Lubricants: A Quick Review

The primary functions of a lubricant are to:

- Lubricate
- Cool
- Protect against corrosion
- Seal
- Maintain Cleanliness

Lubrication Terminology:

**Viscosity**: A lubricant's resistance to flow and is the most important property of a liquid lubricant.

- A low viscosity fluid will pour freely, like water.
- A high viscosity fluid will be thicker and pour more like honey or molasses.
- In laboratory, viscosity is measured by timing oil flow through a calibrated orifice at 40 °C and / or 100°C.

**Pour Point**: the lowest temperature at which oil will still flow.

**Viscosity Index**: the rate at which oil thins out as temperatures increase.

**Lubricant Formulation**

Carefully formulated combinations of base fluids and additives produce a wide variety of lubricants that work effectively in gears and transmissions.
Viscosity Index Improvers: These modify the viscosity or thickness characteristics of the base fluid so that it thins out less as the temperature rises. In doing so, it allows the lubricant to operate over a wider temperature range.

Pour Point Depressants: Some additives work to lower the pour point, meaning the oil will continue to flow at a lower temperature. These additives are known as Pour Point Depressants.

Antifoam: Foam reduces the effectiveness of lubricants. Antifoam additives reduce or stop the foaming from occurring when the lubricant is agitated or aerated.

Rust inhibitors: Inhibit the action of water on ferrous metals (e.g. mild steel).

Corrosion inhibitors: Protect non-ferrous metals such as copper.

Anti-wear additives: Form a protective layer on metal surfaces to reduce friction and wear when the lubricant film is thin, such as in boundary conditions.

Extreme pressure additives: Work similarly to anti-wear additives but function only when heavy loads and high temperatures are encountered.

Solid Additives: Sometimes used in lubricants, more commonly greases, to aid in boundary conditions such as start up, shock loading or sliding lubrication. Common types: Graphite or Moly.
Automotive Gear and Transmission Fluid Trend

Gears:

A gear is simply a wheel with teeth. Early engineers found many uses for them — hoisting heavy loads, raising and lowering anchors on a ship, pre-tensioning catapults, and in wind and water wheel machinery. Early gears were made of wood, but since the time of the industrial revolution in Britain in the 18th century, most gears have been made of metal.

Today, gears are used in numerous every day applications — there are some in your electric toothbrush, your hand-operated egg beater and your bicycle.

Typically, gears are used in pairs and serve to multiply force. The pairing of different gear designs makes them valuable in both industrial and mobile equipment applications, as they can

- Transmit rotation and power
- Change speed
- Change torque
- Change rotation axis and/or direction
- Synchronize speeds

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td> Compact</td>
<td> Need accurate alignment</td>
</tr>
<tr>
<td> Able to transmit heavy loads</td>
<td> Must be lubricated effectively</td>
</tr>
<tr>
<td> Can operate at high speeds</td>
<td> Must be kept at a reasonable temperature</td>
</tr>
<tr>
<td> Efficient</td>
<td> Expensive</td>
</tr>
<tr>
<td> Run smoothly and relatively quietly</td>
<td> Can be design problems</td>
</tr>
<tr>
<td> Do not slip</td>
<td></td>
</tr>
<tr>
<td> Widely available</td>
<td></td>
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</tbody>
</table>

Gear Terminology

**Torque:** The tendency to produce a change in rotational motion.
Torque = Force x moment arm

**Pinion:** The smaller of two meshing gears, usually the driving gear.
Driving Wheel: The gear in a gear pair that supplies the power.

Driven Wheel: The gear in a gear pair that receives power.

Gear Ratio: The relationship between input speed and output speed is known as the gear ratio. The speed at which the gears turn is proportional to the number of teeth they possess. If a pinion has 22 teeth and a wheel has 44, then the gear ratio is 2:1.

Types of Gears

Some of the most commonly used gear types are:
- Spur gears with parallel shafts
- Single and double helical gears
- Straight and spiral bevel gears
- Hypoid gears
- Worm gears

Definitions

Spur gears with parallel shafts: These have straight teeth cut parallel to the axis of the gear shaft. They are a little less expensive than other gears, and are not designed for heavy loads or high speeds - spur gears are often used for the reverse gear in a car.
Single and double helical gears with parallel shafts: The teeth are cut at an angle to the shaft. They tend to run more smoothly than the spur gears, and can carry heavier loads (because the teeth are cut at an angle, there is more surface area — a 2” wheel, for instance, could have 2 ¼ inch teeth) at higher speeds. The single helical gear generates side thrust. Every automotive transmission contains single helical gears. The double helical gear is very expensive to make, and they are not commonly used.

