UNITED STATES MARINE CORPS
ENGINEER EQUIPMENT INSTRUCTION COMPANY
MARINE CORPS DETACHMENT
FORT LEONARD WOOD, MISSOURI 65473-8963

LESSON PLAN

POWER TRAINS

NCOM-E01

ENGINEER EQUIPMENT MECHANIC NCO

REVISED 04/18/2014

APPROVED BY_____ **DATE**_____

INTRODUCTION **(10 MIN)**

(ON SLIDE #1)

1. **GAIN ATTENTION**. Show clip of "The Best Burnout Ever" In order for that burnout to happen the engine was able to transfer the power to the wheels. How does that happen? Powertrains.

_____
_____
_____

(ON SLIDE #2-3)

2. **OVERVIEW**. Good morning/afternoon class, my name is_____. The purpose of this period of instruction is to provide you with the knowledge and skills necessary to identify, troubleshoot, or repair different powertrains configurations.

INSTRUCTOR NOTE
Introduce learning objectives

(ON SLIDE #4)

3. **LEARNING OBJECTIVES**.

a. **TERMINAL LEARNING OBJECTIVES**.

(1) Provided a service request, malfunctioning power train system, appropriate tools, and references, perform advanced repair on a power train system, to restore system to proper function. (1341-MANT-2008)

b. **ENABLING LEARNING OBJECTIVES**.

(1) Without the aid of reference, identify the characteristics of a power train system per the FOS4006NC. (1341-MANT-2008a)

(2) Provided a piece of engineer equipment, tools and references, disassemble power train components per the TM 10996B-OI/1, TM 11412A-OI, and TM-10794B-OI/A. 1341-MANT-2002c (1341-MANT-2008b)

(3) Provided a piece of engineer equipment, tools and references, assemble power train components per the TM 10996B-OI/1, TM 11412A-OI, and TM-10794B-OI/A. (1341-MANT-2008c)

(4) Provided a piece of engineer equipment, tools and references, test/adjust power train components per the TM 10996B-OI/1, TM 11412A-OI, and TM-10794B-OI/A. (1341-MANT-2008d)

(ON SLIDE #5)

4. **METHOD/MEDIA**. This period of instruction will be taught using the lecture method with aid of power point presentation, videos, instructor demonstrations, and practical applications.

5. **SAFETY/CEASE TRAINING (CT) BRIEF**. In case of fire exit the building and assemble in the parking lot for a head count. There is no safety brief associated with this lecture portion. There will be a safety brief given before certain demonstrations and practical applications.

(ON SLIDE #6)

6. **EVALUATION**. There will be a fifty question, multiple choice, closed book examination and a Hands-on evaluation of proper power train trouble shooting procedures. Refer to the training schedule for day and time.

(ON SLIDE #7)

TRANSITION: Now that you understand the purpose of this presentation, the terminal learning objective, enabling learning objective, how the period of instruction will be taught, and how you'll be evaluated, are there any questions? Now let's begin with a discussion on the power train components converter.

BODY **(55HRS 40MIN)**

(ON SLIDE #8-9)

1. **POWER TRAINS COMPONENTS**. **(3Hrs 10Min)**
Engine power is transmitted to the drive wheels by the power train. The power train does (4) jobs, it connects and disconnects power, selects speed ratios, provides a means of reversing and equalizes power to the drive wheels for turning. The Major components of the power train are the torque converter, transmission, differential, final drives and the drive wheels.

(ON SLIDE #10)

a. **Fluid Coupling**. To understand the torque converter, we must first look at the basic fluid coupling.

(ON SLIDE #11)

(1) The main advantage of the fluid coupling is that it eliminates tensional vibration and provides a smooth; jerk less acceleration because of the cushioning of the fluid medium between the two members.

(2) How does a fluid coupling work? If we have two electric fans face to face and fairly close together, and one fan is plugged in and running, the other fan will turn. It will be turned by the energy of the moving air from the operating fan.

(ON SLIDE #12)

INSTRUCTOR NOTE
Show clip of fluid coupling. In this example, the air is the fluid. Because the two fans are not close together and not enclosed, this sort of fluid coupling is not very efficient.

(3) Of course, we know the energy of a liquid in motion is greater than air in motion. Since a liquid weighs more than air, it transmits more force when in motion. To make a more efficient fluid coupling, oil is used as the fluid and the blades are mounted very close together and enclosed in housing.

(ON SLIDE #13)

(a) Fluid couplings are shaped somewhat like a doughnut or an inner tube for a wheel tire.

(ON SLIDE #14-15)

(4) Disassemble. When we take the coupling apart and separate the two halves, we can see a number of straight, radial blades extending from the inside to the outside edge. The blades on the right are a part of the housing. This part is called the pump or impeller. The blades on the left are part of the turbine.

(ON SLIDE #16)

(5) When the turbine on the left is cut along the axis, its cross section will look like the illustration on the right. You will recognize this shape in the following schematic cross section of the fluid coupling.

(ON SLIDE #17)

(6) This schematic represents the fluid coupling. The pump or impeller is shown in red. The pump shaft connects to the engine flywheel. The turbine is shown in blue. The turbine output shaft connects to the drive unit.

(ON SLIDE #18)

(7) Operation. The fluid coupling consists of an impeller (pump), driven by the engine and a turbine mounted on the transmission input shaft. There is no metallic connection between the two members. The assembly is kept filled with oil under control of a relief valve, by means of high capacity pumps. When the crankshaft and impeller rotate, the oil is thrown by centrifugal force from the center to the outside edge of the impeller between the vanes. This increases the velocity of the oil and increases its energy. The oil then enters the turbine vanes at the outside and flows toward the center, giving a rotating motion to the turbine. When the oil from the impeller strikes the turbine blades the energy of the moving oil is absorbed by the turbine and starts the turbine turning.

(a) When the oil starts the turbine turning, as the oil strikes the turbine, it slows down and flows inward toward the center to re-enter the impeller.

