RAYMOND

Maintenance Manual

Model 4450 Sit-Down Counterbalanced Lift Truck With The *ACR System*™

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Models	Serial No.
C30 C35 C35S C40	445-09-10002 and up

1113065A **Issued: 15 Mar 2010**

This publication, 1113065, applies to Raymond Model 4450 Sit-Down Counterbalanced Lift Trucks. Changes occur periodically to the information in this publication.

For revision information, see “Page Revision Record” on page iii.

If you need assistance with your lift truck, or to order additional copies of this manual, contact your local authorized Raymond Dealer.

To locate your local authorized Raymond Dealer, go to www.raymondcorp.com.

Table of Contents

Page Revision Record

This section is a record of all revised pages in this manual. Whenever a page is revised, this section is updated and included in the revision package.

Pages are revised due to technical and non-technical changes described as follows:

- Technical changes – These changes are identified by a vertical line (change bar) in the left margin next to the change. Pages affected by technical changes are identified with "Page Revised: Mo/Day/Yr" in the footer. These pages are also available on the *Raymond* iNet.
- Non-technical changes – These changes consist of typographical and grammatical corrections, paragraph renumbering, repagination, and so on. Non-technical changes are not identified with a change bar, however, affected pages are identified with "Page Revised: Mo/Day/Yr" in the footer.

Document Revision History

1113065A Original Issue . . . . . 15 Mar 2010

Service Bulletin List

The following Service Bulletins have been incorporated into this manual.

Use the blank rows below to log Service Bulletins when they are added to this manual.

Document Number	Subject	Date

Product Improvement Notice List

The following Product Improvement Notices have been incorporated into this manual.

Use the blank rows below to log Product Improvement Notices when they are added to this manual.

Document Number	Subject	Date

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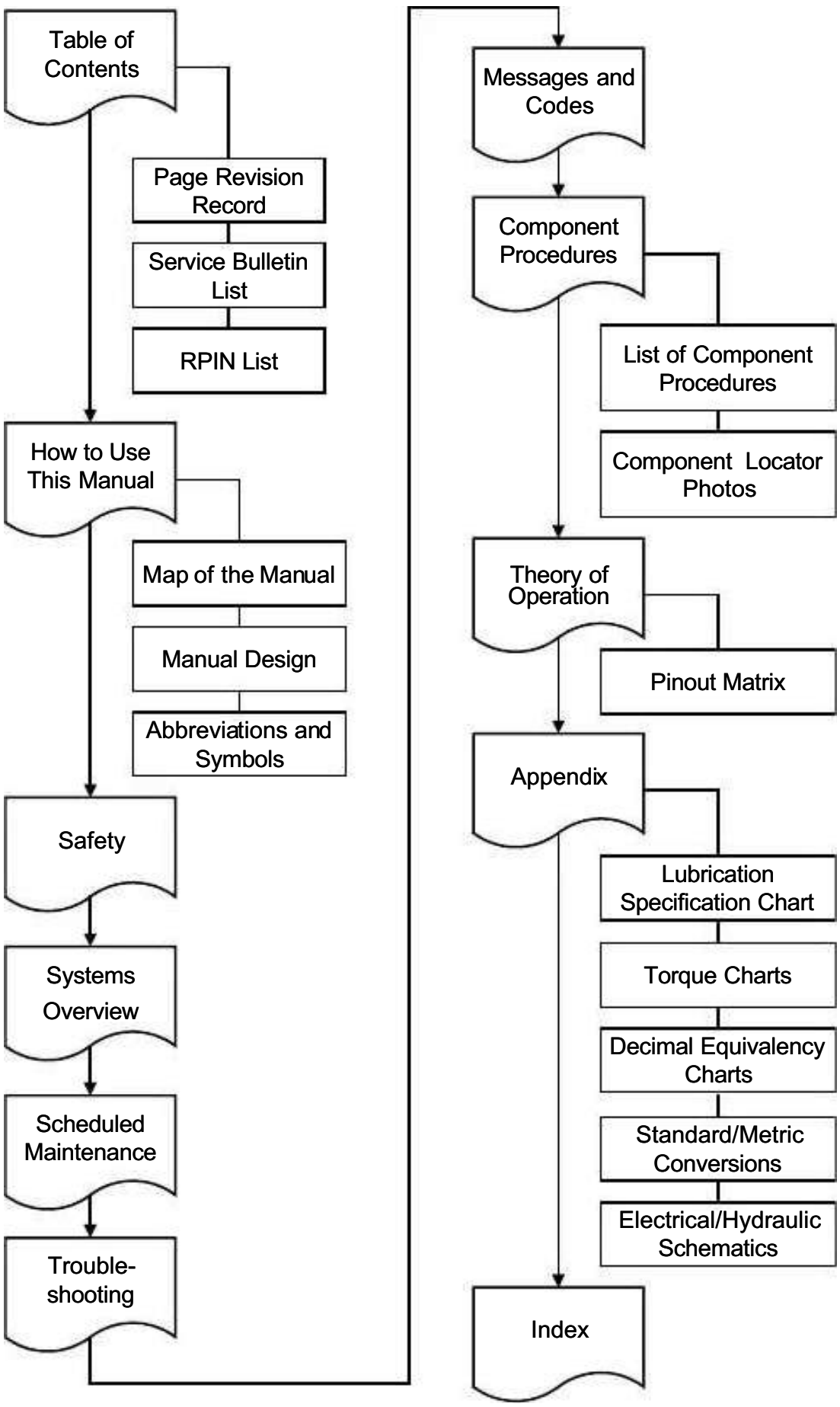
Section 1. How to Use This Manual

Map of the Manual



Manual Design

This manual is designed with the following objectives in mind:

- provide technical coverage for expected levels of user expertise
- anticipate your needs and reduce your decisions regarding maintenance
- reduce page flipping through a "one-stop shopping" approach

The two-line running page header at the top of each page tells you:

- Name of the manual
  (Model 4450 Maintenance Manual)
- Current Chapter Title
  (for example, this page; How to Use This Manual)
- Current topic
  (for example, this page; Manual Design)

This manual consists of the following sections:

- **1. How to Use This Manual** explains the manual format and design as well as abbreviations and symbols used.
- **2. Safety** explains warning and caution notes, general safety rules, and safety rules for batteries, static, jacking, and welding.
- **3. Systems Overview** includes general lift truck overview, programming instructions, and configuration menu.
- **4. Scheduled Maintenance** outlines the recommended schedule of preventive services to keep your lift truck working most efficiently.
- **5. Troubleshooting** is designed to take you from a symptom to a specific sequence of tests in order to isolate a failing component.
- **6. Messages and Codes** lists display messages and electrical fault codes.
- **7. Component Procedures** gives step-by-step procedures for testing, removal, installation, and adjustment of individual truck components. Components are grouped by truck system.

  To find a component procedure, you may use one of three methods:
  - Look up the component name in the List of **Component Procedures**.
  - Find the component in the **Component Locator Photos**.
  - Look up the component name in the maintenance manual **Index**.
- **8. Theory of Operation** explains signal flow within the electrical and hydraulic systems for various conditions of lift truck operation. This chapter also contains a detailed connection point table (Pinout Matrix) designed to assist in testing and troubleshooting the truck.
- **Appendix** contains reference information such as torque values, lubricants, standard/metric conversions, and system schematics.
- **Index** lists subjects alphabetically.

Abbreviations and Symbols

The following abbreviations, acronyms, and symbols are used in this manual.

Term/Symbol	Definition
A	Ampere
AC	Alternating Current
Agnd	analog ground
amp	Ampere or amplifier
approx.	approximately
Assy	assembly
aux	auxiliary
AWG	American Wire Gauge
CAN	Controller Area Network
cc	cubic centimeter
Conn.	Connector or Connection
CS	cold storage
DC	Direct Current
DMM	Digital Multi Meter
EE	UL Electric Truck Type Certification Rating where electrical equipment is completely enclosed
EPO	Emergency Power Off
ESD	Electrostatic Discharge
ESDS	Electrostatic Discharge Sensitive
ft.	foot or feet
gal.	gallon or gallons
GPM	Gallons Per Minute
HCB	Hydraulic Control Board
Hz	Hertz
in.	inch or inches
kg	kilogram(s)
km/hr	kilometers per hour
kPa	kilo Pascal
lbs.	pounds
LED	Light Emitting Diode
mA	milliampere
mm	millimeter
mPa	megapascal
mph	miles per hour
No.	number
Nm	newton meter
OD	Operator Display
opt.	optional
OTM	over-the-mast
pot	potentiometer
PPA	Pump Power Amplifier
psi	pounds per square inch
P/N	Part Number
RPM	Revolutions Per Minute
SAE	Society of Automotive Engineers
SOL	Solenoid
S/W	software
temp	Temperature
TPA	Traction Power Amplifier
UL	Underwriters Laboratories, Inc.
V	Volt or Volts
VDC	Volts Direct Current
VM	Vehicle Manager
wrt	with respect to

Term/Symbol	Definition
w/	with
™	trademark
©	copyright
+	plus or positive
–	minus or negative
±	plus or minus
°	degrees
°F	degrees Fahrenheit
°C	degrees Celsius
%	percent
=	equals

Abbreviations and Symbols

Section 2. Safety

Definitions

Throughout this manual, you will see two kinds of safety reminders:

⚠ WARNING

Warning means a potentially hazardous situation exists, which, if not avoided, could result in death or serious injury.

⚠CAUTION

Caution means a potentially hazardous situation exists, which, if not avoided, may result in minor or moderate injury or in damage to the lift truck or nearby objects. It may also be used to alert against unsafe practices.

General Safety

Do not operate or work on this lift truck unless you are trained, qualified, and authorized to do so, and have read the Owner and Operator Manuals.

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Know the lift truck's controls and what they do.

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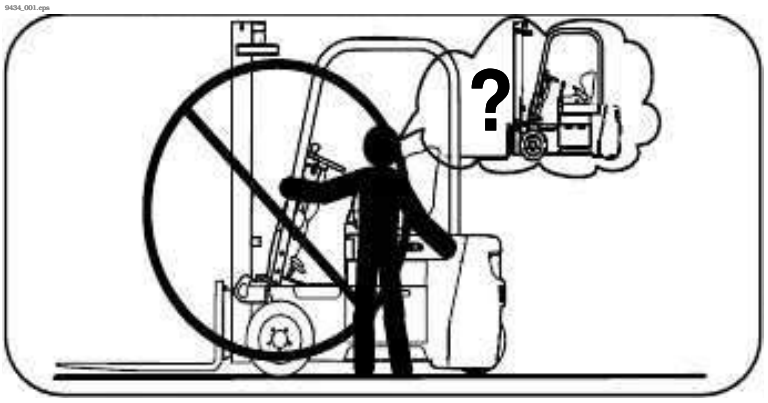

Do not operate this lift truck if it needs repair or if it is in any way unsafe.

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Operate this lift truck only from the operator's position.

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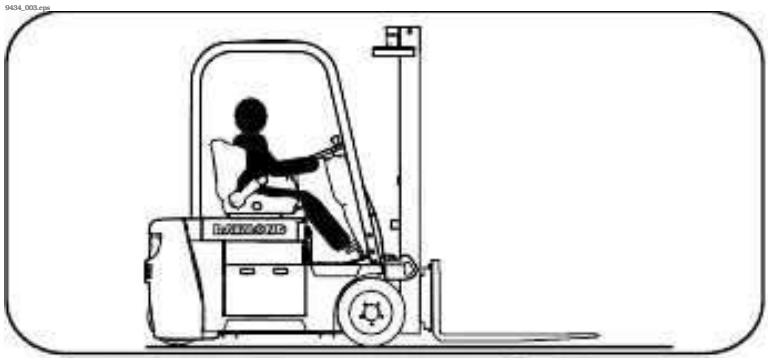

Before working on this lift truck, always turn the key switch OFF and disconnect the battery connector (unless this manual tells you otherwise).

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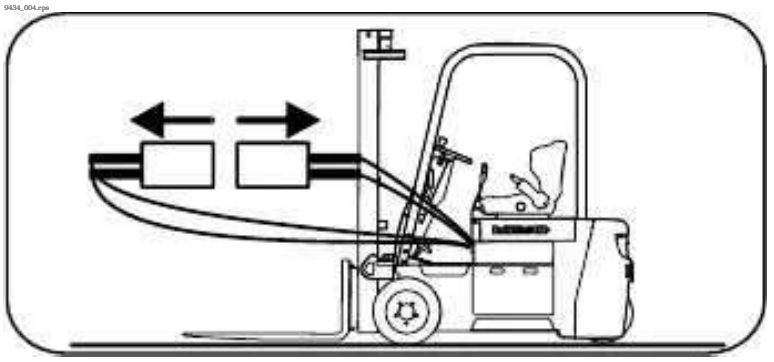

Do not wear watches, rings, or jewelry when working on this lift truck.

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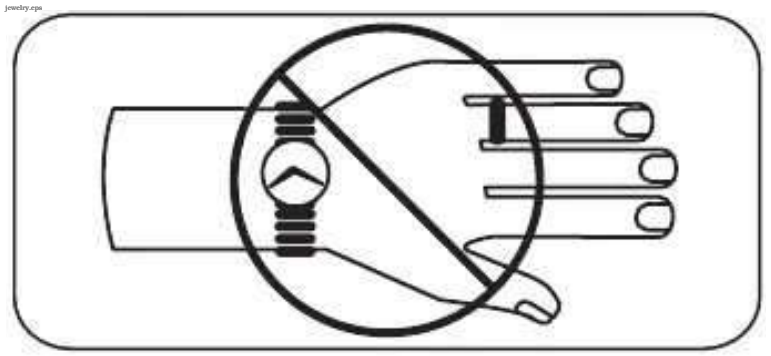

Follow the scheduled lubrication, maintenance, and inspection steps.

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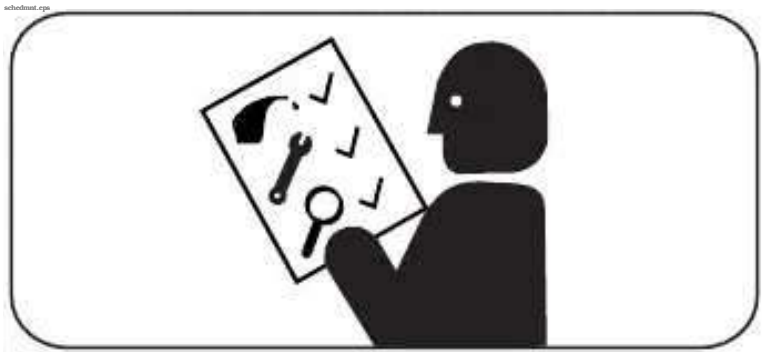

General Safety

Follow exactly the safety and repair instructions in this manual. Do not take shortcuts.

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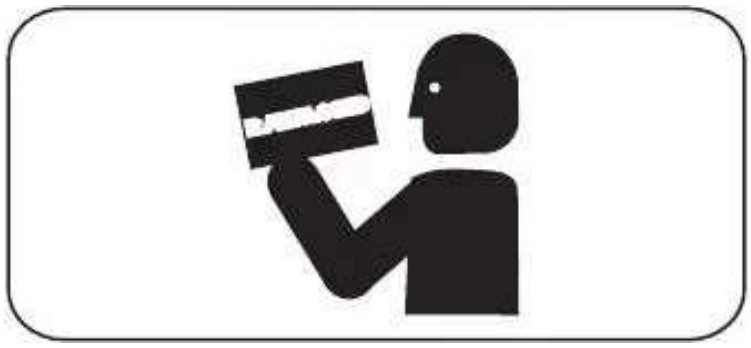

Do not use an open flame near the lift truck.

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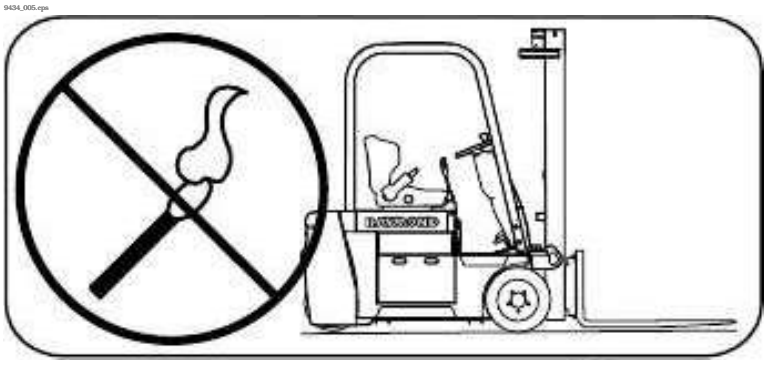

Do not use gasoline or other flammable liquids for cleaning parts.

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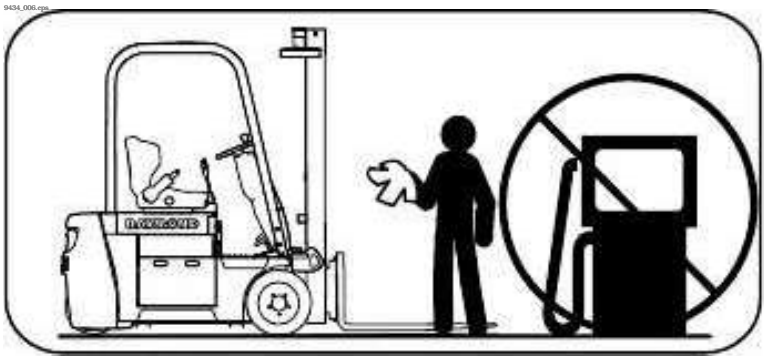

Clean up any hydraulic fluid, oil, or grease that has leaked or spilled on the floor.

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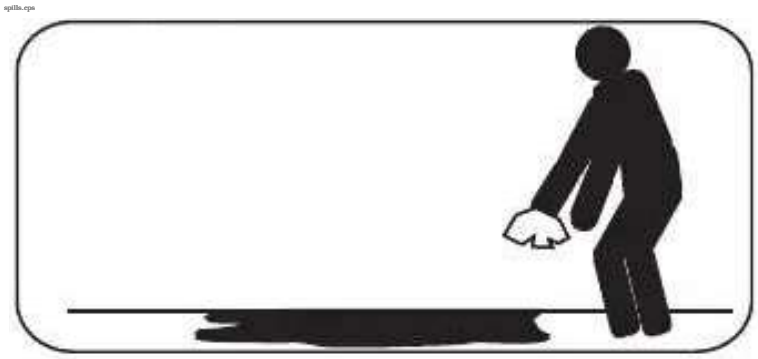

Always park this lift truck indoors.

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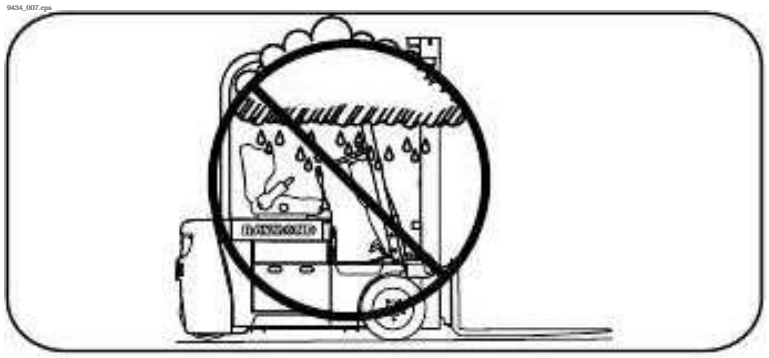

Do not wash this lift truck with a hose.

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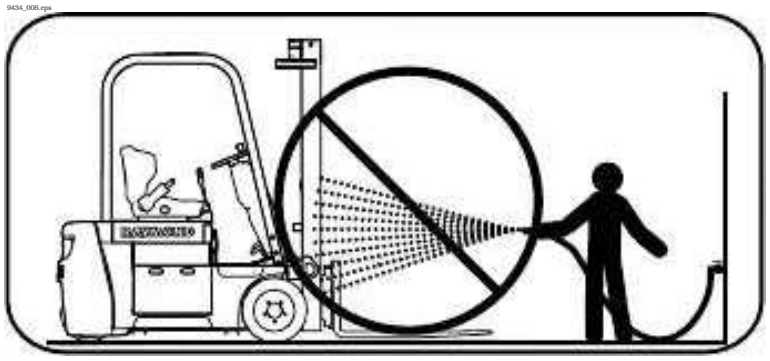

Do not add to or modify this lift truck until you contact your local Raymond dealer to receive written manufacturer approval.

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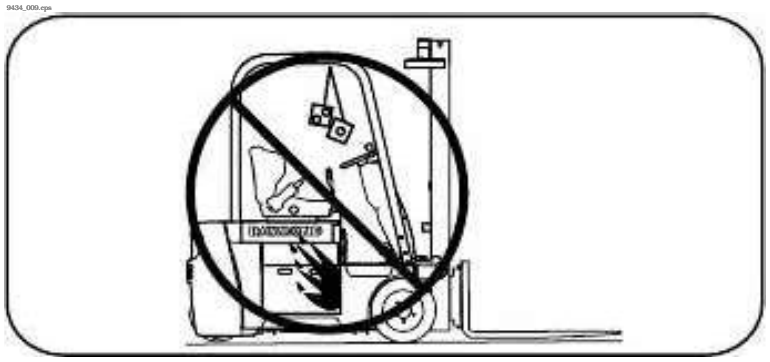

Do not park this lift truck in a cold storage area overnight.

Battery Safety

⚠ WARNING

As a battery is being charged, an explosive gas mixture forms within and around each cell. If the area is not correctly ventilated, this explosive gas can remain in or around the battery for several hours after charging. Make sure there are no open flames or sparks in the charging area. An open flame or spark can ignite this gas, resulting in serious damage or injury.

Battery electrolyte is a solution of sulfuric acid and water. Battery acid causes burns. Should any electrolyte come in contact with your clothing or skin, flush the area immediately with cold water. Should the solution get on your face or in your eyes, flush the area with cold water and get medical help immediately.

Read, understand, and follow procedures, recommendations, and specifications in the battery and battery charger manufacturer's manuals.

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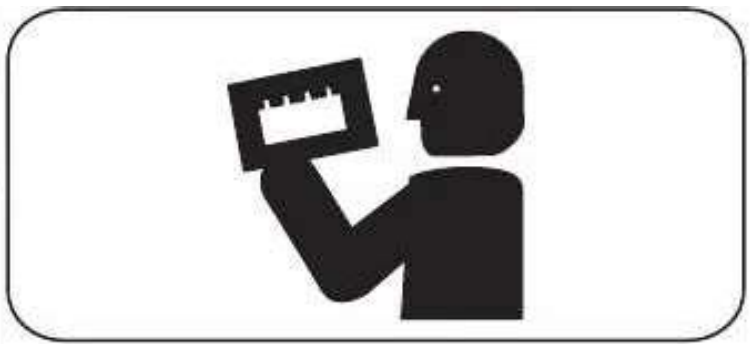

Wear personal protective equipment to protect eyes, face, and skin when checking, handling, or filling batteries. This equipment includes goggles or face shield, rubber gloves (with or without arm shields), and a rubber apron.

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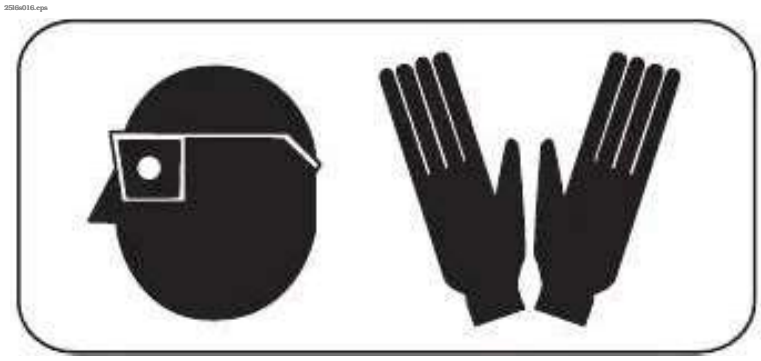

Make sure a shower and eyewash station are nearby in case of an accident.

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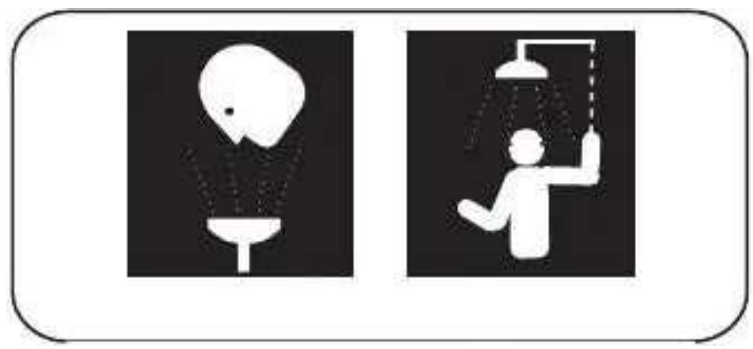

A battery gives off explosive gases. Never smoke, use an open flame, or use anything that gives off sparks near a battery.

Keep the charging area well-ventilated to avoid hydrogen gas concentration.

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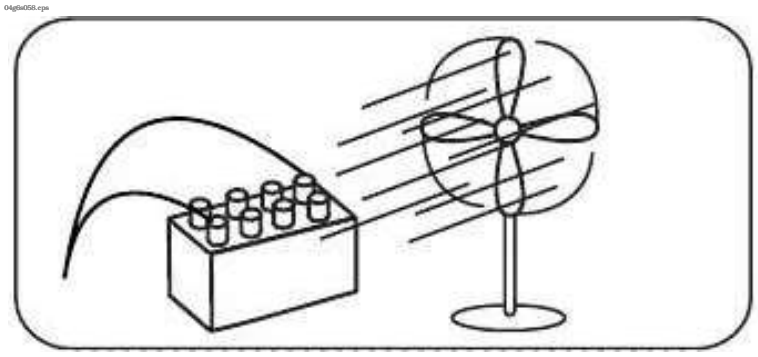

Turn the key switch OFF *before* disconnecting the battery from the lift truck at the battery connector. Do not break live circuits at the

Battery Safety

battery terminals. A spark often occurs at the point where a live circuit is broken.

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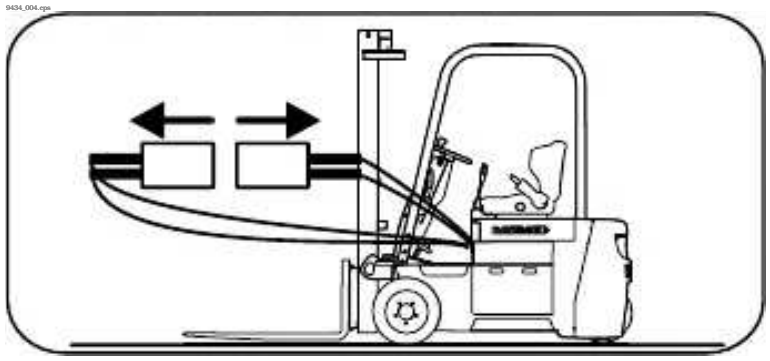

Do not lay tools or metal objects on top of the battery. A short circuit or explosion could result.

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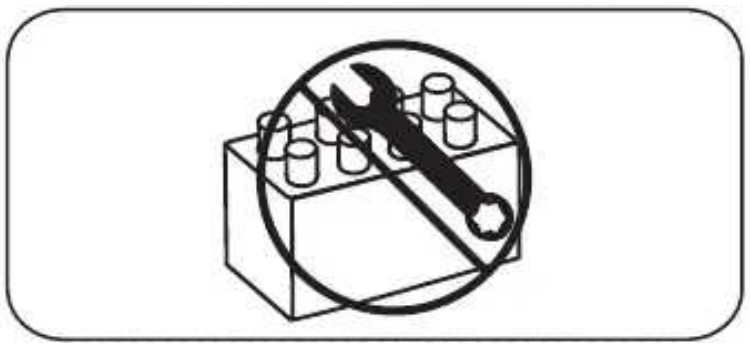
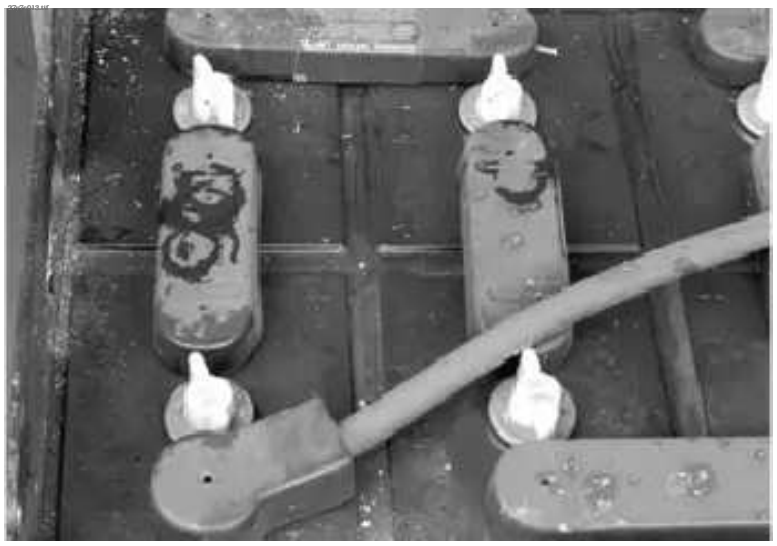


Keep batteries clean. Corrosion causes shorts to the frame and possibly sparks.

Keep plugs, terminals, cables, and receptacles in good condition to avoid shorts and sparks.



Keep filler plugs firmly in place at all times *except* when the electrolyte level is checked, when water is added to the cells, or when the specific gravity is checked.

Make sure the vent holes in the filler plugs are open to allow the gas to escape from the cells.

Do not allow cleaning solution, dirt, or any foreign matter to enter the cells.

Make sure you install the correct size battery. A smaller or lighter weight battery could seriously affect lift truck stability. See the lift truck's specification plate for more information.

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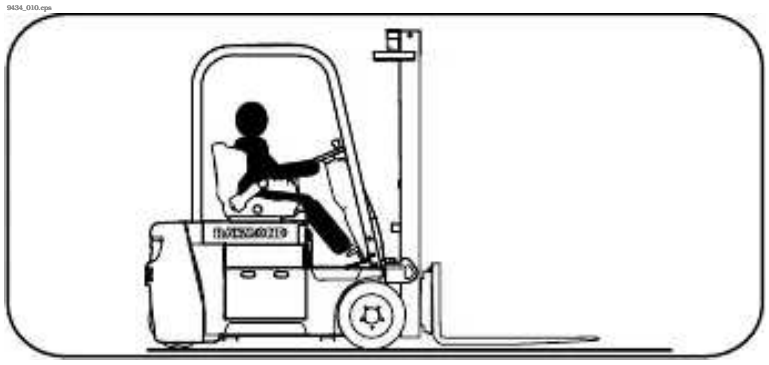

Never plug a battery charger into the lift truck's battery connector. Plug the battery charger only into the battery connector from the battery.

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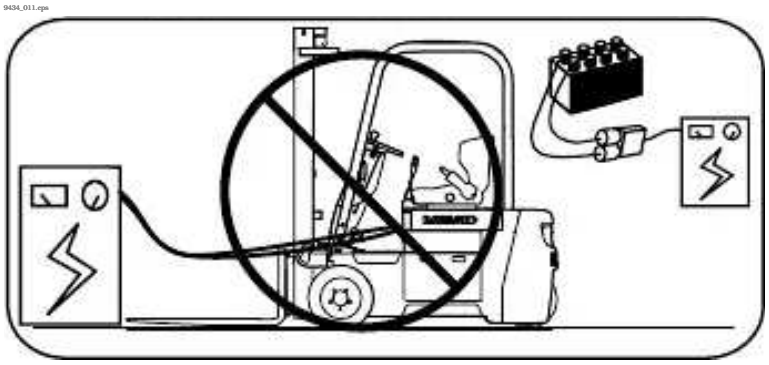

Static Precautions

Electronic circuit boards can contain Electrostatic Discharge Sensitive (ESDS) devices.

Static charges can accumulate from normal operation of the lift truck as well as movement or contact between non-conductive materials such as plastic bags, synthetic clothing, synthetic soles on shoes, and styrofoam coffee cups.

Accumulated static electricity can be discharged to a circuit board or component by touching the parts. Electrostatic Discharge (ESD) is also possible through the air when a charged object is placed close to another surface at a different electrical potential. *Static discharge can occur without seeing or feeling it.*

Whenever working on or near static-sensitive electronics, always use static discharge precautions.

- Wear an ESD wrist strap. Connect the ground lead to the wrist strap connector. Connect the ground clamp to an unpainted, grounded surface on the truck frame. The wrist strap should be equipped with a 1 megohm resistor to protect against shock hazard.
- Handle circuit boards by edges only. Avoid touching edge connectors.
- If you are removing or installing static-sensitive components, place them on a correctly grounded static mat.
- To transport static-sensitive components, including failed components being returned, place the components in an antistatic bag or box (available from your Raymond dealer).

Test the wrist strap and related accessories before each use to make sure they are working correctly.

Figure 2-1. Anti-Static Kit with Wrist Strap and Mat

Figure 2-1 shows the components of the *Raymond* antistatic field service kit, P/N 1-187-059. The kit includes a wrist strap, ground cord, and static-dissipative work surface (mat). Follow the instructions packaged with this kit.

Wrist straps are available in quantities of 25, as P/N 1-187-058/001.

A wrist strap tester is available as P/N 1-187-060/100.

Contact your local authorized Raymond dealer for information.

Jacking Safety

General Precautions

Some maintenance procedures require the lift truck to be elevated off the floor. When jacking the truck, observe the following safety precautions:

1. Lower the forks completely. Remove any load.
2. Set the parking brake and block the wheels to prevent movement of the vehicle.
3. Turn the key switch OFF and disconnect the battery connector.
4. Place the jack under the designated jacking points. See Figure 2-2.
5. Always use solid blocks to support the truck. Never rely on jacks or chains to support the truck.

⚠ WARNING

Use extreme care whenever the truck is jacked up. Never block the lift truck between the telescopic and the floor. Use a suitable hoist to stabilize the mast. Keep hands and feet clear from vehicle while jacking the lift truck. After the lift truck is jacked, place solid blocks or jack stands beneath it to support it. DO NOT rely on the jack alone to support the lift truck.

Figure 2-2. Correct Jacking Locations

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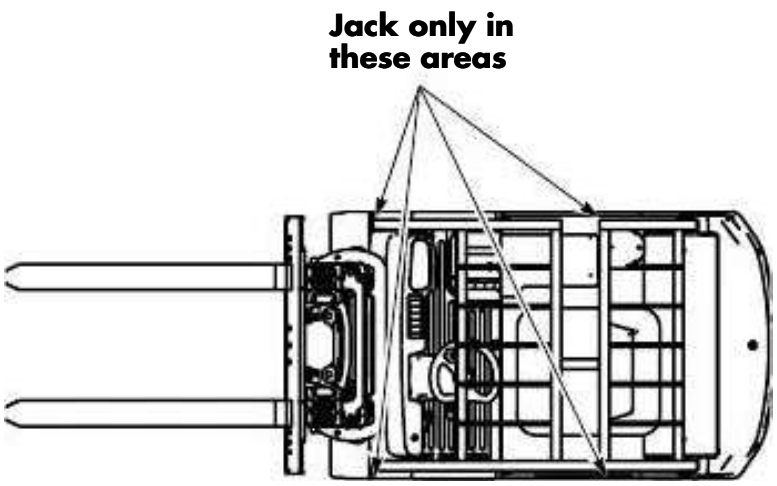


To elevate the lift truck:

1. Place a suitable jack under a designated jacking point. See Figure 2-2.
2. Lift the truck only as far as required to perform the procedure.
3. Securely block the truck in place.

NOTE: It is possible to elevate the front of the lift truck without using a jack.

a. Block the steerable wheels with chocks.

b. Tilt the mast back and place blocks on the floor under the mast mainframe.

c. Tilt the mast forward, lifting the truck off the floor.

Welding Safety

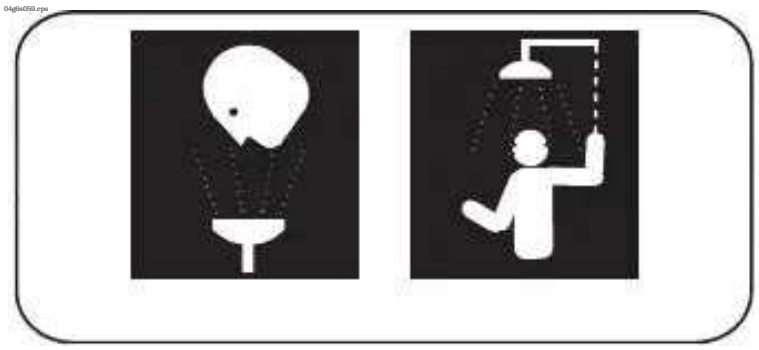
⚠ WARNING

Flame cutting or welding on painted surfaces may produce potentially harmful fumes, smoke, and vapors. Prior to performing flame cutting or welding operations, it is recommended that the coating be removed in the vicinity where the operation(s) will be performed.

Coating removal may be by mechanical methods, chemical methods, or a combination of methods. Perform flame cutting and/or welding operations only in well ventilated areas. Use local exhaust if necessary.

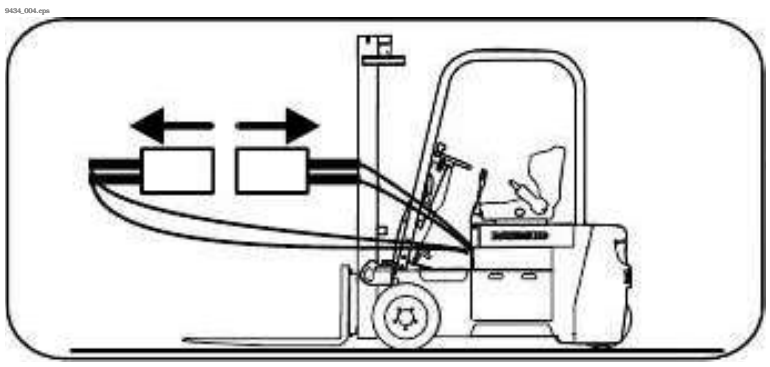
Before working on this lift truck, make sure:

- fire protection equipment is nearby
- you know the location of the nearest eyewash station.



⚠ CAUTION

Disconnect the battery before you attempt to inspect, service, or repair the lift truck.



⚠ WARNING

Before removing a power amplifier, discharge the amplifier's internal capacitor by jumpering the + and – terminals with a 100 ohm 25W resistor.

- Check for shorts to frame as described in "Shorts to Frame" on page 5-2. If you detect any shorts, correct them before you proceed with the welding operation.
- Clean the area to be welded.
- Protect all lift truck components from heat, weld spatter, and debris.
- Attach the ground cable as close to the weld area as possible.
- Disconnect all electrical circuit cards before doing any type of electric resistance welding.
- Do not perform any welding operations near the electrical components.
- If you must do welding near the battery compartment, remove the battery from the lift truck.
- When you are finished welding, re-install circuit cards and perform all ground tests and electrical inspections before operating the lift truck.

Welding Safety

Section 3. Systems Overview

General

This lift truck is capable of operating with a 36V or 48V battery. Operator input/command signals are communicated to various electronic components via a CAN-Bus network. Pressure for lift, tilt, sideshift, and steering is provided by a hydraulic pump driven by an AC motor. The pump motor is controlled by an AC power amplifier (PPA).

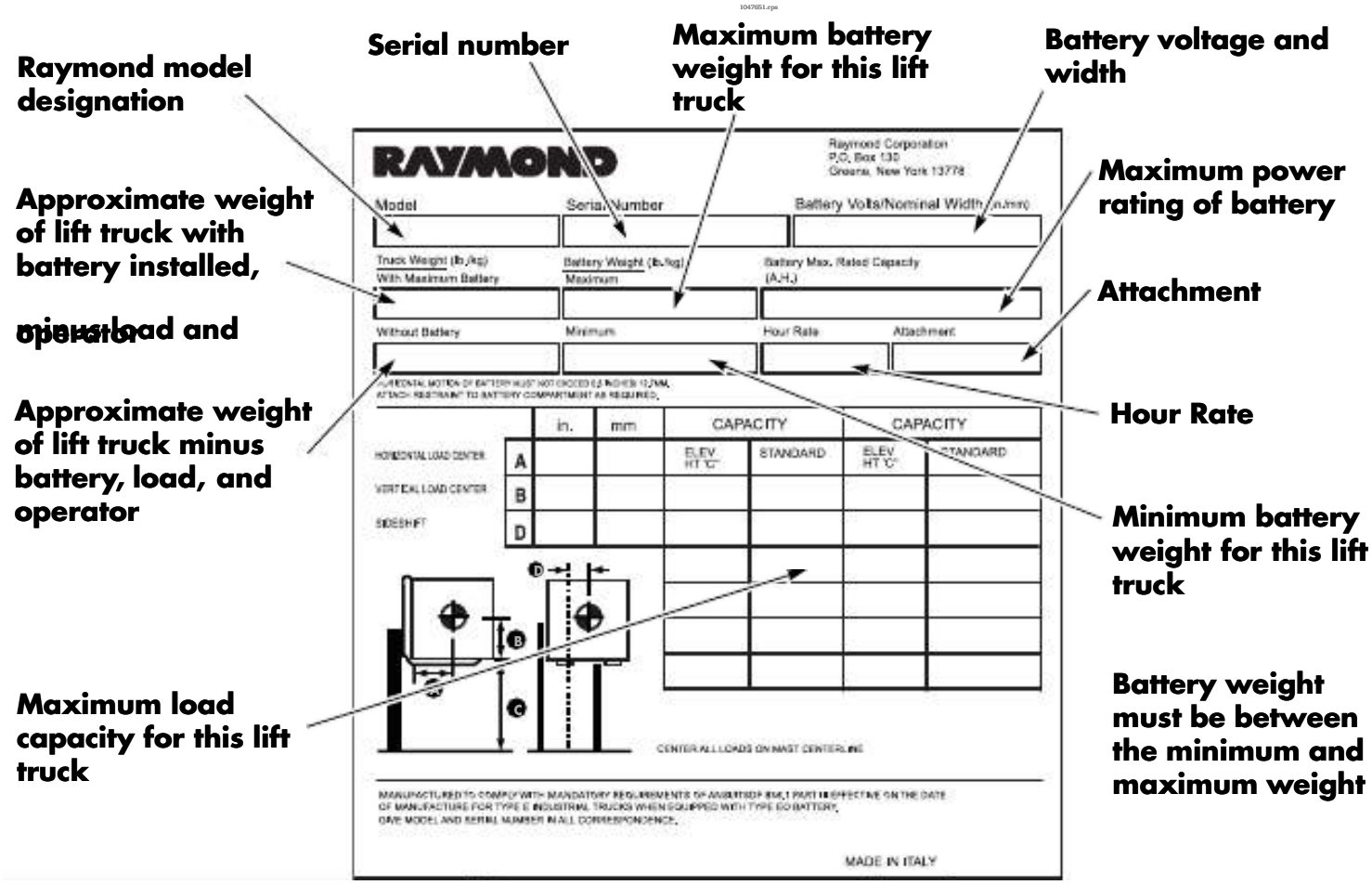
Two independent AC motor/drive unit assemblies provide traction via two dedicated AC power amplifiers (TPAs). The right traction motor is controlled by the Master Traction Power Amplifier (TPA). The left traction motor is controlled by the Slave TPA. Refer to "Traction Power Amplifiers" on page 8-3 for theory of operation.

A multiple disc, oil bath type brake system is located internal to the drive units.

Lift Truck Specifications

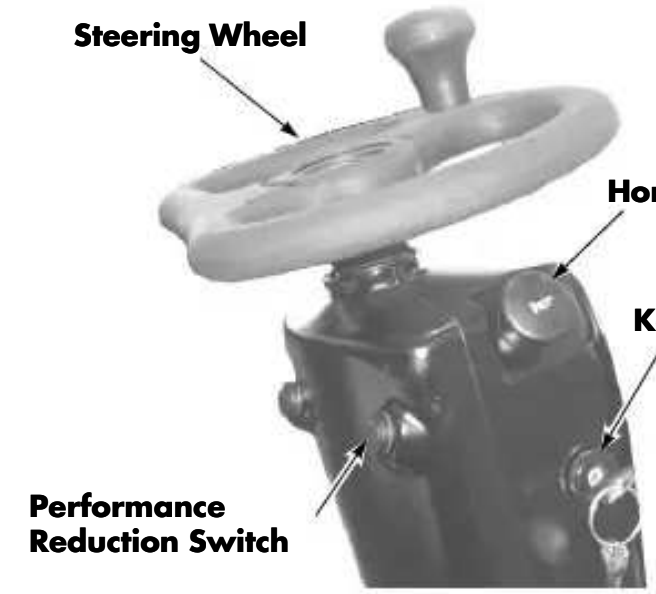
This lift truck is rated for performance by load center and load weight. Review the specification plate, located on the lift truck's dash panel to the right of the steering column, for detailed load capacity and load center information.

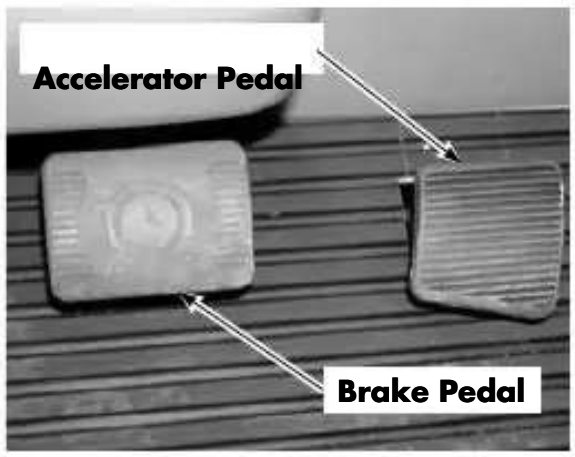
Due to continuous product enhancement, specifications are subject to change without notice or obligation.

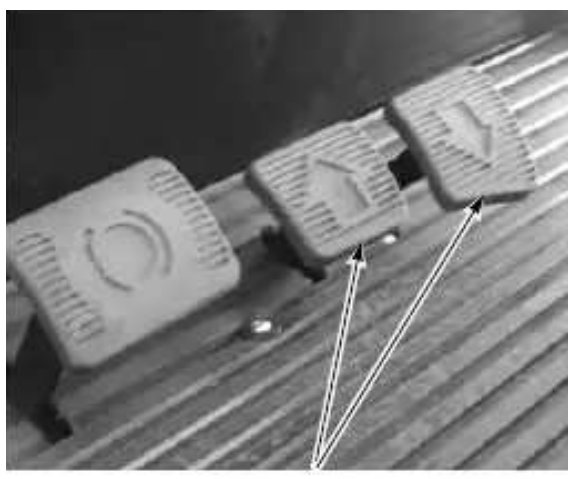


Controls

Figure 3-1. Operator Controls







Performance Modes (L•P•H)

Three selectable performance parameters, L, P, and H, are configured for travel and lift speed, acceleration, and hydraulic flow for attachments.

L = low performance

P = medium performance

H = high performance

These parameters are set at the factory such that H will be maximum speed, L will be slower, and P will be an intermediate speed.

These parameters can be set to meet specific application requirements via FlashWare.

NOTE: This feature *is not* available on EE rated trucks.

Performance Reduction

The performance reduction (turtle) mode reduces the performance parameters in the L, P, and H settings. Turtle mode performance is also configurable via FlashWare.

FlashWare Program

Overview

The FlashWare program allows you to view and configure options and update software on the Model 4450 through the following features:

- Vehicle Manager software
- Learn controls
- Reset Raymond default settings
- Download Software
- Configure LPH parameters

Requirements

FlashWare can be installed on an IBM-compatible PC with Windows 98 or higher operating system.

The PC communicates with the truck software via a USB/CAN interface module and associated cables (dongle). This dongle is available as P/N 230489-001.

Install FlashWare on PC

If you are a customer service technician, obtain FlashWare from your Raymond dealer.

If you are a Raymond dealer technician, obtain FlashWare from the iNet software download site. If you do not have access to the download page on iNet, contact the Parts Distribution Center.

To install FlashWare on the PC, double-click the installation file and follow the instructions on the screen. The software package is a self-extracting executable file. Read the "Readme" file in the software package for the latest detailed installation instructions.

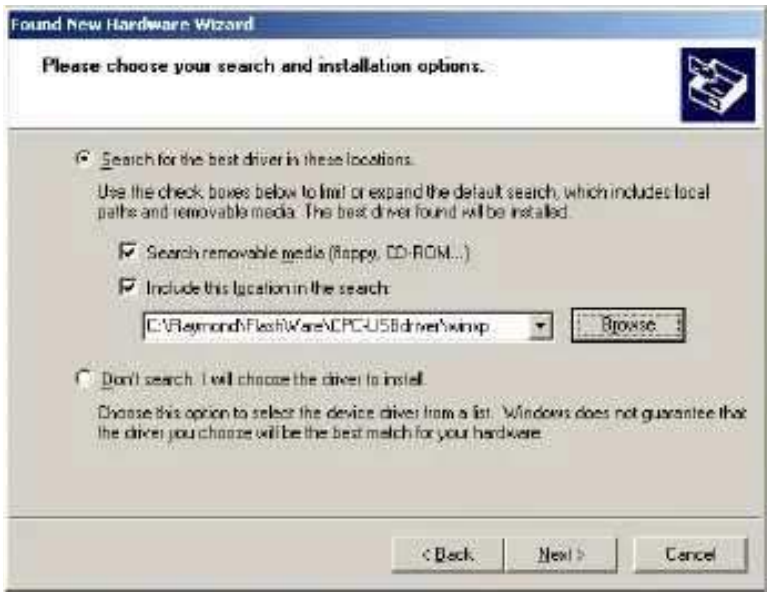
After installing the FlashWare program on the PC, connect the dongle to the PC. The "Found New Hardware Wizard" launches. See Figure 3-2.

Figure 3-2. New Hardware Wizard

The following procedure must be followed to install the correct USB driver on the PC:

1. Select "Install from a list or specific location (Advanced)". Click Next. The following screen displays. See Figure 3-3.

Figure 3-3. Select Operating System



2. Browse for the folder: C:\Raymond\FlashWare\CPC-USBdriver. Choose the subfolder (win2k, win9x, or winxp) that matches the operating system installed on the PC. Click Next. The following screen displays. See Figure 3-4.

NOTE: Figure 3-3 shows the path for the Windows XP operating system only.

Figure 3-4. Hardware Wizard Finish Screen

3. Click Finish. The FlashWare program and USB driver are now installed on the PC.

PC Connection to Truck

⚠CAUTION

Before connecting to the truck, make sure the laptop battery is sufficient to complete the task. If in doubt, plug laptop into a reliable AC power source.

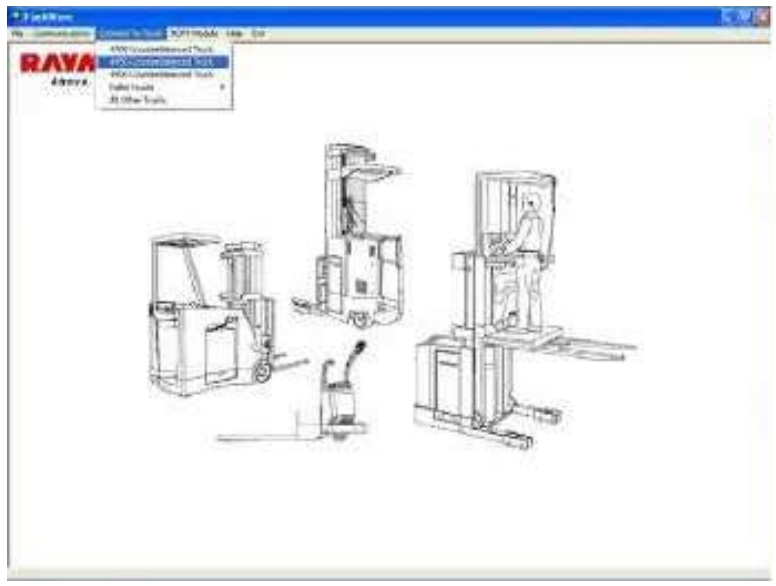
If the laptop powers down while flashing an amplifier, it is possible that an unrecoverable error may occur.

1. Turn the truck key switch OFF.
2. Remove the dashboard cover below the Operator Display.
3. Connect a standard 9-pin serial cable from the USB/CAN interface module to the serial port connector.
4. Connect a standard USB cable from the USB/CAN interface module to a USB port on the PC.

Starting FlashWare

1. Turn the truck key switch ON.
2. Double-click the FlashWare icon on the main desktop screen or navigate via Start > Programs > FlashWare. The truck opening screen appears. See Figure 3-5.

Figure 3-5. Flashware Opening Screen



NOTE: For more detailed information regarding FlashWare, click on Help.

3. From the menu bar, select “Connect to Truck”. From the pull-down menu, select the appropriate model. The “Truck Setup” screen is displayed. See Figure 3-6.

NOTE: A truck connection status indicator is located in the upper left of the “Truck Setup” screen.

Green indicates the PC is correctly connected and ready to communicate with the truck.
Red indicates the PC is not correctly connected/cannot communicate with the truck.

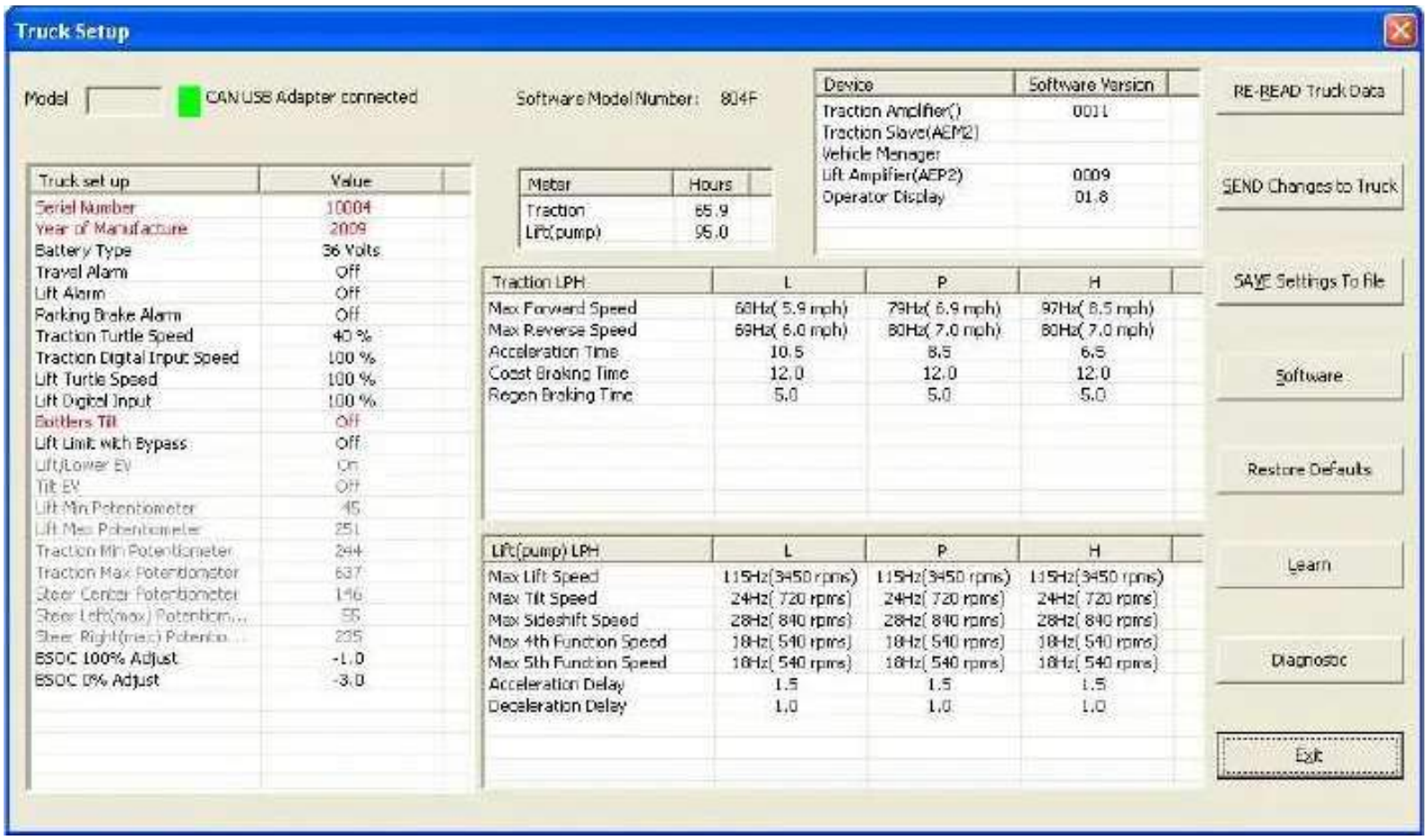
FlashWare Program

Configuration and Truck Setup Options

The “Truck Setup” screen allows you to:

- enable options that were added to the truck since shipment from the factory
- check the serial number, model number, software model number, and software versions of intelligent devices on the truck
- set battery voltage (changing this setting resets all defaults; all potentiometers must be re-Learned)
- configure traction and lift parameters

Figure 3-6. Truck Setup Screen



To Change an Option Setting

Option status is displayed in the “Truck set up” window.

Double click the desired option. Select the correct value in the dialog box. When options are correctly configured, click “SEND Changes to Truck” button.

NOTE: Options displayed in red require authorization codes. When these options are selected, a pop up window appears requesting the authorization code. Contact your local Raymond dealer for the correct forms and procedure for obtaining the authorization code.

Options include (but are not limited to):

Travel Alarm - allows the alarm to sound when the truck is moving as configured.

Lift Alarm - allows the alarm to sound when the truck is lifting/lowering as configured.

Parking Brake Alarm - allows the alarm to sound when the parking brake is engaged and travel is requested.

Bottlers Tilt - limits lift height when mast is tilted forward to the tilt limit switch and limits forward tilt when forks are above the limit switch.

Mast Switch Limit - used to interrupt lift and limit travel speed when forks are above the switch.

High Speed Limit - used to limit maximum travel speed to a programmed percentage of full speed when speed reduction is commanded.

Lift Limit with Bypass - prevents lift when forks are above the limit switch unless the Bypass button is depressed.

Lift/Lower EV - enables the Blocking EV (EV12) for use with the Bottler’s Tilt option.

Tilt EV - enables the Tilt EV (EV13) for use with the Bottler’s Tilt option.

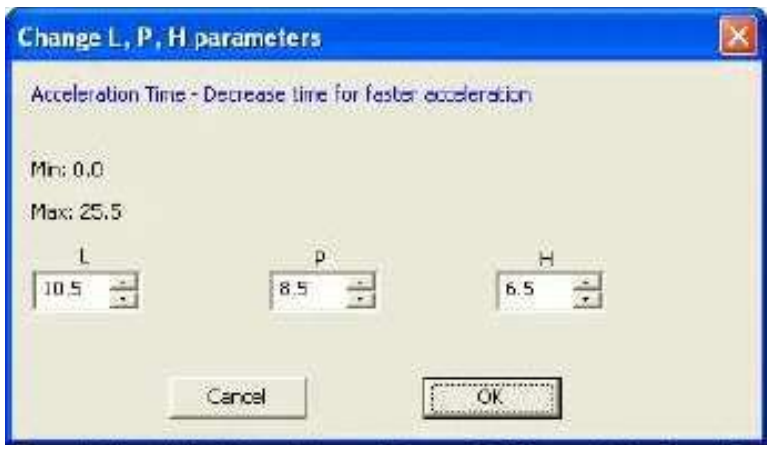
To Change a Performance Setting

Performance settings are displayed in the “Truck set up”, “Traction LPH”, and “Lift (pump) LPH” windows.

