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SAFETY PRECAUTIONS

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SAFETY PRECAUTIONS

SAFETY SIGNS AND SAFETY MESSAGES

Improper service operation can cause accidents. Don't take chances with incorrect or damaged equipment. **Read** and **understand** the procedures for safe driving and maintenance outlined in the is manual. Don't hesitate to ask for help. **Stay alert!** Follow safety rules, regulations, and procedures. Avoid accidents by recognizing dangerous procedures or situations before they occur. **Drive and work safely** and follow the safety signs and their messages on the truck and in this manual.

Safety signs and messages are placed in this manual and on the truck to provide instructions and identify specific areas where potential hazards exist and special precautions should be taken. Know and understand the meaning of these instructions, signs, and messages. Damage to the truck, death, or serious injury to you or other persons may result if these messages are not followed. **If warning decals are damaged, they must be replaced.**

NOTICE

This message is used when special information, instructions, or identification are required relating to procedures, equipment, tools, pressures, capacities, and other special data.

IMPORTANT

This message is used when special precautions should be taken to ensure a correct action or to avoid damage to or malfunction of the truck or a component

CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices.

WARNING

Indicates a potentially hazardous situation which, if not avoided, may result in death or serious injury.

DANGER

Indicates a potentially hazardous situation which, if not avoided, will result in death or serious injury.

SAFETY PRECAUTIONS

GENERAL SAFETY RULES

- Wear **ALL** Personnel Protective Equipment, or PPE, as dictated by the work being done as well as any company policy. It is recommended that safety glasses, a hard hat and protective footwear always be warn as well as hearing protection if noise is excessive.

- Do **NOT** wear loose clothing or jewelry that can catch on controls or other parts of the forklift. Make sure long hair is tied back and out of the way of moving parts.

- Attach an "**OUT OF SERVICE**" or similar warning tag to the key switch before servicing or repairing any forklift. Disconnect battery if leaving unattended.

- Keep **ALL** equipment guards and shield in place and installed correctly to prevent vibration, rubbing and heat buildup.

- Keep a fire extinguisher and first aid kit available **AT ALL TIMES**.

- Use **ONLY** adequately rated lift equipment with capacity labeled or marked. Use supports or straps on any component or structural member that may fall.

GENERAL SAFETY RULES (CONT'D)

- Support equipment and attachments properly when working beneath them. Do **NOT** rely on the vehicle hydraulics or hydraulic jacks to support the equipment.

- Keep the forklift free of dirt and oil. Secure **ALL** loose items such as tools that are not part of the forklift.

- **ALWAYS** use the proper tool for the job and keep tools clean and in good working order.

- **NEVER** stand under suspended loads or raised forks or implements.

- Beware of pedestrians in the area. **NEVER** assume they see you. Do **NOT** proceed until they are aware of your intended actions and have moved clear of the area.

- Read and thoroughly understand the Owner's and Operator's Manual **PRIOR** to operating the forklift.

- Obey **ALL** traffic rules and warning signs.

- Do **NOT** let any unauthorized personnel operate the forklift at any time. **NEVER** carry passengers on **ANY** part of the forklift.

- Do **NOT** stand on or between the counterweight when extended.

- Do **NOT** climb on any part of the mast or overhead guard/cab structure or permit others to do so.

- Stay clear of **ALL** rotating and moving parts.

MAINTENANCE SAFETY PRACTICES

Provisions for Maintenance
Powered industrial trucks may become hazardous if maintenance is neglected or repairs, rebuilds or adjustments are performed contrary to manufacturer's criteria. Therefore maintenance and inspection shall be performed in accordance with the manufacturer's recommendations and the following practices:

- Planned maintenance, including but not limited to, lubrication and inspection shall be performed in accordance with the Preventative Maintenance Schedule provided in this manual.
- Only trained and authorized personnel shall be permitted to maintain, repair, adjust and inspect industrial trucks in accordance with the provided specifications.
- Brakes, Steering Mechanisms, Control Mechanisms, Warning Devices, Lights, Lift Overload Devices, Guards and Safety Devices, Steer Axle Articulation Stops, and Frame Members shall be carefully and regularly inspected and maintained in a safe operation condition.

Before Starting Any Maintenance

- Park the forklift in authorized areas **ONLY**
- Park the forklift on a level surface with the forks fully lowered and the mast tilted forward such that the fork tips touch the ground. **NEVER** work on soft ground.
- Place the transmission in **NEUTRAL**
- Stop the engine **AND** set the Parking Brake
- Remove the key and tag the forklift **OUT OF SERVICE**
- Block the drive wheels. Block the load engaging means, mast, and chassis **WHENEVER** working on them

MAINTENANCE SAFETY PRACTICES (CONT'D)

Cleaning

- When using compressed (pressurized) air always use a general purpose nozzle to blow dust and dirt from work area. **ALWAYS** wear eye protection, protective clothing and protective shoes. Visually inspect the area prior to using an air hose. The maximum pressure should **NOT** exceed 30 psi.

- Use **ONLY** approved, safe cleaning agents and solvents.

- Clean exterior of all parts when repairing. **ALWAYS** wear eye protection when steam cleaning.

- Do **NOT** use steam, solvent, or high pressure to clean electrical components.

Engine and Cooling System

- Stop the engine whenever possible **BEFORE** performing service.

- Always start and run the engine in a well ventilated area. Avoid prolonged running of the engine in closed areas. Vent exhaust to outside. **NEVER** operate the engine in a closed building.

- Do **NOT** remove the radiator cap when the engine is running or hot. Engine coolant is hot and under pressure and can cause severe burns. Allow the truck to cool down to where the radiator cap is cool to the touch. When removing the radiator cap, turn slowly to relieve pressure.

- When adding coolant **MAKE SURE** it is compatible and will mix with existing coolant.

- Cooling system additives contain alkali the can cause personnel injury. Avoid contact with the skin and eyes. Do **NOT** ingest.

- Keep objects **ALL** away from moving fan blades.

MAINTENANCE SAFETY PRACTICES (CONT'D)

- Do **NOT** use starting fluid. Use of starting fluid with an engine equipped with an intake heater can result in severe engine damage.
- Do **NOT** tamper with or modify the exhaust in any way.

Fuel System

- All fuels are flammable and **MUST** be handled with care.
- **NEVER** refuel the machine while the engine is running.
- **NEVER** refuel or service the fuel system while smoking or near open flames or sparks.
- Fuel leaked or spilled on hot surfaces or components **CAN CAUSE A FIRE**.
- Before disconnecting any part of the fuel system on LP gas powered trucks, close LP tank valves and run the engine **UNTIL FUEL IS DEPLETED** and engine stops. If the engine will not run, close LP truck valve and vent fuel slowly in a non-hazardous area.
- Use extreme care to prevent contamination from dirt and moisture. Contaminated fuel can result in **SEVERE** engine damage.
- **ALWAYS** clean up fuel spills.

Hydraulics

- Hydraulic systems present a **HIGH PRESSURE FLUID HAZARD**. System pressure **MUST** be relieved **PRIOR** to repairing, adjusting, or disconnecting **ANY** part of the hydraulic system, including loosening hoses and tubes. With the truck **OFF,** operate all controls including steering and braking to relieve stored pressure. This will also prevent unintended movement of the steering mechanism when servicing.
- **NEVER** use your hands to find a pressure leak. When check for leaks **ALWAYS** use a board or piece of cardboard. **ALWAYS** wear proper hand and eye protection. Even a pinhole size leak can penetrate skin. If **ANY** fluid is injected into the skin it must be treated by a doctor I**MMEDIATELY**.

MAINTENANCE SAFETY PRACTICES (CON'TD)

- At operating temperature the hydraulic tank will be hot. Remove the hydraulic tank filter cap and cleanout cover **ONLY AFTER** engine has been stopped and the filter cap and cleanout cover are cool to the touch. Remove slowly to allow any trapped pressure to escape.

- Hot fluid and components can cause personal injury. Do **NOT** allow hot oil or components to contact the skin.

- Ensure **ALL** hydraulic connections are tight and keep **ALL** components in good repair.

- Inspect hoses for damaged or leaking end fittings, chafed or cut outer covering, localize ballooning or swelling, and evidence of kinking or crushing. **REPLACE** if any of these conditions are present.

- All fluids should be handled with care. If you ingest any fluid or get fluid in the eyes seek **IMMEDIATE** medical attention.

Electrical

- Batteries give off flammable fumes which can explode. Keep sparks, flames and cigarettes **AWAY**. Use a flashlight to check electrolyte level if necessary.

- **BEFORE** servicing the electrical system disconnect the battery negative (-) cable to prevent short circuits.

- Battery electrolyte can cause personal injury if it contacts skin or eyes. **ALWAYS** wear PPE and in case of contact rinse area thoroughly with water and seek **IMMEDIATE** medical attention.

MAINTENANCE SAFETY PRACTICES (CON'TD)

- Charge batteries in well ventilated areas **ONLY**.
- **ALWAYS** wash hands after handling batteries.
- Clean and tighten **ALL** electrical connections. Check for loose or frayed wires and if found repair or replace **BEFORE** operating the forklift.
- Do **NOT** operate in the vicinity of overhead power lines. Electrocution can occur without direct contact.

Wheels and Tires

- Do **NOT** attempt to service a tire unless you have the proper equipment and training.
- **ALWAYS** wear PPE.
- Do **NOT** rely on the vehicle hydraulics or a hydraulic jack to support the forklift. The forklift **MUST** be supported by suitable blocks or stands.
- Keep tires inflated to correct pressure. Do **NOT** over inflate tires.
- Servicing tires is potentially **DANGEROUS**. See Section 4, "TIRE & WHEEL SAFETY" for detailed warnings and precautions.

MAINTENANCE SAFETY PRACTICES (CON'TD)

Fire and Explosion Prevention

- Store all fuels and lubricants in approved, properly marked containers and **AWAY FROM** unauthorized personnel.
- **ALL** oily rags and other flammable material should be placed in protective containers and stored appropriately.
- **NEVER** weld, cut or grind on pipes, tubes, or reservoirs that contain flammable materials.
- Do **NOT** operate in areas where explosive gases are present or suspected.

DO'S AND DON'T'S

Don't mix drugs or alcohol with your job.

Do watch for pedestrians

Don't block safety or emergency equipment

Do wear safety equipment when required.

Don't smoke in **"NO SMOKING"** areas or when refueling.

LOCKOUT TAGOUT PROCEDURE

Purpose

This procedure establishes the minimum requirements for lockout/tagout of energy sources that could cause injury to personnel. All employees shall comply with the procedure.

Responsibility

The responsibility for seeing that this procedure is followed is binding upon all employees. All employees shall be instructed in the safety significances of the lockout/tagout procedure by (designated individual). Each new or transferred affected employee shall be instructed by (designated individuals) in the purpose and use of the lockout/tagout procedure.

Preparation for Lockout/Tagout

Employees authorized to perform lockout/tagout shall be certain as to which switch, valve, or other energy isolating devices apply to the equipment being locked out/tagged out. More than one energy source (electrical, mechanical, or others) may be involved. Any questionable identification of their supervisors. Before lockout/tagout commences, job authorization should be obtained.

Sequence of Lockout/Tagout Procedure

1. Notify all affected employees that a lockout/tagout is required and the reason therefor.
2. If the equipment is operating, shut it down by the normal stopping procedure.
3. Operate the switch, valve, or other energy isolating device so that the energy source(s) (electrical, mechanical, hydraulic, etc.) is disconnected or isolated from the equipment. Stored energy, such as that in capacitors, springs, elevated crane members, rotating flysteam, or water pressure, etc. must also be dissipated or restrained by methods such as grounding, repositioning, blocking, bleeding down, etc.
4. Lockout/tagout the energy isolating devices with an assigned individual lock/tag.
5. After ensuring that no personnel are exposed and as a check on having disconnected the energy sources, operate the push button or other normal operating controls to make certain the equipment will not operate.

CAUTION: Return operating controls to neutral after the test.

6. The equipment is now locked out/tagged out.

Restoring Equipment to Service

1. When the job is complete and equipment is ready for testing or normal service, check the equipment area to see that no one is exposed.
2. When equipment is all clear, remove all locks/tags. The energy isolating devices may be operated to restore energy to equipment.

Procedure Involving More Than One Person

In the preceding steps, if more than one individual is required to lockout/tagout equipment, each shall place their own personal lock/tag on the energy isolating device(s). One designated individual of a work crew or a supervisor, with the knowledge of the crew, may lockout/tagout equipment for the whole crew. In such cases, it shall be the responsibility of the individual to carry out all steps of the lockout/tagout procedure and inform he crew when it is safe to work on the equipment. Additionally, the designated individual shall not remove a crew lock/tag until it has been verified that all individuals are clear.

Rules for Using Lockout/Tagout Procedure

All equipment shall be locked out/tagged out to protect against accidental or inadvertent operation when such operation could cause injury to personnel. Do not attempt to operate any switch, valve, or other energy isolating device bearing a locktag

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NOTICE

THIS SECTION IS FOR TRAINED SERVICE PERSONNEL to use as reference for Planned Maintenance procedures.

Maintenance information for Operators can be found in the "Hoist Material Handling Operator's And Owner's Manual"

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– PLANNED MAINTENANCE

INTRODUCTION

Only Trained and Authorized Personnel should perform planned maintenance. Local Hoist Material Handling dealers are prepared to establish a planned maintenance program for checking and maintaining their lift trucks according to applicable safety regulations.

CAUTION

Powered industrial trucks may become hazardous and dangerous to operate if maintenance is neglected.

As outlined in the HMH Operators Manual, the operator should make a daily safety inspection of the lift truck before operating it. The purpose of this daily examination is to check for any obvious damage and maintenance problems and to have minor adjustments and repairs made to correct any unsafe condition.

In addition to the operator's daily inspection, HMH recommends that the owner set up and follow a periodic planned maintenance (PM) and inspection program . Performed on a regular basis by trained personnel, the program provides thorough inspection and checks of the safe operation condition of the lift truck. The "PM" identifies needed adjustments, potential repairs, or part replacements so they can be addressed before failure occurs. The specific schedule (frequency) for the PM inspections depends on the particular application and lift truck usage.

This section recommends TYPICAL Planned Maintenance and Lubrication Schedules for items essential to the safety, longevity, and performance of the truck. It also outline safe maintenance practices and gives brief procedures for inspections, operational checks, cleaning, lubrication, and minor adjustments.

Specifications for selected components are found in later sections of this manual.

If you have need for more information on the care and/or repair of your truck, contact your HMH dealer.

SAFE MAINTENANCE PRACTICES

The following instructions have been prepared from current industry and government safety standards applicable to industrial truck operation and maintenance. These recommended procedures specify conditions, methods, and accepted practices that aid in the safe maintenance of industrial trucks. They are listed here for the reference and safety of all workers during maintenance operations. Carefully read and understand these instructions and the specific maintenance procedures **before attempting to do any repair work.**

1. Powered industrial trucks can become hazardous if maintenance is neglected. Therefore, suitable maintenance facilities as well as trained personnel and procedures shall be provided.

2. Maintenance and inspection of all powered industrial trucks shall be performed in conformance with the manufacturer's recommendations.

3. Follow a scheduled planned maintenance, lubrication, and inspection system.

4. Only trained and authorized personnel are permitted to maintain, repair, adjust, and inspect industrial trucks - and must do so in accordance with the manufacturer's specifications.

5. Always wear safety glasses. Wear a safety (hard) hat in industrial plants and in special work areas where protection is necessary and required. Hearing protection and any other personal protective equipment (PPE) must comply with OSHA and all company policies specific to the task at hand.

6. Properly ventilate work area, vent exhaust fumes, and keep shop clean and floors dry.

7. Avoid fire hazards and have fire protection equipment present in the work area. **Do not** use an open flame to check for level or leakage fuel, electrolyte, or coolant. **Do not** use open pans of fuel of flammable cleaning fluids for cleaning parts.

8. Operation of the truck to check performance must be conducted in an authorized, safe, clear area.

9. Before starting to operate the truck:

    A. Be seated in the normal operating position and fasten your seat belt.

    B. Make sure the parking brake is applied.

    C. Put the directional control lever in NEUTRAL.

    D. Start the engine.

    E. Check proper function of lift and tilt systems, direction and speed controls, steering, brakes, warning devices, and load handling attachments.

SAFE MAINTENANCE PRACTICES (CONT'D)

10. Before exiting the truck:
    A. Stop the truck.
    B. Fully lower the load-engaging means: mast, carriage, forks or attachments.
    C. Put the direction control in NEUTRAL.
    D. Apply the parking brake by PULLING the park brake switch out.
    E. Stop the engine.
    F. Turn the key switch to the OFF position.
    G. Chock the wheels if the truck must be left on an incline.
11. Brakes, steering mechanisms, control mechanisms, warning devices, lights, governors, lift overload devices, lift and tilt mechanisms, axle articulation stops, load back rest, overhead guard and frame members must be carefully and regularly inspected and maintained in a safe operating condition.
12. Special trucks or devices designed and approved for hazardous area operation must receive special attention to insure that maintenance preserves the original approved safe operating features.
13. Fuel systems must be checked for leaks and condition of parts. Special consideration MUST be given in the case of a fuel system leak. Action must be taken to prevent the use of the truck until the leak has been corrected.
14. All hydraulic systems must be regularly inspected and maintained in conformance with accepted good practices. Tilt and lift cylinders, valves, and other parts must be checked to assure that "drift" or leakage has not developed to the extent that it would create a hazard.
15. When working on the hydraulic system, be sure the engine is turned off, masts are in the fully-lowered position, and hydraulic pressure is relieved in hosing and tubing.
16. The truck manufacturer's capacity, operation, and maintenance instruction plates, tags, or decals must be maintained in legible condition. Illegible or missing decals **MUST** be replaced as mandated by OSHA.
17. Batteries, limit switches, protective devices, electrical conductors, and connections must be maintained in conformance with accepted good practices. Special attention must be paid to the condition of electrical insulation.

SAFE MAINTENANCE PRACTICES (CONT'D)

18. To avoid injury to personnel or damage to the equipment, consult the manufacturer's procedures in replacing contacts on any battery connection.

19. Industrial trucks must be kept in a clean condition to minimize fire hazards and help in the detection of loose or defective parts.

20. Modifications and additions that affect capacity and safe truck operation must not be done without the manufacturer's prior written approval. Capacity, operation, and maintenance instruction plates, tags, or decals must be changed accordingly.

21. Care must be taken to assure that all replacement parts, including tires, are interchangeable with the original parts and of a quality at least equal to that provided in the original equipment. Parts, including tires, are to be installed per the manufacturer's procedures.

22. Use special care when removing heavy components such as counterweights, masts, etc. Be sure that lifting and handling equipment is of the correct capacity and in good condition.

23. Before starting any work on a truck:

    A. Raise drive wheels off floor and use oak blocks or other positive truck positioning devices.

    B. Remove all jewelry.

    C. Put oak blocks under the load-engaging means, inner masts, or chassis before working on them.

    D. Disconnect the battery ground cable (-) before working on the electrical system.

CAUTION

Refer to the "Lifting, Jacking, and Blocking" section in the reference section for complete procedures.

SAFE MAINTENANCE PRACTICES (CONT'D)

IMPORTANT

Your new lift truck has been built to meet all applicable mandatory requirements of ANSI B56.1 Safety Standard for Powered Industrial Trucks. Each truck also includes certain safety devices - such as a horn, operator protective structure, and backup alarms - as standard equipment. No additions, omissions, or modifications should be made that affect compliance to the above requirements or in any way minimize the effectiveness of any safety device.

NOTICE

You should be familiar with additional operating and maintenance safety instructions contained in the following publications:

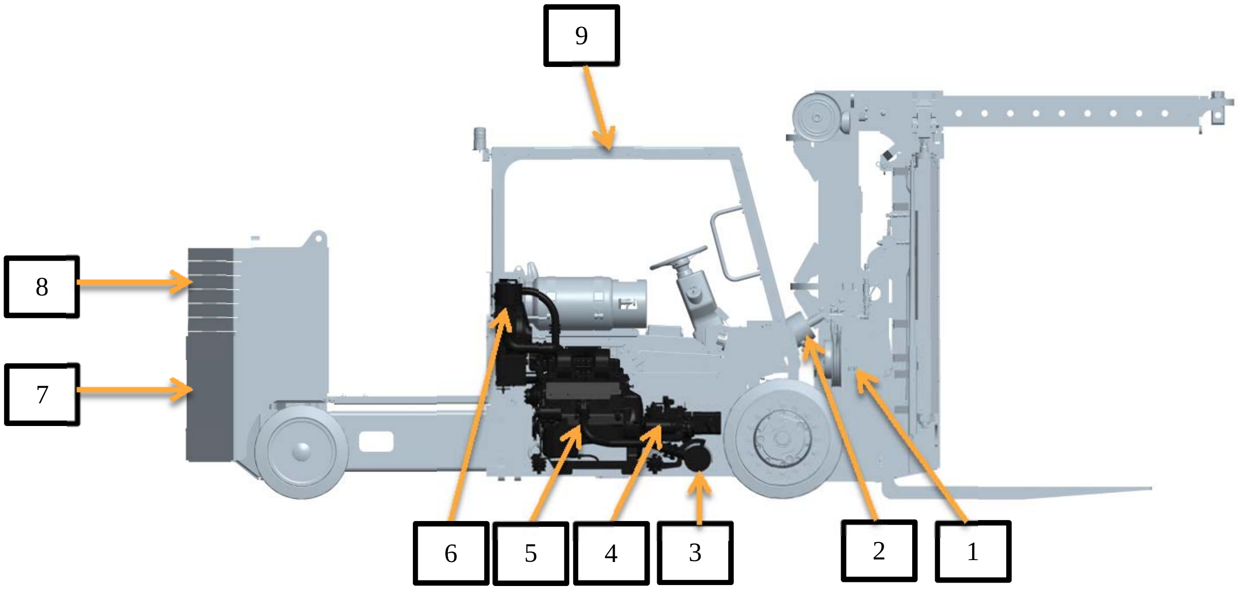
ANSI/ASME B56.1 Safety Standard for Low Lift and High Lift Trucks (Safety Code for Powered Industrial Trucks). Published by: Society of Mechanical Engineers, United Engineering Center, 345 E. 47th Street, New York, NY 100017. This standard is available for free at WWW.ITSDF.ORG

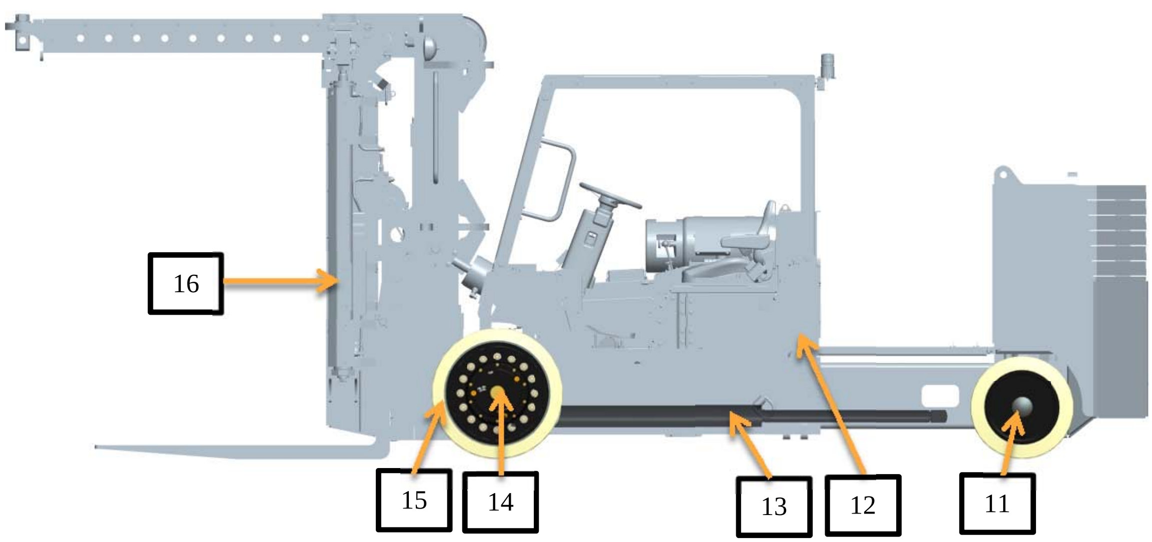
NFPA 505-1982: Fire Safety Standard for Powered Industrial Trucks: Type Designations, Areas of Use, Maintenance and Operation. Available form National Fire Protection Association, Inc., Batterymarch Park, Quincy, MA 02269.

General Industrial Standards, OSHA 2206: OSHA Safety and Health Standards (929 CFR 19010), Subpart N-Materials Handling and Storage, Section 19010.178 Powered Industrial Trucks. For sale by: Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

MAJOR COMPONENT LOCATIONS

Use the illustration below to help locate systems/components included in the PM procedures.





1. Mast, Carriage, & Forks
2. Tilt Cylinders
3. Exhaust System
4. Hydrostatic Pump & Gear Pump
5. Engine
6. Air Cleaner & Cooling System
7. Rear Chassis
8. Counterweights
9. Overhead Guard
11. Steer Axle, Steer Wheel & Steer Tire
12. Front Chassis
13. Frame Extend Cylinder
14. Drive Wheel Torque Hub & Hydrostatic Motor
15. Drive Wheel & Tire
16. Optional Boom Assembly

PLANNED MAINTENANCE INTERVALS

Intervals for scheduled maintenance may need to be reduced as operating conditions dictate. For example, operation in sandy/dusty locations requires shorter maintenance intervals than operation in clean warehouses. The intervals provided in this manual are intended for normal operation. The operating condition classifications are:

Normal Operation

Eight-hours per day, mostly in buildings or in clean, open air environments, operating on paved surfaces.

Severe Operation

Prolonged operating hours/multiple shifts per day.

Extreme Operation

- In sandy or dusty locations, such as cement plants, lumber mills, and coal dust or stone crushing sites.
- High-temperature locations, such as steel mills and foundries.
- Sudden temperature changes, such as constant trips from buildings into open air, or in refrigeration plants.

If the lift truck is used in severe or extreme operating conditions, you must shorten the maintenance intervals accordingly. Your authorized HMH representative can assist in establishing PM schedules for specific applications.

NOTICE

Since the operating environment of lift trucks varies widely, the above descriptions are highly generalized and should be applied as actual conditions dictate.

PREVENTATIVE MAINTENANCE REPORT FORM

SERVICE SYMBOLS	SERVICE INTERVALS									
A-Adjust C-Clean CG-Change	Daily	50	250	500	750	1000	1250	1500	1750	2000
GR-Grease X-Check		Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs
ENGINE										
Oil level - check for evidence of external leakage	X									
Oil and filter element		CG	CG	CG	CG	CG	CG	CG	CG	CG
Crankcase breather				C		C		C		C
Check engine mounts						X				X
FUEL SYSTEM										
Fill fuel tank - check for leaks	X									
Fuel filter		CG	CG	CG	CG	CG	CG	CG	CG	CG
Fuel tank, cap, lines, and clamps			X	X	X	X	X	X	X	X
LP filter		CG	CG	CG	CG	CG	CG	CG	CG	CG
AIR INTAKE SYSTEM										
Check for leaks		X	X	X	X	X	X	X	X	X
Air Cleaner Element				CG		CG		CG		CG
EXHAUST SYSTEM										
Exhaust clamps			X	X	X	X	X	X	X	X
Check for exhaust leaks			X	X	X	X	X	X	X	X
COOLING SYSTEM										
Coolant level	X									
Belt tensioner and belts		X	X	X	X	X	X	X	X	X
Hoses, clamps, and radiator - check for leaks		X	X	X	X	X	X	X	X	X
Radiator (clean externally) as condition warrants		X	X	X	X	X	X	X	X	X
Drain and flush cooling system										CG
ELECTRICAL SYSTEM										
Battery - check water level and specific gravity			X	X	X	X	X	X	X	X
Battery - Clean and inspect terminals			C	C	C	C	C	C	C	C
Battery - Charge and Load test			X	X	X	X	X	X	X	X
STEER AXLE **Torque studs after first 10 hours of service, weekly thereafter										
Visually inspect daily	X									
Lubricate all grease fittings			GR	GR	GR	GR	GR	GR	GR	GR
Inspect and repack hub bearings						GR				GR
Adjust wheel bearings						A				A

Check mounting bolts			X	X	X	X	X	X	X	X
DRIVE AXLE **Torque studs after first 10 hours of service, weekly thereafter										
Visually inspect daily	X									
Planetary hubs - maintain oil level			X	X	X	X	X	X	X	X
Planetary hubs - change oil										CG
Differential - maintain oil level (40/60 Only)			X	X	X	X	X	X	X	X
Differential - change oil (40/60 Only)										CG
Inspect brake linings - (Optional service brakes only)								X		
Check mounting bolts			X	X	X	X	X	X	X	X
PARKING BRAKE										
Actuation	X									
Brake pads (replace as conditions warrant)										X
CHASSIS										
Lubricate remaining grease fittings and linkages			GR	GR	GR	GR	GR	GR	GR	GR
Audio-visual warning devices	X									
Access and anti-slip surfaces (clean)	X/C									
Handrails	X									
Chassis extension tube - wear pads			X	X	X	X	X	X	X	X
Chassis extension tube			GR	GR	GR	GR	GR	GR	GR	GR
HYDRAULIC SYSTEM										
Maintain fluid level to full mark and check for leaks	X									
Check hoses and piping for crackes, chafing, leaking, and loose fittings			X	X	X	X	X	X	X	X
Drain , clean inside tank, and refill system										CG
Suction strainers										CG
Return filter		CG	CG	CG	CG	CG	CG	CG	CG	CG
Hydraulic tank breather			CG	CG	CG	CG	CG	CG	CG	CG
Hydraulic cylinders - check for leaks and damage			X	X	X	X	X	X	X	X
Control valve - check for proper operation and leaks			X	X	X	X	X	X	X	X
Accumulators - check nitrogen precharge (if applicable)			X	X	X	X	X	X	X	X
Hydrostatic pump filter				CG		CG		CG		CG
WHEEL EQUIPMENT										
Inspect rims and rim components for cracks (every time a tire is replaced)										
Check tire position on wheel and make sure tire is not 'walking' on wheel	X									
Check wheels / tires for damage	X									
MAST AND FORKS										
Visually inspect daily	X									
Lubricate mast hinges			GR	GR	GR	GR	GR	GR	GR	GR
Lubricate all mast and attachment grease points		GR	GR	GR	GR	GR	GR	GR	GR	GR

Check all rollers for smooth motion			X	X	X	X	X	X	X	X
Lubricate mast channels			GR	GR	GR	GR	GR	GR	GR	GR
Check mast channels for cracks			X	X	X	X	X	X	X	X
Check carriage for cracks			X	X	X	X	X	X	X	X
Visually inspect forks for cracks and wear			X	X	X	X	X	X	X	X
Check all mast mouting hardware (mast hanger)	X									
BOOM										
Visually inspect daily	X									
Lubricate all grease points		GR	GR	GR	GR	GR	GR	GR	GR	GR
Check all wear pads - replace and adjust as required			X	X	X	X	X	X	X	X
Check extend chain for rust, streching, and cracking (60/80 Only)			X	X	X	X	X	X	X	X
Check extend chain for proper adjustment (60/80 Only)			A	A	A	A	A	A	A	A
Check chain anchors and pins for wear (60/80 Only)			X	X	X	X	X	X	X	X
Lubricate extend chain with chain lube (60/80 Only)			GR	GR	GR	GR	GR	GR	GR	GR
Check boom for cracks			X	X	X	X	X	X	X	X
Check all mouting hardware			X	X	X	X	X	X	X	X

PLANNED MAINTENANCE REPORT FORM (CONT’D)

After any PM inspection, be sure to give a copy of the report to the designated authority or person responsible for lift truck maintenance.

Do not make repairs or adjustments unless authorized to do so.

CAUTION

For safety, it is good practice to:

- **Remove all jewelry before working on the truck.**
- **Disconnect the battery ground cable (-) from the battery before working on electrical components.**
- **Always wear safety glasses. Wear a safety (hard) hat in industrial plants and in special work areas where protection is necessary and required. Hearing protection and any other personal protective equipment (PPE) MUST comply with OSHA and all company policies specific to the task at hand.**

HOW TO PERFORM MAINTENANCE

Visual Inspection
Perform an initial visual inspection of the lift truck and its components. Walk around the truck and take note of any obvious damage. wear, leaks, or general maintenance issues.

Check to be sure all capacity, safety, and warning plates are attached and legible. Illegible or missing data plates and/or decals **MUST** be replaced.

NOTICE

NAMEPLATES AND DECALS: Do not operate a lift truck with damaged or lost decals and nameplates. Replace them immediately. They contain important information.

Final Inspection
Inspect the truck, before and after starting the engine, for any sign of external leakage of fuel, engine coolant, hydrostatic gear oil, etc.

Check for hydraulic oil leaks and loose fittings.

CAUTION

HYDRAULIC FLUID PRESSURE: Do not use your hands to check for hydraulic leakage. Fluid under pressure can penetrate you skin and cause serious injury.

Cab/Overhead Guard
Be sure that the operator's cab/overhead guard structure, as well as all safety devices are in place, undamaged, and attached securely. Be sure that the overhead guard is properly positioned and all mounting fasteners are in place and tight.

HOW TO PERFORM MAINTENANCE (CONT'D)

Load Handling Components

Inspect the mast assembly, carriage, mast rails and rollers, carriage rollers, and lift and tilt cylinders. Look for obvious wear and maintenance problems and damaged or missing parts. Check for any loose parts or fittings. Check for leaks, damaged or loose rollers, and rail wear. Inspect all lift line hydraulic connections for leaks.

IMPORTANT

Mast and forks require special attention and maintenance to remain in safe operating condition. Refer to "Forks" under Mast Section for additional information.

WARNING

Keep hands, feet, and legs out of the mast. Do not use the mast as a ladder. Never try to repair the mast yourself! Always get a trained mechanic.

HOW TO PERFORM MAINTENANCE (CONT'D)

Wheels and Tires

Check the condition of drive and steer wheels and tires. Remove objects that are embedded in the tread. Inspect the tires for excessive wear and breaks or “chunking." Tires exhibiting extensive wear or damage should be replaced immediately.

Check all wheel lug nuts or bolts to be sure none are loose or missing. Replace missing bolts or lug nuts. Torque loose or replaced items to specifications, as indicated on the truck wheel and tire data plate.

MANUFACTURED BY
HOIST MATERIAL HANDLING, INC.
4407 RAILROAD AVE.
EAST CHICAGO, IN 46312
708.458.2200

HOIST MATERIAL HANDLING

⚠ REFER TO VEHICLE SERVICE MANUAL PRIOR TO SERVICING WHEELS OR TIRES. ONLY AUTHORIZED PERSONNEL SHOULD SERVICE WHEELS & TIRES.

TIRE SPECIFICATIONS

AXLE	TIRE SIZE	PLY / STAR RATING	PRESSURE
DRIVE	28 X 16 X 22	N/A	N/A
STEER	22 X 8 X 16	N/A	N/A

WHEEL LUG NUT TORQUE SPECIFICATIONS

WHEELS AND MOUNTS REQUIRE RUN-IN PERIOD ON A NEW VEHICLE AND AFTER EACH TIRE CHANGE.
TORQUE BEFORE VEHICLE IS PUT INTO SERVICE AND EVERY 10 HOURS THEREAFTER UNTIL WHEELS SEAT.
CARE SHOULD BE TAKEN TO KEEP GREASE AND OTHER FOREIGN MATERIAL FROM RIM SEATING SURFACES.

⚠ CAUTION: DO NOT OVERTORQUE

AXLE	WRENCH SIZE	TORQUE - FT.LBS.
DRIVE	1-3/16	250-330 DRY
STEER	N/A	N/A

⚠ DANGER: FIRST STEP IN TIRE DE-MOUNTING OPERATIONS:

ALWAYS REMOVE THE VALVE CORE AND EXHAUST ALL AIR FROM A SINGLE TIRE AND FROM BOTH TIRES OF A DUAL ASSEMBLY PRIOR TO REMOVING ANY RIM COMPONENTS OR ANY WHEEL COMPONENTS SUCH AS NUTS AND RIM CLAMPS.
TO INSURE THAT THE VALVE STEM IS NOT DAMAGED RUN A PIECE OF WIRE THROUGH THE STEM TO MAKE SURE IT IS NOT PLUGGED AND THAT ALL THE AIR IS EXHAUSTED.

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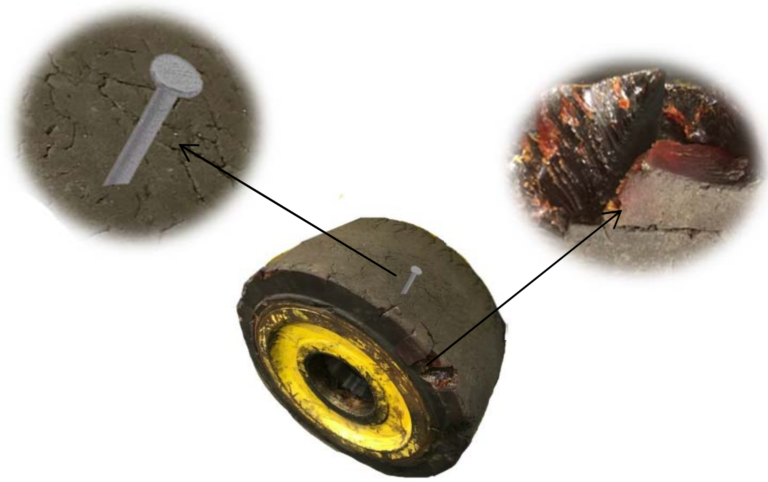
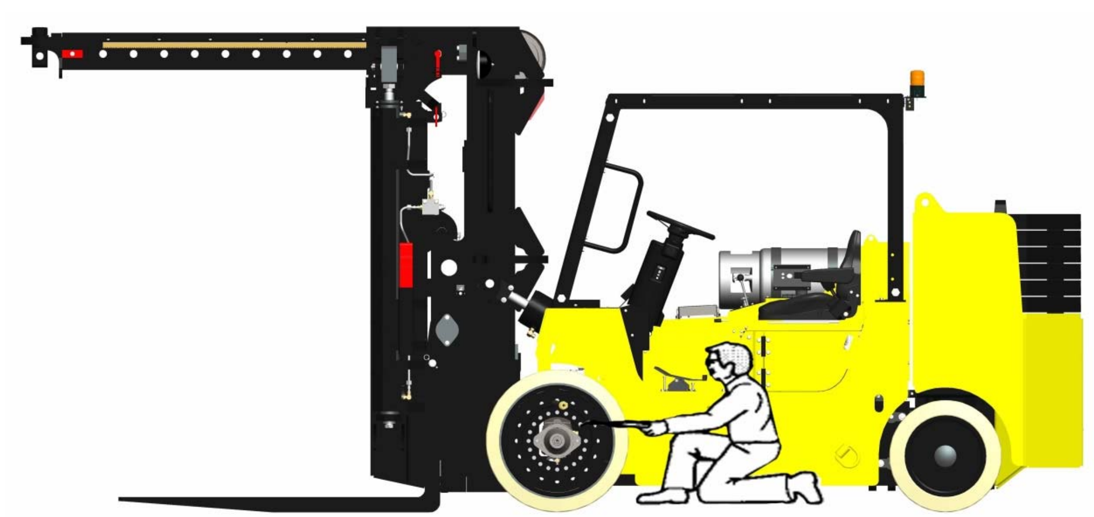




HOW TO PERFORM MAINTENANCE (CONT'D)

Functional Tests

Prior to starting the engine to conduct the functional tests, be sure that:

- The parking brake is APPLIED.
- Directional control lever is in NEUTRAL.
- Forks are fully lowered to the floor or ground.
- All controls are in NEUTRAL or other correct position.
- You have read and are familiar with starting and operating procedures in the FR15/25, FR18/26 & FR25/35 Operators Manual

As you test the following components, be sure they are properly mounted and working correctly.

Horn

Press the horn button to check horn function. If the horn or any other part does not operate, report the failure and repair it before the truck is put into operation.

Neutral Start Switch

Check the operation of the neutral start switch by placing the direction control lever in FORWARD or REVERSE and turning the key switch to the START position. The starter must **NOT** engage until the direction control lever is moved to the NEUTRAL position.

Water Temperature Gauge (Display)

Indicates temperature of engine coolant. Coolant temperature should be in the mid range of the gauge after 10 minutes of operation. If the indicator registers in the "hot" zone, turn off engine until trouble is located and corrected.

Hour Meter (Display)

Start the engine and let it warm up until it runs evenly and accelerates smoothly when you push the accelerator pedal. Check the hour meter for operation with the engine running. **Write the hour meter reading on the PM report form.** Report any malfunction or damage.

HOW TO PERFORM MAINTENANCE (CONT'D)

Parking Brake
Check the function of the parking brake. Release, then reapply. To check the parking brake holding capacity, park the lift truck on a grade and apply the parking brake. Be prepared to use the service brakes in the event the truck begins to roll. The parking brake should hold the lift truck with rated load on a 15% grade.

CAUTION

Do not operate a lift truck if the service or parking brakes are not operating properly.

Lift Mechanisms and Controls
Pull BACK on the tilt control lever and hold until the mast reaches the full back tilt position. Push FORWARD on tilt control the lever to return the mast to the vertical position. Release the tilt control lever.

CAUTION

Be sure that there is adequate overhead clearance before raising the mast.

Pull BACK on the lift control lever and raise the fork carriage to full height. Watch the mast assembly as it rises. Release the lift control lever.

If the maximum fork height is not reached, this may indicate that there is inadequate (low) oil level in the hydraulic tank or severe binding within the mast.

Push FORWARD on the lift control lever. Watch the mast as it lowers. When the forks reach the ground or floor, release the lift control lever.

All movements of the mast, fork carriage shifting, and lift chains must be even and smooth, without binding or jerking. Watch for chains or looseness; the chains should have equal tension and move smoothly without noticeable side to side movement.

Auxiliary Controls
If your lift truck is equipped with fork positioning and /or sideshifting, or any other special functions, test the control lever for correct function and briefly operate each.

HOW TO PERFORM MAINTENANCE (CONT'D)

Steering System

NOTICE

The steering system on your truck, including the steer axle and steering linkage, should be inspected periodically for abnormal looseness, wear, and damage, leaking seals, etc. Also, be alert for any changes in steering action. Hard steering, excessive freeplay (looseness), or unusual sounds when turning or maneuvering indicates a need for inspection and possible servicing.

Check the steering system by moving the steering wheel in a full right turn and then in a full left turn. Return the wheel to the straight-ahead position. The steering system components should operate smoothly when the wheel is turned. Never operate a truck that has a steering system fault.

WARNING

Always fasten your seat belt before driving the truck

Direction Control, Braking, and Declutch
Be sure that the travel area is clear in front of the truck.

1. Release the parking brake by pulling the black parking brake knob out.

2. Slowly depress the top of the operator pedal, away from the operator and travel forward. Remove your foot from the pedal to initiate braking, allowing the pedal to return to neutral position.

   Be sure the travel area is clear behind the truck

3. Slowly depress the bottom of the pedal, toward the operator and travel backward. Remove your foot from the pedal to initiate braking, allowing the pedal to return to neutral position.

   With the pedal in neutral position, the truck will not roll.

   When you have completed the operational tests, park and leave the truck according to the standard shutdown procedure as described in item #10 of the safe maintenance practices of this manual. Be sure to make a record of all maintenance and operating problems you discover.

HOW TO PERFORM MAINTENANCE (CONT'D)

Fluids, Filters, and Engine Accessories
To check fluid levels and other components within the engine compartment, open the hood and remove engine compartment side panels to access the engine compartment.

CAUTION

To avoid the possibility of personal injury, never work in the engine compartment with the engine running, except when it is absolutely necessary to check or make adjustments. Take extreme care to keep hands, tools, loose clothing, etc. away from fan and drive belts and any other moving parts. Also remove watches, bracelets, and rings.

Engine Accessories
Inspect the engine coolant hoses and fan belt. Look for leaking and obvious damage, worn (frayed) condition, breaks, etc. that could cause failure during operation.

Engine Air Cleaner
Check the engine air cleaner for damage and contamination (excessive dirt buildup and clogging). Be sure that the air cleaner hose is securely connected (not loose or leaking). Fan or cone shaped dust deposits on tube or hose surfaces indicates a leak.

Change or service the air cleaner element every 500 operating hours, depending upon your application. Service intervals may also be dictated by the air restriction indicator. When the restriction indicator illuminates on the operator display the air cleaner element **MUST** be replaced immediately.

Battery
Inspect the battery for damage, cracks, leaking condition, etc. If the terminals are corroded, clean and protect them. If the battery has removable cell caps, check to be sure the cells are all filled. Refill them as required with DISTILLED water. Do NOT attempt to open sealed maintenance free style batteries.

HOW TO PERFORM MAINTENANCE (CONT'D)

WARNING

BATTERIES CAN PRODUCE EXPLOSIVE GAS: Do NOT smoke or have open flames or sparks near batteries. An explosion can cause serious injury or death.

Battery Safety

- **Always wear the proper PPE when working on/with batteries. PPE should include: Safety Glasses/Goggles, Rubber Gloves, Face Shield, Chemical Apron, Boots.**
- **Eyewash and drenching facilities should be located as close as possible to the point of exposure of battery handling/servicing areas.**
- **Do NOT smoke in battery changing areas.**
- **Prevent open flames, sparks, or electric arcs in battery changing areas. Do NOT strike the battery with any spark producing item.**
- **Keep tools and other metallic objects away from uncovered batteries. Only use insulated/non-conducting tools to remove cell caps.**
- **Have an ABC dry chemical fire extinguisher readily available.**
- **Neutralize static buildup just before working on any battery by contacting nearest grounded surface.**
- **Ensure area ventilation is sufficient before working on any batteries.**
- **Never touch both battery terminals with your bare hands at the same time!**
- **Remove all jewelry when working with or near batteries.**
- **Use appropriate equipment to load/unload batteries from the truck.**
- **Ensure you are trained in use of any loading/unloading equipment.**
- **Batteries should NEVER be lifted by the post.**

HOW TO PERFORM MAINTENANCE (CONT'D)

Engine Cooling System

Maintaining your forklifts cooling level is critical in preventing overheating. Overheating can not only lead to premature engine failure, it also puts system components at risk for rust, corrosion, premature wear and possible failure.

To check engine coolant level, open the hood to the engine compartment.

WARNING

Do not remove the radiator cap when the radiator is hot. STEAM from the radiator will cause severe burns. Do NOT remove the radiator cap to check the coolant level, refer instead to the "cold" and "hot" full lines on the recovery bottle.

WARNING

Never remove the radiator cap while the engine is running. Stop the engine and wait until it has cooled. Failure to do so could result in serious personal injury from hot coolant or steam blowout and/or damage to the cooling system engine.

If the level is low, add a 50/50 mixture of specified coolant and water to the correct fill level. If you have to add coolant more than once a month or if you have to add more than one quart at a time, pressure test the cooling system for leaks.

- Check the engine oil for presence of coolant leaking into the engine.
- Inspect the coolant condition. Look for excessive contamination, rust or oil in the coolant mixture.
- Check the PM schedule for coolant change intervals.
- Check the condition of the radiator cap rubber seal and radiator filler neck for damage. Be sure they are clean and seal properly.

NOTICE

Your lift truck cooling system is filled with a factory-installed solution of 50% water and 50% permanent-type antifreeze containing rust and corrosion inhibitors. You should leave the solution in year-round. Plain water may be used in an emergency, but replace it with the specified coolant as soon as possible to avoid damage to the system. Do NOT use alcohol or methanol antifreeze.

HOW TO PERFORM MAINTENANCE (CONT'D)

Engine Oil and Filter
With the truck on a flat even surface, locate the engine oil dipstick. Remove the dipstick and wipe it off with a CLEAN rag or paper towel and fully reinsert it into the dipstick tube. Remove the dipstick again and check the level against the fill marks on the dipstick.

It is normal to add some oil between oil changes. Keep the oil level above the ADD mark on the dipstick by adding oil as required. **Do NOT overfill.** Use the correct oil as specified under lubrication section.

Only properly trained personnel should attempt oil changes and filter replacements.

It is necessary to:

- Drain and replace the engine crankcase oil and filter in accordance with provided PM schedule.

- Remove the oil pan drain plug to drain oil after the truck has been run long enough to get the engine oil to operating temperature.

WARNING

Engine oil at operating temperature is hot and can cause burns. Beware of splashing oil.

- Carefully check for leaks after changing oil and installing new filter. Make sure not to over tighten filter and deform, cut or damage, filter gasket. Apply some clean oil to the filter gasket prior to installing to prevent gasket from sticking or cracking.

NOTICE

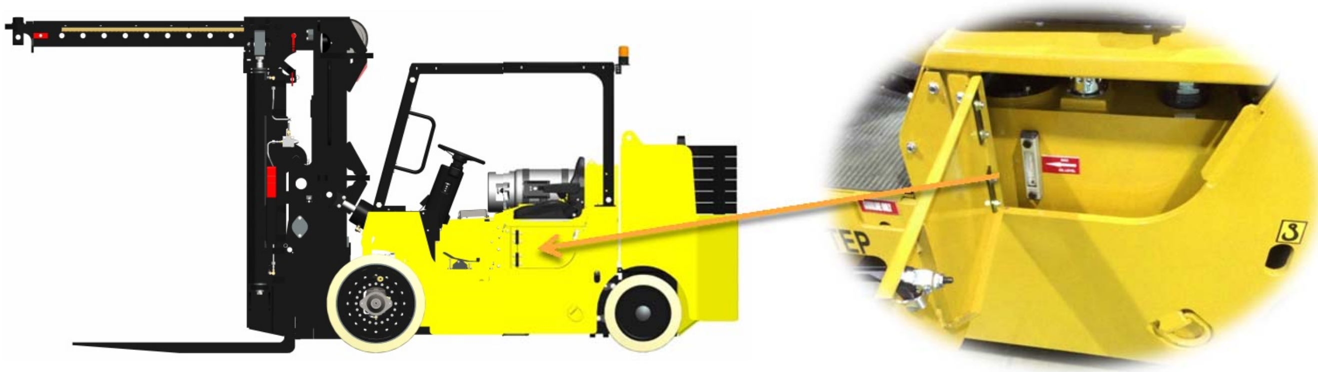
The interval for changing engine oil may vary depending on the application and operating conditions. In order to accurately determine the most appropriate schedule for your lift truck, periodically submitting engine oil samples to a commercial laboratory for analysis is suggested.

Oil Performance Designation: To ensure proper engine performance use only engine oil of the highest quality displaying the API certification mark (starburst) with the appropriate current service category.

Dispose of used oil properly in accordance with company or local government policy

HOW TO PERFORM MAINTENANCE (CONT'D)

Check the hydraulic fluid level. Correct fluid level is important for proper system operation. Low fluid level can cause pump cavitation and damage, while overfilling can cause loss of fluid or lift system malfunction. With the truck on level ground **AND** the mast/forks in the fully lowered position, visually verify fluid level using the sight glass on the face of the hydraulic tank on the LH side of the truck, located behind the LH side cover. Correct fluid level should appear approximately midway on the sight glass. Also take note of fluid appearance, specifically any discoloration (fluid appears darker) or contamination.



Hydraulic fluid expands as its temperature rises. Therefore, it is preferable to check the fluid level at operating temperature (after approximately 30 minutes of truck operation.)
Add recommended hydraulic fluid only as required (see "HMH Series Fluids" in reference section). **Do NOT overfill.**

Hydraulic Fluid and Filter Change
Drain and replace the hydraulic tank fluid every 2,000 operating hours. (Severe service or adverse conditions may require more frequent fluid change.) Replace the hydraulic oil filter elements at every oil change. Remove, clean, and reinstall the hydraulic and steer suction line screens at first PM and every 500 hours thereafter. Check for leaks after installation of the filters. Also, check that the hydraulic line connections at the filter adapter are tightened correctly.

IMPORTANT

Check suction screen for damage or clogging. Make sure lines are not kinked or damaged or collapsed and clamped securely to suction strainers with no air leaks.

Hydraulic Tank Breather Maintenance and Inspection
Remove the sump tank fill cap/breather and inspect for excessive (obvious) contamination and damage. Replace the fill/cap breather, per recommended PM schedule or as required by operating conditions.

NOTICE

Check the planned maintenance interval (operating hours) or the condition of the oil to determine if the transaxle fluid needs to be changed

HOW TO PERFORM MAINTENANCE (CONT'D)

Compressed Air Cleaning

Always maintain a lift truck in a clean condition. Do not allow dirt, dust, line, or other contaminants to accumulate on the truck. Keep the truck free from leaking oil and grease. Wipe up all oil spills. Keep the controls and floorboards clean, dry, and safe. A clean truck makes it easier to see leakage and loose, missing, or damaged parts, and helps prevent fires. A clean truck runs cooler. The environment in which a lift truck operates determines how often and to what extent cleaning is necessary. For example, trucks operating in manufacturing plants that have a high level of dirt, dust, or lint (for example, cotton fibers or paper dust) in the air or on the floor of ground, require more frequent cleaning. The radiator especially may require daily air cleaning to ensure correct cooling. If air pressure does not remove heavy deposits of grease, oil, etc., it may be necessary to use steam or liquid spray cleaner.

IMPORTANT

Lift trucks should be air cleaned at every PM interval or more often if necessary.

Use an air hose with special adapter or extension, a control valve, and a nozzle to direct the air properly. Use clean, dry, low pressure, compressed air. Restrict air pressure to 30 psi (207 kPa), maximum. (OSHA requirement)

CAUTION

Wear suitable eye protection and protective clothing when air cleaning. Never point the air nozzle at anyone.

Air clean the mast assembly, drive axle, radiator-from both counterweight and engine side, engine and accessories, driveline and related components, and steer axle and cylinder.

Critical Fastener Torque Checks

Fasteners in highly loaded (critical) components can quickly fail if they become loose. Loose fasteners can cause damage or failure to the components. For safety, it is important that the correct torque be maintained on all critical fasteners of components that directly support, handle, or control the load and protect the operator.

Critical items include:

- Drive axle mounting
- Drive and steer wheel mounting
- Counterweight mounting
- Overhead guard
- Tilt cylinder mounting and yokes
- Mast mounting and components

FR15/25, FR18/26, & FR25/35 SERVICE MANUAL
LUBRICATION POINTS

INDEX

LUBRICATION POINTS

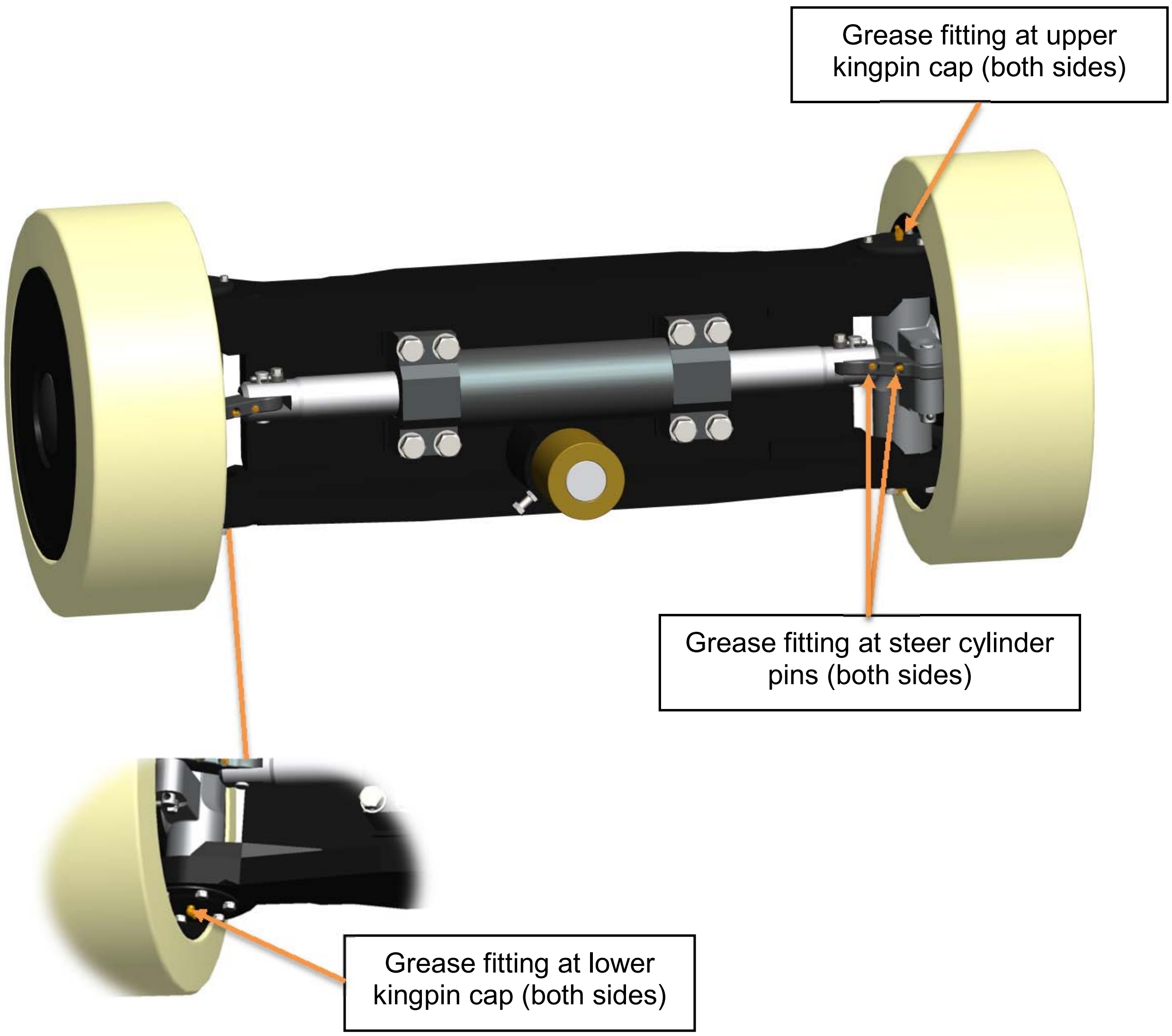
Steer Axle

Lubrication and inspection of your truck's steer axle chassis, including steer wheels, steer axle linkage, steering cylinder, and wheel bearings are easier if the truck is raised and blocked up under the frame.

WARNING

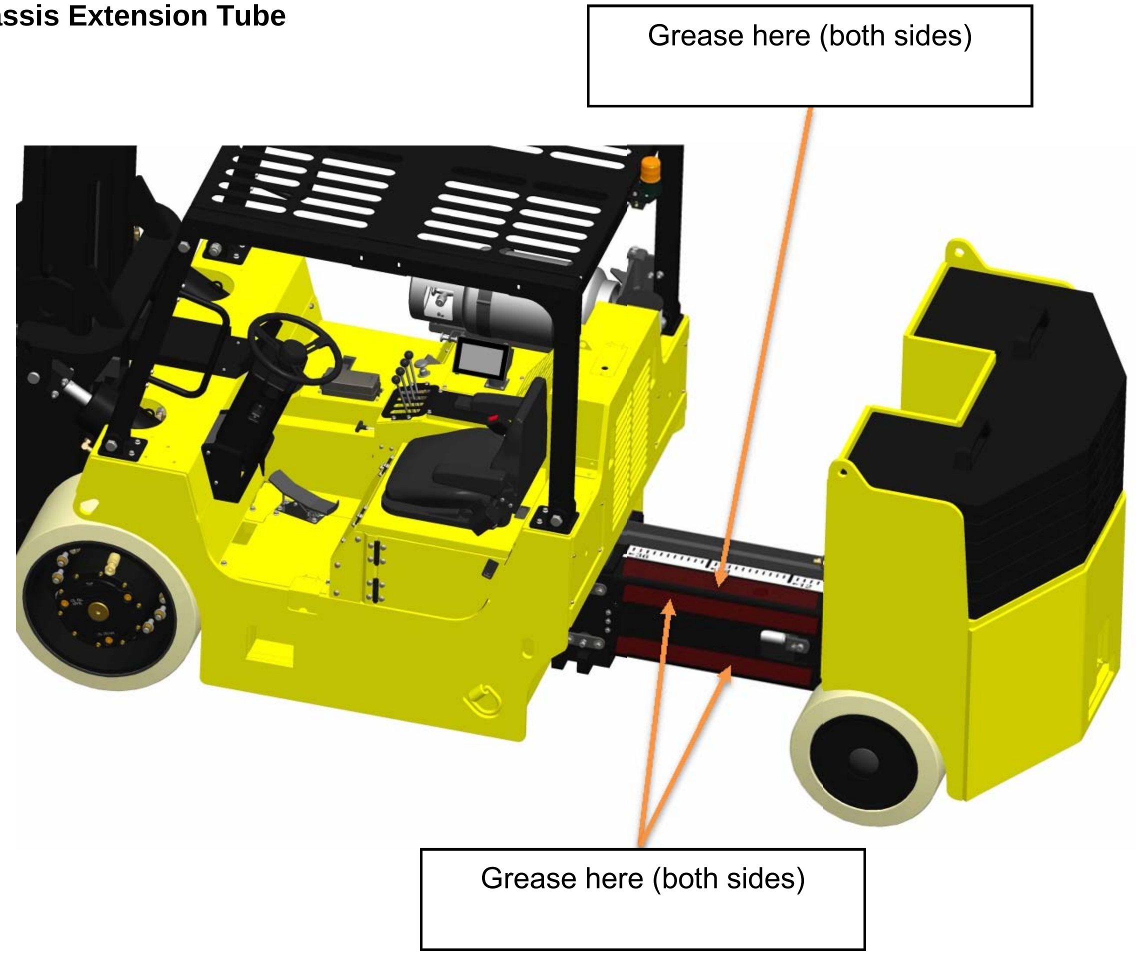
Do not raise the ruck by lifting under the counterweight. Use lifting eyes welded to the frame.

Inspect the steering cylinder piston rods, seals, and fasteners for damage, leaks, and looseness. Lubricate the steer axle linkage rod ends and linkage pivot points. Be sure to clean the grease fittings before lubricating, and remove the excess grease from all points after lubricating. Lubricate miscellaneous linkage as needed.



LUBRICATION POINTS (CONT'D

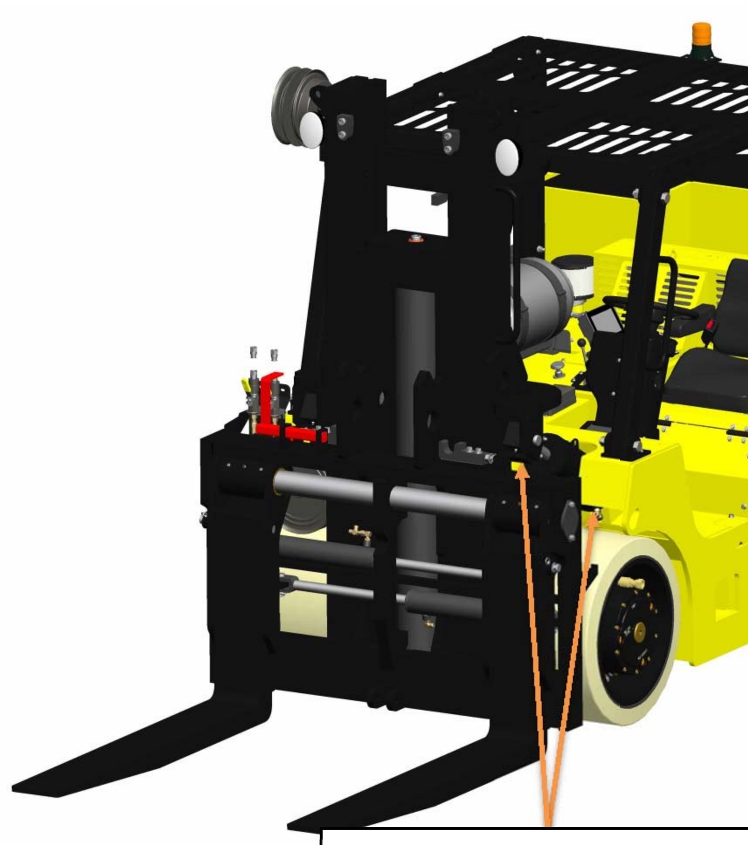
Chassis Extension Tube



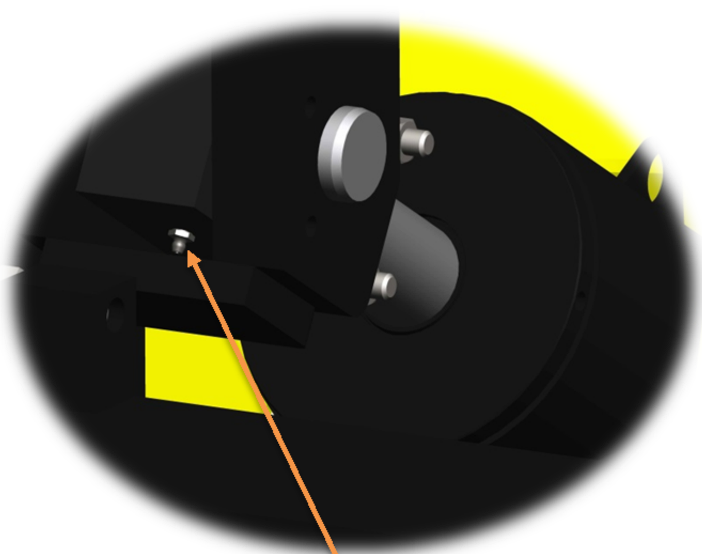
LUBRICATION POINTS (CONT'D)

Tilt Cylinder Lubrication

Clean the fittings and lubricate the tilt cylinder rod end bushings at the mast and tilt cylinder base bushings at the chassis.



Grease fitting at rod ends and base ends of tilt cylinders

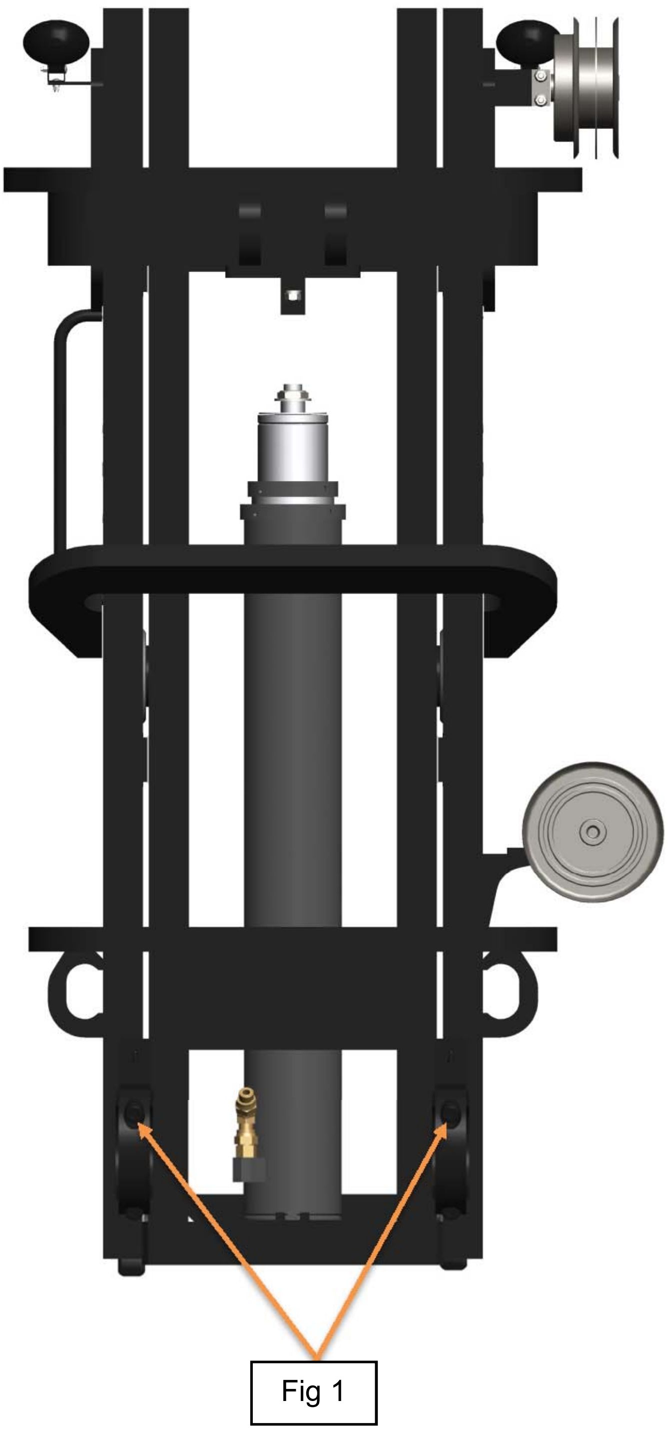


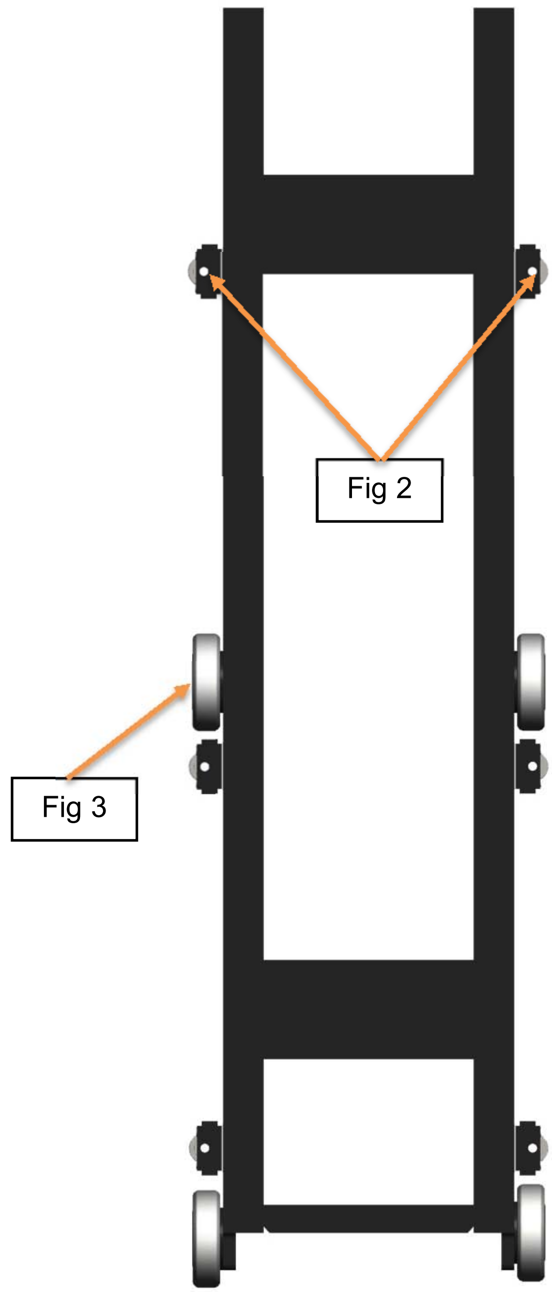
Grease the front tilt cylinder rod end grease zirks. (Both Sides)

Grease the rear tilt cylinder rod end grease zirks.

LUBRICATION POINTS (CONT'D)

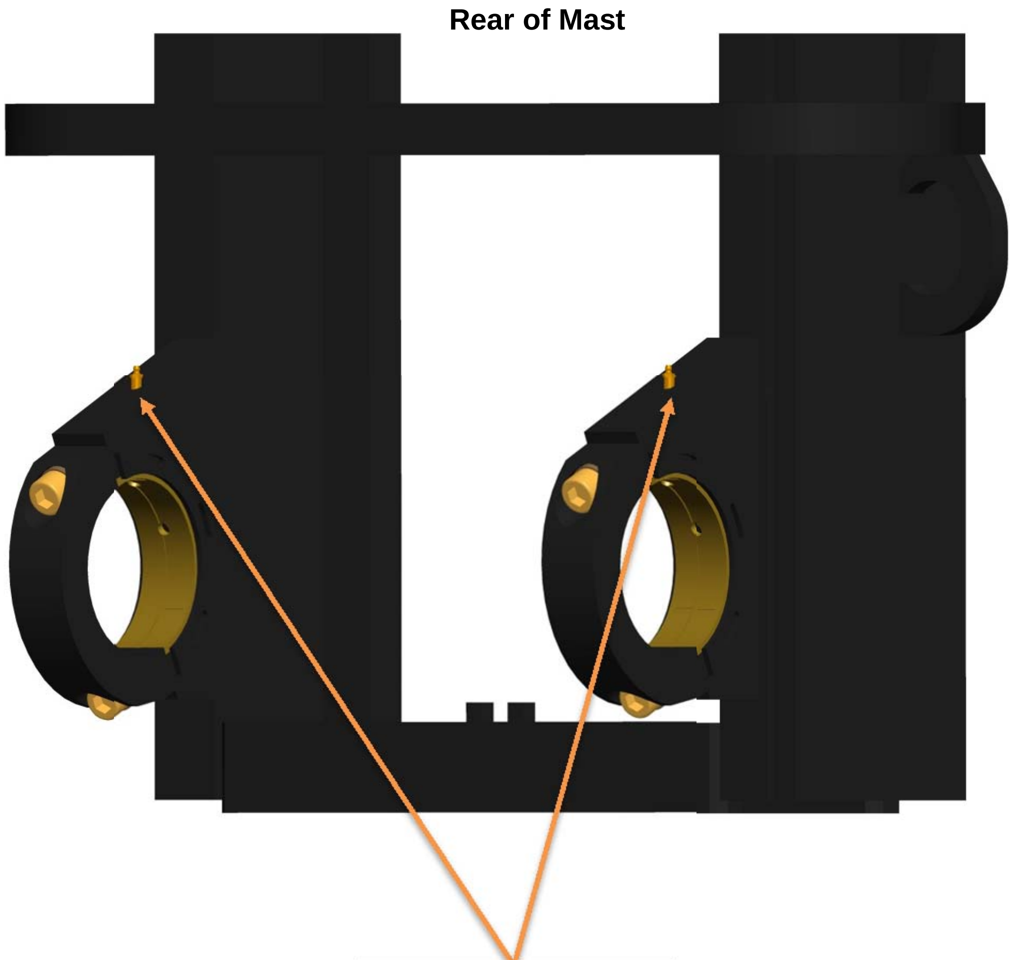
Mast FR25/35
Lubricate the upright trunnion bushings (Fig 1). Lubricate the chain rollers (Fig 2) and the track rollers (Fig 3)





LUBRICATION POINTS (CONT'D)

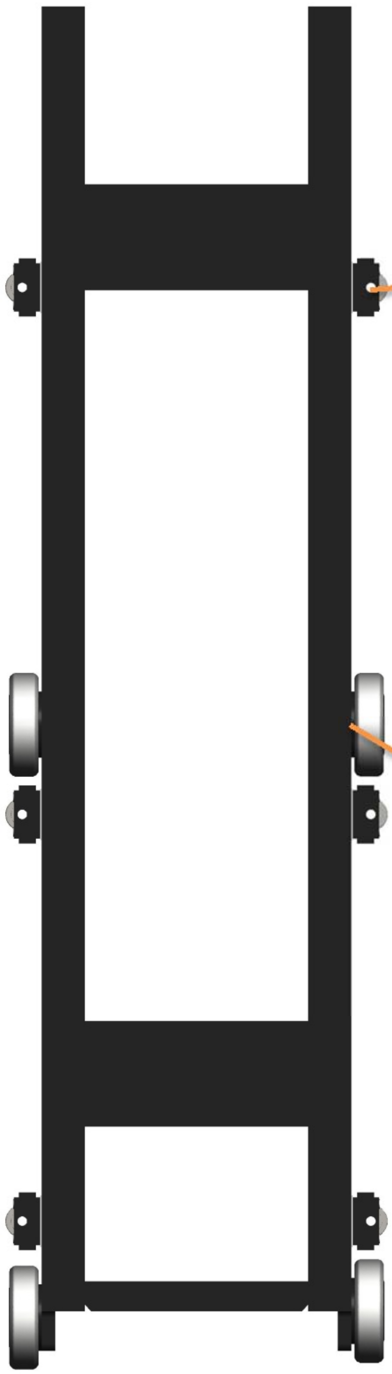
Outer Stage Assembly FR25/35

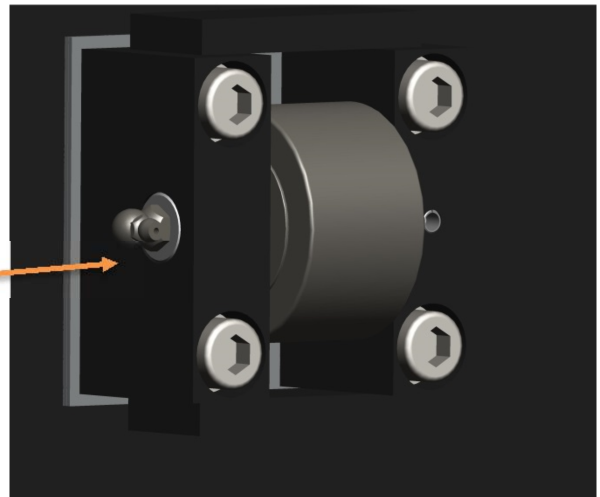


(Fig 1)
Grease fitting at upright pivot (both sides)

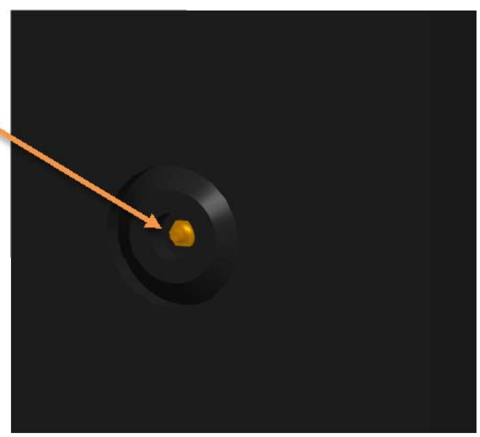
LUBRICATION POINTS (CONT'D)

Inner Stage Assembly FR25/35





(Fig 2)
Grease fitting at web roller
(both sides)

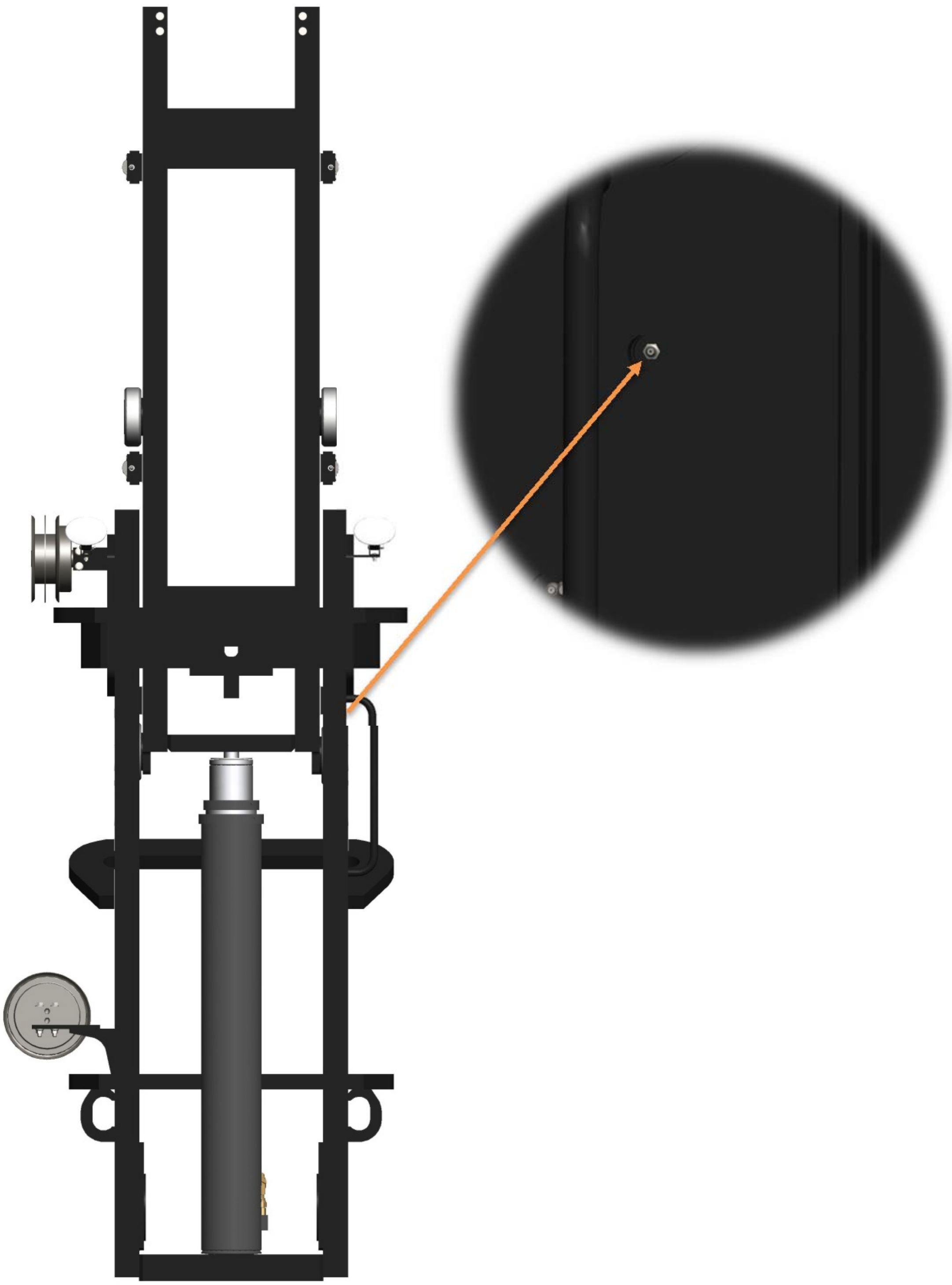


(Fig 3)
Grease track roller
(4 places)

LUBRICATION POINTS (CONT'D)

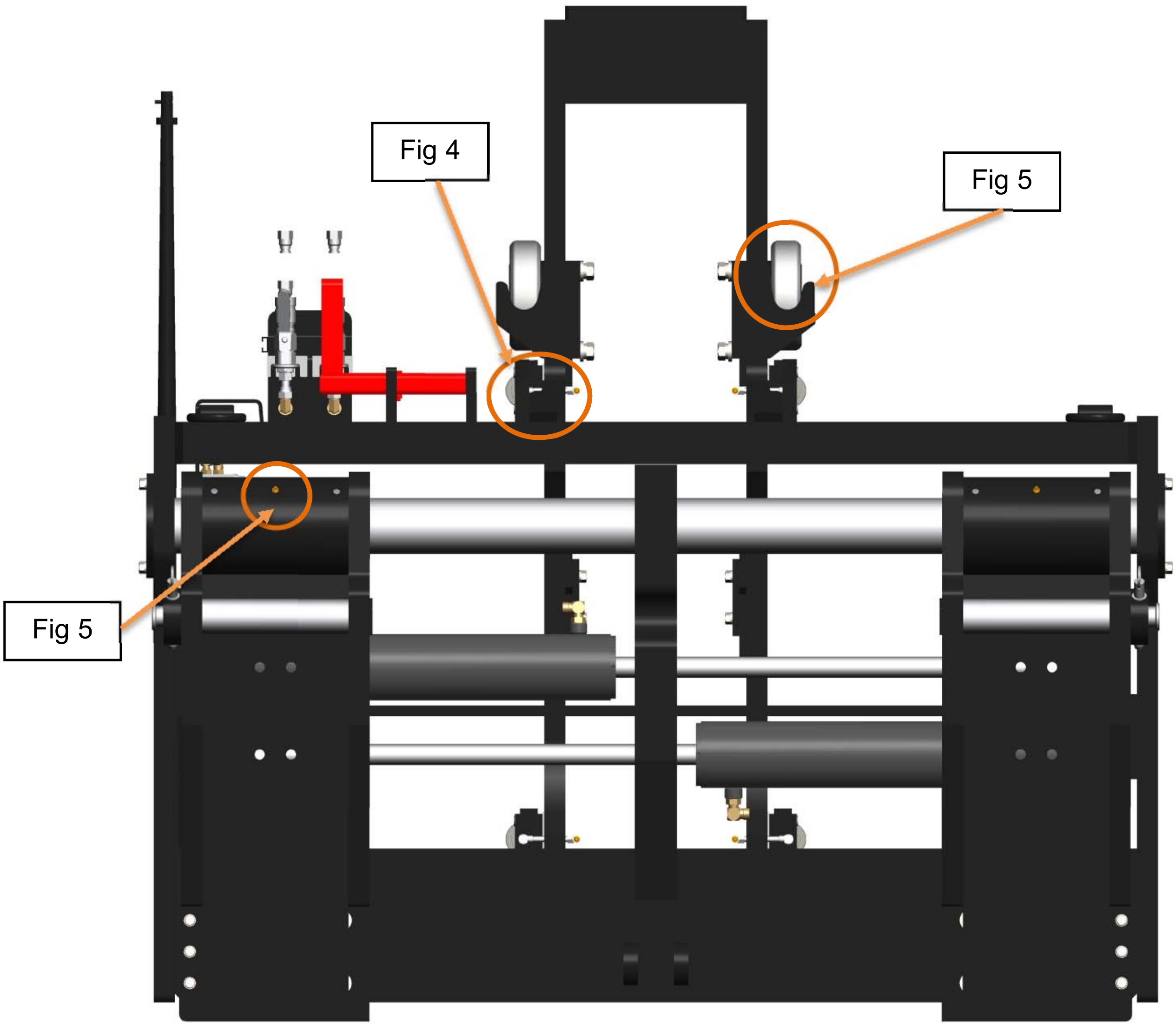
Inner Stage Assembly FR25/35

The inner stage can be raised so that the holes in the outer stage align with the track roller grease zirk. This allows the track roller to be greased from the outside of the mast.

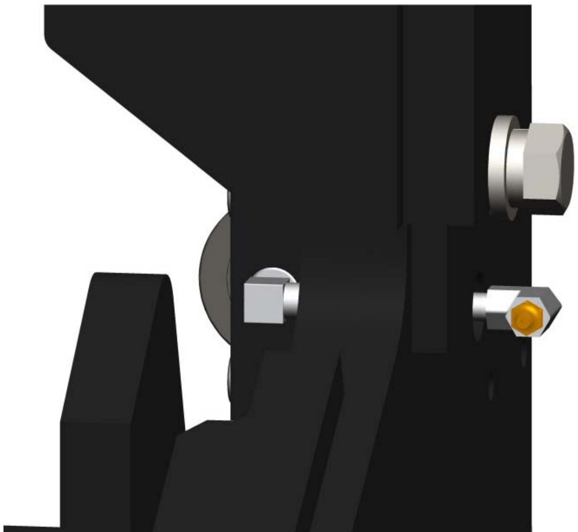


LUBRICATION POINTS (CONT'D)

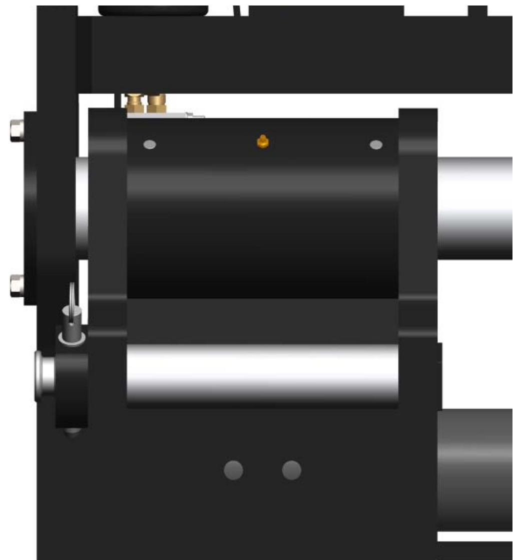
Carriage/Pushers FR25/35



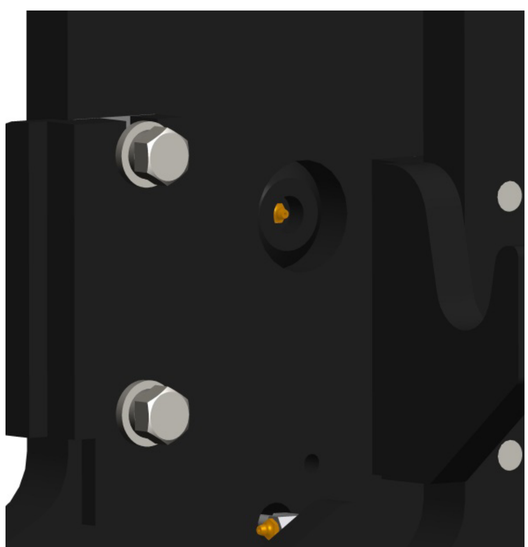
LUBRICATION POINTS (CONT'D)



(Fig 4)
Grease carriage web rollers
(4 places)



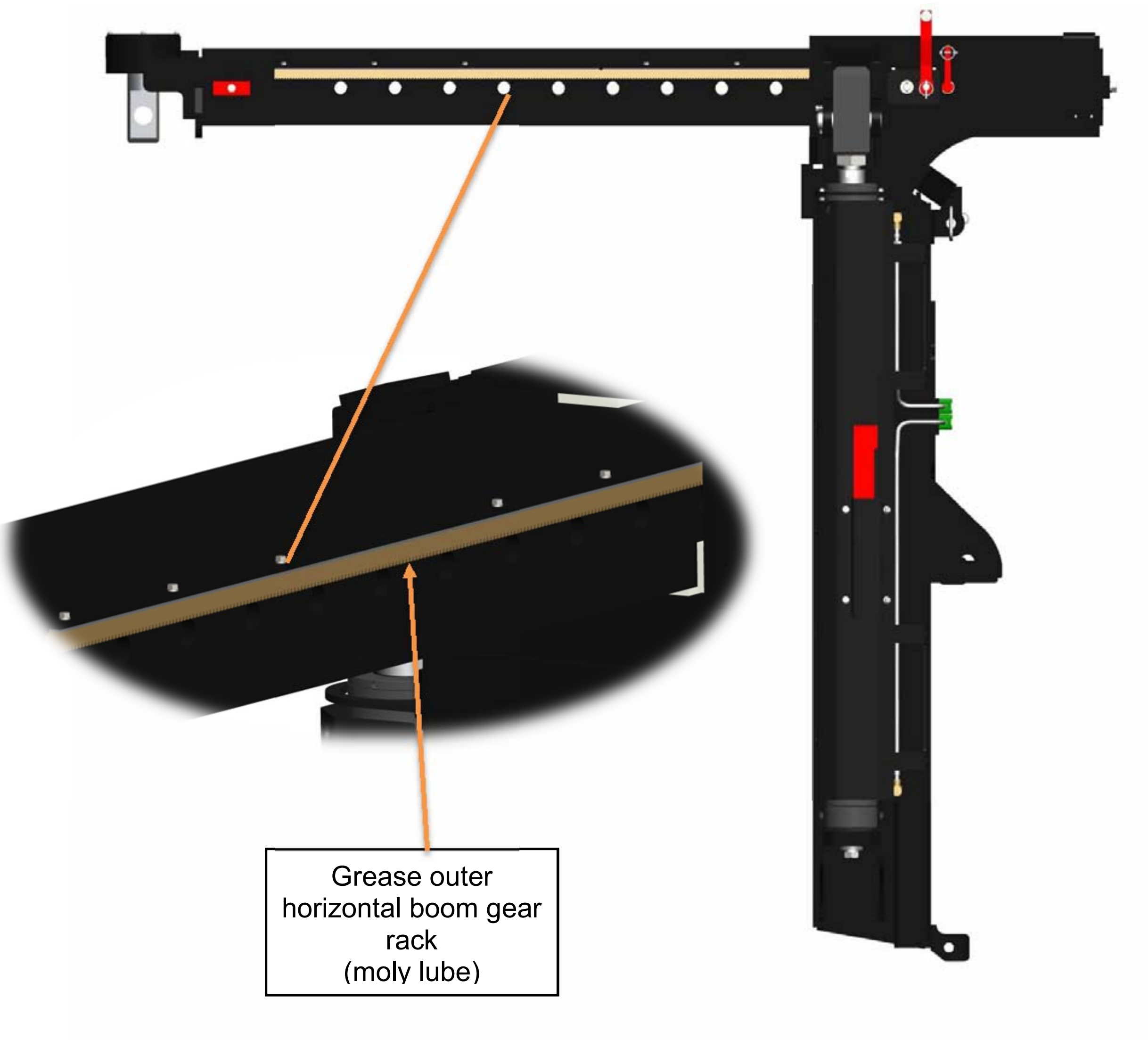
(Fig 5)
Grease fork pushers
(2 places)



(Fig 6)
Grease carriage track rollers
(4 places)

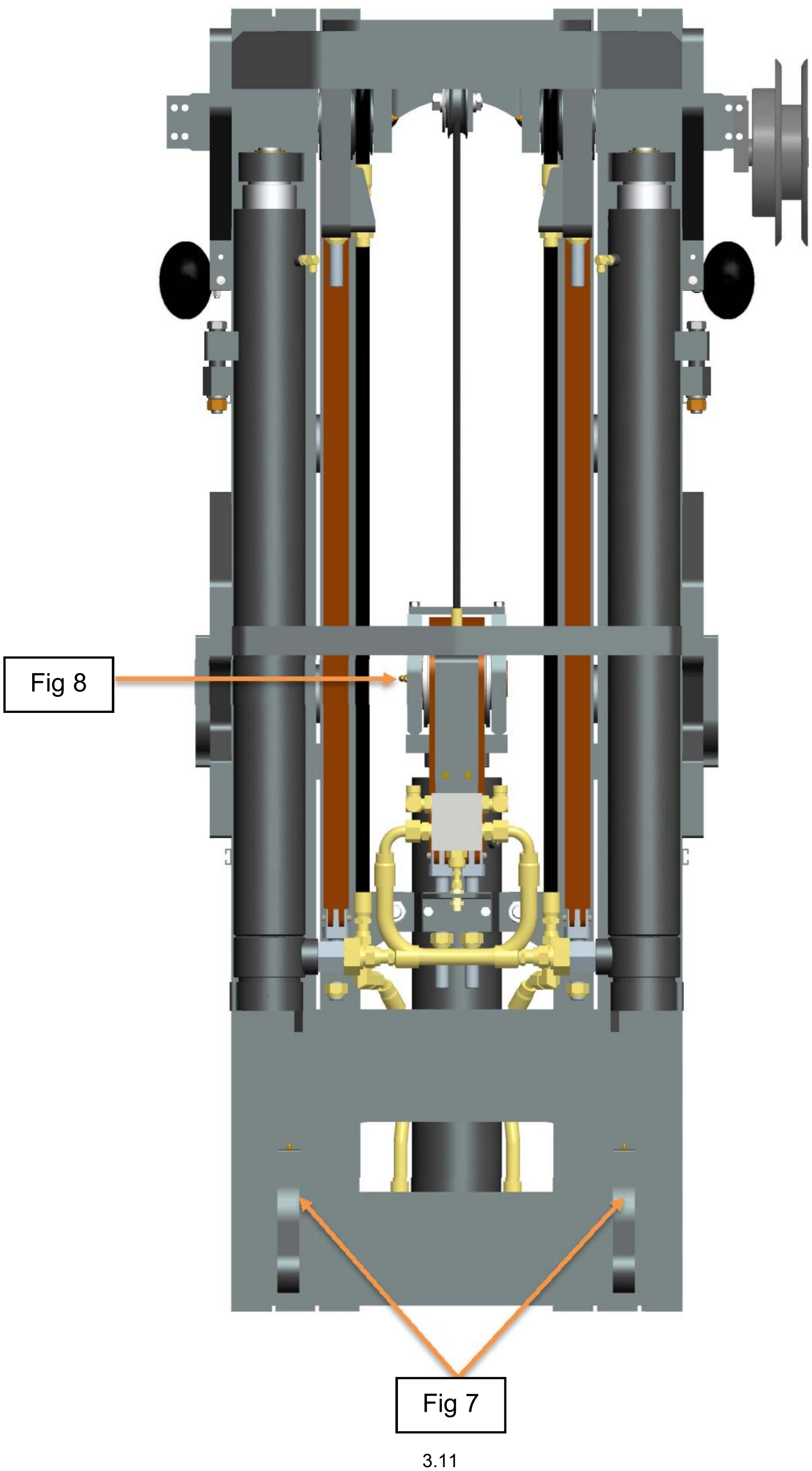
LUBRICATION POINTS (CONT'D)

Boom FR25/35

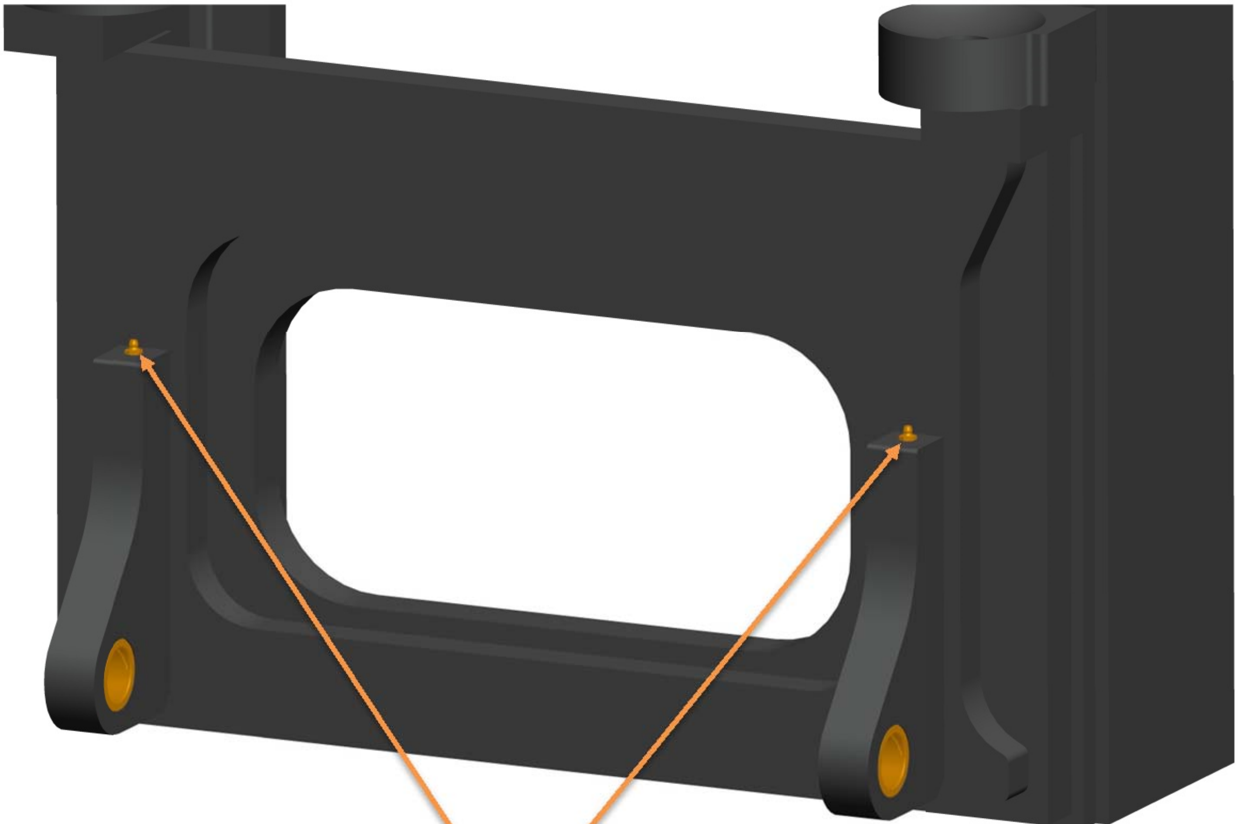


LUBRICATION POINTS (CONT'D)

Mast FR15/25 & FR18/26

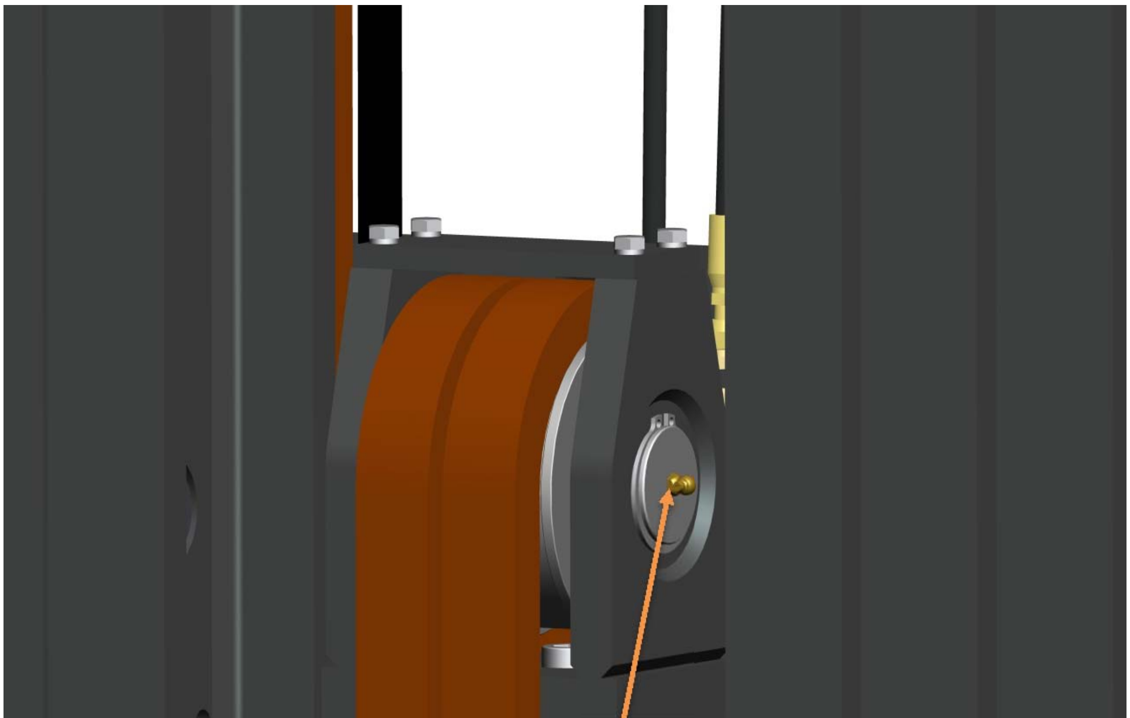


LUBRICATION POINTS (CONT'D)



(Fig 7)
Grease fitting at upright pivot (both sides)

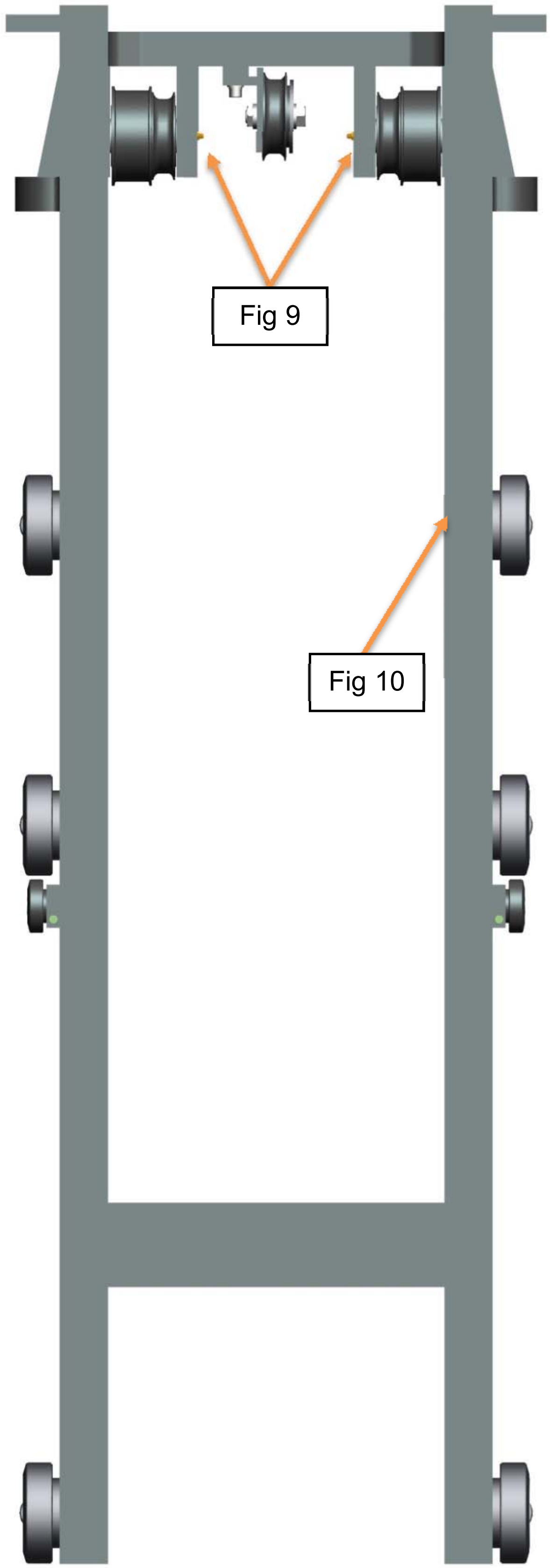
LUBRICATION POINTS (CONT'D)



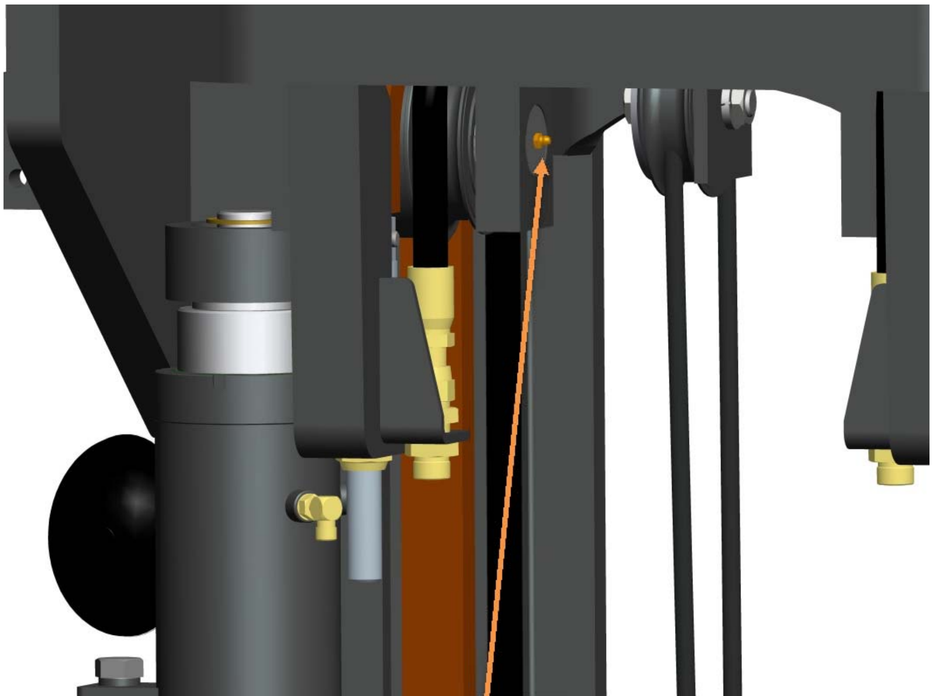
(Fig 8)
Grease fitting at
center chain roller

LUBRICATION POINTS (CONT'D)

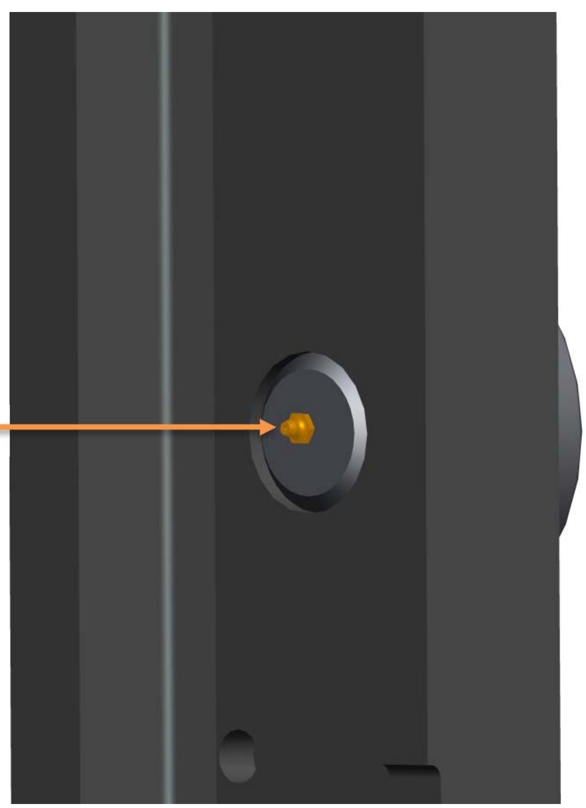
Intermediate Stage Assembly FR15/25 & FR18/26



LUBRICATION POINTS (CONT'D)



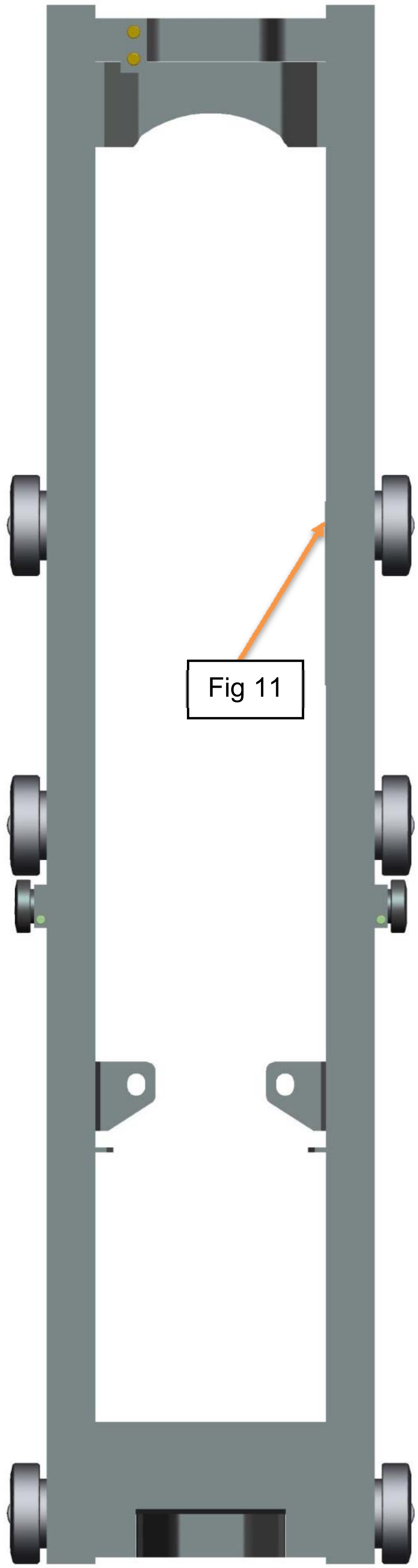
(Fig 9)
Grease fitting at upper chain roller (both sides)



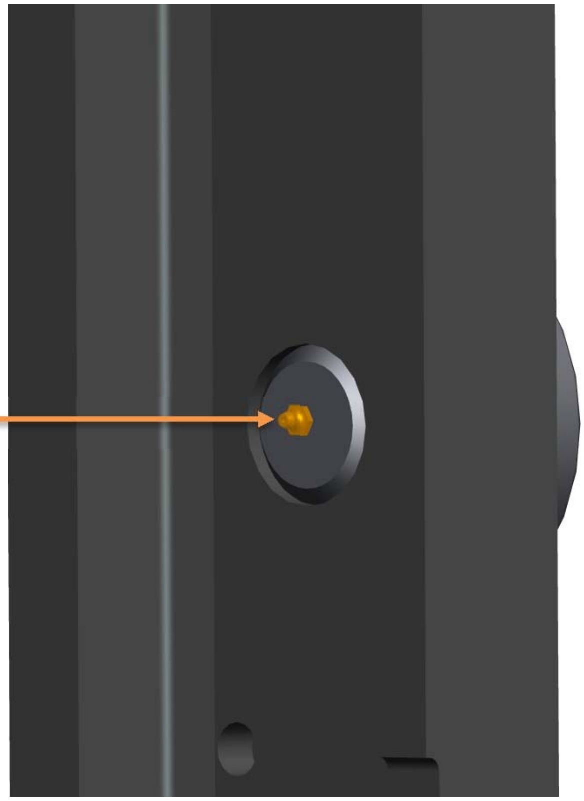
(Fig 10)
Grease fitting at track roller (6 places)

LUBRICATION POINTS (CONT'D)

Inner Stage Assembly FR15/25&FR18/26



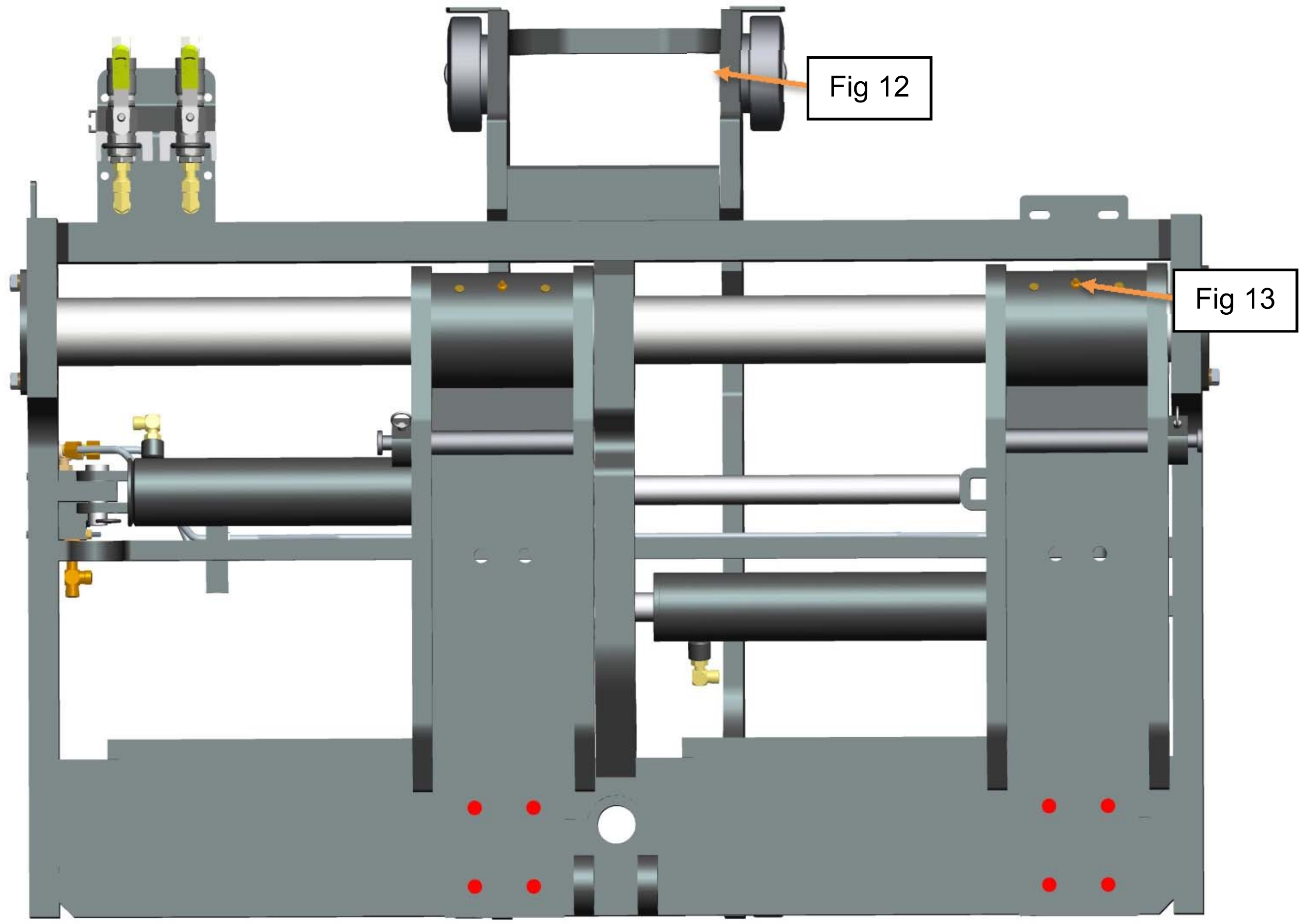
LUBRICATION POINTS (CONT'D)



(Fig 11)
Grease fitting at track roller (6 places)

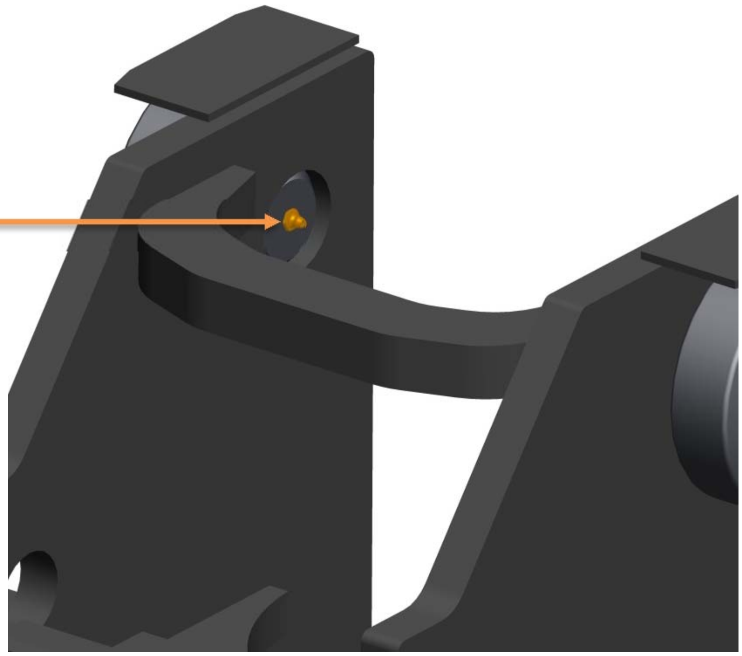
LUBRICATION POINTS (CONT'D)

Carriage/Pushers FR15/25 &FR18/26

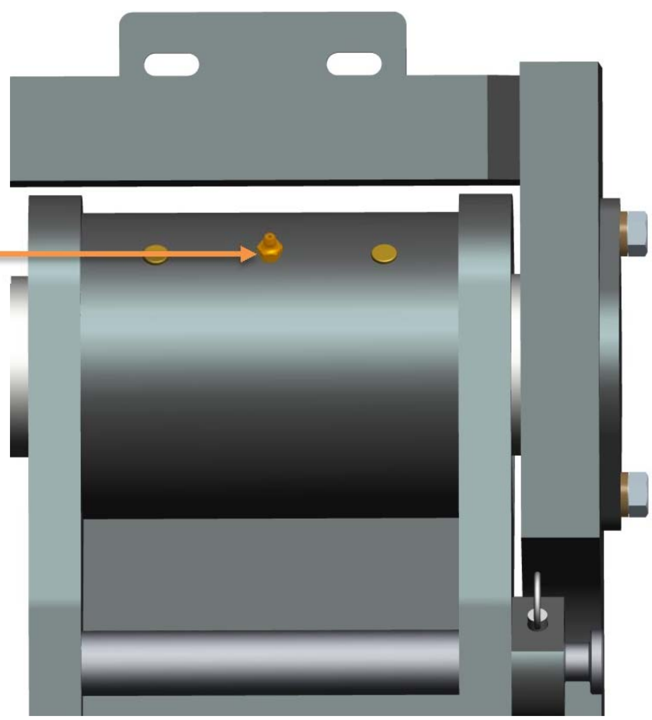


LUBRICATION POINTS (CONT'D)

(Fig 12)
Grease fitting at track roller (4 places)



(Fig 13)
Grease fitting at top of pusher (2 places)



FR15/25, FR18/26, & FR25/35 SERVICE MANUAL *TIRE AND WHEEL SAFETY*

INDEX

WARNINGS AND SAFETY INFORMATION

WARNING

The task of servicing tires and wheels can be extremely dangerous and should be performed by trained personnel only, using the correct tools and following specific procedures. Failure to heed this warning could lead to serious injury or death. Read and understand the "Safety Information" in this catalog.

The safety related information in this section is issues as assistance to supervisory and operational personnel in the actual tire/rim service environment. The responsibility for implementation of this safety information rests with operational and supervisory personnel carrying out the actual service work. Read and fully understand all procedures before attempting tire/wheel servicing.

Wear protective gloves, footwear, safety glasses, hearing protection and head gear when servicing tires and wheels.

Further references explaining safety procedures can be found in literature published by the Rubber Manufacturers Association, Washington D.C.; the Tire Association of North America, Washington D.C.; the National Wheel and Rim Association, Jacksonville, FL; and OSHA, Washington D.C.

SAFETY FIRST!

WARNINGS AND SAFETY INFORMATION (CONT'D)

GENERAL WARNINGS

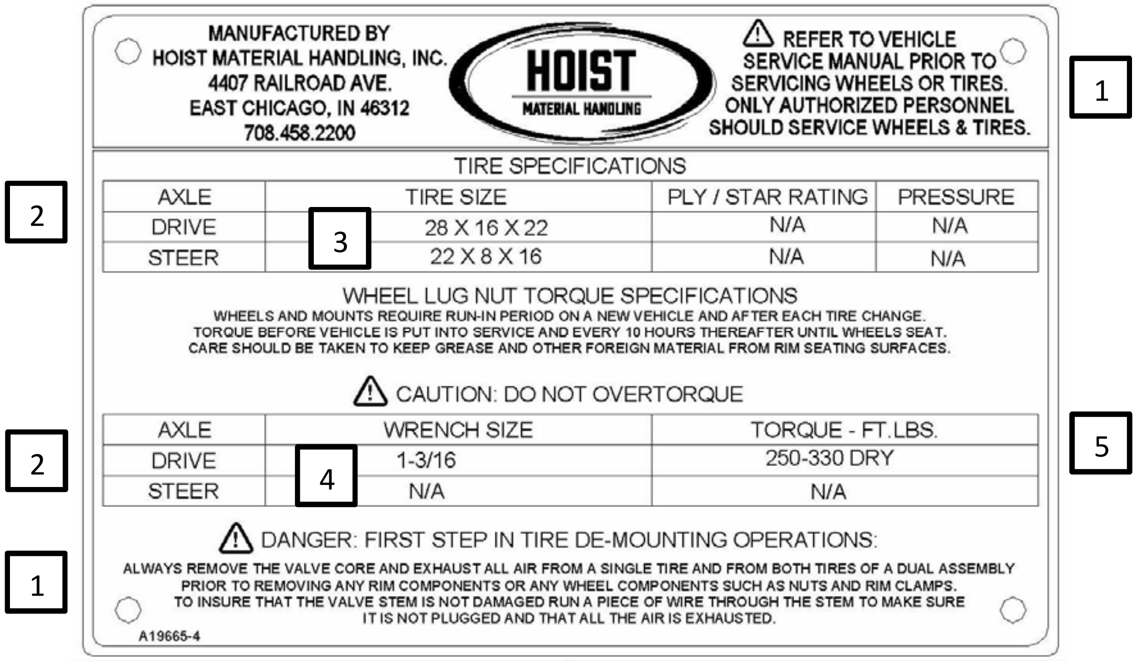
This symbol indicates a warning message

Failure to heed warnings could lead to serious injury or death.

- The task of servicing tires and wheels can be extremely dangerous and should be performed by trained personnel only, using correct tools, and following the procedures presented here and in manufacturers' catalogs, instruction manuals, or other industry and government instruction material.
- Several types of tire changing equipment are available. Installers should be fully trained in correct operating procedures and safety instructions for the specific machine being used. Always read and understand any manufacturer's warning contained in the product literature or posted on the equipment.
- Always wear personal protection equipment such as gloves, footwear, eye protection, hearing protection, and head gear, when servicing tire and wheels.
- Do not, under any circumstances, attempt to rework, weld, heat, or braze any wheels that are cracked, broken, or damaged. Replace with new parts or parts that are not damaged, which are of the same size, type, and make.
- Make sure correct parts are being assembled. Ask your distributor or the manufacturer if you have any doubts.
- Always take care when moving tires and wheels that other people in the area are not endangered.
- Never leave a tire, wheel or assembly unsecured in a vertical position.
- Parts that are cracked, worn, pitted with corrosion or damaged must be destroyed discarded and replaced with good parts.
- Never try to repair wheel, tire component parts. Replace all damaged, worn or suspect parts with good parts.
- When conducting routine tire inspections also conduct a visual inspection of wheel components. Always correct any non-conformities found.
- Misapplication, overloading and exceeding maximum speed may cause tire failure.
- When removing wheels, regardless of how hard or firm the ground appears, put hardwood blocks under the jack.
- Block the tire and wheel on the other side of the vehicle, before you place the jack in position. Place blocks under the truck frame as near as possible to the jack to prevent the truck from falling if the hack should fail.

TIRE AND WHEEL DATA PLATE

A Tire and Wheel Data Plate is affixed to exterior of every truck and is located on the front left-hand side (driver side) of the cab. The following information can be found on the Tire and Wheel Data Plate.



The above data plate is provided as an example only.
Consult the data plate affixed to the truck for information specific to the unit.

1. Warnings: Changing and servicing tires is inherently dangerous and should only be undertaken but trained authorized personnel.
2. Indicates position of tires on truck; steer (rear) or drive (front).
3. Identifies size of tires on unit.
4. Identifies correct wrench size for wheel nuts.
5. Identifies proper torque range for wheel nuts.

WARNING!
DO NOT ATTEMPT TO REPAIR OR REPLACE TIRES AND/OR WHEELS UNLESS PROPERLY TRAINED AND AUTHORIZED TO DO SO.

DO NO REMOVE DATA PLATE FROM THE TRUCK.

1. GENERAL TIRE MAINTENANCE, INSPECTION, AND REPAIR

WARNING
SAFE PARKING
Before working on truck:

1. **Park truck on a hard, level, and solid surface, such as a concrete floor with no gaps or breaks.**
2. **Put upright in vertical position and fully lower forks or attachment.**
3. **Put all controls in neutral. Turn key switch OFF and remove key.**
4. **Apply the parking brake and block the wheels.**

Replace tires when you see damage in the form of chunking, tearing, or cracking, or if you see flat spots. Damaged tires threaten the safety of the machine and the operator and need to be replaced as soon as possible.

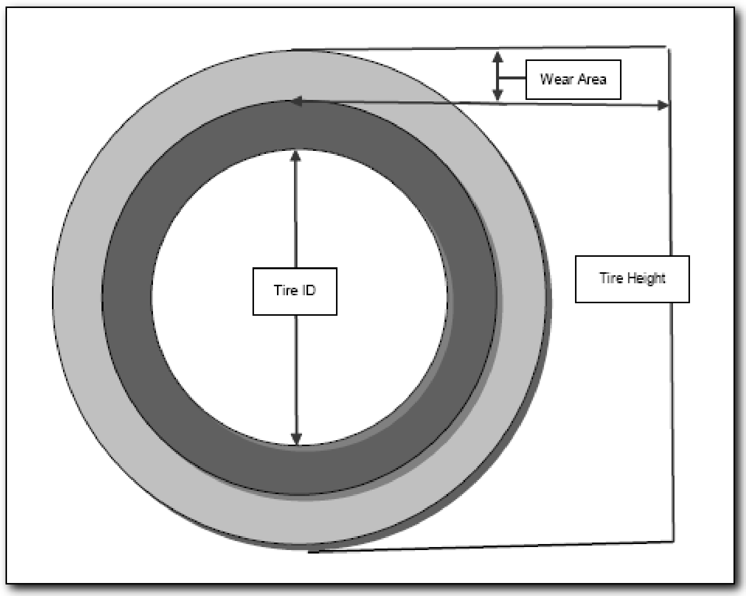
Example of a tire that is severely chunked and needs replacing.

Example of a tire that is cracked and worn and needs replacing.

Example of a tire that is cracked and worn and needs replacing.

GENERAL TIRE MAINTENANCE, INSPECTION, AND REPAIR

As a general rule, if there is less than one inch from the lettering on the tires to the top of the tires, it is time to change the tires.
When determining wear on a tire and when to replace, refer to the image below.



Inspection and Minor Repair

Inspect cushion tires and wheels carefully for:

1. Damaged tires. Check tires for cuts and breaks.
2. Damaged wheels or tires “walking” off wheels.
3. Check for loose nuts or bolts not in position.
4. Check the nuts or bolts for damage.
5. Check all parts for rust or corrosion.
6. Remove all parts that are damaged and install new parts in the same position.
7. Replace parts with the correct sizes and types. See your parts manual. Include your truck serial number when ordering replacement parts.

WHEEL DISMOUNTING AND REMOUNTING

WARNING

SAFE PARKING. Before working on truck:

1. **Park truck on a hard, level, and solid surface, such as a concrete floor with no gaps or breaks.**
2. **Put upright in vertical position and fully lower forks or attachment.**
3. **Put all controls in neutral. Turn key switch OFF and remove key.**
4. **Apply the parking brake and block the wheels.**

1. Lubricate inside diameter of tire to be pressed with Tectyl 506 petroleum grease.

2. Verify wheel has a lead-in chamfer or radius, containing no sharp edges. If the wheel contains any sharp edges, they must be removed before continuing.
3. Place wheel into press with chamfer/radius side facing up.

WHEEL DISMOUNTING AND REMOUNTING (Cont'd)

2. Place the tire onto the wheel, making sure that the tire is sitting squarely on the wheel.

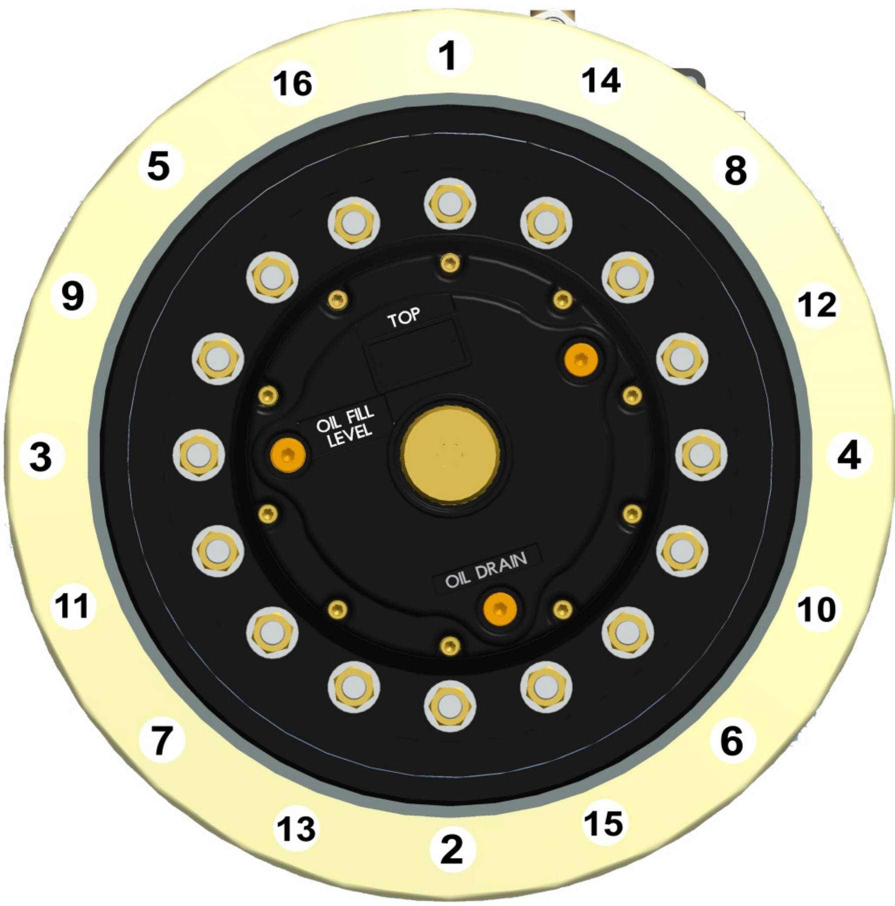
3. Lower the press slowly and press the tire approximately ½" onto the wheel such that the tire is beyond the lead-in chamfer or radius.
4. In order to insure the tire is being pressed squarely, release pressure by raising the press slightly and then re-lower the press onto the tire and continue pressing.
5. Press the tire fully onto the wheel and verify that the required pressure does not increase significantly throughout the pressing process. If the required pressing pressure does increase significantly, see the precautions below.
6. Release pressure by raising the press fully. If the wheel assembly only requires a single tire, then this completes the operation. If the wheel assembly requires dual tires, then proceed with steps 9 thru 14
7. Place the second tire directly on top of the first tire without changing the orientation and location of the wheel assembly in the press.
8. Lower the press slowly and press the second tire approximately ½" onto the wheel such that the tire is beyond the lead-in chamfer or radius.
9. In order to insure the second tire is being pressed squarely, release pressure by raising the press slightly and then re-lower the press onto the tire and continue pressing.
10. Press the second tire fully onto the wheel and verify that the required pressure does not increase significantly throughout the pressing process. If the required pressing pressure does increase significantly, see the precautions below.
11. Release pressure by raising the press fully
12. Remove the new tire and wheel assembly from the press.

PRECAUTIONS

1. If the pressing pressure is seen to be increasing significantly while pressing a tire, then stop the press and release pressure by raising the press. If a curl or several curls of steel have formed in front of the tire at its inside diameter, then the tire/wheel assembly must be turned over and the tire needs to be pressed off. Finally turn the wheel back over and re-press the tire onto the wheel from the opposite end using the procedure above.
2. If the pressing pressure is seen to be increasing significantly while pressing the tire, but no curls of steel have formed, then the tire may be slightly undersized. Continue to press the tire onto the wheel using the procedure above. Keep a close watch that no curls of steel form in front of the tire.

DRIVE WHEEL TORQUE PROCEDURE

After assembling the drive wheel assembly to the drive axle, install the wheel nuts until finger tight. Tighten the wheel nuts in 50 ft.-lb increments in the appropriate sequence shown below. Repeat sequence until achieving final torque value as indicated on the Tire and Wheel Data Plate affixed to the truck being serviced.



FR15/25, FR18/26, & FR25/35 SERVICE MANUAL
POWERTRAIN

INDEX

1.0 GENERAL INFORMATION

The standard products must be used at the following conditions:

- *Not be used in environments with vapors, fumes or dust corrosive and/or abrasive.*
- *Not be used in environments where potentially explosive atmospheres are present.*
- *The environment temperature limit conditions permitted in which products can be used ranging from* ***-15°C to +45°C****.*

The product is designed and constructed so as not to injure the operator in case of malfunction or breakage.

1.1 Manual aim

Information ***This document is drawn up with the "Original instructions" in Italian and translated as "Translation of the original" in English.***

This manual has been devised by the ***Bonfiglioli Trasmital*** *to give necessary information to those authorised to work on this product for example the design engineers, installers, repair and maintenance technicians.*

Besides helping one understand the rules of good manufacturing techniques used, the information given must be carefully read and strictly applied.

Failure to observe this information may lead to health and safety risks to persons as well as economic loss.

Information ***A strict and consistent compliance with the specifications of this technical manual ensure the minimum operating costs and a longer unit life.***

Photographic documentation and drawings are supplied for educational purposes, so as to safely and properly carry out maintenance operations.

Minor deviations from pictures of this manual may appear on the actual gearbox. However, these discrepancies are not relevant to the main parameters, or maintenance functions.

1.2 Information on safety

Carefully read the instructions given in this instruction manual as well as the ones attached to the product and make sure to follow the information concerning safety.

Information ***Personnel, which perform any type of work on the product during its life span, must possess precise technical qualifications as well as recognised skills and experience gained in the specific sector. Failure to do so may lead to health and safety risks to persons.***

It is recommended that when handling the product attention is paid to the information given in this manual or simply follow the instructions given on the packaging (if present).

Utilise the product only for the use specified by the manufacturer. Improper use of the product could lead to health and safety risks to persons as well as economic loss and furthermore will invalidate the guarantee given ***Bonfiglioli Trasmital****.*

Keep the product in perfect working order by following the scheduled maintenance procedure set out by ***Bonfiglioli Trasmital****. Good maintenance will ensure the best performances, a longer period of operation and a constant safeguard towards security requirements.*

Caution ***To undertake maintenance procedures in areas which are hard to reach or otherwise dangerous it is important to follow adequate safety conditions for one self and for others in compliance with the rules and regulations that govern safety in the workplace.***

When replacing worn parts, use original spare parts. Use oils and greases recommended by ***Bonfiglioli Trasmital****. Doing this, will ensure that the product works properly and that the safety level is "acceptable".*

Danger - Warning ***If the surfaces of the product have reached temperatures above 65°C, is necessary to wait for it to cool before running any action, and if necessary the operator should wear anti heat gloves.***

For actions in which you can get in contact with fluids, lubricants and greases should be followed all the warnings contained in safety data sheets of the respective manufacturers and should be used any personal protective equipment provided therein.

3.4 Lifting and handling

If the handling occurs when the product is still packaged, simply follow the instructions given on the packaging and/or use normal hoisting means.

Danger - Warning ***Considering that the size and form of the product do not allow manual shifting, in particular handlings, (e.g. installation) it is necessary to use accessories that guarantee human safety and which also avoid damages to the product, such as eyebolts, hooks, brackets etc. or special tools supplied by Bonfiglioli Trasmital.***

To lift and handle the product, after having opened the packaging, follow the information given below:

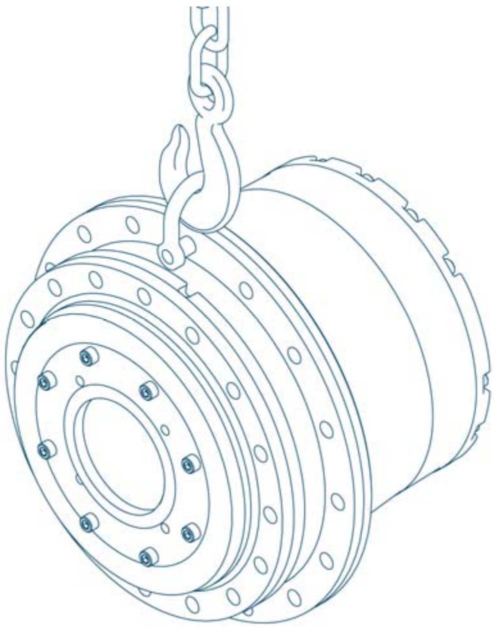
1. *By using a tackle lift and handle with care avoiding impacts.*

To turn gearboxes up side down it is necessary to use the hanging points provided for lifting operations, and in accordance with the rules which have been previously defined.

Wear ever gloves to provide appropriate mechanical protection to the hands.

The up side down operations must be carried out by keeping the gearbox as close as possible to a worktop; it is important to pay attention to its center of gravity so that its weight does not get unbalanced during this handling process.

Gearbox hookings must be made so that they do not come out of the hanging points or they cannot move and cause risks of falling loads; this is very important when the up side down turning operation is carried out by means of ropes or lifting bands which are more subject to displacement risks from loads hanging points.



5.0 INSTALLATION

5.1 Hydraulic motor installation

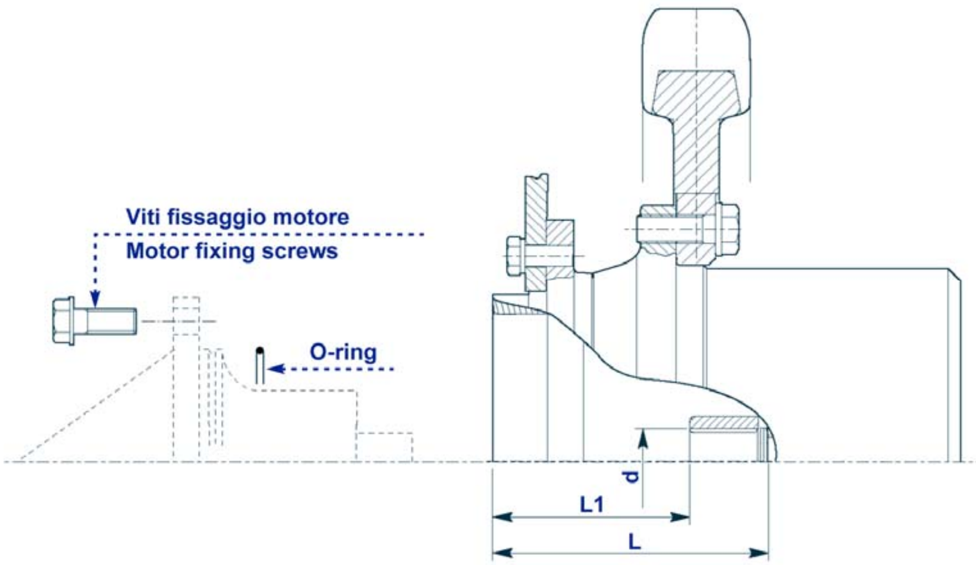
In case of hydraulic motor installation, the following precautions must be observed:

- *Do not force the coupling and do not use inappropriate tools during assembly. Take cure not to damage the flat/cylindrical coupling surfaces.*
- *Do not force the rotary coupling mechanisms with heavy overhung or thrust loads.*
- *To facilitate assembly and avoid the rotary coupling mechanisms wear, use a lubricating synthetic oil paste such as* ***Klüberpaste 46 MR 401*** *or* ***Tecnolube WRL 115*** *or similar product.*
- *The mating areas and the pilot diameter of the gearbox where the motor is to be mounted must be clean and without burrs.*

Information

Before assembling the hydraulic motor, verify by a depth slide gauge the correct assembly of the unit checking the axial distance as shown in the scheme below *(see installation drawing).*

1. *Fit the O-ring seal in its seat in the hydraulic motor and assemble it to the gearbox being careful not to damage the seal already fitted.*
2. *Assemble the Hydraulic motor to the gearbox tightening the screws by a torque wrench at a torque shown on the following table.*



Information

Under no circumstance remove the plastic lid from the power supply ports of the hydraulic motor; this will help avoid the accidental introduction of foreign bodies into the motor, until the hoses are assembled.

5.3 Installation of the track drive on the machine

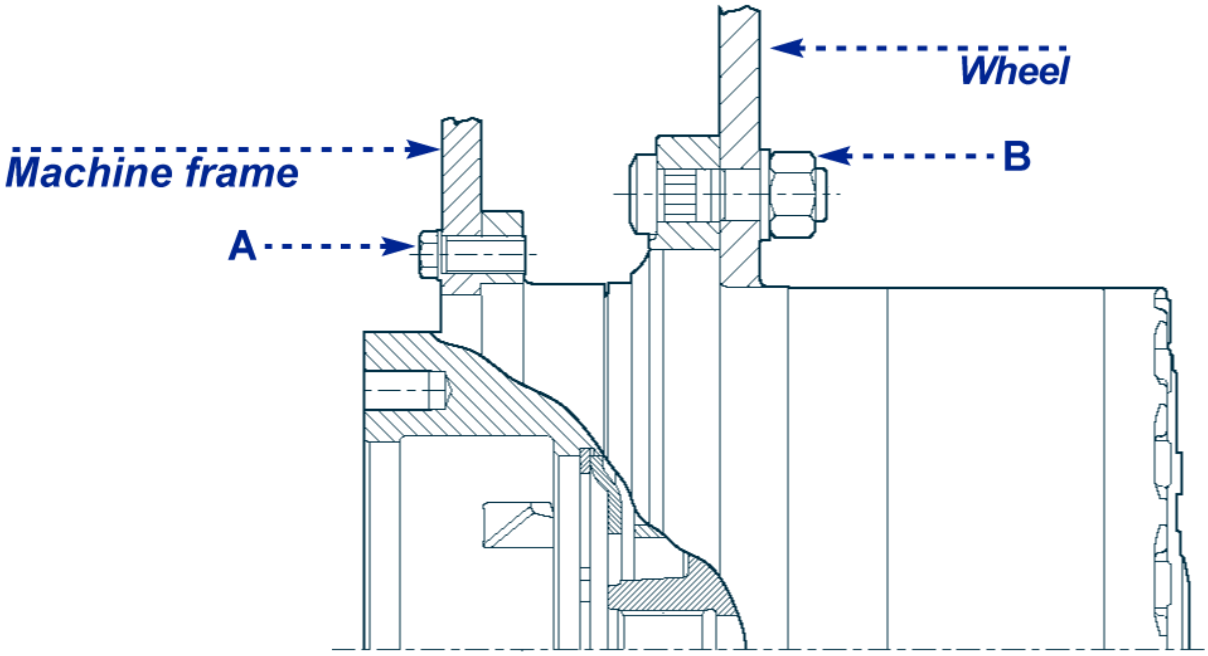
Information

The entire installation process must be planned as early as the general design phase of the machine. The person authorised to do the work must, if necessary, set out a safety plan to protect the health and safety of all persons directly involved and apply all applicable legislation.

1. *Ensure that the structure to wich the gear unit is to be mounted is sufficiently robust and rigid to support its weight and operating stresses.*
2. *Check that the machine to which the gear unit is to be installed is switched and cannot be accidentally switched on again.*
3. *Make sure all mating surfaces are flat.*
4. *Make sure the shaft/shaft or shaft/bore are perfectly aligned for coupling.*
5. *Fit suitable guards to protect against the gear unit's external moving parts.*
6. *We recommend applying a protective paste to all gear/motor mating surfaces and other parts such as **Klüberpaste 46 MR 401** or **Tecnolube WRL 115** or similar product, to ensure optimal coupling and protection against fretting corrosion.*
7. *Move the track drive in the mounting area applying lifting methods shown in section "**Lifting and handling** ".*
8. *Clean the mating surfaces from oils or paint and fit the track drive on the machine frame (for the correct orientation refer to the installation drawing).*
9. *Apply **LOCTITE 270** or similar product on the thread screws **(A)**. Fix the gearmotor to the machine frame tightening all the screws foreseen **(A)** by a torque wrench at a torque shown on the following table.*

5.4 Sprocket fixing

1. *Clean the mating surfaces from oils or paint and assemble the sprocket to the gearmotor.*
2. *Apply **LOCTITE 270** or similar product on the thread screws **(B)**. Fix the sprocket to the gearmotor tightening all the screws foreseen **(B)** by a torque wrench at a torque shown on the following table.*



		Machine frame			Wheel		
Gearbox	Torque Max. (Nm)	Screw A	N°/Nos.	(Nm)	Nut B	Nos.	(Nm)
6 09 W	23.000	M20-8.8	16	415	M22x1,5	16	550-650

5.5 Connection of the hydraulic system

1. **Information** ***Clean hoses thoroughly prior to connection and remove any internal obstructions.***

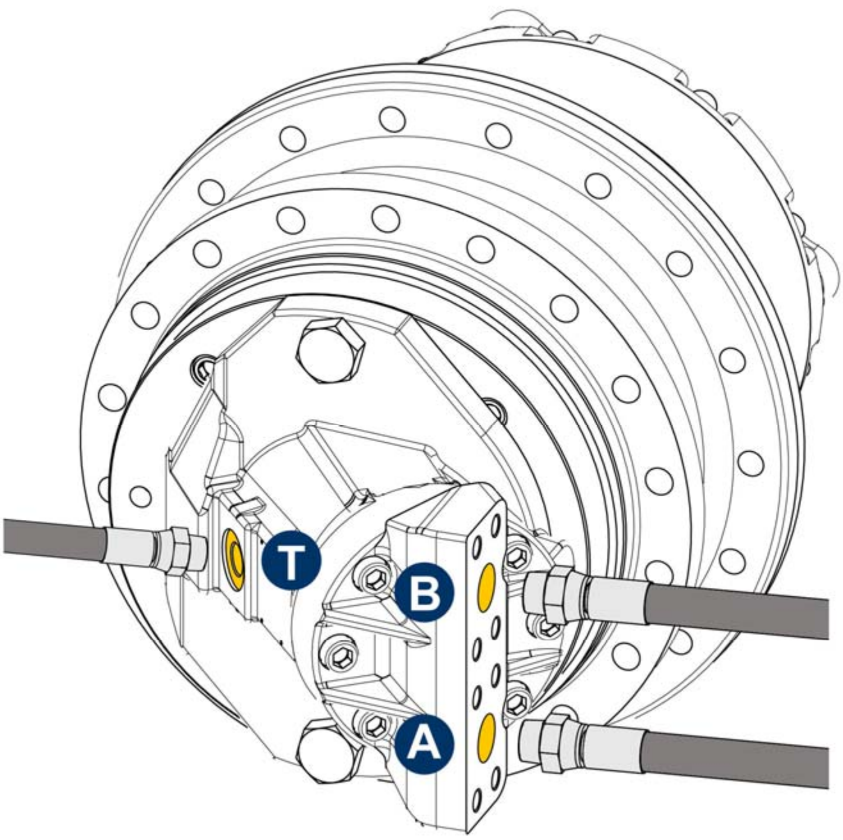
   Prevent any foreign particles from getting into the hoses by removing the plastic caps only at the time of the assembly.

   After hoses are connected to the motor, flow the hydraulic circuit and filter the oil from all the particles that may have contamined it.

2. *Clean the surface to be connected on the hydraulic motor.*
3. *Connect the hoses to the hydraulic motor ports (for hoses sizes and dimensions refer to the installation drawing).*

   Service ports: ***A-B***

   Drain port: ***T***

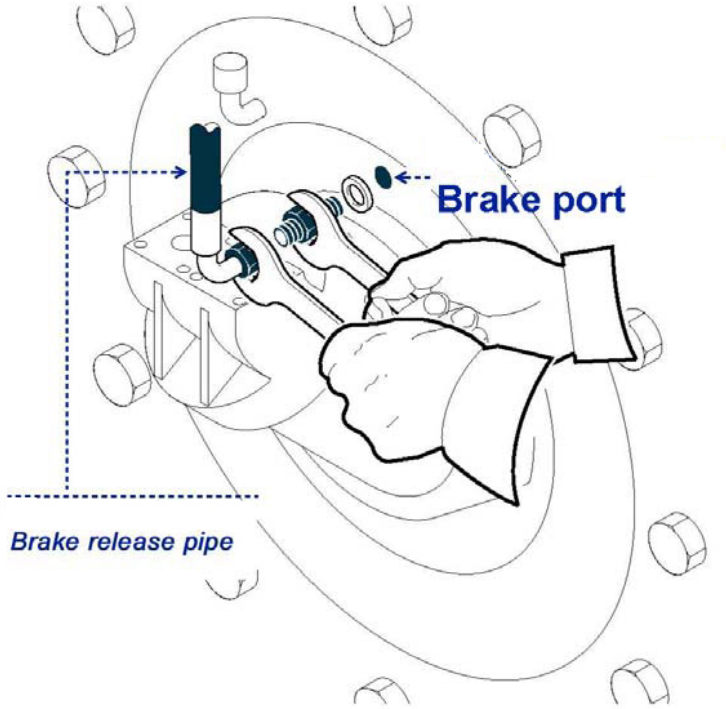


5.6 Connection of the brake

The gearbox drive can be supplied with a safety negative multidisc brake hydraulically driven (parking brake).

For further information see the installation drawing.

1. *To operate the brake, connect the brake pilot pipe to the brake port.*



6.0 LUBRICATION

6.1 Gearbox lubrication

The motor and the gearbox have separate lubrication. The gearbox is lubricated by oil splashing.

*The recommended oil type has to be **EP** characteristics according to **MIL-L-2105 C & API GL5.***

For standard working conditions, the recommended oil is:

Oil type	*Viscosity*
Mineral	**SAE 80W/90**
Synthetic	**SAE 75W/90**

For heavy duty working conditions (high loads, high duty cycles or high ambient temperatures), the recommended oil is:

Oil type	*Viscosity*
Mineral	**SAE 85W/140**
Synthetic	**SAE 80W/140 - SAE 75W/140**

In the following table the most common brands of lubricant and the types recommended are shown.

Information

During the operation the oil temperature must not exceed 85-90°C intermittent, if not otherwise indicated on installation drawing.

Caution

In case of lubrication with syntetic oils, is recommended to use only oils with PAO base if not otherwise specified when ordering.

Do not mix together oils of different brands or characteristics.

Use oils listed in the table or similar products with equivalent characteristics in order to not modify the brake performances (if present).

For information about characteristics of lubricating oils and their proper use, please consult the lubricant suppliers directly.

		Minerali/Minerals		Sintetici/Synthetics	
		-20°C / +30°C (SAE 80W/90)	+10°C / +45°C (SAE 85W/140)	-20°C / +30°C (SAE 75W90)	+10°C / +45°C (SAE 80W140)
SHELL	**SPIRAX S2 A 80W-90** (SPIRAX A 80W90)	●			
	SPIRAX S2 A 85W-140 (SPIRAX A 85W140)		●		
	SPIRAX S5 ATE 75W-90 (TRANSAXLE 75W90)			●	
	SPIRAX S6 AXME 75W-90 (SPIRAX ASX 75W90)			●	
	SPIRAX S 75W140				●
	SPIRAX S 80W140				●
AGIP	ROTRA MP 80W90	●			
	ROTRA MP 85W140		●		
	GEAR SYNTH 75W90			●	
API	EP SAE 80W90	●			
	EP SAE 85W140		●		
	EP SINT 75W90			●	
ARAL	EP PLUS 80W90	●			
	HYP 85W140		●		
	HYP SYNTH 75W90			●	
BP	ENERGEAR HYPO 80W/90	●			
	ENERGEAR HYPO 85W140		●		
	ENERGEAR SHX-M 75W90			●	
	ENERGEAR SHX-S 75W140				●
CASTROL	EPX 80W/90	●			
	EPX 85W/140		●		
	SAF-XO			●	
	MTX FULL SYNTHETIC				●
	SAF-X 75W140				●
CEPSA	TRANSMISSIONES EP 80W90	●			
	TRANSMISSIONES EP 85W140		●		
	TRANSMISSIONES EP FE+LD 75W90			●	
	TRANSMISSIONES EP FE+LD 75W140				●
CHEVRON TEXACO	DELO GEAR LUBRICANT EDI 80W90	●			
	DELO GEAR LUBRICANT EDI 85W140		●		
	TEGRA SYNTHETIC GEAR LUBRICANT 75W90			●	
	TEGRA SYNTHETIC GEAR LUBRICANT 80W140				●
ELF	TRANSELF TYPE B 80W/90	●			
	TRANSELF TYPE B 85W/140		●		
	TRANSELF SYNTH ESE FE 75W90			●	
	TRANSELF SYNTH ESE FE 75W140				●
ERG	GEAR EP 80W/90	●			
	GEAR EP 85W/140		●		
	GEAR EPS 75W90			●	
FUCHS	TITAN SUPER GEAR 80W90	●			
	TITAN SUPER GEAR 85W140		●		
	TITAN CYTRAC HSY 75W90			●	
	TITAN SINTOPOID 80W140				●
I.P.	PONTIAX HD 80W90	●			
	PONTIAX HD 85W140		●		
	PONTIAX HDS 75W90			●	
MOBIL	MOBILUBE HD 80W90	●			
	MOBILUBE HD 85W140		●		
	MOBILUBE 1 SHC 75W90			●	
PAKELO	GLOBAL GEAR SA 80W90	●			
	GEAR OIL EP GL-5 80W90	●			
	GLOBAL GEAR SA 85W140		●		
	GEAR OIL EP GL-5 85W140		●		
	GLOBAL MULTIGEAR TS 75W90			●	
	GLOBAL TRANSMISSION TS 80W140				●
Q8	GEAR OIL XG 80W90	●			
	T 55 85W 90	●			
	T 55 85W140		●		
	T 65			●	
TAMOIL	TAMGEAR MP LUBRICANT 80W90	●			
	TAMGEAR MP LUBRICANT 85W140		●		
	TAMGEAR PERFORMANCE 75W90			●	
TEXACO	GEARTEX EP-C 80W90	●			
	MULTIGEAR 80W90	●			
	GEARTEX EP-C 85W140		●		
	GEARTEX S5 75W90			●	
	MULTIGEAR S 75W90			●	
TOTAL	EP-B 80W90	●			
	TRANSMISSION TM 80W90	●			
	TRANSMISSION TM 85W140		●		
	TRANSMISSION SYN FE 75W90			●	
	TRANSMISSION SYN FE 75W140				●

6.2 Oil filling

Caution ***The gearbox is supplied without oil; anyway it has filling, draining and oil level plugs. Before putting the gearbox into operation, it is necessary to fill it with oil.***

Proceed according to the following instructions:

1. *Check that the gearbox axis is horizontal. Rotate the gearbox housing until the drain plug **(1A)** is on the bottom of the vertical axis of the end cover.*
2. *Unscrew the fill and level oil plugs **(1A-1B).***
3. *Add the lubricating oil from the hole **(1A)** with the features listed in section "**Gearbox lubrication**" untill it flows out from the level hole **(1B)**.*
4. *Screw the filling and level oil plugs **(1A-1B)***
5. *Run the gearmotor, after a few minutes, stop and check the oil level.*
6. *If necessary, refill with lubricant oil.*

For further information see the installation drawing.

Tighten the plugs by a torque wrench at a torque shown on the table in the end of this manual.

6.3 Oil draining and replacement

1. *Check that the gearbox axis is horizontal. Rotate the gearbox housing until the drain plug **(1B)** is on the bottom of the vertical axis of the end cover.*

Danger - Warning ***Remove the oil plugs with extreme caution because an overpressure inside the unit could strongly expel them.***

2. *Unscrew the **plugs (1A-1B)** and let the oil flow in a large enough container; in order to facilitate the draining must be oil still warm.*

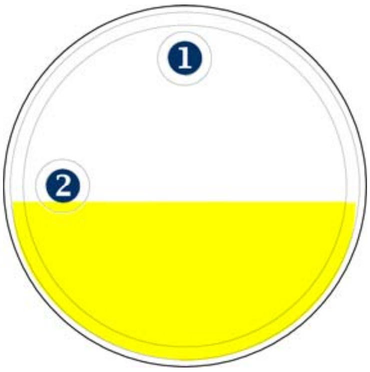
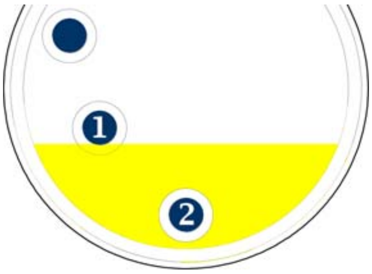
3. *Wait a few minutes until all the oil is drained and then proceed to screw on the plugs **(1A-1B)**.*
4. *Proceed with the oil fill-up according to the following procedures listed in Section "**Oil filling**".*

Danger - Warning ***Do not dispose of the oil in the natural environment but be careful to eliminate it in compliance with the relative rules and regulations that govern locally.***

Information ***Check the correct oil level after filling through the appropriate plug.***

Oil quantity to fill the gearbox is indicated on the following table or on the product installation drawing (Indicative values).

Belove are reported the standard gearbox oil filling-draining sketches.

Oil Plugs Position	Oil Filling	Oil Draining	Gearbox	Oil Qt.
				3,5/3
				

6.4 Gearbox factory filled with oil

Caution ***Before the starting up, check the level of lubricating oil. If necessary, refill with lubricant oil.***

*In case the gearbox is factory filled with lubricant oil at level (as specified when ordering) ,follow the procedures given in detail at sections "**Oil filling**" and "**Oil draining and replacement**" only for the oil replacements following the start up and running in.*

The lubricant oil type is shown on the product installation drawing.

6.5 Characteristics of the Hydraulic System

*The hydraulic motor lubrication must reflect the ISO VG 46 characteristics. It must be filtered with a maximum grade of **10 µm** and with a contamination level equal to or inferior to **class 9 according to NAS 1638** or **22/18/15 according ISO/DIS 4406** (unless otherwise indicated on the product installation drawing).*

Hydraulic fluids with different properties should not be mixed.

Use filter with a visual indicator which can detect clogging from the outside, and with a reliefvalve which by-passes the oil when the filter element is clogged.

Should the machine operate at very low temperature (artic climates) it is essential to use specific guidelines (contact the manufacturer).

As the temperature of the hydraulic oil may be a critical factor we recommend that it be checked.

High operational temperatures will causea corruption of the oxidation resistance level and will accelerate the deterioration process of the hydraulic oil.

The following precautions should be taken:

1. *The temperature ranges of the hydraulic oil during operation have to be within **25°C÷90°C.***
2. *The temperature of oil should reach **-20°C** prior to start operation.*
3. *During operation the oil temperature can rise to **90°C** but this temperature is acceptable only for very short periods of time.*

These temperatues have been set to take into consideration general degrading in viscosity as well as the wear resisting additives used in the oil.

*The lifetime of motor will be reduced significantly if it should continuously above **90°C**.*

7.0 START UP AND RUNNING IN

In this first stage it is advised to follow the measures given below:

1. *Check the correct lubrication of the unit.*

2. *Fill the motor housing with hydraulic oil from the* ***drain port (T)*** *(see the following picture).*

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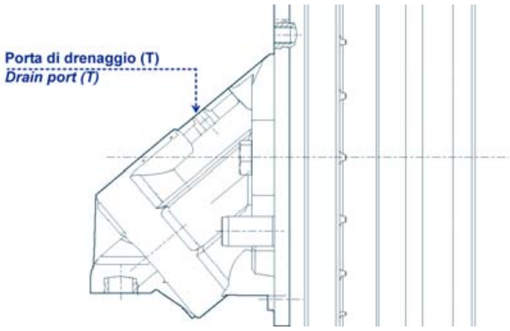


3. *Bleed air from every part of the hyraulic circuit and add oil in the tank if necessary.*

Information ***The presence of residual air in the hydraulic circuit will manifest itself with the presence of foam in the tank and will lead to a jerking of the motor as well as excessive noise coming from the motor and the valves.***

4. *Start the gearmotor at a low speed and gradually increase it after having verified that it functions correctly without any noises or vibrations.*

Information ***Do not reach maximum pressure unless the entire system has been filtered to eliminate any particles of dirt that may be present.***

During the running-in stage follow the steps given below.

5. *Check the correct revolution and direction of rotation.*
6. *Make sure that the functioning is regular and with-out any excessive noises and vibrations.*
7. *Make sure that the oil temperature does not exceed 85-90°C.*

After having terminated this first running-in follow the steps given below.

8. *Check that there are no oil leakages. If present, proceed to remove them.*
9. *Check the level of lubricating oil in the gearmotor.*

10. *It could happen that due to the presence of air, during the first start up, the opening action of the brake could be slowed down. It is advised to repeat the opening and closing function of the brake.*
11. *Check that there are no other problems in general.*

7.2 Speed shift and hydraulic disengagement

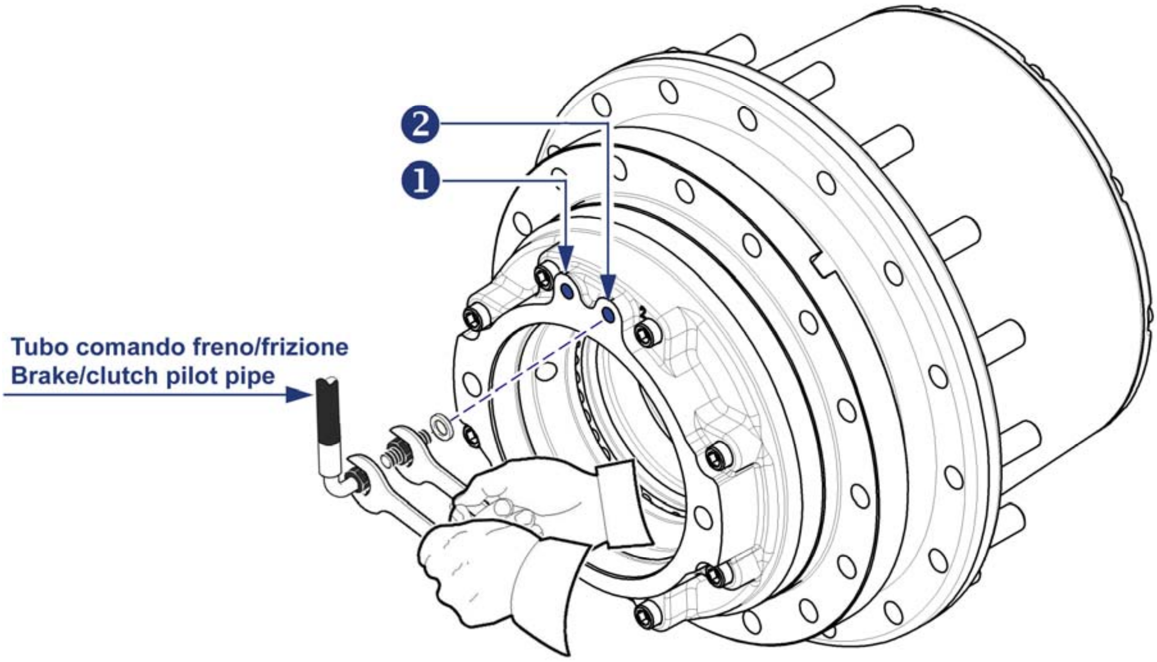
*In the "**710C2/3**" size the gearbox has a negative multidiscs brake/clutches for low/high speed hydraulically driven (speed shift).*
The selected driving speed is transmitted from the hydraulic motor to the gearbox in accordance with the pressurized hydraulic clutch.

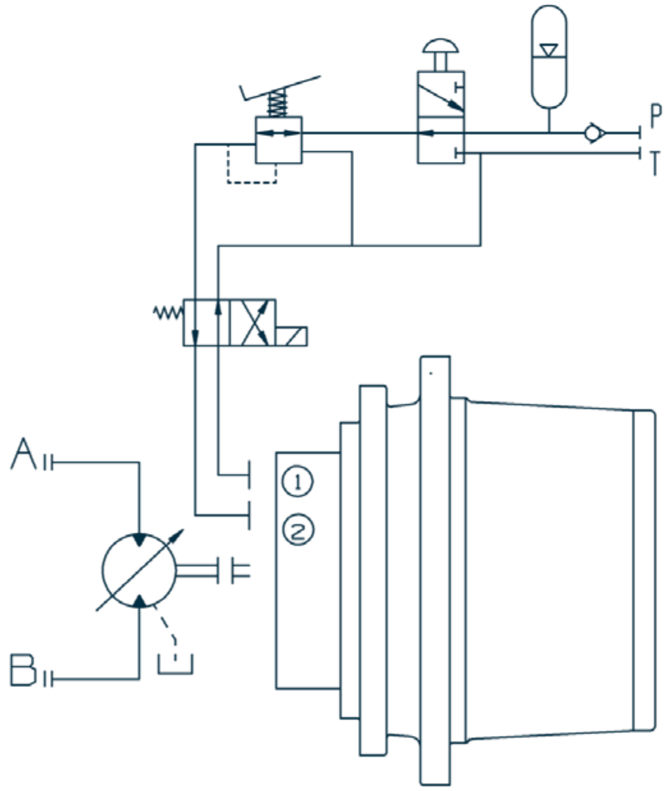
For information regarding the characteristics of the brake/clutch, port types and dimensions, refer to the installation drawing.

Information ***The max wheel speed with disengaged gearbox (pressurized hydraulic clutch) must not overcome the rpm shown in section "Mechanical disengagement" for max continuative period of 1 hr.***

Pericolo - Attenzione ***The disengagement must be connected or disconnected only when the gearbox is stopped on flat ground.***

1. *To operate the brake/clutch, connect the pilot pipes to the followings ports:*
   a. *Low speed clutch port: **"1"***
   b. *High speed clutch port: **"2"***





Comando porta *Presurized port*	Pressione *(bar)* *Pressure (bar)*	Azione *Function*
1-2	0	*Parking brake engaged (gearbox locked)*
		Brake technical data *Braking torque at gearbox output (see installation drawing)*
1	Min Max	***Low speed*** *(ratio and Min/Max pressure data are shown on the installation drawing)*
2	0	
1	0	***High speed*** *(ratio and Min/Max pressure data are shown on the installation drawing).*
2	Min Max	
1	Min Max	*At this condition the hydraulic motor and brake are disconnected to the gearbox: the wheel is idle (Min/Max pressure data are shown on the installation drawing).*
2	Min Max	

Operation:

1. ***Engaged gearbox:***

   At this condition the motion is trasmitted from the hydraulic motor to the gearbox.

2. ***Disengaged gearbox:***

   The clutches are pressurized at the same time, the hydraulic motor will be disengaged from the gearbox: free wheel.

   Danger - Warning ***In this last gearbox status, the machine can freely move. It is responsibility of the machine manufacturer to adopt one supplementary braking system in order to avoid loosing the machine control.***

Information ***Following disengagement, always engage the gearbox when the machine is used normally.***

8.0 VARIANTS

If requested the gearboxes can be supplied with variants previously specified when ordering after agreement with the customer.

1. ***Lubrication:*** *The gearboxes can be supplied with different types of lubricant oil at level.*
2. ***Painting:*** *External surfaces of the unit can be painted with different finish paint coats.*
3. ***Identification labels:*** *Identify visually different product configurations.*

Variants are described on the product installation drawing attached.

9.0 MAINTENANCE

Under normal operating circumstances, no routine maintenance is required, except routine oil checks and oil changes. As recommended in this manual, unusual operating characteristics, such as noise or overheat, should indicate further investigation. Always follow instructions set out in paragraph ***"Information on safety"***

For a proper maintenance of the gearbox, the following checks and operations have to be done.

Controllo / Inspection	**Frequenza / *Frequency***	**Azione / *Action***
Tightening screws	*After the first* ***50*** *operating hours of the gearbox*	*Screws tightening torque check*
Oil level	*Every* ***150*** *operating hours of the gearbox*	*Refill oil if necessary*
1st oil change	*At* ***150*** *operating hours of the gearbox*	*Oil replacement*
Oil plugs with washers or seals	*Every oil change*	*Oil plugs with washers or seals replacement*
Cambi olio successivi (olio minerale) / *Next oil change (mineral oil)*		
Standard conditions	*Every* ***1000*** *operating hours or* ***12*** *mounths*	*Oil replacement*
Heavy duty conditions	*Every* ***500*** *operating hours or* ***12*** *mounths*	*Oil replacement*
Cambi olio successivi (olio sintetico) / *Next oil change (sinthetyc oil)*		
Standard conditions	*Every* ***2000*** *operating hours or* ***24*** *mounths*	*Oil replacement*
Heavy duty conditions	*Every* ***1000*** *operating hours or* ***24*** *mounths*	*Oil replacement*

The values listed on the table above refer to general working conditions values of the gearbox. In case of maintenance with different schedules, they are subject to technical choices made during the product definition.