(b) The heavier yellow arrow represents oil increasing speed and energy as it moves through the impeller. The smaller arrows represent oil slowing down and losing energy to the turbine.

(ON SLIDE #19)

INSTRUCTOR NOTE
Show clip of animated fluid coupling. 1.33min This clip explains the operation of the fluid coupling.

(ON SLIDE #20)

(8) Oil Flow. There are two types of oil flow in a fluid coupling and torque converter, rotary flow (red arrows) and vortex flow (yellow arrows).

(ON SLIDE #21)

(a) Rotary Flow. This occurs when the oil is traveling with the impeller and the turbine in the direction of rotation. The impeller and the turbine must be traveling at nearly the same speed...like when the machine is "coasting" or when it is being "road" with little or no load. The oil is thrown outward by centrifugal force in both the impeller and the turbine (yellow arrows). The oil simply follows the impeller and turbine around and around (red arrows).

(ON SLIDE #22)

(b) Vortex Flow. This occurs when the oil is traveling through the impeller, across 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 would look like a spiral - an imaginary coil of wire.

(ON SLIDE #23)

(c) Under normal operating condition, the oil flow in a fluid will combine both rotary and vortex flow. The imaginary oil flow path will be like a coil of wire that loosens or becomes tighter depending upon the amount or degree of "slip" between the impeller and the turbine.

(d) To summarize, a fluid coupling transmits torque from the source of power to the driven unit. It consists of an impeller and a turbine, each having straight, flat, radial blades. As the impeller turns, it throws oil outward and across into the turbine blades. The energy of the oil in motion turns the turbine. The oil returns to the center, re-enters the impeller and the cycle is repeated. The fluid coupling cannot multiply torque.

(ON SLIDE #24)

(e) In a fluid coupling the input torque equals the output torque. The ratio is one to one.

(ON SLIDE #25)

INSTRUCTOR NOTE
Show clip of fluid coupling. 12.41min

(ON SLIDE #26)

INTERIM TRANSITION: We have just covered fluid coupling. Are there any questions? If not, go ahead and take a ten minute break.

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(ON SLIDE #27)

(BREAK – 10 Min)

INTERIM TRANSITION: Before the break we finished talking about the fluid coupling. Did anyone think of any questions over the break? If not let's talk about the Torque converter.

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(ON SLIDE #28)

b. **Torque Converter**. The hydraulic torque converter is used to reduce the amount of mechanical linkage found in a manual clutch. The torque converter reduces engine lugging and provides a hydrodynamic drive mechanism. It transmits power from the engine to a drive unit. It automatically provides the high torque needed to meet increasing workloads.

(ON SLIDE #29)

(1) Torque.

(a) Mechanics. Something that produces or tends to produce torsion or rotation; the moment of a force or system of forces tending to cause rotation.

(b) Machinery. The measured ability of a rotating element, as of a gear or shaft, to overcome turning resistance.

(ON SLIDE #30)

(2) Mounting. The torque converter can be mounted in two ways:

(a) Directly mounted. The torque converter can be directly mounted to the engine flywheel depending on the manufacturer.

(b) Remotely mounted. The torque converter may be remotely mounted to a propeller shaft connected with the engine, or transfer gears such as in the Caterpillar 621b Scraper. The converter fits in a housing, which is filled with oil. Normally the input-charging pump will be located somewhere on the housing.

(ON SLIDE #31-32)

(3) Components. The following three components make up a basic Torque converter:

(a) Impeller or Pump. To your right is the pump which is the input member to the torque converter. Notice the vanes of the pump. The impeller rotates with the engine, pushes the oil outward and across in the direction of rotation, striking the turbine blades.

(b) Turbine. To your far left is the turbine. The turbine is the input member to the power shift transmission. Here you can see how the vanes match the vanes of the pump. The energy from the impeller sent oil turns the turbine.

(c) Stator. The stator is the torque producing member of the torque converter. Depending on manufacturer, you may find single or double stators. The oil leaves the turbine, moving in the opposite direction of the impeller rotation. The stator causes the oil to change direction, adding its energy to the oil flow, this multiplies the torque.

INSTRUCTOR NOTE
Show the students the cutaway torque converter training aid.

(ON SLIDE #33)

1 The stator is the torque producing member; it has two positions; Locked and Free-wheel:

a Locked position. In the locked position, the stator rotates with the turbine and impeller. This will increase the torque. The increase of torque happens when the oil is redirected by the angle of the fins in the stator. In the locked position maximum torque occurs.

b Free-Wheel. In the free-wheel position the stator is stationary but still redirects the oil into the impeller. Rotary flow is the main type of flow. When this occurs it produces less torque. The ratio will be 1:1. When the stator is freewheeling we have little or no torque.

(ON SLIDE #34)

INSTRUCTOR NOTE
Show clip of How Torque Converter Works. 8.57 min

(ON SLIDE #35)

(4) Troubleshooting. 4 common areas of trouble are:

(a) Overheating. Overheating is major problem in converter operation. It is affected by the design, the type of work, the operator, the air temperature and the condition of the unit. A converter may overheat if the work is heavy for long periods of time. If the converter is undersized for the normal work of the machine it will operate at low efficiency and will tend to overheat. Air in the system is another cause for overheating. Overheating can also be a symptom of other problems in the system.

(b) Noise. Noise is hard to detect without experience. It may sound like a whining or growling noise if the converter is malfunctioning. Worn or dry bearings often produce a hissing noise that will develop into a bumping or thudding sound when they completely fail. Other sources of noise are worn gears, worn or bent shafts, excessive shaft endplay, shafts misaligned with the engine and worn freewheel clutches.

(ON SLIDE #36)

(c) Leaks.

1 Internal Leaks. If oil is lost from the housing by leaking from the pump, turbine or stator, power will be lost or erratic operation will occur. It may be caused by the wrong torque on the converter bolt. If leaks occur from around the converter cover, check the tightness of the cover bolts with a torque wrench. If this fails to correct the leak, disassemble the cover, check the machine surfaces of the cover and flywheel, and install a new gasket.

