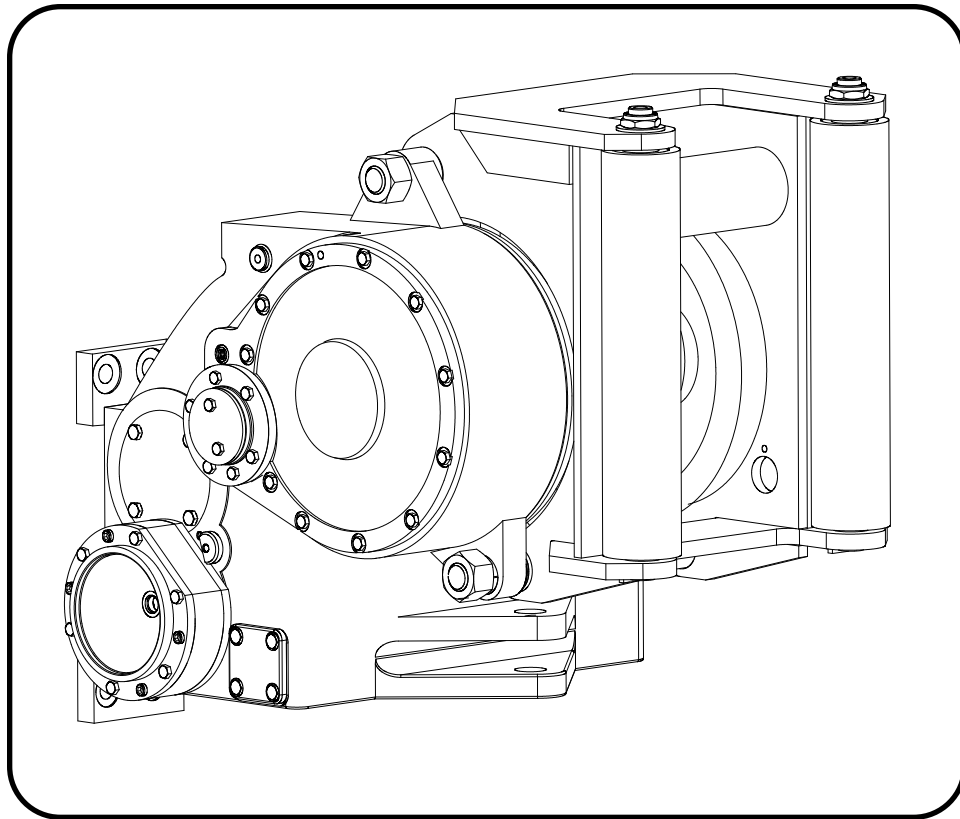


# CARCO®

## MODEL H60VS

# OPERATION AND PREVENTIVE MAINTENANCE MANUAL





# FOREWORD

Please read and understand this entire manual **BEFORE** operating or performing service on your CARCO winch. Retain this publication for future reference.

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

Continuing product improvements may cause changes in your winch, which are not included in this manual. Whenever a question arises regarding your CARCO winch or this publication, please contact the PACCAR Winch Technical Support Department:

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

Fax: (918)-259-1575

E-mail: winch.service@paccar.com.

## Parts and Service

CARCO provides a parts and service through a network of authorized construction equipment dealers. Parts and service are not available directly from CARCO. Please contact your local construction equipment dealer for parts and service, or contact CARCO for help defining a dealer near you.

## Model and Serial Number

The winch model number and serial number are important references as to which optional components were used at the time your winch was manufactured. The serial and model numbers are stamped into the ID tag located on the RH side of the winch case. The serial number is also stamped into the upper RH mounting pad of the winch case. Always refer to the serial and model numbers when requesting information or service parts.

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## Safety Information

Safety and informational callouts used in this manual include:



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



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



*This emblem is used to indicate an informational note or service tip.*

# 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 handling and performance capabilities. The following recommendations are offered only as a guide for the operator. Local rules and regulations will also apply.