Straight and spiral bevel gears for intersecting shafts: These gears are used when it is necessary to transmit power and motion between two shafts that intersect at an angle, such as the boat leg in an inboard or outboard motor of a boat. The straight bevel gears have straight teeth, which limits them to use at low speeds. The spiral bevel gears are cut with angled teeth, and can run much faster and, because of the angled teeth, can take more load. In those instances, an Extreme Pressure additive may be required.
Hypoid gears with shafts at right angles: These are similar to spiral bevel gears, except that the driving and driven shafts are offset — they would not intersect. They require extreme pressure additives and are rarely used in industrial applications. They are however used in the rear axle in rear-wheel drive cars and pick-up trucks.

Cutaway of a truck differential using hypoid gears.
Worm gears used on angled shafts: Are able to produce considerable reductions in speed, which results in substantial increases in torque. The shafts are crossed, and the worm is generally made of steel and the gear of bronze. Friction is considerable, and they require high viscosity lubricants. These gears would be found in gear boxes used for conveyor systems and are used when a large increase in torque and a big decrease in speed are needed.

Severity of Application

- Spur/Helical
- Straight Bevel
- Spiral Bevel
- Hypoid

Planetary Gear System

In this gear system, the yellow gear (the sun) engages all three red gears (the planets) simultaneously. All three are attached to a plate (the planet carrier), and they engage the inside of the blue gear (the ring) instead of the outside. Because there are three red gears instead of one, this gear train is extremely rugged. The output shaft is attached to the blue ring gear, and the planet carrier is held stationary.
Open and Enclosed Gears

Gears are either open and exposed to the environment, or enclosed in housing for protection.

Open Gears

Open gears are used when there is no practical or economical way to provide an enclosed housing which will hold oil for gear lubrication. Open gears generally run at low speeds and are lubricated with tacky greases or open gear lubricants. Open gears are exposed to the elements and can typically be found on large equipment used in mines, quarries and quaysides.

Application Methods for Open Gears
Automotive Gear and Transmission Fluid Trend

Splash:
The teeth in the bottom of the gear wheel dip into an oil bath. This is suitable only for open gear lubricants.

Hand:
More viscous lubricants are hand applied with a brush by the operator on equipment such as slow-turning mining shovels and construction equipment in which there is no lubricant-application system.

Spray:
Solvent is added to thin out high viscosity lubricants, so they can be sprayed. The solvent then evaporates.

Enclosed Gears

Enclosed gears are those contained in a housing or gearbox for protection against the elements. In most instances, the gearbox serves to hold the lubricant. In industrial applications, almost every moving part will be powered by an engine or electric motor driving a gearbox. These are sophisticated engineering components designed and constructed to very high standards.

Application Methods for Enclosed Gears

Splash:
The teeth in the bottom of the gear wheel dip into an oil bath. Splash lubricated gearboxes typically run hotter than other application methods, thus requiring a higher viscosity oil.
Spray:
The lubricant is sprayed close to where the teeth mesh, then drains to the bottom of the gear case where it is re-circulated.

Oil Mist:
The lubricant is atomized and sprayed in a stream of dry, compressed air.

Functions of Gear Lubricants
In addition to the usual functions lubricants perform — such as reducing friction and wear — gear lubricants need to help:

- Dissipate heat by carrying heat away in enclosed gears
- Reduce noise and vibration
- Protect the gear teeth surfaces against shocks, corrosion and infiltration of particles
- Maintain cleanliness by preventing a build-up of deposits, and by carrying away debris

Lubricant Selection By Gear Type

<table>
<thead>
<tr>
<th>Gear Type</th>
<th>R&amp;O</th>
<th>Antiwear</th>
<th>Extreme Pressure</th>
<th>*Compounded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spur</td>
<td>Lightly Loaded</td>
<td>Light to moderate load</td>
<td>Heavy or shock load</td>
<td>Not recommended</td>
</tr>
</tbody>
</table>
Automotive Gear and Transmission Fluid Trend