(ON SLIDE #37)

2 External Leaks. They will occur outside the converter but still affect the operation. These include leaks at the cooler lines, filter lines, and pressure or temperature gauge fittings.

(d) Machine Response. Normally a malfunction in the converter will affect the machines response to load and speed changes. A machine which lacks power and acceleration at low speed may have a turbine freewheel clutch failure. Changes in hydraulic pressure, flow, and temperature also affect the performance of the converter, and thus affect the machines performance.

(ON SLIDE #38)

(5) For a typical converter, the following tests may be performed:

(a) Main pressure (at full throttle-no load)

(b) Converter-out pressure (at full throttle-no load and at full throttle stall in high range)

(c) Lubrication pressure (at full throttle-no load)

(d) Converter-out temperature (during normal operating conditions)

(6) Torque converter stall speed test. It is important to consult the TM prior to conducting a stall test. Some manufactures do not recommend this test. The stall test tells whether or not the engine to torque converter, and transmission are performing satisfactory as a unit.

(ON SLIDE #39)

INTERIM TRANSITION: We have just covered Torque Converter. Are there any questions? If not, go ahead and take a ten minute break.

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(ON SLIDE #40)

(BREAK – 10 Min)

INTERIM TRANSITION: Before the break we were talking about the Torque converter and some tests you can perform. Did anybody come up with any questions over the break? If not let's move into Gears.

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(ON SLIDE #41)

c. **Gears**.

(1) Purpose. Gears are used to transmit rotary motion from one shaft to another. These shafts can be parallel or at right angles to each other.

(ON SLIDE #42)

(a) Gears must be firmly fastened to the shaft. One way of fastening the gears to the shaft are by grooves knows as splines. When the gear is pushed onto the shaft, the splines mate and the gear cannot slip off the shaft.

(ON SLIDE #43)

(b) Mechanical Advantage. Anytime there is a smaller gear driving a larger gear there is an increase in torque. Anytime there is a larger gear driving a smaller gear there is an increase in sped.

(ON SLIDE #44)

(2) Gear Ratio. Gear ratio is a measure of the changes in speed and torque. To determine gear ratio we must compare

each gear in a gear set. The bottom of this slide shows two gears in mesh. What is this ratio? Since both gears have the same number of teeth the gear ratio is 1:1.

(ON SLIDE #45)

(a) Determining gear ratio. You need to know which one is the drive gear and which one is the driven gear, because you always record the drive gear first. By counting the number of teeth on the driving gear and dividing it by the number of teeth on the driven gear, the gear ratio can be determined. In this slide a large gear with 24 teeth is driving a smaller gear with 12 teeth. What is the gear ratio? The gear ratio is 1:2 and if the power flow were reversed; the gear ratio would also be reversed. When one gear is smaller than the other gear, the smaller gear is called the pinion gear. If the pinion gear becomes the driving gear, the gear ratio is 2:1.

(b) What happens if the teeth number is odd? The drive gear has 13 teeth; the driven gear has 27 teeth. They are recorded as 13:27. What happens when the driving gear is larger than the driven gear? A speed advantage is gained but there is less torque.

(ON SLIDE #46)

INSTRUCTOR NOTE

Image of gear ratio
Ask students 2 questions. After each question the animated answers will come up on the click.
What is the gear ratio for the odd set of teeth? 14:21
What is the gear ratio for the even set of teeth? 1:2

(ON SLIDE #47)

(3) Internal and External gears. Internal gears are shaped cylindrically with teeth machined on the inside. External gears are usually circular with teeth around the outside of the gear. There are many subtypes and designs of gears and gear systems.

(ON SLIDE #48)

(a) Bevel Gears. Generally used to change direction. Their teeth are machined at angles to the drive centerline to correspond with the angle of input and output shafts. Bevel gears, like spur gears, engage one tooth at a time; therefore, they are not able to transmit large amounts of torque and are noisy during operation.

(b) Spur Gears. Spur gears are the most common type of gear. The teeth are machined perpendicular to the axis of rotation. Because of the way the teeth are cut, they are generally noisy during operation and are used to change direction and/ or speed.

(ON SLIDE #49)

(c) Worm Gears. Basically these are two different types of gears designed to mesh at right angles to each other. One gear is shaped similar to a helical gear, while the other is straight with teeth machined in a spiral form around the exterior of the shaft. This configuration produces great gear reduction and quiet operation.

(d) Helical Gears. The helical gear has teeth machined at an angle to their centerline of rotation. This enables the gear to engage more than one tooth at a time. This type of gear, therefore, is stronger and able to transmit more torque than the spur gear.

(ON SLIDE #50-51)

d. Bearings

(1) Basically there two categories of bearings which Friction and Antifriction. Friction bearings serve to reduce friction between moving parts. Anti Friction bearings eliminate all friction because they depend on rolling contact rather than sliding contact like friction bearings. Essentially, all bearings provide support for moving parts.

(ON SLIDE #52)

(2) Bearings have four major jobs.

(a) Reduce friction

(b) Reduce wear

(c) Support a rotating shaft

(d) Provide a replaceable wear surface

(ON SLIDE #53)

(3) Bearing Construction.

(a) Outer race or Cup

(b) Inner race or Cup

(c) Cage/Retainer

(d) Balls or Rollers

(ON SLIDE #54)

(4) Inspection and maintenance of bearings.

(a) Always check for breaks, cracks, scoring, etching and rust.

(b) Discoloration is usually caused by lack of lubrication or overheating.

(c) Pitting is usually unavoidable, but many factors tend to hasten pitting such as nicking, scoring, brinelling (when the bearing starts to form on the race), indenting or the operation of bearing with excessive loads or speeds.

(ON SLIDE #55)

(d) Improper lubrication is the main cause of bearing failure. Lubricant must be applied in the proper amounts and at the proper time.

