (consumer), such as a lamp, a starter motor or a radio, the energy conversion takes place and so electricity flows through the circuit. In modern cars we will find the ***lead–acid storage batteries***.

Battery functions

Lead–acid storage battery has three main functions:

1. It is the ***source of power*** for the starter motor and the ignition system when cranking and starting an internal combustion engine.

2. It is the ***stabiliser of voltage*** for the entire automotive electrical system.

3. It ***gives current for a limited time*** when electrical demands exceed the alternator output.

Battery construction

Most of the used batteries are constructed as ***12 V batteries.*** In several types of motor bikes there are small ***6 V batteries*** also used. Lorries with 24 V electrical systems are using two 12 V batteries (in series connected).

The material of the battery case can be hard plastic or hard rubber. Inside this case are the walls for the cells that completely insulate one cell from the other one. The plates and connectors are made from lead alloy.

A typical **12 V** lead–acid **storage battery is made up of six cells connected in series**. Inside the cells do separators separate positive plates and negative plates. The **cells are filled with electrolyte** (sulphuric acid diluted with distilled water).

Each cell produces (if fully charged) ***2,1 V***. This means a ***fully charged battery*** with 6 cells (series connection) ***has a voltage of 12,6 V.***

The ***cells*** itself ***are separated*** by each other. The positive and negative separated plates inside each cell are in the top of the ***plates connected with plate straps***. From there the whole ***battery is cell by cell connected in series.***

We know ***conventional batteries*** (wet, moist or dry charged), ***low–maintenance batteries***, ***maintenance–free batteries*** (low water loss) and ***hybrid batteries*** (negative plates with a lead callium alloy). All of these types in their basic construction are very similar.

Sizes and types

Lead–acid storage batteries vary in size, capacity and cranking power.

The main point is that **a *bigger surface of the plates* brings a *higher capacity of the battery***. A bigger battery by using more plates per cell and/or higher and wider plates has therefore a higher capacity.

In an automotive battery there **are *many thin plates*** to give those big surface area of plate material to the electrolyte ***to generate*** also **a *very high current for a short while*** (starting process). Such kind of battery is not suitable for powering a TV.

Cells, plates, separators

Each of the six cells of a 12 V battery contains ***plates***. Negative plates and positive plates are ***composed of special active material contained in grids.***

Pure lead is too soft for manufacturing of grids, so it is ***alloyed with*** a small percentage of ***antimony for strength***. Every cell contains ***one negative plate more*** than positive plates. The reason is that the active material of the positive plates is softer than the one from the negative plates. By having one negative plate more there is on every side of the positive plates a negative one and the active material from the positive plates cannot break out so easily.

The ***purpose of the grids*** is to provide a supporting ***framework for*** the ***active material*** and also to conduct current. The positive and negative grids are made ***by pasting them with a muddy mixture of lead oxide, sulphuric acid and water.*** Fibre additives give cohesion (stick ability) to keep the active material connected to the grids.

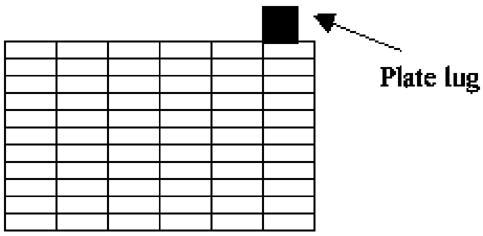
Expanders are added to the negative plate paste to prevent the negative material from contracting during operation and changing into an inactive state, which would inhibit the constant chemical reaction in normal operation i. e. it keeps the plates spongy.

The paste is mechanically applied into the plates and than the plates go on a partial drying process.

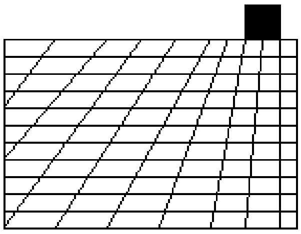
Positive plates are now **pink**.

Negative plates are **slightly grey** due to expander material and binders.

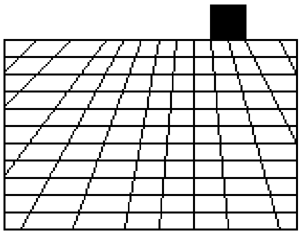
The plate grids can have the following structure:



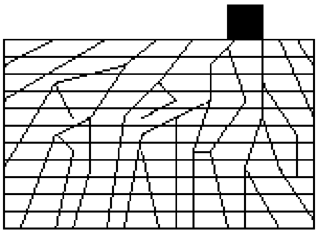
Rectilinear



Radial

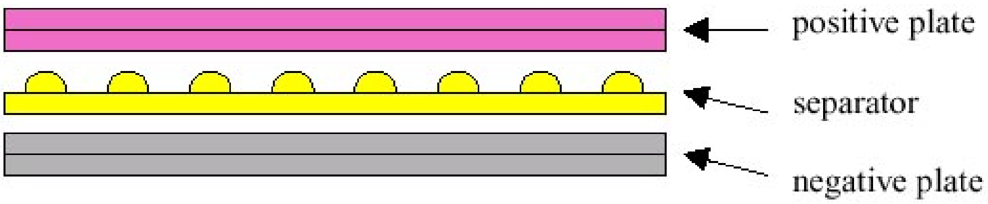


Centre Lug Radial



"Tree"

Separators are ***thin porous sheets* with *insulating abilities***. They are sandwiched between positive and negative plates to prevent shorting.



Fine pores* allow free *electrolyte movement around and through the separators. **Ribs** allow gas bubbles to surface and as the positive plate needs 1,6 times as much electrolyte to operate, ribs are pointed **towards** the **positive plate**.

An alternative type of separator is the **envelope separator** (polyethylene envelope).

Elements

Varying numbers of plates are held together by soldering or pressing the **lugs** of the negative plates and separate of this by soldering or pressing the lugs of the positive plates together. This is formed in the cells, **cell *packs called elements*** by using separators between the negative and positive plates to insulate them from each other.

Remember:

– there is always one negative plate more in the cells.

– more plates = more surface area = greater capacity = higher cranking capacity = greater efficiency.

Terminal posts are formed on the first and the last cell elements of a battery. Short circuit tests are performed on all elements. **Cells** are inserted into **containers** and soldered or pressed **through holes** in the cell walls (by using cell connectors) **in series**.

– ***2,1 V per cell***/element (regardless of size;
– = ***12,6 V*** by using a battery with ***6 cells***.
– = ***6,3 V*** by using a battery with ***3 cells***.

The **cover** (in top of the battery) with the posts is **heat bonded** to the container and normally checked with compressed air for leaks.

Today heavy–duty batteries only have external cell connectors sealed by a special sealing compound (bitumen based). All the smaller batteries have the cell connectors under the battery cover.

Vent plugs and vents

Vent plugs have various designs. They usually have a hole were the ***gas can escape*** but the ***electrolyte*** **splashed into the vent *will drain* back *into the cell.*** The plugs may be screw type or push–in type.

Electrolyte

The battery is activated by addition of electrolyte.

Electrolyte is a mixture of sulphuric acid and distilled water. This **solution causes** the ***chemical actions*** to take place **between** the **lead dioxide** material **of** the **positive plates** and the **lead** material **of** the **negative plates**.

The ***electrolyte is*** also **the *carrier*** by moving ***of* the *electric current*** between the positive and the negative plates **through the separators**.

Lead–acid batteries use a concentrated solution of sulphuric acid and water.

The ***density (specific gravity)*** **of electrolyte in a *fully charged battery***

= *1,260 g/cm³ and above*.

The density **in a *half charged battery***

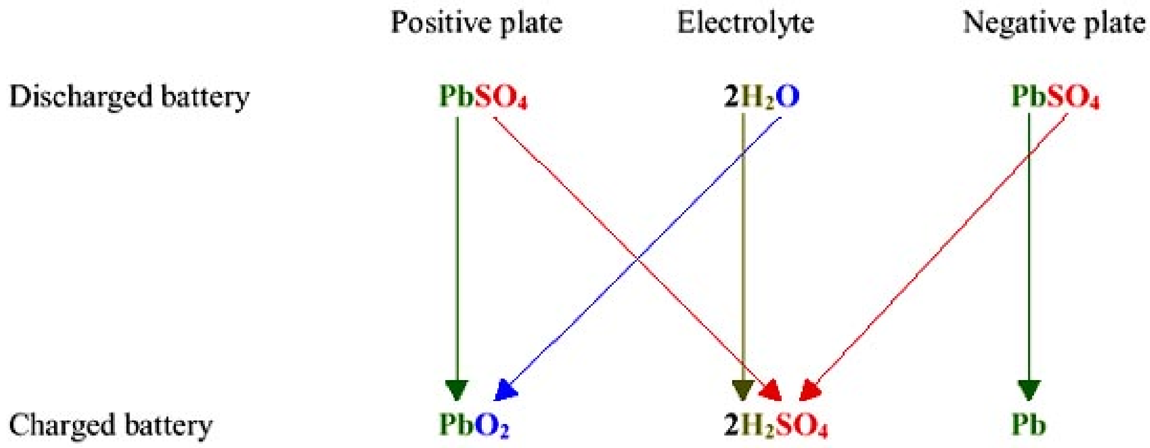
= *1,190 g/cm³*.

The density **in a *discharged battery***

= *1,120 g/cm³*.

The ***specific gravity of water***

= *1,000 g/cm³*.



Chemical reaction

Specific gravity reading	***% state of charge***
1260 and above	100 %
1225	75 %
1190	50 %
1155	25 %
below 1155	discharged

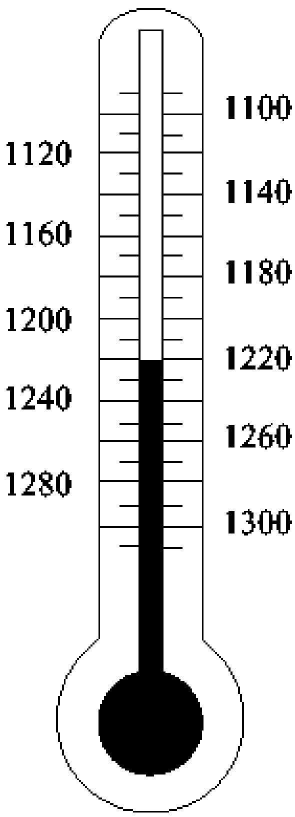
Battery inspection

A ***visual inspection*** is the first step if you should test a used battery. Look carefully for defective cables, eroded cable clamps, accumulated corrosion deposits, cracks in the battery case or cover and loose or broken hold–down devices. Clean, repair and/or replace the parts as required.

Testing with a hydrometer

Handling the hydrometer:

1. Suck up sufficient electrolyte to float the float.
2. Hold the hydrometer vertically; the float must not rub on the tube wall.
3. Read hydrometer on the bottom of meniscus.
4. Keep the hydrometer clean by rinsing after each battery test.



Float of the hydrometer with scale

Test with the hydrometer **after topping up** (if necessary) with distilled water needs **a boost–charge** of the battery for 15 minutes by +/– 20 A to mix H_2O with H_2SO_4 and to obtain an accurate reading. That should be **the only use of a boost charge**.

The ***electrolyte level*** must always be between 1,0 and 1,3 cm over the top of the plates.

Do not overfill the battery with electrolyte. If that is done the **electrolyte will splash out** by using the battery in a car and so it may create problems (see at "visual inspection").

By doing the ***hydrometer test*** is to ***check each cell of the battery***. Compare the lowest and the highest readings. If the difference is higher than 50 points (i.e.: 1. cell = 1250 and the 2. cell = 1190 equals to a **difference of 60 points**) the ***battery should be charged for 8 hours***. After that the **density should be taken again**. If the difference **didn't change under 50 points**, then we have to realise that the battery is **not serviceable anymore**.

If the above mentioned situation isn't like that, then the battery should get fully charged. And also after charging, the density of the electrolyte should be taken again to ensure it is right.

A good possibility can be to give all the cells numbers. So it is easy to follow up the later readings without getting confused by handling more then one battery. **Note**: Heated fluid is less dense. Therefore the float will sink. The ***right reading*** can be taken ***by a temperature of 27°C***. After charging the battery should stand for a while to cool off before the next hydrometer test. Another possibility is to **add 0,004 points** of the read density **for every 5,5°C above** 27°C and to **subtract 0,004 points for every 5,5°C below** the normal temperature factor.

Load test

The load test of a battery takes place by using a ***battery load tester***.

The following steps are important to do:

1. **Determine the load** to be used (as found in the code print).

2. **Do not exceed** this figure.

3. With removed vent caps the tester has to be in switched off position and **care should be taken** by connecting the battery.

4. The **tester is to activate** by adjusting it to the right amount flowing current (see point 1.) and the test is to run **for** a full **15 seconds** (but not longer).

5. During that test the ***voltage should not drop below 9,4 – 9,6 V*** on a 12 V battery.

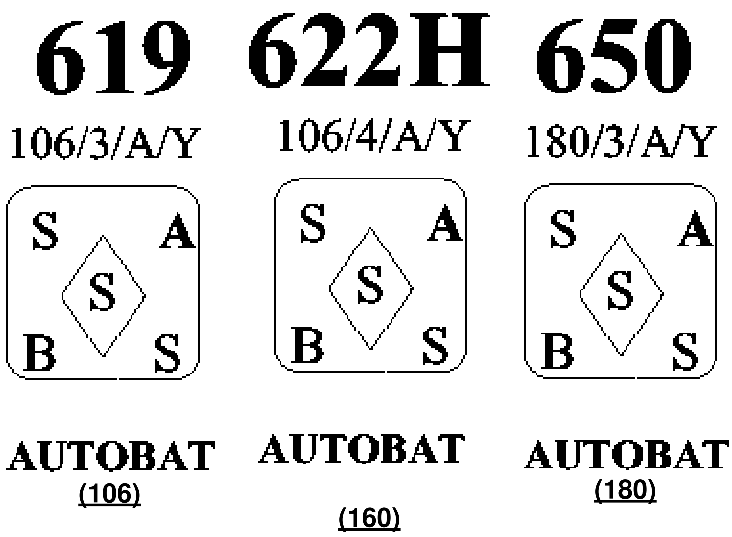
6. If one or more cells experience a high rate of **gassing during that load test**, the battery is **suspect**.

Open-circuit voltage test

If the **battery fails the load test than** is to check its state of charge by making a stabilised ***open-circuit voltage test***. But **after the load test** the battery should be given a time of at least ***10 minutes to recover***.

This test is to do by the use of a voltmeter. The battery must have a **temperature** between 15°C and 35°C. If the battery is in good condition than the voltmeter should show 12,4 V. If the **state of charge is below 75%** the battery should **be recharged and load tested again**. **Fails the battery** the load test the **second time**, the **battery should be replaced**.

Examples for **cold crank capacities** in the case of battery codes:



Battery problems

Most batteries fail due to various forms of abuse. The most common causes are:

1. ***Dirty and corroded battery terminals*** which lead to high resistance in the electrical circuit.

2. ***Loose battery terminals*** cause the melting of the terminals and can result in sparks, which will lead to an explosion in the battery (very dangerous!).

3. ***Vibration***. Holding clamps, which are not properly fixed, tightened results in the active material parting from the grids and the capacity of the battery get reduced.

4. ***Over–tightening of hold down clamps***. The container will crack or cause damage to other parts of the vehicle.

5. ***Hammering on battery poles*** will loosen the terminals or break the internal components. Always use correct sizes of the spanners when replacing/removing terminal clamps. Never loosen by force.

6. ***Dirt and damp*** on the battery will cause a gradual selfdischarge.

7. ***Overcharging*** causes an excessive loss of water and consequently causes the plates to shake off their active material (reducing capacity and service life).

8. ***Undercharging*** causes the plates to sulphate (reducing capacity and service life).

9. ***Standing in a discharged state*** will, too, force in the battery plates sulphation and irreversible damage.

10. ***A faulty regulator or alternator*** will lead to the contents of the points 7. and 8. (see above).

11. ***A loose fan belt*** leads to the discharge of the battery. Periodic attention to the battery as well as to the remainder of the electrical system, including the fan belt tension, is essential for trouble–free service in any vehicle.

12. ***Incorrect electrolyte levels***. If these are to low, plates dry out and sulphate. If these are to high, electrolyte escapes through the air holes, which can lead to acid damages.

13. ***Adding acid instead of water*** increases the density of electrolyte to the point where it attacks the plates.

The battery is the first item to be blamed when a vehicle does not start.

But do you check always the causes shown above?

Charging methods

Follow up the ***manufacturer's operating instructions***. Untrained staff should not be allowed to use test– and charging equipment.

Observe safety precautions. **Never connect or disconnect testing or charging equipment unless they are switched off.**

Generally: ***Charge at or under 6A***. Specific charging rates cannot be specified because of different capacities as well as differences of temperatures, state of charge and battery ages.

Stick to the 6A rule and you cannot go wrong.

Five identical batteries *charged in parallel* by using a charger output = 20 A, gives each battery 4 A.

Batteries ***charged in series*** **receive the full current output of the charger**. Batteries with ***different capacities*** **can be charged in series**, too. But the **charging rate** of the **lowest capacity** must be used.

High rate charge or boost charge is not recommended except for short periods to mix added water with the electrolyte. If the electrolyte ***density is 1,225 g/cm³ or higher***, **than *never* try *charge on* a *higher rates*.**

Constant potential charging:

Starts at high rate and as the battery voltage builds up, rate tapers automatically to lower value.

Constant current charging:

Set the charging rate at 2 – 3% of cold crank capacity – as a general rule keep rate under 6 A. It may take 2 – 3 days at slow rate to restore a partially sulphated battery.

Floating charge:

Battery is continuously connected to charging source.

Trickle charge:

Battery gets charged with less than 1A – it is useful for home use.

Battery stocking:

The stocked batteries need to get proofed of the charging situation. If the voltage drops down below 12,4 V – recharge! Stock rotating is necessary (first in = first out.

When battery self discharges below 11,1 V or below 1,010 g/cm³ of the electrolyte density, it will not recover when recharged.

REMARK: If the battery suddenly (**overnight**) becomes **discharged** (i.e. by headlights) that will not create a problem like mentioned above. In all it will accept a charge and **go back into normal charged situation**.

Jump–starting

Jump starting (booster cable instruction) as a general rule: **Do not jump start vehicles fitted with any computer–operated equipment!** Check manufacture recommendations before jump starting vehicles with electronic fuel injection or board computer.

Jump–starting:

• After looking for the mechanical safe situation on both of the cars (gearbox; handbrake) first of all ensure that both cars are negative grounded.

• Now connect the "dead" positive terminal to "life" positive terminal with red cable.

• Connect one end of black cable to "live" negative terminal and the other end of black cable to the chassis or engine block of the "dead" car. Never connect the black cable to the "dead" negative terminal.

• Ensure that the cables are far enough from fan blades and other rotating parts.

• Start "life" car; bring the engine speed on +/−2000 r.p.m. and attempt to start "dead" car.

• If "dead" car isn't starting within 15 seconds, stop the process and check for fuel or ignition problems.

• If "dead" car starts, allow the engine to idle and remove the cables in reverse order (as above mentioned).

Activating of dry charged battery

A dry charged automotive battery contains no electrolyte until it is used in service. The cell elements are given an initial charge on special equipment at the factory. Then they are thoroughly washed, dried and assembled into battery cases.

A dry charged battery will retain its full charge indefinitely if moisture does not enter the cells. **When *ready for service*, the battery has to be *filled with electrolyte* and (generally) is given a *boost charge*.**

After boost charge the battery at 15 A the electrolyte should have a density of 1,250 g/cm^3 or higher by a temperature not under 16°C.

The ***electrolyte level is after the boost charge to control*** and if necessary add only distilled water.

Change of a battery

If there is to replace a battery of a car than it should be a battery with the ***correct Ah – rate*** suitable for that car. But before replacing we should also ask our selves:

• is it the ***battery it self*** to create problems?
• will ***the same problem*** occur ***after replacing*** the blamed battery?
• can it be ***another fault*** what causes a discharged battery always again?
• is the ***charging system*** suspect and/or is the fan belt may be slipping?

We have to make sure what is going on in that cases to get a satisfied customer.

Automotive battery/TV−battery

An ***automotive battery is designed for many shallow cycles***. At 10 starts per day = 3,600 starts p.a. +/− 10 − 12,000 starts during the time of service life is expected. For that strong forcing cycles **an *automotive battery has many thin plates*** to give a big surface area and ***to generate very high current for a short while***.

<u>An automotive battery is not suitable for powering a TV−set!</u>

A ***TV battery is designed especially for repeated deep cycles***. The ***internal construction is different*** which results in a good life cycle when powering a TV−set. The ***TV battery will be discharged slowly as the TV draws current***. Care should be taken not to discharge the battery too much. That can cause internal damages and shortens the useful battery life (reduces the number of times the battery can be recharged).

Terminology

Active mass:	That part of the battery (pressed into the plate grids) which is subject to chemical change when current is passing (charging; discharging).
Internal resistance:	The internal resistance is the sum of various resistances' of the internal battery circuit. Transfer resistance between the electrodes and the electrolyte, resistance of the electrodes to the flow of electrons, resistance of the internal connecting parts, etc.
Capacity:	Is the quantity of electricity in ampere–hours, which can be drawn from a battery. It is used to classify the batteries.
Terminal voltage:	It is the voltage between the two terminals of the battery.
Charging voltage:	The charging voltage depends on the state of charge of the battery, the charging current and the temperature. It is always higher than the off–load voltage.
Charging current:	It is the current at which a battery gets charged.
Service life:	The normal service life of a battery has a duration of three years but it depends on how well the battery is maintained, the operation conditions and the leakage current.
Nominal voltage:	It is a fixed value and is set at 2,1 V in the case of one lead acid cell.
Nominal capacity:	Nominal value in the case of 20 hours discharge with a discharge current equivalent to one tenth of the nominal capacity. The acid temperature should has +27°C. The final discharge voltage per cell = 1,75 V.
Acid relative density:	It is also called "specific gravity". Battery in charged state 1.260 g/cm^3 or above; battery in half–charged state 1.190 g/cm^3; battery in discharged state 1.120 g/cm^3.
Sulphation:	If a battery is allowed to remain in a discharged condition for a prolonged period, the fine lead sulphate formed during the discharging reaction may transform into coarse lead sulphate which can only be converted back with very great difficulties – if it can be converted back at all.
Unfilled, charged	In this case we do speak about "dry charged" batteries as well.

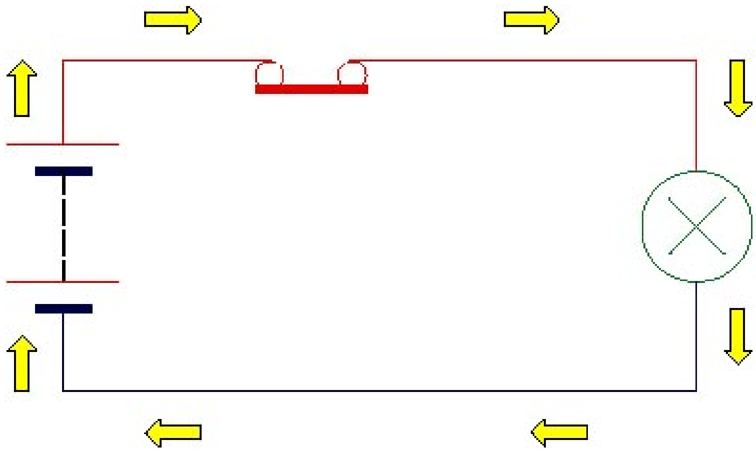
batteries: The battery plates are in a charged condition but for the only reason of a better storability the battery has been supplied without electrolyte. The battery is ready for service within a short time after the electrolyte is being added.

3. Lighting and signal circuits – Accessories and wiring

Lighting and signal circuits

Concerning the **basic electrical information** you do know already what is the need for a simple circuit:

- battery;
- switch;
- consumer (i.e. a lamp);
- conductors (wires and negative connection over the car body).

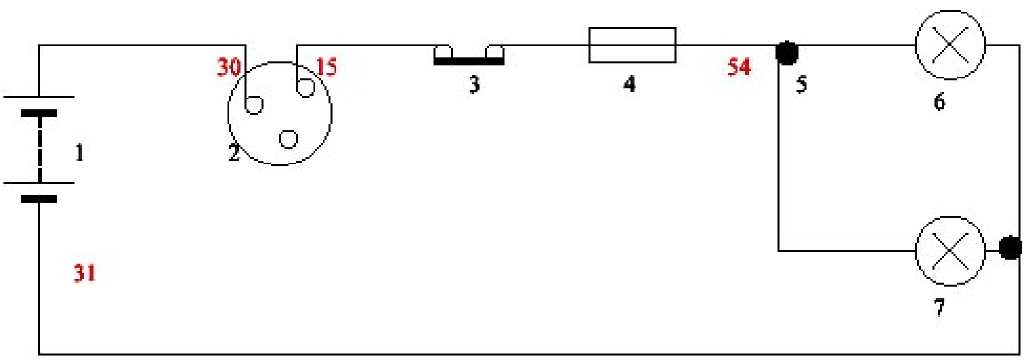


Current flow direction: 

Let's think in a practical way:

We want to know, how the ***stoplights on a car*** are connected. According to the simple circuit shown above there must be a connection for both of the ***bulbs*** for the stoplight. A ***switch*** must be inserted (by working mechanically over the brake pedal or by using the pressure of the brake fluid over the main brake cylinder). The connection to the ***battery*** must be there for some way and we do need a ***fuse*** to protect that circuit in the case of an eventually short circuit. And of course, all that parts are connected on the ***positive side by using wires*** and on the ***negative side*** by using a ***short wire connection to the car body***. From there back ***to the negative terminal of the battery over*** the ***chassis***, the ***engine block*** and the ***battery negative cable***.

Let's see how a ***stoplight circuit*** can be done. See diagram below:



1 – battery
2 – ignition switch

3 – stoplight switch
4 – fuse
5 – cable connection
6; 7– stoplight bulbs

What's new?

The ***ignition switch*** is connected direct or over the starter motor to the battery (positive terminal). Most of the circuits in a car are connected over fuses (by using a fuse box).

The ***circuit*** shows, too, **several** ***numbers*** (30; 15; 54; 31). That numbers are part of a ***number code*** to indicate connections:

- "**30**" = direct connection to the battery;
- "**15**" = connected only than when ignition switch is switched on;
- "**54**" = indication number for the stoplights and several other consumers;
- "**31**" = indication for negative connection.