Information ***In case of important and complex maintenance operations, make reference to The Spare Part Lists Exploded View which can be supplied under request or the suggestions of this manual.***

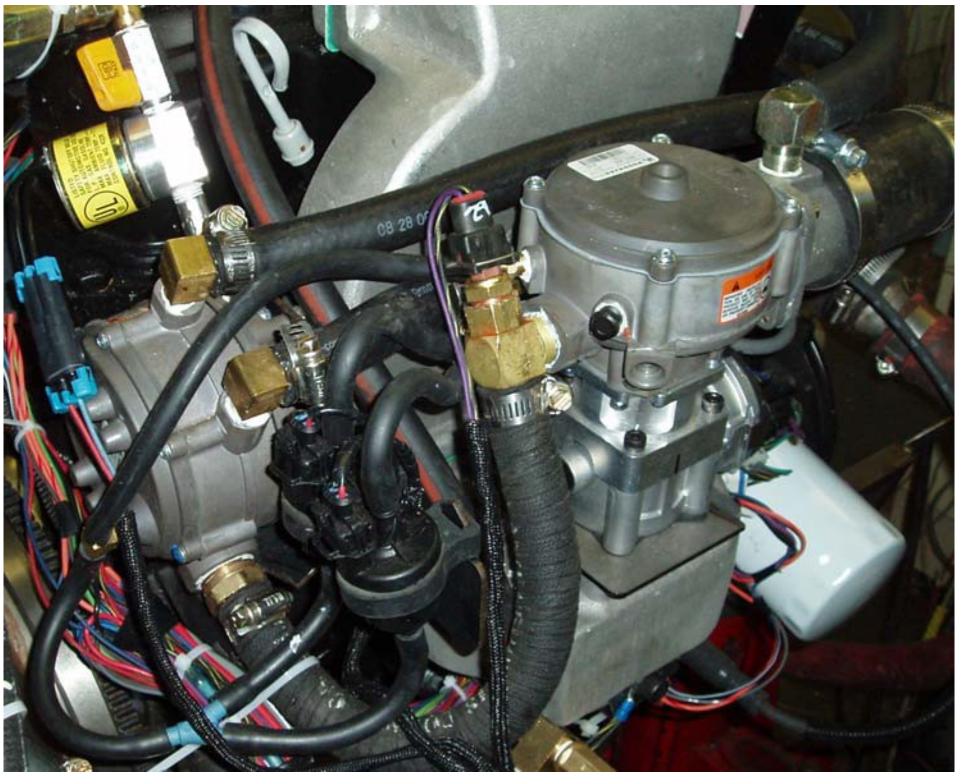
If you need further instructions or if you encounter any particular problems, please feel free to contact the gearbox distributor or our technical service

9.1 Trouble shootings

The following tables can be used to locate issues with the wheel drive gear motors.

Anomalies	Causes	Remedies
External oil leakage:		
From the lifetime seal	*Lifetime damaged*	*Replace lifetime seal*
From the end cover	*O-ring seal damaged*	*Replace O-ring seals*
From the oil plugs	*Plug seal damaged*	*Replace plug seal*
	Plugs or screws loose	*Tighten the plugs/screws*
	Oil exceeding max. level	*Check the oil level*
	Breather plug clogged	*Clean or replace the plug*
From the hydraulic motor	*O-Ring seals damaged*	*Replace O-Ring seals*
	Plugs or screws loose	*Tighten the plugs/screws*
	Internal motor parts damaged	*Check hydraulic motor*
Eccessiva rumorosità / *Too much noise:*		
Inside the hydraulic motor (Mechanical noise)	*Internal motor damaged*	*Contact HMH Factory*
Hydraulic noise (during the slowing down of the motor speed)	*Hydraulic circuit malfunctioning*	*Verify hydraulic circuit*
Inside the gearmotor (reductions)	*Internal damage*	*Contact HMH Factory*

Anomalies	Causes	Remedies
Other:		
Overheating	Insufficient oil level	Check the oil level and refill if necessary
	Hydraulic oil too warm	Check the hydraulic circuit
	Brake not fully released	Check brake release pressure
Insufficient power	Internal motor parts damaged	Contact HMH Factory
Insufficient braking torque	Parking brake malfunctioning	
	-Brake discs worm	Replace brake disc pack
	-Damaged parts	Check brake components
Sprocket locked	Hydraulic motor locked	Contact HMH Factory
	Parking brake locked	Check the complete brake release
	Mechanical components damaged	Contact HMH Factory



WARNING—DANGER OF DEATH OR PERSONAL INJURY

WARNING—FOLLOW INSTRUCTIONS

Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment. Practice all plant and safety instructions and precautions. Failure to follow instructions can cause personal injury and/or property damage.

WARNING—OUT-OF-DATE PUBLICATION

This publication may have been revised or updated since this copy was produced. To verify that you have the latest revision, be sure to check the Hoist website:

www.HOISTLIFT.COM

The revision level is shown at the bottom of the front cover after the publication number. The latest version of most publications is available at:

www.hoistlift.com

If your publication is not there, please contact your customer service representative to get the latest copy.

WARNING—OVERSPEED PROTECTION

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.

WARNING—PROPER USE

Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.

CAUTION—POSSIBLE DAMAGE TO EQUIPMENT OR PROPERTY

CAUTION—BATTERY CHARGING

To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.

CAUTION—ELECTROSTATIC DISCHARGE

Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts.

- Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).
- Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.
- Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.

IMPORTANT DEFINITIONS

- A WARNING indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
- A CAUTION indicates a potentially hazardous situation which, if not avoided, could result in damage to equipment or property.
- A NOTE provides other helpful information that does not fall under the warning or caution categories.

Regulatory Compliance

EPA / CARB Emissions Certification

When properly applied and calibrated, Hoist's MI-07 control system is capable of meeting Environmental Protection Agency (EPA) 2007 Large Spark Ignition (LSI) emission standards (40 CFR Part 1048.101) when operating properly with an approved three-way catalyst. The emission standards, including appropriate deterioration factors over the useful life of the system, are as follows:

HC + NO_X: 2.0 g/hp-hr [2.7 g/kW-hr] CO: 3.3 g/hp-hr [4.4 g/kW-hr]

Evaporative emissions comply with 40 CFR Part 1048.105. These standards apply only to volatile liquid fuels such as gasoline. Note that the engine crankcase must be closed.

As defined in applicable regulations, the engine control system is designed to maintain emissions compliance for seven (7) years or 5000 hours, whichever occurs first, provided appropriate maintenance is performed as defined in the service manual for the system. Maintenance intervals shall be defined and approved by the regulating body. Component warranty shall comply with regulatory requirements (40 CFR Part 1048.120) for all emission related components. Warranty for non-critical emissions components will be as defined in the individual purchase agreement.

North American Compliance

The regulator is UL listed per Category ITPV LP-Gas Accessories, Automotive Type.

The regulator and mixer have tamper-resistant features approved by the California Air Resources Board (CARB).

Special Conditions for Safe Use

Field wiring must be suitable for at least 248°F (120°C).

SECM-48 inputs are classified as permanently connected International Electrotechnical Commission (IEC) measurement Category I. To avoid the danger of electric shock, do not use inputs to make measurements within measurement categories II, III, or IV. See Hoist Material Handling publication 26377, SECM-48 Manual, Chapter 2 for additional information on transient over-voltage input ratings.

SECM-48 input power must be supplied from a power supply/battery charger certified to IEC standard with a Safety Extra Low Voltage (SELV) classified output. Input power should be properly fused according to the wiring diagram in HMH publication 26377, SECM-48 Manual.

SECM-48 inputs and outputs may only be connected to other circuits certified as SELV.

The IP-56 Ingress Protection rating of the control depends on the use of proper mating connectors. See HMH publication 26377, SECM-48 Manual, Chapter 2: Installation—Wiring Connections, Table 2-1 for information on the proper mating connectors for use with this control.

WARNING—EXPLOSION HAZARD
Do not connect or disconnect while circuit is live unless area is known to be non-hazardous.

Substitution of components may impair suitability for Class I, Division 2, or Zone 2 applications.

Electromagnetic Compatibility (EMC)

All MI-07 active electronic components manufactured by the HMH Governor Company have been developed and individually tested for electromagnetic compatibility using standardized industry methods under laboratory test conditions. Actual EMC performance may be adversely affected by the wiring harness design, wire routing, the surrounding structure, other EMC generating components, and other factors that are beyond the control of the HMH Governor Company. It is the responsibility of the vehicle and/or application manufacturer to confirm that the overall system's EMC performance is in compliance with all standards that they wish to apply for their particular use.

Electrostatic Discharge Awareness

All electronic equipment is static-sensitive, some components more than others. To protect these components from static damage, you must take special precautions to minimize or eliminate electrostatic discharges.

Follow these precautions when working with or near the control.

1. Before doing maintenance on the electronic control, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.)
2. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
3. Keep plastic, vinyl, and Styrofoam materials (such as plastic or Styrofoam cups, cup holders, cigarette packages, cellophane wrappers, vinyl books or folders, plastic bottles, and plastic ash trays) away from the control, the modules, and the work area as much as possible.

CAUTION—ELECTROSTATIC DISCHARGE
To prevent damage to electronic components caused by improper handling, read and observe the precautions in HMH manual 82715, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

LPG System Overview

MI-07 General Description

Hoist'semission-certified MI-07 control system provides a complete, fully integrated engine management system that meets or exceeds 2007 emission standards for Large Spark Ignited (LSI) engines established by the California Air Resources Board (CARB) and the Environmental Protection Agency (EPA).

The control system is applicable to naturally aspirated engines ranging in size from 1.5L to 8.1L (25 HP to 170 HP) with up to 8 cylinders running on LPG and/or gasoline in mobile industrial applications.

It provides accurate, reliable, and durable control of fuel, spark, and air over the service life of the engine in the extreme operating environment found in heavy-duty, under hood, on-engine electronic controls.

MI-07 is a closed loop system utilizing a catalytic muffler to reduce the emission level in the exhaust gas. In order to obtain maximum effect from the catalyst, an accurate control of the air fuel ratio is required. A small engine control module (SECM) uses two heated exhaust gas oxygen sensors (HEGO) in the exhaust system to monitor exhaust gas content. One HEGO is installed in front of the catalytic muffler and one is installed after the catalytic muffler.

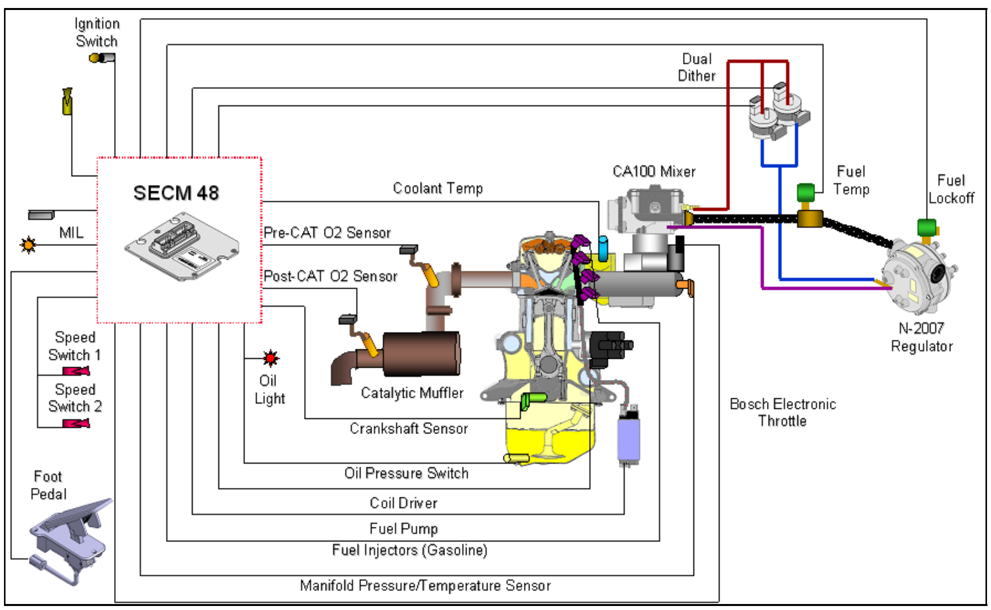


Figure 1. MI-07 Bi-Fuel System for 3.0L Engines

The SECM makes any necessary corrections to the air fuel ratio by controlling the inlet fuel pressure to the air/fuel mixer by modulating the dual fuel trim valves (FTV) connected to the regulator. Reducing the fuel pressure leans the air/fuel mixture and increasing the fuel pressure enriches the air/fuel mixture. To calculate any necessary corrections to the air fuel ratio, the SECM uses a number of different sensors to gain information about the engine's performance. Engine speed is monitored by the SECM through a variable reluctance (VR) or Hall Effect sensor. Intake manifold air temperature and absolute pressure are monitored with a TMAP sensor.

The MI-07 system implements a drive-by-wire (DBW) system connecting the accelerator pedal to the electronic throttle through the electrical harness; mechanical cables are not used. A throttle position sensor (TPS) monitors throttle position in relation to the accelerator pedal position sensor (APP) command. Engine coolant temperature and adequate oil pressure are also monitored by the SECM. The SECM controller has full adaptive learning capabilities, allowing it to adapt control function as operating conditions change. Factors such as ambient temperature, fuel variations, ignition component wear, clogged air filter, and other operating variables are compensated.

MI-07 Closed Loop LP Fuel System

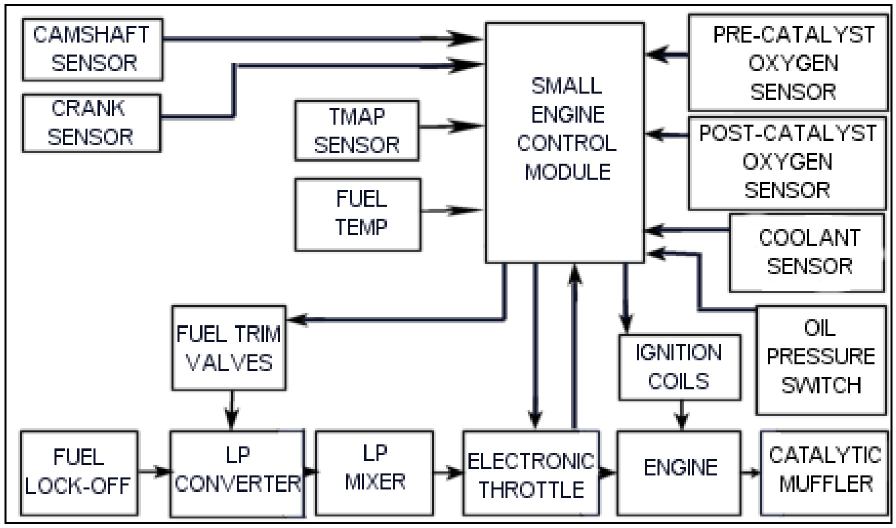


Figure 2. MI-07 Closed Loop Fuel System

MI-07 System Components

The MI-07 control system provides electronic control to the following subsystems on mobile industrial engines:

- Fuel delivery system
- Spark-ignition control system
- Air throttle
- Sensors/Switches/Speed inputs

Key Components

The MI-07 system functions primarily on engine components that affect engine emissions and performance. These key components include the following:

- Engine/Combustion chamber design
- Intake/Exhaust valve configuration, timing and lift
- Intake/Exhaust manifold design
- Catalytic converter and exhaust system
- Throttle body
- Air intake and air filter
- Gaseous fuel mixer †

- Gaseous fuel pressure regulator †
- Fuel trim valves
- Fuel trim orifices
- Small engine control module (SECM), firmware, and calibration †
- Fuel system sensors and actuators
- Ignition system including spark plugs, cables, coils and drivers

•Gasoline injectors and fuel pressure regulator (bi-fuel- systems only) (†) Components of MI-07 system manufactured by Hoist

MI-07 System Features

The MI-07 system uses an advanced speed-density control strategy for fuel, spark, and air throttle control. Key features include the following.

- Closed-loop fuel control with fuel specific controls for LPG and gasoline (MPI) fuels
- Speed-load spark control with tables for dwell, timing, and fuel type
- Speed-load throttle control with table for maximum TPS limiting
- Closed-loop fuel control with two oxygen sensors (one installed pre catalyst and one installed post catalyst). The pre-catalyst oxygen sensor includes adaptive learn to compensate for fuel or component drift. The post-catalyst oxygen sensor includes adaptive learn to compensate the pre-catalyst oxygen sensor setting for oxygen sensor drift and catalyst aging. The pre-catalyst oxygen sensor function includes parameters for transport delay, O_2 set point, excursion rich/lean, jump back rich/lean, and perturbation.
- LPG fuel temperature compensation
- Min/max speed governing
- All-speed isochronous governing
- Fixed-speed isochronous governing with three switch-selectable speeds
- Fuel enrichment and spark timing modifiers for temperature and fuel type
- Transient fuel enrichment based on rate of change of TPS
- Transient wall wetting compensation for gasoline
- Input sensor selection and calibration
- Auxiliary device control for fuel pump, fuel lock-off solenoid, tachometer, MIL, interlocks, vehicle speed limiting, etc.
- CANBus data transfer for speed, torque, etc.
- Anti-restart strategy to inhibit starter engagement while running

Other system features include:

Tamper-Resistance
Special tools, equipment, knowledge, and authorization are required to effect any changes to the MI-07 system, thereby preventing unauthorized personnel from making adjustments that will affect performance or emissions.

Diagnostics

MI-07 is capable of monitoring and diagnosing problems and faults within the system. These include all sensor input hardware, control output hardware, and control functions such as closed-loop fuel control limits and adaptive learn limits. Upon detecting a fault condition, the system notifies the operator by illuminating the MIL and activating the appropriate fault action. The action required by each fault shall be programmable by the OEM customer at the time the engine is calibrated.

Diagnostic information can be communicated through both the service tool interface and the MIL. With the MIL, it is possible to generate a string of flashing codes that correspond to the fault type. These diagnostics are generated only when the engine is not running and the operator initiates a diagnostic request sequence such as repeated actuations of the pedal within a short period of time following reset.

Limp Home Mode
The system is capable of "limp-home" mode in the event of particular faults or failures in the system. In limp-home mode the engine speed is approximately 1000 RPM at no load. A variety of fault conditions can initiate limp-home mode. These fault conditions and resulting actions are determined during calibration and are OEM customer specific.

Service Tool
A scan tool/monitoring device is available to monitor system operation and assist in diagnosis of system faults This device monitors all sensor inputs, control outputs, and diagnostic functions in sufficient detail through a single access point to the SECM to allow a qualified service technician to maintain the system. This Mototune software (licensed by Mototron Communication) is secure and requires a crypt-token USB device to allow access to information.

Bi-Fuel System
A bi-fuel system operates on either LPG or gasoline. The engine will run on only one fuel at a time. The fuel type can be switched while the engine is stopped or running at low speeds and low loads. The fuel selection switch is a three-position type where the center position is fuel off.

Customer-Supplied Components
MI-07 requires additional components to operate that are not included with the system. These include the wire harness, mixer-to-throttle adapter, air horn adapter, mounting brackets, non-critical fittings, and hoses. These items are application specific and are the responsibility of the packager, manufacturer of record (MOR), or
original equipment manufacturer (OEM). Hoist will provide assistance as needed to ensure proper fitting to the MI-07 system components.

NOTE
It is the responsibility of the customer to consult with Woodward regarding the selection or specification of any

LPG Fuel System

Operation

The principles outlined below describe the operation of MI-07 on an LPG fuel system. An LPG fuel system consists of the following components:

- Fuel filter (supplied by customer)
- Electric fuel lock-off solenoid valve
- Fuel pressure regulator/vaporizer
- Two orificed fuel trim valves
- Gas/Air mixer with fixed orifice for trim system and fuel temperature sensor
- Miscellaneous customer-supplied hoses and fittings

Fuel is stored in the customer-supplied LPG tank in saturated liquid phase and enters the fuel system from the tank as a liquid and at tank pressure. Fuel passes through a high-pressure fuel filter and lock-off solenoid, and is then vaporized and regulated down to the appropriate pressure to supply the mixer. The regulator controls the fuel pressure to the gas/air mixer.

Dual Dither Valve

The key to meeting emissions requirements when operating in LPG is the dual dither valve hardware in the fuel system. Similar to the Hoist MI-04 system, the dual dither system modulates the fuel pressure regulator outlet pressure by providing an offset to the regulator secondary stage reference pressure. By adding a second dither valve, or fuel trim valve (FTV), the MI-07 system provides smoother, more accurate control of supply pressure resulting in better control of air fuel ratio and emissions. This smoother control also minimizes wear on fuel system components such as the regulator diaphragm and lever by significantly reducing the pressure pulsations observed with a single FTV.

Regulator Pressure Offset

Regulator pressure offset is achieved through the use of a fixed orifice and a variable orifice in series. The inlet to the fixed orifice is connected to a mixer port that monitors inlet air pressure (roughly equal to ambient pressure). The outlet of the fixed orifice is connected to both the pressure regulator reference port and the inlet to the two FTVs (the variable orifice) that act in parallel. The outlets of the FTVs are connected to a port at the mixer outlet, referred to as Air Valve Vacuum (AVV). Thus, by modulating the FTVs, the pressure regulator reference pressure can be varied between mixer inlet pressure and AVV. For a given change in the pressure regulator reference pressure, the pressure regulator outlet pressure changes by the same amount and in the same direction. The end result is that a change in FTV modulation changes the outlet pressure of the regulator/fuel inlet pressure of the mixer, and thus the AFR. A major benefit of this trim system results from the use of mixer inlet pressure and AVV as the reference pressure extremes. The pressure differential across the mixer fuel valve is related to these same two pressures, and thus so is fuel flow. Given this arrangement, the bias pressure delta scales with the fuel cone pressure delta. The result is that the trim system control authority and resolution on AFR stays relatively constant for the entire speed and load range of the engine.

SECM

The Small Engine Control Module (SECM) controls the LPG lock-off solenoid valve and the FTVs. The lock-off solenoid is energized when fueling with LPG and the engine is turning. FTV modulation frequency will be varied as a function of RPM by the SECM in order to avoid resonance phenomena in the fuel system. FTV control signals will be altered by the SECM in order to maintain a stoichiometric air-fuel ratio. Control signals are based primarily on feedback from the exhaust gas oxygen sensor, with an offset for fuel temperature.

MI-07 LP Fuel Filter

After exiting the fuel tank, liquid propane passes through a serviceable inline fuel filter to the electric fuel lock off. **Figure 3** shows a typical inline type LP fuel filter manufactured by Century. The primary function of the fuel filter is to remove particles and sediments that have found their way into the tank. The LP fuel filter will *not* remove heavy end solids and paraffins that build up in LPG fuel systems as a result of vaporization.

Figure 3. Inline LP Fuel Filter

MI-07 Fuel Lock-Off (Electric)

The fuel lock-off is a safety shutoff valve normally held closed by spring pressure. It incorporates an electric solenoid and prevents fuel flow to the regulator/converter when the engine is not in operation. This is the first of three safety locks in the MI-07 system.

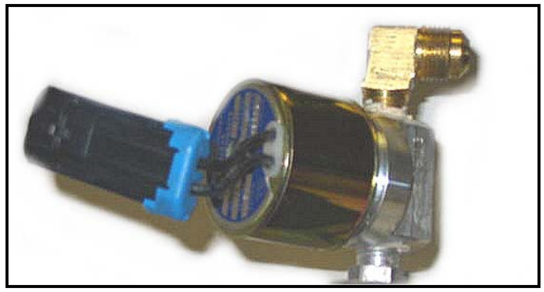


Figure 4. Electric Fuel Lock Assembly

In the MI-07 design, power is supplied to the fuel lock-off via the main power relay with the SECM controlling the lock-off ground (earth) connection. The lock-off remains in a normally closed (NC) position until the key switch is activated. This supplies power to the lock-off and the SECM, but will not open the lock-off via the main power relay until the SECM provides the lock-off ground connection. This design gives the SECM full control of the lock-off while providing additional safety by closing the fuel lock-off in the unlikely event of a power failure, wiring failure or module failure.

When the liquid service valve in the fuel container is opened, liquid propane flows through the LP filter and through the service line to the fuel lock-off. Liquid propane enters the lock-off through the 1/4" NPT liquid inlet port and stops with the lock-off in the normally closed position. When the engine is cranking, the main power relay applies power to the lock-off and the SECM provides the lock-off ground causing current to flow through the windings of the solenoid creating a magnetic field. The strength of this magnetic field is sufficient to lift the lock-off valve off of its seat against spring pressure. When the valve is open liquid propane, at tank pressure, flows through the lock-off outlet to the pressure regulator/converter. A stall safety shutoff feature is built into the SECM to close the lock-off in case of a stall condition. The SECM monitors three engine states: *Crank* - when the crankshaft position sensor detects any engine revolutions; *Stall* - when the key is in the ON position but the crankshaft position sensor detects no engine revolutions; and *Run* - when the engine reaches pre-idle RPM. When an operator turns on the key switch the lock-off is opened, but if the operator fails to crank the engine the SECM will close the lock-off after a number of seconds (calibration specific).

Pressure Regulator/Vaporizer

The pressure regulator/vaporizer receives liquid LPG from the fuel storage tank, drops the pressure, changes the LPG phase from liquid to vapor, and provides vapor phase LPG at a regulated outlet pressure to the mixer. To offset the refrigeration effect of the vaporization process, the regulator will be supplied with engine coolant flow sufficient to offset the latent heat of vaporization of the =LPG. A thermostat installed in the coolant supply line maintains regulator outlet coolant temperature at or below 140°F (60°C) which minimizes the deposit of fuel contaminants and heavy ends in the regulator and assures a more controlled vaporization process with reduced pressure pulsations.

A higher flow pressure regulator is required on larger engines.

Figure 5. Regulator

The regulator is normally closed, requiring a vacuum signal (negative pressure) to allow fuel to flow. This is the second of three safety locks in the MI-07 system. If the engine stops, vacuum signal stops and fuel flow will automatically stop when both the secondary (2nd stage) valve and the primary (1st stage) valve closes. Unlike most other regulator/converters, the primary valve closes *with* fuel pressure rather than against pressure, extending primary seat life and adding additional safety.

Liquid propane must be converted into a gaseous form in order to be used as a fuel for the engine. When the regulator receives the desired vacuum signal it allows propane to flow to the mixer. As the propane flows through the regulator the pressure is reduced in two stages from tank pressure to slightly less than atmospheric pressure. As the pressure of the propane is reduced, the liquid propane vaporizes and refrigeration occurs inside the regulator due to the vaporization of liquid propane. To replace heat lost to vaporization, engine coolant is supplied by the engine driven water pump and pumped through the regulator. Heat provided by this coolant is transferred through to the fuel vaporization chamber.

Operation

(Refer to **Figure 6**.)
Liquid propane, at tank pressure, enters the through the fuel inlet port (**1**). Propane liquid then flows through the primary valve (**2**). The primary valve located at the inlet of the expansion chamber (**3**), is controlled by the primary diaphragm (**4**), which reacts to vapor pressure inside the expansion chamber. Two springs are used to apply force on the primary diaphragm in the primary diaphragm chamber (**5**), keeping the primary valve open when no fuel pressure is present.

A small port connects the expansion chamber to the primary diaphragm chamber. At the outlet of the expansion chamber is the secondary valve (**6**). The secondary valve is held closed by the secondary spring on the secondary valve lever (**7**). The secondary diaphragm controls the secondary lever. When the pressure in the expansion chamber reaches 1.5 psig (10.342 kPa) it causes a pressure/force imbalance across the primary diaphragm (**8**). This force is greater than the primary diaphragm spring pressure and will cause the diaphragm to close the primary valve.

Since the fuel pressure has been reduced from tank pressure to 1.5 psig (10.342 kPa) the liquid propane vaporizes. As the propane vaporizes it takes on heat from the expansion chamber. This heat is replaced by engine coolant, which is pumped through the coolant passage of the regulator. At this point vapor propane will not flow past the expansion chamber of the regulator until the secondary valve is opened. To open the secondary valve, a negative pressure signal must be received from the air/fuel mixer. When the engine is cranking or running a negative pressure signal (vacuum) travels through the vapor fuel outlet connection of the regulator, which is the regulator secondary chamber, and the vapor fuel inlet of the mixer. The negative pressure in the secondary chamber causes a pressure/force imbalance on the secondary diaphragm, which overcomes the secondary spring force, opening the secondary valve and allowing vapor propane to flow out of the expansion chamber, through the secondary chamber to the mixer.

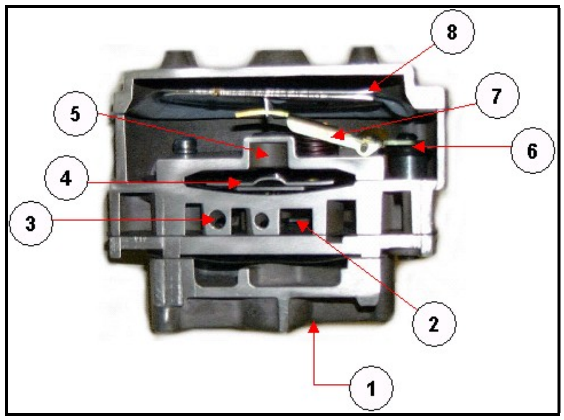


Figure 6. Parts View of Regulator

Because vapor propane has now left the expansion chamber, the pressure in the chamber will drop, causing the primary diaphragm spring force to re-open the primary valve allowing liquid propane to enter the regulator, and the entire process starts again. This creates a balanced condition between the primary and secondary chambers allowing for a constant flow of fuel to the mixer as long as the demand from the engine is present. The fuel flow is maintained at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing will vary depending on how far the secondary valve opens in response to the negative pressure signal generated by the air/fuel mixer. The strength of that negative pressure signal developed by the mixer is directly related to the amount of air flowing through the mixer into the engine. With this process, the larger the quantity of air flowing into the engine, the larger the amount of fuel flowing to the mixer.

MIXER

The mixer is installed above the throttle body and meters gaseous fuel into the airstream at a rate that is proportional to the volumetric flow rate of air. The ratio between volumetric airflow and volumetric fuel flow is controlled by the shaping of the mixer fuel cone and biased by the controllable fuel supply pressure delivered by the pressure regulator. Fuel flow must be metered accurately over the full range of airflows. Pressure drop across the mixer air valve must be minimized to assure maximum power output from the engine

The mixer fuel inlet is fitted with a thermistor-type temperature sensor. This permits the SECM to correct fuel pressure to compensate for variations in fuel temperature. Left uncorrected, fuel temperature variations can cause significant variations in air fuel ratio.

A higher flow mixer is required on larger engines. A lower flow mixer is required on smaller engines.

Figure 7. CA100 Mixer

Mixer Operation

Vapor propane fuel is supplied to the mixer by the pressure regulator/converter. The mixer uses a diaphragm type air valve assembly to operate a gas-metering valve inside the mixer. The gas-metering valve is normally closed, requiring a negative pressure (vacuum) signal from a cranking or running engine to open. This is the third of the three safety locks in the MI-07 system. If the engine stops or is turned off, the air valve assembly closes the gas-metering valve, stopping fuel flow past the mixer. The gas-metering valve controls the amount of fuel to be mixed with the incoming air at the proper ratio. The air/fuel mixture then travels past the throttle, through the intake manifold and into the engine cylinders where it is compressed, ignited and burned.

Figure 8. Mixer Attached to Throttle Body

(Refer to **Figure 9**.)
The air/fuel mixer is mounted in the intake air stream between the air cleaner and the throttle. The design of the main body incorporates a cylindrical bore or mixer bore, fuel inlet (**1**) and a gas discharge jet (**2**). In the center of the main body is the air valve assembly, which is made up of the air valve (**3**), the gas-metering valve (**4**), the air valve diaphragm (**5**), and air valve spring (**6**). The gas-metering valve is permanently mounted to the air valve diaphragm assembly with a face seal mounted between the two parts.

When the engine is not running this face seal creates a barrier against the gas discharge jet, preventing fuel flow with the aid (downward force) of the air valve spring. When the engine is cranking it begins to draw in air, creating a negative pressure signal. This negative pressure signal is transmitted through four vacuum ports in the air valve.

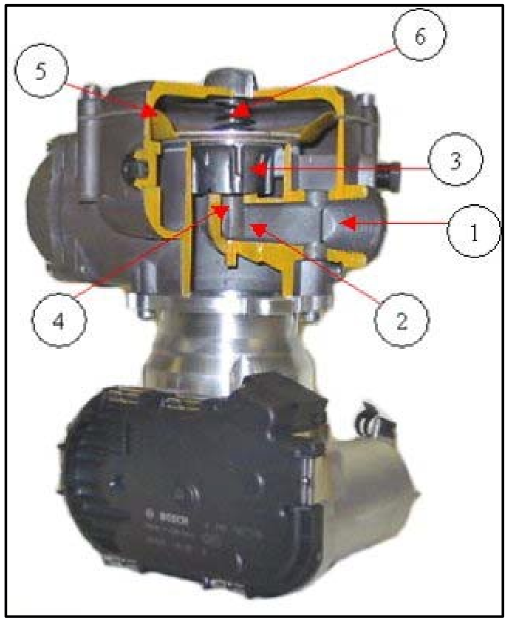


Figure 9. Parts View of Mixer

A pressure/force imbalance begins to build across the air valve diaphragm between the air valve vacuum (AVV) chamber (above the diaphragm) and atmospheric pressure below the diaphragm. Approximately 6 inches H_2O (14.945 mbar) of negative pressure is required to overcome the air valve spring force and push the air valve assembly upward off the valve seat. Approximately 24 inches H_2O (59.781 mbar) pulls the valve assembly to the top of its travel in the full open position.

The amount of negative pressure generated is a direct result of throttle position and the amount of air flowing through the mixer to the engine. At low engine speeds, low AVV causes the air valve diaphragm assembly to move upward a small amount, creating a small venturi. At high engine speeds, high AVV causes the air valve diaphragm assembly to move much farther creating a large venturi. The variable venturi air/fuel mixer constantly matches venturi size to engine demand.

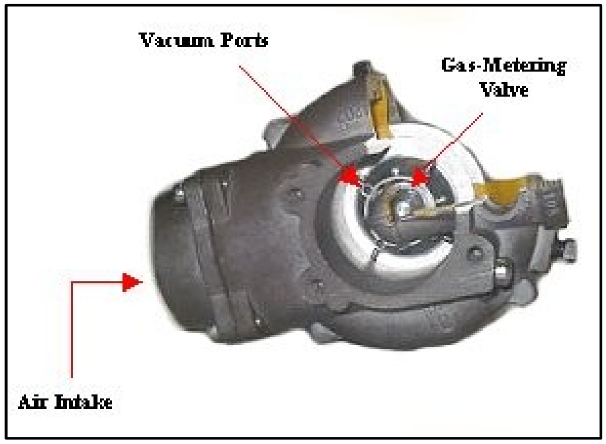


Figure 10. Bottom View of Air Valve Assembly

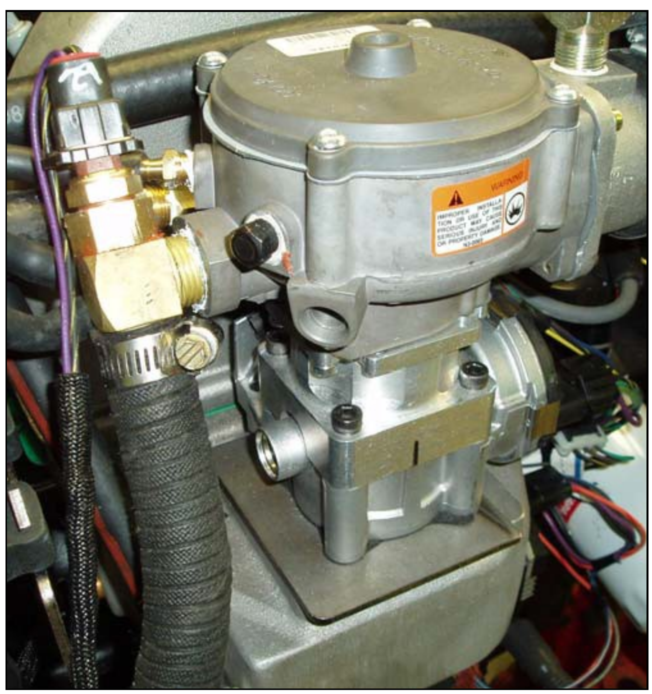


Figure 11. Mixer Installed with Electronic Throttle

A main mixture adjustment valve on the fuel inlet of the is not available in the MI-07 system, however an idle mixture adjustment is incorporated into the mixer (**Figure 12**). The idle mixture adjustment is an air bypass port, adjusting the screw all the way in, blocks off the port and enriches the idle mixture. Backing out the idle adjustment screw opens the port and leans the idle mixture. The idle mixture screw is a screw with locking threads that is factory set with a tamper resistant cap installed after adjustment. Accurate adjustment of the idle mixture can be accomplished by adjusting for a specific fuel trim valve (FTV) duty cycle with the Service Tool software or with a voltmeter. **NOTE: Adjustments should only be performed by trained service technicians.**

Fuel Trim Valve (FTV)

The Fuel Trim Valve (FTV) is a two-way electric solenoid valve and is controlled by a pulse-width modulated (PWM) signal provided by the SECM. Two FTVs are used to bias the output fuel pressure on the LPG regulator/converter (), by metering air valve vacuum (AVV) into the atmospheric side of the secondary regulator diaphragm. An orifice balance line connected to the air inlet side of the mixer provides atmospheric reference to the when the FTVs are closed. The SECM uses feedback voltage from the O_2 sensor to determine the amount of bias needed to the regulator/converter.

In normal operation the maintains fuel flow at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing from the will vary depending on how far the secondary diaphragm opens the secondary valve in response to the negative pressure signal generated by the air/fuel mixer. One side of the secondary diaphragm is referenced to FTV control pressure while the other side of the diaphragm reacts to the negative pressure signal from the mixer. If the pressure on the reference side of the secondary diaphragm is reduced, the diaphragm will close the secondary valve until a balance condition exists across the diaphragm, reducing fuel flow and leaning the air/fuel mixture.

Branch-Tee Fitting

A branch-tee fitting is installed in the atmospheric vent port of the with one side of the branch-tee connected to the intake side of the mixer forming the balance line and referencing atmospheric pressure. The other side of the branch-tee fitting connects to the FTV inlet (small housing side). The FTV outlet (large housing connector side) connects to the AVV port. When the FTVs are open AVV is sent to the atmospheric side of the secondary diaphragm, which lowers the reference pressure, closing the secondary valve and leaning the air/fuel mixture. The
MI-07 system is calibrated to run rich without the FTVs. By modulating (pulsing) the FTVs the SECM can control the amount of AVV applied to the secondary diaphragm. Increasing the amount of time the FTVs remain open (modulation or duty cycle) causes the air/fuel mixture to become leaner; decreasing the modulation (duty cycle) enriches the mixture.

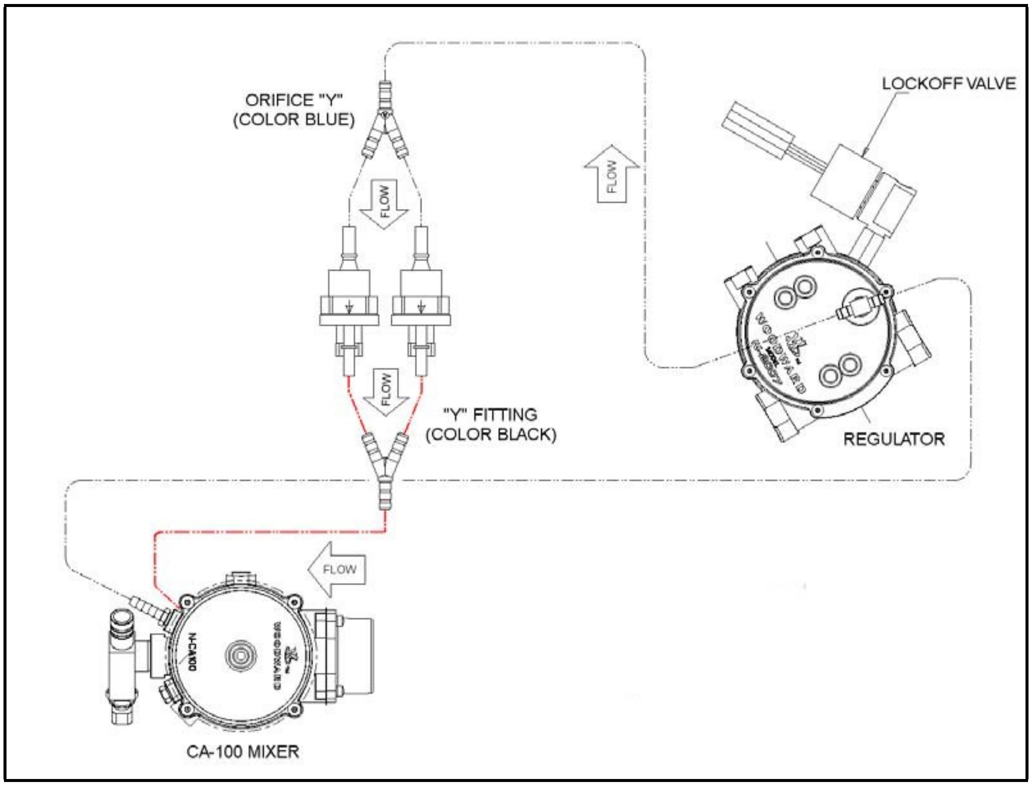


Figure 13. Fuel Trim Valves Connected to MI-07 System

Electronic Throttle System

The electronic throttle system controls engine output (speed and torque) through electronic control of mass airflow to the engine. Any DC motor-actuated or Limited Angle Torque motor (LAT)-actuated throttle with less than 5A peak and 2A steady state can be controlled. The TPS must be directly coupled to the throttle shaft for direct shaft position measurement.

A commonly used throttle is the Bosch DV-E5. This throttle is available in a variety of bore sizes to meet specific engine needs: 32mm, 40mm, and 54mm are readily available throttle bore sizes; other sizes are possible. The Bosch throttle is a fully validated automotive component incorporating a brushed DC motor with gear reduction, dual throttle position sensors, throttle plate, and cast aluminum housing. In the event of an electrical disconnection or other related failure, the throttle plate returns to a limp-home idle position at a no-load engine speed above curb idle speed.
This provides sufficient airflow for the engine to move the vehicle on level ground. Any throttle bodies used for MI-07 meet or exceed the specification for the Bosch throttle bodies.

In terms of response, the throttle is capable of fully opening and closing in less than 50 msec. Position resolution and steady state control should be 0.25% of full travel or better.

MI-07 Electronic Throttle

Conventional throttle systems rely on a mechanical linkage to control the throttle valve. To meet fluctuating engine demands a conventional system will typically include a throttle valve actuator designed to readjust the throttle opening in response to engine demand, together with an idle control actuator or idle air bypass valve.

In contrast, the MI-07 system uses electronic throttle control (ETC). The SECM controls the throttle valve based on engine RPM, engine load, and information received from the foot pedal. Two potentiometers on the foot pedal assembly monitor accelerator pedal travel. The electronic throttle used in the MI-07 system is a Bosch 32mm or 40mm electronic throttle body DV-E5 (**Figure 14**). The DV-E5 is a single unit assembly, which includes the throttle valve, throttle-valve actuator (DC motor) and two throttle position sensors (TPS). The SECM calculates the correct throttle valve opening that corresponds to the driver’s demand, makes any adjustments needed for adaptation to the engine’s current operating conditions and then generates a corresponding electrical (driver) signal to the throttle-valve actuator

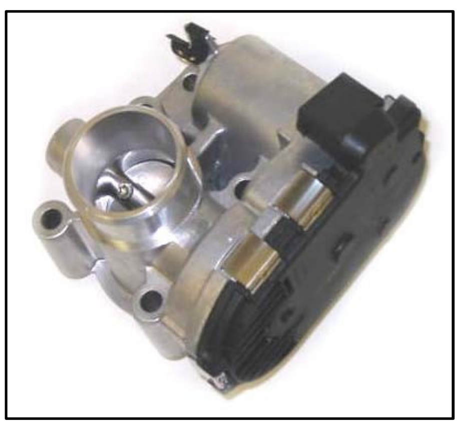


Figure 14. Bosch Electronic Throttle Body

The MI-07 uses a dual TPS design (TPS_1 and TPS_2). The SECM continuously checks and monitors all sensors and calculations that effect throttle valve position whenever the engine is running. If any malfunctions are encountered, the SECM's initial response is to revert to redundant sensors and calculated data. If no redundant signal is available or calculated data cannot solve the malfunction, the SECM will drive the system into one of its limp-home modes or shut the engine down, storing the appropriate fault information in the SECM.

There are multiple limp-home modes available with electronic throttle control:

1. If the throttle itself is suspected of being inoperable, the SECM will remove the power to the throttle motor. When the power is removed, the throttle blade returns to its "default" position, approximately 7% open.
2. If the SECM can still control the throttle but some other part of the system is suspected of failure, the SECM will enter a "Reduced Power" mode. In this mode, the power output of the engine is limited by reducing the maximum throttle position allowed.
3. In some cases, the SECM will shut the engine down. This is accomplished by stopping ignition, turning off the fuel, and disabling the throttle.

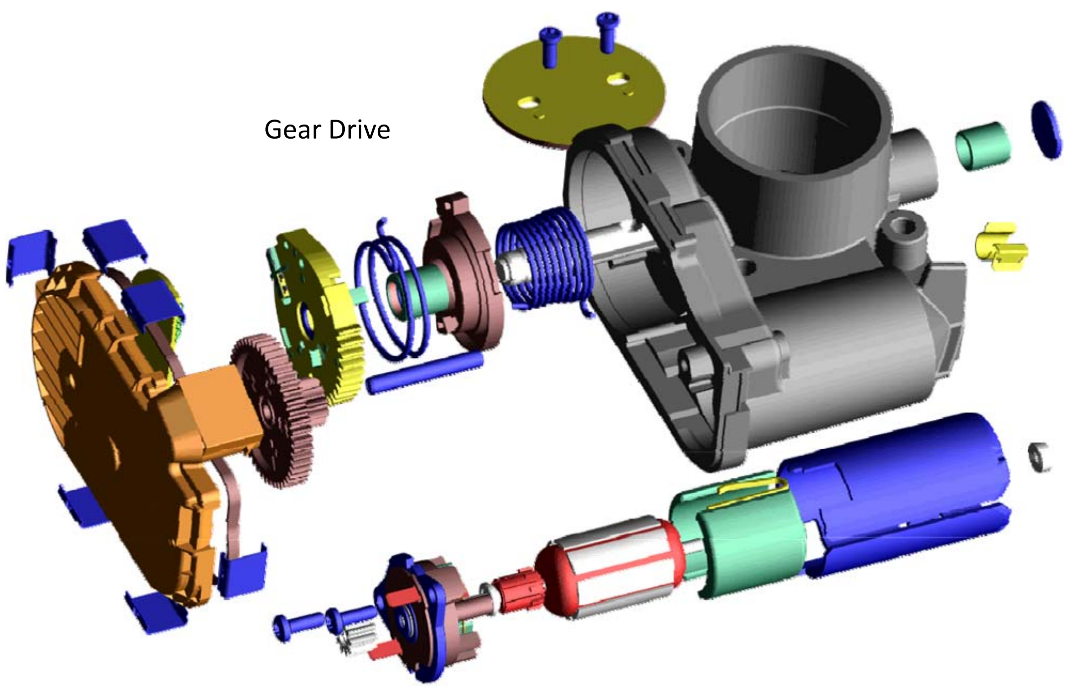


Figure 15. Throttle Body Assembly Exploded View

Ignition System

Spark-ignited engines require accurate control of spark timing and spark energy for efficient combustion. The MI-07 ignition system provides this control. The system consists of the following components:

- SECM
- Ignition coil(s) *
- Crankshaft position sensor *
- Crankshaft timing wheel *
- Cam position sensor *
  (for sequential ignition or fuel injection only)
- Cam timing wheel *
  (for sequential ignition or fuel injection only)
- Spark plugs *

(*) Customer-supplied components

The SECM, through use of embedded control algorithms and calibration variables, determines the proper time to start energizing the coil and fire the spark plug. This requires accurate crank/camshaft position information, an engine speed calculation, coil energy information, and target spark timing. The SECM provides a TTL compatible signal for spark control. The coil must contain the driver circuitry necessary to energize the primary spark coil otherwise an intermediary coil driver device must be provided. The SECM controls spark energy (dwell time) and spark discharge timing.

General Motors (GM) High Voltage Switch (HVS) System

The GM 3.0L engine has a distributed ignition system comprised of one coil and a distributor driven from the engine camshaft. The camshaft rotates at half the speed of the engine thereby guaranteeing that each spark plug will fire once for every two revolutions of the engine.

The GM HVS system provides a control interface that allows external control modules to control engine timing and dwell. When the SECM sends a 5-volt signal to the control interface, the coil control module begins charging the coil. When the SECM signal returns to the ground state, the coil discharges into the distributor, which directs the charge to the appropriate spark plug. In this way, the amount of time the SECM signal is in the high state determines the coil dwell. The moment that the signal returns to the ground state determines when the spark plug fires.

The spark timing cannot be altered by rotating the distributor. The SECM uses the crankshaft position sensor to determine the ignition timing, so changing the position of the distributor will have no effect on the timing.

IGNITION SYSTEM COMPONENTS

In a typical distributed ignition system, a crankshaft position sensor generates a basic timing signal by reading notches on the crankshaft, flywheel, or harmonic balancer. The crank sensor signal goes to the small engine control module (SECM), where it is used to turn the ignition coil on and off via the GM HVS control interface.

The operation of the ignition system is essentially the same as any other ignition system. The coil has a low primary resistance (0.4 to 0.6 ohms) and steps up the primary system voltage from 12 volts to as much as 40,000 volts to produce a spark for the spark plug. The distributor assures that the voltage is directed to the spark plug of the proper cylinder. Resistor spark plugs are generally used to suppress electromagnetic interference (EMI).

MISFIRES

Common ignition system ailments include misfiring, hard starting, or a no start. Spark plugs can still be fouled by oil or fuel deposits, as well as pre-ignition and detonation.

If the crankshaft position sensor fails, the loss of the basic timing signal will prevent the system from generating a spark and the engine will not start or run. A failed driver circuit within the SECM will also prevent proper ignition system operation.

It is important to remember that ignition misfire can also be caused by other factors such as worn or fouled spark plugs, loose or damaged coil connector or terminals, dirty fuel injectors, low fuel pressure, intake vacuum leaks, loss of compression in a cylinder, or even contaminated fuel. These other possibilities should all be ruled out before the distributor control module is replaced.

A SECM controlled engine that cranks but fails to start, in many cases, will often have a problem in the crankshaft or camshaft position sensor circuits. Loss of sensor signals may prevent the SECM from properly synchronizing, thereby preventing the engine from starting and running.

IGNITION SYSTEM CHECKS

The ignition coil can be tested with an ohmmeter. Measure primary and secondary resistance and compare to specifications. If resistance is out of specifications, the coil is bad and needs to be replaced.

Also, pay close attention to the tube that wraps around the spark plug. Cracks can allow voltage to jump to ground causing a misfire. The spark plug terminal should also fit tightly.

If a coil tests bad and is replaced, cleaning the connector and wiring harness terminals of the coil and distributor can often avoid future problems. Corrosion at either place can cause intermittent operation and loss of continuity, which may contribute to component failure. Applying dielectric grease to these connections can help prevent corrosion and assure a good electrical connection.

Magnetic crankshaft position sensors can be tested with an ohmmeter, and the sensor output voltage and waveform can be read with an oscilloscope. The variable reluctance crankshaft position sensor can be checked with an ohmmeter. The resistance of the sensor should be greater than 100Ω and less than 100kΩ. On most vehicles, a defective crank position sensor will usually set a fault code that can be read with the Service Tool.

Heated Exhaust Gas Oxygen Sensors (HEGO)

The MI-07 system utilizes two HEGO (O_2) sensors. One sensor is a pre-catalyst sensor that detects the amount of oxygen in the exhaust stream and is considered the primary control point. Based upon the O_2 sensor feedback, the MI-07 system supplies a stoichiometric air-fuel ratio to the catalytic converter. The catalytic converter then reduces emissions to the required levels. The second sensor is a post-catalyst sensor that detects the amount of oxygen after the catalyst. This sensor is used as a secondary control point to adjust the pre-catalyst setpoint to ensure proper catalyst conversion efficiency.

Once a HEGO sensor reaches approximately 600°F (316°C), it becomes electrically active. The concentration of oxygen in the exhaust stream determines the voltage produced. If the engine is running rich, little oxygen will be present in the exhaust and voltage output will be relatively high. Conversely, in a lean situation, more oxygen will be present and a smaller electrical potential will be noticed.

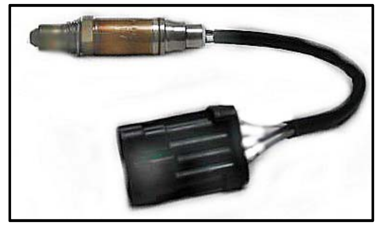


Figure 16 HEG O2 Sensor

In order for the sensor to become active and create an electrical signal below 600°F (316°C) a heated element is added to the sensor housing. Two wires provide the necessary 12 Vdc and ground signal for the heater element. A fourth wire provides an independent ground for the sensor. The pre-catalyst sensor heater is powered by the main power relay and is always powered. The post-catalyst sensor heater is powered from an additional relay that is controlled by the SECM. This relay is only energized when the SECM calculates that water condensation in the exhaust system and catalytic muffler prior to the sensor should be evaporated. This is to avoid thermal shock of the sensor that could prematurely fail the sensor.

The HEGO stoichiometric air-fuel ratio voltage target is approximately 500 mV and changes slightly as a function of speed and load. When the pre-catalyst HEGO sensor sends a voltage signal less than 450 mV the SECM interprets the air-fuel mixture as lean. The SECM then decreases the PWM duty cycle sent to the fuel trim valves in order to increase the fuel pressure to the mixer inlet; thus richening air-fuel mixture. The opposite is true if the SECM receives a voltage signal above 450 mV from the HEGO. The air-fuel mixture would then be interpreted as being too rich and the SECM would increase the duty cycle of the trim valves

CAUTION
The HEGO sensors are calibrated to work with the MI-07 control system. Use of alternate sensors may impact performance and the ability of the system to diagnose rich and lean conditions.

Catalytic Muffler

In order to meet 2007 emission requirements a 3-way catalyst is necessary.

The MI-07 control system monitors the exhaust stream pre and post catalyst and uses this information to control the air-fuel mixture. By using the signals from the HEGOs, the SECM can increase or decrease the amount of oxygen in the exhaust by modulating the FTVs and adjusting the air-fuel ratio. This control scheme allows the SECM to make sure that the engine is running at the correct air to fuel ratio so that the catalyst can perform as required to meet the emissions certification.

The Hoist Small Engine Control Module (SECM) controller has full authority over spark, fuel and air.

Utilizing a Freescale micro controller, the SECM has 48 pins of I/O and is fully waterproof and shock hardened. To optimize engine performance and drivability, the SECM uses several sensors for closed loop feedback information. These sensors are used by the SECM for closed loop control in three main categories:

- Fuel Management
- Load/Speed Management
- Ignition Management

The SECM monitors system parameters and stores any out of range conditions or malfunctions as faults in SECM memory. Engine run hours are also stored in memory. Stored fault codes can be displayed on the Malfunction Indicator Light (MIL) as flash codes or read by the MI-07 Service Tool software through a Controller Area Network (CAN) communication link.

Constant battery power (12 Vdc) is supplied through the fuse block to the SECM and the main power relays. Upon detecting a key-switch ON input, the SECM will fully power up and energize the main power relays. The energized main power relays supply 12 Vdc power to the heated element of the oxygen sensors, fuel lock-off, fuel trim valves (FTVs), gasoline injectors, gasoline fuel pump, crank sensor, cam sensor, and the ignition coils. The SECM supplies voltage to the electronic throttle actuator, oil pressure switch, fuel temperature sensor, and the coolant temperature sensor. Transducer or sensor power (+ 5 Vdc) is regulated by the SECM and supplied to the manifold temperature/air pressure (TMAP) sensor, throttle position sensor (TPS), and the accelerator pedal position sensors (APP_1 & APP_2). The SECM provides a transducer ground for all the sensors, and a low side driver signal controlling the fuel lock-off, MIL, gasoline injectors, gasoline fuel pump, and FTVs.

Fuel Management

During engine cranking at startup, the SECM provides a low side driver signal to the fuel lock-off, which opens the lock-off allowing liquid propane to flow to the regulator. A stall safety shutoff feature is built into the SECM to close the lock- off in case of a stall condition. The SECM monitors three engine states:

Crank, when the crankshaft position sensor detects any engine revolutions

Stall, when the key is in the ON position but the crankshaft position sensor detects no engine revolutions

Run state, when the engine reaches a calibration specific RPM.

When an operator turns on the key switch the lock-off is opened but if the operator fails to crank the engine, the SECM will close the lock-off after a calibration specific number of seconds.

To maintain proper exhaust emission levels, the SECM uses a heated exhaust gas oxygen sensor (HEGO) mounted before the catalyst, to measure exhaust gas content in the LP gas system. Engine speed is monitored by the SECM through a variable reluctance (VR) sensor or Hall-Effect type sensor. Intake manifold air temperature and absolute pressure are monitored with a (TMAP) sensor. The HEGO voltage is converted to an air/fuel ratio value. This value is then compared to a target value in the SECM. The target value is based on optimizing catalyst efficiency for a given load and speed. The SECM then calculates any corrections that need to be made to the air/fuel ratio.

The system operates in open loop fuel control mode until the engine has done a certain amount of work. This ensures that the engine and HEGO are sufficiently warmed up to stay in control. In open loop control mode, the FTV duty cycle is based on engine speed and load. Once the HEGO reaches operating temperature the fuel management is in closed loop control mode for all steady state conditions, from idle through full throttle. In closed loop mode, the FTV duty cycle is based on feedback from the HEGO sensor. The system may return to open-loop operation when engine load or engine speed vary beyond a chosen threshold.

The SECM makes any necessary corrections to the air-fuel ratio by controlling the inlet fuel pressure to the air-fuel mixer Reducing the fuel pressure leans the air/fuel mixture and increasing the fuel pressure enriches the air-fuel mixture. Control is achieved by modulating the fuel trim valves.

Ignition Management

In the normal course of events, with the engine operating at the correct temperature in defined conditions, the SECM will use load and engine speed to derive the correct ignition timing. In addition to load and speed there are other circumstances under which the SECM may need to vary the ignition timing, including low engine coolant temperature, air temperature, start-up, and idle speed control.

SECM Electrical Mounting Recommendations

In order to prevent the possibility of any SECM malfunctions due to EMI/RFI emissions, engine packagers and OEMs should follow industry “best practices” and the SECM mounting and harness recommendations listed below:

- The SECM should be mounted in a location that minimizes the amount of EMI the module is exposed to by locating it as far as practical from all high tension components, such as ignition coils, distributors, spark plug wires, etc. It is recommended that the SECM be mounted at least 29.5” (749 mm) away from the distributor and ignition coil, and at least 20” (508 mm) from the nearest plug wire.
- All wiring harnesses should be routed to minimize coupling (both radiated and conducted), and be securely fastened to minimize movement and maintain proper clearance between the SECM and all ignition system components.
- The OEM must ensure that a high-quality ground connection between the SECM and battery negative (–) is provided and can be maintained for the useful life of the vehicle. This may require the use of star-type washers on all ground lug connections between the SECM and the battery and/or special preparation of all mating surfaces that complete the ground connection in order to ensure that the connection is sound.

Engineering judgment must be exercised on all applications to determine if appropriate measures have been implemented to minimize EMI exposure to the SECM and associated cabling. The above recommendations do not provide any guarantee of proper system performance.

SECM / Sensors

The 48-pin Small Engine Control Module (SECM) and sensors provide the computational power, algorithm logic, sensor inputs and control outputs to control the system. The SECM receives signals from the sensors digitizes these signals, and then, through algorithms and calibration maps, computes the desired output response to effect control of fuel, spark and air to the engine. The SECM also provides a variety of other functions and features. These include system monitoring and diagnostics to aid in maintaining efficient system operation and auxiliary control.

SECM/sensor inputs and control output specifications are specific to the application, but include a selection of the following:

Analog Inputs

The 48-pin SECM is equipped with sufficient analog inputs for the following sensors.

- **Manifold Absolute Pressure (MAP**) 1bar MAP, 0 to 5 V
- **Manifold Air Temperature (MAT)**
  -40°F to 266°F (-40ºC to 130ºC) range, 48 kΩ to 85 Ω sensor range
- **Throttle Position Sensor 1&2 (TPS1 & TPS2)** 0 to 5 V
- **Foot Pedal Position 1&2 (FPP1 & FPP2)** 0 to 5 V
- **Coolant Temperature Sensor (CTS**)
  -40°F to 266°F (-40ºC to 130ºC) range, 48 kΩ to 85 Ω sensor range
- **Fuel Temperature Sensor (FTS)**
  -40°F to 266°F (-40ºC to 130ºC) range, 48 kΩ to 57 Ω sensor range
- **HEGO (3)** 0 to 1 V
- **Auxiliary Analog Input (2)** 0 to 5 V
- **Battery Voltage (Vbatt) (1)** 8-18 V

With the exception of battery voltage, all inputs are 0-5 Vdc, ground referenced. Resolution should be 0.1% or better. Accuracy should be 2% or better.

Frequency/Position Inputs

- **Crankshaft position**
  Variable reluctance (2-wire, 200 V_{pp} max) or 0-5 V Hall Effect with calibration selectable pull-up resistor for open collector sensors
  Permits speed resolution of 0.25 RPM and crankshaft position resolution of 0.5º
- **Camshaft position**
  Variable reluctance (2-wire, 200 V_{pp} max) or 0-5 V Hall Effect with calibration selectable pull-up resistor for open collector sensors

Digital Inputs

- **Oil pressure switch**
  Normally open, internal pull-up resistor provided to detect external switch to ground
- **Fuel select switch**
  Three-position switch for bi-fuel applications to detect gasoline mode, LPG mode, and fuel off (center switch position)

- **Ground speed select switch**
  Permits selecting two different maximum engine speeds
- **Vswitched**
  Switched battery voltage
- **Can Input**
  Governs requested speed
- **Speed Switch Input**
  Two-position switch for RPM governing

Outputs

- **Saturated injector drivers (4)**
  10A peak, 45 V max, 1 injector per channel capable of continuous on-time. Driver circuit designed for minimum turn-on/turn-off delay. Minimum pulse width resolution of 1 μsec
- **FTV drivers (2)**
  10A peak, 45V max. To drive an on/off fuel trim valve with a minimum impedance of 5 ohms. Capable of continuous on-time. Drive circuit designed for minimum turn-on /turn-off delay. FTVs will be pulse width modulated between 8 and 40 Hz with a minimum pulse width resolution of 50 μsec
- **Fuel lock-off solenoid valve**
  Low side switch, 10A peak, 4A continuous 45 V max.
- **Gasoline fuel pump drive**
  Low side switch, 10A, 4A continuous 45 V max.
- **Electronic Spark Timing (EST) (4)**
  TTL compatible outputs. Software configured for distributed ignition system
- **Throttle control (1)**
  H-Bridge, 5A peak, 2.5A continuous at 2500 Hz PWM includes current feedback for diagnostic purposes
- **MIL (Malfunction Indicator Lamp)**
  Low side switch, sufficient to drive a 7W incandescent lamp continuously
- **CANBus**
  CAN 2.0b serial communication for J1939 communications, programming, and diagnostics. Requires proper termination resistance per CAN 2.0b
- **Crank Defeat Relay**
  Stops starter from engaging while engine is running
- **Post-Cat O_2 Sensor Heater Relay**
  Turns on heater to prevent oxygen sensor damage during warmup
- **Check Engine Lamp**
  User-configurable warning lamp

Gasoline Engines

Gasoline Fuel System

A gasoline fuel system includes the following components: Gasoline fuel

pump*
Fuel filter*
Fuel rail*
Pressure regulator*
Fuel injectors*
Small engine control module (SECM)
and related sensors and equipment

(*) Supplied by customer

Multi-Point Injection (MPI) is supplied with this system. However, the SECM lacks sufficient channels to drive each injector individually therefore the injectors are driven in batches of two (1 and 4, 2 and 5, 3 and 6). Fuel injection pressure and flow rate depend on engine-specific fuel injection requirements. A variety of regulators and injectors can be used to fit individual needs. The gasoline fuel pressure regulator is a one-way, non-return configuration. All gasoline specific components are automotive production parts and validated to strict automotive standards. Four (4) injection channels are supported by the SECM but only three are used in this application.

Use of unleaded gasoline of 87 octane or higher is recommended for optimal performance of the MI-07 system.

Gasoline Fuel System Specifications

Fuel	87 octane $(R+M)/_2$ method automotive grade fuel
Fuel System	One-way returnless
Fuel Pump	Minimum of 200 ml/min at rated pressure
Fuel Pressure Regulator	4 bar
Injectors	Bosch High Impedance (OEM installed)

Specifications

Operating Temperature	-20°F to 221°F [-29°C to 105°C]
Long-term Storage Temperature	-40°F to 140°F [-40°C to 60°C]
Short-Term Storage Temperature (Heat Soak)	≥257°F [125°C]
LPG Composition Requirements	HD5/HD10 LPG. Failure to use fuel compliant with HD5 or HD10 standards will void the user warranty.
Fuel Filter Micron Size	10 micron or better at 99% efficiency

Environmental/Electrical Specifications

Ambient Operating Temperature	-20°F to 221°F [-29°C to 105°C]
LP Fuel Temperature	-20°F to 120°F [-29°C to 49°C]
Operating Voltage	8-16 VDC
Over Voltage Operation	18VDC for less than 5 minutes 24 VDC for less than 1 minute

Pressure Regulator Specifications

Fuel Supply Pressure	10psi to 250 psi
Fuel Inlet Fitting	¼" NPT
Fuel Outlet Fitting	One ¾"NPT plug One ¾" NPT to 5/8" hose fitting
Fuel Supply Temperature at Tank Outlet	-20°F to 120°F [-29°C to 49°C]
Primary Pressure Tap	1/8" NPT with plug
Max Flow	50 lbm/hr LPG
Coolant Flow to Vaporizer	>1.0 gpm/100bhp, equipped with 140°F (60°C) thermostat
Fuel Outlet Pressure Set-points	0.7±0.2 IN H_2O (-1.744±0.498mbar) @1.7lbm/hr LPG -2.0 ±.2 inH_2O (-4.982±0.498 mbar) @50 lbm/hr LPG
Mounting	Regulator should be installed with centerline of outlet at least 15° below horizontal to permit drainage of any liquid precipitates from LPG fuel. Diaphragm should be vertically oriented.

Mixer Specifications

Fuel	LPG
Fuel Inlet Fitting	5/8” hose to ½” NPT fitting. Fuel inlet fitted with Delphi temperature sensor
Air Intake Flange	2.25” (15.55mm) ID inlet, four #10-24 screws in 1.94” (49.28mm) square pattern
Mixer Mounting Flange	1.87” (47.49mm) ID outlet, four #12-24 screws arranged in a rectangular pattern
Reference Pressure Ports	Two 1/8” NPT ports. Pressure readings must be identical within 0.25 H_2O (0.623mbar) at all airflows.
Air Valve Vacuum (AFF) Port Size	¼-28 UNF
Fuel Inlet Adjustments	None
Idle Air Adjustment	None
Mounting	Suitable for on-engine mounting in vertical orientation

SECM Specifications

Operating Temperature	-20°F to 221°F [-29°C to 105°C]
Long-term Storage Temperature	-40°F to 140°F [-40°C to 60°C]
Short-term Storage Temperature (Heat Soak)	
Operating Voltage	8-16 VDC SECM microprocessor may reset at voltages below 6.3VDC
Operating Environment	On-engine mounting, under hood automotive. Capable of withstanding spray from a water pressure washer

Fuel Trim Valve (FTV) Specifications

Actuator Type	On/Off two-position valve compatible with LPG
Operating Voltage	8-16 VDC

Ignition System Specifications

Coil Type	Inductive
Coil Supply Voltage	8-16 VDC

Minimum Open Circuit Voltage	>30kV
Minimum Coil Energy	35mJ
Maximum Dwell Time	4 msec
Operating Temperature	-20°F to 221°F [-29°C to 105°C]
Long-term Storage Temperature	-40°F to 140°F [-40°C to 60°C]
Short-Term Storage Temperature (Heat Soak)	≤257°F [125°C]

System Control Performance Specifications

Power /Torque

The MI-07 system maximizes engine power and torque while meeting customer- specific needs for emissions, fuel consumption, durability, and drivability. Bear in mind that engine power is dependent on many variables other than the fuel control system, i.e., compression ratio, friction, valve timing, etc.

Exhaust Emissions

MI-07 is capable of meeting EPA 2007 LSI engine emission standards when operating properly with an approved three-way catalyst. Emission standards must be met on both the LSI engine off-highway transient emissions test cycle and the ISO 8178 type C2 steady-state emissions test cycle.

The fuel control logic, for both LPG and gasoline, employs a closed-loop exhaust gas oxygen control algorithm in order to compensate for fuel system tolerances, aging, altitude, and fuel composition. The algorithm utilizes dual heated exhaust gas oxygen (HEGO) sensors with an output that switches high and low at stoichiometry. When operated with LPG, the control logic compensates for variations in fuel temperature as measured at the mixer inlet.

Drivability / Transient Response

The engine will meet requirements of the EPA LSI engine transient emissions test cycle. It should start, run, accelerate, decelerate, and stop without hesitation or miss-fire.

Recommended Maintenance

Suggested maintenance requirements for an engine equipped with an MI-07 fuel system are contained in this section. The operator should, however, develop a customized maintenance schedule using the requirements listed in this section and any other requirements listed by the engine manufacturer.

Maintenance Tests & Inspections

Test Fuel System for Leaks

- Obtain a leak check squirt bottle or pump spray bottle.
- Fill the bottle with an approved leak check solution.
- Spray a generous amount of the solution on the fuel system fuel lines and connections, starting at the storage container.
- Wait approximately 15-60 seconds, then perform a visual inspection of the fuel system. Leaks will cause the solution to bubble.
- Listen for leaks.
- Smell for LPG odor which may indicate a leak.
- Repair any leaks before continuing.

- Crank the engine through several revolutions. This will energize the fuel lock-off and allow fuel to flow to the pressure regulator/converter. Apply additional leak check solution to the regulator/ converter fuel connections and housing. Repeat leak inspection as listed above.
- Repair any fuel leaks before continuing.

Inspect Engine for Fluid Leaks

- Start the engine and allow it to reach operating temperatures.
- Turn the engine off.
- Inspect the entire engine for oil and/or coolant leaks.
- Repair as necessary before continuing.

Inspect Vacuum Lines and Fittings

- Visually inspect vacuum lines and fittings for physical damage such as brittleness, cracks and kinks. Repair/replace as required.
- Solvent or oil damage may cause vacuum lines to become soft, resulting in a collapsed line while the engine is running.
- If abnormally soft lines are detected, replace as necessary.

Inspect Electrical System

- Check for loose, dirty or damaged connectors and wires on the harness including: fuel lock-off, TMAP sensor, O_2 sensors, electronic throttle, control relays, fuel trim valves, crank position sensor, and cam position sensor.
- Repair and/or replace as necessary.

Check Coolant Level

- The items below are a general guideline for system checks. Refer to the engine manufacturer's specific recommendations for proper procedures.
- Engine must be off and cold.

> **WARNING—PROPER USE**
> **Never remove the pressure cap on a hot engine.**

- The coolant level should be equal to the "COLD" mark on the coolant recovery tank.
- Add approve coolant to the specified level if the system is low.

Inspect Coolant Hoses

- Visually inspect coolant hoses and clamps. Remember to check the two coolant lines that connect to the pressure regulator/converter.
- Replace any hose that shows signs of leakage, swelling, cracking, abrasion or deterioration.

Inspect Battery System

- Clean battery outer surfaces with a mixture of baking soda and water.
- Inspect battery outer surfaces for damage and replace as necessary.
- Remove battery cables and clean, repair and/or replace as necessary.

Inspect Ignition System

- Remove and inspect the spark plugs. Replace as required.
- Remove and inspect distributor cap. Check for cracks or abnormal wear on the output contacts. Replace as required.
- Remove and inspect distributor rotor. Check for abnormal wear on the rotor arm contact. Replace as required.
- Inspect the ignition coil for cracks and heat deterioration. Replace as required.

Replace Spark Plugs

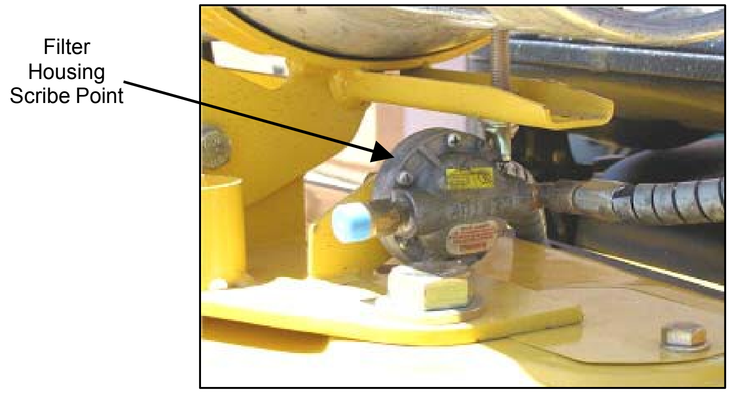
- Using a gentle twisting motion, remove the high voltage leads from the spark plugs. Replace any damaged leads.
- Remove the spark plugs.
- Gap the new spark plugs to the proper specifications.
- Apply anti-seize compound to the spark plug threads and install.
- Re-install the high voltage leads.

> **CAUTION**
> **Do not over tighten the spark plugs.**

Replace LP Fuel Filter Element

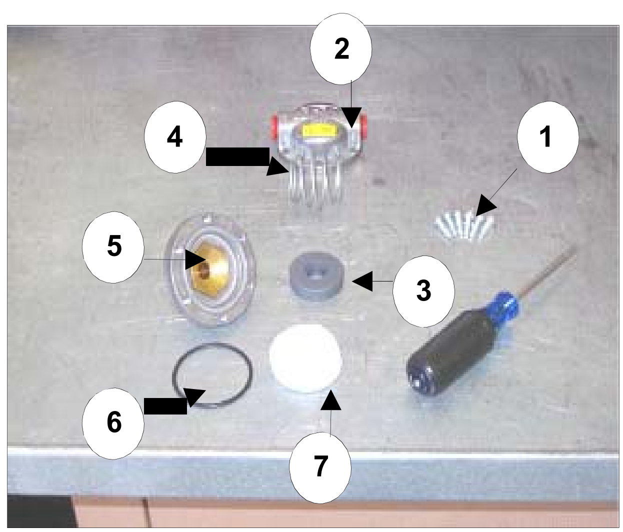
Park the lift truck in an authorized refueling area with the forks lowered, parking brake applied and the transmission in Neutral.

1. Close the fuel shutoff valve on the LP-fuel tank. Run the engine until the fuel in the system runs out and the engine stops.
2. Turn off the ignition switch.
3. Scribe a line across the filter housing covers, which will be used for alignment purposes when re-installing the filter cover.



FUEL FILTER DISASSEMBLY (Steps 4-7)

4. Remove the cover retaining screws (1).
5. Remove top cover (2), magnet (3), spring (4), and filter element (7) from bottom cover (5).
6. Replace the filter element (7).
7. Check bottom cover O-ring seal (6) for damage. Replace if necessary.
8. Re-assemble the filter assembly aligning the scribe lines on the top and bottom covers.
9. Install the cover retaining screws, tightening the screws in an opposite sequence across the cover.
10. Open the fuel valve by slowly turning the valve counterclockwise.
11. Crank the engine several revolutions to open the fuel lock-off. DO NOT START THE ENGINE. Turn the ignition key switch to the off position.
12. Check the filter housing, fuel lines and fittings for leaks. Repair as necessary.



Testing Fuel Lock-off Operation

- Start engine.
- Locate the electrical connector for the fuel lock (A).
- Disconnect the electrical connector.
- The engine should run out of fuel and stop within a short period of time.

NOTE:
The length of time the engine runs on trapped vapor increases with any increase in distance between the fuel lock-off and the pressure regulator/converter.

- Turn the ignition key switch off and re-connect the fuel lock-off connector.

Figure 24. MI-07 System Installed on GM 3.0L Engine

Pressure Regulator/Converter Inspection

- Visually inspect the pressure regulator/converter (B) housing for coolant leaks.
- Refer to Chapter 5 if the pressure regulator/converter requires replacement.

Fuel Trim Valve Inspection (FTV)

- Visually inspect the fuel trim valves (C) for abrasions or cracking. Replace as necessary.
- To ensure a valve is not leaking a blow-by test can be performed.
  1. With the engine off, disconnect the electrical connector to the FTVs.
  2. Disconnect the vacuum line from the FTVs to the pressure regulator/converter at the converter's tee connection.
  3. Lightly blow through the vacuum line connected to the FTVs. Air should not pass through the FTVs when de-energized.
     If air leaks past the FTVs when de-energized, replace the FTVs.

Inspect Air/Fuel Valve Mixer Assembly

- Refer to Chapter 5 for procedures regarding the LP mixer (D).

Inspect for Intake Leaks

- Visually inspect the intake throttle assembly (E), and intake manifold for looseness and leaks. Repair as necessary.

Checking the TMAP Sensor

- Verify that the TMAP sensor (F) is mounted tightly into the manifold or manifold adapter (E), with no leakage.
- If the TMAP is found to be loose, remove the TMAP retaining screw and the TMAP sensor from the manifold adapter.
- Visually inspect the TMAP O-ring seal for damage. Replace as necessary.
- Apply a thin coat of an approved silicon lubricant to the TMAP O-ring seal.
- Re-install the TMAP sensor into the manifold or manifold adapter and securely tighten the retaining screw.

Inspect Engine for Exhaust Leaks

- Start the engine and allow it to reach operating temperatures.
- Perform visual inspection of exhaust system from the engine all the way to the tailpipe. Any leaks, even after the post-catalyst oxygen sensor, can cause the sensor output to be effected (due to exhaust pulsation entraining air upstream). Repair any/all leaks found. Ensure the length from the post- catalyst sensor to tailpipe is the same as original factory.
- Ensure that wire routing for the oxygen sensors is still keeping wires away from the exhaust system. Visually inspect the oxygen sensors to detect any damage.

Installation Procedures

WARNING—PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area.**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator/convertor or mixer.

Hose Connections

Proper operation of the closed loop control greatly depends on the correct vacuum hose routing and fuel line lengths. Refer to the connection diagram below for proper routing and maximum hose lengths when reinstalling system components.

NOTE: Preferred mounting of regulator is off engine.

Hose Specifications

Vacuum hose to comply to SAE 1403 Type L or SAE J30 R7 R8 / EPDM textile reinforced / -40° F to +257° F (-40° C +125° C / Inside Diameter: 7/32" (5.56mm)

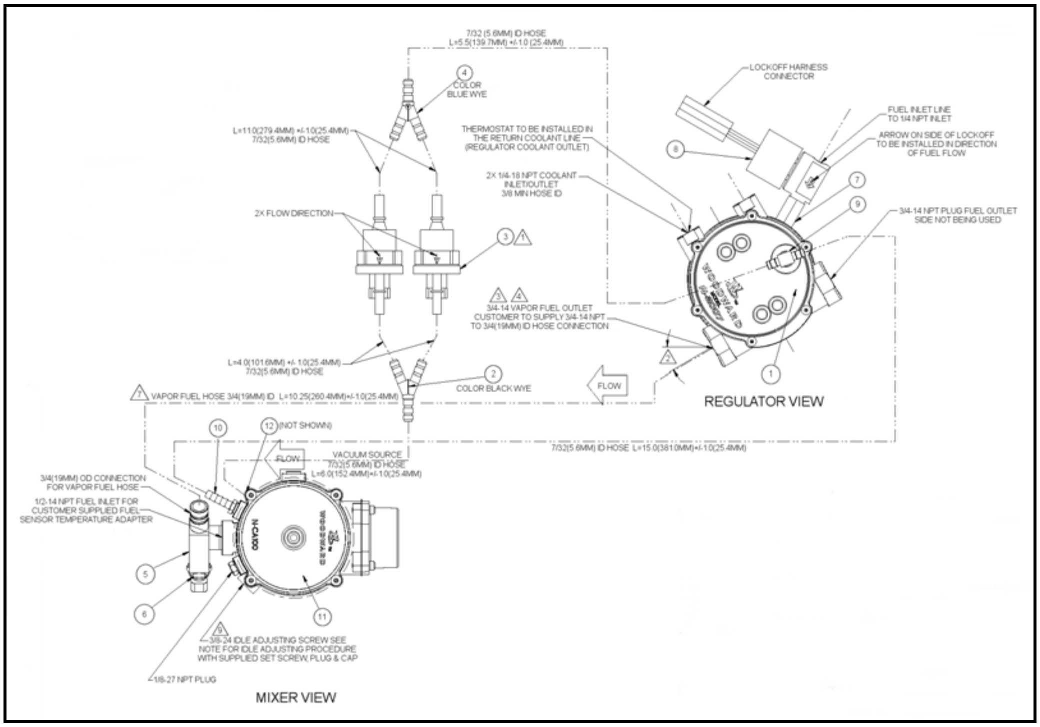


Figure 25 Hose Connections

DIAGRAM NOTES

1 Trim valves must be positioned vertically with flow in direction shown

2 Fuel outlet must be min 15° below horizontal position

3 Only one 90° fitting permissible on vapor fuel line between mixer and regulator (as shown, the temp sensor adaptor is considered the one 90° fitting)

4 Vapor fuel fittings (regulator and mixer) must have a minimum ID of 0.59" (15mm)

7 Vapor hose length to be as short as possible and have no restrictions for best regulator performance

Setting Idle Adjustment

9
1. Set idle adjustment to correct setting.
2. Lock with supplied set screw
3. Cap after adjustment and locking screw.

1 Regulator

2 Plastic WYE fitting (black color) for ¼" (6.355mm) ID tube hose

3 Valve (TEV Bosch Canister)

4 Plastic WYE Fitting (blue color) for ¼" (6.355mm) Id tube hose

5 Adapter (temperature sensor)

6 Sensor (coolant temperature)

7 Nipple (.625 hex 4mp, 2.5L steel)

8 Solenoid (AFS lock off valve)

9 Brass tee fitting ¼ tube x 1/8NPTF x ¼ tube

10 ¼" (6.35mm) hose barb to 1/8" (3.2mm) male pipe .125GBL .62 flow ID

11 Mixer

12 ¼-28 UNF x1/4" (6.35mm) hose barb

Removal and Installation of LP Regulator/Converter

Follow the procedures below for removal and reinstallation of the regulator in certified systems.

Removal Steps

Refer to **Figure 28.**

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.
2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.
3. Key switch in “OFF” position.
4. Remove the fuel inlet line (**1**) from the lock-off, the two vacuum lines (**2**) from the branch-tee fitting in the regulator vent and disconnect the lock- off connector (**3**).
5. Remove the four rear-mounting bolts that hold the regulator to the support bracket. This will allow easier access to the remaining hose clamps.
6. Remove the two cooling lines (**4**) from the regulator. *NOTE: Either drain the coolant system or clamp off the coolant lines as close to the regulator as possible to avoid a coolant spill when these lines are disconnected.*
7. Remove the fuel vapor outlet hose (**5**) from the regulator.
8. Remove the nipple extension (**6**) with the lock-off from the regulator.

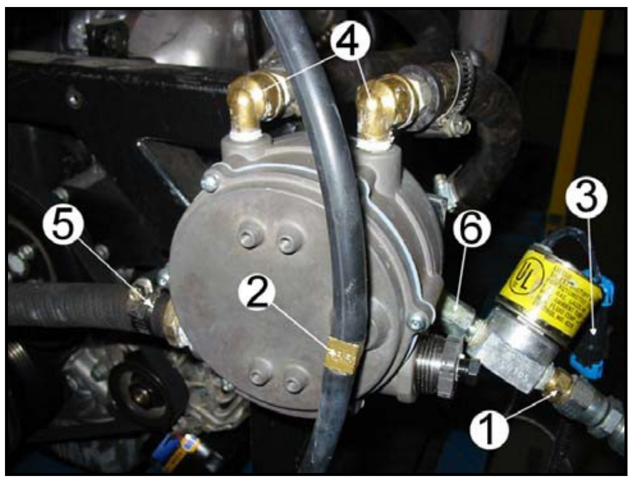


Figure 26. Regulator Installed on Engine

Installation Steps

Refer to **Figure 26.**

1. Install the nipple extension (**6**) with the lock-off to the regulator.
2. Install the fuel vapor outlet hose (**5**) to the regulator.
3. Install the two cooling lines (**4**) to the regulator.
4. Install the four rear-mounting bolts that hold the regulator to the support bracket. Use a torque wrench and tighten each bolt to 60-70 lbf-in (6.78-7.91 N-m).
5. Install the fuel inlet line (**1**) to the lock-off, the two vacuum lines (**2**) to the branch-tee fitting in the regulator vent and re-connect the lock-off connector (**3**).
6. Open the liquid outlet valve in the forklift cylinder or fuel storage container.

Removal and Installation of Mixer

Follow the procedures below for removal and reinstallation of the mixer in certified systems.

Certified Mixer Removal Steps

Refer to **Figure 27**.

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.
2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.
3. Key switch in “OFF” position.
4. Remove the air cleaner hose (**1**).
5. Mark the two vacuum lines (**2**) to the mixer for identification, as they must be reinstalled correctly for proper operation. Remove the two vacuum lines.
6. Remove vapor fuel inlet line (**3**) from the fuel temperature sensor fitting (**4**).
7. Disconnect the fuel temperature sensor connector (**5**).
8. Disconnect the wires leading to the electronic throttle body by pinching the lock tabs on either side of the wiring harness connector. (See **Figure 28** for location of connector.)
9. Loosen the four bolts (**6**) that secure the mixer/adapter/throttle body assembly to the intake manifold.
10. Remove the mixer (**9**), the adapter (**7**), and the throttle body (**8**) as an assembly by gently pulling upwards. Take care not to drop anything down the intake manifold.
11. Gently wiggle and pull to separate mixer and adapter from the throttle body. Take note of the adapter orientation on the mixer, as it must be reinstalled correctly for proper fit on the throttle.
12. Remove the four mounting screws that attach the throttle body adapter to the mixer.
13. Remove the fuel temperature sensor (not shown) from the tee (**4**).
14. Remove the fuel temperature sensor fitting from the mixer. Take note of the fitting’s orientation on the mixer, as it must be reinstalled correctly for proper fit.
15. Remove the short vacuum port barb from the mixer. (See **Figure 29** for location of port barb on mixer.)

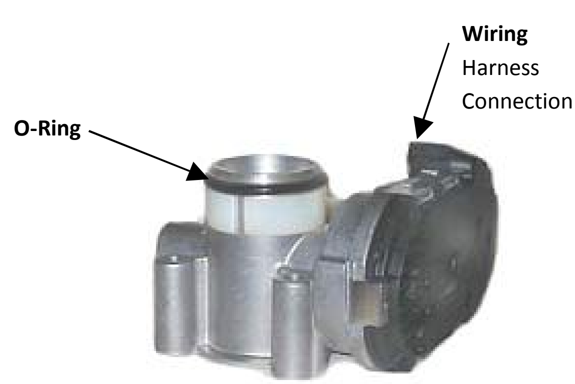


Figure28 O-ring and spacer within mixer adapter assembly

Mixer Installation Steps

Refer to Figure 27

1. Install the vacuum port barb onto the mixer (9)
2. Install the fuel temperature sensor fitting (4) onto the mixer.
3. Install the fuel temperature sensor into the fitting.
4. Install the four mounting screws that attach the throttle adapter (7) to the mixer. See Figure 29
5. Position the mixer/adapter assembly onto the throttle body (8), then drop in the four mounting bolts (6) and gently push down on the assembly until it rests on the throttle body. Be careful not to pinch the O-ring (See Figure 28)
6. Attach the mixer/throttle body assembly to the intake manifold, making sure gasket is in place. Tighten the four mounting bolts.
7. Connect the wiring harness to the throttle body. (See figure 28 for location of connector) Connect the fuel temperature sensor connector (5) to the sensor.
8. Install the vapor fuel line (3) to the fuel temperature sensor fitting.
9. Install the two vacuum lines (2) to the mixer using the previous marks for identification. Vacuum lines must be installed correctly for proper operation.
10. Install the air cleaner hose (1).

WARNING—PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator/converter or mixer.

Regulator Service Testing

For checking the regulator/converter operation, the following tests can be performed (See Chapter 5 for removal/installation of the regulator). To check the secondary regulation (output) a simple vacuum hand pump can be used to simulate the vacuum signal transmitted from the air/fuel mixer when the engine is running. See listing below for required hardware.

Break-Off Test

Secondary Stage Test Hardware

1. Hand vacuum pump
2. Regulator vapor outlet test fitting 3/4” NPT x 1/4” hose barb
3. Union Tee 1/4” NPT with three 1/4” NPT x 1/4” hose barb
4. Vacuum hose
5. 0-3” WC Magnehelic gauge (inches of water column)

Secondary Stage (Break-Off) Test

1. Connect the vacuum pump, the Magnehelic gauge, and the regulator vapor outlet to the Union Tee fitting (**Figure 30**). Make sure there is no leakage at any of the fittings.
2. Using the vacuum pump slowly apply enough vacuum to measure above -2” WC on the gauge. This vacuum signal opens the secondary valve in the regulator/converter.
3. Release the vacuum pump lever and you will see the gauge needle start falling back toward zero. When the pressure drops just below the specified break-off pressure (-0.5 +/- 0.35 “ WC) of the secondary spring, the needle should stop moving.
4. At this point the secondary valve should close. If the secondary valve seat or the secondary diaphragm is leaking the gauge needle will continue to fall toward zero (proportional to the leak size). An excessively

rich air/fuel mixture can be caused by a secondary valve seat leak and the regulator should be replaced.

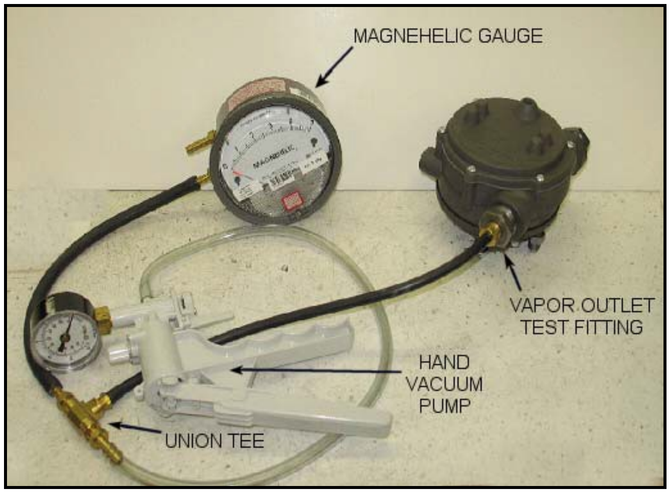


Figure 30. Secondary Stage Test Connection

Pressure Test

Primary Stage Test Hardware

1. Shop air pressure regulator adjusted to 100 psi
2. Shop air hose fitting (1/4" NPT to air hose)
3. Air hose
4. Test gauge fitting (1/16" NPT x 1/4" hose barb)
5. Vacuum hose or vinyl tubing
6. 0-60" WC Magnehelic gauge (inches of water column)

Primary Stage Pressure Test

1. Remove the primary test port plug from the side of the regulator and install the 1/16" NPT hose barb fitting (**Figure 31)**.
2. Connect a compressed air line (shop air ~100 psi) to the liquid propane fuel inlet of the regulator (**Figure 31)**.

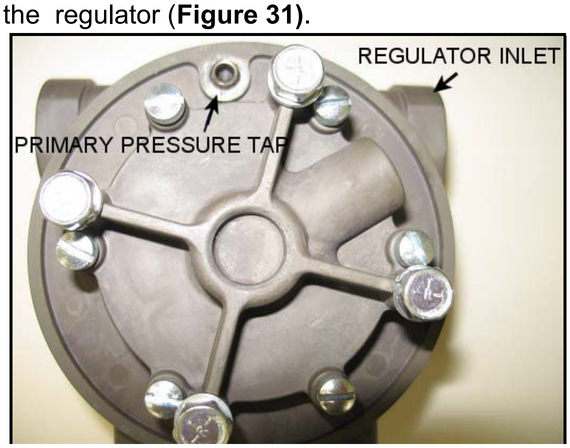


Figure 31. Primary Stage Test Connection

3. Apply compressed air, wait for air to exit the hose barb in the test port, and then connect the Magnehelic gauge (**Figure 32**) to the hose barb using the vacuum hose or vinyl tubing. This prevents the gauge from

reading maximum pressure due to the large velocity of compressed air entering the primary chamber.

4. Make sure there is no leakage at any of the fittings. The static pressure should read between 40-60” of water column on the Magnehelic gauge and maintain a constant pressure for 60 seconds.

Figure 32. Magnehelic Gauge Connection to Hose Barb

5. If the pressure reading begins to **increase**, a leak is most likely present at the primary valve, either the primary valve o-ring or the valve itself. If a leak is present the regulator is defective.
6. If the pressure begins to **decrease**, the secondary seat is probably not making an adequate seal and is leaking. The regulator is defective.
7. If the test is successful, re-install the primary test port plug and check the fittings for leaks. See Chapter 5 for installation of the regulator.

NOTE
The primary stage pressure can also be tested at idle on a running engine. The primary pressure should be between 40 inH20 (99.635 mbar) and 55 inH20 (136.999 mbar) at 750 RPM, idle.

WARNING
- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

AVV (Air Valve Vacuum) Testing

Purpose of Test

Check for excessive or inadequate pressure drop across mixer.

AVV Test Hardware

1. Union Tee fitting, 1/4” (6.35mm) NPT
with three 1/4” (6.35mm) NPT x 1/4” (6.35mm) hose barbs.
2. Vacuum hose.
3. 0-20” H_2O differential pressure Magnehelic gauge.

AVV Test

1. Install Union Tee fitting in the hose between the FTVs and the AVV fitting. Connect this fitting to the low pressure port of the Magnehelic gauge (**Figure 33)**.
2. Leave high pressure port of the Magnehelic gauge exposed to ambient pressure (**Figure 33**).
3. With the engine fully warmed up and running at idle (750 RPM) place the transmission in Neutral. The AVV should be between 5” and 8” H_2O of pressure vacuum.
4. If the measured pressure drop is excessively high, check for sticking or binding of the diaphragm air valve assembly inside the mixer. Replace mixer if necessary.
5. If the measured pressure drop is low, check for vacuum leaks in the manifold, throttle, mixer, TMAP sensor and attached hoses.

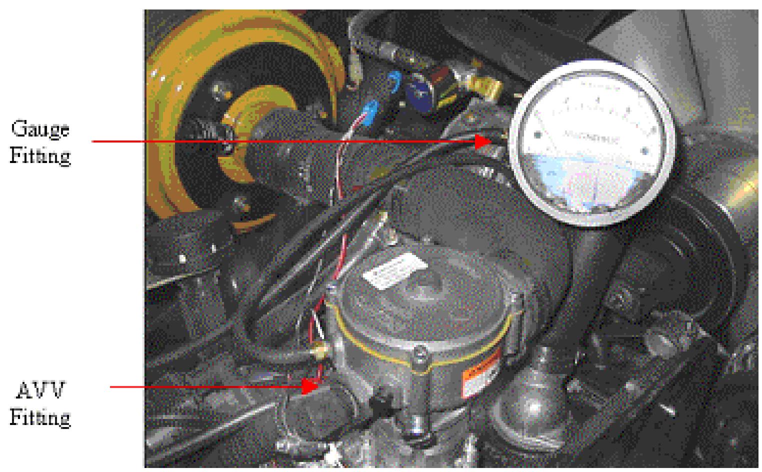


Figure 33. Magnehelic Gauge Connection

Ignition Timing Adjustment

With the MI-07 system, ignition-timing advance is controlled by the SECM. The initial ignition timing needs to be set by the MOR. This setup requires a specific technique for each engine installatio

Connection of MI-07 Service Tool

To use the Service Tool, a Universal Serial Bus (USB) to Controller Area Network (CAN) communication adapter by KVaser will be required along with a Crypt Token (**Figure 34**). The Crypt Token acts as a security key allowing the laptop to retrieve the necessary data from the SECM.

1. Install the Crypt Token in an available USB port in the computer (**Figure 35**).
2. With the ignition key in the OFF position, connect the KVaser communication cable from a second USB port on the computer to the CAN communications cable on the engine. *(*If your laptop computer does not have a second USB port an appropriate USB hub will need to be used).*
3. Connect a timing light to the engine.
4. Turn the ignition key to the ON position *(**Do Not Start the Engine**).*
5. Launch the MotoView program on your computer and open the Service Tool display (**Figure 36**).

Figure 34. KVaser Communication Adapter

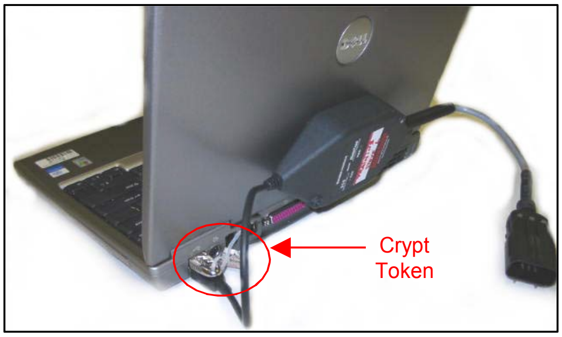


Figure 35. Crypt Token Installed on Laptop

Figure 36. Opening the Service Tool Display

Idle Mixture Adjustment

> **NOTE**
> **Be sure engine is fully warm (ECT>180°F [82°C]) before performing the idle mixture adjustment.**

The mixer requires adjustment of the idle mixture screw to assure optimal emissions and performance. This adjustment accounts for minor part-to-part variations in the fuel system and assures stable performance of the engine at idle. Once adjusted, the idle mixture screw is sealed with a tamper proof cap, after which it need not be adjusted for the life of the vehicle.

Therefore, the only situations in which the idle mixture screw needs to be adjusted are when the engine is initially fitted with a fuel system at the factory and following the field replacement of the mixer. Under these situations, follow the procedures below for adjustment of the idle mixture screw.

Factory Test Preparation:

1. Install the MI-07 fuel system, wiring harness and SECM-48 control module on the engine.
2. All coolant hoses should be attached, filled with coolant and bled to remove any air.
3. Attach LPG fuel lines.
4. Attach wiring harness to battery power.
5. Attach exhaust system.
6. If present, set fuel select switch to LPG fuel.

When operated at the factory, it is critical to simulate the airflow found on a forklift at idle as nearly as possible in order to achieve the proper air valve lift in the mixer. It may be necessary to place a load on the engine to achieve the required airflow without overspeeding the engine. Means of achieving this load include:

a) Place an electrical load on the alternator. The alternator should be able to briefly hold loads of approximately 1.2 kW.

b) Attach the engine to a dynamometer.

Factory Adjustment Procedure:

> **NOTE**
> **Be sure engine is fully warm (ECT>180°F [82°C]) before performing the idle mixture adjustment.**

1. Operating the engine on LPG fuel, start the engine and permit the engine to warm up until the coolant temperature (ECT on Mototune display) is approximately 180°F (82 °C).
2. Set APP input to minimum.
3. Adjust the load until engine speed reaches 750 RPM.
4. Mototune display parameter LP Fuel Control must display “Closed Loop.”
5. Use the Mototune Service Tool to monitor Duty Cycle % on the Mototune display.
6. To adjust the idle mixture screw, use a 3/16” hex or Allen-type wrench. Turning the screw in (clockwise) should increase the duty cycle; turning the screw out (counter-clockwise) should decrease the duty cycle.
7. Adjust the idle mixture screw on the mixer until a reading of **40-47%** is reached for the FTV Duty Cycle in Closed Loop Idle (**Figure 37**).

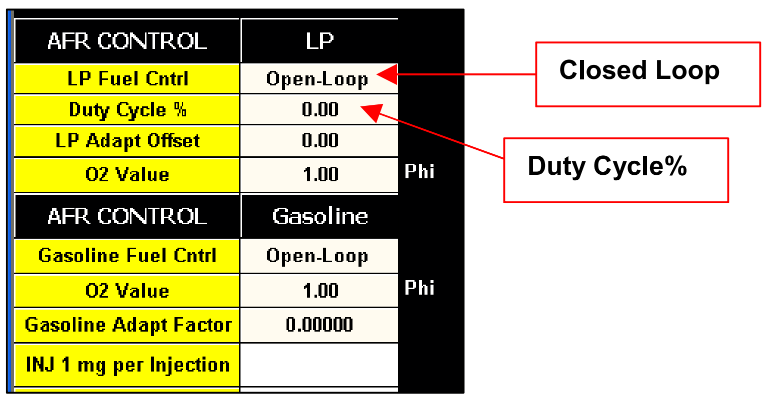


Figure 37. FTV Duty Cycle Percentage Displayed on Service Tool

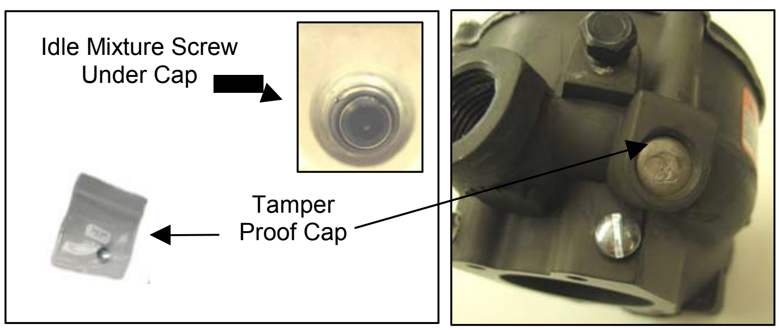
8. Use the accelerator pedal to increase RPM above idle momentarily (*rev the engine*) then release the pedal to return to idle RPM. The duty cycle setting should remain within the adjustment range (**40-47%**).
9. Use the Mototune Service Tool to lock the FTV duty cycle. Set display parameter DitherValveDC_ovr = locked (displayed in screen tab Manual Override 1 under AFR Trim Vales, select “locked” under box labeled Lock DC%).
10. Use the Mototune Service Tool to monitor throttle position (TPS_1) and Exhaust gas oxygen equivalence ratio (“O_2 Value” in Figure 1). While monitoring O_2, slowly increase the pedal input (APP) to achieve a TPS_1 value of 15%.
11. Use the Mototune Service Tool to unlock the FTV duty cycle. Set display parameter DitherValveDC_ovr = unlocked (displayed in screen tab Manual Override 1 under AFR Trim Vales, select “unlocked” under box labeled Lock DC%).
12. If at any time in step 10, O_2 was greater than 1.2 go to step 13. If 0_2 remained below 1.2, proceed to Step 15.
13. Adjust the idle mixture screw on the mixer until a reading of **50-55%** is reached for the FTV Duty Cycle in Closed Loop Idle (**Figure 37**).

14. Use the accelerator pedal to increase RPM above idle momentarily (*rev the engine*) then release the pedal to return to idle RPM. The duty cycle setting should remain within the adjustment range (**50-55%**).

> **NOTE**
> **If the FTV Duty Cycle reading is NOT between 25-60%, check for possible vacuum leaks, manifold leaks, or a faulty mixer.**

15. Turn the ignition key to the **OFF** position to shut down the engine.
16. Install the tamper proof cap on the idle mixture screw adjustment port using a large pin punch, so that no further adjustments can be made (**Figure 38)**.

Figure 38. Installing Tamper Proof Cap



Field Adjustment Procedure:

The idle mixture adjustment should only be necessary on a new mixer that does not have the tamper proof cap installed. The method for making the idle mixture adjustment to a running engine is to use the Service Tool software by connecting a laptop computer to the SECM. If you do not have the Service Tool, a multimeter capable of measuring duty cycle, such as a Fluke 87 III, can be used. If using a multimeter, connect the meter positive lead to the battery positive wire and the meter negative to the FTV signal wire. For the Fluke 87, press the “RANGE” button until 4 or 40 appears in the lower right-hand corner of the display. Press the “Hz” button twice so that the percent sign (%) appears on the right-hand side of the display. The multimeter will then read the duty cycle percentage the just like the Service Tool shown in **Figure 37**.

1. After installing a new mixer, operate the engine on LPG fuel. Start the engine and permit it to warm up until the coolant temperature (ECT on Mototune display) is approximately 180°F (82 °C).
2. Place the transmission in Neutral.
3. Mototune display parameter LP Fuel Control must display “Closed Loop”.
4. Use the Mototune Service Tool to monitor Duty Cycle % on the Mototune display.
5. To adjust the idle mixture screw, use a hex or Allen-type wrench. Turning the screw in (clockwise) should increase the duty cycle; turning the screw out (counterclockwise) should decrease the duty cycle.
6. Adjust the idle mixture screw on the mixer until a reading of **45-55%** is reached for the FTV Duty Cycle in <u>Closed Loop Idle</u> (**Figure 37)**. If engine idle performance is unstable screw the idle screw in slightly to see if stability is obtained, but in no case should duty cycle exceed 60%.
7. Use the accelerator pedal to increase RPM above idle momentarily (*rev the engine*) then release the pedal to return to idle RPM. The duty cycle setting should remain within the adjustment range (**45-55%**).
8. If the FTV duty cycle reading is above **55%** adjust the idle adjustment screw outward and re-check the duty cycle reading. Continue to do this until the FTV duty cycle reading is within the optimum range (**45-55%**). **DO NOT** adjust the screw so far outward that the tamper proof cap cannot be installed. A duty cycle measurement at Closed Loop Idle of **40-60%** is acceptable if the optimum range of **45-55%** cannot be reached through adjustment. If the FTV duty cycle cannot be adjusted below **60%**, the mixer is faulty and should be replaced.

> **NOTE**
> **If the FTV Duty Cycle reading is NOT between 25-60%, check for possible vacuum leaks, manifold leaks, or a faulty mixer.**

9. Turn the ignition key to the **OFF** position to shut down the engine.
10. Install the tamper proof cap on the idle mixture screw adjustment port using a large pin punch, so that no further adjustments can be made (**Figure 38**).

Basic Troubleshooting

Preliminary Checks

MI-07 systems are equipped with built-in fault diagnostics. Detected system faults can be displayed by the Malfunction Indicator Lamp (MIL) and are covered in Chapter 8, Advanced Diagnostics. However, items such as fuel level, plugged fuel lines, clogged fuel filters, and malfunctioning pressure regulators may not set a fault code and usually can be corrected with the basic troubleshooting steps described on the following pages.

If engine or drivability problems are encountered with your MI-07 system, perform the checks in this section before referring to Advanced Diagnostics.

NOTE: Locating a problem in a propane engine is done exactly the same as with a gasoline engine. Consider all parts of the ignition and mechanical systems as well as the fuel system.

BEFORE STARTING . . .

1. Determine that the SECM and the MIL are operating. Verify operation by keying on engine and checking for flash of the MIL.

   When the ignition key is turned on, the MIL will illuminate and remain on until the engine is started. Once the engine is started, the MIL will go out unless one or more fault conditions are present. If a detected fault condition exists, the fault or faults will be stored in the memory of the SECM. Once an active fault occurs the MIL will illuminate and remain ON. This signals the operator that a fault has been detected by the SECM.
2. Determine that there are no diagnostic codes stored, or there is a diagnostic code but no MIL.

VISUAL/PHYSICALCHECK

Several of the procedures call for a “Careful Visual/Physical Check” which should include:

- SECM grounds for being clean and tight.
- Vacuum hoses for splits, kinks, and proper connection.
- Air leaks at throttle body mounting and intake manifold.
- Exhaust system leaks.
- Ignition wires for cracking, hardness, proper routing, and carbon tracking.
- Wiring for pinches and cuts.

Also check:

- Connections to determine that none are loose, cracked, or missing
- Fuel level in vehicle is sufficient
- Fuel is not leaking
- Battery voltage is greater than 11.5 volts
- Steering, brakes, and hydraulics are in proper condition and vehicle is safe to operate

NOTE
The Visual/Physical check is very important, as it can often correct a problem without further troubleshooting and save valuable time.

Basic Troubleshooting

Intermittent Faults

An intermittent fault is the most difficult to troubleshoot since the MIL flashes on at random, causing uncertainty in the number of flashes or the conditions present at the time of the fault. Also, the problem may or may not fully turn "ON" the MIL or store a code.

Therefore, the fault must be present or able to be recreated in order to locate the problem. If a fault is intermittent, use of diagnostic code charts may result in the unnecessary replacement of good components.

CORRECTIVE ACTION
Most intermittent problems are caused by faulty electrical connections or wiring. Perform careful visual/physical check for: • Poor mating of the connector halves or terminal not fully seated in the connector body (backed out). • Improperly formed or damaged terminal. All connector terminals in problem circuit should be carefully reformed or replaced to insure proper contact tension. • Loose connections or broken wires. • Poor terminal to wire connection crimp.
If a visual/physical check does not find the cause of the problem, perform the following: (1) Drive the vehicle with a voltmeter or "Service" tool connected to a suspected circuit. Check if circuit is active and signal is reasonable. (2) Using the "Service" tool, monitor the input signal to the SECM to help detect intermittent conditions. (3) An abnormal voltage, or "Service" reading, when the problem occurs, indicates the problem may be in that circuit. (4) If the wiring and connectors check OK, and a diagnostic code was stored for a circuit having a sensor, check sensor.
An intermittent "Service Engine Soon" light with no stored diagnostic code may be caused by: • Ignition coil shortage to ground and arcing at spark plug wires or plugs. • MIL wire to ECM shorted to ground. • SECM grounds (refer to SECM wiring diagrams).
Check for improper installation of electrical options such as lights, 2-way radios, accessories, etc.
EST wires should be routed away from spark plug wires, distributor wires, distributor housing, coil and generator. Wires from SECM to ignition should have a good connection.

Surges and/or Stumbles

Engine power varies under steady throttle or cruise. Surging and stumbling is characterized by the feeling that the vehicle is speeding up and slowing down with no change in the acceleration pedal.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Be sure driver understands vehicle operation as explained in the operator manual.

PROBABLE CAUSE	CORRECTIVE ACTION
Oxygen sensor malfunction	The fuel management system should maintain a stoichiometric air-fuel ratio under all steady state operating conditions following engine warmup. Failure of the Pre-catalyst O_2 sensor should cause an O_2 sensor fault that can be diagnosed with the MIL or Service Tool.
Fuel system malfunction	**NOTE:** To determine if the condition is caused by a rich or lean system, the vehicle should be driven at the speed of the complaint. Monitoring pre-catalyst O_2 adapts*, dither valve duty cycle, or mechanical injector pulse width will help identify problem. Check fuel supply while condition exists. Check in-line fuel filter. Replace if dirty or plugged. Check fuel pressure.
Ignition system malfunction	Check for proper ignition voltage output using spark tester. Check spark plugs. • Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. • Repair or replace as necessary. • Check condition of spark plug wires. Check ignition timing.
Component malfunction	Check vacuum lines for kinks or leaks. Check alternator output voltage. Repair if less than 9 or more than 16 volts.
Exhaust backpressure	Check condition of exhaust system. Check backpressure before catalyst. It should be less than 3.5 psig (24.13 kPa).

(*) Refer to **Table 1** for description of gaseous and liquid O_2 adapts.

Related MIL Faults:

Pre-catalyst O_2 sensor errors / O_2 control errors
Dither valve DC faults / EST faults / ETC faults

Engine Cranking but Will Not Start / Difficult to Start

Engine cranks OK, but does not start for a long time. Does eventually run, or engine starts but immediately dies.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting"section. Be sure driver is using correct method to start engine as explained in operator's manual. Use "clear flood" mode during cranking by fully depressing the pedal and cranking the engine. If engine does not start, continue troubleshooting.

PROBABLE CAUSE	CORRECTIVE ACTION
Improper fuel selected	Verify "selected" fuel with Service Tool. Make sure fuel select switch is in proper position.
Fuel container empty	Check for LPG vapor from LPG liquid outlet valve on tank. Fill fuel container. Do not exceed 80% of liquid capacity.
Liquid valve closed	Slowly open liquid valve.
Propane excess flow valve closed	Reset excess flow valve in LPG tank. Close liquid valve. Wait for a "click" sound; slowly open liquid valve.
Plugged fuel line	Remove obstruction from the fuel line. • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve. • Leak test.
Clogged fuel filter	Repair/replace as required. *See Chapter 4 Fuel Filter replacement.*
Faulty vapor connection between the pressure regulator/converter and the mixer	Check connection • Verify no holes in hose. • Clamps must be tight. • Look for kinked, pinched and/or collapsed hose.
Fuel lock-off malfunction	Repair/replace fuel lock-off. *See Chapter 4 Fuel Lock-off.*
Pressure regulator/converter malfunction	Test regulator/converter operation and pressure. *See Chapter 6 Tests and Adjustments.*
Incorrect air/fuel or ignition/spark control	*See Chapter 8 Advanced Diagnostics.*
No crankshaft position sensor signal	Verify the crankshaft position signal is present *See Chapter 8 Advanced Diagnostics.*

Engine Cranking but Will Not Start / Difficult to Start (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
SECM / control system malfunction	Check Engine Coolant Temperature (ECT) sensor using the Service Tool; compare coolant temperature with ambient temperature on cold engine. If coolant temperature reading is 5° greater than or less than ambient air temperature on a cold engine, check resistance in coolant sensor circuit or sensor itself. Compare ECT resistance value to "Diagnostic Aids" chart at end of this section. Verify that there is no code for Electronic Throttle Controller (ETC) spring check fault. Check for 0% APP during cranking. Cycle key ON and OFF and listen for throttle check (movement) on key OFF. Check for oil pressure switch faults. Check for ETC "sticking" faults. Check Throttle Position Sensor (TPS) for stuck binding or a high TPS voltage with the throttle closed.
Fuel system malfunction	Check fuel lock off (propane) or fuel pump. The lock off or fuel pump may turn "ON" for some seconds when ignition switch is turned "ON" (calibration specific). Check fuel pressure. Check for contaminated fuel. Check fuses (visually inspect). Check propane tank valve & pickup. A faulty in-tank fuel pump check valve will allow the fuel in the lines to drain back to the tank after engine is stopped. To check for this condition, perform fuel system diagnosis. Check FTV system for proper operation.
Ignition system malfunction	Check for proper ignition voltage output with spark tester. Check spark plugs. Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary. Check for: • Bare or shorted wires. • Loose ignition coil ground. • Pickup coil resistance and connections.

Related MIL Faults:
ETC spring check / ETC faults / EST faults / TPS conflict
APP faults / Encoder error / MAP faults / Injector faults / Oil pressure faults

Lack of Power, Slow to Respond / Poor High Speed Performance / Hesitation During Acceleration

Engine delivers less than expected power. Little or no increase in speed when accelerator pedal is pushed down part way. Momentary lack of response as the accelerator is pushed down. May occur at all vehicle speeds. Usually most severe when first trying to make vehicle move, as from a stop. May cause engine to stall.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Drive vehicle; verify problem exists. Remove air filter and check for dirt or other means of plugging. Replace if needed.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for restricted fuel filter. Check fuel supply. Check for LPG vapor from LPG liquid outlet valve on tank. Check for contaminated fuel. Check for clogged fuel filter and repair or replace as required. *See Chapter 4 Fuel Filter replacement* Check for plugged fuel line and remove any obstruction from the fuel line: • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve and leak test. Check for faulty vapor connection between pressure regulator/converter and mixer: • Verify that there are no holes in hose. • Observe that clamps are tight. • Look for kinked, pinched and/or collapsed hose. Monitor pre-catalyst O_2 with Service Tool. Check for proper pressure regulator operation. *See Chapter 6 Test and Adjustments.* Check for proper air/fuel mixer operation.
Ignition system malfunction	Check spark advance for excessive retarded ignition timing. Use Service Tool. Check secondary voltage using an oscilloscope or a spark tester to check for a weak coil. Check spark plug condition. Check poor spark plug primary and secondary wire condition.

Lack of Power, Slow to Respond / Poor High Speed Performance Hesitation During Acceleration (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
Component malfunction	Check SECM grounds for cleanliness and secure connection. See SECM wiring diagrams. Check alternator output voltage. Repair if less than 9 volts or more than 16 volts. Check for clogged air filter and clean or replace as required. Check exhaust system for possible restriction. Refer to Chart T-1 on later pages. Inspect exhaust system for damaged or collapsed pipes. • Inspect muffler for heat distress or possible internal failure. • Check for possible plugged catalytic converter by comparing exhaust system backpressure on each side of engine. Check backpressure by removing Pre-catalyst O_2 sensor and measuring backpressure with a gauge.
Engine mechanical	*See Engine Manufacturer's Service Manual.* Check engine valve timing and compression Check engine for correct or worn camshaft.

Related MIL Faults:
EST faults
ETC faults
ETC spring check
TPS faults
APP faults
Encoder error
Delayed Shutdown faults

Detonation / Spark Knock

A mild to severe ping, usually worse under acceleration. The engine makes sharp metallic knocks that change with throttle opening (similar to the sound of hail striking a metal roof).

PRELIMINARY CHECKS
Perform the visual checks as described at start of “ Basic Troubleshooting” section.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for proper fuel level: • Check for LPG vapor from LPG liquid outlet valve on tank. • Fill fuel container. Do not exceed 80% of liquid capacity. Check fuel pressure. To determine if the condition is caused by a rich or lean system, the vehicle should be driven at the speed of the complaint. Monitoring with the Service tool will help identify problem.
Cooling system malfunction	Check for obvious overheating problems: • Low engine coolant. • Loose water pump belt. • Restricted air flow to radiator, or restricted water flow through radiator. • Inoperative electric cooling fan. • Correct coolant solution should be a mix of anti-freeze coolant (or equivalent) and water. • High coolant temperature.
Ignition system malfunction	Check ignition timing. Check spark module wiring.
Exhaust system malfunction	Check exhaust backpressure. Check for debris clogging the catalyst. Check that pre-catalyst O_2 sensor is functioning.
Engine mechanical	Check for excessive oil in the combustion chamber and/or blow by from excessive PCV flow. Check combustion chambers for excessive carbon build up. Check combustion chamber pressure by performing a compression test. Check for incorrect basic engine parts such as cam, heads, pistons, etc.

Related MIL Faults:
EST faults
Encoder error
High coolant temperature faults

Backfire

Fuel ignites in intake manifold or in exhaust system, making loud popping noise.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Simulate condition by reviewing operation procedure practiced by vehicle operator.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Perform fuel system diagnosis check: • Check for fuel leaks. • Check for MIL faults. • Check for damaged components.
Ignition system malfunction	Check proper ignition coil output voltage with spark tester. Check spark plugs. Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary. Check spark plug wires for crossfire; also inspect spark plug wires and proper routing of plug wires. Check ignition timing.
Engine mechanical	Check compression: look for sticking or leaking valves. Check intake and exhaust manifold for casting flash and gasket misalignment. Refer to Engine Manufacturer's Service Manual.

Related MIL Faults: EST faults / ETC faults / Encoder error
Pre-catalyst O_2 sensor faults

Dieseling, Run-on

Engine continues to run after key is turned "OFF," but runs very roughly. If engine runs smoothly, check ignition switch and adjustment.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for fuel leaks or leaking injector.
Ignition switching	Make sure power to system is shut off when key is in OFF position.
Fuel lock off valve	Make sure lock off valve is closing properly.
Ignition system malfunction	Check spark advance at idle.

Related MIL Faults: EST faults / ETC faults / Pre-catalyst O_2 sensor faults

Rough, Unstable, Incorrect Idle, or Stalling

Engine cranks OK, but does not start for a long time. Does eventually run, or may start but immediately dies.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" section. Check for vacuum leaks. Check that SECM grounds are clean and tight. See SECM wiring diagram.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Monitor oxygen feedback to help identify the cause of the problem. If the system is running lean or if the system is running rich evaluate further i.e. dither valve duty cycle and injector pulse width. Check for incorrect minimum idle speed that may be caused by foreign material accumulation in the throttle bore, on the throttle valve, or on the throttle shaft. Check that the injectors are clean and functioning. Check for liquid fuel in propane pressure regulator hose. If fuel is present, replace regulator assembly. The pre-catalyst oxygen (O_2) sensor should respond quickly to different throttle positions. If it does not, then check the pre-catalyst O_2 sensor for contamination. If the pre-catalyst O_2 sensor is aged or contaminated, the SECM will not deliver correct amount of fuel, resulting in a drivability problem.
Fuel container empty	Check for LPG vapor from LPG liquid outlet valve on tank. Fill fuel container. Do not exceed 80% of liquid capacity.
Ignition system malfunction	Check ignition system; wires, plugs, etc.
LPG pressure regulator malfunction	Test regulator operation and pressure. *See Chapter 6 Tests and Adjustments*
Air/fuel mixer malfunction	Check mixer.
Component malfunction	Check throttle for sticking or binding. Check PCV valve for proper operation by placing finger over inlet hole in valve end several times. Valve should snap back. If not, replace valve. Check alternator output voltage. Repair if less than 9 or more than 16 volts.
Engine mechanical	Perform a cylinder compression check. *See Engine Manufacturer's Service Manual.*

Rough, Unstable, Incorrect Idle, or Stalling (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
Excess flow valve closed	Reset excess flow valve. • Close liquid valve. • Wait for a "click" sound. Slowly open liquid valve.
Clogged fuel filter	Repair/replace as required *See Chapter 4 Fuel Filter Replacement*
Plugged fuel line	Remove obstruction from the fuel line. • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve & leak test.
Fuel lock-off malfunction	Repair/replace fuel lock-off. *See Chapter 4 Fuel Lock-Off.*
Faulty vapor connection between the pressure regulator/converter and the mixer	Check connection. • Verify no holes in hose. • Clamps must be tight. • Look for kinked, pinched and/or collapsed hose.
Pressure regulator freezes	Check level in cooling system: • Must be full, check coolant strength. • -35°F (-37°C) minimum. Check coolant hoses. • Watch for kinks and/or pinched hoses. • Verify one pressure hose and one return hose. Test regulator. See Chapter 6
Vacuum leak	Check for vacuum leaks . . . • Between mixer and throttle body. • Between throttle body and intake manifold. • Between intake manifold and cylinder head.

Related MIL Faults:
EST faults
ETC Sticking fault
Pre-catalyst adapts error

Cuts Out, Misses

Steady pulsation or jerking that follows engine speed, usually more pronounced as engine load increases, sometimes above 1500 RPM. The exhaust has a steady spitting sound at idle or low speed.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" section.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check fuel system specifically for plugged fuel filter, low pressure. Check for contaminated fuel. Check injector drivers. Disconnect all injector harness connectors. Use injector test light or equivalent 6-volt test light between the harness terminals of each connector and observe if light blinks while cranking. If test light fails to blink at any connector, it is a faulty injector drive circuit harness, connector, or terminal. Check lock off for intermittent connection. Check dither valve operation.
Ignition system malfunction	Check for spark on the suspected cylinder(s) using a shop oscilloscope or spark tester or equivalent. If no spark, check for intermittent operation or miss. If there is a spark, remove spark plug(s) in these cylinders and check for cracks, wear, improper gap, burned electrodes, heavy deposits. Check spark plug wires by connecting ohmmeter to ends of each wire in question. If meter reads over 30,000 Ω, replace wire(s). Visually inspect wires for moisture, dust, cracks, burns, etc. Spray plug wires with fine water mist to check for shorts. Check engine ground wire for looseness or corrosion.
Component malfunction	Check for electromagnetic interference (EMI). A missing condition can be caused by EMI on the reference circuit. EMI can usually be detected by monitoring engine RPM with Service Tool. A sudden increase in RPM with little change in actual engine RPM indicates EMI is present. If problem exists, check routing of secondary wires and check distributor ground circuit. Check intake and exhaust manifolds for casting flash or gasket leaks.
Engine mechanical	Perform compression check on questionable cylinders. If compression is low, repair as necessary. Check base engine. Remove rocker covers and check for bent pushrods, worn rocker arms, broken valve springs, worn camshaft lobes, and valve timing. Repair as necessary.

Related MIL Faults:
EST faults / ETC Sticking fault

High Idle Speed

Engine idles above the range of 750-1000 RPM.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Incorrect idle speed control	Check all hoses and gaskets for cracking, kinks, or leaks. Verify that there are no vacuum leaks. *See Chapter 8 Advanced Diagnostics & Chapter 6 Tests and Adjustments*
Throttle sticking	Replace throttle. *See Fault Code 461: ETC Sticking*
Foot pedal sticking or incorrect pedal signal	Check pedal return spring travel for binding. Check APP function with Service Tool. Verify smooth change of APP reading with pedal movement. *See Chapter 8 Advanced Diagnostics.*
Engine mechanical	Check for vacuum hose leak. Check for PCV malfunction. Check for defective intake gasket.

Related MIL Faults:
ETC Sticking fault
Idle adapt out of range
MAP Sticking fault
MAP high value

Excessive Exhaust Emissions or Odors

Vehicle has high CO emissions.
NOTE: Excessive odors do not necessarily indicate excessive emissions.

PRELIMINARY CHECKS
Verify that no stored codes exist. If emission test shows excessive CO and HC, check items that cause vehicle to run **rich**. If emission test shows excessive NOx, check items that cause vehicle to run **lean** or too hot.

PROBABLE CAUSE	CORRECTIVE ACTION
Cooling system malfunction	If the Service tool indicates a very high coolant temperature and the system is running *lean*: • Check engine coolant level. • Check engine thermostat for faulty part (always open) or for wrong heat range. • Check fan operation
Fuel system malfunction	If the system is running *rich*, refer to “Diagnostic Aids” chart on the next page. If the system is running *lean* refer to “Diagnostic Aids” chart on the next page. Check for properly installed fuel system components. Check fuel pressure.
Ignition system malfunction	Check ignition timing. Check spark plugs, plug wires, and ignition components.
Component malfunction	Check for vacuum leaks. Check for contamination for catalytic converter (look for the removal of fuel filler neck restrictor). Check for carbon build-up. Remove carbon with quality engine cleaner. Follow instructions on label. Check for plugged PCV valve. Check for stuck or blocked PCV hose. Check for fuel in the crankcase.

Related MIL Faults:
Low side driver
Fuel adapt faults
EST faults

Diagnostic Aids for Rich / Lean Operation

SERVICE TOOL ITEM	RICH	LEAN
Pre-catalyst O_2 A/ D counts	Consistently > 250	Consistently < 170
Pre-catalyst O2 sensor switching between high and low	Always high ADC	Always low ADC
Trim valve duty cycle	> 90%	< 10%
Fuel injector pulse width at idle *	< 1.0 msec.	> 8 msec.
Malfunction codes	• Pre-catalyst O_2 sensor failed rich • Pre-catalyst O_2 sensor high • Fuel adapts	• Pre-catalyst O_2 sensor failed lean • Pre-catalyst O_2 sensor low • Fuel adapts
Closed loop operation	Stuck in open loop	Stuck in open loop

(*) The duty cycle injector pulse width criteria for lean or rich operation apply only if the O_2 sensor is functioning properly. If the sensor is not operating properly the criteria may be reversed.

RICH OPERATION
LP (Trim valve duty cycle>90%)

- Inspect hoses from AVV port (port on bottom of mixer) to trim valves and regulator for leaks or blockages, replace as necessary.
- Inspect in-line orifices for blockages (in wye), replace as necessary
- Check trim valves for proper operation, replace as necessary
- Check regulator out pressure, replace if out of spec
- Inspect fuel cone for damage, replace mixer assembly as necessary

Gasoline (Injector Pulse Width<1.0 msec)

- Check gasoline fuel pressure
- Check injectors for sticking, replace as necessary

LEAN OPERATION
LP (Trim valve duty cycle<10%)

- Check for vacuum leaks, replace hoses, o-rings, and gaskets as necessary
- Check balance line for blockage, replace as necessary
- Check vapor hose for restrictions, replace as necessary
- Check trim valves for proper operation, replace as necessary
- Check regulator out pressure, replace if out of spec

Gasoline (Injector Pulse Width>8 msec)

- Check system voltage
- Check fuel pressure
- Check injectors for sticking or obstructions

Chart T-1
Restricted Exhaust System Check

Proper diagnosis for a restricted exhaust system is essential before replacement of any components. The following procedures may be used for diagnosis, depending upon engine or tool used.

CHECK AT PRE-CATALYST OXYGEN (O_2) SENSOR

1. Carefully remove pre-catalyst oxygen (O_2) sensor.
2. Install exhaust backpressure tester or equivalent in place of O_2 sensor using Snap-On P/N EEVPV311A kit and YA8661 adapter or Mac tool. See **Figure 39**.
3. After completing test described below, be sure to coat threads of O_2 sensor with anti-seize compound prior to re-installation.

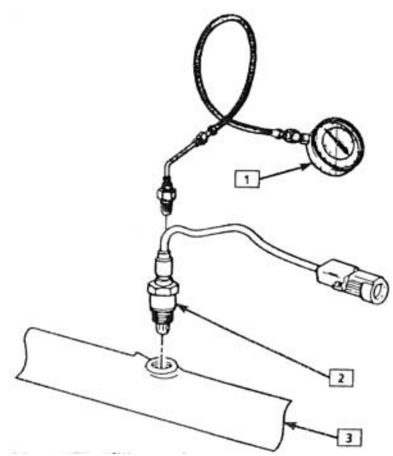


ILLUSTRATION NOTES

[1] Backpressure gage
[2] Pre-catalyst Oxygen (O_2) sensor
[3] Exhaust manifold

Courtesy of GM 1991 Service Manual for Chevrolet Camaro © 1990

Figure 39. Installing Exhaust Backpressure Tester

DIAGNOSIS:

1. With the engine idling at normal operating temperature, observe the exhaust system backpressure reading on the gage. Reading should not exceed 1.25 psig (8.61 kPa).
2. Increase engine speed to 2000 RPM and observe gage. Reading should not exceed 3 psig (20.68 kPa).
3. If the backpressure at either speed exceeds specification, a restricted exhaust system is indicated.
4. Inspect the entire exhaust system for a collapsed pipe, heat distress, or possible internal damage, split welds, or cracked pipe.
5. If there are no obvious reasons for the excessive backpressure, the catalytic converter is restricted and should be replaced using current recommended procedures.

Advanced Diagnostics

MI-07 systems are equipped with built-in fault diagnostics. Detected system faults can be displayed by the Malfunction Indicator Lamp (MIL) as Diagnostic Fault Codes (DFC) or flash codes, and viewed in detail with the use of the Service Tool software. When the ignition key is turned on, the MIL will illuminate and remain on until the engine is started. Once the engine is started, the MIL lamp will go out unless one or more fault conditions are present. If a detected fault condition exists, the fault or faults will be stored in the memory of the small engine control module (SECM). Once an active fault occurs the MIL will illuminate and remain ON. This signals the operator that a fault has been detected by the SECM.

Reading Diagnostic Fault Codes

All MI-07 fault codes are three-digit codes. When the fault codes are retrieved (displayed) the MIL will flash for each digit with a short pause (0.5 seconds) between digits and a long pause (1.2 seconds) between fault codes. A code 12 is displayed at the end of the code list.

EXAMPLE: A code 461 (ETCSticking) has been detected and the engine has shut down and the MIL has remained **ON**. When the codes are displayed the MIL will flash four times (**4**), pause, then flash six times (**6**), pause, then flash one time (**1**) This identifies a four sixty one (**461**), which is the ETCSticking fault. If any additional faults were stored, the SECM would again have a long pause, then display the next fault by flashing each digit. Since no other faults were stored there will be a long pause then one flash (**1**), pause, then two flashes (**2**). This identifies a twelve, signifying the end of the fault list. This list will then repeat.

Displaying Fault Codes (DFC) from SECM Memory

To enter code display mode you must turn **OFF** the ignition key. Now turn **ON** the key but do not start the engine. As soon as you turn the key to the ON position you must cycle the foot pedal by depressing it to the floor and then fully releasing the pedal (pedal maneuver). You must fully cycle the foot pedal three (**3**) times within five (**5**) seconds to enable the display codes feature of the SECM. Simply turn the key **OFF** to exit display mode. The code list will continue to repeat until the key is turned **OFF**.

Clearing Fault (DFC) Codes

To clear the stored fault codes from SECM memory you must complete the reset fault pedal maneuver.

CAUTION
Once the fault list is cleared it cannot be restored.

First turn **OFF** the ignition key. Now turn **ON** the key but do not start the engine. As soon as you turn the key to the ON position you must cycle the foot pedal by depressing it to the floor and then fully releasing the pedal (pedal maneuver). You must fully cycle the foot pedal ten (**5**) times within five (**5**) seconds to clear the fault code list of the SECM. Simply turn the key **OFF** to exit the reset mode. The code list is now clear and the SECM will begin storing new fault codes as they occur.

Fault Action Descriptions

Each fault detected by the SECM is stored in memory (FIFO) and has a specific action or result that takes place. Listed below are the descriptions of each fault action.

Engine Shutdown: The most severe action is an Engine Shutdown. The MIL will light and the engine will immediately shutdown, stopping spark, closing the fuel lock-off closing, and turning off the fuel pump and fuel injectors.

Delayed Engine Shutdown: Some faults, such as low oil pressure, will cause the MIL to illuminate for 30 seconds and then shut down the engine.

Cut Fuel: Fuel flow will be turned off. (Only in gasoline mode)

Cut Throttle: The throttle moves to its default position. The engine will run at idle but will not accelerate.

Turn on MIL: The MIL will light by an active low signal provided by the SECM, indicating a fault condition. May illuminate with no other action or may be combined with other actions, depending on which fault is active.

Soft Rev Limit / Medium Rev Limit / Hard Rev Limit: System will follow various sequences to bring engine speed back to acceptable levels.

Level4 Power Limit / Level3 Power Limit / Level2 Power Limit / Level1 Power Limit: The maximum engine power output will be limited to one of four possible levels. The engine power is calculated from measured engine parameters (e.g. MAP, rpm, fuel flow, etc).

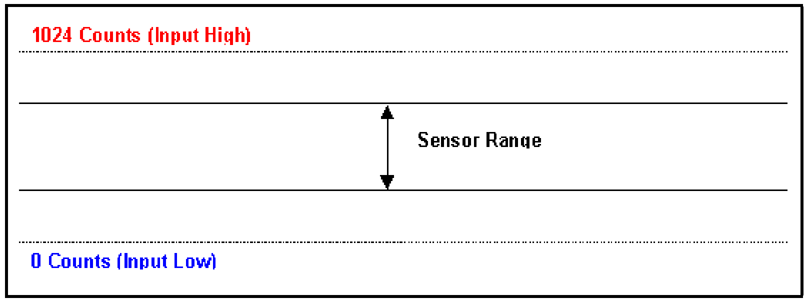
Disable Gas O2 Control: In LPG mode, closed loop correction of air fuel ratio based on the Pre-catalyst O_2 sensor is disabled.

Disable Liquid O2 Control: In Gasoline mode, closed loop correction of air fuel ratio based on the Pre-catalyst O_2 sensor is disabled.

Fault List Definitions

All the analog sensors in the MI-07 system have input sensor range faults. These are the coolant temperature sensor, fuel temperature sensor, throttle position sensors, pedal position sensors, manifold pressure sensor, HEGO sensors, and intake air temperature sensor. Signals to these sensors are converted into digital counts by the SECM. A low/high range sensor fault is normally set when the converted digital counts reach the minimum of 0 or the maximum of 1024

(**1024 = 5.0 Vdc with ~ 204 counts per volt**).



Additionally, the SECM includes software to learn the actual range of the pedal position and throttle position sensors in order to take full advantage of the sensor range. Faults are set if the learned values are outside of the normal expected range of the sensor (e.g. APP1AdaptLoMin)

Table 1. Fault List Definitions

FAULT	DESCRIPTION	CODE
APP1AdaptHiMax	Learned full pedal end of APP1 sensor range higher than expected	641
APP1AdaptHiMin	Learned full pedal end of APP1 sensor range lower than expected	651
APP1AdaptLoMax	Learned idle end of APP1 sensor range higher than expected	661
APP1AdaptLoMin	Learned idle end of APP1 sensor range lower than expected	631
APP1RangeHigh	APP1 sensor voltage out of range high, normally set if the APP1 signal has shorted to power or the ground for the sensor has opened	621
APP1RangeLow	APP1 sensor voltage out of range low, normally set if the APP1 signal has shorted to ground, circuit has opened or sensor has failed	611
APP2AdaptHiMax	Learned full pedal end of APP2 sensor range higher than expected	642
APP2AdaptHiMin	Learned full pedal end of APP2 sensor range lower than expected	652
APP2AdaptLoMax	Learned idle end of APP2 sensor range higher than expected	662
APP2AdaptLoMin	Learned idle end of APP2 sensor range lower than expected	632
APP2RangeHigh	APP2 sensor voltage out of range high, normally set if the APP2 signal has shorted to power or the ground for the sensor has opened	622

Fault List Definitions (Cont'd)

FAULT	DESCRIPTION	CODE
APP2RangeLow	APP_2 sensor voltage out of range low, normally set if the APP_2 signal has shorted to ground, circuit has opened or sensor has failed	612
AutocrankNoCrank	Autocrank output engages the starter motor relay, but no engine speed is seen within AutocrankNSTime	442
AutocrankNoStart	Autocrank output tries to start engine, but is unsuccessful after AutocrankMaxTries crank attempts	441
APP_Sensors_Conflict	APP position sensors do no not track well, intermittent connections to APP or defective pedal assembly	691
CamEdgesFault	No CAM signal when engine is known to be rotating, broken CAM sensor leads or defective CAM sensor	191
CamSyncFault	Loss of synchronization on the CAM sensor, normally due to noise on the signal or an intermittent connection on the CAM sensor	192
CrankEdgesFault	No crankshaft signal when engine is known to be rotating, broken crankshaft sensor leads or defective crank sensor	193
CrankSyncFault	Loss of synchronization on the crankshaft sensor, normally due to noise on the signal or an intermittent connection on the crankshaft sensor	194
ECTOverTempFault	Engine Coolant Temperature is High. The sensor has measured an excessive coolant temperature typically due to the engine overheating.	161
ECTRangeHigh	Engine Coolant Temperature Sensor Input is High. Normally set if coolant sensor wire has been disconnected or circuit has opened to the SECM.	151
ECTRangeLow	Engine Coolant Temperature Sensor Input is Low. Normally set if the coolant sensor wire has shorted to chassis ground or the sensor has failed.	141
ECT_IR_Fault	Engine Coolant Temperature not changing as expected	171
EST1_Open	EST_1 output open, possibly open EST_1 signal or defective spark module	421
EST1_Short	EST_1 output shorted high or low, EST_1 signal shorted to ground or power or defective spark module	431

FAULT	DESCRIPTION	CODE
EST2_Open	EST_2 output open, possibly open EST_2 signal or defective spark module	422
EST2_Short	EST_2 output shorted high or low, EST_2 signal shorted to ground or power or defective spark module	432
EST3_Open	EST_3 output open, possibly open EST_3 signal or defective spark module	423
EST3_Short	EST_3 output shorted high or low, EST_3 signal shorted to ground or power or defective spark module	433
EST4_Open	EST_4 output open, possibly open EST_4 signal or defective spark module	424
EST4_Short	EST_4 output shorted high or low, EST_4 signal shorted to ground or power or defective spark module	434
EST5_Open	EST_5 output open, possibly open EST_5 signal or defective spark module	425
EST5_Short	EST_5 output shorted high or low, EST_5 signal shorted to ground or power or defective spark module	435
EST6_Open	EST_6 output open, possibly open EST_6 signal or defective spark module	426
EST6_Short	EST_6 output shorted high or low, EST_6 signal shorted to ground or power or defective spark module	436
EST7_Open	EST_7 output open, possibly open EST_7 signal or defective spark module	427
EST7_Short	EST_7 output shorted high or low, EST_7 signal shorted to ground or power or defective spark module	437
EST8_Open	EST_8 output open, possibly open EST_8 signal or defective spark module	428
EST8_Short	EST_8 output shorted high or low, EST_8 signal shorted to ground or power or defective spark module	438
ETCSpringTest	Electronic Throttle Control Spring Return Test has Failed. The SECM will perform a safety test of the throttle return spring following engine shutdown. If this spring has become weak the throttle will fail the test and set the fault. **NOTE: Throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly**.	481

FAULT	DESCRIPTION	CODE
ETC_Open_Fault	Electronic Throttle Control Driver has failed. Normally set if either of the ETC driver signals have opened or become disconnected, electronic throttle or SECM is defective.	471
ETC_Sticking	Electronic Throttle Control is Sticking. This can occur if the throttle plate (butterfly valve) inside the throttle bore is sticking. The plate sticking can be due to some type of obstruction; a loose throttle plate or worn components shaft bearings. ***NOTE: Throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.***	461
FuelSelectConflict	Conflict in fuel select signals, normally set if one or both of the fuel select signals are shorted to ground	181
FuelTempRangeHigh	Fuel Temperature Sensor Input is High. Normally set if the fuel temperature sensor wire has been disconnected or the circuit has opened to the SECM.	932
FuelTempRangeLow	Fuel Temperature Sensor Input is Low. Normally set if the fuel temperature sensor wire has shorted to chassis ground or the sensor has failed.	931
GasCatInactive	Post-catalyst O2 sensor inactive on LPG, open O2 sensor signal or heater leads, defective O2 sensor, or defective FTVs	743
GasDesEquivHi	Post-catalyst O2 sensor indicates extended rich operation on LPG	732
GasDesEquivLo	Post-catalyst O2 sensor indicates extended lean operation on LPG	722
GasFuelAdaptRangeHi	In LPG mode, system had to adapt lean more than expected	731
GasFuelAdaptRangeLo	In LPG mode, system had to adapt rich more than expected	721
GasO2FailedLean	Pre-catalyst O_2 sensor indicates extended lean operation on LPG	751
GasO2FailedLean	Pre-catalyst O_2 sensor indicates extended lean operation on LPG	751
GasO2FailedRich	Pre-catalyst O_2 sensor indicates extended rich operation on LPG	771
GasO2NotActive	Pre-catalyst O_2 sensor inactive on LPG, open O_2 sensor signal or heater leads, defective O_2 sensor, or defective FTVs	741

FAULT	DESCRIPTION	CODE
GasPostO2FailedRich	Post-catalyst O_2 sensor control on LPG has reached rich limit and sensor still reads to lean. This could be caused by oxygen leak before or just after sensor, catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O_2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	772
GasPostO2FailedLean	Post-catalyst O_2 sensor control on LPG has reached lean limit and sensor still reads to rich. This could be caused by catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O_2 sensor faults are set diagnose, these first and after correcting these faults recheck if this fault sets.	752
GasPostO2Inactive	Post-catalyst O_2 sensor control on LPG has sensed the O_2 sensor is not responding as expected. If any Pre-O_2 sensor faults are set diagnose these first and after correcting these faults recheck if this fault sets. Possible causes for this fault are sensor disconnected, sensor heater failed, sensor element failed, heater relay, or SECM control of heater relay is disconnected or failed.	742
HbridgeFault_ETC	(Electronic Throttle Control Driver has Failed) Indeterminate fault on Hbridge driver for Electronic Throttle Control. Possibly either ETC+ or ETC- driver signals have been shorted to ground	491
HardOverspeed	Engine speed has exceeded the third level (3 of 3) of overspeed protection	571
IATRangeHigh	Intake Air Temperature Sensor Input is High normally set if the IAT temperature sensor wire has been disconnected, the circuit has opened to the SECM, or a short to Vbatt has occurred.	381
IATRangeLow	Intake Air Temperature Sensor Input is Low normally set if the IAT temperature sensor wire has shorted to chassis ground or the sensor has failed.	371
IAT_IR_Fault	Intake Air Temperature not changing as expected	391

FAULT	DESCRIPTION	CODE
Inj1Open	Gasoline Injector 1 open circuit, broken injector 1 wire or defective injector	131
Inj2Open	Gasoline Injector 2 open circuit, broken injector 2 wire or defective injector	132
Inj3Open	Gasoline Injector 3 open circuit, broken injector 3 wire or defective injector	133
Inj4Open	Gasoline Injector 4 open circuit, broken injector 4 wire or defective injector	134
Inj5Open	Gasoline Injector 5 open circuit, broken injector 5 wire or defective injector	135
Inj6Open	Gasoline Injector 6 open circuit, broken injector 6 wire or defective injector	136
Inj7Open	Gasoline Injector 7 open circuit, broken injector 7 wire or defective injector	137
Inj8Open	Gasoline Injector 8 open circuit, broken injector 8 wire or defective injector	138
LiqCatInactive	Post-catalyst O2 sensor inactive on gasoline, open O2 sensor signal or heater leads, defective O2 sensor, or defective fuel supply system.	843
LiqDesEquivHi	Post-catalyst O2 sensor indicates extended rich operation on gasoline	822
LiqDesEquivLo	Post-catalyst O2 sensor indicates extended lean operation on gasoline	832
LSDFault_AutoCrankDrive	Autocrank drive fault, signal has opened or shorted to ground or power	719
LSDFault_CheckEngine	Check Engine Lamp Fault, signal has opened or shorted to ground or power or defective check engine lamp	714
LSDFault_CrankDisable	Crank Disable Fault, signal has opened or shorted to ground or power or defective crank disable relay	715
LSDFault_CSValve	Cold Start Valve Fault, signal has opened or shorted to ground or power or defective cold start valve	713
LSDFault_Dither1	Dither Valve 1 Fault, signal has opened or shorted to ground or power or defective dither 1 valve	711
LSDFault_Dither2	Dither Valve 2 Fault, signal has opened or shorted to ground or power or defective dither 2 valve	712

FAULT	DESCRIPTION	CODE
LSDFault_FuelPump	Fuel Pump Circuit Fault, signal has opened, shorted to ground or power, or defective relay or fuel pump	716
LSDFault_LockOff	Fuel lock off Valve Fault, signal has opened or shorted to ground or power or defective Fuel lock off valve	717
LSDFault_MIL	Malfunction Indicator Lamp Fault, signal has opened or shorted to ground or power or defective MIL lamp	718
LiqFuelAdaptRangeHi	In Gasoline mode, system had to adapt rich more than expected	821
LiqFuelAdaptRangeLow	In Gasoline mode, system had to adapt lean more than expected	831
LiqO2FailedLean	Pre-catalyst O_2 sensor indicates extended lean operation on gasoline	851
LiqO2FailedRich	Pre-catalyst O_2 sensor indicates extended rich operation on gasoline	871
LiqO2NotActive	Pre-catalyst O_2 sensor inactive on gasoline, open O_2 sensor signal or heater leads, defective O_2 sensor	841
LiqPostO2FailedRich	Post-catalyst O_2 sensor control on gasoline has reached rich limit and sensor still reads to lean. This could be caused by oxygen leak before or just after sensor, catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O_2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	872
LiqPostO2FailedLean	Post-catalyst O_2 sensor control on gasoline has reached lean limit and sensor still reads to rich. This could be caused by catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O_2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	852
LiqPostO2Inactive	Post-catalyst O_2 sensor control on gasoline has sensed the O_2 sensor is not responding as expected. If any Pre-O_2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets. Possible causes for this fault are sensor disconnected, sensor heater failed, sensor element failed, heater relay, or SECM control of heater relay is disconnected or failed.	842

FAULT	DESCRIPTION	CODE
LowOilPressureFault	Low engine oil pressure	521
MAPRangeHigh	Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed.	342
MAPRangeLow	Manifold Absolute Pressure Sensor Input is Low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	332
MAPTimeRangeHigh	Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed.	341
MAPTimeRangeLow	Manifold Absolute Pressure Sensor Input is Low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	331
MAP_IR_HI	MAP sensor indicates higher pressure than expected	351
MAP_IR_LO	MAP sensor indicates lower pressure than expected	352
MAP_STICKING	MAP sensor not changing as expected	353
MediumOverspeed	Engine speed has exceeded the second level (2 of 3) of overspeed protection	572
O2RangeHigh	Pre-catalyst O_2 sensor voltage out of range high, sensor signal shorted to power	921
O2RangeLow	Pre-catalyst O_2 sensor voltage out of range low, sensor signal shorted to ground	911
O2_PostCatRangeHigh	Post-catalyst O_2 sensor voltage out of range high, sensor signal shorted to voltage source (5V or battery)	922
O2_PostCatRangeLow	Post-catalyst O_2 sensor voltage out of range low, sensor signal shorted to ground	912
OilPressureRangeHigh	Oil pressure sensor voltage out of range high, sensor signal shorted to power	523
OilPressureRangeLow	Oil Pressure sensor voltage out of range low, sensor signal shorted to ground	522
PostO2Inactive	PostCatO2 is not varying enough, sensor has been disconnected or the circuit has been opened to the SECM	942

FAULT	DESCRIPTION	CODE
SensVoltRangeHigh	Sensor reference voltage XDRP too high	561
SensVoltRangeLow	Sensor reference voltage XDRP too low	551
ServiceFault1	Service Interval 1 has been reached	991
ServiceFault2	Service Interval 2 has been reached	992
ServiceFault3	Service Interval 3 has been reached	993
ServiceFault4	Service Interval 4 has been reached—time to replace HEGO sensors	994
ServiceFault5	Service Interval 5 has been reached	995
SoftOverspeed	Engine speed has exceeded first level (1 of 3) of overspeed protection	573
SysVoltRangeHigh	System voltage too high	541
SysVoltRangeLow	System voltage too low	531
TPS1AdaptHiMin	Learned WOT end of TPS_1 sensor range lower than expected	271
TPS1AdaptHiMax	Learned WOT end of TPS_1 sensor range higher than expected	251
TPS1AdaptLoMax	Learned closed throttle end of TPS_1 sensor range higher than expected	281
TPS1AdaptLoMin	Learned closed throttle end of TPS_1 sensor range lower than expected	241
TPS1RangeHigh	TPS_1 sensor voltage out of range high, normally set if the TPS_1 signal has shorted to power or ground for the sensor has opened	231
TPS1RangeLow	TPS_1 sensor voltage out of range low, normally set if TPS_1 signal has shorted to ground, circuit has opened or sensor has failed	221
TPS2AdaptHiMax	Learned WOT end of TPS_2 sensor range higher than expected	252
TPS2AdaptHiMin	Learned WOT end of TPS_2 sensor range lower than expected	272
TPS2AdaptLoMax	Learned closed throttle end of TPS_2 sensor range higher than expected	282
TPS2AdaptLoMin	Learned closed throttle end of TPS_2 sensor range lower than expected	242
TPS2RangeHigh	TPS_2 sensor voltage out of range high, normally set if the TPS_2 signal has shorted to power or ground for the sensor has opened	232
TPS2RangeLow	TPS_2 sensor voltage out of range low, normally set if TPS_2 signal has shorted to ground, circuit has opened or sensor has failed	222

FAULT	DESCRIPTION	CODE
TPS_Sensors_Conflict	TPS sensors differ by more than expected amount. ***NOTE: The TPS is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly***	291
TransOilTemp	Excessive transmission oil temperature	933
TSC1RxTimeoutFault	Loss of CAN communication with vehicle controller	199

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
12	**NONE** Signifies the end of one pass through the fault list	NONE	None, used as end of fault list identification
131	**Inj1Open** Gasoline Injector 1 open circuit, broken injector 1 wire or defective injector	(1) TurnOnMil (2) DisableLiqO2Ctrl (3) CheckEngineLight	Check INJ_1 wiring for an open circuit SECM Pin A5 (signal) to Injector 1 Pin A Switched 12V to Injector 1 Pin B Check Injector 1 Resistance, 12 to 14 ohms (cold)
132	**Inj2Open** Gasoline Injector 2 open circuit, broken injector 2 wire or defective injector	(1) TurnOnMil (2) DisableLiqO2Ctrl (3) CheckEngineLight	Check INJ_2 wiring for an open circuit SECM Pin A8 (signal) to Injector 2 Pin A Switched 12V to Injector 2 Pin B Check Injector 2 Resistance, 12 to 14 ohms (cold)
133	**Inj3Open** Gasoline Injector 3 open circuit, broken injector 3 wire or defective injector	(1) TurnOnMil (2) DisableLiqO2Ctrl (3) CheckEngineLight	Check INJ_3 wiring for an open circuit SECM Pin A4 (signal) to Injector 3 Pin A Switched 12V to Injector 3 Pin B Check Injector 3 Resistance, 12 to 14 ohms (cold)
134	**Inj4Open** Gasoline Injector 4 open circuit, broken injector 4 wire or defective injector	(1) TurnOnMil (2) DisableLiqO2Ctrl (3) CheckEngineLight	Check INJ_4 wiring for an open circuit SECM Pin A7 (signal) to Injector 4 Pin A Switched 12V to Injector 3 Pin B Check Injector 3 Resistance, 12 to 14 ohms (cold)
135	**Inj5Open** Gasoline Injector 5 open circuit, broken injector 5 wire or defective injector	NONE	N/A
136	**Inj6Open** Gasoline Injector 6 open circuit, broken injector 6 wire or defective injector	NONE	N/A
137	**Inj7Open** Gasoline Injector 7 open circuit, broken injector 7 wire or defective injector	NONE	N/A

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
138	**Inj8Open** Gasoline Injector 8 open circuit, broken injector 8 wire or defective injector	NONE	N/A
141	**ECTRangeLow** Coolant Sensor failure or shorted to GND	(1) TurnOnMil (2) DelayedEngine Shutdown	Check ECT sensor connector and wiring for a short to GND SECM Pin B15 (signal) to ECT Pin 1 SECM Pin B1 (Sensor GND) to ECT Pin 2 SECM Pin A16, B17 (System GND) to ECT Pin 1 or Pin 2
151	**ECTRangeHigh** Coolant sensor disconnected or open circuit	(1) TurnOnMil (2) DelayedEngine Shutdown	Check if ECT sensor connector is disconnected or for an open ECT circuit SECM Pin B15 (signal) to ECT Pin 1 SECM Pin B1 (Sensor GND) to ECT Pin 2
161	**ECTOverTempFault** Engine coolant temperature is high. The sensor has measured an excessive coolant temperature typically due to the engine overheating.	(1) TurnOnMil (2) DelayedEngine Shutdown	Check coolant system for radiator blockage, proper coolant level and for leaks in the system. Possible ECT short to GND, check ECT signal wiring SECM Pin B15 (signal) to ECT Pin 1 SECM Pin B1 (Sensor GND) to ECT Pin 2 SECM Pin A16, B17 (System GND) to ECT Pin 1 or Pin 2 Check regulator for coolant leaks
171	**ECT_IR_Fault** Engine coolant temperature not changing as expected	TurnOnMil	Check for coolant system problems, e.g. defective or stuck thermostat
181	**FuelSelectConflict** Conflict in fuel select signals, normally set if both of the fuel select signals are shorted to ground	(1) TurnOnMil (2) DelayedEngine Shutdown	Check fuel select switch connection for a short to GND SECM Pin A12 (LPG signal), SECM Pin A15 (LIQ SIGNAL), and SECM Pin B1 (Sensor GND) to SECM Pin A16, B17 (System GND)

(*) Fault actions shown are default values specified by the OEM.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
191	**CamEdgesFault** No CAM signal when engine is known to be rotating, broken crankshaft sensor leads or defective CAM sensor	TurnOnMil	Check CAM sensor connections SECM Pin B10 (signal) to CAM sensor Pin C SECM Pin B1 (Sensor GND) to CAM sensor Pin B SECM Pin B24 (Sensor PWR) to CAM sensor Pin A Check for defective CAM sensor
192	**CamSyncFault** Loss of synchronization on the CAM sensor, normally due to noise on the signal or an intermittent connection on the CAM sensor	TurnOnMil	Check CAM sensor connections SECM Pin B10 (signal) to CAM sensor Pin C SECM Pin B1 (Sensor GND) to CAM sensor Pin B SECM Pin B24 (Sensor PWR) to CAM sensor Pin A Check for defective CAM sensor
193	**CrankEdgesFault** No crankshaft signal when engine is known to be rotating, broken crankshaft sensor leads or defective crank sensor	TurnOnMil	Check Crankshaft sensor connections SECM Pin B5 (Crank+) to Crank sensor Pin 1 SECM Pin B6 (Crank-) to Crank sensor Pin 2 Engine GND to Crank sensor Pin 3 Check for defective Crank sensor
194	**CrankSyncFault** Loss of synchronization on the crankshaft sensor, normally due to noise on the signal or an intermittent connection on the crankshaft sensor	TurnOnMil	Check Crankshaft sensor connections SECM Pin B5 (Crank+) to Crank sensor Pin 1 SECM Pin B6 (Crank-) to Crank sensor Pin 2 Engine GND to Crank sensor Pin 3 Check for defective Crank sensor

(*) Fault actions shown are default values specified by the OEM

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
199	**TSC1RxTimeoutFault** Loss of CAN communication with vehicle controller	TurnOnMil	Check wiring from SECM-48 CAN to vehicle controller—check for continuity on CAN Hi and CAN Lo, also confirm 120 ohm termination resistors are present at both ends Confirm vehicle controller is operational Check CAN communication with CAN monitor such as CANalyzer
221	**TPS1RangeLow** TPS_1 sensor voltage out of range low, normally set if the TPS_1 signal has shorted to ground, circuit has opened or sensor has failed	(1) TurnOnMil (2) CutThrottle	Check throttle connector connection and TPS_1 sensor for an open circuit or short to GND SECM Pin B23 (signal) to ETC Pin 6 SECM Pin B1 (Sensor GND) to ETC Pin 2 SECM Pin B1 (Sensor GND) to SECM Pin A16, B17 (System GND)
222	**TPS2RangeLow** TPS_2 sensor voltage out of range low, normally set if the TPS_2 signal has shorted to ground, circuit has opened or sensor has failed	(1) TurnOnMil (2) CutThrottle	Check throttle connector connection and TPS_2 sensor for an open circuit or short to GND SECM Pin B4 (signal) to ETC Pin 5 SECM Pin B1 (Sensor GND) to ETC Pin 2 SECM Pin B1 (Sensor GND) to SECM Pin A16, B17 (System GND)
231	**TPS1RangeHigh** TPS_1 sensor voltage out of range high, normally set if the TPS_1 signal has shorted to power or the ground for the sensor has opened	(1) TurnOnMil (2) CutThrottle	Check throttle connector and TPS_1 sensor wiring for a shorted circuit SECM Pin B23 (signal) to ETC Pin 6 SECM Pin B1 (Sensor GND) to ETC Pin 2

(*) Fault actions shown are default values specified by the OEM.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
232	**TPS2RangeHigh** TPS_2 sensor voltage out of range high, normally set if the TPS_2 signal has shorted to power or the ground for the sensor has opened	(1) TurnOnMil (2) CutThrottle	Check throttle connector and TPS_1 sensor wiring for a shorted circuit SECM Pin B4 (signal) to ETC Pin 5 SECM Pin B1 (Sensor GND) to ETC Pin 2
241	**TPS1AdaptLoMin** Learned closed throttle end of TPS_1 sensor range lower than expected	(1) TurnOnMil (2) CutThrottle	Check the throttle connector and pins for corrosion. To check the TPS, disconnect the throttle connector and measure the resistance from: TPS Pin 2 (Sensor GND) to ETC Pin 6 (signal) (0.7 Ω ± 30%) TPS Pin 3 (Sensor PWR) to ETC Pin 6 (signal) (1.4 Ω ± 30%)
242	**TPS2AdaptLoMin** Learned closed throttle end of TPS_2 sensor range lower than expected	(1) TurnOnMil (2) CutThrottle	Check the throttle connector and pins for corrosion. To check the TPS, disconnect the throttle connector and measure the resistance from: TPS Pin 2 (Sensor GND) to ETC Pin 5 (signal) (1.3K Ω ± 30%) TPS Pin 3 (Sensor PWR) to ETC Pin 5 (signal) (0.6K Ω ± 30%)
251	**TPS1AdaptHiMax** Learned WOT end of TPS_1 sensor range higher than expected	(1) TurnOnMil (2) CutThrottle	Check the throttle connector and pins for corrosion. To check the TPS, disconnect the throttle connector and measure the resistance from: TPS Pin 2 (Sensor GND) to ETC Pin 5 (signal) (1.3K Ω ± 30%) TPS Pin 3 (Sensor PWR) to ETC Pin 5 (signal) (0.6K Ω ± 30%)

(*) Fault actions shown are default values specified by the OEM.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
252	**TPS2AdaptHiMax** Learned WOT end of TPS_2 sensor range higher than expected	(1) TurnOnMil (2) CutThrottle	Check the throttle connector and pins for corrosion. To check the TPS, disconnect the throttle connector and measure the resistance from: TPS Pin 2 (Sensor GND) to ETC Pin 5 (signal) (1.3K Ω ± 30%) TPS Pin 3 (Sensor PWR) to ETC Pin 5 (signal) (0.6K Ω ± 30%)
271	**TPS1AdaptHiMin** Learned WOT end of TPS_1 sensor range lower than expected	(1) TurnOnMil (2) CutThrottle	Check the throttle connector and pins for corrosion. To check the TPS, disconnect the throttle connector and measure the resistance from: TPS Pin 2 (Sensor GND) to ETC Pin 5 (signal) (1.3K Ω ± 30%) TPS Pin 3 (Sensor PWR) to ETC Pin 5 (signal) (0.6K Ω ± 30%)
272	**TPS2AdaptHiMin** Learned WOT end of TPS_2 sensor range lower than expected	(1) TurnOnMil (2) CutThrottle	Check the throttle connector and pins for corrosion. To check the TPS, disconnect the throttle connector and measure the resistance from: TPS Pin 2 (Sensor GND) to ETC Pin 5 (signal) (1.3K Ω ± 30%) TPS Pin 3 (Sensor PWR) to ETC Pin 5 (signal) (0.6K Ω ± 30%)

(*) Fault actions shown are default values specified by the OEM.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
281	**TPS1AdaptLoMax** Learned closed throttle end of TPS_1 sensor range higher than expected	(1) TurnOnMil (2) CutThrottle	Check the throttle connector and pins for corrosion. To check the TPS, disconnect the throttle connector and measure the resistance from: TPS Pin 2 (Sensor GND) to ETC Pin 5 (signal) (1.3K Ω ± 30%) TPS Pin 3 (Sensor PWR) to ETC Pin 5 (signal) (0.6K Ω ± 30%)
282	**TPS2AdaptLoMax** Learned closed throttle end of TPS_2 sensor range higher than expected	(1) TurnOnMil (2) CutThrottle	Check the throttle connector and pins for corrosion. To check the TPS, disconnect the throttle connector and measure the resistance from: TPS Pin 2 (Sensor GND) to ETC Pin 5 (signal) (1.3K Ω ± 30%) TPS Pin 3 (Sensor PWR) to ETC Pin 5 (signal) (0.6K Ω ± 30%)
291	**TPS_Sensors_Conflict** TPS sensors differ by more than expected amount **NOTE:** ***The TPS is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.***	(1) TurnOnMil (2) CutThrottle	Check the throttle connector and pins for corrosion. To check the TPS, disconnect the throttle connector and measure the resistance from: TPS Pin 2 (Sensor GND) to ETC Pin 5 (signal) (1.3K Ω ± 30%) TPS Pin 3 (Sensor PWR) to ETC Pin 5 (signal) (0.6K Ω ± 30%)

(*) Fault actions shown are default values specified by the OEM.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
331	**MAPTimeRangeLow** Manifold Absolute Pressure sensor input is low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	TurnOnMil	Check TMAP connector and MAP signal wiring for an open circuit TMAP Pin 4 (signal) to SECM Pin B18 TMAP Pin 1 (Sensor GND) to SECM Pin B1 TMAP Pin 3 (Sensor PWR) to SECM Pin B24 Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(Sensor GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (Sensor PWR) to Pin 4 (pressure signal KPA) (3.4kΩ - 8.2kΩ)
332	**MAPRangeLow** Manifold Absolute Pressure sensor input is low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	(1) TurnOnMil (2) EngineShutdown	Check TMAP connector and MAP signal wiring for an open circuit TMAP Pin 4 (signal) to SECM Pin B18 TMAP Pin 1 (Sensor GND) to SECM Pin B1 TMAP Pin 3 (Sensor PWR) to SECM Pin B24 Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(Sensor GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (Sensor PWR) to Pin 4 (pressure signal KPA) (3.4kΩ - 8.2kΩ)

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
341	**MAPTimeRangeHigh** Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed.	TurnOnMil	Check TMAP connector and MAP signal wiring for a shorted circuit TMAP Pin 4 (signal) to SECM Pin B18 TMAP Pin 1 (Sensor GND) to SECM Pin B1 TMAP Pin 3 (Sensor PWR) to SECM Pin B24 Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(Sensor GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (Sensor PWR) to Pin 4 (pressure signal KPA) (3.4kΩ - 8.2kΩ)
342	**MAPRangeHigh** Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed	(1) TurnOnMil (2) EngineShutdown	Check TMAP connector and MAP signal wiring for a shorted circuit TMAP Pin 4 (signal) to SECM Pin B18 TMAP Pin 1 (Sensor GND) to SECM Pin B1 TMAP Pin 3 (Sensor PWR) to SECM Pin B24 Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1 (Sensor GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (Sensor PWR) to Pin 4 (pressure signal KPA) (3.4kΩ - 8.2kΩ)
351	**MAP_IR_HI** MAP sensor indicates higher pressure than expected	TurnOnMil	Check for vacuum leaks. Check that TMAP sensor is mounted properly. Possible defective TMAP sensor.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
352	**MAP_IR_LO** MAP sensor indicates lower pressure than expected	TurnOnMil	Possible defective TMAP sensor.
353	**MAP_STICKING** MAP sensor not changing as expected	TurnOnMil	Check that TMAP sensor is mounted properly. Possible defective TMAP sensor.
371	**IATRangeLow** Intake Air Temperature Sensor Input is Low normally set if the IAT temperature sensor wire has shorted to chassis ground or the sensor has failed.	TurnOnMil	Check TMAP connector and IAT signal wiring for a shorted circuit TMAP Pin 2 (signal) to SECM Pin B12 TMAP Pin 1 (Sensor GND) to SECM Pin B1 To check the IAT sensor of the TMAP disconnect the TMAP connector and measure the IAT resistance Resistance is approx 2400 ohms at room temperature.
381	**IATRangeHigh** Intake Air Temperature Sensor Input is High normally set if the IAT temperature sensor wire has been disconnected or the circuit has opened to the SECM.	TurnOnMil	Check TMAP connector and IAT signal wiring for a shorted circuit TMAP Pin 2 (signal) to SECM Pin B12 TMAP Pin 1 (Sensor GND) to SECM Pin B1 To check the IAT sensor of the TMAP disconnect the TMAP connector and measure the IAT resistance Resistance is approx 2400 ohms at room temperature.
391	**IAT_IR_Fault** Intake Air Temperature not changing as expected	TurnOnMil	Check connections to TMAP sensor. Check that TMAP sensor is properly mounted to manifold.

