

CARCO®

MODEL H110B/H140A SERVICE MANUAL

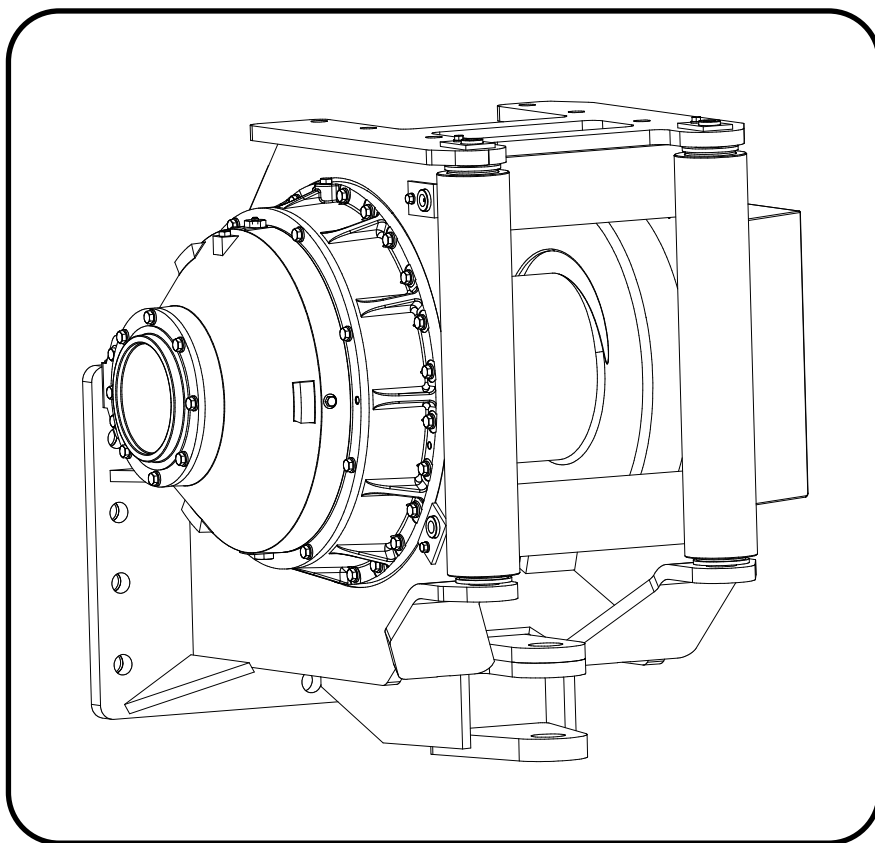


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FOREWORD

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

This manual contains instructions for service and repair of CARCO H110B/H140A hydraulic winches built for use on various crawler tractors. Depending on the specific tractor hydraulics, the winches will be configured with either variable displacement piston motors or fixed displacement vane motors. When instructions apply to only one specific winch configuration, that designation (i.e., Variable displacement motor only) will appear at the beginning of the pertinent text. If not identified in this manner, the text applies to ALL H110B/H140A winches.

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.

Continuing product improvement may cause changes in your winch which may not be included in this manual. Whenever questions arise regarding your CARCO winch or this manual, please contact the PACCAR Winch Technical Support Department:

Phone: 918-251-8511, Monday – Friday, 0800 hrs – 1630 hrs CT
FAX: 918-259-1575
Email: winch.service@paccar.com

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

Please remember, this manual is not a training manual. It cannot tell you everything you need to know about servicing your CARCO winch. If you have not been trained as a heavy equipment mechanic, you should get the proper training before servicing this winch. Only qualified heavy equipment mechanics should service this winch.

NOTE:

The hydraulic motors and selected gear ratios on CARCO H110B/H140A winches are specifically configured for use on the intended tractor. The winch may not be suitable, or advisable, for use on anything other than the intended tractor. Contact the CARCO SERVICE DEPARTMENT with questions regarding retrofitting your winch to other tractors.

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.



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 you 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 CARCO parts. Do not use parts from other winch manufacturers on your CARCO winch. Do not use CARCO 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.

i 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 CARCO 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 CARCO because of safety limitations. Call a CARCO dealer or the CARCO factory prior to attempting winch modifications or before mounting on a different tractor.
11. CARCO H Series winches are powered by the tractor hydraulic system. Discharge all retained hydraulic system pressure before removing any hydraulic lines or fittings. Personal injury may result from sudden release of oil pressure.

To discharge the winch control system pressure, stop the engine and cycle the winch control lever(s) into all positions five (5) times. Refer to the tractor manufacturers operators or service manual for additional information.

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.

THEORY OF OPERATION

DESCRIPTION OF WINCH

The winch assembly consists of six basic component groups:

1. Winch case
2. Hydraulic motor and piping
3. Brake housing assembly
4. Cable drum
5. Planetary reduction group
6. Carrier clutch group

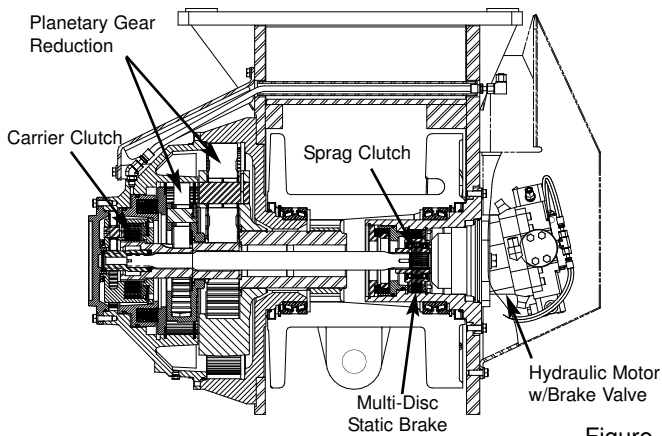


Figure 1

The winch case is a structural member of welded construction designed specifically for use in tractor winch applications. The case supports the output ring gear and the brake housing assembly. The cable drum revolves on four large tapered roller bearings. The hydraulic motor is bolted to the brake housing, which also supports the right hand cable drum bearings. The output ring gear supports the left hand cable drum bearings.

The planetary reduction group contains three planetary gear sets driven by the primary sun gear shaft, which is coupled to the motor shaft by the inner race of the over-running brake clutch assembly. With a total reduction of

156:1, 245:1, or 316:1 the planetary reduction group greatly multiplies the motor torque for high line pulls at maximum efficiency and precise load control.

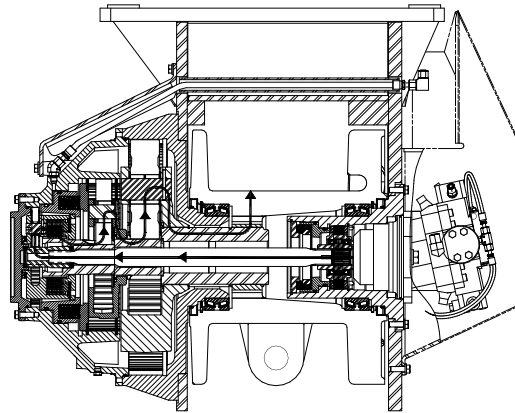


Figure 1A

BASIC WINCH OPERATION

The CARCO H110B/H140A winch contains a hydraulic motor and gear ratio specifically selected to match the winch to the hydraulic power of the specific tractor. This allows the winch to maximize the available hydraulic horsepower.

The winch motor is operated utilizing the full flow of the tractor implement pump via the implement valve, which also controls both the blade and ripper. The ripper section of the implement valve may be used to operate the winch, or in some instances, it may be replaced with a special winch section to enhance the winch performance capabilities. In any case, the valve section used will be a four way, three position valve.

Typically, the winch control valve is connected to the operator's joystick control lever by a series hydraulic hoses. Movement of the control lever directs the oil flow to the

winch motor through hydraulic lines. The hydraulic motor converts the flow and pressure of the hydraulic system into the mechanical energy needed to drive the winch gear train.

The tractor can walk away from a winch load to reposition the tractor for another pull by releasing the drum clutch. The spring applied, hydraulically release carrier clutch locks the primary planet carrier to the secondary planet sun gear to deliver increased torque to the next gear set. When released, the cable drum can rotate by back-driving the final planet carrier, final planet sun gear, secondary planet carrier and secondary sun gear and friction discs of the primary carrier clutch. The gear train does not back drive to the load holding static brake or hydraulic motor when the drum clutch is released. The drum clutch drag increases as tractor ground speed increases due to the viscous drag of the carrier clutch discs and gear train.

DUAL BRAKE SYSTEM – DESCRIPTION

The dual brake system consists of a dynamic brake system and a static brake system. The dynamic brake system has two operating components:

1. Hydraulic Brake valve assembly
2. Hydraulic motor

The brake valve is similar to a counter-balance valve. It contains a check valve to allow free flow of oil to the motor in the Reel-In direction and a pilot-operated, spring-loaded spool valve which blocks the flow of oil out of the motor when the control valve is placed in neutral. When the control valve is moved into the Reel-Out position, the spool in the brake valve remains closed until sufficient pilot pressure is applied to the end of the spool to shift it against the spring pressure and open a passage. After the spool valve cracks open, the pilot pressure becomes flow dependent and modulates the spool valve opening which controls the Reel-Out speed. See figures 2, 3 & 4.

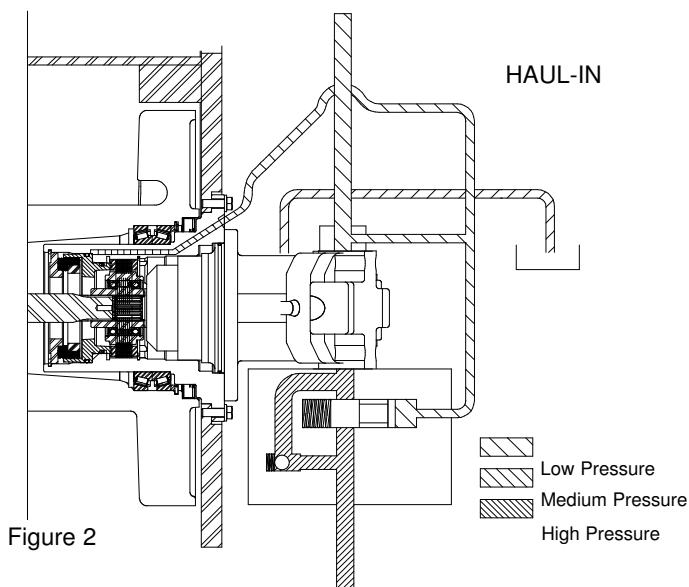


Figure 2

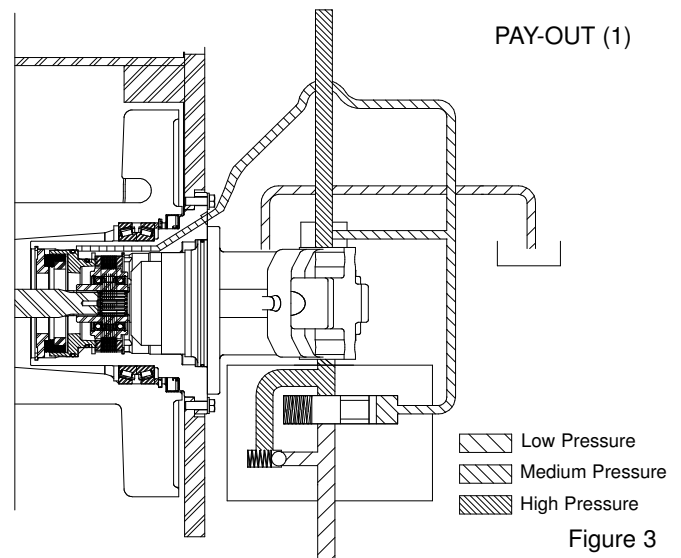


Figure 3

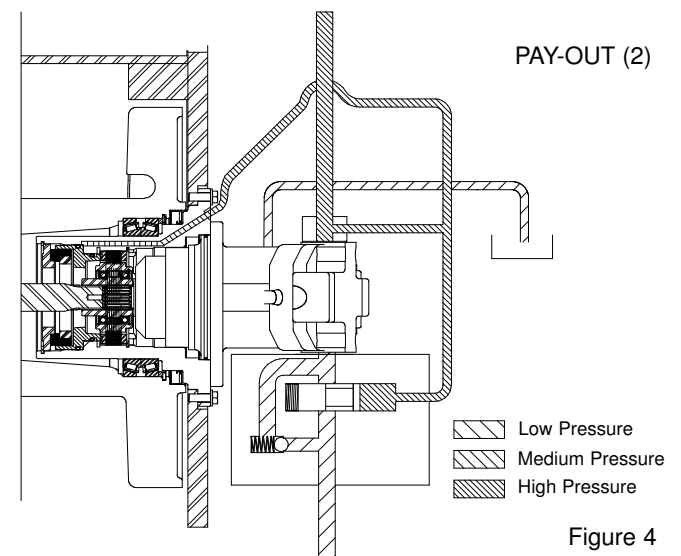


Figure 4

The static brake system has three operating components:

Spring applied, multiple friction disc static brake
Sprag-type overrunning brake clutch assembly
Hydraulic piston and cylinder

The static brake is released by the brake valve pilot pressure at a pressure lower than that required to open the pilot operated spool valve in the brake valve assembly. This sequence assures that dynamic braking takes place in the brake valve and that little, if any, heat is absorbed by the friction discs.

