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This curriculum has been developed as part of the Learning and Knowledge Development (LKD) Facility, initiated by the Swedish International Development Agency (Sida) and the United Nations Industrial Development Organization (UNIDO). The LKD Facility is a platform to promote industrial skills development among young people in emerging economies. Working with the private sector through Public Private Development Partnerships, the LKD Facility supports the establishment and upgrading of local industrial training academies to help meet the labour market’s increasing demand for skilled employees, ultimately contributing to inclusive and sustainable industrial development.
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1. Manual gearbox

Constant-mesh and Synchro-mesh gearbox

Disadvantages of the sliding mesh

Although the mechanical efficiency of the sliding-mesh gearbox was high, it suffered from two great disadvantages:

1) Gear noise due to the type of gear.

2) The difficulty of obtaining a smooth, quiet and quick change of gear without the application of great skill and judgement. Gearbox designs introduced during the last 50 years have endeavoured to overcome these dis-advantages. The first step in the development came when the constant-mesh gearbox was used.

1.1 Sliding mesh

When changing gears, double clutching was necessary. In particular changing from gear number 2 to gear number 1, double clutching was a must. Finding the right engine rpm and ground speed was also needed to enable the gearbox making a smooth shift.

The sliding main shaft gearwheels and their corresponding lay-shaft gearwheel clusters have to be of the spur straight-tooth form, so that when engaged there is no side thrust unlike helical-cut teeth. The major problem with this type of gear engagement is that, while attempting a gear change, the speeds of the input and output shafts are matched first, otherwise the sliding teeth of the mashing gearwheels does not align and hence crashes into each other.

The engine shaft (primary shaft) contains the main drive gear, which rotates at the speed of the clutch shaft. The main drive gear is in constant-mesh with counter shaft (lay shaft). Gears A, B and C are sliding-mesh gears.
1.2 Constant-Mesh Gearbox

This was first used on cars in the early 1930s, but gave way in a short time to other designs, although it is still used on commercial vehicles and tractors.

The main feature is the use of the stronger helical or double helical gears which lead to quieter operation. Each pair of gears is in constant mesh, and gear operation is obtained by locking the respective gear to the main shaft by means of a dog clutch.

The main shaft gearwheels are mounted on bushes or needle rollers, and are located by thrust washers. When the gear is required, a dog clutch, which is splined to the main shaft, is slid along by the selector to engage with the dog teeth formed on the gear. This has the effect of locking the gearwheel to the shaft. There will still be noise if the dog teeth are not rotating at the same speed when the engagement is made, and so double declutching is necessary, but damage caused by a ‘bad’ change will be limited to the dog clutch.

1.3 Synchro-mesh mechanisms

The improvement achieved by fitting a constant-mesh gearbox was great, but a certain amount of skiff was still required to produce a quick, quiet change. The difficulty was in double declutching, and the purpose of carrying out this operation was to equalize the speeds of the two sets of dog teeth before engaging the gear. It soon became apparent that some device was required to synchronize the speeds mechanically, and when the system was invented it was known as the synchro-mesh gearbox.

1.3.1 Constant-load synchro-mesh unit

This was the first type of synchro-mesh used. Fundamentally the box is laid out in the same manner as a constant-mesh, with the exception that a cone clutch is fitted between the dog and gear members.
The female cone of this clutch is formed in a hub, which has internal and external splines. A series of spring-loaded balls is carried in radial holes in the hub, and these push outwards into a groove machined in a sleeve. The selector fork controls the position of the sleeve, which has splines of the same pitch as the dog teeth on the gear.

The initial movement of the selector and sleeve carries the hub towards the gear and allows the cones to contact. At this point, the friction between the cones adjusts the speed of the gearwheel to suit the hub and main shaft. Extra pressure on the lever will allow the sleeve to override the spring-loaded balls, and positively engage with the dogs on the gear.

If the gear change is rushed, there will not be enough time for synchronization, and the change will be noisy. The time taken for the speed to be equalized is governed by the frictional force which exists at the cone faces. This force is controlled by: (a) total spring strength, (b) depth of groove in sleeve, (c) angle of cone, and (d) coefficient of friction between cones; therefore, if, because of mechanical defects, any of these factors is reduced, synchronization will take a longer time, and noise will probably be heard. This time factor has presented problems for the lubrication specialist, since the high-viscosity oil required by the gears takes a considerable time to disperse from the cones.

The solution to this problem was to use a lower-viscosity oil (similar to medium engine oil - SAE 30) and provide a series of grooves on the cone face to cut through the oil film and disperse the lubricant. Up to recent times it was considered essential to drain and refill the gearbox every 8000 km (5000 miles), in order to remove the particles worn from the cones and gear teeth. With extended service schedules now in operation, this mileage has been increased considerably, and some manufacturers have recommended that after the first change no further changes are necessary.

1.3.2 Baulk Ring Synchro-mesh

The baulk ring system, which is sometimes called blocker ring or inertia lock, is a later development of the constant mesh system, and is designed to overcome the main disadvantage of the earlier design - noise or crashing of the gears due to a quick change.

Two main features are incorporated in the baulk ring system:

1) The cone pressure or load is proportional to the speed of change.

2) An interception device prevents positive gear engagement until the speed of the two members is equal.
Various constructions are used to produce these features. Three spring-loaded shifting plates, which push out from the hub into a groove in the sleeve, fit into slots in the baulking cone. Each slot is wider than the plate; the clearance on each side is equal to half the pitch of the splines on the sleeve. The baulking cone, which is made of phosphor-bronze, has specially chamfered teeth on the outside, of a pitch similar to that of the dog teeth on the gear sleeve.

Movement of the gear lever will move the sleeve and shifting plates towards the gear selected. The plates will push the baulking cone into light frictional contact with the gear cone, and the difference in speed will allow the gear cone to carry the baulking cone around to the limit controlled by the plate (half spline movement). Extra pressure on the lever will tend to move the sleeve towards the dog teeth of the gear, but if the two members have different speeds, the dog teeth on the baulking ring will block the passage of the sleeve. In this position the splines on the sleeve are touching the teeth on the baulking ring, and therefore if a greater force is applied to the lever, a greater force will act between the cones and synchronization will be achieved in a shorter time.

As the speeds become equal, the plates assume a central position in the slots of the baulking ring, and all teeth line up; therefore the sleeve can now pass the baulking cone to engage positively with the dog teeth on the gear.
2. Gearboxes for Rear-Wheel Drive

2.1 Four-Speed and Reverse

The gear layout of a four-speed and reverse gearbox suitable for a rear-wheel drive car:
This gearbox uses a baulking-ring type synchro-mesh on all forward speeds. To simplify the construction, a sliding-mesh arrangement is used for reverse.

The type of unit utilizes the hub to press the synchro cones together. It uses three spring-loaded balls in the hub to lock the hub initially to the striker ring and three tangs on the baulking ring, which fit into slots in the hub, gives the baulking action.

