

Chapter 12

Construction Equipment Power Trains

Topics

- 1.0.0 Drive Trains
- 2.0.0 Track and Track Frames
- 3.0.0 Winches and Wire Rope

To hear audio, click on the box. 

Overview

The construction equipment used by the Navy is equipped with power trains that are similar to those of automobiles which we have already discussed. However, when we factor in the size, weight, design, and use, the construction equipment requires power trains that vary greatly in configuration. In this chapter we will discuss the operational characteristics and components of the drive trains, track assemblies, and track frames that are common to construction equipment. Further, you will learn the operation of a winch and be able to identify the characteristics and maintenance of wire rope.


Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the operational characteristics and components of construction equipment drive trains.
2. Identify the operational characteristics and components of track assemblies and track frames on construction equipment.
3. Understand the maintenance procedures used on tracks and track frame assemblies.
4. Understand the operation of a winch.
5. Identify the characteristics and maintenance of wire rope.

Prerequisites

This course map shows all of the chapters in Construction Mechanic Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Automotive Chassis and Body		C
Brakes		
Construction Equipment Power Trains		M
Drive Lines, Differentials, Drive Axles, and Power Train Accessories		
Automotive Clutches, Transmissions, and Transaxles		B A S I C
Hydraulic and Pneumatic Systems		
Automotive Electrical Circuits and Wiring		
Basic Automotive Electricity		
Cooling and Lubrication Systems		
Diesel Fuel Systems		
Gasoline Fuel Systems		
Construction of an Internal Combustion Engine		
Principles of an Internal Combustion Engine		
Technical Administration		

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with italicized instructions telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is

incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 DRIVE TRAINS

There are numerous types of equipment used in construction, from crawler tractors to excavators. However, the way power is distributed varies from piece to piece. The most common drive trains used in modern construction equipment are the mechanical and the hydrostatic drive trains.

1.1.0 Mechanical Drive Trains

The mechanical drive train found in construction equipment is similar to that of the automatic transmission in that a transmission is used in conjunction with a torque converter and shifting is accomplished hydraulically when the operator moves the range selector lever.

1.1.1 Planetary Gearsets

Some power shift transmissions use planetary gearsets to perform the same functions as the transmission just described (*Figure 12-1*). A planetary gearset consists of three members—sun gear, ring gear, and a planetary carrier that holds the planetary gears in proper relation with the sun and ring gear. The planetary gears are free to "walk" around the sun gear or inside the ring gear.

To cause a reduction or increase in torque, six different methods of connecting this gearset to the power train are possible. Direct drive is achieved by locking any two members together, and neutral is obtained by allowing all the gears to turn freely.

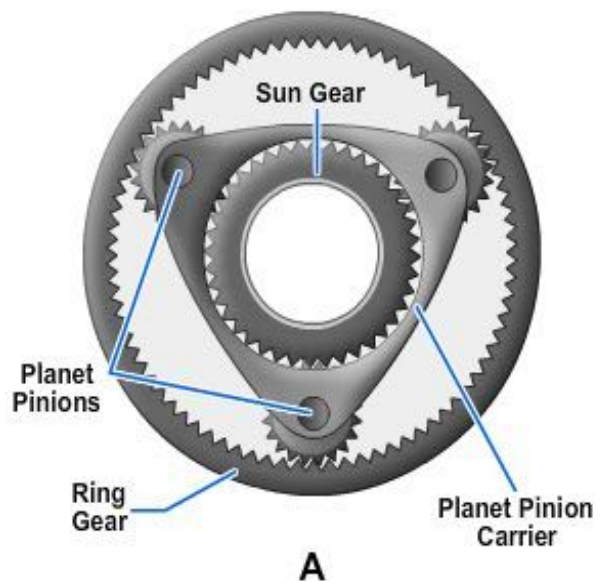


Figure 12-1 — Planetary gearset.

In actual application, planetary gearsets are used as single or multiple units, depending on the number of speed (gear) ranges desired.

On tracked equipment, power for turning the drive sprockets may flow through a planetary gear arrangement that provides maximum reduction. The sun gear forces the planetary gears to revolve in the stationary ring gear and move the carrier in the same direction of rotation as the sun gear. The carrier is connected to the hub on which the sprocket is mounted, causing it to rotate with the carrier. This arrangement produces the maximum torque and speed reduction obtainable from a planetary gearset.

1.1.2 Planetary Steering

Some tracked equipment may be steered by a system that combines planetary steering and **pivot** brakes. The planetary steering system differs from the one previously described in that the planetary pinion gears are two gears of different sizes, machined into one piece (*Figure 12-2*). Two sun gears are also included. One sun gear is splined to the sprocket pinion shaft, and the other is machined on the steering brake hub. The sun gear, machined to the steering brake hub, performs the same function as the ring gear in a conventional planetary system. Bushings are used to isolate the sprocket drive shafts and the steering brake hubs from the bevel gear carrier and the planetary carrier. Lubrication is provided from the oil sump located below the assembly.

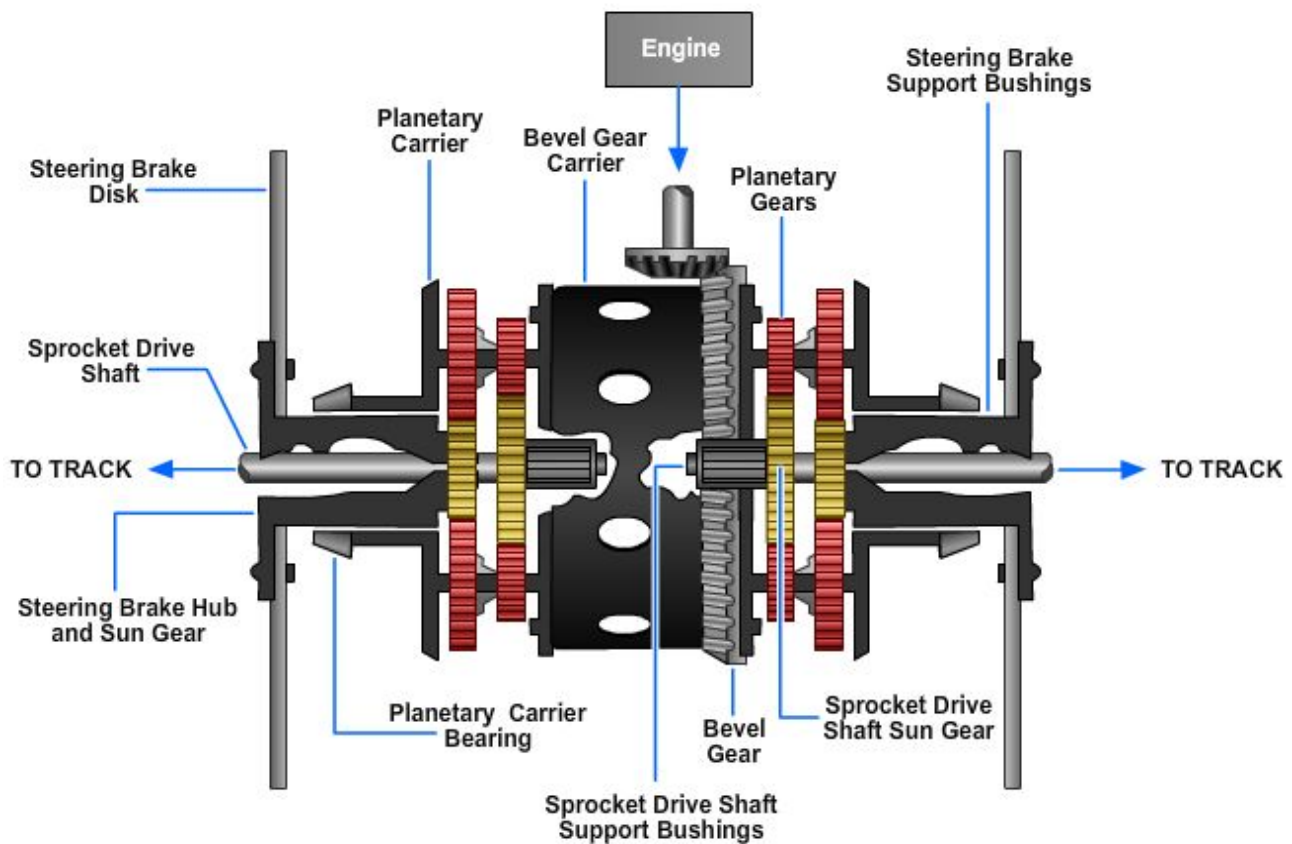


Figure 12-2 — Planetary steering system.

When the tracked equipment travels straight ahead, its steering brakes are held in the applied position by heavy coil springs. Braking prevents the steering brake hub and sun gear from rotating and forces the large planetary pinion gears to "walk" around the sun gear. Then power is transmitted to the sun gear on the sprocket drive shaft from the smaller planetary pinion gears.

When a gradual turn is being made, the operator moves one of the steering levers back far enough to release the steering brake on one end of the planetary system. When the brake is released, the planetary pinion gears stop "walking" around the sun gear on the steering brake hub. This hub then rotates with the planetary carrier, and no power is transmitted to the sprocket drive shaft.

Occasionally, an adjustment of the steering brake is required to prevent slippage when it is engaged. Consult the manufacturer's service manual for adjustment procedures.

1.1.3 Steering Clutches

Steering clutches are used in the clutch-brake system, 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. 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 brake allows the disengaged track to be slowed to tighten the turn, even to the point of stopping the track.

This system is fairly simple and easy to drive; 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. Braking one track also slows the vehicle down significantly, which is a consideration in military vehicles where speed is paramount.

1.2.0 Hydrostatic Drive Train

The hydrostatic drive is an automatic fluid drive that uses fluid under pressure to transmit engine power to the drive wheels or tracks.

Mechanical power from the engine is converted to hydraulic power by a pump-motor team. This power is then converted back to mechanical power for the drive wheels or tracks.

The pump-motor team is the heart of the hydrostatic drive system. Basically, the pump and motor are joined in a closed hydraulic loop; the return line from the motor is joined directly to the intake of the pump, rather than to the reservoir (*Figure 12-3*). A charge pump maintains system pressure, using supply oil from the reservoir.

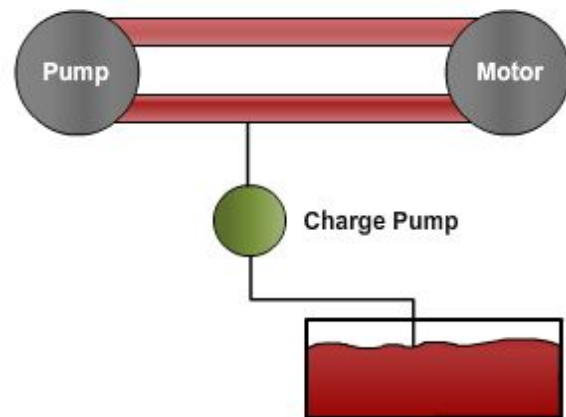


Figure 12-3 — Hydrostatic pump-motor.

The hydrostatic drive functions as both a clutch and transmission. The final gear train then can be simplified with the hydrostatic unit supplying *infinite* speed and torque ranges as well as reverses speeds.

To understand hydrostatic drive, you must understand two principles of hydraulics:

- Liquids have no shape of their own.
- Liquids are not compressible.

The basic hydrostatic principle is as follows (*Figure 12-4*):

- Two cylinders connected by a line are both filled with oil. Each cylinder contains a piston.
- When a force is applied to one of the pistons, the piston moves against the oil. Since the oil will not compress, it acts as a solid connection and moves the other piston.

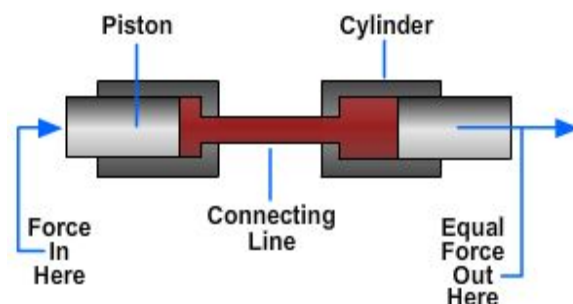


Figure 12-4 — Hydrostatic principle.

In a hydrostatic drive, several pistons are used to transmit power—one group in the PUMP sending power to another group in the MOTOR. The pistons are in a cylinder block and revolve around a shaft. The pistons also move in and out of the block parallel to the shaft.

To provide a pumping action for the pistons, a plate called a swash plate is located in both the pump and motor (*Figure 12-5*). The pistons ride against the swash plates. The angle of the swash plates can be varied, so the volume and pressure of oil pumped by the pistons can be changed or the direction of the oil reversed. A pump or motor with a movable swash plate is called a variable-displacement unit. A pump or motor with a fixed swash plate is called a fixed displacement unit. There are four pump-motor combinations (*Figure 12-6*):

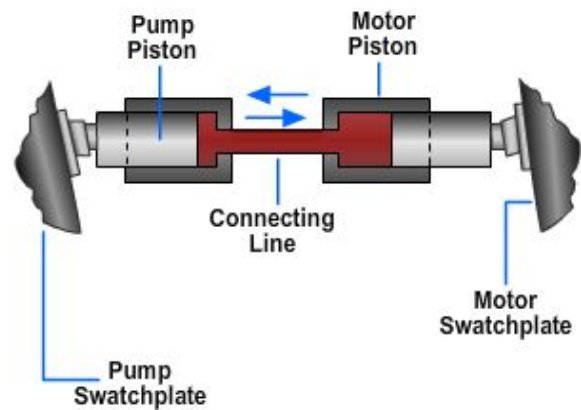
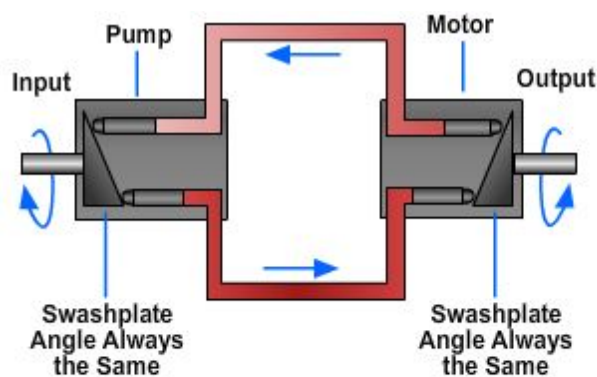
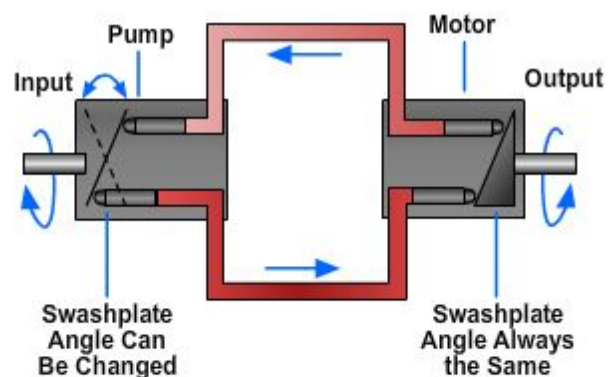


Figure 12-5 — Hydrostatic principle with swash plates.

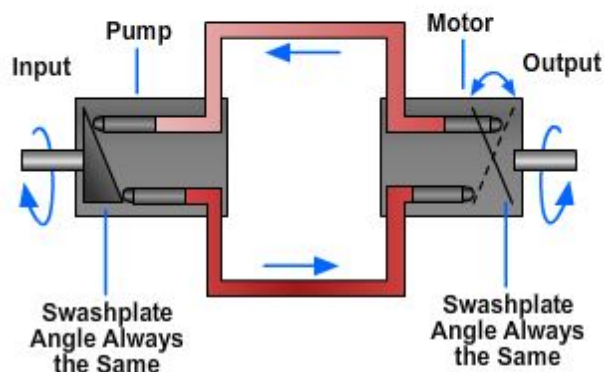
- Fixed displacement pump driving a fixed displacement motor (*Figure 12-6, View A*). This setup will give you constant horsepower and torque at the output with a steady input speed. If input speed varies, horsepower and speed will vary but torque will remain constant. Because both the pump and motor are fixed displacement, this system is like a gear drive; it transmits power without altering the speed or horsepower between the engine and the load.