The friction brake is a load holding brake only and has nothing to do with dynamic braking or the rate of lowering of a heavy or suspended load.

The overrunning brake clutch is splined to the primary sun gear shaft between the motor and the primary sun gear. It will allow this shaft to turn freely in the direction of Reel-In, and lock up to force the brake discs to turn with the shaft in the direction of Reel-Out. (Fig. 5 and 6)

The hydraulic cylinder, when pressurized, will release the spring pressure on the brake discs, allowing the brake discs to turn freely.

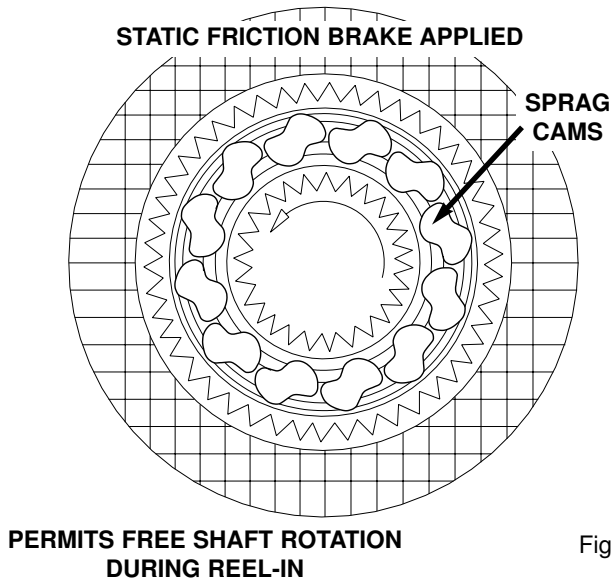


Figure 5

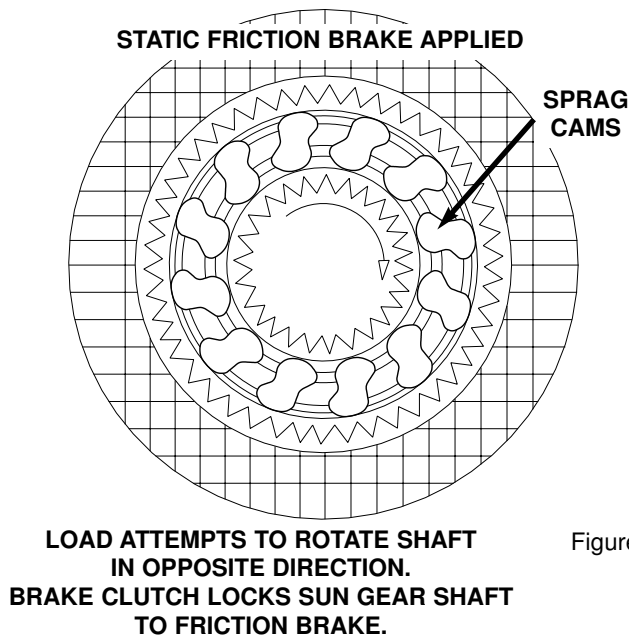


Figure 6

DUAL BRAKE SYSTEM – OPERATION

When pulling in a load (Reel-In), the overrunning brake clutch, which connects the motor shaft to the primary sun gear, allows free rotation through the gear train to the cable drum. The sprag cams lay over and permit the inner race to turn free of the outer race. (Fig. 5). The friction brake remains fully applied. The winch, while reeling in a load, is not affected by any braking action.

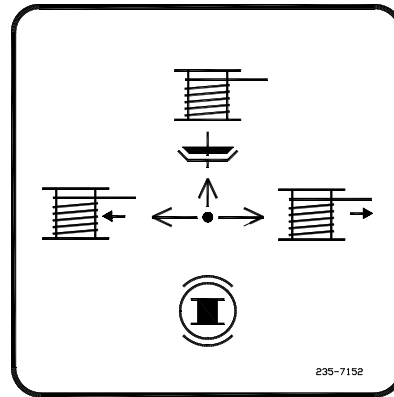
When the Reel-In operation is stopped, the load attempts to turn the primary sun gear in the opposite direction. This reversed input causes the sprag cams to instantly roll upward and firmly lock the shaft to the fully applied friction brake. (Fig. 6)

When the winch is powered in reverse, to Reel-Out the load, the motor can not rotate until sufficient pilot pressure is present to open the brake valve. The friction brake within the winch will completely release at a pressure lower than that required to open the brake valve, typically 350 PSI (2,413 kPa) and 600 PSI (4,137 kPa), respectively. The extent to which the brake valve opens will determine the amount of oil that can flow through it and the speed at which the load will Reel-Out. Increasing the flow of oil to the winch motor will cause the pressure to rise and the opening in the brake valve to enlarge, speeding up the release of the load. Decreasing this flow causes the pressure to lower and the opening in the brake valve to decrease, thus slowing the release of the load.

With the control valve shifted to neutral, the pressure will drop and the brake valve will close, stopping the load. The friction brake will reapply and hold the load after the brake has closed.

The friction brake receives very little wear during the Reel-Out operation. Most of the heat generated by the releasing and stopping of the load is absorbed into the hydraulic oil where it can be readily dissipated.

CONTROL OPERATION



BRAKE-ON (NEUTRAL)

When the winch is not in operation, or when the control lever is released, the handle returns to the center, or **BRAKE-ON**, position by spring force. Any load attached to the winch cable is held firm.

REEL-IN

Moving the control lever in the direction of tractor forward movement provides a signal to direct the oil to the winch motor to pull the cable and load in to the winch. **REEL-IN** drum speed is proportional to the amount of lever movement and the amount of load on the on the winch. When released, the lever will return to **BRAKE-ON** and the winch drum will stop and hold the load firm.

REEL-OUT

Moving the control lever in the direction of tractor reverse movement provides a signal to direct the oil to the winch motor to rotate in the direction to power out the cable.

REEL-OUT drum speed is proportional to the amount of lever movement. When released, the lever will return to **BRAKE-ON** and the winch drum will stop and hold the load firm.

i **NOTE:** When operating in **REEL-OUT** mode, the pressure compensator within the motor is disabled and the winch will work in high speed mode **ONLY**. This feature ensures control of loads lowered on hillsides, such as yo-yo operations on pipeline right-of-ways.

DRUM CLUTCH RELEASE (BRAKE-OFF)

Pushing the control lever away from the operator, toward the RH side of the tractor, provides a signal to direct the oil to release the drum clutch contained within the patented carrier-clutch assembly. With the drum clutch released, the operator can drive away from a load using the inherent resistance of the two final planetary gear stages to keep a tight wrap of cable on the drum to prevent cable-over-run.

CAUTION

When using drum clutch release feature (Brake-Off) drive away from a stationary load at slow speed, in first gear range only. Driving away from loads at higher tractor speeds may result in overspeed damage to the winch gear train.

When the lever is moved to the **BRAKE-OFF** position, the oil in the drum clutch release cavity is blocked causing the drum clutch to remain released indefinitely. The control lever must be returned to **BRAKE-ON**, then, momentarily moved into any other position to cause the drum clutch to reengage and exhaust the oil back to the reservoir.

As long as the **BRAKE-OFF** function is active, an indicator light on the main instrument panel in front of the operator will remain lit.

WARNING

DO NOT use the drum clutch for controlled reeling out of suspended loads. Sudden release of a load may result in property damage, injury or death. Use **ONLY REEL-OUT** to lower any load.

AUTOSPEED MODE

From the operator's perspective, this is the normal and most simple winch control method.

The winch line speed, or drum rotation speed, may be controlled by moving the control lever a very small distance, or by operating the tractor engine, and therefore the tractor implement pump, at a lower RPM.

i **NOTE:** Operating the tractor engine at the lowest idle setting while winching may result in erratic

winch operation. Always operate the tractor at high engine idle to provide the full range of control from the winch, while guaranteeing smooth operation. Operating the engine at lower settings will NOT provide slower winching.

The hydraulic motor used with the "autospeed" control system is a variable displacement, piston-type motor with an internal load-sense circuit. This circuit contains a small piston which adjusts the angle of the motor rotating group from minimum to maximum displacement as the pressure on the work ports (A & B) increases due to the load applied to the winch gear train. When there is little or no load on the winch, the motor rotating group will remain at the preset minimum displacement. As the winch load increases, the pressure at the motor work ports will increase. This same pressure will also act on the load-sensing piston beneath the "X" and "G" ports. As the load sensing piston moves, it directs oil to the motor rotating group shift cylinder which increases the motor displacement to provide increased torque, or pulling power, at a slower line speed.

In this manner, the motor displacement will automatically adjust to provide the maximum hydraulic horsepower for any given line speed and line pull situation.

LOW-SPEED LOCK MODE (LOW LOCK)

Depressing the button near the top of the control lever will force the variable displacement motor to shift the piston to the maximum displacement position, which will allow the winch to operate in the maximum line pull, minimum line speed mode, to enhance precise load control. When shifted into **LOW-LOCK**, an indicator light on the main operator instrument panel will remain lit. To disable **LOW-LOCK**, and return to autospeed mode, press the button again. The indicator light will be off.

WINCH LOCK-OUT

A toggle switch located on the RH operator's console adjacent to the winch control lever may be switched to completely lock out the hydraulic signal to the winch. This can be performed during servicing, or to eliminate the possibility of accidental winch actuation when performing general dozing operations. When activated, an indicator light on the main operator instrument panel will remain lit.

CAUTION

The hydraulic motor and gear ratio is configured to match the hydraulic system of a specific tractor. It may not be possible to mount the winch onto a different tractor model. Installation onto a tractor with a higher flow hydraulic system could result in overspeed damage to the motor and winch gear train. The maximum drum RPM in autospeed, no-load, with a piston motor, is listed below:

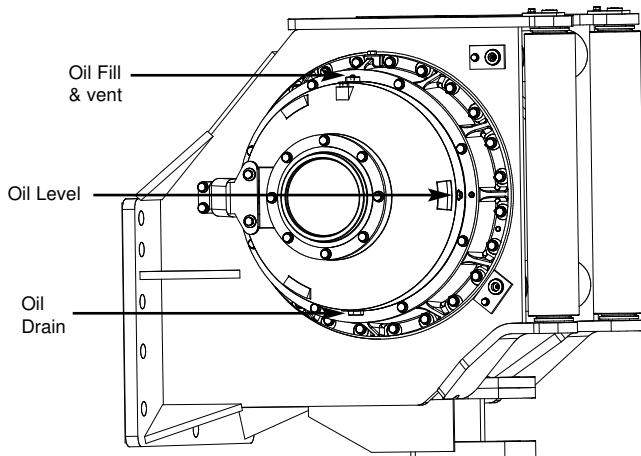
H110B – 156XXXX	28 RPM (+0, -1)
H110B – 245XXXX	18 RPM (+0, -1)
H140A – 316XXXX	14 RPM (+0, -1)

PREVENTIVE MAINTENANCE

A regular program of preventive maintenance for your CARCO 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. The intervals may be gradually increased or decreased with experience of a particular lubricant and evaluation of your application.

GEAR CASE OIL



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 at the horizontal centerline on the drum clutch housing. 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 near the top of the drum clutch housing. Add oil slowly, as the oil must pass through the gear train and fill the drum cavity.

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

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 and filter every 1000 hours or in accordance with the tractor manufacturer's recommendations.

GEAR CASE OIL CHANGE

⚠ WARNING ⚠

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

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.

Remove the drain plug located at the bottom of the drum clutch 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. Allow 15 minutes for the oil to flow through the gear train and fill the cable drum cavity before checking the oil level.

⚠ CAUTION ⚠

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

Oil capacity: approximately 16 qt. (15 L)

VENT PLUG

The vent plug is installed in the oil filler plug located near the top of the drum clutch housing. Whenever the oil is changed, remove the vent plug, clean in safety solvent and reinstall.

i 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. Use cold weather oil as recommended in the tractor hydraulic system instructions.

FAIRLEAD ROLLERS

Grease the fairlead rollers at the beginning of each work-day. The roller shafts have grease fittings at both ends. Apply grease until a small amount pushes out around the shaft.

Use a high quality type 12-hydroxy stearate lithium based product, which contains an EP additive, such as Moly, and meets or exceeds an NGLI Grade 2 specification.

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.