Circumferential movement of the ring, relative to the hub, is arranged by having a clearance between the sides of the tangs and hub. This ensures that the ring can move each way, to the extent of half a spline, to block the passage of the striker ring as it attempts to engage with the dog teeth on the gear.

Uncaged needle rollers are used in this layout to support the lay shaft gears. This bearing arrangement is now common, because in addition to having low friction, the extra rigidity of a needle roller compared with a plain bush gives a more precise gear mesh. As a consequence, the noise is reduced when the gearbox is loaded. This construction makes it more difficult to reassemble the box, but with the aid of a dummy lay shaft of length equal to the gear cluster, the task is made easier.

Every gearbox must have some provision to prevent the escape of oil. For flange joining, either the fitment of a paper-based sealing joint or, on metal-to-metal faces, the application of a sealing compound, is used.

Leakage along the shafts and through the bearings is normally prevented by fitting lip-type seals. These are positioned on the clutch side of the primary shaft bearing and at the universal joint end of the gearbox extension housing.

The speedometer is driven by means of a skew gear from the main shaft. A steel ‘worm’, mounted on the main-shaft and located in the gearbox extension housing, generally drives a plastic moulded pinion; this is connected to either a flexible cable or an electrical transducer.
2.2 Gear Change Mechanism

The seating position often means that the gearbox selectors are situated well forward of the driver’s body. In the past a long ‘floppy’ lever was used, but nowadays the rigidity of a short lever and a remote control mechanism enables the driver to select the gears with greater precision.

2.3 Five-speed and Reverse

During the past few years, the improved fuel consumption achieved by using a line-speed overdrive, has made the Five-speed gearbox a common feature of the modern trucks. The term overdrive means that the propeller shaft turns faster than the engine, so in a five-speed gearbox the fourth gear is the normal ‘top’ or direct-drive gear.

Helical gears are used throughout and each gear on the main-shaft is supported on needle rollers; this reduces noise and improves efficiency. The gearbox casing, which is ribbed to avoid distortion under load, is a lightweight aluminium alloy die casting.
In recent years, computer-controlled manufacturing processes have made it possible to produce gears with great accuracy. This allows running tolerances to be reduced, which in turn leads to a quieter operation. These developments allow the use of oils of low viscosity, so by expending less energy to rotate the lay-shaft the gearbox efficiency is improved. In the gearbox shown, a very thin oil similar to that used in automatic transmissions is recommended.

In common with many other five-speed gearboxes, the fifth-speed gears of the box shown are situated at the rear of the gearbox.

### 2.4 Reverse Detent

Some ‘blocker’ arrangement is fitted to a gearbox to prevent the accidental engagement of reverse gear when the vehicle is moving forward. The simplest form is a spring-loaded detent; this must be overcome by the driver before the lever can be moved to the ‘reverse’ position. To overcome this spring the driver either has to lift the gear lever or exert extra pressure on it.

Five-speed gearboxes sometimes use a gear lever pattern of movement (gate pattern) whereby fifth and reverse are in the same plane, e.g. fifth and reverse are obtained by forward and backward movement of the lever respectively. In these cases a positive gate lock is often used.
3. Gearboxes for front-wheel drive

A transversely mounted engine and transmission assembly is the common arrangement for a front wheel drive car. This compact transaxle configuration normally requires the gearbox input and output shafts to be at the same end, so a two-shaft layout is used.

![Diagram of a car with engine, transmission, clutch, and drive axle](image)

Since a simple (single-reduction) system of gearing is used instead of a compound (double-reduction) system, a lay shaft is not needed.

In this design each shaft is supported by a ball race at the non-driving end; at the other end the radial load is much heavier, so a roller race is fitted. Axial thrust on each shaft is taken by a radial-type ball bearing, so this locates the shaft and maintains alignment, and takes the thrust of the helical gears. The spigot bearing needed with a lay shaft type gearbox is unnecessary with the two-shaft layout, so this gives a more rigid gear assembly, and a quieter gearbox results. A further improvement can be made when needle rollers are used to support the gears on the shafts.

### 3.1 Gear Change Mechanism

Some form of remote control mechanism is essential, because a long lever is far too flexible. The linkage used must be capable of transmitting two distinct motions: longitudinal movement of the gear lever as it is moved from, say, first to second, and transverse movement as needed for the selection of another pair of gears.

During operation, movement of the engine due to torque reaction is accommodated by either using a universal joint or relying on the inherent flexibility of the cable.
4. The operation of the Torque Converter

4.1 Introduction

The torque converter is a form of hydraulic coupling used to transmit power from the engine to the input shaft of the transmission. Torque converters use fluid (oil) to hydraulically connect the flywheel of the engine to the input shaft of the transmission.

Unless the machine is equipped with a lockup clutch, there is no direct connection between
the engine and the transmission, just the fluid drive mechanism.

**There are three types of hydraulic mechanisms used to transmit power;**

- the fluid coupling,
- the torque converter,
- the torque divider.

All are fluid drive devices that use the energy of fluid in motion to transmit power. The torque converter started its ‘career’ as a fluid coupling. (torque converter without a stator).

### 4.2 Fluid Coupling

Operation of a fluid coupling can be compared to the action of two electric fans placed face to face and close together.

If one fan is running the energy of the moving air will cause the other fan to turn.

In a fluid coupling the fluid acts like the air between the two fans. As with the fans, the output fluid power of the driving component acts as the input power for the driven component. Liquid has more mass than air so it transmits more energy. Mechanical power from the engine is converted to fluid power and fluid power is converted back to mechanical power to drive the output shaft.

#### 4.2.1 Impeller and Turbine

A number of straight, radial blades extend from the inside to the outside edge. The blades in the part on the right side are a part of the housing. This part is called the impeller or pump. The blades in the part on the left side are part of the turbine.
4.2.2 Turbine Cross Section

The turbine and impeller have a rounded profile. When the turbine is cut along the axis, its cross section will look like the illustration on the right.

4.2.3 Fluid Coupling Oil Flow

The pump shaft connects to the engine flywheel. The turbine output shaft connects to the driven unit. The impeller and turbine both turn in the housing. They are not directly connected together in any way. The housing is filled with oil.

When the engine is started, the impeller starts turning. As the impeller turns, it throws oil from the centre toward the outside edge. The shape of the impeller and centrifugal force move the oil outward and across into the turbine. The oil strikes the turbine blades. The energy of the moving oil is absorbed by the turbine and starts the turbine turning. As the oil strikes the turbine, the oil slows down and flows inward, toward the centre to re-enter the impeller.
When the oil leaves the turbine, it is flowing in a direction opposite the oil flow in the impeller and tends to oppose the impeller. This fact, we learn later, is an important difference between the fluid coupling and the torque converter.

4.2.3.1 Rotary Oil Flow

Rotary flow occurs when the oil is traveling with the impeller and the turbine in the direction of rotation. This happens when the impeller and the turbine are traveling at nearly the same speed, for example when the machine is “coasting” or when a Bulldozer is pushing with little or no load. The oil is thrown outward by centrifugal force in both the impeller and turbine. The oil simply follows the impeller and turbine around and around.

