Part No. 94817SL

Service Manual

Reelmaster® 4500–D

Preface

The purpose of this publication is to provide the service technician with information for troubleshooting, testing, and repair of major systems and components on the Reelmaster 4500–D.

REFER TO THE TRACTION UNIT AND CUTTING UNIT OPERATOR'S MANUALS FOR OPERATING, MAINTENANCE AND ADJUSTMENT INSTRUCTIONS. Space is provided in Chapter 2 of this book to insert the Operator's Manuals and Parts Catalogs for your machine. Replacement Operator's Manuals are available by sending complete Model and Serial Number to:

The Toro Company
8111 Lyndale Avenue South
Minneapolis, MN 55420

The Toro Company reserves the right to change product specifications or this publication without notice.

This safety symbol means DANGER, WARNING, or CAUTION, PERSONAL SAFETY INSTRUCTION. When you see this symbol, carefully read the instructions that follow. Failure to obey the instructions may result in personal injury.

NOTE: A NOTE will give general information about the correct operation, maintenance, service, testing or repair of the machine.

IMPORTANT: The IMPORTANT notice will give important instructions which must be followed to prevent damage to systems or components on the machine.

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Table Of Contents

Chapter 1

Safety

Table of Contents

Safety Instructions

The REELMASTER 4500 D conforms to the American National Standards Institute's safety standards for riding mowers when rear tires are filled with calcium chloride and two rear wheel weight kits
(Part No. 11–0440) are installed.

CAUTION

TO REDUCE THE POTENTIAL FOR INJURY OR DEATH, COMPLY WITH THE FOLLOWING SAFETY INSTRUCTIONS.

Before Operating

Improper use or maintenance by the operator or owner of the machine can result in injury. Reduce the potential for any injury by complying with the following safety instructions.

WARNING: Engine exhaust contains carbon monoxide which is an odorless, deadly poison. Carbon monoxide is also known to the State of California to cause birth defects. Do not run engine indoors or in an enclosed area.

1. Read and understand the contents of the traction unit and cutting unit operator's manuals before operating the machine. To get replacement manuals, send complete model and serial number to:

The Toro Company
8111 Lyndale Avenue South
Minneapolis, Minnesota 55420–1196

Use the Model and Serial Number when referring to your machine. If you have questions about this Service Manual, please contact:

The Toro Company
Commercial Service Department
8111 Lyndale Avenue South
Minneapolis, Minnesota 55420.

2. Never allow children to operate the machine or adults to operate it without proper instruction.

3. Become familiar with the controls and know how to stop the machine and engine quickly.

4. Keep all shields, safety devices and decals in place. If a shield, safety device or decal is defective or damaged, repair or replace it before operating the machine.

5. Always wear substantial shoes. Do not operate machine while wearing sandals, tennis shoes, sneakers or when barefoot. Do not wear loose fitting clothing that could get caught in moving parts and possibly cause personal injury.

6. Wearing safety glasses, safety shoes, long pants and a helmet is advisable and required by some local ordinances and insurance regulations.

7. Make sure the work area is clear of objects which might be picked up and thrown by the reels.

8. Do not carry passengers on the machine. Keep everyone, especially children and pets, away from the areas of operation.

9. Since diesel fuel is highly flammable, handle it carefully:

A. Use an approved fuel container.

B. Do not remove fuel tank cap while engine is hot or running.

C. Do not smoke while handling fuel.

D. Fill fuel tank outdoors and only to within an inch (25 mm) from the top of the tank, not the filler neck. Do not overfill.

E. Wipe up any spilled fuel.

While Operating

10. Do not run engine in a confined area without adequate ventilation. Exhaust is hazardous and could be deadly.

11. Sit on the seat when starting and operating the machine.

12. Check interlock switches daily for proper operation. If a switch fails, replace it before operating the machine. The interlock system is for your protection, so do not bypass it. Replace all interlock switches every two years.

13. This product may exceed noise levels of 85 dB(A) at the operator position. Ear protectors are recommended for prolonged exposure to reduce the potential of permanent hearing damage.

14. Before starting the engine each day, test lamps, warning buzzer and signal lights to assure proper operation.

15. Pay attention when using the machine. To prevent loss of control:

A. Mow only in daylight or when there is good artificial light.

B. Watch for holes or other hidden hazards.

C. Be extremely careful when operating close to sand traps, ditches, creeks, steep hillsides or other hazards.

D. Reduce speed when making sharp turns. Avoid sudden stops and starts. Use ground speed limiter lever to set pedal travel so excessive ground speed will be avoided during mowing and transport.

E. Look to the rear to assure no one is behind the machine before backing up.

F. Watch for traffic when near or crossing roads. Always yield the right–of–way.

G. Reduce speed when driving downhill.

16. Keep hands, feet and clothing away from moving parts and the reel.

17. Traverse slopes carefully. Do not start or stop suddenly when traveling uphill or downhill.

18. Operator must be skilled and trained in how to drive on hillsides. Failure to use caution on slopes or hills may cause loss of control and vehicle to tip or roll possibly resulting in personal injury or death.

19. When operating 4 wheel drive machine, always use the seat belt and ROPS together and have seat pivot retaining pin installed.

20. If engine stalls or loses headway and cannot make it to the top of a slope, do not turn machine around. Always back slowly straight down the slope.

21. Raise cutting units and latch them securely in transport position before driving from one work area to another.

22. Do not touch engine, muffler or exhaust pipe while engine is running or soon after it is stopped. These areas could be hot enough to cause burns.