GENERAL SPECIFICATIONS

Unit Weight w/o Oil, Cable or Tractor Adapters Approximately 4,025 lb (1,826 kg)

Overall Gear Ratios Available

..... 156:1
..... 245:1
..... 316:1

Cable Drum Dimensions

Barrel Diameter 12.50 in. (318 mm)
Flange Diameter 24.00 in. (610 mm)
Barrel Length 13.25 in. (337 mm)

Gear Case Oil Capacity 16 qt (15 L)

Static Brake Release Pressure approximately 305 psi (2,100 kPa)

Drum Clutch Release Pressure approximately 215 - 350 psi (1,480 - 2,410 kPa)

Cable Storage Capacity

Layer	1-1/4 in. (32 mm)		1-1/8 in. (29 mm)		1 in. (25 mm)	
	Ferrule Part No. 29429		Ferrule Part No. 29428		Ferrule Part No. 29427	
	ft	M	ft	M	ft	M
1	38	11.6	42	12.8	46	14.0
2	83	25.3	90	27.4	99	30.2
3	135	41.2	145	44.2	159	48.5
4	193	58.8	207	63.1	226	68.9
5	---	---	276	84.1	300	91.4

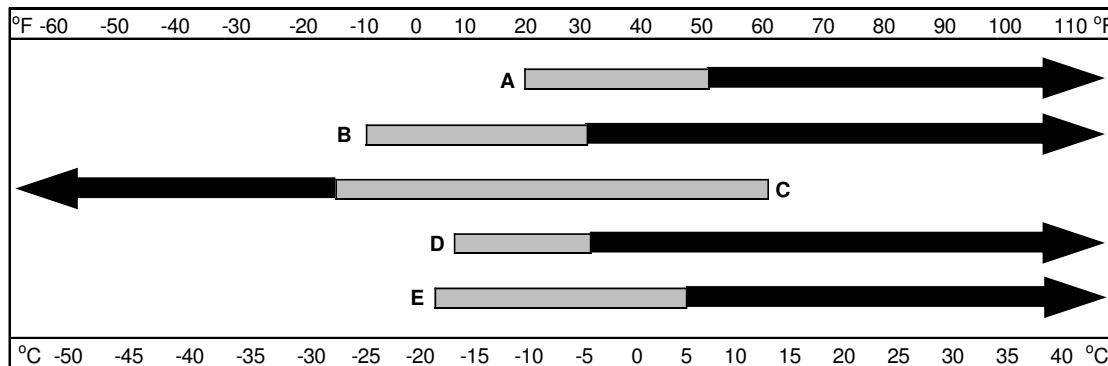
RECOMMENDED OIL

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 - Series 3 Motor Oil SAE 30, MIL-L-2104C
- B - Series 3 Motor Oil SAE 5W30, MIL-L-2104C
- C - Hydraulic Oil, MIL-H-5606
- D - TDTO such as CAT TO-4, SAE 30 wt (recommended)
- E - DEO CF-4 10W30

WINCH REMOVAL AND INSTALLATION

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 operating hydraulic pressures, or that require extensive disassembly to replace, should be replaced with new parts at the time of reassembly.

WINCH REMOVAL

WARNING

Before servicing, make sure any trapped oil pressure in the tractor hydraulic system has been relieved. Personal injury may 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 fill cap. Be sure to activate the winch or tractor hydraulic system lock-out toggle switch(s) or as directed in the tractor service manual.

WARNING

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

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 oil has drained completely. Note: Due to the configuration of the cable drum, a small amount of oil will remain within the drum cavity.

Remove the winch motor hoses from the motor and brake valve. Remove the motor shift hose from the motor "X" port. Remove the motor drain hose from the motor. Remove the drum clutch hose from the elbow on the RH side of the winch case.

WARNING

Winch weighs approximately 4,025 lb. (1,826 kg) without oil, cable and tractor adapters. Make certain the lifting equipment has adequate capacity. Attempting to lift the winch with inadequate equipment may result in personal injury or damage to the winch or property.

Support the winch with a suitable hoist or platform and remove the nuts and bolts securing the winch to the tractor adapters, and move the winch away from the tractor.

WINCH INSTALLATION

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

Align the winch mounting holes with the adapter mounting holes, and install and tighten all fasteners to the recommended torque.

CAUTION

Failure to fill the motor case with hydraulic oil before operating the winch may result in serious damage to the motor.

Fill the hydraulic motor case, through the motor case drain port, with tractor hydraulic oil. Attach the winch control hoses to the motor, as defined in the Parts and Installation Manual.

Fill the winch to the proper level with the recommended oil. Allow 15 minutes for the oil to flow through the gear train and fill the drum cavity before checking the oil level.

Start the tractor engine and operate the engine at low rpm. Alternately place the winch control in the Reel-In, then the Reel-Out position until the winch motor hydraulic circuit is filled with oil and the winch operates smoothly. Check the tractor hydraulic oil reservoir and fill to the proper level 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) as the line speed increases (larger circumference). Therefore, install the minimum length of cable possible for your application so the winch will operate on lower layers (smaller diameter) and deliver the maximum line pull.

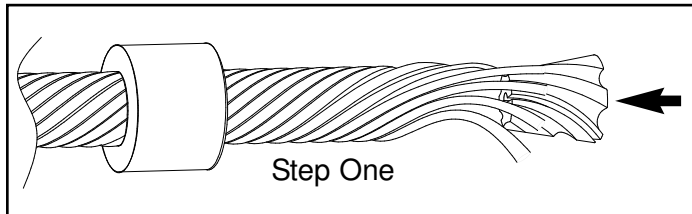
Using larger cable will not always increase strength as the larger cable may be more prone to bending fatigue failure than smaller wire rope. Consult your wire rope supplier for his recommendations for the wire rope and other rigging which best suits your application.

⚠ WARNING ⚠

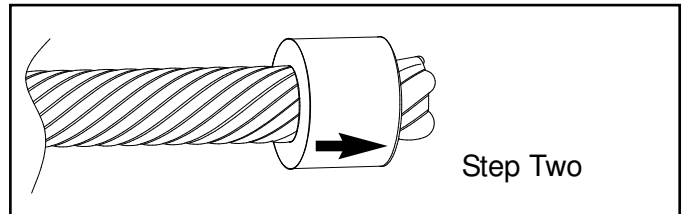
Winch cable anchors (ferrules and ferrule pocket) are **NOT** designed to hold rated loads. Winch loads applied directly to the cable anchor may cause the cable to pull free and result in the sudden loss of load control and cause property damage, injury or death. A minimum of 5 wraps of cable must be left on the drum barrel to achieve rated load. Do not use knots to secure or attach winch cable to drum or hook. We suggest that the last 5 wraps of cable be painted bright red to serve as a visual warning.

INSTALLATION OF SPIRAL FERRULES

Re-useable, field installed spiral ferrules are available from your CARCO or wire rope dealer. These ferrules are for use with six strand, IWRC (Independent Wire Rope Core) type wire rope. Refer to Specifications on page 9.



Insert cable through the small opening of the ferrule. Spread strands and insert spiral wedges between strands and core. Lay strands in individual grooves in spiral wedges.



Tap wedges and cable into ferrule leaving approximately 3/8 in. (10 mm) extending from the top. The first load will seat the cable and wedges securely in the ferrule.

TROUBLESHOOTING

⚠ WARNING ⚠

If a winch exhibits any sign of erratic operation, or load control difficulties (i.e., load creeping or chattering) appropriate trouble shooting tests and needed repairs must be performed immediately. Continued operation under any of the above conditions may result in loss of load control, property damage, serious personal injury or death.

TROUBLE	PROBABLE CAUSE	REMEDY
<p>A</p> <p>The winch will not smoothly Reel-Out the load, or smoothly lower a suspended load.</p>	<p>1. The problem could be a plugged pilot orifice in the brake valve. A plugged orifice may prevent the spool from moving or prevent the spool from moving smoothly, causing jumping or chattering as the load is released.</p> <p>2. The multi disc static brake may not be releasing as a result of a defective brake cylinder seal.</p> <p>i NOTE: <i>If the brake cylinder seal is defective, you may notice oil leaking from the winch vent plug as hydraulic oil fills the gear cavity.</i></p> <p>3. The multi disc static brake will not release as a result of damaged brake discs.</p>	<p>A. Disassemble the brake valve. Clean and inspect all parts. Make certain the .020 in. (0.5 mm) pilot orifice is not obstructed.</p> <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 (6900 kPa) 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>A. Disassemble the brake housing assembly to inspect the brake discs. Replace the brake discs as required.</p>
<p>B</p> <p>Oil leaking from the vent plug.</p>	<p>1. Same as A2.</p> <p>2. Motor seal may be defective as a result of high system back pressure or contaminated oil.</p>	<p>A. Same as A2.</p> <p>A. Case drain circuit back pressure must not exceed 40 PSI (2.8 kg/cm²) measured at the case drain port. Inspect the hydraulic system for a restriction.</p> <p>B. Oil analysis may indicate contamination, which could result in a worn motor shaft and seal. Thoroughly flush the entire hydraulic system and install new filters and oil. Install a new motor seal or replace the motor as needed.</p>

TROUBLE	PROBABLE CAUSE	REMEDY
TROUBLE “B” CONTINUED FROM PREVIOUS PAGE	3. The drum clutch piston seals may be leaking.	<p>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.</p> <p>B. Apply 500 psi (3,450 kPa) to the drum clutch. Close the shut-off valve and let stand for 5 minutes.</p> <p>C. If there is a loss of pressure during the 5 minutes, the drum clutch housing must be removed and disassembled for inspection of the seals and sealing surfaces. Refer to “Drum Clutch Service” section of this manual for additional information.</p>
<p style="text-align: center;">C</p> <p>The brake will not hold a load with the control lever in neutral.</p>	<p>1. Excessive system back pressure acting on the brake release port.</p> <p>2. Friction brake will not hold due to worn or damaged brake discs.</p> <p>3. Brake clutch may be slipping.</p> <p>4. If winch was field installed, check to see that the proper stack valve section was used (motor spool required).</p> <p>5. Drum clutch discs may be worn.</p>	<p>A. The pressure at the lowering port of the motor is also directed to the brake release port. This pressure must drop below 50 PSI (345 kPa) when the controls are returned to neutral, BRAKE-ON. Trace the hydraulic circuit back to the reservoir to locate source of back-pressure.</p> <p>A. Same as A3A.</p> <p>A. Improper planetary gear oil may cause the brake clutch to slip. Drain the old gear oil and flush the winch with a mild solvent. Thoroughly drain the cleaning solvent, and refill the winch with the recommended gear oil listed in the “Preventive Maintenance” section, of this manual.</p> <p>B. Overrunning brake clutch may be damaged or worn. Disassemble and inspect as described in “Overrunning Brake Clutch Service”.</p> <p>A. Disassemble and inspect drum clutch components as described in “Drum Clutch Service” section.</p>

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. Same as C5</p> <p>5. Hydraulic motor locked in high speed, small displacement position.</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>i NOTE: <i>Refer to the tractor service manual for more information regarding the system relief valve.</i></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. Same as C5A.</p> <p>A. Send motor to qualified motor service center.</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
<p>TROUBLE “E” CONTINUED FROM PREVIOUS PAGE</p>	<p>2. Excessively worn or damaged internal winch components.</p>	<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>Use of wrong viscosity hydraulic fluid for ambient operating conditions.</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>A. Same as D1A.</p> <p>A. Same as E1B, C, D, E; operate engine at full throttle</p> <p>A. Conduct operator training as required.</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 supplier 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

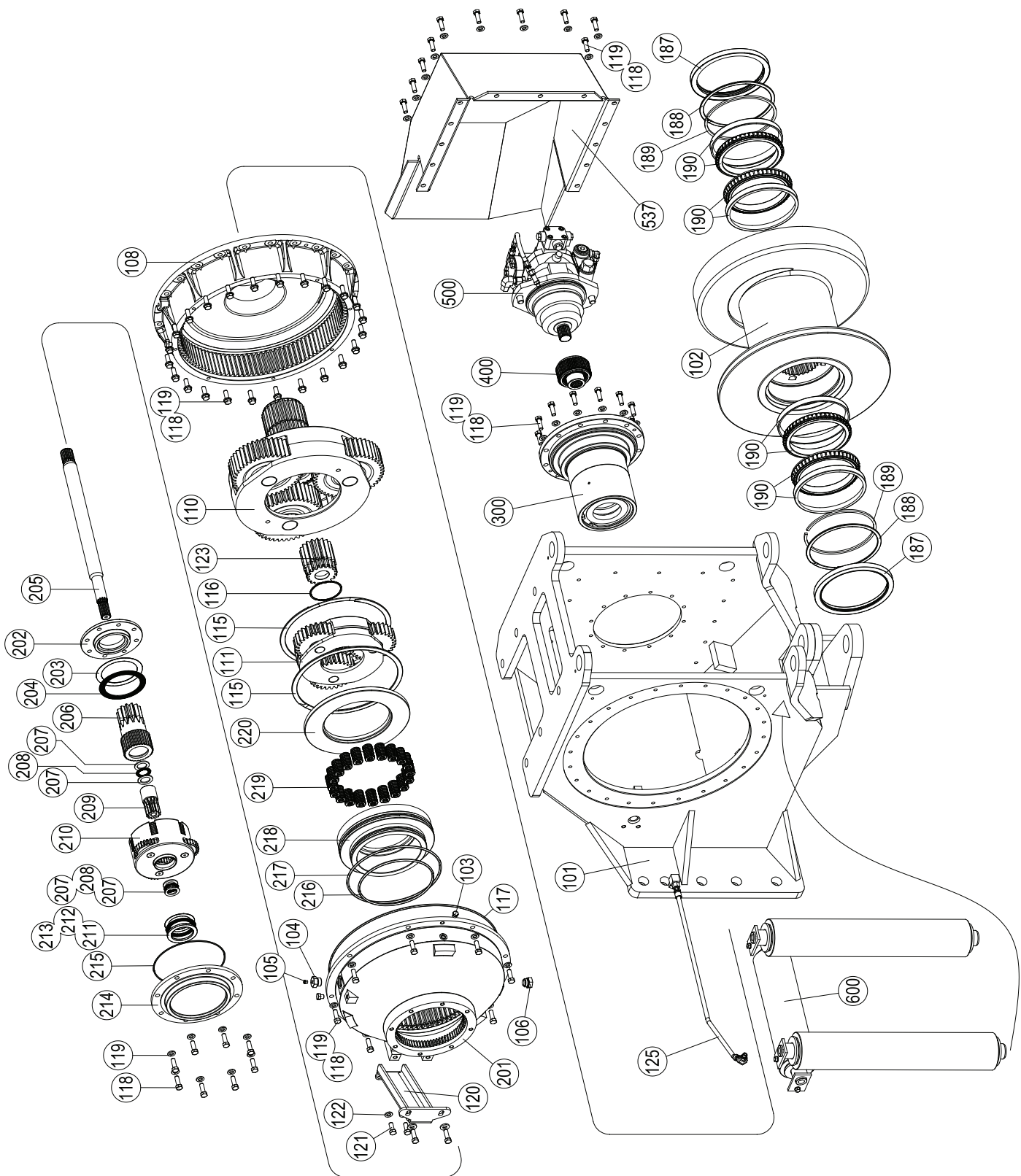
- Before any part is removed from the winch, all service instructions should be read and understood.
- Work in a clean, dust free area, as cleanliness is of utmost importance when servicing hydraulic equipment.
- Inspect all replacement parts, prior to installation, for any damage that may have occurred in shipment.
- Use only genuine CARCO winch replacement parts, which may be obtained through your CARCO dealer. Never reuse expendable parts such as o-rings.
- Inspect all machined surfaces for excessive wear or damage...before reassembly operations are begun.
- Lubricate all o-rings and oil seals with gear oil prior to installation.
- Use a sealing compound on the outside surfaces of oil seals. If using a thread sealant, 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.

