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AUTOMOTIVE POWER TRANSMISSION UNITS

April 10, 1941

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AUTOMOTIVE POWER TRANSMISSION UNITS

Prepared under direction of
The Quartermaster General

SECTION I

GENERAL

1. General.—*a.* This manual describes the functions and operating fundamentals of all the usual devices employed in transmitting the power of the engine to the wheels of a motor vehicle, as well as the several power take-off devices sometimes used. These units include clutches, transmissions, auxiliary transmissions, transmission driven accessories (winches, hoists, and special power take-off equipment), transfer cases, propeller shafts, universal joints, final drives, differentials, live axles, devices for resisting drive torque and thrust, and the bearings used therein.

b. A knowledge of these units is essential to the intelligent operation, maintenance, and repair of the motor vehicle.

c. The more common elements of the power transmission system assembled in their proper relation are shown in figure 1. The transmission, sometimes referred to as the change gears, is driven by the

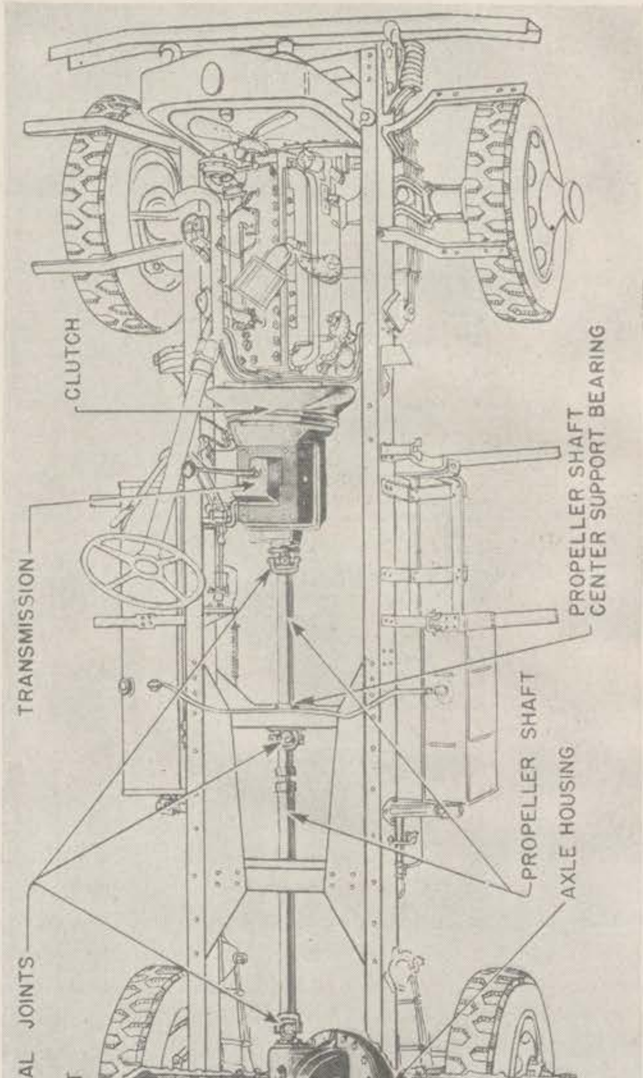


FIGURE 1.—Type of power transmission system.

engine through the clutch and enables a vehicle to operate over different types of roads at different speeds with varying loads by changing gears. Power is transmitted from the transmission to the rear or driving axles by the propeller shaft, universal joints, final drive, and differential.

2. Terminology.—For purposes of clarity and ready reference, the following terms are defined:

Acceleration.—The average rate of change of an increasing velocity or speed, as feet per second per second. The opposite of deceleration.

Angular velocity.—The rate of angular motion, usually expressed in degrees, revolutions per second, or revolutions per minute (r. p. m.).

Automotive.—Self-propelling; hence pertaining to vehicles or machines such as automobiles, motorcycles, airplanes, or motor boats.

Axial.—In the direction of the axis.

Axis.—A center line. A line about which something rotates or about which it is evenly arranged.

Bearing.—A part in which a journal, pivot, or pin turns or revolves. A part on or in which another part slides.

Bevel gear.—One of a pair of meshing gears whose working or pitch surfaces are inclined to the center lines of the driving and driven shafts. The pitch surface is a portion of a cone.

Body.—A mass or portion of matter distinct from other masses, as a moving body.

Bogie.—A unit consisting of two axles joined by a single crosspiece (trunnion axle). Generally used with the rear four wheels of a six-wheeled vehicle.

Bronze.—An alloy consisting essentially of copper and tin.

Bushing.—A detachable lining of bronze, babbit, or other anti-friction metal used as a bearing for a shaft, spindle, or pivot.

Centrifugal force.—The force acting on a rotating body which tends to throw it away from its center of rotation.

Compression.—Act of pressing into a smaller space or reducing in size or volume by pressure.

Concentric.—Having the same center, as circles or spheres, one within another. Opposed to eccentric.

Deceleration.—The average rate of change of a decreasing velocity or speed, as feet per second per second. The opposite of acceleration.

Energy.—Capacity for doing mechanical work, usually measured in foot-pounds.

Foot-pound.—The work done in lifting 1 pound 1 foot. A measurement of energy, work, or torque.

Force.—The action that one body may exert upon another to change its motion or shape. Forces between bodies are always equal in amount and opposite in direction. Forces are measured in pounds.

Friction.—The resistance to relative motion between two bodies in contact. If the bodies are in sliding contact, the resistance is called sliding friction; if they are in rolling contact, it is called rolling friction.

Fulcrum.—The support, as a wedge-shaped piece or a hinge, about which a lever turns.

Gear ratio.—The ratio at which gears can transmit speed or torque. When speed is increased, torque is decreased, and vice versa. For example, a 60-tooth gear driving a 12-tooth gear gives a ratio of 1 to 5, which means that the driven gear revolves five times as fast as the driving gear, increasing speed and reducing torque. On the other hand, a 12-tooth gear driving a 60-tooth gear gives a ratio of 5 to 1, which means that the driven gear revolves five time as slowly as the driving gear, increasing torque and decreasing speed.

Heat.—A form of energy.

Helical.—In the shape of a helix, which is the shape of a screw thread or coil spring.

Herringbone gear.—A gear with double helical teeth inclined in opposite directions from the center of the face.

Horsepower.—A unit for measuring power, which is 550 foot-pounds per second or 33,000 foot-pounds per minute.

Idler gear.—A gear placed between a driving and driven gear to make them rotate in the same direction. It does not affect the gear ratio.

Integral.—Part of the same piece. An integral part as distinguished from a separate part that is fastened on.

Jack shaft.—An intermediate driving shaft.

Member.—Any essential part of a machine or structure.

Meshing.—The mating or engaging of the teeth of two gears.

Pilot.—A short plug at the end of a shaft to aline it with another shaft or rotating part.

Pinion.—The smaller of two mating or meshing gears.

Poppet.—A spring loaded ball engaging a notch. A ball latch.

Power.—The capacity to do work or the rate at which it is done. It is measured in horsepower.

Radial.—Originating from or acting upon a common center, as the spokes in a wheel.

Ratio.—The numerical relation between two things expressed as the division of one quantity by the other. Thus the ratio of 48 to 12 is represented by 48/12 or 48:12, or 4 to 1, as in gear ratio.

Reaction.—An opposing force.

Rotating.—Turning or revolving.

Shackle.—A swinging support for the end of a spring that permits it to vary in length as it deflects.

Solenoid.—A coil of wire that has magnetic properties when an electric current is passed through it.

Spider.—A part consisting of a ring or solid center with projections outward used to space and aline adjoining parts.

Spiral bevel gear.—A bevel gear having curved teeth.

Spline.—A series of parallel keys integral with a shaft, mating with corresponding grooves cut in a hub or fitting.

Spur gear.— A gear having straight teeth.

Strain.—A deformation or change of shape resulting from stress.

Stress.—The forces exerted on, within, or by a body during tension or compression. The opposing reaction of the interior elements of a solid body against forces tending to deform it.

Synchronize.—To make two or more events or operations occur at the proper time with respect to each other.

Tension.—A stress caused by pulling.

Thrust.—A force tending to push a body out of alinement. A force exerted endwise through a member upon another member.

Torque.—A twisting or wrenching effort. Torque is the product of force multiplied by the radial distance from the center of rotation to the point at which it is applied. It is usually measured in foot-pounds.

Torsion.—The act of twisting or the state of being twisted. The deformation of a body caused by twisting.

Trunnion.—Either of two opposite pivots or cylindrical projections from the sides of a part or assembly, supported by bearings, to provide a means of swiveling or turning the part or assembly.

Velocity.—The rate of motion or speed at any instant. Usually measured in miles per hour or feet per second or minute.

Vibrate.—To move back and forth unceasingly over the same path; generally said of the rapid succession of motions of the parts of an elastic body.

Work.—The energy expended to overcome resistance.

Worm.—A short revolving screw, the threads of which mesh with the teeth of a worm gear.

Worm gear.—A gear having concave, helical teeth that mesh with the threads of a worm. Also called a worm wheel.

Section II

CLUTCHES

3. Purpose.—The purpose of a clutch in a motor vehicle is twofold. First, it provides a means of disconnecting the power of the engine from the driving wheels. When the clutch is disengaged by the operator, the engine can run without driving the vehicle. This is made use of when gears are shifted and when the vehicle is stopped after applying the brake. When a vehicle stands for long periods or when the operator leaves it and therefore cannot keep the clutch pedal depressed, the same result can be obtained by placing the transmission in neutral and engaging the clutch. A gasoline engine develops but little power when running at low speed. It takes considerable power to start a vehicle, especially uphill. Means must therefore be provided to allow the engine to run at a sufficiently high speed to develop enough power to start a vehicle and at the same time apply this power to the wheels without jerks and without stalling the engine. Therefore, when a vehicle is started, the clutch allows the engine to take up the load of driving the vehicle gradually and without shock.

4. Operation.—Clutches generally transmit power from the clutch driving member to the driven member by friction. This is accomplished by bringing one or more rotating driving members, secured to the crankshaft, into gradual contact with one or more driven members, secured to the unit being driven, which are either stationary or rotating at a different speed. This contact is established and maintained by strong spring pressure controlled by the driver through the clutch pedal and suitable linkage. As the spring pressure increases, the friction increases. Therefore when the pressure is light, the comparatively little friction between the members permits a great deal of slippage. As the spring pressure increases, less slippage occurs. When the full spring pressure is applied, the speed of the driving and driven members is the same, all slipping stops, and there is in effect a direct connection between the driving and driven shafts.

5. Clutch facings.—The driven members of a clutch are usually faced with a frictional material to assure sufficient friction for a

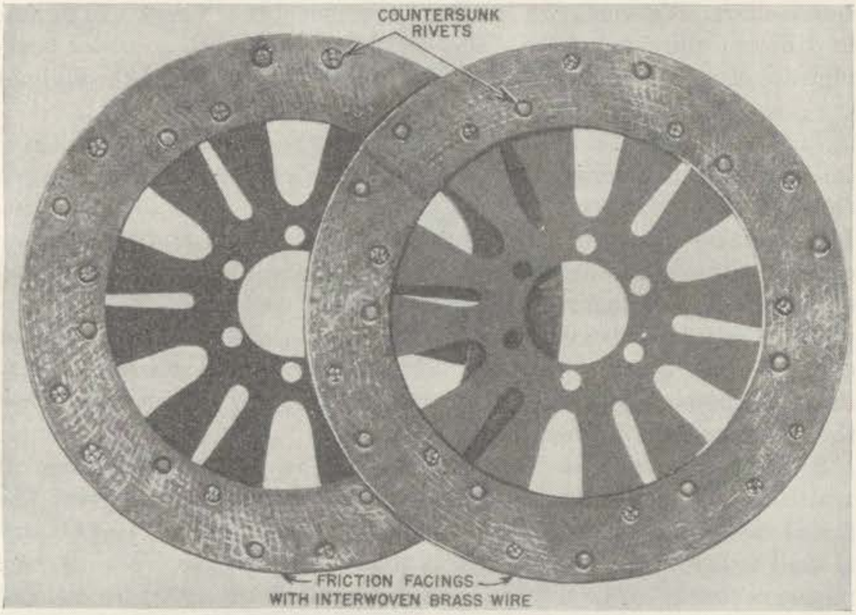


FIGURE 2.—Clutch facings of asbestos fiber interwoven with brass wire riveted to clutch-driven members.

smooth positive drive. Since friction produces heat, the facing material should be heat resistant. Leather was formerly used extensively for this purpose, but since it will not withstand much heat without charring, it is not now used. Today the most usual clutch facings are molded or woven materials containing asbestos fiber. Sometimes brass wire is interwoven with the asbestos fiber to give it additional strength. Such materials are very similar to brake linings and have satisfactory frictional and heat resisting properties. Clutch facings are usually attached to clutch plates or disks by rivets as shown in figure 2.

6. Pilot bearings.—Pilot bearings are used in all automotive main clutches. The purpose of a pilot bearing is to maintain positive alinement between the clutch shaft and the engine crankshaft while allowing each to rotate independently. Probably the most usual pilot bearing arrangement consists of a needle bearing, held in a hole or cup in the rear end of the crankshaft, that supports the forward end of the clutch shaft. The end of the clutch shaft is reduced in diameter to fit into the needle bearing. Ball bearings and plain bronze bushings are sometimes used instead of needle bearings. In some types of clutches, the pilot bearing is formed by a projection of smaller diameter on the rear end of the crankshaft that enters a hole in the clutch shaft. Various pilot bearing arrangements are shown in figures of different clutches. Needle and ball bearings as well as roller bearings are classified as antifriction bearings. They are used throughout the power transmission train and are described in section VII.

7. Clutch release bearings.—Clutch release bearings, sometimes called throwout bearings, are important parts of all automotive main clutches. The function of the release bearing (figs. 3 and 4) is to transfer the heavy thrust of the clutch springs from the driving plate or disks to the clutch housing and clutch pedal while the clutch is disengaged. A ball thrust bearing is almost always used for this purpose. The release bearing is contained in the clutch release shoe, or clutch release bearing housing. It is moved by the release yoke to separate the clutch driving members from the driven members when the clutch pedal is depressed by the driver.

8. Plate clutch.—*a.* The plate clutch has three plates, one of which is clamped between the other two. Exploded and cross sectional views of a plate clutch are shown in figure 3. This type of clutch is used today in most passenger cars and light trucks. The driving members consist of the flywheel and the driving (pressure) plate. The driven member consists of a single plate, or disk, splined to the clutch shaft and faced on both sides with friction material. When the clutch is fully engaged, the driven plate is firmly clamped between the flywheel and the driving plate by pressure of the clutch springs, forming a direct, nonslipping connection between the driving and driven members of the clutch. In this position, the driven plate rotates the clutch shaft to which it is splined. The clutch shaft is connected to the driving wheels through the transmission, propeller shaft, final drive, differential and live axles.

b. When the driver disengages the clutch by depressing the pedal, the release yoke lever is moved on its pivot and pressure is applied to the release shoe containing the release bearing (nonrotating members) and the sleeve which rotates with the clutch assembly. The sleeve in turn presses against the three pressure levers and moves them on their

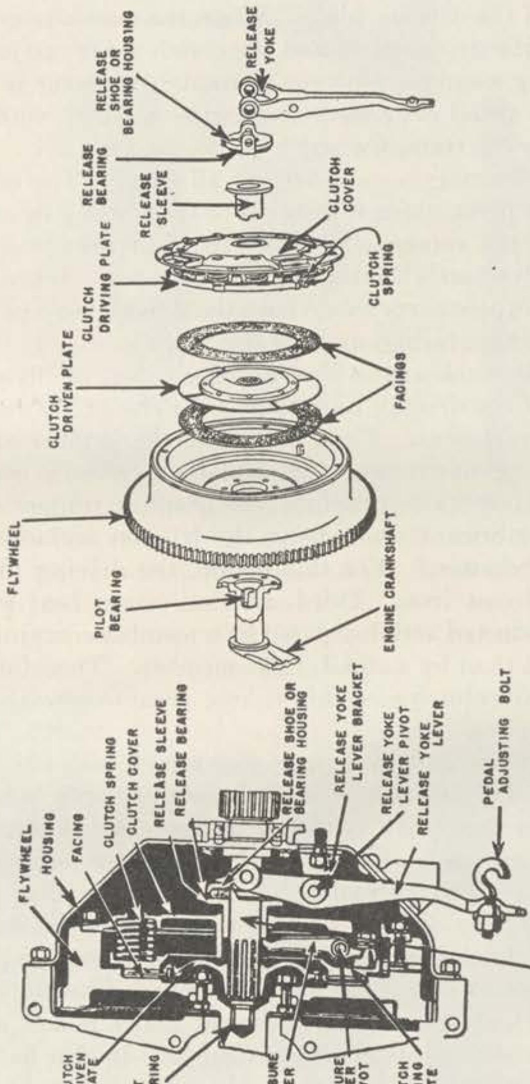


FIGURE 3.—Exploded and cross sectional views of a plate clutch.

pivots. The outer ends of the pressure levers are pivoted to the driving plate and force it back, compressing the clutch springs and relieving the pressure on the driven plate which is then left free between the flywheel and the driving plate. When the clutch is in the disengaged position, the driven plate and the clutch shaft can come to rest while the driving members continue to rotate. As long as the driver keeps the clutch pedal depressed, the engine will run without transmitting power to the transmission.

c. The clutch housing is stationary at all times. The release lever moves only on its pivot which is fastened to the housing by means of its bracket; it does not rotate. All other parts of the clutch assembly rotate with the flywheel when the clutch is engaged. When the clutch is disengaged, all these parts rotate with the flywheel except the driven plate with its friction facings and the clutch shaft.

d. In the plate clutch and in several other types, the flywheel itself is used as one of the driving members of the clutch. This is advantageous for three reasons. First, it reduces the number of parts required, simplifying construction. Second, the flywheel is usually made of cast iron which contains graphite; the graphite content of the cast iron provides a lubricant which helps the friction surfaces to engage gently without "chatter." For this reason, the driving plate is also usually made of cast iron. Third, friction causes heat and heat is more readily conducted and dissipated by a member containing a large amount of metal than by a small, light member. Therefore, in ordinary operation, the clutch assembly is kept from overheating without using cooling devices.

e. In some clutches, a diaphragm spring is used instead of a number of coil springs. This is a saucer-shaped piece of spring steel punched to give it greater flexibility as shown in figure 4. When the clutch is engaged, the spring is almost flat and its entire outer rim exerts pressure against the driving plate. Its action is similar to that of the botton of an ordinary oilcan. Figure 4 also shows the shape of the spring when the clutch is engaged and when it is disengaged.

f. Another popular clutch has a large number of pressure levers arranged in a circle which exert pressure at many points around the pressure plate when the clutch is disengaged. It also has one large coil spring at the center.

g. In an effort to make clutch engagement as smooth as possible and to eliminate "chatter", several methods have been used to give a little flexibility to the driven plate. One method (fig. 5) uses a plate punched to form spokes or segments. The plate is also dished so that the inner and outer edges of the facings make contact with the driving

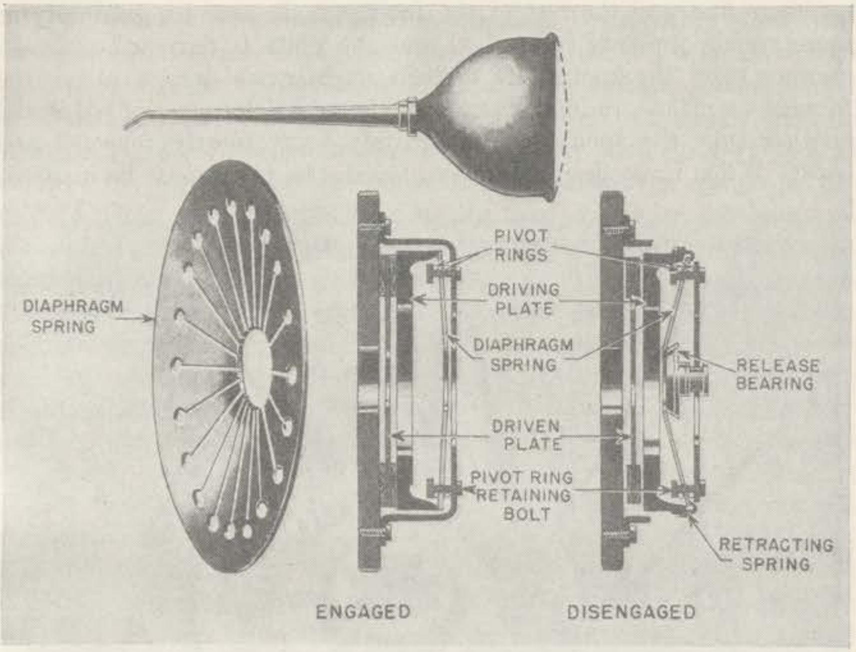


FIGURE 4.—Diaphragm spring for plate clutch operation.

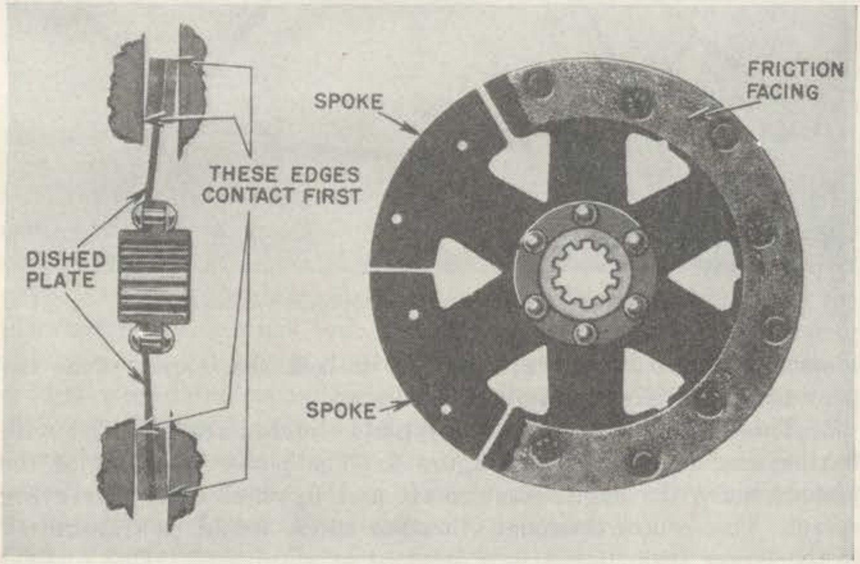


FIGURE 5.—Spoked and dished driven plate showing gradual contact with driving plate.

members first and the rest of the facings make contact gradually as more spring pressure is applied and the plate is flattened out. In another type, the spokes are twisted slightly which also causes the facings to make gradual contact as the plate flattens out. In still another type the spokes are alternately bent slightly forward and back. When these designs are employed, the plate must be made of

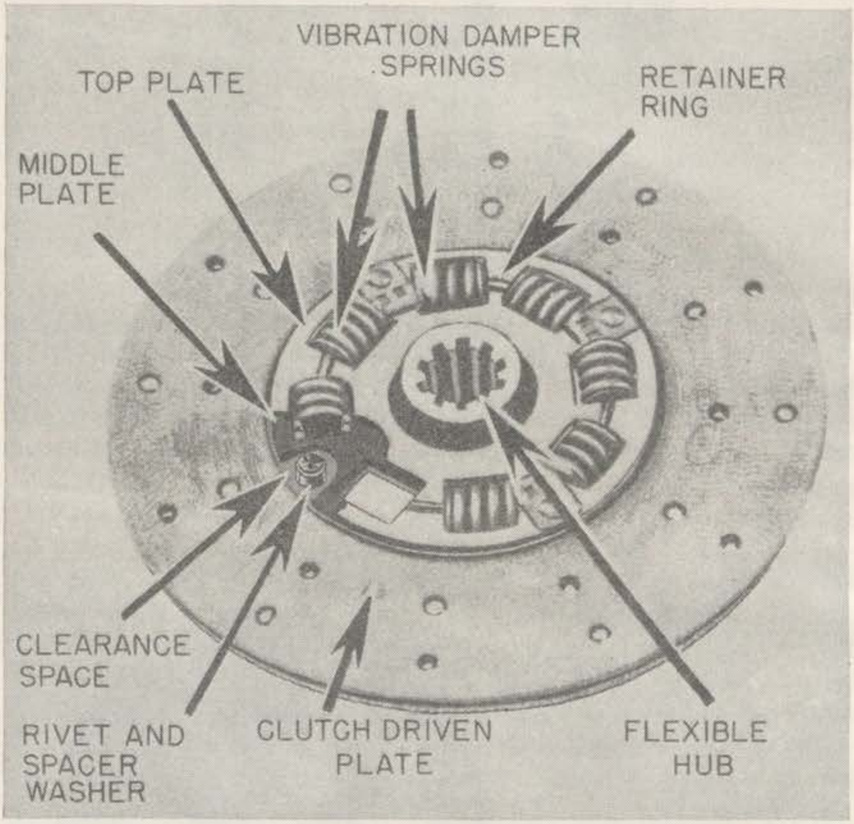


FIGURE 6.—Clutch driven plate with flexible center.

a spring steel so that it will resume its bent shape every time the pressure of the driving members is relieved.

h. The driven members in many plate clutches are provided with flexible centers as shown in figure 6. The power impulses of the pistons make the engine crankshaft and flywheel turn at varying speed. This causes torsional vibration which would be transmitted to the power train unless it is lessened or eliminated. One method of doing this is to provide the driven plates with flexible centers (fig. 6) which absorb much of this vibration by allowing some relative rotation between the driven plate and its hub. The large driven plate to which the facings are attached and the small top plate which is riveted to it are free to rotate around the hub. A smaller middle plate is rigidly attached to the hub. Rivets with spacer washers connect the top and bottom plates through clearance spaces in the middle plate. Coil compression springs are placed in slots punched through the three plates and retained in position by wire rings on both sides of the assembly as shown in figure 6. The driven plate turns slightly with relation to its hub until under extreme conditions the springs are fully compressed, when relative motion stops. Then the plate can rotate slightly backward as the springs decompress. This slight backward and forward rotation permitted by the spring connection between the hub and plate allows the clutch shaft to rotate at a more uniform rate than the crankshaft, thereby eliminating some of the torsional vibration and preventing it being carried back through the transmission. The springs are called damper springs because they damp or check the vibration.

9. Semicentrifugal clutch.—A variation of the ordinary plate clutch is the semicentrifugal clutch (fig. 7) which is used in several passenger cars. The three pressure levers in this clutch are provided with weights on their curved outer ends which fly outward as the engine speed increases. This causes the pressure lever to turn counterclockwise on its pivot, thereby pressing the needle bearing and the driving plate to which it is attached against the driven plate. The higher the engine speed, the greater is the pressure. This device permits the use of less total clutch spring pressure with a corresponding decrease in the pedal pressure necessary to declutch at low engine speeds. This is advantageous when it is necessary to hold the clutch pedal down for fairly long periods, as while waiting for a traffic light. Otherwise, the semicentrifugal clutch is very similar in construction and operation to the ordinary plate clutch.

10. Lubricated plate clutch.—A rather unusual variation of the plate clutch, which has been used in one passenger car for a long time, is shown in figure 8. This clutch has an oiltight case and runs in a light-bodied oil mixed with a small amount of oleic acid. In this respect, it is similar to the lubricated disk clutches described in paragraph 14*c*. The driven plate contains a large number of tempered cork inserts. These inserts are factory assembled and when worn out the entire plate must be renewed.

11. Cone clutch.—The cone clutch was the first type used in automobiles. It is now seldom used in motor vehicles, having been super-

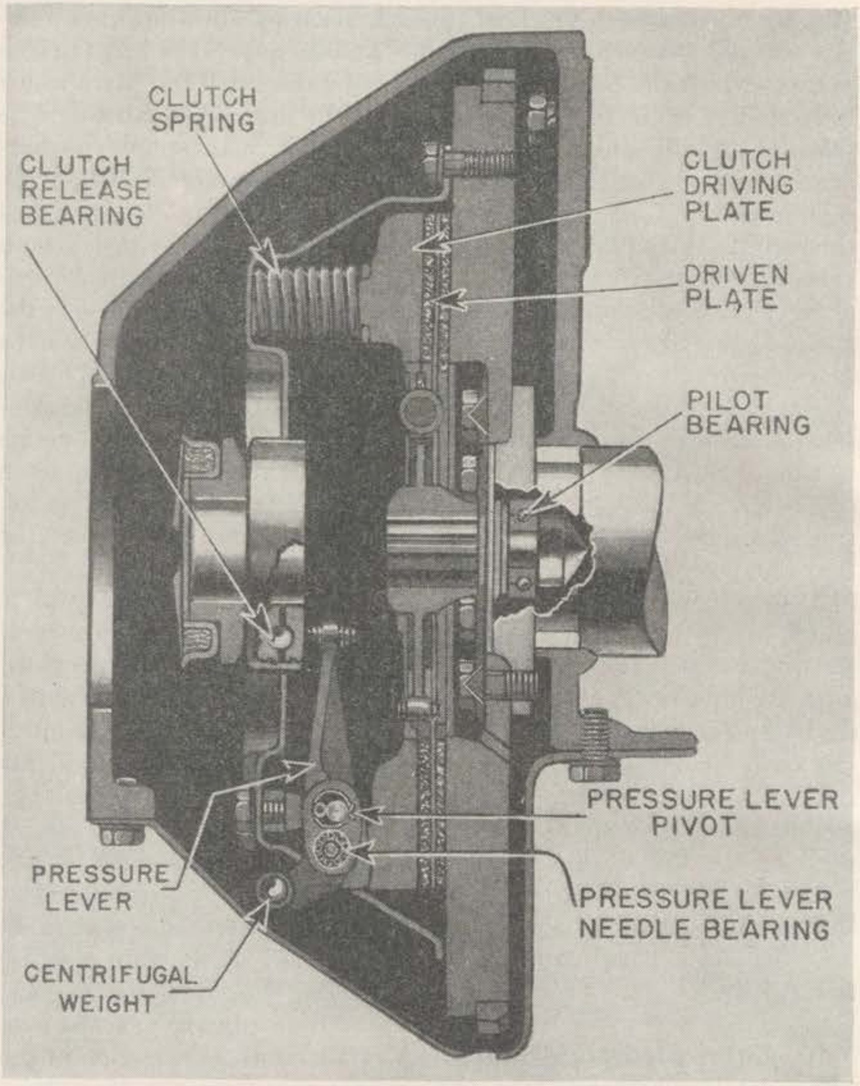


FIGURE 7.—Cross sectional view of semicentrifugal clutch.

seded by the plate and disk types. However, a small cone clutch having a metal-to-metal contact is used in the synchro-mesh transmission described in paragraph 26. The flywheel, which forms the driving member of a cone clutch, has the inside of the rim machined on a taper. The driven member, or cone, faced with friction material fits into the taper of the flywheel rim. The usual type of cone clutch is the direct cone in which the cone disengages from the flywheel away from the engine although the inverted cone and double cone types have had very limited use. In the inverted cone clutch, the cone is turned around the other way and disengages toward the engine. The double cone clutch is a back-to-back arrangement that is used only where very high power must be transmitted. A good idea of the arrangement of parts and operation of the simple, direct cone clutch may be gained from figure 9, which shows the combination plate and cone clutch.

12. Clutch brakes.—Clutch brakes are devices used to stop the driven members from spinning after the clutch is disengaged. Gears

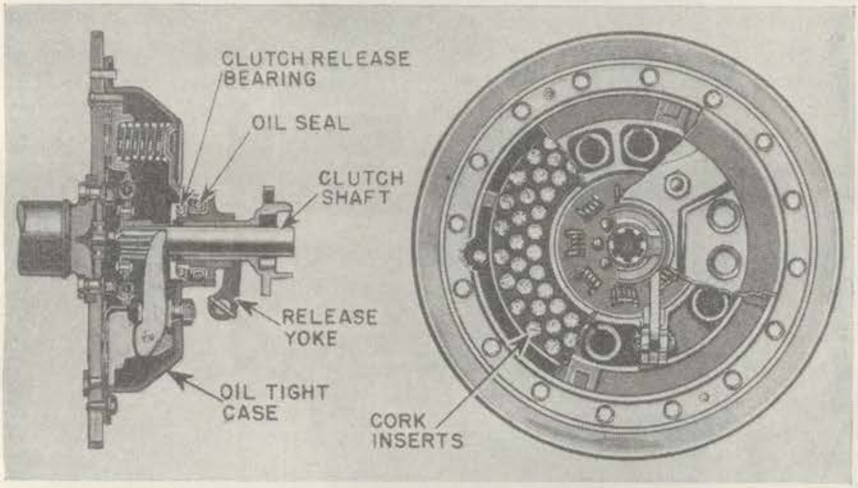


FIGURE 8.—Lubricated (wet) plate clutch with cork inserts in the driven plate.

can be shifted without clashing only when the teeth of the meshing gears are stationary or rotating at approximately equal speeds. Clutch brakes are not necessary with plate and disk clutches of small diameter, but they are sometimes used with large heavy clutches of this type. A clutch brake is simply a mating pair of disks or cones, one of which is faced with friction material. They are arranged so that one of the pair rotates with the driven member and one remains stationary. When the clutch is disengaged, the stationary member bears against the rotating member, under spring pressure, and stops it from spinning.

13. Plate and cone clutch.—The plate and cone clutch (fig. 9) combines the features of both the plate and direct cone clutches. It has a large friction area, will transmit high power, and is especially

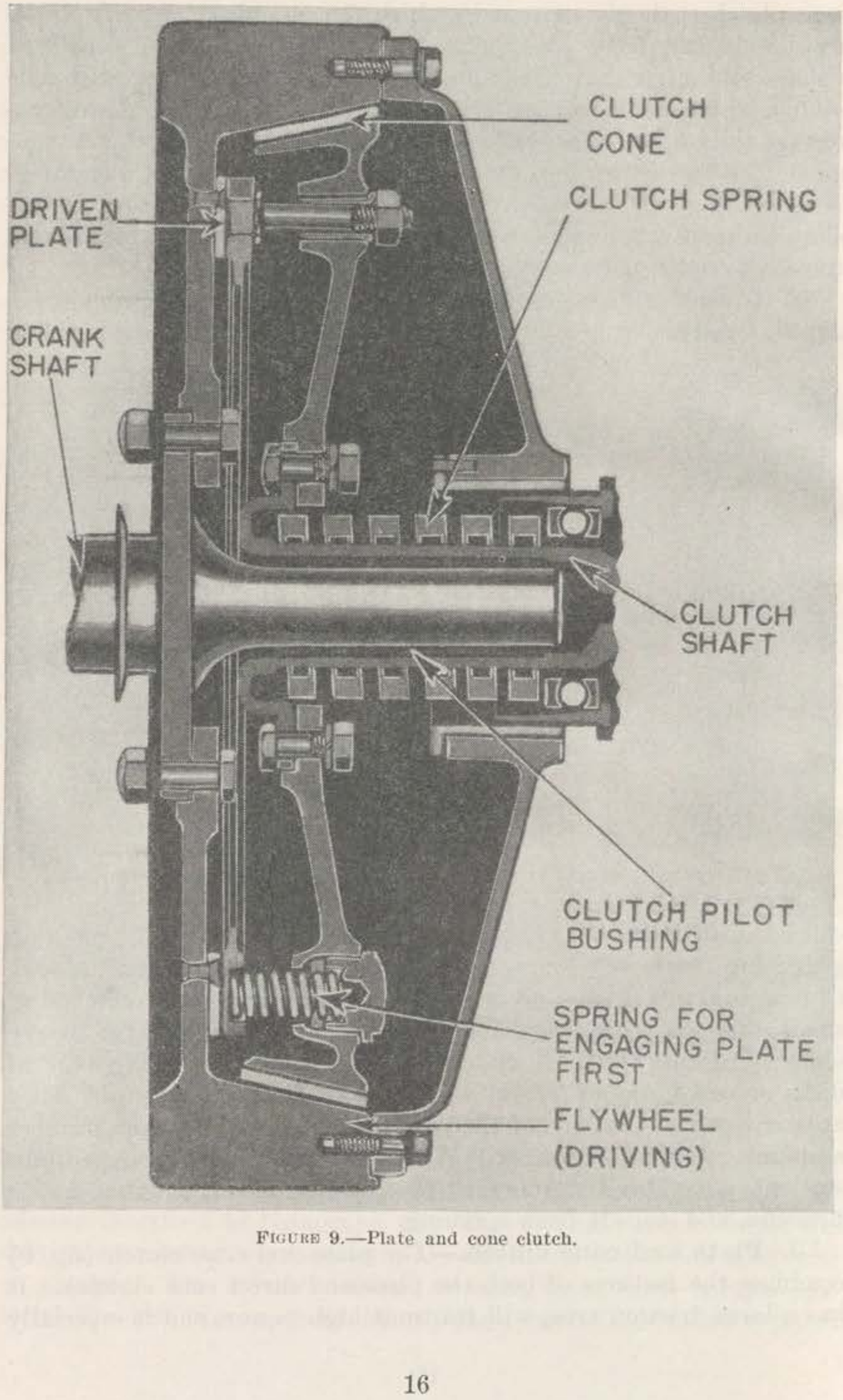


FIGURE 9.—Plate and cone clutch.

adapted to heavy bus and truck use. Springs between the plate and cone cause the plate to make contact with the flywheel before the cone. This particular clutch is disengaged by moving the entire internal assembly back away from the flywheel by means of a release yoke and bearing located to the right of the assembly, but not shown in the figure. The pilot bearing in this clutch consists of a reduced end on the crankshaft that extends into a bushing in the clutch shaft.