## WARNING

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

1. Read all warning tag information and become familiar with all controls **BEFORE** operating the winch.
2. **NEVER** attempt to clean, oil or perform any maintenance on the winch with the tractor engine running, unless specifically instructed to do so in this manual.
3. Before starting the tractor engine, be certain all controls move freely and are placed in the "Brake On" (neutral) position.
4. **NEVER** operate the winch controls unless you are properly seated at the operator's station on the tractor and you are sure all 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 winch drum, cable rollers and entry area of fairleads and arches.
6. Ground personnel should stay in clear view of the tractor operator and clear of the winch drum. **DO NOT** allow ground personnel near a winch line under tension. A safe distance of 1½ 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 the rated winch capacity, which may result in the failure of the 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 the correct size ferrule for the cable and pocket in the winch drum. Never use knots to secure or attach

cable to the winch drum, or the hook to the 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 the rated capacity of the winch. Therefore, a minimum of five (5) complete wraps must be maintained on the winch drum.



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

## RECOMMENDED OPERATING PRACTICES

1. Leather gloves should be used when handling winch cable.
2. Operate the winch to match line speeds to job conditions.
3. Assure that personnel who are responsible for hand signals are clearly visible and that the signals to be used are thoroughly understood by everyone.
4. Inspect winch cable, rigging, winch and tractor at the beginning of each work shift. Defects should be corrected immediately.
5. Position the tractor for the straightest line of pull to reduce the wear on the winch cable and ensure even spooling.
6. When winding winch cable on the winch drum, never attempt to maintain tension by allowing the winch cable to slip through the hands. Always use the "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. The maximum rated bare drum line pull of the Model H60VS winch is 60,000 lb (267 kN).

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 two 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 H60VS 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, stop the engine and cycle the winch control lever(s) into all positions five (5) times. Refer to the tractor manufacturers operators and service manuals 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 the tractor parking brakes and lower any equipment to the ground before dismounting the tractor.
13. The winches described in this manual are neither designed nor intended for use or application 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 the fairlead rollers.
15. Keep equipment in good operating condition. Perform the scheduled servicing and adjustments defined in the "Preventive Maintenance" section of this manual. Use of proper lubricants is crucial.
16. An equipment warm-up procedure is recommended for all tractor start-ups, and is essential at ambient temperatures below +40°F (+5°C). Refer to the "Warm-Up Procedure" listed in the "Preventive Maintenance" section of this manual.

# MODEL DESCRIPTION

The CARCO H60VS winch is a hydraulically driven unit, fully enclosed in a rigid, cast ductile iron housing that is attached to the rear face of a crawler tractor. The winch is driven by a hydraulic motor and is fully dependent upon the tractor hydraulic system for power. The delivery of the oil supply to the winch motor varies with each specific tractor design.

The winch is equipped with equal speed gearing, power-in, power-out and freespool. The gear train and winch loads are held firm by a spring-applied, hydraulically released multi-disc static brake when the controls remain in the neutral "brake-on" position.

When operating the winch in the REEL-IN direction, the motor drives the gear train through a sprag-type over-running brake clutch. The inner race of the brake clutch serves as a coupling between the motor and the winch input shaft. The outer race of the brake clutch is connected to the friction discs of the spring-applied static brake with splines. The inner race turns freely in the REEL-IN direction, allowing the gear train to pull the load toward the winch and tractor. Immediately upon stopping, the sprag cams roll up to lock the inner race to the outer race and firmly hold the gear train. This action eliminates "load fall-back" to provide exceptionally precise load control.

When starting a REEL-OUT maneuver, the hydraulic oil enters the hydraulic motor but cannot escape as the brake valve, essentially a counterbalance valve, is closed. The pressure increases in the motor and the brake release pilot hoses forcing the brake piston against the springs causing the static load holding brake to be released. As the pressure continues to increase, the brake valve begins to meter oil flow out of the motor allowing the gear train and winch drum to rotate. The brake valve continuously modulates the oil flow to provide a smooth and controlled pay-out of the winch cable regardless of load or speed.

A patented combination spring-applied hydraulically released drum clutch and planetary gear carrier couples the winch input shaft to the remaining gear train. When a BRAKE-OFF function is performed, the drum clutch is released, allowing the idler gear, the first reduction gear and the second reduction gear to turn freely. This action enables an operator to drive away from a load utilizing the resistance of the gear train to maintain a tight wrap of cable on the drum.