After trouble shooting 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.

An overall cross-section of the winch, and a parts key is provided for reference on the following two pages. Disassembly instructions begin on page 19.

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Winch Assembly Explosion

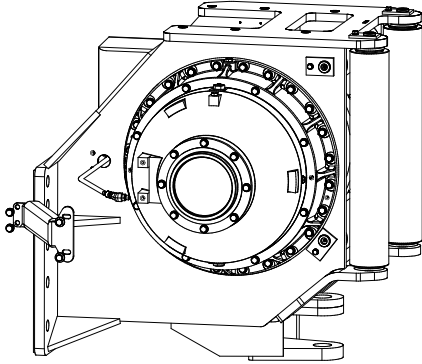


ITEM #	DESCRIPTION	QTY
101	WINCH HOUSING	1
102	CABLE DRUM	1
103	OIL LEVEL PLUG	1
104	OIL FILL PLUG	1
105	VENT RELIEF	1
106	MAGNETIC DRAIN PLUG	1
108	OUTPUT RING GEAR HOUSING	1
110	OUTPUT PLANET CARRIER ASSEMBLY	1
111	SECONDARY PLANET CARRIER ASSEMBLY	1
115	RETAINING RING	2
116	SNAP RING	1
117	O-RING	1
118	CAPSCREW, 1/2-13 UNC X 1-1/2 HEX HD, GD8	54
119	WASHER, HARD FLAT, 1/2	54
120	HOSE GUARD	1
121	CAPSCREW, 1/2-13 X 1-1/4 HEX HD, GD8	2
122	WASHER, HARD FLAT, 1/2	2
123	SUN GEAR	1
125	FREESPOOL HYDRAULIC SIGNAL LINE	1
201	DRUM CLUTCH/ RING GEAR HOUSING	1
202	SPRING RETAINER	1
203	THRUST WASHER	1
204	NEEDLE ROLLER BEARING	1
205	INPUT SHAFT	1

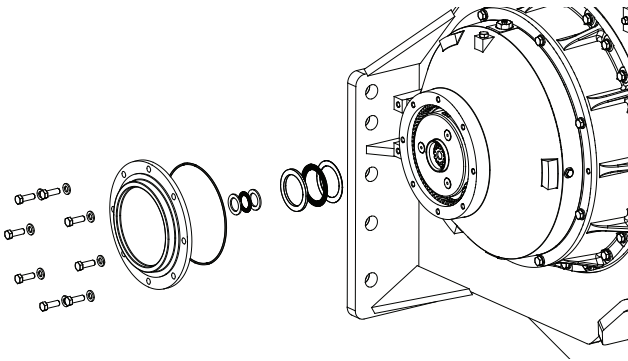
ITEM #	DESCRIPTION	QTY
206	SUN GEAR	1
207	THRUST WASHER	4
208	BEARING	2
209	PRIMARY SUN GEAR	1
210	CARRIER CLUTCH ASSEMBLY	1
211	THRUST WASHER	1
212	NEEDLE ROLLER BEARING	1
213	THRUST WASHER	1
214	COVER	1
215	O-RING	1
216	O-RING	1
217	O-RING	1
218	PISTON	1
219	DIE SPRING	20
220	SPRING BACKING PLATE	1
300	BRAKE SUB ASSEMBLY	1
400	OVERRUNNING CLUTCH ASSMEBLY	1
500	HYDRAULIC MOTOR GROUP	1
537	MOTOR COVER	1
600	FAIRLEAD PARTS GROUP	1
187	DRUM SEAL	2
188	RETAINING RING	2
189	BEARING RETAINING RING	2
190	BEARING CUP AND CONE SET	4

WINCH DISASSEMBLY

1. Remove the wire rope from the cable drum BEFORE disconnecting the hydraulic lines from the winch motor.
2. Drain the gear case oil as described in the "Preventive Maintenance" section of this manual.



3. Remove the hose guard (120) from the LH side of the winch and disconnect the drum clutch hose.



4. Remove the capscrews that secure the end cover (214) to the ring gear assembly. Remove the thrust bearing sets (211,212,213) around the planet carrier hub and from inside the cover center bore.

CAUTION

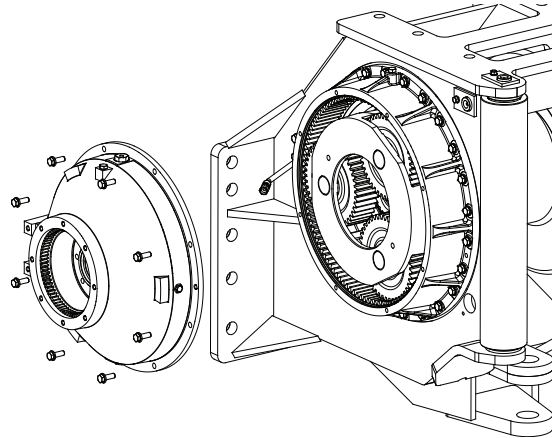
Needle roller thrust bearings are used throughout the planetary reduction group. Handle these bearings with care. If dropped, the metal cage separating the rollers may be damaged, which will result in bearing failure, and possible damage to the winch gear train, if reused.

5. Remove the primary carrier / clutch assembly (210). Remove the thrust bearing set and spring retainer (202, 203, 204). Refer to the "Carrier / Clutch Assembly Service" section of this manual for service procedures.

6. Remove the primary INPUT sun gear (206), the secondary sun gear (209) and the intermediate shaft (205). Be careful not to drop the thrust bearing set from inside the outboard end of the secondary sun gear.

CAUTION

The ring gear assembly and secondary planet carrier assembly weighs approximately 390 lbs (177 kg). Make certain lifting equipment has adequate capacity.



7. There is a 1/2-13 lifting eye hole at the top of the ring gear housing. Support the ring gear assembly (201) - with a hoist and remove the capscrews securing the ring gear assembly to the output ring gear. Remove the ring gear assembly and move it to a suitable work surface. The secondary planet carrier assembly is held to the ring gear with a retaining ring and will come away from the winch with the ring gear assembly. Jackscrew holes are provided to aid removal. Refer to the "Ring Gear Assembly Service" section of this manual for service procedures.

8. Remove the thrust washer from inside the output planet carrier.

CAUTION

The output planet carrier assembly weighs approximately 300 lbs (136 kg). Make certain lifting equipment has adequate capacity.

9. Install a 5/8-11 eyebolt into the output planet carrier. Use a long, solid bar to guide the carrier and a hoist to support the carrier, then remove the planet carrier assembly and drum shaft. Refer to the "Output Planet Carrier Assembly Service" section of this manual for service procedures.

CAUTION

The vertical roller assembly weighs approximately 100 lbs (45 kg). Use proper lifting methods or equipment to guard against damage or injury.

10. Remove the 3/8-inch bolt securing the vertical fairlead roller shaft to the top of the winch housing. Carefully remove the vertical shaft from the housing. The vertical roller weighs 85 lbs. (39 Kg) and must be supported to prevent it from falling out of position with the shaft removed. Remove the roller assembly, and the spacer washers at each end.

CAUTION

The horizontal roller assembly weighs approximately 55 lbs (25 kg). Use proper supporting and lifting methods to guard against damage or injury.

11. Support the horizontal fairlead roller assembly using a nylon lifting sling, or other positive retention method. Remove the 3/8-inch bolt securing the roller shaft assembly to the winch housing. Carefully remove the roller shaft from the LH side of the housing, and remove the spacer washers from each end of the roller assembly.

CAUTION

The cable drum is supported in the winch housing by bearings on the output ring gear and the brake housing. If either of these components is removed, and the cable drum is not supported externally as described in the text, the cable drum may come loose in the housing. The cable drum weighs approximately 540 lbs (245 kg). Damage to parts or personal injury can occur if precautions are not taken.

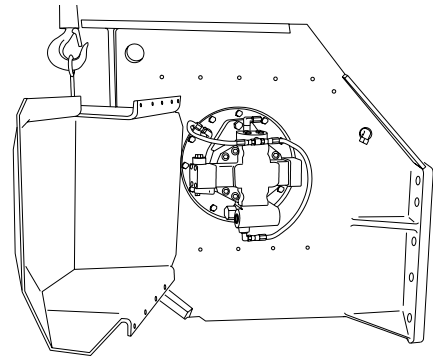
12. Support the cable drum in the winch housing with a suitable hoist and chain. Alternately, use a heavy duty rope (1-inch diameter minimum) tied through the holes in the top plate of the winch housing. At the same time, add wooden blocks under the drum flanges as added support.

CAUTION

The output ring gear weighs approximately 325 lbs (147 kg). Make certain lifting equipment has adequate capacity.

13. If removal of the output ring gear (108) is necessary, remove the capscrews securing the ring gear to the winch housing. Install a 5/8-11 eyebolt into the lifting eye hole in the mounting flange, and remove the ring

gear using a hoist. Jackscrew holes are provided to aid removal. Refer to the "Cable Drum Service" section of this manual for drum bearing and seal service procedures.



CAUTION

The motor cover weighs approximately 95 lbs (43 kg). Make certain lifting equipment has adequate capacity.

14. Remove the motor cover (537) from the RH side of the winch. Install a 1/2-13 eyebolt into the lifting hole in the top center of the cover, and lift with a hoist. The motor cover weighs 95 lbs. (43 Kg).
15. Disconnect the brake release hose from the long adapter on the brake housing.

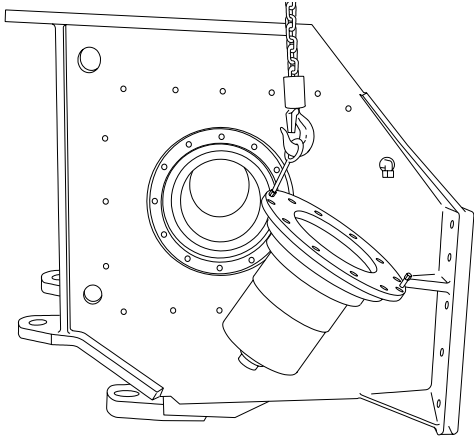
CAUTION

The hydraulic motor assembly weighs approximately 110 lbs (50 kg). Make certain lifting equipment has adequate capacity.

16. Support the hydraulic motor (500) securely with a lifting strap and hoist, and remove the motor mounting fasteners. Carefully remove the hydraulic motor from the winch. The hydraulic motor weighs approx. 125 lbs. (57 Kg).

⚠ CAUTION ⚠

The brake assembly weighs approximately 140 lbs (64 kg). Make certain lifting equipment has adequate capacity.



17. Remove the capscrews securing the brake assembly (300) to the winch housing. Support the brake assembly with a hoist and carefully remove the brake assembly from the winch case. Refer to the “Brake Assembly Service” section of this manual for service procedures.

