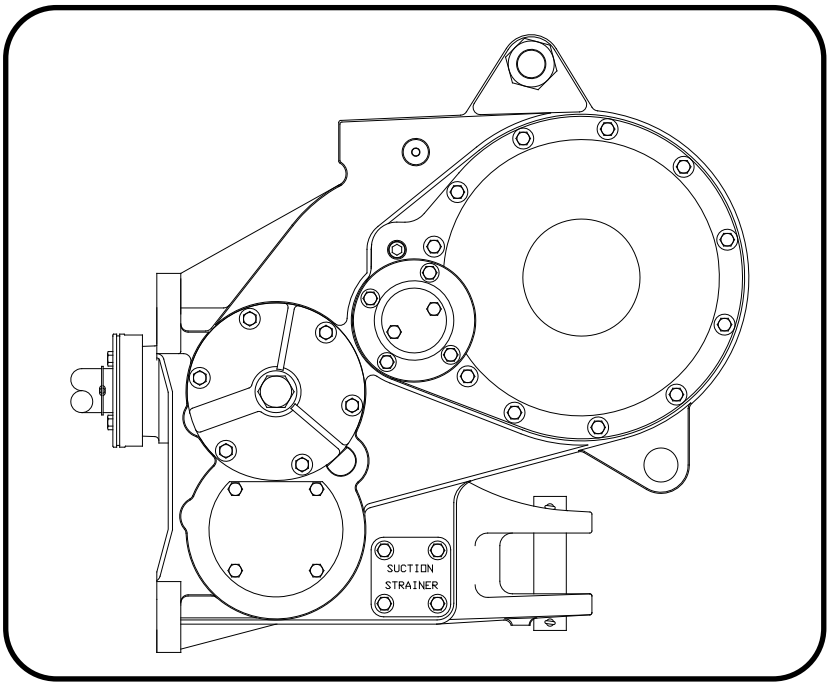
PACCAR WINCH DIVISION

Model PA80

OPERATION AND PREVENTIVE MAINTENANCE MANUAL

TABLE OF CONTENTS



PACCAR WINCH DIVISION
P.O. BOX 547 BROKEN ARROW, OK U.S.A. 74013
PHONE (918) 251-8511 FAX (918) 259-1575
www.paccarwinch.com

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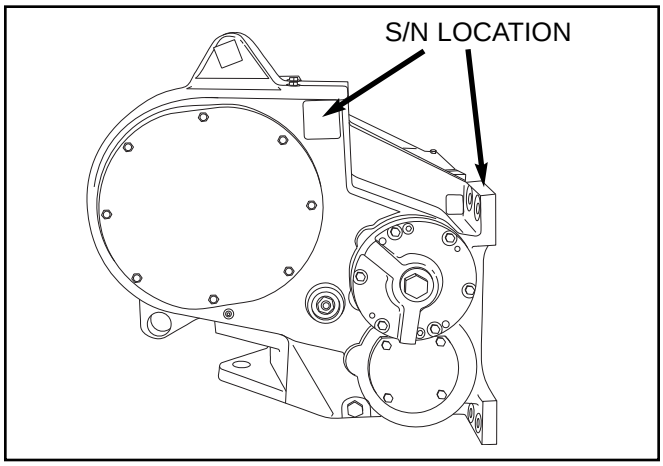
FOREWORD

Please read and understand this entire manual **BEFORE** operating or performing service on your PA80 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 PA80 winch or this publication, please contact the Paccar Winch Service Department at 1-918-251-8511, Monday - Friday, 0800 hrs - 1630 hrs CST, or by fax at 1-918-259-1575, or by e-mail at winch.service@paccar.com.



The winch model number is an important reference as to what optional components were used when the winch was manufactured. The model and serial numbers are stamped into the winch case as shown at left.

Record the information below for future reference. Always include the model and serial numbers when inquiring or ordering parts.