When FREESPOOL is selected, hydraulic oil is routed to the freespool cylinder which is connected to the second reduction piston. As pressure is applied against the piston, the shifter fork, which is coupled to the clutch collar, causes the clutch collar to disengage from the pinion. This allows the pinion and the second reduction gear to turn freely without affecting the internal spring-applied brake.

**i** **NOTE:** *FREESPOOL should only be used to pull wire rope off of the cable drum **by hand**, such as when hooking to a load.*

An optional fairlead assembly is available for the H60VS winch. It may be ordered in either 3-roller or 4-roller design. A fourth roller kit is also available to upgrade a 3-roller assembly to a 4-roller unit. The fairlead is a "bolt-on" design, requiring no welding or special tools to install.

The hydraulic motor size (displacement) and winch gear ratio are matched to the specific tractor hydraulic system to maximize available power. Changes to the motor may be hazardous to the winch or personnel.

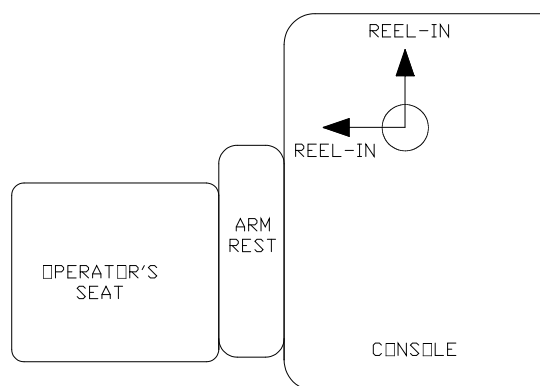
# WINCH OPERATION

## HYDRAULIC SYSTEM DESCRIPTION

Differential steer or hydrostatically controlled tractors are typically designed with a load sense, pressure compensating hydraulic system. These systems are usually equipped with variable displacement piston pumps, which supply oil to the implement valve only when a work function demands flow. Normally the pumps remain at approximately 300-400 PSI (2070 - 2760 kPa) in the low pressure, standby, condition. Moving the winch control lever will cause the pump displacement control system to upstroke to match the demand of the load. If the pressure starts to exceed the pump compensator setting (cylinder reaches full stroke or motor reaches maximum), the pump will destroke to decrease the flow and maintain the pressure at the compensator setting. The significance of this system is that there is no excess flow metered across a relief or partially shifted control valve spool to generate heat. Returning the control lever to BRAKE-ON (neutral) destrokes the pump to low flow, typically 0.2-0.5 GPM (.75-1.9 LPM), and returns the pump to the low standby pressure. Load sense hydraulic systems provide very precise load control while minimizing hydraulic loss efficiencies in the system.

The H60VS winch may be operated with a ripper controller or a CARCO supplied hydraulic joystick. The operation of the lever is dependent upon the lever used and the tractor hydraulic system. Tractor manufacturer supplied levers may be either single-axis or dual-axis joysticks. The CARCO supplied joystick is a dual-axis unit.

The mounting orientation of the control lever will determine the direction of lever actuation. However, in order to conform to current standards, the REEL-IN direction of lever movement **MUST** be either forward, toward the front end of the tractor, or left, toward the operator. The REEL-OUT direction **MUST** be directly opposite of the REEL-IN direction.



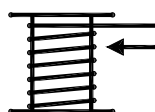
Use of the single-axis joystick requires the use of console-mounted toggle switches to activate BRAKE-OFF and FREESPOOL functions. Use of the dual-axis joystick allows these functions to be activated using the joystick, in the direction utilizing the opposite axis from REEL-IN / REEL-OUT.

## CONTROL OPERATION

The following paragraphs define winch operation for each function. The joystick provides infinitely variable winch speed control. Slight movement of the joystick lever in either REEL- IN or REEL-OUT direction results in very slow and controlled drum speeds. As the lever is moved further from the center neutral position, the drum speed will increase proportionally. When the lever is released, it will spring return to the neutral BRAKE-ON position. Because there are no directional clutches the lever may be moved in very small increments, or feathered, to achieve precise load control without winch wear or damage. The drum clutch function is not variable.

### BRAKE-ON (Neutral)

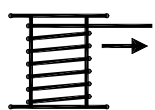
The control lever is spring-returned to center, or BRAKE-ON. The multi-disc, static parking brake is applied by spring force. Loads may be skidded with the lever in this position.