14. Disk clutch.—The disk clutch is one having more than three disks. It is used to obtain greater frictional area than can be had with a plate clutch of the same diameter and consequently it has a greater capacity to transmit power. It is often used on the heavier and more expensive passenger cars and on trucks. It consists of alternate driving and driven disks. The driving disks are rotated by the flywheel through a cylindrical housing which has inner splines or lugs that engage corresponding teeth on the rims of the disks. The driven disks are splined or otherwise connected to the clutch shaft. When the clutch is engaged, the disks are all pressed tightly together by the clutch spring. When the clutch is disengaged, the pressure is relieved and there is no longer sufficient friction for the driving disks to rotate the driven disks. Consequently the clutch shaft and driven disks can come to rest while the driving members continue to rotate with the engine flywheel.

a. A popular and simple form of the disk clutch, sometimes called a double plate clutch, is shown in figure 10. It is substantially the same as the plate clutch (fig. 3) except that another driven disk and an intermediate driving disk are added. The driving disk and pressure plate are connected to the flywheel by parallel pins. Both driven disks are mounted on the same splined hub in this case, although some manufacturers employ two separate hubs. The release mechanism is the same as that for the plate clutch.

b. A multiple disk clutch extensively used and suitable for transmitting high power, is shown in figure 11. A large number of disks are used, often as many as eleven driving and ten driven disks for heavy trucks. The driving disks have teeth around their outside edges, similar to gear teeth, that mesh with internal teeth in the clutch case which is bolted to and rotates with the flywheel. The driven disks are carried on parallel pins which are solidly set in the clutch spider. This construction permits movement of all the disks and the pressure plate in order to provide clearance between them. When the clutch is engaged, the spring presses the pressure plate forward, holding all the disks firmly together. This causes the clutch spider to revolve and turn the clutch shaft to which it is keyed.

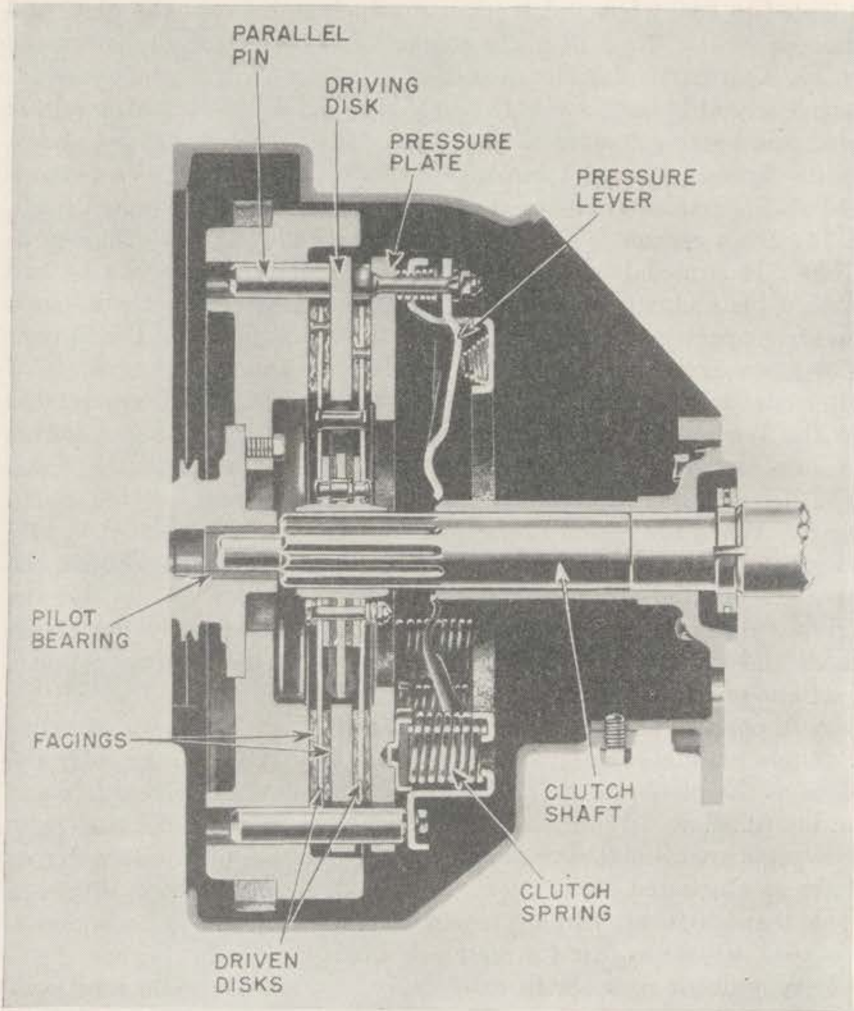


FIGURE 10.—Disk clutch with two driven disks.

When the clutch pedal is depressed, it acts through the release yoke and bearing, moving the pressure plate backward. This action disengages the vise-like grip of the driving disks upon the driven disks and allows the driven disks and clutch shaft to come to rest while the driving members continue to rotate. In multiple disk clutches, the facings are usually attached to the driving disks. This reduces the weight of the driven disks and consequently their tendency to continue spinning after the clutch is released. Because of the considerable number of disks involved, the pressure plate has to move

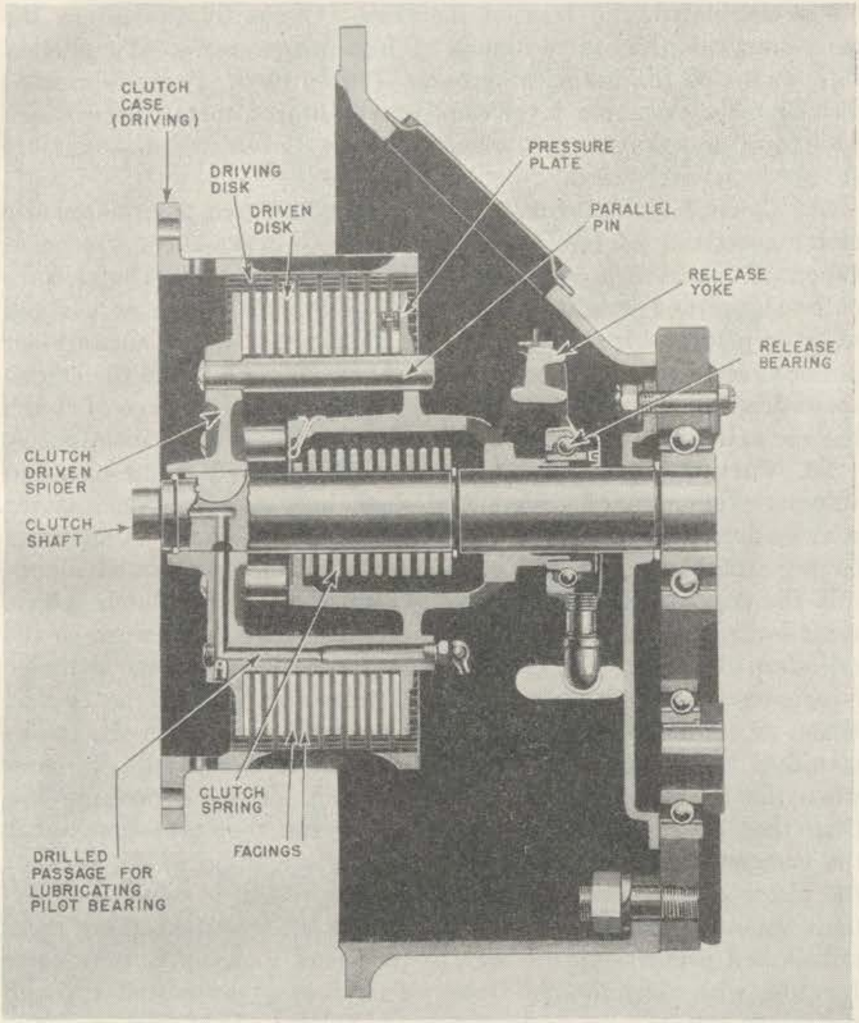


FIGURE 11.—Multiple disk clutch.

farther to separate the plates completely than it does in clutches having fewer driving and driven members. There is, therefore, less mechanical advantage on the clutch pedal and a greater foot pressure is required to depress it. The tendency to drag after declutching is somewhat greater than in single plate clutches.

c. In a lubricated disk clutch, sometimes known as a "wet" disk clutch, the disks and entire internal assembly run in an oil bath. The gradual engagement between the driving and driven plates is partly effected by pressing the oil from between the disks. As the oil is eliminated, the friction increases. Obviously the oil in the bath must not thicken too much at low temperatures. To prevent this, engine oil diluted with kerosene is often used. Some lubricated disk clutches employ a large number of unfaced metal disks which have metal-to-metal contact when engaged. Lubricated disk clutches are not extensively used.

15. Centrifugal clutch.—The centrifugal clutch is an automatic clutch consisting of internal shoes similar to brake shoes which are expanded inside of a cast iron clutch drum by the centrifugal force of two governor weights. The clutch starts to engage at a speed of 400 r. p. m. and is fully engaged at 800 r. p. m. Quick engagement can be effected by rapid acceleration of the engine. When the engine speed drops to 400 r. p. m., the clutch disengages. This type of clutch has had extensive application on buses having automatic transmissions.

16. Vacuum-operated automatic clutches.—Vacuum-operated automatic clutches of different designs are used on some motor vehicles but their principle of operation is the same. A cylinder having suitable valves and containing a piston is mounted alongside the engine. The piston rod is connected to the clutch release shaft lever in such a way that the piston, in moving forward in the cylinder, disengages the clutch. The forward end of the cylinder is connected through valves to the intake manifold of the engine. When an engine is running, there is a partial vacuum in the intake manifold which increases when the throttle is closed and decreases when the throttle is opened. A vacuum is simply a pressure less than that of the atmosphere; the lower the pressure, the higher the vacuum. When atmospheric pressure is applied to the back of the pistol and the pressure in front of the piston is reduced to less than atmospheric by the vacuum in the intake manifold, there is an unbalanced pressure on the back of the pistol that causes it to move forward with considerable force. This force, transmitted through the piston rod, is used to disengage the clutch. This type of clutch control can be arranged to disengage the clutch automatically every time the accelerator is released and to reengage it when the accelerator is depressed.

a. One design of vacuum clutch is shown in figure 12. When the solenoid valve is opened from the control switch on the instrument panel, the intake manifold of the engine is connected to the control valve plunger which controls the vacuum in the power cylinder. Releasing the accelerator pedal pulls this plunger out, a vacuum is formed in the front of the cylinder, air is admitted to the rear of the cylinder through a check valve in the piston and a bypass in the

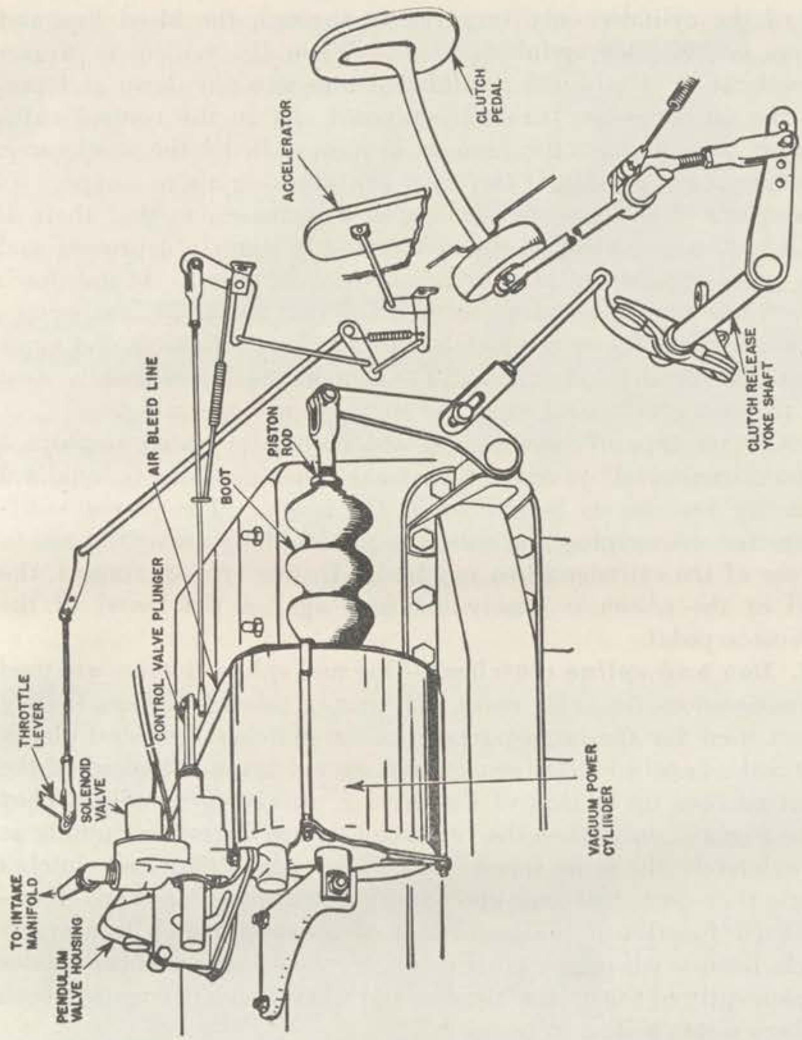


FIGURE 12.—Vacuum-operated clutch.

piston rod, and the piston moves forward, disengaging the clutch. When the accelerator pedal is depressed, the plunger closes the vacuum port and admits air to the front of the power cylinder, equalizing the pressure on both sides of the piston. The clutch springs then pull the piston back, forcing air out of the rear of the cylinder through the air bypass which is a groove in the piston rod. The air bypass extends to within 1½ inches of the piston and is closed as soon as its inner end enters the seal in the cylinder head. The piston is allowed to move rapidly up to this point where the clutch plates are ready to engage. Now the air can escape from the rear of the cylinder only very slowly through the bleed line and cushion control, or pendulum, valve. When the vehicle is at rest or accelerating slowly, the pendulum hangs straight down and permits the air to escape through a tapered slot in the control valve plunger. The farther the plunger is pushed in by the accelerator, the larger is the portion of the taper slot allowing air to escape. As the accelerator is depressed, the air flow increases, so that there is slow clutch engagement as the accelerator is slightly depressed and more rapid engagement as it is increasingly depressed. If the clutch engages too rapidly, tending to jerk the car, the pendulum swings backward, partially or completely closing the air passage and slowing up the clutch engagement. The clutch pedal is normally used only for emergencies and when the engine is not operating.

b. Another type of vacuum-operated automatic clutch employs a "vacuum suspended" piston, which means that pressure is equalized by having vacuum on both sides of the piston. The pressure difference for disengaging the clutch is produced by admitting air to the rear of the cylinder when required. In this type of control, the travel of the piston is closely balanced against the travel of the accelerator pedal.

17. Dog and spline clutches.—Dog and spline clutches are used in transmissions, transfer cases, and power take-off devices. They are not used for the same purpose as the clutches described above. They make metal-to-metal contact and cannot bring the speed of the driven member up to that of the driving member gradually. They can be engaged only when the two members are at rest or running at approximately the same speed. They are called "positive" clutches because they do not depend upon friction to transmit power. However, their function is similar to that of the main clutch in a motor vehicle, because when they are disengaged, the driving member rotates independently of the driven member and when they are engaged, both members rotate as a unit.

a. The dog, or gear, clutch shown in cross section in figure 13 consists of a driven gear with internal teeth cut on the inside of its rim. It has a splined hub and slides on its shaft. The internal teeth of the driven gear mesh with external teeth on the driving gear which is a part of the driving shaft. A pilot bearing keeps both shafts in alinement and permits them to rotate independently when the clutch is disengaged.

b. The spline clutch (fig. 14) is similar in its action to the dog clutch. It connects or disconnects two splined shafts by means of a sliding splined hub.

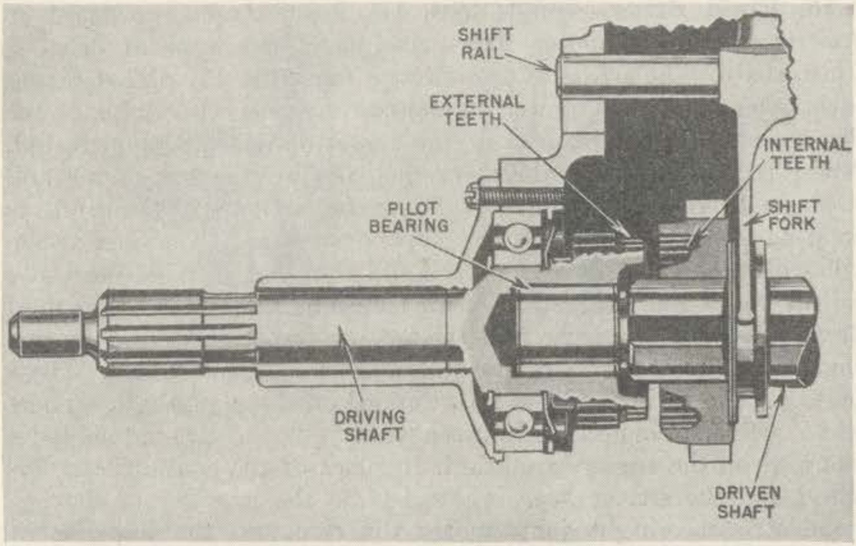


FIGURE 13.—Dog or gear clutch.

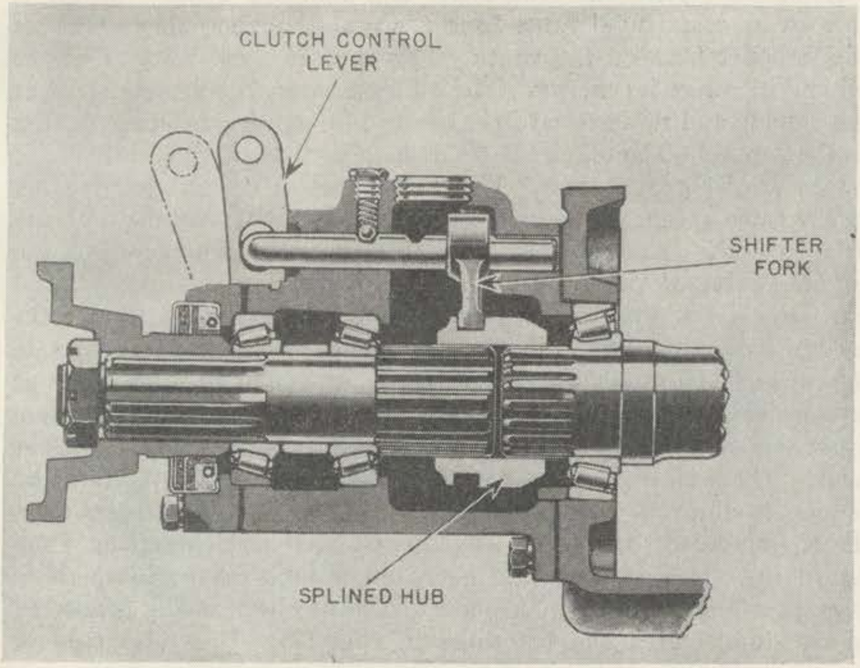


FIGURE 14.—Spline clutch.

18. Fluid drive.—Fluid drive has lately been introduced in American motor vehicles. The principle of this type of drive is illustrated by the action of two electric fans (fig. 15) placed facing each other; one with power connected, and the other with power disconnected. As the speed of the power-driven fan is increased, power is transmitted to the motionless fan by the flow of air and it starts to rotate. The free running fan gains speed until it is rotating almost as rapidly as the power-driven fan. The same action takes place in the fluid drive, or liquid coupling as it is sometimes called, except that oil instead of air transmits the power. The fluid drive consists of a centrifugal pump, or impeller, driven by the engine; and a runner or turbine mounted on the driven shaft. These parts are shown in figure 16 unassembled on the crankshaft. There is no metallic connection between them. The entire assembly is mounted on the engine crankshaft in place of the conventional flywheel and the starter gear is attached to the impeller or driving member. An oiltight joint unites the case and the impeller so that the runner or driven member is inclosed between them. The driven shaft is made oiltight by a spring loaded bronze sealing ring attached to the center of the case. The assembly is about four-fifths full of oil. When the crankshaft and impeller rotate, the oil is thrown by centrifugal force from the center to the outside edge of the impeller between the vanes. This increases the velocity of the oil and increases its energy. The oil then enters the runner vanes at the outside and flows toward the center imparting a rotating motion to the runner. The oil circulates as long as the impeller and runner rotate at different speeds. When the two members are rotating at the same speed, the oil stops circulating. Both members of the drive are the same so that when coasting, the wheels drive the engine as they do in the usual type of drive. In this case, the oil circulates in a reverse direction. When the engine is idling, the energy imparted to the oil by the impeller is insufficient to rotate the runner. However, the percentage of power lost through slippage at normal driving speeds is said to be very small, ranging from 1 percent at 25 miles per hour to ¼ of 1 percent at 60 miles per hour. The principal purpose of the fluid drive is to eliminate torsional vibration thereby giving a smooth flow of power from the engine to the wheels, and to eliminate all jerks resulting from use of the clutch and shifting gears. The fluid drive is sometimes used as a liquid coupling in place of the flywheel and is connected to the usual clutch and transmission (fig. 17). It is also used in

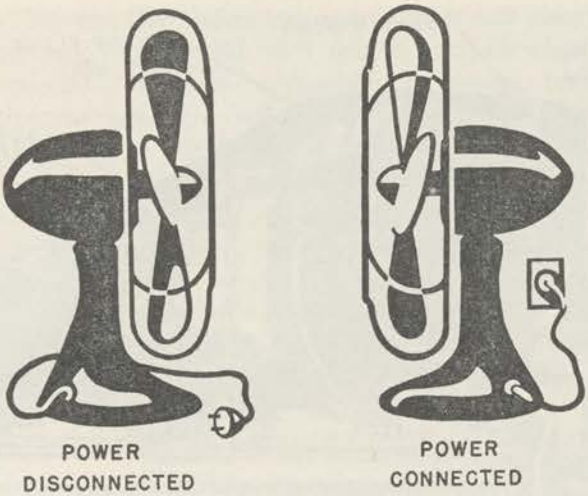


FIGURE 15.—Principle of the fluid drive.

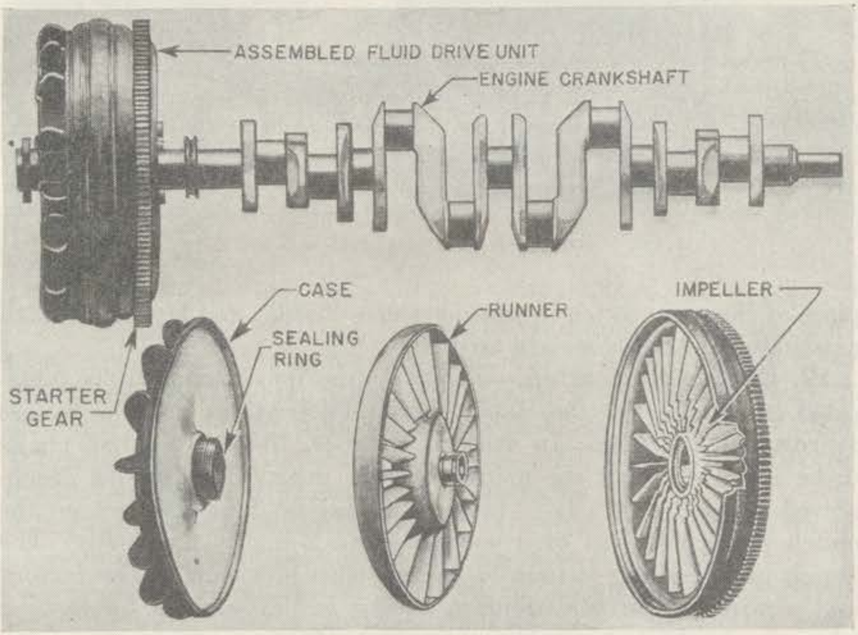


FIGURE 16.—Units of a fluid drive assembly.

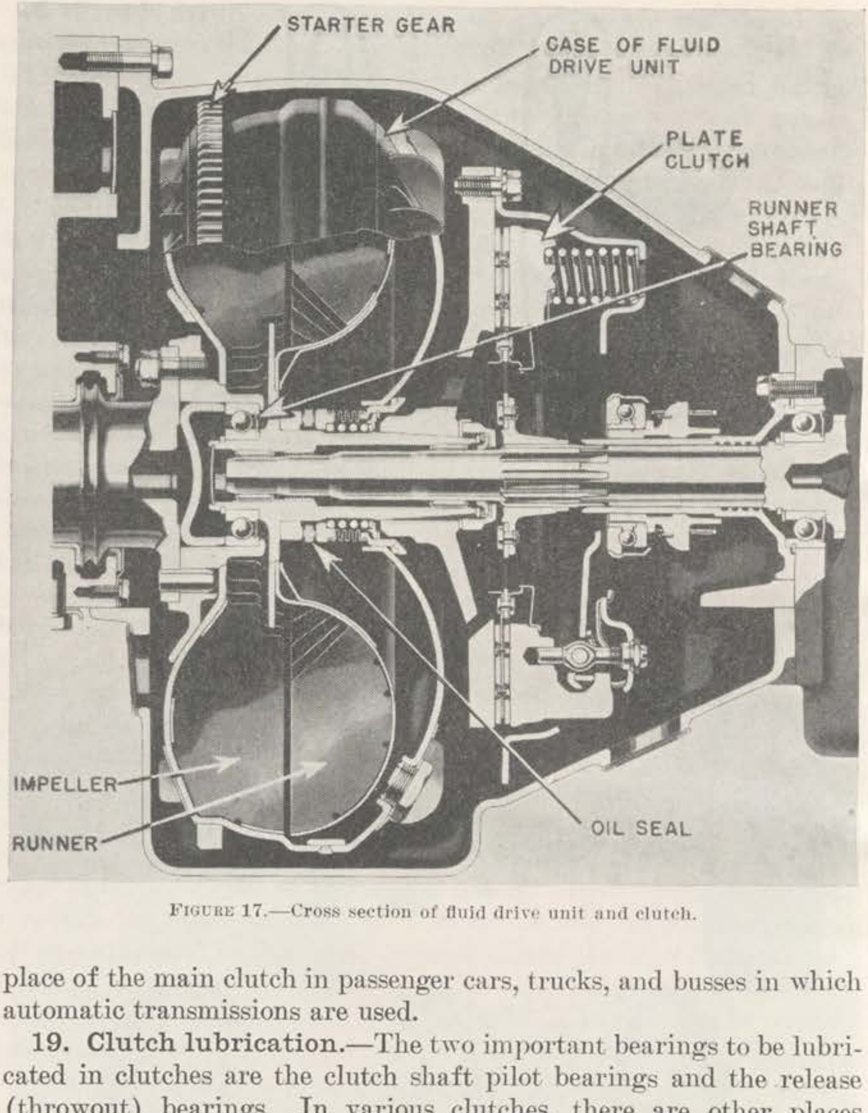


FIGURE 17.—Cross section of fluid drive unit and clutch.

place of the main clutch in passenger cars, trucks, and busses in which automatic transmissions are used.

19. Clutch lubrication.—The two important bearings to be lubricated in clutches are the clutch shaft pilot bearings and the release (throwout) bearings. In various clutches, there are other places to be lubricated and the manufacturer's instructions should be observed in each case. It is important that no lubricant get on the clutch plates or disks of dry clutches as it makes them slip. The clutch pilot bearing is usually packed with lubricant at the factory and requires no further attention until it is disassembled for repairs, when it should be repacked. A grease fitting outside the clutch housing, which is connected to the bearing by means of a tube, is often provided for the clutch realease (throwout) bearing. Sometimes an oil reservoir packed with felt is used, to which oil can be added occasionally through a flexible connection from the floor boards. In some cases, the release bearing like the pilot bearing is packed with grease at the factory and requires no further attention until the clutch is disassembled for repair. When clutch release bearings are provided with grease fittings and are greased every time the chassis is lubricated, care should be taken not to overlubricate and cause lubricant to work into the clutch plates or disks. The internal parts of a lubricated (wet) disk clutch are lubricated by the oil contained in the case. The oil level should be checked occasionally through the oil filler plugs and oil of the kind and quantity recommended by the manufacturer added as required. Fluid drives are lubricated in the same manner as lubricated (wet) disk clutches.

Section III

TRANSMISSIONS AND OVERDRIVES

20. General.—*a. Construction.*—The transmission of a motor vehicle consists of a train of gears contained in a case usually immediately back of the clutch housing through which the power of the engine is transmitted from the clutch shaft to the propeller shaft. When an overdrive or transfer case is used, it is placed between the transmission and propeller shaft or shafts.

b. Purpose.—The transmission serves several purposes. With the gears in the neutral position, it provides a means, in addition to the clutch, of disconnecting the power of the engine from the driving wheels. It also changes the direction of rotation of the driving wheels when the gears are meshed in the reverse position. This is necessary because the engine crankshaft always rotates in one direction. Further, when the gears are meshed in the low- or second-speed position, the transmission allows the engine to run at a high speed while the vehicle runs at a low speed. However, the most important function of the transmission is to provide sufficient mechanical advantage to increase the torque or turning effort delivered by the engine to turn the driving wheels. More torque is needed when a vehicle is started, heavily loaded, climbing a hill, or traversing rough or soft terrain, than when it is running lightly loaded on a smooth, hard, level pavement.

21. Use of terms.—The terms given below are used frequently in the discussion of the mechanics of the motor vehicle and other machines. The student should familiarize himself with their meanings in order to understand texts or lectures on automotive or other mechanical subjects.

a. Work.—When a body is moved against resistance or is accelerated, work must be done upon it. The work done is the force exerted multiplied by the distance through which it moves. Work is measured in foot-pounds. Thus, if a weight of 1 pound is lifted 1 foot, 1 foot-pound of work is done. If a body offering a resistance (load) of 1 pound is moved for a distance of 1 foot in any direction, 1 foot-pound of work is done. If a 5-pound resistance is moved ½ foot, 2½ foot-pounds of work are done, etc. The amount of work done in raising a 5-pound weight 10 feet and a 10-pound weight the same distance is shown in figure 18.

b. Power.—Power is the rate of doing work. The unit of power generally employed in automotive practice is the horsepower, which is 33,000 foot-pounds per minute, or 550 foot-pounds per second. Thus, if an engine develops 1 horsepower for 1 hour (60 minutes), it does 1 horsepower-hour of work of $33{,}000 \times 60 = 1{,}980{,}000$ foot-pounds. A horsepower is a unit of power, but a horsepower-hour is a unit of work equal to 1,980,000 foot-pounds. The term "horsepower" may refer to capacity for doing work as well as the rate at which work is actually done. Thus, a 100-horsepower engine will develop 100 horsepower when fully loaded or working at capacity; but it develops or delivers less than 100 horsepower when it is not fully loaded.

c. Torque.—Torque is turning effort. It is the force exerted multiplied by the distance from the center of rotation. For example, a force of 40 pounds exerted on the end of a 1-foot pipe wrench would produce 40 pounds times 1 foot, or 40 foot-pounds of torque or turning effort on the pipe. Forty pounds of force exerted on the end of a 2-foot pipe wrench would produce 40 pounds times 2 feet, or 80 foot-pounds of torque on the pipe. This indicates why it is easier to unscrew a pipe coupling with a 2-foot wrench than with a 1-foot wrench. While it is easier to turn the pipe with the longer wrench, the end of the 2-foot wrench must travel twice as far as the end of the 1-foot wrench to make one turn. This fact has to do with mechanical advantage explained in *d* below.

d. Mechanical advantage.—(1) Mechanical advantage is the force exerted by a machine divided by the force required to drive the machine. The distance traveled by the driving force divided by the distance traveled by the force exerted by the machine is also a measure of mechanical advantage. The number of foot-pounds of work used to drive a mechanism will exactly equal its output, except for those lost in overcoming the friction of the mechanism. At the top of figure 18 is shown a 5-pound weight suspended by a rope passing over a pulley. A pull of 5 pounds (force driving the machine) is required

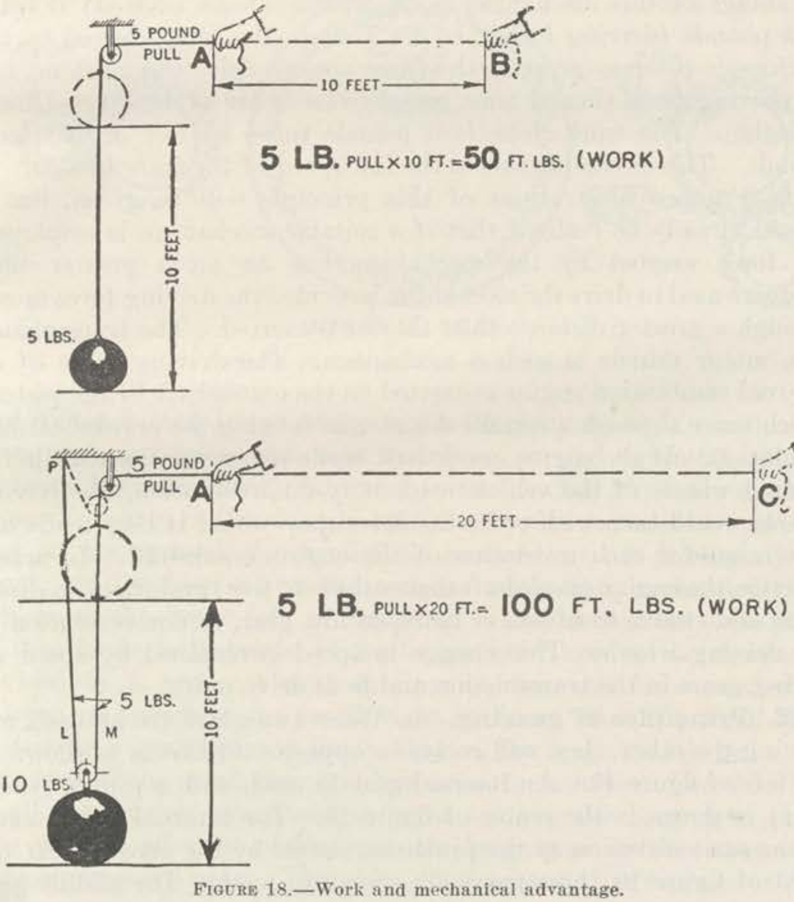


FIGURE 18.—Work and mechanical advantage.

on the rope through a distance of 10 feet in order to raise the 5-pound weight (force exerted by the machine) a distance of 10 feet. In this mechanism, the mechanical advantage is 5 divided by 5 or 1. That is, there is no mechanical advantage because the driving force required is just as much as the force exerted by the machine and both forces move through the same distance. The total work done is 5 pounds times 10 feet or 50 foot-pounds. This is comparable to the direct drive in a transmission. At the bottom of figure 18, the weight is shown increased to 10 pounds and suspended by an additional pulley. The weight is now suspended by two parts of the rope so the pull in each part remains 5 pounds, the same as in the first case. With this mechanism, the 10-pound weight can also be raised 10 feet by the same 5-pound pull that was required for the 5-pound weight in the first case, but the pulling force must travel twice as far. The mechanical advantage of this mechanism is 10 pounds (force exerted) divided by 5 pounds (driving force), or 2. That is, the force exerted by the machine is twice as great as the force used to drive the machine, but the driving force (hand) must travel twice as far as the exerted force (weight). The work done is 5 pounds times 20 feet or 100 foot-pounds. This is comparable to the low speed of the transmission.

(2) Further illustrations of this principle will be given, but it should already be realized that if a suitable mechanism is employed, the force exerted by the mechanism can be much greater than the force used to drive the mechanism provided the driving force moves through a greater distance than the force exerted. The transmission of a motor vehicle is such a mechanism. The driving force of an internal combustion engine is exerted on the crankshaft by the pistons which move through a certain distance in turning the crankshaft one revolution. If the engine crankshaft made two revolutions while the driving wheels of the vehicle made only one revolution, the driving wheels would turn with twice the force they would if they made one revolution for each revolution of the engine crankshaft. In actual practice, the engine crankshaft makes three to five revolutions in direct drive and twelve to fifteen or more, in low gear, to one revolution of the driving wheels. This change in speed is obtained by speed reducing gears in the transmission and final drive units.

22. Principles of gearing.—*a.* When two gears are in mesh, one driving the other, they will rotate in opposite directions as shown at the left of figure 19. An internal gear in mesh with a pinion (small gear) is shown in the center of figure 19. The internal gear rotates in the same direction as the pinion as shown by the arrows. At the right of figure 19, three gears are shown in mesh. The middle gear is usually an idler gear which transmits the driving effort of one of the outside gears to the other and make them rotate in the same direction.

b. Gear ratio is a term frequently used. The word "ratio" implies division. For example, the ratio of 48 to 12 is 48 divided by 12, or 4, which is usually expressed as a ratio of 4 to 1. The ratio of 10 to 4 is 10 divided by 4, or 2½ to 1. The term "gear ratio" applies to the number of revolutions the driving gear makes while the driven gear is making one revolution. The gear ratio is found by dividing the number of teeth on the driven gear by the number of teeth on the driving gear (with the exception of worm gears). An idler gear between the driving and driven gears makes no difference in the gear ratio.

