

CARCO

MODEL H50VS SERVICE MANUAL

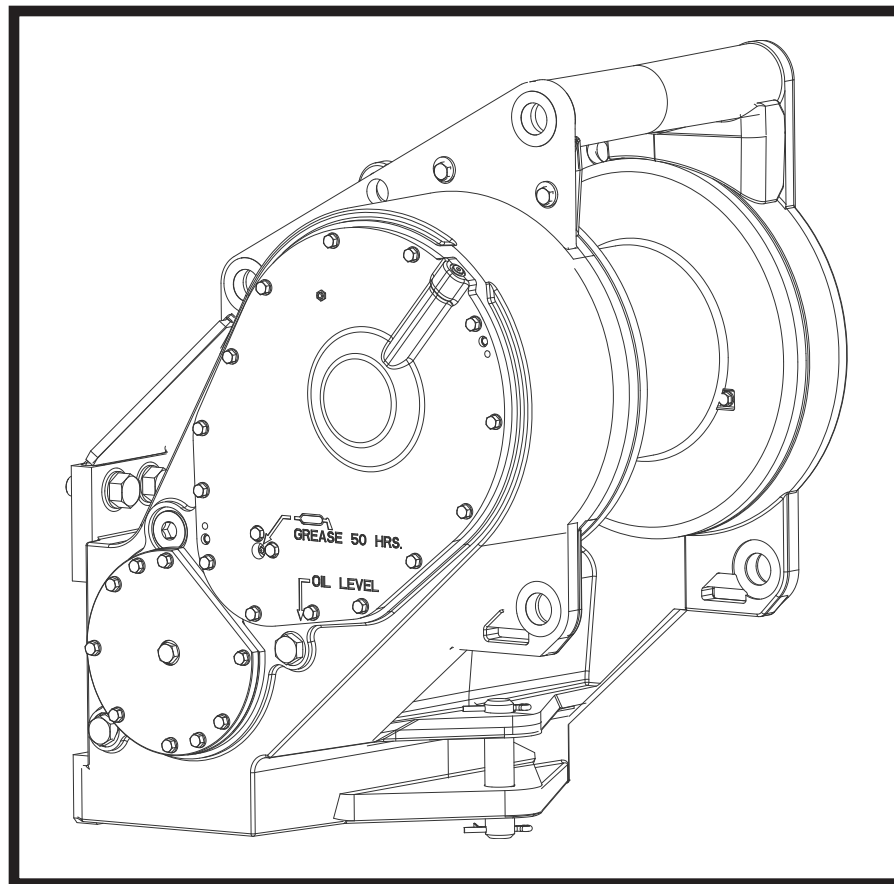


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FOREWORD

Please read and understand this entire manual BEFORE operating or servicing your PACCAR winch. Retain this manual for future reference.

Some illustrations in this manual may show details or attachments which may be different from your winch. Also, some components may have been removed for clarity.

Whenever a question arises regarding your PACCAR winch, or this manual, please contact your nearest Caterpillar dealer, or the PACCAR SERVICE DEPARTMENT at:

Phone: 918-251-8511, Monday – Friday, 0800 hrs – 1630 hrs CST

FAX: 918-259-1575

Email: winch.service@paccar.com

Provide the complete winch MODEL NUMBER and SERIAL NUMBER when making inquiries.

Safety and informational callouts used in this manual include:



This emblem is used to warn against potential or unsafe practices which COULD result in personal injury, and product or property damage if proper procedures are not followed.



This emblem is used to warn against unsafe practices which COULD result in severe personal injury or death if proper procedures are not followed.

GENERAL SAFETY RECOMMENDATIONS

Safety for operators and ground personnel is of prime concern. Always take the necessary precautions to ensure safety to others as well as yourself. To ensure safety, the tractor and winch must be operated with care and concern by the operator for the equipment, and a thorough knowledge of the machine's performance capabilities. The following recommendations are offered as a general safety guide. Local rules and regulations will also apply.

WARNING

FAILURE TO OBEY THE FOLLOWING SAFETY RECOMMENDATIONS MAY RESULT IN PROPERTY DAMAGE, INJURY OR DEATH.

1. Read all warning tag information and become familiar with all controls BEFORE operating the winch.
2. Never attempt to clean, oil or perform any maintenance on the winch with the engine running, unless instructed to do so in this manual.
3. Before starting the tractor, be certain all controls move freely and are placed in the "Brake-On" (neutral) position.
4. Never operate winch controls unless you are properly seated at the operators station on the tractor and are sure personnel are clear of the work area.
5. Never attempt to handle winch cable when the hook end is not free. Keep all parts of body and clothing clear of cable rollers, cable entry area of fairleads and winch drum.
6. Ground personnel should stay in view of tractor operator and clear of winch drum. Do not allow ground personnel near winch line under tension. A safe distance of at least 1 ½ times the working length of the cable should be maintained. Never allow anyone to stand under a suspended load.
7. Avoid sudden "shock" loads or attempting to "jerk" a load free. This type of operation may cause heavy loads in excess of rated capacity, which may result in failure of cable and/or winch.
8. Use only GENUINE PACCAR parts. Do not use parts from other winch manufacturers on your PACCAR winch. Do not use PACCAR parts on winches from other manufacturers.
9. Use correct size ferrule for cable and pocket in winch drum. Never use knots to secure or attach cable. The cable anchor or ferrule pocket in the cable drum is designed to provide a self release in the event a back-

sliding load must be released from the tractor in an emergency situation. The cable anchor or ferrule alone will NOT support rated line pull. Therefore, a minimum of five (5) complete wraps of cable must be maintained on the winch drum.

NOTE: *We suggest painting the last five wraps of cable bright red to serve as a visual warning.*

Recommended Operating Practices

1. Leather gloves should be used when handling winch cable.
2. Operate the winch to match line speeds to job conditions.
3. Assure that personnel who are responsible for hand signals are clearly visible and that the signals to be used are thoroughly understood by everyone.
4. Inspect winch cable, rigging, winch and tractor at the beginning of each work shift. Defects should be corrected immediately.
5. Position tractor for straightest line of pull to reduce wear on winch cable and ensure even spooling.
6. When winding winch cable on the winch drum, never attempt to maintain tension by allowing winch cable to slip through hands. Always use "hand-over-hand" technique, being careful to keep hands and clothing away from winch drum and fairlead rollers.
7. Be sure of tractor ground stability before winching in a load.
8. Store unused chokers, slings and rigging in a neat and orderly fashion to prevent damage to equipment or injury to personnel.
9. Do not operate the winch under loads that exceed the maximum rated bare drum line pull. If excessive loads are encountered, use a multi-part line and sheave blocks. Any attempt to exceed the capacity of one winch (such as coupling 2 or more tractors together) is extremely hazardous.

10. The factory approved adaptations for PACCAR winches are designed and intended for use on specific models of crawler tractors. Changing winches between tractors is not possible in some cases because of differences in tractor models. Some changes cannot be approved by PACCAR because of safety limitations. Call the tractor dealer or the PACCAR factory prior to attempting winch modifications or before mounting on a different tractor.
11. PACCAR H50 winches are powered by the tractor hydraulic system. Turn off engine and discharge all retained hydraulic system pressure before removing any hydraulic lines or fittings. Personal injury may result from sudden release of oil pressure.
12. On machines having hydraulically, mechanically and/or cable controlled equipment, be certain the equipment is either lowered to the ground or blocked securely before servicing, adjusting and/or repairing the winch. Always apply tractor parking brakes and lower equipment before dismounting the tractor.
13. The winches described in this manual are neither designed nor intended for use or application to equipment used in the lifting or moving of persons.
14. Install guarding to prevent personnel from getting any part of their body or clothing caught at a point where the cable is wrapped onto the drum or drawn through fairlead guide rollers.
15. Keep equipment in good operating condition. Perform scheduled servicing and adjustments listed in the "Preventive Maintenance" section of this manual. Use recommended lubricants.
16. An equipment warm-up procedure is recommended for all start-ups and essential at ambient temperatures below +40°F (5°C). Refer to "Warm-Up Procedure" listed in the "Preventive Maintenance" section of this manual.
17. Don't weld on any part of the winch without PACCAR Winch Division approval.

WINCH DESCRIPTION

The PACCAR H50 winch is a hydraulically driven winch utilizing a dedicated piston pump for power input. The winch hydraulic oil pump is usually installed on the tractor transmission pump and the tractor implement pump is installed on the winch pump in a piggy-back arrangement when the winch is installed on the tractor. The winch includes both planetary and standard spur gears as well as a spring applied, hydraulically released multi-disc static brake for holding the load secure while in the neutral "Brake-On" position. The winch case is designed to bolt to the rear face of the tractor.

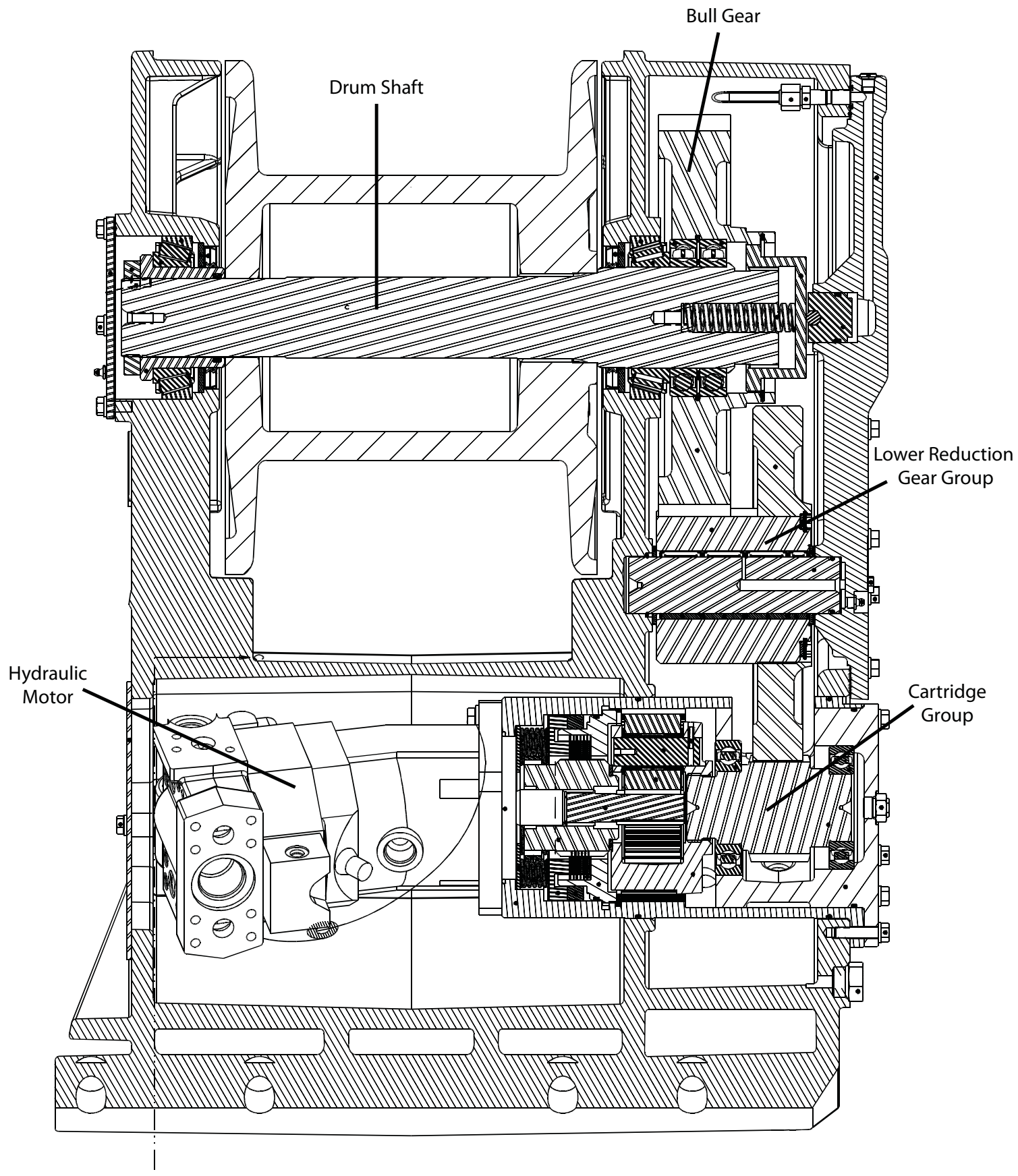
When operated in either the Reel-In or Reel-Out direction, the variable displacement, piston hydraulic motor drives the gear train. Winch line speed and load control are proportionate to the amount of oil being delivered to the winch motor by the hydrostatic control system. The winch brake must be released by pilot pressure through the winch control valve in both Reel-In and Reel-Out directions.

The Freespool mechanism is a spring-engaged, hydraulically released, splined gear-type connection. As the control lever is moved into the Freespool position, the oil is ported through the winch logic valve assembly to release the brake, and into the freespool cylinder to force

the freespool piston against the coil spring and disengage the splined connection. This allows the winch cable to be pulled off the cable drum by hand.