Model No. _____

Serial No. _____

In-Service Date _____

MODEL NUMBER DESCRIPTION

COMPLETE WINCH MODEL NUMBER - PA80 / A 0 0 0 0 0 - D7G

PA80 - BASIC WINCH MODEL (80,000 LBS RATED FIRST LAYER LINE PULL)
A - BEVEL GEAR RATIO (1:1)
0 - OVERWIND (CABLE IS PULLED ONTO THE DRUM OVER THE TOP)
0 - STANDARD BRAKE
0 - WITHOUT FREESPOOL
0 - NO FAIRLEAD
D7G - FACTORY BUILT FOR CATERPILLAR D7G TRACTOR

Safety and informational callouts used in this manual include:

⚠ WARNING ⚠

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

⚠ CAUTION ⚠

CAUTION - 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 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 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 the rated winch capacity, which may result in the failure of the cable and/or winch.**

8. Use only GENUINE Paccar Winch parts. Do not use parts from other winch manufacturers on your PA80 winch. Do not use Paccar Winch 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. Use fairleads when side pulls are common.

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. 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 adaptions for Paccar winches are designed and intended for use on specific models of crawler tractors. Changing winches between trac-

tors is not possible in some cases because of differences in tractor models. Some changes cannot be approved by Paccar because of safety limitations. Call a Paccar Winch dealer or the Paccar Winch factory prior to attempting winch modifications or before mounting on a different tractor.

11. 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 tractor engine and cycle the winch control lever into all positions five (5) times.

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 PA80 Power Shift winch is a single drum unit which mounts to the rear of a crawler tractor. It is driven by engine power through a PTO (power take-off). The winch may be operated independently or with the tractor transmission engaged. When operated properly, it is capable of utilizing maximum engine horsepower. The winch has equal speed gearing, power-in and power-out, using multiple-disc oil actuated friction clutches and a spring-applied hydraulically released multiple-disc oil brake.

WINCH OPERATION

HYDRAULIC SYSTEM

The winch contains an independent, internal hydraulic system. The winch housing serves as a reservoir and stores filtered oil for the internally mounted hydraulic pump. The pump is driven by a gear pressed onto the bevel pinion. The pump supplies oil whenever the PTO shaft is rotating. Oil from the pump is routed through a pressure filter then directed to the winch control valve where a stand-by system pressure is maintained at 320-410 PSI (2,200 – 2,830 kPa).

The system oil pressure is routed through the control valve body to the Directional and Brake control cartridges. Movement of the Directional control spool opens passages which direct oil to apply the REEL-IN (forward) or REEL-OUT (reverse) clutches and release the spring applied multi-disc oil brake.

Movement of the Brake spool will direct oil to release the brake only. The movement of the spools responds to the position of the operators Power Shift control lever by means of flexible control cables.

The winch hydraulic system is equipped with an accumulator. The accumulator stores a small amount of oil at system pressure to assist the application of the clutches and release of the brake under all operating conditions. The stored oil supply may also be used to release the spring applied brake whenever the tractor engine or torque converter is stalled. The accumulator stored oil supply is continuously refilled by the winch pump and valve whenever the PTO shaft is turning.

On tractors which supply PTO power through the torque converter, it is possible to cause the torque converter to stall if the tractor engine speed is too low. It is important that engine idle speed be set to factory specifications.

GEAR TRAIN

The winch bevel pinion, bevel gears, hydraulic pump and clutch friction discs are rotating whenever the tractor PTO shaft is rotating. Application of a clutch, REEL-IN or REEL-OUT, and the simultaneous release of the

brake will cause the rotation of the remaining gear train and cable drum.

The clutch shaft assembly (with bevel gears) must turn 40.4 times for one (1) rotation of the cable drum.

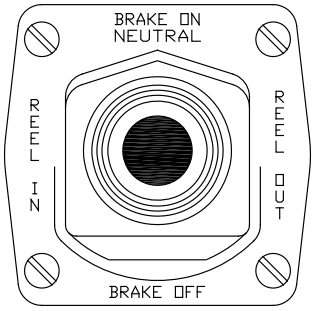
The direction of the tractor PTO shaft rotation and the right and left hand clutch location is determined by facing the rear of the tractor.