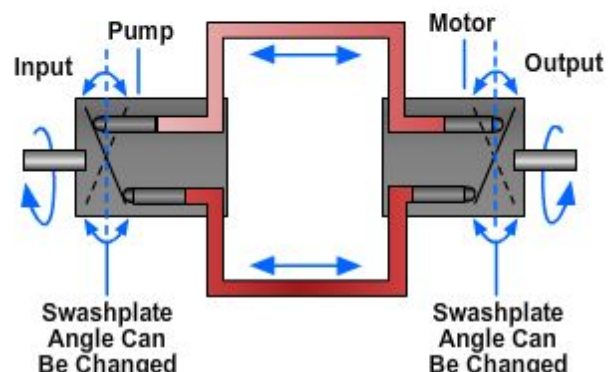
**A. Fixed Displacement Pump
Fixed Displacement Motor**



**B. Variable Displacement Pump
Fixed Displacement Motor**



**C. Fixed Displacement Pump
Variable Displacement Motor**



**D. Variable Displacement Pump
Variable Displacement Motor**

Figure 12-6 — Pump and motor combination for hydrostatic drives.

- Variable displacement pump driving a fixed displacement motor (*Figure 12-6, View B*). Since the pump is variable, output speed is variable and torque output is constant for any given pressure. This setup provides variable speed and constant torque.
- Fixed displacement pump driving a variable displacement motor (*Figure 12-6, View C*). In this setup changing the motor displacement varies output speed. When motor displacement decreases, output speed increases, but output torque drops. When the setup is balanced, it gives a constant horsepower output.
- Variable displacement pump driving a variable displacement motor (*Figure 12-6, View D*). This setup gives an output of both constant torque and constant horsepower. It is the most flexible of all the setups, but it is also the most difficult to control.

The direction of output shaft rotation can be reversed in variable setups by shifting either the pump or the swash plate of the motor over center.

Remember: three factors control the operation of a hydrostatic drive:

- Rate of oil flow—gives the speed.
- Direction of oil flow—gives the direction.
- Pressure of the oil—gives the power.

The pump is driven by the engine of the machine and is linked to the speed set by the operator. It pumps a constant stream of high-pressure oil to the motor. Since the motor is linked to the drive wheels or tracks of the machine, it gives the machine its travel speed.

The advantages of hydrostatic drive are as follows:

- Infinite speeds and torque
- Easy one-lever control
- Smooth shifting
- "On the go" shifting
- High torque available for starting up
- Flexible location—no drive lines
- Low maintenance and service
- Reduction of shock loads
- Compact size
- Elimination of clutches and large gear trains

1.2.1 Hydrostatic Drive Operation

So that you will understand how a hydrostatic drive operates, we will explain the operation of a typical system. The system we will use has an axial piston pump and motor, which is the most common hydrostatic drive system. The pump has a variable displacement, while the motor has a fixed displacement. Now look at the complete system in operation: forward, neutral, and reverse.

1.2.1.1 Forward

(Figure 12-7) When the operator moves the speed control lever forward, the spool in the displacement control valve, also known as the FNR valve (Forward, Neutral, and Reverse), moves from its neutral position. This action allows pressure oil to flow into the upper servo cylinder, forcing the swash plate to tilt. Oil expelled by the opposing servo cylinder returns through the displacement control valve (FNR valve) to the pump case.

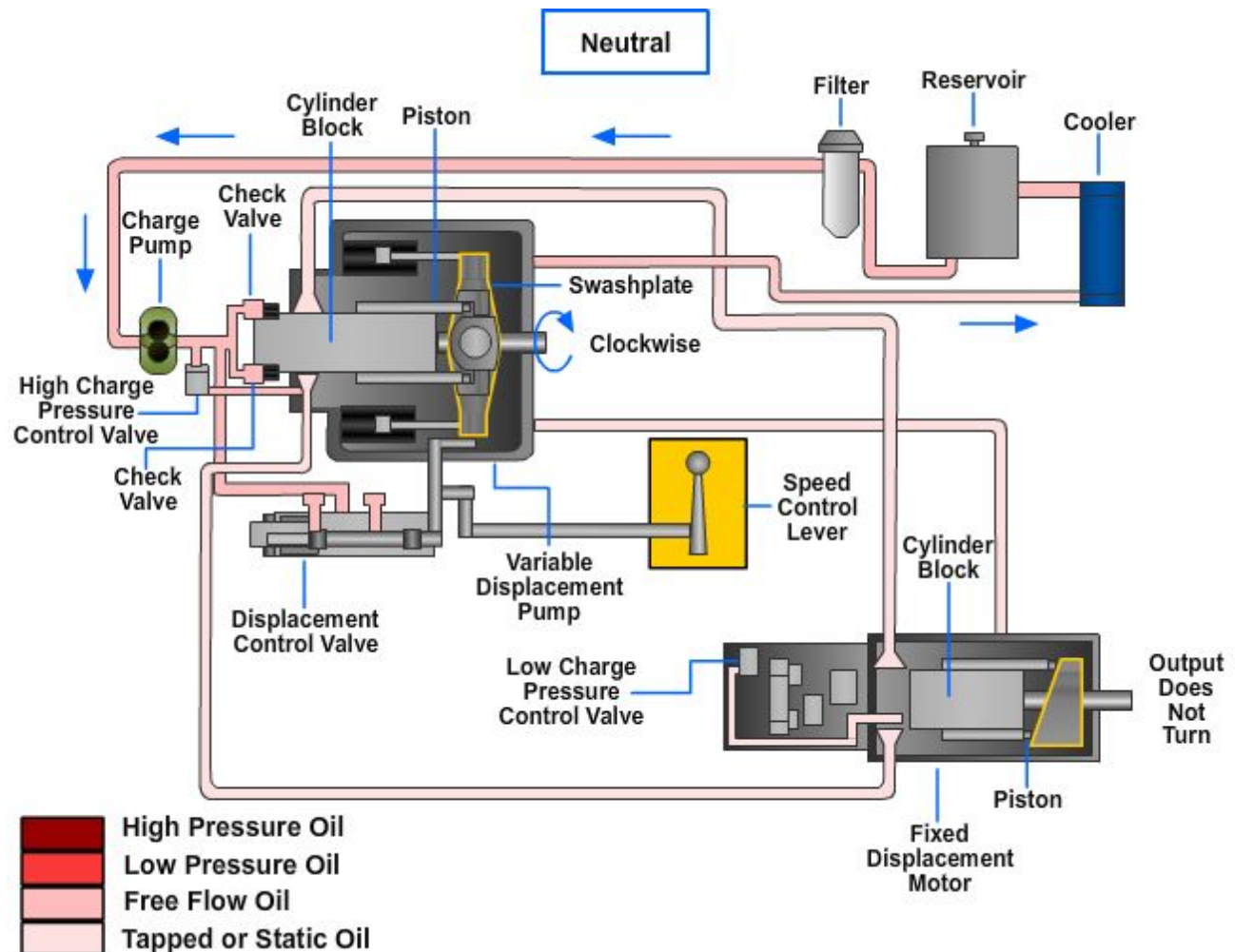


Figure 12-7 — Hydrostatic drive operation.

As the swash plate reaches the tilt set by the speed control lever, the displacement control valve (FNR valve) spool returns to a neutral position, trapping the oil to both servo cylinders and holding the swash plate in its titled position. The swash plate will remain titled until the operator moves the speed control lever.

With the pump drive shaft and cylinder block rotating clockwise and the swash plate titled to the rear, it is now time to start pumping. As the cylinder rotates past the pump inlet port, the inlet check valve opens. Oil is then forced by the charge pump into the piston bores that align with the inlet port under low charge pressure. As rotation continues, oil is forced out of the outlet port at high pressure by the pump pistons when they align with the outlet port. This flow of oil drives the motor.

The distance the pistons *reciprocate* in and out of the cylinder block depends on the angle of the swash plate of the pump. This determines the volume of oil displaced per revolution of the pump--the greater the angle, the greater the volume of oil that flows from the pump. As the angle of the swash plate is varied so will the volume of oil displaced from the pump.

As pressure oil enters the inlet port of the motor, the pistons that align with the inlet port push against the swash plate. Since the fixed swash plate is always tilted, the pistons slide down the inclined surface and the resulting forces rotate the cylinder block. This in turn rotates the output shaft driving the machine forward.

As the cylinder block continues to rotate clockwise, oil is forced out the outlet port at low pressure and returns to the pump where it is recirculated through the pump and back to the motor.

This is called a “closed system” because the oil keeps circulating between the pump and the motor. The only extra oil comes from the charge pump that maintains a given flow of oil through the system whenever the machine is running.

A shuttle valve, located in the motor manifold and controlled by high oil pressure, prevents high oil pressure from entering the low-pressure side of the system. This action keeps the charge circuit open to the low-pressure valve while the system is running.

The high-pressure relief valve, located in the motor manifold, monitors the pressure of the forward flow of oil and protects the system from too high pressures. If pressure exceeds the rated psi, a relief valve opens and oil bypasses the cylinder block in the motor. This will either slow or stop the machine. The bypassed oil returns to the pump. This action continues until the load is reduced below the rated psi. Then the relief valve closes and oil again flows to the cylinder block, moving the machine forward.

1.2.1.1 Neutral

With the speed control lever in neutral, free oil flows from the reservoir through the oil filter to the charge pump (*Figure 12-7*). The charge pump pumps the oil past the high charge pressure control valve and into the main pump housing. The oil circulates through the housing and returns through the oil cooler and back to the reservoir.

Trapped oil is held in the cylinder block of the pump, in the motor, and in the connecting lines between the pump and motor by two check valves in the pump end cap.

When the control lever is in neutral, the swash plate in the pump is also in neutral and the pistons within the pump are not pumping. Therefore no oil is being moved to provide either forward or reverse motion.

The cylinder block in the pump rotates in a clockwise direction and is driven by the engine of the equipment. Rotation is viewed from the drive shaft end of the pump. Because the oil is not being pumped to the motor, the cylinder block in the motor is stationary and the output shaft does not move.

NOTE

With the drive system in neutral, the high charge pressure control valve (located at the charge pump) controls pump pressure. When the system is activated for reverse or forward, the low charge pressure control valve located in the motor manifold controls the charge pressure at a lower psi.

1.2.1.1 Reverse

(*Figure 12-7*) As the speed control valve is moved to reverse, the spool in the displacement control valve (FNR valve) moves out of neutral, allowing pressure oil to flow into the lower servo cylinder and tilting the swash plate forward.

When the swash plate reaches its desired tilt, which is set by the control lever, the displacement control spool returns to neutral. This action traps the oil to both servo

cylinders and keeps the swash plate tilted. The swash plate will remain in position until the speed control lever is moved again by the operator.

With the swash plate tilted forward and the pump drive shaft and cylinder block rotating clockwise, the ports reverse and the inlet port becomes the outlet and the outlet port becomes the inlet. As the pump cylinder block rotates past the pump inlet port, a check valve opens and oil is forced by the charge pump into the piston bores that align with the inlet port of the pump. As rotation continues, the oil is pressurized and forced out of the outlet port of the pump by each of the pistons as they align with the outlet port. This action forces oil to flow to the motor, and as high-pressure oil from the pump enters the inlet port of the motor, the pistons are pushed against the swash plate. The pistons slide down the inclined surface of the swash plate, rotating the cylinder block. This action rotates the drive shaft counterclockwise, driving the piece of equipment in reverse. As the motor cylinder block continues to rotate, oil is forced out the outlet port at low pressure and returns to the pump.

NOTE

The pump drive shaft and cylinder block always rotate clockwise, but the motor drive shaft and cylinder block rotate in clockwise and counterclockwise directions, depending on the direction of the oil entering the pump.

1.2.2 Maintenance of Hydrostatic Drives

As with any hydraulic system, the hydrostatic drive system is fairly easy to maintain. The fluid provides a lubricant and protects against overload. Like any other mechanism, it must be operated properly; too much speed, too much heat, too much pressure, or too much contamination will cause damage.

Before removing any part of the system, ensure that the area is clean. Use steam-cleaning equipment if available; however, do **NOT** let any water into the system. Ensure that all hose and line connections are tight. If steam cleaning is not possible, diesel fuel or a suitable solvent may be used. Be certain to remove all loose dirt and foreign matter that may contaminate the system. Impurities, such as dirt, lint, and chaff, cause more damage than any one thing. Always seal openings when doing work to prevent foreign matter from entering the system.

Clean the workbench or table before disassembling any hydrostatic system component for servicing. Be sure that all tools are clean and free of dirt and grease.

NOTE

NEVER perform internal service work on the shop floor or ground or where there is a danger of dust or dirt being blown into the parts.

Before you disassemble of any system component for internal service, certain items must be available, including the following:

- Clean plastic plugs of various sizes to seal the openings when removing hydraulic hoses and lines.
- Clean plastic bags to place over the ends of the lines and hoses. Secure the bags to the lines and hoses with rubber bands.
- A container of solvent to clean internal parts. Ensure that all parts are clean before replacing them. You may use compressed air to dry the parts after cleaning.

- A container of hydraulic fluid to lubricate the internal parts as they are reassembled.
- A container of petroleum jelly to lubricate surfaces where noted by the manufacturer during reassembly.

Anytime you service and reassemble the components, always install new O-rings, seals, and gaskets. This provides tight seals for mating parts and eliminates leakage.

NOTE

For instructions on the disassembly and reassembly of hydrostatic components, refer to the manufacturer's service manual. Never operate the hydraulic system empty. Always check the fluid supply after servicing the system. If fluid is to be added to the system, use ONLY the fluid recommended in the service manual.

Test your Knowledge (Select the Correct Response)

1. What are the two most common types of drive trains used in modern construction equipment?
 - A. Mechanical and hydromechanical
 - B. Pneumatic and mechanical
 - C. Hydrostatic and mechanical
 - D. Pneumatic and hydrostatic

2.0.0 TRACK and TRACK FRAMES

The undercarriage of crawler-mounted equipment contains two major components—Track Assembly and Track Frame. This undercarriage is provided on equipment that must have positive traction to operate efficiently (*Figure 12-8*).

2.1.0 Track Assembly

The track assembly consists of a continuous chain surrounding the track frame and drive sprocket. The links of the chain provide a flat surface for the track rollers to pass over as they support the equipment. Track shoes are bolted to the outside links of the chain and distribute the weight of the equipment over a large surface area.

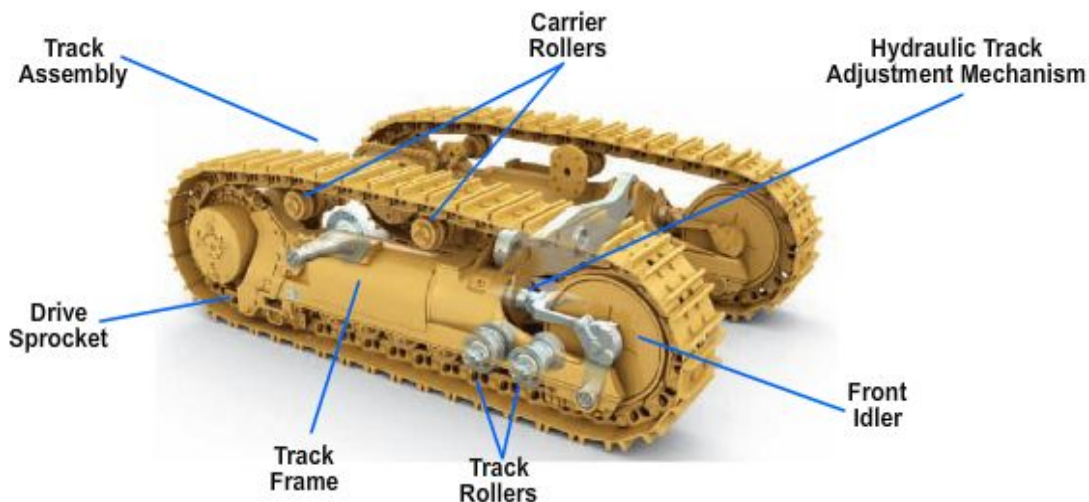


Figure 12-8 — Side view of a crawler tractor chassis.