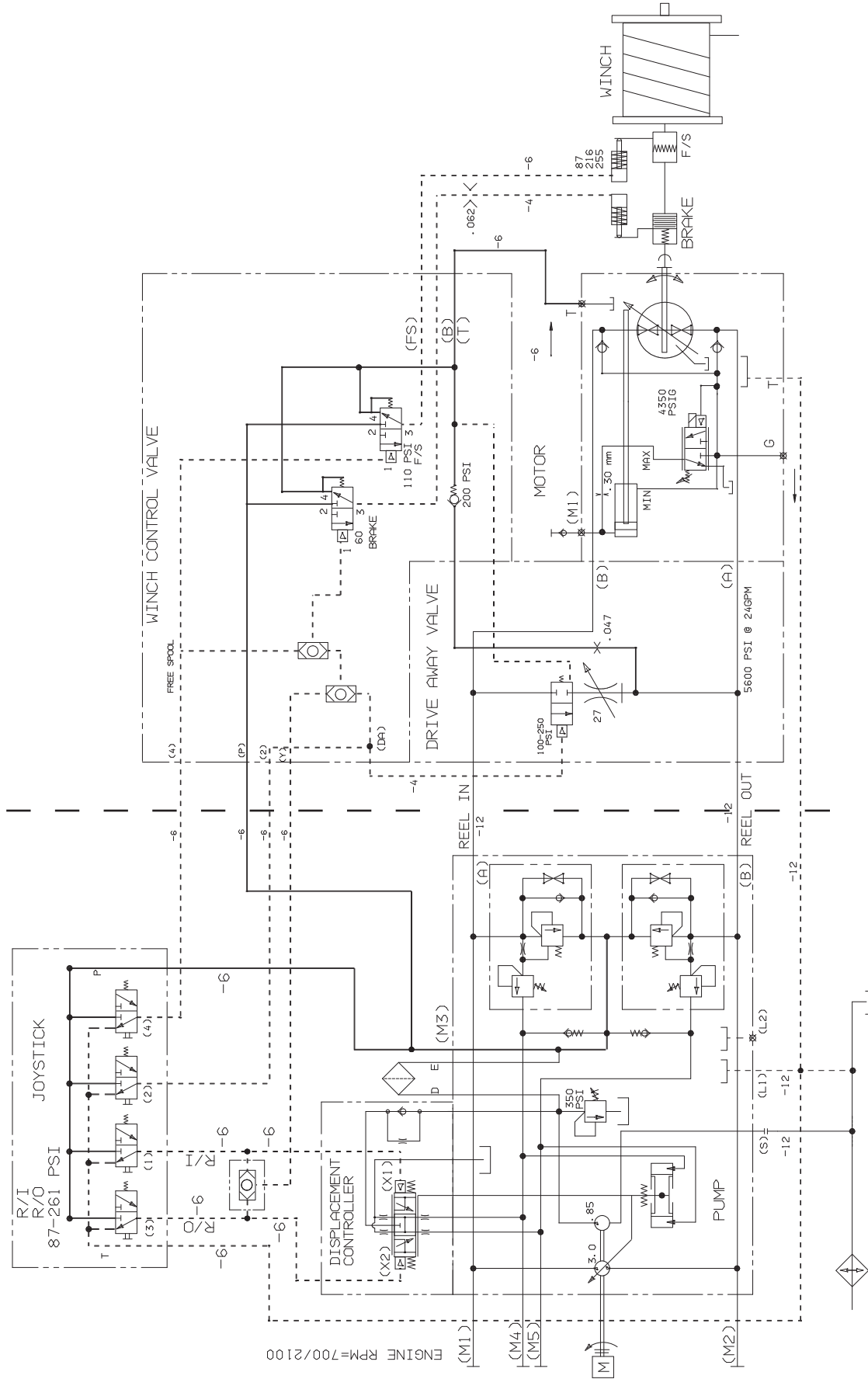
"Drive-Away" mode is controlled by the winch motor. This function allows the operator to drive the tractor away from the load while back driving the motor with the winch gear train. When the control lever is moved into the Drive-Away position, the winch motor / cartridge valve assembly limits the flow of the hydraulic oil through the motor and the winch brake to allow for smooth, controlled pay-out of the winch cable. The maximum back driven speed of the winch motor is limited by a flow control valve set to achieve approximately 2.6 mph (4.2 km/h) tractor ground speed at the winch bare drum condition.

An optional three roller or four roller fairlead assembly is available for applications in which slight side directional pulls are routinely encountered. Use of a fairlead assembly will help to maximize winch case and wire rope life by eliminating wear due to contact in these applications.



TRACTOR

WINCH

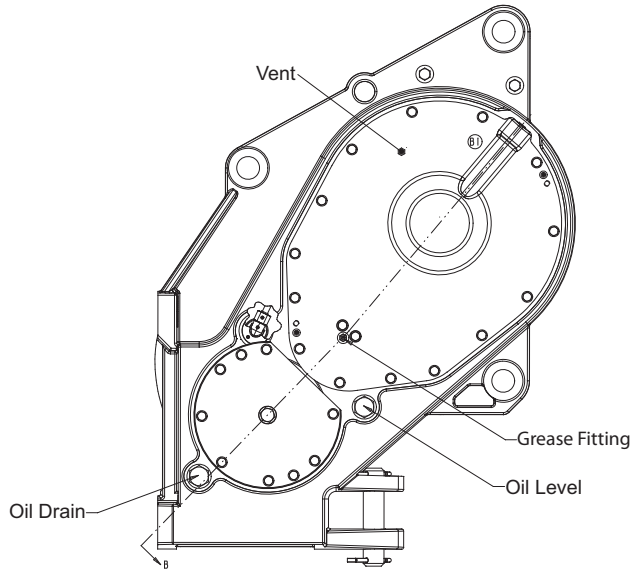


Typical H50 Hydraulic Winch Schematic
(Hydraulic Winch Control Valve)

PREVENTATIVE MAINTENANCE

A regular program of preventive maintenance for your PAC-CAR winch will minimize the need for emergency servicing and promote long product life and trouble-free service.

The service intervals suggested in this manual will optimize component service life.



GEAR CASE OIL LEVEL

The winch assembly should be visually inspected for leaks at the beginning of each workday. If oil leaks are found, the gear case oil level must be checked. If no leaks are detected, the oil level may be checked once every 250 hours or monthly. The oil level plug is located below the left hand gear cover toward the rear of the winch. Position the tractor on a flat, level surface and remove the plug. The oil should be at the bottom of the level plug hole.

Add oil as required through the oil filler plug located above the lower bearing carrier.

Refer to the recommended oil chart for the proper oil for your application.

GREASE

There is one grease fitting on each side of the winch case to which grease should be added every 50 hours. Use a NLGI #2 EP (extreme pressure) grease with a Lithium complex base that meets or exceeds NLGI GC or GC/LB requirements. Pump grease into the upper right drum bearing grease fitting until grease comes out the small vent hole in the cover. Pump about ½ ounce into the grease fitting for the second reduction shaft on the left side of the winch. This will be about 10 strokes with a standard volume (1.0 to 1.5 grams/stroke) lever operated grease gun.

TRACTOR HYDRAULIC RESERVOIR LEVEL

The tractor hydraulic oil reservoir level should be checked at the sight glass daily, or in accordance with the tractor

manufacturer's recommendations. Use the type of hydraulic oil recommended by the tractor manufacturer.

Change the tractor hydraulic oil in accordance with the tractor manufacturer's recommendations.

GEAR CASE OIL CHANGE

Change the winch gear case oil after the first 100-250 hours of operation, then every 1000 hours or six (6) months, whichever occurs first.

⚠ WARNING ⚠

Hot oil can cause injury. Make certain the oil has cooled to a safe temperature (less than 110°F or 43°C) before servicing the winch.

NOTE: Grease displaced from the second reduction gear shaft bearings during greasing may drain from the winch with the oil.

Remove the drain plug located at the bottom left side of the winch housing. Drain the oil into a suitable container and recycle or dispose of the used oil in an environmentally responsible manner. Contact your local government agency for information concerning proper disposal. Install the plug securely after the oil has been drained. To reduce oil drain time, remove the filler/vent plug.

Refill the winch to the proper level with the recommended oil.

Oil capacity: approximately 5 qt. (4.7 L)

⚠ CAUTION ⚠

DO NOT operate the winch while the oil is drained. Serious damage to internal components may result.

HYDRAULIC OIL FILTER

If a hydraulic oil filter was installed when the winch was installed on the tractor, replace it on the same interval as the other tractor hydraulic oil filters.

VENT PLUG

The vent plug is installed in the left hand gear cover. Whenever the oil is changed, remove the vent plug, clean in safety solvent and reinstall.

NOTE: Do not replace the vent plug with a solid plug. The normal expansion of the gear oil during operation will cause a build-up of pressure in the gear case, which may lead to seal leakage.

WINCH CABLE (WIRE ROPE)

Inspect the entire length of wire rope and the hook in accordance with the rigging manufacturer's recommendations.

MOUNTING FASTENERS

Check / tighten all winch mounting fasteners to recommended torque after the first 100-250 hours of operation, then every 1000 operating hours or six (6) months, whichever occurs first.

WARM-UP PROCEDURE

The tractor engine should be run in accordance with the tractor manufacturer's recommendations to warm up the hydraulic system, with the winch control in the neutral, brake-on position. For cold weather operation, use cold weather oil as recommended in the tractor hydraulic system instructions.

The winch should then be operated under a no-load condition, in reel-in and reel-out direction several times to circulate warm hydraulic oil and gear lubricant through the brake and gear train.

WARNING

A warm-up procedure is recommended at each start-up and is mandatory at ambient temperatures below +40° F (4° C). Failure to warm-up the tractor/winch oil may result in temporary brake slippage and loss of load control due to high back pressures attempting to release the static brake. This condition may result in property damage, injury or death.

INSPECTION

Every 10,000 hours or four (4) years, whichever occurs first, the winch should be disassembled for a thorough inspection of all wear items. Refer to the disassembly and assembly sections of this manual for additional information.

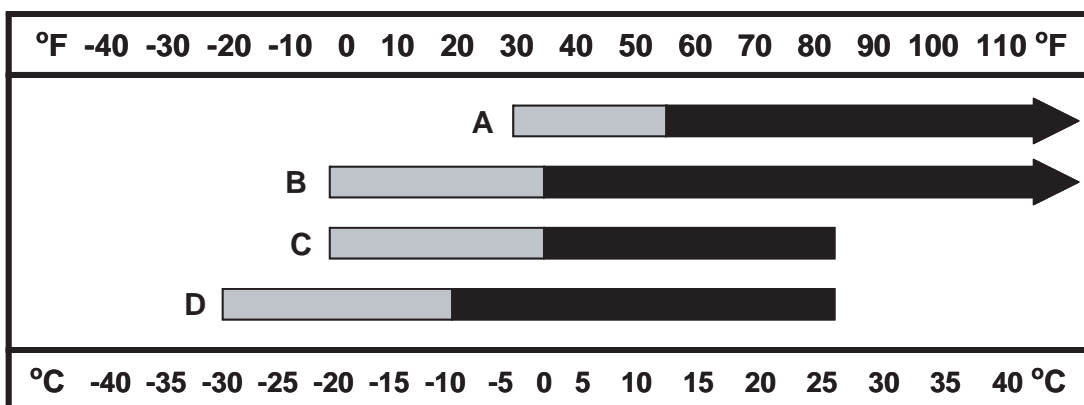
RECOMMENDED OIL

We have published the following specification to help determine which lubricant is best suited to your application.

The oil must possess high temperature oxidation stability, rust and corrosion protection, good dispersant and detergent characteristics, anti-wear additives and remain compatible with nitrile base seals.

Your lubricant supplier should assure you that his product meets this specification. If there is any doubt as to the suitability of a lubricant, contact the PACCAR Winch Service Department, providing a copy of the product specifications.

Prevailing Ambient Temperature



! WARNING !



Cold start-up in this ambient temperature range requires extended equipment warm-up to prevent erratic clutch and brake operation which may result in property damage, injury or death.

- A - HTF Type C3/C4 SAE 30, CAT TO4 SAE30
- B - CAT TO4 SAE 10W30
- C - HTF Type C4/C4 SAE 10, CAT TO4 SAE 10W
- D - CAT TO4 SAE 5W20 spc.

Basic Oil Requirements

15,000 SUS maximum allowed viscosity at cold start-up; requires extended equipment warm-up.

3,000 SUS maximum allowed viscosity at cold start-up; requires normal equipment warm-up.

60 SUS minimum allowed viscosity at maximum winch operating temperature assuming ambient plus 80 °F (27 °C).

Oil must possess high temperature oxidation stability, rust and corrosion protection, good dispersant and detergent characteristics, anti-wear additives and remain compatible with nitrile base seals.

WINCH REMOVAL AND INSTALLATION

⚠ WARNING ⚠

Before servicing, make sure any trapped oil pressure in the tractor hydraulic system has been relieved. Personal injury can result from a sudden release of oil pressure. Relieve trapped pressure by cycling the blade and winch control levers several times after the tractor engine has been turned off. Relieve any trapped oil pressure in the hydraulic reservoir by opening the cap. Ensure that the tractor's master electrical circuit switch is off.