NOTE: Performance (speed) values set within the Truck set up window are applied equally to LPH parameters.

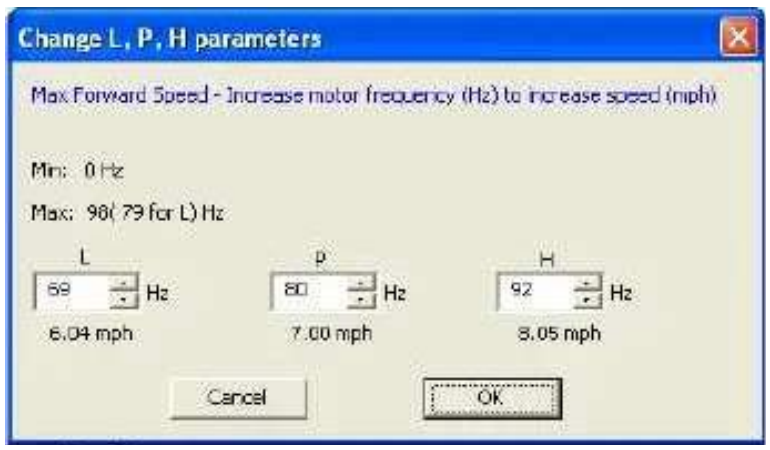
Double-click the desired parameter to be changed in a dialog box. See Figure 3-7.

Figure 3-7. Parameter Information



NOTE: All motor speed dialog must be entered in hertz, not mph or rpm. The conversion is automatically shown in the dialog box below the corresponding entry. See Figure 3-8.

Figure 3-8. Motor Speed Dialog Box



After a parameter is changed, click OK, then click “Send Changes to Truck” to complete the request.

FlashWare Program

Lift (pump) Configuration for Attachments

Set the pump motor speed to accommodate different flow requirements of optional attachments installed on the truck. Typically, sideshift and/or 4th function is associated with attachment operation.

Refer to Table 3-1 as a guideline for approximate flow rates based on RPM (Hz) settings.

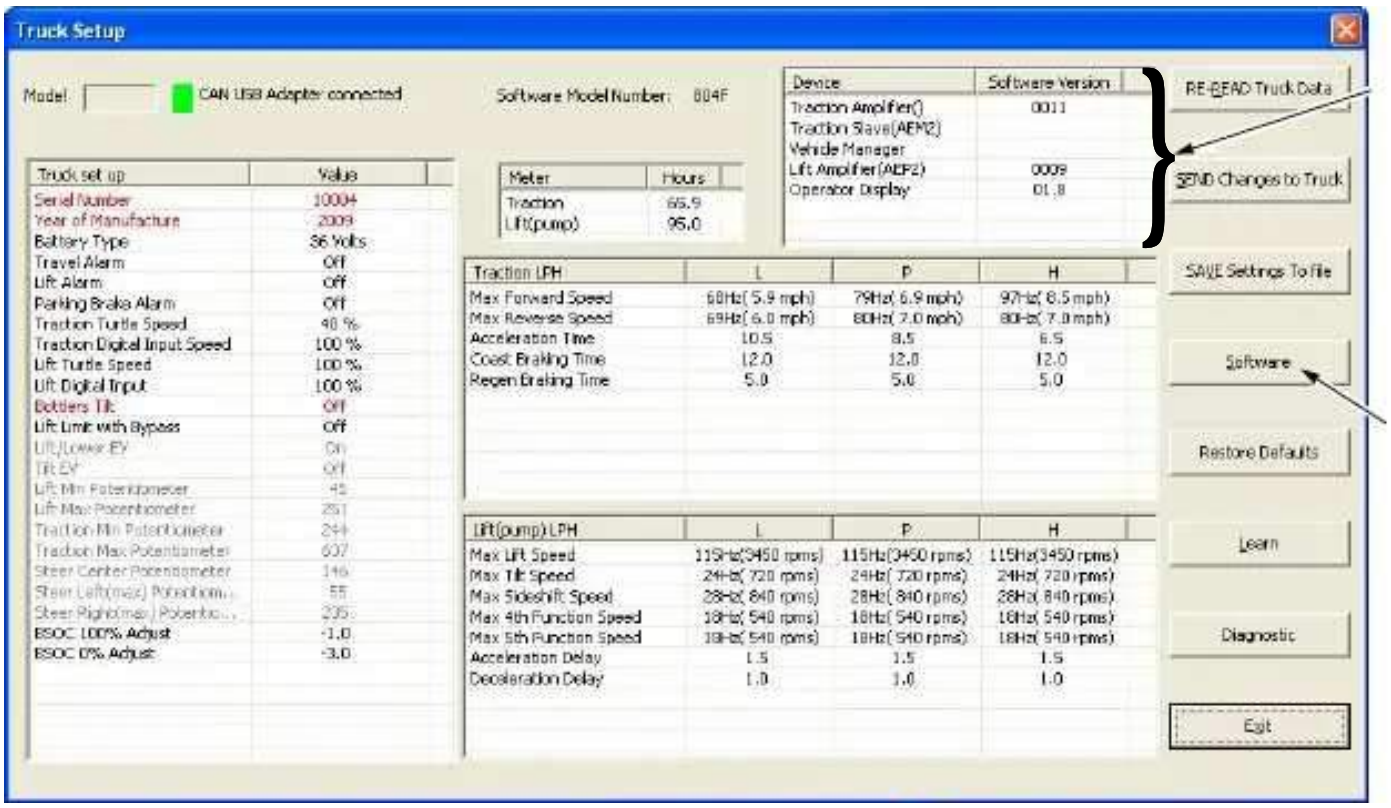
Table 3-1. Pump Flow Rates

RPM	GPM (approx.)
1000	3.1
1500	4.7
2000	6.3
2100	6.6
2200	6.9
2300	7.2
2400	7.5
2500	7.9
2600	8.2
2700	8.5
2800	8.8
2900	9.1
3000	9.4
3500	11.0

Software Management

Intelligent devices installed on the truck and their current version of software are displayed on the "Truck Setup" screen. See Figure 3-9.

Figure 3-9. Software Management

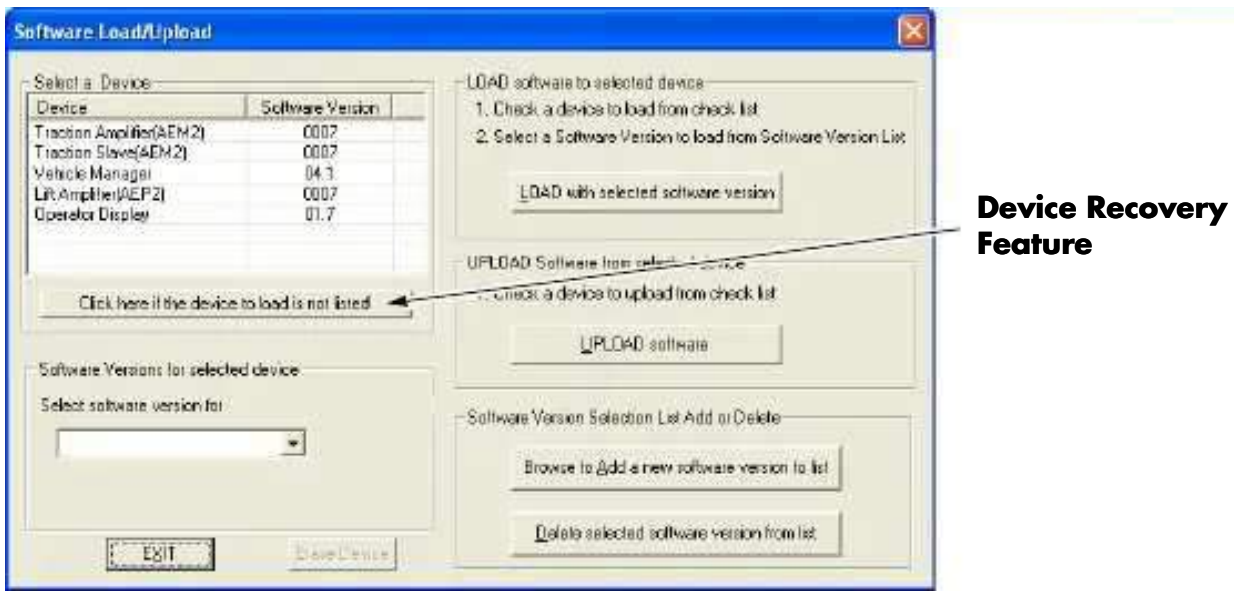


List of Intelligent Devices and current S/W versions

Click to install/ update software

To install/update software, click on the "Software" button. See Figure 3-9. The "Software Load/Upload" screen is displayed. See Figure 3-10.

Figure 3-10. Software Load/Upload Screen



Device Recovery Feature

Device Recovery

Use this feature if the desired device is not listed. See Figure 3-10. The "Device Recovery" screen is displayed. See Figure 3-11.

Figure 3-11. Device Recovery Screen

RE-READ Truck Data

This feature re-reads the truck's current configuration and resets FlashWare to reflect the truck's current settings.

SEND Changes to Truck

This feature transmits all changes made on the "Truck Setup" screen to the truck's memory.

SAVE Settings To file

This feature is used to store the vehicle's current configuration for future reference.

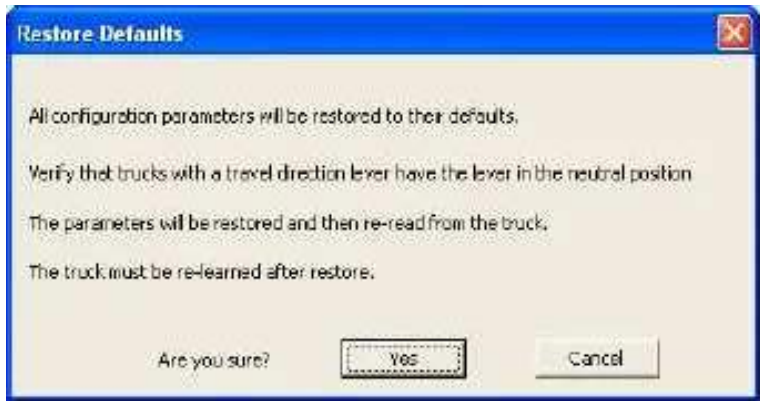
Restore Defaults

Use this feature to reset vehicle configuration back to factory default settings. See Figure 3-12.

All potentiometers must be re-Learned after setting Raymond defaults.

NOTE: Record customer-specific configurations, for example; speed, acceleration, lift, and coast from the "Truck Setup" screen *before* resetting defaults.

Figure 3-12. Restore Defaults



LEARN

NOTE: While FlashWare is the preferred method for performing Learn, an alternative method can be performed when a laptop computer is not available. Refer to "Alternative LEARN" on page 3-16.

Click the Learn button to learn a potentiometer on the truck. Select the potentiometer to be Learned from the "Learn Potentiometer" screen. See Figure 3-13.

Figure 3-13. Learn Potentiometer

Learn Travel

To learn the travel potentiometer (P2), select Travel from the "Learn Potentiometer" screen menu and perform the steps in the screen displayed. See Figure 3-14.

Figure 3-14. Learn Travel

Learn Steer

To learn the steer potentiometer (P1), select Steer from the "Learn Potentiometer" screen menu and perform the steps in the screens displayed. See Figure 3-15.

NOTE: For each step, press the brake pedal just enough to start the hydraulic pump for power steering.

NOTE: The right, left, and center steer positions must be learned when Learn Steer is performed.

Learn Center Steer requires the truck to travel. Perform Learn Steer in an open area.

Figure 3-15. Learn Steer

NOTE: When learning the Center steer position, travel forward in a straight line a short distance to eliminate tire roll-up. Stop, then click OK.

Learn Lift

NOTE: Not required on trucks equipped with fingertip controls. To learn the lift potentiometer (P3), select Lift from the "Learn Potentiometer" screen menu and perform the steps in the screen displayed. See Figure 3-16.

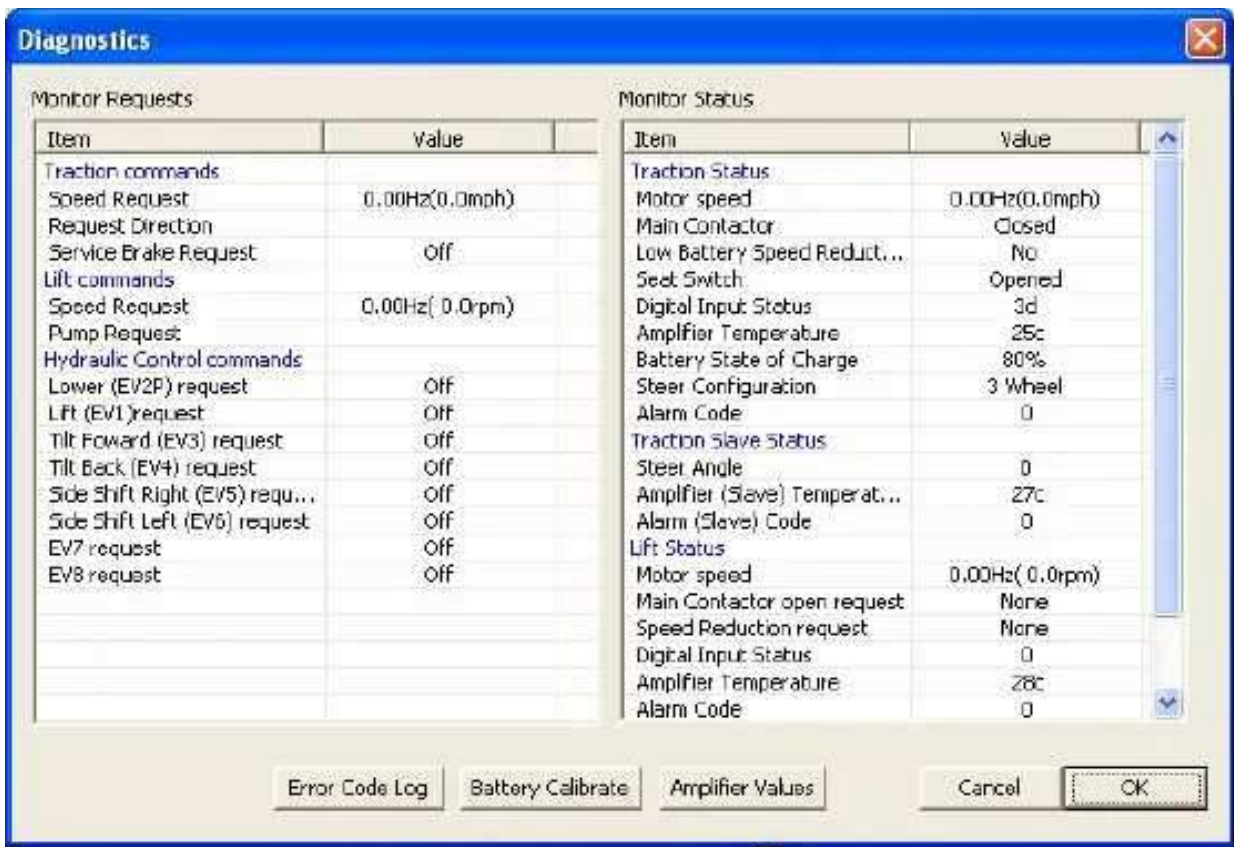
Figure 3-16. Learn Lift

FlashWare Program

Diagnostics

This feature displays input/output values and status of various systems or devices on the truck. To view, click on the "Diagnostics" button on the "Truck Setup" screen.

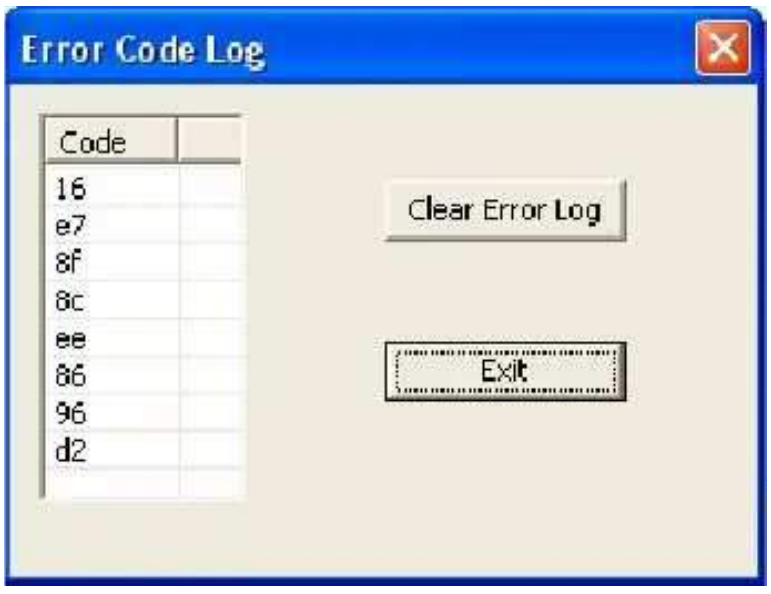
Figure 3-17. Diagnostics Screen



Error Code Log

Displays the fault code history of the truck.

Figure 3-18. Error Code Log Screen

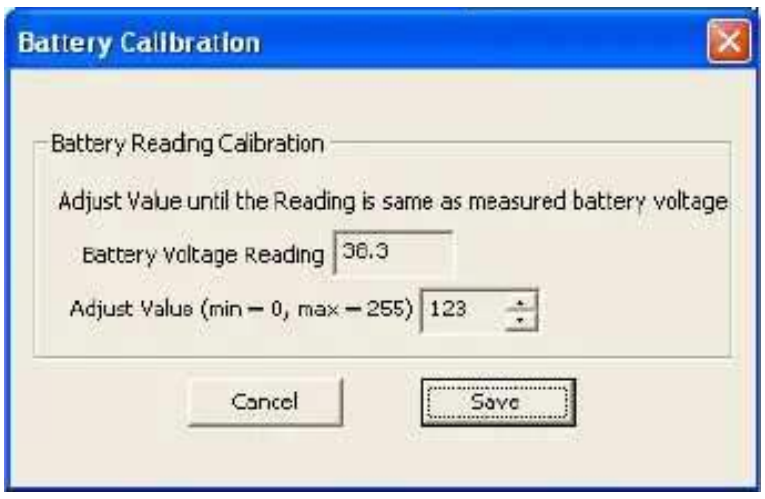


Battery Calibrate

The Adjust Value entered here is used to calibrate the Battery Discharge Indicator. See Figure 3-19.

NOTE: Make sure the battery being used is fully charged.

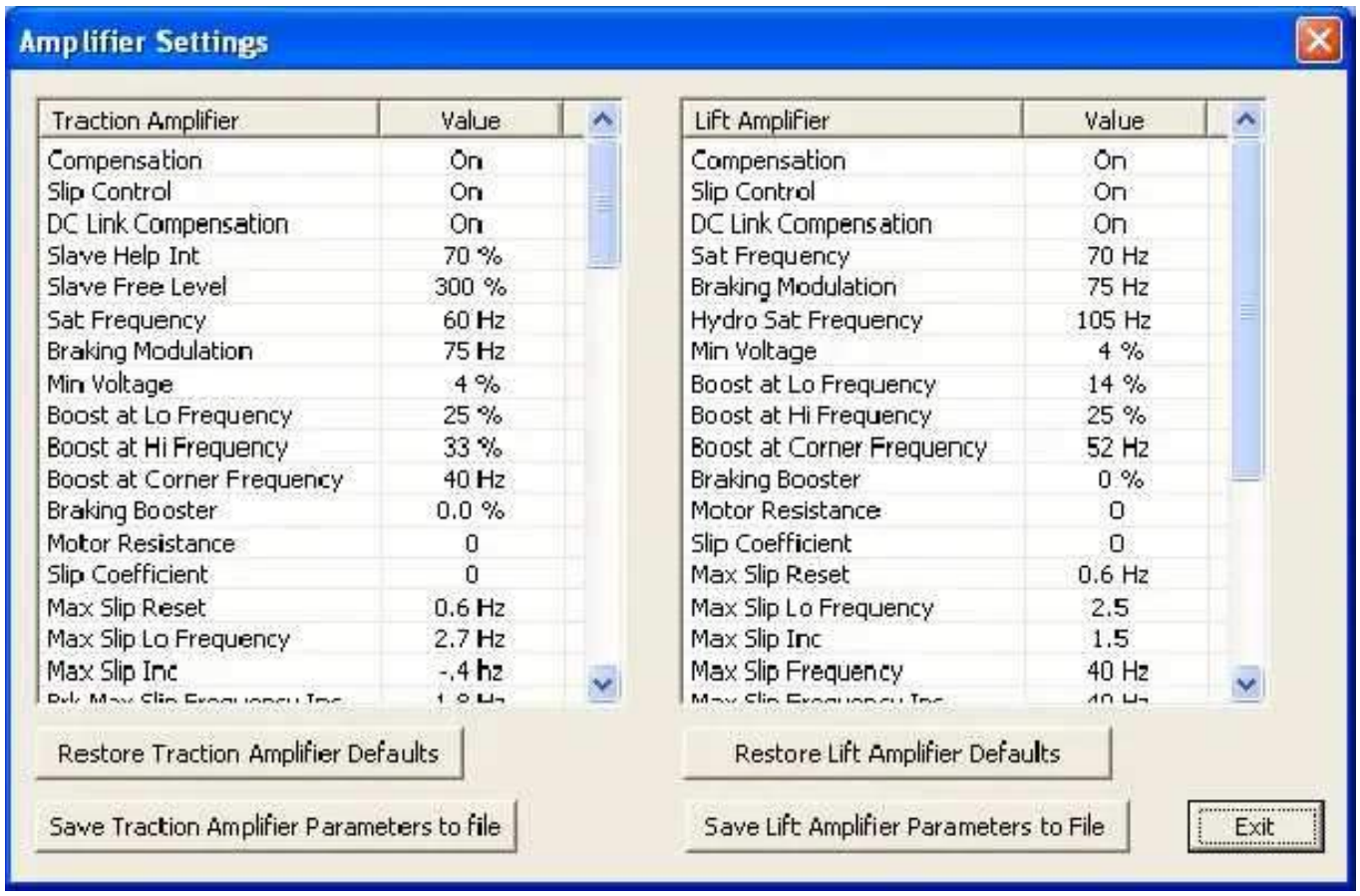
Figure 3-19. Battery Calibrate



Amplifier Values

Displays current amplifier values. See Figure 3-20.

Figure 3-20. Amplifier Values



Alternative LEARN

When FlashWare is not available, learning pots can be done using the LPH and Performance Reduction (Turtle) buttons on the truck steering column.

NOTE: In this procedure, the LPH button can be considered an ENTER button and the Performance Reduction (Turtle) button can be considered a TOGGLE button to change selections.

Five selections are available with this procedure: Ld (Learn drive), LL (Learn lift), Learn Right Steer position, Learn Left Steer position, and Learn Center Steer position, which are indicated by the steer position LEDs.

⚠CAUTION

Read and understand this procedure thoroughly. Values can be mislearned and the lift truck can move if these procedures are not performed correctly.

If, while learning the traction pot, the parking brake is not set or the directional control is not in neutral, the truck will travel.

While learning the lift pot, the carriage will lift. Make sure there are no overhead obstructions.

With the key switch ON, sitting in the seat, parking brake engaged, and the travel directional lever in neutral, do the following:

Enter Learn Mode

1. Press the LPH and Turtle buttons at the same time and release.
2. Press the Turtle button and release.
3. Press the LPH and Turtle buttons at the same time again and release.
4. Press the LPH button once and release.
5. Press the LPH and Turtle buttons at the same time again and release. A flashing "n" should be displayed and the Battery Charge Indicator LED's will flash.
6. Press the Turtle button and release. A flashing "y" should be displayed and the Battery Charge Indicator LED's will flash.
7. Press the LPH button and release. (Learn mode is now accessed.) "Ld" should now be flashing on the display. Press the Turtle button to toggle between selections.

Learn the Traction Potentiometer

⚠CAUTION

The parking brake must be engaged and the travel directional lever must be in neutral or the truck will travel.

1. While in Learn mode with "Ld" flashing (Ld = Learn drive), press and release the LPH button. A solid "Ld" should be displayed and the Battery Charge Indicator LED's will flash.
2. Depress and hold the traction forward pedal (on dual pedal trucks) or traction pedal (on single pedal trucks).
3. Press and release the LPH button to store the value. A solid "Ld" should be displayed and the Battery Charge Indicator LED's should be on solid as well, indicating the new learned value has been stored. Release the pedal.
4. Press and release the LPH button to exit. A flashing "Ld" should be displayed.
5. If another selection is to be learned, toggle the Turtle button until the desired selection is displayed. If no other selections are to be learned, toggle the Turtle button until the truck exits Learn mode and performs SelfTest. Cycle the key switch after exiting Learn Mode.

Learn the Lift Potentiometer

NOTE: This procedure applies to trucks equipped with Lever Controls only.

1. While in Learn mode, toggle the Turtle button until "LL" is flashing (LL = Learn lift).

2. Press and release the LPH button. A solid "LL" should be displayed and the Battery Charge Indicator LED's will flash.

⚠CAUTION

The carriage will lift when the next step is performed. Make sure there are no overhead obstructions.

3. Pull and hold the lift lever to the maximum lift position.
4. Press and release the LPH button to store the value (as soon as LPH is pressed, the lift lever can be released). A solid "LL" should be displayed and the Battery Charge Indicator LED's should be on solid as well, indicating the new learned value has been stored.
5. Press and release the LPH button to exit. A flashing "LL" should be displayed.
6. If another selection is to be learned, toggle the Turtle button until the desired selection is displayed. If no other selections are to be learned, toggle the Turtle button until the truck exits Learn mode and performs SelfTest. Cycle the key switch after exiting Learn Mode.

Learn the Steer Potentiometer

NOTE: The right, left, and center steer positions must be learned when Learn Steer is performed.

Learn Center Steer requires the truck to travel. Perform Learn Steer in an open area.

1. Enter Learn mode. Toggle the Turtle button until the right steer position LED flashes.

NOTE: The LED that is flashing is the position that is going to be learned. For example: If the right LED is flashing, you must learn the right steer position with the wheel turned all the way to the right, and so on.

2. Press and release the LPH button to select Learn for the right steer position. The right steer direction LED will be on solid and the Battery Charge Indicator LED's will flash.
3. Depress the brake pedal to start the hydraulic pump and allow steering.
4. Steer to the right fully and hold.
5. Press and release the LPH button to store the value. The right steer direction LED and the Battery Charge Indicator LED's should be on solid.
6. Press and release the LPH button to exit. The right steer direction LED should now flash and the Battery Charge Indicator LED's should go out.
7. Toggle the Turtle button until the left steering LED is flashing.
8. Press and release the LPH button to select Learn for the left steer position. The left steer direction LED will be on solid and the Battery Charge Indicator LED's will flash.
9. Depress the brake pedal to start the hydraulic pump and allow steering.
10. Steer to the left fully and hold.
11. Press and release the LPH button to store the value. The left steer direction LED and the Battery Charge Indicator LED's should be on solid.
12. Press and release the LPH button to exit. The left steer direction LED should now flash and the Battery Charge Indicator LED's should go out.
13. Toggle the Turtle button until the center steering LED is flashing.
14. Press and release the LPH button to select Learn for the center steer position. The center steer direction LED will be on solid and the Battery Charge Indicator LED's will flash.
15. Travel forward in a straight line a short distance to eliminate tire roll-up and stop.
16. Press and release the LPH button to store the value. The center steer direction LED and the Battery Charge Indicator LED's should be on solid.
17. Press and release the LPH button to exit. The center steer direction LED should now flash and the Battery Charge Indicator LED's should go out.

Alternative LEARN

18. If another selection is to be learned, toggle the Turtle button until the desired selection is displayed. If no other selections are to be learned, toggle the Turtle button until the truck exits Learn mode and performs SelfTest. Cycle the key switch after exiting Learn Mode.

Section 4. Scheduled Maintenance

Maintenance Guidelines

Following a regularly scheduled maintenance program:

- promotes maximum truck performance
- prolongs truck life
- reduces costly down time
- avoids unnecessary repairs

Scheduled maintenance includes:

- lubrication
- cleaning
- inspection
- service

Perform all of the scheduled checks and maintenance during the suggested intervals.

The time intervals given in this guide are based on Pump Hours under normal operating conditions.

When operating under Severe or Extreme conditions, perform these services more often as indicated in the chart below.

Operating Conditions	Working Environment	Service Frequency
Light to Moderate	An eight hour day of basic material handling	180 days or 500 pump hours
Severe	• Extended heavy duty operation • Freezer operation • Sudden temperature changes such as going from freezer to room temperature	250 hours
Extreme	• All UL Type EE rated lift trucks • Dusty or sandy conditions such as in cement plants, lumber or flour mills, coal dust or stone-crushing areas • High temperature areas such as in steel mills, foundries, enclosed (Type EE) applications • Corrosive atmosphere such as in chlorine or salt-sea air environments	100 hours

Initial 90 Day/250 Pump Hour Maintenance

Perform the following maintenance tasks 90 days after the lift truck is put into service or at 250 Pump Hours, whichever comes first.		
Component	**Task**	**Refer to**
Drive Units	Change fluid.	Page 7-14
Hydraulic Reservoir	Change fluid and filter.	Page 7-44, Page A-2
Power Amplifiers	Retorque power cable terminal nuts to 11 ft. lb. (15 Nm).	

Every 180 Days/500 Pump Hours

Perform the following tasks every 180 days/500 pump hours.		
Component	**What to do**	**Refer to**
Accelerator Pedal(s)	Verify travel function is smooth and responsive through full range of acceleration.	
Battery	Check the weight stamped on the battery in the lift truck against the minimum and maximum allowable weights on the specification tag for the lift truck. Report any lift trucks that are running with batteries under the minimum or over the maximum allowable weight. Inspect all battery connectors and leads for damage and cuts in protective coatings. Make sure the battery gates are in place and not damaged. Make sure the battery has no more than 0.5 in. (13 mm) free play in any direction.	
Brakes	In an open area, measure stopping distance. Traveling 2 to 3 mph (3.2 to 4.8 km/hr) empty, push the brake pedal. The empty lift truck should stop within 2 to 4 feet (0.6 to 1.2 m). During normal operation, with a rated load and traveling at top speed, the lift truck should stop within approx. one and one-half truck lengths. Stopping distance depends on the load, floor, and tire condition. Check for fluid leaks. Check parking brake for correct operation.	Page 7-15 Page 7-19
Chassis	General visual inspection of structural members for cracks.	
Contactors	Inspect contactor tips. Replace contactors with burnt or pitted contactor tips. Failure to replace the contactor may prevent the contactor from opening or closing causing unscheduled downtime. With the key switch OFF and the battery disconnected, check the plunger for smooth operation with no binding. If binding occurs, the lift truck may malfunction or exhibit intermittent fault codes.	
Drain Holes	Make sure battery compartment drain holes are not clogged.	
Drive Units	Check fluid.	Page 7-14
Electrical Cables	Inspect all power cables for nicks or cuts. Replace any cable that is damaged or shows signs of excessive heat. Failure to do so causes intermittent system shutdowns and/or electronic failures.	
Forks	Inspect.	Page 4-8
Hardware	Check bolt torque of major components (motors, pump, drive units, manifolds, mast-to-chassis mounting bolts, overhead guard). Tighten any loose hardware. Replace broken or missing hardware.	Page A-4
Horn	Check that horn sounds correctly when activated.	
Hydraulic Hoses	Inspect all hydraulic hoses for leaks, nicks, cuts, chafing, and bulges. Replace damaged hoses as soon as possible. Inspect all fittings for leaks. Repair any leaks immediately. Inspect over-the-mast hoses for correct tension. Make sure over-the-mast pulleys spin freely and show no signs of wear.	
Hydraulic Reservoir	Check fluid level.	

Perform the following tasks every 180 days/500 pump hours.		
Component	**What to do**	**Refer to**
Lift Chains	Check adjustment. Inspect for excessive stretch or wear. Lubricate.	Page 4-7 Page 7-58 Page A-2
Lights	Check for correct operation.	
Lubrication	Apply grease to all fittings.	Page A-2
Mast	Wipe old grease off mast uprights and apply new grease. Examine mast bearings. Inspect rails for abnormal wear, metal flakes, or shavings. Repair any grooves worn in the mast deeper than 1/8 in. (3 mm). Check upright and sideshift guide shoe (puck) adjustment.	Page 7-53 Page 7-60
Motors	Check cable lugs to make sure they are tight to the terminal studs. Securing nuts should be torqued to 18 ft. lb. (24 Nm). Replace any cable that shows signs of excessive heat. Check sensor wires for sound connection and condition. Blow out the inside of the motor with compressed air.	
Overhead Guard	Inspect guard for physical damage. If structurally damaged, replace the guard.	
Power Amplifiers and Fan	Check torque on power amplifier connections. Check for correct fan operation. Make sure power amplifier heatsink fins are free of debris and that air flows freely through them.	Page A-4
Seat Belt	Check for signs of wear, fraying, or damage.	
Seat Switch	Check for correct activation and deactivation of the seat switch.	
Shorts to Frame	Check for electrical shorts to frame. Wipe compartments clean.	Page 5-2
Static Strap	Make sure static strap is not worn or broken. Clean debris from strap.	
Steering	Check that steering system function is smooth and responsive. Inspect pivot points and bearings in the steering linkage. Inspect wheel bearings for side play. There should be no more than 0.002 in. (0.05 mm) of movement. If excessive, torque the retaining nut to 44 ft. lb. (60 Nm) and spin the wheel in both directions 2 to 3 turns. Back off retaining nut and torque to 14.7 ft. lb. (20 Nm). Check for side play and make sure the bearing is not binding. If binding, replace bearings.	
Switches	Check all switches for correct operation and adjust as needed.	
Ventilation Slots	Make sure ventilation slots in the chassis are clear of obstructions and debris. Clean the fan filter.	
Warning Decals	Replace missing, illegible, or damaged decals.	
Warning Light	If equipped, check for correct operation.	
Wheels/Tires	Examine for bond failure, chunking, and excessive or uneven wear. Inspect drive axles for excessive play.	

Every 360 Days/2000 Pump Hours

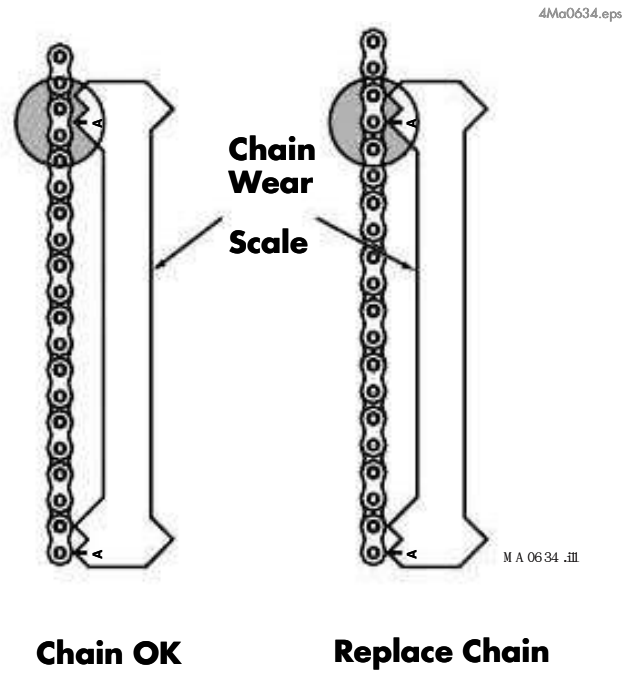
Perform the following maintenance tasks every 360 days or 2000 pump hours, whichever comes first.		
Component	**What to do**	**Refer to**
Drive Units	Change fluid.	Page 7-14, Page A-2
Hydraulic Reservoir	Change fluid and filter.	Page 7-44, Page A-2
Lift Pump	Separate lift pump and motor. Apply molybdenum anti-seize compound (P/N 990-638) to the splines.	Page 7-48

Chain Maintenance

Lift Chain Inspection

Make sure chains are not damaged. Check the chain for wear using a Chain Gauge (P/N 950-350/CG). See Figure 4-1.

Figure 4-1. Chain Gauge



Replace chains with genuine *Raymond* spare parts. See "Lift Chains" on page 7-58.

Condition-Cause Chart

Condition	Cause	Maintenance Procedure
Chain Elongation	Wear	Use a chain gauge or lay the chain on a flat surface and push it together. Measure and mark a 12 in. (305 mm) length that has operated over the pulley sheave. Stretch the chain; if more than 1/3 in. (8.5 mm) play is detected, replace the chain.
Rust and corrosion	Steam cleaning or degreasing new truck chains	Lubricate chain frequently.
Cracked Plates	~~Infrequent Oiling~~ Rust	Replace the chain.
	Corrosion	
	Chain Fatigue	
Tight Joints	Bent pins or plates	Replace the chain.
	Rusty joints or peened plate edges	Replace the chain.
Chain side wear	Chain misalignment	Replace the chain.

Fork Inspection

The following tools are required to perform fork inspection:

- Fork Wear Caliper (P/N 922-369)
- Tape Measure or ruler
- 24 in. Framing Square
- 4 ft. Level

Do the following when performing Scheduled Maintenance.

Surface Inspection

Remove the forks from the carriage. Visually inspect all fork surfaces for signs of damage, including, but not limited to:

- cracks
- excessive wear
- excessive heat
- deformation
- unauthorized modifications

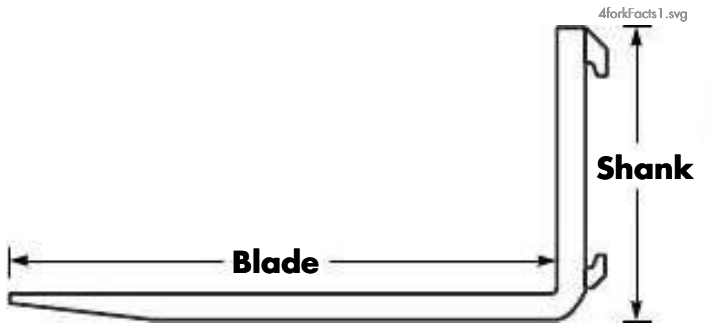
Pay special attention to the heel and welds attaching mounting components. If any damage is found, remove the fork from service.

Straightness of Blade and Shank

NOTE: This measurement can be done with the forks on or removed from the carriage.

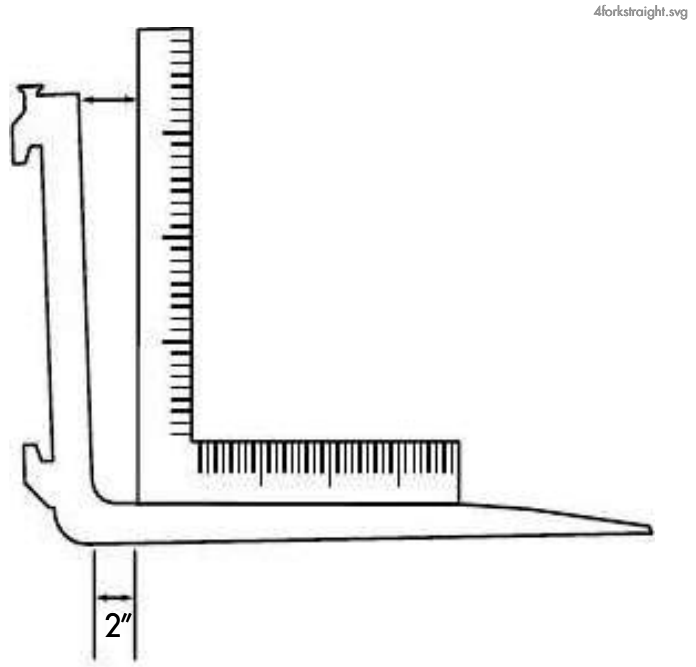
1. Measure the length of the blade and the height of the shank. See Figure 4-2.

Figure 4-2. Measuring Fork Blade and Shank



2. Multiply these numbers by 0.5%. The smallest number is your maximum deviation.
   - *Length of blade* _____ x 0.005 = _____
   - *Height of shank* _____ x 0.005 = _____
3. Place a 24 in. framing square on the blade of the fork, 2 in. away from the heel of the fork. See Figure 4-3.
4. Measure the distance between the face of the shank and the framing square at the top of the shank. See Figure 4-3.

Figure 4-3. Fork Measurement with Framing Square



5. Compare this measurement, minus 2 in., to the smallest maximum deviation number determined in step 2.
6. If the maximum deviation number is exceeded, remove the fork from service.

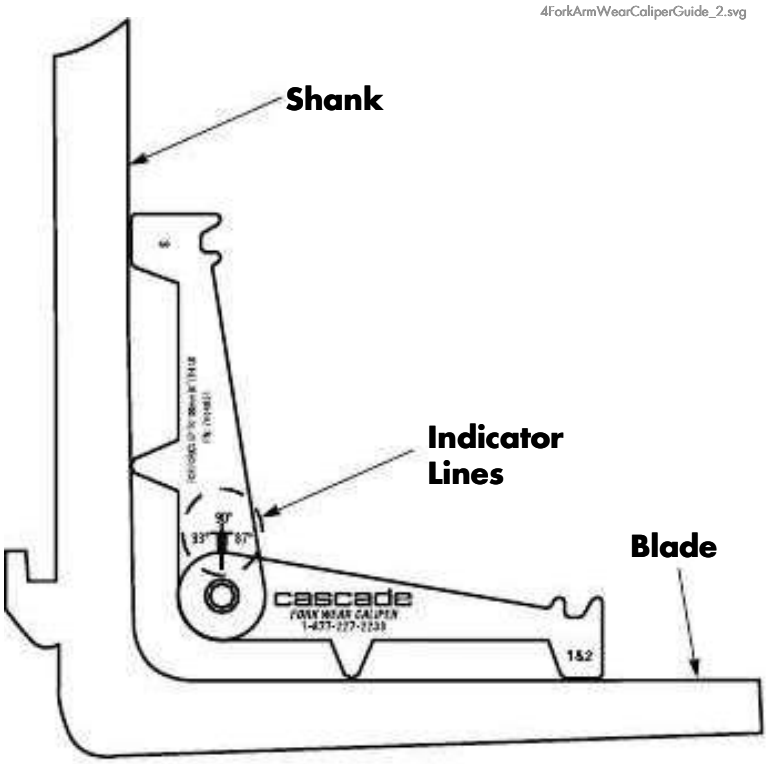
Fork Angle

NOTE: This measurement can be done with the forks on or removed from the carriage.

1. Place the fork caliper on the blade. Make sure that the two extruded points are touching the blade of the fork. See Figure 4-4.
2. Now open and move the caliper so the two extruded points are touching the shank. See Figure 4-4.

Figure 4-4. Fork Angle

4ForkArmWearCaliperGuide_2.svg



3. When all four extruded points are in contact with the fork, gently remove the caliper and note the reading on the indicator line, located right above the hinge pin. See Figure 4-4.
4. If the deviation is greater than 3° of the original angle, remove the fork from service.

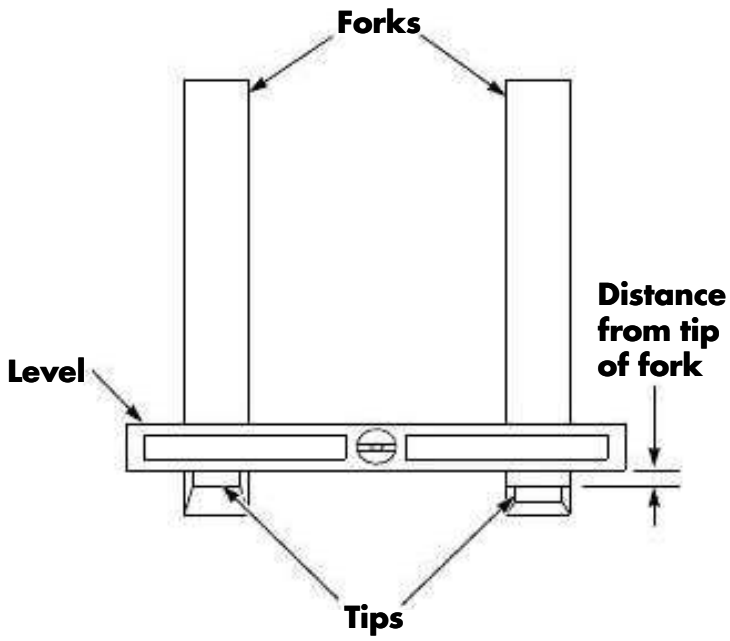
NOTE: Most forks are manufactured with a 90° angle; therefore, a reading greater than 93° or less than 87° is unacceptable. However, there are some forks that are purposely manufactured to angles greater than or less than 90°.

Fork Tip Height

1. With forks on the carriage, measure the length of the blade. See Figure 4-2.
   - For forks 42 in. (106.7 cm) or less, max. deviation is 0.25 in. (6.3 mm).
   - If length of fork is >42 in. (106.7 cm), multiply length of blade by 3%. *Blade length* _____in. x 3% = _____in. This is the maximum deviation.
2. Elevate forks approx. 4 ft. (1.2 m) off the floor.
3. Place a 4 ft. level across the tips of the forks. See Figure 4-5.
4. Raise one end of the level to make it level. See Figure 4-5.
5. Measure the distance from the tip of the fork. See Figure 4-5.

Figure 4-5. Measuring Fork Tip Height

4Fork Inspection.jpg



6. Compare this measurement to the maximum deviation.
7. If the maximum deviation number is exceeded, remove the fork from service.

Positioning Locks (if applicable)

1. With the forks on the carriage, visually inspect the positioning locks for damage.
2. Test the positioning locks to verify they work correctly.
3. If the positioning locks are damaged or do not work correctly, remove the fork from service.

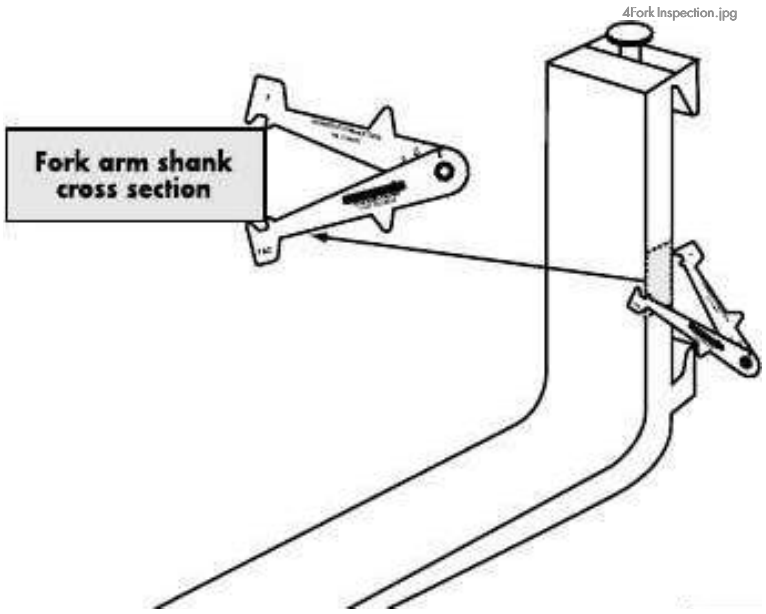
Wear

Fork Blade and Shank

1. Remove the forks from the carriage.
2. Approx. half way up the shank, set the front teeth of the jaws of the caliper on the shank. Make sure the caliper is held square across the shank to get an accurate reading. The caliper is now set to measure fork blade wear. Carefully remove the caliper from the shank. See Figure 4-6.

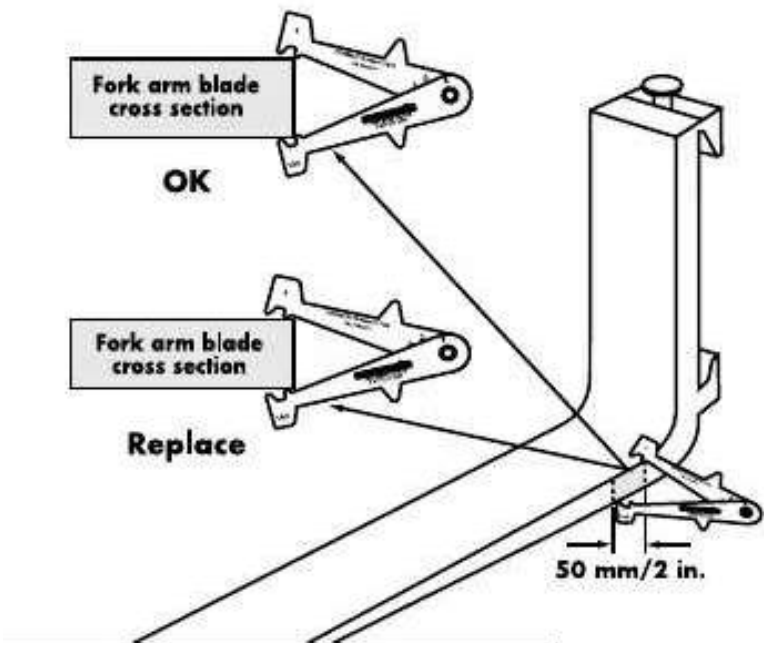
Wear

Figure 4-6. Measuring Fork Shank



3. Measure 2 in. (50 mm) out from the heel of the fork.
4. Place the caliper over the flanks of the fork arm blade at this 2 in. (50 mm) point. See Figure 4-7.

Figure 4-7. Measuring Fork Blade Wear



5. If the inside teeth of the caliper hit the fork, there is <10% wear. If the inside teeth pass freely over the fork arm, there is >10% wear and the fork must be removed from service.

CAUTION

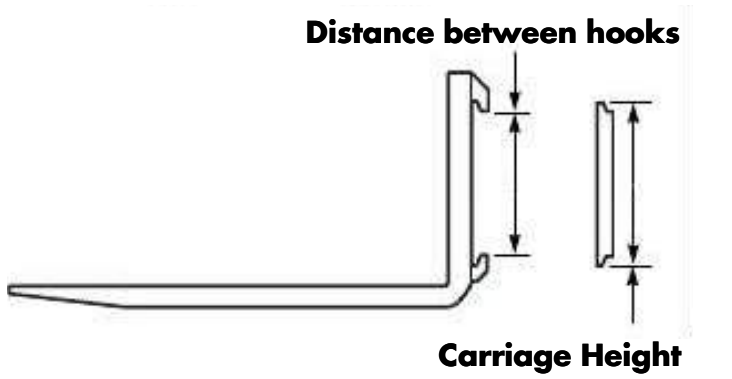
If there is greater than 10% wear of the fork arm, the fork has at least a 20% reduction in capacity.

NOTE: The caliper is designed to measure forks up to 4 in. (100 mm). It is not to be used on full or lumber tapered forks. For these forks, you must know the original fork blade thickness and take a measurement of the fork arm thickness. If the difference in the measurement exceeds 10% of the original thickness, the fork must be removed from service.

Fork Hooks

1. Remove the forks from the carriage.
2. Determine the fork mounting class.
   a. Measure the height of the carriage or the distance between the hooks. See Figure 4-8.

Figure 4-8. Determining Fork Mounting Class



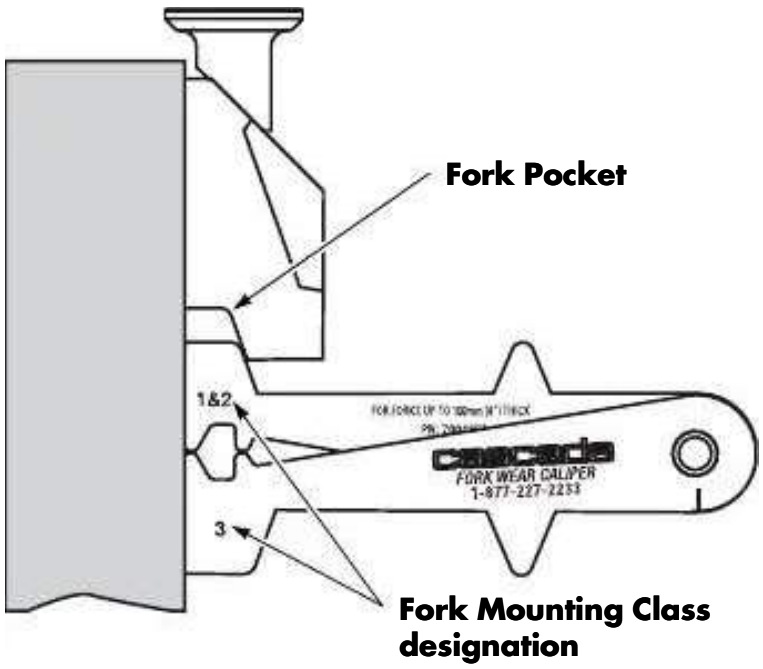
   b. Compare this measurement to the table below.

Fork Mounting Class	Distance Between Hooks in. (mm)	Carriage Height in. (mm)
1	12.05 (306)	13 (331)
2	15.04 (382)	16 (407)
3	18.78 (477)	20 (508)

3. Locate the correct extruded edge on the caliper for the fork mounting class. See Figure 4-9.
4. Slide the extruded edge up into the hook pocket. See Figure 4-9.
5. If the caliper's extruded edge *completely slides up into the fork pocket*, remove the fork from service. See Figure 4-9.

Figure 4-9. Fork Hook Inspection

4Fork Inspection.jpg



Markings

Make sure the fork's marking (individual load rating) is legible (typically located on side of fork). If fork marking is not legible, remove the fork from service.

Wear

Section 5. Troubleshooting

Electrical Troubleshooting

General

⚠ WARNING

Block the lift truck so that the drive tires are off the floor whenever a troubleshooting procedure requires turning the key switch ON. This prevents accidents caused by unexpected lift truck travel.

Unless otherwise directed, disconnect the battery connector when you check electrical circuits or components with an ohmmeter. Electrical current can damage an ohmmeter.

Before removing a power amplifier, discharge the amplifier's internal capacitor by jumpering the + and – terminals with a 100 ohm 25W resistor.

- Many problems can be caused by a dirty battery. Make sure the battery is clean.
- Save time and trouble by looking for simple causes first.
- Use a Digital MultiMeter (DMM) such as a Fluke meter for all measurements. Analog meters can give inaccurate readings and load down sensitive electronic circuits enough to cause failure. Make sure meter cables are connected to the correct meter jacks and that the correct function and scale are selected.
- Printed circuit boards are conformal coated. Make sure meter leads make a good electrical connection with test points.
- When measuring voltage, connect the positive meter lead to the connector or probe point marked (+) in the test. Connect the negative meter lead to the connector or probe point marked (–).
- Whenever measuring resistance, turn the key switch OFF and disconnect the battery connector. Battery current can damage an ohmmeter. Isolate the component from the circuit.

Shorts to Frame

"Shorts to frame" is an industry term for unintentional current leakage paths between normally isolated electrical circuits and their metal enclosures.

Shorts to frame may be metallic connections, such as a wire conductor contacting metal through worn insulation. More often, shorts to frame are resistive "leakage" paths caused by contamination and/or moisture.

These leakage paths can result in unwanted electrical noise on the metallic lift truck structure and can cause incorrect operation.

Shorts to frame are caused by:

- Accumulation of dirt
- Battery electrolyte leakage
- Breakdown in insulation
- Bare wires
- Pinched wiring harness
- Incorrect mounting of circuit cards

Shorts to frame can occur at numerous locations on a lift truck, including:

- Batteries
- Motors
- Cables, wiring, and harnesses
- Heatsinks
- Bus bars
- Solenoids
- Contactors
- Terminal strips
- Switches
- Power panel insulation
- Circuit card mounts

Shorts to Frame Test

1. Turn the key switch OFF and disconnect the battery connector.
2. To test the battery for shorts to case, connect a 12V test light to the battery case from battery B+, and then to the battery case from battery B–. If the light illuminates at all, even momentarily, there is a *serious* problem with the battery, either external contamination or internal damage. *Do not continue until this condition is corrected*. The meter may be damaged if you proceed before correcting this condition.

   Install another battery in the truck and repeat this procedure from Step 1.

   If the test light does not illuminate, continue to the next step.
3. Use a DMM set on the ampere function to measure the current leakage from the battery case to battery B+ and from the battery case to battery B–. Begin measuring at the highest ampere scale and work toward the lowest. A reading of more than 0.001A (1mA) indicates a *serious* short. *Do not continue until this condition is corrected*. The meter may be damaged if you proceed before correcting this condition.

   Install another battery in the lift truck and repeat this procedure from Step 1.

   If the current is less than 0.0002A (0.2mA), go to Step 4. If the current is greater than 0.0002A (0.2mA) and less than 0.001A (1mA), remove the battery from the truck, then continue with Step 4. Make sure the battery case does not touch the truck frame during the remaining tests.
4. With the battery disconnected (or removed and disconnected) from the truck, use a DMM to measure the resistance from lift truck frame to truck B+, to truck B– (*not battery B+ and B–*), and to all fuses and motors. A reading of less than 1000 ohms indicates a *serious* short. *Do not continue until this condition is corrected*. The meter may be damaged if you proceed before correcting this condition.

   a. To identify the cause of the short to frame, disconnect circuit components until the low resistance condition disappears. Do not reconnect components one at a time, but leave them disconnected until the low resistance reading disappears. Prevent disconnected terminals or connectors from touching the lift truck frame or other conductive surfaces.

      The most likely areas to check are:

      - Motors
      - Heatsinks
      - Power cables
      - Power circuit components
      - Control circuit components

   b. Repair or replace the component causing the low resistance condition. Repeat Step 4.

   c. Reconnect all other components previously disconnected, one at a time, measuring resistance between steps. If a reading is less than 1000 ohms when reconnecting a component, that component or its wiring is faulty; repair or replace as appropriate.

   d. When, after all components are reconnected, you get readings greater than 1000 ohms, continue with the next step.
5. Reconnect the battery connector and turn the key switch ON. If the battery was previously removed, make sure the battery case does not touch the lift truck frame.

NOTE: The functions being checked must be energized. Example: to check for shorts to frame in the travel circuit, travel must be requested.

6. Use a DMM set to the current function to measure current leakage to the truck frame from B+, B–, and all fuses and motor terminals. Begin measuring at the highest ampere scale and work toward the lowest. If the current is less than 0.001A (1mA), go to step 7. If the current is more

than 0.001A (1mA), continue with the following steps.

a. To identify the cause of the short to frame, disconnect circuit components until the leakage current reads less than 0.001A (1mA). Do not reconnect components one at a time, but leave them disconnected until the leakage current reads less than 0.001A (1mA). Prevent disconnected terminals or connectors from touching the lift truck frame or other conductive surfaces.

   The most likely areas to check are:

   - Motors
   - Heatsinks
   - Power cables
   - Power circuit components
   - Control circuit components

b. Repair or replace the component(s) causing the leakage current. Repeat Step 6.

c. Reconnect all other components previously disconnected, measuring current between steps. If a reading is more than 0.001A (1mA) when reconnecting a component, that component or its wiring is bad. Repair or replace as appropriate.

7. When, after all components are reconnected, you get a reading less than 0.001A (1mA) there is no short to frame condition with the truck or the battery. If you previously removed the battery from the truck, re-install the battery.

Fuses

Test/Inspection

Examine the fuse for signs of overheating, discoloration, cracking, or other physical damage. Replace the fuse if you find any of these conditions. To test a fuse, remove it from the lift truck. The resistance should be less than 1 ohm. Refer to Table 5-1 for fuse location.