CONTROL OPERATION

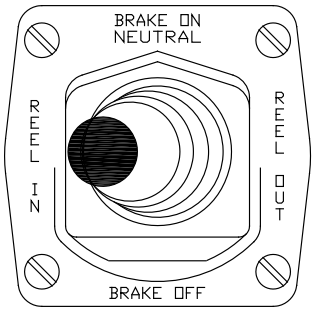
The control lever must ALWAYS be moved to its full travel in either the REEL-IN (forward) or REEL-OUT (reverse) position. The speed of rotation of the cable drum is controlled by varying the tractor throttle or the engine RPM. Sufficient hydraulic pressure is available to fully apply the clutches at engine (PTO) speeds above the tractor low idle setting.

⚠CAUTION⚠

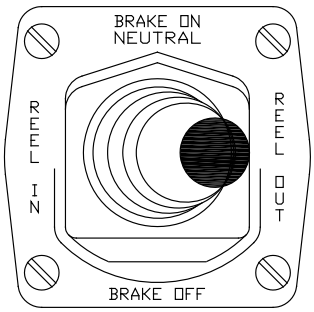
Any attempt to regulate cable drum speed (line speed) through the control lever by partially applying the clutch or “feathering” the clutches will result in excessive heat due to slippage, and severe damage to clutch discs may result.



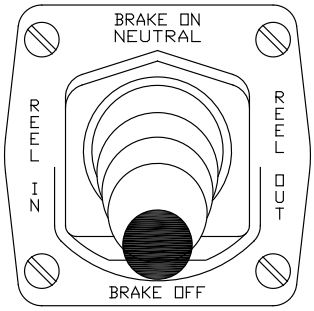
BRAKE-ON (neutral)
The control lever is spring-centered to the BRAKE-ON position. The winch brake is applied by spring force. The cable drum will not move. Use this control position for towing or skidding loads.



REEL-IN (forward)
The control lever is moved in the direction of tractor forward travel to the fully engaged position. The winch brake is hydraulically released and the REEL-IN clutch is hydraulically applied.



REEL-OUT (reverse)
The control lever is moved toward the rear of the tractor to the fully engaged position. The winch brake is hydraulically released and the REEL-OUT clutch is hydraulically applied.



BRAKE-OFF
The brake is hydraulically released by pulling the control lever toward the operator. Partial release is achieved by slowly moving the lever out of the BRAKE-ON position. The amount of brake release is proportional to the distance the lever is moved.

Full brake release in the BRAKE-OFF direction is achieved by moving the lever into the detented, or locked position at the end of the lever travel. With the brake fully released, the tractor may drive away from a load still attached to the wire rope.

Always return the lever to the BRAKE-ON position when BRAKE-OFF operations are completed or the winch is not in use.

Typical Logging Maneuver:

The hook man must be in clear sight of the operator at all times. With the winch cable fully spooled onto the winch cable drum, back the tractor close to the log to be skidded. **When the hook man holds the winch cable hook and signals he is ready, set the engine throttle at low RPM and move the winch control lever fully into the reel-out position.** Monitor the movement of the hook man. **Increase the speed of the engine to increase the speed of the winch to keep pace with the hook man. Do Not reel-out cable faster than the hook man can walk.** Excessively loose cable may become tangled and damaged when the winch is operated in reel-in under load.

After the winch cable is attached to the log, make certain the hook man has moved clear of the load by a distance of 1-1/2 times the working length of the cable. The working length of the cable is the distance from the winch to the log.

With the engine RPM near low idle, move the winch control lever fully into the reel-in position to reel-in slack cable and test the rigging of the cable to the log. If the rigging is secure, increase the engine RPM to pull the log close to the winch.

When the log is close to the winch, press the decelerator as you move the winch control lever to Brake-On (neutral). Make certain the hook man remains clear of the load. Press the decelerator and place the tractor transmission in first gear, forward. **Release the decelerator and increase engine speed as the tractor moves forward skidding the log.**

If traction is poor and the tractor cannot skid the log, press the decelerator and place the winch control fully in the Brake-Off position. With the tractor transmission in first gear, forward, release the decelerator and move the tractor forward, away from the log. Continue moving forward until the load can no longer be pulled in a reasonably, straight line or the winch cable has reeled out to the middle of the first layer of cable.