### REEL-IN

With the control lever in this position, the winch drum will pull in the cable and load. Cable 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.

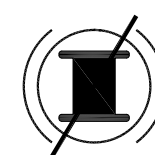
**IMPORTANT:** The control lever **MUST** be installed such the direction of movement for REEL-IN is either forward, toward the front of the tractor, or to the left, toward the operator.



### REEL-OUT

With the control lever in this position, the winch drum will rotate to power out the cable. Cable 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.

**IMPORTANT:** When using tractor supplied dual-axis control levers, ensure the direction of movement is directly opposite of the REEL-IN direction.



### BRAKE-OFF (Drum Clutch Release)

When this function is activated, the internal drum clutch will be released with hydraulic pressure, allowing the operator to drive away from a load. The resistance of the gear train will keep a tight wrap of cable on the drum to prevent cable over-run. It should be noted that cable can **NOT** be pulled off the drum by hand while in BRAKE-OFF mode.

BRAKE-OFF is typically activated by pressing a toggle switch on the RH tractor console, or by moving the control lever in the proper direction when using a dual-axis control lever. When using a dual-axis lever, the lever should be "detented", or held in position mechanically, to allow the operator to use both hands for tractor operation.

## ⚠ WARNING ⚠

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

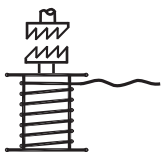


### LOW LOCK

LOW LOCK is activated by pressing a toggle switch on the RH tractor console, forcing the variable displacement motor to shift into the maximum displacement setting, for maximum line pull and minimum line speed to enhance load control. Deactivating LOW-LOCK, by pressing the toggle switch back to the normal position, will return the winch motor to full auto-speed operation, allowing the motor to self adjust between the maximum and factory-set minimum displacements to achieve the best match of line speed and line pull for the application.

## ⚠ CAUTION ⚠

The H60VS hydraulic motor and gear ratio is configured to match the specific tractor hydraulic system. It may not be possible to install the winch to 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.



### FREESPOOL

When activated, the winch cable drum will be disconnected from the hydraulic motor and primary gear train so that cable may be pulled off the drum by hand.

FREESPOOL is typically activated by pressing a toggle switch on the RH tractor console, or by moving the control lever in the proper direction when using a dual-axis control lever. When using a dual-axis lever, the lever should be "detented", or held in position mechanically.



**NOTE:** FREESPOOL is to be used **ONLY** for handling wire rope by hand. **DO NOT** attempt to release a load using FREESPOOL or to engage or disengage the gear train while the cable drum is rotating or when the tractor is in motion.

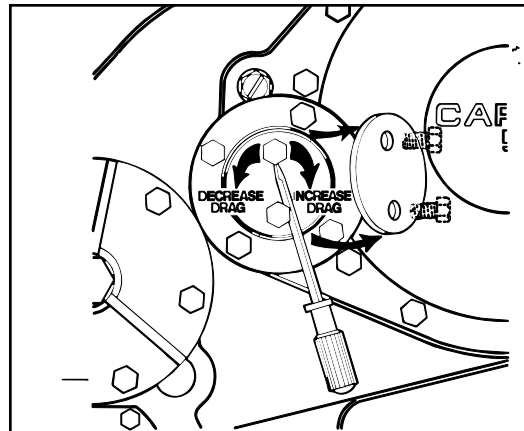
## ⚠ WARNING ⚠

FREESPOOL is **ONLY** to be used when the tractor is stopped, for pulling wire rope off the cable drum by hand. **DO NOT** use FREESPOOL when the tractor is in motion, to release a load or to move away from a load that is attached to the cable. Damage to the gear train and a loss of load control may result. Loss of load control may result in property damage, injury or death.

To release a load, or to move away from a load, the REEL-OUT function, or the BRAKE-OFF function **MUST** be used. Remove any load from the winch cable **BEFORE** selecting the FREESPOOL function.

The tractor and winch cable drum **MUST** be stopped **BEFORE** engaging the gear train. Gear train damage **WILL** result from attempting to engage the gear train while the cable drum is rotating.