23. If cutting unit strikes a solid object or vibrates abnormally, stop immediately, turn engine off, set parking brake and wait for all motion to stop. Inspect for damage. If reel or bedknife is damaged, repair or replace it before operating. Do not attempt to free blocked cutting unit by moving Mow/Backlap lever rapidly between FORWARD and BACKLAP. Damage to hydraulic system may result. Lever should easily return and hold in the STOP position.

24. Before getting off the seat:

A. Move traction pedal to neutral.

B. Set parking brake.

C. Disengage cutting units and wait for reels to stop.

D. Stop engine and remove key from switch.

E. Do not park on slopes unless wheels are chocked or blocked.

25. The optional TORO tow bar is for emergency towing only. Use only the special tow bar if it becomes necessary to tow machine. Use trailer for normal transport.

Maintenance and Service

26. Before servicing or making adjustments, stop engine and remove key from the switch.

27. Assure entire machine is properly maintained and in good operating condition. Frequently check all nuts, bolts and screws.

28. Frequently check all hydraulic line connectors and fittings. Assure all hydraulic hoses and lines are in good condition before applying pressure to the system.

29. Keep body and hands away from pin hole leaks or nozzles that eject high pressure hydraulic fluid. Use cardboard or paper to find hydraulic leaks. Hydraulic fluid escaping under pressure can penetrate skin and cause injury. Fluid accidentally injected into the skin must be surgically removed within a few hours by a doctor or gangrene may occur.

30. Before any hydraulic system maintenance, stop engine and lower cutting units to the ground so all pressure is relieved.

31. For major repairs or other assistance, contact your local Toro Distributor.

32. To reduce potential fire hazard, keep engine area free of excessive grease, grass, leaves and dirt. Clean protective screen on back of engine frequently.

33. If engine must be running to perform maintenance or an adjustment, keep hands, feet, clothing and other parts of the body away from cutting units and other moving parts. Keep everyone away.

34. Do not overspeed the engine by changing governor setting. Maximum engine speed is 2500 rpm + or – 100 rpm. To assure safety and accuracy, have an Authorized Toro Distributor check maximum engine speed.

35. Shut engine off before checking or adding oil to the crankcase.

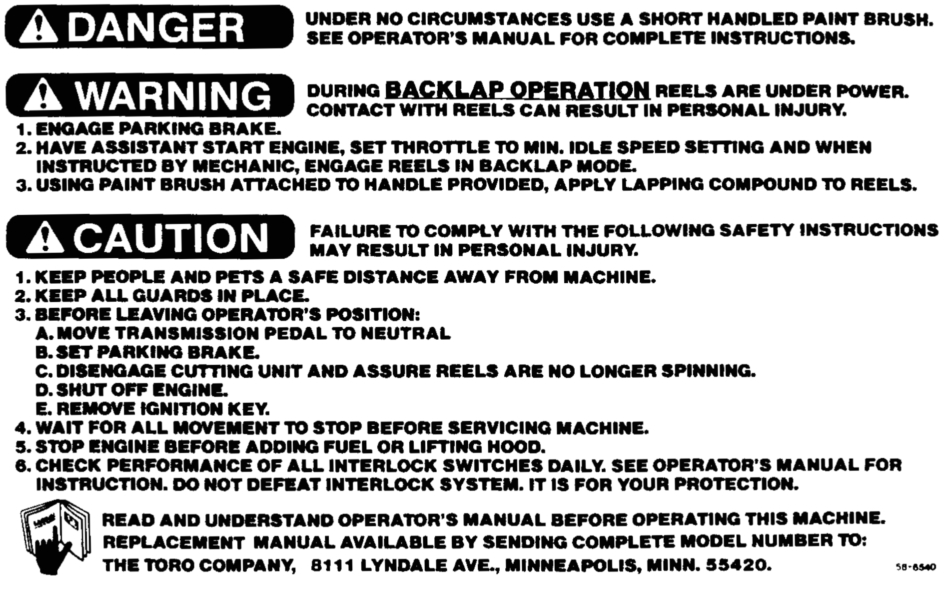
36. Disconnect battery before servicing the machine. If battery voltage is required for troubleshooting or test procedures, temporarily connect the battery.

37. Toro recommends that two people be used to backlap reels. Each person has specific duties and you must communicate with one another.

38. For optimum performance and safety, use genuine Toro replacement parts and accessories. Replacement parts and accessories made by other manufacturers could be dangerous and may void the product warranty of The Toro Company.

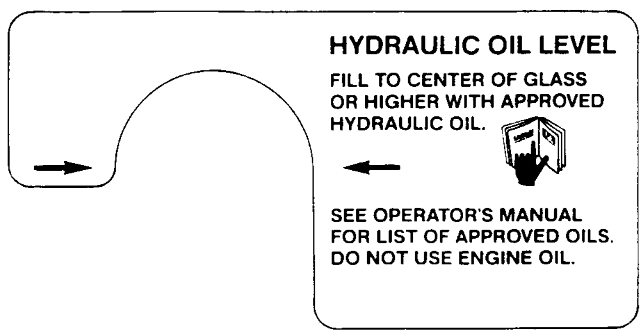
Safety and Instruction Decals

The following safety and instruction decals are installed on the traction unit. If any become damaged, replace them. Decals are listed in your Parts Catalog. Order replacements from your Authorized TORO Distributor.