(e) When replacing bearings you should always replace the race as well since they tend to wear together.

(ON SLIDE #56)

(f) Maintenance.

1 Packing bearing by hand. Place a liberal amount of bearing, marine, or automotive grease in the palm of your hand.

2 Place the bearing in the grease in your hand and spin the bearing back and forth to spread the grease inside the bearing.

3 Add more grease to you palm as needed.

4 Flip the bearing over and repeat steps 2 and 3 until the bearing no longer takes grease from your hand, indicating that the bearing is fully packed.

(ON SLIDE #57)

INSTRUCTOR NOTE
Show clip on "How to Pack/Grease Trailer Wheel Bearings" 3 min

INTERIM TRANSITION: Are there any questions? If not let's move into the demonstration.

INSTRUCTOR NOTE
Perform the following demonstration.

(ON SLIDE #59)

DEMONSTRATION. (30 MIN) Demonstration will be conducted in the work bay. The purpose of this demonstration is to show how to hand pack a bearing with grease. Normal class size is 25. There is one instructor required for this evolution

STUDENT ROLE: Students should gather around the instructor at the work table to watch demonstration, ask questions if they have any.
INSTRUCTOR ROLE: Have bearing and a bucket or tube of grease at the demonstration area. Ensure students are in position where they can see. Wearing rubber gloves, scoop a palm full of grease in one hand hold the bearing in the other hand rotate the bearing until the bearing is packed, explaining as you move through the demonstration.

1. Safety Brief: At all times proper PPE (safety glasses and rubber gloves) will be worn.

2. Supervision and Guidance: The instructor will explain that if the bearing isn't packed the first rotation keep packing until completely packed.
3. Debrief: (If applicable) (Allow students the opportunity to comment on what they experienced and/or observed. Provide overall feedback, guidance on any misconceptions, and review the learning points of the demonstration

INTERIM TRANSITION: During the demonstration we covered the how to hand pack a bearing. Do you have any questions? If not, take a 10 min break and we'll come back and perform the Practical Application.

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(BREAK – 10 MIN)

INTERIM TRANSITION: Do you have any questions? If not, lets move into the Practical Application.

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INSTRUCTOR NOTE
Introduce the following practical application.

PRACTICAL APPLICATION. (1 HR) Have students come in 5 at a time so that all five can perform the Practical application at the same time. The purpose of this Prac Ap is to see if students understand how to hand pack a bearing with grease. Normal class size is 25. There is one instructor required for this evolution

PRACTICE: Students will have proper PPE. There should be one student per work station. Each student will have their own bearing to pack. Once they've received instructions from the instructor they should begin packing their bearings.

PROVIDE-HELP: Instructor is going from one work station to the next observing and answering questions from the students.

1. Safety Brief: Ensure students have on safety glasses and rubber gloves.
2. Supervision and Guidance: Instructor is moving around the room, assisting students, and answering questions as they arise.
3. Debrief: N/A

(ON SLIDE #60)

INTERIM TRANSITION: We've just finished the Practical Application on how to hand pack a bearing. Do you have any questions? If not, take a 10 min break and we'll come back talk about Transfer Gears.

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(ON SLIDE #61)

(BREAK – 10 MIN)

INTERIM TRANSITION: During the break did anyone think of any questions about bearings? If not, Let's talk about Transfer Gears.

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(ON SLIDE #62-63)

e. **Transfer gears**. The transfer case receives power from the transmission and sends it to both the front and rear axles. This can be done with a set of gears, but the majority of transfer cases manufactured today is chain driven. On some vehicles, such as four-wheel-drive trucks or vehicles intended for off-road use, this feature is controlled by the operator. The operator can put the transfer case into either "two-wheel-drive" or "four-wheel-drive" mode. This is sometimes accomplished by means of a shifter, similar to that in a manual transmission. On some vehicles this may be electronically operated by a switch instead. Some vehicles, such as all-wheel-drive sports cars, have transfer cases that are not selectable. Such a transfer case is permanently "locked" into all-wheel-drive mode.

INSTRUCTOR NOTE
They are commonly used on 4 wheel drive vehicles as well as the Caterpillar 120M road grader and the Armored Combat Excavator (ACE).

(ON SLIDE #64)

(1) Drive types.

(a) Gear-driven. There are two different types of "internal workings" found in most transfer cases. Gear-driven transfer cases can use sets of gears to drive either the front or both the front and rear driveshafts. These are generally strong, heavy units that are used in large trucks, but there are currently several gear drive cases in production for passenger cars.

(ON SLIDE #65)

(b) Chain-driven. Chain-driven transfer cases use a chain to drive most often only one axle, but can drive both axles. Chain-driven transfer cases are quieter and lighter than gear-driven ones. They are used in vehicles such as compact trucks, full size trucks, Jeeps and SUVs. Some off-road driving enthusiasts modify their vehicles to use gear-driven transfer cases, accepting the additional weight and noise to gain the extra strength they generally provide.

(ON SLIDE #66)

(2) Housing type.

(ON SLIDE #67)

(a) Married. Transfer cases are also classified as either "divorced"/"independent" or "married". "Married" transfer cases are bolted directly to the transmission. Sometimes a "married" transfer case is an integral part of the transmission and the two components share the same housing, as is commonly found on recent short wheel-based equipment and some other four-wheel-drive cars.

(ON SLIDE #68)

(b) Divorced/Independent. An "independent" transfer case is completely separate from the transmission; it is bolted to the transmission output shaft and a short driveshaft travels from the transfer case to the front and rear differentials. Independent transfer cases are used on very long wheelbase vehicles, such as commercial trucks or military trucks.

(ON SLIDE #69)

(3) Components of the transfer gear set:

(a) Input Gear, in mesh from the engine flywheel.

(b) Forward Clutch Gear, in mesh with the Idler gear.

(c) Reverse Clutch Gear, in mesh with the Idler gear turning in the opposite direction.