## FREESPOOL ADJUSTMENT



Using a long screw driver or pry bar, turn the threaded adjuster clockwise until tight. Tap the adjuster with a hammer to seat the bearing and continue turning until the adjuster can no longer be tightened. Back the adjuster out no more than 1/16 turn maximum and secure with lock plate and cap screws. Tighten the cap screws to 75 lb•ft (102 N•m) torque.



**NOTE:** Tightening the threaded adjuster pushes the tapered bearing cup (outer race) into closer contact with the bearing cone and increases the bearing drag; much like tightening a wheel bearing nut on an automobile or truck. The snug fitting bearing cup will **NOT** move outward with the threaded adjuster when the adjuster is loosened. The winch must be operated under load for a brief period to allow the gear train load to push the outer bearing cup outward against the threaded adjuster before a reduction in bearing drag can be noticed.

## ⚠ CAUTION ⚠

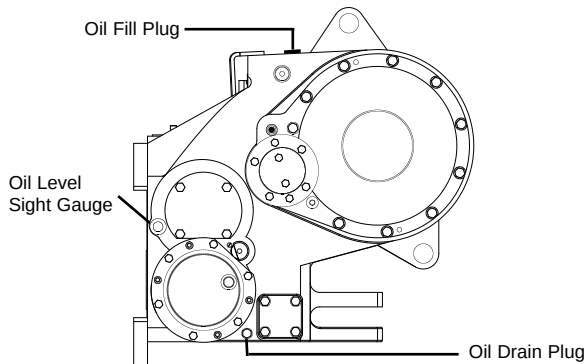
Do not back off adjuster more than 1/16 turn as this allows excessive shaft end play and may cause gear train misalignment, accelerated wear and noise.



# 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 LEVEL

Check the oil level weekly with the tractor and winch in a level position. Remove the access cover located above the clutch assembly on the LH side of the unit. The oil level should be just below the bottom of the opening. Add oil as required through the fill port on the top LH side of the winch case.

Refer to the page 8 for oil recommendations for your application.

## GEAR CASE OIL CHANGE

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

## ⚠ WARNING ⚠

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

To drain the oil, place the tractor and winch in a level position and remove the drain plug located on the lower LH side of the winch case, or remove the square cover from the lower rear LH side of the winch. Drain the oil into a suitable container and recycle or dispose of used oil in an environmentally responsible manner. Install the drain plug securely after all oil has been drained.

Refill the winch to the proper level with the recommended oil. Refer to page 8 for oil recommendations.

**OIL CAPACITY:** Approximately 48 qt (45 L)

## ⚠ CAUTION ⚠

To prevent serious damage to the winch gear train, do **NOT** operate the tractor engine while the oil is drained from the winch.

## TRACTOR HYDRAULIC RESERVOIR LEVEL

The tractor hydraulic reservoir oil level should be checked 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.

## VENT PLUG

The vent is located on the LH side of the winch near the top of the winch case. It is very important to keep this vent clean and unobstructed to limit leakage and winch seal damage. When changing the winch oil, remove the vent and thoroughly clean in safety solvent and reinstall. Do **NOT** replace with a solid plug.

## WINCH CABLE (WIRE ROPE)

Inspect the entire length of wire rope, and the chokers and hooks according to the wire rope and 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 hours or six months, whichever occurs first.

## WARM-UP PROCEDURE

## ⚠ WARNING ⚠

A warm-up procedure is recommended at each start-up, and is essential at ambient temperatures below +40°F (+4°C). Failure to warm the oil and the winch hydraulic system may result in erratic clutch/brake operation may result in property damage, personal injury or death.

Start the tractor engine and operate at the lowest RPM setting with the winch control in BRAKE-ON (neutral), allowing sufficient time to warm the hydraulic fluid.

After initial warm-up, operate the winch under a no-load condition, in both REEL-IN and REEL-OUT directions, several times to prime the lines with warm hydraulic fluid and circulate the winch gear oil. This action will minimize the temporary increase in brake-off drag caused by cold oil.

## FAIRLEAD ROLLERS

For units with the optional fairlead assembly installed, grease the rollers at the beginning of each work day. The vertical rollers have grease fittings at the top and the bottom of the shaft. The horizontal rollers have only one grease fitting located on the LH end of the shaft. 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 NLGI Grade 2 specification.