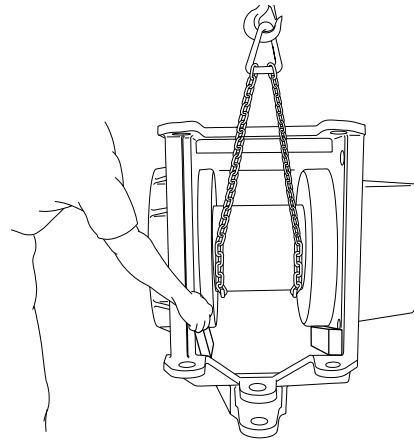
NOTE: To aid handling, a brake cylinder lifting fixture similar to that shown on page 37 may be fabricated. The fixture is fastened to the two (2) motor mounting holes and will assist in balancing the assembly during removal and installation.

⚠ CAUTION ⚠

The cable drum weighs approximately 540 lbs (245 kg). Make certain lifting equipment has adequate capacity.

⚠ CAUTION ⚠

The cable drum is supported in the winch housing by bearings on the output ring gear and the brake housing. If either of these components is removed, and the cable drum is not supported externally as described in the text, the cable drum may come loose in the housing. The cable drum weighs approximately 540 lbs (245 kg). Damage to parts or personal injury can occur if precautions are not taken.



18. Support the cable drum with a hoist and lifting strap, remove the supporting rope described earlier, and remove the cable drum through the rear opening of the winch housing. Refer to the “Cable Drum Service” section of this manual for drum bearing and seal service procedures.
19. Clean and inspect all removed components and sub-assemblies at this time. Refer to the appropriate areas of this manual for specific service procedures.

CARRIER / CLUTCH ASSEMBLY SERVICE

DISASSEMBLY

Apply light pressure to the thrust ring (10) and remove the retaining ring (11). Then remove the thrust ring, brake plates, friction discs and wave springs (7,8,9) from the carrier.

Remove the planet gear shafts (3) by driving the roll pins (6) into the center of the shafts. Slide the planet gear shafts out of the carrier. Use a punch to drive the roll pins out of the gear shafts. **DO NOT** reuse the roll pins – replace with new during reassembly.

Remove the planet gears, bearings and thrust washers (2,4,5) from the carrier.

Thoroughly clean and inspect all planetary components for damage or abnormal wear. The bearing rollers should not exhibit any irregularities. If the rollers show any sign of spalling, corrosion, discoloration, material displacement, or other abnormal wear, the bearing(s) should be replaced. Inspect the bearing cage for unusual wear or deformation, particularly the cage separator bars. If there is any damage that will impair the ability of the cage to separate, retain, guide the rollers properly, the bearing **MUST** be replaced. The thrust washer contact areas must be free of serious surface irregularities that may cause abrasion or friction. The gears and planet shafts should be inspected for abnormal wear or pitting. Replace all components as required.

i NOTE: Use care in handling the carrier to prevent damaging the hub on the gear side of the carrier, as this is a bearing surface.

Place each friction disc (8) on a clean, flat surface, and check for distortion using a straightedge. The friction material should appear evenly across the entire surface, with visible grooves. Replace the friction discs if the splines are worn to a point, if the disc is distorted, or if the friction material is worn unevenly.

Place each steel brake plate (7) on a clean, flat surface and check for distortion using a straightedge. Check both surfaces for signs of material transfer or heat. Replace the brake discs if distortion or heat discoloration is present.

Place each wave spring (9) on a clean, flat surface. Check for distortion or damage and replace as required. Check the free height of each spring and replace if the measurement is .19 in. (4.8 mm) or less.

ASSEMBLY

Install the bearing into a planet gear. Place a thrust washer on each side of the gear and insert the gear assembly into an opening in the carrier. Slide the planet shaft through the carrier, and into and through the gear and thrust washers.

Carefully align the pin hole in the carrier with the hole in the planet shaft, and drive a **NEW** roll pin into place. The roll pin should be recessed into the carrier to a depth of .35 in. (9 mm). Using a center-punch, stake the carrier next to the pin hole. This will distort the hole so that the roll pin will not back out in service.

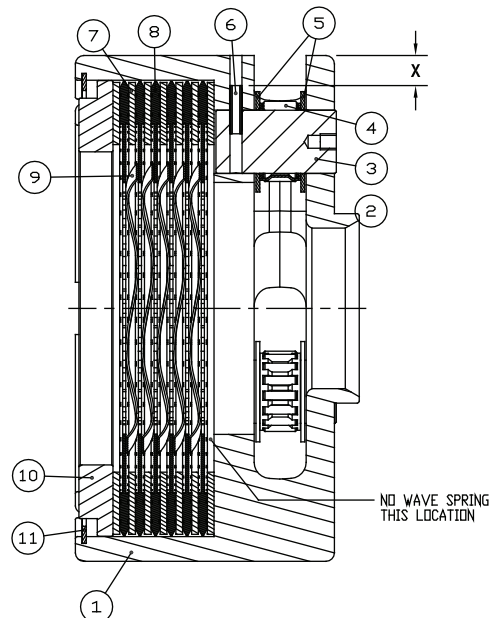
Repeat for each of the planet gears.

Position the carrier with the clutch end up. Lubricate the friction discs with new winch oil prior to assembly. Install a steel brake plate (7) in the bottom of the carrier, aligning the tangs on the plate with the slots in the carrier. Next, install a friction disc (8). After the first friction disc, install parts in the following sequence: steel brake plate, wave disc, friction disc. Install the last steel disc.

i NOTE: In the bottom of the clutch housing, there is no wave spring installed between the first brake plate and friction disc.

Install the thrust ring (10) into the carrier on top of the clutch pack.

Apply light pressure to the thrust ring and install the retaining ring (11). Make sure the retaining ring is seated fully in the housing groove. The ends of the retaining ring must be contained by the groove in the carrier and **NOT** the slots.



SECONDARY PLANET CARRIER SERVICE

DISASSEMBLY

1. The preferred method of removing the planet gear shaft (14) is to first remove the roll pin (11). This can usually be done by inserting a punch into the hole in the end of the shaft and forcing the roll pin up and out of the hole through the carrier (68).

If the roll pin cannot be easily removed, and must be sheared, please observe the following:

Use a pipe or tube section large enough to support the area around the planet gear shaft. Also, ensure the entire carrier assembly is supported at the same level. When adequately supported, drive or press the gear shaft out of the carrier while shearing the roll pin.



The secondary planet carrier assembly weighs approximately 80 lbs (36 kg). Make certain lifting equipment has adequate capacity.

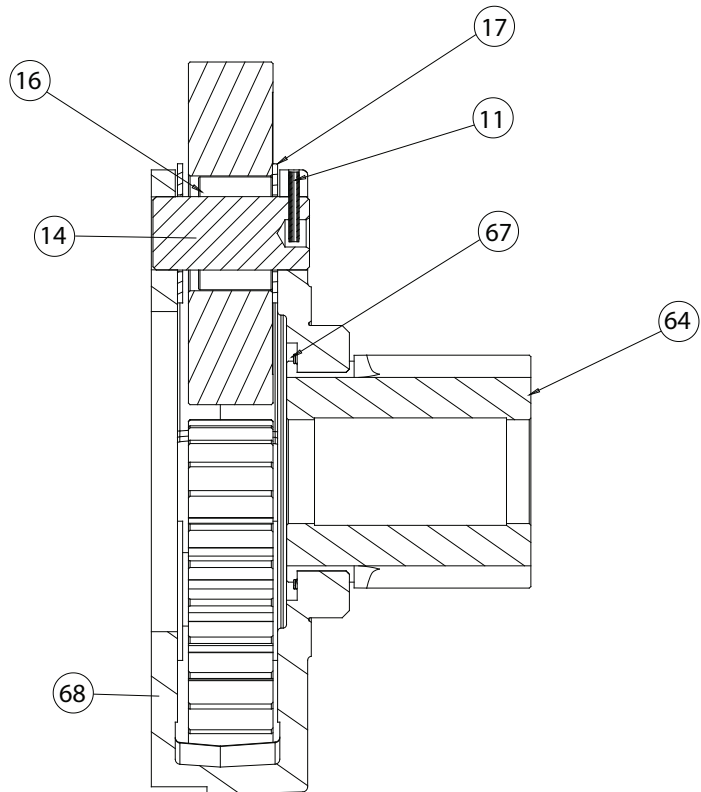
2. Slide the gear shaft out of the carrier.
3. Slide the planet gear (15) out of the carrier and carefully remove the loose bearing rollers (16). Use a clean shop towel or other means to keep from dropping the rollers. Repeat for all planet gears.
4. If required, remove the retaining ring (16) from the inboard end of sun gear (64) and remove the sun gear from the carrier.
5. Thoroughly clean all parts and inspect for damage and wear. The bearing rollers should be inspected for signs of spalling, corrosion, discoloration, material displacement or abnormal wear. Inspect the planet gears and shafts for pitting or wear. Replace all components as required.

ASSEMBLY

1. If previously removed, insert the sun gear through the planet carrier hub and install the retaining ring to secure the sun gear to the carrier.
2. Liberally coat the bore of a planet gear with a good grade of oil soluble grease.
3. Support the planet gear on a thrust washer. With the gear centered on the thrust washer, install twenty (20) bearing rollers into the bore. Coat the rollers with a

small amount of grease to help hold them in place as needed. Install the remaining thrust washer onto the planet gear

4. Carefully install the entire gear assembly, including the thrust washers on the top and bottom surface, install it into the planet carrier opening. Insert the planet gear shaft into the gear bore and align the small hole in the shaft with the hole in the edge of the carrier.
5. Drive a roll pin into the carrier and planet gear shaft. When installed properly, approx. 1/2 of the rollpin should engage the shaft and 1/2 should engage the carrier. Once installed, use a center punch and "stake" the carrier next to the pin hole to distort the carrier hole so the roll pin will not back out in service.
6. Repeat steps 2 – 5 for the remaining planet gears.



ITEM NO.	DESCRIPTION	QTY.
-	SECONDARY PLANET CARRIER ASSEMBLY	1
11	SPIROL PIN	3
14	PLANET PIN	3
15	PLANET GEAR	3
16	ROLLER	42
17	THRUST WASHER	6
64	SUN GEAR	1
67	RETAINING RING	1
68	SECONDARY PLANET CARRIER	1

OUTPUT PLANET CARRIER SERVICE

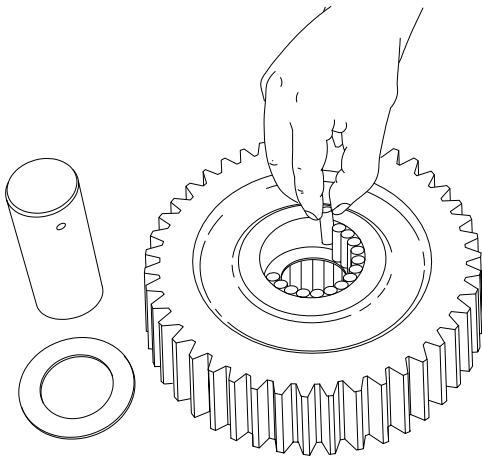
DISASSEMBLY



The output planet carrier assembly weighs approximately 300 lbs. (136 kg). Make certain lifting equipment has adequate capacity.

Remove the planet gear shafts (3) by driving the roll pins (7) into the center of the shafts, then push the shafts out of the planet carrier (1) while supporting the planet gear (2). Use a punch to drive the roll pins out of the gear shafts.

Each gear contains two (2) sets of twenty (20) loose bearing rollers (4), separated by a bearing spacer (5). Carefully remove the rollers and spacers for inspection. Thoroughly clean all parts and inspect for damage or abnormal wear, as was done for the primary and secondary planet assemblies.



ITEM NO	DESCRIPTION	QTY.
-	OUTPUT PLANET CARRIER ASSEMBLY	1
1	OUTPUT PLANET CARRIER	1
2	PLANET GEAR	3
3	PLANET PIN	3
4	ROLLER	120
5	BEARING SPACER	3
6	THRUST WASHER	6
7	ROLL PIN	3
8	RETAINING RING	1
9	DRUM SHAFT	1
10	RETAINING RING	2
11	THRUST RACE	1

ASSEMBLY

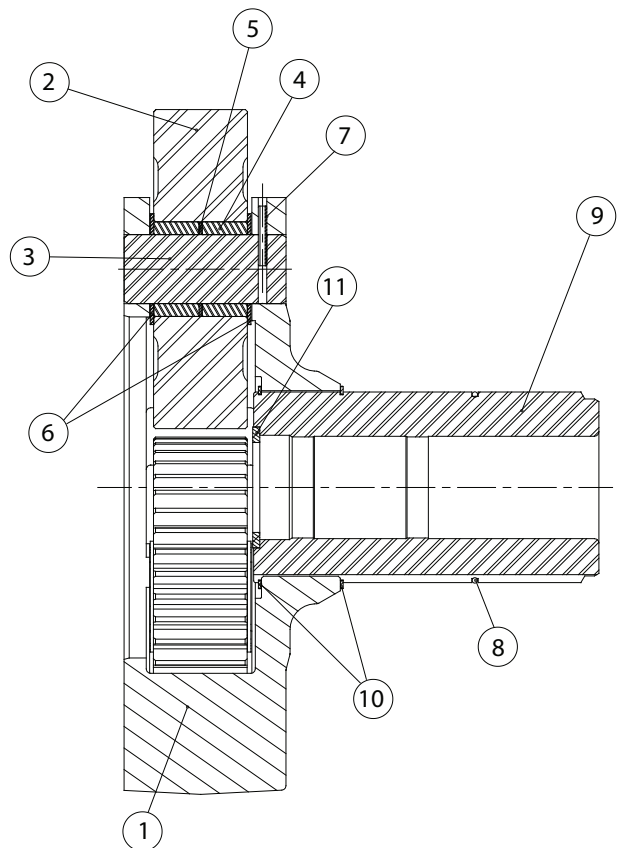
Support the planet gear (2) on one of the thrust washers (6) and install twenty (20) rollers (4) at one end of the bore. A light coating of grease on the bore, and on the rollers will aid retention of the rollers in the bore during assembly. Install the bearing spacer (5), then install the remaining twenty (20) rollers in the bore. Repeat this procedure for all three output planet gears.

