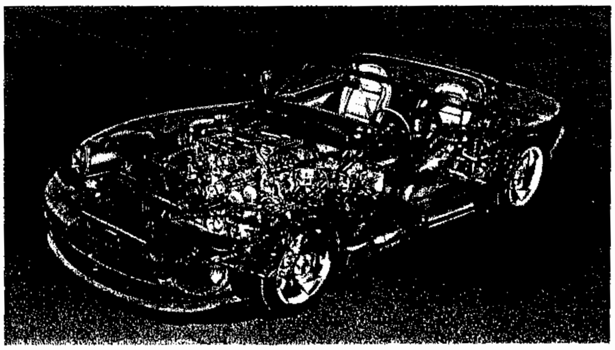
Modern Automotive Technology

James E. Duffy



Publisher
The Goodheart-Willcox Company, Inc.
Tinley Park, Illinois

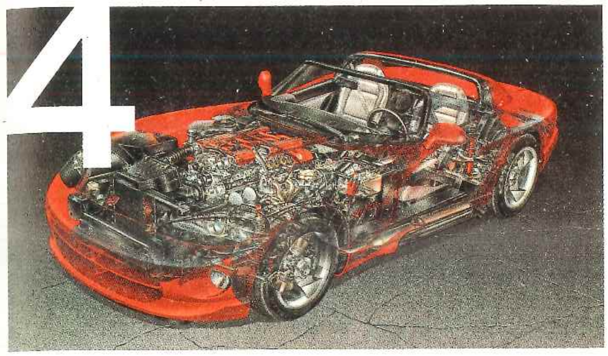
Library of Congress Catalog Card Number 92-46515
International Standard Book Number 0-87006-043-0

6 7 8 9 10 94 97 96

Library of Congress Cataloging in Publication Data

Duffy, James E.
Modern automotive technology / by James E. Duffy

p. cm.
Rev. ed. of: Modern automotive mechanics. c1990.
Includes index.
ISBN 0-87006-043-0
1. Automobiles. 2. Automobiles—Maintenance and repair.
I. Duffy, James E. Modern automotive mechanics.
II. Title.
TL146.D84 1994
629.28'722--dc20 92-46515
CIP



4 Power Tools and Equipment

After studying this chapter, you will be able to:

- □ List the most commonly used power tools and equipment.
- □ Describe the uses for power tools and equipment.
- □ Compare the advantages of one type of tool over another.
- □ Explain safety rules that pertain to power tools and equipment.

To be a productive mechanic in today's auto shop, you must know when and how to use power tools and equipment. They increase the ease and speed of many repair operations.

Power tools are tools using electricity, compressed air, or hydraulics (liquid confined under pressure). Large shop tools such as floor jacks, parts cleaning tanks, and steam cleaners, are classified as *shop equipment*.

This chapter stresses the importance of properly selecting and using power tools and equipment. They can be very dangerous if misused. Always follow the operating instructions for the particular tool or piece of equipment. If in doubt, ask your instructor for a demonstration.

AIR COMPRESSOR

An *air compressor* is the source of compressed (pressurized) air for the auto shop. Look at Fig. 4-1. An air compressor normally has an electric motor that spins an air pump. The air pump forces air into a large, metal storage tank. Metal air lines feed out from the tank to several locations in the shop. The mechanic can then connect flexible air hoses to the metal lines.

An air compressor turns ON and OFF automatically to maintain a preset pressure in the system.

DANGER! Shop air pressure is usually around 100 to 150 psi (689 to 1 034 kPa). This is enough pressure to severely injure or kill. Respect shop air pressure!

Air hoses

High pressure *air hoses* are connected to the metal lines from the air compressor. Since they are flexible, they allow the mechanic to take a source of air pressure to the vehicle being repaired. Quick-disconnect type couplings are used on air hoses. To connect or disconnect an air hose, slide back the outer fitting sleeve and push or pull on the hose.

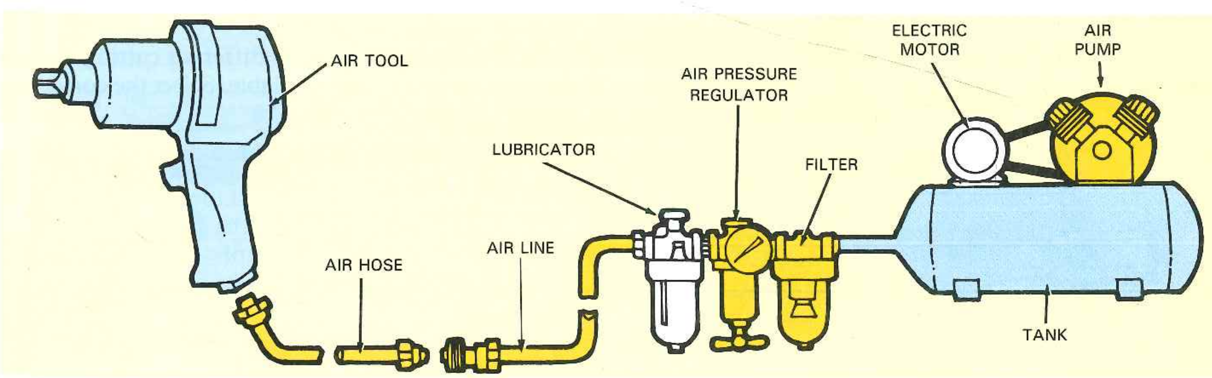


Fig. 4-1. Basic parts of a typical shop air pressure system. Air compressor develops air pressure. Filter removes moisture. Regulator allows mechanic to control system pressure. Metal line and flexible hose carry air to tool. (Florida Dept. of Voc. Ed.)

AIR TOOLS

Air tools, also called *pneumatic tools,* use air pressure for operation. They are labor-saving tools, well worth their cost.

Always lubricate an air tool before use. Squirt a few drops of air tool oil (light oil) into the air inlet fitting. This protects the internal parts of the tool, increasing service life and tool power.

Air wrenches (impact wrenches)

Air wrenches or *impact wrenches* provide a very fast means of installing or removing threaded fasteners. Look at Fig. 4-2A and B. An impact wrench uses compressed air to rotate a driving head. The driving head holds a socket which fits on the fastener head.

A button or switch on the air wrench controls the direction of rotation. In one position, the impact tightens the fastener. The impact loosens the fastener in the other direction.

Impact wrenches come in 3/8, 1/2, and 3/4 in. drive sizes. A 3/8 drive impact is ideal for smaller bolts (sockets between 1/4 and 9/16 in. for example). The 1/2 in. drive is general purpose for medium to large fasteners (head sizes between 1/2 and 1 in.). The 3/4 in. drive impact is for extremely large fasteners and is NOT commonly used in auto service.

CAUTION! Until you become familiar with the operation of an air wrench, be careful not to overtighten bolts and nuts or leave them too loose. It is easy to strip or break fasteners with an air tool.

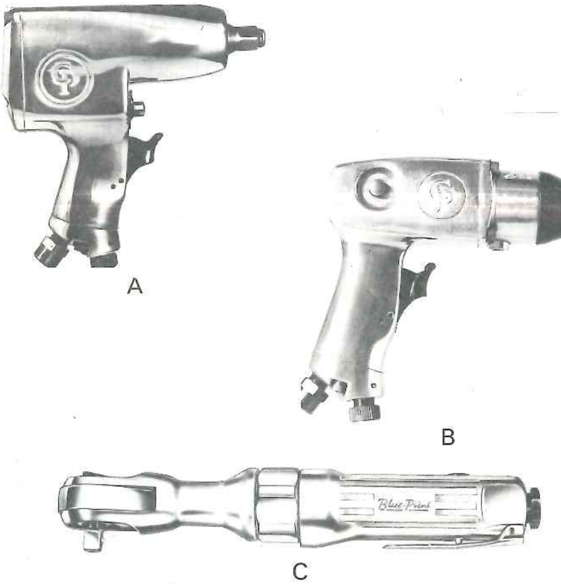


Fig. 4-2. Air wrenches. A — 1/2 in. drive impact wrench. B — 3/8 drive impact wrench. C — 3/8 in. drive air ratchet. (Hennessy Industries, Inc. and Snap-On Tools)

Air ratchet

An *air ratchet* is a special impact type wrench designed for working in tight quarters. Look at Fig. 4-2C. It is very slim and will fit into small areas. For instance, an air ratchet is commonly used when removing water pumps. It will fit between the radiator and engine easily.

An air ratchet normally has a 3/8 in. drive. It does not have very much turning power. Final tightening and initial loosening must be done by hand.

Impact sockets and extensions

Special *impact sockets* and *extensions* must be used with air wrenches. They are thicker and much stronger than conventional sockets and extensions. A conventional socket can be ruined or broken by the hammering blows of an impact wrench.

Special impact sockets and extensions are easily identified. They are usually FLAT BLACK, not chrome.

Air hammer (Chisel)

An *air hammer* or *chisel* is useful during various driving and cutting operations. Look at Fig. 4-3. The air hammer is capable of producing about 1000 to 4000 impacts per minute. Several different cutting or hammering attachments are available. Select the correct one for the job.

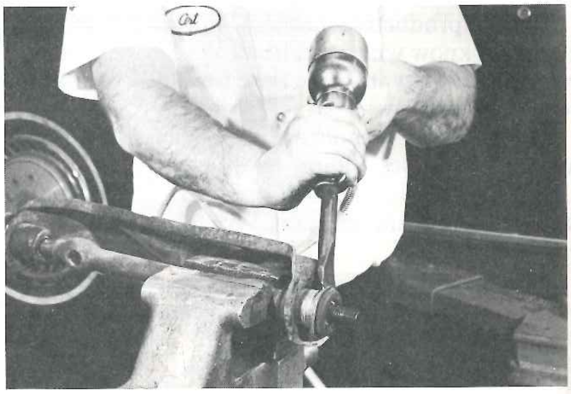


Fig. 4-3. Air hammer is being used to quickly drive bushing out of suspension arm. Wear safety glasses. (Moog)

CAUTION! Never turn an air hammer ON unless the tool is pressed tightly against the workpiece. If not, the tool head can fly out of the hammer with great force — as if shot from a gun!

Blow gun

An air powered *blow gun* is commonly used to dry and clean parts washed in solvent. See Fig. 4-4. It is also used to blow dust and loose dirt off a part before disassembly.

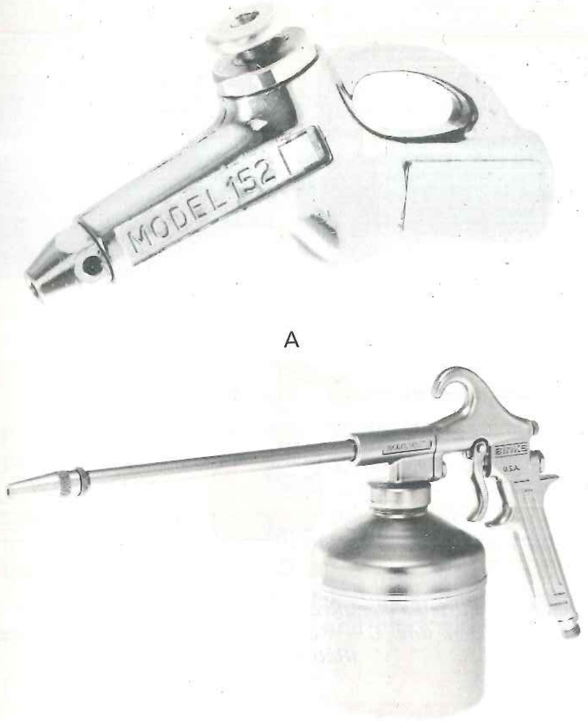


Fig. 4-4. A — Blow gun, commonly used to blow parts clean and dry after washing in solvent. B — Solvent gun can be used to wash parts. (Binks)

When using a blow gun, wear eye protection. Direct the blast of air away from yourself and others. Do not blow brake and clutch parts clean. These parts contain asbestos, a cancer causing substance.

Air drill

An *air drill* is excellent for many repairs because of its power output and speed adjustment capabilities. Its power and rotating speed can be set to match the job at hand. Look at Fig. 4-5. With the right attachment, air drills can drill holes, grind, polish, and clean parts.

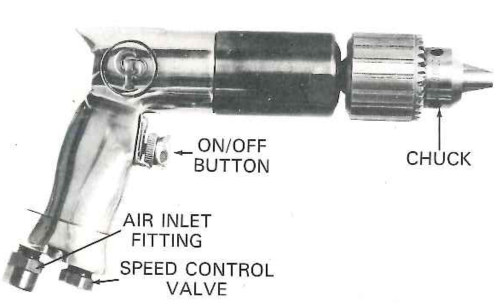


Fig. 4-5. Air drill speed can be adjusted. It is capable of very high turning force. (Hennessy Industries, Inc.)

A ***rotary brush,*** Fig. 4-6, is used in an air or electric drill for rapid cleaning of parts. It will quickly rub off old gasket material, carbon deposits on engine parts, and rust, with a minimum amount of effort.

CAUTION! Only use a high speed type rotary brush in an air drill. A brush designed for an electric drill may fly apart. To be safe, always adjust an air drill to the SLOWEST ACCEPTABLE SPEED.

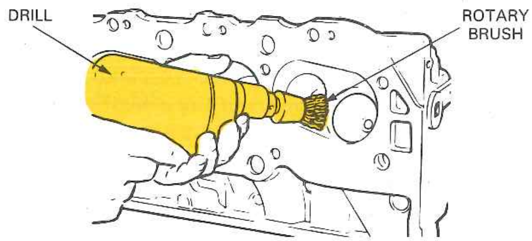


Fig. 4-6. Rotary brush is commonly used in a drill for cleaning off old gaskets or carbon. Wear eye protection!

A ***rotary file*** or ***stone*** can be used in either an air drill, electric drill, or an air (die) grinder, Fig. 4-7. It is handy for removing metal burrs and nicks.

Make sure the stone is not turned too fast by the air tool. Normally the speed specifications (maximum allowable rotating speed) will be printed on the file or stone container.

Fig. 4-7. Die grinder with a high speed stone installed. This tool is used for removing burrs and for other smoothing operations. (Robert Bosch)

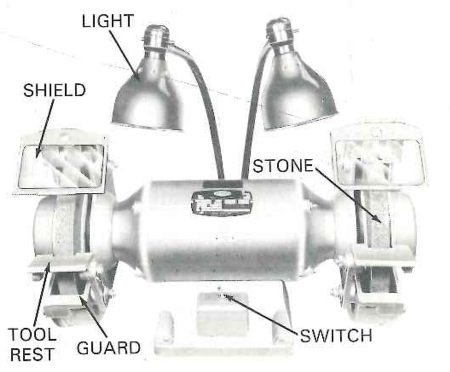


Fig. 4-8. Bench grinder stone is used to sharpen tools. Brush can be used to clean and polish small parts. Keep shields, tool rests, and guards in place. (Sioux Tools)

BENCH GRINDER

A *bench grinder,* Fig. 4-8, can be used for grinding, cleaning, or polishing operations. The hard grinding wheel is used for sharpening or deburring. The soft wire wheel is for cleaning and polishing.

A few BENCH GRINDER RULES to follow are:

1. Wear eye protection and keep your hands away from the stone and brush.
2. Keep the tool rest adjusted close to the stone and brush. If the rest is NOT up close, the part can catch in the grinder.
3. Do NOT use the wire wheel to clean soft metal parts (aluminum pistons or brass bushings, for example). The rubbing, abrasive action of the wheel can remove metal, scuff, and ruin the part. Use a solvent and a dull hand scraper on soft metal parts that could be damaged.
4. Make sure the grinder shields are in place.

DRILLS

Twist drills or *drill bits* are used to drill holes in metal and plastic parts. They fit into either an electric or air powered drill, Fig. 4-9. Drill bits are commonly made of either carbon steel or high speed steel. High speed steel is better because of its resistance to heat. It will not lose its hardness when slightly overheated.

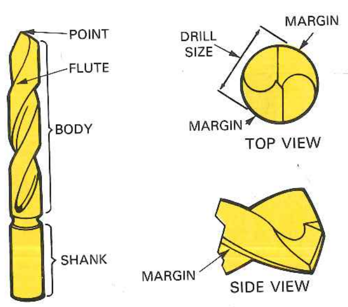


Fig. 4-9. Study basic parts of drill bit. (Florida Dept. of Voc. Ed.)

Portable electric drill

A drill bit is chucked (mounted) and rotated by an *electric drill,* Fig. 4-10. A special *key* must be used to tighten the drill bit in the drill. A portable electric drill will work fine on most small drilling operations.

Drill press

A large *drill press* is needed for drilling large holes, deep holes, or a great number of holes in several parts, Fig. 4-11. The drill press handle allows the bit to be pressed into the work with increased force. Also, the drill chuck will accept very large bits.

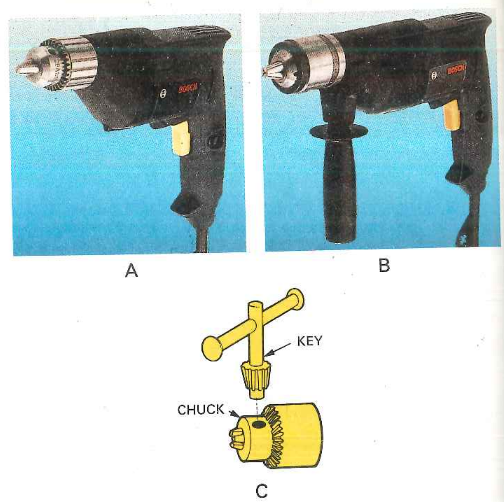


Fig. 4-10. Portable electric drills. A — Small, 3/8 in. drill. B — Larger, 1/2 in. drill. C — Key is used to tighten bit in chuck. (Robert Bosch)

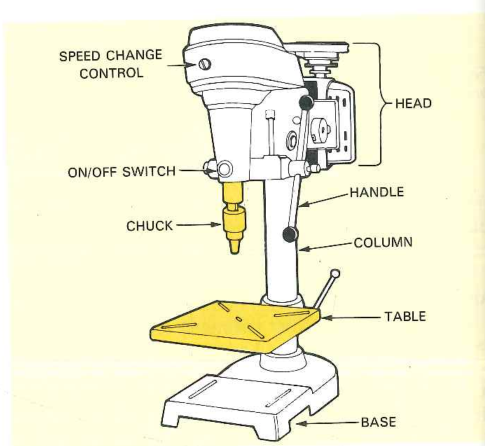


Fig. 4-11. Note parts of drill press. It is for drilling deep or large holes when part will fit on table. (Florida Dept. of Voc. Ed.)

A few DRILL PRESS RULES to follow include:

1. Secure the part to be drilled in a vise or with C-clamps.
2. Use a center punch to indent the part and start the hole.
3. Remove the key before turning on the drill.
4. To prevent possible injury, release drilling pressure right before the bit breaks through the bottom of the part. A drill bit tends to catch when breaking

through. This can cause the drill or part to rotate dangerously.

5. Oil the bit as needed.

TIRE CHANGER

A *tire changer* is a common piece of shop equipment used to remove and replace tires on wheels. Some are hand-operated and others use air pressure. Do not attempt to operate a tire changer without proper supervision. Follow the directions provided with the changer.

BUMPER LIFTS

Bumper lifts or *jacks,* either air or manually powered, are used to raise one end of a car. Lifting pads fit under the front or rear bumper. See Fig. 4-12A.

When raising the front of a car, place the transmission in neutral and release the parking brake. This will let the vehicle roll and will prevent the car from pulling off the lift.

After raising, secure on jack stands. Place in park. Apply the emergency brake and block the wheels.

FLOOR JACKS

A *floor jack* is also used to raise either the front, sides, or rear of a vehicle. Look at Fig. 4-12B.

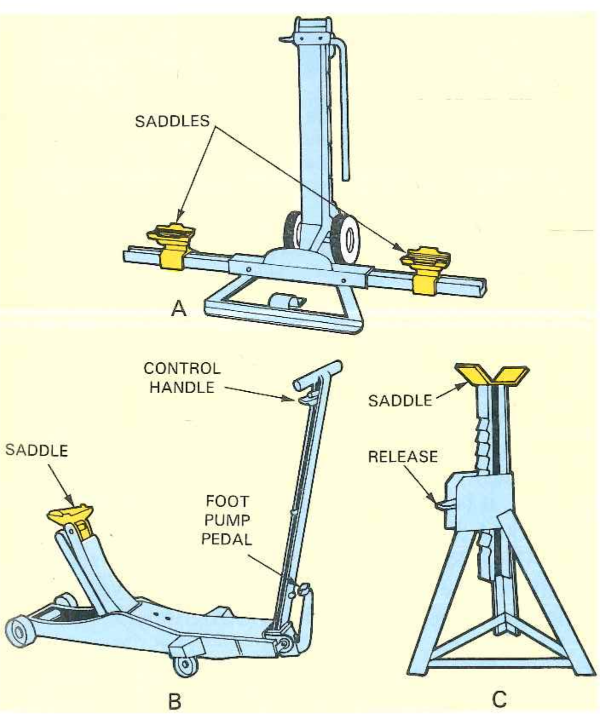


Fig. 4-12. Vehicle lifting equipment A — Bumper lift. B — Floor jack is for raising car only. C — Jack stands are needed before working under car. (Florida Dept. of Voc. Ed.)

To avoid vehicle damage, place the jack saddle under a solid part of the car (frame, suspension arm, rear axle). If you are NOT careful, it is very easy to smash an oil pan, muffler, floor pan, or other sheet metal part.

As with a bumper jack, the vehicle should be free to roll while being raised. After raising, place the vehicle on jack stands. Block wheels and place in park.

Normally, to raise the vehicle, you must turn the jack handle or knob clockwise and pump the handle. To lower, turn the pressure relief valve counterclockwise slowly.

JACK STANDS

Jack stands support a vehicle during repair. After raising it with a jack, place stands under the vehicle, Fig. 14-12C. It is NOT SAFE to work under vehicles held by a floor jack or bumper lift.

Note! The next chapter details the use of lifts, jacks, and jack stands.

TRANSMISSION JACK

Special *transmission jacks* are designed for removing and installing transmissions. One type is similar to a floor jack. However, the saddle is enlarged to fit the bottom of a transmission.

Another type of transmission jack is used when the car is raised on a vehicle lift, Fig. 4-13. It has a long post which can reach high into the air to support the transmission.

ENGINE CRANE

A portable *engine crane* is used to remove and install engines, Fig. 4-14. It has a hydraulic hand jack

Fig. 4-13. Transmission jack is designed for removing, transporting, and installing transmissions when using an overhead lift. Hydraulic lift is foot operated and raises to height of 72 in. (OTC Div. of SPX Corp.)

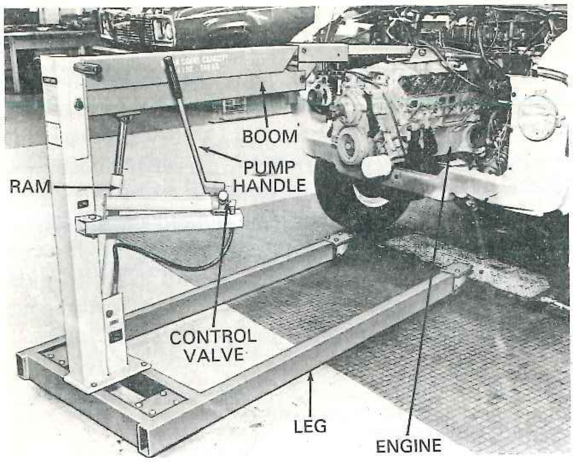


Fig. 4-14. Hydraulic engine crane can be used to lift heavy objects such as engines, transmissions, transaxles, rear axle assemblies.

for raising and a pressure release valve for lowering. An engine crane is also handy for lifting heavy engine parts (intake manifolds, cylinder heads), transmissions, and transaxles.

HYDRAULIC PRESS

A *hydraulic press* is used to install or remove gears, pulleys, bearings, seals, and other parts requiring high pushing force. One is shown in Fig. 4-15.

A hydraulic press uses a hand jack. By pumping the jack, press-fit parts can be pushed apart or together. A valve releases pressure.

NOTE! A hydraulic press can exert TONS OF FORCE. Wear face protection and use recommended procedures.

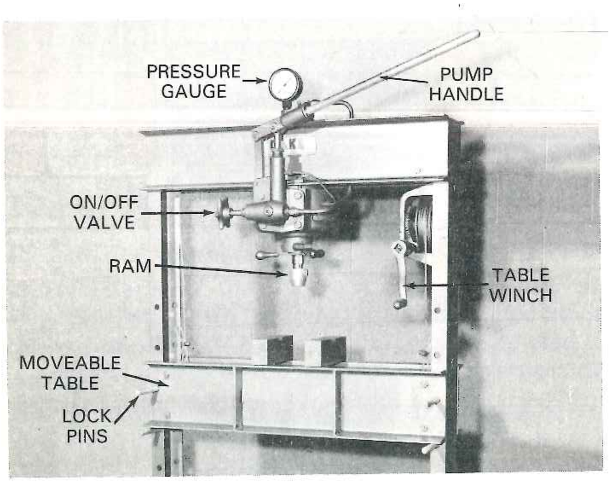


Fig. 4-15. Hydraulic press is needed for numerous pressing operations. It is commonly used to remove and install bearings, bushings, seals, and other pressed-on parts. Note! Double-check lock pins before using press. If not installed, cables in unit could snap. (Dake Corp.)

ARBOR PRESS

An *arbor press* performs the same function as a hydraulic press but at lower pressures. It is a hand-operated, mechanical press for smaller jobs.

ENGINE STAND

An *engine stand* is used to hold an engine while it is overhauled (rebuilt) or repaired. The engine bolts to the stand. For convenience, the engine can usually be rotated and held in different positions.

COLD SOLVENT TANK

A *cold solvent tank,* Fig. 4-16, removes grease and oil from parts. After removing all old gaskets and scraping off excess grease, you can scrub the parts clean

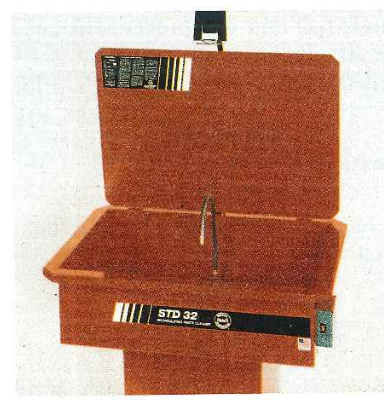


Fig. 4-16. Cold solvent tank is for removing oil and light grease from parts. Unit sprays filtered solvent on parts. Rub parts with brush for rapid cleaning. (Build-All)

in the solvent. A blow gun is normally used to remove the solvent.

STEAM CLEANER AND HIGH PRESSURE WASHER

A *steam cleaner* or *high pressure washer* are used to remove heavy deposits of dirt, grease, and oil from the outside of large assemblies (engines, transmissions, transaxles). Look at Fig. 4-17. For environmental reasons, it is often advisable to wire brush and collect oil-soaked dirt before steaming or washing.

DANGER! A steam cleaner operates at relatively high pressures and temperatures. Follow your safety rules and specific operating instructions.

OXYACETYLENE TORCH

An *oxyacetylene torch* outfit can be used to cut, bend, and weld or braze (join) metal parts, Fig. 4-18. Its rapid cutting action is extremely beneficial. For ex-

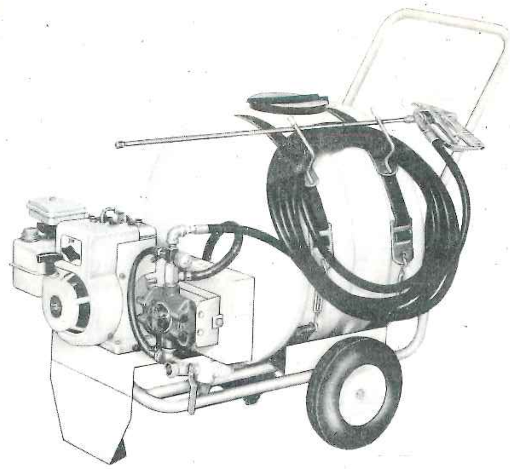


Fig. 4-17. High pressure washer will remove greasy buildup on outside of assemblies before teardown. (Sioux Tools)

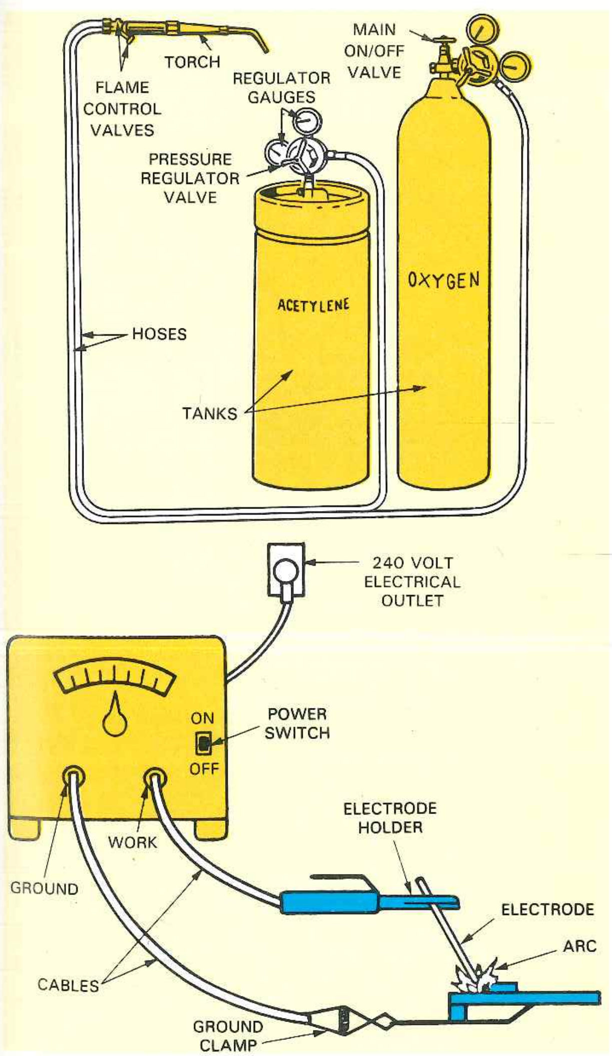


Fig. 4-18. Top. Oxyacetylene outfit can be used for cutting or welding metal. Bottom. Study basic parts of arc welder. (Sun)

ample, a cutting torch is often used to remove old, deteriorated exhaust systems. Tremendous heat is produced by burning acetylene gas and oxygen.

ARC WELDER

An *arc welder* is also used to weld metal parts together, Fig. 4-18. It uses high electric current and the resulting electric arc to produce welding heat.

If at all possible, you should take a welding course in school. This will help prepare you for auto mechanics. DO NOT attempt to weld or cut until properly trained.

SOLDERING GUN

A *soldering gun* or *iron* is normally used to solder (join) wires, Fig. 4-19. An electric current heats the tip of the gun. Then, the hot gun tip can be used to heat the wires and melt the solder. When the solder solidifies (hardens), a strong, solid connection is produced.

BATTERY CHARGER

A *battery charger* is used to recharge (energize) a discharged (de-energized) car battery. It forces current back through the battery. Normally, the red charger lead connects to the battery positive (+) terminal. The black charger lead connects to the negative (−) battery terminal.

WARNING! Always connect the battery charger leads to the battery BEFORE turning the charger ON. This will prevent sparks that could ignite any battery gas. The gases around the top of a battery can EXPLODE violently.

DROP LIGHT

A *drop light,* Fig. 4-20, provides a portable source of illumination (light). The light can be taken to the repair area under the vehicle, hood, or engine.

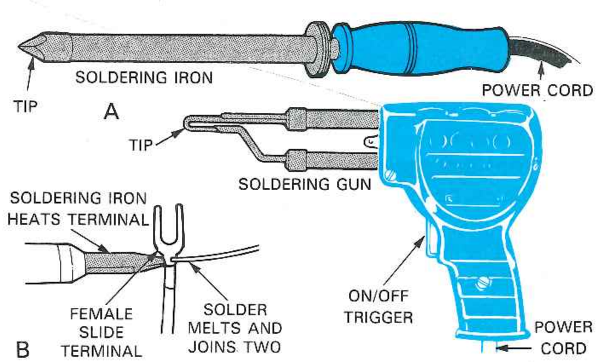


Fig. 4-19. A — Soldering iron and soldering gun. B — Soldering iron or gun produces enough heat to melt solder for joining wires and small metal terminals. (Florida Dept. of Voc. Ed.)

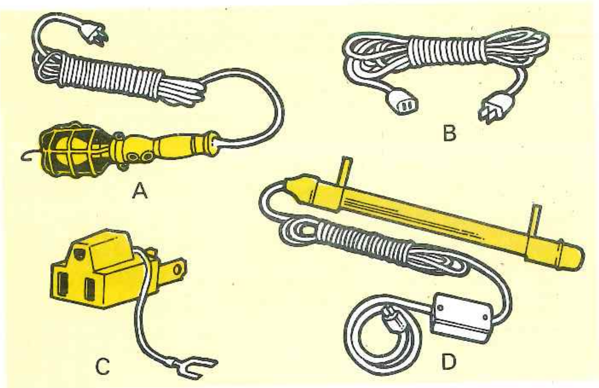


Fig. 4-20. A — Drop light. B — Drop or extension cord. C — Three-prong adapter with ground terminal and ground wire for safety. D — Fluorescent drop light. (Florida Dept. of Voc. Ed.)

WHEEL PULLERS

Wheel pullers are needed to remove seals, gears, pulleys, steering wheels, axles, and other pressed-on parts. A few puller types are pictured in Fig. 4-21. Special pulling operations will be covered in later chapters.

DANGER! Pullers can exert TONS OF FORCE. They must be used properly to prevent injury or part damage. Wear eye protection!

JUMPER CABLES

Jumper cables are used to start engines with a dead (discharged) battery. The cables can be connected between the dead battery and another battery. This will let you crank and start the vehicle. See Fig. 4-22.

When connecting jumper cables, connect positive to positive and negative to negative. Also, keep sparks away from the dead battery. Connect the negative cable to the vehicle frame so that any sparks will not occur near the battery.

CREEPER

A *creeper* is useful when working under a car supported on jack stands, Fig. 4-23A. It lets the technician easily roll under vehicles without getting dirty.

Stool creeper

A *stool creeper* allows the technician to sit while working on parts low to the ground. See Fig. 4-23B. For example, a stool creeper is often used on brake repairs. The brake parts and tools can be placed on the creeper. The service technician can sit and still be eye level with the brake assembly.

ROLL-AROUND CART

A larger *roll-around cart* or table is handy for taking a number of tools to the job. One is pictured in

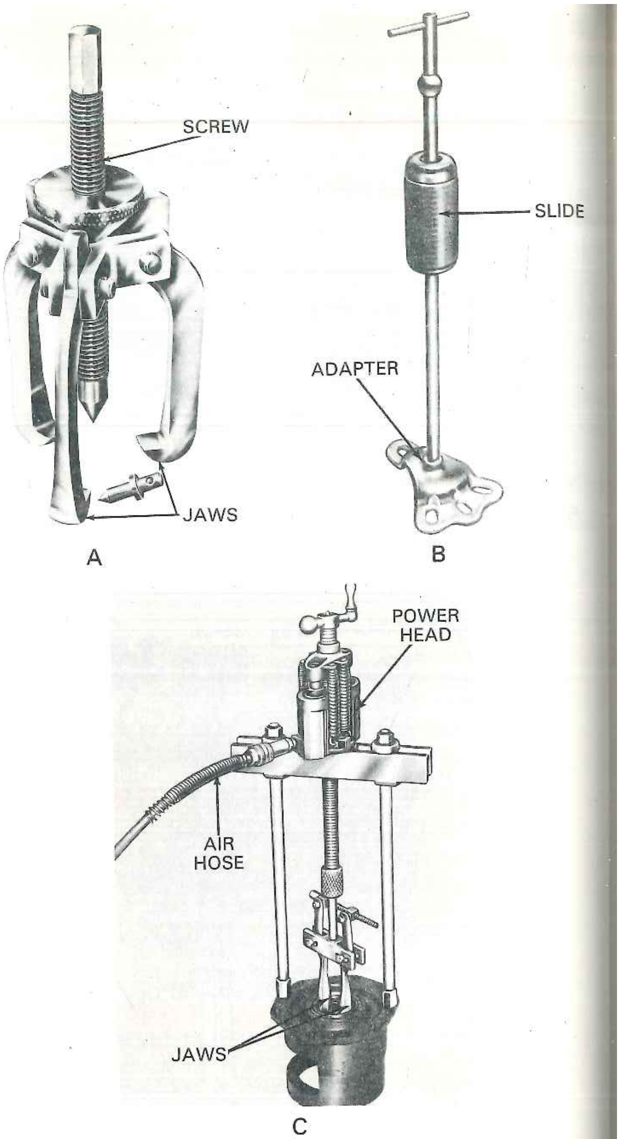


Fig. 4-21. A — Three-jaw puller. B — Slide hammer puller. C — Power puller. (OTC Div. of SPX Corp.

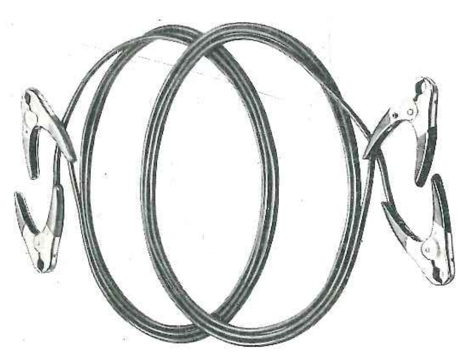


Fig. 4-22. Jumper cables are for emergency starting. Connect red lead to positive terminal of both batteries. Black is for negative and ground. (Snap-On Tools)

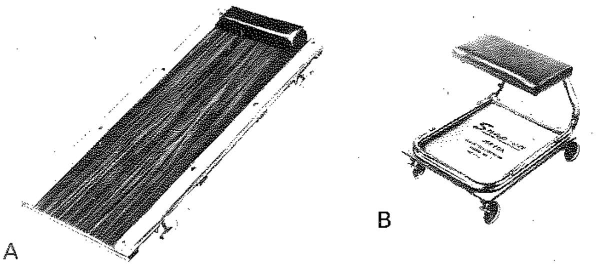


Fig. 4-23. A — Creeper is for working under car. B — Stool creeper is commonly used during brake and suspension repairs. You can sit on the stool and store tools on bottom. (Snap-On Tools)

Fig. 4-24. Since the technician is working on a car raised on a lift, the cart positions all of the needed tools within "hand's reach." This saves time and effort.