2.1.1 Track Chain

Figure 12-9 shows a cutaway view of a section of track chain, showing the internal arrangement of the pins and bushings. As the tractor operates, the drive sprocket teeth contact the track pin bushings and propel the tractor along the track assembly.

The pins and bushings wear much faster than other parts of the track because of their constant pivoting as the track rotates around the track frame. This pivoting results in internal wear of both the pin and the bushing. As the pins and bushings wear, the track lengthens. When it does, the track is adjusted to remove excessive slack.

Bushings that show lots of wear on the outside are good indicators of inner wear that is also nearing the maximum allowed by the manufacturer, if the track is to be rebuilt. To determine whether the track should be removed for rebuilding or replacement, measure the outside of the bushings and track "pitch" (length of the track). Use an outside caliper and ruler, as shown in Figure 12-10.

Measure the outside of the bushing where it shows the most wear and compare it to the manufacturer's specifications. Measure track pitch with a ruler or tape measure, across four track pins, after tightening the track to remove any slack, as shown in Figure 12-11.

Should the bushing wear or track length be excessive, remove the track for rebuilding unless facilities and time do not permit. Rebuilding a track will nearly double the useful life of the pin and bushings.

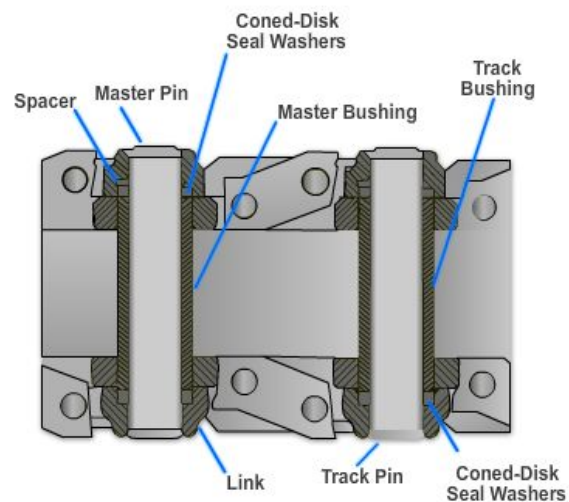


Figure 12-9 — Cutaway view of a section of a track chain.



Figure 12-10 — Bushing wear measurement.

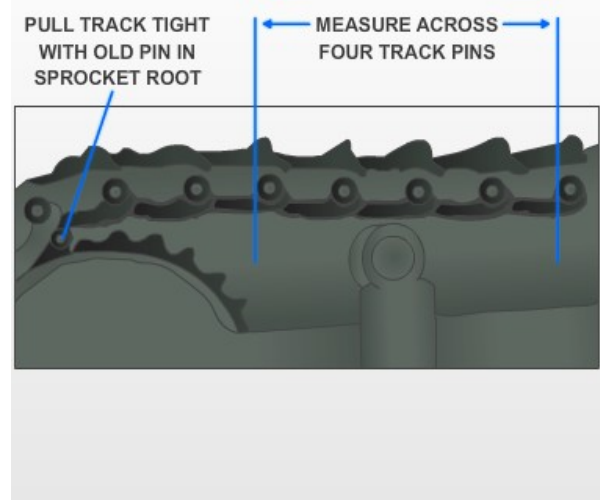


Figure 12-11 — Track pitch measurement.

2.1.2 Track Shoes

The most common track shoe is the grouser shoe shown in *Figure 12-12*. This shoe is standard on all crawler-mounted dozers. The extreme service track shoe is equipped on crawler-mounted dozers that operate primarily in rocky locations, such as rock quarries and coral beaches (*Figure 12-13, View A*). Notice the grouser, or raised portion of the shoe, is heavier than on the standard grouser shoe.

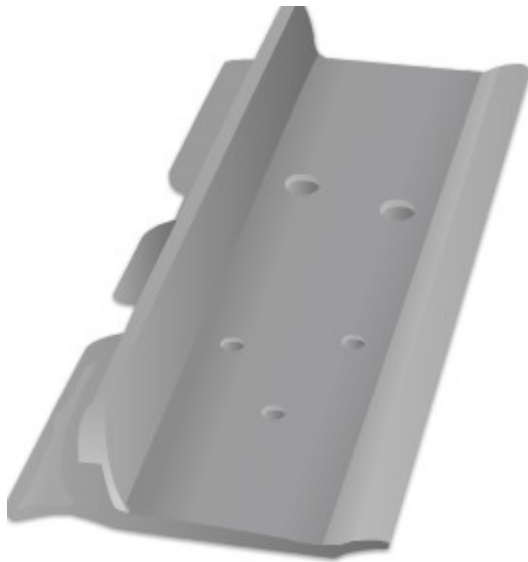


Figure 12-12 — Standard grouser shoe.

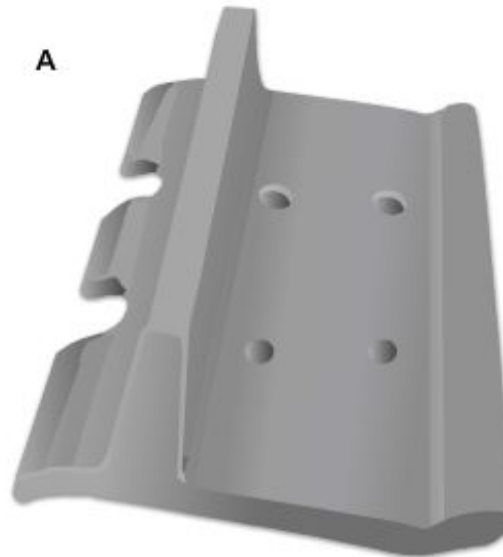


Figure 12-13 — Extreme service track shoe.

Another shoe common to track-mounted front-end loaders is the multipurpose shoe (*Figure 12-13, View B*). This shoe has three grousers that extend a short distance above the shoe and are equally spaced across its face. The multipurpose shoe allows more maneuverability with less wear on the track and track frame components.

NOTE

The grouser absorbs most of the wear, and its condition indicates when the track needs replacement or overhaul.

2.2.0 Track Frame

The track frame, as the name implies, serves as a framework and support for the track assembly, rollers, front idler, recoil spring, and adjusting mechanism.

Track frame alignment may be fixed or shim adjusted, depending on the manufacturer. When shims are used, there are a couple of ways alignment may be maintained. One way is using shims where the frame attaches to the rear pivot and also near the center of the track frame where it is mounted against the main frame guide brackets. Another way is to use a diagonal brace and shims at the rear pivot to align the track frame.

2.2.1 Track Frame Rollers

Two types of track frame rollers are used on tracked equipment—those located on the lower portion of the track frame which supports the weight of the tractor, and those above the track frame which supports the track assembly as it passes over the track frame.

Carrier rollers are single-flanged rollers mounted on brackets which extend above the track frame and support the track assembly (*Figure 12-14*). Two of these rollers are on each side of the tractor. The flange extends upward between the links of the track chain, keeping the chain in alignment between the drive sprocket and the front idler.

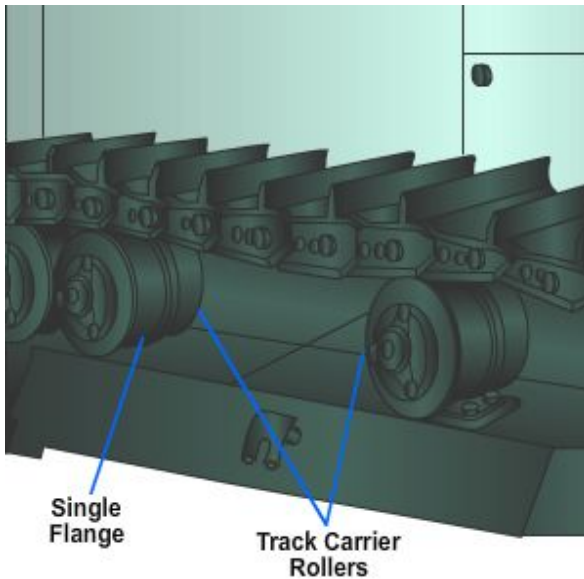


Figure 12-14 — Track carrier rollers.

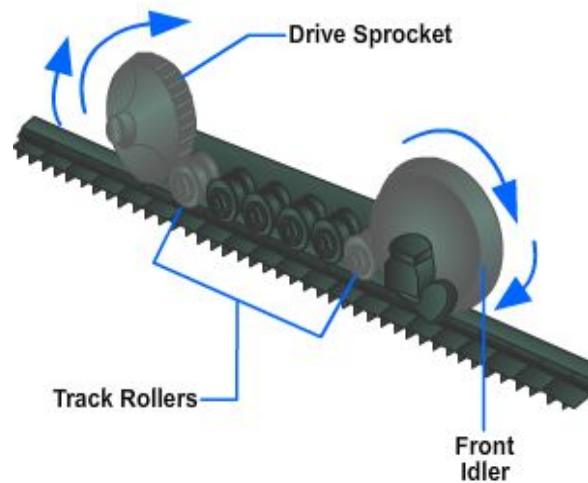


Figure 12-15 — Track rollers in the track frame.

Track rollers are double- and single-flanged rollers that support the weight of the tractor, ensure that the track chain is aligned with the track frame as it passes under the rollers, and prevent side-to-side track movement and derailment (*Figure 12-15*). In a normal arrangement, a double-flanged roller is directly in front of the drive sprocket, followed by a single-flanged roller. The rollers alternate forward to the front idler.

The front idler, as shown in *Figure 12-15*, serves as a guiding support for the track chain. The idler is spring-loaded and mounted on slides or guides that allow it to move back and forth inside the track frame as the tractor passes over uneven terrain. The spring loading effect causes the idler to maintain the desired tension regardless of operating conditions.

2.2.2 Recoil Spring

The recoil spring is a large coil spring placed in the track frame in a way that enables the spring to absorb shock from the front idler. The spring is compressed before installation and held in place by stops or spacers. The track adjusting mechanism, by pressing against the spring stop, maintains the desired tension on the track assembly by holding the idler and yoke in a forward position. The operation of the recoil springs depends on the amount of tension on the track.

2.2.3 Adjusting Mechanism

The adjusting mechanism (*Figure 12-8*) must be extended enough to remove slack between the front idler and spring. This adjustment may be made by either manual or hydraulic means. Many older tractors have manual adjustments, whereas newer tractors are adjusted hydraulically with a grease gun. Grease is pumped into the yoke cylinder and extends it until enough tension is placed on the recoil spring to remove the slack from the track. Tension is released by loosening the vent screw located next to the adjustment fitting.

NOTE

Do **NOT** lubricate the adjustment fitting when performing maintenance on the tractor.

2.2.4 Track Guiding Guards

Accumulation of rock and dirt packed in the track causes the tracks to tighten, resulting in additional wear and stress on track components. The use of track guiding guards minimizes these sources of possible depreciation. Another function of the track guiding guards is maintaining proper track alignment; this is considered secondary, but actually is the most important function.

Guiding guards should be repaired when damaged, since a damaged guard is worthless as far as protection for track components or assisting in maintaining track alignment. When installing new tracks on a piece of equipment, check the condition of the guards. These guards should be in a condition to guide the track squarely into alignment with the rollers properly. The three guards are as follows:

- Front Guiding Guards receive the track from the idler and hold it in line for the first roller. The front roller then can be fully utilized for its intended purpose, carrying its share of the load without having to climb the side of an improperly aligned track.
- Rear Guiding Guards hold the track in correct alignment with the driving sprocket, permitting a smooth even power flow from the sprocket to the track. With proper alignment, gouging of the track link and sprocket teeth is eliminated.
- Center Guiding Guards or track roller guards are available as attachments. These center guards keep the track in line between the rollers when operating in rocky, steep, or uneven terrain. The center guards reduce the wear on roller flanges and track links.

2.3.0 Maintenance of Track and Track Frame Assemblies

Some maintenance of track and track frames is performed at the jobsite by the field maintenance crew. This maintenance consists of track adjustment, lubrication based on hours as required by the manufacturer, and inspection of the track and track frame components.

2.3.1 Track Adjustment

If the tracks are adjusted too tightly, there will be too much friction between the pins and bushings when the track links swivel as they travel around the sprocket and front idler. This friction causes the pins, bushings, links, sprocket, and idler to wear rapidly. Friction in a tight track also robs the tractor of needed horsepower.

Tracks that are too loose fail to stay aligned and tend to come off when the tractor is turned. As a result, the idler flanges, roller flanges, and the sides of the sprocket teeth wear down. A loose track will whip at high tractor ground speed, damaging the carrier rollers and their supports. If loose enough, the drive sprockets will jump teeth (slide over track bushings) when the tractor moves in reverse. Should this happen, the sprocket and bushings will wear rapidly.

One method for determining proper track tension is placing a straightedge over the front carrier roller and idler with all the slack removed from the rest of the track. Using a ruler, measure from the top of the track shoe to the bottom edge of the straightedge. For the correct measurement, refer to the manufacturer's manual.

If it becomes necessary to adjust the track in the field, the following method can be used. Remove all slack from the track. With all slack removed, release the pressure until the front idler moves back 1/2 inch. This will provide the required slack in the track until the tractor can be readjusted to the manufacturer's specifications.

NOTE

Always check the manufacturer's maintenance manual for the proper procedures when adjusting tracks.

2.3.2 Lubrication

The track pins and bushing are hardened and require no lubrication. Many rollers and idlers are equipped with lifetime seals that are factory lubricated and sealed. However, track rollers, carrier rollers, and idlers equipped with grease fittings must be lubricated on a scheduled basis that is set by the manufacturer.

NOTE

Use **ONLY** a hand-operated grease gun on these fittings and pump only until resistance is felt. Further pumping will damage the seals.

2.3.3 Inspection

When performing routine maintenance, inspect the complete track and undercarriage for signs of abnormal wear, leaking rollers or idlers, and misaligned, loose, or missing parts. Should you find any loose track shoes, you should check the torque on all the shoe bolts. Any bolts not meeting specifications should be retightened to the prescribed torque.

If the track appears to be out of alignment, report this to your supervisor, who will determine what action is required. Leaking roller and idler seals should be replaced as soon as possible to prevent any further damage to the equipment.

2.3.4 Shop Repairs

Repairs made to tracks and track frames in the maintenance shop are usually limited to replacing roller or idler seals and bearings or repairing a hydraulic track adjuster. On occasion, you may find a roller or track that is badly worn and requires replacement.

NOTE

NEVER replace components of the track or track frame without consulting the wear limitation charts in the manufacturer's service manual.

2.3.4.1 Track Removal

Steps for the removal of the track are as follows (*Figure 12-16*):

1. Release track tension, either by manually backing off the track adjuster or by loosening the vent screw on the hydraulic track adjuster.
2. Remove the master pin. The master pin can be identified by a locking device or hole drilled in its end that distinguishes it from the other pins in the chain. Move the tractor backward slowly or, on some models, forward to bring the master pin just below the level of the drawbar. Place a block under the grouser on a shoe that allows the master pin to be centered on the front idler. With the master pin centered on the front idler, remove any locking device. If the master pin has a locking device, the pin can be removed by using a sledgehammer and a soft

metal drift pin. Should the pin be drilled, a portable press must be used to remove the pin. Do not lose the bushings, which may drop out with the pin.