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
421	**EST1_Open** EST_1 output open, possibly open EST_1 signal or defective spark module	TurnOnMil	Check coil driver wiring and connector for open circuit SECM Pin A9 (EST_1) to ignition module Pin B. Verify GND on ignition module Pin C (of both connectors) Verify +12 Vdc on ignition module Pin D. Refer to application manual for specific engine details.
422	**EST2_Open** EST_2 output open, possibly open EST_2 signal or defective spark module	TurnOnMil	Check coil driver wiring and connector for open circuit SECM Pin A10 (EST_2) to ignition module Pin A. Verify GND on ignition module Pin C Verify +12 Vdc on ignition module Pin D Refer to application manual for specific engine details.
423	**EST3_Open** EST_3 output open, possibly open EST_3 signal or defective spark module	TurnOnMil	Check coil driver wiring and connector for open circuit SECM Pin A3 (EST_3) to ignition module Pin A. Verify GND on ignition module Pin C Verify +12 Vdc on ignition module Pin D Refer to application manual for specific engine details.
424	**EST4_Open** EST_4 output open, possibly open EST_4 signal or defective spark module	TurnOnMil	Check coil driver wiring and connector for open circuit SECM Pin A6 (EST_4) to ignition module Pin A. Verify GND on ignition module Pin C Verify +12 Vdc on ignition module Pin D Refer to application manual for specific engine details.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
425	**EST5_Open** EST_5 output open, possibly open EST_5 signal or defective spark module	NONE	N/A
426	**EST6_Open** EST_6 output open, possibly open EST_6 signal or defective spark module	NONE	N/A
427	**EST7_Open** EST_7 output open, possibly open EST_7 signal or defective spark module	NONE	N/A
428	**EST8_Open** EST_8 output open, possibly open EST_8 signal or defective spark module	NONE	N/A
431	**EST1_Short** EST_1 output shorted high or low, EST_1 signal shorted to ground or power or defective spark module	NONE	N/A
432	**EST2_Short** EST_2 output shorted high or low, EST_2 signal shorted to ground or power or defective spark module	NONE	N/A
433	**EST3_Short** EST_3 output shorted high or low, EST_3 signal shorted to ground or power or defective spark module	NONE	N/A
434	**EST4_Short** EST_4 output shorted high or low, EST_4 signal shorted to ground or power or defective spark module	NONE	N/A
435	**EST5_Short** EST_5 output shorted high or low, EST_5 signal shorted to ground or power or defective spark module	NONE	N/A
436	**EST6_Short** EST_6 output shorted high or low, EST_6 signal shorted to ground or power or defective spark module	NONE	N/A

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
437	**EST7_Short** EST_7 output shorted high or low, EST_7 signal shorted to ground or power or defective spark module	NONE	N/A
438	**EST8_Short** EST_8 output shorted high or low, EST_8 signal shorted to ground or power or defective spark module	NONE	N/A
440	**AutocrankNoCrank** No crank rpm was found during commanded autocrank	(1) TurnOnMil (2) EngineShutdown	Check wiring from SECM-48 LSO pin to low side of autocrank relay coil. Check wiring from Master Power Relay to high side of autocrank relay coil. Check wiring from autocrank relay swtich contacts. Check starter motor.
441	**AutocrankNoStart** Starting rpm was not seem during commanded autocrank	TurnOnMil	Make sure engine is getting fuel (fuel supply OK, fuel shutoff open, fuel lockoff working). Make sure there are no MIL faults. Make sure there are no problems with the load on the engine that would prevent starting.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
461	**ETC_Sticking** Electronic Throttle Control is sticking. This can occur if the throttle plate (butterfly valve) inside the throttle bore is sticking. The plate sticking can be due to some type of obstruction, a loose throttle plate, or worn components shaft bearings. **NOTE:** ***The throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.***	(1) TurnOnMil (2) EngineShutdown (3) CutThrottle	Check for debris or obstructions inside the throttle body • Check throttle-plate shaft for bearing wear Check the ETC driver wiring for an open circuit SECM Pin A17 (H1+) to ETC Pin 1 SECM Pin A18 (H1-) to ETC Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle ETC Pin 1 (H1+) to Pin ETC 4 (H1-) ~3.0-4.0Ω
471	**ETC_Open_Fault** Electronic Throttle Control Driver has failed, normally set if driver signals have failed open or become disconnected, electronic throttle or SECM is defective.	(1) TurnOnMIL (2) CutThrottle	Check the ETC driver wiring for an open circuit SECM Pin (H1+) A17 to ETC Pin 1 SECM Pin A18 (H1-) to ETC Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle ETC Pin 1 (H1+) to Pin 4 (H1-) ~3.0-4.0Ω

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
481	**ETCSpringTest** Electronic Throttle Control Spring Return Test has failed. The SECM will perform a safety test of the throttle return spring following engine shutdown. If the drive mechanism is damaged, or the return spring has lost tension the throttle will fail the test and set the fault. ***NOTE: The throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.***	(1) TurnOnMil (2) EngineShutdown (3) CutThrottle	Perform throttle spring test by cycling the ignition key and re-check for fault
491	**HbridgeFault_ETC** Electronic Throttle Control Driver has failed. Indeterminate fault on Hbridge driver for electronic throttle control. Possibly either ETC+ or ETC- driver signals have been shorted to ground	(1) TurnOnMil (2) CutThrottle	Check ETC driver wiring for a shorted circuit SECM Pin A17 (H1+) to ETC Pin 1 SECM Pin A18 (H1-) to ETC Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle ETC Pin 1 (H1+) to ETC Pin 4 (H1-) ~3.0-4.0Ω
521	**LowOilPressureFault** Low engine oil pressure	(1) TurnOnMil (2) DelayedEngine Shutdown	Check engine oil level Check electrical connection to the oil pressure switch SECM Pin B9 (signal) to Oil Pressure Switch
522	**OilPressureRangeLow** Low engine oil pressure	(1) TurnOnMil (2) DelayedEngine Shutdown	Check engine oil level Check electrical connection to the oil pressure switch SECM Pin B9 (signal) to Oil Pressure Switch
523	**OilPressureRangeHigh** High engine oil pressure	(1) TurnOnMil (2) DelayedEngine Shutdown	Check engine oil level Check electrical connection to the oil pressure switch SECM Pin B9 (signal) to Oil Pressure Switch

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
531	**SysVoltRangeLow** System voltage too low	TurnOnMil	Check battery voltage • Perform maintenance check on electrical connections to the battery and chassis ground • Check battery voltage during starting and with the engine running to verify charging system and alternator function • Measure battery power at SECM with a multimeter (with key on) SECM Pin A23 (Switched 12V) to SECM Pin A16 (Engine GND) SECM Pin A23 (Switched 12V) to SECM Pin B17 (Engine GND)
541	**SysVoltRangeHigh** System voltage too high	(1) TurnOnMil (2) DelayedEngine Shutdown	Check battery and charging system voltage • Check battery voltage during starting and with the engine running • Check voltage regulator, alternator, and charging system • Check battery and wiring for overheating and damage • Measure battery power at SECM with a multimeter (with key on) SECM Pin A23 (Switched 12V) to SECM Pin A16 (Engine GND) SECM Pin A23 (Switched 12V) to SECM Pin B17 (Engine GND)

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
551	**SensVoltRangeLow** Sensor reference voltage XDRP too low	(1) TurnOnMil (2) DelayedEngine Shutdown	Measure transducer power at the TMAP connector with a multimeter TMAP Pin 3 (Sensor PWR) to TMAP Pin 1 (Sensor GND) Verify transducer power at the SECM with a multimeter SECM Pin B24 (Sensor PWR) to SECM Pin B1 (Sensor GND) Verify transducer power at ETC with a multimeter ETC Pin 3 (Sensor PWR) to ETC Pin 2 (Sensor GND) Verify transducer power to the foot pedal with a multimeter.
561	**SensVoltRangeHigh** Sensor reference voltage XDRP too high	(1) TurnOnMil (2) DelayedEngine Shutdown	Measure transducer power at the TMAP connector with a multimeter TMAP Pin 3 (Sensor PWR) to TMAP Pin 1 (Sensor GND) Verify transducer power at the SECM with a multimeter SECM Pin B24 (Sensor PWR) to SECM Pin B1 (Sensor GND) Verify transducer power at ETC with a multimeter ETC Pin 3 (Sensor PWR) to ETC Pin 2 (Sensor GND) Verify transducer power to the foot pedal with a multimeter.
571	**HardOverspeed** Engine speed has exceeded the third level (3 of 3) of overspeed protection	(1) TurnOnMil (2) HardRevLimit	Usually associated with additional ETC faults • Check for ETC Sticking or other ETC faults Verify if the lift truck was motored down a steep grade

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
572	**MediumOverspeed** Engine speed has exceeded the second level (2 of 3) of overspeed protection	(1) TurnOnMil (2) MediumRevLimit	Usually associated with additional ETC faults • Check for ETC Sticking or other ETC faults Verify if the lift truck was motored down a steep grade
573	**SoftOverspeed** Engine speed has exceeded the first level (1 of 3) of overspeed protection	(1) TurnOnMil (2) SoftRevLimit	Usually associated with additional ETC faults • Check for ETC Sticking or other ETC faults Verify if the lift truck was motored down a steep grade
611	**APP1RangeLow** APP_1 sensor voltage out of range low, normally set if the APP_1 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check foot pedal connector • Check APP_1 signal at SECM PIN B7 (signal)
612	**APP2RangeLow** APP_2 sensor voltage out of range low, normally set if the APP_2 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check foot pedal connector • Check APP_2 signal at SECM PIN B16 (signal)
621	**APP1RangeHigh** APP_1 sensor voltage out of range high, normally set if the APP_1 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check foot pedal connector • Check APP_1 signal at SECM PIN B7 (signal)
622	**APP2RangeHigh** APP_2 sensor voltage out of range high, normally set if the APP_2 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check foot pedal connector • Check APP_2 signal at SECM PIN B16 (signal)
631	**APP1AdaptLoMin** Learned idle end of APP_1 sensor range lower than expected	TurnOnMil	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_1 signal at SECM Pin B7 (signal)

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
632	**APP2AdaptLoMin** Learned idle end of APP_2 sensor range lower than expected	TurnOnMil	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_2 signal at SECM Pin B16 (signal)
641	**APP1AdaptHiMax** Learned full pedal end of APP_1 sensor range higher than expected	TurnOnMil	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_1 signal at SECM Pin B7 (signal)
642	**APP2AdaptHiMax** Learned full pedal end of APP_2 sensor range higher than expected	TurnOnMil	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_2 signal at SECM Pin B16 (signal)
651	**APP1AdaptHiMin** Learned full pedal end of APP_1 sensor range lower than expected	TurnOnMil	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_1 signal at SECM Pin B7 (signal)
652	**APP2AdaptHiMin** Learned full pedal end of APP_2 sensor range lower than expected	TurnOnMil	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_2 signal at SECM Pin B16 (signal)
661	**APP1AdaptLoMax** Learned idle end of APP_1 sensor range higher than expected	TurnOnMil	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_1 signal at SECM Pin B7 (signal)
662	**APP2AdaptLoMax** Learned idle end of APP_2 sensor range higher than expected	TurnOnMil	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_2 signal at SECM Pin B16 (signal)

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
691	**APP_Sensors_Conflict** APP position sensors do no not track well, intermittent connections to APP or defective pedal assembly	1) TurnOnMil (2) CutThrottle	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_1 signal at SECM Pin B7 (signal) • Cycle the pedal several times and check APP_2 signal at SECM Pin B16 (signal)
711	**LSDFault_Dither1** Dither Valve 1 Fault, signal has opened or shorted to ground or power or defective dither 1 valve	(1) TurnOnMil (2) DisableGasO2Ctrl (3) DisableGasPostO2Ctrl	Check FTV_1 for an open wire or FTV connector being disconnected FTV_1 Pin 1 (signal) to SECM Pin A1 FTV_1 Pin 2 (Switched 12V) to SECM Pin A23 Check FTV_1 for an open coil by disconnecting the FTV connector and measuring resistance (~26Ω ± 2Ω)
712	**LSDFault_Dither2** Dither Valve 2 Fault, signal has opened or shorted to ground or power or defective dither 2 valve	(1) TurnOnMil (2) DisableGasO2Ctrl (3) DisableGasPostO2Ctrl	Check FTV_2 for an open wire or FTV connector being disconnected or signal shorted to GND FTV_2 Pin 1 (signal) to SECM Pin A2 FTV_2 Pin 2 (Switched 12V) to SECM Pin A23 Check FTV_2 for an open coil by disconnecting the FTV connector and measuring resistance (~26Ω ± 2Ω)
713	**LSDFault_CSValve**	NONE	N/A
714	**LSDFault_CheckEngine**	NONE	N/A
715	**LSDFault_CrankDisable** Crank Disable Fault, signal has opened or shorted to ground or power or defective crank disable relay	NONE	N/A

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
716	**LSDFault_FuelPump** Fuel pump circuit fault, signal has opened, shorted to ground or power, or defective relay or fuel pump	TurnOnMil	Check fuel pump circuit for an open wire or connector being disconnected or signal shorted to GND Fuel Pump Pin B (signal) from SECM Pin A13 Fuel Pump Pin A (power) from main relay 1 Pin A23 Check fuel pump circuit for an open coil by disconnecting fuel pump connector and measuring resistance (~26Ω ± 3Ω) Check for 12V to fuel pump
717	**LSDFault_LockOff** Fuel lock off Valve Fault, signal has opened or shorted to ground or power or defective Fuel lock off valve	TurnOnMil	Check fuel lock off valve for an open wire or connector being disconnected or signal shorted to GND Lockoff Pin B (signal) to SECM Pin A11 Lockoff Pin A (Switched 12V) to SECM Pin A23 Check Lockoff for an open coil by disconnecting the Lockoff connector and measuring the resistance (~26Ω ± 3Ω)
718	**LSDFault_MIL** Malfunction Indicator Lamp Fault, signal has opened or shorted to ground or power or defective MIL lamp	NONE	N/A
721	**GasFuelAdaptRangeLo** In LPG mode, system had to adapt rich more than expected	(1) TurnOnMil (2) DisableGasO2Ctrl (3) DisablePostGasO2Ctrl	Check for vacuum leaks. Check fuel trim valves, e.g. leaking valve or hose Check for missing orifice(s).
722	**GasDesEquivLo** In LPG mode, system had to adapt rich more than expected	NONE	N/A

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
731	**GasFuelAdaptRangeHi** In LPG mode, system had to adapt lean more than expected	(1) TurnOnMil (2) DisableGasO2Ctrl (3) DisablePostGasO2Ctrl	Check fuel trim valves, e.g. plugged valve or hose. Check for plugged orifice(s).
732	**GasDesEquivHi** In LPG mode, system had to adapt lean more than expected	NONE	N/A
741	**GasO2NotActive** Pre-catalyst O_2 sensor inactive on LPG, open O_2 sensor signal or heater leads, defective O_2 sensor	(1) TurnOnMil (2) DisableGas O2Ctrl (3) DisableGasPostO2Ctrl	Check that Pre-catalyst O_2 sensor connections are OK. O_2 Pin A (Sensor GND) to SECM Pin B1 O_2 Pin B (signal) to SECM Pin B13 O_2 Pin C (Engine GND) to SECM Pins A16, B17 O_2 Pin 1 (Switched 12V) to SECM Pin A23 Verify O_2 sensor heater circuit is operating by measuring heater resistance (2.1Ω ± 0.4Ω) O_2 Pin C (Engine GND) to O_2 Pin D (Switched 12V)

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
742	**GasPostO2NotActive** Post-catalyst O_2 sensor inactive on LPG, open O_2 sensor signal or heater leads, defective O_2 sensor.	(1) TurnOnMil (2) DisableGasPost O2Ctrl	Check that Post-catalyst O_2 sensor connections are OK. O_2 Pin A (Sensor GND) to SECM Pin B1 O_2 Pin B (signal) to SECM Pin B19 O_2 Pin C (Engine GND) to SECM Pins A16, B17 O_2 Pin D (Heater PWR) to Post O_2 Heater Relay Pin 87. This relay only turns on after engine has been running for some time and SECM has calculated that water condensation in exhaust has been removed by exhaust heat. Post O_2 Heater Relay has switched 12V applied to the relay Pins 85, 30. The relay coil ground is controlled by SECM Pin A20 to activate the relay to flow current through the post O_2 heater. Verify O_2 sensor heater circuit is operating by measuring heater resistance ($2.1\Omega \pm 0.4\Omega$) O_2 Pin C (Engine GND) to Relay Pin 30 (Switched 12V)
743	**GasCatInactive**	NONE	N/A
751	**GasO2FailedLean** Pre-catalyst O_2 sensor indicates extended lean operation on LPG	(1) TurnOnMil (2) DisableGas O2Ctrl (3) DisableGasPostO2Ctrl	Check for vacuum leaks. Check fuel trim valves, e.g. leaking valve or hose. Check for missing orifice(s).

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
752	**GasPostO2FailedLean** Pre-catalyst O_2 sensor indicates extended lean operation on LPG	(1) TurnOnMil (2) DisableGasPost O2Ctrl	Correct other faults that may contribute to 752 (e.g. faults pertaining to fuel trim valves, Pre-Cat O_2, Post Cat O_2 sensor) Check for vacuum leaks Check for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 742 corrective actions).
771	**GasO2FailedRich** Pre-catalyst O_2 sensor indicates extended rich operation on LPG	(1) TurnOnMil (2) DisableGas O2Ctrl (3) DisableGasPostO2Ctrl	Check fuel trim valves, e.g. plugged valve or hose. Check for plugged orifice(s).
772	**GasPostO2FailedRich** Pre-catalyst O_2 sensor indicates extended rich operation on LPG	(1) TurnOnMil (2) DisableGasPostO2Ctrl	Correct other faults that may contribute to 772 (e.g. faults pertaining to FTVs, Pre-Cat O_2, Post Cat O_2 sensor) Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 742 corrective actions).
821	**LiqFuelAdaptRangeHi** In Gasoline mode, system had to adapt lean more than expected	(1) TurnOnMil (2) DisableLiquidO2Ctrl (3) DisableLiqPostO2Ctrl	Check for vacuum leaks. Low gasoline fuel pressure, perform gasoline pressure test. Injector problems, e.g. plugged, defective injector.
831	**LiqFuelAdaptRangeLow** In Gasoline mode, system had to adapt rich more than expected	(1) TurnOnMil (2) DisableLiquidO2Ctrl (3) DisableLiqPostO2Ctrl	Low gasoline fuel pressure, perform gasoline pressure test Injector problems, e.g. leaking, defective injector.
832	**LiqDesEquivLo** In gasoline mode, system had to adapt rich more than expected	NONE	N/A

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
841	**LiqO2NotActive** Pre-catalyst O_2 sensor inactive on gasoline, open O_2 sensor signal or heater leads, defective O_2 sensor	(1) TurnOnMil (2) DisableLiquid O2Ctrl (3) DisableLiqPostO2Ctrl	Check that Pre-catalyst O_2 sensor connections are OK. O_2 Pin A (Sensor GND) to SECM Pin B1 O_2 Pin B (signal) to SECM Pin B13 O_2 Pin C (Engine GND) to SECM Pins A16, B17 O_2 Pin D (Switched 12V) to SECM Pin A23 Verify O_2 sensor heater circuit is operating by measuring heater resistance (2.1Ω ± 0.4Ω) O_2 Pin C (Engine GND) to Pin D (Switched 12V)

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
842	**LiqPostO2NotActive** Post-catalyst O_2 sensor inactive on gasoline, open O_2 sensor signal or heater leads, defective O_2 sensor.	(1) TurnOnMil (2) DisableLiqPost O2Ctrl	Check that Post-catalyst O_2 sensor connections are OK. O_2 Pin A (Sensor GND) to SECM Pin B1 O_2 Pin B (signal) to SECM Pin B19 O_2 Pin C (Engine GND) to SECM Pins A16, B17 O_2 Pin D (Switched 12V) to Post O_2 Heater Relay Pin 87. This relay only turns on after engine has been running for some time and SECM has calculated that water condensation in exhaust has been removed by exhaust heat. Post O_2 Heater Relay has SECM switched 12V applied to the relay Pins 86, 30. The relay coil ground is controlled by SECM Pin A20 to activate the relay to flow current through the post O_2 heater. Verify O_2 sensor heater circuit is operating by measuring heater resistance ($2.1\Omega \pm 0.4\Omega$) O_2 Pin C (Engine GND) to Relay Pin 30 (Switched 12V)
843	LiqCatInactive	NONE	N/A
851	**LiqO2FailedLean** Pre-catalyst O_2 sensor indicates extended lean operation on gasoline	(1) TurnOnMil (2) DisableLiquid O2Ctrl (3) DisableLiqPostO2Ctrl	Check for vacuum leaks. Low gasoline fuel pressure, perform gasoline pressure test. Injector problems, e.g. plugged, defective injector

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
852	**LiqPostO2FailedLean** Pre-catalyst O_2 sensor indicates extended lean operation on gasoline	(1) TurnOnMil (2) DisableLiqPost O2Ctrl	Correct other faults that may contribute to 852 (e.g. faults pertaining to Injectors, MAP, IAT, Pre-Cat O_2, Post Cat O_2 sensor. Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 842 corrective actions).
871	**LiqO2FailedRich** Pre-catalyst O_2 sensor indicates extended rich operation on gasoline	(1) TurnOnMil (2) DisableLiquid O2Ctrl (3) DisableLiqPostO2Ctrl	High gasoline fuel pressure, perform gasoline pressure test Injector problems, e.g. leaking, defective injector
872	**LiqPostO2FailedRich** Pre-catalyst O_2 sensor indicates extended rich operation on gasoline	(1) TurnOnMil (2) DisableLiqPostO2Ctrl	Correct other faults that may contribute to 872 (e.g. faults pertaining to Injectors, MAP, IAT, Pre-Cat O_2, Post Cat O_2 sensor. Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 842 corrective actions).
911	**O2RangeLow** Pre-catalyst O_2 sensor voltage out of range low, sensor signal shorted to ground	NONE	N/A
912	**O2_PostCatRangeLow** Post-catalyst O_2 sensor voltage out of range low, sensor signal shorted to ground	NONE	N/A
921	**O2RangeHigh** Pre-catalyst O_2 sensor voltage out of range high, sensor signal shorted to power	(1) TurnOnMil (2) DisableLiquid O2Ctrl (3) DisableGas O2Ctrl	Check if O_2 sensor installed before catalyst is shorted to +5Vdc or battery. O_2 Pin B (signal) to SECM Pin B13 SECM Pin B24 (Sensor PWR) to SECM Pin B13 SECM Pin A23 (Switched 12V) to SECM Pin B13

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
922	**O2_PostCatRangeHigh** Post-catalyst O_2 sensor voltage out of range low, sensor signal shorted to ground	(1) TurnOnMil (2) DisableGasPostO2Ctrl (3) DisableLiqPostO2Ctrl	Check if O_2 sensor installed after catalyst is shorted to +5Vdc or battery. O_2 Pin B (signal) to SECM Pin B19 SECM Pin B24 (Sensor PWR) to SECM Pin B19 SECM Pin A23 (switched 12V) to SECM Pin B19
931	**FuelTempRangeLow** Fuel Temperature Sensor Input is Low normally set if the fuel temperature sensor wire has shorted to chassis ground or the sensor has failed.	TurnOnMil	Check fuel temp sensor connector and wiring for a short to GND SECM Pin B14 (signal) to FTS Pin 1 SECM Pin B1 (Sensor GND) to FTS Pin 2 and SECM (Engine GND) Pin A16, B17
932	**FuelTempRangeHigh** Fuel Temperature Sensor Input is High normally set if the fuel temperature sensor wire has been disconnected or the circuit has opened to the SECM.	TurnOnMil	Check if fuel temp sensor connector is disconnected or for an open FTS circuit SECM Pin B14 (signal) to FTS Pin 1 SECM Pin B1 (Sensor GND) to FTS Pin 2
933	**TransOilTemp** Excessive transmission oil temperature	(1) TurnOnMil (2) Delayed EngineShutdown	Refer to drivetrain manufacturer's transmission service procedures.
942	**PostO2Inactive** PostCatO2 is not varying enough, sensor has been disconnected or the circuit has been opened to the SECM	None	Check for other faults: Confirm Post Cat HEGO is wired into wiring harness Confirm Post Cat HEGO heater is wired and turned on Confirm Post Cat HEGO is properly positioned in exhaust and no leaks in exhaust system.
991	**ServiceFault1** Service Interval 1 has been reached	None	Perform service procedure related to Service Interval 1 (determined by OEM)

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
992	**ServiceFault2** Service Interval 2 has been reached	None	Perform service procedure related to Service Interval 2 (determined by OEM)
993	**ServiceFault3** Service Interval 3 has been reached	None	Perform service procedure related to Service Interval 3 (determined by OEM)
994	**ServiceFault4** Service Interval 4 has been reached—replace HEGO sensors	TurnOnMil	Replace Pre-catalyst HEGO sensor Replace Post-catlyst HEGO sensor
995	**ServiceFault5** Service Interval 5 has been reached	None	Perform service procedure related to Service Interval 5 (determined by OEM)

Parts Description

Fuel System Components

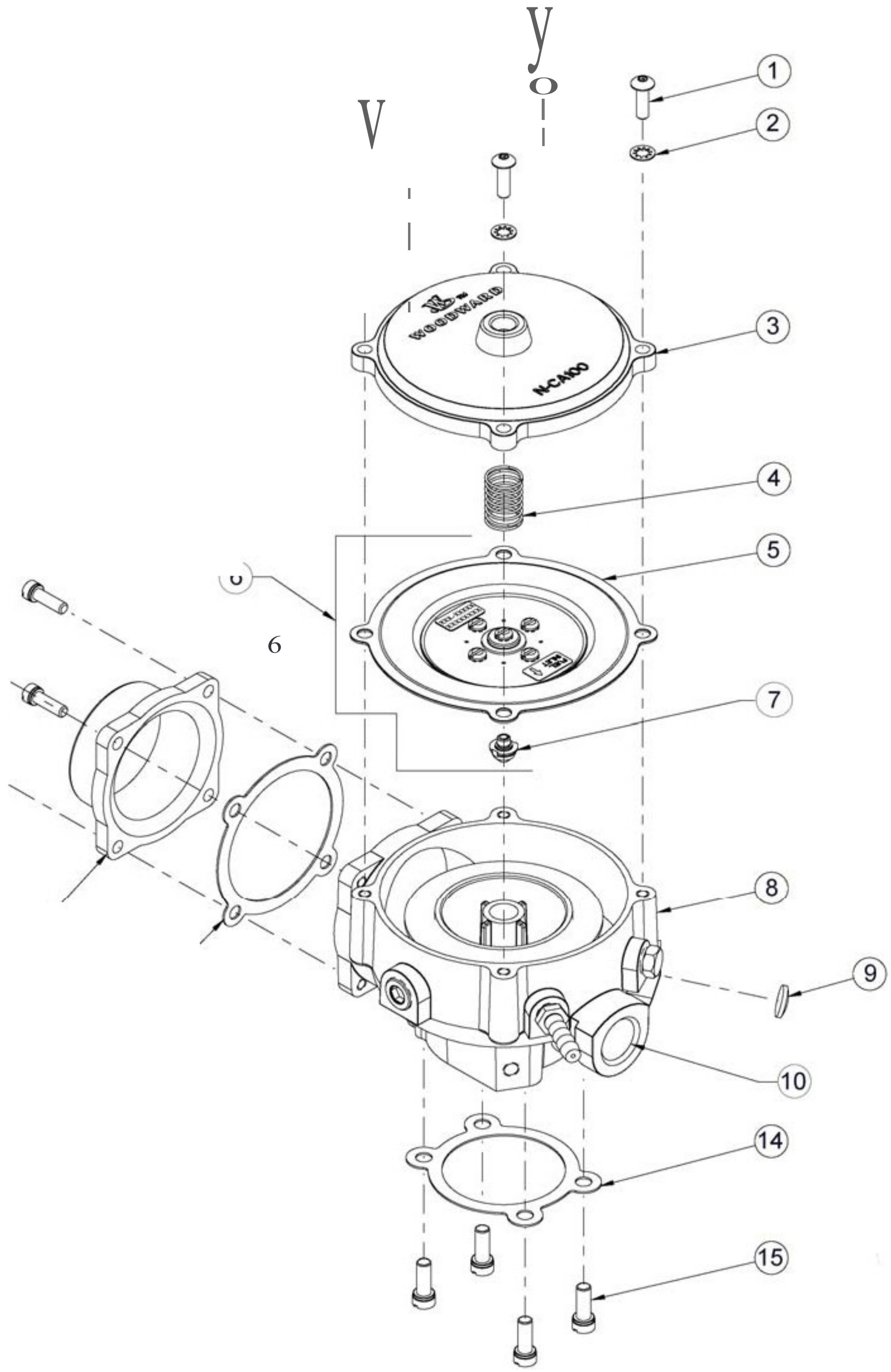


Figure 40 Exploded View -Mixer

Mixer Parts List

REF NO.	DESCRIPTION	QTY
1	Torx Screws (T-25) #10-24 x 5/8”	4
2	Lockwashers (T-210) #10 SST	4
3	Mixer Cover	1
4	Mixer Spring	1
5	Diaphragm	1
6	Air Valve Assembly	1
7	Gas Valve Cone (part of air valve assembly)	1
8	Mixer Body	1
9	Expansion Plug Cap Ø 1/2” x 1/16” thick (Ø 12.7mm x	1
10	Fuel Inlet	1
11	Air Horn Gasket	1
12	Air Horn Adapter 2-1/16” (52.37mm)	1
13	Fillister Head Screws SEMS Lockwasher 10-24 UNC x 5/8”	4
14	Throttle Body Gasket	1
15	Fillister Head Screws SEMS Split Lockwasher #12-24 x 5/8”	4

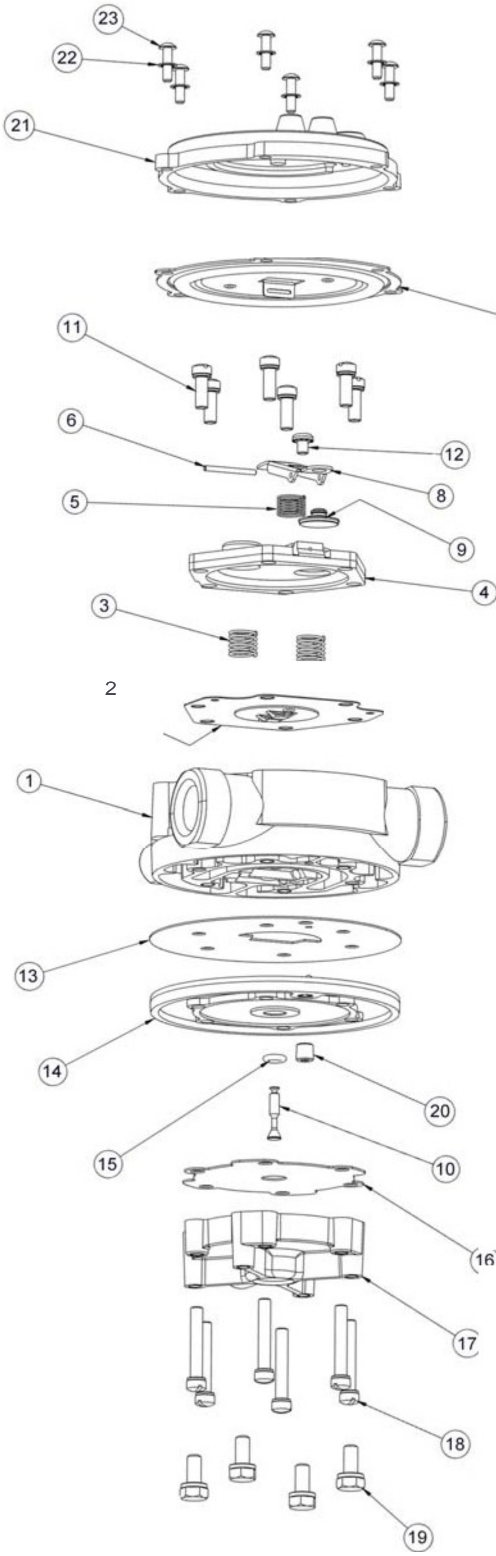


Figure 41. Exploded View Regulator

Regulator Parts List

RE F NO.	DESCRIPTION	QTY
1	Body	1
2	Diaphragm, Primary Assembly	1
3	Springs, Primary Assembly	2
4	Cover, Primary Assembly	1
5	Spring, Secondary Seat, Red	1
6	Dowel Pin Ø 0.094” x 1” L (Ø 2.39mm x 25.4mm L) Hardened Steel	1
7	Diaphragm, Secondary Assembly	1
8	Lever, Secondary	1
9	Seat, Secondary	1
10	Valve Primary	1
11	Fillister Head Screws SEMS Split Lockwasher #12-24 x 5/8”	6
12	Pan Head Screw SEMS Ext. Tooth Lockwasher #12-24 x 1/4”	1
13	Body Gasket	1
14	Back Plate	1
15	O-ring, Size 107 GLT Viton®	1
16	Bottom Plate Gasket	1
17	Plate Cover	1
18	Fillister Head Screws SEMS Split Lockwasher #12-24 x 1-3/8”	6
19	Hex Head Screws SEMS Split Lockwasher 1/4-20 x 5/8”	4
20	Plug, Socket Head Pipe (T-086)	1
21	Cover, Secondary Diaphragm	1
22	Lockwasher, Int. Tooth (T-210) #8 SST	6
23	Torx Screws (T-15) #8-32 x 5/8”	6

LPG & LPG Fuel Tanks

Liquefied petroleum gas (LPG) consists mainly of propane, propylene, butane, and butylenes in various mixtures. LPG is produced as a by-product of natural gas processing or it can be obtained from crude oil as part of the oil refining process. LPG, like gasoline, is a compound of hydrogen and carbon, commonly called hydrocarbons.

In its natural state, propane is colorless and odorless; an odorant (ethyl mercaptan) is added to the fuel so its presence can be detected. There are currently three grades of propane available in the United States. A propane grade designation of HD5 (not exceeding 5% propylene), is used for internal combustion engines while much higher levels of propylene (HD10) are used as commercial grade propane along with a commercial propane /butane mixture.

APPROXIMATE COMPOSITION OF HD5 PROPANE BY VOLUME

Propane (C_3H_8)	Propylene	Butane (C_4H_{10})	Iso-Butane	Methane (CH_4)	TOTAL
90.0% min.	5% max.	2.0%	1.5%	1.5%	100%

An advantage of LPG is the ability to safely store and transport the product in the liquid state. In the liquid state propane is approximately 270 times as dense as it is in a gaseous form. By pressurizing a container of LPG we can effectively raise the boiling point above -44° F (-42° C), keeping the propane in liquid form. The point at which the liquid becomes a gas (boiling point) depends on the amount of pressure applied to the container.

This process operates similarly to an engine coolant system where water is kept from boiling by pressurizing the system and adding a mixture of glycol. For example, water at normal atmospheric pressure will boil at 212° F (100°) C. If an engine’s operating temperature is approximately 230° F (110° C) then the water in an open un-pressurized cooling system would simply boil off into steam, eventually leaving the cooling system empty and overheating the engine. If we install a 10-psig cap on the radiator, pressurizing the cooling system to 10 psig, the boiling point of the water increases to 242° F (117° C), which will cause the water to remain in liquid state at the engine’s operating temperature.

The same principle is applied to LPG in a container, commonly referred to as an LPG tank or cylinder. Typically an LPG tank is not filled over 80% capacity to allow for a 20% vapor expansion space. Outside air temperature affects an LPG tank and must be considered when using an LPG system. **Figure A1** shows the relationship between pressure and temperature in a LPG tank at a steady state condition.

LPG Tank Pressure VS Temperature

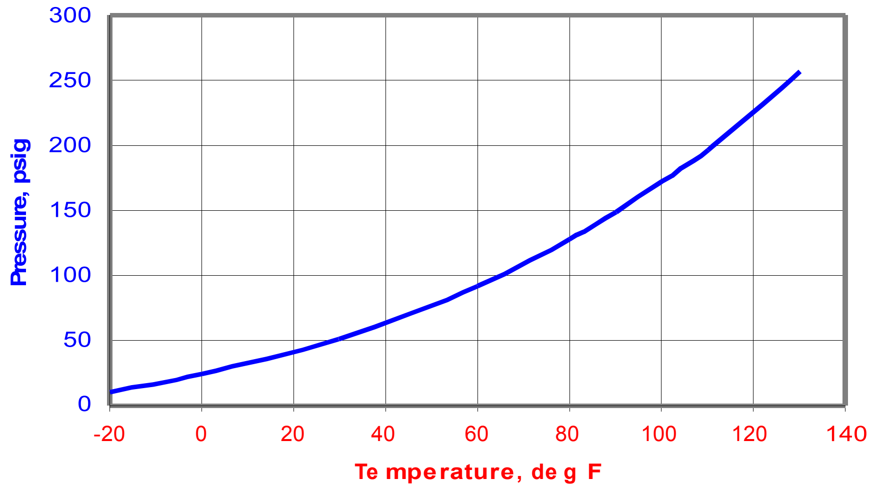
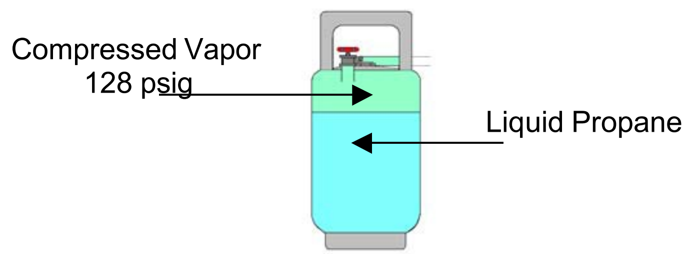


Figure A1. LPG Tank Pressure vs Temperature

With 128 psig vapor pressure acting against the liquid propane, the boiling point has been raised to slightly more than 80° F (27° C).



NOTE

Vapor pressure inside an LPG tank depends on the propane temperature, not the amount of liquid inside the tank. A tank that is 3/4 full of liquid propane at 80°F (27°C) will contain the same vapor pressure as a tank that is only 1/4 full of liquid propane.

LPG's relative ease of vaporization makes it an excellent fuel for low-RPM engines on start-and-stop operations. The more readily a fuel vaporizes, the more complete combustion will be. Because propane has a low boiling point (-44° F [-42° C]), and is a low carbon fuel, engine life can be extended due to less cylinder wall wash down and little, if any, carbon build up.

LPG Fuel Tanks

The two styles of LPG storage containers available for industrial use and lift truck applications are portable universal cylinders and permanently mounted tanks. Portable universal cylinders are used primarily for off-highway vehicles and are constructed in accordance with the DOT-TC (United States Department of Transport – Transport Canada). The cylinders are referred to as universal because they can be mounted in either a vertical or horizontal position (**Figure A2**).

Figure A2. Portable Universal Cylinder

> **NOTE**
> **A 375-psig relief valve is used on a DOT forklift tank. The relief valve must be replaced with a new valve after the first 12 years and every 10 years thereafter.**

The tank must be discarded if the collar is damaged to the point that it can no longer protect the valves. It must also be replaced if the foot ring is bent to the point where the tank will not stand or is easily knocked over.

Installing LPG Fuel Tanks

When installing a tank on a lift truck, the tank must be within the outline of the vehicle to prevent damage to the valves when maneuvering in tight spaces. Horizontal tanks must be installed on the saddle that contains an alignment pin, which matches the hole in the collar of the tank. When the pin is in the hole, the liquid withdrawal tube is positioned to the bottom of the tank. A common problem is that often these guide-pins are broken off, allowing the tank to be mounted in any position. This creates two problems: (1) Exposure of the liquid withdrawal tube to the vapor space may give a false indication that the tank is empty, when actually it is not. (2). The safety relief valve may be immersed in liquid fuel. If for any reason the valve has to vent, venting liquid can cause a serious safety problem.

> **CAUTION**
> **Exchange empty tank with a pre-filled replacement tank. Wear safety glasses and gloves when exchanging a tank**

LPG Fuel Tank Components

1. Fuel Gauge
2. 80% Stop Bleeder
3. Pressure Relief Valve
4. Service Valve (Tank end male coupling)
5. Filler Valve
6. Alignment Pin
7. Vapor Withdrawal Tube (used only with vapor withdrawal)
8. 80% Limiter Tube
9. Liquid Withdrawal Tube

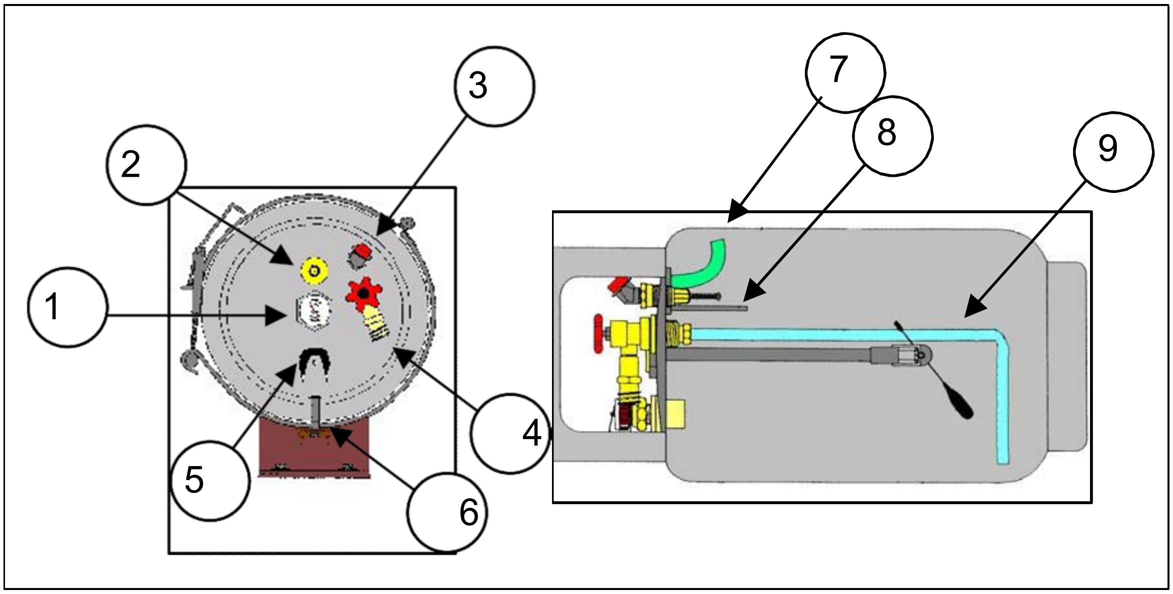


Figure A3. LPG Fuel Tank Components

Fuel Gauge

In **Figure A3** a visual fuel gauge is used to show the fuel level in the tank. A mechanical float mechanism detects the liquid propane level. A magnet on the end of the float shaft moves a magnetic pointer in the fuel gauge. Some units have an electronic sending unit using a variable resistor, installed in place of a gauge for remote monitoring of the fuel level. The gauge may be changed with fuel in the tank. **DO NOT REMOVE THE FOUR LARGE FLANGE BOLTS THAT RETAIN THE FLOAT ASSEMBLY WHEN FUEL IS IN THE TANK!**

> **WARNING**
> **It is not a legal practice to fill the tank through the liquid contents gauge.**

In some applications a fixed tube fuel indicator is used in place of a float mechanism. A fixed tube indicator does not use a gauge and only indicates when the LPG tank is 80% full. The fixed tube indicator is simply a normally closed valve that is opened during refueling by the fueling attendant. When opened during refueling and the tanks LPG level is below 80%, a small amount of vapor

will exit the valve. When the LPG tank level reaches 80% liquid propane will begin exiting the valve in the form of a white mist (Always wear the appropriate protective apparel when refueling LPG cylinders). In order for this type of gauge to be accurate, the tank must be positioned properly. When full (80% LPG) the valve is closed by turning the knurled knob clockwise. Typically a warning label surrounds the fixed tube gauge which reads **STOP FILLING WHEN LIQUID APPEARS.**

Pressure Relief Valve

A pressure relief valve is installed for safety purposes on all LPG tanks. Portable fuel tank safety pressure relief valves are a normally closed spring-loaded valve and are calibrated to open at 375 psig tank pressure. This will allow propane vapor to escape to the atmosphere. When tank pressure drops below the preset value, the valve closes.

Service Valve

The service valve is a manually operated valve using a small hand wheel to open and close the fuel supply to the service line (fuel supply line). The service valve installs directly into the tank and has two main categories, liquid and vapor service valves. Liquid service valves used on portable LPG tanks use a 3/8” (NPT) male pipe thread on the service valve outlet for attachment of a quick disconnect coupler.

An excess flow valve is built into the inlet side of the service valve as a safety device in case of an accidental opening of the service line or damage to the service valve itself. The excess flow valve shuts off the flow of liquid propane if the flow rate of the liquid propane exceeds the maximum flow rate specified by the manufacturer.

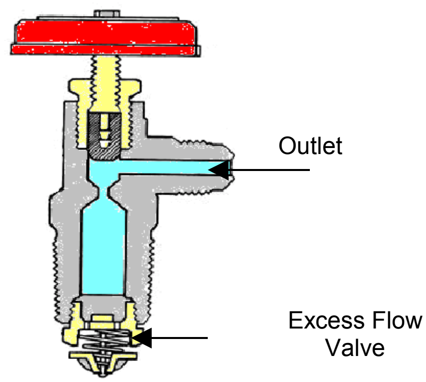


Figure A4. Service Valve

CAUTION

The service valve should be completely open when the tank is in use. If the valve is partly open, the vehicle may not get enough fuel to operate efficiently.

In addition to possibly starving the engine for fuel, a partly open valve may restrict the flow enough to prevent the excess flow valve from closing in the event of a ruptured fuel line.

Most liquid service valves have an internal hydrostatic relief valve and are usually labeled “**LIQUID WITH INTERNAL RELIEF.**” The hydrostatic relief valve protects the fuel service line between the tank and the lock off from over pressurization. The internal hydrostatic relief valve has a minimum opening pressure of 375 psig and a maximum pressure of 500 psig. These relief valves have an advantage over external relief valves because the propane is returned to the tank in the event of an over pressurization instead of venting the propane to the atmosphere.

Quick Disconnect Coupling

The liquid withdrawal or service valve on a DOT tank has male threads and accepts the female portion of a quick disconnect coupling (**Figure A5**). The female portion is adapted to the liquid hose going to the fuel system. Both halves are equipped with 100% shutoffs, which open when coupled together to allow fuel flow. The coupler has two seals. One is an o-ring and the other is a flat washer. The o-ring prevents leakage from the shaft on the other coupling and the flat washer seals when the coupler is fully connected.

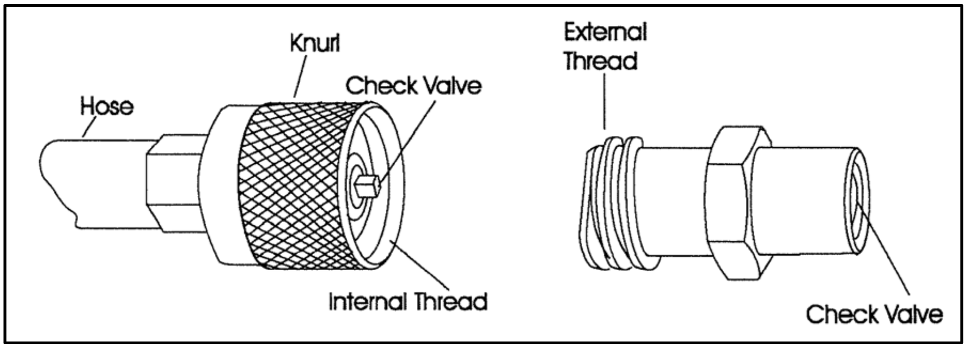


Figure A5. Quick Disconnect Coupling

NOTE
The flat seal and/or the o-ring will sometimes pop off when disconnecting and slide up the shaft of the mating connector, causing the valve not to open when fully mated. Remove the extra washer or o-ring from the shaft and reconnect the coupling.

Filler Valve

The liquid filler valve (**Figure A6**) has a male thread to receive a fuel nozzle and typically has a plastic or brass screw on cap that is retained with a small chain or plastic band to keep debris out of the filler valve. The filler valve is a one-way flow device that uses two check valves to allow fuel to enter the tank but prevent it from exiting. Both check valves are backpressure type check valves, designed so that backpressure from the tank assists the check valves own spring pressure to close the valve. The first valve uses a neoprene on metal seal and the second valve uses a metal on metal seal.

A weakness ring is machined into the filler valve just above the check valves and will allow the filler valve to shear off in case of an accident. The valve will break or shear off above the check valves so that the tank will be sealed and no liquid propane can escape.

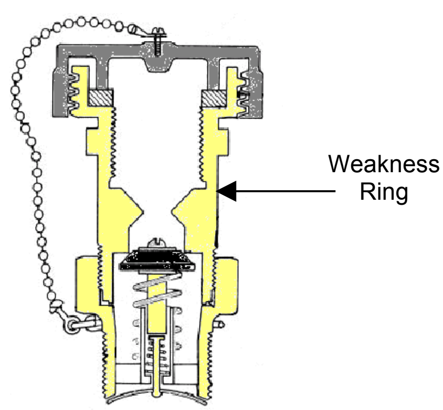
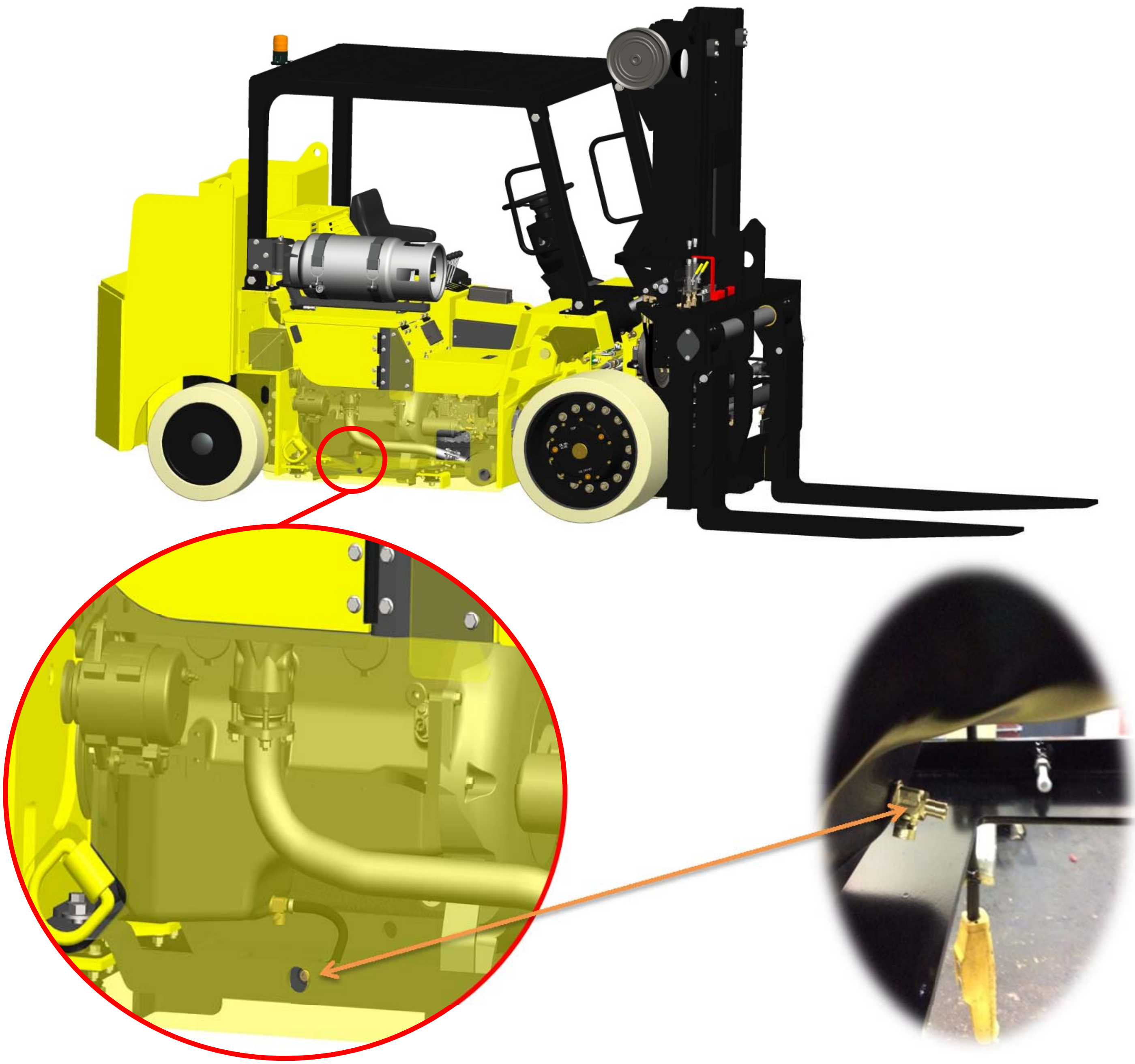


Figure A6. Liquid Filler Valve

Abbreviations

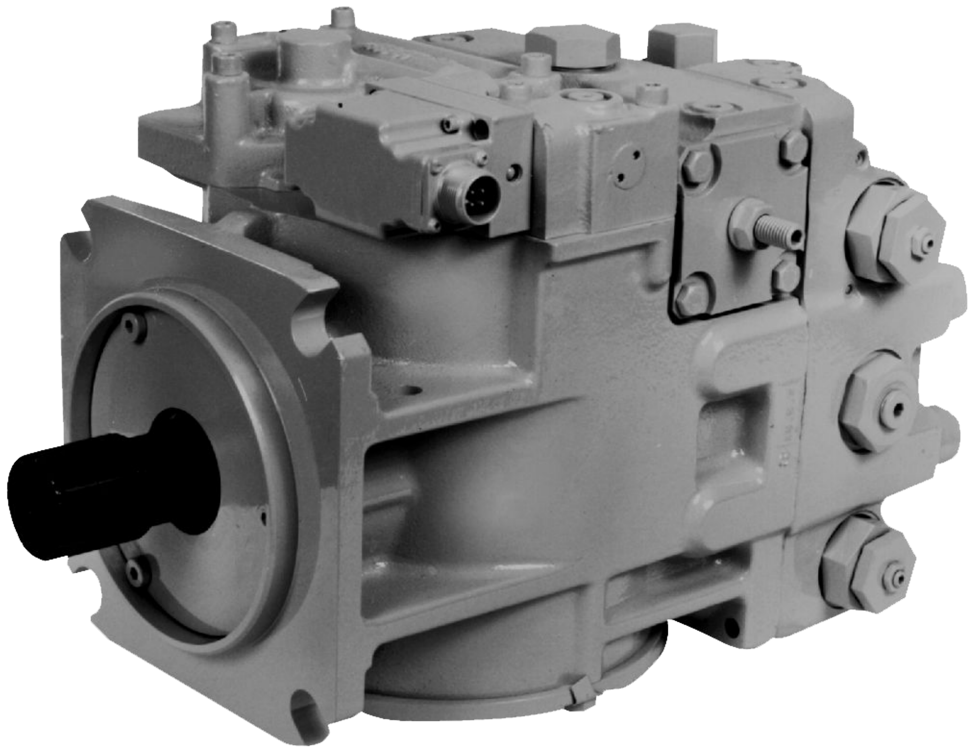
ACFM	Actual cubic feet per minute at the specified suction conditions
AFR	Air fuel ratio
BHP	Brake horsepower
Bi-Fuel	Able to operate on either of two fuels
CTS	Coolant temperature sensor
CNG	Compressed natural gas
Dual Fuel	Able to run simultaneously on two fuels, e.g. diesel and natural gas. Often this term is incorrectly used to describe bi-fuel operation. Spark-ignited engines are typically bi-fuel while compression ignition engines are dual-fuel.
ECM	Engine control module
FPP	Foot pedal position
FPV	Fuel primer valve
FTS	Fuel temperature sensor
FTV	Fuel trim valve
GPM	Gallons per minute of flow
HEGO	Heated exhaust gas oxygen (sensor)
LAT	Limited-angle torque motor
LPG	Liquified petroleum gas
MAP	Manifold absolute pressure
MAT	Manifold air temperature
MIL	Malfunction indicator lamp
MOR	Manufacturer of record for emissions certification on the engine
OEM	Original equipment manufacturer
PHI	Relative fuel-air ratio or percent of stoichiometric fuel (actual fuel-air ratio / stoichiometric fuel-air ratio)
RPM	Revolutions per minute
SECM	Small engine control module
TMAP	Temperature and manifold absolute pressure
TPS	Throttle position sensor
VDC	Voltage of direct current type
VE	Volumetric efficiency
WOT	Wide open thro

Remote Oil Drain



The truck is fitted with a Remote Oil Drain for the engine. The shut-off valve should be (and stay) open. It can be shut in the event the engine needs to be removed from the sled it's mounted to. There is a drain fitting at the access hole, which is a ¼" pipe plug that is directly inside the access hole in the side plate. To drain the oil, simply remove the pipe plug through the access hole in the side plate.

HYDROSTATIC PUMP



General instructions

Follow these general procedures when repairing variable displacement closed circuit pumps.

Remove the unit

Prior to performing major repairs, remove the unit from the vehicle/machine. Chock the wheels on the vehicle or lock the mechanism to inhibit movement. Be aware that hydraulic fluid may be under high pressure and/or hot. Inspect the outside of the pump and fittings for damage. Cap hoses after removal to prevent contamination.

Keep it clean

Cleanliness is a primary means of assuring satisfactory pump life, on either new or repaired units. Clean the outside of the pump thoroughly before disassembly. Take care to avoid contamination of the system ports. Cleaning parts by using a clean solvent wash and air drying is usually adequate.

As with any precision equipment, keep all parts free of foreign materials and chemicals. Protect all exposed sealing surfaces and open cavities from damage and foreign material. If left unattended, cover the pump with a protective layer of plastic.

Replace all O-rings and gaskets

Use new O-rings and gaskets during reassembly. Lightly lubricate all O-rings with clean petroleum jelly prior to assembly.

Secure the unit

For repair, place the unit in a stable position with the shaft pointing downward. It will be necessary to secure the pump while removing and torquing end covers, controls, and valves.

Safety precautions

Always consider safety precautions before beginning a service procedure. Protect yourself and others from injury. Take the following general precautions whenever servicing a hydraulic system.

Unintended machine movement

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

Flammable cleaning solvents

Warning

Some cleaning solvents are flammable. To avoid possible fire, do not use cleaning solvents in an area where a source of ignition may be present.

Fluid under pressure

Warning

Escaping hydraulic fluid under pressure can have sufficient force to penetrate your skin causing serious injury and/or infection. This fluid may also be hot enough to cause burns. Use caution when dealing with hydraulic fluid under pressure. Relieve pressure in the system before removing hoses, fittings, gauges, or components. Never use your hand or any other body part to check for leaks in a pressurized line. Seek medical attention immediately if you are cut by hydraulic fluid.

Personal safety

Warning

Protect yourself from injury. Use proper safety equipment, including safety glasses, at all times.

Introduction

Symbols used in this literature

- WARNING may result in injury
- CAUTION may result in damage to product or property
- Reusable part
- Non-reusable part, use a new part
- Non-removable item
- Option - either part may exist
- Superseded - parts are not interchangeable
- Measurement required
- Flatness specification
- Parallelism specification
- External hex head
- Internal hex head
- Torx head
- O-ring boss port
- Tip, helpful suggestion
- Lubricate with hydraulic fluid
- Apply grease / petroleum jelly
- Apply locking compound
- Inspect for wear or damage
- Clean area or part
- Be careful not to scratch or damage
- Note correct orientation
- Mark orientation for reinstallation
- Torque specification
- Press in - press fit
- Pull out with tool – press fit
- Cover splines with installation sleeve
- Pressure measurement/gauge location or specification

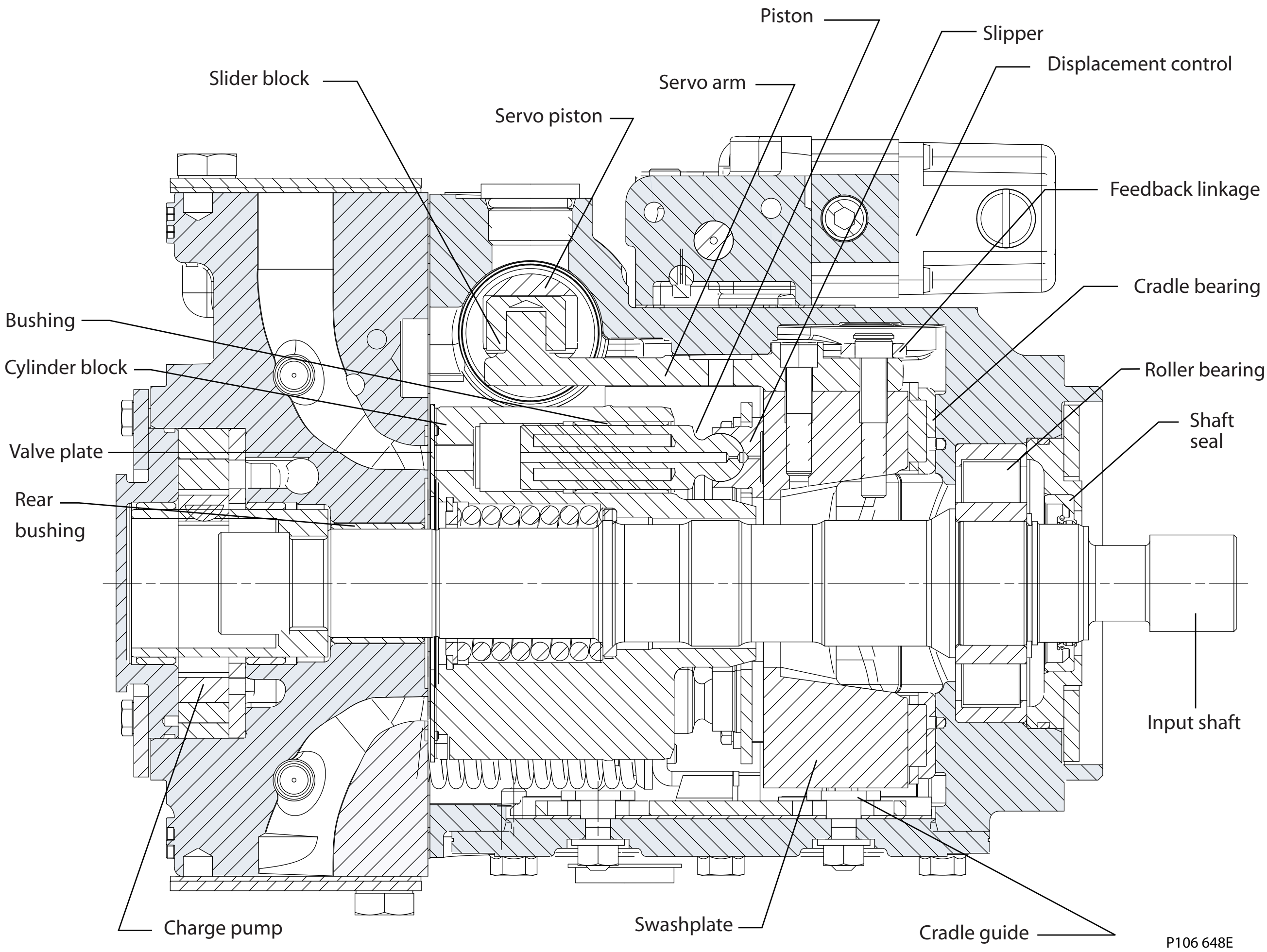
The symbols above appear in the illustrations and text of this manual. They are intended to communicate helpful information at the point where it is most useful to the reader. In most instances, the appearance of the symbol itself denotes its meaning. The legend above defines each symbol and explains its purpose.

Design

Closed circuit piston pumps convert input torque into hydraulic power. The input shaft transmits rotational force to the cylinder block. Bearings support the input shaft at the front and rear of the pump. The shaft is splined into the cylinder block. A lip-seal at the front end of the pump prevents leakage where the shaft exits the pump housing. The spinning cylinder block contains nine reciprocating pistons. A ball joint at one end connects each piston to a brass slipper. Fixed-clearance hold-down brackets keep the slippers in contact with the swashplate. The reciprocating movement of the pistons occurs as the slippers slide against the inclined swashplate during rotation. The valve plate connects one half of the cylinder block to low pressure and the other half to high pressure. As each piston cycles in and out of its bore, fluid is drawn from the inlet and displaced to the outlet thereby imparting hydraulic power into the system. A small amount of fluid flows from the cylinder block/valve plate and slipper/swashplate interfaces for lubrication and cooling. Case drain ports return this fluid to the reservoir.

The angle of the swashplate controls the volume of fluid displaced into the system. The servo piston forces the swashplate into an inclined position. The pump control, acting on input from the operator, by modulating pressure balance across the servo piston, sets displacement in the system circuit.

Cross section

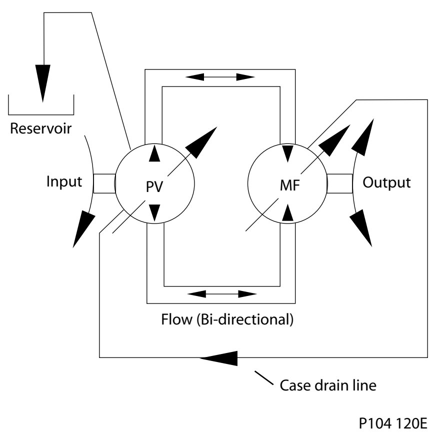


The system circuit

The basic closed circuit

Hydraulic lines connect the main ports of the pump to the main ports of the motor. Fluid flows in either direction from the pump to the motor then back to the pump in this closed circuit. Either of the hydraulic lines can be under high pressure. In pumping mode the position of the pump swashplate determines which line is high pressure as well as the direction of fluid flow.

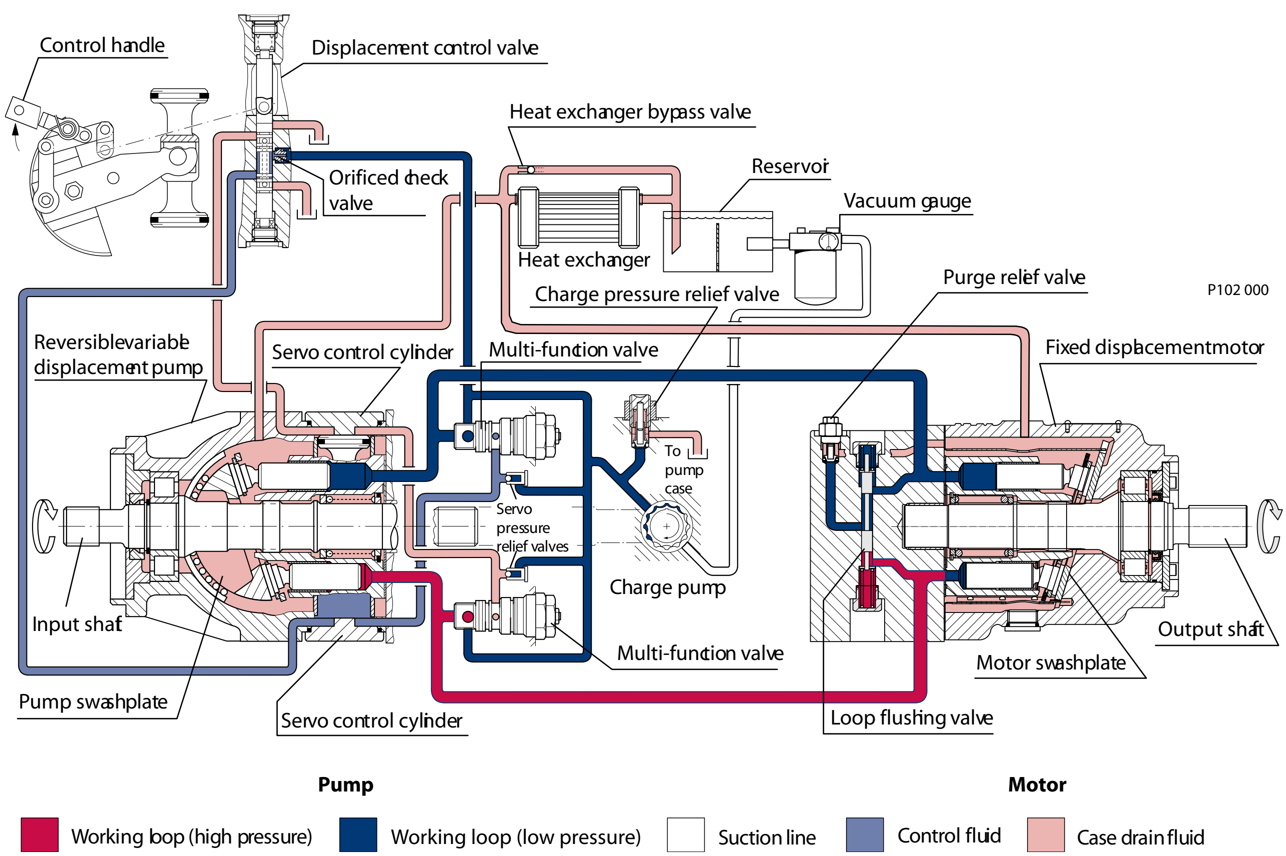
Basic closed circuit diagram



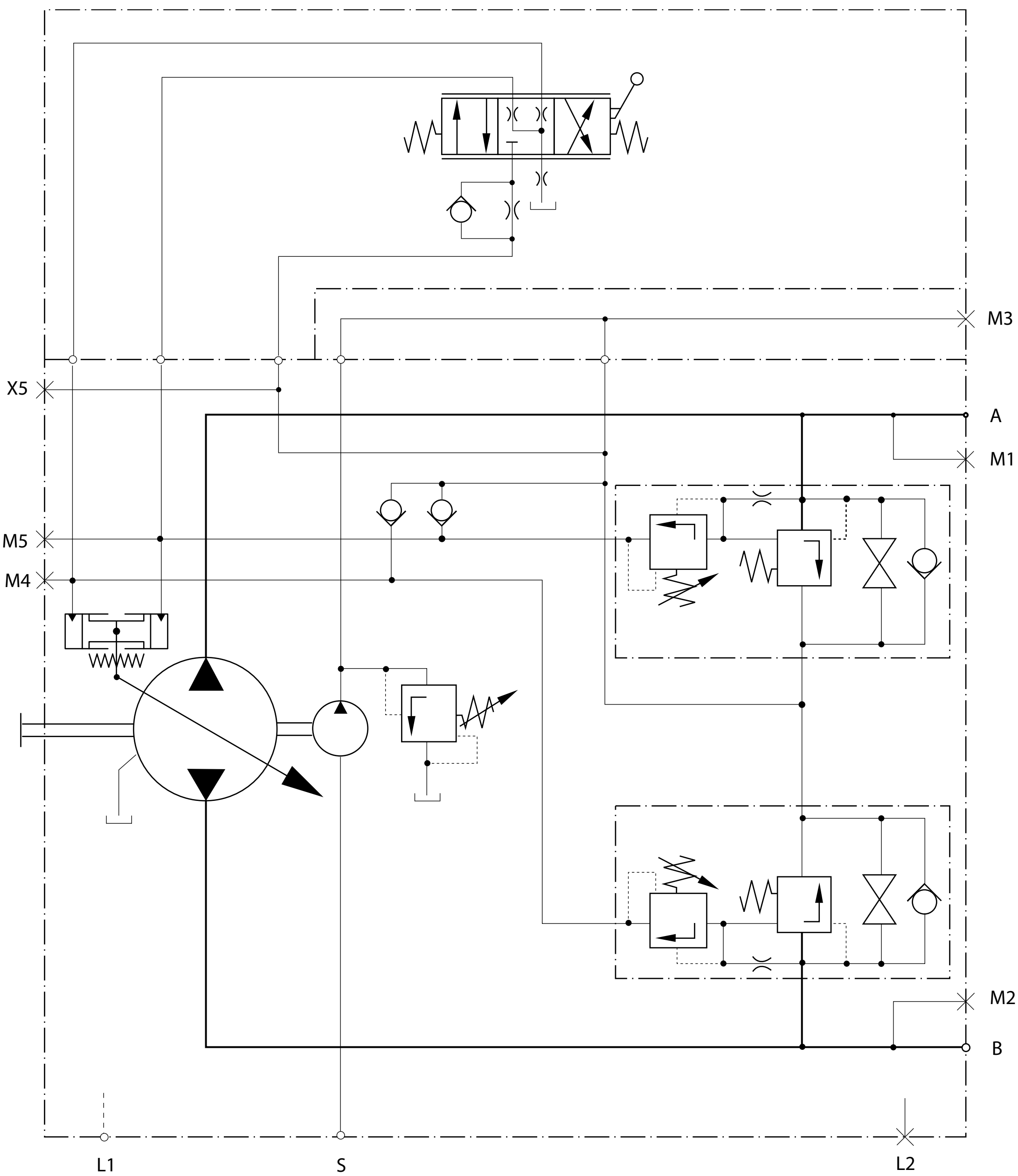
Case drain and heat exchanger

The pump and motor require case drain lines to remove hot fluid from the system. The topmost port drains the motor to ensure the case remains full of fluid. Fluid routes through the lower drain port on the pump and out the topmost port to the reservoir. A heat exchanger, with a bypass valve, cools the case drain fluid before it returns to the reservoir.

System circuit diagram



Pump schematic

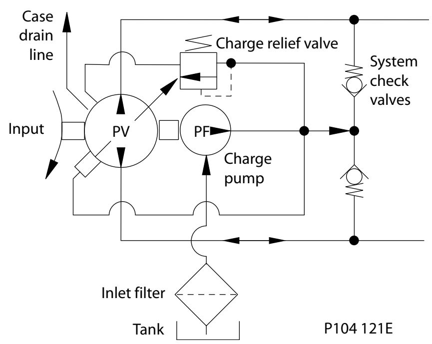


Charge pump

The charge pump is necessary to supply cool fluid to the system, to maintain positive pressure in the main system loop, to provide pressure to operate the control system, and to make up for internal leakage. Charge pressure must be at its specified pressure under all conditions to prevent damage to the transmission.

The charge pump is a fixed-displacement, gerotor type pump driven off the main pump shaft. The charge relief valve limits charge pressure.

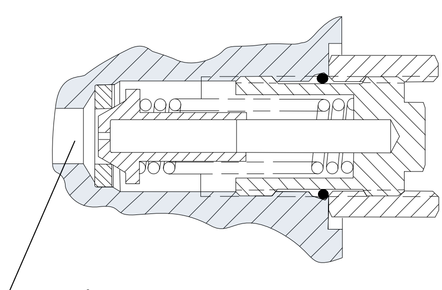
Pump charge system



Charge relief valve

The charge relief valve on the pump maintains charge pressure at a designated level. A direct-acting poppet valve relieves fluid when charge pressure reaches a certain level. This level is nominally set referencing case pressure at 1500 rpm. This nominal setting assumes the pump is in neutral (zero flow). In forward or reverse, charge pressure is lower. The pump model code specifies the charge relief valve setting.

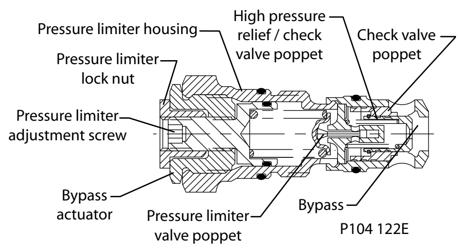
Charge pressure relief valve



Multi-function valves

The multi-function valve incorporates the system check valve, the pressure limiter valve, the high pressure relief valve, and the bypass valve in a replaceable cartridge. These functions are described separately. There are two multi-function valve cartridges in each pump to handle functions in either direction. See corresponding sections for adjustments and repairs.

Multi-function valve

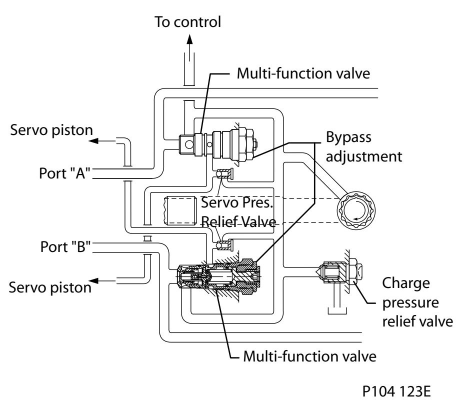


Some multi-function valves do not include a pressure limiter valve

Pressure limiter and high pressure relief valves

The pumps have a sequenced pressure limiting system and high pressure relief valves. When the system pressure reaches the preset, the pressure limiter system rapidly de-strokes the pump to limit system pressure. For unusually rapid load application, the high pressure relief valve immediately limits system pressure by cross-porting system flow. The pressure limiter valve acts as the pilot for the high pressure relief valve spool. The high pressure relief valve is sequenced to operate at approximately 35 bar (500 psi) above the level that initiates the pressure limiter valve.

Circuit diagram showing pressure control mechanism



For some applications, such as dual path vehicles, the pressure limiter function may be defeated so that only the high pressure relief valve function remains.

System check valves

The system check valves allow pressurized flow from the charge pump to enter the low pressure side of the loop. This is needed as the pump generally loses system pressure due to lubrication/cooling flow and other factors. Since the pump operates in either direction, the system uses two check valves to direct the charge supply into the low pressure lines. The system check valves are part of the multi-function valve assembly.

Bypass valves

You can operate the bypass valves to move the vehicle or mechanical function when the pump is not running. Manually resetting the valve position opens the valve. The bypass valves are built into the multi-function valves.

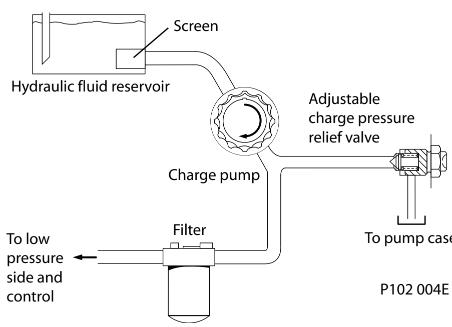
Speed sensors

An optional speed sensor can provide unit speed information. The sensor reads a magnetic ring on the unit's cylinder block. See the corresponding section to locate, install, and adjust the speed sensor.

Charge pressure filtration

The pressure filter can be mounted on the pump or remotely for ease of servicing. You will typically find a 100-125 µm mesh screen, in the reservoir or the charge inlet. This system requires a filter capable of withstanding charge pressure (reference to atmosphere - add case pressure).

Charge pressure filtration



Manual displacement control (MDC)

The manual displacement control converts a mechanical input signal to a hydraulic signal using a spring-centered four-way servo valve. This valve ports hydraulic pressure to either side of a dual-acting servo piston. The servo piston rotates the cradle swashplate through an angular rotation of ±17°, varying the pump's displacement from full in one direction to full in the opposite direction.The angular position of the pump swashplate is proportional to the rotation of the control input shaft.

Non-Linear MDC

The non-linear manual displacement control operates in the same manner except that it is designed so the change in the angular position of the pump swashplate progressively increases as the control input shaft is rotated toward its maximum displacement position.

Solenoid override valve for MDC

A solenoid override valve option is available for the MDC. This safety feature returns the swashplate to zero displacement. It is available in normally open (activate to allow) or normally closed (activate to disallow) options..

Neutral start switch (NSS)

The neutral start switch is an optional feature available with the MDC. When connected properly with the vehicle's electrical system, the neutral start switch ensures that the prime mover can start only when the control is in neutral position.

Overview

This section defines the operating parameters and limitations for the pump with regard to input speeds and pressures. For actual parameters, refer to the operating parameters for each displacement.

Input speed

Minimum speed is the lowest input speed recommended during engine idle condition. Operating below minimum speed limits the pump's ability to maintain adequate flow for lubrication and power transmission.

Continuous speed is the highest input speed recommended at full power condition. Operating at or below this speed should yield satisfactory product life.

Maximum speed is the highest operating speed permitted. Exceeding maximum speed reduces product life and can cause loss of hydrostatic power and braking capacity. Never exceed the maximum speed limit under any operating conditions.

Warning

Unintended vehicle or machine movement hazard

Exceeding maximum speed may cause a loss of hydrostatic drive line power and braking capacity. You must provide a braking system, redundant to the hydrostatic transmission, sufficient to stop and hold the vehicle or machine in the event of hydrostatic drive power loss.

System pressure

System pressure is the differential pressure between system ports A and B. It is the dominant operating variable affecting hydraulic unit life. High system pressure, which results from high load, reduces expected life. System pressure must remain at or below continuous pressure during normal operation to achieve expected life.

Continuous pressure is the average, regularly occurring operating pressure. Operating at or below this pressure should yield satisfactory product life.

Maximum pressure is the highest intermittent pressure allowed. Maximum machine load should never exceed this pressure. For all applications, the load should move below this pressure.

All pressure limits are differential pressures referenced to low loop (charge) pressure. Subtract low loop pressure from gauge readings to compute the differential.

Charge pressure

An internal charge relief valve regulates charge pressure. The charge pump supplies the control with pressure to operate the swashplate and to maintain a minimum pressure in the low side of the transmission loop.

Minimum charge pressure is the lowest pressure allowed to maintain a safe working condition in the low side of the loop. Minimum control pressure requirements are a function of speed, pressure, and swashplate angle, and may be higher than the minimum charge pressure shown in the operating parameters table.

Maximum charge pressure is the highest charge pressure allowed by the charge relief adjustment, and provides normal component life. You can use elevated charge pressure as a secondary means to reduce the swashplate response time.

The charge pressure setting in the order code is the set pressure of the charge relief valve with the pump in neutral, operating at 1800 min-1 (rpm), and with a fluid viscosity of 32 mm2/sec (150 SUS). The charge pressure setting is referenced to case pressure. Charge pressure is the differential pressure above case pressure.

Charge inlet pressure

At normal operating temperature charge inlet pressure must not fall below *rated charge inlet pressure*.

Minimum charge inlet pressure is only allowed at cold start conditions. In some applications it may be necessary to warm up the fluid by running the engine at limited speed until the system fluid temperature reaches an acceptable level.

Case pressure

Under normal operating conditions, do not exceed the *rated case pressure*. During cold start, maintain the case pressure below maximum intermittent case pressure.

Caution

Possible component damage or leakage

Operation with case pressure in excess of stated limits may damage seals, gaskets, and/or housings, causing external leakage. Performance may also be affected since charge and system pressure are additive to case pressure.

Temperature and viscosity

Temperature

The high temperature limits apply at the hottest point in the transmission loop, which is normally the motor case drain. Maintain system temperature below the quoted *rated temperature*.

Never exceed the *maximum intermittent temperature*.

Cold oil will generally not affect the durability of the transmission components, but it may affect the ability of oil to flow and transmit power; therefore temperatures should remain 16 °C [30 °F] above the pour point of the hydraulic fluid.

The *minimum temperature* relates to the physical properties of component materials.Size heat exchangers to keep the fluid within these limits. Test heat exchangers to verify that these temperature limits are not exceeded.

Viscosity

For maximum efficiency and bearing life, ensure the fluid viscosity remains in the *recommended range*.

Minimum viscosity should be encountered only during brief occasions of maximum ambient temperature and severe duty cycle operation.

Maximum viscosity should be encountered only at cold start.

Fluid and filter recommendations

To ensure optimum pump life, perform regular maintenance of the fluid and filter. Contaminated fluid is the main cause of unit failure. Maintain fluid cleanliness when servicing.

Check the reservoir daily for proper fluid level, the presence of water, and rancid fluid odor. Fluid contaminated by water may appear cloudy or milky or free water may settle in the bottom of the reservoir. Rancid odor indicates the fluid has been exposed to excessive heat. Change the fluid immediately if these conditions occur. Correct the problem immediately.

Inspect vehicle for leaks daily.

Change the fluid and filter at the intervals shown in the table. Change fluid after first 500 hours.

Fluid and filter change interval

Reservoir type	Max oil change interval
Sealed	2000 hours
Breather	500 hours

Caution

High temperatures and pressures result in accelerated fluid aging. Change fluid more frequently if operating under extreme conditions.

Change the fluid more frequently if it becomes contaminated with foreign matter (dirt, water, grease, etc.) or if the fluid is subjected to temperature levels greater than the recommended maximum.

Dispose of used hydraulic fluid properly. Never reuse hydraulic fluid.

Change filters whenever the fluid is changed or when the filter indicator indicates a filter change. Replace all fluid lost during filter change.

General

Follow this procedure when starting-up a new pump installation or when restarting an installation in which the pump was removed.

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

Prior to installing the pump, inspect for shipping damage.

Start-up procedure

1. Ensure that the hydraulic fluid and system components (reservoir, hoses, valves, fittings, and heat exchanger) are clean and free of contamination.
2. Install new system filter element(s) if necessary. Check that inlet line fittings are properly tightened and there are no air leaks.
3. Install the pump. Install a 50 bar [1000 psi] gauge in the charge pressure gauge port M
4. Fill the housing by adding filtered fluid in the upper case drain port. Open the case plug in the top of the control to assist with air bleed.
5. Fill the reservoir with hydraulic fluid of the recommended type and viscosity. Use a 10-micron filler filter. Fill inlet line from reservoir to pump.
6. Disconnect the pump control input signal.

   After start-up the fluid level in the reservoir may drop due to filling of the system components. Check the level in the reservoir to maintain a full fluid level throughout the start-up procedure.

   Caution

   Damage to hydraulic components may occur from failure to maintain fluid supply.

7. Use a common method to disable the engine to prevent the engine from starting. Crank the starter for several seconds. Do not to exceed the engine manufacturer's recommendation. Wait 30 seconds and then crank the engine a second time. This operation helps remove air from the system lines. Refill the reservoir to recommended full fluid level.
8. When charge pressure reaches 3.5 bar [50 psi], enable and start engine. Let the engine run for a minimum of 30 seconds at low idle to allow the air to work itself out of the system. Check for leaks at all line connections and listen for cavitation. Check for proper fluid level in reservoir.

   Caution

   Air entrapment in fluid under high pressure may damage hydraulic components.
   Do not run at maximum pressure until system is free of air and fluid has been thoroughly filtered.

9. When adequate charge pressure is established (as shown in model code), increase engine speed to normal operating rpm to further purge residual air from the system.
10. Shut off the engine. Connect the pump control signal. Start the engine, checking to be certain the pump remains in neutral. Run the engine at normal operating speed and carefully check for forward and reverse control operation.
11. Continue to cycle between forward and reverse for at least five minutes to bleed all air and flush system contaminants out of loop.

    Normal charge pressure fluctuation may occur during forward and reverse operation.

12. Check that the reservoir is full. Remove charge pressure gauge. The pump is now ready for operation.

Required tools

You can perform the service procedures described in this manual using common mechanic's tools. Special tools, if required are shown. Use calibrated pressure gauges to ensure accuracy. Use snubbers to protect pressure gauges.

Port locations and gauge installation

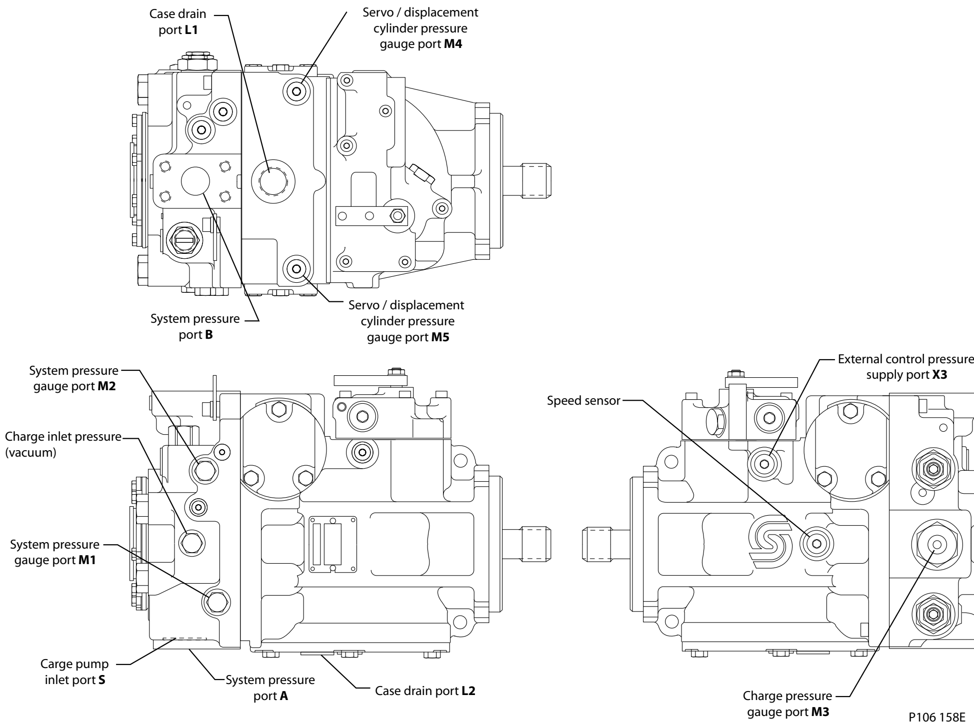
The following sections list the ports for each type of hydraulic unit. The fitting size and recommended pressure gauge are also specified.

The following table and drawings show the port locations and gauge sizes needed.

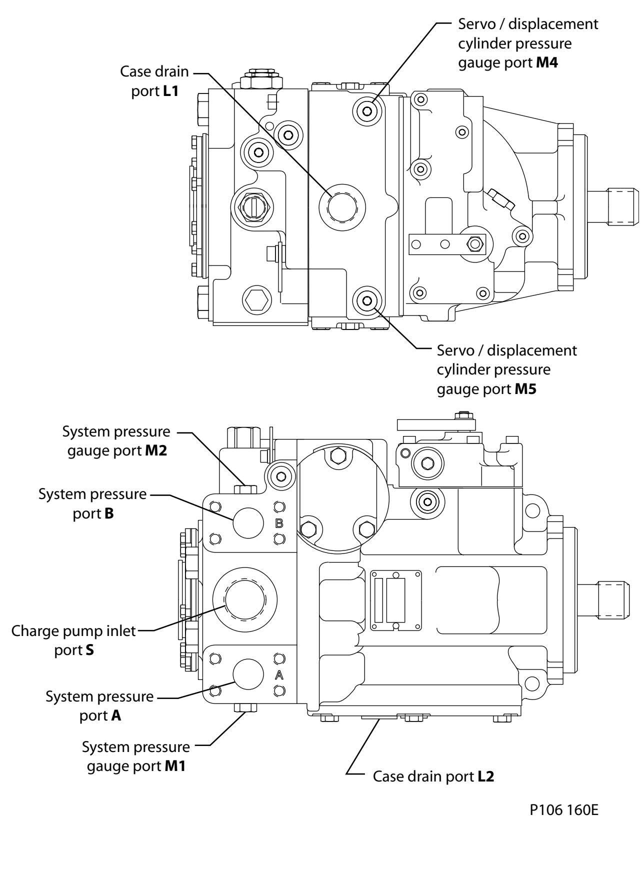
Port information

<table>
<tr><th>Port identifier</th><th>Pressure obtained</th><th>Gauge size</th><th colspan="2">Port size</th></tr>
<tr><td>M1, M2</td><td>System pressure</td><td>1000 bar [10 000 psi]</td><td colspan="2">9/16-18</td></tr>
<tr><td>M3 (M6)</td><td>Charge pressure</td><td>50 bar [1000 psi]</td><td colspan="2">9/16-18</td></tr>
<tr><td>M4, M5</td><td>Servo pressure</td><td>50 bar [1000 psi]</td><td colspan="2">9/16-18</td></tr>
<tr><td rowspan="4">L1, L2</td><td rowspan="4">Case pressure</td><td rowspan="4">10 bar [100 psi]</td><td>030-042</td><td>7/8-14</td></tr>
<tr><td>055-100</td><td>1-1/16-12</td></tr>
<tr><td>130</td><td>1-5/16-12</td></tr>
<tr><td>180-250</td><td>1-5/8-12</td></tr>
<tr><td>X1, X2</td><td>HDC/EDC control pressure</td><td>50 bar [1000 psi]</td><td colspan="2">7/16-20 or 9/16-18</td></tr>
<tr><td>X3</td><td>External control pressure</td><td>50 bar [1000 psi]</td><td colspan="2">9/16-18</td></tr>
<tr><td rowspan="4">S</td><td rowspan="4">Charge pump inlet</td><td rowspan="4">Vacuum gauge,
Tee into inlet line</td><td>030-042</td><td>1-1/16-12</td></tr>
<tr><td>055-075</td><td>1-5/16-12</td></tr>
<tr><td>100-180</td><td>1-5/8-12</td></tr>
<tr><td>250</td><td>1-1/2 SAE-split flange</td></tr>
</table>

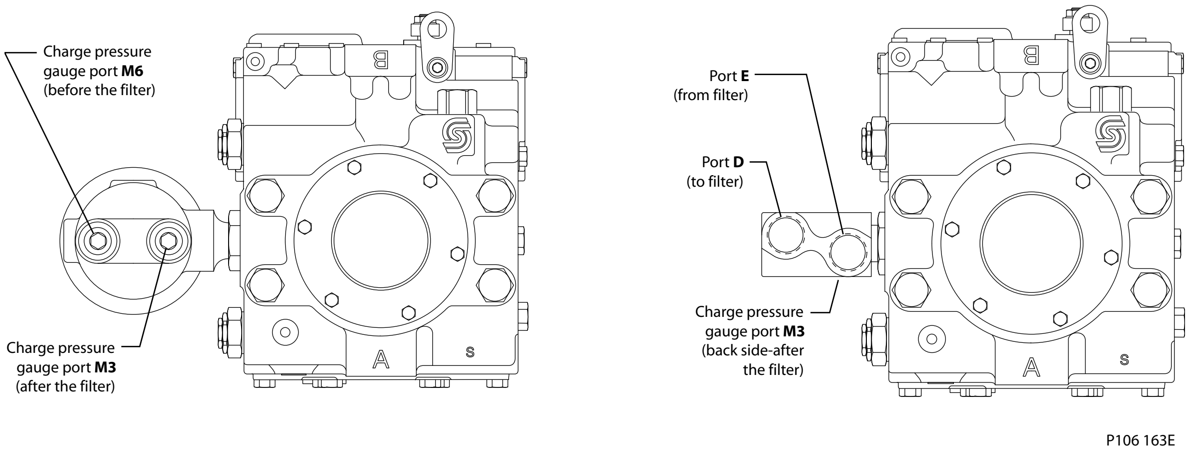
Pump with side port end cap and manual displacement control



Pump with twin port end cap and manual displacement control



Pump with side port end cap and remote pressure filtration / Pump with side port end cap and integral pressure filtration



Overview

This section provides general steps to follow if certain undesirable system conditions occur. Follow the steps in a section until you solve the problem. Some of the items are system specific. For areas covered in this manual, we reference the section. Always observe the *safety precautions* listed in the *Introduction section* and those relating to your specific equipment.

Neutral difficult or impossible to find

Item	Description	Action
Input to pump control	Input to control module is operating improperly.	Check control input and repair or replace as necessary.
Pump displacement control	Control linages are not secure, control orifices are blocked.	Adjust, repair, or replace control module as necessary.
Multifunction valve	Multifunction valve is leaking.	Swap multifunction valves. If system changes direction, replace defective valve.

System operating hot

Item	Description	Action
Oil level in reservoir	Insufficient hydraulic fluid will not meet cooling demands of system.	Fill reservoir to proper level.
Heat exchanger	Heat exchanger is not sufficiently cooling the system.	Check air flow and input air temperature for heat exchanger. Clean, repair, or replace heat exchanger.
Charge pressure	Low charge pressure will overwork system.	Measure charge pressure. Inspect and adjust or replace charge relief valve, or repair leaky charge pump.
Charge pump inlet vacuum	High inlet vacuum will overwork system. A dirty filter will increase the inlet vacuum. Inadequate line size will restrict flow.	Check charge inlet vacuum. If high, inspect inlet filter and replace as necessary. Check for adequate line size, length or other restrictions.
System relief pressure settings	If the system relief settings are too low, the relief valves will be overworked.	Verify settings of pressure limiters and high pressure relief valves and adjust or replace multi-function valves as necessary.
For internal leakage in motor	Leakage will reduce low side system pressure and overwork the system.	Monitor motor case flow without loop flushing in the circuit (use defeat spool). If flow is excessive, replace motor.
System pressure	High system pressure will overheat system.	Measure system pressure. If pressure is high, reduce loads.

Transmission operates normally in one direction only

Item	Description	Action
Input to pump control	Input to control module is operating improperly.	Check control input and repair or replace as necessary.
Pump displacement control	Control linkages are not secure, control orifices are blocked.	Repair or replace control module as necessary.
System pressure limiters, high pressure relief valves, or system check valves	Interchanging the multi-function valves will show if the problem is related to the valve functions contained in the multi-function valves.	Interchange multi-function valves. If the problem changes direction, repair or replace the valve on the side that does not operate.
Charge pressure	If charge pressure decays in one direction, the loop flushing valve may be sticking in one direction.	Measure charge pressure in forward and reverse. If pressure decays in one direction, inspect and repair the motor loop flushing valve.

System will not operate in either direction

Item	Description	Action
Oil level in reservoir	Insufficient hydraulic fluid to supply system loop	Fill reservoir to proper level.
Input to pump control	Input to control module is operating improperly	Check control input and repair replace as necessary.
Pump displacement control	Control linkage is not secure, control orifices are blocked, etc.	Repair or replace control module as necessary.
Bypass valve(s) open	If bypass valve(s) are open, the system loop will be depressurized.	Close bypass valves. Replace multi-function valve if defective.
Charge pressure with pump in neutral	Low charge pressure is insufficient to recharge system loop.	Measure charge pressure with the pump in neutral. If pressure is low, go to Pump charge relief valve; otherwise continue with Charge pressure with pump in stroke.
Charge pressure with pump in stroke	Low charge pressure with the pump in stroke indicates a motor charge relief valve or system pressure relief valve may be improperly set.	Measure charge pressure with pump in stroke. If pressure is low, adjust or replace motor charge relief valve, otherwise go to Charge pumps.
Pump charge relief valve	A pump charge relief valve that is leaky or set too low will depressurize the system.	Adjust or replace pump charge relief valve as necessary.
Charge pump inlet filter	A clogged filter will under supply system loop.	Inspect filter and replace if necessary.
Charge pumps	A malfunctioning charge pump will provide insufficient charge flow.	Repair or replace the charge pump.
Pump displacement control	Control linkages are not secure, control orifices are blocked.	Repair or replace control module as necessary.
System pressure	Low system pressure will not provide power necessary to move load.	Measure system pressure. Continue to next step.
System multi-function valves	Defective multi-function valves will cause system to pressure to be low.	Repair or replace multi-function valve(s).

Low motor output torque

Item	Description	Action
System pressure at motor	Low system pressure at the motor will reduce torque	Measure system pressure at motor. If pressure limiter setting is low, increase setting.
Variable motor stuck at minimum displacement	Minimum motor displacement yields low output torque.	Check control supply pressure or repair displacement control. Check motor control orifices.
Internal leakage	Internal leakage will reduce system pressure.	Check for leaking O-rings, gaskets and other fittings. Repair unit as required, or replace leaking unit.

Improper motor output speed

Item	Description	Action
Oil level in reservoir	Insufficient hydraulic fluid will reduce motor speed.	Fill oil to proper level.
Pump output flow	Incorrect outflow will affect output speed. Incorrect output flow indicates the swashplate is out of position.	Measure pump output and check for proper pump speed. Ensure the pump is in full stroke.
Variable motor displacement control	If variable motor displacement control is not functioning correctly, variable motor swashplate may be in wrong position.	See if variable motor displacement control is responding. If not, repair or replace control.
Internal leakage	Internal leakage will reduce system pressure.	Check for leaking O-rings, gaskets, and other fittings. Repair unit as required, or replace leaky unit.

System noise or vibration

Item	Description	Action
Oil in reservoir	Insufficient hydraulic fluid will lead to cavitation.	Fill reservoir to proper level.
Air in system	Air bubbles will lead to cavitation.	Look for foam in reservoir. Check for leaks on inlet side system loop and repair. Afterwards, let reservoir settle until foam dissipates. Run system at low speed to move system fluid to reservoir. Repeat.
Pump inlet vacuum	High inlet vacuum causes noise. A dirty filter will increase the inlet vacuum.	Inspect and replace filter as necessary. Check for proper suction line size.
Shaft couplings	A loose shaft coupling will cause excessive noise.	Replace loose shaft coupling or replace pump or motor.
Shaft alignment	Misaligned shafts cause noise.	Align shafts.

System response is sluggish

Item	Description	Action
Oil level in reservoir	Insufficient hydraulic fluid causes sluggish response.	Fill reservoir to proper level.
Multi-function valves pressure settings	Incorrect pressure settings affects system reaction time.	Adjust or replace multi-function valves.
Pump inlet vacuum	High pump inlet vacuum reduces system pressure.	Measure charge inlet vacuum. If high, replace inlet filter.
Prime mover speed	Low engine speed reduces system performance.	Adjust engine speed.
Charge and control pressures	Incorrect charge or control pressures affects system performance.	Measure charge and control pressures and correct if necessary.
System internal leakage	Internal leakage reduces system pressure.	Check for leakage in O-rings, gaskets, and other fittings.

Standard procedures, inspections, and adjustments

Before working on the pump, clean the outside of the pump.

Caution

Contamination can damage internal components and void your warranty. Take precautions to ensure system cleanliness when removing and reinstalling system lines.

1. With the prime mover off, thoroughly clean the outside of the pump.
2. If removing the pump, tag each hydraulic line connected to the pump. If hydraulic lines are disconnected, plug each open port with a clean plug, to ensure that dirt and contamination do not get into the pump.
3. Ensure the surrounding areas are clean and free of contaminants.
4. Inspect the system for contamination.
5. Visually inspect the hydraulic fluid for signs of system contamination, fluid discoloration, foam in the fluid, sludge, or small metal particles.
6. If there are signs of contamination in the hydraulic fluid, replace all filters, drain and flush the hydraulic system, and fill with the correct filtered hydraulic fluid.
7. Flush the lines before replacing the hydraulic fluid.

Adjustments

This section offers instruction on inspection and adjustment of pump components. Read through the entire related section before beginning a service activity. Refer to *Pressure measurement* for location of gauge ports and suggested gauge sizes.

Charge pressure relief valve adjustment

The following procedure explains how to check and adjust the charge pressure relief valve.

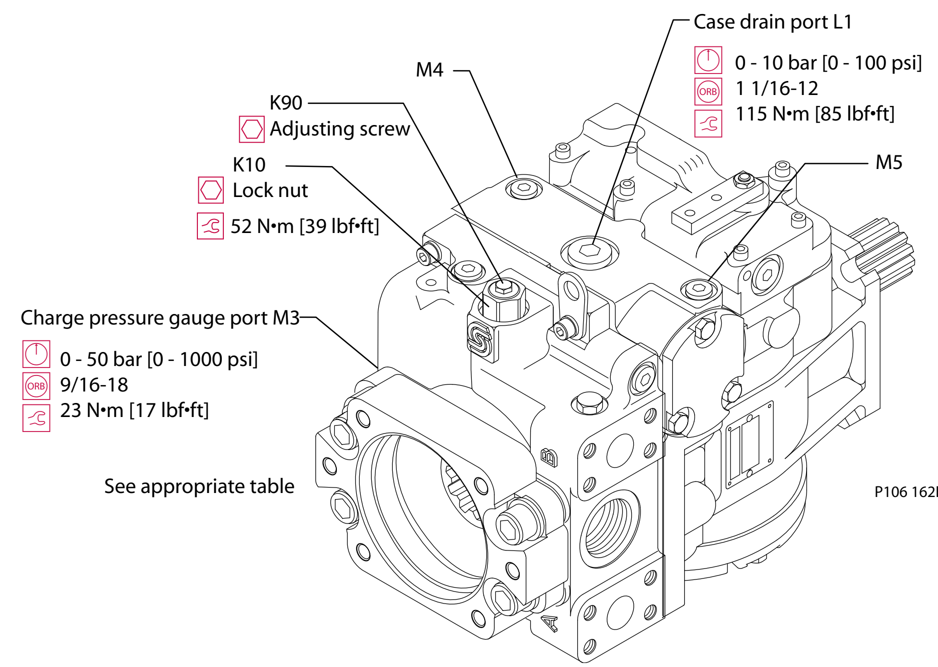
Warning

The following procedure may require the vehicle/machine to be disabled (wheels raised off the ground, work function disconnected, etc.) in order to prevent injury to the technician and bystanders. Take necessary safety precautions before moving the vehicle/machine.

1. Install a 50 bar [1000 psi] pressure gauge in the pump charge pressure gauge port (M3). Install a 10 bar [100 psi] gauge to measure case pressure (tee into L1 or L2 or use servo gauge port M4 or M5). Operate the system with the pump in neutral (zero displacement) when measuring pump charge pressure.

2. The table shows the acceptable pump charge pressure range for some charge relief valve settings. These pressures assume 1500 min^{-1} (rpm) and a reservoir temperature of 50°C [120°F], and are referenced to case pressure.

Charge pressure relief valve



Listed pressures assume a pump speed of 1500 min^{-1} (rpm). At higher pump input speeds (with higher charge flows) the charge pressure will rise over the rated setting.

Charge pressure ranges

Model code	Measured charge pressure*
20	18.1 – 21.7 bar [262 –315 psi]
24	22.0 – 26.9 bar [319 – 390 psi]
28	25.8 – 30.7 bar [37.4 – 44.5 psi]
* This is the actual charge pressure port gauge reading minus the case pressure port gauge reading.	

3. Earlier production pumps have a shim adjustable charge pressure relief valve. Shim kits are available from. Remove the plug using a 1in hex wrench and exchange shims behind the spring to adjust charge pressure. Torque plug to 68 N•m [50 lbf•ft].
4. Later production pumps have an external screw-adjustable charge pressure relief valve. Loosen locknut (K10) and turn the adjusting screw (K90) using a screwdriver or 1/2 in. hex wrench to adjust charge pressure setting.

Lock nut wrench size

Frame size	Wrench size
030 – 100	1-1/16 inch

5. Clockwise rotation of the plug increases the setting and counterclockwise rotation decreases the setting (at a rate of approximately 3.9 bar [50 psi] per turn). Torque lock nut to 52 N•m [39 lbf•ft].

6. Once you achieve the desired charge pressure setting, remove the gauges and plug the ports.

Multi-function valve pressure adjustment

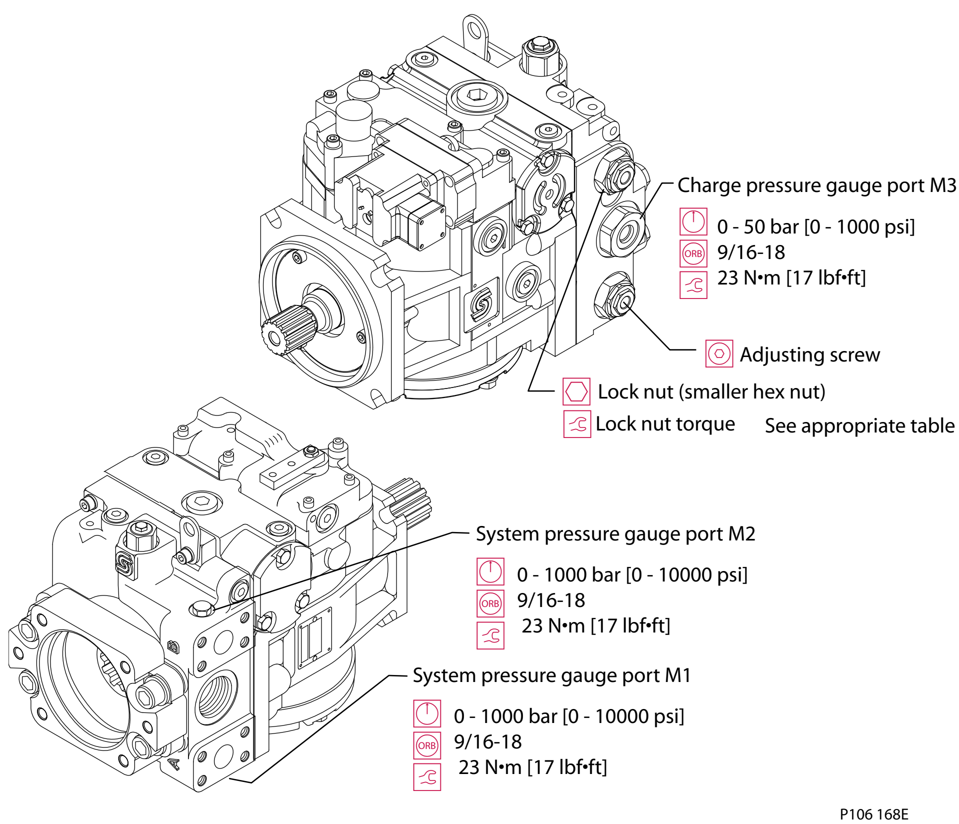
You accomplish adjustment of the pressure limiter setting and the high pressure relief valve (HPRV) setting simultaneously. The HPRV setting is automatically set approximately 35 bar [500 psi] above the pressure limiter setting.

Lock the motor output shaft by locking the vehicle's brakes or rigidly fixing the work function so it cannot rotate or cap the system ports.

Warning

Take necessary precautions that the motor shaft remains stationary during the adjustment procedure.

Multi-function valve adjustment



1. Install two 1000 bar (or 10 000 psi) pressure gauges in the high pressure gauge ports (M1 and M2). Install a 50 bar (or 1000 psi) pressure gauge in the pump charge pressure gauge port (M3).
2. Start the prime mover and operate at normal speed.
3. Loosen locking nut.
4. Insert an internal hex wrench into the pressure adjusting screw.

   A plastic dust plug is installed in the adjusting screw.

5. The model code shows the factory preset pressure limiter setting. It is referenced to charge pressure, so the pressure limiter setting is the difference between the high and low pressure sides of the system loop. Activate or move the control input so that pressure increases in the high pressure side of the closed circuit to the pressure limiter pressure setting. The pressure limiter setting is reached when the pressure stops increasing and remains steady at a given pressure level (as shown on the gauges).

6. Return the pump to its neutral (zero flow) position and adjust the pressure limiter setting by rotating the pressure adjusting screw with an internal hex wrench.

   Clockwise rotation of the pressure adjustment screw increases the pressure setting, and counterclockwise rotation decreases the pressure setting. Each complete rotation of the pressure adjusting screw changes the pressure as shown in the following table.

   Pressure limiter adjustment data

	Lock nut wrench size and torque	Adjusting screw size	Approximate pressure change per revolution of adjusting screw
	19 mm 20 N•m [15 lbf•ft]	5 mm	90 bar [1300 psi]

7. To verify the actual pressure setting, actuate or move the control input so that the pump again develops pressure in the high pressure circuit to the newly adjusted pressure limiter pressure setting: then read the high pressure gauge. Allow the pump to return to its neutral position. The pressure in the high pressure circuit should return to the charge pressure setting.
8. While holding the pressure adjusting screw stationary, tighten the pressure adjusting screw lock nut. Torque as shown in the table.

   Do not overtorque.

9. Shut down the prime mover, remove the gauges and install the gauge port plugs. Replace the plastic dust plugs (if used).

Use the same procedure for setting the pressure limit of the other multi-function valve. Move or activate the control input signal in the opposite direction so that high pressure develops in the opposite side of the closed circuit.

Engaging the bypass function

The multi-function valve cartridges perform the bypass function. Shut down the prime mover when engaging the bypass function. Open both the bypass valves to engage the bypass function.

Caution

Damage to the pump and motor can result from rotating these components without charge flow for lubrication. Bypass valves are intended for moving a machine or vehicle for very short distances at very slow speeds. They are not tow valves.

1. loosen the bypass actuator three turns. Refer to table for wrench size.

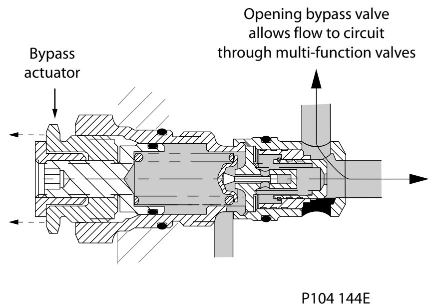
   Do not rotate more than 3-1/2 revolutions, as additional rotation will permit external leakage.

2. For units with an MDC-type control, prior to moving the vehicle or otherwise causing the motor shaft to turn, move the control handle of the manual displacement control on the pump to the maximum full forward position. Hold the handle in this position during bypass valve operation.
3. To close the bypass valve, tighten the bypass actuator. See table provided for proper torque.

Bypass actuator wrench size

Wrench size
1-1/16 inch

Multi-Function Valve with Bypass Function Engaged



Bypass actuator torque

Torque
41 N•m [30 lbf•ft]

Displacement limiter adjustment

You can limit the maximum displacement in either direction.

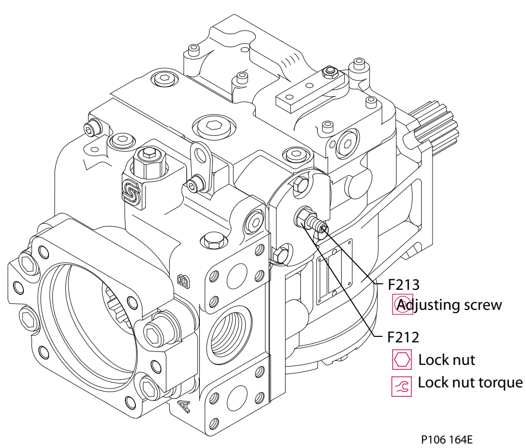
1. Loosen the lock nut (F212) while holding the adjusting screw (F213) steady.
2. Rotate the adjusting screw some amount (using information in the following table). Rotating the adjusting screw clockwise decreases the maximum displacement of the pump while rotating the adjusting screw counterclockwise increases the maximum displacement.

Caution

Take care in adjusting displacement limiters to avoid undesirable flow or speed conditions. Re-torque lock nut (F212) after every adjustment to prevent an unexpected change in operating conditions and to prevent external leakage during unit operation.

3. One turn of the adjusting screw changes the maximum displacement as shown in table below
4. After establishing the desired maximum displacement setting, torque the lock nut to the torque shown in table below.

Displacement limiter adjustment



	Lock nut wrench size and torque	Adjusting screw size	Approximate displacement change per revolution of adjusting screw
	13 mm 24 N•m [18 lbf•ft]	4 mm	3.5 cm^3/(rev) [0.21 in^3/rev]

Standard manual displacement control (MDC) adjustment

There are no adjustable elements in the manual displacement control. Centering springs and washers on each end of the control spool hold it in its neutral position. Since there is no centering spring on the control input shaft, the shaft automatically assumes the appropriate position when the control is installed on the pump.

Non-linear manual displacement control (MDC)

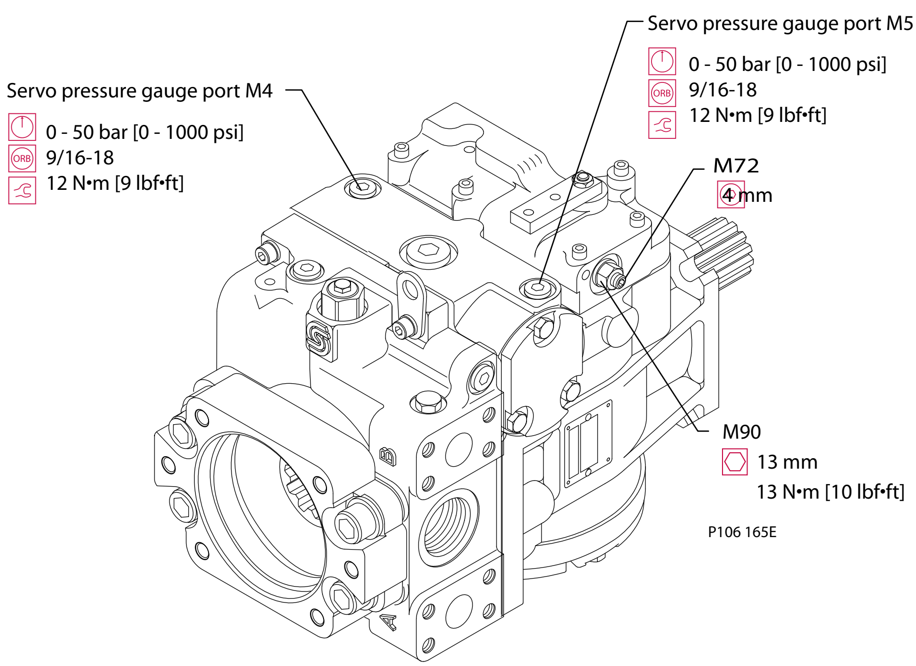
A centering spring, located on the control input shaft, locates the control shaft in its neutral position. A bias spring on the control spool maintains a force on the spool and the control linkage to eliminate free-play in the linkage.

Neutral adjustment is the only adjustment that can be made on the nonlinear manual displacement control. All other functions are preset at the factory. Perform neutral adjustment on a test stand or on the vehicle/machine with the prime mover operating.

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

MDC neutral adjustment



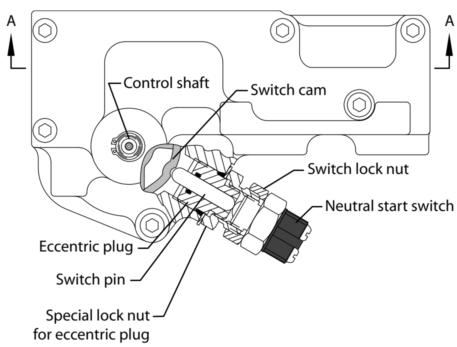
1. Install a 50 bar [1000 psi] gauge in each of the two servo cylinder gauge ports (M4 and M5). Disconnect the external control linkage from the control handle and make certain the control shaft is in its neutral position. Start the prime mover and operate at normal speed.
2. Loosen the lock nut (M90) on the neutral adjusting screw (M72) with a 13 mm hex wrench.
3. Using a 4 mm internal hex wrench, rotate the neutral adjusting screw clockwise until the pressure increases on one of the pressure gauges. Note the angular position of the wrench. Then rotate the adjusting screw counterclockwise until the pressure increases by an equal amount on the other gauge. Note the angular position of the wrench.
4. Rotate the adjusting screw clockwise half the distance between the locations noted above. The gauges should read the same pressure, indicating that the control is in its neutral position.
5. Hold the adjusting screw stationary and tighten the lock nut to 13.5 N•m [10 lbf•ft]. Do not overtorque the nut.
6. Once the neutral position is set, stop the prime mover, remove the gauges, and install the gauge port plugs. Reconnect the external control linkage.

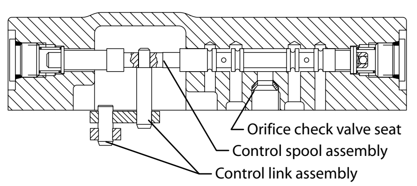
MDC Neutral start switch (NSS) adjustments

The Neutral Start Switch (NSS) provides a means to prevent the system prime mover from starting while the pump control handle is in-stroke. When the control input shaft is in its neutral position, the switch pin engages a slot on the eccentric cam attached to the control shaft. This allows the spring loaded NSS to close, completing the electrical starting circuit for the prime mover. When the control input shaft is not in its neutral position, the eccentric cam opens the NSS switch.

The neutral start switch is threaded into the special lock nut for the eccentric plug. Turning the NSS clockwise (CW) moves the NSS closer to the switch cam on the control shaft, and narrows the NSS deadband. Turning the NSS counterclockwise (CCW) moves the NSS farther from the switch cam on the control shaft, widening the NSS deadband. The switch pin is located in an eccentric plug which is turned to move the center of the NSS deadband.

MDC with neutral start switch / View at section A-A





View A-A P104 146E

Adjust the Neutral Start Switch to meet the following three requirements:

1. The distance you can move the control handle without opening the NSS is the *NSS deadband*. The distance you can move the control handle without moving the control spool enough to port hydraulic fluid to the pump displacement control cylinders is the *control deadband*. These deadbands must be concentric.

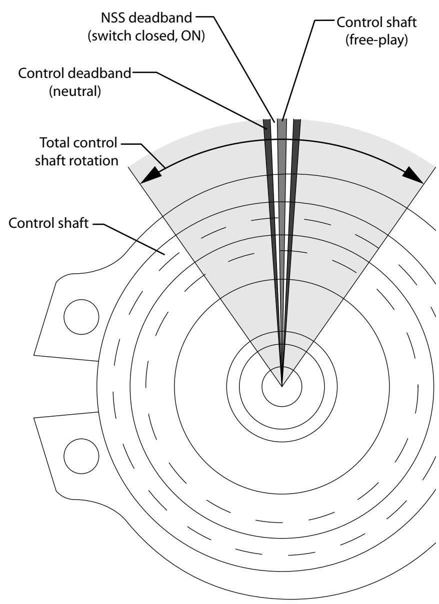
   Since you cannot adjust the position of the control deadband, you must adjust the position of the NSS deadband to match it.

2. The NSS deadband must be wide enough so the NSS will not open within the loose area of control handle movement caused by normal operating clearances in the control linkage (control shaft free-play).

   By setting the NSS to open outside this area, the control spool springs or control shaft centering spring can always return the handle to neutral and re-close the NSS.

3. The NSS deadband must be narrow enough so the NSS will open before the unit builds 7 bar [100 psi] differential system pressure in either direction.

Neutral start switch adjustment requirements

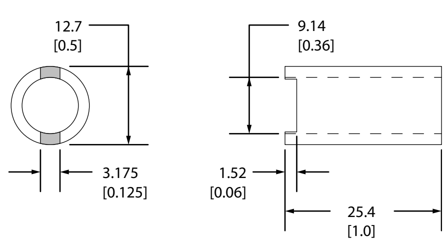


P104 147E

Neutral start switch eccentric plug adjustment (condition i)

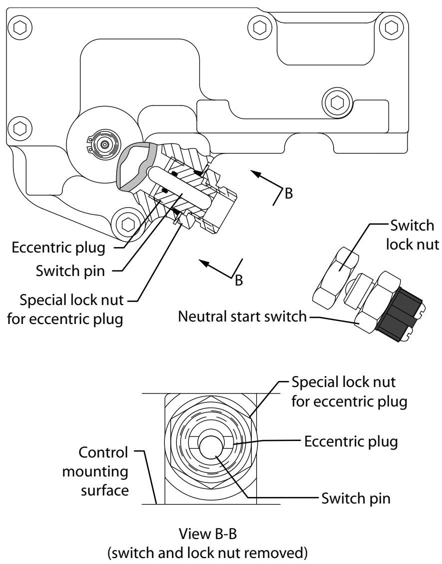
Center the NSS deadband and the control deadband in relation to each other. Since you cannot adjust the position of the control deadband, you must adjust the position of the NSS deadband to match it. The switch pin is located in an eccentric plug which you turn to move the center of the NSS deadband. Ensure the MDC is installed on the pump and in its neutral position when adjusting the neutral start switch eccentric plug. The accompanying drawing provides dimensions for an eccentric plug adjustment tool.

Eccentric plug adjustment tool



P104 149E

NSS with eccentric plug



1. Hold the switch and eccentric plug from turning and use a 1-1/8 inch wrench to loosen the lock nut. Remove the neutral start switch.

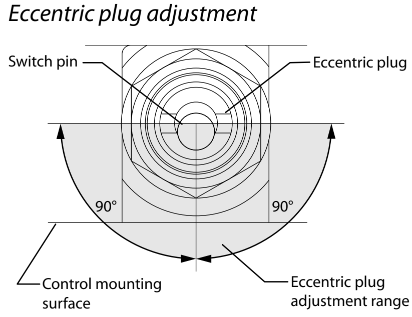
Warning

Do not start the prime mover while the neutral start switch is removed from the control. Case pressure will force the pin out of the eccentric plug, causing oil loss.

2. Note the slots on the eccentric plug for the adjustment tool. Hold the eccentric plug in place with the adjustment tool, and loosen the lock nut with a 1-1/8 inch wrench.
3. Position the eccentric plug so the switch pin is offset toward the control mounting surface. This will provide the best contact between the pin and the cam on the control shaft.
4. Hold the control shaft in its neutral position (in the center of the control shaft free-play area). Locate the switch pin in the slot of the switch cam by turning the eccentric plug while checking the pin position (depth) in the plug. When the pin engages the cam slot, the pin will be at its maximum depth in the plug. Hand tighten the plug lock nut to hold the eccentric plug in position.
5. Turn the control shaft an equal amount in either direction from neutral. The switch pin should move out of the eccentric plug an equal distance when the control shaft is turned. Turn the eccentric plug to center the switch pin with the cam slot. Only a small amount of adjustment in either direction is needed to center the pin.
6. While holding the eccentric plug in place, tighten the eccentric plug lock nut to 27 N•m [20 lbf•ft]. Reinstall and adjust the switch as outlined in the previous section.

The eccentric plug normally requires between 5-1/2 and 6-1/2 turns to install into the control housing.

Eccentric plug adjustment



Caution

Do not turn the eccentric plug into or out of the housing beyond specifications.

7. Once the switch is correctly adjusted, hold the switch in place and tighten the lock nut to 27 N•m [20 lbf•ft] torque.

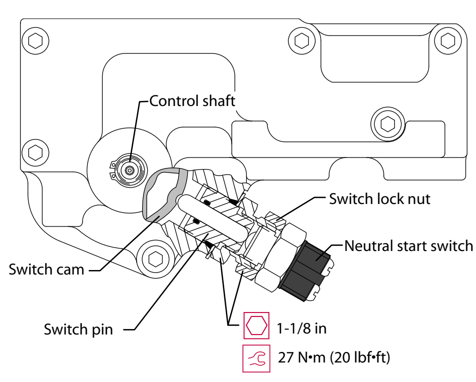
NSS deadband adjustment (conditions ii & iii)

The NSS deadband must be wide enough so the NSS will not open within the control shaft free-play area, and it must be narrow enough so the NSS will open before the unit builds 7 bar (100 psi) differential system pressure in either direction.

1. Install two 1000 bar [10 000 psi] pressure gauges in the system pressure gauge ports M1 and M2.
2. Using two 1-1/8 inch wrenches, hold the neutral start switch from turning and loosen the lock nut.
3. Disconnect the external control linkage and make certain the control shaft is in its neutral position.
4. Attach a continuity checker to the terminals of the switch. With the control shaft in its neutral position, turn the switch clockwise (CW) until the switch opens, then turn the switch counterclockwise (CCW) until it closes. Turn the switch counterclockwise (CCW) an additional 1/4 turn (90°) after the switch closes.
5. Hold the switch in place and tighten the lock nut to 27 N•m (20 lbf•ft) torque.
6. With the continuity checker attached to the switch, rotate the control handle (or the control shaft) in each direction to assure the switch opens when the control is not in the neutral position.
7. If the switch closes in neutral and satisfactorily opens in each direction, proceed to check the switch with the prime mover running. The switch must open before the unit builds 7 bar [100 psi] differential system pressure in either direction.

   If the switch opens after the unit builds system pressure in either direction, loosen the switch lock nut and turn the switch clockwise (CW) 1/12 turn (30°). Tighten the switch lock nut and recheck the switch operation. Repeat this procedure if necessary.
8. If the switch does not open with an equal movement of the control handle in each direction, turn off prime mover, remove the pressure gauges, and continue with the next section.
9. If neutral start switch operation is satisfactory, turn off the prime mover, remove the pressure gauges, and reconnect the external control linkage.

Neutral start switch



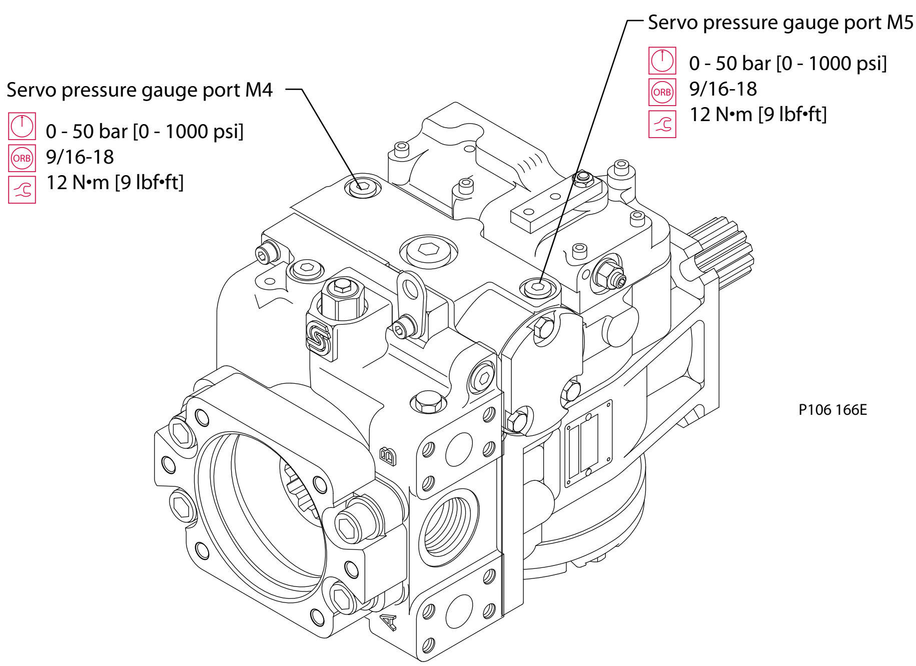
Checking switch continuity

Recheck switch continuity to determine whether additional adjustment of the eccentric plug is necessary.

Warning

The following procedure may require the vehicle/machine to be disabled (wheels raised off the ground, work function disconnected, etc.) while performing the procedure in order to prevent injury to the technician and bystanders. Take necessary safety precautions before moving the vehicle/machine.

Checking switch continuity



1. Install a 50 bar [1000 psi] gauge in each of the two servo cylinder gauge ports (M4 and M5). Attach a continuity checker to the terminals of the neutral start switch.
2. Energize the starter circuit, and start the prime mover.
3. While operating at normal speed and with the pump in its neutral (zero flow) position, note the pressure reading on the gauges. Note this reading as the base pressure.
4. Slowly move the control handle in one direction while observing the pressure gauges and the continuity checker. The switch must open before the pressure on either gauge increases more than 1 bar [15 psi] from the base pressure obtained at neutral.
5. Slowly move the control handle in the opposite direction. Again, The switch must open before the gauge pressure increases more than 1 bar [14.5 psi] from base pressure.
6. Verify continuity again when the control is returned to neutral.
7. If the switch does not open at base pressure plus 0 to 1 bar [0 to 14.5 psi] in either direction, stop the prime mover and readjust the eccentric plug as described in the previous section. If the pressure difference is equal in each direction but greater than 1 bar [14.5 psi], loosen the switch lock nut and turn the switch clockwise 1/12 turn (30°) to increase the sensitivity. Retighten the lock nut and recheck pressure differences and continuity.
8. After verifying proper control and switch operation, stop the prime mover. Remove the continuity checker and pressure gauges. Reinstall the servo pressure port plugs and reconnect the electrical leads from the machine starter circuit to the NSS. Install and adjust, the external control linkage if necessary.

Speed sensor adjustment

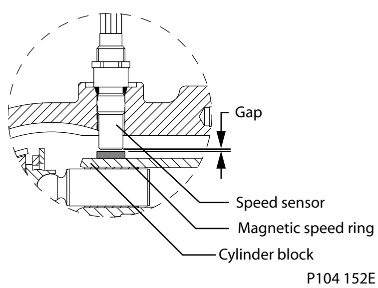
When installing or adjusting the speed sensor on a pump, it must be set at a specific distance from the speed ring on the unit's cylinder. To locate the position of the speed sensor on the unit or description see the corresponding section.

1. Loosen the sensor lock nut with an 11/16 inch hex wrench.
2. Turn the sensor clockwise (CW) by hand until it contacts the speed ring.
3. Turn the sensor counterclockwise (CCW) 1/2 turn (180°) to establish the nominal gap of 0.71 mm [0.028 inch].
4. Then turn the sensor clockwise (CW) until the wrench flats on sensor body are positioned at a 22° angle to the pump shaft center line.

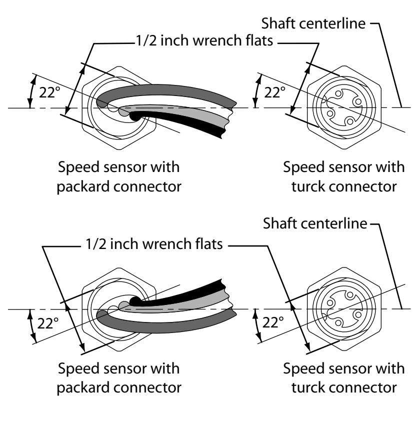
   Most open-end wrenches have a 22° handle offset.

5. The final sensor position should be between 1/2 (180°) and 1/4 turn (90°) counterclockwise (CCW) from the point where the sensor contacts the speed ring.
6. Hold sensor in position with a 1/2 inch hex wrench while tightening the lock nut to 13 N•m [10 lbf•ft].

Cross section view of speed sensor in variable pump



Positioning speed sensor relative to pump shaft



Standard procedures

Removing the pump

Before working on the pump, clean the outside of the pump. If the pump has an auxiliary pump attached, remove both pumps as a single unit. Tag and cap all hydraulic lines as they are disconnected and plug all open ports to ensure that contamination does not enter the system.

Caution

Contamination can damage internal components and void your warranty. Take precautions to ensure system cleanliness when removing and reinstalling system lines

Disassembly

1. With the prime mover off, thoroughly clean the outside of the pump.
2. Tag, cap, and disconnect each hydraulic line connected to the pump. As hydraulic lines are disconnected, plug each open port, to ensure that dirt and contamination do not enter the system.
3. Remove the pump and its auxiliary pump (if applicable) as a single unit.

Inspection

1. Ensure the work surface and surrounding area are clean and free of contaminants.
2. Inspect the system for contamination.
3. Look at the hydraulic fluid for signs of system contamination, fluid discoloration, foam, sludge, or small metal particles.

Reassembly

1. Before replacing the pump on the machine, replace all filters and drain and fill the hydraulic system with the correct hydraulic fluid.
2. Flush the lines before replacing the hydraulic fluid.

Shaft seal and shaft replacement

You can replace the shaft and seal without major disassembly of the unit. Clean pump and surrounding area thoroughly. Disconnect and remove the pump from the unit, and clean it thoroughly before starting repairs. Mark all connections for later reassembly.

Shaft removal

1. Position the pump with the shaft facing up.

   If the unit is positioned horizontally, or moved or jarred while the shaft is out, the cylinder block could move out of place, making shaft installation difficult.

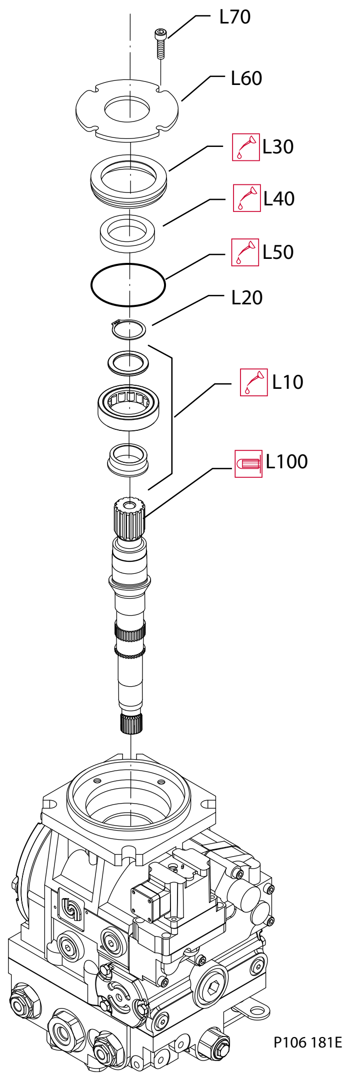
2. Remove the three or four screws (L70) holding the retainer plate (L60) and seal carrier (L30) to the housing, using a 10 mm hex wrench (042 unit), a 5 mm internal hex wrench (055 through 100 units), or a 6 mm internal hex wrench (130 through 250 units). Remove the retainer plate.

   Certain earlier production units use a one piece retainer plate and seal carrier.

3. After removing the screws, the spring force on the shaft may move the seal carrier out of its bore by approximately 5 mm [1/4 inch]. If the seal carrier does not move from its bore, pry it from its bore and/or lightly tap the end of the shaft with a soft mallet.
4. Remove the O-ring (L50) from the seal carrier and discard.
5. Place seal carrier and seal in an arbor press and press out the seal (L40).

6. Remove shaft (L100) and roller bearing assembly (L10) from pump. You can transfer the bearing assembly to the new shaft.
7. Using snap-ring pliers, remove the retaining ring (L20) that secures the roller bearing assembly. Remove the roller bearing assembly.

Shaft assembly



Inspection

1. Inspect the seal carrier, the new seal and the O-ring for any damage or nicks.
2. Inspect the shaft and bearing for rust, wear, or contamination. Spin the bearing in your hand feeling for roughness. Replace if necessary.

Reassembly

1. Using the arbor press, press the new seal (L40) into seal carrier (L30). Be careful not to damage the seal.

   If the shaft is not being replaced proceed to step 3.

2. Place roller bearing assembly on new shaft and secure with the retaining ring.
3. Install an installation sleeve or wrap spline or keyed end of shaft with plastic film to prevent damage to the sealing lip on the seal during installation.

4. Lubricate and install a new O-ring (L50) on the seal carrier. Lubricate the seal with clean petroleum jelly.
5. Assemble the seal carrier and seal over the shaft and into the housing bore. Install the retainer plate (if used).
6. Install the screws and torque to the appropriate value in the table to the right.

Torque the screws in a sequenced pattern then recheck.

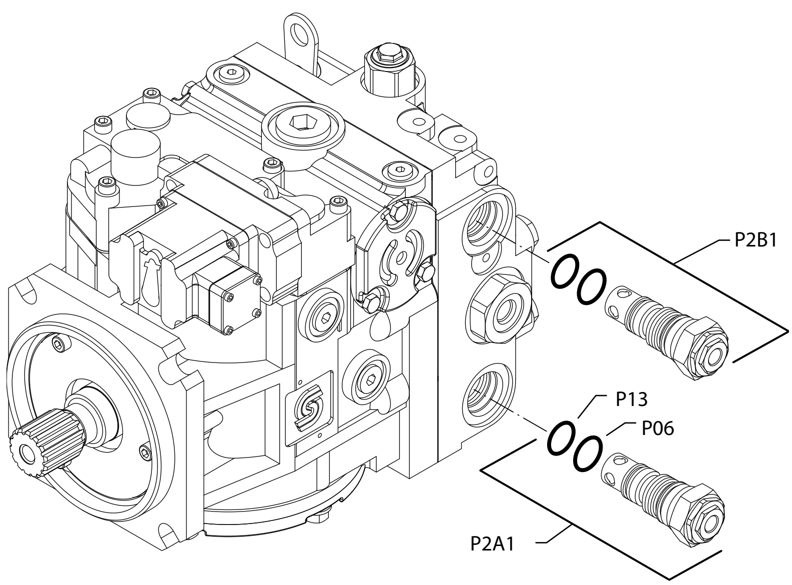
Shaft retainer screw torque

Torque
12 N•m [9 lbf•ft]

Multi-function valve cartridges

Older multifunction valves (pre 1988) contain different components. See *multifunction valves - Pre 1988* for disassembly instructions.

Multi-function valve removal / installation



Removal

1. Remove multi-function valves (P2A1 and P2B1) using hex wrench listed in table.

Multi-function valve wrench size

Wrench size
1-1/4 inch

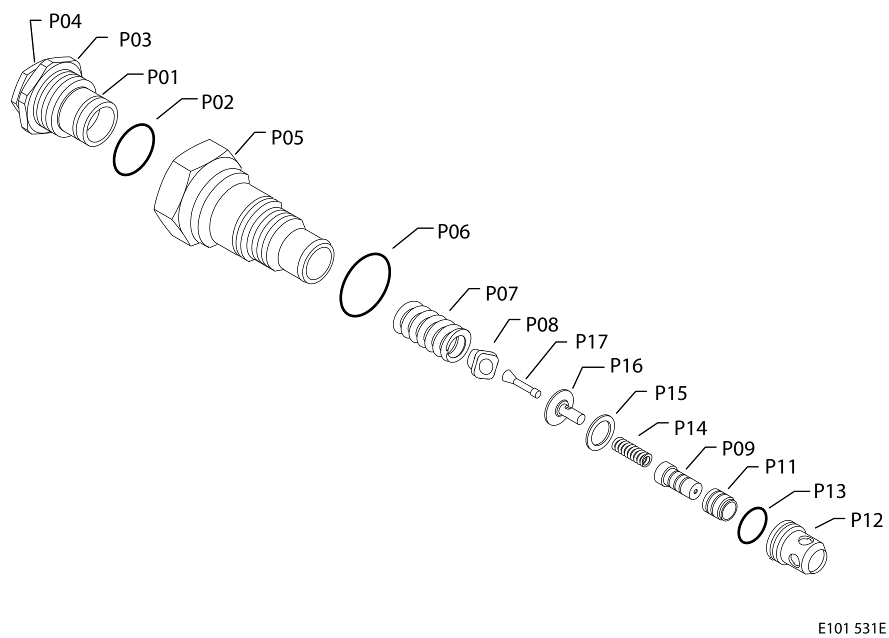
2. Remove and discard O-rings (P13 and P06).
3. Relieve spring pressure by removing bypass actuator (P03), using a 1-1/16 wrench. To retain pressure setting, do not separate adjusting screw (P01), and locknut (P04) from bypass actuator (P03).

4. Remove and discard O-ring (P02).

Multi-function valves are sold as complete units only. You may purchase O-rings separately.

5. The poppet seat section is pressed over a lip. Place the cartridge in a vise and pry the poppet seat (P12) off with an appropriate tool. Maintain sufficient control to prevent the internal components from flying loose. Do not damage parts during disassembly.
6. Remove internal parts (P07, P08, P17, P16, P15, P14, P09, and P11).

Multi-function valve



Inspection

Context for the current task

Clean and inspect all disassembled parts.

Reassembly

1. Lubricate and install internal components (P07, P08, P17, P16, P15, P14, P09, P11, and P12).
2. Place the cartridge in a vise and press on the poppet seat (P12).
3. Lubricate and install new O-rings (P02, P06, P13).
4. Install bypass actuator (P03) with pressure limiter valve (P01). Torque to 40 N•m [30 lbf•ft]

Caution

If pressure limiter (P01) was removed from bypass actuator (P03), adjust pressure limiter to model code specifications.

5. Install cartridges and torque as shown in the table.

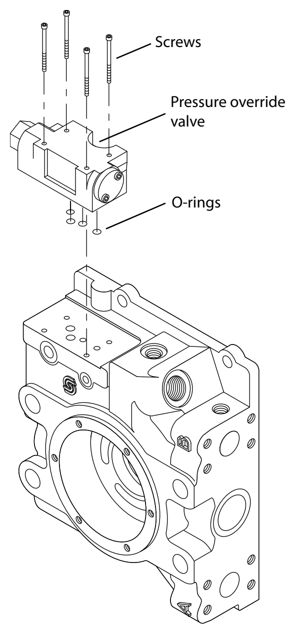
Caution

Do not overtorque the multi-function valve cartridges

Multi-function valve torque

Torque
89 N•m [66 lbf•ft]

Pressure override valve components



Charge pressure relief valve

The charge pressure relief valve is screw adjustable . Screw adjustable charge relief valve is shown.

Removal

1. Remove the shim adjustable charge relief valve plug with a 1 inch hex wrench.

   Before removing the screw adjustable relief valve plug, mark the plug (K90), lock nut (K10), and housing to approximately maintain the original adjustment when assembling. Remove the screw adjustable charge relief valve plug by loosening the lock nut with a hex wrench corresponding to the table.

   Lock nut wrench size

Wrench size
1-1/16 inch

   Unscrew the plug using a large screwdriver or 1/2 inch hex wrench. Remove and discard the O-ring (K50).

2. Remove the spring (K70) and relief valve poppet (K80).

Inspection

Inspect the poppet (K80) and mating seat in the endcap for damage or foreign material.

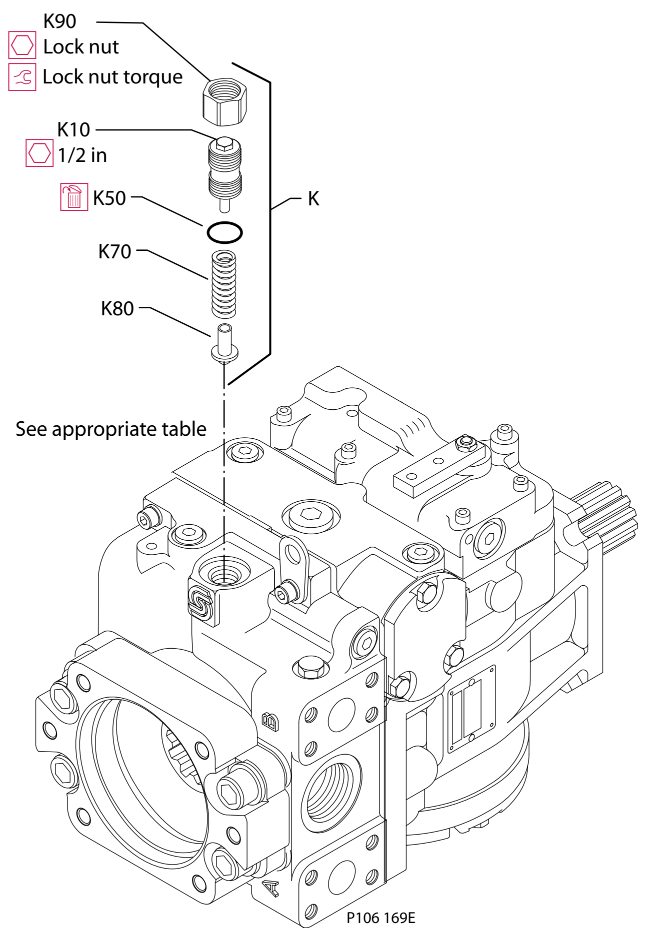
When inspecting shim adjustable valves, do not alter the shims or interchange parts.

Reassembly

Install the poppet (K80) and spring (K70). For shim adjustable valves, install the shims and plug, torque to 68 N•m [50 lbf•ft]. For screw adjustable valves, install the plug with its lock nut, aligning the marks made at disassembly, and torque the lock nut to 52 N•m [38 lbf•ft].

Check the charge pressure and adjust, if necessary. Refer to Charge pressure adjustments.

Charge pressure relief valve



Adding an Auxiliary pad to a pump previously without one

1. If installing an auxiliary pad kit on a pump that was previously without one, remove the existing cover and carefully remove the alignment pin from the charge pump parts.
2. Install the pin in its hole in the new charge pump cover (which has a hole for the auxiliary coupling) and retain with petroleum jelly.

   The alignment pin runs through the charge pump parts to keep them in proper alignment.

3. Install the new charge pump cover with the alignment pin pushed through the aligned charge pump parts.Torque the screws per the instructions in the following *Charge pump* topic.
4. Lubricate and install the O-ring. Install the auxiliary pad. Refer to the following *Auxiliary pad*, and *Charge pump* topics for instructions.

Auxiliary pad

Removal

1. Remove the four end cap screws (J80). Remove and discard special washers (J70).

Caution

On earlier production frame size 75 pumps with twin ports, secure the end cap to the pump housing with a clamp to avoid gasket damage.

2. Remove the auxiliary pad (J60) and discard the O-rings (J50 and J90).

Aux. pad screw wrench size

Wrench sizes
10 mm internal hex

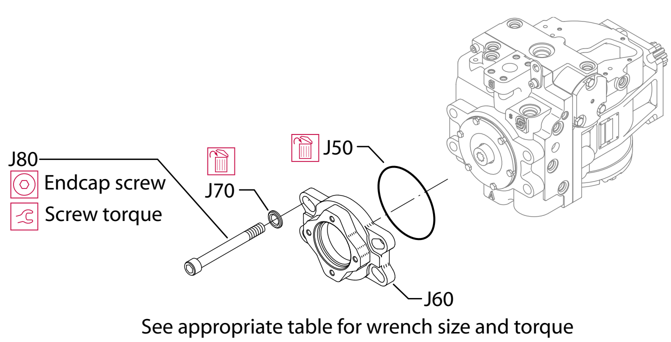
Inspection

1. Inspect the auxiliary pad for damage and replace if any damage is found.
2. Take care to assure the surfaces are clean and free of any foreign material or paint prior to installing the auxiliary pad.

Caution

Do not allow the force of the cylinder block spring and swashplate leveler springs to separate the end cap from the pump housing. Gasket damage and external leakage may result.

Auxiliary pad components (typical)



Reassembly

1. Lubricate and install O-ring (J50) on end cap pilot.
2. Install the auxiliary mounting pad (J60) on rear of endcap.
3. Install four large screws (J80) and new washers (J70) through the mounting pad and end cap into the housing. Torque per the accompanying table.

Torque endcap screws in a criss-cross pattern

End cap screw torque

Torque
75 N•m [55 lbf•ft]

Charge pump

The following procedure shows how to remove and install a charge pump.

Removal

1. For pumps with an auxiliary mounting pad, refer to the *Auxiliary Pad instructions*.

Caution

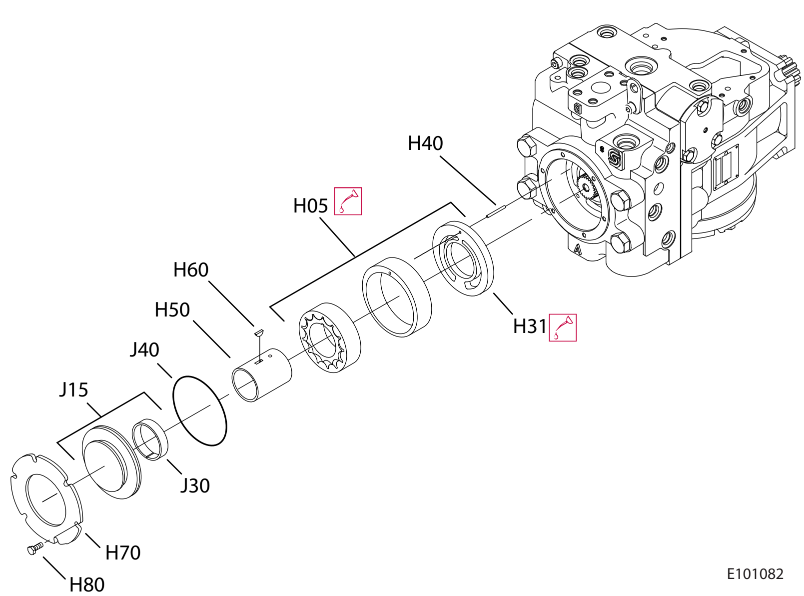
On earlier production frame size 75 pumps with twin ports, secure the endcap to the pump housing with a clamp to avoid gasket damage.

2. Remove the six screws (H80) holding the charge pump cover retainer (H70).
3. Remove the retainer (H70) and the charge pump cover (J15). Remove and discard O-ring (J40). Note the orientation of the gerotor assembly (H05).

Retainer screw wrench size

Wrench size
10 mm

Current charge pump configuration



4. Remove the charge pump coupling (H50) and charge pump drive key (H60).
5. Remove the charge pump gerotor assembly (H05).
6. Remove the alignment pin (H40).
7. Remove the inner port plate (H31).

Inspection

Inspect all parts for abnormal wear or damage and replace if necessary.

If installing a different displacement charge pump, the gerotor assembly, gerotor outer eccentric ring, and inner port plate (early and late production pumps) or outer spacer plate(s) (intermediate production pumps) must be replaced together. If different thickness port plates are used in an early production charge pump assembly, the thicker plate is the inner port plate (installed next to the pump end cap).

Different production charge pump assemblies include a different quantity / type of port plates and spacer plates.

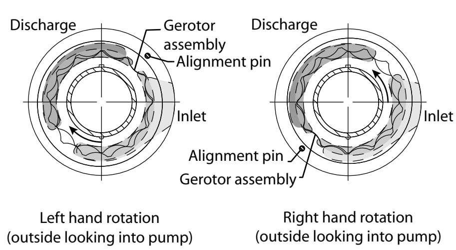
Reassembly

Be sure to install the charge pump in the proper orientation. If unsure of charge pump rotation, refer to the model code.

The orientation of the gerotor assembly outer eccentric ring and the location of the alignment pin in the end cap determine the charge pump rotation..

Do not mix charge pump parts from different production periods. Always install as a complete assembly.

Orienting alignment pin



1. Install the inner port plate (H31) and the gerotor assembly outer ring.
2. Install the alignment pin (H40) to properly orient the port plates and outer eccentric ring for corresponding pump rotation.
3. Prior to installation, lubricate the I.D., O.D., and side faces of the gerotor assembly.
4. Install the gerotor assembly (H05).
5. Install the outer port plate (early production and intermediate production pumps only).
6. Install the spacer plate, if present (intermediate production pumps).
7. Install the charge pump drive key (H60) into the charge pump coupling (H50) and retain with petroleum jelly.

   Intermediate production 75 cm^3 and 100 cm^3 pumps use the same charge pump coupling. Two keyways are provided in the coupling for the charge pumps used in these units. The rear keyway (with identifier groove) is used in 75 cm^3 pumps. The front keyway (closest to the internally splined end of the shaft) is used in 100 cm^3 pumps.

8. Install the charge pump coupling. The internally splined end of the coupling must engage the main pump shaft.

   The outside diameter of the internally splined end of some early production charge pump couplings were chamfered. Early production end caps may not be machined to accept a non-chamfered coupling. Always use a chamfered charge pump coupling in pumps with the early endcap.

9. For pumps with an auxiliary mounting pad, install the auxiliary drive coupling.
10. For pumps with no auxiliary pad, install a new O-ring (J40) onto charge pump cover. (If an auxiliary pad is installed, an O-ring is not used on the cover.)
11. Carefully remove the alignment pin from the charge pump parts. Install the pin in its hole in the charge pump cover (J15) (see previous page for correct orientation) and retain with petroleum jelly. Install the cover (with alignment pin) into the end cap and aligned charge pump parts. (Take care not to damage the cover O-ring, if used.)

   Caution

   In order to avoid loss of charge pressure in pumps with an auxiliary mounting pad, always install the charge pump cover with the pad drain hole located on the same side of the end cap as the charge inlet port. Refer to the section "Auxiliary Pad Installation" for details.

12. Install the charge pump cover retainer (H70) and the six internal hex screws (H80). Torque the screws per the table at the right..

Retainer screw torque

Torque
16 N•m [11.85 lbf•ft]

13. For pumps with auxiliary mounting pads, install the O-ring and auxiliary mounting pad adaptor onto the end cap. Refer to the corresponding section for instructions on auxiliary pad installation.

Integral charge pressure filter replacement

Removal

1. Remove the filter canister (N40) from the filter head (N10) as described on the canister.
2. Hold the filter head in place and loosen the lock nut (N20) using the wrench size corresponding to pump frame size.
3. Rotate the filter head counterclockwise to remove it from the housing. Remove and discard the O-ring (N15).
4. Remove the hydraulic tube (N25) from its bore in the endcap.

Lock nut wrench size and torque

Wrench size	Torque
1-3/8 inch	70 N•m [52 lbf•ft]

Inspection

Inspect the filter head and lock nut sealing surfaces. If you find any nicks or scratches, replace the damaged components.

Reassembly

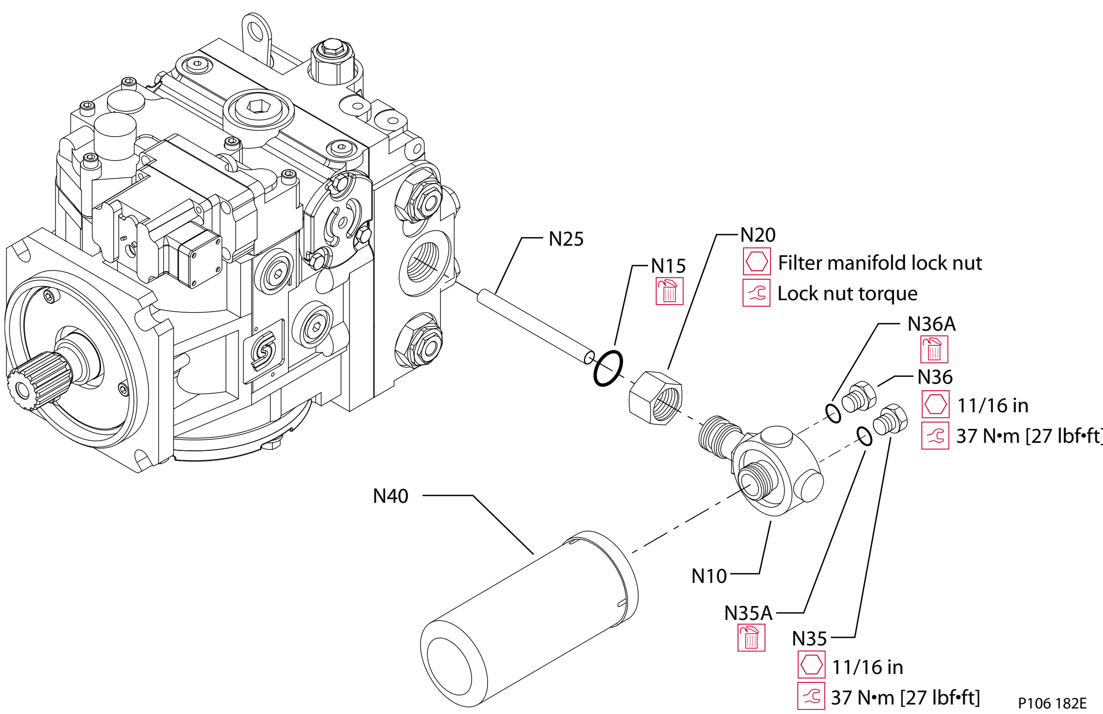
1. Install the hydraulic tube (N25) into it's bore in the endcap. Install the filter head (N10) into the port using a new O-ring (N15). The hydraulic tube should go in with low force.
2. After rotating the filter head clockwise so that the threads engage with the threads in the endcap, continue to rotate it clockwise between 6 and 7 revolutions. Position head as desired.

Caution

Failure to install the filter manifold or filter head to a sufficient depth in the end cap will result in insufficient engagement of the tube in the end cap bore. This may allow unfiltered oil to bypass the filter and enter the charge system.

3. While holding the filter head in the desired position, tighten the swivel lock nut (N20) and torque as shown in table.
4. Install a new filter canister (N40) per the instructions on the filter canister.

Integral charge pressure filter



Pump control cover plate

Removal

1. Thoroughly clean external surfaces prior to removal of cover plate.

2. Using a 5 mm internal hex wrench, remove the six cover plate mounting screws (M90). Remove the cover plate (M1) and gasket (M11) from housing. Discard the gasket.

Caution

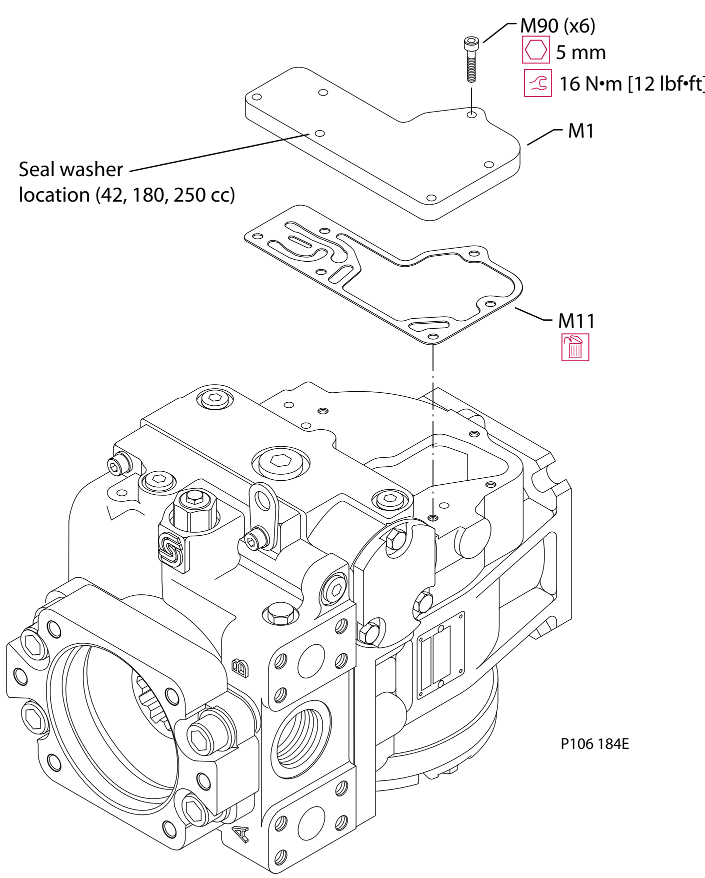
Protect exposed surfaces and cavities from damage and foreign material.

Reassembly

Install a new gasket on the housing. Install the cover plate and install the screws. Torque the screws to 16 N•m [12 lbf•ft].

Install a sealing washer under the head of any mounting screws that are installed into through holes in the housing.

Pump controls cover plate

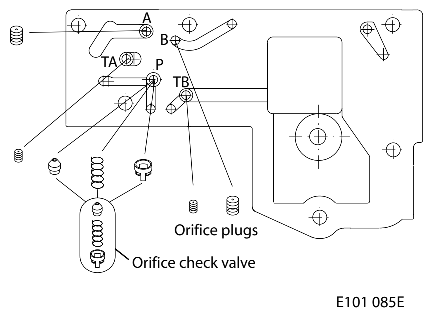


Displacement control orifices

1. Remove the control assembly as described in the instructions for the specific displacement control.
2. Orifice plugs may be located in the control assembly, at the pump housing face. Remove the orifice plugs one at a time (to avoid mixing them up) with a 4mm internal hex wrench. Note the location of each plug, do not interchange plugs. Clean, reinstall, and torque the orifice plugs to 3N•m [2lbf•ft].

3. Assemble the control onto the pump. Refer to the instructions for the specific control.

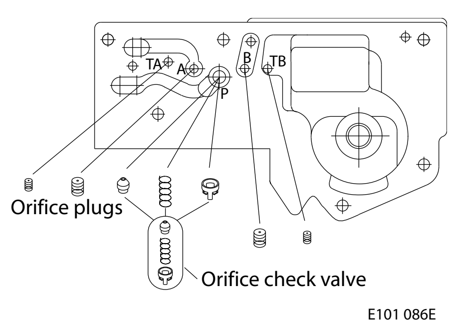
Underside of an HDC/EDC module showing orifice locations



Displacement control orifice check valve

1. Remove the control assembly as described in the instructions for the specific displacement control.
2. The orifice check valve is located in the control assembly, at the surface of the pump housing face. Remove the spring retainer and spring from the orifice check valve cavity and then remove the orifice check valve.
3. Clean and install the orifice check valve in the cavity and then install the spring and spring retainer to hold the orifice check valve in position.
4. Assemble the control onto the pump. Refer to the instructions for the specific control.

Underside of an MDC module showing orifice locations



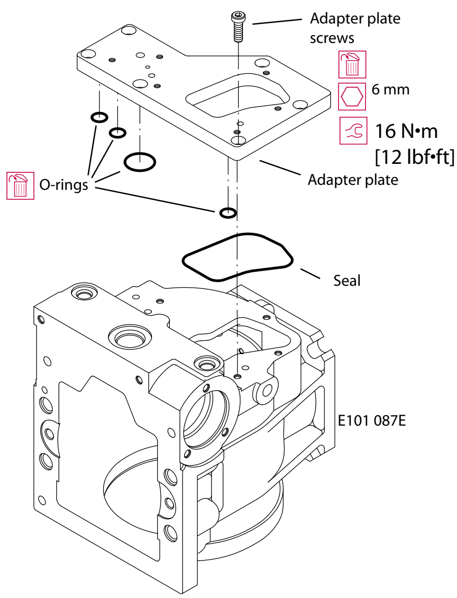
Displacement control adapter plate (early production 130 pumps only)

Do not remove the adapter plate unless leakage is evident. The mounting screws with sealing compound are difficult to remove.

The screws fastening the control adapter plate to the housing have sealing compound on the threads. You may remove them with a 6 mm internal hex wrench if necessary. Remove and discard the O-rings and seals.

When installing the adapter plate, replace screws (with sealing compound), and ensure the new O-rings and seal are in the proper position. Torque the screws to 32 N•m [24 lbf•ft].

Displacement control adapter plate (early production 130 cm^3 pumps only)



Manual displacement control (MDC)

Removal

1. Thoroughly clean external surfaces prior to removal of control.
2. Using a 5 mm internal hex wrench, remove the six control mounting screws (M90). Remove the control (M1) (with orifice check valve (T40) and spring (T30)) and control gasket (M11) from the housing. Discard the gasket.

If necessary, remove the control handle (M70) by removing the locking nut (M72) and washer (M71).

Caution

Protect exposed surfaces and cavities from damage and foreign material.

Reassembly

1. Install a new gasket (M11). Inspect control to assure that the control orifice check valve and spring are in their proper position in the control.
2. Install the control. Engage the pin on the control linkage into the mating hole in the link attached to the swashplate.
3. With the control in position, move control lever both directions to check proper engagement of control linkage pin. If properly assembled, lever will return to center. If lever does not return to center, remove the control and repeat the above procedure.

   If removed, install the control handle (M70) and locking nut (M72) with washer (M71). Hold the position of the handle and torque the locking nut to 13.5 N•m [10 lbf•ft] using an 8mm hex wrench.

4. Align the control gasket and install the screws. Torque the screws to 16 N•m [12 lbf•ft].

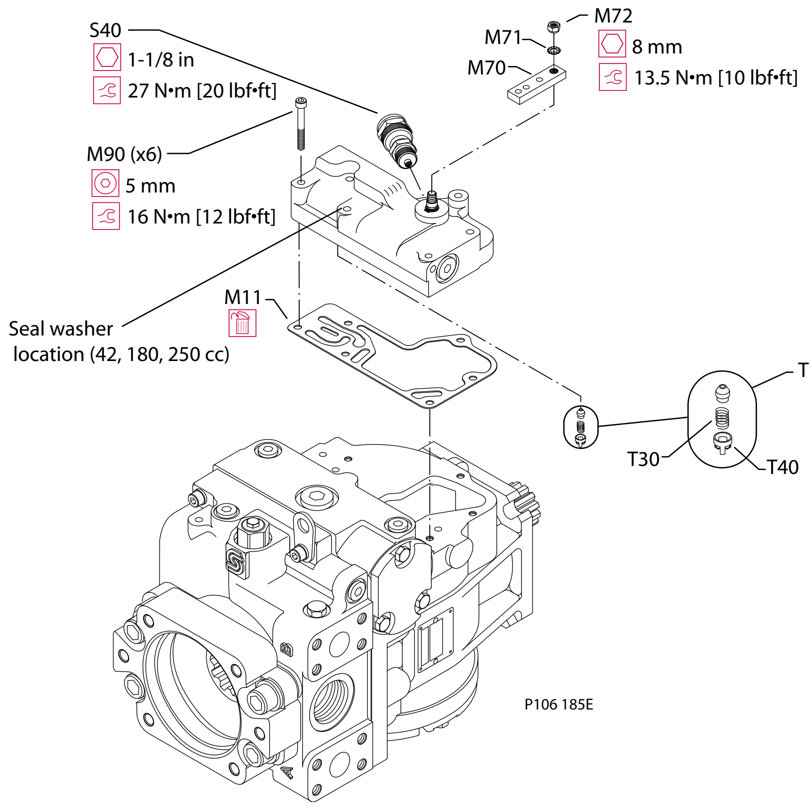
Warning

The neutral start switch neutral must be readjusted after reassembling the MDC module.

Install a sealing washer under the head of mounting screws that are installed into through holes in the housing.

5. If the control is equipped with a neutral start switch, refer to MDC Neutral start switch adjustment instructions.

MDC removal/installation



Solenoid override valve for MDC

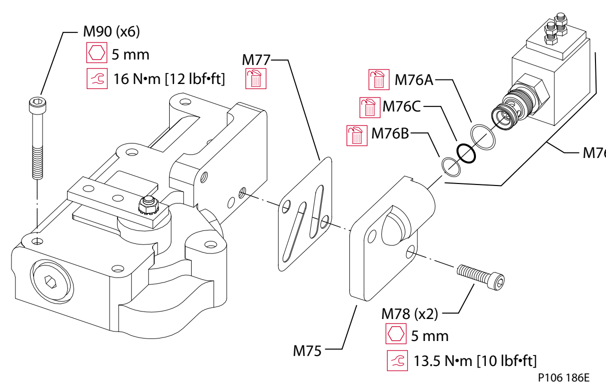
Removal

1. Thoroughly clean external surfaces prior to removal of valve.
2. Remove the solenoid from the valve by removing the nut with a 3/4 inch hex wrench. Remove the solenoid valve (M76) from the manifold (M75) with a 7/8 inch hex wrench.
3. Using a 5 mm internal hex wrench, remove the two screws (M78) and remove solenoid manifold (M75) from housing. Remove and discard the gasket (M77).

Reassembly

1. Torque valve (M76) to 24 N•m [17.7 lbf•ft]. Torque solenoid nut to 6 N•m [5 lbf•ft]. Do not overtorque the solenoid nut.
2. Install a new gasket on the control housing. Install the manifold onto the control housing, align the gasket, and install the screws. Torque the screws to 13.5 N•m [10 lbf•ft].

Solenoid override valve removal/installation



Solenoid override valve for MDC with pressure released brake

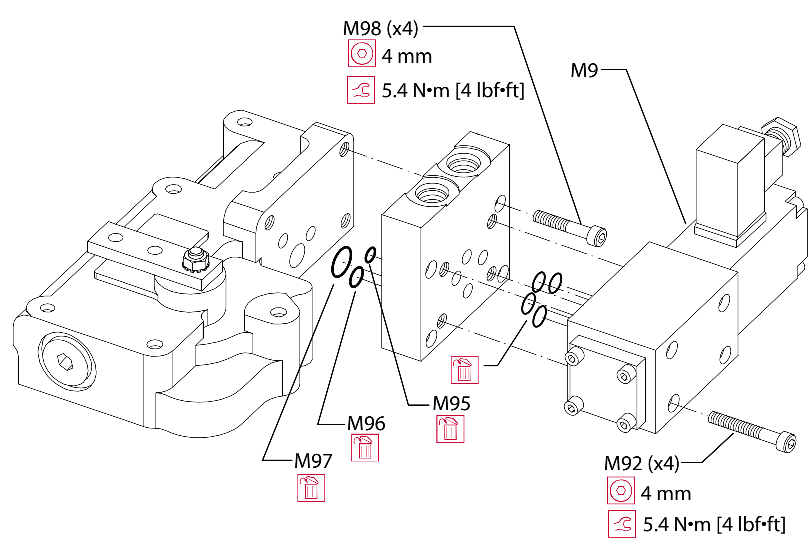
Removal

1. Thoroughly clean external surfaces prior to removal of valve.
2. Using a 4 mm internal hex wrench, remove the four solenoid valve mounting screws (M92). Remove the solenoid valve (M9) (with O-rings) from the adapter plate. Discard the O-rings.
3. Using a 4 mm internal hex wrench, remove the four adapter plate mounting screws (M98). Remove the adapter plate and O-rings (M95, M96, and M97) from the control housing. Discard the O-rings.

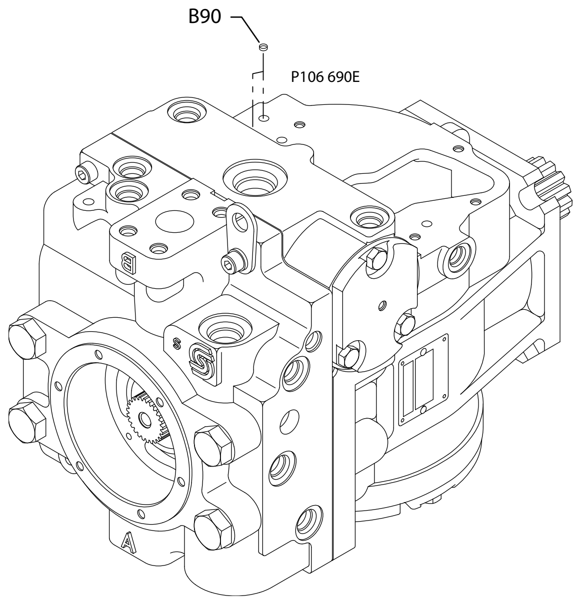
Reassembly

1. Using petroleum jelly to retain them, install new O-rings (M96, M96, M97) on the adapter plate. Place the adapter plate into position and install the screws (M98). Torque the screws to 5.4 N•m [4 lbf•ft].
2. Using petroleum jelly to retain them, install new O-rings onto the solenoid valve assembly (M9) and install the solenoid valve onto the adapter plate. Install the screws (M92) and torque to 4 N•m [4 lbf•ft].

Solenoid override valve removal/installation



Filter screen installation



Speed sensor

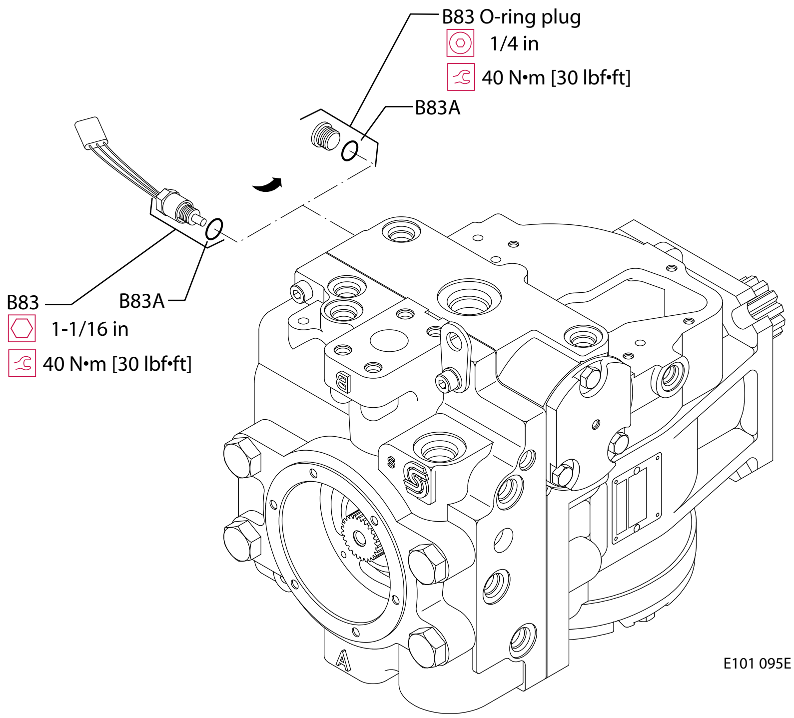
Removal

1. Loosen the lock nut using a 11/16 in hex wrench.
2. Unscrew the speed sensor (B83) from the pump housing. Remove and discard the O-ring (B83A).

Reassembly

1. Install a new O-ring before reinstalling the sensor.
2. Reinstall the speed sensor (with lock nut and O-ring) into the housing. Adjust the gap between the sensor and the magnetic speed ring as instructed in Speed sensor adjustment (page 46) and torque the sensor lock nut to 13 N•m [10 lbf•ft].
3. If a speed sensor is not installed, use a 1/4 in internal hex wrench to torque the housing plug (B83) to 40 N•m [30 lbf•ft].