Cleanliness around all hydraulic components is of utmost importance. Before starting any repair procedures, be sure to thoroughly clean the parts to be removed, as well as adjacent areas on the tractor, to avoid entry of dirt into the winch and winch control system. Do not leave any ports or access openings exposed to the weather. Seal or cap the openings to prevent entry of dust, moisture, or other foreign material. Cap or plug all exposed hydraulic ports and fittings.

During disassembly, care should be taken not to damage seals and O-rings that are to be reused. Replace any such parts that are damaged or otherwise defective. Certain O-rings and seals specified in the replacement instructions must not be reused. In general, seals and O-rings that work under full operating hydraulic pressures, or that require extensive disassembly to access, should be replaced with new parts at the time of reassembly.

WINCH REMOVAL

Place the tractor and winch in a level position and drain the oil from the winch into a suitable container. Install the drain plug securely after the oil has drained completely.

Support the winch with a suitable hoist or platform, and remove the fasteners securing the winch to the tractor mounting brackets, then carefully move the winch away from the tractor so the hydraulic hoses can be disconnected.

Remove the hydraulic hoses from the winch motor and valve. Remove the motor case drain hose from the motor.

⚠ WARNING ⚠

The H50VS winch weighs approximately 1,400 lbs. (635 kg) without oil, cable and tractor mounting brackets. Make certain the lifting equipment has adequate capacity. Attempting to lift the winch with undersized equipment can result in serious injury or damage to the winch or other property.

⚠ WARNING ⚠

Hot oil can cause injury. Make certain the oil has cooled to a safe temperature (less than 110°F or 43°C) before servicing the winch.

WINCH INSTALLATION

Remove dirt, paint and rust from the mounting surfaces of the winch and tractor mounting brackets.

Attach the winch control hoses to the motor as defined in the parts and installation guide.

Align the winch mounting holes with the holes in the mounting brackets, and install and tighten all fasteners to the recommended torque. Refer to the winch parts and installation guide.

Fill the winch to the proper level with the recommended oil.

NOTE: *It may be necessary to fill the motor case with hydraulic oil before start-up to protect against motor failure due to starting dry.*

Start the tractor engine and operate the engine at low RPM. Alternately place the winch control in the REEL-IN and REEL-OUT positions until the winch motor hydraulic circuit is filled with oil and the winch operates smoothly. Check the tractor hydraulic oil reservoir level and fill as required.

WIRE ROPE INSTALLATION

All winches are rated at bare drum line pull. As the cable drum fills, the line pull will decrease (loss of leverage) while the line speed increases (larger circumference). Therefore, it is recommended to install the minimum length of cable possible for use in your application to allow the winch to operate on the lower layers (smaller diameter) and deliver the maximum amount of line pull.

Using larger diameter cable will not always increase strength as the larger cable may be more vulnerable to bending fatigue failure than the smaller rope. Consult your wire rope supplier for their recommendations for the style of wire rope and other rigging best suited to your application.

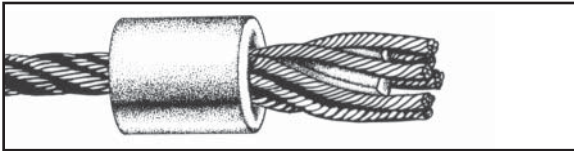
⚠ WARNING ⚠

Winch cable anchors (ferrule and ferrule pocket) are NOT designed to hold full rated load. Winch loads applied directly to the cable anchor may allow the cable to pull free, resulting in the sudden loss of load control and property damage, injury or death. A minimum of five (5) wraps of cable must remain on the drum barrel to achieve full rated load. Do NOT use knots to secure or attach the winch cable. It is suggested that the last five (5) wraps of cable be painted bright red to serve as a visual warning.

INSTALLATION OF SPIRAL FERRULES

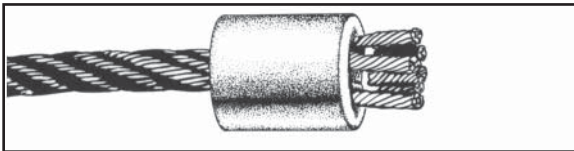
Re-usable, field-installable spiral ferrules are available from the factory or from your wire rope supplier. These ferrules are for use with six (6) strand, IWRC (Independent Wire Rope Core) type wire rope.

Step One



Insert the cable through the small opening and out the large opening of the ferrule. Spread the strands and insert the wedge halves between the strands and over the core. Lay separate strands in the individual grooves in the wedges.

Step Two



Tap the wedges and cable into the ferrule, leaving approximately 3/8 in. (10 mm) extending beyond the ferrule end. The first load applied will seat the cable and wedges securely within the ferrule.

TROUBLESHOOTING

The following troubleshooting section is provided as a general guide. You may also need to contact the Original Equipment Manufacturer (OEM) for additional information.

⚠ WARNING ⚠

If a hoist exhibits any sign of:

- Erratic operation such as poor load control, load creeping down or chattering.
- Unusual noise.
- Gear oil leaks
- A sudden rise in wear particles from oil analysis

The hoist **MUST** be removed from service until the problem has been corrected. If a hoist has been subjected to a sudden heavy load (shock-load) or overload, the hoist must be removed from service, disassembled and all internal components thoroughly inspected for damage. Continued operation with a defect may result in loss of load control, property damage, injury or death.

TROUBLE	PROBABLE CAUSE	REMEDY
<p>A</p> <p>The winch will not smoothly reel-out or reel-in the load.</p>	<ol style="list-style-type: none"> 1. The multi-disc static brake may not be releasing as a result of a defective brake cylinder seal. <p>NOTE: If the brake cylinder seal is defective, you may notice oil leaking from the winch vent plug as hydraulic oil fills the gear cavity.</p> <ol style="list-style-type: none"> 2. The multi-disc static brake will not release as a result of damaged brake discs. 	<p>A. Check the brake cylinder seal as follows:</p> <p>Disconnect the small hose from the brake release port. Connect a hand pump with an accurate gauge and shut-off valve to the -4 fitting in the brake release port.</p> <p>Apply 1000 PSI (70.3 kg/cm²) to the brake. Close the shut-off valve and let stand for five (5) minutes.</p> <p>If there is any loss of pressure during the five (5) minutes, the brake housing assembly should be disassembled for inspection of the brake cylinder and piston sealing surfaces and replacement of the seals. Refer to "Brake Housing Assembly Service" for more information.</p> <p>Disassemble the brake housing assembly to inspect the brake discs. Replace the brake discs as required.</p>

TROUBLE	PROBABLE CAUSE	REMEDY
<p style="text-align: center;">B</p> <p>Oil leaking from the vent plug.</p>	<ol style="list-style-type: none"> 1. Same as A2. 2. Motor seal may be defective as a result of high hydraulic motor case drain pressure or contaminated oil. 3. The freespool piston seals may be leaking. 	<ol style="list-style-type: none"> A. Same as A2. A. Hydraulic motor case drain pressure must not exceed 40 PSI (2.8 kg/cm²). Inspect the hydraulic system for a restriction. B. Oil analysis may indicate contamination, which could result in a worn motor shaft seal. Thoroughly flush the entire hydraulic system and install new filters and oil. Install a new motor seal. A. Disconnect the drum clutch release hose from the drum clutch housing. Connect a hand pump with an accurate gauge and shut-off valve to the -6 adapter. B. Apply 250 psi (1,724 kPa) to the drum clutch. Close the shut-off valve and let stand for 5 minutes. C. If there is a loss of pressure during the 5 minutes, the freespool piston must be removed and disassembled for inspection of the seals and sealing surfaces. Refer to "Freespool Group Service" section of this manual for additional information.
<p style="text-align: center;">C</p> <p>The brake will not hold a load with the control lever in neutral.</p>	<ol style="list-style-type: none"> 1. Excessive system pressure acting on the brake release port. 2. Friction brake will not hold due to worn or damaged brake discs. 3. Defective 3-way valve in valve manifold on motor. 	<ol style="list-style-type: none"> A. Install gauge at brake release port to check pressure when joystick is in neutral. A. Same as A3A. A. Same as C1A.

TROUBLE	PROBABLE CAUSE	REMEDY
<p>D</p> <p>The winch will not pull the rated load.</p>	<p>1. The hydraulic system relief valve may be set too low. The relief valve may need replacement or repair.</p> <p>2. Be certain the hydraulic system temperature is not more than 200° F (93° C). Excessive hydraulic oil temperatures increase motor and pump internal leakage.</p> <p>3. Winch line pull rating is based on 1st layer of wire rope.</p> <p>4. Hydraulic motor locked in high speed, small displacement position.</p> <p>5. Winch brake not releasing.</p>	<p>A. Check system relief pressure as follows:</p> <p>Install an accurate gauge into the tractor pump pressure port per the tractor manual.</p> <p>Apply a stall pull load on the winch while monitoring the pressure.</p> <p>Compare the gauge reading to the winch specifications. Adjust the relief valve as required, if necessary.</p> <p>NOTE: Refer to the tractor service manual for more information regarding the system relief valve.</p> <p>A. Check system relief valve, per D1A.</p> <p>B. Same as E2A.</p> <p>A. Refer to winch performance data for more information.</p> <p>A. Send motor to qualified motor service center.</p> <p>A. See section "A"</p>
<p>E</p> <p>The winch runs hot.</p>	<p>1. Be certain the hydraulic system temperature is not more than 200° F (93° C). Excessive hydraulic oil temperatures may be caused by:</p>	<p>A. Same as D2A.</p> <p>B. Plugged heat exchanger (where used).</p> <p>Thoroughly clean exterior and flush interior of heat exchanger.</p> <p>C. Too low or too high oil level in hydraulic reservoir.</p> <p>Fill/drain reservoir to proper level.</p> <p>D. Same as D1A.</p> <p>E. Tractor hydraulic pump not operating efficiently.</p> <p>Tractor low on horsepower or RPM. Tune / adjust tractor engine for optimum performance. See tractor service manual for more information.</p>

TROUBLE	PROBABLE CAUSE	REMEDY
TROUBLE "E" CONTINUED FROM PREVIOUS PAGE	2. Excessively worn or damaged internal winch components.	<p>Check suction line for damage.</p> <p>Pump worn or damaged. Inspect /replace pump as needed. See tractor service manual for more information.</p> <p>A. Disassemble winch for inspection & replacement of worn or defective components.</p>
<p>F</p> <p>Winch "chatters" while pulling rated load.</p>	<p>1. Same as D1.</p> <p>2. Hydraulic oil flow to motor may be too low.</p> <p>3. Controls being operated too quickly or not smoothly.</p> <p>4. Winch brake not fully releasing</p>	<p>A. Same as D1A.</p> <p>A. Same as E1B, C, and E.</p> <p>A. Conduct operator training as required.</p> <p>A. See section "A"</p>
<p>G</p> <p>The wire rope does not spool smoothly on the cable drum.</p>	<p>1. Incorrect wire rope lay being used. There is a distinct advantage in applying wire rope of the proper direction of lay. When the load is slacked off, the remaining coils on the drum will stay closer together and maintain an even layer. If rope of incorrect lay is used, the coils will spread apart each time the load is removed. Then, when reeling in is resumed, the wire rope has a tendency to criss-cross and overlap on the drum. The possible result is flattened and crushed wire rope, ultimately resulting in diminished rope life.</p> <p>2. The winch may have been overloaded, causing permanent set in the wire rope.</p>	<p>A. Consult your wire rope distributor for recommendation of the wire rope best suited for your specific application.</p> <p>A. Replace the wire rope and conduct operator training as required.</p>

SERVICE PRECAUTIONS

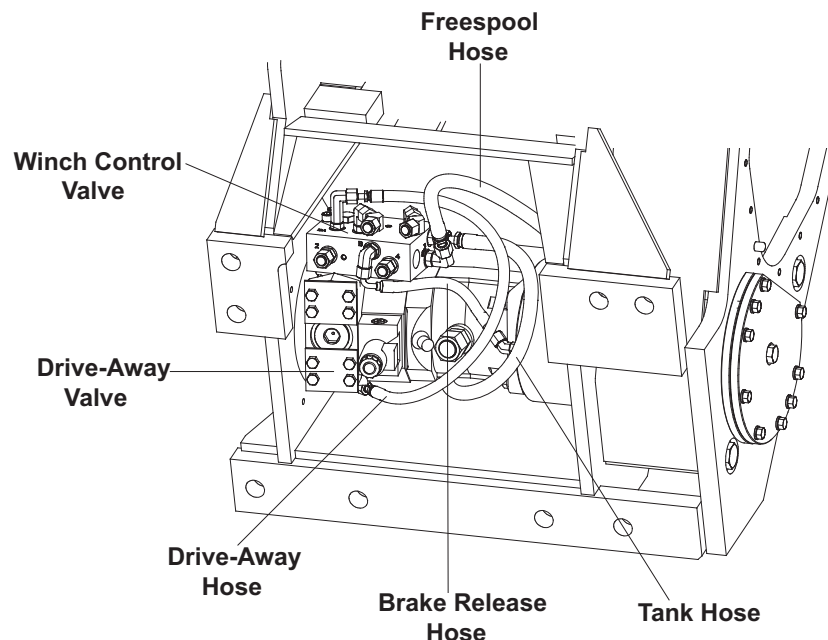
After troubleshooting the winch and its hydraulic system as covered in the “Trouble Shooting” section of this manual, and the problem is determined to be in the winch, use the following procedure to disassemble the winch as needed.