FENDER COVERS

Fender covers are placed over fenders, upper grille, or other body sections to protect them. They protect the finish from nicks and scratches. See Fig. 4-25A. Never lay your tools on a painted surface. Scratches could result.

Seat covers

Seat covers are placed over seats to protect them from dirt, oil, and grease that might be on your

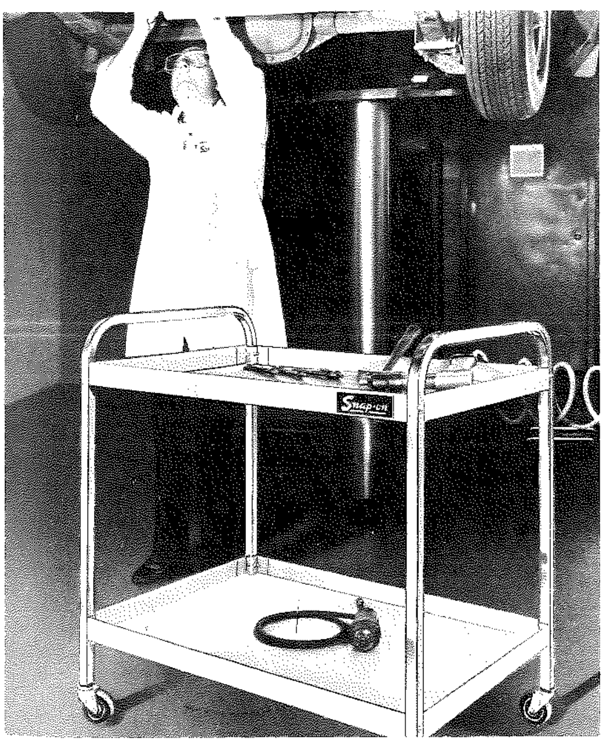


Fig. 4-24. Roll-around cart allows you to take several tools to car. This saves several trips to tool box.

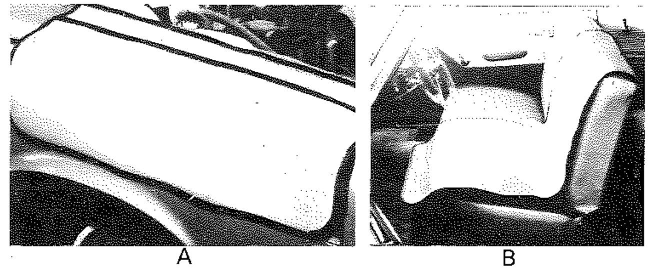


Fig. 4-25. Always take good care of customer's car. A — Fender covers protect paint from nicks and dents. B — Seat cover protects upholstery from dirty work clothes. (Snap-On Tools)

workclothes. The covers are normally used while driving the vehicle in and out of the shop or while working in the passenger compartment. Look at Fig. 4-25B.

KNOW THESE TERMS

Air compressor, Air tool, Impact socket, Blow gun, Rotary brush, Engine crane, Hydraulic press, Solvent tank, Battery charger, Drop light, Wheel puller, Jumper cables, Creeper, Fender cover.

REVIEW QUESTIONS

1. Power tools use __________, __________ __________, or ________________ as sources of energy.
2. Shop air pressure is only about 25 psi or 172 kPa and cannot cause injuries. True or False?
3. Which of the following is NOT a commonly used air tool?
   a. Impact wrench. c. Air chisel.
   b. Air ratchet. d. Air saw.
4. A __________ __________ is used to blow dirt off parts and to dry parts after cleaning.
5. A rotary brush is used in an electric or air drill for rapid cleaning of parts. True or False?
6. List four important rules for a bench grinder.
7. List five important rules for a drill press.
8. Use this tool to support the car while working under the car.
   a. Floor jack. c. Transmission jack.
   b. Jack stands. d. Bumper jack.
9. Explain the use of a solvent tank.
10. What are wheel pullers for?

ACTIVITIES FOR CHAPTER 4

1. Using an automotive tool catalog, develop a list of power tools needed to equip the school's automotive repair shop. Find prices and add up the cost.
2. Research safety literature on power equipment used in an automotive repair facility.
   a. Develop a bibliography of resources for safe use of power equipment.
   b. Develop a list of safety rules for their use.

25 Exhaust Systems, Turbocharging

After studying this chapter, you will be able to:
- ☐ Describe the basic parts of an exhaust system.
- ☐ Compare exhaust system design differences.
- ☐ Perform exhaust system repairs.
- ☐ Explain the fundamental parts of a turbocharging system.
- ☐ Describe the construction and operation of a turbocharger and wastegate.
- ☐ Remove and replace a turbocharger and wastegate.
- ☐ Demonstrate an understanding of safety procedures for working on exhaust systems and turbochargers.

This chapter begins by covering the basic parts of an exhaust system. It then explains how to repair the system by replacing rusted or damaged components. The second part of the chapter covers turbocharging.

BASIC EXHAUST SYSTEMS

An *exhaust system* quiets engine operation and carries exhaust fumes to the rear of the vehicle. The parts of a typical exhaust system are shown in Fig. 25-1. They include:

1. EXHAUST MANIFOLD (connects cylinder head exhaust ports to header pipe).
2. HEADER PIPE (steel tubing that carries exhaust gases from exhaust manifold to catalytic converter or muffler).
3. CATALYTIC CONVERTER (device for removing pollutants from engine exhaust).
4. INTERMEDIATE PIPE (tubing sometimes used between header pipe and muffler or catalytic converter and muffler).

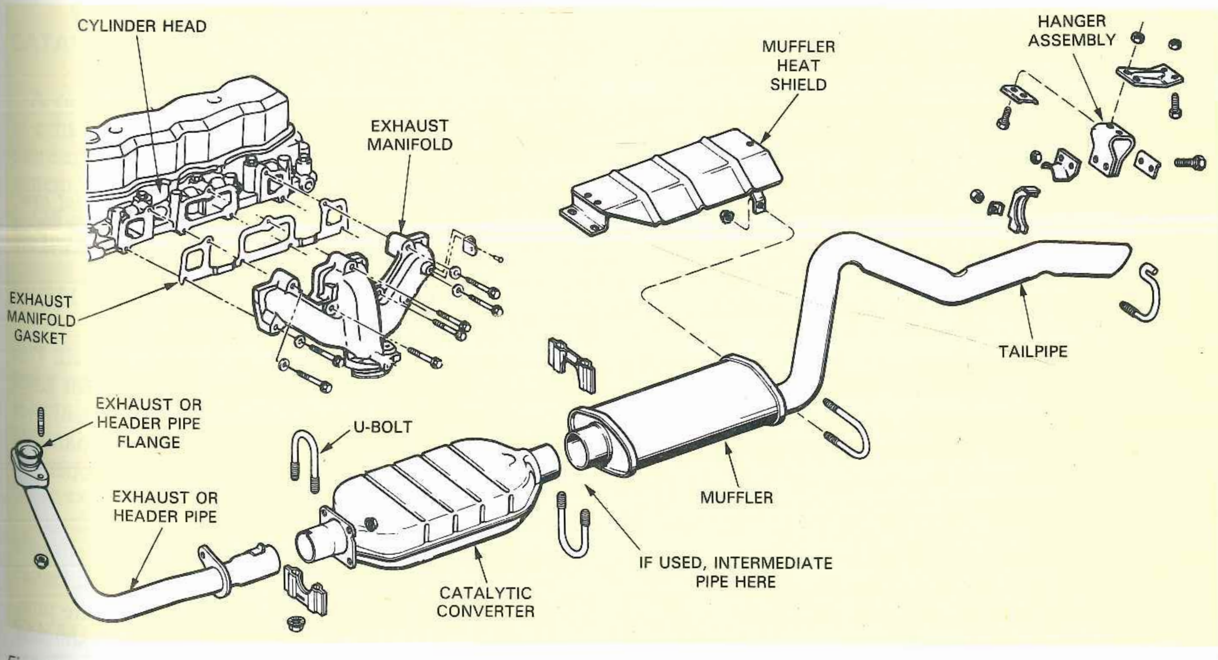


Fig. 25-1. *Note parts of typical exhaust system. Exhaust comes out of cylinder head, into manifofld, and then through system. (Chrysler Corp.)*

5. MUFFLER (metal chamber for damping pressure pulsations to reduce exhaust noise).
6. TAILPIPE (tubing that carries exhaust from muffler to rear of car body).
7. HANGERS (devices for securing exhaust system to underside of car body).
8. HEAT SHIELDS (metal plates that prevent exhaust heat from transferring into another object).
9. MUFFLER CLAMPS (U-bolts for connecting parts of exhaust system together).

When an engine is running, extremely hot gases blow out of the cylinder head exhaust ports. The gases enter the exhaust manifold. They flow through the header pipe, catalytic converter, intermediate pipe, muffler, and out the tailpipe.

Exhaust back pressure

Exhaust back pressure is the amount of pressure developed in the exhaust system when the engine is running. High back pressure reduces engine power. A well designed exhaust system should have LOW back pressure.

The restriction of the exhaust pipes, catalytic converter, and muffler contribute to exhaust back pressure. Larger pipes and a free-flowing muffler, for example, would reduce back pressure.

Single and dual exhaust systems

A *single exhaust system* has one path for exhaust flow through the system. Typically, it has only one header pipe, main catalytic converter, muffler, and tailpipe. The most common type, it is used from the smallest four-cylinder engines, on up to large V-8 engines.

A *dual exhaust system* has two separate exhaust paths to reduce back pressure. It is two single exhaust systems combined into one. A dual exhaust system is sometimes used on high performance cars with large V-6 or V-8 engines. It lets the engine "breath" better at high rpm.

A *crossover pipe* normally connects the right and left side header pipes to equalize back pressure in a dual system. This also increases engine power slightly.

EXHAUST MANIFOLD

An *exhaust manifold* bolts to the cylinder head to enclose the exhaust port openings, Fig. 25-2. The manifold is usually made of cast iron. It is sometimes made of stainless steel or lightweight steel tubing. The cylinder head mating surface is machined smooth and flat. An exhaust manifold gasket is commonly used between the cylinder head and manifold to help prevent leakage.

The outlet end of the exhaust manifold has a single round opening with provisions for stud bolts or cap screws. A gasket or O-ring (doughnut) seals the connection between the exhaust manifold outlet and header pipe to prevent leakage.

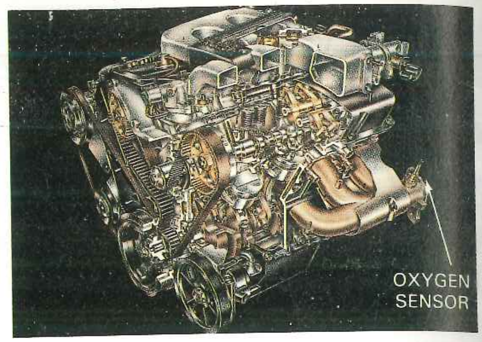


Fig. 25-2. Lower right shows exhaust manifold which bolts over exhaust ports on side of cylinder head. Note oxygen sensor at end of manifold. (Chrysler Corp.)

Exhaust manifold heat valve

An *exhaust manifold heat valve* forces hot exhaust gases to flow into the intake manifold to aid cold weather starting. Look at Fig. 25-3.

A butterfly valve may be located in the outlet of the exhaust manifold. A heat sensitive spring or a vacuum diaphragm and temperature sensing vacuum switch may operate the valve.

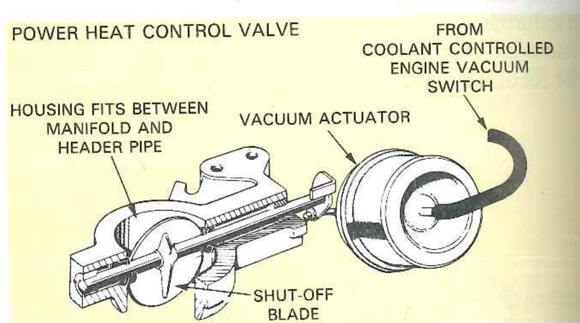


Fig. 25-3. Heat control valve, sometimes called heat riser, forces hot exhaust gases into intake manifold. This helps engine run smoothly. Valve opens as engine warms up. (Chrysler)

When the engine is cold, the heat valve is closed. This increases EXHAUST BACK PRESSURE. Hot gases blow into an exhaust passage in the intake manifold, Fig. 25-4. This warms the floor of the intake manifold to hasten fuel vaporization. The heat valve opens as the engine warms up.

EXHAUST PIPES

The *exhaust pipes* (header pipe, intermediate pipe, and tailpipe) are usually made of rust resistant steel tubing. The inlet end of the header pipe has a flange for securing the pipe to the exhaust manifold studs,

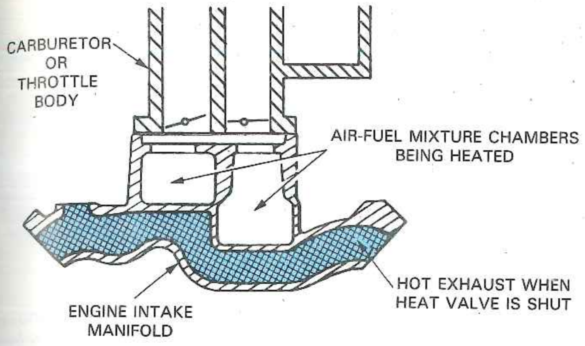


Fig. 25-4. Heat control valve causes back pressure in exhaust system. This directs a large amount of hot exhaust into chamber in bottom of intake manifold. This actions warms and helps vaporize fuel. (Pontiac)

Fig. 25-1. One end of each pipe may be enlarged to fit over the end of the next pipe.

HEAT SHIELDS

Heat shields are located where the exhaust system (especially catalytic converter and muffler) are close to the car body. The shields prevent too much heat from transferring into the car body or ground. Refer to Fig. 25-1.

DANGER! Always reinstall all exhaust system heat shields. Without a heat shield, car undercoating, carpeting, dry leaves on the ground, and other flammable materials could catch on fire!

CATALYTIC CONVERTER

A *catalytic converter* is used to reduce the amount of exhaust pollutants entering the atmosphere. One or more catalytic converters can be located in the exhaust system, Fig. 25-1.

For details of catalytic converters, refer to Chapters 39 and 40 which cover emission control systems.

MUFFLERS

A *muffler* reduces the pressure pulses and resulting noise produced by the engine exhaust. When an engine is running, the exhaust valves are rapidly opening and closing. Each time an exhaust valve opens, a blast of hot gas shoots out of the engine. Without a muffler, these exhaust gas pulsations are very loud.

Fig. 25-5 shows the inside of a muffler. Note how chambers, tubes, holes, and baffles are arranged to cancel out the pressure pulsations in the exhaust.

EXHAUST SYSTEM SERVICE

Exhaust system service is usually needed when a component in the system rusts and begins to leak. Because engine combustion produces water and acids, an exhaust system can fail in a relatively short time.

DANGER! A leaking exhaust system could harm the passengers of a car. Since engine exhaust is poisonous, a leaky exhaust can allow toxic gases to flow through any opening in the body and into the passenger compartment.

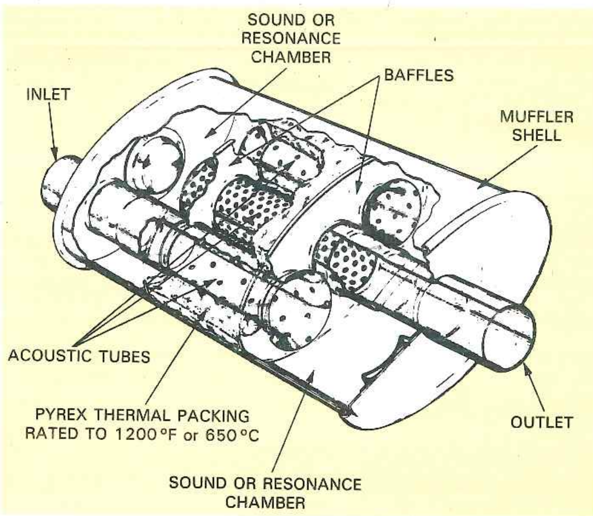


Fig. 25-5. Basic muffler contains baffles, resonance chambers, and acoustic tubes to reduce exhaust noise. (American Exhaust Industries)

Exhaust system inspection

To inspect an exhaust system, raise the car on a lift. Using a drop light, closely inspect the system for problems (rusting, loose connections, leaks). In particular, check around the muffler, all pipe connections, gaskets, and pipe bends.

DANGER! Parts of the exhaust system, especially the catalytic converter, can be VERY HOT. Remember not to touch any component until after it has cooled.

Exhaust system repairs

Faulty exhaust system parts must be removed and replaced. If only the muffler is rusted, a new muffler can be installed in the existing system. After prolonged service, several parts or ALL of the exhaust system may require replacement.

When repairing an exhaust system, remember the following:

1. Use RUST PENETRANT on all threaded fasteners that will be reused, Fig. 25-6. This is especially important on the exhaust manifold flange nuts or bolts.
2. Use an air chisel, cut-off tool, cutting torch, or hacksaw to remove faulty parts. Make sure you

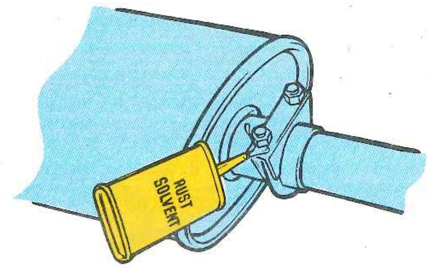


Fig. 25-6. Rust penetrant or solvent will ease removal of badly rusted fasteners. (AP)

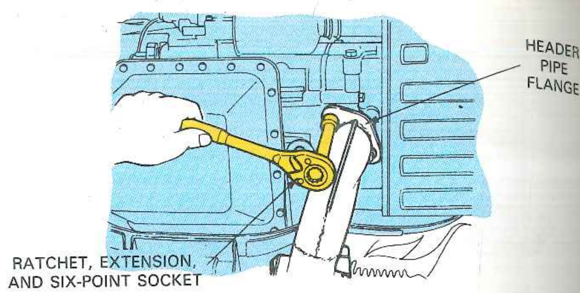


Fig. 25-8. Header pipe fasteners can be difficult to remove. Use rust penetrant, six-point socket, extension, and ratchet. This will usually remove fasteners. (Subaru)

do NOT damage parts that will be reused. See Fig. 25-7 for some examples.

3. A SIX-POINT SOCKET and ratchet or air impact will usually allow quick fastener removal without rounding off the fastener heads. Refer to Fig. 25-8.
4. Wear SAFETY GLASSES or goggles to keep rust and dirt from entering your eyes.
5. Obtain the correct replacement parts.
6. A *pipe expander* should be used to enlarge pipe ends as needed, Fig. 25-9.A *pipe shaper* can be used to straighten dented pipe ends, Fig. 25-10.
7. Make sure all pipes are fully inserted. Position all clamps properly, as in Fig. 25-11.
8. Double-check the routing of the exhaust system. Keep adequate clearance between it, the car body, and chassis. See Fig. 25-12.
9. Tighten all clamps and hangers evenly. Torque the fasteners only enough to hold the parts. Over-tightening will smash and deform the pipes, possibly causing leakage.
10. When replacing an exhaust manifold, use a gasket and check sealing surface flatness. If the manifold is warped, it must be machined flat. Torque the exhaust manifold bolts to specs, Fig. 25-13.
11. Always use new gaskets and O-rings.
12. Check heat riser operation using the information in a service manual.
13. Install all heat shields.
14. Check the system for leaks and rattles after repairs.

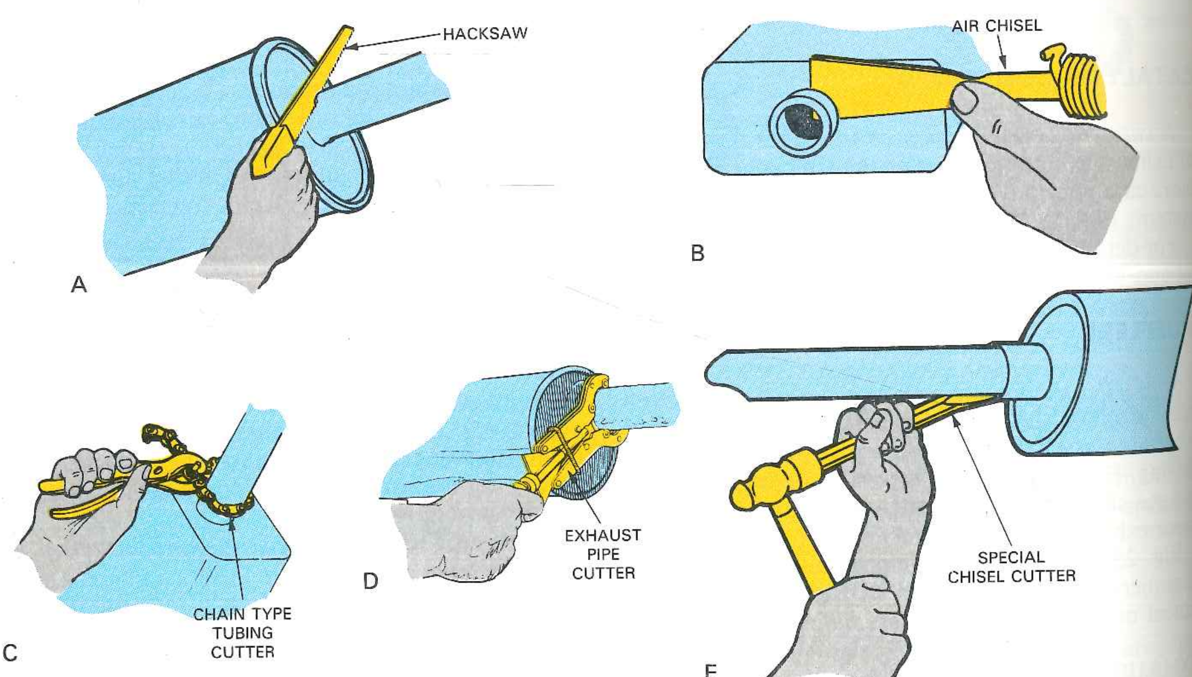


Fig. 25-7. Several methods of removing old exhaust system parts. A — Hacksaw. B — Air chisel. C — Chain type cutting tool. D — Exhaust pipe cutter. E — Specially shaped, hand type cutter or chisel. (AP Parts, Lisle, and Florida Dept. of Voc. Ed.)

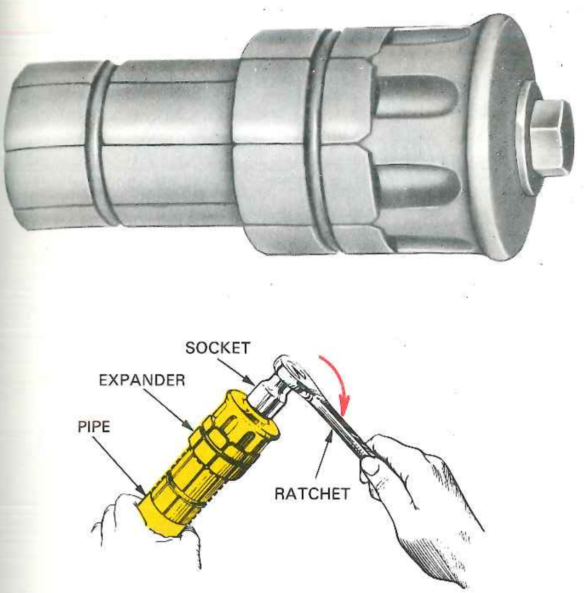


Fig. 25-9. Pipe expander will enlarge ID (inside diameter) of pipes. Then one pipe will fit over another. (Lisle)

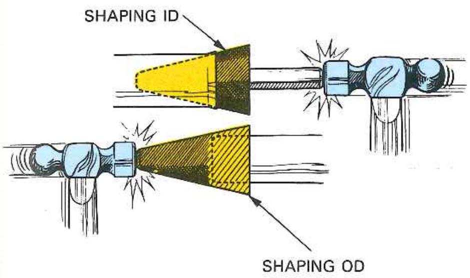


Fig. 25-10. Pipe shaper will round dented pipe ends. (Lisle)

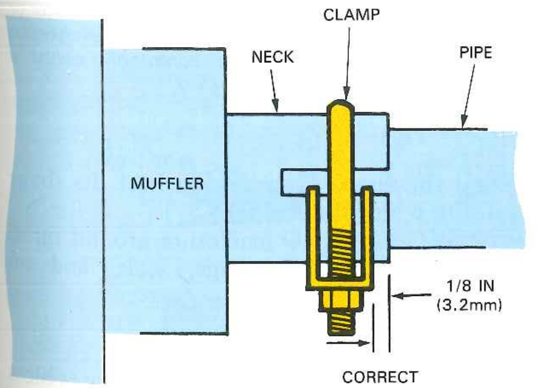


Fig. 25-11. Make sure muffler clamps are installed correctly. Clamp must be positioned around both pipes. If not, one pipe can pull out of other. (Florida Dept. of Voc. Ed.)

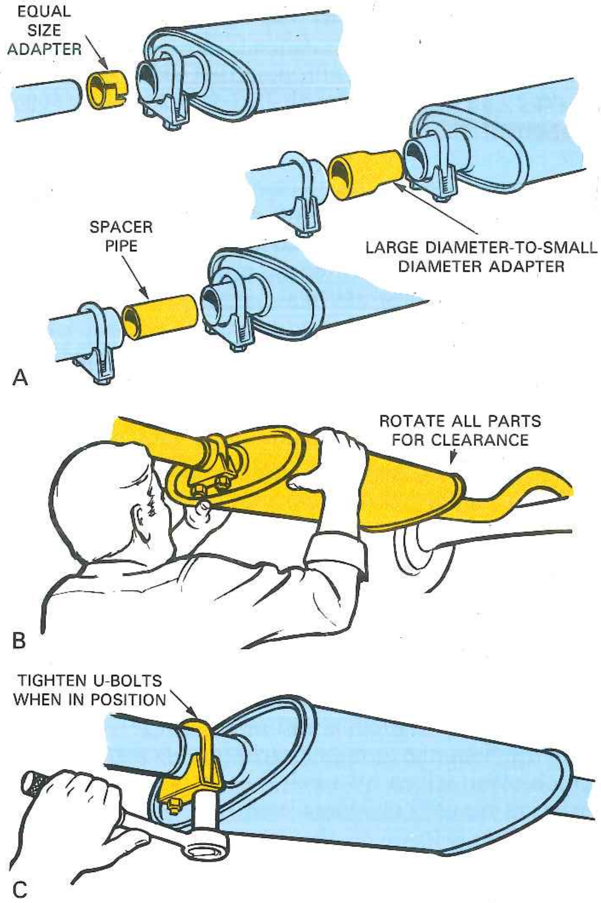


Fig. 25-12. A — Adapters are sometimes needed to make muffler work on existing system. B — Double-check exhaust system-to-car clearance carefully. C — After checking clearance, tighten all clamps evenly and properly. (AP Parts)

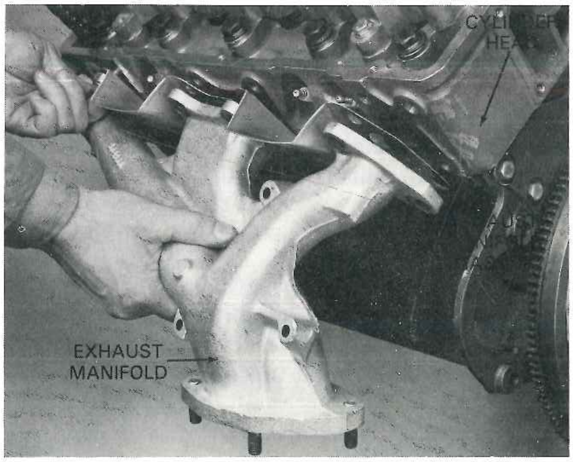


Fig. 25-13. Exhaust gasket is normally recommended. Gasket is held in position as all fasteners are started by hand. Torque fasteners to recommended value in a crisscross pattern. (Saab)

SUPERCHARGERS AND TURBOCHARGERS

A *supercharger* is an air pump that increases engine power by pushing a denser air-fuel charge into the combustion chambers. With more fuel and air, combustion produces more heat energy and pressure to push the piston down in the cylinder.

Sometimes termed a ***blower,*** the supercharger raises the air pressure in the engine intake manifold. Then, when the intake valves open, more air-fuel mixture (gasoline engine) or air (diesel engine) can flow into the cylinders.

A ***normally aspirated engine,*** nicknamed *atmospheric engine,* uses atmospheric pressure (14.7 psi or 100 kPa at sea level) to push air into the engine. It is a nonsupercharged engine. With only outside air pressure as a moving force, only a limited amount of fuel can be burned on each power stroke.

Supercharger types

There are three basic types of superchargers:

1. Centrifugal supercharger.
2. Rotor (Rootes) supercharger.
3. Vane supercharger.

These types are shown in Fig. 25-14. Note the differences in construction and operation.

In the field, the term "supercharger" generally refers to a blower driven by a belt, gears, or chain. Superchargers are used on large diesel truck engines and racing engines. However, they are sometimes found on high performance passenger cars.

The term ***turbocharger*** or ***"turbo"*** refers to a blower driven by engine exhaust gases. Turbochargers are commonly used on passenger cars, trucks, and competiton engines.

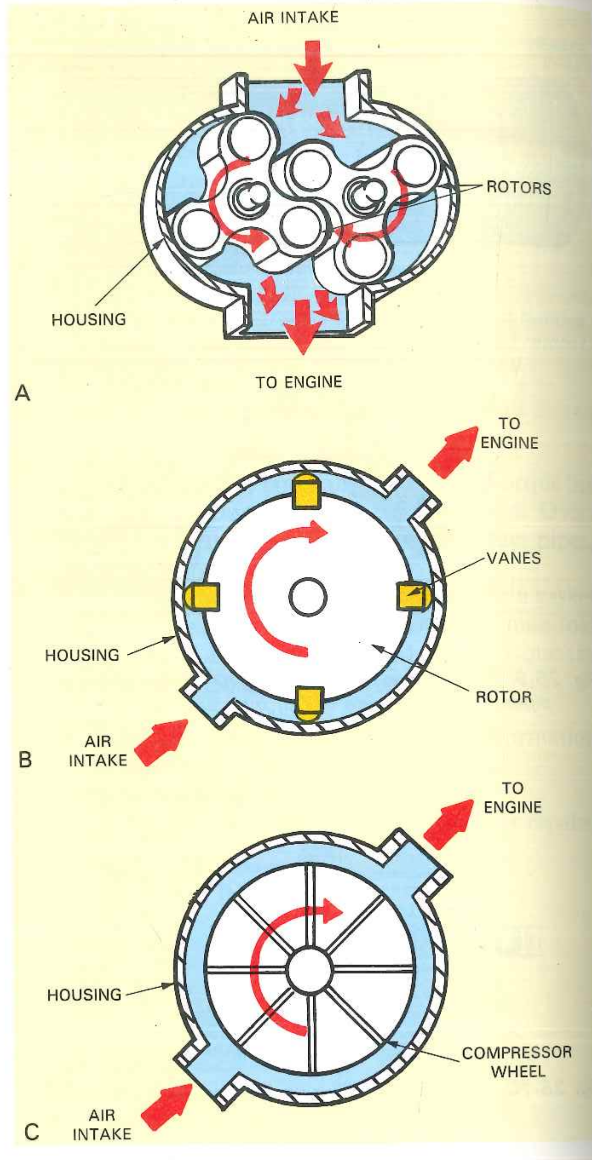


Fig. 25-14. Three basic types of superchargers. A — Rotor or Rootes type supercharger. B — Vane type supercharger. C — Centrifugal supercharger, more commonly called a turbocharger. (Chrysler)

TURBOCHARGERS

A *turbocharger* is an exhaust driven supercharger (fan or blower) that forces air into the engine under pressure. Turbochargers are frequently used on small gasoline and diesel engines to increase power output. By harnessing engine exhaust energy, a turbocharger can also improve engine efficiency (fuel economy and emission levels). This is especially true with a diesel engine.

As shown in Fig. 25-15, the basic parts of a turbocharger are:

1. TURBINE WHEEL (exhaust driven fan that turns turbo shaft and compressor wheel).
2. TURBINE HOUSING (outer enclosure that routes exhaust gases around turbine wheel).
3. TURBO SHAFT (steel shaft that connects turbine and compressor wheels. It passes through center of turbo housing).
4. COMPRESSOR WHEEL (driven fan that forces air into engine intake manifold under pressure).
5. COMPRESSOR HOUSING (part of turbo housing that surrounds compressor wheel. Its shape helps pump air into engine).
6. BEARING HOUSING (enclosure around turbo shaft that contains bearings, seals, and oil passages).

Turbocharger operation

When the engine is running, hot exhaust gases blow out the open exhaust valves and into the exhaust manifold. The exhaust manifold and connecting tubing route these gases into the turbine housing. Refer

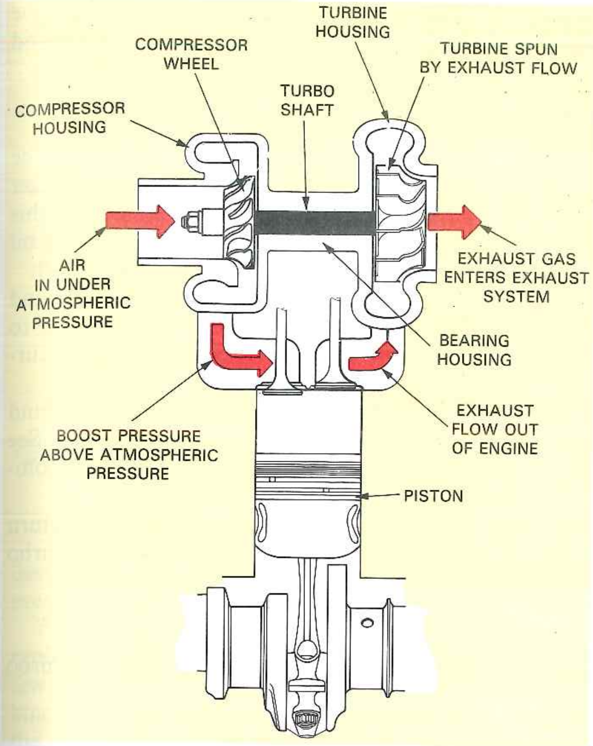


Fig. 25-15. Turbocharger uses exhaust gas flow to spin turbine wheel. Turbine wheel spins shaft and compressor wheel. Compressor wheel then pressurizes air entering engine for more power output. (Mercedes Benz)

to Fig. 25-16.

As the gases pass through the turbine housing, they strike the fins or blades on the turbine wheel. When engine load is high enough, there is enough exhaust gas flow to rapidly spin the turbine wheel, Fig. 25-16.

Since the turbine wheel is connected to the compressor wheel by the turbo shaft, the compressor wheel rotates with the turbine. Compressor wheel rotation pulls air into the compressor housing. Centrifugal force throws the spinning air outward. This causes air to flow out of the turbocharger and into the engine cylinder under pressure.

Turbocharger location

A turbocharger is usually located on one side of the engine. See Fig. 25-17. An exhaust pipe connects the engine exhaust manifold to the turbine housing. The exhaust system header pipe connects to the outlet of the turbine housing.

A ***blow-through turbo system*** has the turbocharger located before the carburetor or throttle body. The turbo compressor wheel only pressurizes air. Fuel is mixed with the air after air leaves the compressor.

A ***draw-through turbo system*** locates the turbocharger after the carburetor or throttle body assembly. As a result, both air and fuel (gasoline engine) pass through the compressor housing.

Theoretically, the turbocharger should be located as close to the engine exhaust manifold as possible. Then, a maximum amount of exhaust heat will enter the

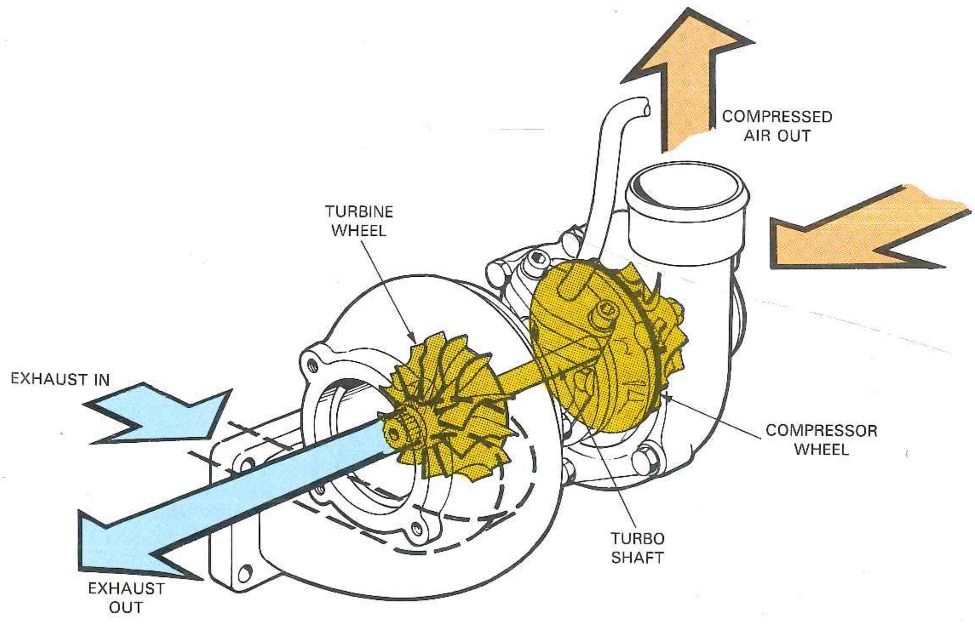


Fig. 25-16. Exhaust flow spins turbine wheel, shaft, and compressor wheel. Normally wasted energy in exhaust is used to increase compression stroke pressure in cylinders for more violent combustion. (Saab)

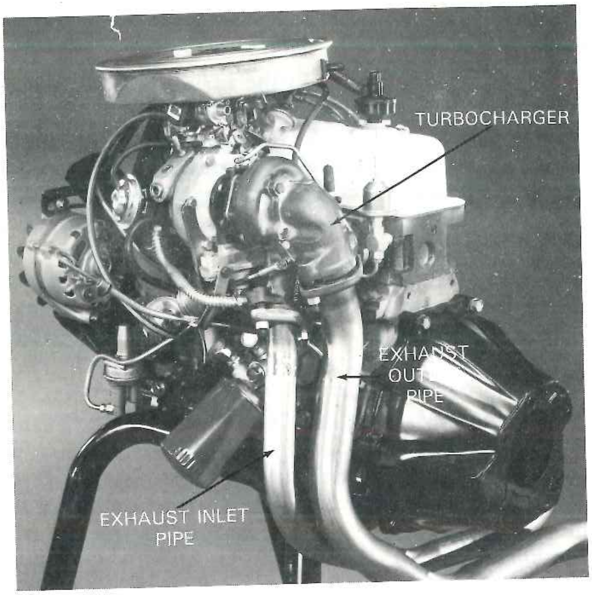


Fig. 25-17. Turbocharger normally bolts to one side of engine. Pipes route exhaust through turbine housing. Compressed air leaves turbo and enters intake tract and engine. (Ford)

turbine housing. When the hot gases move past the spinning turbine wheel, they are still expanding and help rotate the turbine.