Typical location of speed sensor



Fastener size and torque chart

Item	Fastener	Frame size	Wrench size	Torque
B83	Speed sensor lock nut	030-250	1-1/16 in hex	13.5 N•m [10 lbf•ft]
E60	Side cover screw Blind holes	030-042	10 mm hex	13.5 N•m [10 lbf•ft]
		055-100	13 mm hex	32 N•m [24 lbf•ft]
		130-250	17 mm hex	64 N•m [37 lbf•ft]
E60	Side cover screw Thru holes	030-042	10 mm hex	10.4 N•m [7.7 lbf•ft]
		055-100	13 mm hex	32 N•m [24 lbf•ft]
		130-250	17 mm hex	32 N•m [47 lbf•ft]
F111/ F211	Servo cylinder screw	030-055	8 mm hex	13.5 N•m [10 lbf•ft]
		075-250	10 mm hex	32.5 N•m [24 lbf•ft]
G90/G9 7	End cap screw	030-042	5 mm internal hex	13.5 N•m [10 lbf•ft]
		055-100	6 mm internal hex	32.4 N•m [24 lbf•ft]
		130	10 mm hex	38 N•m [28 lbf•ft]
		180-250	10 mm hex	110 N•m [81 lbf•ft]
H80	Charge pump retaining screw	030-100	10 mm hex	16 N•m [11.85 lbf•ft]
		130-250	13 mm hex	32 N•m [24 lbf•ft]
J80	End cap screw	030	8 mm internal hex	58 N•m [43 lbf•ft]
		early 042	8 mm internal hex	75 N•m [55 lbf•ft]
		late 042	10 mm internal hex	75 N•m [55 lbf•ft]
		055	19 mm hex	122 N•m [90 lbf•ft]
		075-100	24 mm hex	298 N•m [220 lbf•ft]
		100-130	14 mm internal hex	298 N•m [220 lbf•ft]
		180-250	17 mm internal hex	580 N•m [429 lbf•ft]
K10	Charge pressure valve plug	030-250	1/2 in hex	NA
K90	Charge pressure lock nut	030-100	1-1/16 in hex	52 N•m [38 lbf•ft]
		130-250	1-5/8 in hex	52 N•m [38 lbf•ft]
L70	Shaft retaining screw	030-042	10 mm hex	12 N•m [9 lbf•ft]
		055-100	5 mm internal hex	16 N•m [12 lbf•ft]
		130-250	6 mm internal hex	32 N•m [24 lbf•ft]
M72	MDC handle nut	030-250	8 mm	13.5 N•m [10 lbf•ft]
M78	De-stroke valve manifold screw	030-250	5 mm internal hex	13.5 N•m [10 lbf•ft]
M85	Eccentric plug lock nut	030-250	1-1/8 in hex	27 N•m [20 lbf•ft]
M88	Neutral start switch lock nut	030-250	1-1/8 in hex	27 N•m [20 lbf•ft]
M90	Control mounting screw	030-250	5 mm internal hex	16 N•m [12 lbf•ft]
M92	Solenoid valve mounting screw	030-250	4 mm internal hex	5.4 N•m [4 lbf•ft]
M98	PCP mounting screw	030-250	4 mm internal hex	5.4 N•m [4 lbf•ft]
N10	Filter reducer assembly	030-042	1-1/4 in hex	70 N•m [52 lbf•ft]
		055-130	1-1/2 in hex	122 N•m [90 lbf•ft]
		180-250	1-1/2 in hex	156 N•m [115 lbf•ft]
N37	Filter plug assembly	030-250	1/4 in internal hex	27 N•m [20 lbf•ft]

Item	Fastener		Wrench size	Torque
P2B1/A1	Multi-function valve		1-1/4 in hex	89 N•m [66 lbf•ft]

Plug size and torque chart

If any plugs or fittings are removed from the pump during servicing,install and torque as indicated in the accompanying table.

Caution

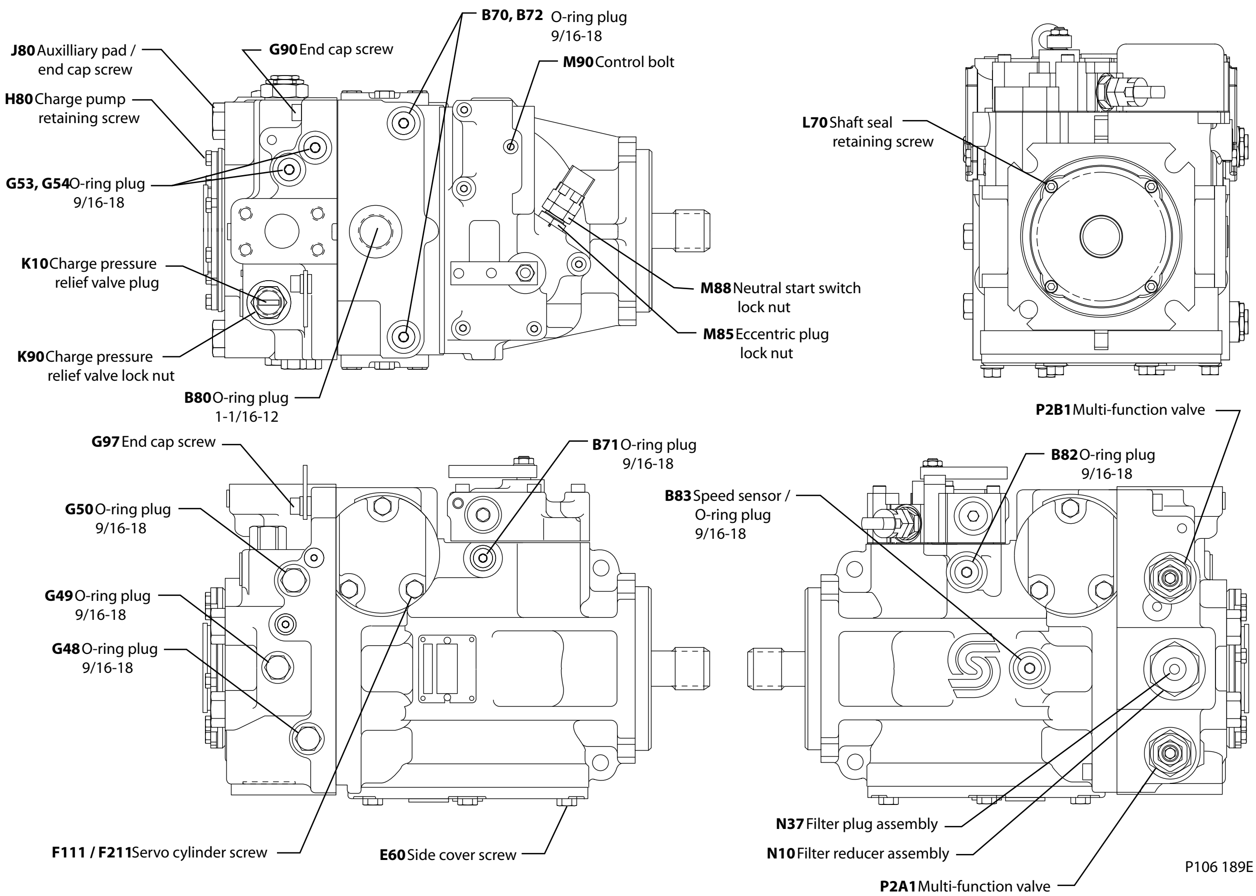
Torque plugs or fittings installed into aluminum housings to the lower values specified for internal hex plugs of the same size.

Always install new O-rings before reinstalling the plugs or fittings.

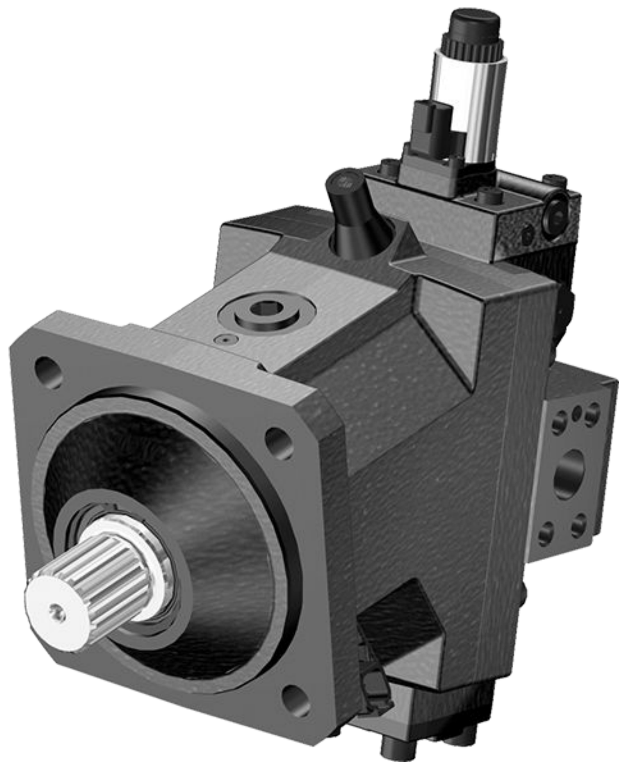
Item	O-ring plug	Wrench size	Torque
B70, B72	9/16-18	3/16 internal hex wrench	40 N•m [30 lbf•ft]
B71	9/16-18	3/16 internal hex wrench	12 N•m [9 lbf•ft]
B80	1-1/16-12	9/16 internal hex wrench	115 N•m [85 lbf•ft]
B82, B83	9/16-18	1/4 internal hex wrench	40 N•m [30 lbf•ft]
G18	7/16-20	3/16 internal hex wrench	12 N•m [9 lbf•ft]
G45-G50	9/16-18	11/16 inch hex wrench	40 N•m [30 lbf•ft]
G52-G54	9/16-18	1/4 internal hex wrench	23 N•m [17 lbf•ft]
H90 (not shown)	1-5/16-12	5/8 internal hex wrench	70 N•m [52 lbf•ft]
N35, N36 (not shown)	9/16-18	11/16 inch hex wrench	37 N•m [27 lbf•ft]
N37	9/16-18	1/4 internal hex wrench	40 N•m [30 lbf•ft]

Fasteners and plugs

Fastener and plug locations



HYDROSTATIC MOTOR



Safety precautions

Always consider safety precautions before beginning a service procedure. Protect yourself and others from injury. Take the following general precautions whenever servicing a hydraulic system.

Unintended machine movement

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

Flammable cleaning solvents

Warning

Some cleaning solvents are flammable. To avoid possible fire, do not use cleaning solvents in an area where a source of ignition may be present.

Fluid under pressure

Warning

Escaping hydraulic fluid under pressure can have sufficient force to penetrate your skin causing serious injury and/or infection. This fluid may also be hot enough to cause burns. Use caution when dealing with hydraulic fluid under pressure. Relieve pressure in the system before removing hoses, fittings, gauges, or components. Never use your hand or any other body part to check for leaks in a pressurized line. Seek medical attention immediately if you are cut by hydraulic fluid.

Personal safety

Warning

Protect yourself from injury. Use proper safety equipment, including safety glasses, at all times.

Hazardous material

Warning

Hydraulic fluid contains hazardous material. Avoid prolonged contact with hydraulic fluid. Always dispose of used hydraulic fluid according to environmental regulations.

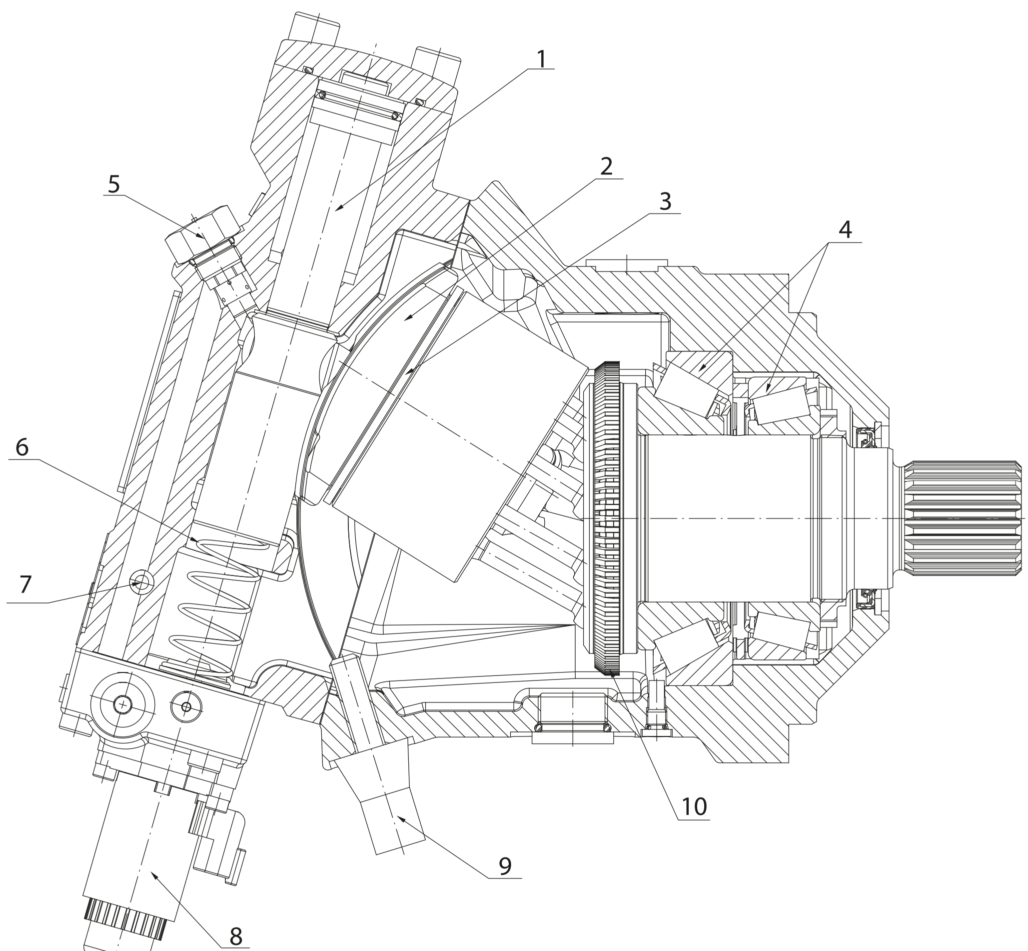
Symbols used in literature

WARNING may result in injury	Tip, helpful suggestion
CAUTION may result in damage to product or property	Lubricate with hydraulic fluid
Reusable part	Apply grease / petroleum jelly
Non-reusable part, use a new part	Apply locking compound
Non-removable item	Inspect for wear or damage
Option - either part may exist	Clean area or part
Superseded - parts are not interchangeable	Be careful not to scratch or damage
Measurement required	Note correct orientation
Flatness specification	Mark orientation for reinstallation
Parallelism specification	Torque specification
External hex head	Press in - press fit
Internal hex head	Pull out with tool – press fit
Torx head	Cover splines with installation sleeve
O-ring boss port	Pressure measurement/gauge location or specification

The symbols above appear in the illustrations and text of this manual. They are intended to communicate helpful information at the point where it is most useful to the reader. In most instances, the appearance of the symbol itself denotes its meaning. The legend above defines each symbol and explains its purpose.

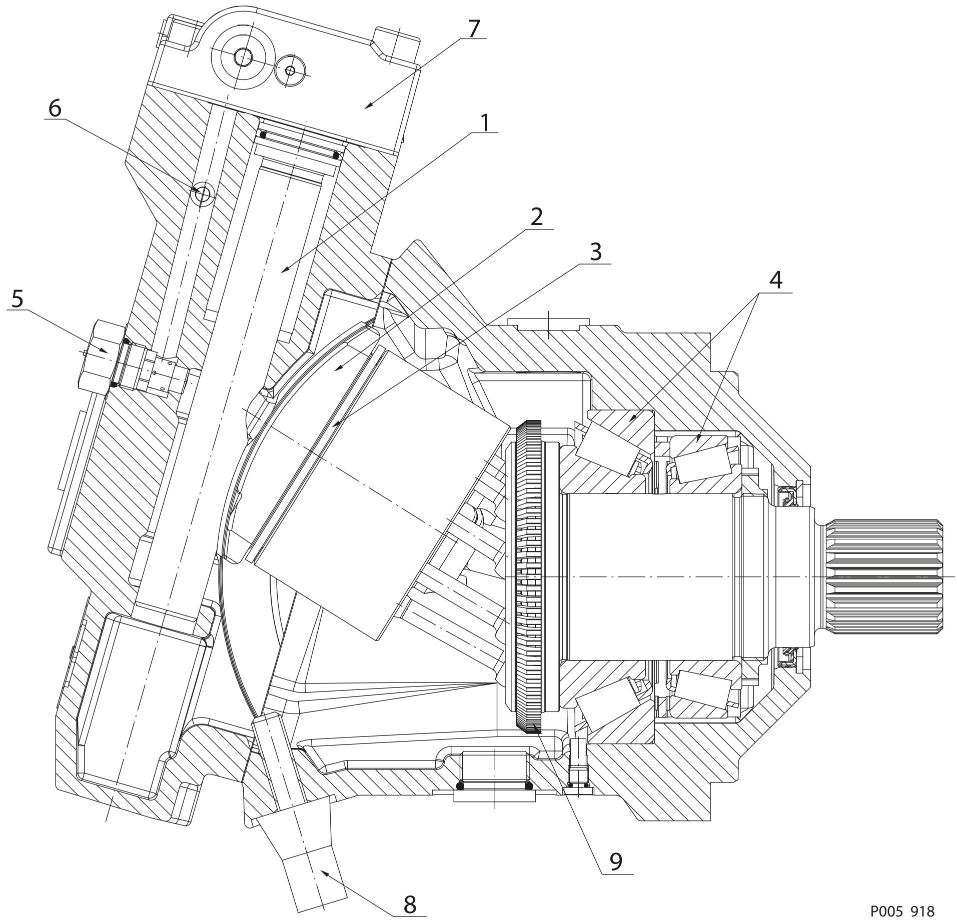
Design of H1 bent axis motor

Cross-section of H1 motor with electric proportional control



1. Differential servo piston
2. Valve segment
3. Bearing plate
4. Tapered roller bearing
5. Loop flushing relief valve
6. Ramp spring
7. Loop flushing shuttle spool
8. Electric proportional control
9. Minimum displacement limiter
10. Speed ring (optional)

Cross-section of H1 motor with electric two-position control



1. Differential servo piston
2. Valve segment
3. Bearing plate
4. Tapered roller bearing
5. Loop flushing relief valve
6. Loop flushing shuttle spool
7. Electric two-position control
8. Minimum displacement limiter
9. Speed ring (optional)

General description

Series H1 variable displacement motors are bent axis design, incorporating spherical pistons.

These motors are designed primarily to be combined with other products in closed circuit systems to transfer and control hydraulic power. Series H1 motors have a large maximum/minimum displacement ratio of 5:1 and high output speed capabilities.

The expanded function of zero degree capability, coupled with a high performance 32 degree maximum angle, creates opportunities to easily improve the machine performance for:

- Wheel assist on the steering axle of high inertia machines (i.e. combines) and could include Anti Slip Control
- Off-highway machines requiring Anti Slip Control (i.e. Ag. sprayer)
- Multi-motor applications requiring optimized work and transport modes (i.e. wheel loader, Ag sprayer) utilizing the zero degree position for maximum transport speed
- Improved machine (i.e. single drum roller) gradeability through precise Anti Slip Control

The Anti Slip Control reduces ground damage, increases traction control and improves machine controllability for the operator.

SAE, Cartridge (not available for 210 cm^3 and 250 cm^3) and DIN (not available for 250 cm^3) flange with radial or axial high pressure port configurations are available including the loop flushing device.

A complete family of controls and regulators are available to fulfill the requirements of a wide range of applications.

Motors normally start at maximum displacement. This provides maximum starting torque for high acceleration.

All controls utilize internally supplied servo pressure. This may be overridden by a pressure compensator which functions when the motor is operating in motor and pump modes. A defeat option is available to disable the pressure compensator override when the motor is running in pump mode during deceleration/braking.

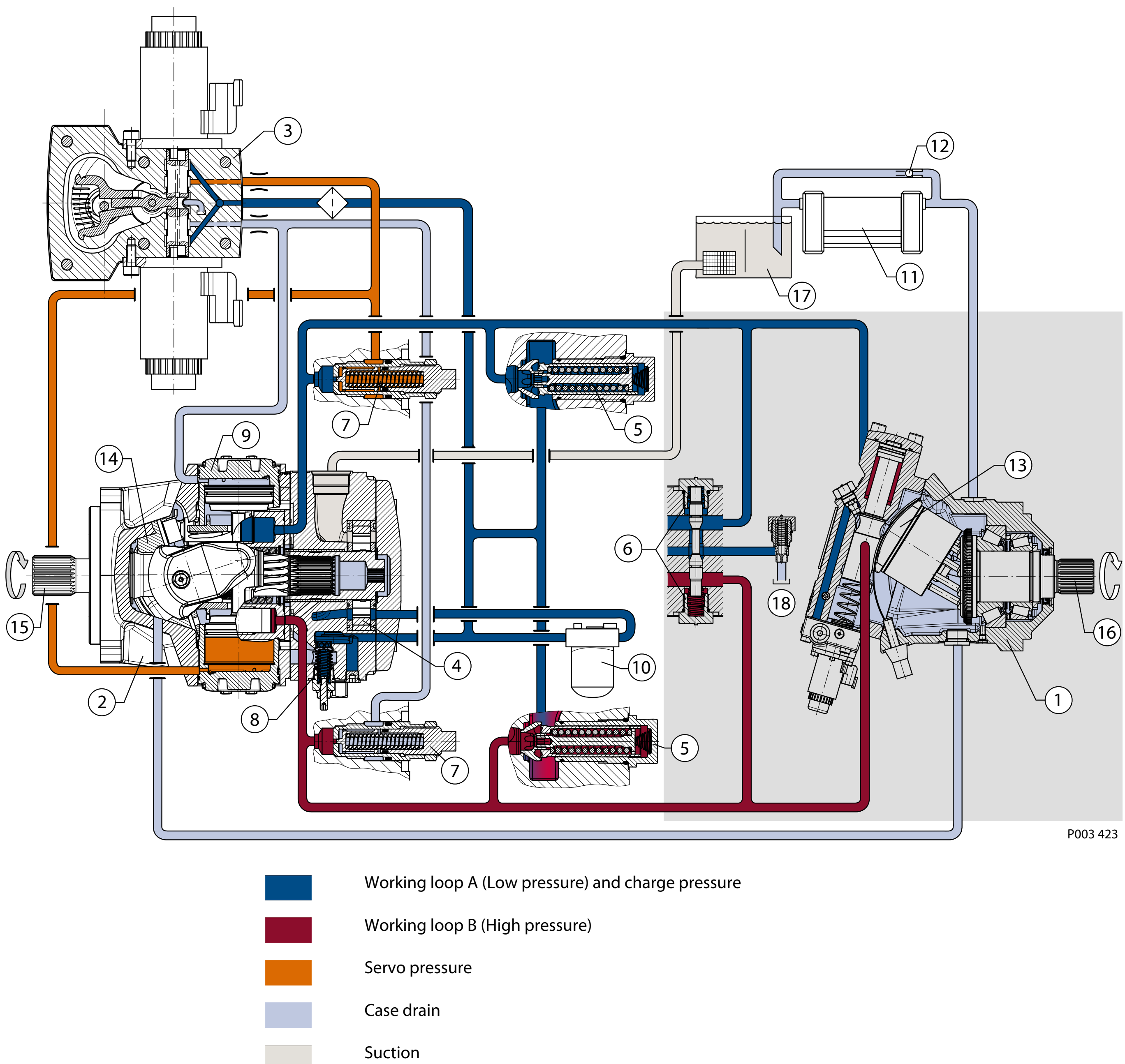
The pressure compensator option features a low pressure rise to ensure optimal power utilization throughout the entire displacement range of the motor.

Speed sensor options are available to cover all frame sizes and flange styles.

They are capable of sensing the following, all in one package:

- Speed
- Direction (only group "J", option "S")
- Temperature (only group "J", option "S")

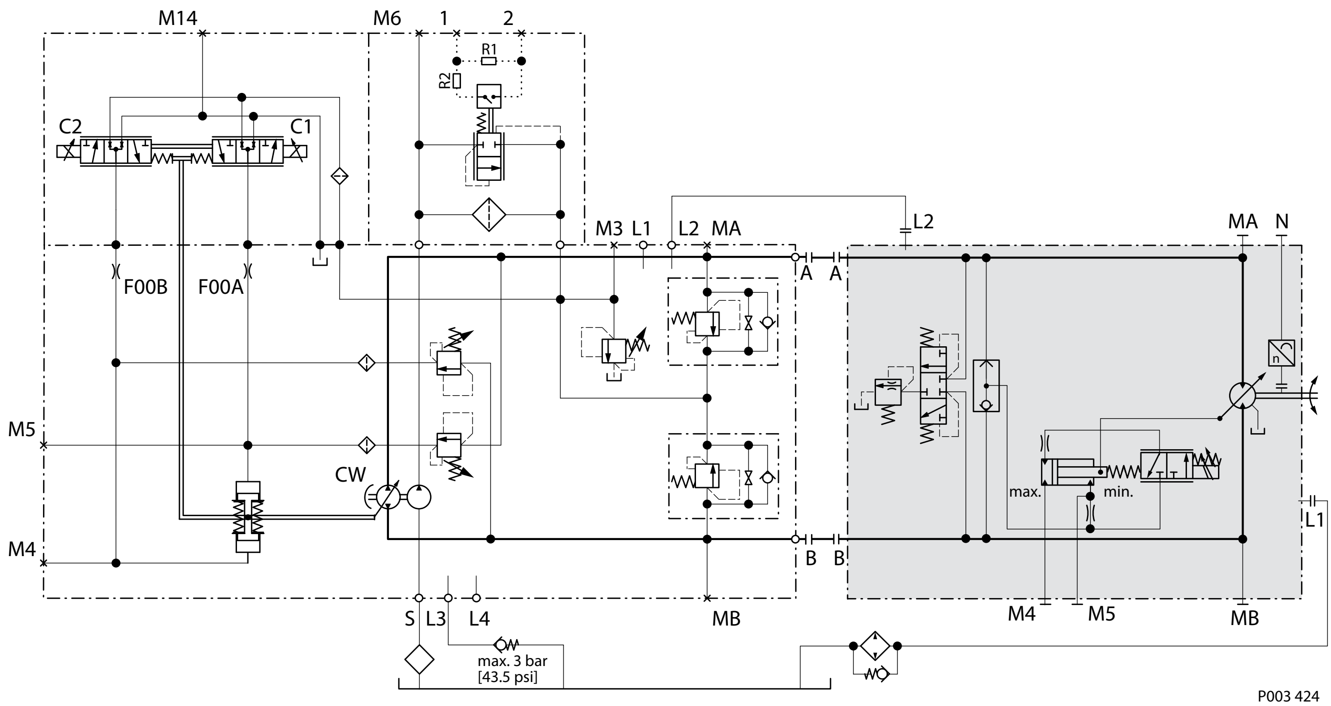
H1 pictorial diagram



1. Bent Axis Variable Displacement Motor
2. Axial Piston Variable Displacement Pump
3. Electric Displacement Control (EDC)
4. Charge Pump
5. Charge Check / High Pressure Relief Valve
6. Loop Flushing Valve
7. Pressure Limiter Valve
8. Charge Pressure Relief Valve
9. Servo Cylinder
10. Charge Pressure Filter
11. Heat Exchanger
12. Heat Exchanger Bypass Valve
13. Valve Segment
14. Pump Swashplate
15. Input Shaft
16. Output Shaft
17. Reservoir
18. to Motor Case

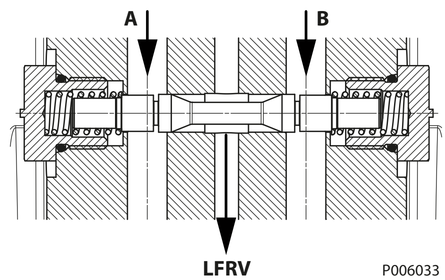
H1 system schematic

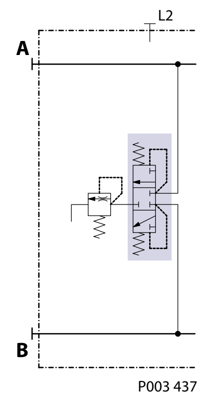
System schematic H1 pump and H1 motor with EDC



The schematic above shows the function of a hydrostatic transmission using an H1 axial variable displacement pump with electric proportional displacement control (EDC) and an H1 bent axis variable displacement motor with electric proportional control (L*) and integrated loop flushing device.

System delta pressure will cause the shuttle spool to shift, allowing the low side system pressure to flow to the loop flushing relief valve.





Legend:

A	System loop A
B	System loop B
LFRV	to Loop flushing relief valve

Warning

Unintended vehicle or machine movement hazard.

Excessive motor loop flushing flow may result in the inability to build required system pressure in some conditions. Maintain correct charge pressure under all conditions of operation to maintain pump control performance in hydrostatic systems.

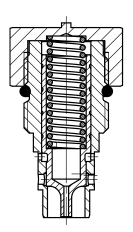
Loop flushing relief valve

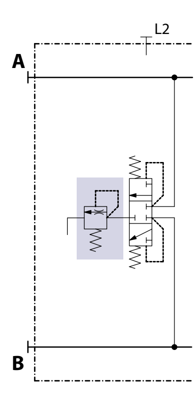
The loop flushing relief valve is incorporated into all H1 motors. Use the loop flushing option in installations that require fluid to be removed from the low pressure side of the system circuit due to cooling requirements.

The loop flushing relief valve is also used to facilitate the removal of contaminants from the loop.

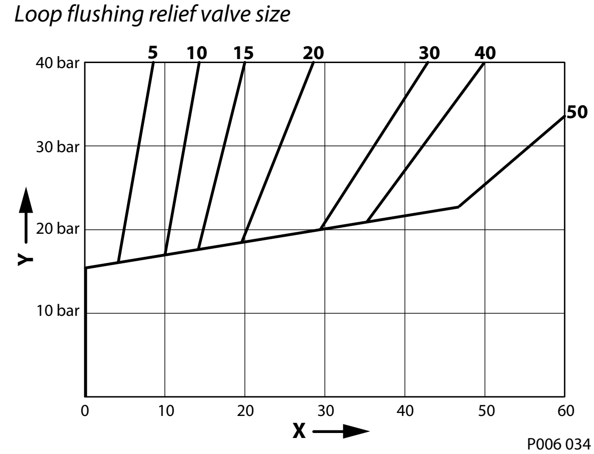
The loop flushing valve is equipped with an orificed charge pressure relief valve designed with a cracking pressure of 16 bar [232 psi].

Valves are available with several orifice sizes to meet the flushing flow requirements of all system operating conditions.





Loop flushing relief valve size



Legend:

X Loop flushing flow (l/min)

Y Low system pressure minus case pressure (bar)

Speed sensor

Two optional speed sensors are available. The speed sensor is designed for rugged outdoor, mobile or heavy industrial speed sensing applications. The detection of the speed is contactless and does not need any calibration or adjustments.

	Order number	
	149055	**11102032**
Supply voltage	4.5 – 8 V_{DC}	7 – 32 V
Speed signals	two, 90° phase shift	one
Direction signal	one	–
Temperature signal	one	–

Temperature ratings

Parameter	**Min**	**Max**	**Note**
Operating Temperature-Range	-40°C	104°C	115°C Intermittent = Short term t < 1min per incident and not exceeding 2 % of duty cycle based load-life

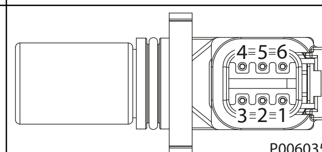
Protection characteristics

Parameter		**Note**
Protection code IP-Class	IP67 and IP69k according IEC 60529 & DIN 40050	• IP67 w/o connector installed • IP69k with connector installed
EMC-Emission	EN 61000-6-3	
EMC- Immunity (EMI)	100 V/m incl. 1 kHz AM 80 %, ISO 11452-5 and ISO 11452-2	
ESD: Air discharge Contact discharge	EN 61000-4-2: 15 kV 8 kV	
Vibration	30 G (294 m/s^2)	
Shock	50 G (490 m/s^2)	
Case pressure	5 bar maximum	

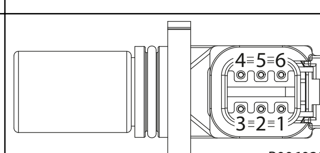
Technical data

	Min.	**Max.**	**Note**
Supply voltage range	4.5 V_{DC}	8 V_{DC}	
Supply protection	-	30 V_{DC}	30 V over voltage protection. Shuts off above 9 V.
Max. required supply current	-	25 mA	
Max. output current	-	50 mA	
Operation mode	**NPN& PNP**		Push-Pull amplifier

Technical data (continued)

		Min.	Max.	Note
Output signal range	Low & clockwise	5%	12%	
	High & counterclockwise	88%	95%	
Temperature signal		-40°C = 2.203V	104°C = 0.734V	V_o=1.795V – [0.0102 · T]
Detectable frequency range		1 Hz	10 000 Hz	
Speed and temperature sensor		Order number **149055**		
Connector terminals				*Sensor pinout:* **1** Speed signal 2 **2** Direction signal **3** Speed signal 1 **4** Supply **5** Ground **6** Temperature
Color of connector		Black		

Technical data

		Min.	Max.	Note
Supply voltage range		7 V_{DC}	32 V_{DC}	
Supply protection		-	36 V_{DC}	36 V over voltage protection and -36 V permanent reverse polarity protection
Max. required supply current		-	30 mA	
Max. output current		-	50 mA	
Operation mode		**NPN** open collector		With internal 2k7 pull-up resistor to supply
Output signal range	Low	2%	10%	
	High	55%	85%	Max. output voltage 24V
Detectable frequency range		1 Hz	10.000 Hz	
Speed and temperature sensor		Order number **11102032**		
Connector terminals				*Sensor pinout:* **1** NC **2** NC **3** Speed signal 1 **4** Supply **5** Ground **6** NC
Color of connector		White (natural plastic color)		

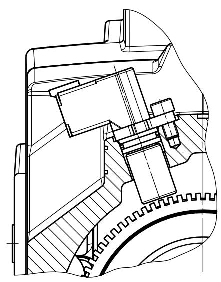
Mating connectors

Material Number	Name	Note
11033865	Assembly Bag, DEUTSCH, DTM06 6-SOCKET Black	(20-24 AWG) / 0.2 – 0.5 mm^2
11033863	Assembly Bag, DEUTSCH, DTM06 6-SOCKET Grey	

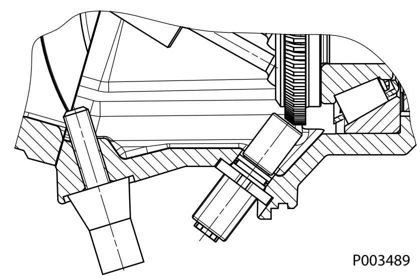
For more information, see *Speed and Temperature Sensor, Technical Information* 11046759.

Sensor position

SAE and DIN housing


P003450

Cartridge housing


P003489

Target ring

Target ring size	H1B 060	H1B 080	H1B 110	H1B 160	H1B 210	H1B 250
Number of teeth	71	78	86	95	104	108

Displacement limiter

All Series H1 motors incorporate mechanical displacement limiters.

The **minimum displacement** of the motor is preset at the factory with a set screw in the motor housing. A tamper-proof cap is provided.

Output speed

Start and low speed stability. The motor produces maximum starting torque at maximum displacement. Stable operation can be achieved at 15–34 rpm, ± 5 %, depending on system pressure, in applications that require low speed stability. Motor output speed becomes more stable as speed increases.

Rated speed is the highest output speed recommended at full power condition. Operating at, or below this speed will yield satisfactory product life.

Maximum speed is the highest operating speed permitted. Exceeding maximum speed reduces the product life and can cause loss of hydrostatic power and dynamic braking capacity. Never exceed the maximum speed limit under any operating conditions.

Operation between rated and maximum speed is reserved for **intermittent operation** (see *H1B speed range diagrams for open and closed circuit* on page 15) not to exceed 10 minutes durations, 2% of duty cycle based load-life, and 310 bar system delta pressure. Speed above rated are anticipated to occur during downhill braking (negative power). Contact factory for any operation above Rated speed when negative power is not involved.

During hydraulic braking and downhill conditions, the prime mover must be capable of providing sufficient braking torque in order to avoid pump over speed. This is especially important to consider for turbocharged and Tier 4 engines.

Warning

Unintended vehicle or machine movement hazard.

Exceeding maximum speed may cause a loss of hydrostatic drive line power and braking capacity. You must provide a braking system, redundant to the hydrostatic transmission, sufficient to stop and hold the vehicle or machine in the event of hydrostatic drive power loss. The braking system must also be sufficient to hold the machine in place when full power is applied.

System pressure

System pressure is the differential pressure between high pressure system ports. It is the dominant operating variable affecting hydraulic unit life. High system pressure, which results from high load, reduces expected life. Hydraulic unit life depends on the speed and normal operating, or weighted average, pressure that can only be determined from a duty cycle analysis.

Application pressure is the high pressure relief or pressure limiter setting normally defined within the order code of the pump. This is the applied system pressure at which the driveline generates the maximum calculated pull or torque in the application.

Maximum working pressure is the highest recommended application pressure. Maximum working pressure is not intended to be a continuous pressure. Propel systems with application pressures at, or below, this pressure should yield satisfactory unit life given proper component sizing.

Maximum pressure is the highest allowable application pressure under any circumstance. For applications which are above the maximum working pressure, please contact Hoist Material Handling

Minimum pressure must be maintained under all operating conditions to avoid cavitation.

All pressure limits are differential pressures referenced to low loop (charge) pressure. Subtract the low loop gauge pressure from the high loop gauge pressure readings to compute the differential.

Summing pressure is the sum of both the low and high loop pressures. Summing pressure above 30 bar [435 psi] guarantees reliable use within the rated speed.

Servo pressure is the pressure in the servo system and is supplied from the high side of the loop to keep the motor at the required displacement.

Case pressure

Under normal operating conditions, **the rated case pressure** must not be exceeded. During cold start, case pressure must be kept below maximum intermittent case pressure. Size drain plumbing accordingly.

Caution

Possible component damage or leakage.

Operation with case pressure in excess of stated limits may damage seals, gaskets, and/or housings, causing external leakage. Performance may also be affected since charge and system pressures are referenced to case pressure.

External shaft seal pressure

In certain applications, the output shaft seal may be exposed to external pressures. The shaft seal is designed to withstand an external pressure up to 0.25 bar [3.6 psi] above the case pressure. The case pressure limits must also be followed to ensure the shaft seal is not damaged.

Temperature

The high temperature limits apply at the hottest point in the transmission, which is normally the motor case drain. The system should generally be run at or below the published **rated temperature**.

The **maximum intermittent temperature** is based on material properties and should never be exceeded.

Cold oil will generally not affect the durability of the transmission components, but it may affect the ability of oil to flow and transmit power. Therefore, temperatures should remain 16 °C [30 °F] above the pour point of the hydraulic fluid.

The **minimum temperature** relates to the physical properties of component materials.

Size heat exchangers too keep the fluid within these limits. HMH recommends testing to verify that these temperature limits are not exceeded.

Fluid and filter recommendations

To ensure optimum life, perform regular maintenance of the fluid and filter. Contaminated fluid is the main cause of unit failure. Take care to maintain fluid cleanliness when servicing.

Check the reservoir daily for proper fluid level, the presence of water, and rancid fluid odor. Fluid contaminated by water may appear cloudy or milky or free water may settle in the bottom of the reservoir. Rancid odor indicates the fluid has been exposed to excessive heat. Change the fluid immediately if these conditions occur. Correct the problem immediately.

Inspect vehicle for leaks daily.

Change the fluid and filter per the vehicle/machine manufacturer’s recommendations or at these intervals. We recommend first fluid change occur at 500 hours of operation. Change the fluid more frequently if it becomes contaminated with foreign matter (dirt, water, grease, etc) or if the fluid is subjected to temperature levels greater than the recommended maximum.

Fluid and filter change interval

Reservoir type	Max oil change interval
Sealed	2000 hours
Breather	500 hours

Caution

High temperatures and pressures accelerate fluid aging. This may require more frequent fluid changes.

Change filters when changing fluid or when the filter indicator directs. Replace all fluid lost during filter change

Warning

Hydraulic fluid contains hazardous material. Avoid contact with hydraulic fluid. Always dispose of used hydraulic fluid according to state, and federal environmental regulations. Never reuse hydraulic fluid.

Port locations and gauge installation

The following table and drawing show the port locations and gauge sizes needed.

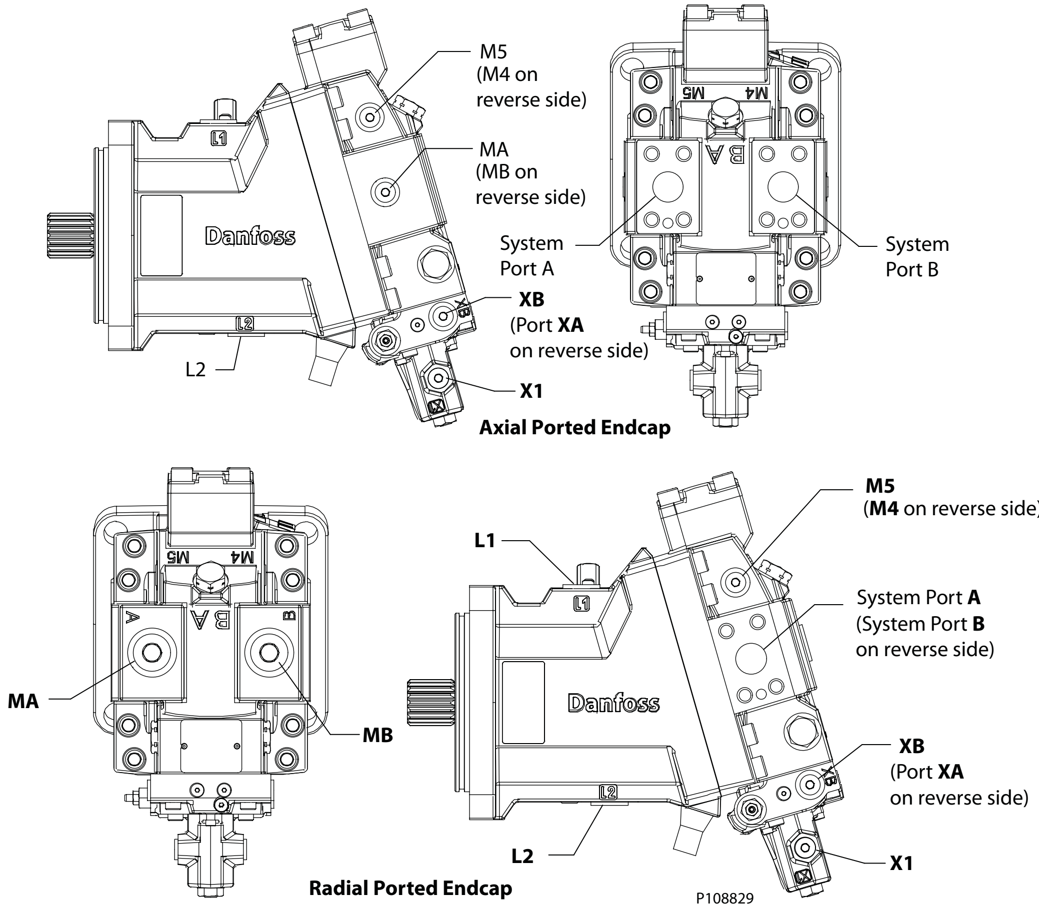
Port Information

Port identifier	060		080		110/160		210/250		Pressure obtained	Gauge size, bar [psi]
	Port size	Wrench size int. hex	Port size	Wrench size int. hex	Port size	Wrench size int. hex	Port size	Wrench size int. hex		
L1, L2	7/8-14 UNF	3/8	7/8-14 UNF	3/8 in.	1 1/16-12UN	9/16 in.	1 5/16-12UN	5/8 in.	Case drain	10 [100]
MA, MB (Radial endcap)	7/8-14 UNF	3/8	1 1/16-12UN	9/16 in.	1 1/16-12UN	9/16 in.	1 1/16-12UN	9/16 in.	System pressure	600 [10,000]
MA, MB (Axial endcap)	9/16-18 UNF	1/4	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	System pressure	600 [10,000]
M4	9/16-18 UNF	1/4	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	Servo pressure rod end	600 [10,000]
M5	9/16-18 UNF	1/4	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	Servo pressure piston end	600 [10,000]
X1	9/16-18 UNF	1/4	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	Control pressure supply, hydraulic actuator	100 [1500]
XA	9/16-18 UNF	1/4	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	BPD, PCOR inactive at A	100 [1500]
XB	9/16-18 UNF	1/4	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	9/16-18 UNF	1/4 in.	BPD, PCOR inactive at B	100 [1500]

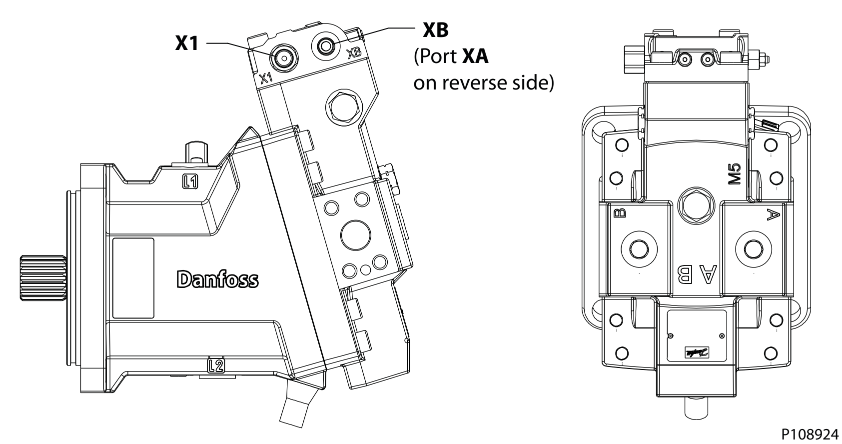
System Ports

Port identifier	060	080, 110	160/210/250
	Split flange boss, thread M10 x 1.5	**Split flange boss, thread M12 x 1.75**	**Split flange boss, thread M12 x 1.75**
A	3/4 inch code 62 per ISO 6162 Type 1, min. thread 18mm [0.71 in]	1 inch code 62 per ISO 6162 Type 1, min. thread 23mm [0.91 in]	1 1/4 inch code 62 per ISO 6162 Type 1, min. thread 23mm [0.91 in]
B	3/4 inch code 62 per ISO 6162 Type 1, min. thread 18mm [0.71 in]	1 inch code 62 per ISO 6162 Type 1, min. thread 23mm [0.91 in]	1 1/4 inch code 62 per ISO 6162 Type 1, min. thread 23mm [0.91 in]

Port locations proportional control



Port locations hydraulic 2-position controls with PCOR (control specific ports only)



Procedure

Warning

This service procedure may require disabling the vehicle / machine (raising the wheels off the ground, disconnecting work function) while performing, to prevent injury to the technician and bystanders. Take the necessary safety precautions.

Always follow this procedure when starting-up a new H1 installation or when the motor has been removed.

1. Before installing the motor, inspect the units for possible damage incurred during shipping and handling.
2. Make certain all system components (reservoir, hoses, valves, fittings, heat exchanger, and so forth) are clean before filling with fluid.
3. Fill the reservoir with recommended hydraulic fluid. Pass this fluid through a 10 micron (nominal, no bypass) filter before it enters the reservoir.
4. Fill the inlet line leading from the reservoir to the pump.
5. Check inlet line for properly tightened fittings. Make sure the inlet line is free of restrictions and air leaks.
6. Fill the motor and pump housings with clean hydraulic fluid before start up. Fill by pouring filtered oil into the upper case drain port.

   Caution

   Never start the prime mover unless the motor and pump housings are filled completely with clean hydraulic fluid.

7. For closed loop systems, install a 0-60 bar [0-1000 psi] pressure gauge in the charge pressure gauge port of the pump to monitor the charge pressure during start-up.

   For open circuit systems, use gauges in system ports.

8. Disconnect any external control input signal from the pump control until after initial start-up. This ensures that the pump remains in its neutral position.
9. Jog (slowly rotate) prime mover until charge pressure starts to rise.
10. Start the prime mover and run at the lowest possible speed until charge pressure builds.

    Warning

    Do not start the prime mover unless the pump is in neutral position (swash plate at 0° angle). Take necessary precautions to prevent machine movement in case pump is actuated (in stroke) during initial start-up.

    If necessary, bleed excess air from the high pressure lines through the high pressure system gauge ports.

11. Once charge pressure is established, increase to normal operating speed. Charge pressure should be as indicated in the pump model code. If charge pressure is low, shut down and determine cause.

    Caution

    Low charge pressure may affect ability to control the machine.

12. Shut down the prime mover.
13. Connect the external control input signal.
14. Reconnect the machine function if disconnected earlier.
15. Start the prime mover, checking to ensure the pump remains in neutral.

16. Check for forward and reverse machine operation, with the prime mover at normal operating speed.

    Charge pressure may decrease slightly during forward or reverse operation.

17. Continue to cycle slowly between forward and reverse for at least five minutes.
18. Shut down prime mover.
19. Remove gauges. Replace plugs at the gauge ports.
20. Check reservoir level. Add filtered fluid if needed.

The motor/transmission is now ready for operation.

Overview

This section provides general steps to follow if you observe undesirable system conditions. Follow the steps until you solve the problem. Some of the items are system specific. Always observe the safety precautions in the *Introduction* section.

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

Electrical troubleshooting

Item	Description	Action
Motor operates at one displacement only.	Control coil failure	Measure resistance at coil pins. Proportional controls: Resistance should be 14.20 Ohms (24V) or 3.66 Ohms (12V) at 20°C [70°F]. Two-position controls: Resistance should be 8.4 Ohms (24V) or 34.5 Ohms (12V) at 20°C [70°F]. Replace coil if necessary.
Erratic motor function	Electrical connection to motor is intermittent.	Disconnect connector, check wires and terminals, reconnect wires. Check terminals for corrosion and correct position.

Sluggish operation

Check		Cause	Corrective action
1.	Control orifices	Blocked or restricted orifice may cause sluggish response. Orifices installed in the wrong locations may cause PCOR control to be sluggish.	Remove, inspect and clean all orifices. Ensure the appropriate orifices are installed and in the correct location.
2.	Threshold setting (proportional controls)	Inappropriately high or low threshold setting may shift the motor at the wrong time.	Check threshold setting. Adjust if necessary.
3.	Control spool	A sticky control may cause sluggish response or no response.	Clean and inspect the control spool. Replace if necessary.
4.	Pressure compensator setting	Low pressure compensator setting may shift motor to maximum displacement at lower pressure.	Check pressure compensator setting. Adjust if necessary.
5.	Control input signal	An improper or erratic input signal to the control may cause sluggish response.	Check input signal and correct if necessary.
6.	Internal leakage	Excessive leakage will cause lower charge pressure and affect performance.	Install loop flushing defeat option and measure case flow. If case flow is excessive, motor may require major repair. Contact your HMH authorized service center.

System operating hot

Check		Cause	Corrective action
1.	Oil level	Insufficient hydraulic fluid may cause overheating.	Fill reservoir to proper level.
2.	Heat exchanger	Blocked heat exchanger or low air flow may cause system overheating.	Check temperature upstream and downstream of heat exchanger. Clean, repair, or replace heat exchanger if necessary.
3.	Loop flushing flow	Restricted orifice in loop flushing cartridge reduces flow.	Measure case drain flow. Clean or replace orifice cartridge.
4.	Loop flushing shuttle	Loop flushing shuttle may be sticking in one direction.	Ensure shuttle moves freely in its bore.

Check		Cause	Corrective action
5.	Air in system	Entrained air generates heat under pressure	Look for foam or bubbles in reservoir. Check for leaks on inlet side of charge pump.
6.	Internal leakage	Excessive internal leakage may overheat the system.	Install loop flushing defeat option and monitor case flow. If case flow is excessive, motor may require major repair. Contact your HMH authorized service center.

Excessive noise or vibration

Check		Cause	Corrective action
1.	Oil level in reservoir	Insufficient hydraulic fluid may cause cavitation.	Fill reservoir to proper level.
2.	Air in system	Air bubbles may lead to cavitation.	Look for foam or bubbles in reservoir. Check for leaks on inlet side of charge pump.
3.	Shaft coupling	Loose shaft coupling may create excess noise.	Replace loose shaft coupling. Replace or repair motor if shaft splines show excessive wear.
4.	Shaft alignment	Misaligned shafts may create excessive noise and vibration and can damage motor.	Correct shaft misalignment.

Motor operates normally in one direction only

Check		Cause	Corrective action
1.	Charge pressure	If charge pressure is low in one direction, the loop flushing shuttle spool may be sticking to one side.	Measure charge pressure in forward and reverse. If pressure drops significantly lower in one direction, inspect and repair loop flushing shuttle spool.
2.	Pressure compensator control	If pressure compensator operates in one direction only, the motor may stay at minimum displacement in the opposite direction.	Check brake pressure defeat spool. It may be sticking or receiving an improper signal. Repair spool or correct input signal.

Improper output speed

Check		Cause	Corrective action
1.	Oil level in reservoir	Insufficient hydraulic fluid may reduce system efficiency.	Fill reservoir to proper level.
2.	Threshold setting	Improper threshold setting may cause motor to have wrong displacement for given signal.	Check threshold setting. Refer to Control Service Manual for adjustment procedure.
3.	Pressure compensator setting	Improper pressure compensator setting may shift motor displacement at wrong pressure.	Check pressure compensator setting. Adjust if necessary. Refer to Control Service Manual for adjustment procedure.
4.	PC spool	Pressure compensator spool sticking may shift motor to improper displacement.	Check pressure compensator spool. Repair or replace if needed. Refer to Control Service Manual for adjustment procedure.
5.	Control orifices	Blocked or restricted orifice may cause motor to shift improperly.	Remove, inspect and clean all orifices.
6.	Control spool	Sticky proportional control spool may cause motor to shift improperly.	Check control spool for proper operation. Repair if necessary. Refer to control adjustment procedure.
7.	Control input signal	Improper input signal may cause motor to shift improperly.	Correct control input signal.
8.	Internal leakage	Excess internal leakage may cause lower charge pressure and affect motor performance including output speed.	Install loop flushing defeat option and measure case flow. If case flow is excessive, motor may require major repair. Contact your HMH authorized service center.

Low output torque

Check		Cause	Corrective action
1.	Pressure compensator setting	High pressure compensator setting may cause improper motor displacement for torque required.	Check and adjust pressure compensator setting.
2.	Control orifices	Blocked or restricted orifice may cause motor to shift improperly.	Remove, inspect and clean all orifices.
3.	Pressure compensator spool	Sticking pressure compensator spool may cause control to hold motor at minimum displacement.	Remove and inspect pressure compensating spool. Repair or replace control if necessary.
4.	Control spool	Sticking control spool may cause motor to shift improperly.	Remove and inspect control spool. Repair or replace control if necessary.
5.	Two position solenoid	Two position control not shifting motor to maximum displacement.	Inspect solenoid valve for bent stem or damaged coil. Repair or replace if necessary.
6.	Control input signal	Improper control input signal may cause motor to stay at minimum displacement.	Correct control input signal.
7.	Threshold setting (proportional control)	Improper threshold setting may cause improper motor displacement for torque required.	Check and adjust threshold setting.
8.	Internal leakage	Excess internal leakage may cause charge pressure to decay, reducing output torque.	Install loop flushing defeat option and monitor case flow. If case flow is excessive, motor may require major repair. Contact your HMH authorized service center.

Required tools

The service procedures described in this manual can be performed using common mechanic's hand tools. Special tools, if required, are shown. When testing system pressures, calibrate pressure gauges frequently to ensure accuracy. Use snubbers to protect gauges.

Standard procedures

Caution

Contamination can damage internal components and void the manufacturer's warranty. Take precautions to ensure system cleanliness when removing and reinstalling system lines

1. With the prime mover off, thoroughly clean all dirt and grime from the outside of the motor. Ensure the surrounding areas are clean and free of contaminants such as dirt and grime.
2. If removing the motor, tag each hydraulic line connected to the motor. If you disconnect hydraulic lines, plug each open port to keep dirt and contamination out of the motor.
3. Inspect the system for contamination. Look at the hydraulic fluid for signs of system contamination, such as oil discoloration, foam in the oil, sludge, or small metal particles.
4. Remove the motor as a single unit.

   Caution

   Be careful not to damage solenoids and electrical connections when using straps or chains to remove motor from machine.

5. Perform motor function test.
6. Before re-installing the motor on the machine, drain the system, flush all lines, replace all filters, and fill with new hydraulic fluid.

Minimum displacement limiter

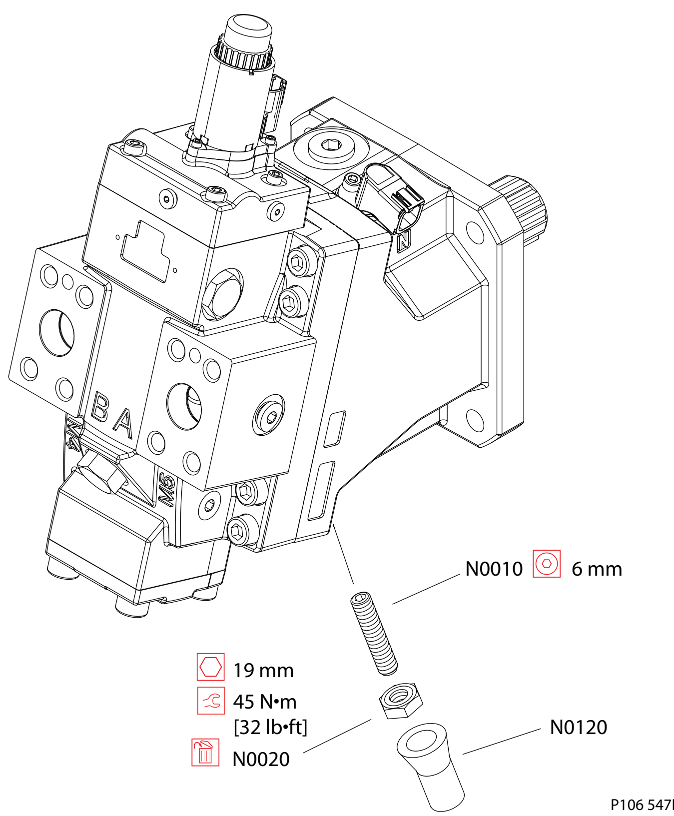
Adjusting the minimum displacement limiter

1. Remove cap (N0120).

   Removing the cap destroys the caps locking mechanism. Replace with a new cap.

2. Using a 6 mm internal hex wrench, hold adjusting screw (N0010) in place.
3. Using a 19 mm hex wrench, loosen seal locknut (N0020).
4. Turn adjusting screw clockwise to increase minimum displacement or counterclockwise to decrease minimum displacement. Minimum displacement is inversely related to maximum shaft speed. To increase maximum speed, decrease minimum displacement. Adjusting displacement limits also affects output torque. Refer to table for displacement change per turn.
5. When properly adjusted, hold adjusting screw in place and torque seal locknut to 45 N•m [32 lbf•ft].
6. With motor on machine or test stand, verify correct motor function. Refer to *Port locations and gauge installation* on page 27 for location of gauge ports and suggested gauge sizes.
7. Install new cap (N0120).

Minimum displacement limiter



Displacement change per turn

Model	Displacement change
250	5.5 cm^3 [0.34 in^3]
210	5.1 cm^3 [0.31 in^3]
160	4.1cm^3 [0.25 in^3]
110	3.2 cm^3 [0.20 in^3]

Displacement change per turn (continued)

Model	Displacement change
080	2.6 cm^3 [0.16 in^3]
060	2.1 cm^3 [0.13 in^3]

Optional threshold adjustment - electric proportional controls

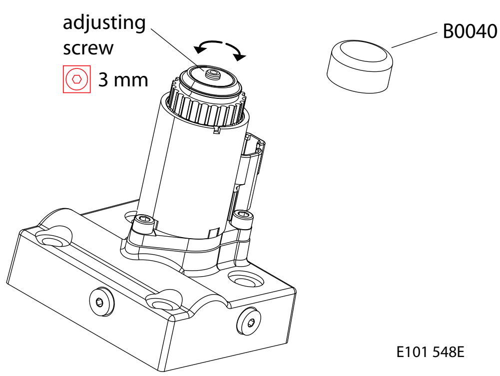
Adjusting threshold on test stand

1. Connect flow meter to A or B system port. Refer to *Port locations and gauge installation* on page 27 for port locations.
2. Connect solenoid to PWM signal generator at 100 Hz.

Threshold is the electric signal when the motor starts to change from maximum to minimum displacement.

3. Run prime mover at operating speed.

Threshold adjustment



4. Adjust PWM signal to current listed in model code. Note flow reading.
5. 5. If adjustment is necessary, remove cap (B0040). Using a 3mm internal hex wrench, turn adjusting screw clockwise or counterclockwise until flow starts to change from maximum. Test your adjustment by lowering the current, then increasing the current until the displacement starts to change. Readjust the setting if necessary.
6. When threshold is adjusted correctly, stop prime mover, install cap (B0040), and install motor on vehicle. Run vehicle and test for proper motor operation.

Adjusting threshold on a machine or test stand without flow meter

1. Install 600 bar [10,000 psi] gauges to ports M5 and M4. Connect solenoid to PWM signal.
2. Raise wheels off ground, or disconnect the work function.

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

3. Run prime mover at operating speed. Stroke the pump to get some rotation of motor shaft.
4. Increase signal current until M4 pressure becomes 1/2 of the M5 pressure. Check the signal current at this point.
5. If adjustment is necessary, remove cap (B0040). Turn the adjusting screw until the signal current matches the model code setting.

6. When threshold is adjusted correctly, stop prime mover, install cap. Run vehicle and test for proper motor operation.
7. Remove from test stand.

Optional threshold adjustment - hydraulic proportional controls

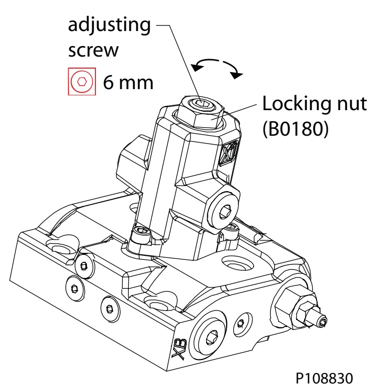
Adjusting threshold on test stand

1. Connect flow meter to A or B system port. Refer to *Port locations and gauge installation* on page 27 for port locations.
2. Connect a variable pressure supply to X1 port (0-50 bar).

Threshold is the pressure at which the motor starts to change from maximum to minimum displacement.

3. Run prime mover at operating speed.

Threshold adjustment



4. Adjust control pressure to pressure listed in model code. Note flow reading.
5. If adjustment is necessary, remove nut (B0180). Using a 6mm internal hex wrench, turn adjusting screw clockwise or counterclockwise until flow starts to change from maximum. Test your adjustment by lowering the pressure, then increasing the pressure until the displacement starts to change. Readjust the setting if necessary.
6. When threshold is adjusted correctly, stop prime mover, install nut (B0180), and install motor on vehicle. Run vehicle and test for proper motor operation.

Adjusting threshold on a machine or test stand without flow meter

1. Install 600 bar [10,000 psi] gauges to ports M5 and M4. Connect a variable pressure supply to X1 port (0-50 bar).
2. Raise wheels off ground, or disconnect the work function.

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

3. Run prime mover at operating speed. Stroke the pump to get some rotation of motor shaft.
4. Increase X1 pressure until M4 pressure becomes 1/2 of the M5 pressure. Check the X1 pressure at this point.

5. If adjustment is necessary, remove nut (B0180). Turn the adjusting screw until the X1 pressure matches the model code setting.
6. When threshold is adjusted correctly, stop prime mover, install nut (B0180). Run vehicle and test for proper motor operation.
7. Remove from test stand.

Pressure compensator OVERRIDE (PCOR) adjustment

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. To protect against unintended movement, secure the machine or disable/disconnect the mechanism while servicing.

PCOR adjustment for all except P1/P2

Setup

1. Install motor in machine.
2. Install 600 bar pressure gauge at system port MA or MB (whichever side is regulated by the PCOR). Optionally, the gauge can be installed in the system gauge port M5.
3. Install sensor to read engine speed.
4. Install sensor to read wheel speed.
5. Install data acquisition device which is able to record data over time using the sensors installed in steps 2 – 4 above.
6. Deactivate any inching systems connected to the brakes if applicable.
7. Prepare site for testing (two options are available).
   a) Lift machine so wheels are no longer engaging the ground, or
   b) Use a straight, flat surface to drive machine during testing.

Testing

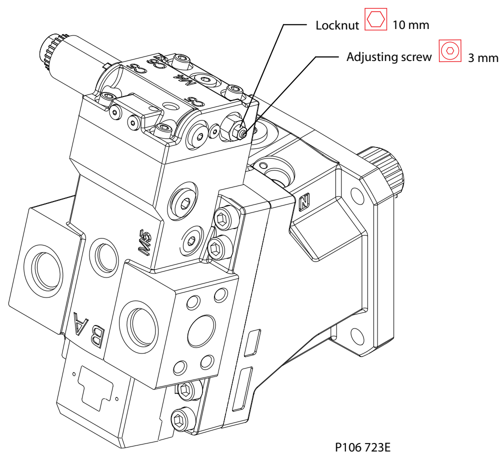
1. Start machine engine.
2. Set engine to high idle (rated speed) and maintain for the duration of the testing.
3. Turn the machine wheels at a constant speed (motor will be at minimum displacement).
   a) Allow wheels to turn at constant speed if using setup 7a.
   b) Drive machine at constant speed if using setup 7b.
4. Begin data acquisition (system pressure, engine speed, and wheel speed).
5. Slowly apply the service brake to continuously increase the load on the system until the wheel speed (setup 7a) or driving speed (setup 7b) decreases by approximately 1/3.
6. Stop machine and turn off engine.
7. Stop data acquisition.

Analysis

1. Using appropriate software for the data acquisition device, plot the system pressure, wheel speed and engine speed versus time.
2. As the system pressure increases (from applying the brakes), the engine speed and wheel speed will start decreasing.
3. When the system pressure stops rising and remains constant, that pressure will be the PCOR setting. The engine speed should remain constant during this period while the wheel speed continues to decrease. See Graph below.

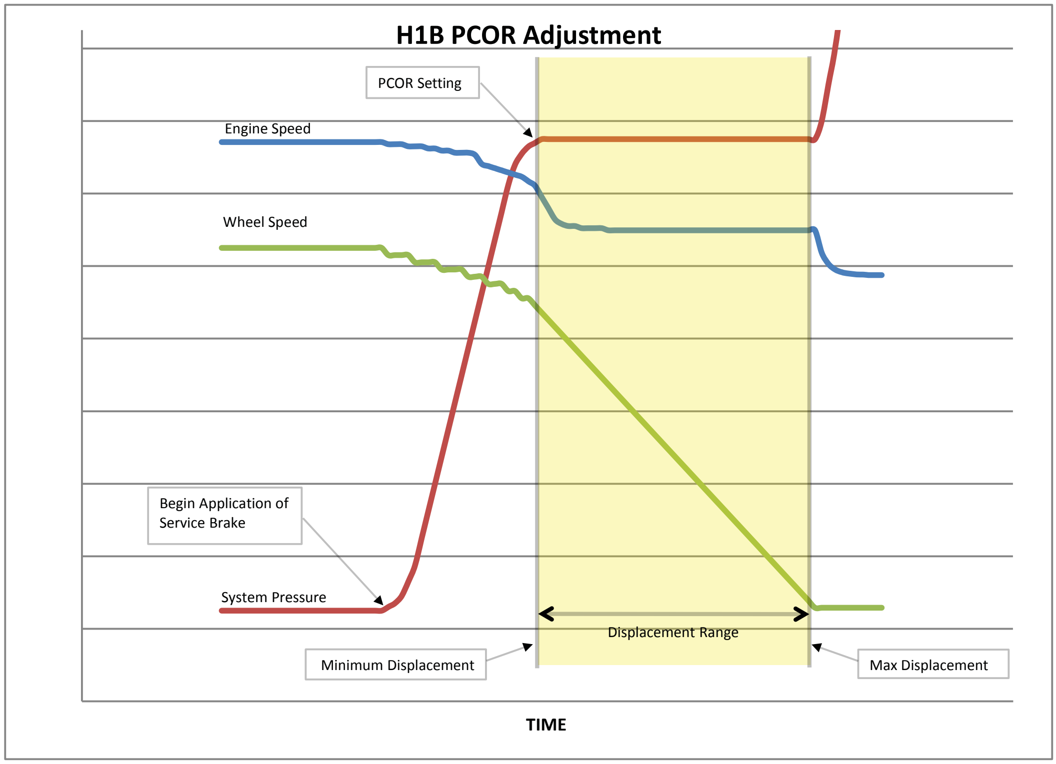
Adjustment

1. If adjustment is required, use a 3mm internal hex to hold the PCOR adjusting screw in place and use a 10mm wrench to loosen the PCOR lock nut. One full turn of the adjusting screw changes the PCOR setting by approximately 90 Bar.
   a) Turn adjusting screw clockwise to increase the PCOR setting.
   b) Turn adjusting screw counterclockwise to decrease the PCOR setting.



2. Use a 3mm internal hex to hold the PCOR adjusting screw in place and use a 10mm wrench to tighten the lock nut to 8 N-m [6 lbf-ft].

3. Repeat Testing, Analysis, and Adjustment steps as necessary to reach the desired PCOR setting.



Brake pressure defeat option

No adjustment is available for the brake pressure defeat option. Coil is either energized or de-energized, if coil is used.

PCOR adjustment for P1/P2 controls

PCOR setting is electrically adjusted using a proportional solenoid.

Nominal settings 240 bar [3500 psi] at 800 mA (12 V), 400 mA (24 V) or per model code.

Shaft seal

Removal

1. 1. Using snap ring pliers, remove retaining ring (G0030).
2. 2. Use a slide-hammer style puller to remove seal (G0020). Be careful not to damage the shaft or seal bore when removing. Discard seal.

Inspection

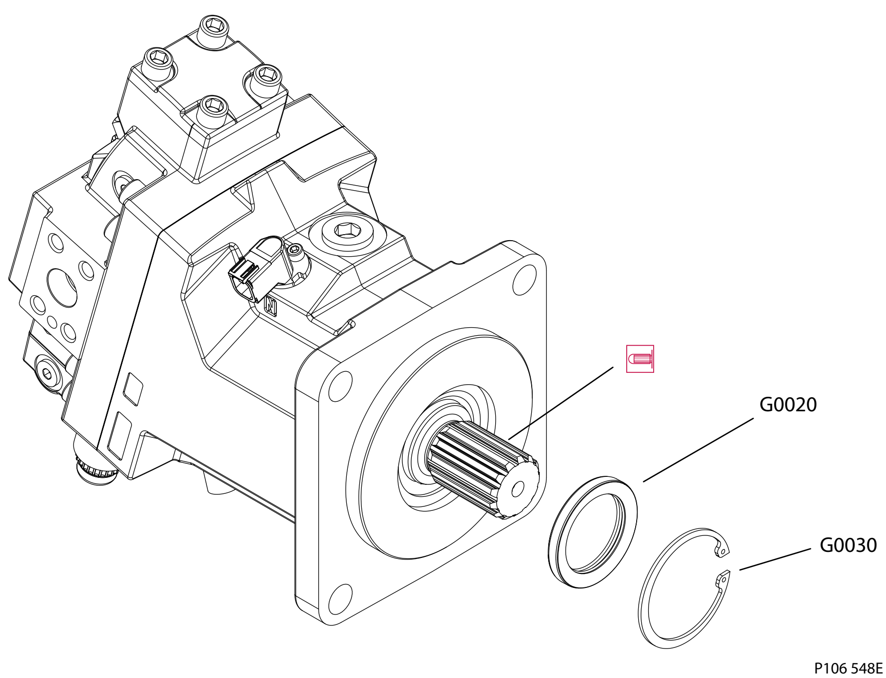
Inspect retaining ring for wear or damage. Replace if necessary. Inspect shaft for wear or groove at seal area.

Assembly

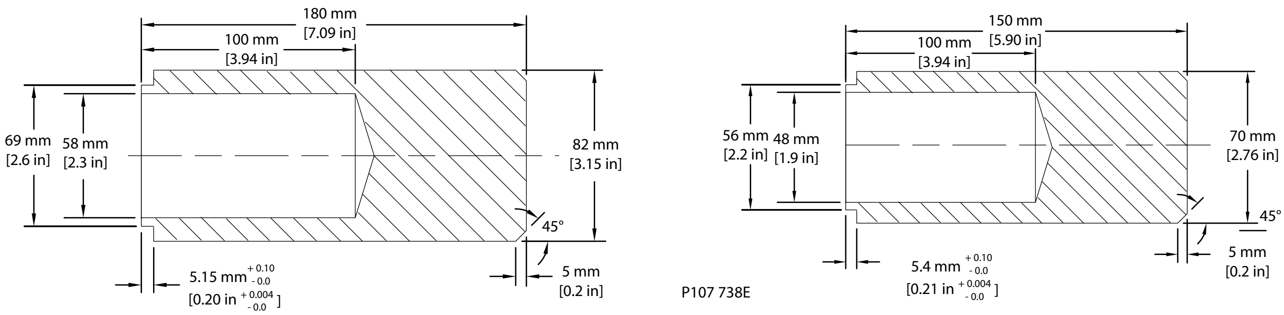
1. Lubricate inside diameter of new seal. Cover the shaft splines with shaft cover or packing tape to avoid damaging the seal during installation.
2. Using seal installation tool, press seal into housing bore.
3. Using a snap ring pliers, install retaining ring (G0030).
4. Use seal installation tool to press seal and retaining ring into housing until retaining ring snaps into its groove.

If not using seal installation tool: Do not press seal beyond snap-ring groove. Stop pressing just when you have room to install the retaining ring into the bore. Pressing the seal and snap-ring together ensures proper installation depth. Using the seal installation tool prevents pressing the seal too deeply.

Shaft seal



110/160/210/250 - Seal installation tool dimensions, 060/080 - Seal installation tool dimensions



Electric proportional solenoid replacement

Removal

1. Disconnect electrical connection and remove three cap screws (B0050) using a 4 mm internal hex wrench.
2. Remove the solenoid (B0010) and O-ring (B0035A). Discard the O-ring.
3. Remove valve spool (C0100).

Inspection

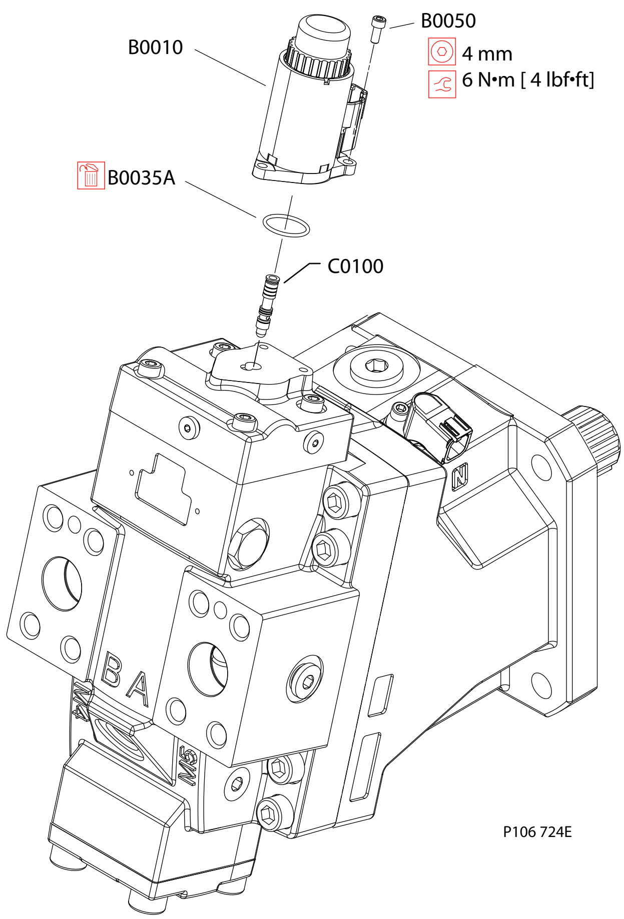
Clean and inspect valve spool and all machined surfaces for damage or wear. Replace parts if necessary.

Assembly

1. Lubricate and install valve spool (C0100).
2. Using petroleum jelly, lubricate and install new O-ring (B0035A).
3. Install cap screws (B0050) using a 4 mm internal hex wrench. Torque screws to 6 N•m [4 lbf•ft].

4. Reconnect electrical connections and test the motor for proper operation.

Replacing solenoid



Hydraulic proportional actuator replacement

Removal

1. Remove three cap screws (B0050) using a 4 mm internal hex wrench.
2. Remove the actuator (B0010).

Inspection

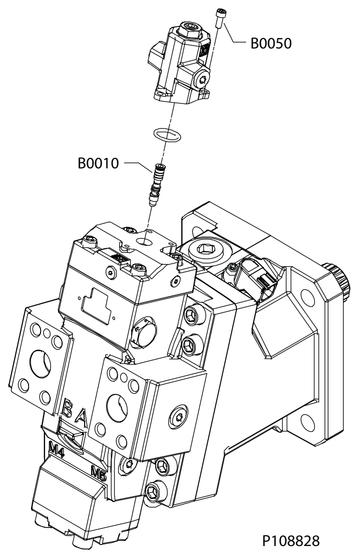
Clean and inspect all machined surfaces for damage or wear. Replace parts if necessary.

Assembly

1. Install cap screws (B0050) using a 4 mm internal hex wrench. Torque screws to 6 N•m [4 lbf•ft].

2. Test the motor for proper operation.

Replacing actuator



Control module replacement

Removal

1. Remove four cap screws (C0110 and/or C0120). Refer to table for wrench sizes.
2. Remove control (C0010) from motor. Remove and discard gasket (C0130).
3. Proportional control only - using a magnet, remove spring seat (F0030) and spring (F0040).

Inspection

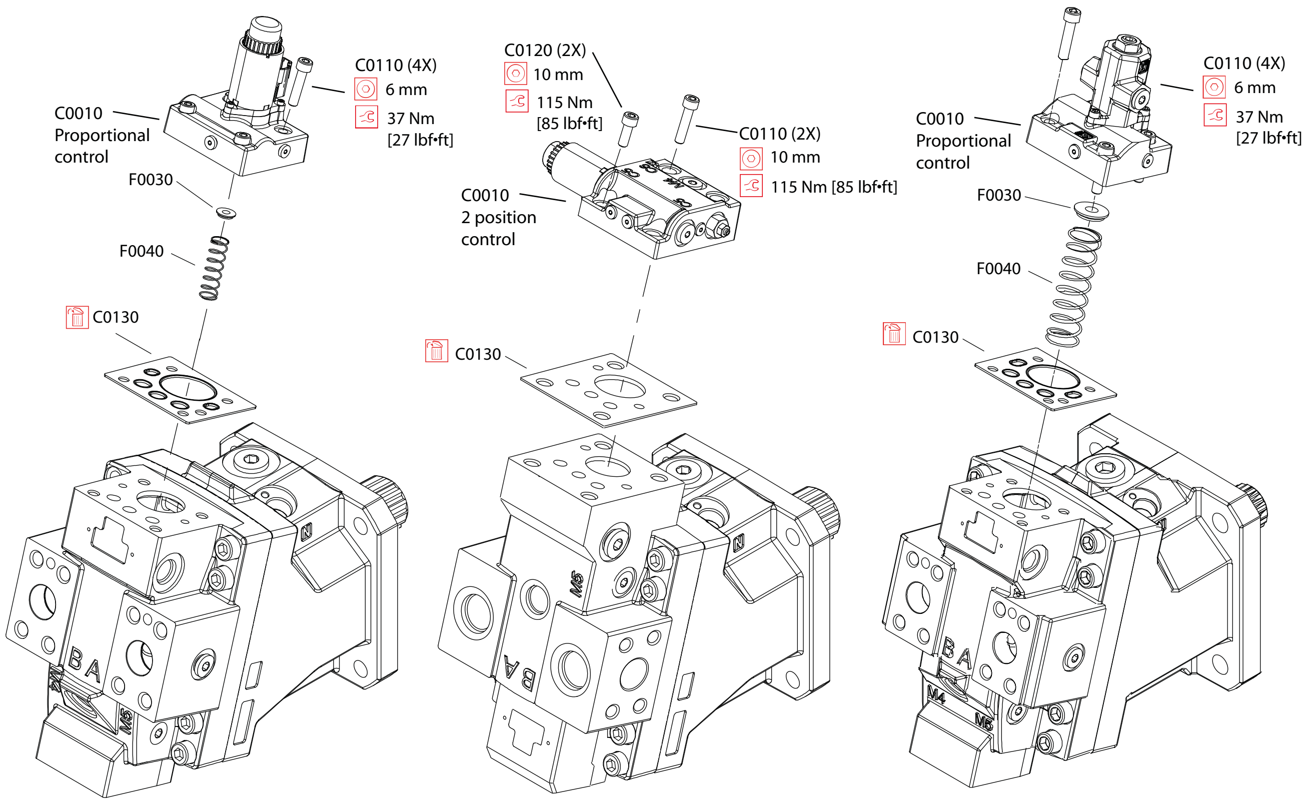
Clean and inspect the machined surfaces on the control and the endcap. If you find any nicks or scratches, replace control or endcap. Inspect valve spool, washer, and spring. Replace if necessary.

Assembly

1. Lubricate and install spring (F0040) and spring seat (F0030) into servo.
2. Install a new gasket (C0130). Position control on motor.

3. Install four cap screws (C0110 and/or C0120). Torque (C0110) to 37 N•m [27 lbf•ft] for proportional control. Torque (C0110) and (C0120) to 115 Nm [85 lbf•ft] for 2 position control.

Control module removal/installation



Electric proportional control *Two position control* *Hydraulic proportional control*

P106 520E

C0110 and C0120 Wrench Size

Control	Screw	Internal Hex Wrench
Electric and Hydraulic proportional	C0110	6 mm
Two-position	C0110 C0120	10 mm 10 mm

Electric proportional control module

Coil O-rings are not included in the overhaul seal kit. They may be purchased as a separate kit.

Disassembly

1. Remove the plastic cap (B0040) and O-ring (B0029). Discard the O-ring.
2. Remove the solenoid nut (B0027) using a 26mm 12-point socket. Remove and discard the O-ring (B0028).
3. Remove the coil (B0020A). Remove and discard the O-ring (B0025).
4. Use a 4 mm internal hex wrench to remove screws (B0050). Remove solenoid (B0010).
5. Remove and discard O-ring (B0035A).

6. Remove spool (C0100).
7. Using a 1/4 in internal hex wrench remove plug (C0050) and discard O-ring (C0050A).
8. Use a 5 mm internal hex to remove shuttle valve (C0025).
9. Using a 1/8 in internal hex wrench, remove 3 plugs (C0060) and discard O-rings (C0060A).
10. Using a 3 mm internal hex, remove 2 orifices (E00T3 and E00T2).

Inspection

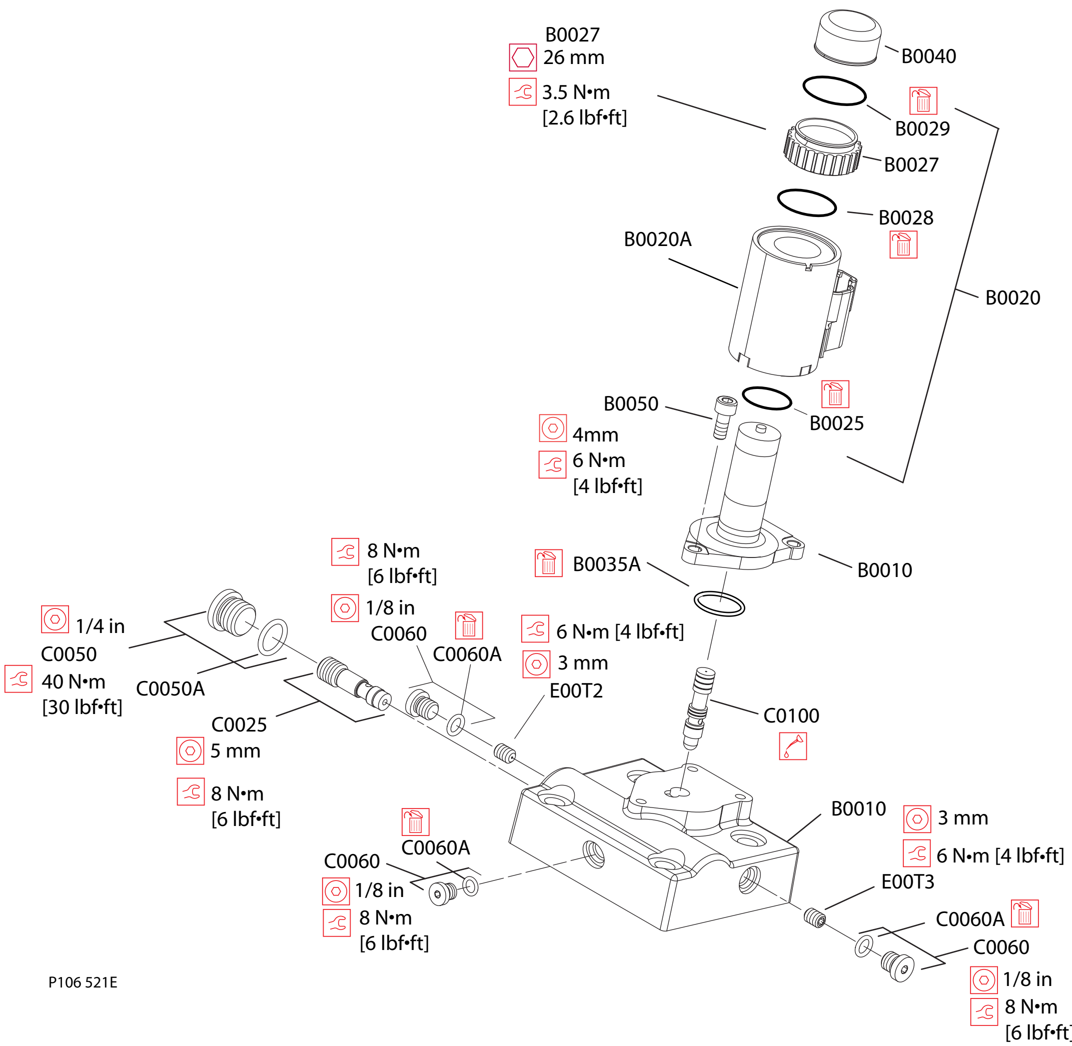
Inspect the machined surfaces on the control and the endcap. If you find any nicks or scratches, replace the control or endcap assembly. Check that shuttle ball moves freely in housing (C0025).

Assembly

1. Install orifices (E00T3 and E00T2). Torque to 6 N•m [4 lbf•ft].
2. Lubricate and install new O-rings (C0060A). Using a 1/8 inch internal hex wrench, install and torque plugs (C0060) to 8 N•m [6 lbf•ft].
3. Lubricate and install spool (C0025) into control block. Using a 5 mm internal hex wrench, torque to 14 N•m [11 lbf•ft]
4. Install new O-ring (C0050A). Using a 1/4 inch internal hex wrench, install and torque plug (C0050) to 40 N•m [30 lbf•ft].
5. Lubricate and install spool (C0100).
6. Lubricate and install new O-ring (B035A).
7. Install solenoid (B0010). Using a 4 mm internal hex wrench. Install screws (B0050). Torque to 6 N•m [4 lbf•ft].
8. Lubricate and install new O-ring (B0025) onto solenoid. Install coil (B0020A). Lubricate and install new O-ring (B0028) onto solenoid.
9. Install coil nut (B0027) and torque to 3.5 N•m [2.6 lbf•ft] using a 26mm 12-point socket. Do not overtorque.

10. Install new O-ring (B0029) and plastic cap (B0040) to solenoid.

Proportional control block assembly



Hydraulic proportional control module

Disassembly

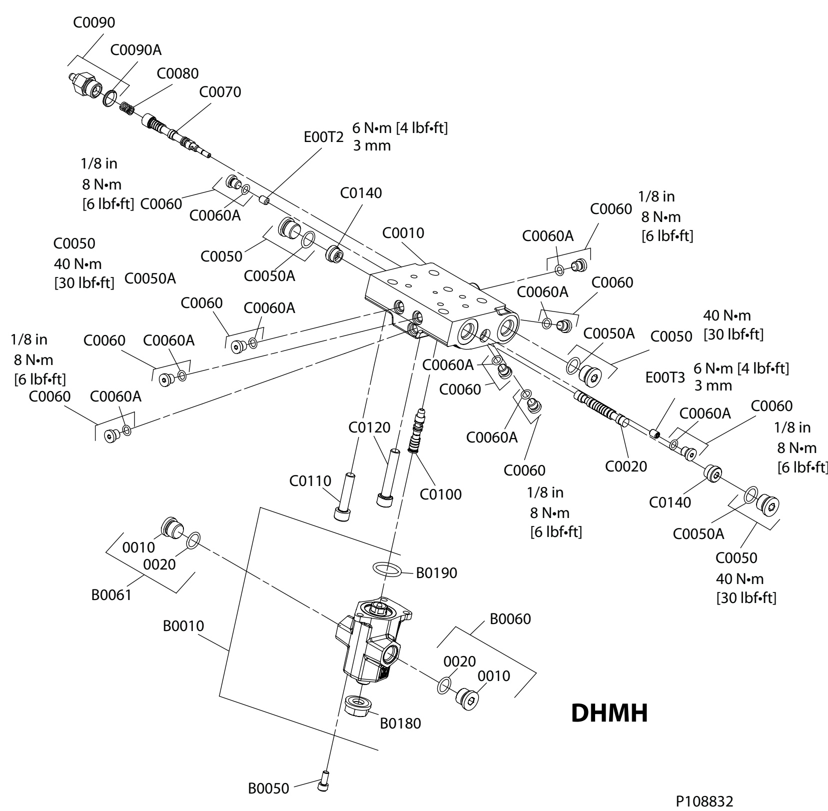
1. Use a 4 mm internal hex wrench to remove screws (B0050). Remove actuator (B0010).
2. Remove and discard O-ring (B0035A).
3. Using a 1/4 in internal hex wrench remove plug (C0050) and discard O-ring (C0050A).
4. Use a 5 mm internal hex to remove shuttle valve (C0025).
5. Using a 1/8 in internal hex wrench, remove 3 plugs (C0060) and discard O-rings (C0060A).
6. Using a 3 mm internal hex, remove 2 orifices (E00T3 and E00T2).

Inspection

Inspect the machined surfaces on the control and the endcap. If you find any nicks or scratches, replace the control or endcap assembly. Check that shuttle ball moves freely in housing (C0025).

Assembly

1. Install orifices (E00T3 and E00T2). Torque to 6 N•m [4 lbf•ft].
2. Lubricate and install new O-rings (C0060A). Using a 1/8 inch internal hex wrench, install and torque plugs (C0060) to 8 N•m [6 lbf•ft].
3. Lubricate and install spool (C0025) into control block. Using a 5 mm internal hex wrench, torque to 14 N•m [11 lbf•ft]
4. Install new O-ring (C0050A). Using a 1/4 inch internal hex wrench, install and torque plug (C0050) to 40 N•m [30 lbf•ft].
5. Install actuator (B0010). Using a 4 mm internal hex wrench. Install screws (B0050). Torque to 6 N•m [4 lbf•ft].



6. If replacing the hydraulic actuator, set the threshold pressure to the proper setting. Refer to *Adjusting threshold on test stand* on page 37

Electric two-position control module

Coil O-rings are not included in the overhaul seal kit. They are included with the purchase of a new coil.

Disassembly

1. Use a 26 mm 12-point socket to remove coil nuts (B0026) and O-ring (B0028).
2. Remove coils (B0022) and O-rings (B0024). Discard O-rings.
3. Using a 17 mm open-end wrench on the flats provided, remove solenoid assemblies (B0032).
4. Remove and discard O-rings (B0034).
5. Using a 1/8 inch internal hex wrench, remove four plugs (C0060). Remove and discard O-rings (C0060A).

6. Using a 1/4 inch internal hex wrench, remove two plugs (C0050). Remove and discard O-rings (C0050A).
7. Using a 17 mm hex wrench, remove pressure compensator adjusting plug (C0090). Remove and discard O-ring (M223).
8. Remove springs (C0030) and (C0080). Remove spools (C0020) and (C0070).
9. If necessary, use a 3 mm internal hex wrench to remove orifices (E00T2) and (E00T3).

Inspection

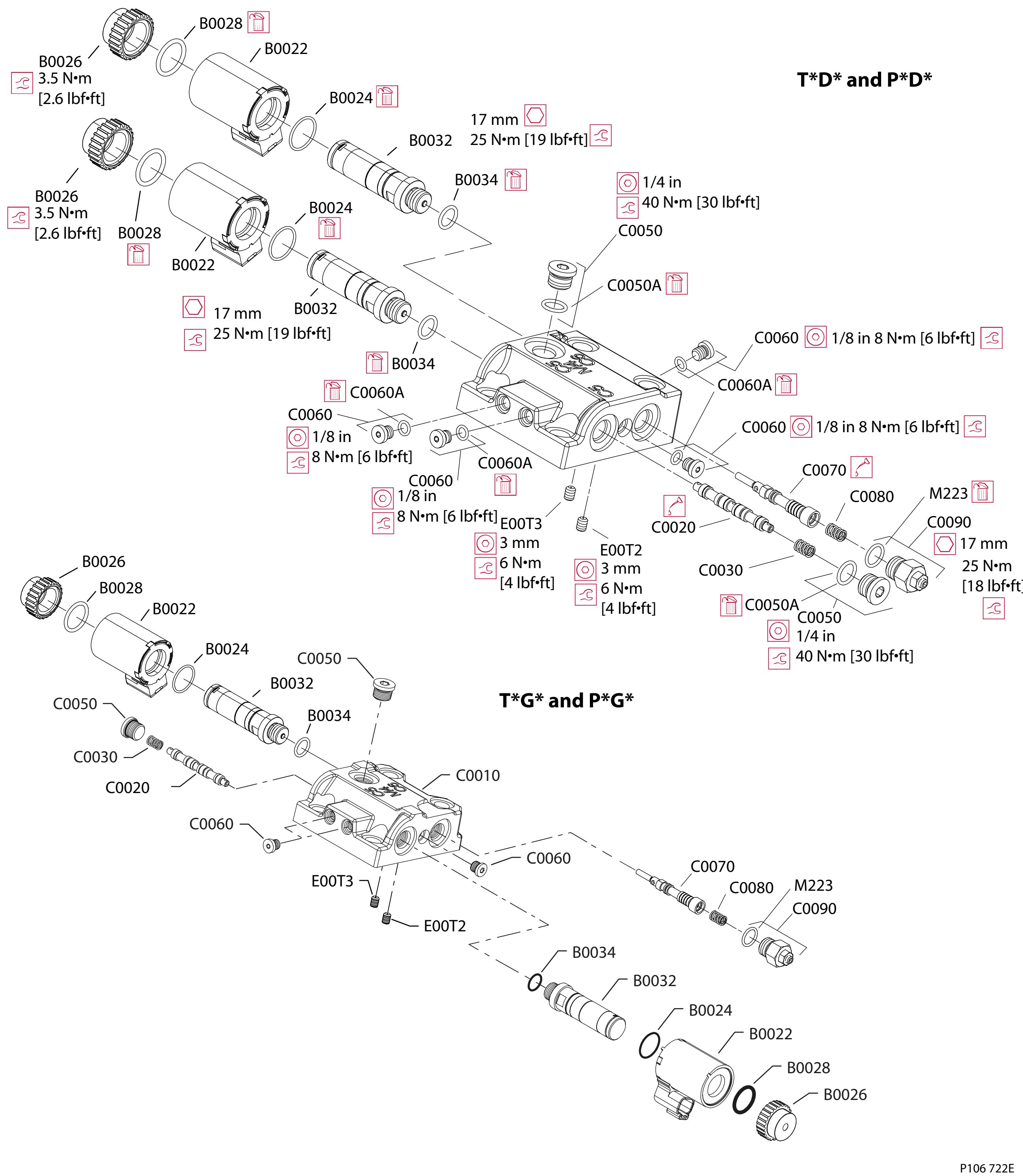
Clean and inspect the machined surfaces on the control and the endcap. If any nicks or scratches are found, replace the control/endcap assembly.

Assembly

1. If previously removed, install orifices (E00T3 and E00T2) using a 3mm internal hex wrench. Torque to 6 N•m [4 lbf•ft].
2. Lubricate and install spools (C0020) and (C0070) and springs (C0080) and (C0030).
3. Lubricate and install O-ring (M223). Install pressure compensator adjusting plug (C0090). Torque to 40 N•m [30 lbf•ft].
4. Lubricate and install two O-rings (C0050A). Using a 1/4 inch internal hex wrench, install plugs (C0050). Torque to 25 N•m [19 lbf•ft].
5. Lubricate and install four O-rings (C0060A). Using a 1/8 inch internal hex wrench, install plugs (C0060). Torque to 8 N•m [6 lbf•ft].
6. Lubricate and install O-rings (B0034).
7. Using a 17 mm open-end wrench on the flats provided, install solenoids (B0032). Torque to 25 N•m [19 lbf•ft] .
8. Lubricate and install new O-rings (B0024) on solenoids.
9. Install coils (B0022). Lubricate and install new O-rings (B0028).

10. Using a 26 mm 12-point socket, install coil nuts (B0026). Torque to 3.5 N•m [2.6 lbf•ft]. Do not overtorque.

2 position control assembly



Hydraulic two-position control module

Disassembly

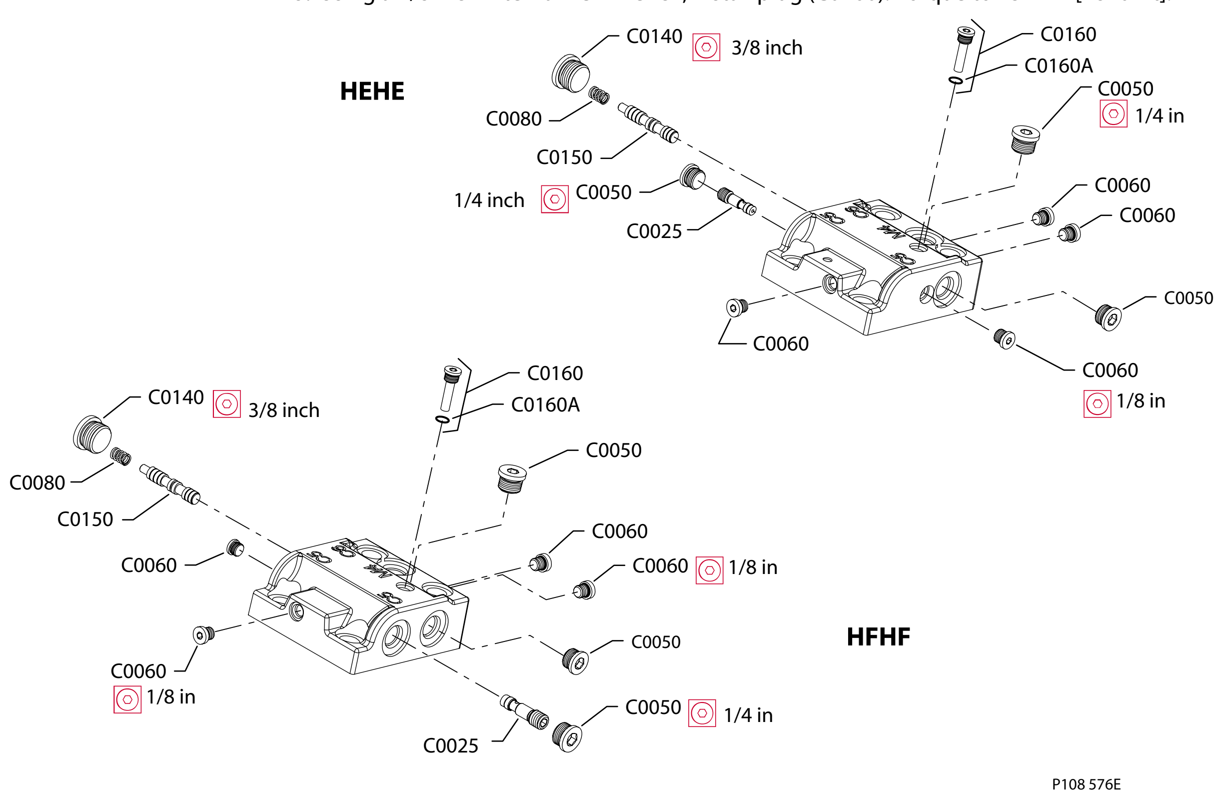
1. Using a 1/8 inch internal hex wrench, remove plug (C0160). Remove and discard O-ring (C0160A).
2. Using a 1/8 inch internal hex wrench, remove three plugs (C0060). Remove and discard O-rings (C0060A).
3. Using a 1/4 inch internal hex wrench, remove two plugs (C0050). Remove and discard O-rings (C0050A).
4. Use a 5mm internal hex wrench to remove the shuttle valve (C0025).
5. Using a 3/8 internal hex wrench, remove plug (C0140). Remove and discard O-ring (C0140A).
6. Remove spring (C0080). Remove spool (C0150).
7. If necessary, use a 3 mm internal hex wrench to remove orifices (E00T2) and (E00T3).

Inspection

Clean and inspect the machined surfaces on the control and the endcap. If any nicks or scratches are found, replace the control/endcap assembly.

Assembly

1. Lubricate and install spool (C0150) and spring (C0080).
2. Using a 3/8 inch internal hex wrench, install plug (C0140). Torque to 25 N•m [18 lbf•ft].
3. Lubricate and install spool (C0025).
4. Using a 1/4 inch internal hex wrench, install two plugs (C0050). Torque to 40 N•m [30 lbf•ft].
5. Using a 1/8 inch internal hex wrench, install four plugs (C0060). Torque to 8 N•m [6 lbf•ft].
6. Using a 1/8 inch internal hex wrench, install plug (C0160). Torque to 25 N•m [18 lbf•ft].



Hydraulic two-position control module with PCOR

Disassembly

1. Using a 1/8 inch internal hex wrench, remove two plugs (C0060). Remove and discard O-rings (C0060A).
2. Using a 1/4 inch internal hex wrench, remove three plugs (C0050). Remove and discard Orings (C0050A).
3. Use a 5mm internal hex wrench to remove the shuttle valve (C0025).
4. Using a 22 mm hex wrench, remove adapter (B0300). Remove and discard O-ring (QB0300).
5. Using a 17 mm hex wrench, remove pressure compensator adjusting plug (C0090). Remove and discard O-ring (M223).
6. Remove spring (C0080). Remove spool (C0070).
7. If necessary, use a 3 mm internal hex wrench to remove orifices (E00T2) and (E00T3).

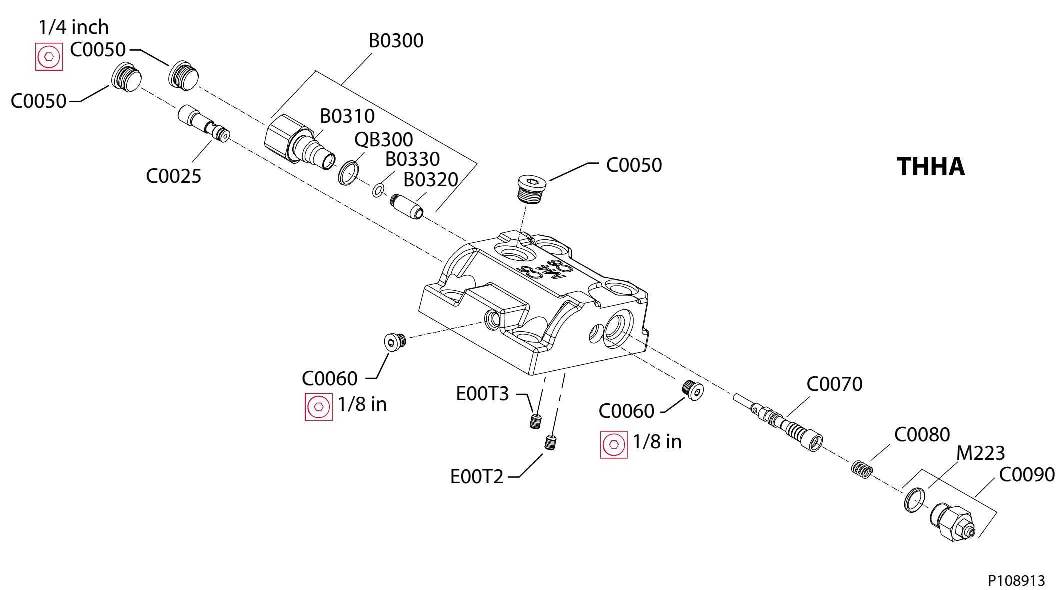
Inspection

Clean and inspect the machined surfaces on the control and the endcap. If any nicks or scratches are found, replace the control/endcap assembly.

Assembly

1. If previously removed, install orifices (E00T3 and E00T2) using a 3mm internal hex wrench. Torque to 6 N•m [4 lbf•ft].
2. Lubricate and install spool and (C0070) and spring (C0080).
3. Lubricate and install O-ring (M223). Install pressure compensator adjusting plug (C0090). Torque to 40 N•m [30 lbf•ft].
4. Lubricate and install O-ring (QB0300). Install adapter (B0300). Torque to 67 N•m [49 lbf•ft].
5. Lubricate and install spool (C0025).
6. Using a 1/4 inch internal hex wrench, install three plugs (C0050). Torque to 40 N•m [30 lbf•ft].
7. Using a 1/8 inch internal hex wrench, install two plugs (C0060). Torque to 8 N•m [6 lbf•ft].

Assemble two position control - THHA



Hydraulic two-position control module with PCOR and hydraulic BPD

Disassembly

1. Using a 1/8 inch internal hex wrench, remove three plugs (C0060). Remove and discard O-rings (C0060A).
2. Using a 1/4 inch internal hex wrench, remove four plugs (C0050). Remove and discard O-rings (C0050A).
3. Using a 1/4 inch internal hex, remove plug (C0140). Remove spool (C0020).
4. Use a 5mm internal hex wrench to remove the shuttle valve (C0025).
5. Using a 22 mm hex wrench, remove adapter (B0300). Remove and discard O-ring (QB0300).
6. Using a 17 mm hex wrench, remove pressure compensator adjusting plug (C0090). Remove and discard O-ring (M223).
7. Remove spring (C0080). Remove spool (C0070).
8. If necessary, use a 3 mm internal hex wrench to remove orifices (E00T2) and (E00T3).

Inspection

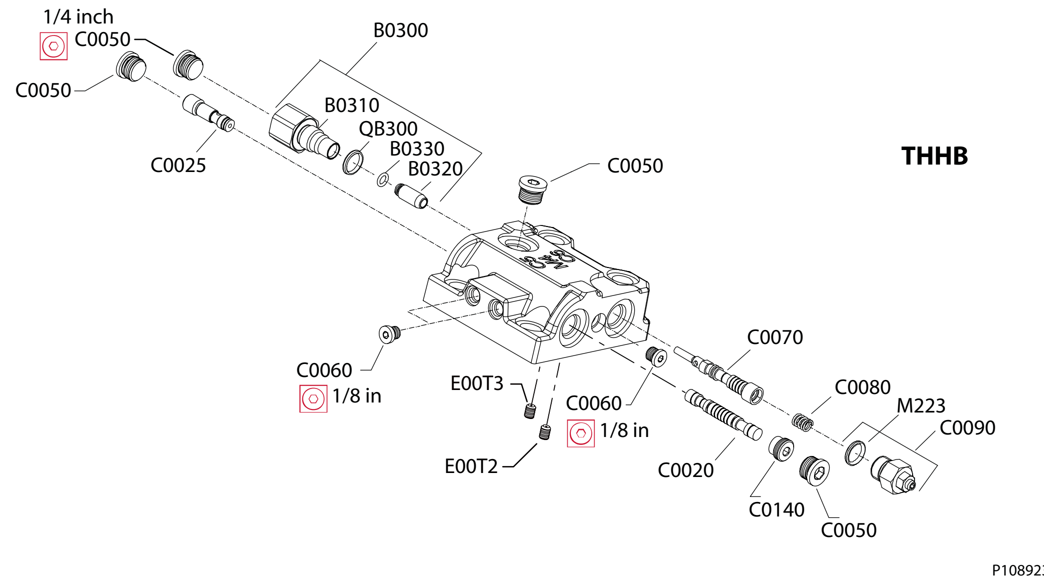
Clean and inspect the machined surfaces on the control and the endcap. If any nicks or scratches are found, replace the control/endcap assembly.

Assembly

1. If previously removed, install orifices (E00T3 and E00T2) using a 3mm internal hex wrench. Torque to 6 N•m [4 lbf•ft].
2. Lubricate and install spools and (C0070) and spring (C0080).
3. Lubricate and install O-ring (M223). Install pressure compensator adjusting plug (C0090). Torque to 40 N•m [30 lbf•ft].
4. Lubricate and install O-ring (QB0300). Install adapter (B0300). Torque to 67 N•m [49 lbf•ft].
5. Lubricate and install spool (C0020).
6. Using a 1/4 inch internal hex wrench, install plug (C0140). Torque to 14 N•m [10 lbf•ft].
7. Lubricate and install shuttle (C0025).
8. Using a 1/4 inch internal hex wrench, install four plugs (C0050). Torque to 40 N•m [30 lbf•ft].

9. Using a 1/8 inch internal hex wrench, install three plugs (C0060). Torque to 8 N•m [6 lbf•ft].

Assemble two position control - THHB



Maximum displacement limiter two-position controls

It is not necessary to remove the maximum displacement limiter unless it is being replaced.

Disassembly

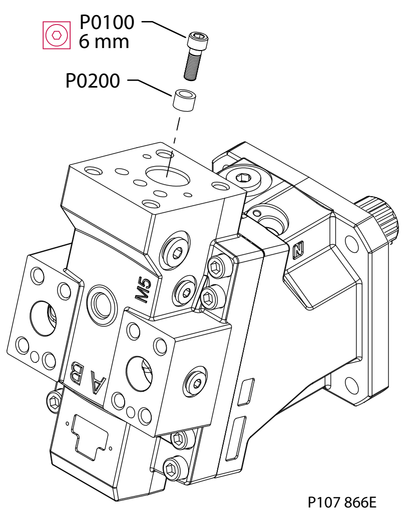
Models with maximum displacement limiter: Remove screw (P0100) using a 6 mm internal hex, and spacer (P0200).

Assembly

Install spacer (P0200) and screw (P0100).

Using a 6 mm internal hex, torque screw to 37 N•m [28 lbf•ft].

Maximum displacement limiter parts



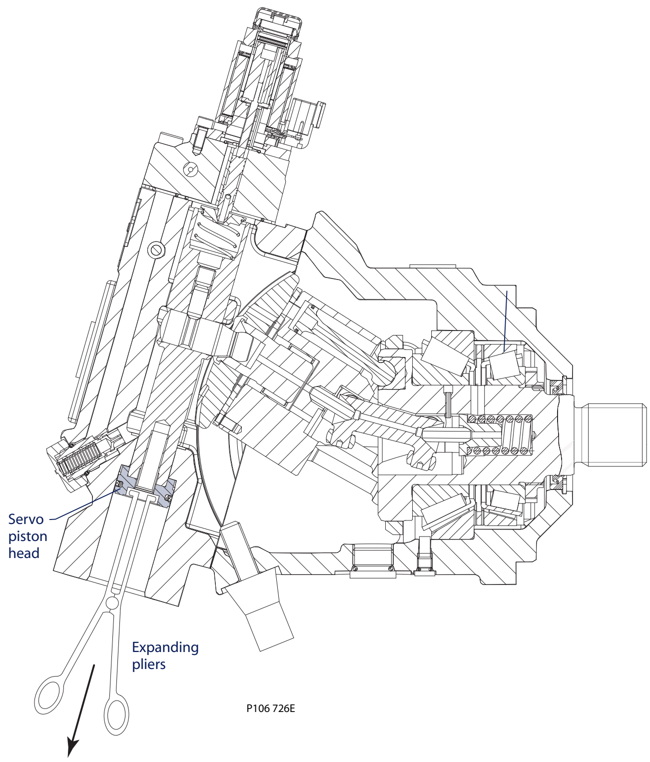
Servo piston cover – proportional control

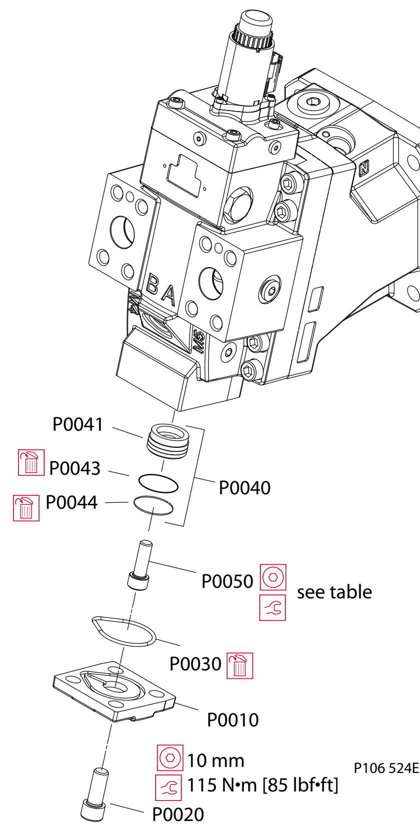
Removal

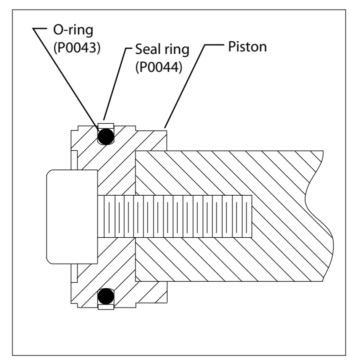
1. Using a 10 mm internal hex wrench, remove four screws (P0020).
2. Remove servo piston cover (P0010).
3. Remove and discard O-ring (P0030).
4. Remove screw (P0050). See table for wrench size.

5. Using expanding pliers, remove piston head (P0040). Remove and discard seal ring (P0044) and O-ring (P0043).

Servo piston cover and bushing







P0050 wrench size and torque

Model	Wrench size	Torque
060/080	8 mm	66 N•m [49 lbf•ft]
110	10 mm	115 N•m [85 lbf•ft]
160/210/250	12 mm	213 Nm [157 lbf•ft]

Inspection

Clean and inspect bushings and machined surfaces for wear or damage. If wear or damage are found, replace component in question.

Assembly

1. Lubricate and install new O-ring (P0043) and seal ring (P0044) on piston (P0041).

Allow seals time to relax before installing piston.

2. Install piston and install screw (P0050). Torque screw (P0050) per table.
3. Lubricate and install new O-ring (P0030) and install servo piston cover (P0010).
4. Using a 8 mm or 10 mm internal hex install screws (P0020). Torque to 115 N•m [85 lbf•ft].

Replace speed sensor

Removal

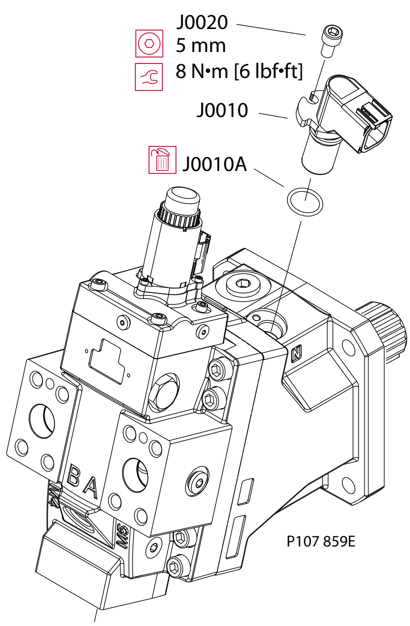
1. Using a 5 mm internal hex wrench, remove screw (J0020).

2. Remove speed sensor (J0010).
3. Discard O-ring (J0010A).

Assembly

1. Lubricate and install new O-ring (J0010A).
2. Install speed sensor (J0010).
3. Using a 5 mm internal hex wrench, install screw (J0020). Torque to 8 N•m [6 lbf•ft].

Speed sensor



Loop flushing spool

Removal

1. Remove plugs (K0030) using a 24 mm hex wrench.
2. Remove and discard O-rings (K0030A).
3. Use a magnet to remove springs (K0020) and spool (K0010).

Inspection

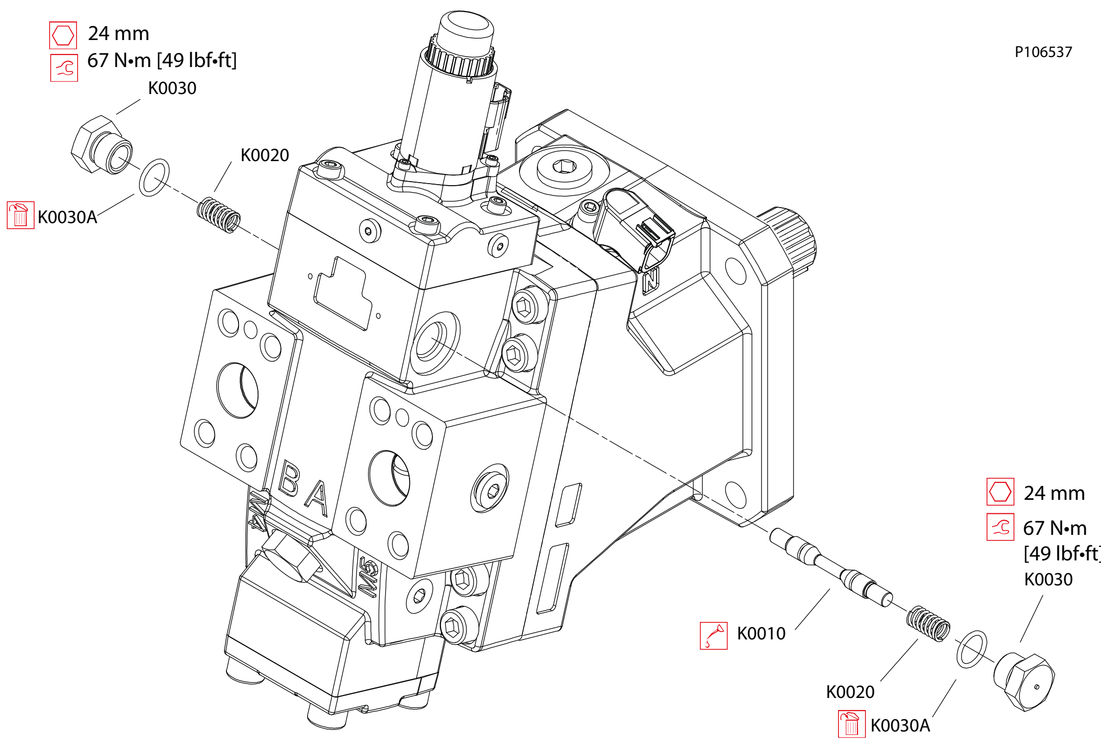
Clean and inspect spool (K0010). If spool is damaged or worn replace it. Replace springs if they are cracked or bent.

Reassembly

1. Lubricate and install spool (K0010).
2. Lubricate and install springs (K0020).
3. Lubricate and install new O-rings (K0030A).

4. Using a 24 mm hex wrench, install plugs (K0030). Torque to 67 N•m [49 lbf•ft]

Loop flushing assembly



Loop flushing charge relief valve

Removal

1. Using a 24 mm hex wrench remove valve (L00**)
2. Remove and discard O-ring (L0050).

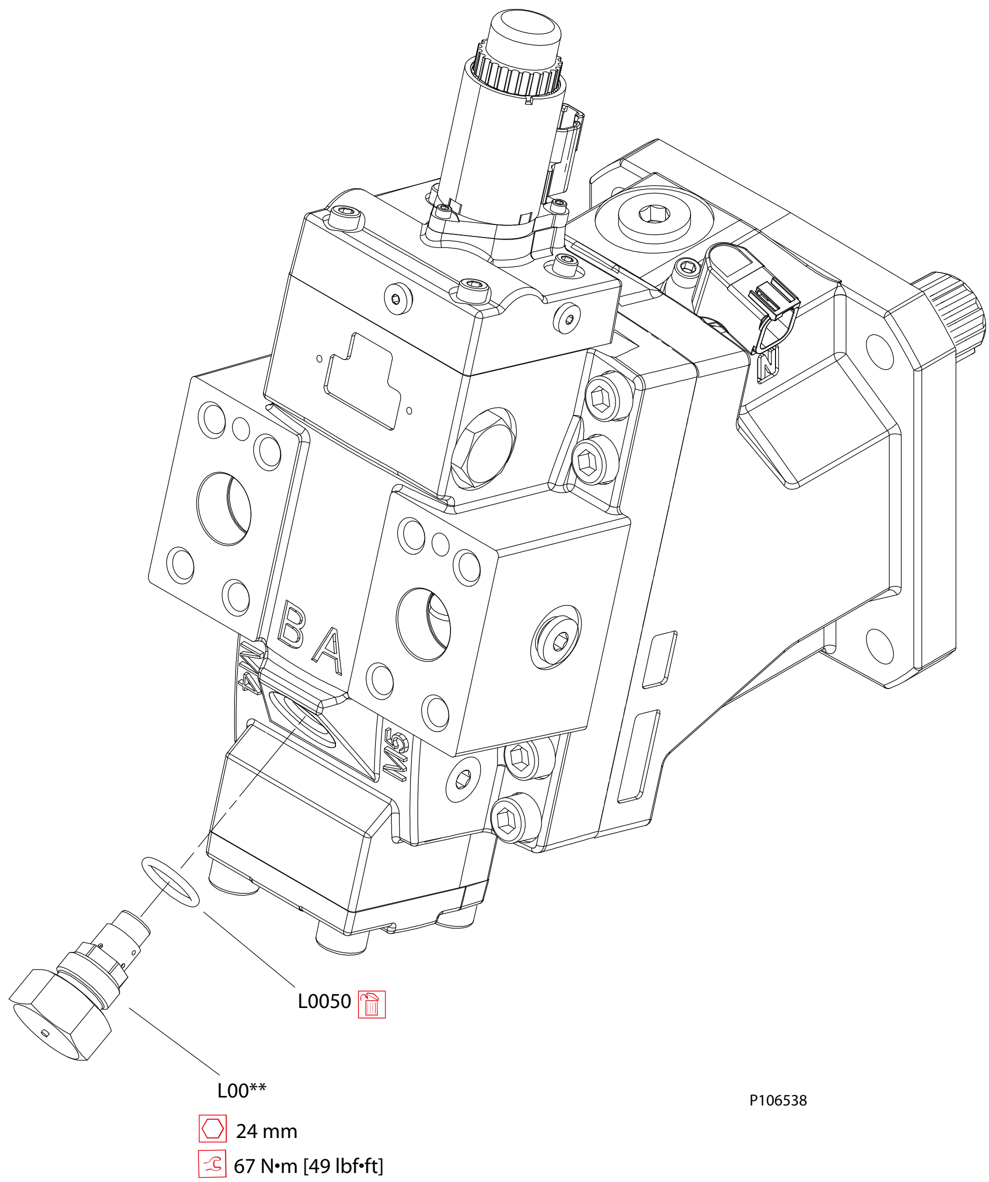
Do not disassemble valve. If you suspect malfunction, replace valve.

Assembly

1. Install new O-ring (L0050).

2. Using a 24 mm hex wrench, install valve (L00**). Torque to 67 N•m [49 lbf•ft].

Loop flushing charge relief valve replacement



Minimum Displacement limiter

Removal

1. Remove cap (N0120).

   Removing the cap destroys the caps locking mechanism. Replace with a new cap.

2. While holding the position of the adjustment screw, remove the seal locknut (N0020) using a 19mm hex wrench. Discard the locknut. After removing the locknut, mark the position of the limiter screw for reassembly.
3. Using a 6 mm internal hex, remove displacement limiter screw (N0010).

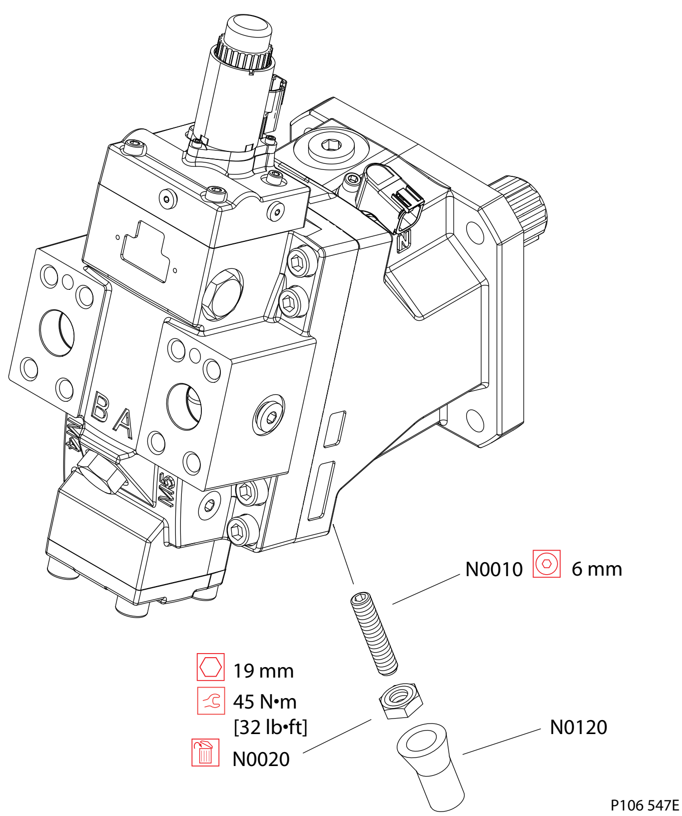
Inspection

Inspect set screw for wear or damage. Replace set screw if necessary.

Assembly

1. Using a 6 mm internal hex wrench, install adjustment screw (N0010) to original position.
2. Using a 6 mm internal hex wrench, to hold the position of the adjustment screw, install a new seal locknut (N0020) using a 19mm hex wrench. Torque to 45 N•m [32 lbf•ft].
3. Install new cap (N0120).

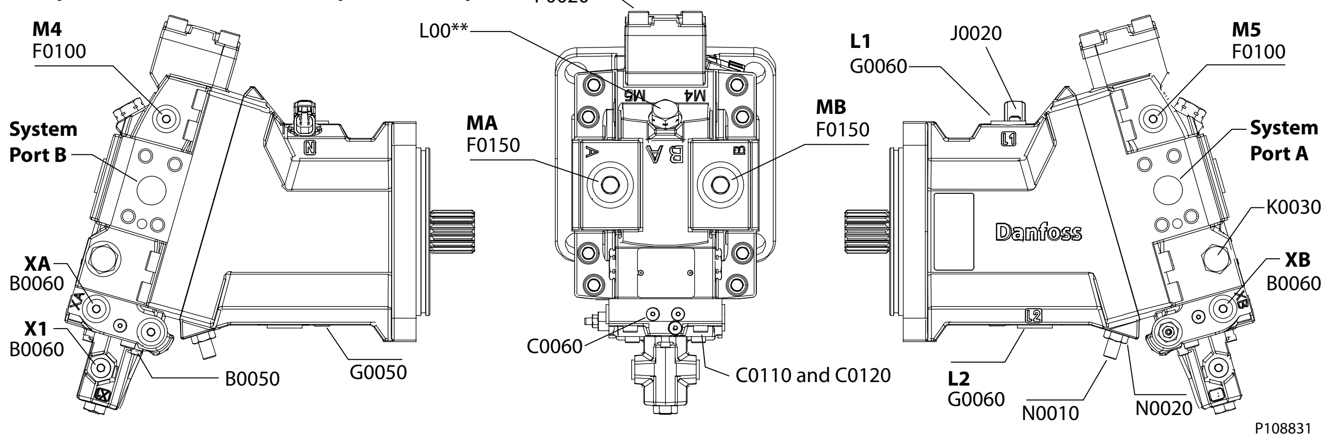
Displacement limiter assembly



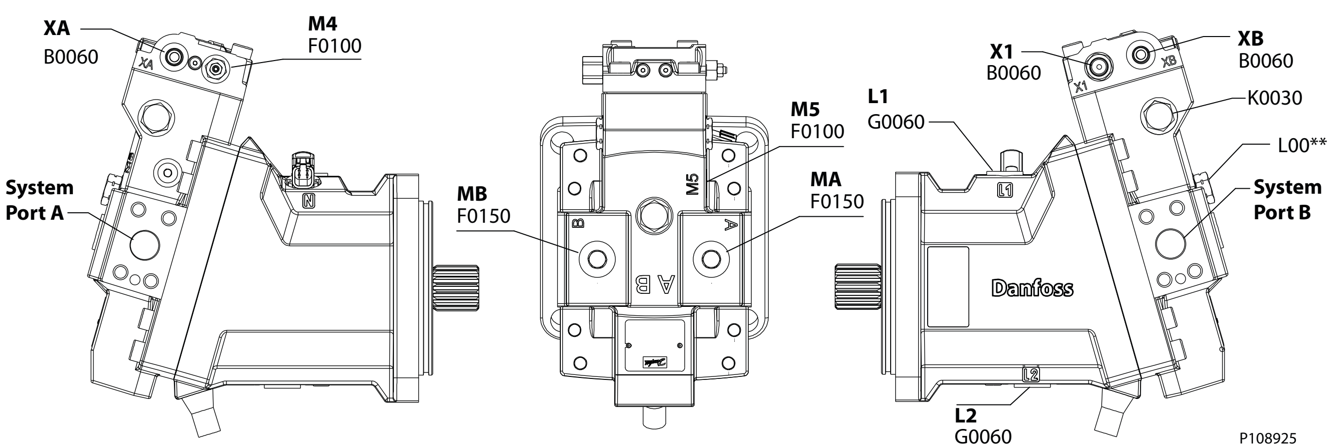
Fasteners and plugs

Port, plug and fastener locations

Proportional controls with radial ported endcap



Two position controls with radial ported endcap



Fastener size and torque chart

Item	Fastener	Wrench size	Torque
B0050	Solenoid screws	4 mm internal hex	6 N•m [4 lbf•ft]
C0110 (proportional)	Control assembly screws	6 mm internal hex	37 N•m [28 lbf•ft]
C0110 & C0120 (two-position)	Control assembly screws	10 mm internal hex	115 N•m [85 lbf•ft]
J0020	Speed sensor screw	5 mm internal hex	8 N•m [6 lbf•ft]
N0010	Displacement limiter screw	6 mm internal hex	N/A
N0020	Displacement limiter locknut	19 mm	45 N•m [32 lbf•ft]
P0020	Servo piston cover screws	10 mm internal hex	115 N•m [85 lbf•ft]

Plug size and torque chart

Item	O-ring plug	Wrench size	Torque
B0060	9/16 - 18UNF	1/4 internal hex	40 N•m [30 lbf•ft]
C0050 (not shown)	9/16-18 UNF	1/4 internal hex	40 N•m [30 lbf•ft]
C0060	5/16 - 24UNF	3/8 internal hex	8 N•m [5 lbf•ft]
F0100	9/16 - 18UNF	1/4 internal hex	40 N•m [30 lbf•ft]
F0150 (060) Radial endcap	1-1/16 - 12 UN	9/16 internal hex	95 N•m [70 lbf•ft]
F0150 (080, 110, 160, 250) Radial endcap	1-1/16 - 12 UN	9/16 internal hex	115 N•m [85 lbf•ft]
G0050	5/16 - 24UNF (SAE and DIN flange)	1/8 internal hex	8 N•m [5 lbf•ft]
G0055 (cartridge model only) (not shown)	7/16 - 20UNF (Cartridge)	3/16 internal hex	8 N•m [5 lbf•ft]
G0060 (060, 080)	7/8 - 14UN	3/8 internal hex	70 N•m [52 lbf•lb]
G0060 (110, 160)	1-1/16 - 12UN	9/16 internal hex	70 N•m [52 lbf•lb]
G0060 (250)	1-5/16 - 12UN	5/8 internal hex	70 N•m [52 lbf•lb]
K0030	M18 - 1.5	24 mm hex	67 N•m [49 lbf•ft]
L00**	M18 - 1.5	24 mm hex	67 N•m [49 lbf•ft]
F0160 Axial endcap (not shown)	9/16-18 UNF	1/4 internal hex	40 N•m [30 lbf•ft]

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STEER AXLE

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The FR Series steer axle was designed to allow service of the wheel components without removing the axle from the truck. To replace or service the steer axle or the articulation bushings, the axle will need to be removed from the truck.

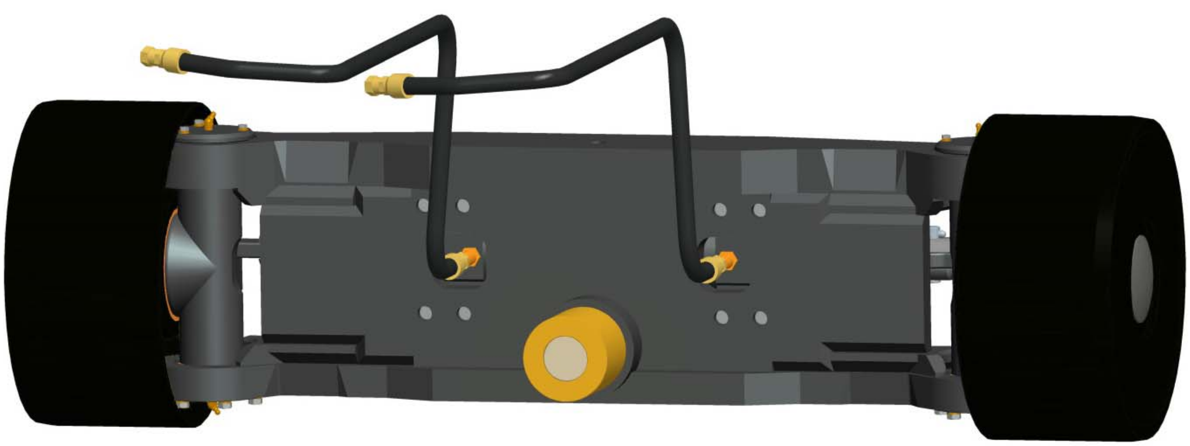
WARNING

READ AND THOROUGHLY UNDERSTAND "BLOCKING UP THE TRUCK" IN APPENDIX PRIOR TO REMOVING STEER AXLE FROM TRUCK

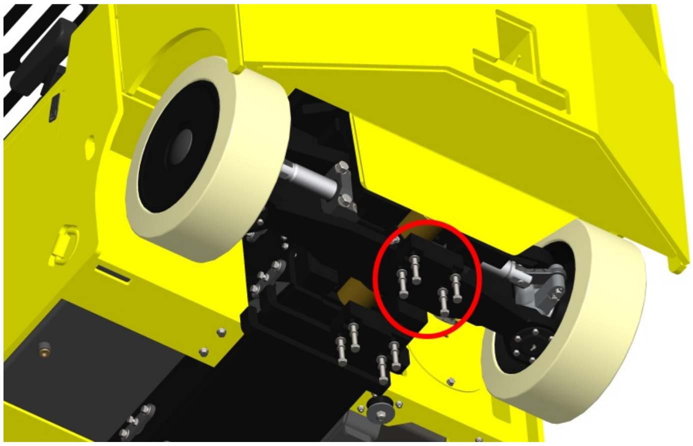
Removing the steer axle
When removing the steer axle, it is recommended to remove the counterweight plates from the rear chassis to make the back end of the truck lighter. To remove the steer axle from the chassis, jack up or lift the rear of the truck and position blocks under the frame in accordance with the procedure found in "Blocking Up the Truck" locating in the Appendix of this manual.

WARNING
ALWAYS MAKE SURE THE CHASSIS LOCK PIN IS ENGAGED WHEN WORKING ON THE TRUCK IN THE RETRACTED POSITION

Once the blocks are in place, disconnect the steering hydraulic hoses from the hydraulic fittings on the steer cylinder. These are located on the front of the axle, towards the operator.

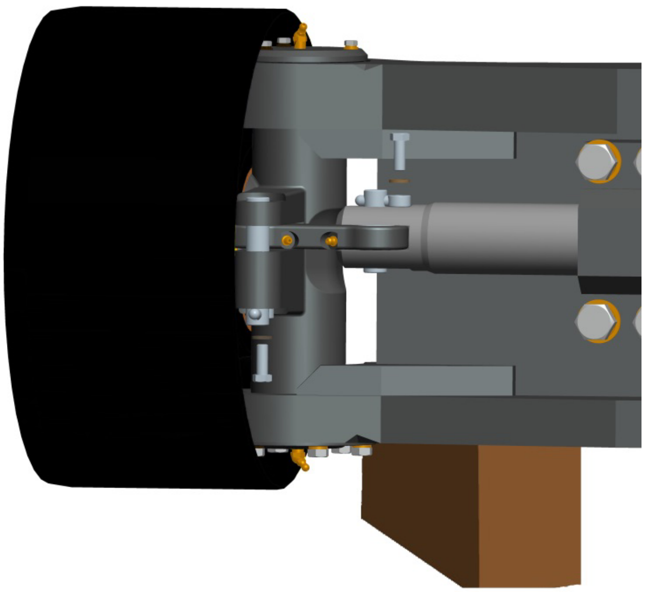


Removing the steer axle (Cont'd)
The steer axle is retained in the chassis at the articulation pins by the articulation blocks and steer axle caps. There are two articulation blocks each with its own cap, one located on the front side of the steer axle and one on the rear side. Position a hydraulic jack under the steer axle beam for support and remove the four hex head bolts from the steer axle caps (the top half of the block is welded to the frame, picture depicted out of chassis). With the steer axle caps removed, the steer axle can now be lowered and removed from the truck.

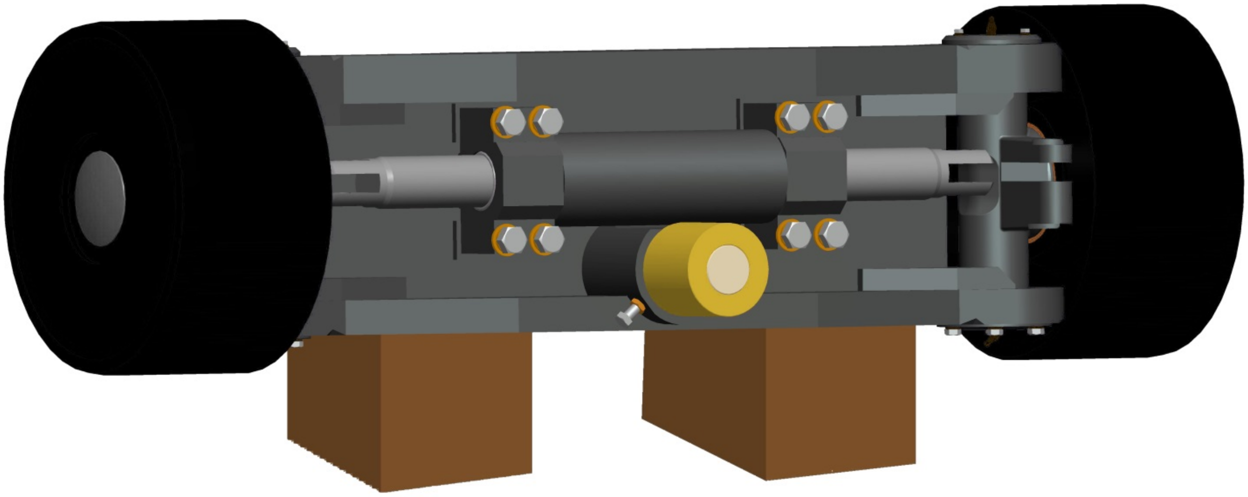


Removing the Steer Cylinder
The steer axle must be removed from the frame to remove the steer cylinder. Place the steer axle on stands with the cylinder on the side. Do not place the cylinder up, the wheels will swing down when the cylinder is removed, causing an unnecessary hazard, and making it difficult to reinstall.

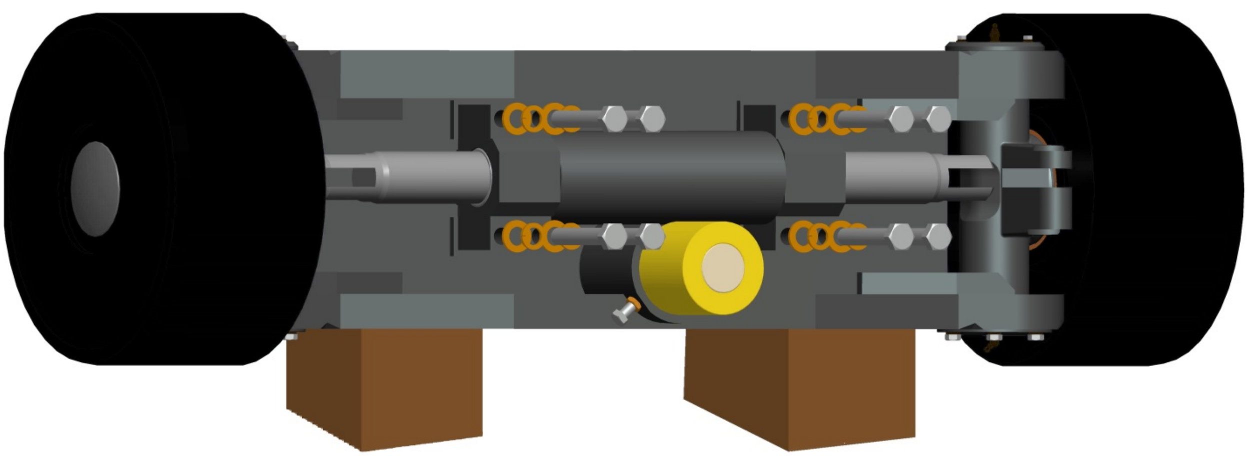
Turn the wheel to one side to provide easy access to both pins on the steering link. Remove the hex head bolts and lock washers retaining the steer link pin keepers on the steer cylinder rod ends and knuckles as shown below and remove the pin keepers.



Remove the steer links on both sides of the cylinder.



Remove the eight Socket Head Cap Screws that hold the gland nuts on the steer cylinder to the frame. Next remove the steer cylinder by using a strap and lifting device to pull it out of the front of the axle.



Disassembly/Assembly of Steer Cylinder
Before disassembly, the steer cylinder must be cleaned and free of dirt, grease, and other contaminants. Servicing of the cylinder components must be performed in a clean environment to avoid the potential for leaks and damage. Keep hands and all tools clean when handling the internal components of the steer cylinder.

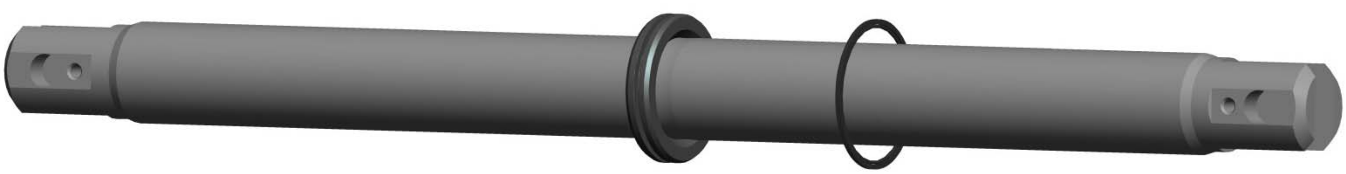
Remove the two fittings from the gland nuts.

Remove both gland ends from the cylinder assembly by tapping the inside of each gland end with a rubber mallet. The gland ends will separate from the cylinder tube and can then be slid off of the cylinder rod. Be careful not to nick or scratch the cylinder rod.

With the gland ends removed, the cylinder rod piston assembly can be removed from the cylinder tube as shown below.

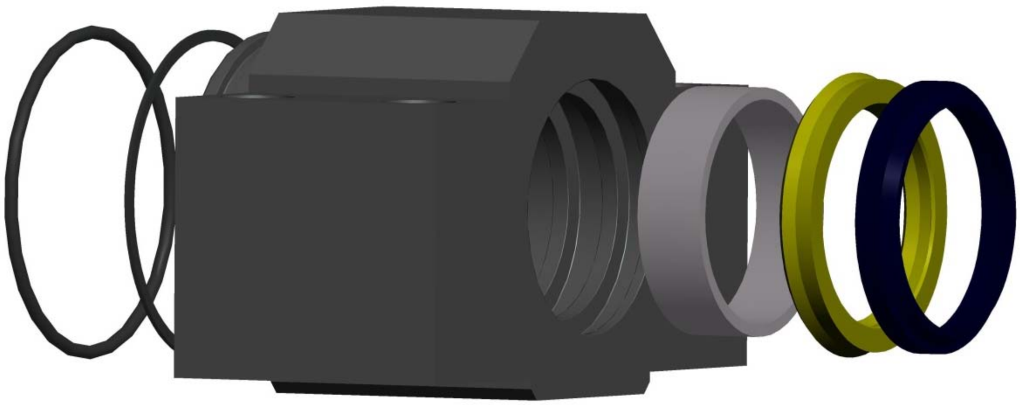
The seals can now be replaced in the gland ends and cylinder rod. Before replacing the seals, inspect the machined surfaces that retain the seals making sure they are clean and free of damage. Inspect the outside surface of the cylinder rod for nicks and scratches and make sure there is no damage. If there are deep scratches or nicks on the surface of the cylinder rod it must be replaced or repaired prior to reassembling the cylinder. Inspect the bore of the cylinder tube for damage as well.

Remove the piston seal ring from the cylinder rod as shown below. Lubricate the new piston seal ring with hydraulic oil and install the new piston seal ring onto the cylinder rod piston. Lubricate both the piston seal ring and the bore of the cylinder tube. Install the piston rod into the cylinder tube making sure not to damage the seal ring.



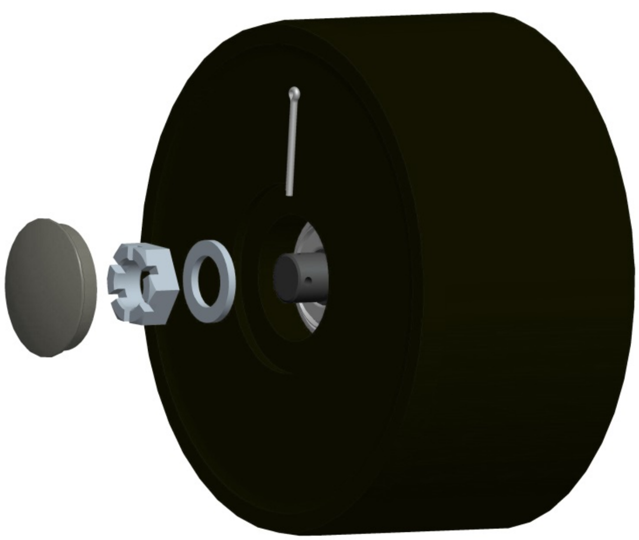
Remove all seals from the gland taking note of the order and position of all seals as shown below. Lubricate the new seals with hydraulic oil and reinstall them to the gland in the correct order.

Lubricate the gland nut seals, cylinder rod, and cylinder tube bore with hydraulic oil. Install the first gland end onto the cylinder rod making sure not to damage the seals. Using a clean flat surface to line up the gland ends, install the second gland end onto the cylinder rod making sure not to damage the seals. Use a rubber mallet to seat the gland ends in the cylinder tube. The steer cylinder is now assembled and can be reassembled into axle beam in the reverse order as described in the disassembly procedure.

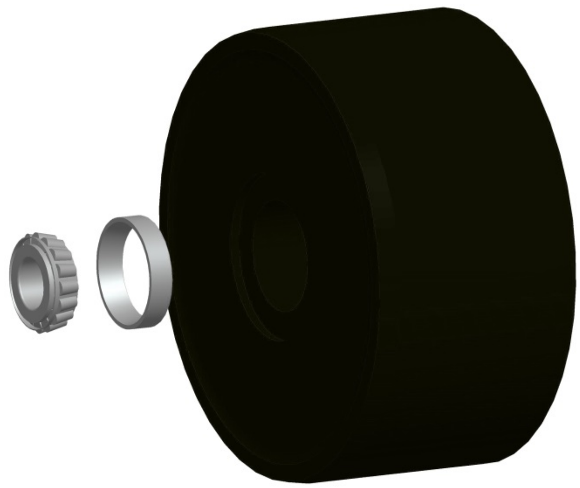


Disassembly/Assembly of Steer Wheel

Remove the steer wheel cap to access the spindle nut. Remove the cotter pin, nut and washer from the spindle.



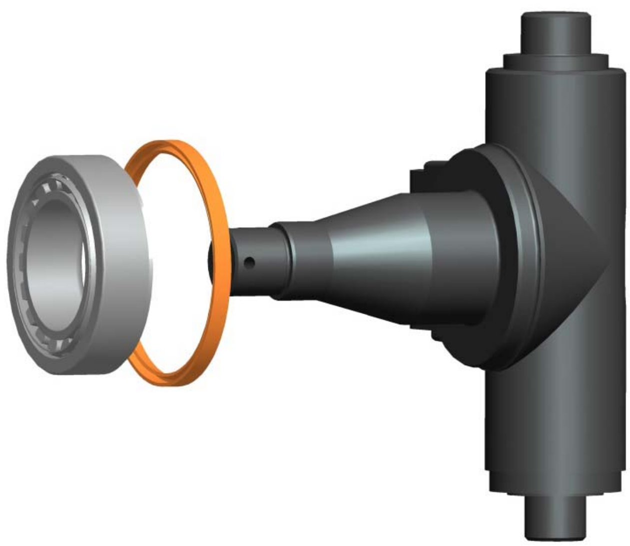
Disassembly/Assembly of Steer Wheel (Cont'd)
Remove the steer wheel and bearings from the spindle using a rubber mallet to knock the old bearings out.



Install new bearing races by lining up the races to the wheel and pressing with the correct size arbor. Make certain that each bearing race is seated squarely in the wheel against the appropriate shoulder.

Any time the steer wheels are removed, it is important to inspect, and replace as necessary, the inner grease seals to prevent contamination to the bearing sets.

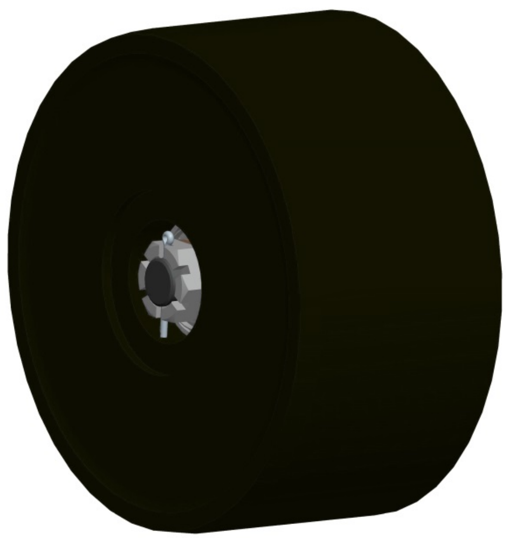
To remove the inner grease felt seal, first remove the inner bearing cone from the steer knuckle as shown below.



Install the new inner grease seal over the knuckle until it seats against the seal ring support followed by the new inner bearing cone. When installing the new bearing cones repack with good quality grease as identified in the "Titan Fluids" section in the Reference Section of this manual. It is also recommended to repack wheel bearing cones using a grease packing tool.

Disassembly/Assembly of Steer Wheel (Cont'd)
Remove the grease retainer and install the new grease felt in the groove on the retainer. Install against the grease retainer followed by the new inner bearing cone. When installing the new bearing cones repack with good quality grease as identified in the "Titan Fluids" section in the Reference Section of this manual. It is also recommended to repack wheel bearing cones using a grease packing tool.

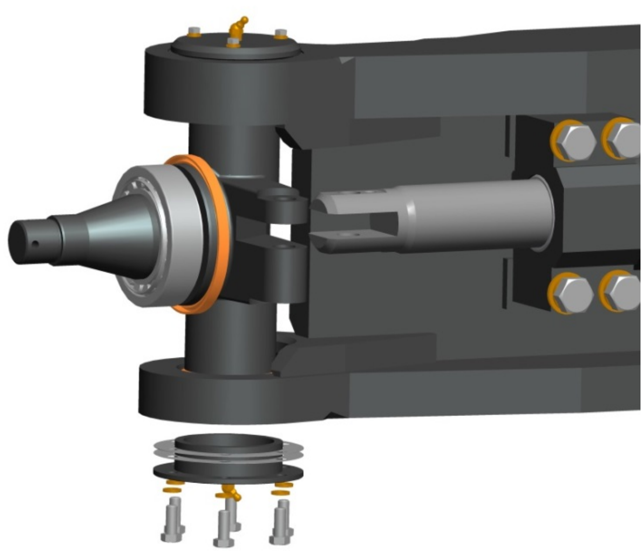
With an approved lifting device, reinstall the steer wheel onto the steer knuckle. Install the outer bearing cone, nut, washer, and cotter pin as shown below. Replace the steer wheel cap.



Disassembly/Assembly of Steer Knuckle
The kingpin bearings can be greased from the lube fittings located in the center of the upper and lower bearing caps as indicated in the "Lubrication Points" section of this manual.

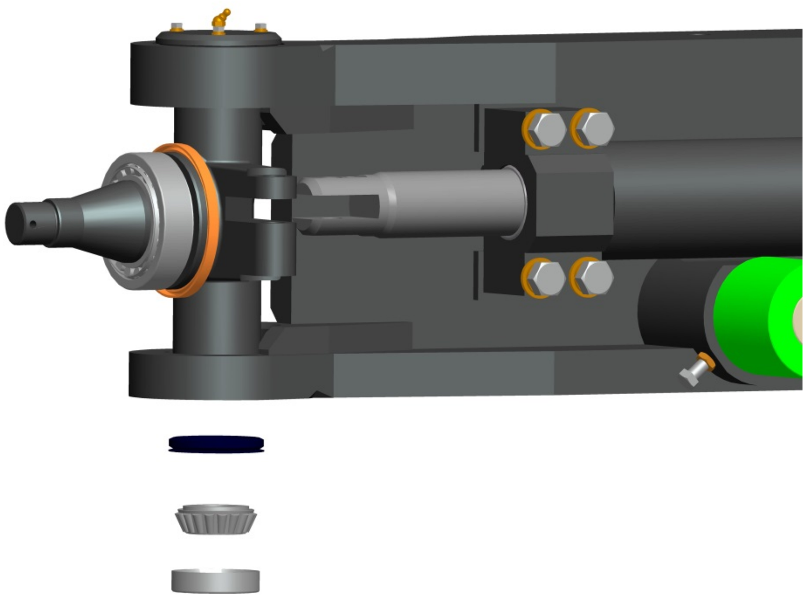
Remove steer wheel assembly using previous steer wheel disassembly/assembly procedure.

Remove the upper bearing cap mounting screws, flat washers, and lock washers as shown below.

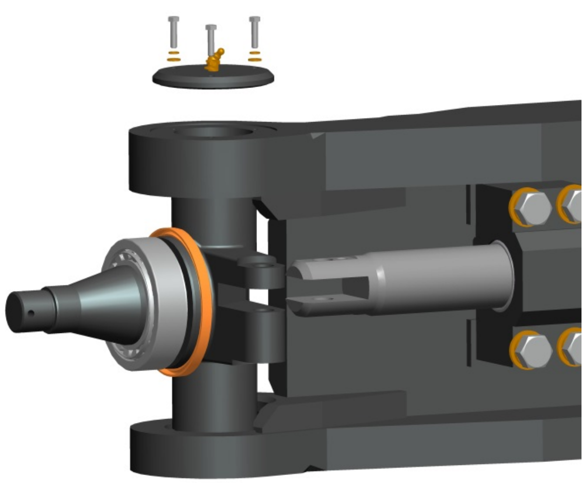


Disassembly/Assembly of Steer Knuckle (Cont'd)

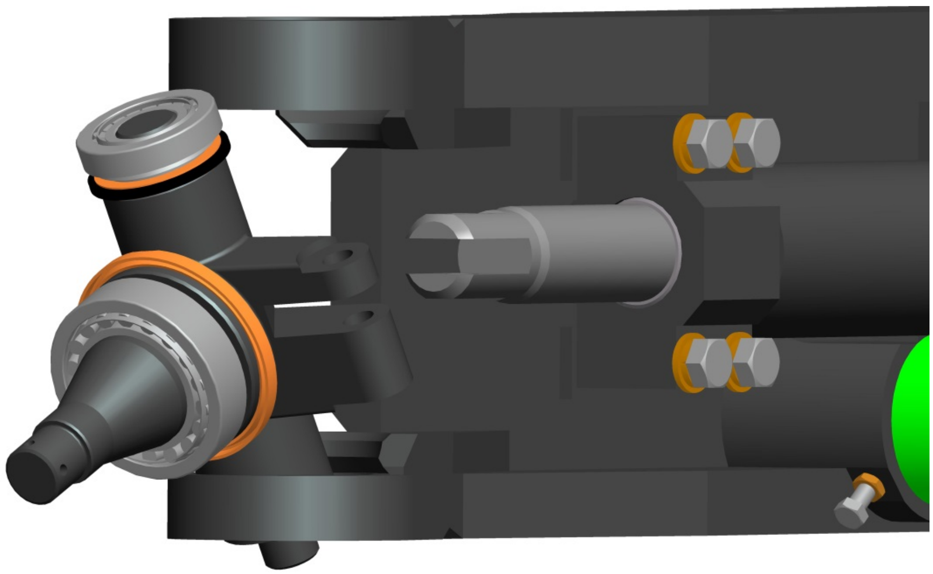
Remove the lower kingpin bearing cone (may require a bearing extractor), lower oil seals and lower oil seal retainer by sliding them off of the steer knuckle and thru the steer axle beam as shown below.



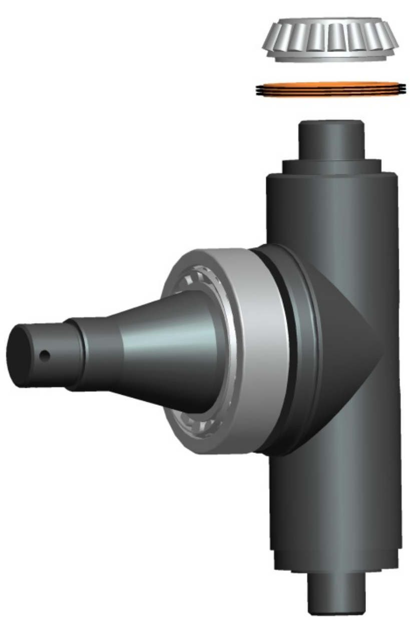
Remove the upper cap mounting screws and lock washers shown below in order to remove upper bearing cap.



Disassembly/Assembly of Steer Knuckle (Cont'd)
Drop the steer knuckle down until the top of the upper bearing cone is clear of the steer axle beam and can be rotated out of the axle.

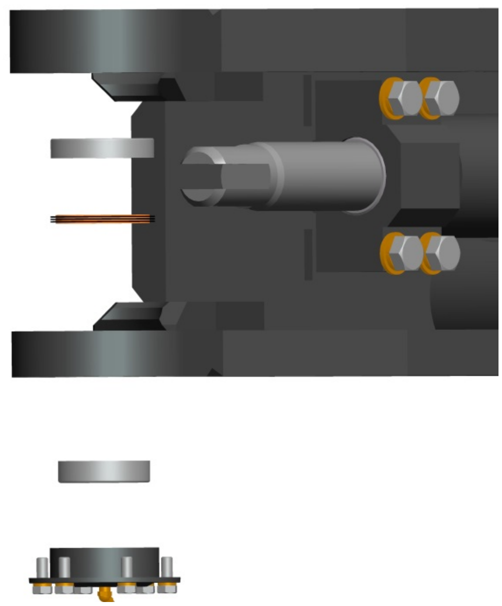


With the knuckle out of the axle beam, remove the upper bearing cone (may require a bearing puller) from the knuckle kingpin. The upper bearing seal and retainer shown below can now be removed as well.



Disassembly/Assembly of Steer Knuckle (Cont'd)

Inspect the seal retainer for damage and replace as necessary. Install a new seal, making sure it seats properly on the seal retainer. Install the new upper bearing cone. Repack the bearing cone using a bearing packing kit. To replace bearing races in the steer axle frame, use a brass punch to knock out the old bearing races. Replacing races in lower caps may require the use of a bearing puller.



Prior to installing new bearing races in the axle beam and caps, be sure the bearing seats are free of dirt and defects. Install the new bearing races using a press or mandrel. Make sure all bearing races are pressed squarely in the steer axle frame and lower caps and are seated properly against the appropriate shoulders.

Reinstall the knuckle in the steer axle frame followed by the lower seal retainer, new seals, and new bearing cone. Reinstall the lower cap (with new race) using the original mounting screws and lock washers. Complete the installation by installing the upper cap using the original mounting screws and lock washers.

SEE ALSO: "GENERAL BEARING HANDLING AND INSPECTION" IN REFERENCE SECTION

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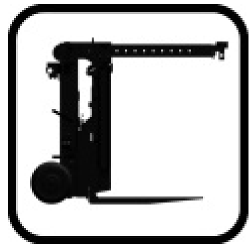

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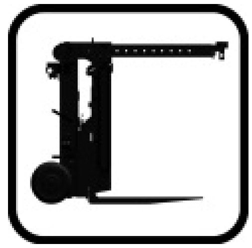

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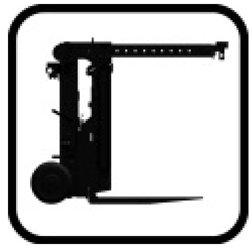

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Introduction

This section provides general maintenance, service and troubleshooting procedures for FR Series masts and associated components. Always refer to your serial number specific Parts Manual for information on the components used on your forklift.

WARNING:
BEFORE OPERATING THE FORKLIFT, OR ATTEMPTING ANY SERVICE OR MAINTENANCE WORK, MAKE SURE YOU HAVE READ AND THOROUGHLY UNDERSTAND BOTH THE OPERATOR MANUAL AND THE SAFETY PRECAUTIONS INCLUDED IN THIS MANUAL.
FAILURE TO DO SO MAY RESULT IN SERIOUS HARM OR DEATH.

WARNING:
THE PROCEDURES FOR REMOVING AND SERVICING MASTS AND MAST COMPONENTS REQUIRE HOISTING AND BLOCKING SOME LARGE HEAVY COMPONENTS. MAKE SURE ALL HOISTING EQUIPMENT IS PROPERLY RATED AND APPROPRIATE FOR THE TASK AT HAND. READ AND THOROUGHLY UNDERSTAND HOW TO PROPERLY BLOCK THE FORKLIFT AND/OR COMPONENTS BEFORE ATTEMPTING TO DO SO.

Do not walk or stand under raised forks
Keep your arms and fingers away from moving parts of the mast
Do not reach through open areas of the mast
Failure to follow these warnings can result in serious injury

Service Intervals

All Mast components should be visually checked every day as part of the Operator's Daily Inspection.
As indicated in the PM schedule included in Section 2:

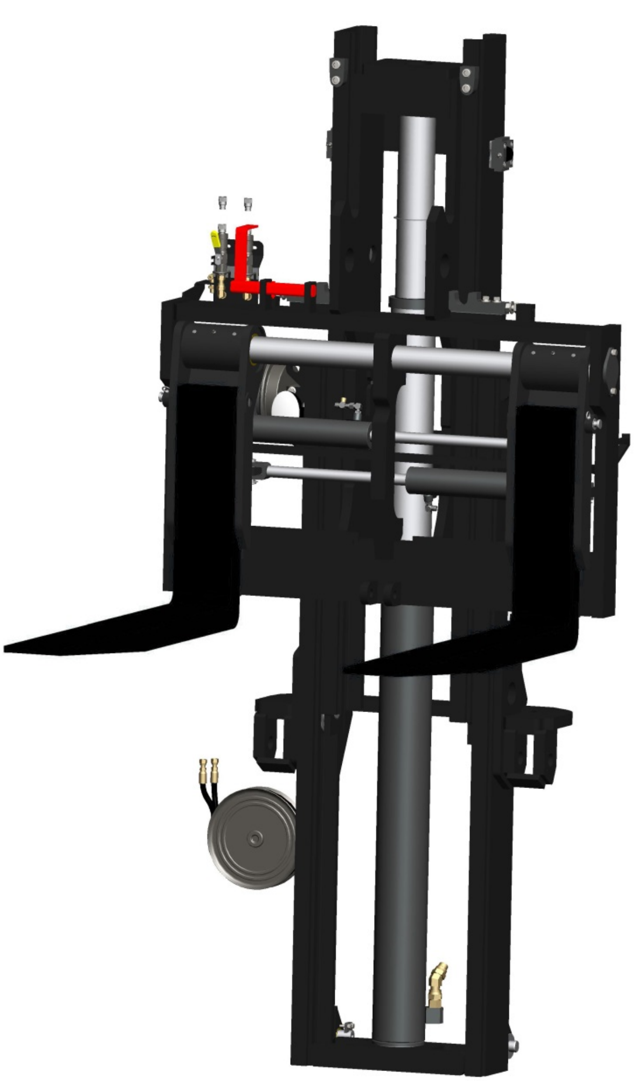
- A thorough visual inspection of the entire mast assembly should be performed by a trained service professional every 250 hours.
- Lift chains should be inspected and lubricated every 250 hours.
- Lift chain tension should be checked every 250 hours.
- Mast and carriage rollers should be checked for proper alignment every 250 hours.
- Mast racking should be checked after the initial 8 hours of operation.

General Description

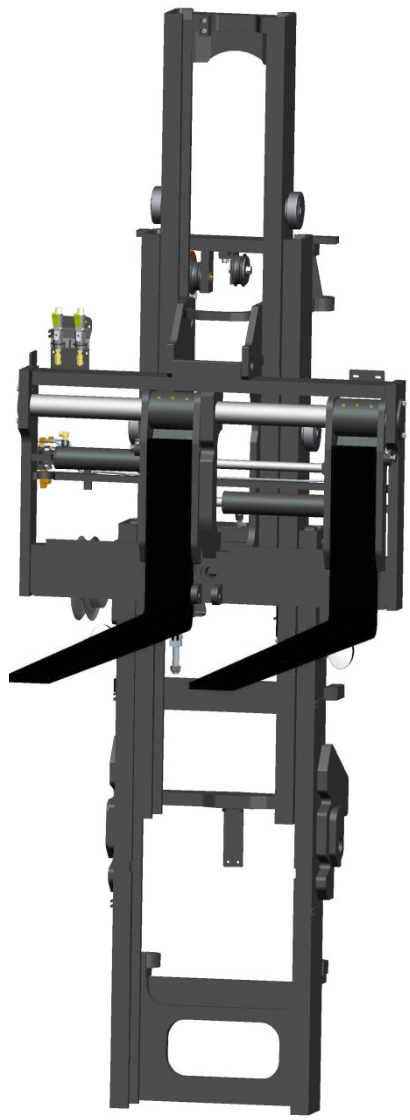
The mast assembly includes the inner stage assembly, outer stage assembly, lift cylinder, carriage, forks and boom.

Types of Masts & Carriages

Also referred to as an 'upright', the mast is the vertical mechanism on the front of the lift truck that does the work of raising, lowering, and tilting the load. Each type of mast is offered in multiple lift height iterations.



FR25/35

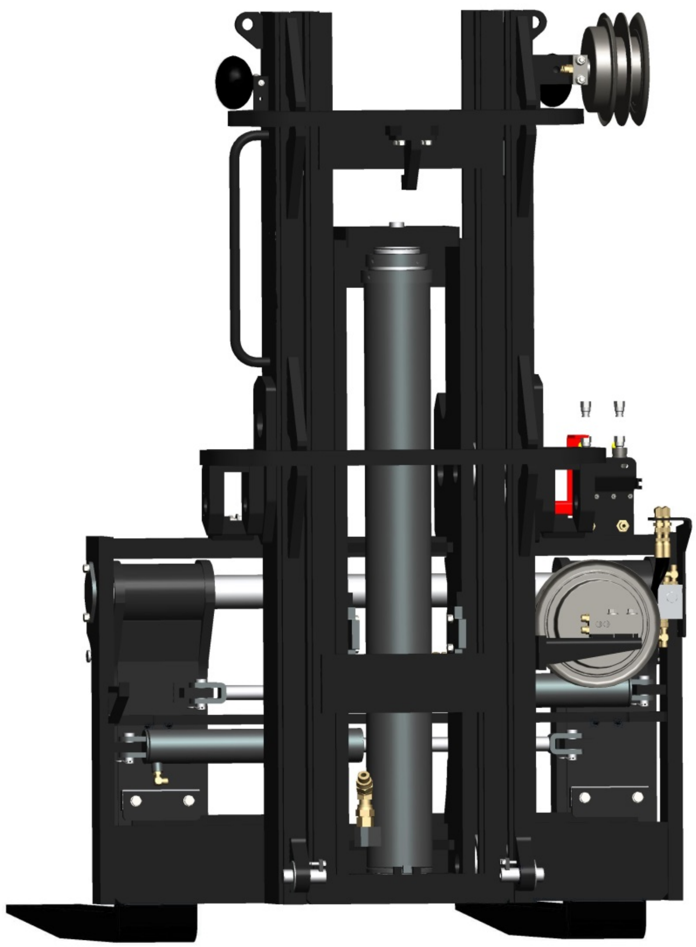


FR15/25 & FR18/26
3-Stage

FR15/25 & FR18/26
2-Stage FFL

FR25/35

Referred to as Hi-Vis due to the lack of a center cylinder, 2-stage Hi-Vis masts have two single-acting lift cylinders nested directly behind the mast channels on either side of the truck. The lift cylinders are mounted to the outer stage and act directly on the inner stage. The inner stage includes lift chain assemblies from which the carriage and forks are supported. As the lift cylinders raise the inner stage, the lift chain assemblies also raise the carriage. This means that for every 1” of lift cylinder extension, the fork height will increase 2”.

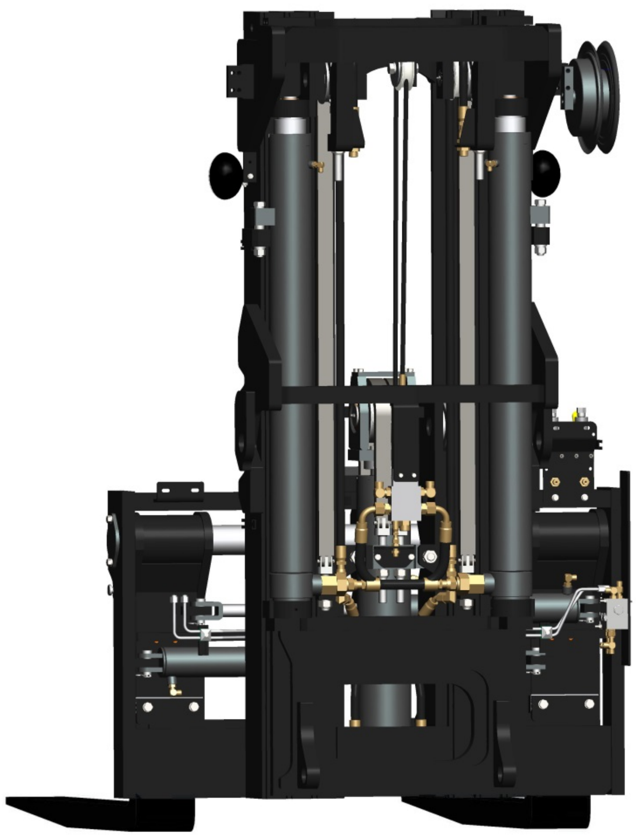


Outer Stage Assembly
The outer stage assembly is mounted to the drive axle. The outer stage assembly does not raise or lower.