In our example the stoplights are only working if the ignition switch is switched on (over "15").

If over the wire on the long way to the stoplights **a short circuit is coming up, then the fuse blows up** and so the other wire connections inside the car are ***protected*** in case of developing heat and burning out.

Think about this: A modern and fully equipped car has between 50 and 70 interior and exterior lamps and many different other consumers as well!

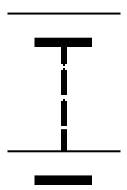
Generally speaking the lighting and signal circuits are known as ***single wire systems*** since they are used of the car frame for the return connections.

Complete lighting and signal circuits are separated into ***individual circuits*** by using one or more switches and lights or other consumers.

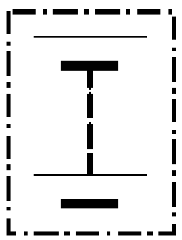
Note the following difference: The lighting and signal ***consumers are connected in parallel*** **but the** ***controlling switches are in series to the circuit groups and the battery.***

Signs of electrical equipment

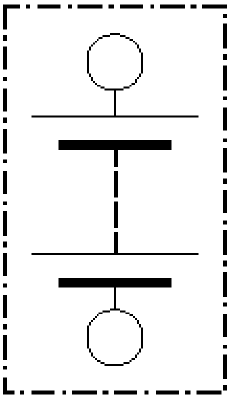
Battery:



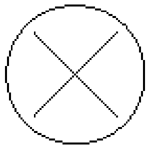
or



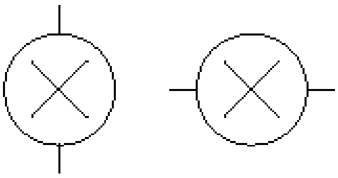
or



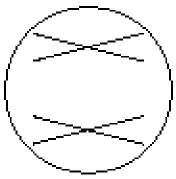
Bulb single filament:



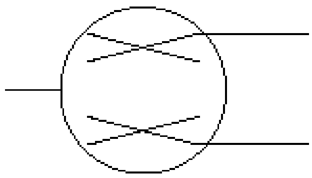
–with wire connection:



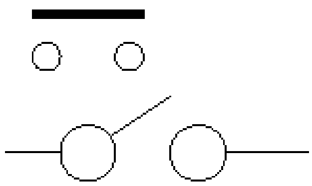
Bulb double filament:



–with wire connection:

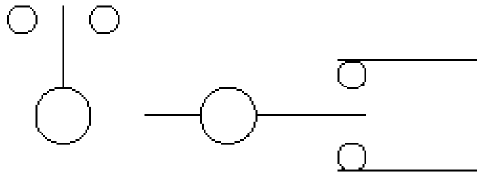


One way switch open:

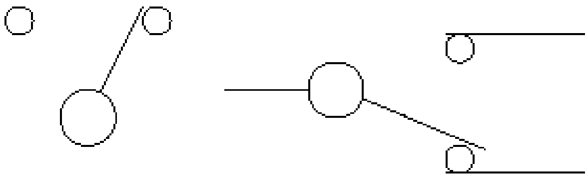


–and closed:

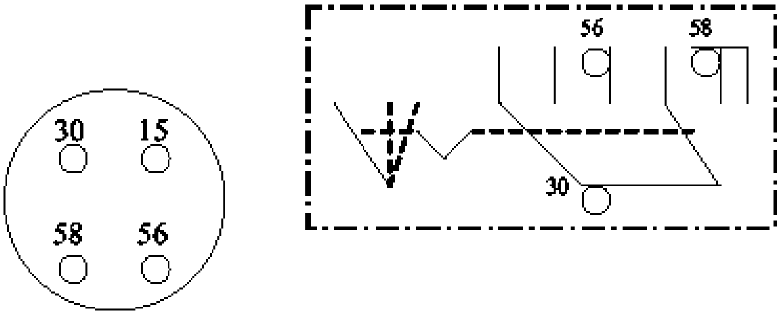
Two way switch open:



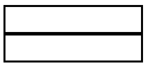
–and closed on one side:



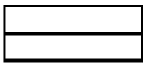
Multi way switches:



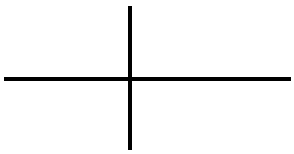
Fuse (generally):



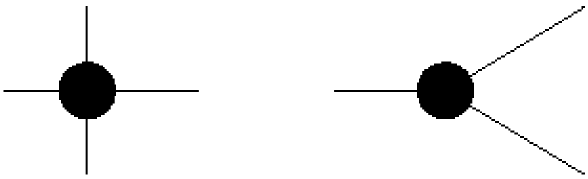
–with named "A":



Across wires:
(without electrical connection)



Wire connection:



Switches

As shown already above there are different needs for switches in cars. For example: In a horn circuit a ***one–way switch*** is mostly used. And so is used a ***mechanical one–way switch***. Also the stoplight circuit may have a mechanical one–way switch, but there is another possibility by using an oil–pressure one–way switch that is included into the brake fluid circuit and therefore placed on the main brake cylinder.

In an indicator circuit must be at least a ***two–way switch*** for switching on the left side or the right side of the indicator lamps.

But ***multi way switches*** **(provided for special purposes)** are in use as:

Ignition switch **(switched off; switched on; starting)**,

Light switch **(switched off; side/rear light switched on; side/rear light and headlight switched on),**

Wiper switch **(switched off; slowly speed switched on; faster speed switched on; interval wiper moving switched on; wiper motor single movement and/or windscreen washer unit switched on –by shortly pressing–).**

Fuses, fuse boxes

As mentioned before we do need ***fuses to protect circuits in case of a short circuit***. What does it mean?

It can happen that a positive wire looses its connection and comes i. e. on the frame of the car **= short circuit**. A wire can rub on a part of metal and after the insulation is rubbed through **= short circuit**. And **also an accident of a car can create something like that**. ***Another important reason for using fuses*** is the possibility that an **overload occurs in a circuit**.

In all that cases the **fuse** for the specific circuit **burns out/blows up** and open up the circuit. **No further damage will result.** In connection with a **circuit breaker** (relay) that breaker **remains open** until the problem is solved.

If there is no protection by using fuses then an electrical unit of the car can be affected and unfortunately that car can burn up.

Fuses are mostly placed in fuse boxes or include some different relays and other components in so–called **central units**.

We do know ***glass fuses***, ***ceramic (continental) fuses*** and ***rectangular fuses***. The most usable ampere strength are 7,5 A, 8 A, 10 A, 15 A, 20 A, 25 A, 30 A and on several vehicles possibly up to 70 A.

Information can be seen on the following tables:

– what current strength is flowing by using different consumers:

Several electrical circuits	**Flowing current in ampere (A)**
Ignition	**5 A**
Starting unit	**100 A – 300 A**
Headlights	**12 A – 20 A**
Side/rear lights	**2 A – 4 A**
Stop lights	**4 A**
Wipers	**6 A**
Air conditioning	**12 A – 20 A**
Interior lights	**1 A – 2 A**
Radio	**1 A – 1,5 A**

Note: That values are depending on the manufacturer of a specific vehicle and its type. The equipment it self develop further and we will find changes by the value of the flowing ampere as well as new components placed inside cars (i. e. board computer).

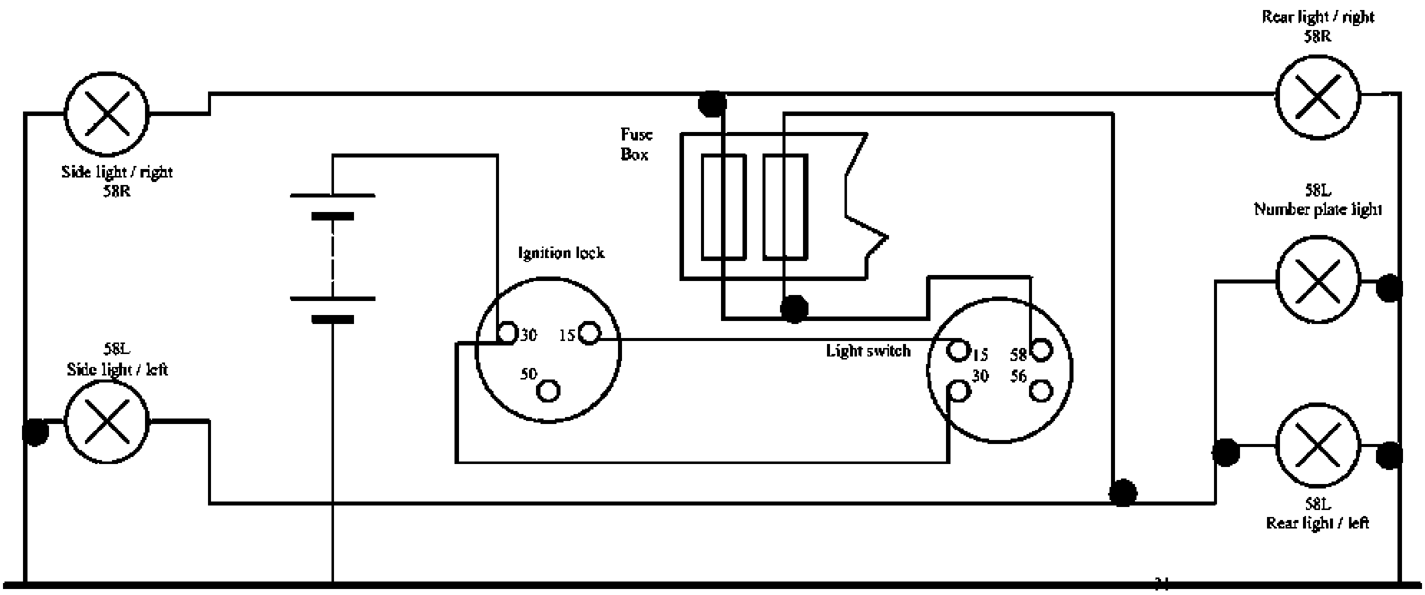
– and what ampere value of fuses can be in use in several electrical circuits:

Electrical circuits	**Ampere value of fuses**
Gauges; alarm system	7,5 A
Side/rear lights; head lights; interior lights; electric arial; electric mirrors	10 A
Wipers; washers; stop lights; cigarette lighter; hazard unit; indicator circuit	15 A
A/C clutch; blower motor	25 A
Electrical movable seats; central locking unit; electric windows	30 A

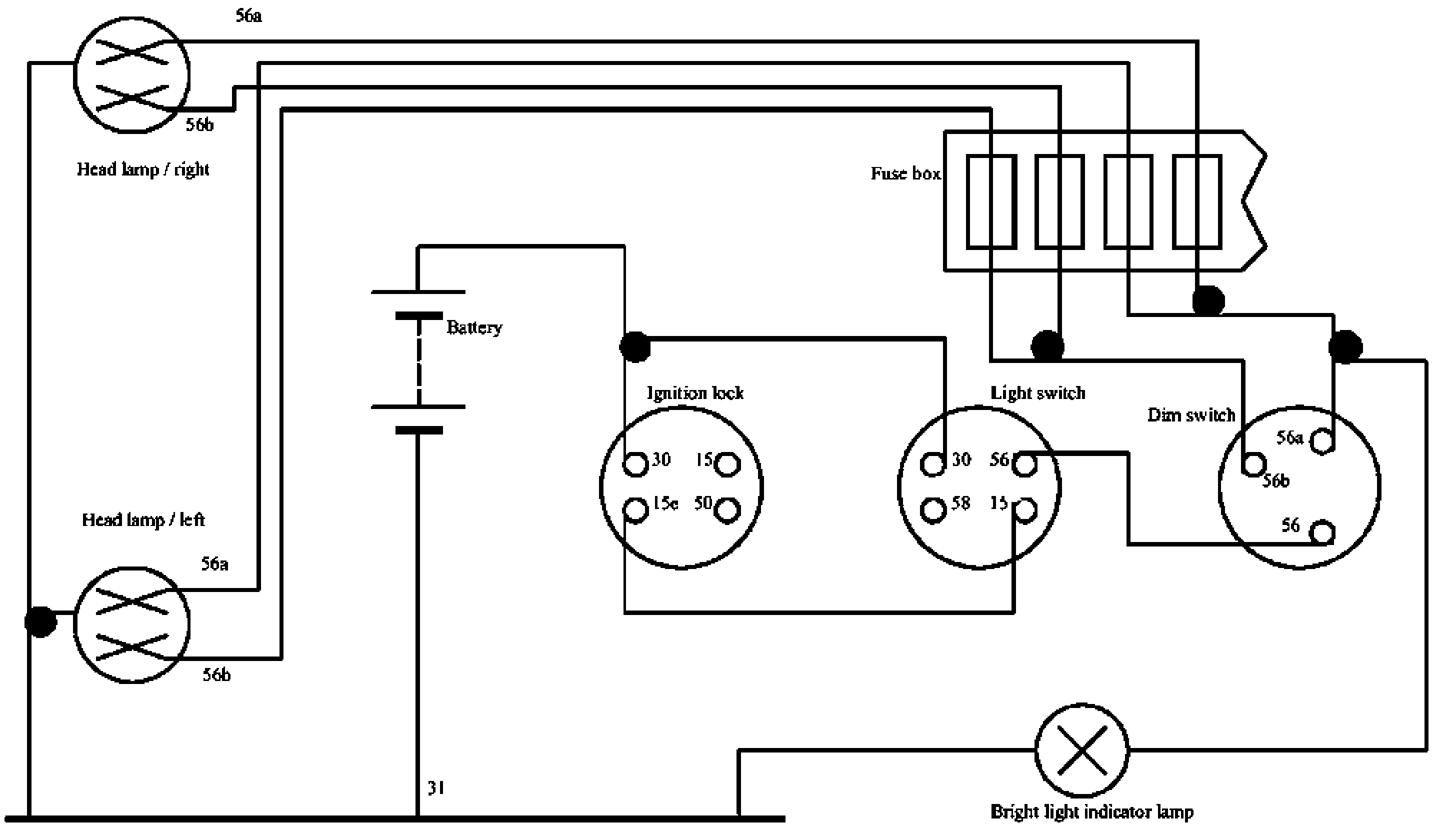
Note: See information under first table.

Electrical circuits

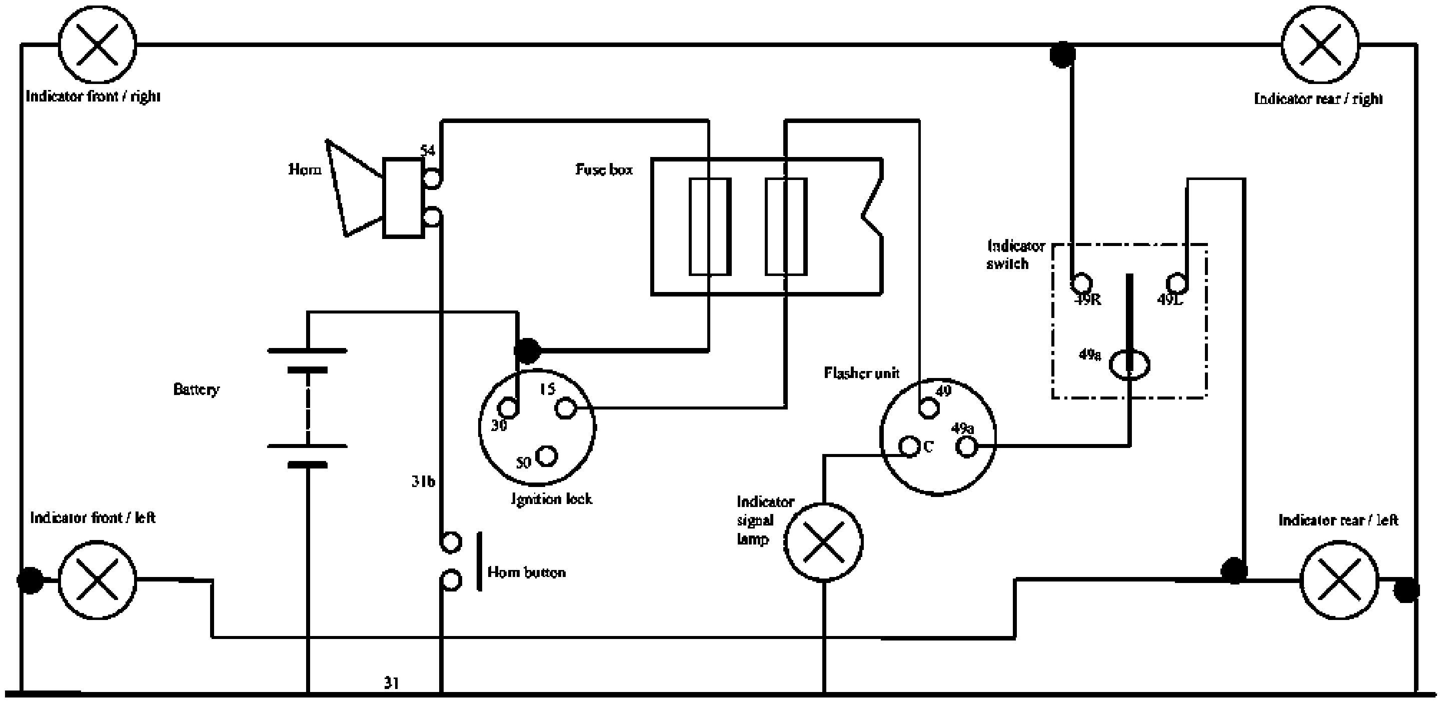
(examples):



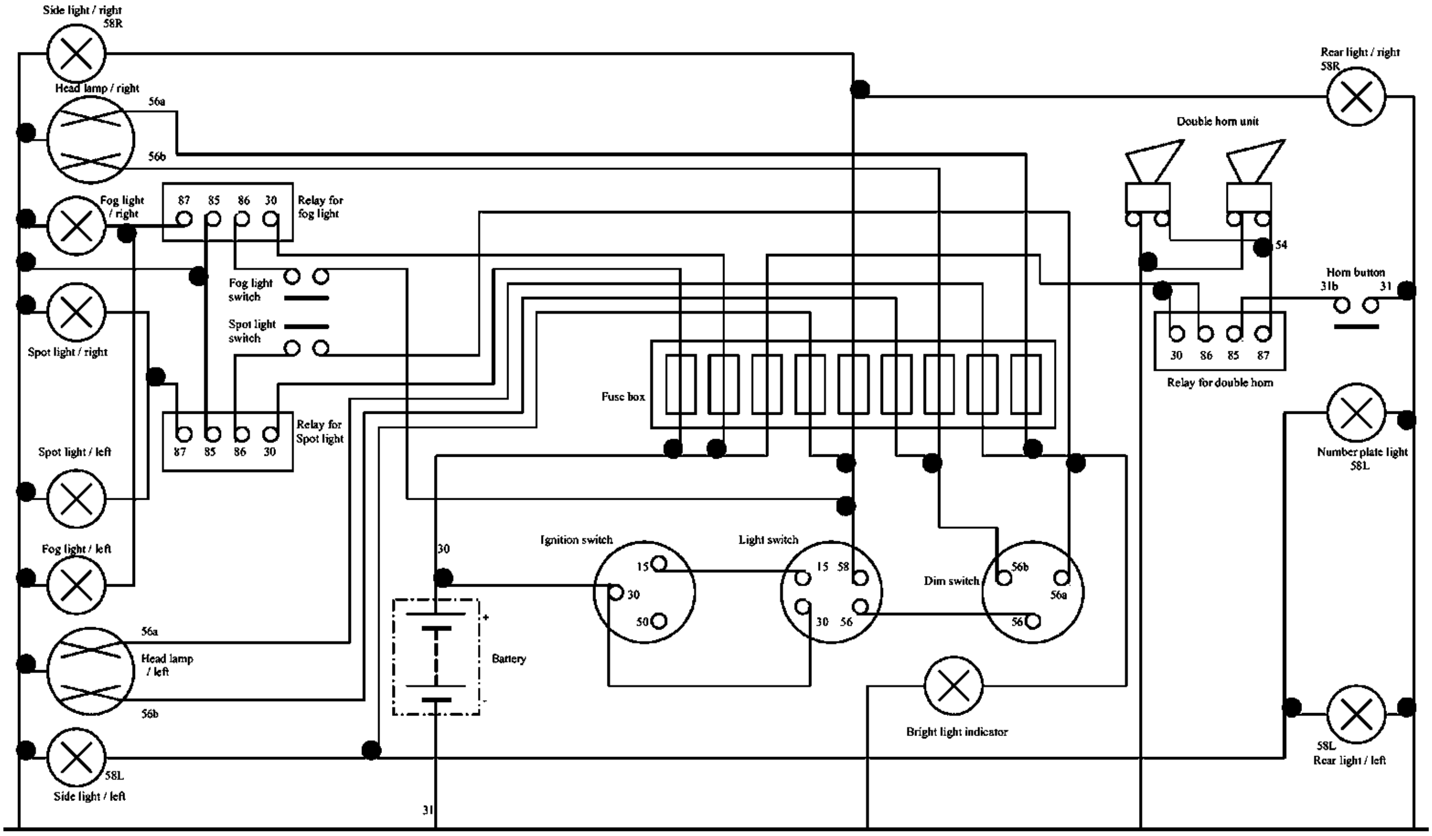
1SIDE/REAR LIGHT CIRCUIT



HEADLIGHT CIRCUIT



INDICATOR CIRCUIT AND HORN CIRCUIT



HEADLIGHT, SIDE / REAR LIGHT, SPOTLIGHT, FOGLIGHT AND DOUBLE HORN CIRCUITS AS ONE COMPLETE CIRCUIT DIAGRAM

NOTE: There are still more lighting and signal circuits. The circuits shown above are again only examples. That means we do find differences in the case of connection of circuits from the side of the manufacturers.

Further information to different electrical circuits will be given during the course it self.

Connections

As is to find in the examples of different circuits there are different possibilities to connect them:

– ***Side/rear light*** circuits are always connected over the connection number **"30"**. These lights are usable without switching on the ignition lock. Often these kind of circuits are connected **over two fuses** and so separately for right (side/rear light) and left (side/rear light) side.

In <u>countries with left traffic (like Namibia, too)</u> the *numberplate light* has to be connected together with the left rear light.

– ***Headlight*** circuit can be connected over the connection number **"30"**, **"15"** or **"15e"**. Connected over "15" means the headlight is working if the ignition lock is switched on. Connected over "15e" means in that case the ignition lock must be switched on before the headlight is working, but during the starting process it goes automatically off. Mostly the headlight is connected over two or four fuses.

Two fuses: Bright (main beam) light is separated from the dim (dip beam) light.

Four fuses: Each and every filament of the headlights is going separately over one fuse.

The *bright light indicator lamp* on the dashboard is *a must in case of the traffic rules and regulations* and always has to work by using the bright light and it has to be a *BLUEISH* colour.

– ***Indicator*** circuit is mostly connected over "15" by using one fuse. This enables us to protect the circuit included the flasher unit. The **flasher unit** (an electromagnetic or electronically switch) is responsible for flashing of the indicator lights. If **one signal lamp** for both of the sides of the indicator is indicating on the dashboard, than there is a connection of that signal lamp direct to the flasher unit "c". When there are **two signal lamps** (separately for right and left side), than these 36 are connected to the different sides of the indicator circuit it self. **The signal lamp(s) has(ve) to be green.**

– ***Spotlights*** are often connected, mostly by **using a relay**, over the connection number **"56a"** (bright light of the headlight) and also if the spotlights are switched on, they work only than when the bright lights are working. **One fuse** before the relay is normally used.

– ***Fog lights*** (by using a relay, too) can be connected over **"58"** (side/rear light) or over **"56b"** (dim light of the headlight). **One fuse** before the relay is in the circuit.

– ***Horn* circuit.** Mostly used in cars that are ***single horn* and *double horn*** units by using electromagnetic horns. Also ***pneumatic horns*** working over an electromagnetic air pump are in use. Those different circuits are connected over **"30"** or **"15"** by using **one fuse**. A double horn unit is working with a relay. That is necessary because of its higher current flow.

Cables/wires

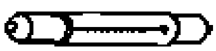
Cables are provided to ***carry the electrical energy*** from one point to another ***according to the* existing *connection*** with a minimum of energy loss. The **cable conductor is made from many strands of copper wire bunched together to form a core**. These kinds of cables that are used in motor vehicles are important because of its **higher flexibility** than a single large diameter strand. Another important aspect is, if one or more strands are damaged and fail to carry the energy, then the remaining strands will share out the additional electrical load and continue to conduct.

To carry a large current without a considerable voltage drop and without generating excessive heat, the cable must have a minimum of electrical resistance. ***The resistance is direct proportional to the length and the size of the conductor.***

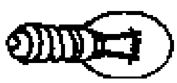
Number and diameter in mm of strands	***Size of cable in mm²***	***Maximal current rating in A***	***Voltage drop per m of conductor (12 V units)***	***Application***
14/0,30	1,0	8,75	0,0189	Side/rear lights
21/0,30	1,5	12,75	0,013	Headlights
65/0,30	4,5	35,00	0,004	Alternator circuit; Ammeter circuit
37/0,71	15,0	105,00	0,0013	Battery cable in petrol cars (sedan)

Bulbs

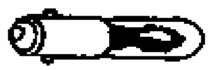
According to the different electrical units in vehicles there might be a need for 6V, 12 V or 24 V bulbs. ***The type of bulbs, their sizes and the strength of the filaments depend on what those bulbs are used for.***



a) Festoon

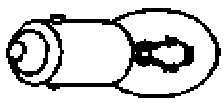


b) Miniature Edison screw

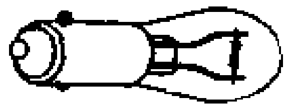


c) Miniature centre contact

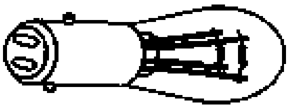
d) Capless glass

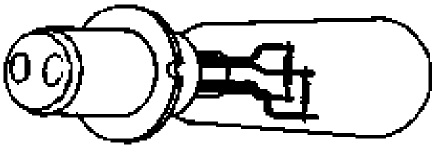


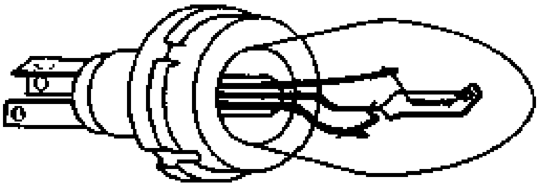
e) Single–contact small

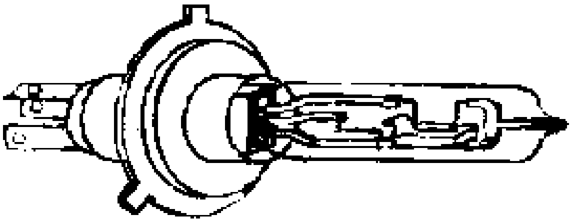


f) Single–contact small bayonet cap bayonet cap


g) Double−contact small


h) Pre−focus double filament


i) Pre−focus shielded double filament


j) Pre−focus tungsten−halogen

Fault finding

To find a fault in a circuit is it necessary to know how that circuit is connected.