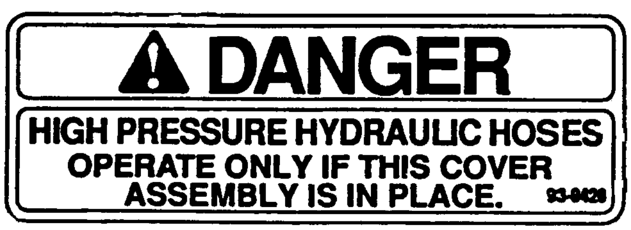


ON PANEL IN FRONT OF OPERATOR'S SEAT
(Part No. 58–6540)

ON LIFT ARMS
(Part No. 61–3610)



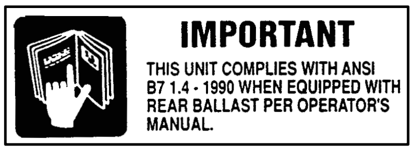
ON LEFT SIDE OF MACHINE
(Part No. 59–7290)



ON PANEL IN FRONT OF OPERATOR'S SEAT
(Part No. 93–9426)

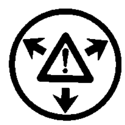
ON STEERING CONSOLE
(Part No. 77–4830)

NEAR RADIATOR FILL CAP
(Part No. 58–6940)



ON FRAME ABOVE RIGHT REAR WHEEL
(Part No. 88–6700)

UNDER SEAT NEAR OIL FILL CAP
(Part No. 58–6530)

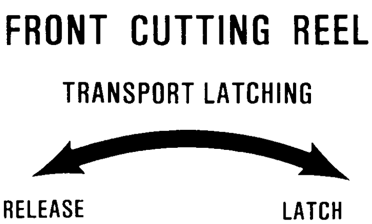


ON RADIATOR CAP
(Part No. 59–8440)

NEAR FUEL TANK FILL CAP
(Part No. 49–2280)

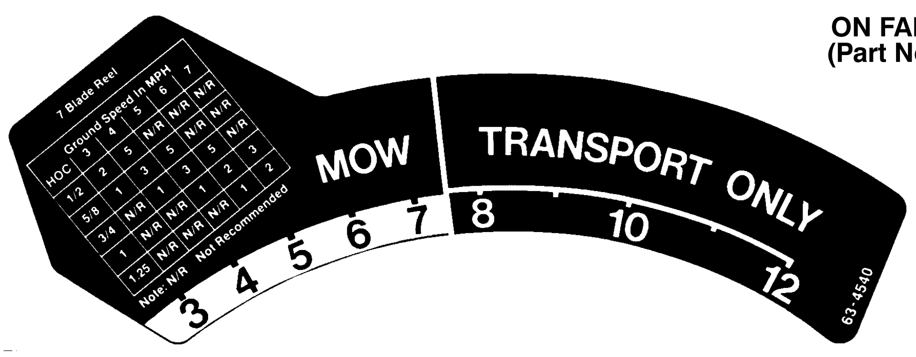
ON FRAME ABOVE REAR WHEELS
(Part No. 58–5910)

ON CUTTING UNIT
(Part No. 76–8760)

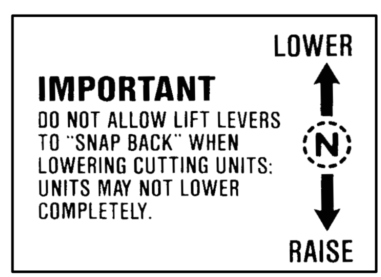


NEAR FRONT CUTTING UNIT RELEASE LEVER
(Part No. 59–7960)

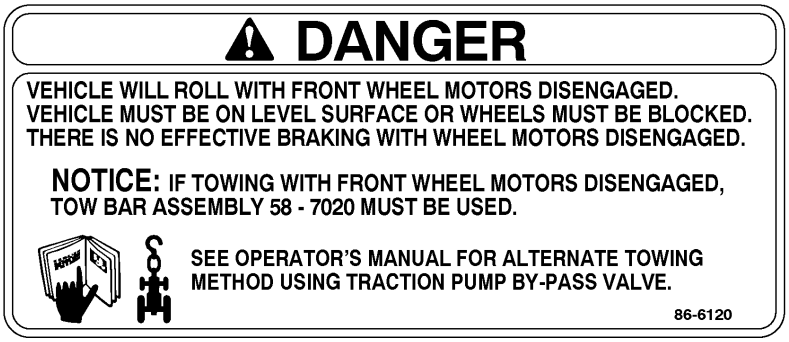
ON FAN SHROUD
(Part No. 76–8750)