Inner Stage Assembly
The inner stage assembly is supported and guided by the outer stages assembly as it raises. Eccentric bearing assemblies allow for forward and backward adjustment between the inner and outer stage assemblies.

FR15/25 & FR18/26 3-Stage

3-stage masts have two single-acting lift cylinders nested behind the mast channels on either side of the truck. The lift cylinders are mounted to the outer stage assembly and act directly on the intermediate stage assembly. The intermediate stage assembly includes lift chain assemblies from which the inner stage assembly is supported. The inner stage assembly also includes lift chain assemblies from which the carriage and forks are supported. As the lift cylinders raise the intermediate stage assembly, the intermediate stage lift chain assemblies raise the inner stage assembly. As the inner stage assembly is raised, the inner stage assembly lift chain assemblies raise the carriage. This means that for every 1” of lift cylinder extension, the fork height will increase 3”. Due to the nature of the construction of the various mast stages, 3-stage mast often have a limited amount of free lift as well.



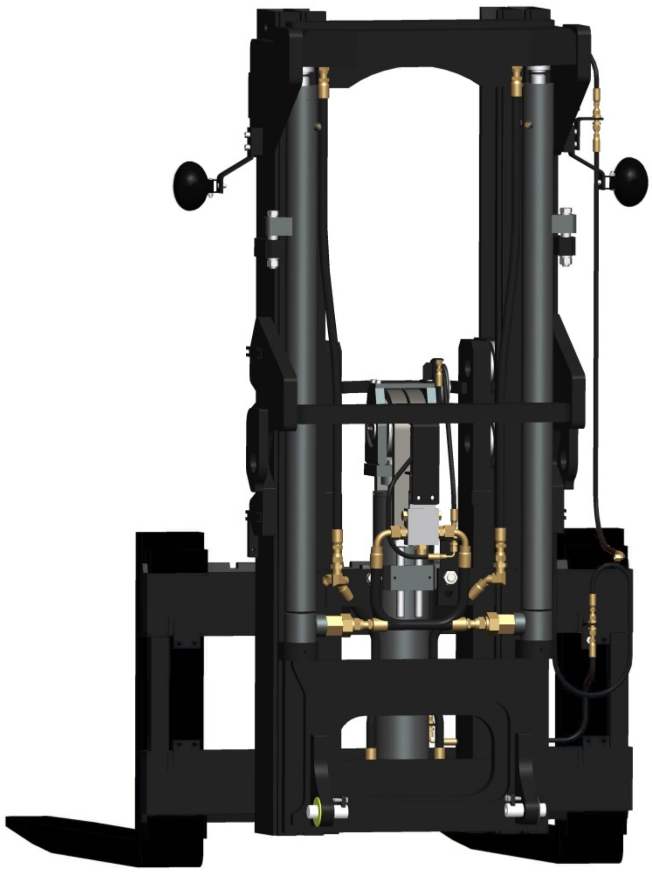
Outer Stage Assembly
The outer stage assembly is mounted to the drive axle. The outer stage assembly does not raise or lower.

Inner Stage Assembly
The inner stage assembly is supported and guided by the outer stage assembly as it raises. Eccentric bearing assemblies allow for forward and backward adjustment between the inner and outer stage assemblies.

Intermediate Stage Assembly
The intermediate stage assembly is supported and guided by the outer stage assembly as it raises. Eccentric bearing assemblies allow for forward and backward adjustment between the inner and outer stage assemblies.

FR15/25 & FR18/26 2-Stage

Also known as Free Lift masts due to the fact that the collapsed height of the mast does NOT increase through the first stage of lift, 2-Stage FFL masts have a center lift cylinder that raises the carriage and two side cylinders that raise the inner stage when the center cylinder has reached full stroke. When the carriage reaches the end of travel in the inner stage assembly, a stop is engaged and the inner stage assembly then raises until the lift cylinder is fully extended.



Outer Stage Assembly
The outer stage assembly is mounted to the drive axle. The outer stage assembly does not raise or lower.

Inner Stage Assembly
The inner stage assembly is supported and guided by the outer stage assembly as it raises. Eccentric bearing assemblies allow for forward and backward adjustment between the inner and outer stage assemblies.

Mast Wear In

It is not uncommon for a new mast to show signs of flaking, leafing, peeling or what appears as some minimal roller gouging. This appearance is indicative of the rollers seating during an initial break-in period and is considered normal. This condition will alleviate itself after a nominal wear-in period. Grease applied to the channel can, and will, retain any particles or flaking and actually serve to properly work harden the surface(s) in question.

Masts are not typically lubricated prior to shipment to prevent contamination of dirt and other debris during transit. When applying grease make sure surfaces are clean and dry and free of any debris. Do NOT use steam or pressure washing to clean the areas to be greased as these processes can contaminate chains and rollers and compromise their internal lubrication. Do NOT apply excessive amounts of grease causing the rollers to slide rather then roll.

To properly access all portions of the rail it may be necessary to extend the mast channels and carriage.

WARNING:
OBSERVE SAFE BLOCKING PRACTICES WHEN SECURING MAST TO PREVENT INJURY

Mast Service

WARNING:
Lifting or jacking any large piece of equipment, such as a fork truck, prevents obvious hazards. It must be done with great care and forethought. Consult the truck weight information that can be found on the data plate specification to ensure that your lifting equipment is of adequate capacity.

WARNING:
Defective equipment can cause accidents! All tools and lifting equipment must be in good condition and meet the load requirements and have OSHA labels when required. Tools with defects can fail and cause severe injury or death.

To service the carriage or inner stage, the assemblies must be removed from the outer stage. The carriage is removed from the bottom of the inner stage. To perform the services to the rollers, pins, and make other repairs, use the following instructions in this section.

Note: If the mast assembly is removed from the truck, face the carriage up.

REFERENCE INNER STAGE SERVICE & CARRIAGE REMOVAL IN THIS MANUAL

Mast Specialty Tools List

Roll Pin Punch Set

Brass Punch Set

Rubber Mallet

Hydraulic Press

Snap Ring Pliers

Bushing Driver Set

Servicing Lift Cylinders

Cylinder packing, wipers and bushings are subject to contamination from both external and internal foreign materials which can be abrasive in nature resulting in wear or damage to parts that require they be replaced. Genuine replacement seals are available in kits to rebuild/repack all lift cylinders.

Before attempting any cylinder rebuild it is strongly recommended that the proper tools are available. Having the correct tools will make the job of servicing cylinders easier and reduce the risk of inadvertent damage to the cylinder.

ADJUSTABLE SPANNER WRENCH

NYLON STRAP WRENCH

STOP RING WRENCH

PACKING ASSEMBLY TOOL & PULLERS

Hose Reel Service and Troubleshooting

Some trucks equipped with auxiliary functions such as fork positioning and/or sideshift, and certain lift height iterations, will include hose reels fixed to the top of the outer stage on the outboard side of the mast channels. The hose reels provide a simple and effective method of plumbing from the stationary outer stage to the carriage connection points for the fork positioner and sideshifter cylinders. Hose reels require periodic maintenance and may at some point require service.

Special Instructions Definitions

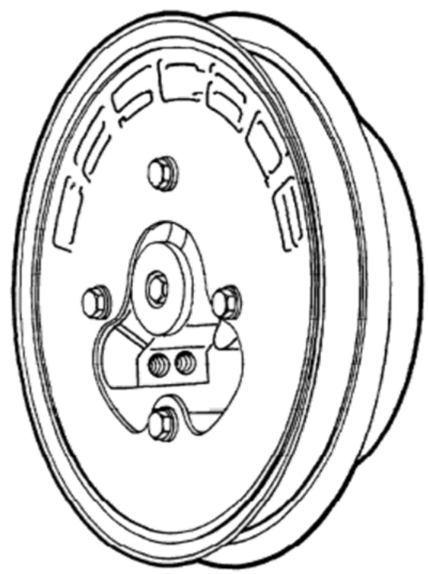
⚠ WARNING

A statement preceded by **⚠WARNING** is information that should be acted upon to prevent **bodily injury.** A **WARNING** is always inside a ruled box.

CAUTION
A statement preceded by **CAUTION** is information that should be acted upon to prevent **machine damage.**

IMPORTANT
A statement preceded by **IMPORTANT** is information that possesses special significance.

NOTE
A statement preceded by **NOTE** is information that is handy to know and may make your job easier.



Periodic Maintenance

500 Hour Maintenance

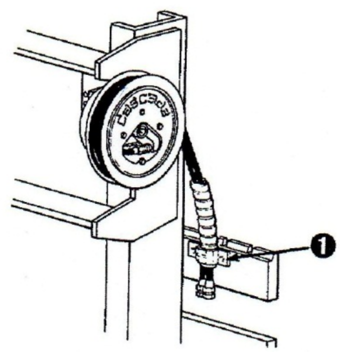
After each 500 hours of lift truck operation, perform the following procedures.

- ☐ Retorque the mounting capscrews. Use the torque specifications shown in Section 5.
- ☐ Retighten all hydraulic hose fittings.
- ☐ Check hoses for cracks, peeling or leaking. Replace as required.

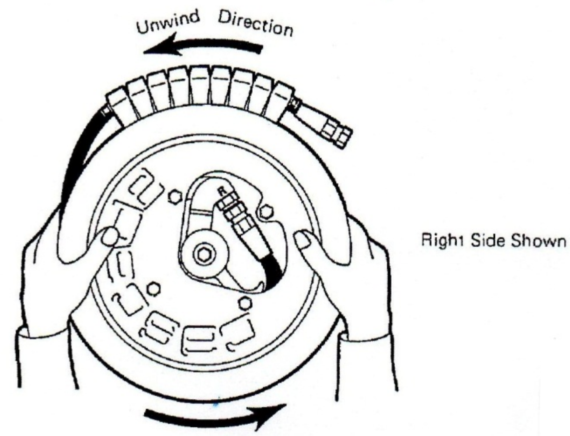
Disconnecting the Reel

NOTE: It is not necessary to remove the reel assembly from the truck. All service procedures may be done in place; but for purposes of this manual, they will be done on the work bench.

❶ Remove the twinline hoses from the hose terminal.

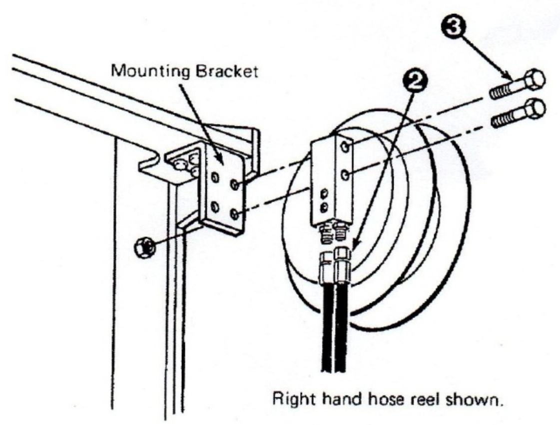


> **WARNING:** Hold hoses firmly while disconnecting them from the carriage. Allow the reel spring to unwind slowly while maintaining tension on the loose hose ends. Note the number of prewinds while unwinding the hose reel. For reassembly, tighten the hose terminal clamp capscrews to 15–20 ft.-lbs. (20–27 N·m).

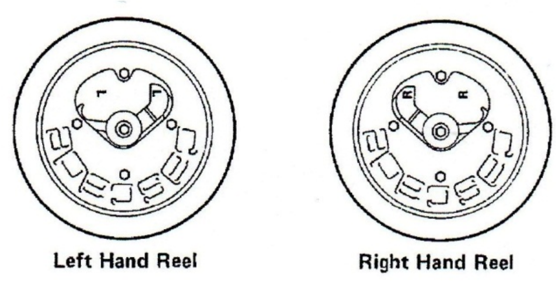


❷ Disconnect the truck valve hoses from the hose reel mounting block. Tag the hoses to prevent switching of hydraulic functions during reassembly.

❸ Remove the capscrews and self-locking nuts fastening the reel to the mounting bracket. Remove the reel from the mast. For reassembly, tighten the capscrews to 30–35 ft.-lbs. (40–47 N·m).

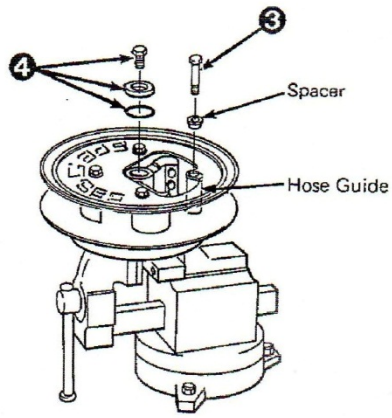


❹ Determine whether the reel is a right or left hand model (viewed from the outer flange side of the reel). **This must be noted for future reference.** If the reel is left-handed, an "L" will show on the hub casting. If the reel is right-handed, an "R" will show on the hub casting.

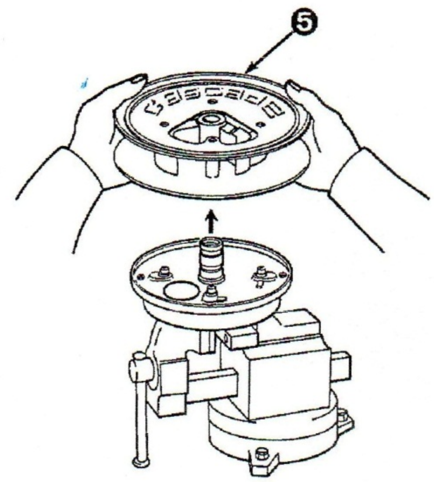


Reel Disassembly

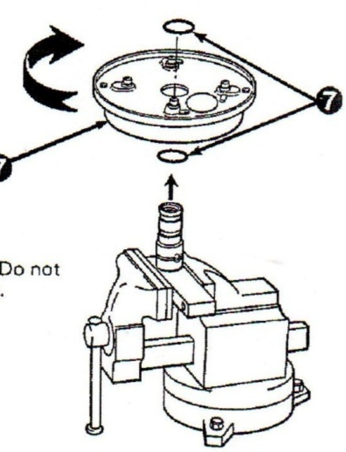
1. Clamp the reel mounting block in a vice.
2. Remove the twinline hose.
3. Remove the capscrews fastening the flanges and hub to the spring/shaft assembly. For reassembly, tighten the capscrews to 10–14 ft.-lbs. (13–19 N·m).
4. Remove the capscrew, end cap and O-ring from the shaft end. For reassembly, tighten the capscrews to 10–14 ft.-lbs. (13–19 N·m).



5. Grasping both flanges and hub as an assembly, slowly rotate as you pull them off the shaft.
6. Separate the hub from the flanges.

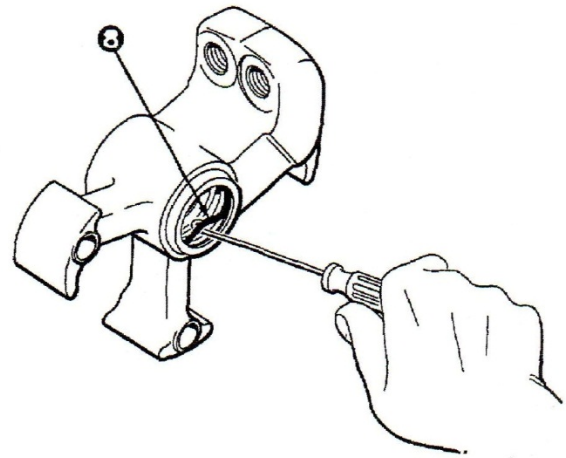


7. Rotate the spring assembly to disengage the declutching pin and slide the O-rings and spring assembly off the shaft, being careful not to damage the shaft O.D.



CAUTION: Do not damage shaft.

Reel Disassembly (continued)



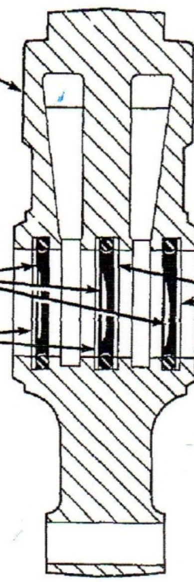
8. Remove the three O-rings and four back-up rings from the hub bore. Remove O-rings first by prying them out with a hook-type dental tool or a small flat screw driver. (Use Cascade O-ring Tool Part No. 674424.) Use the same tool to remove teflon rings next.

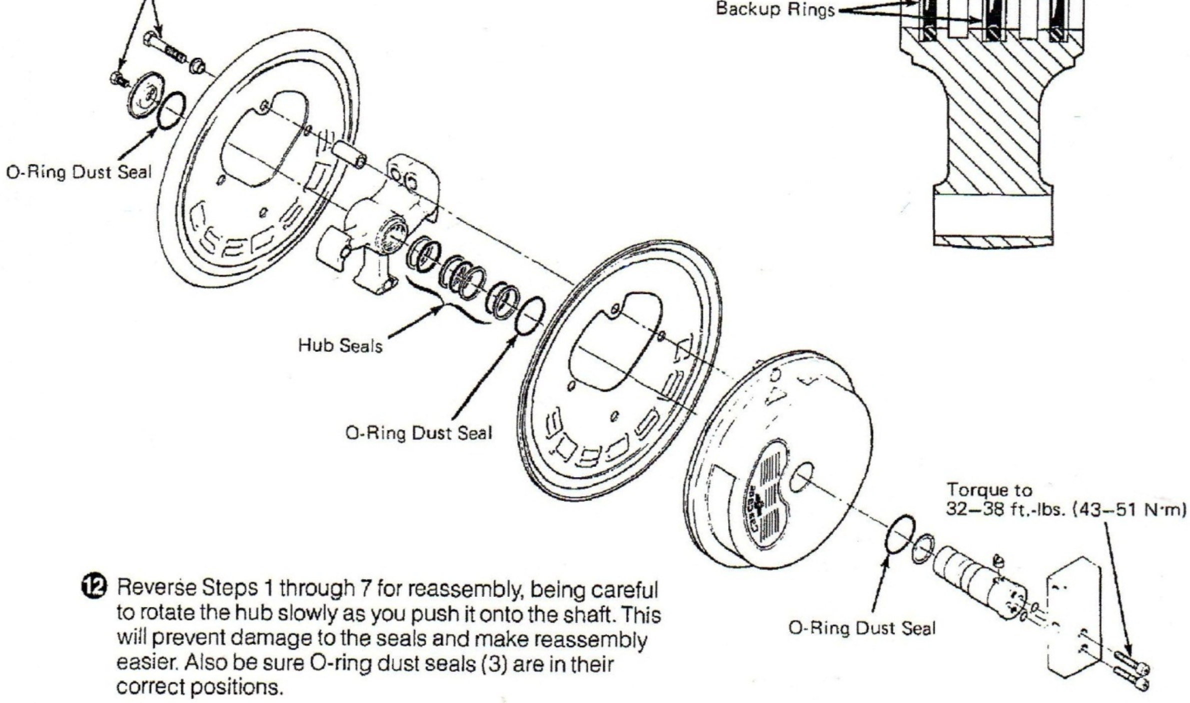
   NOTE: Do not scratch or damage groove surfaces.

9. Clean the hub and shaft with a non-corrosive solvent. Inspect the following areas:
   - The sealing surface on the shaft is nickel plated. If minor surface imperfections are noted, use emery cloth (320 Grit) to lightly smooth up. Sand radially around the shaft. If sharp edges or grooves are found, shaft replacement is necessary.
   - Hub grooves must be free of sharp nicks or projections to prevent cutting of the outside diameter of the O-ring during installation.
   - If the O-ring seal nearest the spring assembly was damaged and allowed hydraulic oil to leak into the spring can, drain the spring can before reassembly. If excessive oil is left in the spring assembly, it will seep out after reassembly and appear as though there is a serious oil leak.

10. Apply a liberal amount of petroleum jelly or hydraulic oil (STP) to the shaft, seals and the interior of the hub before reassembling.

11. Install the four back-up rings into their respective hub grooves. Next, install three O-ring seals.



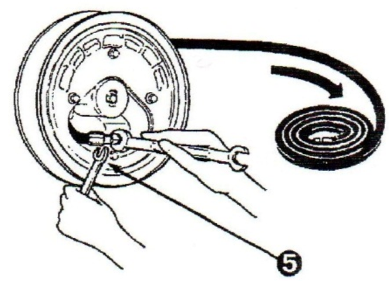


12. Reverse Steps 1 through 7 for reassembly, being careful to rotate the hub slowly as you push it onto the shaft. This will prevent damage to the seals and make reassembly easier. Also be sure O-ring dust seals (3) are in their correct positions.

Hose Replacement

1. Disconnect the twinline hoses from the hose terminal.

> **WARNING:** Hold hoses firmly while disconnecting them from the carriage. Allow the reel spring to unwind slowly while maintaining tension on the loose hose ends.



2. Count the number of prewinds while unwinding the hose reel.
3. Disconnect the hoses from the reel hub. It is not necessary to remove the outer flange.
4. Remove the hoses from the reel.
5. Connect the new hoses to the reel hub fitting.

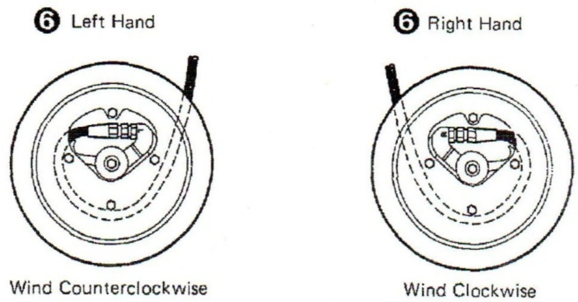
   NOTE: Thermoplastic twinline hose has a natural bend or set. Wind the hose with the bend of the hose matching the flange bend. Do not twist hose when tightening fittings.

6. Wind the new hose assembly completely onto the reel in the direction indicated (viewed from the outer flange side):

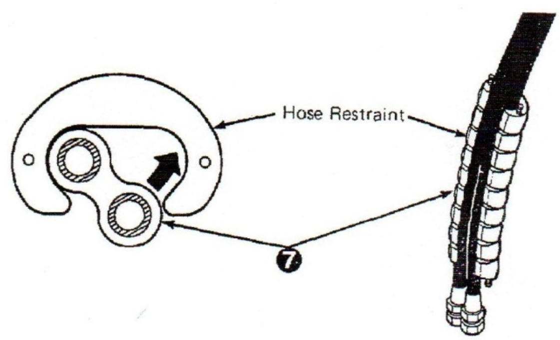
   Right Hand Reel: Wind hoses clockwise.

   Left Hand Reel: Wind hoses counterclockwise.

   A Right or Left hand reel is determined as viewed from the flange side of the reel. An "R" or "L" letter on the hub casting will identify the reel.



7. Remove the restraint from old hoses by twisting off. Install new hoses by twisting into the restraint.



8. Prewind the reel spring by grasping the end of the hose and turning the reel the specified number of complete turns in the direction indicated (viewed from the outer flange side).

   Right Hand Reel: Wind reel clockwise.

   Left Hand Reel: Wind reel counterclockwise.

   Normal prewinds = No. 4–11 - 5 turns
   No. 6–13 - 5 turns
   No. 6–16 - 5 turns
   No. 8–16 - 5 turns

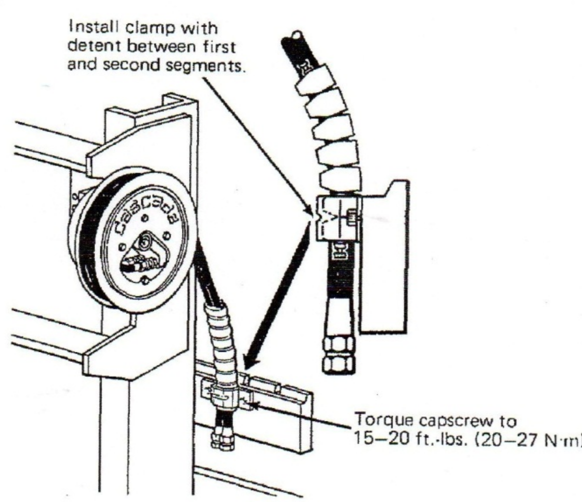
   If more tension is required, the reel can be prewound additional turns. The maximum total turn capacity of the reel is:

   No. 4–11 - 11 turns
   No. 6–13 - 13 turns
   No. 6–16 - 13 turns
   No. 8–16 - 13 turns

   Total Turns = Prewind Turns + Working Turns

   Caution: Exceeding the total turn capacity of the reel will damage the reel spring.

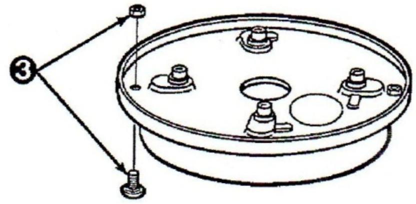
9. Reconnect the hoses to the hose terminal. Tighten the hose terminal capscrews to 15–20 ft.-lbs. (20–27 N·m).
10. Cycle mast carriage slowly to ensure adequate hose length and alignment on reel.



Reversing the Reel

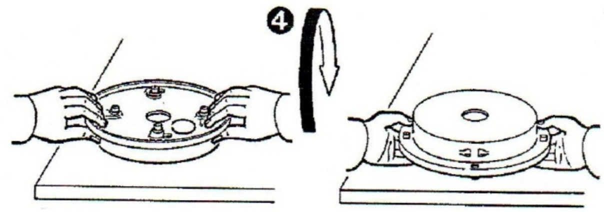
The reel assembly can be converted from a right hand reel to a left hand reel or from left to right as follows:

1. Disconnect the reel assembly from the truck as described in Section 5.1.
2. Disassemble the reel to gain access to the spring assembly as described in Section 5.2, steps 1 through 7.
3. Remove four nuts and bolts that retain the spring can cover.

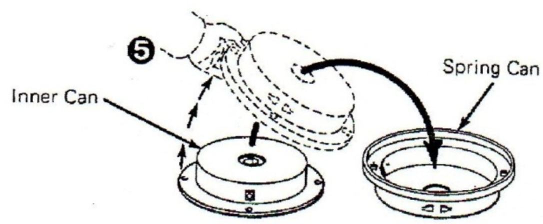


> **WARNING:** Once the spring cover is removed, the spring itself should never be allowed to be turned to any position other than flat without manually covering the spring. The spring is banded but can come out by gravity or bouncing.

4. Turn the spring can assembly, making sure that can and cover stay together.

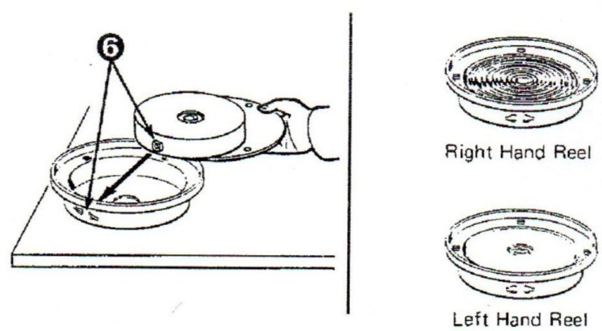


5. Lift off the spring can, leaving the cover and spring on the work bench. Flip over spring can.

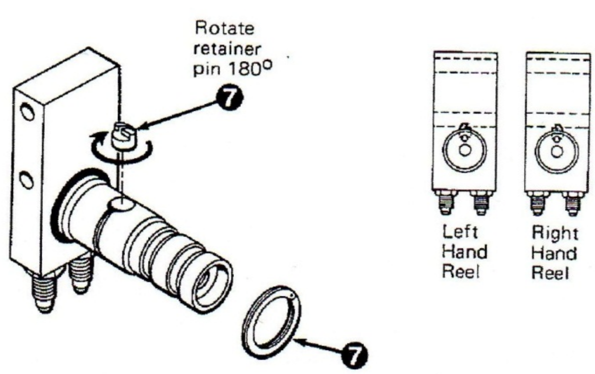


> **WARNING:** Do not remove spring from inner can.

6. To reverse the spring direction, use the spring cover and slide the spring into the can. Align the can notch with the spring washer. When complete, the spring winding will be exposed for a right hand reel and covered for a left hand application.



7. Reverse the spring retainer pin by removing the snap ring and rotating the retainer pin 180°. Replace the snap ring.



8. For reassembly, reverse the above procedures except as follows:
   - Tighten the spring can cover nuts to a torque of 30–40 in.-lbs. (3–4 N·m).
   - Install the hub and flanges on the shaft in the orientation shown in Section 5.1 Step 4.

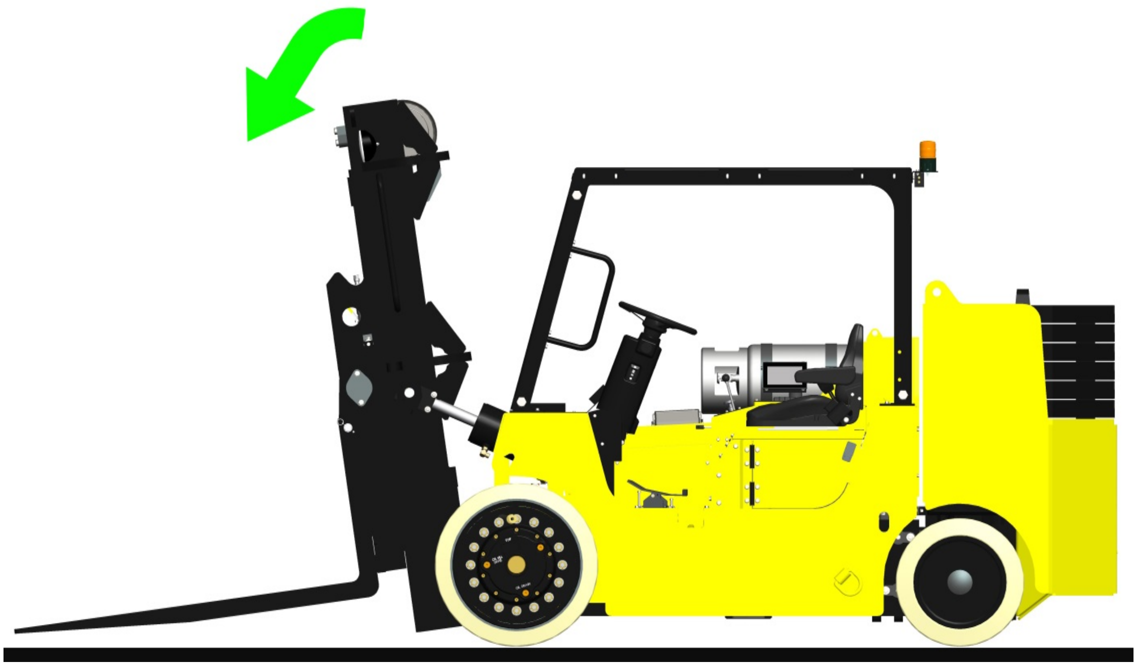
Troubleshooting

PROBLEM	PROBLEM CAUSE	SOLUTION
Excessive wear on hose.	Hose reel and hose terminal are not in proper alignment.	Align the hose terminal and hose reel properly. They must be on the same center line and mounted squarely to each other.
	Hose reel flanges damaged.	Repair or replace damaged parts.
Hose jumps off reel during operation.	Hose reel not aligned with hose terminal.	Align hose terminal with hose reel.
	Incorrect prewind of spring.	Prewind spring.
Hose binds during operation.	Hose reel spring is broken.	Replace the spring.
	Flanges are bent.	Straighten or replace flanges. See Section 5.2.
Hose reel leaks at hub.	Worn or cut seals in the rotating hub.	Replace all seals. When a hose reel requires immediate replacement of any one of the O-rings or back-up rings, it is important that all the rings be replaced. If all the rings are not replaced at the same time, the reel will only have to be disassembled again in a short period of time to replace the older rings. The seal kit offered by Cascade includes all of the O-rings and back-up rings necessary to rebuild one hose reel. Order Seal Kit No. 672563.
	Loose or damaged fittings.	Tighten or replace damaged fittings.
	Scored seal areas.	Replace the damaged shaft or use an emery cloth (320 grit) to remove the nicks from the shaft or hub.

Tilt Check and Adjustment

Mast tilt should be checked and adjusted periodically as well as any time the mast has been removed and reinstalled.

To check tilt adjustment first raise the forks enough so that the fork tips just clear the ground at full forward tilt.



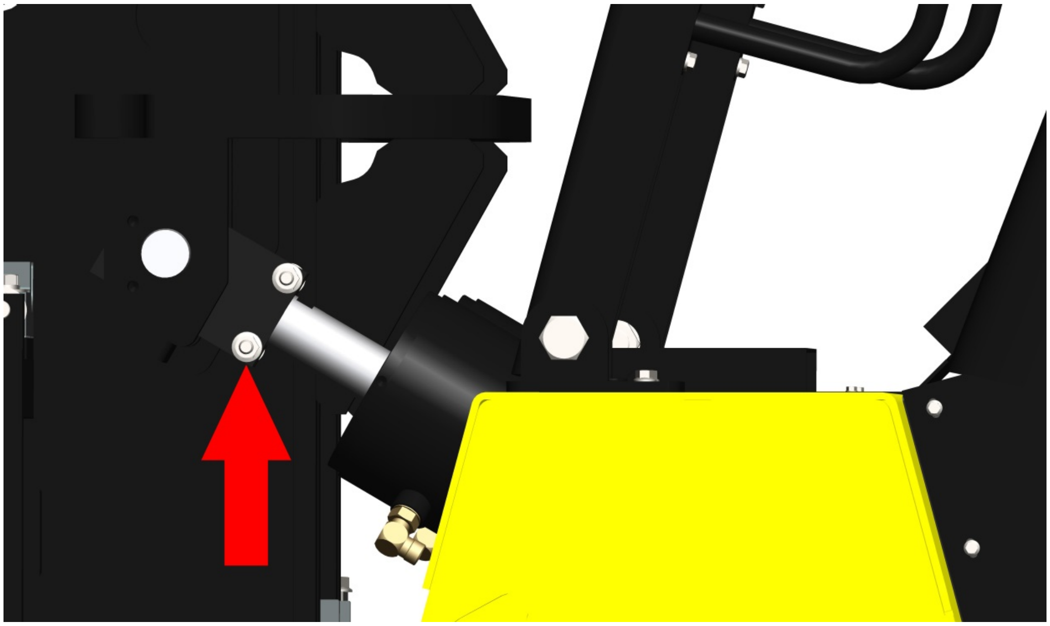
Reposition the mast to the vertical position. Slowly tilt forward watching for any mast ‘racking’ or ‘twisting’ motion as the mast moves toward the end of travel.

If no ‘racking’ or ‘twisting’ is observed, repeat the process for rearward tilt.

If any ‘racking’ or ‘twisting’ is observed in the forward direction this indicates that one tilt cylinder is reaching full extension before the other and the rod end requires adjustment.

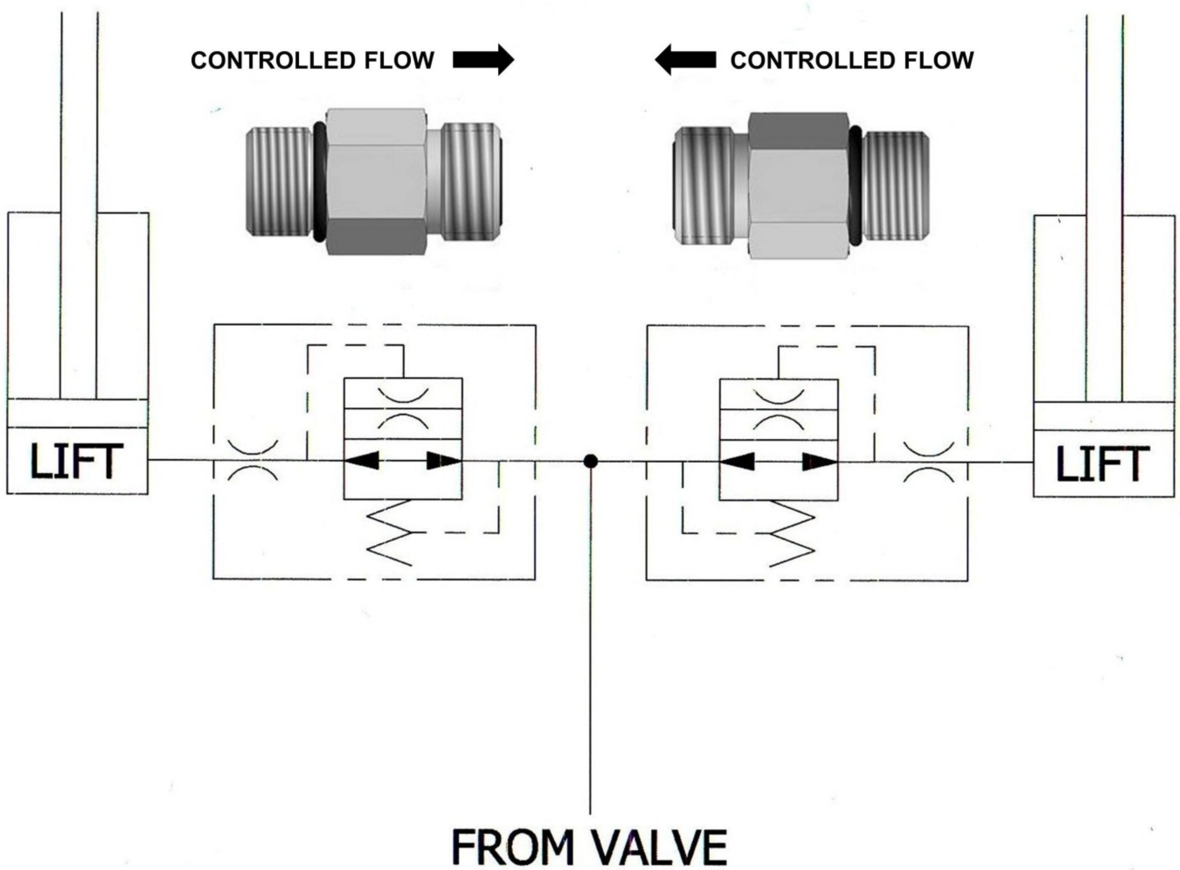
If any ‘racking’ or ‘twisting’ is observed in the rearward direction this indicates that one tilt cylinder is collapsing fully before the other and the rod end requires adjustment.

To adjust the tilt cylinder rod end first loosen the rod end clamping fastener.



With the clamping fasteners loose, use a wrench on the flats in the tilt cylinder rod to rotate the rod in the treaded cylinder rod end to adjust the mast forward or rearward as required.
Tighten clamping fasteners and re-check for ‘racking’ or ‘twisting’.
Repeat process as required until cylinders fully extend and retract in unison.

Safety Valves
Safety valves, or velocity fuses, are included in the base end of all cylinders. When lowering, safety valves allow free flow of hydraulic fluid below the specified limit dictated by the design of the valve. If the hydraulic fluid exceeds the specified limit, a line break is assumed and the flow is blocked holding the load in place. To reset the safety valve, the load must be raised slightly before attempting to lower again. If the safety valves continually trip, the lowering speed of the mast should be checked and adjusted such that the lowering flow does not exceed the trip point of the valves. *SEE SECTION 8: "OPERATOR DISPLAY".*
Safety valves are NOT serviceable items. Faulty or malfunctioning safety valves MUST be replaced. Do NOT attempt to repair.

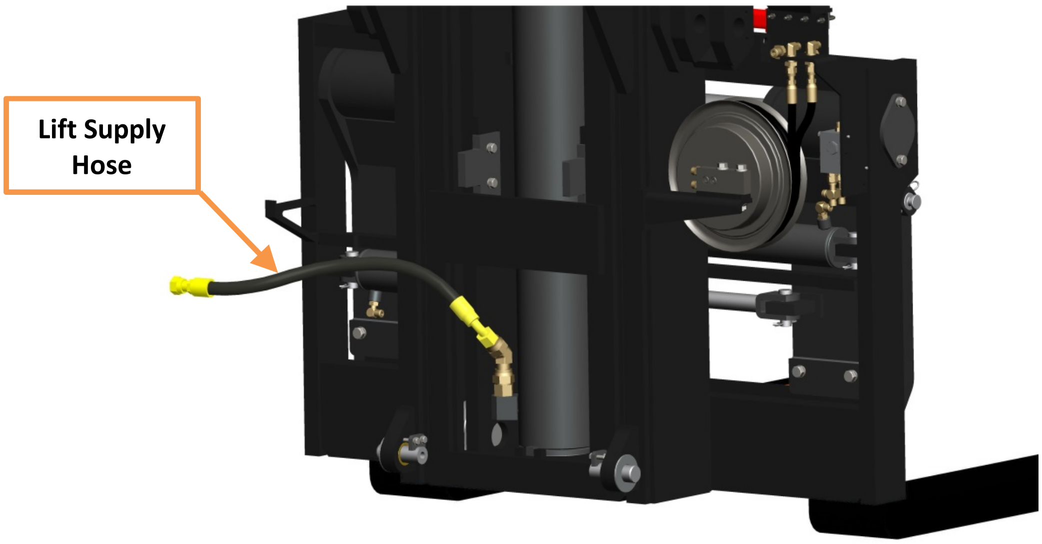


Mast Removal FR25/35

Mast removal requires the use of an overhead crane and a work area with a level concrete floor of sufficient strength to adequately support the weight of the forklift.

Prior to beginning any service, make sure the forks are completely lowered, proper shutdown procedures have been followed, and the parking brake is set. Make sure the counterweight is fully retracted and the chassis locking pin is locked in place.

Block the wheels and front of chassis to prevent unintended movement. Disconnect the lift supply hose and plug the hose end and cap the fitting to prevent contamination.



Carefully disconnect the balance of the hydraulic function hoses on the right hand side of the mast where they attach to the steel lines, and to the hose reels. The hose reels are spring loaded so be very cautious of the recoil. (*SEE HOSE REEL INSTRUCTIONS IN THIS SECTION*)

Plug the hose ends and cap the tubes to prevent contamination.

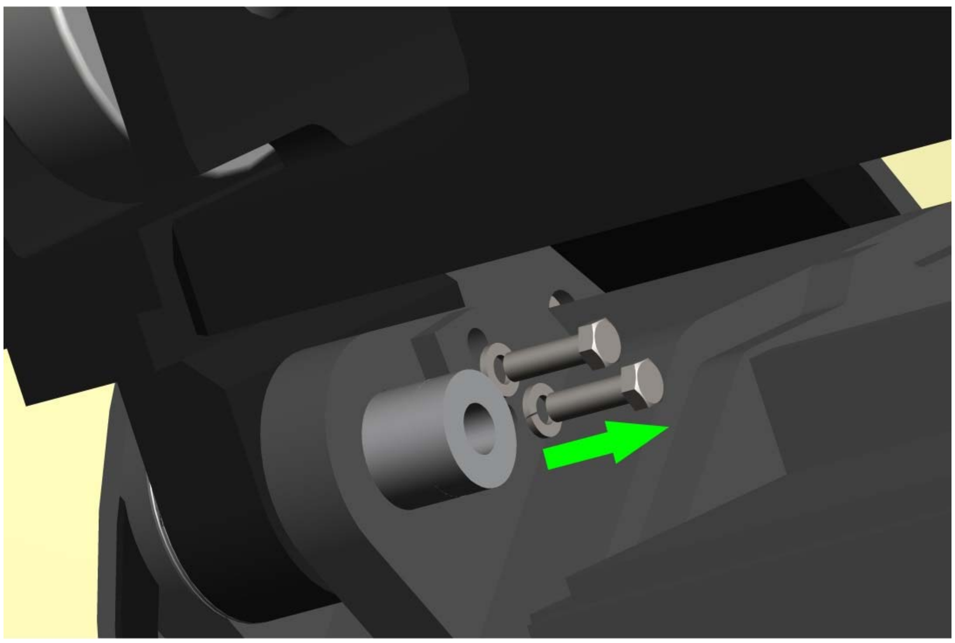
Position the hoses on the chassis side out of the way so they do not become entangled or hinder the mast removal process.
Remove the forks from the carriage and store them so they are well out of the way of the mast removal process. The mast can be removed with or without the carriage attached. If removing with the carriage attached, make sure the carriage is chained to the mast to keep it from sliding.
REFER TO CARRIAGE AND FORK REMOVAL SECTIONS IN THIS MANUAL.
Block the rear wheels.
Apply the parking brake and shut down the truck.
Route a properly rated lifting strap under all of the mast upper cross-members and attach to the overhead crane.
Using the overhead crane, take up any slack in the lifting strap.
Disconnect the tilt cylinders.
Using properly rated chains, raise the front of the truck enough to reach the mast mounts.

Whenever moving the mast/carriage assembly with an overhead crane, remove the crowbar assembly from the carriage.

From the underside of the truck, remove the hardware and keeper plate from the mast mount pin. Remove the mast pins from the chassis and mast mounts.

WARNING:

WITH THE PINS REMOVED, THE MAST MAY SWING. USE CAUTION!



Lay the mast horizontally on the ground, carriage side up, using blocks to level

WARNING:

DO NOT STAND THE MAST UPRIGHT!

Re-install mast in reverse order.
Reconnect the tilt cylinders
After installation grease all lubrication points.

Inner Stage Service FR25/35

The inner stage must be removed to service the web rollers. The inner can only be removed after the carriage and forks have first been removed from the mast. *SEE CARRIAGE AND FORK REMOVAL IN THIS MANUAL.*

The lift cylinder must be removed to remove the inner stage. *SEE LIFT CYLINDER REMOVAL IN THIS MANUAL*

Attach an overhead crane to the inner stage, using a properly rated lifting strap, and raise the inner stage gently out of the outer stage assembly.

WARNING

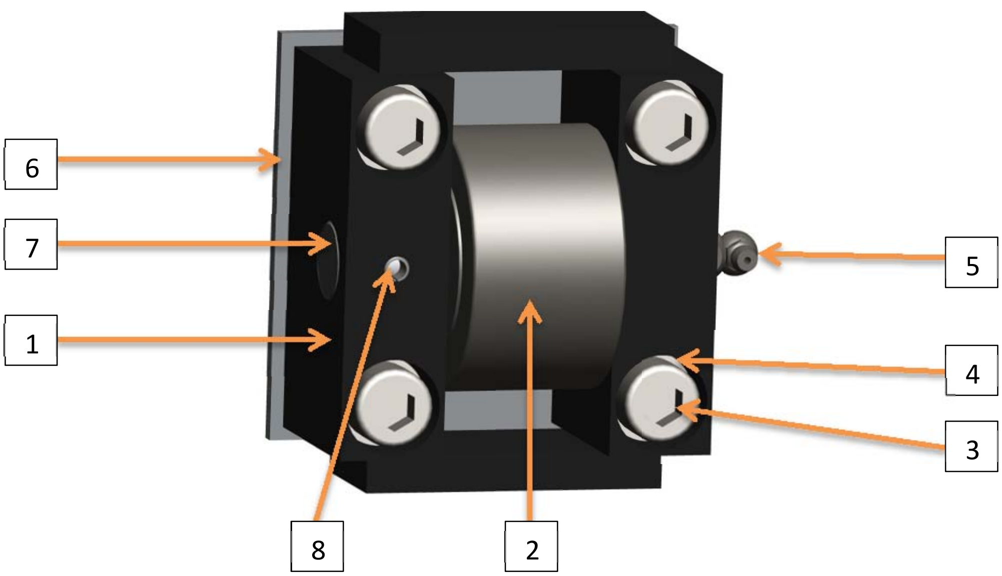
When the inner stage is free of the outer stage, it can potentially swing. Do NOT attempt to remove the inner stage with personnel in the area or proximate to anything that might potentially be struck and/or damaged.

Inspecting Mast and Carriage Play FR25/35

Visually inspect the inner mast stage and carriage as the forks are raised and lowered for any noticeable side-to-side 'kick'.
With the truck off, the forks on the ground, and the parking brake set, measure between the various stages of the mast on each side as well as between the carriage side plates and inner mast checking for consistency.
If there is visible 'kick' on the inner mast or carriage, or if the gap between stages or between the carriage and inner mast varies by more than 1/8" from side to side, the web roller assembly requires shimming.

Web Roller Assembly FR25/35

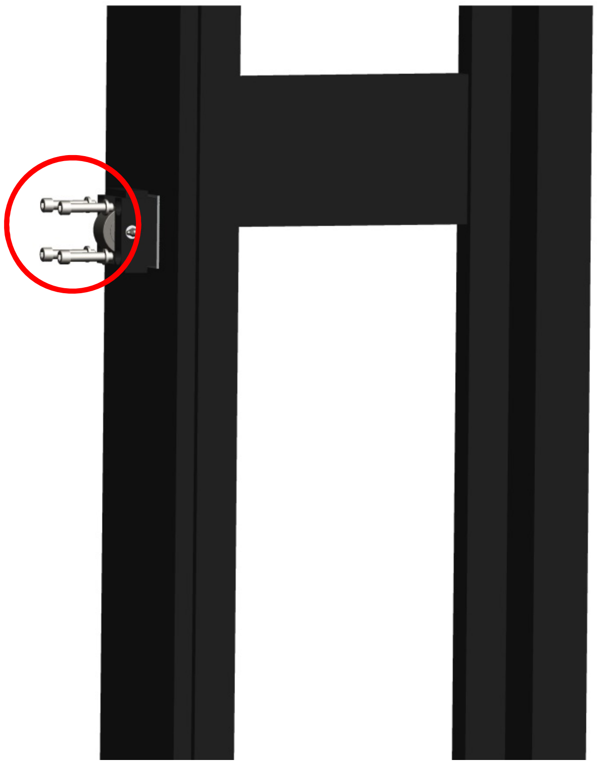
The FR25/35 masts incorporate web roller assemblies to control the lateral side to side movement of the inner stage. The web roller assembly must be greased to maintain proper roller function. *(See Preventative Maintenance Report Form in this manual)*



Item Number	Description	Quantity
1	Web Roller Cage	1
2	Web Roller Bearing	1
3	Mounting Bolt	4
4	Lock Washer	4
5	Grease Fitting	1
6	Web Roller Shim	A/R
7	Web Roller Pin	1
8	Roll Pin	1

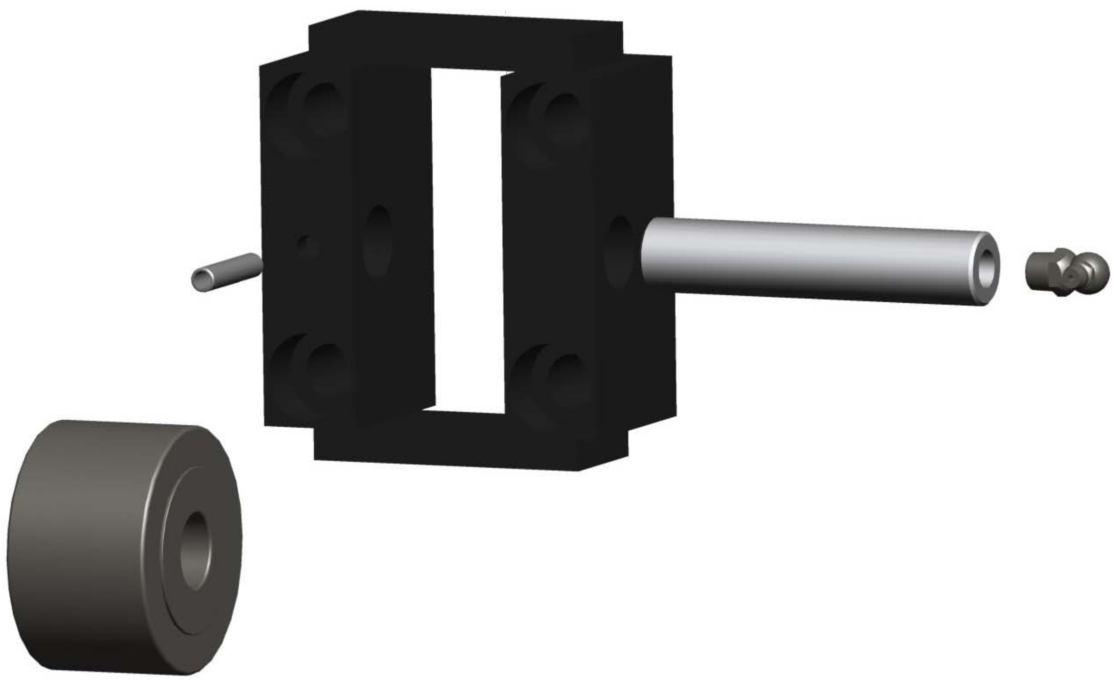
Shimming the Web Roller Assembly FR25/35

The web roller may need to be shimmed over time to maintain proper mast function. Using an Allan socket, remove the four (4) mounting bolts and lock washers from the web roller cage. Remove the web roller assembly and shims from the rail, careful not to lose the shims as they are loose from the cage. Shim the web roller until the side to side movement has no 'kick' or the gap between stages is even.



Replacing the Web Roller Bearing FR25/35

The web roller bearing rides on the web roller pin, which is held in by a ¼” roll pin. Remove the roll pin from the web roller cage using a roll pin removal tool. Remove the grease fitting from the pin. Knock the web roller pin from the cage using a rubber mallet and punch. The roller can now be removed.



Lift Cylinder Removal FR25/35

To remove the lift cylinder from the mast, first remove the carriage. *REFER TO CARRIAGE REMOVAL IN THIS SECTION.*

With the carriage removed, disconnect the lift supply hose and plug the hose end.

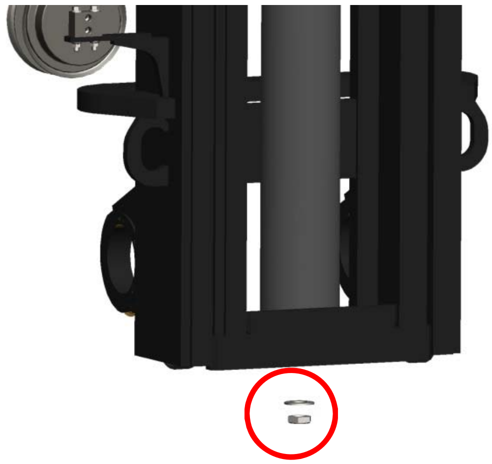
Remove the safety valve and associated fittings at the base end of the cylinder and plug the cylinder port to prevent contamination.

Support the cylinder with a properly rated cylinder sling.

Remove the locknut and flat washer on the underside of the outer stage bottom plate.

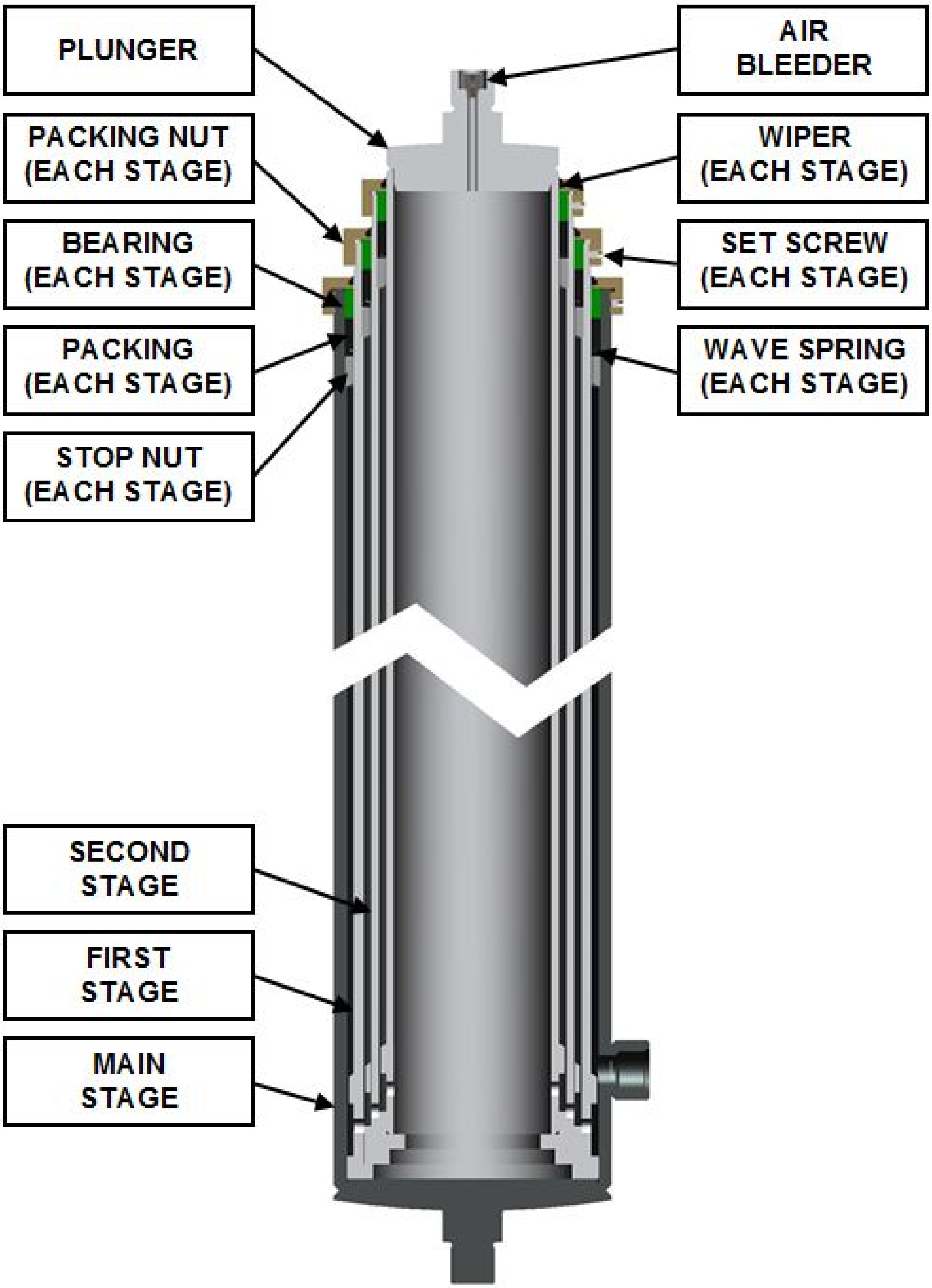
WARNING:

WITH THE LOCKNUT REMOVED THE CYLINDER MAY SWING. USE CAUTION!

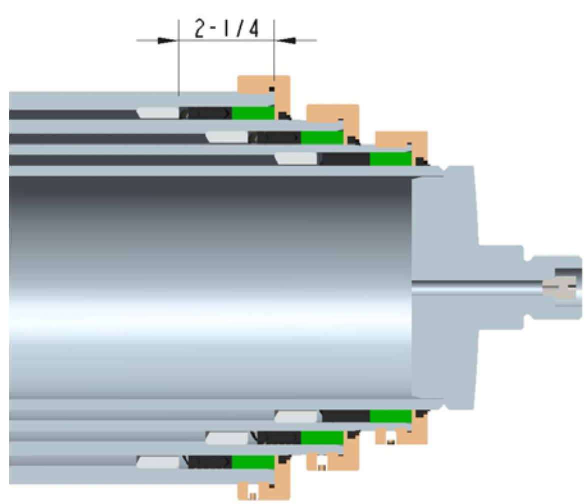


With the locknut removed, lift the cylinder vertically so that the threaded stud on the cylinder end cap clears the outer stage bottom plate and remove cylinder from mast.

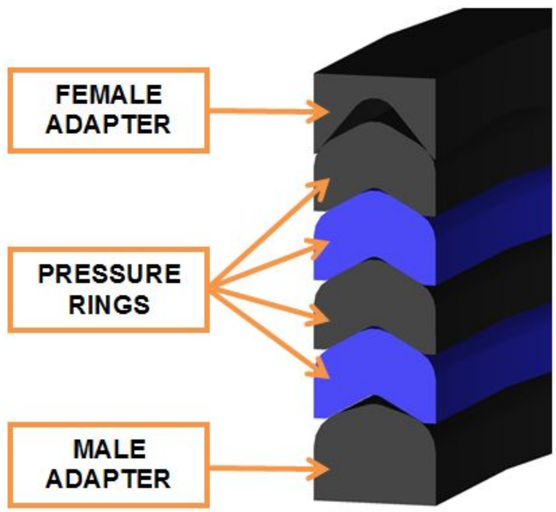
Telescopic Cylinders FR25/35
A cross section of a typical single acting telescopic cylinder is shown below for reference purposes.



Open the air bleeder and remove the cylinder port plug to drain the oil from the cylinder.
Drain the oil with the cylinder lying in the horizontal position with the port facing down.
Once the oil has completely drained, secure the cylinder to a work bench or appropriate stand in a vertical orientation with the rod end up. The work position should have access to an overhead crane.
Clean packing nut thread area and spray with penetrating oil (WD-40).
Remove set screws from all packing nuts.
Starting with the smallest stage, remove all packing nuts using an adjustable spanner wrench.
Remove wiper from each packing nut and discard
Clean the thread and bearing area with solvent and a lint free rag.
Remove all bearings and packing using puller tools.
Remove wave springs with a narrow screwdriver.
Unthread stop nuts from all stages with stop ring wrenches.
Use a strap wrench to prevent the sleeve containing the stop ring from rotating during removal.
Turn the stop ring wrench clockwise to unthread the stop nuts.
Removal of the sleeves will lift out unthreaded stop nuts.
All bores in the packing areas and the outside diameters of the plungers must be free of scratches. Polish with a fine paper or crocus cloth. All parts must be clean and free of contaminants.
Reassemble the cylinder starting with the largest stage.
Lubricate the appropriate stop nut with grease and slide it over the sleeve with the wrench holes facing up.
Thread the stop nut in the appropriate stage with the proper stop ring wrench.
Hold the sleeve with a strap wrench to prevent it from rotating.
Turn the stop ring wrench counter clockwise to tighten the stop nut. Tighten until the stop nut bottoms out.
Reinstall wave spring with the gap edge against the stop nut.
Remove shims from new packing set and measure packing height (outside of cylinder) under finger pressure.
Add one shim for each 1/32” that the packing measures under 1 1/8”.
Measure depth from the top of the stop nut to the top of the tube. This dimension should nominally measure 2 ¼” but may vary slightly based on the seating of the stop nut.
Add one shim to the packing set for every 1/32” that this dimension measures over 2 ¼” or remove one shim for every 1/32” that this dimension measures under 2 ¼”.



Soak packing in hydraulic oil for a few minutes.
Install packing one ring at a time in the proper sequence, with the male adapter installed first flat side toward the wave spring.
Pressure rings should be installed alternating between colors, starting with a blue ring, followed by the female adapter.



Once installed, the packing height does NOT need to be checked. Installation of the bearing and packing nut will compress the wave spring and establish proper preload on the packing.
Install the bearing and install new wiper in the packing nut.

Apply anti-seize compound to the threads on the sleeve and install packing nut using spanner wrench to tighten.
If the packing height is correct, the packing nut should bottom out on sleeve.
Install new setscrew in packing nut.
Repeat process for remaining stages.

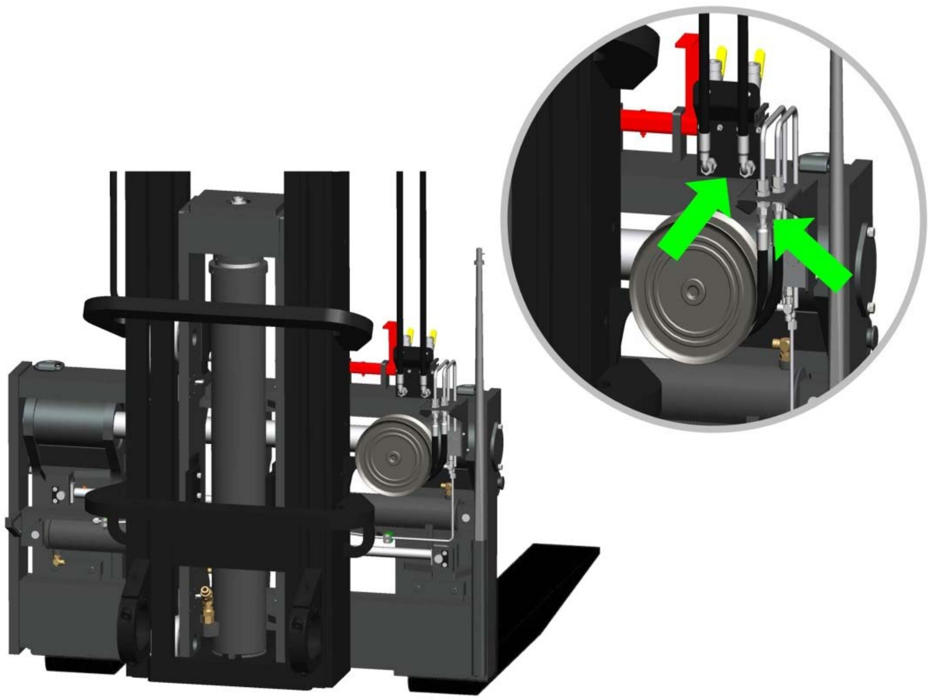
After the cylinder is reinstalled in the forklift, air must be bled from the cylinder.
To bleed the air, fully extend the cylinder with NO LOAD on the forks.
Lower the forks so that they stop approximately 6” off the ground.
Open the air bleeder and allow trapped air to escape.
Once a steady stream of oil appears close the air bleeder.

Carriage Removal FR25/35

Remove forks and pusher from carriage. *REFER TO FORK AND PUSHER REMOVAL SECTION IN THIS MANUAL.*

Disconnect the hoses coming from the mast upper hose reel where they connect to the back of bulkhead fittings at the shutoff valve assembly. Disconnect the hoses coming from the mast lower hose reel where they connect to the underside of the bulkhead fittings on the bulkhead bracket coming off the back right hand side of the carriage. Cap the fittings to prevent leaking.

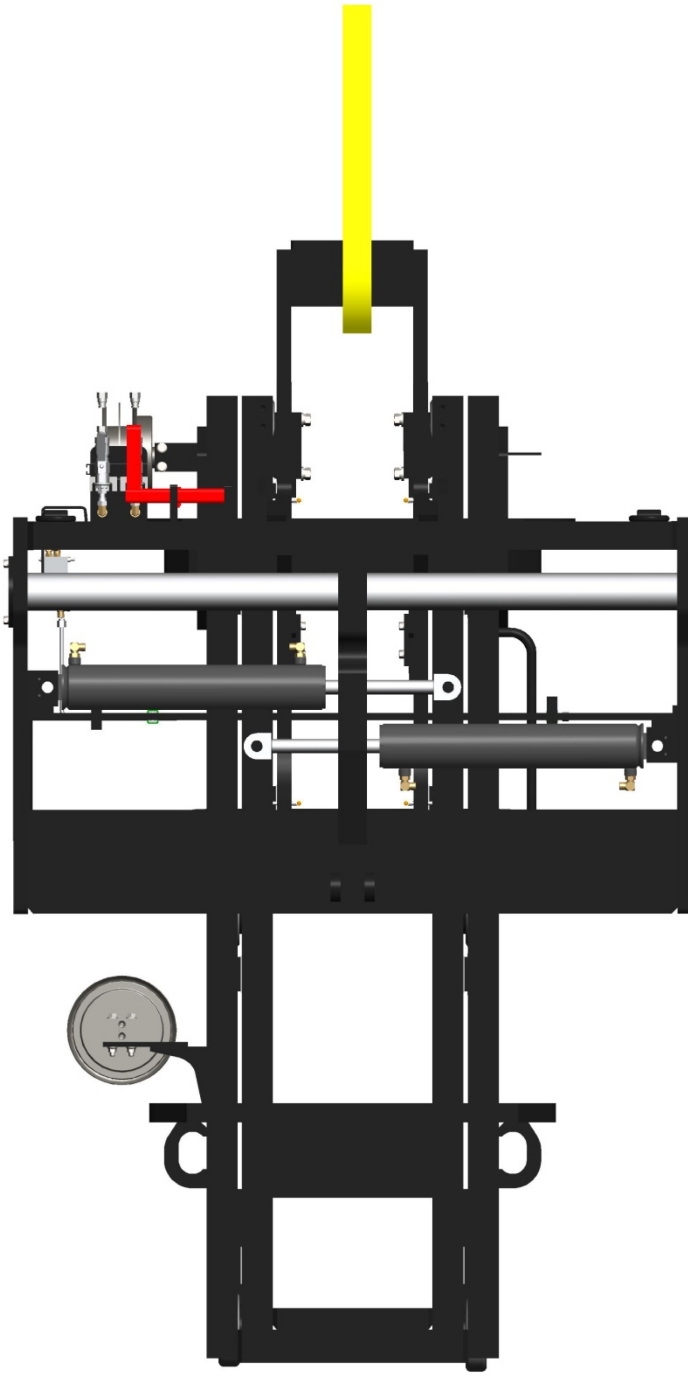
Remove the crowbar assembly from the carriage to prevent injury.



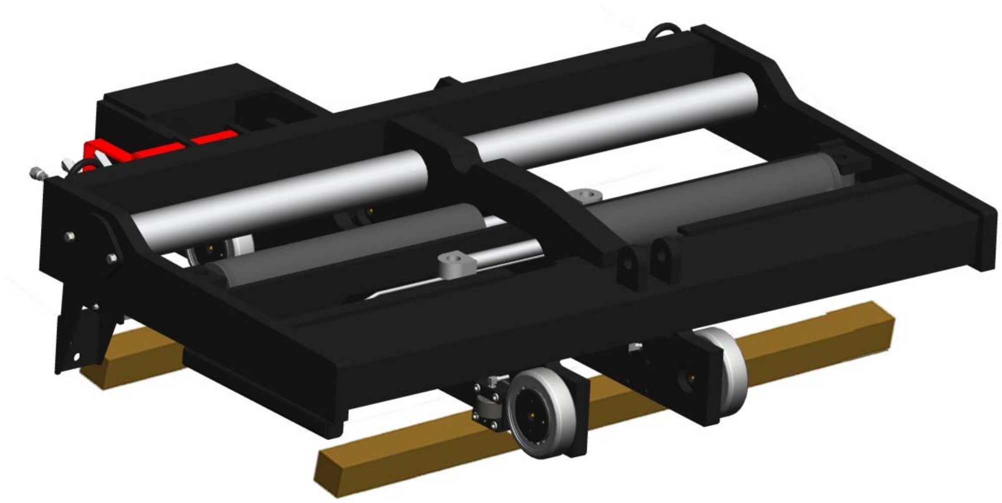
WARNING:
HOSES CAN SWING AND CAUSE INJURY. MAKE SURE HOSES ARE TIED OFF PROPERLY TO PREVENT INJURY OR DAMAGE TO PROPERTY.

Remove the carriage stop blocks from the top of the inner by removing the two bolts and washers.

Remove the lift cylinder. *REFER TO LIFT CYLINDER REMOVAL SECTION IN THIS MANUAL*. Wrap a properly rated lifting strap around the upper cross-member of the carriage and use an overhead crane to lift carriage from the inner stage assembly.



Rest the carriage on the ground with the carriage face up on wood blocks. Keep the carriage evenly supported until it is completely on the ground and does not tip or shift on the wood blocks.

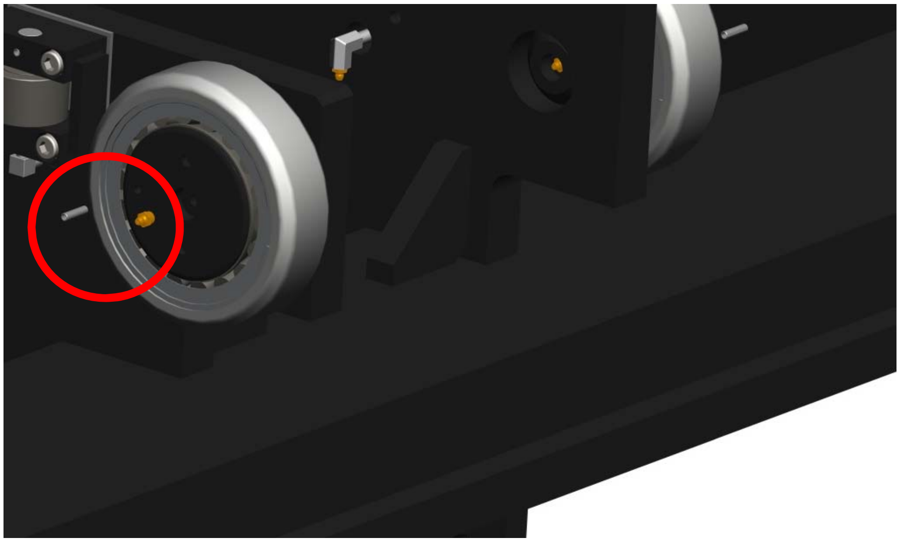


CAUTION

Carriage may swing or shift when clear of the mast channels. Make sure there are no pedestrians in the area while the carriage is being removed.

Replacing Carriage Roller Bearings FR25/35
Lie the carriage face down to access the carriage rollers.

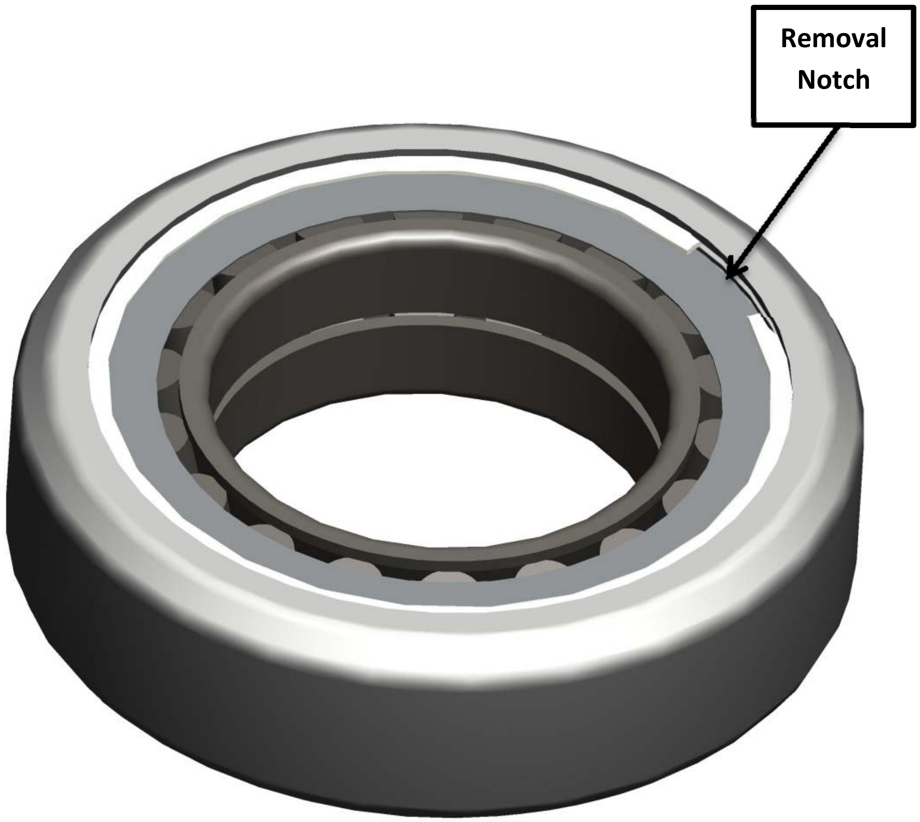
To remove the carriage rollers for service or replacement, the keeper plates will need to be removed. The keeper plates are held in by a roll pin and then screwed into the face of the stub shaft. Remove the roll pin and grease fitting from the face of the keeper plate.



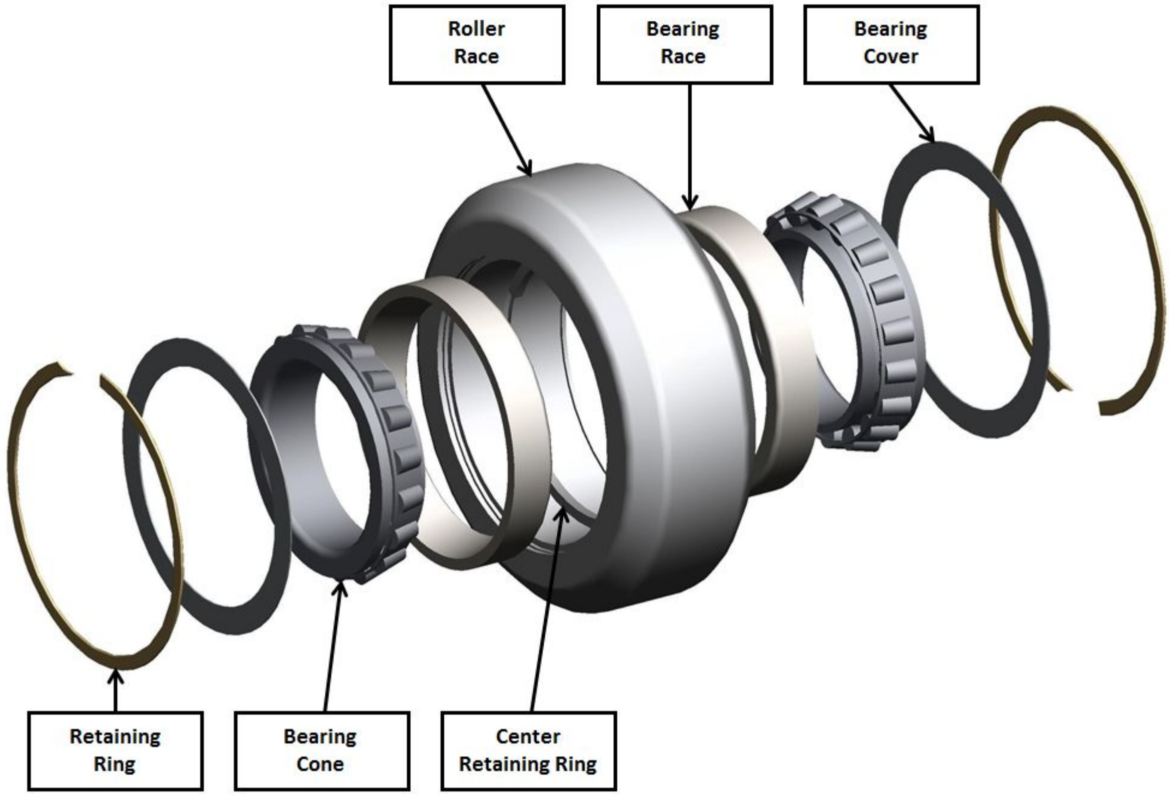
Using a spanner wrench, unscrew and remove the keeper plate. Remove the roller from the stub shaft.

WARNING!
If not supported, the roller will fall out of the carriage with the stubshaft removed.

With the roller assembly removed, remove the retaining rings from both sides of the roller race. The retaining rings are designed with removal notches to enable easy extraction from the housing grooves. The notch forms a small gap between the ring and the roller race permitting a blunt object, such as a screwdriver, to be inserted at the end of the ring to pry the free end out radially and up.
Insert the screwdriver behind the removal notch, pry out the first end of the ring and manually spiral the ring around until it is free of the groove.



With the retaining rings removed, the bearing covers and bearings can now be disassembled.
Prior to installing new bearings, ensure that the center retaining ring is undamaged and seated properly in its groove. Be sure bearing seats are free of dirt and defects.
Install new bearing races from each side of the roller race using a press or mandrill as required.
Make certain races are pressed in squarely and seated against center retaining ring.
Repack bearing cones and reinstall followed by the bearing covers and retaining rings.
To reinstall the retaining rings, insert one end of the ring into the groove. Wind the ring by pressing down around the circumference until the entire ring is inserted into the groove.



Press the reassembled roller back on the stubshaft and reinstall the keeper plate using the spanner wrench.
Set bearings within .001 preload to .005 end play.
Install new roll pin using a roll pin punch.

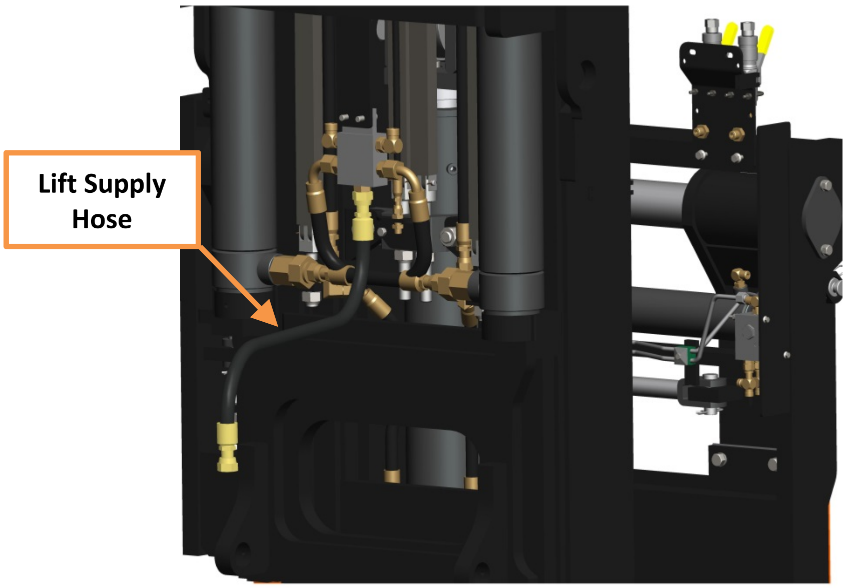
SEE ALSO: “GENERAL BEARING HANDLING AND INSPECTION” IN REFERNCE SECTION

Mast Removal FR15/25 & FR18/26

Mast removal requires the use of an overhead crane and a work area with a level concrete floor of sufficient strength to adequately support the weight of the forklift.

Prior to beginning any service, make sure the forks are completely lowered, proper shutdown procedures have been followed, and the parking brake is set. Make sure the counterweight is fully retracted and the chassis locking pin is locked in place.

Block the wheels and front of chassis to prevent unintended movement. Disconnect the lift supply hose and plug the hose end and cap the fitting to prevent contamination.



Carefully disconnect the balance of the hydraulic function hoses on the right hand side of the mast where they attach to the steel lines, and to the hose reels. The hose reels are spring loaded so be very cautious of the recoil. (*SEE HOSE REEL INSTRUCTIONS IN THIS SECTION*)

Plug the hose ends and cap the tubes to prevent contamination.

Position the hoses on the chassis side out of the way so they do not become entangled or hinder the mast removal process.

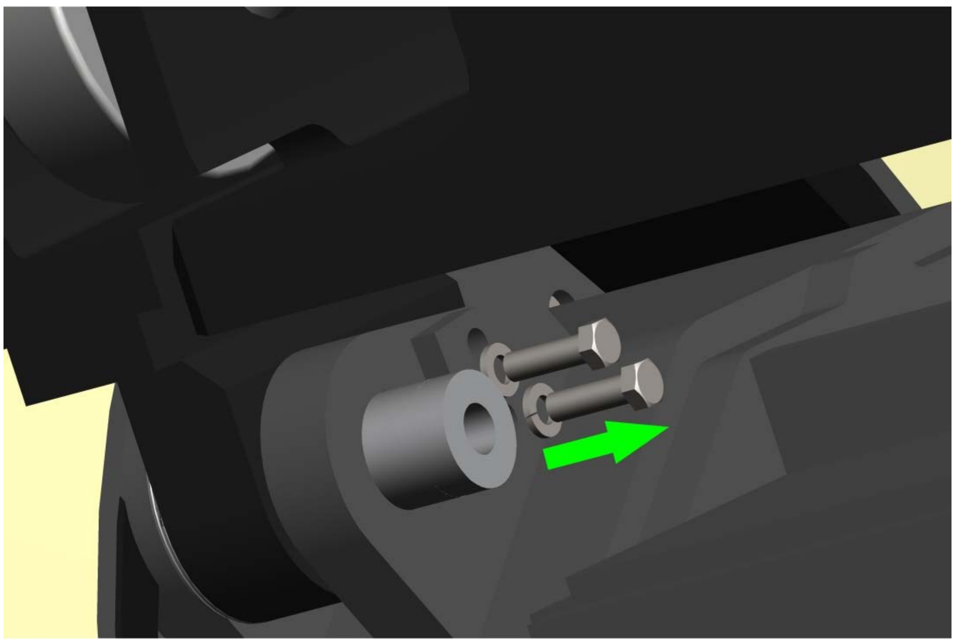
Remove the forks from the carriage and store them so they are well out of the way of the mast removal process. The mast can be removed with or without the carriage attached. If removing with the carriage attached, make sure the carriage is chained to the mast to keep it from sliding. *REFER TO CARRIAGE AND FORK REMOVAL SECTIONS IN THIS MANUAL.*
Remove the cylinder drain system roller and bracket from the intermediate stage. *REFER TO INTERMEDIATE STAGE SERVICE.*
Block the rear wheels.
Apply the parking brake and shut down the truck.
Route a properly rated lifting strap under all of the mast upper cross-members and attach to the overhead crane.
Using the overhead crane, take up any slack in the lifting strap.
Disconnect the tilt cylinders.
Using properly rated chains, raise the front of the truck enough to reach the mast mounts.

Whenever moving the mast/carriage assembly with an overhead crane, remove the crowbar assembly from the carriage.

From the underside of the truck, remove the hardware and keeper plate from the mast mount pin. Remove the mast pins from the chassis and mast mounts.

WARNING:

WITH THE PINS REMOVED, THE MAST MAY SWING. USE CAUTION!



Lay the mast horizontally on the ground, carriage side up, using blocks to level

WARNING:

DO NOT STAND THE MAST UPRIGHT!

Re-install mast in reverse order.
Reconnect the tilt cylinders
After installation grease all lubrication points.

Inner Stage ServiceFR15/25 & FR18/26

Both the inner stage and intermediate stage must be removed to service the mast channel rollers and chain rollers. The inner stage and intermediate stage can only be removed after the carriage and forks have first been removed. *REFER TO CARRIAGE AND FORK REMOVAL IN THIS MANUAL.* Remove the auxiliary hydraulic lines from the mast (if so equipped)

To remove the inner stage, the center lift cylinder, chains, and hydraulics will first need to be removed. The center lift chain will be removed when removing the carriage (*SEE CARRIAGE REMOVAL*) Disconnect the center lift cylinder hydraulic hose from the outer stage, cap off to prevent spillage, and remove from the hose roller at the top of the inner stage (fig1). Remove the cylinder drain hose from the inner stage; cap off to prevent spillage (fig 2). Remove the two hoses connecting the flow control valves at the bottom of the center lift cylinder to the mast hydraulic system; cap off to prevent spillage (fig 3).

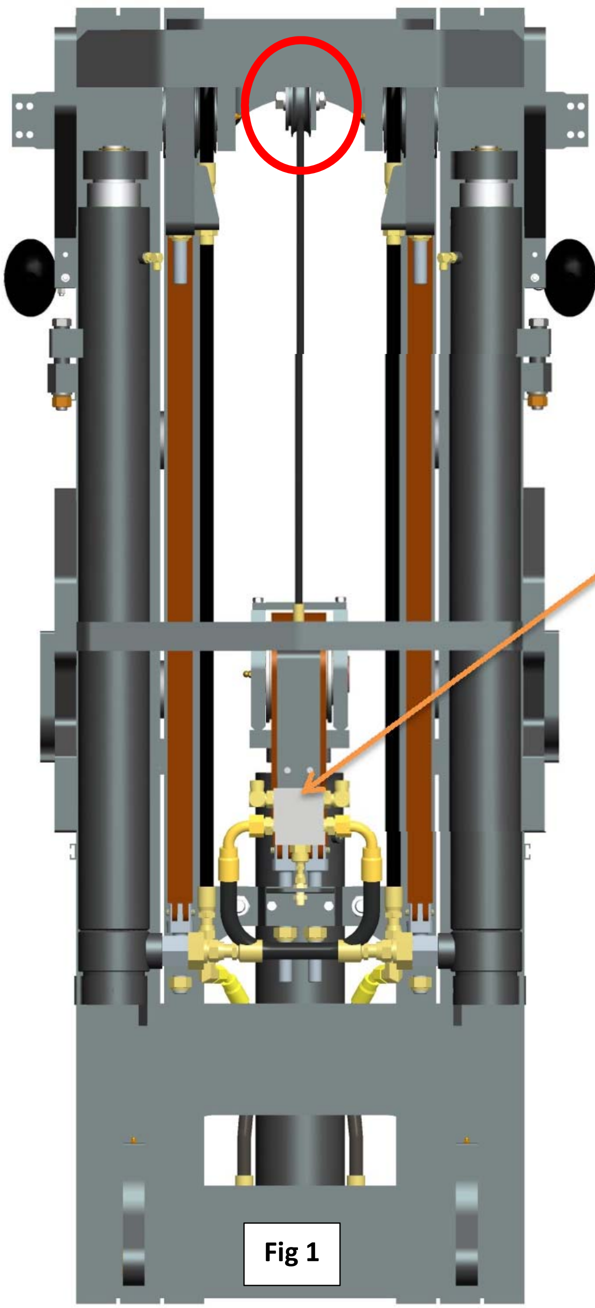


Fig 1

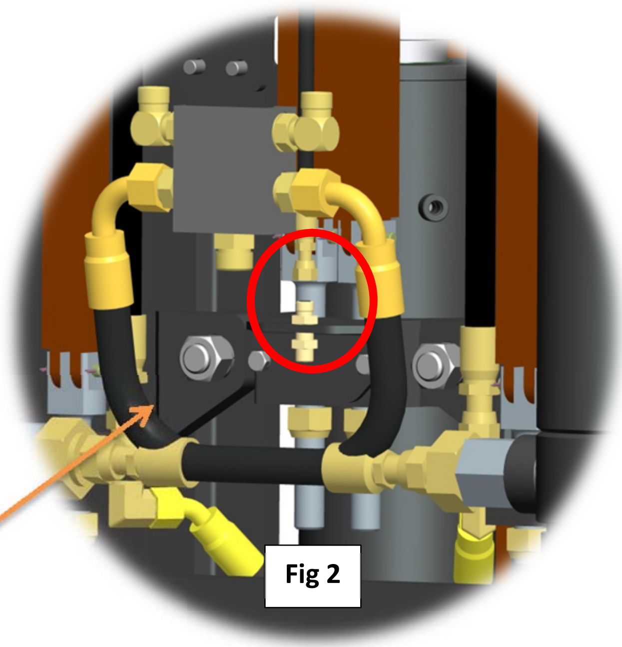


Fig 2

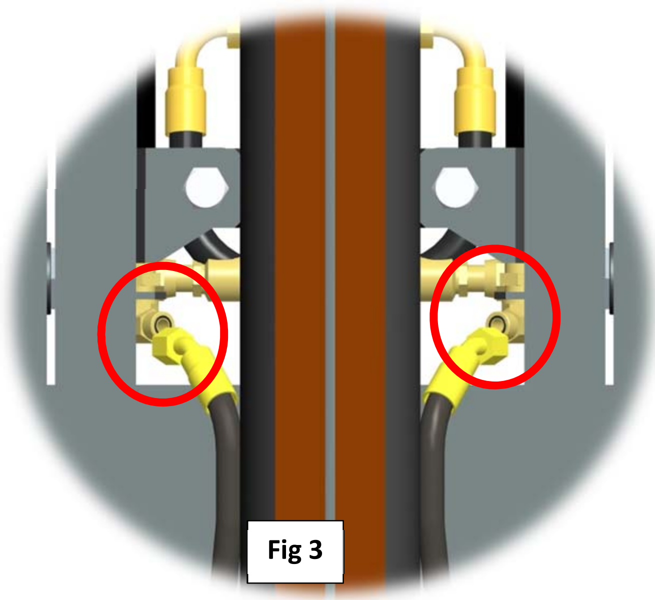
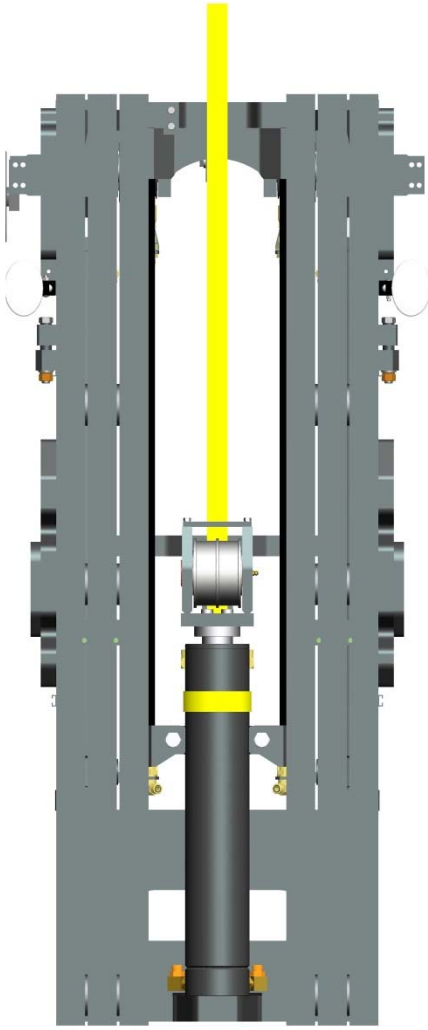


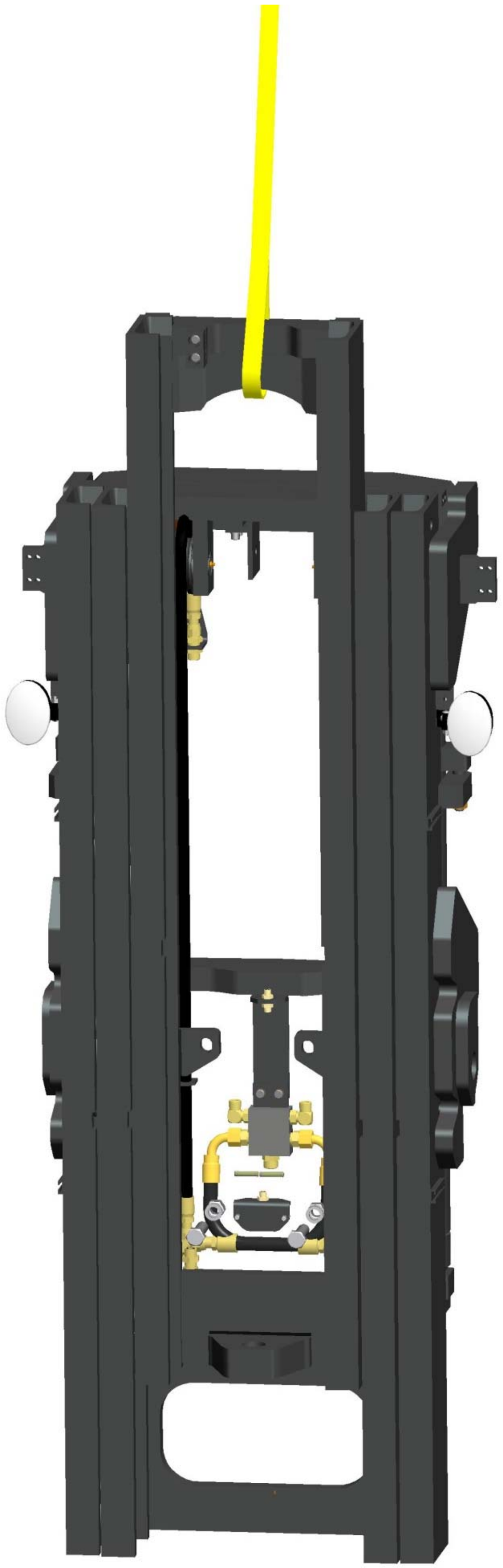
Fig 3

Use a properly rated lifting strap to support the center lift cylinder as shown below. Remove the center lift cylinder mounting bolts and hardware and use lifting strap to remove cylinder.



WARNING:
When the cylinder is removed, it can potentially swing. Do <u>NOT</u> attempt to remove the cylinder with personnel in the area or proximate to anything that might potentially be struck and/or damaged.

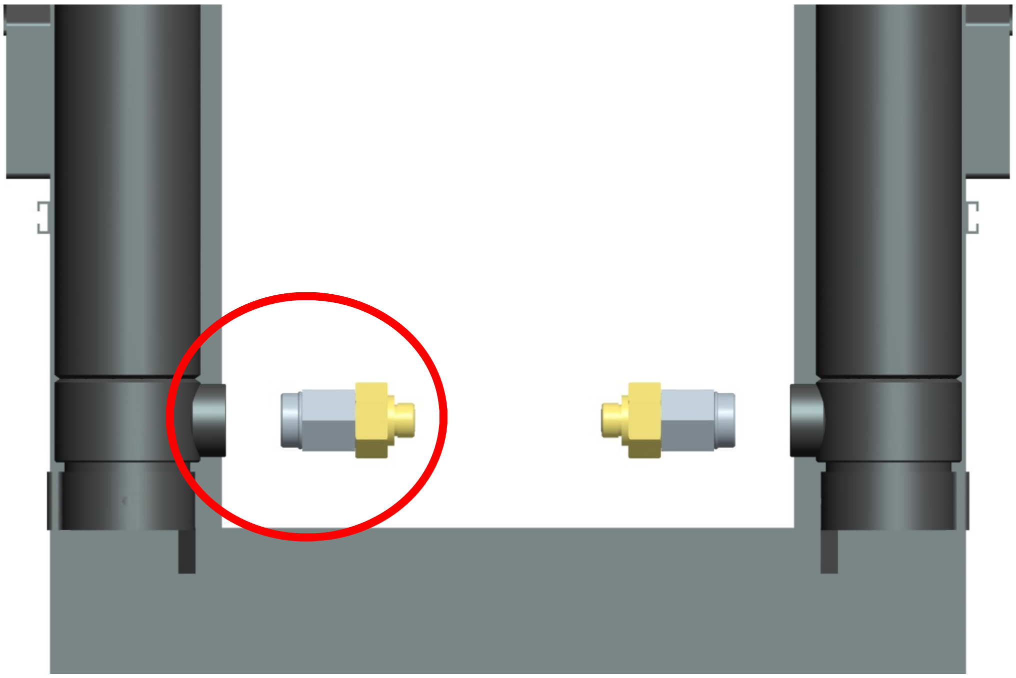
With a properly rated lifting strap or chain, remove the inner stage from the intermediate stage. Lay the inner stage on boards or a pallet.



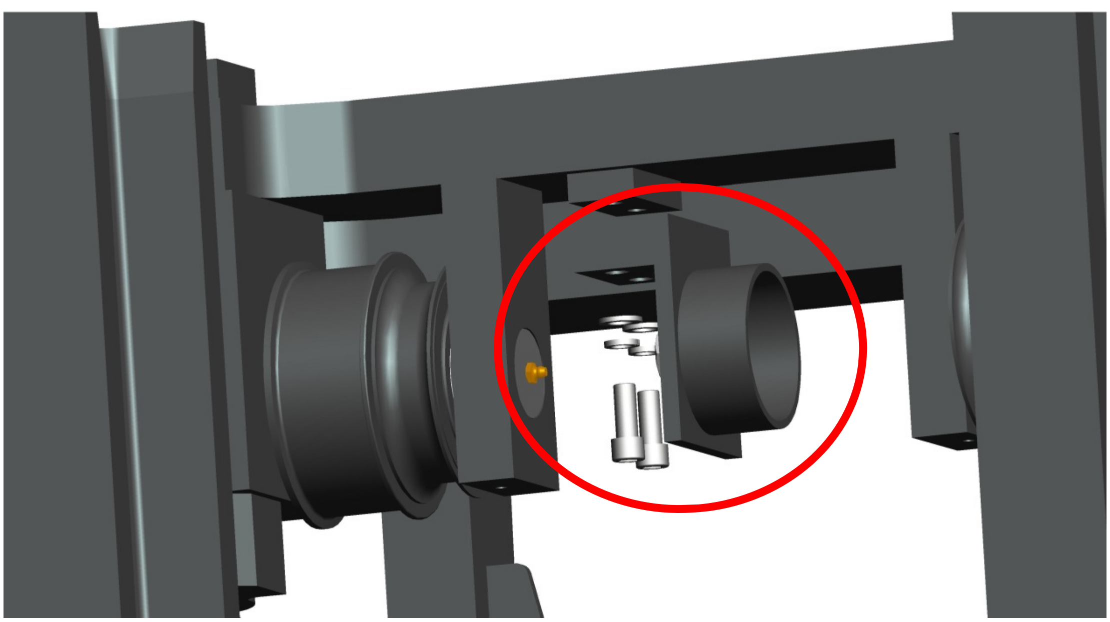
WARNING:
When the inner stage is removed, it can potentially swing. Do <u>NOT</u> attempt to remove the inner stage with personnel in the area or proximate to anything that might potentially be struck and/or damaged.

Intermediate Stage Service FR15/25 & FR18/26

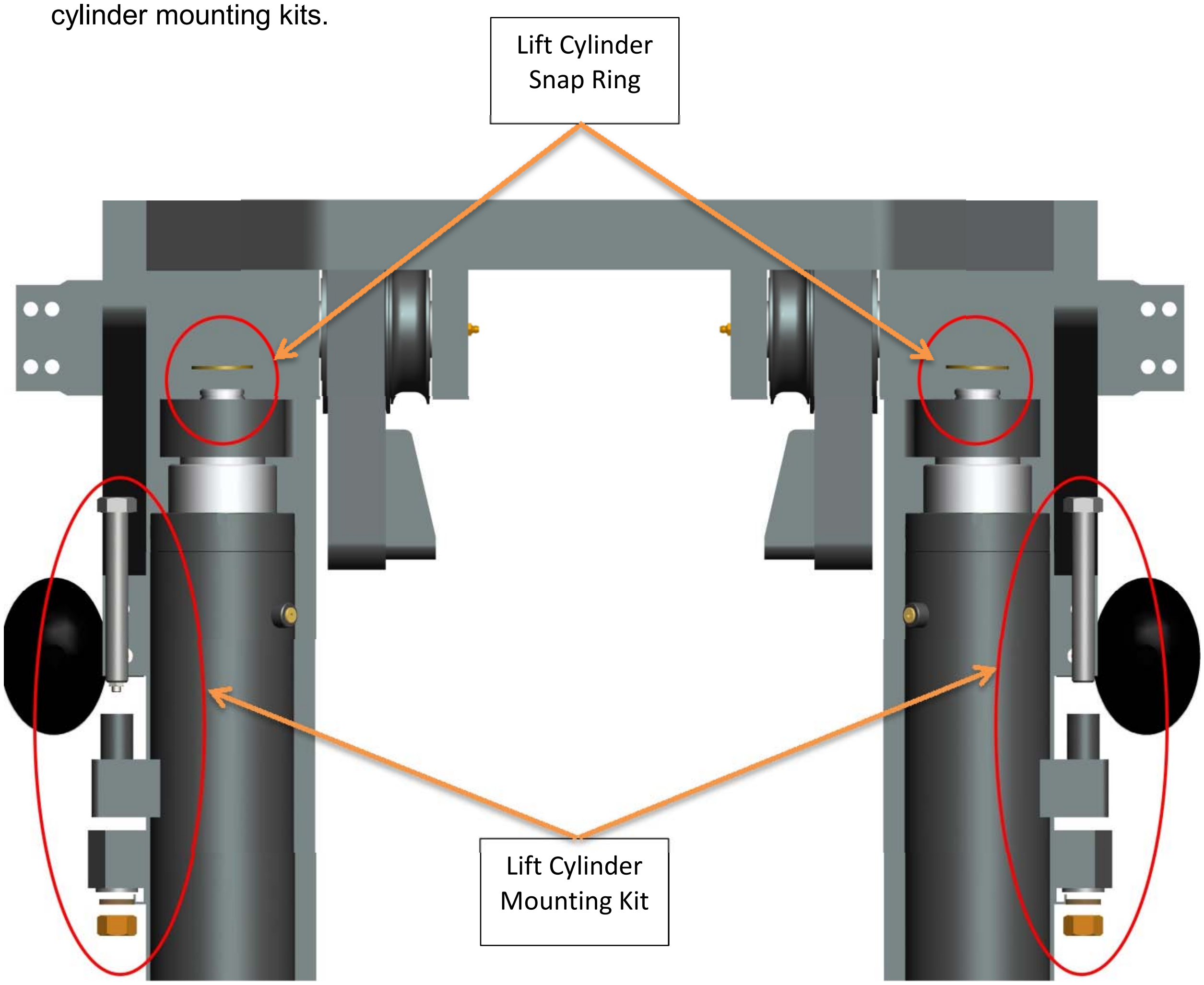
The intermediate stage can only be removed after the inner stage is removed. Remove all remaining hydraulic hoses and flow limiters from the secondary lift cylinders.



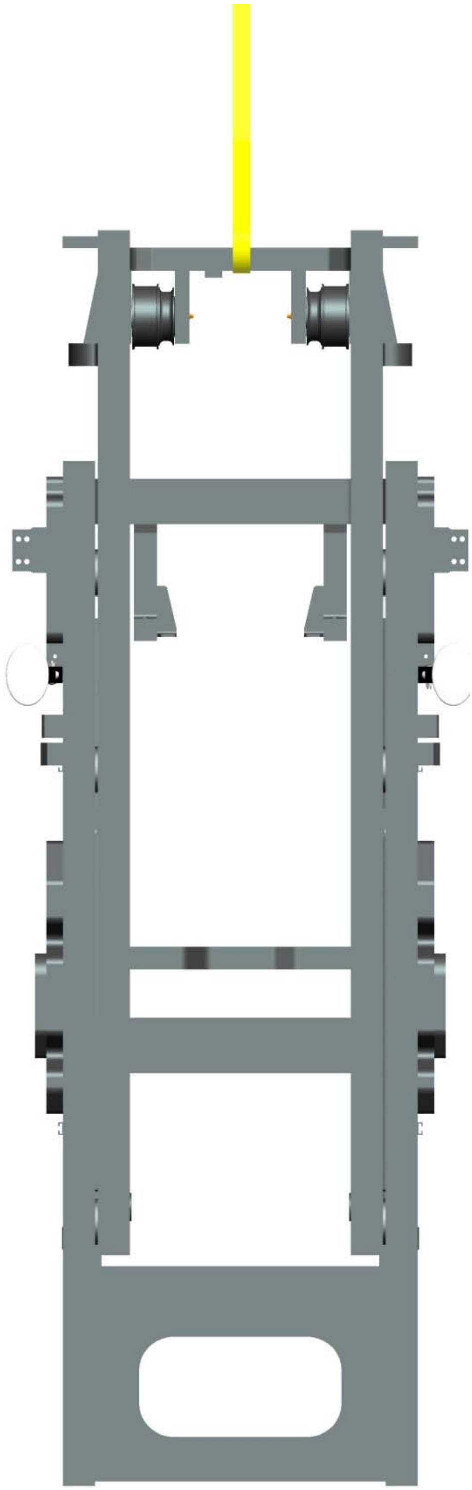
Remove the drain system roller assembly bracket from the intermediate mast.



Remove the lift cylinder snap rings. The cylinders will remain secured to the outer stage by the cylinder mounting kits.



With a properly rated lifting strap or chain, remove the inner stage from the intermediate stage. Lay the inner stage on boards or a pallet.



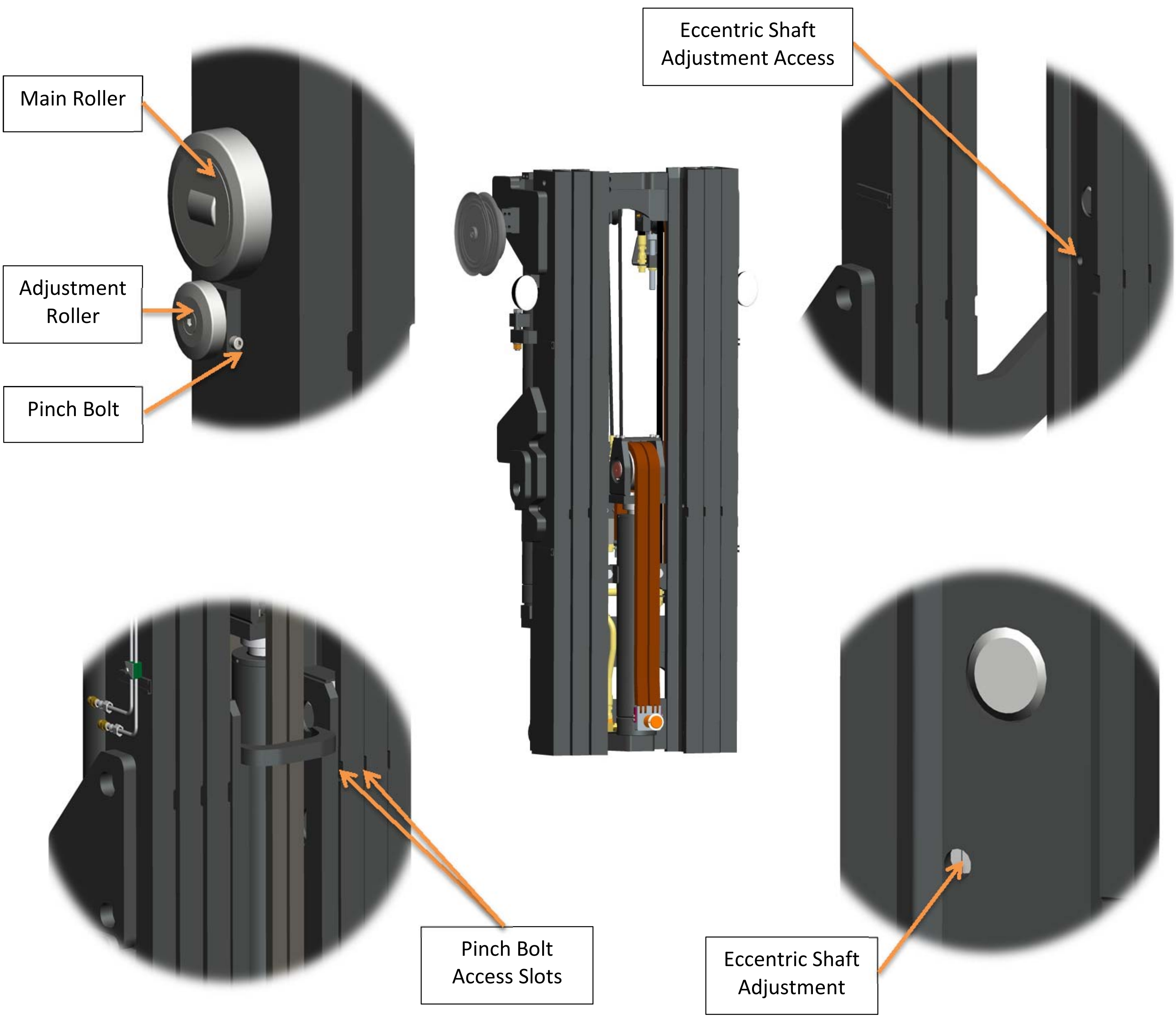
WARNING:
When the intermediate stage is removed, it can potentially swing. Do NOT attempt to remove the intermediate stage with personnel in the area or proximate to anything that might potentially be struck and/or damaged.

Inner and Intermediate Stage Adjustment FR15/25 & FR18/26

Some iterations of mast assemblies, dependent on lift height, feature adjustment rollers (or tightener bearings) on the inner and intermediate stages which can be adjusted to ensure that these stages remain at true vertical, front-to-back, as lift height increases. (Fig x)

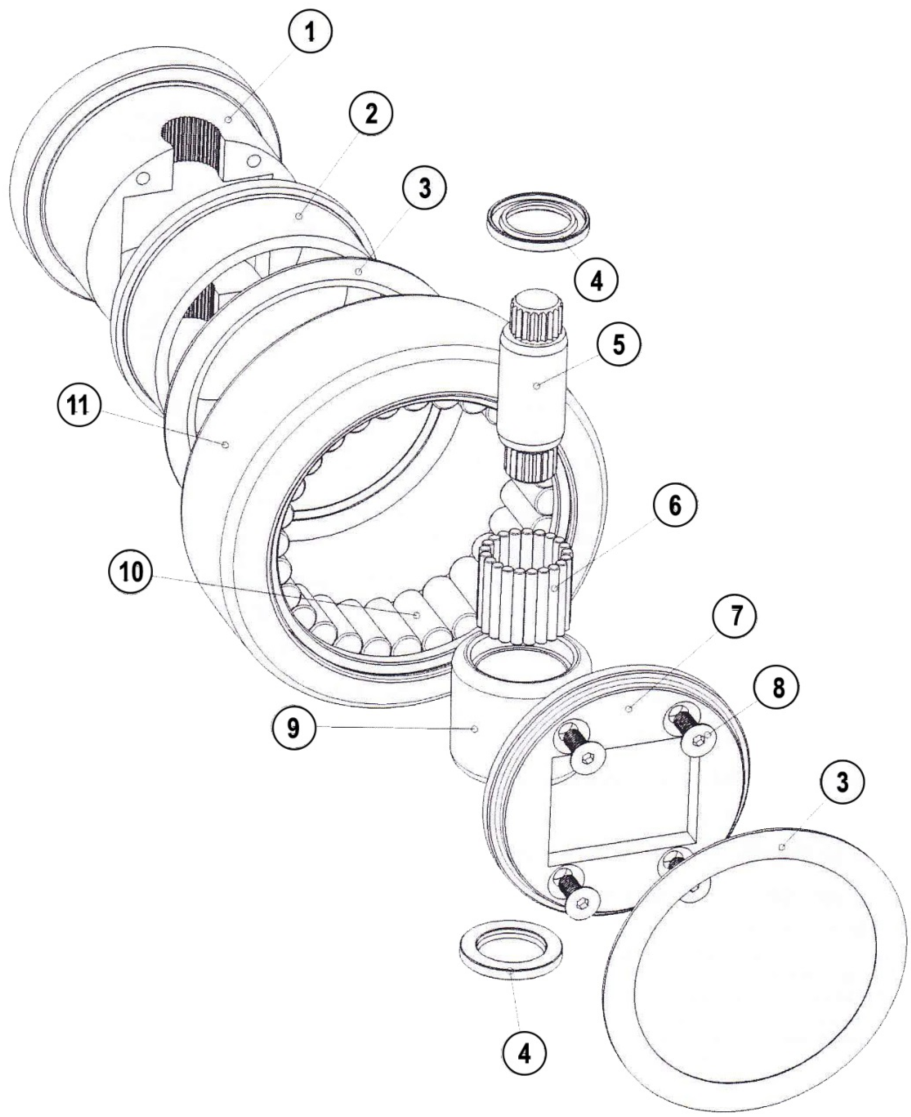
The adjustment rollers are supported by eccentric shafts which seat in mounting blocks welded to the outside of the mast channels of the various stages. The position (rotation) of the eccentric shafts is fixed via the use of pinch bolts in the mounting blocks. Slots provided in the front face of the mast channels of the various stages provide access to the pinch bolts.

To adjust the rollers, loosen the pinch bolts through the access slots. Using a screwdriver, adjust the rotation of the eccentric shafts thru the access holes located on from the inboard side of the mast channel web so that adjustment roller is contacting the back flange of the mast channel of the adjacent stage. Re-tighten the pinch bolts through the access slots. Tightener bearings should always be adjusted in corresponding right hand and left hand pairs.



Mast Rail Roller FR15/25 & FR18/26

The inner stage has six axial bearings located on the channels that allow the inner stage to travel up and down in the outer stage channels. To disassemble the roller, first remove the four M6 Flat head cap screws from the face of the roller. Items 2 through 11 can be removed as one piece. The shaft is welded in and should only be removed when there is damage to the shaft. Remove the roller from the new assembly and replace it onto the old stubshaft. Use thread locker on the M6 screws before installing the new assembly. Use the screws (item 8) and all new parts from the new assembly on the original stubshaft. The stubshaft from the new assembly can be saved or scrapped.



1. Stubshaft
2. Inner Ring
3. Rubber Seal
4. Oil Seals
5. Pin
6. Needle
7. Front Washer
8. Screw M6x16FHCS
9. Side Roller
10. Roller
11. Outer Ring

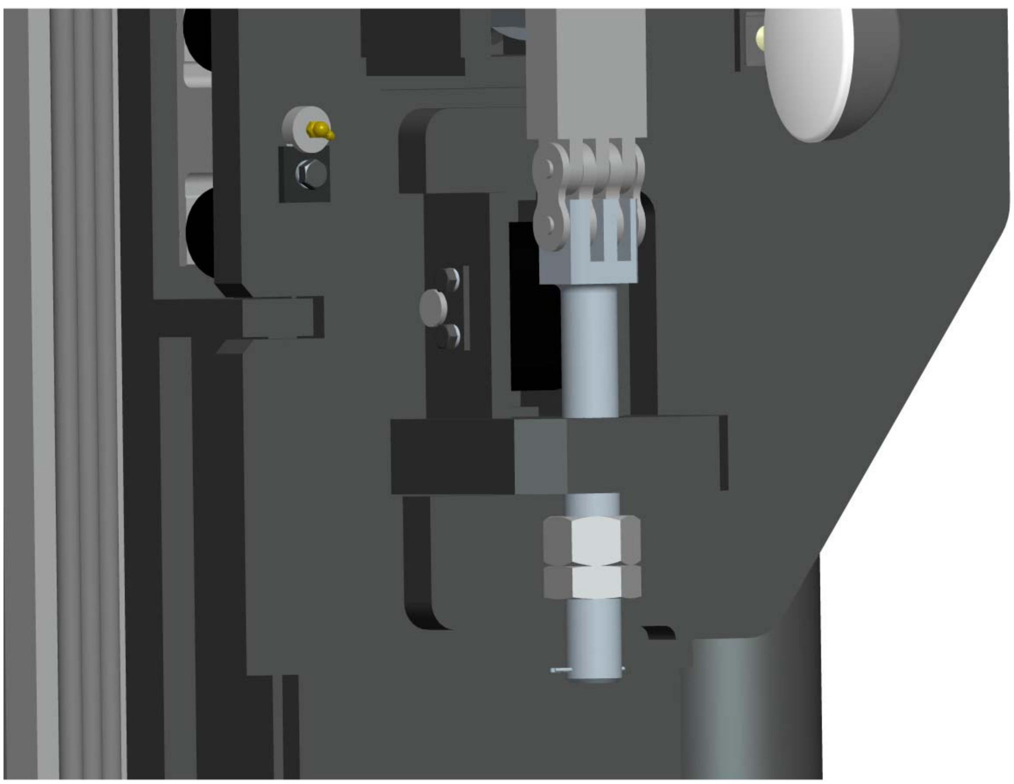
Items 2 thru 11 can be removed as an assembly.

Lift Chains FR15/25 & FR18/26

Mast lift chain assemblies are sized and designed to provide safe, reliable and efficient transmission of lifting force from hydraulic cylinder(s) to the forks. Safe operation of the forklift with minimal downtime relies on the proper care and maintenance of the lift chains. Unsatisfactory chain performance is most often the result of poor maintenance. Lift chains require periodic maintenance to provide maximum service life.

Lift Chain Adjustment

Lift chains should be adjusted to provide equal tension in each strand of chain to ensure proper load distribution and mast operation. Chain assemblies include chain anchors on the carriage and outer mast assembly. Lift chains can be adjusted by repositioning the nuts on the outer mast chain anchors. Lift chains are correctly adjusted when the lower carriage rollers reach their lowest position at an equal distance from the lower edge of the inner mast which would also position the bottom of each fork an equal distance from the floor. Chain adjustment should be checked by verifying equal lower roller position from one side of the carriage to the other as well as by verifying the bottoms of the forks are also an equal distance from the ground. Check for equal tension by extending the inner mast, with NO LOAD on the forks, to put the chains under tension. Press the center of one chain with your thumb and then press in the same place on the opposite chain. Each chain should have an equal feel of ‘give’.



Make sure that both chain anchor nuts for each chain anchor are back in place and that there is a cotter pin in the end of each anchor.

Lift Chain Lubrication

Like all bearing surfaces, the precision-manufactured, hardened-steel, joint-wearing surfaces of leaf chain require a film of oil between all mating parts to prevent accelerated wear.

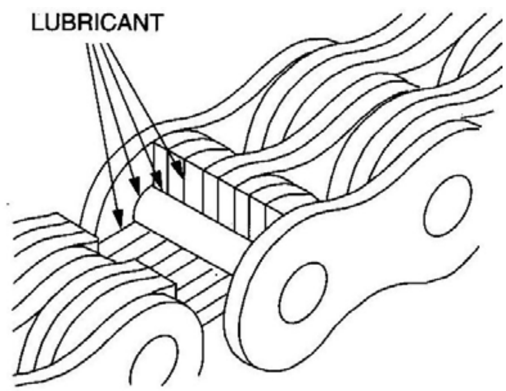
Use Chain and Cable Lube for lubrication of chains.

Maintaining a lubricant film on all chain surfaces will:

- Minimize joint wear.
- Improve corrosion resistance.
- Reduce the possibility of pin turning.
- Minimize tight joints.
- Promote smooth, quiet chain action.
- Lower chain tension by reducing internal friction in the chain system.

Laboratory wear tests show #40 oil to have a greater ability to prevent wear than #10 oil. Generally, the heaviest (highest viscosity) oil that will penetrate the joint is the best.

Oil must penetrate the chain joint to prevent wear. Applying oil to external surfaces will prevent rust, but oil must flow into the live bearing surfaces for maximum wear life.



The frequency of lubrication will vary with the operating conditions and the environment. The best lubrication time is during each P.M. (50-250 hours or four weeks maximum actual truck operating time). Trucks parked outdoors, or in very severe service, may need lubrication more often to keep a layer of oil on all chain surfaces.

To prepare the chain for oiling, brush the leaf chain plates with a stiff brush or wire brush. This will clear the space between plates so that oil may penetrate the live bearing area.

Oil may be applied with a narrow paint brush or directly poured on. Chain should be well-flooded to be sure the oil penetrates the joint.

In difficult to reach locations, use a good quality oil under pressure, such as an aerosol can or pump pressure spray.

Lift Chain Environmental Considerations

Environments in which material handling and lifting mechanisms operate can vary widely, from outdoor moisture to mildly corrosive or highly corrosive industrial atmospheres, in addition to abrasive exposures such as sand and grit. Some effects can be as follows:

Moisture - Corrosive rusting reduces chain strength by pitting and cracking.

Temperature - Low temperature reduces chain strength by embrittlement. Going in and out of cold storage results in moisture from condensation.

Chemical Solutions or Vapors - Corrosive attack on the chain components and/or the mechanical connections between the chain components. Cracking can be (and often is) microscopic. Propagation to complete failure can be either abrupt or may require an extended period of time.

Abrasives - Accelerated wearing and scoring of the articulating members of the chain (pins and plates), with a corresponding reduction in chain strength. Due to the inaccessibility of the bearing surfaces (pin surfaces and plate apertures), wear and scoring are not readily noticeable to the naked eye.

Each specific application should be evaluated, based on the degree of exposure and the areas of possible operation. A chain replacement schedule should be established to prevent chain failure. This schedule can be established by frequent inspection. Based on the observations, the frequency of inspection can be changed. The inspection procedure development should go on until a projected time of replacement can be predicted. A chain by its very nature and exposure should be considered an expendable item and a safe chain replacement schedule established.

It is further recommended that chains used in cold stores exposed to very low temperatures, or chains used in corrosive atmospheres, receive frequent, very thorough inspections until such time as a reliable replacement cycle has been determined.

Lift Chain Shock Loads

Dynamic shock loading can impose abnormal loads above the endurance limit of leaf chain. These shock loads can greatly impact the performance and life of lift chains. Examples of situations which can result in shock loading of lift chain include:

- High velocity movement of load, followed by sudden, abrupt stops.
- Carrying loads in suspension over irregular surfaces such as railroad tracks, potholes, and rough terrain.
- Attempting to “inch” loads which are beyond the rated capacity of the handling or lifting mechanism.

The above load cycles and environmental conditions make it difficult to predict chain life. It is therefore necessary to conduct frequent inspections until replacement life can be reasonably predicted.

Lift Chain Inspection and Wear Measurement
Each 50-250 hours of operation (more frequently in severe or extreme environments as indicated above), chains should be inspected and lubricated. Inspection should focus on the following:

Rust and Corrosion
Corrosion will reduce the load-carrying capacity of lift chain because corrosion causes sideplate cracking. Protect lift chains from corrosion whether in service or in storage. The factory lubrication on the chains is a very good rust and corrosion inhibitor. The factory lubrication is applied in a hot dip tank to assure complete penetration into the joint. After the chain has been put in service, there must be a layer of oil on the chains at all times. Heavy motor oil is used as a lubricant and a corrosion inhibitor.

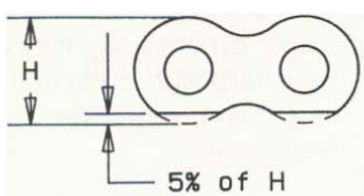
During inspection, check for a layer of oil on the external chain surfaces. Under some operating conditions, it will be necessary to lubricate chains between P.M.'s.

Chains with corrosion must be inspected for cracked plates. Outside plates are especially susceptible to stress-corrosion cracking. If chains have heavy rust or corrosion, they must be removed from the stage for a complete inspection for cracked plates. If the plates are cracked, all chains on the truck must be replaced. Lubricate chains when they are installed on the stage.

Edge Wear
Check the chain for wear on the link plate edges caused by running back and forth over the sheave. The maximum reduction of material should not exceed 5%.

This can be compared to a normal link plate height by measuring a porting of chain that does not run over the sheave. Distorted or battered plates on leaf chain can cause tight joints and prevent flexing.

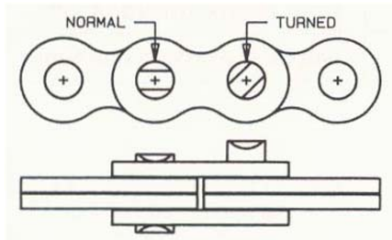
Worn contours and worn surfaces on the outside links or pin heads should not exceed 5% of new link height.



Do not repair chains by cutting out the worn section and joining a new piece. If part of a chain is worn, replace all the chains on the truck.

Turning or Protruding Pins
Highly loaded chain operating with inadequate lubrication can generate abnormal frictional forces between pin and link plates. In extreme instances, the torque could surpass the press fit force between the pins and the outside plates, resulting in pin rotation. When chain is allowed to operate in this condition, a pin or series of pins can begin to twist out of a chain, resulting in failure. The pin head rivets should be examined to determine if the "VEE" flats are still in correct alignment. Chain with rotated/displaced heads or abnormal pin protrusion should be replaced immediately. Do not attempt to repair the chain by welding or driving the pin(s) back into the chain. Once the press fit integrity between outside plates and pins has been altered, it cannot

be restored. Any wear pattern on the pin heads or the sides of the link plates indicated misalignment in the system. This condition damages the chain and increases frictional loading, and shouldn't be corrected.



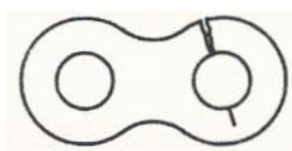
Cracked Plates

The chains should periodically be inspected very carefully, front and back as well as side to side, for any evidence of cracked plates. If any single crack is discovered, the chain(s) should be replaced. Determine the causes of the crack before installing the new chain so the condition does not repeat itself.

- Fatigue Cracking - Fatigue cracks are a result of repeated cyclic loading beyond the chain's endurance limit. The magnitude of the load and frequency of it succulence are factors which determine when fatigue failure will occur. The loading can be continuous or intermittent (impulse load).

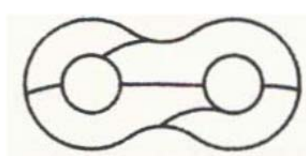
Fatigue cracks generally run from the pin hole toward the edge of the link plate approximately 90° from the line of pull.

Fatigue cracks always start at the link plate pin hole (point of highest stress), and are perpendicular to the chain pitch line. They are often microscopic in their early stage. Unlike a pure tensile failure, there is no noticeable yielding (stretch) of the material.



- Stress-Corrosion Cracking - The outside link plates, which are heavily press fitted to the pins, are particularly susceptible to stress corrosion cracking. Like fatigue cracks, these initiate at the point of highest stress (pin hole), but tend to extend in an arc-like path between the holes in the pin plate.

Arc-like cracks in plates are a sign of stress corrosion.



More than one crack can often appear on a link plate. In addition to rusting, this condition can be caused by exposure to an acidic or caustic medium or atmosphere.

Stress corrosion is an environmentally-assisted failure. Two conditions must be present: a corrosive agent and static stress. In the chain, static stress is present at the pin hole due to the press fit pin. No cyclic motion is required, and the plates can crack during idle periods. The reactions of many chemical agents (such as battery acid fumes) with hardened steel can liberate hydrogen, which attacks and weakens the steel grain structure.

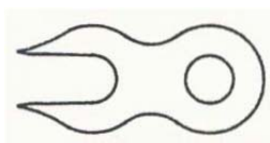
For this same reason, never attempt to electroplate a leaf chain or its components. The plating process liberates hydrogen and hydrogen embrittlement cracks will appear. These are similar in appearance to stress corrosion cracks.

- Corrosion Fatigue - Corrosion fatigue cracks are very similar (in many cases identical) to normal fatigue cracks. They generally start at the pin hole and move perpendicular (90°) to the chain pitch line.

Corrosion fatigue is not the same as stress corrosion. Corrosion fatigue is the combined action of an aggressive (dirty or abusive) environment and a cyclic stress (not a static stress alone, as in stress corrosion).

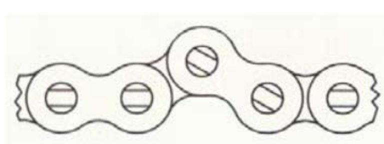
<u>Ultimate Strength Failure</u>
This type of failure is cause by overloads far in excess of the design load.

Broken Plate Cause by Overload



<u>Tight Joints</u>
All joints in leaf chain should flex freely. Tight joints resist flexure and increase internal friction, increasing chain tension required to lift a load. Increased tension accelerators wear and fatigue problems.

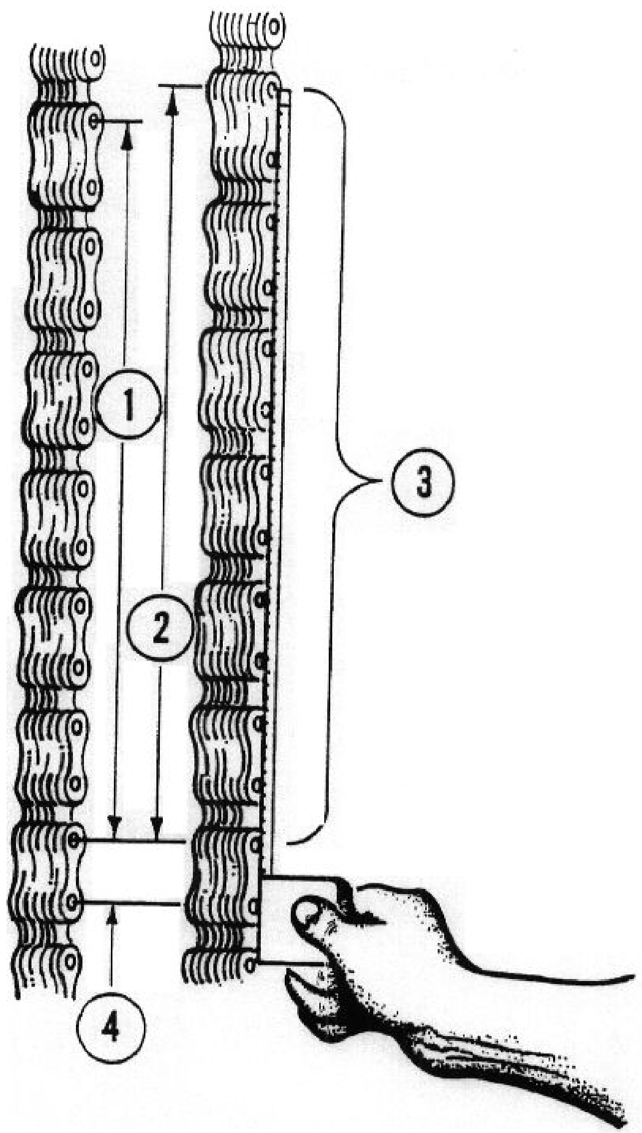
If lubrication does not loosen a tight joint, the chain may have corrosion and rust problems or bent pins, and must be replaced.



<u>Elongation</u>
Lift chains elongate (stretch) over time and every chain inspection should include a measurement to identify when chains have stretched over the allowable limit and require replacement. Chains should be measured in the section that moves over the sheaves as those sections receive the most frequent articulation and the most amount of wear. Measuring the chain near its clevis terminals could give an erroneous reading as it does not flex as frequently, if at all. Chain measurements should be compared against the following table which is based on a maximum wear elongation of 3%. The “span measurement” is based on a measurement from pin center to pin center for the number of pins indicated. Chains exceeding the maximum “span measurement” must be replaced.

CHAIN SERIES	CHAIN PITCH (In.)	MEASURING SPAN IN NO. OF PINS	RECOMMENDED MEASURING LOAD		MAX. SPAN MEASUREMENT NO. OF PINS CENTER TO CENTER	
			Lbs.	Kg	In.	MM
BL1266	1-1/2	9	1020	463	12.36	314
BL1666	2	7	1950	885		

Do NOT repair chains by cutting out the worn section and joining a new piece. If part of a chain is worn, replace all the chains on the truck.



1. **New chain length**
2. **Worn chain length**
3. **Span**
4. **Pitch**

Lift Chain Replacement

Short sections of leaf chain must never be joined together to form a longer length. NEVER join new chain sections to old chain sections.

Lift chains must always be replaced in pairs. It is virtually impossible to keep a balanced load between chains if a new chain is put into service opposite an old chain. The joints in the old chain may have worn through the hardest layer of the case-hardened pins, and the old chain will wear much faster than the new chain, creating problems keeping equal chain tension. The new chain will wear more slowly, causing it to hold more of the load, resulting in early wear and failure.

Do not remove the lubricant from new chains. The manufacturer's lubricant helps prevent wear and corrosion. If the original factory lubrication has dried or been removed, apply Chain and Cable Lube.

After the old chains have been removed from the mast, very carefully inspect the chain anchors and sheaves. Broken, cracked, or worn anchors must be replaced. Replace worn sheaves and check the sheave bearing for wear.

Do not paint new chain before or after installation. Paint will help prevent corrosion, but will also prevent lubricant from reaching the pin surface for proper joint lubrication.

Use new anchor pins when installing new chains. Old pins may contain fatigue cracks that could cause failure. After the chains have been connected to the anchors, adjust the chain tension.

Correct chain installation and upright adjustment will increase chain service life.

Lift Chain Maintenance Checklist

A. Lift Chain Inspection
   Every truck PM (50-250 hours) check for:
   1. Cracked plates
   2. Rust and corrosion
   3. Turned pins
   4. Tight joints
   5. Wear- measure portion of chain that flexes over sheaves

B. Lift Chain Lubrication
   Every truck PM (50-250 hours), or as dictated by environment:
   1. Apply Chain and Cable Lube
   2. Lubricate full length of all strands

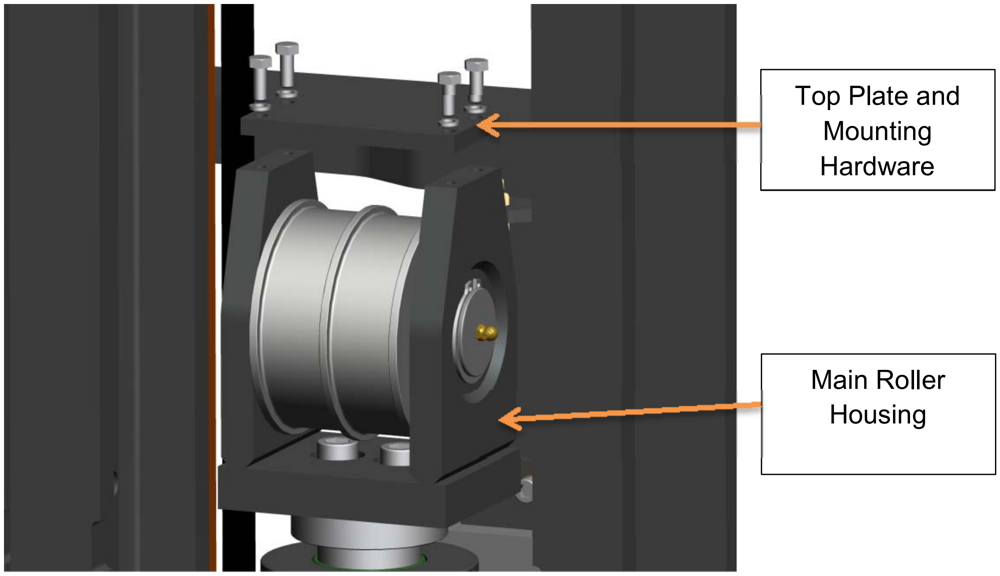
C. Lift Chain Replacement
   1. All chains must be replaced if any strand has wear of 3% or more, or if any of the conditions listed in Section A are found during inspection
   2. Order replacement chains from your authorized parts dealer
   3. Replace all chains as a set
   4. Do not remove lubricant from or apply paint to new chains
   5. Replace anchor pins and worn or broken anchors when installing new chains
   6. Adjust tension on new chains

Center Chain Roller FR15/25 & FR18/26

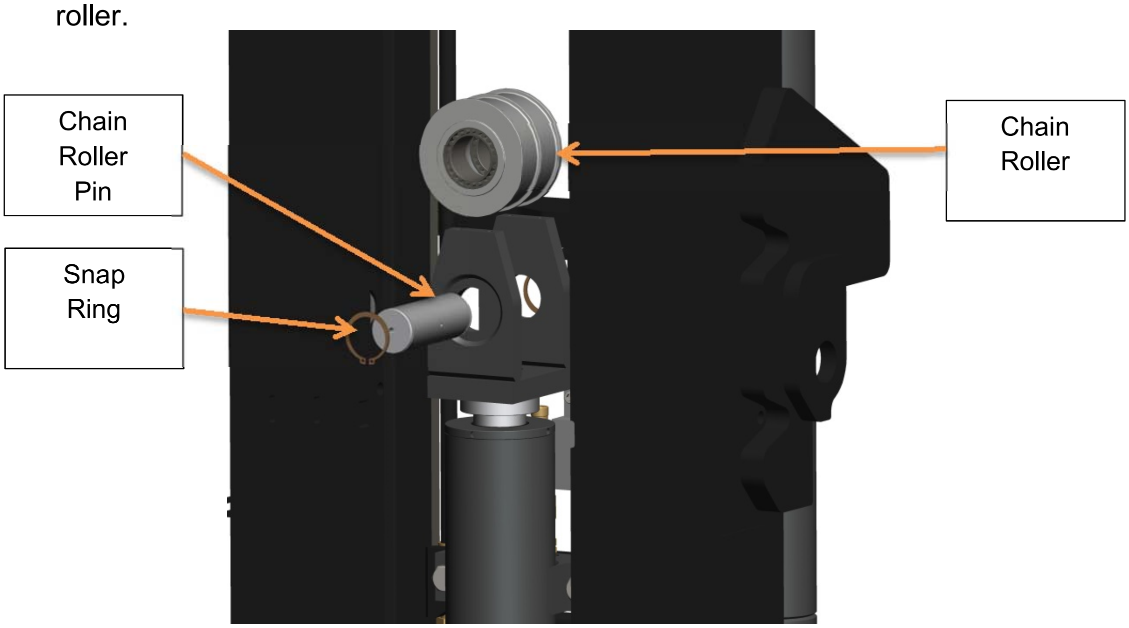
The chain roller is located on top of the center lift cylinder, inside the main roller support assembly.

The lift chain must be removed before you can remove the chain roller. (see section*)

Remove the four bolts and lock washers from the top of the main roller support assembly. Remove the top plate from the main roller support assembly.



Turn the cylinder housing and rod until the pin can be removed. Using snap ring pullers, remove the snap ring at each end of the chain roller pin and with the roller supported, slide the pin out of the roller and roller housing. With the roller removed, the bearings can now be pulled from the roller.



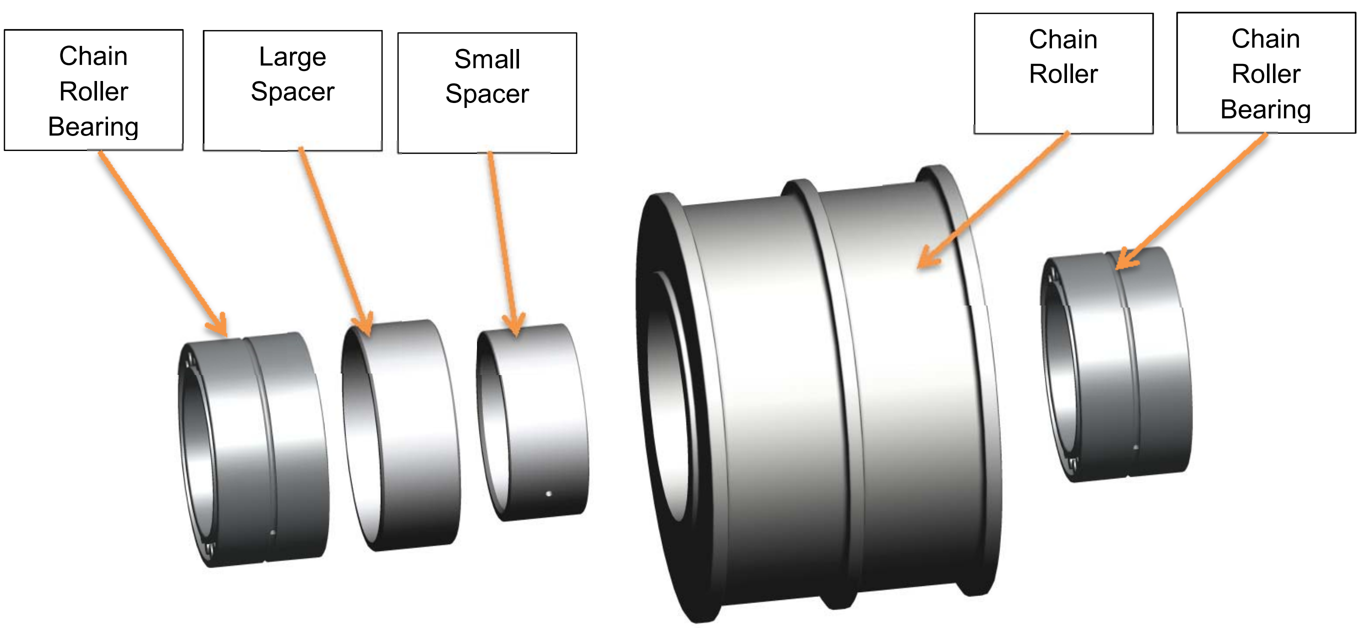
DO NOT HAMMER THE PIN DIRECTLY, IT WILL CAUSE THE PIN TO MUSHROOM.

Center Chain Housing Removal FR15/25 & FR18/26

Remove the two socket head capscrews and washers that retain the chain roller housing to the top of the lift cylinder rod.

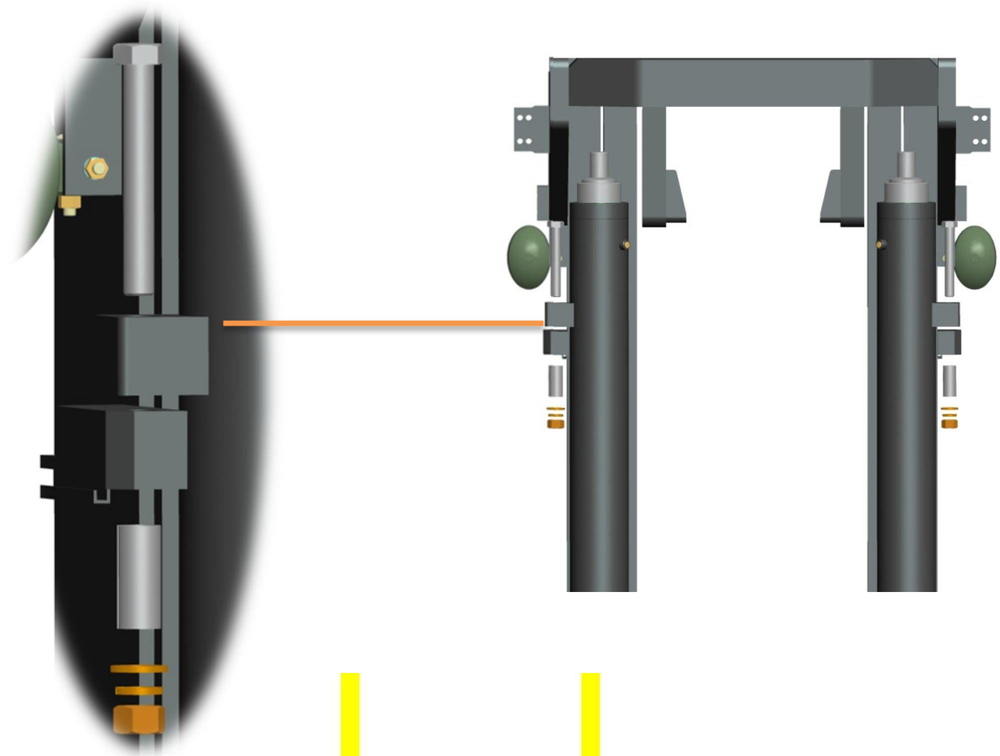
Center Chain Roller Disassembly/Assembly FR15/25 & FR18/26

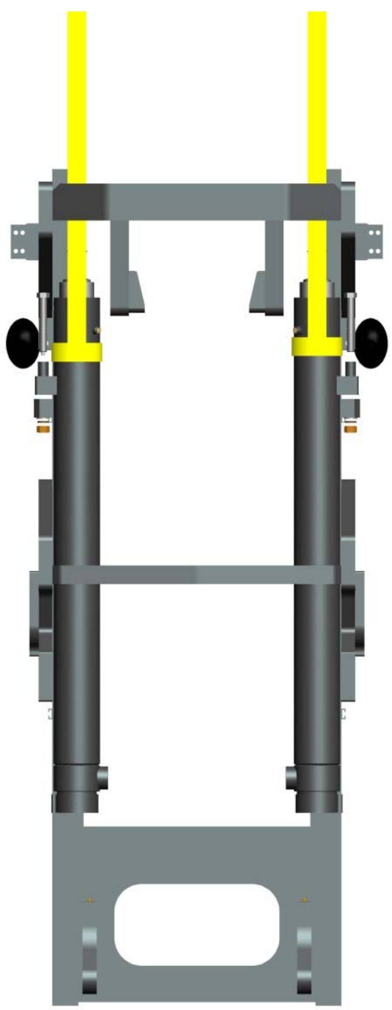
The chain roller assembly consists of the chain roller, two bearings, and two spacers; one large diameter and one small diameter. To disassemble the chain roller assembly, gently knock out the bearings and spacers. To reassemble, press one bearing in until flush with the face of the roller. Then install the large spacer followed by the small spacer inside the large spacer. Press the second bearing in from the opposite side of the first bearing until flush with the face of the roller. Be sure to press the bearings into the roller evenly.



Side Lift Cylinder Removal FR15/25 & FR18/26

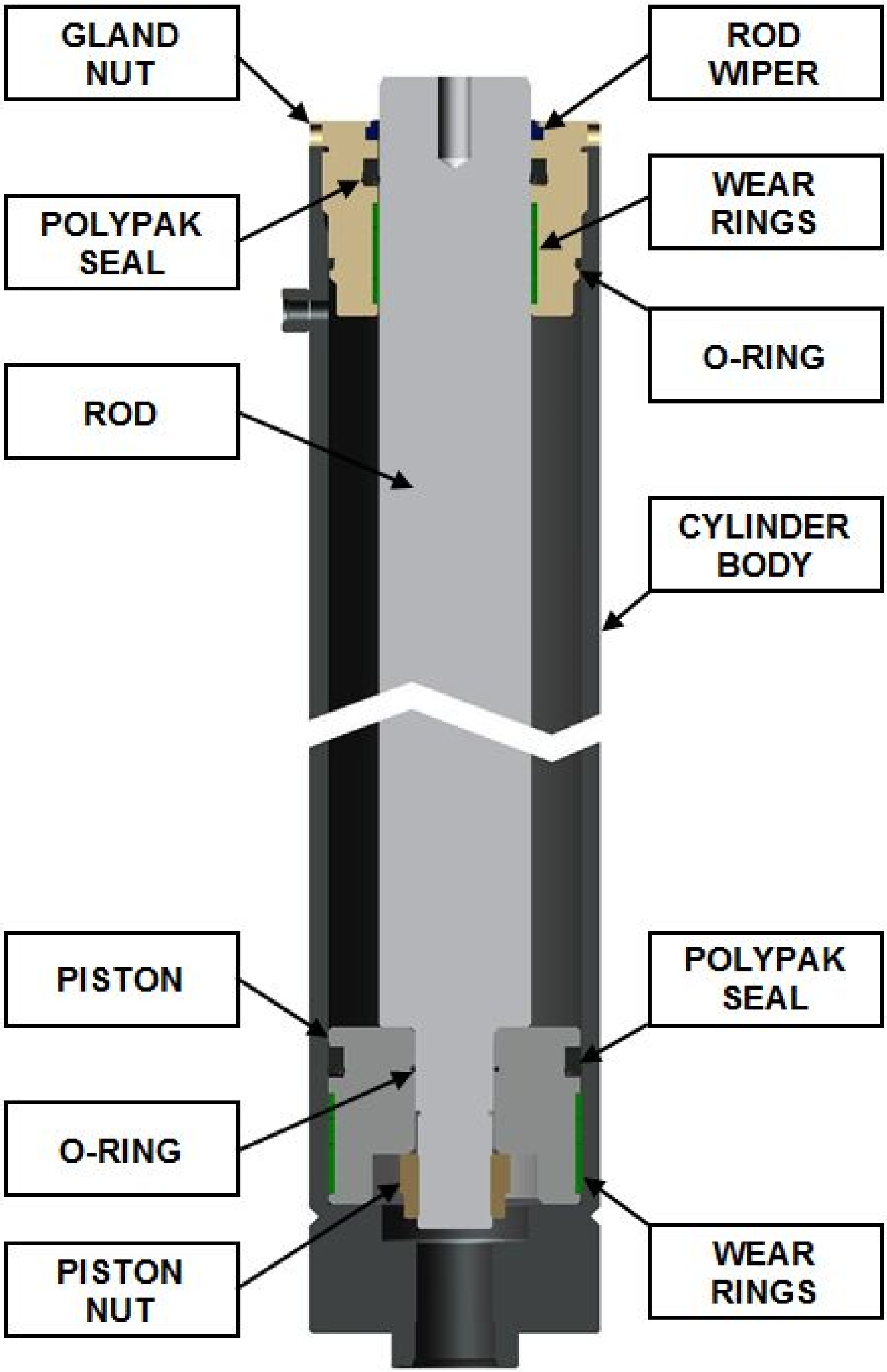
Wrap a properly rated lifting strap around the cylinder and apply sufficient tension to support the cylinder. Remove the lift cylinder mounting kit from the outer stage. The spacer will need to be pressed out. Remove the cylinder from the outer stage.





Single Stage Cylinders FR15/25 & FR18/26

A cross section of a typical single acting single stage cylinder is show below for reference purposes.



Single Stage Cylinders (Con't)

Drain the oil with the cylinder with the base end port facing down (for some cylinders this will be in the vertical position while for others this will be with cylinder in horizontal position).

Once the oil has completely drained, secure the cylinder to a work bench or appropriate stand in a vertical orientation with the rod end up. The work position should have access to an overhead crane.

Remove the gland nut using an adjustable spanner wrench.

Remove the rod/piston assembly from the cylinder body.

Inspect all components for nicks and scratches. Minor nicks and scratches can be removed using a 400 grit emery cloth. Minor nicks and scratches are those which will NOT bypass oil under pressure. If minor nicks and scratches cannot be removed with an emery cloth, the affected parts MUST be replaced. If the piston must be removed, use a strap wrench and emery cloth to secure the rod while removing the piston nut.

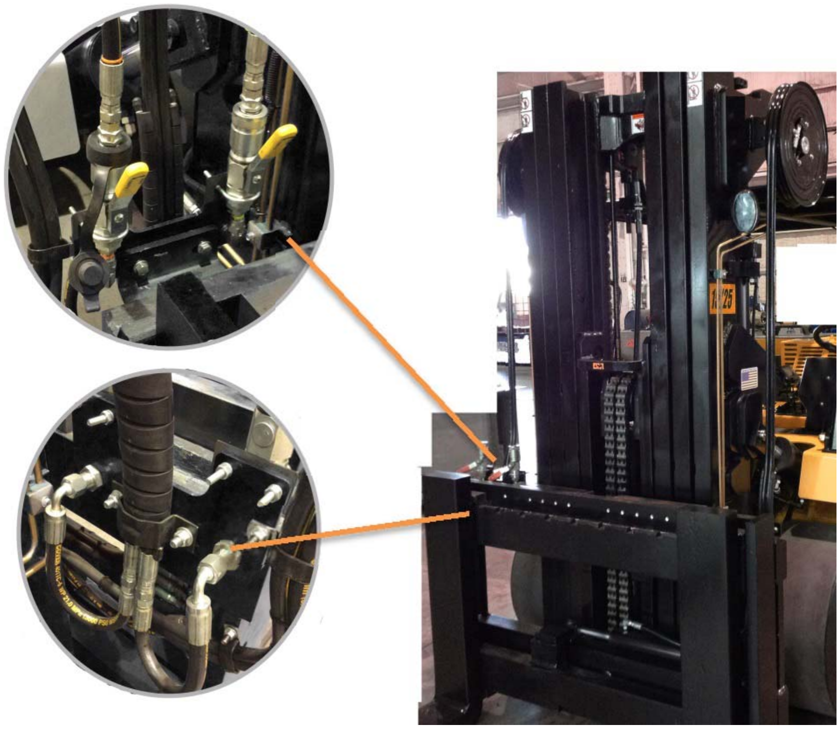
Replace seals, O-rings, wear rings and wiper noting the correct direction of seals and O-ring backup rings. The cylinder will NOT operate correctly if seals and/or O-rings are installed incorrectly.

Lubricate new seals with petroleum jelly before installing.

Apply anti-seize compound to the threads of the cylinder body and install gland nut using spanner wrench to tighten. The gland nut should bottom out on end of cylinder body.

Carriage Removal FR15/25 & FR18/26
Remove forks and pusher from carriage. *REFER TO FORK AND PUSHER REMOVAL SECTION IN THIS MANUAL.*
Disconnect the hoses coming from the mast upper hose reel where they connect to the back of bulkhead fittings at the shutoff valve assembly. Cap the fittings to prevent leaking.

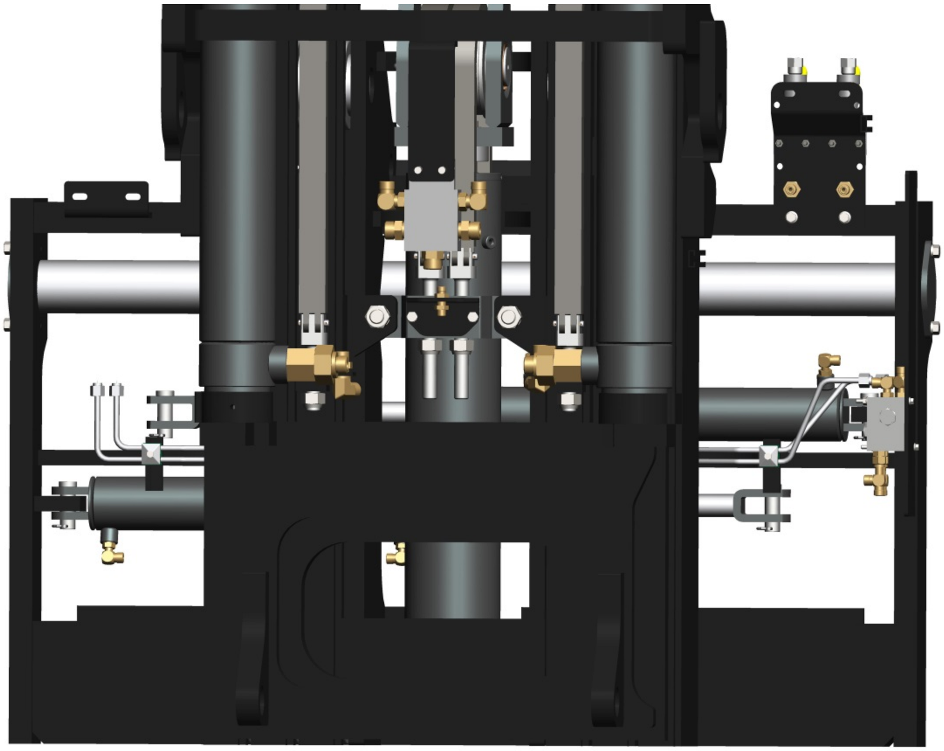
Remove the crowbar assembly from the carriage to prevent injury



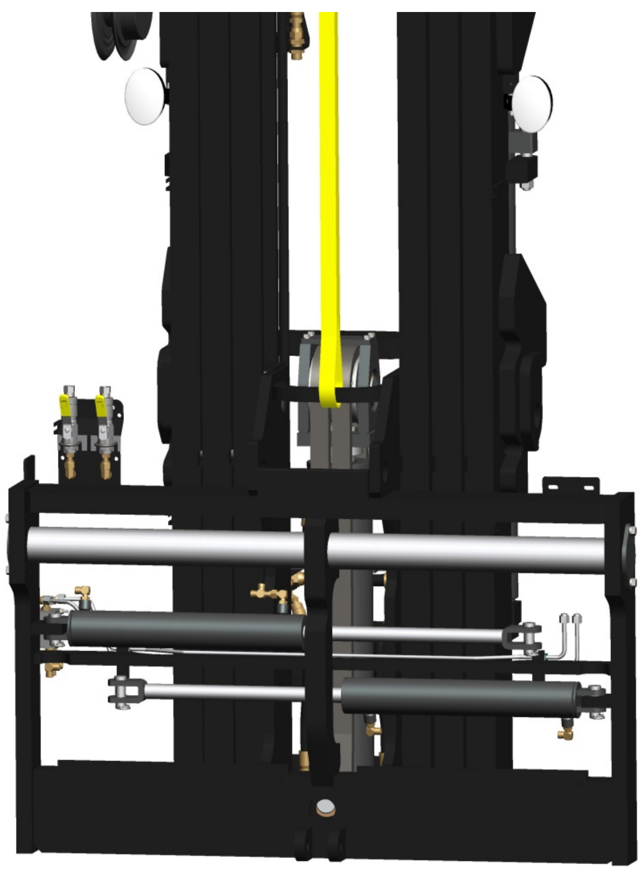
WARNING:
HOSES CAN SWING AND CAUSE INJURY. MAKE SURE HOSES ARE TIED OFF PROPERLY TO PREVENT INJURY OR DAMAGE TO PROPERTY.

Remove the carriage stop block from the top of the inner by removing the two bolts and washers.

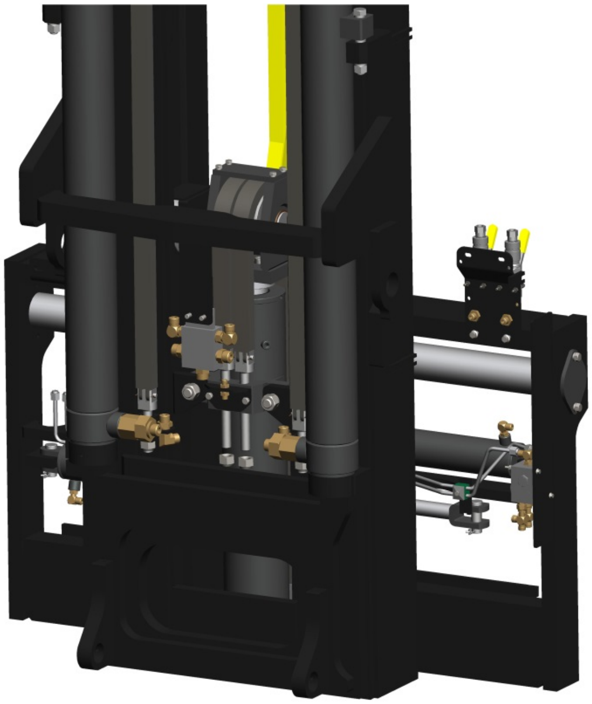
Disconnect the hydraulic drain system hose and the hydraulic hoses at the bulkheads at the backside of the carriage. Plug the hose ends and cap the fittings to prevent contamination.

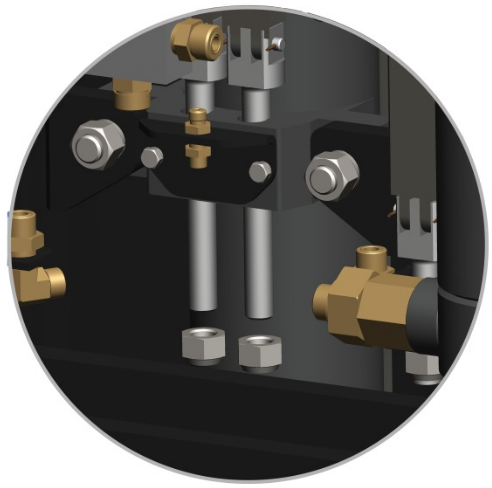


Secure the carriage with a properly rated lifting strap or chain, and, using an overhead crane or other appropriate lifting means, slightly raise the carriage to alleviate any tension from the carriage lift chains.

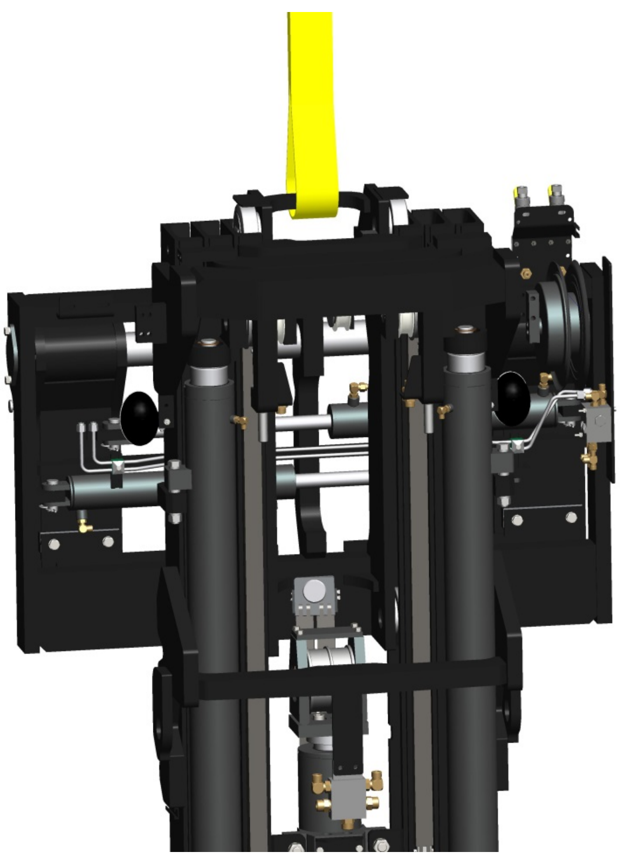


With the carriage properly secured, remove the rear chain anchor nuts where the carriage lift chains are secured to the center cylinder body.

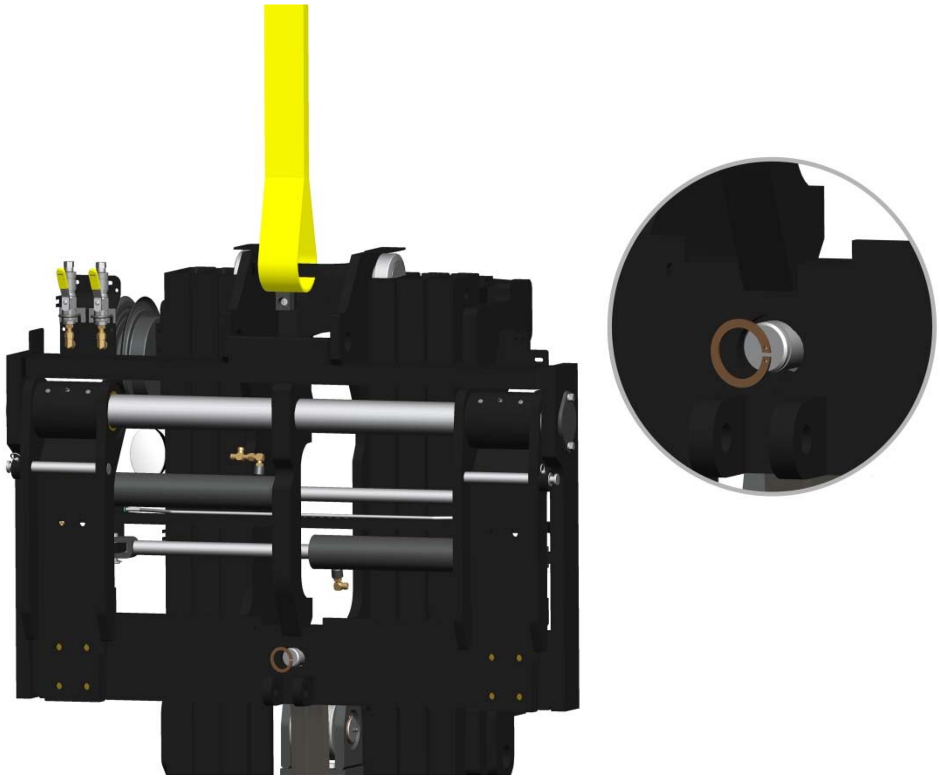




Pull the chain assembly through the chain roller housing assembled to the top of the cneter lift cylinder and let the chains hang freely. Using the overhead crane or other appropriate lifting means, lift the carriage to a position where the bottom bar is above the center lift cylinder assembly to provide access to the front chain anchor.



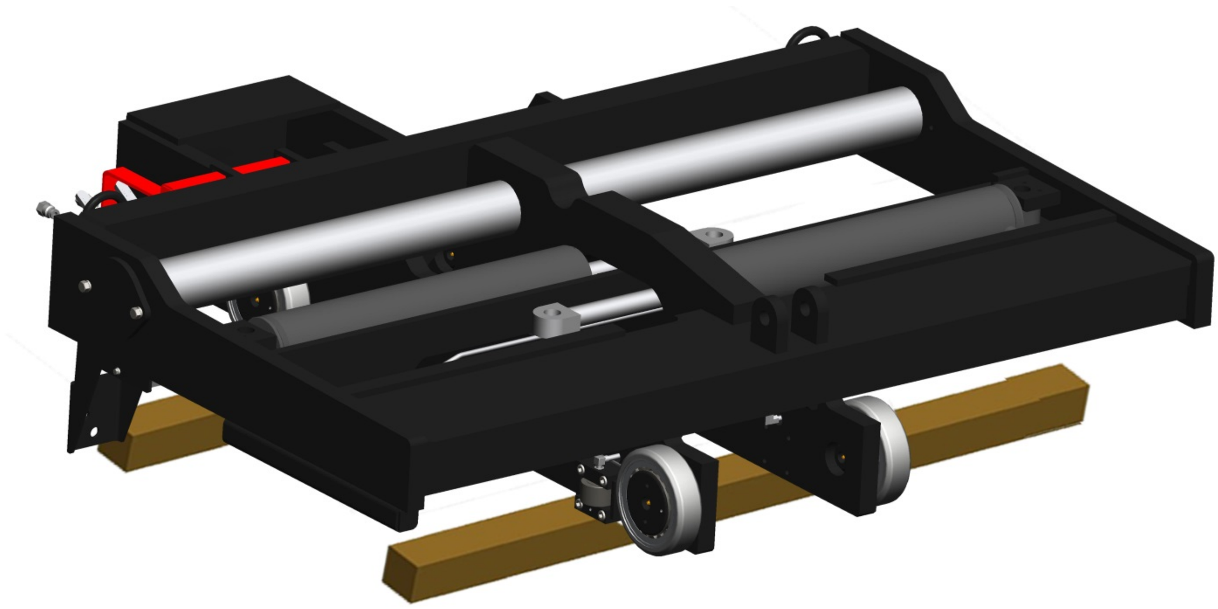
From the front side of the mast, use a pair of snap ring pliers to remove the front chain anchor snap ring.



Remove the chain completely and place with forks. The carriage can now be removed from the mast completely using the overhead crane or other appropriate lifting means.

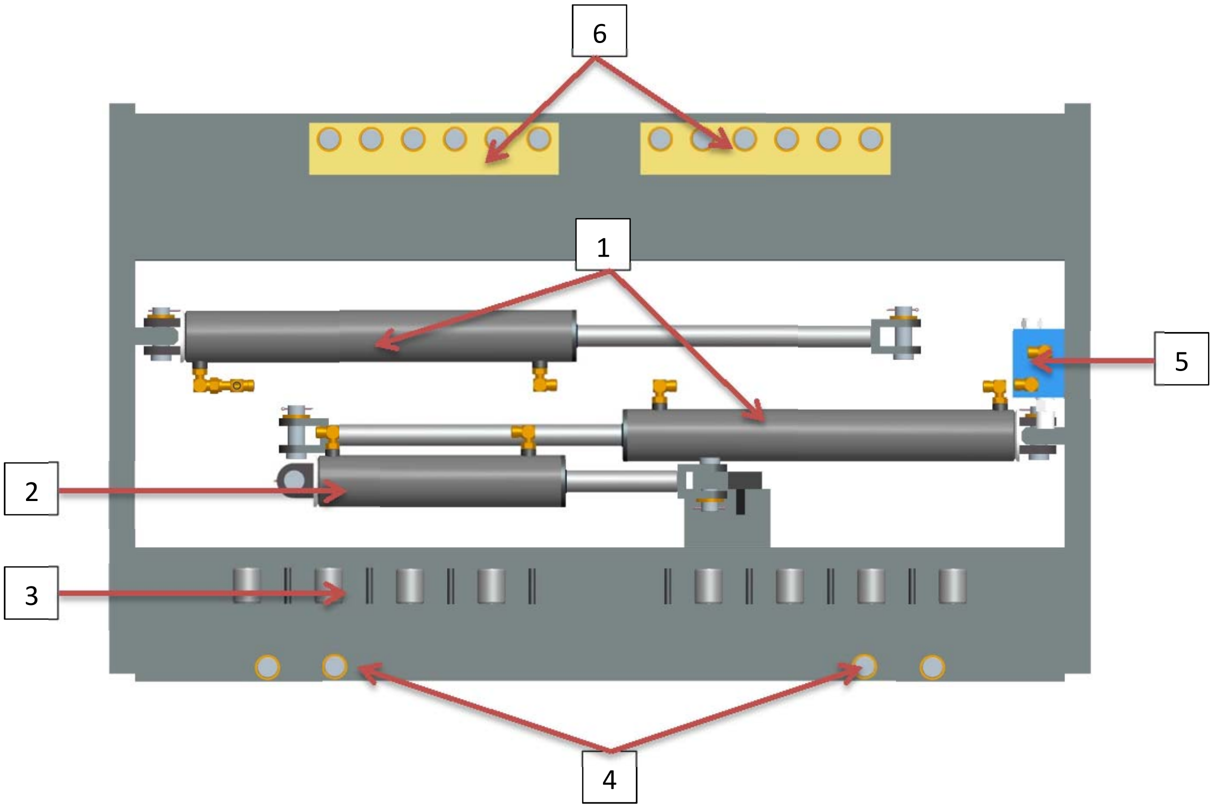
WARNING:
When the carriage is removed, it can potentially swing. Do <u>NOT</u> attempt to remove the carriage with personnel in the area or proximate to anything that might potentially be struck and/or damaged.

Lay the carriage on a pallet or boards.