In some cases ***manufacturer instructions*** may help, but an auto−electrician must be able to follow up a faultfinding process by knowing what he or she is doing.

Helpful is the **colour code** of the cables in many cars as well. Unfortunately there will not always be the right cable colour. It is possible that several cables are replaced or an additional installation was made by the use of some different coloured cables.

The ***test lamp*** is an important tool that can be used to find out where or how far the connection of a circuit is still in order. In another case we can also follow up a disconnection as well as a short circuit.

Also usable in such cases like that is a ***voltmeter***. It is important to know how to handle that specific instrument.

If a fuse is blown up in a circuit, then **there is never to replace that fuse only**. It must be clear what was the reason for the fuse to blow up. ***The fault is concrete to find before that circuit is properly in order again.***

During the course we will follow up what different main faults may occur and how to go about fault finding.

Lighting systems/ Signal systems

Why we do speak about lighting and signal systems?

By the use of a ***lighting system*** we want to ensure that with these different types of lighting circuits ***we can see*** especially at night where to drive and we must 39 as well ***we are seen*** by the other traffic members.

Such circuits like **side/rear light** included number plate light and dashboard light**, headlight**, **fog light**, **fog rear light**, **spotlight** belong to the lighting system.

Examples for the ***signal system*** are the circuits of the **horn**, **indicator**, **hazard**, **stoplight**, special warning lights (i. e. for the police, vehicles with abnormal loads). Of course, a stoplight is a light as well and you may think now it belongs to the lighting system as well. But in that case is to realise ***a signal***, even it is a light, ***gives to the other traffic members a special message*** and this is the first priority of a signal.

There is only one unit what we can accept to belong to both of the systems. The **reverse light** let us see what is going on behind the car if we want to drive backwards and it is a message for the others that car will drive backwards.

Technical drawing of circuit diagrams

Before we may start drawing circuit diagrams we have to ensure that all the parts of the *drawing equipment* are *complete and in order*.

– ***Handle the drawing paper in a way to avoid dirtiness.***

– ***Work with cleaned hands.***

– **Use *more than one pencil* for the different strength of the lines.**

Hardness of pencils:

6B; 5B; 4B = very soft,
2B; HB = soft,
H:F = average,
2H; 3H = fairly hard.

– ***Rubber, rubber shield, compass and extension, protractor, drawing set squares, drawing square (T–square) and scale ruler* are the further parts of equipment to ensure a proper drawing result.**

Construction line:

Outline:

Dotted line:

Center line:

Dimension line:

And of course all your drawing equipment has to be clean and functional in order.

Using more than one pencil are important for the *different strength of lines*. Construction–lines i. e. should be very thin to make it possible removing them easily if they disturb the circuit. But these lines can also be inside a finalised circuit when you were working very careful and those lines are not disturbing the circuit and its connections.

Negative ground–lines and cable connection direct from the battery can be made thicker than the normal used dimension lines for all the other wire connections.

***All the wires should be drawn in the same strength.* There is a difference allowed for the ground line and for the direct connection of/from the battery; they can be made stronger.**

Projection line:

Arrows:

Before you really start to draw circuit diagrams, find out which components have to be included.

You should follow up what components do you need for each and every circuit and think about to make first a list of all the different electrical circuits include the components you plan (and of course, it must be right). That means you really have to **ensure all the switches, fuses, lamps, relays, gauges and other accessories are included**.

On the other hand, there is also to **clear up on what position the electrical parts are to place** in the drawing by **finding a way that the wire connections are relatively easy to follow up and by avoiding unnecessary crossing of wires**. Make sure for your self, to draw circuit diagrams is not a drawing exercise only; all your **connections must be right** and you have to think about such things as:

- **where in a circuit is to bring in a switch and other equipment by thinking to bring the wire connection into a good position and by having enough space for all the wires in the diagram;**

- **what position is important for a fuse and especially for a fuse box by drawing more complicated circuits with many fuse connections;**

- **how is the right connection of a relay to be done and what other demand is may be given to follow up several details of a relay, a switch, a electric motor, a coil;**

Find out what you have really to do:

- **what kind of circuit you have to draw?**

- **do you need to include the battery, the ignition system or another not named circuit (or a part of a circuit) to complete the circuit exercise?**

- **do you have to write down the terminal numbers and/or the names of the electric parts?**

- **can you really be sure (if you got a paper with shown electrical parts) all the necessary parts are already prepared on that drawing paper?**

It is important to read careful the demands out of the given exercise. One example in this case:

A) Draw included the battery and the ignition lock an indicator circuit by connection of two signal indicator lamps for the dashboard.

B) Draw an indicator circuit starting by a connection point "15" in connection with one signal indicator lamp for the motor vehicle and one for the trailer.

Did you find out the differences between A) and B)?

Try to answer this question by your self, find a possible result and than discuss your result with the instructor.

And please, always you have to **draw on a *concentrate* way**. Mistakes can be done fast and such things are often difficult to clean up again.

If you prepared a list for all the necessary parts than use that list to mark step by step what is already taken over in your drawing. **If you made a free hand sketch** first than ensure that all of them is properly included and connected there and after you are sure follow up that sketch by working out the final drawing.

Note (AND NEVER FORGET!)

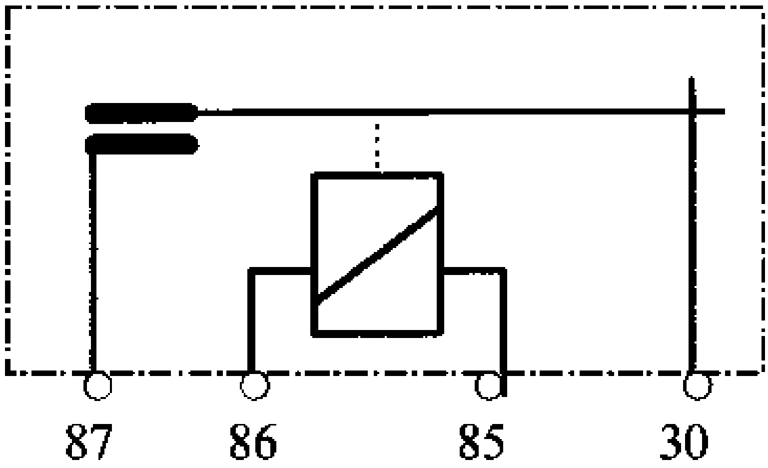
In a Technical Drawing is **never allowed**:

➡ to draw a line free hand!
➡ to write or draw something into the drawing by using a pen!
➡ to write numbers and letters without to take care about the equal size and direction!

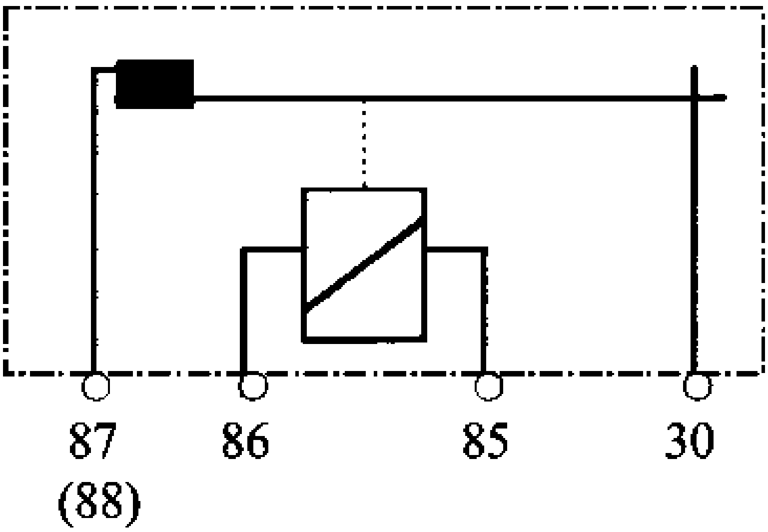
Basics of the function of relays (additional theme)

Kinds and function of relays

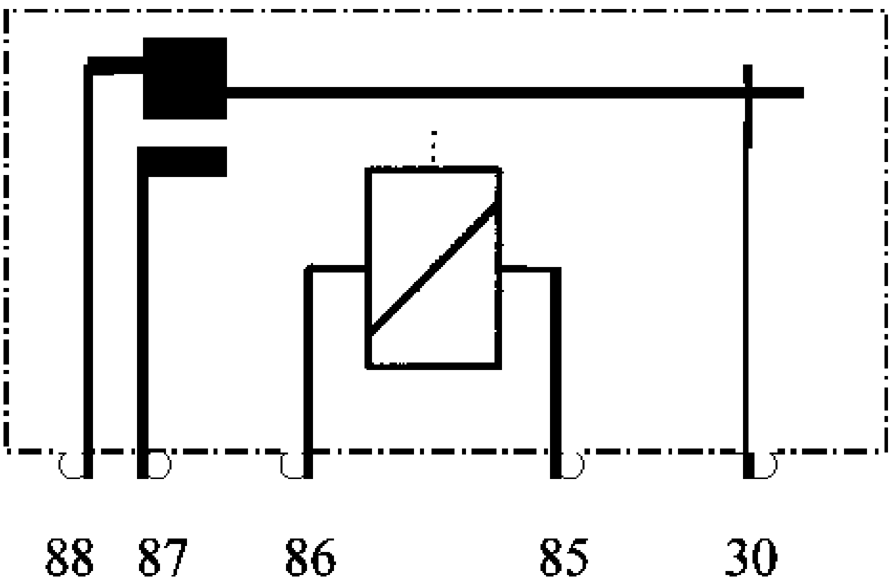
Basically we do know three different kinds of relays:



1. Normally open relay



2. Normally closed relay



3. Change over relay

How a relay works?

Let's find out by explaining the ***function of a normally open relay.***

The ***main parts of a relay*** are the ***winding***, the ***iron core***, the ***movable arm*** in top of the iron core, the ***contact points*** and the ***terminals***.

By using a relay we have to realise there are "***two internal circuits***" in use: the "***steering circuit***" between the terminals 85 and 86 and the "***main circuit***" between the terminals 30 and 87.

By ***connecting the terminal "85" to the ground and the terminal "86" to the positive***, there are a so–called ***steering circuit*** that gets current. In addition: **the winding around the iron core get energised**. If this happens then **the iron core is building up a magnetic field**. Now through that **the movable arm in the top of it (between the terminals "30" – from positive and "87" – to the consumer*)* pulls downwards and the contact points will closed**. By closing the contact points the so–called ***main circuit*** is closed.

The ***reason to use a relay*** is given **because of a higher current flow** for example in double horn, fog light or spotlight circuits.

A **stronger current follows up on a shorter way by using a steering and a main circuit that does not have such long cables** is **economically useful** by less used stronger cable and the further usability of the normal switches with the small contact points. There is also a ***safety aspect*** in the case of shorter ways for several main circuits with higher current flow and by saving the small contact points to get fast damaged because that material is to soft for the higher current flow.

As it is explained above **there is no possibility for using a permanent magnet in a relay**. It must be an electromagnet (by using a winding and an iron core) to switch on and off that relay.

Auto−Electric Basic Technology − Part 2

Table of Contents

Auto−Electric Basic Technology − Part 2 1
1. Fundamentals of magnetism 1
Effects of electric current 1
Magnetism 3
Electromagnetism 4
Magnetic conductivity 5
Solenoid 5
2. Function of electromagnetic components 5
Kinds and function of relays 6
Further electromagnetic components 8
3. Starting systems 8
Principles of electric motors 8
Starter motor principles 10
Practical starter motors 11
Starter drives 13
Inertia drive starter motor 14
Single−stage sliding gear starter motor 14
Pre−engaged starter motor 15
Faultfinding and repair of starter motors 18
4. Charging systems 22
Fundamentals 22
Electromagnetic induction 23
DC−generator 25
Regulator types for DC−generators 28
DC−generator failures 32
Routine checks 33
Generator terminology 33
Permanent magnet generators 34
Alternator/AC−generator 34
Principle of voltage regulation 43
Types of regulators 44
System inspection and checks 48

Auto–Electric Basic Technology – Part 2

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Technische Zusammenarbeit (GTZ) GmbH

AUTO – ELECTRIC/BASIC – TECHNOLOGY

Special edition in the field of Vocational Training in Namibia

1. Fundamentals of magnetism

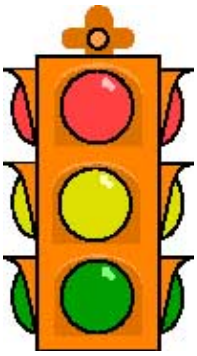
Effects of electric current

There are **four effects of electricity** that a flow of current will produce:

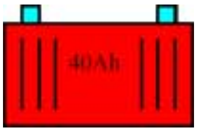
1. **Heating effect:** The friction created by the movement of the electrons causes a generation of heat in the material known as resistive heating. The resistive heating is made use of in

elements of electric stoves etc.

2. **Lighting effect:** By passing of an electric current through thin wires of metal with a high melting point (i. e. wolfram, tungsten) those wires heat up so strongly that they begin to glow. In this state they serve as a source of light. The higher the temperature, the greater the light yields. In bulbs the wires are placed in a vacuum or in a protective gas. So the wire cannot oxidise. A current flow trough gas can also be used to produce light as a result of the collisions between the charged gas particles (fluorescent tubes)

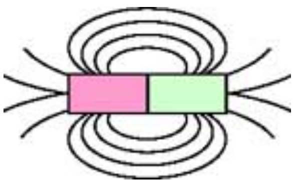


3. **Chemical effect:** The passage of a current can split up the molecules in liquids and solids, a process known as electrolysis. This forms the basis to produce an e.m.f. (electromotive force or voltage) by a battery.



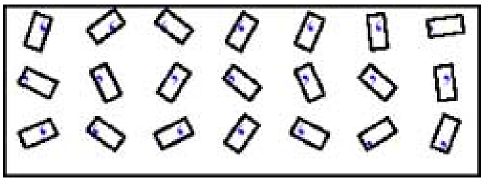
4. **Magnetic effect:** The current flow in a conductor or coil sets a magnetic field flux or force around it which is more pronounced when an iron core is present. The strength of that force (symbol: F) depends upon the value of the current and the number of turns on the coil/winding.

F = ampere–turns (A.T.)

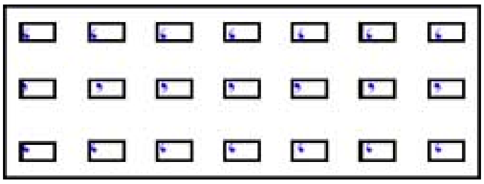


Magnetism is, like electricity as well, still a mystery. We know many laws governing its behaviour and have applied it in the automotive field but no one knows what magnetism really is.

The effects of magnetism were first discovered when it was found that pieces of iron core and also other pieces of iron on several places of the earth attract each other.



Not magnetised iron bar



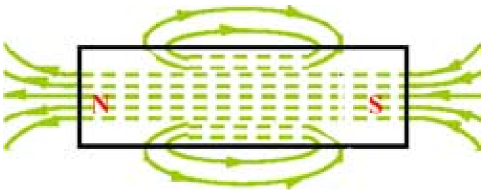
Magnetised iron bar

In the automotive needs of magnetism there are used **permanent magnets** as well as **electromagnets**, depending what we do want to reach with that different types of magnets.

Magnetism

Magnetism we do find in nature mostly as permanent magnets. Magnets attract iron filings (and nickel & cobalt). In the vicinity of the magnet there is a magnetic field with a definite direction, which is strongest at the ends of the magnet.

See below the field lines of permanent magnet bar:

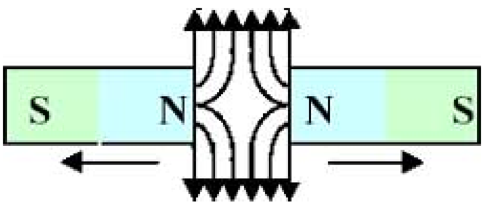


Field lines of a bar magnet

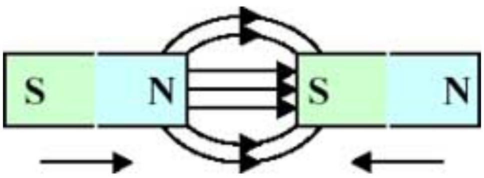
If a bar magnet is positioned on a pointed pivot so that it can move freely, it aligns it self in a north–south direction. The pole–pointing north (of the geographical pole of the earth) is the North Pole of the magnet; the opposite is the South Pole.

The field lines are imaginary plots, which indicate the direction of the magnetic force. In the space surrounding it (air or non–magnetic material) they run from the north to the South Pole. Inside the magnet, they run from the South Pole to the North Pole. The field lines are therefore closed (continuous).

If a magnet gets divided or broken, in **every part will be obtained a north and a South Pole**.



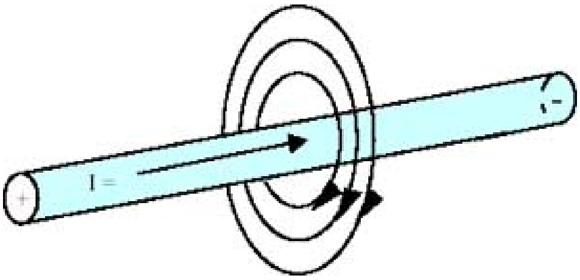
Field lines at like poles



Field lines at unlike poles

Electromagnetism

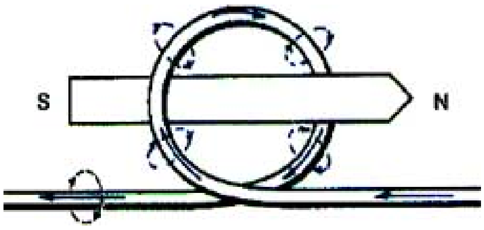
If trough a conductor a current flows then **it is surrounded by a magnetic field** in the form of concentric circles.



Magnetic field of a conductor with current flowing through it

If a **conductor** is **wound into a coil**, the magnetic field lines are concentrated together inside this coil. And there inside the field lines of the individual turn of the coil are added together.

If a **conductor** is **formed into a loop** the lines of force on the outside of the loop spread out into space.



Magnetic field around a loop

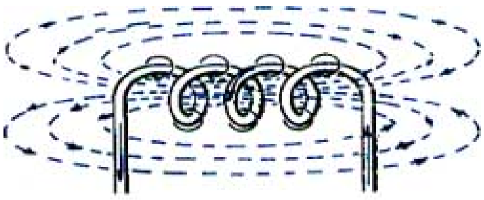
Lines on the inside of the loop are confined and crowded together. This increases the **density** of lines **of force** in that area and a **much greater effect is produced with the same amount of current.**

The total number of coil field lines refers to the magnetic force depending on the current intensity and the number of windings. That means, too, the same magnetic effect can be reached by

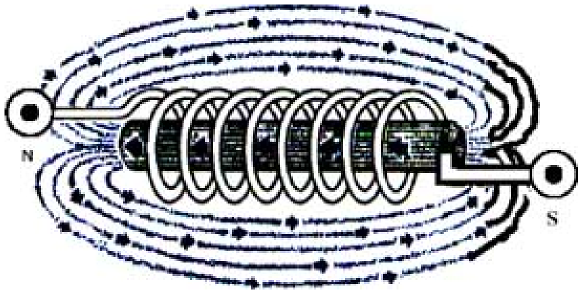
– a low current strength and a large number of windings or by
– a high current strength and a small number of windings.

By increasing the number of loops, the magnetic field will be greatly increased.

By winding the loops or a coil on a soft iron core, the field is further intensified. That means the magnetism of this electromagnet increases. On that way there is a possibility to build different electromagnets by using different strength of the magnetic fields.

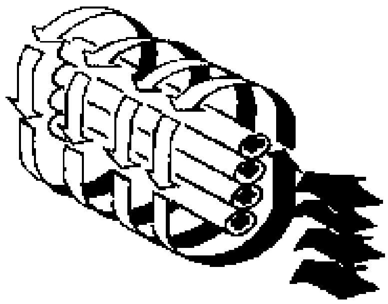


Magnetic field around a coil



Strengthened magnetic field of a coil wound around a core of soft iron

When **several more current–carrying conductors are placed side by side, the lines of magnetic force join and surround all of the conductors.**



Current–carrying conductors placed side by side

This kind of magnetic pattern is obtained i.e. in coils of the solenoid of starter motors, of the ignition coil etc.

Magnetic conductivity

The **conductivity of air for the lines of force is defined by Kelvin**. "**It is the ease with which lines of force may be established in any medium as compared with a vacuum**".

When a soft iron core is inserted in a coil to form a true electromagnet, the lines of force will be increased several hundred times. That means there are more lines of force created. Field coils in starter motors, regulator–windings on iron–cores and ignition coils are using all the same principle.

Solenoid

A solenoid is a tubular coil of wire. It is designed to produce a magnetic field. Mostly the solenoid includes an iron core that is free to move in the tubular coil. The **movement** of such kind **of an iron core is used** to operate in the case **of mechanical work** i.e. as a switch. If a solenoid is used to close/open the contact points of an electrical switch then is it called an electromagnetic switch.

> **NOTE:** The South Pole of the iron core is adjacent to the North Pole of the coil. The polarity of a **movable iron core** is induced by the lines of force from the coil. The poles of the coil and the core are in opposite polarity and **so there is an attraction that draws the movable core into the centre of the coil whenever current flows through the coil**.

2. Function of electromagnetic components

Out of the last chapter we do know already that in the automotive field is given a far use of electromagnetic components. In this chapter, you get not the information to all the possible components. The function of such parts/components like starter motors included starter solenoid or like generators and alternators included the types of electromagnetic regulators will be handled in the following chapters.

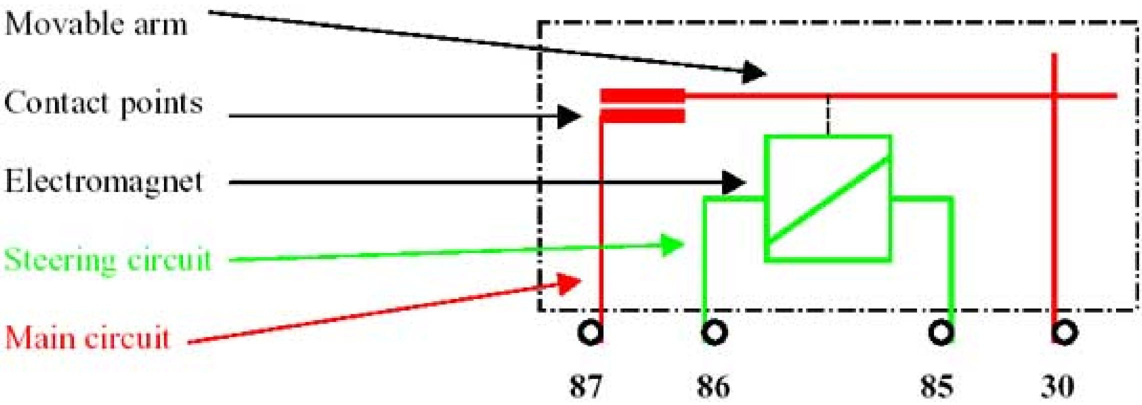
Kinds and function of relays

Now let us follow up three different kinds of relays:

The **main parts of a relay** are the **winding**, the **iron core**, the **contact points** and the **terminals**.

1. Normally open relay

As you can see in the sketch below the contact points **of this relay** are open **as long as** the electromagnet is not energized**.**



How works such kind of a relay?

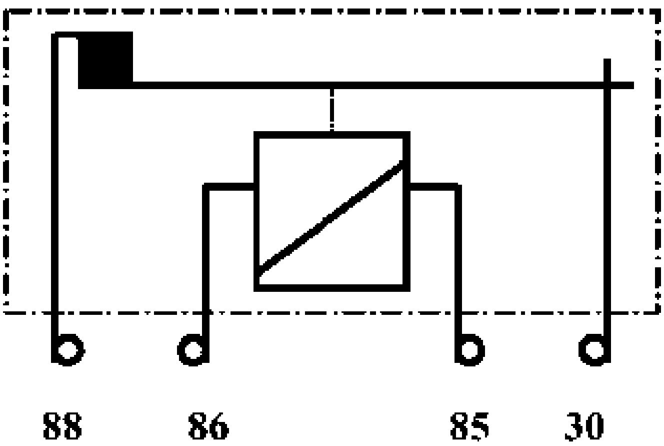
Between the terminal numbers “85” and “86” there is placed the electromagnet (winding & soft iron core). This part of the relay we may name as steering circuit. That means, if we connect one of these terminals to the ground and the other one to the positive a current flow through the winding and build up a magnetic field. The strength of the built up magnetic field develops higher by the soft iron core and is in the end strong enough to pull the movable arm with one contact point downwards by making contact with the other contact point. This is possible because the magnetic power is now stronger as the mechanical power of the spring what holds the movable arm normally in the top. When the contact points are closed the main circuit is closed as well.

Now the current from the side of the terminal “30” flows over the contact points to the terminal “87” and from there to the connected consumer.

> **Note**: if there is not a current flow through the steering circuit and **the contact points are not closed anymore** then the main circuit opens again and so **the connected consumer is switched off**.