<table>
<thead>
<tr>
<th>Type</th>
<th>Load</th>
<th>Grade</th>
<th>Temperature</th>
<th>Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helical</td>
<td>Lightly Loaded</td>
<td>Light to moderate load</td>
<td>Heavy or shock load</td>
<td>Not recommended</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bevel</td>
<td>Lightly Loaded</td>
<td>Light to moderate load</td>
<td>Heavy or shock load</td>
<td>Not recommended</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypoid</td>
<td>Not recommended</td>
<td>Not recommended</td>
<td>Recommended</td>
<td>Not recommended</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worm</td>
<td>Not recommended</td>
<td>Not recommended</td>
<td>Satisfactory for temperatures &lt; 60°C</td>
<td>Recommended</td>
</tr>
</tbody>
</table>

*Animal or vegetable fat and/or oil are added to the petroleum base oil

*Greases are often used to lubricate small "lubricated for life" reducers
*Greases are also used for gearboxes that have a tendency to leak
*Grease is typically used in lawn mower gearboxes

**Base Oils for Gear Lubricants**

Mineral oils are widely used as the base for gear oils because they can lubricate, cool and protect efficiently, cost-effectively and safely. Synthetic oils are used for gears with a high degree of sliding or that operate at high temperatures for extended periods. Semi-fluid greases may be used – especially for lubricated-for-life gear boxes. They are less efficient at cooling and should be restricted to small, slow-running gear sets.

**Viscosity for Gear Lubricants**

As with all lubricants, viscosity is a gear oil’s most important characteristic. It needs to be high enough to maintain an adequate oil film, without causing the gears to lose power and without losing too much cooling efficiency.

Many lubricants are classified according to their ISO (International Standards Organization) Viscosity Grade at 40 °C.

Most gear oils fall in the range of ISO viscosity grades 46-680 (centistokes @ 40 °C).

The Viscosity Index (VI) must be high enough to keep the viscosity within required limits as temperatures rise.
The chart at right compares viscosity grades as defined by the ISO (International Standards Organization), the American Gear Manufacturers Association (AGMA) and the Society of Automotive Engineers (SAE) gear oil and motor oil classifications.

### Selection of Lubricants

<table>
<thead>
<tr>
<th>Gear Type</th>
<th>Operating Conditions</th>
<th>Oil Type and Additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spur</td>
<td>Light load</td>
<td>Straight mineral</td>
</tr>
<tr>
<td></td>
<td>High Speed/High Temp</td>
<td>Turbine or hydraulic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R&amp;O synthetic fluid</td>
</tr>
<tr>
<td>Helical</td>
<td>Normal or moderately heavy loads</td>
<td>Full EP Mineral Oil</td>
</tr>
<tr>
<td></td>
<td>Heavy or shock loads, particularly where good resistance to</td>
<td>EP Synthetic Fluid</td>
</tr>
<tr>
<td></td>
<td>corrosion is required</td>
<td></td>
</tr>
<tr>
<td>Straight bevel</td>
<td>Abnormally heavy loads (case-hardened gears)</td>
<td>EP Synthetic Fluid</td>
</tr>
<tr>
<td>Spiral bevel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypoid</td>
<td>Normal Load</td>
<td>Full EP Mineral Oil</td>
</tr>
<tr>
<td></td>
<td>Severe service</td>
<td>EP Synthetic Fluid</td>
</tr>
<tr>
<td>Worm</td>
<td>Normal Load</td>
<td>Compounded mineral</td>
</tr>
<tr>
<td></td>
<td>Excessive Temperature</td>
<td>Synthetic</td>
</tr>
</tbody>
</table>
Transmissions:

One could argue that the transmission is a next step in the evolution of the gear. Transmissions involve transferring power from one set of gears to another. A transmission is used to transmit power from an engine to a differential and wheels. A transmission allows you to have more than one gear ratio choice, thereby allowing you different torque or speed choices, such as in a car which has 5th gear for high speeds and 1st gear for acceleration and high torque.

![Transmission Diagram](image)

Manual Transmission

Every car has a certain rpm range where they will make the most power. This rpm range is known as the power band. A transmission (when racing) is used to keep a car within that range no matter what speed. At other times a transmission is used to keep a car at a low rpm in order to reduce fuel consumption. Transmissions must serve another purpose as well. They have to have the ability to take the power created by the engine and be able to connect and disconnect it to the drivetrain. At times a car requires more power to perform a task, for example when towing something and all transmissions (including automatic) have lower gears there so you can drop a gear. By dropping a gear you increase your engine rpm at a given speed. More engine revolution means that for every revolution of the tires you get more power stokes.

The transmission is located between your clutch and drive shaft.