Optional CLV SS, FF, SSFP Overview FR15/25 & FR18/26

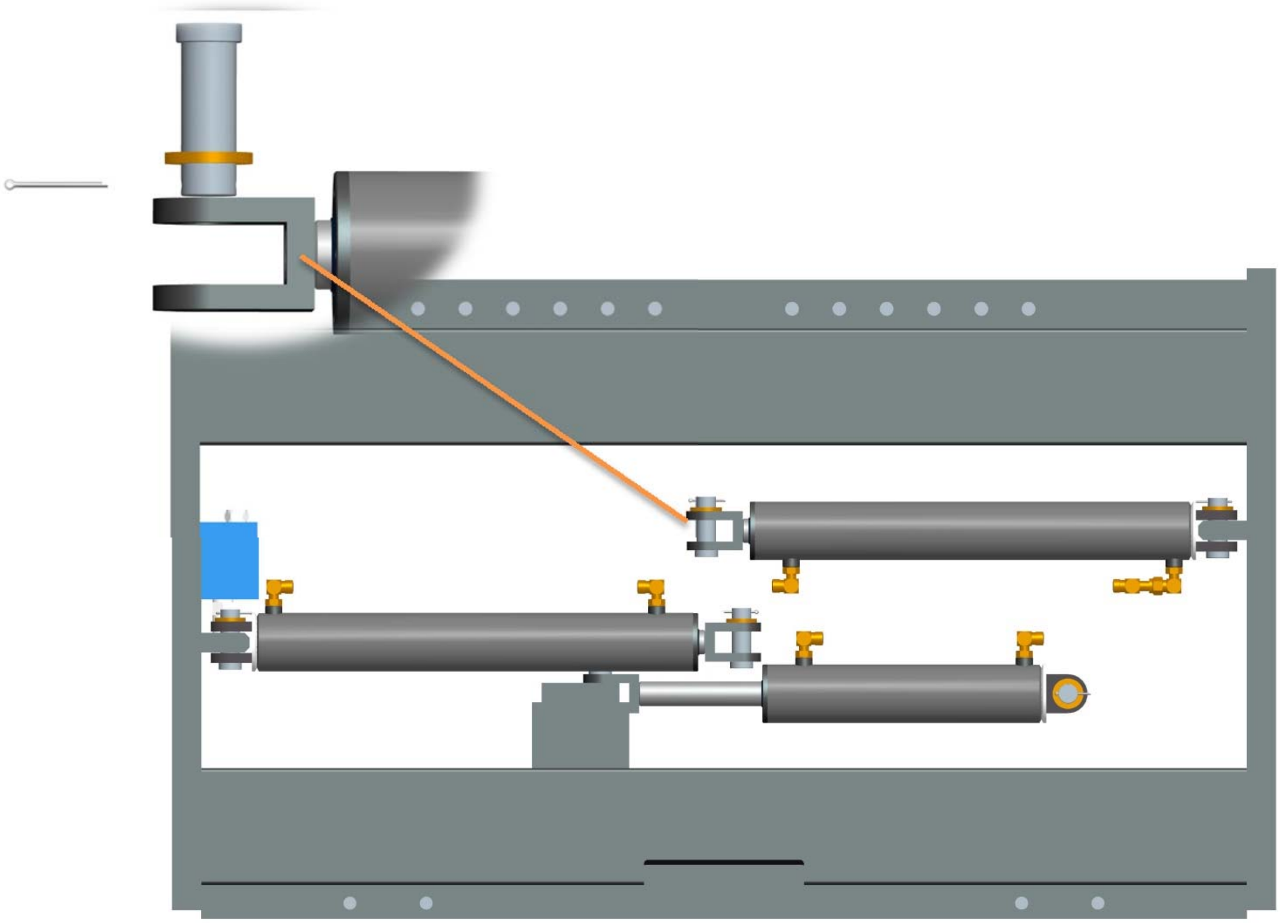
The optional CLV SS, FP, & SSFP are mounted to the standard CLV carriage with upper and lower retainer blocks.



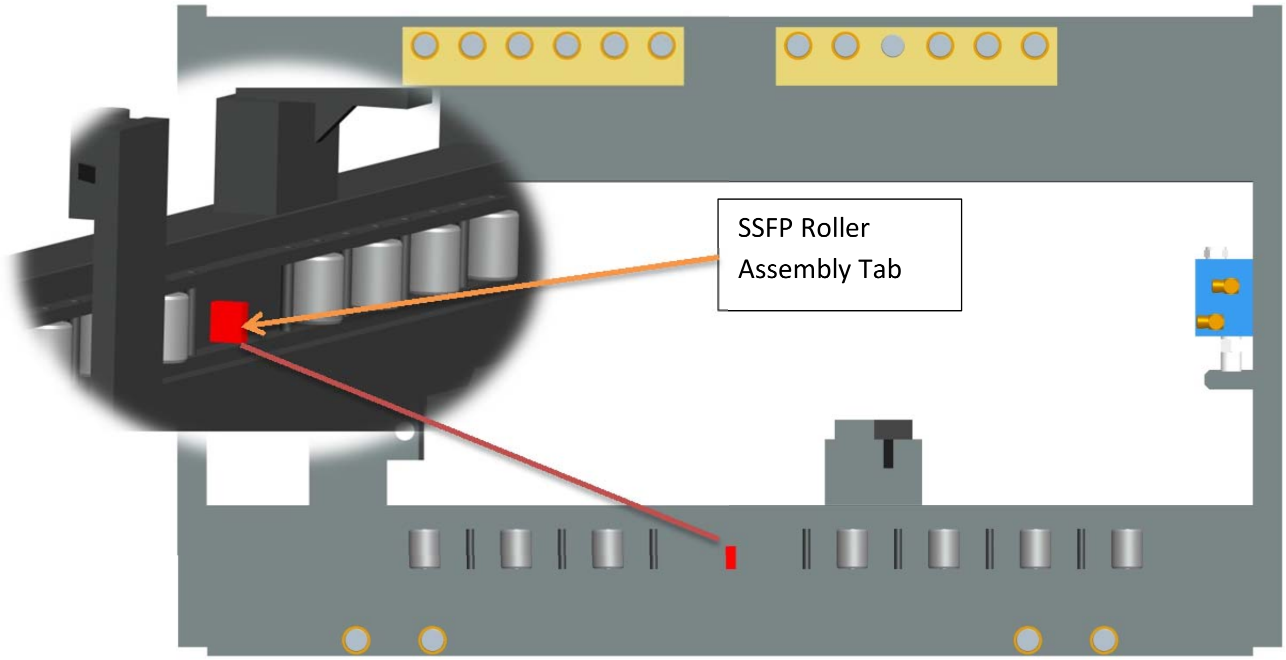
1. Fork Position Cylinders– Position the forks side to side on the carriage
2. Side Shift Cylinder – Shifts the entire carriage
3. SSFP Roller Assembly – Allows the carriage to shift on the face of the apron.
4. Lower Carriage Hook-Holds the carriage to the apron
5. Side Shift Manifold-Directs fluid to the side shift and fork position cylinders
6. Upper Carriage Retainer – Attaches the carriage to the apron

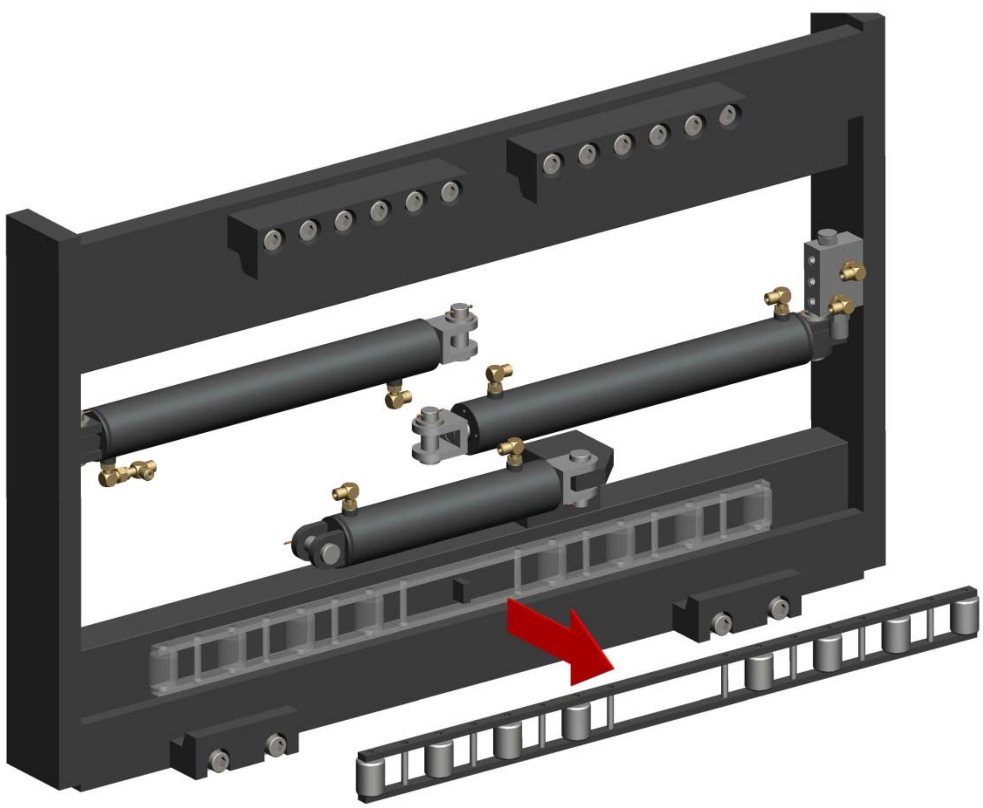
Optional SS/FP/SSFP Disassembly/Assembly FR15/25 & FR18/26

Retract all cylinders so as not to damage the rods during disassembly. To remove the fork position (FP) and or side shift (SS) cylinders, remove the hoses and cap them off so as to avoid spillage. The forks and pushers will need to be removed prior to removing the fork position cylinders. *REFER TO THE FORK AND PUSHER REMOVAL SECTION IN THIS MANUAL.* Remove the cotter pins, FP cylinder clevis pins and washers from the mounting ends of the cylinders. The cylinders can now be removed. To reinstall the cylinders, repeat the steps in reverse order.



The SSFP roller assembly is retained on the optional SS/FP/SSFP by a small block on the back of the optional SS/FP/SSFP weldment (highlighted in red in view). The SSFP roller assembly can only be removed with the optional SS/FP/SSFP removed from the CLV carriage assembly. The SSFP roller assembly can be removed by sliding it out from under the tab shown below.





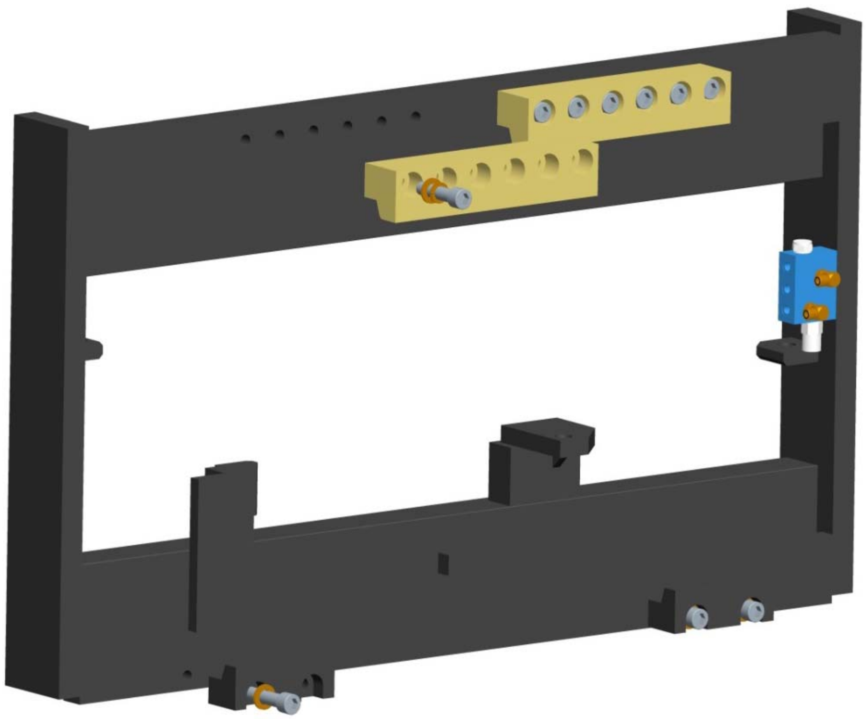
The upper and lower retainers are attached to the optional SS/FP/SSFP with socket head capscrews (SHCS). The optional SS/FP/SSFP must be removed from the carriage to remove the upper hooks. The lower retainers must be removed with the optional SS/FP/SSFP still on the carriage.

Upper Retainer Removal

Remove the six M20x80 SHCS, lock washers, and washers from each retainer and remove the retainer. Reinstall the SHCS using Loctite on the threads. *REFER TO THE TORQUE CHART IN THIS MANUAL*

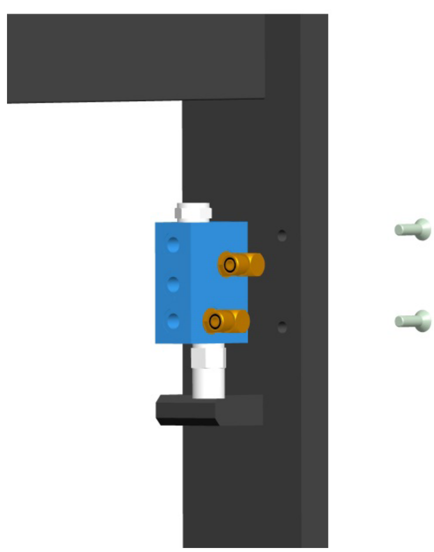
Lower Retainer Removal

Remove the two M20x80 SHCS, lock washers, and washers from each retainer and remove the retainer. Reinstall the SHCS. *REFER TO THE TORQUE CHART IN THIS MANUAL.*



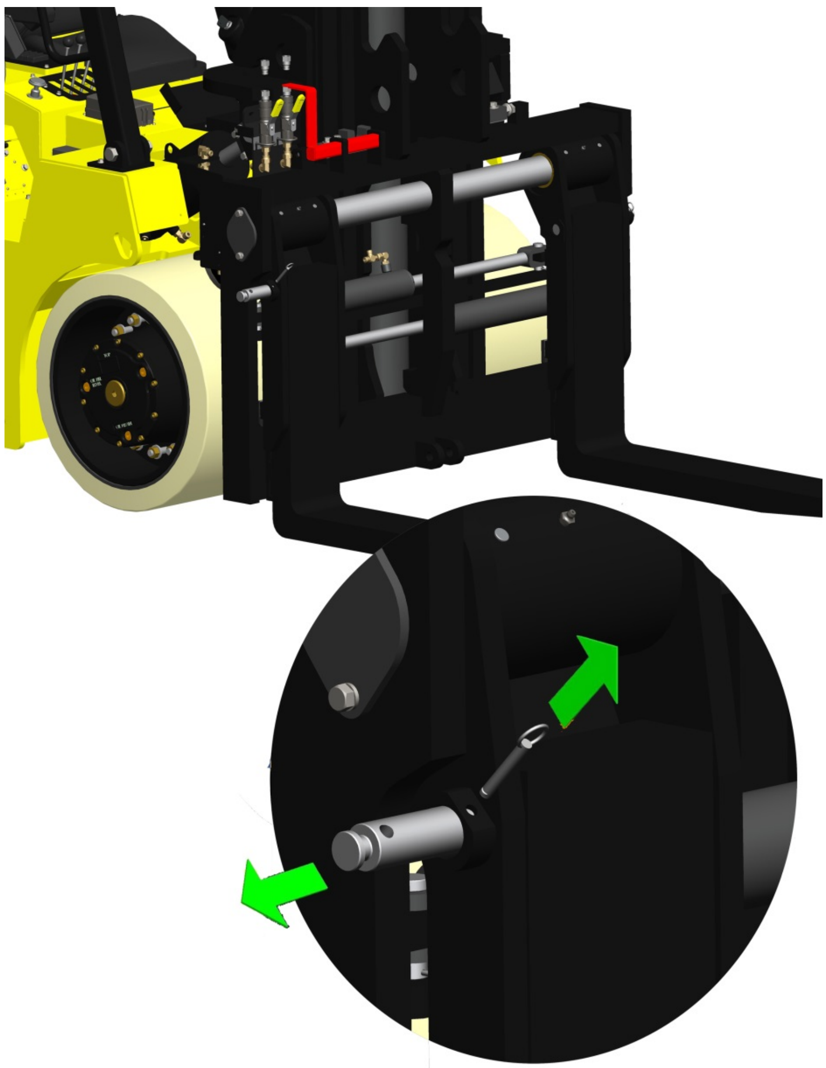
Side Shifter Manifold Assembly Removal

The side shifter manifold assembly is attached to the optional SS/FP/SSFP with two 3/8-16x11/4 flat head capscrews (FHCS). To install the SS manifold assembly, install the FHCS. *REFER TO THE TORQUE CHART IN THIS MANUAL.*



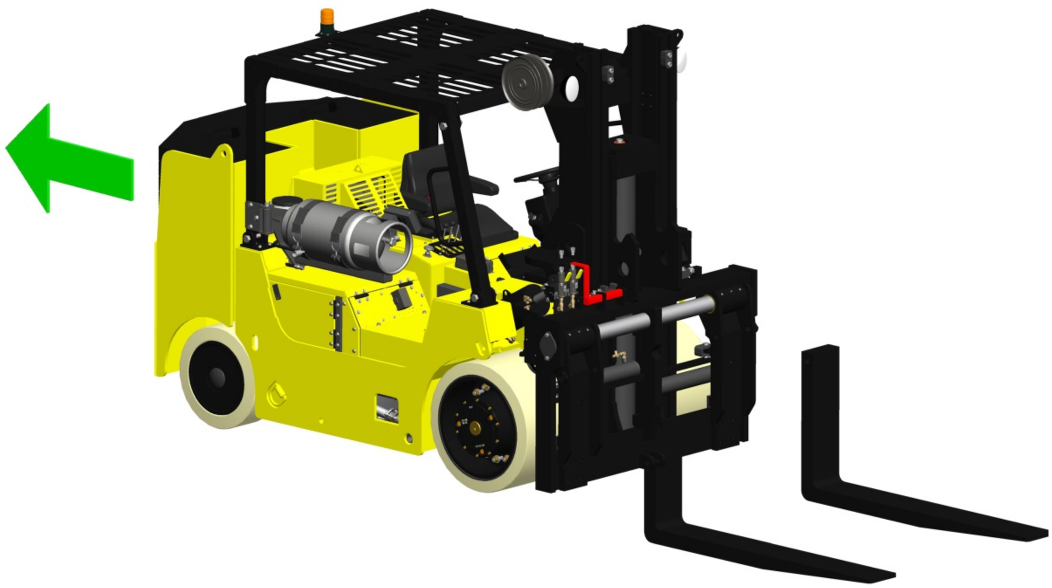
Fork Removal
To remove the forks from the carriage, position the mast to true vertical, *position the forks as far outbound as possible,* fully lower the forks to the ground and apply the parking brake and shut the truck off.

Remove the quick release pin from each fork pusher by grapping the ring and pulling upward. With the quick release pins removed, the fork retaining pins can now be pulled out sideways from each pusher.



Fork Removal (Cont'd)

With the fork retaining pins removed, carefully back the truck away from the forks.



Apply the parking brake and shut the truck off.

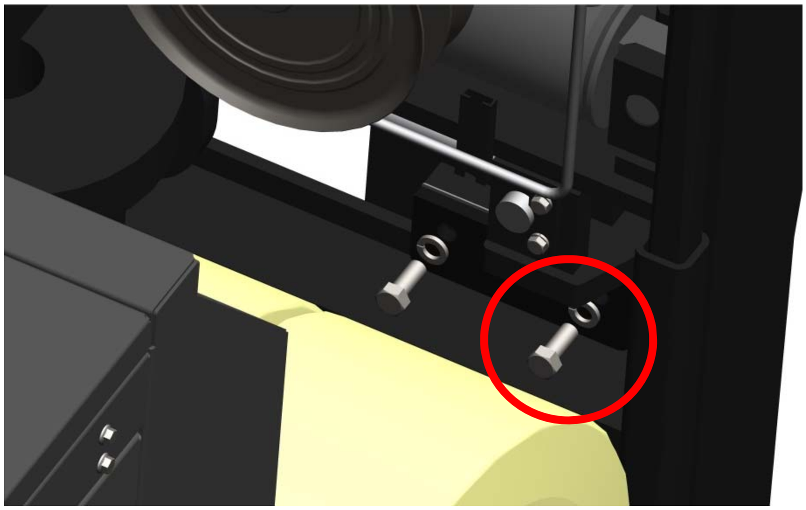
Reinsert the fork retaining pins and quick release pins into the fork pushers so that they do not get misplaced.

To re-install the forks, follow the above procedure in reverse order.

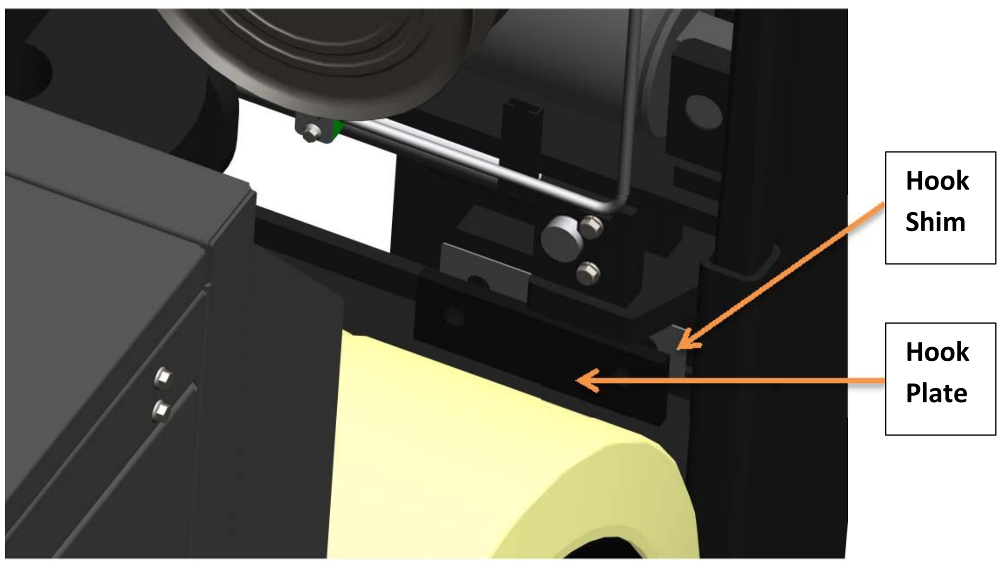
Fork Pusher Removal

With the forks removed and the pushers positioned as far outbound as possible, the pushers can be removed for service. The pushers are mounted to the main carriage pin and retained with bolt-on hook plates at the carriage bottom bar.

To detach the pushers from the bottom of the carriage, remove the bolts and washers from the hook plates mounted to the backside of the pushers.



Remove the hook plate and shim from the back of the pusher.



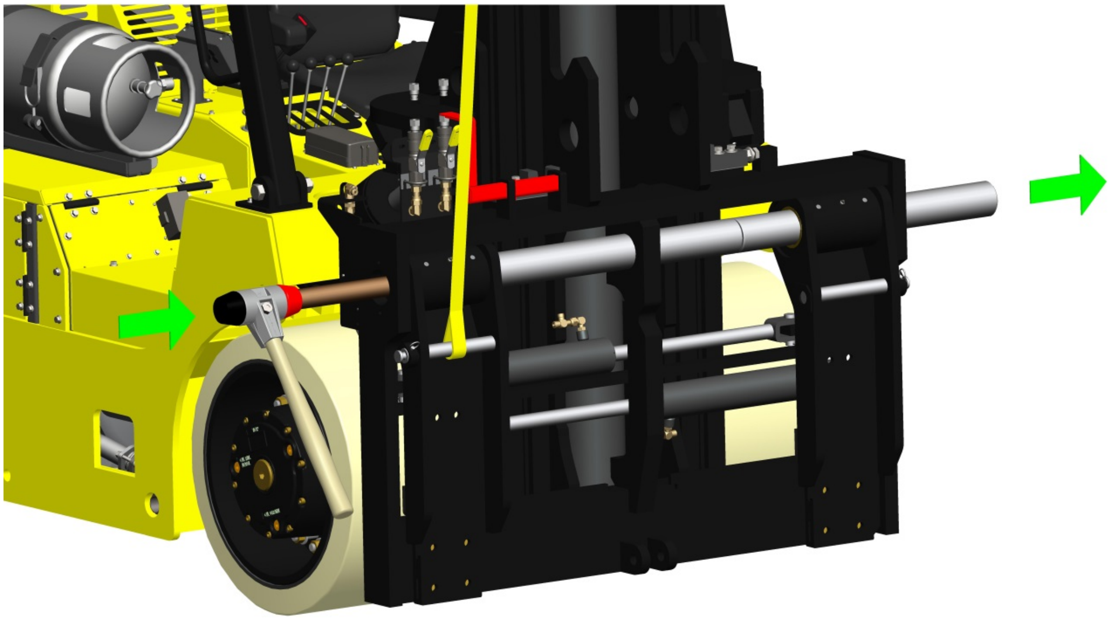
WARNING:

WITH THE HOOK PLATE AND SHIM REMOVED, THE PUSHER CAN SWING AWAY FROM THE CARRIAGE.

Fork Pusher Removal (Cont'd)
To detach the pusher from the top of the carriage, remove the two bolts and keeper plate on both sides of the carriage.

BOTH pin keeper plates have to be removed from the carriage. Wrap a properly rated lifting strap around the fork pin on the pusher being removed to support it from falling when the main carriage pin is being knocked out.

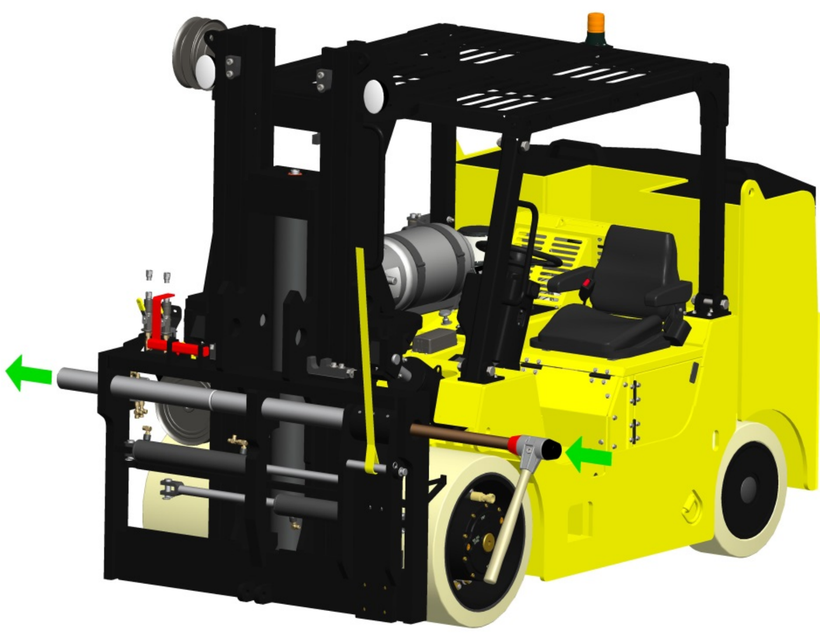
- Use a mallet and a large drift to push the carriage forks pins partially out of the fork frame. *Note: While not visually apparent, there are individual left and right carriage fork pins that meet in the center of the carriage at the carriage center support.* Do NOT push the carriage fork pins all the way thru the fork frame and out of the carriage. ONLY PUSH THE PINS ENOUGH TO CLEAR THE FORK PUSHER/FORK ON THE SIDE BEING WORKED ON. The carriage center support will support the near side carriage fork pin and the carriage side plate will support the far side carriage fork pin



Alternatively, the ends of the main carriage pins include tapped holes that can be used in conjunction with a pin puller (slide hammer) to remove the pins individually by pulling outboard. To clear the pushers, the pins will have to be completely removed.

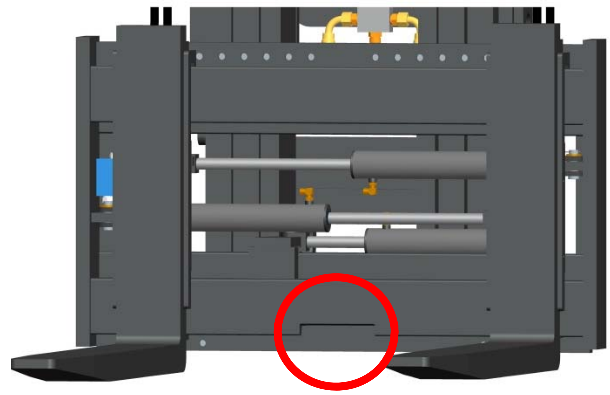
- Using the overhead crane lay the pusher on a pallet.

- Secure the pusher and repeat the procedure for the opposite pusher.



- Using the mallet and drift, push carriage fork pins back to their original positions with ends flush to the carriage side plates. Reinstall carriage pin keeper plates and hardware so they don't get misplaced.

Fork Removal FR15/25 & FR18/26 CLV Carriage
To remove the forks from the carriage or optional SS/FP/SSFP, raise the forks off the ground just enough to place a pallet underneath the forks. With the truck running, and the parking brake ON, position o forks so that one fork hook aligns with the notch in the bottom of the carriage or optional SS/FP/SSFP. There is a set screw on the outboard side of the fork pusher or trucks fitted with optional SS/FP/SSFP. Remove the set screw.

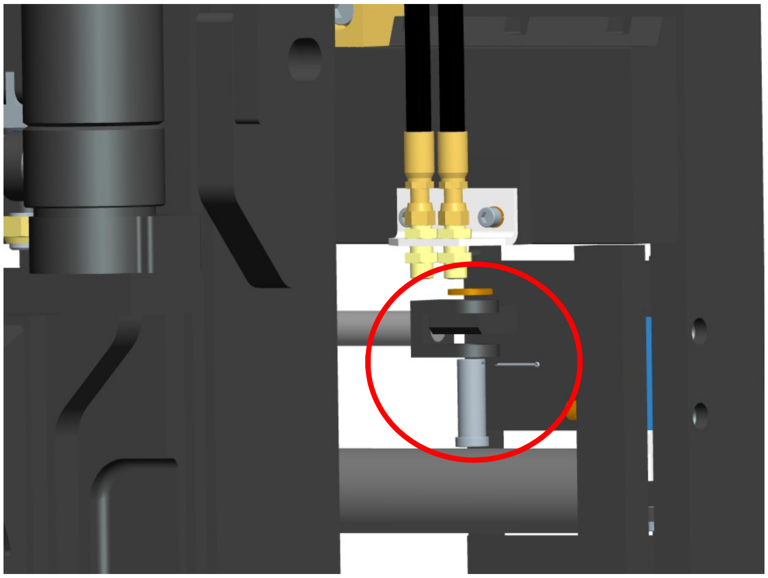


Wrap a properly rated lifting strap around the tip of the fork, use a Jib crane, and gently pull the fork up so that the bottom hook disengages from the bottom bar. The top hook will still be on the top bar. Now slide the fork outbard away from the center notch and repeat for the opposite fork. When both forks are unhooked from the bottom carriage bar, lower the carriage so that the forks rest on the pallet and the upper fork hooks disengage from the upper bar.

WARNING:
Lifting the fork too high or unsteadily can cause the fork to come off of the top bar and cause injury or death. Always use caution when removing forks.

Fork Pusher Removal/Installation FR15/25 & FR18/26

The fork pushers cradle the forks and ride on the top crossbar of the optional SS/FP/SSFP, allowing the forks to travel smoothly on the ITA bar. With the forks off the carriage, the pushers can now be removed. Remove the fork positioner cylinders hardware from the back of each pusher.



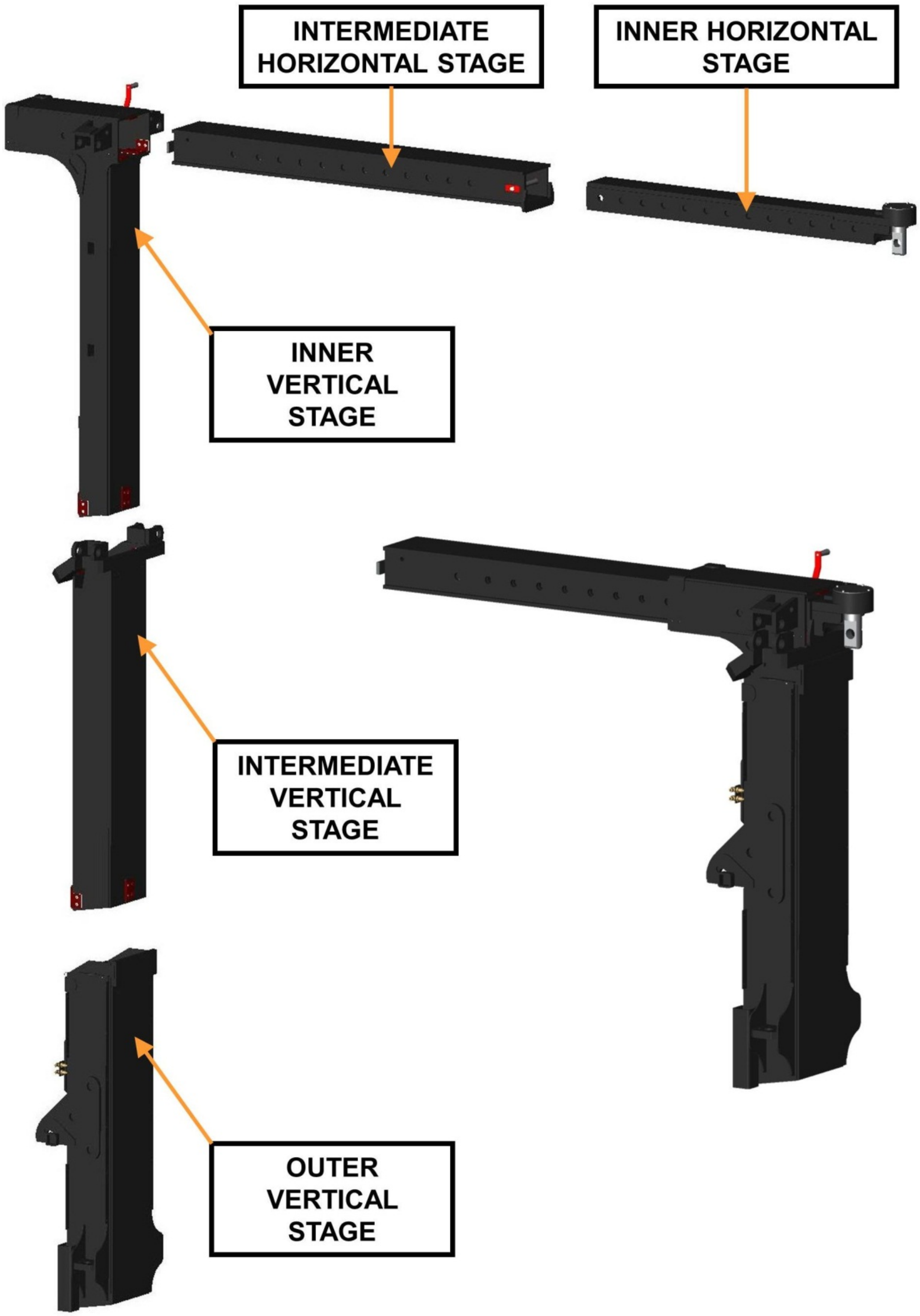
The pushers can now be lifted directly up off of the upper ITA bar and placed on the pallet with the forks and hardware. To reinstall the fork pushers, follow the steps in reverse order.

Fork Installation

Align the forklift with the pallet the forks are stored on. Make sure fork pushers are reinstalled on the optional SS/FP/SSFP prior if applicable. Drive the lift truck up to one fork with the bottom bar notch aligned with the lower fork hook and the top bar positioned slightly below the upper fork hook. Raise the carriage until the upper fork hook properly seats on the top bar of the carriage or optional SS/FP/SSFP. Slide the fork outboard away from the center notch on the bottom bar making sure the lower fork hook is properly engaged. Repeat the process for the other fork.

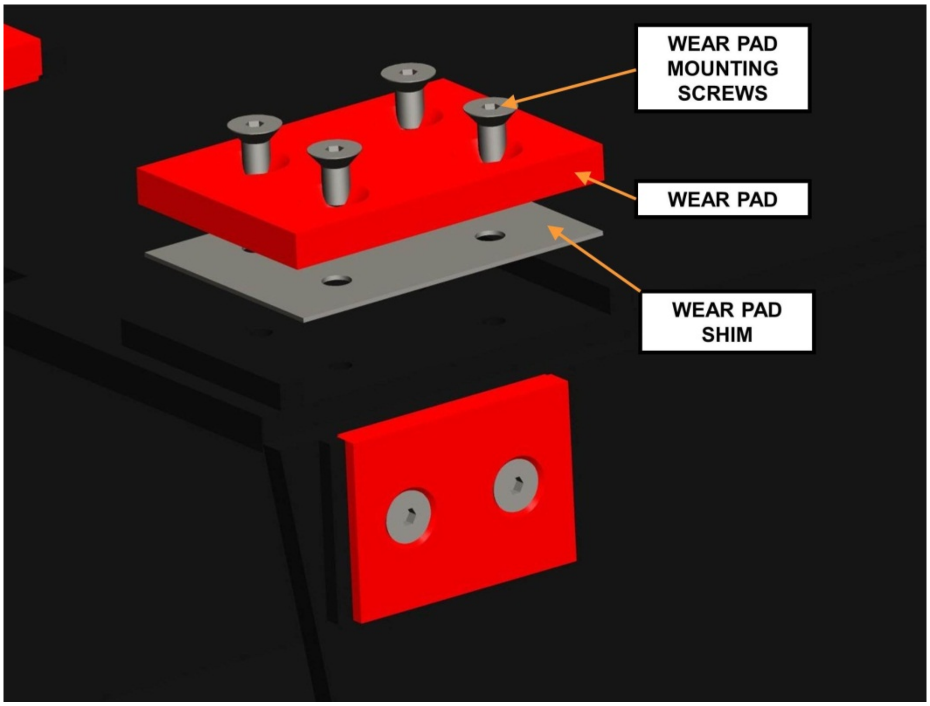
Boom Overview FR25/35

The boom consists of three vertical stages and two horizontal stages. The outer vertical stage is the main stage that attaches to the carriage of the lift truck.

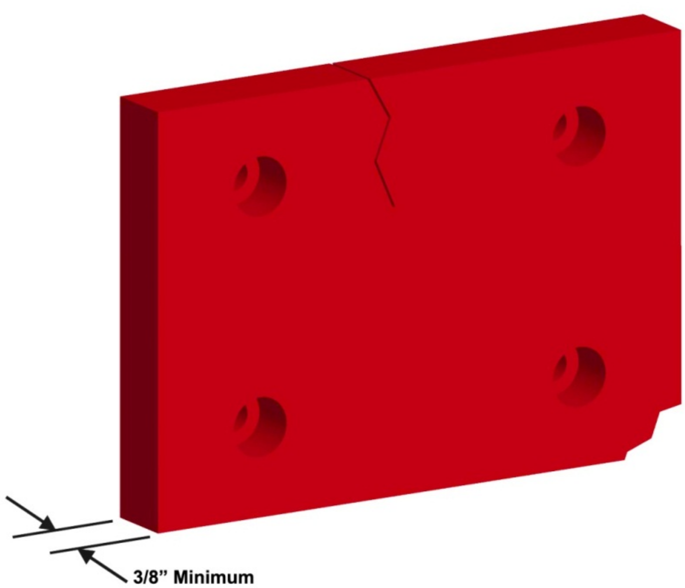


Wear Pads

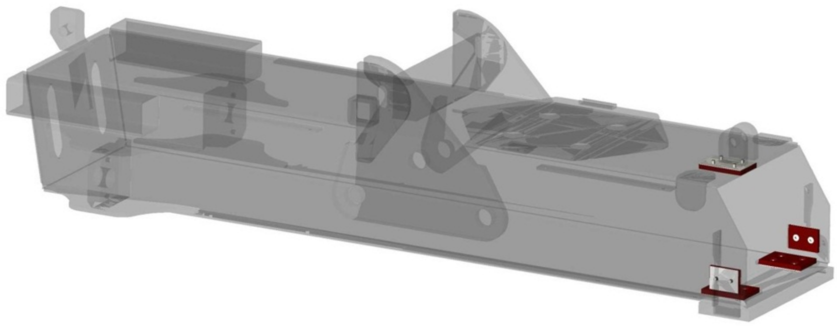
Wear pads keep each stage centered and insures that it tracks properly.
The wear pad material also provides a lower coefficient of friction allowing the stages to travel smoothly with reduced effort.
As the name implies, the pads will wear over time and can be shimmed to reduce excessive play between stages.

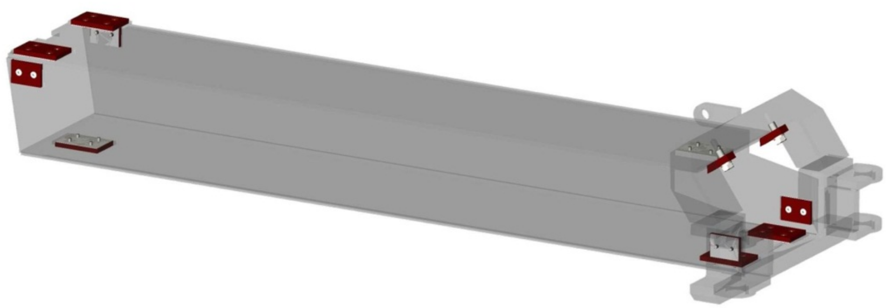


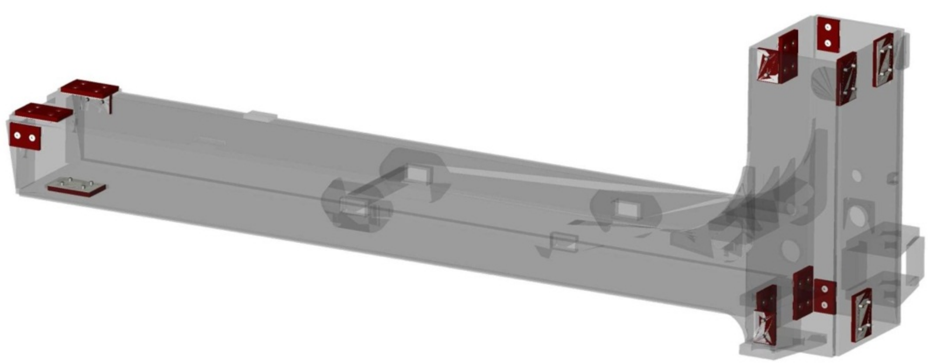
Replace any wear pads that become cracked, damaged, or worn to 3/8" thickness, or less.



Wear Pad Locations







In order to shim or replace wear pads, individual stages of the boom will have to be disassembled. Refer to the specific stage sections of this manual for disassembly procedures.

Horizontal Intermediate Stage Assembly FR25/35
The horizontal intermediate stage nests inside the horizontal fixed stage of the inner vertical boom. A gear rack installed on the left hand side of the horizontal intermediate stage is driven by gearbox assembly, allowing the boom to be manually cranked in and out. Before removing the horizontal intermediate stage, remove the gearbox assembly to avoid possible tooth damage to either the gearbox or the gear rack assembly. (*REFER TO THE GEARBOX ASSEMBLY SECTION OF THIS MANUAL)*.

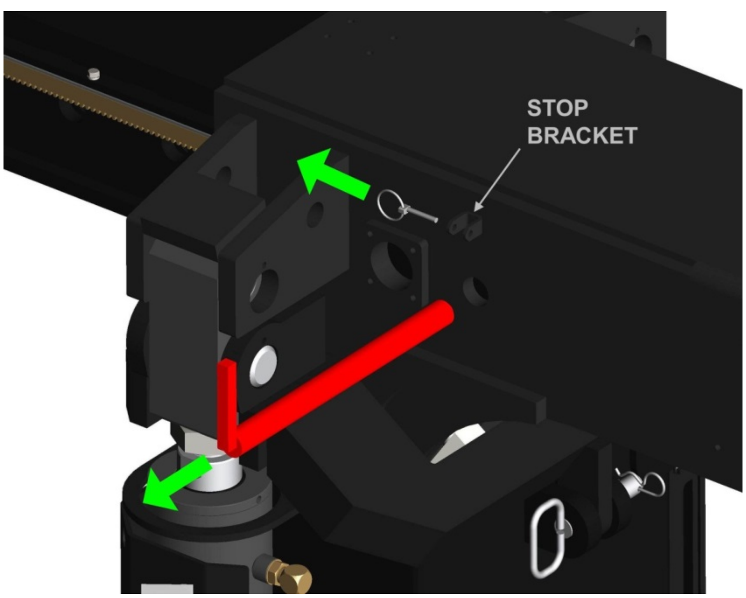
WARNING

Before beginning any service work, make sure the mast is positioned to true vertical, the carriage is fully lowered, the parking brake is applied and the lift truck has been turned off and the key removed.

WARNING

Do NOT climb on the truck to do service. Use a ladder, work platform or other approved means when working at elevation.

The position of the horizontal intermediate stage is fixed to the outer vertical boom by the horizontal intermediate stage retaining pin weldment, which is inserted through both stages. A safety pin secures the locking pin inside a stop bracket, preventing inadvertent movement during normal operation of the boom. Remove the safety pin from the stop bracket and pull the pin weldment outboard away from the boom.



Using lifting bars and chains or straps, support the intermediate horizontal section of the boom with an overhead crane or other suitable lifting device. Use care to avoid contacting and damaging the rack gear on the right hand side of the intermediate stage.

A safety stop prevents the intermediate horizontal stage from inadvertently being adjusted beyond its range. In order to remove the intermediate horizontal stage, the safety stop must first be removed.

Carefully slide the intermediate stage forward out of the horizontal fixed stage of the inner vertical boom and place the intermediate stage on blocks, support stands, or other suitable work surface. To reinstall the horizontal intermediate stage assembly, reverse the procedure as described above.

WARNING

The horizontal intermediate stage may swing when removed from the boom attachment. Never attempt to remove any boom stages until the area is clear of all personnel. NEVER stand in front of the boom when removing stages.

Gear Rack Assembly

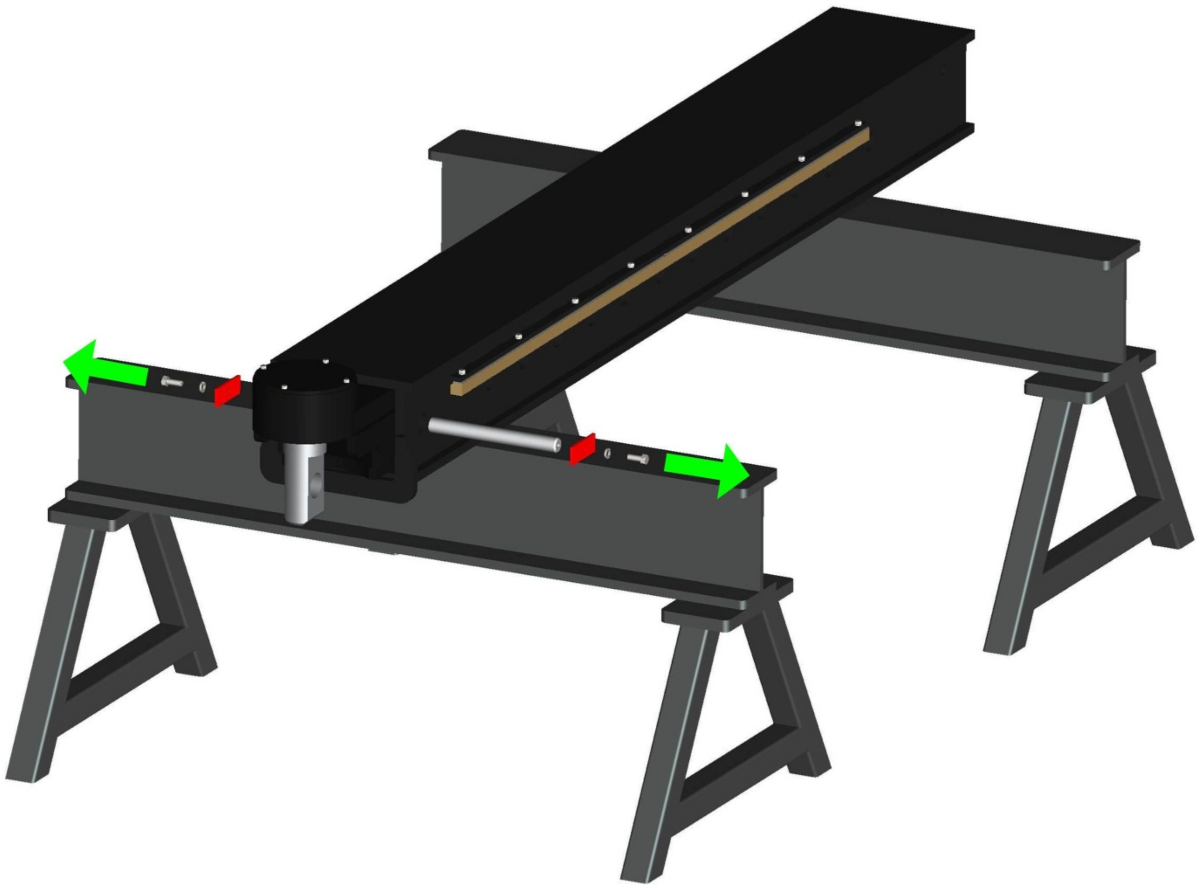
The gear rack assembly is mounted to the left hand side of the horizontal intermediate stage. Shims provide adjustability to ensure proper engagement between the gear rack and the gearbox assembly. The rack can be replaced or shimmed as needed. To replace the rack or shims, remove the 8 bolts and washers from the top of the gear rack mount. Remove the gear rack and shims and replace as needed. When reinstalling the gear rack, make sure the teeth on the rack are clean and free from debris.

Horizontal Inner Stage FR25/35

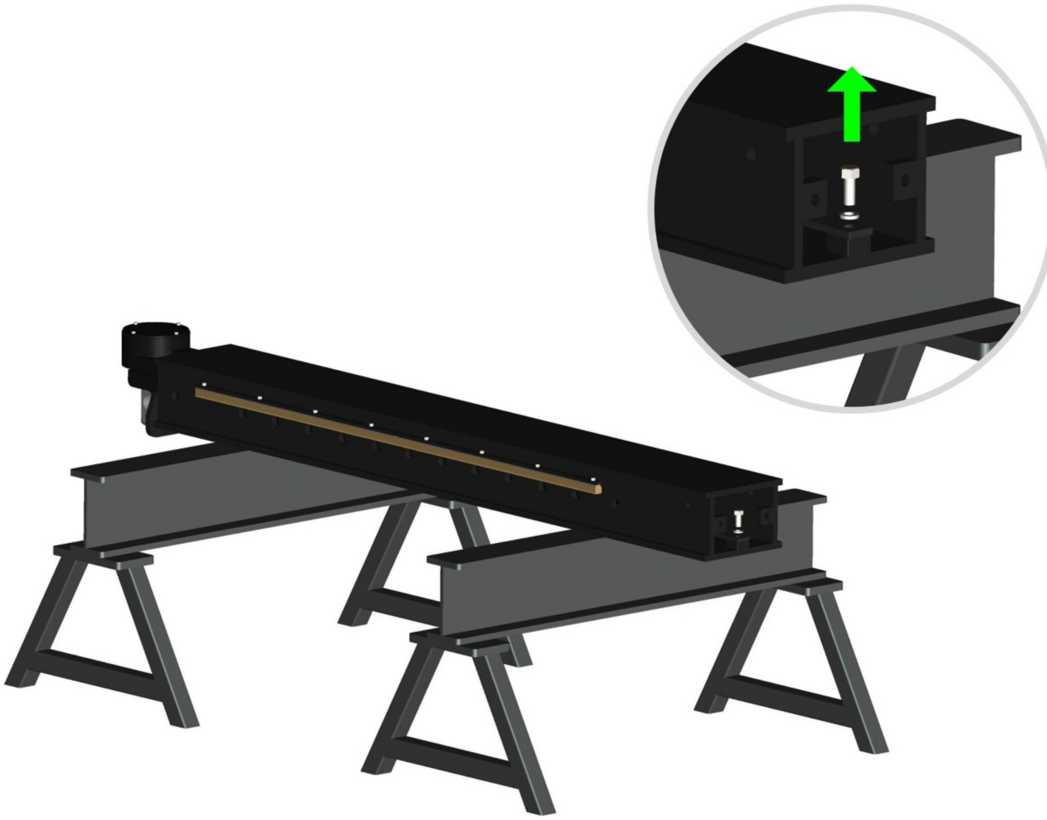
The horizontal inner stage nests inside the horizontal intermediate stage and can be manually adjusted to provide additional reach after adjustment of the intermediate stage is exhausted. *SEE OPERATOR MANUAL FOR THIS MODEL FOR PROPER INNER HORIZONTAL STAGE ADJUSTMENT PROCEDURE*

The position of the horizontal inner stage is fixed to the horizontal intermediate stage by the horizontal inner stage retaining pin, which is inserted through both stages.

Remove the inner stage pin keepers and hardware and pull the pin outboard, away from the stage.



A safety stop prevents the inner horizontal stage from inadvertently being adjusted beyond its range. In order to remove the inner horizontal stage, the safety stop must first be unfastened. *(Note: the actual stop will remain in the inner stage when the stage is removed)*.



Carefully slide the inner stage forward out of the intermediate stage just enough to provide sufficient extension to support using lifting bars and chains or straps and an overhead crane or other suitable lifting device.

With the front supported, continue to slide the inner stage out of the intermediate stage enough to add rear support chains or straps. **BE CAREFUL NOT TO SLIDE THE INNER STAGE ALL THE WAY OUT.**

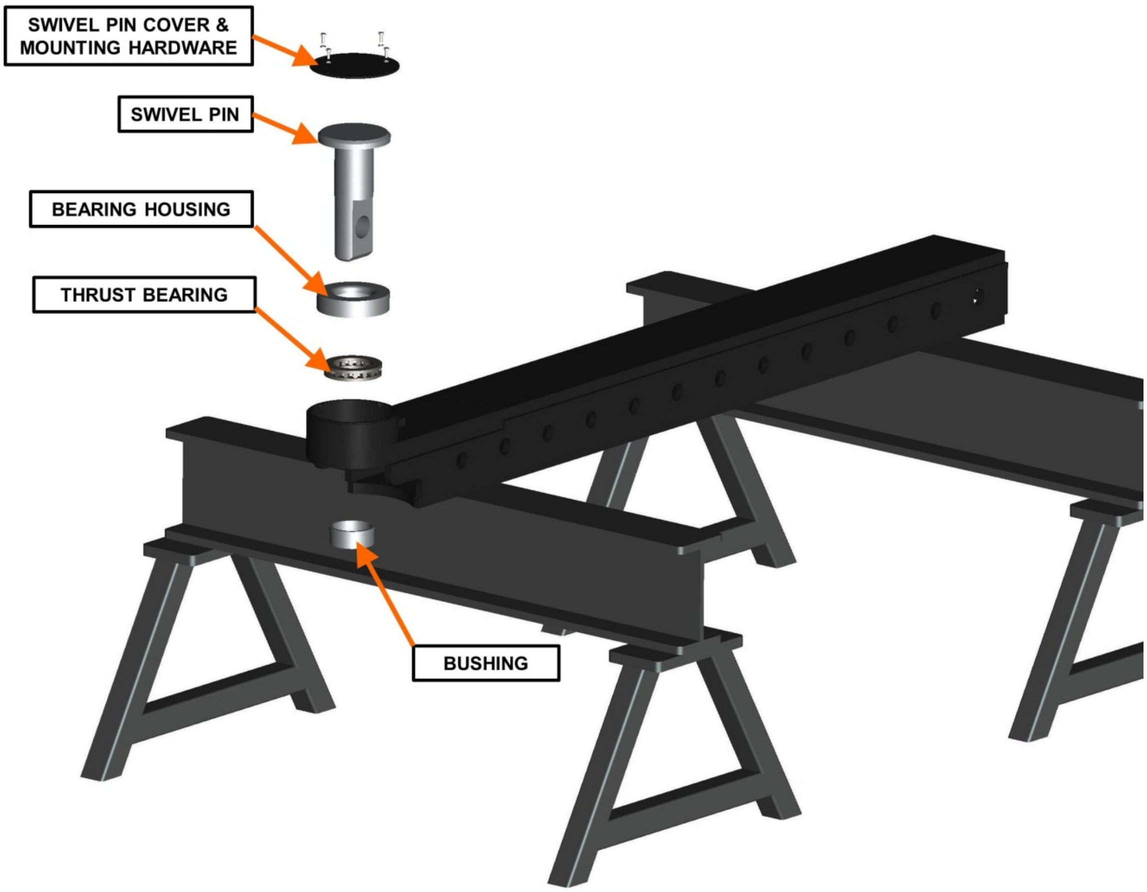
WARNING

The horizontal inner stage may swing when removed.
Never attempt to remove any boom stages until the area is clear of all personnel. NEVER stand in front of the boom when removing stages.

Place the intermediate stage on blocks, support stands, or other suitable work surface.

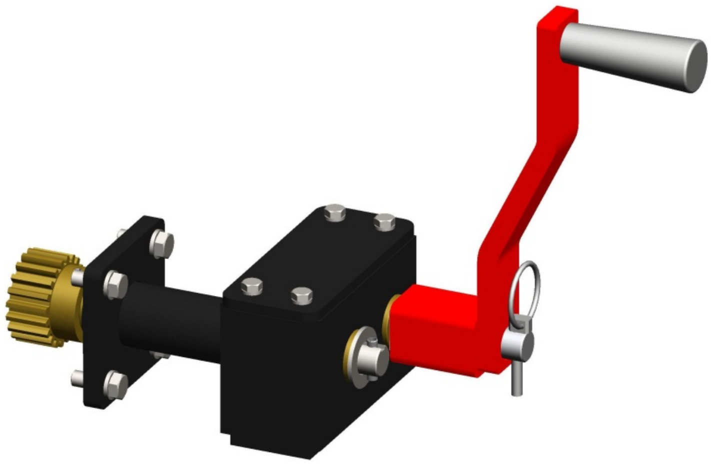
To reinstall the horizontal inner stage, reverse the procedure as described above.

A swivel pin, used for rigging suspended loads, is located at the end of the inner horizontal stage. To inspect or replace swivel pin components, remove the swivel pin cover by removing the retaining hardware.
Knock the pin out of the horizontal inner boom using a rubber mallet from the underside of the stage. Remove the thrust bearing housing and using a bearing puller, remove the thrust bearing. The thrust bearing is self- lubricating and does not need to be greased. Tap the swivel pin bushing out. Inspect the new bearing for dirt and debris, clean, grease and re-install in reverse order.



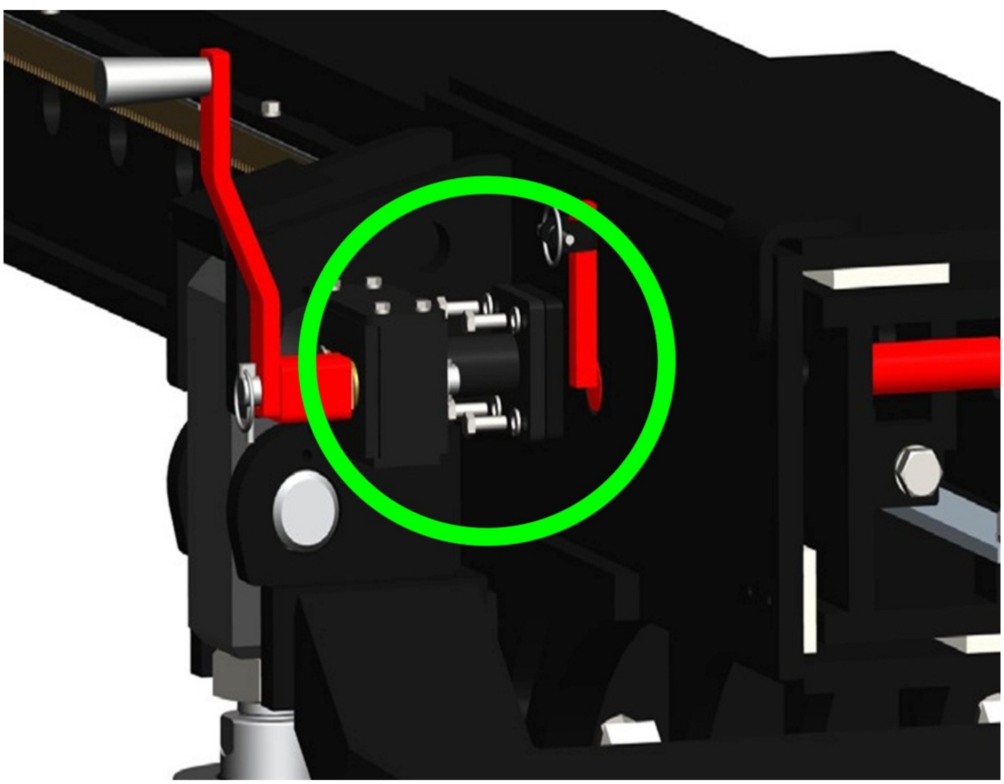
Boom Gearbox Assembly FR25/35

The gearbox assembly, used for manually repositioning the intermediate stage of the horizontal boom, can be removed complete for servicing.

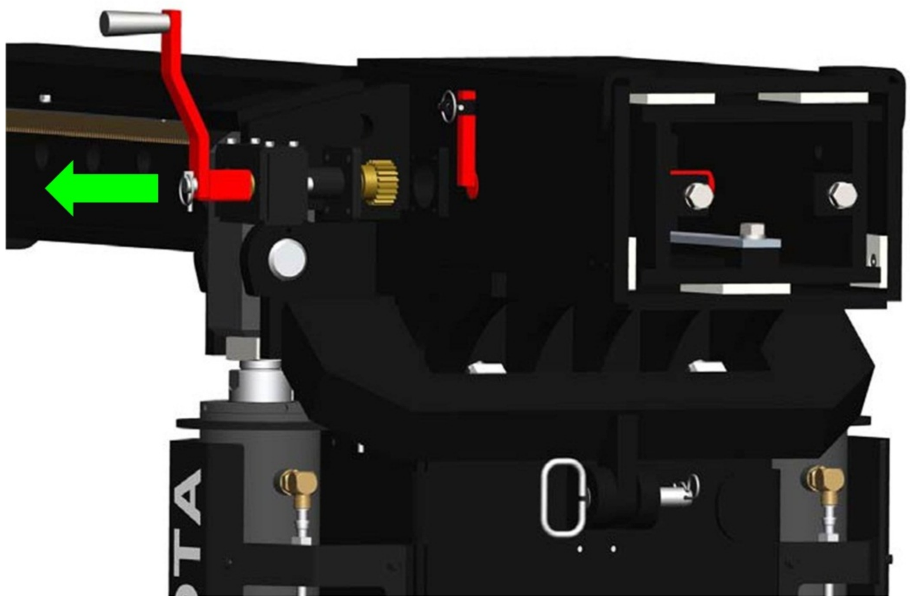


Removing the Gearbox Assembly

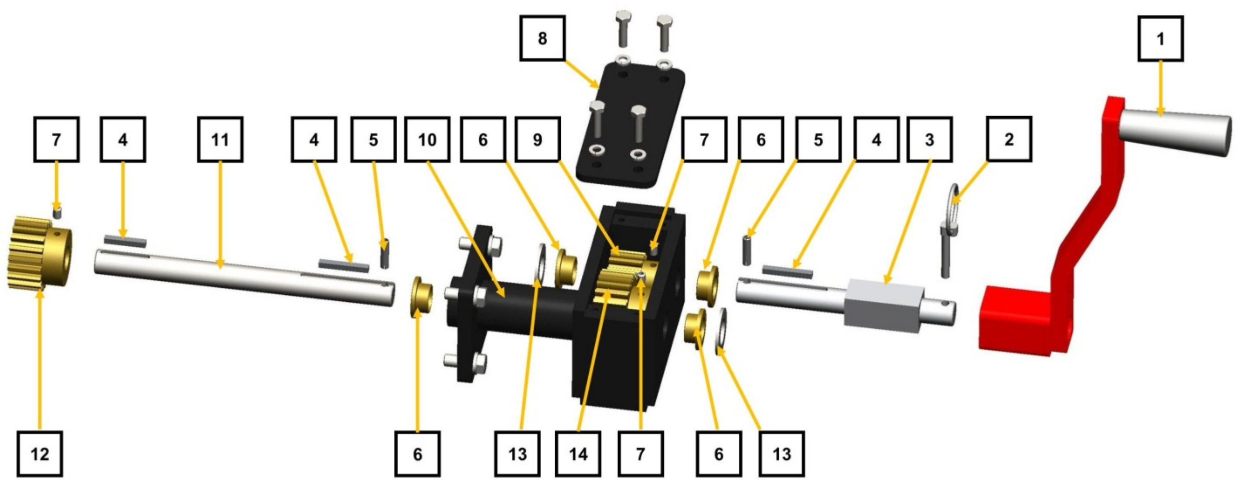
To remove the gearbox from the boom assembly, support the weight of the gearbox and remove the four bolts and washers that fasten the gearbox weldment to the boom.



Slide the gearbox out of the boom horizontally. Place the complete gearbox on a clean, debris free work surface to keep from contaminating the gears.



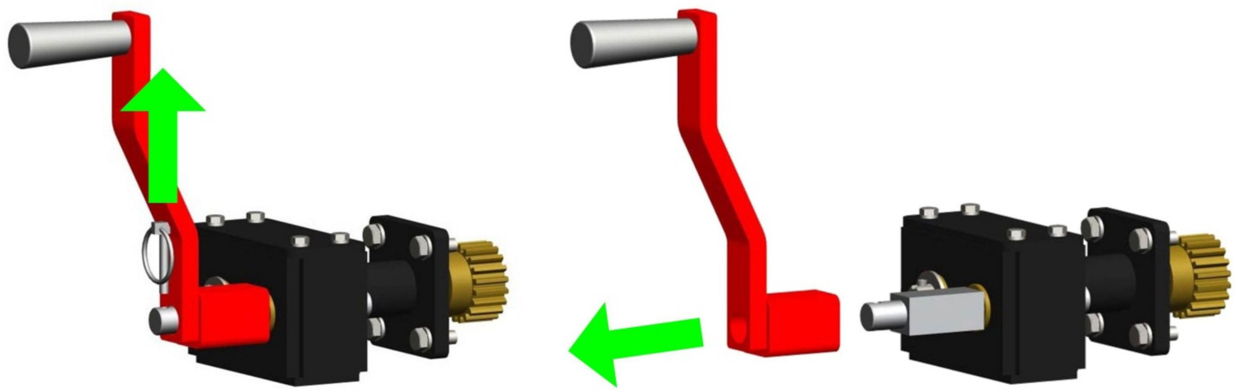
Gearbox Assembly Component Identification



1. Crank Handle
2. Locking Pin
3. Gear Shaft, Driver
4. Key
5. Roll Pin
6. Flanged Bushing
7. Set Screw
8. Gearbox Cover & Hardware
9. Spur Gear, Driver
10. Gearbox Weldment
11. Gear Shaft, Driven
12. Spur Gear, Rack
13. Washer
14. Spur Gear, Driven

Gearbox Component Removal and Replacement

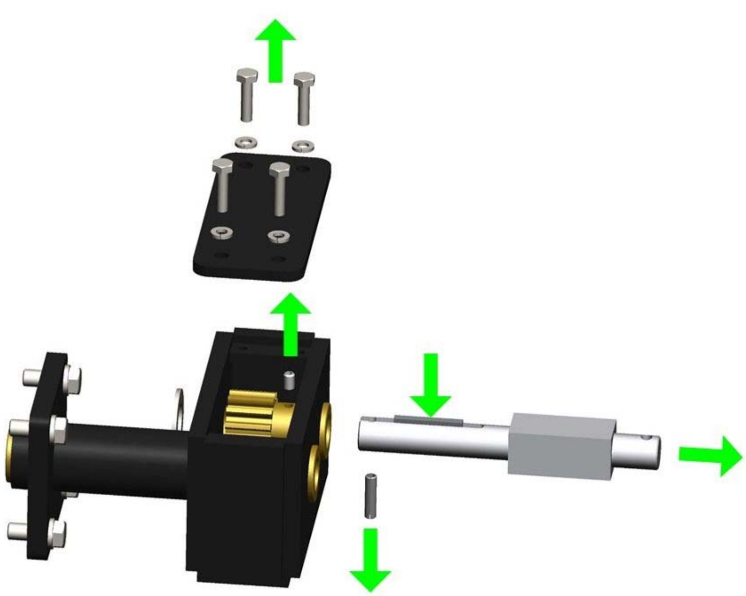
The crank handle can be replaced by removing the locking pin from the shaft and then sliding the handle outboard off of the shaft. To install a new crank handle reverse the procedure.



To service the driver gear shaft and driver spur gear;

- Remove the gearbox cover mounting hardware and cover.
- Remove the set screw from the driver spur gear.
- Remove the roll pin from the inboard end of the driver gear shaft.
- Slide the driver gear shaft outboard. (*Note: The driver spur gear key should slide out with the gear shaft. Make sure to secure the key for reassembly)*
- Inspect the flanged bushings for wear and replace as necessary.
- Inspect the driver gear shaft and driver spur gear for wear or damage. Replace as necessary.

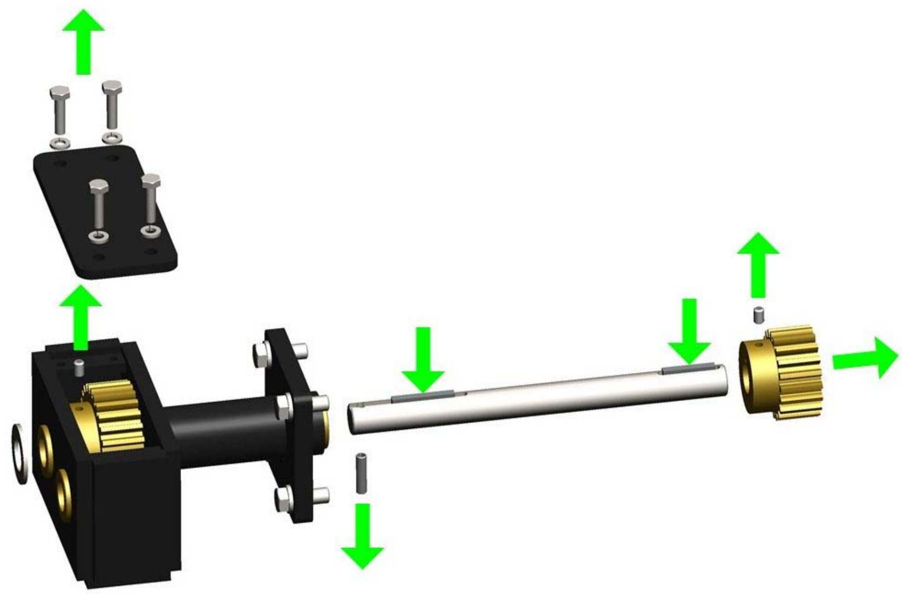
Reassemble by reversing above procedure. *Note: When reinstalling make sure driver spur gear key is in place.* Apply Loctite to set screw before reinstalling into driver spur gear.



To service the driven gear shaft and driven spur gears;

- Remove the gearbox cover mounting hardware and cover.
- Remove the set screw from the driven spur gear.
- Remove the roll pin from the outboard end of the driven gear shaft.
- Slide the driven gear shaft outboard. (*Note: The driven spur gear key should slide out with the gear shaft. Make sure to secure the key for reassembly)*
- Remove the set screw from the rack spur gear and slide off driven gear shaft. Make sure to secure the key for reassembly.
- Inspect the flanged bushings for wear and replace as necessary.
- Inspect the driven gear shaft, driven spur gear, and rack spur gear for wear or damage. Replace as necessary.

Reassemble by reversing above procedure. *Note: When reinstalling make sure driven spur gear key and rack spur gear key are in place.* Apply Loctite to set screws before reinstalling into spur gears.



When replacing driven and driver spur gears, blow out the gearbox weldment using compressed air to remove any dirt or debris. Verify proper gear tooth engagement and that gears move freely with no binding or sticking.

Vertical Stages FR25/35

The boom features 3 vertical stages, an outer fixed stage, an intermediate stage, and an inner stage.

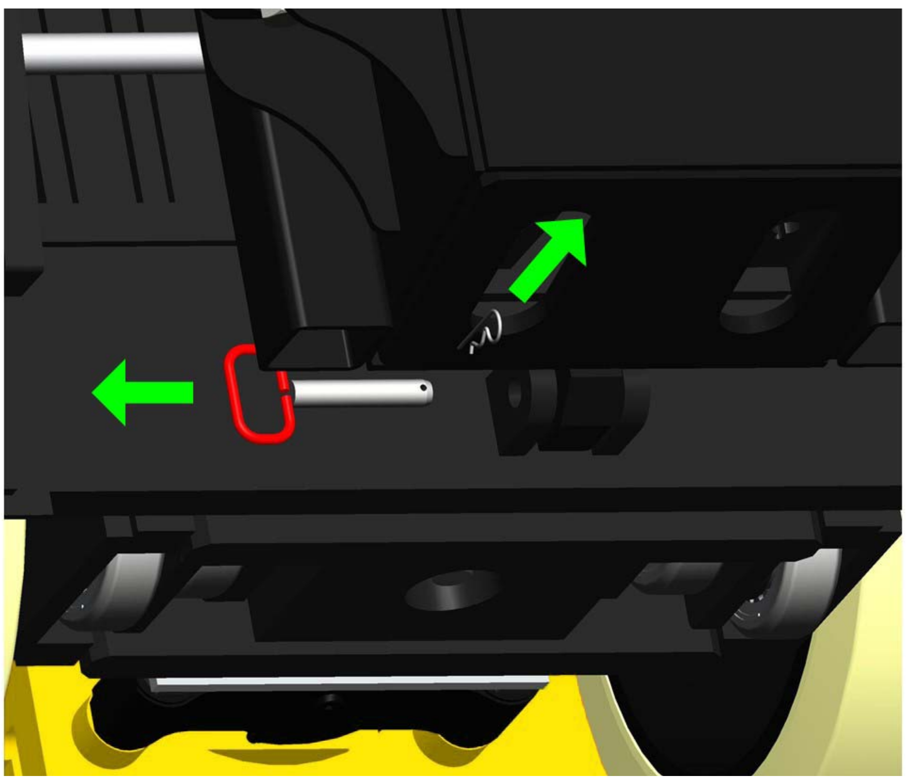
To remove the vertical stages from the lift truck for servicing, the intermediate horizontal stage must be first removed. *SEE SECTION 7.48 OF THIS MANUAL FOR INTERMEDIATE HORIZONTAL STAGE REMOVAL PROCEDURE.*

WARNING

Before beginning any service work, make sure the mast is positioned to true vertical, the carriage is fully lowered, the parking brake is applied and the lift truck has been turned off and the key removed.

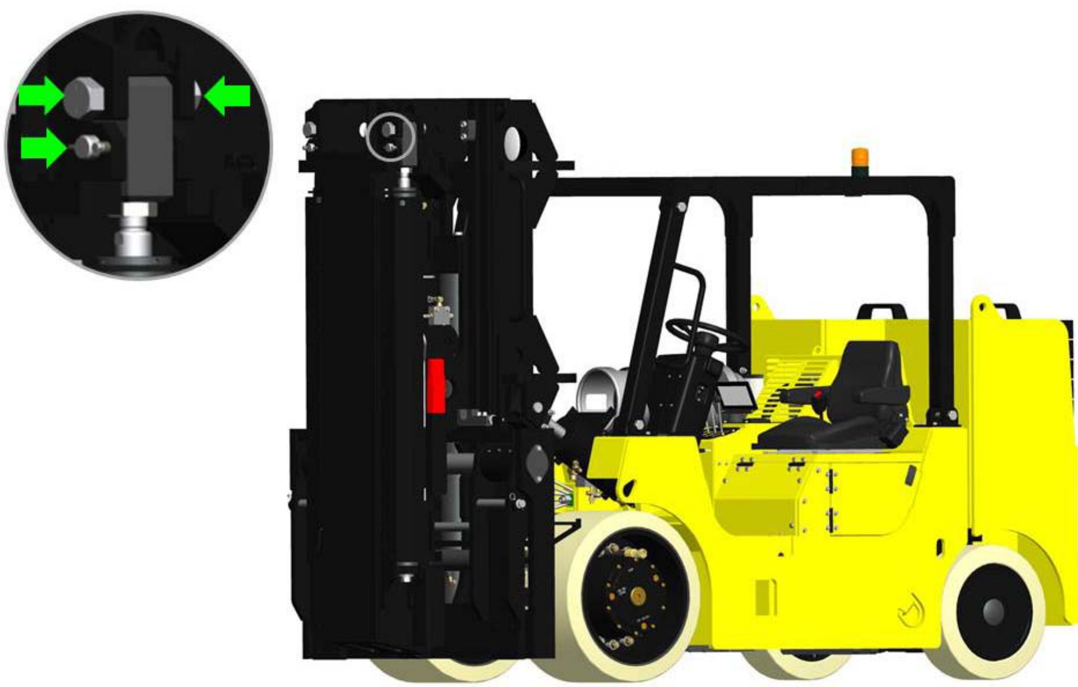
Prior to removing the vertical stages, first remove the retainer pin located at the center of the front face of the carriage near the bottom. In order to remove the retainer pin, a safety pin will have to be removed first.

FAILURE TO REMOVE THE RETAINER PIN WILL RESULT IN DAMAGE TO THE BOOM AND/OR CARRIAGE.



Install the upper boom retainer pin *(stowed in the tool compartment on the left hand side of the truck)* so that the outer and intermediate stages are pinned together. This will prevent the intermediate stage from being inadvertently lifted when removing the vertical stages.

The boom cylinder pins should be installed in the lower set of mounting holes that are part of the INTERMEDIATE vertical stage weldment. In order to prevent the inner vertical stage from inadvertently lifting when removing the vertical stages, bolts should be installed in the upper set of cylinder pin mounting holes that are part of the INNER vertical stage weldment and thru the upper holes in the cylinder rod ends. Lock nuts should be installed on the opposite side to prevent bolts from loosening during the removal process.



With all of the stages properly secured, shackles can be attached thru the bores in the INNER stage cylinder mount weldments. Using properly rated straps or chains, gently raise the vertical stages off of the lift truck carriage using an overhead crane or other suitable lifting device.

WARNING

The vertical stages may swing when removed from the lift truck carriage.
Never attempt to remove any boom stages until the area is clear of all personnel. NEVER stand in front of the boom when removing stages.

Carefully place the vertical stages on blocks, support stands, or other suitable work surface.

To remove the inner vertical stage, first remove the bolts and nuts from the upper set of cylinder pin mounting holes that are part of the INNER vertical stage weldment and thru the upper holes in the cylinder rod ends.

Using shackles and properly rates chains or straps, support the inner stage from the cylinder mounting ear weldments with an overhead crane or other suitable lifting device. Carefully slide the inner stage out of the intermediate stage enough to expose the side-to-side lock bar opening. **DO NOT SLIDE THE INNER OUT PAST THE SECOND LOCK BAR OPENING.**

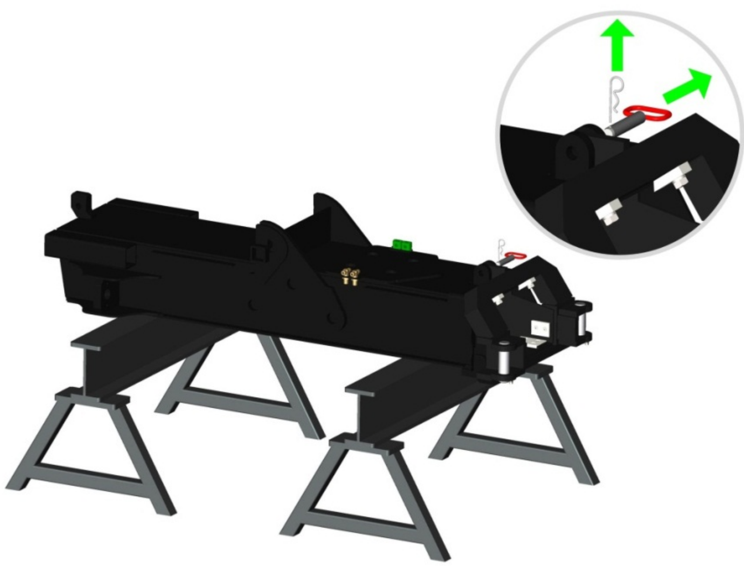
WARNING

Make sure supports, stands, or work surface is sufficiently stable and adequately anchored to the floor before attempting to slide inner stage out of intermediate.

Install a properly rated lift strap thru the lock bar opening and support with overhead crane or other suitable lifting device. With the inner stage supported at both locations, slide it out of the intermediate stage the remainder of the way.

To remove the intermediate vertical stage, the boom lift cylinder must first be removed. REFER TO BOOM LIFT CYLINDERS SECTION IN THIS MANUAL FOR REQUIREMENTS OF CYLINDER REMOVAL.

With the cylinders removed, reinstall the cylinder rod end pins in the mounting ears of the intermediate section. Remove the upper boom retainer pin, which connects the intermediate stage to the outer stage, and re-stow pin in the tool compartment on the left hand side of the truck.



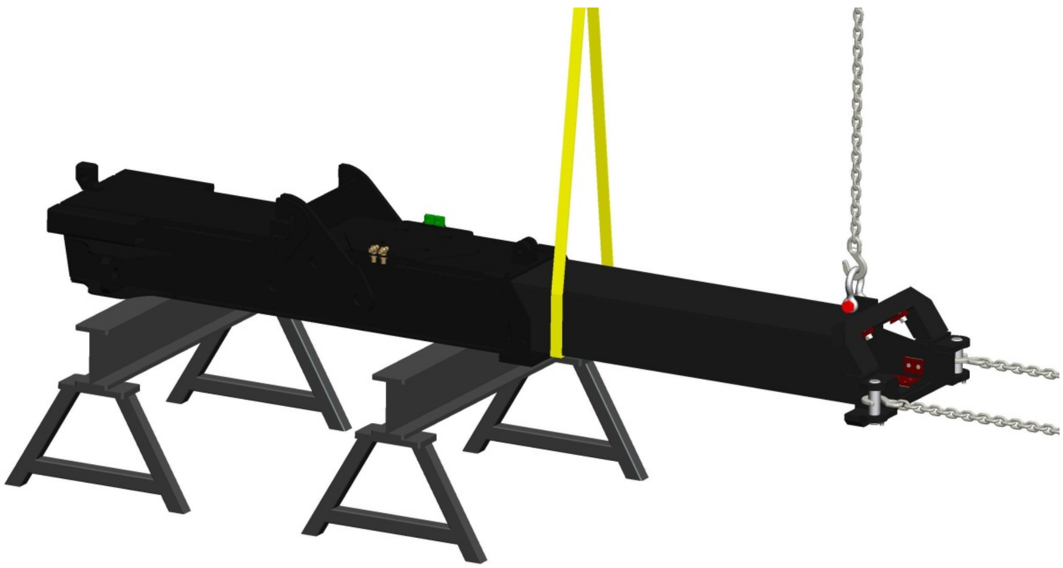
Use the cylinder pins, shackles, and properly rated chains or straps to pull the intermediate stage out of the outer stage just enough to place another shackle on the upper boom pin ear on the intermediate stage. Support the intermediate stage with an overhead crane or other suitable lifting device. Pull the intermediate stage out enough to use a lifting strap around the body of the intermediate stage for a secondary lifting point. DO NOT PULL THE INTERMEDIATE STAGE

ALL THE WAY OUT. The MAXIMUM the intermediate stage should be pulled prior to adding the lift strap should be 5'.

WARNING

Make sure supports, stands, or work surface is sufficiently stable and adequately anchored to the floor before attempting to slide intermediate stage out of outer stage.

With the intermediate stage supported at both locations, slide it out of the outer stage the remainder of the way.



To reinstall the vertical intermediate stage assembly, reverse the procedure as described above.

Boom Lift Cylinders FR25/35
The boom lift cylinders are located on either side of the boom and provide the powered vertical lift of the boom attachment. The cylinders must be removed from the boom for servicing.

In order to remove the cylinders, the inner vertical stage must be raised to allow sufficient clearance. *Refer to the Operators Manual for this model for procedures on raising the inner vertical boom.*

WARNING

Before beginning any service work, make sure the mast is positioned to true vertical, the carriage is fully lowered, the parking brake is applied and the lift truck has been turned off and the key removed.

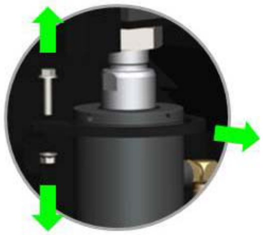
WARNING

Do NOT climb on the truck for access.
Use a ladder, portable stairs, or other suitable operator support platform for access.

Remove the lift cylinder guards from the boom by removing the fastening hardware and sliding the covers off. Reinstall the hardware on the covers and lie on a pallet so as not to damage them. The cylinders will stay in position as they are secured by retainer brackets, upper cylinder pins, and lower retaining hardware.

With the covers removed, the hydraulic piping to each cylinder can be removed. Disconnect the hydraulic tube assemblies at both the top and bottom of the each cylinder.

Remove the cylinder retainer brackets located toward the top of each cylinder by removing the hardware.

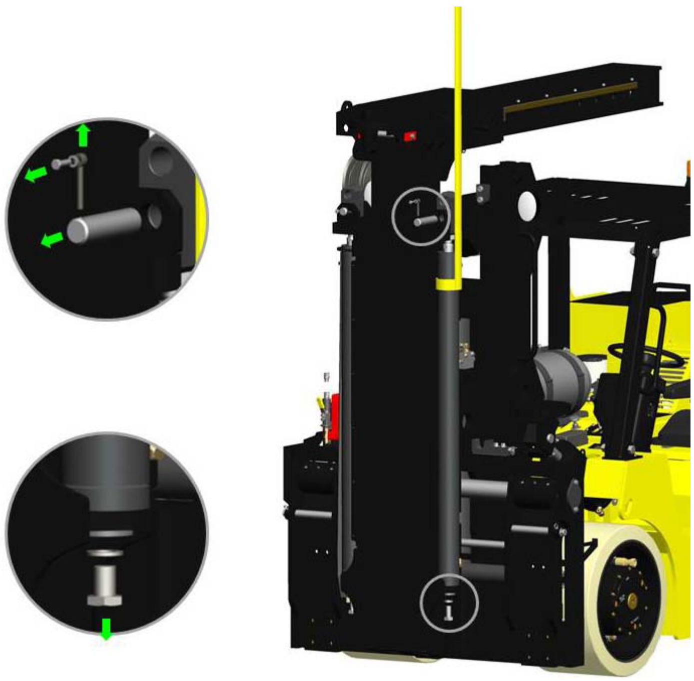


Secure a lifting strap around the top of the lift cylinder and support the cylinder with an overhead crane or other suitable lifting device.

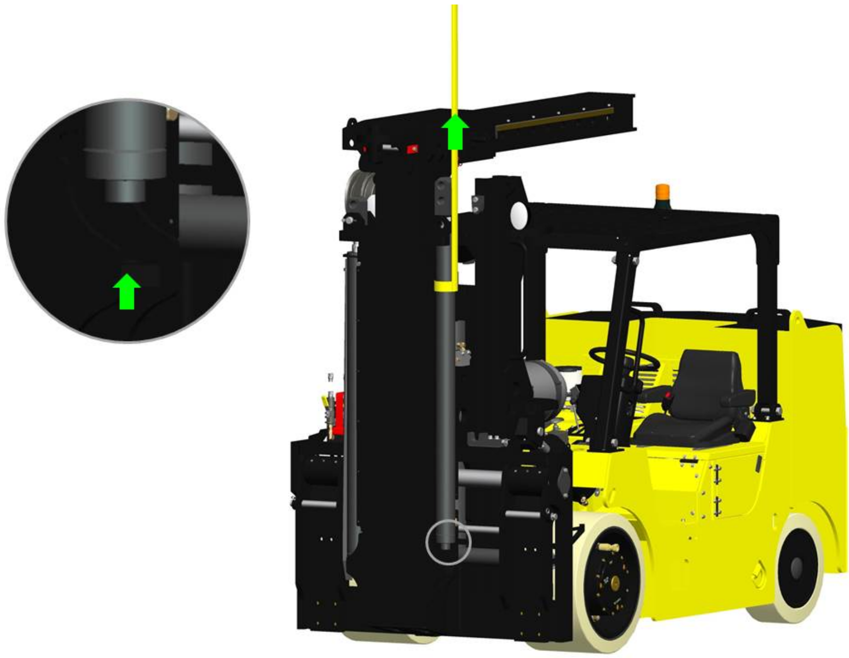
Remove the upper cylinder pin by first removing the pin retainer hardware and pin retainer. Use a small drift to knock the upper cylinder pin out from the rear. Remove the retaining hardware from the base end of the cylinder.

WARNING

Make sure the area is clear of all personnel and use caution when removing the upper cylinder pin and lower retaining hardware as unintended movement of the cylinder may result.



Raise the cylinder enough so that the threaded boss on the base end of the cylinder clears the lower mount.



Once the cylinder is high enough to clear the lower mount it can be moved outboard and away from the truck. Place the cylinder on a pallet and repeat for opposite side.

Boom Cylinders FR25/35

In the event a cylinder requires servicing, it must be removed from the truck or attachment. When removing cylinders plug ports to prevent oil leakage and to prevent contamination.

WARNING

Before attempting to remove any cylinder for servicing or replacement, proper precautions must be taken to make sure all residual hydraulic pressure has been relieved. Crack fittings slowly and allow any residual pressure to bleed off before loosening further.

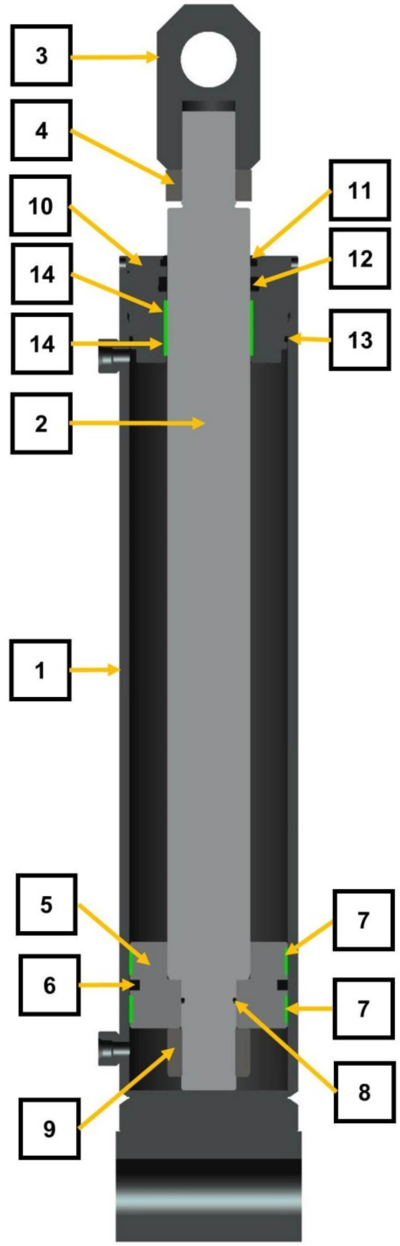
Do NOT attempt to service cylinders if the truck has been recently operated. Hydraulic fluid will be hot and can potentially cause burns. Allow sufficient time for the fluid to cool down.

Cylinder packing, wipers and bushings are subject to contamination from both external and internal foreign materials which can be abrasive in nature resulting in wear or damage to parts that require they be replaced. Genuine replacement seals are available in kits to rebuild/repack all cylinders.

Before attempting any cylinder rebuild it is strongly recommended that the proper tools are available. Having the correct tools will make the job of servicing cylinders easier and reduce the risk of inadvertent damage to the cylinder.

Cylinder Component Identification

1. Cylinder Body
2. Cylinder Rod
3. Rod End
4. Jam Nut
5. Piston
6. Piston Seal
7. Wear Ring
8. O-ring
9. Lock Nut
10. Gland Nut
11. Rod Wiper
12. Rod Seal
13. O-ring w/Backup Ring
14. Wear Ring



Boom Lift Cylinder Servicing

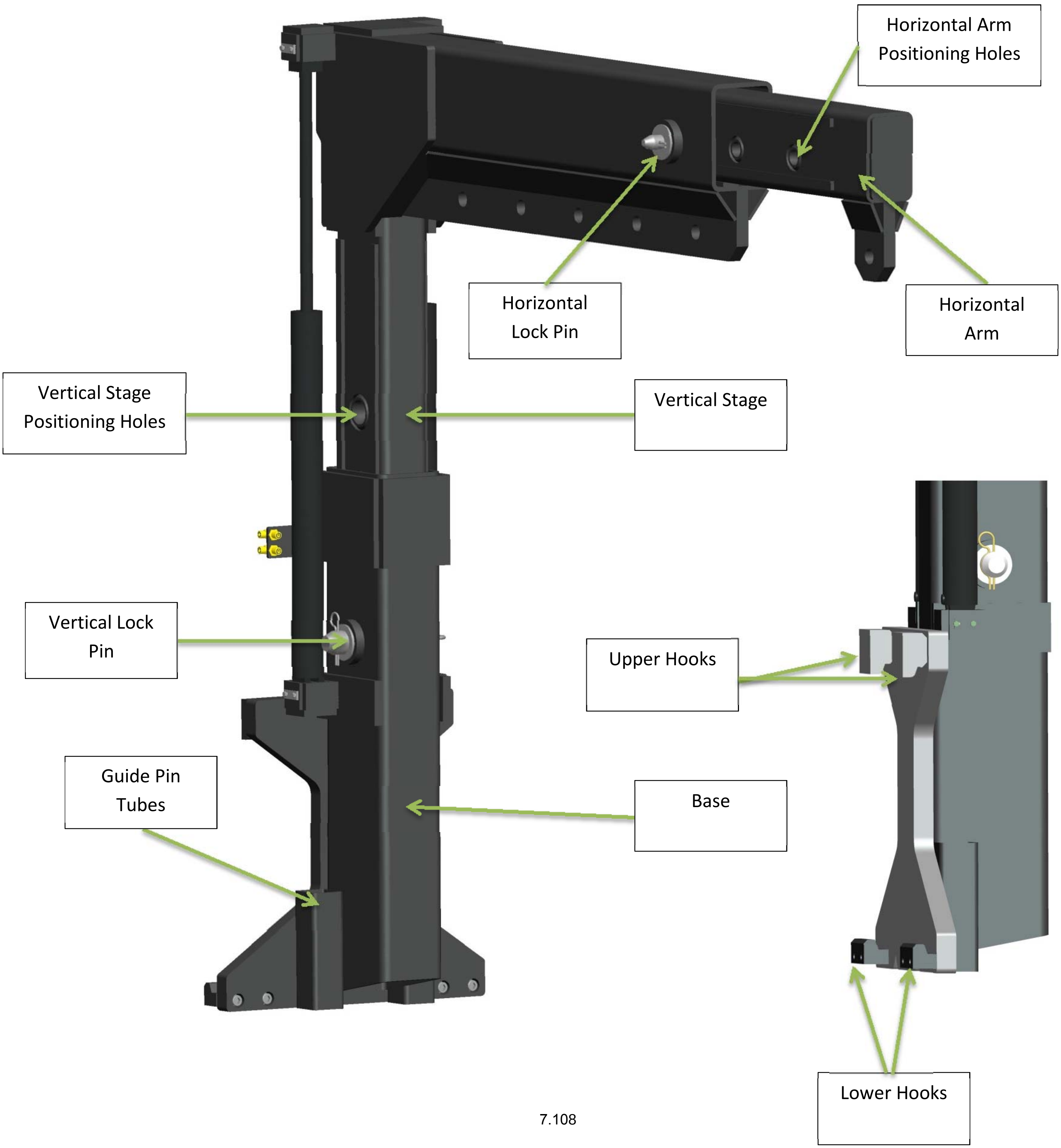
- Remove plugs and completely drain cylinder of all oil.
- Secure the cylinder to a workbench, appropriate stand, or gently hold in vise.
  Be careful not to nick or scratch the chrome rod. Using a spanner wrench, remove the gland nut.
- Carefully remove the rod/piston assembly from the cylinder body.
- Inspect all components for nicks and scratches including the inside of the cylinder body.
  Minor nicks and scratches can be removed using a 400 grit emery cloth. Minor nicks and scratches are those that will NOT bypass oil under pressure. If minor nicks and scratches cannot be removed with an emery cloth, the affected parts MUST be replaced.
- If the piston must be removed, use a strap wrench and emery cloth to secure the rod while removing the piston nut.
- Replace seals, O-rings, Wear Rings and Wiper noting the correct order, direction of Seals and position of Backup Rings.
  The cylinder will NOT operate correctly if Seals and/or O-rings are installed incorrectly
- Lubricate new Seals with petroleum jelly before installing.
- Apply anti-seize compound to the threads of the cylinder body and install Gland Nut using spanner wrench to tighten. The Gland Nut should bottom out on the end of the Cylinder Body.

PISTON LOCK NUT TORQUE TABLE

THREAD SIZE	TORQUE VALUE	
	Ft-Lbs	N·m
3/8-24 UNF	25-30	35-42
1/2-20 UNF	40-60	55-80
5/8-18 UNF	95-105	130-140
3/4-16 UNF	175-225	240-305
7/8-14 UNF	200-275	270-370
1-14 UNF	300-380	405-515
1 1/8-12 UNF	400-500	540-675
1 1/4-12 UNF	500-600	675-810
1 1/2-12 UNF	700-800	950-1085
1 3/4-12 UNF	800-900	1085-1220

Boom Overview FR15/25 & FR18/26

The boom consists of the vertical boom stage, boom base stage, and a boom horizontal arm. The outer vertical stage is the main stage that attaches to the carriage of the lift truck. The boom can be serviced while in the stand. *SEE OPERATOR MANUAL FOR BOOM DISMOUNTING INSTRUCTIONS.*

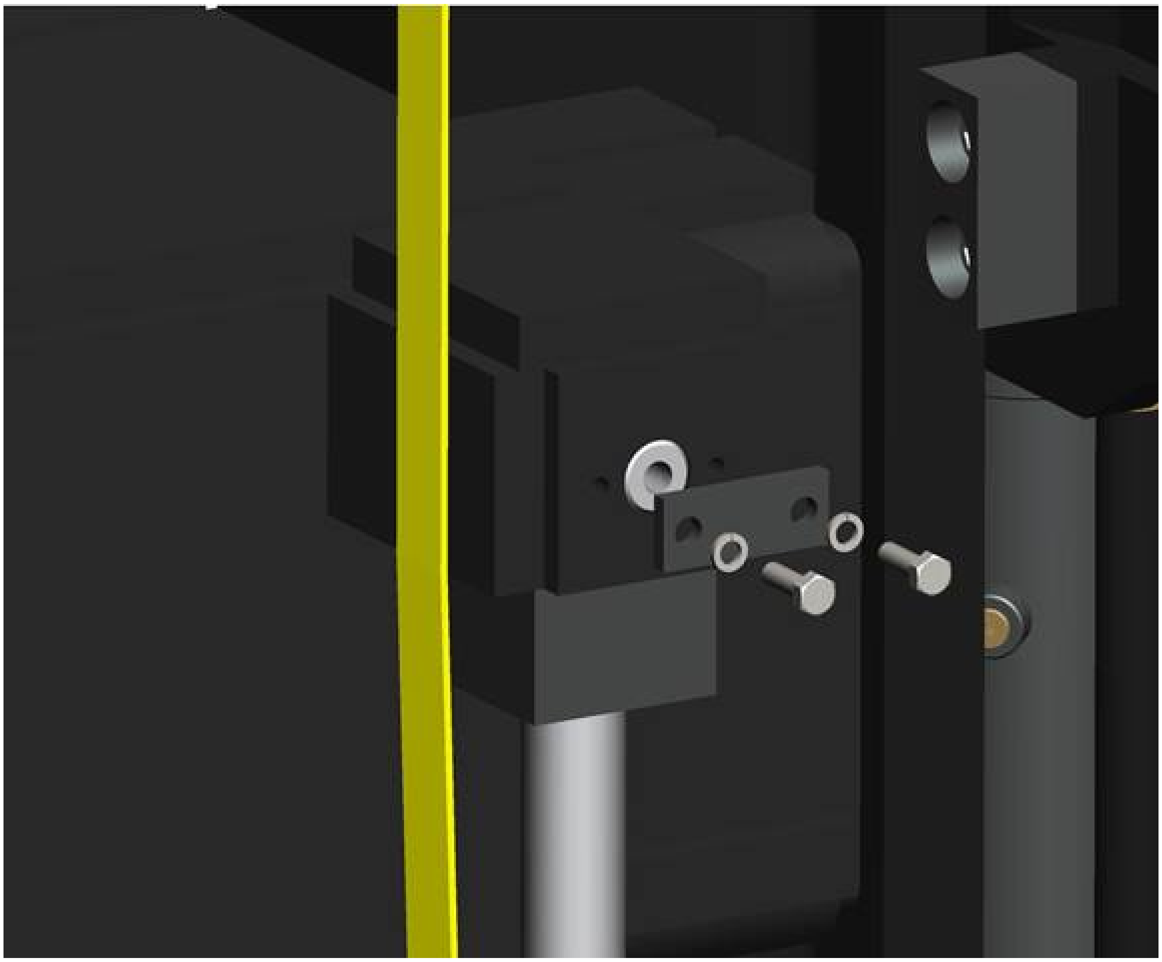


Boom Lift Cylinders FR15/25 & FR18/26

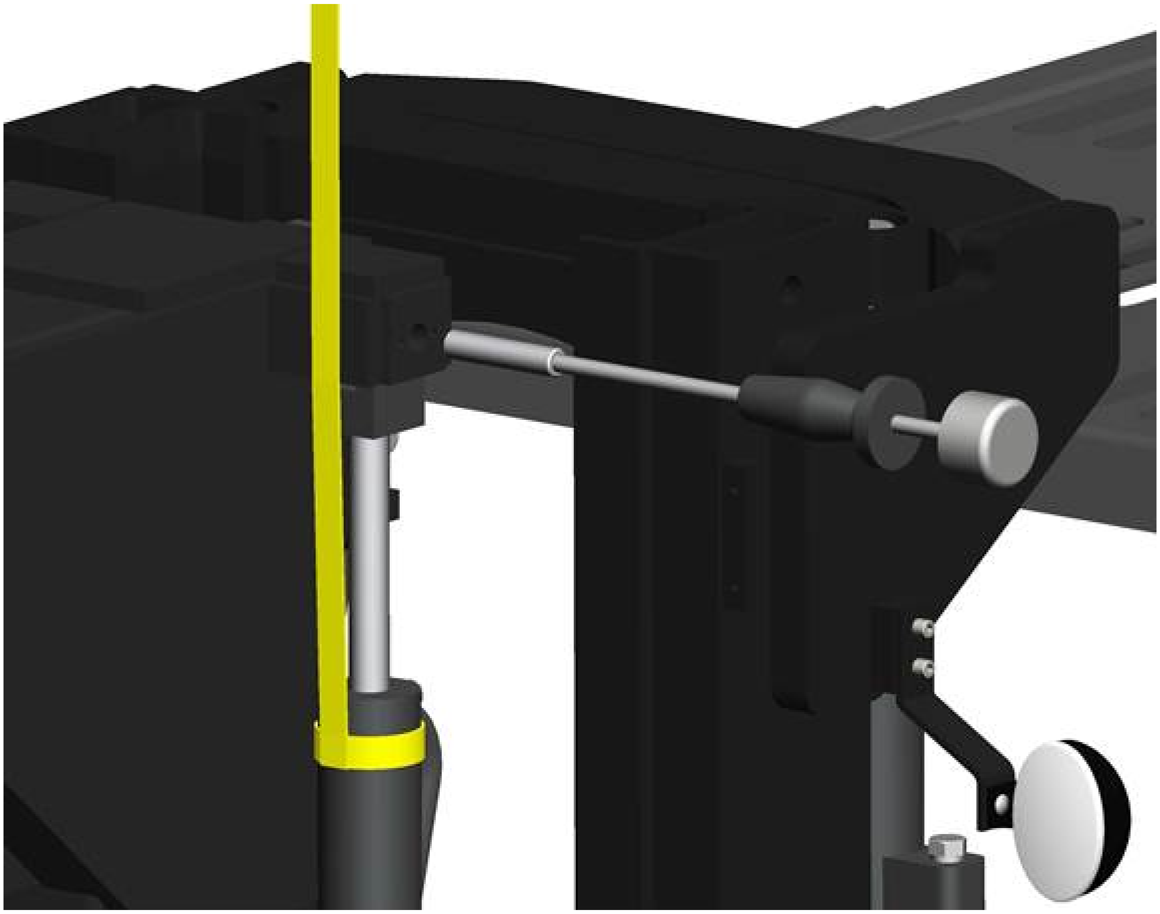
The boom lift cylinders are located on either side of the boom and provide the powered vertical lift of the boom attachment. The cylinders must be removed from the boom for servicing.

- Raise inner vertical one position and pin in place. Completely lower carriage, shut truck off, set parking brake and chock drive wheels to prevent unintended movement.
- Support the boom lift cylinder with a properly rated strap or other approved lifting device.

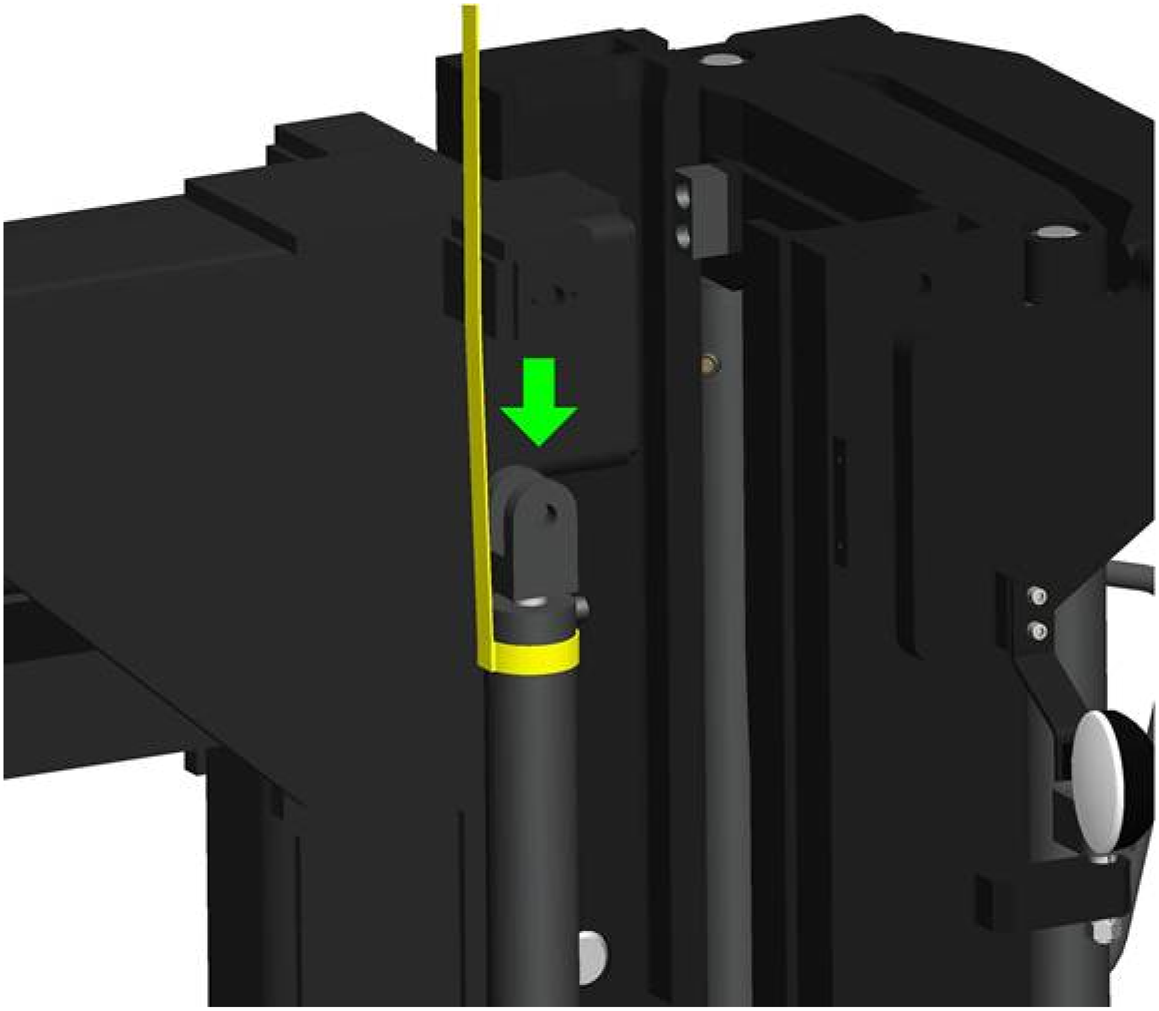
- Remove boom lift cylinder upper pin retainer hardware and the pin retainer itself



- Using a pin puller, remove the boom lift cylinder upper pin.



- Make sure the cylinder support strap is taught and fully supporting the weight of the cylinder. Slowly retract the cylinder rod.



- Remove the boom lift cylinder lower pin retainer hardware and retainer itself in the same manner the upper was removed. Using a pin puller, remove the boom lift cylinder lower pin.
- Slowly raise the cylinder upwards enough to clear the lower boom lift cylinder mount, and then outboard until clear of the boom structure and lift truck. Place the cylinder on a pallet or workbench.

Boom Cylinders FR15/25 & FR18/26

In the event a cylinder requires servicing, it must be removed from the truck or attachment. When removing cylinders plug ports to prevent oil leakage and to prevent contamination.

WARNING

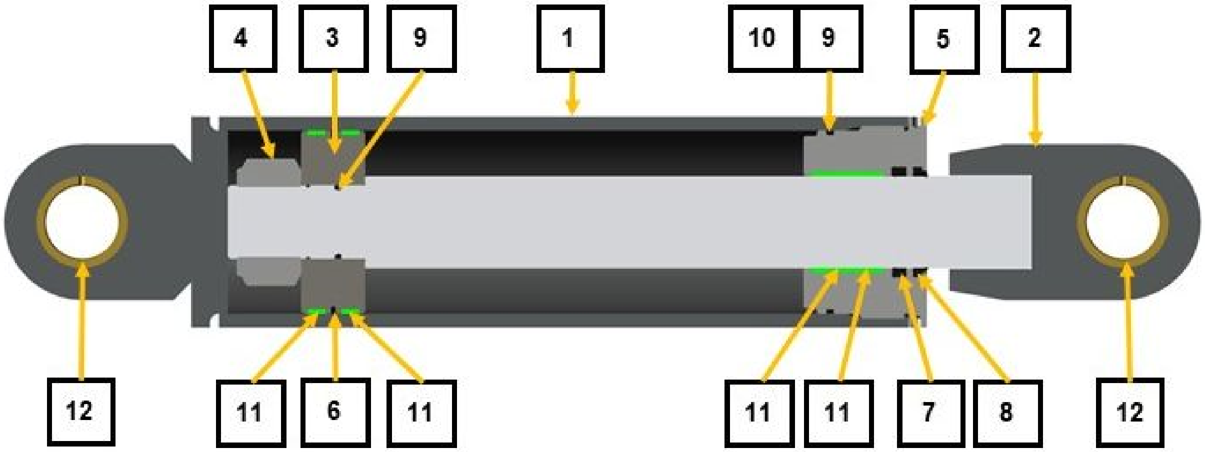
Before attempting to remove any cylinder for servicing or replacement, proper precautions must be taken to make sure all residual hydraulic pressure has been relieved. Crack fittings slowly and allow any residual pressure to bleed off before loosening further.

Do NOT attempt to service cylinders if the truck has been recently operated. Hydraulic fluid will be hot and can potentially cause burns. Allow sufficient time for the fluid to cool down.

Cylinder packing, wipers and bushings are subject to contamination from both external and internal foreign materials which can be abrasive in nature resulting in wear or damage to parts that require they be replaced. Genuine replacement seals are available in kits to rebuild/repack all cylinders.

Before attempting any cylinder rebuild it is strongly recommended that the proper tools are available. Having the correct tools will make the job of servicing cylinders easier and reduce the risk of inadvertent damage to the cylinder.

Double Acting Cylinder component identification



1. **Cylinder Body**
2. **Rod Weldment/Assembly**
3. **Piston**
4. **Lock Nut**
5. **Gland Nut**
6. **Piston Seal**
7. **Rod Seal**
8. **Rod Wiper**
9. **O-Ring**
10. **Backup Ring**
11. **Wear Ring**
12. **Bushing/Bearing**

Boom Lift Cylinder Servicing

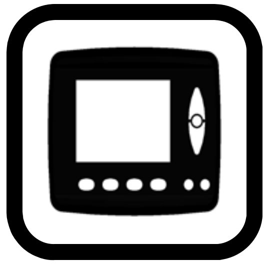
- Remove plugs and completely drain cylinder of all oil.
- Secure the cylinder to a workbench, appropriate stand, or gently hold in vise.
  Be careful not to nick or scratch the chrome rod.

.
- Carefully remove the rod/piston assembly from the cylinder body.
- Inspect all components for nicks and scratches including the inside of the cylinder body.
  Minor nicks and scratches can be removed using a 400 grit emery cloth. Minor nicks and scratches are those that will NOT bypass oil under pressure. If minor nicks and scratches cannot be removed with an emery cloth, the affected parts MUST be replaced.
- If the piston must be removed, use a strap wrench and emery cloth to secure the rod while removing the piston nut.
- Replace seals, O-rings, Wear Rings and Wiper noting the correct order, direction of Seals and position of Backup Rings.
  The cylinder will NOT operate correctly if Seals and/or O-rings are installed incorrectly
- Lubricate new Seals with petroleum jelly before installing.
- Apply anti-seize compound to the threads of the cylinder body and install Gland Nut using spanner wrench to tighten. The Gland Nut should bottom out on the end of the Cylinder Body.

PISTON LOCK NUT TORQUE TABLE

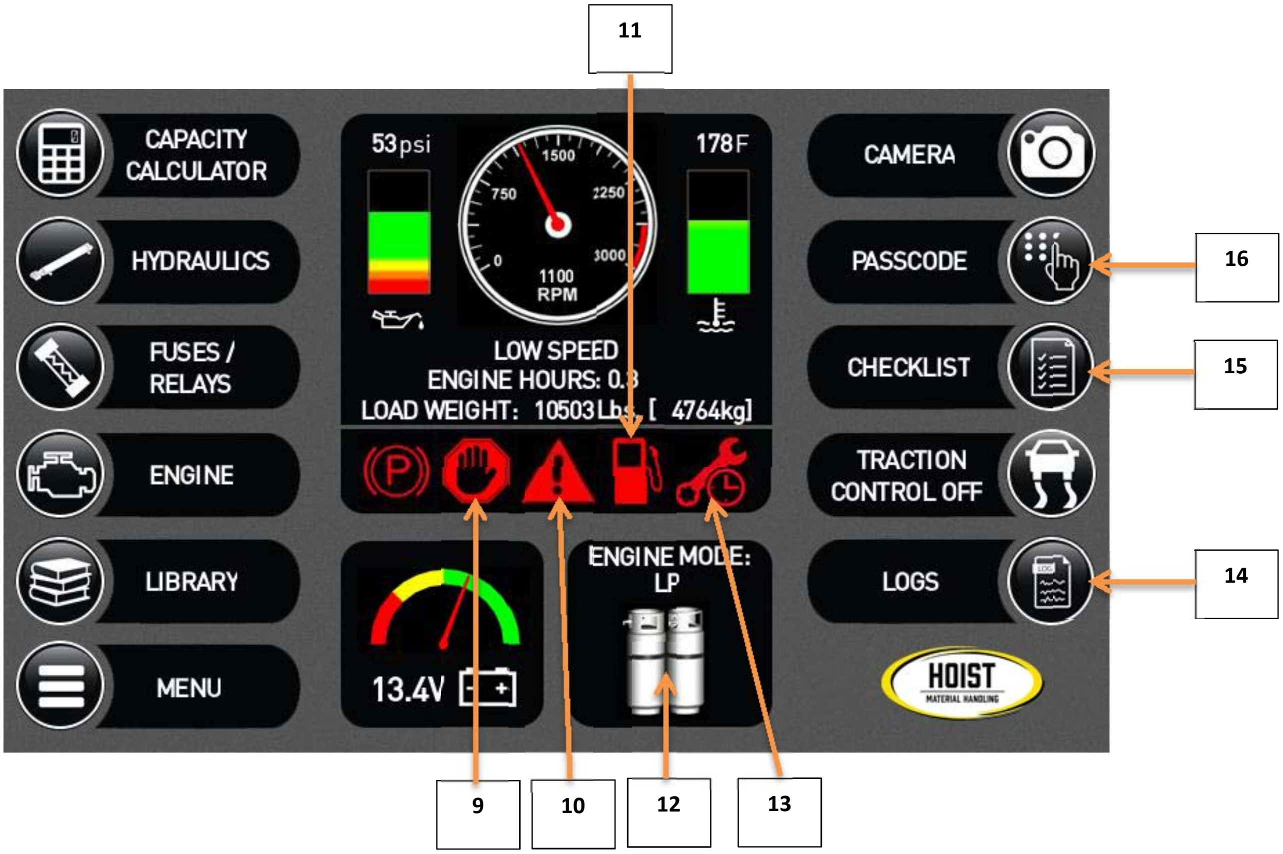
THREAD SIZE	TORQUE VALUE	
	Ft-Lbs	N·m
3/8-24 UNF	25-30	35-42
1/2-20 UNF	40-60	55-80
5/8-18 UNF	95-105	130-140
3/4-16 UNF	175-225	240-305
7/8-14 UNF	200-275	270-370
1-14 UNF	300-380	405-515
1 1/8-12 UNF	400-500	540-675
1 1/4-12 UNF	500-600	675-810
1 1/2-12 UNF	700-800	950-1085
1 3/4-12 UNF	800-900	1085-1220

FR15/25, FR18/26, & FR25/35 SERVICE MANUAL *DISPLAY*

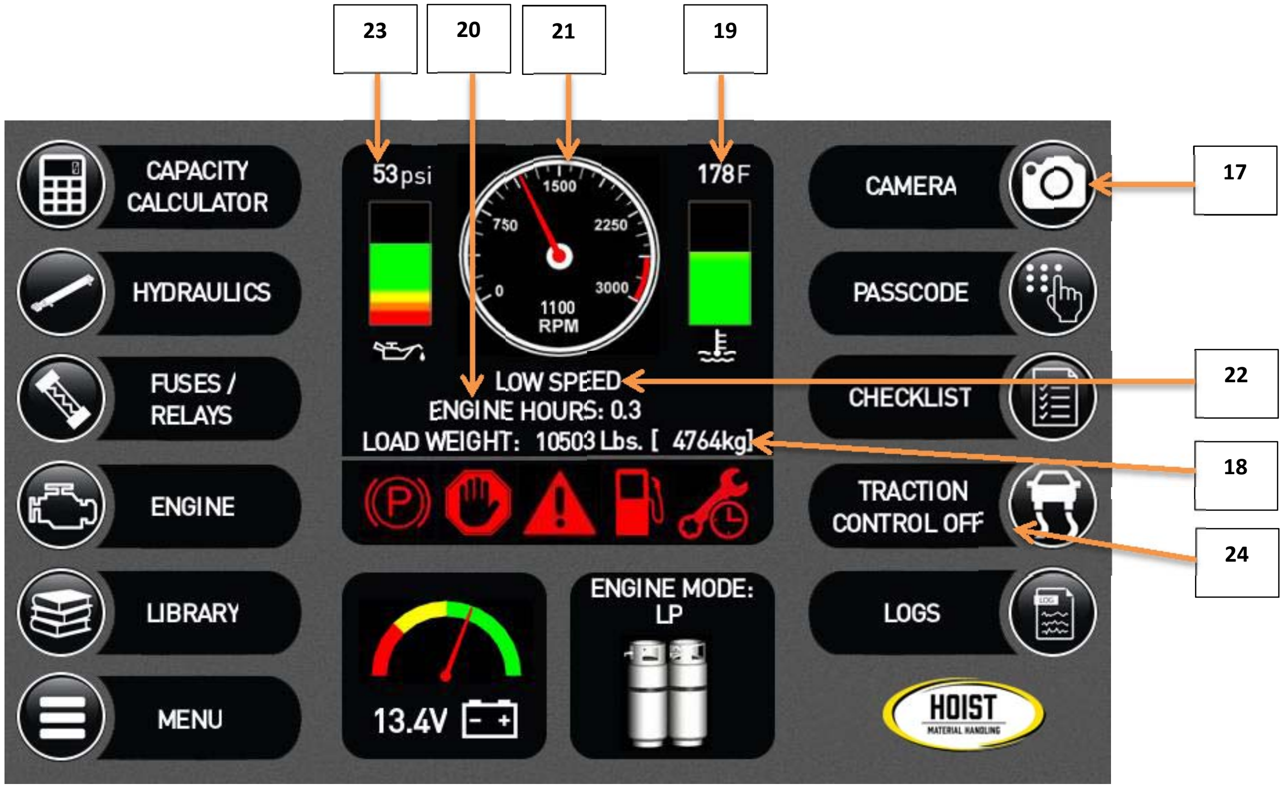


INDEX

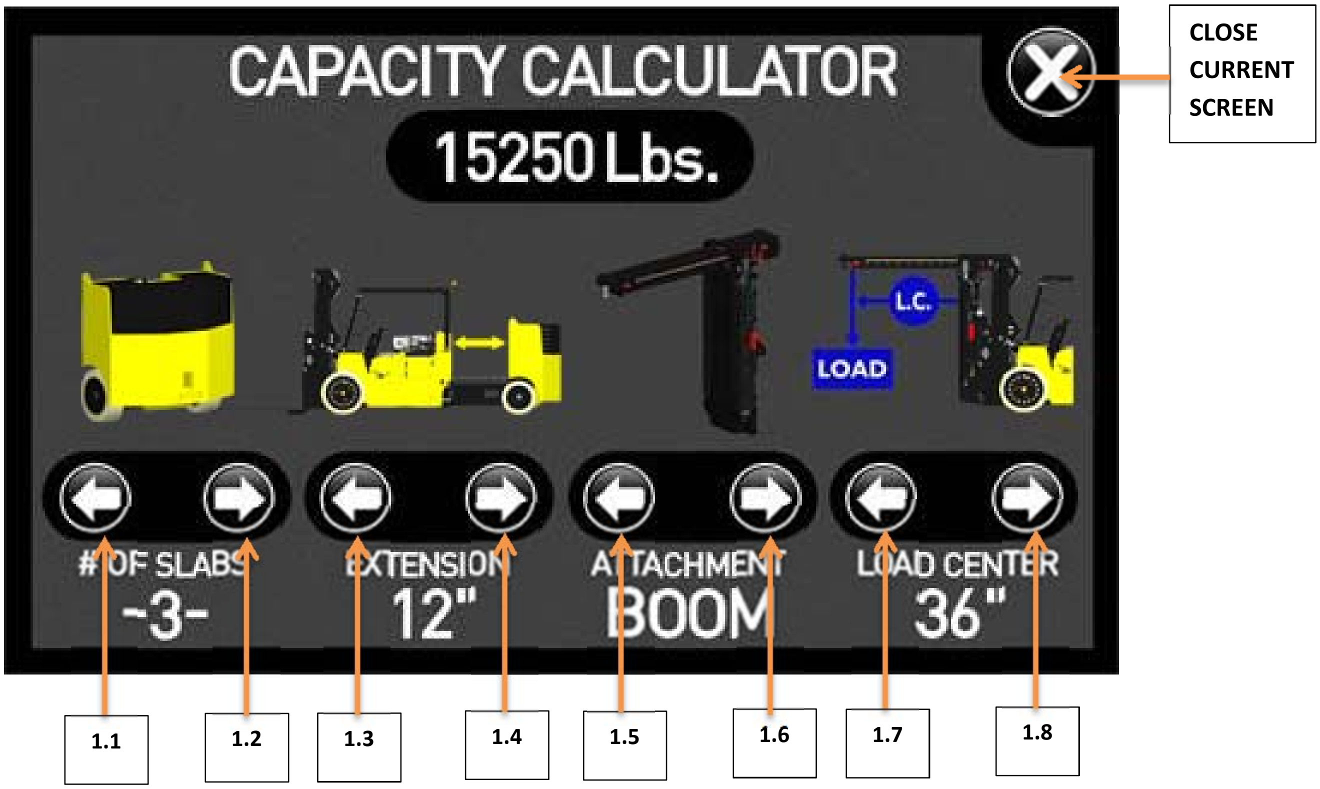
Item No	Item	Function
1	Capacity Calculator Button	Press to go to Capacity Calculator Screen.
2	Hydraulics Button	Press to go to the Hydraulics Screen.
3	Fuses/Relays Button	Press to go to Fuses/Relays Screen.
4	Engine Button	Press to go to the Engine Screen.
5	Library Button	Press to go to Library Screen.
6	Menu Button	Press to go to the Menu Screen. This Button is for Service Technicians.
7	Park Brake Indicator	Illuminates when the Park Brake is APPLIED.
8	Battery Charge Indicator	Displays Current Battery State of Charge.



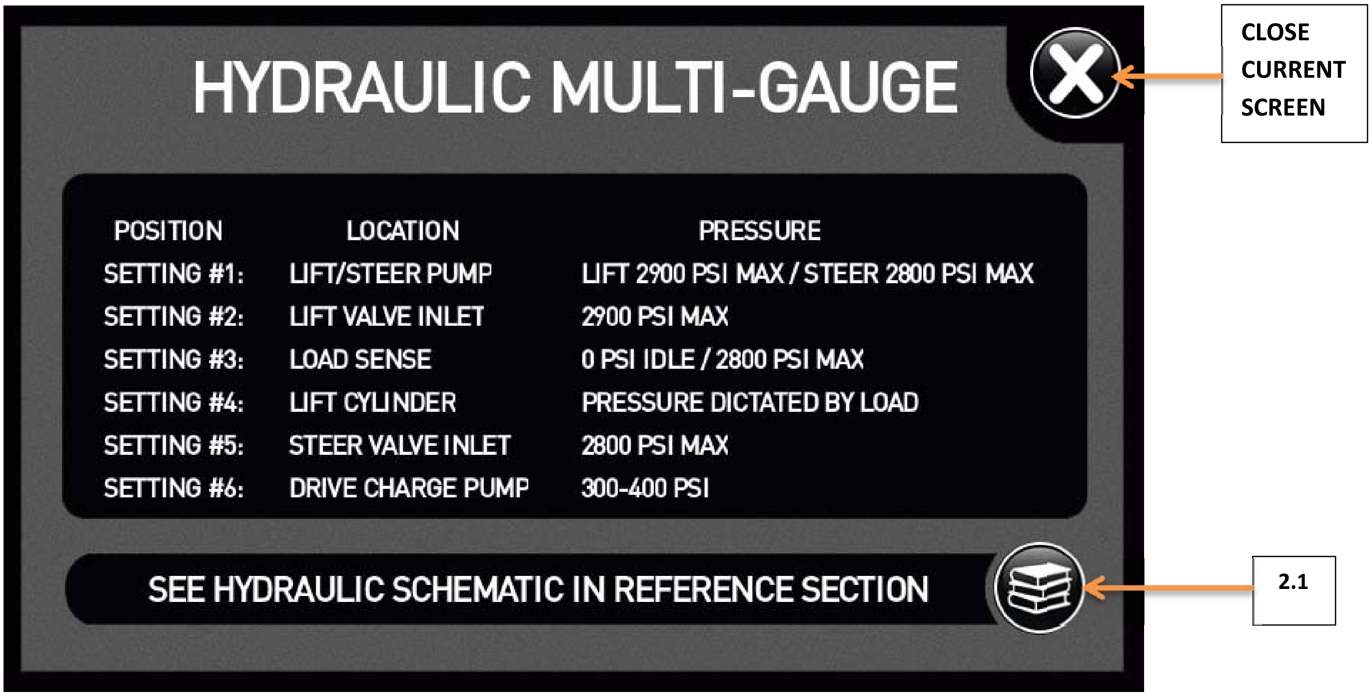
Item No	Item	Function
9	Stop Engine Indicator	Illuminates when there is a CRITICAL Engine Error. Engine should be Stopped IMMEDIATELY.
10	Service Engine Indicator	Illuminates when there is a Engine Error. Engine should be Serviced IMMEDIATELY.
11	Low Fuel Indicator	Illuminates when the Engine is Low on Fuel.
12	Engine Mode	Displays Current Mode of Engine. Engine Modes: LP or Gasoline
13	Service Indicator	Illuminates when Scheduled Maintenance is REQUIRED.
14	Logs Button	Press to go to the Logs Screen.
*15	Checklist Button	Press to go to the Checklist Screen.
*16	Passcode Button	Press to go to the Passcode Screen.
*Indicates OPTIONAL feature		



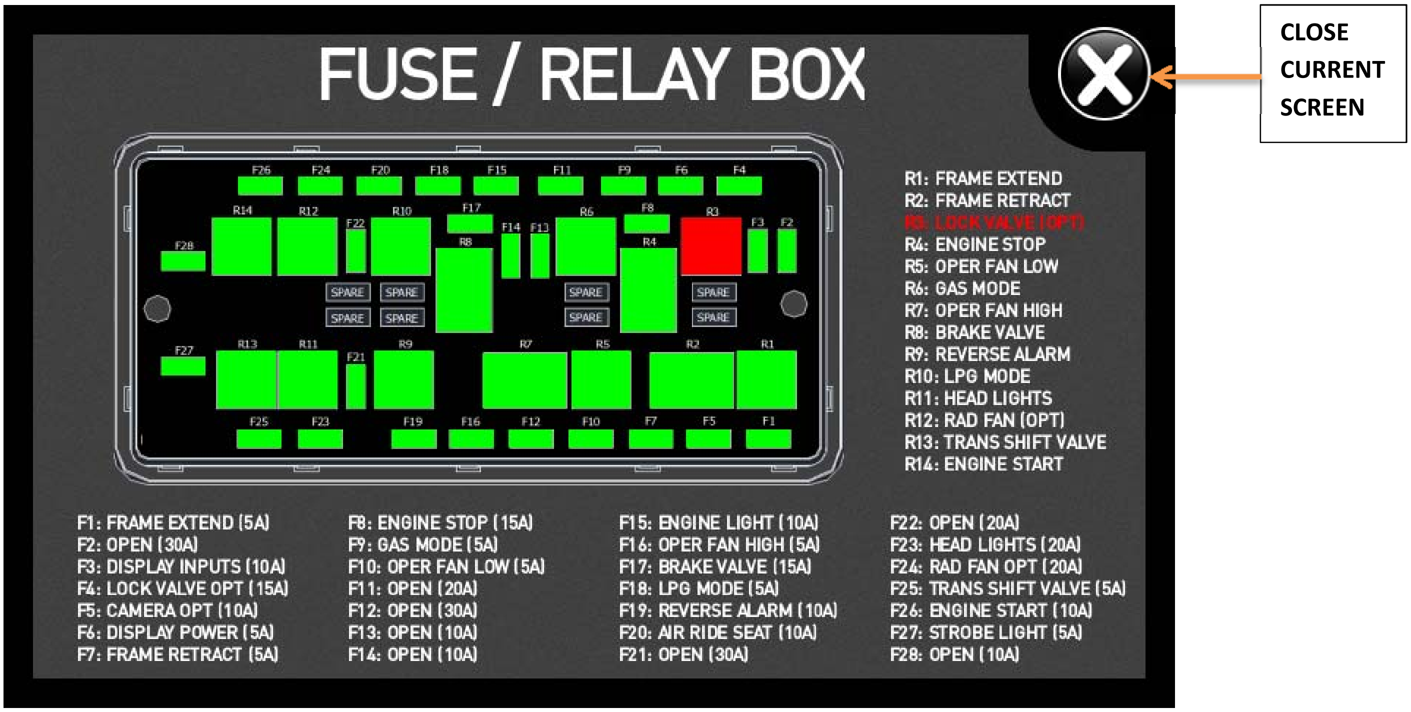
Item No	Item	Function
*17	Camera Button	Press to go to the Camera Screen.
18	Load Weight Indicator	Displays Current Load Weight on Forks/Boom.
19	Engine Temperature Gauge	Displays Current Water Temperature of the Engine.
20	Engine Hours Counter	Displays Cumulative Truck Engine Hours.
21	Tachometer	Displays Current Speed of Engine in RPMs.
22	Pump Speed	Displays Current Speed of Hydrastatic Pump.
23	Oil Pressure Gauge	Displays Current Oil Pressure of Engine.
*24	Traction Control Button	Press to turn Traction Control Mode on and off.
*Indicates OPTIONAL feature		

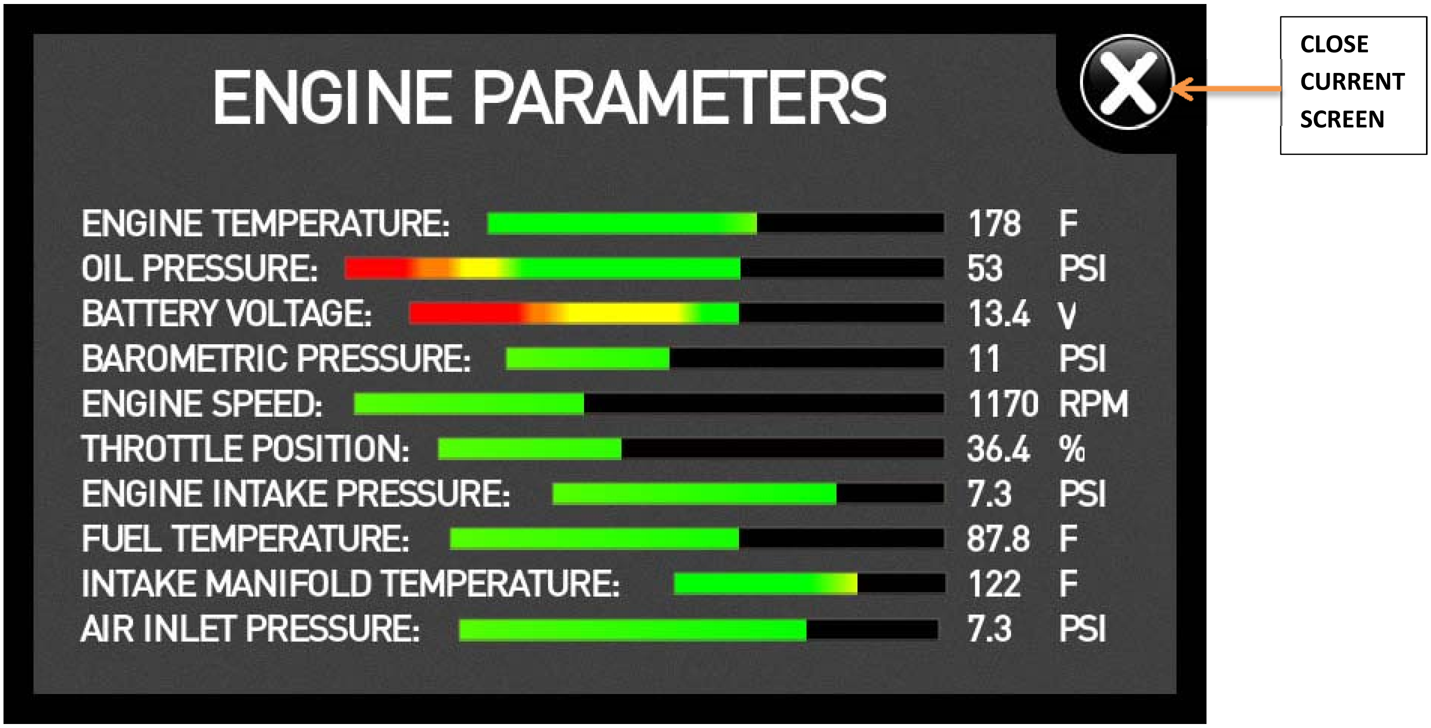


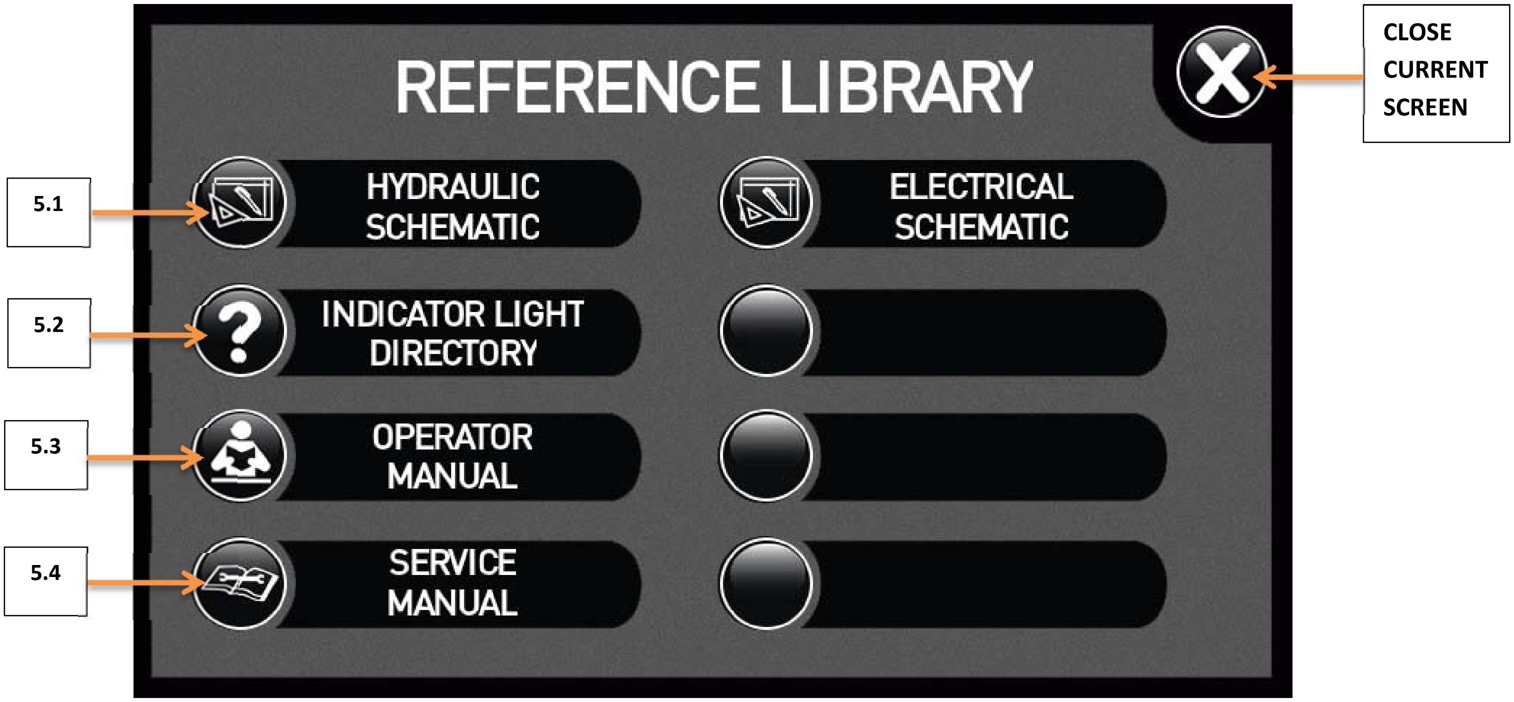
Item No	Item	Function
1.1	Left Arrow Button	Press to Decrease the # of Slabs.
1.2	Right Arrow Button	Press to Increase the # of Slabs.
1.3	Left Arrow Button	Press to Decrease the Counterweight Extension. (Decreases in Increments of 12")
1.4	Right Button	Press to Increase the Counterweight Extension. (Increases in Increments of 12")
1.5	Forks Button	Press to Change Attachment Type to Forks.
1.6	Boom Button	Press to Change Attachment Type to Boom.
1.7	Left Arrow Button	Press to Decrease the Load Center of the Load. (Decreases in Increments of 12")
1.8	Right Arrow Button	Press to Increase the Load Center of the Load. (Increases in Increments of 12")



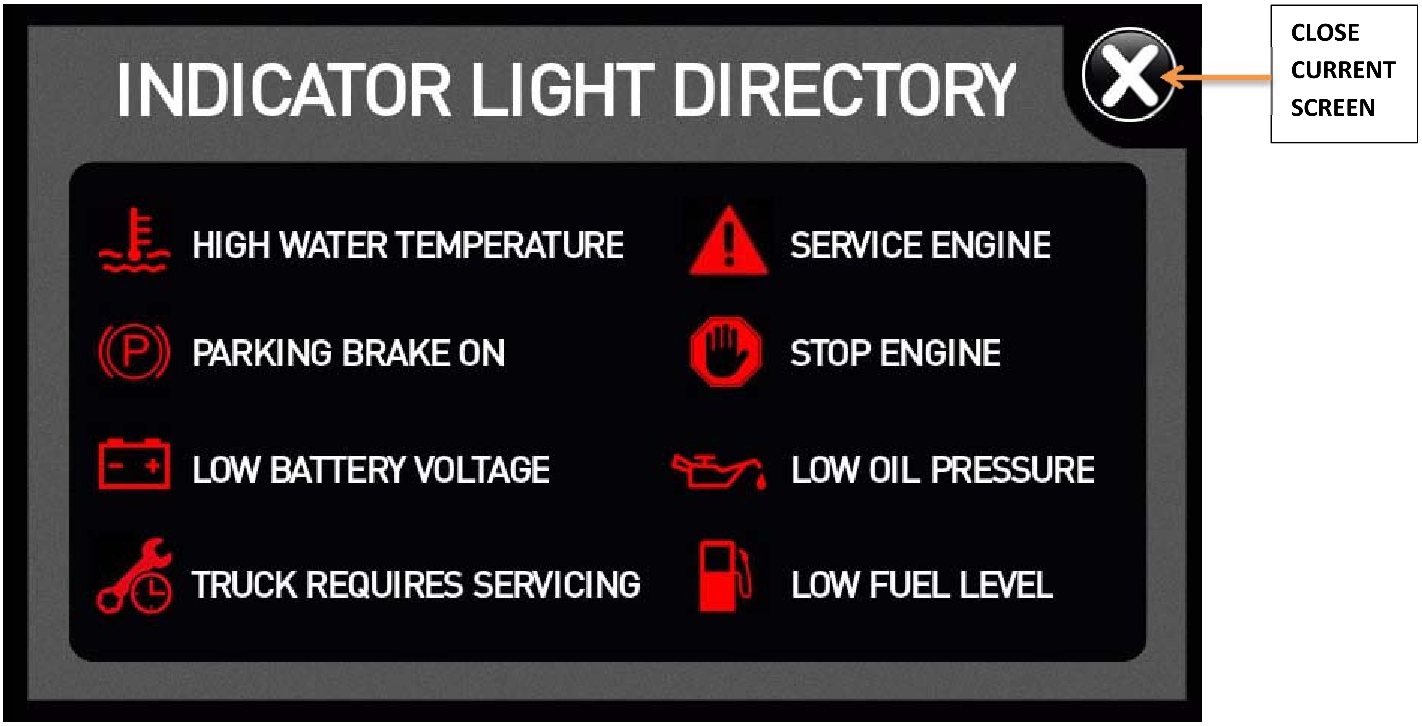
Item No	Item	Function
2.1	Library Button	Press to go to Library Screen.


FUSE / RELAY BOX
CLOSE CURRENT SCREEN
R1: FRAME EXTEND
R2: FRAME RETRACT
R3: LOCK VALVE (OPT)
R4: ENGINE STOP
R5: OPER FAN LOW
R6: GAS MODE
R7: OPER FAN HIGH
R8: BRAKE VALVE
R9: REVERSE ALARM
R10: LPG MODE
R11: HEAD LIGHTS
R12: RAD FAN (OPT)
R13: TRANS SHIFT VALVE
R14: ENGINE START
F1: FRAME EXTEND (5A)
F2: OPEN (30A)
F3: DISPLAY INPUTS (10A)
F4: LOCK VALVE OPT (15A)
F5: CAMERA OPT (10A)
F6: DISPLAY POWER (5A)
F7: FRAME RETRACT (5A)
F8: ENGINE STOP (15A)
F9: GAS MODE (5A)
F10: OPER FAN LOW (5A)
F11: OPEN (20A)
F12: OPEN (30A)
F13: OPEN (10A)
F14: OPEN (10A)
F15: ENGINE LIGHT (10A)
F16: OPER FAN HIGH (5A)
F17: BRAKE VALVE (15A)
F18: LPG MODE (5A)
F19: REVERSE ALARM (10A)
F20: AIR RIDE SEAT (10A)
F21: OPEN (30A)
F22: OPEN (20A)
F23: HEAD LIGHTS (20A)
F24: RAD FAN OPT (20A)
F25: TRANS SHIFT VALVE (5A)
F26: ENGINE START (10A)
F27: STROBE LIGHT (5A)
F28: OPEN (10A)

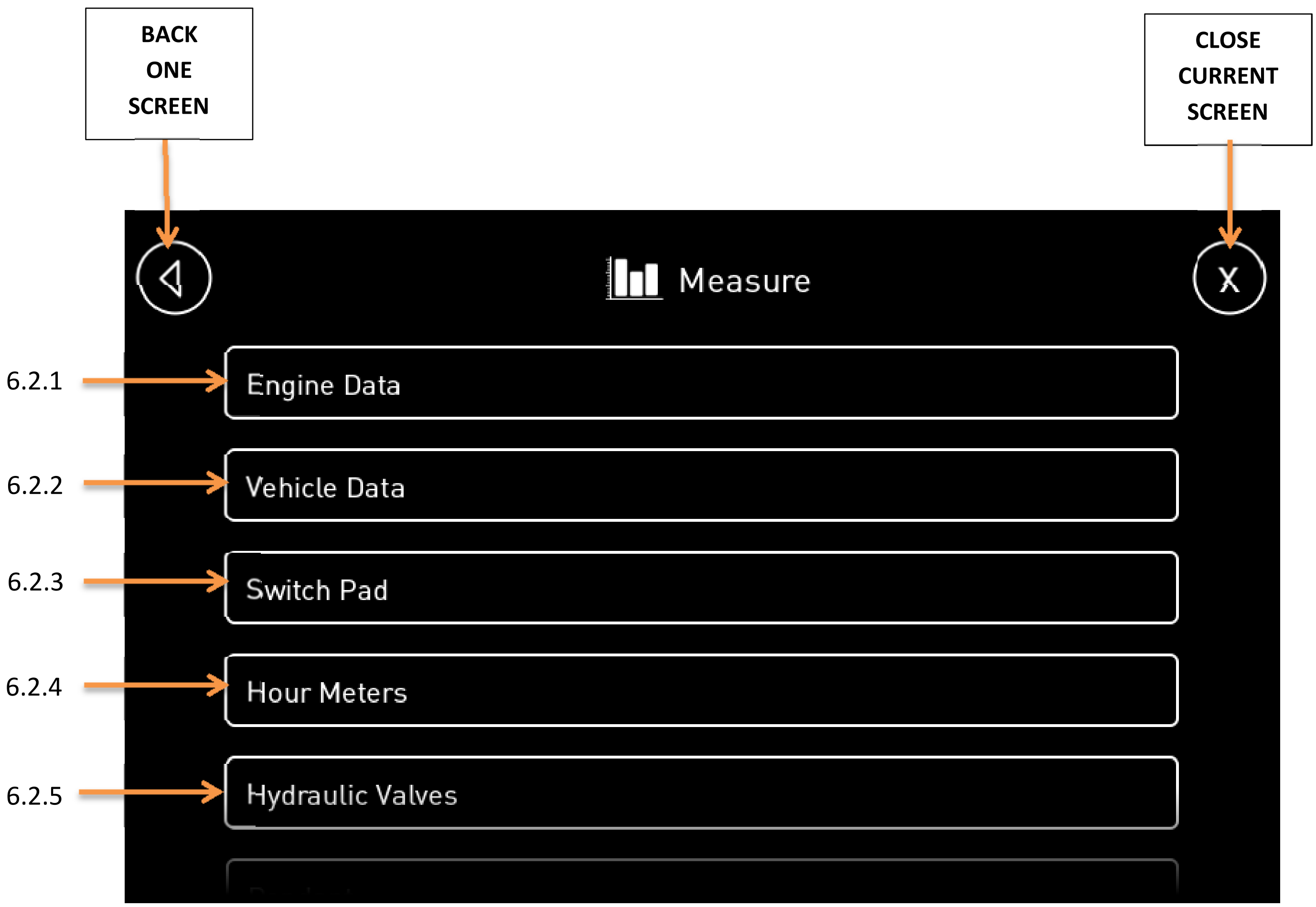

ENGINE PARAMETERS
ENGINE TEMPERATURE: 178 F
OIL PRESSURE: 53 PSI
BATTERY VOLTAGE: 13.4 V
BAROMETRIC PRESSURE: 11 PSI
ENGINE SPEED: 1170 RPM
THROTTLE POSITION: 36.4 %
ENGINE INTAKE PRESSURE: 7.3 PSI
FUEL TEMPERATURE: 87.8 F
INTAKE MANIFOLD TEMPERATURE: 122 F
AIR INLET PRESSURE: 7.3 PSI
CLOSE CURRENT SCREEN

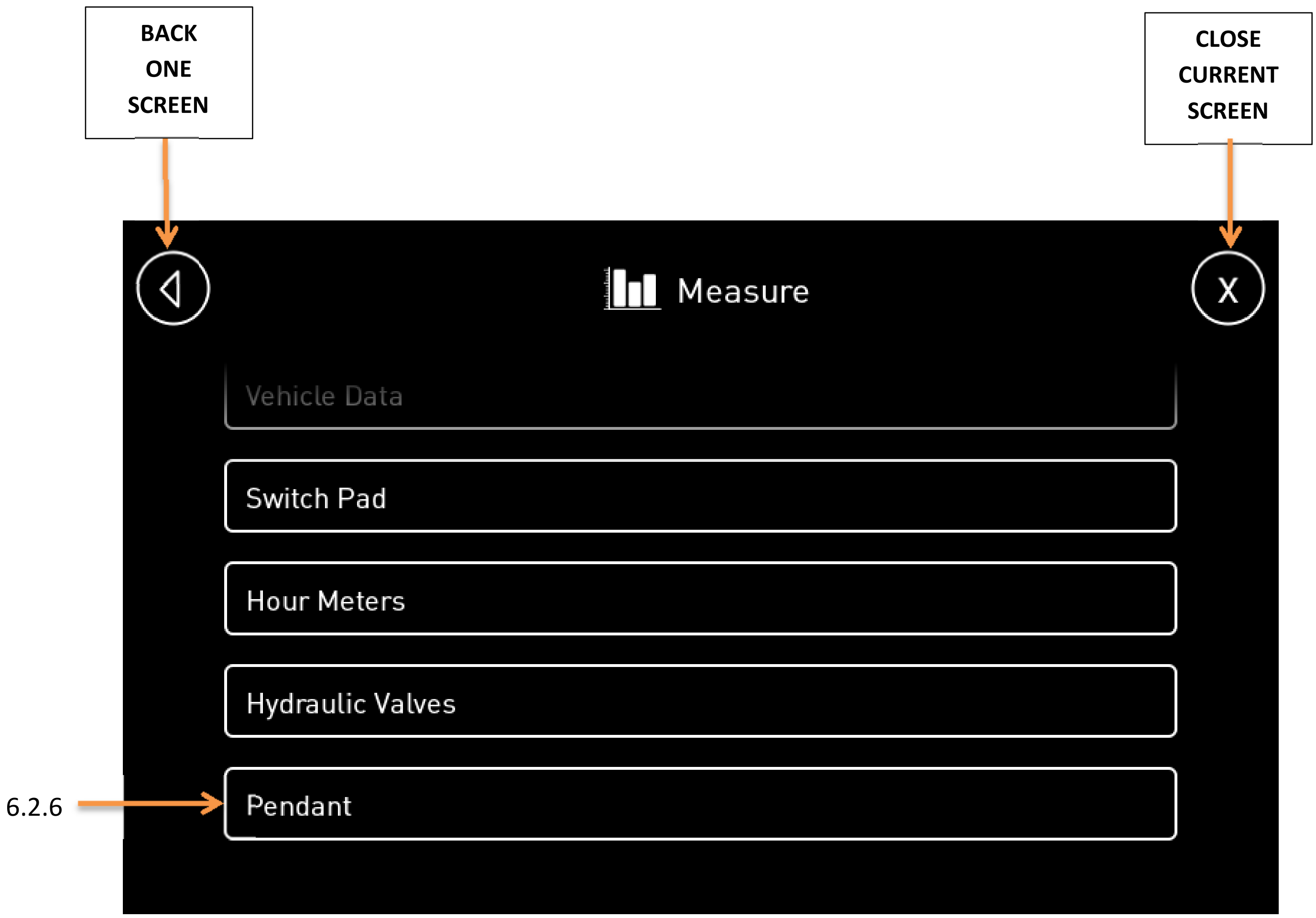


	Item	Function
5.1	Hydraulic Schematic Button	Press to review Hydraulic Schematic PDF file.
5.2	Indicator Light Button	Press to go to Indicator Light Screen.
5.3	Operator Manual Button	Press to review Operator Manual PDF file.
5.4	Service Manual Button	Press to review Service Manual PDF file.
5.5	Electrical Schematic Button	Press to review Electrical Schematic PDF file.


INDICATOR LIGHT DIRECTORY
HIGH WATER TEMPERATURE
SERVICE ENGINE
PARKING BRAKE ON
STOP ENGINE
LOW BATTERY VOLTAGE
LOW OIL PRESSURE
TRUCK REQUIRES SERVICING
LOW FUEL LEVEL
CLOSE CURRENT SCREEN

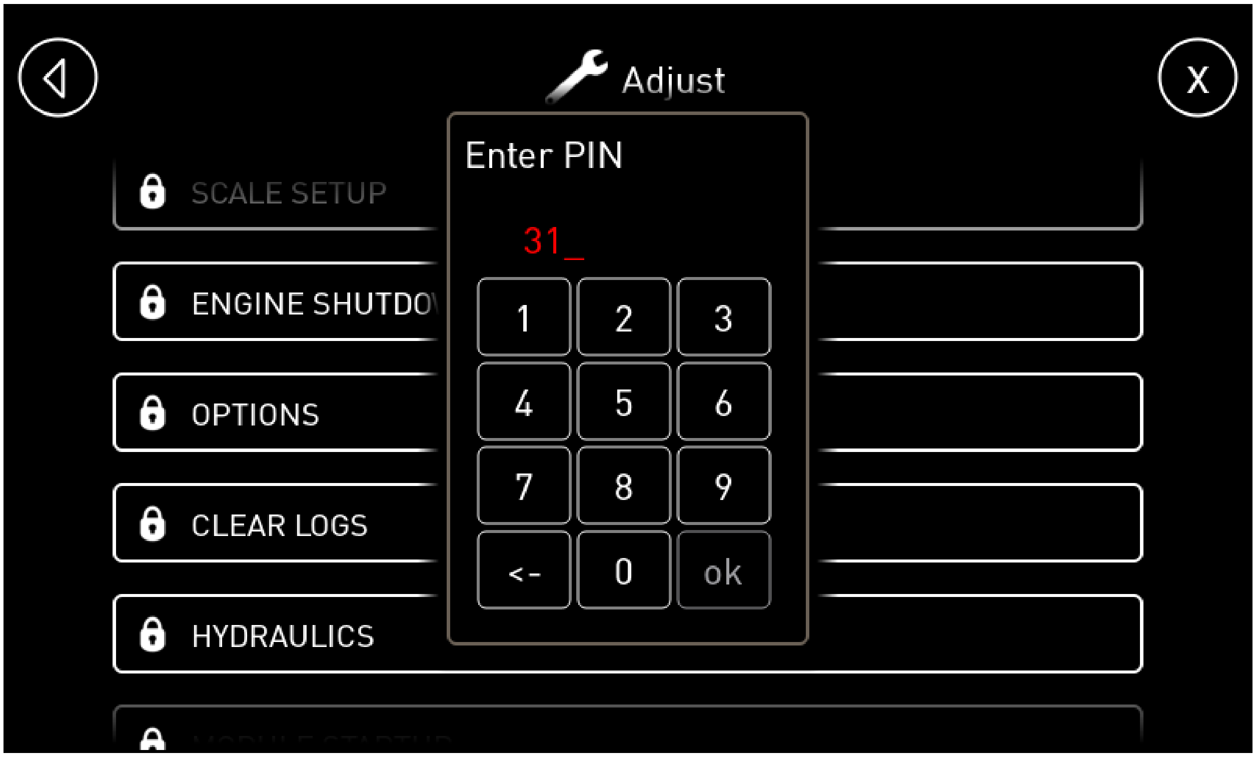

Main
System
Measure
Adjust
Preferences
X
CLOSE CURRENT SCREEN

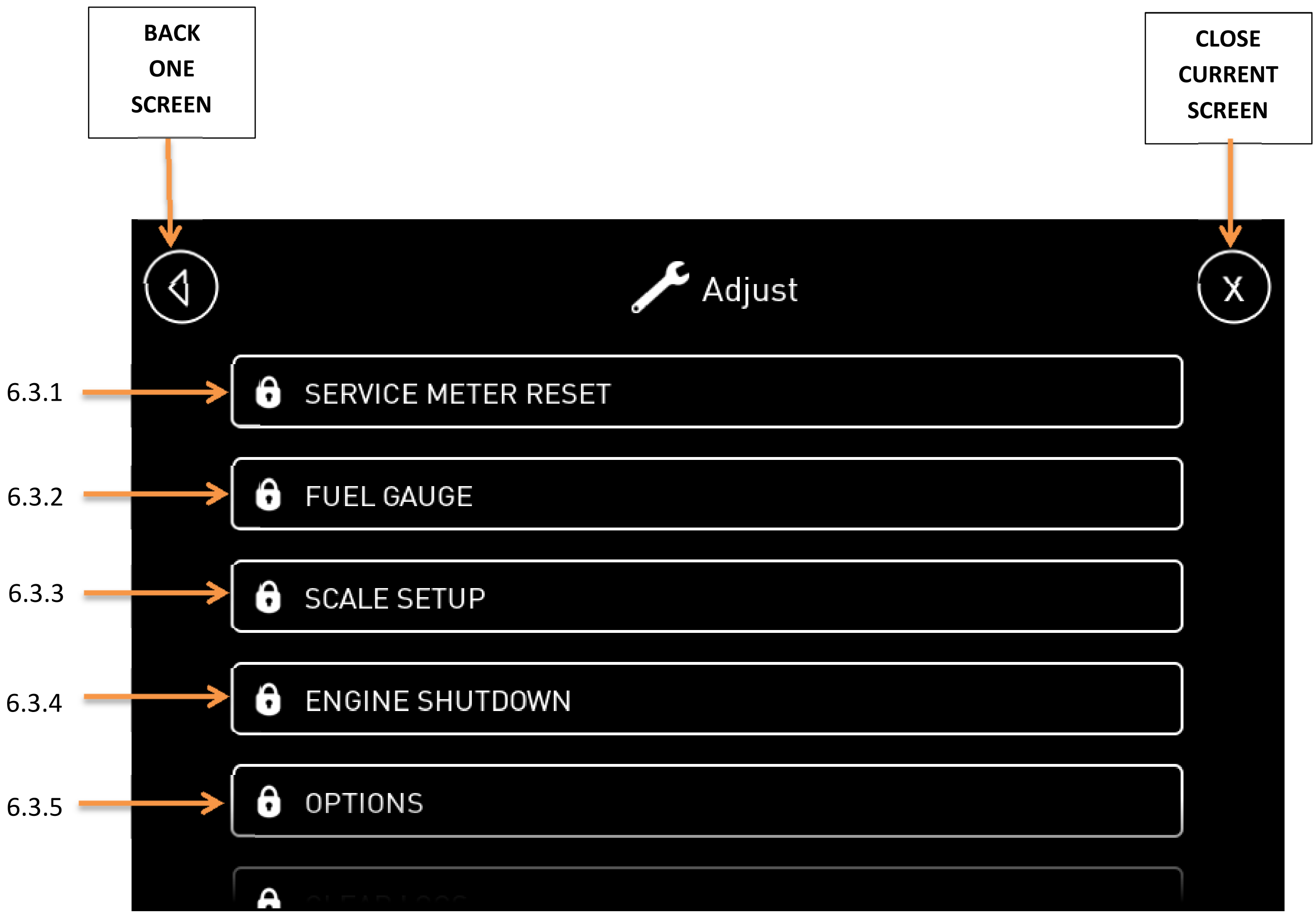

BACK ONE SCREEN
CLOSE CURRENT SCREEN
Measure
X
6.2.1
Engine Data
6.2.2
Vehicle Data
6.2.3
Switch Pad
6.2.4
Hour Meters
6.2.5
Hydraulic Valves

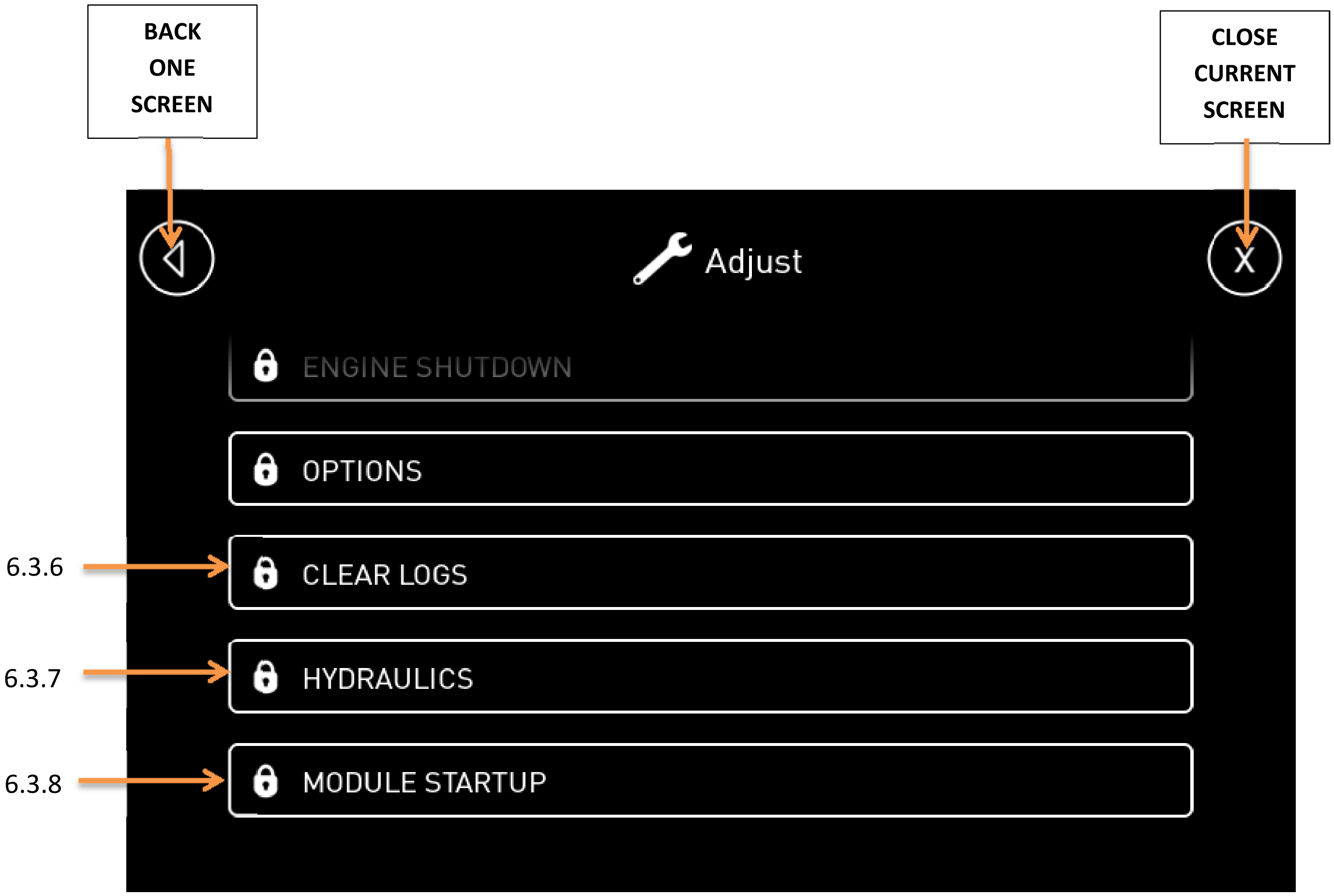


Item No	Item	Function
6.2.1	Engine Data Button	Press to review Engine Data Parameters.
6.2.2	Vehicle Data Button	Press to review Vehicle Data Parameters.
6.2.3	Switch Pad Button	Press to review Switch Pad Input Status.
6.2.4	Hour Meters Button	Press to review all Hour Meter Readings.
6.2.5	Hydraulic Valves Button	Press to review Hydraulic Valve Output Status.
6.2.6	Pendant Button	Press to review Pendant Button Input Status.

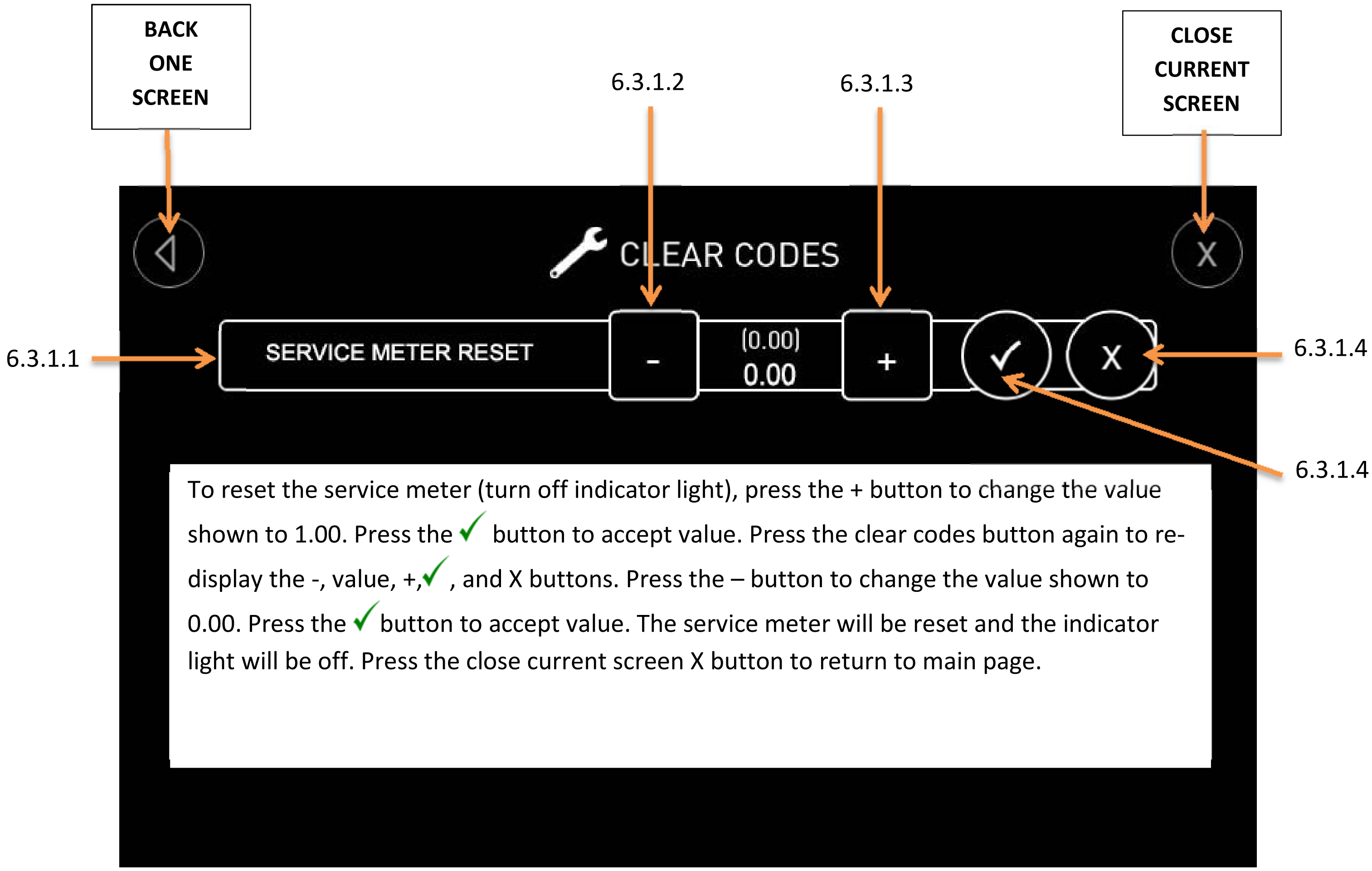
Functions with the Padlock Icon require an authorization code for access. These functions are generally not available to operators. Additional functionality is available to authorized service technicians who have been provided an access code while some functionality is restricted to OEM use. Any group requiring an access code will automatically display the Pin Code Input Screen when accessed. Enter provided PIN code and press "OK" to continue.