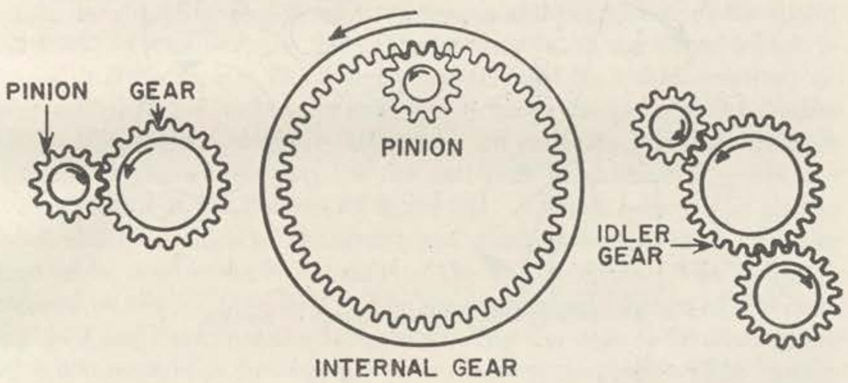


FIGURE 19.—Rotation of meshed gears.

c. When a load is too heavy to be lifted by hand, a crowbar or lever may be used as shown in the upper part of figure 20. If the distance from the block (fulcrum) to the hand is twice the distance from the box to the block, only half the force is required to raise the box off the ground that would be required to lift it directly by hand; but the hand moves twice as far as the box, as shown by the arrows at the lower left of figure 20. The mechanical advantage of this device is the ratio of the longer lever arm to the shorter; 2 divided by 1, or 2. A gear driving another may be compared to a lever, as shown at the lower right of figure 20. The small gear is driving a gear twice as large; that is, the large gear is twice the diameter of the small gear and has twice the number of teeth. The small gear makes two complete turns to turn the large gear once. The turning effort available from the large gear is twice that used to turn the small gear. Therefore, the mechanical advantage of this

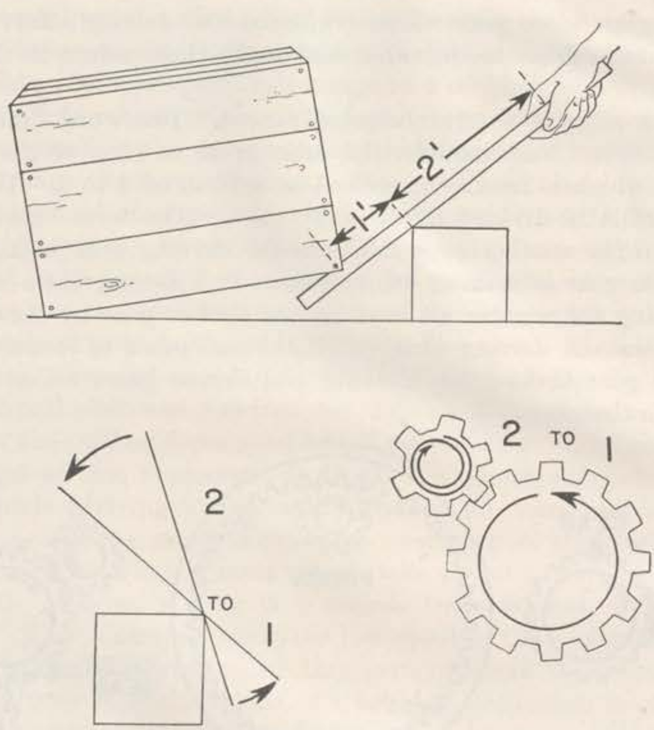


FIGURE 20.—Mechanical advantage of gearing.

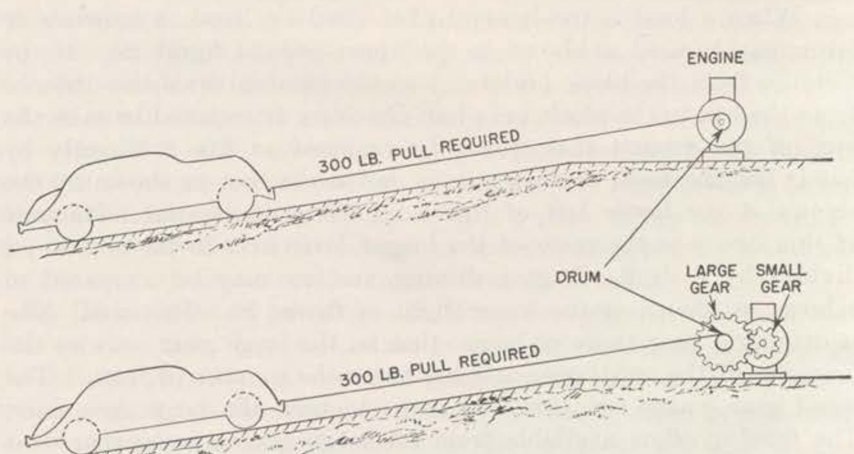


FIGURE 21.—Application of the gearing principle.

device is also 2. Disregarding a small friction loss, the mechanical advantage of two meshed gears is the same as the gear ratio. If the large gear shown at the lower right of figure 20 drives the small one, the turning effort exerted by the small gear is half that used to turn the large driving gear; that is, reversing the path of power transmission in a gear train also reverses the mechanical advantage.

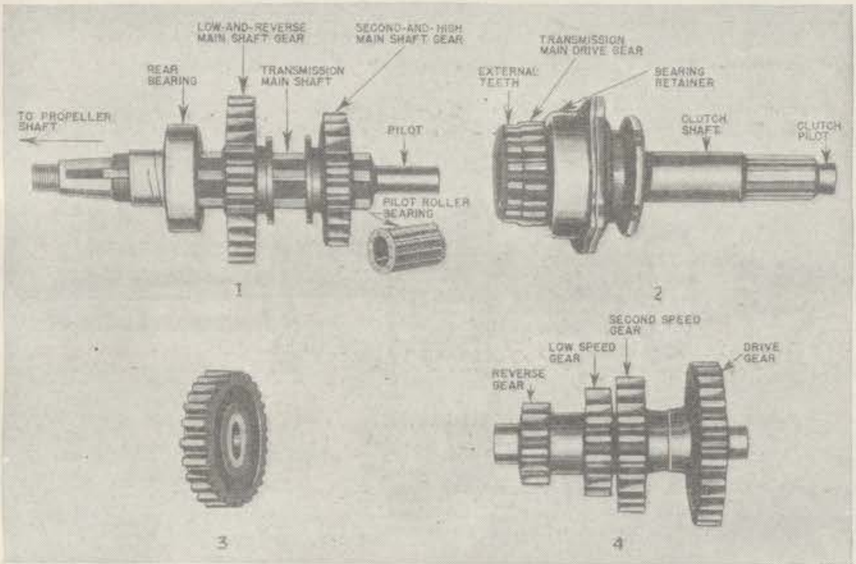
d. Figure 21 shows these principles applied directly to the motor vehicle. An automobile is placed at the foot of a hill and its engine is removed and placed at the top. One end of a rope is attached to the car and the other end is wound around a drum on the engine clutch shaft as shown at the top of figure 21. A pull of 300 pounds is required to move the car; that is, if a spring scale were connected in the rope, it would read 300 pounds when the car started to move. The engine develops 150 foot-pounds of torque and the radius of the drum is 1 foot. Therefore, the force at the outside of the drum which is the pull of the rope is 150 foot-pounds divided by 1 foot (radius) or 150 pounds. This pull is not sufficient to move the car and the engine will stall when the clutch is engaged. In order to increase the pull on the rope enough to start the car and pull it up the hill, gears are used as shown at the bottom of figure 21. A small gear is put on the clutch shaft in place of the drum and meshed with a gear twice as large on a countershaft parallel to the clutch shaft. The drum is fastened on the countershaft. The mechanical advantage of the gear train is 2 and therefore the force exerted on the rope is doubled, making it 300 pounds or just enough to start the automobile. The engine makes two revolutions while the drum makes one; that is, the driving force of the engine acts through twice the distance that it did without the gearing and the force exerted by the drum is twice as great. The arrangement at the top of figure 21 represents direct drive and that at the bottom of figure 21 represents low gear drive. This explains the chief function of the transmission in a motor vehicle which is to provide sufficient mechanical advantage to increase the torque on the driving wheels to the amount required by driving conditions.

e. Two types of gears are generally used in transmissions: spur gears and helical gears. Spur gears have their teeth cut straight across the face of the gear, while helical gears have their teeth cut diagonally across the face. Helical gears run more silently than spur gears and are widely used for this reason. Herringbone gears are sometimes used but these are really double helical gears with the teeth cut slanting in both directions to the center of the gear face. The object of this design is to equalize the side thrust which occurs in plain helical gears.

23. Types of transmissions.—*a.* The motor vehicle transmission provides three or more forward gear ratios and one reverse, commonly known as speeds. With the usual three-speed transmission, the propeller shaft runs at engine crankshaft speed in direct drive about half as fast in second speed and about one third as fast in low gear. The speed reduction in reverse is somewhat greater than in low. There is a further speed reduction in the final drive which varies from 3 to 1 in some passenger vehicles to 5 to 1 in others. Therefore, in direct drive, the engine crankshaft makes from three to five revolutions while the driving wheels are making one revolution; in second speed, the engine makes about six to ten revolution to one of the driving wheels; and in low speed, the engine makes from approximately nine to fifteen revolutions while the driving wheels turn once. The speed reduction in reverse in still greater.

b. Three types of transmissions have been used in motor vehicles: progressive, planetary and selective; today the selective type is used almost exclusively. With this form of transmission, it is possible to shift directly from neutral to any speed or from any speed to neutral. With the progressive transmission, in shifting from the highest to the lowest speed or back again, it is necessary to pass through an intervening speed. It is used only on motorcycles today. The planetary transmission is no longer used in motor vehicles but planetary gears are used in overdrives, in some dual-ratio rear axles, and in the hydramatic transmission.

c. The three-speed selective transmission is used at present on almost all passenger cars and light trucks. The gear arrangements of a transmission of this type having spur gears are shown in figures 22 to 27, inclusive. The parts are shown in their correct relative positions but unassembled in the case. The names and functions of the parts are as follows: The clutch shaft and transmission main drive gear (fig. 22 ②) are one piece and rotate with the clutch driven plate or disks; that is, they rotate all the time the clutch is engaged. The transmission main drive gear is in constant mesh with the countershaft drive gear (fig. 22 ④). Since all the gears in the countershaft cluster are either made integral or keyed on, they also rotate at the time the clutch is engaged. The transmission main shaft (fig. 22 ①) is held in line with the clutch shaft by a pilot bearing at its front end, similar to the clutch pilot bearing, which allows it to rotate or come to rest independently of the clutch shaft. The transmission second-and-high and low-and-reverse main shaft gears, shown on the main shaft, have grooved hub extensions into which fit the shift forks which slide them back and forth on the main shaft spline. Thus, the second-and-high main shaft gear can be shifted rearward to mesh with the countershaft second speed gear. The second-and-high main shaft gear also has internal teeth which mesh with the external teeth on the rear of the transmission main drive gear when the gear is shifted forward into the direct-drive position. The low-and-reverse main shaft gear can be shifted forward to mesh with the countershaft low speed gear or rearward to mesh with the reverse idler gear. The countershaft reverse gear is usually in constant mesh with the reverse idler gear (fig. 22 ③). In some transmissions, the reverse idler gear is shifted to mesh with



① Transmission main shaft assembly.
② Clutch shaft assembly.
③ Reverse idler gear.
④ Countershaft gear cluster.

FIGURE 22.—Principal gear groups of a three-speed selective transmission.

the countershaft reverse gear at the same time that the low-and-reverse main shaft gear is shifted to mesh with the reverse idler gear.

d. The main, counter, and clutch shafts with their respective gears are mounted on antifriction bearings in the transmission case. Shift rails and forks are provided to move the gears when the control lever is moved by the driver to change speeds. The countershaft is generally placed below the main shaft which permits a deep, narrow case. This construction allows a considerable quantity of oil in the case without danger of leakage since the oil level is maintained below the oil seals where the clutch shaft enters the case and the main shaft leaves it.

e. In figure 23, the gears are shown in the neutral position. The clutch shaft drives the countershaft through the main drive gear and countershaft drive gear. None of the countershaft gears are in mesh with the main shaft sliding gears, however, so the main shaft is not driven. Therefore, when the gears are in this position, there is no connection between the engine and the driving wheels so the vehicle remains stationary while the engine is running. In the transmission shown in figure 23, the gear ratio between the transmission main drive gear and the countershaft drive gear is about

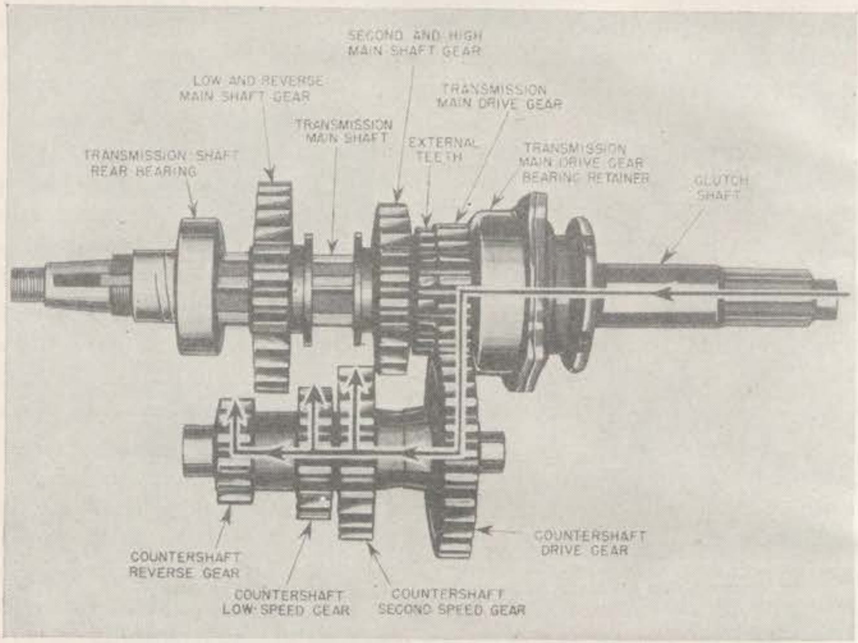


FIGURE 23.—Transmission gears in neutral position.

1.5 to 1. Therefore the countershaft rotates at approximately 0.7 times the speed of the clutch shaft or crankshaft. The path of transmitted power is shown by arrows.

f. The low-speed position of the gears is shown in figure 24. The low-and-reverse main shaft gear has been shifted forward to mesh with and be driven by the countershaft low-speed gear. The path of power transmission is shown by the arrows. The countershaft rotates at about half crankshaft speed. There is a further speed reduction between the countershaft low-speed gear (driving) and the low-and-reverse main shaft gear (driven) of about 1.5. Therefore the crankshaft rotates 1.5×1.5=2.25 times for each turn of the propeller shaft.

g. The second-speed position is shown in figure 25. In passing from low speed to second speed, both sliding gears have been shifted rearward; the low-and-reverse main shaft gear out of engagement into

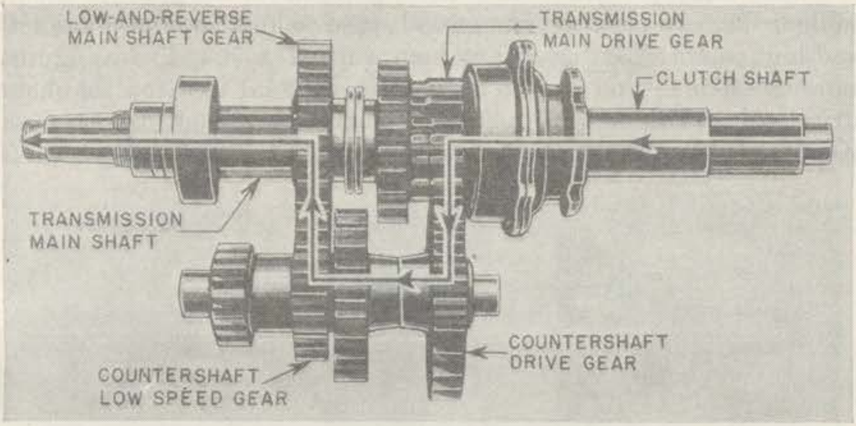


FIGURE 24.—Transmission gears in low-speed position.

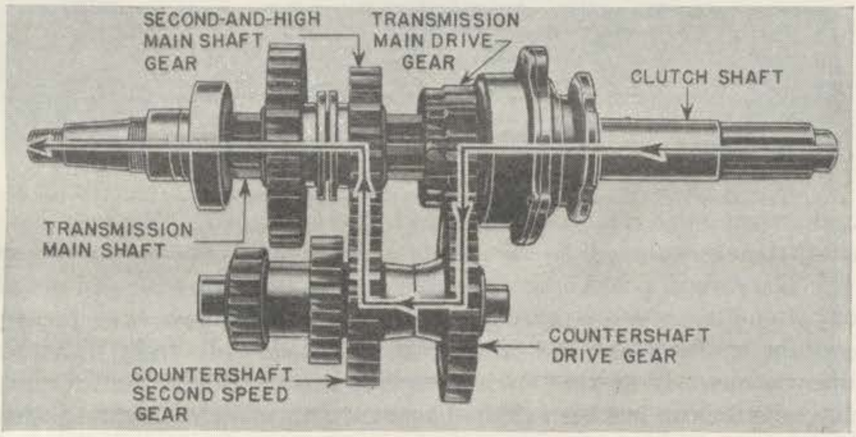


FIGURE 25.—Transmission gears in second-speed position.

the neutral position and the second-and-high main shaft gear into mesh with the countershaft second speed gear. The clutch shaft and the main drive gear are now driving the countershaft through the countershaft drive gear (as is the case in all speeds) and the countershaft is driving the main shaft through the countershaft second-speed gear and the second-and-high main shaft gear as shown by the arrows.

Since the countershaft second-speed gear and the second-and-high main shaft gear are the same size, their gear ratio is 1 to 1. This means that the transmission main shaft rotates at the same speed as the countershaft; that is, the engine crankshaft makes about 1.5 revolutions to one of the propeller shaft.

h. The high-speed, or direct-drive, position of the gears is shown in figure 26. In passing from second speed to high speed, the second-and-high main shaft gear has been shifted forward, causing the internal teeth in this gear to engage the external teeth on the main drive gear. This is an application of the dog clutch described in paragraph 17. It makes a direct connection between the clutch shaft

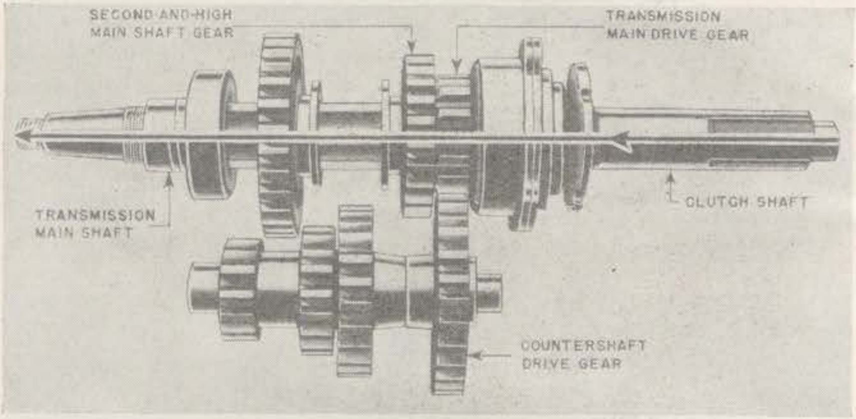


FIGURE 26.—Transmission gears in high-speed or direct-drive position.

and transmission main shaft as shown by the arrows. The propeller shaft therefore rotates at crankshaft speed.

i. The reverse position of the gears is shown in figure 27. In order to better illustrate the reverse idler gear, the parts have been turned end for end and are shown from the opposite side from previous illustrations. In passing from neutral to reverse, the low-and-reverse main shaft gear has been shifted rearward to mesh with the reverse idler gear. The sole function of this gear is to make the transmission main shaft rotate in the opposite direction to the clutch shaft as shown by the short, heavy arrows; it does not influence the gear ratio between the countershaft reverse gear and the low-and-reverse main shaft gear. The gear ratio between these gears is about 2. In reverse, therefore, the crankshaft rotates $1.5 \times 2 = 3$ times for every revolution of the propeller shaft.

j. For the purpose of simplicity, the transmission described above is of the spur gear type. In modern practice, however, helical gears are widely used because they run more quietly than spur gears. There is a side thrust on a helical gear, due to the angularity of the teeth, which tends to slide the gears out of mesh. This difficulty is avoided in constant-mesh transmissions because the gears do not slide on the shaft. When sliding helical gears are employed in a transmission the splines on which they slide are also cut helically to the same angle as the teeth, which offsets the side thrust.

24. Transmission controls.—*a.* The three-speed selective transmission described in paragraph 23*c* is operated by a control lever

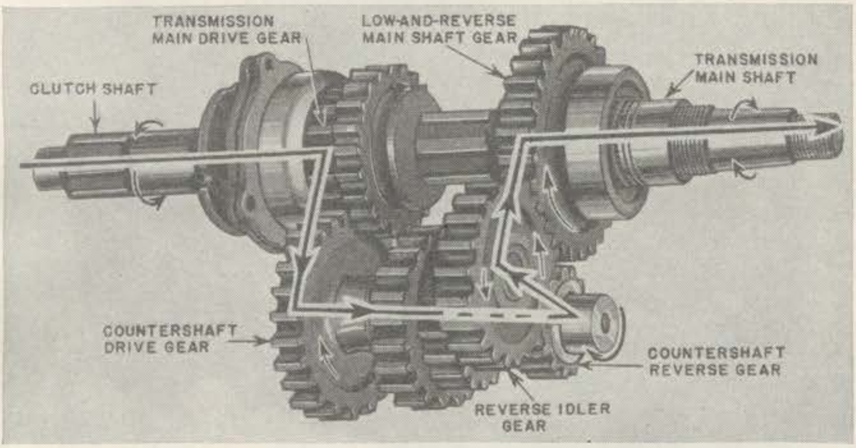


FIGURE 27.—Transmission gears in reverse position.

assembled to, and extending from the transmission cover as shown in figure 28. The lever has a ball fulcrum fitting into a socket in the cover. It is kept from rotating by a set screw entering a slot in the side of the ball fulcrum but is free to move back, forward, and sidewise. The end of the lever below the ball fulcrum engages slots in the shift-fork castings attached to the shift rails. In the neutral position, the end of the level engages both slots, but there is an interlock device (usually a ball or pin engaging notches in each rail) that permits one rail to move at a time, but not both. This prevents two speeds being engaged at once. When the control lever handle is pressed to the left, the slot in the low-and-reverse shift rail is engaged and the fork can be moved back or forward. After the low-and-reverse shift rail has been returned to the neutral position, the control lever can be pressed to the right and the second-and-high shift rail and fork can be moved forward or back. The shift rails are held in the different speeds and the neutral position by spring loaded balls, or poppets, engaging notches in the shift rails.

b. Since 1939, transmission control levers on the steering column have come into general use. These are generally used with the synchro-mesh type transmission and are described in paragraph 26*d*.

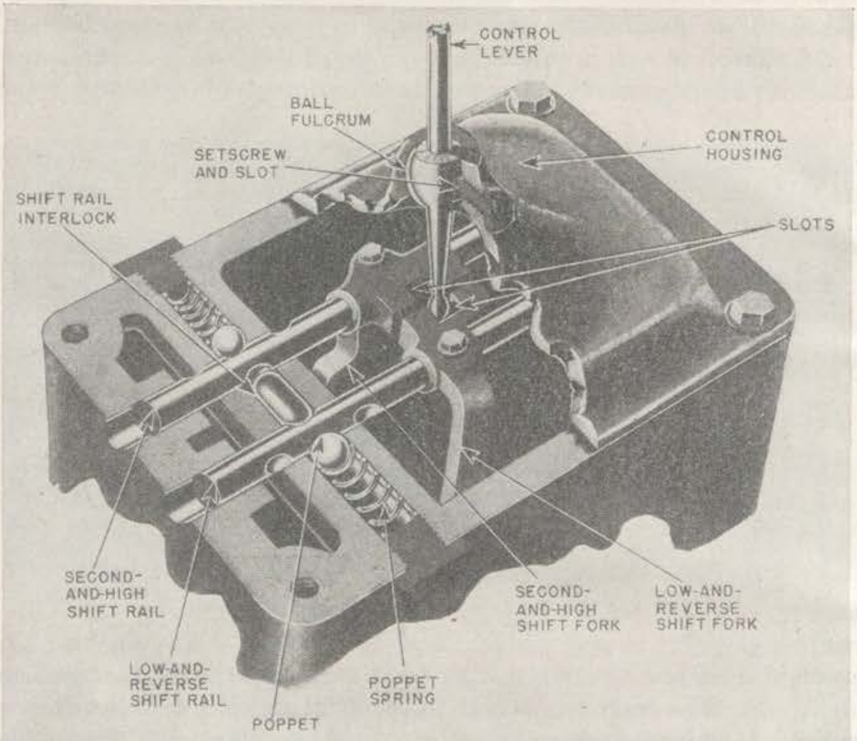


FIGURE 28.—Transmission shifting mechanism.

25. Constant-mesh transmissions.—In transmissions of this type, all the countershaft gears and the transmission main drive gear are fixed to their shafts; the low-and-reverse and second-and-high main shaft gears rotate on the main shaft. All the main shaft and mating countershaft gears are constantly meshed as shown in figure 29. A speed change is made by sliding the driving member of a dog clutch along the splined main shaft until it meshes with a driven member integral with the required gear, causing it to rotate with the main shaft. Constant-mesh gears are seldom used for all speeds. Common practice is to employ constant-mesh helical gears for second speed, or for low and second speed, and a sliding helical or spur gear for low and reverse, or for reverse only.

26. Synchro-mesh transmissions.—*a.* The synchro-mesh transmission is a type of constant-mesh transmission that permits gears to be selected without clashing by synchronizing the speeds of mating parts before they engage. It employs a combination metal-to-metal friction cone clutch and a dog or gear positive clutch to engage the

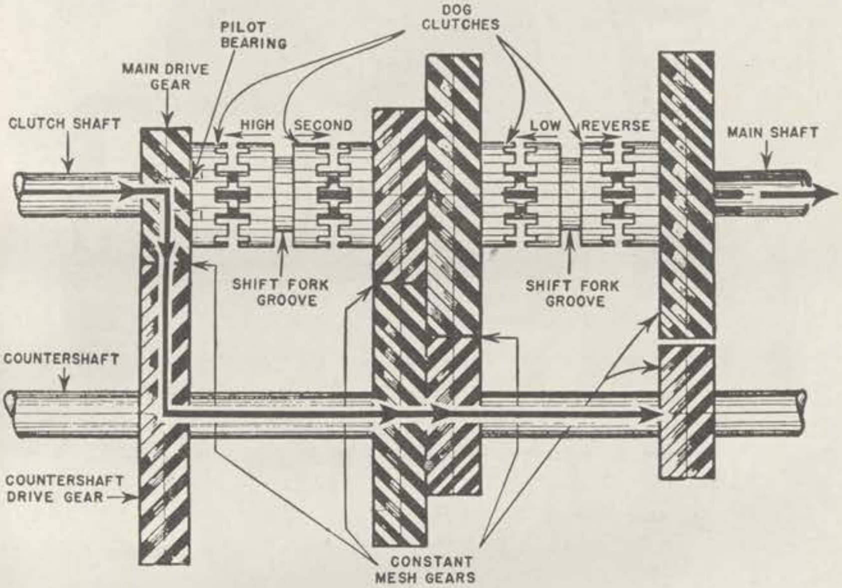


FIGURE 29.—Principles of constant-mesh transmissions.

main drive gear and second speed main shaft gear with the transmission main shaft. The friction cone clutch engages first, synchronizing, or bringing the driving and driven members to the same speed, after which the dog clutch engages easily without clashing. This process is accomplished in one continuous operation when the driver declutches and moves the control lever in the usual manner. The construction of synchro-mesh transmissions varies somewhat with different manufacturers but the principle is the same in all.

b. The construction of a popular synchro-mesh clutch is shown in figure 30. The driving member consists of a sliding gear splined to the transmission main shaft with bronze internal cones on each side. It is surrounded by a sliding sleeve having internal teeth which are

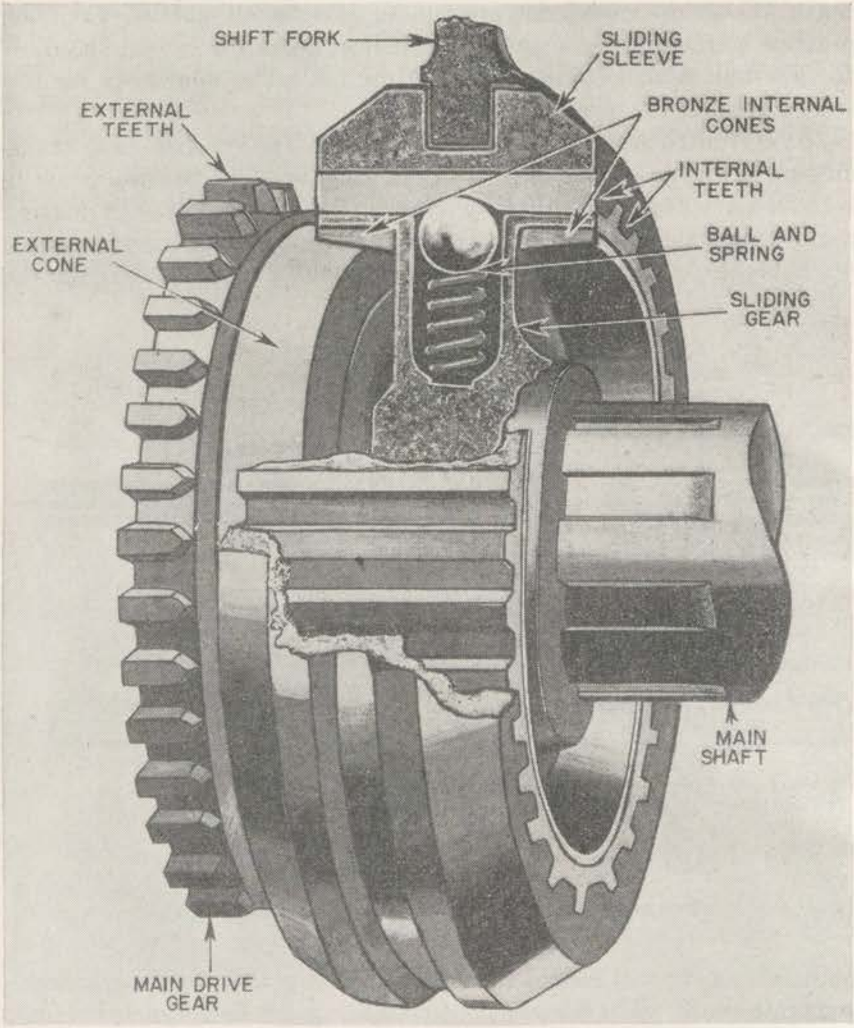


FIGURE 30.—Synchro-mesh clutch disengaged.

meshed with the external teeth of the sliding gear. The sliding sleeve is grooved around the outside to receive the shift fork. Six spring loaded balls in radial drilled holes in the gear fit into an internal groove in the sliding sleeve and prevent it from moving endwise relative to the gear until the latter has reached the end of its travel. The driven members are the main drive gear and second-speed main shaft gear, each of which has external cones and external teeth machined on its sides to engage the internal cones of the

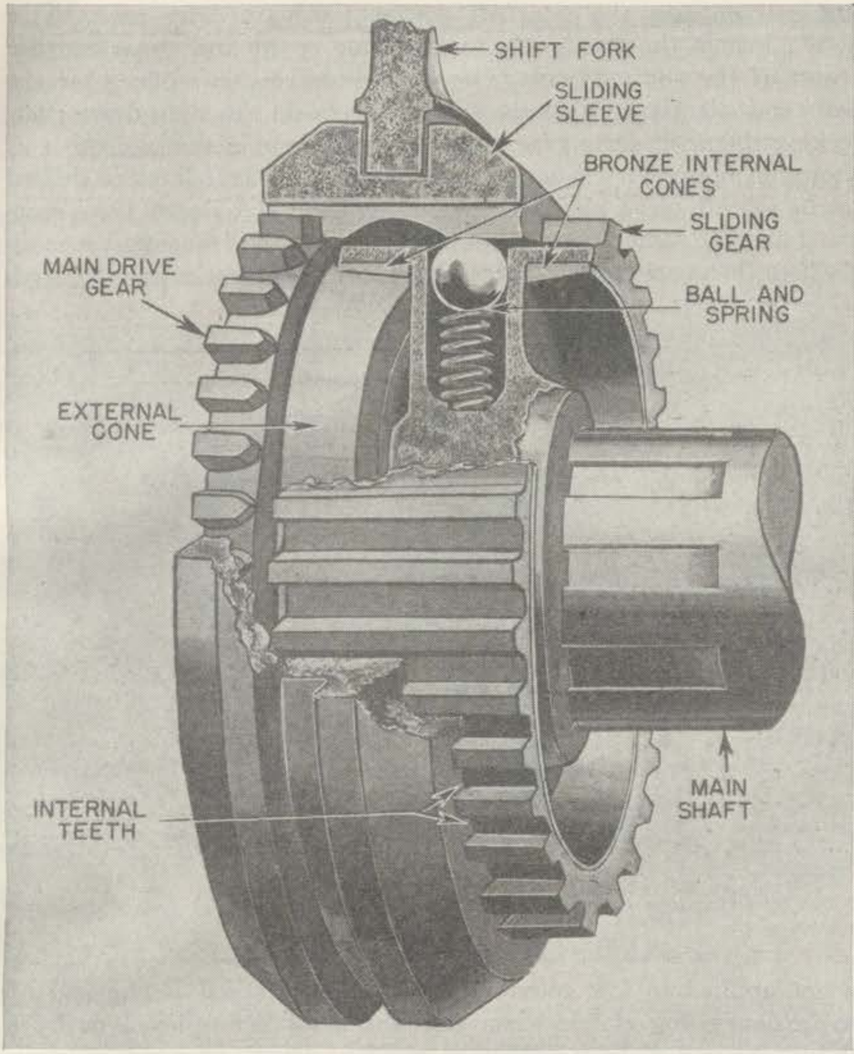


FIGURE 31.—Synchro-mesh clutch engaged.

sliding gear and the internal teeth of the sliding sleeve. The synchro-mesh clutch is shown disengaged in figure 30 and engaged in figure 31.

c. The synchro-mesh clutch operates as follows: When the transmission control lever is moved by the driver to the high speed or direct drive position, the shift fork moves the sliding gear and sliding sleeve forward as a unit until the internal cone on the sliding gear engages the external cone on the main drive gear. This action brings the two gears to the same speed and stops endwise travel of the sliding gear. The sliding sleeve then slides over the balls and silently engages the external teeth on the main drive gear, locking the main drive gear and transmission main shaft together as shown in figure 31. When the transmission control lever is shifted to the second speed position, the sliding gear and sleeve move rearward and the same action takes place, locking the transmission main shaft to the second speed main shaft gear. The synchro-mesh clutch

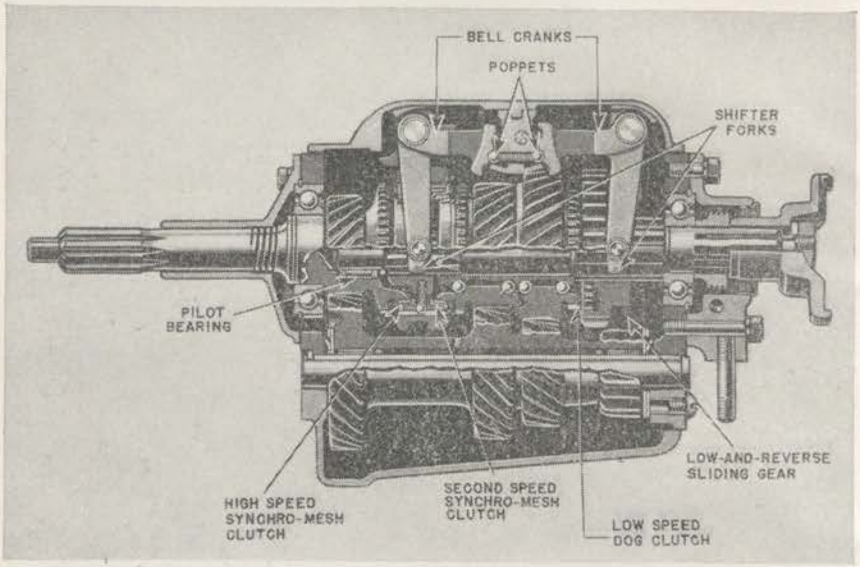


FIGURE 32.—Synchro-mesh transmission with arrangement for steering column transmission control.

is not applied to low speed or reverse. Low speed is engaged by an ordinary dog clutch when constant mesh is employed or by a sliding gear; reverse is always engaged by means of a sliding gear. Figure 32 shows a synchro-mesh transmission in cross section which uses constant mesh helical gears for the three forward speeds and a sliding spur gear for reverse.

d. This transmission is controlled by a steering column control lever (fig. 33). The positions for the various speeds are the same as those for the vertical control lever except that the lever is horizontal. The shifter forks are pivoted on bell cranks which are turned by a steering column control lever through the linkage shown.