![Transmission Diagram](image)

The transmission uses gears to allow the power from the engine to be used in different ways. For example, while traveling up a hill you want more power to go to your wheels for every revolution. By putting it in a low gear it will allow your car to climb the hill easier. To be in a low gear means that the
transmission uses a small gear on the engine output shaft and large one on the drive shaft. This will allow the engine to apply more power per revolution of the drivetrain.

When traveling on a highway, you wouldn't need as much power and you also want the wheels to move faster than the engine. That means that you would want a larger gear on the engine output shaft and a smaller gear on your drive shaft. That would allow the tires to move faster than the engine. Usually the ratio of the 6th gear in a 6-speed is around 1.0, so for every one revolution of the crankshaft there is one revolution of the driveshaft.

Parts

A basic transmission somewhat looks like this.

The crankshaft is always spinning when the car is moving unless of course you decide to stall your car. The shaft coming from the clutch spins the layshaft. The layshaft then spins the two blue gears, which are on bearings. The bearing allows the blue gears to spin on their own when they are not engaged, this way they will not affect anything. The collar is connected to the gear fork which is overly simplified in this picture, however, in a car that is how you would change gears. The collar is directly connected to the drive shaft, that means which ever gear it connects to it directly links the two together, that is the gear and the driveshaft. When the teeth on the collar, known as dog teeth, move into one of the blue gears by the gear fork, it will make the drive shaft turn. When the drive shaft
turns the tires will turn. Just so you know I used the colors only to make it easier to explain they are, however, not as colorful in a real car.

Double-Clutching

A problem with this configuration is that it does not have "synchros." In order to make the collar spin at the right speed you must do a maneuver called the double-clutch. In many older cars you must double-clutch. The first thing you do is push the clutch pedal down in order to disengage the engine from the transmission. This will allow you to put the car in neutral. The next step is to release the clutch and rev the engine till the rpm value of the engine is where it should be in the next gear. This will get the next gear and the collar rotating at the same speed. Finally, you push the clutch in a second time and put the car in its next gear. It is necessary to get the collar and the next gear at the same speed or you will grind the teeth on the collar. Everytime you need to change gears you will need to use the clutch twice, that is why it is known as "double-clutching." Double-clutching was necessary in many trucks.

The Shifter

If you turn the gear selector on the picture to the right 90 degrees you will see how using a shift knob can change the gears. You must also consider that moving the shift knob backwards pushes the fork forwards because of the pivot point. Also moving the shift knob left and right changes the fork that you move. These motions can be seen in the following image.
Reverse.

To allow your car to go in reverse and extra gear is needed, called the idler gear. This gear reverses the motion of the drive shaft, which in turn will reverse the motion of the tires.

In the image below you will see that the blue gear connected with the idler gear will be moving in the opposite direction.

This gear would always be moving in the opposite motion as the other gears, therefore if you wanted to try and push the shift knob into reverse while moving forward it would not work. The dog teeth would not engage and they would just grind up and make a lot of noise.
Synchronizers

In modern cars double-clutching is replaced by a synchronizer. The synchronizer's purpose is to connect the collar to the gear before the teeth touch the gear. This will allow the collar to synchronize its speed with the gear so that the dog teeth will not grind. This is the basic image of a synchronizer.

The cone protruding from the blue gear is what makes contact with the cone shaped part of the synchronizer. Friction between these two parts is what synchronizes the speed of the collar and the gear. The cone shaped part of the synchronizer slides in so that the teeth can connect with the gear.

Clutches

A clutch makes it possible to stop, either in a car or in any other mechanism. The engine is left running, but it is disconnected from the object it is driving, in which case it will be cars. Without a clutch, stopping a car would require killing/shutting off the engine first. The clutch makes it possible to disconnect the engine from everything else.

Parts

Clutches are devices with 2 shafts. The first shaft is the crank shaft. The second is the drive shaft. The crank shaft is connected to the pistons and is what drives/turns the drive shaft. At the end of the crank shaft there is a flywheel. There are many other parts and I will list them but I will explain what they do in the next section. You can also view the diagram below. The following parts are the parts that connect the drive shaft to the flywheel: clutch plate, pressure plate, diaphragm spring, studs, throw out bearings, clutch housing, release fork, and bell housing.
How do clutches work?