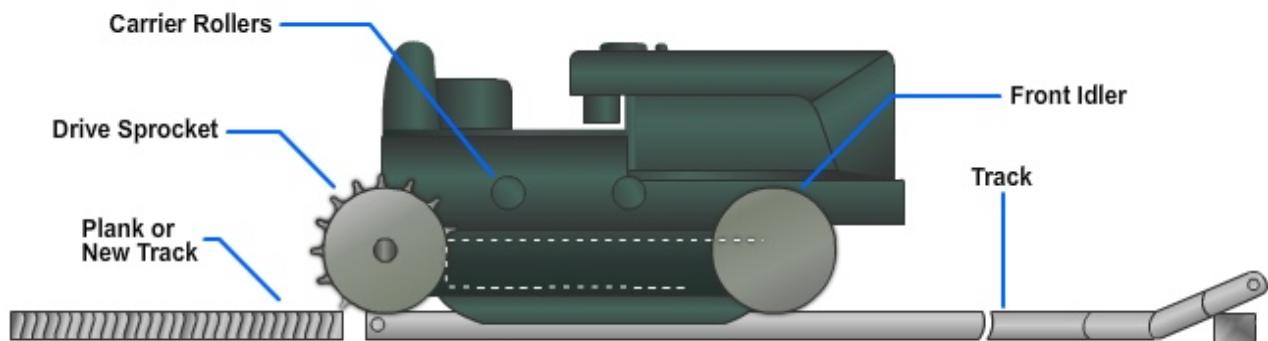


Figure 12-16 — Removing tracks.

3. Remove the track from the carrier rollers and idler. Slowly move the tractor forward or backward away from the loose ends of the track. Make sure no one is in the way of the tractor or the loose end of the track when it falls off the sprocket or front idler.
4. Move the tractor off the track. Place a plank at the rear of the track. The plank should be about the same thickness as the track, yet narrow enough to fit between the track frame and guards, and long enough so that the entire tractor can rest on the plank.

NOTE

After removing the tracks, always see that the tractor is securely blocked while repairs are being performed.

Anytime a track is removed, thoroughly inspect the track frame components for excessive wear and misalignment. Removal, disassembly, and replacement vary by model and manufacturer. Consult the manufacturer's service manual for exact procedures.

2.3.4.2 Track Replacement

To replace the tracks, back the tractor off the plank and onto the new tracks so the drive sprocket properly meshes with the track rail. Continue backing until the tractor is just ahead of the rear end of the track. Then place a bar in the track, and help the track climb over the sprocket, carrier rollers, and idler as the tractor is driven forward (*Figure 12-17*). When the track comes together, install the master pin and any locking device. Once the track is together, adjust the track tension using the manufacturer's recommended procedures.

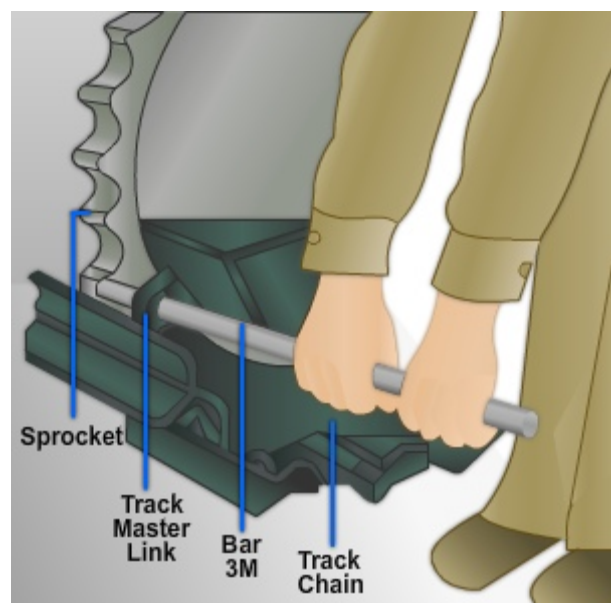


Figure 12-17 — Pulling track over the sprocket.

Test your Knowledge (Select the Correct Response)

2. How many track links should you measure across when checking track pitch?
- A. Five
 - B. Four
 - C. Three
 - D. Two

3.0.0 WINCHES and WIRE ROPE

Using a winch and some type of rigging, a vehicle can pull itself or another vehicle through such obstacles as muddy or rough terrain. This is the primary reason for providing winches on military vehicles.

In the Naval Construction Force (NCF), an in depth management program for maintenance and use of all rigging gear is required to ensure all operations are performed safely and professionally.

3.1.0 Winches

Most winches that you will encounter are used on tactical vehicles and construction equipment. On tactical equipment, the winch is mounted behind the front bumper and is secured to the front cross member of the frame or between the two side frame rails. In some cases, it may be mounted behind the cab of the vehicle. The typical front-mounted winch is a jaw-clutch worm-gear type (*Figure 12-18*).

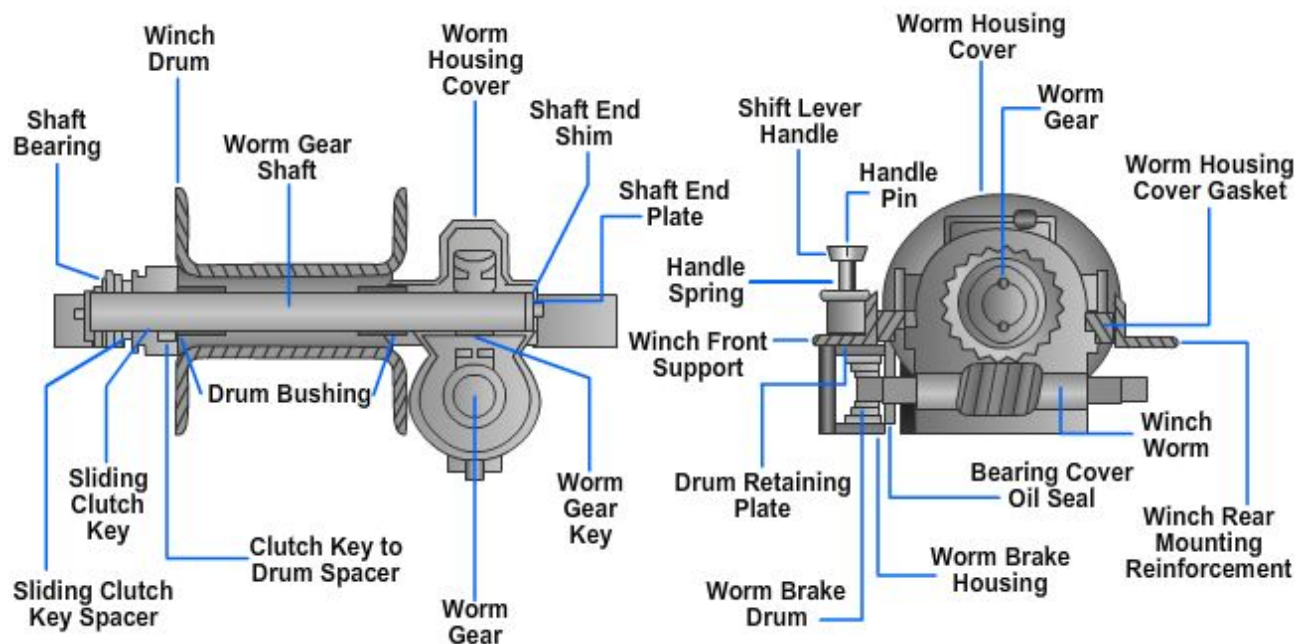


Figure 12-18 — Jaw-clutch worm-gear winch.

The jaw-clutch winch consists of a worm gear that is keyed to a shaft. A bushed drum is mounted on the worm-gear shaft, which is controlled by a hand operated sliding clutch. The worm shaft is driven by power from the power takeoff through a solid drive shaft and universal joints. The universal joint yoke, connected to the worm shaft of the winch, has a provision for a shear pin that is made of mild steel. This pin has a predetermined breaking strength that allows it to shear when the winch is overloaded.

A hand-operated sliding clutch is keyed to the worm-gear shaft outside of the winch drum and must be engaged with the jaws on the side of the winch drum when the winch is to be operated. Disengagement of the sliding clutch permits the drum to turn on the worm-gear shaft.

The two brakes that provide control of the winch drum are as follows:

The Worm Brake Shaft prevents the winch drum from rotating under load when the power takeoff is disengaged.

The Shifter Bracket Brake prevents the drum from overrunning the cable when the cable is being unreeled.

Some winches may be equipped with an automatic level-winding device to spool the cable on the drum in tight, even coils and layers. This prevents crushing of the cable due to loose, crossed coils and layers, and it allows off leads of the cable while maintaining level winding.

A broken shear pin usually causes faulty operation of winches. Internal damage of the winch can be caused by the use of a shear pin that has too high a breaking strength. Internal winch failure, resulting from overload, is commonly found to be sheared keys or a broken worm shaft. Often, when the cable is wound unevenly under tension, the winch housing will be cracked or broken. This will require replacement of the assembly.

NOTE

NEVER install a shear pin that is not of the proper shearing strength. Damage to the winch will occur when overloaded.

The winch that you will most likely encounter on construction equipment is the one attached to the rear of a crawler tractor, also known as a dozer. It is mounted on the rear of the dozer and is directly geared to the rear power takeoff (*Figure 12-19*). This arrangement permits development of a line of pull that is 50 to 100 percent greater than straight dozer pull. The winch is used for uprooting trees and stumps, hoisting and skidding stress, freeing mired equipment, and supporting amphibious construction operations.

When performing maintenance on a winch, ensure that the gear case has the recommended amount and type of lubricant. Should disassembly of the winch be required for repairs, follow the procedures given in the manufacturer's manual.

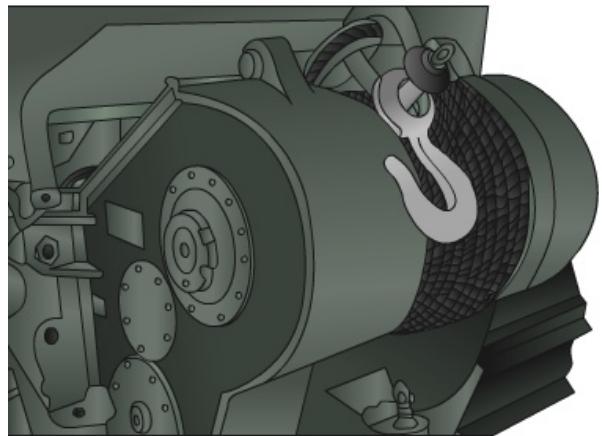


Figure 12-19 — Winch attachment on a dozer.

3.2.0 Wire Rope

Many of the movable components on cranes and attachments are moved by wire rope. Wire rope is a complex machine composed of a number of precise moving parts. The moving parts of wire rope are designed and manufactured to bear a definite relationship to one another to have the necessary flexibility during operation.

Wire rope may be manufactured by either of two methods. If the strands, or wires, are shaped to conform to the curvature of the finished rope before laying up, the rope is termed **Preformed Wire Rope**. If they are not shaped before fabrication, the wire rope is termed **Non-Preformed Wire Rope**. The most common type of manufactured wire rope is preformed. When cut, the wire rope tends not to unlay and is more flexible than non-preformed wire rope. With nonpreformed wire rope, twisting produces a stress in the wires; therefore, when it is cut or broken, the stress causes the strands to unlay.



WARNING

When the wire is cut or broken, the almost instantaneous unlaying of the wire or strands of the non-preformed wire rope can cause serious injury. This situation is apt to occur especially to someone who is careless or not familiar with this characteristic of the rope.

3.2.1 Composition of Wire Rope

Wire rope is composed of three parts: **wires**, **strands**, and **core** (Figure 12-20). A predetermined number of wires of the same or different size are fabricated in a uniform arrangement of definite lay to form a strand. The required number of strands are then laid together symmetrically around the core to form the wire rope.

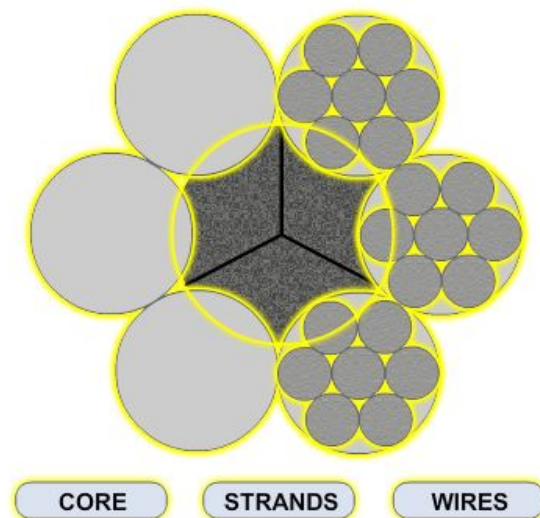


Figure 12-20 – Parts of a wire rope.

3.2.1.1 Wire

Wire rope varies in size and can consist of steel, iron, or other metals. The number of wires to a strand varies, depending on the intended purpose of the rope. Wire rope is designated by the number of strands per rope and the number of wires per strand. Thus a one-half inch, 6 x 19 rope has six strands with 19 wires per strand. It has the same outside diameter as a one-half inch, 6 x 37 rope that has six strands with 37 wires (of smaller size) per strand.

3.2.1.2 Strand

The design arrangement of a strand is called the construction. The wires in the strand may be all the same size or a combination of different sizes. *Figure 12-21* show some of the more typical wire rope constructions. The most common strand constructions you may encounter are as follows:

- Ordinary construction: Wires are all the same size.
- Seale construction: Each strand consists of three rings of wire. The first ring of wires around the center wire of the strand is of smaller diameter than the center and outer layers. Large diameter wires resist abrasion while smaller diameter wires provide flexibility.
- Warrington construction: Each strand has two layers of wire about a center wire. The outer layer consists of wires that are alternately large and small. This alternating wire size combines flexibility with abrasion resistance.

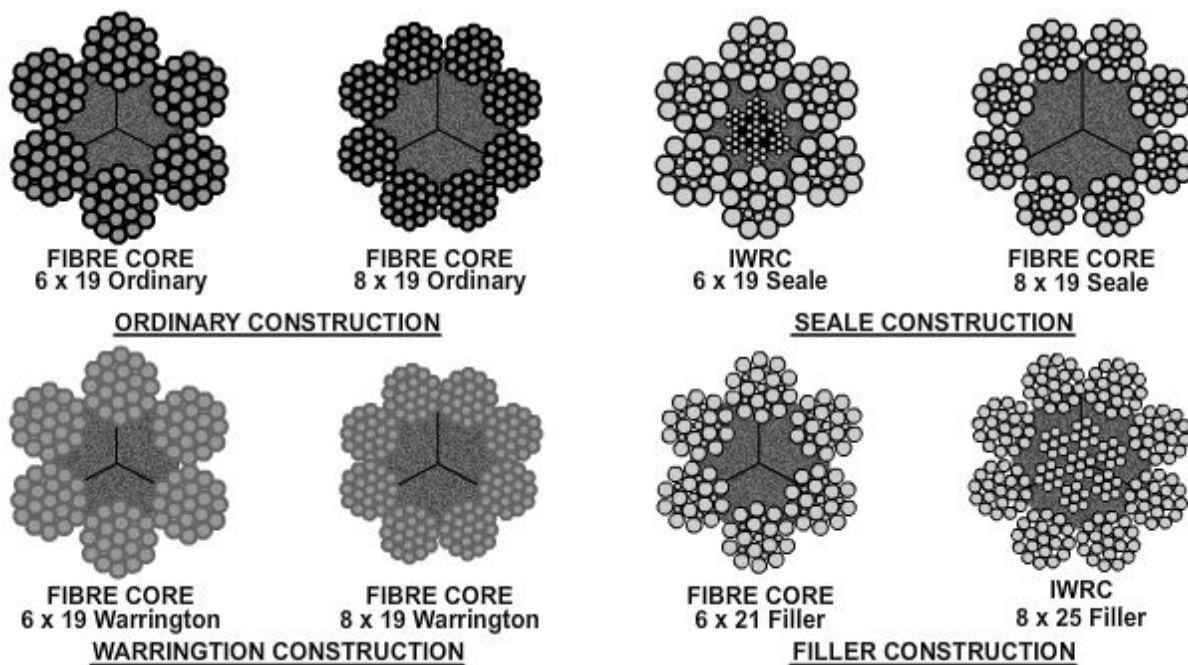


Figure 12-21 — Common strand construction.