2. Normally closed relay

The contact points **of the relay** are closed **as long as** the electromagnet isn’t energized**.**

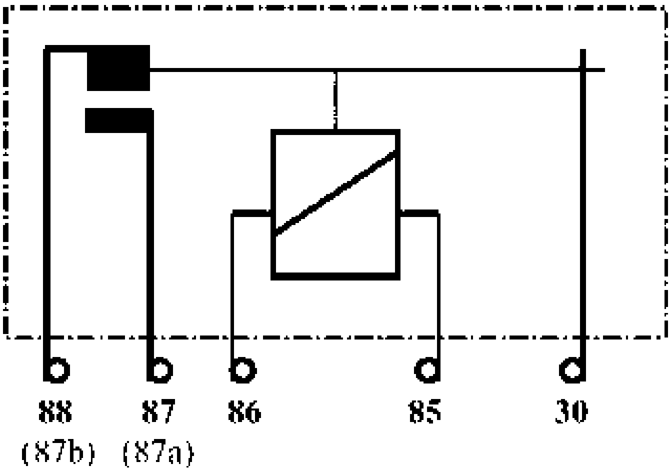


As you can see in the sketch above by the situation of closed contact points the so named main circuit of the relay between the terminals “30” and “87” is closed as well. That means when the electromagnet of this kind of relay isn’t energised the consumer connected to the terminal “87” works.

First by energising of the electromagnet (steering circuit) and so pulling down the movable arm the main circuit get switched off and the consumer doesn’t work anymore.

3. Change over relay

By using this third type of relay there is always one contact point (“87” or “88”) in closed position with the terminal “30”. By the example of the sketch below the contact point of the terminal “30” is in connection with the upper contact “88” as long as the steering circuit isn’t energised. **If the electromagnet is switched on the connection changes over to make contact between “30” and lower the contact point** (in the example of the sketch it is the terminal “87”).



Such a relay can be used for example to connect spot light and fog light over it to change automatically in connection with the dim light/bright light.

Why there is a need to use relays?

The reason to use in several cases a relay is given by a higher current flow in some circuits like for double horn, spotlight, fog light or for the headlight.

But practically you will find always again i. e. headlight circuits in motor vehicles without using a relay.

It is to realise that this depends on the kind of installation for some circuits in a motor vehicle include the use of different parts like switches.

By using a relay the needed stronger current follows up a shorter way (main circuit over the relay). For the steering circuit to the relay (by a small amount of the steering current) is it possible to use a much thinner cable. By looking to the **safety aspect** shorter ways of the high current flow can be created and about this is to think as well by the installation through the metal body of a car. The use of original installed switches is a further point by a later installation of a circuit and this is an **economically aspect**. For example a change from a single horn to a double horn circuit can lead to a problem by using the original horn button. If the contact points of that button are to weak/to soft the points can fast be damaged and on the other hand installing another horn button can be more expensive as the connection of a relay.

Final remark to the relays:

There is never a possibility to use inside a relay a permanent magnet. It have always to be an electromagnet (by the use of a winding and an iron core) to ensure the relay can be switched on and/or off.

Further electromagnetic components

Up to now there were handled relays only but we do have much more other electromagnetic components in motor vehicles in use.

Here let's mention only some of the other electromagnetic components because they get their necessary attention by following up that several topics in the later modules.

Solenoid:

It is a special kind of a relay used in connection with the starter motor by protection of the ignition lock and as link between the battery and the starter motor.

Electromagnetic regulator:

This types of electromagnetic components are used for the regulation of the voltage/current output of generators and alternators to ensure by speeding up of the engine that the voltage/current increases not to high and damages other electrical components.

The regulator is a very important component to ensure that the recharging process goes on properly and the battery remains always in good condition

Flasher unit:

The flasher unit is used in the indicator circuit and is responsible to let the switched on indicator lamps (left or right side) and if necessary all the indicator lamps by the use of the hazard unit flash.

Ignition coil:

Responsible to build up the high–tension voltage needed for developing of strong sparks for the ignition system.

Electric motors:

Such kind of motors, like wiper motor or washer motor are used in cars in different types. They can be built with permanent magnet (for the stator or the rotor) as well as with electromagnets. In the end the basic principles are always the same by using the magnetic force to let that different types of electric motors rotate in the case of the necessary target.

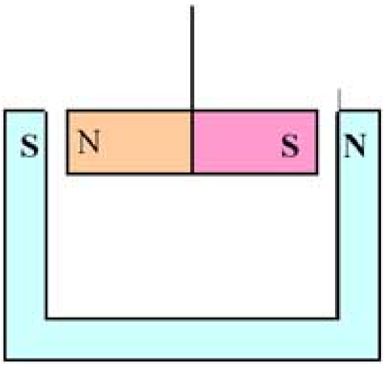
3. Starting systems

Principles of electric motors

In the first step we have to find out how generally an electric motor works. Mainly the work of an electric motor is based on magnetic force.

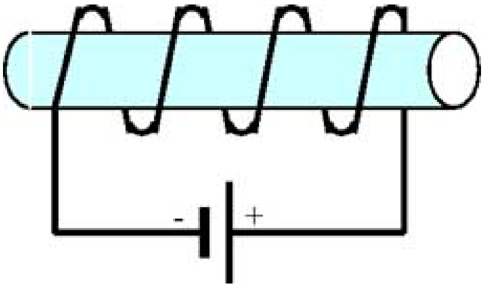
But let's follow up step by step what is going on.

An important fact about a magnet is its pole seeking. If we bring a bar magnet free movable into the magnetic field of a horseshoe magnet, the bar magnet will swing to line up with its North Pole pointing to the horseshoe's South Pole. So the South Pole of the bar magnet will point to the opposite of the horseshoe magnet. That means **like poles repel**, **unlike poles attract – a basic fact for the work of an electric motor** but the first step only.



Magnets are pole seeking when free to

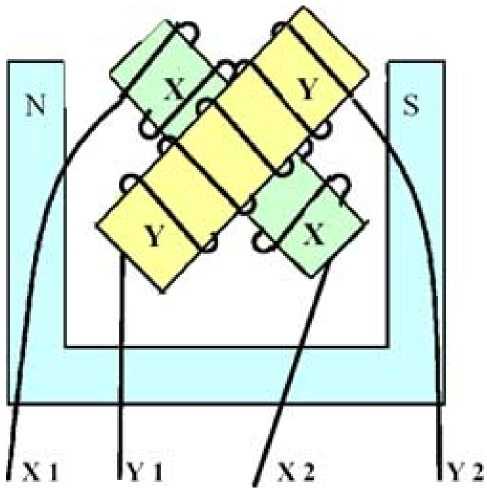
The next step is to take a short iron bar what is nonmagnetic. Around this iron bar we wind a few turns of a wire and the ends of the wire we do connect to a battery. In fact **we do have now an electromagnet**. An electromagnet works as long as it is connected to the electrical source. If we bring this (switched on) electromagnet between the jaws of a horseshoe magnet than the magnetised bar will line up north to south and south to north.



Basic electromagnet

Now, here is the **most important** part: **reverse the battery connections** and the **polarity will also reverse**. The bar will swing round into opposite position, but it may swing clockwise or anti–clockwise.

To ensure that the electromagnet swings always in the same direction there is a need to take another small bar, form a cross with the first piece and wind the same number of turns of wire on each bar. So we do have now four loose ends of wires.



1. **If we connect the wires (X 1 and X 2) of the bar "X" to the battery by suspending the cross between the jaws of a horseshoe magnet again than the cross will swing round and the bar with the connected wire ends will line up with the horseshoe poles.**

2. **If we disconnect those wires from the battery and we connect the wires (Y 1 and Y 2) of the other electromagnet bar "Y" than this one will now line up with its ends to the horseshoe poles.**

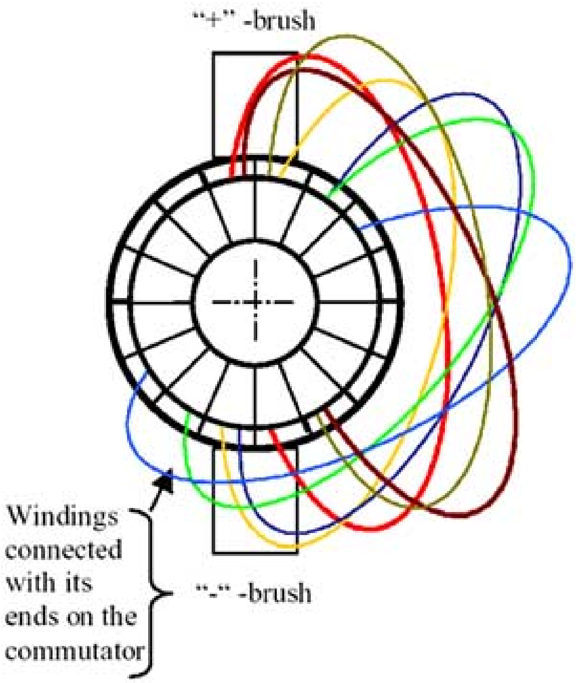
3. **Now we go back to the first pair of wires (X 1 and X 2) and** reconnect them but in reverse **than we will realise the** cross swings further in the same direction **as before.**

This is already a simple kind of an electric motor!

What is to do now? We have to bring the ends of the wounded wires together in a kind of a commutator (as shown on the left) and by the use of two brushes (+ and –) that simple kind of electric motor will rotate.

By using **more windings** with wire ends around an iron core and by the use of **stronger material** for the windings **the magnetic force gets strengthened**. By connecting the windings around a commutator on all its different segments we ensure that the rotating movement goes on in a straight way in one direction. And of course, all the windings must be connected like already explained.

The segments of the commutator are insulated to each other. The necessary "positive" and "negative" connections for the, now so–called, armature is going over at least two brushes. By rotation of our simple armature the brushes are moving over the commutator. To avoid irritation of the direction of the rotating movement, the windings (wire ends) of the armature of an electric motor are not by direct 180^0 connected as you can see on the sketch on the left as well.



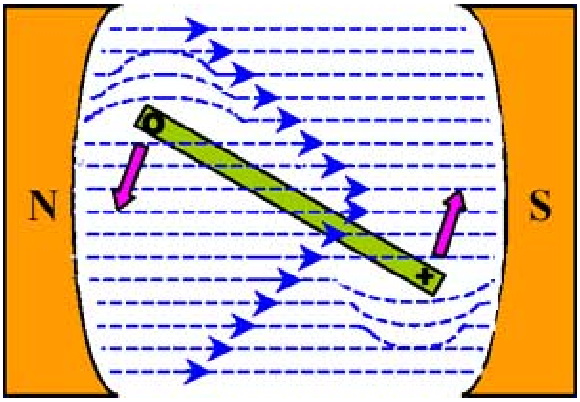
Front sight of a commutator include examples of connected windings

Starter motor principles

A starter motor is –this we do know now– an electric motor and operates on the principle that **a current–carrying conductor moves inside a magnetic field**.

The direction of movement of all these conductors wound on the armature goes on from a strong magnetic field to a weaker magnetic field. So we get a **circular magnetic field**. This leads to weaken and to cancel–out the lines of magnetic field force from the side of the exciter windings with its pole shoes.

The effect is, there is a **stronger magnetism above the current–carrying conductors** then below them and therefore **this leads to a downward thrust**. The **downward thrust** on one side **and** the **upward thrust** on the other side **of every current carrying winding** of the armature in a starter motor **causes the rotation**.



Field force lines react to distortion of the magnetic field

(left: downward thrust/right: upward thrust)

The rotation will continue because each time the armature windings pass the vertical position and over the commutator (together with the armature rotating) the armature windings are automatically so connected that the current continues to flow away from the right−hand toward the left−hand winding. And as mentioned already the winding ends of the armature windings are so connected that it is ensured that the rotation goes on in one direction.

Practical starter motors

Although we do have now the basic motor design as above, it needs a great deal to build a real starter motor.

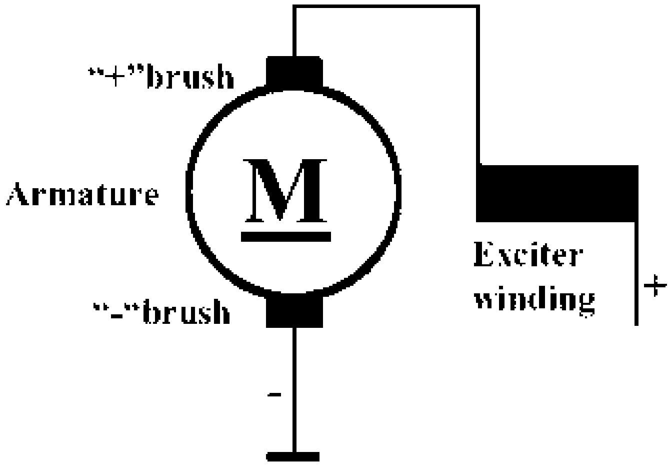
A starter motor must be able to turn a cold engine fast enough to get it started and so it must be able to rotate with an amount of current up to 350 amps.

The horseshoe magnet is changed for a starter motor into **pole shoes with strong windings** around them inside the housing. The **commutator is composed of separate copper bars** by the use of **insulation material between them** and the amount of windings is now much higher. Modern starter motors have four brushes and four magnetic pole pieces (shoes) and the armature runs now in bearings and as well as often in bushes. There are also possibilities of **different types of commutator**. Often we can realise on the armature is existing a **drum commutator** but it can be as well a **face** (disc) **commutator**.

How ever, **all these are not affecting the basics; it is a design feature to give extra power for the work what the starter motor is supposed to do**.

Starter motors are **DC series−wound motors** and so the exciter windings (field windings) and the armature windings are **arranged in series**.

The current consumption of a starter motor is very high. The range of current may set up **between 350A and 2000A**. Therefore the **windings** are **relatively few but thick** strands of copper wire. In these kind of motors the **current strength** at the greatest rate at the time the starter motor begins to rotate.



DC Series–wound motor

For that there are **three reasons**:

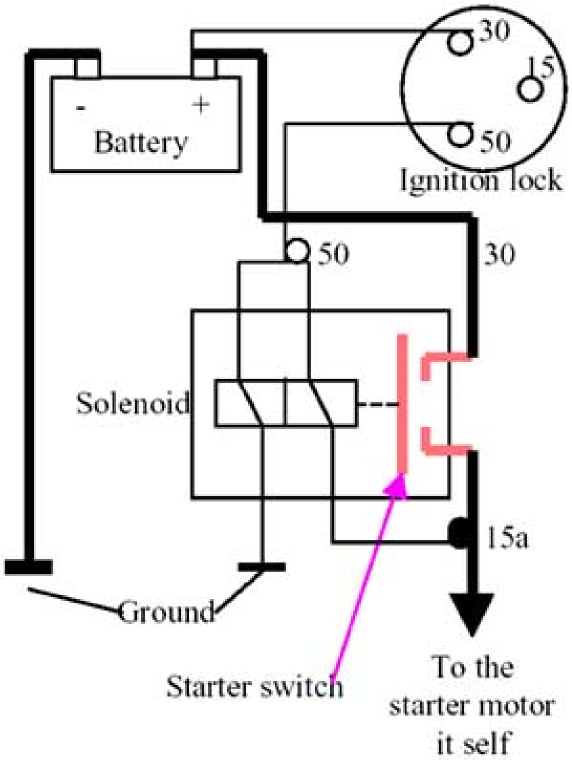
– at the time the starter motor begins to rotate the **torque of the motor** has the highest rate and get reduced after;

– when the motor torque gets reduced the speed builds up and the current level falls in the case of **self induction of current** (because of rotation of the armature with its windings in the magnetic field of the field windings);

– beginning the starting process the **friction of the engine** is at the highest rate as well and gets reduced afterwards.

Another part of the starter motor is also essential to look for although it is not direct a part of the motor itself: **the solenoid**.

Because of the enormously heavy current needed to turn the car's engine, by trying to let it pass through the ignition lock would create a big problem. That means, the flowing strong current during the starting process would result in a strong burning inside the ignition lock because that current flow let melt the lock over the connected contact points. **The solenoid is the link between the heavy cable from the battery** and from there **to the starter motor**. **Over the ignition lock flows** during the starting process **a small amount of current only to energise the electromagnet** of the solenoid which is responsible for closing the heavy–duty switch inside.



You have to realise now:

The purpose of the starting system is to use electricity from the battery for the rotation of an electric motor (starter motor) to turn over the engine during the starting process.

The starting system consists of:

– the **battery**,
– a **starter motor**,
– a **solenoid of the starter motor**,
– an **ignition switch** and
– related **electrical wires**.

Starter drives

We can operate now with a powerful motor for the starting process and we do have a method of switching it. But still there is a need to couple it to the engine. In this case we do use a starter drive.

There are **four different main types of starter drives** generally in use:

– the **inertia drive** (shock drive),
– the **pre–engaged drive**,
– the **single–stage sliding gear drive** and
– the **sliding–armature drive**.

In all of the cases, the flywheel of the engine in which they are used is fitted with a toothed ring around the circumference. The **pinion** of the different types **of starter motors** is mostly **made from steel** and **has a special pattern of teeth**.

The **pinion cannot rigidly be attached to the armature shaft** of the starter motor **because** the armature **would be driven at a too high speed** when the engine had started and **so the starter motor would be damaged**. To avoid such kind problems there are may be used

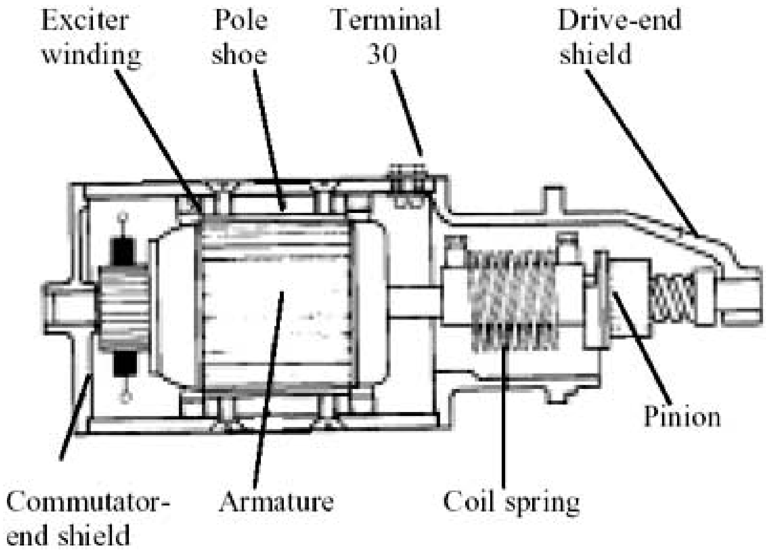
– a **roller–type overrunning clutch** or
– a **multi–plate clutch**.

During the operation of the starter motor the used type of **clutch interrupts the power flow** between the pinion and the armature shaft when the engine begins to turn faster then the starter motor. By stopping the starting process the pinion will withdraw from the flywheel under the use of one of the above mentioned four types of starter drives.

Inertia drive starter motor

Inertia drive starter motors use the rapidly accelerated energy in the armature. This goes on before the engagement of the pinion takes place.

The starter motors pinion is carried by a steeply pitched screw thread on the armature shaft. This kind of starter motor works **without a solenoid** and therefore the starter switch has strong contact points (operated by hand or by foot) to connect the current flow from the battery to the starter. **When the starter motor operates and runs rapidly up to full speed; the inertia drive** (bendix drive) **is forced by action of the thread on the armature shaft.** So the drive get propelled in the direction of the ring gear into engagement with the flywheel. A **damping spring is arranged** between shaft and pinion hub **to ensure that the power flow to the flywheel starts not too violently**.



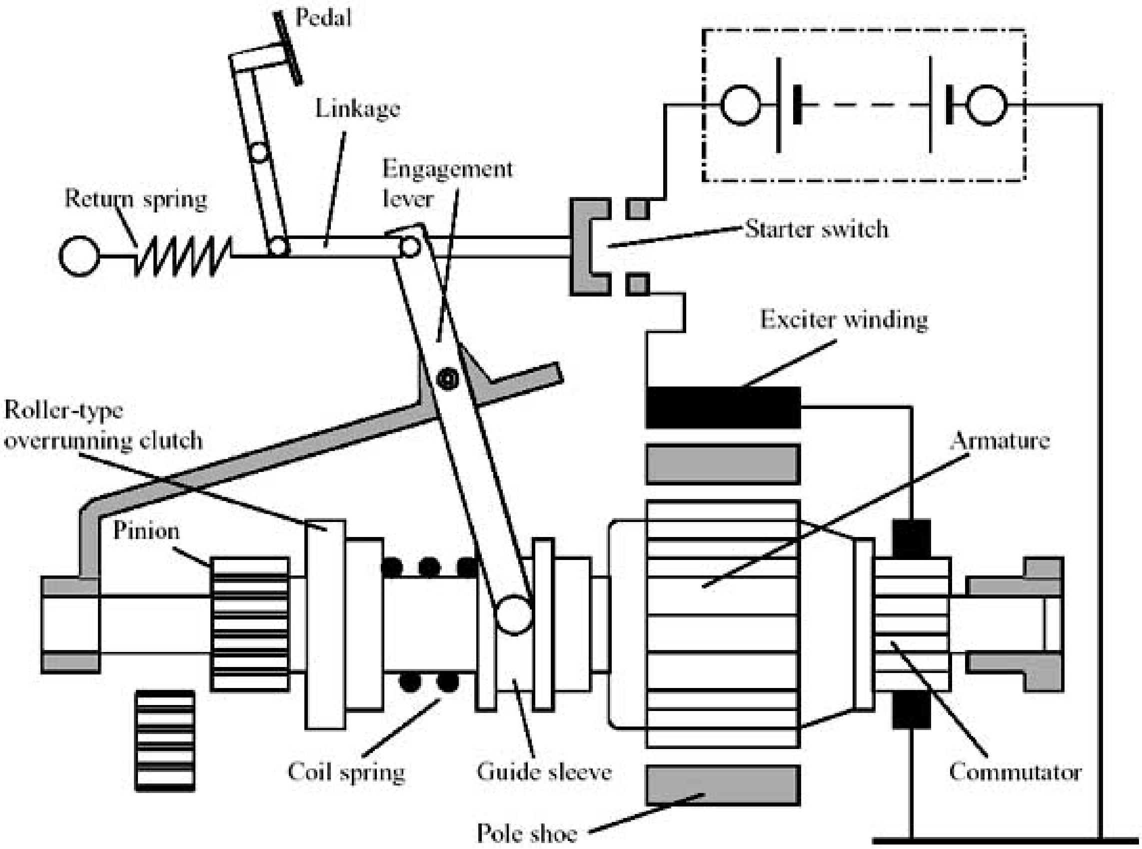
After engine has started and runs faster then the engaged pinion get ejected from the flywheel by moving backwards on the spiral thread.

Because of the violent engagement of the pinion into the flywheel damages can easy appear. That is the reason to use in modern cars instead of these types the **pre−engaged starter motors**.

Single−stage sliding gear starter motor

The mechanical operated starter switch is often operated by foot.

On the armature shaft are existing **longitudinal grooves** where the **pinion** is located and **it may move axially**. Mostly the pinion gets engaged with the flywheel by the use of a lever. Only then **when the pinion is fully engaged into the flywheel the starter switch gets closed** and therefore **the starter motor starts to rotate**. The pre−loaded engagement spring behind pinion and clutch takes responsibility for fast pinion engages in the flywheel.



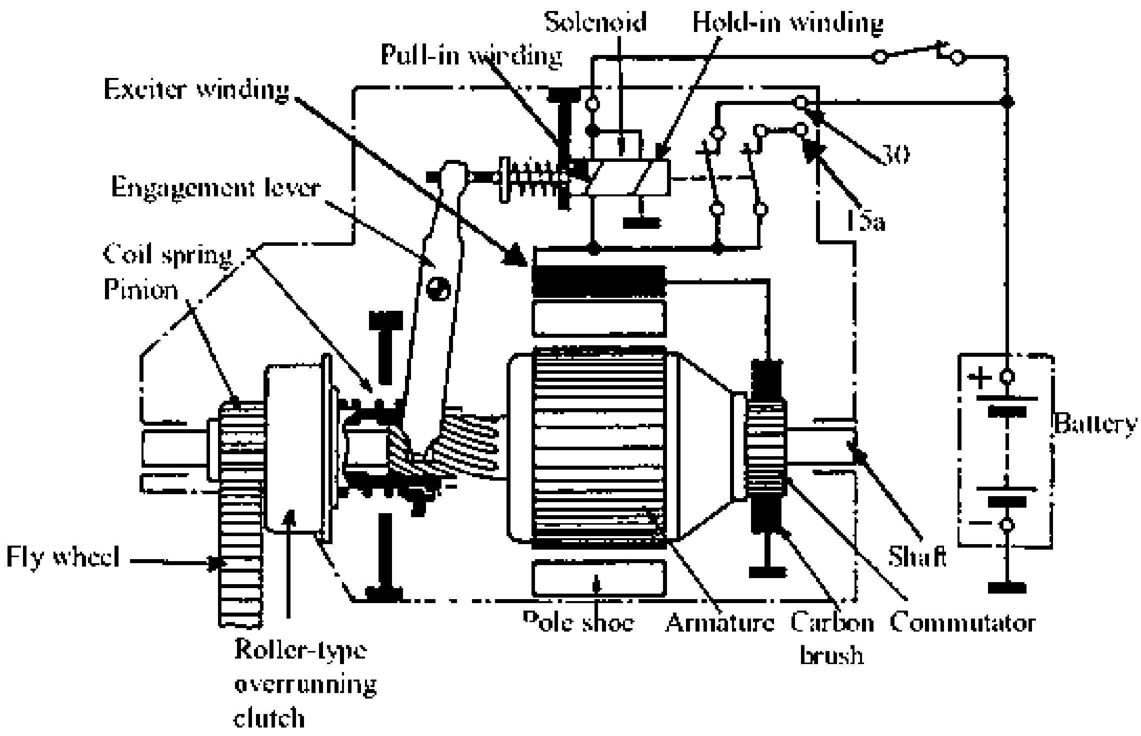
Remark: See explanation of the roller−type−overrunning clutch.

Pre−engaged starter motor

Like the inertia drive the pre−engaged starter motor has a **thread on the armature shaft** for the engagement of the pinion into the flywheel.

The **driving assembly moves forwards** against the spring **by the help of an engagement lever/fork**. Energising the solenoid (ignition lock in start position) and therefore building up a magnetic field pulls the shaft of the electromagnetic starter switch inside. **The steeply pitched thread causes a slow rotation of the pinion and let its teeth easy engage between the tooth gaps of the flywheel.** If the teeth of the pinion cannot mesh between those of the flywheel the spring of the driving assembly is compressed. This will be the case until the armature starts slightly to turn and finalise the engagement (the starter switch inside the solenoid closes and now the armature of the starter motor is able to rotate). **The starter motor builds up its whole electric power and so the starting process goes on.**

After the engine is running faster then the starter motor, the still engaged **pinion runs freely in the flywheel**. **The roller−type−overrunning clutch avoids damages** of the starter motor **due to a higher speed** as long as the pinion isn't disengaged by the release of the ignition lock.