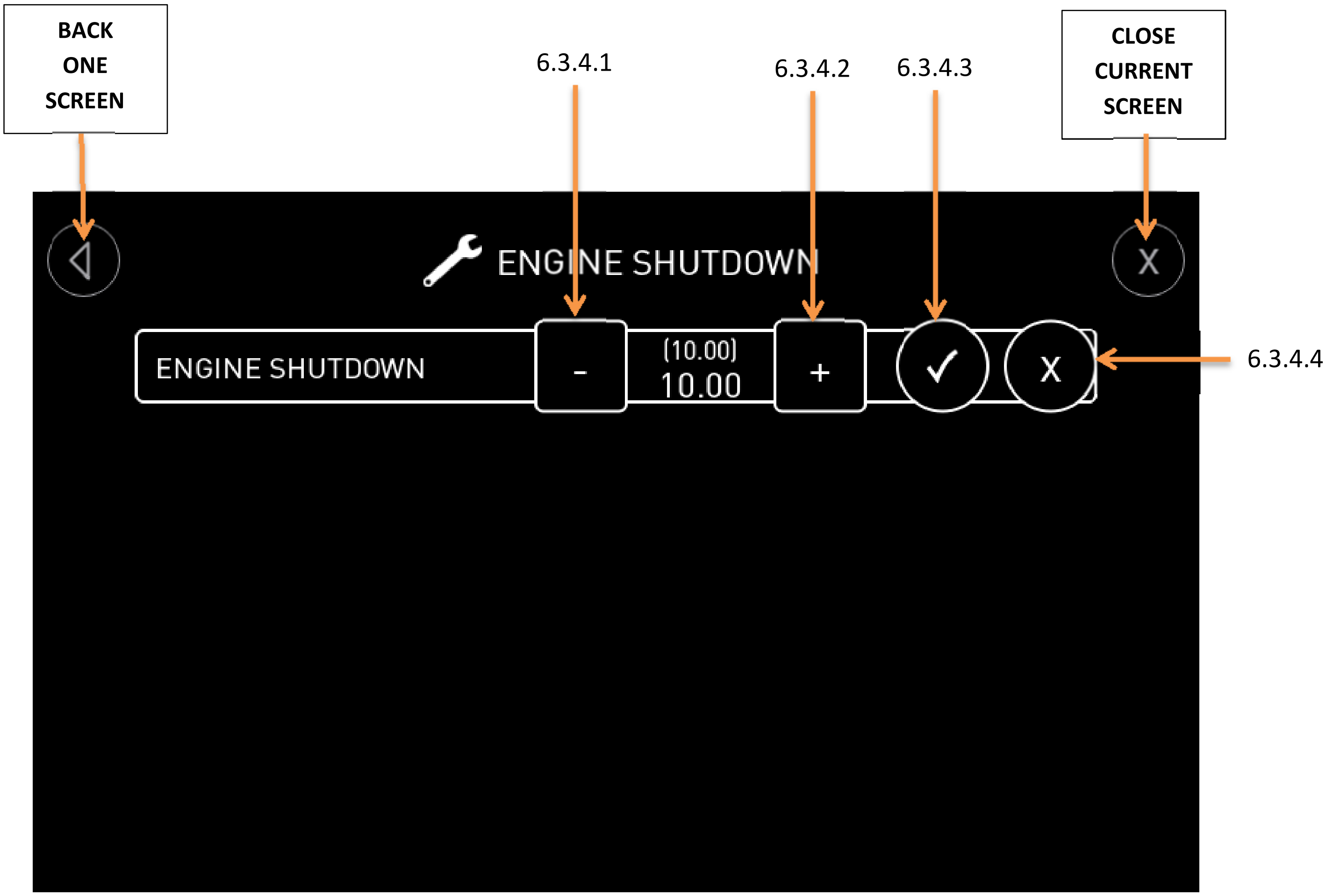

BACK
ONE
SCREEN
CLOSE
CURRENT
SCREEN
Adjust
X
6.3.1
SERVICE METER RESET
6.3.2
FUEL GAUGE
6.3.3
SCALE SETUP
6.3.4
ENGINE SHUTDOWN
6.3.5
OPTIONS



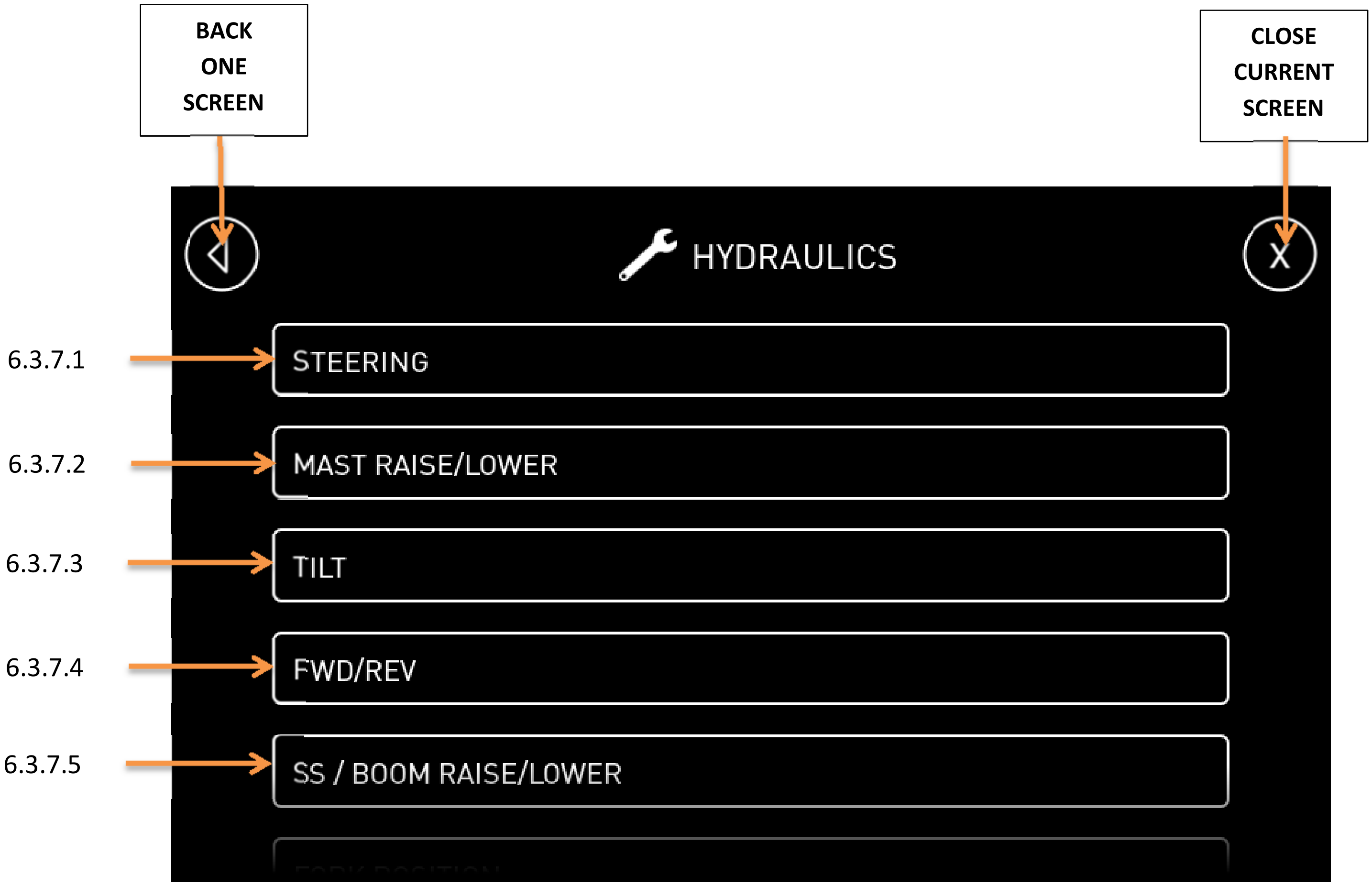
Item No	Item	Function
6.3.1	Service Meter Reset	Press to go to Service Meter Reset Screen and turn off indicator light.
6.3.2	Fuel Gauge	OEM access only. Contact your authorized dealer for assitance calibrating Fuel Gauge.
6.3.3	Scale Setup	OEM access only. Contact your authorized dealer for assistance in re-calibrating scale.
6.3.4	Engine Shutdown	Press to go to Engine Shutdown Screen to set engine shutdown timer.
6.3.5	Options	OEM access only. Contact your authorized dealer for assistance changing vehicle options.
6.3.6	Clear Logs	OEM access only. Contact your authorized dealer for assitance clearing logs.
6.3.7	Hydraulics	Press to go to Hydraulics Screen to adjust hydraulic function speeds.
6.3.8	Module Startup	Press to go to Module Startup Screen to start modules while troubeshooting vehicle with engine not running.

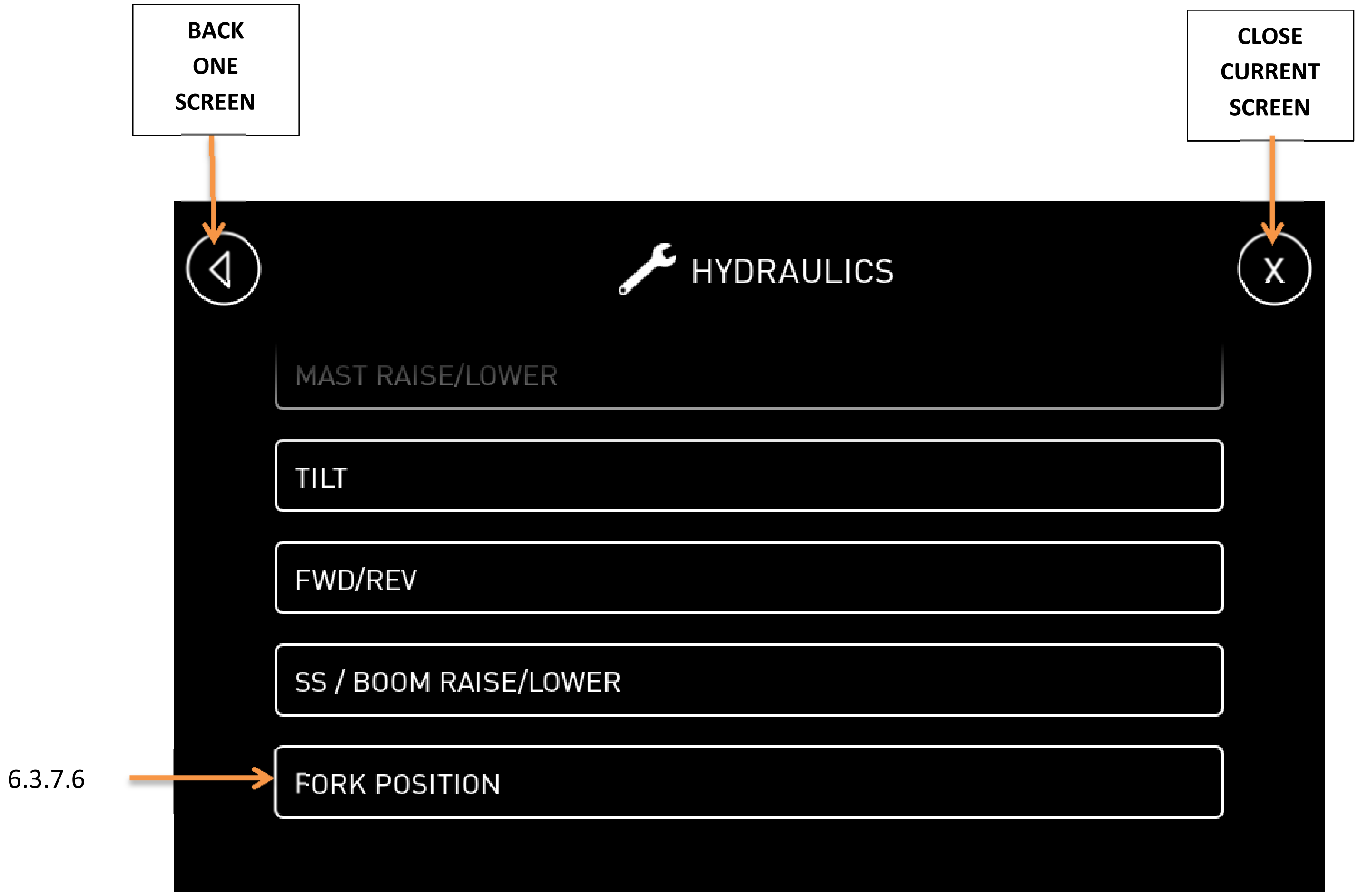


Item No	Item	Function
6.3.1.1	Service Meter Reset Button	Press to display +, value,-, ✓
6.3.1.2	Minus Button	Press to adjust value to '0'
6.3.1.3	Plus Button	Press to adjust value to '1'.
6.3.1.4	X Button	Press to Decline adjusted value.
6.3.1.5	Check Button	Press to Accept adjusted value.

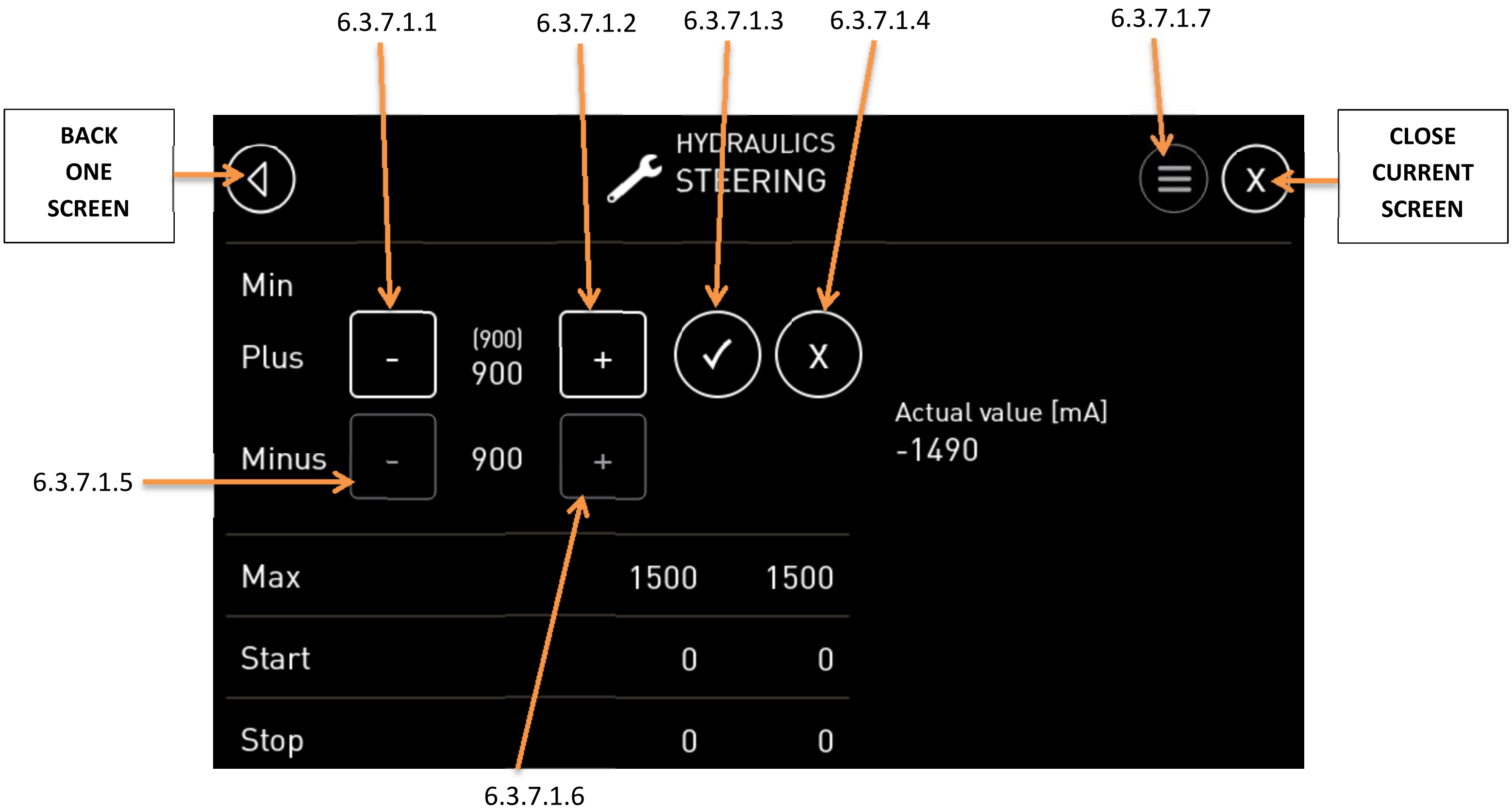


Item No	Item	Function
6.3.4.1	Service Meter Reset	Press to decrease time in Minutes that engine will shutdown automatically after operator leaves seat.
6.3.4.2	Plus Button	Press to increase time in Minutes that engine will shutdown automatically after operator leaves seat.
6.3.4.3	Check Button	Press to Accept adjusted value.
6.3.4.4	X Button	Press to Decline adjusted value.


BACK ONE SCREEN
CLOSE CURRENT SCREEN
HYDRAULICS
6.3.7.1
STEERING
6.3.7.2
MAST RAISE/LOWER
6.3.7.3
TILT
6.3.7.4
FWD/REV
6.3.7.5
SS / BOOM RAISE/LOWER

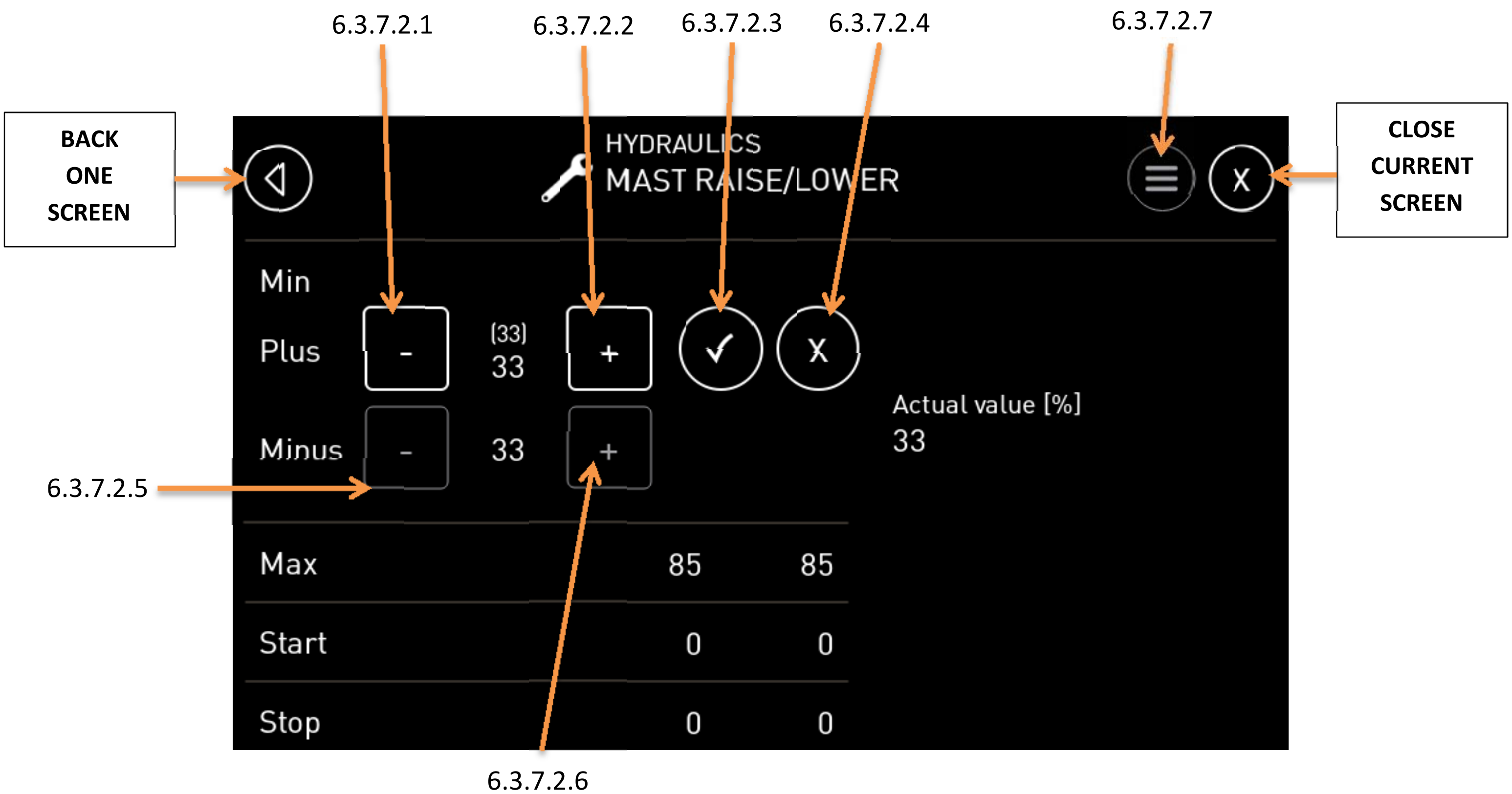


Item No	Item	Function
6.3.7.1	Steering	Press to adjust speed of Steering.
6.3.7.2	Mast Raise/Lower	Press to adjust the speed of Mast Lift and Lower.
6.3.7.3	Tilt	Press to adjust the speed of the Tilt function.
6.3.7.4	Forward/Reverse	Press to adjust Forward and Reverse speed of the vehicle.
6.3.7.5	SS/Boom Raise/Lower	Press to adjust the speed of Side Shift when forks are installed or Raise and Lower when boom is installed.
6.3.7.6	Fork Position	Press to adjust the speed of the fork postion function.



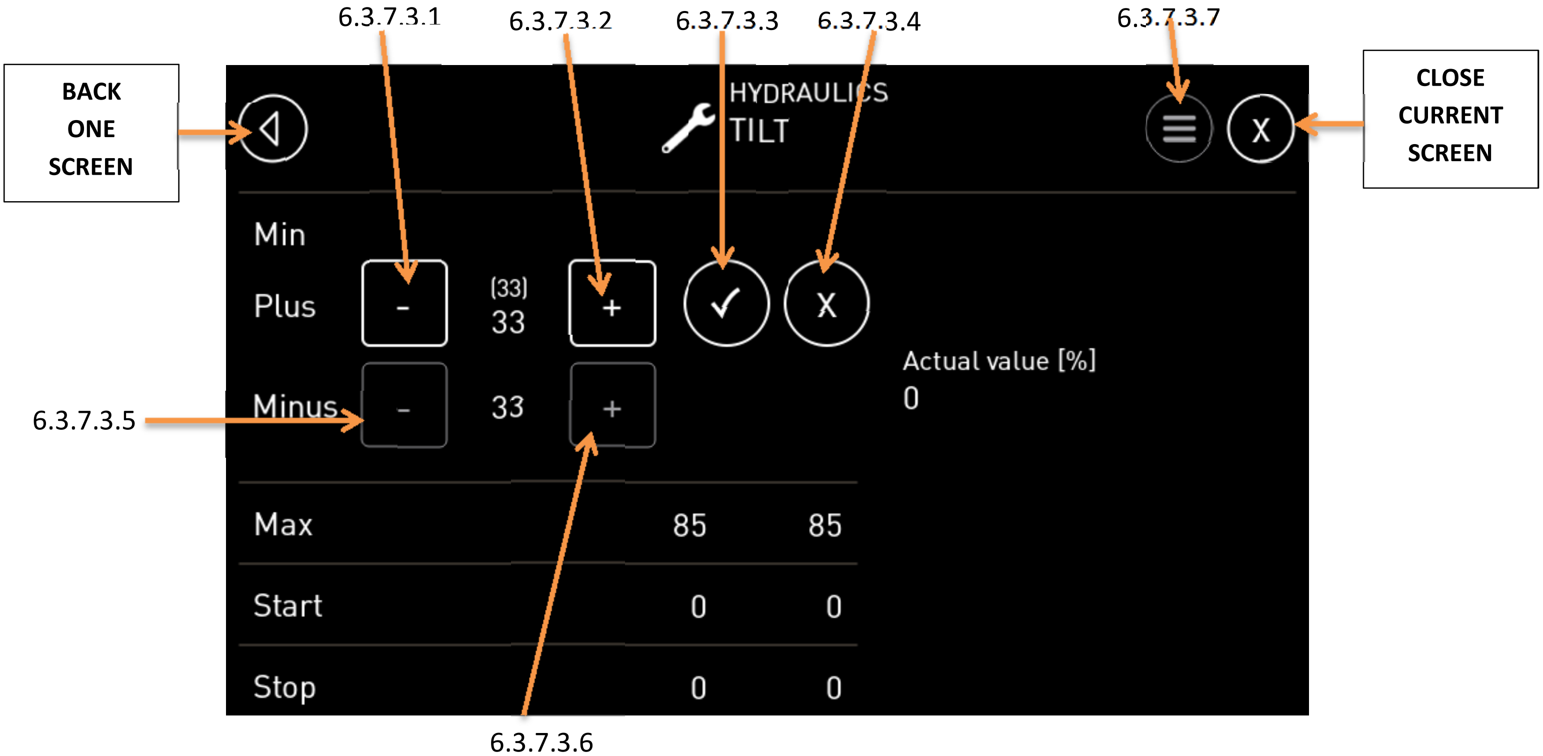
Item No	Item	Function
6.3.7.1.1	Plus Decrease Button	Press to decrease the minimum current to the valve when first starting to steer right using the pendant.
6.3.7.1.2	Plus Increase Button	Press to increase the minimum current to the valve when first starting to steer right using the pendant.
6.3.7.1.3	Check Button	Press to accept adjusted value.
6.3.7.1.4	X Button	Press to to decline adjusted value.
6.3.7.1.5	Minus Decrease Button	Press to decrease the minimum current to the valve when first starting to steer left using the pendant.
6.3.7.1.6	Minus Increase Button	Press to increase the minimum current to the valve when first starting to steer left using the pendant.
6.3.7.1.7	Reset Value Button	Press to reset the adjusted value to the factory default value.

All buttons listed (6.3.7.1.1-6.3.7.1.7) are used to set Minimum Current, Maximum Current, Start Slope and Stop Slope of Mast Raise and Lower. Minimum Current represents the power to the control valve when slowly raising/lowering. Maximum Current represents the power to the control valve when raising/lowering at full speed. Start Slope represents the time to accelerate from raise/lower stopped to maximum raise/lower speed. Stop Slope represents the time to decelerate from maximum raise/lower speed to stopped raise/lower.



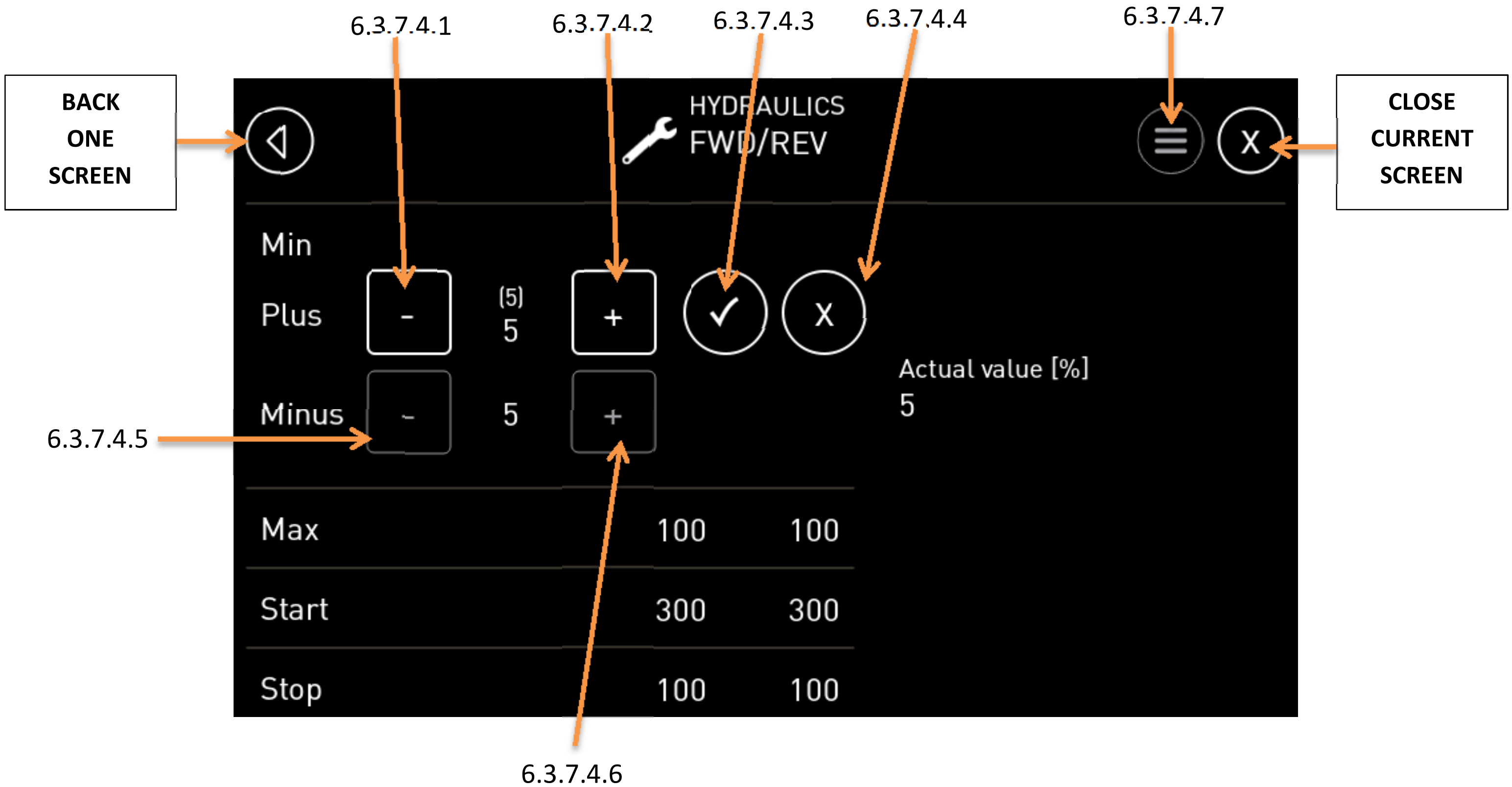
Item No	Item	Function
6.3.7.2.1	Plus Decrease Button	Press to decrease the minimum current to the valve when first starting to Lift using the pendant.
6.3.7.2.2	Plus Increase Button	Press to increase the minimum current to the valve when first starting to Lift using the pendant.
6.3.7.2.3	Check Button	Press to accept adjusted value.
6.3.7.2.4	X Button	Press to to decline adjusted value.
6.3.7.2.5	Minus Decrease Button	Press to decrease the minimum current to the valve when first starting to Lower using the pendant.
6.3.7.2.6	Minus Increase Button	Press to increase the minimum current to the valve when first starting to Lower using the pendant.
6.3.7.2.7	Reset Value Button	Press to reset the adjusted value to the factory default value.

All buttons listed (6.3.7.2.1-6.3.7.2.7) are used to set Minimum Current, Maximum Current, Start Slope and Stop Slope of Mast Raise and Lower. Minimum Current represents the power to the control valve when slowly raising/lowering. Maximum Current represents the power to the control valve when raising/lowering at full speed. Start Slope represents the time to accelerate from raise/lower stopped to maximum raise/lower speed. Stop Slope represents the time to decelerate from maximum raise/lower speed to stopped raise/lower.



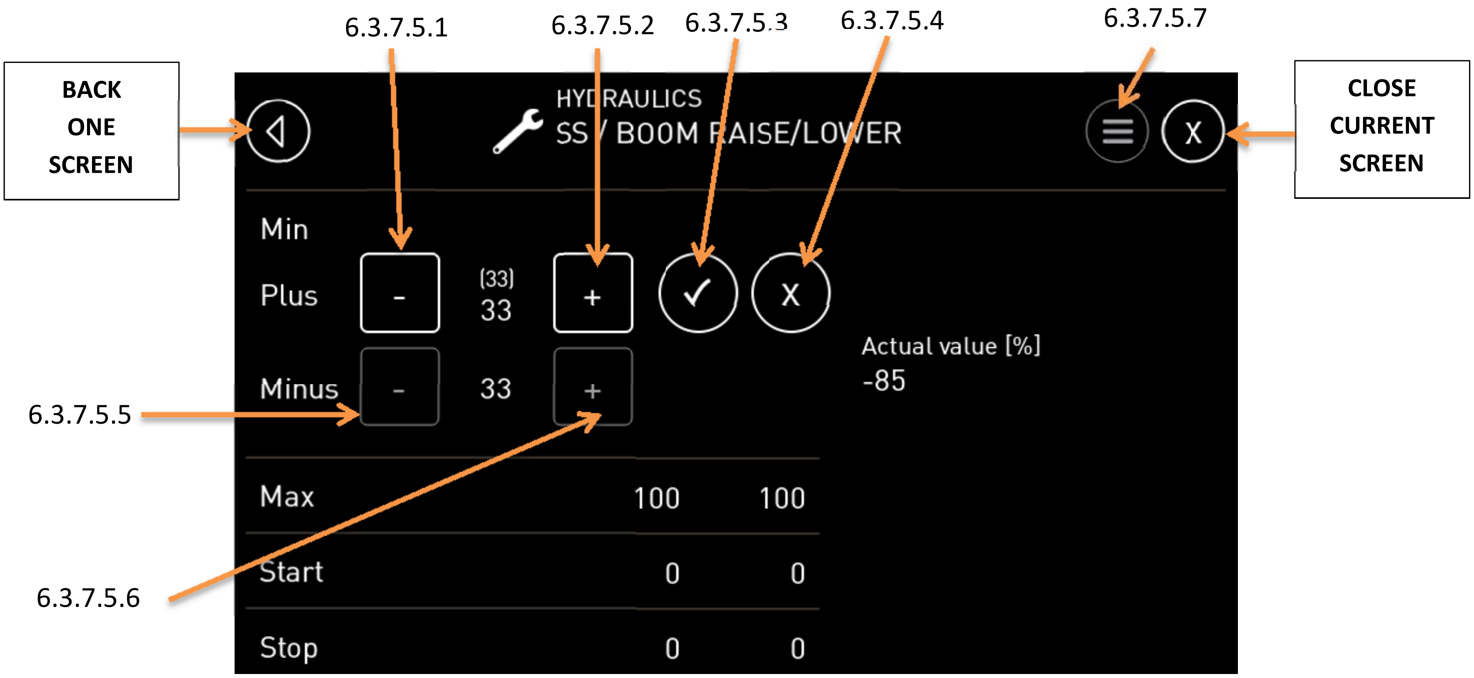
Item No	Item	Function
6.3.7.3.1	Plus Decrease Button	Press to decrease the minimum current to the valve when first starting to Tilt Back using the pendant.
6.3.7.3.2	Plus Increase Button	Press to increase the minimum current to the valve when first starting to Tilt Back using the pendant.
6.3.7.3.3	Check Button	Press to accept adjusted value.
6.3.7.3.4	X Button	Press to to decline adjusted value.
6.3.7.3.5	Minus Decrease Button	Press to decrease the minimum current to the valve when first starting to Tilt Forward using the pendant.
6.3.7.3.6	Minus Increase Button	Press to increase the minimum current to the valve when first starting to Tilt Forward using the pendant.
6.3.7.3.7	Reset Value Button	Press to reset the adjusted value to the factory default value.

All buttons listed (6.3.7.3.1-6.3.7.3.7) are used to set Minimum Current, Maximum Current, Start Slope and Stop Slope of Mast Raise and Lower. Minimum Current represents the power to the control valve when slowly raising/lowering. Maximum Current represents the power to the control valve when raising/lowering at full speed. Start Slope represents the time to accelerate from raise/lower stopped to maximum raise/lower speed. Stop Slope represents the time to decelerate from maximum raise/lower speed to stopped raise/lower.



Item No	Item	Function
6.3.7.4.1	Plus Decrease Button	Press to decrease the minimum current to the valve when first starting to move Forward/Reverse using the pendant.
6.3.7.4.2		Press to increase the minimum current to the valve when first starting to move Forward/Reverse using the pendant.
6.3.7.4.3	Check Button	Press to accept adjusted value.
6.3.7.4.4	X Button	Press to to decline adjusted value.
6.3.7.4.5	Minus Decrease Button	Press to decrease the minimum current to the valve when first starting to move Forward/Reverse using the pendant.
6.3.7.4.6	Minus Increase Button	Press to increase the minimum current to the valve when first starting to move Forward/Reverse using the pendant.
6.3.7.4.7	Reset Value Button	Press to reset the adjusted value to the factory default value.

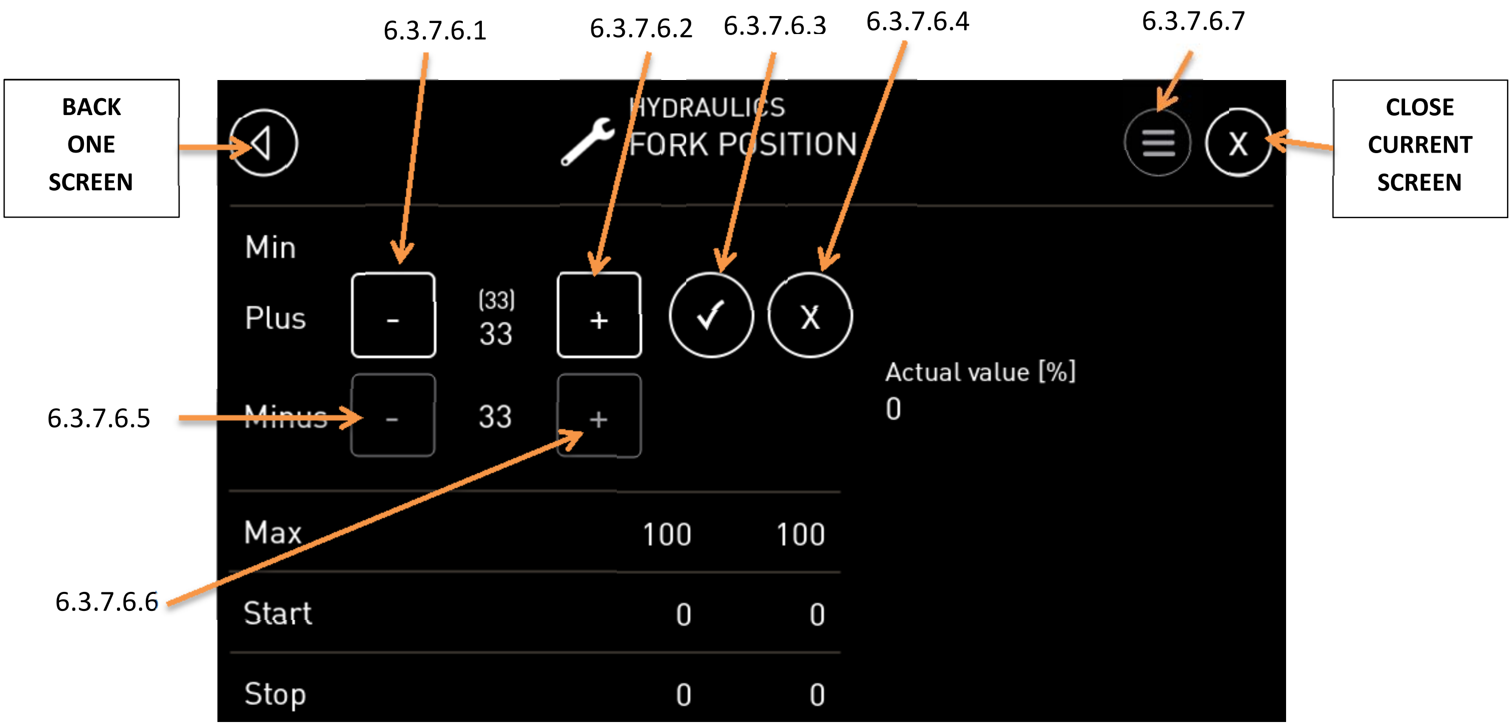
All buttons listed (6.3.7.4.1-6.3.7.4.7) are used to set Minimum Current, Maximum Current, Start Slope and Stop Slope of Mast Raise and Lower. Minimum Current represents the power to the control valve when slowly raising/lowering. Maximum Current represents the power to the control valve when raising/lowering at full speed. Start Slope represents the time to accelerate from raise/lower stopped to maximum raise/lower speed. Stop Slope represents the time to decelerate from maximum raise/lower speed to stopped raise/lower.



Item No	Item	Function
6.3.7.5.1	Plus Decrease Button	Press to decrease the minimum current to the valve when first starting to Side Shift Left using the pendant.
6.3.7.5.2	Plus Increase Button	Press to increase the minimum current to the valve when first starting to Side Shift Left using the pendant.
6.3.7.5.3	Check Button	Press to accept adjusted value.
6.3.7.5.4	X Button	Press to to decline adjusted value.
6.3.7.5.5	Minus Decrease Button	Press to decrease the minimum current to the valve when first starting to Side Shift Right using the pendant.
6.3.7.5.6	Minus Increase Button	Press to increase the minimum current to the valve when first starting to Side Shift Right using the pendant.
6.3.7.5.7	Reset Value Button	Press to reset the adjusted value to the factory default value.

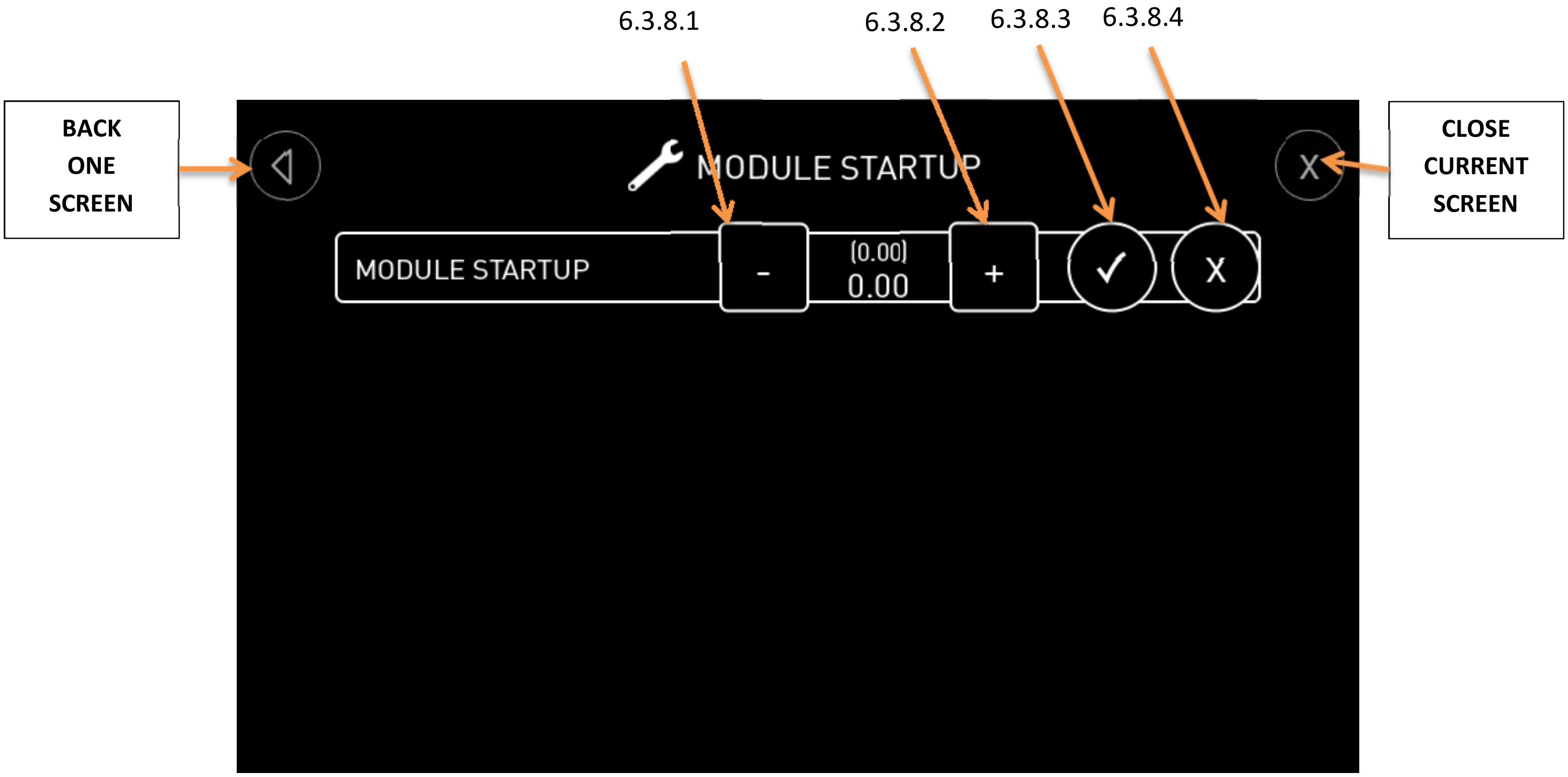
All buttons listed (6.3.7.5.1-6.3.7.5.7) are used to set Minimum Current, Maximum Current, Start Slope and Stop Slope of Mast Raise and Lower. Minimum Current represents the power to the control valve when slowly raising/lowering. Maximum Current represents the power to the control valve when raising/lowering at full speed. Start Slope represents the time to accelerate from raise/lower stopped to maximum raise/lower speed. Stop Slope represents the time to decelerate from maximum raise/lower speed to stopped raise/lower.

All buttons listed (6.3.7.5.1-6.3.7.5.7) are used to set Side Shift when the vehicle is used with forks or Boom Raise/Lower when vehicle is used with a Boom attachment.



Item No	Item	Function
6.3.7.6.1	Plus Decrease Button	Press to decrease the minimum current to the valve when first starting to Fork Position Out using the pendant.
6.3.7.6.2	Plus Increase Button	Press to increase the minimum current to the valve when first starting to Fork Position Out using the pendant.
6.3.7.6.3	Check Button	Press to accept adjusted value.
6.3.7.6.4	X Button	Press to to decline adjusted value.
6.3.7.6.5	Minus Decrease Button	Press to decrease the minimum current to the valve when first starting to Fork Position In using the pendant.
6.3.7.6.6	Minus Increase Button	Press to increase the minimum current to the valve when first starting to Fork Position In using the pendant.
6.3.7.6.7	Reset Value Button	Press to reset the adjusted value to the factory default value.

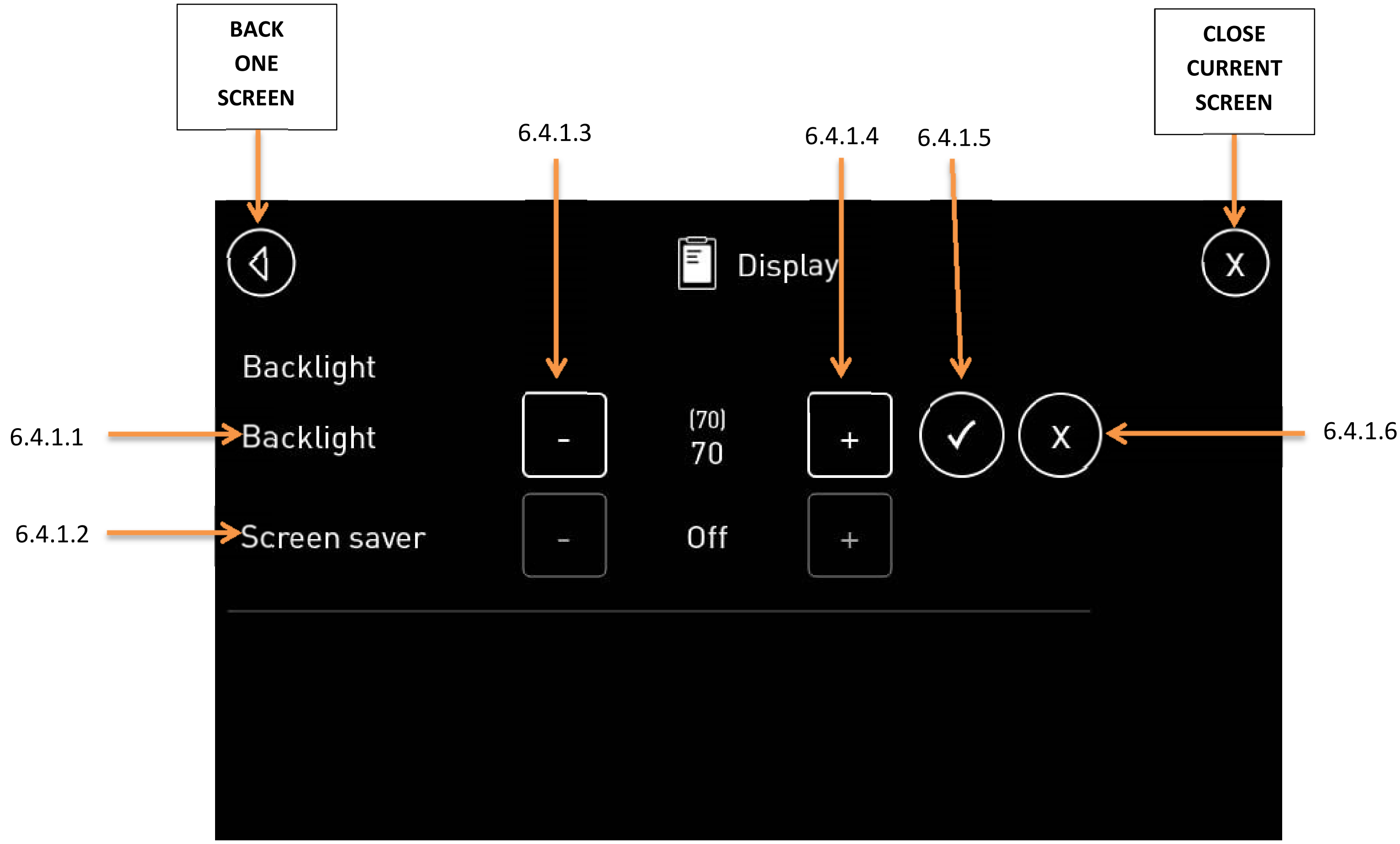
All buttons listed (6.3.7.6.1-6.3.7.6.7) are used to set Minimum Current, Maximum Current, Start Slope and Stop Slope of Mast Raise and Lower. Minimum Current represents the power to the control valve when slowly raising/lowering. Maximum Current represents the power to the control valve when raising/lowering at full speed. Start Slope represents the time to accelerate from raise/lower stopped to maximum raise/lower speed. Stop Slope represents the time to decelerate from maximum raise/lower speed to stopped raise/lower.



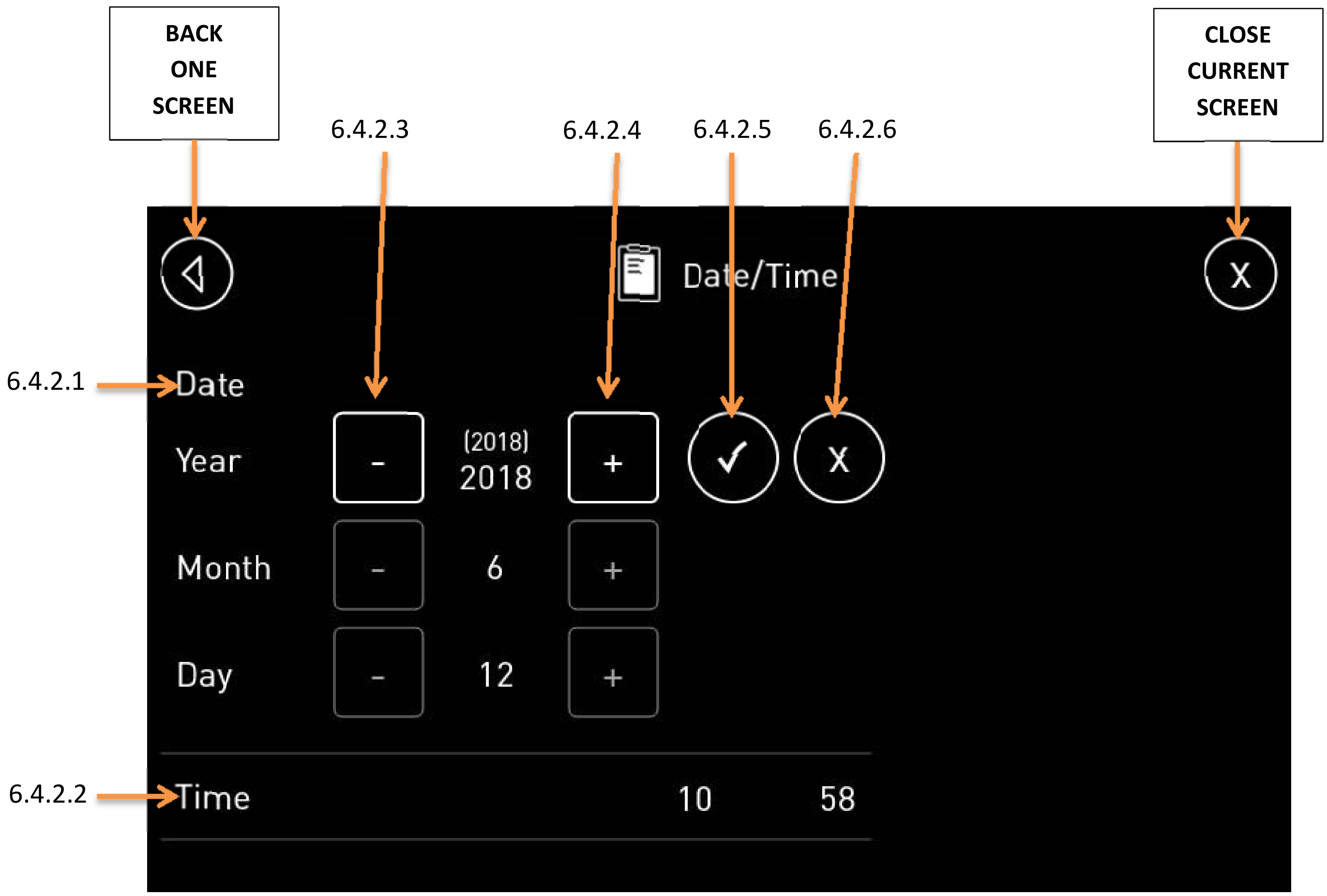
Item No	Item	Function
6.3.8.1	Minus Button	Press to set Module Startup to 0. All expander modules will be disabled unless engine is running.
6.3.8.2	Plus Button	Press to set Module Startup to 1. All expander modules will be enabled regardless if engine is running.
6.3.8.3	Check Button	Press to Accept adjusted value.
6.3.8.4	X Button	Press to Decline adjusted value.

Settings 6.3.8.1 - 6.3.8.4 are used to turn all expander modules on/off to allow troubleshooting of vehicle with engine not running via measure screens.

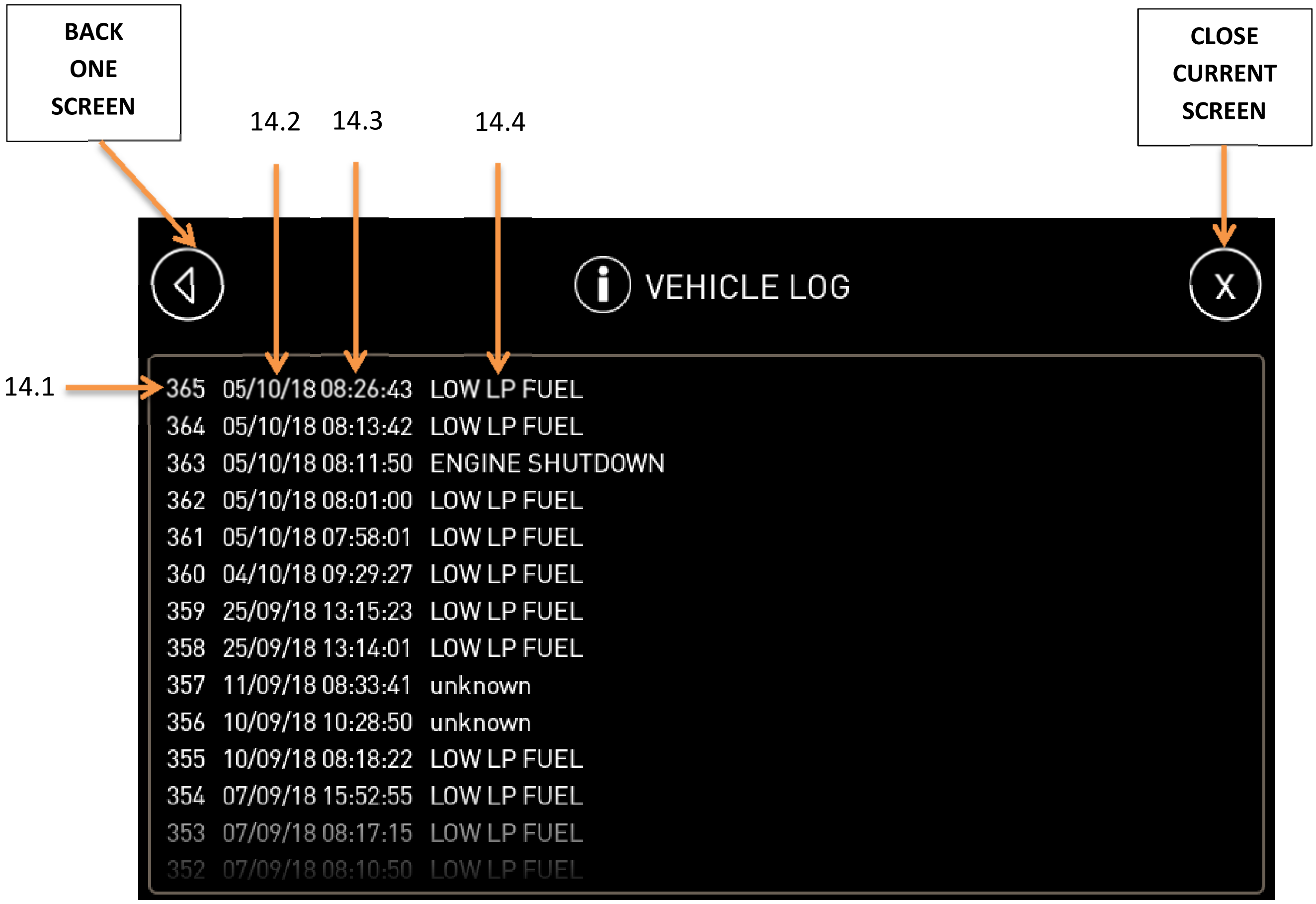
Item No	Item	Function
6.4.1	Display Preferences Button	Press to adjust Display Preferences
6.4.2	Date/Time Preferences Button	Press to set Date/Time



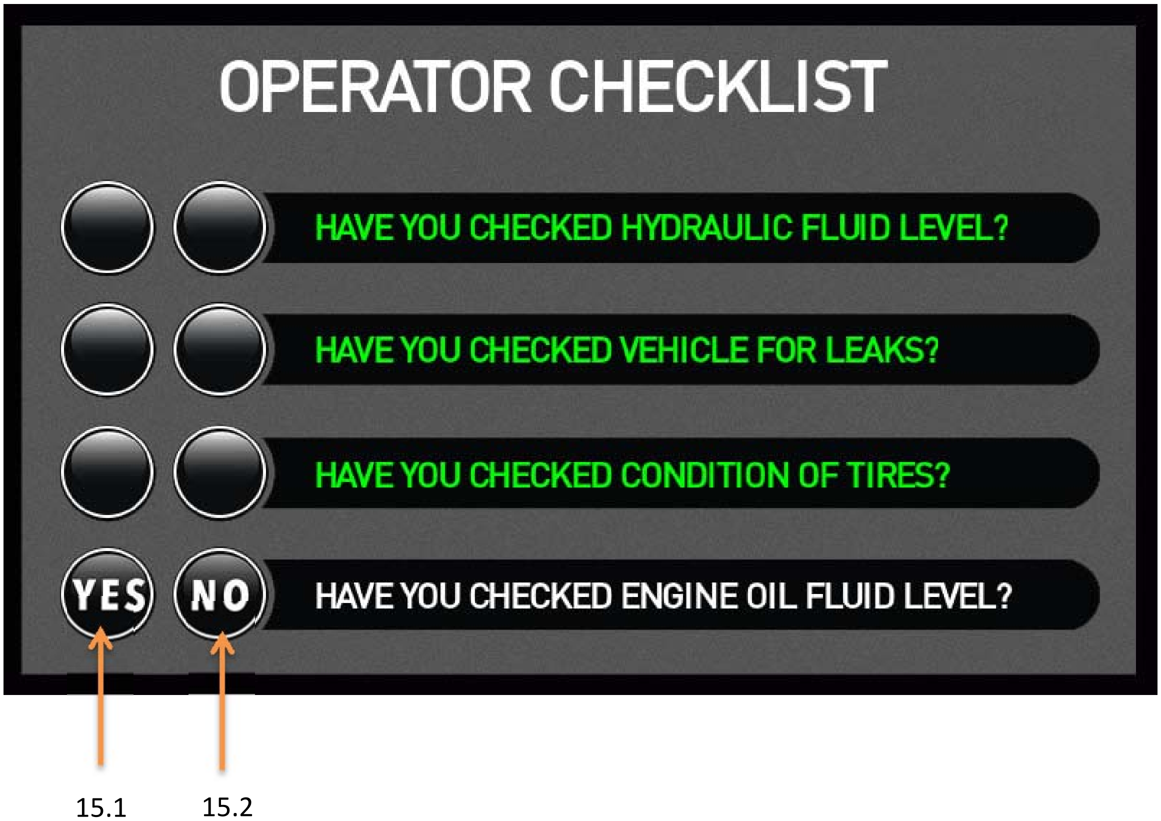
Item No	Item	Function
6.4.1.1	Backlight Adjustment	Press to adjust Backlighting Preferences
6.4.1.2	Screen Saver	Scree Saver fucntion is not enabled.
6.4.1.3	Minus Button	Press to Decrease value.
6.4.1.4	Plus Button	Press to Increase value.
6.4.1.5	Check Button	Press to Accept adjusted values
6.4.1.6	X Button	Press to Cancel adjusted values.



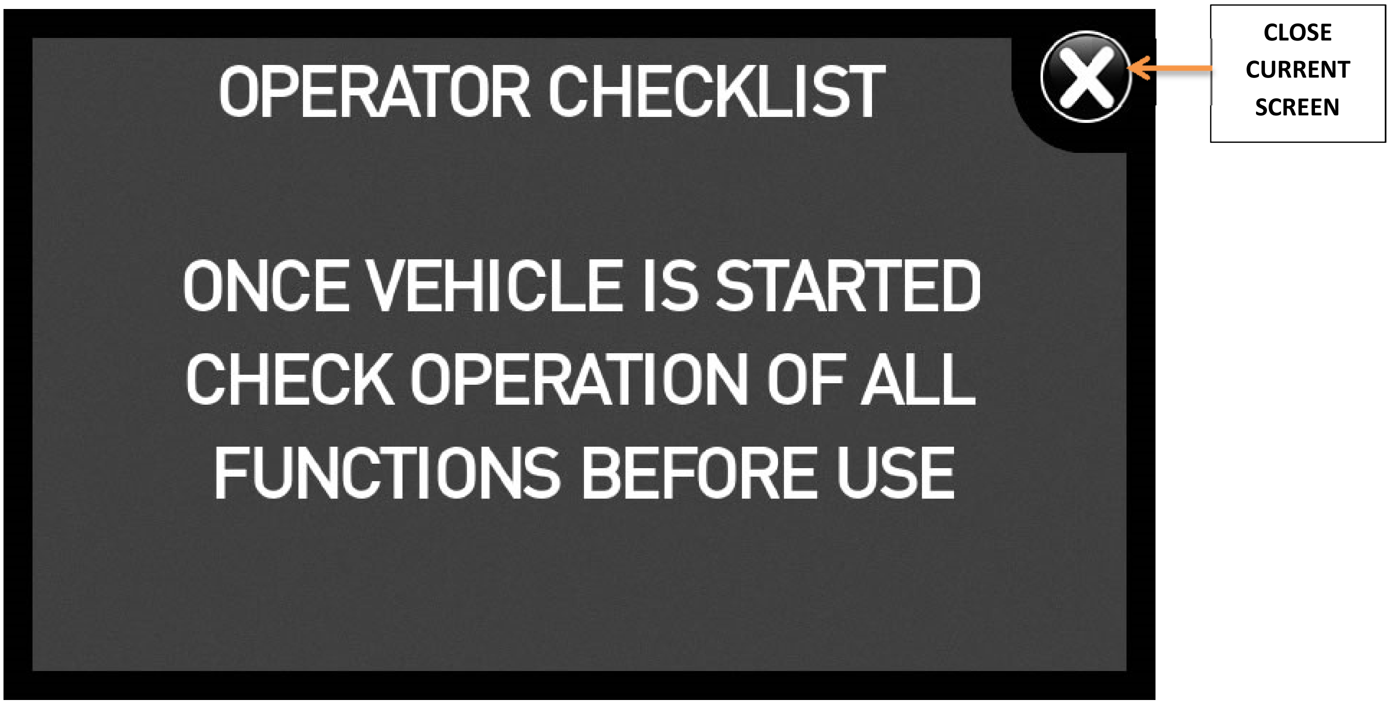
Item No	Item	Function
6.4.2.1	Date Adjustment	Press to adjust Date values
6.4.2.2	Time Adjustment	Press to adjust Time values
6.4.2.3	Minus Button	Press to Decrease value
6.4.2.4	Plus Button	Press to Increase value
6.4.25	Check Button	Press to Accept adjusted values.
6.4.2.6	X Button	Press to Cancel adjusted values.

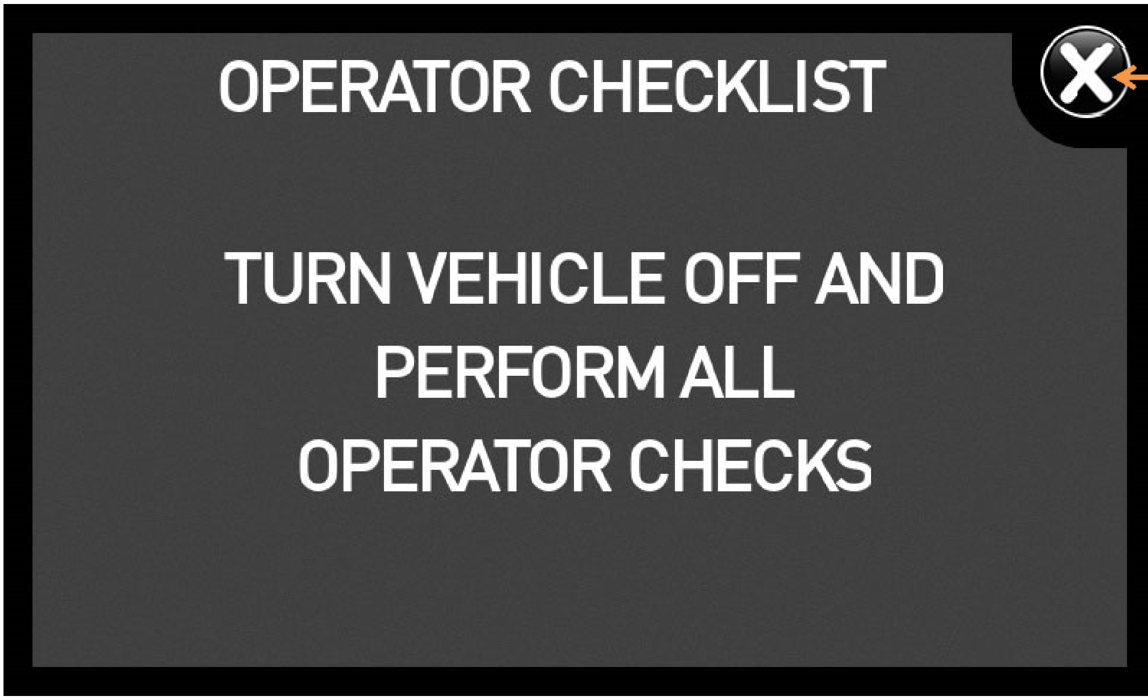


Item No	Item	Function
14.1	Event Number	Lists the Event Number of the logged event. Event numbers are listed in sequential order.
14.2	Event Date	The Event Date of the logged event is listed in American English format.
14.3	Event Time	The Event Time of the logged event is listed in 24 hour time format.
14.4	Logged Event	The Logged Event is listed. Contact your authorized dealer for further detail of any Logged Event.

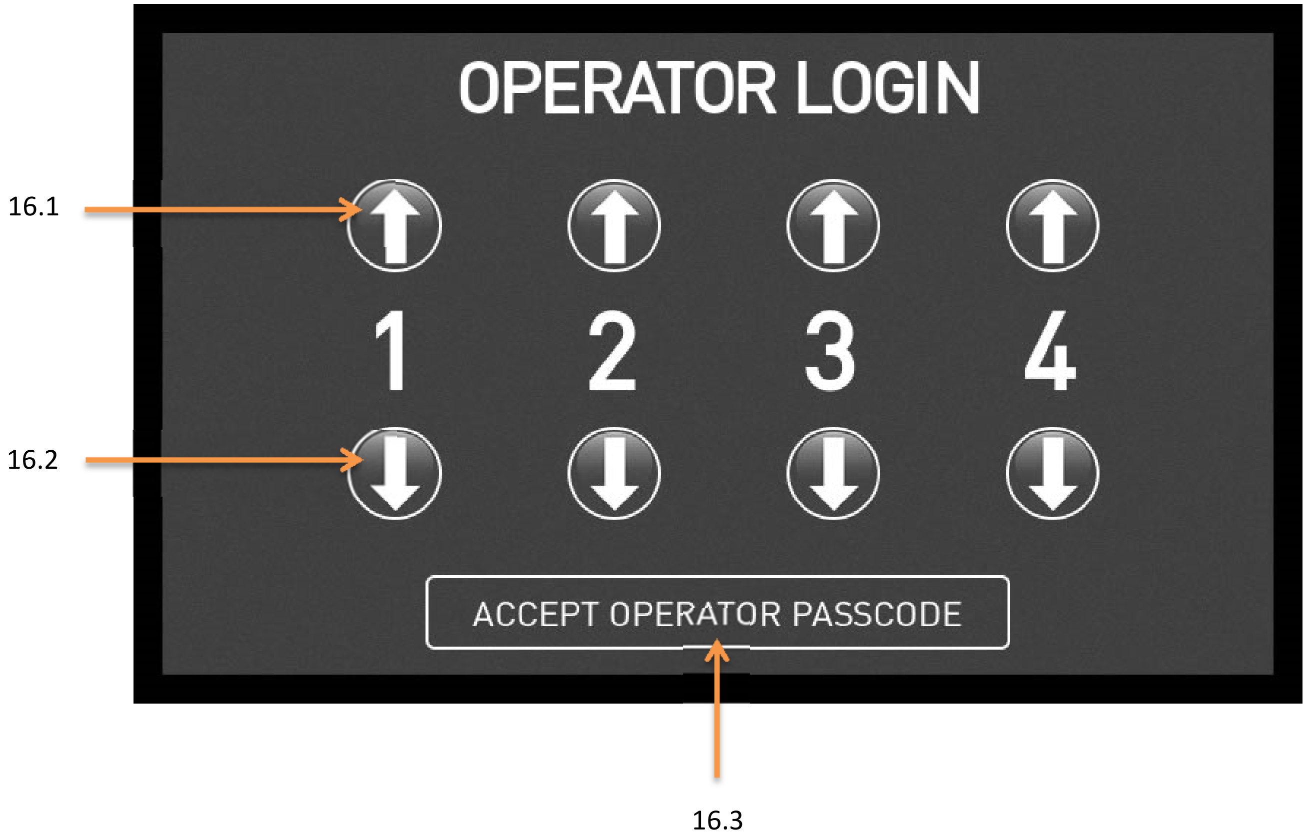


Item No	Item	Function
15.1	Yes Button	Press to answer YES to checklist item.
15.2	No Button	Press to answer NO to checklist item

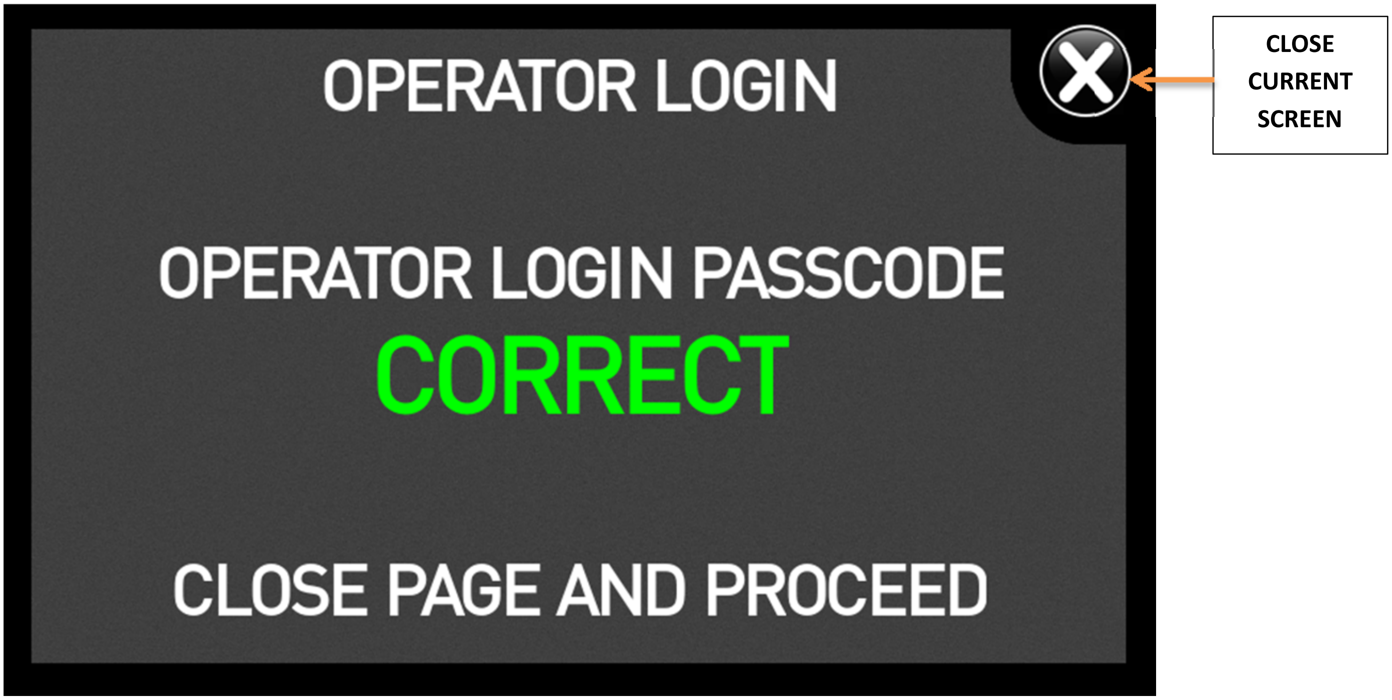

OPERATOR CHECKLIST
ONCE VEHICLE IS STARTED CHECK OPERATION OF ALL FUNCTIONS BEFORE USE
CLOSE CURRENT SCREEN

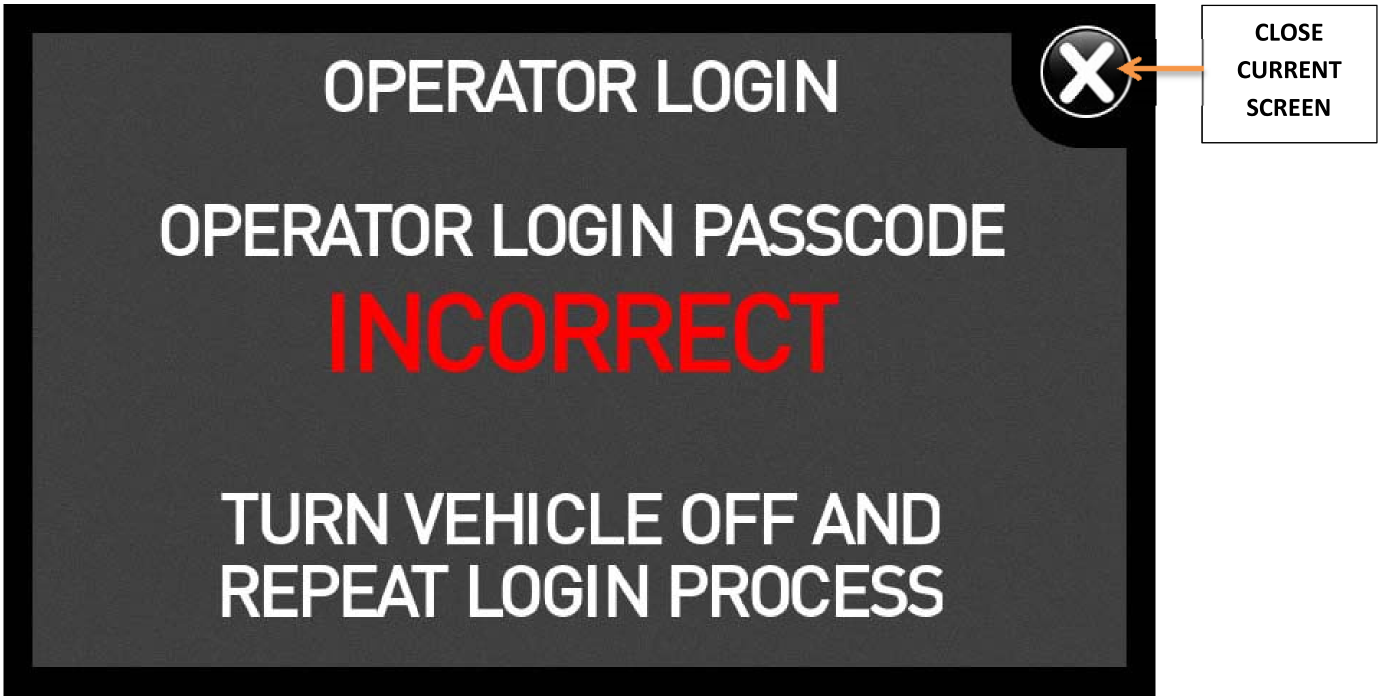


CLOSE CURRENT SCREEN



Item No	Item	Function
16.1	Up Arrow Button	Press to increase value.
16.2	Down Arrow Button	Press to decrease value.
16.3	Accept Operator Passcode Button	Press to enter complete passcode.


OPERATOR LOGIN
OPERATOR LOGIN PASSCODE
CORRECT
CLOSE PAGE AND PROCEED
CLOSE CURRENT SCREEN


OPERATOR LOGIN
OPERATOR LOGIN PASSCODE
INCORRECT
TURN VEHICLE OFF AND
REPEAT LOGIN PROCESS
CLOSE
CURRENT
SCREEN

CLOSE CURRENT SCREEN

FR15/25, FR18/26, & FR25/35 SERVICE MANUAL *ELECTRICAL*

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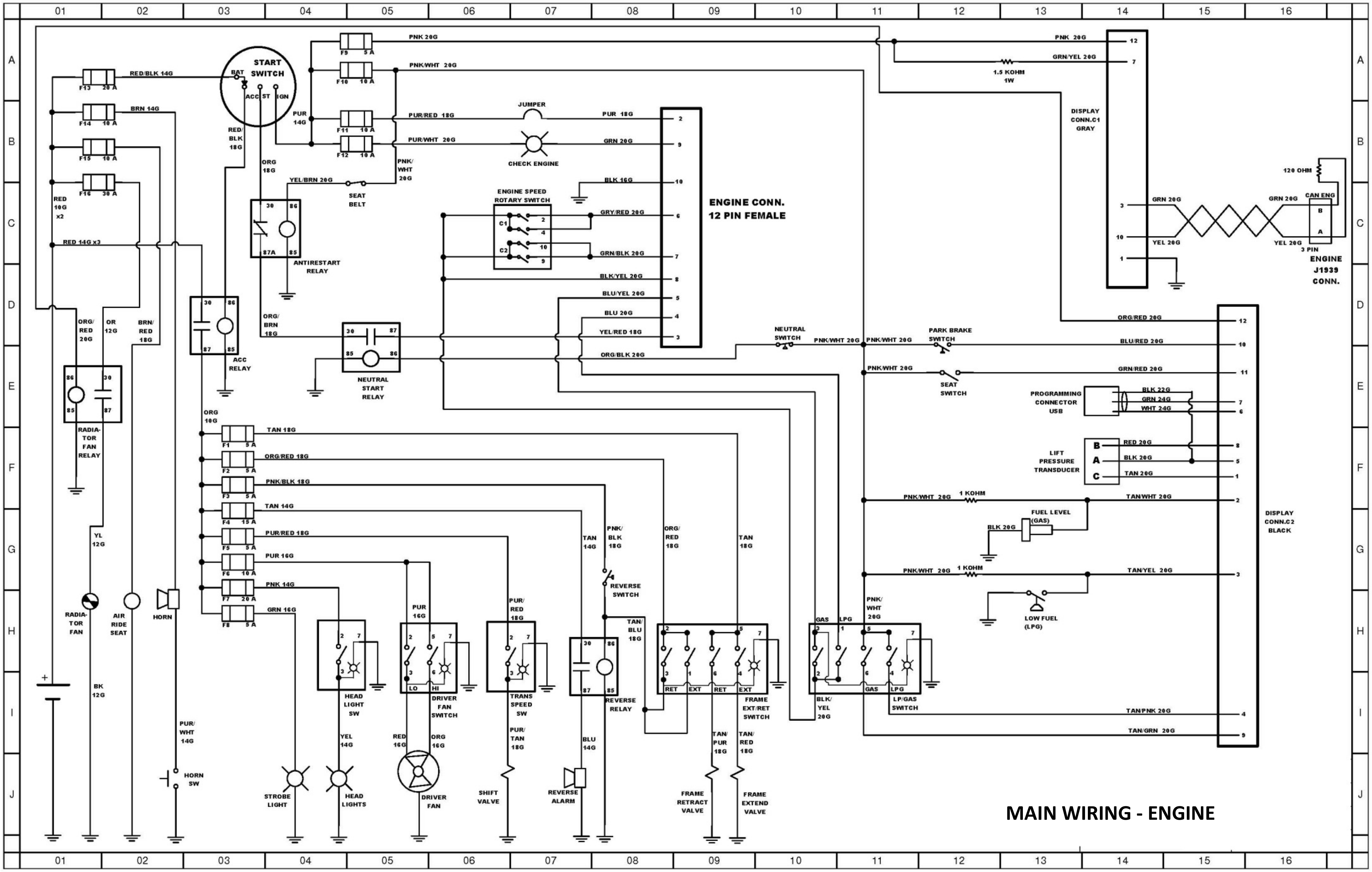
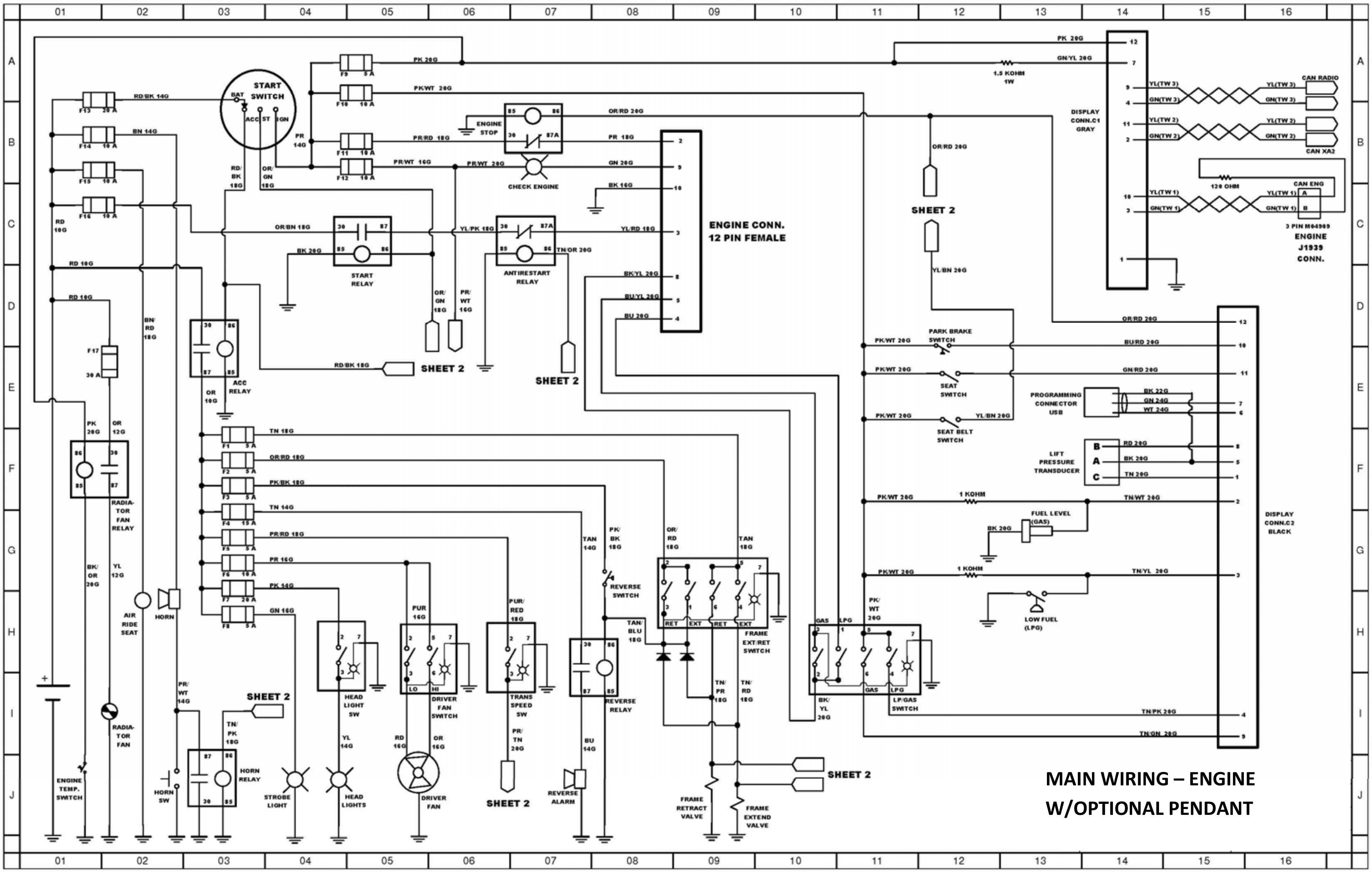
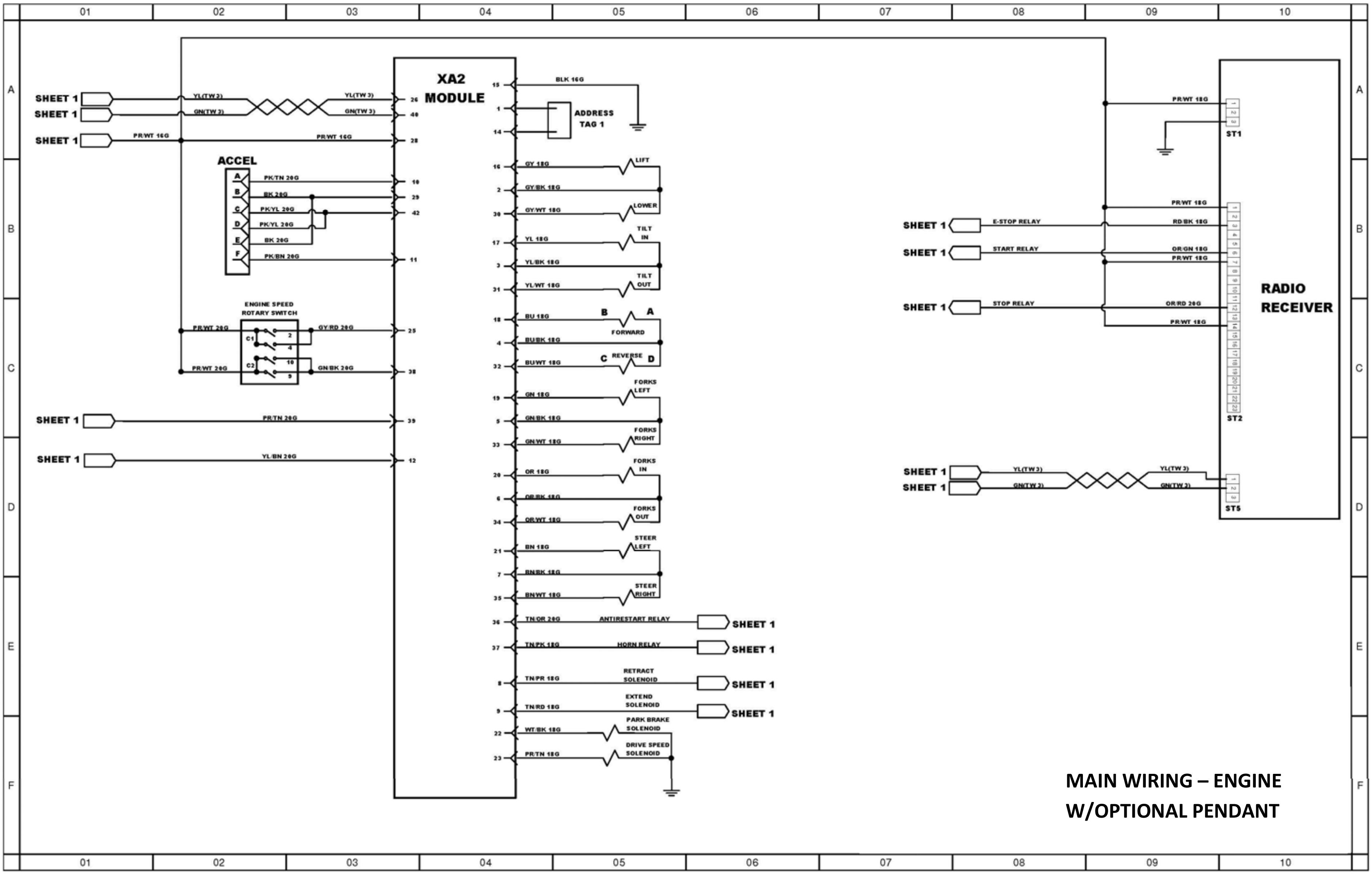
FR15/25, FR18/26, & FR25/35 SERVICE MANUAL – ELECTRICAL

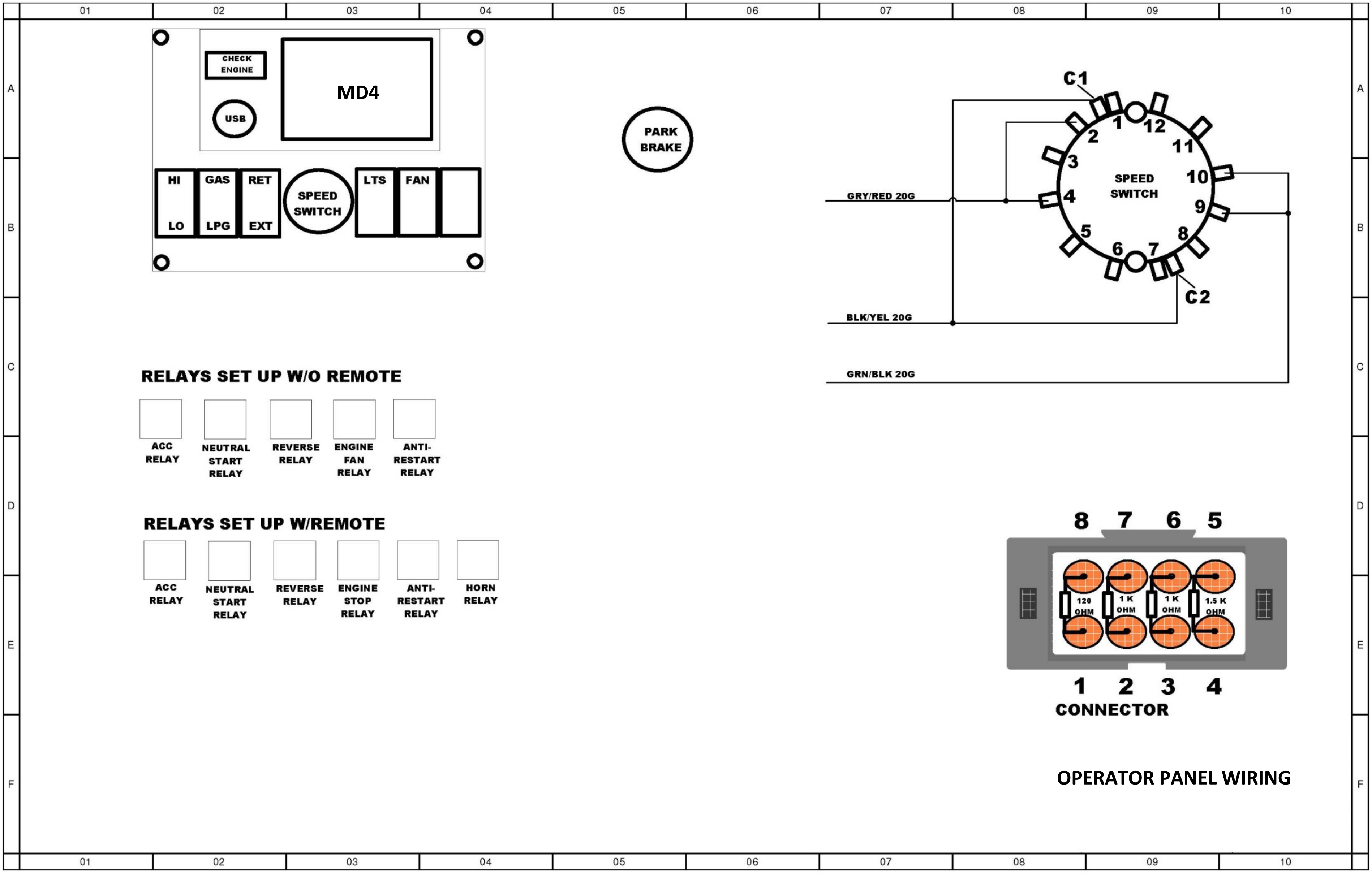




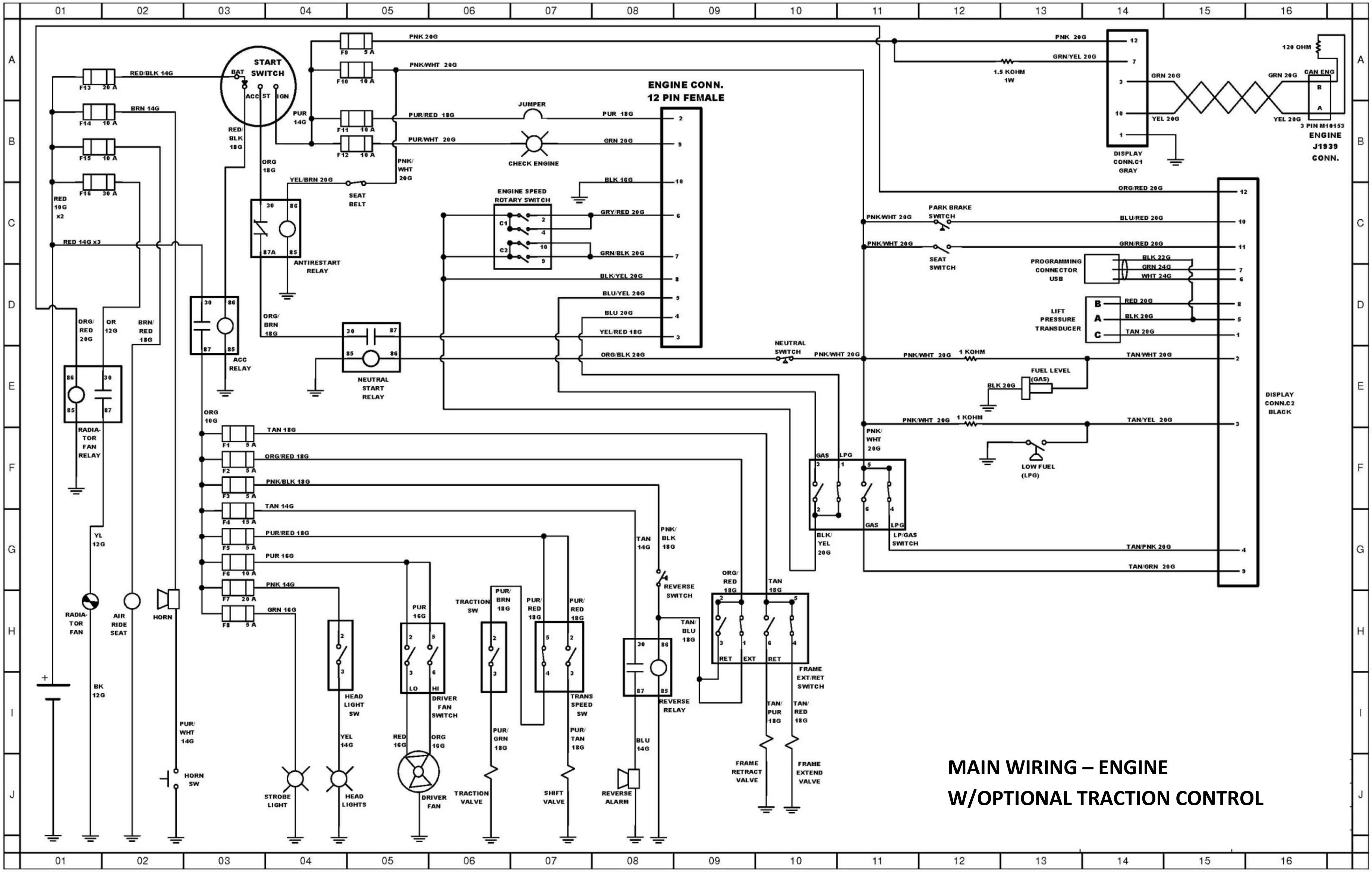
MAIN WIRING – ENGINE W/OPTIONAL PENDANT



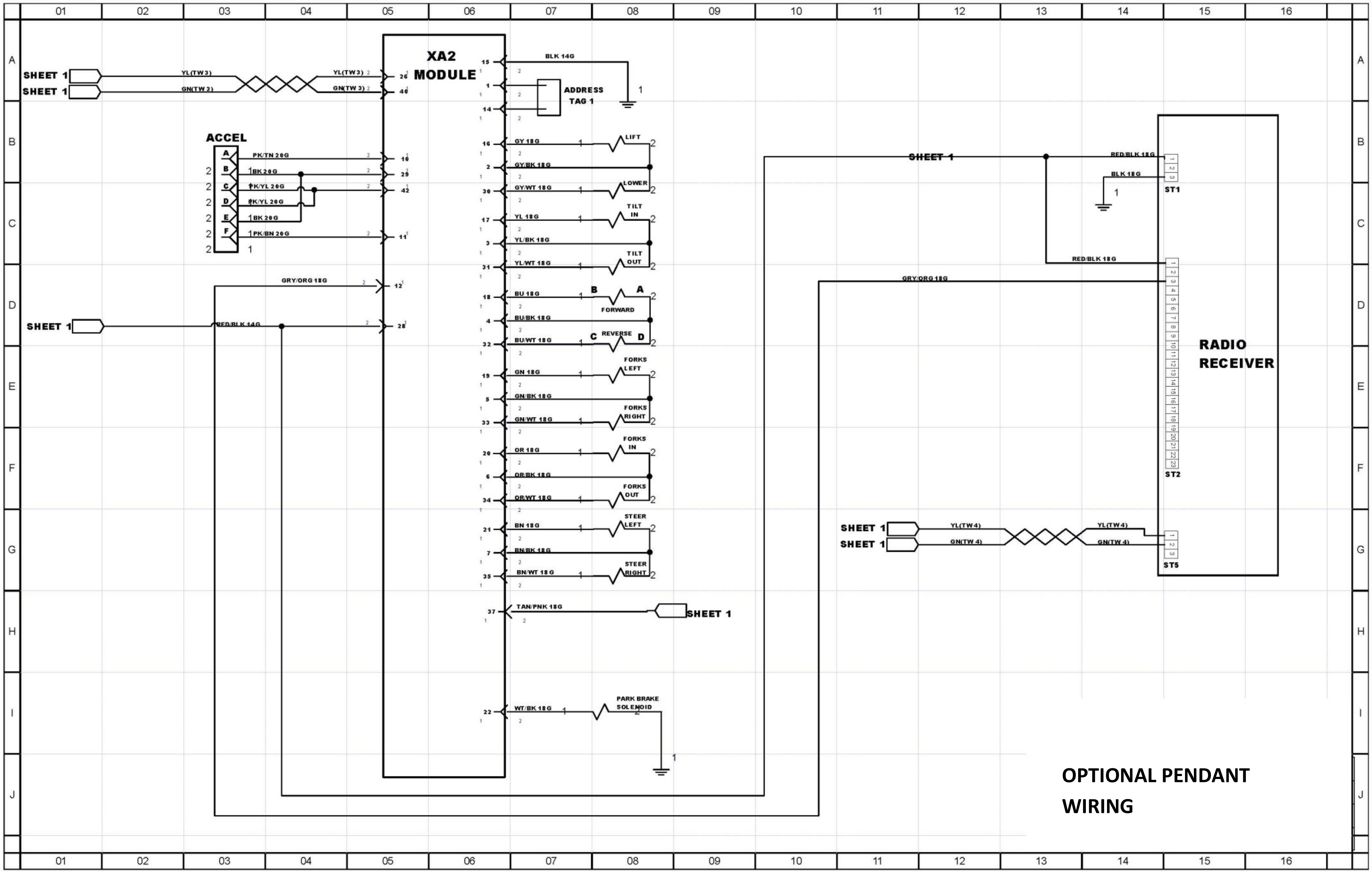
MAIN WIRING – ENGINE
W/OPTIONAL PENDANT



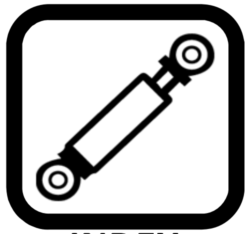
OPERATOR PANEL WIRING



MAIN WIRING – ENGINE
W/OPTIONAL TRACTION CONTROL


XA2 MODULE
ACCEL
ADDRESS TAG 1
RADIO RECEIVER
ST1
ST2
ST5
SHEET 1
YL(TW3)
GN(TW3)
YL(TW4)
GN(TW4)
BLK 14G
PK/TN 20G
BK 20G
PK/YL 20G
PK/BN 20G
GRY/ORG 18G
RED/BLK 14G
RED/BLK 18G
BLK 18G
GY 18G
GY/BK 18G
GY/WT 18G
YL 18G
YL/BK 18G
YL/WT 18G
BU 18G
BU/BK 18G
BU/WT 18G
GN 18G
GN/BK 18G
GN/WT 18G
OR 18G
OR/BK 18G
OR/WT 18G
BN 18G
BN/BK 18G
BN/WT 18G
TAN/PNK 18G
WT/BK 18G
LIFT
LOWER
TILT IN
TILT OUT
FORWARD
REVERSE
FORKS LEFT
FORKS RIGHT
FORKS IN
FORKS OUT
STEER LEFT
STEER RIGHT
PARK BRAKE SOLENOID
OPTIONAL PENDANT WIRING

FR15/25, FR18/26, & FR25/35 SERVICE MANUAL *HYDRAULICS*



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QUALITY HYDRAULIC FLUIDS

Today's hydraulic fluid has to be tougher to provide peak pressure and instant power through hours of constant operation. It must stand up to the rigors of day to day day operation in all types of applications. It has to be ready to go on cold winter mornings and not let down on hot summer afternoons. This means more oil wear requiring the need for built-in quality.

Quality Hydraulic Fluid Needs:

- Anti-wear properties to prevent scuffing and excessive wear at high speeds, as well as high-pressure operations.
- High stability to resist oxidation, prevent varnish formation and deposits that foul systems.
- Additives to prevent rust formation from moisture condensation.
- Anti-foam agents to break up air bubbles in the fluid and prevent "foaming" that can cause sluggish, erratic operations.
- Good viscosity index for easy flow at low temperatures without thinning out at high temperatures after extended use.
- Seal conditioner properties to prevent cracking or excessive swelling of seal that can result in fluid leaks.

The need for good quality hydraulic fluid is very important in today's hard working vehicles. In today's demanding systems just any hydraulic fluid won't do. The wrong fluid is a sure path to trouble. Always make sure that the hydraulic fluid you use meets or exceeds vehicle manufacturer's specification.

HYDRAULIC FITTINGS: ASSEMBLY & TORQUE

- **Pipe Fittings**
- **37° JIC Flare Fittings**
- **O-Ring Boss Fittings**
- **O-Ring Face Seal Fittings**
- **Flareless Fittings**
- **Split Flange Adapters**

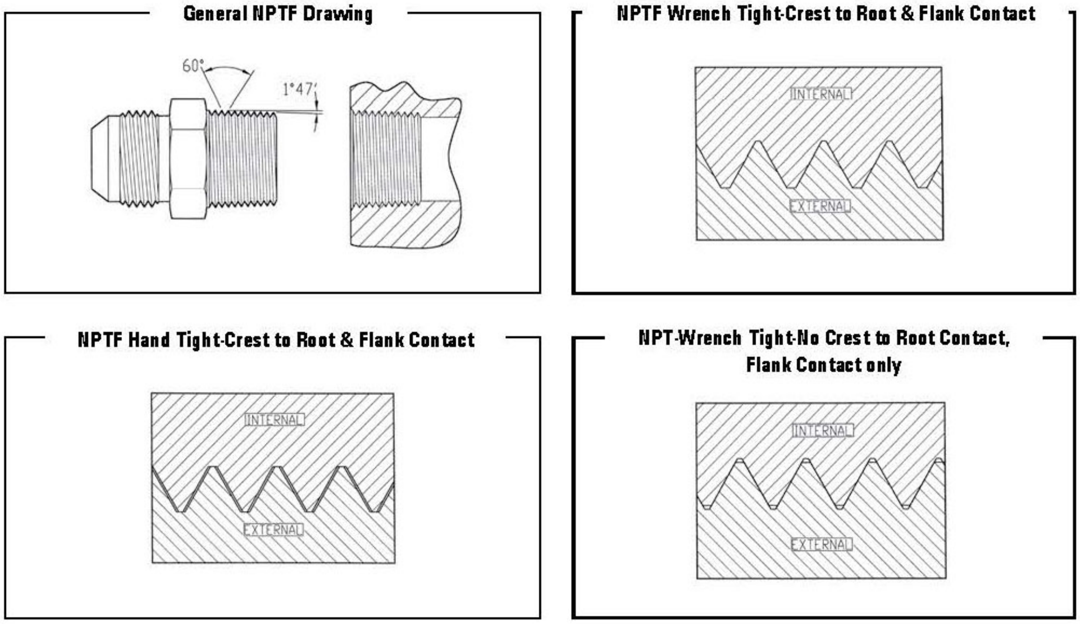
Informational Tips

Over-Torque Abuse can lead to fitting damage resulting in leakage. Use proper torque specifications regarding thread type and size.

HYDRAULIC FITTINGS: ASSEMBLY & TORQUE (CONT'D)

PIPE FITTINGS

Pipe Threads



The pipe fitting has been with us since hydraulics first appeared on the scene and it is still with us today on applications used all over the world. The difference is that today's pipe thread comes in many different Standards. The most common pipe threads in North America are designated as:

NPT = American (National) Standard Pipe Taper
NPTF = American (National) Standard Pipe Taper Fuel (Dryseal)

Both NPT and NPTF taper pipe threads seal by deformation of threads. NPTF threads have a Dryseal designation with the Crest-Root contact designed so that no spiral leak path is left. Pressure Connections uses the NPTF thread, except where noted, because it has greater holding power and resistance to leakage. Although NPTF threads are designed to seal without the use of any pipe sealant, pipe sealant is normally used and recommended for added protection against leakage, galling, and spreading the torque evenly when tightening.

Sealant Paste Application: After marking sure the threads are clean, evenly apply the paste over the threads exercising care not to leave any air pockets or bubbles. Be sure to leave the first 1/2 to 1-1/2 threads bare to avoid system contamination. *CAUTION: Do not use both paste and tape simultaneously.*

Sealant Tape Application: After making sure the threads are clean, tightly wrap the tape in the *clockwise* direction overlapping half the width of the tape with each wrap. Apply no more than two plies per thread leaving the first two threads bare to avoid system contamination.

Pipe Thread Assembly: With proper sealant applies, tighten the pipe threads **2 full turns** past finger tight on **sizes up to 1/2"** with **larger sizes** being **1.5 – 2.5 full turns** past finger tight. To obtain a correct alignment for elbows and tees follow these instructions and then continue tightening to the desired point. Be careful NOT to accidentally back off or loosen a pipe thread to obtain the correct alignment because this may result in a spiral leak path. It should be noted that a pipe thread is NOT recommended for vibration or temperature cycling environments. Pipe threads should also be limited to ONE use in high pressure hydraulic applications

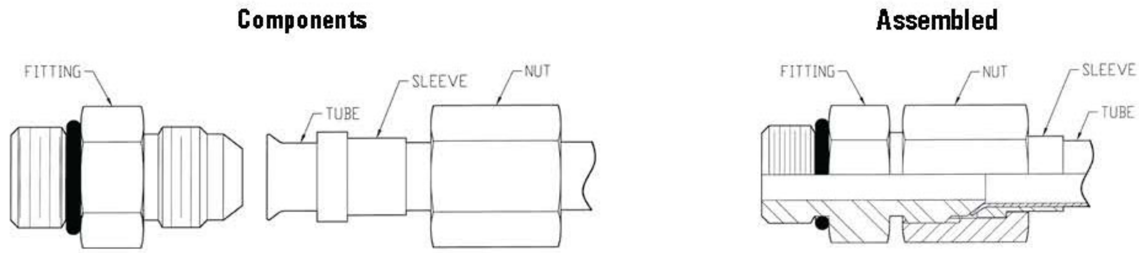
Pipe Points

- Since **Pipe Threads Crush** to create a seal, they should be limited to one use only, unless the application is low pressure.
- To prevent **System Contamination** avoid placing sealant on the first two threads.
- We recommend **Anaerobic Pipe Sealant** for the best pipe seal.
- ™Teflon tape should be wrapped around the threads a maximum of two times and should NOT be used with anaerobic pipe sealant.

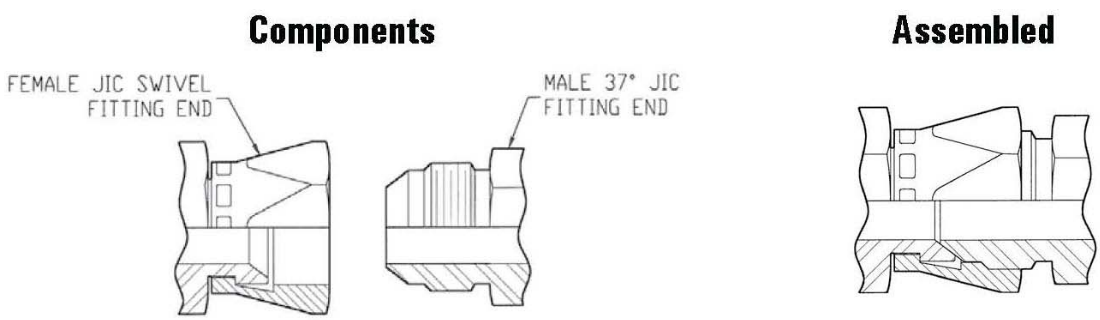
™Teflon is a trademark of DuPont

HYDRAULIC FITTINGS: ASSEMBLY & TORQUE (CONT'D)

37° JIC FLARE FITTINGS



The 37° JIC (Joint Industrial Council) Flare is a reliable, straight thread, single-flare design that is used world-wide. It is popular in many applications and environments because it is compact and easy to assemble. It also features high holding power with low torque requirements. The 37° JIC connection consists of three pieces: the nut, the sleeve, and the fitting in a range of sizes from 1/8" up through 2". The sleeve not only absorbs vibration, but acts as a support to the flare during assembly and helps reduce the risk of twisting the tube. Since it is a metal-to-metal seal, it can be reliably connected and reconnected multiple times. Because flaring is necessary, it is NOT recommended for thick wall tubing, and the tubing used should not be harder than Rockwell B65.



The 37° Female JIC Swivel (FJX) is designed to accept a male 37° JIC Flare. No tube nut or sleeve is required because the swivel nut is permanently crimped onto the body containing a female 37° flare. Female JIC Swivels use the same torque values as the Male 37° JIC Flares.

37° JIC Flare Torque Values

F.F.F.T.	Size	lb.-ft. min/max.
–	-02	6–7
–	-03	8–9
2	-04	11–12
2	-05	14–15
1 1/2	-06	18–20
1 1/2	-08	36–39
1 1/2	-10	57–63
1 1/4	-12	79–88
1	-14	94–103
1	-16	108–113
1	-20	127–133
1	-24	158–167
1	-32	245–258

Flats From Finger Tight (F.F.F.T.)
is a Turns Method that counts the number of hex flats past the finger tightened position.

Assembly Steps With a Visual Check

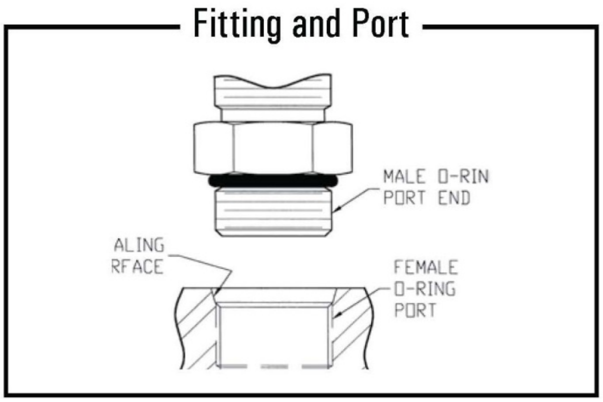
1. With the tube flare, make sure the tubing and threads are clean.
2. Lubricate the threads with 10W hydraulic oil.
3. Hand tighten the nut/sleeve (approx.. 30 lb-in.).
4. Make alignment marks on the nut and fitting.
5. Proceed to tighten to F.F.F.T. or lb-ft. values.
6. When fully tightened make a 2nd set of alignment marks at the fully tightened position.

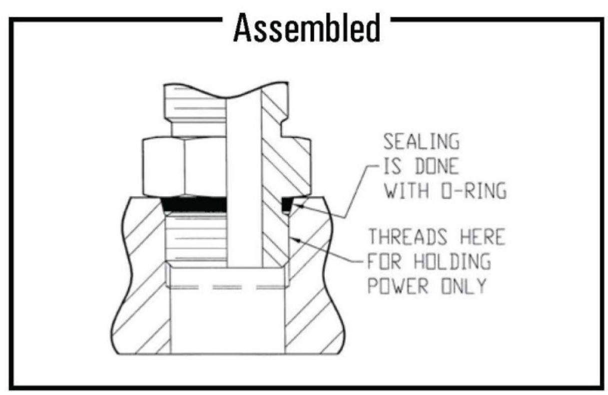
This completes a 37° JIC Flare connection with quick reference visual marks to monitor the nut if it has backed off.

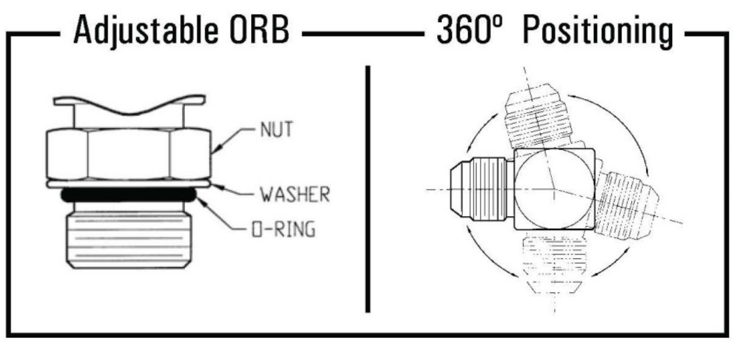
- Torque values are for threads lubricated with 10W hydraulic oil.
- Sizes -02 through -08 are less tolerant to over-torque abuse.
- Over-torque abuse reduces the clamping force resulting in loss of seal and a reduction in flow.

HYDRAULIC FITTINGS: ASSEMBLY & TORQUE (CONT'D)

O-RING BOSS FITTINGS







Pressure Connections uses a **90 durometer, Buna-N (Nitrile) O-ring**, with other compounds available upon request. The threads of the SAE straight thread O-Ring Boss (ORB) and the straight thread 37° JIC Flare are the same threads. The difference is the way each thread seals. While the JIC seals on a metal-to- metal flare, the ORB seals on an O-ring. This type of seal offers the best leak free connection, even if small nicks and dings are found on the sealing surfaces of the ports. This O-ring connection is highly recommended for medium and high pressure systems, and is excellent in vibration and/or temperature cycling environments. Since the seal takes place at the O-ring and not the threads, the fitting can be use multiple times. Simply replace the O-ring and it is ready for service again.

The **elbows and tees** have an **adjustable ORB thread** that allows **360° positioning** when tightening for an easy connection.

Size		lb·ft min./max.
-02	=	6–7
-03	=	8–10
-04	=	13–15
-05	=	17–21
-06	=	22–25
-08	=	40–43
-10	=	43–57
-12	=	68–75
-14	=	90–99
-16	=	112–123
-20	=	146–200
-24	=	154–215
-32	=	218–290

O-Ring Boss Assembly

1. Inspect the components and make sure the port, O-ring, sealing surfaces, and threads are clean, and free of damage.
2. Install an O-ring if needed. Take special care not to cut it on the threads. We install our O-rings with special mandrels, or cones.
3. Lubricate the threads and O-ring with 10W hydraulic oil.
4. For an adjustable ORB, completely back off the locknut/washer.
5. Hand tighten the fitting unit it contacts the port spotface.
6. Proceed to tighten the proper specified torque value.

This completes an O-Ring Boss connection.

HYDRAULIC FITTINGS: ASSEMBLY & TORQUE (CONT'D)

O-RING FACE SEAL FITTINGS

O-Ring Face Seal (OFS) fittings were designed to eliminate leakage problems and still handle the greater pressure of today's hydraulic systems, and are dimensionally standardized in SAE J1453. An OFS connection uses a Buna-N, 90 Durometer O-Ring that seats into a groove in the face of the fitting. As the connection is tightened the o-ring compresses against a flat-face sleeve that is brazed onto the end of a tube, and makes a metal-to-metal seal creating a cavity that supports the o-ring. The sleeve also prevents twisting of the tube and supports it during the assembly process.

In addition, as the assembly is being tightened, a noticeable rise in torque is realized that deters over-torque abuse and avoids distortion. This is why the OFS design can be used multiple times by just simply replacing the o-ring. Standard material is steel with a RoHs compliant 96-hour salt spray finish that exceeds the SAE 72-hour salt spray requirement.

Assembly Steps:
Inspect the tubing to make sure that it is free of defects, nicks, dings, scratches, etc.

1. **Cut off the tube** square +/-1°. A tubing cutter is highly recommended to ensure the cut off is square.

2. **De-burr the inside and outside of the tube** and make sure the tube is free of debris. When de-burring, make sure an angle of no more than 45° by 0.020" on the outside of the tube appears.

3. **Prepare the tube end, braze sleeve, and silver braze ring** by dipping them all in a cleaning solvent.

4. **Polish a 1/2" of the outside of the tube** using an aluminum-free, silicon carbide emery cloth and dust it off afterwards. Avoid touching it as any impurities such as oil, grease, and oxidation will impair the flow of silver, and reduce the strength of the braze joint.

5. **Slide the nut onto the tube and secure the tube is a vise** for brazing in an upright position. This will allow gravity to pull the braze sleeve down on the tube as the silver braze ring melts.

6. **Apply a high temperature flux** (+700° to +18000°F) to the outside of the tube and the inside of the braze sleeve socket where the tube slips in. Flux must be applied to any area that is to be heated or needs to be clean for a proper braze joint. Verify that the braze sleeve is free of rust.

7. **Insert the silver braze ring** into the braze sleeve socket and slip the braze sleeve onto the prepared tube end. Braze rings come in both preformed sizes and wire rolls that are at least 45% silver alloy. Cut a section of wire that is just shy of 3 times the braze sleeve socket diameter and bend it in to a circle.

8. **Completely coat the assembly with additional flux.** Flux prevents oxidation of the metal during the heating process and clean the surfaces to help the silver flow evenly throughout the braze joint. It also serves as a temperature monitor as heat is applied.

9. **Begin the brazing process.** A single flame torch can be used, however, a multiple flamed torch is recommended for sizes 3/4" and up. Adjust the flame to a blue blase with an occasional yellow flicker. Direct the base of the flame at the braze sleeve so that the assembly will heat up evenly. Due to different expansion rates the tubing and the braze sleeve should be of the same material. As the assembly heats up, and the silver braze ring begins to melt, the braze sleeve will drop on the tube and become fully seated. Slight force may be needed.

10. After the silver flows throughout the joint remove the flame so as not to char the flux. **Allow to cool for approximately 10 seconds and then cool the assembly by dipping it into hot water** (+140° to +180°F). This will crack the flux residue for removal with a wire brush, but be careful not to scratch the flat surface. If a post braze cleaner, or flux remover, has been added to the water, it may cause premature rusting. Therefore, neutralize them by dipping the assembly in a cleaning solvent afterwards. A light coating of penetrating oil can also be applied.

11. **A final inspection of the braze joint** should reveal a silver fillet all the way around the tube/braze sleeve. Silver braze should also be found in the other end of the braze sleeve without any excess on the flat-face. A void in the fillet could mean a leak path and an excess of silver on the flat-face will interfere with a good seal. Small amounts of excess can be sanded, but if the flat-face cannot be restored it will have to be re-brazed using a new braze sleeve.

12. Now that the connection is ready to be made**, inspect the components** for dirt, grit, nicks, dings, and scratches, etc. that might interfere with a good seal.

13. **Lubricate the O-ring and the threads** with 10W hydraulic oil and insert the O-ring onto its groove (Ours are preinstalled).

14. With the nut already slid onto the tube, position the sleeve flat-face up to the O-ring on the fitting and **hand tighten the nut onto the threads.**

15. **Torque to the specified value** to complete the connection.

Torque Values & Turns Past Finger Tight

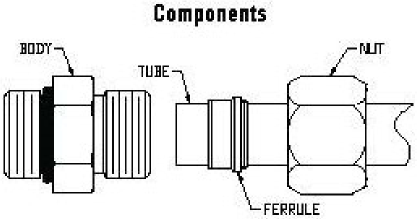
Dash	Torque	Turns	Turns
Size	lb-ft	OFS	FOFX
-04	18	1/4 – 1/2	1/2– 3/4
-06	20	1/4 – 1/2	1/2– 3/4
-08	40	1/4 – 1/2	1/2– 3/4
-10	60	1/4 – 1/2	1/2– 3/4
-12	85	1/4 – 1/2	1/3– 1/2
-16	110	1/4 – 1/2	1/3– 1/2
-20	140	1/4 – 1/2	1/3– 1/2
-24	180	1/4 – 1/2	1/3– 1/2

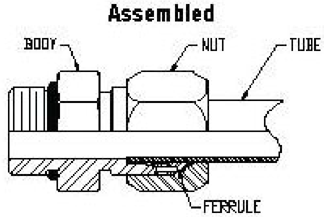
Brazing

As the Temperature Rises...	
+212° F	Water Boils Off
+600° F	Flux Starts to Bubble
+800° F	Flux Becomes Translucent
+1100° F	Flux Thins and Becomes Clear and Dark
+1125° F	Silver Braze Ring Melts
+1140° F	Silver Flows Easily Throughout the Joint Allowing the Braze Sleeve to Drop and be Fully Seated. At This Point the Metal Will Take on a Dark Reddish Look.

HYDRAULIC FITTINGS: ASSEMBLY & TORQUE (CONT'D)

FLARELESS FITTINGS





Tubing Wall Thickness
Steel / Stainless Steel
min. - max.

-04	= 0.028–0.065	-10	= 0.058–0.120
-06	= 0.035–0.095	-12	= 0.065–0.120
-08	= 0.049–0.120	-16	= 0.083–0.148

Grip", or "Bite Type" fittings, This fitting provides a compact connection that is reliable, durable, and reusable.

The Flareless connection is a 3-piece design consisting of; the Nut, the Ferrule, also called a Sleeve, and the Body. It is popular for a variety of applications and environments worldwide, not only because it is reliable and easy to assemble, but because the Flareless connection holds pressure so well that the tubing fails before the Flareless connection comes apart.

As the Flareless nut screws onto the body it slides the ferrule along the tube and presses it into the internal 24° cone of the body. As the hardened ferrule is being compressed into the body it bites 360° onto the O.D. of the tube forcing the tube to also seat against the body. This creates a high pressure seal that is excellent against vibration as the connection force is distributed over multiple points, which dampen vibrations that can cause a connection to come loose.

No special tools are required as NO flare is needed. Therefore, it is recommended for a wide range of seamless, medium to extra-heavy wall tubing with a maximum hardness of Rockwell B72. Steel and stainless steel tubing is the most common, but aluminum, copper, monel, titanium, and plastic tubing can be used as well.

Flareless Assembly Instructions

1. Select tubing that meets the recommended SAE requirements for Flareless fittings and also meets the parameters per your environment and application. See table below.

2. **Cut the tubing** reasonably square (+/- 1°). A tubing cutter is NOT recommended for hard tubing like steel and stainless steel as this creates an internal burr, which is hard to remove and causes a restriction in flow.

3. **Lubricate** the threads and the ferrule with 10W hydraulic oil.

4. **Slide the Nut** onto the tube and **then the Ferrule**, both oriented per the diagram on page 10.7

5. **"Set" the Ferrule** onto the tube by inserting the tube into the pre-set tool, or fitting body, and threading the nut on finger tight. A pre-set tool is for setting the ferrule onto the tube prior to assembly. Continue by making a visual mark on the nut, and while pressing the tube firmly against the tool or fitting, tighten the nut another 1-3/4 turns from finger-tight.

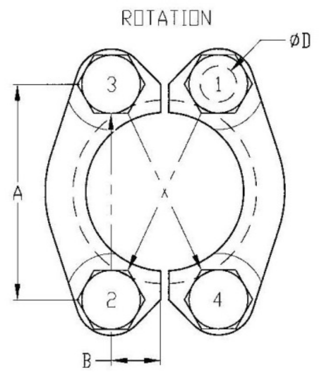
6. **An Inspection** should be made after the initial assembly to ensure that the ferrule has been properly "set" onto the tube. Disassemble the connection and make sure that the ferrule is "biting" into the tube properly.

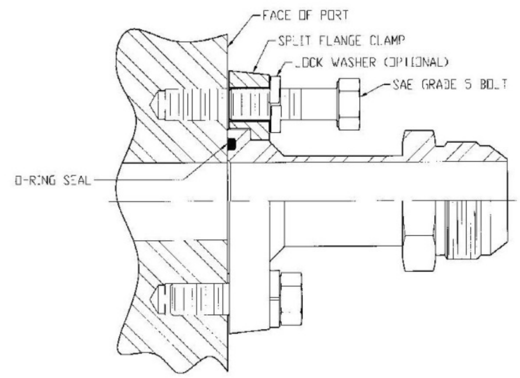
7. With the ferrule properly "set" onto the tube re-tighten the connection to finger tight and then wrench-tighten another 1/3-1/2 of a turn. It is important to use the same nut ferrule-body matched set to achieve a good connection. **This completes a Flareless connection.**

Caution: A Flareless connection cannot be checked by wrench torque, as a proper connection depends on the movement of the ferrule into the 24° cone of the body in order to effectively "bite" into the tube. This is why Pressure Connections only uses hardened ferrules.
FFX: Female Flareless Swivels assemble to finger tight and then wrench-tighten another 3/4 of a turn from finger tight for all sizes.

HYDRAULIC FITTINGS: ASSEMBLY & TORQUE (CONT'D)

SPLIT FLANGE ADAPTERS





Pressure Connections offers **Split Flange Adapters** to convert Code 61 or Code 62 flange ports to JIC or O-ring Face Seal (OFS) connections. Ranging in sizes from 1/2" up to 2", these adapters are a convenient and cost effective way to replace expensive hose fittings. They not only make hose alignment easy, but once in place, the hose assembly can be replaced with standard hose swivel ends. This eliminates the need for special part numbers and extra inventory. Hydraulic equipment can then be quickly interconnected while maintaining an unbroken split flange O-ring connection.

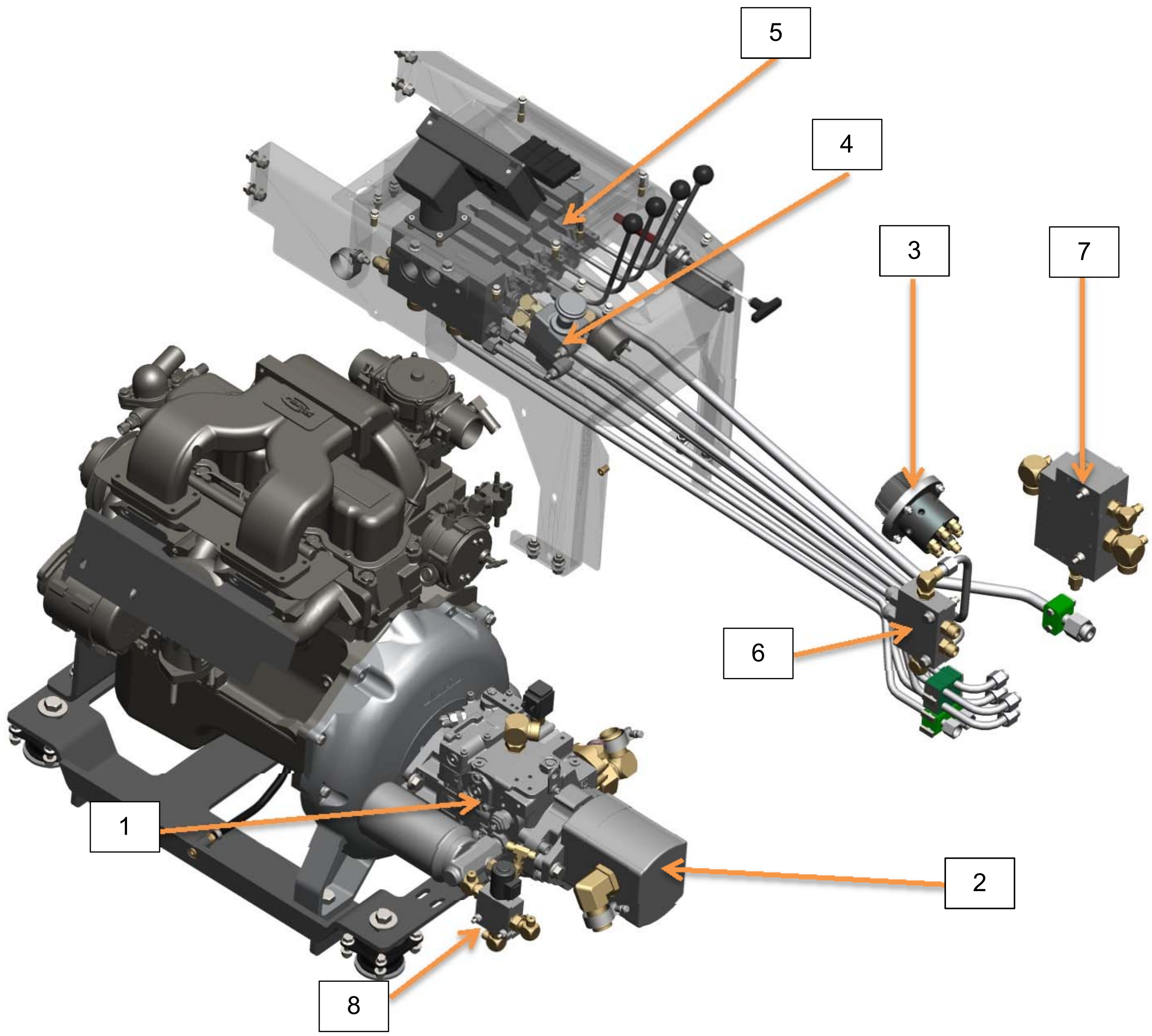
The **4-Bolt Flange Design** is used worldwide for connecting pumps and motors in hydraulic systems. Split flange halves work by clamping down on the port surface thereby compressing the O-ring into a metal groove in the flange head. The flange head makes metal-to-metal contact with the port surface, leaving no place for the O-ring to extrude or deform under pressure. There are no spiral leak paths, sealing compounds, or gasket misalignments to contaminate the system or get in the way of a leak-free connection in a 4-Bolt Flange Design. The components that make up the Code 61 and Code 62 flange design are standardized by SAE under J518. Those components are: the flange head adapter, a pair of 2-bolt split flange halves (clamps), four Grade 5 bolts and washers, and a 90 durometer O-ring. The flange port design divides the load into four bolts, which require less torque than other port designs of a comparable size. The flange head hose assembly can be removed quickly by pivoting one of the split flange halves out of the way. Simply remove one of the split flange bolts and loosen the others.

Assembly is easy. Standard bolts are used (Grade 5 or better), so no special tools are required. First, make sure that the port surface and the flange head, including the O-ring groove, are free of nicks, dings, dirt, grit, or other foreign matter. Next, lubricate the O-ring with 10W hydraulic oil and insert it into the groove of the flange head. Then insert the four bolts with washers through the bolt holes of the split flange halves and thread them in to the port finger tight – the flange head should be centered in-between. Partially tighten each bolt according to the rotation diagram shown above until the specified torque values are obtained. This method will reduce the chance of pinching the O-ring and/or over flexing the flange. It should be noted that the split flange halves never actually touch the port surface. A clearance of 0.010" to 0.030" should always be measured after the torque values are reached. Only the flange head makes a metal-to-metal contact. Code 61 and Code 62 have different bolt patterns and are not interchangeable, except for the O-ring.

Flange Bolt Torque Values

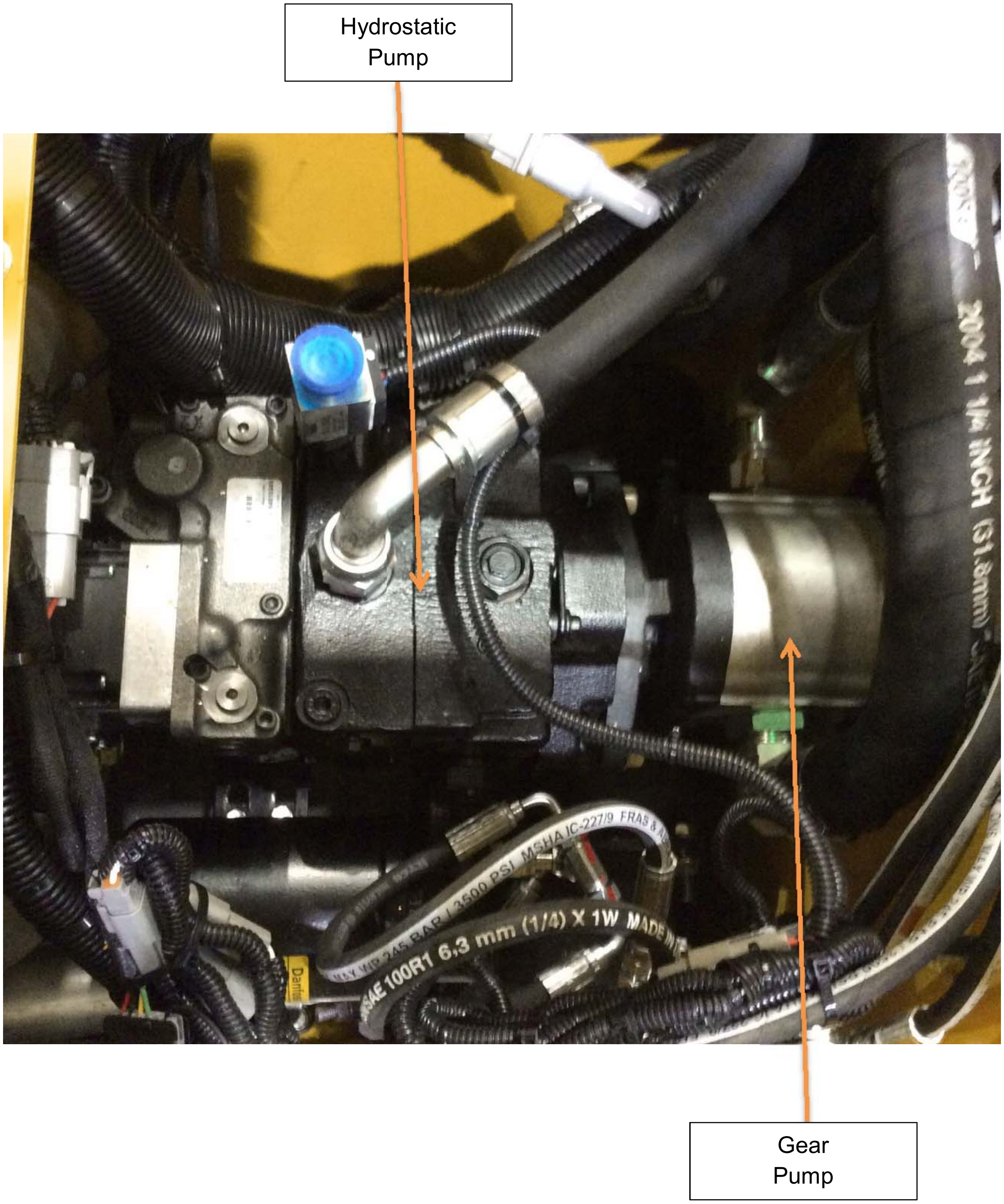
Code 61			Code 62	
lb.-ft.	Bolts	Size	lb.-ft.	Bolts
		–08	–	–
21–29	3/8 - 16	–12	26–34	3/8 - 16
26–35	3/8 - 16	–16	26–50	7/16 - 14
36–46	7/16 - 14	–20	63–75	1/2 - 13
46–58	1/2 - 13	–24	117–153	5/8 - 11
56–66	1/2 - 13	–32	–	–

GENERAL ARRANGEMENT

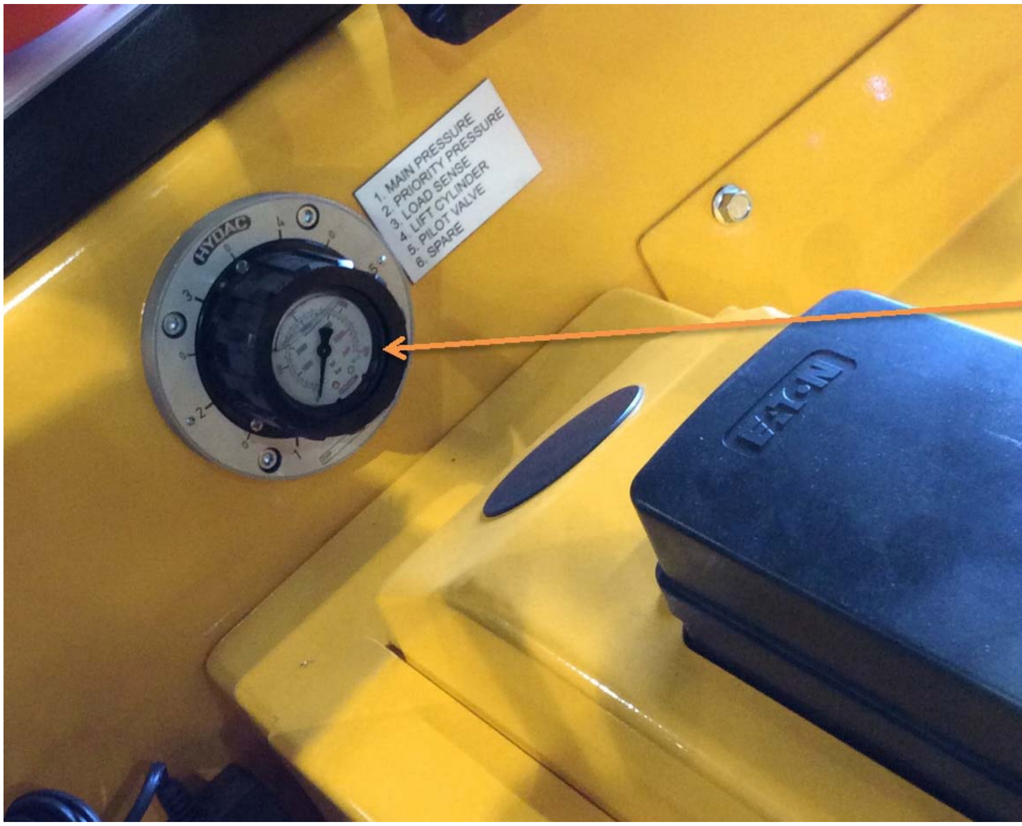


1. Hydrostatic Pump
2. Gear Pump
3. Hydraulic Multigauge
4. Parking Brake Selector Valve
5. Hydraulic Control Valve
6. Counterbalance Valve
7. Load Sense Priority Valve
8. Solenoid Dump Valve

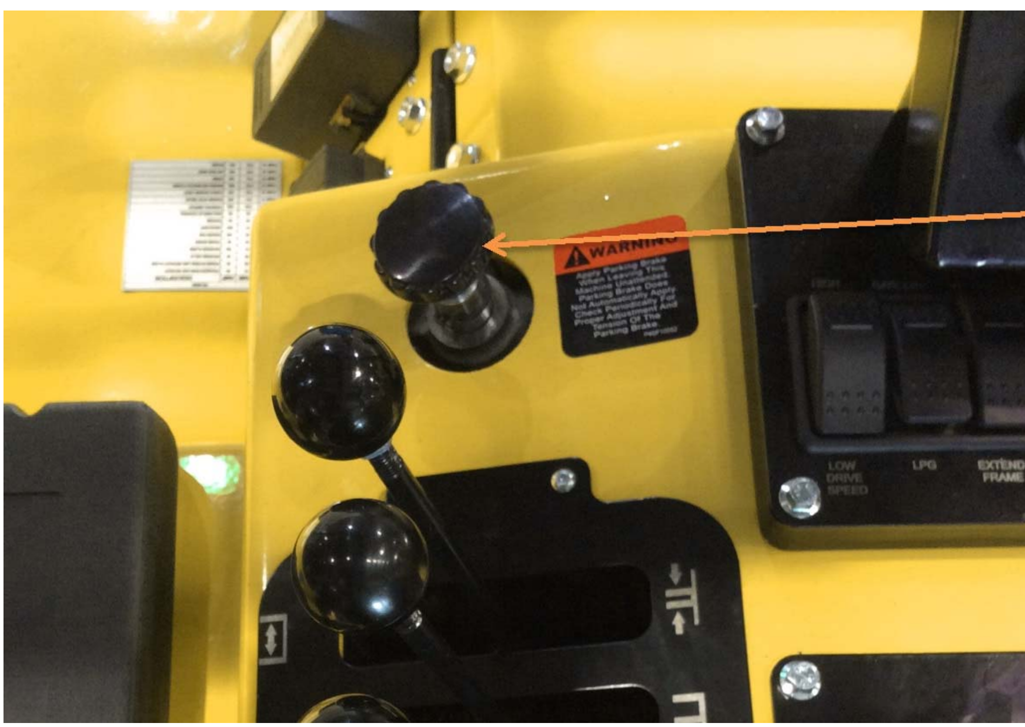
GENERAL ARRANGEMENT (CONT'D)



<u>GENERAL ARRANGEMENT (CONT'D)</u>

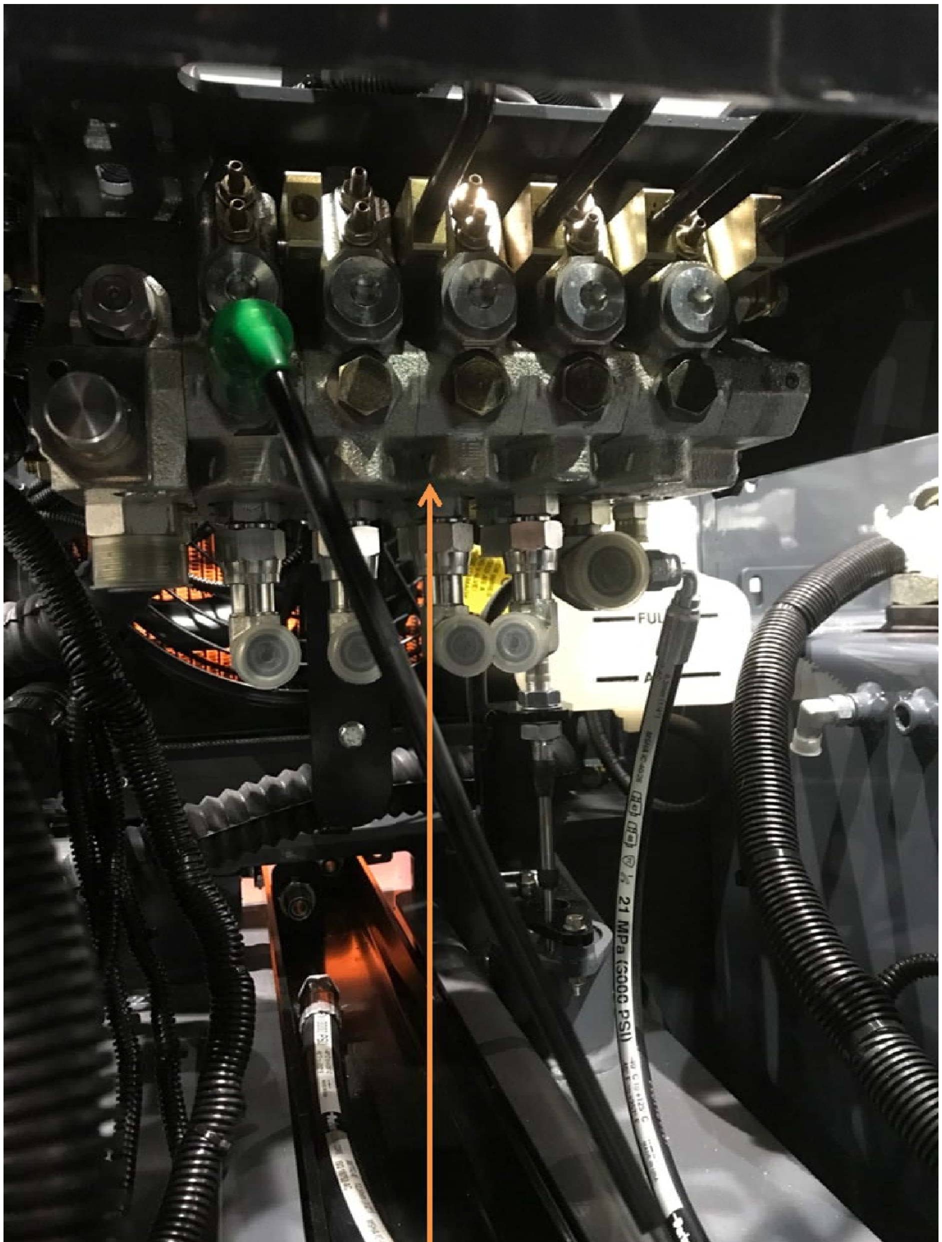


Hydraulic Multigauge



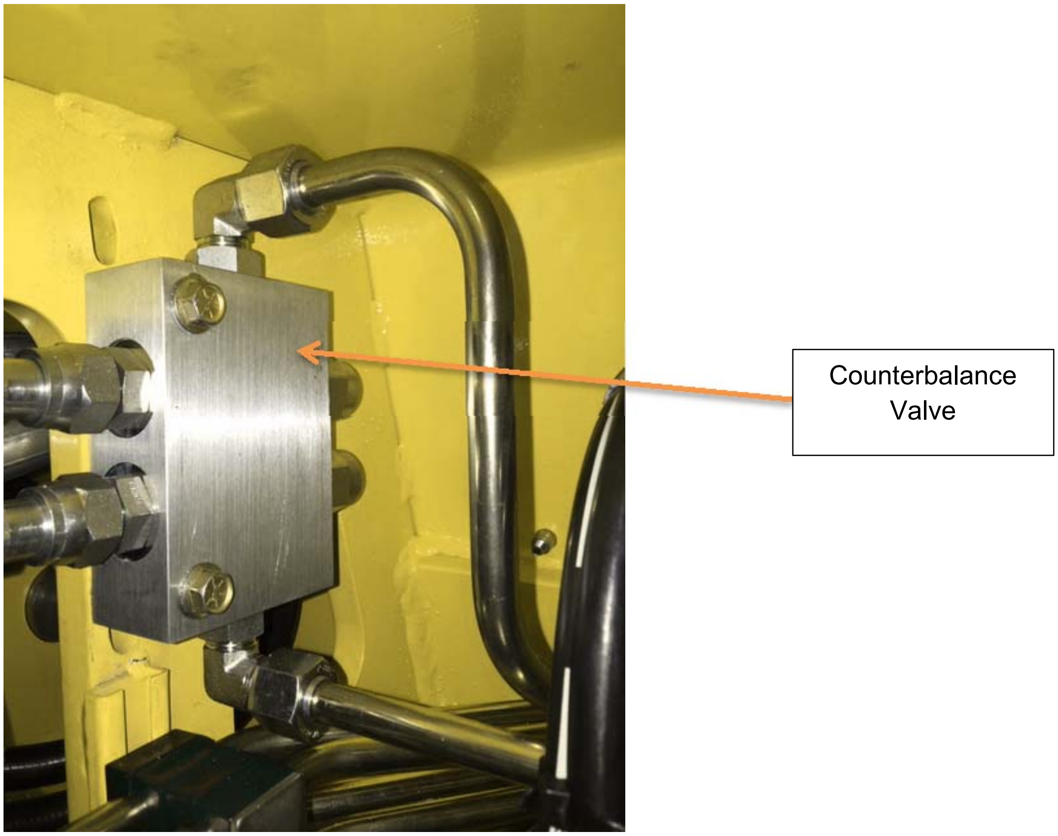
Parking Brake Selector Valve

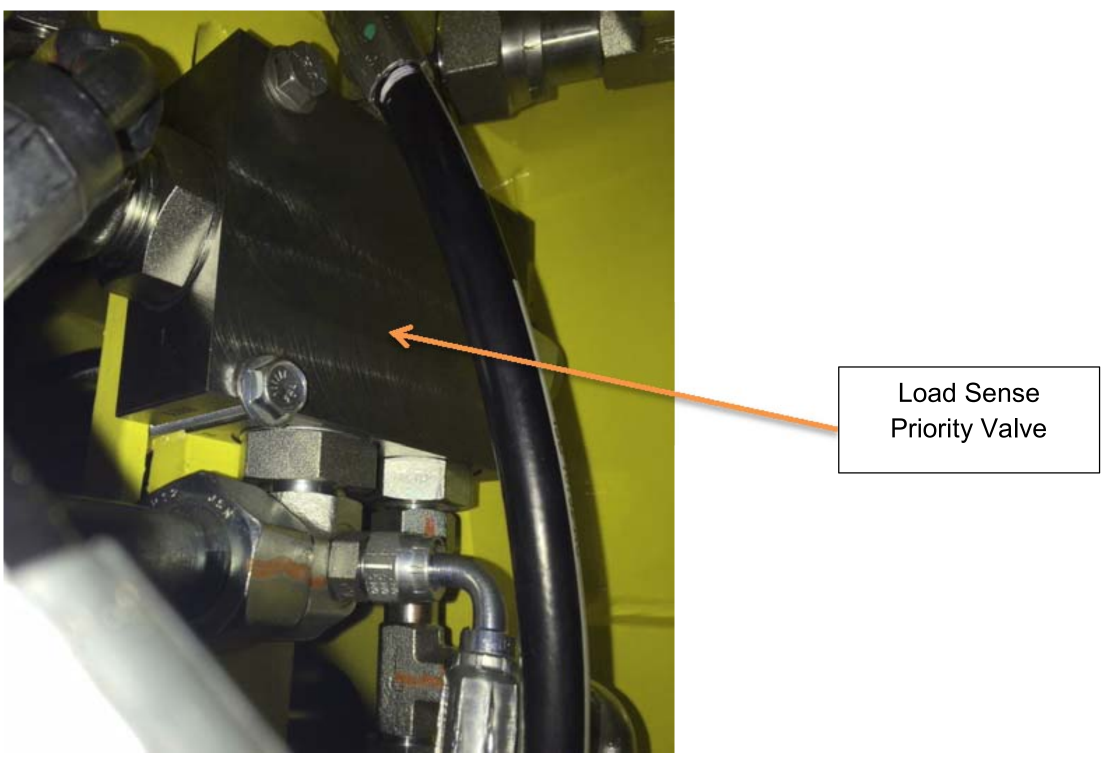
GENERAL ARRANGEMENT (CONT'D)



Hydraulic Control Valve

GENERAL ARRANGEMENT (CONT'D)



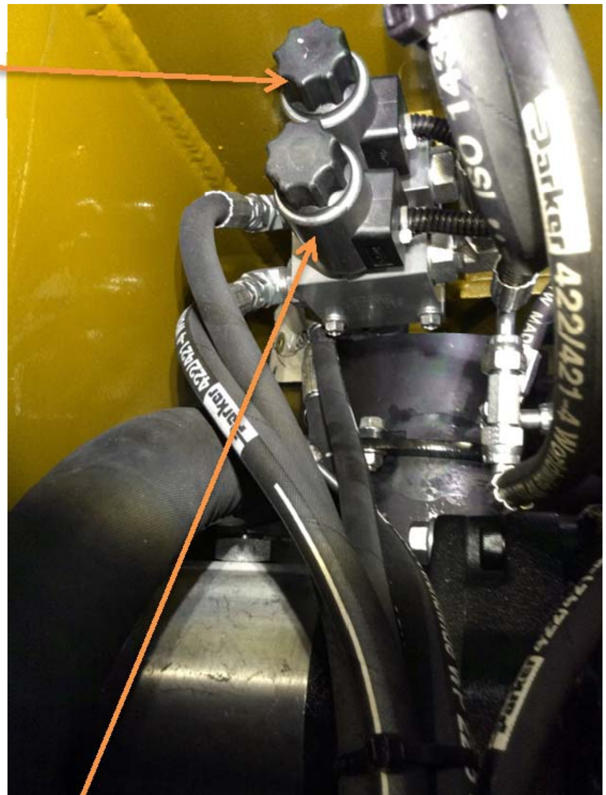


GENERAL ARRANGEMENT (CONT'D)

Adjustable Relief Valve

GENERAL ARRANGEMENT (CONT'D)

Solenoid Dump Valve (Optional Remote Only)



Solenoid Dump Valve

MULTI-GAUGE

The FR15/25, FR18/26, & FR25/35 trucks include a diagnostic multi-station gauge isolator, or "Multi-gauge".

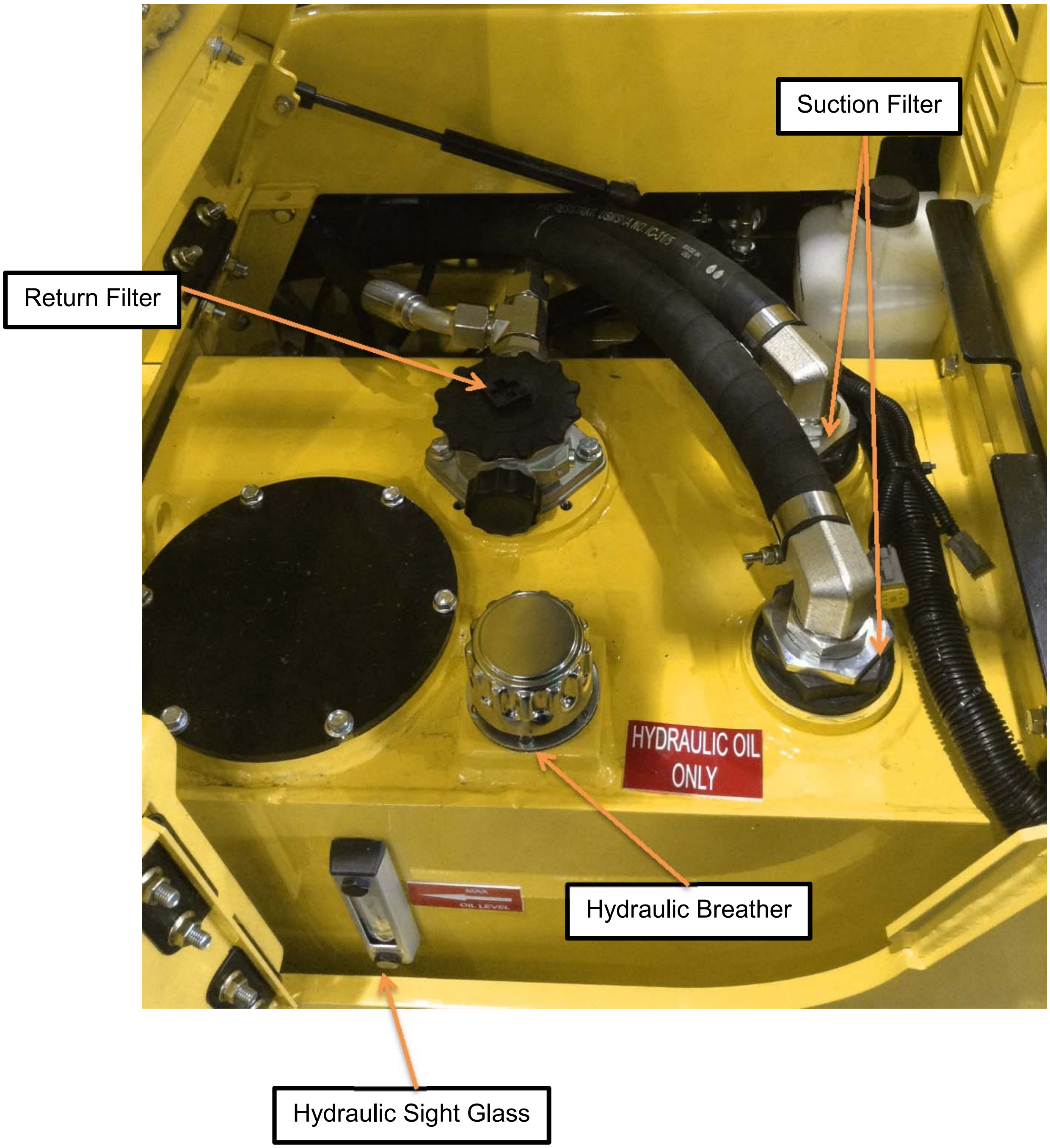
The Multi-gauge eliminates the need to tap into individual hydraulic circuits reducing the time required for diagnostic assessment, as well as the possibility of fluid spills.

The Multi-gauge is located to the right of the operator on the front of the dash plate.

The Multi-gauge is used to check 6 different pressures in the hydraulic system as indicated in the photo below. Pressure is read with the arrow on the rotary knob pointing to one of the 6 different measuring positions. By turning the knob, each of the 6 different measuring positions can be selected. Between each measuring position there is a zero position to relieve gauge pressure. Build-in detents lock any selected position.

Various sections included in the Hydraulics portion of this manual will refer to pressure checks. The Multi-gauge should be used to make all required checks.

HYDRAULIC TANK



HYDRAULIC SYSTEM RETURN FILTER

The hydraulic system return filter, located on the top surface of the hydraulic tank, MUST be changed every 250 hours in accordance with the Planned Maintenance Schedule provided in this manual. It is recommended that the filter is replaced in accordance with the recommended intervals during scheduled PMs to minimize the possibility of having to pull the truck out of active service due to a filter indicator warning. Use a wrench to remove the black cap on the top of the filter housing and remove the element.

Filter Element

HYDRAULIC SUCTION HOSES & FILTER

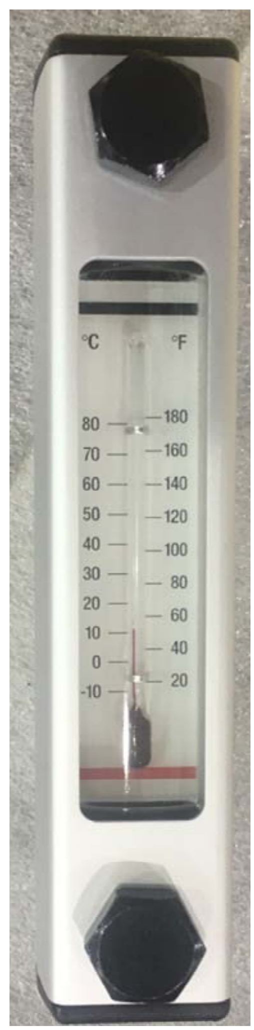
The hydraulic suction hoses supply oil to the steer/brake and main hydraulic pumps. Hydraulic oil is drawn thru strainers located at the top of the hydraulic tank to the inlet side of the pumps. Any air entering the system can disrupt the flow of oil and can potentially result in cavitation and/or damage to the pumps. To prevent possible cavitation of the pumps, the suction hose clamps must be checked for tightness and positive sealing. The clamps on each end of the suction hoses should be checked at each scheduled PM.

Suction Filter

HYDRAULIC BREATHER & SIGHT GLASS

The hydraulic tank breather is located on the top of the hydraulic tank. The breather prevents contamination and water from the surroundings from entering the system in connection with fluctuations of the oil level in the hydraulic tank. The breather is also where hydraulic fluid is added to the tank. There is a dipstick on the breather that is not used; always use the hydraulic sight glass to check hydraulic oil levels. The hydraulic sight glass is located on the front of the hydraulic tank and measures the hydraulic fluid level. (*REFER TO PLANNED MAINTENANCE SECTION OF THIS MANUAL)*

Hydraulic Tank Breather



Hydraulic Sight Glass

COUNTERBALANCE VALVES

Three port counterbalance cartridges (with pilot-to-open assist) are modulating devices that allow free flow from port 2 (inlet) to port 1 (load) and then block reverse flow until a pilot pressure inversely proportional to the load pressure is applied at port 3 (pilot). The modulation of a counterbalance valve is a function of both the load pressure and the pilot pressure, yielding an “inverse pilot ratio:; light loads require more pilot pressure and heavy loads less pilot pressure to open the counterbalance valve, helping to improve stability and providing fine motion control.

Counterbalance valves control motion by guaranteeing the directional valve always sees a positive load pressure, even with overrunning loads. Sun counterbalance valves (pilot-to-open assist) will shut off with very low (approaching zero) leakage. Absent nicks in the seating area, silting (even with “clean” oil) will normally produce a zero leak seal within minutes after closing. Deceleration control of moving loads can be provided with the proper selection of directional valves and/or circuitry. They also incorporate a relief function from port 1 (load) to port 2 (inlet) which provides protection from load and/or thermal over pressure. Three port counterbalance valves with reverse flow check valves are suitable for counterbalancing **constant fixed loads** where the valve is set at 1.3 times the constant load induced pressure, with Port 3 not used. Counterbalance cartridge valve characteristics:

- Low relief valve hysteresis over a wide flow range.
- Good tolerance to contamination.
- Operating pressures to 5000 psi (350 bar).
- Flow capacities to 120 gpm (460 L/min.)
- Adjustment screw can be used to lower the setting, providing an emergency manual release when pilot pressure is not available.
- Optional check valve springs available. 25psi (1,7 bar) is standard and recommended to avoid normal shock damage. 4 psi (0,3 bar) is available to minimize cavitation.
- Intentional minor leakage past the pilot piston is standard on many valves to purge air from the pilot line and improve stability. Sealed pilot pistons are standard on some models.

Turning the adjust screw clockwise (facing the valve) **lowers** the pressure setting while counterclockwise movement **increases** the setting. (Think of the adjust screw as a manual override.)

Counterbalance valve should always be pressure set prior to their installation into the system, for more than just safety reasons. **Most importantly, they are very difficult to accurately set once installed on ta machine.** On rare occasions, it may be necessary to adjust the valve after installation. Following is a suggested setting method that can be used in an emergency. Keep in mind it is **strongly recommended** that counterbalance cartridges always be factory set by Sun.

COUNTERBALANCE VALVES (CONT'D)

Emergency Setting of counterbalance cartridges when installed in a system by visually observing maximum load pressure via the system gauge.

1. Observe all safety requirements regarding the operation of the machine and associated device.
2. Ensure that you are in control of the hydraulic support for the equipment and that no unanticipated **hazardous** machine movements can occur.
3. Make note of any "pinch points" and make sure any machine movement that occurs during the adjustment phase will not cause injury. Note, especially, the location of the counterbalance valve adjustment as it relates to this movement.
4. Be aware that the direction of rotation of the adjustment to increase the setting is **counterclockwise** and the setting will not be exact due to circuit interactions and the manner in which the valve is adjusted.
5. If there is no hydraulic system pressure gauge, install one so system pressure can be observed and noted.
6. Start with the counterbalance valve at the standard factory setting (this information is shown on the *Sun Counterbalance Valve Pressure Settings vs. Turns* table on table below, as well as individual cartridge product pages shown on the Sun website).
7. If your valve has a "C" or "J" range (2000-500 psi / 140-350 bar) or a "G" range (2000-6000psi / 140-350 bar) **increase** the setting one full turn (counterclockwise) before proceeding.
8. Set up the machine with the **maximum** load on the actuator that is being supported by the counterbalance valve (If the actuator cause angular motion, make sure the actuator is in the maximum load position.) Slightly and slowly (with minimum flow) raise the load.
9. Observe the gauge and record the maximum pressure generated when raising the load.
10. Using the *Sun Counterbalance Valve Pressure Setting vs. Turns* table (see table below) verify the amount of psi per turn corresponding to your model valve. Multiply the observed load pressure by 1.3 and readjust the counterbalance valve to the calculated pressure by either increasing (turning counterclockwise) or decreasing (turning clockwise) to vary the setting. (*Note*: you will **not** be able to observe the final setting of the valve on the gauge, as this setting will be **higher** than the highest load induced pressure.)

SUN COUNTERBALANCE VALVE PRESSURE SETTING vs. TURNS TABLE

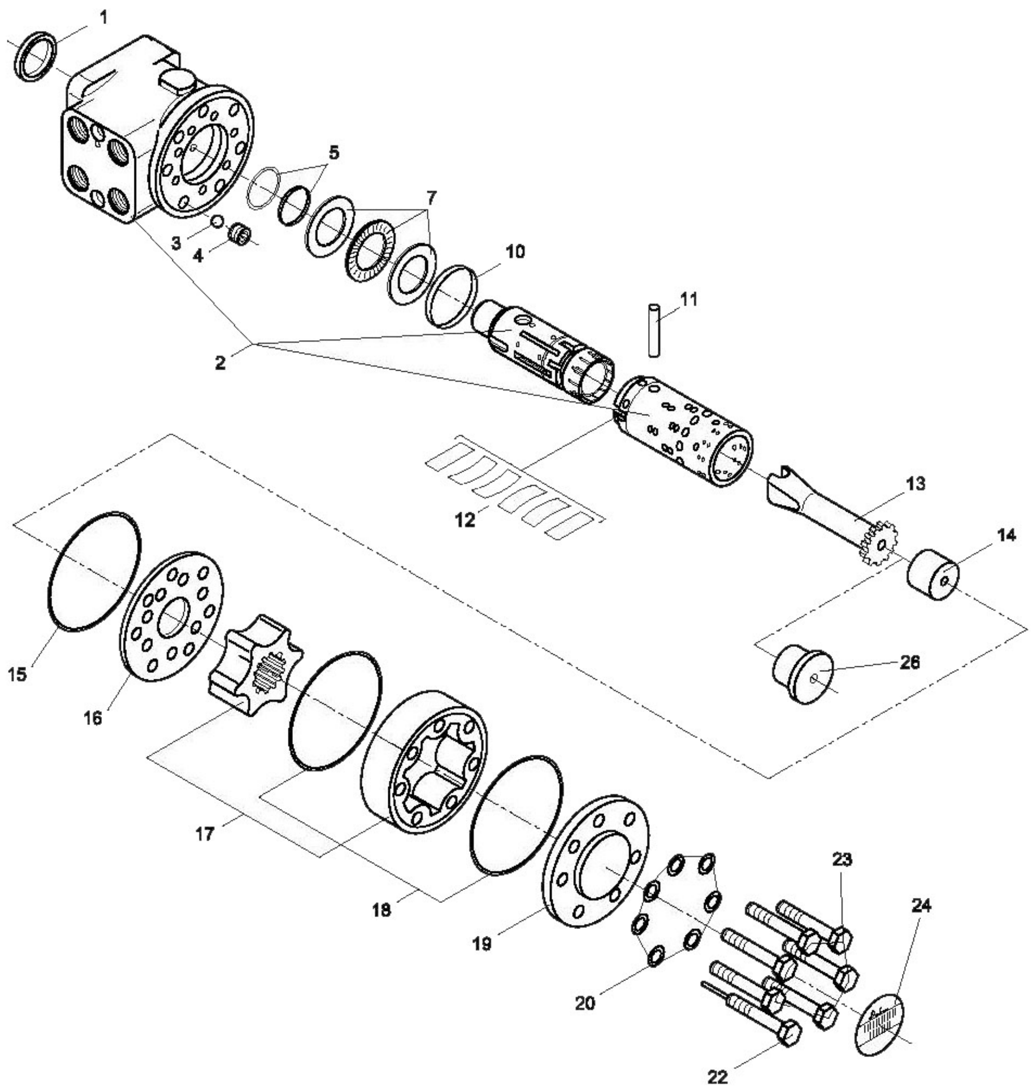
The pressure ranges shown below are the **Preferred Load Holding Adjustment Ranges.** However, the cartridge listed below can be adjusted down to 200 psi (14 bar) or less, and the *Approximate psi (bar) vs. turn* column covers pressure starting at the **preferred minimum** pressure setting and are effective up tot a maximum pressure which, in most cases will be above the listed **preferred maximum** value shown for an individual cartridge. **Approximate psi (bar) vs. Turn Values** should be considered "nominal", and can vary somewhat from valve to valve.

Total Number of Turns	Pressure – psi (bar) (Adjustment Range)	Approximate psi (bar) vs. Turn	Standard Setting psi (bar)
.75-4.0	1000-4000 (70-280)	**1300 (91)**	3000 (210)

STEER CONTROL UNIT

STEER CONTROL UNIT (CONT'D)

Exploded View Steer Unit



1. Dust Seal Ring
2. Housing + Spool + Sleeve
3. Ball 8.5 mm [0.33in]
4. Thread Bushing
5. O-Ring with Kin-Ring or Roto Gyld
7. Bearing Assembly
10. Rings for Springs
11. Cross Pin 6 • 41 mm [0.24 • 1.61 in]
12. Neutral Position Springs
13. Cardan Shaft
14. Spacer
15. O-Ring 80.5 • 1.5 mm [3.17 • 0.06 in]
16. Distributor Plate
17. Gearwheel
18. O-Ring 75.92 • 1.78 mm [2.99 • 0.07 in]
19. End Cover
20. Washer 8.2 • 11.9 • 1.0 mm [0.32 • 0.47 • 0.04 in]
22. Special Screw
23. Screw
24. Name Label
26. Spacer

STEER CONTROL UNIT (CONT'D)

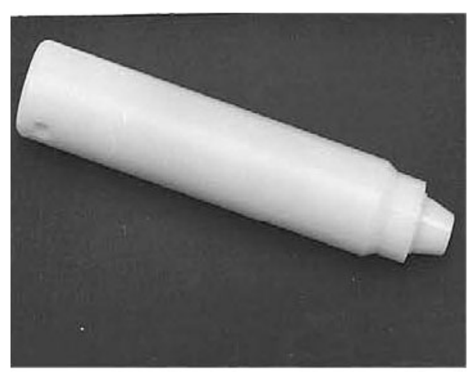
Tools

Holding Tool

Guide Ring

Assembly Tool for O-Ring
and Kin-Ring/Roto Glyd

Assembly Tool for Lip Seal



Special tools are available for servicing steer control units. Contact your authorized Hoist dealer for further information of these items.

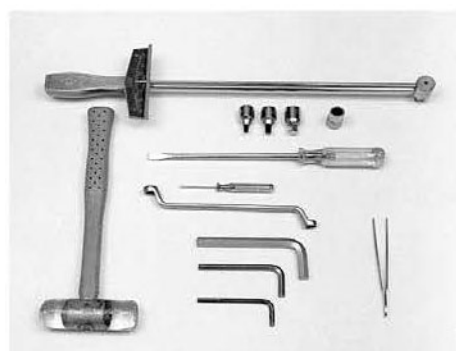
STEER CONTROL UNIT (CONT'D)

Tools (cont.)