(d) Idler Gear, in mesh with the forward and reverse gears.

(e) Planetary Input Gear, in mesh with the idler gear is the transmission input gear. These are all spur cut gears.

(ON SLIDE #70)

INTERIM TRANSITION: We have just covered gears, bearings, and transfer gears. Are there any questions? If not go ahead and take a ten minute break.

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(ON SLIDE #71)

(BREAK – 10 Min)

INTERIM TRANSITION: Before the break we finished the torque converter, gears, bearings and transfer gears, are there any other questions? If not let’s move onto the power shift transmission.

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(ON SLIDE #72)

f. **Power shift transmission**.

(1) The power shift transmission is widely used in all types of engineer equipment; it is used for both on and off road equipment. Here we have a power shift transmission removed from its housing. The basic make up of this transmission is a stack of wet multiple clutch packs, and planetary gears. Let's break one of these clutch packs down and identify its components.

(ON SLIDE #73)

(2) There are two basic components of the power shift transmission. The clutch pack and the planetary gear set.

(ON SLIDE #74)

(a) Clutch Pack Components.

1 Anchor. The first component in the multiple hydraulic clutch pack is the anchor. Around the inner circumference is the clutch applied piston. Around the inner and outer circumference of the piston we have piston seals.

2 Friction disc. The friction disc is where the member of the clutch pack is internally splined.

3 Reactionary plate. Next to the friction disc is the reactionary plate (every other one) or held member of the clutch pack. Now we have the components. We can see how each clutch pack functions.

(ON SLIDE #75)

(b) Clutch Pack Applied. The clutch pack in a power shift is hydraulically applied and spring released:

1 Oil coming in the anchor through drilled passages strikes the back of the clutch applied piston (gray).

2 This piston is forced into the first friction disc. With constant pressure against the piston the entire clutch is sandwiched applying the clutch. Notice the friction disc is splined to a gear.

3 Once the operator releases the clutch (selects a different speed or direction range), the heavy spring forces the clutch applied piston back into its housing, releasing the clutch.

(ON SLIDE #76)

g. **Planetary Gear Set**.

(1) Sun Gear. The first component in the planetary gear set is the sun gear, meshed with the sun gear is planetary pinion gears.

(2) The planetary gears and carrier are bearing or bushings mounted and are able to revolve on their own axis. The planet gears are mounted to the planetary carrier which makes up the second component of the planetary gear set the planetary carrier.

(3) Ring gear. The rings fit around the rest of the components in the planetary gear set.

(ON SLIDE #77)

INSTRUCTOR NOTE
Image of planetary gear set

The ring gear has internal teeth which mate with the teeth on the smaller planet gears, these gears in turn mate with the center or sun gear. Many changes in speed and torque are possible, depending on which parts are held and which parts are driven. The Planetary gears are similar to our solar system. The **Planet pinion gears** each turn on their own axis while rotating around the **Sun gear**. This is much like the earth and other planets rotating around the sun. The planet pinion gears in turn mesh with the inside of the **Ring gear**.

(ON SLIDE #78)

(4) In order to get power transmitted to the rear wheels we need three things:

(a) An input gear.

(b) An output gear.

(c) A held member.

(d) With these three items you can now transmit power.

(ON SLIDE #79-83)

TRANSITION: So far we have covered torque converter, gears, bearings, transfer gears, power shift transmission and planetary gear sets. Are there any questions? If not I have some for you.

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Q1 What is the main advantage of a fluid coupling?
A1 Provides a smooth, jerk less acceleration.

Q2 What are the components of a fluid coupling?
A2 Impeller / Pump and Turbine.

Q3 What are the two types of flow and which one produces the most torque?
A3 Rotary flow, Vortex flow. Vortex flow produces the most torque.

Q1 What is torque?
A1 Something that produces torsion or rotation.

Q2 What are two ways a torque converter can be mounted?
A2 Directly and Remotely.

Q3 What are the two stator positions?
A3 Locked position and Free position.

Q4 What torque converter test is not preferred my most manufactures?
A4 Torque converter stall speed test

(Q1)What gear is used to transfer more torque?
(A1)Helical Gear.

(Q2)What are the components that make up a bearing?
(A2)Inner race, Outer race, Cage, Balls.

(Q3)What are the two types of transfer gear housings?
(A3)Married and Divorced/Independent

(Q1) What are the four different types of gears?
(A1) Bevel, Spur, Worm, Helical.

(Q2) How many components are there to a basic torque converter?
(A2) 3, Impeller (Pump), Stator, Turbine.

(Q3) What are the major components of the power shift transmission?
(A3) Clutch Packs, and Planetary Gear Sets. Take a 10 min Break

(ON SLIDE #84)

(BREAK -10 MIN)

TRANSITION: Before the break we were talking about the components of the powershift transmission. Now let's talk about the operation of the transmission.

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(ON SLIDE #85)

2. **TRANSMISSION OPERATION. (3Hrs 10Min)**

a. **Operation.**

(1) There is a clutch and a planetary set for each transmission speed and for both directions, forward and reverse.

(ON SLIDE #86)

(2) Engine power is transmitted to the red input shaft by way of the torque converter or torque divider. The sun gears for reverse and forward are mounted to the input shaft and rotate whenever the input shaft is being driven. The gray piece in the center is a center carrier and carries the planet gears for forward and second speed.

(3) The blue shaft is the output shaft, and the sun gears for the speed planetary sets are mounted on the output shaft.

(ON SLIDE #87)

(4) The direction half of the transmission. This part of the transmission is now engaged in forward gear. The red input shaft is being driven and since the red sun gears are mounted on the input shaft, they, the sun gears, are also being driven. The reverse sun gear, the one on the left, is forcing its planet gears to rotate; but they are not transmitting power.

(a) Remember: For a planetary set to transmit power, drive; one member must drive, one member must be held, and the third member will then be driven. Since nothing is being held in the first planetary, no power is being transmitted.