With rotary oil flow, there is minimum “slip” or difference in rotational speed between the impeller and the turbine. The turbine output torque is zero.

4.2.3.2 Vortex Oil Flow

Vortex oil flow, occurs when the oil is traveling outward through the impeller, across to the turbine and inward through the turbine back to the impeller. The impeller is turning with the engine. The turbine is stalled or held stationary by a load. The oil traveling across and striking the turbine blades limits oil movement in the direction of rotation with the impeller. The oil flow path looks like a spiral.

When we have vortex flow, there is maximum “slip” between the impeller and the turbine. The output torque is greatest when the turbine is stalled.

Under normal operating conditions, the oil flow in a fluid coupling will combine both rotary and vortex flow. The imaginary oil flow path will be like a coil of wire, which loosens or becomes tighter depending upon the amount or degree of “slip” between the impeller and the turbine.
In a fluid coupling, the input torque equals the output torque. The fluid coupling transmits power but will not multiply torque. As the oil flows from the impeller to the turbine in a fluid coupling, the oil is not moving in the same direction as the turbine. This produces an unnecessary load on the engine. A stator is required to multiply torque.

### 4.3 Torque Converter

A torque converter is a fluid coupling with the addition of a stator.

Like the fluid coupling, the torque converter couples the engine to the transmission and transmits the power required to move the machine. The housing is cut away to see the working parts inside.

Unlike the fluid coupling, the torque converter can also multiply torque from the engine, which increases torque to the transmission. The torque converter uses a stator, which redirects fluid back into the impeller in the direction of rotation. The force of oil from the stator increases the amount of torque transferred from the impeller to the turbine creating torque multiplication.

The torque converter basic components are a rotating housing, impeller, turbine, stator and output shaft.

#### 4.3.1 Torque Converter Components

The rotating housing and impeller turn with the engine, the turbine turns the output shaft, and the stator is fixed and held stationary by the torque converter housing.

The oil flows upward from the rotating impeller, around the inside of the housing and downward past the turbine. From the turbine, oil is redirected back to the impeller by the stator.
The rotating housing is connected to the flywheel and surrounds the entire torque converter. An inlet relief valve and an outlet relief valve control the amount of oil pressure that is held in the torque converter.

A) Impeller Forces Oil against Turbine

The impeller is the driving member of the torque converter. It is splined to the flywheel and turns at engine RPM. The impeller contains blades, which force oil against the blades of the turbine. As it spins, the impeller is throwing the oil outward toward the inside of the rotating housing. Oil is moving in the direction of rotation when it comes off the impeller blades.

The turbine is the driven member of the torque converter with vanes that receive the oil flow from the impeller. Impact of the oil from the impeller on turbine vanes causes it to rotate. The turbine causes the output shaft (which is splined to the turbine) to turn. The oil is moving in the opposite direction of engine/flywheel rotation when it comes off the turbine fins.

B) Stator Redirects Oil to Impeller

The stator is the stationary reaction member with vanes that multiply force by redirecting fluid flow from the turbine back to the impeller. The purpose of the stator is to change the direction of the flow of oil between the turbine and the impeller.
Direction change will increase the momentum of the fluid, thereby increasing the torque capacity of the converter. The stator is connected to the torque converter housing. Momentum of the oil is in the same direction as the impeller. Oil hits the backside of the impeller blades causing the impeller to rotate. This is known as the reaction.

4.3.2 Torque Converter Principles

The torque converter absorbs impact loads. The viscosity of the torque converter oil is a good medium for transmitting power. Oil is necessary to reduce cavitation, carry away heat, and to lubricate torque converter components.

The torque converter adjusts to the machine load. Under a high load, the impeller spins faster than the turbine to increase torque and reduce speed. With a small load on the machine the impeller and turbine rotate at nearly the same speed. Speed increases and torque decreases. Under a stall condition, the turbine is stationary and the impeller is rotating. Maximum torque is produced when the turbine is stopped.

4.3.3 Torque Converter Benefits

The torque converter multiplies torque when needed for the load and helps keep the engine from stalling during high load applications. The torque converter also allows the hydraulics of the machine to continue to work and permits the use of a power shift transmission.

4.3.4 Lockup Clutch Torque Converter

Some machines need torque converter drive under certain conditions and direct drive during other conditions.

The lockup clutch torque converter provides a direct connection between the transmission and engine.

It also operates the same way as a conventional torque converter when it is not in lockup mode.

The lockup clutch is located inside the torque converter housing.

When the lockup clutch is engaged, the clutch connects the rotating housing directly to the output shaft and the turbine. The output shaft will turn at engine speed. Direct drive provides the highest drive train efficiency at high speeds. The lockup clutch connects the
turbine to the rotating housing. The rotating housing rotates at the same speed as the impeller. The lockup clutch is automatically engaged anytime the machine operating conditions demand direct drive.

To further improve the efficiency of machines equipped with torque converters, different torque converters have been designed;

- Impeller clutch torque converter
- Variable capacity torque converter
- Torque divider

### 4.4 Torque divider

Some Bulldozers are equipped with Torque dividers

**Purpose:** Engine torque is transmitted to the output shaft over two paths;

a) When a dozer is ‘digging in’, Torque converter drive automatically provides the high torque multiplication needed to meet the increasing load.

b) When drifting a pile or moving the machine without a load, direct drive is more efficient.

**Operation:** Note that the flywheel drives both the sun gear and the impeller.
The turbine is splined to the ring gear and drives the ring gear. The output shaft is splined to the planet carrier and is driven by the planet carrier only. The planet gears are driven by the ring gear and the sun gear. In the torque divider, the engine torque is transmitted to the output shaft over two paths. Hence its name is torque divider. One path is through the direct mechanical connection to the sun gear. The other path is through the torque converter to the ring gear. Because of the larger radius of the ring gear, most of the torque split goes through the torque converter and the ring gear. Assume that there is no load on the machine. The flywheel drives both the impeller and the sun gear directly. If we assume that the impeller and turbine are rotating at the same speed, the ring gear and the sun gear will be rotating at the same speed too. With no load on the machine, the output shaft is not restricted and all the parts of the planetary rotate in the same direction and at the same speed.

When increasing load, the output shaft and planet carrier slow down, but the sun gear continues to rotate at engine speed. This condition forces the planet gears to rotate on their shafts instead of revolving around the sun gear. This causes the ring gear to slow down, and when the output shaft is slowed down enough the ring gear will rotate in reverse direction. Remember, the ring gear and the turbine are one unit. When the output shaft and the carrier slow down the gear ratio between the planet gears and the ring gear causes a rapid slowing down of ring gear rotation. If the slowdown is fast enough, the direction of ring gear and turbine can be reversed.

Because the impeller is driven by the flywheel at engine speed, when the ring gear and turbine slow down the oil from the impeller drives the turbine. Because of the speed
difference between the impeller and the turbine there is torque multiplication and the turbine transmits torque through the planet gears and carrier.

Because of the gear ratio in the planetary, the ring gear and the turbine slow down much faster than the output shaft. This means that picking up a load causes faster torque multiplication than would occur if only a torque converter were used.