The poppets shown in figure 32 engage notches at the inner end of each bell crank. Other types of synchro-mesh transmissions controlled by steering column levers have shift rails and forks moved by a linkage similar to those used with a vertical control lever.

e. Transmissions of heavy duty trucks are not always equipped with synchro-mesh gears. To assure smooth engagement of the gears in such transmissions, double clutching is often employed. In shifting to a lower gear ratio, or speed, double clutching is accomplished in six steps as follows: first, depress the clutch pedal; second, move the transmission control lever to neutral position; third, release the clutch pedal and at the same time depress the accelerator until the engine

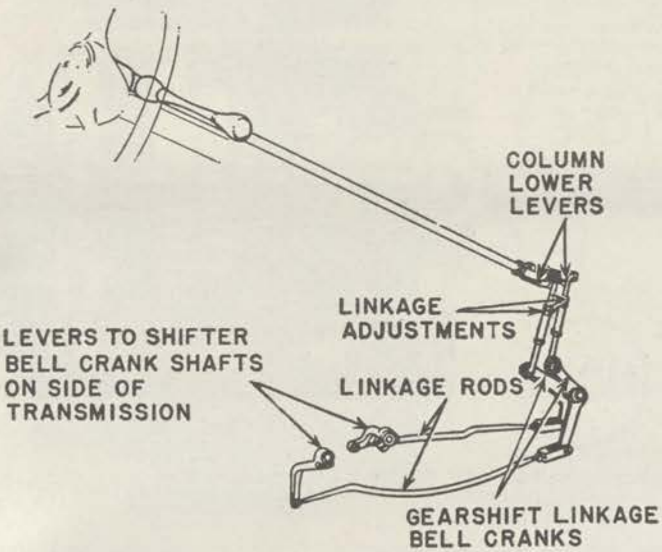


FIGURE 33.—Steering column transmission control linkage.

is running somewhat faster than it would be if the lower speed were already engaged; fourth, depress the clutch pedal; fifth, move the transmission control lever to the next lower speed; sixth, release the clutch pedal and at the same time depress the accelerator to maintain the speed of the engine as the load is again connected to it by the reengagement of the clutch. The procedure is the same for shifting to a higher speed, except that the engine is not accelerated while the gears are in neutral. This procedure sounds rather complicated but becomes almost automatic with practice.

27. Typical truck transmissions.—*a.* More gear ratios are required for trucks than for passenger cars because of the wide variation in loads carried by trucks. Therefore, four- and five-speed transmissions are often used. Figure 34 shows a popular four-speed truck transmission which uses spur gears. The various speeds are obtained by sliding the gears on the transmission main shaft into mesh with the fixed countershaft gears. The reverse idler gear is a double gear and also slides in and out of mesh with the countershaft reverse gear and the main shaft reverse gear.

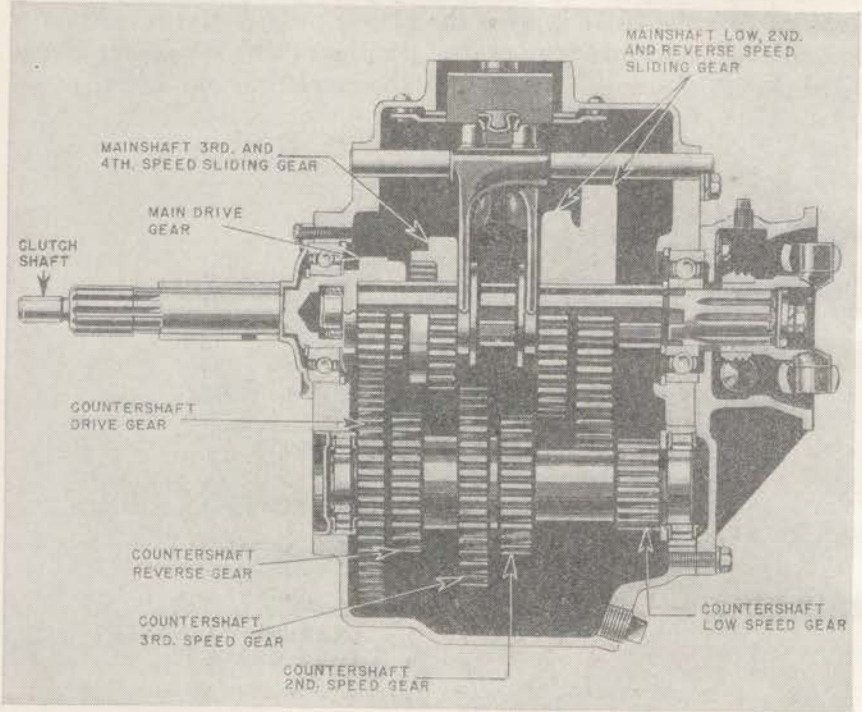


FIGURE 34.—Four-speed truck transmission.

b. The control lever moves three shift rails and forks, two of which are shown in figure 34. The front fork moves the main shaft gear forward for direct and backward for third speed; the middle fork moves the main shaft low-second-and-reverse gear forward for second speed and back for low. The back fork moves the reverse idler, which is a double gear, forward to mesh with the countershaft reverse gear and the low-second-and-reverse main shaft gears and backward out of mesh. The positions of the control lever for the various speeds are shown in figure 35.

The gear ratios (engine crankshaft to propeller shaft) are—

Low, 7.23 to 1.
Second, 3.48 to 1.
Third, 1.71 to 1.
Fourth, 1 to 1.
Reverse, 7.15 to 1.

c. A five-speed transmission for a truck is shown in cross section in figure 36. Third and fourth speeds in the transmission are constant mesh helical gears. Sliding spur gears engage second, low, and reverse. The reverse idler gear is in constant mesh with the countershaft reverse gear as shown in the insert in figure 36.

28. Freewheeling.—*a.* A few years ago some type of freewheeling, or coasting, device was incorporated into passenger motor vehicles by most manufacturers. Freewheeling devices consist of some form of overrunning clutch built into the transmission or connected in back of it. They all include a control, usually on the instrument panel, to make the device operative or inoperative. When it is inoperative, the transmission functions in the usual way. When the freewheeling device is operating, the engine drives the vehicle except when the vehicle gains sufficient momentum to drive the engine. Then the engine is automatically disconnected from the driving wheels, the vehicle coasts, and the engine idles. As soon as the vehicle speed is reduced and equals that of the engine, the freewheeling device again connects the engine to the driving wheels. The wear on the brakes is much more severe with freewheeling than without it, since

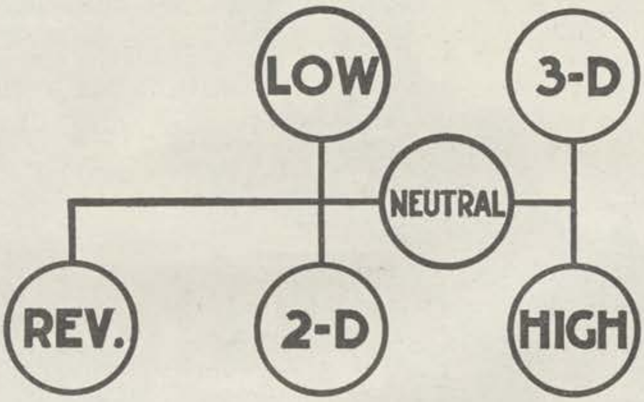


FIGURE 35.—Positions of the control lever for a four-speed transmission.

no braking action can be had from the engine. This is probably the main reason why this device is now seldom used except in connection with overdrives.

b. The purpose of the freewheeling device is to save gasoline. Another advantage claimed for it is that it permits shifting between second and high gears without declutching; the clutch being used only for starting and stopping.

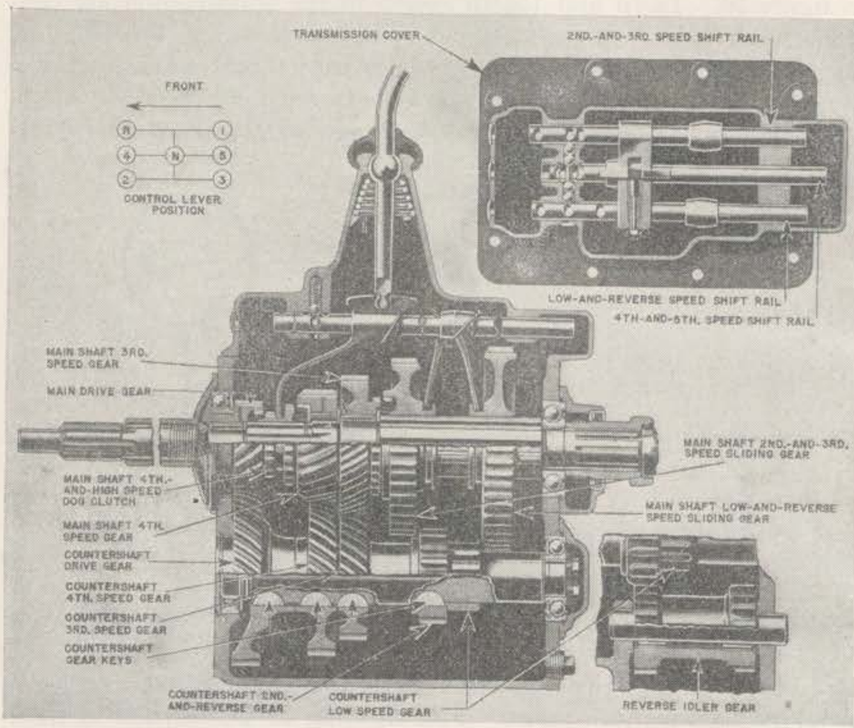


FIGURE 36.—Five-speed truck transmission.

c. Figure 37 shows a freewheeling device built into the transmission. The freewheeling unit consists of an overrunning clutch which can be shifted back and forth on the transmission main shaft. The outer shell of the clutch has internal teeth at each end which engage with external teeth on the high- or second-speed main shaft gear. Freewheeling is possible, therefore, only in second or high gear with this arrangement. The overrunning clutch consists of three groups of four rollers, each in wedge-shaped pockets, held in contact by springs which form the connection between the driving and driven members. When the shell is driving, the rollers are forced into the narrow ends of the pockets, locking the shell to the splined hub cam. When the speed of the hub cam exceeds the speed of the shell, the rollers are forced into the wide ends of the pockets where they are loose, unlocking the driving and driven members and allowing them to rotate independently. The freewheeling device shown is put into or taken out of operation by a button on top of the handle of the transmission control lever.

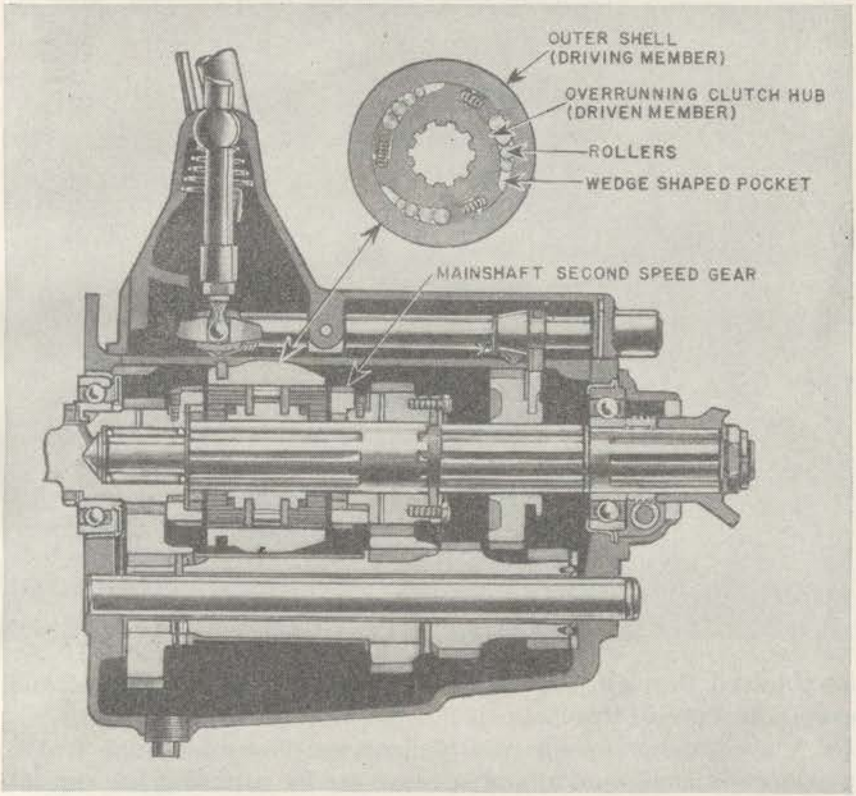


FIGURE 37.—Freewheeling unit built into transmission.

d. Another type of freewheeling device, separate from the transmission and connected at the rear of it, has the driving and driven members connected by an expanding coil spring.

29. Overdrives.—*a.* A knowledge of planetary gears, a form of gear train ordinarily used to obtain speed reductions, is necessary before the overdrive can be understood. These gears consist of three elements shown diagrammatically in figure 38. The central gear is known as the "sun gear." Three or more gears, mounted on a spider, rotate on their axes and also in space around the sun gear. These are called planetary gears because their motion around the sun gear is the same as the motion of the planets revolving in their orbits around the sun. There is also an internal gear surrounding the planetary gears and in mesh with them. Any one of the three parts of the gear train (sun gear, spider, or internal gear) may be used as the driving member to drive one of the other two members while the third member is held stationary. The methods of determining the various gear ra-

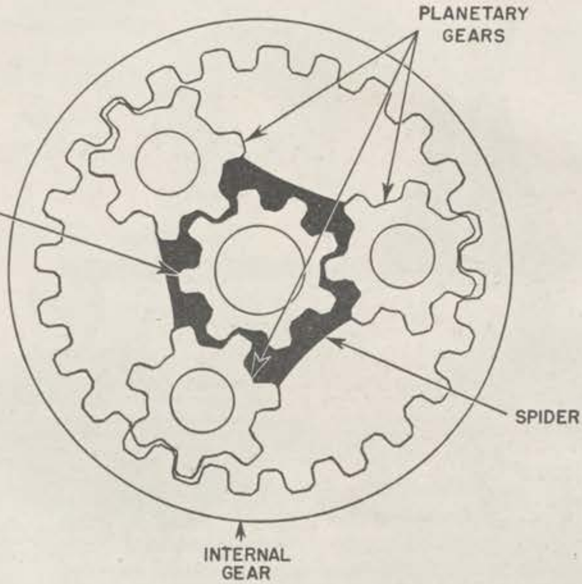


FIGURE 38.—Planetary gear train.

tios obtained through planetary gearing are rather complicated and beyond the scope of this manual.

b. A transmission overdrive provides a gear ratio less than 1 to 1. It reduces oil consumption and engine wear by requiring less revolutions of the engine for a given mileage than required if direct drive is used, and reduces gasoline consumption by providing a more suitable gear ratio for high speeds on level roads. When in operation, the overdrive reduces the engine-to-rear-axle gear ratio by approximately 30 percent. A freewheeling device is usually incorporated in the overdrive which also helps to save gasoline. The overdrive is usually a separate unit bolted to the rear of the transmission case.

c. A control button is provided on the instrument panel to lock the overdrive out of operation when necessary. The overdrive can be locked out when the car is standing still or when it is running.

When the car is running, this must be done only at speeds below 25 miles per hour when the overdrive is freewheeling. The accelerator is depressed, making the engine drive the vehicle, and the control button is pulled out without releasing the clutch. While the button is being pulled out, the accelerator is released momentarily to complete the shift and the overdrive will be locked out of operation.

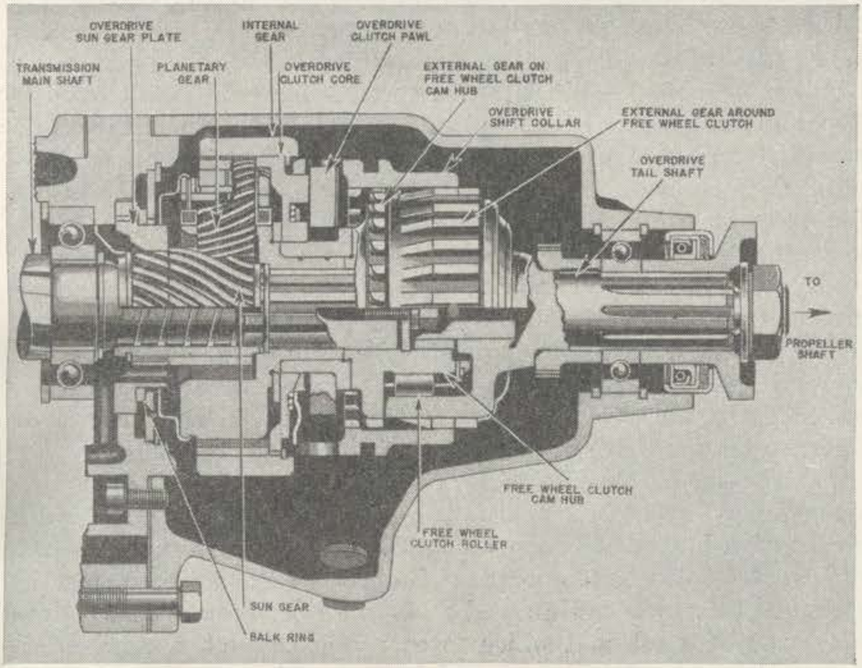


FIGURE 39.—Overdrive unit.

d. When overdrive operation is required, the control button is pushed in and the vehicle accelerated above the overdrive cut-in speed of approximately 33 miles per hour. Then the accelerator is released momentarily making the propeller shaft speed greater than the transmission main shaft speed, the automatic clutch engages, and when the accelerator is depressed again the overdrive is operating. When this takes place, freewheeling becomes inoperative since it operates only below the cut-in speed, or until the overdrive clutch is engaged. The overdrive unit (fig. 39) has four paths of power transmission as follows:

(1) *Control button pulled out; overdrive locked out of operation.*— The transmission mainshaft drives the overdrive tail shaft, to which the propeller shaft is connected, through the overdrive shift collar

which is engaged with the external gear around the freewheel clutch and driven by the external gear on the freewheel clutch cam hub which is splined to the transmission mainshaft.

(2) *Control button pushed in; car speed below cut-in speed (33 miles per hour).*—The overdrive shift collar is disengaged from the gear on the freewheel clutch cam hub and the drive is from the latter to the overdrive tail shaft through the freewheel clutch. The vehicle is then freewheeling as described in paragraph 28.

(3) *Control button pushed in; car speed above cut-in speed (33 miles per hour).*—When the car speed is above the cut-in speed of 33 miles per hour and the accelerator is released momentarily a reversal of torque takes place (propeller shaft drives engine). Centrifugal force causes the overdrive clutch pawls to engage slots in the overdrive shift collar which are in line with the clutch pawls when the vehicle is in overdrive; that is, when the control button is pushed in. The drive is now from the planetary gears which rotate around the stationary sun gear, to the internal gear which causes the 30 percent reduction in engine-to-axle ratio. The drive from the internal gear to the tail shaft, to which the propeller shaft is connected, is through the overdrive clutch core to the overdrive shift collar to the overdrive tail shaft.

(4) *Control button pushed in; car speed above 33 miles per hour (step-down).*—When the vehicle is operating in overdrive and quick acceleration is required for passing another car or ascending a hill, the overdrive can be temporarily eliminated without decreasing the car speed below the cut-in speed of 33 miles per hour. This is done by means of a solenoid which is energized through a relay when the accelerator pedal is depressed beyond wide open throttle position. When the solenoid is connected, a plunger which is held in engagement with the sun gear plate by a light spring is released. The relay also cuts the engine ignition for about two revolutions to cause a reversal of torque relieving the tooth pressure and permitting a pawl to disengage from the sun gear plate. By the time the pawl is fully released, the ignition has been restored and the pawl engages a step on the balk ring. The sun gear is now free to rotate and the drive is from the transmission main shaft through the freewheel clutch to the tail shaft, as given in (2) above, even though the overdrive clutch pawls are still engaged in the slots of the overdrive shift collar. This condition will continue until the accelerator is completely released, the spring loaded pawl returns to one of the notches in the sun gear plate locking the sun gear and restoring the overdrive; that is, the condition described in (3) above.

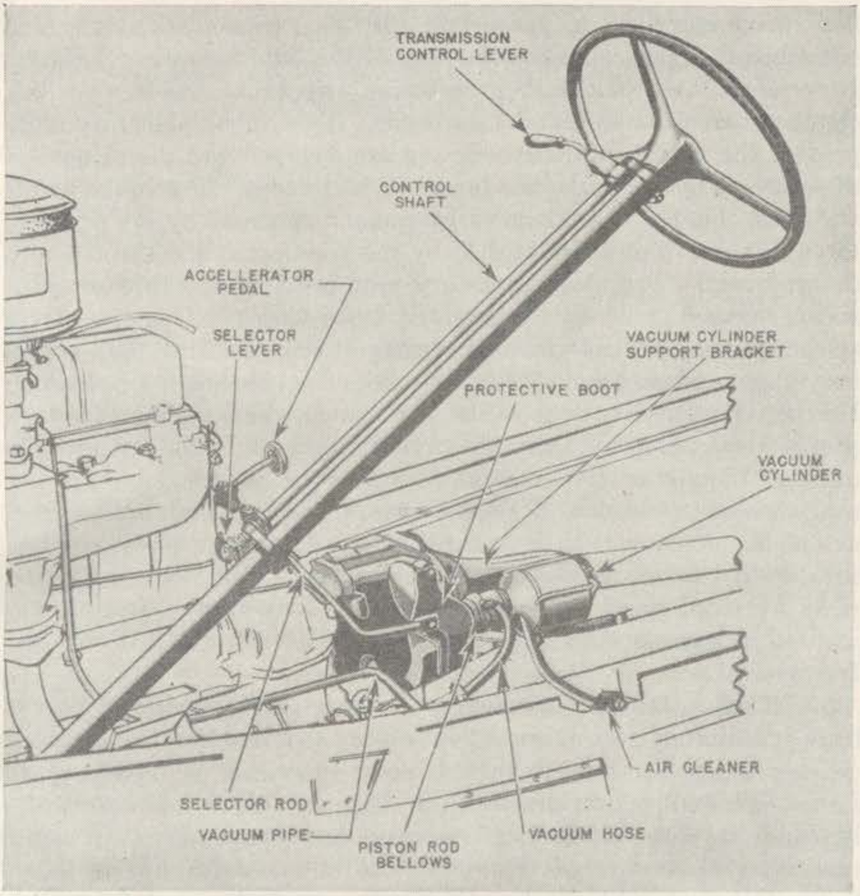


FIGURE 40.—Vacuum-assistor gear shift mechanism.

30. Vacuum power gear shift.—At least one passenger car now has a vacuum gear shift in connection with a synchro-mesh transmission as standard equipment. A vacuum-power cylinder similar to that described in paragraph 16, mounted alongside the transmission case, furnishes the power for shifting the gears. This system is sometimes known as the vacuum-assistor type because both manual effort and power of the vacuum cylinder are used to make gear changes. Most of the effort is exerted automatically. However, the gears can be shifted by manual operation of the steering column control lever alone when the engine is not running. The arrangement of this device is shown in figure 40.

31. Hydramatic drive.—One passenger car manufacturer is offering a four-speed, automatic transmission in conjunction with the fluid drive described in paragraph 18. This transmission is a unit contained in a case bolted to the back of the liquid coupling housing. It contains three planetary gear trains, two brake bands, two disk clutches, two oil pumps, and a governor. Two of the planetary units provide the four forward speeds and are engaged and disengaged in these speeds by the brake bands and disk clutches. The brake bands and disk clutches are operated by pistons actuated by oil pressure through valves jointly controlled by the position of the throttle and the governor. The third planetary unit provides the reverse speed and is engaged manually by means of a dog clutch. There is a lever on the steering column which has four positions: neutral, high range, low range, and reverse. Neutral is used when the engine is started. Driving is ordinarily done in the high range where all four forward speeds are available. Only the accelerator and brake are used in driving; there is no clutch pedal. Moving the hand lever to the low range cuts out third and fourth speeds, leaving first and second available. A manual shift is made to the low range position when it is desired to use the second gear as a brake and when a hill too steep for third speed is encountered and it is desired to ascend it at a speed in excess of 15 miles per hour. The manual shift is used for reverse.

32. Transmission lubrication.—*a.* A high quality, heavy-bodied, semifluid gear lubricant is usually required for transmission gears. A lighter, fluid lubricant may sometimes be necessary to assure distribution over and around the gears and to facilitate shifting and prevent "channeling" at very low temperature. Heavier transmissions may require heavier-bodied lubricants to prevent lubrication failures. SAE 90 gear lubricant is generally used for winter operation and SAE 140 for summer operation. On rare occasions, it may be advisable to use SAE 140 in winter and SAE 250 in summer for extremely heavy duty trucks, but only when specifically recommended by the manufacturer.

b. In transmissions having the countershaft below the main shaft, the lubricant should at least touch the bottom of the countershaft. Excessively high oil levels tend to make the main shaft oil seal leak, and if there is a transmission brake, its lining as well as clutch linings may become oil-soaked.

c. Transmissions are usually filled through a filler plug at the side of the case which also serves as an oil-level indicator. These units should be checked at least every 1,000 miles and lubricant added when necessary. They should be drained and refilled each 6,000 miles or 6 months of operation, preferably in the spring and the fall of each year.

Section IV

AUXILIARY TRANSMISSIONS; TRANSFER CASES; POWER TAKE-OFFS

33. General.—*a*. Trucks require more engine-to-axle gear ratios than passenger cars because of the wide variation in loads and the different types of roads and terrain over which they are operated. The usual truck transmission provides four or five gear ratios, or speeds. In order to double the number of gear ratios available, two methods are used; one is a dual ratio driving axle and the other is a two-speed auxiliary transmission located at the rear of the main transmission. The auxiliary transmission is sometimes preferred because it does not add to the unsprung weight of the vehicle, while the dual ratio axle does. In the case of all wheel drives, two-speed transfer cases serve the purpose of auxiliary transmissions.

b. Heavy duty trucks for use in military service must operate over steep grades and rough, muddy, and sandy soil. In order to provide enough tractive effort to enable a vehicle to pull itself out of bad spots, all wheel drives are used almost exclusively for military purposes. When vehicles are driven by all four or all six wheels, a transfer case is added back of the transmission to furnish one or more additional propeller shaft connections and to provide the necessary offset to permit the front propeller shaft to clear the engine crankcase.

c. Motor vehicles for special purposes require engine-driven accessories such as winches, hoists, and pumps. These machines are driven off some part of the power transmission train by a gear attachment known as a "power take-off."

34. Auxiliary transmissions.—*a*. These are very similar to main transmissions except that they usually have only two speeds and no reverse. They are also obtainable with three forward speeds. The auxiliary transmission is mounted on a frame cross member back of the main transmission and is connected to the transmission main shaft by a short propeller shaft and universal joints.

b. A cross sectional view of a two-speed auxiliary transmission is shown in figure 41. It is of the constant-mesh type employing helical gears. The main drive gear is integral with the drive shaft and is in constant mesh with the countershaft drive gear. A pilot bearing alines the main shaft with the drive shaft. The countershaft low-speed gear is in constant mesh with the low-speed main shaft gear which runs free on the main shaft when direct drive is used. A gear type dog clutch, splined to the main shaft, slides forward to make a positive connection between the drive shaft and main shaft and rearward to clutch the low-speed main shaft gear fast to the main shaft. Radial ball bearings are used throughout.

c. Since the shifter shaft slides straight forward and back, no

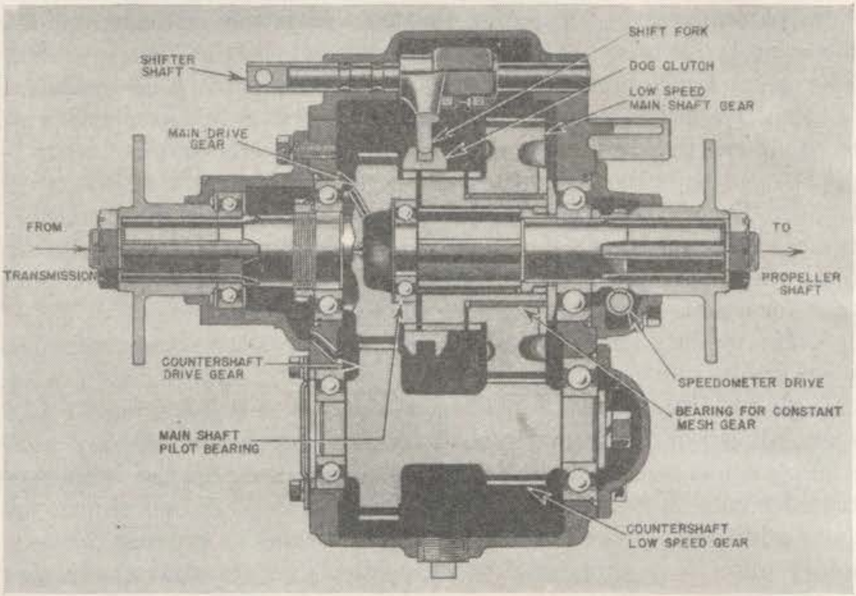


FIGURE 41.—Sectional view of auxiliary transmission showing gear arrangement.

special control is required and any lever may be used. The auxiliary transmission gears can be shifted while the vehicle is standing still or in motion, provided the clutch is disengaged, in the same way as the main transmission gears.

d. The underdrive gear ratio of the auxiliary transmission shown in figure 41 is 2.34 to 1, although 1.5 or 2 to 1 is more usual. The underdrive may be used in conjunction with any of the main transmission speeds and therefore doubles the number of speeds available. When the auxiliary transmission is in high speed, power is transmitted directly through it to the propeller shaft and the speeds available are those of the main transmission. When the auxiliary transmission is in low speed, it provides a reduction for each speed of the main transmission. It can readily be seen that when the low speed of the auxiliary transmission is used with the lowest speed of the main transmission, it causes a very large torque to be exerted by the driving wheels.

e. Auxiliary transmissions are lubricated the same as main transmissions.

35. Transfer cases.—*a.* The simplest type of transfer case consists of a drive gear, idler gear, and driven gear mounted on shafts and bearings in a case (fig. 42). It is the type used on light four-

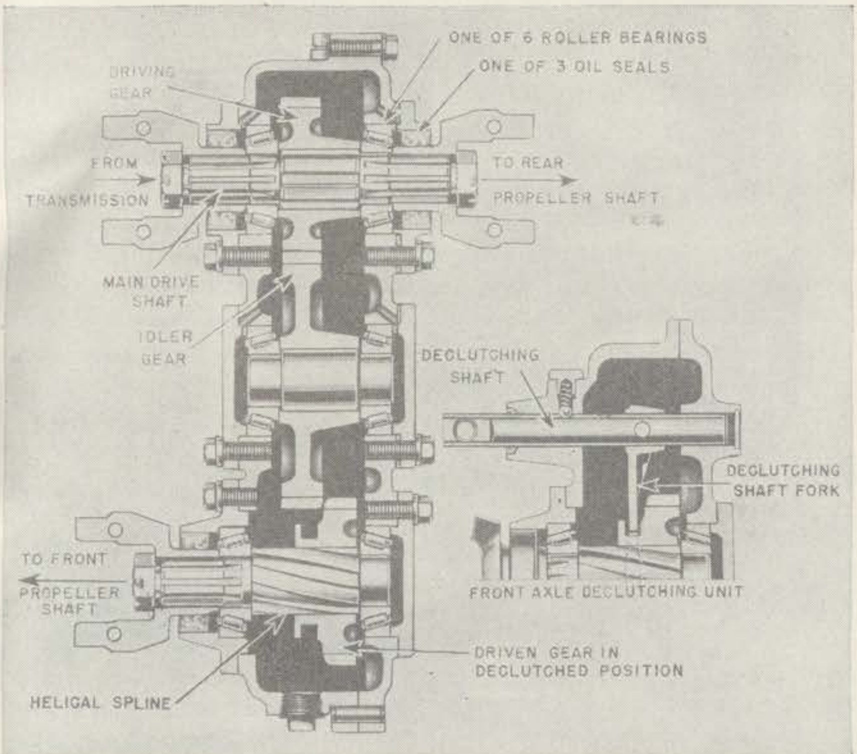


FIGURE 42.—Single-speed transfer case.

wheel drive vehicles. The transfer case is placed in the same location as the auxiliary transmission and the drive gear shaft is connected to the transmission in the same way. The rear propeller shaft is connected to the rear end of the drive gear shaft and to the rear axle through universal joints. The front axle propeller shaft is connected to the driven gear shaft. Helical gears are used throughout.

b. The transfer case (fig. 42) has a sliding driven gear on a helical spline that can be slid out of mesh by means of a lever in the driver's cab connected to the shift rail and fork, shown in the insert in figure 42. This disconnects the front axle drive, permitting the vehicle to be driven by the rear wheels only. Formerly many transfer cases

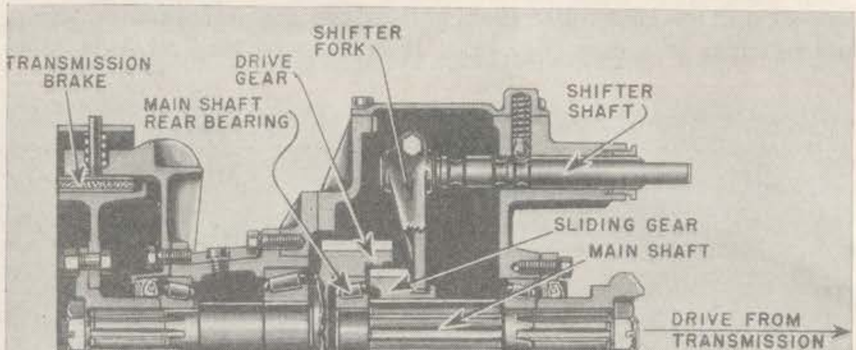


FIGURE 43.—Cross section of two-speed transfer case.

were used without this feature; that is, four-wheel drive had to be used at all times. This resulted in excessive wear on the front tires when the vehicle was run on hard pavements and excessive wear on the transfer case mechanism. Most of the newer transfer cases have some means of disconnecting the front-wheel drive and the all-wheel drive is used only when additional traction is needed. However, some transfer cases of this type are equipped with an interlocking mechanism that makes it impossible to shift the low and reverse gears in the transmission unless the transfer case is in four-wheel drive. Therefore, when this device is used, the shift connecting the front-wheel drive should always be made just before stopping or parking the vehicle to allow the immediate and easy shifting of the low and reverse gears when the vehicle is again to be started.

c. Transfer cases for heavier vehicles incorporate two speeds. Thus they perform the same function as auxiliary transmissions in addition to providing the offsets and adidtional propeller shaft connections for all wheel drives. A common type of two-speed transfer case is shown in figure 43. In this mechanism, the mainshaft has a sliding spur gear and is alined with the drive gear shaft by a pilot bearing. The helical drive gear, idler gear, and driven gear are in constant mesh. When the sliding gear is moved rearward, its external teeth engage internal teeth in the drive gear forming a positive connection between the main shaft and the drive gear and shaft. The path of power transmission is from the transmission to the drive gear to the idler gear to the driven gear and through the driven shaft to the front and rear propeller shafts. The drive gear shaft, in this case, is connected only to the hand brake drum. When the sliding gear is moved forward into mesh with the low-speed gear, the drive is from the transmission to the main shaft to the sliding gear to the low-speed gear to the idler gear, to the driven gear, to the driven shaft and propeller shafts. The sliding gear is in a neutral position between the drive gear and the low-speed gear when the spring loaded ball, or poppet, engages the middle notch on the shifter shaft (fig. 43). The front-wheel drive declutching mechanism consists of a sliding sleeve spline clutch. The actual connections of this transfer case installed in a four-wheel drive vehicle are shown in figure 44.

d. This same type of transfer case is used for a six-wheel drive vehicle having an independent propeller shaft connected to each rear axle. In this case, the propeller shaft to the rearmost rear axle is connected to the drive gear shaft in back of the brake drum. A short part of it, having universal joints at each end, passes through a bearing mounted on the forward rear axle. This arrangement is shown at the top of figure 45 and the control levers and linkage are shown at the bottom of figure 45.

e. A single-speed transfer case having an interaxle differential is shown in figure 46. If the front pair of wheels is not exactly the same diameter as the rear pair of wheels, due to tire wear, there must be slippage between them unless a differential gear is interposed between the axles; and the front and rear wheels must travel at different

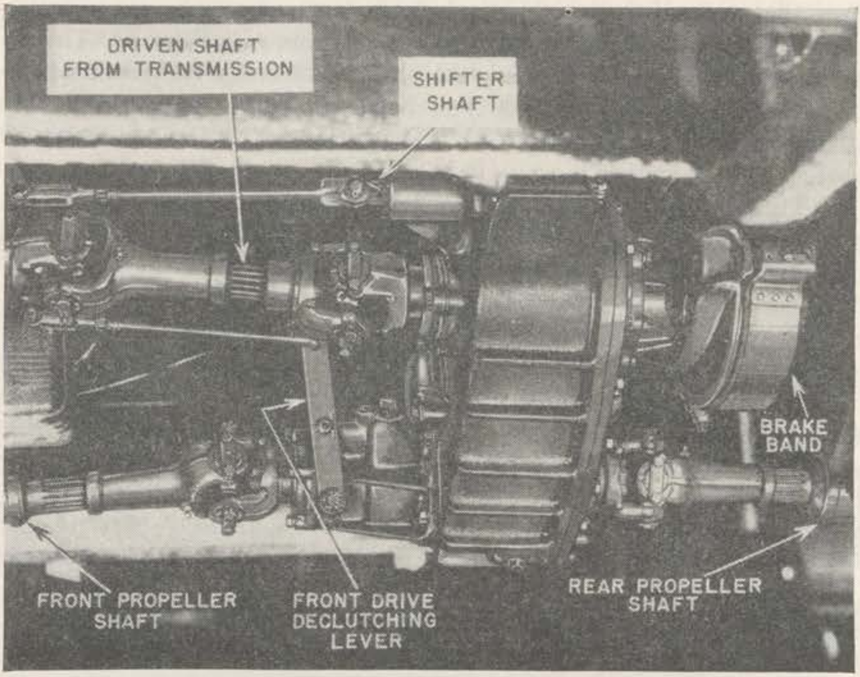


FIGURE 44.—Transfer case installed in a four-wheel drive truck.