(b) However, the second clutch has been engaged and has stopped the ring gear. The second sun gear is driving its planet gears. Since the ring gear is being held, the planet gears are being forced to revolve around the inside of the ring gear. The planet gears, then, will drive the carrier on which they are mounted; and the carrier will rotate in the direction indicated by the arrow.

(ON SLIDE #88)

(5) The speed half of the transmission. Now, looking at the speed gear half of the range transmission, we can see that the ring gear for second speed is stopped. The connecting carrier is rotating and causing the second speed planet gear to revolve around the inside of the ring gear. Since the ring gear is being held, and the planet gears are driving, the sun gear for second speed is being driven.

(a) The ring gear for first speed, on the right, is idling, and its planetary gear set is not transmitting power.

(ON SLIDE #89)

INSTRUCTOR NOTE
Ask students the following questions, click after student gives the correct answer. What direction is selected? Reverse What speed is selected? 1st Have students explain what is drive, driven and held on both the input and output shafts.

(ON SLIDE #90)

b. **Transmission arrangement**:

(1) Drop Box Configurations. There are a couple different types of drop box transmission configurations. Depending on the length, height of equipment and where the engine is located will dictate which configuration will be used. A couple of examples are the MMV compared to the TRAM.

(ON SLIDE #91)

(a) Drop box transmission without a transfer case. The MMV has the engine and transmission mounted to the side of the tractor. This transmission is unique because the direction

and speed gears are stacked vertically. This will allow the power flow to transmit power from lower transmission output shaft to the transfer case (mounted horizontally) which then is connected to the final drive.

(ON SLIDE #92)

(b) Drop box transmission with a transfer case. The TRAM has the engine mounted towards the rear of the tractor. The transmission looks and operates similar to a powershift. The clutches and planetary gears are stacked horizontally. Because of the location of the engine, transmission, and front and rear differentials, a down drop box with a transfer case is used.

(ON SLIDE #93)

(2) The Drop Box Arrangement. Drop box transmissions provide torque multiplication and have the same basic operations as a powershift transmission but can be arranged in different configurations. The drop box transmission can be broken down into three sections:

(a) Converter Section. Provides hydrodynamic link from the engine.

(b) Range Gear Section. Contains direction and speed clutches.

(c) Final Drive Section. Contains transfer gears and power flow shafts to direct power flow.

(ON SLIDE #94-95)

c. **The hydraulic drive**. A hydraulic drive system is a drive or transmission system that uses pressurized hydraulic fluid to drive hydraulic machinery. This drive uses fluid under pressure to transmit power to the wheels or track.

(1) There are two basic types of hydraulic drives in use today.

(ON SLIDE #96)

(a) Hydrodynamic Drive. Uses fluids at high speeds but relatively low pressures. An example would be a water pump or torque converter.

(ON SLIDE #97)

(b) Hydrostatic Drive. Uses fluids at high pressure but relatively low speeds. Energy is transferred by the fluid itself in a closed circuit between the pump and the motor. This is the most commonly used due to its compact size, and high pressure application.

(ON SLIDE #98)

(c) There are three factors that control the operation of the hydrostatic drive.

1 Rate of Flow. Gives the speed

2 Direction of Flow. Gives the direction

3 Pressure of the Oil. Gives the torque

(ON SLIDE #99)

(d) Hydrostatic drive components, the following components make up the heart of the basic system:

1 Pump. Fixed or Variable displacement, depending on application.

2 Hydraulic oil circuit. Hoses or lines to direct pressurized fluid.

3 Motor. Fixed or Variable displacement, depending on application.

(ON SLIDE #100)

(e) Pump and motor combinations. Depending on the application four different combinations can be used in a hydrostatic system:

1 Fixed Displacement, Pump and Motor - provides direct power output of both torque and speed.

2 Variable Displacement, Pump and Fixed Displacement, Motor- Provides variable speed and constant torque.

3 Fixed Displacement, Pump and Variable Displacement, Motor- Provides fixed power input speed but variable torque.

4 Variable Displacement, Pump and Variable Displacement, Motor- Provides all of the above speed and torque advantages but requires additional control circuits and additional operator experience.

(ON SLIDE #101)

INSTRUCTOR NOTE
Image of all four types of pump and motor combinations

(ON SLIDE #102)

e. **Propeller shafts(Drive shafts)**. From the transmission, propeller shafts transmit power to our differentials or final drives.

(1) Propeller Shaft Types. The two (2) most common types are:

(ON SLIDE #103)

(a) Solid Shaft. Has a fixed length and a universal joint at each end. Used when transmitting power from fixed plane to another.

(ON SLIDE #104)

(b) Telescoping Shaft. Has sliding elements that may have 2 or 3 u-joints. It allows flexibility while still able to transmit power.

(ON SLIDE #105)

1 Universal Joints. are necessary to join two rotating shafts in different plains. The most common type is the Cardon or Hooke joint. This joint consists of two U-shaped yokes fastened to the ends of the two shafts to be connected. Inside these yokes is a cross-shaped journal which holds the yokes together and allows each yoke to bend or pivot, with respect to the other. This allows one shaft to drive the other at angles up to 30 degrees out of alignment.

(c) There are two types of Cardon Universal joints

1 Single. One needle bearing sealed assembly.

2 Double. Two assemblies mounted on a flexible housing.

(ON SLIDE #106)

INTERIM TRANSITION: Now that we have covered transmission operation are there any questions? If not let's take a 10 minute break.

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(ON SLIDE #107)

(BREAK-10 MIN)

INTERIM TRANSITION: Before the break we finished talking about transmission operation. Are there any other questions? If not let's move into the transmission disassembly demonstration.

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_____
_____

INSTRUCTOR NOTE:
Perform the following demonstration.

(ON SLIDE #108)

DEMONSTRATION. (1 HR) Introduce the students in groups of no more than 5 to the transmission that they will be using during the disassembly and reassembly process.
STUDENT ROLE: The students will become familiar with their transmission.
INSTRUCTOR ROLE: Walk through the disassembly and reassembly process of the transmission using training aids.