**Power shift transmission**

*Counter shaft and Planetary gears*

*Fully - Automatic transmission*

If the transmission is fully automatic, the hydrodynamic torque converter is followed by a planetary (epicyclic) gear cluster. The various gear ratios are automatically selected by a hydraulic or electromechanical control unit according to engine load and ground speed.

The word “Power Shift” means “shifting while power is not interrupted”. No need for a clutch, shifting on the go.

Heavy earth moving and construction machinery are equipped with automatic- or semi-automatic power shift transmissions. A power shift in combination with a torque converter will enable smooth and easy shifting. In this module we will discuss the difference between a planetary power shift and a countershaft power shift.

The hydraulic assist transmission is a train of gears which can be shifted without interrupting the flow of power. The gears are kept in constant mesh while two or more hydraulic clutches control the flow of power “on the go.”
The parts work together as follows:

- Hydraulic clutches, controlling the power flow
- Gear train, transmits the power flow

When the operator shifts gears, hydraulic oil engages the clutches that route power to the selected gears. A hydraulic clutch is normally an alternating pack of friction disks and plates. The clutch is engaged when pressure oil is sent to push the piston against the disks and plates, clamping them together. The disks are splined to the drum, while the plates are splined to the hub. As a result, input power through the drum is sent on through the hub to the output by the engaged clutch.

The clutch is disengaged when oil pressure is released and the piston moves away from the clutch pack. This frees the disks from the plates and the power flow is stopped. Spring action or oil pressure on the other side of the piston may be used to help release the disks and plates.

4.5 Countershaft transmissions

Countershaft transmissions allow one set of gears to be shifted without disturbing the other gear ratios in the transmission.

A) High – Low speed unit
The simplest countershaft transmission is the high-low speed unit. It has two hydraulic clutches and four gears in mesh.
B) Low speed

Whenever one clutch is engaged, the other is disengaged. The input and output shafts are not connected unless the Low or High drive clutch is engaged. When engaged, this clutch sends input power from the outer drum through the inner hub.

C) High speed

In High drive, both shafts are locked together (direct drive) and rotate at the same speed. This gives high speed.

For low speed, the Low speed clutch is engaged. Gear $G_1$ is fixed on the input shaft so power is routed through mating gear $G_2$, along the countershaft, out through gears $G_3$ and $G_4$ and to the Low speed clutch drum. Power then flows through the engaged clutch pack to the inner hub which is fixed to the output shaft.
The output shaft turns at a slower speed than the input shaft, giving the low speed. The actual speed depends upon the ratio of the two gear sets.

Underdrive means that the output shaft turns slower than the input. In some units the output turns faster than the input and these are called overdrives.

**Countershaft Transmission**  
**Planetary Transmission**
Countershaft transmission

![Diagram of countershaft transmission]

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<tr>
<td>3</td>
<td>Input from Diesel engine</td>
</tr>
<tr>
<td>4</td>
<td>Forward clutch</td>
</tr>
<tr>
<td>5</td>
<td>1st gear clutch</td>
</tr>
<tr>
<td>6</td>
<td>2nd gear clutch</td>
</tr>
<tr>
<td>7</td>
<td>Drive shaft to rear axle and wheels</td>
</tr>
<tr>
<td>8</td>
<td>Drive shaft to front axle and wheels</td>
</tr>
</tbody>
</table>

Countershaft meaning, shafts and gears rotate clockwise and counter clockwise. The picture above represents a typical transmission, used by most Wheel loaders. To obtain first gear (speed) forward, multiplate clutch 4 and speed clutch 5 need to be locked both at the same time.

Oil pressure is needed to lock the clutches.

Small coil spring are installed and needed to release the steel- and friction plates when oil pressure has been released.
Planetary Gears

Countershaft Gears
- Clockwise
- Counterclockwise
- Clockwise

Hence the Name Countershaft Transmission
Countershaft transmission

<Diagram of a countershaft transmission with labeled parts>

1. Torque converter
2. Transmission oil pump
3. Turbine shaft
4. Intermediate shaft High and Low
5. Intermediate shaft reverse and 2nd forward
6. Intermediate shaft 1st and 3rd gear
7. to rear axle
8. to front axle
9. ATF
10. Parking brake
11. Countershaft transmission
12. Intermediate gear
13. Transmission oil pump
14. Turbine shaft
15. Intermediate shaft High and Low
16. Intermediate shaft reverse and 2nd forward
17. Intermediate shaft 1st and 3rd gear
18. to rear axle
19. to front axle
20. ATF
21. Parking brake
4.6 Planetary transmissions

Planetary gears work like our solar system. The pinions or planet gears each turn on their own axis, at the same time rotate around the sun gear. This is much like the earth and other planets rotating around the sun.

4.6.1. Planetary gears speed ranges

<table>
<thead>
<tr>
<th>DRIVING</th>
<th>HELD</th>
<th>DRIVEN</th>
<th>DIRECTION</th>
<th>FASTER/ SLOWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun gear</td>
<td>Gear</td>
<td>Planet carrier</td>
<td>Same</td>
<td>Slower</td>
</tr>
<tr>
<td>Ring Gear</td>
<td>Sun Gear</td>
<td>Planet Carrier</td>
<td>Same</td>
<td>Slower</td>
</tr>
<tr>
<td>Planet Carrier</td>
<td>Ring Gear</td>
<td>Sun Gear</td>
<td>Same</td>
<td>Faster</td>
</tr>
<tr>
<td>Planet Carrier</td>
<td>Sun Gear</td>
<td>Ring Gear</td>
<td>Same</td>
<td>Faster</td>
</tr>
<tr>
<td>Sun Gear</td>
<td>Planet Carrier</td>
<td>Ring Gear</td>
<td>Opposite</td>
<td>Slower</td>
</tr>
<tr>
<td>Ring Gear</td>
<td>Planet Carrier</td>
<td>Sun Gear</td>
<td>Opposite</td>
<td>Faster</td>
</tr>
<tr>
<td>2 Elements rotating together</td>
<td>Same</td>
<td>Same</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Without one planetary gear set, seven (7) speed ranges can be obtained. However, power shift transmissions are always using a multiple number of planetary gears sets. In addition, some power shift transmissions are having a separate clutch pack for Forward and Reverse. Those clutches are usually equipped with more clutch and steel plates than the speed clutches.

When used with hydraulic clutches and brakes, the planetary can serve as a direct coupler a reduction gear or a reversing gear.

A planetary gear set allows gear ratios to be changed without actually engaging or
disengaging gears. As a result, there is little or no interruption of the power flow.

Planetary gears are compact units which allow the input and output shafts to rotate on the same axis and eliminate the countershaft. In planetary sets, the gear load is spread over several gears, decreasing the load on each tooth.

The planetary system also spreads the load evenly around the circumference of the system, eliminating the sideways stress on the shafts.