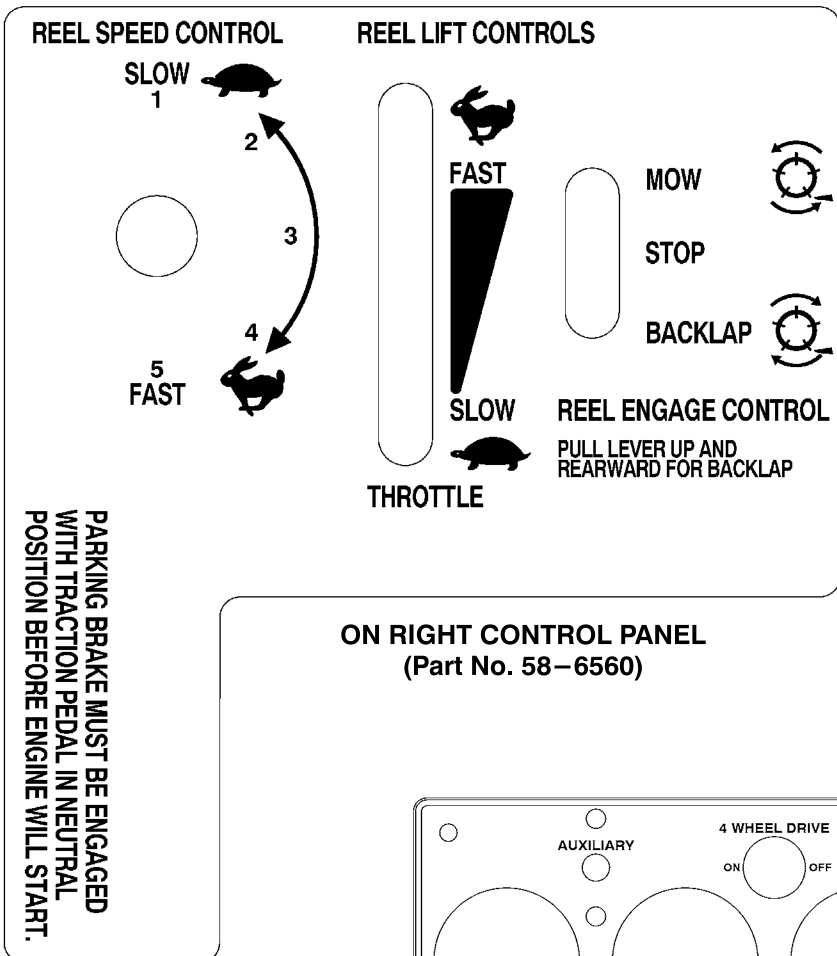
NEXT TO TRACTION PEDAL ON STEERING CONSOLE
(Part No. 63–4540, Model 03702 & 03704)
(Part No. 63–4530, Model 03703 & 03705)



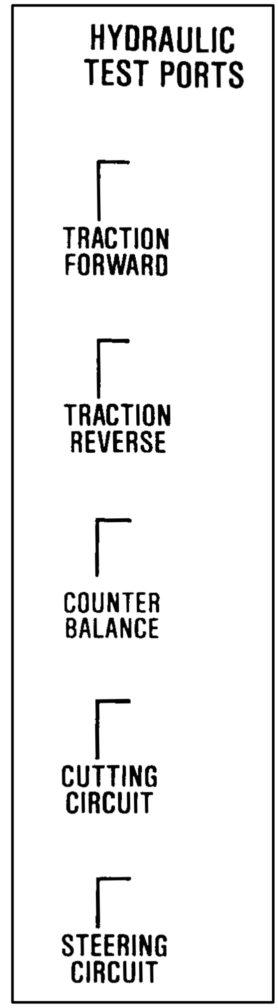
NEXT TO LIFT LEVERS
(Part No. 62–6290)



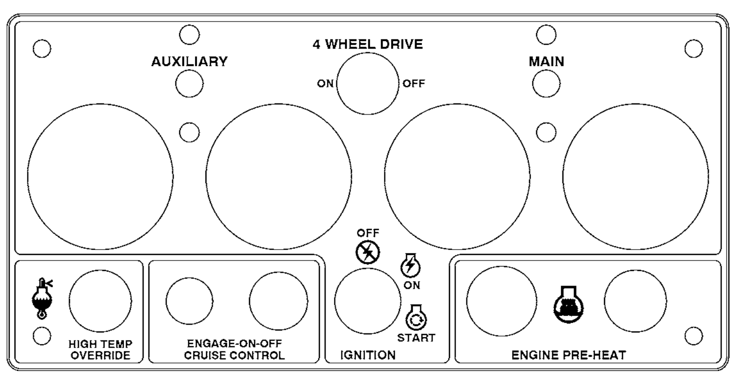
ON FRONT CARRIER & TOW BAR
(Part No. 86–6120)



ON RIGHT CONTROL PANEL
(Part No. 58–6560)



NEAR TEST PORTS
(Part No. 58–6680)



ON RIGHT CONTROL PANEL
(Part No. 92–5656)

Product Records and Manuals

Table of Contents

Product Records

Record information about your Reelmaster 4500–D on the OPERATION AND SERVICE HISTORY REPORT form. Use this information when referring to your machine.

Insert Operator's Manuals and Parts Catalogs for your Reelmaster 4500–D at the end of this section.