Turbocharger lubrication

Turbocharger lubrication is needed to protect the turbo shaft and bearings from damage. A turbocharger can operate at speeds up to 100,000 rpm. For this reason, the engine lubrication system forces motor oil into the turbo shaft bearings. Look at Fig. 25-18.

Oil passages are provided in the turbo housing and bearings. An oil supply line runs from the engine to the turbo. With the engine running, oil enters the turbo under pressure. See Fig. 25-19.

Sealing rings (piston type rings) are placed around the turbo shaft, at each end of the turbo housing. See Fig. 25-18. They prevent oil leakage into the compressor and turbine housings.

A drain passage and drain line allow oil to return to the engine oil pan after passing through the turbo bearings.

Turbo lag

Turbo lag refers to a short delay before the turbo

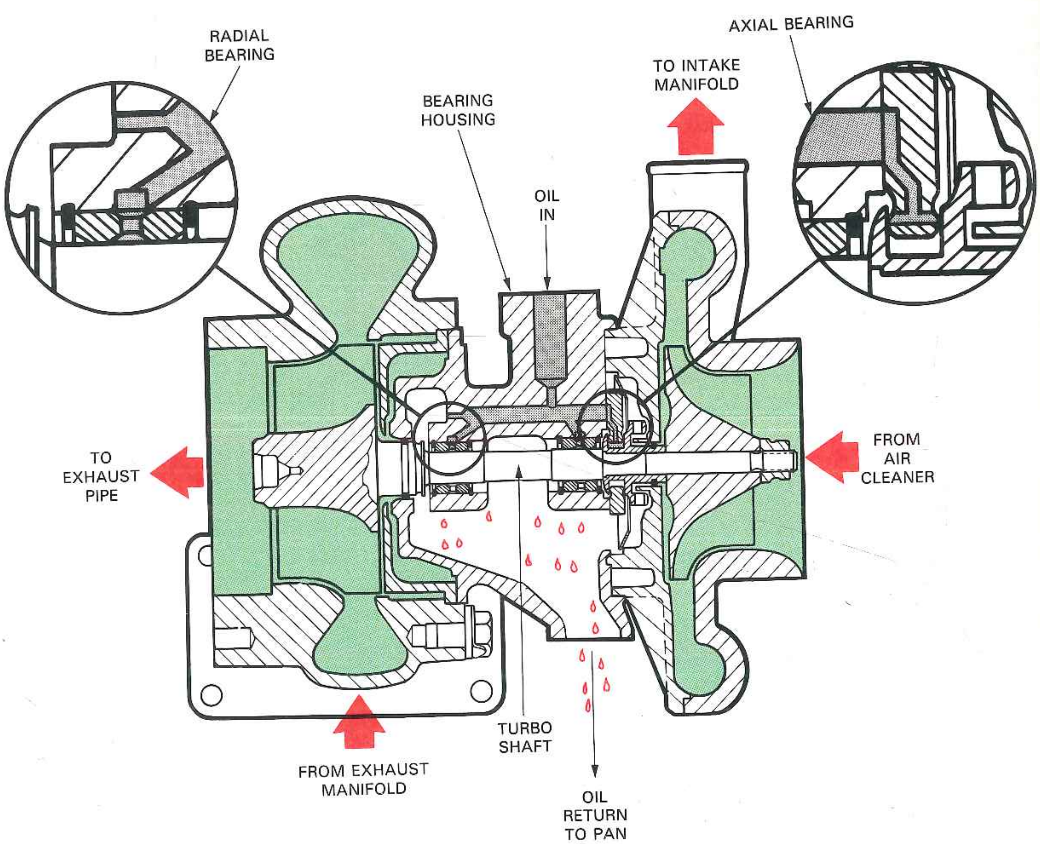


Fig. 25-18. High turbo speeds requires pressure lubrication. Engine oil is fed to turbo through oil line. Oil flows through bearings and then drains into oil pan through drain line. (Saab)

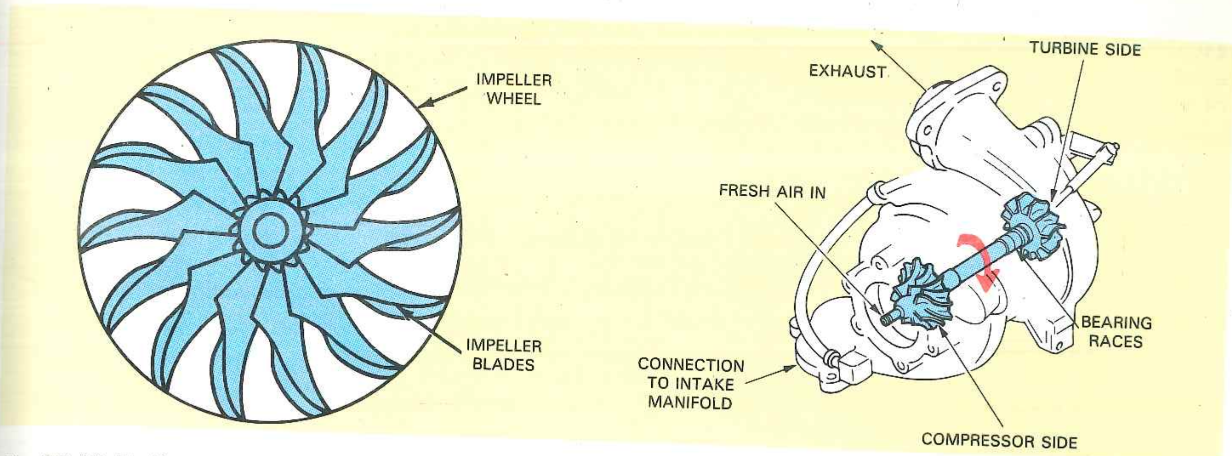


Fig. 25-19. Turbine and compressor wheels have specially shaped fins or blades that act as fans. Exhaust flow spins turbine fan. Spinning compressor fan blows air into engine under pressure. (Chrysler)

develops sufficient *boost* (pressure above atmospheric pressure).

When the car's accelerator pedal is pressed down for rapid acceleration, the engine may lack power for a few seconds. This is caused by the compressor and turbine wheels not spinning fast enough. It takes time for the exhaust gases to bring the turbo up to operating speed.

Modern turbo systems suffer very little from turbo lag. Their turbine and compressor wheels are very light so that they can accelerate up to rpm quickly.

Turbocharger intercooler

A *turbocharger intercooler* is an air-to-air heat

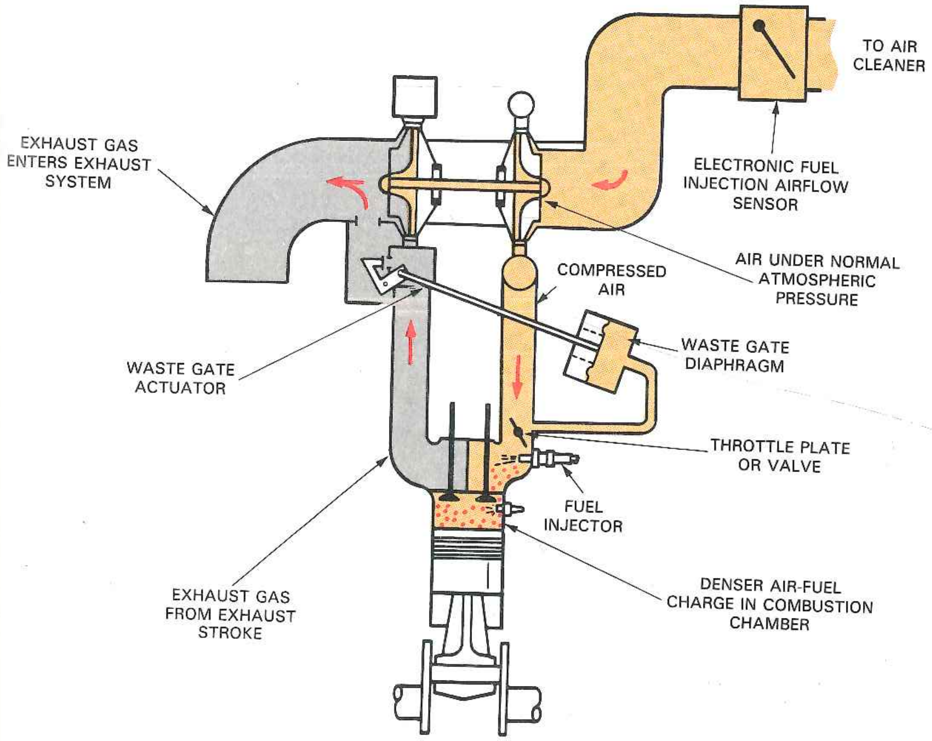


Fig. 25-20. Study basic exhaust and inlet airflow through complete turbo system. (Ford)

exchanger that cools the air entering the engine. It is a radiator-like device mounted at the pressure outlet of the turbocharger (or supercharger).

Outside air flows over and cools the fins and tubes of the intercooler. Then, when the air flows through the intercooler, heat is removed.

By cooling the air entering the engine, engine power is increased because the air is more dense (contains more oxygen by volume). Cooling also reduces the tendency for engine detonation.

WASTE GATE

A *waste gate* limits the maximum amount of boost pressure developed by the turbocharger. It is a butterfly or poppet type valve that allows exhaust to bypass the turbine wheel. See Fig. 25-20.

Without a waste gate, the turbo could produce too much pressure in the combustion chambers. This could lead to detonation (spontaneous combustion) and engine damage.

Basically, a waste gate is a valve operated by a diaphragm assembly, Fig. 25-21. Intake manifold pressure acts on the diaphragm to control waste gate valve action. The valve controls the opening and closing of a passage around the turbine housing, Fig. 25-22.

Waste gate operation

Fig. 25-23 illustrates the basic operation of a turbocharger waste gate. Under partial load, the system routes all of the exhaust gases through the turbine housing. The waste gate is closed by the diaphragm spring. This assures that there is adequate boost to increase engine power.

Under full load, boost may become high enough to overcome diaphragm spring pressure. Manifold pressure compresses the spring and opens the waste gate valve. This permits some of the exhaust gases to flow through the waste gate passage and into the exhaust system. Less exhaust is left to spin the turbine. Boost pressure is limited to a preset value.

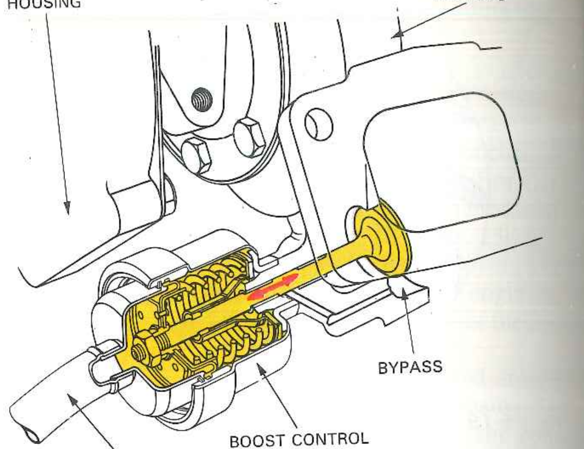


Fig. 25-22. Note hose that connects waste gate with compressor housing. When boost pressure is too high, pressure acts on waste gate diaphragm to open valve and reduce boost. (Garrett)

TURBOCHARGED ENGINE MODIFICATIONS

A turbocharged engine normally has several modifications to make it withstand the increased

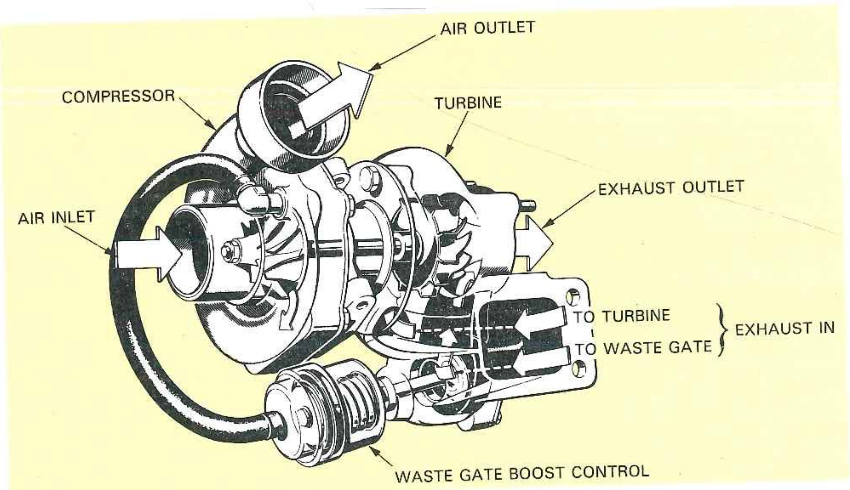


Fig. 25-21. Waste gate or boost control is a valve in turbine housing. When needed, it can open to limit boost pressure by reducing amount of exhaust acting on turbine wheel. (Mercedes Benz)

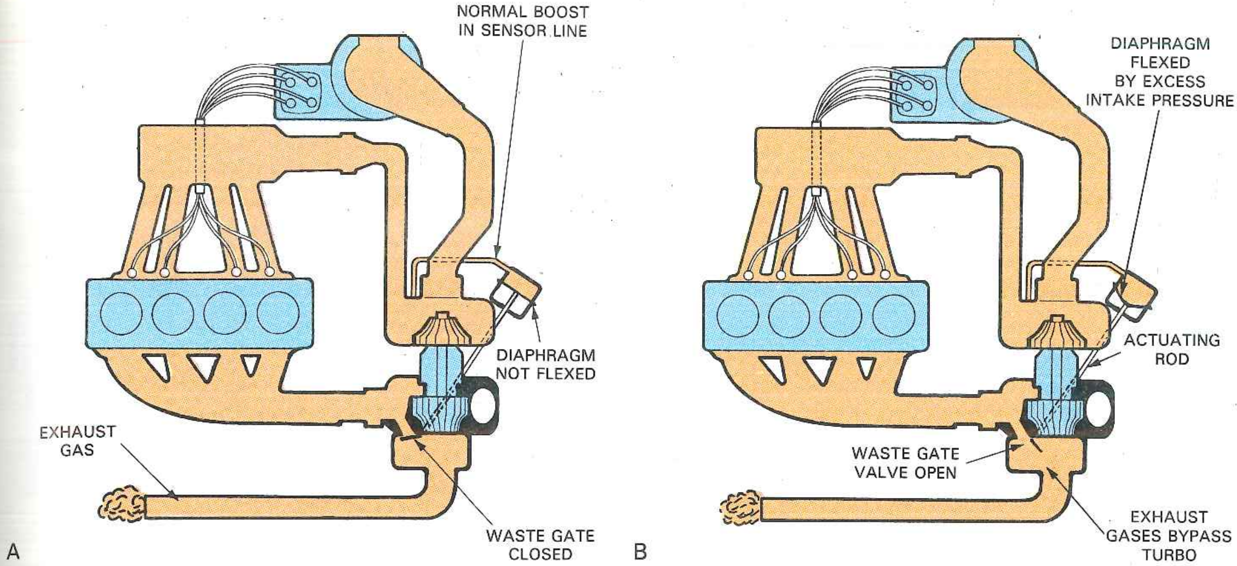


Fig. 25-23. Study operation of complete turbo system. A — Under part throttle, normal boost conditions, waste gate remains closed. All exhaust flow is directed over turbine wheel. B — Under full load, boost pressure may increase too much. High intake pressure deflects waste gate diaphragm to open waste gate valve. This allows some of the exhaust to bypass turbine wheel. Turbine wheel slows down and reduces boost pressure. (Saab)

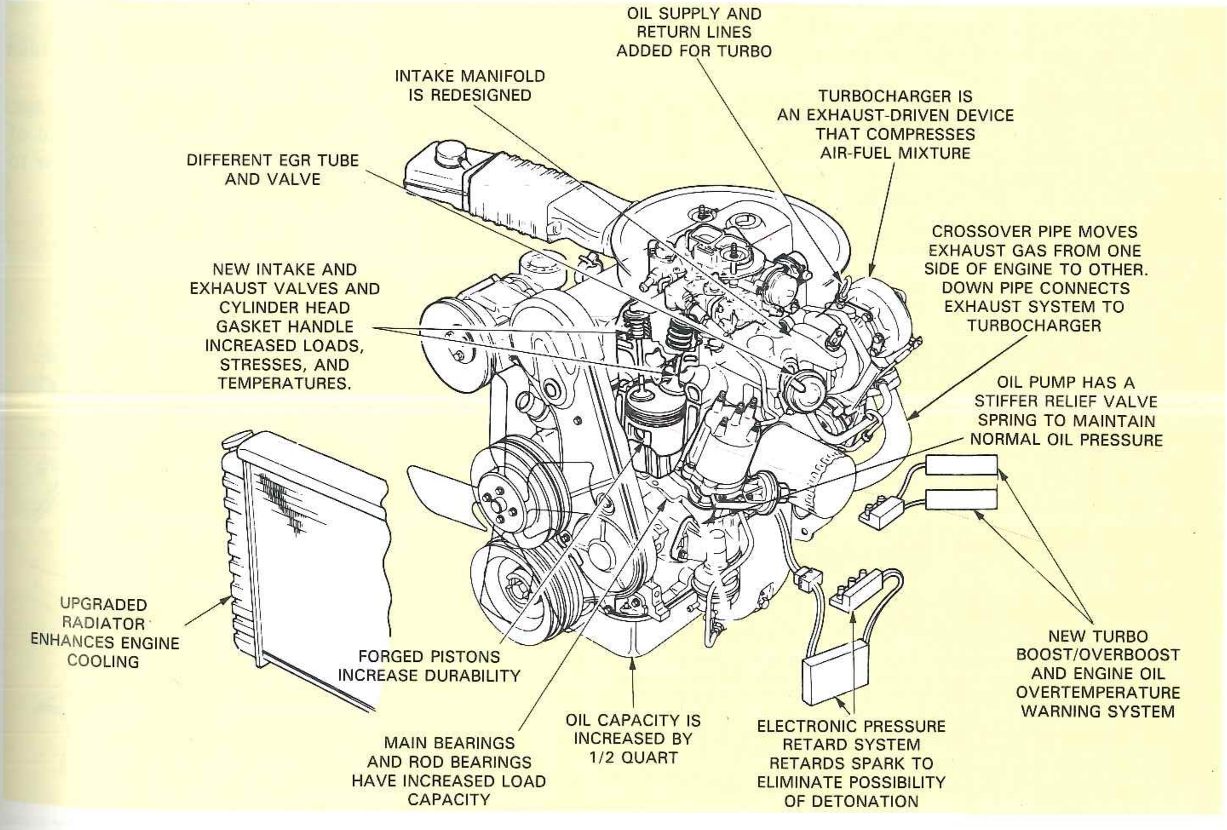


Fig. 25-24. Note many engine modifications commonly used with turbocharging. Turbocharging increases demands on engine. (Ford)

horsepower. A few of these are shown in Fig. 25-24 and include:

1. Lower compression ratio.
2. Stronger rods, pistons, and crankshaft.
3. Higher volume oil pump and an oil cooler.
4. Larger cooling system radiator.
5. O-ring type head gasket.
6. Heat resistant valves.
7. Knock sensor (ignition retard system).

KNOCK SENSOR

A *knock sensor* is used to retard ignition timing if the engine begins to knock (detonate or ping). The sensor is mounted on the engine. It works something like a microphone. When it "hears" a knocking sound, an electrical signal is sent to the on-board computer. The computer then retards the timing until the knock stops.

A knock sensor helps the computer keep the ignition timing advanced as much as possible. This improves engine power and gas mileage. It also protects the engine from detonation damage.

TURBOCHARGING SYSTEM SERVICE

Turbocharging system problems usually show up as inadequate boost pressure (lack of engine power), leaking shaft seals (oil consumption), damaged turbine or compressor wheels (vibration and noise), or excess boost (detonation).

Refer to a factory service manual for a detailed troubleshooting chart if needed. It will list the common troubles for the particular turbo system.

To protect a turbocharger from damage, most auto makers recommend that the oil in a turbocharged engine be changed more frequently (about every 3000 miles or 4 827 km). The turbo bearings and shaft, because of the high rotating speeds, are very sensitive to oil contaminants. Engine oil must be kept clean to assure long turbocharger life.

Checking turbocharging system

There are several checks that can be made to determine turbocharging system condition. These include:

1. Check connection of all vacuum lines to waste gate and oil lines to turbo, Fig. 25-25.
2. Use a regulated, low pressure air hose to check for waste gate diaphragm leakage and operation.
3. Use the dash gauge or a test gauge to measure boost pressure (pressure developed by turbo under a load). If needed, connect the pressure gauge to an intake manifold fitting. Compare to specs.
4. Use a stethoscope to listen for bad turbocharger bearings.

Checking turbocharger

To check the internal condition of a turbo, remove the unit from the engine, as in Fig. 25-26. Unbolt the connections at the turbo. Remove the oil lines and take the unit to your workbench.

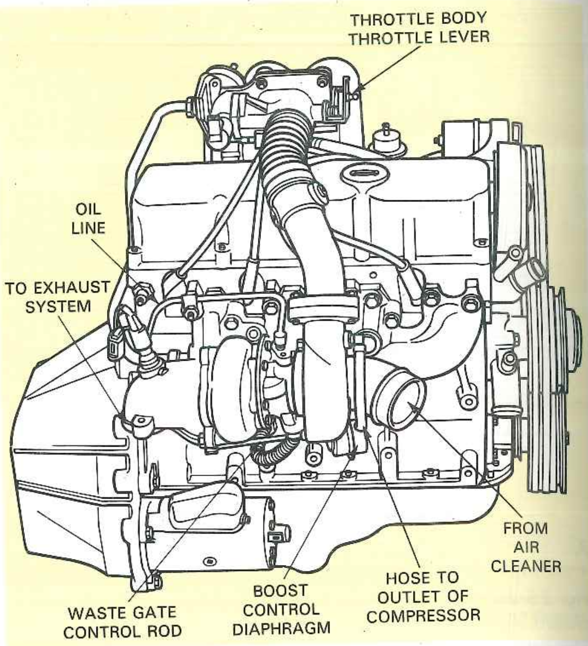


Fig. 25-25. Side view of engine shows location and mounting of turbocharger. (Ford)

Inspect the turbocharger wheels for physical damage. The slightest knick or dent will throw the unit out of balance, causing vibration. Fig. 25-27 shows how to measure turbo bearing and shaft wear.

WARNING! Never use a hard metal object or sandpaper to remove carbon deposits from the turbine

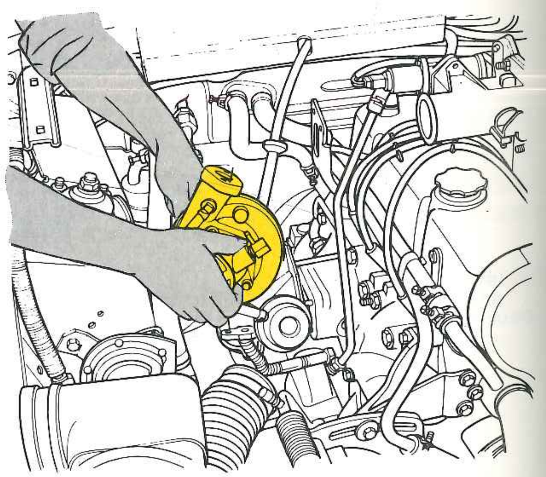


Fig. 25-26. After removing mounting fasteners and any other parts, turbo can be lifted off for replacement. A turbo cannot be repaired in-shop. A new unit is normally installed. (Ford)

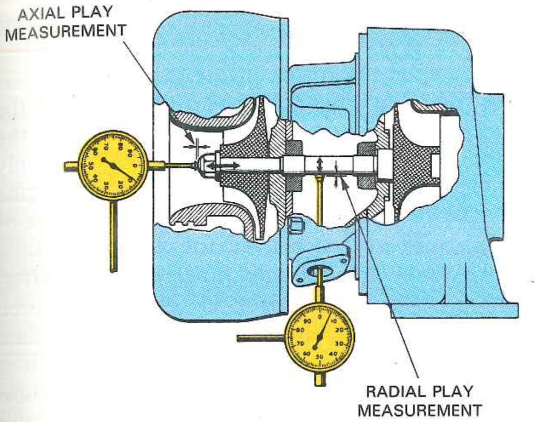


Fig. 25-27. Dial indicator can be used to check radial and axial play of turbo shaft. If not within specs, replace unit. (Waukesha)

wheel. If you gouge or remove metal, the wheel can vibrate and destroy the turbo. Only use a soft wire brush and solvent to clean the turbo wheels.

Installing new turbocharger

Many turbocharger problems are NOT repaired in the field, Fig. 25-28. Most mechanics install a new or rebuilt unit. When installing a turbo, you should:

1. Make sure the new turbo is the correct type. Compare part numbers.
2. Use new gaskets and seals.
3. Torque all fasteners to specs.
4. If needed, change engine oil and flush oil lines before starting engine.
5. If the failure was oil related, check oil supply pressure in feed line to turbo.

Waste gate service

An *inoperative waste gate* can either cause too much or too little boost pressure. If stuck open, the turbo will not produce boost pressure and the engine will lack power. If stuck closed, detonation and engine damage can result from excessive boost.

Before condemning the waste gate, always check other parts. Check the knock sensor (spark retard system if used) and the ignition timing. Make sure the vacuum-pressure lines are all connected properly.

Follow service manual instructions when testing or replacing a waste gate. As shown in Fig. 25-29, waste gate removal is simple. Unbolt the fasteners. Remove the lines and lift the unit off of the engine. Many manuals recommend waste gate replacement, rather than in-shop repairs.

Figs. 25-30 and 25-31 show turbocharged engines. Can you identify all of the parts. Trace flow of fuel charge into and exhaust out of engine.

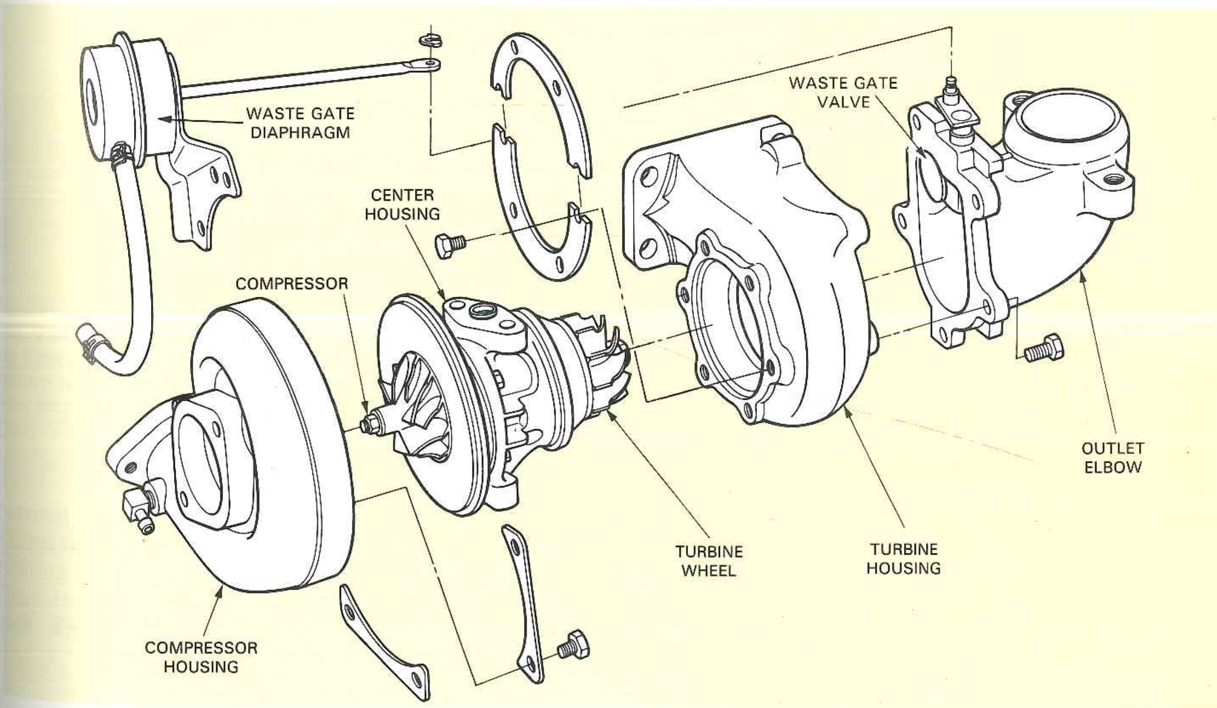


Fig. 25-28. Exploded view of modern turbocharger. Only external parts are servicable. Turbine-compressor wheel is very precise, balanced assembly. Slightest nick or chip on blade can cause unit to explode in service. (Ford)

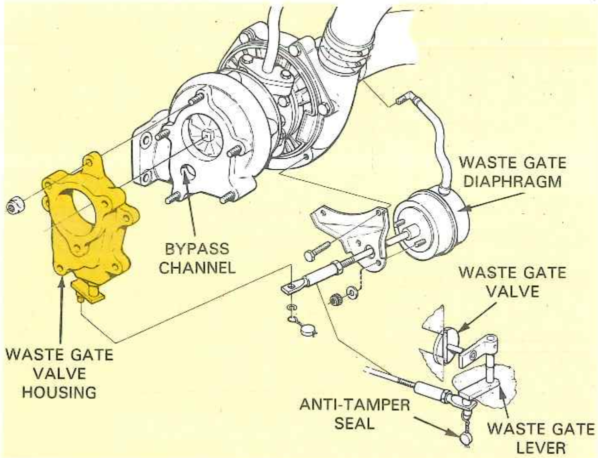


Fig. 25-29. Waste gate normally bolts to side of turbo housing. Linkage rod connects diaphragm with valve mechanism. Also note seal that prevents tampering with boost setting. Although overboost will increase power, it can also cause engine damage. (Saab)

SUPERCHARGERS

A supercharger is a compressor or blower driven by a belt, chain, or gears. Unlike a turbocharger, it is NOT driven by engine exhaust gases. Most passenger car superchargers are driven by a belt on the front of the engine. See Fig. 25-32.

The belt drives the rotors inside the supercharger. As the rotors turn, they compress the air inside the housing and force the air, under pressure, into the engine intake manifold. An intercooler is commonly used between the supercharger outlet and the engine to cool the air and to increase power (cool charge of air carries more oxygen needed for combustion).

Superchargers have the advantage of NOT suffering from turbo lag and the delay in power as the turbo gains speed. A supercharger will instantly produce boost pressure at low engine speeds because it is mechanically linked to the engine crankshaft. This low-speed power and instant throttle response is desirable in a passenger car for passing, entering high-speed interstate highways, etc.

Fig. 25-33 shows the major parts included in a supercharger system.

KNOW THESE TERMS

Exhaust manifold, Header pipe, Catalytic converter, Muffler, Tailpipe, Hangers, Heat shields, Muffler clamps, Back pressure, Crossover pipe, Exhaust manifold heat valve, Rust penetrant, Air chisel, Pipe expander, Pipe shaper, Supercharger, Turbocharger,

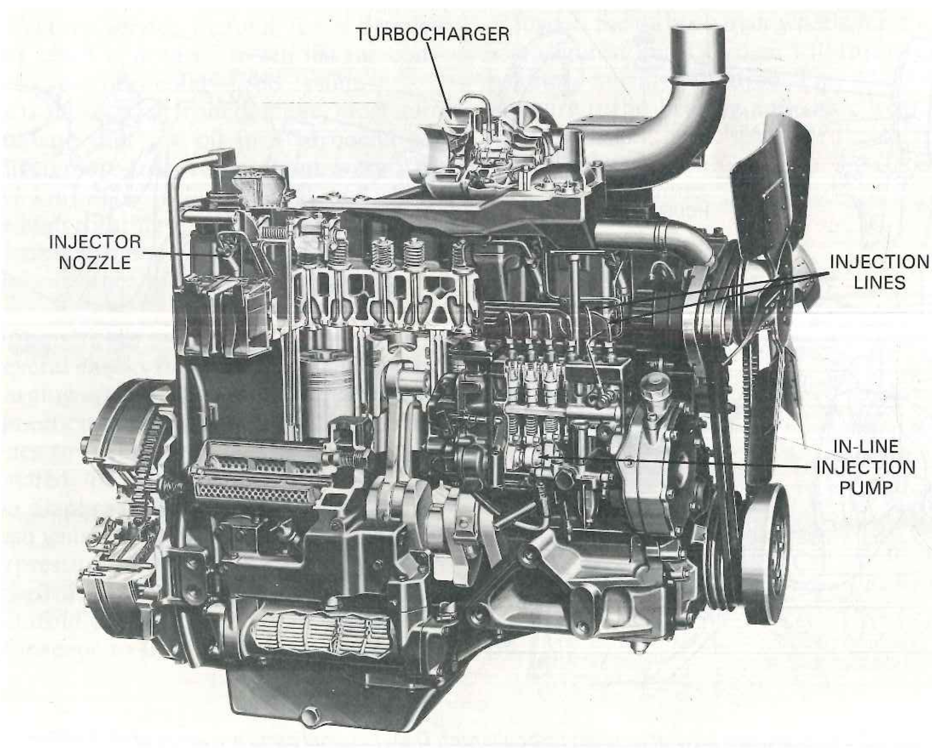


Fig. 25-30. How many parts of this turbocharged diesel engine can you identify? (Deere & Co.)

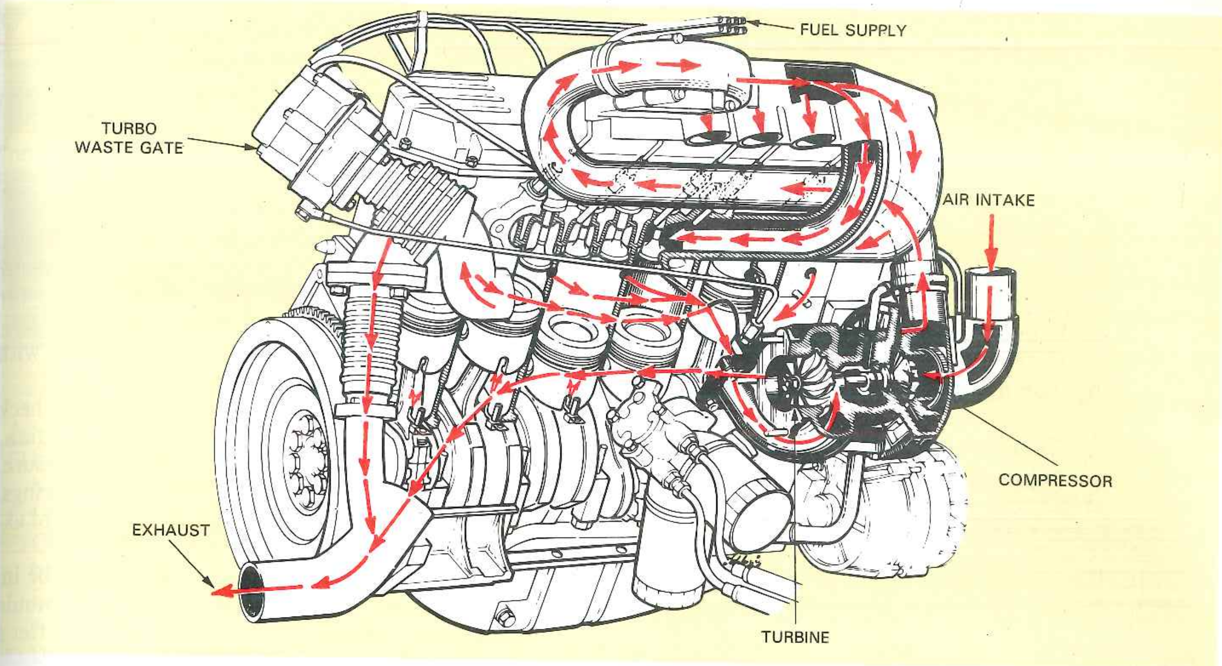


Fig. 25-31. This is a turbocharged, in-line, six-cylinder engine. (Audi)

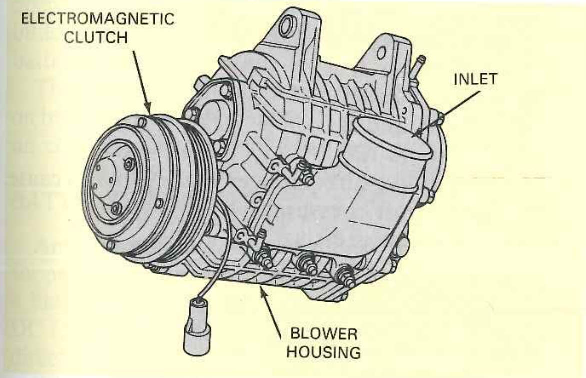


Fig. 25-32. Supercharger is normally driven by belt running up from engine crankshaft. Electric clutch can be used to turn blower on and off as needed. For example, blower might only kick on at full throttle when there is demand for more engine power. (Toyota)

Normal aspiration, Turbine wheel, Turbine housing, Turbo shaft, Compressor wheel, Compressor housing, Bearing housing, Turbo bearing, Blow-through turbo, Draw-through turbo, Sealing rings, Turbo lag, Waste gate, Knock sensor, Boost pressure.