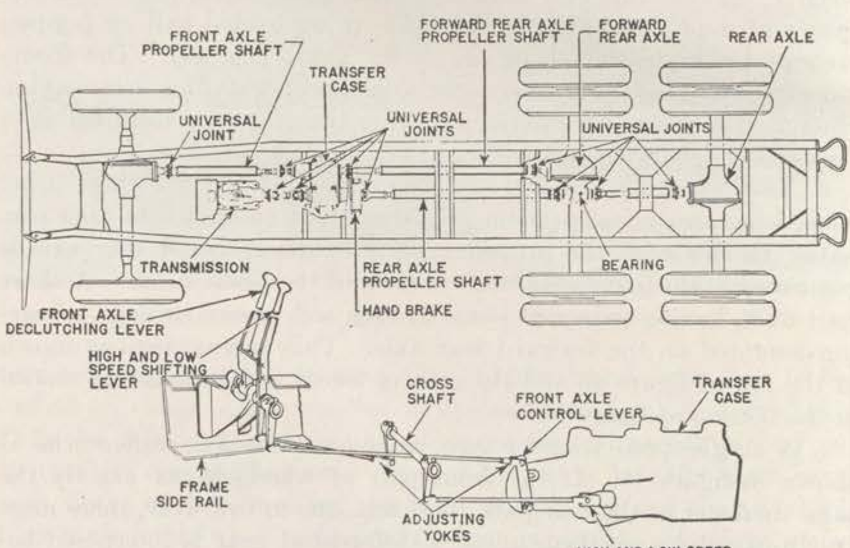


FIGURE 45.—Transfer case connected to front driving axle and dual rear axles.

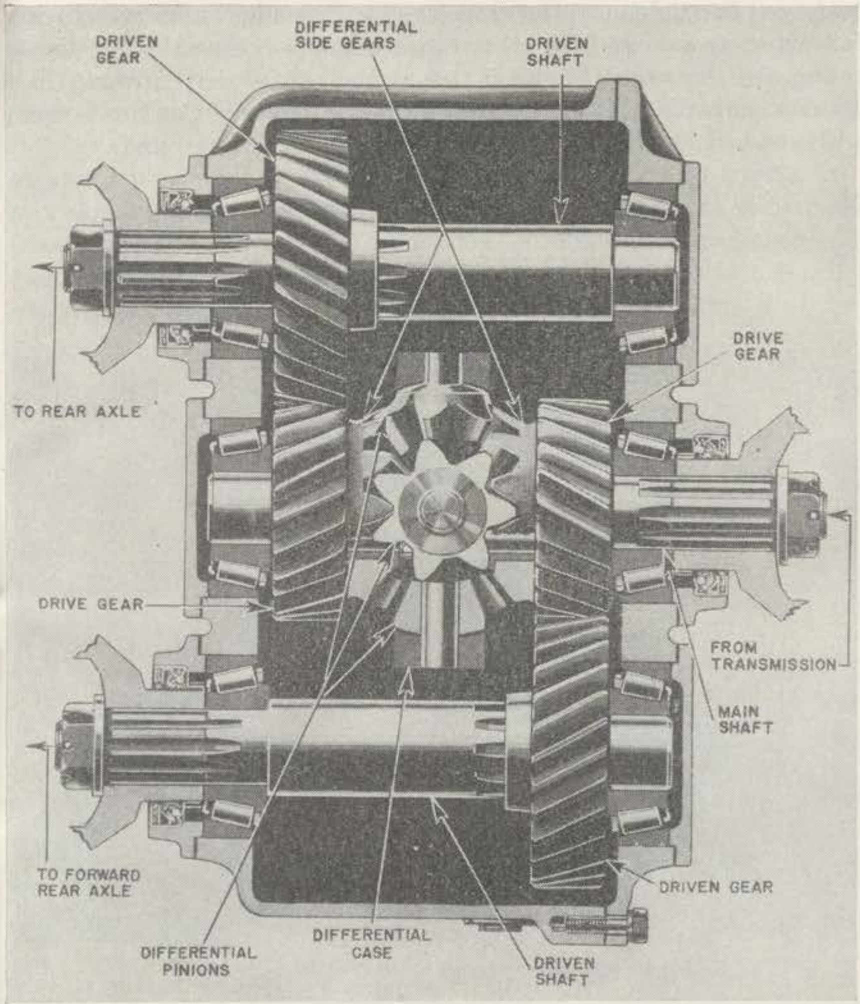


FIGURE 46.—Transfer case with interaxle differential for dual rear axle drive.

rates of speed when the vehicle makes turns. The interaxle differential works the same as the driving axle differential described in paragraph 48. The transfer case shown is for a six-wheeled vehicle which drives on the rear four wheels; the front wheels are not driven. The transmission is connected through the main shaft to the differential case in which the four differential spur pinions are pivoted. These pinions drive the differential side gears which are integral with the helical drive gears. The latter drive the two helical driven gears which drive the two driven shafts to which the propeller shafts are connected through universal joints. One propeller shaft goes to the forward rear axle and the other to the rearmost rear axle. A disadvantage of this type of drive is that if one pair of driven wheels lose traction and spin, the other pair will not be driven. For this reason, a differential lock as described in *f* below is sometimes used.

f. A type of transfer case employing a silent chain and interaxle differential is shown in figure 47. The drive is from the sprocket on the driving shaft through the silent chain to a sprocket on the differential case, thence through the differential case and pinions to the differential side gears to the driven shafts to which the propeller shafts are

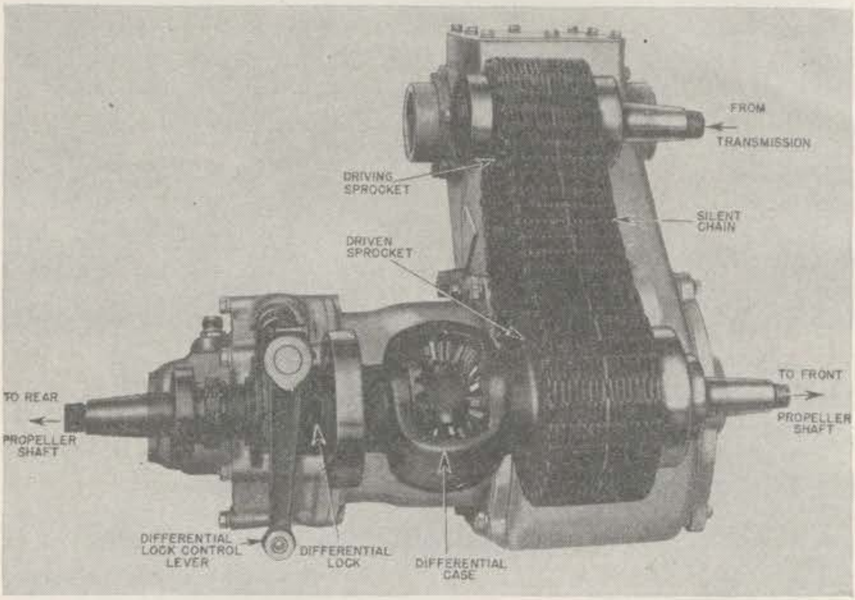


FIGURE 47.—Silent chain type transfer case with differential.

connected. Transfer cases of this type are provided with a differential lock consisting of a dog clutch which locks the two driven shafts together. It is operated by a lever in the driver's cab. If either the front or rear wheels lose traction and spin leaving the other pair stationary, the differential is locked out of action and power is distributed equally to both pairs of wheels.

g. The automatic compensator transfer case (fig. 48) contains a mechanism that automatically disengages the front-wheel drive at any time the front wheels rotate faster than the rear wheels, as in turning a corner; that is, overrunning of the front wheels is permitted. This transfer case is the same as the two-speed transfer case described in e above except for the driven gear and shaft assembly. The driven gear is wider and it floats on the driven shaft except when clutched to it by one of the ratchet-toothed dog clutches splined to the driven shaft on either side of the driven gear. The ratchet teeth on these clutches are opposed; that is, the jaws of the rear clutch engage the

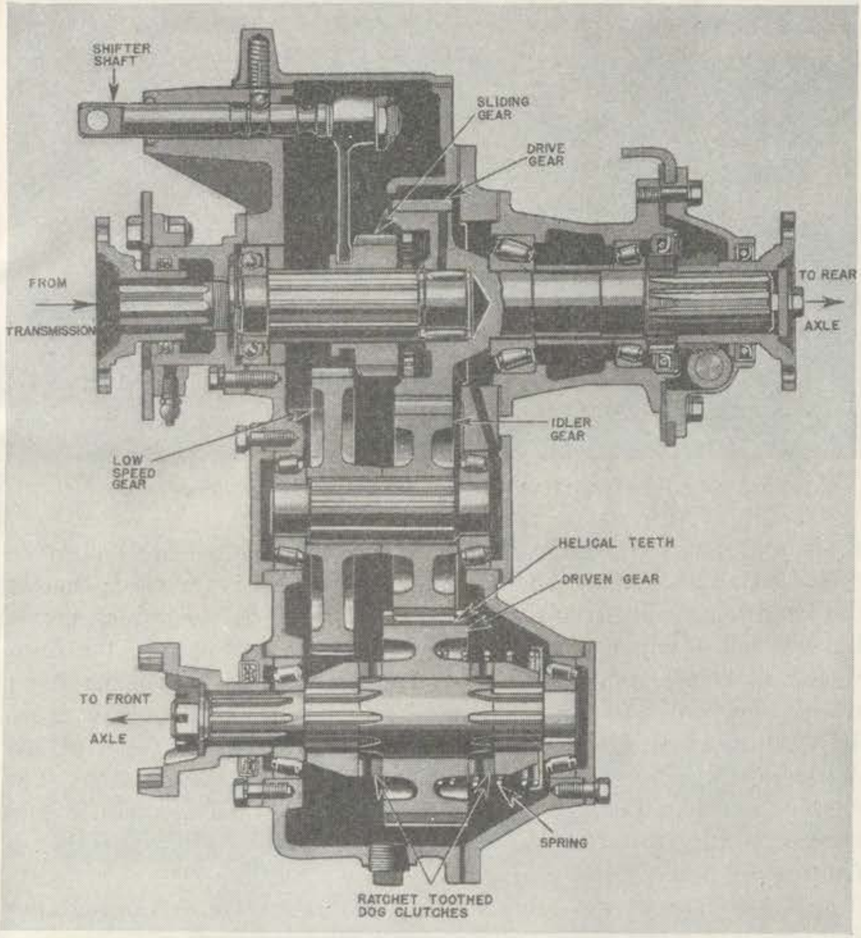


FIGURE 48.—Transfer case with automatic compensator.

teeth on the rear of the driven gear hub when the vehicle is moving forward, and the jaws on the front clutch engage when the vehicle is in reverse. The driven gear is free to move forward or back on the driven shaft. When the vehicle is driven forward, the side pressure on the helical teeth of the driven gear causes it to move rearward against spring pressure, engage the rear clutch, and rotate the driven

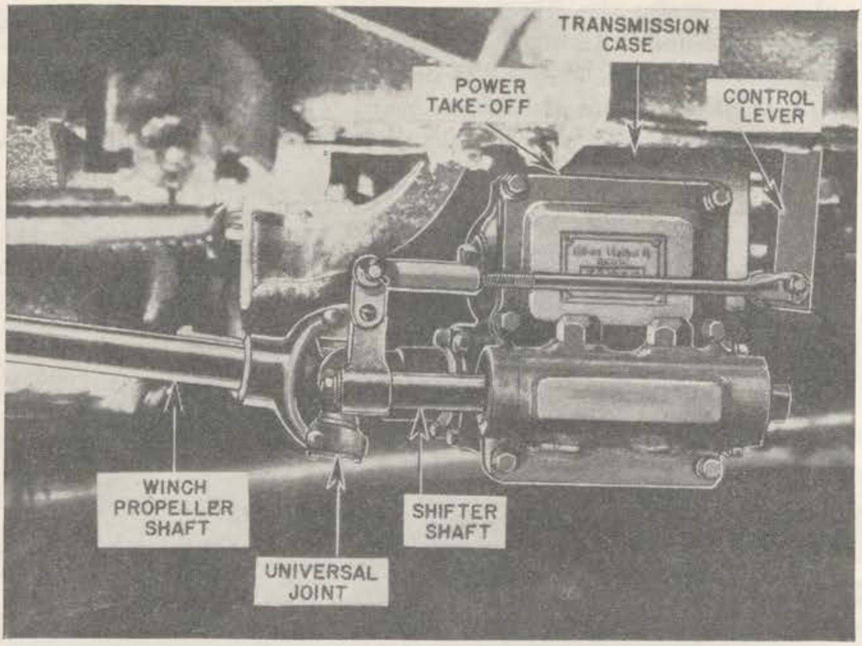


FIGURE 49.—Power take-off connected at left side of transmission.

shaft and front propeller shaft. When the front wheels start to rotate faster than the rear ones, the driving action is reversed; that is, the front wheels begin to drive instead of being driven, which moves the gear out of engagement with the rear clutch and permits the front wheels to rotate independently of the rear ones. When the front wheels slow down to the same speed as the rear ones and are again driven instead of driving, side pressure on the helical teeth of the driven gear again moves it into engagement with the rear clutch. The same action takes place in an opposite direction when the vehicle is in reverse, at which time the forward clutch engages and disengages the front-wheel drive.

h. Transfer cases are lubricated in the same way as transmissions and auxiliary transmissions.

36. Power take-offs.—*a.* These are attachments for connecting the engine to power driven auxiliary machinery when its use is required. (See par. 33*c*.) They are attached to the transmission, auxiliary transmission, or transfer case.

b. A power take-off installed at the left side of a transmission is shown in figure 49. It is used to drive a winch, located at the front of the truck, through the universal joint and propeller shaft.

c. The simplest type of transmission power take-off is the single-gear, single-speed type shown in figure 50. This unit is bolted over an opening provided for the purpose at the side of the transmission case. This opening is closed by a cover plate when no power take-off is used. The opening in the transmission case and the power take-off unit are so designed that when the latter is bolted on, the power take-off gear meshes with a gear on the transmission countershaft. As

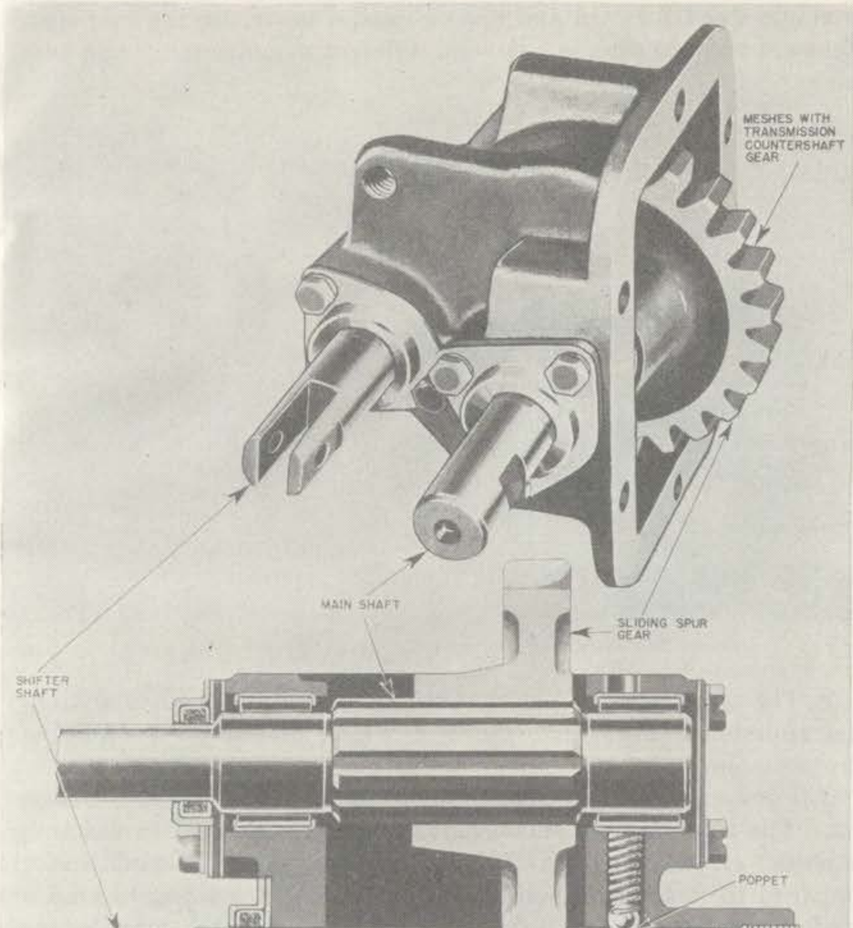


FIGURE 50.—Single-speed, single-gear, power take-off.

shown in figure 50, the gear slides on the splined main shaft off which the power is taken. The shifter shaft, controlled by a lever in the driver's cab, slides the gear in and out of mesh with the countershaft gear. Since it is driven by the countershaft, the power take-off shaft rotates in the same direction as the engine crankshaft.

d. Transmission power take-offs are available in several different designs: a single-speed, two-gear model in which the rotation of the power take-off shaft is opposite to that of the engine; a model having a single-speed forward and reverse; and a model having two speeds forward and one reverse. Several different mountings are also available.

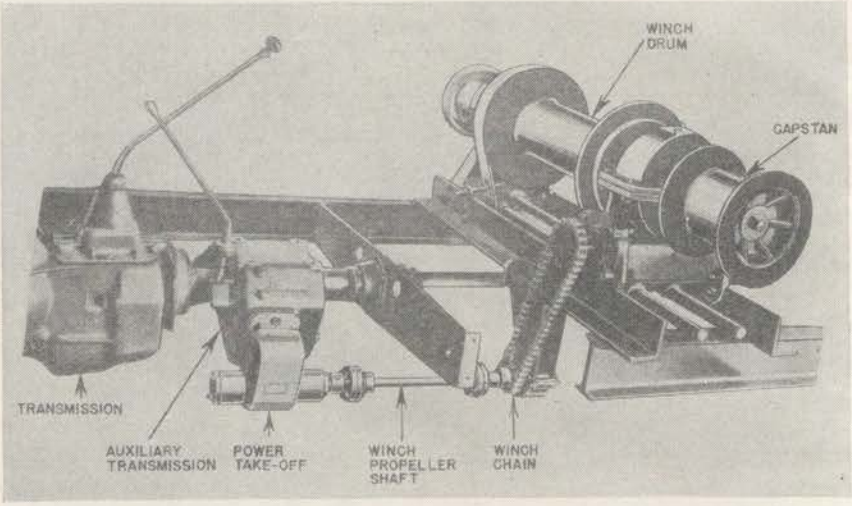


FIGURE 51.—Auxiliary transmission power take-off driving winch.

e. The same types of power take-offs are also applied to auxiliary transmissions. Figure 51 shows a winch driven off an auxiliary transmission.

f. Power is sometimes taken off a transfer case as shown in figure 52. The transfer case drive shaft, which is connected to the transmission, extends through the case and the power take-off shaft is engaged to it by a dog clutch. This transfer case has two speeds and a neutral position. It is necessary to put the transfer case sliding gear in the neutral position if the vehicle is to be stationary while the power take-off is in use. If the power take-off is needed while the vehicle is in motion, the transfer case may be shifted either into high or low range. With this arrangement, the power take-off will work on any speed of the transmission. The positions of all the cab control levers of one model of vehicle are shown diagrammatically in figure 53 as they are placed on the instruction plate in the cab. When the power take-off clutch is engaged the winch capstan operates; but the winch drum does not rotate until the winch clutch is engaged.

g. The several types of power take-offs have been described as operating winches; but their use for operating various kinds of hoists, pumps, and other auxiliary power-driven machinery is essentially the same.

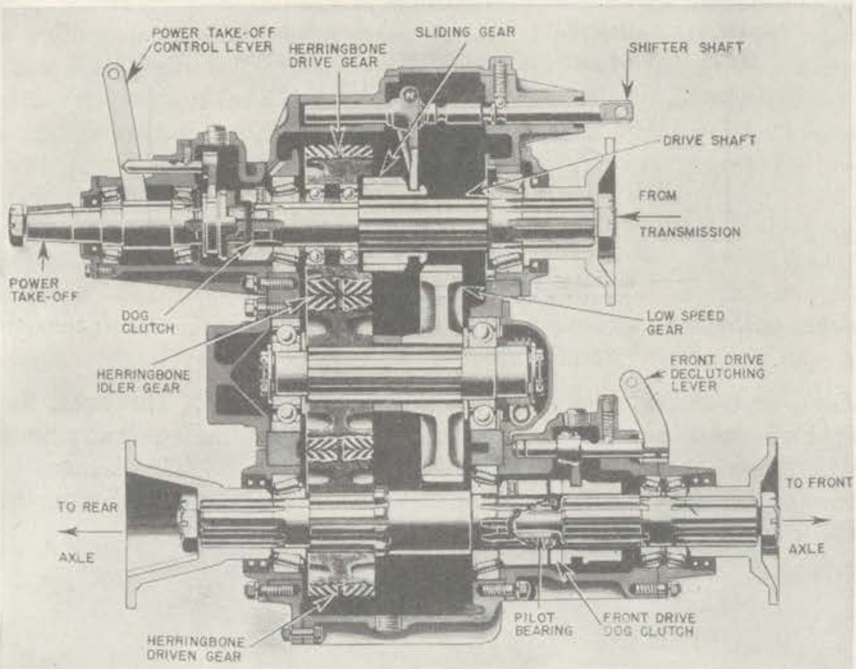


FIGURE 52.—Two-speed transfer case with power take-off.

h. Crash trucks usually have small gear pumps driven by transmission power take-offs. Fire engines have large pumps which are driven off the transmission main shaft. This shaft passes through the driving member of the pump and the pump is connected to it by a dog clutch. When this clutch is engaged, it also disengages the propeller shaft from the driving wheels. Thus the pump can be driven while the vehicle is stationary and can be controlled by the main transmission and clutch.

i. Power take-offs do not ordinarily require separate lubrication, being lubricated by the oil in the transmissions, auxiliary transmis-

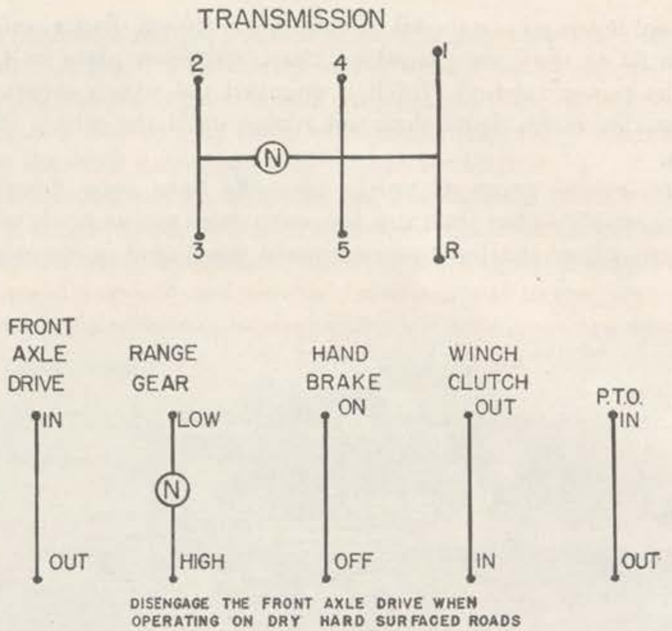


FIGURE 53.—Positions of transmission control lever and transfer case control lever for two-speed transfer case with power take-off.

sions, or transfer cases to which they are connected. However, the type of power take-off that is connected to a transmission or auxiliary transmission sometimes requires separate drainage. This is usually accomplished by removing a separate drain plug or one or more of the lower cap screws in the lower bearing caps.

SECTION V

PROPELLER SHAFTS AND UNIVERSAL JOINTS

37. General.—Power must be transmitted from the transmission to the live axle through a variable angle, because the driving axle of a motor vehicle is attached to the springs while the transmission is mounted on the frame, resulting in relative motion between the two. The distance between the two members is also constantly changing slightly due to the flexing of the springs. Some type of flexible drive is required, therefore, between the transmission and driving axle. The chain and sprocket drive was first used for this purpose, but it has been almost supplanted as a motor vehicle drive by the propeller shaft and universal joint.

38. Propeller shafts.—There are two types of propeller shafts: solid and tubular. The torsional stress in a propeller shaft varies from zero at the axis to a maximum at the outside. Since the center of a shaft resists only a small portion of the load, hollow shafts are used wherever practicable. A solid shaft is somewhat stronger than a hollow shaft of the same diameter, but a hollow shaft is stronger than a solid shaft of the same weight. Solid shafts are generally used for torque tube drives (par. 45*b*) because shafts of small diameters are required to fit inside the shaft housing. Hollow shafts are always used for Hotchkiss drives (par. 45*d*) where the shafts are in the open.

39. Slip joints.—*a.* A slip joint is provided at one end of the propeller shaft to provide for end play; that is, lengthening and shortening of the propeller shaft as the springs flex and the axle moves up and down. The usual type of slip joint consists of a splined stub shaft, welded to one end of the propeller shaft, which fits into a splined sleeve integral with the universal joint yoke. (See fig. 54.)

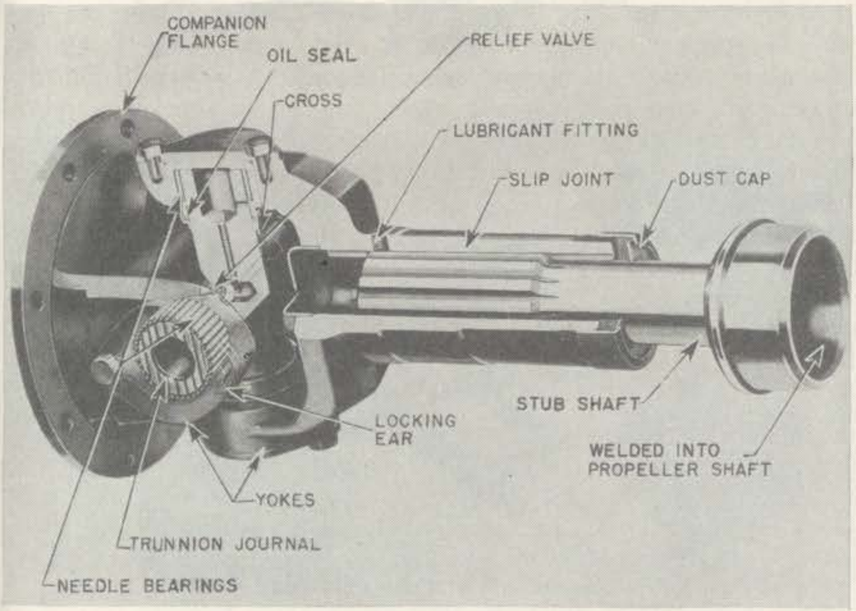


FIGURE 54.—Slip joint and universal joint.

b. Lubrication of slip joints is important because if they do not slide freely there will be an excessive end thrust on the bearings that support the propeller shaft and the universal joints which will cause rapid wear and possible failure. A chassis lubricant is usually recommended by the manufacturer.

40. Universal joints.—A universal joint is a connection between two shafts that permits a driving shaft to drive a driven shaft at an angle.

a. Hooke's coupling.—An early type of universal joint is the Hooke's coupling (fig. 55) consisting of a cross with two yokes pivoted to its ends. Most universal joints in use today embody the same principles.

b. Cross and two yokes.—A type of universal joint widely used is the cross and two yokes (figs. 54 and 56) which is very similar to Hooke's coupling. The cross is drilled to receive lubricant for the needle bearings which pivot the ends of the cross, or trunnions, to the

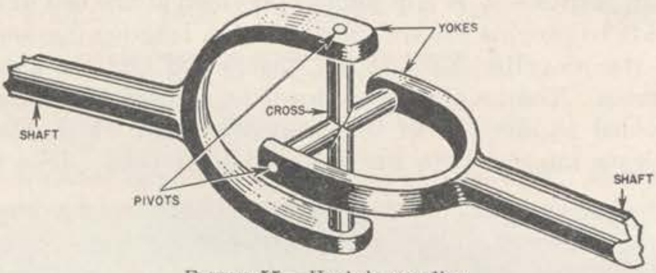


FIGURE 55.—Hooke's coupling.

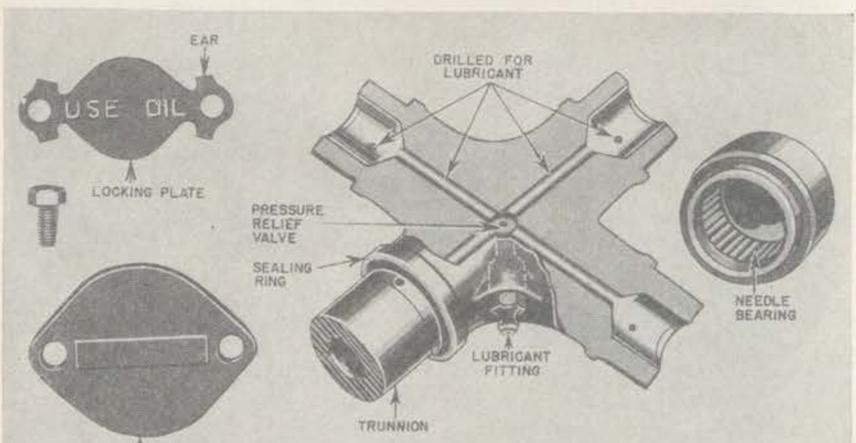


FIGURE 56.—Universal joint cross and bearings.

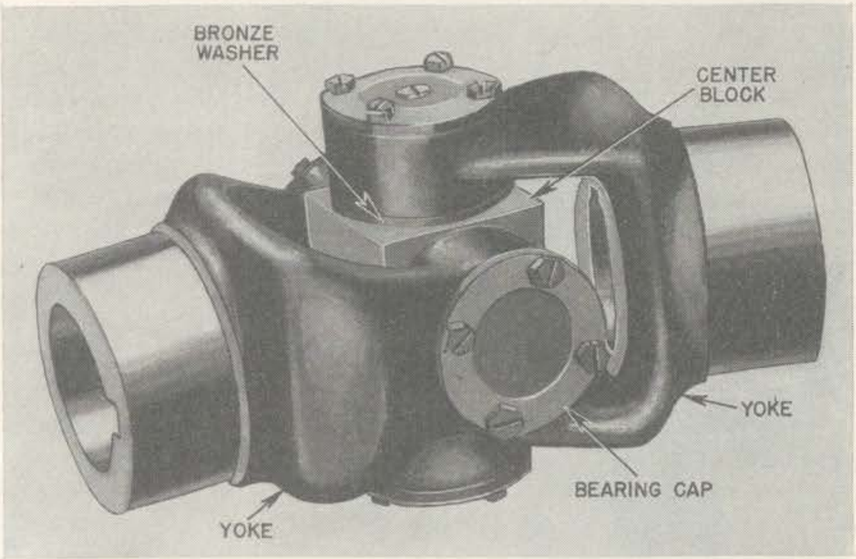


FIGURE 57.—Assembled cross pin universal joint.

two yokes. Caps held by cap screws and locking plates hold the needle bearings in place in the yokes. A relief valve is shown at the center of the cross. This is to prevent damage to the needle bearing retaining parts and oil seals in case excessive oil pressure is applied to the fitting. The universal joint is shown assembled in figure 54. One yoke is integral with the splined sleeve of the slip joint and the other yoke is integral with a companion flange which bolts to a mating flange on the transmission shaft. The oil seals can be seen at the inner ends of the needle bearings. The ears on the locking plates are bent up to prevent the cap screws from loosening.

c. Cross pin type.—This universal joint, which is somewhat different from the preceding type both in construction and operation, is shown assembled in figure 57 and in cross section in figure 58. Two pins, one having an enlarged cross section at the middle and the other of uniform diameter, are locked into a cubical block by means of a hollow locking screw. Both pins and the locking screw are drilled for lubrication. Four cups with needle bearings fit into the yokes and around the ends of the pins. The cups are held in the yokes by cap screws and locking plates with ears which are bent up to prevent the cap screws from loosening. Bronze washers between the yokes and sides of the center block take part of the torque transmitted by the joint, while in the type described in *b* above, all of the torque must be transmitted through the needle bearings. The bronze washers

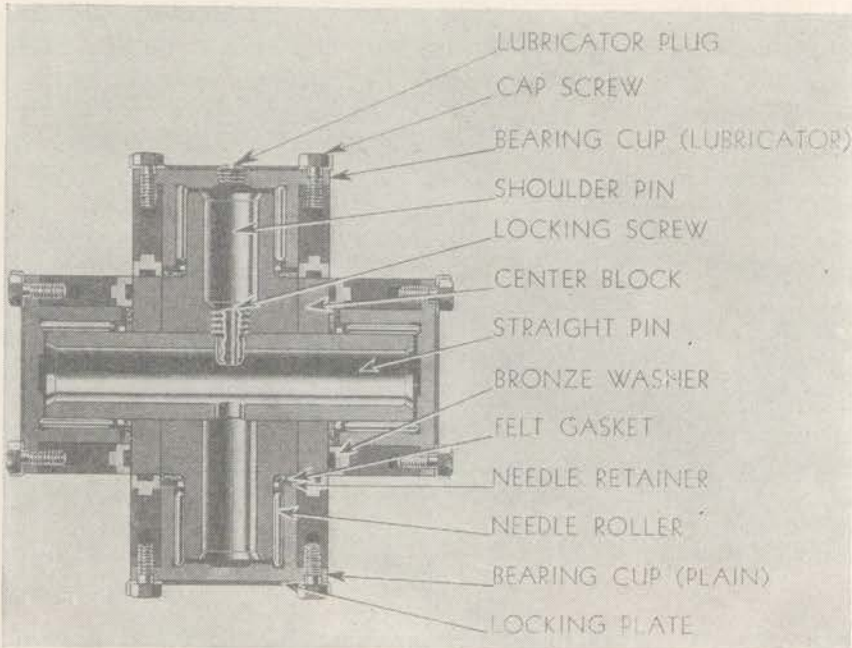


FIGURE 58.—Cross section of cross pin universal joint.

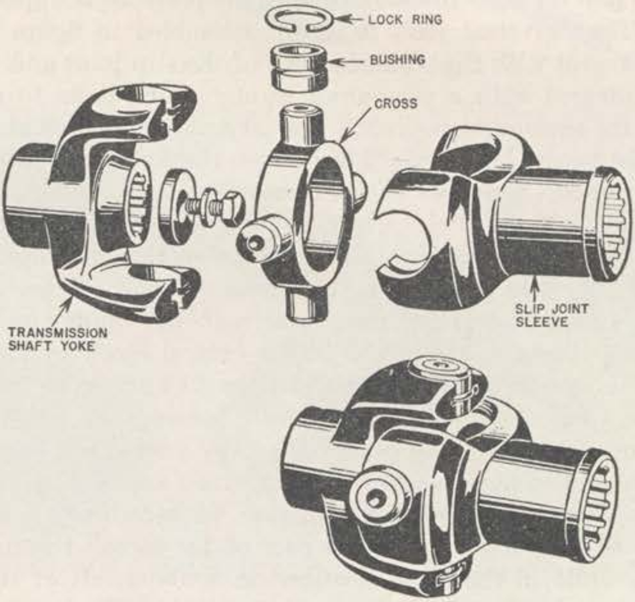


FIGURE 59.—Ring and trunnion universal joint.

can be replaced with oversize ones in case of wear. A plug is screwed into the end of one of the needle bearing caps which is removed to fill the passages with lubricant. Felt gaskets are placed under each needle bearing and cup to retain the lubricant.

d. Ring and trunnion type.—This type of universal joint (fig. 59) is quite similar to the cross and two yokes type, but the trunnions are integral with a ring instead of a cross. Steel bushings held in the yokes by wire lock rings are used in place of needle bearings. The universal joint is used in a torque tube drive and the entire assembly runs in oil in a ball housing connecting the torque tube to the rear of the transmission case.

e. Split ring type.—In this design of universal joint (fig. 60) the trunnions are integral with the yokes and a split ring holds the bushings in place around the trunnions. The two halves of the ring are held together by bolts with lock washers, or castle units and cotter pins. It has no means of retaining lubricant and is used only in torque tube drives where the entire assembly runs in oil.

f. Split ring and pin type.—This type (fig. 61) is similar to the split ring type in that a split ring holds the trunnions in place. One pair of trunnions is integral with one of the yokes. The other yoke and pair of trunnions are formed by the projecting ends of a pin inserted in a block integral with a companion flange. The split ring is so designed that it retains lubricant and no other housing is required.