- Filler construction: Filler wire has small wires filling the voids between the rings of wire in the strand. These small wires are not counted when designating the number of wires in the strand. This construction type provides abrasion and fatigue resistance.
- Flattened construction: Strands are somewhat triangular in shape, and sometimes formed around a triangular center wire.

3.2.1.3 Core

The wire rope core supports the strands laid around it. There are three types of wire rope cores:

- **Fiber core** consists of a hard fiber such as manila, hemp, plastic, paper, or sisal. The fiber core offers the advantage of increased flexibility. It also serves as a cushion to reduce the effects of sudden strain and acts as an oil reservoir to lubricate the wire and strands (to reduce friction). Wire rope with a fiber core is used when flexibility of the rope is especially important.
- **Wire strand core** resists more heat than a fiber core and also adds about 15 percent to the strength of the rope. However, the

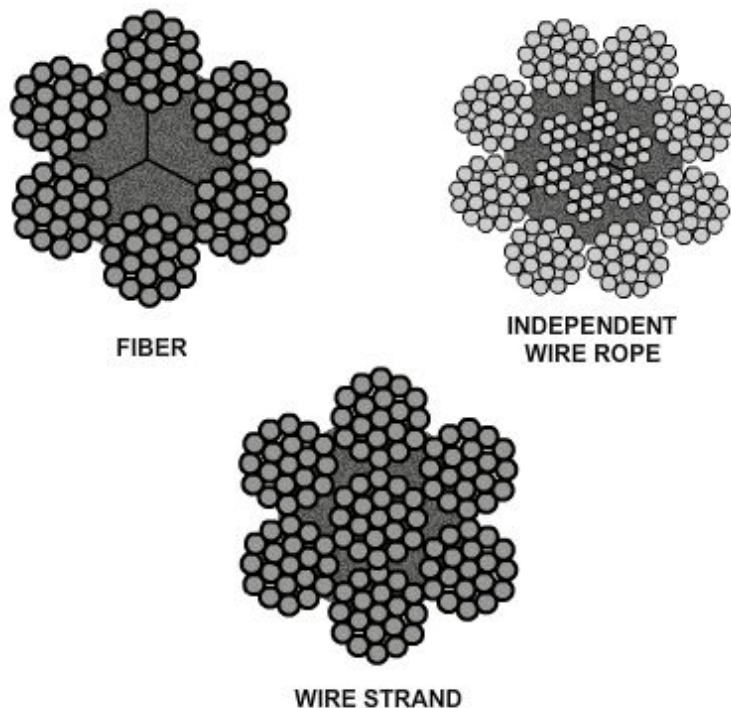


Figure 12-22 — Core construction.

wire strand core makes the wire less flexible than a rope with a fiber core.

- **Independent wire rope core (IWRC)** is a separate wire rope over which the main strands of the rope are laid. This core strengthens the rope, provides support against crushing, and supplies maximum resistance to heat. Refer to *Figure 12-22*.

3.2.2 Grades of Wire Rope

There are four primary grades of wire rope:

- Mild plow steel
- Plow steel
- Improved plow steel
- Extra improved plow steel

3.2.2.1 Mild Plow Steel Wire Rope

Mild plow steel wire rope is tough and pliable. It can stand repeated strain and stress and has a tensile strength (resistance to lengthwise stress) of from 200,000 to 220,000 pounds per square inch (psi). These characteristics make it desirable for cable tool drilling and other uses in which abrasion occurs.

3.2.2.2 Plow Steel Wire Rope

Plow steel wire rope is unusually tough and strong. This steel, which got its name from the original high-carbon crucible furnace steel used to produce plowshares, has a tensile strength of 220,000 to 240,000 psi. Plow steel wire rope is suitable for hauling, hoisting, and logging.

3.2.2.3 Improved Plow Steel Wire Rope

Improved plow steel (IPS) wire rope is one of the best grades of rope available and is the wire rope most commonly used in the NCF. This type of rope is stronger, tougher, and more resistant to wear than either mild plow steel or plow steel. Each square inch of IPS can stand a strain of 240,000 to 260,000 pounds. This makes it especially useful for heavy-duty service, such as on cranes with excavating and weight-handling attachments.

3.2.2.4 Extra Improved Plow Steel Wire Rope

Extra improved plow steel (EIP) is 15% stronger than IPS. Various manufacturers have their own name for this grade. It was developed for applications needing greater safety factors without a diameter increase, such as rotary oil-well drilling, and for maximum resistance to abrasive wear, such as that resulting from draglines in strip mining through rocky terrain. This premium grade has tensile strength ranging from 280,000 to 340,000 psi.

3.2.3 Lays of Wire Rope

The term lay refers to the direction of the twist of the wires in a strand and to the direction that the strands are laid in the rope. In some instances, both the wires in the strand and the strands in the rope are laid in the same direction, while in other instances, the wires are laid in one direction and the strands are laid in the opposite direction, depending on the intended use of the rope. Most manufacturers specify the types and lays of wire rope to be used on their piece of equipment. Be sure and consult the operator's manual for proper application.

There are five types of lays used in wire rope (*Figure 12-23*).

3.2.3.1 Right Regular Lay

The wires in the strands are laid to the left, while the strands are laid to the right to form the wire rope.

3.2.3.2 Left Regular Lay

The wires in the strands are laid to the right, while the strands are laid to the left to form the wire rope. In this lay, each step of fabrication is exactly opposite from the right regular lay.

3.2.3.3 Right Lang Lay

The wires in the strands and the strands in the rope are laid in the same direction; in this instance the lay is to the right.

3.2.3.4 Left Lang Lay

The wires in the strands and the strands in the rope are also laid in the same direction; in this instance the lay is to the left.

3.2.3.5 Reverse Lay

The wires in one strand are laid to the right, the wires in the nearby strand are laid to the left, the wires in the next strand are to the right, and so forth, with alternate directions from one strand to the other. Then all the strands are laid to the right.

3.2.3.6 Lay length of Wire Rope

The length of a rope lay is the distance measured parallel to the center line of a wire rope in which a strand makes one complete spiral (or turn) around the rope. The length of a strand lay is the distance measured parallel to the center line of the strand in which one wire makes one complete spiral turn around the strand. Lay length measurement is shown in *Figure 12-24*.



RIGHT REGULAR LAY



LEFT REGULAR LAY



RIGHT LANG LAY



LEFT LANG LAY



REVERSE LAY

Figure 12-23 — Lay of wire rope.

3.2.4 Characteristics of Wire Rope

The NCF use several types of wire, typically those with 6, 7, 12, 19, 24, or 37 wires in each strand. Usually the wire rope has six strands laid around the core.

The two most common types of wire rope are 6 x 19 and 6 x 37 (*Figures 12-25 and 12-26*). The 6 x 19 type, which has 6 strands with 19 wires in each strand, is the stiffest and strongest construction of the wire rope and the most suitable for general hoisting operations. The 6 x 37 wire rope, six strands with 37 wires in each strand, is very flexible, making it most suitable for cranes and other pieces of equipment in which sheaves are smaller than usual. The wires in the 6 x 37 are smaller than the wires in the 6 x 19 and consequently do not stand as much abrasive wear

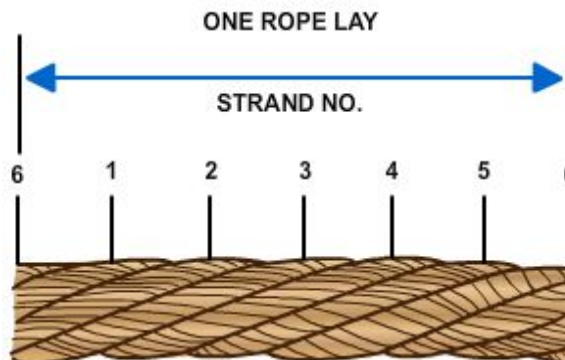
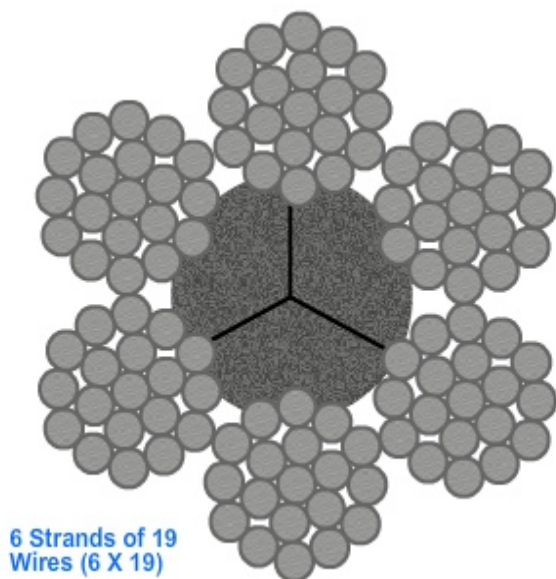


Figure 12-24 – Lay length of wire rope.

Consider several factors when selecting a wire rope for use in a particular kind of operation. There is not a wire rope in existence that equally withstands all kind of wear and stress. Because of this, selecting a rope is often a matter of compromise, sacrificing one quality to have another more critical characteristic.



Figures 12-25 – 6 x 19 wire ropes.

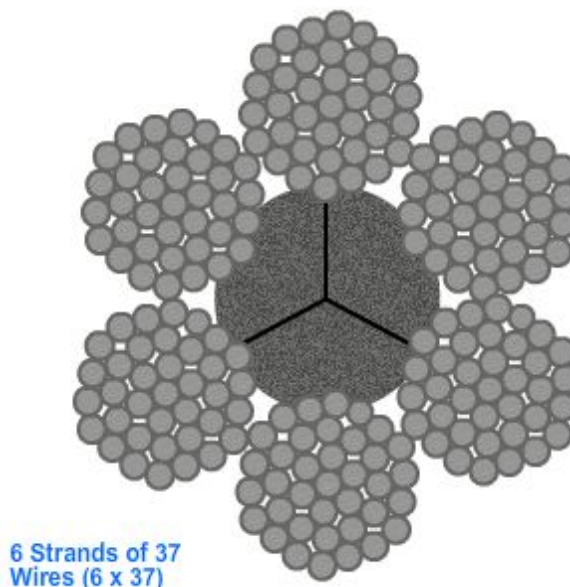


Figure 12-26 – 6 x 37 wire rope.

3.2.4.1 Tensile Strength

Tensile strength is the strength necessary to withstand a certain maximum load applied to the rope. It includes a reserve of strength measured in a so-called factor of safety.

3.2.4.2 Crushing Strength

Crushing strength is the strength necessary to resist the compressive and squeezing forces that distort the cross section of a wire rope as it runs over sheaves, rollers, and hoist drums when under a heavy load. Regular lay rope distorts less in these situations than lang lay.

3.2.4.3 Fatigue Resistance

Fatigue resistance is the ability to withstand the constant bending and flexing of wire rope that runs continuously on sheaves and hoist drums. Fatigue resistance is important when the wire rope must run at high speeds. Such constant and rapid bending of the rope can break individual wires in the strands. Lang lay ropes are best for service requiring high fatigue resistance. Ropes with smaller wires around the outside of their strands also have greater fatigue resistance, since these strands are more flexible.

3.2.4.4 Abrasion Resistance

Abrasion resistance is the ability to withstand the gradual wearing away of the outer metal as the rope runs across sheaves and hoist drums. The rate of abrasion depends mainly on the load carried by the rope and its running speed. Generally, abrasion resistance in a rope depends on the type of metal of which the rope is made and the size of the individual outer wires. Wire rope made of the harder steels, such as improved plow steel, has considerable resistance to abrasion. Ropes that have larger wires forming the outside of their strands are more resistant to wear than ropes having smaller wires which wear away more quickly.

3.2.4.5 Corrosion Resistance

Corrosion resistance is the ability to withstand the dissolution of the wire metal that results from chemical attack by moisture in the atmosphere or elsewhere in the working environment. Ropes, such as guy wires, that are put to static work may be protected from corrosive elements by paint or other special dressings. Wire rope may also be galvanized for corrosion protection. Most wire ropes used in crane operations must rely on their lubricating dressing to double as a corrosion preventative.

3.2.5 Measuring Wire Rope

Wire rope is designated by its diameter in inches, as shown in *Figure 12-27*. The correct method of measuring the wire rope is to measure from the top of one strand to the top of the strand directly opposite it. Measuring across two side by side strands is not correct.

To ensure an accurate

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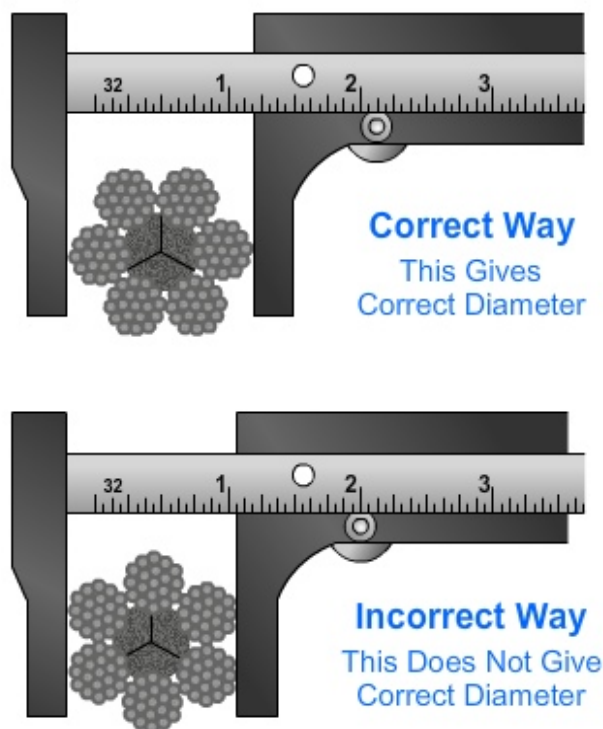


Figure 12-27 — Correct and incorrect methods of measuring wire rope.

measurement of the wire rope's diameter, always measure the rope at three places, at least five feet apart. Use the average of the three measurements as the diameter of the rope.

3.2.6 Wire Rope Safe Working Load

The safe working load (SWL) of wire rope is the load that can be applied and still obtain the most efficient service and prolong the life of the rope.

The formula for computing the SWL of a wire rope is the diameter of the rope squared, multiplied by 8 ($D \times D \times 8 = \text{SWL in tons}$).

Example: The wire rope is 1/2 inch in diameter. Compute the SWL for the rope.

The first step is to convert the 1/2 into a decimal number by dividing the bottom number of the fraction into the top number of the fraction: (1 divided by 2 = .5). Next, compute the SWL formula: ($.5 \times .5 \times 8 = 2 \text{ tons}$). The SWL of the 1/2 inch wire rope is 2 tons.

NOTE

Do NOT downgrade the SWL of wire rope if it is old, worn, or in poor condition. Cut up and discard wire rope in these conditions.