REVIEW QUESTIONS

1. An exhaust system __________ engine operation and carries __________ __________ to the rear of the car.

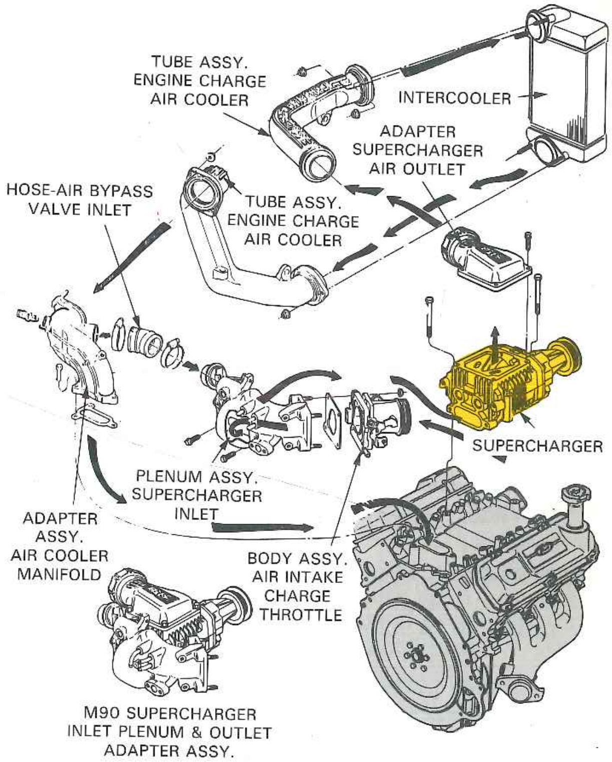


Fig. 25-33. Note basic components in a supercharging system. This supercharger bolts to top of engine. Trace flow of air through components. (Ford Motor Co.)

Match the following exhaust system parts with their definition. (Do not write in text.)

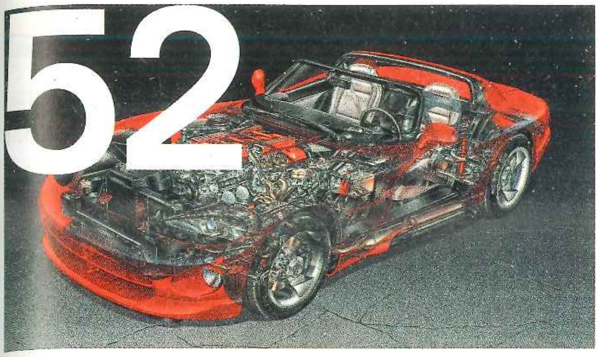
____ 2. Heat shield.
____ 3. Catalytic converter.
____ 4. Intermediate pipe.
____ 5. Hangers.
____ 6. Header pipe.
____ 7. Tailpipe.
____ 8. Muffler clamp.
____ 9. Exhaust manifold.
____ 10. Muffler.

a. U-bolt for connecting parts of exhaust system.
b. Tubing that connects exhaust manifold to rest of system.
c. Chamber for damping out pressure pulsations.
d. Carries exhaust from muffler to rear of car body.
e. Connects cylinder head exhaust ports to header pipe.
f. Prevents heat from transfering into other objects.
g. Connects exhaust manifold to tailpipe.
h. Device for removing pollutants from exhaust.
i. Pipe between catalytic converter and muffler.
j. Connects exhaust system to underside of car body.

11. Define the term "exhaust back pressure."
12. A dual exhaust system is commonly used on small, high fuel economy engines. True or False?
13. An exhaust __________ __________ __________ forces hot exhaust gases to flow into the intake manifold to aid cold weather starting.
14. When is exhaust system service commonly needed?
15. List fourteen rules to remember when servicing an exhaust system.
16. A ______________ is an air pump that increases engine power by pushing a denser air-fuel charge into the combustion chambers.
17. What is a normally aspirated engine?
18. Which of the following is NOT a type of supercharger?
    a. Vane.
    b. Gear.
    c. Rotor.
    d. Centrifugal.
19. Explain the term "Turbocharger."
20. In the field, the term "supercharger" generally refers to a blower driven by a __________, __________ or __________ .
21. List and explain the six basic parts of a turbocharger.
22. A ____________ turbocharger has the turbo located before the carburetor or throttle body.
23. A turbocharger can operate at speeds up to ________ rpm.
24. __________ __________ refers to the short delay before the turbo develops sufficient __________ (pressure above atmospheric pressure).
25. A waste gate limits the minimum amount of boost produced by the turbocharger. True or False?
26. What could happen if a waste gate did not open?
27. List seven engine modifications commonly found on a turbocharged engine.
28. Which of the following is NOT a recommended practice when servicing a turbocharging system?
    a. Inspect vacuum and oil lines to turbo and waste gate.
    b. Remove carbon from turbo compressor with gasket scraper.
    c. Use regulated, low pressure air hose to check waste gate diaphragm leakage and operation.
    d. Use pressure gauge to measure boost pressure.
    e. Use stethoscope to listen for bad turbo bearings.
29. A turbocharger was badly damaged because of excess bearing and shaft wear.
    Technician A says that a new unit should be installed and that oil pressure to the turbo should be checked. Engine oil should be changed after a short break-in period.
    Technician B says that the oil should be drained and all lines should be flushed before installing the new turbo. Oil pressure to the unit should also be checked.
    Who is correct?
    a. Technician A
    b. Technician B
    c. Both A and B
    d. Neither A nor B
30. An inoperative turbocharger waste gate can cause:
    a. High boost pressure.
    b. Low boost pressure.
    c. Low engine power.
    d. Detonation.
    e. All of the above are correct.

ACTIVITIES FOR CHAPTER 25

1. Research the internal combustion process and produce a cutaway sketch of an exhaust system. Use it to explain why high backpressure will reduce engine power.
2. Using knowledge of atmospheric pressure, demonstrate to the shop class why a turbocharger or a supercharger will increase engine power.
3. Collect literature from dealerships on turbocharged and nonturbocharged engines. Develop a table of horsepower-to-displacement ratios. (This can be done by dividing the rated horsepower by the number of cubic inches or liters of displacement for each engine.) Draw up a report of your findings and present them to the class as an outside assignment.



Manual Transmission Fundamentals

After studying this chapter, you will be able to:
- □ Describe gear operating principles.
- □ Identify and define all of the major parts of a transmission.
- □ Explain the fundamental operation of a manual transmission.
- □ Trace the power flow through transmission gears.
- □ Compare the construction of different types of manual transmissions.
- □ Explain the purpose and operation of a transmission overdrive ratio.

A ***manual transmission*** must be shifted by hand. It is normally bolted to the clutch housing at the rear of the engine. See Fig. 52-1. The clutch disc rotates the transmission input shaft. Gears inside the transmission transfer engine power to the drive shaft and rear wheels. A column or floor shift lever allows the driver to select which set of transmission gears to engage.

A manual transmission should not be confused with an automatic transmission or automatic transaxle. It is normally used in a front engine, rear-wheel or front-wheel drive vehicle. A foot-operated friction clutch is

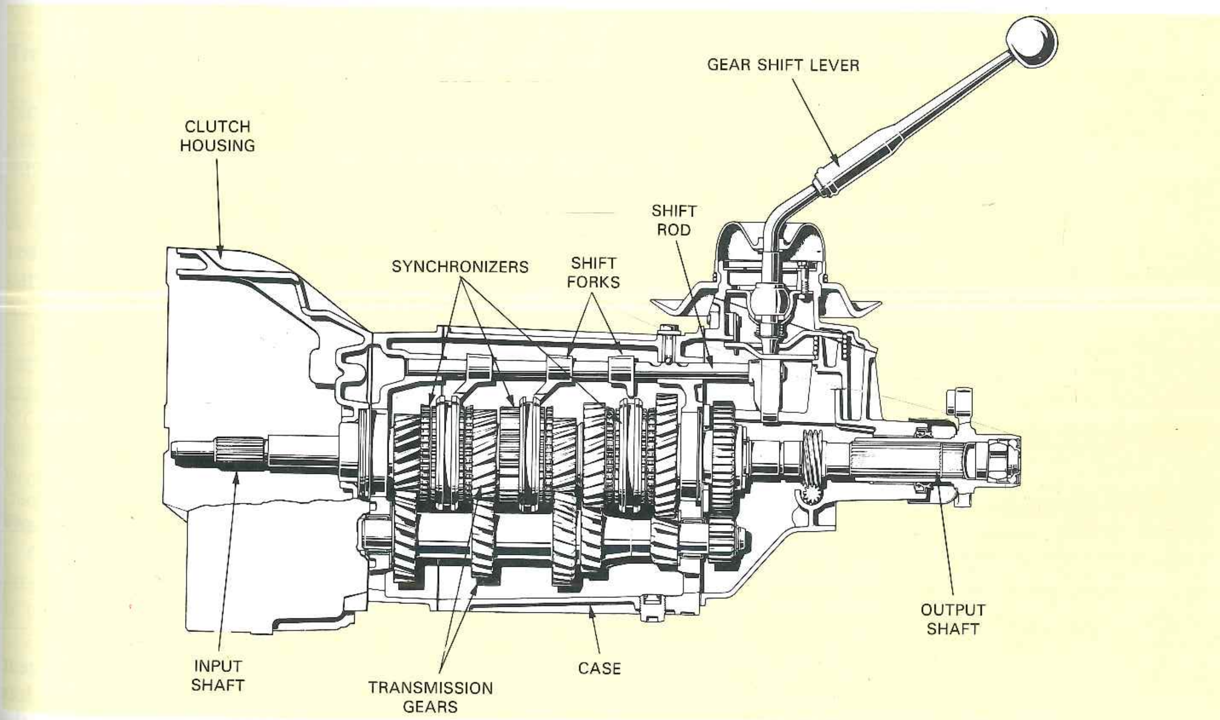


Fig. 52-1. Study basic names and locations of manual transmission parts. This will help you as you learn about each part in more detail. (Fiat)

needed to disengage the engine.

An automatic transmission, covered in Chapters 54 and 55, uses hydraulic pressure and sensing devices to shift gears. It detects engine speed and load to determine shift points. An automatic transmission also uses a fluid coupling instead of a dry friction clutch.

A transaxle combines both the transmission and the differential into a single housing. It is commonly used with front-wheel drive vehicles. A transaxle can contain either a manual or automatic transmission. Transaxles are covered in Chapters 60 and 61.

BASIC TRANSMISSION PARTS

To understand later sections of the chapter, study the parts of the transmission in Fig. 52-1. Learn to identify and locate the fundamental components. This knowledge will prepare you for more specific details of transmission construction and operation.

1. TRANSMISSION INPUT SHAFT (shaft, operated by clutch, that turns gears inside transmission).
2. TRANSMISSION GEARS (provide a means of changing output torque and speed leaving transmission).
3. SYNCHRONIZERS (devices for meshing or locking gears into engagement).
4. SHIFT FORKS (pronged units for moving gears or synchronizers on their shaft for gear engagement).
5. SHIFT LINKAGE (arms or rods that connect driver's shift lever to shift forks).
6. GEAR SHIFT LEVER (lever allowing driver to change transmission gears).
7. OUTPUT SHAFT (shaft that transfers rotating power out of transmission to drive shaft).
8. TRANSMISSION CASE (housing that encloses transmission shafts, gears, and lubricating oil).

PURPOSE OF A MANUAL TRANSMISSION

A *manual transmission* is designed to change the vehicle's drive wheel speed and torque in relation to engine speed and torque. Without a transmission, the engine would not develop enough power to accelerate from a standstill. The engine would stall or lug as soon as the clutch was engaged.

With a transmission in low or first gear, the engine crankshaft has to turn several times to make the drive shaft and wheels turn once. This increases the torque going to the wheels, but reduces vehicle speed.

Then, as the transmission is shifted through the gears and into high, the engine and drive shaft begin to turn at approximately the same speed. Wheel and vehicle speed increases, while engine speed drops.

A manual transmission in proper operating condition should:

1. Be able to increase torque going to the drive wheels for quick acceleration.
2. Supply different gear ratios to match different engine load conditions.
3. Have a reverse gear for moving backwards.
4. Provide the driver with an easy means of shifting transmission gears.
5. Operate quietly, with minimum power loss.

GEAR FUNDAMENTALS

Gears are round wheels with teeth machined on their perimeter (rim). They are commonly used to transmit turning effort from one shaft to another. Basically, one size gear is used to turn another size gear to change output speed and torque (turning power). This is illustrated in Fig. 52-2.

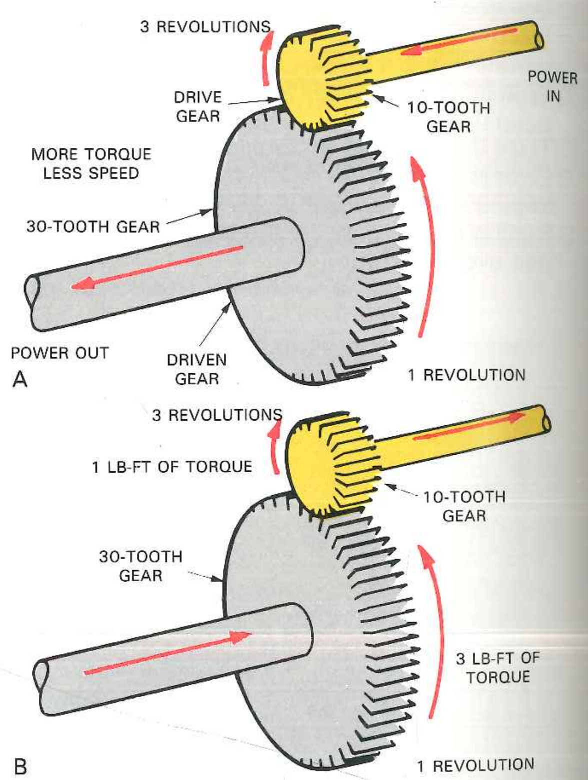


Fig. 52-2. A — When a small gear drives a larger gear, it increases torque output but reduces rotating speed of output. B — When a larger gear drives a smaller gear, torque is reduced but rotating speed increases at output.

Gear ratios

A *gear ratio* is the number of turns a driving gear must turn before the driven gear turns one complete revolution. Gear ratio is calculated by dividing the number teeth on the driven gear by the number of teeth on the driving gear.

For example, look at Fig. 52-3. If the drive gear has 12 teeth and the driven gear 24 teeth (24 divided by 12), the gear ratio would be TWO TO ONE, written 2:1.

In this example, the drive gear would have to revolve two times to turn the other gear once. As a result, the speed of the larger, driven gear would be half as fast as the drive gear. However, the torque on the shaft of the larger gear would be twice that of the input shaft.

Various sizes of drive and driven gears can be used to produce any number of gear ratios. As the number of teeth on the driven gear increase in relation to the number of teeth on the drive gear, the gear ratio increases. A gear ratio of 10:1 would be larger than a ratio of 5:1, for example.

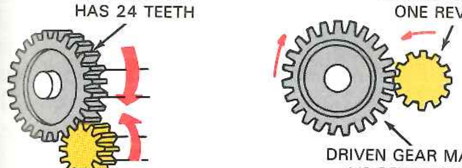


Fig. 52-3. Gear ratio is determined by number of teeth on drive and driven gears. If drive gear has half as many teeth as driven gear, a two to one ratio would be produced. (Deere & Co.)

Transmission gear ratios

Transmission gear ratios vary with the manufacturer. However, approximate gear ratios average 3:1 for first gear, 2:1 for second gear, 1:1 for third or high gear, and 3:1 for reverse gear.

In first or low gear, there would be a high gear ratio. A small gear would drive a larger gear This would reduce output speed but increase output torque. The car would accelerate easily, even with low engine rpm and low power conditions.

In high gear, the transmission frequently has a 1:1 ratio. The transmission output shaft would spin at the same speed as the engine crankshaft. There would be NO torque *multiplication* (increase), but the vehicle would travel faster. Very little torque is needed to propel a vehicle at a constant speed on level ground.

Gear reduction and overdrive

Gear reduction occurs when a small gear drives a larger gear to increase turning force. Gear reduction is used in the lower transmission gears, Fig. 52-2.

An ***overdrive ratio*** results when a larger gear drives a smaller gear. As shown in Fig. 52-2, the speed of the output gear increases, but torque drops.

Gear types

Manual transmissions commonly use two types of gears: spur gears and helical gears.

Spur gears have their teeth cut parallel to the centerline of the gear shaft. As shown in Fig. 52-4A, they are sometimes called straight-cut gears.

Spur gears are somewhat noisy and are no longer used as the main drive gears in a transmission. They may be used for the sliding reverse gear, however.

Helical gears have their teeth machined at an angle to the centerline of gear rotation. Modern transmissions commonly use helical gears as the main drive gears. See Fig. 52-4B. Helical gears are quieter and stronger than spur gears.

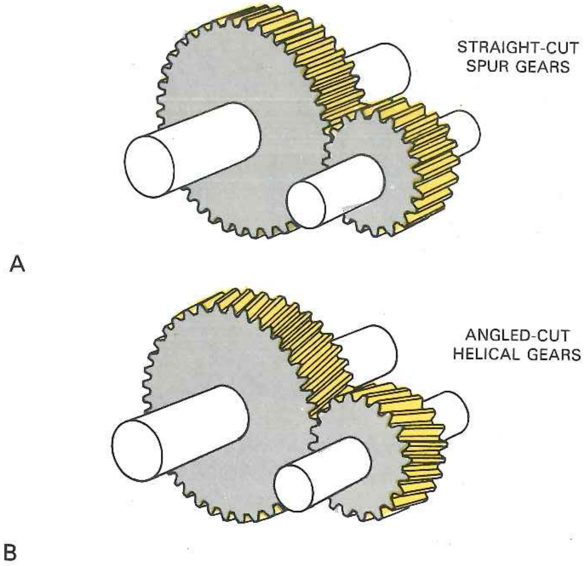


Fig. 52-4. Two basic types of gears used in manual transmissions are straight-cut spur gears and angled-cut helical gears. (Deere & Co.)

Gear backlash

Gear backlash is the small clearance between the meshing gear teeth. Clearance allows lubricating oil to enter the high friction area between the gear teeth. This reduces friction and wear. Backlash also allows the gears to heat up and expand during operation without binding or being damaged.

MANUAL TRANSMISSION LUBRICATION

The bearings, shafts, gears, and other moving parts in a transmission are lubricated by oil throw-off or *splash*. As the gears rotate, they sling oil around inside the transmission case.

Typically, 80 or 90W ***gear oil*** is recommended for use in a manual transmission. However, follow manufacturer's recommendations.

TRANSMISSION BEARINGS

Manual transmissions normally use three basic types of bearings: ball bearings, roller bearings, and needle bearings. These three types are shown in Fig. 52-5. Bearings are used to reduce the friction between the surfaces of rotating parts in the transmission.

The bearings are lubricated by oil spray from the spinning transmission gears. Typically, *antifriction bearings* (bearing using a rolling action) fit between the transmission shafts and housing or between some of the gears and shafts. These are high friction points that must be capable of withstanding the engine's power.

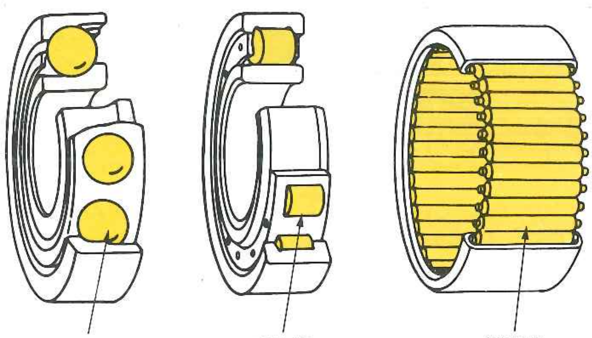


Fig. 52-5. Three types of antifriction bearings found in transmissions: ball, roller, and needle. (Deere & Co.)

MANUAL TRANSMISSION CONSTRUCTION

Now that you have a general grasp of gear and transmission principles, we will assemble each part of a working transmission. We will start out with the case, then install the shafts, gears, bearings, and other parts.

Transmission case

The *transmission case* must support the transmission bearings and shafts and provide an enclosure for gear oil. Refer to Fig. 52-6. A manual transmission case is usually cast of either iron or aluminum. Aluminum is becoming more common because of its lightness.

A drain plug and a fill plug are usually provided in the transmission case. The drain plug is on the bottom of the case. The fill plug is on the side of the case.

The fill plug also serves as a means of checking the oil level in the transmission. Typically, the oil should be level with the fill plug when the transmission is at operating temperature.

Extension housing and front bearing hub

The *extension housing,* also called the *tailshaft housing,* bolts to the rear of the transmission case. It encloses the transmission output shaft and holds the rear oil seal. See Fig. 52-6.

A flange on the bottom of the extension housing provides a base for the rubber transmission mount, also called rear motor mount. A gasket usually seals the mating surfaces between the transmission case and extension housing.

A *front bearing hub,* sometimes called *front bearing cap,* covers the front transmission bearing and acts as a sleeve for the clutch throw-out bearing. It bolts to the transmission case. A gasket fits between the front hub and case to prevent oil leakage.

Transmission shafts

Basically, a manual transmission has four steel shafts mounted inside its case. It normally has an input shaft, countershaft, reverse idler shaft, and an output shaft. Figs. 52-7 and 52-8 show the general location and shape of these shafts.

The ***input shaft,*** often termed *clutch shaft,* transfers rotation from the clutch disc to the countershaft gears in the transmission. The outer end of the shaft is

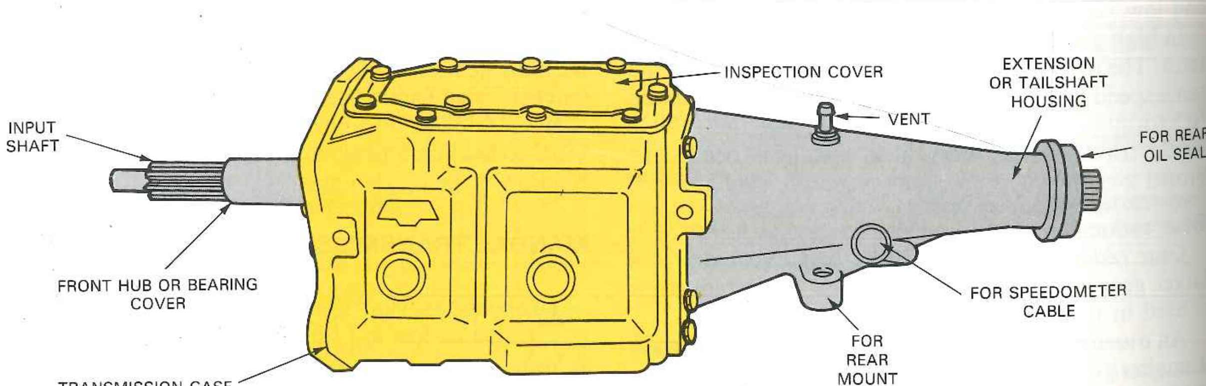


Fig. 52-6. Case is center section of transmission. Extension housing bolts to rear of case. Front bearing cover bolts to front of case. It encloses front output shaft bearing and supports clutch throw-out bearing. This transmission also has a sheet metal inspection cover bolted to top of case. (GMC)

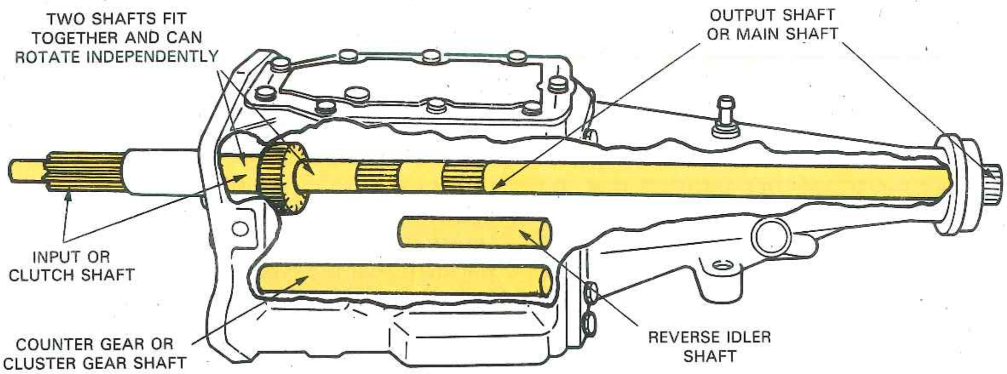
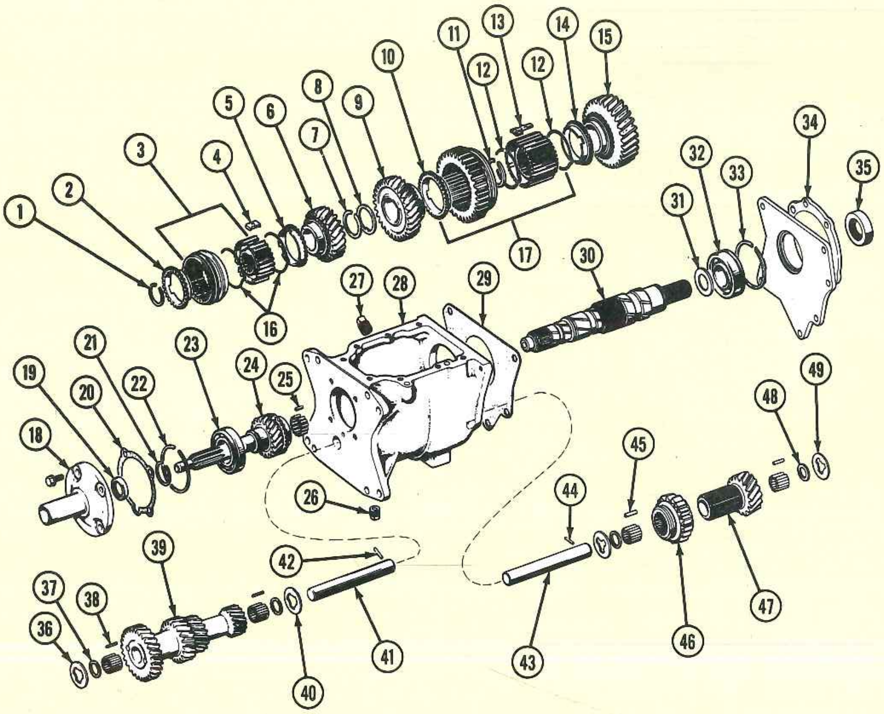


Fig. 52-7. Note how transmission shafts are located in transmission case. Input shaft is driven by clutch. Output shaft is on same centerline as input shaft. Countershaft and reverse idler shafts mount below and to one side in case.



1. 3rd-4th GEAR SNAP RING
2. 4th GEAR SYNCHRONIZER RING
3. 3rd-4th GEAR CLUTCH ASSEMBLY
4. 3rd-4th GEAR PLATE
5. 3rd GEAR SYNCHRONIZER RING
6. 3rd SPEED GEAR
7. 2nd GEAR SNAP RING
8. 2nd GEAR THRUST WASHER
9. 2nd SPEED GEAR
10. 2nd GEAR SYNCHRONIZER RING
11. MAIN SHAFT SNAP RING
12. 1st-2nd SYNCHRONIZER SPRING
13. LOW-2nd PLATE
14. 1st GEAR SYNCHRONIZER RING
15. 1st GEAR
16. 3rd-4th SYNCHRONIZER SPRING
17. 1st-2nd GEAR CLUTCH ASSEMBLY
18. FRONT BEARING CAP
19. OIL SEAL
20. GASKET
21. SNAP RING
22. LOCK RING
23. FRONT BALL BEARING
24. CLUTCH SHAFT
25. ROLLER BEARING
26. DRAIN PLUG
27. FILL PLUG
28. CASE
29. GASKET
30. SPLINE SHAFT
31. 1st GEAR THRUST WASHER
32. REAR BALL BEARING
33. SNAP RING
34. ADAPTER PLATE
35. ADAPTER SEAL
36. FRONT COUNTERSHAFT GEAR THRUST WASHER
37. ROLLER WASHER
38. REAR ROLLER BEARING
39. COUNTERSHAFT GEAR
40. REAR COUNTERSHAFT THRUST WASHER
41. COUNTERSHAFT
42. PIN
43. IDLER GEAR SHAFT
44. PIN
45. IDLER GEAR ROLLER BEARING
46. REVERSE IDLER SLIDING GEAR
47. REVERSE IDLER GEAR
48. IDLER GEAR WASHER
49. IDLER GEAR THRUST WASHER

Fig. 52-8. Exploded view shows major parts of typical transmission. Note four shafts and components. (Chrysler) splined. The inner end of the shaft has a gear machined on it. See Fig. 52-8.

A bearing in the transmission case supports the input shaft in the case. Anytime the clutch disc turns, the input shaft gear and gears on the countershaft turn.

The ***countershaft,*** also called *cluster gear shaft,* holds the countershaft gear into mesh with the input gear and other gears in the transmission. It is located slightly below and to one side of the clutch shaft, Fig. 52-9.

Normally, the countershaft does NOT turn in the transmission case. It is locked in the case by either a steel pin, force fit, or locknuts. Refer to Fig. 52-8.

The ***reverse idler shaft*** is a short shaft that supports the reverse idler gear, Fig. 52-8. It normally mounts stationary in the case about midway between the countershaft and output shaft. See Fig. 52-7. Then, the reverse idler gear can mesh with gears on both the countershaft and output shaft.

The transmission ***output shaft,*** also called *main shaft,* holds the output gears and synchronizers. See Fig. 52-8. The rear of this shaft extends to the back of the extension housing. It connects to the drive shaft to turn the rear wheels of the vehicle.

The output shaft is splined in the center. In modern transmissions, the gears are free to revolve on the output shaft, but the synchronizers are locked on the shaft by splines. The synchronizers will only turn when the shaft itself turns.

TRANSMISSION GEARS

Transmission gears can be typically classified into four groups: input shaft gear, countershaft gears, out-

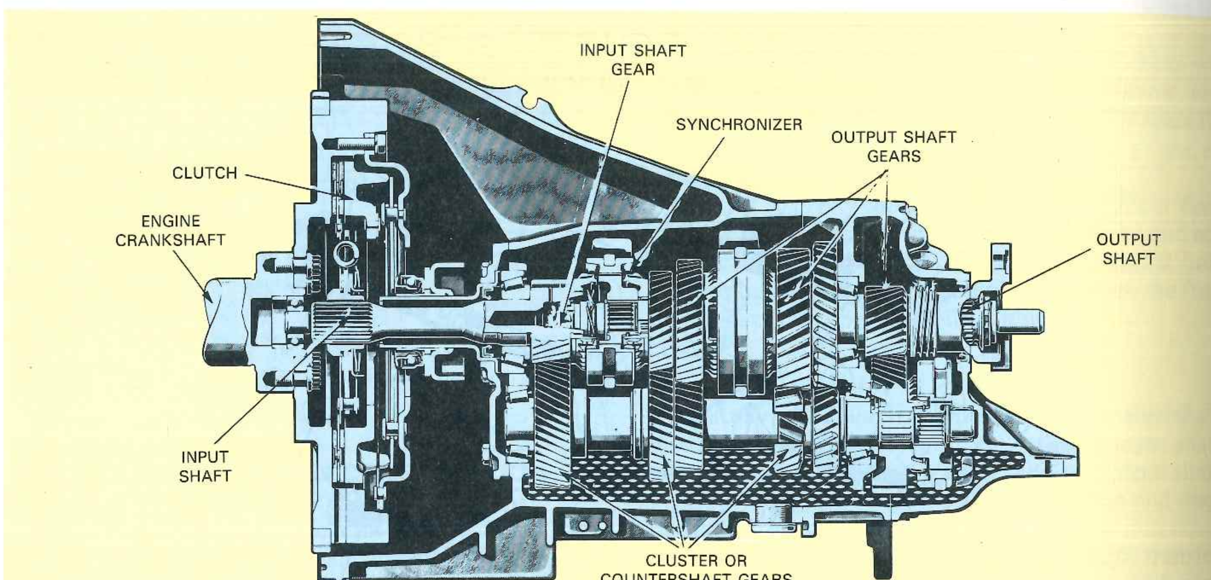


Fig. 52-9. Cutaway of modern transmission shows gears assembled on their shafts. Gear on clutch or input shaft drives countershaft gears. Countershaft gears turn output gears on main or output shaft. (Mercedes Benz)

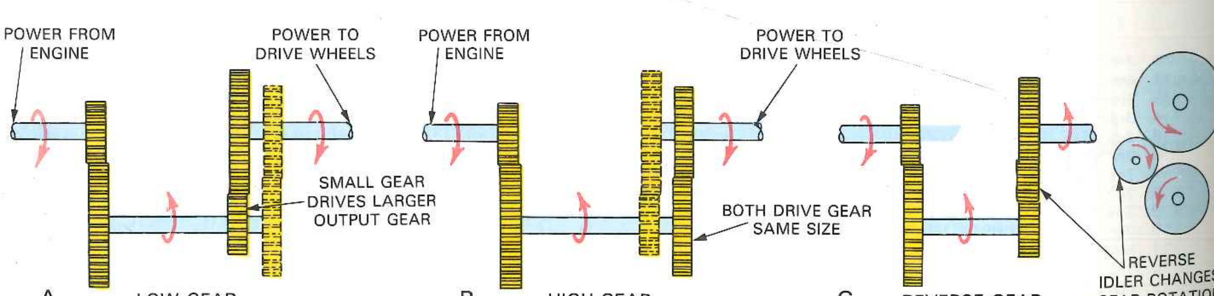


Fig. 52-10. Simplified transmission action. A — Low gear. Input shaft gear turns gears on countershaft. Small countershaft gear drives larger output shaft gear to produce gear reduction. B — High gear. Engaged gears are same size. Output shaft turns faster than when in low gear. Less torque increase is needed. C — Reverse. Reverse idler gear is used between countershaft gear and output shaft gear. This reverses direction of rotation at output shaft. (Deere & Co.)

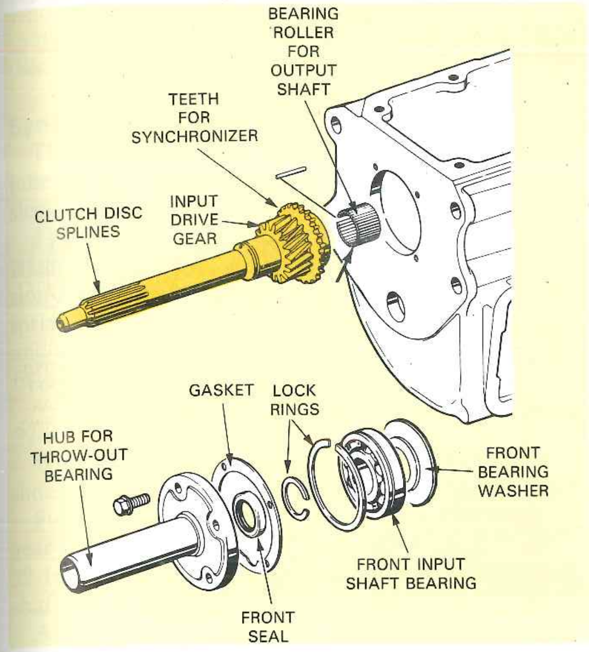


Fig. 52-11. Exploded view of input shaft and gear. Gear is normally machined part of shaft. Large bearing supports shaft in front of transmission case. Individual roller bearings support rear of shaft. Snap rings secure assembly in case. (Chrysler)

put shaft gears, and reverse idle gear. Illustrated in Fig. 52-9, the input shaft gear turns the countershaft gears. The countershaft gears turn the output shaft gears and reverse idle gear.

In low gear, a small gear on the countershaft drives a larger gear on the output shaft, Fig. 52-10A. This provides a high gear ratio for accelerating. Then, in high gear, a larger countershaft gear drives an equal or smaller size output shaft gear, Fig. 52-10B. This reduces the gear ratio and the vehicle moves faster.

When in reverse, power flows from the countershaft gear, to the reverse idler gear, and to the engaged gear on the output shaft. This reverses output shaft rotation as shown in Fig. 52-10C.

Input gear assembly

Mentioned briefly, the *transmission input gear* is a machined part of the steel input shaft. Fig. 52-11 shows an input gear with its related parts. Study the shape and relationship of each component carefully.

The input gear drives the forward gear on the countershaft gear. A small set of spur gear teeth are usually located next to the main, helical drive gear. This small gear is for engagement of the synchronizer.

Countershaft gear assembly

The *countershaft gear,* also called *countergear,* turns the gears on the output shaft. This gear is actually several gears machined out of a single piece of steel. Hence, it is often called the *cluster gear,* Fig. 52-12.

When the input gear drives the matching countershaft gear, all of the countershaft gears turn as a single unit. However, since each forward gear is a different size, the countershaft gear unit is capable of providing several gear ratios.

Note in Fig. 52-12 how the countershaft gear rides on roller bearings. Thrust washers fit on each end of the gear to set end play or case-to-gear clearance.

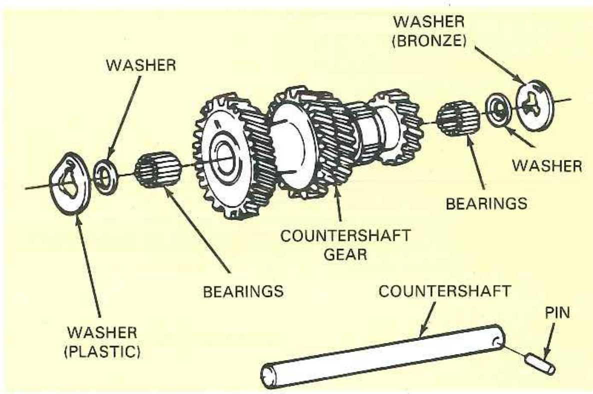


Fig. 52-12. Countershaft assembly. Countershaft gear has several gears formed as a single unit. They mount on roller bearings and countershaft. Washers control end play of unit in case. (Ford Motor Co.)

Reverse idler gear assembly

A *reverse idler gear assembly* is shown in Fig. 52-13. Note how it is constructed like the other transmission shaft-gear assemblies just discussed.