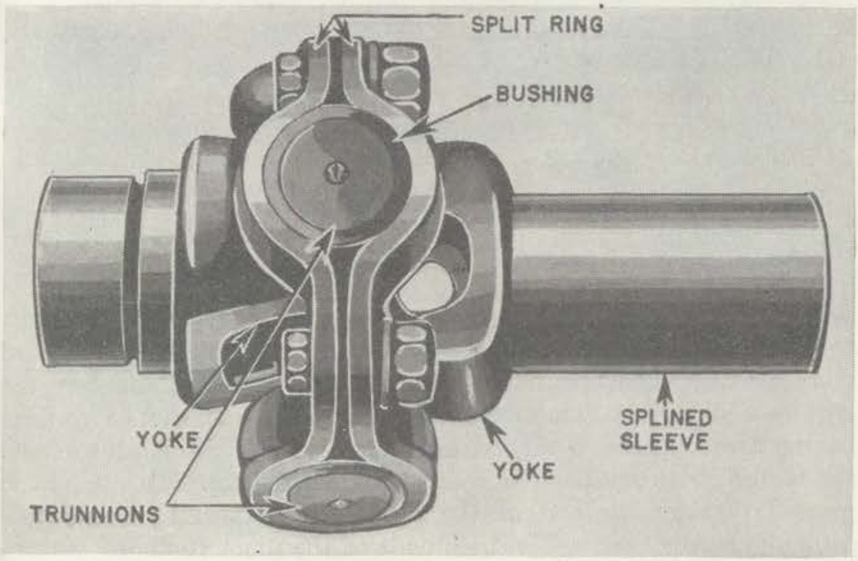


FIGURE 60.—Split ring universal joint.

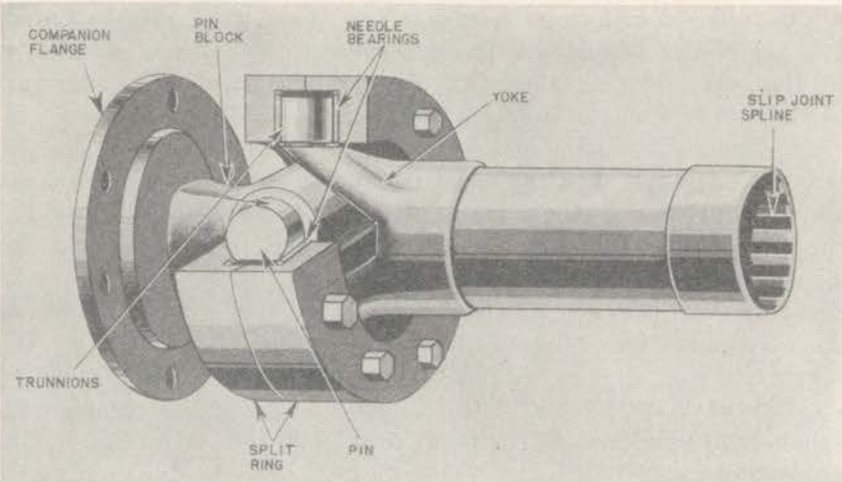


FIGURE 61.—Universal joint with split ring and pin.

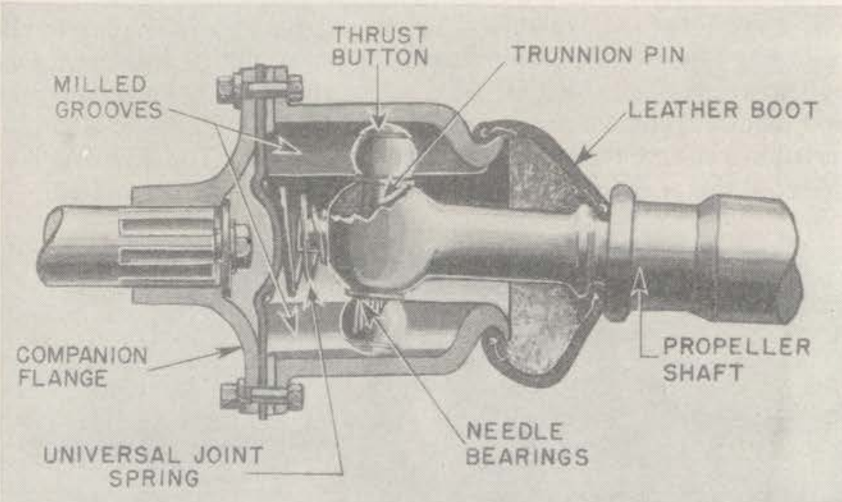


FIGURE 62.—Sliding ball and trunnion universal joint.

g. Sliding ball and trunnion type.—This type differs from any of those discussed above in that it permits end movement and does not require a slip joint. One member consists of a cup-shaped forging having two opposed U-shaped milled grooves. This is attached to the transmission shaft by a companion flange (fig. 62). A pin is pressed through the end of the propeller shaft and hollow balls rotate on needle bearings on both ends of the pin. Rounded buttons are inserted into the ends of the pin. These balls and buttons fit into the milled grooves in the cup forging and together with the pin form the other member. Since the pin and balls can turn both longitudinally and transversely in the grooves in the cup forging, universal joint action is obtained with only one pair of trunnions. The pin and balls can also move in and out of the cup making a slip joint unnecessary. A spring is placed between the driving and the driven shafts, as shown in figure 62. When universal joints of this type are used at both ends of the propeller shaft, which is the usual practice, springs in both joints limit the endwise movement of the propeller shaft in the two cups and prevent the balls from bottoming in the grooves. A leather boot, to keep out dust and confine the lubricant, completes the assembly.

41. Velocity fluctuations.—*a.* All the universal joints described so far cause speed fluctuations in the propeller shaft, the amount of the fluctuation depending upon the degree of angle between the driving and driven shafts. This will be discussed more fully in paragraph 58*a* in connection with front-wheel drive.

b. When two universal joints are employed, one at either end of the propeller shaft, the second universal joint is used to compensate for the speed fluctuations caused by the first. In order to accomplish this, the angle between the transmission shaft (driving) and the propeller shaft (driven) must be the same as the angle between the propeller shaft (driving) and the final drive shaft (driven). This will be the case if the transmission shaft and final drive shaft are parallel (fig. 63) in which angles *A* and *B* are equal. The other requirement is that both yokes of the universal joints attached to the propeller shaft lie in the same plane as shown in figure 63. When this arrangement is used, some torsional vibration is imparted to the propeller shaft, but no velocity fluctuation is transmitted to the

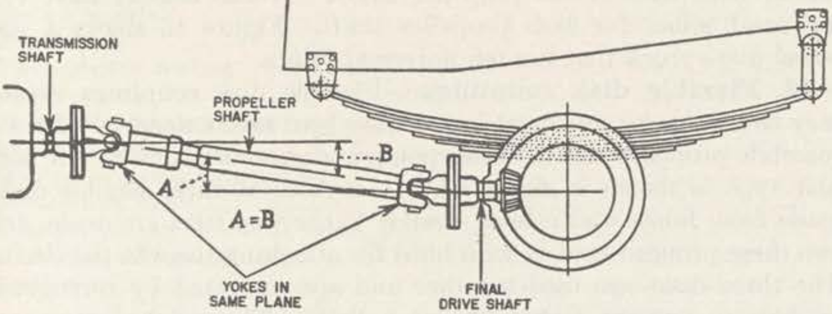


FIGURE 63.—Arrangement of drilling and driven shafts and universal joints to compensate for speed fluctuation.

driving axle and wheels. If, however, the yokes of the universal joints on the propeller shaft lie in planes perpendicular to each other, the velocity fluctuation caused by the first universal joint will be doubled by the second. It is very important, therefore, that the parts be assembled correctly.

c. Only one universal joint is ordinarily used in a torque tube drive. When the usual type of universal joint is used, the fluctuation in the speed of the propeller shaft relative to the transmission shaft is not compensated for and is carried to the rear axle and driving wheels. It is minimized by making the angle between the transmission shaft and propeller shaft as small as possible. It can be eliminated by using one constant velocity universal joint (par. 58*b*).

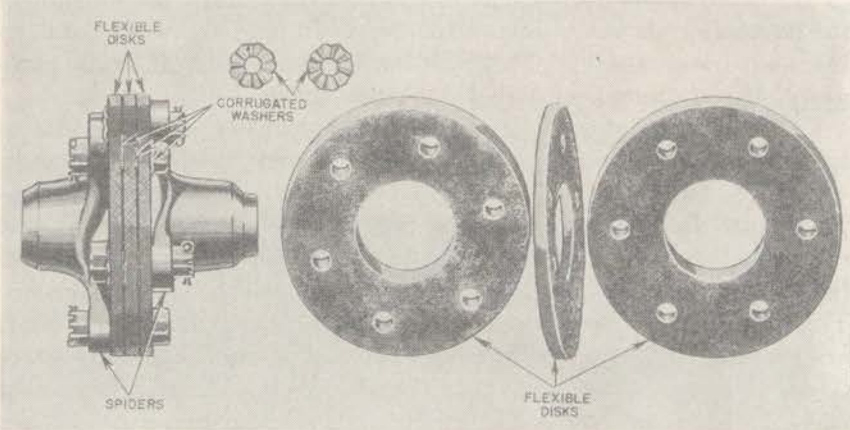


FIGURE 64.—Flexible disk coupling.

d. Passenger vehicles usually have one or two universal joints at one or both ends of the propeller shaft. Trucks usually have two universal joints for each propeller shaft. Figure 45 shows a six-wheel drive truck that has ten universal joints.

42. Flexible disk couplings.—Flexible disk couplings, which may be considered universal joints, have been used extensively for automobile propeller shafts, water pump and generator drives. A popular type is shown in figure 64. It consists of three flexible disks made from fabric and rubber, similar to the way tires are made, and two three-pronged spiders with hubs for attaching them to the shafts. The three disks are used together and are separated by corrugated washers to prevent friction between them. They each contain six holes (fig. 64). One spider is fastened on each side of the disks by bolts which go through in alternate holes. This type of joint permits a certain amount of end play due to the flexibility of the disks and can be used without a slip joint when the amount of end play is small. It runs quietly, requires no lubrication, and does not need to be protected from road dirt. However, it will not transmit power through a large angle, about 10° being the maximum.

43. Lubrication.—*a*. The slip joint of a propeller shaft entirely enclosed in a housing provided with a lubricant fitting requires greasing with chassis lubricant about every 1,000 miles.

b. A propeller shaft slip joint enclosed within a torque tube is usually lubricated automatically from an adjacent unit or assembly and requires no attention. A center bearing is often used, which is lubricated from a fitting on the outside of the torque tube once a month or every 1,000 miles.

c. Slip joints of propeller shafts having partially exposed splines, such as the drive shafts of some winches, must be lubricated with a heavy-bodied fluid to prevent the joint from rusting and sticking.

d. As a rule, the lubricant used on universal joints should be fibrous and fairly viscous so that it will not "throw off" as the joint rotates at high speed. Oil is recommended for lubricating some makes of universal joints, in which case "Use Oil" is usually imprinted on the joint.

SECTION VI

FINAL DRIVES; DIFFERENTIALS; LIVE AXLES

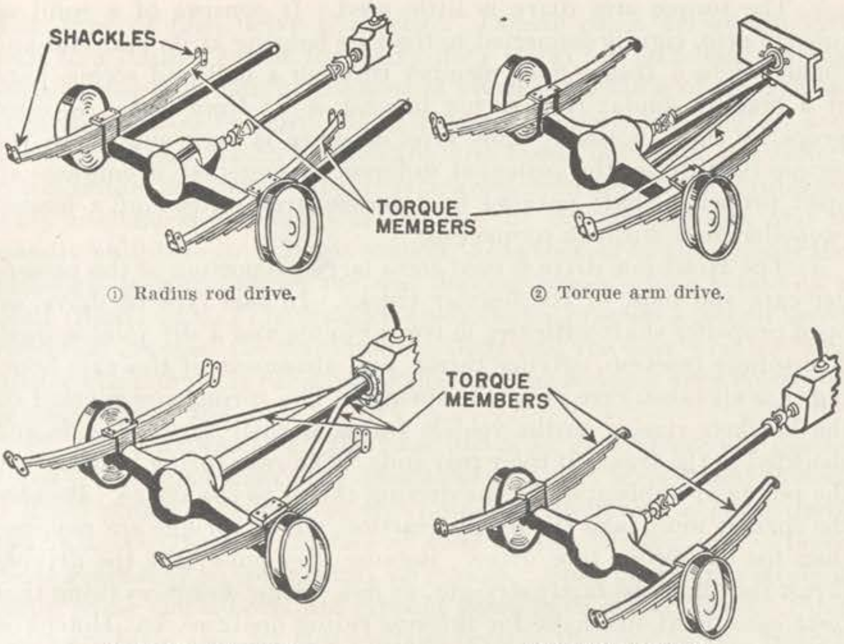
44. Final drive.—*a*. A final drive is that part of a power transmission system between the propeller shaft and the differential. Its function is to change the direction of the power transmitted by the propeller shaft through 90° to the driving axles. At the same time it provides a fixed reduction between the speed of the propeller shaft and the axle driving the wheels. In passenger cars, this speed reduction varies from about 3 to 1 to 5 to 1. In trucks, it varies from about 5 to 1 to 11 to 1.

b. The gear ratio of a bevel gear final drive is found by dividing the number of teeth on the bevel drive gear by the number of teeth on the pinion. For a worm gear, it is found by dividing the number of teeth on the worm gear by the number of threads on the worm. In case of chain drives, the sprockets are considered as gears and the number of teeth on the driven sprocket is divided by the number of teeth on the driving sprocket.

45. Types of drive.—When a turning force, or torque, is exerted through the final drive and axle shafts to turn the driving wheels, there is an equal and opposite torque, or reaction, tending to turn the axle housing in the opposite direction. The tractive effort of the wheels on the road which propels the vehicle forward or backward is also exerted on the axle housing. Some member or members must be provided, therefore, to prevent the axle housing from turning and to transmit the forward or backward thrust of the driving wheels to the frame of the vehicle. Four methods and at least one combination of these methods are used for accomplishing this result. They are radius rod drive, torque arm drive, torque tube drive, and Hotchkiss drive. (See fig. 65.)

a. In the radius rod drive, two radius rods, sometimes known as torque rods, are used to transmit the driving thrust to the frame and to maintain the alignment of the rear axle. The radius rods are connected both to the rear axle and to the frame by jointed connections which permit full vertical, and sometimes lateral, movement of the axle housing relative to the frame. Therefore, the torque reaction is resisted by the springs, as in the Hotchkiss drive. An open propeller shaft with two universal joints is usually employed with this type of drive. This type of drive is used only to a very limited extent. Similar radius rods are employed in the bogie four-rear-wheel drive (par. 55*a*) but in that case there are radius rods both at the top and bottom of the axle housing and therefore they also take the torque reaction.

b. The torque tube drive is used on a number of passenger and light commercial vehicles. In this type of drive, the propeller shaft is housed in a steel tube. The rear end of the tube is rigidly bolted to the rear axle housing by a flange and its front end is connected to the transmission or a frame cross member through a ball and socket



① Radius rod drive. ② Torque arm drive.

③ Torque tube drive. ④ Hotchkiss drive.

FIGURE 65.—Types of drive.

joint. One universal joint, the center of which is placed at the center of the ball and socket joint of the torque tube, is used in the propeller shaft. A slip joint is used in the propeller shaft, since there is some lengthening and shortening of the shaft as the rear axle moves up and down. A center bearing for the propeller shaft is generally put in the torque tube. Two radius rods connect the ends of the axle housing with the forward end of the torque tube and maintain the axle housing alined at right angles to the torque tube. The springs are shackled at both ends. With this type of drive, both the torque reaction and the driving thrust are taken by the torque tube. Since the springs are relieved from both torque reaction and driving thrust, they can be made flexible, which it is thought imparts better riding qualities to the vehicle than other types of drive. When the torque tube drive is employed, the driving pressure is applied toward the forward end of the frame, either through the engine mountings or a frame cross member; whereas, in the torque rod and Hotchkiss drives, it is applied at the rear of the frame. Some designers prefer one and some the other. Both are satisfactory.

c. The torque arm drive is little used. It consists of a solid or tubular arm, rigidly connected to the axle housing at its rear end and connected to a frame cross member through a ball and socket joint or a bracket similar to a spring bracket at its front end. An open propeller shaft is used. This type of drive is very similar to the torque tube drive, the principal difference being that it employs an open propeller shaft parallel to a torque arm instead of a housed propeller shaft within a torque tube.

d. The Hotchkiss drive is used for a large proportion of the passenger cars and most of the heavier trucks. In this type of drive, an open propeller shaft with two universal joints and a slip joint is used. The torque reaction, driving thrust, and alinement of the axle housings are all taken care of by the springs. The springs are pivoted on the brackets riveted to the vehicle frame at their forward ends and shackled to the frame at their rear ends. The rear spring brackets are the points of application of the driving thrust to the frame. Because the springs must take the torque reaction, stiffer springs are required than for the torque tube drive. Because they must take the driving thrust they must be fairly straight, or flat. Some designers thing that these considerations make for inferior riding qualities, but Hotchkiss drives are used very extensively with complete satisfaction. An advantage of the Hotchkiss drive is that the flexible connection between axle and frame throws less strain on the driving mechanism than other types of drive. When sudden loads are applied, as in letting the clutch in suddenly or quickly applying the brakes, the axle housing can rock slightly which cushions the shock on the parts and prevents extremely high pressures between the gear teeth of the final drive mechanism.

e. One manufacturer employs a semitorque tube drive for passenger and light commercial vehicles. It is the same as the conventional torque tube drive, except that the torque tube has a slip joint and no radius rods are used. The torque tube resists the torque reaction; but since it has a slip joint, it cannot take the driving thrust. As in the Hotchkiss drive, the springs transfer the driving thrust to the frame and maintain axle alinement. Therefore this drive might be said to be semitorque tube and semi-Hotchkiss.

46. Chain drives.—In early automobiles the final drive consisted of a chain and two sprockets. The engine was placed with the crankshaft crosswise in the frame. The crankshaft was connected through a clutch to a transmission and a sprocket on the transmission shaft was connected to a sprocket on the differential case of the rear axle. The speed reduction was accomplished by having a small sprocket on the transmission shaft and a larger one on the rear axle.

This type of final drive is obsolete. Double chain drives are still used to a limited extent for heavy duty work. A jackshaft, having sprockets at each end, is mounted at about the middle of the chassis on a frame cross member. It is driven through a bevel pinion and bevel drive gear which furnish the first speed reduction and differential in the same way as the driving axles described in paragraph 49. This mechanism is located at the rear of the transmission and is usually built into it. Chains connect the sprockets on the ends of the jackshaft to sprockets on the rear driving wheels which rotate on a dead (fixed) axle. The sprockets and chains provide a second speed reduction between the transmission shaft and the rear wheels. The double chain drive is rugged and efficient, but becomes very noisy and is open to mud and dirt.

47. Gear drives.—All the final drives in general use are geared types. The commonest type consists of a pair of bevel gears; that is, a drive pinion connected to the propeller shaft and a bevel drive gear attached to the differential case on the driving axle. These bevel gears may be spur, spiral, or hypoid. Spur gears have straight teeth, while spiral-bevel and hypoid gears have curved teeth. Spur gears are little used for this purpose because they are noisy. Spiral-bevel gears are most used. Hypoid gears are used in several passenger cars and light trucks because they permit the bevel drive pinion to be placed below the center of the bevel drive gear, thereby lowering the propeller shaft to give more body clearance. Worm gears are also used extensively in trucks because they allow a large speed reduction. These consist of helical worms, similar to screws, and meshing toothed gears. The worms have single, double, triple, or quadruple threads. These types of gears are shown in figure 66. Internal gear final drives were once popular and are still used in rare instances. They permit a large speed reduction like the double chain drive to which they are similar. A jackshaft is driven by the propeller shaft through bevel gears and differential as it is in the double chain drive (par. 46) except that the jackshaft is mounted on the dead rear axle and parallel to it. Spur pinions, keyed on the ends of the jackshaft, drive internal gears attached to the wheels. The first gear reduction takes place in the bevel pinion and drive gear and the second in the internal gears.

48. Differentials.—*a.* When a column of marching men turns a corner, the man in the inside file must take short steps, almost marking time, while the man in the outside file must take long steps and walk a much greater distance to make the turn as shown in figure 67. When a motor vehicle turns a corner, the wheels on

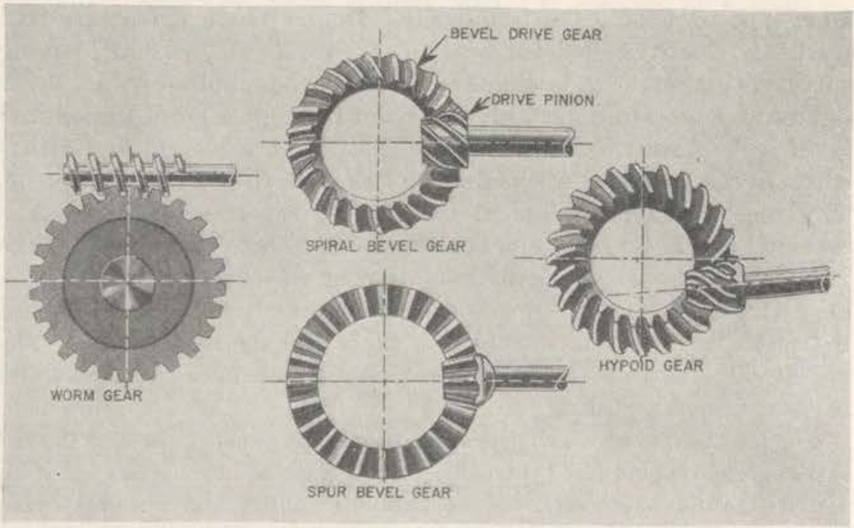


FIGURE 66.—Gears used in final drives.

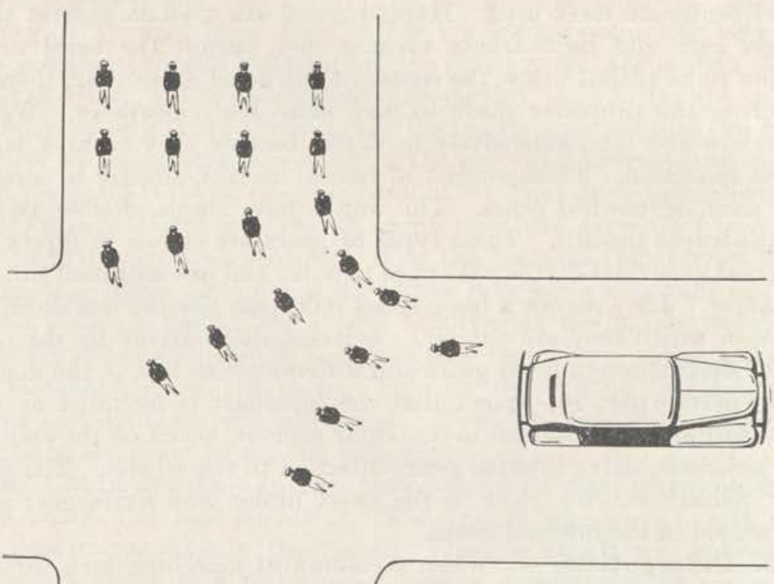


FIGURE 67.—Track of inside and outside wheels when turning a corner.

the outside of the turn must rotate faster and travel a greater distance than the wheels on the inside. This causes no difficulty with the front wheels of the usual passenger car which are not driven because each rotates independently of the other on opposite ends of a dead axle or on independent spindles (knee action). In order for the rear wheels to turn at different speeds, however, their individual axle shafts must be connected to the bevel drive gear in such a way that each shaft can turn at a different rate of speed and still be driven as a single unit. This is the function of the differential. The type of differential in general use (fig. 68) consists of a differential case bolted or riveted to the bevel drive gear, and two or more differential pinions pivoted radially in the case and meshed with two differential side gears. These are splined to the two axle shafts which drive the wheels. The axle shafts pass through each side of the differential case but rotate independently of it. Spur bevel gears are almost always used for the differential pinions and side gears. Usually, either two or four differential pinions are employed.

b. An actual differential, with the parts in their proper relative positions but without their housing, is shown in figure 69. Figure 70 shows an exploded view of a differential. The differential pinions are pivoted on the trunnions of a spider. These trunnions extend outward beyond the pinions and their outer ends are held in recesses between the two parts of the case which holds the side gears

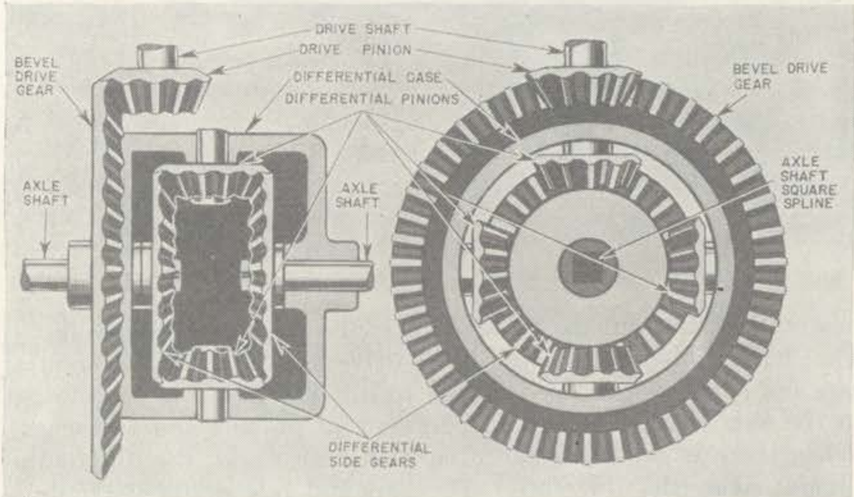


FIGURE 68.—Differential.

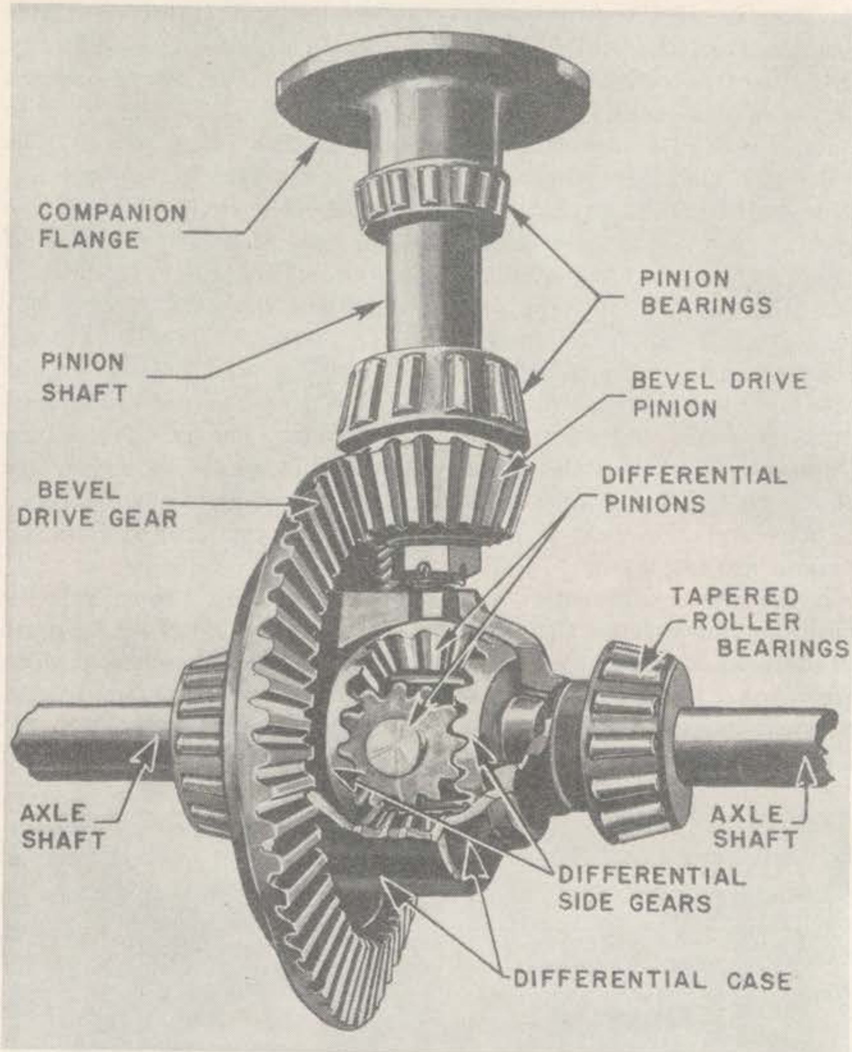


FIGURE 69.—Differential with part of case cut away.

in mesh with the pinions. The action of the differential is as follows: The drive pinion rotates the bevel drive gear and the differential case and spider which are attached to it. The power is transmitted to the axle shafts through the differential pinions and side gears. When there is equal resistance on each rear wheel, the differential pinions rotate the differential side gears and axle shafts at the same speed which is the speed of the bevel drive gear. In this case, there

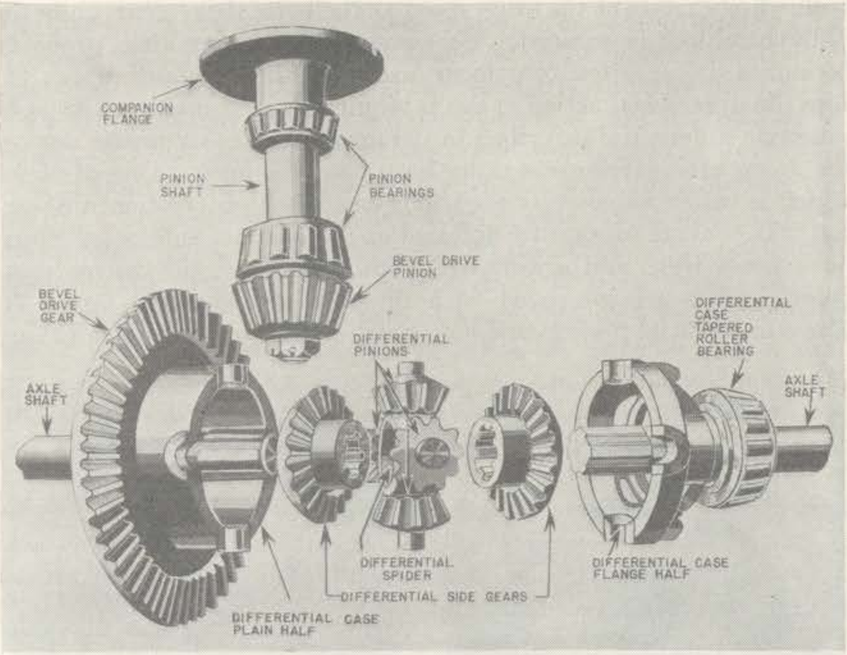
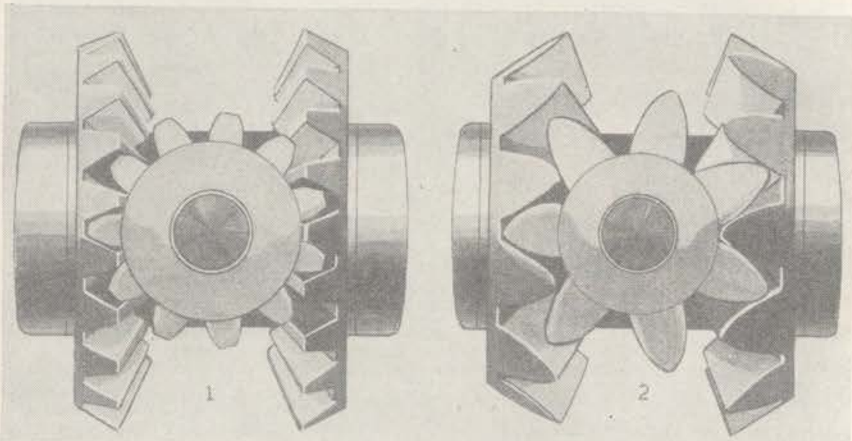


FIGURE 70.—Parts of differential.

is no relative motion between the pinions and the side gears; that is, the pinions are not turning on the spider trunnions and their teeth are not moving over the teeth of the side gears. When the vehicle turns a corner, one wheel must turn faster than the other. Consequently there is a movement of the differential pinions around the spider trunnions and over the teeth of the side gears. This makes one side gear, axle shaft, and wheel revolve faster than the the other. Any movement of the differential pinions over the side gears accelerates one axle shaft and retards the other. The average speed of the two side gears, axle shafts, and wheels is always the speed of the bevel drive gear.

c. A fault in the usual differential is that if one driving wheel loses traction and spins, the other wheel which has more traction remains stationary and does not drive the vehicle. In order to overcome this, several devices have been employed from time to time. One of these is the manually controlled differential lock. This is simply a dog clutch, controlled by a hand lever, which clutches one axle shaft fast to the differential case and bevel drive gear. This forms a rigid connection between the two axle shafts and makes both wheels rotate at the same speed as the bevel drive gear while the differential lock is engaged. This device is used very little, probably because a driver often forgets to disengage the differential lock before the differential action is again required. It is used on a type of interaxle differential described in paragraph 35*f*. Automatic devices for doing almost the same thing have been designed. One of these, which is rather extensively used today, is the high traction differential. It consists of a set of differential pinions and side gears which have fewer teeth and a different tooth form from the conventional gears. These are compared with the standard gears in figure 71. These differential pinions and side gears depend on a variable radius.



① Conventional differential pinion and side gears. ② High traction differential pinion and side gears.

FIGURE 71.—High traction differential gears compared with standard differential gears.

from the center of the differentia. pinion to the point where it comes in contact with the side gear teeth which is in effect a variable lever arm. The operating theory of this differential is beyond the scope of this manual. However, as long as there is relative motion between the pinions and side gears, the torque is unevenly divided between the two driving shafts and wheels; whereas, with the usual differential, the torque is evenly divided at all times. With the high traction differential, the torque becomes greater on one wheel and less on the other as the pinions move around until both wheels start to rotate at the same speed. When this occurs, the relative motion between the pinion and side gears stops and the torque on each wheel is again equal. This device assists considerably in starting the vehicle or keeping it rolling in cases where one wheel encounters a slippery spot and loses traction while the other wheel is on a firm spot and has traction. It will not work, however, when one wheel loses traction completely. In this respect it is inferior to the differential lock.

49. Live axles.—*a.* A live axle is one that supports part of the weight of a vehicle and also drives the wheels connected to it. The term is applied to the entire assembly which consists of a housing containing a bevel drive pinion, bevel drive gear, differential and axle shafts together with their bearings, and sometimes additional mechanisms. The term "live axle" is opposed to the term "dead axle." A dead axle is one that carries part of the weight of a vehicle but does not drive the wheels. The wheels rotate on the ends of the dead axle. The usual front axle of a passenger car is a dead axle and the rear axle is a live axle. In four-wheel drive vehicles, both front and rear axles are live axles and in six-wheel drive vehicles, all three axles are live axles.

b. There are four types of live axles: plain, semifloating, three-quarter floating, and full floating. These are distinguished by the way in which the axle shafts are connected and what stresses they must carry.

50. Plain live axle.—The plain, or nonfloating, rear axle was one of the first used. In this type, the axle shafts are supported in the housing by roller bearings at the center and at the outer ends. The rear wheels are keyed on tapers at the outer ends of the axle shafts and held by castle nuts and cotter pins. In addition to turning the wheels, the rotating axle shafts carry the entire weight of the rear of the vehicle on their outer ends. All stresses caused by turning corners, skidding or wobbling wheels are taken by the axle shafts. The differential side gears are keyed on the inner ends of the axle shafts which carry the weight of the differential case. The stresses created by the operation of the differential are taken by the axle shafts. Side thrust on the axle shafts is taken care of by the roller bearings, and ball bearings are provided at each side of the differential case to take care of end thrust. This type of rear axle is now obsolete.

51. Semifloating.—The semifloating rear axle (fig. 72) is used on most passenger and light commercial vehicles. The principal difference between it and the plain live axle is in the manner of supporting the differential assembly. In the plain live axle, the differential case is carried on the inner ends of the axle shafts. In the semifloating axle, it is carried by bearings mounted in the differential carrier. The axle shafts are splined to the differential side gears. This relieves the axle shafts of the weight of the differential and the stresses caused by its operation which are taken by the axle housing. The inner ends of the axle shafts transmit only turning effort, or torque, and are not

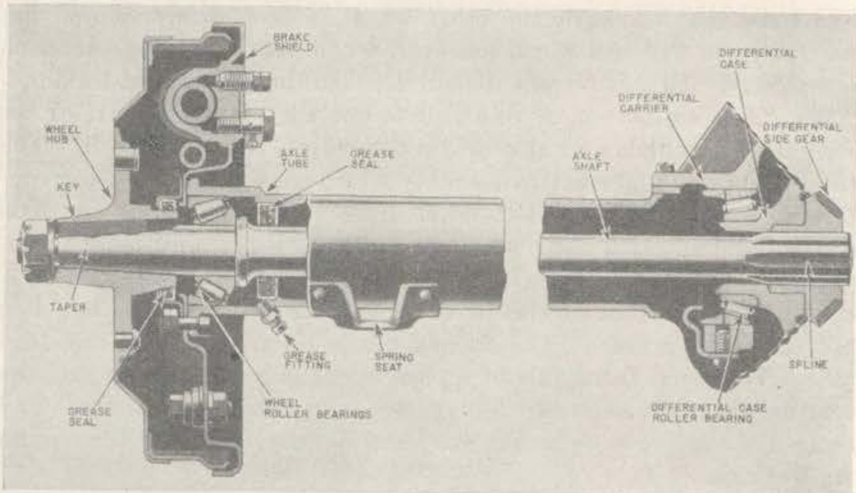


FIGURE 72.—Semifloating rear axle.