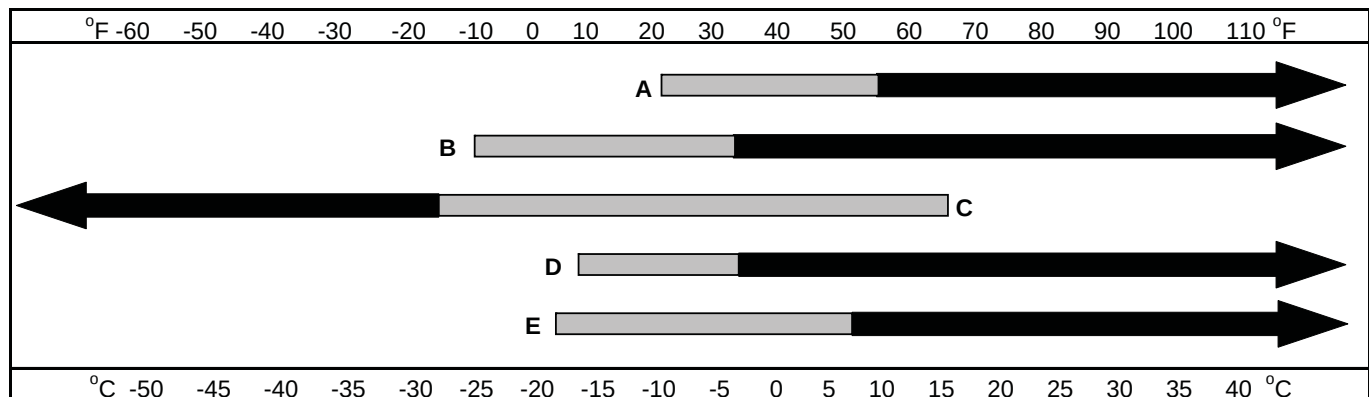
## RECOMMENDED OIL

We have published the following specification to help you 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 still 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 wt, MIL-L-2104C
- B - Series 3 Motor Oil SAE 5W30, MIL-L-2104C
- C - Hydraulic Oil, MIL-H-5606
- D - CAT TO-4 30 wt (recommended)
- E - CAT DEO CF-4 10W30

# GENERAL SPECIFICATIONS

Unit Weight (without oil or cable) ..... Approximately 2,515 lb (1,141 kg)

Gear Ratios Available :

Overall Ratio.....139.3  
.....218.0

## Cable Drum Dimensions

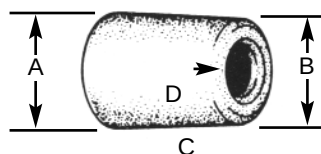
Barrel Diameter .....10 in. (254 mm)  
Flange Diameter .....19 7/8 in. (504 mm)  
Barrel Length .....12 3/8 in. (314 mm)  
Throat Clearance .....approx 9 in. (229 mm)

## Cable Storage Capacity

3/4 in. (19 mm) .....319 ft. (97 m)  
7/8 in. (22 mm) .....226 ft. (69 m)  
1 in. (25 mm) .....154 ft. (47 m)

## Cable Ferrule Part Number

3/4 in. (19 mm) .....29424  
7/8 in. (22 mm) .....29425  
1 in. (25 mm) .....29426



Cable Ferrule Dimensions  
A - 2-3/16 in. (56 mm)  
B - 2-1/32 in. (52 mm)  
C - 2-5/8 in. (67 mm)  
D - To match cable diameter

Gear Case Oil Capacity .....48 qt (45 L)  
Static Brake Release Pressure .....approximately 400 PSI (2,760 kPa)  
Brake-Off (Drum Clutch Release) Pressure .....approximately 320 PSI (2,205 kPa)

# RECOMMENDED FASTENER TORQUE

Higher or lower torques for special applications will be specified such as the use of spanner nuts, nuts on shaft ends, jam nuts and where distortion of parts or gaskets is critical.

Lubricated torque values based on use of SAE 30wt engine oil applied to threads and face of bolt or nut.