⚠ CAUTION ⚠

Always maintain at least 5 full wraps of cable on the drum to prevent the cable from pulling loose of the ferrule pocket. Winch cable that has come loose from the ferrule (anchor) pocket will cause loss of load control which may result in property damage, injury, or death.

Stop the tractor. Place the tractor transmission in neutral with the tractor brakes fully applied. Press the decelerator and move the winch control lever from the Brake-Off position to the Brake-On position. Pause one or two seconds then place the winch control lever fully into the Reel-In position and release the decelerator pedal to let the engine speed increase to enough RPM to safely reel-in the log. Increase engine speed if the torque converter is stalled at lower RPM.

Continue reeling in until the load is close to the tractor. Depress the decelerator and release the winch control lever to the Brake-On (NEUTRAL) position. Repeat skidding or winching as needed.

NOTE: *If the log slides back down the hill when moving the tractor forward with the winch control in the full Brake-Off position, the brake may be partially released by keeping the control lever between the Brake-On position and the fully released Brake-Off. The control lever is held in the fully released Brake-Off position by a spring loaded detent mechanism. The brake will be partially released as the control lever travels from the Brake-On to the full Brake-Off position.*

⚠ CAUTION ⚠

Always return the control lever to the Brake-On position after the maneuver is completed. The winch hydraulic control system will overheat if the winch control lever remains in the Brake-Off position for extended periods. Overheating the hydraulic control system will result in reduced winch component service life.

Summary:

Avoid making several short pulls when a longer pull could be made. Short pulls use more cycles of the winch, clutches, brakes, and hydraulics which increases heat and decreases component service life. Short pulls also increases the cycles of the tractor transmission, steering clutches and torque converter which has the same affect of increasing wear and decreasing component service life. More diesel fuel is consumed making several short pulls than a few long pulls.

⚠ CAUTION ⚠

Always shift the winch control lever FULLY into reel-in or reel-out. NEVER attempt to control the speed of the winch or load by partially shifting (feathering) the winch control lever. Clutch and brake component damage will occur.

PREVENTIVE MAINTENANCE AND SPECIFICATIONS

A regular program of preventive maintenance for your PA80 winch will minimize the need for emergency servicing and ensure long life and trouble-free service.

NOTE: *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 the recommendations of an independent oil analysis.*

1. OIL LEVEL

Check oil level at the beginning of each work shift, with the tractor and winch in a level position. The oil must be visible in the center of the sight gauge, located on the RH side of the winch. If a solid plug is used in place of the sight gauge, then remove the oil level plug and be sure the oil level is up to the bottom of the opening. If required, add oil through the oil fill port. Refer to "Recommended Oil" on page 7.

2. OIL CHANGE, FILTER AND STRAINER SERVICE

The oil and pressure filter should be changed and the suction strainer cleaned after the first 100 hours of operation, then every 1,000 operating hours or six (6) months, whichever occurs first.

⚠ WARNING ⚠

Hot oil may cause severe injury. Make certain the oil has cooled to a 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. Reinstall the plug securely after the oil has been completely drained. After draining, remove the four (4) suction strainer cover capscrews and the cover. Remove the suction strainer from the winch case then remove the metal band and magnetic rods from the strainer. Thoroughly wash the strainer in clean safety solvent and blow dry with compressed air. Inspect the wire mesh for damage or clogging from debris. Do not reuse a damaged suction strainer. Install the magnetic rods and the metal band onto the suction strainer. Lubricate the O-ring and install the strainer and cover into the winch case.

OIL CAPACITY . . . . . 78 qt (74 L)

The pressure filter is located inside the large access cover on the RH side of the winch. Remove the filter with a strap-wrench.

Lubricate the filter seal ring and adapter threads with new winch oil and install the new filter element onto the filter head. Hand-tighten ½ - ¾ turn after the seal ring makes contact with the filter head.

⚠ CAUTION ⚠

Do not operate the engine without oil in the winch. Serious damage to internal components may result.

Fill winch to proper level with recommended lubricant. Start the tractor and operate the engine at low idle. Correct any leaks.