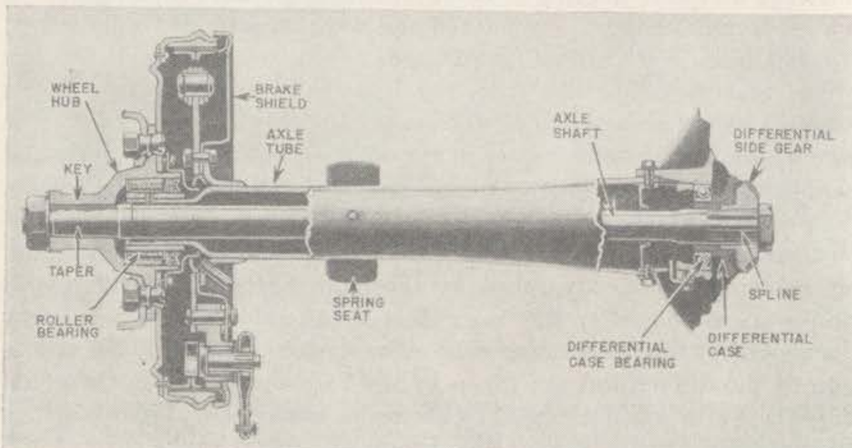


FIGURE 73.—Three-quarter floating rear axle.

acted upon by any other force. They are said to be "floated." The wheels are keyed to the outer ends of the axle shafts and the outer bearings are between them and the housing as in the plain live axle. The axle shafts therefore take the stresses caused by turning, skidding, or wobbling of the wheels. In both the plain and semifloating live axles, a wheel can come off in case an axle shaft breaks or twists off. The axle shaft cannot be removed until the wheel is pulled off.

52. Three-quarter floating.—The three-quarter floating rear axle (fig. 73) is used on a few passenger cars. The inner ends of the axle shafts are sometimes secured with nuts and the axle shafts cannot be withdrawn without removing the differential cover. In other designs, the axle shaft can be withdrawn after the nuts holding the hub flange have been removed. The wheels, however, are supported by bearings on the outer ends of the axle tubes. The housing instead of the axle shafts carries the weight of the car. Since the wheel is rigidly keyed on a taper at the end of the axle shaft as in the semi-floating axle, the stresses caused by turning, skidding, and wobbling of the wheel are still taken by the axle shaft.

53. Full floating.—The full floating rear axle (fig. 74) is used on most heavy trucks. It is the same as the three-quarter floating axle except that each wheel is carried on the end of the axle tube on two ball or roller bearings and the axle shafts are not rigidly connected to the wheels. Each wheel is driven through a dog clutch, or through a spline clutch, or through a flange on the end of the axle shaft that is bolted to the outside of the wheel hub. The latter construction is frequently used but is not truly full floating, since there is a rather rigid connection between the axle shaft and the wheel hub. With the true full floating axle, the axle shaft transmits only the turning effort, or torque. The stresses caused by turning, skidding, and wobbling of the wheels are taken entirely by the axle housing through the wheel bearings. The axle shafts can be removed and replaced without removing the wheel or disturbing the differential.

54. Types of rear axle assemblies.—*a.* Figure 75 shows a semi-floating rear axle of the type generally used in passenger cars. The final drive consists of a spiral bevel pinion and gear. Spur gears

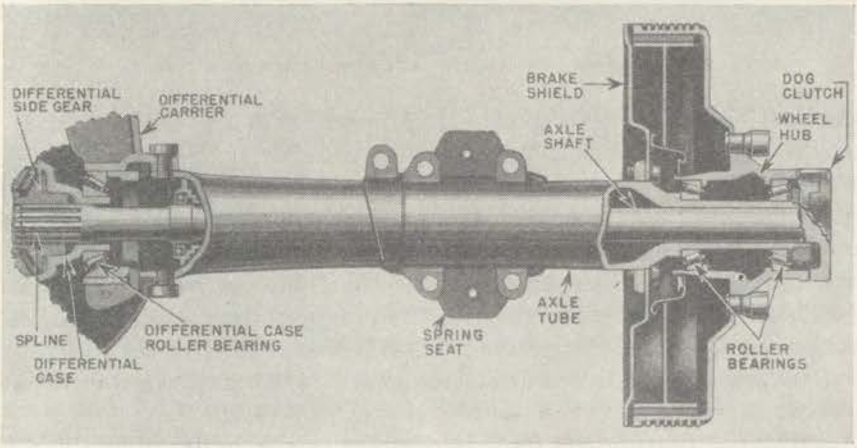


FIGURE 74.—Full floating rear axle.

were formerly used for this purpose, but they have been generally replaced by spiral bevel gears because they run more quietly. The drive pinion which is connected to the propeller shaft by the companion flange (fig. 75) runs in two tapered roller bearings mounted in the differential carrier and is considered a part of the rear axle assembly. The drive pinion meshes with the spiral bevel drive gear which is riveted to the differential case. The differential case rotates in tapered roller bearings mounted in the differential carrier. The inner races of these bearings fit on machined extensions on each side of the case and the outer races are held in brackets cast integral with the differential carrier. The differential carrier is a casting which holds

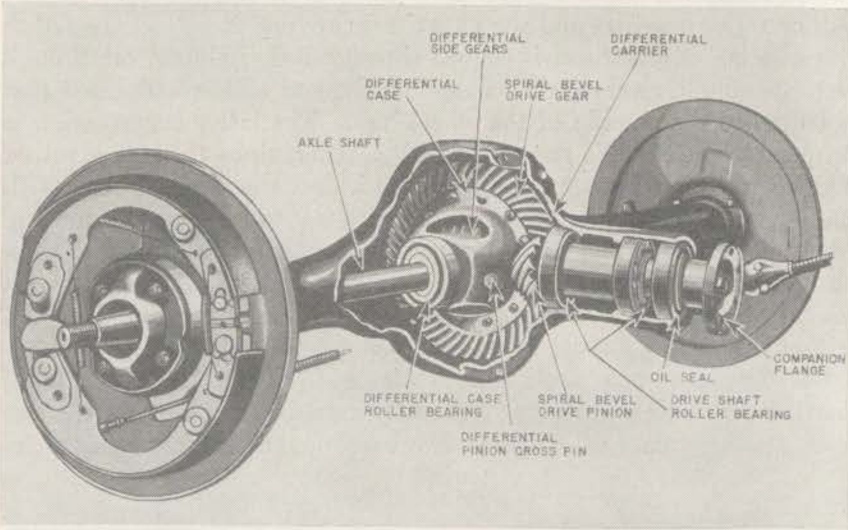


FIGURE 75.—Semifloating rear axle with a spiral bevel gear.

the final drive and differential. It is inserted in the forward opening of the rear axle housing and fastened with cap screws through a gasket to make the joint oiltight. The axle shafts are splined to the differential side gears. Machined hub extensions on these gears rotate in plain bearings in each side of the differential case. The rear axle has two differential pinions. The path of power transmission is from the propeller shaft to the pinion drive shaft and pinion to the spiral bevel drive gear, to the differential case, to the differential pinions, to the differential side gears, to the axle shafts, to the wheels.

b. Hypoid gearing has come into rather extensive use in late years, mainly for passenger cars. The middle portion of a hypoid rear axle is shown in figure 76. This rear axle is practically the same as the spiral bevel gear rear axle except that the drive pinion and bevel drive gear are cut with a somewhat different tooth form which permits the drive pinion to mesh with the bevel drive gear below the center of the latter. This construction allows the propeller shaft to be lowered and sometimes makes a shaft tunnel in the floor of the rear compartment of the vehicle unnecessary. Due to their design, hypoid gears operate under extremely high tooth pressure and require a special hypoid lubricant. (See par. 60*b*.)

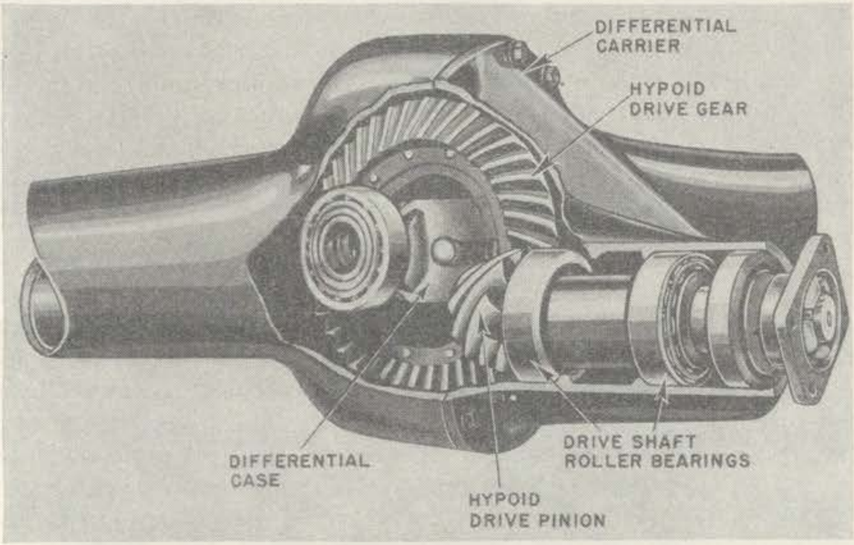


FIGURE 76.—Hypoid rear axle.

c. The worm gear rear axle (fig. 77) is used in some trucks mainly because it allows a large speed reduction. It is the same as the bevel pinion and bevel drive gear rear axle described in paragraph 54*a*, except that the bevel pinion and bevel drive gear are replaced by a worm and worm gear. The threads on the worm are similar to screw threads and may be single, double, triple, or quadruple. The worm shown has quadruple threads; that is, there are four helical grooves cut in the worm. The worm meshes with a gear having helical teeth cut in its outside circumference. The worm may be compared to a screw and the worm gear to a nut. As the worm rotates, it pulls the gear around. The worm is usually made of steel and the worm gear of bronze. The driving worm may be mounted either at the top of the worm gear (fig. 77) or at the bottom. It is usually necessary to place the worm at the top in order to allow sufficient road clearance under the rear axle housing. The rear worm bearing must be very strong and rugged since it takes the entire thrust reaction from driving the worm gear. If play develops in the worm due to wear, this bearing must also withstand repeated impact. When the vehicle is operated in reverse, or when the road wheels are driving the mechanism, the front bearing resists these forces. Sometimes a worm of "hourglass" form is used in the worm gear final drive. This type of worm meets more teeth on the worm gear and therefore provides more tooth bearing surface and consequently less stress in the teeth.

d. Double reduction rear axles are often used for heavy duty trucks. A usual design of the full floating type is shown disassembled in figure 78. The first gear reduction is obtained through a spiral bevel pinion and gear as in the common single reduction rear axles. The bevel

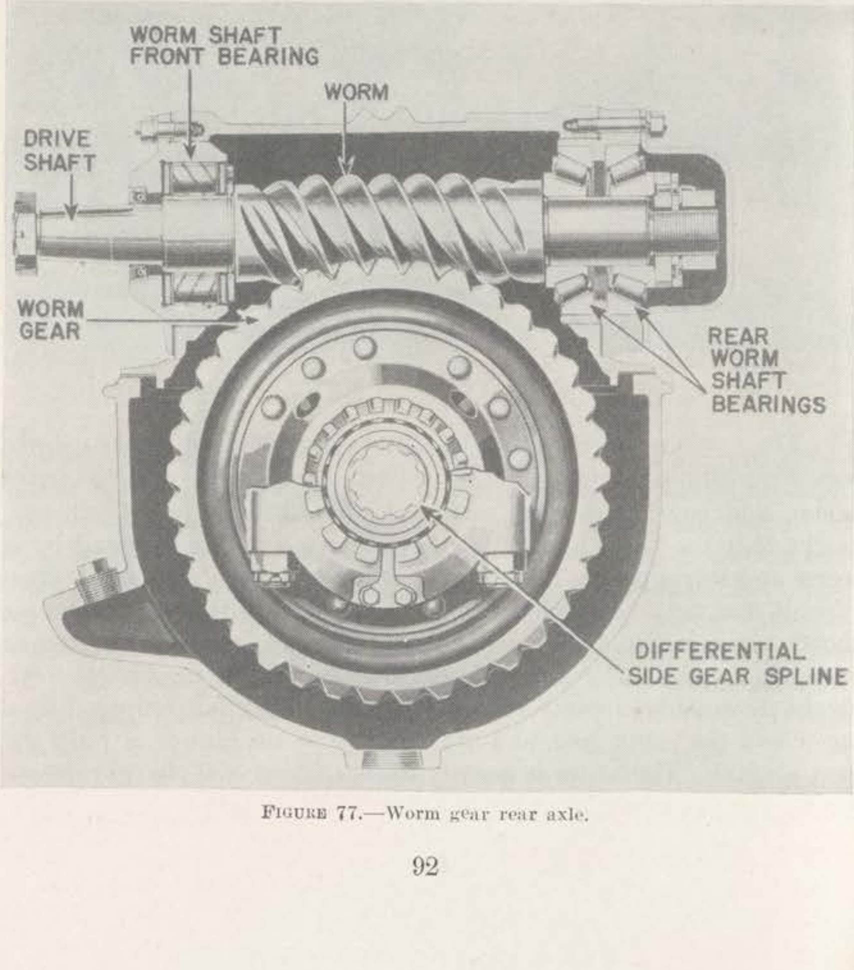


FIGURE 77.—Worm gear rear axle.

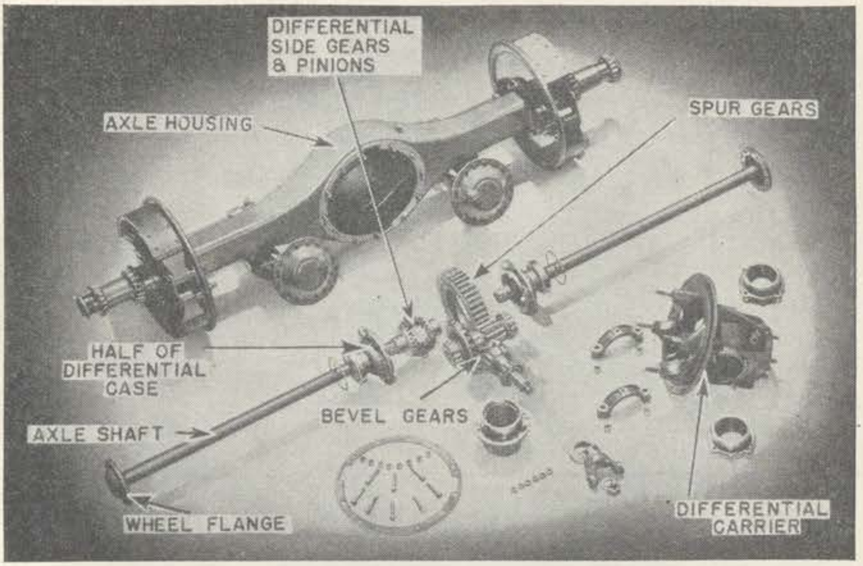


FIGURE 78.—Arrangement of gears in double reduction rear axle.

pinion runs in brackets on the differential carrier in two roller bearings (fig. 78). The bevel gear is mounted rigidly on a jackshaft with a spur pinion that runs on roller bearings at each end, which are also mounted in the differential carrier. The spur pinion drives a spur gear bolted to the differential case. These parts are shown in their proper relative positions in figure 78. The differential and axle shafts are the same as those already described.

e. Dual ratio, or two-speed, rear axles are sometimes used on trucks and passenger cars. They contain two different gear ratios which can be selected at will by the driver, usually by a manual control lever. A dual ratio rear axle serves the same purpose as the auxiliary transmission described in paragraph 34 and, like the latter, it doubles the number of gear ratios available for driving the vehicle under the various load and road conditions. This type of rear axle is shown in cross section in figure 79. It is driven by the conventional spiral bevel pinion and bevel drive gear, but a planetary gear train is placed between the bevel drive gear and differential case. (See par. 29*a* for an explanation of planetary gears.) The internal gear of the planetary train is rigidly bolted to the bevel drive gear. A ring on which the planetary gears are pivoted is bolted to the differential case. A member consisting of the sun gear and a dog clutch slides on one of the axle shafts and is usually controlled by a hand lever accessible to the driver. When this sliding part is in the high ratio posi-

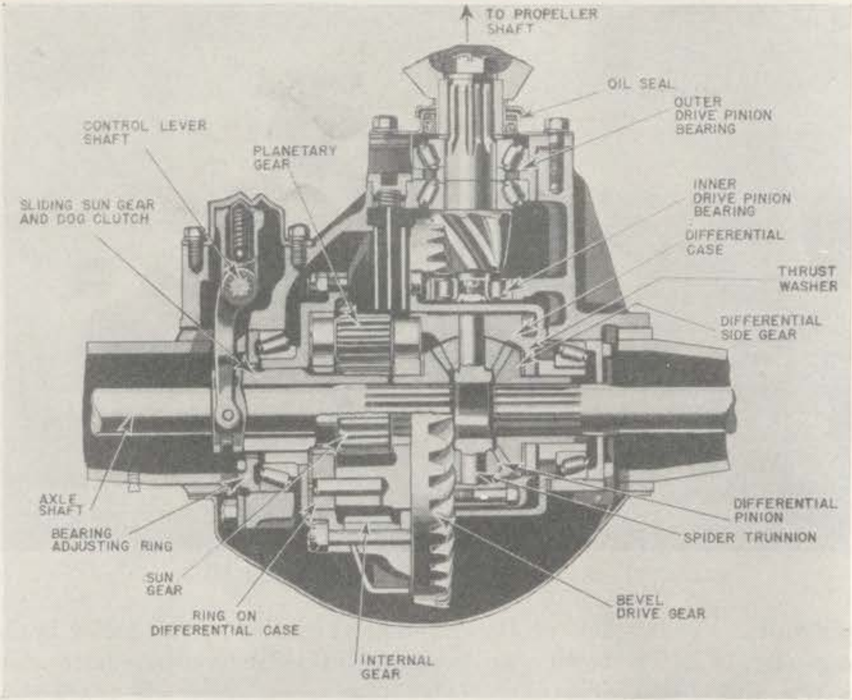


FIGURE 79.—Sectional view of dual ratio rear axle.

tion, the sun gear meshes with internal teeth on the ring carrying the planetary gears and disengages the dog clutch from the left bearing adjusting ring which is rigidly held in the differential carrier. In this position (fig. 80), the planetary gear train is locked together, there is no relative motion between the gears in the planetary train, and the differential case is driven directly by the bevel drive gear the same as in the conventional, single ratio rear axle. In the lower ratio position (fig. 81), the sun gear (not shown) is slid out of mesh with the ring carrying the planetary gears and the dog clutch makes a rigid connection with the left bearing adjusting ring. Since the sun gear is integral with the dog clutch, it is also locked fast to the bearing adjusting ring and remains stationary. The internal gear rotates the planetary gears around the stationary sun gear and the differential case is driven by the ring on which the planetary gears are pivoted. This action produces the gear reduction or low speed of the axle.

f. Double reduction, dual ratio rear axles are also sometimes used in heavy duty motor vehicles. Rear axles of this type combine the features of the double reduction and dual ratio axles in one unit. A

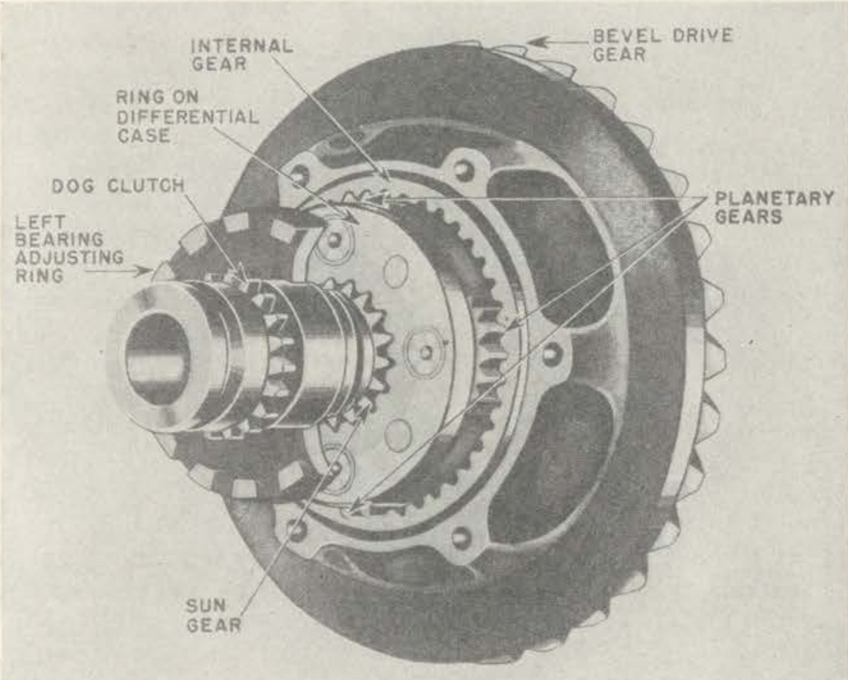


FIGURE 80.—Position of gears for high ratio. (Planetary gears are locked and cannot revolve.)

popular design is shown in figure 82 with part of the differential housing cut away. A spiral bevel pinion drives a jackshaft through a spiral bevel drive gear. Two helical pinions of different sizes and a two-way dog clutch are mounted on the jackshaft. The two helical pinions are not fast to the jackshaft but rotate freely on it on bearings. They are in constant mesh with two helical gears of correspondingly different sizes, both rigidly mounted on the differential case. The sliding dog clutch is controlled by a hand lever and clutches either one of the helical pinions fast to the jackshaft. The clutch is shown in the low-speed position in figure 82. The drive is from the propeller shaft to the drive pinion, to the bevel drive gear, to the jackshaft, to the right helical pinion, to the right helical gear, to the differential case, to the differential pinions, to the differential side gears, to the axle shafts, to the wheels. When the dog clutch is in the high-speed position (moved to the left) the drive is the same except that it is through the other pair of helical gears.

55. Four-rear-wheel drives.—Motor vehicles that carry extremely heavy loads are often equipped with four rear wheels in

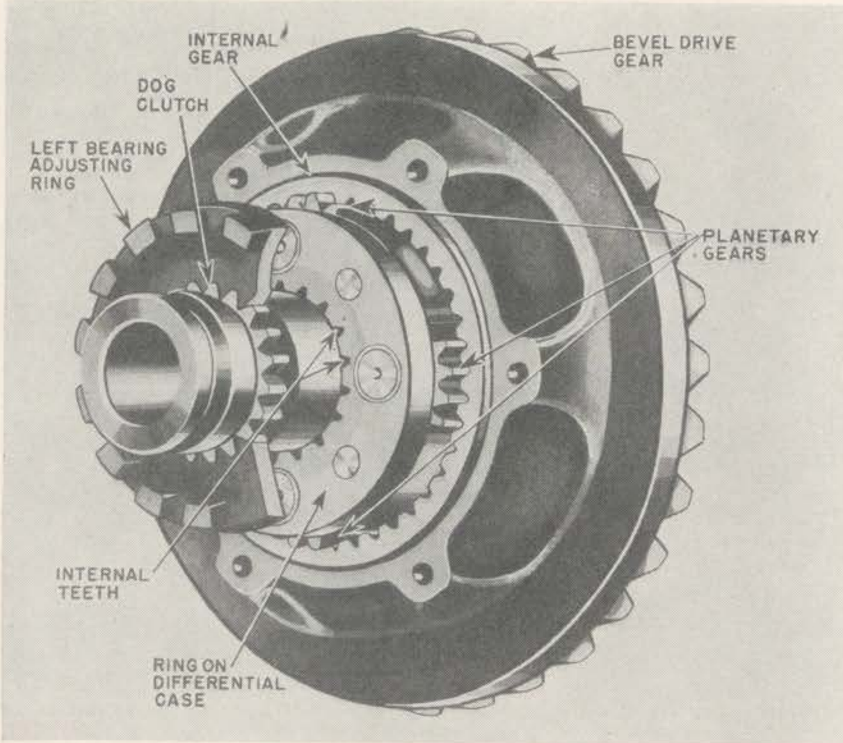


FIGURE 81.—Position of gears for low ratio. (Planetary gears are free to revolve.)

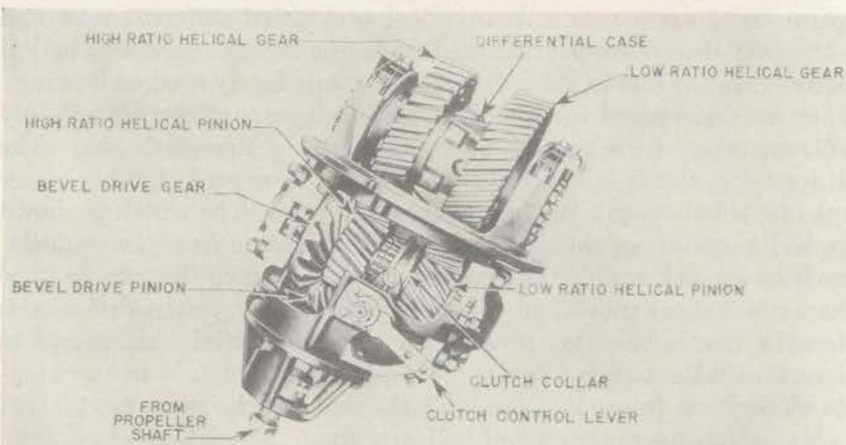


FIGURE 82.—Double reduction, dual ratio rear axle.

order to increase traction and to avoid excessive weight on the rear tires; that is, the weight of the load is divided among twice as many tires as when only one rear axle is used. Dual wheels are generally used with this arrangement; therefore, the weight of the rear of the vehicle and load is divided among eight tires instead of four.

a. Different spring suspensions are used but the bogie type (fig. 83) is most general. A bogie consists of two axles joined by a trunnion axle. The trunnion axle passes directly beneath the rear cross member of the frame and cannot be seen in figure 83. It is rigidly attached to the frame by two support brackets. The springs are attached to the frame by spring seats which pivot on each end of the trunnion axle. The ends of the springs rest on hardened steel plates that are integral parts of the axle housings. The tractive effort of the driving wheels is transmitted to the vehicle frame through six torque rods. Two of these, connecting each axle with the frame cross member, are shown in figure 83. There are four more underneath, connecting each end of each axle to the frame cross member, which are concealed by the springs in figure 83. When the vehicle moves forward, the forward driving axle pulls the chassis and the rear driving axle pushes it by means of the torque rod system. The torque rods also prevent the tendency of the driving axles to roll over when the vehicle is

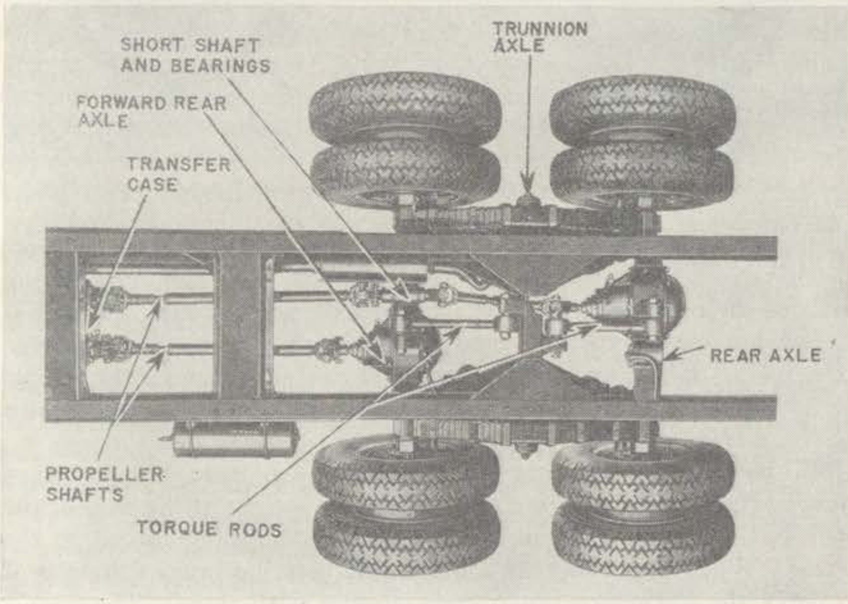


FIGURE 83.—Bogie four-wheel drive with independent propeller shafts.

being driven and when the brakes are applied. In addition, they maintain the vertical positions of the axles.

b. Vehicles having this equipment may be either four- or six-wheel drive. Sometimes the dual rear axles are driven by independent propeller shafts from a transfer case as shown in figure 83. In this case the propeller shaft to the rearmost rear axle is divided into three parts, the short middle part passing through bearings mounted on the forward rear axle. The transfer case may contain an inter-axle differential but usually does not.

c. Another arrangement is the tandem drive (fig. 84) employing double reduction axles. A single propeller shaft from the transmission or transfer case is connected to the forward rear axle drive pinion

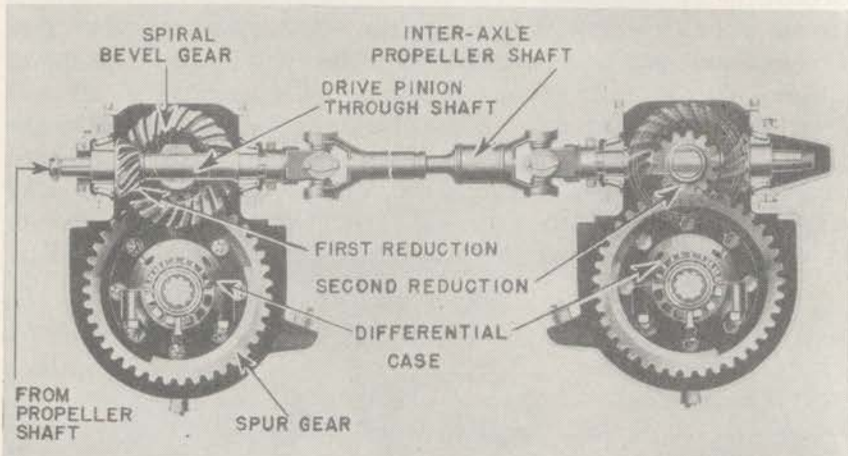


FIGURE 84.—Tandem dual rear axle arrangement with double reduction final drives.

through a shaft and another short, interaxle propeller shaft connects the drive pinion shaft of the forward rear axle with the drive pinion shaft of the rearward rear axle. Ordinarily no interaxle differential is used, but one is sometimes used which is built into the forward rear axle. With the tandem drive, no transfer case is required if the vehicle drives on the four rear wheels only. If the front wheels are also driven, a transfer case is required.

56. Rear axle housing construction.—*a.* Rear axle housings must be strong. In addition to carrying the weight of the rear of the vehicle, they must transmit the starting and braking torque to the frame. When the brakes are applied, the rotating brake drums tend to carry the stationary brake shoes around with them. The torque thus created is transmitted to the axle housing by the brake shields to which the brake shoes are anchored. It is necessary therefore that the axle housing ends be fastened very solidly to the central housing when they are not integral with it. A stress similar to that caused by braking, but opposite in direction, is placed on the axle housing when the vehicle is accelerated. Besides these torsional stresses, the axle housing also must resist the thrust of driving the vehicle produced by the tractive effort of the driving wheels. This thrust is transmitted by the axle housing to the frame through the springs, a torque tube, torque arm, or radius rods, according to which type of drive is employed. When the vehicle is retarded, a pull instead of a push is exerted on the frame by these parts.

b. In general, rear axle housings are of three types; pressed steel, single-piece castings, and built-up.

(1) The pressed steel housing is used for some light vehicles. This type of housing is formed in halves from sheet steel in the dies of large presses and the two halves are then welded together. The weld may be either along the side or top and bottom.

(2) Single-piece cast housings are used mainly for very heavy duty trucks where exceptional strength is required. They are usually made of cast steel but have been made of malleable iron and cast aluminum.

(3) The axle housing ends of both pressed steel and single-piece cast housings are often reinforced by inserting drawn steel tubes.

(4) Built-up rear axle housings are the most usual. They consist of one or more castings forming the enlarged portion at the center, to which axle housing ends of seamless drawn steel are attached. They are usually pressed into bored holes in the central castings and riveted or welded.

c. Rear axle spring seats are cast integral, welded, or riveted on the rear axle housing. Brake shaft brackets are ordinarily bolted fast. Brake shields are usually riveted to flanges cast integrally or welded to the housing ends.

d. Many rear axle housings are designed so that the final drive and differential mechanism may be inspected by removing a steel cover. The mechanism may be taken out by first pulling the axle shafts and then removing the differential carrier. Others, of the split type, must be removed from the chassis, which must be otherwise supported before they can be disassembled. A rear axle having a split housing is shown disassembled in figure 85.

57. Front-wheel drives.—*a.* In four- or six-wheel drives the front wheels are driven through a driving axle assembly very similar to a rear axle. It may be of the single or double reduction type.

Figure 86 shows a usual arrangement of transfer case, propeller shafts, universal joints, driving axles, and springs for a four-wheel drive vehicle. Front-wheel drives are ordinarily Hotchkiss drives with the front springs pivoted at the rear and shackled at the front. Axles are of the full floating type. As in the case of rear live axles, the axle housings are usually built up but they may be pressed steel for light vehicles and single piece castings for extremely heavy duty vehicles. The split type housing is frequently used. The prin-

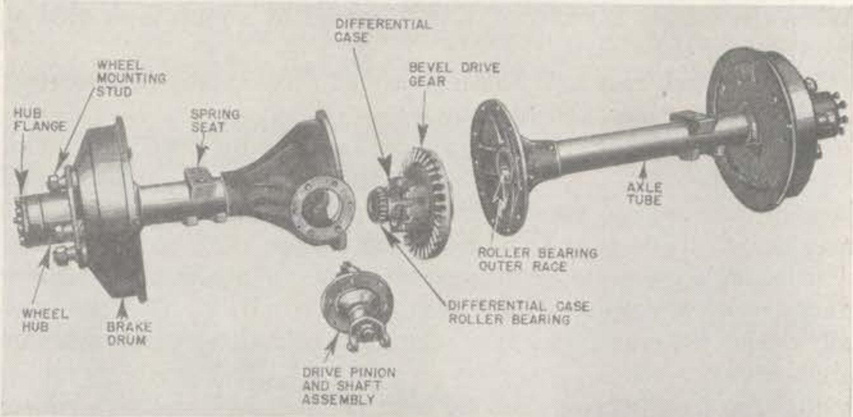


FIGURE 85.—Disassembled rear axle having a split housing.

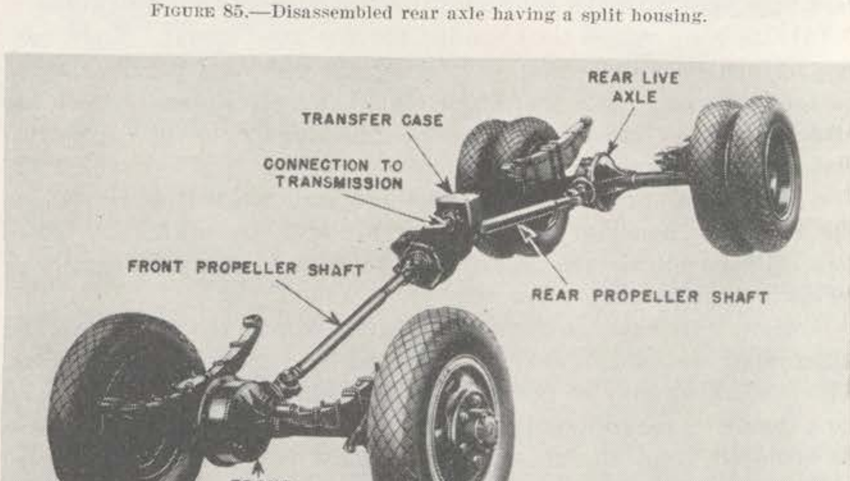


FIGURE 86.—Arrangement of transfer case, propeller shafts, universal joints, and live axles for four-wheel drive.

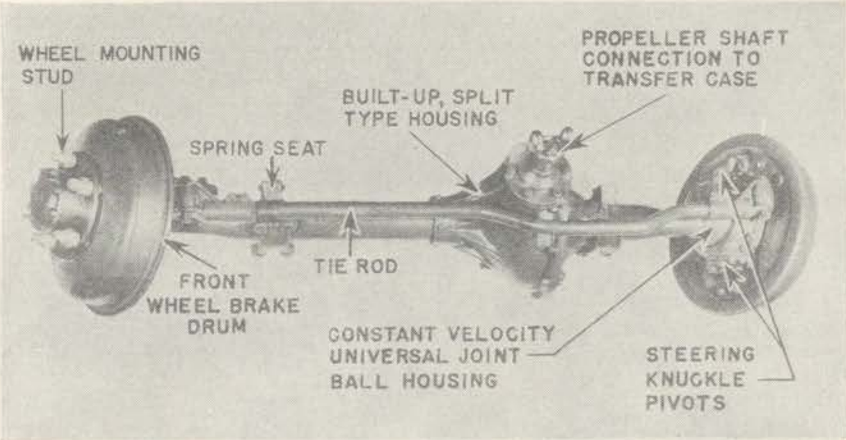


FIGURE 87.—Front live axle assembly.

cipal difference between front live axles and rear axles is that in front wheel drives provision must be made for steering. In rear driving axles, the axle shafts are directly connected to the wheels. Since the front wheels must turn on the steering knuckle pivots, they are usually driven by the axle shafts through universal joints concentric with the steering knuckle pivots. Figure 87 shows the housings of the steering knuckle pivots and constant velocity universal joints, as well as the tie rod, brake drums, hub flanges, and wheel mounting studs for a typical front live axle assembly.

b. A type of front wheel drive which drives the front wheels through gearing and permits them to steer without the use of a universal joint is shown in figure 88. It has been used to a very limited extent. A spiral bevel pinion keyed to the end of the axle shaft drives the lower half of a double bevel gear on the lower end of the steering knuckle pivot. The top half of the double gear meshes with a fourth gear that is integral with the wheel hub. The gear and hub turn on the steering knuckle. When the wheels are cramped, the bevel gear on the wheel hub rotates around the bevel gear on the steering knuckle pivot.