Assembly Tool for Cardan Shaft

Assembly Tool for Dust Seal

Standard Tools Required:
Torque Wrench 0-70 N.m.
13 mm Socket Spanner
6.8 and 12 mm Sockets
12 mm Screwdriver
1 mm [0.08 in] Screwdriver
13 mm Spanner
6.8 and 12 mm Socket Spanners
Plastic Hammer
Tweezers

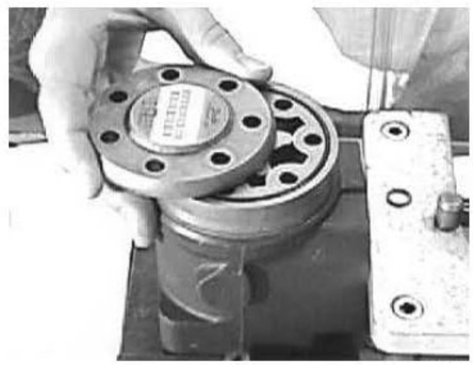


STEER CONTROL UNIT (CONT'D)

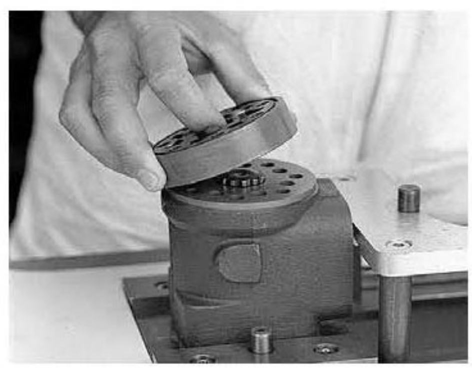
Disassembly

Dismantle steering column from steering unit and place the steering unit in the holding tool.
Remove out the screws in the end cover (6-off plus one special screw)

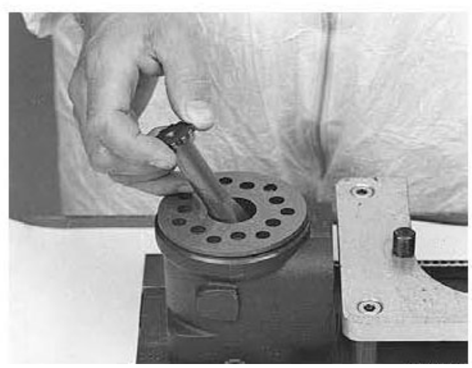
Remove the end cover, sideways.



Lift the gearwheel set (with spacer if fitted) off the unit. Take out the two O-rings.



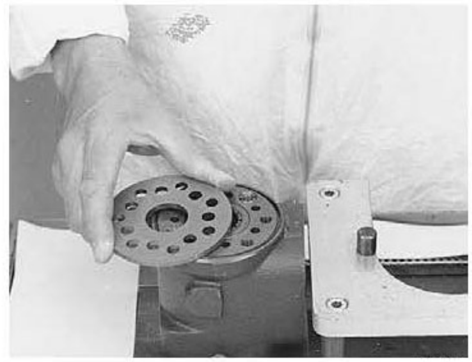
Remove the cardan shaft.



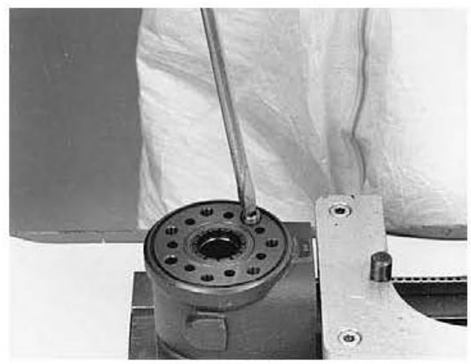
STEER CONTROL UNIT (CONT'D)

Diassembly (Cont.)

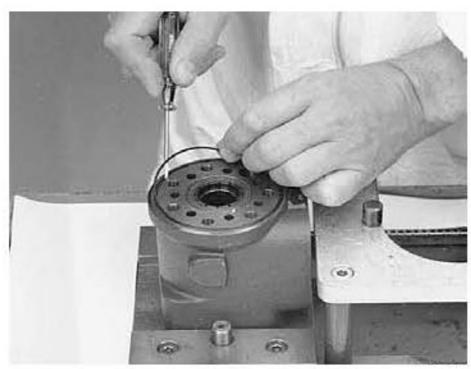
Remove distributor plate.



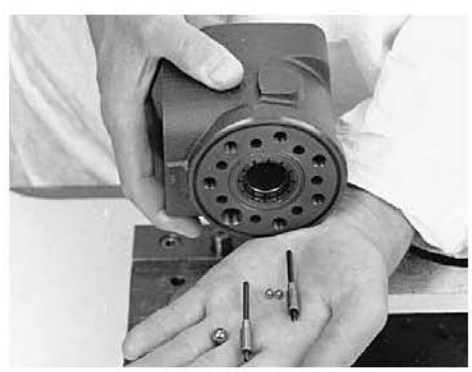
Screw out the threaded bush over the check valve.



Remove the O-ring.



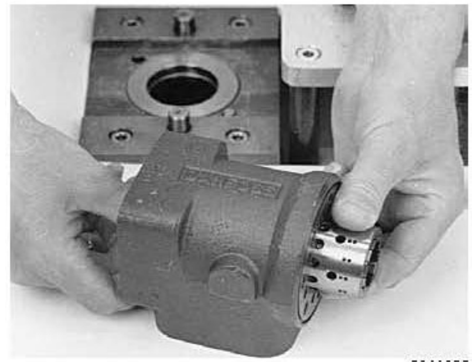
Carefully shake out the check valve ball (Ø8 mm)



STEER CONTROL UNIT (CONT'D)

Disassembly (Cont.)

Take care to keep the cross pin in the sleeve and spool horizontal. The pin can be seen through the open end of the spool. Press the spool inwards and the sleeve, ring, bearing races, and needle bearing will be pushed out of the housing together.



Take ring, bearing races, and needle bearing from sleeve and spool. The outer (thin) bearing race can sometimes "stick" in the housing, therefore check that it has come out.

Press out the cross pin. Use the special screw from the end cover.

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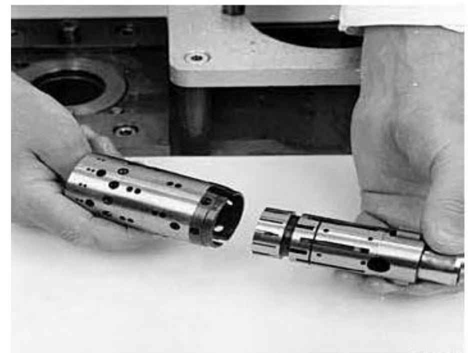
STEER CONTROL UNIT (CONT'D)

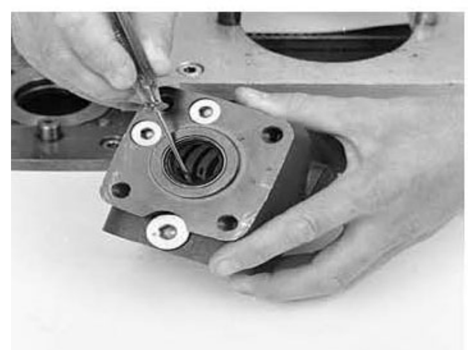
Disassembly (Cont.)

Carefully press the spool out of the sleeve.

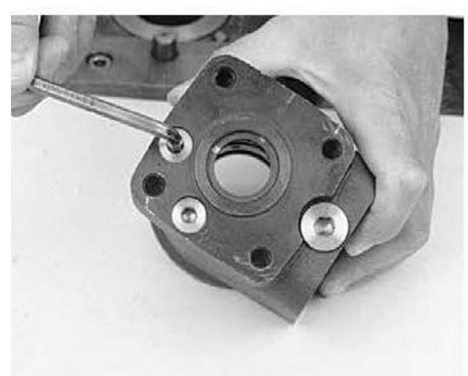


Press the neutral position springs out of their slots in the spool.

Remove dust seal and O-ring/Kin-ring/Roto Glyd.



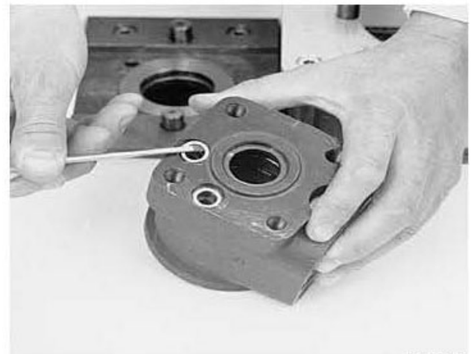
Remove plugs from shock valves using a 6 mm hexagon socket spanner.



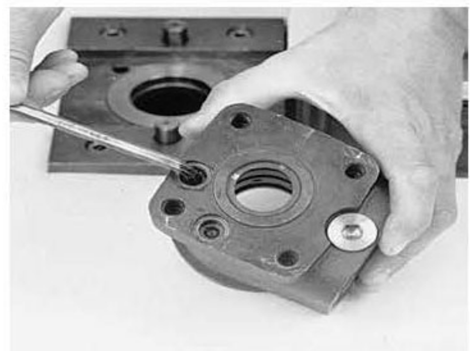
STEER CONTROL UNIT (CONT'D)

Disassembly (Cont.)

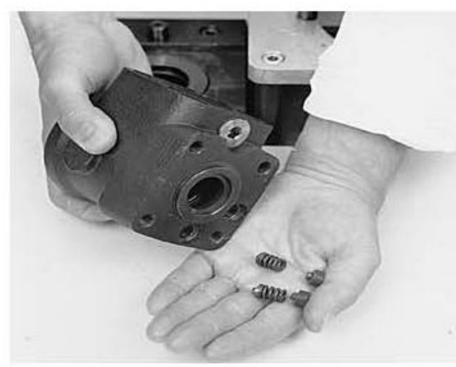
Remove seal washers (2-off).



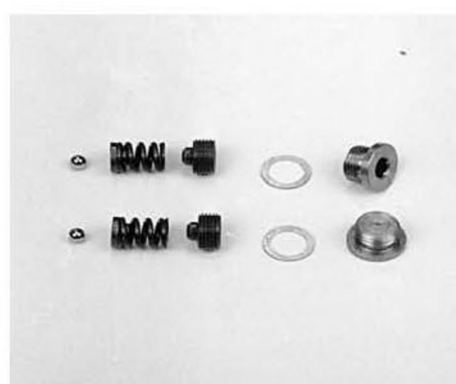
Unscrew the setting screws using a 6 mm ⬡ hexagon socket spanner.



Carefully shake out the two springs and two valve balls into your hand. The valve seats are bonded into the housing and cannot be removed.



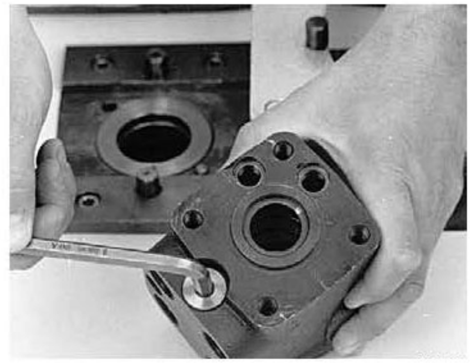
The shock valves are now dismantled.



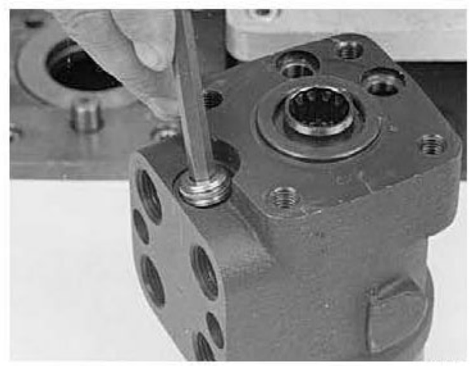
STEER CONTROL UNIT (CONT'D)

Disassembly the Pressure Relief Valve

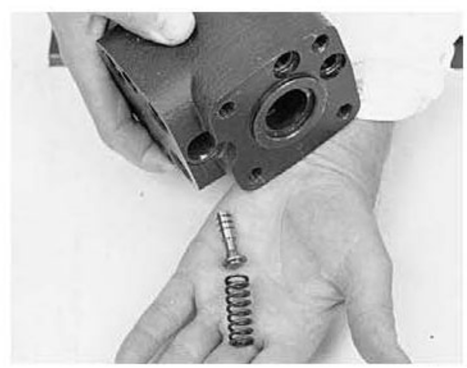
Screw out the plug using an 8 mm ⬡ hexagon socket spanner. Remove seal washers.



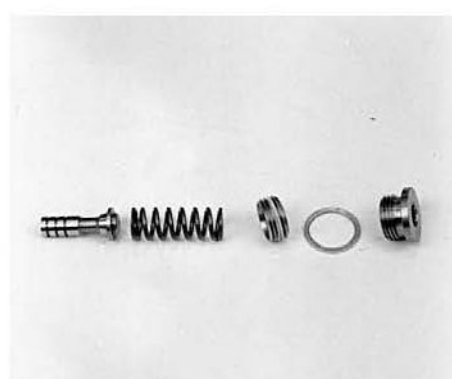
Unscrew the setting screw using an 8 mm ⬡ hexagon socket spanner.



Carefully shake out spring and piston. The valve seat is bonded into the housing and cannot be removed.



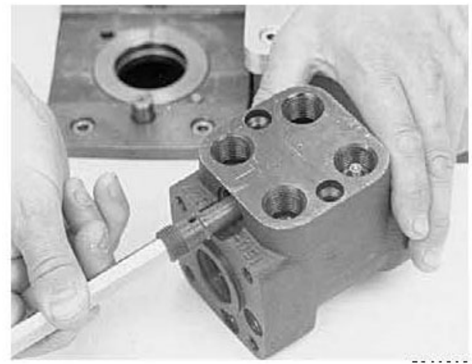
The pressure relief valve is now disassembled.



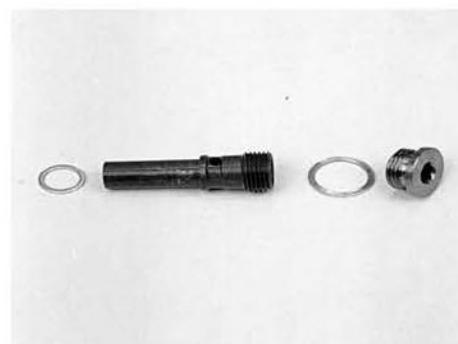
STEER CONTROL UNIT (CONT'D)

Disassembled the Pressure Relief Valve (Cartridge)

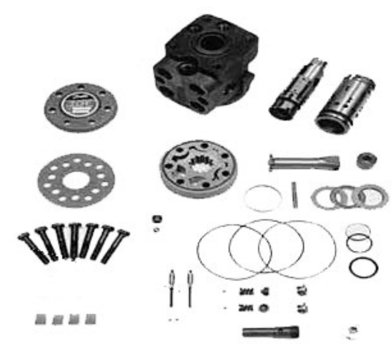
Screw out the pressure relief valve using an 8 mm hexagon socket spanner. Remove the seal ring. If the valve is defective, it must be replaced.



The pressure relief valve is now disassembled.



The steering unit is now disassembled.



Cleaning
Clean all parts carefully in Shellsol K or the like.

Lubrication
Before assembly, lubricate all parts with hydraulic oil.

Inspection and Replacement
Replace all seals and washers. Check all parts carefully and make any replacements necessary.

STEER CONTROL UNIT (CONT'D)

Assembling

Place the two flat neutral position springs in the slot.
Place the curved springs between the flat ones and press them into place.

Line up the spring set.

Guide the spool into the sleeve. Make sure that spool and sleeve are placed correctly in relation to each other.

STEER CONTROL UNIT (CONT'D)

Assembling (Cont.)

Assemble spool and sleeve.

When assembling spool and sleeve only one of two possible ways of positioning the spring slots is correct. There are three slots in the spool and three holes in the sleeve in the end of the spool/sleeve opposite to the end with spring slots. Place the slots and holes opposite each other so that parts of the holes in the sleeve are visible through the slots in the spool.

Assemble the spool/sleeve and make sure the marks on spool and sleeve are opposite each other (see drawing page 10.63).

Press the springs together and push the neutral position springs into place in the slave.

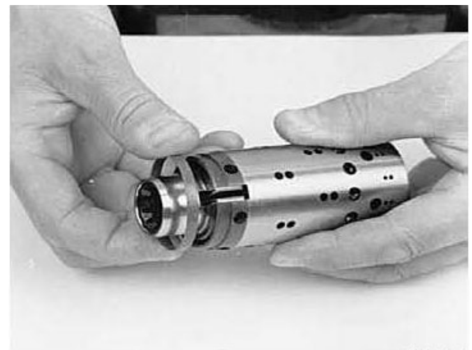
Line up the springs and center them.

STEER CONTROL UNIT (CONT'D)

Assembling (Cont.)

Guide the ring down over the sleeve.

The ring should be able to move free of springs.



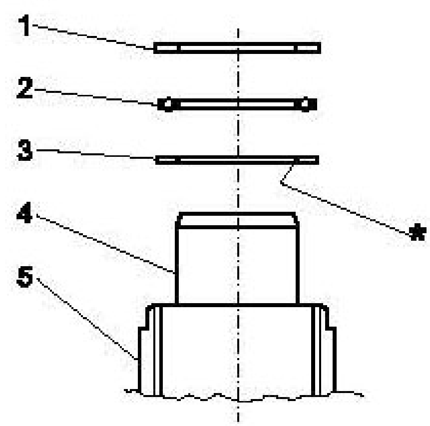
Fit the cross pin into the spool/sleeve.

Fit bearing races and needle bearings as shown on the drawing next page.

STEER CONTROL UNIT (CONT'D)

Assembling Bearing

1. Outer Bearing Race
2. Needle Bearing
3. Inner Bearing Race
4. Spool
5. Sleeve



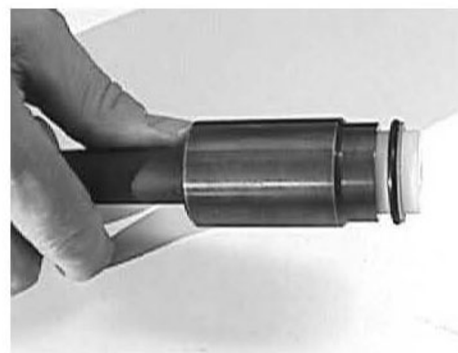
The inside chamfer on the inner bearing race must face the inner spool.

STEER CONTROL UNIT (CONT'D)

Installation Instructions for O-Ring/Kin-Ring/Roto Glyd

Turn the steering unit until the bore is horizontal. Guide the outer part of the assembly tool into the bore for the spool/sleeve.

Grease o-ring and kin-ring/Roto Glyd with hydraulic oil and place them on the tool.



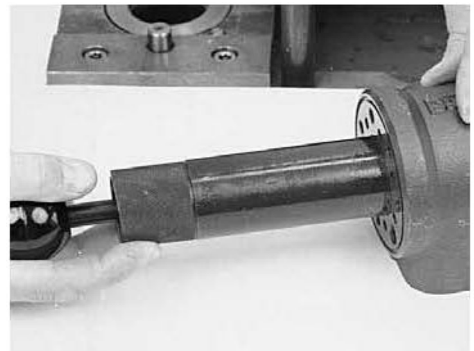
Hold the outer part of the assembly tool in the bottom of the steering unit housing and guide the inner part of the tool right to the bottom.

Press and turn the o-ring/kin-ring into position in the housing.

STEER CONTROL UNIT (CONT'D)

Installation Instructions for O-Ring/Kin-Ring/Roto Glyd (Cont.)

Draw the inner and outer parts of the assembly tool out of the steering unit bore, leaving the guide from the inner part in the bore.

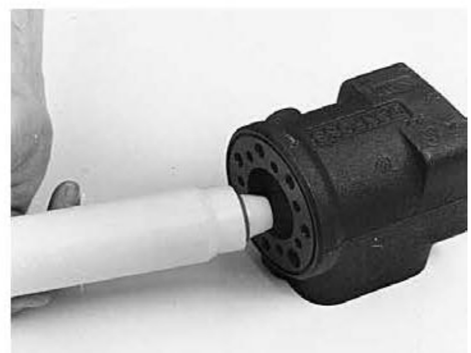


STEER CONTROL UNIT (CONT'D)

Installation Instructions for Lip Seal

Lubricate the lip seal with hydraulic oil and place it on the assembly tool.

Guide the assembly tool right to the bottom.



Press and turn the lip seal into place in the housing.

With a light turning movement, guide the spool and sleeve into the bore.

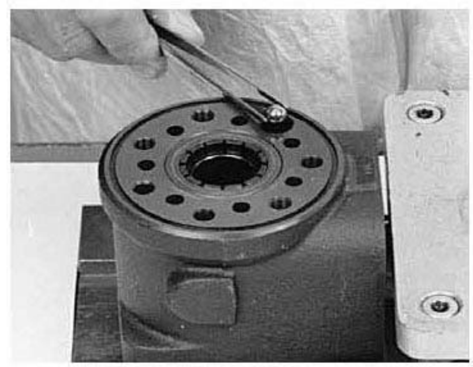
Fit the spool set holding the cross pin horizontal.

STEER CONTROL UNIT (CONT'D)

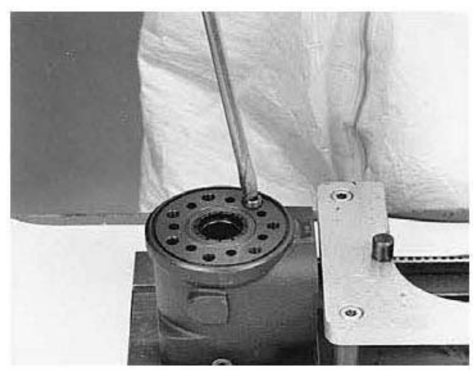
Installation Instructions for Lip Seal (Cont.)

The spool set will push out the assembly tool guide. The o-ring and kin-ring/Roto Glyd are now in position.

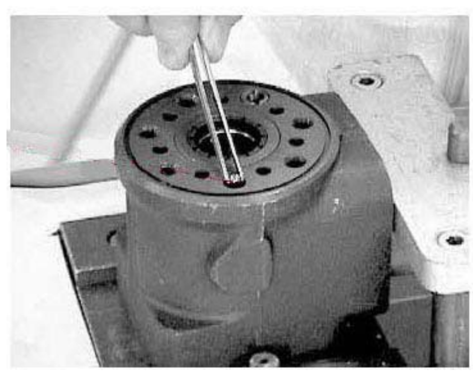
Turn the steering unit until the bore is vertical again. Put the check valve ball into the hole indicated by the arrow on the face of the unit.



Screw the threaded bush lightly into the check valve bore. The top of the bush must lie just below the surface of the housing.



Place a ball in the two holes indicated by the arrows on the face of the unit.

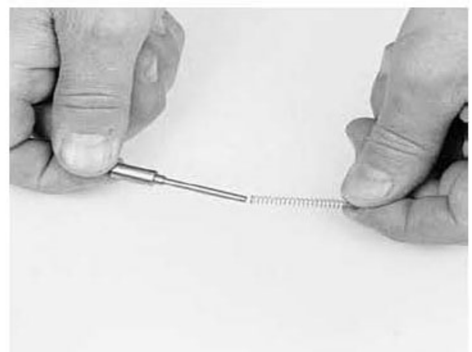


STEER CONTROL UNIT (CONT'D)

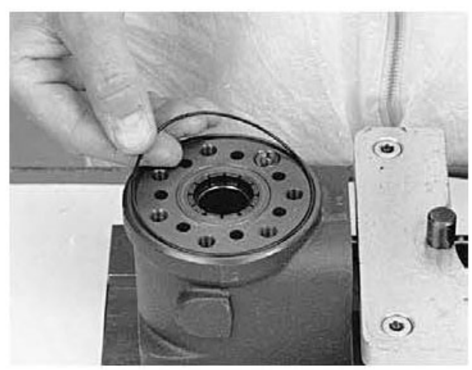
Installation Instructions for Lip Seal (Cont.)

Place a new pin in the same two holes.

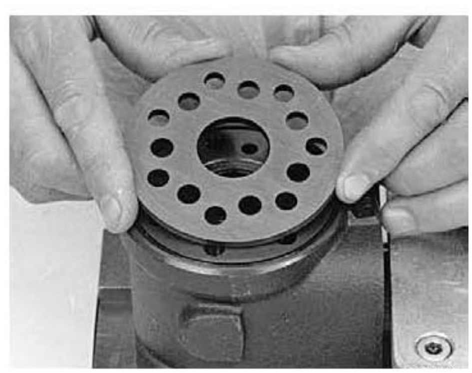
In some cases, a spring has to be fitted on the pin before it is placed in the housing.



Grease the o-ring with mineral oil approx. viscosity 500 mm 2/s [SUS] at 20° C [68° F].



Place the distributor plate so that the channel holes match the holes in the housing.

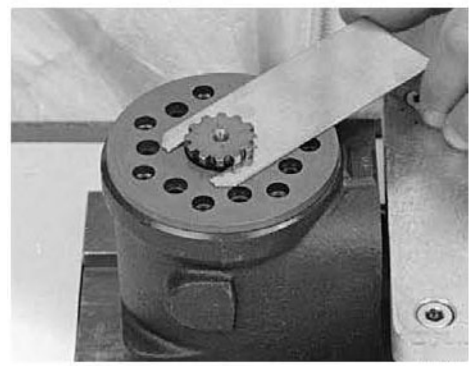


STEER CONTROL UNIT (CONT'D)

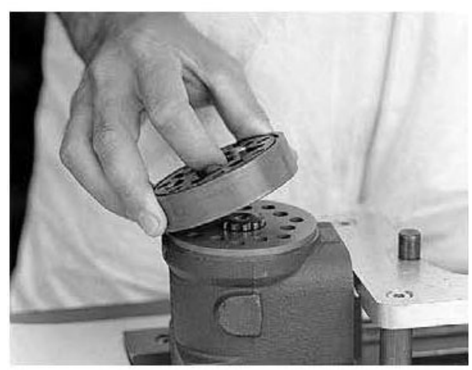
Installation Instructions for Lip Seal (Cont.)

Guide the cardan shaft down into the bore so that the slot is parallel with the connection flange.

Place the cardan shaft as shown – so that it is held in position by the mounting fork.

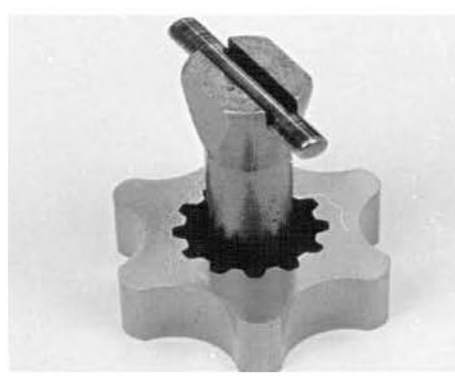


Grease the two o-rings with mineral oil approx. viscosity 500 mm 2/s [SUS] at 20° C [68° F] and place them in the two grooves in the gear rim. Fit the gearwheel and rim on the cardan shaft.



CAUTION

Fit the gearwheel (rotor) and cardan shaft so that a tooth base in the rotor is positioned in relation to the shaft slot as shown. Turn the gear rim so that the seven trough holes match the holes in the housing.

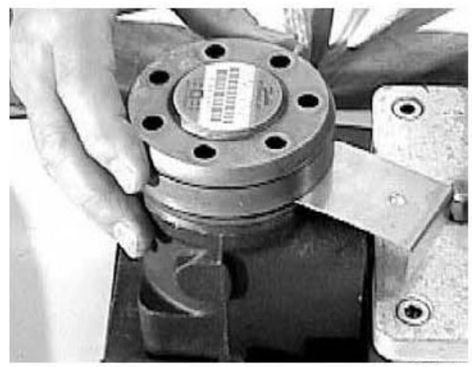


STEER CONTROL UNIT (CONT'D)

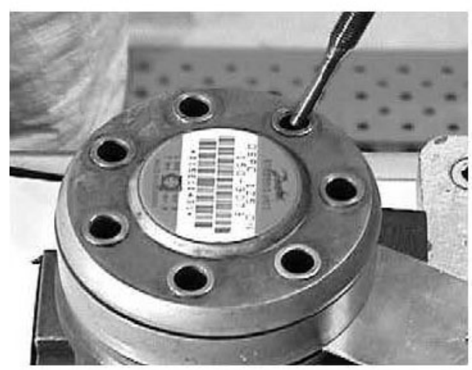
Installation Instructions for Lip Seal (Cont.)

Fit the spacer, if any.

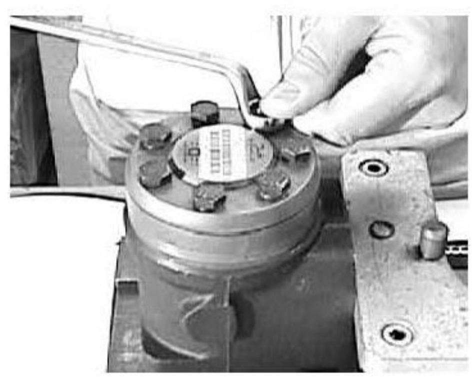
Place the end cover in position.



Fit the special screw with washer and place it in the hole shown.

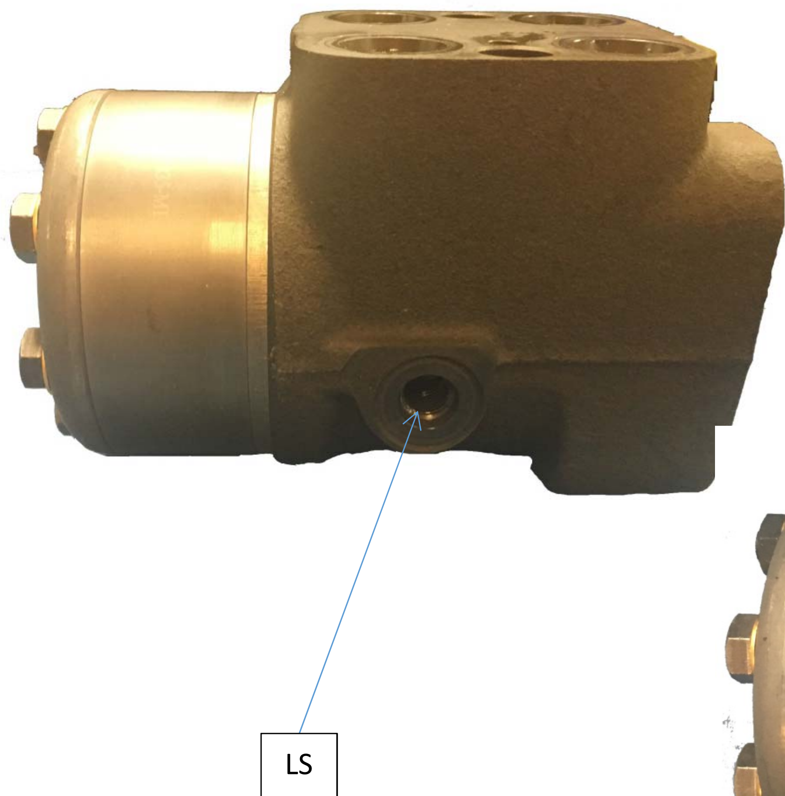


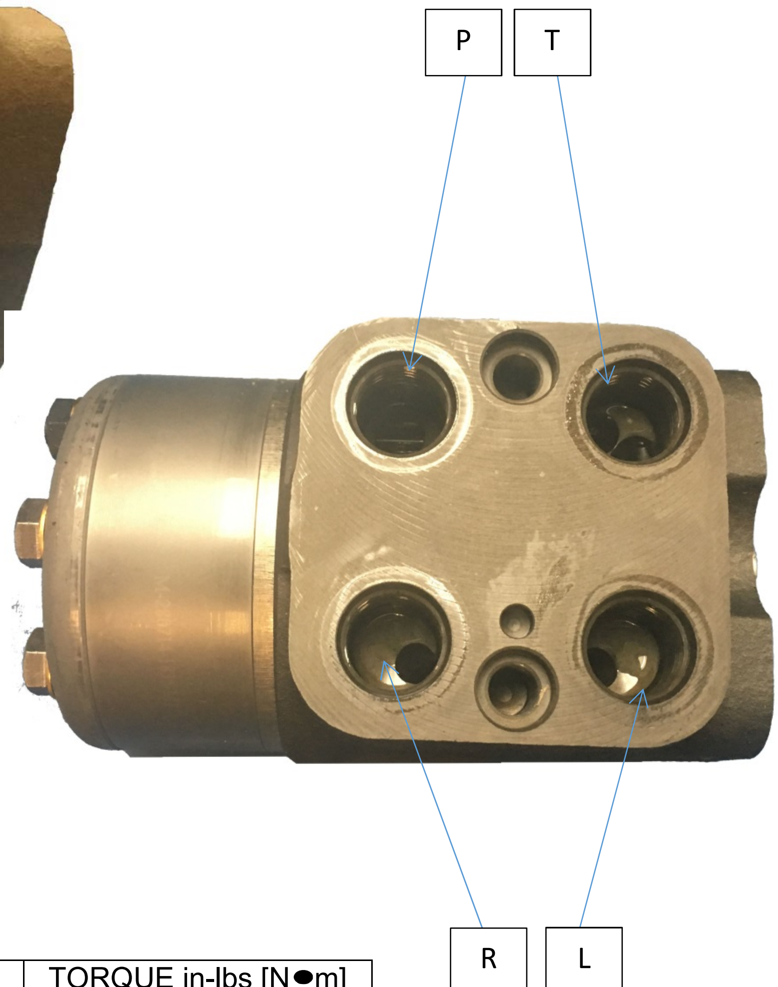
Fit the six screws with washers and insert them. Cross-tighten all the screws and the rolled pin with a torque of 30 +/- 6 N.M. [265.5 +/- 53 lbfin]. The unit can now be function tested.



STEER CONTROL UNIT (CONT'D)

Maximum Tightening Torque and Hydraulic Connections



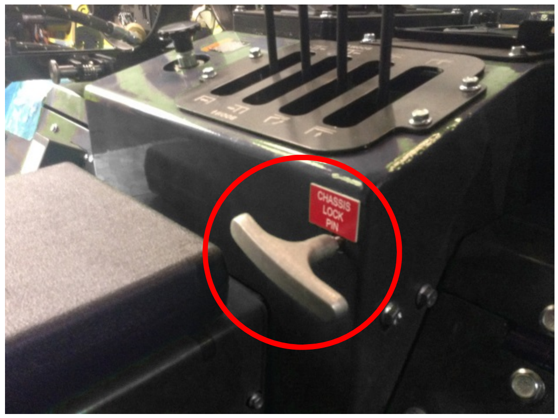


LS:	Load sense
T:	Tank
L:	Left port
P:	Pump
R:	Right port

PORT LOCATION	THREAD SIZE	TORQUE in-lbs [N●m] w/copper washer
LS	7/16-20UNF	180 [20]
T,L,P,R	¾-16 UNF	530 [60]

EXTEND CYLINDER REMOVAL

Unlock the chassis lock pin and extend the counterweight to full extension. Set the parking brake and shut the truck down. Make sure the boom assembly is not on the truck (if applicable).

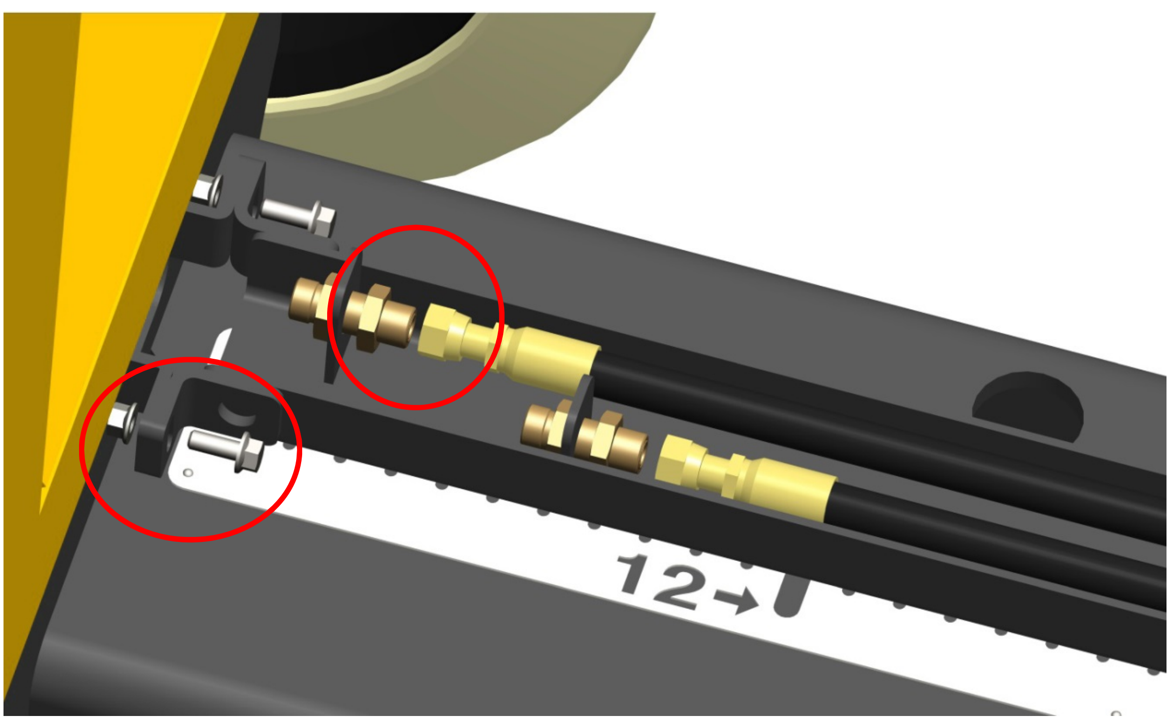


Block the front wheels so the truck cannot roll forward. Block under the front chassis tube toward the rear.

EXTEND CYLINDER REMOVAL (CONT'D)

Remove the counterweights from the rear chassis using an approved lifting device. NOTE: Counterweights will have to be removed individually.

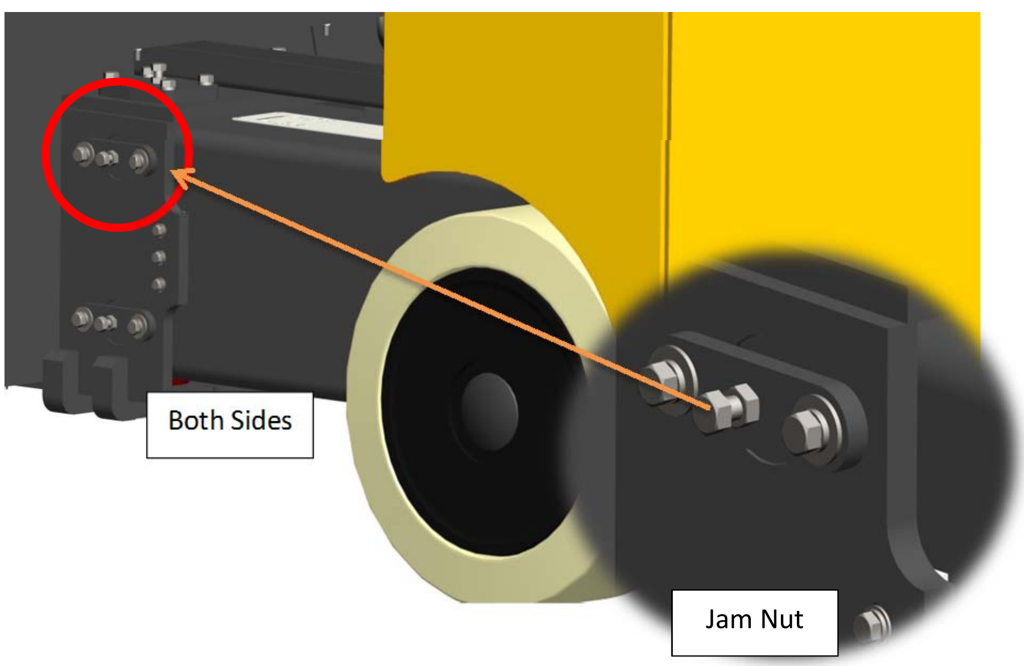
Disconnect the steer cylinder hoses and the steer cylinder hose channel from the rear chassis.



EXTEND CYLINDER REMOVAL (CONT'D)

Remove the hardware, rod keeper, and pin from the extend cylinder rod end. (Figure 3) Wrap the cylinder rod with something protective so as to not damage when removing.

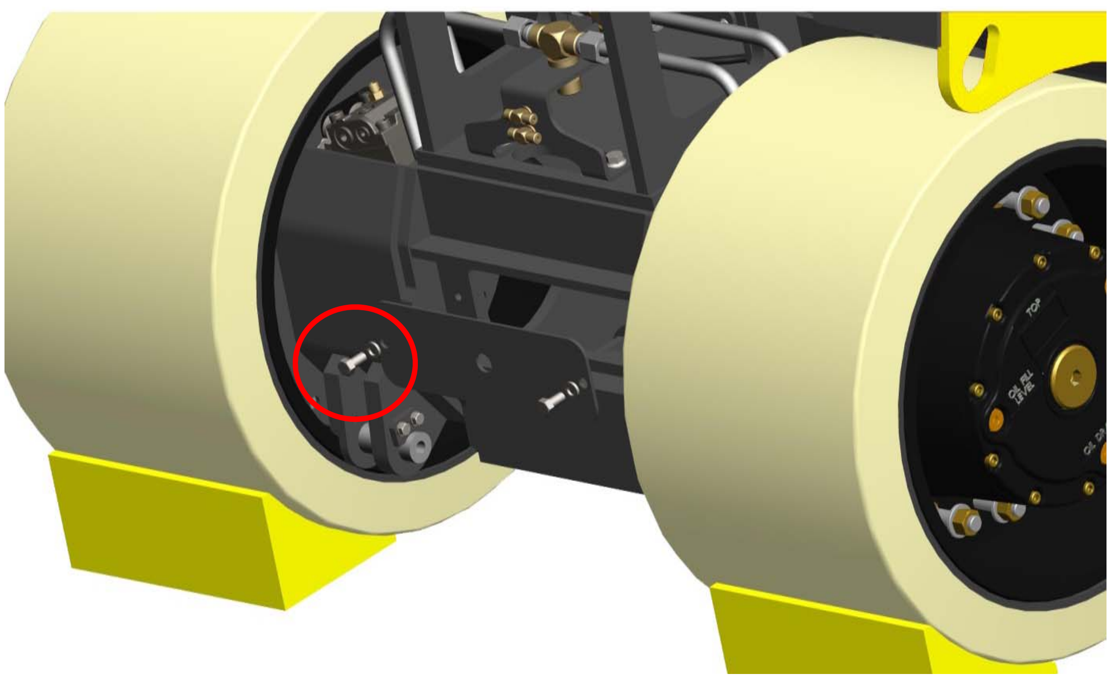
Loosen all of the tube wear pads on the front chassis by unthreading the jam nut on the middle bolt.



EXTEND CYLINDER REMOVAL (CONT'D)

Using a properly rated forklift, hook to the counterweight tow pin and pull the rear chassis straight out of the front chassis.

Remove the front access panel and hardware from the front chassis.

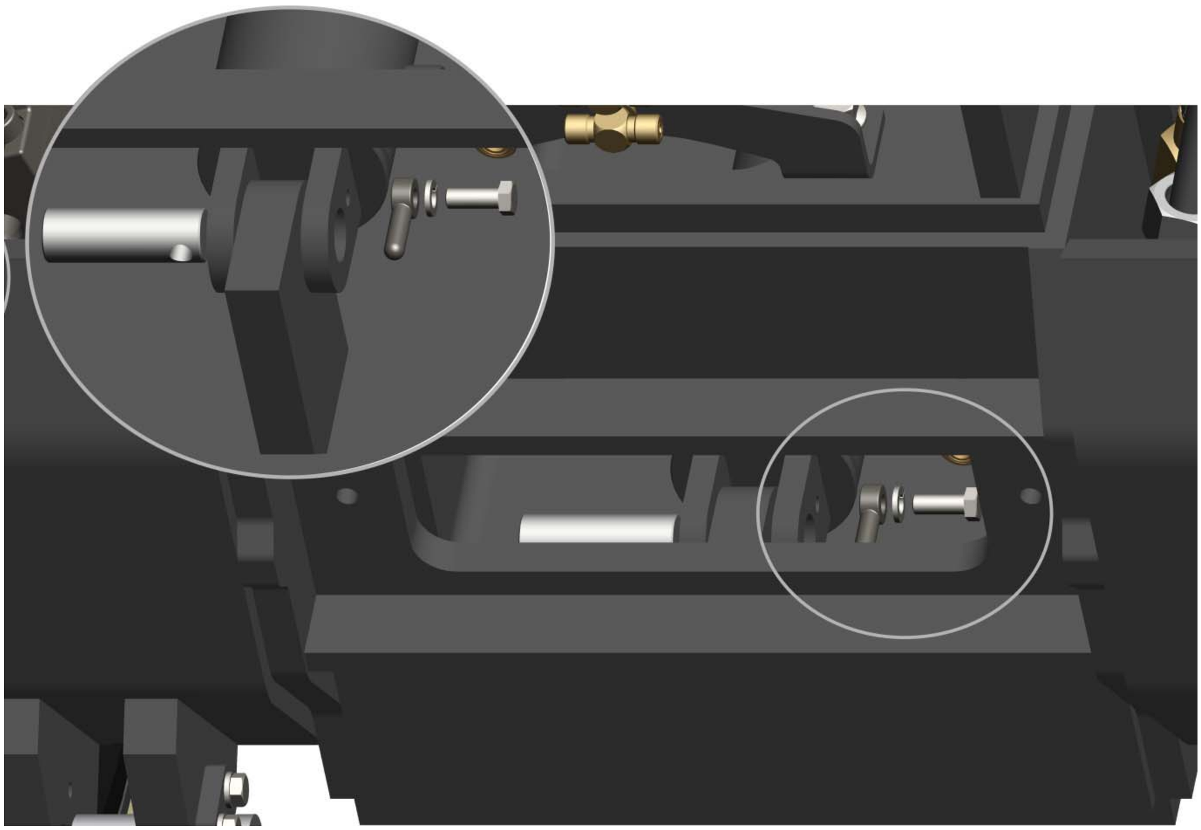


EXTEND CYLINDER REMOVAL (CONT'D)

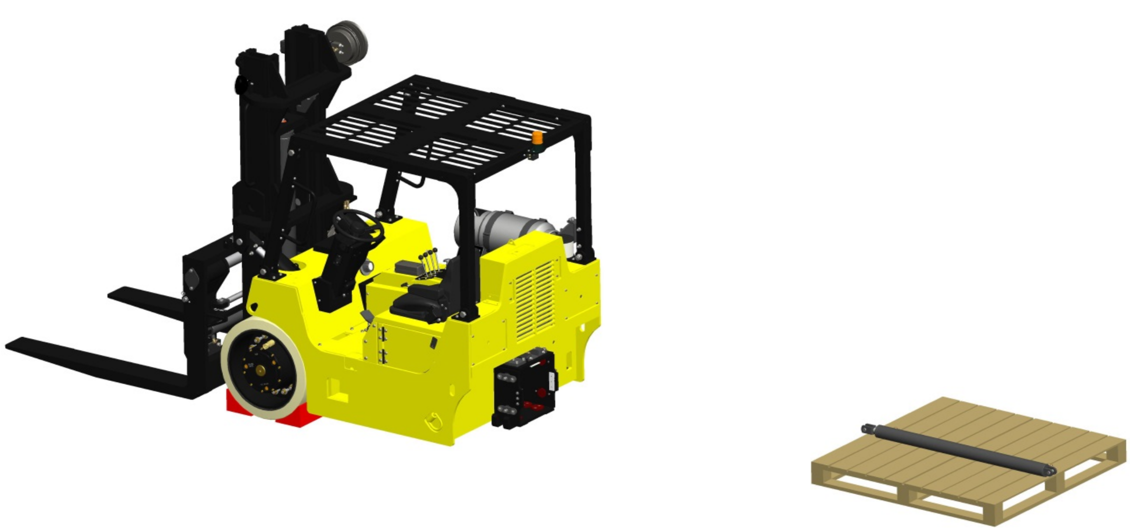
Disconnect the hoses from the extend cylinder and cap off to prevent spillage.

EXTEND CYLINDER REMOVAL (CONT'D)

Remove the pin keeper, hardware and pin from the front cylinder clevis located under the access panel.



Remove the cylinder through the rear of the front chassis and place on a pallet.



In General

The trouble-shooting charts and maintenance hints that follow are of a general system nature but should provide an intuitive feeling for a specific system. The more general information is covered in the immediately following paragraphs.

It should be noted that a seemingly uncomplicated procedure such as relocating or changing a component part can cause problems. Because of this, the following points should be considered.

A. Each component in the system must be compatible with and form an integral part of the system. For example, an inadequate size filter on the inlet of a pump can cause cavitation and subsequent damage to the pump. Only use genuine OEM replacement parts.

B. All lines must be of proper size and free of restrictive bends. Undersized or restricted line results in a pressure drop in the line itself. Always replace hydraulic lines with the original size.

C. Some components must be mounted in a specific position with respect to the other component or the lines. The housing of an in-line pump, for example, must remain filled with fluid to provide lubrication. Do NOT relocate components.

Knowing the System

Probably the greatest aid to trouble-shooting is the confidence of knowing the system. Every component has a purpose in the system. The construction and operation characteristics of each one should be understood. Some additional practices which will increase your ability and also the useful life of the system follow:

A. Know the capabilities of the system. Each component in the system has a maximum rated speed, torque, or pressure. Loading the system beyond the specification simply increases the possibility of failure.

B. Know the correct operating pressures. Always set and check pressures with a pressure gauge. How else can you know if the operating pressure is above maximum rating of components? The question may arise as to what the correct operating pressure is. If it isn't specified on the hydraulic schematic, the following rule should be applied:

> The correct operating pressure is the lowest pressure which will allow adequate performance of the system function and still remain below the maximum rating of the components.

Once the correct pressures have been established, note them on the hydraulic schematic for future references.

Developing Systematic Procedures

Analyze the system and develop a logical sequence for setting valves, mechanical stops, interlocks, and electrical controls. The initial time spent on such a projects could save hours of system down-time.

Recognizing Trouble Indications

The ability to recognize trouble indications in a specific system is usually acquired with experience. However, a few general trouble indications can be discussed.

A. Excessive heat means trouble. A misaligned coupling places an excessive load on bearings and can be readily identified by the heat generated. A warmer than normal tank return line on a relief valve setting. Hydraulic fluids which have a low viscosity will increase the internal leakage of components resulting in a heat rise. Cavitation and slippage in a pump will also generate heat.

B. Excessive noise means wear, misalignment, cavitation or air in the fluid. Contaminated fluid can cause a relief valve to stick and chatter. These noises may be the result of dirty filters, or fluid, high fluid viscosity, excessive drive speed, low reservoir level, or loose intake lines.

Maintenance

Three simple maintenance procedures have the greatest effect on hydraulic system performance, efficiency, and life. Yet, the very simplicity of them may be the reason they are so often overlooked. What are they? Simply these:

A. Changing filters and strainers.

B. Maintaining a clean sufficient quantity of hydraulic fluid of the proper type and viscosity.

C. Keeping all connections tight, but not to the point of distortion, so that air is excluded from the system.

The following charts are arranged in five main categories. The heading of each one is an effect which indicates a malfunction in the system. For example, if a pump is exceptionally noisy, refer to Chart I titled EXCESSIVE NOISE. The noisy pump appears in Column A under the main heading. In Column A there are four probable causes for a noisy pump. The causes are sequenced according to the likelihood of happening or the ease of checking it. The first cause is cavitation and the remedy is “a”. If the first cause does not exist, check for cause number 2, etc.

1

EXCESSIVE NOISE

- **A — PUMP NOISY**
  1. Cavitation — Remedy: a
  2. Air in Fluid — Remedy: b
  3. Coupling Misaligned — Remedy: c
  4. Pump Worn or Damaged — Remedy: e
- **B — MOTOR NOISY**
  1. Coupling Misaligned — Remedy: c
  2. Motor Worn or Damaged — Remedy: e
- **C — RELIEF VALVE NOISY**
  1. Setting too close to operating pressure or to another valve setting — Remedy: d
  2. Worn Poppet and Seal — Remedy: e

Remedies:

a. Any or all of the following: Replace dirty filters – Clean clogged inlet line – Clean reservoir breather vent – Change system fluid – Change to proper pump drive motor speed – Overhaul or replace pump.

b. Any or all of the following: Tighten leaky inlet connections – Fill reservoir to proper level – Bleed air from system – Replace pump shaft seal.

c. Align unit and check condition of seals and bearings.

d. Using multi-gauge, adjust to correct pressure.

e. Overhaul or replace.

2

EXCESSIVE HEAT

A — PUMP HEATED

1. Fluid Heated
   Remedy: See Column D
2. Cavitation
   Remedy: a
3. Air in Fluid
   Remedy: b
4. Relief or Unloading Valve Set too High
   Remedy: d
5. Excessive Load
   Remedy: c
6. Worn or Damaged Pump
   Remedy: e

B — MOTOR HEATED

1. Fluid Heated
   Remedy: See Column D
2. Relief or Unloading Valve Set too High
   Remedy: d
3. Excessive Load
   Remedy: c
4. Worn or Damaged Motor
   Remedy: e

C — RELIEF VALVE

1. Fluid Heated
   Remedy: See Column D
2. Valve Setting Incorrect
   Remedy: d
3. Worn or Damaged Valve
   Remedy: e

D — FLUID HEATED

1. System Pressure Too High
   Remedy: d
2. Unloading Valve Set too High
   Remedy: d
   d
3. Fluid Dirty or Low Supply
   Remedy: f
4. Incorrect Fluid Viscosity
   Remedy: f
5. Faulty Fluid Cooling System
   Remedy: e
6. Worn Pump, Valve, Motor, Cylinder or Other Component
   Remedy: c

Remedies:

a. Any or all of the following: Replace dirty filters – Clean clogged inlet line – Clean reservoir breather vent – Change system fluid – Change to proper pump drive motor speed – Overhaul or replace pump.

b. Any or all of the following: Tighten leaky inlet connections – Fill reservoir to proper level – Bleed air from system – Replace pump shaft seal.

c. Align unit and check condition of seals and bearings – Locate and correct mechanical binding – Check for work load in excess of circuit design.

d. Using multi-gauge, adjust to correct pressure.

e. Overhaul or replace.

f. Change filters and also system fluid if of proper viscosity – Fill reservoir to proper level.

3

INCORRECT FLOW

A — NO FLOW

1. Pump not Receiving Fluid
   Remedy: a
2. Pump Drive Motor Not Operating
   Remedy: e
3. Pump to Drive Coupling Sheared
   Remedy: c
4. Pump Drive Motor Turning in Wrong Direction
   Remedy: g
5. Directional Control Set in Wrong Position
   Remedy: f
6. Entire Flow Passing Over Relief Valve
   Remedy: d

B — LOW FLOW

1. Flow Control Set Too Low
   Remedy: d
2. Relief or Unloading Valve Set Too Low
   Remedy: d
3. External Leak in System
   Remedy: b
4. Yoke Actuating Device Inoperative (Variable Displacement Pumps)
   Remedy: e
5. Worn Pump, Valve, Motor, Cylinder, or Other Component
   Remedy: e

C — EXCESSIVE FLOW

1. Flow Control Set Too High
   Remedy: d
2. Yoke Actuating Device Inoperative (Variable Displacement Pumps)
   Remedy: e

Remedies:

a. Any or all of the following: Replace dirty filters – Clean clogged inlet line – Clean reservoir breather vent – Fill reservoir to proper level – Overhaul or replace pump.

b. Tighten leaky connections – Bleed air from system.

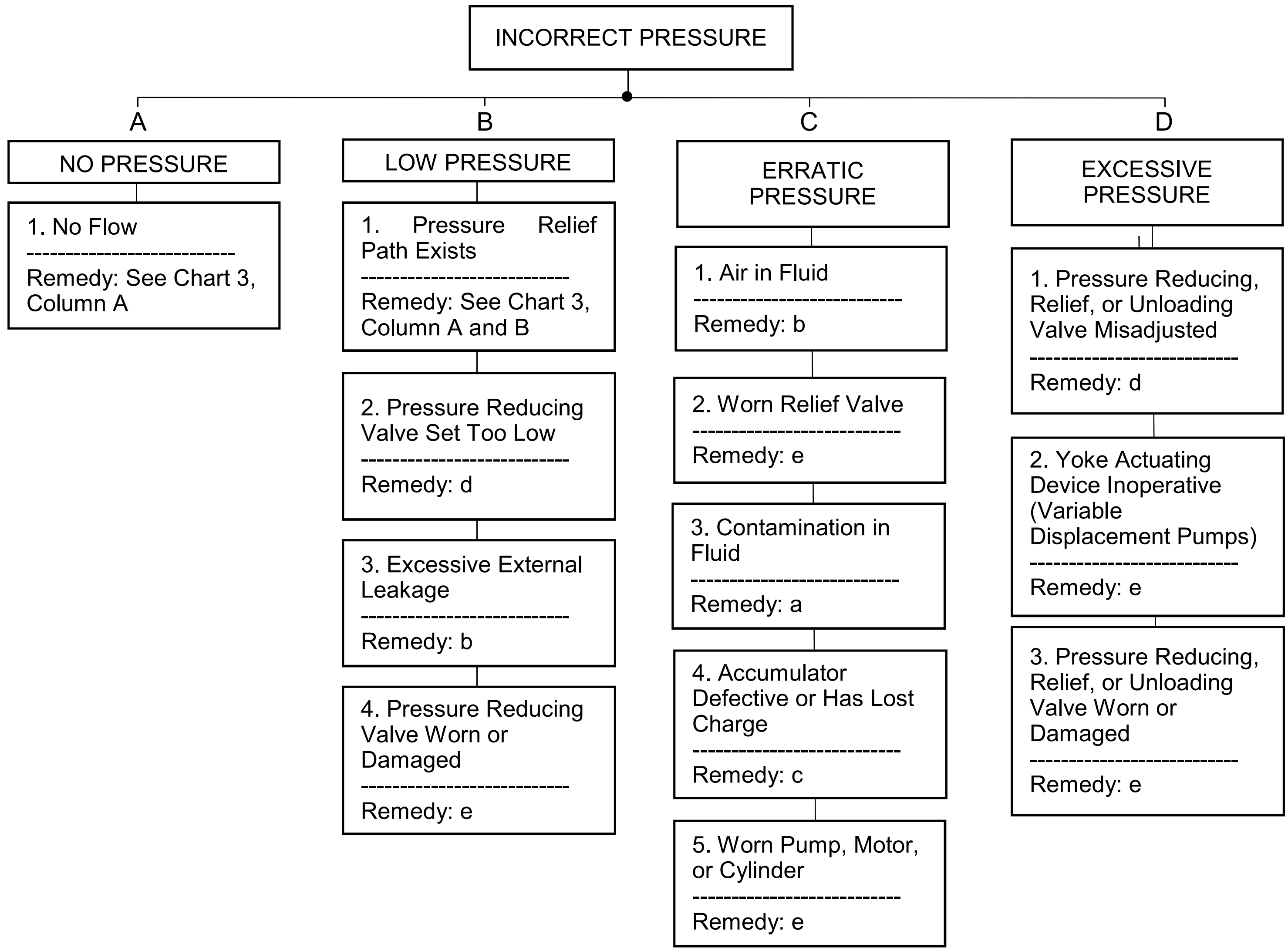
c. Check for damaged pump or pump drive – Replace and align coupling.

d. Adjust.

e. Overhaul or replace

f. Check electrical circuit on solenoid operated controls.

4



Remedies:

a. Replace dirty filters and system fluid.

b. Tighten leaky connections (fill reservoir to proper level and bleed air from system).

c. Check gas valve for leakage – Charge to correct pressure – Overhaul if defective

d. Adjust.

e. Overhaul or replace.

5

FAULTY OPERATION

- **A — NO MOVEMENT**
  1. No Flow or Pressure — Remedy: See Chart 3 A
  2. Limit or Sequence Device (Mechanical, Electrical, or Hydraulic) Inoperative or Misadjusted — Remedy: c
  3. Mechanical Bind — Remedy: b
  4. Worn or Damaged Cylinder or Motor — Remedy: c
- **B — SLOW MOVEMENT**
  1. Low Flow — Remedy: See Chart 3
  2. Fluid Viscosity Too High — Remedy: a
  3. Insufficient Control Pressures for Valves — Remedy: See Chart 4
  4. No Lubrication of Machine Ways or Linkage — Remedy: d
  5. Worn or Damaged Cylinder or Motor — Remedy: c
- **C — ERRATIC MOVEMENT**
  1. Erratic Pressure — Remedy: See Chart 4
  2. Air in Fluid — Remedy: See Chart 1
  3. No Lubrication of Linkage — Remedy: d
  4. Worn or Damaged Cylinder or Motor — Remedy: c
- **D — EXCESSIVE SPEED OR MOVEMENT**
  1. Excessive Flow — Remedy: See Chart 3

Remedies:

a. Fluid may be too cold or should be changed to clean fluid of correct viscosity.

b. Locate bind and repair.

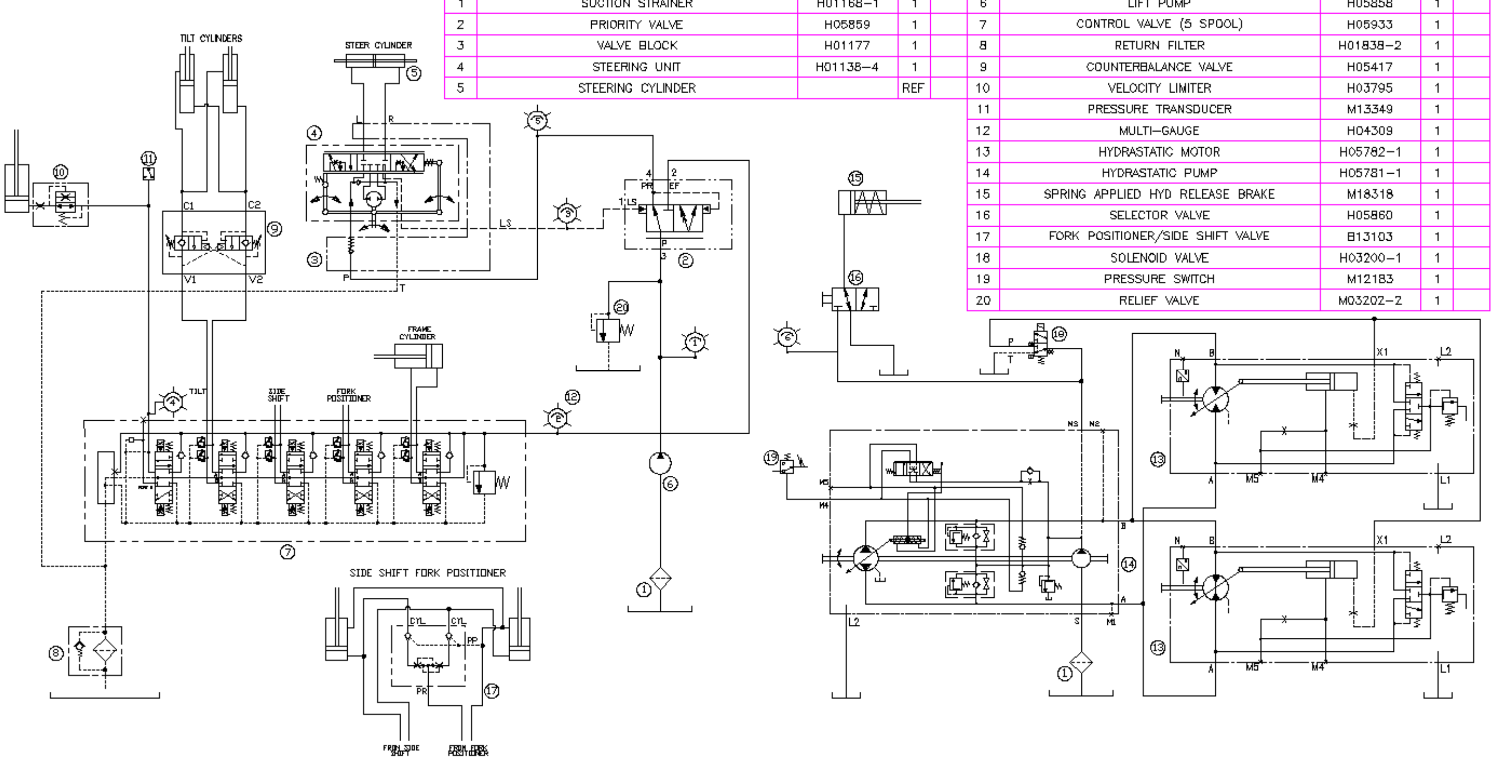
c. Overhaul or replace.

d. Lubricate.

HYDRAULIC SCHEMATIC

The following schematic is provided for reference purposes only and is intended to give a general representation of the interaction of the various components discussed in this manual. It is NOT intended to be representative of all of the various options and configurations available on the FR series. Refer to your Serial Number specific Parts Manual for the Hydraulic Schematic applicable to your truck PRIOR TO ATTEMPTING ANY HYDRAULIC SERVICE.

ITEM	MAT'L / DESCRIPTION	PART No.	QTY	BUY or MAKE
1	SUCTION STRAINER	H01168–1	1	
2	PRIORITY VALVE	H05859	1	
3	VALVE BLOCK	H01177	1	
4	STEERING UNIT	H01138–4	1	
5	STEERING CYLINDER		REF	
6	LIFT PUMP	H05858	1	
7	CONTROL VALVE (5 SPOOL)	H05933	1	
8	RETURN FILTER	H01838–2	1	
9	COUNTERBALANCE VALVE	H05417	1	
10	VELOCITY LIMITER	H03795	1	
11	PRESSURE TRANSDUCER	M13349	1	
12	MULTI–GAUGE	H04309	1	
13	HYDRASTATIC MOTOR	H05782–1	1	
14	HYDRASTATIC PUMP	H05781–1	1	
15	SPRING APPLIED HYD RELEASE BRAKE	M18318	1	
16	SELECTOR VALVE	H05860	1	
17	FORK POSITIONER/SIDE SHIFT VALVE	B13103	1	
18	SOLENOID VALVE	H03200–1	1	
19	PRESSURE SWITCH	M12183	1	
20	RELIEF VALVE	M03202–2	1	

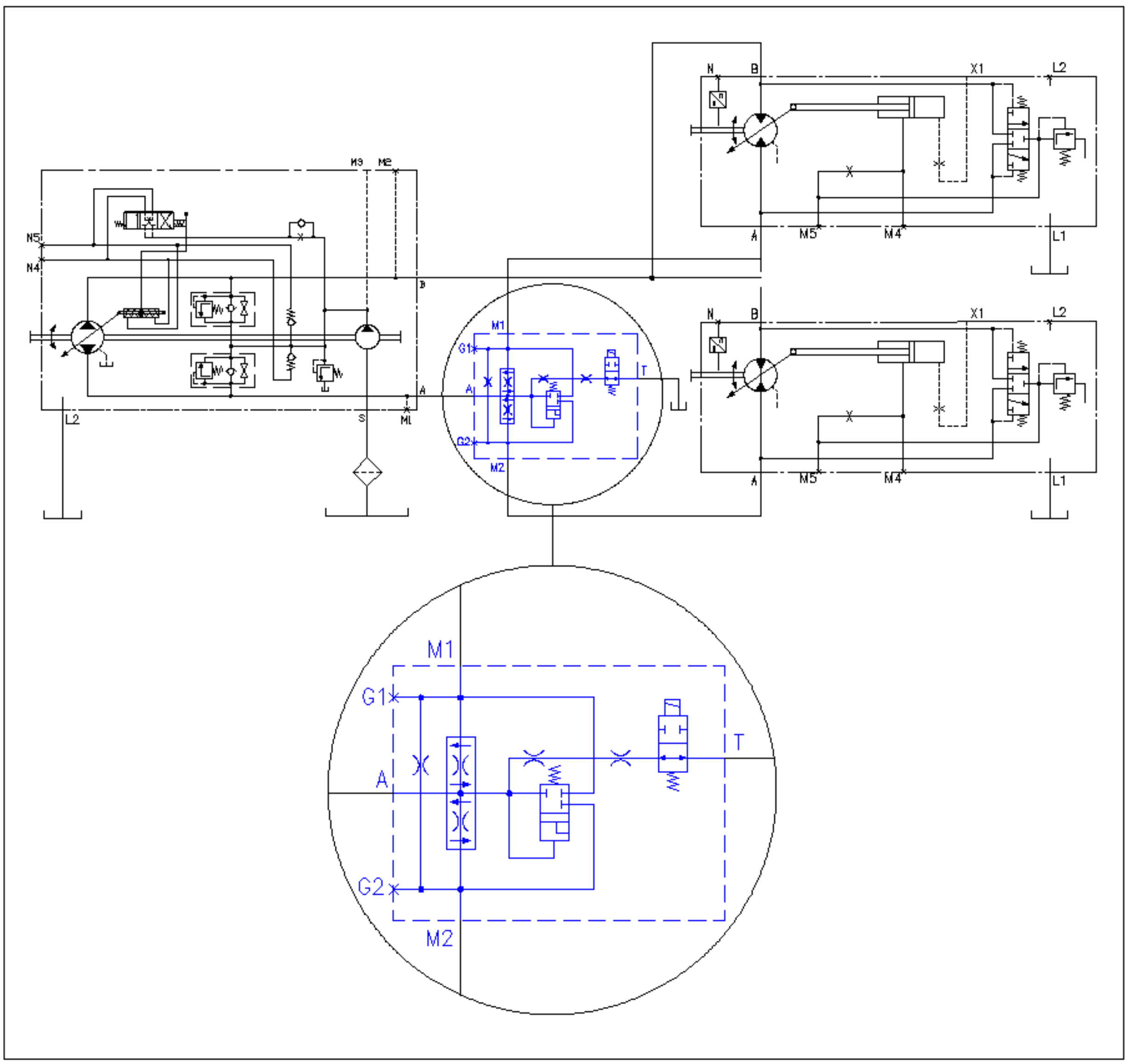


FR15/25, FR18/26, & FR25/35 SERVICE MANUAL
OPTIONAL EQUIPMENT

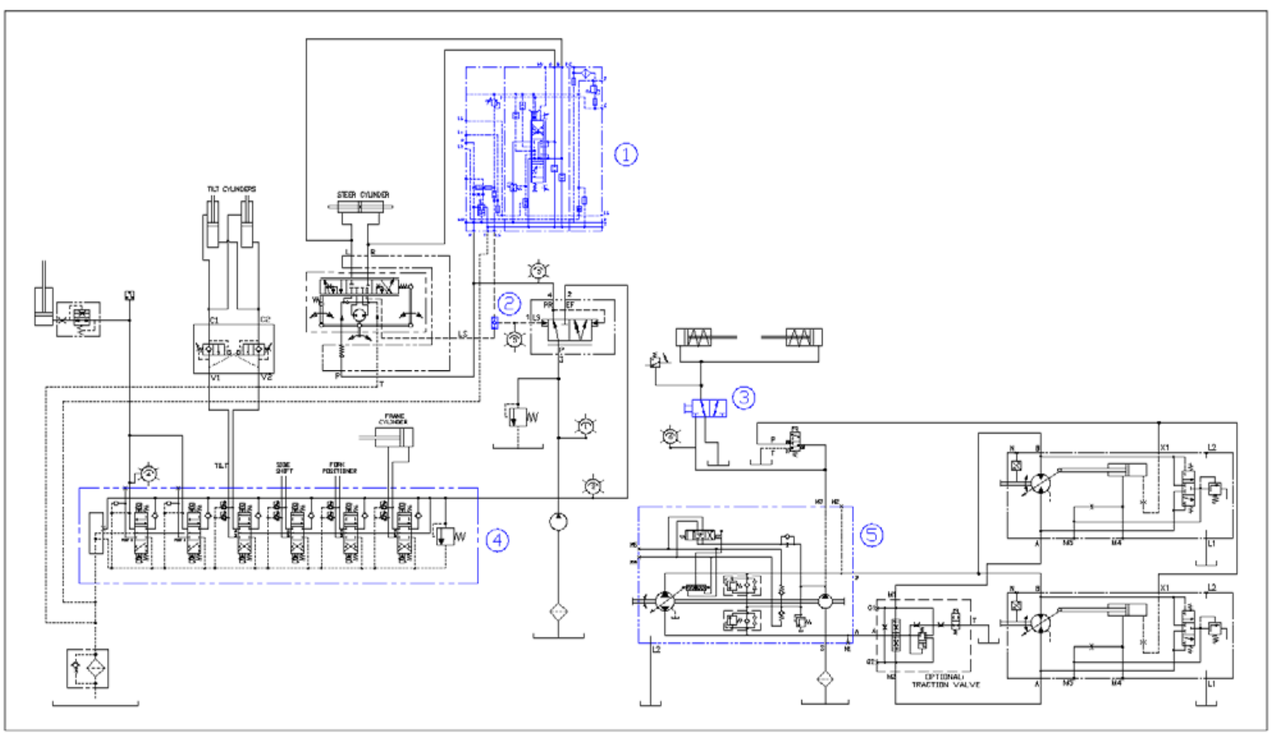
INDEX

OPTIONAL TRACTION CONTROL SYSTEM

The Hoist Material Handling FR Series offers an optional traction control system. This system utilizes a traction control valve in the hydraulic system of the vehicle shown on the hydraulic schematic below in blue. This valve provides electrically actuated traction control accessed directly through the operator display of the vehicle. In normal operation (de-energized) fluid passes freely through the valve. When energized, fluid is forced through a flow divider/combiner providing equal flow to each wheel, preventing wheel spin or motor over speed.



OPTIONAL PENDANT CONTROL SYSTEM



HYDRAULIC SYSTEM:

When an optional pendant control system is installed the hydraulic components highlighted below in blue are changed/added to the hydraulic system of the truck.

1) A single spool electronic proportional control valve is added in parallel with the standard orbital steer valve as shown. This valve is used to control the steer cylinder when the operator uses the remote control. The valve is a load sense style valve directly controlled by the XA2 module (see electrical section).

2) A shuttle valve is added to the load sense circuit of the hydraulic system as shown above. The shuttle valve insures that the higher load sense pressure between the standard orbital valve and optional electronic steer valve is commanded back to the priority valve to provide proper steering pressure.

3) The standard push/pull mechanical parking brake valve normally fit to the truck is replaced with a push/pull button and a solenoid valve as shown. In normal operation (energized) the solenoid provides pump pressure to the spring applied/hydraulic release brake caliper to release the parking brake. When the operator applies the parking brake via the push/pull button on the vehicle or the button on the pendant, the solenoid valve is de-energized and direct flow between the caliper and hydraulic tank applies the parking brake.

4) Electronic proportionally controlled solenoids are added to all sections of the main hydraulic control valve (excluding the frame extend/retract section as this section is already electrically controlled). The solenoids are directly controlled by the XA2 module when the operator uses any mast/boom function on the remote control. Each valve section uses 2 solenoids (A & B side of valve section) to control any specific vehicle function. The solenoids are used in parallel with the mechanical handles of the control valve to provide required functionality from the operator’s area or from the remote control.

5) The compensator of the pump is changed from a mechanical linkage style to an electronic proportionally control style. In conjunction with this modification, the monotrol pedal of the truck is also changed from a mechanical type to an electronic proportional type. The drive of the vehicle is therefore controlled electrically directly from the XA2 module when the operator uses either the monotrol pedal or the drive joystick located on the remote control.

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OPTIONAL EQUIPMENT

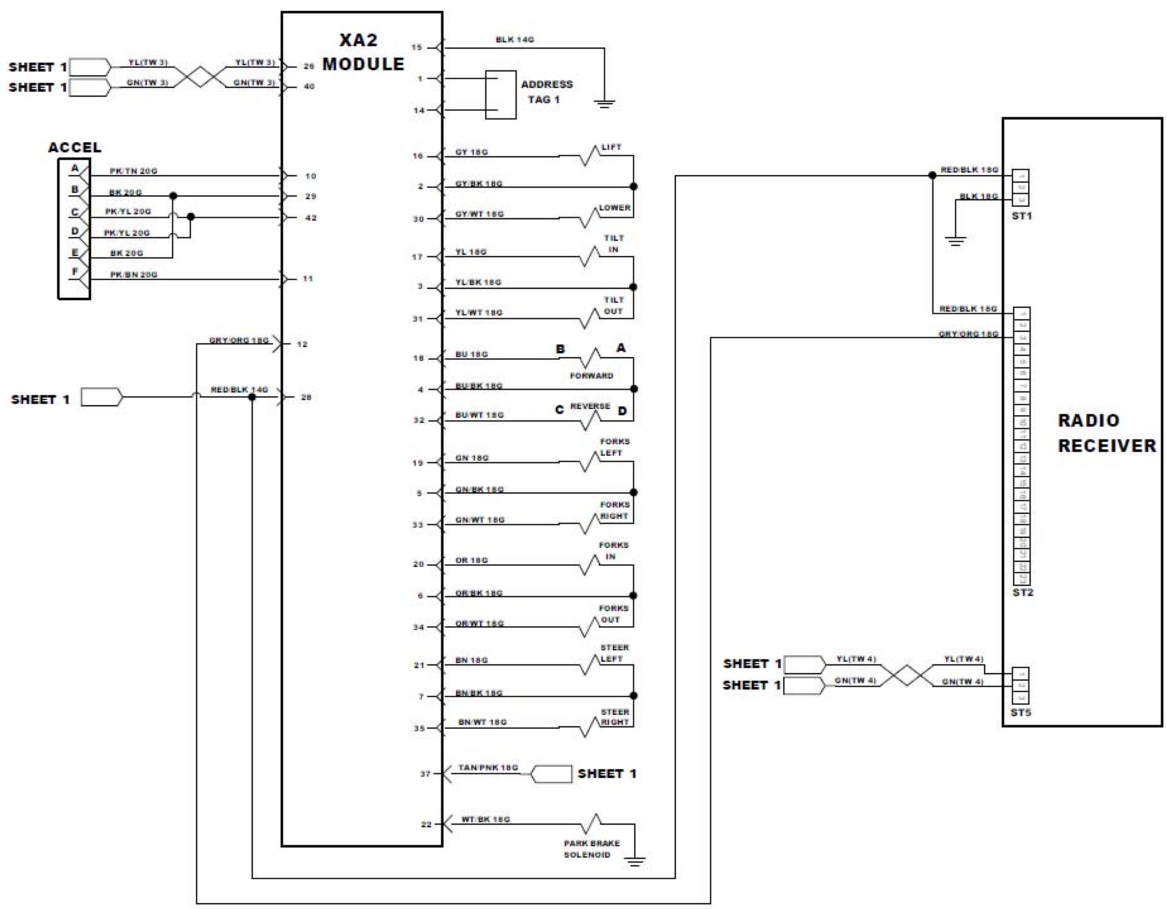
ELECTRICAL SYSTEM:

When the optional pendant control system is installed the following electrical components shown on the attached electrical schematic are added as well.

1) An additional XA2 expander module is added to accomodate the additional I/O requirement of the accelerator, valve solenoids, parking brake solenoid and pendant E-stop button. Note: an address tag of 1 is used with this module as shown to identify it from the original XA2 module on the truck.

2) A radio receiver and remote control is added to the truck. See the controls section of the operators manual for identification of the remote control functionality. The radio receiver is used to communicate between the remote control and the additional XA2 module.

3) An electronic monotrol accelerator replaces the mechanical monotrol pedal. The output of the accelerator is communicated to the XA2 module as shown in the following electrical schematic.



The remote control uses a Nickel-metal hydride rechargeable battery. This battery needs to be charged when the battery indicator on the remote control turns RED. In order to remove the battery from the back of the remote, place a finger in the battery notch provided and pull the battery towards you as shown.

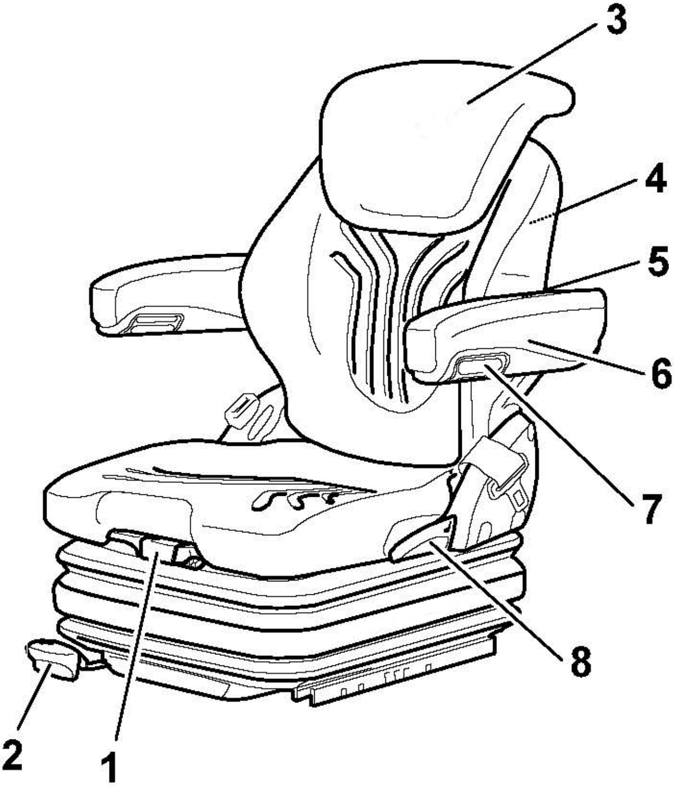
Connect the battery charger provided with the truck in the cigarette lighter of the vehicle. An optional AC charger is available upon request. Once the charger is powered up insert the battery into the charger as shown. The charging process will start automatically.

The current operating status is indicated via three LEDs.

LED green: Illuminates when the battery is charged.
LED orange: Illuminates when the battery is being charged (shown above).
LED red: Illuminates when the battery is deep discharged or faulty.

Note: When a deep discharged battery is inserted into the charger, the red LED illuminates for some time before the charging process (orange LED illuminates) starts.

Once the green LED is illuminated unplug the charger and remove battery. Insert charged battery into remote control. The remote control is now ready for use.


3
4
5
6
7
8
2
1

- The operating instructions must be read in full before use.
- The operating instructions must be kept in the vehicle and always be at hand.
- The driver’s seat may only be fitted, serviced and repaired by specialist personnel.
  The respective national regulations and the vehicle manufacturer’s fitting instructions must be observed.
  The national fitting regulations can be obtained from GRAMMER AG or from agencies of the company, or from the vehicle manufacturer.
- A correctly functioning and individually adjusted driver's seat is essential to your health. Take adequate care of your seat and have it serviced regularly to ensure that it functions correctly.

  ⚠ The functional checks are to be carried out at least as regularly as vehicle services (see maintenance plan for vehicle).
- These operating instructions should always be kept with the driver's seat. If the seat is passed on to a third party, it must be accompanied by the relevant operating instructions.
- Subject to modifications serving engineering progress and deviations compared to the standard type seat arising therefrom.

⚠ Safety instructions

- Driver's seats that have been adjusted incorrectly have a smaller moving area.
  In order to prevent any personal injury, the seat must be adjusted for the driver's weight **before use** and **before every change of driver**.
- To prevent injury, **no objects should be placed within the moving area** of the driver's seat.
- **Before commissioning** of the driver’s seat, possible **packaging material** has to be removed from the seat cushion and the backrest upholstery.
- To eliminate any risk of accident, the settings must be checked to ensure they are correctly engaged **before the vehicle is driven**.
- Adjustments must **not** be made **while driving**.
- Only touch the handle for setting the fore/aft adjustment at the indented grip provided for that purpose (do not put your whole hand around it).
  – **RISK OF CRUSHING** –
- **After removal of the backrest upholstery**, the backrest frame must be supported, for example held in place, before the backrest adjuster is operated. If you fail to do so, there is a danger that the backrest frame may jerk forward and **cause injury**.

- **Any changes to the series standard of the seat** (for example fitting parts which are not original **GRAMMER** AG parts) may impair the safety standard to which it has been tested. **Functions may be impaired**, threatening your **safety**. For this reason, **any change in design of the seat** must be approved by **GRAMMER** AG.
- During the removal and installation of the driver's seat, the corresponding instructions by the specific vehicle manufacturer must be strictly observed!
- Do not hold onto the covers for lifting the driver's seats. If you do so anyway, there is an **increased risk of injury due to loosening or breaking covers**.
- Before you remove the driver's seat, disconnect all plug-in connections between the seat and the vehicle supply network. When you replace the plug-in connectors, make sure they are tight (dust, water).
- Seatbelts are fitted or can be retrofitted to the driver's seat. Seatbelts **may only be fitted on the approval of the vehicle manufacturer**, as they increase the load in the seat mounting area.
  Seatbelts must be fitted in accordance with specific national regulations and guidelines, and must be approved by **GRAMMER** AG.
- Seatbelts must be fastened **before driving**.
  The seatbelts must be replaced after an accident.
  Where seatbelts are fitted to the driver's seat, the **seat** and **seat mounting** must be checked **additionally** by specialist personnel after an accident has occurred.
- Fasteners must be **checked regularly for tight seat**. If the seat wobbles, there may be loose bolts or other faults.
- If you notice that the seat does not function correctly (for example a defective suspension of the driver's seat; improper curvature of the lumbar support or damaged bellows), **contact a specialist workshop immediately** to arrange for repairs to be carried out.
  If you fail to do so, your health may be affected and the **risk of accident increased**.
- Before the vehicle is used, switches that might be in the seat (for shutting down mechanical equipment when the driver leaves his/her seat) must be checked for **proper function**.
  If malfunctions are detected, the vehicle must not be driven.
  – **INCREASED RISK OF ACCIDENT** –
- **Loads must not be placed on seats with a built-in switch**, except for the driver's weight during normal use, as the vehicle may otherwise start to move by itself.
  – **INCREASED RISK OF ACCIDENT** –
  If you take off the weight from the seat while driving, this will cause the vehicle to stop.
- Do not indent the bellows while there is load on the driver's seat.
  – **RISK OF CRUSHING** –
- Make sure that the **interior of the driver's seat** remains free of **foreign particles** or **liquids**.

- The driver's seat is **not watertight** and must be protected against splashes of water!
- Any conversion or refitting work on a **GRAMMER** AG driver's seat must be performed exclusively in **authorized workshops** by **trained** or **suitably qualified personnel** and in adherence with the applicable operating, maintenance and installation instructions and in compliance with all relevant national regulations.
- **Improper installation and assembly** bear the risk of **bodily injury** or **property damage** and the proper function of the driver's seat or mounted parts can no longer be guaranteed.
- The driver's seat is **free of maintenance**. Worn parts such as rollers, shock absorbers and the fixation must be checked from time to time.
- **Before driving,** you must check if all seat settings selected guarantee a **safe operation** of the vehicle.

Connecting data

- If you need to connect cables to the vehicle supply network, strictly observe the following instructions:

  Before you connect an **electrical consumer** fitted in the driver's seat (e. g. the seat heater or the seat ventilation), you must obtain the relevant electrical data for the respective vehicle with reference to voltage, protection and the kind of connections from the manufacturer, from **GRAMMER** AG or the company's agencies.
  For safety reasons, the installation and connection to the vehicle supply network must be carried out by authorized specialist personnel only.

  The seat connections must be protected independently of other vehicle components.

Seat heater / compressor	
12V DC	10A
24V DC	7,5A
48V DC	5A

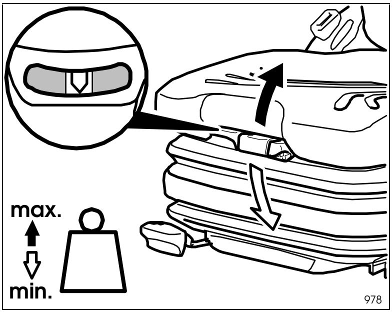
Seat switch – Current carrying capacity	
12V DC	10mA (min.)

Notes concerning seat switch: Minimum and maximum current carrying capacity for purely resistive load.
In case of inductive or capacitive load, the manufacturer must install a protective circuit breaker for the consumers in the vehicle. If there are any uncertainties, **please ask the vehicle manufacturer before making connections**.

For building an electric connection, select an electric circuit by means of which the electric consumers of the driver's seat are separated from the live network when **the ignition is switched off**.

Guarantee and liability

- **GRAMMER** AG does not disclaim any guarantee or liability for damage resulting from incorrect assembly, use or repair of the seats.
- Further details on the guarantee granted by **GRAMMER** AG are stated in your contractual documents (see invoice or delivery note). Guarantee claims against **GRAMMER** AG beyond the guarantee obligations described there are excluded.



Weight adjustment

The seat is adjusted for the driver's weight by pulling or pressing the lever for seat weight adjustment and with the driver sitting on the seat.

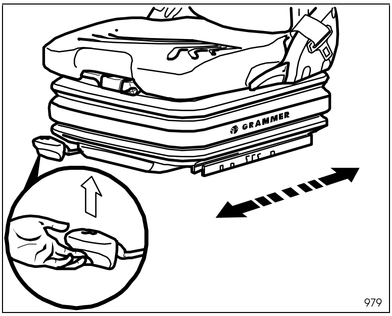
The driver's weight is adjusted correctly when the arrow is in the middle clear area of the viewing window.

Within this viewing area, the individual height can be adjusted to a minimum spring movement.

When the minimum/maximum weight adjustment has been reached, you can hear it reaching the upper or lower end stop.

☞ To prevent damage to the health and material, the setting for the driver's weight must be checked and adjusted individually before the vehicle is driven.

☞ In order to avoid compressor damage during weight adjustment, the compressor must be operated no longer than 1 minute.



Fore/aft adjustment

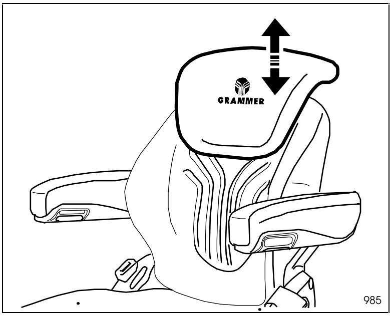
The fore/aft adjustment is released by lifting the locking lever.

⚠ **WARNING! Risk of accident!**
Do not operate the locking lever while driving.

WARNING! Risk of crushing!
Only touch the lever at the indented grip, do not reach back under the lever.

☞ After the adjustment, the locking lever must latch into the desired position with an audible click. It should not be possible to move the driver's seat into another position when it is locked.

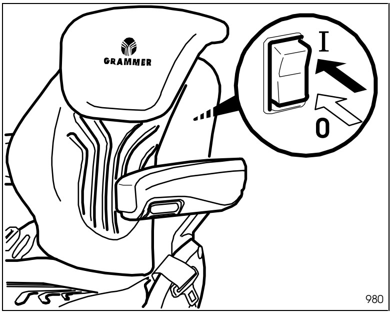
☞ Do not lift the locking lever with your leg or calf.



Backrest extension * **

The backrest extension can be individually adjusted by pulling it upwards or pushing it downwards over the various locking increments up the end stop.

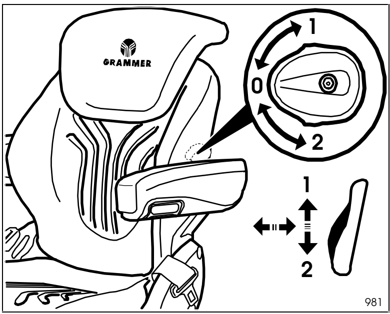
To remove the backrest extension, pull it upwards over the end stop.



Seat heater * **

The seat heater can be turned on/off by pressing the switch.

1 = seat heater OFF
2 = seat heater ON



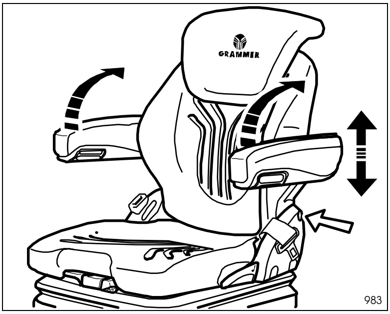
Lumbar support

The lumbar support increases both the seating comfort and the performance of the driver.

By turning the adjustment knob upwards, the curvature in the upper part of the backrest cushion can be adjusted. By turning the knob downwards, the curvature in the lower part of the backrest cushion can be adjusted.

0 = No curvature
1 = Max. curvature at the top
2 = Max. curvature at the bottom

* if fitted ** optional extra



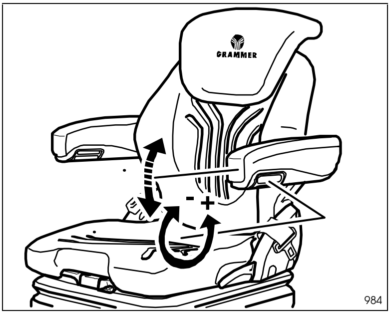
Armrests * **

The armrests can be folded back if required and the height individually adjusted.

To adjust the armrests for height, separate the round cap (see arrow) from the cover, loosen the hexagon nut (size 13 mm) behind it and adjust the armrests to the desired position (5-steps) and tighten the nut again (**25Nm**). Replace the cap onto the nut.

⚠ **WARNING:**
If the belt roller is fitted, do not install the armrest in the lowest position as otherwise the belt roller might not function correctly.

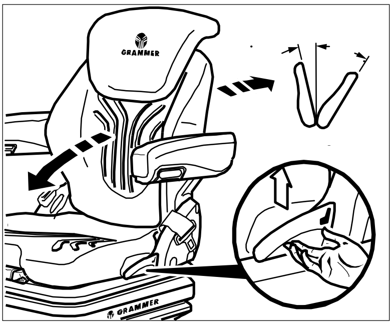
Carry out a **functional test** of the belt roller.



Armrest adjustment *

The inclination of the armrests can be modified by turning the adjustment knob.

When turning the knob to the outside (+) the front part of the armrest will be lifted, when turning the knob to inside (-) it will be lowered.



Backrest adjustment

Pull up the locking lever to release the backrest catch. When releasing the backrest catch, do not apply load to the backrest by pressing against it.

By exerting pressure on or off the front or rear part of the seat pan it can be moved to the desired position. Release the locking lever to lock the backrest.

☞ It should not be possible to move the backrest into another position after it has been locked.

* if fitted ** optional extra

Dirt can impair the function of the seat,
So make sure you keep your seat clean.

Upholstery does not need to be removed from the seat frame for cleaning.

Caution: take care with the backrest - it may jerk forward and cause injury!
When cleaning the backrest cushion, the backrest must be held in place when operating the backrest lever.

ATTENTION: Do not clean the seat with a pressure washer!

When cleaning the upholstery, make sure the upholstery is not soaked.

Use standard commercially available **upholstery or plastics cleaning agent. Test first for compatibility** on a small, concealed area.


Voyager

Troubleshooting Guide

No image on monitor

- Verify camera cable connection at monitor.
- Verify camera is connected to camera cable.
- Connect camera directly to monitor if possible.
- Connect known good camera/cable to monitor.
- Connect known good camera to existing cable.
- Connect known good cable between monitor and existing camera.

Flickering or rolling Image

- Switch to secondary camera input on monitor.
  - If image is stable, replace monitor.
- Check for 12V+ to monitor.
- Connect known good camera/cable to monitor.
  - If image is stable, check camera/cable.
  - If image still flickers/rolls replace monitor.

No Sound

- Verify monitor supports audio feature.
- Verify volume is turned up on monitor.
- Verify Audio Trigger is connected on monitor's harness where applicable.
- Verify camera cable connection at monitor.
- Verify camera is connected to camera cable.
- Connect camera directly to monitor if possible.
- Connect known good camera/cable to monitor.
- Connect known good camera to existing cable.
- Connect known good cable between monitor and existing camera.

Reverse Image

- Locate metal screw cap on rear of camera (it should be installed in one of two recessed ½" threaded holes) by repositioning the cap to the opposite location will trigger the magnetic switch and reverse the image.
- On some HMH Monitor models there are provisions for reversing the image. Please refer to the monitor manual for location and instructions.

No color

- Verify monitor supports color feature.
- Verify proper lighting.
- Connect known good camera.
- Verify voltage levels to monitor and camera. Low Voltage may cause loss of color as well.
- Check the condition of the cabling between camera and monitor.

FR15/25, FR18/26, & FR25/35 SERVICE MANUAL *REFERENCE MATERIAL*

INDEX

RECOMMENDED FLUIDS

Always use high quality fluids and lubricants!

WARNING! ALWAYS USE A CLEAN, APPROVED LABELED CONTAINER TO PREVENT CONTAMINATION.

HYDRAULIC FLUID
TYPE: AW32
CAPACITY: 33 Gallons

PLANETARY WHEEL DRIVE
TYPE: 80W90 GEAR LUBE
CARRIER: 3.5 QUARTS

ENGINE
TYPE: 5W30
CAPACITY: 5 QT w/OIL FILTER

ENGINE COOLANT
TYPE: 50% SOFT WATER MIXTURE.
NOTE: DO NOT USE MORE THAN 50% ANTIFREEZE ABOVE -35F [-37C]. **NEVER** USE MORE THAN 68% ANTIFREEZE UNDER ANY CONDITION!

CHASSIS/MAST/STEER AXLE GREASE
TYPE: LITHOPLEX RT2 GREASE

CHASSIS TUBE EXTENSION
TYPE: MOLYLUBE

BLOCKING UP THE TRUCK

Blocking Apparatus

When using wood blocks, use ONLY solid, one-piece oak products only. BEFORE USING, check for:

- Soundness and uniform thickness
- The following defects
    - Visible soft or rotted spots
    - Splits or cracks that travel more than half the length of block
    - Excessively rounded corners
    - Soaked with oil

When using jack stands, all stands should meet the following criteria:

- 1.5 times the rated capacity
- Capacity ratings marked on all stands
- Free of structural defects and material damage
- Finished edges and corner to help prevent slippage

WARNING

Overhead chains and/or the use of another lift truck should NEVER be used as the main support apparatus. Under NO circumstances should a forklift jack be used as the main support apparatus. Do NOT work under equipment that is not supported under the main frame of the unit.

WARNING

When the lift truck must be blocked up for maintenance and/or repair, the removal of the following assemblies will cause large changes in the center of gravity: mast, drive axle, engine and transmission, and the counterweight.

When the lift truck is on blocks, additional blocks MUST be used in the following positions to maintain stability:

- Before removing the mast and drive axle, put blocks under the counterweight so that lift truck cannot fall backwards.
- Before removing the counterweight, put blocks under the mast assembly so that the lift truck cannot fall forward.

The work surface MUST be solid, even, and level when the lift truck is put on blocks. Do NOT attempt to support equipment that is on dirt, gravel, or crushed stone.

BLOCKING UP THE TRUCK (CONT'D)

General Work Rules When Blocking Up a Lift Truck
Never stand on, straddle, or place feet on blocking.
When positioning blocking under a lift truck, use a hand-hook or bar to place blocks and keep all body parts clear of pinch points.
Place load across grain of block. NEVER place load on the end of the block.
Do NOT stack blocking.
Blocking used in conjunction with jack stands should be kept to a minimum.

Retract the counterweight and lock the chassis lock pin in place.
Remove the counterweight slabs from the rear chassis.

WARNING
NEVER BLOCK THE CHASSIS WITH THE COUNTERWEIGHT EXTENDED!

How to Raise the Drive Tires

1. Retract the counterweight and lock the chassis locking pin in place.
2. Position blocks on both sides (front and back) of the steer tires to prevent movement of the lift truck.
3. Put the mast in a vertical position. Position a block under each channel of the outer mast weldment.
4. Tilt the mast forward until the drive tires are raised from the ground surface.
5. Position additional blocks under the frame behind the drive tires. MAKE SURE the blocks are under the main frame and NOT under either the hydraulic reservoir or fuel tank assembly.
6. If the hydraulic system is not functioning, use a hydraulic jack placed under the side of the main frame as close to the front of the lift truck as possible. MAKE SURE that the jack has a MINIMUM capacity of at least 1.5 times the weight of the truck. Refer to the Truck Data and Capacity Plate to confirm truck weight.


Fig 1


Fig 2


Fig 3

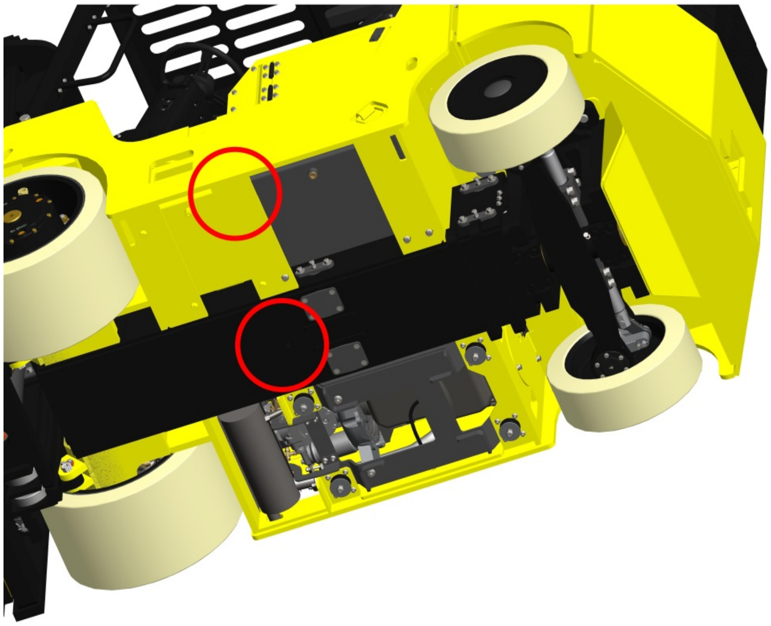
BLOCKING UP THE TRUCK (CONT'D)

How to Raise the Steer Tires

1. Apply the Parking Brake.
2. Position blocks on both sides (front and back) of the drive tires to prevent movement of the lift truck.
3. Use a hydraulic jack to raise the steer tires. MAKE SURE that the jack has a MINIMUM capacity of at least 2/3 of the lift truck total weight. Refer to the Truck Data and Capacity Plate to confirm truck weight. Position the jack under the steer axle beam or main frame as close to the rear of the lift truck as possible.
4. Position blocks under the frame in front of the steer axle. MAKE SURE the blocks are under the main frame and NOT under either the hydraulic reservoir or fuel tank assembly.

BLOCKING UP THE TRUCK (CONT'D)

Jack Points



To jack the front of the truck at either side, the jack must be placed under the channel supports on either side of the frame. Make sure the rear block is put directly under the center of the frame as shown above.

WARNING
Verify the jack has sufficient capacity before attempting to raise the truck.

BLOCKING UP THE TRUCK (CONT'D)

Rear Lift Points
Before raising the rear of the truck, block the drive tires and make sure the parking brake is applied. Rear lift points are provided as an aid for raising the steer axle. Lift eyes can accommodate properly rated shackles and/or chain hooks and chains.

WARNING

DO NOT use the lift eyes as the main support apparatus. Position blocks under the frame in front of the steer axle, centered under the center chassis tube.

HOW TO MOVE A DISABLED TRUCK

If your truck becomes disabled, it might be necessary to tow your truck back to the shop for repairs. To prevent further damage, use the following procedures.

IMPORTANT

Before towing the truck be sure to put the hydrostatic drive into bypass.

IMPORTANT

It is important for your safety to use the proper equipment and carefully follow these recommendations for safe towing. Failure to follow these recommendations may result in injury, death, and damage to the lift truck.

Retract the counterweight and lock the chassis locking pin in place.

WARNING

DO NOT tow a lift truck if there is a problem with the brakes or tires, or if the steering cannot be operated. DO NOT tow up or down ramps and steep inclines. DO NOT attempt to tow a lift truck if the traction or weather conditions are poor.

HOW TO MOVE A DISABLED TRUCK (CONT'D)

Bypass Function

For vehicles with hydrostatic travel drive, as long as there is no downstream mechanical interruption of the drive train (switch to idle/free running), the flow can be altered using a bypass function in order to tow the vehicle out of the immediate danger zone.

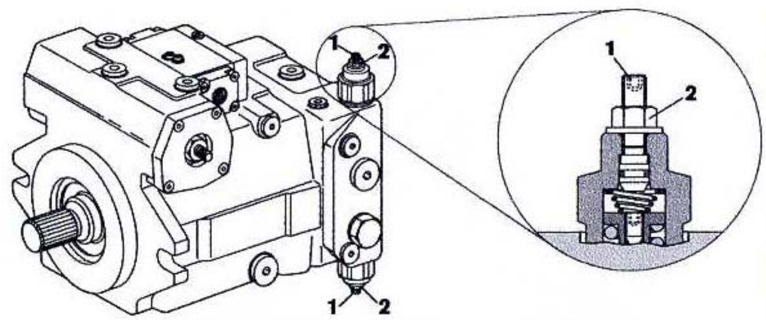


Fig A: Activating the bypass function

Activating the bypass function

To activate the bypass function:

1. Switch off the combustion engine.
2. Loosen the lock nut (2) by turning counter-clockwise one half-rotation with a hex wrench.
3. Use an Allen key to screw in the screw (1) clockwise until the screw (1) is against the spring disc. This is apparent by the increased resistance. Then turn the screw (1) one additional half turn into the spring disc.
4. Tighten the lock nut (2) clockwise with a torque of 16 ft/lbs (22Nm)

Towing Speed

Excessive speeds and extended load/vehicle movement must be avoided while moving in bypass function. The load or vehicle should be moved not more than 20% of maximum speed and for a duration not exceeding 3 minutes. Damage to drive motor(s) is possible. When the bypass function is no longer needed, care should be taken to re-seat the HPRV hex plugs to the normal operating position.

Towing distance

The vehicle may only be towed out of the immediate danger zone.

HOW TO MOVE A DISABLED TRUCK (CONT'D)

CAUTION

RISK OF DAMAGE!

High towing speeds and longer towing distances result in impermissible heat generation and insufficient lubrication. This will damage the axial piston unit.

- Only tow the vehicle out of the immediate danger zone.

CAUTION

RISK OF DAMAGE!

During and after towing, the axial piston units are hot.

- Wear protective clothing

Deactivating the bypass To deactivate the bypass function:

1. Immediately following towing, switch off the bypass function.
2. Restore the function of the high-pressure relief valve. To do this, perform the settings made under item "Activating the bypass function" in reverse order: Loosen the lock nut (2) with a hex wrench, then turn the screw (1) counter-clockwise with an Allen key until it reaches the stop.

CAUTION

RISK OF DAMAGE!

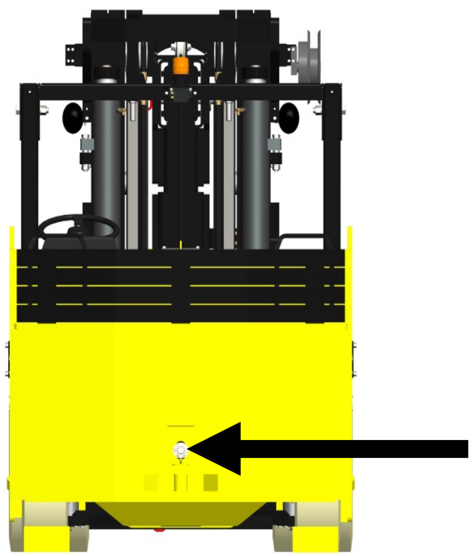
While towing with the bypass function activated, the closed hydraulic circuit empties itself. This can result in unintended functions when restarting the travel drive.

- Start the travel drive only after completely filling and air bleeding the hydraulic circuit.

HOW TO MOVE A DISABLED TRUCK (CONT'D)

Be sure to apply the parking brake AND block the drive wheels on the disabled truck while working around it. Make sure the counterweight is retracted and chassis lock pin is locked. NEVER tow the truck with the counterweight extended or the chassis lock pin not in place.

1. When possible, raise the carriage (forks) on the disabled truck about 12 inches (305mm) from the floor or ground. Secure the carriage in place with a chain.
2. Obtain another piece of equipment, suitable for towing, of equal or greater capacity carrying a partial load for increased traction.
3. Check that the counterweight bolts are in place and properly torqued.
4. Use an approved solid metal tow bar with towing coupler to connect to the towing pin in the counterweight. The counterweight tow pin can be lifted vertically to aid in wrapping properly rated chain and/or installing chain hooks.
5. Disconnect the driveline and release the parking brake.



6. SLOWLY tow the disabled truck backward, being mindful of your surroundings and making certain the area is clear of all personnel. An operator MUST be on the towed truck in the normal operating position with seatbelt secured. Careful towing is necessary to prevent possible injury to personnel or damage to the truck. DO NOT TOW THE TRUCK ANY FARTHER THAN IS ABSOLUTELY NECESSARY.
7. Park the disabled truck in authorized areas only. Fully lower the forks to the floor, make sure the pedal is in the neutral position, turn the ignition switch to the OFF position, set the parking brake, and tag the truck out of service. Block the wheels to prevent the truck from rolling as necessary.

JUMPSTARTING A DISABLED TRUCK

If your lift truck battery is discharged ("dead"), you can start your lift truck by "jumping" the 12 volt, negative-ground electrical system. This is achieved with one (1) battery or two (2) batteries connected in parallel. The booster battery or batteries must be fully charged and in good condition. This section explains how to perform this procedure safely. To avoid damage to your lift truck and to the battery or batteries or the possibility of harm to yourself, follow all instructions and warnings carefully. If you have any doubts, ask for help from an experienced technician.

CAUTION

USE ONLY a 12 volt, negative ground system to jump your truck.

WARNING

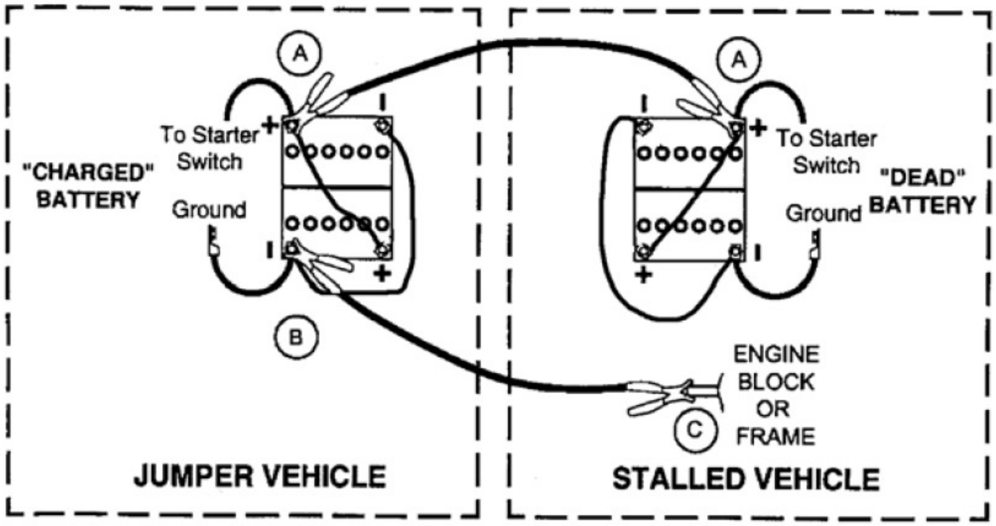
BATTERIES CONTAIN SULFURIC ACID. Avoid acid contact with skin, eyes, or clothing. If acid contacts your eyes or skin, immediately flush with water and get immediate medical assistance. Wear safety glasses, aprons, and gloves when working near the battery to protect against possible splashing of acid solution.

1. If the discharged battery has filler caps, check the fluid level. **Do not use an open flame to check and do not smoke.** If low, add DISTILLED WATER to correct the level. Be sure to install the caps before jump-starting. **Note:** Do not jump start, charge, or test a sealed-type battery if the test indicator appears illuminated or has a bright color. Install a new battery.
1. Position the truck with 12-volt booster battery as near to the disabled truck as necessary for the jumper cables to reach both batteries. **Note:** Use caution and care when connecting a booster battery to prevent sparks.
2. On both trucks:
    A. Apply the parking brake
    B. Put the directional control lever in the NEUTRAL position.
    C. Turn the key/start switch to the OFF position.
    D. Turn all accessories to the OFF position and leave them off until after the engine has been started and the jumper cables have been removed.

WARNING

BATTERIES EMIT EXPLOSIVE GAS. Do not smoke or have open flame or sparks in the battery charging area or near batteries. An explosion can result and cause injury or death. When charging or using a battery in an enclosed space, always provide adequate ventilation.

JUMPSTARTING A DISABLED TRUCK (CONT'D)



Typical 12-Volt System

3. Connect the jumper cables in the following sequence:

   A. Connect a jumper cable from the positive (+; RED) terminal on one battery to the positive (+; RED) terminal on the other battery. ⚠ **Caution: Never connect positive (+; RED) to negative (-; BLACK) or negative to positive.**

   B. Connect one end of the second cable to the grounded negative (-; BLACK) terminal of the "jumper vehicle" battery.

   C. Connect the other end of the second cable to a stationary, solid, metallic point **on the engine** of the "stalled vehicle," **not to the negative** (-; BLACK) **terminal of its battery.** Make this connection point at least 18 inches (457 mm) away from the battery, if possible. Do not connect it to pulleys, fans, or other parts that move. **NOTE: Do not touch hot manifolds that can cause burns.**

4. Start the engine on the "jumper vehicle" and run the engine at a moderate speed for a minimum of five minutes.

5. Start the engine on the "stalled vehicle." Follow the starting instructions in Section 5, "Starting and Operating Procedures" in this manual. Be sure that the engine is at idle speed before disconnecting the jumper cables.

6. Remove the jumper cables by reversing the installation sequence **exactly.** Start by removing the last jumper cable from the stalled vehicle first. Remove the cable end from the engine block first and then the opposite end of the negative (-; BLACK) cable.

7. Remove both ends of the positive (+; RED) cable.

Connecting A Laptop to the Truck

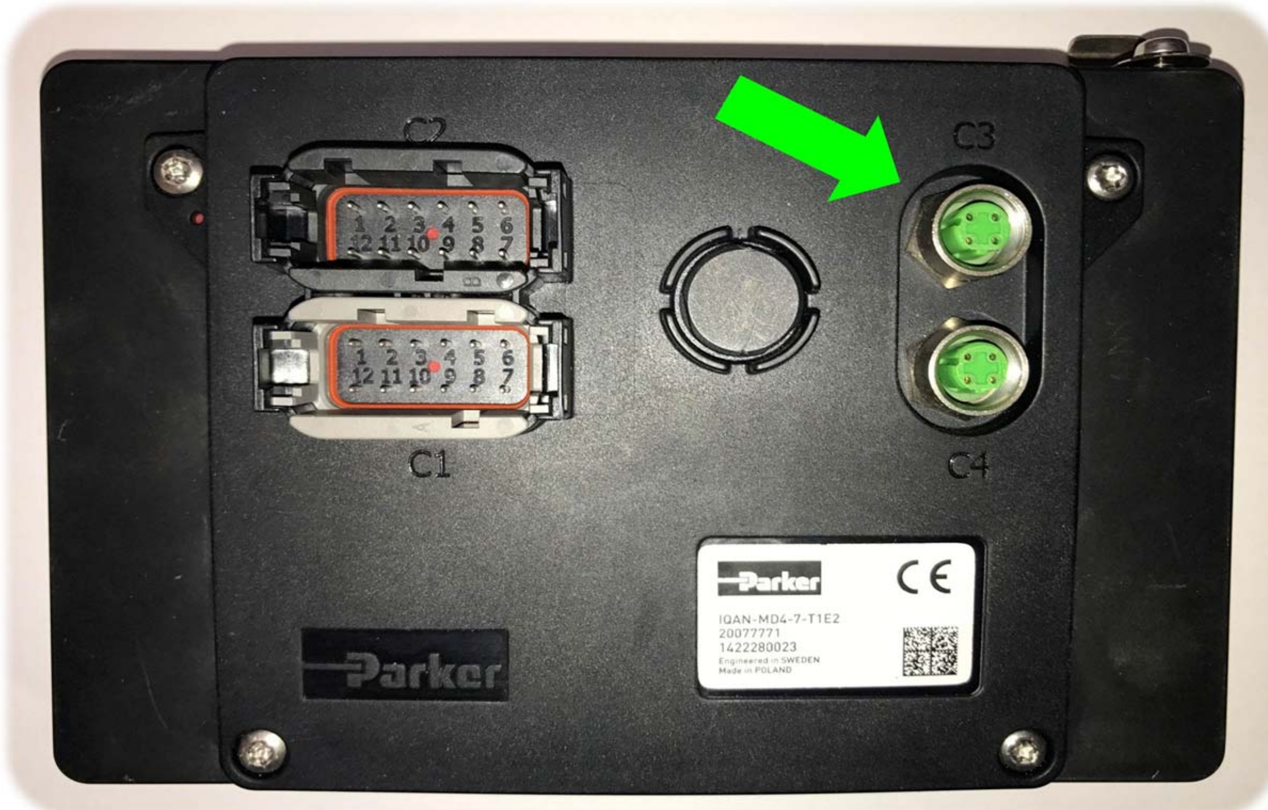
Most vehicle adjustments and diagnostics, such as measuring vehicle inputs and outputs, adjusting optional pendant hydraulic speeds, resetting service meter, viewing vehicle logs, etc., can be accomplished using the Operator Display as outlined in Section 8 of this manual.

In the event a new or modified program needs to be uploaded to the truck, or the existing program downloaded, a laptop with the latest version of IqanDesign (available from your authorized dealer) loaded is utilized. Additionally, on any vehicles with preprogrammed data logs such as those fitted with an optional shock sensor, data logs can be downloaded to the laptop in Excel format and edited as desired.

A specialized Ethernet 4-pin connector cable is required to connect the laptop to the vehicle. This cable (P/N M20233) is available from your authorized dealer.

The vehicle 4-pin connection port is located on the underside of the operator display located on the center console. The port can be accessed by removing the plug covers from the back of the display. To reach the C1 and C2 connectors, the display will need to be removed from the display mount.

The 4-pin connector on the cable MUST be connected to the C3 port on the back of the operator display.



When programs are uploaded or downloaded, vehicle power must be on with the parking brake set. There should be no load on the truck and the forks should be on the ground with all other safe maintenance practices adhered to.

GENERAL BEARING HANDLING AND INSPECTION

- General Bearing Handling and Inspection
- Bearing Storage
- Removing Bearings From Equipment
- Damaged Bearings
- Installation
- Lubrication

GENERAL BEARING HANDLING AND INSPECTION (CONT'D)

⚠ WARNING

Failure to observe the following warnings could create a risk of serious injury.

Proper maintenance and handling practices are critical. Always follow installation instructions and maintain proper lubrication.

Never spin a bearing with compressed air. The rolling elements may be forcefully expelled.

⚠ CAUTION

Failure to observe the following cautions could create a risk of serious injury.

Do not attempt to disassemble unitized bearings.

Remove oil or rust inhibitor from parts before heating to avoid fire or fumes.

If a hammer and bar are used for installation or removal of a part, use a mild steel bar (e.g. 1010 or 1020 grade). Mild steel bars are less likely to cause release of high speed fragments from the hammer, bar or the bering.

NOTE

This manual is not intended to substitue for the specific recommendations of your equipment supplier.

Every reasonable effort has been made to ensure the accuracy of the information contained in this catalog, but no liability is accepted for errors, omissions or for any other reason.

General Bearing and Handling

Bearings are a vital component in major industrial equipment. Bearing problems can result in costly downtime, equipment damage and breakdowns. In addition, large industrial bearings represent a significant capital investment.

To attain reliable operation with high equipment performance and the lowest possible maintenance costs, it is essential to follow proper handling practices. This includes bearing storage, removal, cleaning, inspection and installation.

The useful life of any bearing depends to a great extent on the care and maintenance it receives. This is especially true in industrial applications, where operating conditions tend to be harsh, loads are heavy, and contamination from dirt and scale are common.

Details about specific handling and inspection processes for different types of bearings are included in those sections of this manual. This section addresses general processes and practices that apply to all anti-friction bearing designs.

Bearing Storage

Bearings with special anti-corrosion coatings are available, but most bearings are not manufactured from corrosion resistant materials. When handling and storing bearings, care must be taken to ensure that they will not rust or corrode. Even a small amount of moisture or chemical left on an unprotected bearing by a glove or hand can result in a small etched area, which may initiate bearing fatigue.

New and remanufactured Timken bearings are shipped with a protective coating, are typically covered in a protective paper or other wrapping, and are shipped in a carton or crate. When receiving a new or remanufactured bearing, do not remove it from its packaging until ready to install in the application.

Do not store bearings directly on concrete floors, where water can condense and collect on the bearing. Store the bearings on a pallet or shelf, in an area where the bearings will not be subjected to high humidity or sudden and severe temperature changes that may result in condensation forming.

Always put oiled paper or, if not available, plastic sheets between rollers and cup races of tapered roller bearings.

Removing Bearings from Equipment

Each type of bearing design has a unique removal process. Regardless of the bearing type, the bearing must be removed with extreme care. If done incorrectly, you can damage the bearings, shafts or housings, requiring expensive repairs.

For smaller bearings, there are a variety of pullers available to assist with bearing removal (Fig. 1). Information concerning special pullers or other removal devices can be obtained by contacting your Timken representative.

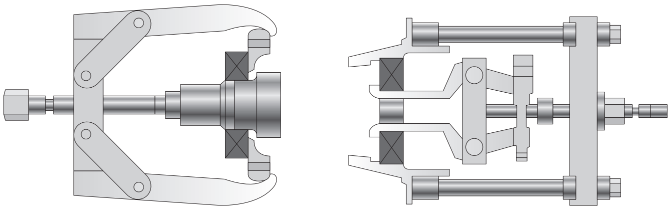


Fig. 1. Pullers for bearing removal.

For bearings installed with a tight or press fit, or that have become locked in place on a shaft and cannot be removed with a mechanical puller, the inner ring of the bearing can be heated to ease removal. Heat lamps or other heating devices can be used. If a torch is used, it will change the properties of the bearing steel and the bearing must be discarded.

⚠ **WARNING** ***Failure to observe the following warnings could create a risk of serious bodily harm.***

Tensile stresses can be very high in tightly fitted bearing components. Attempting to remove such components by cutting the cone (inner race) may result in a sudden shattering of the component causing fragments of metal to be forcefully expelled. Always use properly guarded presses or bearing pullers to remove bearings from shafts, and always use suitable personal protective equipment, including safety glasses.

Lifting Large Bearings

Large bearings can be lifted and moved using a variety of slings, hooks, chains and mechanical devices. Some large bearings are manufactured with tapped holes in the face of inner rings or outer rings. Eyebolts or other points of attachment can be inserted in these lifting holes (Fig. 2).

Many large bearings have threaded lifting holes in the cage ring that can be used to lift the inner ring assembly.

Fig. 2. Eyebolts can be inserted into lifting holes.

⚠ **CAUTION** ***Failure to observe the following cautions could create a risk of injury.***

If the bearing is to be reused or returned for repair, do not use heat from a torch.

Extreme heat from a torch can alter the bearing hardness and metallurgical structure, resulting in irreparable damage.

A clean, heavy duty nylon sling provides one of the best means of handling large bearing components because it eliminates the possibility of burring or scratching.

Regardless of what method is used to lift the bearings, use care to avoid damaging any of the bearing surfaces. Be especially cautious when lifting or moving bearings that are equipped with a cage. The cage is typically the most deformable component of the bearing and is more susceptible to damage.

Cleaning

After removing a bearing from a piece of equipment, thoroughly clean it to remove all scale, water, lubricant, debris and any other contaminants. Bearings must be cleaned thoroughly to allow for proper bearing inspection.

Smaller bearings can be cleaned in a wash tank that circulates a cleaning solution such as kerosene, mineral spirits or a commercial solvent through the bearing (Fig. 3). Use the cleaning solution to remove all lubricant and contamination, making sure that the internal rolling elements are completely clean.

Fig. 3. Smaller bearings can be cleaned in a wash tank.

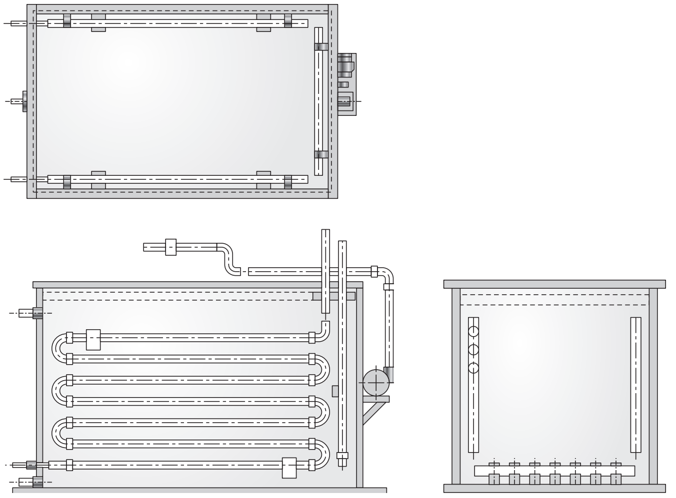


Fig. 4. Tanks are heated with electric coils and a pump is used to agitate the cleaning solution.

⚠ **WARNING** ***Failure to observe the following warnings could create a risk of serious bodily harm.***

Proper maintenance and handling practices are critical. Failure to follow installation instructions and to maintain proper lubrication can result in equipment failure.

Never spin a bearing with compressed air. The rolling elements may be forcefully expelled.

Alkali cleaners, such as trisodium phosphate (TSP) mixed two or three ounces per gallon of hot water, may also be used. Hot cleaning solutions are often used as a final cleaning or rinse after the initial cleaning.

For large bearings, or to clean large numbers of bearings, special cleaning equipment such as a large tank containing appropriate cleaning solution is required. Tanks are typically heated with electrical coils, and a pump is used to agitate the cleaning solution (Fig. 4). Final cleaning is done by suspending the bearing and using a hose to flush away any contamination.

To reduce bearing contamination from other sources, all parts of the housing, shaft and gears should also be thoroughly cleaned. After the bearing has been cleaned, it can be dried with compressed air, taking care not to let the bearing spin.

After cleaning, the bearing should be carefully inspected for damage and wear. If the bearing is not going to be returned to service immediately, it should be covered with a coating of light oil to protect against rust and corrosion.

Inspection

When a piece of equipment is taken out of service for routine inspection or maintenance, take the opportunity to also inspect and measure the bearings to ensure that they are still within tolerance specifications for the application. In some applications, the expected bearing life may be the limiting factor in the equipment maintenance schedule.

The schedule for equipment tear downs for bearing inspection will vary depending on operating conditions. Consult your equipment maker for the appropriate inspection schedule.

Between equipment tear downs where full bearing inspections are conducted, you should conduct routine inspections to ensure that bearings are operating normally and have proper lubrication. To reduce the need for these inspections, and to more closely monitor bearing and equipment health, Timken condition monitoring systems are available that sense the vibration and temperature in bearings.

The inspection area must be clean and free from dirt and debris to avoid contaminating the bearing. Even a small piece of debris that enters a bearing can create a point of high stress that could lead to spalling and early fatigue.

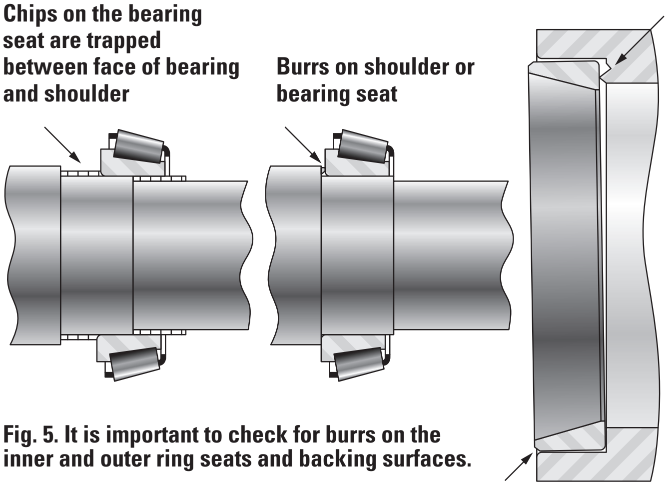


Fig. 5. It is important to check for burrs on the inner and outer ring seats and backing surfaces.

In addition to examining the bearing, a full inspection should include the housing and shaft. Check for burrs or metal chips on the inner and outer ring seats and backing surfaces (Fig. 5). Burrs or chips can be removed by scraping or filing the damaged surfaces.

Inspect the shaft for proper size, roundness, burrs or other damage. A 12-point check of the shaft with a micrometer is suggested (see page 33). If there is evidence of shaft or housing wear, it should be checked against original equipment manufacturer's specifications.

⚠ **CAUTION** ***Failure to observe the following cautions could create a risk of injury.***

Do not attempt to disassemble unitized bearings.

Remove oil or rust inhibitor from parts before heating to avoid fire or fumes.

If a hammer and bar are used for installation or removal of a part, use a mild steel bar (e.g. 1010 or 1020 grade). Mild steel bars are less likely to cause release of high speed fragments from the hammer, bar or the bearing.

Damaged Bearings

Despite taking proper precautions, bearings may become damaged either through improper storage and handling or through normal wear in use. Bearings that have been damaged or are no longer within specifications may still be returned to service after repair or refurbishment. Some bearings can be refurbished more than once. Eventually all bearings will sustain sufficient wear or damage and will have to be replaced.

If a bearing is damaged or worn beyond repair sooner than expected, do not discard it. The nature of the damage can provide valuable clues that can help analyze and identify possible causes, leading to corrective actions that will help ensure longer bearing life in the replacement bearing.

There are several Timken resources available to assist you in analyzing bearing damage, including online resources at timken.com and publications with photos representing common types of bearing damage. Contact your Timken representative for more information.

Bearing Repair

Small areas of damage on bearing races, and on the contact surface of the rolling elements, can sometimes be repaired by grinding out the loose metal. Any raised or rough areas should be smoothed flat with grinding and polishing tools.

Light rust or corrosion should be removed with emery paper (240 – 320 # grit). As much of the damage should be removed as possible to prevent it from contaminating the bearing when it is returned to service.

For more complex bearing repairs, Timken offers remanufacture and repair services.

Installation

Do not remove the bearing from its packaging until you are ready to mount it. The packaging provides protection from contamination.

When installing a new bearing, do not remove the lubricant or preservative applied by the manufacturer. The preservatives used on almost all bearings are fully compatible with commonly used oils and other lubricants. Leaving it in place will protect the bearing from fingerprints and corrosion.

Bearings should be installed in a clean environment, free from dust, debris, moisture and other contaminants. When installing a bearing in the field, make an effort to ensure a clean work area. Use protective screens around the work area, and provide a clean resting surface for the bearing and other components until they can be installed.

Before beginning the installation, plan your work. Be certain that you have the correct replacement bearing and necessary additional components. Also determine what tools will be required, including adjustment tools if appropriate, and have them on hand. Finally, if the bearing needs to be lubricated as part of the installation process, have the appropriate lubricants and tools available. Planning your work will enable you to perform the installation more quickly with few delays, shortening the amount of time the bearing is out of the equipment and exposed to contamination and possible handling damage.

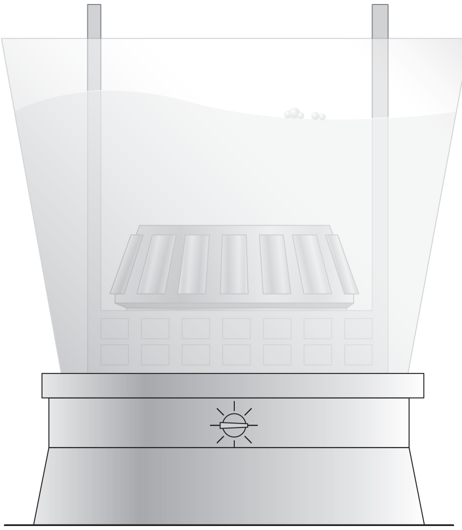


Fig. 6. Bearings can be heated in a pan or metal container filled with oil.

Fig. 7. Induction heater.

Thoroughly clean all machine components near where the bearing will be installed, giving special attention to the mounting surfaces and housings. Housings should be cleaned, including blowing out the oil holes. If the equipment has blind holes where air is ineffective, use a magnetic rod to remove metal chips that might have become lodged there during machining or maintenance.

Shaft surfaces that will support and contact the bearing must be clean and free from nicks or burrs. Shaft shoulders and spacer rings contacting the bearing should be square with the shaft axis. The shaft fillet must be small enough to clear the radius of the bearing.

Do not install bearings in a damaged or worn housing, or on a damaged or worn shaft. Inner and outer ring seat damage should be repaired by using properly fitted sleeves. Shafts can be built up by metal spray and machined to the correct size. If there is not a press fit on the shaft, a weld overlay and re-grind process is recommended to bring the shaft back to specification.

Heating Bearings

In applications that require a tight fit of the inner ring on the shaft, it can be easier to install the bearing if it is first heated to expand slightly. For applications that require a tight fit of the outer ring in a housing, it may also be possible to heat the housing to expand it, allowing the bearing to install more easily.

Small bearings can be heated using several methods. They can be heated in a pan or metal container filled with oil (Fig. 6). A screen or platform should be used to keep the bearing from resting on the bottom of the pan where heat is applied.

A heat lamp can also be used to heat rings, and the temperature regulated by adjusting the distance from the light to the ring.

The fastest method of safely heating bearings is an induction heater (Fig. 7). Induction heaters work very quickly. Take care to avoid heating the bearing to temperatures higher than 120°C (250°F).

For larger bearings, you may need to use an oil bath to heat the bearing (Fig. 8). Maximum temperature of the oil bath should not exceed 120°C (250°F). The bearing should be positioned in the center of the tank, and allowed to heat long enough to fully expand. Do not allow the bearing to come in direct contact with the heat source.

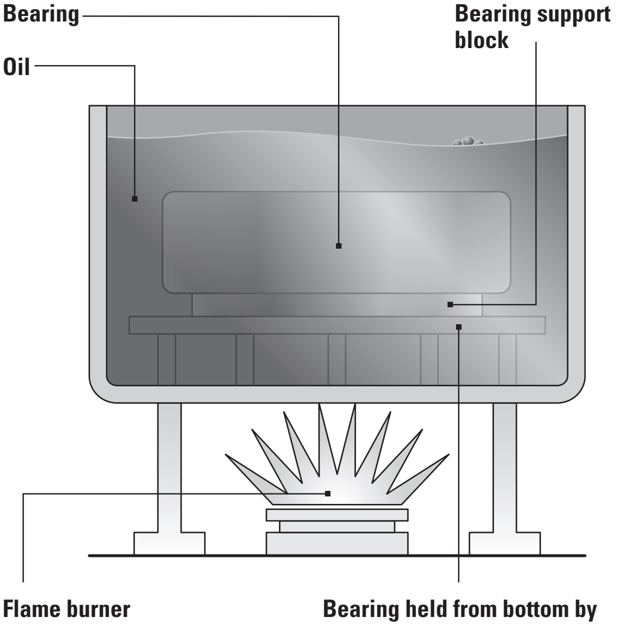


Fig. 8. Oil bath.

⚠ CAUTION ***Failure to observe the following cautions could create a risk of injury.***

If the bearing is to be reused or returned for repair, do not use heat from a torch.

Extreme heat from a torch can alter the bearing hardness and metallurgical structure, resulting in irreparable damage.

Keep the bearings away from any localized high-heat source that may raise the bearing temperature too high, resulting in race hardness reduction.

When heating bearings, be sure that they have enough time to fully heat. Bearings typically require 20 to 30 minutes of soak time per inch of inner-ring cross section to fully heat in an oil tank.

While the bearing is still warm, remove it from the heater or tank and place it on the shaft. Slide the bearing up the shaft until it squarely contacts the shaft shoulder. Then install the locknut/washer or clamping plate to prevent the bearing from backing off the shoulder while cooling. As the bearing cools, the locknut or clamping plate should be tightened.

Thermal growth of components can be calculated using the formula:

$d \times \Delta T \times \alpha$ = Thermal Growth

Where:

d = bearing bore diameter

ΔT = maximum bearing temperature after heating minus ambient temperature

α = coefficient of linear expansion: 11×10^{-6}/ °C (6.1×10^{-6}/ °F) for ferrous metal shaft and housing materials

Sample Calcuation

Example:

For a bearing with a 3-1/2 in. bore heated from an ambient temperature of 70° F to 200° F, the thermal growth of the bearing bore diameter can be calculated as follows:

Thermal Growth = 3.500" x (200° - 70°) x 6.1×10^{-6} = 0.0028 in.

For a bearing with a 90 mm bore heated from an ambient temperature of 21° C to 93° C:

Thermal Growth = 90 mm x (93° - 21°) x 11×10^{-6} = 0.071 mm

Temperature Guidelines for Heating or Cooling

Rolling Element Bearings for Installation

These maximum and minimum temperatures, as well as maximum time-at-temperature limits, have been established to prevent metallurgical transformation of steel components, and potential, detrimental physical changes in seals or non-metallic components. During the manufacturing process, bearing rings and rolling elements are heat treated to define the strength, hardness and dimensional stability for proper operation. Heating or cooling bearings or bearing components beyond these limits may affect performance.

These suggestions are merely guidelines and, as new data is developed, the values as shown may change. These guidelines do not cover all Timken® products.

NOTE: Always use protective safety equipment and clothing when handling parts that have been heated or cooled.

Never heat a bearing with a torch, as localized heating will irreparably damage bearing components.

Never rapidly heat or freeze a bearing or bearing component.

Only use approved equipment, methods and controls to achieve desired temperature.

Always follow OEM instructions to ensure bearings and rings are properly positioned after heating or cooling.

Heating

Standard class bearings or rings (with metallic cages and without seals):

- Include Class 2, 4, 7, K, N, ABEC-1 and ABEC-3
- 93°C (200°F) - 24 Hours
- 121°C (250°F) - 8 Hours

Precision bearings or rings (with non-metallic cages and polymer or elastomer seals):

- Special considerations may apply for phenolic cages or special fluorocarbon lip seals.
- Include Class 3, 0, 00, 000, C, B, A, AA, ABEC 5 and 7

Precision and superprecision class bearings and rings (any)

- 66°C (150°F) - 24 Hours

Cooling (Freezing)

Freezing standard class bearings and rings

- 54°C (-65°F) - 1 Hour

Freezing precision class outer rings or cups

- -29°C (-20°F) - 2 Hours

Note: This temperature can be obtained by commercial freezer/ refrigeration equipment.

Cone Bore Temperature Reading in Degrees

Cone Bore	Thermometer Temperature Reading in Degrees		
	65° C 150° F	90° C 200° F	120° C 250° F
mm in.	mm in.	mm in.	mm in.
25.4 1	0.012 0.0005	0.020 0.0008	0.027 0.0011
50.8 2	0.025 0.0010	0.040 0.0016	0.055 0.0022
76.2 3	0.036 0.0014	0.058 0.0023	0.081 0.0032
101.6 4	0.048 0.0019	0.078 0.0031	0.109 0.0043
127 5	0.061 0.0024	0.099 0.0039	0.137 0.0054
152.4 6	0.073 0.0029	0.119 0.0047	0.165 0.0065
177.8 7	0.086 0.0034	0.139 0.0055	0.193 0.0076
203.2 8	0.096 0.0038	0.157 0.0062	0.218 0.0086
228.6 9	0.109 0.0043	0.177 0.0070	0.246 0.0097
254 10	0.121 0.0048	0.198 0.0078	0.274 0.0108
279.4 11	0.134 0.0053	0.218 0.0086	0.302 0.0119
304.8 12	0.147 0.0058	0.238 0.0094	0.330 0.013
330 13	0.157 0.0062	0.256 0.0101	0.355 0.014
355.6 14	0.170 0.0067	0.276 0.0109	0.383 0.0151
381 15	0.182 0.0072	0.297 0.0117	0.411 0.0162
406.4 16	0.195 0.0077	0.317 0.0125	0.439 0.0173
431.8 17	0.208 0.0082	0.337 0.0133	0.467 0.0184
457.2 18	0.218 0.0086	0.355 0.014	0.492 0.0194

Cone Bore	Thermometer Temperature Reading in Degrees		
	65° C 150° F	90° C 200° F	120° C 250° F
mm in.	mm in.	mm in.	mm in.
482.6 19	0.231 0.0091	0.375 0.0148	0.520 0.0205
508 20	0.243 0.0096	0.396 0.0156	0.548 0.0216
533.4 21	0.256 0.0101	0.416 0.0164	0.576 0.0227
558.8 22	0.269 0.0106	0.436 0.0172	0.604 0.0238
584.2 23	0.279 0.011	0.454 0.0179	0.629 0.0248
609.6 24	0.292 0.0115	0.475 0.0187	0.657 0.0259
635 25	0.304 0.012	0.495 0.0195	0.685 0.027
660.4 26	0.317 0.0125	0.515 0.0203	0.713 0.0281
685.8 27	0.330 0.013	0.535 0.0211	0.741 0.0292
711.2 28	0.340 0.0134	0.553 0.0218	0.767 0.0302
736.6 29	0.353 0.0139	0.574 0.0226	0.795 0.0313
762 30	0.365 0.0144	0.594 0.0234	0.823 0.0324
787.4 31	0.378 0.0149	0.614 0.0242	0.85 0.0335
812.8 32	0.391 0.0154	0.635 0.025	0.878 0.0346
838.2 33	0.401 0.0158	0.652 0.0257	0.904 0.0356
863.6 34	0.414 0.0163	0.673 0.0265	0.932 0.0367
889 35	0.426 0.0168	0.693 0.0273	0.960 0.0378
914.4 36	0.439 0.0173	0.713 0.0281	0.988 0.0389

GENERAL BEARING HANDLING AND INSPECTION (CONT'D)

Pressing on Bearings

Smaller bearings may be pressed onto the shaft or into a housing with an arbor press and mounting tube. Between the press ram and the bearing, use a tube of soft steel with an inside diameter slightly larger than the shaft. The outside diameter of the tube should not exceed the maximum shoulder height for the bearings. The tube should be square at both ends, thoroughly clean inside and out, and long enough to clear the end of the shaft after the bearing is mounted.

- Inspect the shaft and housing for proper size, roundness, burrs or other damage. A 12-point check of the shaft with a micrometer is suggested (see page 33).
- Coat the shaft with light machine oil or assembly paste to reduce the force needed to press the bearing on the shaft.
- Use a tube or pipe with an inner diameter (I.D.) that is slightly larger than the outer diameter (O.D.) of the shaft. The O.D. of the tube or pipe should be small enough that it does not contact the rolling elements or cage of the bearing.
- Position the tube on the inner ring and apply steady pressure with sufficient force to smoothly press the ring into place, and firmly against the shoulder or backing surface (Fig. 9).

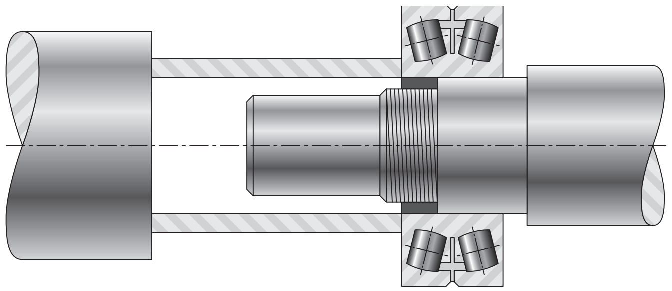


Fig. 9. Positioning the tube on the inner ring.

Never attempt to make a press fit on a shaft by applying pressure to the outer ring of an assembled bearing. However, because they have a separable outer ring, the outer ring of tapered roller bearings can be pressed into a housing. See page 61.

For specific information regarding bearing installation in your equipment, contact the equipment manufacturer.

Adjusting Bearing Clearance

The space between the rolling elements and the races of an anti-friction bearing is known as the bearing clearance, referred to in tapered roller bearings as the lateral, lateral clearance or end play. In other types of anti-friction bearings such as spherical, cylindrical, or ball bearings, the radial internal clearance or RIC, is specified. Clearance is desirable in applications where allowance must be provided for thermal growth of components, to accommodate for slight misalignment or other application requirements.

Bearings may also have zero clearance, with the contact surfaces of the rolling elements brought into contact with the races in line-to-line contact.

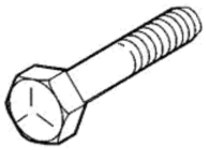
Finally, bearings may have the rolling elements and races brought into contact with a defined initial force, a condition known as preload. This enables precise control over the internal geometry of the mating parts, and is desirable where runout must be held within critical limits, such as high precision applications.

Bearings with separable races, such as tapered roller bearings, allow the clearance (preload) to be "adjusted" to meet application requirements. Other types of bearings are manufactured with a known clearance or preload, but the clearance can be slightly reduced through an interference fit on the inner or outer race.

For information about adjusting various types of bearings, see the section of this manual for each bearing design.

STANDARD TORQUE VALUES

Standard torque values are to be used on all fasteners unless otherwise specified



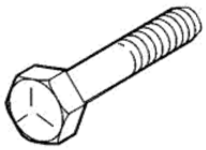
GRADE 5
COURSE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
1/4 -20	9	12	8	11	5	7
5/16 -18	18	24	16	22	11	15
3/8 -16	31	42	28	38	19	26
7/16 -14	50	67	45	61	30	41
1/2 -13	75	101	68	92	46	62
9/16 -12	108	146	98	133	66	89
5/8 -11	154	209	140	190	91	123
3/4 -10	264	358	240	325	160	217
7/8 -9	429	582	390	529	260	353
1 -8	638	865	580	786	390	529
1 1/8 -7	787	1,066	715	969	480	651
1 1/4 -7	1,111	1,506	1,010	1,369	675	915
1 3/8 -6	1,463	1,984	1,330	1,803	885	1,200
1 1/2 -6	1,936	2,625	1,760	2,386	1,170	1,586
1 3/4 -5	3,047	4,131	2,770	3,756	1,850	2,508
2 -4.5	4,576	6,204	4,160	5,640	2,780	3,769

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



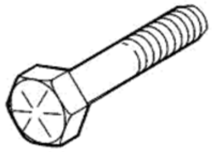
GRADE 5
FINE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
1/4 -28	10	13	9	12	6	8
5/16 -24	20	27	18	24	12	16
3/8 -24	35	48	32	43	21	28
7/16 -20	55	75	50	68	34	46
1/2 -20	85	115	77	104	51	69
9/16 -18	121	164	110	149	73	99
5/8 -18	171	231	155	210	105	142
3/4 -16	297	403	270	366	180	244
7/8 -14	473	641	430	583	285	386
1 -14	721	977	655	888	435	590
1 1/8 -12	886	1,201	805	1,091	535	725
1 1/4 -12	1,232	1,670	1,120	1,519	745	1,010
1 3/8 -12	1,661	2,252	1,510	2,047	1,010	1,369
1 1/2 -12	2,178	2,953	1,980	2,685	1,320	1,790

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



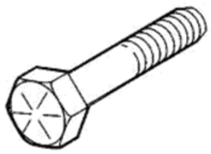
GRADE 8
COURSE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
1/4 -20	12	16	11	15	7	9
5/16 -18	25	34	23	31	15	20
3/8 -16	44	60	40	54	27	37
7/16 -14	69	94	63	85	42	57
1/2 -13	106	143	96	130	64	87
9/16 -12	154	209	140	190	93	126
5/8 -11	215	291	195	264	130	176
3/4 -10	374	507	340	461	230	312
7/8 -9	605	820	550	746	365	495
1 -8	902	1,223	820	1,112	550	746
1 1/8 -7	1,276	1,730	1,160	1,573	775	1,051
1 1/4 -7	1,804	2,446	1,640	2,224	1,100	1,491
1 3/8 -6	2,365	3,207	2,150	2,915	1,430	1,939
1 1/2 -6	3,135	4,250	2,850	3,864	1,900	2,576
1 3/4 -5	4,939	6,696	4,490	6,088	3,000	4,067
2 -4.5	7,425	10,067	6,750	9,152	4,500	6,101

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



GRADE 8
FINE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
1/4 -28	13	18	12	16	8	11
5/16 -24	28	37	25	34	17	23
3/8 -24	50	67	45	61	30	41
7/16 -20	78	106	71	96	47	64
1/2 -20	119	161	108	146	72	98
9/16 -18	171	231	155	210	105	142
5/8 -18	242	328	220	298	145	197
3/4 -16	418	567	380	515	255	346
7/8 -14	666	902	605	820	405	549
1 -14	1,012	1,372	920	1,247	615	834
1 1/8 -12	1,430	1,939	1,300	1,763	870	1,180
1 1/4 -12	2,002	2,714	1,820	2,468	1,210	1,641
1 3/8 -12	2,695	3,654	2,450	3,322	1,630	2,210
1 1/2 -12	3,531	4,787	3,210	4,352	2,140	2,901

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified

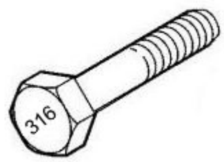
316 STAINLESS STEEL COURSE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
1/4 -20	6	7	5	7	3	4
5/16 -18	12	16	11	15	7	9
3/8 -16	21	28	19	26	13	18
7/16 -14	32	43	29	39	20	27
1/2 -13	50	67	45	61	30	41
9/16 -12	70	95	64	87	43	58
5/8 -11	97	131	88	119	59	80
3/4 -10	121	164	110	149	72	98
7/8 -9	193	261	175	237	116	157
1 -8	292	395	265	359	174	236
1 1/8 -7	407	552	370	502	247	335
1 1/4 -7	578	783	525	712	348	472
1 3/8 -6	754	1,022	685	929	456	618
1 1/2 -6	1,001	1,357	910	1,234	605	820
1 3/4 -5	1,584	2,148	1,440	1,952	954	1,293
2 -4.5	2,376	3,221	2,160	2,929	1,440	1,952

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



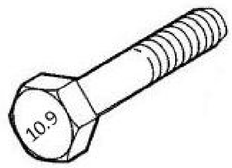
316 STAINLESS STEEL FINE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
1/4 -28	7	9	6	8	4	5
5/16 -24	13	18	12	16	8	11
3/8 -24	23	31	21	28	14	19
7/16 -20	36	49	33	45	22	30
1/2 -20	55	75	50	68	34	46
9/16 -18	78	106	71	96	48	65
5/8 -18	110	149	100	136	67	91
3/4 -16	138	186	125	169	81	110
7/8 -14	215	291	195	264	130	176
1 -14	325	440	295	400	200	271
1 1/8 -12	457	619	415	563	280	380
1 1/4 -12	638	865	580	786	385	522
1 3/8 -12	858	1,163	780	1,058	520	705
1 1/2 -12	1,133	1,536	1,030	1,396	685	929

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



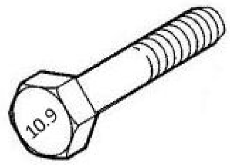
METRIC GRADE 10.9
COURSE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
6 -1.00	11	14	10	14	7	9
8 -1.25	26	36	25	34	17	23
10 -1.50	50	68	48	65	32	43
12 -1.75	88	120	84	114	56	76
14 -2.00	142	192	135	183	89	121
16 -2.00	221	299	210	285	140	190
20 -2.50	425	577	405	549	270	366
22 -2.50	578	783	550	746	370	502
24 -3.00	735	997	700	949	465	630
27 -3.00	1,082	1,466	1,030	1,396	685	929
30 -3.50	1,460	1,979	1,390	1,885	925	1,254
36 -4.00	2,552	3,459	2,430	3,295	1,620	2,196
42 -4.50	4,074	5,524	3,880	5,261	2,590	3,512
48 -5.00	6,122	8,300	5,830	7,904	3,890	5,274

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



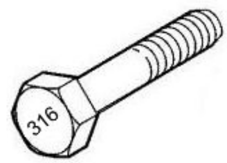
METRIC GRADE 10.9 FINE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
6 -0.75	12	16	11	15	7	9
8 -1.00	29	39	26	35	18	24
10 -1.25	56	76	51	69	34	46
12 -1.50	97	131	88	119	59	80
14 -1.50	160	216	145	197	96	130
16 -1.50	248	336	225	305	150	203
18 -1.50	396	537	360	488	240	325
20 -1.50	545	738	495	671	330	447
22 -1.50	726	984	660	895	440	597
24 -2.00	946	1,283	860	1,166	575	780
27 -2.00	1,353	1,834	1,230	1,668	820	1,112
30 -1.50	2,035	2,759	1,850	2,508	1,230	1,668

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



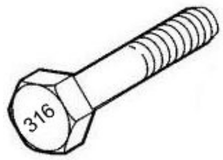
METRIC 316 STAINLESS STEEL COURSE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
6 -1.00	5	7	5	7	3	4
8 -1.25	13	17	12	16	8	11
10 -1.50	24	33	23	31	15	20
12 -1.75	41	56	39	53	26	35
14 -2.00	65	88	62	84	41	56
16 -2.00	101	137	96	130	64	87
20 -2.50	200	270	190	258	125	169
22 -2.50	268	363	255	346	170	230
24 -3.00	341	463	325	441	215	292
27 -3.00	499	676	475	644	315	427
30 -3.50	672	911	640	868	430	583
36 -4.00	1,176	1,594	1,120	1,519	750	1,017
42 -4.50	1,890	2,562	1,800	2,440	1,195	1,620
48 -5.00	2,835	3,844	2,700	3,661	1,800	2,440

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



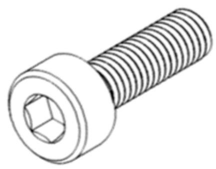
METRIC 316 STAINLESS STEEL FINE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
6 -0.75	5	7	5	7	3	4
8 -1.00	13	18	12	16	8	11
10 -1.25	26	36	24	33	16	22
12 -1.50	45	61	41	56	27	37
14 -1.50	74	100	67	91	45	61
16 -1.50	112	152	102	138	68	92
18 -1.50	182	246	165	224	110	149
20 -1.50	253	343	230	312	155	210
22 -1.50	336	455	305	414	205	278
24 -2.00	435	589	395	536	265	359
27 -2.00	627	850	570	773	380	515
30 -1.50	941	1,275	855	1,159	570	773

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



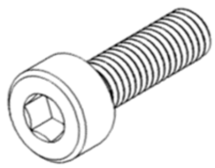
SOCKET HEAD COURSE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
1/4 -20	14	19	13	18	8	11
5/16 -18	29	39	26	35	18	24
3/8 -16	51	69	46	62	31	42
7/16 -14	81	110	74	100	49	66
1/2 -13	127	172	115	156	75	102
9/16 -12	176	239	160	217	105	142
5/8 -11	237	321	215	292	145	197
3/4 -10	424	574	385	522	255	346
7/8 -9	677	917	615	834	410	556
1 -8	1,012	1,372	920	1,247	615	834
1 1/8 -7	1,436	1,946	1,305	1,769	870	1,180
1 1/4 -7	2,024	2,744	1,840	2,495	1,230	1,668
1 3/8 -6	2,657	3,602	2,415	3,274	1,610	2,183
1 1/2 -6	3,526	4,780	3,205	4,345	2,135	2,895
1 3/4 -5	5,555	7,532	5,050	6,847	3,370	4,569
2 -4.5	8,349	11,320	7,590	10,291	5,060	6,860

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



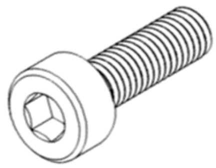
SOCKET HEAD
FINE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
1/4 -28	15	21	14	19	10	14
5/16 -24	32	43	29	39	20	27
3/8 -24	57	78	52	71	35	47
7/16 -20	90	122	82	111	55	75
1/2 -20	143	194	130	176	84	114
9/16 -18	193	261	175	237	120	163
5/8 -18	270	365	245	332	165	224
3/4 -16	468	634	425	576	285	386
7/8 -14	748	1,014	680	922	455	617
1 -14	1,139	1,544	1,035	1,403	690	936
1 1/8 -12	1,612	2,185	1,465	1,986	975	1,322
1 1/4 -12	2,244	3,042	2,040	2,766	1,360	1,844
1 3/8 -12	3,025	4,101	2,750	3,728	1,835	2,488
1 1/2 -12	3,966	5,376	3,605	4,888	2,405	3,261

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



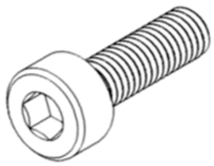
METRIC SOCKET HEAD GRADE 12.9 COURSE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
6 -1.00	12	16	11	15	8	11
8 -1.25	29	40	28	38	19	26
10 -1.50	57	77	54	73	36	49
12 -1.75	100	135	95	129	63	85
14 -2.00	163	221	155	210	105	142
16 -2.00	247	335	235	319	160	217
20 -2.50	483	655	460	624	305	414
22 -2.50	656	890	625	847	415	563
24 -3.00	830	1,125	790	1,071	525	712
27 -3.00	1,218	1,651	1,160	1,573	770	1,044
30 -3.50	1,649	2,235	1,570	2,129	1,050	1,424
36 -4.00	2,877	3,901	2,740	3,715	1,830	2,481
42 -4.50	4,610	6,250	4,390	5,952	2,930	3,973
48 -5.00	6,920	9,382	6,590	8,935	4,390	5,952

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified



METRIC SOCKET HEAD GRADE 12.9 FINE THREAD

BOLT SIZE - PITCH	DRY		LUBRICATED		WITH ANTI-SEIZE	
	Ft-Lbs.	N•m	Ft-Lbs.	N•m	Ft-Lbs.	N•m
6 -0.75	13	17	12	16	8	11
8 -1.00	33	45	30	41	20	27
10 -1.25	63	85	57	77	38	52
12 -1.50	109	148	99	134	66	89
14 -1.50	182	246	165	224	110	149
16 -1.50	275	373	250	339	170	230
18 -1.50	446	604	405	549	270	366
20 -1.50	616	835	560	759	375	508
22 -1.50	820	1,111	745	1,010	500	678
24 -2.00	1,067	1,447	970	1,315	645	875
27 -2.00	1,529	2,073	1,390	1,885	925	1,254
30 -1.50	2,299	3,117	2,090	2,834	1,390	1,885

Lubricated values refer to fasteners in the 'as received' condition of either a light preservative oil coating on unplated fasteners or no oil coating on plated fasteners. The lubricated values also assume NO FURTHER STEPS ARE TAKEN to add additional lubrication prior to assembly. Anti-seize values apply to parts that have an anti-seize lubricant applied just prior to installation.

STANDARD TORQUE VALUES (CON'T.)

Standard torque values are to be used on all fasteners unless otherwise specified

PREVAILING TORQUE LOCK NUT

COURSE THREAD

NUT SIZE -PITCH	GRADE G	
	MAX. (Ft-Lbs.)	MIN. (Ft-Lbs.)
1/4 -20	12.5	8.3
5/16 -18	20.0	12.9
3/8 -16	32.0	21.0
7/16 -14	51.0	34.0
1/2 -13	85.0	55.0
9/16 -12	120.0	80.0
5/8 -11	143.0	95.0
3/4 -10	240.0	160.0
7/8 -9	360.0	260.0
1 -8	530.0	410.0

PREVAILING TORQUE LOCK NUT

FINE THREAD

NUT SIZE - PITCH	GRADE G	
	MAX. (Ft-Lbs.)	MIN. (Ft-Lbs.)
1/4 -28	13.3	8.8
5/16 -24	19.2	12.9
3/8 -24	33.0	22.0
7/16 -20	60.0	40.0
1/2 -20	89.0	59.0
9/16 -18	132.0	88.0
5/8 -18	175.0	115.0
3/4 -16	270.0	170.0
7/8 -14	402.0	247.0
1 -14	645.0	398.0

FRACTIONAL/DECIMAL/MILLIMETER CONVERSIONS

Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters
0.0625	1/16	1.5875	1.0625	1 1/16	26.9876	2.0625	2 1/16	52.3877	3.0625	3 1/16	77.7878	4.0625	4 1/16	103.1879
0.1250	1/8	3.1750	1.1250	1 1/8	28.5751	2.1250	2 1/8	53.9752	3.1250	3 1/8	79.3753	4.1250	4 1/8	104.7754
0.1875	3/16	4.7625	1.1875	1 3/16	30.1626	2.1875	2 3/16	55.5627	3.1875	3 3/16	80.9628	4.1875	4 3/16	106.3629
0.2500	1/4	6.3500	1.2500	1 1/4	31.7501	2.2500	2 1/4	57.1502	3.2500	3 1/4	82.5503	4.2500	4 1/4	107.9504
0.3125	5/16	7.9375	1.3125	1 5/16	33.3376	2.3125	2 5/16	58.7377	3.3125	3 5/16	84.1378	4.3125	4 5/16	109.5379
0.3750	3/8	9.5250	1.3750	1 3/8	34.9251	2.3750	2 3/8	60.3252	3.3750	3 3/8	85.7253	4.3750	4 3/8	111.1254
0.4375	7/16	11.1125	1.4375	1 7/16	36.5126	2.4375	2 7/16	61.9127	3.4375	3 7/16	87.3128	4.4375	4 7/16	112.7129
0.5000	1/2	12.7001	1.5000	1 1/2	38.1002	2.5000	2 1/2	63.5003	3.5000	3 1/2	88.9004	4.5000	4 1/2	114.3005
0.5625	9/16	14.2876	1.5625	1 9/16	39.6877	2.5625	2 9/16	65.0878	3.5625	3 9/16	90.4879	4.5625	4 9/16	115.8880
0.6250	5/8	15.8751	1.6250	1 5/8	41.2752	2.6250	2 5/8	66.6753	3.6250	3 5/8	92.0754	4.6250	4 5/8	117.4755
0.6875	11/16	17.4626	1.6875	1 11/16	42.8627	2.6875	2 11/16	68.2628	3.6875	3 11/16	93.6629	4.6875	4 11/16	119.0630
0.7500	3/4	19.0501	1.7500	1 3/4	44.4502	2.7500	2 3/4	69.8503	3.7500	3 3/4	95.2504	4.7500	4 3/4	120.6505
0.8125	13/16	20.6376	1.8125	1 13/16	46.0377	2.8125	2 13/16	71.4378	3.8125	3 13/16	96.8379	4.8125	4 13/16	122.2380
0.8750	7/8	22.2251	1.8750	1 7/8	47.6252	2.8750	2 7/8	73.0253	3.8750	3 7/8	98.4254	4.8750	4 7/8	123.8255
0.9375	15/16	23.8126	1.9375	1 15/16	49.2127	2.9375	2 15/16	74.6128	3.9375	3 15/16	100.0129	4.9375	4 15/16	125.4130
1.0000	1	25.4001	2.0000	2	50.8002	3.0000	3	76.2003	4.0000	4	101.6004	5.0000	5	127.0005

Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters
5.0625	5 1/16	128.5880	6.0625	6 1/16	153.9881	7.0625	7 1/16	179.3882	8.0625	8 1/16	204.7883	9.0625	9 1/16	230.1884
5.1250	5 1/8	130.1755	6.1250	6 1/8	155.5756	7.1250	7 1/8	180.9757	8.1250	8 1/8	206.3758	9.1250	9 1/8	231.7759
5.1875	5 3/16	131.7630	6.1875	6 3/16	157.1631	7.1875	7 3/16	182.5632	8.1875	8 3/16	207.9633	9.1875	9 3/16	233.3634
5.2500	5 1/4	133.3505	6.2500	6 1/4	158.7506	7.2500	7 1/4	184.1507	8.2500	8 1/4	209.5508	9.2500	9 1/4	234.9509
5.3125	5 5/16	134.9380	6.3125	6 5/16	160.3381	7.3125	7 5/16	185.7382	8.3125	8 5/16	211.1383	9.3125	9 5/16	236.5384
5.3750	5 3/8	136.5255	6.3750	6 3/8	161.9256	7.3750	7 3/8	187.3257	8.3750	8 3/8	212.7258	9.3750	9 3/8	238.1259
5.4375	5 7/16	138.1130	6.4375	6 7/16	163.5131	7.4375	7 7/16	188.9132	8.4375	8 7/16	214.3133	9.4375	9 7/16	239.7134
5.5000	5 1/2	139.7006	6.5000	6 1/2	165.1007	7.5000	7 1/2	190.5008	8.5000	8 1/2	215.9009	9.5000	9 1/2	241.3010
5.5625	5 9/16	141.2881	6.5625	6 9/16	166.6882	7.5625	7 9/16	192.0883	8.5625	8 9/16	217.4884	9.5625	9 9/16	242.8885
5.6250	5 5/8	142.8756	6.6250	6 5/8	168.2757	7.6250	7 5/8	193.6758	8.6250	8 5/8	219.0759	9.6250	9 5/8	244.4760
5.6875	5 11/16	144.4631	6.6875	6 11/16	169.8632	7.6875	7 11/16	195.2633	8.6875	8 11/16	220.6634	9.6875	9 11/16	246.0635
5.7500	5 3/4	146.0506	6.7500	6 3/4	171.4507	7.7500	7 3/4	196.8508	8.7500	8 3/4	222.2509	9.7500	9 3/4	247.6510
5.8125	5 13/16	147.6381	6.8125	6 13/16	173.0382	7.8125	7 13/16	198.4383	8.8125	8 13/16	223.8384	9.8125	9 13/16	249.2385
5.8750	5 7/8	149.2256	6.8750	6 7/8	174.6257	7.8750	7 7/8	200.0258	8.8750	8 7/8	225.4259	9.8750	9 7/8	250.8260
5.9375	5 15/16	150.8131	6.9375	6 15/16	176.2132	7.9375	7 15/16	201.6133	8.9375	8 15/16	227.0134	9.9375	9 15/16	252.4135
6.0000	6	152.4006	7.0000	7	177.8007	8.0000	8	203.2008	9.0000	9	228.6009	10.0000	10	254.0010

Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters
10.0625	10 1/16	255.5885	11.0625	11 1/16	280.9886	12.0625	12 1/16	306.3887	13.0625	13 1/16	331.7888	14.0625	14 1/16	357.1889
10.1250	10 1/8	257.1760	11.1250	11 1/8	282.5761	12.1250	12 1/8	307.9762	13.1250	13 1/8	333.3763	14.1250	14 1/8	358.7764
10.1875	10 3/16	258.7635	11.1875	11 3/16	284.1636	12.1875	12 3/16	309.5637	13.1875	13 3/16	334.9638	14.1875	14 3/16	360.3639
10.2500	10 1/4	260.3510	11.2500	11 1/4	285.7511	12.2500	12 1/4	311.1512	13.2500	13 1/4	336.5513	14.2500	14 1/4	361.9514
10.3125	10 5/16	261.9385	11.3125	11 5/16	287.3386	12.3125	12 5/16	312.7387	13.3125	13 5/16	338.1388	14.3125	14 5/16	363.5389
10.3750	10 3/8	263.5260	11.3750	11 3/8	288.9261	12.3750	12 3/8	314.3262	13.3750	13 3/8	339.7263	14.3750	14 3/8	365.1264
10.4375	10 7/16	265.1135	11.4375	11 7/16	290.5136	12.4375	12 7/16	315.9137	13.4375	13 7/16	341.3138	14.4375	14 7/16	366.7139
10.5000	10 1/2	266.7011	11.5000	11 1/2	292.1012	12.5000	12 1/2	317.5013	13.5000	13 1/2	342.9014	14.5000	14 1/2	368.3015
10.5625	10 9/16	268.2886	11.5625	11 9/16	293.6887	12.5625	12 9/16	319.0888	13.5625	13 9/16	344.4889	14.5625	14 9/16	369.8890
10.6250	10 5/8	269.8761	11.6250	11 5/8	295.2762	12.6250	12 5/8	320.6763	13.6250	13 5/8	346.0764	14.6250	14 5/8	371.4765
10.6875	10 11/16	271.4636	11.6875	11 11/16	296.8637	12.6875	12 11/16	322.2638	13.6875	13 11/16	347.6639	14.6875	14 11/16	373.0640
10.7500	10 3/4	273.0511	11.7500	11 3/4	298.4512	12.7500	12 3/4	323.8513	13.7500	13 3/4	349.2514	14.7500	14 3/4	374.6515
10.8125	10 13/16	274.6386	11.8125	11 13/16	300.0387	12.8125	12 13/16	325.4388	13.8125	13 13/16	350.8389	14.8125	14 13/16	376.2390
10.8750	10 7/8	276.2261	11.8750	11 7/8	301.6262	12.8750	12 7/8	327.0263	13.8750	13 7/8	352.4264	14.8750	14 7/8	377.8265
10.9375	10 15/16	277.8136	11.9375	11 15/16	303.2137	12.9375	12 15/16	328.6138	13.9375	13 15/16	354.0139	14.9375	14 15/16	379.4140
11.0000	11	279.4011	12.0000	12	304.8012	13.0000	13	330.2013	14.0000	14	355.6014	15.0000	15	381.0015

Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters	Inches (decimal)	Inches (Fraction)	Millimeters
15.0625	15 1/16	382.5890	16.0625	16 1/16	407.9891	17.0625	17 1/16	433.3892	18.0625	18 1/16	458.7893	19.0625	19 1/16	484.1894
15.1250	15 1/8	384.1765	16.1250	16 1/8	409.5766	17.1250	17 1/8	434.9767	18.1250	18 1/8	460.3768	19.1250	19 1/8	485.7769
15.1875	15 3/16	385.7640	16.1875	16 3/16	411.1641	17.1875	17 3/16	436.5642	18.1875	18 3/16	461.9643	19.1875	19 3/16	487.3644
15.2500	15 1/4	387.3515	16.2500	16 1/4	412.7516	17.2500	17 1/4	438.1517	18.2500	18 1/4	463.5518	19.2500	19 1/4	488.9519
15.3125	15 5/16	388.9390	16.3125	16 5/16	414.3391	17.3125	17 5/16	439.7392	18.3125	18 5/16	465.1393	19.3125	19 5/16	490.5394
15.3750	15 3/8	390.5265	16.3750	16 3/8	415.9266	17.3750	17 3/8	441.3267	18.3750	18 3/8	466.7268	19.3750	19 3/8	492.1269
15.4375	15 7/16	392.1140	16.4375	16 7/16	417.5141	17.4375	17 7/16	442.9142	18.4375	18 7/16	468.3143	19.4375	19 7/16	493.7144
15.5000	15 1/2	393.7016	16.5000	16 1/2	419.1017	17.5000	17 1/2	444.5018	18.5000	18 1/2	469.9019	19.5000	19 1/2	495.3020
15.5625	15 9/16	395.2891	16.5625	16 9/16	420.6892	17.5625	17 9/16	446.0893	18.5625	18 9/16	471.4894	19.5625	19 9/16	496.8895
15.6250	15 5/8	396.8766	16.6250	16 5/8	422.2767	17.6250	17 5/8	447.6768	18.6250	18 5/8	473.0769	19.6250	19 5/8	498.4770
15.6875	15 11/16	398.4641	16.6875	16 11/16	423.8642	17.6875	17 11/16	449.2643	18.6875	18 11/16	474.6644	19.6875	19 11/16	500.0645
15.7500	15 3/4	400.0516	16.7500	16 3/4	425.4517	17.7500	17 3/4	450.8518	18.7500	18 3/4	476.2519	19.7500	19 3/4	501.6520
15.8125	15 13/16	401.6391	16.8125	16 13/16	427.0392	17.8125	17 13/16	452.4393	18.8125	18 13/16	477.8394	19.8125	19 13/16	503.2395
15.8750	15 7/8	403.2266	16.8750	16 7/8	428.6267	17.8750	17 7/8	454.0268	18.8750	18 7/8	479.4269	19.8750	19 7/8	504.8270
15.9375	15 15/16	404.8141	16.9375	16 15/16	430.2142	17.9375	17 15/16	455.6143	18.9375	18 15/16	481.0144	19.9375	19 15/16	506.4145
16.0000	16	406.4016	17.0000	17	431.8017	18.0000	18	457.2018	19.0000	19	482.6019	20.0000	20	508.0020