3. CONTROL CABLE and PRESSURE ADJUSTMENT

While the access cover is removed, it is advisable to verify the control cable adjustment and hydraulic main relief pressure. Place the Power Shift control lever in the center “BRAKE-ON” (neutral) position. Install the yoke pins into the cable yokes / control valve spools and secure with hitch pins. The yoke pins should slip easily into the bores without any binding. The control valve spools are spring centered. If you notice any binding, turn the cable adjusters (on the front of the winch case) in or out as needed to obtain a “free-pin” condition.

⚠ CAUTION ⚠

Discharge accumulator oil supply **BEFORE** removing any hydraulic lines or servicing the winch. Personal injury may result from the sudden release of oil pressure.

Make certain the accumulator stored oil supply has been properly discharged.

To discharge the accumulator, shut the engine off and slowly cycle the Power Shift control lever into full REEL-IN and REEL-OUT position a minimum of five (5) times.

Install an accurate 0-600 PSI (0-5000 kPa) pressure gauge onto the gauge port quick-disconnect adapter, located next to the control cables on the right hand, front of the winch. Start the tractor and operate the engine at approximately 800 – 1000 RPM. The maximum pressure during the “charging” mode should peak at 390 – 410 PSI (2690 – 2830 kPa) when the valve changes to the “unloading” mode.

TIP: *Place the control lever in brake-off to use some of the oil stored in the accumulator which will cause the control valve to cycle from “unloading” into “charging” so that peak pressure can be observed.*

During normal operation, the control pressure will decay approximately 15-20% from the peak pressure then charge back up to 390 – 410 PSI when the valve cycles. If the maximum peak pressure needs adjustment, locate the differential pressure unloading (PU) cartridge on top of the control valve. Loosen the jam nut and, with a 3/16 in. hex key, turn the adjusting screw clock wise

(CW) to increase peak pressure and counter-clock wise (CCW) to decrease peak pressure.

⚠CAUTION⚠

The control valve has several exhaust ports that will spray oil out toward the technician when the control valve is operated. Install the cover between tests or use a piece of cardboard to deflect the oil spray.

Stop the engine, discharge the stored oil pressure from the accumulator as described earlier and move the test gauge to the “B” port on the brake assembly. A -6 ORB adapter is needed.

Start the tractor engine and operate at approximately 800-1000 RPM. Move the control lever into the brake-off position and observe the brake release pressure at port “B” on the brake.

Adjust the control cable to achieve the highest pressure, approximately the same as the main system pressure, when the control lever is latched in the brake-off position. The pressure gauge MUST read 0 PSI (0 kPa) in the brake-on position.

⚠CAUTION⚠

If the brake release pressure does NOT return to 0 PSI (0 kPa) when the control lever is in the brake-on position, the brake may slip when holding a heavy load which may result in loss of load control, property damage, injury or death. This condition indicates that the control cable is not adjusted correctly and may also result in excessive heat and accelerated wear of brake and hydraulic components.

Place the control lever in brake-on position, remove the pressure gauge from the brake test port and install the plug.

Operate the engine at approximately 1200 RPM for five minutes to recharge the hydraulic system. Check for proper operation of all functions and check for leaks. Install the access cover and tighten the eight fasteners to 75 lb-ft (102 N-m) torque.

4. VENT PLUG

The vent plug is located on the RH forward side of the winch case. It is very important to keep this vent clean and unobstructed. Whenever the oil is changed, remove the vent plug, clean in solvent and reinstall. **DO NOT** replace with a solid plug.

5. WINCH CABLE (wire rope)

Inspect the entire length of wire rope according to the wire rope manufacturer's recommendations.

6. MOUNTING BOLTS

Check / tighten all winch mounting fasteners to the recommended torque after the first 100 hours of operation, then every 1,000 operating hours or six (6) months, whichever occurs first.

7. WARM-UP PROCEDURES

⚠ 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 winch hydraulic system may result in erratic brake / clutch operation, which may result in property damage, personal injury or death.

Start the tractor engine and operate at low idle for five (5) minutes.