3.2.7 Wire Rope Failure

Some of the common causes of wire rope failure are the following:

- Using incorrect size, construction, or grade.
- Dragging over obstacles.
- Lubricating improperly.
- Operating over sheaves and drums of inadequate size.
- Overriding or cross winding on drums.
- Operating over sheaves and drums with improperly fitted grooves or broken flanges.
- Jumping of sheaves.
- Exposing to acid or corrosive liquid or gases.
- Using an improperly attached fitting.
- Allowing grit to penetrate between the strands promoting internal wear.
- Subjecting to severe or continuing overload.
- Using an excessive ***fleet angle***.

3.2.8 Handling and Care of Wire Rope

To maximize the safe, dependable service of wire rope, take care to perform the maintenance necessary to keep the wire rope in good condition. Various ways of caring for and handling wire rope are discussed below.

3.2.8.1 Coiling and Uncoiling

Once a new reel is open, it may be coiled or faked down (laid in a coil or series of long loops to allow the rope to run freely without kinking) like line. For left lay wire rope, coil counterclockwise. For right lay wire rope, coil clockwise. Because of the resilience of the wire, it can be resistant to being coiled down. When this occurs, it is not useful to force the wire down the turn because it will just spring up again. Instead, throw the wire in a back turn (*Figure 12-28*), and it will lie down properly. A wire rope, when faked down, runs right off. But when wire rope is wound in a coil, it has to be unwound manually.

Wire rope tends to kink during uncoiling or unreeling, especially if it has been in use for a long time. A kink can cause a weak spot in the rope that wears out more quickly than the rest of the rope.

A good method for unreeling wire rope is to run a pipe or rod through the center and mount the reel on drum jacks or other supports so the reel is off the ground. In this position, the reel turns as the rope unwinds, and the rotation of the reel helps keep the rope strait. During unreeling, pull the rope strait forward and try not to rush. To avoid kinking, NEVER unreel wire rope from a stationary reel. Refer to *Figure 12-29*.

To uncoil a small twist of wire rope, simply stand the coil on edge and roll it along the ground like a wheel or hoop. Do not lay the coil flat on the floor/ground and uncoil it by pulling on the end—such practice can kink and/or twist the rope.

3.2.8.2 Kinks

One of the most common forms of damage resulting from improper handling of wire rope is kink development. A kink starts with the formation of a loop. A loop that has not yet been pulled tight enough to set the wires or strands of the rope into a kink can be removed by turning the rope at either end in the direction appropriate to restore the lay (*Figure 12-30*).

If you attempt to remove a loop simply by pulling it tight, a kink will result, and the rope will be irreparably damaged. Kinking is preventable through proper uncoiling and unreeling methods and by handling the rope correctly at all times.

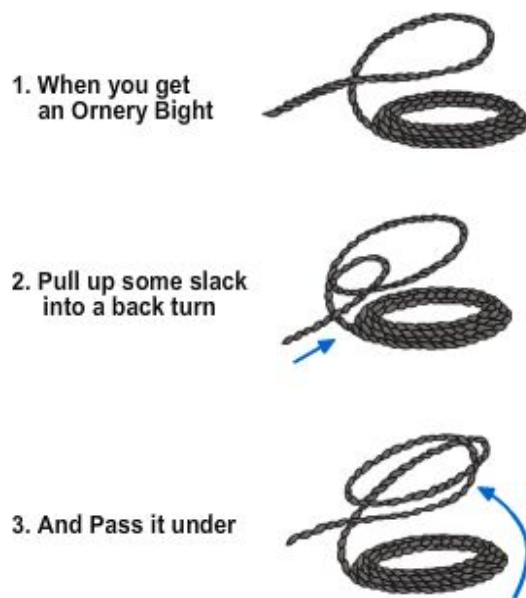


Figure 12-28 – Throwing a back turn.

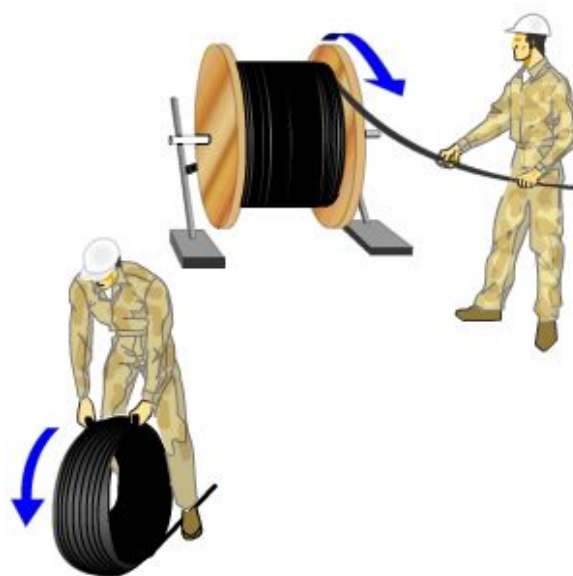


Figure 12-29 — Unreeling wire rope and uncoiling wire rope.

3.2.8.3 Drum Winding

Spooling wire rope on a crane hoist drum causes a slight rotating tendency due to the spiral lay of the strands. Two types of hoist drums are used for spooling wire rope:

- Grooved drum: On grooved drums, the grooves generally give sufficient control to wind the wire rope properly, whether it is right or left lay rope.
- Smooth-Faced Drum: On smooth-faced drums, the only influence on the wire rope in winding the first layer is the fleet angle. The slight rotational tendency of the rope can be used as an advantage in keeping the winding tight and uniform.

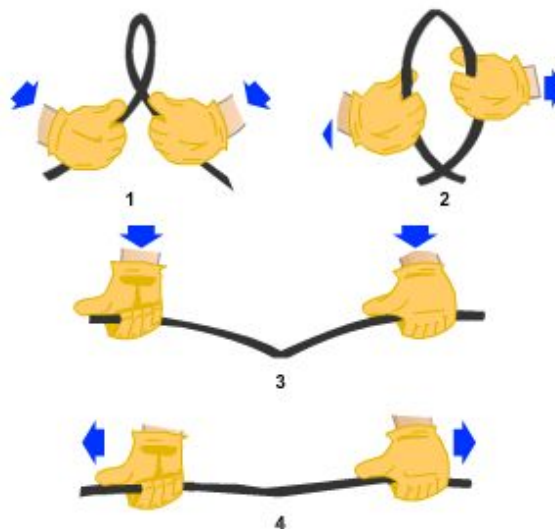


Figure 12-30 – Removing a loop.

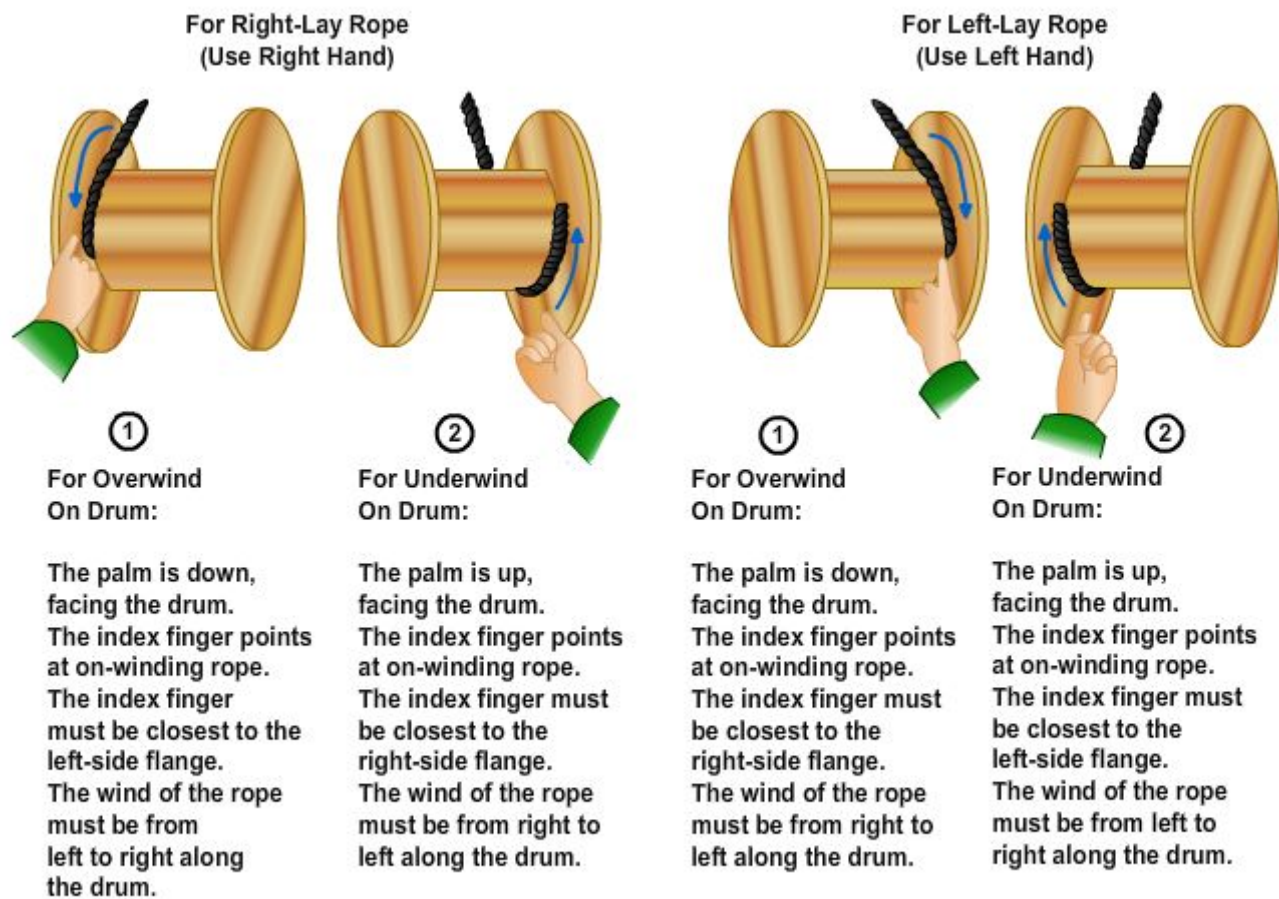
NOTE

Using the wrong type of wire rope lay causes the rotational tendency of the rope to be a disadvantage because it results in loose and non-uniform rope winding on the hoist drum.

Figure 12-31 shows drum winding diagrams for selection of the proper lay of rope. If you are standing behind the hoist drum and looking toward an oncoming overwind rope, the rotating tendency of right lay rope is toward the left, whereas, the rotating tendency of a left lay rope is toward the right.

Refer to *Figure 12-31*. With overwind reeving and a right lay rope on a smooth-faced drum, the wire rope bitter end attachment to the drum flange should be at the left flange. With underwind reeving and a right lay rope, the wire rope bitter end (the end of a rope that is tied off) attachment should be at the right flange.

When wire rope is run off one reel onto another or onto a winch or drum, it should be run from TOP TO TOP or from BOTTOM TO BOTTOM (*Figure 12-32*).



If a smooth-face drum has been cut or scored by an old rope, the methods shown may not apply.

Figure 12-31 — Different lays of wire rope winding on hoist drums.

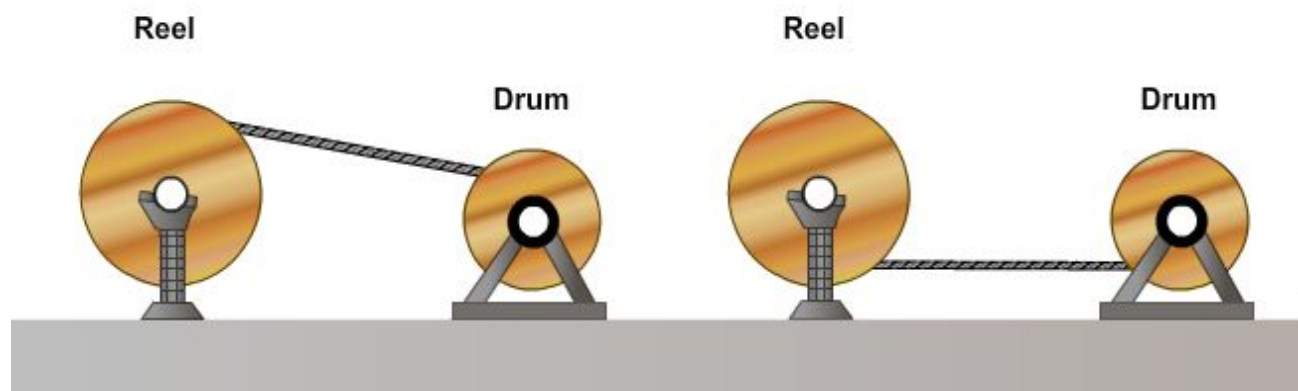


Figure 12-32 — Transferring wire rope from reel to drum.

3.2.8.4 Fleet Angle

The fleet angle is formed by running wire rope between a sheave and a hoist drum whose axles are parallel to each other (*Figure 12-33*). Too large a fleet angle can cause the wire rope to climb the flange of the sheave and can also cause the wire rope to climb over itself on the hoist drum.

3.2.8.5 Sizes of Sheaves

The diameter of a sheave should never be less than 20 times the diameter of the wire rope. An exception is 6 x 37 wire for which a smaller sheave can be used because this wire rope is more flexible.

Use the chart shown in *Table 12-1* to determine the minimum sheave diameter for wire rope of various diameters and construction.

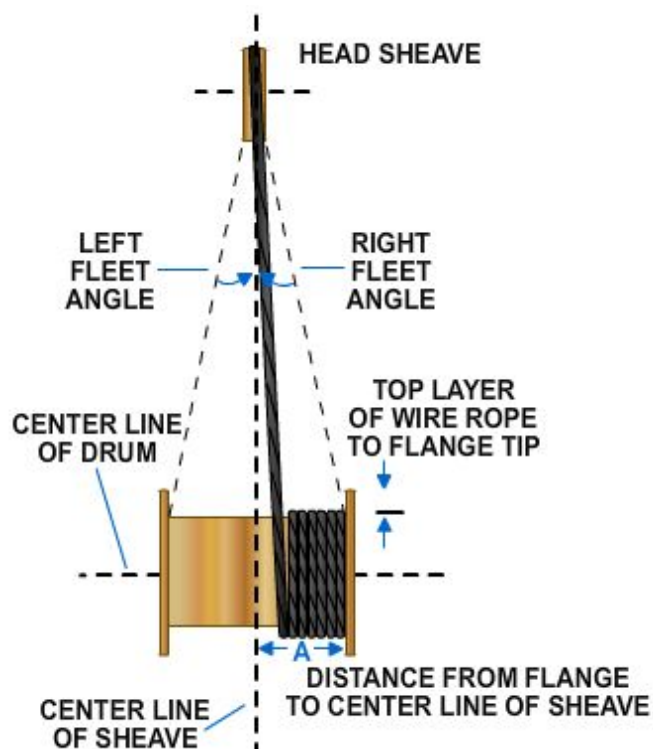


Figure 12-33 Fleet angle relationship.

Table 12-1 — Suggested Minimum Tread Diameter of Sheaves and Drums.

Rope diameter in inches	Minimum tread diameter in inches for given rope construction *			
	6 x 7	6 x 19	6 x 37	8 x 19
1/4	10 1/2	8 1/2		6 1/2
3/8	15 3/4	12 3/4	6 3/4	9 3/4
1/2	21	17	9	13
5/8	26 1/4	21 1/4	11 1/4	16 1/4
3/4	31 1/2	25 1/2	13 1/2	19 1/2
7/8	36 3/4	29 3/4	15 3/4	22 3/4
1	42	34	18	26
1 1/8	47 1/2	38 1/4	20 1/2	29 1/4
1 1/4	52 1/2	42 1/2	22 1/2	32 1/2
1 1/2	63	51	27	39

* Rope construction is in strands times wires per strand.