Move the gear assembly and the supporting thrust washer into place in one of the planet gear openings in the carrier. Carefully slide the gear and washer into alignment with the planet shaft bore. Install the second thrust washer (4) on the upper side of the gear.

Slide the planet shaft (3) through the carrier assembly, into and through the gear assembly and thrust washers.

Carefully align the roll pin hole in the carrier with the hole in the planet shaft and drive a new roll pin into place. Always use **NEW** roll pins. Approximately 1/2 of the rollpin should engage the shaft and 1/2 should engage the carrier.

Make certain the roll pin is slightly recessed in the carrier and stake into place with a center punch



RING GEAR ASSEMBLY SERVICE

DISASSEMBLY



The ring gear assembly and secondary planet carrier assembly weighs approximately 390 lbs (177 kg). Make certain lifting equipment has adequate capacity.

1. Place the ring gear assembly on a table with the planetary gear set facing up.
2. Remove the retaining ring (7) that secures the planet gears to the ring gear housing. Lift the planet carrier assembly out of the ring gear. Refer to the "Secondary Planet Carrier Service" section of this manual for service procedures.



The secondary planet carrier assembly weighs approximately 80 lbs (36 kg). Make certain lifting equipment has adequate capacity.

3. Use a press or a compression tool to force the pressure plate (6) down against the spring force. Apply just enough force to allow the pressure plate to clear the lower retaining ring. Remove the retaining ring (7) from the groove and remove the pressure plate.
4. Remove the twenty-four (24) clutch springs (5).



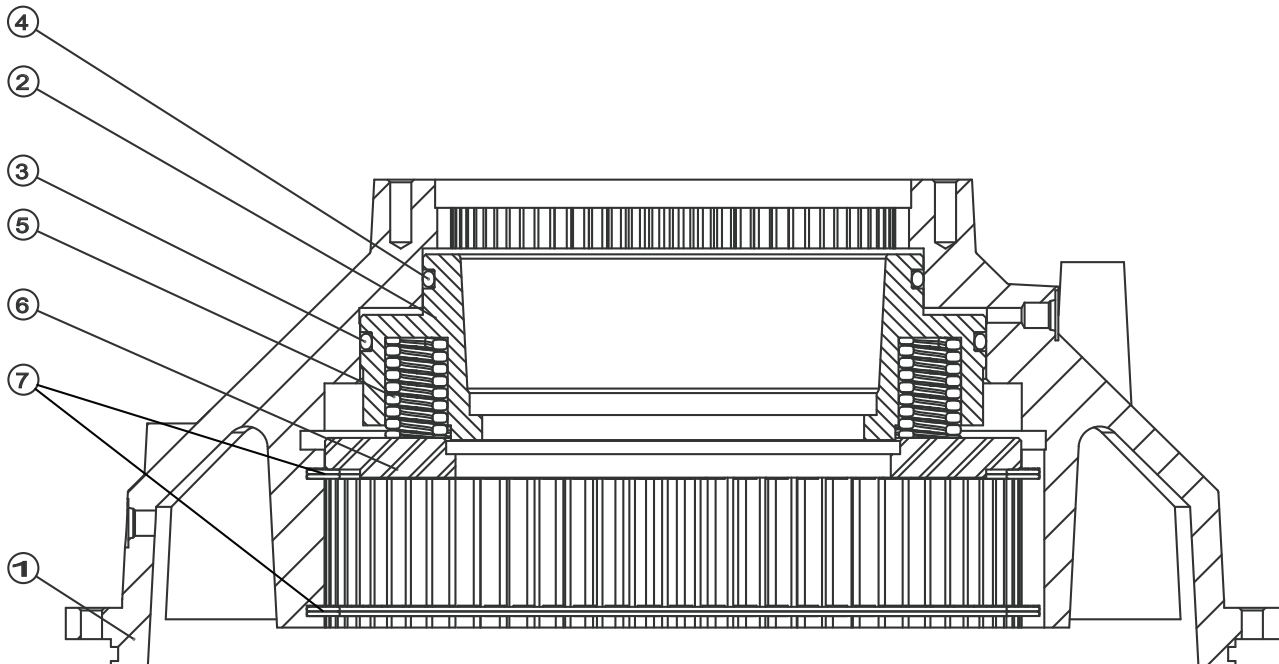
The ring gear housing weighs approximately 260 lbs (118 kg). Make certain lifting equipment has adequate capacity.

5. Turn the ring gear housing over with the large end down. Tap the clutch piston (2) out of the ring gear using a rubber mallet or a soft driver. Discard the o-rings.
6. Thoroughly clean all parts and inspect for damage or wear. Check the piston sealing surfaces for any scoring could damage seals or create any sealing problems. Make certain the clutch pressure port is open and free of any contamination.



Failure to replace the clutch springs as a complete set may result in uneven clutch application pressure, and accelerated and repeated drum clutch and clutch spring failure.

7. Check the clutch spring (5) free length; minimum free length should be 2.38 in. (60.3 mm). Check the springs for any sign of cracks or other failure. If any spring must be replaced for any reason, then ALL clutch springs must be replaced.



ASSEMBLY



The ring gear housing weighs approximately 260 lbs (118 kg). Make certain lifting equipment has adequate capacity.

1. Place the ring gear housing on a clean work surface with the large end facing up.
2. Install new o-rings (3,4) into the clutch piston (2) grooves. Lubricate the o-rings liberally and install the piston into the ring gear housing. Apply even pressure to the piston to seat the piston seals into the ring gear and press the piston into place. Be sure to seat the piston into the bottom of the ring gear bore.
3. Install twenty-four (24) springs into the spring bores of the piston.
4. Place the pressure plate (6) into the ring gear housing on top of the springs. Make sure that the shoulder for the retaining ring is facing upward.
5. Apply even pressure as needed to force the pressure plate below the retaining ring groove and install the retaining ring (7). Make certain the retaining ring is fully seated into the groove before releasing the pressure plate.



The secondary planet carrier assembly weighs approximately 80 lbs (36 kg). Make certain lifting equipment has adequate capacity.

6. Place the secondary planet carrier assembly into the ring gear with the output sun gear facing upward.
7. Install the retaining ring (7) into the groove above the planet gears. Make certain the retaining ring is fully seated into the bottom of the groove.

BRAKE ASSEMBLY SERVICE

DISASSEMBLY



The brake assembly weighs approximately 140 lbs (64 kg). Make certain lifting equipment has adequate capacity.

1. Place the brake assembly on a press table with the motor end, or large end, down. Apply pressure to the spring retainer (315) to force the retainer just clear of the retaining ring (316). Remove the retaining ring. Slowly release the force applied to the spring retainer.
2. Remove the spring retainer and sixteen (16) brake springs (313).
3. Turn the brake housing over so that the motor end now faces upward.
4. Remove the retaining ring (304) from the brake housing. It may be necessary to tap the brake spacer (305) downward to provide clearance to easily remove the retaining ring.
5. Remove the spacers (305) and brake discs (306, 307) from the housing.
6. Tap the piston downward to remove the piston. Discard the o-rings and back-up rings (309, 310, 311, 312).
7. Thoroughly clean and inspect all parts at this time. Check the brake piston and housing bore sealing surfaces for any scoring which could damage the seals or create any sealing problems. Make certain the brake release pressure port is clear and free of any contamination.

8. Check the cable drum bearing and seal surfaces on the outside of the brake housing for damage or excessive wear.
9. Place each friction disc on a clean, flat surface and check for any distortion using a straightedge. The friction material should appear evenly across the entire surface, with visible grooves. Replace the discs if the splines are worn to a point, if there is any distortion, or if the friction material is worn unevenly.
10. Place each steel disc on a clean, flat surface and check for any distortion using a straightedge. Check both surfaces for signs of material displacement or heat. Replace the steel discs if the splines are worn to a point or if the discs are distorted or heat damaged.
11. Check the brake spring free length; minimum free length should be 1.44 in. (36.5 mm). Check the springs for any sign of cracks or other failure. If a single brake spring must be replaced for any reason, then ALL brake springs must be replaced.



Failure to replace the brake springs as a set may result in uneven brake application pressure, and accelerated and repeated brake system and brake spring failure.

ASSEMBLY

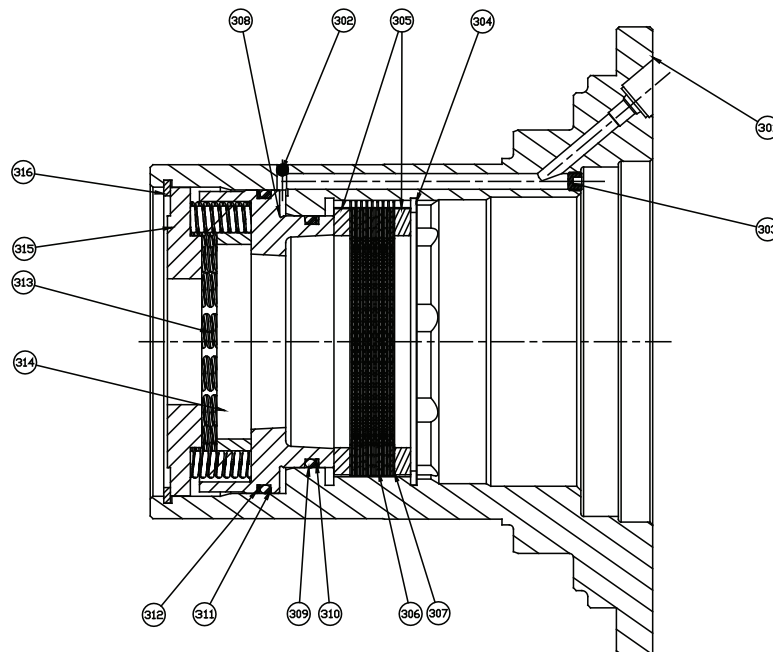


The brake housing weighs approximately 110 lbs (50 kg). Make certain lifting equipment has adequate capacity.

1. Place the brake housing on a clean, flat surface with the motor end, or large end, facing up.
2. Install a brake spacer (305) into the bottom of the splined bore.
3. Lubricate the friction discs in clean oil, using the same oil as that intended for the winch gear cavity. Install a steel brake disk (306) on top of the brake plate spacer. Next, install a friction disc (307). Then alternate steel and friction discs until the last steel disc is placed on top – nine (9) steel discs and eight (8) friction discs in total.
4. Install the second brake plate spacer (305) on top of the last steel brake disc. Install the retaining ring (304) into the groove above the spacer. Make certain the retaining ring is fully seated into the groove.
5. Turn the brake housing over and rest it on the motor end. Make certain the brake plates and spacers are resting flat on the bottom of the bore and are not hung up or held out of position. Insert the over-running brake clutch assembly to more closely align the splines of the friction discs. Either support the brake clutch assembly in position with a spacer on the table, or remove it completely.
6. Lubricate the o-rings and back-up rings (309, 310, 311, 312) with light grease or petroleum jelly. Install the o-rings and back-up rings into the piston grooves. Be sure to install the back-up rings to the outside of the o-rings toward the ends of the piston. Ensure the concave surface of the back-up rings is against the o-rings.
7. Install the piston (308) into the brake housing bore. Apply light, even pressure to the piston to seat it against the brake plate spacer.
8. Insert the spring spacer (314) into piston bore. Insert sixteen (16) brake springs (313) into the spring pockets created by the spacer. Two (2) openings will remain in the spacer. Make certain that the openings are located 180° apart.
9. Install the spring retainer (315) on top of the brake springs. Using a press, apply even pressure to the retainer to force it just below the bottom face of the retaining ring groove and install the retaining ring (316). Make certain that the retaining ring is fully seated in the groove before removing the pressure from the retainer.

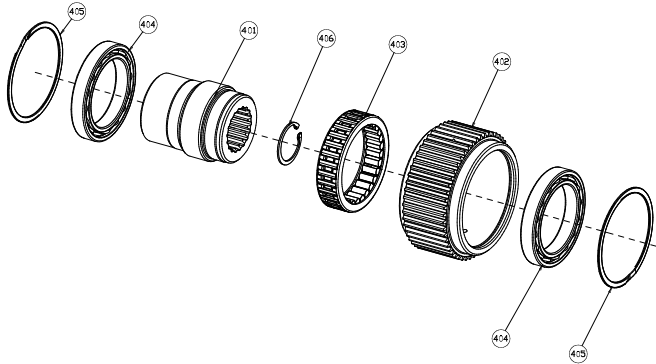
BRAKE ASSEMBLY PRESSURE TEST

Install the long tube fitting into the brake release port of the brake housing. Connect a hand pump with an accurate 0-2000 PSI (0 - 1,380 kPa) gauge and a shut-off valve to the fitting. Apply 1,000 PSI (6,900 kPa) to the brake. Close the shut-off valve and let the unit stand for 3 – 5 minutes. If after this time, there is any pressure loss, the brake assembly should be disassembled for inspection of the sealing surfaces and brake piston seals, and repaired as needed. Perform this test after any repair to the brake assembly.