A clutch has to be able to disconnect from the engine and then reconnect when its needed. In order to disconnect the spinning engine from the transmission you press the clutch pedal. The pedal is connected to the **release fork**. The fork pushes the **throw out bearings** in the center of the assembly. When the bearings move towards the flywheel they push **diaphragm spring** in the center. This makes the outsides of the spring move as well. But the trick is that the outside moves in the opposite direction, backwards, because the **studs** are acting as a pivot point for the diaphragm spring. The spring on the outside is connected to the **pressure plate**. So when the diaphragm spring moves backwards it takes the pressure plate with it. The pressure plate is connected to the **clutch plate**. So when the pressure plate moves backwards the clutch plate is pulled off of the flywheel and there for disconnecting the engine from the transmission. The clutch plate is the plate that contacts the flywheel and is what will reconnect the engine to the transmission. The flywheel is usually connected to a chain which runs to the electric starter engine.
In order to reconnect, you release the clutch pedal. This pulls back the bearings. The diaphragm spring goes back to original position (remember before they were pushed backwards, so now the go forwards) and force the pressure plate against the clutch plate. The clutch plate once again makes contact with the flywheel. The friction makes the transmission turn.

Lubricant for Manual Transmission

One of the main drivers behind vehicular technology changes is fuel economy. The American Auto OEM gets highly penalized if they miss to meet/achieve CAFÉ fuel economy norms. Now Auto OEMs are investing huge money on R&D, and they are conducting lot of research work not only on engine technology and aerodynamics (unique body structure to reduce air drag/resistance force), but also on transmission system where 7-8% energy saving potential is existing. Now auto OEMs are giving enough priority on lubricant technology also for transmission system along with transmission hardware to achieve desired fuel economy.

The output shaft (drive shaft/propeller shaft) has enough RPM, therefore torque might not be very high which allow to recommend thinner viscosity grade lubricant which has good flowability at lower temperature and adequate film thickness at operating temperature to ensure durability of transmission system. Now, it is achievable to get substantial fuel economy due to selection of lower viscosity grade lubricant. On the other side, the lubricating oil should have high EP (Extreme Pressure) characteristic to provide good protection to gears of transmission system.

One important component of manual transmission system is Synchronizer, which is made of yellow metal, a main reason of manual transmission system brake down. The yellow metal of Synchronizer gets easily corroded by very aggressive EP additive of lubricating oil, and it is forcing to accept mild EP additive for formulation of manual transmission oil to ensure durability of Synchronizer. Therefore, API GL-4 gear oil is recommended for manual transmission system with OEM recommended
viscosity grade. The American OEMs sometimes has special non synchronized manual transmission system, and API MT-1 gear oil (EP characteristic is in between API GL-4 & GL-5) is recommended for this type of manual lubrication system.

<table>
<thead>
<tr>
<th>API Spec</th>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL-4</td>
<td>Active</td>
<td>The designation API GL-4 denotes lubricants intended for axles with spiral bevel gears operating under moderate to severe conditions of speed and load or axles with hypoid gears operating under moderate speeds and loads. These oils may be used in selected manual transmission and transaxle applications where MT-1 lubricants are unsuitable. The manufacturer's specific lubricant quality recommendations should be followed.</td>
</tr>
<tr>
<td>MT-1</td>
<td>Active</td>
<td>The designation API MT-1 denotes lubricants intended for nonsynchronized manual transmissions used in buses and heavy-duty trucks. Lubricants meeting the requirements of API MT-1 service provide protection against the combination of thermal degradation, component wear, and oil-seal deterioration, which is not provided by lubricants in current use meeting only the requirements of API GL-1, 4, or 5.</td>
</tr>
</tbody>
</table>

DIFFERENTIAL GEARBOX

The differential gears are located in the center of the front and rear axels depending on which type of drive train your car has. In a FWD car it is in the front and in a RWD car it is in the rear, respectively. AWD cars are special though; there are 3 differentials; one on the front axel, one the back axel, and one in between the two axels in the middle of the drive shaft. The additional differential is there so that the front and rear tires can move at different speeds.
The differential gears are placed between half shafts on each axel. By dividing the axel it will allow the car's wheels to turn at the different speeds it needs to.

**Functions of Differential Gearbox**

While driving your wheels spin at different rates especially when turning. In a turn, your outer wheels will move across a greater distance then the inner wheels. The outer wheels must also travel this greater distance in the same amount of time it takes for the inner wheels to travel the shorter distance. That means the outer wheels must be able to spin faster then the inner wheels.

The problem is that the **driving** wheels - wheels being driven by the engine - must be connected to each other so that when the engine turns the axel both wheels will turn. They must also be able to turn at different rates meaning they must be disconnect in some way. If they were not able to move at different speeds and the axel directly connected both wheels it would be almost impossible to turn. A tire would have to spin or slip. This slip or spin would cause a lot of strain on the axel and could end up ruining the car. A differential makes it possible for your wheels to be connected to your engine while being able to spin at different speeds.