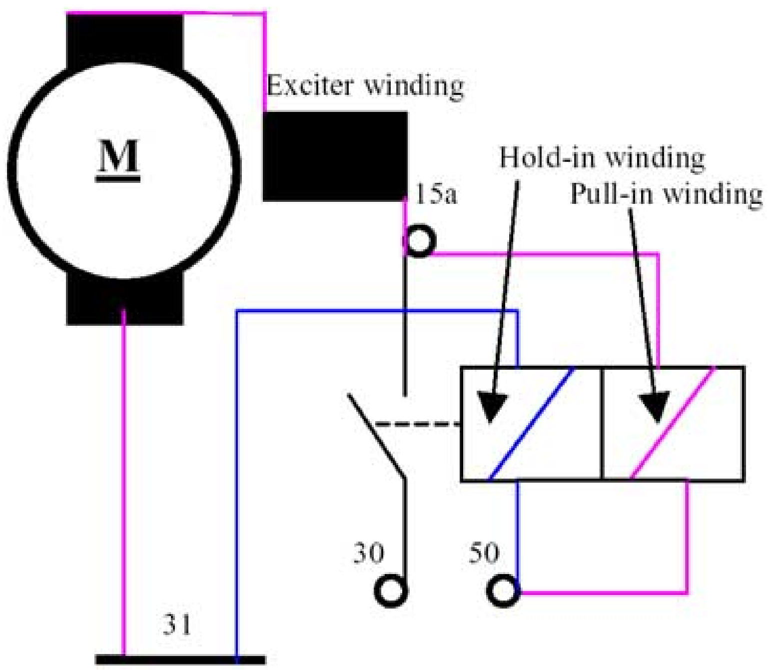
Solenoid

The **solenoid** switch **has two windings. One is the so–called pull–in winding and the other one is the hold–in winding.** Both of them build up (by energising them) a magnetic field what ensures that the solenoid shaft gets pulled inside the solenoid it self.

The **pull–in winding is connected with** one end to the **terminal "50" and** with the other end to the **"15a"**. Therefore this winding get its negative connection over the exciter windings, the plus brushes, the commutator, the armature windings and then over the minus brushes by connection to the ground. As long as the armature doesn't rotate that minus connection is available.

> **Note:** When the rotation takes place the pull–in winding isn't energised anymore.

The **hold–in winding is connected to** the **terminal "50"** as well **and** on the other side **direct to the ground**.

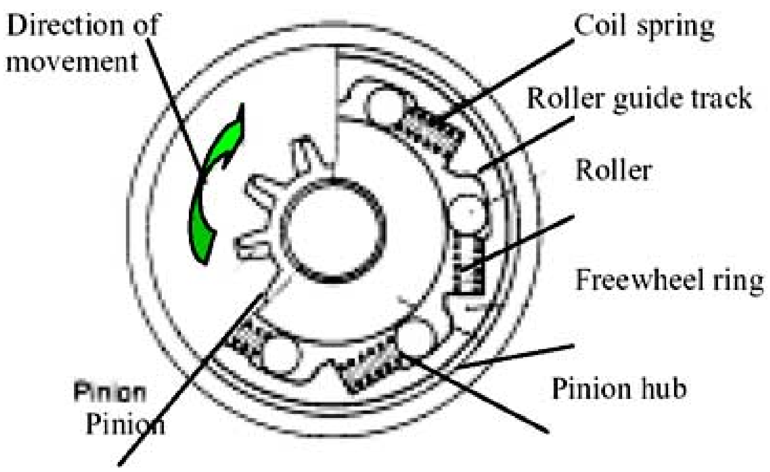


Internal circuit of a pre–engaged starter motor with the solenoid

The built up magnetic field of this winding is strong enough to hold the shaft inside of the solenoid. Therefore is it acceptable when the pull–in winding switches off.

Roller–type–

The main parts are the **freewheel–ring** with its roller slide tracks, the **rollers**, the **coil springs** and the **housing for the clutch**. In driving direction of the starter motor the rollers are pressed into the narrower section of their tracks and this couples the pinion to the starter motor.



After starting the rollers are forced into the opposite direction and so against the springs.

The rollers reach the wider section of the tracks and so the armature of the starter motor is not engaged anymore by having a higher engine speed as long as the ignition lock is still hold in start position.

Now there is not a need anymore to hold the ignition switch in start position and the **starting process should be stopped** realising that the engine runs it self.

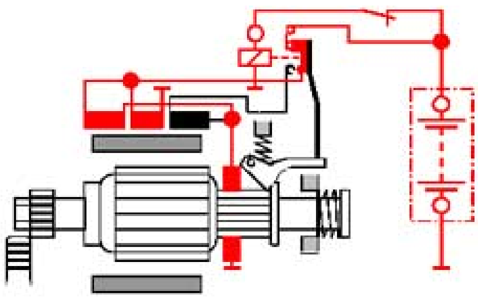
Sliding armature starter motor

Such kind of **heavy starter motors** are especially used in trucks, tanks and big stationary diesel engines etc. and mostly they are built as 24 V motors. **In switched off position the armature is axially placed out of the exciter windings.** The pinion is driven from the armature shaft in connection with a multi–plate clutch.

The starter motor has three exciter windings behind each other:

– the **auxiliary winding**,
– the **hold–in winding** (shunt–wound) and
– the **main winding** (series–wound).

For the need **to move axially the armature has extra long sizes for the bearings/bushes and a special wide commutato**r. Further important parts are the return spring, a control relay with a contact bridge and a locking part with release disc and release lever.

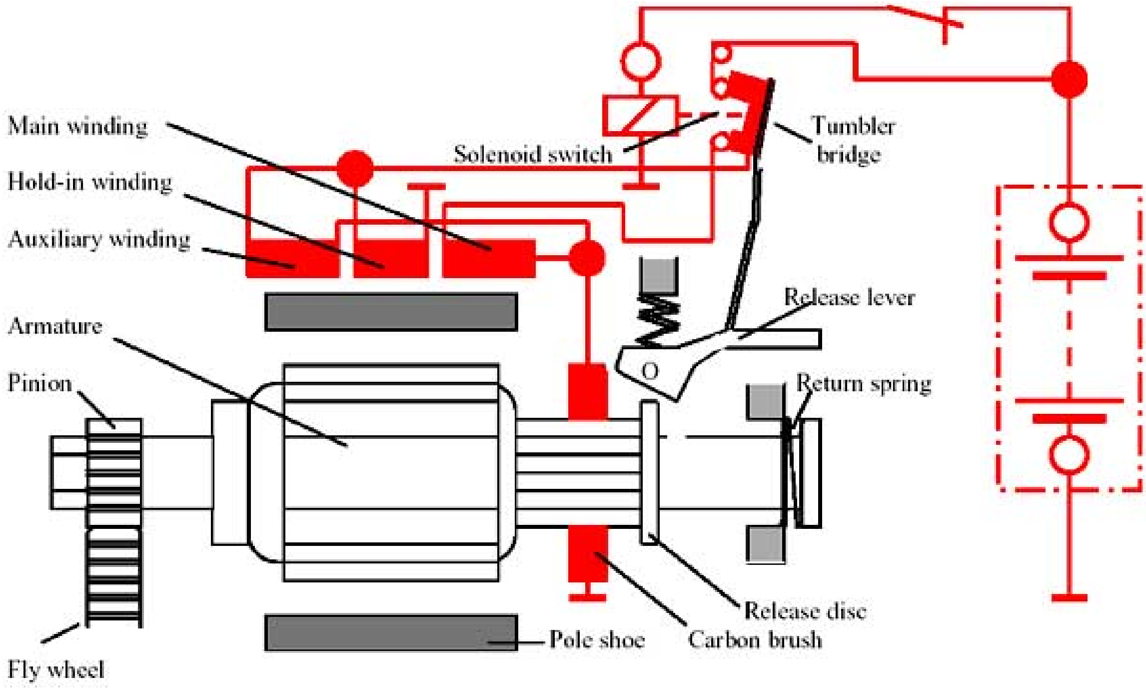


Sliding armature starter motor STAGE 1

In the **first step** the armature is by energised auxiliary and hold–in windings still axially displaced but starts already to engage into the flywheel and rotates slowly.

In **step two** the release disc raises the release lever to switch on the control relay. And now the main winding is over the relay switched on as well, the armature is forced (by the magnetic field from the side of the main winding) to slide in the driving position.

The installed clutch ensures the smoothly process by engaging of the pinion into the flywheel. After the engine has started the clutch prevents dangerous speed of the starter motor as long as the pinion is engaged in the flywheel by interrupting the power flow.



Sliding armature starter motor STAGE 2

Working rules

• The commutator must be clean with a smooth surface. There is no need to go over the commutator with sandpaper if the surface is smooth. If the commutator is not round it must be skimmed. Never try to dress the surface with a file or with emery cloth.

• The insulation between the commutator segments must be cut or milled out to a depth about half of the width of the gap.

• The carbon brushes must move freely in the brush holders. There should never be any kind of lubricant. Worn out brushes must be renewed and if necessary the commutator surface must be skimmed.

• If the armature shaft runs in bearings (they are normally self–lubricating types) they should not come into contact with cleaning agents which dissolve crease. If there used bushes than they should lubricate with oil.

• Oxidised battery clamps, loose terminals, burned switch contacts and defective wiring all increase circuit resistances and often lead to starter failures.

• The starting process needs a strong current flow. Therefore is it a good practice to switch off all other consumers during starting the engine.

Faultfinding and repair of starter motors

To remove a starter motor out of a car is usually easy.

Don't forget: The first step has to be the disconnection of the battery.

After that are to disconnect the cables from the starter motor. Now the bolts (what are holding the starter motor) are to loosen. Mostly the starter motors are hold by so called “through bolts” with these the starter motor is fixed through the flange of the drive end shield of the starter and the clutch housing. But we should take care to avoid the starter motor falls down. To remove it out of the clutch housing can be necessary from above or from under the engine. This depends on the type of car and the space in the engine room.

By dismantling the starter motor we will find several different ways in concerning the type of the starter motor. These differences are to follow up during the practice and therefore here are mentioned the basically steps only. If fitted we have to remove the cover band and than we have to withdraw the brushes from their holders by hooking up the springs and pulling the brushes free. By removing the bolts/nuts from the solenoid and the starter motor we dismantle the whole unit further.

> **Note:** Always is to ensure **knowing the order by reassembling the unit**. The separated **parts** should be **orderly placed** to avoid falling down or loosing them.

By working on the armature shaft **hold it firmly** but not too tightly in a vice. Care should be taken by removing the **pinion stop collar**. To do this the stop collar is first to move in direction of the drive assembly. Than can be removed the **pinion stop retaining ring** (normally by using a snap ring pliers) and now is it easy to remove the stop collar and the drive assembly.

After dismantling the whole starter motor all the parts must be washed and for this is **paraffin** to use.

Avoid the use of any explosive liquid.

By the use of compressed air/non–fluffing cloth the parts are to dry.

Most of the **faults on starter motors** are mechanical and can be **checked by visual inspection**.

The following pages show up general information to

– **troubleshooting** and
– **inspection of a starter motor**.

Troubleshooting

Inoperative starter motor

– loose or corroded battery terminals,
– discharged or unserviceable battery,
– open cranking circuit,
– inoperative solenoid or relay,
– faulty ignition switch,
– defective starter motor,
– inoperative neutral safety switch,
– internal ground in starter motor windings,
– grounded starter motor field windings,
– armature is rubbing on pole shoes.

Starter motor rotates but pinion does not engage

– broken teeth in flywheel gear ring,
– rusted starter drive shaft,
– defective starter drive,
– slipping overrunning clutch.

Slow cranking speed

– discharged battery or defective cell,
– excessive resistance in starter motor,
– excessive resistance in starting circuit,
– engine oil too heavy for condit ions,
– excessive engine friction,

– burned solenoid contacts,
– loose terminal connection – battery/starter motor,
– worn bushes/bearings,
– bent armature.

Starter motor does not disengage

– faulty ignition switch,
– short circuit in solenoid,
– broken solenoid plunger spring,
– broken solenoid starter switch,
– faulty starter relay,
– worn out bush on drive end shield,
– broken drive return spring,
– defective overrunning clutch.

Inspection of a starter motor

1. Commutator end shield

– cracks on the shield,
– brush spring tension,
– length and leads of brushes,
– size of bush.

2. Drive end shield

– cracks on the shield,
– size of bush,
– mouthing of holes and threads.

3. Armature

– rub marks on the armature core,
– wear of shaft,
– rotation marks on shaft,
– wear of commutator.

4. Field windings

– insulation of the windings,
– tightness and rub marks of pole shoes.

5. Drive assembly

– stickiness and slip of overrunning clutch,
– size of bush,
– wear of drive gear,
– drive spring tension.

6. Solenoid

– damages on plastic housing,
– wear of main posts/terminals,
– wear of plunger and return spring,
– wear of engagement lever and pin.

Reassemble a starter motor

To reassemble a starter motor we have just to realise that this is a straightforward reversal of the dismantling procedure. It is to check that no necessary insulation get out of order by reassembling the motor. There is **never** a need to **try** a step of **reassembling with force** because all the parts right handled are easy to fit.

During the reassemble procedure there are some parts to lubricate. On the **solenoid plunger is to apply** a light smear of **light oil** to make sure it can slide freely. The **engagement lever is to tip** on the movable connections **into grease** and **grease** as well **is to bring on the spiral thread of the shaft** of the armature. The armature shaft ends are running mostly in bushes and so the **bushes must be well lubricate with light oil**. If **bearings** are used (they should not be washed with paraffin!) than is to **ensure that enough grease is inside** for a freely movement of the armature.

If the **solenoid** was opened the **starter switch** there inside **must be clean and dry**. For the **contacts** of the switch is to ensure that they are **in good condition** because they are the link to the starter motor it self for the whole current flow.

Starter motor tests

There are many ways to test starter motors. First of all there should be a test of a starter motor on−car followed up with a no−load test. If there is still a need than is to test the starter motor on the test bench to find finally out the cause of the problem.

On−car test for voltage drop:

1. The voltmeter leads are to connect to the positive terminal of the battery and to the starter motor terminal “30”. The voltage drop should not exceed 0,5 volt.

2. The voltmeter leads connected to the positive terminal of the battery and to the solenoid terminal “50” should in the result not bring a higher voltage trop then 0,1 up to 0,3 volt.

3. For connection of the voltmeter leads to the battery negative terminal and the ground is a drop of 0,3 volt acceptable.

On−car test for amperage draw:

In that case the engine must be at normal operating temperature.

1. The secondary wire on the ignition coil is to disconnect and to ground.

2. Connect the load tester to the battery negative and positive terminal while the load control knob of the tester is in decreased (counter−clockwise) position.

3. Observe during starting operation the amount of voltage but do not crank the engine for more then 15 seconds.

4. There after turn the load control knob of the tester clockwise (increase) until the voltmeter indicates the same voltage as while the starter motor cranked the engine.

5. Observe now the amperage draw on the ammeter and compare it with the manufacturer’s specification (normally between 150 A and 350 A).

Bench tests:

Armature and exciter winding ground circuit test:

If the armature insulation or exciter winding insulation has failed it would exist conduction to the armature core or to the starter motor housing.

Armature test:

The test can be done by using a voltmeter. By testing the armature is the positive terminal of a battery to connect to the armature shaft (jumper cable). The voltmeter is to connect to the battery negative terminal and in turn to each commutator segment. If there **appears** any amount of **voltage** on the scale the **armature winding is grounded**.

The armature can be tested as well by using the armature growler.

Exciter winding test:

To test the exciter winding there is to connect a jumper cable from one battery terminal to the starter housing. The other battery terminal is to connect with one voltmeter lead while the other voltmeter lead is to bring in contact with the starter terminal. By doing this keep the brushes away from the housing. If any **voltage is indicated** than the **windings are grounded**.

Bench test of the starter motor:

First of all the starter motor has to be mounted firmly by using the right flange and by bringing it into the right position to the flywheel of the test bench. The right position can be found easier when energising the solenoid what brings the pinion in front to mesh the flywheel. But in that way should not be connected the positive lead to the main post of the starter motor. By testing on the starter motor test bench is possible a no−load test as well as a load test and by cranking of the pinion in the flywheel the properly function of the drive assembly can also be ensured.

By running the engaged starter motor can be made a **no−load test** without using the break pedal for the flywheel. Typical can be a **current flow from 50 A up to 90 A** and a **speed** of the starter motor between **6,000 and 11,500 rpm** at **10 volts**.

Using the break pedal and therefore the **load test** should **not** take **longer then 15 seconds**. The **amperage draw** is to follow up concerning the manufacturer specification (normally between **150 A and 350 A**). The **overrunning clutch** of the drive assembly **should not slip** at this time. If it is slipping the overrunning clutch is suspect.

> **Note: Testing** a starter motor **on the test bench needs knowledge** and **injures are possible if care is not taken**. The **testing procedure has to be done from authorised workshop members only** and **by following up the instructions** step by step for working on the test bench.

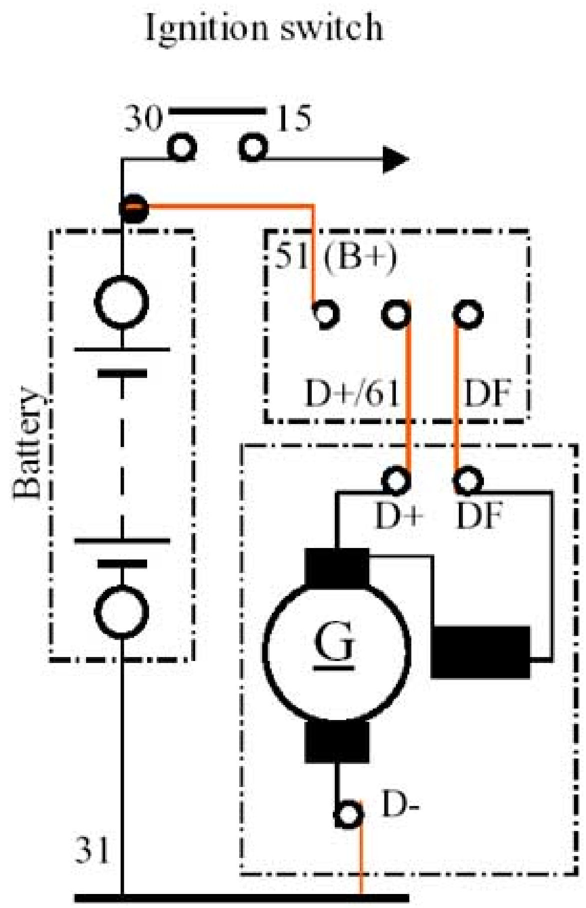
4. Charging systems

Fundamentals

By **using a generator or an alternator** we are able **to supply the electrical system** of a motor vehicle **with energy**. That means, by using a motor vehicle we do need electrical energy and for that we can use the stored energy in the battery. But this energy is only as long available as the battery is not discharged. Without generator or alternator we can not drive over longer distances and especially at night by the use of such strong consumers like headlights the stored energy of a battery is relatively fast completely used.

The purposes of a recharging system − with its components like generator or alternator and of course a regulator − is **to supply electrical energy during the vehicle operation**. That process **is directed to all the switched on electrical consumers** (i. e. ignition system, lighting and signal equipment) **and** at the same time **there is a supply of energy to the battery** to keep this electrical source in charged condition.

The **regulator** of the recharging **system is needed to regulate the output of the generated energy**. The reason is that by **raising up of the engine speed more electrical energy** is produced. Therefore is a need to **regulate this process to prevent overcharging of the battery and possible damages on the consumers**.



Connection of a shunt–wound generator and a regulator into the battery circuit

How we can now explain what **an automotive generator** is?

It is an **electromagnetic device that converts mechanical energy supplied by the (running) engine into electrical energy**. The automotive generator is therefore driven over the connection of a V–belt from the engine and produces **based on electromagnetic induction** electrical energy.

Electromagnetic induction

Do we look back to the basically explanation of the working principles of a starter motor than we should remember how electromagnetic induction takes place. But let's repeat again:

If an electric conductor (wire or wire loop) **cuts through its rotation in a magnetic field the lines of force of this magnetic field, a voltage gets induced in the conductor.**

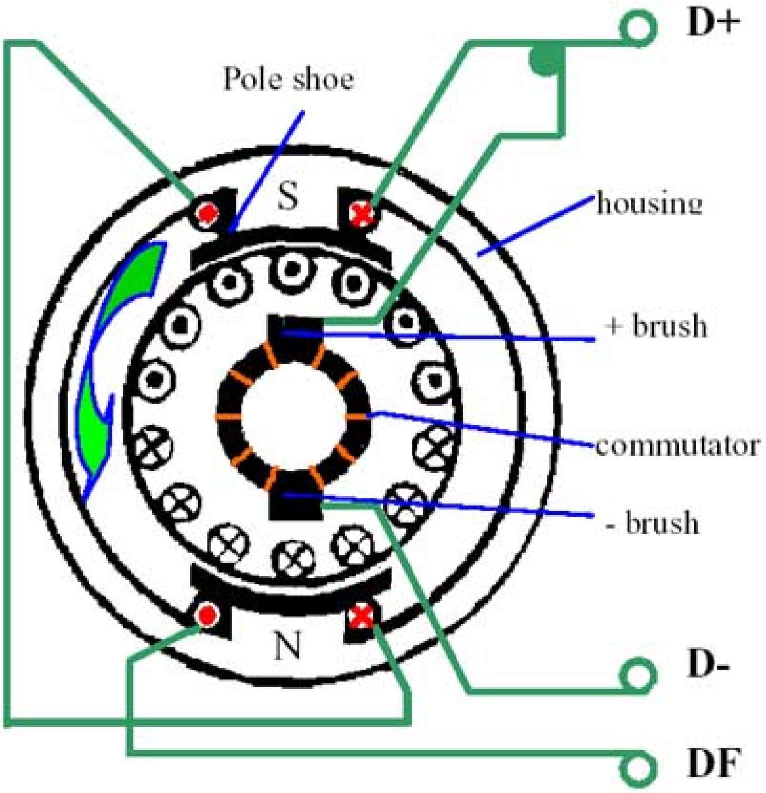
As **more conductors** are **rotating in a magnetic field** and as the **speed of rotation increases** as **more** and faster the **field lines get cut** and **therefore the induced voltage raises** up. **See** also pages 57 and 58 in the chapter **"Starting systems"**.

But now there is another question to clear up. **How is the magnetic field produced?**

The magnetic field can exist by using permanent magnets where the rotating windings (wire loops) can be placed in. This could be a very simple design without big technical problems. Such construction we do use in dynamos for bicycles. But we do know **an electromagnet allows** in the end **a higher output**. The term electromagnetism includes further the fact that the **strength of an electromagnetic field results** from the **number of windings**, the **strength of current flow** through them and the magnetic field can even **get more strengthened by placing an iron core** inside a winding. To work therefore with **electromagnets as excitation (exciter) windings** make it possible to **increase or decrease the current in the winding and also to increase or decrease the induced voltage**.

After the current flow of the exciter windings is switched off the electromagnet loses its magnetism. But **a slightly rest magnetism remains** and this we do need for starting the inducing of voltage again by running the recharging system next time.

In order to multiply the induction of voltage not only one wire loop is rotating in the magnetic field of the exciter windings. **A number of loops** all together **known as armature winding are rotating inside the exciter windings**.



Circuit of a DC–generator in connection with exciter windings and armature winding

Output of the system and demands on it

Power demand of consumers:	
Ignition	20 W
Electric fuel pump	50…70 W
Electronic fuel	
injection	70..100 W
Car radio	10…15 W
Side/rear lights (each)	5…10 W
Headlamps (each)	55..100 W
Car heater	20…60 W
Indicator lamps (each)	21 W
Stop lamps (each)	21 W

The **output** of the generator or alternator **must match the whole electrical system** of a motor vehicle. That means the output must be ideally as far as possible to enable the entire system in case of a **powerful and trouble–free operation** and **this includes the battery capacity and the need of electrical power in demand** of all the installed electrical systems. What this means?

– The **ignition system** must be always ready for operation.

– The **electric radiator fan** and the **fuel pump** must operate properly.

– The **signals** and in darkness the **lighting system** must get enough electrical energy to operate in all situations.

– Additional systems like **hazard system, wipers, cooling and heating system, electric windows, car radio** and so on must work as needed and last not least.

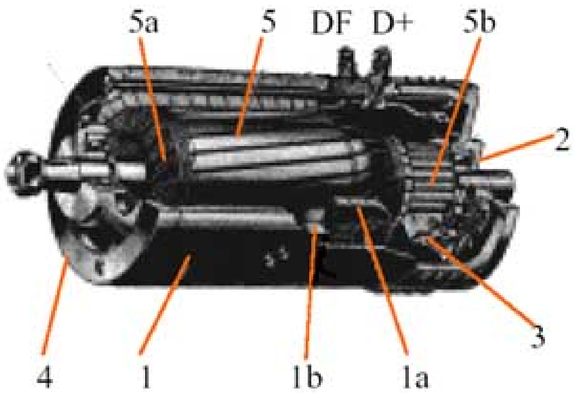
– The **battery must get regularly charged**.

Power demand of consumers:	
Electric radiator	200 W
Blower for heating/	
cooling	80 W
Heated rear window	120 W
Rear window wiper	30…65 W
Horns/fanfares (each)	25…40 W
Electric arial	60 W
Fog lamps (each)	55 W
Starter motor	250..2000 W
Glow plugs/diesel	
engines (each)	100 W

Therefore **it is never a right way to use** in a motor vehicle just only **a battery with a higher capacity without to ensure that the whole system is working properly together**. In such a case is to **approve** how far is it possible and necessary to adjust the generator/alternator **output** over the regulator so **that the system operates further powerful and proper** by recharging the battery fully. It can be a need by the use of a stronger generator/alternator to replace the regulator as well.

DC–generator

The lead–acid battery in motor vehicles led to the development of the **DC–generators**. For a long time this generator system was used and has been able to fulfil the given demands.