- Before any part is removed from the winch, all service instructions should be read and understood.
- Work in a clean, dust-free area, as cleanliness is of utmost importance when servicing hydraulic equipment.
- Use only genuine factory replacement parts, which may be obtained through your heavy equipment dealer. Never re-use expendable items, such as O-rings.
- Inspect all machined surfaces for excessive wear or damage before reassembly operations start.
- Lubricate all O-rings and oil seals with clean gear oil prior to installation.
- Use a sealing compound on the outside surfaces of oil seals. If using a thread sealant on fasteners or fittings, avoid getting excess sealant inside parts or passages that conduct oil.
- Thoroughly clean all parts in a good grade of safety solvent. Wear protective clothing as required.

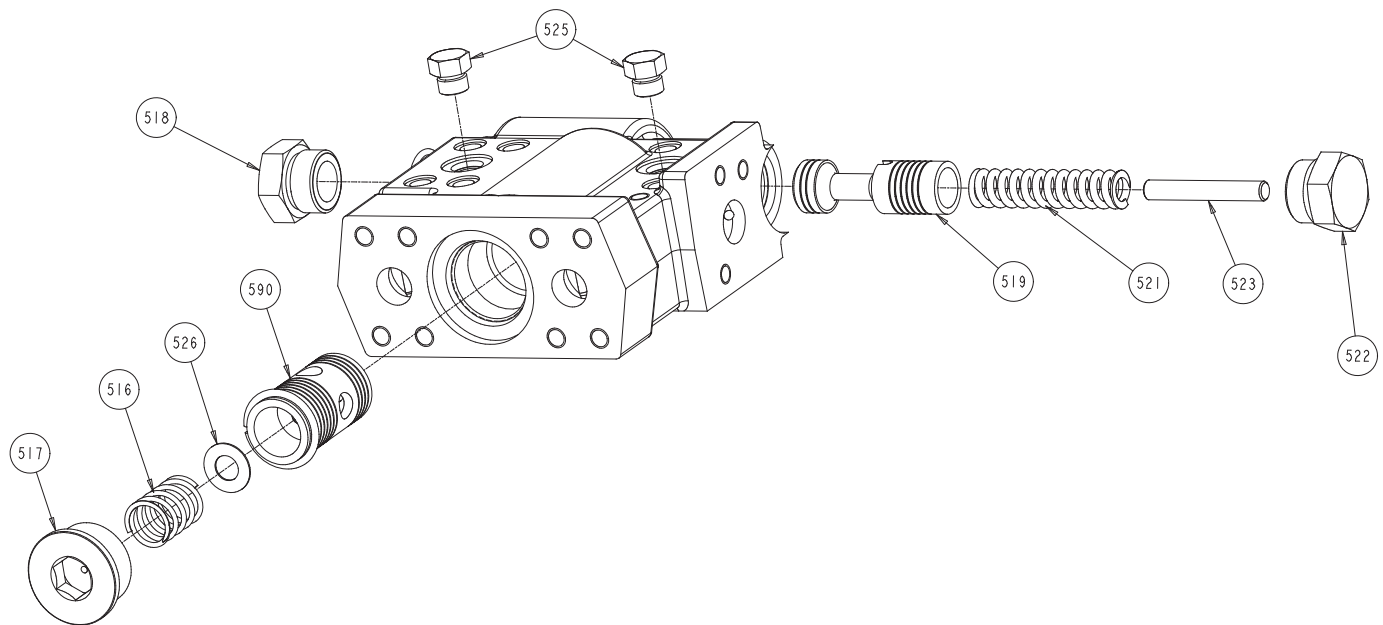
Hydraulic Motor Group (Hydraulically Operated Winch Control Valve)

The typical hydraulic schematic is on pg.7

Contamination of the hydraulic system will shorten the life of the components and system. Work in a clean dust-free area when servicing any part of the hydraulic system.



Drive-away Valve Drawing



The hydraulic group consists of the hydraulic motor, winch control valve, drive-away valve, and hoses and fittings. Ports to measure loop pressure on the drive-away valve can be accessed at the lower right winch case cover, but the winch must be removed from the tractor for most service on the hydraulic group.

NOTE: Some hose connections and fittings may be difficult to tighten after the hydraulic motor and valves are installed. Before installing the motor and valves, check fittings for tightness and install and tighten any hoses that will be difficult to access after installation.

DISASSEMBLY

1. Remove the winch from the tractor to access the hydraulic motor group and hoses. (See Winch Removal on pg. 12)
2. Tag the hoses from the tractor to the winch for reassembly and then disconnect hoses from the winch control valve, drive-away valve, and hydraulic motor.
3. Remove the components needed for servicing.
4. Remove the bolts securing the hydraulic motor to the winch and remove the hydraulic motor by pulling it straight out from the cartridge assembly. If the motor coupling comes out with the motor, refer to the assembly section for installation instructions before installing.

ASSEMBLY

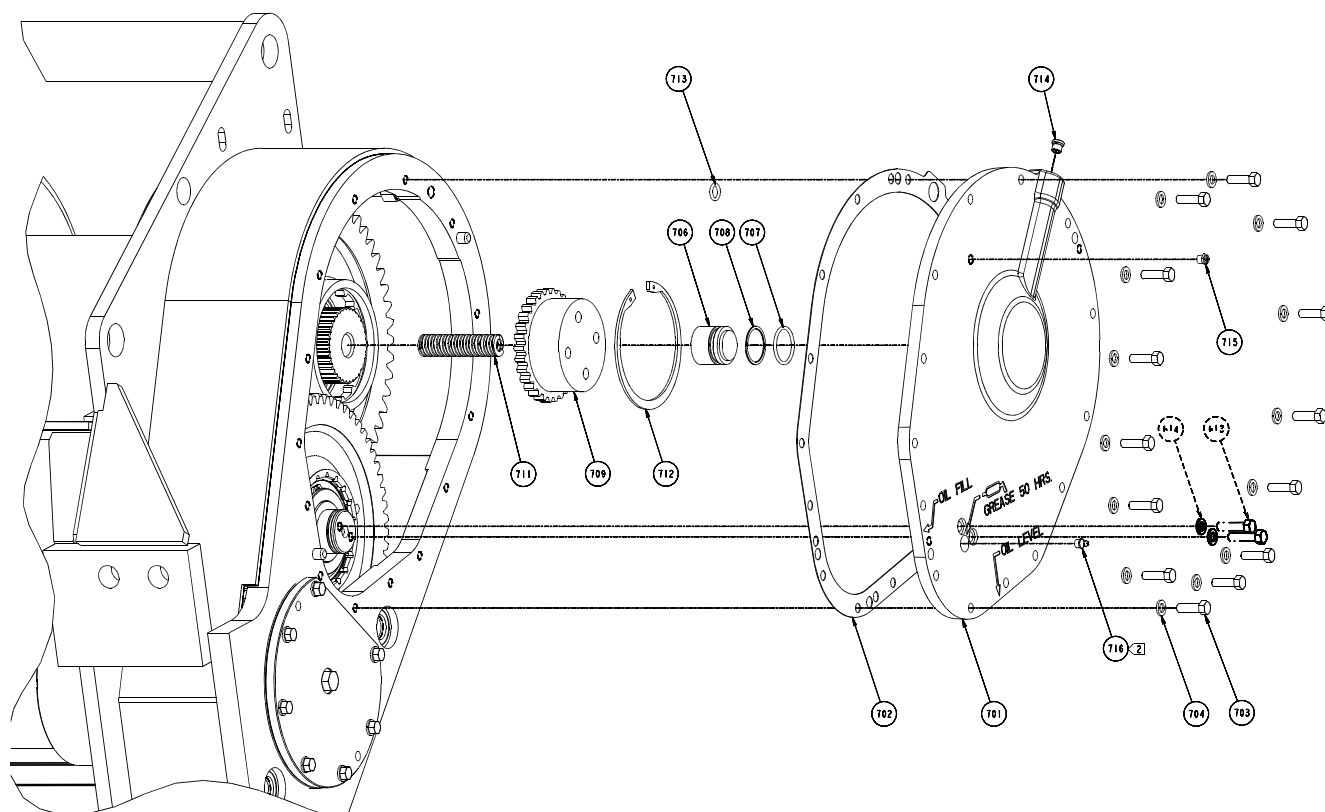
1. Ensure the motor and valve subassemblies are assembled and ready for installation in the winch. Ensure the bulkhead fitting for winch freespool is installed.

NOTE: Some hose connections will be difficult to tighten after the hydraulic motor is installed. Before installing the motor, check for tightness hoses and fittings that may be difficult to get to with the motor in place.

2. Install a new o-ring on the motor pilot and install the motor in the winch engaging the motor splines with the splines of the motor coupling.
3. Install new o-rings between the drive-away valve and the motor and install the valve on the motor.
4. Install new o-rings between the winch control valve and the motor and install the valve on the motor.
5. Reconnect the brake release, freespool, drive-away, and tank hose.
6. The remaining hose connections between the tractor and the winch will be connected when the winch is installed on the tractor.

WINCH DISASSEMBLY

FREESPOOL GROUP DISASSEMBLY



⚠ WARNING ⚠

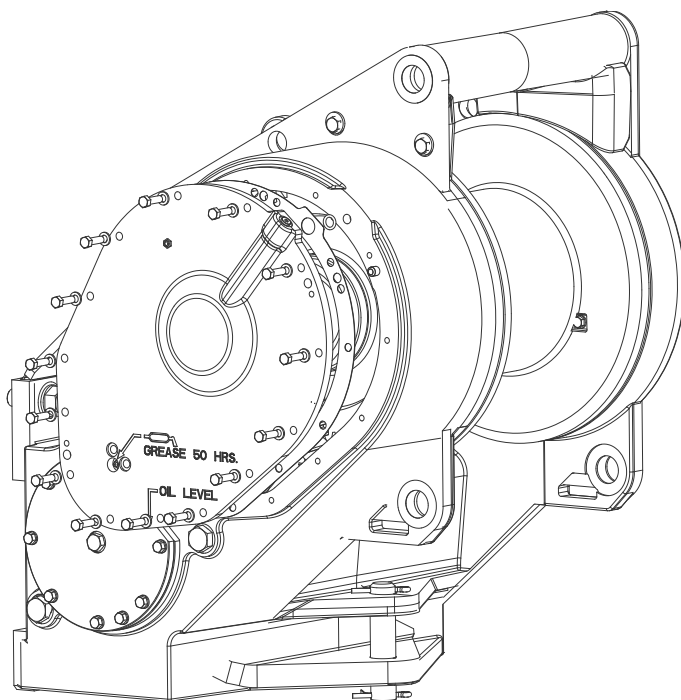
Ensure the winch oil is cool and hydraulic pressure is released before any work is done on the winch. High pressure oil and hot oil can cause death or personal injury.

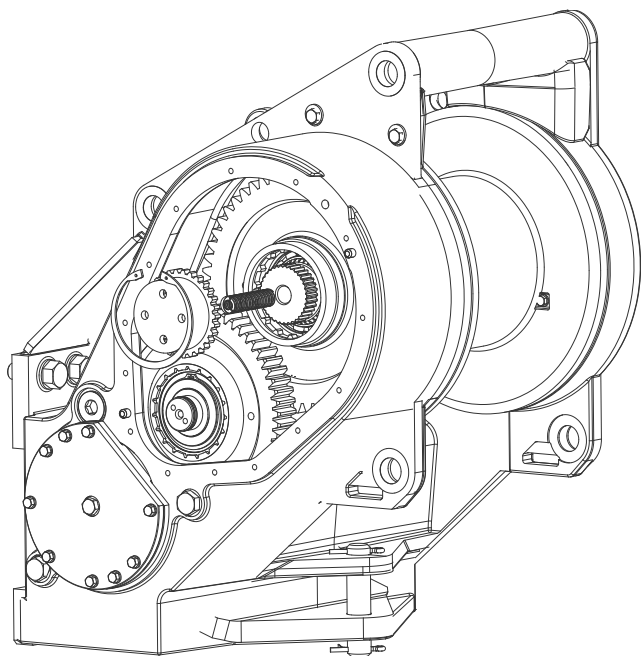
1. Bleed the pressure from the tractor hydraulics by cycling the joystick with power on but with the tractor engine off.
2. Drain the oil from the winch.

⚠ CAUTION ⚠

The gear cover weighs 47 lbs. Ensure the gear cover is supported before removing all of the fasteners holding it to the winch case. Failure to support the gear cover may result in personal injury or property damage.

3. Loosen but leave threaded in position bolt (703) at 12 o'clock position on gear cover (701). Remove remaining bolts (703) from gear cover (701). Remove bolts (613) from gear shaft. Support the gear cover (701), remove loosened bolt (703), and remove gear cover (701).
4. Remove o-ring (713) and gasket (702) from the gear cover. Replace o-ring and gasket.