Table 5-1. Fuse Location

Fuse	Rating	Location	Function
FT1	250A	Traction Power Amplifier	B+ to the Master Traction Power Amplifier
FT2	250A	Traction Power Amplifier	B+ to the Slave Traction Power Amplifier
FP	350A	Pump Power Amplifier	B+ to the Pump Power Amplifier
F1	6.3A	Main Fuse Panel	B+ to Key Switch
F2	5A		B+ for opt. equipment
F3	10A		B+ to opt. Hydraulic Control Board (HCB)
F4	15A		B+ to the DC/DC Converter
F5	5A	+24V Fuse Panel	+24V to Power Amp Fan
F6	5A		+24V to Horn
F7	4A		Not Used
F8	4A		+24V for opt. Warning Light
F9	0.4A		Not Used
F10	4A		+24V to opt. Rear Work Lights
F11	4A		+24V to opt. Forward Work Lights
F12	1A		Not Used
F13	4A		+24V to opt. Travel Alarm
F14	4A		+24V to Tilt Solenoid

Fuse	Rating	Location	Function
F15	4A	Fuse Panel on armrest bracket near HCB	+24V for opt. Fingertip Control - Lift/Lower
F16	4A		+24V for opt. Fingertip Control - Tilt
F17	4A		+24V for opt. Fingertip Control - Sideshift
F18	4A		+24V for opt. Fingertip Control - 4th Aux
F19	4A		Not Used
F20	4A		
F21	4A		+24V for Drain solenoid
F22	4A	+24V Fuse Panel	+24V to Lift-Limit Solenoid
F23	0.4A		Operator Display and opt. Armrest Board

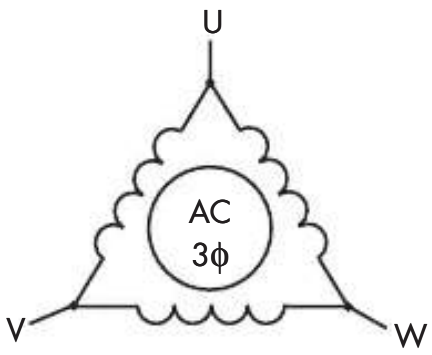
Motor Troubleshooting

AC motors used on this truck are brushless, 3-phase, internally delta-connected, variable speed motors.

The AC motor has a rotor (in place of the DC armature) and a stator (in place of the DC field). There is no electrical connection to the rotor; current is induced in the rotor. The stator has three windings staggered 120° apart, and three external connections labeled U, V, and W. See Figure 5-1.

Figure 5-1. Traction Motor Circuits

motor_AC3phaseA.eps,motor_AC3phaseB.eps



Open Winding

If the AC motor fails with an open winding, the motor moves unevenly, as if hunting, and there will be a ticking sound. Rotation is much slower than normal.

Using a clamping ammeter, measure current in each of the motor power cables. The open phase reads significantly lower than the other two phases.

Shorted Winding

If the AC motor fails with a shorted winding, the motor moves unevenly, as if hunting, and there is a high-pitched sound.

Using a clamping ammeter, measure current in each of the motor power cables. The shorted phase reads significantly higher than the other two phases.

Wiring

Visually inspect all wiring and electrical components for:

- Loose connections or connectors
- Loose or broken terminals
- Damaged terminals, blocks, or strips
- Exposed wire at terminations, excessive strip gap
- Abrasions, scrapes, nicks in the wire, damage from overheating or burns, or other general insulation damage
- Broken wire strands and shorted conditions (especially those that are close to metal edges or surfaces)

During troubleshooting and repairs, it may be necessary to unplug a connector, move a harness, cut a cable tie, or remove the wire from a bracket. Note the location of the wire and all protective or securing attachments before moving the harness.

Electrical Troubleshooting

After repair, return or replace all protective and/or securing hardware to its original condition. Protective materials are necessary to provide reliable performance of the interconnect system.

Examine and maintain any added materials used to dress and protect the wire. This includes spiral wrap, brackets, cable ties, fasteners, and flexible conduit.

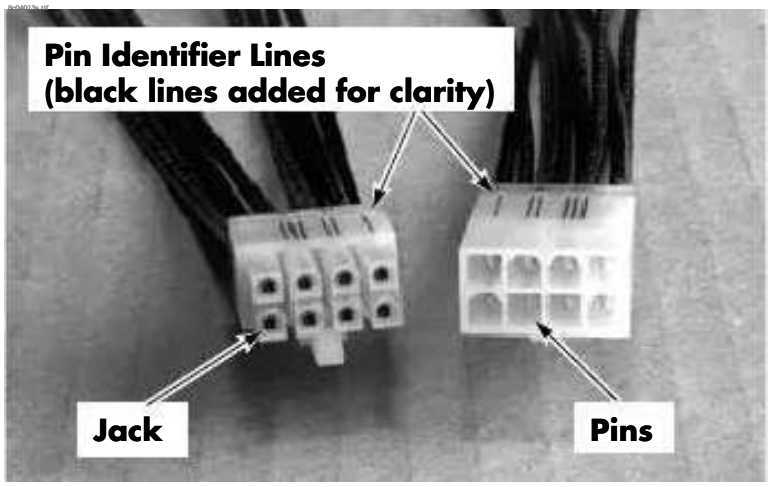
Do not attach cable ties so tight that they pinch cable harnesses. Avoid attaching cables to hydraulic hoses that expand with pressure, pinching the attached electrical cables.

Use a DMM to check for wiring continuity.

Electrical Connections

Molex connectors have ridges on the sides to help locate pin number 1. The short side has a single ridge at pin number 1. The long side has 1, 2, and 3 raised ridges at pin numbers 1, 2, and 3. See Figure 5-2.

Figure 5-2. Molex Jack and Pin Connector



Connector Locator Table

Table 5-2. Connector Location

Connector	Truck Location	Function/Destination
JAM	Hydraulic Control Board	(Not Used)
JAUX	Armrest Board	Conn. for Horn (PB12) and opt. switches
JBRA		Conn. for Tilt switches (SW19 & SW20) and Pot (P5)
JCAN		Conn. for opt. Armrest Board
JCM	Hydraulic Control Board	Conn. for Solenoids from Hydraulic Control Board (HCB)
JP	Pump Power Amplifier	Main Conn. for PPA
JSOLL	Armrest Board	Conn. for Lift/Lower switches (SW17 & 18) and Pot (P4)
JT1	Traction Power Amplifier	Main Conn. for Master TPA
JT2	Traction Power Amplifier	Main Conn. for Slave TPA
JTRA	Armrest Board	Conn. for Sideshift switches (SW21 & SW22) and Pot (P6)
JV		Not Used
J1V		Conn. for 4th Aux switches (SW23 & SW24) and Pot (P7)
J1+/–	Battery Conn.	Battery Conn.
J4	Brake Fluid Reservoir	Conn. for Low Brake Fluid Sensor (SW3)
J8	Steering Column	Conn. for Horn Push Button switch (PB4)
J9		Conn. for Key switch (SW1)
J11	Under floor panel near Horn	Conn. for Horn (HR1)
J13	Near Pump Motor	Conn. for Pump Motor encoder (EN3) and temp switch (TS3)
J14	Near Steer Pot	Conn. for Steer Pot (P1)
J15	Near Right Traction Motor	Conn. for Right Traction Motor encoder (EN1) and temp switch (TS1)
J16	Near Left Traction Motor	Conn. for Left Traction Motor encoder (EN2) and temperature switch (TS2)
J17	Near Pump Motor	Conn. for Pump Motor temp switch (TS3)
J20	Near Battery Conn.	Intermediate Conn. for Seat switch (SW2)
J21	Dash Cover	Conn. for Emergency Disconnect (PB1)
J22		Intermediate Conn. for Seat switch (SW2)
J24	Under Seat	Conn. for Seat switch (SW2)
J30	Dash Cover	Conn. for Parking Brake switch (SW7)
J31	Under floor panel near switch	Conn. for Brake Pedal switch (SW6)
J32		Conn. for Travel Pot (P2) and Travel Enable switch (SW8)
J33		Conn. for Forward Pedal (SW4) and Reverse Pedal (SW5) switches
J34	Dash Cover	Conn. to Vehicle Manager
J35	Front side of Dash Cover	Intermediate Conn. for various switches

Electrical Troubleshooting

Connector	Truck Location	Function/Destination
J36	Steering Column	Conn. for LPH switch (PB3)
J37		Conn. for Speed Reduction switch (PB2)
J39		Conn. for Forward Hand Direction switch (SW9) and Backward Hand Direction switch (SW10)
J40	Dash Cover	Conn. to Vehicle Manager
J41	Near Valves	Conn. for Lift Pot (P3)
J42		Conn. for Lift switch (SW11)
J43		Conn. for Tilt switch (SW12)
J44		Conn. for Sideshift switch (SW13)
J45		Conn. for 4th Function switch (SW14)
J46		Not Used
J47	Near Valves	Conn. for Lowering switch (SW15)
J48	Under floor panel	Intermediate Conn. for Hyd. Functions
J50	Under Battery Conn.	Intermediate Power Conn. from Battery
J52	Under floor panel	Conn. for B+ to DC/DC converter
J60	Near HCB	Intermediate Conn. for Hyd. Solenoids from HCB
J61		
J62	Under floor panel	Intermediate Conn. for 24VDC fuse panel
J63		Intermediate Conn. for 24VDC fuse panel
J70+/–	Near lift pump	Conn. for opt. Travel Alarm (BZ1)
J71	Front of fan	Conn. for Power Amp Fan (FN1)
J72	Right side of Hyd. Reservoir	Intermediate Conn. for Tilt Limit Solenoid (EV13) and Lift/Lower Limit Solenoid (EV12)
J73	Left side of Hyd. Reservoir	Conn. for Angle Tilt Prox. switch (SW30)
J75		Conn. for opt. End of Free Lift switch (SW16) and opt. Mast Height switch (SW31)
J81	Traction Power Amplifier	Conn. at Traction Power Amplifier for B–
J90		Not Used
J91	Left side rear under Amps	Conn. for Left Brake and Tail Lights
J92	Dash Cover	Intermediate Conn. for opt. Forward Right Working Light (LP6)
J93		Intermediate Conn. for opt. lights
J94		Conn. for opt. Backward Work Lights switch (SW29)
J95		Conn. for opt. Warning Lamp switch (SW27)
J96	Under floor panel	Conn. for DC/DC converter
J97	Dash Cover	Conn. for opt. Warning Light (LP5)
J99		Conn. for opt. Forward Work Lights switch (SW28)
J100	Front side of Dash Cover	Conn. for Auxiliary Power strip
J101	Dash Cover	Conn. for opt. Lift-Limit Push Button switch (PB9)

Connector	Truck Location	Function/Destination
J102	Right rear	Conn. for Right Brake and Tail Lights
J103	At Light	Conn. for opt. Forward Right Work Light (LP6)
J104		Conn. for opt. Forward Left Work Light (LP7)
J105		Conn. for opt. Backward Left Work Light (LP9)
J106		Conn. for opt. Backward Right Work Light (LP8)
J107	Near Valves	Conn. for Lowering Solenoid (EVP1)
J108		Conn. for Lifting Solenoid (EV2)
J109		Conn. for Tilt Forward Solenoid (EV3)
J110		Conn. for Tilt Backward Solenoid (EV4)
J111		Conn. for Left Sideshift Solenoid (EV5)
J112		Conn. for Right Sideshift Solenoid (EV6)
J113		Conn. for 4th Function Solenoid (EV7)
J114		Conn. for 4th Function Solenoid (EV7)
J115		Conn. for Tilt Limit Solenoid (EV13)
J117		Conn. for Drain Solenoid (EVP)
J118		Not Used
J121	Near Valves	Conn. for Lift/Lower Limit Solenoid (EV12)
J131	Near Battery Conn.	Intermediate Conn. for opt. Armrest Board
J132	Right side Dash Cover	Conn. for CAN-Bus Interface
J137		Conn. for Operator Display
J138	Bottom of Armrest Board	Intermediate Conn. for opt. Armrest Board
J140	HCB	Main Conn. for HCB
J141	Armrest Board	Conn. for opt. Lift-Limit Push Button switch (PB13)
J142		Conn. for Horn switch (PB12)
J406	Armrest Board	Conn. for Lift/Lower switches (SW17 & SW18) and Pot (P4)
J407		Conn. for Tilt switches (SW19 & SW20) and Pot (P5)
J408		Conn. for Sideshift switches (SW21 & SW22) and Pot (P6)
J409		Conn. for 4th Aux switches (SW23 & SW24) and Pot (P7)
PPA B+	Pump Power Amplifier	Conn. for B+ to PPA
PPA B–		Conn. for B– to PPA
PPA (U)		Conn. for 1 of 3 AC outputs to Pump Motor
PPA (V)		
PPA (W)		
MTPA B+	Master Traction Power Amplifier	Conn. for B+ to Master TPA
MTPA B–		Conn. for B– to Master TPA
STPA B+	Slave Traction Power Amplifier	Conn. for B+ to Slave TPA
STPA B–		Conn. for B– to Slave TPA

Electrical Troubleshooting

Connector	Truck Location	Function/Destination
TPA (UM)	Master Traction Power Amplifier	Conn. for 1 of 3 AC outputs to Right Traction Motor
TPA (VM)		
TPA (WM)		
TPA (US)	Slave Traction Power Amplifier	Conn. for 1 of 3 AC outputs to Left Traction Motor
TPA (VS)		
TPA (WS)		

Hydraulic Troubleshooting

When performing hydraulic troubleshooting procedures:

- Lower the carriage fully and center the sideshift.
- Stabilize the top of the mast with an overhead chain hoist.
- Make sure hydraulic lines and components are fully installed.
- Whenever possible, keep the key switch OFF and the battery connector disconnected.
- Cap open hydraulic lines to prevent contamination.
- Relieve pressure in hydraulic lines before disconnecting.

⚠CAUTION

After elevating the carriage for troubleshooting, make sure to use blocks to secure the carriage.

Use extreme care when blocking the mast for any reason. Never remove a block when it is supporting the mast.

Symptom Tables

Refer to schematics beginning on page A-12.

Refer to the Theory of Operation "Pinout Matrix" on page 8-13 for troubleshooting individual conductors or components.

Travel Functions

Dead Truck	
Condition	**Cause/Action**
No Display	• Low or bad battery • Check EPO. • Check B– to TPA. • Check key switch circuit. • Check DC/DC converter per Pinout Matrix. • Check voltage per Pinout Matrix.

Slow or Sluggish Acceleration, Normal Lift	
Condition	**Cause/Action**
Mechanical	• Debris in the wheel hub, axle, or steer tire assembly • Check adjustment of the parking brake. • Check the drive motor shaft and bearings.
Electrical	• Verify TPA setting using FlashWare. • Check steer pot. • Check motor encoders. • Replace TPA.

Hydraulic Functions

If hydraulic fluid contamination is suspected, flush the hydraulic system and fill with new fluid. See “Hydraulic Fluid” on page 7-44.

Travel OK - No Hydraulic Functions	
Condition	**Cause/Action**
Pump Motor Runs	Check pump discharge pressure.

Travel OK, Steering OK - No Other Hydraulic Functions	
Condition	**Cause/Action**
Pump Motor Runs	• Check for fluid pressure on the Load Sensing hose at the steer orbitrol. • Check the hydraulic circuit between the priority valve and the control valve assembly. • Replace the priority valve. • Lever Controls - inspect “check valve” in lever assembly for contamination. • Fingertip Controls - check +V from HCB to solenoids.
Pump Motor Does Not Run	• Lever Controls - check for the presence of B– at J48-6 to all switches. • Fingertip Controls - check for the presence of B+ at J48-12 and B– at J48-14.

Travel OK - No or Sluggish Steering; All Other Hydraulic Functions OK
• Check steer pressure. • Replace the priority valve.

Travel OK, Steering OK - Individual Hydraulic Function not Working; Other Auxiliary Functions OK	
Condition	**Cause/Action**
Pump Motor Does Not Run When Individual Aux Function Requested	*Lever or Fingertip Controls:* • Check output voltage from the appropriate switch while requesting function per the Pinout Matrix. *Fingertip Controls Only:* • Check output voltage from appropriate potentiometer while requesting function per the Pinout Matrix. • Check output voltage to the appropriate solenoid while requesting function per the Pinout Matrix.

Symptom Tables

Slow Lift, Normal Lower - All Other Hydraulic Functions OK

- Use FlashWare diagnostics to check lift commands.
- Check lift pressure.
- Fingertip Controls - check EV2 for correct operation/contamination.
- Verify lift pot voltage per Pinout Matrix. Learn lift pot.
- Check lift settings in FlashWare.
- Lever Controls - check EV14.
- Fingertip Controls - check EVP1.
- Check flow control V1.
- Check spool valve for contamination.

No or Slow Lower

- Check the lift flow control for contamination, wear, or damage.
- Check EV14 (Lower Blocking Valve) per Pinout Matrix.

Section 6. Messages and Codes

Operator Display Messages

When the key switch is turned ON, the Operator Display cycles all of the indicator icons/lights.

Refer to Figure 6-1 and Table 6-1 for the icons present on the Operator Display and their function or meaning.

Figure 6-1. Operator Display

operatordisplay.tif

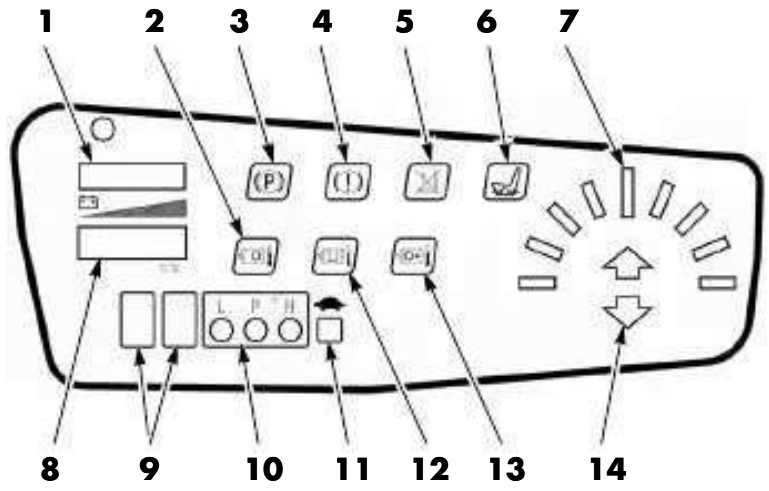
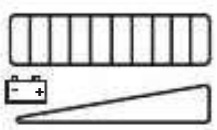
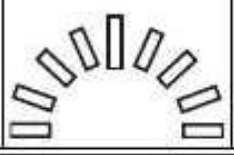


Table 6-1. Operator Display Icons and Definitions

Item	Icon	Description	Function
1		Battery Charge Indicator	With the battery fully charged, the right green LED is illuminated. As the battery discharges, the LEDs illuminate from right to left. When the battery has discharged to within 10% of the configured cutback setting, the first red LED is illuminated and the Lift Reduction icon (5) begins to blink. This represents that the battery is in reserve and must be recharged. When the battery has discharged to the configured cutback setting, the first red LED will blink and the Lift Reduction icon is illuminated.
2		Left Traction Motor overtemperature icon	Illuminates when the motor temperature has exceeded 266°F/130°C (36V); 248°F/120°C (48V).
3		Parking Brake icon	Illuminates when the parking brake is ON.
4		Brake Fluid Low icon	Illuminates when the level of brake fluid in the reservoir has fallen below the minimum level.
5		Lift Reduction icon	Blinks when the battery has discharged to within 10% of the configured cutback setting. Illuminates when the battery has discharged to the configured cutback setting, indicating lift speed is reduced.
6		Seat icon	Illuminates when: • operator leaves the seat without turning the Key switch OFF • optional battery gate switches are open All functions are disabled.
7		Steer direction indicator	Indicates steer direction.

Item	Icon	Description	Function
8		Electronic hour meter	The hour meter provides readings in hours and tenths of an hour. It is activated when the pump is activated.
9		Alphanumeric error code display	Displays error codes.
10		Performance mode indicator	Identifies which performance mode is selected: • L = low performance • P = medium performance • H = high performance
11		Performance reduction (turtle) icon	Illuminates when the performance reduction function is active.
12		Pump motor overtemperature icon	Illuminates when the motor temperature has exceeded 266°F/130°C (36V); 248°F/120°C (48V).
13		Right traction motor overtemperature icon	Illuminates when the motor temperature has exceeded 266°F/130°C (36V); 248°F/120°C (48V).
14		Travel direction icon	Indicates the direction of travel selected.

Codes

Intermittent Codes

If a code appears intermittently, check for shorts to frame. Refer to Shorts to Frame on page 5-2. Check or install static strap.

Multiple Codes

If multiple codes are displayed, compare all codes to determine if they have anything in common. Examine the functions of the truck: what works and what does not. Compare the codes with truck functions to determine the best starting point for troubleshooting. This helps avoid replacement of parts that do not resolve the issue.

A code can be displayed and then another seemingly unrelated code will follow. Codes are generated by multiple managers. The first code displayed does not necessarily mean it is more significant than subsequently displayed codes.

In some cases, it is possible for codes to be displayed that should not be displayed on the truck (option not on truck, truck specific code not for this truck, and so on). This can be caused by a bad TPA, PPA, VM, Armrest Board, or Hydraulic Control Board, shorts to frame, or swapping parts. If an invalid code is displayed, use FlashWare to determine if the truck's identity or options have been changed.

Communication Codes

Check power to all managers. This includes the TPAs, PPA, VM, Armrest Board, and Hydraulic Control Board.

Using FlashWare, determine if the truck identity or options have been changed. Look for software model versions that are either incorrect or missing. If a manager is not able to communicate with FlashWare this can help identify where to start looking for problems.

Check communication wires between all modules for continuity and shorts to frame per Pinout Matrix. If OK, replace affected manager.

NOTE: The Operator's Display is a read-only device. "d-series" codes indicate that the display is not receiving communication from one or more managers. Check communication lines between the display and affected manager(s). Check for communication codes between affected manager(s) and other managers.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
01	**Code 01: Master TPA Internal Fault** The power amplifier has detected an internal fault.	Check voltage to TPA. Check communication wires between all modules for continuity and shorts to frame per the Pinout Matrix. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
02	**Code 02: Master TPA Internal Fault** Fault in the area of memory in which the adjustment parameters are stored.	If code does not clear by cycling key, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA. If code clears, the adjustable parameters have been reset to default values and require resetting to customer's requirements via FlashWare.
03	**Code 03: Master TPA Internal Fault** The power amplifier has detected an internal fault.	Check voltage to TPA. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
04	**Code 04: Master TPA Internal Fault** Correct current draw by the motor is not seen by the TPA.	Check motor cables for continuity. Check motor cable connections for correct torque. Compare current from all 3 phases. If one phase is significantly higher or lower than the other two, replace the motor. Measure voltage and resistance across coil and contact tips per the Pinout Matrix. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
05	**Code 05: Battery Sense Out-of-Range/Master TPA** The Master TPA monitors the battery voltage at +V Key. If voltage is below a set threshold, the code is displayed. The TPA also monitors the voltage on its internal capacitors. If voltage goes above a set threshold, the code is displayed. This most likely occurs during plugging.	Measure voltage into amplifier at +V Key. Check configured battery voltage (36V or 48V) with FlashWare. If incorrect, set correct battery voltage in FlashWare (and re-Learn pots) or replace battery with correct battery. Measure battery voltage at the Master TPA +BATT connection during plugging. If the voltage exceeds 63V, replace the TPA. Test power cables to the motor for shorts to frame and other cables. Test the motor for shorts to frame. Resistance must be >1 Megohm. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
06	**Code 06: Short in Master TPA** When the Key switch is turned ON, the TPA momentarily powers each motor phase and monitors current. If current is seen when it should not be, this code is displayed.	Test power cables for shorts. Swap the connections from the Master TPA to the left traction motor using appropriately sized jumper cables and turn the Key switch ON. If code changes, replace the motor. If the code is still displayed, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
07	**Code 07: Open in Master TPA** When the Key switch is turned ON, the TPA monitors each motor phase for current draw. If current is not seen when it should be, this code is displayed.	Check cables to the motor and TPA for continuity and correct torque. Swap the connections from the master TPA and the Slave traction motor using appropriately sized jumper cables and turn the Key switch ON. If code changes, replace the motor. If the code is still displayed, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
08	**Code 08: Traction Contactor Open When Commanded Closed** Correct voltage is not seen by the TPA at +BATT when CT3 is commanded closed.	Inspect the contactor for physical binding and welded tips. Check the fuse for the TPAs (FT1 and FT2). Measure voltage and resistance across coil. Check cables from the battery to the TPA for continuity and correct torque. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
09	**Code 09: Master TPA Internal Fault** Failure of the current sensor.	Check power cables at the motor and TPA for continuity and correct torque. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
10	**Code 10: Master TPA Precharge Failure** When the key switch is turned ON, the TPA attempts to charge the internal capacitors. If the capacitors are not charged to B+ in a certain amount of time, this code is displayed.	Check for B– at the TPA power input. Check for B+ from JT1-1 (+V Key). If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
11	**Code 11: Master TPA Overtemperature** Internal temperature on the Master TPA is >167°F (75°C). Performance is reduced to 212°F (100°C); travel is shut down above 212°F (100°C).	Check fan for correct operation. Fan should operate within about one minute after turning key ON. If not, troubleshoot fan. Check/clean air filter. Allow TPA time to cool. If code clears, check cables to the motor and TPA for continuity and correct torque. Check for brake drag. If code does not clear, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
12	**Code 12: Right Traction Motor Temperature Above 266°F** Right traction motor overtemperature, above 266°F (130°C), or temperature switch is bad.	If motor temperature is <266 °F (130°C), check wiring to temperature switch TS1 from VM. If motor temperature is >266°F (130°C), allow motor to cool and measure current draw on each phase of the motor. All three phases should be approx. equal. If not, replace the motor. Check for binding in the drive unit or dragging brakes. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
13	**Code 13: Right Traction Motor Encoder Error** Incorrect or no input seen by the Master TPA from the right traction motor encoder.	Test the +12V and GND inputs to both encoders and the output from channels A and B to the amp from both encoders. Check resistor between 12V and GND. If OK, check for shorts to frame. Check voltage to the TPA. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
14	**Code 14: Master TPA Temperature Sensor Out-of Range** Temperature sensor has exceeded values expected.	Check fan for correct operation. Fan should operate within about one minute after turning Key switch ON. If not, troubleshoot fan. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
15	**Code 15: Amplifier Enable** No B– input seen by the TPA.	Check for B– at both TPAs Safety In and Safety Out circuits (JT1-11 and 19; JT2-11 and 19). If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
16	**Code 16: Master TPA Detected CAN-Bus Error** The Master TPA has not received a communication message from the VM, HCB, or PPA.	Test battery voltage under load. In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
17	**Code 17: CAN-Bus Node Offline** Too much time between communication from the VM, Slave TPA, HCB or PPA to the Master TPA has elapsed. This code can also be caused by an open in a cable from the amplifier to the traction motors.	Check the power cables to the traction motors. Check both traction motor encoders, temperature sensors for opens, shorts and shorts to frame. In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
18	**Code 18: Relay 1 Not Energized By TPA** The Master TPA commanded Relay 1 to energize with truck configured for a 48V battery. Did not receive correct feedback.	Check Relay 1 by disconnecting from circuit. Check output to Relay 1 from Master TPA. If OK, replace Relay 1. If not OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
19	**Code 19: Traction Contactor Driver Shorted** The Master TPA detected excessive current draw when the CT3 contactor was commanded closed.	Measure voltage and resistance across coil. Check JT2-4 (Config) wiring and connection. Check wires to coil for shorts to other wires and the frame. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
1A	**Code 1A: Slave TPA Not Responding** Slave TPA is bad.	Replace the Slave TPA.
1C	**Code 1C: Battery Low** The voltage at the +V Key input to the Master TPA is down to 10% of charge level (performance reduction). Current will be reduced to 50% of programmed levels.	Check battery voltage and specific gravity - static and under load. (Refer to battery manufacturer for correct voltage and specific gravity information.) If battery voltage is correct, measure voltage at JT1-1 on the Master TPA. If voltage is not equal to battery voltage, check voltage at all connection points back to the battery. Repair the connection where the voltage drop is or replace the component causing the voltage drop. Check voltage at JT1-7 and JT1-14 (EN1 Phase A and B). If voltage at TP1-1 is correct, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
1E	**Code 1E: Traction Contactor Closed When Commanded Open** The Master TPA commanded the CT3 contactor open and the tips are still closed.	Check the contactor for physical binding and welded tips. Measure voltage and resistance across coil. Check motors for shorts from windings to case. The TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
20	**Code 20: Traction Contactor Coil Driver Error** Failure of the contactor driver.	Measure voltage and resistance across coil. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
21	**Code 21: Traction Contactor Coil Shorted** The TPA measured too much current draw when the CT3 contactor was commanded closed.	Measure resistance across coil and wires to the coil. Check wires for shorts to other wires and truck frame. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
23	**Code 23: Seat Switch Open** The seat switch or an optional battery gate switch opened during operation.	Troubleshoot seat switch, optional battery gate switches, and associated wiring. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
25	**Code 25: Incorrect Battery Installed** When the Key switch is turned ON, the TPA checks the battery voltage and compares it with the "SET BATTERY" parameter setting. If the actual voltage is 20% higher or lower than the set value, this code is displayed.	Verify battery voltage. If wrong voltage, set correct voltage via FlashWare (and re-learn pots) or install correct voltage battery. If battery and parameter settings are OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
26	**Code 26: Incorrect Start Procedure** General incorrect starting procedure. May appear in conjunction with Code 81.	If the directional switch is left in forward or reverse position when the operator leaves the seat, Code 81 is displayed after a brief time-out (approx. 30 sec). If the code still appears after lever is returned to neutral, cycle the Key switch to clear. Check GND and 12V from Master TPA to Steer Pot. Test switches for correct operation. Check continuity of wires from switches to cards.
28	**Code 28: Steer Sensor Out-of-Range** The input voltage from the steer pot is outside the required values.	Check wires to the pot for opens or shorts. Check pot supply and output voltage. Check pot mounting and connection. Check for shorts to frame. Adjust pot to approx. 5.5V with wheels straight. Restore Defaults and run Learn.
29	**Code 29: Requesting Travel In Both Directions** Forward and Reverse switches are closed at the same time.	Troubleshoot switches and wiring. If OK, replace VM.
2A	**Code 2A: Master TPA Internal Fault** Master TPA has an incorrect configuration.	Verify connections to Master TPA. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
2C	**Code 2C: Master TPA Parameter Restore Error** Internal failure of the Master TPA.	Verify connections to Master TPA. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
2E	**Code 2E: Parking Brake Switch Error** SW7 is closed when travel is detected.	Troubleshoot switch and wiring.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
31	**Code 31: PPA Internal Fault** The power amplifier has detected an internal fault.	Check voltage to the PPA. Check communication wires between PPA, TPA, and VM for continuity and shorts to frame. If OK, replace PPA.
32	**Code 32: PPA Internal Fault** Fault in the area of memory where the adjustable parameters are stored.	If code does not clear by cycling Key switch, replace the PPA. If code clears, the adjustable parameters have been reset to default values and require resetting to customer's requirements via FlashWare.
33	**Code 33: PPA Internal Fault** Internal failure of the PPA.	Check voltage to the PPA. If OK, replace the PPA.
34	**Code 34: PPA Internal Fault** Correct current draw by the motor is not seen by the PPA.	Check battery voltage under load. Check for shorts to frame. Check cables to the motor for continuity and correct torque. Compare current from all 3 phases. If one phase is significantly higher or lower than the other two, replace the motor. Swap the connections from the PPA to the traction motor using appropriately sized jumper cables and turn the key switch ON. If code changes, replace the motor. If the code is still displayed, replace the PPA.
35	**Code 35: Battery Sense Out-of-Range** The PPA monitors the battery voltage at +V Key. If voltage is below a set threshold, this code is displayed. The PPA also monitors the voltage on its internal capacitors. If voltage goes above a set threshold, this code is displayed.	Measure voltage into amplifier at +V Key. Check configured battery voltage (36V or 48V) with FlashWare. If incorrect, set correct battery voltage in FlashWare (and re-learn pots) or replace battery with correct battery. Test the power cables to the motor for shorts to the truck frame and/or other cables. Test the motor for shorts to frame. Resistance must be >1 Megohm. If OK, replace the PPA.
36	**Code 36: Short in PPA** When the Key switch is turned ON, the PPA momentarily powers each motor phase and monitors current. If no current is seen, this code is displayed.	Check battery voltage under load. Check for shorts to frame. Check power cables for shorts. Swap the connections from the PPA to the traction motor using appropriately sized jumper cables and turn the Key switch ON. If code changes, replace the motor. If the code is still displayed, replace the PPA.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
37	**Code 37: Open in PPA** When the Key switch is turned ON, the PPA monitors each motor phase for current draw. If current is seen when it should not be, this code is displayed.	Check voltage to the PPA. Check cables to the motor and PPA for continuity and correct torque. Swap the connections from the PPA to the traction motor using appropriately sized jumper cables and turn the Key switch ON. If code changes, replace the motor. If the code is still displayed, replace the PPA.
38	**Code 38: Pump Contactor Open When Commanded Closed** Correct voltage is not seen by the PPA at +BATT when CT2 is commanded closed.	Inspect the contactor for physical binding and welded tips. Check the fuse for the PPA (FP). Measure voltage and resistance across coil. Check cables from battery to the PPA for continuity and correct torque. If OK, replace the PPA.
39	**Code 39: PPA Internal Fault** Failure of the current sensor.	Check cables to the motor and PPA for continuity and correct torque. If OK, replace the PPA.
40	**Code 40: PPA Precharge Failure** When the Key switch is turned ON, the PPA attempts to charge the internal capacitors. If the capacitors are not charged to B+ in a certain amount of time, this code is displayed.	Check for B– at the –BATT connection of the PPA. Check for B+ from the Key switch to the +V Key connection on the PPA. If OK, replace the PPA.
41	**Code 41: PPA Overtemperature** Internal temperature of the PPA is >167°F (75°C). Performance is reduced between 167 and 212°F (75 and 100°C); travel and lift are shut down above 212°F (100°C).	Check fan for correct operation. Fan should operate within about one minute after turning Key switch ON. If not, troubleshoot fan. Allow PPA time to cool. If code clears, check cables to pump motor and PPA for continuity and correct torque. Check amp draw on the three phases of the motor. Make sure they are equal. If they are not equal, replace the pump motor. If amp draw is high, check mast for binding. If code remains, replace PPA.
42	**Code 42: Pump Motor Temperature Out-of-Range** Pump motor overtemperature, >266°F (130°C), or temperature switch bad.	If motor temperature is <266°F (130°C), check wiring to switch (TS3). If motor temperature is >266°F (130°C), check motor amp draw. If high, check for binding in mast. If OK, replace the PPA.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
43	**Code 43: Pump Motor Encoder Error** Incorrect or no input seen by the PPA from the pump motor encoder. This code can also be caused by a lack of power to the PPA when there is a pump request.	Test the +12V and GND inputs to the encoder and the output from channels A and B to amplifier. If OK, check for shorts to frame. Check voltage to PPA. If OK, replace the PPA.
44	**Code 44: PPA Temperature Sensor Out-of Range**	Check wires to temperature switch for shorts. If OK, replace the PPA.
45	**Code 45: Amplifier Enable** No B– input seen by the PPA.	Check for B– at the PPA power input. Make sure gray jumper wire is connected between JP-9 and 11. If voltage is not correct, replace PPA.
46	**Code 46: PPA Detected CAN-Bus Error** The PPA has not received a communication message from the VM, HCB, Master, or Slave TPA.	Check voltage to TPAs, PPA, VM, and HCB. Check communication wires between all modules for continuity and shorts to frame. Check both traction motor encoders, temperature sensors for opens, shorts, and shorts to frame. In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
47	**Code 47: CAN-Bus Node Offline** Too much time between communication from the VM, HCB, master or Slave TPA to the PPA has elapsed. This code can also be caused by an open in a cable from the amplifier to the pump motor.	Check both traction motor encoders, temperature sensors for opens, shorts and shorts to frame. In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
48	**Code 48: CT2 Contactor Open When Commanded Closed** Correct voltage is not seen by the PPA at +BATT when CT2 is commanded closed.	Check the contactor for physical binding and welded tips. Check the fuse for the PPA (FP). Measure voltage and resistance across coil. Check cables from battery to PPA for continuity and correct torque. If OK, replace PPA.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
49	**Code 49: Pump Contactor Driver Shorted** The PPA detected excessive current draw when the CT2 contactor was commanded closed.	Measure voltage and resistance across coil. Check wires to coil for shorts to other wires and the frame. If OK, replace the PPA.
4C	**Code 4C: Battery Low** The voltage at the +V Key input to the PPA is down to 10% of charge level (performance reduction). Current is reduced to 50% of programmed levels.	Check battery voltage and specific gravity - static and under load. *Refer to battery manufacturer for correct voltage and specific gravity information.* If battery voltage is correct, measure voltage at JP-1 on the PPA. If voltage is not equal to battery voltage, check voltage at all connection points back to the battery. Repair the connection causing the voltage drop or replace the component causing the voltage drop. Check voltage at JP-7, JP-8, JP-14, and JP-15 (EN3 connections). If voltage at JP-1 is correct, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
4E	**Code 4E: Pump Contactor Closed When Commanded Open** The PPA commanded the CT2 contactor open and the tips are still closed.	Check the contactor for physical binding and welded tips. Measure voltage and resistance across coil. If OK, replace the PPA.
50	**Code 50: Pump Contactor Coil Driver Error** The CT2 contactor driver is bad.	Measure resistance across coil and wires to the coil. Check wires for shorts to other wires and truck frame. If OK, replace the PPA.
51	**Code 51: Pump Contactor Coil Shorted** The PPA measured too much current when the CT2 contactor was commanded closed.	Measure resistance across coil and wires to the coil. Check wires for shorts to other wires and truck frame. If OK, replace the PPA.
53	**Code 53: Seat Switch Open** Seat switch open during lift.	Troubleshoot seat switch, optional battery gate switches, lift switch, and associated wiring.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
55	**Code 55: Incorrect Battery Installed** When the Key switch is turned ON, the PPA checks the battery voltage and compares it with the "SET BATTERY" parameter setting. If the actual voltage is 20% higher or lower than the set value, this code is displayed.	Check battery voltage. Set correct battery voltage via FlashWare (and re-learn pots) or replace battery with correct voltage battery. If battery and parameter settings are OK, replace PPA.
56	**Code 56: Incorrect Start Up Sequence** Incorrect start procedure. May appear in conjunction with Code 81.	If the directional switch is left in forward or reverse position when the operator leaves the seat, Code 81 may be displayed after a brief timeout (approx. 30 sec). If the code still appears after lever is returned to neutral, cycle the Key switch to clear. Test switches for correct operation. Check continuity of wires from switches to cards.
57	**Code 57: Hydraulic Control Board Time-Out** An error was detected in communication between the Hydraulic Control Board and the PPA.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
58	**Code 58: PPA Internal Fault** Failure on the current sensor.	Check cables to the motor and PPA for continuity and correct torque. Replace the PPA.
5A	**Code 5A: PPA Internal Fault** PPA internal failure.	Replace the PPA.
5C	**Code 5C: PPA Parameter Restore Error** PPA internal failure.	Replace the PPA.
61	**Code 61: Slave TPA Internal Fault** The Slave TPA has detected an internal fault.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
62	**Code 62: Slave TPA Internal Fault** Fault in the area of memory where the adjustable parameters are stored.	If code does not clear by cycling key, replace the Slave TPA. If code clears, the adjustable parameters have been reset to default values and require resetting to customer's requirements via FlashWare.
63	**Code 63: Slave TPA Internal Fault** The power amplifier has detected an internal fault.	Check voltage to the Slave TPA. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
64	**Code 64: Slave TPA Internal Fault** Correct current draw by the motor is not seen by the TPA.	Check voltage to Slave TPA. Check motor cables for continuity and correct torque. Compare current from all 3 phases. If one phase is significantly higher or lower than the other two, replace the motor. Measure voltage and resistance across coil and contact tips. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
65	**Code 65: Slave TPA Detected Battery Sense Out-of-Range** The Slave TPA monitors the battery voltage at +V Key. If voltage does not match configured voltage or is below set threshold, this code is displayed. The TPA also monitors the voltage on its internal capacitors. If voltage goes above 63VDC, this code is displayed.	Measure voltage into amplifier at +V Key. Check configured battery voltage (36V or 48V) with FlashWare. If incorrect, set correct battery voltage in FlashWare (and re-learn pots) or replace battery with correct battery. Measure battery voltage at the Slave TPA +BATT connection during plugging. If the voltage exceeds 63V, replace the Slave TPA. Test the power cables to the motor for shorts to the truck frame and the other cables. Test the motor for shorts to frame. Resistance must be >1 Megohm. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
66	**Code 66: Short in Slave TPA** When the Key switch is turned ON, the Slave TPA momentarily powers each motor phase and monitors current. If current is seen when it should not be, this code is displayed.	Check voltage to the Slave TPA. Swap the connections from the Master TPA to the left traction motor using appropriately sized jumper cables and turn the key switch ON. If code changes, replace the motor. If the code is still displayed, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
67	**Code 67: Open in Slave TPA** When the Key switch is turned ON, the Slave TPA monitors each motor phase for current draw. If current is not seen when it should be, this code is displayed.	Check voltage to the Slave TPA. Check cables to the motor and Slave TPA for continuity and correct torque. Swap the connections from the Master TPA and motor with the Slave TPA and traction motor using appropriately sized jumper cables and turn the Key switch ON. If code changes, replace the motor. If the code is still displayed, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
68	**Code 68: Traction Contactor Open When Commanded Closed** Correct voltage is not seen by the Slave TPA at +BATT when CT3 is commanded closed.	Inspect the contactor for physical binding and welded tips. Check the fuse for the TPAs (FT1 and FT2). Measure voltage and resistance across coil. Test cables from battery to Slave TPA for continuity and correct torque. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
69	**Code 69: Slave TPA Internal Fault** The current sensor is bad.	Check cables to the motors and Slave TPA for continuity and correct torque. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
70	**Code 70: Slave TPA Precharge Failure** When the Key switch is turned ON, the Slave TPA attempts to charge the internal capacitors. If the capacitors are not charged to B+ in a certain amount of time, this code is displayed.	Check for B– at the Slave TPA power input. Check for B+ to JT2-1 (+V Key). If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
71	**Code 71: Slave TPA Overtemperature** Internal temperature of the Slave TPA is >167°F (75°C). Performance is reduced to 212°F (100°C); travel is shut down above 212°F (100°C).	Check fan for correct operation. Fan should operate within about one minute after turning Key switch ON. If not, troubleshoot fan. Allow Slave TPA time to cool. If code clears, check cables to left traction motor and Slave TPA for correct torque and continuity. Check for brake drag. If code remains, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
72	**Code 72: Left Traction Motor Temperature Above 266°F** Left traction motor overtemperature, >266°F (130°C), or temperature switch is bad.	If motor temperature is <266°F (130°C), check wiring to temperature switch TS2 from VM. If motor temperature is >266°F (130°C), allow motor to cool and measure current draw on each phase of the motor. All three phases should be equal. If not, replace the motor. If they are equal, check for binding in the drive unit or dragging brakes. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
73	**Code 73: Left Traction Motor Encoder Error** Incorrect or no input seen by the Slave TPA from the Left Traction Motor encoder.	Test the +12V and GND inputs to both encoders and the output from channels A and B to the amp from both encoders. If OK, check for shorts to frame. Check voltage to the Slave TPA. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
74	**Code 74: Slave TPA Temperature Sensor Out of Range** Temperature sensor has exceeded values expected.	Check fan for correct operation. Fan should operate within approx. one minute after turning Key switch ON. If not, troubleshoot fan. If OK, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.
76	**Code 76: Slave TPA Detected CAN-Bus Error** The Slave TPA has not received a communication message from the Master TPA, VM, HCB, or PPA.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
77	**Code 77: Slave TPA CAN-Bus Node Offline** Too much time between communication from the VM and PPA to the Slave TPA has elapsed. This code can also be caused by an open in a cable from the amplifier to the traction motors.	Check the power cables to the traction motors. Check both traction motor encoders and temperature sensors for opens, shorts, and shorts to frame. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
7A	**Code 7A: Master TPA Not Responding** Master TPA is bad.	Check voltage to Master TPA. Replace the Master TPA.
7C	**Code 7C: Slave TPA Internal Fault** Slave TPA internal fault.	Check voltage to Slave TPA. Replace the Slave TPA.
81	**Code 81: Directional Microswitch Closed** VM detected directional microswitches (SW9 or SW10; SW4 or SW5 on dual pedal trucks) closed prior to power up. This code can also be caused by activating the travel enable switch (SW8) before seat switch (SW2) and/or optional battery gate switch (SW30) is activated.	If the directional switch is left in forward or reverse position when the operator leaves the seat, Code 81 is displayed after a brief time-out (approx. 30 sec). If the code still appears after lever is returned to neutral, cycle the Key switch to clear. Test switches for correct operation. Check continuity of wires from switches to cards. Flash truck components with latest version of software and re-learn pots. If OK, replace the VM.
83	**Code 83: Traction Pot Open Circuit** VM detected the voltage from the traction pot is below the allowable voltage range.	Test for correct voltage to and from the traction pot. If voltage is not correct, check continuity of the wires. If OK, replace the VM. If not OK, replace the pot.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
84	**Code 84: Travel Enable Switch Failure** VM detected travel enable microswitch (SW8) is bad.	Troubleshoot switch and wiring. Check for shorts to frame. Troubleshoot seat and optional battery gate switches and wiring. If OK, replace the VM. If not OK, repair/replace the switch/wiring.
85	**Code 85: Warning Configuration Error** Software error.	Check configured battery voltage (36V or 48V) with FlashWare. If incorrect, set correct battery voltage in FlashWare (and re-learn pots) or replace battery with correct voltage battery. Replace VM.
86	**Code 86: Traction Potentiometer Out-of-Range** Traction Pot is outside the learned voltage range. This code can also be displayed if there is no power to the Master TPA or if one of the power cables to the traction motors is open.	If this code is displayed in conjunction with another code, troubleshoot per that code. Verify battery voltage. If wrong voltage, check configured battery voltage (36V or 48V) with FlashWare. If incorrect, set correct battery voltage in FlashWare or replace battery with correct battery (and re-learn pots). Check both traction motor encoders, temperature sensors, and connections. Check power to the Master TPA. Check the power cables to the traction motors. Check pot voltages. If OK, run Learn. If not OK, replace the pot.
87	**Code 87: Seat/Battery Gate Interlock Switch Open** A function was activated while the seat or optional battery gate interlock switch was open.	Troubleshoot switches and wiring. If input from switches are OK, replace VM.
89	**Code 89: Parking Brake Switch Error** SW7 is closed when travel is detected.	Troubleshoot switch and wiring. If the truck is not moving and the parking brake is set, troubleshoot the left and right traction motor encoders.
8A	**Code 8A: VM Internal Fault** A fault was detected by the VM during power up.	Replace the VM.
8B	**Code 8B: TPA Fault** The TPAs informed the VM that a fault is present.	Check voltage to the TPAs. Check history for TPA codes and troubleshoot per them. If none are present, the TPA may be bad. Swap the TPAs. If the code changes, replace the bad TPA.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
8C	**Code 8C: TPA Communication Error** The VM did not receive communication from the TPAs.	Check power to the Master and Slave TPAs. Check the power cables to the traction motors for shorts to other wires or shorts to frame. Check both traction motor encoders, temperature sensors, and connections for shorts to frame or other wires. In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
8D	**Code 8D: Lift Limit** Lift-Limit switch (SW31) is open.	Check for correct configuration via FlashWare. (*This code is normal and is displayed when beyond limits for option.*) Check Lift-Limit/Bypass switch (SW31) and wiring. If OK, replace VM.
8E	**Code 8E: Bottler's Tilt Limit** Bottler's Tilt limit switch (SW30) is open.	Check for correct configuration via FlashWare. (*This code is normal and will occur when beyond limits for option.*) Check Bottler's Tilt limit switch (SW30) and wiring. If OK, replace VM.
8F	**Code 8F: Requesting Travel In Both Directions** Forward and Reverse switches (directional lever on column) are closed at the same time.	Troubleshoot switches and wiring. If OK, replace VM.
91	**Code 91: Configuration Error** The VM has detected a configuration error due to lack of information from the Hydraulic Control Board or Armrest Board during SelfTest.	Check power to the Armrest Board and Hydraulic Control Board (HCB). Use FlashWare to verify correct options and configuration settings for the truck. In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version: Slave TPA, PPA, VM or HCB. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
92	**Code 92: Communication Error Detected By The VM** The VM has not received information from the PPA, TPA, or Armrest Board.	Check power to Master and Slave TPAs, PPA, VM, and HCB. Check the power cables to the motors for shorts to other cables and to the frame. Check both traction motor encoders, temperature sensors, and connections and for shorts to frame or other wires. In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
93	**Code 93: Communication Error Detected By The VM** The VM has not received information from the Operator Display.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
94	**Code 94: Internal Fault** The VM has detected an internal fault.	Replace the VM.
96	**Code 96: VM Internal Fault** Fault in the area of memory where the adjustable parameters are stored.	Verify battery voltage. If wrong voltage, set correct voltage via FlashWare (and re-learn pots) or install correct voltage battery. Check for shorts to frame. If code does not clear by cycling Key switch, replace the VM. If code clears, the adjustable parameters have been reset to default values. Reset to customer's requirements via FlashWare. Re-learn all pots.
A1	**Code A1: Hydraulic Control Board Internal Fault** Fault in the area of memory where the adjustable parameters are stored on the Hydraulic Control Board.	If code does not clear by cycling key, replace the Hydraulic Control Board. If code clears, the adjustable parameters have been reset to default values and require resetting to customer's requirements via FlashWare.
A2	**Code A2: Solenoid Valve Error** A short was detected in the circuits between the 5th Solenoid Valve (EV11) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
A3	**Code A3: CAN-Bus Error Detected** **By Hydraulic Control Board** The Hydraulic Control Board has not received CAN messages from the VM, PPA, TPA, or Armrest Board.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
A4	**Code A4: Internal Hydraulic Control Board Fault** Problem in the hardware circuit.	Replace the Hydraulic Control Board.
A6	**Code A6: Solenoid Valve Error** A short was detected in the circuits between the Lifting Valve (EV2) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
A7	**Code A7: Solenoid Valve Error** A short was detected in the circuits between the Tilting Valves (EV3 or 4) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
A8	**Code A8: Solenoid Valve Error** A short was detected in the circuits between the Sideshift valves (EV5 or 6) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
A9	**Code A9: Solenoid Valve Error** A short was detected in the circuits between the 4th Function valves (EV7 or 8) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
AA	**Code AA: Incorrect Battery Installed** When the Key switch is turned ON, the Hydraulic Control Board checks the battery voltage and compares it with the "SET BATTERY" parameter setting. If the actual voltage is 20% higher or lower than the set value, this code is displayed.	Check battery voltage. Set correct battery voltage via FlashWare (and re-learn pots) or install correct voltage battery. If OK, replace the Hydraulic Control Board.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
AB	**Code AB: Hydraulic Control Board Driver Fault** The positive supply to the valves is shorted or open.	Measure voltage and resistance across coils and wires. If OK, replace the Hydraulic Control Board.
AC	**Code AC: Solenoid Group 1 Driver Error** An open was detected in the circuits between the Lifting Valve (EV2) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
AD	**Code AD: Solenoid Group 2 Driver Error** An open was detected in the circuits between the Tilting Valves (EV3 or 4) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
AE	**Code AE: Solenoid Group 3 Driver Error** An open was detected in the circuits between the Sideshift valves (EV5 or 6) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
AF	**Code AF: Solenoid Group 4 Driver Error** An open was detected in the circuits between the 4th Function valves (EV7 or 8) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
b.0	**Code B0: Coil Shorted** A short was detected in the circuits between the 5th Solenoid Valve (EV11) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
b.1	**Code b.1: Hydraulic Control Board Power Supply Failure** Low voltage is seen at the Hydraulic Control Board.	Check for B+ to Hydraulic Control Board. If present, replace Hydraulic Control Board. If not present, check circuit from the Hydraulic Control Board back to CT1.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
b.2	**Code b.2: EVP Driver KO** An open was detected in the circuits between the Drain valve (EVP) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
b.3	**Code b.3: EV11 Driver KO** An open was detected in the circuits between the 5th Solenoid Valve (EV11) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
b.4	**Code b.4: Internal Hydraulic Control Board Fault** Internal failure of Hydraulic Control Board.	Replace Hydraulic Control Board.
b.5	**Code b.5: EVP Driver Shorted** A short was detected in the circuits between the Drain valve (EVP) and the Hydraulic Control Board.	Measure voltage and resistance across coil and wires. If OK, replace the Hydraulic Control Board.
C1	**Code C1: Open in Brake Light Circuit** An open was detected in the brake light circuit.	Check bulbs. Check for voltage to both lights.
C2	**Code C2: Open in Fore or Aft Working Light Circuits** An open was detected in the fore/aft working light circuits.	Check bulbs. Check for voltage to both lights.
C3	**Code C3: Open in Fore/Aft Working Light or Brake Light Circuits** An open was detected in the fore/aft working light or brake light circuits.	Check bulbs. Check for voltage to lights.
C4	**Code C4: Open in Tail Light Circuits** An open was detected in both reverse light circuits.	Check bulbs. Check for voltage to both lights.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
C5	**Code C5: Open in Brake or Tail Light Circuits** An open was detected in the rear light circuits.	Check bulbs. Check for voltage to all lights.
C8	**Code C8: Option. Open Circuit** An open was detected in the travel alarm or warning light, or safety lowering valve circuits.	Check the travel alarm, warning light, working lights, and/or lowering control valve circuits. Verify voltage from Master TPA to CT3. Verify CT3 functions correctly.
d.1	**Code d.1: TPA Power Supply or CAN-Bus Failure** The Display did not receive communication from the TPA.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
d.2	**Code d.2: VM Power Supply or CAN-Bus Failure** The Display did not receive communication from the VM.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
d.3	**Code d.3: d1 + d2**	Use steps for Codes d1 and d2.
d.4	**Code d.4: PPA Power Supply or CAN-Bus Failure** The Display did not receive communication from the PPA.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
d.5	**Code d.5: d.1 + d.4**	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
d.6	**Code d6: d.4 + d.2**	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
d.7	**Code d7: d.4 + d.2 + d.1**	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
d.8	**Code d.8: Armrest Board Power Supply or CAN Bus Failure** The Display did not receive communication from the Armrest Board.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
d.9	**Code d.9: d.8 + d.1**	Use steps for d.8 and d.1.
d.A	**Code d.A: d.8 + d.2**	Use steps for d.8 and d.2.
d.b	**Code db: d.8 + d.2 + d.1**	Use steps for d.8, d.2, and d.1.
d.C	**Code dC: d.8 + d.4**	Use steps for d.8 and d.4.
d.d	**Code dd: d.8 + d.4 + d.1**	Use steps for d.8, d.4, and d.1.
d.E	**Code dE: d.8 + d.4 + d.2**	Use steps for d.8, d.4, and d.2.

Codes

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
d.F	**Code dF: d.8 + d.4 + d.2 + d.1**	Connect FlashWare and see if the versions for the Display, TPA, PPA, VM, and Armrest Board can be seen. If the Display is not shown, check connections to the Display. If OK, replace the Display. If the other devices are not shown, check connections to the VM from the Display. Verify power to the devices. If OK, replace the VM. If no devices are shown, check for shorts between the CAN High and CAN Low wires. Measure resistance between the CAN High and CAN Low pins going into the Display. The reading should be approx. 180 ohms. If open or shorted, replace the Display.
E1	**Code E1: Incorrect Start Procedure for the Armrest Board or Levers** One of the switches on the Armrest Board or one of the lever control switches is out-of-neutral prior to key ON or the seat switch or battery gate switches are closed.	Check the lever/fingertip controls for binding. Check the seat switch and battery gate switches. Test switches.
E2	**Code E2: Lift Potentiometer (Lever Control) Out-of-Range** Voltage from the lift pot is outside the expected operating range.	Check pot for binding. Make sure battery voltage is configured correctly. Learn pot. Test pot voltage. Check static strap. Check for shorts to frame. Restore amplifier and VM defaults in FlashWare.
E3	**Code E3: Tilt Potentiometer Out-of-Range** Voltage from the tilt pot is outside the expected operating range.	Make sure battery voltage is configured correctly. Learn Pot. Test pot voltage.
E4	**Code E4: Sideshift Potentiometer Out-of-Range** Voltage from the sideshift pot is outside the expected operating range.	Make sure battery voltage is configured correctly. Learn Pot. Test pot voltage.
E5	**Code E5: 4th Function Potentiometer Out-of-Range** Voltage from the 4th Function pot is outside the expected operating range.	Make sure battery voltage is configured correctly. Learn Pot. Test pot voltage.
E7	**Code E7: Armrest Board Warning** The Armrest Board is in the process of downloading default parameters.	Cycle the Key switch. Default and Learn via FlashWare. If code does not clear, replace Armrest Board.

Refer to the "Pinout Matrix" beginning on page 8-13 for all voltage and resistance values and component interconnection.		
Code	**Description**	**Notes/Corrective Action**
E8	**Code E8: Armrest Board Internal Fault** Failure of the restore default parameter download.	Cycle the Key switch. Default and Learn via FlashWare. If code does not clear, replace Armrest Board.
E9	**Code E9: Armrest Board Internal Fault**	Replace the Armrest Board.
EA	**Code EA: Hydraulic Control Board or PPA Error** A code is present on both the Hydraulic Control Board and PPA.	Check for codes from the Hydraulic Control Board and PPA and troubleshoot accordingly. Check CT2 coil from PPA per Pinout Matrix. Check pump motor and temp switch circuits. Check PPA Safety circuit between JFP-5 and 11.
EB	**Code EB: Armrest Board Internal Fault** Lift-Limit Bypass switch on the Armrest Board is closed.	Check fingertip switches for binding. Test voltage of the switch. Replace the Armrest Board.
EC	**Code EC: Armrest Board Internal Fault**	Replace the Armrest Board.
ED	**Code ED: CAN-Bus Error Detected By Hydraulic Control Board** The Armrest Board is unable to communicate with the Hydraulic Control Board.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
EE	**Code EE: CAN-Bus Error Detected By PPA** The Armrest Board has not received communication from the PPA.	In FlashWare, observe the software version of each device in the Truck Setup screen. Check voltage to the device that is not showing a software version. Check communication wires between the devices not showing the software version for continuity and shorts to frame. If OK, replace the device not showing the software version.
EF	**Code EF: Requesting Travel In Both Directions** Forward and Reverse switches are closed at the same time.	Troubleshoot switches and wiring. If OK, replace Armrest Board.