As for the **non-driving** wheels, they do not need differentials for they spin independently from everything else.

**What Happens In a Regular Differential?**

1. The drive shaft turns a crown wheel.
2. The crown wheel rotates, rotating the planet pinions. However, the planet pinions are not spinning they are revolving.
3. The planet pinions turn the sun gears.
4. The sun gears spin and turn the axels, which turns the tires.
The crown wheel turns both wheels at the same rate. But when the car turns the planet pinions start to spin in the opposite directions. This allows the tires on the outside of the turn and get ahead of the inside tires. The differential makes the turn sharper, smoother, and quicker.

Concerns

Differentials will allow tires to spin at different speeds but one of the biggest problems comes when a tire slips, such as on ice. A car will not move because the supplied torque is given to the spinning tire. That means the other tire on the ground will not be able to push the car. Now-a-days there is a solution. A Limited-Slip Differential (or LSD) will solve this.

A LSD has a mechanism within the gears that will lock at a certain point. There is a set of clutches and a spring between the pinion gears. When the tires are spinning evenly the spring and clutch are off the pinion gears. When a tire is spinning at a different speed the springs push out on the clutches against the pinions forcing them to spin together. Note: This occurs even when turning. Depending on the springs and clutches there is a way to get past the locking ability by push through it (such as when turning and the tires are firm on the ground). When a tire is slipping on ice the clutches will locks the gears inside the differential supplying torque to both tires. This will allow you do maneuver over the ice.
Another kind of differential used mostly in AWD vehicles is called a **Viscous Coupling Differential**. This differential will transfer torque from one set of tires to the other set of tires.

This differential has two power output shafts, two sets of discs, and a large sealed cylinder of thick liquid surrounding the discs. When one set of tires are off the ground and spinning faster than the other set of tires, their corresponding discs spin faster as well. When the thick fluid spins with the faster moving discs, it takes the other set of discs with it. This is transferring of torque to the gripping tires.

One might ask about turning and how this differential affects it. While turning the front and rear tires might spin at different speeds, but not at a big enough rates to cause any effects in this differential.

Differentials in many 4WD vehicles are also special. They are called **Locking Differentials**. That means they can lock there wheels together so they spin at the same speed, done so from an interior switch. This helps when off-roading and rock climbing. This makes it impossible to turn though.

**Lubricants for Differential Gearbox**

The output shaft (half shaft) of differential gearbox has low RPM, therefore it has very high torque (Power = Torque x RPM). The gear teeth is experiencing enormous load due to high offset of hypoid gear and high torque, therefore system durability is the key design parameter of lubricating oil for differential gearbox, not fuel economy. The higher viscosity grade is always recommended for differential gear box. On the other side, the differential gearbox does not have any yellow metal make Synchronizer like manual transmission system, which allows designer to recommend lubricant with very high EP characteristic. Therefore, API GL-5 type of lubricant is being recommended for differential gearbox.
If the differential gearbox does not have hypoid gear, but has spiral bevel gear, then load on gear teeth is not very high, and in this case API GL-4 can also be recommended.

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</tr>
<tr>
<td>GL-5</td>
<td>Active</td>
<td>The designation API GL-5 denotes lubricants intended for gears, particularly hypoid (see note) gears, in axles operating under various combinations of high-speed/shock load and low-speed/high-torque conditions.</td>
</tr>
</tbody>
</table>

**Automatic Transmission**

Like manual transmission, the automatic transmission's primary job is to allow the engine to operate in its narrow range of speeds while providing a wide range of output speeds.
Without a transmission, cars would be limited to one gear ratio, and that ratio would have to be selected to allow the car to travel at the desired top speed. If you wanted a top speed of 80 mph, then the gear ratio would be similar to third gear in most manual transmission cars.

You've probably never tried driving a manual transmission car using only third gear. If you did, you'd quickly find out that you had almost no acceleration when starting out, and at high speeds, the engine would be screaming along near the red-line. A car like this would wear out very quickly and would be nearly undriveable.

So the transmission uses gears to make more effective use of the engine's torque, and to keep the engine operating at an appropriate speed. When towing or hauling heavy objects, your vehicle's transmission can get hot enough to burn up the transmission fluid. In order to protect the transmission from serious damage, drivers who tow should buy vehicles equipped with transmission coolers.