3.2.8.6 Reverse Bends

Whenever possible, place drums, sheaves, and blocks used with wire rope to avoid reverse or S-shaped bends. Reverse bends cause the individual wires or strands to shift too much and increase wear and fatigue. For a reverse bend, the drums and blocks affecting the reversal should be of a larger diameter than ordinarily used and should be spaced as far apart as possible.

3.2.8.7 Seizing and Cutting

Wire rope makers are careful to lay each wire in the strand and each strand in the rope under uniform tension. If the ends of the rope are not secured properly, the original balance of tension is disturbed and maximum service is not possible because the load weight ends up being unevenly distributed. Before cutting steel wire rope, place seizing on each side of the cutting point (*Figure 12-34*).

Determining the size and number of seizings and the distance between them depends on several rules of thumb:

- The number of seizings applied is equal to approximately 3 times the rope's diameter.
- The width of each seizing is between 1 and 1 ½ times as long as the diameter of the rope.
- Space seizing a distance equal to twice the wire rope's diameter.

A common method used to make a temporary wire rope seizing involves winding the seizing wire uniformly, using tension on the wire. After taking the required number of turns, twist the ends of the wires counterclockwise by hand so that the twisted portion of the wires are near the middle of the seizing. Grasp the ends with end-cutting nippers. Cut the ends and pound them down on the rope, then use a serving bar (or iron) to increase tension on the seizing wire when putting on the turns.

A wire rope can be cut in a number of ways. One effective and simple method is to use a hydraulic wire rope cutter.

Seize all wire before cutting it, then place the rope in the cutter so that the blade comes between the two central seizings. With the release valve closed, jack the blade against the rope at the location of the cut and continue to operate the cutter until the cut is complete.

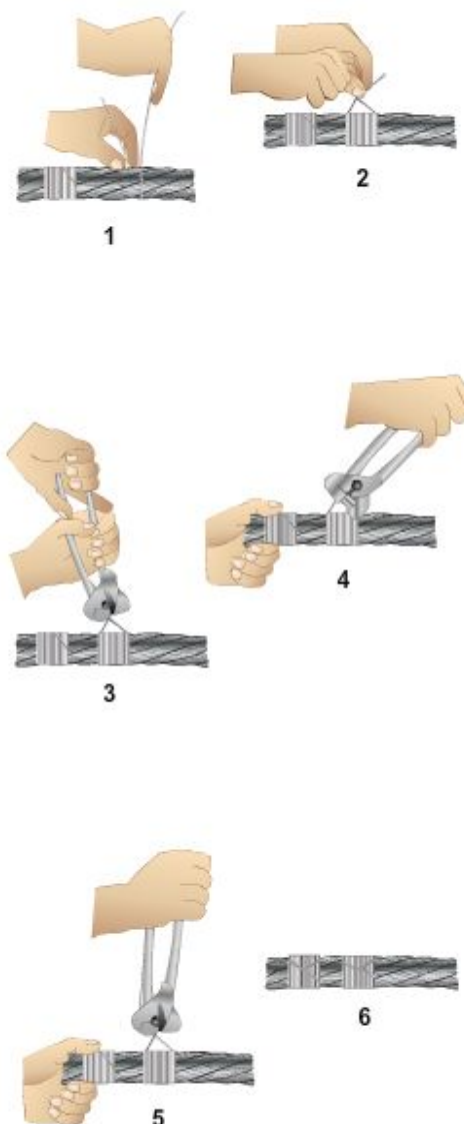


Figure 12-34 — Seizing wire rope.

3.2.9 Wire Rope Maintenance

Wire rope bending around hoist drums and sheaves will wear like any other metal article, so lubrication is just as important to an operating wire rope as it is to any other piece of working machinery. For a wire rope to operate correctly, its wires and strands must be free to move. Friction from corrosion or lack of lubrication shortens the service life of wire rope.

Deterioration from corrosion is more dangerous than that from wear because corrosion ruins the inside wires, a process hard to detect by inspection. Deterioration caused by wear can be detected by conducting internal and external inspections.

3.2.9.1 Inspections

Unless experience with specific operating conditions indicates that more frequent inspections are required, visually inspect all running wire rope in service quarterly to determine whether deterioration has resulted in appreciable loss of original strength and constitutes a safety hazard.

3.2.9.1.1 External Inspection

The external inspection criteria for general usage running wire rope are as follows:

- Reduction of nominal rope diameter due to loss of core support or internal or external corrosion or wear of individual outside wires. The diameter should be measured in a circumscribing circle in six or more places on the wire rope, as shown in *Figure 12-27*.
- Number of broken outside wires and degree of distribution or concentration of broken wires.
- Corroded, pitted, or broken wires at the end connections.
- Corroded, cracked, bent, worn, or improperly applied end connections.
- Severe kinking, crushing, or distortion of rope structure.
- Evidence of heat damage from any cause.

3.2.9.1.2 Internal Inspection

A wire rope can be opened for internal inspection only when completely relaxed. Using care to avoid damaging the strands or core, open the wire rope in six or more places by working a marlin spike beneath two strands. Carefully rotate the spike to expose the core and underside of the strands. Inspect for evidence of internal corrosion, broken wires, or core failure. Give particular attention to the wire rope in areas close to end fittings, those lengths that pass over sheaves, onto drums, or that remain exposed to or immersed in seawater. If a wire rope has been opened properly and carefully, and internal condition does not show cause for removal, the strands can be returned to their original working positions without distorting the wire rope or impairing future usefulness. Only qualified personnel shall be authorized to inspect wire rope.

3.2.9.1.3 Rejection Criteria

The following is a list of conditions that indicate a wire rope should be removed from service:

- A. The nominal rope diameter is reduced by more than the amount shown in *Table 12-2* for the applicable size rope, or there is an unexpected increase in lay length as compared to previous lay length measurements.
- B. Six broken wires in one rope lay length, or three broken wires in one strand lay length.
- C. One broken wire within one rope lay length of any end fitting.
- D. Wear of 1/3 the original diameter of outside individual wires, evidenced by flat spots almost the full width of the individual wire, extending one lay length or more.
- E. Pitting due to corrosion or nicks extending one lay length or more.

Table 12-2 — Wire Rope Allowable Diameter Reduction.

Rope Diameter (Inches)	Maximum Allowable Nominal Diameter Reduction (Inches)
5/16 and smaller	1/64
3/8 to 1/2	1/32
9/16 to 3/4	3/64
7/8 to 1 1/8	1/16
1 1/4 to 1 1/2	3/32
1 9/16 to 2	1/8
2 1/8 to 2 1/2	5/32

- F. Severe kinking, crushing, or any other damage resulting in distortion of the rope structure.
- G. Evidence of internal corrosion, broken wires on the underside of strands or in the core.

3.2.9.2 Lubrication

Both internal and external lubrication protect a wire rope against wear and corrosion. Internal lubrication can be properly applied only when the wire rope is being manufactured, and manufacturers customarily coat every wire with a rust-inhibiting lubricant and lay it into the strand. The core is also lubricated in manufacturing.

Lubrication applied in the field is designed not only to maintain surface lubrication but also to prevent the loss of the internal lubrication provided by the manufacturer. The Navy issues an asphaltic petroleum oil that must be heated before using. This lubricant is known as Lubricating Oil for Chain, Wire Rope, and Exposed Gear and comes in two types:

- Type I, Regular: This type of lubricant does not prevent rust and is used where rust prevention is unnecessary. For example, elevator wires used



Figure 12-35 — Trough method of lubricating wire rope.

inside structures that are not exposed to the weather, but still require lubrication.

- Type II, Protective: A lubricant and an anti-corrosive, it comes in three grades:
 - Grade A: For cold weather (60°F and below)
 - Grade B: For warm weather (between 60°F and 80°F)
 - Grade C: For hot weather (80°F and above)

Apply the oil, issued in 25-pound or 35-pound buckets and also in 100-pound drums, with a stiff brush, or draw the wire rope through a trough of hot lubricant (Refer to *Figure 12-35*). The frequency of application depends upon service conditions; as soon as the last coating has appreciably deteriorated, renew it.



Avoid prolonged skin contact with oils and lubricants. Consult the Materials Safety Data Sheet (MSDS) on each item before use for precautions and hazards.

A good lubricant to use when working in the field, as recommended by *Naval Ships Technical Manual Chapter 613*, is Mil-Spec lubricant (MIL-G-18458).

Do not lubricate wire rope that works a dragline or other attachments that normally bring the wire rope in contact with soils. The lubricant will pick up fine particles of material, and the resulting abrasive action will be detrimental to both the wire rope and sheave.

As a safety precaution, always wipe off any excess oil when lubricating wire rope, especially with hoisting equipment. Too much lubricant can get into brakes or clutches and cause them to fail. When machinery is in use, its motion may sling excess oil around and over crane cabs and onto catwalks, making them unsafe.

NOTE

Properly dispose of wiping rags and used or excess lubricant as hazardous waste. See your supervisor for details on local disposal requirements.

3.2.10 Wire Rope Attachments

Many attachments can be fitted to the ends of wire rope so the rope can be connected to other wire ropes, pad eyes, or equipment.

3.2.10.1 Wedge Socket

The wedge socket is the most often used attachment for connecting ends of wire rope to pad eyes or like fittings on cranes and earthmoving equipment (*Figure 12-36*). The socket is always applied to the bitter end of the wire rope.

NOTE

The wedge socket has only 70 percent of the breaking strength of the wire rope due to the crushing action of the wedge.

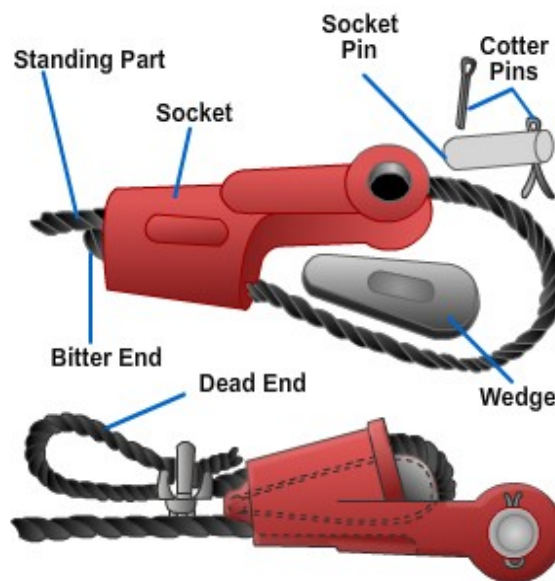


Figure 12-36 – Wedge socket.

3.2.10.2 Speltered Socket

Speltering is the best way to attach a closed or opened socket in the field. Speltering is the process of attaching the socket to the wire rope by pouring hot zinc or an epoxy resin compound around it (*Figure 12-37*). Only qualified personnel should perform speltering.

Forged steel speltered sockets are as strong as the wire rope itself; they are required on all cranes used to lift personnel, ammunition, acids, and other dangerous materials.

NOTE

Spelter sockets develop 100 percent of the breaking strength of the wire rope.

3.2.10.3 Wire Rope Clips

Wire rope clips make eyes in wire rope (*Figure 12-38*). The U-shaped part of the clip with the threaded ends is the U-bolt; the other part is the saddle. The saddle is stamped with the diameter of the wire rope that the clip will fit. Always place a clip with the U-bolt on the bitter end, not on the standing part of the wire rope. If clips are attached incorrectly, the standing part of the wire rope will be distorted or have mashed spots. A rule of thumb when attaching a wire rope clip is NEVER to saddle a dead horse.

Two simple formulas for figuring the number of wire rope clips needed are as follows:

- $3 \times \text{the wire rope diameter} + 1 = \text{Number of clips}$
- $6 \times \text{the wire rope diameter} = \text{Spacing between clips}$

Another type of wire rope clip is called the twin-base clip, often referred to as the universal or two-clamp (*Figure 12-39*). Both parts of this clip are shaped to fit the wire rope so that the clip cannot be attached incorrectly. The twin-base clip allows for a clear 360-degree swing with the wrench when tightening the nuts.

3.2.10.4 Thimble

When an eye is made in a wire rope, a metal fitting called a thimble is usually placed in the

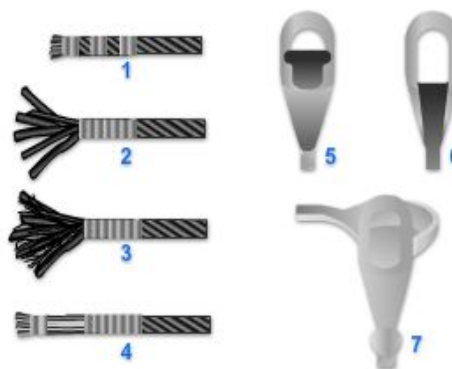


Figure 12-37 — Speltering a socket.

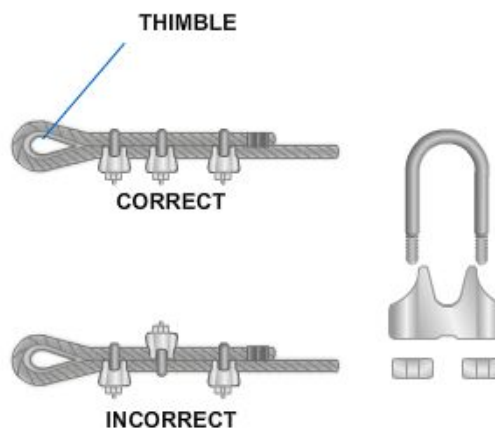


Figure 12-38 — Wire rope clips.

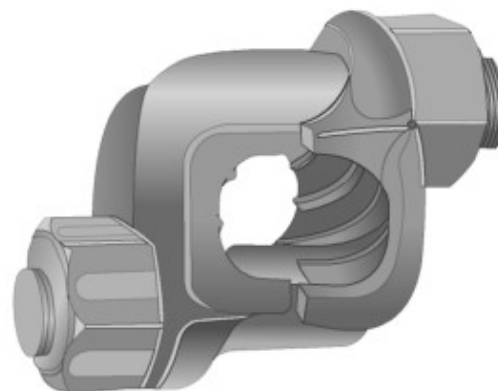


Figure 12-39 – Twin-base wire rope clip.

eye (*Figure 12-38*). The thimble protects the eye against wear. Wire rope eyes with thimbles and wire rope clips can hold approximately 80 percent of the wire rope strength.

After the eye made with clips has been strained, retighten the clip nuts. Check now and then for tightness or damage to the rope caused by the clips.

3.2.10.5 Swaged Connections

Swaging makes an efficient and permanent attachment for wire rope (*Figure 12-40*). A swaged connection is made by compressing a steel sleeve over the rope by using a hydraulic press. When the connection is made correctly, it provides 100 percent of the capacity of the wire rope.

Carefully inspecting the wires leading into these connections is important because of the pressure put upon the wires in this section. If there is one broken wire at the swaged connection, or there is a crack in the swage, replace the fitting.



Figure 12-40 — Swaged connections.

3.2.10.6 Hooks and Shackles

Hooks and shackles are handy for hauling or lifting loads without tying them directly to the object with a line, wire rope, or chain. They can be attached to wire rope, fiber line, blocks, or chains. Shackles should be used for loads too heavy for hooks to handle.

When hooks fail due to overloading, they usually straighten out and lose or drop their load. When a hook is bent, DO NOT straighten it and put it back into service. Instead, cut it in half (with a cutting torch) and discard it.

Inspect hooks at the beginning of each work day and before lifting a full-rated load. If it is unclear whether the hook will bear the intended load, use a shackle. Use hooks that close and lock where there is danger of catching on an obstruction, particularly in hoisting buckets, cages, or skips, and especially during shaft work. Hooks and rings used with a chain should have about the same length as the chain.

Follow the manufacturers' recommendations in determining the SWLs of various sizes and types of specific and identifiable hooks. Test all hooks for which no applicable manufacturer's recommendations are available to twice the intended SWL before initially putting them into use.