Codes

Section 7. Component Procedures

List of Component Procedures

List of Component Procedures

Section 7. Component Procedures

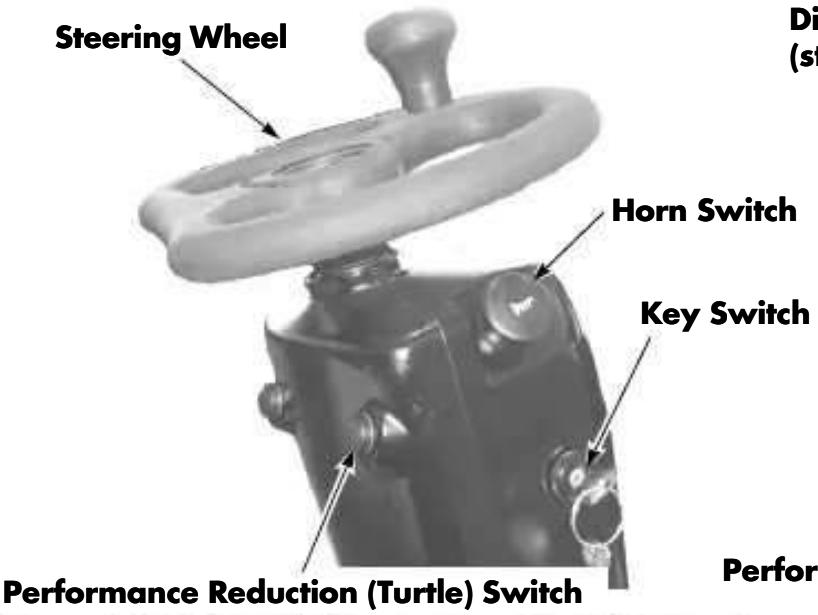
Component Locator Photos

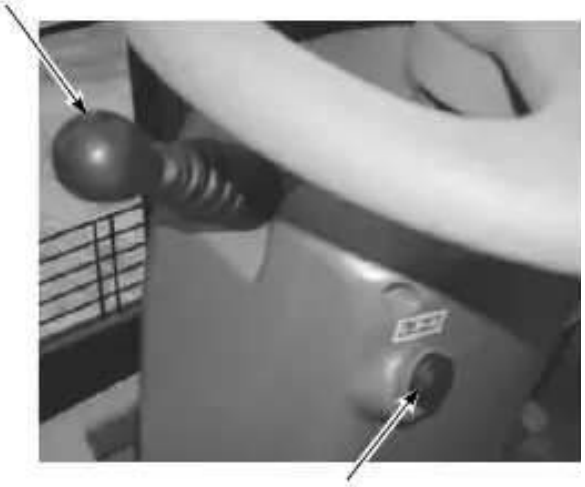
Figure 7-1. Major Components

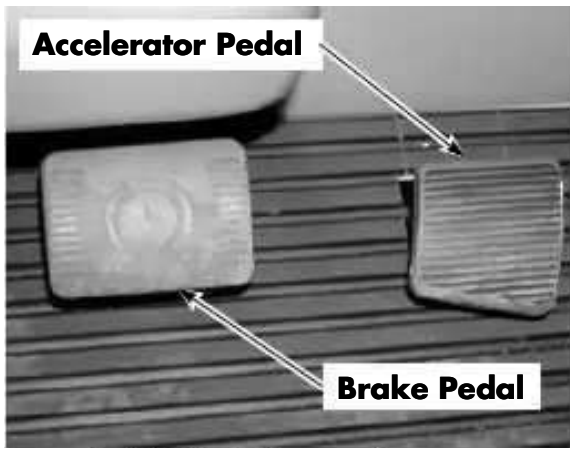
DSC0012B_silhouette.jpg

Component Locator Photos

Figure 7-2. Operator Compartment Controls

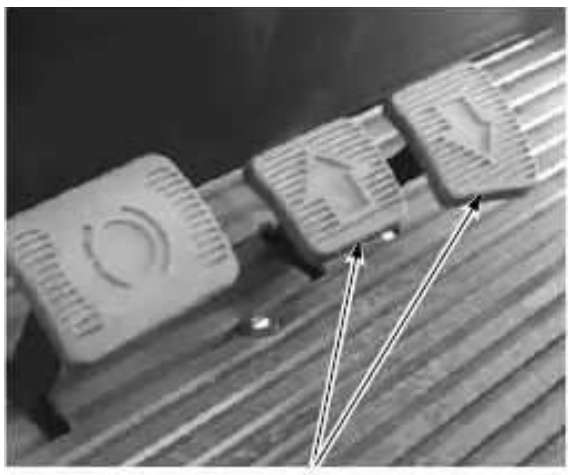






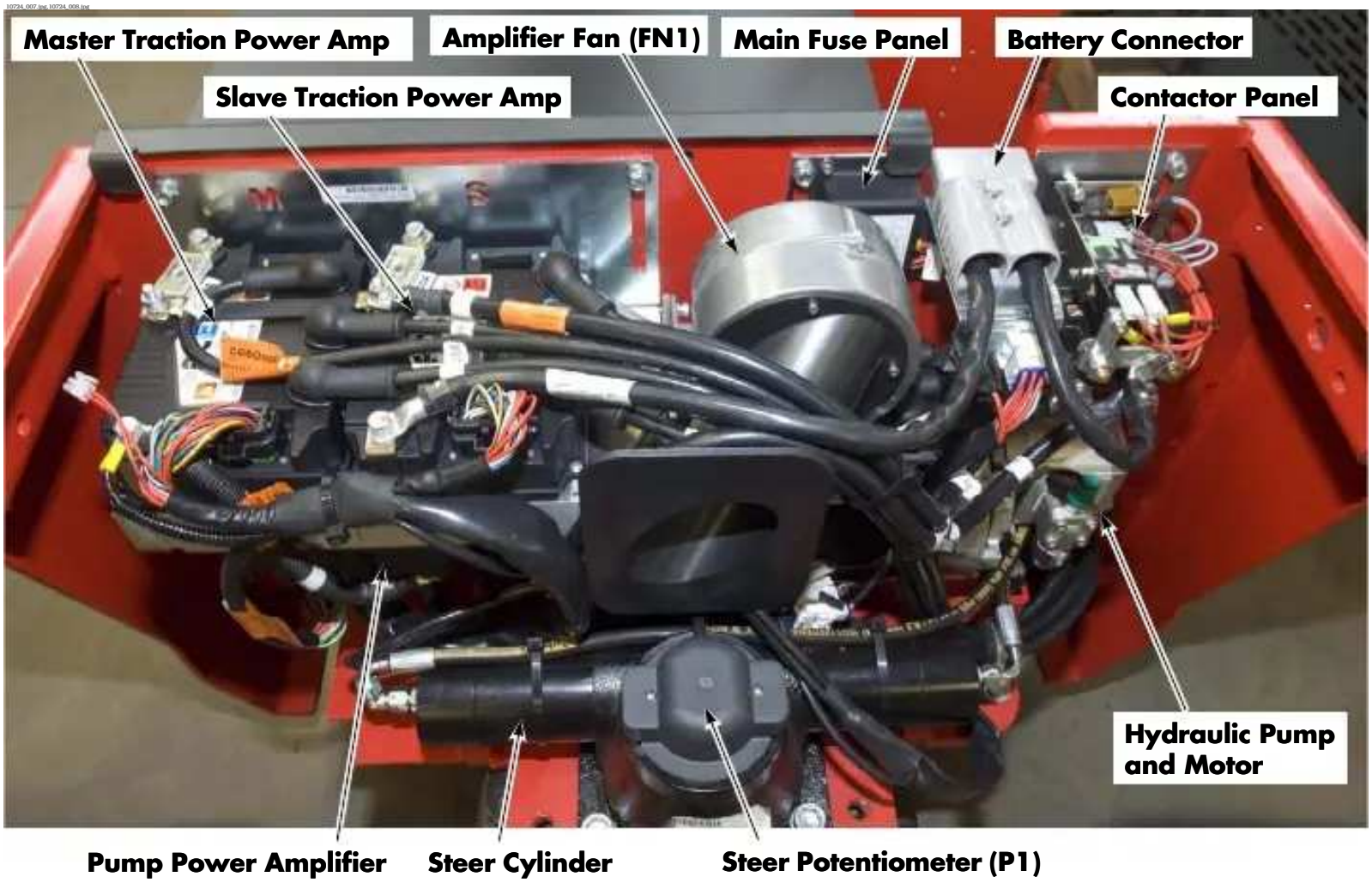
Hydraulic Function Levers

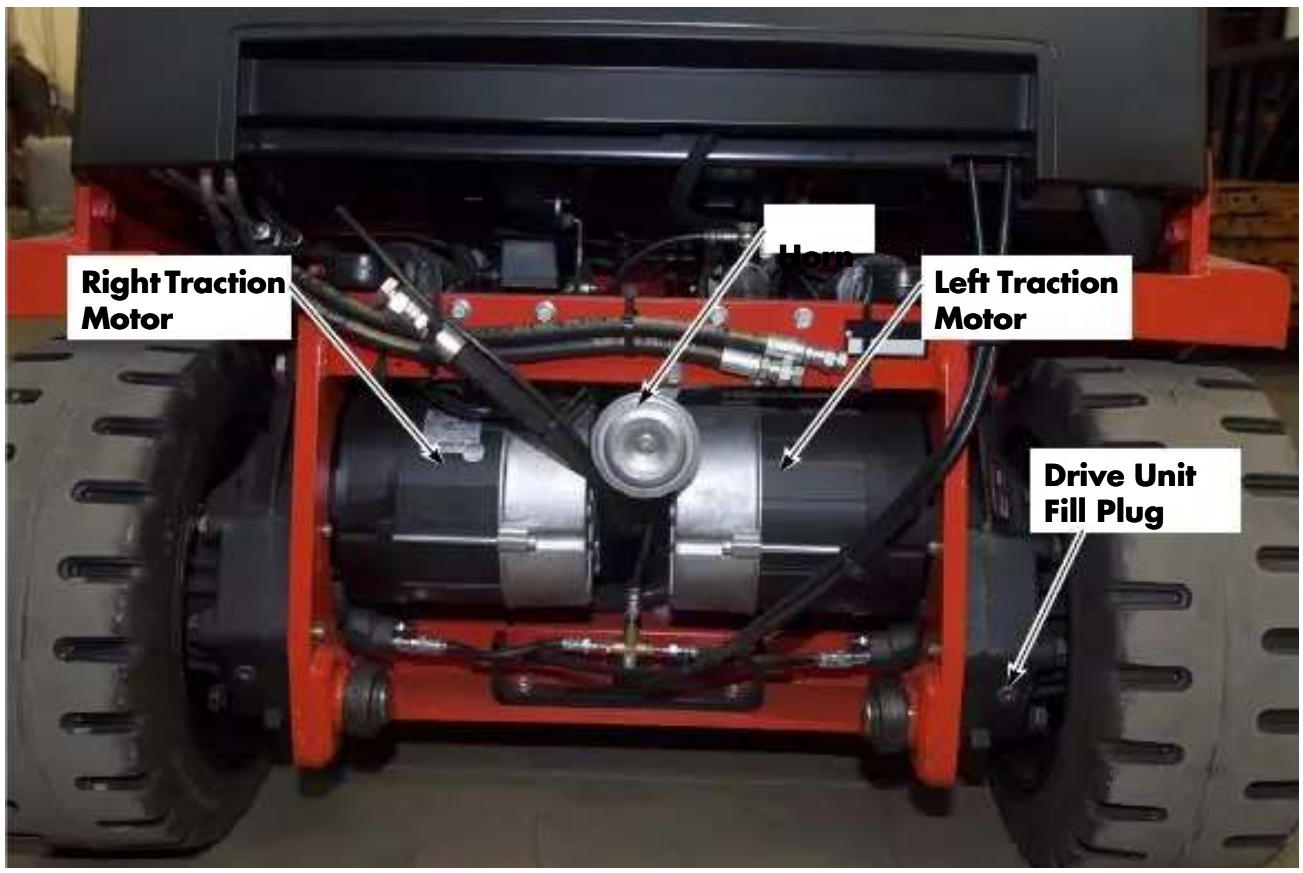
Hydraulic Function Fingertip Controls with additional horn switch (optional)



Forward/Reverse Accelerator pedals (optional)

Figure 7-3. Front and Rear View (counterweight and mast removed)





Component Locator Photos

Figure 7-4. Tractor Front

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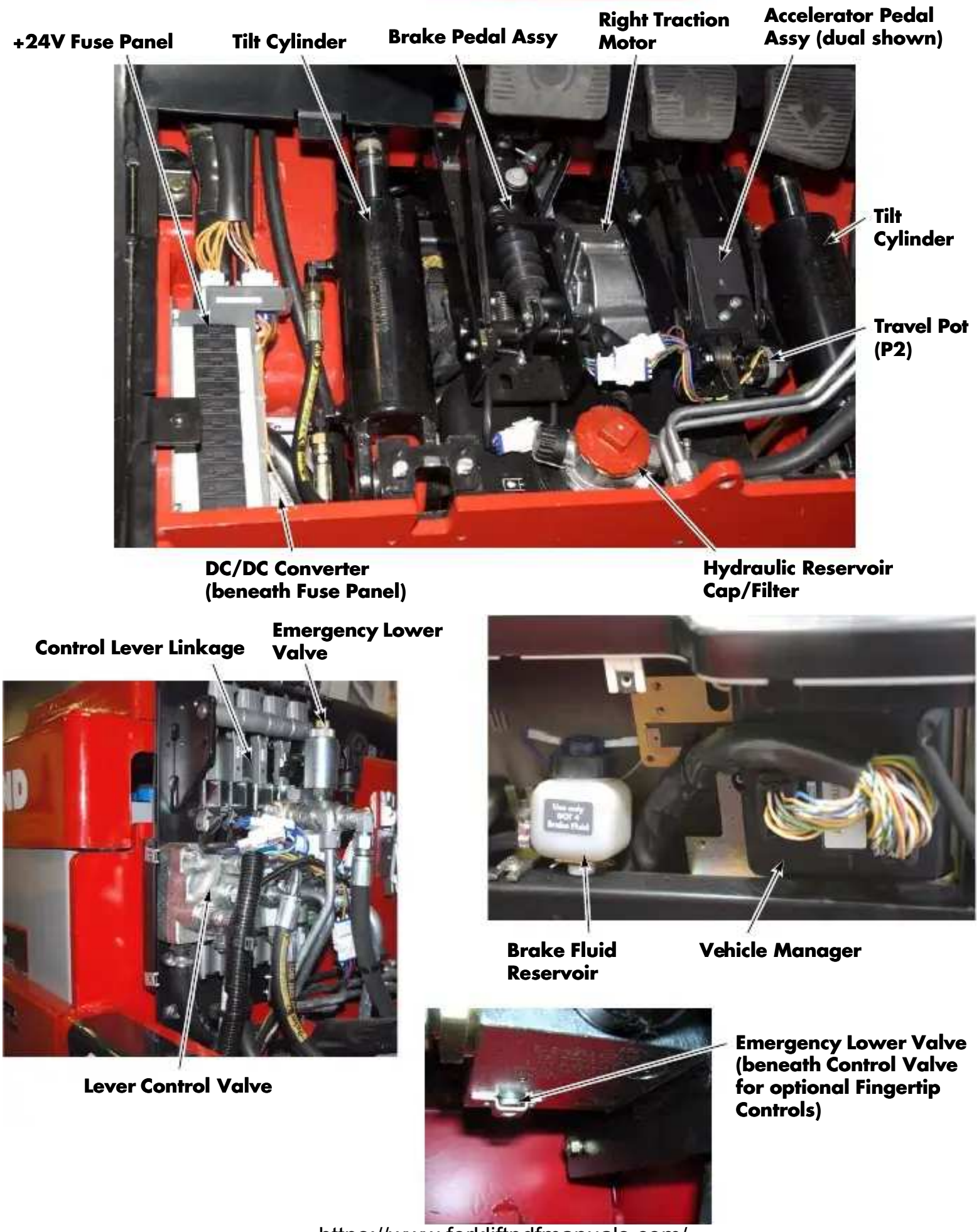


Special Tools

The following tools are available from your local authorized Raymond dealer.

Table 7-1. Special Tools

Tool	Part Number	Purpose
Anti-static Field Kit	1-187-059	ESD protection
Anti-static Wrist Straps	1-187-058/001	
Anti-static Wrist Strap Tester	1-187-060/100	
Crimp Tool	1069861	Crimp power cable lugs
Chain Gauge	950-350/CG	Lift chain inspection
Connector Unlatching	950-042	Separate AMP connectors
Fork Wear Caliper	922-369	Fork inspection
Pin Extraction	950-009	AMP connector pin extraction
Pin Extraction	950-026	MOLEX connector pin extraction
Pressure Fitting Adapter - Metric	1620-04CE	Required to connect pressure gauge with SAE fitting to pump pressure port.
Surge Protector	154-010-801	ESD/voltage surge protection for serial type FlashWare connections
USB/CAN Interface Module	230489-001	FlashWare connection to truck

Special Tools

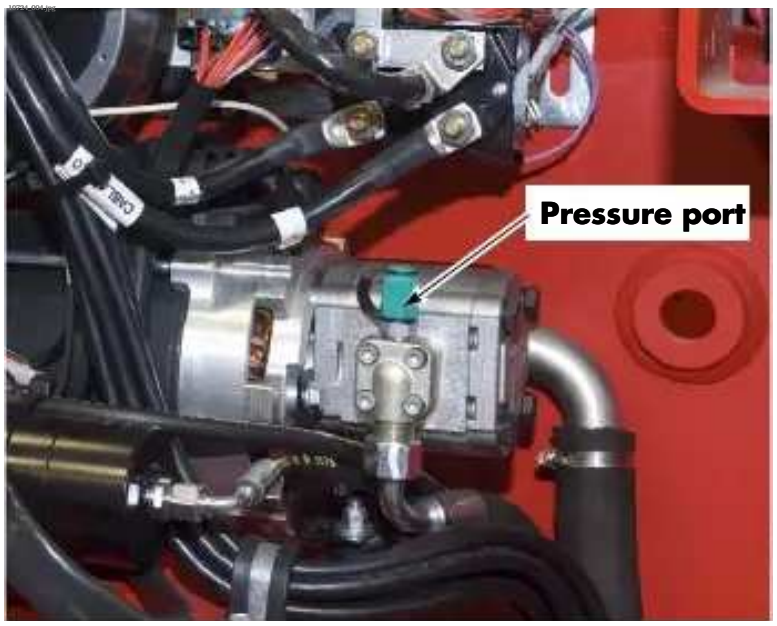
Steering and Controls

Steering Pressure Adjustment

Steer pressure is adjusted at the steer orbitrol located on a bracket at the base of the steering column.

1. Using Metric Pressure Fitting Adapter P/N 1620-04CE, install a pressure gauge at the pump pressure port. See Figure 7-5.

Figure 7-5. Pump Pressure Port



2. On the steer orbitrol, remove the protective cap using a ball-ended socket head wrench. This allows access to the pressure adjustment screw. See Figure 7-6.

Figure 7-6. Steer Orbitrol

3. Turn the steering wheel all the way to the right or left. Check the steer pressure. Steering pressure should measure between 1305 and 1450 psi (9000 and 10,000 kPa).
4. Turn the pressure adjustment screw clockwise to increase pressure or counterclockwise to decrease pressure.
5. Replace the protective cap.

Drive and Brake

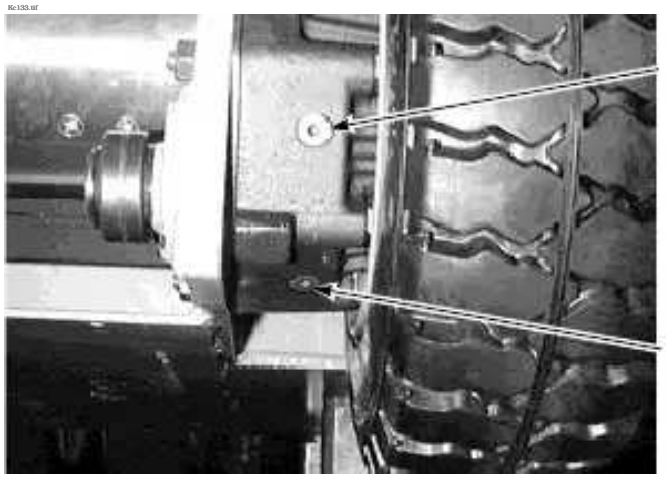
Drive Unit/Motor Assemblies

The drive unit/motor assemblies, one for each drive wheel, consist of a planetary gear type drive unit and an AC motor.

Changing Fluid

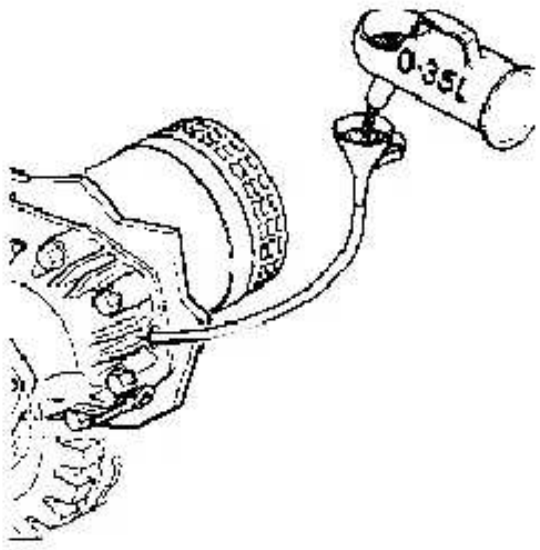
1. Run the truck for a few minutes to warm the fluid.
2. Clean the area around the fluid fill and drain plugs. See Figure 7-7.

Figure 7-7. Drive Unit Plug Locations



3. Place a suitable container below the drain plug.
4. Remove both the fill and the drain plugs. Allow the fluid to drain out completely.
5. Clean any ferrous residue from the magnetic drain plug. Replace the drain plug, torquing to 16 ft. lb. (22 Nm).
6. Use a flexible hose with either a syringe or a funnel to add new fluid (type ATF II D or equivalent) through the fill plug hole until it starts overflowing (approx. 0.75 pints, 0.35 liter). See Figure 7-8. Install the fill plug. Torque to 16 ft. lb. (22 Nm).

Figure 7-8. Filling with Funnel and Flexible Hose



7. Clean the area around the fluid fill and drain plugs.
8. Run the truck for several minutes. Check the fluid level again.

Drive Unit Removal

1. Park the lift truck on a level surface. Engage the parking brake. Turn the key switch OFF and disconnect the battery connector.
2. Block the steerable wheels to prevent truck movement.

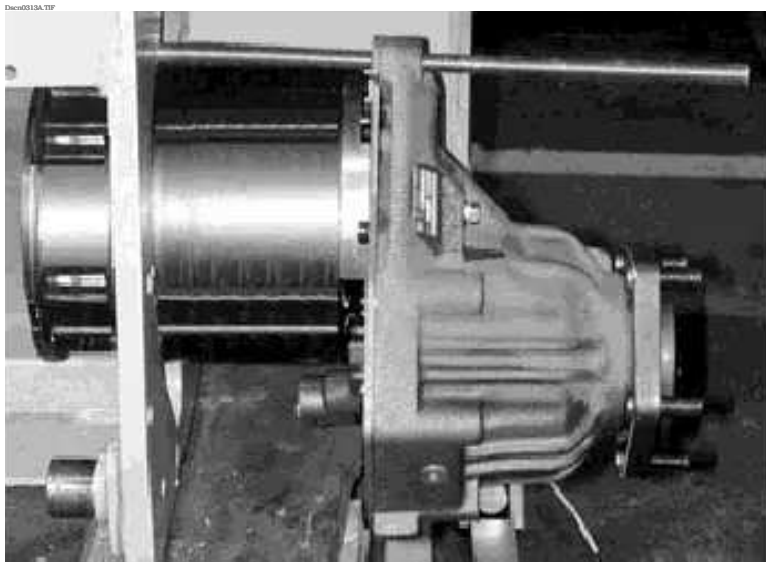
⚠ WARNING

Use extreme care whenever the truck is jacked up for any reason. Never block the truck between the telescopic and the floor. Use a suitable hoist to stabilize the mast. Keep hands and feet clear from beneath vehicle while jacking. Use jack stands or solid blocks to support truck. Do not rely on the jack alone. See "Jacking Safety" on page 2-8.

3. Jack the front of the truck.
4. Release the parking brake.
5. Drain the fluid (see "Changing Fluid").
6. Remove the drive wheel.
7. Disconnect all hoses and cables connected to the parking brake, service brake, and traction motor.

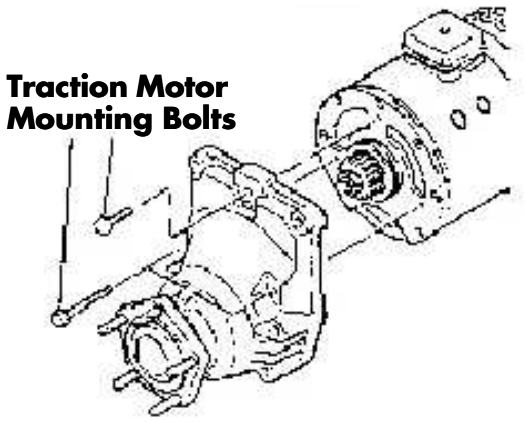
8. Remove the drive unit/motor assembly from the tractor as follows:
   a. Remove the upper front drive unit mounting bolt and install an M14 x 30 threaded rod as shown in Figure 7-9 to support the drive unit/motor assembly.

Figure 7-9. Traction Motor/Drive Unit Removal



   b. Remove the remaining five mounting bolts. Slide the drive unit/motor assembly out of the chassis.
   c. If the traction motor is to be removed from the drive unit, remove the three bolts attaching the drive unit to the motor. See Figure 7-10.

Figure 7-10. Traction Motor Mounting Bolt Location



⚠CAUTION

When separating the motor from the drive unit, do not damage the gears or O-ring sealing surface in the housing.

Cover the opening of the drive unit to prevent contamination while the motor is removed.

Drive Unit Installation

1. Carefully assemble the drive unit to the traction motor. Make sure the pinion and spur gears mesh correctly.
2. Torque the motor to drive unit mounting bolts to 17 ft. lb. (23 Nm).
3. Install the drive unit/motor assembly into the chassis in the reverse of removal.
4. Torque the drive unit to chassis mounting bolts to 100 ft. lb. (135 Nm).

Brake Service

Disassembly

NOTE: Replace brake disk sets in both drive units at the same time to ensure correct braking.

Figure 7-11. Exploded View of Drive Unit

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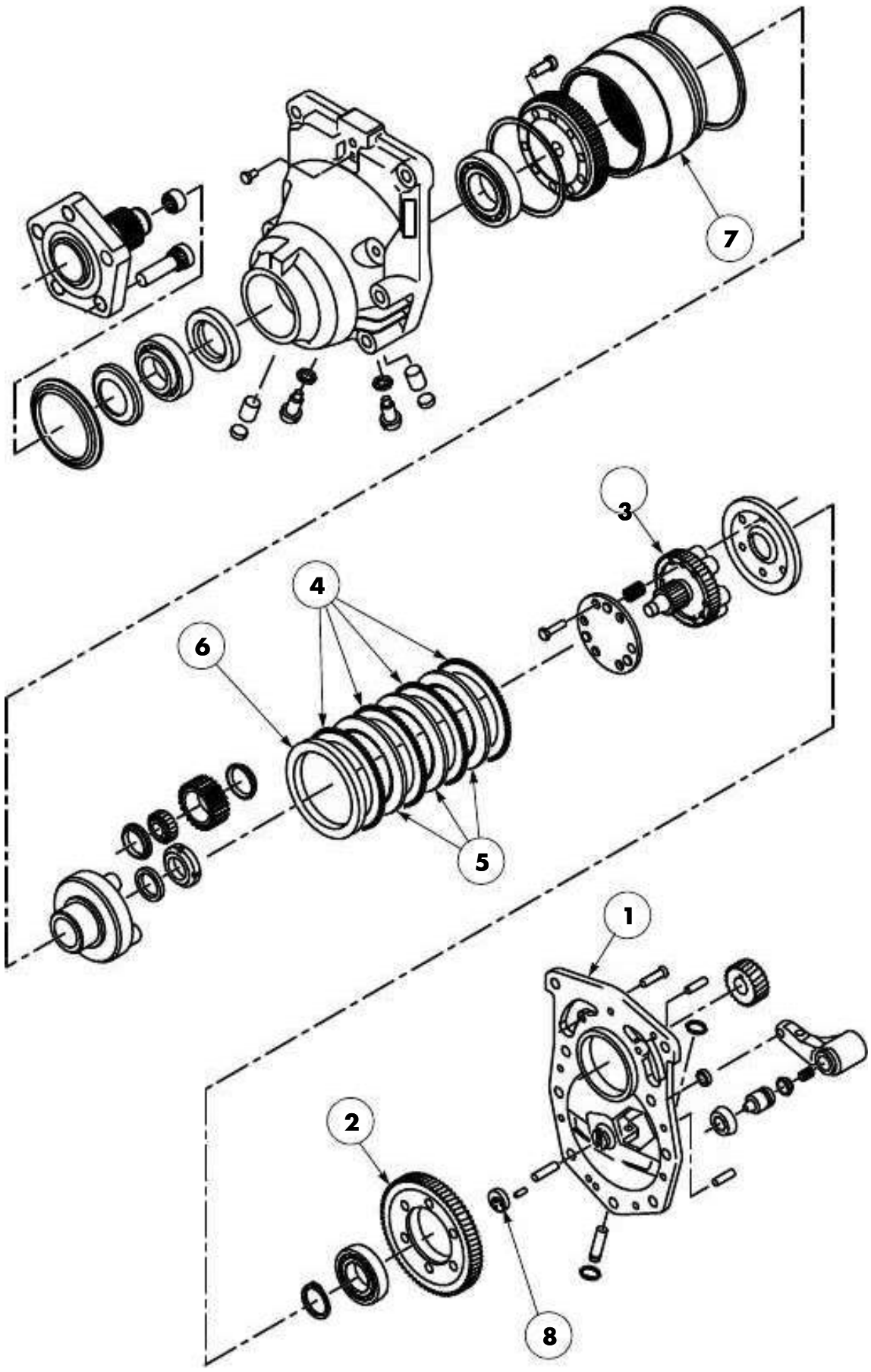


Refer to Figure 7-11 for bracketed numbers referenced in this procedure.

Place the drive unit in a holding device or on the wheel bolts to perform the following steps.

1. Use an impact wrench to loosen the countersunk bolts in the cover [1].

⚠CAUTION

Do not damage mating surfaces during disassembly.

2. Carefully pry the cover [1] off the drive unit.

NOTE: When the housing cover is removed, the spur gear [2] remains connected to the internal disk carrier [3] as a single unit.

3. Remove the disk set (four external tooth [4] and three internal tooth disks [5]) and thrust washer [6] from the ring gear [7].
4. Lightly rub the new internal tooth disks with a flat sanding block to visually establish “high spots”. These “high spots” must be in alignment when installed to ensure correct braking. See Figure 7-12.

Figure 7-12. High Spots On Brake Disk

5. Assemble the new disk set in the following order:
   - thrust washer [6]
   - external tooth disk [4]
   - internal tooth disk [5]
   - external tooth disk [4]
   - internal tooth disk [5]
   - external tooth disk [4]

NOTE: Align the “high spots” on the internal tooth disks for maximum “spring” action.

6. Insert the disk set into the ring gear [7].
7. Put the internal disk carrier [3] into the correct fitting position. Slide the disks into their correct position by slightly turning or moving the internal disk carrier.
8. Carefully remove the internal disk carrier from the fitting position. Make sure that the position of the disk is not changed.

NOTE: If the wearable brass brake activation pad [8] is replaced, make sure it is positioned correctly. See Figure 7-13.

Figure 7-13. Brake Activation Pad

Assembly

1. Thoroughly clean all the parts and remove all residual thread-locking compound.
2. Check brake disks for wear and damage. Replace if necessary.

NOTE: Replace brakes in sets only.

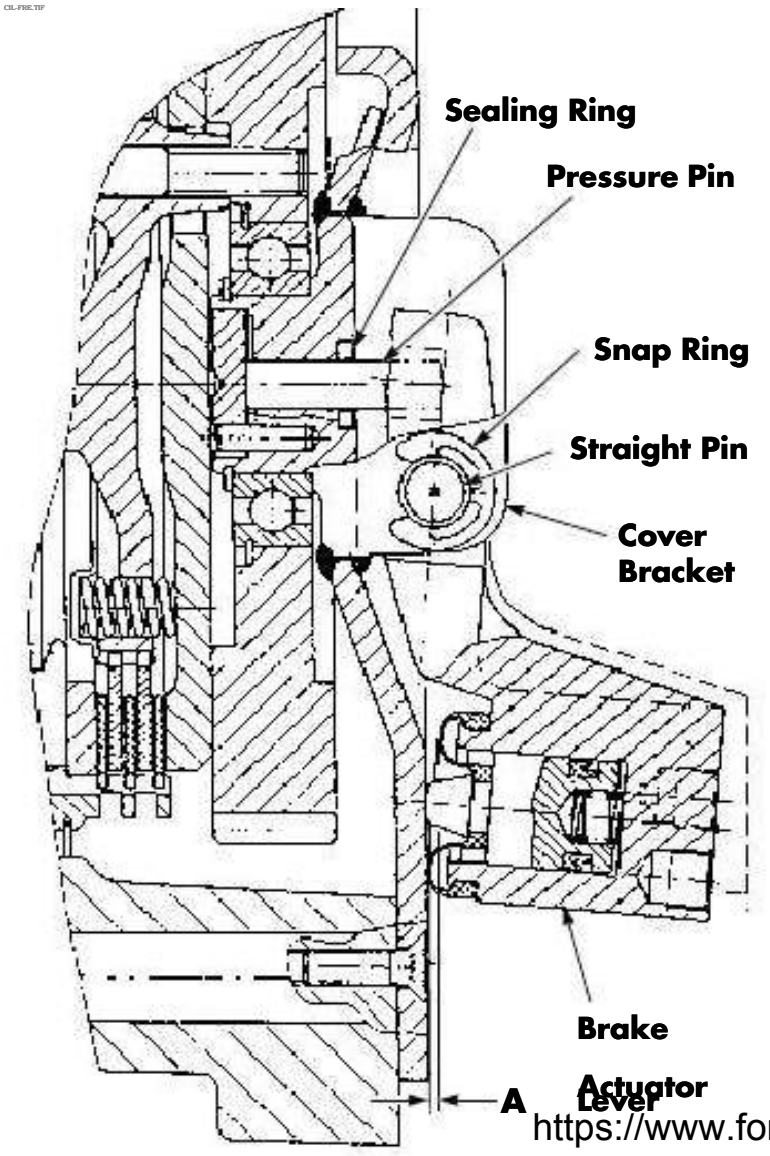
3. Smooth the sealing surface with an oilstone or a double-smooth file.

4. Replace all sealing elements using mastic sealants (such as Loctite®).
5. Assemble the cover to the drive unit.
6. Check that silicone was spread on the sealing surface of the cover.
7. Align the two 8 mm holes in the cover with the two straight pins in the drive unit.
8. Drive the cover onto the drive unit. Move the cover lightly and tap on it with a plastic hammer.
9. Use blue thread-locking compound (P/N 990-462) to secure the countersunk bolts that fasten the cover. Torque the bolts to 6.6 ft. lb. (9 Nm).

Mounting Brake Actuator Lever to Drive Unit

1. Apply a light coating of grease to the sealing lip of the sealing ring. See Figure 7-14.

Figure 7-14. Brake Actuator Lever Mounting



2. Install the sealing ring.
3. Install the pressure pin.
4. Install the brake actuator lever into the cover bracket. Make sure the brake lever is correctly positioned. See Figure 7-14.
5. Drive a straight pin through both the cover bracket and the brake lever.
6. Secure the straight pin with two snap rings.
7. Check the setting clearance (A). Setting clearance (A) should measure between 0.016 and 0.039 in. (0.4 mm and 1.0 mm).

NOTE: Different length pressure pins are available to maintain correct setting clearance.

Storage

- If no motor is attached, seal the drive unit to prevent contamination.
- Fill the drive unit with oil. Turn the drive shaft several times, then drain the oil. Pack the drive unit in a closed plastic container.

Parking Brake

Check

⚠ WARNING

Use extreme care whenever the truck is jacked up for any reason. Never block the truck between the telescopic and the floor. Use a suitable hoist to stabilize the mast. Keep hands and feet clear from beneath vehicle while jacking. Use jack stands or solid blocks to support truck. Do not rely on the jack alone. See "Jacking Safety" on page 2-8.

With the traction tires jacked up off the floor, engage the parking brake lever three clicks.

Verify brake resistance on both drive tires. Adjust if necessary.

Adjustment

1. Check condition of parking brake cables.
2. Refer to Figure 7-15. Adjust the cable so that, with the traction tire of the floor:
   - the drive tires turn freely by hand on the first and second click
   - resistance to rotation by hand is present on the third and fourth click, however, rotation is still possible
   - the drive tires can not be turned by hand on the fifth click.

Figure 7-15. Parking Brake Adjustment

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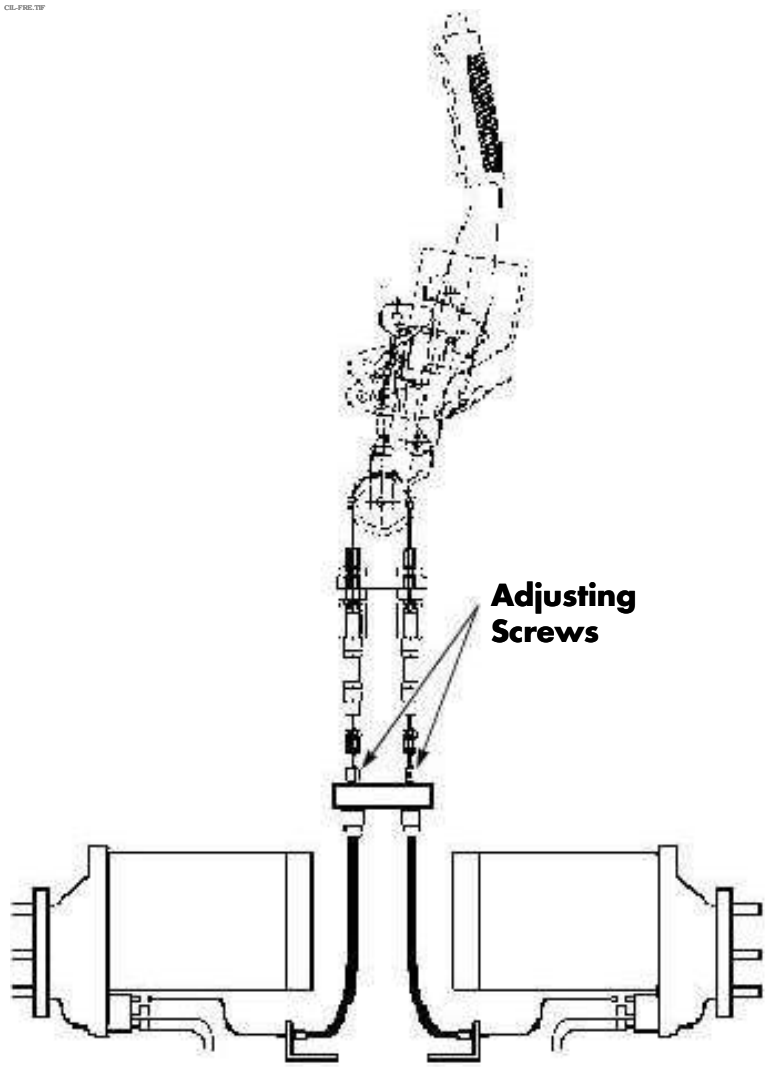


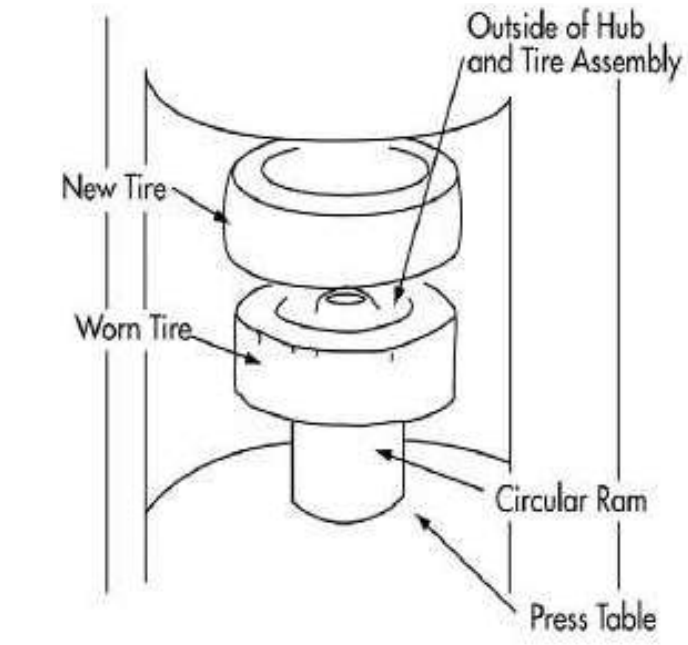
Tire Replacement

CAUTION

Any misalignment of the tire and hub while the tire is being pressed onto the hub can damage the hub. For this reason, chamfers are provided on the outside edge of the hub and on the end of the inside diameter of the tire's metal insert. The chamfers help to center the hub and tire during the pressing operations and reduce the possibility of misalignment. To prevent damage, the hub must be installed on the circular ram with its chamfered side up.

1. Check inside surface of metal insert on new tire. Use sandpaper to remove any scaling or rust. Clean inside of metal insert and lubricate it with a soap solution.
2. Place circular ram on the press table. See Figure 7-16. The length of the ram must be longer than width of the old tire to allow complete removal of old tire. The outside diameter of ram must be small enough to fit loosely in the insert of tire but must be large enough to rest squarely on flat surface on outer edge of hub.

Figure 7-16. Drive Tire Installation



3. If outside edge of hub is not flush with edge of metal insert in the old tire, measure how far hub is recessed inside tire. The new tire must be placed in the same position the old tire was installed on hub. You can use a spacer (slightly smaller in diameter than inside diameter of tire insert and same thickness as depth of recess) to obtain correct amount of recession.
4. Position hub assembly with old tire on top of circular ram so outside of wheel is positioned upward. The outside edge of hub has a chamfer to help guide new tire onto wheel. The chamfered edge must always be leading edge when a tire is pressed onto hub.
5. Center hub assembly on top of ram and make sure that they mate squarely.
6. Position new tire with its chamfered insert facing hub. Align new tire and hub so that they are concentric.
7. Begin pressing new tire onto hub and old tire off wheel. Run press slowly for the first few inches of travel, because this is the critical stage of the operation. If tire begins to cock to one side, stop press and realign tire. A sharp jar with soft-headed mallet usually realigns tire on hub.

NOTE: If new tire does not press on with a minimum of 5 tons (68,947 kPa) pressure, replace hub.

8. Release press. Remove wheel, tire assembly, and old tire from press table.

   Inspect wheel and tire assembly.

Electrical Components

Power Amplifiers

Before replacing a power amplifier, record the current performance parameters for reference when setting parameters in the new amplifier.

⚠ WARNING

Before removing a power amplifier, discharge the amplifier's internal capacitor by jumpering the + and – terminals with a 100 ohm 25W resistor.

Terminal Hardware

⚠CAUTION

Do not attempt to repair power cable terminal lugs without approved tools. If a power cable has worn or damaged lugs, replace the cable or refer to "Power Cable Repair" on page 7-32. Do not substitute other kinds of nuts for the flanged nuts. Failure to use correct cables, flanged nuts, and torque values can result in overheating and damage to components.

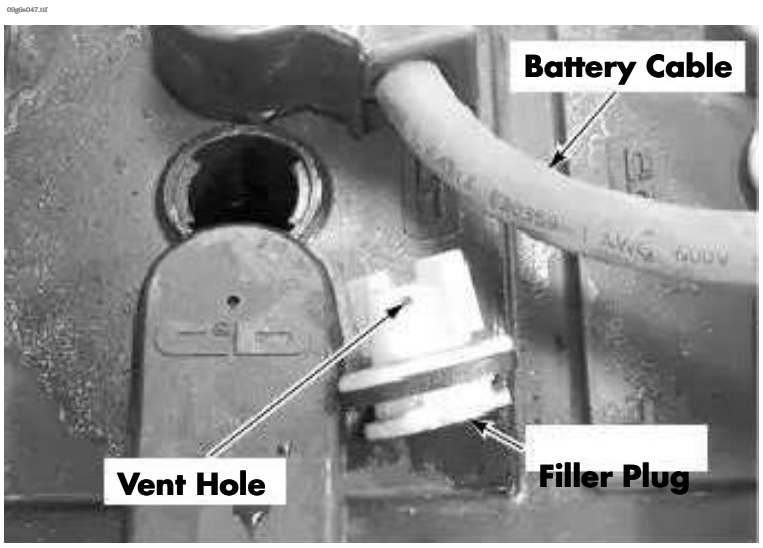
Whenever you connect power cables to a motor or power amplifier, do not over-tighten nuts or bolts. On motors with stud terminal securing nuts, use a second wrench on the securing nut to avoid twisting the stud.

Battery Procedures

Battery Exterior Cleaning

1. Read, understand, and follow procedures, recommendations, and specifications in the battery and battery charger manufacturer's manuals.
2. Wear personal protective equipment. See "Battery Safety" on page 2-5.
3. Turn the key switch OFF and disconnect the battery connector. Remove the battery from the lift truck.
4. Inspect the battery cables to make sure they are not frayed or loose. Inspect the battery connector. Make sure there is no foreign material inside the connector. Make sure the filler plugs are tight and the vent holes in the filler plugs are not plugged.

Figure 7-17. Battery Cable and Filler Plug



5. Keep the top of the battery clean and dry. Corrosion, dust, and moisture provide a conducting path to short-circuit cells or create shorts to ground.

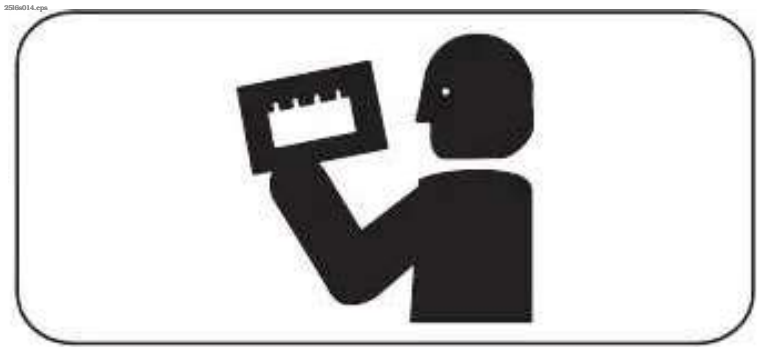
⚠CAUTION

Do not clean the top of the battery with the soda solution while it is installed in the lift truck. Water can seep into the electrical components and cause serious damage.

6. Wash dirty batteries (or any that have had electrolyte spilled on them) with a solution of 1 lb. (0.45 kg) of baking soda added to 0.5 gal. (1.9 liters) of hot water.
7. Use a brush with flexible bristles to clean the entire top of the battery with the soda solution. Wait until all foaming stops, indicating that the battery exterior is neutralized.
8. Rinse the battery with clean water.
9. Dry the battery completely before reinstalling it.
10. Reinstall the battery in the lift truck.
11. Connect the battery connector. Close the battery cover and secure the latch.

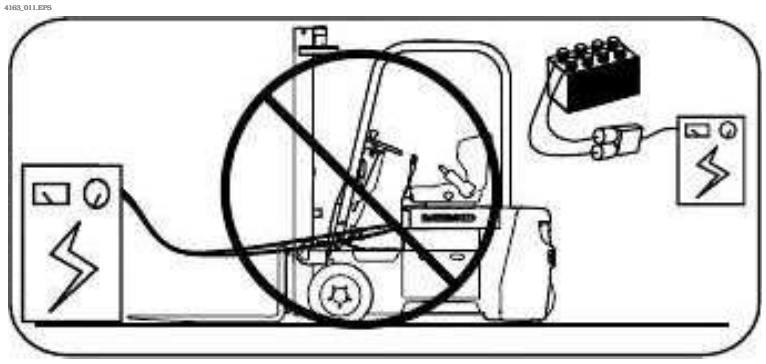
Testing, Charging, and Maintenance

For information on testing, charging, and maintaining your lift truck battery, consult the battery manufacturer's specifications and instruction manual.



⚠CAUTION

Never connect a battery charger directly to the lift truck. This can cause severe damage the lift truck's electrical system. Plug the charger into the battery connector only.



Wiring and Harness Connectors

General Repair Procedures

See "Electrical Troubleshooting" on page 5-2.

Whenever working on the lift truck, use care around wiring harnesses.

- Carefully connect and disconnect all connections.
- Do not pry connectors apart with unspecified tools.

There should be a wire marker at each termination. If the marker is missing or unreadable, remark the wire to allow easier identification.

NOTE: It is normal to find unused connectors for uninstalled options that have had heat shrink applied over them and have been strapped to the harness.

Repair

CAUTION

Use correct electrostatic discharge precautions. See "Static Precautions" on page 2-7.

When pulling a wire out through a bundle, cut off the pin or socket so it does not snag. When replacing wires, in some cases you can tape or solder one end of a new wire to one end of the failed wire. Then you can pull the old wire out of the bundle and pull the new wire into the bundle, all at the same time. Disconnect the old wire from the new wire.

In other cases, it is easier to secure a new wire to the outside of the existing wire bundle with straps of an appropriate size. The failed wire can be left in the bundle, or can be pulled by one end to remove it from the bundle.

When replacing wires, follow these guidelines:

- Use the appropriate tools to remove and insert terminations at each connector.
- Remove damaged terminations and discard. Never reuse a termination from a wire.
- Do not cut away a terminal lug and reuse the wire strands that were crimped into the original lug.
- When stripping wire, use new wire strands for new terminations. Use a new wire with extra length to allow for cutting and stripping of the ends to install new terminations.
- Use a new wire that is the same gauge (typically 18 gauge AWG), size, type, and color as the wire it is replacing.
- Use a hand stripper capable of stripping by wire gauge number. Use care not to nick or cut any of the wire strands. Discard and replace a wire with damaged strands. Insert the wire strands the correct length into termination before crimping.

Soldering Procedures

To prevent damage from excessive heat when soldering small components in assemblies, follow these guidelines.

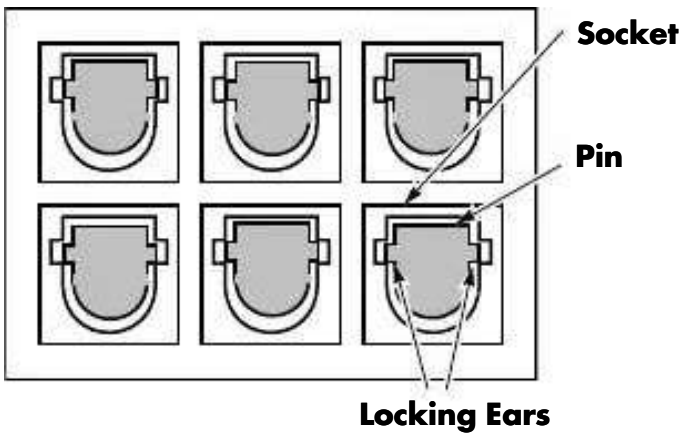
Make sure the soldering tip is clean. A dirty tip does not transfer heat well and encourages long dwell time and greater pressure. Apply light pressure on the terminal.

- Flux: rosin base
- Solder: 60/40 rosin core or equivalent
- Solder Iron: 55 watt max
- Tip Size: 0.118 in. (3 mm) diameter by 1.182 in. (30 mm) long screwdriver tip
- Tip Temperature: 500°F (260°C) max
- Terminal Contact Time: 6 seconds max
- After soldering, clean the terminals with a brush dampened with an alcohol-based cleaner (P/N 990-600/FOF). Do not allow any cleaner to seep into the switches or potentiometers, or contact contamination may occur.

NOTE: Components damaged due to solvent saturation *will not* be covered under warranty.

Molex Connectors

Figure 7-18. Molex Connector, end view



For pin orientation of Molex connectors, see Figure 5-2 on page 5-6. Molex connectors have pins with locking ears which engage ridges in the plastic connector body. To remove a pin from a Molex connector, these locking ears must be depressed far enough to clear the ridge in the connector.

Pin Extraction

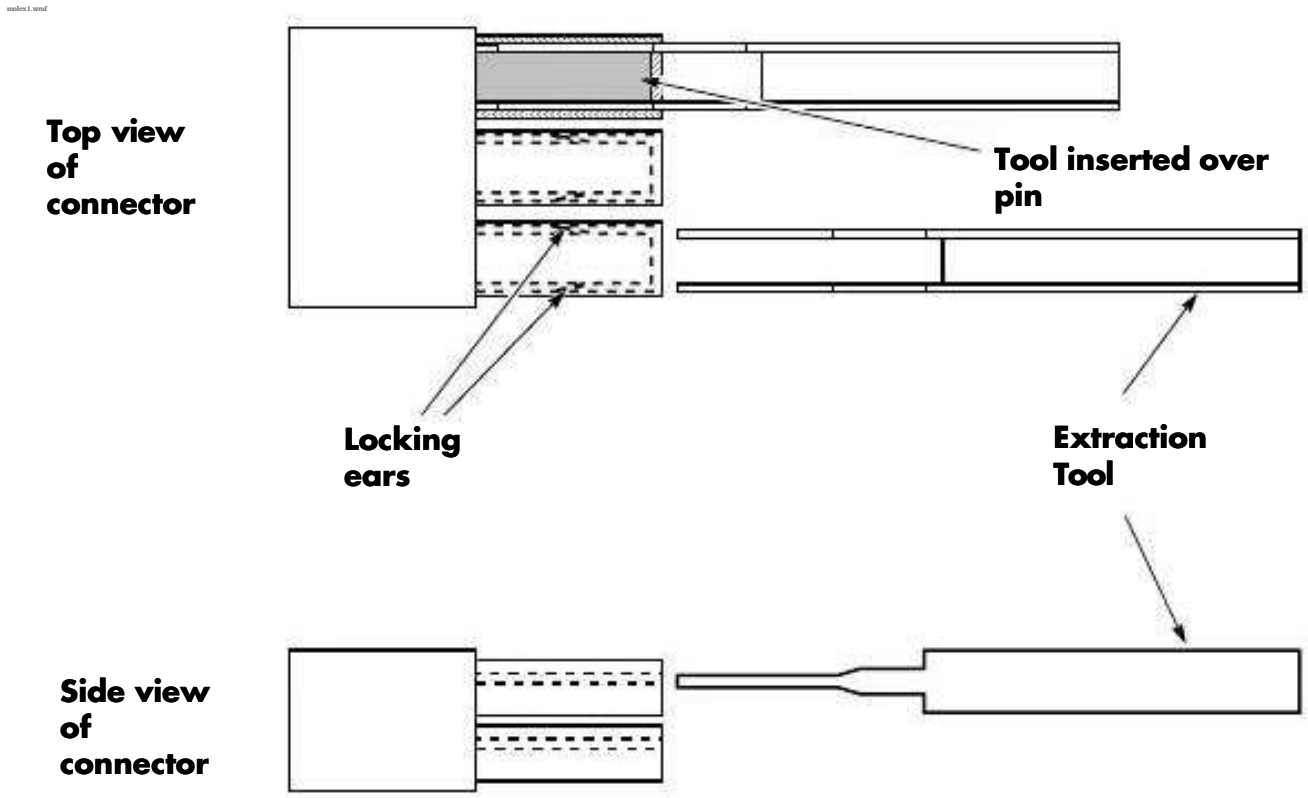
To remove a pin from a Molex connector, use pin extraction tool P/N 950-026.

1. Insert the extraction tool over the pin and push all the way into the connector. This releases the locking ears on the pin. See Figure 7-19.
2. Pull the wire and pin from the connector.

Pin Insertion

To insert a pin into a Molex connector, insert the pin into the back side of the connector and push the wire all the way in until it clicks. The locking ears have now engaged the connector.

Figure 7-19. Pin Extraction



AMP Harness/Harness Connectors

AMP connectors provide water-resistant connection by the use of seals between wires and connectors and between the mating connector halves.

To maintain the integrity of water-resistant seals, use the following procedures when working with AMP connectors.

Figure 7-20. AMP Water-Resistant Connector

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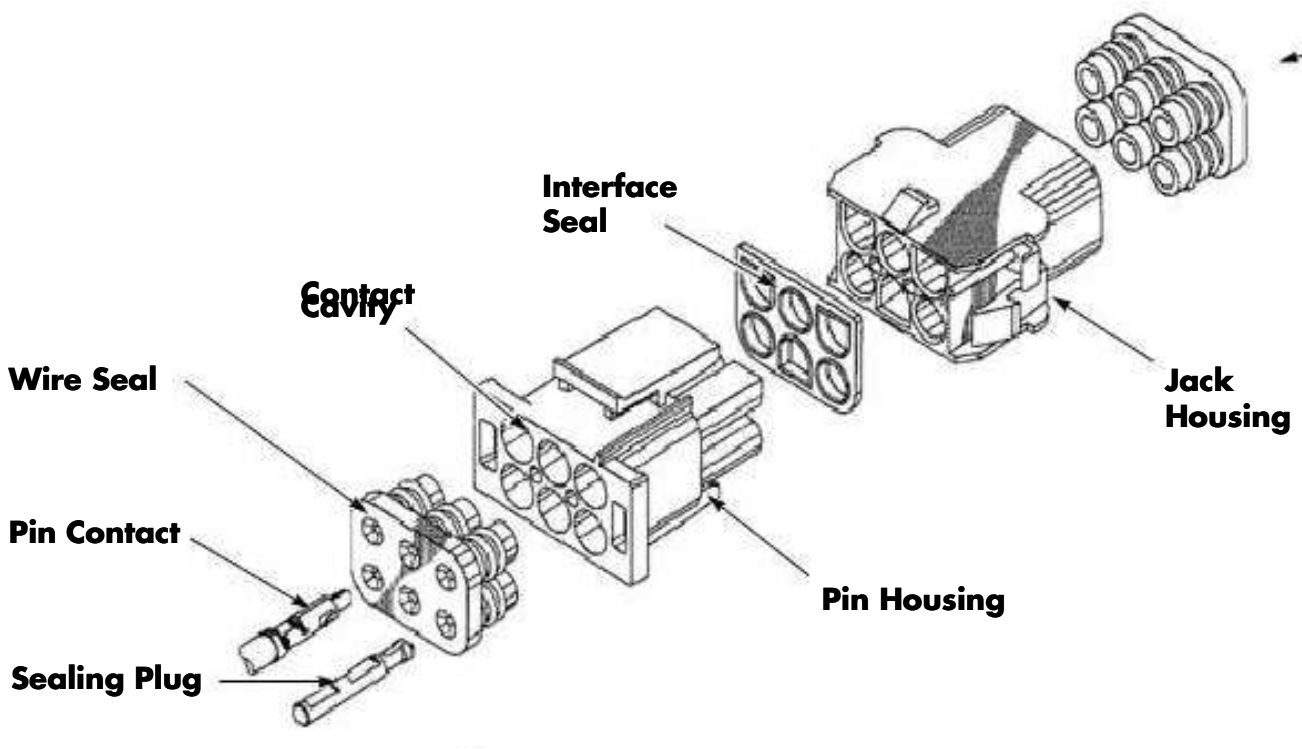

Pin Extraction

To aid in separating AMP connectors, use unlatching tool P/N 950-042. To remove a pin from an AMP connector, use pin extraction tool P/N 950-009.

1. While holding the wire seal, push the selected wire forward, then insert the extraction tool into the contact socket. See Figure 7-21.

Figure 7-21. AMP pin extraction

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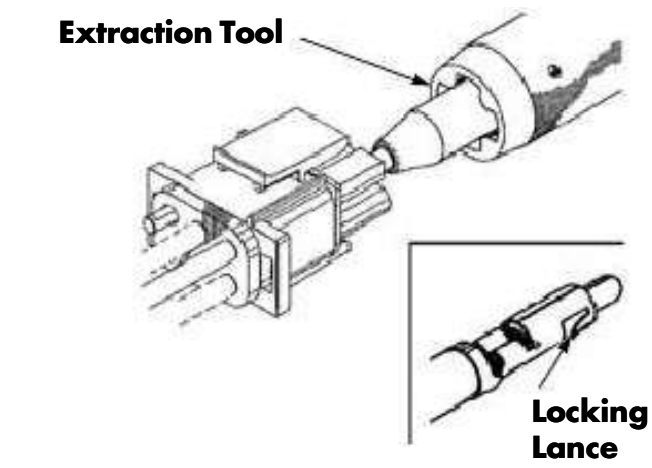

2. Pull the wire gently until you feel the contact locking lances disengage.
3. Holding the wire seal and connector housing together, rotate the wire while pulling it through the wire seal. This

prevents damage to the seal. See Figure 7-22.