Equivalents and Conversions

Decimal and Millimeter Equivalents

Fractions	Decimals	mm	Fractions	Decimals	mm
1/64	0.015625	— 0.397	33/64	0.515625	— 13.097
1/32	0.03125	— 0.794	17/32	0.53125	— 13.494
3/64	0.046875	— 1.191	35/64	0.546875	— 13.891
1/16	0.0625	— 1.588	9/16	0.5625	— 14.288
5/64	0.078125	— 1.984	37/64	0.578125	— 14.684
3/32	0.9375	— 2.381	19/32	0.59375	— 15.081
7/64	0.109275	— 2.778	39/64	0.609375	— 15.478
1/8	0.1250	— 3.175	**5/8**	0.6250	— 15.875
9/64	0.140625	— 3.572	41/64	0.640625	— 16.272
5/32	0.15625	— 3.969	21/32	0.65625	— 16.669
11/64	0.171875	— 4.366	43/64	0.671875	— 17.066
3/16	0.1875	— 4.762	11/16	0.6875	— 17.462
13/64	0.203125	— 5.159	45/64	0.703125	— 17.859
7/32	0.21875	— 5.556	23/32	0.71875	— 18.256
15/64	0.234375	— 5.953	47/64	0.734375	— 18.653
1/4	0.2500	— 6.350	**3/4**	0.7500	— 19.050
17/64	0.265625	— 6.747	49/64	0.765625	— 19.447
9/32	0.28125	— 7.144	25/32	0.78125	— 19.844
19/64	0.296875	— 7.541	51/64	0.796875	— 20.241
5/16	0.3125	— 7.938	13/16	0.8125	— 20.638
21/64	0.328125	— 8.334	53/64	0.828125	— 21.034
11/32	0.34375	— 8.731	27/32	0.84375	— 21.431
23/64	0.359375	— 9.128	55/64	0.859375	— 21.828
3/8	0.3750	— 9.525	**7/8**	0.8750	— 22.225
25/64	0.390625	— 9.922	57/64	0.890625	— 22.622
13/32	0.40625	— 10.319	29/32	0.90625	— 23.019
27/64	0.421875	— 10.716	59/64	0.921875	— 23.416
7/16	0.4375	— 11.112	15/16	0.9375	— 23.812
29/64	0.453125	— 11.509	61/64	0.953125	— 24.209
15/32	0.46875	— 11.906	31/32	0.96875	— 24.606
31/64	0.484375	— 12.303	63/64	0.984375	— 25.003
1/2	0.5000	— 12.700	**1**	1.000	— 25.400
1 mm = 0.03937 in.			**0.001 in. = 0.0254 mm**		

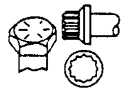
U.S to Metric Conversions

	To Convert	Into	Multiply By
Linear Measurement	Miles	Kilometers	1.609
	Yards	Meters	0.9144
	Feet	Meters	0.3048
	Feet	Centimeters	30.48
	Inches	Meters	0.0254
	Inches	Centimeters	2.54
	Inches	Millimeters	25.4
Area	Square Miles	Square Kilometers	2.59
	Square Feet	Square Meters	0.0929
	Square Inches	Square Centimeters	6.452
	Acre	Hectare	0.4047
Volume	Cubic Yards	Cubic Meters	0.7646
	Cubic Feet	Cubic Meters	0.02832
	Cubic Inches	Cubic Centimeters	16.39
Weight	Tons (Short)	Metric Tons	0.9078
	Pounds	Kilograms	0.4536
	Ounces (Avdp.)	Grams	28.3495
Pressure	Pounds/Sq. In.	Kilopascal	6.895
	Pounds/Sq. In.	Bar	0.069
Work	Foot-pounds	Newton-Meters	1.356
	Foot-pounds	Kilogram-Meters	0.1383
	Inch-pounds	Kilogram-Centimeters	1.152144
Liquid Volume	Quarts	Liters	0.9463
	Gallons	Liters	3.785
Liquid Flow	Gallons/Minute	Liters/Minute	3.785
Temperature	Fahrenheit	Celsius	1. Subract 32° 2. Multiply by 5/9

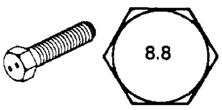
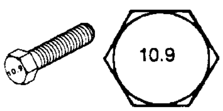
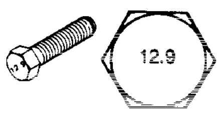
Torque Specifications

Use these torque values when specific torque values are not given. DO NOT use these values in place of specified values. Torque values listed are for lubricated threads. Plated threads are considered to be lubricated.

Capscrew Markings and Torque Values - U.S. Customary

SAE Grade Number	5				8			
Capscrew Head Markings								
Capscrew Body Size	Capscrew Torque - Grade 5				Capscrew Torque - Grade 8			
	Cast Iron		Aluminum		Cast Iron		Aluminum	
	ft-lb	Nm	ft-lb	Nm	ft-lb	Nm	ft-lb	Nm
1/4-20	7	9	6	8	11	15	9	12
-28	9	12	7	9	13	18	10	14
5/16-18	15	20	12	16	22	30	18	24
-24	17	23	14	19	24	33	19	25
3/8-16	30	40	20	25	40	55	30	40
-24	30	40	25	35	45	60	35	45
7/16-14	45	60	35	45	65	90	50	65
-20	50	65	40	55	70	95	55	75
1/2-13	70	95	55	75	95	130	75	100
-20	75	100	60	80	110	150	90	120
9/16-12	100	135	80	110	140	190	110	150
-18	110	150	85	115	155	210	125	170
5/8-11	135	180	110	150	190	255	150	205
-18	155	210	120	160	215	290	170	230
3/4-10	240	325	190	255	340	460	270	365
-16	270	365	210	285	380	515	300	410
7/8-9	360	490	280	380	550	745	440	600
-14	390	530	310	420	610	825	490	660
1-8	530	720	420	570	820	1100	660	890
-14	590	800	480	650	890	1200	710	960

Capscrew Markings and Torque Values – Metric

Commercial Steel Class	8.8				10.9				12.9			
Capscrew Head Markings												
Thread Diameter	Capscrew Torque - Class 8.8				Capscrew Torque - Class 10.9				Capscrew Torque - Class 12.9			
	Cast Iron		Aluminum		Cast Iron		Aluminum		Cast Iron		Aluminum	
mm	ft-lb	Nm	ft-lb	Nm	ft-lb	Nm	ft-lb	Nm	ft-lb	Nm	ft-lb	Nm
6	5	9	4	7	9	14	7	11	9	14	7	11
7	9	14	7	11	14	18	11	14	18	23	14	18
8	18	25	14	18	23	32	18	25	27	36	21	28
10	30	40	25	30	45	60	35	45	50	70	40	55
12	55	70	40	55	75	105	60	80	95	125	75	100
14	85	115	65	90	120	160	95	125	145	195	110	150
16	130	180	100	140	175	240	135	190	210	290	165	220
18	170	230	135	180	240	320	185	250	290	400	230	310