Operate the winch alternately in Reel-In and Reel-Out with no load to warm the oil and lubricate the gear train.

SERVICE SPECIFICATIONS

Unit Weight, without oil, cable or winch adapters
2,400 lb (1,090 kg)

Cable Drum Dimensions:
- Barrel Diameter . . . . . .11.5 in. (292 mm)
- Flange Diameter . . . . . .19-7/8 in. (505 mm)
- Barrel Length . . . . . .13 in. (330 mm)
- Throat Clearance . . . . . .Approx.9 in. (229 mm)

Cable Storage Capacity:
- 1 in (25 mm) . . . . . .180 ft (55 m)
- 1-1/8 in. (28 mm) . . . . . .115 ft (35 m)

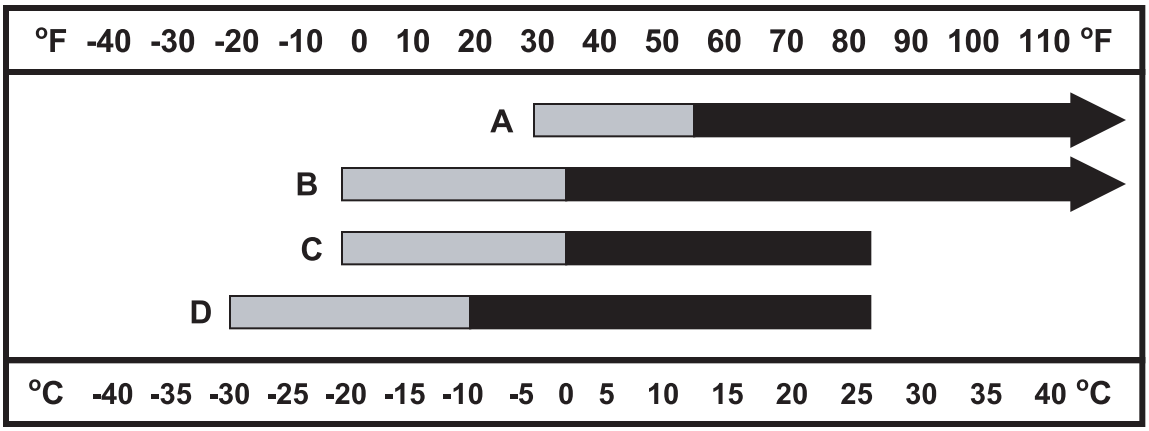
Hydraulic System (winch case)
- Oil Capacity . . . . . .78 qt (74 L)

Operating Pressure . . . . . .390 - 410 psi
(2,690 - 2,930 kPa)

RECOMMENDED OIL

We have published the following specification to help you determine which lubricant is best suited to your application. 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 detailed copy of the product specifications.

Prevailing Ambient Temperature



! WARNING !

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

A - HTF Type C3/C4 SAE 30, CAT TO4 SAE30
B - Case TCH MS 1210, CAT TO4 SAE 10W30, JD HY-GARD J20C
C - HTF Type C4/C4 SAE 10, CAT TO4 SAE 10W, KOM HDTF 10
D - CAT TO4 SAE 5W20 spc., JD HY-GARD LOW VISCOSITY J20D

Basic Oil Requirements

15,000 SUS maximum allowed viscosity at cold start-up; requires extended equipment warm-up.
3,000 SUS maximum allowed viscosity at cold start-up; requires normal equipment warm-up.
60 SUS minimum allowed viscosity at maximum winch operating temperature assuming ambient plus 80 °F (27 °C).

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

The general purpose torque shown in the chart below applies to SAE Grade 5 and Grade 8 bolts, studs and standard steel full, thick and high nuts.

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 30 engine oil applied to threads and face of bolt or nut.

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

RECOMMENDED FASTENER TORQUE

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

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

To convert lb-ft to kg-m, multiply lb-ft value by 0.1383.

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)	centimeters3 (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)	meters3 (m3)	X 35.315	= $feet^3$ (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^2)	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_2O (60^oF)	X 0.2488	= kilopascals (kPa)	kilopascals (kPa)	X 4.0193	= inches H_2O (60^oF)
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 106	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}