Figure 7-22. Removing wire

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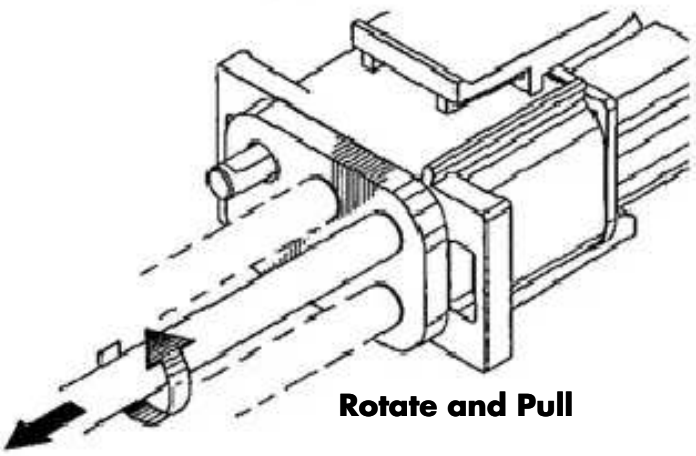

Pin Insertion

1. Make sure the connector has a wire seal attached to the connector back. See Figure 7-23.

Figure 7-23. Wire Seal

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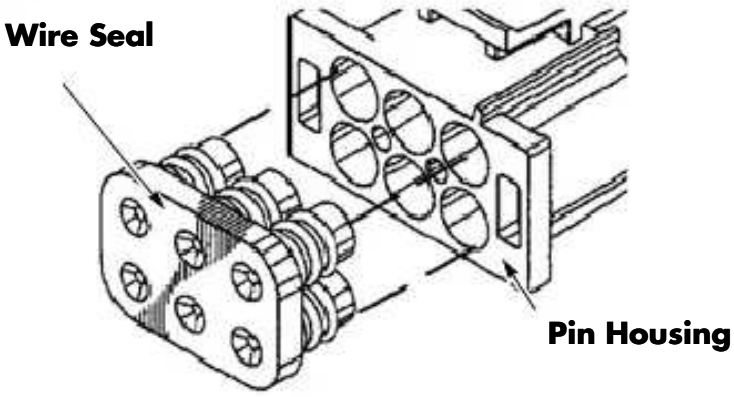

2. If re-inserting a wire previously removed, make sure the pin contact locking lances are extended to their original position.
3. Grasp the wire close behind the contact insulation barrel and push the wire straight through the wire seal into the socket until it clicks. Pull back gently to make sure the contact is locked in place. See Figure 7-24.

Figure 7-24. Wire insertion

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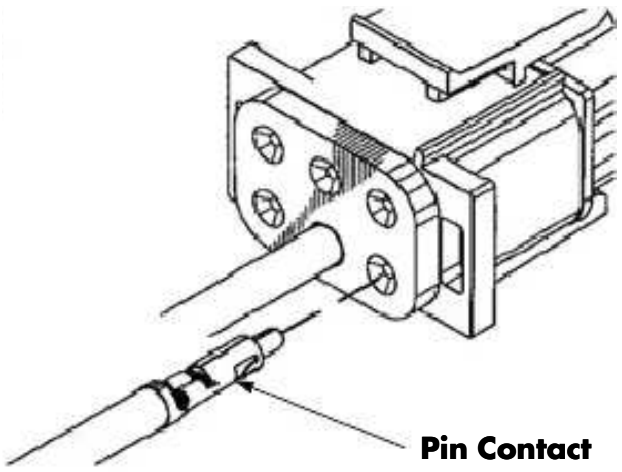
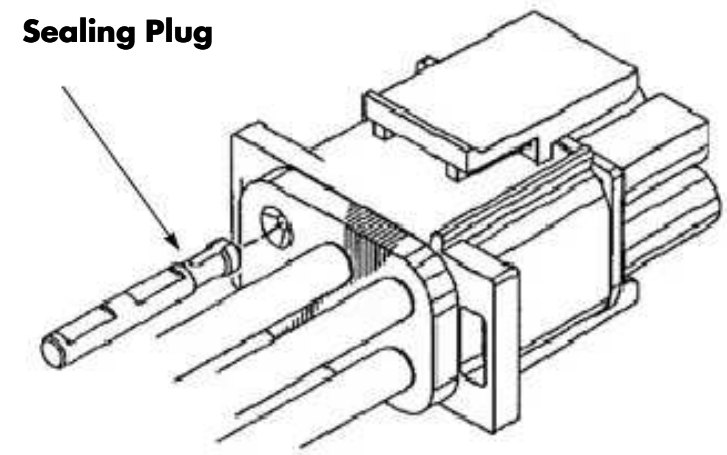


Seals

1. Use a wire seal at the back (wire end) of each connector half. See Figure 7-23.
2. Plug unused pin positions with sealing plugs. See Figure 7-25.

Figure 7-25. Sealing Plug

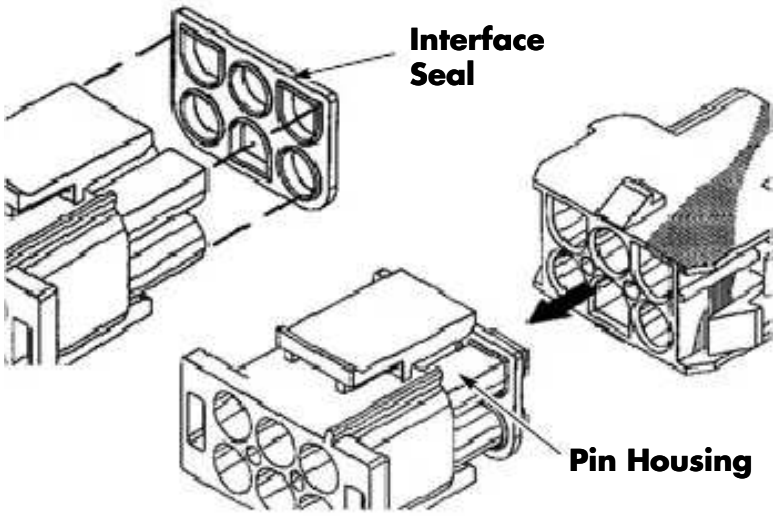
4570_005.tif



   a. Align the split tapered end of the sealing plug with the unused opening in the wire seal. Push the plug through the wire seal into the connector until it snaps into position.
   b. Sealing plugs can be removed by pulling with needle-nose pliers while grasping the wire seal and connector.
3. Use an interface seal between pin and jack halves of the connector. To prevent damage to the seal, use the matching connector cap to slide the interface seal over the contact silos on the pin housing. See Figure 7-26.

Figure 7-26. Interface Seal

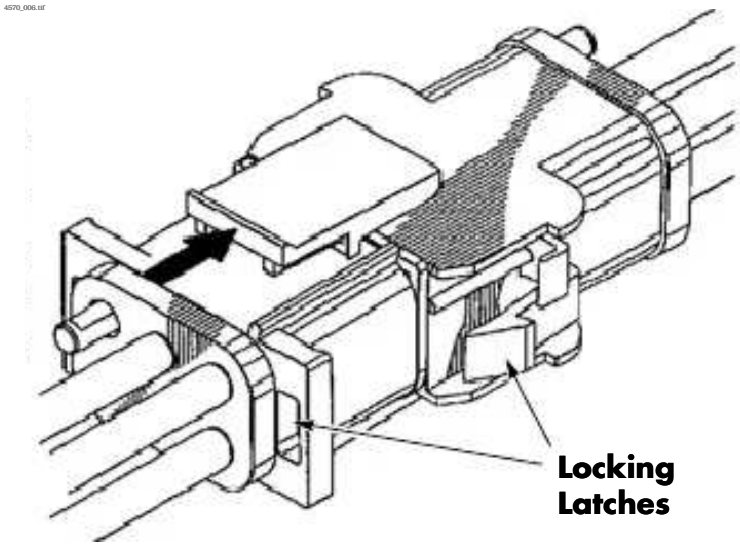
4570_003.tif



4. When mating connectors, make sure the polarized silos are correctly oriented. Push pin and jack halves of the connector together until locking latches engage. See Figure 7-27.

Figure 7-27. Latching AMP connector

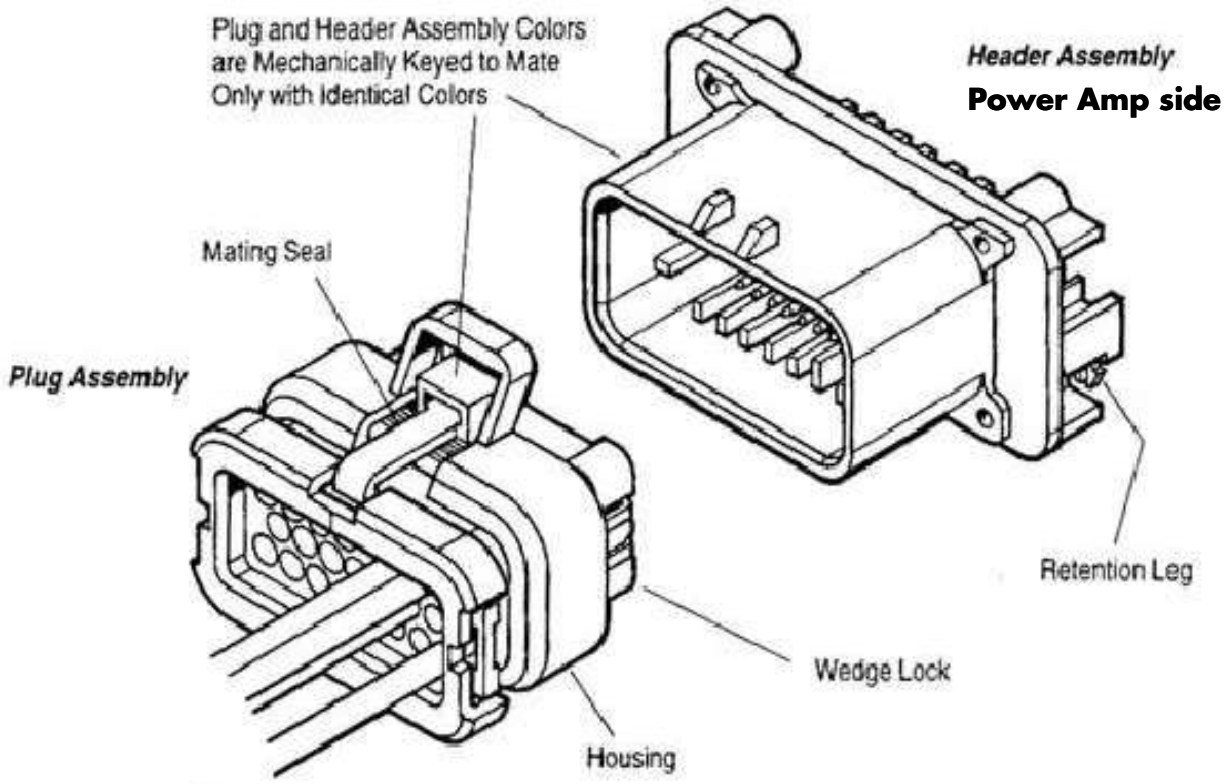
4570_006.tif



AMP Harness/Power Amplifier Connector

Connector Components

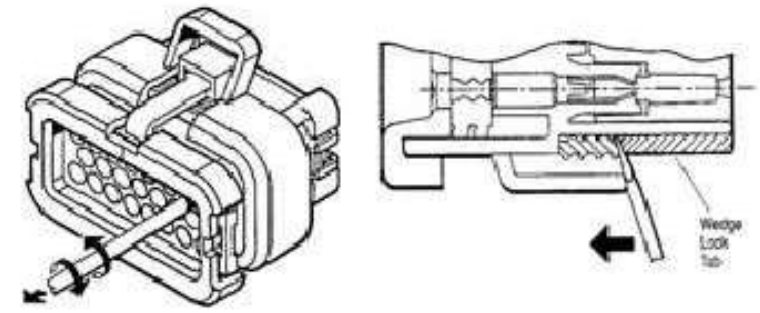
Figure 7-28. Power Amplifier Connector Components



Disassembly (Contact Removal)

1. Insert a 4.8 mm screwdriver blade between the mating seal and one of the red wedge lock tabs. See Figure 7-29.
2. Pry open the wedge lock to the open position.
3. While rotating the wire back and forth over a half turn (1/4 turn in each direction), gently pull the wire until the contact is removed.

Figure 7-29. AMP JPT1 Connector



Contact Insertion

The axial concentricity of the crimped contact shall fall into an area defined by a 2 mm diameter cylinder whose center is the centerline of the contact front end. See Figure 7-30.

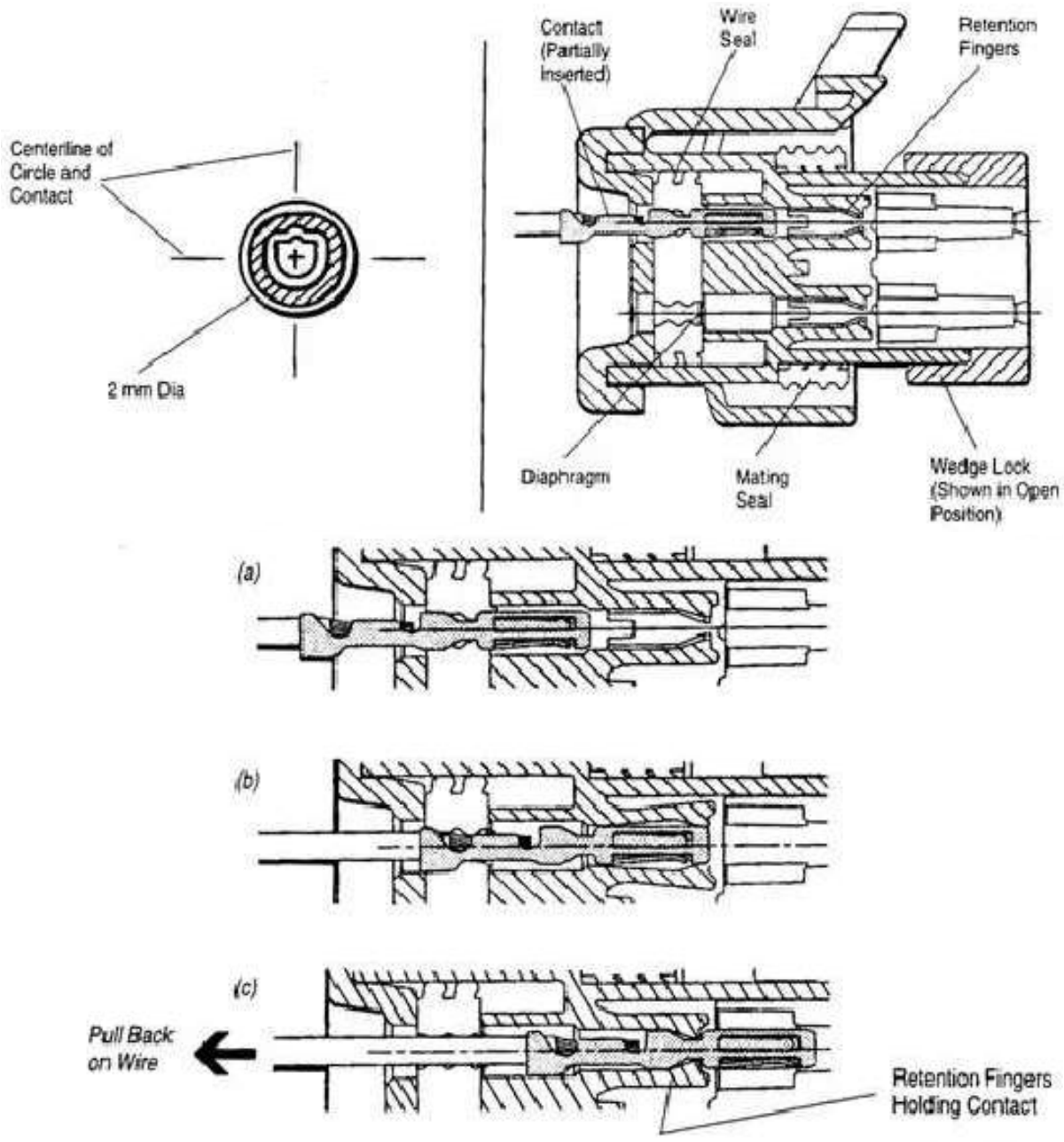
Assembly

Make sure the wedge lock is open.

1. To insert a contact, push it straight into the appropriate circuit cavity as far as it will go. See Figure 7-30 (a) and (b).
2. Pull back on the contact wire with a force of 1 or 2 lbs. to make sure the retention fingers are holding the contact. See Figure 7-30 (c).

Figure 7-30. Contact Insertion

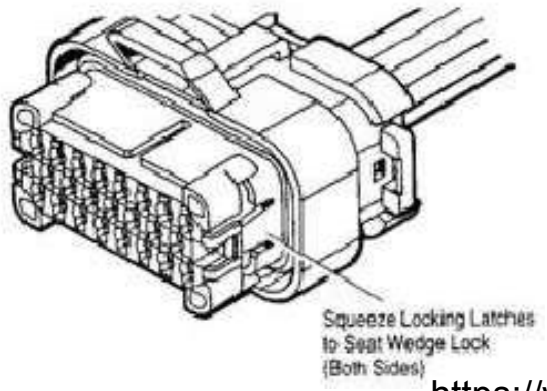
amp004.tif,amp005.tif



3. After all contacts have been inserted, the wedge lock must be closed to its locked position. Release the locking latches by squeezing them inward. See Figure 7-31.

Figure 7-31. Wedge Lock Latches

amp003.tif

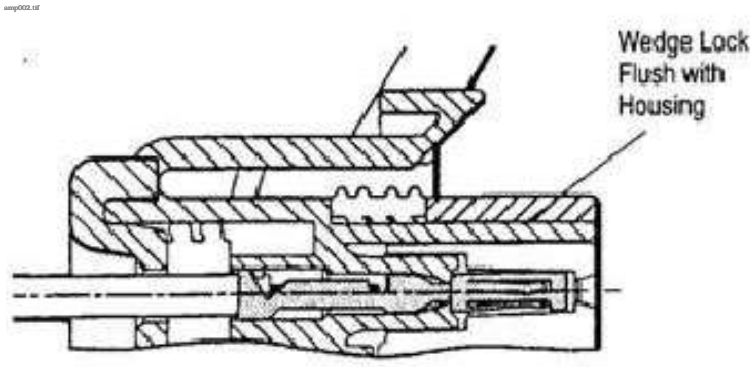


⚠CAUTION

Be very careful when putting the wedge lock in the locked position. Forcing the wedge lock can cause damage to the connector. Make sure the wedge lock is aligned correctly. If resistance is felt, slightly adjust the wedge lock until it slides in freely.

4. Slide the wedge lock into the housing until it is flush with the housing. See Figure 7-32.

Figure 7-32. Wedge Lock Flush With Housing



Testing

Do not pierce wire insulation with a sharp point while troubleshooting.

The wedge lock has slotted openings in the forward (mating) end. These slots accommodate circuit test tabs that are approx. 3.3 by 0.6 mm, which prevent damage to the receptacle. For circuit testing in the field, use a flat probe such as a pocket knife blade. Do not use a probe with a sharp point.

Power Cables

Check power cables for:

- evidence of overheating
- burned spots in the cable
- nicks in the insulation
- damaged or overheated terminal lugs
- damaged mounting hardware or brackets

Replace damaged cables or mounting hardware as necessary.

Power cables are marked on the terminal lug with the location where they belong. If the marking is missing or is not readable, remark the cable with the correct information.

NOTE: Terminal lugs may be replaced in the field using the appropriate crimping tools. Crimping tool, lugs, and heat-shrink are available through the Parts Distribution Center. Failure to use correct cables, terminal hardware, and torque values can result in overheating and damage to components.

Power Cable Repair

Traditional lug crimping techniques for power cables on DC motors may not meet the higher current requirements of AC motors. Use Manual Crimp Tool (P/N 1069861) when crimping power cables for all AC motors. This tool may also be used to repair power cables for DC motors.

1. Remove the bad cable(s).
2. Using the removed cable(s) for reference, cut an appropriate amount of replacement cable of the same gauge.
3. Set the adjustment screw on the manual crimp tool head to match the cable gauge.
4. Strip the cable jacket to fit the terminal to be crimped. Refer to Table 7-2 and Table 7-3.

Table 7-2. Cable Jacket Strip Length - Short Barrels

AWG	Lug P/N	Strip Length
1/0	1002215/001-004	11/16 in. (17 mm)
2/0	1002215/005-008	13/16 in. (21 mm)
3/0	1002215/009-012	1 in. (25 mm)
4/0	1002215/013-015	1-1/16 in. (27 mm)

Table 7-3. Cable Jacket Strip Length - Long Barrels

AWG	Lug P/N	Strip Length
1/0	1002217/001-003	1-9/16 in. (40 mm)
2/0	1002217/004-006	
3/0	1002217/007-009	
4/0	1002217/010-011	1-11/16 in. (43 mm)

5. Insert cable into terminal.
6. Place cable and terminal into tool die and crimp. Refer to pictures below for what completed crimps should look like.

Figure 7-33. Short Barrel Terminal

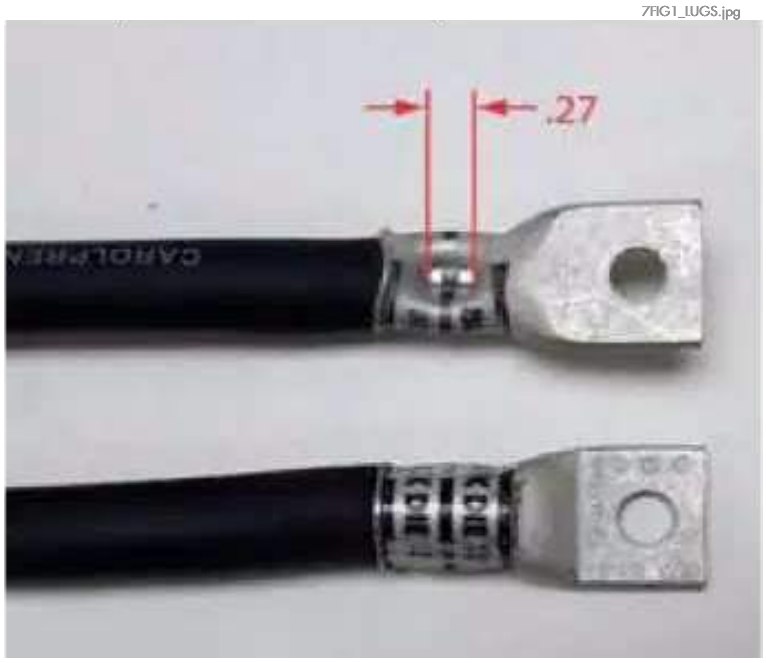
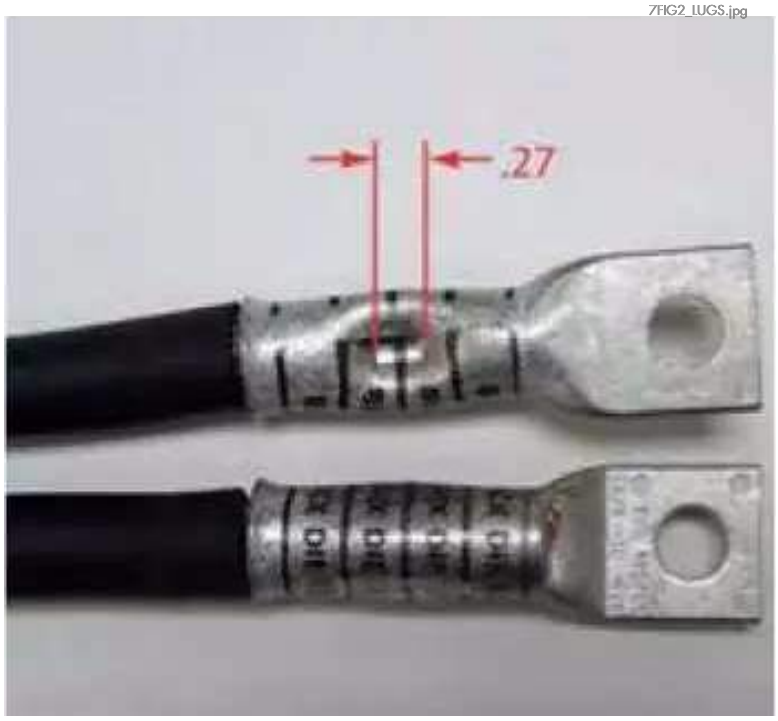


Figure 7-34. Long Barrel Terminals



7. Apply heat shrink tubing (P/N 611-035) to the terminal after crimping.
   a. For short barrels, use 1.75 in. (45 mm) of tubing. Apply 1 in. (25 mm) over the jacket extending 0.75 in. (19 mm) over the barrel.
   b. For long barrels, use 2.5 in. (64 mm) of tubing. Apply 1 in. (25 mm) over the jacket extending 1.5 in. (38 mm) over the barrel.

Fuses

For a complete list of fuses, amperage ratings, and functional descriptions, refer to page 5-4.

Power Amplifier Fuses

Fuses for the Traction and Pump Power Amplifiers are attached to their respective power amplifier located in the rear compartment. See Figure 7-35.

Figure 7-35. Power Fuses - Traction Power Amps

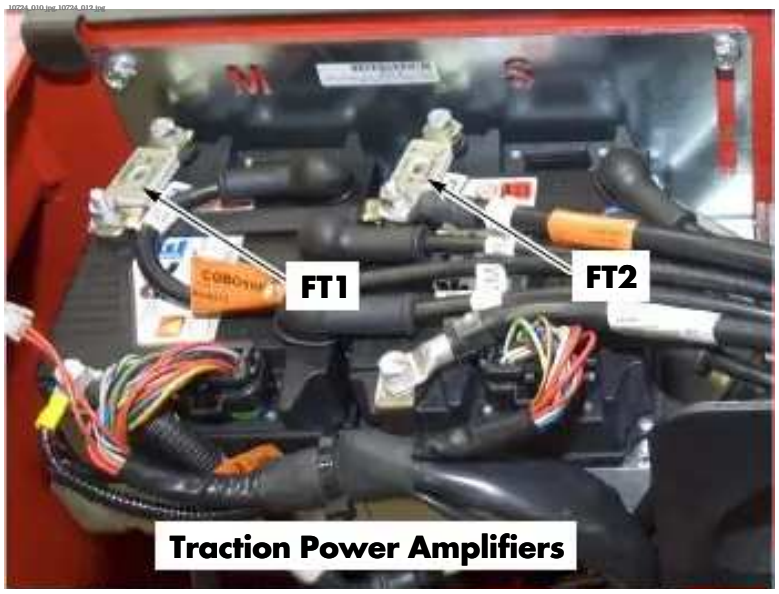
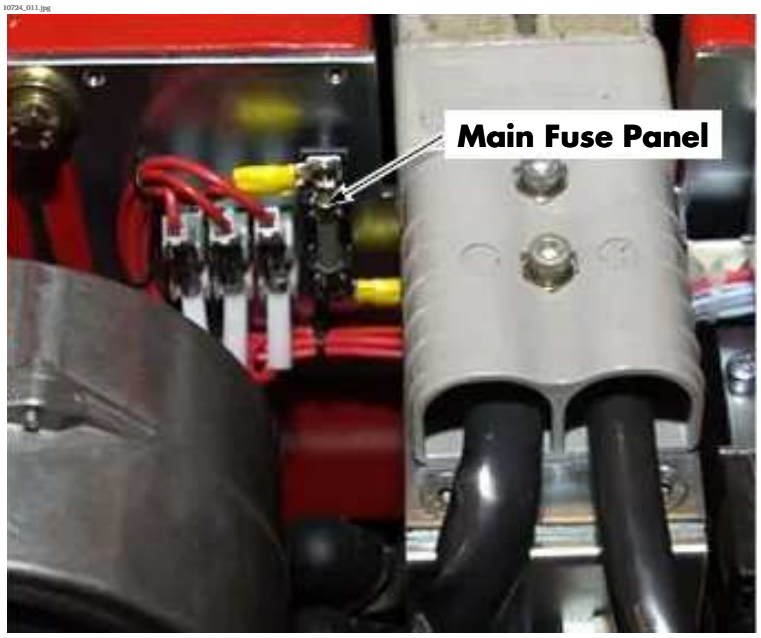


Figure 7-36. Power Fuse - Pump Power Amp

Main Fuses

Fuses for the key switch, DC/DC Converter, Hydraulic Control Board, and optional equipment terminal strip are located on the Main Fuse Panel located near the battery connector in the rear compartment. See Figure 7-37.

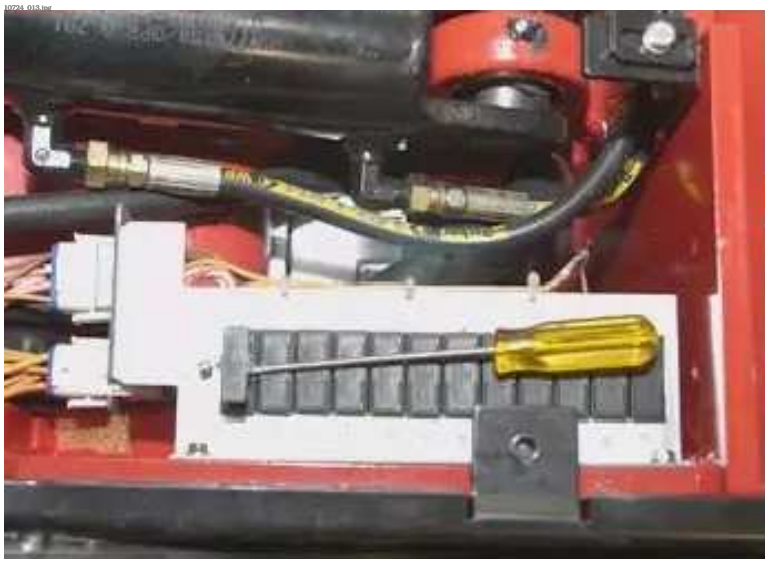
Figure 7-37. Main Fuse Panel



+24V Fuse Panel

Fuses for +24V components are located on a panel mounted on the left side of the under floor compartment. See Figure 7-38.

Figure 7-38. +24V Fuse Panel

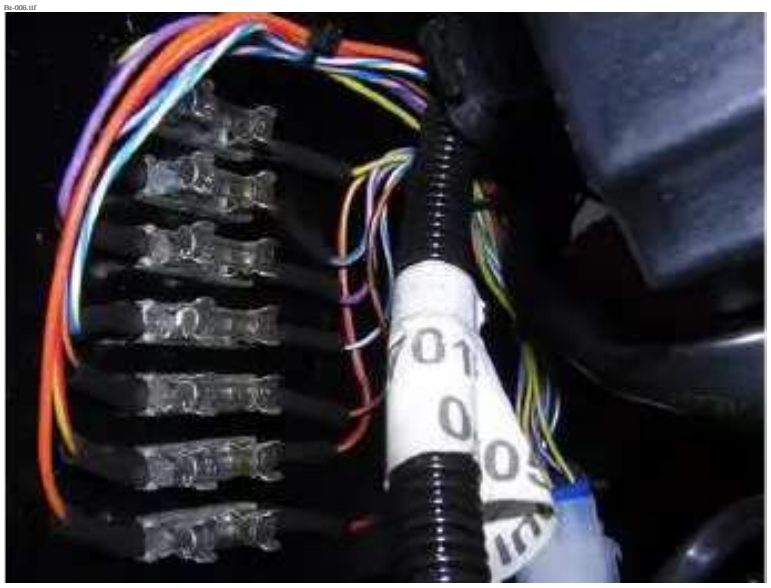


NOTE: A thin screwdriver can be used to access the desired fuse. Carefully push the fuse out with the tip of the screwdriver.

Optional Fingertip Control Fuses

Fuses for optional fingertip controls are located on the armrest mounting bracket near the Hydraulic Control Board. See Figure 7-39.

Figure 7-39. Fuse Panel Near Hydraulic Control Board

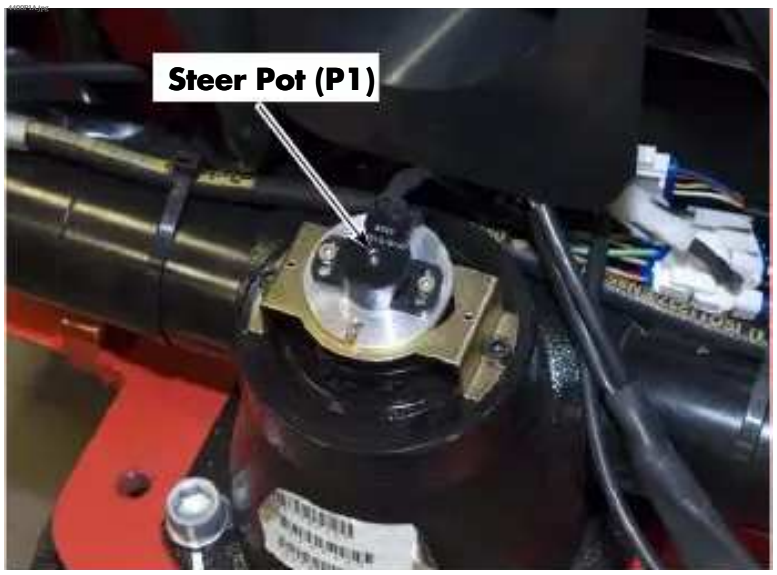


Potentiometers

Steer Potentiometer (P1)

The steer potentiometer (pot) is located under a dust cap attached to a bracket on the top of the steer actuator. See Figure 7-40.

Figure 7-40. Steer Pot



Removal

1. Turn the key switch OFF and disconnect the battery connector.
2. Unplug the wiring harness connector from the steer pot and remove dust cap.
3. Remove the two screws and washers securing the steer pot to the mounting bracket.
4. Carefully lift the steer pot straight off the shaft.

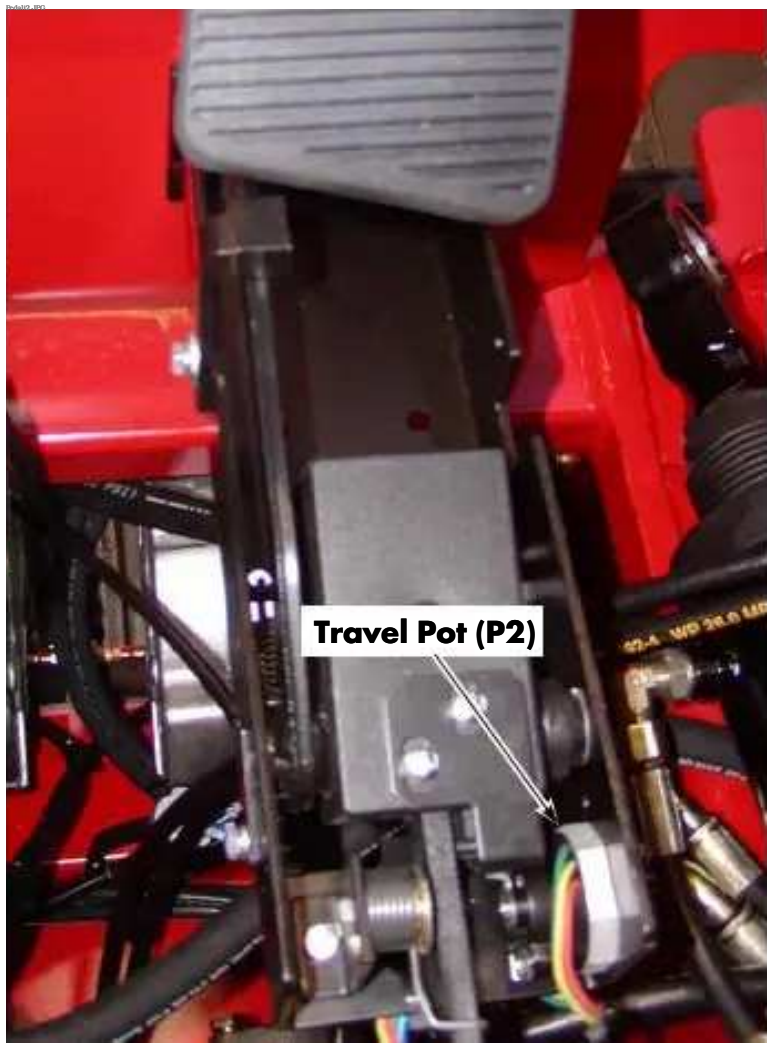
Installation

1. Install the steer pot on the circular disk or bracket.
2. Plug the wiring harness connector into the steer pot.
3. Run Learn for the steer pot in FlashWare. See “Learn Steer” on page 3-13.
4. Secure the dust cap to the top of the steer actuator.

Travel Potentiometer (P2)

The travel pot is located in the right rear of the pedal assembly. See Figure 7-41.

Figure 7-41. Accelerator Pedal Assy. (single pedal shown)



Removal

1. Turn the key switch OFF and disconnect the battery connector.
2. Remove the operator compartment floor.
3. Unplug the wiring harness connectors to the traction pot and switch(es).
4. Remove the accelerator pedal assembly from the lift truck.
5. Remove the travel pot from the accelerator pedal assembly.

Installation

1. Install the new travel pot in the pedal assembly.
2. Install the pedal assembly in the lift truck.

3. Plug the wiring harness connectors into the travel pot and switch(es).
4. Run Learn for the travel pot in FlashWare. See “Learn Travel” on page 3-12.

Lift Potentiometer (P3)

Removal

1. Turn the key switch OFF and disconnect the battery connector.
2. Remove the control valve cover.
3. Unplug the wiring harness connector to the lift pot.
4. Loosen the socket head screw securing the clamp on the lift pot shaft.
5. Remove the hardware securing the lift pot to the bracket.
6. Remove the pot from the bracket.

Figure 7-42. Lift Pot Location

Installation

1. Place the lift pot shaft through the hole in the control valve bracket. Align the locator pin with the hole in the mounting plate.
2. Install the lock washer, nut, and washer ring on the lift pot shaft.
3. Adjust the lift pot. Measure resistance between the green and the yellow/red wire. Use a screwdriver to turn the pot shaft until the meter reads approx. 5K ohms.
4. Tighten the socket head screw in the shaft clamp.
5. Verify resistance decreases linearly when the lift lever is pulled.
6. Verify the lift microswitch operates correctly.
7. Run Learn for the lift pot in FlashWare. See “Learn Lift” on page 3-13.

Motor Encoder Bearing

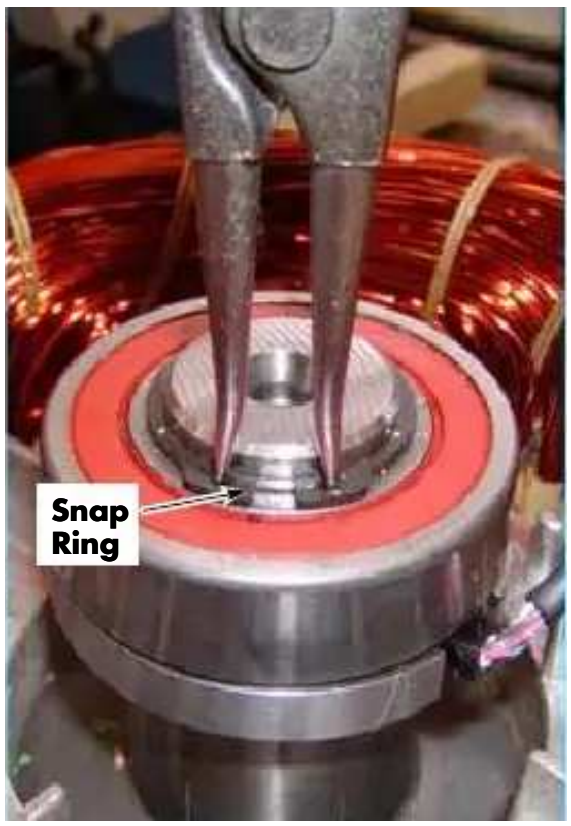
Removal

1. Turn the key switch OFF and disconnect the battery connector.
2. Disconnect all cables and connectors at the motor and remove the motor.
3. Remove the four bolts that secure the top end bell to the bottom end bell. See Figure 7-43.

Figure 7-43. Retaining Bolt Removal

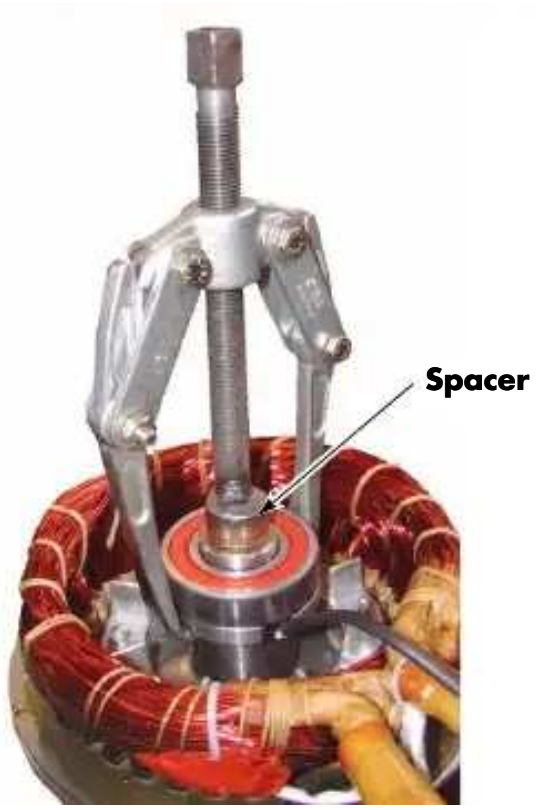
4. Mark the position of the top end bell and bottom end bell relative to the stator.
5. Remove top end bell.
6. Remove the snap ring. See Figure 7-44.

Figure 7-44. Snap Ring Removal



7. With a spacer between the motor shaft and bearing puller, remove the encoder bearing. See Figure 7-45.

Figure 7-45. Encoder Bearing Removal



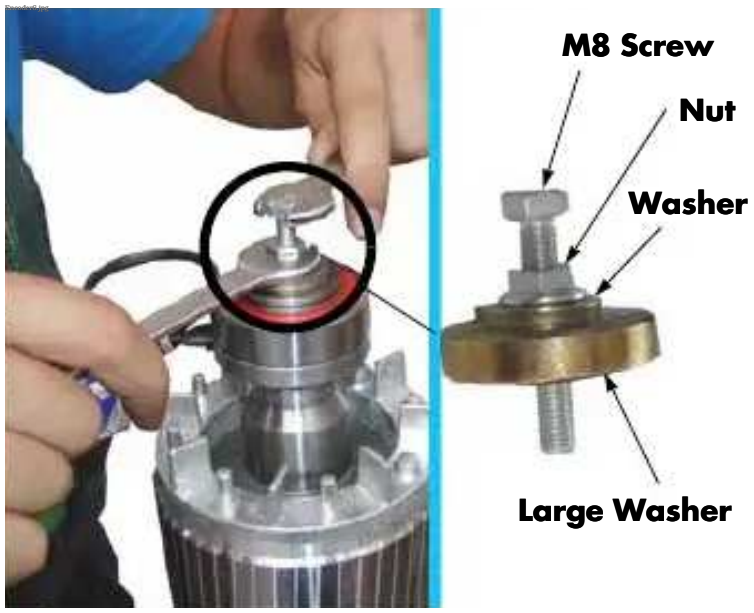
Installation

1. Lubricate motor shaft before installing new encoder bearing. See Figure 7-46.

Figure 7-46. Lubricate Motor Shaft

2. Drive the new encoder bearing onto the motor shaft using an M8 screw, nut, and washers. See Figure 7-47.

Figure 7-47. Encoder Bearing Installation



3. Slowly turn the nut until the bearing is seated. See Figure 7-48.

Figure 7-48. Driving Encoder Onto Motor Shaft

4. Install the snap ring. See Figure 7-49.

Figure 7-49. Snap Ring Installation

5. Correctly install top end bell.
6. Torque the end bell retaining bolts as follows:
   - Traction motor - 15 ft. lb. (20 Nm)
   - Pump motor - 8 ft. lb. (11 Nm)
7. Re-install motor.
8. Reconnect all connectors and power cables. Torque motor cable securing nuts to 18 ft. lb. (24 Nm).
9. Reconnect the battery connector and turn the key switch ON.
10. Test truck operation.

Motor Temperature Switch Repair

Temperature switches for the traction and pump motors are integral to the motor. When a motor temperature switch fails, it can be replaced using the procedures that follow.

Traction Motor

1. Turn the key switch OFF and disconnect the battery connector.
2. Disconnect all cables and connectors at the motor.
3. Mark the position of the top end bell and bottom end bell relative to the stator, then remove the snap ring.
4. Remove the four bolts that secure the top end bell to the bottom end bell.
5. Remove the top end bell. Use care that the encoder bearing remains in the bottom end bell to reduce the chance of damaging the bearing.
6. Install a new temperature switch using the high temperature silicone (neutral curing) supplied with the temperature sensor. Mount the sensor close to the location of the original. Secure the cable with a cable tie to one of the power leads.
7. Install the top end bell in the position that was previously marked. Verify correct stator installation and install snap ring.
8. Secure the top end bell to the bottom end bell using the four bolts previously removed. Torque the end bell retaining bolts to 15 ft. lb. (20 Nm).
9. Reconnect all connectors and power cables. Torque motor cable securing nuts to 18 ft. lb. (24 Nm).
10. Reconnect the battery connector and turn the key switch ON.

Pump Motor

1. Turn the key switch OFF and disconnect the battery connector.
2. Disconnect the temperature switch connector.
3. Disconnect cables and motor harness connections, making sure that you note locations for reassembly later.
4. Separate the pump assembly from the lift pump motor and remove lift pump motor.
5. Remove the four bolts that secure the top end bell to the bottom end bell.
6. Remove the top end bell. Use care that the bearing remains in the bottom end bell to reduce the chance of damaging the bearing.
7. Install a new temperature sensor using the high temperature silicone (neutral curing) supplied with the temperature switch. Mount the sensor close to the location of the original. Secure the cable with a cable tie to one of the power leads.
8. Carefully press the top end bell to the stator. Do not pinch the cables or allow contact with the rotor. Verify correct stator installation.
9. Secure the top end bell to the bottom end bell using the four bolts previously removed. Torque the end bell retaining bolts to 8 ft. lb. (11 Nm).
10. Reinstall pump motor to the pump assembly.
11. Reconnect connector and power cables.
12. Reconnect the battery connector and turn the key switch ON.

Cold Storage Conditioning

NOTE: Conversion of lift trucks for cold storage operation requires prior Raymond approval via Form S207.

Lift trucks operated in a cold storage environment require the following:

- All-weather hydraulic fluid (P/N 1017238)

NOTE: Do *not* add any additive to this hydraulic fluid.

- Sealed seat switch (P/N 312347-000).
- Sealed electrical connectors. See "Connector Sealing".

Connector Sealing

Fill sockets and the front and back of both halves of unsealed connectors with cold storage sealing compound (P/N 990-445). Connect wires and connectors. Coat the outside and where connectors attach to the circuit board. Coat terminals and terminal strips.

NOTE: Self-sealing AMP connectors (reference page 7-26) do not need sealing treatment.

Corrosion Inhibitor Coating

Coat or spray bare metal surfaces listed below with Corrosion Inhibitor Coating (P/N 990-644):

- Main and free lift chain pulleys and shafts
- Main and free lift chain anchors and threaded pins

Hydraulic Components

Hydraulic Fluid

Changing Fluid

To change the hydraulic fluid, park the truck on a flat surface with the mast tilted back and the forks lowered. Set the parking brake.

1. Disconnect one of the outboard hoses that feeds the auxiliary functions.
2. Direct the hose into a waste container with a capacity greater than 5.5 gallons (21 liters). To drain the reservoir, operate an auxiliary function until you hear air in the system.

⚠CAUTION

Operating the pump with the system drained can damage the pump.

3. Turn the key switch OFF and disconnect the battery connector.
4. Remove the floor of the operator compartment to access the reservoir and filter.
5. Remove cap with filter. Remove the filter from the cap.
6. Install a new filter on the cap.
7. Reconnect the outboard hose.
8. Fill the reservoir with new, clean hydraulic fluid. Refer to "Lubrication Specification Chart" on page A-2. Install cap with filter.
9. Install the operator compartment floor.
10. Test to make sure the hydraulic system is functioning correctly.
11. Make sure there are no fluid leaks.

Bleeding the Hydraulic System

You must bleed the hydraulic system whenever you:

- Change the hydraulic fluid and filter
- Change a hydraulic hose
- Disconnect a hydraulic fitting
- Notice that the load is bouncing
- Remove a hydraulic pump
- Remove the hydraulic reservoir

TF and TT Masts

1. Reconnect the battery connector and turn the key switch ON. Sit on the seat and lift the forks 6 to 12 in. (150 to 300 mm) off the ground.
2. *Free Lift Cylinders* - Loosen (do not remove) the bleed screw on the lift cylinder to let any air escape. Hold a shop rag close to and beneath the bleed screw to keep any hydraulic fluid from spraying out. When all of the air has escaped and hydraulic fluid starts coming out of the bleed screw hole, securely tighten the bleed screw.

NOTE: *Main Lift Cylinders* are self-bleeding. Lift and lower the forks several times.

3. Lower the forks all the way to the floor.

NOTE: When bleeding the hydraulic system, bleed all cylinders.

4. Bleed the auxiliary system:
   a. Tilt the mast all the way forward and backward several times.
   b. If the lift truck has sideshift, shift the carriage all the way to the left and right several times.
5. Check the hydraulic fluid level. Add hydraulic fluid as needed.

Quad Masts

1. Without a load, extend the free lift cylinder and continue to extend the main lift cylinders to 90% of full stroke. Retract all cylinders completely. Repeat three times.
2. Extend the cylinders without a load at 50% lift speed, then build full system pressure at the end the main lift cylinder stroke. Retract cylinders. Repeat four times.
3. Cycle the mast with a half load (50% rated capacity) through full cylinder extension [illegible]. The cylinders should extend smoothly. Repeat the steps if cylinder

- Remove a hydraulic cylinder

extension is not smooth.

Hydraulic Pressure Adjustment

Lift and auxiliary function pressures are adjusted at the control valve. On trucks with lever controls, the lift, tilt, sideshift, and 4th aux functions have individual adjustment points on the control valve. On trucks with fingertip controls, only the lift pressure is adjustable. See Figures 7-50 and 7-51.

Figure 7-50. Pressure Adjustment Points - Lever Controls

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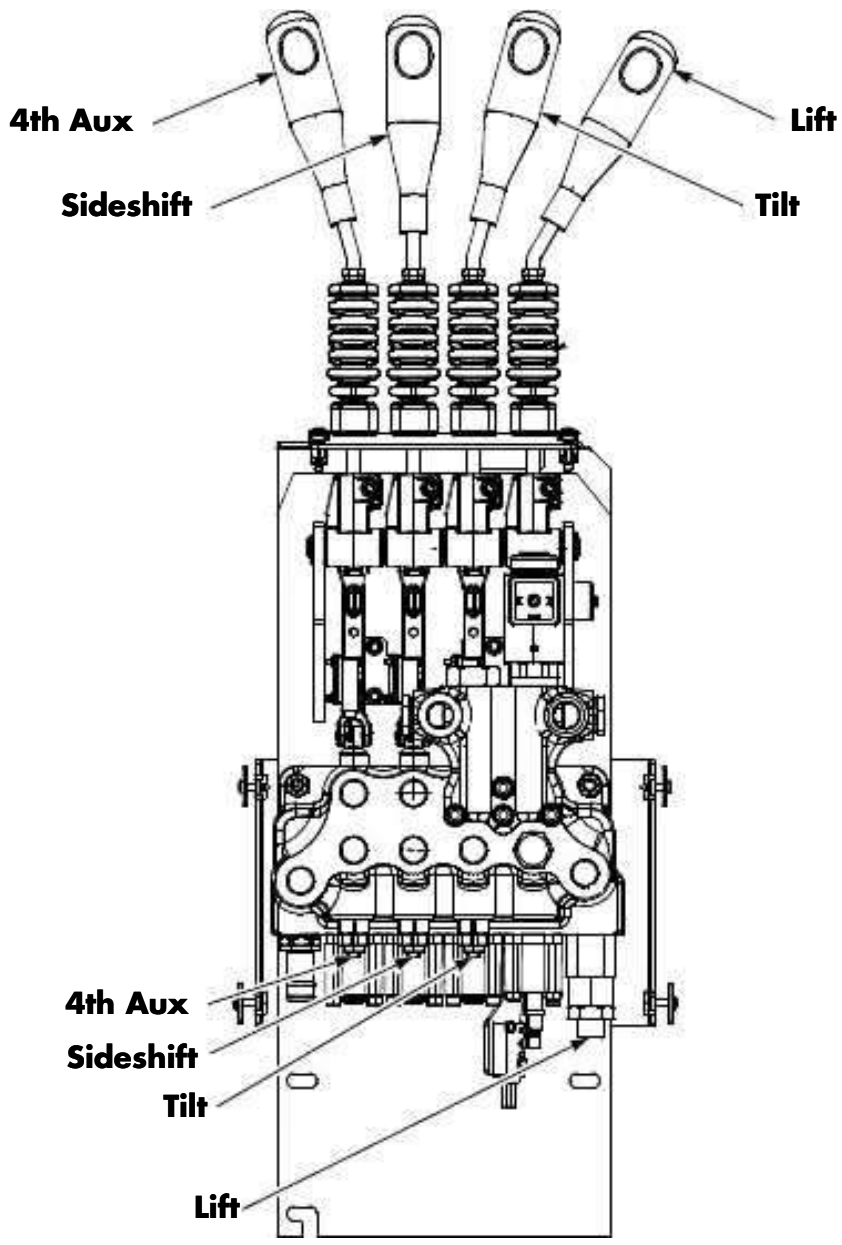
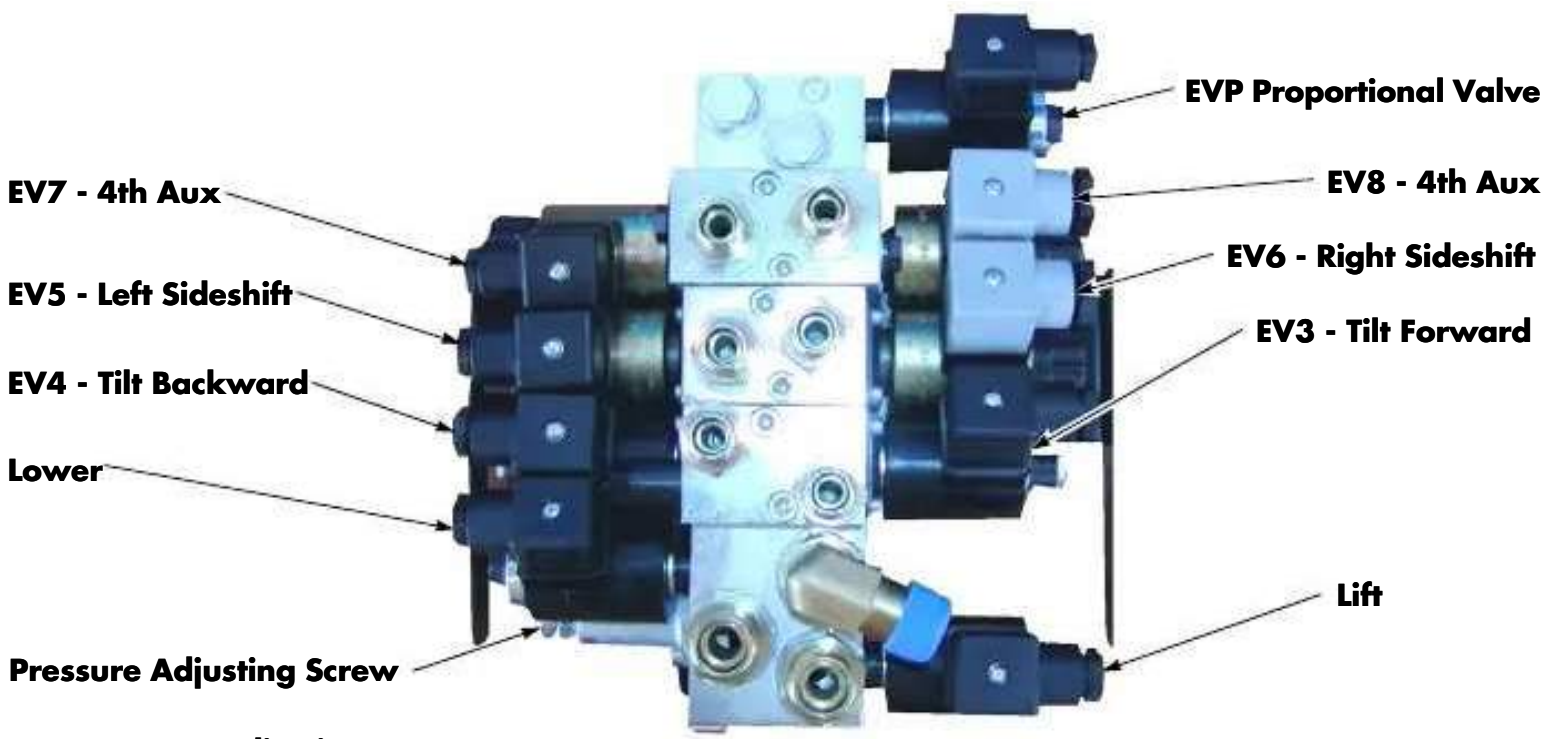


1. Loosen retaining nut.
2. Turn pressure adjusting screw:
   clockwise to increase pressure
   counterclockwise to decrease pressure
3. Tighten retaining nut.

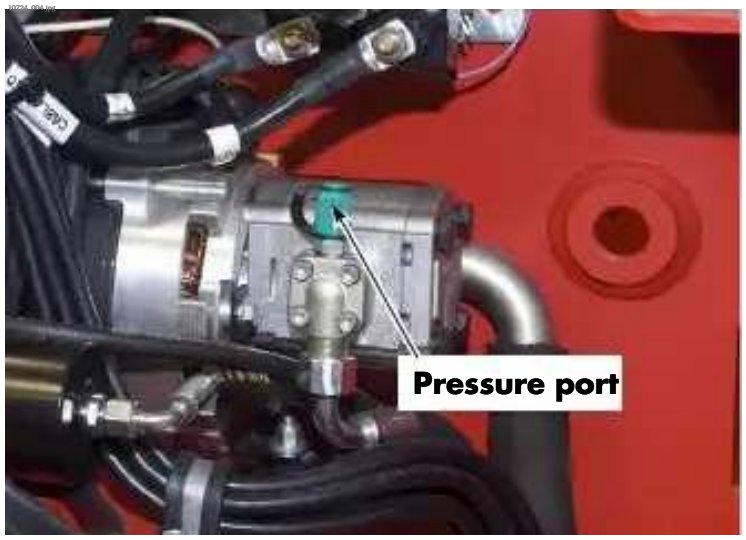
Figure 7-51. Pressure Adjustment Points - Fingertip Controls



Lift Pressure Adjustment

1. Lower the carriage completely.
2. Turn the key switch OFF and disconnect the battery connector.
3. Remove the cover to gain access to the pump pressure port and the hydraulic control valve cover.
4. Using Metric Pressure Fitting Adapter P/N 1620-04CE, install a pressure gauge capable of reading at least 5000 psi (34,470 kPa) at the pump pressure port. See Figure 7-52.