⚠ WARNING ⚠

Exercise caution when compressing the freespool clutch spring, removing the retaining ring, and releasing the tension on the freespool clutch spring. Death or personal injury can result from parts propelled by spring force.

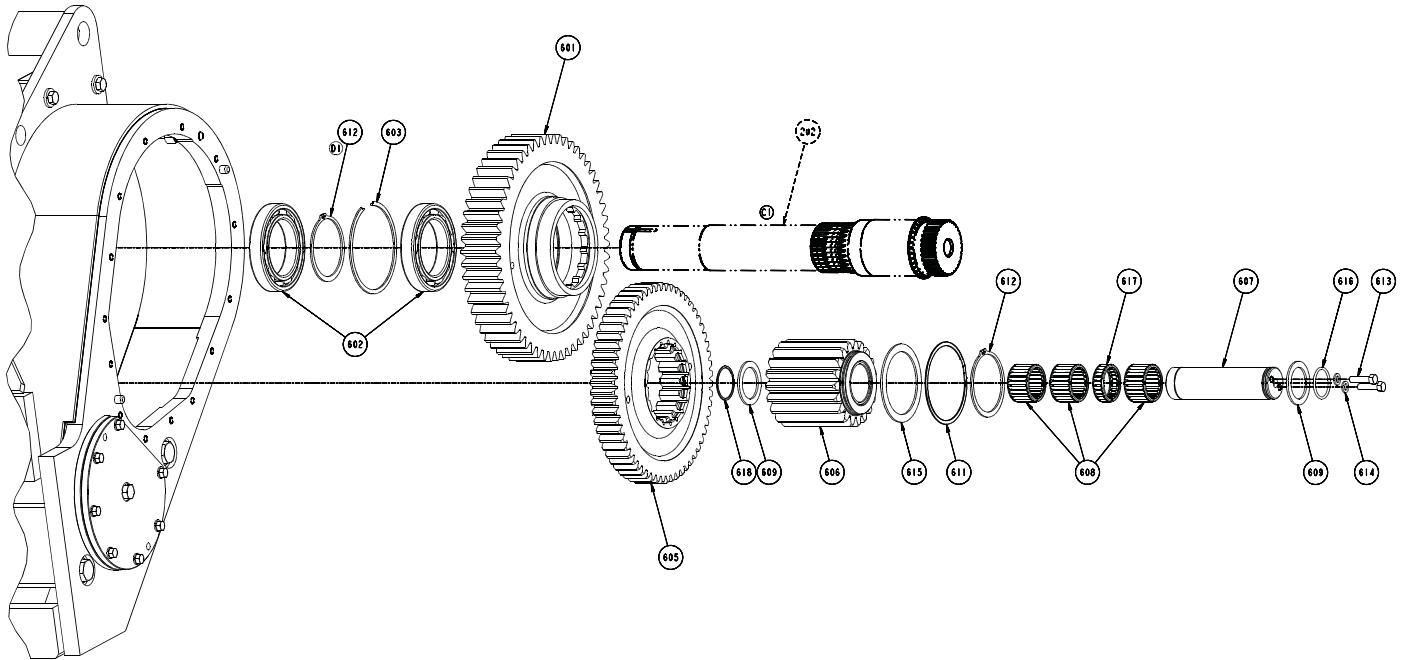
FREESPOOL GROUP ASSEMBLY

Wash all parts in solvent before assembly.

1. Place spring (711) in drum shaft (202). Slide freespool clutch (709) onto bull gear (601).
2. Place retaining ring (712) on freespool clutch (709). Install compression tool in position using the two ½"-13 tapped holes in the bull gear (601).
3. Compress spring (711) and install retaining ring (712) using retaining ring pliers.
4. Install o-ring (707) and back-up ring (708) on piston (706). Install piston (706) in gear cover (701).
5. Install new o-ring (713) in gear cover (701). Position gear cover (701) with a new gasket (702) on winch and secure with capscrews (703) and lockwashers (704). Torque capscrews to chart specification.
6. Install capscrews (613) and lockwashers (614) in gear cover to support the gear shaft (607).
7. Fill the winch with oil prior to operating.

5. Use compression tool and the two ½"-13 tapped holes in the bull gear (601) to compress spring (711) behind freespool clutch (709), and remove retaining ring (712) with retaining ring pliers. Carefully release tension on spring by backing off compression tool and remove freespool clutch (709) and spring (711) from drum shaft.
6. Remove piston (706), back-up ring (708), and o-ring (707) from gear cover (701). Replace o-ring and back-up ring.

LOWER REDUCTION GEAR DISASSEMBLY



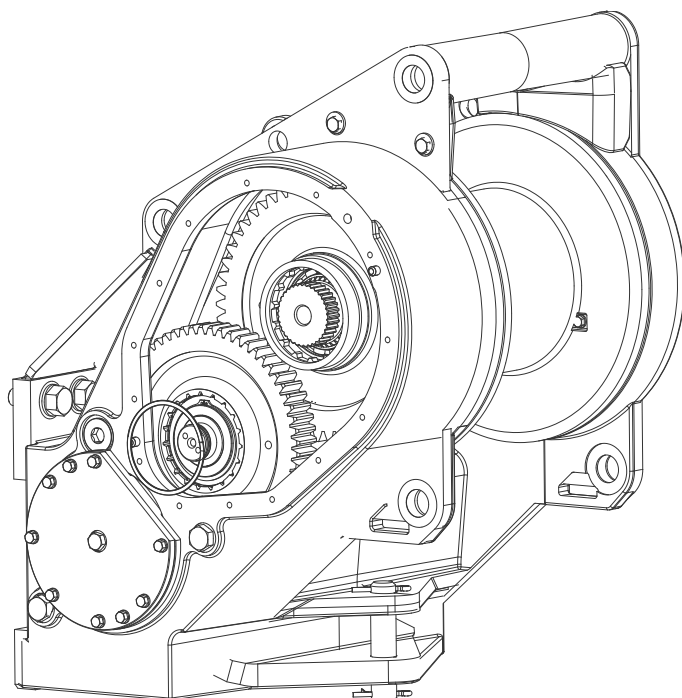
Remove the freespool group – refer to Freespool Group section in this manual.

The drum group must be disassembled before the bull gear can be removed, so disassembly of both groups is done together.

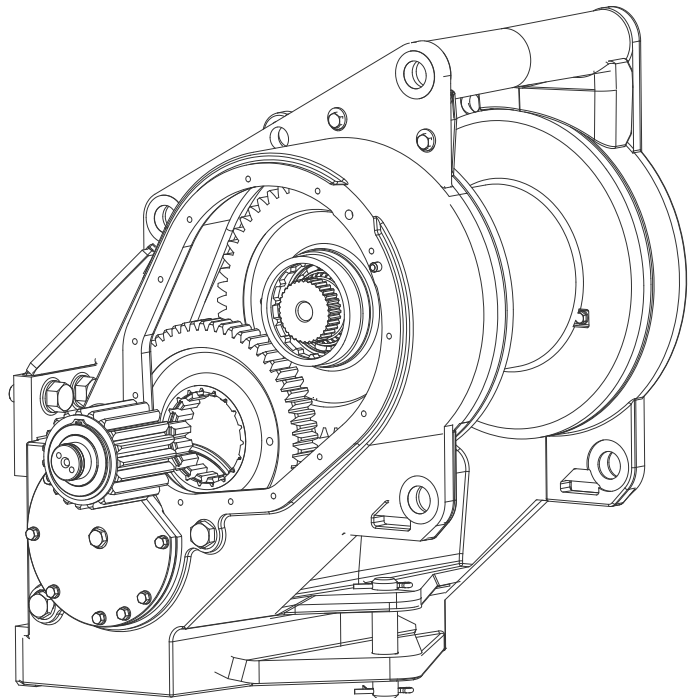
The lower reduction gears must be removed before the removal of the upper bull gear or before the removal of any components in the cartridge assembly.

CAUTION

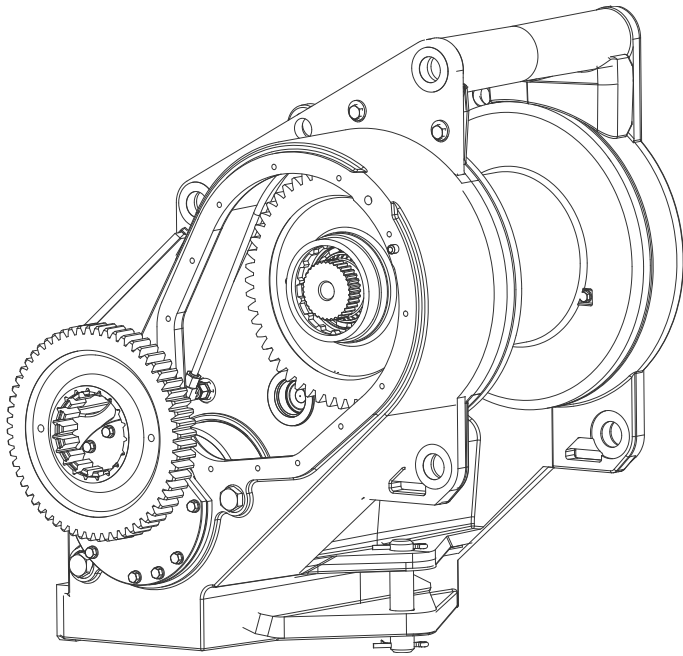
The 1st reduction gear (605) weighs 38 lbs, and 2nd reduction gear (606) weighs 22 lbs. Use necessary lifting equipment to support them in the winch case.



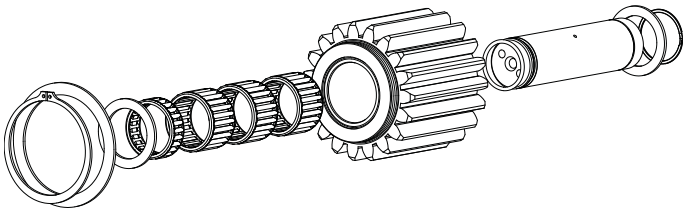
1. Remove the retaining ring (611) from the groove in the 1st reduction gear (605).



2. Insert a screwdriver between the splines of the 1st reduction gear (605) and the 2nd reduction gear (606). Slowly pry against the back of the washer (615) while supporting the gears. Roll the 1st reduction gear (605) forward and remove the 2nd reduction gear (606) and assembled parts from the winch case.



3. Remove the 1st reduction gear (605) from the winch case.



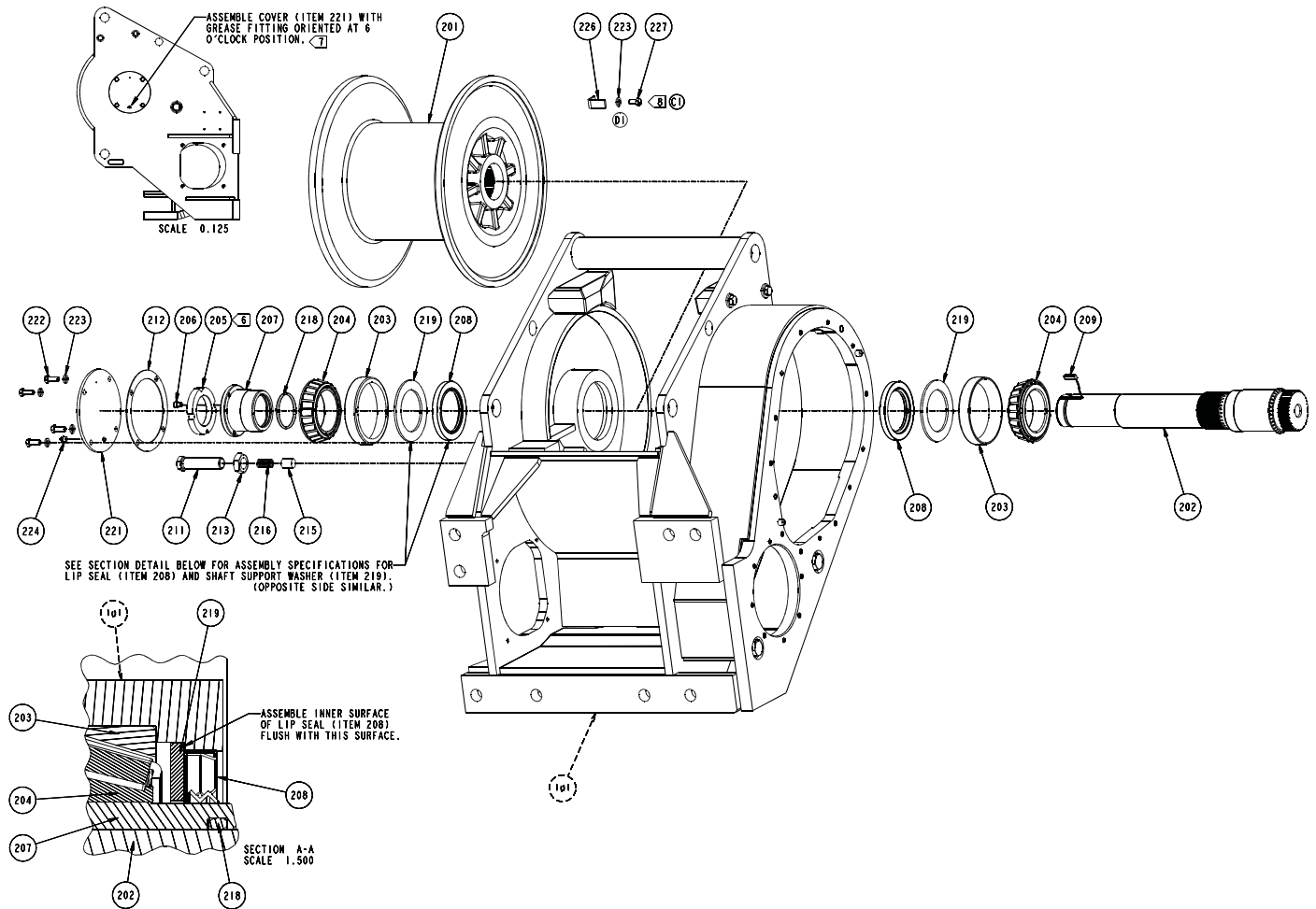
4. Place the 2nd reduction gear (606) and assembled components on a clean work bench. Remove the retaining ring (618) and thrust race (609) from the shaft (607). Slide the shaft out of the gear.
5. Remove o-ring (616) from shaft and replace. Remove bearings (608 and 617) from 2nd reduction gear (606). Remove thrust race (609), retaining ring (612), and washer (615).