OVER-RUNNING CLUTCH SERVICE

wear, corrosion, pitting or heat discoloration.



i **NOTE:** Outer race, Inner race, and Over-running clutch are NOT SOLD individually as replacement parts. If any of these parts require replacement, the entire over-running clutch assembly must be replaced. Use a marking pen to carefully note the relative orientation between the inner and outer races, and the direction of free rotation of the inner race. The clutch MUST be re-assembled correctly for proper winch operation.

⚠ WARNING ⚠

The polished surfaces of the inner and outer race and the over-running cams must be perfectly smooth to insure positive engagement of the clutch. The slightest defect may reduce clutch effectiveness, which may lead to loss of load control and result in property damage, injury or death. It is generally recommended to replace the entire clutch assembly if any component is defective. For these reasons, the over-running clutch assembly should be disassembled for inspection only if the winch has exhibited any unusual operation that would point toward a clutch malfunction, or the over-running clutch assembly shows external signs of mechanical damage.

DISASSEMBLY

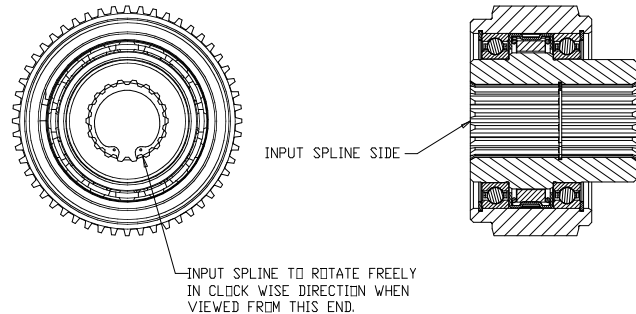
1. Remove one of the retaining rings (405) from the outer race. Push the inner race (401), bearings (404), and over-running clutch (403) through the outer race (402).
2. Use a small punch and hammer to carefully tap one of the bearings off of the inner race. The over-running clutch can now be removed from the inner race. Closely inspect the over-running clutch and the polished surfaces of the inner and outer race for wear, cracks, pitting, corrosion or mechanical damage. Closely inspect the bearings for any signs of damage,

⚠ WARNING ⚠

Failure to assemble the over-running clutch assembly with all parts oriented correctly may result in reduced brake effectiveness, which may lead to loss of load control and result in property damage, injury, or death.

ASSEMBLY

1. If both bearings have been removed from the inner race, install one of them now.
2. Install the over-running clutch onto the inner race. Rotate the inner race slightly to get the clutch started onto the inner race.
3. Install the other bearing onto the inner race.
4. The outer race should have one retaining ring installed in one end. Carefully slide the inner race, with bearings and clutch, into the outer race. Install the other retaining ring into the outer race.



CABLE DRUM SERVICE

DISASSEMBLY

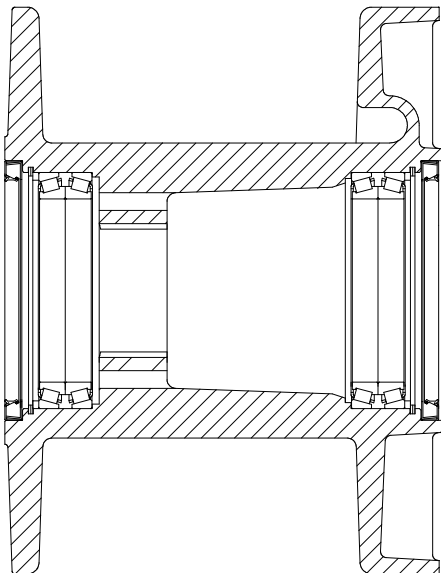


The cable drum is supported in the winch case by bearings on the output ring gear and the brake housing. If either of these components is removed, and the drum is not supported externally as described on page 20, the cable drum may come loose in the case. The cable drum weighs approximately 540 lb. (245 kg). Injury or damage to parts may occur if precautions are not taken.

1. Remove the cable drum as described on pages 20 through 22 of this manual.
2. Place the cable drum on a suitable work surface. The seals (187) must be removed to gain access to the drum bearings. Next, remove the spiral retaining ring (188) and the spacer ring (189) from the drum. Inspect the drum bearings (190) while installed in the drum. If scored, heat discolored or damaged in any other way, they should be removed and replaced.



NOTE: The bearings should only be removed if replacement is necessary as unintentional damage may occur during the removal process.

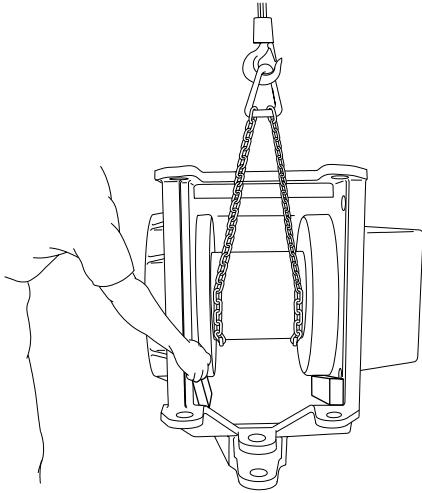


3. To remove the drum bearings, drive the bearing cones from the drum bore using a long, soft metal punch. Remove the inner bearing cups using a multi-jaw puller or by welding pulling lugs directly to the cups. Either method will destroy the bearing cups and require replacement.

ASSEMBLY

1. Chill the inner bearing cup in dry ice to shrink the diameter to aid installation. Install the bearing cup into the cable drum bearing bore. Use a .002 in. (.05 mm) feeler gauge to make certain the cup is fully seated against the drum barrel shoulder.
2. Lubricate the bearing cones with winch oil and install into the bearing cup. The bearing cones will be back-to-back with the large end of the cones in contact with each other.
3. Chill the outer bearing cup, as previously described, and install into the drum against the bearing cones. Take care during assembly to avoid damaging the bearing cage on the cone.
4. Install the spacer ring, then the spiral retaining ring into the cable drum.
5. Apply non-hardening sealing compound to the outside surface of the seal housing at installation. With the drum seal properly positioned in the drum bore, place a large steel plate over the seal for protection and press or drive it into place. The cable drum is ready for installation as described on the following page.
6. To maintain alignment, alternately install the ring gear and then the brake housing assembly into the cable drum bearings. The bearings have a snug slip-fit which requires extreme care during installation.

WINCH ASSEMBLY



CAUTION

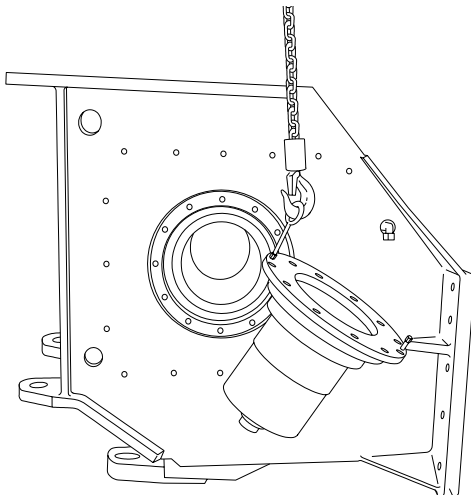
The cable drum weighs approximately 540 lbs (245 kg). Make certain lifting equipment has adequate capacity.

1. If the cable drum has been removed, support the drum securely between the winch housing walls with a suitable hoist and chain. The cable pocket end, or wide flange, must be located to the motor side, or RH side, of the housing.

CAUTION

The output ring gear weighs approximately 325 lbs (147 kg). Make certain lifting equipment has adequate capacity.

2. Install the output ring gear into the bore on the LH side of the housing. Apply a light coating of multi-purpose grease to the seal land on the ring gear pilot. Be careful to not damage the oil seal in the cable drum during installation. Locate the lifting eye boss at the topmost position. Tighten the capscrews to 110 lb-ft (149 N-m).



CAUTION

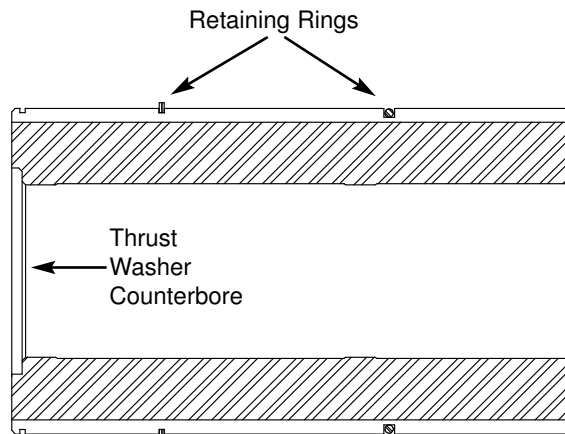
The brake assembly weighs approximately 140 lbs (64 kg). Make certain lifting equipment has adequate capacity.

3. Install the brake assembly into the bore on the RH side of the housing. Apply a light coating of multi-purpose grease to the seal land on the ring gear pilot. Be careful to not damage the oil seal in the cable drum during installation. Position the brake housing so that the brake release port is located in the upper LH quadrant, and the two-bolt motor mounting pattern is vertical. Tighten the capscrews to 110 lb-ft (149 N-m).
4. If not previously installed, install the over-running brake clutch into the brake assembly at this time. Insert the long end of the inner race inward toward the gearing. Ensure that the inner race turns freely in the clock-wise (CW) direction when looking at the input, or motor shaft end.

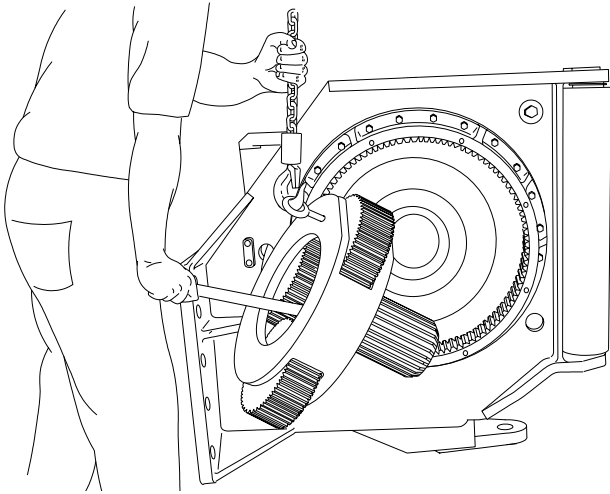
WARNING

Failure to assemble the over-running clutch with all parts oriented correctly may result in reduced brake effectiveness, which may lead to loss of load control and result in property damage, injury or death.

5. Apply a light coat of multi-purpose grease or petroleum jelly to the motor pilot o-ring, and install the o-ring onto the motor pilot. Install the hydraulic motor onto the brake housing, making sure to properly align the splines in the over-running brake clutch. Position the motor such that it angles toward the tractor. Tighten the capscrews to 280 lb-ft (380 N-m).



6. Make certain both mid-position retaining rings are properly seated in the grooves of the drum drive shaft. Install the shaft into the output planet carrier at this time, as described in the "Output Planet Carrier Service" section of this manual. Make certain the thrust washer counter bore is installed toward the planet gears.



CAUTION

The output planet carrier assembly weighs approximately 300 lbs (136 kg). Make certain lifting equipment has adequate capacity.

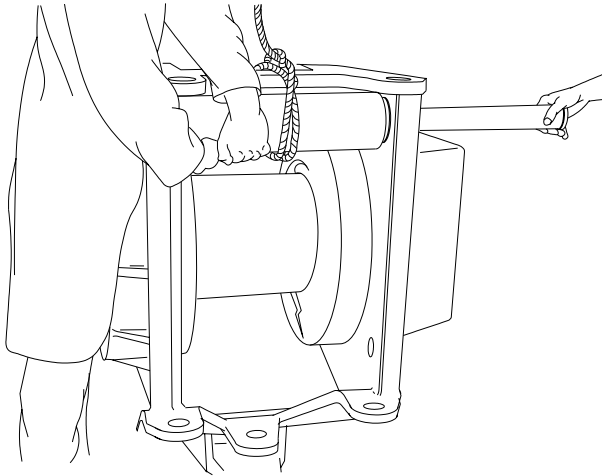
7. Install the output planet carrier assembly into the output ring gear while aligning the drum drive shaft and cable drum splines.
8. Apply multi-purpose grease to the thrust washer and install it into the counterbore in the drum drive shaft.
9. Install the input shaft (205) through the cable drum and into the brake clutch. Make certain the shaft is fully inserted into the brake clutch inner race.

CAUTION

The ring gear assembly and secondary planet carrier assembly weighs approximately 390 lbs (177 kg). Make certain lifting equipment has adequate capacity.