Figure 7-52. Pump Pressure Port



5. Reconnect the battery connector and turn the key switch ON.
6. Place the maximum rated load on the forks.
7. Elevate the carriage past free lift (when the telescopics begin to lift). Record the pressure required to lift the load.
8. Lower the carriage and remove the load.
9. Elevate the carriage in a safe area until the upper limit is reached (lift bypass is

activated).

NOTE: Loosen the locking nut and turn the lift pressure adjustment screw clockwise to increase pressure, counterclockwise to decrease the pressure.

10. Continue trying to lift. Turn the lift pressure adjusting screw (see Figure 7-50 or Figure 7-51) to obtain a pressure reading 200 psi (1379 kPa) greater than the pressure required to lift the maximum rated load (the value recorded in step 7).
11. Check the pressure again. Repeat this procedure until the correct pressure reading is obtained. Tighten the locking nut.
12. Turn the key switch OFF and disconnect the battery connector.
13. Remove pressure gauge from the pump pressure port and replace cap.
14. Reinstall covers.

Auxiliary Function Pressure Adjustment

1. Lower the carriage completely.
2. Turn the key switch OFF and disconnect the battery connector.
3. Remove the cover to gain access to the pump pressure port and the hydraulic control valve cover.
4. Using Metric Pressure Fitting Adapter P/N 1620-04CE, install a pressure gauge at the pump pressure port.
5. Reconnect the battery connector and turn the key switch ON.
6. Activate an auxiliary function to bypass.

NOTE: Loosen the locking nut for the function requiring adjustment and turn the pressure adjustment screw clockwise to increase pressure, counterclockwise to decrease the pressure.

7. Check the pressure. Adjust the corresponding pressure adjustment screw to 2300 psi (16000 kPa) max (see Figure 7-50).
8. Tighten the locking nut.
9. Turn the key switch OFF and disconnect

10. Remove pressure gauge from the pump pressure port and replace cap.
11. Reinstall covers.

the battery connector.

Hydraulic Pump and Motor

If the pump is to be removed, disconnect hoses. If motor only is to be removed, leave the hoses attached to the pump.

Separating Pump and Motor

There are four bolts on the end of the pump. Two bolts are shorter and hold the pump together. The other two bolts are longer and thread into the end bell of the motor. See Figure 7-53.

Figure 7-53. Pump Mounting Bolts

Apply molybdenum anti-seize compound (P/N 990-638) to the pump shaft splines before reassembly.

After reassembly, torque the pump mounting bolts to 33 ft. lb. (45 ±5 Nm).

Quad Mast Cylinder Service

Main or Free Lift Cylinders

1. Remove the cylinder from the mast. See "Cylinder Removal and Installation" on page 7-65.
2. Use a claw-type spanner wrench to remove the retainer from the shell.
3. Remove the plunger/piston assembly from the shell.
4. Inspect all components for nicks or burrs. Minor nicks or burrs can be removed with 400-grit emery cloth.

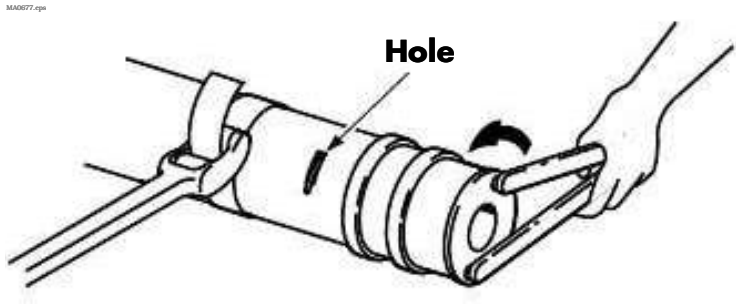
   NOTE: Minor nicks are those that do not bypass oil when under pressure. If they cannot be removed with emery cloth, replace the part. If the piston requires replacement, refer to "Piston Removal".
5. Replace the retainer and piston seals, back-up rings, O-rings, and bearing. Lubricate the new seals with petroleum jelly prior to installation. *Note correct seal direction. The seal lip always points toward the pressure side of cylinder.* The cylinder will not operate correctly if the seals are installed backwards.
6. *Main Lift Cylinder* - Install the plunger retainer on the plunger. Install the plunger/piston assembly into the cylinder shell. Using the claw spanner and strap wrenches, tighten the retainer to 95 to 125 ft. lb. (129 to 169 Nm).

   Free Lift Cylinder - Install the plunger retainer on the plunger. Install the plunger/piston assembly into the cylinder shell. Pour 1/2 cup (120 ml) hydraulic oil into the cylinder cavity between the shell and rod. Using the claw spanner and strap wrenches, tighten the retainer to 95 to 125 ft. lb. (129 to 169 Nm).

Piston Removal

1. Remove the plunger/piston assembly from the cylinder shell.
2. Use a strap wrench and 400-grit emery cloth to secure the plunger while turning the piston with a pin type spanner wrench. See Figure 7-54.

Figure 7-54. Piston Removal



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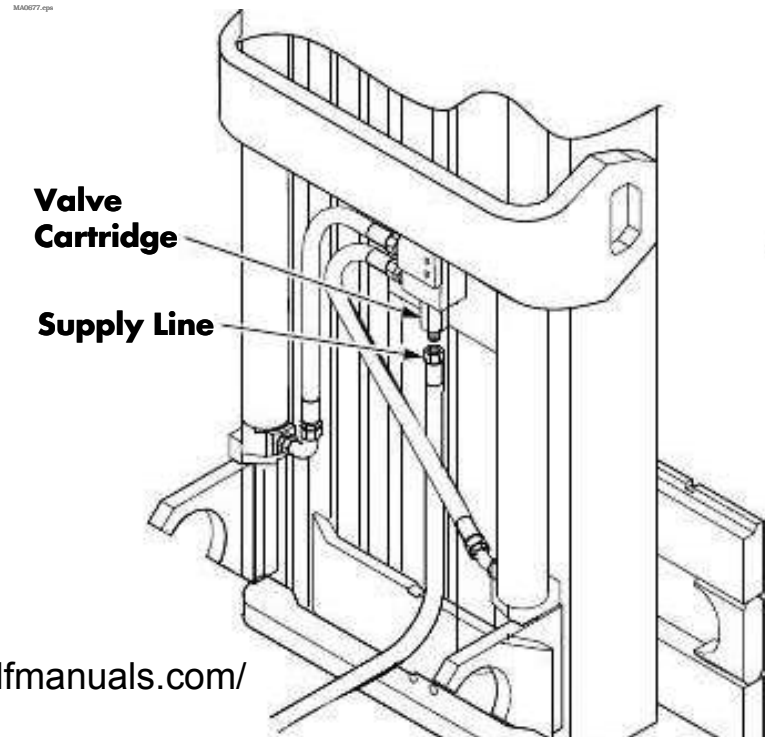
3. Turn the piston until the snap wire end is visible through the hole. Use a screwdriver to start the wire end out the hole. Turn the piston to feed the wire out.
4. Pull the piston from the plunger.
5. For reassembly, reverse the removal procedure. Install a new snap wire when installing the piston.

Valve Cartridge Replacement

1. Lower mast completely.
2. Remove supply hose from the valve cartridge. Plug the hose. See Figure 7-55.

Figure 7-55. Valve Cartridge Replacement



the cylinder shell.

3. Remove the valve cartridge from the lowering control valve. Note the stamped part number on the cartridge when ordering a replacement.

⚠ WARNING

Replacing the valve cartridge with a different part number may cause the mast to malfunction.

4. Install new valve cartridge.
5. Connect supply hose.

Section 7.Component Procedures

Mast

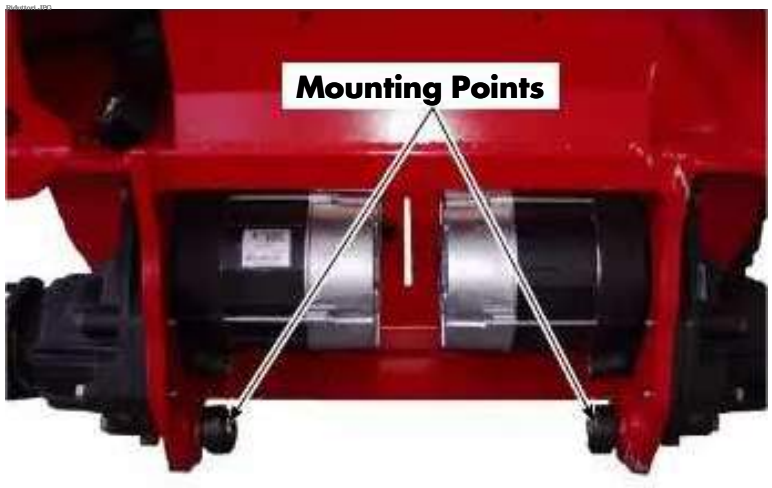
Mast Removal and Installation

The base of the mast is attached to the tractor frame near the traction motors and to the tilt cylinders.

Removal

1. Park the lift truck on a level surface and engage the parking brake. Lower the carriage completely and remove forks.
2. Tilt the mast completely forward.
3. Turn the key switch OFF and disconnect the battery connector.
4. Block the steerable wheels to prevent truck movement.
5. Double wrap a sling around the top of the mast. Attach a suitable lifting device and lift until the sling is snug.
6. Remove the lower bearing caps and bolts clamping the base of the mast to the chassis. See Figure 7-56.

Figure 7-56. Mast-to-Frame Mounting Points



NOTE: The bearing caps are machined. Mark each bearing cap so it is returned to the correct side during mast installation.

7. Disconnect the auxiliary supply hoses at the sides of the mast.
8. Disconnect the main hydraulic hose at the base of the mast.
9. Remove the screws, lock washers, and plate securing the pins through the tilt cylinder yoke and mast mounting brackets. Remove cylinder mounting pins.
10. Lift the mast away from the lift truck slowly until you have enough room to reach the bleeder hose. Disconnect the bleeder hose, then continue moving the mast away from the lift truck.
11. Slowly lower mast until it lays flat on floor.

Installation

1. Double wrap a sling around the top of the mast. Attach a suitable lifting device and slowly lift the mast to vertical.
2. Slowly move the mast toward the lift truck, aligning the mast mounts.
3. Before the mast is fully in position, connect the bleeder hose to the reservoir.
4. Finish aligning the mast on mast mounts.
5. Place the pins through the tilt cylinder yoke and mast mounting brackets.

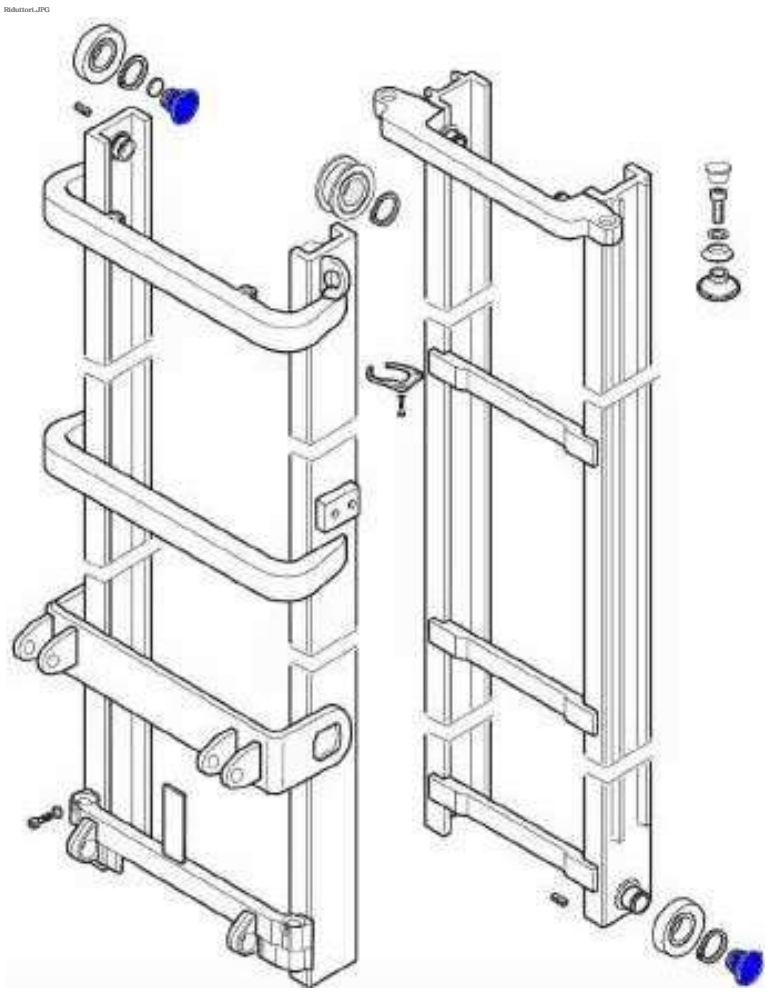
NOTE: Make sure bearing caps are returned to correct side during mast installation.

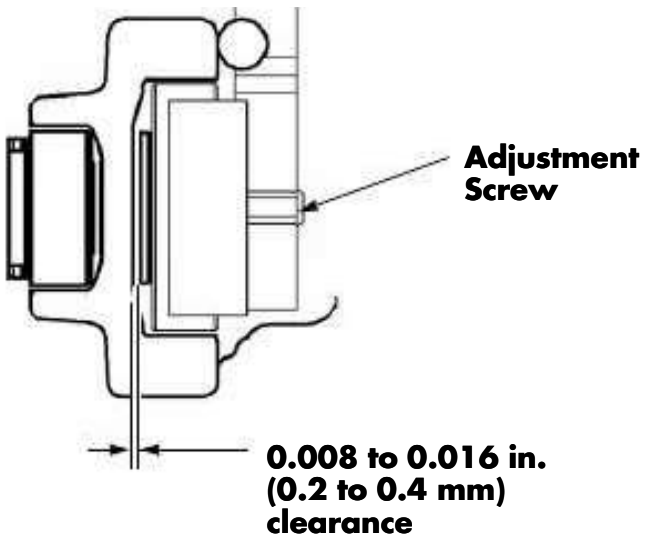
6. Install the lower bearing caps and bolts securing the base of the mast to the chassis. Torque the mast to chassis securing bolts to 36 ft. lb. (49 Nm).
7. Connect the main hydraulic hose at the base of the mast.
8. Connect the auxiliary supply hoses at the sides of the mast.
9. Install the screws, lock washers, and plate securing the pins through the tilt cylinder yoke and mast mounting brackets.
10. Jack the truck enough to remove the blocks, then lower to the floor.
11. Remove the sling from the top of the mast.
12. Grease the mast mounting points at the tilt cylinder and the frame.
13. Install forks.
14. Reconnect the battery connector and turn the key switch ON.
15. Bleed the hydraulic system.
16. Test operation of the lift truck before returning to service.

Guide Shoe (Puck) Adjustment - TF/TT Mast

Adjust mast guide shoe clearance to 0.008 to 0.016 in. (0.2 to 0.4 mm). See Figure 7-57.

Figure 7-57. Guide Shoe Adjustment





Fork Carriage - TF/TT Masts

Removal

1. Remove load backrest and forks.
2. Elevate the carriage above the free lift cylinders to gain access to the upper and lower carriage stop bolts. See Figure 7-58.

Figure 7-58. Fork Carriage Stop Bolts

3. Secure the carriage to a hoist with straps so it does not fall. See Figure 7-59.

Figure 7-59. Secure Carriage to Hoist

4. Remove the four carriage stop bolts. See Figure 7-58.
5. Remove the hose retaining clamps (if present).
6. Remove the attachment hose reel and hoses (if present).
7. Disconnect and plug aux. hoses (if present).
8. Loosen the center hose cover bracket to allow the hoses to move back.
9. Remove the carriage chain anchor nuts. With the chain anchor nuts removed, use the hoist to lower the carriage to the floor.

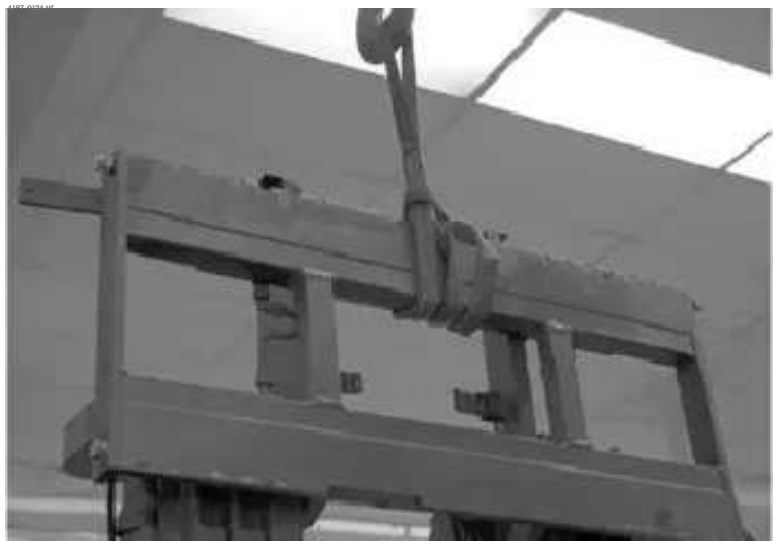
NOTE: Only the rollers hold the carriage to the telescopics at this time. Secure the carriage so it does not fall when the inner telescopic is lifted up.

10. Use the lift truck's hydraulic system to elevate the telescopics until the inner telescopic is lifted off the carriage. Once the carriage is free from the inner telescopic, back the truck away from the carriage.

OR

Lift the carriage out of the top of the mast. With the strap and hoist attached to the carriage, and the chain anchor nuts removed, move the hoses and chains out of the way. Use the hoist to lift the carriage out of the top of the mast, then lower the carriage to the floor. See Figure 7-60.

Figure 7-60. Carriage Removal/Installation Through Top of Mast



Installation

Install the carriage through either the top or the bottom of the mast.

Top Installation

1. Align the carriage rollers with the inner telescopic rails.
2. Slowly lower the carriage through the inner telescopics to a convenient work height.
3. Loosely install the chain anchor nuts.
4. Install the fork carriage stop bolts.
5. Reconnect all hoses and hose retaining clamps.
6. Adjust the fork carriage height and securely tighten the chain anchor nuts. Refer to "Lift Chains" on page 7-58.
7. Install load backrest and forks.

Bottom Installation

1. Place the carriage on the floor beneath the inner telescopics.
2. Either use a hoist or the truck's hydraulic system to slowly lower the inner telescopic over the carriage rollers.
3. Loosely install the chain anchor nuts.
4. Install the fork carriage stop bolts.
5. Reconnect all hoses and hose retaining clamps.
6. Adjust the fork carriage height. Securely tighten the chain anchor nuts. Refer to "Lift Chains" on page 7-58.
7. Install load backrest and forks.

Fork Carriage with Sideshift - TF/TT Masts

Removal

1. Remove the load backrest, if installed.
2. Remove the forks.
3. Elevate the carriage to a convenient work height.
4. Turn the key switch OFF and disconnect the battery connector.
5. Remove the four socket head capscrews holding the side plate from either side of the carriage. See Figure 7-61.

Figure 7-61. Example of Side Plate Bolt Removal

6. Pull the carriage frame to the side until half of the carriage overhangs the sideshift mechanism. See Figure 7-62.

Figure 7-62. Carriage Frame Partially Removed

7. Wrap a strap around the middle of the carriage frame. Attach the strap to an overhead hoist. See Figure 7-63.

Figure 7-63. Example of Carriage Frame Attached to Hoist

8. With the hoist supporting the carriage frame, continue pulling the carriage to the side until the sideshift mechanism is cleared. See Figure 7-64.

Figure 7-64. Carriage Frame Removal

NOTE: The lower carriage shims and slider may fall out when the carriage is pulled to the side. The carriage shims and slider are installed between the lower sideshift ram housing and the carriage frame.

Installation

1. Attach a safety strap to the middle of the carriage frame.
2. Suspend the carriage frame beside the sideshift mechanism.

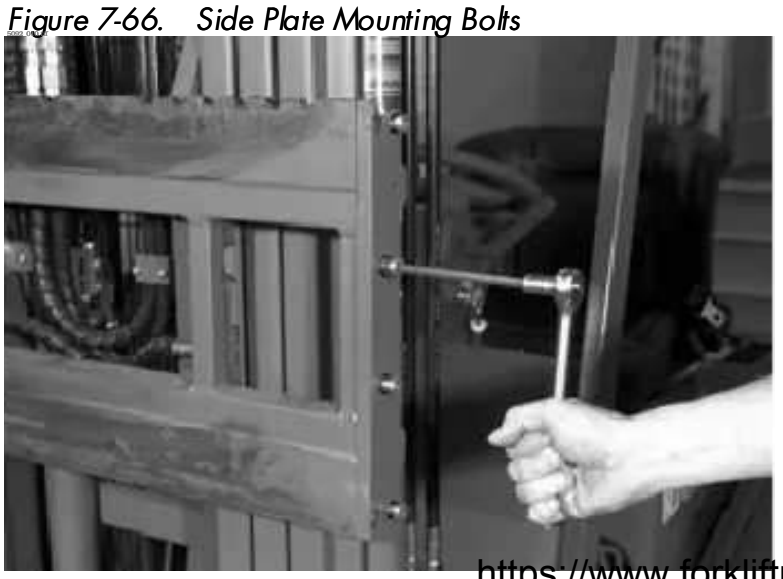
NOTE: Confirm that all shims and sliders are in position as the sideshift frame is installed.

3. Carefully slide the carriage frame onto the sideshift mechanism. Remove the strap when it begins to interfere with reinstalling the carriage frame. See Figure 7-65.

Figure 7-65. Carriage Frame Installation

4. Apply thread-locking compound to the four socket head capscrews. Secure the side plate to the carriage. See Figure 7-66.

Figure 7-66. Side Plate Mounting Bolts



5. Slowly sideshift in both directions. Make
6. Maximum sideshift in both directions to check that there is no binding or excessive play, and that the carriage moves smoothly in both directions.
7. Install the forks on the sideshift carriage.
8. Install the load backrest, if present.

sure the rams touch both sides of the frame.

Lift Chains

Adjustment

1. Lower the fork carriage fully.
2. Tilt the mast so the forks are parallel with the floor.
3. Measure from the floor to the top of the fork.
4. Elevate the fork carriage to gain access to the chain anchors. Block the fork carriage and mast to prevent lowering while working on the lift truck.
5. Turn the key switch OFF and disconnect the battery connector.
6. Adjust the anchor nuts equally until the forks are 2 in. (51 mm) off the floor, when measured to the top surface of the fork at the fork bend.

NOTE: Make sure the forks are parallel with the floor.

7. Repeat the preceding steps until you obtain the correct lowered height.
8. Liberally apply oil to each chain. See "Lubrication Specification Chart" on page A-2.
9. Test operation.

Removal

⚠ WARNING

Use extreme care when blocking the mast for any reason.

1. Lower the fork carriage onto wooden blocks to slacken the chains.
2. Turn the key switch OFF and disconnect the battery connector.
3. Remove the master links at the carriage chain anchors.
4. Remove the chain and chain anchors by unscrewing the nuts on the adjustable chain anchors.
5. Remove cotter pins at both chain anchors to separate the chain from the anchors.
6. Inspect the chain. See "Lift Chain Inspection" on page 4-7. Replace both chains when either is worn.

Installation

1. On a work bench or floor, attach the adjustable chain anchor to the chain using a new master link.
2. Install cotter pins (for each anchor) through both pins and bend to secure.
3. With carriage lowered, key switch OFF, and battery connector disconnected, insert the chain anchor (with chain attached) over the sheave and into the chain anchor block.
4. Thread on the lock nut by hand to hold the chain in place.
5. Insert the opposite end of the chain between the fork carriage and the lift cylinder. The end of the chain should be near the main frame chain anchor.
6. Fasten the chain to the anchor with a master link and secure with a cotter pin.
7. Repeat steps 1-6 for the other chain.
8. Holding the chain anchor with locking pliers, tighten the chain anchor nuts until 1 in. (25.4 mm) of thread is visible below the nut.
9. Reconnect the battery connector and turn the key switch ON.
10. Slowly raise the carriage, using the lift lever, until the carriage is raised off the blocking.
11. Remove the blocking, then slowly lower the carriage all the way down.

NOTE: The carriage may rest on the floor with slack in the chains.

12. Keeping equal tension on the chains, adjust the chain anchor nuts so the carriage is slightly off the floor.
13. Tilt the mast so the forks are parallel with the floor.

14. With the forks level with the floor and the key switch OFF, adjust the anchor nuts

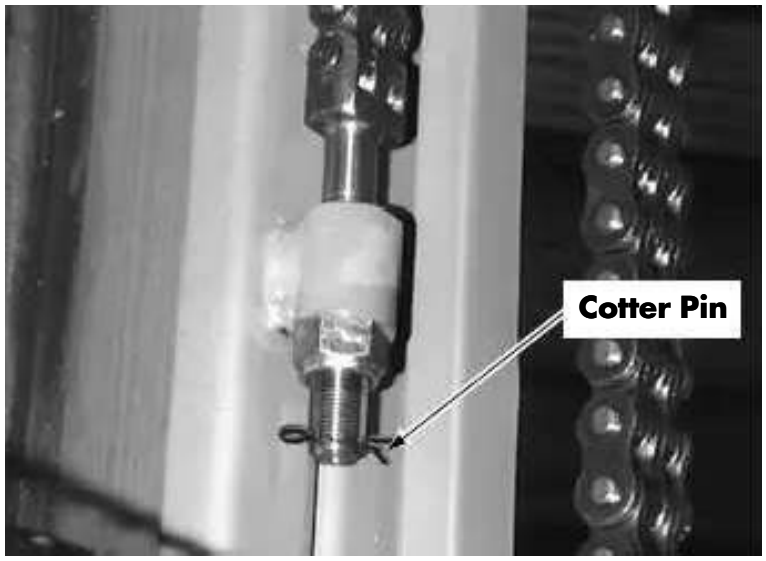
equally until the forks are 2 in. (51 mm) off the floor, when measured to the top surface of the fork at the fork bend.

15. Liberally apply oil to each chain. See "Lubrication Specification Chart" on page A-2.
16. Test the operation of the lift chains.

Lift Chain Anchor Bolts

Make sure the lift chain anchor bolts are not damaged and the adjusting nuts are locked by a cotter pin. See Figure 7-67.

Figure 7-67. Chain Anchor Bolts



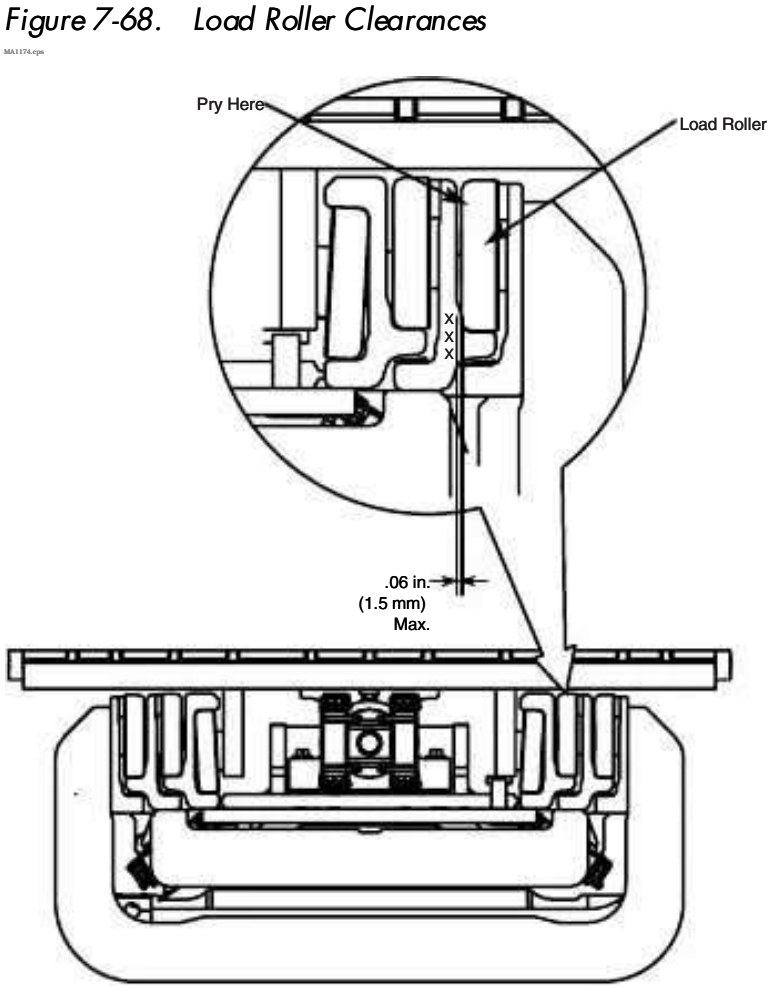
Quad Mast Service

Bubbled items in figures correspond to steps in associated procedure.

Mast Inspection

During normal Scheduled maintenance checks, pry between the upright and load roller so the opposite load roller is tight against the upright. Measure the clearance for the pair of rollers at XXX shown in Figure 7-68.

Figure 7-68. Load Roller Clearances



Each pair of load rollers on the uprights and carriage should be shimmed so that a total side to side clearance no greater than 0.06 in. (1.5 mm) occurs at the tightest point throughout the travel of the member.

Disassembly

NOTE: Quad Mast uprights require complete disassembly in order to service load rollers, thrust plugs/blocks, and

Refer to Figure 7-69.

1. Remove the internal hose reeving from the mast while it is on the truck.
2. Remove the mast assembly from the truck. Refer to "Removal" on page 7-52.
3. Remove the main lift cylinders from the mast. Refer to "Cylinder Removal and Installation" on page 7-65.
4. Using an overhead chain hoist, turn the mast over (face up).
5. Remove the free lift cylinder from the mast. Refer to "Free Lift Cylinder Removal - Mast on Floor" on page 7-66.
6. Remove the carriage from the mast. Refer to "Removal - Mast on Floor" on page 7-65.
7. Remove the free lift chain anchors and chains from the inner upright center cross member and tag for reassembly.
8. Disconnect the free lift cylinder hose from the tube and remove the stop/hose bracket/tube assembly.
9. Disconnect the inner main chain anchors from the lower end of the inner upright and the upper end of the outer intermediate upright.
10. Move the inner upright downward. Remove the free lift hose sheave, hose, and main chain sheaves at the top of the inner intermediate upright.

NOTE: The lower end of the inner upright must be raised slightly to clear the inner intermediate upright lower crossmember.

11. Remove the inner main lift chains and tag for reassembly.
12. Remove the load rollers from the lower end of the inner upright. Remove the load rollers and thrust plugs from the upper end of the inner intermediate upright. Note the number of shims behind each for reassembly.
13. Attach an overhead hoist to the inner upright and remove it through the top end of the inner intermediate upright.

NOTE: The stub shafts on the lower end of the

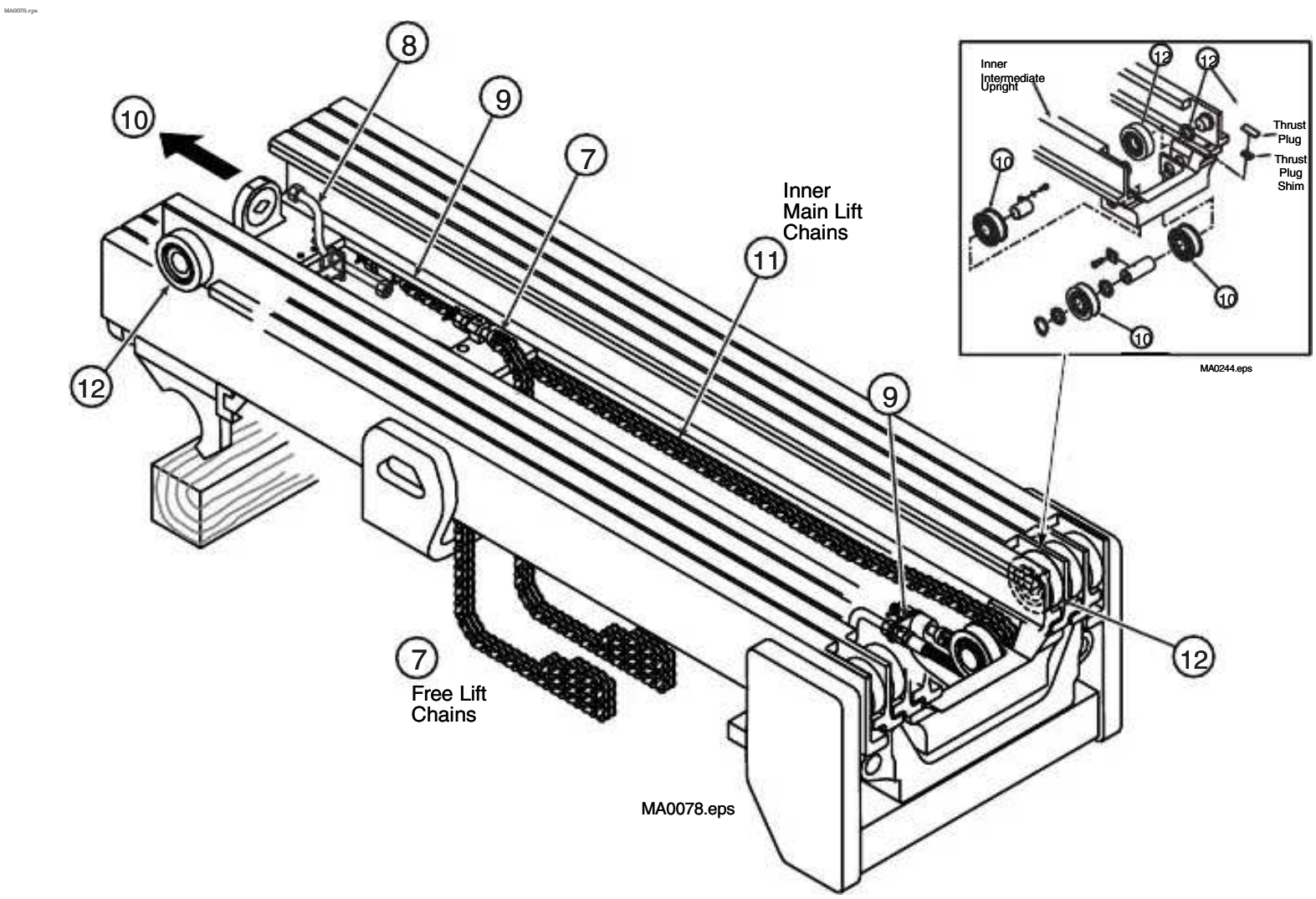
chain/hose sheaves.

inner upright come out of the inner

intermediate upright between the rail cutout and the stub shaft.

14. Remove the outer main lift chain anchors from the lower end of the inner intermediate upright and the top end of the outer upright. Set the chains aside and tag for reassembly.
15. Remove the lower stop from the outer intermediate upright.
16. Remove the chain sheaves from the outer intermediate upright.
17. Roll the inner intermediate upright downward and remove the lower rollers. Remove the upper rollers and thrust plugs from the outer intermediate upright. Note the number of shims behind each roller for reassembly.
18. Attach an overhead hoist to the inner intermediate upright and remove it through the top end of the outer intermediate upright.
19. Roll the outer intermediate upright downward and remove the lower rollers. Remove the upper rollers and thrust blocks from the outer upright. Note the number of shims behind each roller and thrust block for reassembly.
20. Attach an overhead hoist to the outer intermediate upright and remove it through the top end of the outer upright.

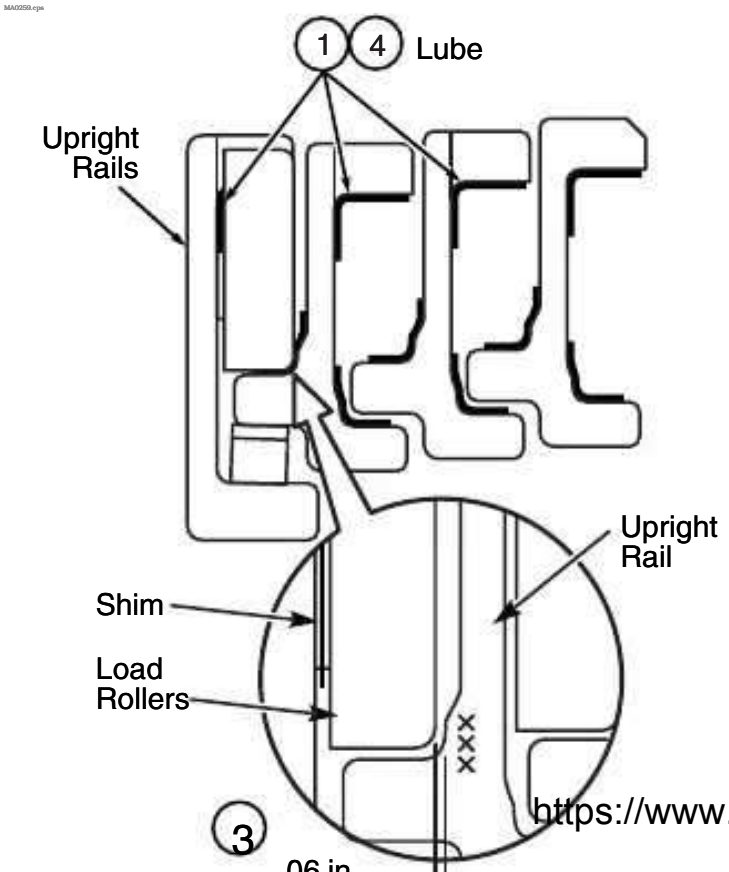
Figure 7-69. Quad Mast Disassembly



Reassembly

1. Lubricate the full length of the outer upright rails. See "Lubrication Specification Chart" on page A-2.
2. Attach an overhead hoist to the outer intermediate upright and install it through the top of the outer upright. Position it out the lower end of the outer upright approx. 6 in. (15 cm).
3. Assemble shims, load rollers, and thrust blocks to the upper end of the outer upright. Assemble shims and load rollers to the lower end of the outer intermediate upright.
   - *Roller Shimming* - Install shims to provide a total side-to-side clearance of 0.06 in. (1.5 mm) max. at the tightest point throughout the travel of the upright. See Figure 7-70. Pry between the upright and the load roller so that the opposite load roller is tight against the upright. Measure the clearance for the pair of rollers at the XXX shown in Figure 7-70. Use an equal number of shims on each side.

Figure 7-70. Load Roller Clearance/Channel Lubrication



NOTE: Roll the uprights past installed thrust plugs/blocks before checking load roller clearance.

   - *Thrust Plug/Block Replacement* - Install thrust plugs/blocks to provide a clearance of 0.06 in. (1.5 mm) max. between an upright and its corresponding thrust plug/block. See Figure 7-71. Pry between the upright upper cross members. Measure the clearance at the XXX shown to determine which thickness thrust plug/block to use. Thrust plugs/blocks may be shimmed as required.
4. Lubricate the full length of the outer intermediate upright rails. See "Lubrication Specification Chart" on page A-2 and Figure 7-70.
5. Attach an overhead hoist to the inner intermediate upright and install it through the top end of the outer intermediate upright. Position it out the lower end of the outer intermediate upright approx. 6 in. (15 cm).
6. Install shims and load rollers to the lower end of the inner intermediate upright. Install shims, load rollers, and thrust plugs to the upper end of the outer intermediate upright. Refer to step 3 for roller shimming and thrust plug clearance measurement.
7. Install the chain sheaves to the upper end of the outer intermediate upright. Install the outer main lift chain anchors and chains over the outer intermediate upright chain sheaves.

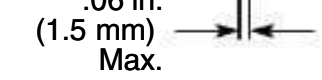


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Figure 7-71. Outer Intermediate Upright Installation

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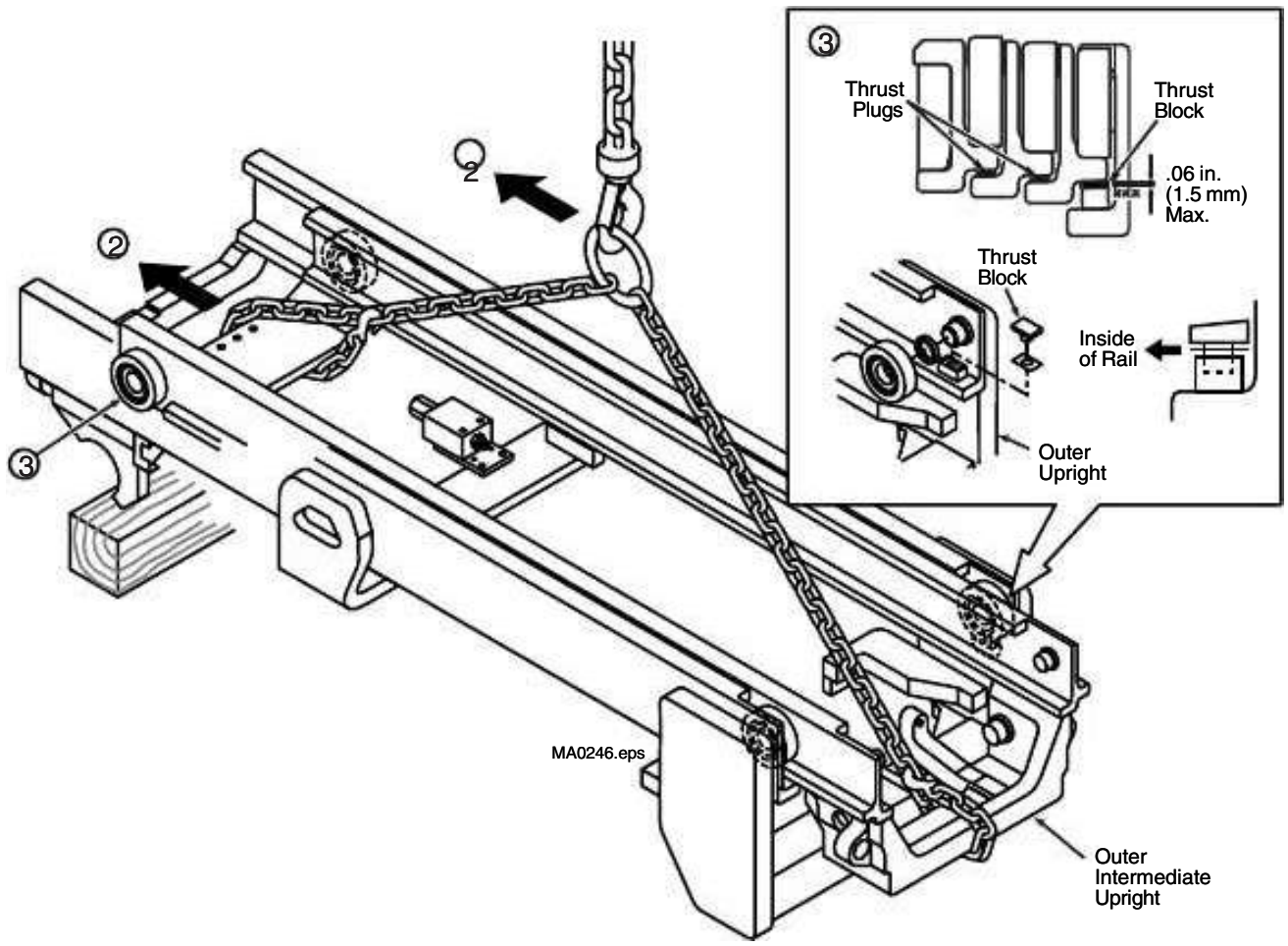

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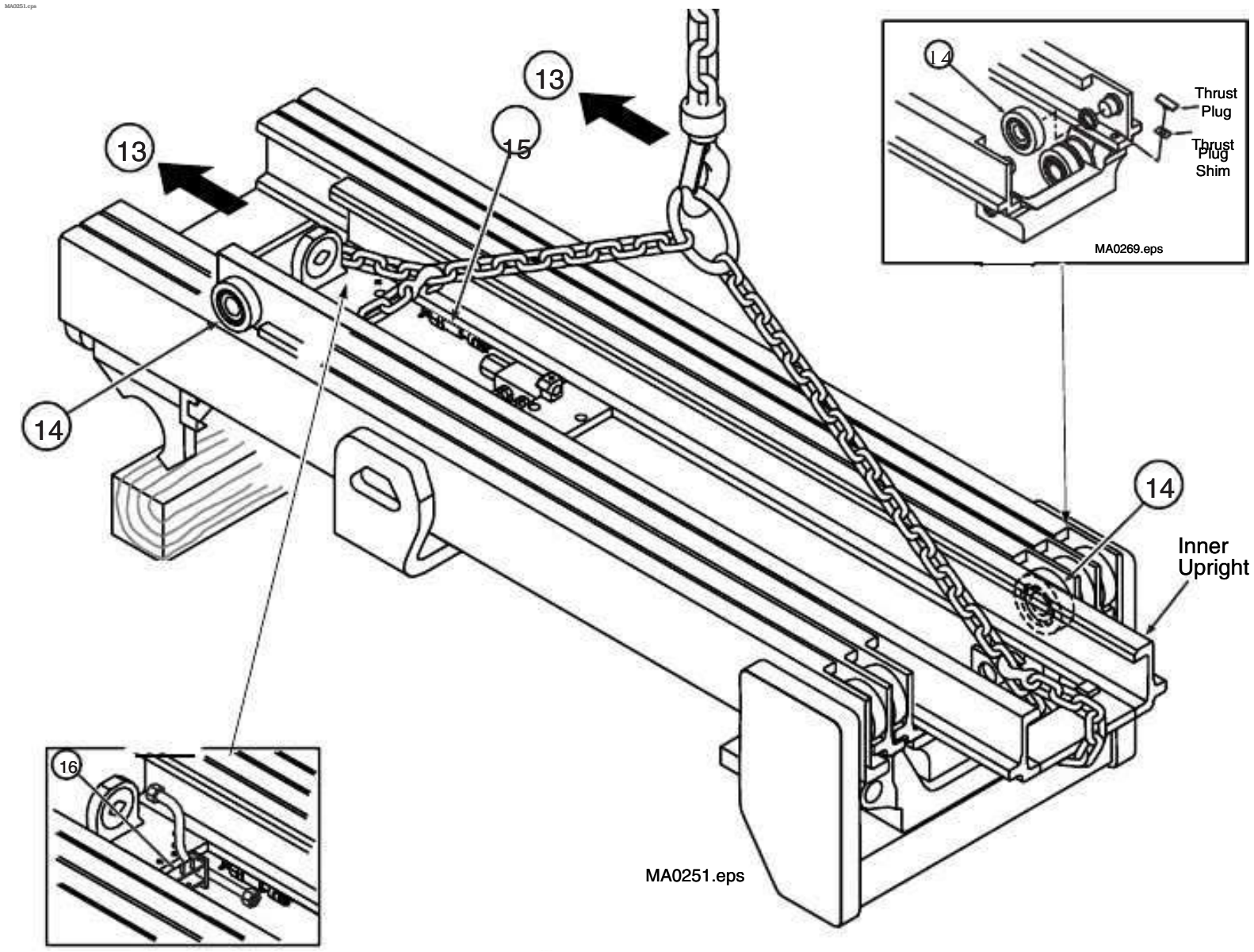
8. Install the outer main lift chain anchors (long anchors) to the lower end of the inner intermediate upright.
9. Install the lower stop on the outer intermediate upright. Torque the capscrew to 81 to 88 ft. lb. (110 to 120 Nm).
10. Install the main chain sheaves, free lift sheaves, and hose in the inner intermediate upright. Torque the retainer capscrews to 26 to 30 ft. lb. (35 to 40 Nm).
11. Install the upper inner main chain anchors to the outer intermediate upright. Install the free lift hose bracket and tube.
12. Lubricate the inner intermediate upright rails. See “Lubrication Specification Chart” on page A-2.
13. Attach an overhead hoist to the inner upright and install through the top of the inner intermediate upright. Position it out the lower end of the inner intermediate upright approx. 6 in. (25 cm).
14. Assemble shims and load roller to the upper end of the inner intermediate upright. Refer to step 3 for roller shimming and thrust plug clearance measurement.
15. Install the inner main lift chain anchors (long anchors) on the back side, lower end of the inner upright. Connect the inner main lift chains.
16. Install the stop/hose bracket/tube assembly on the lower end of the inner upright. Torque the capscrews to 81 to 88 ft. lb. (110 to 120 Nm).

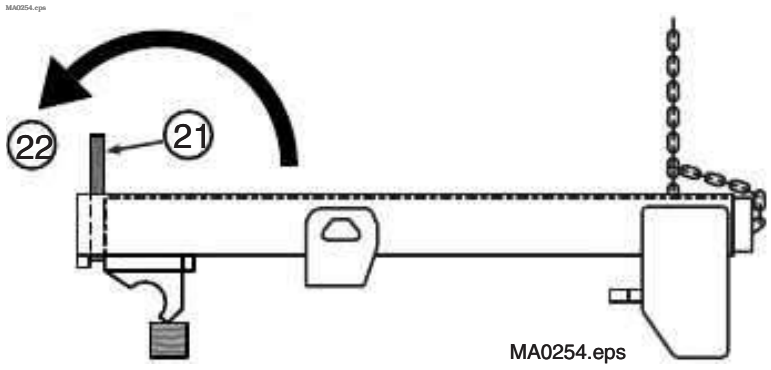
lower end of the inner upright. Assemble shims, load rollers, and thrust plugs to the

Figure 7-72. Inner Upright Installation



17. Install the free lift chain anchors (short anchors) and chains to the inner upright center crossmember.
18. Install the free lift cylinder supply hose to the free lift cylinder tube. Leave the tubing clamp loose.
19. Install the carriage. See "Installation - Mast on Floor".
20. Install the free lift cylinder. See "Free Lift Cylinder Installation - Mast on Floor" on page 7-66. Connect the tube to the cylinder fitting and tighten the tubing clamp.
21. Place a 2 x 4 in. (5 x 10 cm) wood block between the outer and outer intermediate lower cross members to prevent upright movement.
22. Turn the mast over (face down), rotating it on its lower end. Make sure the mast is re-blocked in a level position. See Figure 7-73.

Figure 7-73. Blocking Uprights Before Turning Mast Over



23. Install main lift cylinders. See "Main Lift Cylinder Installation - Mast on Floor" on page 7-66.

24. Install the Mast. Refer to "Installation" on page 7-52.

25. Install the internal hose reeving. See "Reeving" on page 7-66.
26. Adjust the main and free lift chains.
27. Check the mast for skewing.

Carriage

Removal - Mast on Floor

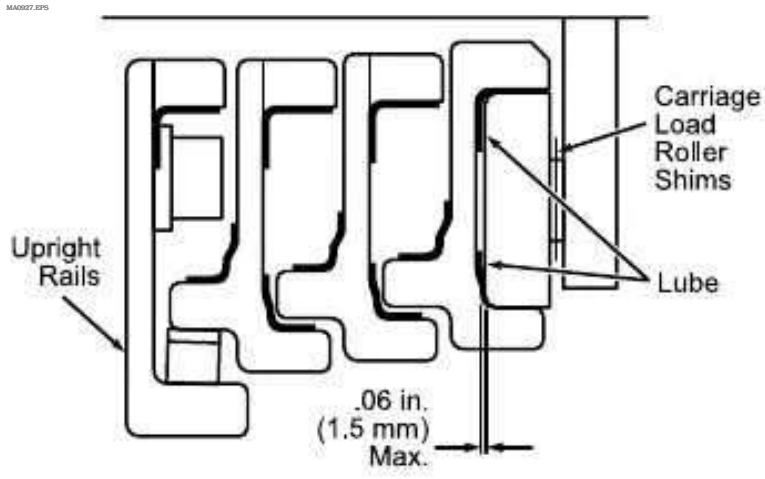
1. Remove mast from truck. See "Removal" on page 7-52.
2. Remove the pins fastening the free lift chains to the carriage chain anchors.
3. Disconnect the internal reeving hoses from the carriage fittings (if equipped). Plug the hose ends.
4. Remove the socket head stops on the inner upright lower cross member. For reassembly, tighten to 80 ft. lb. (110 Nm).
5. Roll the carriage to the bottom end of the mast.
6. Attach an overhead hoist to the carriage side bars and remove the carriage through the bottom end of the mast.
7. Remove the load rollers, noting the number of shims behind each roller for reassembly.

Installation - Mast on Floor

Reverse the removal procedure and do the following:

1. Inspect the carriage.
2. Lubricate the inner upright rails. Refer to "Lubrication Specification Chart" on page A-2.
3. Assemble shims and load rollers on the carriage. Install load roller shims to provide a total side to side clearance of 0.06 in. (1.5 mm) at the tightest point throughout the travel of the carriage. Use equal numbers of shims on each side.
4. Adjust the carriage side thrust rollers for unrestricted clearance along the travel of the carriage. Turn the eccentric mount base of each roller toward the upright rail. Torque the capscrews to 79 to 80 ft. lb. (95 to 110 Nm).

Figure 7-74. Carriage Side Thrust Roller Adjustment



5. Check and adjust the free lift chains.
6. Adjust mast tilt. See "Mast Tilt Adjustment" on page 7-72.

Cylinder Removal and Installation

Main Lift Cylinder Removal - Mast on Floor

1. Remove the mast from the truck. See "Removal" on page 7-52.
2. Insert a 2 x 4 in. (5 x10 cm) wood block between the lower cross members of the outer upright and outer intermediate upright to prevent uprights from moving out the bottom of the mast.
3. Lay the mast face-down on wood blocks. Block under each end of the outer upright so the mast is level and the inner uprights and carriage are free to move.
4. Using a 1 in. wrench, disconnect the cylinder supply hoses from the cylinder inlet ports. Using a 1 in. socket, remove the special long fittings from the cylinder

to decrease clearance. See Figure 7-74.

ports and install plugs.

5. Remove the snap ring from the top of the left hand cylinder rod, the tube, and fitting from the top of the right hand cylinder rod. Plug the cylinder port.
6. Roll the uprights through the top of the mast 1 to 2 ft. (30 to 60 cm) and disengage the cylinder rods from the outer intermediate upright.
7. Lift the cylinder from its base mounting boss in the outer upright and angle inward. Remove the cylinders through the sides of the uprights.
8. Note the number of shims (if equipped) on each cylinder rod.

Main Lift Cylinder Installation - Mast on Floor

For installation, reverse the Removal procedure. Bleed the system. See "Bleeding the Hydraulic System" on page 7-44.

Free Lift Cylinder Removal - Mast on Floor

1. Remove the mast from the truck. See "Removal" on page 7-52.
2. Lay the mast face-up, blocking under the lower mounts so the mast is level.
3. Roll the carriage upward to allow slack in the free lift chains and internal reeving.
4. Remove the snap ring fastening the crosshead to the cylinder rod.
5. Pull the crosshead with chains and hoses off the cylinder rod.
6. Roll the carriage above the free lift cylinder.
7. Using a 1 in. wrench, disconnect the tube from the cylinder fitting. Cap the cylinder fitting and plug the tube.
8. Using a 5 mm hex head wrench, remove the cylinder strap.
9. Remove the cylinder from the mast.

Free Lift Cylinder Installation - Mast on Floor

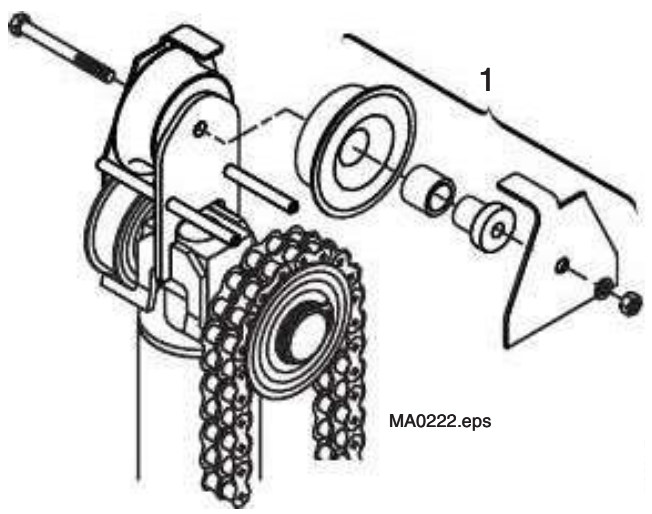
For installation, reverse the Removal procedure. Bleed the system. See "Bleeding the Hydraulic System" on page 7-44.

Reeving

Internal Reeving Installation

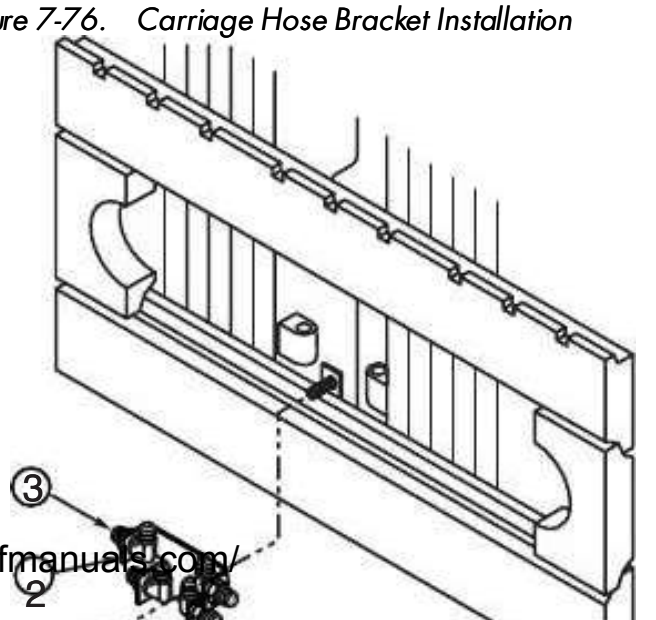
1. Install the shaft, sheave, and hose guards to the crosshead center plate. See Figure 7-75. Leave the capscrew and nut finger tight to allow for hose installation.

Figure 7-75. Crosshead Center Plate Assembly



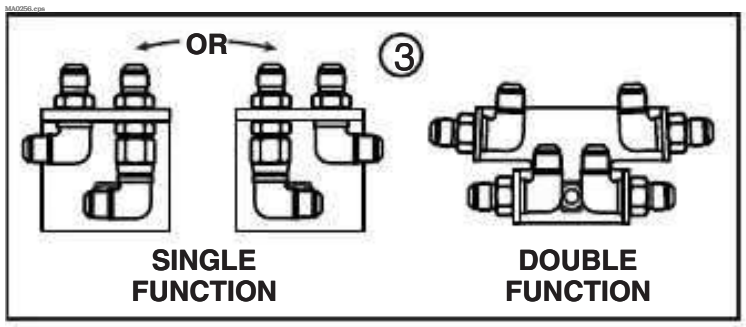
2. Install the carriage hose bracket to the center tab on the lower carriage bar. See Figure 7-76.