58. Constant velocity universal joints.—*a*. The speed fluctuations caused by the usual types of universal joint (par. 41) do not cause much difficulty in propeller shafts where they have to drive through only small angles. In front-wheel drives, where the wheels are cramped to angles up to 30° in steering, velocity fluctuations present a serious problem. Ordinary universal joints cause hard steering, slippage, and tire wear each time the vehicle turns

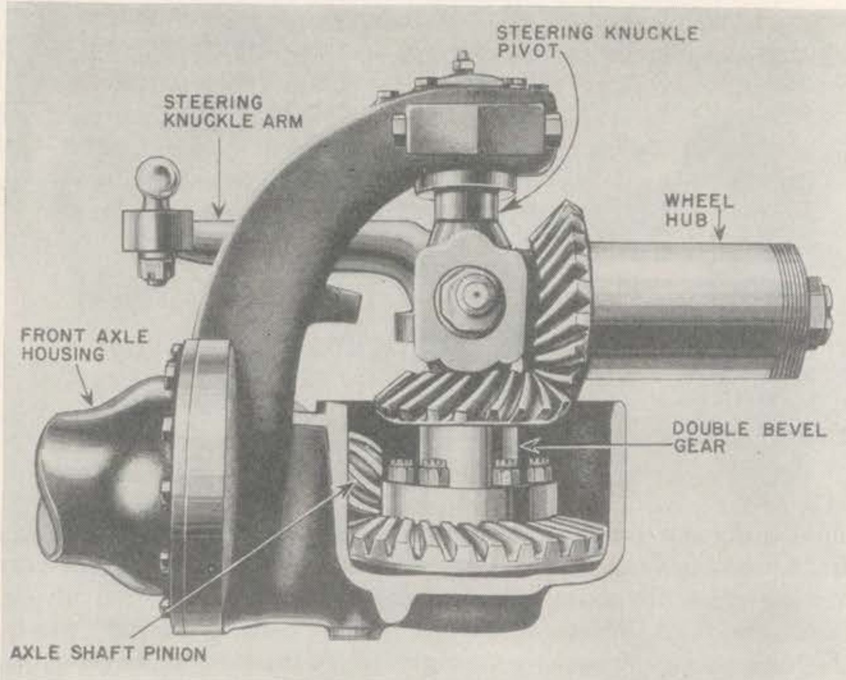


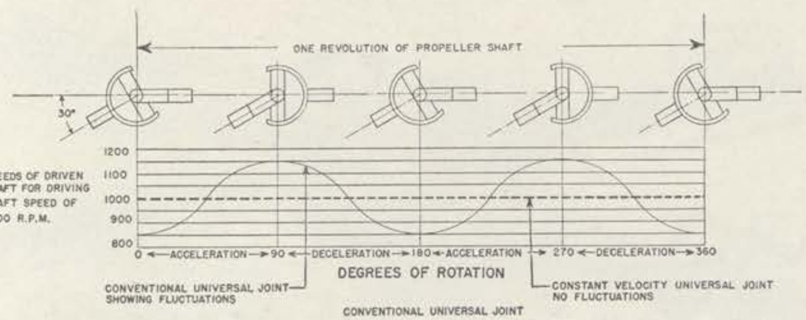
FIGURE 88.—Helical gear steering for a front-wheel drive.

a corner. Front-wheel drives were not very successful until constant velocity universal joints were developed. These are used exclusively today to connect the front axle shafts to the driving wheels. They eliminate the pulsations and consequent torsional vibration, or "whipping", of the shaft driven through the universal joint. When the driving shaft runs at constant velocity, the driven shaft does not run at constant velocity when the ordinary universal joint is used. There is an acceleration and deceleration twice per revolution producing for a speed of 3,000 r. p. m., for example, 12,000 changes per minute in the driven shaft velocity. The variations of the angular velocity during one revolution, or 360°, of a shaft driven through a conventional universal joint by a driving shaft running at constant velocity are shown in figure 89 in revolutions per minute. The driving shaft is running at a constant velocity of 1,000 r. p. m. and the driven shaft is driven at an angle of 30° to it. In a quarter of a revolution, the speed of the driven shaft varies from a minimum of 866 r. p. m. to a maximum of 1,155 r. p. m. The speed of the driven shaft equals that of the driving shaft only at four points during the revolution; that is, 45°, 135°, 225°, and

315°, where the curve intersects the constant velocity (dotted) line. The positions of the universal joint yokes and trunnions at the quarter points are shown in figure 89. The extent of each fluctuation depends upon the degree of angle at which the driving shaft drives the driven shaft. The maximum variations for other angles of drive are shown in the table in figure 89.

b. Two types of constant velocity universal joints are popularly used in front-wheel drive vehicles for connecting the axle shafts to the wheels; the Rzeppa and the Bendix-Weiss type. Each of these universal joints connects the driving and driven members by rolling contact between accurately fitted balls and grooves, or races. Both are practical for drive angles up to 30°. In order for the driving shaft (running at constant velocity) to drive the driven shaft at constant velocity, it is required that the plane of driving engagement between the two yokes of the universal joint be maintained at half the shaft angle. This principle is applied in both these constant velocity universal joints; that is, a plane passed through the points of contact of the balls with their races would at all times bisect the angle between the driving and driven shafts as shown in figure 91. A plane passed through the cross of the usual type of universal joint would bisect the angle between shafts at only four points during each revolution, hence the speed fluctuation.

c. The Rzeppa type of universal joint is shown unassembled in figure 90 and assembled in figure 91. It consists of three main elements; a driving member, a driven member, and a close-fitting ball cage separating the driving and driven members. These three members have spherical contact surfaces and are assembled concentrically. Each of the six balls engage a groove in the driving member with a



SHAFT ANGLE IN DEGREES	8	10	15	20	25	30	40
MAXIMUM VARIATION IN DRIVEN SHAFT SPEED PERCENT	2	3	6.9	12.4	19.7	28.9	54

FIGURE 89.—Speed fluctuations caused by conventional universal joint.

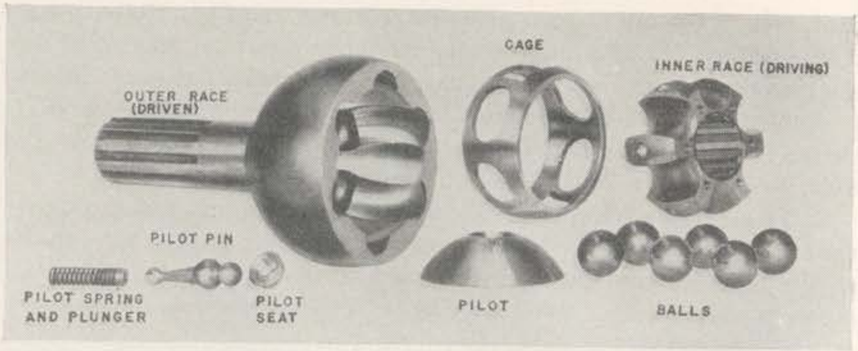


FIGURE 90.—Rzeppa type of constant velocity universal joint unassembled.

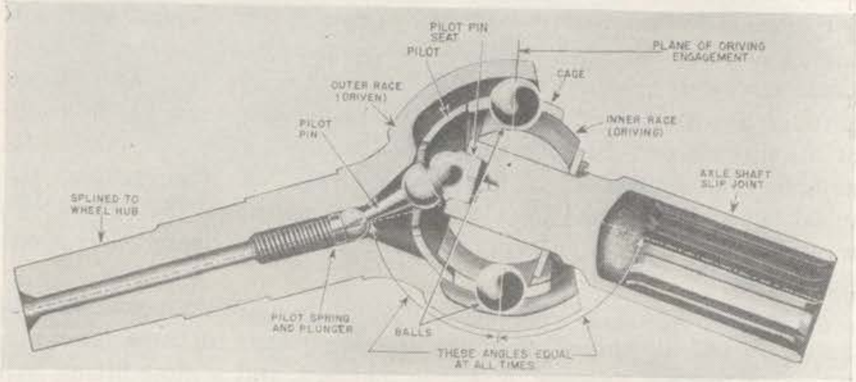


FIGURE 91.—Rzeppa type of constant velocity universal joint assembled.

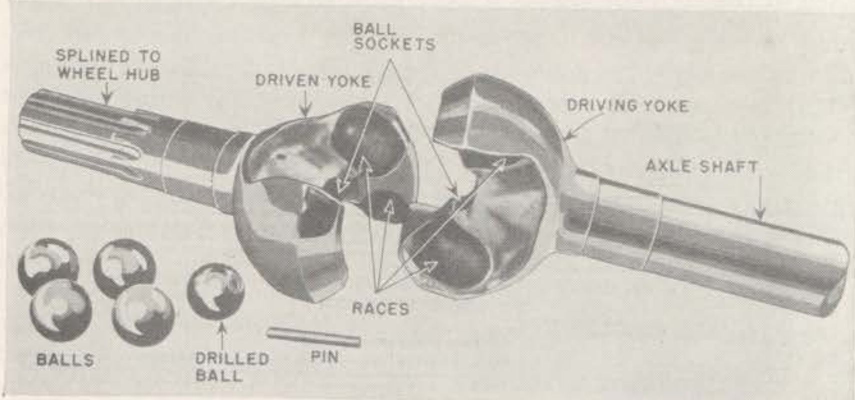


FIGURE 92.—Bendix-Weiss type of constant velocity universal joint unassembled.

groove in the driven member; thus the balls form the driving contact. The pilot pin has ball ends, is held in its seat in the end of the driving shaft by the pilot spring and plunger, and passes through a hole in the pilot. The pilot assembly is the device that controls the position of the cage and balls. The pilot pin is so designed that it always forms an angle with the driven shaft that is half the drive angle and is so connected to the pilot and ball cage that it maintains the plane of ball contact at half the angle between the driving and driven shafts.

d. The Bendix-Weiss type of constant velocity universal joint is shown unassembled in figure 92 and assembled in figure 93. As in the Rzeppa type of universal joint, there is rolling contact between the driving and driven members and constant velocity is obtained by maintaining the plane of driving engagement between the two yokes at half the shaft angle. Four steel balls are placed in nonconcentric, intersecting races cut in the yokes. Without any ball retainer, cage, or other positioning device, the races cause the balls to roll angularly one-half the distance traversed by the yoke. A fifth steel ball, somewhat smaller than the rest, fits into ball sockets at the centers of both yokes. This ball has a hole drilled partly through it and is retained in position by a pin which extends into a drilled hole concentric with the ball socket in one of the yokes. This ball does not rotate but merely acts as a thrust block between the two yokes and as a lock in holding the other four balls in position. This universal joint also permits a small amount of end movement by allowing the balls to roll endwise in their races, thus making slip joints unnecessary. It is

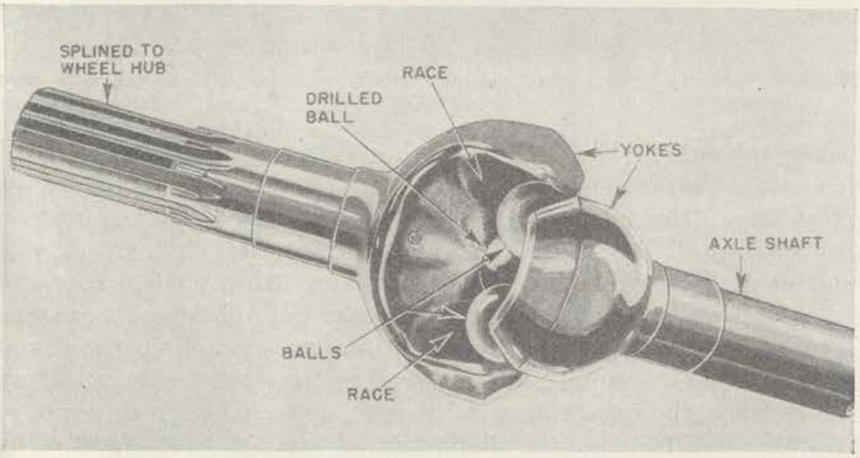


FIGURE 93.—Bendix-Weiss type of constant velocity university joint assembled.

thought that the balls roll with much less effort than is required to slide a spline. Figure 94 shows this type of constant velocity universal joint assembled in a front live axle.

59. Interwheel differential.—One of the latest developments in front-wheel drives is dual wheels having an interwheel differential which makes them easily steerable. Each wheel is equipped with its own brake. Vertical steering knuckle pivots are used. The differential is of the spur gear type, the pinions having a tooth form that gives it the same action as the high traction differential described in

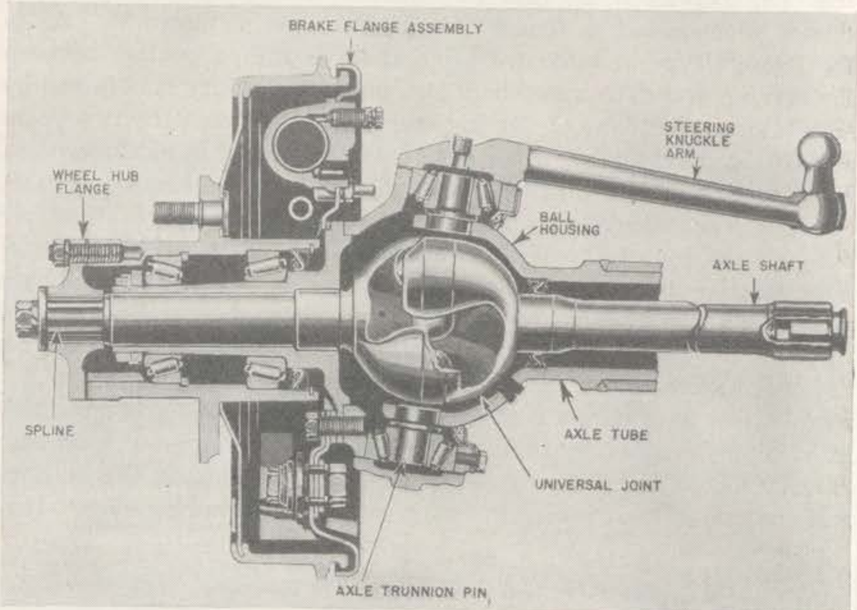


FIGURE 94.—Bendix-Weiss type of constant velocity universal joint assembled in front live axle.

paragraph 48*c*. When dual front wheels are used in addition to dual rear wheels, a greater portion of the total load can be carried by the front axle. This makes possible a greater pay load without increasing the overall length of the vehicle. Interwheel differentials can also be used for front dead axles, live rear axles, tandem rear live axles, and trailer dead axles to provide for the difference in distance traveled by each of the pair of dual wheels in rounding curves and for the different rolling radius of each of the dual wheels caused by the crown of the road, ruts, etc. It is thought that a great saving in tire wear results due to the elimination of slippage which must occur when dual wheels are rigidly bolted together.

60. Lubrication.—*a.* In the bevel gear or worm driven live axle, it is common practice to use an ordinary gear lubricant of S A E 90 or 140 viscosity for winter and SAE 140 or 250 for summer. However, the exact grade to be used depends essentially upon the clearances and pressures involved and whether the unit does light or heavy duty. Manufacturers' recommendations should be observed.

b. The hypoid gear drive (par. 54*b*) is a rather recent development that requires special lubrication. Due to the fact that the pinion in this drive is below the center of the bevel drive gear, the pressures between the contact surfaces of the teeth are much higher than in the more usual spiral bevel final drive. This necessitates a specially compounded lubricant known as a hypoid, or powerful E. P. (extreme pressure) lubricant. Such a lubricant is manufactured by adding chlorine compounds, sulphur, lead soaps, and other ingredients to a mineral oil. When inspection indicates that a hypoid lubricant must be added to the original lubricant in the housing, the same kind of lubricant *must* be used. If the only lubricant available is of a different kind or make, the old hypoid lubricant must be completely drained out of the housing before the new lubricant is added.

c. The axle housing should be filled with gear lubricant to within ½ inch of the filler plug opening which provides enough lubricant for the moving gears to dip into and still prevents it from reaching too high a level when expanded from heat. Live axle housings should not be filled to too high a level because the lubricant when expanded by frictional heat tends to break through the seals at the outer ends of the axles and leak or seep onto the brake linings.

Section VII

BEARINGS

61. General.—Essentially a bearing is a support for a load. In automotive practice, bearings support moving parts most of which are rotating parts.

a. Bearings used in automotive power transmission systems may be classified, depending on the way in which friction is produced in them, according to forms as follows:

(1) *Sliding surface bearings.*—Include those that depend on lubricating films of oil, grease, graphite, or other material for their sliding qualities.

(2) *Rolling contact bearings.*—Include all forms of ball and roller bearings known as antifriction bearings.

(3) *Sliding rolling face bearings.*—Include those found in gear teeth, cams, and some forms of roller bearings.

b. Bearings may be classified by function as follows:

(1) *Radial bearing.*—A bearing applied to a rotating shaft to hold its axis in line and prevent movement in a radial (sidewise) direction.

(2) *Thrust bearing.*—A bearing applied to a shaft to prevent free endwise movement or to take endwise loads on a rotating member.

(3) *Angular bearing.*—A bearing to constrain a shaft against both radial (sidewise) and axial (endwise) movement; the load is received in an angular direction.

62. Sliding surface bearings.—*a.* These include bearings for rotating parts and for parts that merely slide over each other without turning. Most of the bearings of the mechanisms described in this manual are for rotating parts. However, two examples of bearings for parts that do not rotate relative to each other are the shift rails in transmissions which merely slide endwise in holes in the case and slip joints of propeller shafts.

b. The simplest type of sliding surface bearing applied to a rotating part is one in which an accurately finished shaft, or journal, rotates in an accurately finished hole without any bushing, the two being separated by an oil film. Such bearings are used for differential side gears. Ground extensions of the side gear hubs rotate in ground holes in the differential case. Both parts are usually case hardened. These bearings receive the radial loads on the side gears. Bronze washers are placed between the side gears and the case to take the thrust loads. Similar bearings are used for differential pinions, the difference being that the holes are in the rotating pinions which turn on the stationary differential spider or cross pin. Such bearings are usually known as plain bearings and are used only for low speeds or light duty or both.

c. Probably the next simplest plain bearing, also of the sliding-surface type, is the bushing which is replaceable when worn. A bushing is usually of bronze and is pressed into a hole and reamed to fit, forming a lining in which a journal rotates. Plain bushings are suitable for radial loads only. Bronze bushings were formerly used to a considerable extent in automotive power transmission systems but have been almost entirely superseded by antifriction bearings. Bronze bushings are still used extensively for wrist pin bushings in internal combustion engines.

d. Another simple type of bearing of the sliding surface type is the babbitt bearing which is also a plain bearing. Babbitt metal is an alloy, mainly of copper and tin, having low friction properties. It may be cast directly in the hole surrounding the journal or in a separable bronze or steel backing which is inserted in the bearing housing. Sometimes graphite is cast in the metal to give it self-lubricating qualities. Babbitt bearings may be solid or split. The split type provides a means for compensating for wear by removing shims from under the bearing cap. Babbitt bearings are used mostly for radial loads but sometimes flanges are cast at the ends of the bearings which also enable them to resist end thrust. Such bearings are not used in present day automotive power transmission systems.

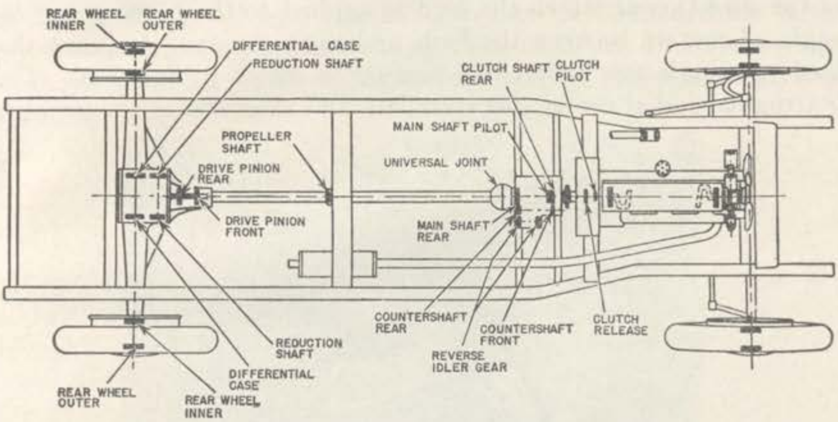


FIGURE 95.—Usual location of antifriction bearings in truck chassis.

They are used in internal combustion engines for crankshaft main and connecting rod bearings and are more fully described in TM 10-570.

63. Ball and roller bearings.—These are used throughout automotive power transmission systems. The usual locations of antifriction bearings in a truck chassis are shown in figure 95. They are commonly known as antifriction bearings because friction is largely eliminated in them since they depend upon rolling contact rather than sliding contact. Ball bearings often are referred to as having point contact between balls and raceways; in the same sense, roller bearings are said to have line contact between rollers and races. These are merely descriptive terms, since the elastic deformation occurring under load results in substantial areas of contact in either type. Starting friction of ball and roller bearings is but slightly greater than running friction, an important advantage in machinery that is required to start frequently under load. They can also sustain high overloads for short periods without failure. Ordinarily a ball or roller bearing does not fail suddenly, but gives warning by a gradual decrease in smoothness of running; whereas the plain bearing is subject to an accelerated type of failure often resulting in seizure and making it necesary to take the machine out of operation for immediate repairs.

a. Types of ball bearings.—A ball bearing consists essentially of a grooved inner race and outer race with a number of balls spaced by a suitable cage or retainer between them. They are made with either a single or double row of balls. Ball bearings for various purposes differ considerably in the details of their construction but are of three general types; radial, thrust, and angular. These terms are descriptive of the direction at which the load is applied to the bearing and the angle of contact between the balls and races designed to resist that load. A single row radial ball bearing is shown in figure 96. This bearing has radial contact between balls and races and is designed pri-

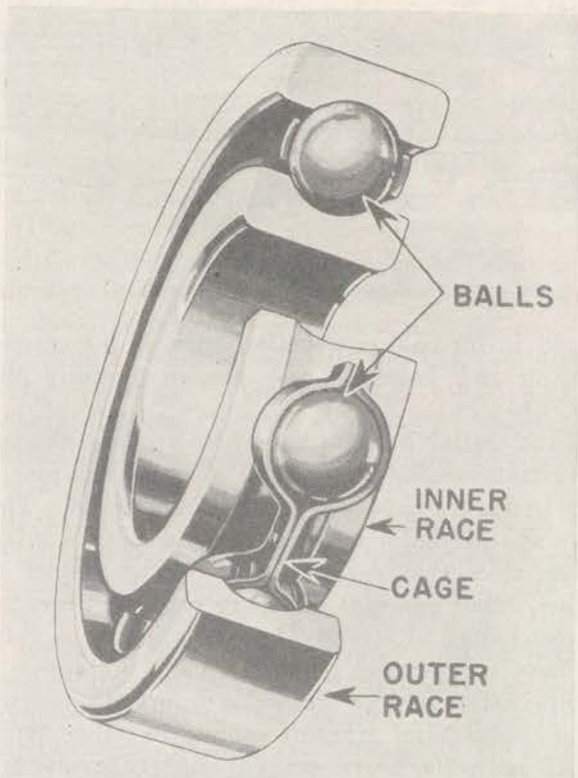


FIGURE 96.—Single row radial ball bearing.

marily to resist radial loads but also provides for lengthwise stability where moderate lengthwise displacement is permissible. It is suitable for usual combined radial and thrust loads and for high speeds. The double row radial ball bearing (fig. 97) is suitable for heavy combined radial and thrust loads, medium speed, and close control of endwise movement under reversing thrust. Single row, angular contact ball bearings (fig. 98) have substantial thrust capacity and provide rigid lengthwise support in one direction only. Double row, angular contact bearings are available which have high combined load capacity together with rigid lengthwise support in both directions. Thrust bearings of the so-called flat type (fig. 99) have a contact angle of 90° or a load line between ball and race that is parallel with the axis of the shaft. The small bore race is secured to the shaft and the large bore race is supported by the housing. Thrust in one direction presses the races and balls together; thrust in the other direction separates

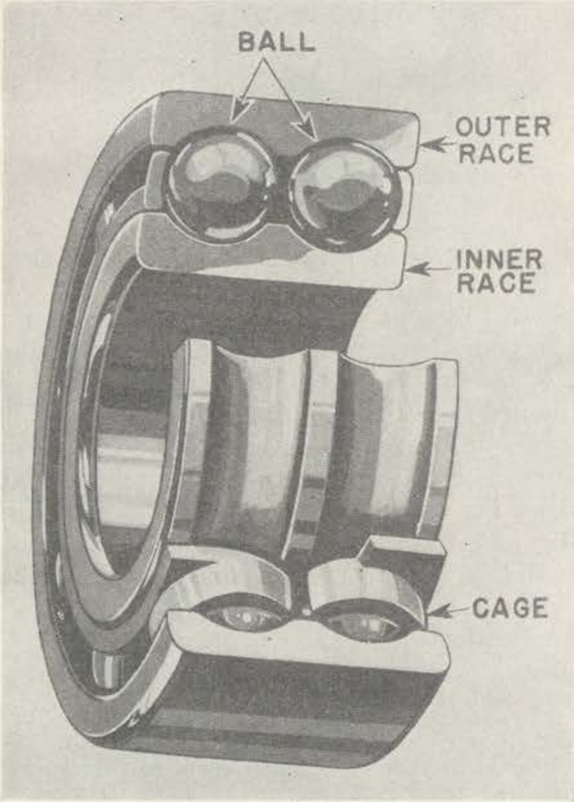


FIGURE 97.—Double row radial ball bearing.

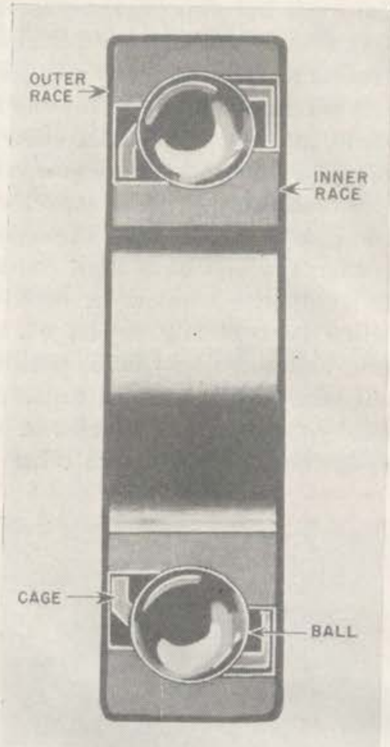


FIGURE 98.—Single row angular contact ball bearing.

them. Therefore, this type is essentially a one direction thrust bearing. Thrust in both directions necessitates the use of duplicate units or a bearing of the double direction thrust type. Such bearings are suitable for limited speeds and minimum lengthwise displacement.

b. Types of roller bearings.—As in the case of ball bearings, the details of construction of roller bearings vary considerably for different applications, but there are three general types; straight roller, tapered roller, and spherical roller. Like ball bearings, they are designed for radial, thrust, and combined loads. Roller bearings, which have greater contact area than ball bearings, are used for heavy duty applications.

(1) Cylindrical, or straight, roller bearings are bearings in which the outer races, rollers, and inner races are all cylindrical. Rollers are usually solid as shown in figure 100 and the rollers are guided by flanges on one or both races. If both races are flanged, the bearing has some ability to resist end thrust, otherwise it is good for radial

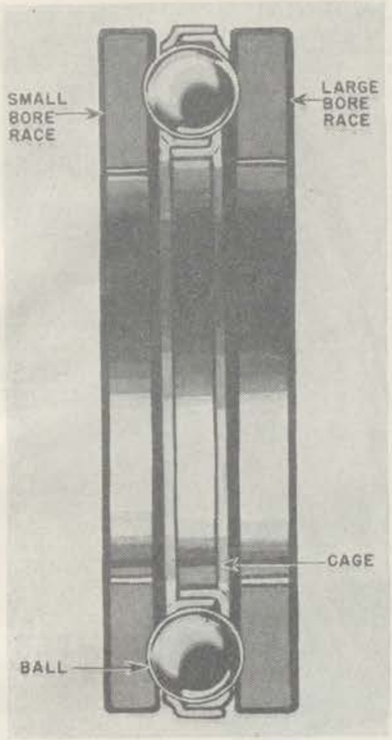


FIGURE 99.—Flat type thrust ball bearing.

loads only. One manufacturer uses rollers formed by helically winding strips of alloy steel into hollow cylinders which are then heat treated and ground to size. This construction imparts some flexibility to the rollers and enables them to adjust themselves to small inaccuracies. Rollers wound right and left hand are assembled alternately in the bearing and held in proper alinement by a cage retainer. These bearings are made with solid inner and outer races, with solid outer race and no inner race, and with a split outer race and no inner race. Figure 101 shows such a bearing having a solid outer and inner race and with no inner race; that is, the shaft itself forms the inner race. Needle bearings, or quill bearings as they are sometimes called, are cylindrical roller bearings in which the diameter of the roller is not over one-eighth the roller length. Separate outer and inner races may be used, or the inner race may be the shaft and the outer race integral with the housing. No spacing cage is ordinarily used; the rollers are merely constrained against endwise

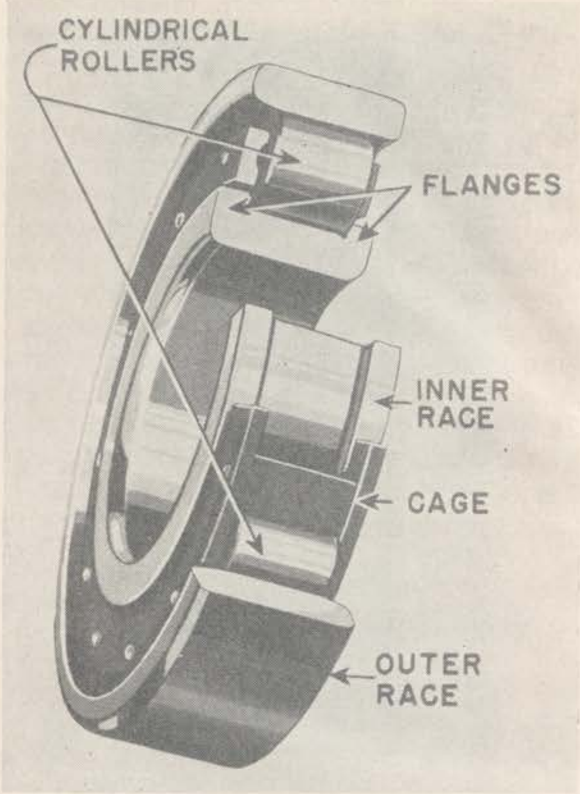


FIGURE 100.—Cylindrical roller bearing with solid rollers.

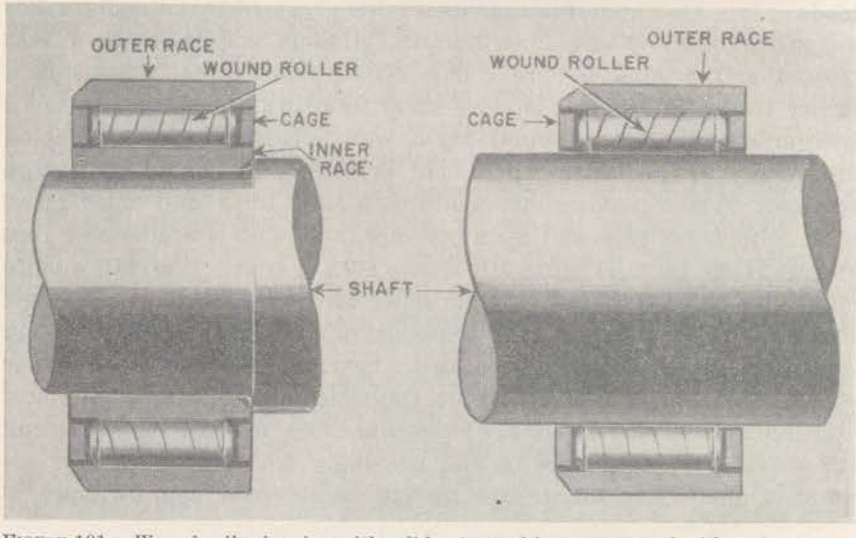


FIGURE 101.—Wound roller bearing with solid outer and inner races and with no inner race.

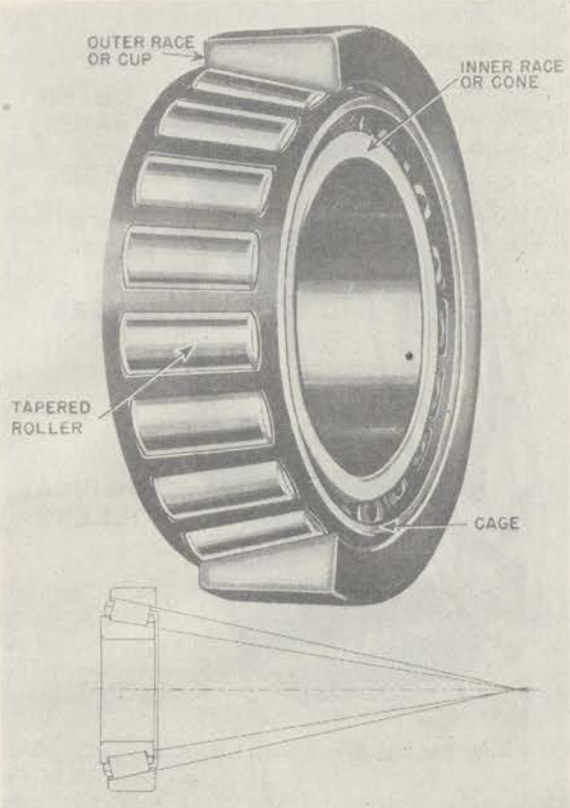


FIGURE 102.—Principle and assembly of tapered roller bearing.

movement. Needle bearings are suitable for radial loads only. These bearings are used where a high load carrying capacity is required in a small space. Typical needle bearings applied to a universal joint are shown in figures 54 and 56.

(2) Tapered roller bearings (fig. 102) are used extensively in automotive power transmission systems, especially for the more heavily loaded rotating members. The rolling members and raceways of the tapered roller bearings are constructed on the elements of a cone, so that lines that coincide with the contacting surfaces of rollers and races all meet at a common point on the axis of the bearing as shown at the bottom of figure 102. True rolling contact is thus obtained. The essential parts are an inner race, or cone; an outer race, or cup; tapered rollers; and a cage, or roller retainer. These bearings are suitable for heavy duty and can withstand radial loads

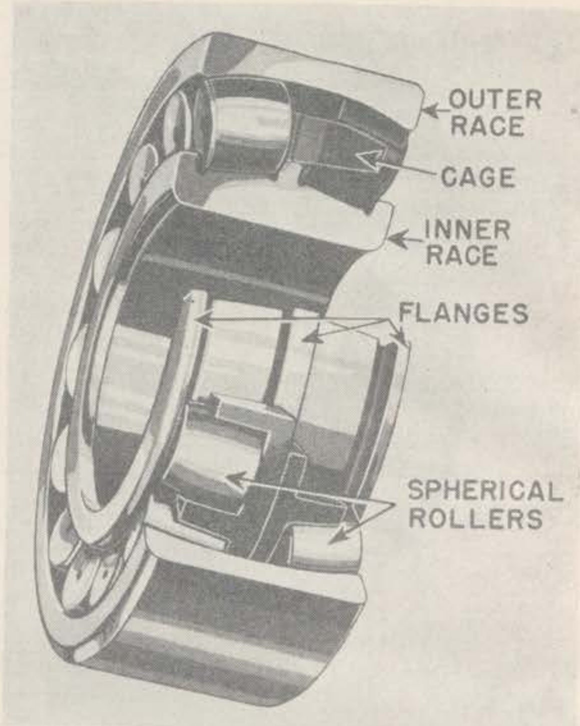


FIGURE 103.—Double row spherical roller bearing.

and thrust loads in one direction or a combination of both. Such bearings are also available with double and quadruple rows of tapered rollers. Flat thrust bearings having tapered rollers and suitable for thrust loads only are also available.

(3) Spherical roller bearings (fig. 103) are similar to cylindrical roller bearings except that the outer race is a spherical surface having its center at the center of the bearing. The rollers are barrel-shaped and have line contact with both the inner and outer races. Cages and flanges space and aline the rollers. Such bearings are self-alining and are suitable for extremely heavy duty aplications. They are used little, if at all, in automotive practice.

64. Lubrication.—*a.* A basic requirement of ball and roller bearing lubrication is protecting the highly finished surfaces from corrosion. The supporting surfaces of the cage, or retainer, are essentially plain bearings and require an oil film. A small quantity of oil or grease will lubricate a bearing if it is evenly distributed. An excess quantity of lubricant is undesirable because it will cause the bearing to heat and aggravate leakage from the bearing housing. Operating temperature is the controlling factor in selecting the proper grade of lubricant. Load, speed, and weather conditions directly affect this temperature, as does the particular type of bearing and the shaft enclosures.

b. The antifriction bearings in automotive power transmission systems are not lubricated as separate units but as parts of assemblies such as clutches, transmissions, universal joints, transfer cases, rear axles, etc. If these assemblies are lubricated in accordance with TM 10-540, with the lubricant prescribed for each, the bearing requirements will be satisfied.

Appendix

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INDEX

INDEX

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