The animation below shows how all of the parts are hooked up in a transmission.
The key difference between a manual and an automatic transmission is that the manual transmission locks and unlocks different sets of gears to the output shaft to achieve the various gear ratios, while in an automatic transmission, the same set of gears produces all of the different gear ratios. The planetary gearset is the device that makes this possible in an automatic transmission.

The Planetary Gearset

When you take apart and look inside an automatic transmission, you find a huge assortment of parts in a fairly small space. Among other things, you see:

- An ingenious planetary gearset
- A set of bands to lock parts of a gearset
- A set of three wet-plate clutches to lock other parts of the gearset
- An incredibly odd hydraulic system that controls the clutches and bands
- A large gear pump to move transmission fluid around

From left to right: the ring gear, planet carrier, and two sun gears

The center of attention is the **planetary gearset**. About the size of a cantaloupe, this one part creates all of the different gear ratios that the transmission can produce. Everything else in the transmission is there to help the planetary gearset do its thing. An automatic transmission contains two complete planetary gearsets folded together into one component. See

Any planetary gearset has three main components:

- The **sun gear**
- The **planet gears** and the planet gears' **carrier**
- The **ring gear**

Each of these three components can be the input, the output or can be held stationary. Choosing which piece plays which role determines the gear ratio for the gearset.
Powershift Transmission

A powershift transmission, like an automatic transmission, is equipped with a torque converter to disengage from transmission. Typically uses spur and helical gears.

Automatic Transmission Fluid

An automatic transmission fluid helps:

- Transmit hydrodynamic energy in the torque converter
- Transmit hydrostatic energy in hydraulic control circuits and servo mechanisms
- Lubricate shaft bearings, thrust bearings and gears
- Transmit sliding friction on bands & clutches
- Act as heat transfer fluid to control temperature

Some of the key performance features required are:

- Oxidation stability
- Long oil life
- Fluid contamination control (to handle friction debris and metallic wear debris)
- Clutch friction management
Few key Specification for Automatic Transmission Oil

Dexron Type A, Suffix A

Specification introduced in 1957. It requires the oil to meet certain limits regarding its kinematic viscosity.

Dexron IID

General Motors Dexron®-IID Specification. ATF issued in 1975. Contained ATF cooler corrosion requirements not listed in Dexron® - II.

Dexron IIE

General Motors Specification Dexron®-IIE. ATF issued in 1991 requiring improved low temperature performance compared to Dexron®-IID, 20 000 cP at minus 40 °C.

Dexron IIIF

GM specification for Automatic transmission oil introduced in 1994. Successor of Dexron IID and IIE.

Dexron IIIG

Successor of Dexron III(F) automatic transmission fluid. This has the same low temperature characteristics as Dexron IIE, but with modifications to anti-oxidancy and friction material. Introduced in 1997.

Dexron IIIH

Dexron III licence H was introduced in June 2003 to replace the Dexron III G fluid. It has an oxidatively stable base oil (group 2 or group 3). Oils according to this specification have longer maintenance of friction properties and anti-shrudder properties, better foam control and a longer fluid life.

Dexron VI

Specification introduced in 2005 to replace Dexron IIIH. This specification requires better stay-in-grade properties, oxidative stability and anti-foam characteristics. Oils meeting this specification can be used with extended drain intervals and are energy conserving.
Tractor Transmission Hydraulic Fluids

In a modern tractor, the hydraulic system, drive train, power shift transmission, power take-off clutch, and wet brakes are all part of the same system.

As a result, the lubricant needs to be able to fulfill the functions of

- Hydraulic oil
- Gear oil
- Transmission oil
- Wet brake oil

The fluid needs to lubricate, cool, transmit power in the torque converter and power system, disperse wear particles and contribute the right friction characteristics for wet brakes and clutches.

Powershift Transmissions

Powershift transmissions are similar to automatic transmissions in that they do not require the use of a clutch, however they are designed for heavier loads. As well, the operator normally still does the shifting. Caterpillar has been the main user of powershift transmissions and developed the Caterpillar TO-4 specification with these transmissions in minds.
Other manufacturers such as John Deere, Volvo, etc., use their own versions of powershift transmissions, however the lubricant requirements are different. Some use Allison TES-295, DEXRON IIH or JD-20A approved oils.

Powershift transmissions are typically used in large mobile construction equipment such as road graders, excavators and loaders.

**Manual Transmission Fluids**

A manual transmission is equipped with a dry clutch to disengage the engine from the transmission. Synchromeshes are installed on helical gears to provide smooth gear changes. A manual transmission requires the operator to choose the gear in use.