EQUIPMENT OPERATION AND SERVICE HISTORY REPORT
for
REELMASTER® 450-D and 4500-D

TORO Model and Serial Number:__________-_________

Engine Numbers: ____________________

Cutting Unit Serial Numbers: ____________________ ______________________

____________________ ______________________

____________________ ______________________

Date Purchased: ____________________ Warranty Expires__________

Purchased From: ____________________

____

____

Contacts: Parts ____________________ Phone__________________

Service ____________________ Phone__________________

Sales ____________________ Phone__________________

See your TORO *Distributor/Dealer for other Publications, Manuals, and Videos from* The TORO Company.

REELMASTER® 450-D and 4500-D Maintenance Schedule

Minimum Recommended Maintenance Intervals:

Maintenance Procedure	Maintenance Interval & Service Type:
Lubricate Reel Control Valve Grease Fitting	Every 50hrs *A Level Service*
Lubricate Reel Speed Control Valve with Oil	
Lubricate all Grease Fittings	
Check Battery Condition and Connections	
‡ Change Engine Oil and Filter	Every 100hrs *B Level Service*
Drain water from Hydraulic Tank	
† Check Engine Fan and Alternator Belt	
Inspect Cooling System Hoses	
Service Air Cleaner Filter Element	Every 200hrs *C Level Service*
Inspect Cutting Unit Reel Drive Belts	
† Torque Wheel Lug Nuts	
Replace Fuel Filter	Every 400hrs *D Level Service*
Inspect Fuel Lines and connections	
‡ Torque Cylinder Head and Adjust Valves	
‡ Check Engine RPM (idle and full throttle)	
Drain and Clean Fuel Tank	Every 800hrs *E Level Service*
‡ Replace Hydraulic Oil Filter	
Replace Hydraulic Tank Breather	
‡ Change Front Planetary Gear Lube	
Pack Rear Axle Bearings (2wd)	
Check Rear Wheel Toe-in	

† Initial break in at 10 hours

‡ Initial break in at 50 hours

Annual Recommendations	
Replace all Moving Hydraulic Hoses	**Annual Recommendations:** *Items listed are recommended every 1500 hours or 2 years whichever occurs first.*
Replace Safety Switches	
Cooling System - Flush/Replace Fluid	
Change Hydraulic Oil	

See Operator's and Service Manual for specifications and procedures)

REELMASTER® 450-D and 4500-D Daily Maintenance Check List

Unit Designation:__________

Daily Maintenance:(duplicate this page for routine use) TORO ID#:_______-_______

Maintenance Check Item	Daily Maintenance Check For Week Of _______________						
	MON _____HRS	TUES _____HRS	WED _____HRS	THURS _____HRS	FRI _____HRS	SAT _____HRS	SUN _____HRS
✓ Safety Interlock Operation							
✓ Parking Brake Operation							
✓ Engine Oil Level							
✓ Fuel Level							
✓ Cooling System Fluid Level							
Drain Water/Fuel Separator							
✓ Dust Cup and Baffle (Air Filter)							
✓ Radiator & Screen for Debris[1]							
Clean Traction Pedal Lockout							
✓ Unusual Engine Noises[2]							
✓ Unusual Operating Noises							
✓ Hydraulic System Oil Level							
✓ Hydraulic Hoses for Damage							
✓ Fluid Leaks							
✓ Tire Pressure							
✓ Instrument Operation							
✓ Warning Lamps Operation							
✓ Reel-to-Bedknife Adjustment							
✓ Height-of-Cut Adjustment							
Lubricate All Grease Fittings[3]							
Touch-up damaged paint							

[1] = Use only low pressure compressed air for debris removal. **Do not use water**.

[2] = Check Glow Plugs and Injector Nozzles, if hard starting, excess smoke, or rough running is noted.

[3] = Immediately after every washing, regardless of the interval listed.

Notation for areas of concern: Inspection performed by:________________

Item	Date	Information
1		
2		
3		
4		
5		
6		
7		

(See Operator's and Service Manual for specifications and procedures)

REELMASTER® 450-D and 4500-D Supervisor Maintenance Work Order

Date: ____________

(duplicate this page for routine use)

Unit Designation:	TORO I.D. #: ________-________	Remarks:
Hours:	Service to perform (circle):	
Technician:	**A B C D E Other**	

A -Service (every 50 hours)
- ☐ Lubricate Reel Control Valve Fitting
- ☐ Lubricate Reel Speed Valve with Oil
- ☐ Lubricate all Grease Fittings
- ☐ Check Battery Condition/Connections
- ☐ ____________
- ☐ ____________
- ☐ ____________
- ☐ ____________
- ☐ ____________

B -Service (every 100 hours)
- ☐ Change Engine Oil and Filter
- ☐ Drain water from Hydraulic Tank
- ☐ Check Engine Fan and Alternator Belt
- ☐ Inspect Cooling System Hoses
- ☐ **A-Service** required
- ☐ ____________
- ☐ ____________
- ☐ ____________
- ☐ ____________