The **main components** of a DC–generator:

– **Housing** (stator frame) {1} with exciter windings {1a}, pole shoes {1b} and terminals (DF; D+ and sometimes D–);

– **Commutator end shield** {2};

– **Brush holder** with carbon brushes {3};

– **Drive end shield** {4};

– **Armature** {5} with armature winding {5a}, laminated iron core and commutator {5b} and mounted bearings;

– **Pulley** with **fan**.

Function

The **DC–generator is a shunt wound type**. **Exciter windings** are **in parallel to** the **armature winding**. The DC–generator is a **self–exciting machine.** A small amount of **rest magnetism** always remains in the pole shoes after it was magnetised ones. The pole shoes are surrounded by the exciter windings. **These windings generate the magnetic field.** The **armature rotates** supported accurately in its bearings between the pole shoes whereby the **air gap** is kept as small as possible (reason: a **bigger air gap reduces due to magnetic resistance the magnetic field force**). The insulated **armature wires** are wound in the slots of the laminated iron core and with its **ends connected** (soldered or pressed) **to the laminated commutator**. The **winding heads are wrapped to resist the centrifugal force**.

If the armature starts to rotate the small amount of **rest magnetism** of the pole shoes **induces a low voltage** in the armature winding. A **corresponding excitation current flows** than **in the exciter winding** what causes that **the slight magnetic field gets built up** and the rest magnetism get therefore **strengthened**. A **larger voltage** will now be **induced in the armature winding** what **leads** further **to strengthen the magnetic field** of the exciter windings. This **process is repeating** as long as the predetermined level is reached whereby the induced voltage depends on the speed of the armature rotation.

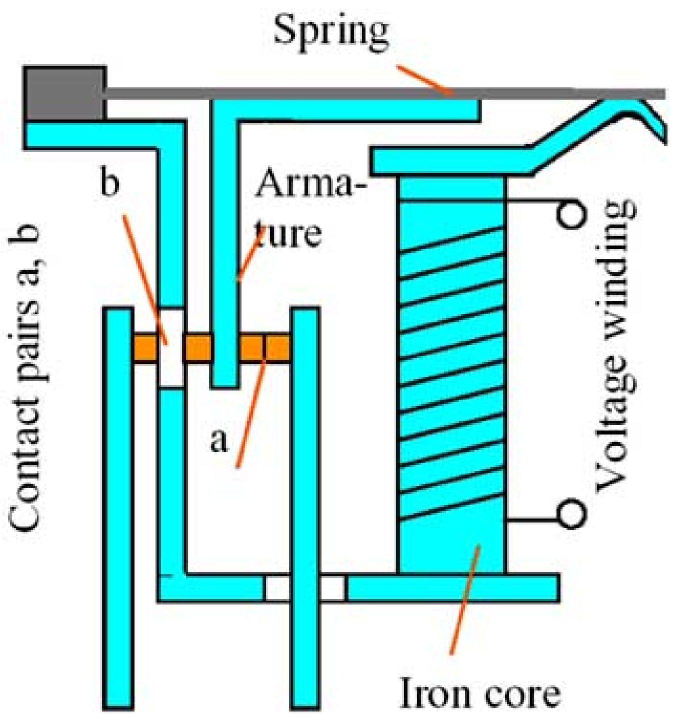
The **voltage output** of a DC–generator can be **regulated in terms of varying the exciter current**.

DC–generator voltage regulation

The **generator voltage** must be kept as **constant** as possible. The **current value** must be **correct regardless of speed and load** to ensure that electrical consumers are **not** troubled by **a higher voltage output**. So is it necessary to **protect** the consumers **against over–voltage** and to prevent the **battery from** being **over–charged**.

The **voltage regulation element varies** the **strength of the magnetic field** of the exciter winding **by decreasing or increasing the exciter current** depending on the rotation speed. In the end this means, a **current decrease in the exciter winding** causes a **voltage drop in the armature**.

To **regulate the generator voltage** is possible by opening and closing the contacts of an **electromagnetic voltage regulator** because the **self–induction in** the **exciter winding prevents** a suddenly **rising of** the **exciter current when** the **contacts are closed**. On the other hand it leads to a **current drop** when the **contacts are open**.

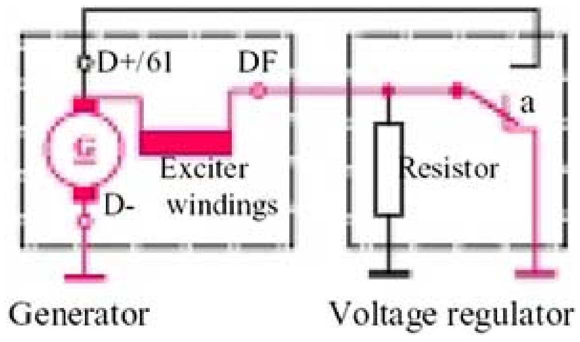


Voltage regulation element (schematic diagram)

In the following diagrams is shown how **the voltage regulation** takes place. It is to realise that the different **settings don't show up the output** of the generator directly. **It gives** you **the different situations** depending on the running speed concerning increase/decrease **of voltage of the exciter windings** and therefore the increased/decreased strength of the magnetic field. **Out of this we do get the regulated output** from the DC–generator over the regulator.

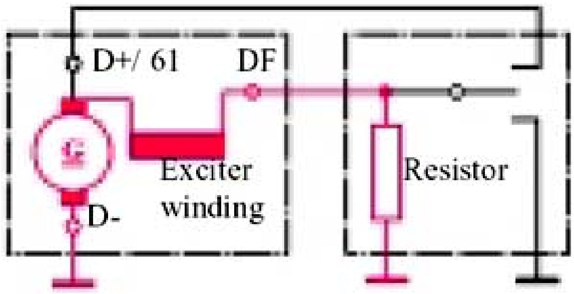
Lower setting:

The running speed in this situation is low as well as the voltage of the exciter windings. Therefore holds the spring the **contact pair "a" closed** and the regulating resistor is bridged. The **exciter windings** are direct **connected to ground** and so **the voltage** of those windings is able to **rises up**.



Middle setting:

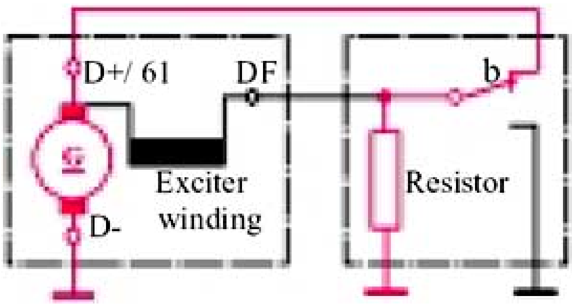
Depending on a **higher running speed** the **voltage** of the exciter windings **rises up further** and also the **magnetic field get strengthened**. Reaches the voltage a value above its predetermined setting than the **armature** of the regulator **moves into the middle setting** by a developed higher voltage of the voltage winding of the regulator and therefore a stronger magnetic field of that winding and the iron core. The **contact pair "a" opens** and the **resistor**, connected direct to the ground, is now brought **into the circuit**. This leads to a reducing of the exciter current and the **generator voltage output gets reduced** as well.



Upper setting:

If the **voltage output** of the generator **rises up further** induced by a stronger magnetic field and as a result of a increased speed the **magnetic field** of the voltage winding and iron core **of the regulator get** also **further strengthened**. This leads to the connection of the **contact pair "b"** by pulling further down the armature of the regulator. Now there are **connected both ends of the exciter winding to positive** what **causes the end of voltage induction** as long as the contact pair is closed. If therefore is no current flow anymore going on there will also **rapidly decrease the magnetic field of the regulator**. And in that case the spring–hold **armature returns to the middle/lower setting**. This means **the voltage** of the generator **increases again** and the whole **process** as it is explained above **continues**.

In the end there is going on by the regulation of the generator output a very fast **switching process** in the matter of milliseconds with a **frequency of 50 to 200 periods per second**. By following up this process the **voltage output of the generator remains approximately constant**. A sudden rise of the exciter current is not possible because of the self–induction in the exciter winding. **Increasing or decreasing** mechanically **the pressure of the spring in the regulator** make it possible to get a **higher or lower output of the regulated generator**.



The electromagnetic regulators where used in the past in connection with the Dc–generators as well as with AC–generators.

Regulator types for DC–generators

Voltage regulators can be attached to the generators or installed on a separate place.

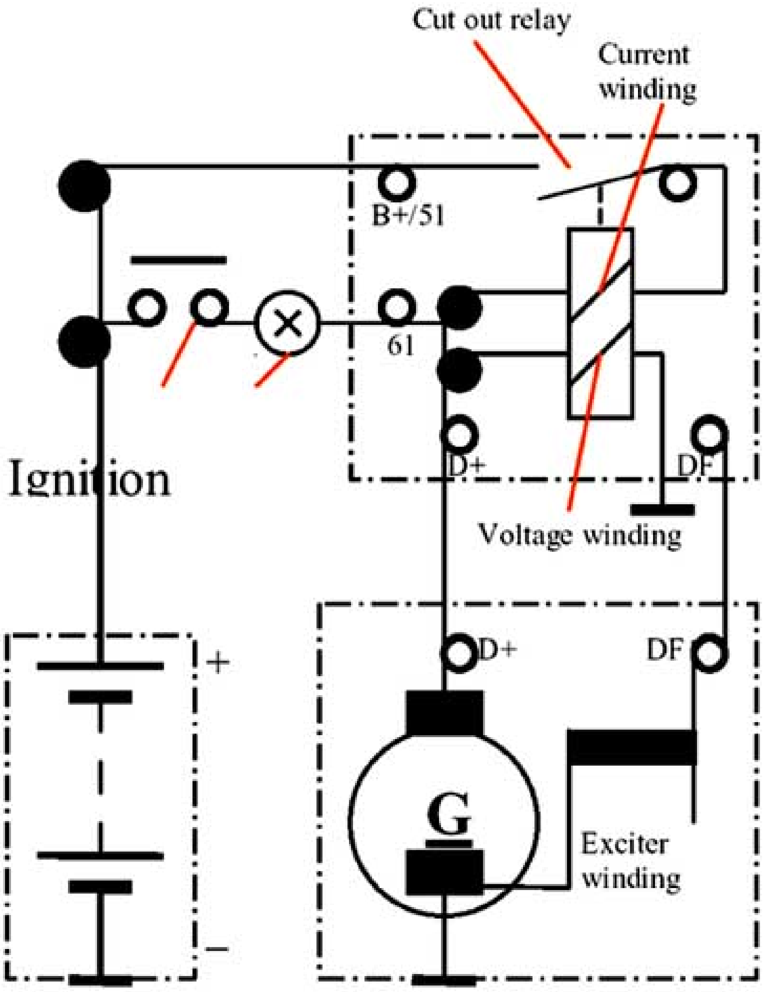
There are **regulators with different contact systems** (single or double contact) with varying numbers **of elements** (two– or three–element regulators) and different **regulating characteristics** (inclined, steep–droop or variode characteristic).

If there is used **a two–element regulator** it has a voltage regulation element and a cut out relay. By using **a three–element regulator** there is in addition a current regulation element attached.

Voltage regulation element controls the charging voltage on a safe value. When the battery needs to get charged the voltage regulator cuts out the resistor of the exciter field circuit – the flow of current increases – the generator output is boost. When the battery is fully charged the resistor is brought into the exciter field circuit – the charging current decreases – the generator output goes down. In addition this happens in the same way by switching on or off more or less consumers and by having therefore a higher or lower need of flowing current.

The **current regulation element is a magnetic switch** inside the charging circuit **to protect the DC−generator from overload** by limiting the current output to a safe value.

The **cut−out relay** is designed to **prevent the battery from discharging through the generator** when the engine is turning on a slow speed and therefore the charging rate of the generator goes below the rate of the battery. That means if the generator voltage is lower then the battery voltage the cut out relay interrupts the connection between generator and battery to prevent a reverse current flow. This prevents as well the generator from being connected as a motor.

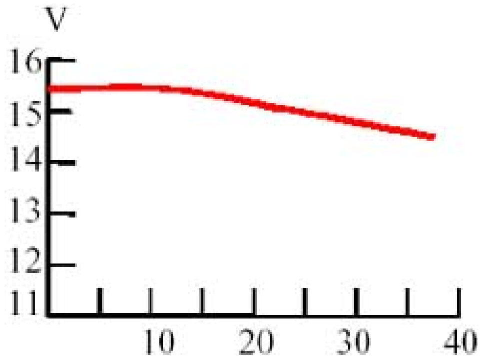


Because of increased electrical loads many DC−generator regulators are provided with **voltage regulator units of a double−contact type**. These units are equipped with two sets of contact points to hold the high field current of the exciter winding inside the generator and to prevent therefore an uncontrolled overload of the electrical system of the motor vehicle.

The voltages induced by a DC−generator in relation to the load are referred as regulator characteristic.

Regulator with inclined characteristic:

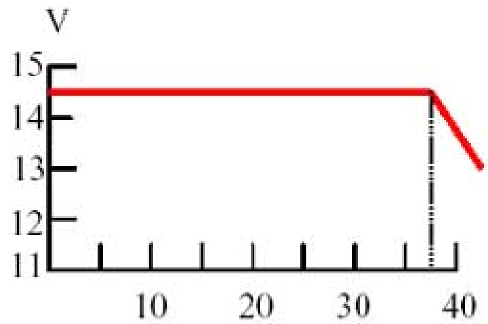
It **prevents overloading of the generator**. The current from the generator passes through a coil on the voltage regulation element (one up to two windings). The effective magnetic field of the voltage regulation element increases as result by this additional coil when the load current increases. The regulator contacts of the voltage regulation element move than to the middle/upper setting even when the generator voltage is lower. Therefore the regulated value of voltage becomes lower.



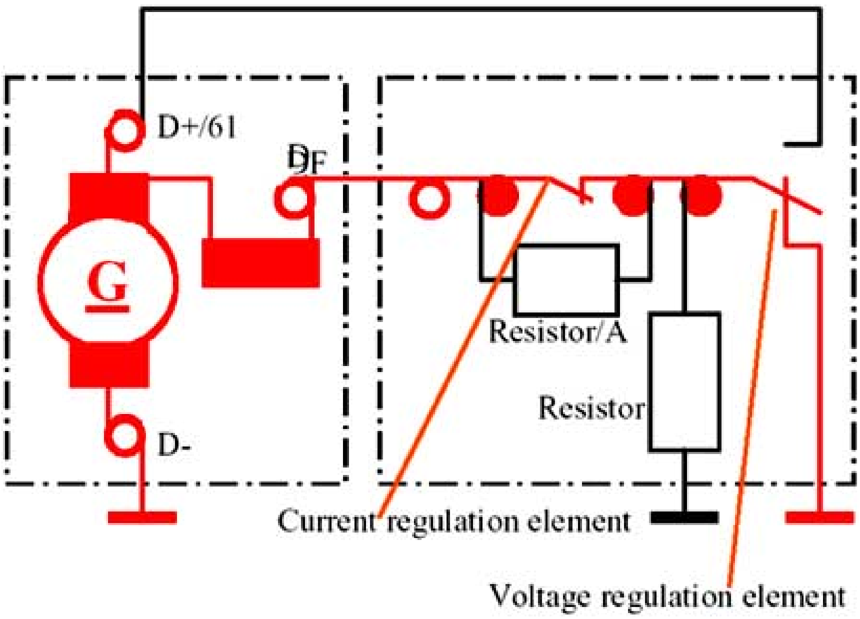
Inclined characteristic by an additional winding on the voltage regulation element

Regulator with steep–droop characteristic:

In this case there is built into the regulator an additional current regulation element. Starting with the idle speed of the engine the regulating voltage remains almost constant. Until the maximum generator current is reached the voltage regulation effect takes place only. When the maximum generator current is reached the voltage gets reduced steeply and so the output is controlled. This additional current regulation element protects the generator against overloading. On this type of regulator the lower setting contacts of the voltage regulation element are not direct wired to the ground. They are connected over the so–called off–load contact of the current regulation element. Therefore the exciter winding is then grounded when the lower setting contacts of the voltage regulation element and the regulation resistor is inserted into the circuit of the current regulation element. In this case the exciter current gets reduced and controls the voltage.



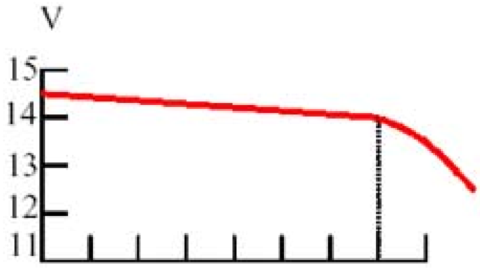
Steep–droop characteristic by an additional current regulation element



Regulator with voltage regulation element and additional current regulation element

Regulator with variode characteristic:

This type of regulator has a voltage regulation element and a cut out relay. The voltage regulation element has an additional control winding with an in series connected variode (diode). This additional winding and the variode are in parallel to the resistor of the regulator.



Variode characteristic By an additional control winding with a variode

A voltage drop takes place at the resistor when a load is applied by the control winding with its variode. When the maximum generator current is reached the voltage drop in the resistor gets so great that the variode becomes conductive and now current flows in the control winding. The voltage regulation contacts are in the lower setting because of the voltage drop in the generator armature occurring at maximum load. The magnetic field built up in the control winding strengthens the magnetic field of the voltage coil from the voltage regulation element when a load is present. The contacts of the voltage regulator element are now in middle or upper setting and therefore the generator voltage is controlled.

The characteristic is related to the steep–droop characteristic but the break–away–characteristic is not so abrupt.

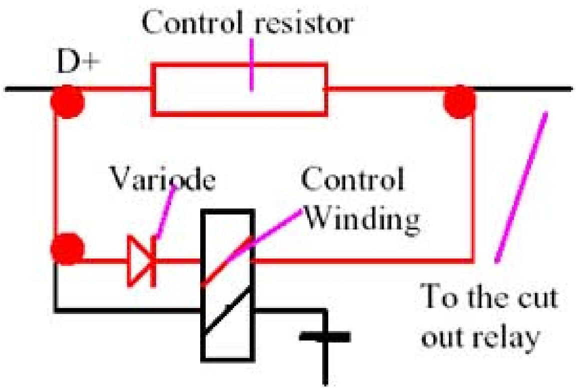
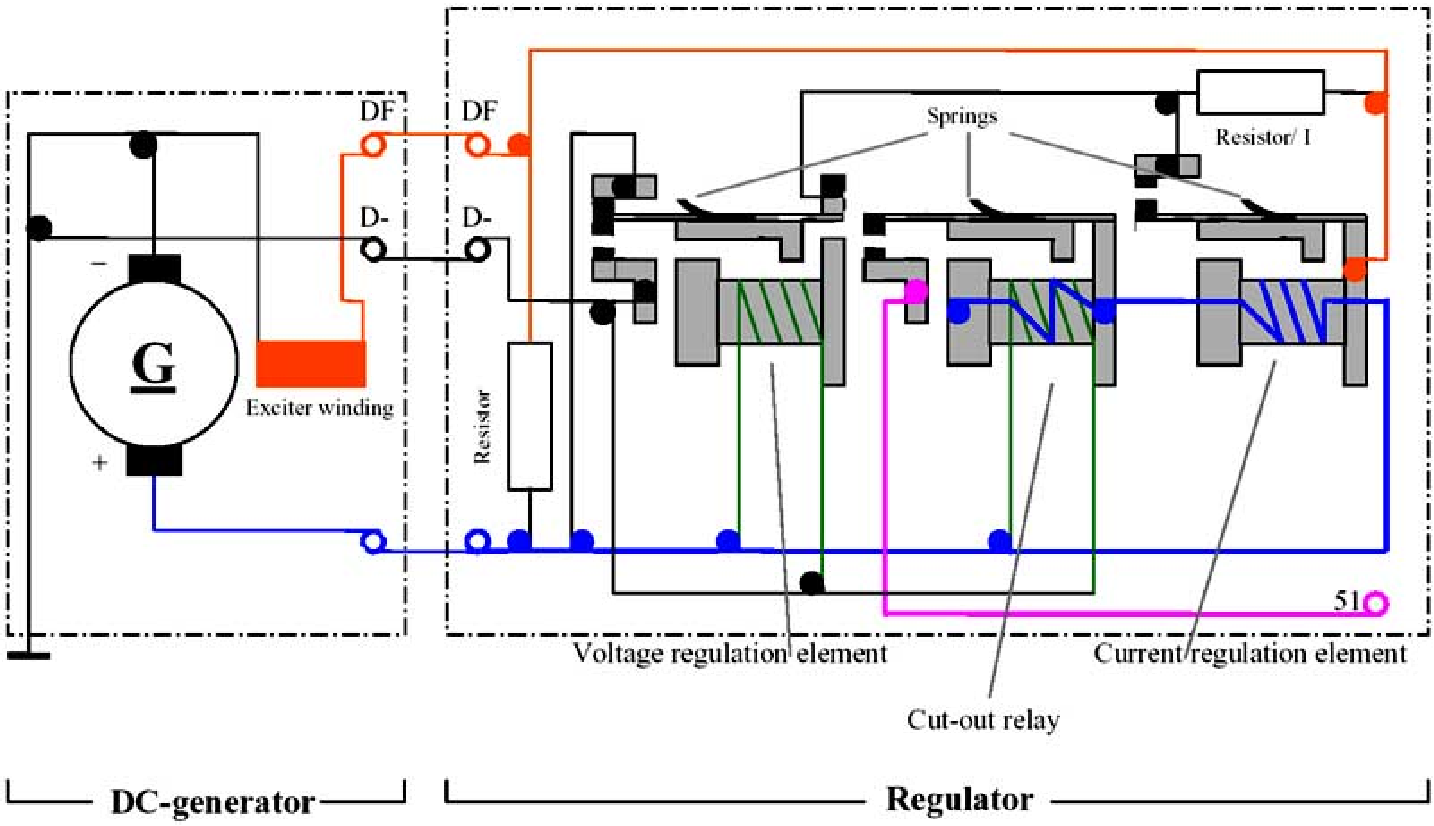


Diagram of the principle of the variode regulator



Regulator diagram with voltage regulation element, current regulation element and cut–out relay

DC–generator failures

Wear on the **carbon brushes** and the **commutator** are the mostly problems of generator failures.

Normally the brushes wear first but when they become smaller the **spring pressure** (holding them in contact with the commutator) weakens. This leads eventually to continuous sparking (**arcing**) between brushes and commutator. This **arcing causes rapid wear on the commutator**. If this process goes on over longer time the **soldered connection** between commutator segments and windings **may melt** what causes that the generator **output drops down** and finally it **can lead to cease**.

Loss of the generator output can also drain the **battery** because the current taken from it by the switched on consumers will not be replaced. A warning of the output drop of the generator is sometimes given over the **charging lamp** on the dashboard. That lamp **may glow slightly**. If the **charging lamp goes on** during vehicle operation than is after stopping the engine first the **V–belt** to check. Should it be in order than is to check the output of the generator or if necessary the generator is to **remove for further checks** and it is on the test bench and eventually repair.

Checks are made easier if the generator is clamped in a vice. To **check the brushes** the commutator end–shield is to remove by unscrew the through–bolts. Most of the generators are having a **lug** under the end–shield **to locate** it **correctly**.

Now is to follow up what condition the carbon brushes and of course the commutator have. Always the **brush holders** are to clean (to ensure a slightly move of the brushes) before fitting new brushes. The ends of the **brushes** must be shaped to match the curve of the commutator. The **commutator** is to clean as well and its **segment surfaces** should not be glazed, pitted or scored. Other major defects can be **faulty insulation** between the segments, **broken connection** to the windings, **melted solder connections** or **lost segments**. If the **commutator is to worn out** it has to be **skimmed** on a lathe and there after the **mica insulation** between the segments may need to **cut back** at least 0,5 up to 1,0 mm deep and **correctly** from one segment to the next one.

Always the **whole generator** is to clean before reassembling. To **remove** any **dust and dirt** is it possible to use a **soft brush** as well as a cleaning agent like **paraffin**. And before re−assembling all the generator parts have to be **dry**. The field terminal often has an **insulation sheet** fitted and this is not to forget to **replace it**. Also the **drive end−shield** the **commutator end−shield** and the **armature** (as well as the bushes or bearings) are to **check for wear**. The armature should not have **signs of rubbing** on the pole shoes.

Than the **exciter windings** are to **test for continuity**. A **circuit tester** used between the terminals D+ and DF will light up if they are intact. The armature is finally to test with the so−called **armature growler**.

By re−assembling the whole generator is to make sure that all the parts get fitted together in the **right position** and there after the generator should be tested on **the test bench** (testing on the test bench will be a complete topic under the chapter “alternator”.

Routine checks

The unit of DC−generator and regulator should be checked once a year. Looking at the generator it should **not** be **dirt or dampness placed on the side of the commutator end−shield** where it can easily **lead to stacked carbon brushes and further problems affecting the commutator**. A very important maintenance job is to **inspect the fan belt** of its correct tension. A loose fan belt is a short way to flat the battery. But overtighten the belt puts excessive strain on the generator bearings especially on the side of the drive end−shield. The usual recommendation is **13 – 20 mm deflections** in the belt’s longest run.

The **regulator** is to check as well. Also here dirt and dampness may affect the resistors placed under the base plate of the regulator. Two further parts are mainly important to be looked for:

− checking of the **contacts of cleanliness** and that they are **not burned out** to ensure the proper function;

− controlling the **spring plate tension** on the contact points because they are the ones to ensure the **right adjustment for operating** the regulator bent with the correct strength;

− checking the **output** of the recharging unit we should follow up by using a voltmeter an amount of **13 – 13,5V** (or the correct value given from the manufacturer) for a 12V unit;

Adjustment of the regulator is normally not necessary. If there is on any way a need than is to use a voltmeter for the output adjustment of the recharging unit as above mentioned. For the eventually adjustment of the cut−out relay is to use a sensitive voltmeter by connecting it between the generator output terminal and earth. Than the speed of the engine is to increase slowly. Above idle speed when the voltage output take place higher then 12,8V the contacts of the cut−out relay should close. **Even a small bend on the spring plates can create a bigger voltage change**. Therefore it is not easy to get the correct adjustment for opening/closing these contact points.

Generator terminology

Nominal voltage: The voltage of the electrical system of a motor vehicle included the battery.

Generator voltage: The voltage at which the generator is normally operated (7, 14 or 28 V).

Maximum current: The current what the generator is able to deliver without exceeding its speed and temperature limit.