Figure 7-76. Carriage Hose Bracket Installation



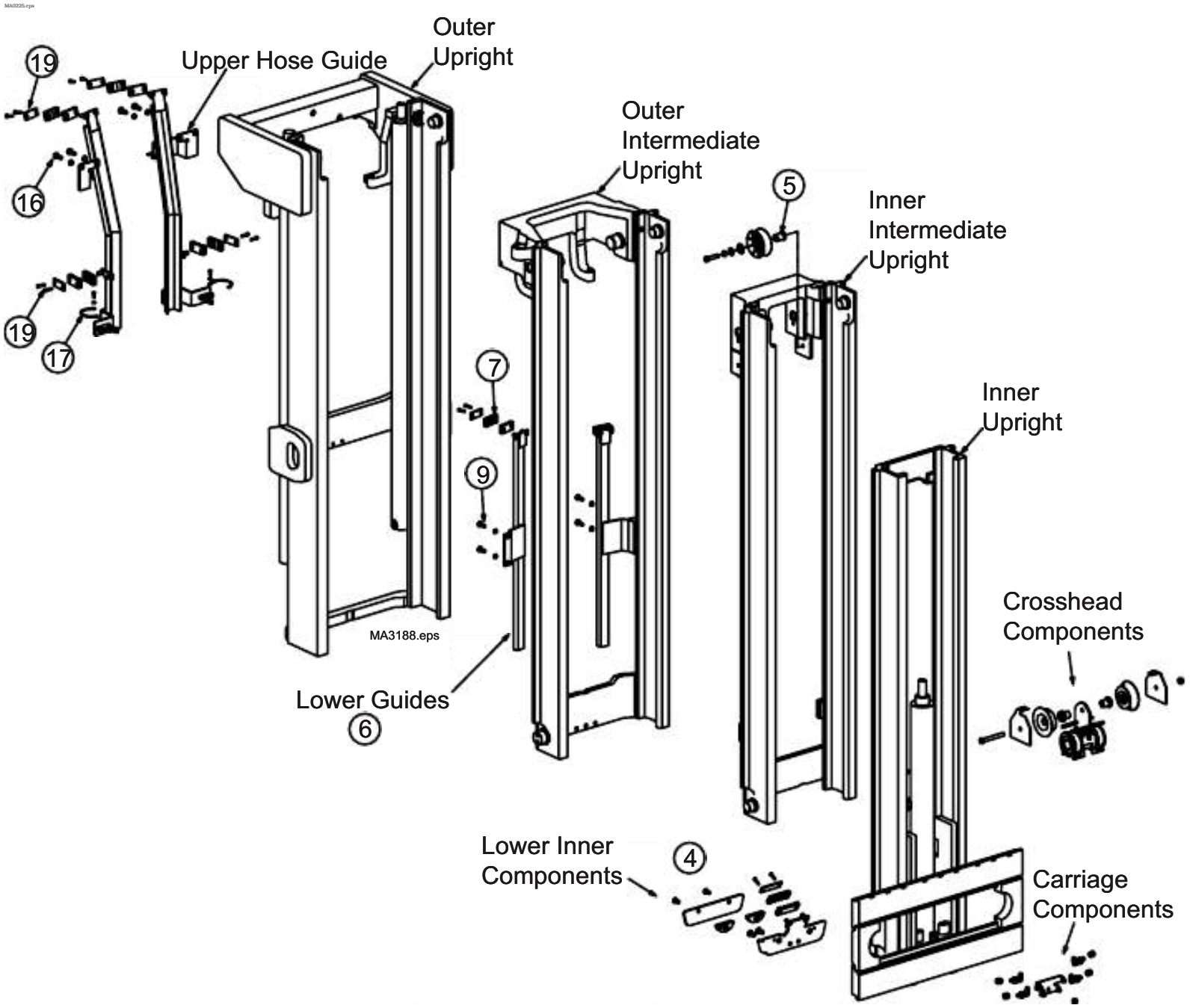
3. Install the fittings on the bracket. See Figure 7-77.
   - *Single Function* - Install the fittings to the left or right side location. Tighten the fittings finger tight.
   - *Double Function* - Install the fittings to the left and right side location. Tighten the fittings finger tight.

Figure 7-77. Fitting Installation



4. Install the lower internal hose reeving bracket and plastic inserts to the block at the bottom of the inner upright weldment. See Figure 7-78. Torque the capscrew to 52 ft. lb. (71 Nm).
5. Install the shaft and hardware to the inner intermediate upright chain sheave shaft. See Figure 7-78. Torque the capscrew to 52 ft. lb. (71 Nm).
6. Install the lower hose guide to the outer intermediate upright. Torque the capscrew to 30 ft. lb. (41 Nm).
7. Install hose clamps to lower guide. Leave capscrews finger tight.

Figure 7-78. Hose Reeving Hardware Installation on Uprights



8. Completely lower the carriage. Route the short hoses down behind the carriage bar to the carriage bracket fittings. Connect the hose ends to the fittings, leaving the hose ends finger tight.

NOTE: For *Double Function*, the No. 4 hoses connect to the two right fittings (viewed from the operator's seat.

9. Route the hoses over the crosshead sheaves.

10. Route the hoses down between the freelift cylinder and crossmember. Position the hoses in their natural curve over the

11. Connect the long hoses to the short hoses behind the freelift cylinder. The outside hose(s) is approx. 4 in. (102 mm) shorter than the inside hose(s). See Figure 7-79.

12. Pull down on the hoses with approx. 30 lbs. of force. Clamp the hoses to the lower bracket attached to the inner upright crossmember. Torque the capscrews to 7 to 11 ft. lb. (10 to 15 Nm).

13. Position the hoses with the tabs on the inner upright bracket as shown in Figure 7-79.

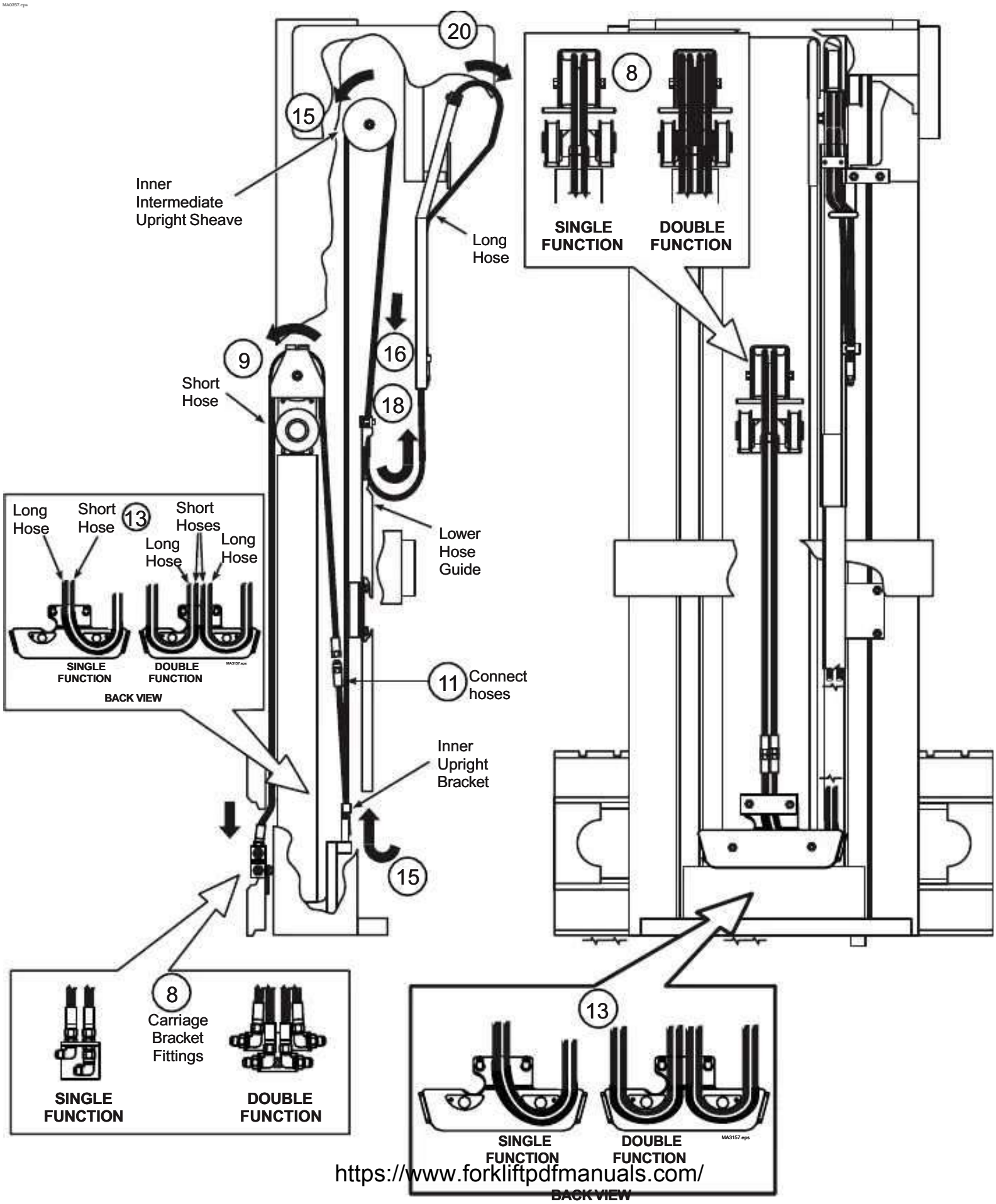
14. Install the lower internal hose reeving cover plate and hardware. Tighten the

crosshead sheaves. Tighten the hose ends at the carriage bracket.

capscrews to 30 ft. lb. (41 Nm).

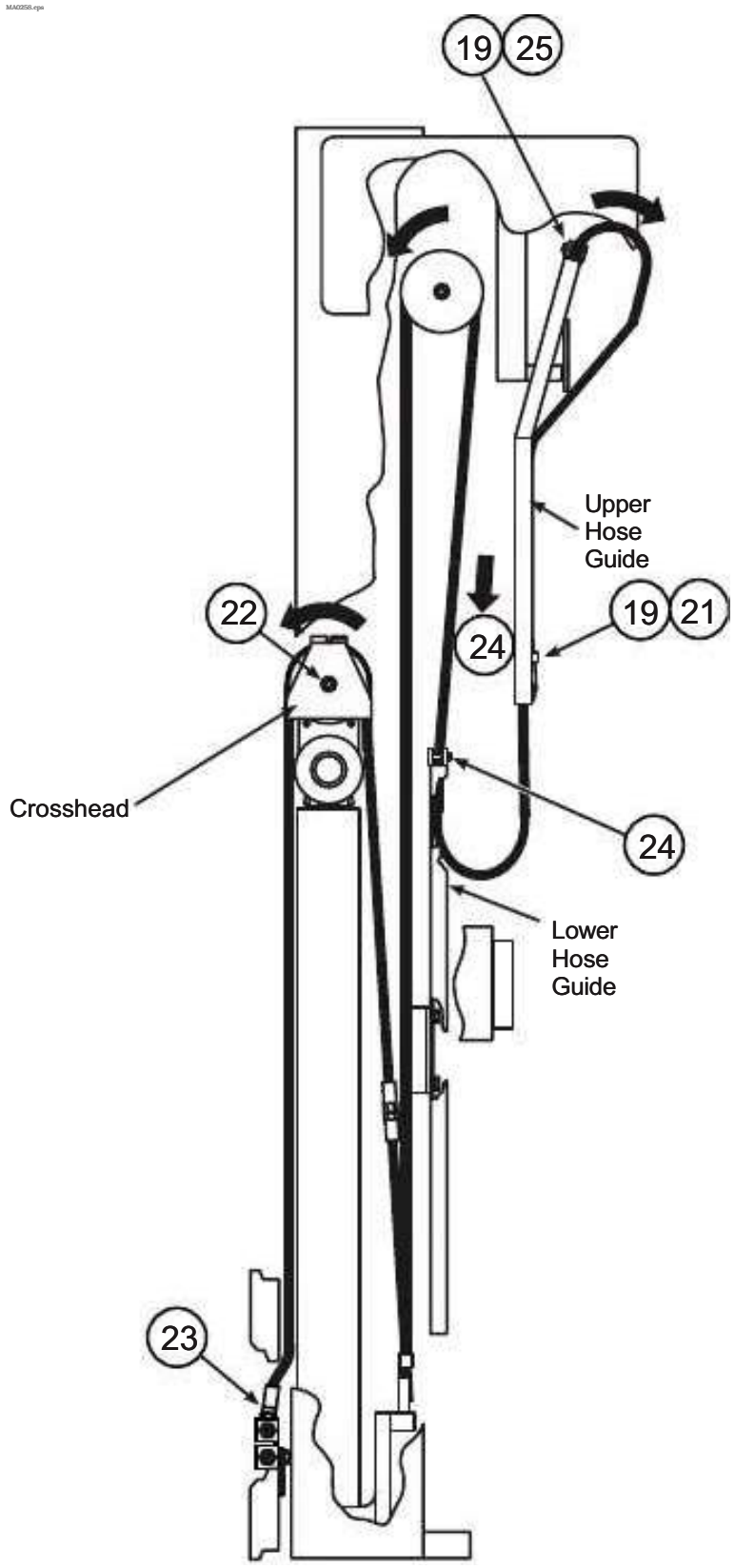
15. Route the hoses up toward the top of the mast following the inner lift chains. Bend the hoses over the inner intermediate upright sheave and install the sheave on the shaft bolted to the intermediate upright. Install washer and retaining ring to shaft.
16. Route hoses down to the lower hose guide. Place hoses under the hose clamp at the top of the lower hose guide. Pull downward on the hoses with 20 lbs. force. Tighten clamp capscrews enough to stop hose movement.
17. Install the upper hose guide to the outer upright. Tighten the capscrew to 30 ft. lb. (41 Nm).
18. Loop the hoses approx. 5 in. (125 mm) below the bottom of the lower hose clamp and rout upward into the upper hose guide.
19. Install the hose clamps to the upper hose guide. Leave capscrews finger tight.
20. Route the hoses under the hose clamps at the top of the upper hose guide. Tighten the capscrews finger tight.
21. Route the hoses under the hose clamps at the bottom of the upper hose guide. Do not tighten the clamp capscrews.
22. Torque the crosshead cover plate capscrew to 52 ft. lb. (71 Nm).

Figure 7-79. Hose Reeving Installation



23. Align the hoses by twisting the hose ends to travel centered in the crosshead on the natural curve of the hose. The hoses should travel parallel to each other. Hold the hoses while tightening the fittings to keep the hoses from twisting.
24. Loosen the hose clamps at the top of the lower hose guide. Pull down on the hoses with 40 lbs. of force. Tighten the hose clamp capscrews to 7 to 11 ft. lb. (10 to 15 Nm).
25. Loosen the hose clamps on the upper hose guide. Adjust the hoses to the natural hose bend and align evenly spaced in the guide rails. Tighten the hose clamp capscrews to 7 to 11 ft. lb. (10 to 15 Nm).
26. Raise and lower the mast slowly through several cycles and check for correct hose alignment, clearances and hose tracking in the guides.

Figure 7-80. Hose Reeving Installation - continued

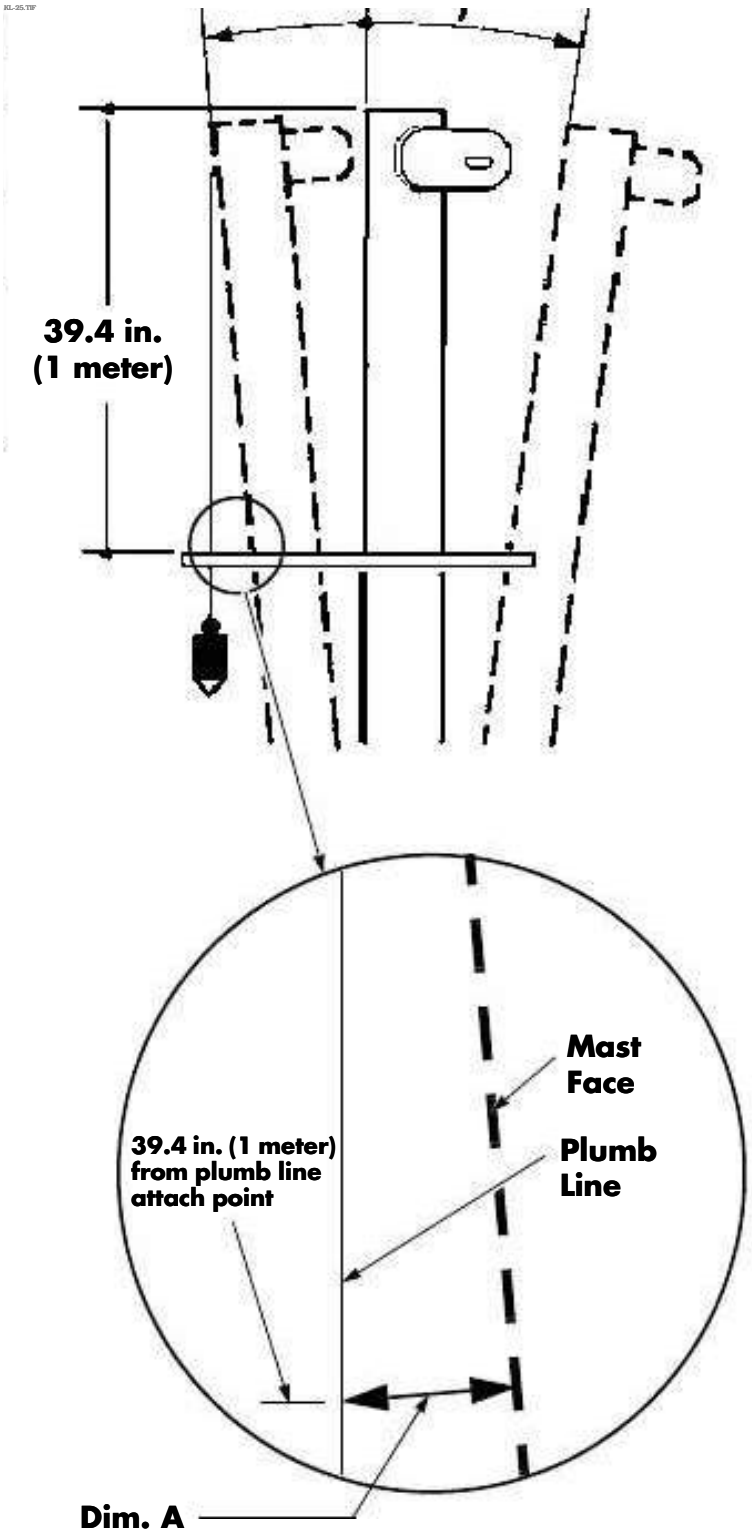


Mast Tilt Adjustment

Perform the following procedure when adjusting mast tilt.

1. Attach a plumb line to the mast. See Figure 7-81.

Figure 7-81. Measuring Mast Tilt



3. Place a square on the mast 39.4 in. (1 meter) below where the plumb line is attached and measure the distance between the face of the mast and the plumb line.
4. Repeat steps 1 thru 3 using the back of the mast main frame for backward tilt.
5. Adjust the stroke of the tilt cylinders as necessary to achieve the correct mast tilt. Refer to Figure 7-81 and Table 7-4.

Table 7-4. Mast Tilt Parameters

Tilt Type	Mast	Fwd Tilt		Back Tilt	
		Angle	Dim. A	Angle	Dim. A
Std	TT TF	3°	2 in. (52 mm)	6°	4.1 in. (105 mm)
	Quad			4°	2.7 in. (70 mm)
Optional	TT TF	5°	3.4 in. (87 mm)	6°	4.1 in. (105 mm)
Bottler's Tilt	TT	9°	6.2 in. (156 mm)		

Mast Tilt Position Switch Adjustment (Bottler's Tilt Only)

Trucks equipped with the Bottler's Tilt option require mast mounted switches (S16 and S30) for the VM to determine carriage and mast position.

Adjust the Mast Tilt Position Switch (S30) so that it opens when the mast is tilted beyond 3° forward.

1. Attach a plumb line to the mast. See Figure 7-81.
2. Place a square on the mast 39.4 in. (1 meter) below where the plumb line is attached and tilt the mast forward 3° (2 in./52 mm at Dim. A in Figure 7-81).
3. Adjust Mast Tilt Position Switch (S30) bracket so that the switch opens when the mast is tilted further forward.

2. Tilt the mast forward completely.

Section 8. Theory of Operation

System Architecture

This truck can be configured to accept either a 36V or 48V battery. The truck uses AC drive and lift technology. The standard truck uses conventional hydraulic controls via lever operated spool valves mounted on the right side console. An optional configuration uses fingertip controls mounted on an armrest to the right of the operators seat. A DC/DC converter provides 24V to the cooling fans, brake, tail, rotating, and work lights.

The electrical control system consists of the components listed in Table 8-1.

Table 8-1. Electrical Control System Components

Component	Function
*Vehicle Manager (VM)	Serves as an interface for all control signals and performs analog/digital signal conversions. Manages tail and brake light operation based on traction motor encoder input. Shares primary memory with the Operator Display
*Master Traction Power Amplifier (TPA)	Controls the right traction motor
*Slave Traction Power Amplifier (TPA)	Controls the left traction motor
*Pump Power Amplifier (PPA)	Controls the pump motor
DC/DC Converter	Converts battery voltage to required DC voltage
*Operator Display (OD)	Displays truck systems information. Shares primary memory with the VM
*Armrest Board	Optional Fingertip Controls/VM interface
*Hydraulic Control Board (HCB)	Coil driver board for hydraulic solenoids. Required for optional Fingertip Controls
Contactor 1 (CT1)	Provides B+ to the DC/DC Converter and Hydraulic Control Board (for optional Fingertip Controls)
Contactor 2 (CT2)	Provides B+ to the PPA
Contactor 3 (CT3)	Provides B+ to the TPAs
*Electrical control system components communicate via a Control Area Network (CAN-Bus).	

Systems Overview

This section is an overview of the components that make up the control systems of the truck.

See "Pinout Matrix" beginning on page 8-13 for specific input, output, and voltage information.

Vehicle Manager

The Vehicle Manager (VM) provides several functions. It interfaces with the travel direction switches and accelerator potentiometer. The VM stores the learned values for the travel and lift potentiometers. It also stores the default configuration values. With the standard spool valve hydraulic controls, lift/lower, sideshift, tilt, 4th, and 5th auxiliary function switch/potentiometer requests are input directly to the VM. The VM distributes 24V power to the operational and working lights on the truck. It also contains the circuits that activate the brake and tail lights based on inputs from the TPA. Refer to "Hydraulic System" on page 8-7 for specific information on the operation of standard and optional hydraulic systems.

Traction Power Amplifiers

There are two Traction Power Amplifiers (TPA) that power/control the AC Traction Motors. The controllers are designated as Master and Slave. The Master controls the Right Traction Motor (RTM) and the Slave controls the Left Traction Motor (LTM). The Master and Slave communicate with each other as well as with other devices connected to the CAN-Bus. Requests for travel direction and speed are communicated from the VM via the CAN-Bus. The TPAs supply voltage to the traction motors to comply with the travel request. They then monitor motor operation and adjust the voltage to the motors to maintain motor performance equal to the request. The TPAs receive an input from the steer potentiometer and regulate motor direction and speed with regard to steer wheel angle. The Master TPA stores the learned value for the steer potentiometer. Motor

FlashWare and are stored in the TPAs. The Master and Slave are capable of generating error codes. See "Codes" on page 6-4.

Pump Power Amplifier

The Pump Power Amplifier (PPA) is an AC motor controller that controls the motor used to provide hydraulic power for all hydraulic functions. The PPA communicates with other devices via the CAN-Bus. Requests for all hydraulic functions (including steering) are communicated to the PPA via the CAN-Bus from the VM or from the Armrest Board (fingertip control configurations). The PPA then supplies a voltage to the pump motor. The pump motor operating parameters may be different for the various hydraulic functions. Parameters such as delay, maximum speed, and maximum motor current can be configured with FlashWare and are stored in the PPA. The PPA is capable of generating error codes. See "Codes" on page 6-4.

Amplifier Fan

The truck is equipped with a cooling fan for the TPAs and PPA. This fan is energized by the VM within approx. one minute of turning the key switch ON. If this fails to occur, the TPAs and PPA could overheat.

DC/DC Converter

A DC/DC converter provides 24V to the lights, cooling fan, solenoid valves, horn, travel alarm, and other options. It also provides 24V to the Hydraulic Control Board on trucks with the Fingertip Controls option. A dedicated 12A fuse is located on the end opposite the connector.

Operator Display

The Operator Display (OD) receives communications from the CAN-Bus and 24V power from the VM. Various icons illuminate to inform the operator of the status of the truck. The OD also displays hour meters and Battery

parameters such as acceleration, speed limiting, coast, motor braking, motor current, and creep speed can be configured with

State-of-Charge (BSOC), however BSOC is calculated by the Master TPA. The OD also contains a two position alphanumeric display

that provides error and status code information. See “Operator Display Messages” on page 6-2.

Armrest Board

The truck can be equipped with optional Fingertip hydraulic controls that are located on the armrest on the right side of the operator’s seat. The Armrest Board receives inputs from the fingertip hydraulic function controls based on operator input. Hydraulic output flow is controlled by proportional and solenoid valves instead of the spool valves used on the standard hydraulic system. The Armrest Board processes the request and informs the Hydraulic Control Board which solenoids to energize and the PPA to energize the pump motor, providing the hydraulic flow necessary for the given function.

The Armrest Board can also initiate error codes for the components (potentiometers and switches) that it interfaces with. See “Codes” on page 6-4.

Hydraulic Control Board

The Hydraulic Control Board is a hydraulic driver board that receives commands via the CAN-Bus from the Armrest Board. It contains coil drivers for the hydraulic solenoids and is required for the optional Fingertip controls. The Armrest Board communicates hydraulic function requests to the Hydraulic Control Board, which energizes the solenoids. The parameters regarding the operation of the solenoid valves that the Hydraulic Control Board controls can be adjusted and set in FlashWare. The Hydraulic Control Board can initiate error codes for the coil circuits that it controls. See “Codes” on page 6-4.

CT1

CT1 provides B+ to the DC/DC Converter and Hydraulic Control Board (for optional Fingertip Controls). The CT1 contactor coil is designed to operate on approx. 36V. Because these trucks accept both 36V and 48V batteries, voltage to CT1 from a 48V battery must be reduced. This

When a 48V battery is installed in a truck configured (via FlashWare) for a 48V battery, RL1 is energized. The RL1 contact tips open, redirecting current through a 56 ohm resistor wired in parallel with the RL1 contact tips. The 56 ohm resistor reduces the voltage approx. 8V, thus providing approx. 40V to the CT1 contactor coil.

When a 36V battery is installed in a truck configured (via FlashWare) for a 36V battery, RL1 is not energized. The RL1 contact tips remain closed, causing current to bypass the 56 ohm resistor wired in parallel with the RL1 contact tips, thus providing B+ to the CT1 contactor coil.

CT2

CT2 provides B+ to the PPA.

CT3

CT3 provides B+ to the TPA.

is accomplished via a control relay (RL1) that is energized when the key switch is turned ON.

Traction System

Travel

After SelfTest, travel is allowed. Travel can be requested via one of two configurations.

Standard configurations utilize a hand activated direction lever located on the steering column. The lever is moved forward (toward the mast) for forward travel and back (away from the mast) for reverse travel. It is used in conjunction with a single foot activated travel pedal located on the floor of the operator compartment to the right of the brake pedal. Travel speed is based on how far the pedal is depressed. The further down the pedal is depressed, the faster the truck travels.

An optional configuration utilizes two pedals located on the floor of the operator compartment, to the right of the brake pedal. The left pedal is depressed for forward travel and the right pedal for reverse travel. Travel speed is based on how far either pedal is depressed. The further down the pedal is depressed, the faster the truck travels.

NOTE: For two-pedal configuration, a jumper must be installed between J33-4 and J33-5.

Hand Direction Lever

Moving the lever from the neutral position toward the mast closes Forward switch (SW9). Moving the lever from the neutral position away from the mast closes Reverse switch (SW10). These directional inputs are sent to the VM. The VM monitors the Enable switch (SW8) and the Travel Pot (P2). When the travel pedal is depressed, the Enable switch (SW8) closes. This informs the VM to recognize the Hand Direction Lever switch (SW9 and SW10) inputs. Output voltage from Travel Pot (P2) is compared to its previously Learned value and the VM converts the voltage value into a percentage-of-request. The VM converts travel direction and the percentage of the request into a message that is sent via the CAN-Bus to the Traction Power Amplifiers (TPAs) and Operator Display (OD). The TPAs send the voltage to the Traction Motors to satisfy the direction and speed request received by the VM. The TPA monitors the encoders (EN1 and EN2) to verify that travel direction and speed match what was requested.

The VM constantly monitors the travel request and updates the information to the TPAs as changes occur. All operational parameters that affect motor torque and speed are controlled by the TPAs. The TPAs also monitor the temperature switches (TS1 and TS2). The temperature switches are normally closed. They open when an overtemperature condition exists in the motor, causing a reduction in travel speed to allow the motor to cool. An icon on the Operator Display is also illuminated to alert the operator.

Two Pedal Configuration

The optional Forward and Reverse travel direction pedals are located to the right of the brake pedal on the operator compartment floor. The left pedal is depressed for forward travel and the right pedal for reverse travel. When either pedal is depressed, the corresponding Forward switch (SW4) or Reverse switch (SW5) closes, sending an input to the VM as a request for forward or reverse travel. The VM monitors the Travel Pot (P2). Output voltage from P2 is compared to its previously Learned value and the VM converts the voltage value into a percentage-of-request. The VM converts travel direction and percentage-of-request into a message that is sent via the CAN-Bus to the Traction Power Amplifiers (TPAs) and Operator Display (OD). The TPAs send the voltage to the Traction Motors to satisfy the direction and speed request received by the VM. The TPAs monitor the encoders (EN1 and EN2) to verify that travel direction and speed match what was requested. The VM constantly monitors the travel request and updates the information to the TPAs as changes occur. All operational parameters that affect motor torque and speed are controlled by the TPAs. The TPAs also monitor the temperature switches (TS1 and TS2). The temperature switches are normally closed. They open when an overtemperature

sent via the CAN-Bus to the Traction Power Amplifiers (TPAs) and Operator Display (OD).

condition exists in the motor, causing a reduction in travel speed to allow the motor to

cool. An icon on the Operator Display is also illuminated to alert the operator.

When the truck is moving and the travel pedal is released or travel direction is reversed, the same sequence of events takes place. The VM does not request plugging or regeneration: it just requests travel in the opposite direction at a particular RPM. The VM communicates this information to the TPAs via the CAN-Bus. The TPAs calculate both direction and RPM to determine whether the request from the VM must be met with a travel, a plug, or a regeneration control output to the traction motors. The VM energizes the Braking Lights. The brake pedal may be depressed to apply the hydraulic brake, aiding in slowing the truck.

NOTE: The Braking Lights are not energized by depressing the brake pedal alone. The lights energize when the truck is traveling and a change in requested direction is sensed by the TPAs and relayed to the VM via the CAN-Bus.

Hydraulic System

NOTE: A priority valve is used to ensure adequate hydraulic pressure is available to the steering system at all times. If adequate flow is not available for steering, the priority valve diverts fluid from any other requested function.

Lift/Lower

Standard Lever Controls

Lift

The VM monitors the lift control lever switch (SW11) and the voltage from the wiper of the lift pot (P3). When lift is requested, the VM senses SW11 has closed. The VM checks battery voltage (for lift reduction) and the Lift Limit option that could prevent activation of the lift system. Output voltage from the lift pot is also sensed by the VM. It is compared to the previously Learned value of the pot and the VM converts the voltage value into a percentage of total request. The Pump Power Amplifier (PPA) receives the lift request via the CAN-Bus. The PPA generates the correct voltage to the pump motor to run the pump at the requested RPM. From the pump, fluid flows first to the priority valve.

When the lift/lower valve is in the neutral position, fluid bypasses the lift/lower valve and is either available for other functions or returned to the reservoir.

When lift is requested, fluid flows to the lift cylinders. Lift motor RPM is determined by the position of the lift lever, which determines the output voltage of P3. The free lift cylinders elevate first because less pressure is required. Once the free lift cylinders reach the stops, the pressure increases enough to start elevating the main lift cylinders.

Lower

A solenoid lift valve (EV14) normally closed valve connected in line with the lift/lower line.

When lower is requested and the operator is on the seat, 24V is applied to the solenoid, opening the valve. Hydraulic fluid flows from the lift cylinders through the valve to the reservoir. If the operator is not on the seat (SW2 open) when lower is requested, voltage to the solenoid stays at 0V, causing the load holding valve to remain closed. Lower is inhibited.

Optional Fingertip Controls

Lift

The Armrest Board monitors the lift switch (SW17) and the voltage from the wiper of lift/lower pot (P4). When lift is requested, SW17 closes. This is sensed by the Armrest Board. The Armrest Board encodes the lift request into a digital message and communicates it to the VM via the CAN-Bus. The VM checks the battery voltage (for lift reduction) and the Lift Limit option, which could prevent the activation of the lift system. Output voltage from P4 is interpreted by the Armrest Board. The Armrest Board converts the voltage value into a percentage of total request. The PPA receives the lift request via the CAN-Bus. The PPA generates the correct voltage to the pump motor to run the pump at the requested RPM. From the pump, fluid flows first to the priority valve.

The lift request is also sent to the Hydraulic Control Board. The Hydraulic Control Board interprets the message and provides controlling voltage to the lifting solenoid EV2, causing EV2 to open, providing fluid to the lift cylinders. The Hydraulic Control Board also energizes the proportional solenoid valve, EVP. This valve opens proportionally to the lift request from P4 and provides a path back to reservoir for the fluid not used by the lift cylinders. For maximum lift, EVP is fully energized.

When the lift solenoid valve is de-energized, fluid bypasses the lift/lower valve and is either available for other functions or returns to the

A load holding solenoid valve (EV14) comes standard on trucks with lever controls. It is a

reservoir through the proportional lift solenoid valve (EVP).

Motor RPM and position of the EVP are determined by the position of the fingertip control, which determines the output of P4. The free lift cylinders elevate first because less pressure is required. Once the free lift cylinders reach the stops, the pressure increases enough to start elevating the main lift cylinders.

Lower

The Armrest Board monitors the lower switch (SW18) and the voltage from the wiper of lift/lower pot (P4). When lower is requested, SW18 closes and P4 voltage changes. This change is sensed by the Armrest Board. The lower request is encoded into a digital message that is communicated to the Hydraulic Control Board via the CAN-Bus. The Hydraulic Control Board interprets the message and provides

controlling voltage to the lowering solenoid EVP1. This causes EVP1 to open proportionally to the request and allows fluid from the cylinders to return to the reservoir. The rate of lower is dependent on the position of the fingertip control, which determines the output of P4, but is restricted to a maximum rate of 115 ft./min. by a flow restrictor valve located in the distribution manifold at the base of the main frame, between the lift cylinders. Flow controls in each cylinder restrict lowering speed.

Emergency Lower

An emergency lower valve, located on the control valve (base of the solenoid valve assembly on Fingertip Controls), allows the carriage to be lowered in the event of a loss of power to the truck. See Figure 7-4 on page 7-8.

When the emergency lower valve is opened, hydraulic fluid is allowed to pass through the emergency lower valve at a constant rate.

Auxiliary Functions

NOTE: A priority valve is used to ensure adequate hydraulic pressure is available to the steering system at all times. If adequate flow is not available for steering, the priority valve diverts fluid from any other requested function.

Auxiliary functions are activated by the operator moving one of the auxiliary function levers or optional fingertip controls. Tilt and Sideshift are discussed below for both configurations. Operational theory for the 4th function is similar to tilt and sideshift.

Standard Lever Controls

Tilt

When tilt is requested, the tilt switch (SW12) closes. This is sensed by the VM. The Pump Power Amplifier (PPA) receives the RPM request via the CAN-Bus. The pump motor operates at a fixed RPM that is configurable using the FlashWare program.

Oil is pumped through the activated side of the tilt valve to the tilt cylinders. Return oil flows from the other side of the cylinders through the tilt valve, and back to the reservoir.

When tilt is not requested, all fluid bypasses the tilt valve and is either available for use by other functions or returned to the reservoir.

There are two flow controls in the tilt system. One flow control, located in the spool valve, provides the correct flow rate.

The second flow control (V2) is located in the adapter fitting on the control valve assembly. V2 controls fluid flow in the return circuit when tilting forward. If fluid flow in the return circuit is excessive (for example: the tilt system is supplied with fluid at the lift system delivery rate), the control restricts the return flow to reduce forward tilt speed.

Sideshift

When sideshift is requested, the sideshift switch (SW13) closes. This is sensed by the VM. The Pump Power Amplifier (PPA) receives the RPM request via the CAN-Bus. The pump motor operates at a fixed RPM that is configurable using the FlashWare program.

Oil is pumped through the activated side of the sideshift valve to the sideshift cylinders. Return oil flows from the cylinders, through the sideshift valve, and back to the reservoir.

When sideshift is not requested, all fluid bypasses the sideshift valve and is either available for use by other functions or returns to the reservoir.

Optional Fingertip Controls

Tilt

When tilt is requested, the tilt switch (SW19 or S20) closes. This is sensed by the Armrest Board. Output voltage from the tilt pot (P5) is also sensed by the Armrest Board. The Armrest Board encodes the tilt request into a digital message and communicates it to the Hydraulic Control Board via the CAN-Bus. The Hydraulic Control Board relays the RPM to the PPA. The PPA generates the correct voltage to the pump motor to run the pump.

The Hydraulic Control Board interprets the message and provides controlling voltage to the tilt solenoids (EV3 or EV4) from a coil driver located on the board.

A flow control valve (V2) between the tilt solenoid valves and tilt cylinders prevents excessive forward tilt speed when lift and tilt are requested simultaneously. This valve also keeps the forks from drifting when the tilt command is removed from the tilt solenoid.

When tilt is not requested, all fluid bypasses the tilt valve and is either available for use by other functions or returns to the reservoir.

reduce forward tilt speed.

functions or returns to the reservoir.

Sideshift

When sideshift is requested, the sideshift switch (SW21 or SW22) closes. This is sensed by the Armrest Board. Output voltage from the sideshift pot (P6) is also sensed by the Armrest Board. The Armrest Board encodes the sideshift request into a digital message and communicates it to the Hydraulic Control Board via the CAN-Bus. The Hydraulic Control Board relays the RPM to the PPA. The PPA generates the correct voltage to the pump motor to run the pump.

The Hydraulic Control Board interprets the message and provides controlling voltage to the sideshift solenoids (EV5 or EV6) from a coil driver located on the board.

Oil is pumped through the energized sideshift solenoid (EV5 or EV6) to the sideshift cylinders. A flow restrictor in the solenoid valve provides correct flow for sideshift.

When sideshift is not requested, all fluid bypasses the sideshift valve and is either available for use by other functions or returns to the reservoir.

Steering System

System Components

- Steer Orbitrol – Hydraulically couples operator request (from steer tiller) to the steering axle.
- Pump Power Amplifier (PPA) – Controls the speed of the pump motor. Receives input from the brake switch (SW6) or accelerator potentiometer (P2), VM, and TPA via the CAN-Bus.
- AC Pump Motor – Drives the hydraulic pump.
- Priority Valve – Routes hydraulic fluid from the pump to the steering, lift, and auxiliary systems. Ensures the steering system receives priority over lift and aux functions.
- Hydraulic Pump – Provides fluid to the Steer Orbitrol via the Priority Valve.
- Steer Potentiometer (P1) – Provides steer wheel position feedback to the TPA Master. P1 also provides input to the steer wheel position indicator on the Operator Display.

System Overview

The steering system is a hydraulically activated system. A steer request is generated when the operator rotates the steering wheel in either a clockwise or counterclockwise direction. The steering system uses the same hydraulic fluid as the lift and auxiliary systems by means of a priority valve. Because steering takes priority over all other hydraulic functions, the priority valve ensures that sufficient oil flow to the steering system is always present.

Fluid capacity is checked by the Priority Valve. Excess oil is sent to the Control valve for other functions. When the steering wheel is turned, the orbitrol measures a volume of oil proportional to the movement of the steering wheel and sends it to the steer cylinder.

The pump motor starts when travel is requested by the VM or the Service Brake pedal is depressed. Depressing the service brake pedal also causes the pump motor to run.

Functional Description

A forward or reverse travel request is received by the VM or the Service Brake pedal is depressed. SW6 closes and GND is removed from the VM and is encoded into a digital message that is sent to the PPA. The PPA generates the correct voltage to the pump motor to run the pump.

The priority valve ensures adequate hydraulic pressure to the steering system at all times, regardless of other hydraulic demands on the system.

When the pump motor starts, fluid is delivered to the orbitrol through port CF of the priority valve. As pressure builds in the steering system, the pilot moves the priority valve against spring tension, dividing the fluid flow and delivering a restricted flow to the steering system (through CF) and an unrestricted flow to the lift and auxiliary functions (through EF).

When the orbitrol is rotated, the pressure at LS increases, assisting the spring to move the priority valve toward the steering only position. Fluid is directed to the steer cylinder.

Steer Position Feedback is provided to the TPA from the Steer Pot (P1) located on top of the steer assembly.

The pump motor starts when travel is requested, providing hydraulic flow to the

Options

Standard Lever Controls

Bottler's Tilt

Bottler's Tilt allows the mast to be tilted further forward when under free lift mast height. The limit is 9° forward, 6° backward. The option is controlled by two switches, a Blocking Solenoid (EV12), and a Tilt Limit Solenoid (EV13).

When the forks are fully lowered and the mast is centered, the End of Free Lift switch (SW16) and the Angle Tilt Proximity switch (SW30) are normally closed. When tilt is requested, tilt functions as normal. However, when the forks are elevated above free lift, SW16 opens, causing a change in state to be seen at the VM. If tilt is then requested, the VM allows forward Tilt until it sees a change in state of SW30. If the VM sees SW16 and SW30 open, it commands the Tilt Limit Solenoid (EV13) to activate, stopping return flow from the tilt cylinders and preventing further forward tilt. If the mast is then lowered until SW16 closes, tilt forward is allowed.

If lift is requested while the mast is tilted fully forward, lift is allowed until the End of Free Lift switch opens. When the VM again sees SW30 and SW16 open, it de-energizes the Blocking Solenoid (EV12), blocking flow to the lift cylinders. When the mast is tilted back until SW30 closes, EV12 is energized, allowing flow to the lift cylinders.

Lift-Limit with Bypass

Lift-Limit with Bypass consists of a switch placed on the mast that prevents lift past a certain height. To lift beyond this height, the operator must activate a switch.

This is accomplished by having a Mast Height switch (SW31), Lift-Limit Push Button switch (PB9), and a Blocking Solenoid (EV12). de-energizes EV12, blocking fluid to the lift cylinders. To continue lifting, PB9 must be depressed and the lift request resumed.

Finger Tip Controls

Bottler's Tilt

Theory of operation for Bottler's Tilt on a fingertip controlled truck is the same as for a lever controlled truck with the exception of the Tilt Limit Solenoid. When the VM senses a change in state at the switches that limit lift or tilt, the VM sends a communication message to the Hydraulic Control Board. The Hydraulic Control Board then removes the request for the requested function.

Lift-Limit with Bypass

Theory of operation for Lift-Limit with Bypass on a fingertip controlled truck is the same as for a lever controlled truck with the exception of the Blocking Solenoid (EV12). When the VM senses a change in state at the switches that limit lift, the VM sends a communication message to the Hydraulic Control Board. The Hydraulic Control Board then removes the request for the requested function.

If switch SW31 is opened during a lift request, the VM sees the change of state and

Pinout Matrix

The pinout matrix chart lists functions and normal voltages of terminals and harness connector pins. The matrix columns have the following meanings:

- **Item**: sequential number to aid in reference.
- **Connection**: actual connector/wire designation or component as identified on the electrical schematic (listed alpha-numerically).
- **Function Description**: brief definition of the signal carried on the wire.
- **Theory of Operation**: detailed description of the signal carried on the wire. If the signal is variable, the state of a related component that causes the signal to vary is indicated. Also identifies possible causes for lack of correct signal.
- **Normal Level**: the approximate voltage that must be seen on that wire for the state indicated. Unless otherwise indicated, voltages are measured with respect to (wrt) B–.
- **Signal Source**: the device or connection that supplies the signal directly to the wire.
- **Signal User**: the device or connection where the wire directly delivers the signal.

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
1	JCAN-1	CAN L	Low component of the digital communications between the PPA and optional Fingertip Armrest Board.	N/A	PPA	Fingertip Armrest Board
2	JCAN-2	CAN H	High component of the digital communications between the PPA and optional Fingertip Armrest Board.	N/A	PPA	Fingertip Armrest Board
3	JCAN-3	GND	B– supply from Battery. This B– is used by the optional Fingertip Armrest Board. If not present, follow back towards B– until loss can be determined.	B–	BT1	Fingertip Armrest Board
4	JCAN-4	NOT USED				
5	JCAN-5	+V	+24V supply to Armrest Board from VM (J34-12). If not present, check Fuse F23, wiring, and connections.	+24V	VM	Armrest Board
6	JCAN-6	GND	B– supply from battery. This B– is used by the optional Fingertip Armrest Board. If not present, follow back towards B– until loss can be determined.	B–	BT1	Fingertip Armrest Board
7	JCM-1	LOW	Voltage from the HCB to turn on the Lowering Solenoid (EVP1). If not present, check the HCB, wiring, and connections.	Approx. 2 to 12V wrt B+ when lowering (approx. 18 ohms across coil)	HCB	EVP1

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
8	JCM-2	+V	Voltage from the HCB to the Lowering (EVP1) and Lifting (EV2) Solenoids. If not present, check the HCB, wiring, and connections. **Note:** This voltage is common to both solenoids. If this voltage is lost, neither solenoid works.	36V when lifting or lowering	HCB	EVP1, EV2
9	JCM-3	LIFT	Voltage from the HCB to turn on the Lifting Solenoid (EV2). If not present, check the HCB, wiring, and connections.	Approx. 24V wrt B+ when lifting (approx. 27 ohms across coil)	HCB	EV2
10	JCM-4	TILT FW	Voltage from the HCB to turn on the Tilt Forward Solenoid (EV3). If not present, check the HCB, wiring, and connections.	Approx. 15V wrt B+ (approx. 18 ohms across coil)	HCB	EV3
11	JCM-5	+V	Voltage from the HCB to the Tilt Forward (EV3) and Tilt Backward (EV4) Solenoids. If not present, check the HCB, wiring, and connections. **Note:** This voltage is common to both solenoids. If this voltage is lost, neither solenoid works.	B+	HCB	EV3, EV4
12	JCM-6	TILT BW	Voltage from the HCB to turn on the Tilt Backward Solenoid (EV4). If not present, check the HCB, wiring, and connections.	Approx. 15V wrt B+ (approx. 18 ohms across coil)	HCB	EV4
13	JCM-7	L SIDESHIFT	Voltage from the HCB to turn on the Left Sideshift Solenoid (EV5). If not present, check the HCB, wiring, and connections.	Approx. 18V wrt B+ (approx. 22 ohms across coil)	HCB	EV5
14	JCM-8	+V	Voltage from the HCB to the Left (EV5) and Right (EV6) Sideshift Solenoids. If not present, check the HCB, wiring, and connections. **Note:** This voltage is common to both solenoids. If this voltage is lost, neither solenoid works.	B+	HCB	EV5, EV6
15	JCM-9 thru 11	NOT USED				
16	JCM-12	4th FUNCTION	Voltage from the HCB to turn on the 4th Function Solenoid (EV7). If not present, check the HCB, wiring, and connections.	Approx. 18V wrt B+ (approx. 22 ohms across coil)	HCB	EV7

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
17	JCM-13	+V	Voltage from the HCB to the 4th Function (EV7 and EV8) Solenoids. If not present, check the HCB, wiring, and connections. **Note:** This voltage is common to both solenoids. If this voltage is lost, neither solenoid works.	B+	HCB	EV7, EV8
18	JCM-14	4th FUNCTION	Voltage from the HCB to turn on the 4th Function Solenoid (EV8). If not present, check the HCB, wiring, and connections.	Approx. 18V wrt B+ (approx. 22 ohms across coil)	HCB	EV8
19	JCM-15	R SIDESHIFT	Voltage from the HCB to turn on the Right Sideshift Solenoid (EV6). If not present, check the HCB, wiring, and connections.	Approx. 18V wrt B+ (approx. 22 ohms across coil)	HCB	EV6
20	JCM-16 thru 18	NOT USED				
21	JCM-19	DRAIN	Voltage from the HCB to turn on the Drain Solenoid (EVP). If not present, check the HCB, wiring, and connections.	Approx. 2 to 15V wrt B+ when requesting lift and/or any aux function (approx. 18 ohms across coil)	HCB	EVP
22	JCM-20	+V	Voltage from the HCB to the Drain Solenoid (EVP). If not present, check the HCB, wiring, and connections.	B+	HCB	EVP
23	JCM-21 and 22	NOT USED				
24	JCM-23	GND	B– supply to optional HCB. This B– is shared by many components prior to and after the VM. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	B– at J1	HCB
25	JP-1	+V KEY	B+ from Key switch to power internal circuitry in the PPA. Also used by the PPA to create 5 and 12V internally.	B+	Key Switch	PPA
26	JP-2	NOT USED				
27	JP-3	IN	Input from optional Mast Height switch (SW31) to the PPA. Travel speed is reduced when B+ is supplied to the PPA on this pin.	Switch Closed: B+ Open: 0V	Key Switch	PPA
28	JP-4 thru 6	NOT USED				
29	JP-7	A PHASE	Channel A input from the Pump Motor (PM) encoder (EN3) to the PPA. The PPA uses this input to	Lifting: approx. 6V Not Lifting: 0	EN3	PPA

			PPA. The PPA uses this input along with Channel B to determine pump motor RPM.	Not Lifting: 0 or 11V		

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
30	JP-8	+12V	Voltage supplied to the PM EN3 to power its circuitry.	12V	EN3	PPA
31	JP-9	GND	B– from the PPA to the SAFETY IN connection at JP-11.	B+ wrt J1+ <0.5V wrt B– at J1–	PPA	PPA
32	JP-10	NOT USED				
33	JP-11	SAFETY IN	13.2V from the PPA that is taken low by the GND at JP-9. Without this pin drawn low, the PPA does not function.	13.2V	PPA	PPA
34	JP-12 and 13	NOT USED				
35	JP-14	B PHASE	Channel B input from the Pump Motor (PM) encoder (EN3). The PPA uses this input along with Channel A to determine pump motor RPM.	Lifting: approx. 6V Not Lifting: 0 or 11V	EN3	PPA
36	JP-15	GND ENCODER	B– from the PPA to the Pump Motor (PM) encoder (EN3).	B+ wrt J1+ <0.5V wrt B– at J1–	PPA	EN3
37	JP-16	–V COIL	B– from the PPA to the CT2 contactor coil when the PPA wants to close the contactor.	B+ wrt J1+ <0.5V wrt B– at J1–; drops to 22V wrt B– holding voltage	PPA	CT2
38	JP-17	+V COIL	B+ from CT1 to PPA and CT2 contactor coil.	B+	CT1	PPA, TPAs
39	JP-18 and 19	NOT USED				
40	JP-20	CAN L	Low component of the digital communications between the PPA and other devices.	N/A	TPAs, VM, PPA	TPAs, VM, PPA
41	JT2-21	CAN H	High component of the digital communications between the PPA and other devices.	N/A	TPAs, VM, PPA	TPAs, VM, PPA
42	JP-22	TERM	9V from the PPA to the Pump Motor temperature switch (TS3). When switch is closed, voltage is taken to B–, informing the PPA the motor is operating within normal temp. When switch opens, an overtemp message is displayed.	Closed: 1V Open: approx. 5V	PPA	PPA
43	JP-23	GND TERM	B– from the PPA to the Pump Motor temperature switch (TS3).	B+ wrt J1+ <0.5V wrt B– at J1–	PPA	TS3

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
44	JT1-1	+V KEY	B+ from Key switch to power internal circuitry in the Master TPA. Also used by the TPA to create 5 and 12V internally.	B+	Key Switch	Master TPA
45	JT1-2	+V POT	12V from the Master TPA to the Steer Feedback Pot (P1).	12VDC	Master TPA	Steer Feedback Pot
46	JT1-3	SPEED RED.	Optional Speed Reduction switch input to the Master TPA. Travel speed is reduced when B+ is supplied to the TPA on this pin.	Switch Closed: B+ Open: 0V	Speed Reduction Switch	Master TPA
47	JT1-4	NOT USED				
48	JT1-5	GND POT	B– from the Master TPA to the Steer Feedback Pot (P1).	B+ wrt J1+ <0.5V wrt B– at J1–	Master TPA	Steer Feedback Pot
49	JT1-6	SEAT	B+ from the Master TPA to the Seat switch. When the switch is closed, B+ is taken to B–, informing the amp the switch is closed.	Switch Open: B+ Closed: 0V	Master TPA	Master TPA
50	JT1-7	A PHASE	Channel A input from the Right Traction Motor (RTM) encoder (EN1). The amp uses this input along with Channel B to determine travel speed and direction.	Traveling: approx. 6V Parked: 0 or 11V	EN1	Master TPA
51	JT1-8	+12V	Voltage supplied to the RTM EN1 to power its circuitry.	12VDC	EN1	Master TPA
52	JT1-9	GND	B– from the Master TPA to the Seat switch. When the switch is closed, B+ is taken to B–, informing the amp the switch is closed.	B+ wrt J1+ <0.5V wrt B– at J1–	Master TPA	TPAs
53	JT1-10	C POT	Input to the Master TPA from the wiper of the Steer Feedback Pot (P1). Used by the amp to determine when to limit travel speed.	Full Left: 1.5V Centered: 5.5V Full Right: 10V	Steer Feedback Pot	Master TPA
54	JT1-11	SAFETY IN	Input to the Master TPA from JT2-19. Without pin drawn low, Master TPA does not function.	B+ wrt J1+ <0.5V wrt B– at J1–	Slave TPA	Master TPA
55	JT1-12 and 13	NOT USED				
56	JT1-14	B PHASE	Channel B input from the Right Traction Motor (RTM) encoder (EN1). The amp uses this input along with Channel A to determine travel speed and direction.	Traveling: approx. 6V Parked: 0 or 11V	EN1	Master TPA

57	JT1-15	GND ENCODER	B– from the Master TPA to the Right Traction Motor (RTM) encoder (EN1).	B+ wrt J1+ <0.5V wrt B– at J1–	Master TPA	EN1

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
58	JT1-16	–V COIL	B– from the Master TPA to the CT3 contactor coil when the amp wants to close the contactor.	B+ wrt J1+ <0.5V wrt B– at J1–	Master TPA	CT3
59	JT1-17	+V COIL	B+ from CT1 to the Master TPA and CT3 contactor coil.	B+; drops to 24V wrt B– holding voltage	CT1	PPA, TPAs
60	JT1-18	–V COIL AUX	B– from the Master TPA to Relay 1 (RL1 at J50-4) coil. If 36V battery, RL1 stays de-energized. If 48V battery, RL1 is energized to allow 12V drop across R4, providing 36V to CT1. If not present, check the Master TPA, wiring, and connections. Approx. 1K ohm across coil.	B+ wrt J1+ <0.5V wrt B– at J1–; drops to 14V holding voltage	TPA	RL1
61	JT1-19	SAFETY OUT	Output from Master TPA to JT2-11 (same as JT1-11).	B+ wrt J1+	Master TPA	Slave TPA
62	JT1-20	CAN L	Low component of the digital communications between the Master TPA and other devices.	N/A	TPAs, VM, PPA	TPAs, VM, PPA
63	JT1-21	CAN H	High component of the digital communications between the Master TPA and other devices.	N/A	TPAs, VM, PPA	TPAs, VM, PPA
64	JT1-22 and 23	NOT USED				
65	JT2-1	+V Key	B+ from Key switch to power internal circuitry in the Slave TPA. Also used by the TPA to create 5 and 12V internally.	B+	Key Switch	Slave TPA
66	JT2-2 and 3	NOT USED				
67	JT2-4	CONF.	B+ from key switch to identify the amp as the slave.	B+	Key Switch	Slave TPA
68	JT2-5	NOT USED				
69	JT2-6	SEAT	B+ from the Master TPA to the Seat switch. When the switch is closed, B+ is taken to B–, informing the Slave TPA the switch is closed.	Switch Open: B+ Closed: 0V	Master TPA	Slave TPA
70	JT2-7	A PHASE	Channel A input from the Left Traction Motor (LTM) encoder (EN2). The Slave TPA uses this input along with Channel B to determine travel speed and direction.	Traveling: Approx. 6V Parked: 0 or 11V	EN2	Slave TPA
71	JT2-8	+12V	Voltage supplied to the LTM EN2 to	12V	EN2	Slave TPA

			power its circuitry.			
72	JT2-9 and 10	NOT USED				

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
73	JT2-11	SAFETY IN	Input from Master TPA (JT1-11). Without pin drawn low, Slave TPA does not function.	B+ wrt J1+	Master TPA	Slave TPA
74	JT2-12 and 13	NOT USED				
75	JT2-14	B PHASE	Channel B input from the Left Traction Motor (LTM) encoder (EN2). The Slave TPA uses this input along with Channel A to determine travel speed and direction.	Traveling: Approx. 6V Parked: 0 or 11V	EN2	Slave TPA
76	JT2-15	GND ENCODER	B– from the Slave TPA to the Left Traction Motor (LTM) encoder (EN2).	B+ wrt J1+ <0.5V wrt B– at J1–	Slave TPA	EN2
77	JT2-16	NOT USED				
78	JT2-17	+V COIL	B+ from CT1 to Slave TPA and CT3 contactor coil.	B+	CT1	PPA, TPAs
79	JT2-18	NOT USED				
80	JT2-19	SAFETY OUT	Output from Slave TPA to JT1-11. Without pin drawn low, Master TPA does not function.	B+ wrt J1+	Slave TPA	Master TPA
81	JT2-20	CAN L	Low component of the digital communications between the Slave TPA and other devices.	N/A	TPAs, VM, PPA	TPAs, VM, PPA
82	JT2-21	CAN H	High component of the digital communications between the Slave TPA and other devices.	N/A	TPAs, VM, PPA	TPAs, VM, PPA
83	JT2-22	NOT USED				
84	J1+	B+	B+ from the positive battery terminal. If not present, make sure battery is connected and check associated wiring.	B+	BT1	CT1, CT2, CT3 tips, F1 and F2
85	J1–	B–	B– from the negative battery terminal. If not present, make sure battery is connected and check associated wiring.	Battery voltage wrt J1+	BT1	Entire truck
86	J4	OIL BRAKE	Provides input to the VM (J34-17) from Low Brake Fluid Sensor (SW3). If not present, check switch, fluid, wiring, and connections.	Approx. 5V open; 0V closed	B–	VM
87	J8-1	GND	Ground to Horn Push Button switch (PB4) from VM (J34-6). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	PB4

88	J8-2	HORN IN	Horn Push Button (PB4) input to VM (J34-16). If not present, check switch, wiring, and connections.	Approx. 5V open; 0V closed	PB4	VM

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
89	J8-3 and 4	NOT USED				
90	J11(–)	HR1 GND	B– to the Horn (HR1). If not present, check wiring and connections.	Battery voltage wrt BT1+	B–	Horn
91	J11 IN	HORN OUT	Control voltage to Horn (HR1) from the VM (J34-9). If not present, check VM, switch, wiring, and connections.	+24V normal goes to 0V when horn button is depressed	VM	Horn
92	J11(+)	+24V	+24V to the Horn (HR1) from the DC/DC Converter. If not present, check F6, wiring, and connections. Approx. 65 ohms across coil (J11+ to J11–).	+24V	DC/DC Converter	Horn
93	J13-1	+12V	+12V to the Pump Motor (PM) Encoder (EN3). If not present, check the PPA, wiring, and connections.	+12V	PPA	EN3
94	J13-2	GND ENCODER	Ground to the Pump Motor (PM) Encoder (EN3). If not present, check the PPA, wiring, and connections.	Battery voltage wrt BT1+	PPA	EN3
95	J13-3	B PHASE	Channel B from the Pump Motor (PM) Encoder (EN3). If not present, check voltage to the encoder, wiring, and connections.	Approx. 6V running; 0V or 11V static	EN3	PPA
96	J13-4	A PHASE	Channel A from the Pump Motor (PM) Encoder (EN3). If not present, check voltage to the encoder, wiring, and connections.	Approx. 6V running; 0V or 11V static	EN3	PPA
97	J13-5 thru 9	NOT USED				
98	J14-A	C POT	Input from the Steer Feedback Pot (P1) to the Master TPA (JT1-10). If not present, check the Steer Feedback Pot, wiring, and connections.	Full Left: 1.5V Centered: 5.5V Full Right: 10V	P1	Master TPA
99	J14-B	GND POT	Ground from the Master TPA (JT1-5) to the Steer Feedback Pot (P1). If not present, check the Master TPA, wiring, and connections.	Battery voltage wrt BT1+	Master TPA	P1
100	J14-C	+V POT	+12V from the Master TPA (JT1-2) to the Steer Feedback Pot (P1). If not present, check the Master TPA, wiring, and connections. Approx. 1.8 Kohms across pot J14-B to J14-C.	+12V	Master TPA	P1
101	J15-1	+12V	+12V to the Right Traction Motor (RTM) encoder (EN1) from the	+12V	Master TPA	EN1

			Master TPA (JT1-8). If not present, check the Master TPA, wiring, and connections.			