Output shaft gears

The *output shaft gears* or *main shaft gears* transfer

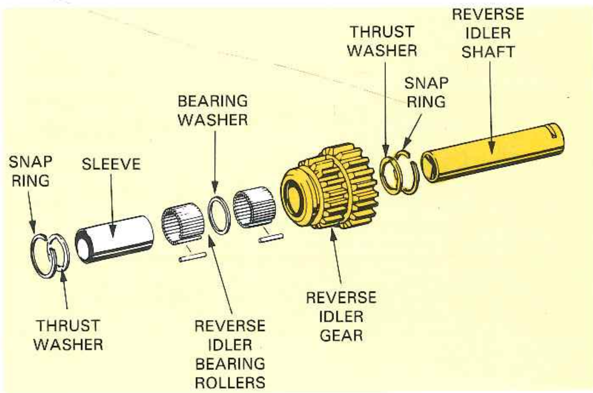


Fig. 52-13. Reverse idler gear and shaft assembly. (Chrysler)

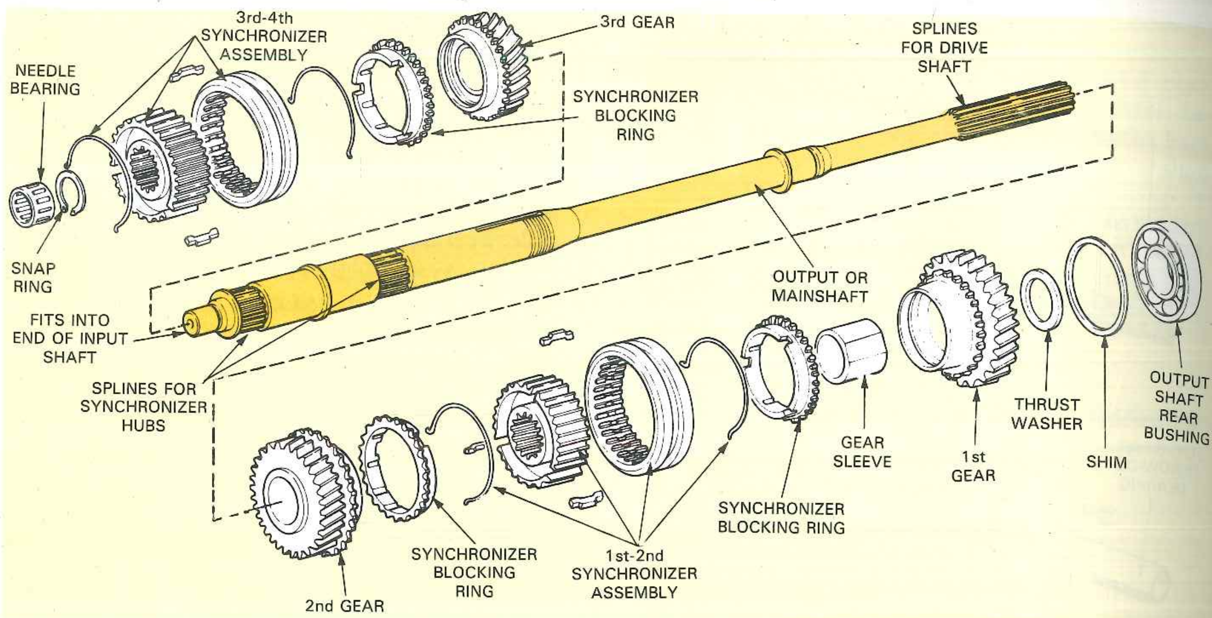


Fig. 52-14. Output or main shaft is long shaft extending through transmission tailshaft housing. Drive shaft is splined to rear of this shaft. Note how output gears and synchronizers install on shaft. (Mazda)

rotation from the countershaft gears to the output shaft. Only one of the output shaft gears is normally engaged and locked to the shaft at a time.

Fig. 52-14 pictures a set of output shaft gears. Notice how it has a main drive gear (helical gear) and a smaller synchronizer gear (spur gear).

The inside bore of each output shaft gear is smooth so that it can spin freely on its shaft when not engaged. Normally, one output shaft gear will be provided for each transmission speed, including reverse.

TRANSMISSION SYNCHRONIZERS

A *transmission synchronizer,* Fig. 52-14, has two functions. It must:

1. Prevent the gears from grinding or clashing during engagement.
2. Lock the output gear to the output shaft.

When the synchronizer is away from an output gear, the output gear freewheels or spins on the output shaft. No power is transmitted to the output shaft. When the

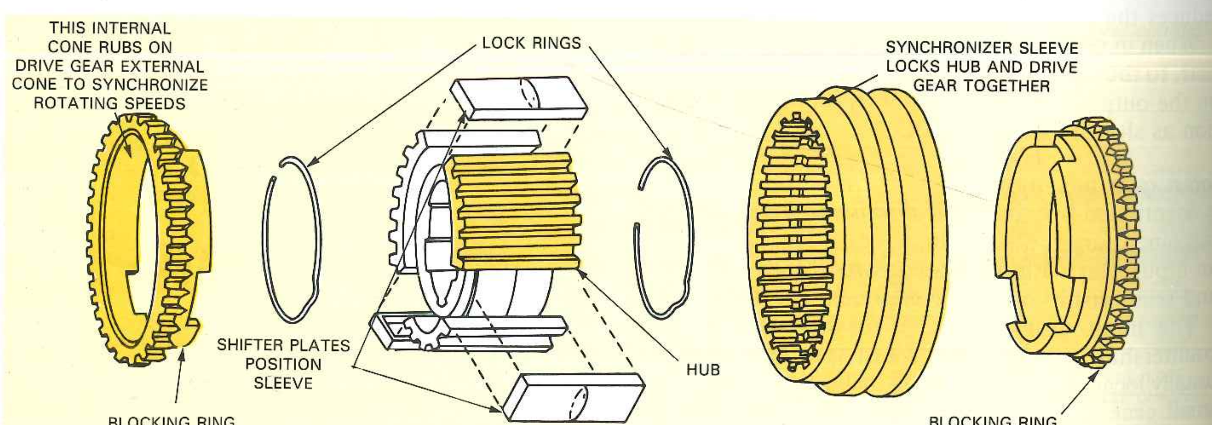


Fig. 52-15. Basic synchronizer components. Hub is splined to output shaft. It will slide but not turn on shaft. Sleeve fits over hub. Shifter plates position sleeve. Blocking rings allow sleeve to slide into and mesh with output gear without clashing or grinding. (Deere & Co.)

synchronizer is slid against a gear, the gear is locked to the synchronizer and to the output shaft. Power is then sent out the transmission and to the rear wheels.

Synchronizer construction

The most popular type synchronizer consists of an inner splined hub, inserts, insert springs, an outer sleeve, and blocking rings. See Fig. 52-15.

The synchronizer hub is splined on the output shaft. It is held in a stationary position between the transmission gears. Inserts fit between the hub and sleeve. The springs push the inserts into the sleeve. This helps hold and center the sleeve on its hub. The blocking rings fit on the outer ends of the hub and sleeve.

Synchronizer operation

When the driver shifts gears, the synchronizer sleeve slides on its splined hub toward the main drive gear.

First, the *blocking ring* cone rubs on the side of the gear cone, setting up friction between the two, Fig. 52-16. This causes the gear, synchronizer, and output shaft to begin to spin at the SAME SPEED.

As soon as the speed is equalized or synchronized, the sleeve can slide completely over the blocking ring and over the small, spur gear teeth on the drive gear. This locks the output gear to the synchronizer hub and to the shaft. Power then flows through that gear and to the rear wheels.

FULLY SYNCHRONIZED TRANSMISSION

Fully synchronized means that all of the forward output gears use a synchronizer. This allows the driver to downshift into any lower gear (except reverse) with the car moving. Most modern manual transmissions are fully synchronized.

Many older three-speed transmissions did NOT have first gear synchronized. The driver had to wait until the vehicle came to a complete stop before downshifting into first. Trying to shift into first with the vehicle in motion would cause first gear to clash.

SHIFT FORKS

The *shift forks* fit around the synchronizer sleeves to transfer movement to the sleeves from the gear shift linkage. This is illustrated in Fig. 52-17.

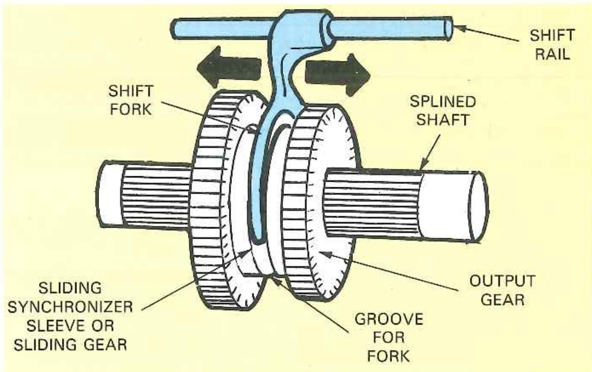


Fig. 52-17. Shift fork is used to move synchronizer sleeve or sliding gear on splined shaft. Shift linkage or rail operates shift fork.

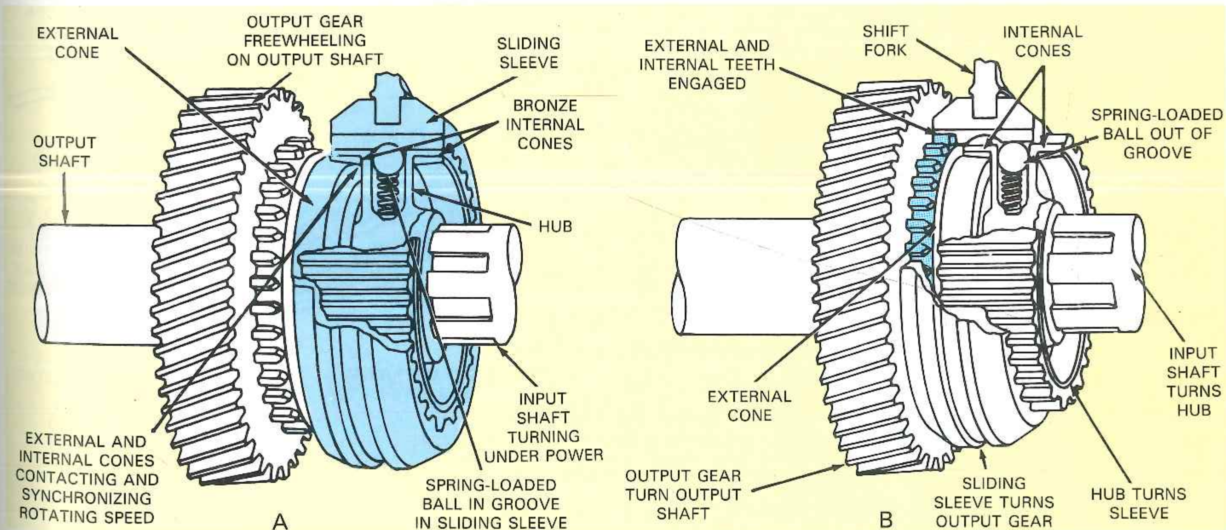


Fig. 52-16. Synchronizer operation. A — As synchronizer sleeve moves into output gear, cone on sleeve rubs against cone on gear. Friction makes gear and sleeve begin to turn at same speed. B — When at same speed, sleeve can slide over and mesh with small, spur teeth on side of output gear. This locks output gear, sleeve, hub, and input shaft together. Output gear is then engaged to output shaft.

The shift fork fits into a groove cut into the synchronizer sleeve. A linkage rod or shift rail connects the fork to the driver's shift lever. When the lever moves, the linkage or rail moves the shift fork and sleeve to engage the correct transmission gear.

Fig. 52-18 pictures a typical, complete shift fork assembly. Study the parts and how they fit together.

TRANSMISSION SHIFT LINKAGE AND SHIFT LEVER

There are two general types of transmission linkage: EXTERNAL ROD type and INTERNAL SHIFT RAIL type. Both perform the same function. They connect the shift lever with the shift fork mechanism.

Look at Fig. 52-19. It shows the components of an external shift rod type linkage. The rods fit into levers on the shift mechanism and fork assembly. Spring clips hold the rods in the levers. One end of each linkage rod is threaded so that the linkage can be adjusted.

An internal rail type is shown in Fig. 52-20.

When the driver shifts gears, the bottom of the shift lever catches in one of the gates (notched unit attached to shift rail), Fig. 52-21. Each gate is mounted on a shift rail. As a result, movement of the lever places a prying action on the rail. Since the fork is located on the rail, it is also moved to change transmission gears. Spring-loaded balls are sometimes used to lock the shift rail(s) into position when in neutral or in gear.

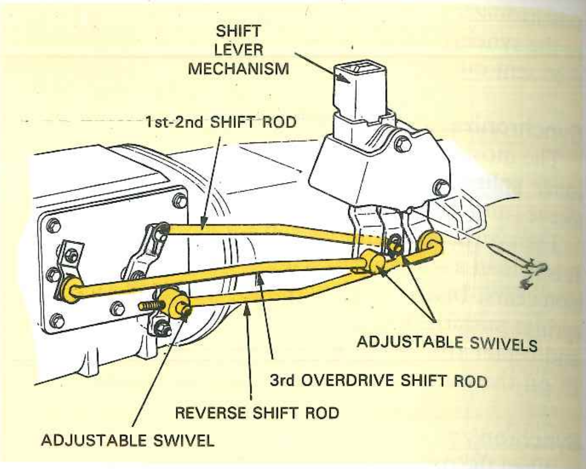


Fig. 52-19. Side view of transmission showing shift linkage and lower part of shift lever. Study parts. (Chrysler)

Variations in shift rail linkages are also available. However, their basic construction and operation are

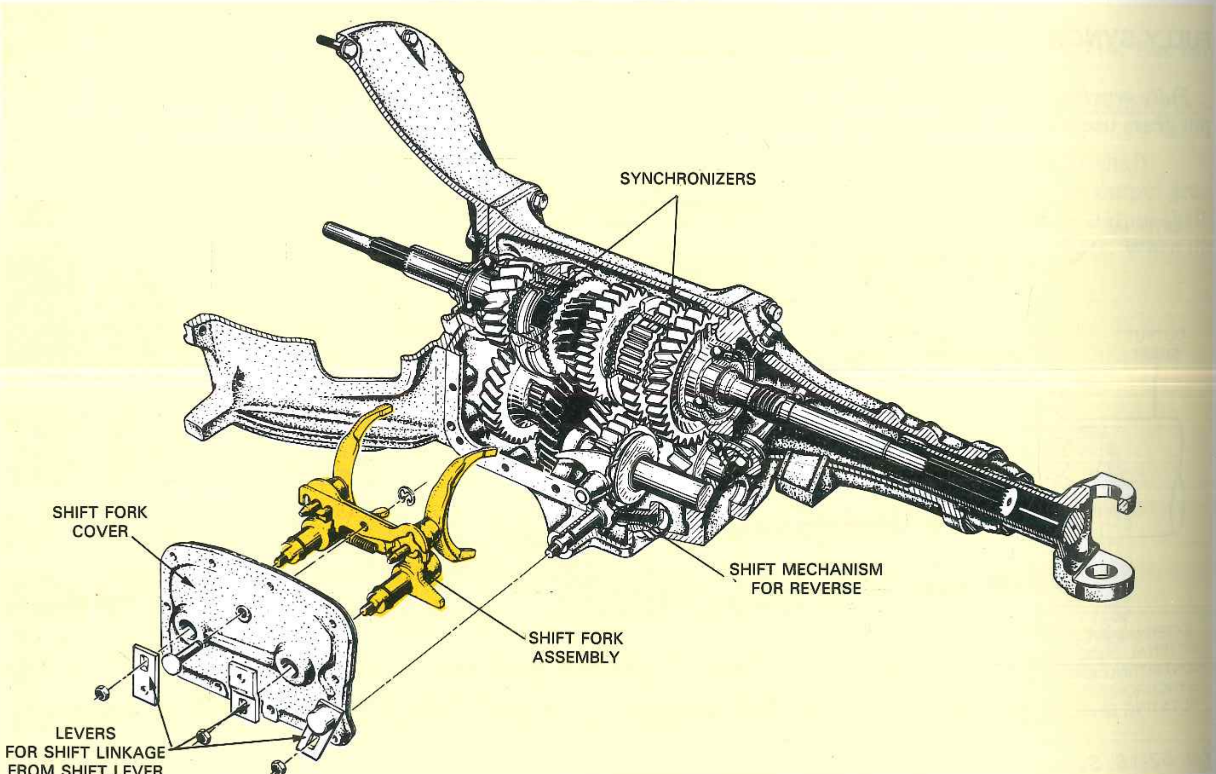


Fig. 52-18. Shift fork fits over groove machined in center of synchronizer sleeve. Movement of shift linkage to transmission moves shift fork forward or rearward in transmission to engage different output gear. (Plymouth)

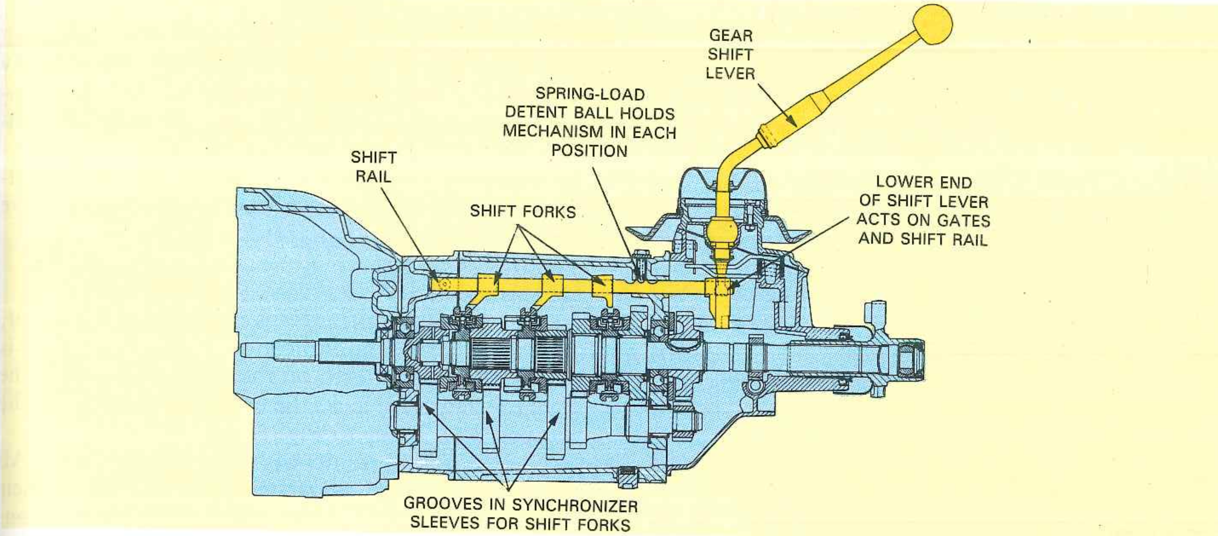


Fig. 52-20. This transmission uses an internal shift rail mechanism instead of external shift rods. Shift lever acts on rail. Rail then operates shift forks and synchronizer sleeves. (Fiat)

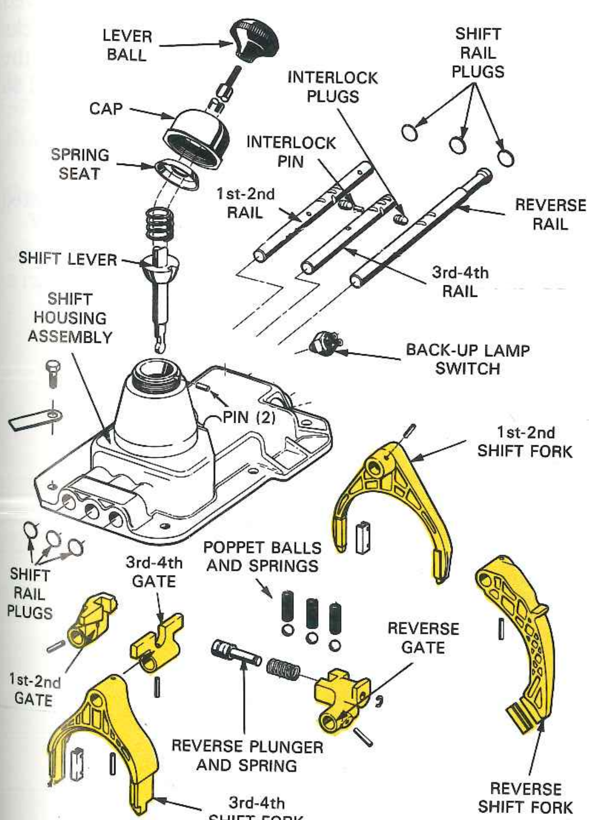


Fig. 52-21. Exploded view of shift mechanism for late model transmission. Shift lever acts on shift gates. Shift gates are attached to shift rails. Rails move forks for gear changes. Spring-loaded balls and plunger help position shift forks during each gear change. Note back-up lamp switch. (Chrysler)

almost the same.

The transmission shift lever assembly can be moved to cause movement of the shift linkage or rail, shift forks, and synchronizers.

The parts of a floor mounted shift lever assembly are shown in Figs. 52-19, 20, and 21. One has external shift rods and the others internal rails. Fig. 52-22 pictures a steering column mounted shift lever. Study the parts and how they function.

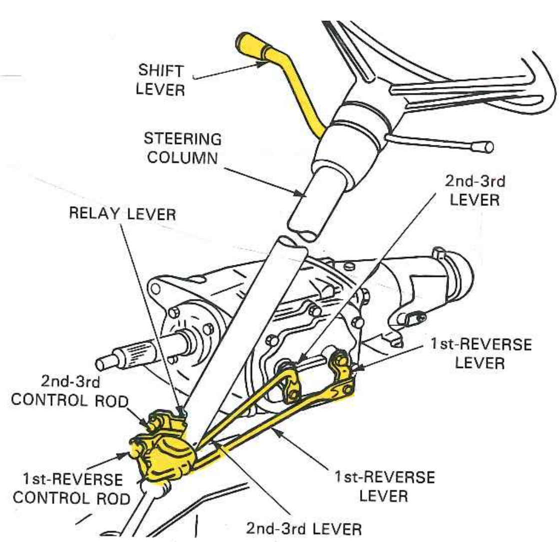


Fig. 52-22. Column type shift mechanism. Gear shift lever operates levers on bottom of column. Rods then transfer movement to transmission. (GMC)

TRANSMISSION TYPES

There are several types of manual transmissions: three-speed, four-speed, five-speed, and transmissions with overdrive in high gear. Transmissions with more forward speeds provide a better selection of gear ratios.

Older vehicles were commonly equipped with three-speed transmission. Modern vehicles, however, frequently have four or five-speed transmissiosns. Extra gear ratios are needed for the smaller, low horsepower, high efficiency engines of today.

TRANSMISSION POWER FLOW

Now that you understand the basic parts and construction of a manual transmission, we will cover the flow of power through actual manual transmissions.

First gear

To get the vehicle moving from a standstill, the driver moves the gear shift lever into first. The clutch pedal must be pressed to stop power flow into the transmission. The linkage rods move the shift forks so that first gear synchronizer is engaged to first output gear. The other output gears are in neutral. Look at Fig. 52-23.

As the driver releases the clutch pedal, the clutch shaft gear begins to spin the countershaft gears. Since only first gear is locked to the output shaft, a small gear on the countershaft drives a larger gear on the output shaft. The gear ratio is approximately 3:1 and the vehicle accelerates easily.

Second gear

To shift into second, the driver depresses the clutch and moves the shift lever. With the engine momentarily disconnected from the transmission, the first gear synchronizer is slid away from first gear. Second-third synchronizer is then engaged. See Fig. 52-24.

Now power flow is through second gear on the output shaft. A gear ratio of about 2:1 is produced to give the vehicle a little more speed.

Third gear

When the gear shift lever is moved into third gear, there is no torque multiplication. The synchronizer is slid over the small teeth on the input shaft gear. The synchronizer sleeve locks the input shaft directly to the output shaft. Refer to Fig. 52-25.

A 1:1 gear ratio results with no torque increase. All of the output shaft gears freewheel or spin on their shaft. Power flow is straight through the transmission. The vehicle travels at highway speeds while the engine rpm is relatively low.

Reverse

When shifted into reverse, a synchronizer is moved into the reverse gear on the output shaft. This locks the gear to the output shaft. Power flows through the countershaft, reverse idler gear, reverse gear, and to the drive shaft, as in Fig. 52-26.

Neutral

In neutral, all of the synchronizer sleeves are located

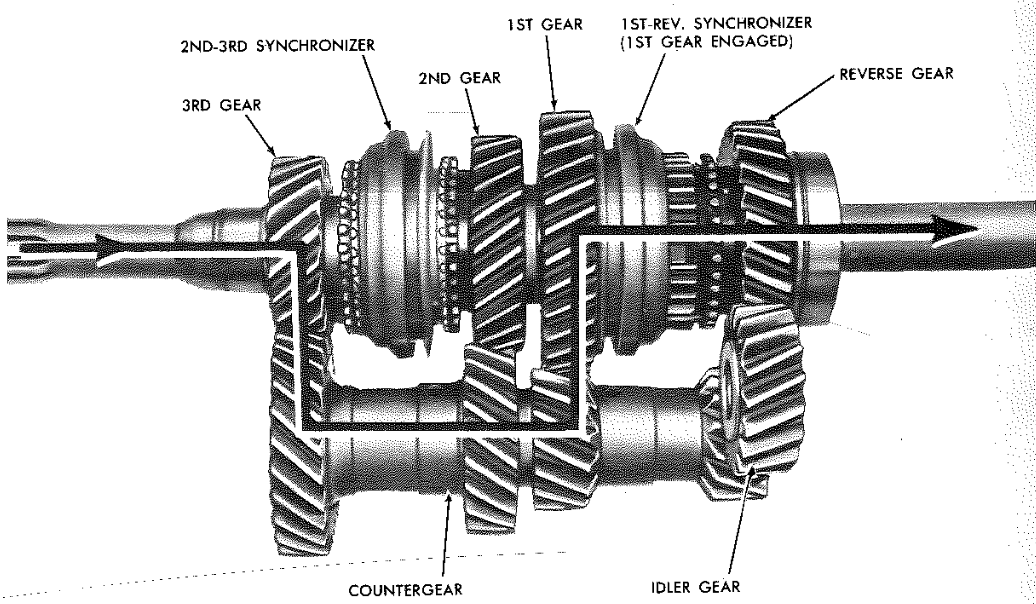


Fig. 52-23. Transmission in first gear. First-reverse synchronizer engaged with first output gear. Other synchronizer is in neutral position. First output gear is locked to output shaft and transfers high torque to drive shaft. (Chevrolet)

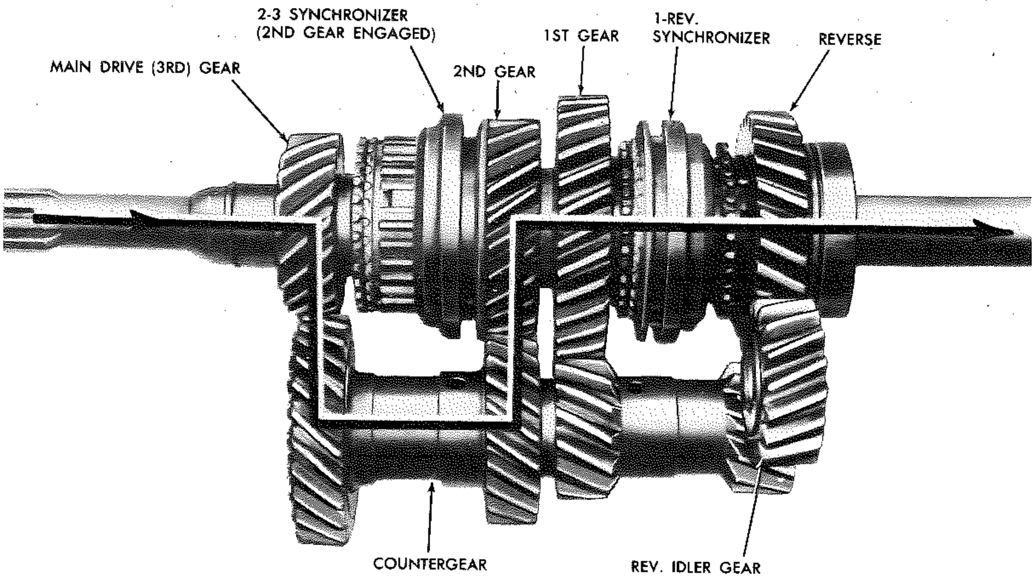


Fig. 52-24. Transmission in second gear. First-reverse synchronizer is moved into neutral. Second-third synchronizer is engaged with second output gear, locking it to its shaft. (Chevrolet)

in the center of their hubs, Fig. 52-27. This allows all of the output shaft gears to freewheel on the output shaft. No power is transmitted to the output shaft.

Overdrive gear

When in high gear, many modern transmissions have overdrive. Either fourth (4-speed) or fifth (5-speed) has a ratio of less than 1:1 (0.87:1 for example) to increase fuel economy.

Fig. 52-28 shows the power flow through a late model, 5-speed, overdrive transmission. It is designed for a low horsepower, diesel engine. Trace flow through the transmission in each gear. The first four forward speeds allow the diesel to accelerate quickly. The overdrive high gear keeps engine rpm down at highway speeds to increase fuel economy and engine service life.

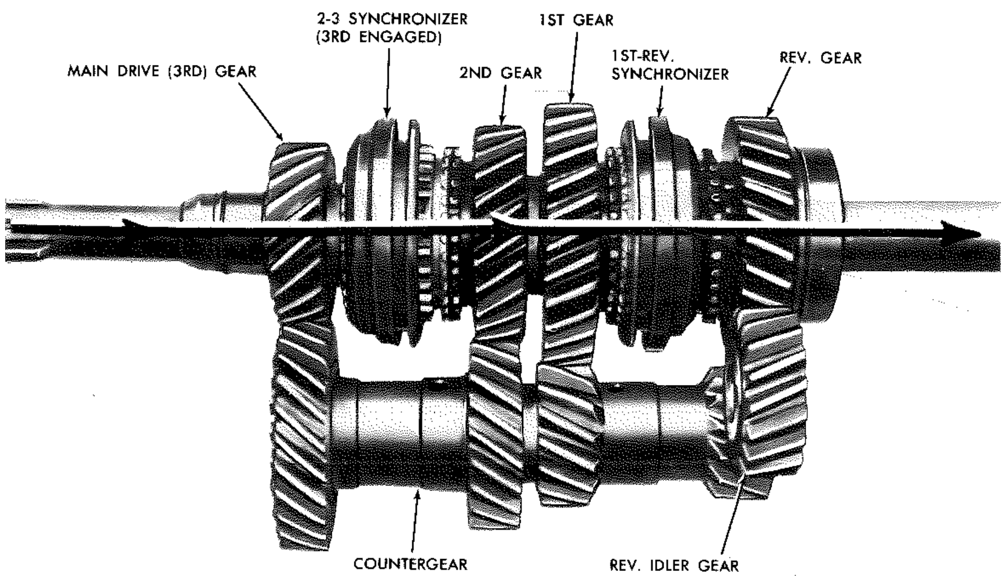


Fig. 52-25. Transmission in third gear. Second-third gear synchronizer is slid to engage gear on input shaft. This locks input shaft directly to output shaft. Both shafts turn at same speed for no gear reduction. (Chevrolet)

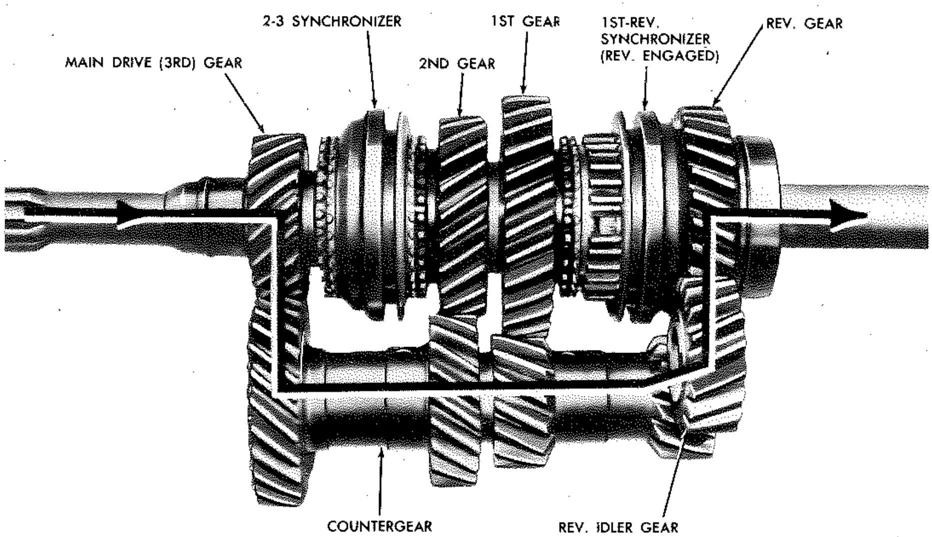


Fig. 52-26. Transmission in reverse. Second-third synchronizer moved into neutral. First-reverse synchronizer slid into mesh with reverse output gear. Countershaft gear drives reverse idler. Idler drives output shaft backwards. (Chevrolet)

OTHER TRANSMISSION DESIGNS

Many transmission design variations are used by the numerous auto manufacturers. However, all transmissions use the basic operation and construction principles just explained.

Review the transmission parts in Figs. 52-29 and 52-30. Can you explain the basic function of each part?

SPEEDOMETER DRIVE

Normally, a manual transmission has a worm gear on the output shaft that drives the speedometer gear and cable. See Fig. 52-29. The gear on the output shaft turns a plastic gear on the end of the speedometer cable. The cable runs through a housing up to the speedometer head (speed indicator assembly) in the dash.

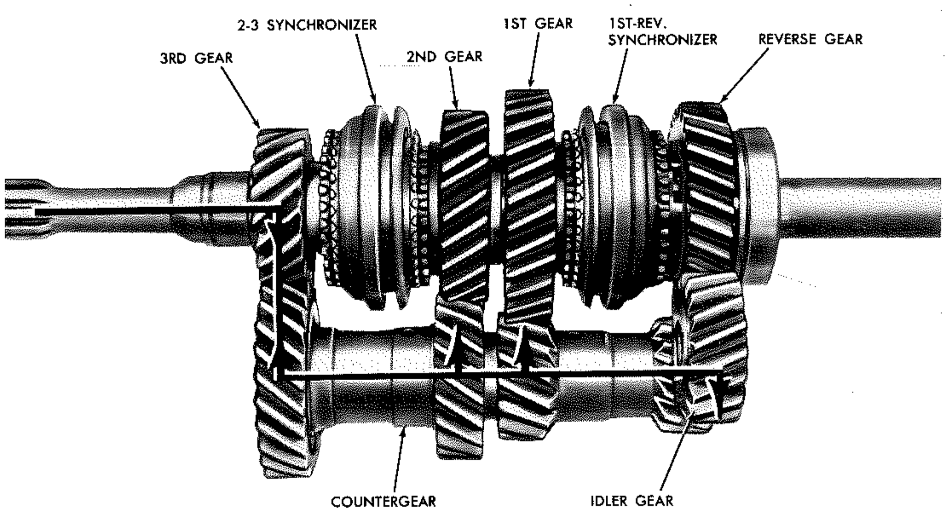


Fig. 52-27. In neutral, both synchronizers are in center positions. No output gears are locked to output shaft. Gears freewheel and do not transfer power to drive shaft. (Chevrolet)

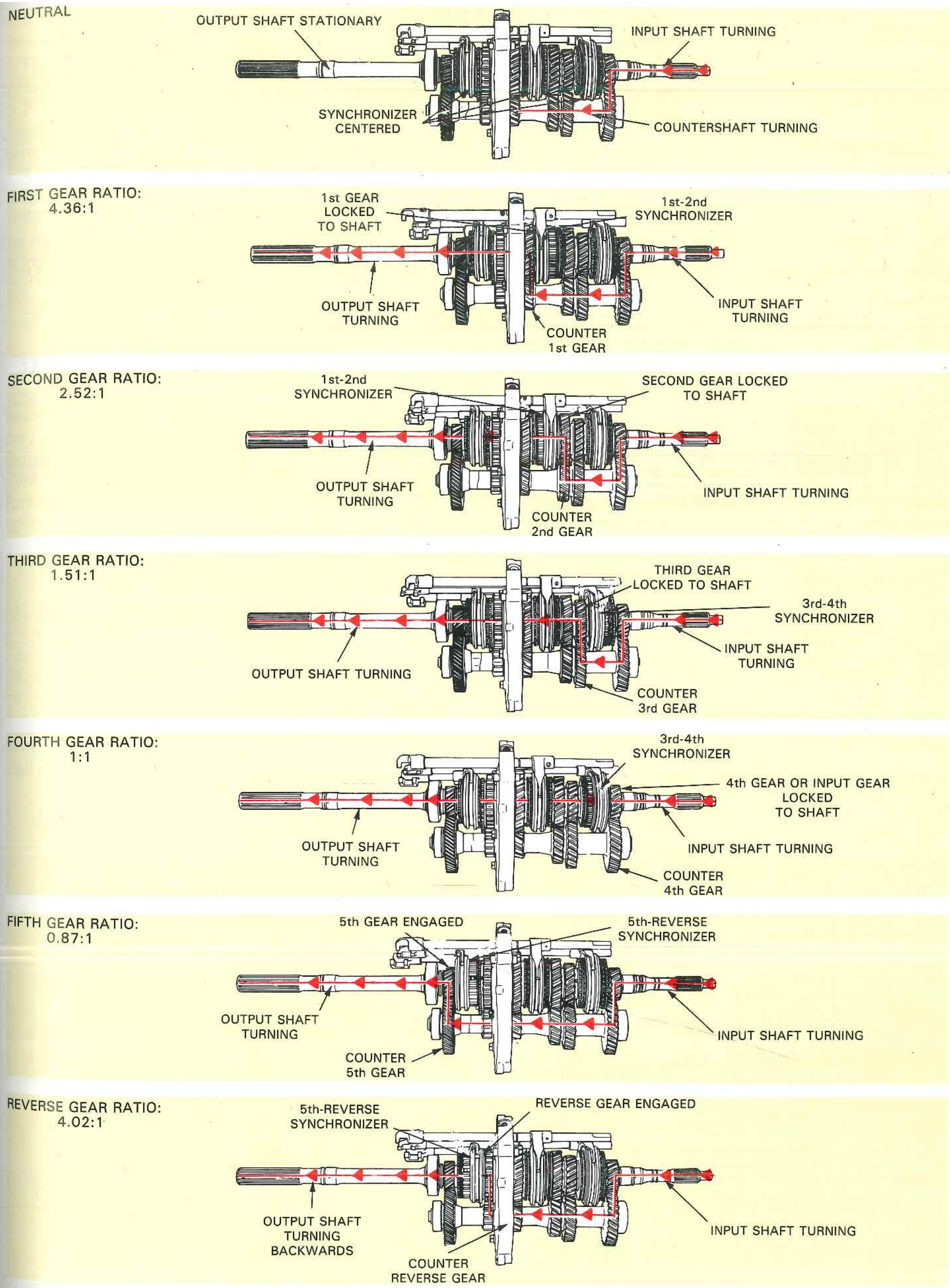


Fig. 52-28. Power flow through a five speed transmission with overdrive in high gear. Study each illustration carefully.