1. Safety Brief: At all times proper PPE will be worn. Ensure all tool are kept off the floor and any oil spills are cleaned up in a timely manner.

2. Supervision and Guidance: The instructor will show the students the different components of the transmission using available training aids.
3. Debrief: (If applicable) (Allow students the opportunity to comment on what they experienced and/or observed. Provide overall feedback, guidance on any misconceptions, and review the learning points of the demonstration.

INTERIM TRANSITION: Now that we know what is going to be expected when you disassemble and reassemble your transmissions are there any question. If not let's start taking your transmission apart.

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INSTRUCTOR NOTE:
Perform the following practical.

PRACTICAL APPLICATION (26 Hrs) In groups no larger than 5 the students will have their assigned toolboxes, technical manuals and assigned transmissions with work stations. There will be at least one instructor supervising the exercise. The purpose of this practical application is to disassemble and reassemble their transmissions.
PRACTICE: In their groups the students will follow the technical manuals to disassemble and reassemble their transmissions.
PROVIDE HELP: The instructor may assist in the disassembly process if needed.
1. Safety Brief: At all times proper PPE will be worn to include safety boots. Safety glasses will be worn anytime liquid under pressure is being used.
2. Supervision and Guidance: The instructor will walk around to the different groups and supervise the disassembly and reassembly answering any questions the students may have. Students may take breaks as needed.

(ON SLIDE #109-111)

TRANSITION: Now that we have completed the tear down and reassembly of your transmissions are there any questions? If not I have some for you.

(Q1) What are the two sides of a transmission?
(A1) Speed and direction.

(Q2) What are the three sections of a drop box transmission?
(A2) Converter Section,Range Gear Section,Final Drive Section.

(Q3) What are three factors that control the operation of the hydrostatic drive?
(A3) Rate of Flow. Gives the speed, Direction of Flow. Gives the direction, Pressure of the Oil. Gives the torque.

(Q4) The two most common types of propeller shafts are?
(A4) Solid and Telescoping.

Lets take a break and then let's talk about final drives.

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(BREAK-10 MIN)

TRANSITION: Before the break we finished talking about transmission operation. Are there any other questions? If not let's move into final drives.

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_____
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(ON SLIDE #112)

3. **FINAL DRIVES (3Hrs)**

a. **Differentials.**

(1) Differentials do 2 basic jobs.

(a) First, a differential transmits power around the corner to the drive axles.

(b) Second, it allows each drive wheel to rotate at different speeds when turning, and still propel its own load.

(ON SLIDE #113)

(2) Operation. When the machine is moving straight ahead, both wheels are free to rotate. Engine power comes in on the pinion gear and rotates the ring gear. The four bevel pinions and the two bevel gears are carried around by the differential housing and all gears rotate as one unit. Each axle receives the same rotation and so each wheel turns at the same speed. When the machine turns a sharp corner only one wheel is free to rotate.

(ON SLIDE #114)

INSTRUCTOR NOTE
Show clip of "How a Differential Works and Types of Differentials" 4.44 Min.

(ON SLIDE #115)

(3) Types of differentials.

(a) Standard Differential. Transmits power from the pinion and ring gear, to the side gears and spider gears, and through the axle shaft that has the least resistance. This can be a disadvantage on soft or slippery surfaces, as the tire with the least resistance will spin.

(ON SLIDE #116)

(b) Heavy Duty Differential. Similar to the standard duty, but has multiple Worm cut spider gears for added strength and tooth contact.

(c) Locking Differentials. Four types of locking differentials may be found on heavy equipment:

(ON SLIDE #117)

1 Automatic (No Spin). The "No Spin" locking differential uses internal cams to lock both wheels in straight forward movement. In a turn the outside wheel will begin to spin faster, causing the internal cam to disengage and allow the outside wheel to freely rotate.

(ON SLIDE #118)

2 Air. Air pressure moves a sliding yoke over the free axle and locks it to the differential.

(ON SLIDE #119)

3 Hydraulic. Uses Hydraulic fluid pressure to engage a disk clutch and locks the side gears together within the differential.

(ON SLIDE #120)

4 Mechanical. The simplest differential. The differential is locked using mechanical levers and a fork which slides the collar to lock the splines.

(ON SLIDE #121)

b. **Axle Shafts**.

(1) Full Floating. Used in many heavy-duty applications. Each drive wheel is carried on the outer end of the axle housing by a pair of tapered roller or ball bearings located within the wheel hub. The bearings are positioned outside the axle housing. In this way, the axle housing takes full weight of the vehicle and absorbs all stresses or end thrust caused by turning, skidding, etc. The axle shaft then only transmits the torque from the engine and so "floats" in the axle housing. The shaft is connected to the drive wheel through a bolted flange and the axle shaft can be removed or serviced without removing the drive wheel.

(ON SLIDE #122)

INSTRUCTOR NOTE
Show clip of "It Floats" 5.39 Min.

(ON SLIDE #123)

(2) Semi Floating. Semi floating axel shafts float in the differential in the same way as full floating axels. The main difference is at the outer ends of the axle housing. Here a single bearing assembly is positioned between the axle shaft and axle housing. Therefore, the shaft supports the weight of the vehicle as well as transmitting the engine torque. The axle shafts must now take all stresses caused by turning, skidding, etc. Two types of wheel bearings are used in semi floating axles they can be tapered roller bearings or ball bearings.

(ON SLIDE #124)

c. **Pinion Drive**. A spur gear and pinion are used for the final gear reduction on many tractors and self-propelled machines. This enables the differential to transmit power at higher speeds and low torque. Pinion drives are primarily found on tracked vehicles.

(1) Types of pinion and gear reductions.