**Note:** Fluids for manual (or standard) transmissions typically do not contain Extreme Pressure Additives, as synchromeshes are made of yellow metals. If the oil reaches too high a temperature, the EP additive would chemically attack the yellow metal.

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**Gear and Transmission Lubricants for Trucks**

Three transmission designs are used in the trucking industry.

**Manual Transmission**: fully manual transmissions, typically having between nine and 13 speeds. They represent more than 90 percent of the transmissions in use.
Auto Shift: a design launched by Eaton which requires the driver to depress the clutch only when starting and stopping. The remaining shifts are controlled electronically with sensors. The driver can override the automatic shifting to a degree. It is fundamentally a manual transmission.

Powershift/Automatic Transmissions: designs such as the CEEMAT are available but have not been met with much acceptance. They require a different quality lubricant.

Performance Standards

The industry has developed a standard to define the requirements for heavy-duty manual transmissions entitled API MT-1. It defines enhanced performance in areas including:

- Thermal stability
- Copper corrosion
- Wear protection
- Seal durability

Eaton has embraced this standard and included MT-1 fluids along with their other recommendations:

- MIL-2104D Engine oils
- CAT TO-4 fluids
- API MT-1 and MIL-PRF-2105 oils
- API GL-1 oils are no longer officially referenced

Lubricants for Transmissions and Axles

Technology and component design have been driven by a number of factors:

- Increased/extended warranty expectations and equipment durability
- Improved ease of operation/driver acceptance
- Decreased maintenance requirements

As a result there has been significant impact on the lubricants required:

- The development of additive technologies that can survive higher operating temperatures while providing the durability and fluid life necessary to support the OEM’s extended warranty and drain programs
- The development of a range of specific synthetic fluids which are linked to OEM extended warranty/drain programs with intervals approaching 500,000 miles.
Truck Transmissions

**Eaton Fuller/Dana Spicer:**

- Synthetic transmission oils SAE 50 (20W/50) for extended drains
- Engine oils SAE 50 / SAE 30
- Mineral 80w/90 gear oils

**Others:**

- MT-1, MIL-L-2105D, MIL-PRF-2105E
- GL-1, GL-4, GL-5 75w90 or 80w90 gear oils
- Mack GO-H, Mack GO-J

Truck Differentials Performance Specifications

**Differential gear oil specifications:**

- API GL-4, GL-5
- API MT-1
- MIL-L-2105D
- MIL-PRF-2105E
- Mack GO-H
- Mack GO-J

**Extended warranty and drain approvals:**

- Mack GO-J Plus
- ArvinMeritor (formerly Rockwell) O76-E, O76-N and O76-Q
- Dana Corporation (formerly Eaton Corp.) PS-037, PS-163 and PS-109 (obsolete)

**Universal Tractor Transmission oil (UTTO)**

The primary uses for Universal Tractor Transmission Oil (UTTO) are farm tractors and combines. However, it also can be used in non-farm applications that have wet brakes, hydraulics, transmissions, or applications in which operators want to simplify the number of lubricants in inventory. These include bulldozers, road graders, front-end loaders, and forestry equipment that have hydraulics and Powershift transmissions; busses and trucks that have Powershift transmissions; mining equipment with hydraulics; and lift trucks - from warehouse size to steel mill size - with wet brakes.
Advantages:

UTTO offer many advantages for operator comfort and equipment productivity and durability. The superior friction performance eliminates the screeching noise known as chatter in wet brakes. It provides excellent shift performance in Powershift transmissions. Both these factors help reduce operator fatigue.

It also offers a fine balance of superior anti-wear properties to protect final drive gears without hurting the soft, yellow metal in the hydraulic pump. Better copper protection prevents corrosion in axial piston hydraulic pumps. Pumps don't lose pressure and productivity is enhanced.

Super Tractor Oil Universal (STOU)

The key difference between Super Tractor Oil Universal (STOU) and Universal Tractor Transmission Oil (UTTO), is that, STOU can be used as a tractor engine oil as well as a transmission, final drive, wet brake and hydraulic fluid. Other than that, the two fluids are used in the same types of vehicles and equipment.

Advantages:

STOU is an innovative technology in the industry. It has boosted soot control for reduced wear and viscosity increase; superior anti-wear performance for reduced pitting and scoring in final drives; superior friction performance for transmission clutches and exceptional shiftability; viscosity modifiers to provide the desired viscosity grade.