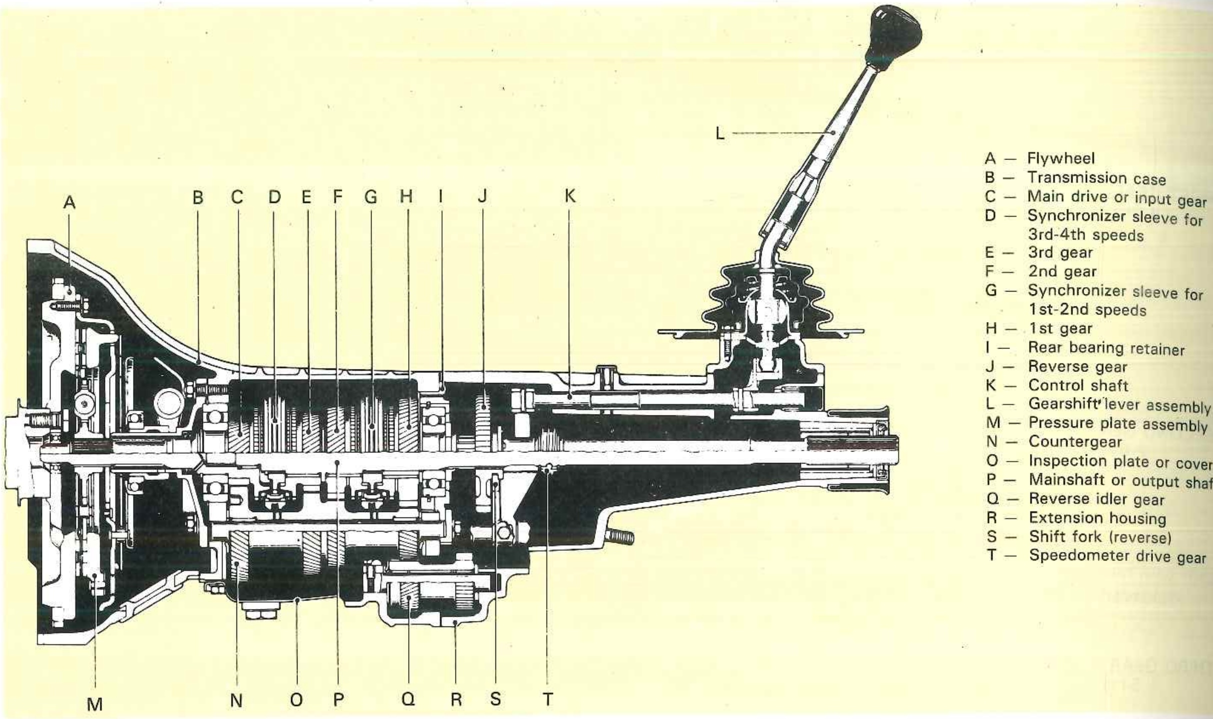


Fig. 52-29. Cutaway view of late model four speed transmission. Note part names and locations. (Chrysler)

A retainer and bolt hold the cable assembly in the transmission extension housing.

Whenever the output shaft turns, the speedometer cable turns. This makes the speedometer head register the road speed of the vehicle.

MANUAL TRANSMISSION SWITCHES

Two types of electric switches are sometimes mounted on the manual transmission: the back-up light switch and the ignition spark switch.

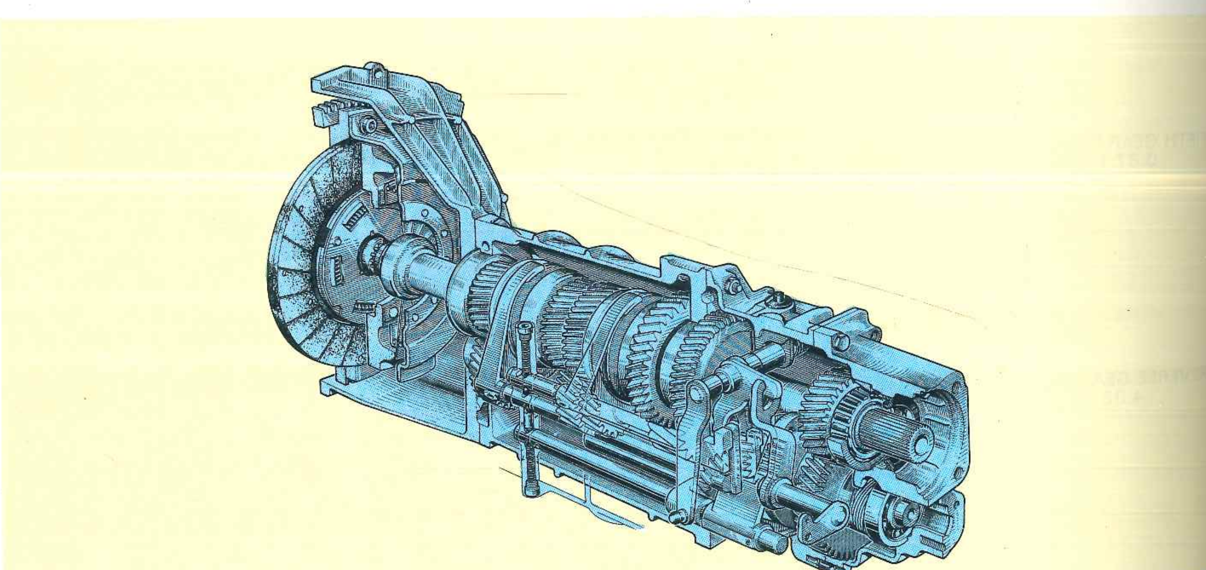


Fig. 52-30. Five speed, manual transmission with clutch installed on input shaft. Can you describe function of major parts? (Peugeot)

The ***back-up light switch*** is an electric switch closed by the action of the reverse gear shift linkage. Refer to Fig. 52-21. When shifted into reverse, the linkage closes the switch to connect the back-up lamps to battery.

A few manual transmissions have an ***ignition spark switch*** which only allows distributor vacuum advance in high gear. The switch usually mounts in the side of the transmission. It is normally closed until activated in high gear. This retards the ignition timing in lower gears to reduce exhaust pollution.

KNOW THESE TERMS

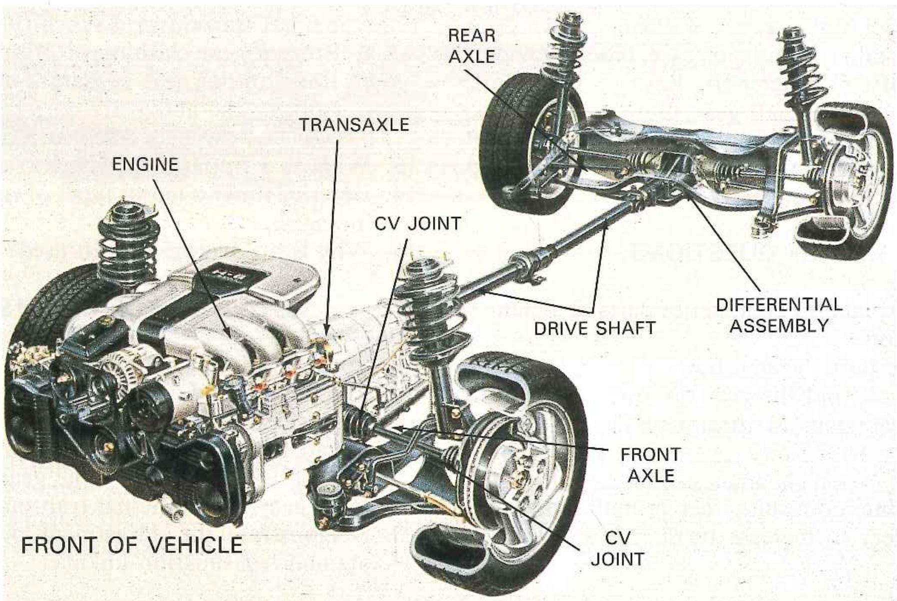
Manual transmission, Gear ratio, Gear reduction, Overdrive ratio, Spur gears, Helical gears, Gear backlash, Gear oil, Transmission case, Extension housing, Input shaft, Countershaft, Reverse idler shaft, Output shaft, Countershaft gear, Output shaft gears, Synchronizer, Fully synchronized transmission, Shift fork, Transmission linkage, Shift rail, Shift lever, Back-up light switch, Ignition spark switch.

REVIEW QUESTIONS

1. List and explain the eight major parts of a manual transmission.
2. Define the term "gear ratio."
3. How do you find the gear ratio of two gears?
4. Approximate manual transmission gear ratios are ________ for first, ________ for second, ________ for high, and ________ for reverse.
5. A gear reduction results when a small gear drives a larger gear to increase turning force. True or False?
6. This would be an overdrive ratio.
   a. 1:1.
   b. 0.87:1.
   c. 1:0.87.
   d. 3:1.
7. ________ ________ is the small clearance between the meshing gear teeth for lubrication and heat expansion.
8. Typically, ________ or ________ gear oil is used in a manual transmission.
9. What is the transmission extension housing?
10. Name and describe the four shafts in a manual transmission.
11. List and explain the general gear classifications found in a manual transmission.
12. A manual transmission synchronizer is used to:
    a. Prevent gear clashing or grinding.
    b. Lock output gear to output shaft.
    c. Both of the above are correct.
    d. None of the above are correct.
13. What is a fully synchronized transmission?
14. Describe the two major types of transmission shift linkages.
15. Why is an overdrive ratio used?

ACTIVITIES FOR CHAPTER 52

1. Locate a drive gear and a driven gear on a manual transmission and determine the gear ratio when the two gears are meshed. Show your calculations.
2. Locate the transmission section in a shop manual and study the names of the gears. Locate these same gears on an actual transmission.
3. Demonstrate the adjustment procedures for a manual transmission linkage.



Note parts of this four-wheel drive system. Engine and transaxle are at front; a drive shaft transmits power to rear differential assembly. (Subaru)

54 Automatic Transmission Fundamentals

After studying this chapter, you will be able to:

- ☐ Identify the basic components of an automatic transmission.
- ☐ Describe the function and operation of the major parts of an automatic transmission.
- ☐ Trace the flow of power through automatic transmissions.
- ☐ Explain how an automatic transmission shifts gears.
- ☐ Compare different types of automatic transmissions.

An *automatic transmission* performs the same functions as a standard transmission. However, it "shifts gears" and "releases the clutch" automatically. A majority of modern cars use an automatic transmission (or transaxle) because it saves the driver from having to move a shift lever and depress a clutch pedal.

As you will learn, an automatic transmission normally senses engine rpm (speed) and engine load (engine vacuum or throttle position) to determine gear shift points. It then uses internal oil pressure to shift gears. Computers can also be used to sense or control automatic transmission shift points.

BASIC AUTOMATIC TRANSMISSION

Before detailing the construction and operation of each individual part, it is important for you to have a general idea of how an automatic transmission works. Then, you will be able to relate the details of each part to the complete transmission assembly.

Refer to Fig. 54-1 as the following parts of an automatic transmission are introduced.

1. TORQUE CONVERTER (fluid coupling that connects and disconnects engine and transmission).
2. INPUT SHAFT (transfers power from torque converter to internal drive members and gearsets).
3. OIL PUMP (produces pressure to operate

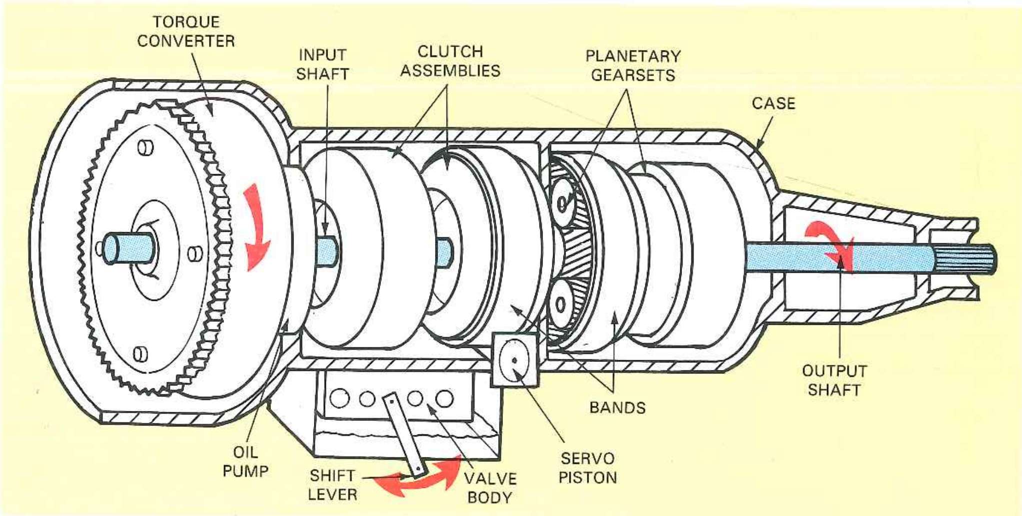


Fig. 54-1. Study basic parts of simplified automatic transmission. Note general shape and location of components. This will help prepare you to learn details of each part.

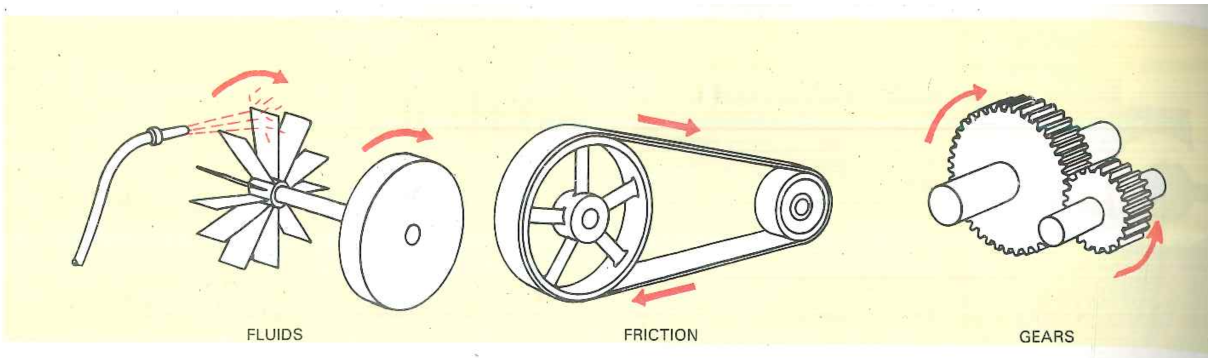


Fig. 54-2. An automatic transmission uses these methods of transmitting power. (Deere & Co.)

hydraulic components in transmission).

4. VALVE BODY (operated by shift lever and sensors, controls oil flow to pistons and servos).
5. PISTONS and SERVOS (actuate bands and clutches).
6. BANDS and CLUTCHES (apply clamping or driving pressure on different parts of gearsets to operate them).
7. PLANETARY GEARSETS (provide different gear ratios and reverse gear).
8. OUTPUT SHAFT (transfers engine torque from gearsets to drive shaft, and rear wheels).

TRANSMITTING POWER

As you will see, an automatic transmission uses three methods to transmit power: fluids, friction, and gears. This is illustrated in Fig. 54-2.

The torque converter uses FLUID to transfer power. The bands and clutches use FRICTION. The transmission GEARS, not only transmit power, they can increase or decrease speed and torque.

TRANSMISSION HOUSINGS AND CASE

An automatic transmission is normally constructed with four main components: converter housing, case, pan, and rear extension housing. These parts support and enclose all of the other components in the transmission. Refer to Fig. 54-3.

The ***converter housing*** or *bell housing* surrounds the converter and holds the transmission against the engine. It is usually made of aluminum.

Bolts fit through holes in the converter housing and attach to the engine block. The converter housing also keeps road dirt, rocks, and other debris off the spinning torque converter and flywheel, Fig. 54-3.

The ***transmission case*** encloses the clutches, bands, gearsets, and inner ends of the transmission shafts. The converter housing bolts to the front of the case. The

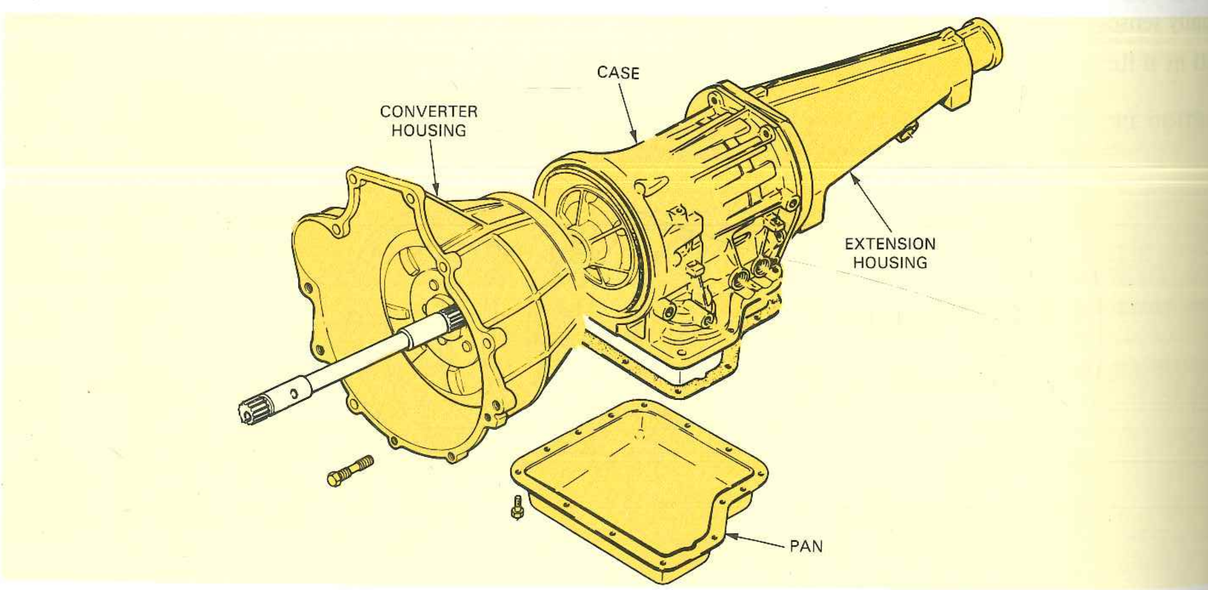


Fig. 54-3. Most automatic transmissions are constructed with front converter housing, central case, rear extension housing, and lower pan. Most parts fit inside case.

extension housing bolts to the rear of the case. The valve body and pan bolt to the bottom of the case. It may be made of aluminum or cast iron, Fig. 54-3.

The ***oil pan,*** also called *transmission pan,* collects and stores a supply of transmission fluid. It is usually made of thin, stamped steel or cast aluminum. The pan fits over the valve body. A gasket or sealant prevents leakage between the case and oil pan, Fig. 54-3.

The ***extension housing*** slides over and supports the output shaft. The housing uses a gasket on the front and a seal on the rear to prevent oil leakage. It is often made of aluminum, or sometimes cast iron, Fig. 54-3.

TORQUE CONVERTER

The *torque converter* is a fluid clutch that performs the same basic function as a manual transmission's dry friction clutch. It provides a means of uncoupling the engine for stopping the car in gear. It also provides a means of coupling the engine for acceleration.

Torque converter principles

Two house fans can be used to demonstrate the basic action inside a torque converter. Look at Fig. 54-4. One fan is plugged in and is spinning. The other fan is NOT plugged into electrical power.

Since the whirling fan is facing the other, it can be used to spin the unplugged fan, transferring power through a fluid (air). This same principle applies inside a torque converter, but oil is used instead of air.

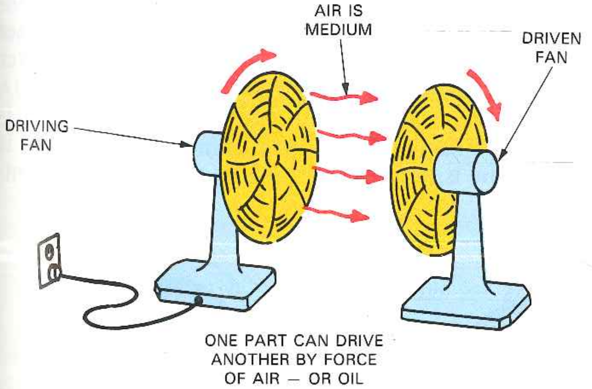


Fig. 54-4. Two fans demonstrate principle of fluid coupling or torque converter. (Deere & Co.)

Torque converter construction

A torque converter consists of four basic parts: the outer housing, an impeller or pump, a turbine, and a stator. These parts are shown in Fig. 54-5.

The impeller, stator, and turbine have curved or curled fan blades, as shown in Fig. 54-6. They work like our simple example of one fan driving another. The impeller drives the turbine.

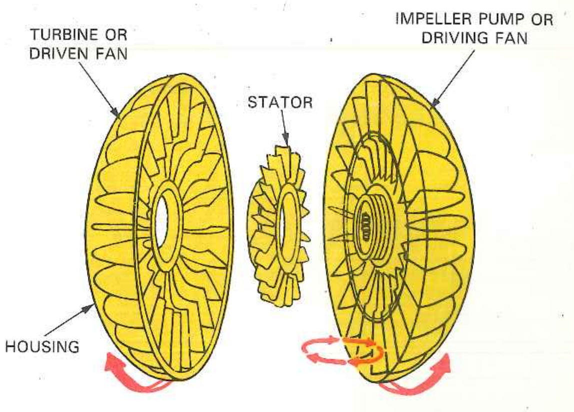


Fig. 54-5. Four major parts of torque converter: housing, impeller or pump, stator, and turbine. (Texaco)

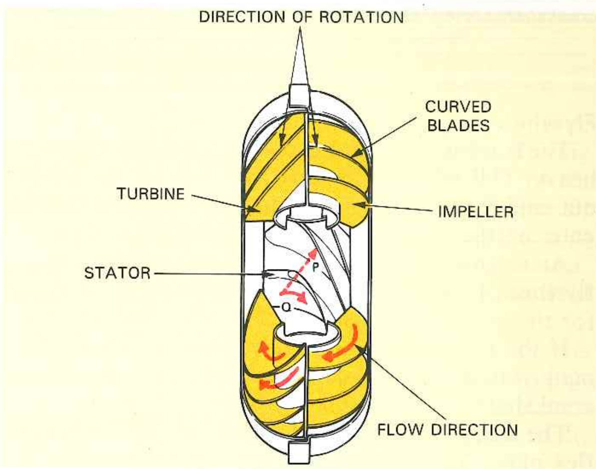


Fig. 54-6. Blades on impeller and stator direct oil circulation onto blades of turbine. Impeller is driven by engine. Turbine is driven by impeller. (Subaru)

Converter housing

The impeller, stator, and turbine are housed inside a doughnut-shaped housing. The converter housing is normally made of two pieces of steel welded together. The housing is filled with transmission fluid (oil).

The ***impeller*** is the driving fan that produces oil movement inside the converter whenever the engine is running. It is sometimes called the *converter pump,* Figs. 54-6 and 54-7.

The ***turbine*** is a driven fan splined to the input shaft of the automatic transmission. It fits in front of the stator and impeller in the housing. The turbine is NOT fastened to the impeller, but is free to turn independently. Oil is the only connection between the two.

The ***stator*** is designed to improve oil circulation inside the torque converter. It increases efficiency and torque by causing the oil to swirl around inside the converter housing. This makes use of all of the force produced by the moving oil.

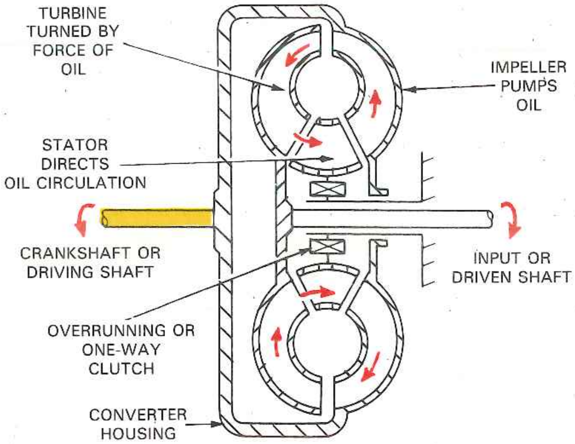


Fig. 54-7. Crankshaft is fastened to converter housing and impeller. Stator is mounted on one-way clutch. When engine crankshaft spins fast enough, oil movement rotates turbine and transmission input shaft. (Subaru)

Flywheel action

The transmission torque converter is very large and heavy. This allows it to serve as a flywheel to smooth out engine power pulses. Its inertia reduces vibration entering the transmission and drive line.

An automatic transmission uses a very thin and light flywheel. It is simply a stamped disc with a ring gear for the starting motor.

If the ring gear is on the torque converter, a *flex plate,* without a ring gear, can be used to connect the crankshaft to the torque converter.

The crankshaft bolts to one side of the flywheel or flex plate. The converter bolts to the other side.

Torque converter operation

With the ENGINE IDLING, the impeller spins slowly. Only a small amount of oil is thrown into the stator and turbine. Not enough force is developed inside the torque converter to spin the turbine. The car would remain stationary with the transmission in gear.

During ENGINE ACCELERATION, the engine crankshaft, converter housing, and impeller begin to spin faster. More oil is thrown out by centrifugal force. This makes the turbine begin to turn. As a result, the transmission input shaft and vehicle start to move, but with some slippage, Fig. 54-7.

At CRUISING SPEEDS, the impeller and turbine spin at almost the same speed, with very little slippage. When the impeller is spun fast enough, centrifugal force throws the oil out hard enough to almost lock the impeller and turbine. See Fig. 54-7.

Converter one-way clutch

A *one-way clutch* allows the stator to turn in one direction but not the other. See Fig. 54-8. The stator mounts on the clutch mechanism. Stator action is only needed when the impeller and turbine are turning at different speeds.

The one-way clutch locks the stator when the impeller is turning faster than the turbine. This causes the stator to route oil flow over the impeller vanes properly. Then, when turbine speed almost equals impeller speed, the stator can freewheel on its shaft, so not to obstruct oil flow.

Torque multiplication

Torque multiplication refers to the ability of a torque converter to increase the amount of engine torque applied to the transmission input shaft. Just as a small gear driving a large gear increases torque, a torque converter can act as several different gear ratios to alter torque output. Torque can be doubled by the converter under certain conditions.

Torque multiplication occurs when the impeller is spinning FASTER than the turbine. For instance, if the engine is accelerated quickly, the engine and im-

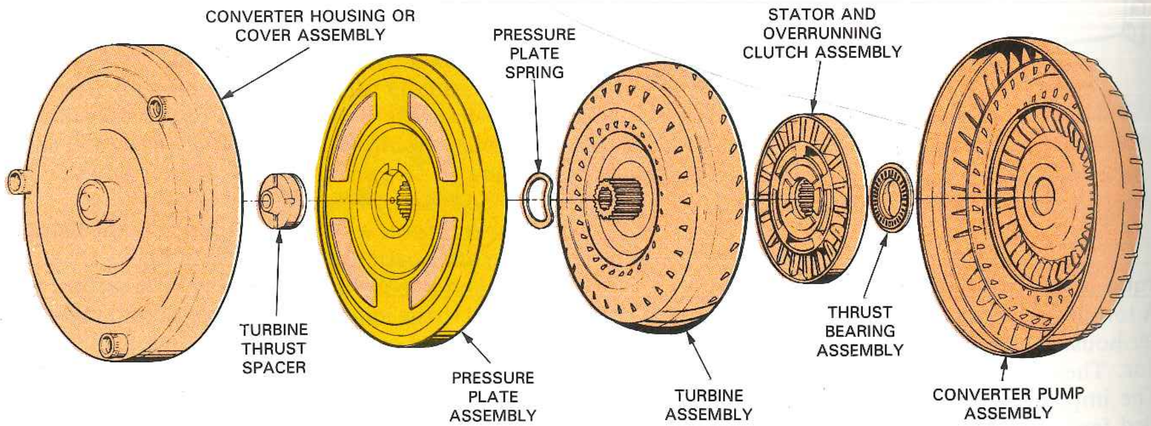


Fig. 54-8. Lock-up torque converter is conventional converter with a friction pressure plate added. The pressure plate can be used to lock turbine to converter housing, eliminating slippage and increasing fuel economy. (Oldsmobile)

peller rpm might increase rapidly while the turbine is almost stationary. At this time, torque multiplication would be maximum. When the turbine speed nears impeller speed, torque multiplication drops off.

Torque is increased in the converter by sacrificing motion. The turbine spins slower than the impeller during torque multiplication.

Torque converter stall speed

The *stall speed* of a torque converter basically occurs when the impeller is at maximum speed without rotation of the turbine. This causes the oil to be thrown off the stator vanes at tremendous speeds. The greatest torque multiplication occurs at stall speed.

Lock-up torque converters

A *lock-up torque converter* has an internal friction clutch mechanism for locking the impeller to the turbine in high gear. In a conventional converter, there is always some slippage between the impeller and turbine. By locking these components with a friction clutch, the torque converter does not slip. This improves fuel economy.

Typically, a lock-up mechanism in a torque converter consists of a hydraulic piston, torsion springs, and clutch friction material. See Figs. 54-8 and 54-9.

In lower transmission gears, the converter clutch is released. The torque converter operates normally, allowing slippage and torque multiplication.

Then, when shifted into high or direct drive, oil is channeled to the converter piston. The piston pushes the friction discs together to lock the converter. The torsion springs help dampen engine power pulses entering the drivetrain. Refer to Fig. 54-9.

AUTOMATIC TRANSMISSION SHAFTS

Typically, an automatic transmission has two main shafts: the input shaft and output shaft.

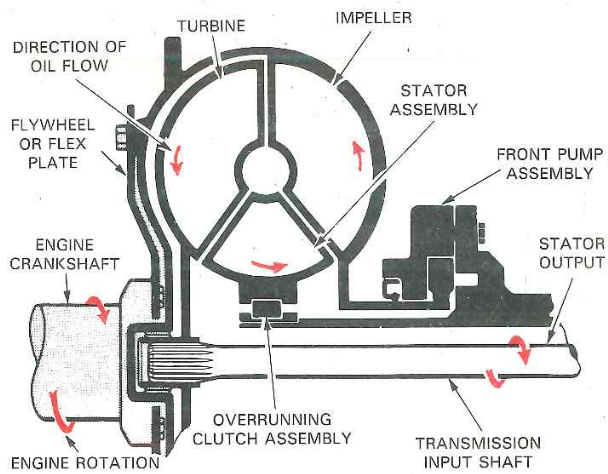


Fig. 54-10. Transmission input shaft extends through stator support. Shaft is splined to turbine. Also note how stator mounts on one-way clutch. (Ford)

An automatic transmission ***input shaft*** or ***turbine shaft*** connects the torque converter with the driving components in the transmission. Look at Fig. 54-10.

Each end of the input shaft has male (external) splines. These splines fit into splines in the torque converter turbine and a driving unit in the transmission. The input shaft rides on bushings. Transmission fluid lubricates the shaft and bushings.

The ***output shaft*** connects the driving components in the transmission with the drive shaft. Refer to Fig. 54-11. This shaft runs in the same centerline as the input shaft. Its front end almost touches the input shaft.

STATOR SUPPORT

The ***stator support,*** also called *stator shaft,* is usually a stationary shaft splined to the torque converter stator

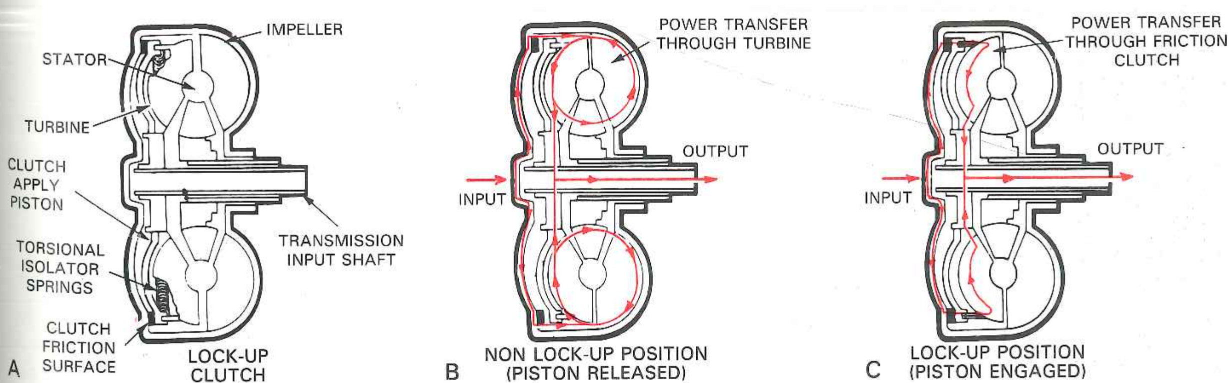


Fig. 54-9. Lock-up torque converter operation. A — Parts of lock-up converter. B — In lower gears, no oil pressure acts on clutch apply piston. Torque converter operates like conventional unit, impeller drives turbine. C — In high gear, oil is transferred into piston chamber. Clutch apply piston forces friction surfaces together. Turbine is mechanically locked to converter housing and impeller. Crankshaft drives transmission input shaft directly, without slippage.

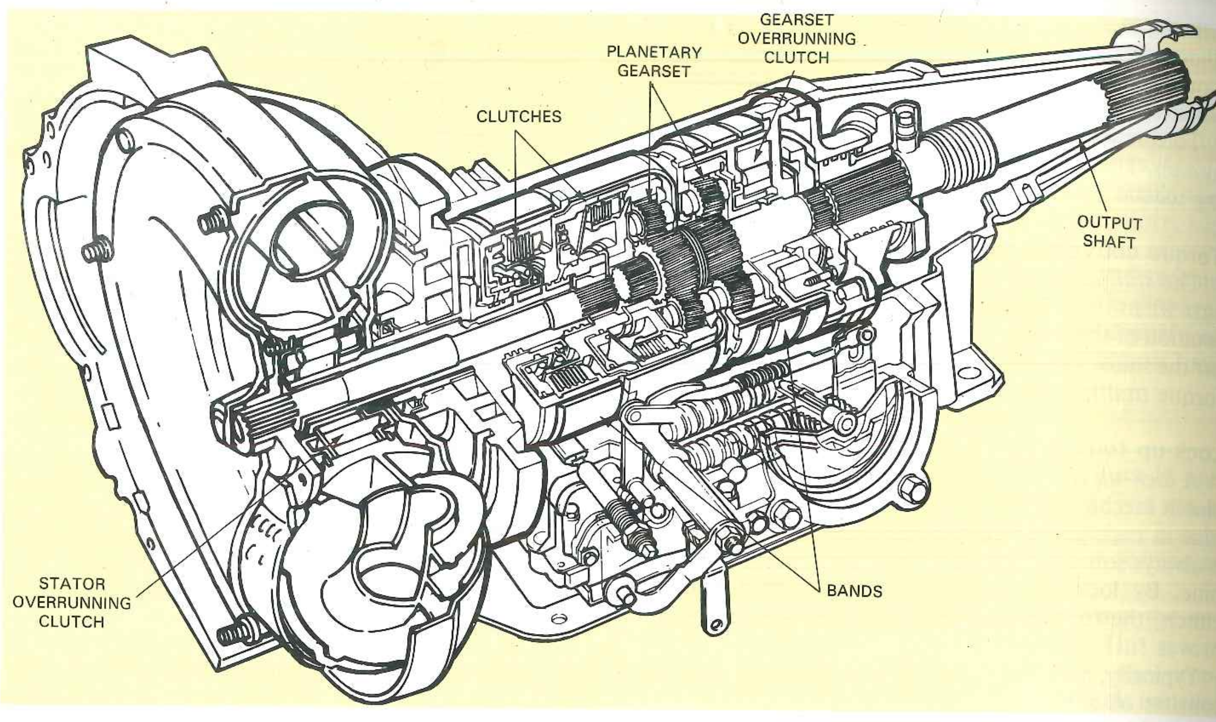


Fig. 54-11. Study location of gearsets and holding devices. Clutches, bands, and rear one-way clutch operate gearsets. Other one-way clutch operates torque converter stator. (Ford Motor Co.)

assembly. As pictured in Fig. 54-10, it is a tube that extends forward from the front of the transmission. It surrounds the input shaft.

PLANETARY GEARS

A *planetary gearset* consists of a sun gear, several planet gears, a planet gear carrier, and a ring gear. A simple planetary gearset is shown in Fig. 54-12.

The name planetary gearset is easy to remember because it refers to our solar system. Just as our planets (Earth, Jupiter, Mars) circle the sun, the planet gears revolve around the sun gear.

As you can see, a planetary gearset is always in mesh. It is very strong and compact. An automatic transmission will commonly use two or more planetary gearsets.

By holding or releasing the components of a planetary gearset, it is possible to:

1. Reduce output speed and increase torque (gear reduction).
2. Increase output speed while lowering torque (overdrive).
3. Reverse output direction (reverse gear).
4. Serve as a solid unit to transfer power (one-to-one ratio).
5. Freewheel to stop power flow (park or neutral).