Zero−current speed: The speed of the generator at which (after it is warmed up) the generator voltage is reached by not delivering any current. In that stage the voltage regulator connects the generator to the battery.

Maximum speed limit: The speed of the generator rotation at maximum. Exceeding it let the risk of mechanical damages occur.

Type references: These references show up letters and numerical specifications and gives details of size and pattern of the generator and its electrical specification. The regulator must be always the right specification according to the generator to which it will be connected.

A DC−generator with 12V and a specified output of 130W needs a regulator with 12V and 130W. A higher wattage of the regulator reduces the output of the recharging unit; a less regulator wattage may lead to burning out of the regulator windings.

Permanent magnet generators

Such kind of generators we do find built in motorcycles and small stationary engines. **The rotating pole wheel includes a number of permanent magnets as well as the generator armature (voltage winding).** By rotation of the permanent magnets an **alternating current is induced** in the armature. The current needs to be **rectified by using diodes** (see chapter "alternator").

The generator armature is built for a **specified current** to supply the whole electrical system with the right current strength. Permanent magnet **generators need not to get regulate** because **they are self−regulating** in terms of the specific generator armature.

Reasons for introduction of alternators/AC−generators

Especially the increase of **power demands** on modern cars by the **growing number of electrical and electronic devices** led together with further requirements to the situation that a stronger output of the recharging system was needed. By the use of DC−generators was it not possible to reach this. World wide was going on also an increase of town driving include longer waiting times on engine idle speed. Waiting times and many stops by increased traffic were **resulting in insufficient battery charging**. The development of the **alternator brought a successful improvement in all that cases**. But it was only possible by the advance of **semiconductor technology**. The reason for this is that **a<u>lternators are generating alternating current</u>**. Therefore the **<u>output of an alternator must get rectified using rectifier diodes</u>**. First then the output is usable for the electrical system of a motor vehicle

<u>Advantage</u>: Power gets delivered even **when** the **engine is idling**. The **rotational speed** of the alternator can be **higher** what is important by using modern engines with higher engine speed. The equipment of an alternator is **<u>much better</u>** by a **less of mechanical−dynamic influences**, by the **influence of higher temperatures** and in the case of **much longer operation times and longer periods before maintaining** is needed.

Alternator/AC−generator

For modern **engines running at higher revs** in motor vehicles with **extra electrical equipment** the **DC−generator has limitations**. To generate the extra current **demand requires a much bigger physical size of the armature** and therefore of the complete **generator** until weight and size **become excessive**. The higher revs of the armature **increase the centrifugal force** what causes the **armature windings** in a tendency to **throw outwards**. Also the increased current output **increases the wear between brushes and commutator**.

That we do know. The way out of these problems was (by developing the field of electronic and its semiconductors) the alternator**.** The **alternator output** is alternating current what **needs to get rectified by the use** of special semiconductors called **diodes.**

Whereas the DC−generator consists of a series of windings (coils) rotating inside a magnetic field, **the alternator is also something like that but hereby a magnetic field is rotating inside a series of coils** (inside changed to outside). This gives us several advantages (mentioned already on page 40). Let's follow up these figures step by step again:

1. **The rotating magnet, the rotor**, is an electromagnet with variable strength (as in the DC−generator field coils) can be made strong enough to rotate at much **higher speed without getting damaged**. **The field windings** contain a relatively small amount of wires

and so the damage in case of centrifugal force is minimised.

2. **The field current is low** and also when it must be a contact by using brushes to conduct the current to the field windings, **the wear on the brushes is very little**. A **second reason for reduced wear on brushes is they** have not to **run over a commutator** anymore but instead of this **over smoothly slip rings**.

3. **The main windings** now existing and **fixed on the side of the stator can be made much heavier**. They are **kept cooler** during operating then in a DC–generator and therefore in the end **a higher output is possible** by probably the same unit weight.

4. An **alternator delivers an useful amount of current already at idle speed of the engine** and there are not developing difficulties facing **traffic problems** at low speeds or "stop and go" situations.

Getting an output of alternating current out of the alternator is the use of diodes to rectify AC to DC. The diode assembly/rectifier is a **small unit** mostly built in the alternator. Such a **unit can handle quite large current and let the current pass in one direction only**.

The generated current from the alternator flows first in one direction and then in the other one. But **the rectifier unit using these diodes block the reverse current** and therefore the **result is a pulsing unidirectional current**.

Alternator construction

Three major units are existing in an alternator:

– A **rotor**, which provides the magnetic field.
– A **stator**, where voltage and current gets produced.
– A **diode assembly** (rectifier), which changes ac to dc.

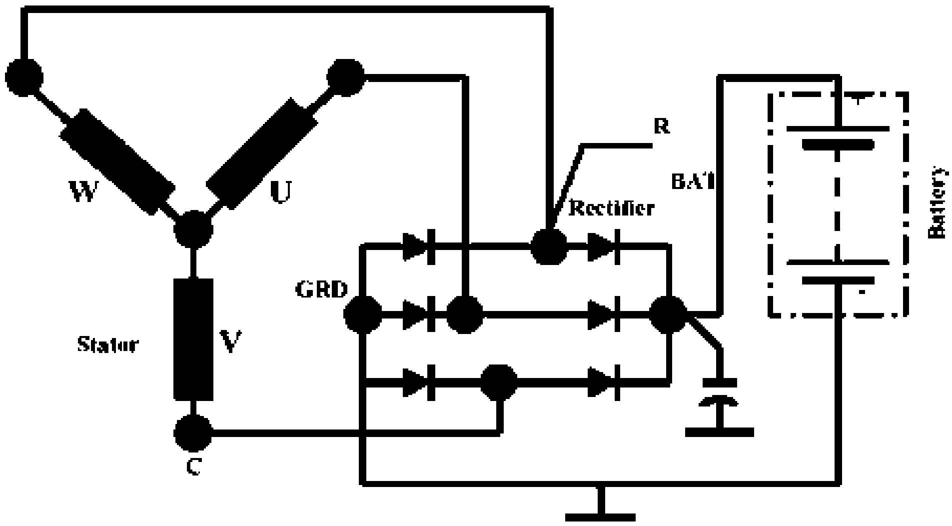
The rotor has an **iron core** on a shaft **with a wire wound as coil** around it. This coil is enclosed between two iron pole pieces with **inter spaced claws**. The ends of the coil are connected to two slip rings. There over are riding during rotation **small brushes**. **One** of these brushes **is connected to the alternator field terminal** (the insulated brush). **The other brush is grounded**.

The **stator has three sets of windings** that are assembled around the inside circumference of a laminated iron core.

The iron core is also often used as a part of the alternator frame. In its function **it provides** between those inter spaced pole claws of the rotor **a path for the flow of the magnetic flux**. **Each winding** of the stator **generates a separate voltage.**

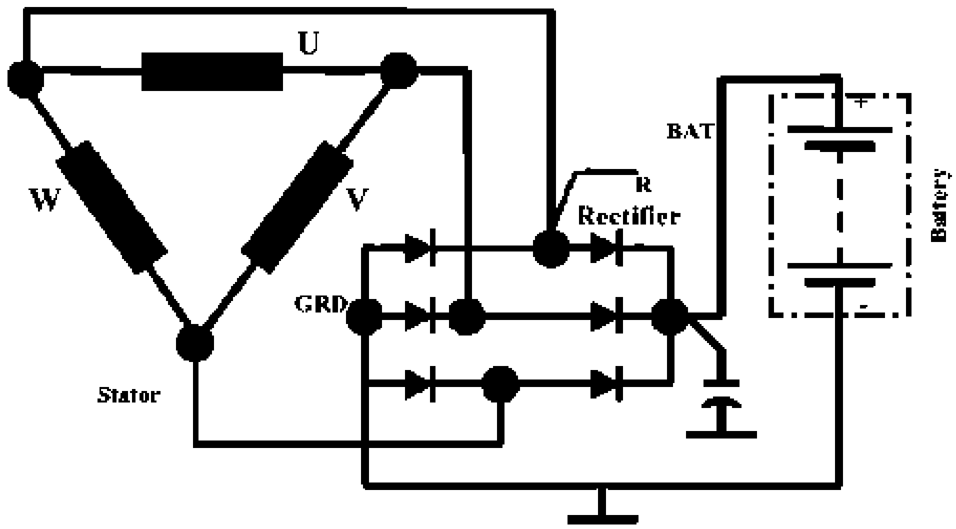
One end of each winding is connected to a positive and a negative diode as a first possibility. The other ends of the stator windings **are connected to form a "Y" arrangement**.

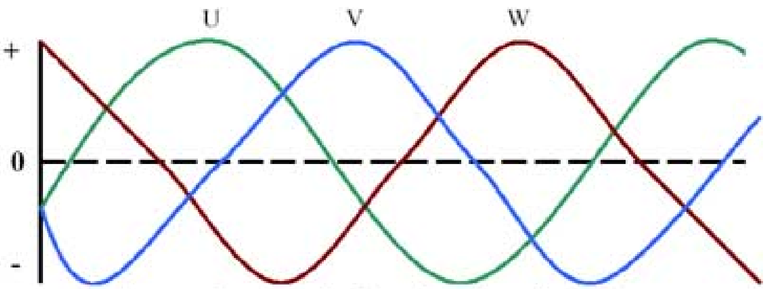
The **other type of connection** is used especially on heavy–duty applications. In that case **the windings are connected to form a triangle (delta–connected stator)**. However, each winding of the stator generates a separate voltage and therefore the **alternator is a three– phase unit**.



Three-phase "Y" circuit stator is formed

Three-phase "delta-connected" stator is formed



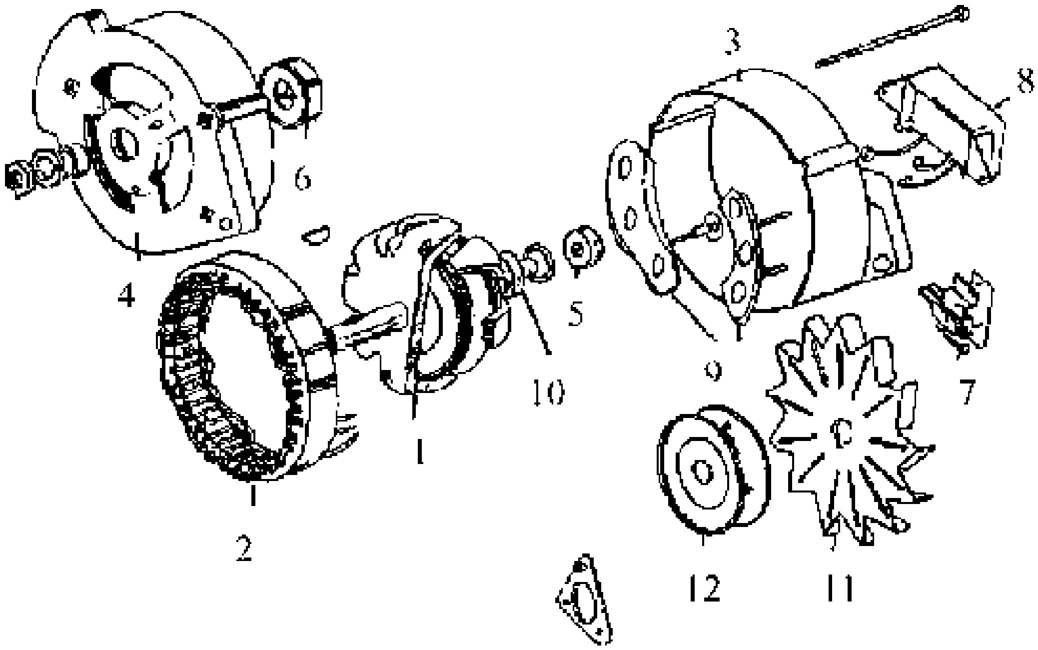


Curves of generated voltage in a three phase alternator

The **diode assembly** consists of six diodes (basically) but often we do find alternators having **nine diodes**. The **diodes** are **connected to** the **stator leads**. So a diode assembly may have six power diodes and three exciter diodes **for converting** the **three–phase current into direct current**. The **negative diodes** are mounted into the slip ring end shield or in a heat sink bolted to the end shield. The **positive ones** are mounted in a heat sink and they are **insulated** from the end shield.

The stator is clamped between slip ring end shield and drive end shield. These front and rear housings are hold together by through bolts. The rotor is rotates in **bearings** housed in both of the end shields.

The **carbon brushes** are pressed against the **slip rings** for supplying the excitation current to the rotating excitation winding. Often **electronic regulators** are built into alternators. They form a unit with the brush assembly. Using **electromagnetic regulators** – they are built in a motor vehicle separate from the alternator.



Legend to the alternator components shown below

1 – Claw pole rotor

2 – Stator

3 – Slip ring end shield

4 – Drive end shield

5 – Bearing (on slip ring side)

6 – Bearing (on pulley side)

7 – Brush holder with brushes

8 – Regulator

9 – Diode assembly/Rectifier

10 – Slip rings

11 – Fan

12 – Pulley

Function of an alternator

In an **alternator are no permanent magnets to provide the magnetic field**. A magnetic field gets induced first when the engine is switched on. That means, **the battery has to provide current for building up the electromagnetic field**. This is **the reason for not getting push–started a car with an alternator by having a totally flat battery**.

Voltage can be induced over **two ways**:

1. By **moving a coil** of wires through a magnetic field;

– **Remember (!):** this way was used in the old **DC (direct current) –generator**. Voltage gets induced in coils of wires as the assembly (armature) rotated in a stationary magnetic field.

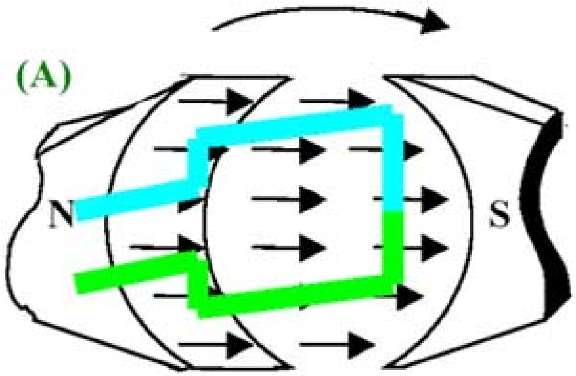
2. By keeping the coil stationary and **moving the magnetic field**;

–On this principle the **AC (alternating current) –generator, the alternator**, operates. The magnetic field (rotor) is rotated and voltage gets generated in the stationary coils (stator).

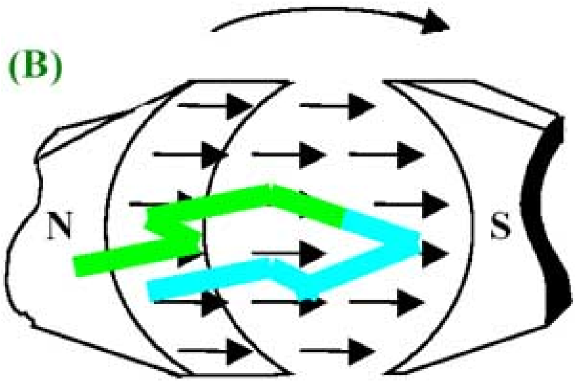
Therefore the **rotor becomes an electromagnet supplied with a small amount of electricity from the battery** through the brushes running over the slip rings. The **rotation** of this electromagnet **induces a much larger current in the stator windings**.

Let's remember: In general **we do know** that **voltage will be induced** in a coil **whenever** there **is a change in the magnetic field lines** (lines of force**) by cutting these lines** passing through the coil **because of the rotation of the coil or the magnetic field**.

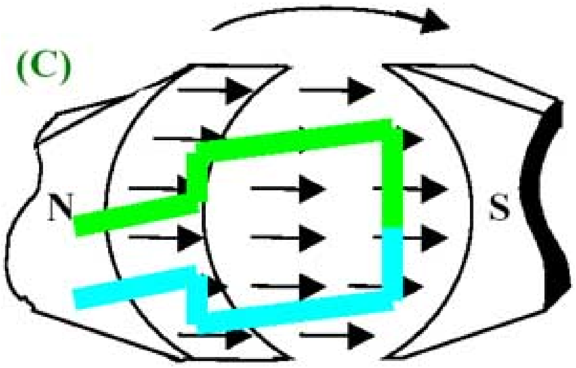
When the **coil** is **in vertical position** then is a balance of the lines surrounding the conductor, **no field lines are cut** and so **no voltage** gets **induced (Figure A)**.

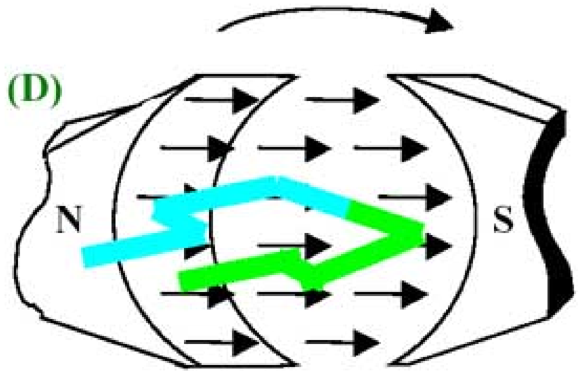


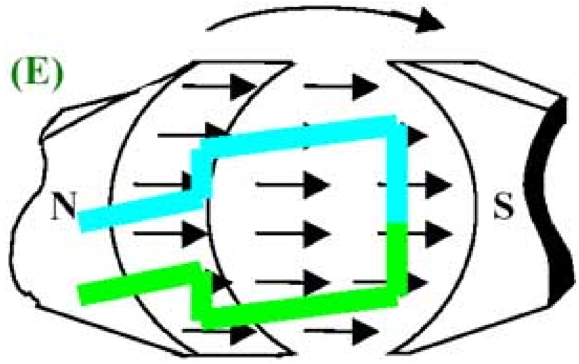
Coming by rotation **out of the vertical position** means, **increasingly lines will be cut**; the **generated voltage increases** as well and reaches its **maximum by** the **horizontal position (Figure B)**.



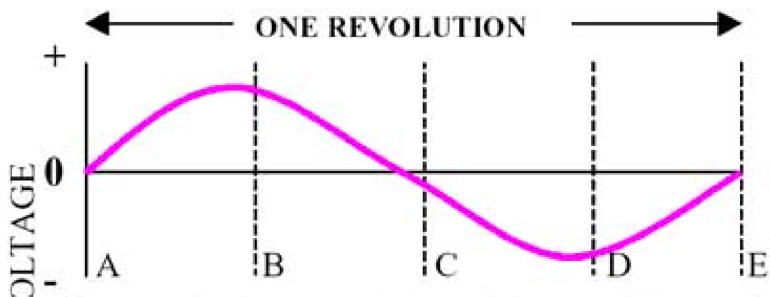
After passing position **(B)**, the **voltage** starts to **decrease** as fewer lines are being cut. It will become **zero when position (C) is reached**. As rotation continuous another maximum **(D)** and there after another zero–situation will be reached. But the **lines being cut in the opposite direction and** the **generated current will flow in the opposite direction (E)**.







Because of the **change of the current direction** it **is called alternating current**. All the automotive generators produce alternating current.



Curve of voltage variation of the revolving coil

To satisfy the needs of the storage batteries and the various electric systems the **alternating current must get rectified to direct current**.

To make use of the generated electrical energy by:

a) having a **DC–generator**

the **rectification is taking place by using the commutator** with its separate insulated segments.

b) using a **AC–generator (alternator)**

the electrical energy gets **rectified by diodes** built into the alternator.

We do know already; **before an alternator will start to induce voltage direct current must flow through the rotor winding in order to magnetise the claw poles**. That means, the rotor must be **externally excited** before the **alternator delivers voltage and current**.

When the **ignition switch** get switched **on**, voltage is supplied to one side of the charging indicator lamp on the dashboard. This causes a small amount of **current** to pass through the regulator to the insulated brush. That current flows through the slip ring to the winding, the other slip ring and the other brush to the ground. **By passing through the winding the current creates a magnetic field** (see: "Fundamentals of magnetism") in each section of the rotor. Because of the ground connection, the charging indicator lamp now works.

The **magnetic field** of the rotor **induces voltage in the stator windings** when the rotor starts turning. And ones again – **it is alternating current because**:

Do you know it?

The **rotor sections have alternate north and south poles** and the **current direction is reversed each half revolution** of the rotor (see: sketches before in this chapter and the chapter before).

The stator sends this **three−phase alternating current** to the **diode assembly** (rectifier) **what permits the current to pass in one direction only**.

Over this process **direct current is provided** at the alternator output terminal.

In an alternator there are three circuits:

1. Pre−excitation circuit

When the ignition switch is switched on, battery **current flows over** the charging indicator lamp to the **excitation winding of the rotor** and from there **to the regulator and to the ground** (alternator with mounted regulator).

Having an alternator with separate regulator, the current flows first to the regulator and after that it flows to the excitation winding.

The **alternator gets pre−excited**.

Do you still know why is this necessary?

The reason for that is, **to cause the self−excitation required for building up the magnetic field and so to generate by the running alternator the required voltage**. The **charging indicator lamp** is in the pre−excitation circuit **acting as a resistor** when the ignition switch get switched on. **Current flow through the lamp causes a magnetic field strong enough and needed for self−excitation**.

Later, even during idle speed of the engine the excitation filed is so strong that the alternator excites itself.

Then it isn't an external excitation necessary anymore and the generating of electric power takes place.

2. Excitation circuit

The **excitation circuit produces a magnetic field in the excitation winding and this in case to induce the required voltage in the three−phase winding of the stator as long as the alternator is operating**. **During operation** time of the alternator **there is no external power needed** because the **alternator excites itself** (see: pre−excitation circuit).

When alternator starts, the residual magnetism (very low) together with the pre−excited magnetism induces a slight voltage in the stator winding. That voltage causes a small flow of current in the rotor winding; the magnetic field gets further strengthened; the stator voltage increases. There is going on an **interaction (repeated continuously) while the speed of rotation increases** until the alternator is fully excited and the generator voltage reached.

Please follow up again the principles in order to ensure your knowledge!

3. Generator circuit

The **alternating voltage induced in the three phases must get rectified**. There are used the so−called **power diodes** in the **bridge circuit** for delivering **to the output terminal "B+"**. This is the path of the generator or main current for charging the battery and for the needs of the electrical loads of the switched on consumers.

For the **current** to **flow from the alternator to the battery**, the **alternator voltage must be higher than the battery voltage**. By using a regulator the output of the recharging unit is by 12V motor vehicles mostly adjusted between 13,8V and 14,8V. More about regulation you will find in "Regulation of alternators".

Why is a rectification of the generated current necessary?

Rectification of AC voltage

Semiconductor diodes are important getting a straight rectification. And first the development of diodes was allowing the introduction of three−phase alternators in motor vehicles.

Having **alternating current** produced in an alternator means we do have waves from each phase of the generated three−phase current. These **Waves are changing periodically (depending on the speed of rotor rotation) between negative and positive.** The **rectifier diodes (power diodes) cause negative half−waves to be suppressed** but they **allow flowing through only of the positive half−waves**. The **output** is in the end **a pulsating direct current**. **Each phase** is therefore **connected to two diodes**, one for **the positive half−wave** and the other one for the **negative half−wave**.

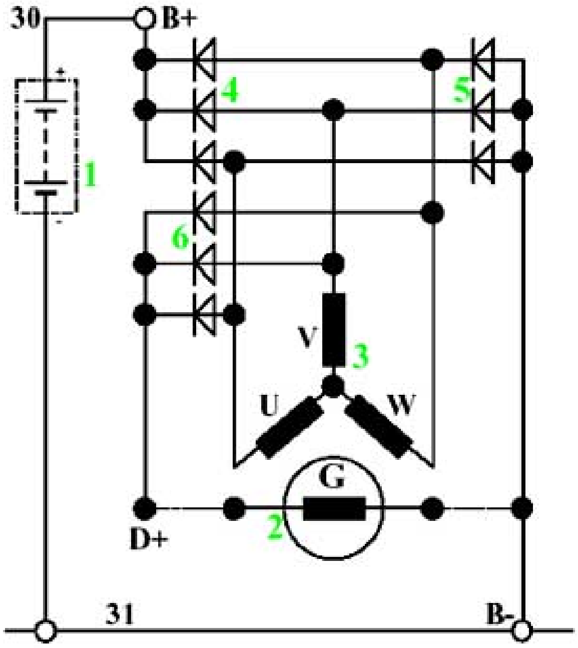
The connection of the all those six diodes of the so−called **bridge circuit**:

– the three positive diodes are connected on the terminal "B+";
– the three negative diodes are connected on the terminal "B−"/ground.

So we do get **after rectification a slightly rippled generator voltage**.

The **battery connected in parallel smoothes** the generated **electrical energy further**.

The **rectifier diodes** in the alternator **are used as well for preventing the battery from discharging** through the three−phase winding in the stator. For that is a need, **when the engine stops** or the **alternator operates to slowly so that the alternator isn't yet self−excited**. The **diodes do not allow** the **current flow in** this **reverse direction**.



1 – Battery

2 – Excitation winding

3 – Stator winding

4 – Diodes in positive plate

5 – Diodes in negative plate

6 – Exciter diodes

Three further diodes are often being used in the alternator are **the so–called exciter diodes**. These diodes are used **for** the **rectification** of the small amount **of excitation current** flowing to the rotor in case of magnetising the claw poles.

When **voltage** is **applied across a rectifier diode**, the diode allows **current flow in only one direction**. The current flow direction is in symbols shown by arrows indicating the forward direction. And the **current flow stops in the opposite direction** (reverse direction).

Diodes in the positive and negative plates are fully identical with other diodes in case of their operation. Differences are existing concerning the design by the use in alternators. **The knurled metal casings of the diodes in the positive plate act as cathodes** and they are **pressed into heat sink** which is connected in the end to the positive pole of the battery; the **diodes allows current to pass to the terminal "B+"**. The **diodes in the negative plate act as anodes** and they are **connected over the heat sink to the ground**.

The relatively small **exciter diodes** (dealing with the low excitation current) **consume** only **around 1W** (watt) but the larger and high–rated **power diodes** (in positive and negative plates) in the charging circuit **take up to 25W** per single diode.