Avoid using thread lubricants as the applied torque may vary by 10-40% depending upon product used.

| Bolt Dia.<br>Inches | Thds Per<br>Inch | Torque (LB-FT) |       |         |       |
|---------------------|------------------|----------------|-------|---------|-------|
|                     |                  | Grade 5        |       | Grade 8 |       |
|                     |                  | Dry            | Lubed | Dry     | Lubed |
| 1/4                 | 20<br>28         | 8              | 6     | 12      | 9     |
| 5/16                | 18<br>24         | 17             | 13    | 24      | 18    |
| 3/8                 | 16<br>24         | 31             | 23    | 45      | 35    |
| 7/16                | 14<br>20         | 50             | 35    | 70      | 50    |
| 1/2                 | 13<br>20         | 75             | 55    | 110     | 80    |
| 9/16                | 12<br>18         | 110            | 80    | 150     | 110   |
| 5/8                 | 11<br>18         | 150            | 115   | 210     | 160   |

| Bolt Dia.<br>Inches | Thds Per<br>Inch | Torque (LB-FT) |       |         |       |
|---------------------|------------------|----------------|-------|---------|-------|
|                     |                  | Grade 5        |       | Grade 8 |       |
|                     |                  | Dry            | Lubed | Dry     | Lubed |
| 3/4                 | 10<br>16         | 265            | 200   | 380     | 280   |
| 7/8                 | 9<br>14          | 420            | 325   | 600     | 450   |
| 1                   | 8<br>14          | 640            | 485   | 910     | 680   |
| 1 1/8               | 7<br>12          | 790            | 590   | 1290    | 970   |
| 1 1/4               | 7<br>12          | 1120           | 835   | 1820    | 1360  |
| 1 3/8               | 6<br>12          | 1460           | 1095  | 2385    | 1790  |
| 1 1/2               | 6<br>12          | 1940           | 1460  | 3160    | 2370  |

To convert LB-FT to kg-m, multiply by 0.1383

To convert LB-FT to N-m, multiply by 1.356

# 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 <sup>2</sup> (sq.in.)   | X 645.15  | = millimeters <sup>2</sup> (mm <sup>2</sup> ) | millimeters <sup>2</sup> (mm <sup>2</sup> ) | X 0.000155 | = inches <sup>2</sup> (sq.in.)   |
| feet <sup>2</sup> (sq.ft.)     | X 0.0929  | = meters <sup>2</sup> (m <sup>2</sup> )       | meters <sup>2</sup> (m <sup>2</sup> )       | X 10.764   | = feet <sup>2</sup> (sq.ft.)     |
| VOLUME                         |           |                                               |                                             |            |                                  |
| inches <sup>3</sup> (cu.in.)   | X 0.01639 | = liters (l)                                  | liters (l)                                  | X 61.024   | = inches <sup>3</sup> (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 <sup>3</sup> (cu.in.)   | X 16.39   | = centimeters <sup>3</sup> (cc)               | centimeters3 (cc)                           | X 0.06102  | = inches <sup>3</sup> (cu.in.)   |
| feet <sup>3</sup> (cu.ft.)     | X 28.317  | = liters (l)                                  | liters (l)                                  | X 0.03531  | = feet <sup>3</sup> (cu.ft.)     |
| feet <sup>3</sup> (cu.ft.)     | X 0.02832 | = meters <sup>3</sup> (m <sup>3</sup> )       | meters3 (m3)                                | X 35.315   | = feet <sup>3</sup> (cu.ft.)     |
| fluid ounce (fl.oz.)           | X 29.57   | = millileters (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 <sup>2</sup> )      | kilograms/sq.cm. (kg/cm2)                   | 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 <sub>2</sub> O (60°F) | X 0.2488  | = kilopascals (kPa)                           | kilopascals (kPa)                           | X 4.0193   | = inches H <sub>2</sub> 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 <sup>6</sup>                | deci                                        | (d)        | = 0.1 or 10 <sup>-1</sup>        |
| kilo                           | (k)       | = 1,000 or 10 <sup>3</sup>                    | centi                                       | (c)        | = 0.01 or 10 <sup>-2</sup>       |
| hecto                          | (h)       | = 100 or 10 <sup>2</sup>                      | milli                                       | (m)        | = 0.001 or 10 <sup>-3</sup>      |
| deka                           | (da)      | = 10 or 10 <sup>1</sup>                       | micro                                       | (μ)        | = 0.000.001 or 10 <sup>-6</sup>  |