Planetary reduction

One method of obtaining a gear reduction and torque

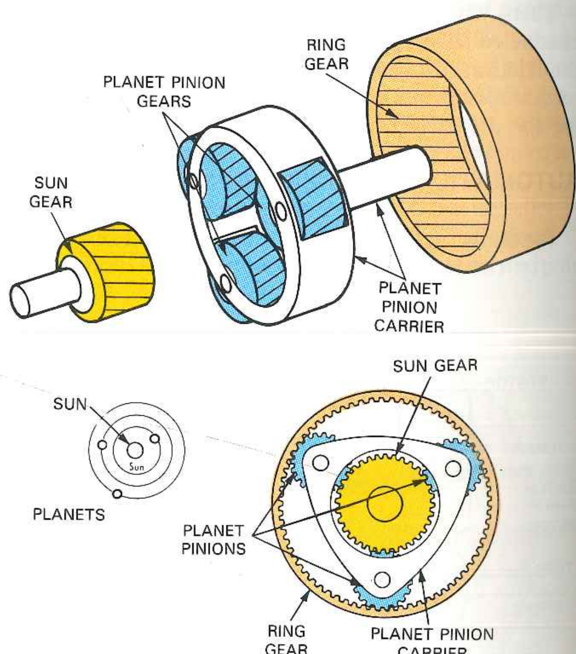


Fig. 54-12. Simplified planetary gearset. Planet gears fit between ring gear and sun gear. Planet gears are mounted on planet carrier. Gears are always in mesh, making a compact, strong, and dependable assembly. Name (planetary gears) is derived from how planet gears revolve around sun gear, like solar system planets.

increase is to hold the sun gear (stop it from turning) while driving the ring gear. This makes the planet carrier the output member. Refer to Fig. 54-13A.

When power turns the ring gear, the planet pinion gears "walk" (rotate) around the locked sun gear. The planet gears move in the same direction as the ring gear, but NOT as fast. As a result, more torque is applied to the output member (planet carrier) and output shaft.

Gear reduction can also be produced in the planetary gearset by turning the sun gear and holding the ring gear.

Planetary overdrive

Driving the carrier while holding the ring gear achieves an overdrive ratio in a planetary gearset. Look at Fig. 54-13B.

The input shaft powers the planet carrier. The sun gear is the output member driving the output shaft. The planet gears "walk" in the ring gear and power the sun gear. The sun gear spins faster than the carrier. Torque is lost but speed is increased.

Planetary reverse

A planetary gearset can also reverse output direction. The input shaft drives the sun gear, as in Fig. 54-13C. The carrier is held and the ring gear turns the output shaft. The planet pinion gears simply act as idler gears. They reverse the direction of rotation between the sun gear and ring gear.

Planetary direct drive

A planetary gearset will act as a solid unit when TWO of its members are held. This causes the input and output members to turn at the same speed, Fig. 54-13D.

Planetary neutral

When none of the planetary members are held, the unit will NOT transfer power. This freewheeling condition is used when an automatic transmission is placed in neutral or park.

Compound planetary gearset

A *compound planetary gearset* combines two

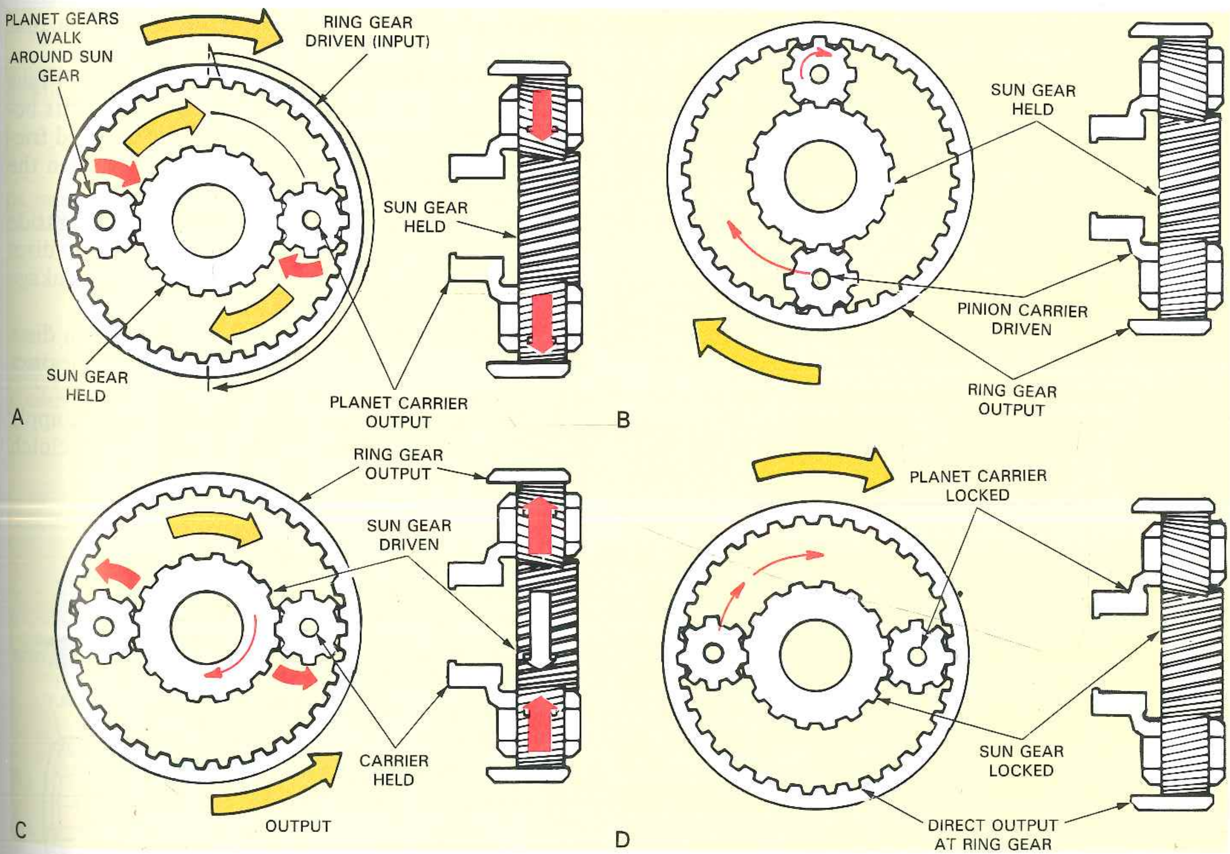


Fig. 54-13. Study how different planetary gearset members can be held to provide different gear ratios and reverse. A — Simple gear reduction. Sun gear is stationary. Ring gear is driven. Planet carrier is output. Input torque increases and speed decreases. B — Overdrive. Sun gear is held stationary. Pinion carrier is driven. Ring gear is output and turns faster than input. C — Simple reverse gear. Pinion carrier is held. Sun gear is driven. Ring gear turns backwards as output. D — Direct drive results when any two members of planetary gearset are held, or by driving any two members from same input.

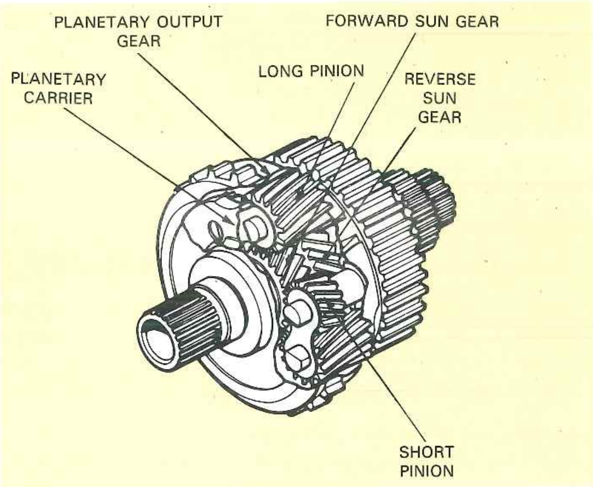


Fig. 54-14. Compound planetary gearset acts like two gearset assemblies mounted together. Normally, a common ring gear is used for two separate sets of planet gears. (Subaru)

planetary units in one housing or ring gear. It may have two sun gears or a long sun gear to operate two sets of planet pinion gears, Fig. 54-14.

With this design, short planet gears engage forward sun gear. Long planet gears mesh with the rear sun gear. The ring gear engages both sets of planet gears.

Another design, called Simpson Compound Gearset, uses a long sun gear to operate two sets of planet gears on the same ring gear. This type is common.

A compound planetary gearset is used because it can provide more forward gear ratios than a simple planetary gearset.

CLUTCHES AND BANDS

Automatic transmission *clutches* and *bands* are friction devices that drive or lock planetary gearset members. They are used to cause the gearsets to transfer power. Refer again to Figs. 54-1 and 54-11.

Multiple disc clutches

A *multiple disc clutch* has several clutch discs that can be used to couple or hold planetary gearset members. As shown in Fig. 54-15, the front clutch assembly usually drives a planetary sun gear. The next clutch transmits power to the planetary ring gear when engaged. This can vary, however.

A clutch assembly generally consists of a drum, hub, apply piston, spring(s), driving discs, driven discs, pressure plate, and snap rings.

Clutch construction

The ***clutch drum,*** also called a *clutch cylinder,* encloses the apply piston, discs, pressure plate, seals, and other parts of the clutch assembly, Fig. 54-15.

The ***clutch hub*** fits inside the clutch discs and clutch drum. It has teeth on its outer surface that engage the teeth on the driving discs. The front clutch hub is also splined to the transmission input shaft.

The ***driving discs*** are usually covered with friction lining. They have teeth on their inside diameter that engage the clutch hub. See Fig. 54-15.

The ***driven discs*** are steel plates that have outer tabs that lock into the clutch drum. A driven disc fits between each driving disc. This enables the hub and friction discs to turn the steel discs and drum when the clutch is activated.

The ***clutch apply piston*** slides back and forth inside the clutch drum to clamp the driving and driven discs together. Seals fit on the piston to prevent fluid leakage during clutch application.

The ***pressure plate*** serves as a stop for clutch discs when the piston is applied. The piston pushes the discs against the pressure plate. Look at Fig. 54-15.

A ***clutch spring*** or springs are used to push the apply piston away from the clutch discs during clutch disengagement. One is shown in Fig. 54-15.

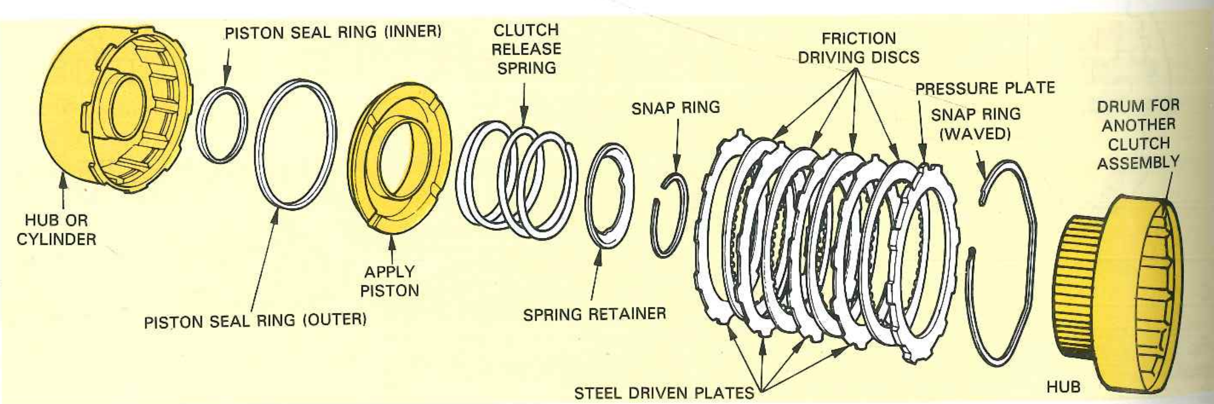


Fig. 54-15. Study construction of clutch assembly from automatic transmission. Clutch parts and hub fit inside clutch drum. Also note difference in clutch discs. Driving discs are splined to hub. Driven discs are locked in drum by tabs. (Chrysler)

Clutch operation

When oil pressure is blocked from the piston, the return spring pushes the clutch discs apart, Fig. 54-16A. Power is no longer transferred through the clutch. The driving and driven discs are free to turn independently.

During clutch engagement, oil pressure is routed into the clutch drum. Shown in Fig. 54-16B, oil pressure acts on the large piston. The piston is then forced into the clutch discs. Friction locks the driving and driven discs together to transfer power through the clutch assembly.

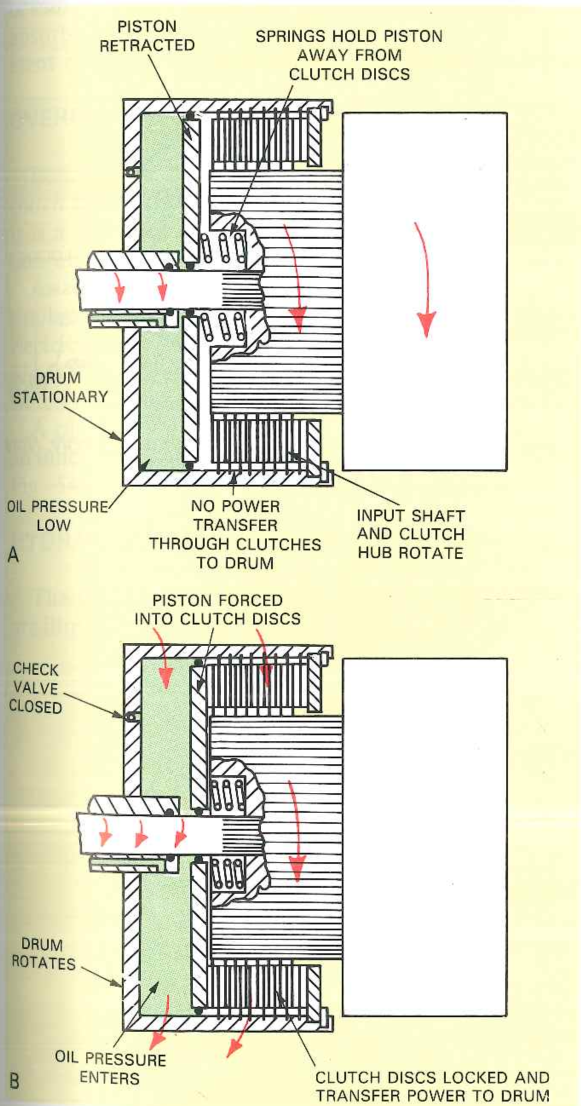


Fig. 54-16. Basic clutch operation. A — No oil pressure enters drum. Springs hold piston away from clutch discs. Input shaft turns clutch hub and driving discs but driven discs and drum remain stationary. B — Oil is routed into clutch drum. Oil pressure pushes piston into clutch discs, forcing discs into pressure plate. This locks discs, hub, and drum together. Power is then transferred from input to drum.

Driving shell

A *driving shell* or *clutch shell* is commonly used to transfer power to one of the planetary sun gears, Fig. 54-17. It is a thin, metal cylinder-shaped part that frequently connects the front clutch drum and sun gear.

The shell may surround the second clutch assembly and forward planetary gearset. Tabs on the shell fit into notches on the front clutch drum. This makes the shell, drum, and sun gear turn together.

Bands and servos

Automatic transmission ***bands*** are also friction devices for holding members of the planetary gearsets. Two or three bands are commonly used in modern transmissions. Bands are shown in Figs. 54-1, 54-11, 54-17, and 54-18.

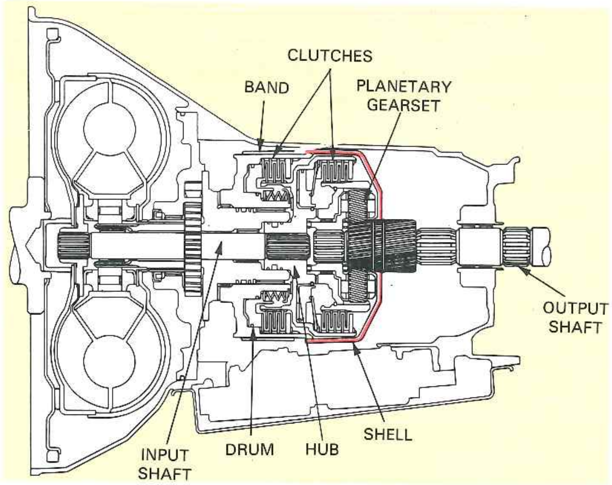


Fig. 54-17. Drive shell connects front drum to sun gear. Note how it surrounds second clutch assembly and front planetary gearset. When front clutch is locked, shell turns sun gear. Also note band used to hold front drum and sun gear stationary. (Ford)

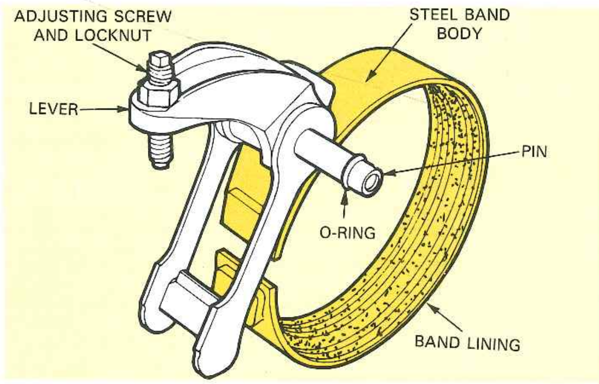


Fig. 54-18. Band is steel strap with friction lining on its inner surface. One end of band is anchored in case. (Dodge)

Servos are apply pistons that operate the bands. Fig. 54-19 shows the parts of a band and servo assembly.

Band and servo construction

A band is a steel strap with *lining* (friction material) on its inner surface. The band's lining can be clamped around clutch drum to stop drum rotation.

The friction material on the inside of the band is designed to operate in automatic transmission fluid. It resists the lubricating qualities of the fluid.

The *servo piston* is a metal plunger that operates in a cylinder machined in the transmission case. Rubber seals fit around the outside of the piston to prevent fluid leakage. See Fig. 54-20.

A rod on the servo piston attaches to one end of the brake band. The other end of the brake band is anchored to the transmission case.

A *band adjustment screw* provides a means of adjusting the band-to-drum clearance. It moves the band closer to the drum as the friction material wears.

Servo seals prevent fluid leakage around the servo piston and cylinder. Snap rings hold the piston in its cylinder.

Transmission band operation

To activate a brake band, oil pressure is sent into the servo cylinder. Pressure acts on the servo piston. The piston then slides in the cylinder and pushes on one end of the brake band, as in Fig. 54-20.

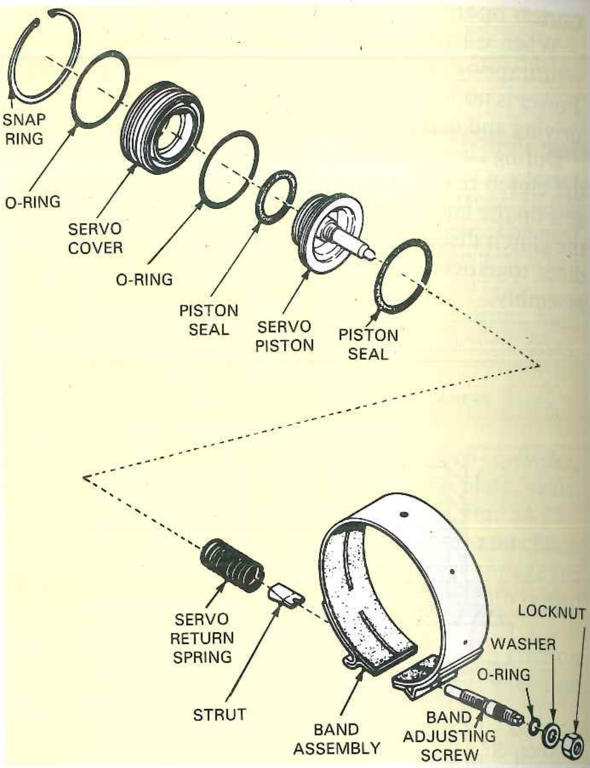


Fig. 54-19. Exploded view of band and servo assembly. Note relationship between parts. (Subaru)

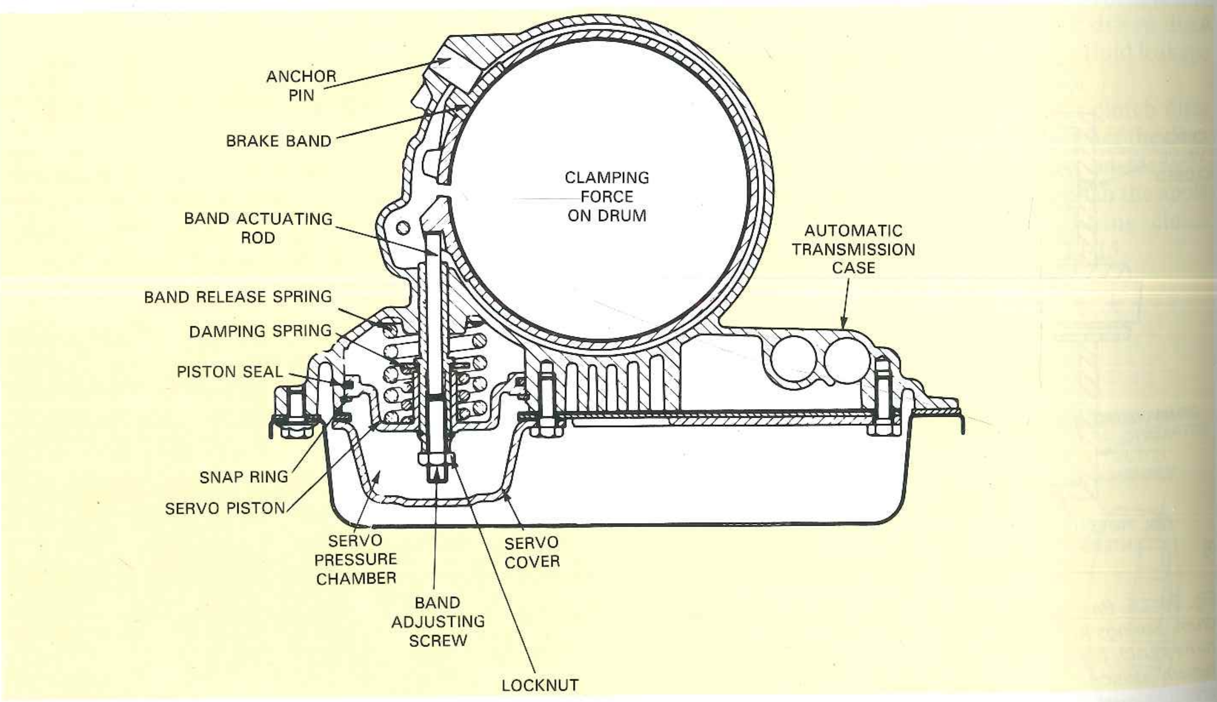


Fig. 54-20. Servo piston and band action. When oil pressure enters servo pressure chamber, servo piston slides up in cylinder. Actuating rod then pushes on band to squeeze band inward on drum. (Fiat)

Since the other end of the band is anchored, the band tightens or squeezes around the drum. The friction material rubs on the drum and stops it from turning. This keeps one of the planetary components from revolving.

When the oil flow to the piston servo is blocked, the servo spring pushes on the piston. This slides the piston rod away from the band. The band then releases the drum and planetary gearset member.

Accumulator

An *accumulator* is used in the apply circuit of a band or clutch to cushion initial application. It temporarily absorbs some of the oil pressure to cause slower movement of the apply piston.

OVERRUNNING CLUTCHES

Besides the bands and clutches, an *overrunning clutch* can be used to hold a planetary gearset member. It is a one-way, roller clutch that locks in one direction and freewheels in the other.

An overrunning clutch for the planetary gears is similar to the ones in a torque converter stator or an electric starting motor drive gear. The typical locations of automatic transmission overrunning clutches (stator clutch and gearset clutch) are illustrated in Fig. 54-11.

A planetary gearset overrunning clutch consists of an inner race, set of springs, rollers, and an outer race. Fig. 54-21 shows overrunning clutch operation.

HYDRAULIC VALVE ACTION

The basic action of a hydraulic valve and a piston are illustrated in Fig. 54-22. Oil pump pressure causes oil to flow through the spool valve pressure lines to the left end of the piston cylinder. This pushes the piston to the right.

When the spool valve is moved the other way, pump pressure is not sent to the piston. The piston is then forced back into its cylinder.

Valves like this are used to operate the band servos and clutch pistons.

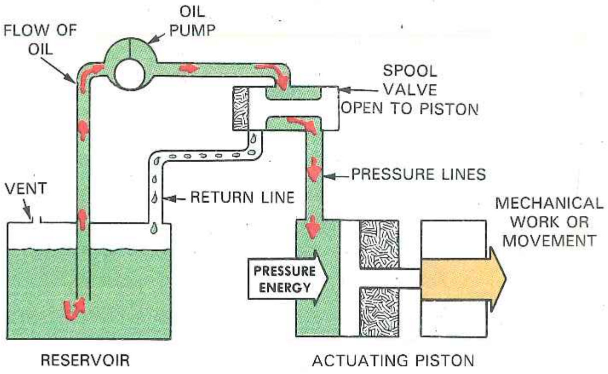


Fig. 54-22. Basic hydraulic circuit. Pump draws oil out of reservoir and forces it through spool valve. In this position, spool valve routes oil to piston. Piston uses oil pressure to produce movement or clamping pressure. (Chrysler)

HYDRAULIC SYSTEM

The *hydraulic system* for an automatic transmission typically consists of a pump, pressure regulator valve, manual valve, vacuum modulator valve, governor valve, shift valves, servos, pistons, and valve body.

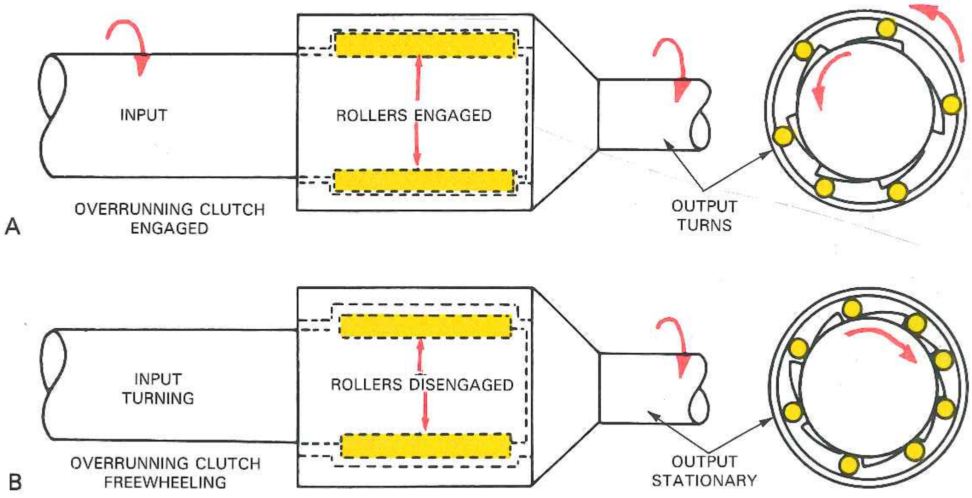


Fig. 54-21. Overrunning or one-way clutch action A — When driven in one direction, rollers lock between ramps on inner race and on outer race. Both races turn together. This action can also be used to stop movement of planetary member, for example. B — When turned in other direction, rollers walk off ramps. Two races are free to turn independently. (Deere & Co.)

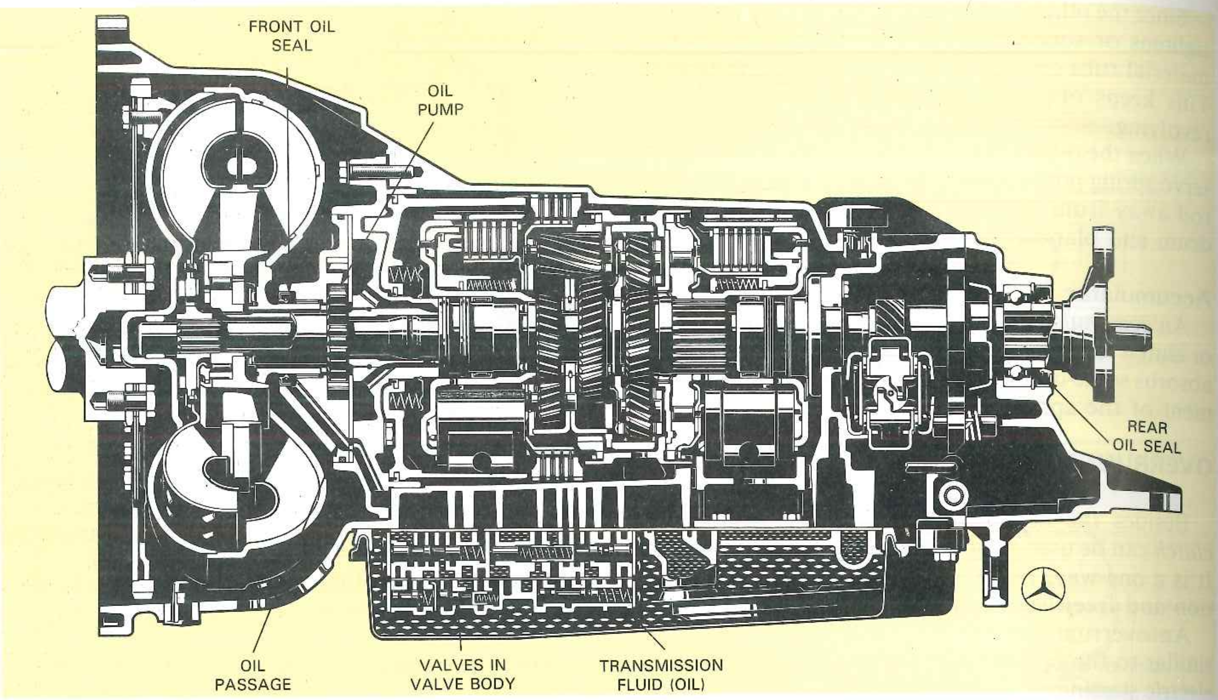


Fig. 54-23. Oil pump is normally located in front of case. Oil is drawn out of pan, circulated through passages to hydraulic components. Also note location of oil seals. (Mercedes Benz)

These parts work together to form the "brain" (sensing) and "muscles" (control) of an automatic transmission. See Fig. 54-23.

The hydraulic system also forces oil to high friction points in the transmission. This prevents wear and overheating by lubricating the moving parts.

Hydraulic pump (oil pump)

The *hydraulic pump,* also called the *oil pump,* produces the pressure to operate an automatic transmission. Automatic transmissions can have one or two pumps. They are often located behind the torque converter or in the valve body.

Look at Fig. 54-23. The sleeve or collar on the rear of the torque converter drives the pump.

The automatic transmission oil pump has several basic functions:

1. Produces pressure to operate the clutches, bands, and gearsets.
2. Lubricates the moving parts in the transmission.
3. Keeps the torque converter filled with oil for proper operation.
4. Circulates oil through the transmission and cooling tank (radiator) to transfer heat.
5. Operates hydraulic valves in the transmission.

There are two commonly used oil pumps: the gear type and the rotor type, Fig. 54-24.

When the torque converter spins the oil pump, transmission fluid is drawn into the pump from the

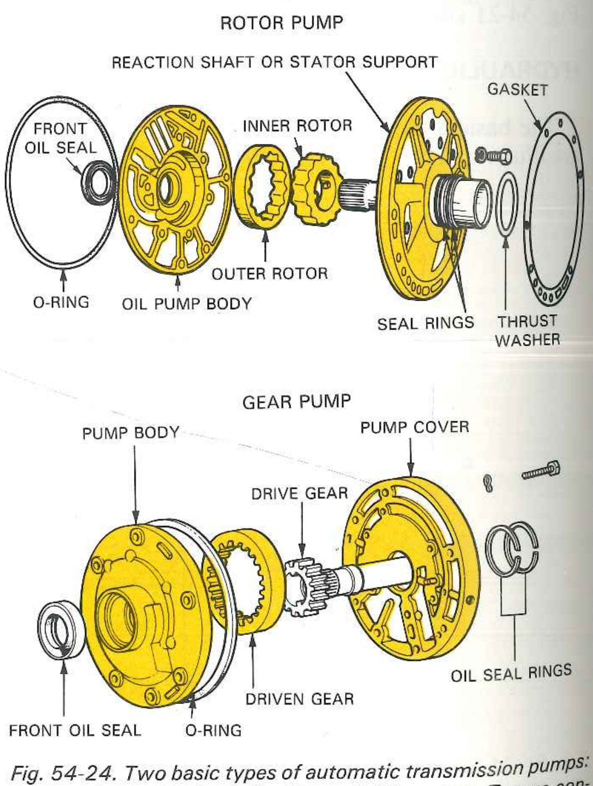


Fig. 54-24. Two basic types of automatic transmission pumps: rotor and gear. Study similarities and differences. Torque converter normally drives pump. (Chrysler and Toyota)

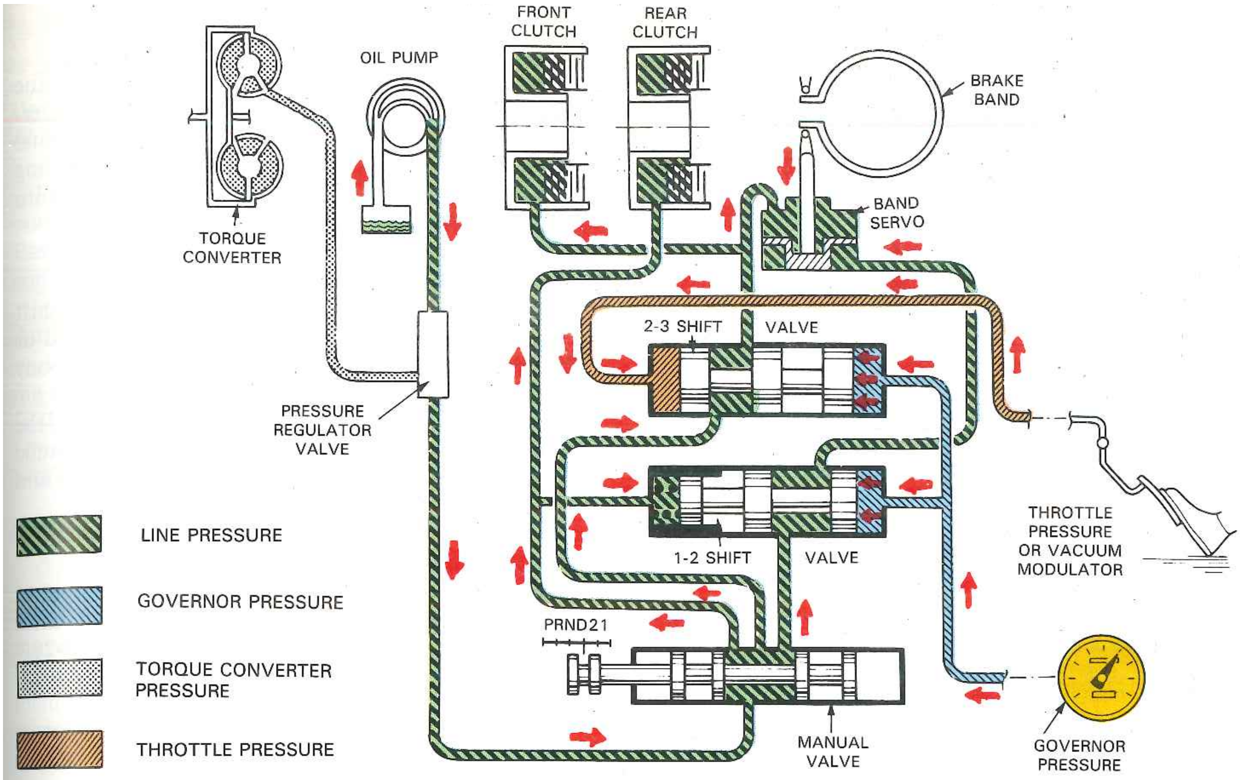


Fig. 54-25. Simplified circuit showing hydraulic action in automatic transmission. Manual valve pressure, throttle valve pressure, and governor valve pressure operate balance or shift valves. Shift valves then direct oil pressure to correct clutch or band pistons. Study this diagram carefully. (Nissan)

pan. The pump compresses the oil and forces it to the pressure regulator. This is illustrated in Fig. 54-25.

Pressure regulator

The *pressure regulator* limits the maximum amount of oil pressure developed by the oil pump, Fig. 54-25. It is a spring-loaded valve that routes excess pump pressure out of the hydraulic system. This assures proper transmission operation.

Manual valve

A *manual valve,* operated by the shift mechanism, allows the driver to select park, neutral, reverse, or different drive ranges. When the gear shift lever is moved, the shift linkage moves the manual valve. As a result, the valve routes oil pressure to the correct components in the transmission. Look at Fig. 54-25.

Vacuum modulator valve

The *vacuum modulator valve,* also termed *throttle valve,* senses engine load (vacuum) and determines when the transmission should shift to a higher gear. Refer to Figs. 54-25 and 54-26. A vacuum line runs from the engine intake manifold to this valve.

As engine vacuum (load) rises and falls, it moves the diaphragm inside the vacuum modulator. This, in turn, moves the rod and hydraulic valve to change throttle control pressure in the transmission. In this way, the vaucum modulator can match transmission shift points to engine loading.

For example, if a vehicle is climbing a steep hill (under a heavy pull), engine vacuum will be very low. This will allow the spring in the modulator to slide the modulator valve further into the transmission. The valve then directs oil pressure to delay the upshift. The transmission stays in a lower gear longer to allow the car to accelerate up the hill. Look at Fig. 54-26.