C -Service (every 200 hours)
- ☐ Service Air Cleaner Filter Element
- ☐ Inspect Cutting Unit Reel Drive Belts
- ☐ Torque Wheel Lug Nuts
- ☐ **A** and **B Service** required
- ☐ ____________
- ☐ ____________
- ☐ ____________
- ☐ ____________
- ☐ ____________

D -Service (every 400 hours)
- ☐ Replace Fuel Filter
- ☐ Inspect Fuel Lines and Connections
- ☐ Torque Cylinder Head/Adjust Valves
- ☐ Check Engine RPM (Idle/Full Throttle)
- ☐ **A**, **B**, and **C Service** required
- ☐ ____________
- ☐ ____________
- ☐ ____________
- ☐ ____________

E -Service (every 800 hours)
- ☐ Drain and Clean Fuel Tank
- ☐ Replace Hydraulic Oil Filter
- ☐ Replace Hydraulic Tank Breather
- ☐ Change Front Planetary Gear Lube
- ☐ Pack Rear Axle Bearings (2WD)
- ☐ Check Rear Wheel Toe-in
- ☐ **A**, **B**, **C**, and **D Service** required
- ☐ ____________
- ☐ ____________

Other - Annual Service and Specials
- ☐ Replace Moving Hoses
- ☐ Replace Safety Switches
- ☐ Coolant System - Flush/Replace Fluid
- ☐ Change Hydraulic Oil
- ☐ ____________
- ☐ ____________
- ☐ ____________
- ☐ ____________
- ☐ ____________

(See Operator's and Service Manual for specifications and procedures)

Form No. 95-849-SL

Chapter 3

Engine

Table of Contents

Engine

Specifications

Item	Description
Make / Designation	Mitsubishi 4DQ7 Water–cooled, 4–stroke, swirl–combustion chamber type Diesel
Number of Cylinders	4
Bore x Stroke mm (in.)	88 x 94 (3.465 x 3.701)
Total Displacement cc (cu. in.)	2286 (139.5)
Compression Ratio	21.7:1
Firing Order	1 – 3 – 4 – 2
Dry Weight (approximate) kg (lb.)	200 (441)
Fuel	Grade No. 2D diesel fuel (ASTM specification)
Fuel Injection Pump	CAV–DPA type
Governor	Centrifugal flyweight
Idle Speed (no load)	1150 $\pm$ 20 RPM
High Idle (no load)	2500 $^{+25}/_{-0}$ RPM
Fuel Injector Nozzle	Throttle type
Fuel Injection Pressure kg/cm^2 (psi)	120 $^{+10}/_{-0}$ (1706 $^{+142}/_{-0}$)
Injection Timing	18° B.T.D.C.
Engine Oil	SAE 10W30 SF, CD
Crankcase Oil Capacity liter (U.S. qt.)	6.5 (6.9) with filter
Cooling System Capacity liter (U.S. qt.)	14 (14.8)
Starter	12VDC 2 KW
Alternator	12 VDC – 35 AMP
Glow Plug	Sheathed type

Special Tools

Order special tools from *TORO SPECIAL TOOLS AND APPLICATIONS GUIDE (Commercial Products*).

Some tools may be listed in the Reelmaster 4500–D Parts Catalog. Tools may also be available from a local supplier.

Filter Cleaner

Filter cleaner. Mix with water and use solution to wash the Donaldson air cleaner element.

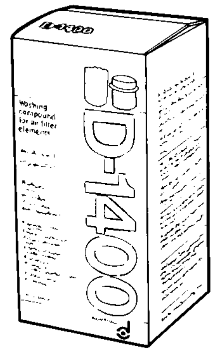


Figure 1

Diesel Engine Compression Test Kit

Diesel engine compression test kit. 0 – 1000 PSI gauge allows testing of diesel engines to check general operating condition of engine. Includes case, gauge with hose, glow plug hole adapters and instructions.

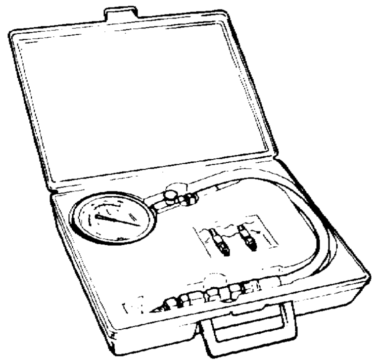


Figure 2

Piston Pin Tool

Piston pin tool is used to remove and install the wrist pin without distorting the piston. Includes an adapter for use with Mitsubishi and most other engines.

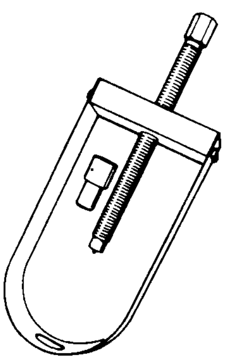


Figure 3

Nozzle Tester

Nozzle tester. Tests condition and opening pressure of fuel injection nozzles.