LOWER REDUCTION GEAR

ASSEMBLY (Refer to drawing on p.21)

1. Pack all bearings with grease prior to installation. Use NLGI #2 EP (extreme pressure) grease with a Lithium complex base that meets or exceeds NLGI GC/LP requirements.
2. Install retaining ring (618) on shaft (607). Place thrust race (609) on the shaft. Slide bearings (608) and (607) into the gear (606). The bearings must be installed in the correct order (refer to drawing on p.21).
3. Place washer (618) on gear (606) and install retaining ring (612) in the groove in gear (606). Install new o-ring (616) on shaft.
4. Place 1st reduction gear (605) in the winch case. Roll the gear forward on the pinion and install the assembled 2nd reduction gear (606) and shaft (607).
5. Install retaining ring (611) in 1st reduction gear (605) and install thrust race (609).
6. To ensure the second reduction shaft is fully packed with grease, pump one ounce of grease (NLGI #2 EP with a Lithium complex base) into the bearings through the grease fitting after the gear cover is installed. This will be about 20 strokes with a standard volume (1.0 to 1.5 grams/stroke) lever operated grease gun.

DRUM AND BULLGEAR DISASSEMBLY

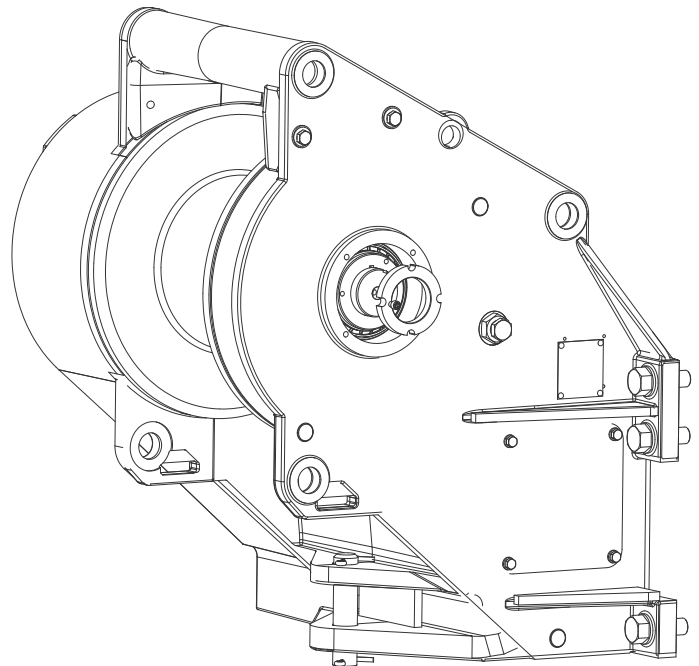


The lower reduction gears must be removed before the removal of the upper bull gear or before the removal of any components in the cartridge assembly.

⚠ WARNING ⚠

The winch drum weighs approximately 240 lbs (109 kg). Ensure rigging for lifting or supporting the drum is properly rated. Death or personal injury may result if the winch drum is not properly supported.

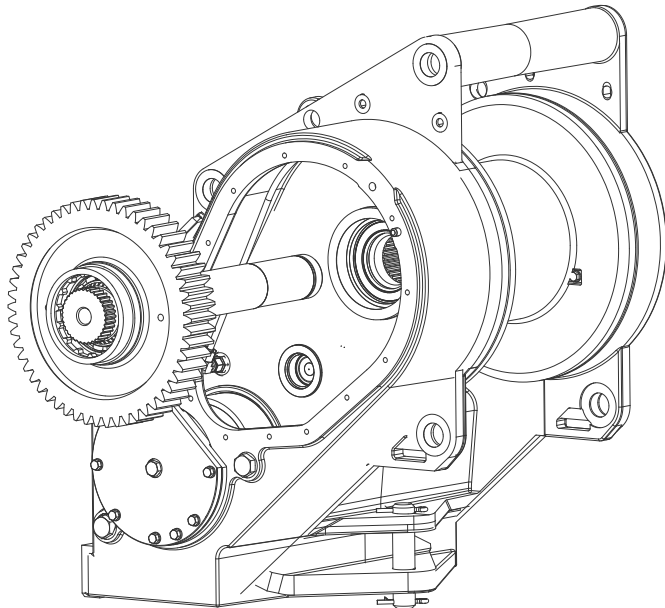
1. Support the winch drum (201) with an overhead hoist and lifting strap.
2. Remove bearing cover capscrews (222) and lockwashers (223), bearing cover (221), and gasket (212).



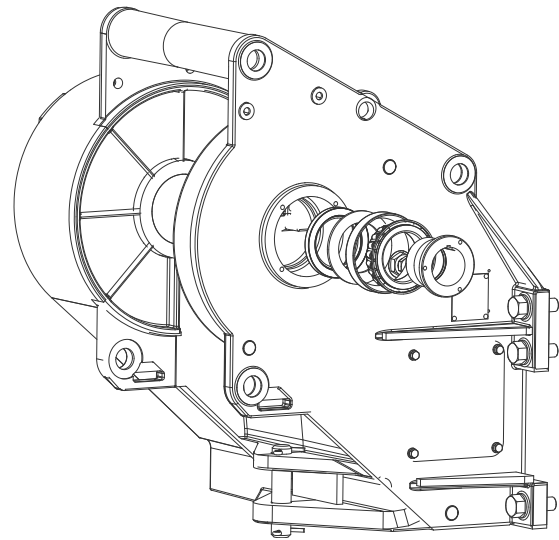
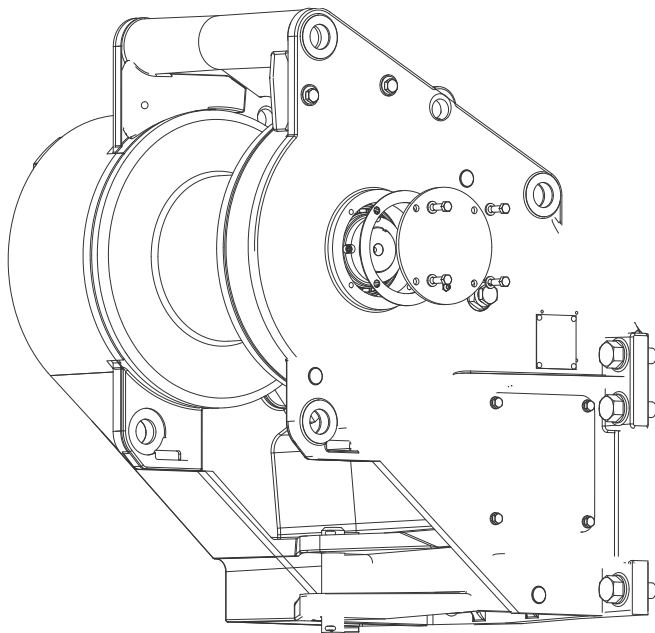
3. Remove socket head capscrew (206) which secures the locknut (205) in position. Use a spanner wrench to remove the locknut (205).

CAUTION

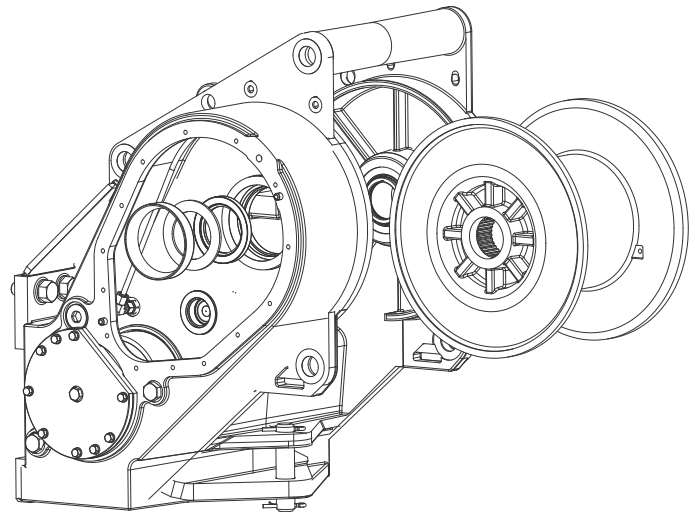
The bull gear (601) and shaft (202) weigh approximately 125 lbs (57 kg) as a unit. Use proper lifting equipment when removing them from the winch drum.



4. Install a lifting link in one of the 1/2-13 tapped hole in the bull gear and use rigging to support the drum shaft and bull gear which will be removed as a unit.
5. Remove the bearing sleeve (207) and bearing (204) from the drum shaft (202). Remove and discard o-ring (218) from bearing sleeve. Carefully pull bull gear (601) supported by rigging away from winch case to remove bull gear and winch shaft (202) from the winch case.



6. Inspect the bearing cups (203) for wear or damage and replace if necessary. To remove the bearing cups, use a torch to heat the inside surface at two places 180 degrees apart until orange in color. Allow to cool for 30 minutes, and the bearing cup will slide out of the bore.
7. Remove the bearing (204) from the bearing sleeve (207) using a hydraulic press and bearing puller assembly.
8. Slide bearing (204) from drum shaft (202). Remove bearing (602) from inside the bull gear (601). Remove retaining rings (603) and (612), and remove the remaining bearing (602). Remove the drum shaft (202) from the bull gear (601).



9. Loosen the top bolts which fasten the fairlead assembly to the winch, if equipped. Remove the bottom bolts which fasten the fairlead assembly to the winch. Pull the bottom of the fairlead assembly away from the winch to provide clearance for removing the drum from the winch case. Tighten the upper bolts to hold the fairlead assembly in position and then remove the drum.
10. Remove washers (219) and seals (208) from both sides of the winch drum.

DRUM AND BULLGEAR

ASSEMBLY (see drawings on pg. 21 & 23)

1. Install seals (208) into winch case driving them from the drum area of the case until flush with the winch case.
2. Apply grease to one side of each washer (219) and install in winch case with the greased side toward the seal. The grease will help hold the seal in place until the bearing cups (203) are installed.
3. Install bearing cups (203) on each side of the winch case.



The winch drum weighs approximately 240 lbs (109 kg). Ensure rigging for lifting or supporting the drum is properly rated.

4. Use a hoist and rigging equipment to lift the drum between the winch and fairlead assembly into the winch case and align the bores of the drum and winch case.
5. Loosen the top bolts on the fairlead assembly and swing the assembly down until the lower holes in the fairlead are aligned with the winch case. Install the lower bolts in the fairlead assembly and torque to specification in torque chart.
6. Pack bull gear bearings (602) and drum bearings (204) with NLGI #2 EP (extreme pressure) grease with a Lithium complex base that meets or exceeds NLGI GC or GC/LB requirements.
7. Use a hydraulic press to install the bearing (204) onto the bearing sleeve (207). Install a new o-ring (218) on the bearing sleeve (207).
8. Install bearing (602) into bull gear (601) and install retaining ring (603) in bull gear (601). Install retaining ring (612) and the second bearing (602) in the bull gear (601).
9. Install drum shaft (202) into bull gear (601). Slide bearing (204) onto the drum shaft (202).
10. Use a lifting link in one of the 1/2-13 tapped hole in the bull gear. Use rigging to support the drum shaft and bull gear and install in the winch drum.
11. Install the bearing sleeve (204) with bearing installed into the winch.
12. Install the bearing locknut (205) on the drum shaft. Torque to $35 \pm \text{lb}\cdot\text{ft}$ ($47 \pm 20 \text{ N}\cdot\text{m}$). Loosen the bearing locknut back to the next full indentation. Install the capscrew (206) to secure the locknut.
13. Install cover (221) with new gasket (225) and using bolts (222) and lockwashers (223).
14. Pump grease (NLGI #2 EP with a Lithium complex base) into grease fitting in cover (221) until it comes out the small vent hole in the cover.