**The basic parts of the planetary system are:**

- Sun gear, centre of system
- Planet pinions and carrier, rotate around sun gear
- Ring gear, surrounds the other parts

A planetary transmission uses hydraulic clutches and brakes to control the rotation of the planetary parts.

The planetary gears may be simple or compound units.

Planetary gears work on the principle that when any two parts are locked together, all three parts rotate as a unit.

The sun gear shaft is the power input, while the output shaft is fastened to the planet pinion carrier. For high speed, the direct drive clutch engages and locks the sun gear to the planet pinion carrier, making the input and output shafts rotate in unison for a direct drive.
5. Final drives

The planetary gear reduction system is smaller and more compact than the pinion type. Planetary systems are also more durable under heavy loads since torque loads are spread more evenly over several gears.

The use of planetary gear systems is becoming more common on earth moving and construction equipment, as engine horsepower and pulling loads are increased.
The planetary gear set may be located next to the differential or at the outer ends of the final drive (wheel hub/rim). Both types operate the same.

**Operation**

The planetary gear reduction system receives engine power from the differential through the final drive shaft and sun gear. The sun gear is an integral part of the final drive shaft and so turns with the shaft. The sun gear meshes with the planet pinions which are mounted in the planet pinion carrier.

As the sun gear turns, it forces the planet pinions to “walk around” the inside of the ring gear as shown by the arrows. The planet pinion carrier is forced to rotate in the same direction as the sun gear, thus delivering engine power to the drive wheels but at a reduced speed and an increased torque.

The axle shaft is carried on two tapered bearings with the inner end of the shaft splined to the planet carrier. The bearings are positioned internally at both ends between the axle housing and shaft. With this type of axle, the axle shaft supports the weight of the machine and absorbs end thrust, as well as transmitting engine torque.

### 5.1.1 Planetary Mounted next to Differential

With this planetary, a straight, in-line axle is achieved. This permits a large range of wheel tread adjustments on farm tractors for various widths of crop rows.

In addition, all gears are located in one compact housing.
5.1.2 Planetary Located in Wheel Hub (Rim) or Sprocket

When the planetary is located at the outer ends of the final drive, the final drive system is enclosed in one rigid housing. That is, the differential housing, both axle housings, and the planetary gear housings are connected to form a one-piece construction.

The axle shaft in this system is the full-floating type which was described earlier. The only difference is that the planetary carrier drives the wheel hub instead of a flanged end of the axle shaft.

The advantages of “in-wheel-hub-mounted-final-drives” opposed to “near-differential-mounted-final-drives are:

- Smaller size (less heavy) of half shaft needed
- Less problems with breaking of half shaft as the reduction of drive is plus/minus 3.5 times half shaft to 1 revolution of drive wheel/sprocket. Reduction of half shaft wind-up (torsion of half shaft)

Disadvantage of “in-wheel-hub-mounted-final-drives” are:

- Soil or clay can stick around the final drive hub and in the wheel rim, causing increase of temperature. Increase of temperature with little change to dissipate heat, will cause the oil in the final drive to overheat. Multiplate brake discs also create heat.

Danger: in some extreme cases, due to these high temperatures, the tyre might explode. For this reason, scraper tyres are often filled with nitrogen instead of air (oxygen). Nitrogen will avoid the tyre to explode.
5.2 Maintenance of final drives

The reliability of any final drive depends upon good maintenance, operating at rated load, and proper repair once a failure has occurred.

Watch these key points when diagnosing final drive failures:

- Excessive drive shaft end-play
- Overheating
- Lack of lubrication

5.2.1 Excessive Shaft End-play

Excessive drive shaft endplay is normally caused by loose shaft bearings.

However, it can also be created by:

1) Foreign material in the lubricant which will wear bearings rapidly;
2) Overloading the machine either by weight or engine torque;
3) Poorly adjusted bearings at the time of assembly.

A continuous noise or knock is a good sign of loose or damaged bearings. On machines with semi-floating axles, such as automobiles, the knocking noise can be heard in the differential case, since the ends of the axle shaft are rapping the spacer block. Readjustment of the bearings that are worn or damaged will not provide a satisfactory repair. Instead, replace the bearings.

Compare the roller ends of a new tapered bearing with a worn bearing. Worn bearing rollers have no shoulder compared to a new bearing—replace them.

5.2.2 Overheating

Many final drives are damaged simply by over-heating. This is caused by not maintaining the lubricant at the proper level or by using the wrong type of lubricant.

Galling, pitting, or scoring on the surface of a part indicates the lack of lubricating film and that over-heating has occurred. Overloading and abuse of the machine will also cause overheating. Excessive loads cause deflection in the final drive assembly and concentrate stresses and friction in one area.

5.2.2 Lack of lubrication

Loss of lubricant through worn and broken oil seals and gaskets may cause severe damage to the final drive. While some bearings are automatically lubricated by oil creeping along the drive shaft from the differential, others are sealed off and require separate lubrication.
When installing a new oil seal, make sure it is flexible or pliable in the area where the seal fits around the shaft. Soak the seal in oil before installing it.

5.3 Adjusting Final Drives

To prevent premature failures, adjust the final drives properly. This includes adjusting the axle bearings either preloading or allowing a specified endplay.

5.3.1 Adjusting Axle Bearings

Loose gears or bearings that are too tight or too loose will break down prematurely, regardless of their strength and design. Bearings must be adjusted to the manufacturer’s specifications. Some designs require the bearings to be preloaded, while others require a slight amount of shaft endplay.

5.3.2 Preloading Bearings

When the manufacturer’s instructions call for pre-loading the bearings, bearings must be placed under slight tension. In some cases, this is done by slight overtightening of the bearing adjusting nut, while in other designs it is done with shims. Preload is normally measured in inch-pounds of rolling or rotating torque (not starting torque).

Some torque specifications will include frictional drag such as oil seals, gears, etc. in the final drive. If it is not included, measure the rolling torque while the axle shaft still has a slight amount of endplay, and add this torque reading to the specified torque.

Then make the necessary bearing pre-load adjustment. Also, when new bearings are installed, a greater amount of torque will be required. Always make the preload adjustment in small increments until the proper preload is obtained.

There are several methods of measuring rolling torque. One method is to use a special tool or adapter with a torque wrench.
This gives a direct reading on the wrench.

**Checking bearing Preload with pull scale (spring balance)**

Another method of checking the preload torque is by means of a cord and pull scale. The preload is figured by multiplying the radius (distance from the centre of the drive shaft to a point on the circumference from which the cord is pulled) by the reading on the pound scale.

**For example:** Assume the radius is 4 inches (100 mm) and the reading on the scale is 7 pounds (31 N). Multiply 4 inches (100) by 7 pounds (31) and you will have 28 inch-pounds (3.1 N•m) of rolling torque (100*31 = 3100 N•mm = 3.1 N•m).

### 5.3.3 Adjusting For Endplay

Some types of drive axles call for the axle shaft to have a slight amount of endplay. This means that the shaft when properly adjusted must be free to move endways within the limits specified. The end movement in most cases is between 0.001 and 0.010 inch (0.025 and 0.25 mm).