10. Install the o-ring into the groove of the secondary ring gear assembly then apply a light coat of multi-purpose grease or petroleum jelly to the o-ring. Install the ring gear assembly over the input shaft and onto the output ring gear. Make certain that the ring gear assembly flange seats fully against the output ring gear before tightening the capscrews and that the drain plug is positioned at the bottom of the winch. Tighten the capscrews to 110 lb-ft (149 N-m).

11. Install the spring retainer (202) into the clutch piston inside the ring gear assembly. Be sure to install the large diameter end first. Seat the spring retainer fully in the clutch bore.
12. Apply a light coat of multi-purpose grease to the needle roller bearing and thrust washer (203, 204). Install the needle roller bearing against the spring retainer, followed by the thrust washer.
13. Align the secondary sun gear (206) with the planet gears and install the sun gear through the spring retainer.
14. Apply a light coat of multi-purpose grease to the needle roller bearing and thrust washer set (207, 208). Install the bearing set into the sun gear bore over the input shaft. First, install a thrust washer (207), followed by the needle bearing (208), then the second thrust washer (207).
15. Install the primary sun gear (209) over the input shaft and into the secondary sun gear.
16. Install the carrier clutch assembly (210) onto the sun gears. Make sure the clutch disc teeth are in proper alignment with the secondary sun gear. The planet gears should install approx 1/2 in. (13 mm) beyond the end of the primary sun gear.
17. Install the o-ring (215) into the groove in the end cover and Lubricate the cover o-ring with multi-purpose grease or petroleum jelly.
18. Apply a light coat of multi-purpose grease to the needle roller bearing and thrust washers (207, 208) for both the cover center bore and hub on the carrier clutch housing.
19. Install the .03 in. (0.8 mm) thick thrust washer onto the carrier clutch hub. Install the needle roller bearing, followed by the .22 in. (5.6 mm) thick thrust washer. The thick washer will be outboard of the carrier.
20. Install the thrust washers and needle roller bearing into the center bore of the end cover. Make certain the bearing is installed between the thrust washers.
21. Carefully install the end cover onto the ring gear housing. Make certain the thrust bearings and washers remain in position until the cover is properly located. Tighten the capscrews to 110 lb-ft (149 N-m).
22. Install the fitting and drum clutch hose assembly (125) to the drum clutch release port in the ring gear housing. Attach the hose guard to the winch housing. Tighten the capscrews to 110 lb-ft (149 N-m).



23. Install the horizontal fairlead shaft and roller assemblies into the winch housing. Insert the shaft into the housing from the LH, or gear side. Make certain the spacer washers are installed at both ends of the fairlead roller. Tighten the capscrew to 45 lb-ft (61 N-m).
24. Install the vertical fairlead roller and shaft assemblies. Insert the shafts from the top of the housing. Make certain the spacer washers are installed at both ends of the fairlead roller. Tighten the capscrew to 45 lb-ft (61 N-m).
25. Grease the fairlead rollers as specified in the "Preventive Maintenance" section of this manual. Fill the winch to the proper level with the recommended oil.
26. Install all motor plumbing then refill the tractor hydraulic reservoir as required. Refer to the tractor operation and maintenance manual for specific procedures and recommendations.

27. Prefill the hydraulic motor with hydraulic fluid thru the tank port on the top side of the motor. Reinstall the fitting and hose to the motor tank port.

28. Start the tractor engine and cycle the winch in both directions, with no load, a few times to purge air from the lines. Check all fittings and connections for leaks and repair as required. Turn the tractor engine off when testing is complete.

29. Check and refill the tractor hydraulic reservoir as needed.

CAUTION

The motor cover weighs approximately 95 lbs (43 kg). A ½-13 tapped eyebolt hole is located in the top to aid handling. Make certain lifting equipment has adequate capacity.

30. Install the motor cover. Tighten the capscrews to 110 lb-ft (149 N-m).

BRAKE VALVE SERVICE

The brake valve is a reliable hydraulic valve with internal components manufactured to close tolerances. Due to the close tolerances and mating of components, the valve housing, spool, piston and check poppet are not available as replacement parts.

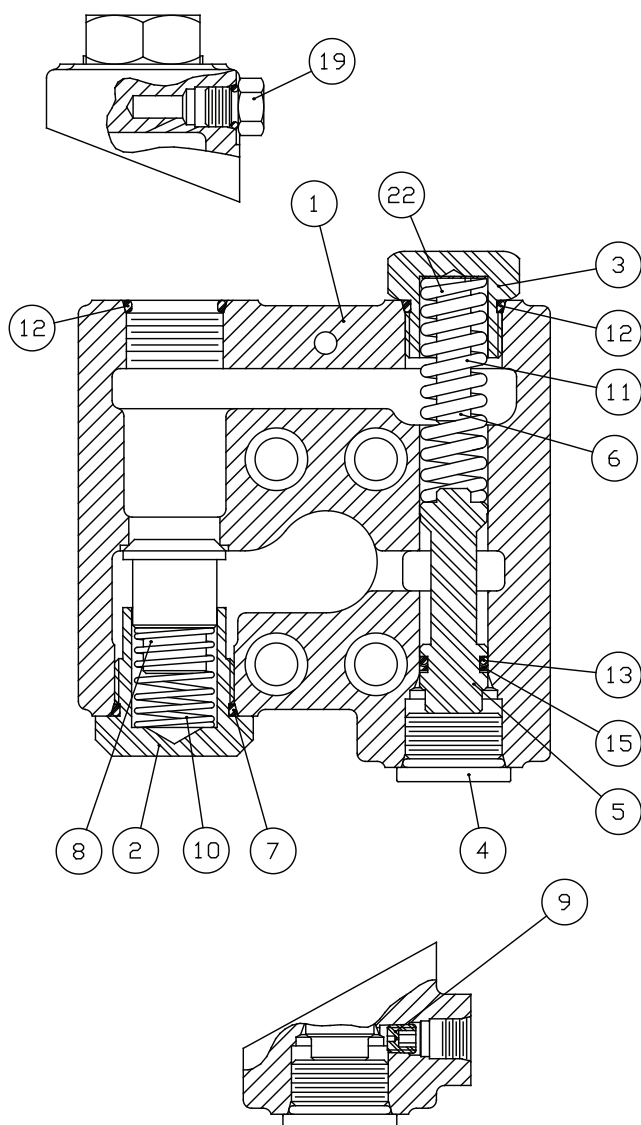
Before disassembling the brake valve, be sure you have conducted all applicable troubleshooting operations and are certain the brake valve is causing the malfunction.

Thoroughly clean the outside surfaces of the valve and work in a clean dust free area, as cleanliness is of utmost importance when servicing hydraulic components.

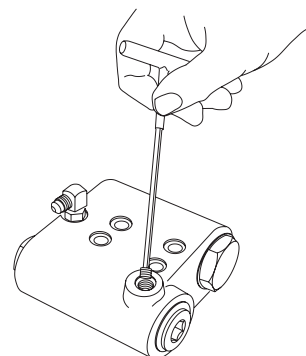
BRAKE VALVE ASSEMBLY		
ITEM	DESCRIPTION	QTY.
1	VALVE HOUSING (NSS)	1
2	CHECK VALVE RETAINER	1
3	SPRING RETAINER	1
4	PLUG	1
5	SPOOL (NSS)	1
6	DAMPER PISTON (NSS)	1
7	O-RING	1
8	CHECK VALVE POPPET (NSS)	1
9	PILOT ORIFICE	1
10	CHECK VALVE SPRING	1
11	SPOOL SPRING	1
12	O-RING	2
13	O-RING	1
14	O-RING	1
15	BACK-UP RING	1
16	BACK-UP RING	1
19	PLUG	1
22	SHIM	A-R

NSS - NOT SERVICED SEPARATELY. REPLACE COMPLETE VALVE ASSEMBLY.

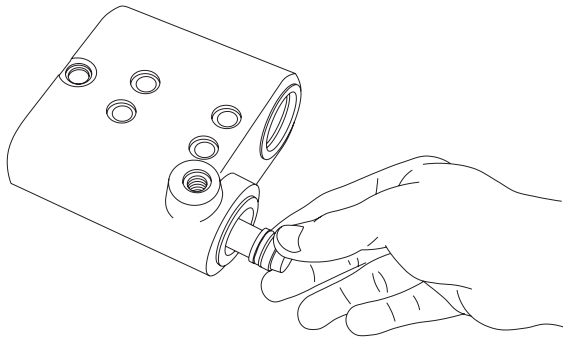
A-R - AS REQUIRED



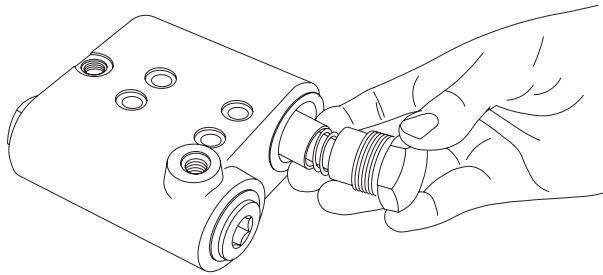
DISASSEMBLY



1. Remove the pilot orifice (9) from the brake release (BR) port using a 5/32 in. Allen wrench.
2. Remove the plug (19) from the drain port.
3. Remove the spool spring retainer (3) and spool spring (11). Check spring free length. Replace spring if less than 1 15/16 in. (49.2 mm) long.



4. Remove spool plug (4) and carefully remove spool (5).



5. Remove the check valve spring retainer (2), spring (10) and check valve poppet (8). Check spring free length. Replace spring if less than 1-1/2 in. (38.1 mm) long.

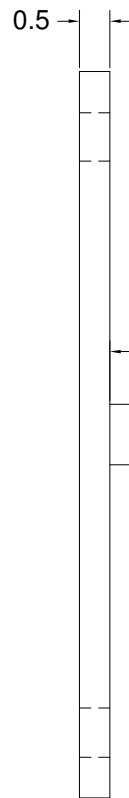
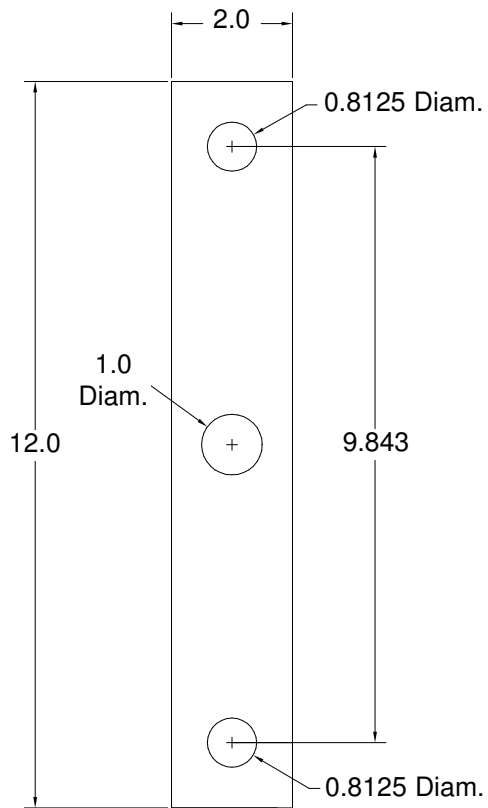
CLEAN AND INSPECT

1. Discard all O-rings and back-up rings. Clean all parts in solvent and blow dry. Inspect polished surfaces of spool for damage that may cause binding or leakage. Inspect spool bore in valve housing for damage or scoring. Inspect check valve seat in valve housing and check valve poppet. If the spools, bores or valves are damaged, the entire valve must be replaced as these parts are not serviced separately.
2. Inspect the .020 inch orifice in the pilot orifice (9) to be certain it is open.

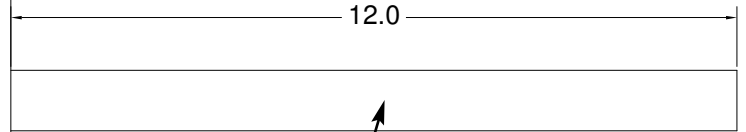
ASSEMBLY

1. Install new O-rings on the plug and spring retainers.
2. Install new O-rings and back-up rings on the spool. It is important that the back-up ring is on the correct side of its O-ring. Take care not to cut the O-ring during assembly. Let the spool set for ten minutes before installing them in their respective bores. This will allow the O-ring to return to their original size after being stretched.
3. Lubricate the spool bore and spool O-rings with hydraulic oil. Carefully install the spool into the valve housing. Always install the spool from the plug end as shown to minimize the possibility of damaging the O-ring. Install the plug, spool spring and spring retainer.
4. Install the check valve poppet, spring and check valve spring retainer.
5. Install the solid plug into the "drain" port.
6. Install the pilot orifice into the valve housing.
7. The brake valve is complete and ready to be installed on winch motor.

BRAKE CYLINDER LIFTING FIXTURE



All dimensions in inches



This piece can be a solid bar or piece
of heavy wall pipe or tubing.

Attach fixture to Brake Cylinder at the two holes
used for the hydraulic motor. Use two 3/4 - 10
grade 5 capscrews, 1 1/4 inches long.

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

°Celsius = 0.556 (°F - 32)

°Fahrenheit = (1.8°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