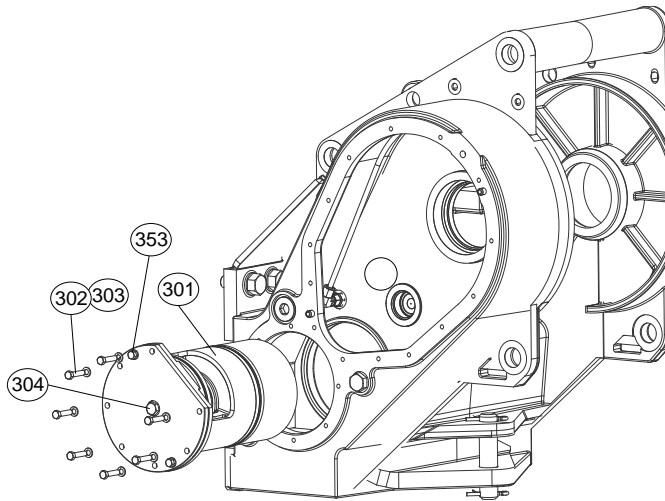


The bull gear (601) and shaft (202) weigh approximately 125 lbs (57 kg) as a unit. Use proper lifting equipment when installing them in the winch drum.

CARTRIDGE ASSEMBLY UNIT REMOVAL

The cartridge assembly can be removed as a unit for servicing. However, removing the cartridge assembly requires the removal of the winch from the tractor and removal of the winch motor. The individual components within the cartridge assembly can be service with the winch on the tractor.

1. Remove the first reduction gear from the winch. Refer to the Lower Reduction Gear Disassembly section of this manual.
2. Remove the hydraulic motor from the winch only if you are removing the cartridge assembly as a complete unit. To remove the motor, refer to the Hydraulic Motor Group section on this manual.

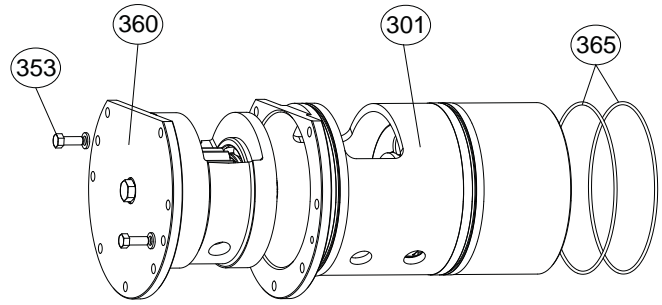


3. Remove the bolts (302) and lockwashers (303) that fasten the cartridge assembly (301) to the winch case. The two bolts shown installed in the drawing above will remain installed at this step.



The cartridge assembly weighs 122 lbs (55 kg). Use rigging rated for this weight.

4. Remove plug (304) from the cartridge assembly and install a $\frac{3}{4}$ - 16 eyebolt.



5. Remove the two bolts (353) which fasten the pinion and carrier group (360) to the brake cylinder (310). Install two of the longer bolts (302) removed in Step 1 in place of the two bolts just removed and leave about 5/8 inch protruding.
4. Pull on the bolts to remove the cartridge assembly from the winch case.
5. Place the cartridge assembly on a work bench for further disassembly.

Refer to disassembly instructions for Brake Cylinder, Planet Carrier, and Pinion Carrier for further disassembly.

CARTRIDGE ASSEMBLY UNIT INSTALLATION

1. Replace o-rings (305) and lightly coat with multi-purpose grease. Install bolts (302) and lockwashers (303) which attached the pinion and carrier group (360) to the cartridge assembly (301).
2. Remove plug (304) from the pinion and carrier group (360) and install a $\frac{3}{4}$ - 16 eyebolt in its place.

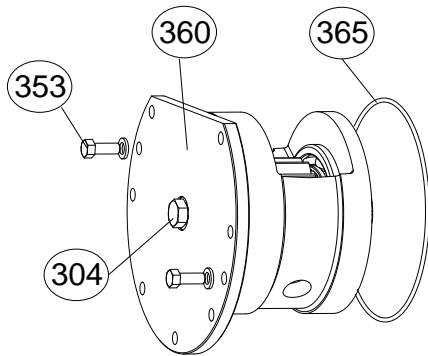


The cartridge assembly weighs 122 lbs (55 kg). Use rigging rated for this weight

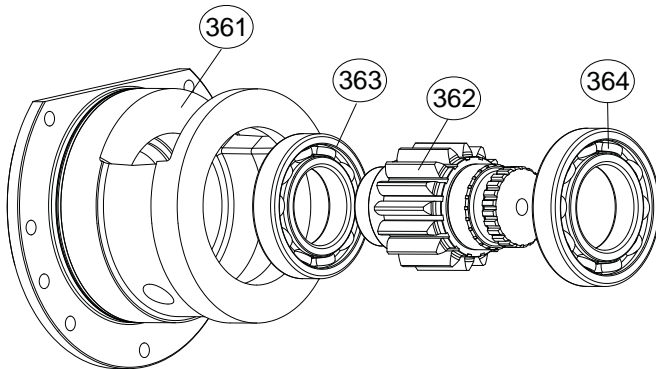
3. Attach hoist or lifting device to the eyebolt in preparation for cartridge installation in the winch case.
4. Carefully install the cartridge assembly into the winch case. Install the capscrews (302) and lockwashers (303) to secure the cartridge assembly to the winch case. Torque the capscrews.

PINION CARRIER DISASSEMBLY

Proceed to Step 4 if the complete cartridge is removed from the winch. This procedure assumes the parts will be serviced with the winch on the tractor, but the same steps are followed if working on a bench.



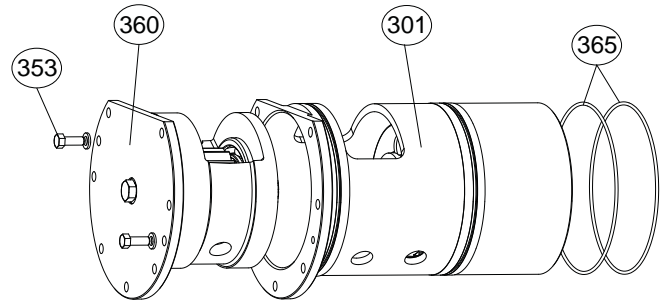
1. Remove the plug (304) and install a $\frac{3}{4}$ - 16 inch eye-bolt in place of it.
2. Remove the bolts (353) which fasten the Pinion Carrier Group (360) in the cartridge assembly (301). Remove the remaining bolts (302) which fasten the cartridge assembly to the winch case.
3. Pull on the eyebolt to remove the pinion carrier group (360) from the cartridge assembly (301). Place the pinion carrier group on a work bench for further disassembly.



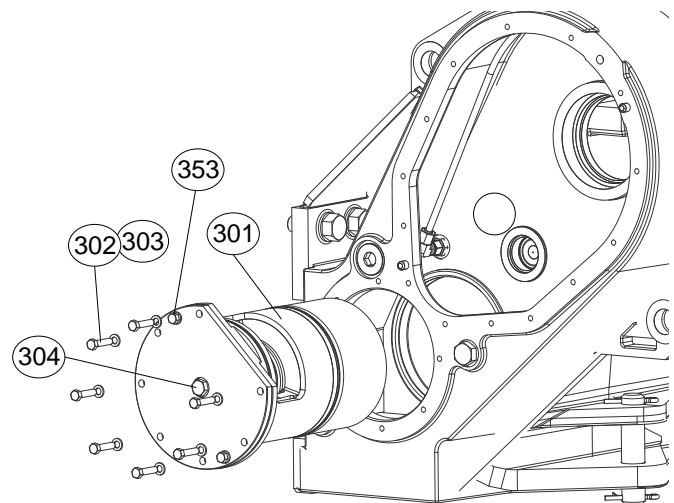
4. Use a forcing screw / cross block assembly to remove the pinion (362) and two bearings (363) and (364) from the bearing carrier (361).
5. Use bearing pullers to remove the bearings (363) and (364) from the pinion (362).
6. Remove and discard o-ring (365) from bearing carrier.

PINION CARRIER ASSEMBLY

1. Use an induction heater to heat the inner race of bearing (364) and install on pinion (362).
2. Heat bearing (363) and install on pinion (364).
3. Use a hydraulic press to install the pinion with bearings into the bearing carrier (361).
4. Install a new o-ring (365) on bearing carrier (361) and grease lightly before installation.

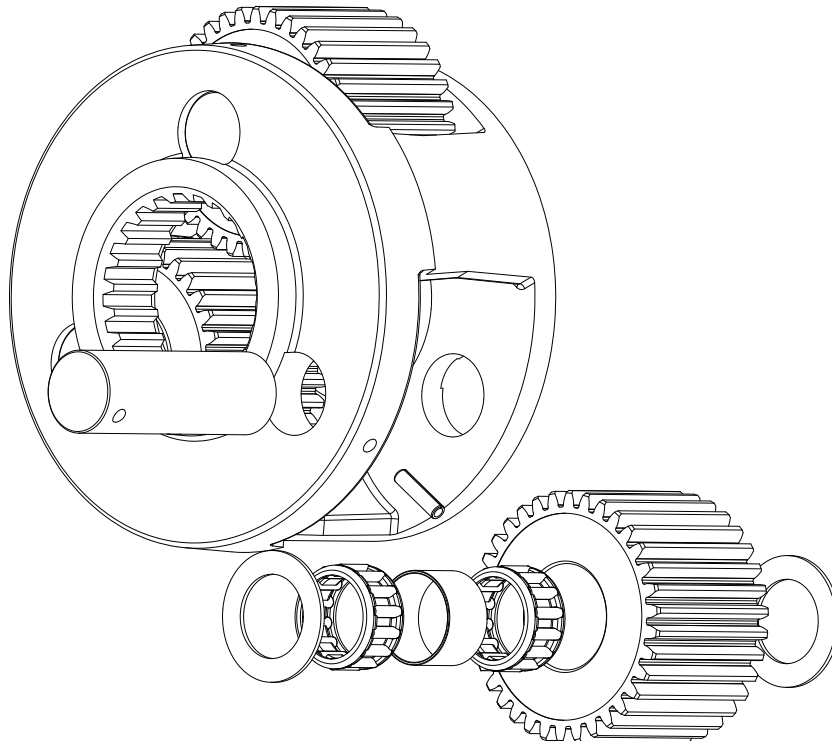


5. Install the pinion and carrier group (360) in the cartridge assembly (310). Install the capscrews (353) and lockwashers (354) that attach the pinion and carrier group to the brake cylinder (310).



6. Install capscrews (302) and lockwashers (303) which attach the cartridge assembly (310) to the winch case and torque. Install the plug (304) in the pinion and carrier group.

PLANET CARRIER



DISASSEMBLY

1. Remove the planet gears by driving the roll pins into the center of the planet shafts.
2. Use a punch to drive the roll pins from the planet shafts. Do not reuse the roll pins.
3. Now you can remove the planet shafts, bearings, spacer, thrust washers and gears. Thoroughly clean all parts and inspect for damage and wear. The bearing rollers should not exhibit any irregularities. If the rollers show any sign of spalling, corrosion, discoloration, material displacement or abnormal wear, the bearing should be replaced. Likewise, the cage should be inspected for unusual wear or deformation, particularly the cage bars. If there is any damage that will impair the cage's ability to separate, retain and guide the rollers properly, the bearing should be replaced. The thrust washer contact areas should be free from any surface irregularities that may cause abrasions or friction. The gears and shafts should be inspected for abnormal wear or pitting. Replace if necessary.

ASSEMBLY

1. Place the output planet carrier on workbench with splined coupling side down. Install output thrust plate in center of carrier.
2. Insert two (2) bearings and a bearing spacer into a gear with the spacer between the bearings. Place a thrust washer on each side of the gear and position in a carrier opening. Slide the shaft through the carrier, thrust washer, bearing-gear sub-assembly and remaining thrust washer.
3. Carefully align the pin hole in the carrier with the hole in the planet gear shaft and drive the roll pin into place. Always use NEW roll pins. When properly positioned, 50% of the roll pin will engage the planet gear shaft and 50% will remain in the planet carrier.
4. Note that the roll pin is slightly recessed in the carrier when properly installed. With a center punch, stake the carrier next to the pin hole as shown. This will distort the hole so the pin will not back out. Repeat these steps for each of the three planet gears.

BRAKE CYLINDER SERVICE

The Brake Cylinder is a subassembly of the Cartridge Assembly. It can be serviced with the winch on the tractor or on a bench if the entire Cartridge Assembly is removed from the winch. The hydraulic motor must be removed to remove the entire Cartridge Assembly.