(a) Pinion drive within differential case.(Single reduction), mc 1150e and m-9 ace. The advantages of having the gear reduction directly driven from the differential are all gears are enclosed within the differential- transmission case. This is a more compact unit and only one lubrication system is needed. The final drive is in a straight line, permitting a straight axle shaft. Power is transmitted to the drive wheels through pinion gears which are connected to the differential output. The pinions mesh with the larger final drive gears which in turn rotate the axle shaft. Commonly used on light tracked vehicles.

(ON SLIDE #125)

(b) Pinion drive on outer ends of final drive (double reduction). Placing the pinion and gear reduction drive at the outer end of the final drive gives more clearance under the axle. The gears are contained in a separate case or housing and have their own oil reservoir. This is normally used in medium to heavy tracked vehicles.

(ON SLIDE #126)

d. **Chain Drive**. The chain final drive system provides a greater clearance under the axle than any other system. An example is the 120M grader. The advantage of chain drives are they are efficient and do not slip, they are fairly flexible and

compact and inexpensive. The disadvantage of a chain drive is its tendency to loosen due to wear and stretching. Wear can be held to a minimum by having the chain operate in an oil bath. In most cases provisions are made to take up the chain slack.

(ON SLIDE #127)

e. **Steering**.

(1) Tracked Vehicles/ The Clutch-Brake system. Is where the output of a single power source drives both tracks directly. Since they are physically connected to each other, the tracks must turn at the same speed and the vehicle will travel in a straight line.

(a) To allow for turns, each track can be disconnected from the engine with a clutch, allowing that track to slow and the vehicle to turn fairly gently ... a "free turn".

(ON SLIDE #128)

(b) A brake allows the disengaged track to be slowed to tighten the turn, even to the point of stopping the track so the vehicle turns in a very tight radius ... a "braked turn". This system is fairly simple and easy to drive, and most of the tanks of the First World War used this method of steering. However, it is not very efficient. Braking one track slows the vehicle, and wastes a large portion of the power produced by the engine to be converted into heat. While this is not a significant problem in a small vehicle, a large vehicle with a large engine can produce a tremendous amount of heat in a very short time.

(c) Braking one track also slows the vehicle down significantly, which is a consideration in military vehicles where speed is paramount. It is also a bit unpredictable in steering. The braking force vs. yaw curve is basically flat, meaning that a tiny change in braking force can result in a huge change in the rate of turn. Lastly, the Clutch-Brake system does not allow a vehicle to execute a neutral turn.

(ON SLIDE #129)

(2) Operation. Hydraulic oil from the charging pump is directed through the control valve, and pushes a piston, slowing or locking the clutch pack, thus changing the speed of the track on that side.

(ON SLIDE #130)

(3) Brake Band. The Brake band works in conjunction with the steering clutch while the engine is running; a separate parking brake lever is connected in the linkage for parking purposes.

(ON SLIDE #131)

INTERIM TRANSINTION: Now that we have covered final drives are there any questions? If not let's move on to the disassembly and reassembly of the axles.

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INSTRUCTOR NOTE:
Perform the following demonstration.

DEMONSTRATION. (1 HR) Introduce the students in groups of no more than 5 to the axel that they will be using during the disassembly and reassembly process.
STUDENT ROLE: The students will become familiar with their axel.
INSTRUCTOR ROLE: Walk through the disassembly and reassembly process of the axle using training aids.

1. Safety Brief: At all times proper PPE will be worn. Ensure all tool are kept off the floor and any oil spills are cleaned up in a timely manner.
2. Supervision and Guidance: The instructor will show the students the different components of the axle using available training aids.
3. Debrief: (If applicable) (Allow students the opportunity to comment on what they experienced and/or observed. Provide overall feedback, guidance on any misconceptions, and review the learning points of the demonstration.

INTERIM TRANSITION: Now that we know what is going to be expected when you disassemble and reassemble your axles are there any question? Lets take a break and then we will start taking your axles apart.

_____
_____
_____

(BREAK 10 min)

INTERIM TRANSITION: Are there any question? lets start taking your axles apart.

_____
_____
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INSTRUCTOR NOTE:
Perform the following demonstration.

PRACTICAL APPLICATION (17 Hrs 30 min) In groups no larger than 5 the students will have their assigned toolboxes, technical manuals and assigned axles with work stations. There will be at least one instructor supervising the exercise. The purpose of this practical application is to disassemble and reassemble their axles.
PRACTICE: In their groups the students will follow the technical manuals to disassemble and reassemble their axles.
PROVIDE HELP: The instructor may assist in the disassembly process if needed.
1. Safety Brief: At all times proper PPE will be worn to include safety boots. Safety glasses will be worn anytime liquid under pressure is being used.
2. Supervision and Guidance: The instructor will walk around to the different groups and supervise the disassembly and reassembly answering any questions the students may have. Students may take breaks as needed.

(ON SLIDE #132)

TRANSITION: Now that we have completed the tear down and reassembly of your axles are there any questions? If not I have some questions for you.

(Q1) What 2 basic jobs do the differentials perform?
(**A1) First, a differential transmits power around the corner to the drive axles. Second, it allows each drive wheel to rotate at different speeds when turning, and still propel its own load.**

(Q2) What are four types of locking differentials that may be found on heavy equipment?
(A2) Automatic (No Spin), Air, Mechanical, and Hydraulic.

(Q3) Which type of axle shafts are more commonly used on heavy equipment?
(A3) Full Floating.

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(ON SLIDE #133)

SUMMARY: **(10 Min)**

Over the past eight days we have covered components, transmission operation and final drives. With all the information that you have received I am confident that you will be able to conduct your job with higher efficiency. At this time fill out any IRF's that you have after that take a ten minute break.

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_____
_____

REFERENCES:	**PUBLICATION ID**
624KR Loader Operation and Test	TM 11412A-OI
Backhoe Loader, Caterpillar Model 420E IT	TM 10996B-OI/1
FORKLIFT, EXTENDABLE BOOM (EBFL)	TM 10794B-OI/A
Power Trains	FOS4006NC