**Measuring end-play of half-shaft**

**Pre-loading using:**

- spring balance or torque wrench
6. What is a Differential?

The differential is a device that splits the engine torque two ways, allowing each output to spin at a different speed.

<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Drive shaft (pinion)</td>
</tr>
<tr>
<td>B</td>
<td>Drive pinion</td>
</tr>
<tr>
<td>C</td>
<td>Crown wheel</td>
</tr>
<tr>
<td>D</td>
<td>Small gear (pinions)</td>
</tr>
<tr>
<td>E</td>
<td>Sun gear</td>
</tr>
<tr>
<td>F</td>
<td>Half shaft</td>
</tr>
<tr>
<td>G</td>
<td>Differential housing</td>
</tr>
</tbody>
</table>

The differential is found on all modern cars and trucks, wheel loaders, dump trucks, mobile excavators, and also in many all-wheel-drive (full-time four-wheel-drive) vehicles. These all-wheel-drive vehicles need a differential between each set of drive wheels, and they need one between the front and the back wheels as well, because the front wheels travel a different distance through a turn than the rear wheels.

Part-time four-wheel-drive systems don’t have a differential between the front and rear wheels; instead, they are locked together so that the front and rear wheels have to turn at the same average speed. This is why these vehicles are hard to turn on concrete when the four-wheel-drive system is engaged.
The differential has three jobs:
- To aim the engine power at the wheels
- To act as the final gear reduction in the vehicle, slowing the rotational speed of the transmission one final time before it hits the wheels
- To transmit the power to the wheels while allowing them to rotate at different speeds (This is the one that earned the differential its name.)

6.1 Off Road

Another time differentials might get you into trouble is when you are driving off-road. If you have a four-wheel drive truck, or an SUV, with a differential on both the front and the back, you could get stuck. Now, remember a differential always applies the same torque to both wheels. If one of the front tires and one of the back tires comes off the ground, they will just spin helplessly in the air, and you won’t be able to move at all.

The solution to these problems is the limited slip differential (LSD). Limited slip differentials use various mechanisms to allow normal differential action when going around turns. When a wheel slips, they allow more torque to be transferred to the non-slipping wheel.

6.2 Clutch-type Limited Slip Differential

The clutch-type LSD is probably the most common version of the limited slip differential. This type of LSD has all of the same components as a standard differential, but it adds a spring pack and a set of clutches. Some of these have a cone clutch that is just like the synchronizers in a manual transmission.
The spring pack pushes the side gears against the clutches, which are attached to the cage. Both side gears spin with the cage when both wheels are moving at the same speed, and the clutches aren’t really needed - the only time the clutches step in is when something happens to make one wheel spin faster than the other, as in a turn.

The clutches fight this behavior, wanting both wheels to go the same speed. If one wheel wants to spin faster than the other, it must first overpower the clutch. The stiffness of the springs combined with the friction of the clutch determine how much torque it takes to overpower it.

Getting back to the situation in which one drive wheel is on the ice and the other one has good traction: With this limited slip differential, even though the wheel on the ice is not able to transmit much torque to the ground, the other wheel will still get the torque it needs to move. The torque supplied to the wheel not on the ice is equal to the amount of torque it takes to overpower the clutches. The result is that you can move forward, although still not with the full power of your car.

Another way avoiding slip is by using a differential lock. A differential lock will lock both half-shafts together making them both turning at the same speed.
7. Hydrostatic drives

**Hydrodynamics;**
- Torque converter
- Power shift

**Hydrostatics;**
- Hydraulics pump
- Transfer case
- Hydraulic motor

**Schematic of hydrostatic drive**

<table>
<thead>
<tr>
<th>Number;</th>
<th>Description;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Axial piston pump, variable displacement, bi-directional</td>
</tr>
<tr>
<td>2</td>
<td>Hydraulic motor</td>
</tr>
<tr>
<td>3</td>
<td>Feed pump (charge and servo pump)</td>
</tr>
<tr>
<td>4</td>
<td>Neutral valve (2/2 way) to enable towing the vehicle</td>
</tr>
<tr>
<td>5 &amp; 6</td>
<td>Cross over relief valves (secondary relief valve)</td>
</tr>
<tr>
<td>7 &amp; 8</td>
<td>Flush valves</td>
</tr>
<tr>
<td>9</td>
<td>Pressure relief valve</td>
</tr>
<tr>
<td>10 &amp; 11</td>
<td>Check valves</td>
</tr>
<tr>
<td>12</td>
<td>Hydraulic oil filter</td>
</tr>
<tr>
<td>13</td>
<td>Hydraulic oil cooler</td>
</tr>
<tr>
<td>14</td>
<td>Pressure relief valve</td>
</tr>
</tbody>
</table>
Many wheel loaders are hydrostatic driven. Hydrostatic drives allow the engine to be fitted in different locations, without disturbing the drive line. Hydraulic hoses are replacing the clutch and gearbox. Therefore making it possible to mount the engine at any position.
General description
Refer to the schematic diagram for the structure of the entire power transmission system. Apart from the repairs explained in this chapter, the advantages of the entire drive system, which was specially developed for the requirements of a wheel loader, are also discussed briefly.

The aim of developing an extremely easy-to-operate machine has been realized mainly through the use of a modern, hydrostatic drive system. Operation must be easy to learn and uncomplicated since wheel loaders are often used by all types of personnel. The built-in hydrostatic drive with its automatic control provides driving characteristics which are the same as, or even surpass, those of passenger vehicles. The direction of travel and the gear ratio are changed semi automatically. Although the direction of travel change and the gear ratio can be shifted under full load, these procedures result in no wear, in contrast to normal hydrodynamic gearing systems with the corresponding couplings which must take up the energy. When operating with the machine, the automatic system thinks" for the driver and optimally adapts the speed to the road resistance. The diesel engine’s power output is distributed by the automatic drive unit in the case of all operating and drive operations in such a way that it is always available to the assemblies which have priority in the individual operations without „stalling“ the diesel engine. For this reason, a power rating which is relatively small compared to the operating capacity of the machine is sufficient for all operations. This also involves low fuel consumption which is an extremely important advantage considering present-day fuel prices.

7.2 Transfer Gearbox (Drop box)

The transfer gearbox is designed in the form of a bevel-geared two-speed gearbox. It has the task of converting and distributing the input torque (hydraulic motor) to the rear axle and via the universal drive shaft to the front axle (all-wheel drive). A particular advantage of this design lies in the fact that the other axle receives the entire drive torque from the transfer box in case of poor traction of one axle.

7.3 Universal drive shaft

Despite the differing input or output angle between the front axle input and transfer gearbox output, the universal drive shaft has the task of smoothly transmitting the torque.