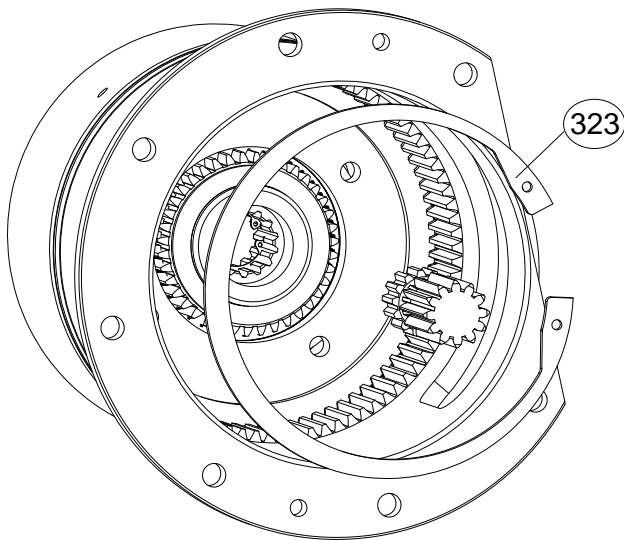
The procedure below assumes the brake cylinder is being serviced with the winch on the tractor, but the same steps are followed if the cartridge assembly is on a work bench.

DISASSEMBLY

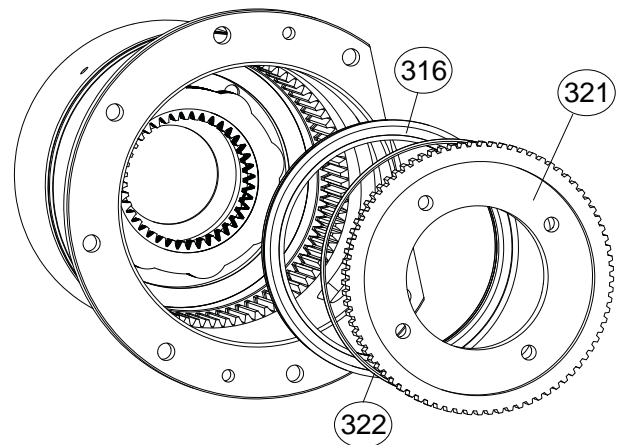
⚠ WARNING ⚠

Spring force is applied to the brake cylinder. Parts propelled by released spring force can result in death or injury.

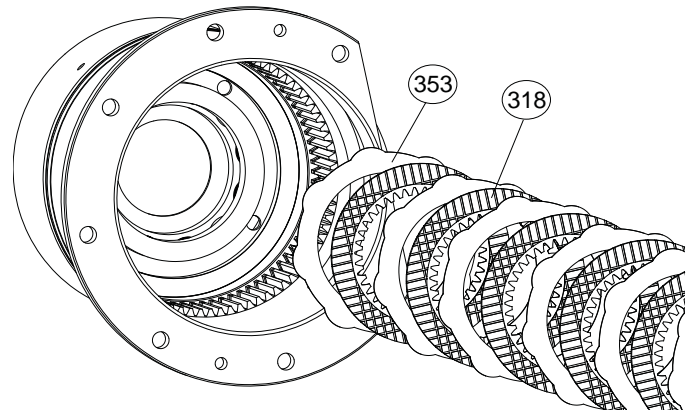
1. Install a slotted compression tool on the winch housing cartridge opening to compress the brake springs so that the retaining ring (323) can be removed. The compression tool should be offset away from the opening in the retaining ring to provide clearance for the retaining ring pliers.



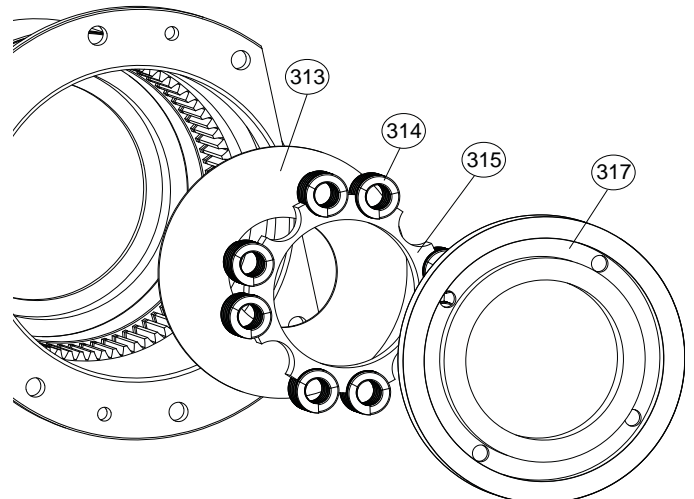
2. Compress the brake pack. Carefully remove the retaining ring (323). Slowly back off the compression tool to remove the force on the brake springs, and then remove the compression tooling.



3. Remove the brake retainer (321), seal (316), o-ring (322).



4. Remove friction discs (318), brake discs (319), and brake piston (317) from the housing. These components can be removed as a unit.



5. Remove brake piston (317), friction discs (318), and brake discs (319) from brake retainer (321).
6. Remove the seal (316) and o-ring (322) from the brake retainer (321).
7. Remove the springs (314), spring spacer (315), and spring back-up plate (313).

CLEAN AND INSPECT

1. Thoroughly clean and inspect all brake cylinder assembly parts. Check the brake piston and sealing surfaces on the brake cylinder for signs of scoring and wear. Check the piston seal for cracks, surface irregularities, and heat damage and replace if any imperfections are found.
2. Place friction disc on a flat surface and check for distortion with a straight edge. Friction material should appear even across the entire surface with the groove pattern visible. Replace friction disc if the splines are worn to a point, disc is distorted, friction material is worn unevenly, or the groove pattern is worn away.
3. Place the steel brake discs on a flat surface and check for distortion with a straight edge. Check surface for signs of material transfer or heat. Replace the steel discs if it is not flat, the outer lobes are distorted, or the disc shows signs of heat damage.
4. Check springs for cracks or failure. Check the springs free length, and if less than 1.5 inches (38.1 mm) replace all of the springs. The springs must be replaced as a set; if one of the springs must be replaced all must be replaced.

ASSEMBLY

1. Install the spring backup plate (313) in the cartridge assembly.
2. Apply general purpose grease (NGLI No. 2) to one side of each spring and one side of the spring spacer to hold in place during installation.
3. Space springs (314) evenly around the spring spacer (315). The spacing should be two springs then a vacant space followed by two springs and repeated until all eight springs are installed.
4. Install the springs (314) and spring spacer (315) in the cartridge assembly. The grease will hold the components in position on the spring backup plate (313).
5. Install the piston seal (316) and a new o-ring (322) on the brake retainer (321). The spring (o-ring) in the seal must be installed toward the external teeth of the brake retainer (321).
6. Place the brake retainer (321) on a clean work surface with the external teeth down. Apply a light coat of gear oil to the friction surface of the friction disc before installation. Install the brake discs (319) and friction discs (318). Begin with a steel brake disc () and then install a friction disc. Alternate steel and friction discs until all of the discs are installed. There are 7 steel brake discs and 6 friction discs in all.
7. Position the brake piston (317) onto the brake retainer and discs. Carefully align the teeth on the friction discs (318), and then slide the motor coupling (331) into the assembled brake parts to fully align the friction disc splines. Remove the motor coupling.
8. Apply a light coat of multipurpose grease (NLGI No.2) to the o-ring (322) and seal (316) and install the assembled brake components in the brake cylinder (317). Carefully slide the motor coupling (331) into the assembled components.

WARNING

Spring force is applied to the brake cylinder. Parts propelled by released spring force can result in death or injury.

9. Use snap-ring pliers to slide retaining ring (323) against the brake retainer (321).
10. Install compression tool on winch case at cartridge assembly bolts so the retaining ring (323) can be installed in the brake cylinder.
11. Using compression tool, slowly apply force to brake springs so that retaining ring can be installed. If necessary, use a screwdriver or punch to move retaining ring into groove.
12. Slowly and carefully release force on brake springs and ensure retaining ring remains fully seated in brake cylinder groove.

METRIC CONVERSION TABLE

English to Metric

Metric to English

LINEAR

inches (in.)	X 25.4	= millimeters (mm)	millimeters (mm)	X 0.3937	= inches (in.)
feet (ft.)	X 0.3048	= meters (m)	meters (m)	X 3.281	= feet (ft.)
miles (mi.)	X 1.6093	= kilometers (km)	kilometers (km)	X 0.6214	= miles (mi.)

AREA

inches ² (sq.in.)	X 645.15	= millimeters ² (mm ²)	millimeters ² (mm ²)	X 0.000155	= inches ² (sq.in.)
feet ² (sq.ft.)	X 0.0929	= meters ² (m ²)	meters ² (m ²)	X 10.764	= feet ² (sq.ft.)

VOLUME

inches ³ (cu.in.)	X 0.01639	= liters (l)	liters (l)	X 61.024	= inches ³ (cu.in.)
quarts (qts.)	X 0.94635	= liters (l)	liters (l)	X 1.0567	= quarts (qts.)
gallons (gal.)	X 3.7854	= liters (l)	liters (l)	X 0.2642	= gallon (gal.)
inches ³ (cu.in.)	X 16.39	= centimeters ³ (cc)	centimeters ³ (cc)	X 0.06102	= inches ³ (cu.in.)
feet ³ (cu.ft.)	X 28.317	= liters (l)	liters (l)	X 0.03531	= feet ³ (cu.ft.)
feet ³ (cu.ft.)	X 0.02832	= meters ³ (m ³)	meters ³ (m ³)	X 35.315	= feet ³ (cu.ft.)
fluid ounce (fl.oz.)	X 29.57	= milliliters (ml)	milliliters (ml)	X 0.03381	= fluid ounce (fl.oz.)

MASS

ounces (oz.)	X 28.35	= grams (g)	grams (g)	X 0.03527	= ounces (oz.)
pounds (lbs.)	X 0.4536	= kilograms (kg)	kilograms (kg)	X 2.2046	= pounds (lbs.)
tons (2000 lbs.)	X 907.18	= kilograms (kg)	kilograms (kg)	X 0.001102	= tons (2000 lbs.)
tons (2000 lbs.)	X 0.90718	= metric tons (t)	metric tons (t)	X 1.1023	= tons (2000 lbs.)
tons (long) (2240 lbs.)	X 1013.05	= kilograms (kg)	kilograms (kg)	X 0.000984	= tons (long) (2240 lbs.)

PRESSURE

inches Hg (60 °F)	X 3600	= kilopascals (kPa)	kilopascals (kPa)	X 0.2961	= inches Hg (60 °F)
pounds/sq.in. (PSI)	X 6.895	= kilopascals (kPa)	kilopascals (kPa)	X 0.145	= pounds/sq.in. (PSI)
pounds/sq.in. (PSI)	X 0.0703	= kilograms/sq.cm. (kg/cm ²)	kilograms/sq.cm. (kg/cm ²)	X 14.22	= pounds/sq.in. (PSI)
pounds/sq.in. (PSI)	X 0.069	= bars	bars	X 14.5	= pounds/sq.in. (PSI)
inches H ₂ O (60 °F)	X 0.2488	= kilopascals (kPa)	kilopascals (kPa)	X 4.0193	= inches H ₂ O (60 °F)
bars	X 100	= kilopascals (kPa)	kilopascals (kPa)	X 0.01	= bars

POWER

horsepower (hp)	X 0.746	= kilowatts (kW)	kilowatts (kW)	X 1.34	= horsepower (hp)
ft.-lbs./min.	X 0.0226	= watts (W)	watts (W)	X 44.25	= ft.-lbs./min.

TORQUE

pound-inches (in.-lbs.)	X 0.11298	= newton-meters (N-m)	newton-meters (N-m)	X 8.851	= pound-inches (in.-lbs.)
pound-feet (ft.-lbs.)	X 1.3558	= newton-meters (N-m)	newton-meters (N-m)	X 0.7376	= pound-feet (ft.-lbs.)
pound-feet (ft.-lbs.)	X .1383	= kilograms/meter (kg-m)	kilogram/meter (kg-m)	X 7.233	= pound-feet (ft.-lbs.)

VELOCITY

miles/hour (m/h)	X 0.11298	= kilometers/hour (km/hr)	kilometers/hour (km/hr)	X 0.6214	= miles/hour (m/h)
feet/second (ft./sec.)	X 0.3048	= meter/second (m/s)	meters/second (m/s)	X 3.281	= feet/second (ft./sec.)
feet/minute (ft./min.)	X 0.3048	= meter/minute (m/min)	meters/minute (m/min)	X 3.281	= feet/minute (ft./min.)

TEMPERATURE

$$^{\circ}\text{Celsius} = 0.556 (^{\circ}\text{F} - 32)$$

$$^{\circ}\text{Fahrenheit} = (1.8 \times ^{\circ}\text{C}) + 32$$

COMMON METRIC PREFIXES

mega	(M)	= 1,000,000 or 10 ⁶	deci	(d)	= 0.1 or 10 ⁻¹
kilo	(k)	= 1,000 or 10 ³	centi	(c)	= 0.01 or 10 ⁻²
hecto	(h)	= 100 or 10 ²	milli	(m)	= 0.001 or 10 ⁻³
deka	(da)	= 10 or 10 ¹	micro	(μ)	= 0.000.001 or 10 ⁻⁶