Mousing is a technique often used to close the open section of a hook to keep slings,

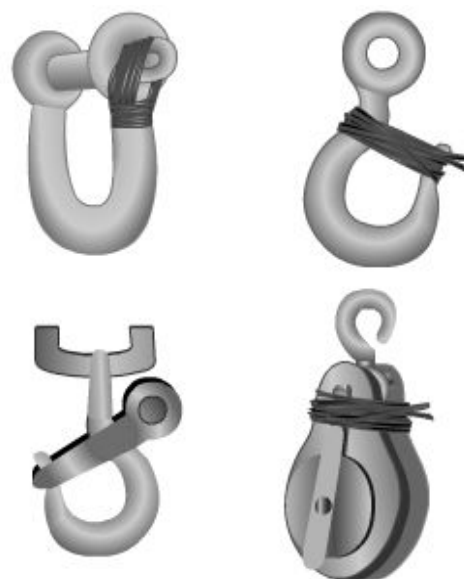


Figure 12-41 — Mousing.

straps, and similar attachments from slipping off the hook (*Figure 12-41*).

Mouse hooks with rope yarn, seizing wire, or a shackle. When using rope yarn or wire, make 8 or 10 wraps around both sides of the hook. To finish off, make several turns with the yarn or wire around the sides of the mousing, and then tie the ends securely.

Two types of shackles used in rigging are the anchor (*Figure 12-42*) and the chain (*Figure 12-43*). Both are available with screw pins or round pins.

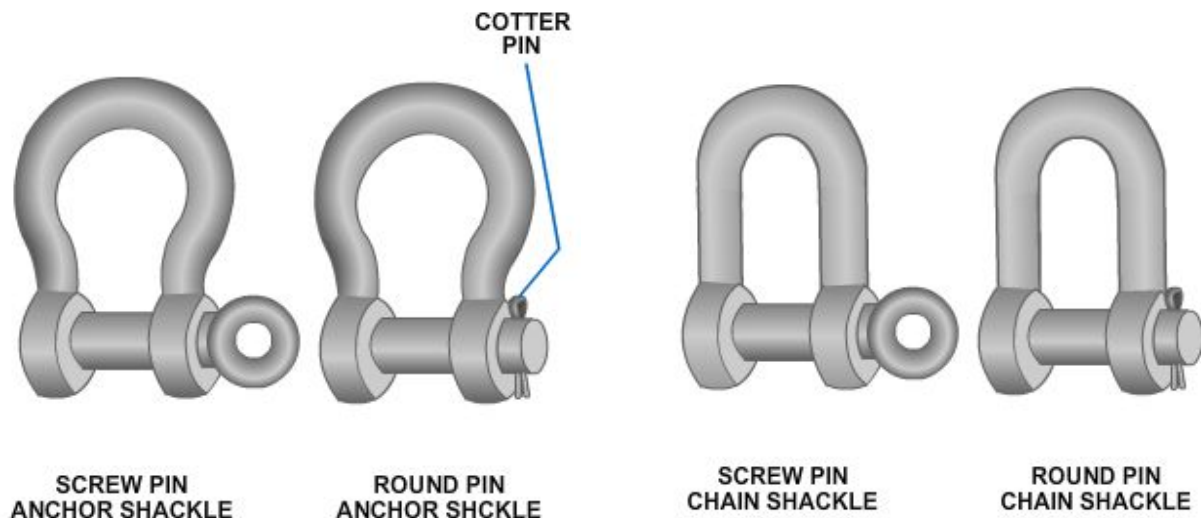


Figure 12-42 — Anchor shackles.

Figure 12-43 — Chain shackles.

Use shackles in the same configuration as they were manufactured. NEVER replace the shackle pin with a bolt. When the original pin is lost or does not fit properly, do not use the shackle. All pins must be straight, and cotter pins must be used or all screw pins must be seated.

Never pull a shackle from the side because this causes it to bend, which reduces the capacity tremendously. Always attach a screw pin shackle with the screw pin on the dead end of the rope. If you place it on the running end, the movement of the rope may loosen the pin.

Shackles are moused whenever there is a chance of the shackle pin working loose and coming out because of vibration. To mouse a shackle, simply take several turns with seizing wire through the eye of the pin and around the bow of the shackle. *Figure 12-41* shows what a properly moused shackle looks like.

3.2.10.7 Eyebolts

Eyebolts are often attached to a heavy load by a manufacturer in order to aid in hoisting the load. One type of eyebolt called a ringbolt is equipped with an additional movable lifting ring. Eyebolts and ringbolts can be either shoulderless or shoulder type.

The shoulder type is recommended for use in hoisting applications because it can be used with angular lifting pulls, whereas the shoulderless type is designed only for lifting a load vertically. Angular loading reduces the SWL of eyebolts and ringbolts. Always apply loads to the plane of the eye to reduce bending. This procedure is particularly important for using bridle slings.

3.2.10.8 Lifting Lugs

Lifting lugs are typically attached to the object being lifted by a manufacturer. They are designed and located to balance a load and support it safely. Use lifting lugs for straight, vertical lifts only.

3.2.10.9 Turnbuckle

Turnbuckles are used to adjust the length of rigging connections and are available in a variety of sizes. Three common types of turnbuckles are the eye, jaw, and hook ends. They can be used in any combination. The SWL for turnbuckles is based on the diameter of the threaded rods. The SWL can be found in the manufacturer's catalog. The SWL of turnbuckles with hook ends is less than the same size turnbuckle with other types of ends.

3.2.10.10 Beam Clamps

Beam clamps connect hoisting devices to beams so that the beams can be lifted and positioned properly.

3.2.10.11 Plate Clamps

Plate clamps attach to structural steel plates to allow for easier rigging attachment and handling of the plate. There are two basic types of plate clamps: the serrated jaw type and the screw type.

Serrated clamps are designed to grip a single plate for hoisting and are available with a locking device. Screw clamps are considered the safest and rely on the clamping action of a screw against the plate to secure them. Serrated clamps are for vertical lifting, whereas screw clamps can be used from a horizontal position through 180 degrees. Plate clamps are designed to lift only one plate at a time.

3.2.10.12 Spreader and Equalizer Beams

Spreader beams are used to support long loads during lifting operations. They eliminate the hazard of load tipping, sliding, or bending. They reduce low sling angles and the tendency of the slings to crush the load.

Equalizer beams are used to balance the load on sling legs and to maintain equal loads on dual hoist lines when making tandem lifts

Test your Knowledge (Select the Correct Response)

3. What term is used to describe a wire rope that has strands or wires shaped to conform to the curvature of the finished rope?
 - A. Non-preformed wire
 - B. Preformed wire
 - C. Non-conform wire
 - D. Conform wire

4. Which components are part of the construction of a wire rope?
 - A. Wires
 - B. Strands
 - C. Core
 - D. All of the above

Summary

In this chapter, you were introduced to the function of the power trains of construction equipment. You learned how the power made by the engine is transmitted to the tracks, and the different parts of the track assemblies and frames were discussed. You also learned about the winch and how it works, and the different types of wire rope and how to maintain them so the equipment operators can do their jobs well. The knowledge gained here will help you acquire mastery of these systems, which will enable you to be a better construction mechanic.

Review Questions (Select the Correct Response)

1. What component is the center gear in a planetary gearset?
 - A. Planet pinion
 - B. Ring gear
 - C. Sun gear
 - D. Planetary carrier
2. How many different ways can the planetary gearset be engaged to either increase or decrease torque?
 - A. Eight
 - B. Six
 - C. Four
 - D. Two
3. In a planetary gearset, direct drive is achieved by locking what component?
 - A. Planetary carrier
 - B. Planet pinion
 - C. Ring gear
 - D. Any two members together
4. In a planetary steering system, the sun gear, machined to the steering brake hub, performs the same function as what gear in a conventional planetary system?
 - A. Pinion
 - B. Planetary
 - C. Carrier
 - D. Ring
5. In a planetary steering system, braking prevents what action?
 - A. Sprocket drive shaft and steering brake hub from rotating
 - B. Steering brake hub and sun gear from rotating
 - C. Power being transmitting from the sun gear to the sprocket drive shaft
 - D. Pinion gears from walking around the sun gear on the steering brake hub
6. Adjusting the steering brakes of a planetary steering system is required because it provides what advantage?
 - A. Even braking
 - B. Prevention of slippage
 - C. Even lining wear
 - D. Elimination of brake pull

7. In a hydrostatic drive train, mechanical power from the engine is converted to hydraulic power by what components?
- A. Piston and cylinder
 - B. Swash plate and displacement control valve
 - C. Pump and motor
 - D. Charge pump and cylinder block
8. **(True or False)** A hydrostatic drive is designed to accomplish the functions of both a clutch and a transmission.
- A. True
 - B. False
9. What component of a hydrostatic drive train can have its angle varied so the volume and pressure of oil pumped by the pistons can be changed or the direction of the oil reversed?
- A. Displacement control valve
 - B. Low charge pressure control valve
 - C. Shuttle valve
 - D. Swash plate
10. In a hydrostatic drive train, what pump-motor combination will provide variable speed and constant torque?
- A. Fixed displacement pump and fixed displacement motor
 - B. Variable displacement pump and fixed displacement motor
 - C. Fixed displacement pump and variable displacement motor
 - D. Variable displacement pump and variable displacement motor
11. In a hydrostatic drive train, what pump-motor combination is the most flexible but is also the most difficult to control?
- A. Fixed displacement pump and fixed displacement motor
 - B. Variable displacement pump and fixed displacement motor
 - C. Fixed displacement pump and variable displacement motor
 - D. Variable displacement pump and variable displacement motor
12. Which factor has no bearing on the control of the operations of a hydrostatic drive?
- A. Rate of oil flow
 - B. Direction of oil flow
 - C. Pressure of the oil
 - D. Quality of the oil

13. What valve, located in the motor manifold, monitors the pressure of the forward flow of oil and protects the system from exceeding the rated psi?
- A. Inlet check
 - B. High-pressure relief
 - C. Shuttle
 - D. Low charge pressure control
14. What are the two major components of the undercarriage on crawler-mounted equipment?
- A. Track assembly and front idler
 - B. Track frame and drive sprocket
 - C. Front idler and drive sprocket
 - D. Track frame and track assembly
15. The length of a track will gradually increase during normal use as a result of wear on the _____.
- A. track assembly and track frame
 - B. track links
 - C. sprocket and idler
 - D. pins and bushings
16. What track frame component maintains alignment of the track assembly as it passes over the track frame?
- A. Track roller
 - B. Guiding guard
 - C. Front idler
 - D. Carrier roller
17. The operation of the recoil springs depends upon the amount of tension on what component?
- A. Idler
 - B. Sprocket
 - C. Track
 - D. Track frame
18. What track guiding guards reduce the wear on the roller flanges and track links?
- A. Front
 - B. Rear
 - C. Center
 - D. Bottom

19. When the track on a crawler tractor is too loose, it may _____.
A. cause the idler to wear rapidly
B. come off when the tractor is turned
C. damage track rollers
D. increase pin and bushing wear
20. When removing a track, you can easily identify the master pin because it _____.
A. is larger than the other pins
B. has a locking device or a hole drilled in its end
C. has a capital "M" cast into the end
D. has three stripes engraved on it
21. The typical front-mounted winch is classified as what type of winch?
A. Sliding-clutch worm gear
B. Sliding-collar worm gear
C. Jaw-clutch worm gear
D. Sliding-jaw worm gear
22. What component protects a winch from being overloaded?
A. Clutch key
B. Worm-gear key
C. Shear pin
D. Handle pin
23. What brake prevents the drum from overrunning the cable when the cable is being unreeled?
A. Worm
B. Shifter-bracket
C. Winch support
D. Shift lever
24. Failure of the winch to operate is usually the result of what component being broken or damaged?
A. Drive shaft
B. Shear pin
C. Universal joint
D. PTO gear
25. Which strand construction has alternating large and small wires that provide a combination of great flexibility with a strong resistance to abrasion?
A. Ordinary
B. Seale
C. Warrington
D. Filler

26. Each square inch of improved plow steel can withstand a strain that is within what range of pressure, in pounds?
- A. Between 100,000 and 140,000
 - B. Between 240,000 and 260,000
 - C. Between 300,000 and 340,000
 - D. Between 440,000 and 440,000
27. What type of wire rope damage starts with the formation of a loop?
- A. Crush spots
 - B. Wear spots
 - C. Kinks
 - D. Broken wires
28. In wire rope rigging, the diameter of sheave should never be less than how many times the diameter of the wire rope?
- A. 10
 - B. 20
 - C. 30
 - D. 40
29. Of the three grades of Type II, Protective A lubricant, which grade would be used in temperatures of between 80°F and 110°F?
- A. Grade A
 - B. Grade B
 - C. Grade C
30. What term is used to describe the technique of attaching a socket to a wire rope by pouring hot zinc around it?
- A. Seizing
 - B. Speltering
 - C. Wedging
 - D. Swaging
31. Which formula is used to obtain the number of wire clips required for a wire rope?
- A. 6 x wire rope diameter
 - B. 3 x wire rope diameter
 - C. 6 x wire rope diameter + 1
 - D. 3 x wire rope diameter + 1

32. Wire rope eyes with thimbles and wire rope clips can hold approximately what percentage of strength of a wire rope?
- A. 60
 - B. 70
 - C. 80
 - D. 90
33. Which piece of equipment is used to connect hoisting devices to beams?
- A. Beam clamp
 - B. Plate clamp
 - C. Eyebolt
 - D. Turnbuckle

Trade Terms Introduced in this Chapter

Pivot	A point upon and about which something rotates or oscillates.
Infinite	Unlimited or unmeasurable in extent of space, or duration of time.
Reciprocate	To make a return, as for something given.
Preformed wire rope	Wire rope that has strands or wires that are shaped to conform to the curvature of the finished rope before laying up.
Non-preformed wire rope	Wire rope that has strands or wires that are not shaped before fabrication.
Wires	Rope consisting of steel, iron, or other metal in various sizes. The number of wires to a strand varies, depending on the intended purpose of the rope. Wire rope is designated by the number of strands per rope and the number of wires per strand.
Strands	Several pieces of wire are wrapped around a core that constitutes wire rope. These pieces of wire wrapped around the core are called the strands.
Core	Wire rope consists of strands of wire wrapped around a core. The wire rope core supports the strands laid around it. There are three types of core.
Tensile strength	The strength necessary to withstand a certain maximum load applied to the rope. It includes a reserve of strength measured in a so-called factor of safety.
Abrasion	A scraped spot or area; the result of rubbing or abrading.
Corrosion	The act, process, or condition of being eaten away slowly.
Fleet angle	The distance from the drum to the sheave is the controlling factor in the fleet angle.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Medium/Heavy Duty Truck Engines, Fuel & Computerized Management Systems 2nd Edition, Sean Bennett, The Thomson/Delmar Learning Company, INC., 2004. (ISBN-13:978-1-4018-1499-1)

Heavy Duty Truck Systems 4th Edition, Sean Bennet, Delmar Cengage Learning, 2006. (ISBN-13:978-1-4018-7064-5)

Modern Automotive Technology 7th Edition, James Duffy, The Goodheart-Wilcox Company, Inc., 2009. (ISBN: 978-1-59070-956-6)

Manual Drive Trains and Axles, Chris Johanson, James Duffy, The Goodheart-Wilcox Company, Inc., 2004. (ISBN: 1-59070-320-0)

Power trains, Fundamentals of Service, Deere and Company, John Deere Inc., 2005. (ISBN: 0-86691-325-4)

COMFIRSTNCDINST 11200.2, Naval Construction Force (NCF) Equipment Management Instruction. 06 JAN 2006.

NAVFAC P-307, Management of Weight Handling Equipment. June 2006.

Wire and Fiber Rope and Rigging, Naval Ship's Technical Manual, NAVSEA S9086-UU-STM-000/CH-613, Chapter 613, Commander, Naval Sea System Command, Washington, DC, 1978.

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