7.4 Axles

The axles have the task of transmitting the drive torque to the wheels. The drive power can be correspondingly reduced due to a wheel slipping by means of the differential effect. The front and rear axles have 25 % or 40 % block differentials for this purpose. (limited slip differential)
7.5 Hydrostatic Drive Train

Key:

1  To the drive motor  5  Transfer case (Drop box)
2  Hydraulic pump  6  Universal drive shaft (prop-shaft)
3  Hydraulic motor  7  Front axle (with diff.)
4  Rear axle  8  Final drive

The main components of the hydrostatic drive are listed above. The hydraulic pump is an axial piston pump of swash plate design, the hydraulic motor is an axial piston motor of inclined axle design. This combination, in conjunction with an “automatic” control, makes the device into a construction machine which can be easily driven even by untrained drivers. The control optimally adapts the driving speed to the road resistance so that the diesel engine and the driver are not excessively “stressed”.

In order to be able to efficiently carry out repairs to the machine, it is essential that the function is understood. Therefore, please read the explanations carefully, since they provide you with precise information on the fault or damage with the aid of the following diagrams, thus saving you, under certain circumstances, a great deal of time in faultfinding operations.
Basic knowledge of the function of a hydrostatic transmission system and an axial piston pump is assumed. Following the oil circuit, this description starts with the auxiliary pump 3.

This pump which is mounted coaxially to the hydraulic pump and like the main pump, is driven by the combustion engine, has three main tasks:

1. It supplements the leakage oil of the closed circuit and the drained flushing oil via the drain equipment.
2. It supplies the control and regulating system of the main pump with the necessary oil.
3. It cools the circuit.

The information herewith below belongs to figure 2 (see next page)

The pump obtains the hydraulic oil from tank 8. The leakage oil of the variable displacement pump and the variable displacement motor as well as the excess supply oil is rerouted back to the tank through cooler 7 via the T connections.

Depending on the drive speed, the flow from auxiliary pump 3 acts on the orifice of control valve 6. The control pressure is built up in this way acts on the piston at the connection X₁ or X₂, depending on the direction of travel selected on switch 14, on the displacement of the pump.

The control pressure increases as the speed increases; the swivel plate is swiveled out further by means of the hydraulic displacement and the rate of flow is increased at the operating line B.

This flow causes the drive speed to increase at the drive shaft. A corresponding torque is required depending on the load on the drive. The maximum possible drive torque is obtained when the motor is swiveled out at a maximum (illustrated position), whereby the operating pressure also determines the value of the drive torque.

For this reason, a large torque is transmitted to the drive wheels due to the pivoted position when accelerating (starting off) the vehicle. The illustrated position of the displacement is obtained by the high pressure which acts on the displacement piston via the non-return ball valve and the control piston, see Fig. 2.

The control piston of the motor switches against the high pressure and the spring force if the high pressure drops in the acceleration phase and the control pressure acting on the displacement above the control lines at X₁ is predominant.
Main Components

1. Hydraulic Pump
2. Hydraulic Motor
3. Supply Pump
4. Supply Pressure Valve
5. High Pressure Valve
6. Control Valve
7. Cooler
8. Tank
9. Inlet Filter
10. Inch Pedal
11. Accelerator
12. Electrical Direction-of-Drive Valve
13. Electrical Direction-of-Drive Valve
14. Direction-of-Drive Switch
15. Adjustment Orifice

The cylinder, together with the control lens, is shifted to a smaller swivel angle via the hydraulic displacement.

The motor displacement becomes smaller and the drive speed increases further. The control piston is switched back and displacement swivels further out in order to transmit a larger drive torque when a preselected high pressure is exceeded.

A control characteristic is specified on control valve 6 this causes a corresponding control pressure to build up in a determined speed range. When the drive engine (combustion engine) is overloaded, its speed is reduced, the control valve causes a control pressure drop which swivels back the pump.
An automatic overload prevention facility is provided by means of the resulting drop in the flow rate, causing the drive engine to run at the optimum speed after a brief and slight drop in engine speed.

A selector valve is pressurized via the control lines on the displacement motor in order to prevent uncontrolled displacement procedures from occurring during downhill travel or braking and also in the case of the resulting change in the directional forces. This assigns the high pressure to the appropriately switched direction of drive, thus preventing uneven control operations.

The control pressure can be reduced (inching) by means of pedal 10 via the lever on control valve 6 and in conjunction with the accelerator 11. In this way, it is possible to smoothly start off at full engine speed. The variable displacement pump can be prematurely swiveled back by the decrease of the control pressure; the drive additionally brakes the machine hydraulically.

8. Conclusion

The variable displacement pump with the variable displacement motor forms a mobile drive unit with all the necessary components for the closed circuit. The speed-dependent automotive control provides a sensitive change of the drive speed by utilizing the optimum torques without overloading the drive motor.
Setting data

**Caution:** All measurements must be measured when the machine is at Operating Temperature (temperature tank 70°C).

**Pressures**

- High pressure forward: $M_1$ 410 bar (± 10 bar)
- High pressure reverse: $M_2$ 410 bar (± 10 bar)

**Figure 4**

- Control pressure $X_1$: 25 - 27 bar
- Control pressure $X_2$: 25 - 27 bar
- Supply pressure $M_3$: 26 - 28 bar
- Central control pressure $M_4$: 26 - 28 bar

**Speeds**

(measured on the diesel engine by a pulse measuring instrument)

- Idling speed: 800 rpm (± 50 rpm)
- Maximum no-load speed: 2600 rpm (± 50 rpm)
- Thrust speed (against drive): > 2500 rpm
- Starting speed: 1100 (± 50 rpm)
- Speed for obtaining the maximum high pressure: 2000 (-100 rpm)

**Speeds** (with 20-24 tires)

- On-road gear: > 36 km/h
- Off-road gear: > 12 km/h
- Tractive power in on-road gear: > 2.6 t (20 - 24 tires)
Figure 3
Hydraulic pump

1. Swash Plate
2. Piston Barrel
3. Port plate
4. Supply and control pressure pump
5. Orifice for setting the displacement time
6. Pressure limiting valve (supply/control pressure)
7. Pressure limiting valve with supply valve (high pressure)
8. Displacement cylinder
9. Control Valve (three positions)
10. Stroke magnet ‘a’
11. Stroke magnet ‘b’
12. Regulating valve

A,B  Operating lines
S  Inlet line for supply and control pressure pump
T₂  Tank connection (leakage)
G  Pressure connection for auxiliary circuits
R  Venting
X₁, X₂  Test points (control lines)
Mₐ, Mₖ  Test points (operating lines)

Figure 5 (next page)
Hydraulic pump with regulating valve

1. Drive mechanism
2. Supply pump
3. Regulating valve
4. Solenoid valve
5. Setting element

Figure 6
Control valve

\[ P_1 = \text{Supply pump pressure before the control valve} \]

\[ P_2 = \text{Pressure behind the control valve orifice (supply pressure)} \]

\[ P_3 = \text{Control pressure} \]

Function of the control valve

The control and supply pump 2 turning at the speed of the combustion engine with a constant displacement volume produces a speed-proportional volume flow. A pressure differential \((P_1 - P_2) = \Delta P\), occurs at the orifice 3 in this way. This pressure differential influences the equilibrium position of the orifice piston so that the control edge 4 opens and pilot oil flows to the positioning piston of the variable displacement pump 7.