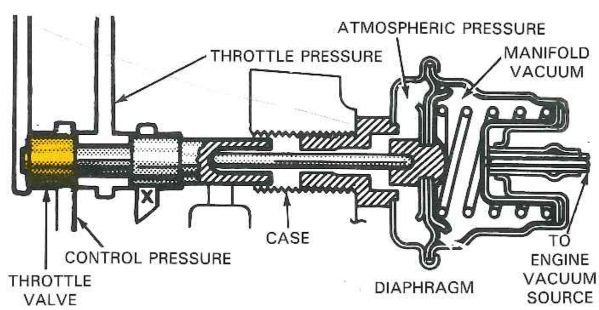


Fig. 54-26. Vacuum modulator operates throttle valve. Engine vacuum allows modulator to sense engine load. For example, with engine acceleration and high load, vacuum drops. The vacuum modulator spring could then overcome vacuum pull on the diaphragm. The spring would push the valve to the left. This would alter throttle oil pressure, keeping the transmission in a lower gear. (Ford)

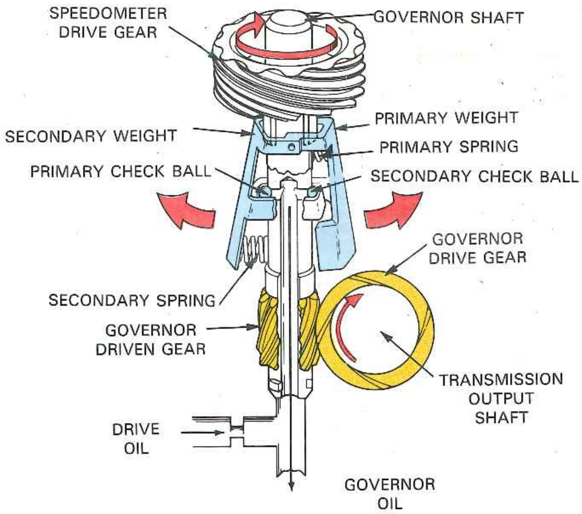


Fig. 54-27. Governor senses engine vehicle speed. Gear on transmission output shaft spins governor. As speed increases, centrifugal weights are thrown outward. This opens the governor valve enough to change governor pressure and cause an upshift. (Cadillac)

Governor valve

The *governor valve* senses vehicle speed to help control gear shifting. The vacuum modulator and governor work together to determine shift points. See Fig. 54-25.

Illustrated in Fig. 54-27 is one type of governor assembly. It consists of a drive gear, centrifugal weights, springs, hydraulic valve, and shaft. The governor gear is usually meshed with a gear on the transmission output shaft. Whenever the car and output shaft are moving, the centrifugal weights rotate.

When the output shaft and weights are spinning slowly, the weights are held IN by the governor springs. This causes a low pressure output and the transmission remains in a low gear ratio.

As engine and shaft speed increase, the weights are thrown out further and governor pressure increases. This moves the shift valve and causes the transmission to shift to a higher gear.

Other types of governor valves are also used. However, they do the same job.

Shift valves (balanced valves)

Shift valves, also called *balanced valves,* use control pressure (oil pressure from regulator, governor, throttle, and manual valves) to operate the bands, servos, and gearsets. Fig. 54-25 shows how the shift valves are connected to the other transmission components.

Oil pressure from the other transmission valves act on each end of the shift valves. For example, if the pressure from the governor is high and the pressure from the throttle and manual valves are low, the shift valves will be moved sideways in their cylinder.

In this way, the shift valves are sensitive to engine load (throttle valve oil pressure), engine speed (governor valve oil pressure) and gear shift position (manual valve oil pressure). The shift valves move according to these forces and keep the transmission shifted into the correct gear ratio for the driving conditions.

Kickdown valve

A *kickdown valve* causes the transmission to shift into a lower gear during fast acceleration. A rod or cable links the carburetor or fuel injection throttle body to a lever on the transmission.

When the driver presses down on the gas pedal, the lever moves the kickdown valve. This causes hydraulic pressure to overide normal shift control pressure and the transmission downshifts, Fig. 54-28.

Valve body

The *valve body* contains many of the hydraulic valves (pressure regulating valve, shift valves, manual valve, etc.) of an automatic transmission. See Fig. 54-28.

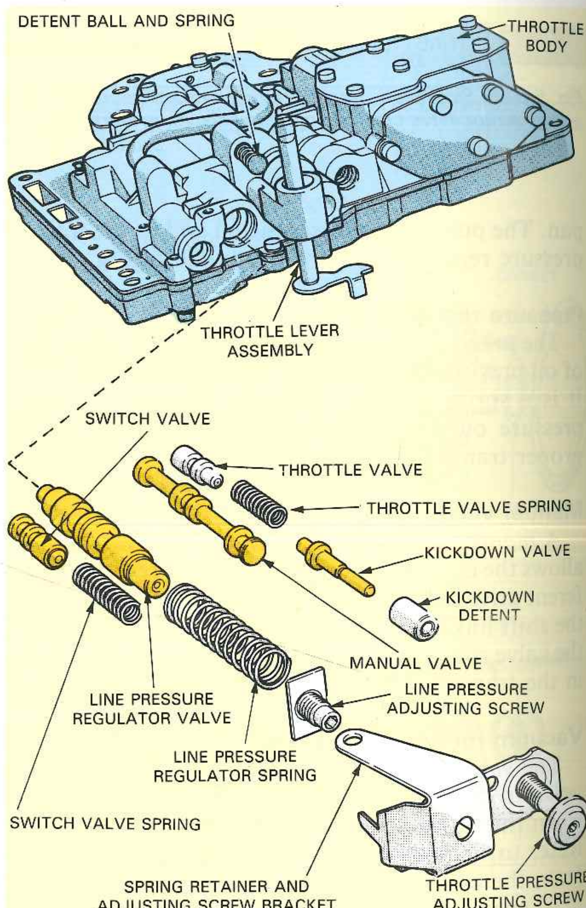


Fig. 54-28. Valve body bolts to bottom of transmission case. It houses manual valve, pressure regulator valve, kickdown valve, and other valves. (Plymouth)

The valve body bolts to the bottom of the transmission case. It is housed in the transmission pan. A filter or screen is usually attached to the bottom of the valve body, Fig. 54-29.

Passages in the valve body route fluid from the pump to the valves and then into the transmission case. Passages in the case carry fluid to the other hydraulic components.

Automatic transmission fluid

Automatic transmission fluid is a special type oil having several additives that make it compatible with the friction clutches and bands in the transmission. Different types of automatic transmission fluids are available for different transmissions.

Transmission oil cooling

A tremendous amount of heat is developed inside an automatic transmission. When the torque converter slips, friction heats the fluid. This heat must be removed or transmission failure could result.

Many transmissions have an oil cooling system which includes external oil lines and a cooling tank inside the engine radiator. Look at Fig. 54-30.

When the engine is running, the transmission pump forces oil through the cooling lines and into the radiator tank. Since transmission oil is hotter than the engine coolant, oil temperature drops. The cooled oil returns to the transmission through the other line.

Some cars, especially those designed to pull a heavy load (trailers, boats) have an auxiliary *transmission oil cooler*. It is a small radiator, separate from the engine radiator. Air passes over the radiator to cool the transmission fluid.

PARKING PAWL

A *parking pawl* is used to lock the transmission output shaft and keep the car from rolling when not in use. Fig. 54-31 shows its basic action.

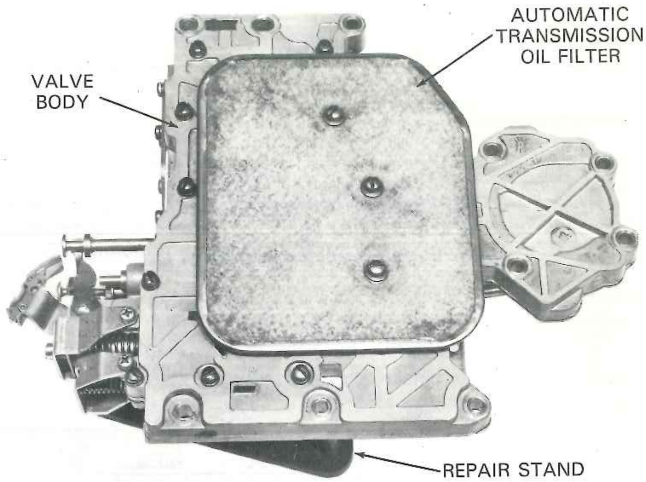


Fig. 54-29. Oil filter is fastened to bottom of valve body. It removes particles of dirt before they can enter hydraulic circuit. (Chrysler Corp.)

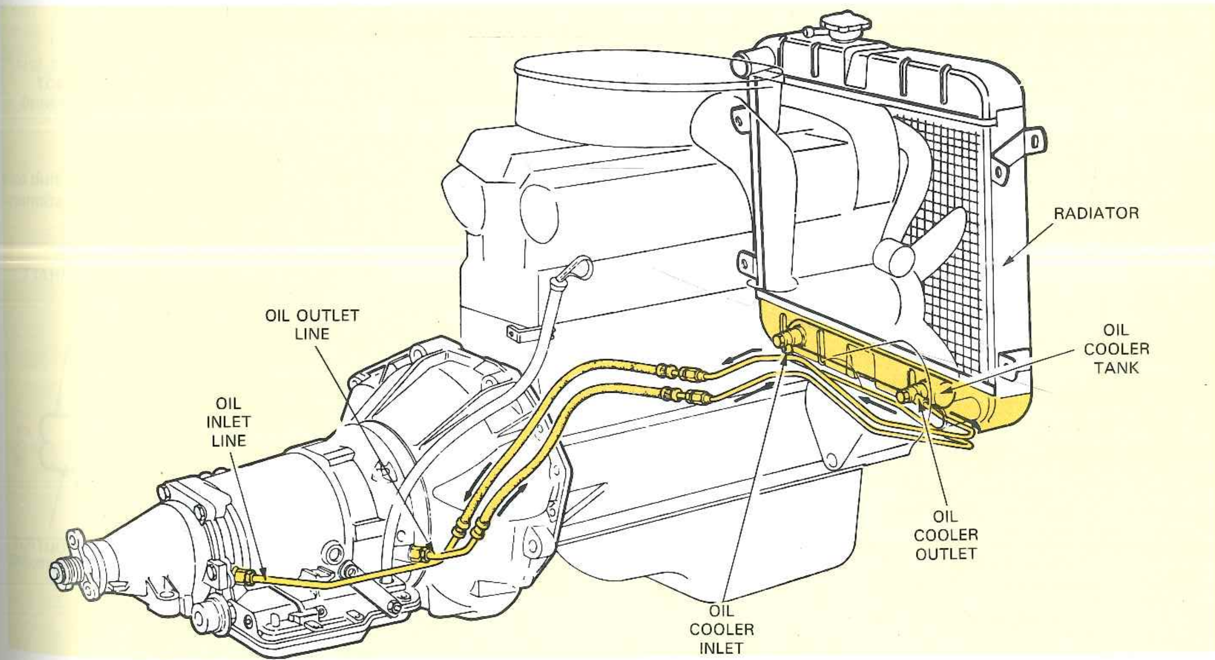


Fig. 54-30. Oil cooler tank is commonly used in transmission. Oil pump pushes oil through lines and cooler tank to maintain acceptable oil temperature. (Fiat)

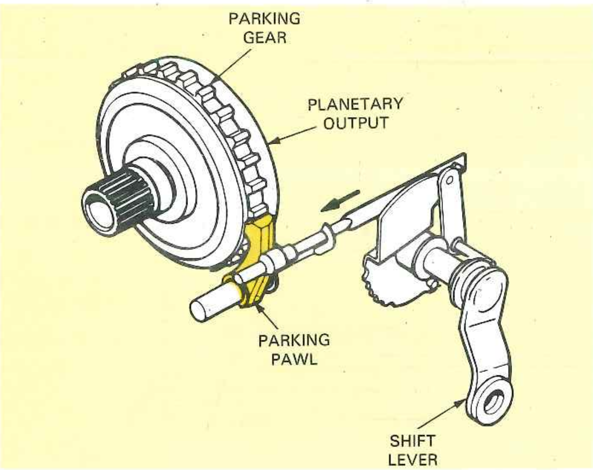


Fig. 54-31. Parking pawl is simply a latch that locks into large teeth on parking gear. Since pawl is mounted on case, this locks parking gear and output shaft. (Subaru)

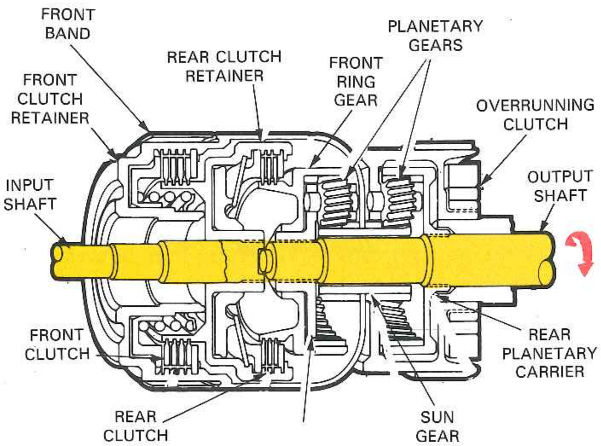
AUTOMATIC TRANSMISSION POWER FLOW

The flow of power through an automatic transmission depends on its specific design. However, you should have a GENERAL understanding of how power is transmitted through the major parts of modern transmissions.

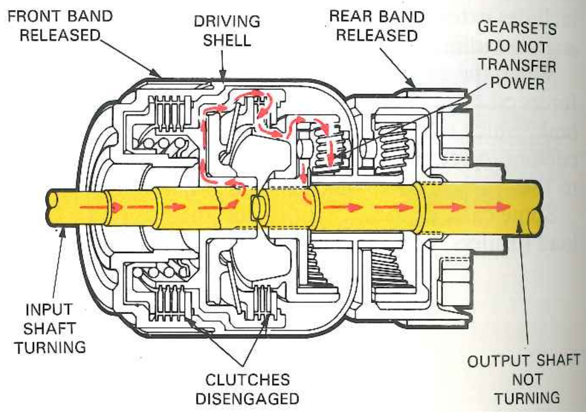
Fig. 54-32 shows how torque moves from the input shaft to the output shaft. This is a typical three-speed transmission. Study each illustration carefully, noting which clutches, bands, and gearset members are activated.

Overdrive power flow

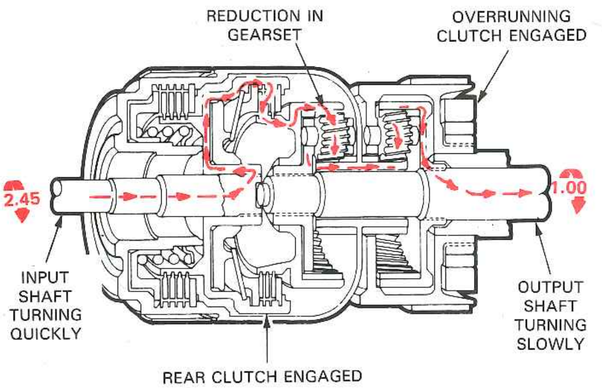
Fig. 54-33 shows the power flow through a late model, four-speed, overdrive automatic transmission in high gear. This is a new design that uses two input shafts (turbine shaft and direct input shaft). Trace the power flow and compare it to the other more conventional transmissions covered earlier.



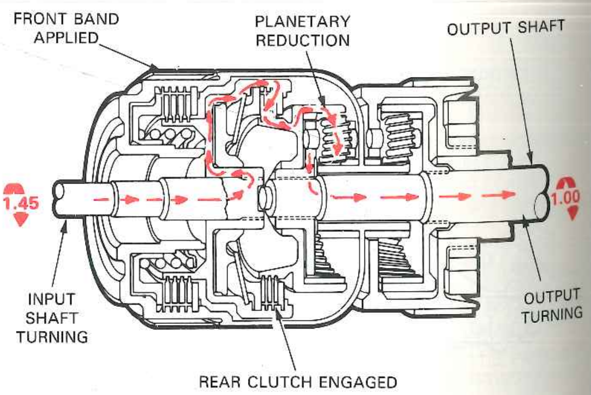
A – Study parts relating to power flow.



B – Neutral. Clutches and bands disengaged. Input shaft and hub turn but power does not flow through clutches or drum. Output stationary.

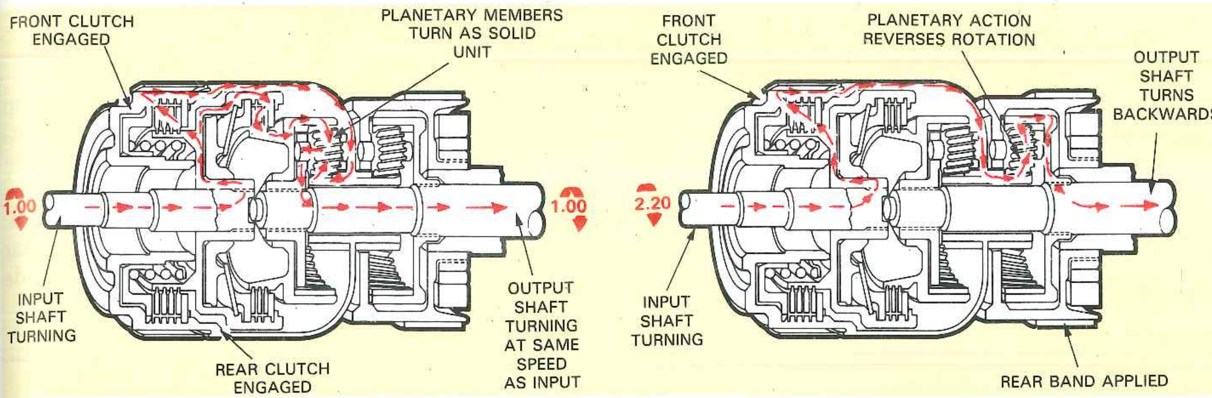


C – First gear. Rear clutch and overrunning clutch engaged. Gear reduction through planetary gearsets results in high ratio, high torque output to driveline.



D – Second gear. Front band applied. Rear clutch engaged. Power flows through input, hub, clutch, drum, and front gearset to output. Less reduction results.

Fig. 54-32. Power flow through a typical automatic transmission. (Chrysler)



E — Third gear. Front and rear clutches engaged. Planetary members locked for direct drive. One-to-one ratio for higher vehicle speeds results.

F — Reverse. Front clutch and rear band applied. Power flows through clutch, shell, and sun gear to rear planetary gearset which reverses rotation.

(Fig. 54-32 continued)

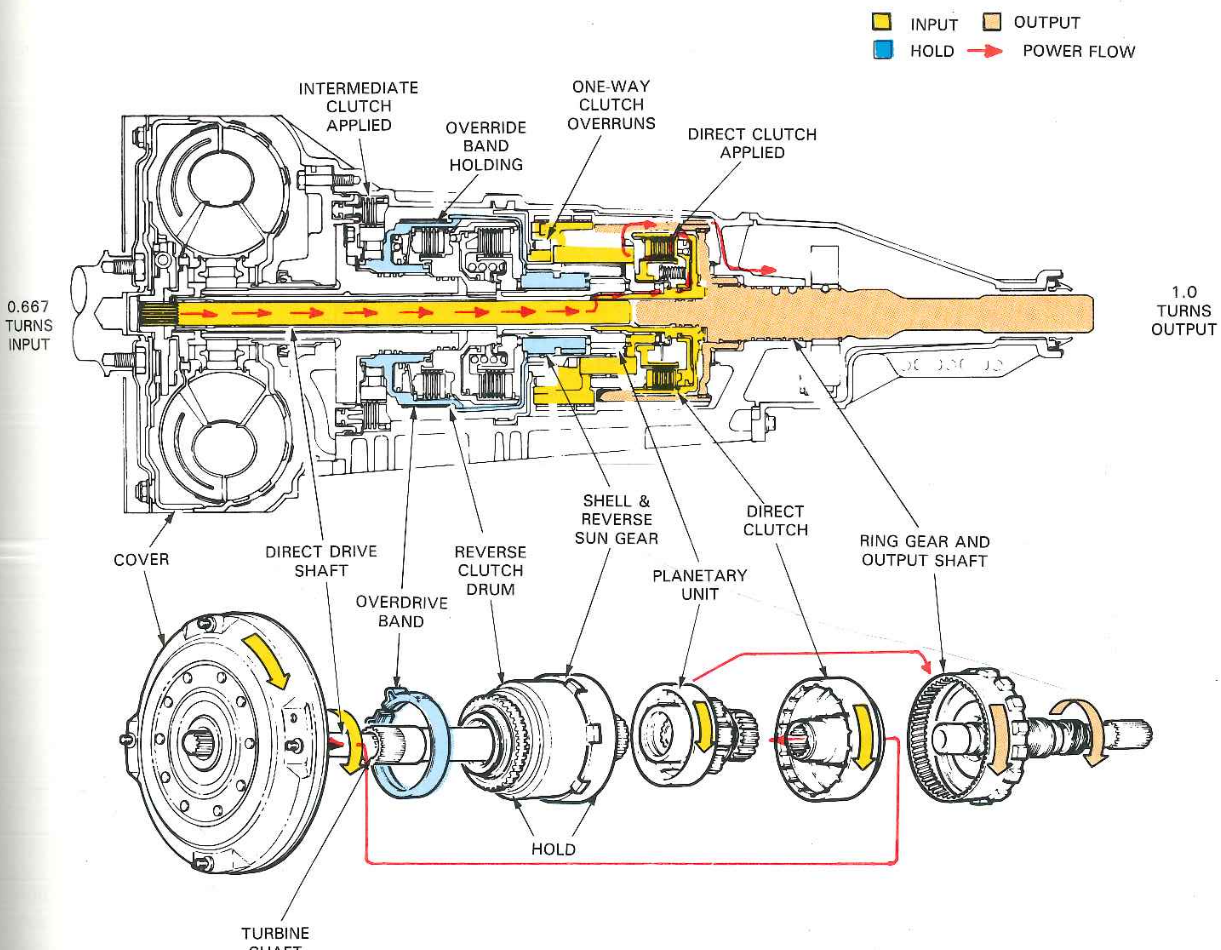


Fig. 54-33. Power flow in high gear of modern four-speed automatic with overdrive. Study differences with transmissions already covered in chapter. (Ford)

COMPLETE TRANSMISSION ASSEMBLIES

Fig. 54-34 through 54-36 show different types of automatic transmissions. Study each closely. As you look at each part, try to remember its function.

Refer to service manuals for more information on a particular automatic transmission. The manual will give hydraulic circuit diagrams, specific illustrations, as well as detailed operating and construction descriptions for major components.

AUTOMATIC TRANSMISSION ELECTRONIC CONTROLS

Many new vehicles use the on-board computer to help control transmission shift points and monitor transmission operation. A simplified diagram of an electronic control system is given in Fig. 54-37.

The computer typically monitors engine speed, load, throttle position, transmission output shaft speed, gear shift position, and other variables. It can then provide

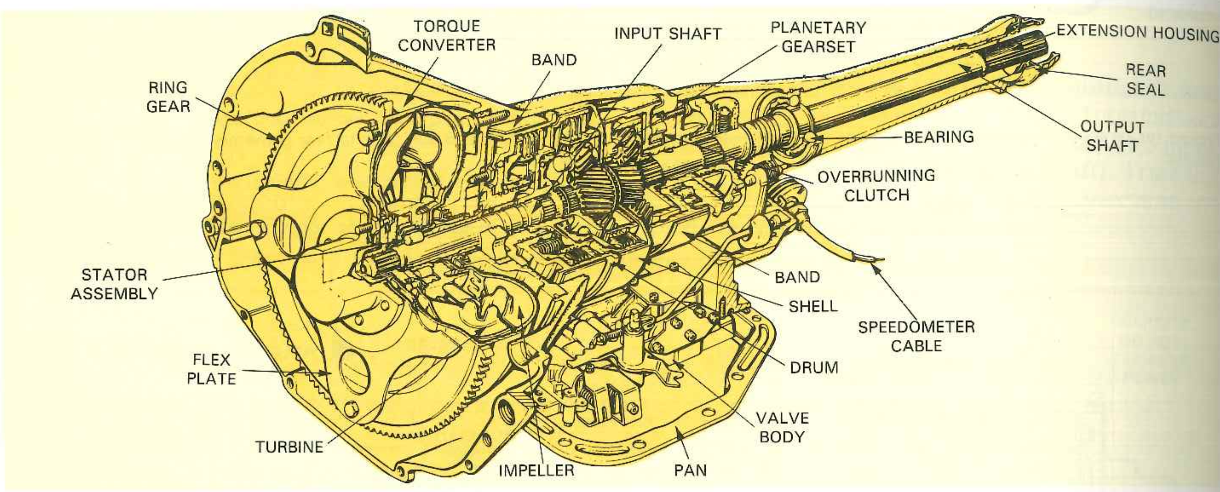


Fig. 54-34. This is a three-speed automatic transmission. Study part locations. Can you recall their function? (Dodge)

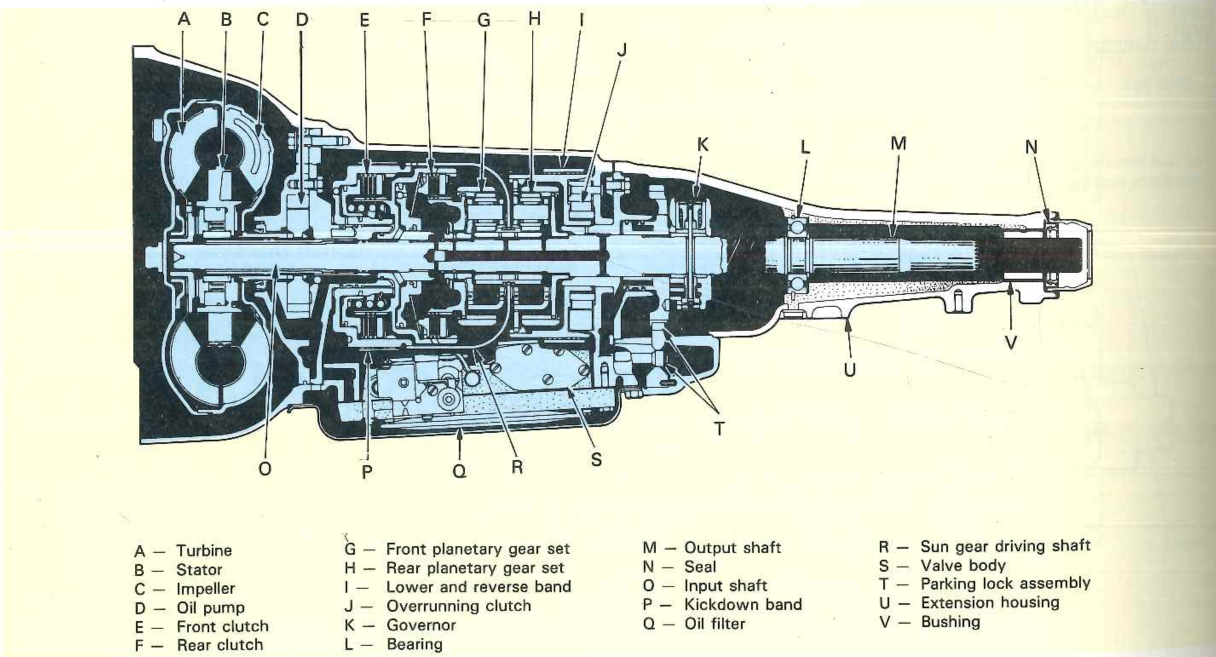


Fig. 54-35. Cutaway of Chrysler Torqueflite transmission. Compare it to the transmission in previous illustration. (Chrysler Corporation)

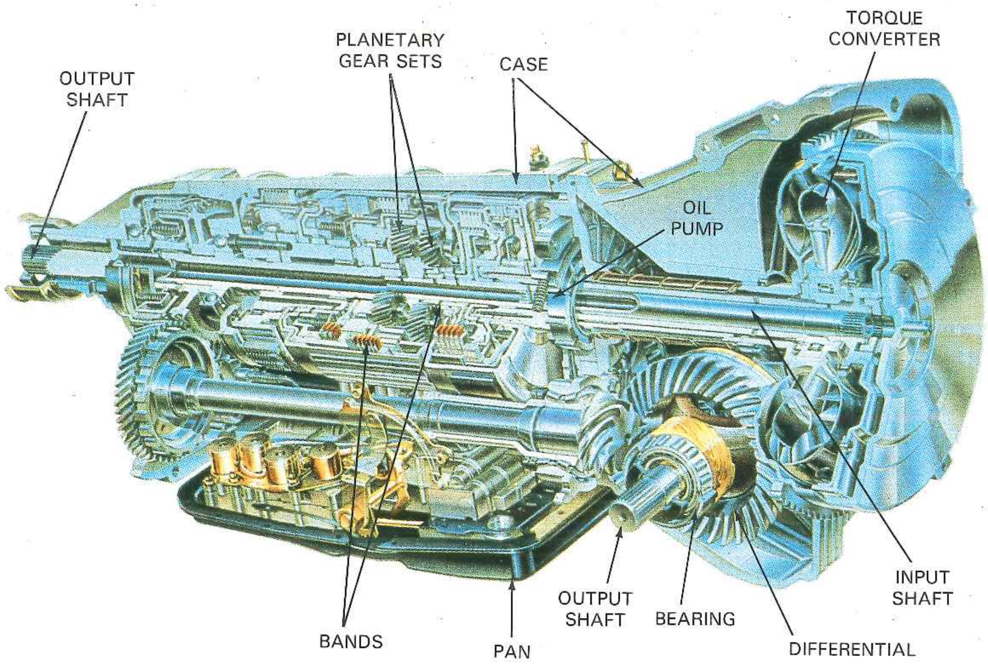


Fig. 54-36. Cutaway view shows internal parts of an all-wheel automatic transmission. (Subaru)

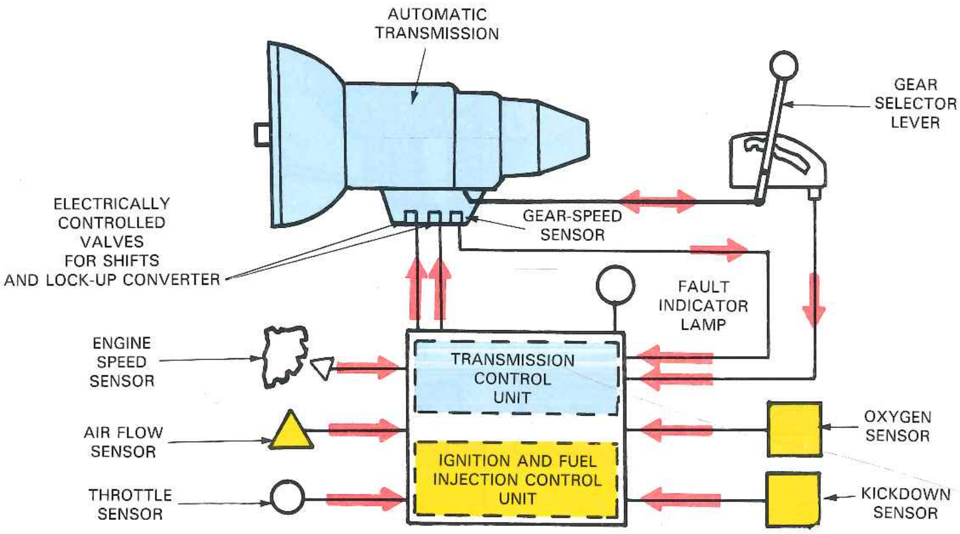


Fig. 54-37. Some late model automatic transmissions use a computer to help control shift points. Note flow of data to and from computer and transmission.

control for transmission shift points, torque converter lockup, ignition timing, fuel injection timing, emission control system operation, and other functions. This keeps the transmission and other engine systems functioning at maximum efficiency.

ELECTRONIC TRANSMISSION CONTROL

Electronic transmission control involves using sensors, actuators, and a computer to controls shift points, torque converter lockup, etc. Basically, solenoids on the transmission can be used to move hydraulic valves. This allows the computer to help control automatic transmission operation.

Note! For more information on computers, sensors, actuators, and electronic control of automotive transmissions, refer to Chapters 74, 75, and 76 in the back of the book.

CONTINUOUSLY VARIABLE TRANSMISSION

A *continuously variable transmission,* abbreviated CVT, has an infinite number of driving ratios, NOT three, four, or five forward speeds, as with conventional transmissions. It uses centrifugally operated two-piece pulleys whose diameters are variable. V-belts—usually two of them—run between the pulley sets. This arrangement takes the place of the planetary gearsets.

Fig. 54-38 shows a simplified drawing of a CVT. During initial acceleration, a small drive pulley turns a larger pulley, drive reduction results.

As speed increases, centrifugal force pushes the halves of the drive pulley together. The belt rides out in the pulley, increasing the pulley's effective diameter. As a result, a larger pulley drives a smaller pulley for more vehicle speed.

A CVT transmission is used in some foreign makes and is being experimented with by many U.S. manufacturers. It is capable of increasing fuel economy approximately 25 percent because it keeps the engine at its most efficient operating speed. Engine rpm can be kept relatively constant. The engine does NOT have to accelerate through each gear. The result is an almost perfectly smooth increase in vehicle speed.

KNOW THESE TERMS

Converter housing, Case, Extension housing, Torque converter, Impeller, Stator, Turbine, Lock-up converter, Overrunning clutch, Torque multiplication, Stall speed, Stator support, Planetary gearset, Multiple disc clutch, Clutch piston, Drum, Hub, Shell, Band, Servo, Oil pump, Pressure regulator, Manual valve, Kickdown valve, Valve body, Accumulator, Automatic transmission fluid, Transmission cooler, Parking pawl, Automatic transmission electronic controls, Continuously variable transmission.

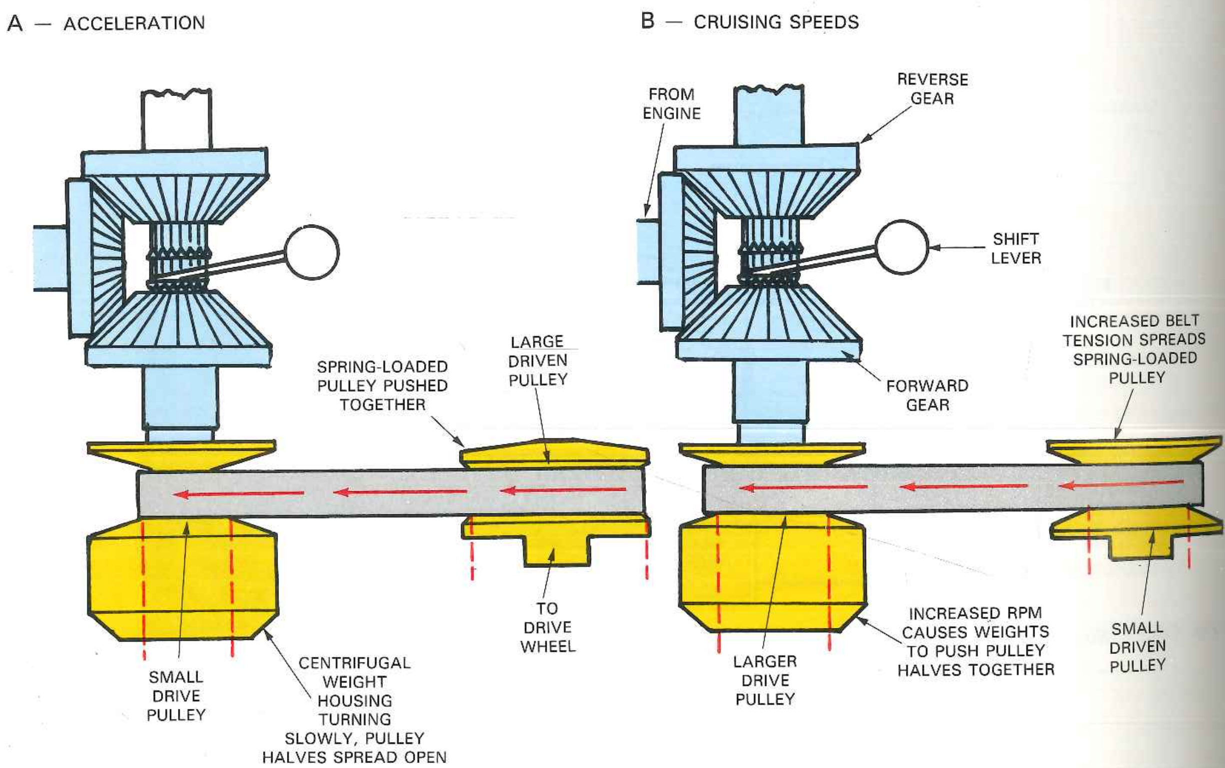


Fig. 54-38. Basic action of continuously variable transmission. Centrifugal weights in housing cause pulley diameters to change with vehicle speed. Two drive belt mechanisms are commonly used on automobiles. A — Upon initial acceleration, drive pulley has small diameter and driven pulley has larger diameter. This provides gear reduction for rapid acceleration. B — As car and pulley speed increase, centrifugal weights push one pulley together, increasing its diameter. This increases belt tension, pulling other pulley apart. As a result, ratio constantly decreases with increase in speed.

REVIEW QUESTIONS

1. List and explain the eight major parts of an automatic transmission.
2. An automatic transmission uses the following methods of transferring power.
   a. Friction.
   b. Fluids.
   c. Gears.
   d. All of the above.
   e. None of the above.
3. Describe the four major housings or components of an automatic transmission.
4. A _________ _________ is a fluid clutch that provides a means of coupling and uncoupling the engine and transmission.
5. Which of the following is NOT part of a torque converter?
   a. Band.
   b. Stator.
   c. Impeller.
   d. Turbine.
6. _________ _________ refers to the ability of a torque converter to increase the amount of engine torque applied to the transmission's input shaft.
7. Define the term "stall speed."
8. Why do many late model vehicles use a lock-up torque converter?
9. A planetary gearset consists of a _______ gear, several _______ gears, _______ gear _______, and a _______ gear.
10. List five functions of a planetary gearset.
11. Automatic transmission _______ and _______ are friction devices that drive and lock planetary gearset members.
12. Explain the operation of a clutch apply piston.
13. What is a servo?
14. An _________ is used in the apply circuit of a band or clutch to cushion initial application.
15. An overrunning clutch locks in one direction and freewheels in the other. True or False?
16. List and describe the major parts of the hydraulic system in an automatic transmission.
17. List five functions of the oil pump in an automatic transmission.
18. This valve senses engine speed (transmission output shaft rpm) to help control gear shifting.
    a. Vacuum modulator valve.
    b. Governor valve.
    c. Regulator valve.
    d. Manual valve.
19. How do the shift or balanced valves work?
20. Engine oil is compatible with the friction material in an automatic transmission. True or False?

ACTIVITIES FOR CHAPTER 54

1. Disassemble an automatic transmission and identify the parts.
2. Demonstrate to the class how an automatic transmission works.
3. Design and set up a demonstration that will help explain the operating principle of an automatic transmission.