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
102	J15-2	GND ENCODER	Ground to the Right Traction Motor (RTM) encoder (EN1) from the Master TPA (JT1-15). If not present, check the Master TPA, wiring, and connections.	Battery voltage wrt BT1+	Master TPA	EN1
103	J15-3	B PHASE	Channel B from the Right Traction Motor (RTM) encoder (EN1) to the Master TPA (JT1-14). If not present, check voltage to the encoder, wiring, and connections.	Approx. 6V running; 0V or 11V static	EN1	Master TPA
104	J15-4	A PHASE	Channel A from the Right Traction Motor (RTM) encoder (EN1) to the Master TPA (JT1-7). If not present, check voltage to the encoder, wiring, and connections.	Approx. 6V running; 0V or 11V static	EN1	Master TPA
105	J15-5	GND	Ground from the VM (J34-6) to the RTM Temperature switch (TS1). If not present, check the VM, wiring, and connections.	Battery voltage wrt BT1+	VM	TS1
106	J15-6	R-TR TEMP SW	Input to the VM (J34-26) from the RTM Temperature switch (TS1). Input is low under normal operating conditions. If a overtemp condition exists (>266°F (130°C), input is high. Allow to cool. If still open (high), check the switch, wiring, and connections.	Approx. 0V closed; 5V open	TS1	VM
107	J15-7 thru 9	NOT USED				
108	J16-1	+12V	+12V to the Left Traction Motor (LTM) encoder (EN2) from the Slave TPA (JT2-8). If not present, check the Slave TPA, wiring, and connections.	+12V	Slave TPA	EN2
109	J16-2	GND ENCODER	Ground to the Left Traction Motor (LTM) Encoder (EN2) from the Slave TPA (JT2-15). If not present, check the Slave TPA, wiring, and connections.	Battery voltage wrt BT1+	Slave TPA	EN2
110	J16-3	B PHASE	Channel B from the Left Traction Motor (LTM) encoder (EN2) to the Slave TPA (JT2-14). If not present, check voltage to the encoder, wiring, and connections.	Approx. 6V running; 0V or 11V static	EN2	Slave TPA
111	J16-4	A PHASE	Channel A from the Left Traction Motor (LTM) encoder (EN2) to the Slave TPA (JT2-7). If not present,	Approx. 6V running; 0V or 11V static	EN2	Slave TPA

			check voltage to the encoder, wiring, and connections.			

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
112	J16-5	GND	Ground from the VM (J34-6) to the LTM Temperature switch (TS2). If not present, check the VM, wiring, and connections.	Battery voltage wrt BT1+	VM	TS2
113	J16-6	L-TR TEMP SW	Input to the VM (J34-27) from the LTM Temperature switch (TS2). Input is low under normal operating conditions. If a overtemp condition exists (>266°F (130°C), input is high. Allow to cool. If still open (high), check the switch, wiring, and connections.	Approx. 0V closed; 5V open	TS2	VM
114	J16-7 thru 9	NOT USED				
115	J24-1	SEAT	B– from the Master TPA to the Seat switch. When the switch is closed, B+ is taken to B–, informing the amp the switch is closed.	B+ wrt J1+ <0.5V wrt B– at J1–	Master TPA	TPAs
116	J24-2	+V OUT	B+ from the Master TPA to the Seat switch. When the switch is closed, B+ is taken to B–, informing the amp the switch is closed.	Switch Open: B+ Closed: 0V	Master TPA	Master TPA
117	J30-1	GND	Ground to the Parking Brake switch (SW7) from the VM (J34-6). If not present, check wiring and connections.	Battery voltage wrt BT1+	VM	SW7
118	J30-2	NOT USED				
119	J30-3	PARK	Input to the VM (J34-14) from the Parking Brake switch (SW7). If not present, check switch, wiring, and connections.	Approx. 5V brake set; 0V brake released	SW7	VM
120	J31-1	GND	Ground to the Brake Pedal switch (SW6) from the VM (J34-6). If not present, check wiring and connections.	Battery voltage wrt BT1+	VM	SW6
121	J31-2	BRAKE	Input to the VM (J34-15) from the Brake Pedal switch (SW6). If not present, check switch, wiring, and connections.	Approx. 5V pedal not depressed; approx. 0V pedal depressed wrt J31-1	SW6	VM
122	J31-3	NOT USED				

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
123	J32-1	C POT	Input from the wiper of the Travel Pot (P2) to the VM (J34-3). If not present, check pot, wiring, and connections. The pot may need to be re-learned. **Note:** To check pot, unplug connector and measure resistance between pins 2 and 3. Approx. 4.6 Kohms should be read (J32-2 to J32-3).	Approx. 2V difference between neutral and pedal depressed	P2	VM
124	J32-2	N POT	Ground to Travel Pot (P2) from the VM (J34-2). If not present check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	P2
125	J32-3	VCC	+10V to Travel Pot (P2) from VM (J34-5). If not present, check VM, wiring, and connections.	+10V	VM	P2
126	J32-4	GND	Ground to Travel Enable switch (SW8) from the VM (J34-6). If not present, check VM, wiring, and connections. (*Single Pedal Only*)	Battery voltage wrt BT1+	VM	SW8
127	J32-5	EN.	Input from the Travel Enable switch (SW8) to the VM (J34-32). If not present, check switch, wiring, and connections. (*Single Pedal Only*)	Approx. 5V pedal released; 0V pedal depressed	SW8	VM
128	J32-6	/EN.	Input from the Travel Enable switch (SW8) to the VM (J34-31). If not present, check switch, wiring, and connections. (*Single Pedal Only*)	Approx. 0V pedal released; 5V pedal depressed	SW8	VM
129	J33-1	GND	Ground to Forward Pedal switch (SW4) from the VM (J34-6). If not present, check VM, wiring, and connections. (*Dual Pedal System*)	Battery voltage wrt BT1+	VM	SW4
130	J33-2	FW	Input from the Forward Pedal switch (SW4) to the VM (J34-30). If not present check switch, wiring, and connections. (*Dual Pedal System*)	Approx. 5V pedal released; 0V pedal depressed	SW4	VM
131	J33-3	/FW	Input from the Forward Pedal switch (SW4) to the VM (J34-20). If not present, check switch, wiring, and connections. (*Dual Pedal System*)	Approx. 0V pedal released; 5V pedal depressed	SW4	VM
132	J33-4	GND	Ground from the VM (J34-6). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	VM

(*Dual Pedal System*)

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
133	J33-5	CONFIG.	Configuration input to the VM (J34-25). This input allows VM to recognize Dual Pedal. If not present, check jumper, wiring, and connections.	Approx. 0V w/dual pedals; approx. 5V without dual pedals	VM	VM
134	J33-6	NOT USED				
135	J33-7	GND	Ground to Reverse Pedal switch (SW5) from the VM (J34-6). If not present, check VM, wiring, and connections. (*Dual Pedal System*)	Battery voltage wrt BT1+	VM	SW5
136	J33-8	BW	Input from the Reverse Pedal switch (SW5) to the VM (J34-19). If not present, check switch, wiring, and connections. (*Dual Pedal System*)	Approx. 5V pedal released; approx. 0V pedal depressed	SW5	VM
137	J33-9	/BW	Input from the Reverse Pedal switch (SW5) to the VM (J34-18). If not present, check switch, wiring, and connections. (*Dual Pedal System*)	Approx. 0V pedal released; approx. 5V pedal depressed	SW5	VM
138	J33-10 thru 12	NOT USED				
139	J34-1	TAIL LIGHT	Output from VM to the Tail Lights (LP2 and LP4). If not present, check VM, wiring, and connections.	+24V	VM	LP2, LP4
140	J34-2	N POT	Negative reference for the Travel Pot (P2). If this reference is lost or intermittent, the travel pot does not function correctly and may throw codes. If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	P2
141	J34-3	C POT	Wiper input from the Travel Pot (P2). Voltage varies depending on travel request. The pot may need to be re-learned. If not present, check pot, wiring, and connections. **Note:** To check pot, unplug connector and measure resistance between pins 2 and 3. Approx. 4.6 Kohms should be read (J34-2 to J34-3).	Approx. 2V difference between neutral and pedal fully depressed.	P2	VM
142	J34-4	AN AUX				
143	J34-5	VCC	Voltage to Travel Pot (P2). If not present, check VM, wiring, and connections.	Approx. 10V wrt J34-2	VM	P2

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
144	J34-6	GND	One of the grounds supplied by the VM to multiple components. If ground is not present at this connection, check for B– coming into the VM at (J34-7, 8, 10) and (J40-17).	Battery voltage wrt BT1+	VM	PB2,3,4; SW3,4, 5,6,7,8, 9,10,16, 30; TS1,2; PB9
145	J34-7	GND	B– supply to the VM. This B– is shared by many components prior to and after the VM. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	B– at J1	VM
146	J34-8	GND	B– supply to the VM. This B– is shared by many components prior to and after the VM. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	B– at J1	VM
147	J34-9	HORN OUT	Output from the VM to activate the Horn (HR1 at J1-1). If not present, check VM, horn push button, and wiring.	+24V; 0V deactivated	VM	HR1
148	J34-10	GND	B– supply to the VM. This B– is shared by many components prior to and after the VM. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	B– at J1	VM, Horn
149	J34-11	+24V	+24V input to VM from DC/DC converter (J96-4). If not present, check converter, wiring, and connections.	+24V	DC/DC Converter	VM
150	J34-12	+24V CAN	+24V output from the VM to Armrest Board (JCAN-5) and Operator Display (J137-5). If not present, check VM, wiring, and connections.	+24V	VM	Armrest Board, OD
151	J34-13	BRAKE LIGHT	+24V output from VM to the Brake Lights (LP1 and LP3) when traveling and changing direction or traveling and pressing brake pedal. If not present, check VM, wiring, and connections.	+24V	VM	Brake Lights
152	J34-14	PARK	Input to the VM from Parking Brake switch (SW7 at J30-3). If not present, check switch, wiring, and connections.	Approx. 5V brake set; 0V brake released	SW7	VM
153	J34-15	BRAKE	Input to the VM from the Brake Pedal switch (SW6 at J31-2). If not present,	Approx. 5V pedal not depressed;	SW6	VM

			check switch, wiring, and connections.	approx. 0V pedal depressed		

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
154	J34-16	HORN IN	Input to VM from Horn switch (PB4 at J8-2). If not present, check horn switch, wiring, and connections.	Switch open: approx. 5V; Closed: 0V	PB4	VM
155	J34-17	OIL BRAKE	Input to VM from Low Brake Fluid Sensor (SW3). If not present, check switch, wiring, and connections.	Switch open: approx. 5V; Closed: 0V	SW3	VM
156	J34-18	/BW	Input to VM from Reverse Foot Pedal switch (SW5 at J33-9). If not present, check switch, wiring, and connections. (*Dual Pedal System*)	Switch open: 0V; Closed: approx. 5V	SW5	VM
157	J34-19	BW	Input to VM from Reverse Hand Direction switch (SW10 at J39-7) or Reverse Foot Pedal switch (SW5 at J33-8). If not present, check switches, wiring, and connections.	Switch open: approx. 5V; Closed: 0V	SW5, SW10	VM
158	J34-20	/FW	Input to VM from Forward Foot Pedal switch (SW4 at J33-3). If not present, check switch, wiring, and connections. (*Dual Pedal System*)	Approx. 0V switch open; approx. 5V switch closed	SW4	VM
159	J34-21	CAN L	Low component of the digital communications between the VM, Operator Display (J137-1) and CAN-Bus Interface (J132-2).	N/A	VM, OD	VM, OD
160	J34-22	CAN L	Low component of the digital communications between the VM and Armrest Board (JCAN-1).	N/A	VM	CAN-Bus Interface, VM, Armrest Board
161	J34-23	CAN L	Low component of the digital communications between the VM and other devices.	N/A	VM, TPAs, PPA	VM, TPAs, PPA
162	J34-24	+24V	+24V input to VM from DC/DC converter (J96-4). If not present, check converter, wiring, and connections.	+24V	DC/DC Converter	VM
163	J34-25	CONFIG	Input to the VM to identify the type of directional controls on the truck (*standard Hand Direction Lever or optional Dual Pedal System*). If truck has the standard Hand Direction Lever, the input is high. If the truck has the optional Dual Pedal System, the input is low.	Approx. 5V w/Hand Direction Lever; Approx. 0V w/Dual Pedal System	J33-5	VM

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
164	J34-26	R-TR TEMP SW	Input to VM from Right Traction Motor (RTM) Temp switch (TS1 at J15-6). When the switch opens, an error code is displayed. Allow to cool. If still open (high), check switch, wiring, and connections.	Approx. 0V when OK; approx. 5V when open (overheated)	TS1	VM
165	J34-27	L-TR TEMP SW	Input to VM from Left Traction Motor (LTM) Temp switch (TS2 at J16-6). When the switch opens, an error code is displayed. Allow to cool. If still open (high), check switch, wiring, and connections.	Approx. 0V when OK; approx. 5V when open (overheated)	TS2	VM
166	J34-28	L P H	Input to the VM from the LPH switch (PB3 at J36-2). If not present, check switch, wiring, and connections.	Approx. 0V when PB3 closed; approx. 5V open	PB3	VM
167	J34-29	SP. RED.	Input to VM from the Speed Reduction switch (PB2 at J37-3). If not present, check switch, wiring, and connections.	Approx. 0V when PB2 closed; approx. 5V open	PB2	VM
168	J34-30	FW	Input to VM from Forward Hand Direction switch (SW9 at J39-5) or Forward Foot Pedal switch (SW4 at J33-2). If not present, check switches, wiring, and connections.	5V switch open; 0V switch closed	SW4, SW9	VM
169	J34-31	/EN.	Input to the VM from Travel Enable switch (SW8 at J32-6). Used in conjunction with Travel Pot (P2) for trucks configured with Hand Direction Lever. If not present, check switch, wiring, and connections.	Approx. 0V w/pedal released; approx. 5V w/pedal depressed	SW8	VM
170	J34-32	EN.	Input to the VM from Travel Enable switch (SW8 at J32-5). Used in conjunction with Travel Pot (P2) for trucks configured with Hand Direction Lever. If not present, check switch, wiring, and connections.	Approx. 5V w/pedal released; approx. 0V depressed	SW8	VM
171	J34-33	CAN H	High component of the digital communications between the VM, Operator Display (J137-2), and CAN-Bus Interface (J132-7).	N/A	OD, VM	VM, OD
172	J34-34	CAN H	High component of the digital communications between the VM and Armrest Board (JCAN-2).	N/A	VM	CAN-Bus Interface, VM, Armrest Board

173	J34-35	CAN H	High component of the digital communications between the VM and other devices.	N/A	VM, TPAs, PPA	VM, TPAs, PPA

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
174	J36-1	GND	Ground to LPH switch (PB3) from the VM (J34-6). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	PB3
175	J36-2	L P H	Provides input to VM (J34-28) from the LPH switch (PB3). If not present, check switch, wiring, and connections.	Approx. 0V when PB3 closed; approx. 5V open	PB3	VM
176	J37-1	GND	Ground to Speed Reduction switch (PB2) from the VM (J34-6). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	PB2
177	J37-2	NOT USED				
178	J37-3	SP. RED.	Provides input to VM (J34-29) from the Speed Reduction switch (PB2). If not present, check switch, wiring, and connections.	Approx. 0V when PB2 closed; approx. 5V open	PB2	VM
179	J39-1	GND	Ground to Forward Hand Direction switch (SW9) from the VM (J34-6). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	SW9
180	J39-2	GND	Ground to Reverse Direction switch (SW10) from the VM (J34-6). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	SW10
181	J39-3 and 4	NOT USED				
182	J39-5	FW	Provides input to VM (J34-30) from Forward Hand Direction switch (SW9). If not present, check switch, wiring, and connections.	Approx. 5V switch open; 0V switch closed	SW9	VM
183	J39-6	NOT USED				
184	J39-7	BW	Provides input to VM (J34-19) from Reverse Hand Direction switch (SW10). If not present, check switch, wiring, and connections.	Approx. 5V switch open; 0V switch closed	SW10	VM
185	J39-8	NOT USED				
186	J40-1	LIFTING	Input to VM from Lifting switch (SW11 at J42-3). If not present, check switch, wiring, and connections.	Approx. 5V open; 0V closed	SW11	VM
187	J40-2	FAN DRIVE	Output from the VM to the Power Amp Fan (FN1 at J74-3). If not present, check VM, wiring, and	Approx. 5V ON; 0V OFF	VM	FN1

			connections. Should be present within a minute of turning key switch ON.			

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
188	J40-3	SIDESHIFT	Input to VM from Sideshift switch (SW13 at J44-3). If not present, check switch, wiring, and connections.	Switch open: approx. 5V; Closed: 0V	SW13	VM
189	J40-4	4TH	Input to VM from 4th Function switch (SW14 at J45-3). If not present, check switch, wiring, and connections.	Switch open: approx. 5V; Closed: 0V	SW14	VM
190	J40-5	NOT USED				
191	J40-6	GND	One of the grounds supplied by the VM to multiple components. If ground is not present at this connection check for B– coming into the VM at (J34-7, 8, 10) and (J40-17).	Battery voltage wrt BT1+	VM	SW11, 12, 13, 14, 15, PB5
192	J40-7	VCC	Supply voltage to the Lift Pot (P3 at J41-1) from the VM. If not present, check VM, wiring, and connections.	Approx. 5V	VM	P3
193	J40-8	CAN L	Low component of the digital communications between the VM and optional HCB (J140-4). If option is not present, a jumper with terminating resistor is installed between J48-8 and 15.	N/A	VM	HCB
194	J40-9	N POT	Negative reference for the Lift Pot (P3 at J41-3). If this reference is lost or intermittent, the lift pot does not function correctly and may throw codes. If not present, check VM, wiring, and connections. **Note:** Check P3 by disconnecting it from the circuit and reading across it. Approx. 5.2 Kohms should be read across J41-1 and 3.	Battery voltage wrt BT1+	VM	P3
195	J40-10	TILT	Input to VM from Tilt switch (SW12 at J43-3). If not present, check switch, wiring, and connections.	Approx. 5V open; 0V closed	SW12	VM
196	J40-11	C POT	Wiper input from the Lift Pot (P3 at J41-2). Voltage varies depending on lift request. The pot may need to be re-learned. If not present, check pot, wiring, and connections.	Approx. 0V in neutral; approx. 5V w/full lift requested	P3	VM
197	J40-12	AUX IN 3	Input to VM from the optional End of Travel Lift switch (SW16 at J75-1). If not present, check switch, wiring,	Approx. 5V open; 0V closed	SW16	VM

			and connections. (*Bottler's Tilt Option*)			

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
198	J40-13	AUX IN 1	Input to VM from the optional Lowering switch (SW15 at J47-3). If not present, check switch, wiring, and connections.	Approx. 5V open; 0V closed	SW15	VM
199	J40-14	AUX IN 2	Input to VM from the Angle Tilt Prox. switch (SW30 at J73-1). If not present, check switch, wiring, and connections. (*Bottler's Tilt Option*)	Approx. 5V open; 0V closed	SW30	VM
200	J40-15	CAN H	High component of the digital communications between the VM and optional HCB (J140-13). If option is not present, a jumper with terminating resistor is installed between J48-8 and 15.	N/A	VM	HCB
201	J40-16	AUX OUT 1	Output from VM, through Fuse F13, to the optional Travel Alarm (BZ1 at J104). If not present, check VM, wiring, and connections.	+24V	VM	BZ1
202	J40-17	GND	B– supply to VM. This B– is shared by many components prior to and after the VM. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	B– at J1	VM
203	J40-18	AUX IN 4	Input to the VM from the optional Lift Limit Push Button switch (PB9 at J101). If not present, check switch, wiring, and connections.	Approx. 5V open; 0V closed	VM	PB9
204	J40-19	AUX OUT 2	Output from the VM, through fuse 14, to Tilt Limit Solenoid (EV13 at J115-1). Output depends on condition of SW16 and SW30. (*Bottler's Tilt Option*)	+24V	VM	EV13
205	J40-20	+24V AUX	+24V input to VM from DC/DC converter (J96-4). If not present, check converter, wiring, and connections.	+24V	DC/DC Converter	VM
206	J40-21	+24V AUX	+24V input to VM from DC/DC converter (J96-4). If not present, check converter, wiring, and connections.	+24V	DC/DC Converter	VM
207	J40-22	AUX OUT 3	Output from the VM, through Fuse F22, to Lift/Lower Limit Solenoid (EV12 or EV14). Output depends on condition of SW31 and	+24V	VM	EV12 or EV14

			PB9. (*Lift/Lower Bypass Option*)			
208	J40-23	NOT USED				

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
209	J41-1	VCC	Supply voltage to the Lift Pot (P3) from the VM (J40-7). If not present, check VM, wiring, and connections.	Approx. 5V	VM	P3
210	J41-2	C POT	Wiper input from the Lift Pot (P3) to VM (J40-11). Voltage varies depending on lift request. The pot may need to be re-learned. If not present, check pot, wiring, and connections.	Approx. 0V in neutral; approx. 5V w/full lift requested	P3	VM
211	J41-3	N POT	Negative reference for the Lift Pot (P3) from the VM (J40-9). If this reference is lost or intermittent, the Lift Pot does not function correctly and may throw codes. If not present, check VM, wiring, and connections. **Note:** Check P3 by disconnecting it from the circuit and reading across it. Approx. 5.2 Kohms should be read across J41-1 and 3.	Battery voltage wrt BT1+	VM	P3
212	J42-1	GND	One of the grounds supplied by the VM (J40-6) to Lift switch (SW11). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	SW11
213	J42-2	NOT USED				
214	J42-3	LIFTING	Input to VM (J40-1) from the Lift switch (SW11). If not present, check switch, wiring, and connections.	Approx. 5V open; 0V closed	SW11	VM
215	J43-1	GND	One of the grounds supplied by the VM (J40-6) to Tilt switch (SW12). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	SW12
216	J43-2	NOT USED				
217	J43-3	TILT	Input to VM (J40-10) from the Tilt switch (SW12). If not present, check switch, wiring, and connections.	Approx. 5V open; 0V closed	SW12	VM
218	J44-1	GND	One of the grounds supplied by the VM (J40-6) to Sideshift switch (SW13). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	SW13
219	J44-2	NOT USED				
220	J44-3	SIDESHIFT	Input to VM (J40-3) from the Sideshift switch (SW13). If not present, check switch, wiring, and connections.	Approx. 5V open; 0V closed	SW13	VM

221	J45-1	GND	One of the grounds supplied by the VM (J40-6) to 4th Function switch (SW14). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	SW14

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
222	J45-2	NOT USED				
223	J45-3	4th FUNCTION	Input to VM (J40-4) from the 4th Function switch (SW14). If not present, check switch, wiring, and connections.	Approx. 5V open; 0V closed	SW14	VM
224	J46-1	+24V	+24V to optional 5th Function switch (PB5) from Fuse F7. If not present, check fuse, wiring, and connections.	+24V	DC/DC Converter	PB5
225	J46-2	5TH SOLENOID (optional)	When switch (PB5) is closed, voltage is allowed to pass to optional 5th Solenoid Valve (EV11). If not present, check switch, wiring, and connections.	+24V	PB5	EV11
226	J47-1	GND	One of the grounds supplied by the VM (J40-6) to optional Lowering switch (SW15). If not present, check VM, wiring, and connections.	Battery voltage wrt BT1+	VM	SW15
227	J47-2	NOT USED				
228	J47-3	AUX IN 1	Input to VM (J40-13) from the optional Lowering switch (SW15). If not present, check switch, wiring, and connections.	Approx. 5V open; 0V closed	SW15	VM
229	J47-4	NOT USED				
230	J70+	AUX OUT 1	Output from VM (J40-16), through Fuse F13, to the optional Travel Alarm (BZ1). If not present, check VM, fuse, wiring, and connections.	+24V	VM	BZ1
231	J70–	GND	B– supply to optional Travel Alarm (BZ1). This B– is shared by many components prior to and after the VM. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	B– at J1	BZ1
232	J71-1	GND	B– supply to Power Amplifier Fan (FN1). This B– is shared by many components prior to and after the fan. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	B– at J1	FN1
233	J71-2	+24V	+24V to the Power Amplifier Fan (FN1) from Fuse F5. If not present, check fuse, wiring, and connections.	+24V	DC/DC Converter	FN1

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
234	J71-3	FAN DRIVE	Output from the VM (J40-2) to the Power Amp Fan (FN1). If not present, check VM, wiring, and connections. Should be present within a minute of turning Key switch ON.	Approx. 5V on; 0V off	VM	FN1
235	J71-4	NOT USED				
236	J73-1	AUX IN 2	Input to VM (J40-14) from the Angle Tilt Prox. switch (SW30). If not present, check switch, wiring, and connections. (*Bottler's Tilt Option*)	Approx. 5V open; 0V closed	SW30	VM
237	J73-2	Gnd	B– from VM (J34-6) to Angle Tilt Prox. switch (SW30). If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	VM	SW30
238	J73-3	+24V	+24V to optional Angle Tilt switch (SW30) from DC/DC converter. If not present, check Fuse F12, wiring, and connections.	+24V	DC/DC Converter	SW30
239	J75-1	AUX IN 3	Input to VM (J40-12) from the optional End of Free Lift switch (SW16). If not present, check switch, wiring, and connections. (*Bottler's Tilt Option*)	5V open; 0V closed	SW16	VM
240	J75-2	B–	B– from VM (J34-6) to optional End of Free Lift switch (SW16). If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	VM	SW16
241	J75-3	+V OUT	Voltage from PPA (SW1) to optional Mast Height switch (SW31). If not present, check the PPA, wiring, and connections.	B+	Key Switch	SW31
242	J75-4	IN	Input to the PPA (JP-3) from the optional Mast Height switch (SW31). If not present, check switch, wiring, and connections.	0V open; B+ closed	SW31	PPA
243	J75-5 and 6	NOT USED				
244	J81	B–	B– connection at Master Traction Power Amplifier for all amps.	Battery voltage wrt BT1+	BT1	Entire truck
245	J91-1	GND	B– to the Left Brake Light (LP3) and Left Tail Light (LP4). If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	BT1	LP3, LP4

			be determined.			
246	J91-2	TAIL LIGHT	Output from the VM (J34-1) to the Left Tail Light (LP4). If not present, check VM, wiring, and connections.	+24V ON; 0V OFF	VM	LP4

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
247	J91-3	TAIL LIGHT	Output from VM (J34-1) to the Tail Lights (LP2 and LP4). Jumper in place to allow voltage to J102-2. If not present, check VM, wiring, and connections.	+24V ON; 0V OFF	VM	LP2, LP4
248	J91-4	BRAKE LIGHT	Output from the VM (J34-13) to the Left Brake Light (LP3) when traveling and changing direction or traveling and pressing brake pedal. If not present, check VM, wiring, and connections.	+24V ON; 0V OFF	VM	LP3
249	J91-5	BRAKE LIGHT	Output from VM (J34-13) to the Right Brake Light (LP1) when traveling and changing direction or traveling and pressing brake pedal. Jumper in place to allow voltage to J102-4. If not present, check VM, wiring, and connections.	+24V ON; 0V OFF	VM	LP1
250	J91-6	NOT USED				
251	J94	+24V	+24V to optional Backward Work Lights switch (SW29) from Fuse F10. If not present, check fuse, wiring, and connections.	+24V	DC/DC Converter	SW29
252	J95	+24V	+24V to optional Warning Light from Fuse F8. If not present, check fuse, wiring, and connections.	+24V	DC/DC Converter	Warning Light
253	J96-1	B+	B+ to DC/DC converter when CT1 coil is energized. If not present, check F4, SW1, CT1 coil, CT1 tips, wiring, and connections.	B+	CT1	DC/DC Converter
254	J96-2	B–	B– to DC/DC converter. If not present, make sure battery is connected. Check wiring and connections. A jumper is installed to J96-5.	Battery voltage wrt BT1+	B–	DC/DC Converter
255	J96-3	NOT USED				
256	J96-4	+24V	+24V from DC/DC converter to 24V circuit. If not present, check for power and ground to converter.	+24V	DC/DC Converter	+24V Circuits
257	J96-5	B–	B– to DC/DC converter. If not present, make sure battery is connected. Check wiring and connections. A jumper is installed to J96-2.	Battery voltage wrt BT1+	B–	DC/DC Converter

258	J97	AG+, N–	Connection for optional Warning Light (LP5).	+24V ON; 0V OFF	VM	LP5

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
259	J99	+24V	+24V to optional Forward Work Lights switch (SW28) from Fuse F11. If not present, check fuse, wiring, and connections.	+24V	DC/DC Converter	SW28
260	J100-1	B+	B+ to auxiliary power strip from J50-11. If not present, check Fuse F2, wiring, and connections.	B+	BT1	Aux Power
261	J100-2	NOT USED				
262	J100-3	B–	B– to auxiliary power strip. If not present, make sure battery is connected. Check wiring and connections.	Battery voltage wrt BT1+	B–	Aux Power
263	J101	L–, CH input	Connection for optional Lift-Limit Push Button switch (PB9).	Approx. 5V open; 0V closed	VM	VM
264	J102-1	GND	B– supply from battery to LP1 and LP2. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	BT1	LP1 and LP2
265	J102-2	TAIL LIGHT	Output from VM (J34-1) to the Right Tail Light (LP2). If not present, check VM, wiring, and connections.	+24V	VM	Tail Lights
266	J102-3	TAIL LIGHT	Tied to J102-2.	+24V	VM	Tail Lights
267	J102-4	BRAKE LIGHT	Output from VM (J34-13) to the Right Brake Light (LP1) when traveling and changing direction or traveling and pressing brake pedal. Jumper in place to allow voltage at J91-5. If not present, check VM, wiring, and connections.	+24V	VM	Brake Light
268	J102-5	BRAKE LIGHT	Tied to J102-4.	+24V	VM	Brake Light
269	J102-6	NOT USED				
270	J103	AC+, N–	Connection for optional Forward Right Work Light (LP6).	+24V	SW28	LP6
271	J104	AC+, N–	Connection for optional Forward Left Work Light (LP7).	+24V	SW28	LP7
272	J105	AH+, N–	Connection for optional Backward Left Work Light (LP9).	+24V	SW29	LP9
273	J106	AH+, N–	Connection for optional Backward Right Work Light (LP8).	+24V	SW29	LP8
274	J107-1	+V	Voltage from the HCB (JCM-2) to the	B+	HCB	EVP1

			Lowering (EVP1) Solenoid. If not present, check the HCB, Fuse F15, wiring, and connections.			

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
275	J107-2	LOW	Voltage from the HCB (JCM-1) to turn on the Lowering Solenoid (EVP1). If not present, check the HCB, wiring, and connections.	Approx. 2-12V wrt B+ lowering; (approx. 18 ohms across coil)	HCB	EVP1
276	J108-1	+V	Voltage from the HCB (JCM-2) to the Lifting Solenoid (EV2). If not present, check the HCB, Fuse F15, wiring, and connections.	B+	HCB	EV2
277	J108-2	LIFT	Voltage from the HCB (JCM-3) to turn on the Lifting Solenoid (EV2). If not present, check the HCB, wiring, and connections.	Approx. 24V wrt B+ when lifting (approx. 27 ohms across coil)	HCB	EV2
278	J109-1	+V	Voltage from the HCB (JCM-5) to the Tilt Forward Solenoid (EV3). If not present, check the HCB, Fuse F16, wiring, and connections.	B+	HCB	EV3
279	J109-2	TILT FW	Voltage from the HCB (JCM-4) to turn on the Tilt Forward Solenoid (EV3). If not present, check the HCB, wiring, and connections.	Approx. 15V wrt B+ (approx. 18 ohms across coil)	HCB	EV3
280	J110-1	+V	Voltage from the HCB (JCM-5) to the Tilt Backward Solenoid (EV4). If not present, check the HCB, Fuse F16, wiring, and connections.	B+	HCB	EV4
281	J110-2	TILT BW	Voltage from the HCB (JCM-6) to turn on the Tilt Backward Solenoid (EV4). If not present, check the HCB, wiring, and connections.	Approx. 15V wrt B+ (approx. 18 ohms across coil)	HCB	EV4
282	J111-1	+V	Voltage from the HCB (JCM-8) to the Left Sideshift Solenoid (EV5). If not present, check the HCB, Fuse F17, wiring, and connections.	B+	HCB	EV5
283	J111-2	L SIDESHIFT	Voltage from the HCB (JCM-7) to turn on the Left Sideshift Solenoid (EV5). If not present, check the HCB, wiring, and connections.	Approx. 18V wrt B+ (approx. 22 ohms across coil)	HCB	EV5
284	J112-1	+V	Voltage from the HCB (JCM-8) to the Right Sideshift Solenoid (EV6). If not present, check the HCB, Fuse F17, wiring, and connections.	B+	HCB	EV6
285	J112-2	R SIDESHIFT	Voltage from the HCB (JCM-15) to turn on the Right Sideshift Solenoid (EV6). If not present, check the HCB, wiring, and connections.	Approx. 18V wrt B+ (approx. 22 ohms across coil)	HCB	EV6

286	J113-1	+V	Voltage from the HCB (JCM-13) to the 4th Function Solenoid (EV7). If not present, check the HCB, Fuse F18, wiring, and connections.	B+	HCB	EV7

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
287	J113-2	4th FUNCTION	Voltage from the HCB (JCM-12) to turn on the 4th Function Solenoid (EV7). If not present, check the HCB, wiring, and connections.	Approx. 18V wrt B+ (approx. 22 ohms across coil)	HCB	EV7
288	J114-1	+V	Voltage from the HCB (JCM-13) to the 4th Function Solenoid (EV8). If not present, check the HCB, Fuse F18, wiring, and connections.	B+	HCB	EV8
289	J114-2	4th FUNCTION	Voltage from the HCB (JCM-14) to turn on the 4th Function Solenoid (EV8). If not present, check the HCB, wiring, and connections.	Approx. 18V wrt B+ (approx. 22 ohms across coil)	HCB	EV8
290	J115-1	AUX OUT 2	Output from the VM (J40-19), through Fuse F14, to Tilt Limit Solenoid (EV13). Output depends on condition of SW16 and SW30. (Bottler's Tilt Option)	+24V	VM	EV13
291	J115-2	GND	B– supply from battery to the Tilt Limit Solenoid (EV13). If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	BT1	EV13
292	J117-1	DRAIN	Voltage from the HCB (JCM-19) to turn on the Drain Solenoid (EVP). If not present, check the HCB, wiring, and connections.	Approx. 2-13V wrt B+ when lifting or performing an aux function (approx. 18 ohms across coil)	HCB	EVP
293	J117-2	+V	Voltage from the HCB (JCM-20) to turn on the Drain Solenoid (EVP). If not present, check the HCB, Fuse F21, wiring, and connections.	B+	HCB	EVP
294	J121-1	AUX OUT 3	Output from the VM (J40-22), through Fuse F22, to Lift/Lower Limit Solenoid (EV12 or EV14 at J121-1). Output depends on condition of SW31 and PB9. (*Lift/Lower Bypass Option*)	+24V	VM	EV12 or EV14
295	J121-2	GND	B– supply from battery to the Lift/Lower Limit Solenoid (EV12 or EV14). If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	BT1	EV12 or EV14
296	J131-1	CAN L	Communication line between VM (J34-22) and optional Armrest Board	N/A	VM	Armrest Board, PPA

			(JCAN-1). Without optional Armrest Board, a jumper is installed at J131-1 to J131-2.			

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
297	J131-2	CAN H	Communication line between VM (J34-34) and optional Armrest Board (JCAN-2). Without optional Armrest Board, a jumper is installed at J131-1 to J131-2.	N/A	VM	Armrest Board, PPA
298	J137-1	CAN L	Low component of the digital communications between the Operator Display and VM (J34-21).	N/A	VM	Operator Display
299	J137-2	CAN H	High component of the digital communications between the Operator Display and VM (J34-33).	N/A	VM	Operator Display
300	J137-3	GND	B– supply from battery to the Operator Display. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	BT1	Operator Display
301	J137-4	NOT USED				
302	J137-5	+V	+24V supply to Operator Display from the VM (J34-12). If not present, check Fuse F23, wiring, and connections.	+24V	VM	Operator Display
303	J137-6	GND	B– supply from battery to the Operator Display. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	BT1	Operator Display
304	J140-1	B+	B+ to HCB. If voltage is not present, check Fuse F3, wiring, and connections.	B+	F3	HCB
305	J140-2	B+	B+ to HCB. If voltage is not present, check Fuse F3, wiring, and connections.	B+	F3	HCB
306	J140-3	GND	B– supply from battery to the optional HCB. If not present, follow back towards B– until loss can be determined.	Battery voltage wrt BT1+	BT1	HCB
307	J140-4	CAN L	Low component of the digital communications between the HCB and VM (J40-8).	N/A	VM	HCB
308	J140-5 thru 12	NOT USED				
309	J140-13	CAN H	High component of the digital communications between the HCB and VM (J40-15).	N/A	VM	HCB
310	J140-14	NOT USED				

311	J406-A	NOT USED				

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
312	J406-B	+V POT	Voltage to the Lifting/Lowering Pot (P4). If not present, check the Armrest Board, wiring, and connections.	Approx. 5V	Armrest Board	Lifting/ Lowering Fingertip Module
313	J406-C	C POT	Output from the Lifting/Lowering Pot (P4) wiper to the Armrest Board. If not present, check P4, wiring, and connections. **Note:** Check P4 by disconnecting it from the circuit and reading across it. Approx. 4 Kohms should be read across J406-B and D.	Approx. 2.5V in neutral; range 0V to 5V	Lifting/ Lowering Fingertip Module	Armrest Board
314	J406-D	GND POT	Ground to the Lifting/Lowering Pot (P4). If not present, check the Armrest Board, wiring, and connections.	Battery voltage wrt BT1+	Armrest Board	Lifting/ Lowering Fingertip Module
315	J406-E	MICRO	Input from Lifting/Lowering Directional switch (SW17). If not present, check switch, wiring, and connections.	Approx. 5V closed; 0V open	Lifting/ Lowering Fingertip Module	Armrest Board
316	J406-F	MICRO	Input from Lifting/Lowering Directional switch (SW18). If not present, check switch, wiring, and connections.	Approx. 5V closed; 0V open	Lifting/ Lowering Fingertip Module	Armrest Board
317	J406-G	GND	Ground to Lifting/Lowering Directional switches (SW17 and SW18). If not present, check the Armrest Board, wiring, and connections.	Battery voltage wrt J1+	Armrest Board	Lifting/ Lowering Fingertip Module
318	J407-A	NOT USED				
319	J407-B	+V POT	Voltage to the Tilt Pot (P5). If not present, check the Armrest Board, wiring, and connections.	Approx. 5V	Armrest Board	Tilt Fingertip Module
320	J407-C	C POT	Output from the Tilt Pot (P5) wiper to the Armrest Board. If not present, check P5, wiring, and connections. **Note:** Check P5 by disconnecting it from the circuit and reading across it. Approx. 4 Kohms should be read across J407-B and D.	Approx. 2.5 V in neutral; range 0V to 5V	Tilt Fingertip Module	Armrest Board
321	J407-D	GND POT	Ground to the Tilt Pot (P5). If not present, check the Armrest Board, wiring, and connections.	Battery voltage wrt BT1+	Armrest Board	Tilt Fingertip Module
322	J407-E	MICRO	Input from Tilt Pot Directional switch	Approx. 5V	Tilt	Armrest

			(SW19). If not present, check switch, wiring, and connections.	closed; 0V open	Fingertip Module	Board

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
323	J407-F	MICRO	Input from Tilt Pot Directional switch (SW20). If not present, check switch, wiring, and connections.	Approx. 5V closed; 0V open	Tilt Fingertip Module	Armrest Board
324	J407-G	GND	Ground to Tilt Directional switches (SW19 and SW20). If not present, check the Armrest Board, wiring, and connections.	Battery voltage wrt J1+	Armrest Board	Tilt Fingertip Module
325	J408-A	NOT USED				
326	J408-B	+V POT	Voltage to the Sideshift Pot (P6). If not present, check the Armrest Board, wiring, and connections.	Approx. 5V	Armrest Board	Sideshift Fingertip Module
327	J408-C	C POT	Output from the Sideshift Pot (P6) wiper to the Armrest Board. If not present, check P6, wiring, and connections. **Note:** Check P6 by disconnecting it from the circuit and reading across it. Approx. 4 Kohms should be read across J406-B and D.	Approx. 2.5V in neutral; range 0V to 5V	Sideshift Fingertip Module	Armrest Board
328	J408-D	GND POT	Ground to the Sideshift Pot (P6). If not present, check the Armrest Board, wiring, and connections.	Battery voltage wrt BT1+	Armrest Board	Sideshift Fingertip Module
329	J408-E	MICRO	Input from Sideshift Pot Directional switch (SW21). If not present, check switch, wiring, and connections.	Approx. 5V closed; 0V open	Sideshift Fingertip Module	Armrest Board
330	J408-F	MICRO	Input from Sideshift Pot Directional switch (SW22). If not present, check switch, wiring, and connections.	Approx. 5V closed; 0V open	Sideshift Fingertip Module	Armrest Board
331	J408-G	GND	Ground to Sideshift directional switches (SW21 and SW22). If not present, check the Armrest Board, wiring, and connections.	Battery voltage wrt J1+	Armrest Board	Sideshift Fingertip Module
332	J409-A	NOT USED				
333	J409-B	+V POT	Voltage to the 4th Aux Pot (P7). If not present, check the Armrest Board, wiring, and connections.	Approx. 5V	Armrest Board	4th Aux Fingertip Module
334	J409-C	C POT	Output from the 4th Aux Pot (P7) wiper to the Armrest Board. If not present, check P7, wiring, and connections. **Note:** Check P7 by disconnecting it from the circuit and reading across it. Approx. 4 Kohms should be read	Approx. 2.5V in neutral; range 0V to 5V.	4th Aux Fingertip Module	Armrest Board

			across J409-B and D.			
335	J409-D	GND POT	Ground to the 4th Aux Pot (P7). If not present, check the Armrest Board, wiring, and connections.	Battery voltage wrt BT1+	Armrest Board	4th Aux Fingertip Module

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
336	J409-E	MICRO	Input from 4th Aux Pot (P7) Directional switch (SW23). If not present, check switch, wiring, and connections.	Approx. 5V closed; 0V open	4th Aux Fingertip Module	Armrest Board
337	J409-F	MICRO	Input from 4th Aux Pot (P7) Directional switch (SW24). If not present, check switch, wiring, and connections.	Approx. 5V closed; 0V open	4th Aux Fingertip Module	Armrest Board
338	J409-G	GND	Ground to 4th Aux Pot (P7) Directional switches (SW23 and SW24). If not present, check the Armrest Board, wiring, and connections.	Battery voltage wrt J1+	Armrest Board	4th Aux Fingertip Module
339	PPA B+	B+	B+ to the PPA through Fuse FP. If not present, make sure the battery is connected. Check contactor, fuse, wiring, and connections.	B+	J1+	PPA
340	PPA B–	B–	B– from the battery to the PPA. If not present, make sure the battery is connected. Check wiring and connections.	Battery voltage wrt BT1+	BT1	PPA
341	PPA (U)	PPA (U)	One of three phases from the PPA to the Pump Motor. Voltage is measured between any two phases. If not present, check the PPA, wiring, and connections.	0 to approx. 20VAC; Approx. 200A ramping; Approx. 250A full lift	PPA	PM
342	PPA (V)	PPA (V)	One of three phases from the PPA to the Pump Motor. Voltage is measured between any two phases. If not present, check the PPA, wiring, and connections.	0 to approx. 20VAC; Approx. 200A ramping; Approx. 250A full lift	PPA	PM
343	PPA (W)	PPA (W)	One of three phases from the PPA to the Pump Motor. Voltage is measured between any two phases. If not present, check the PPA, wiring, and connections.	0 to approx. 20VAC; Approx. 200A ramping; Approx. 250A full lift	PPA	PM
344	TPA B+	B+	B+ to the TPAs through Fuses FT1 and FT2. If not present, make sure the battery is connected. Check contactor, fuse, wiring, and connections.	B+	J1+	TPAs
345	TPA B–	B–	B– from the battery to the TPAs. If not present, make sure the battery is connected. Check the wiring and connections.	Battery voltage wrt BT1+	J1–	TPAs

			connections.			

Pinout Matrix

Item	Connection	Function Description	Theory of Operation	Normal Level	Signal Source	Signal User
346	TPA (UM)	TPA (UM)	One of three phases from the Master TPA to the Right Traction Motor. Voltage is measured between any two phases. If not present, check the TPA, wiring, and connections.	0 to approx. 20VAC; Approx. 50A ramping; Approx. 35A full speed on jack	Master TPA	Right Traction Motor
347	TPA (VM)	TPA (VM)	One of three phases from the Master TPA to the Right Traction Motor. Voltage is measured between any two phases. If not present, check the TPA, wiring, and connections.	0 to approx. 20VAC; Approx. 50A ramping; Approx. 35A full speed on jack	Master TPA	Right Traction Motor
348	TPA (WM)	TPA (WM)	One of three phases from the Master TPA to the Right Traction Motor. Voltage is measured between any two phases. If not present, check the TPA, wiring, and connections.	0 to approx. 20VAC; Approx. 50A ramping; Approx. 35A full speed on jack	Master TPA	Right Traction Motor
349	TPA (US)	TPA (US)	One of three phases from the Slave TPA to the Left Traction Motor. Voltage is measured between any two phases. If not present, check the TPA, wiring, and connections.	0 to approx. 20VAC; Approx. 50A ramping; Approx. 35A full speed on jack	Slave TPA	Left Traction Motor
350	TPA (VS)	TPA (VS)	One of three phases from the Slave TPA to the Left Traction Motor. Voltage is measured between any two phases. If not present, check the TPA, wiring, and connections.	0 to approx. 20VAC; Approx. 50A ramping; Approx. 35A full speed on jack	Slave TPA	Left Traction Motor
351	TPA (WS)	TPA (WS)	One of three phases from the Slave TPA to the Left Traction Motor. Voltage is measured between any two phases. If not present, check the TPA, wiring, and connections.	0 to approx. 20VAC; Approx. 50A ramping; Approx. 35A full speed on jack	Slave TPA	Left Traction Motor

Section A. Appendix

Lubrication Specification Chart

Approved *Raymond* Lubricants			
Where Used	**Type**	**Specification**	***Raymond* Part Number**
Drive Unit Gear Case	Transmission Fluid	ATF II Type A suffix A	990-623/001 (1 gal/3.8 liters) 990-623/004 (1 qt./0.9 liter)
Hydraulic Brake	Brake Fluid	SAE J1730-JAN80 DOT-4	990-DOT/004
Hydraulic Reservoir (Non-CS trucks (+50°F to +120°F) (+10°C to +49°C)	Hydraulic Fluid	ISO 46 Anti-Wear Hydraulic Fluid	990-616/04 (1 qt./0.9 liter) 990-616/01 (1 gal/3.8 liters) 990-616/03 (5 gal/18.9 liters)
Hydraulic Reservoir (CS trucks) (–20°F to 0°F) (–29°C to –18°C) (confined to freezer)	Hydraulic Fluid	MIL-H-5606E	990-618/01 (1 gal/3.8 liters)
Hydraulic Reservoir (CS trucks) (0°F to +50°F) (–18°C to +10°C) (in and out of freezer)	Hydraulic Fluid	ISO VG32	1017238 (5 gal/18.9 liters) 1017238/01 (55 gal/208 liters)
Lift Chains	Teflon Grease	Aerosol	990-652/001 (spray)
Mast Uprights, Bearings	Grease	NLGI Grade 2	1012992/01 (10 cartridges/case) 1012992/02 (5 gal/18.9 liters)
Mast Uprights, Bearings, (CS trucks)	Grease w/Teflon	NLGI Grade 2	1012992/01 (10 cartridges/case) 1012992/02 (5 gal/18.9 liters)

Thread Adhesives, Sealants, and Lubricants

Application	Raymond P/N	*Loctite* Number/Color
Thread-locking 1/4 in. and below	990-403	222/Purple
Thread-locking 1/4 to 3/4 in., contamination tolerant	990-536	243/Blue
Thread-locking 1 in. and under	990-544	271/Red
Thread-locking 1 in. and under, contamination tolerant	990-463	603/Green
Thread-locking 1 in. and over	990-571	277/Red
Thread-locking Cleaner/Primer	990-538	7075
Thread-locking Primer	990-533	T7471
Hydraulic Sealant, fittings up to 2 in.	990-552	569
Molybdenum Anti-Seize Compound (Molykote)	990-638	Silver
Gasket Cement	990-556	Permatex 300
Cover Plate Sealant	990-443	587/UltraBlue
Corrosion Inhibitor Coating	990-456/001	N/A
Silicone Sealant (cold storage)	990-445	Dow Corning III

NOTE: *Loctite* is a registered trademark of the Loctite Corporation. Brand endorsement is not implied here, but listed only as a commonly identified product.

Component Specific Torque/Information

Chart

Component	Sub-Component(s)	Thread-Locking Compound	Torque to:
Counterweight	mounting bolts	N/A	200 ft. lb. (300 Nm)
Drive Unit	fluid fill and drain plugs	N/A	16 ft. lb. (22 Nm)
	mounting bolts to chassis	N/A	100 ft. lb. (135 Nm)
Hydraulic Pump	mounting bolts to motor	990-536	33 ft. lb. (45 Nm)
Mast	bearing cap bolts (secures mast base to chassis)		36 ft. lb. (49 Nm)
Power Amplifiers	power cables	N/A	8.8 to 11 ft. lb. (12 to 15 Nm)
Pump Motor	end bell retaining bolts	N/A	8 ft. lb. (11 Nm)
	power cables	N/A	18 ft. lb. (24 Nm)
Quad Mast Cylinders	check valves (right side main lift cylinder)	990-403	50 in. lb. (5.65 Nm)
	lift cylinder piston retainer	N/A	95 to 125 ft. lb. (129 to 169 Nm)
Static Strap	mounting hardware	990-536	15 ft. lb. (21 Nm)
Steer Axle	mounting bolts	N/A	96 ft. lb. (130 Nm)
Steer Wheels	lug nuts	N/A	133 ft. lb. (180 Nm)
Traction Motor	power cables	N/A	18 ft. lb. (24 Nm)
	end bell retaining bolts		15 ft. lb. (21 Nm)
	mounting bolts to drive unit	N/A	17 ft. lb. (23 Nm)
Traction Wheels	lug nuts	N/A	103 ft. lb. (140 Nm)
Tire Replacement	A minimum pressure of 5 tons (4536 kg) is required to press on a new tire. If the minimum pressure is not met, replace the hub.		

Torque Chart - Standard (Ferrous)

Grade Identification Marking	None					
Size	SAE Grade 2 Bolts Tightening Torque		SAE Grade 5 Bolts Tightening Torque		SAE Grade 8 Bolts Tightening Torque	
	Dry	Oiled	Dry	Oiled	Dry	Oiled
	in. lb.	in. lb.	in. lb.	in. lb.	in. lb.	in. lb.
4-40	5	4	8	6	12	9
4-48	6	5	9	7	13	10
6-32	10	8	16	12	23	17
8-32	19	14	30	22	41	31
8-36	20	15	31	23	43	32
10-24	27	21	43	32	60	45
10-32	31	23	49	36	68	51
1/4-20	66	49	96	75	144	108
1/4-28	78	56	120	86	168	120
	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.	ft. lb.
5/16-18	11	8	17	13	25	18
5/16-24	12	9	19	14	25	20
3/8-16	20	15	30	23	45	35
3/8-24	23	17	35	25	50	35
7/16-14	30	24	50	35	70	55
7/16-20	35	25	55	40	80	60
1/2-13	50	35	75	55	110	80
1/2-20	55	40	90	65	120	90
9/16-12	65	50	110	80	150	110
9/16-18	75	55	120	90	170	130
5/8-11	90	70	150	110	220	170
5/8-18	110	85	180	130	240	180
3/4-10	160	120	260	200	380	280
3/4-16	180	140	300	220	420	320
7/8-9	140	110	400	300	600	460
7/8-14	155	120	440	320	660	500
1-8	220	160	580	440	900	680
1-12	240	170	640	480	1000	740
1 1/8-7	300	220	800	600	1280	960
1 1/8-12	340	260	880	660	1440	1080
1 1/4-7	420	320	1120	840	1820	1360
1 1/4-12	460	360	1240	920	2000	1500
1 3/8-6	560	420	1460	1100	2380	1780
1 3/8-12	640	460	1680	1260	2720	2040
1 1/2-6	740	560	1940	1460	3160	2360
1 1/2-12	840	620	2200	1640	3560	2660

1 1/2-12	840	620	2200	1640	3360	2660

NOTE: Use “oiled” values for bolts with thread-locking compound.

Torque Chart - Metric

Ferrous Metric Bolts, Coarse Thread (The grade rating is stamped on the head of the bolt)				
Diameter (in millimeters)	Grade 8.8		Grade 10.9	
	Torque (with bolts oiled)		Torque (with bolts oiled)	
	Nm	ft. lb.	Nm	ft. lb.
6	8.6	6	12	9
8	21	15	29	21
10	42	30	68	43
12	72	55	101	75
16	174	130	245	181
20	340	255	475	350
24	580	435	820	605
NOTE: Use “oiled” values for bolts with thread-locking compound.				

Brass MS63 Metric Bolts, Coarse Thread		
Diameter (in millimeters)	Torque (with bolts oiled)	
	Nm	in. lb.
3	0.5	4.4
3.5	0.79	7.0
4	1.2	10
5	2.2	19
6	3.9	34
8	9	79
10	17	150
NOTE: Use “oiled” values for bolts with thread-locking compound.		

Torque Chart - Standard (Brass)

Brass MS63 Standard Bolts, Coarse Thread		
Size	**Torque (with bolts oiled)**	
	Nm	**in. lb.**
4-40	0.37	3.3
4-48	0.40	3.6
6-32	0.69	6.1
6-40	0.77	6.8
8-32	1.24	11
8-36	1.24	11
10-24	1.58	14
10-32	1.92	17
1/4-20	3.96	35
1/4-28	4.52	40
5/16-18	8.25	73
5/16-24	9.15	81
3/8-16	14.69	130
3/8-24	16.61	147
NOTE: Use “oiled” values for bolts with thread-locking compound.		

Decimal Equivalent Chart

4ths	8ths	16ths	32nds	64ths	To 3 Places	To 2 Places	MM Equivalent
				1/64	.016	.02	0.397
			1/32		.031	.03	0.794
				3/64	.047	.05	1.191
		1/16			.062	.06	1.587
				5/64	.078	.08	1.984
			3/32		.094	.09	2.381
				7/64	.109	.11	2.778
	1/8				.125	.12	3.175
				9/64	.141	.14	3.572
			5/32		.156	.16	3.969
				11/64	.172	.17	4.366
		3/16			.188	.19	4.762
				13/64	.203	.20	5.159
			7/32		.219	.22	5.556
				15/64	.234	.23	5.593
1/4					.250	.25	6.350
				17/64	.266	.27	6.747
			9/32		.281	.28	7.144
				19/64	.297	.30	7.540
		5/16			.312	.31	7.937
				21/64	.328	.33	8.334
			11/32		.344	.34	8.731
				23/64	.359	.36	9.128
	3/8				.375	.38	9.525
				25/64	.391	.39	9.922
			13/32		.406	.41	10.319
				27/64	.422	.42	10.716
		7/16			.438	.44	11.112
				29/64	.453	.45	11.509
			15/32		.469	.47	11.906
				31/64	.484	.48	12.303
1/2					.500	.50	12.700

Decimal Equivalent Chart

4ths	8ths	16ths	32nds	64ths	To 3 Places	To 2 Places	MM Equivalent
				33/64	.516	.52	13.097
			17/32		.531	.53	13.494
				35/64	.547	.55	13.891
		9/16			.562	.56	14.288
				37/64	.578	.58	14.684
			19/32		.594	.59	15.081
				39/64	.609	.61	15.478
	5/8				.625	.62	15.875
				41/64	.641	.64	16.272
			21/32		.665	.66	16.669
				43/64	.672	.67	17.065
		11/16			.688	.69	17.462
				45/64	.703	.70	17.859
			23/32		.719	.72	18.256
				47/64	.734	.73	18.653
3/4					.750	.75	19.050
				49/64	.766	.77	19.447
			25/32		.781	.78	19.844
				51/64	.797	.80	20.241
		13/16			.812	.81	20.637
				53/64	.828	.83	21.034
			27/32		.844	.84	21.431
				55/64	.859	.86	21.828
	7/8				.875	.88	22.225
				57/64	.891	.89	22.622
			29/32		.906	.91	23.019
				59/64	.922	.92	23.416
		15/16			.938	.94	23.812
				61/64	.953	.95	24.209
			31/32		.969	.97	24.606
				63/64	.984	.98	25.003
					1.000	1.00	25.400

Standard/Metric Conversions

To Convert...	Multiply, Add, or Subtract...
Area	
Square Inches to Square Centimeters	Square Inches x 6.452
Square Centimeters to Square Inches	Square Centimeters x 0.155
Square Feet to Square Meters	Square Feet x 0.093
Square Meters to Square Feet	Square Meters x 10.753
Square Yards to Square Meters	Square Yards x 0.836
Square Meters to Square Yards	Square Meters x 1.196
Distance	
Inches to Millimeters	Inches x 25.4
Millimeters to Inches	Millimeters x 0.039
Inches to Centimeters	Inches x 2.54
Centimeters to Inches	Centimeters x 0.394
Feet to Meters	Feet x 0.305
Meters to Feet	Meters x 3.281
Yards to Meters	Yards x 0.914
Meters to Yards	Meters x 1.094
Miles to Kilometers	Miles x 1.609
Kilometers to Miles	Kilometers x 0.621
Mass	
Ounces to Grams	Ounces x 28.35
Grams to Ounces	Ounces x 0.035
Ounces to Kilograms	Ounces x 0.028
Kilograms to Ounces	Kilograms x 35.27
Pounds to Kilograms	Pounds x 0.454
Kilograms to Pounds	Kilograms x 2.2
Pressure	
Pounds per Square Inch (PSI) to kiloPascals	PSI x 6.894
kiloPascals to Pounds per Square Inch (PSI)	kiloPascals x 0.145
Speed	
Miles per hour to Kilometers per hour	Miles per hour x 1.609
Kilometers per hour to Miles per hour	Kilometers per hour x 0.6214
Temperature	
Fahrenheit to Celsius	(°F minus 32) x 0.555
Celsius to Fahrenheit	(°C x 1.8) plus 32
Torque	
Inch Pounds (in. lbs.) to Newton Meters (Nm)	Inch Pounds x 0.113
Newton Meters (Nm) to Inch Pounds (in. lbs.)	Newton Meters x 8.85
Foot Pounds (ft. lbs.) to Newton Meters (Nm)	FootPounds x 1.3568
Newton Meters (Nm) to Foot Pounds (ft. lbs.)	Newton Meters x 0.737