The pressure \(P_3\) is built up in the control line, this pressure moves the orifice piston until the control edge 4 closes again. The reverse sequence of operations occurs when the differential pressure is reduced at the orifice, the control edge 9 opens and the pilot oil is outlet until the orifice piston is once again in equilibrium. In this way, a correlation is set-up between the drive speed and the pilot pressure due to the control valve, i.e. a reduction of the engine speed results in an immediate drop in the pilot pressure. Overloading of the engine is prevented in this way.

The compression spring 5 can be pre-tensioned by turning the displacement pin 10 so that the spring force is predominant even at maximum engine speed, i.e. the pilot pressure is 0 and the drive brakes the vehicle.

A specific pressure loss is obtained by combining the accelerator and inch pedal (control valve).

The pilot pressure is kept constant by inching from the coupling point on despite increased engine speed.
KEY:

1. Control valve
2. Orifice
3. Accelerator pedal
4. Displacement pin for pretension
9. Practical Exercises

1) Given a Transmission, you are to carry out the following;

Disassemble and Assembling Transmission, including full inspection;

1) Select the correct hand tools, Special Service tools, equipment’s and accessories

2) Use the correct workshop manual

3) Follow the procedure for Disassemble, Inspection and Reassembling as given in the workshop manual

a) Record the various tools used for disassembling the transmission

b) Record the various tools used for Reassembling the transmission
c) List the various inspection carried out and write a brief notes on each inspection
2) Given a Front Axle, you are to carry out the following; Disassemble and Assembling Transmission, including full inspection;

1) Select the correct hand tools, Special Service tools, equipment’s and accessories

2) Use the correct workshop manual

3) Follow the procedure for Disassemble, Inspection and Reassembling as given in the workshop manual

a) Record the various tools used for disassembling the axle

b) Record the various tools used for Reassembling the axle
c) List the various inspection carried out and write a brief notes on each inspection
3) Given a Rear Axle, you are to carry out the following;

Disassemble and Assembling Transmission, including full inspection;

1) Select the correct hand tools, Special Service tools, equipment’s and accessories

2) Use the correct workshop manual

3) Follow the procedure for Disassemble, Inspection and Reassembling as given in the workshop manual

a) Record the various tools used for disassembling the axle

b) Record the various tools used for Reassembling the axle
c) List the various inspection carried out and write a brief notes on each inspection
4) Given a transfer box, you are to carry out the following;

Disassemble and Assembling Transfer box, including full inspection;

1) Select the correct hand tools, Special Service tools, equipment’s and accessories

4) Use the correct workshop manual

5) Follow the procedure for Disassemble, Inspection and Reassembling as given in the workshop manual

a) Record the various tools used for disassembling the transfer box

b) Record the various tools used for Reassembling the transfer box
c) List the various inspection carried out and write a brief notes on each inspection
5) Planetary final drive

Wheel Assemblies (planetary final drive), bearings and seals

Given a Planetary final drive, you are to carry out the following;

Disassemble and Assembling a Planetary final drive, including full inspection;

1) Select the correct tools and accessories
6) Use the correct workshop manual
7) Use a torque wrench, if necessary
8) Measure the piston rod for straightness
9) Install new oil seals, using the right procedure

Tools needed:
- Spanner wrench
- Torque wrench (multiplier)
- Bearing cup puller
- Puller assembly
- Ratchet box wrench
- Adapter

Assembly and disassembly is based on a Caterpillar 920 Wheel loader. Specifications belonging to your practical training model, might therefore differ from the information given.
Start by:

a) removing rim and tyre
b) remove brake head assemblies
c) remove final drives

1. Remove the lock wire and bolts.
2. Fasten a hoist to the wheel assembly, or support it with a bottle jack.
3. Use a torque multiplier to remove the nut that holds the wheel assembly on the spindle.
4. Bend the locks from bolts. Remove the bolts, locks and plates that hold ring gear in position. Remove ring gear.

5. Remove hub assembly from the spindle.

6. Remove the wheel assembly. The weight of the wheel assembly is 145 lb. (65 kg).

7. Install four 3/8”-16 NC forcing screws in hub assembly. Tighten the forcing screws until they make contact with the outer wheel hearing cone. Tighten the forcing screws evenly to remove the hearing cone from the hub assembly.

8. Remove the bushing from hub assembly with a bearing puller.

9. Remove the outer half of the Duo-Cone floating seal from the wheel assembly.

10. Remove the rubber tonic sealing ring from the metal floating ring.

11. Remove the wheel brake disc from the wheel assembly.

12. Remove the outer bearing cup with a bearing puller.

13. Remove the inner bearing cup a bearing puller.

14. Remove the inner bearing cone from the spindle.
15. Measure the distance between the half shaft and the “stopper” (bronze thrust bearing) that is fitted in the planetary carrier. Adjust or remove shims, if necessary.

**Install Wheel Assembly**

**Tools needed:**

a) seal installer
b) lifting bracket
c) spanner wrench

1. Install the rubber toric sealing ring on the metal floating seal for each half of the Duo-Cone floating seal.

**NOTE:** The rubber seal and the metal ring that makes contact with it must be clean and dry. Put a small amount of SAE 30 oil on the outside surface of the metal seal ring that does not make contact with the rubber seal.
2. Install one half of the Duo-Cone floating seal on the spindle using a seal installation sleeve.

3. Install the inner bearing cone on the spindle.

4. Lower the temperature of the bearing cups and install them in the wheel assembly.

5. Install the brake disc on the wheel assembly and tighten the bolts to a torque of 195 ± 20 lb.ft. (265 ± 25 N.m).

6. Install the other half of the Duo-Cone floating seal in the wheel assembly with a seal installation sleeve.

7. Lower the temperature of the bushing and install it in the hub assembly.

8. Install the outer bearing cone on the hub assembly.

9. Fasten a hoist to the wheel assembly or support it with a bottle jack. Put the wheel assembly in position on the spindle.

10. Install the hub assembly on the spindle.

11. Install the ring gear and the plates, bolts and locks that hold it to the hub assembly.

12. Install the nut on the spindle.
13. Tighten the nut with a torque wrench while the wheel is turned with an 8 in. (20.3 cm) long lb. in. (N.m) Torque Wrench. The torque must be 75 ± 25 lb.in. (8.5 ± 2.8 N.m). For other lb.in. torque wrenches, the correct torque indication can be found with this formula:

\[
C = \frac{A \times T}{A \times T}
\]

“C” is the torque wrench reading.
“A” is the length of the torque wrench
“B” is the distance from the centre of the wheel to the wheel stud.
“T” is torque on bearings (T = 160 ± 50 lb.in. (18.1 ± 5.7 N.m)

14. Turn wheel slowly at a constant speed for one or two turns to check torque reading after adjustment has been made.

15. Tighten the nut more if needed to get the groove (slot) in alignment with the bolt hole. Install the bolts and lock wire.

**NOTE:** The torque wrench must be installed on wheel nut so it is in line with the centre of the wheel as shown.
Record your findings in the space below:
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