Charging indicator lamp

Using a **charging indicator lamp** in a motor vehicle, is often done on the following basically way:

One lead can be connected to the side of the switched on ignition switch (terminal 15) and the other lead of the indicator lamp is then in connection with the terminal "D+". Over this "**D+**" the indicator lamp get ground being connected over the **"+"–brush,** to one **slip ring,** to the **rotor winding**, to the **other slip ring**, to the **"–"–brush** and to the **ground**. When the rotor starts to turn the ground connection isn't available anymore because of the inducing of voltage also in the rotor winding and therefore the indicator lamp goes off.

On anyway the connection of the charging indicator lamp depends on the use of electronic or electromagnetic regulators and on further possibilities followed up by the different manufacturers.

Regulation of alternators

Increase of the **rotor revolution** results in **increase** of **voltage and current**. For that reason is needed a **regulator to hold** the **output from the alternator -regulator unit** as **constant** as possible.

Up to now electromagnetic regulators are still in use but the built−in−regulator (electronic regulators) inside the alternator gets more popularity.

It was mentioned already that the **regulation of the output of an alternator** is a **very important** aspect. The **voltage** of an operating alternator **raises up as long as** the **rotation speed increases**. Therefore a decreasing of the engine speed brings as well a decrease of the voltage output.

A regulator brought in connection with the alternator **is needed to keep the voltage constant** over the changes of the **engine speed by differ load and rotation speed** of the alternator.

It is to ensure that there is a **protection against overvoltage** and **the battery must be prevented from being over−charged**. Therefore a **voltage regulator must** be connected to each alternator in order to ensure the requirements.

If there would not be provided a regulation then an excessively high current will damage the battery, the alternator and other electric elements connected in a motor vehicle.

Principle of voltage regulation

Basically **the voltage regulator is an automatic switch that controls the output of the charging system**. In **result** of this **voltage and current will not exceed a value once adjusted**.

The **principle of voltage regulation is based on** the **regulation of the excitation current and so of the excitation field in the rotor of the alternator**.

The **alternator terminal voltage (Va)** between the two terminals B+ and B− is the one to be kept constant. As it was mentioned already, in a motor vehicle with a 12V−battery the **regulation** takes place on a range **between 13,8V up to 14,8V**.

As long as the **generated voltage remains below the adjusted regulation value the regulator will not be in operation**. When the **generated voltage develops higher than the adjusted tolerance** then **the regulator reduces the voltage depending on the load**. This goes on **by interrupting the excitation current**. Therefore **the excitation of the alternator decreases and** that happens with **the voltage as well**. **Drops the voltage below the value**, by operation of the regulator **the excitation increases** again **and so the voltage raises up** to the set value **again**. This all is going on **very fast by** the means of **milliseconds and so the** alternator/generator **output is regulated to the required value**.

As you may realise now, **a periodic switching on and off of the excitation voltage regulates the alternator output**. The excitation winding of the alternator shows up as a high inductive load. When it is **switched on** then the **excitation current increases gradually** in a time **going along with the building up of the magnetic field**. **On the opposite** by **decreasing of the current** (switched−off situation), this **goes along with the decay of the magnetic field**. An immediate effect is therefore not taking place.

A **regulator of a DC−generator** fulfils **three functions** by acting with the **voltage regulator**, the **current regulator** and the **cut−out relay** as three parts.

On the side of a charging unit **by using an alternator the function of the cut−out relay is done by the diodes**. The **current limitation** is **not necessary** anymore because of the alternator function (current−limiting characteristic) where a **low voltage** is **induced in the excitation winding** what **counteracts with** the **resultant generator voltage**.

Do you know, why the excitation current does not undergo an abrupt increase and decrease?

Types of regulators

Mainly we have **build–in regulators** direct in connection with the alternators and we do have as well (still) **separate regulators** put on a protected place in the engine room of the vehicle.

1. **Electromagnetic vibrating–type regulators**

   – see on the pages 32 up to 36

2. **Transistor regulators**

   – in different types concerning to the types of alternators and the various manufacturer

3. **Hybrid regulators**

Transistor regulators

Transistor regulators got developed in terms of several demands concerning service life, regulating accuracy and maintenance freedom. These types of regulators **do not have mechanically moving parts** and therefore also not such contacts. The transistor regulators are in modern vehicles standard equipment and mostly built into the alternators.

The transistors gets always again to the working phases "switched" on and off in order **to control the alternator voltage output by regulating the alternator field current**. The most important elements are **transistors** and **zener diode**. What are the **advantages of these breakerless transistor regulators**?

The main points are:

– shorter switching times and electronic temperature compensation permit narrow regulation tolerances;

– there is no wear possible and this maintenance–free;

– high switching currents allow a reduction in the number of types;

– spark–free switching prevents radio interference;

– insensitive to shock, vibration and climatic effects;

– compact construction permits mounting on the alternator while regulator and brush holder are forming a unit.

All these are points for a **high reliability** and a **low failure rate** making the recharging unit safer under also difficult conditions.

Transistor

The transistor has the **function to switch the excitation current rapidly** with the **two phases "on" and "off"**. As well **higher currents can be handled**. A transistor is **very compact,** has **no mechanically moving parts** and is as well **maintenance free**.

Zener diode

This is a special type of diode named developer.

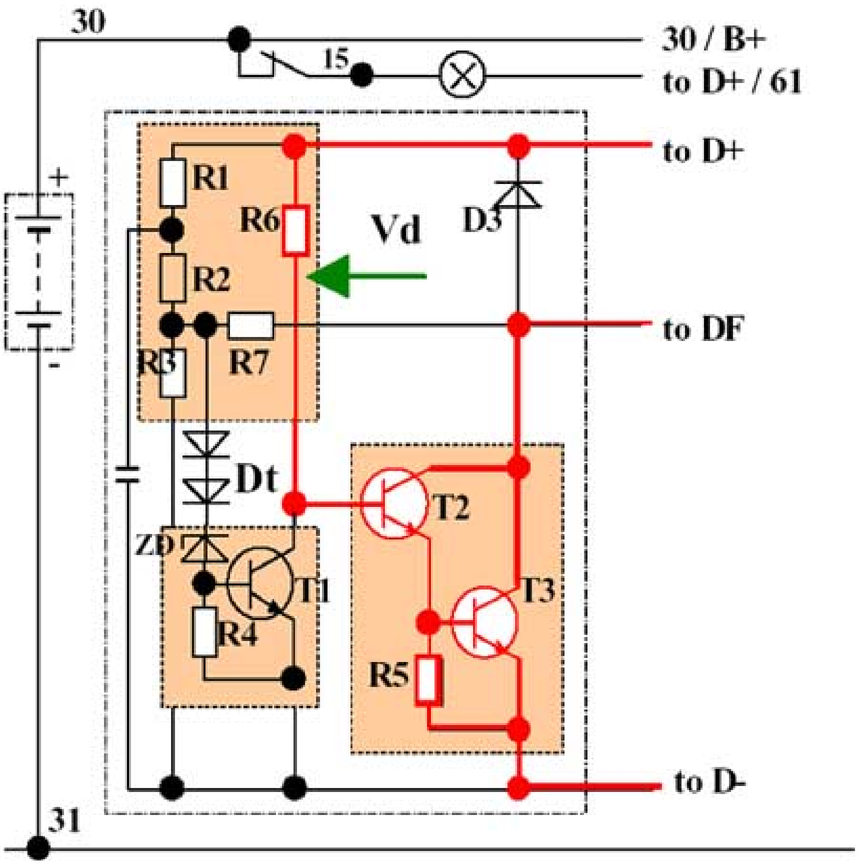
Zener diodes are in the regulators in order to **control the transistors**. Semiconductor diodes do not form an absolute barrier in the reverse direction.

When the breakdown voltage is exceeded then the **breakdown current raises** suddenly and steeply. If this **breakdown current is excessive**, **a normal diode can be destroyed**. **This situation is covered by the zener diode.**

Operating principles

Condition "ON": As long as the actual value is below the set value of the alternator and as long as the breakdown voltage of the zener diode is not reached! **no current flows in the circuit containing the zener diode**. **No current can reach the base of the transistor** (1) because **the zener diode is in nonconducting state**.

But with the transistor (1) **a control current can flow from the exciter diodes and terminal "D+" over a resistor to the base of the transistor (2) and switch it on**. **Transistor (2) closes** now **the connection between terminal "DF" and the base of transistor (3)**. **Excitation current flows now through the transistor (3) and increases during "on"–time, raising up the alternator voltage. At the same time** there is as well a **raising up in the voltage across** the **voltage divider and** the zener diode.



ON – condition

R – Resistors

T – Transistors

ZD – Zener diode

Dt – Temperature compensation diodes

D3 – Decay diode

Vd – Voltage divider

Condition “OFF”: When the **voltage exceeds the set value**, **the zener diode starts to conduct**. This goes on **when the breakdown voltage is reached**.

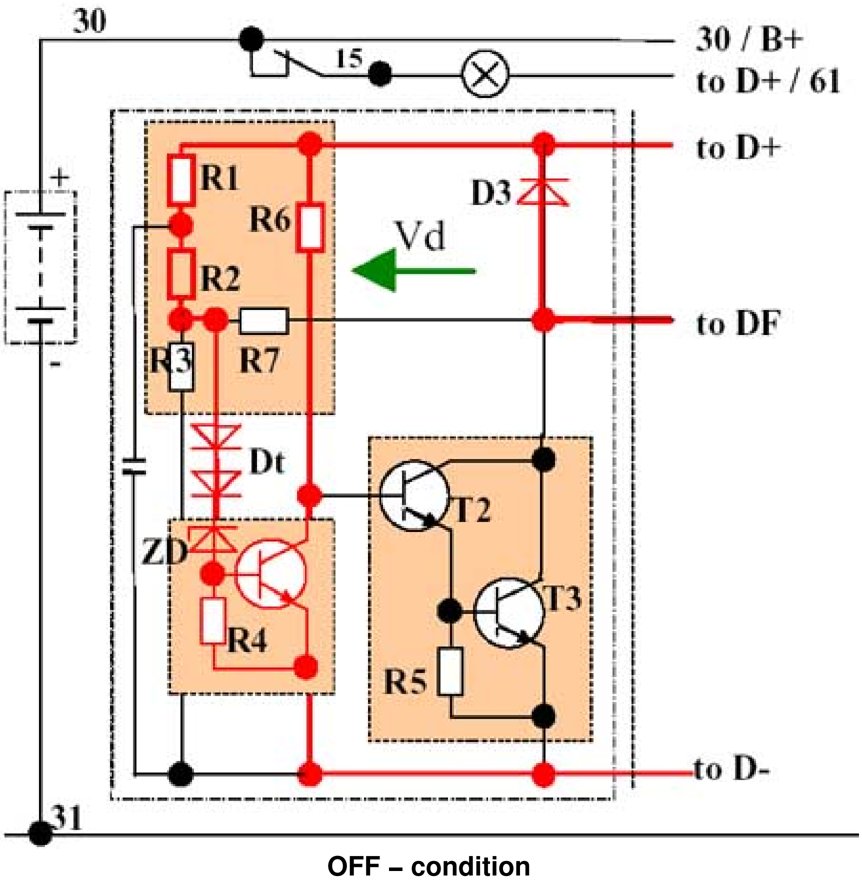
The **current flows** now **from terminal “D+” over the resistors** 1, 2 and 4 and **the zener diode** to the **base of transistor** (1). **The transistor conducts**.

Therefore **the voltage** at the base **of transistor (2) drops down to zero** with respect to the emitter and so the **base– current stops flowing**. Now the **transistor (2)** and **(3)** are **blocked**.

The **excitation circuit is suppressed and the alternator voltage drops**.

To avoid destroying of the transistors (2) and (3) –– as a **result of a voltage peak due to self–induction of the excitation winding** –– there is connected in parallel to the excitation winding a **“free–wheeling diode” (decay diode) to discharge the (decaying) excitation current**.

As soon as **the alternator voltage is below the set value and the zener diode has returned to the nonconducting state**, the excitation current is switched on again.



OFF – condition

R – Resistors

T – Transistors

ZD – Zener diode

Dt – Temperature compensation diodes

D3 – Decay diode

Vd – Voltage divider

The different types of regulators follow up in the end the same operating principles. The regulator must match the electrical system of a motor vehicle and must the voltage keep constant by different rotation speed and load situations.

And so **the "ON"/"OFF" ratio depends on the rotation speed** of the alternator and on **the load current**.

Often an **attached capacitor** can **smooth further the rippled DC–alternator voltage**.

Temperature influence

A further point is important to look for as well.

The **charging current must be higher in cold weather than in hot weather** concerning to the needs of the attached battery into the motor vehicle.

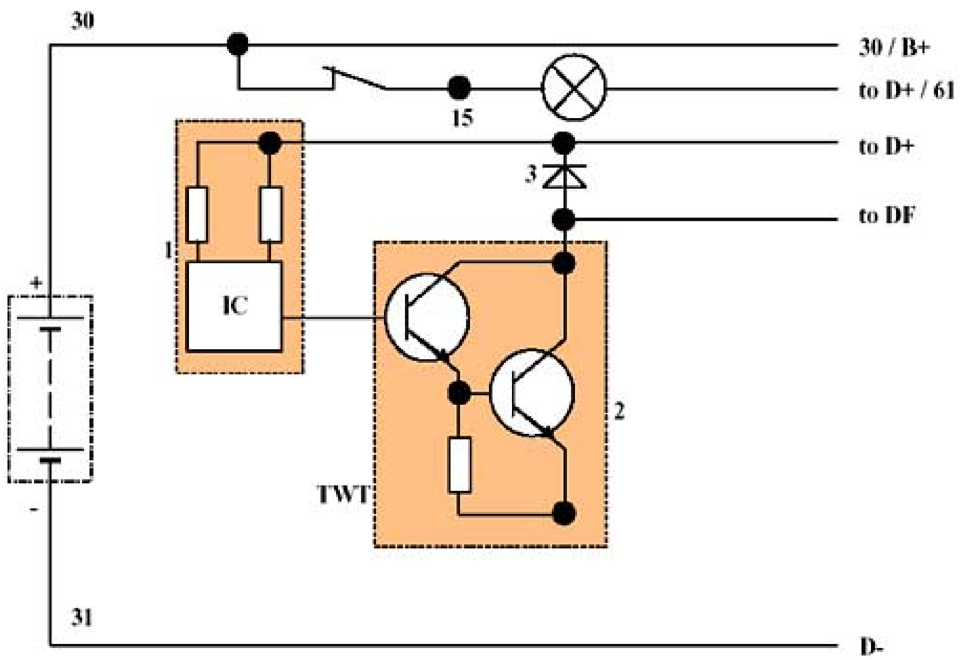
To meet the requirements, the **transistor regulators are provided with electronic temperature compensation**. For reaching that temperature compensation is used the zener diode, the resistors and the diodes "D1" and "D2" connected in forward direction.

Hybrid regulator

A **hybrid regulator** is further developed out of the transistor regulator. The main part of a hybrid regulator is an **integrated circuit (IC)**. The IC combines all the control functions:

- comparison of set and actual values (control stage)
- temperature compensation
- triggering of the output stage.

This **technique allows a very compact construction** by using a ceramic plate ––to make the arrangement of the components such as capacitors and resistors––, film techniques, integrated circuits and of course transistors. Near the very **compact construction** the remarkable points for the use of hybrid regulators are to see in the **few components and connections** and therefore allowing a **high production rate** and very important, the **high reliability by extreme operating conditions**.



IC – Integrated circuit

1 – Thick film substrate with IC control stage and resistors

2 – Power stage TWT

3 – Decay diode

Over–voltage protection

It is usually not a need for additional **protection against over–voltage** concerning the electronic components. The **battery** it self **with its very low internal resistance damps all the occurring voltage peaks** in the electrical circuits of the motor vehicle. But **in several cases** it can be **dangerous without protection for diodes**, **transistors** and **thyristors** in any of the built in electronic equipment inside a motor vehicle. It can lead to **punctures in the thin semiconductors** and in the insulating films. The **result may be operation failures or completely destroying** of those components.

For example in the case of a regulator failure overvoltage may occur. The **ignition system** may have an **influence** as well. When such equipment like **electric motors** get **switched off**, **lose contacts appear** or wires get broken then there **are possibilities of voltage peaks**. The **electronic components** like **diodes have to be secured against voltage** what can reach **up to 350V** (concerning the ignition system). **Over–voltage protection is also indicated** when the motor vehicle is **without connected battery** (by transport, during service etc.).

The **zener diode protects effectively** and on a simple way the electronic components in the alternator. For that reason the **zener diode is connected between the terminal "B+" and the ground**. But the connection is **in reverse direction to the battery voltage**. Voltage peaks are limited to about 30V in case of 12V systems. **In addition** can be **used a capacitor** also connected between "B+" and ground by getting voltage peaks up to 400 V.

Let's remind what was said to the so–called **decay diode** (see page 54 "Condition off") concerning the voltage peak generated in the excitation winding. This diode works therefore as well as **a component for over–voltage protection**.

Further equipment (with windings) like any kind of relays, electric motors, magnetic clutches etc. can **a similar effect of voltage peaks** let occur**. To avoid danger** for the semiconductor devices in the electrical system is **in addition a decay diode connected**.

Alternator cooling

The alternator is inside a motor vehicle to find direct near the engine. The **engine** is hot and so it heats up as well the alternator. The **radiation** of the alternator it self has of course an influence too. So, it is to ensure that the alternator works properly and for this reason **the alternator must get cooled**. The temperature should **not** be **higher than 70 up to 80° C**. The ventilation must be ensured by the **use of a fan** in order to cool the alternator and (very important) the diodes. Working on that system for any reason means therefore for an auto–electrician to ensure this situation. To do so means: **using the right fan and not any one**, **controlling the tension of the V–belt and cleaning the alternator from dust and dirt** what can easily come into the alternator especially by driving in wetness and on gravel roads.

System inspection and checks

There should be a regularly inspection followed up concerning to the recommended intervals from the manufacturer. But in modern alternators the maintenance is minimised by the **use of pre–lubricated rotor bearings and long brushes.** So we can expect a running of the alternator without problems over 100,000 up to 200,000 km if there are not extremely situations for the recharging unit. It is always a good decision to **check first** of all **the battery's state of charge** and the **condition of all the cables and their proper**

connection from the side **of the starting and charging systems**. Then is to go on with the necessary electrical tests of the charging system.

1. Drive end shield

– cracks on the shield,
– sit of the bearing,
– mouthing of holes.

2. Slip–ring end shield

– cracks on the shield,
– sit of the bearing,
– mouthing of holes,
– sit/threads of the brush holder/regulator unit,

3. Brush holder/regulator

– cracks on the holder,
– brush spring tension,
– length and leads of the brushes,
– leads on the regulator.

4. Rectifier assembly

– cracks on the heat sinks,
– sit of the pressed diodes,
– function of the diodes.

5. Stator

– rub marks on the core,
– insulation of the windings.

6. Rotor

– rub marks on the claw poles,
– wear on the shaft,
– rotation marks on the shaft,
– wear of the slip rings,
– sit of the bearings,
– lubricating of the bearings,
– insulation of the winding.

7. Fan and pulley

– wear on fan and pulley,
– bent flanks on fan and pulley,
– tightened sit of fan and pulley.

Check for tightness of all the **mounting bolts** (good ground connection).

Check the **V–belt** of the right size and for wear.

Check the alternator outside for **dust and dirt**.

Test the **alternator output**.

Working with care

• **Avoid reverse polarity** by doing any battery service. In that case the **diodes can be damaged**.

• When wires get disconnected or when the test leads get connected **the system should never get shorted**.

– Grounding the field terminal leads to the **damage of the regulator**.
– Grounding of the output terminal leads to **damages in the alternator and regulator**.

• The **alternator is never to operate in an open circuit**. If there is no battery or electrical load the alternator can build up a **high voltage up to 120V**. Out of this the **diodes can be damaged** and this situation is **dangerous for your health**.

• You should **never try to polarise an alternator**. There is no need to do so. It can further lead to **damages of the diodes and other components**.

By having a problem on a charging system, there are to do some **small checks before** for instance removing the alternator out of the motor vehicle:

– **Check the V–belt** of functioning without slipping by having the right tension.

– **Check charging indicator lamp** on the dashboard; it should work when the ignition switch is switched on and as long as the engine isn't running.

– **Check all the wires of proper connection** by being not corroded or burnt.

– **Measure the current output** by connecting an ammeter in series between the alternator output terminal and the positive terminal of the battery. If there is existing a problem then should be followed up a **circuit resistance test**. It is to find out whether the problem exists in the insulated circuit, the ground circuit or the alternator in general.

– **Insulated circuit resistance test:** The voltmeter is to connect across each insulated circuit connection. The charging system is to test under load. If the voltage exceeds the specification of the manufacturer then the connection has an excessive resistance.

– **Ground circuit resistance test:** One lead of the voltmeter is to connect to the negative battery terminal and the other voltmeter lead to the alternator housing. The voltage reading should appear concerning the specification of the manufacturer.

– Measure the voltage output in two steps:

1) Connect the voltmeter in parallel with the negative lead to the ground and the positive one to the output terminal. Follow up the readings according to the specification of the manufacturer.

2) Connect the voltmeter in parallel with the negative lead to the ground and the positive lead to the positive terminal of the battery. The readings should be nearly equal if there is not an excessive resistance. Concerning to the specification of the manufacturer by having 12V systems the **charging**

voltage will be between 13,8V and 14,8V.

Alternator removal

If there is finally a need to remove the alternator then it must be done by following up the these steps:

1) **Ignition switch** must be **switched off**.
2) **Negative connection** is to **remove from battery**.
3) The **leads from** the **alternator** are **to disconnect**.
4) **Unscrew** the **mounting bolts** (mostly three).

Alternator disassembly

Hold your **workplace in order** also then **when you are in the process of the work**. **Disassemble** the alternator **by being concentrated and knowing clearly how to reassemble** again. A last step by disassembling is **cleaning of the separated parts**. All **the disassembled parts and components** must get **kept for further procedures** on a save place on your workbench. Work carefully by means it is to clean, to keep and to handle on the right way but it is nothing to destroy. In the end all parts must be cleaned and dry for the ongoing tests.

Alternator tests

Rotor tests:

Testing the rotor for an open circuit, connect the test lamp leads to each slip ring. The test lamp should work. If the lamp fails to work then the circuit is open and therefore not operable.

Testing the rotor for a short circuit, connect one lead of the test lamp to the rotor shaft and the other one to one slip ring. If the lamp works then there is a short circuit between the winding and the shaft.

Stator tests:

Testing the windings for an open circuit the test lamp is to connect to each of the stator leads in turn and thereby two at the time. If the lamp does not work then there is an open circuit in a winding.

Testing the stator windings for a short circuit, the test lamp is to use by connecting one test lamp lead to the stator core and the other one to each of the stator leads. When the test lamp works then that winding has the failure to be connected to the ground.

Diode tests:

For **positive diode tests** is to connect one test lead to the output terminal of the alternator and the other one to the metal strap or pin of each positive diode in turn. Having a tester by showing the results as well in zones (good or bad) then the pointer should be on the good side and the value should be relatively equal.

For **negative diode tests**, one test lead is to connect with the heat sink and with the other one is to touch each negative diode in turn by getting again the same results as by the positive diodes if they are in order. By **testing separate diodes** there is to bring one test lead to the diode base and the other one to the diode lead. In one direction the test lamp should work while in the reverse direction the lamp shouldn't. If in both of the test procedures the lamp works then the diode is shorted. If the lamp doesn't work at all then the diode is open circuit.

Testing equipment

Those where the easiest ways to test basically components of the alternator. Depending on the different situation of workshops there can be more and very **varying testing equipment**.

For example the **combination of volt and ammeter and in addition a loading resistor and alternator tester** for testing diodes, rectifier assemblies, stator windings and rotor windings.

There are available as well the so−called **compact tester**. Also they can be used for alternator tests and in addition as motor tester, for the ignition system and as exhaust−gas analyser.

An **alternator test bench** is usable for all the necessary testing procedures of the alternator−regulator unit. In connection with this tester is the possibility to speed up the alternator and therefore the tests can go on under vary conditions. Of course the separated components of an alternator can be tested as well.

The surely best solution for a bigger workshop is the **combination test bench** for alternators and generators, diodes, starter motors, ignition distributors and ignition coils. But every workshop must decide what is the really need of what testing equipment and so it must suit for the purpose of the specified workshop.

By testing with the different equipment must definitely followed up the right steps by doing the tests. It should be always taken care not to damage any component by testing and therefore is strictly to handle like the given procedures from the manufacturer of the testing equipment. To ensure a long service life of the testing equipment always any test should be done only, when a responsible person is nearby.

Alternator reassembling

After all the tests are done and the may be defective parts are replaced as well as all the parts of the alternator are cleaned up and the bearings are lubricated the **alternator can be reassembled**. By doing this is to follow up the **reverse order of disassembling**. Care has to be taken to **make all the connection right and tighten all bolts properly**.

Troubleshooting

Charging indicator lamp is flickering:

– Alternator V−belt is loose or worn out
– Loose or corroded wiring connection
– Loose or corroded battery cable clamps/terminals
– Poor ground at alternator/regulator
– Defective regulator
– Faulty alternator

Charging indicator lamp works continuously:

– Loose, worn out or broken V−belt
– Open or grounded wire from battery to alternator
– Corroded/loose battery cable clamps/terminals
– Grounded field circuit
– Defective regulator
– Faulty alternator (rotor, stator, diodes, brushes)
– Malfunction in other electrical systems

Charging indicator lamp doesn’t work by switching on the ignition lock:

– Bulb is blown up
– Battery is discharged or defective
– Leads loose or defective
– Regulator defective
– Short circuit of a diode (positive) in the alternator
– Carbon brushes worn out
– Oxide surface on the slip rings
– Open circuit in excitation winding

Low charging/unsteady charging:

– Excessive charging circuit resistance
– Corroded or shorted cables
– Excessive carbon brushes or slip rings
– Defective alternator diodes
– Open stator winding

Excessive charging:

– Defective regulator
– Grounded alternator field wire, field terminal or connections
– Internally grounded alternator field

Lights and/or fuses burn out:

– Too high alternator output
– Defective wiring in charging circuit
– Defective regulator
– Grounded alternator field wire, field terminal or connections
– Internally grounded alternator field

Noisy alternator:

– Loose or worn out V–belt
– Bent pulley flanges
– Loose alternator mounting
– Worn out/defective alternator bearings
– Interference between rotor fan and stator leads
– Open or shorted diodes
– Open or shorted wiring in the stator