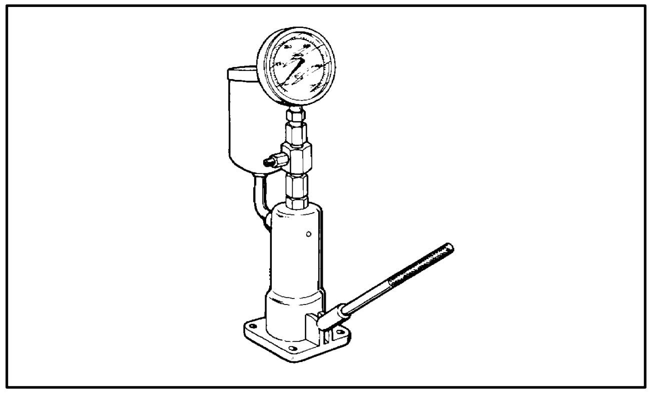


Figure 4

Nozzle Test Adapter

Nozzle test adapter is required to test the fuel injection nozzles.

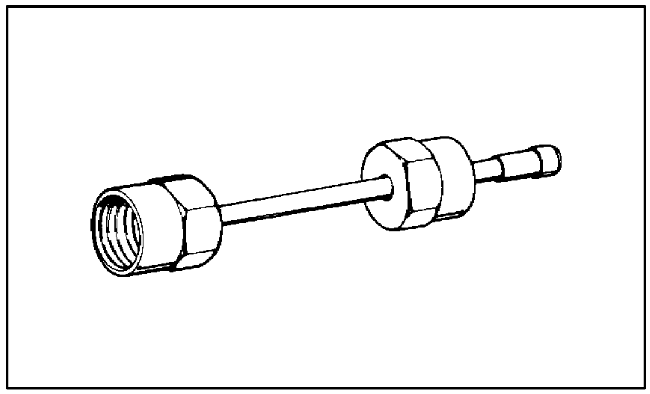


Figure 5

General Information

Most repairs and adjustments require tools which are commonly available in many service shops. Special tools are described in the Special Tools section. The use of some specialized test equipment is explained, however, the cost of the test equipment and the specialized nature of some repairs may dictate that the work be done at a engine repair facility. If no parts list is available be sure to provide your Distributor with the TORO Model Number and Serial Number.

The engine used in the Reelmaster 4500–D is manufactured by Mitsubishi Heavy Industries. Service and repair parts for Mitsubishi engines are supplied through TORO Distributors. Repair parts may be ordered by TORO Part Number

Alternator Belt

1. Proper tension will allow 3/8 in. (10 mm) deflection when a force of 10 lbs. is applied on the belt midway between the pulleys.

2. If deflection is not 3/8 in. (10 mm), loosen alternator mounting bolts. Increase or decrease alternator belt tension and tighten bolts. Check deflection of belt again to assure tension is correct.

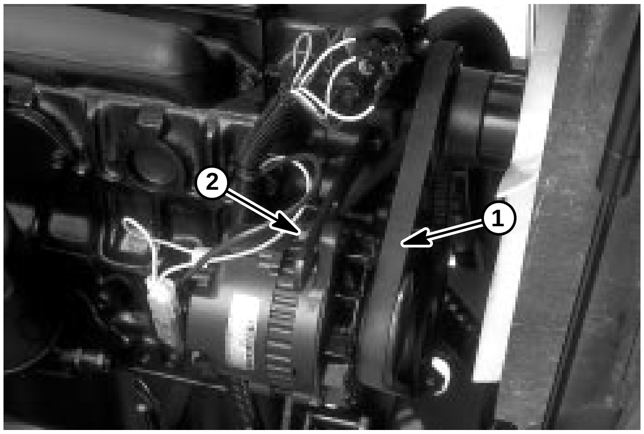


Figure 6

1. Alternator belt
2. Mounting bolt

Engine

Priming Fuel System

IMPORTANT: The fuel system must be primed when a new engine is started for the first time, if it runs out of fuel or if maintenance is performed on the fuel system.

1. Raise engine cover.

2. Loosen fuel filter bleed plug one turn. Using a shop towel to absorb fuel, push priming plunger until a steady stream of fuel runs out of hole in plug. When fuel stops foaming, tighten plug during the downstroke of the priming plunger. Wipe up any spilled fuel.

Note: It may be necessary to bleed the air out of the fuel line between the fuel filter and the injection pump. To do this, loosen the fitting on the injection and repeat bleeding procedure.

3. Normally the engine will now start. If engine does not start, loosen each injector fitting at the engine and crank engine until steady stream of fuel runs out of fitting. Tighten fitting when foaming of fuels stops.

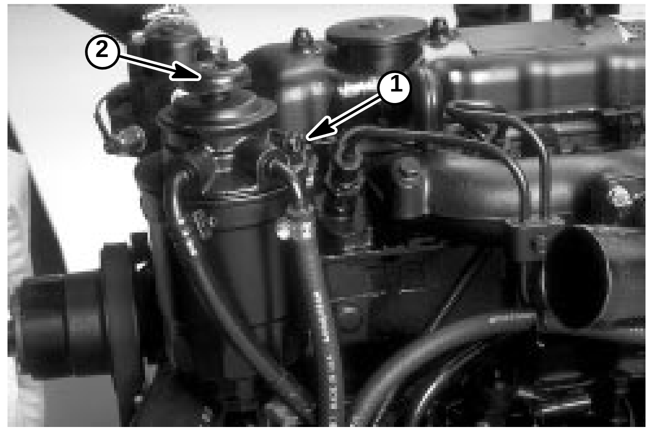


Figure 7

1. Bleed plug
2. Priming plunger

Service Manual

Mitsubishi 4DQ7
Diesel Engine

Reelmaster® 4500-D

TORO

Reprinted from Mitsubishi Pub. No. 99609 - 10101

INDEX

WARNING! Do not use starting fluids, such as ether, as a starting aid; the potential for a dangerous explosion will result.

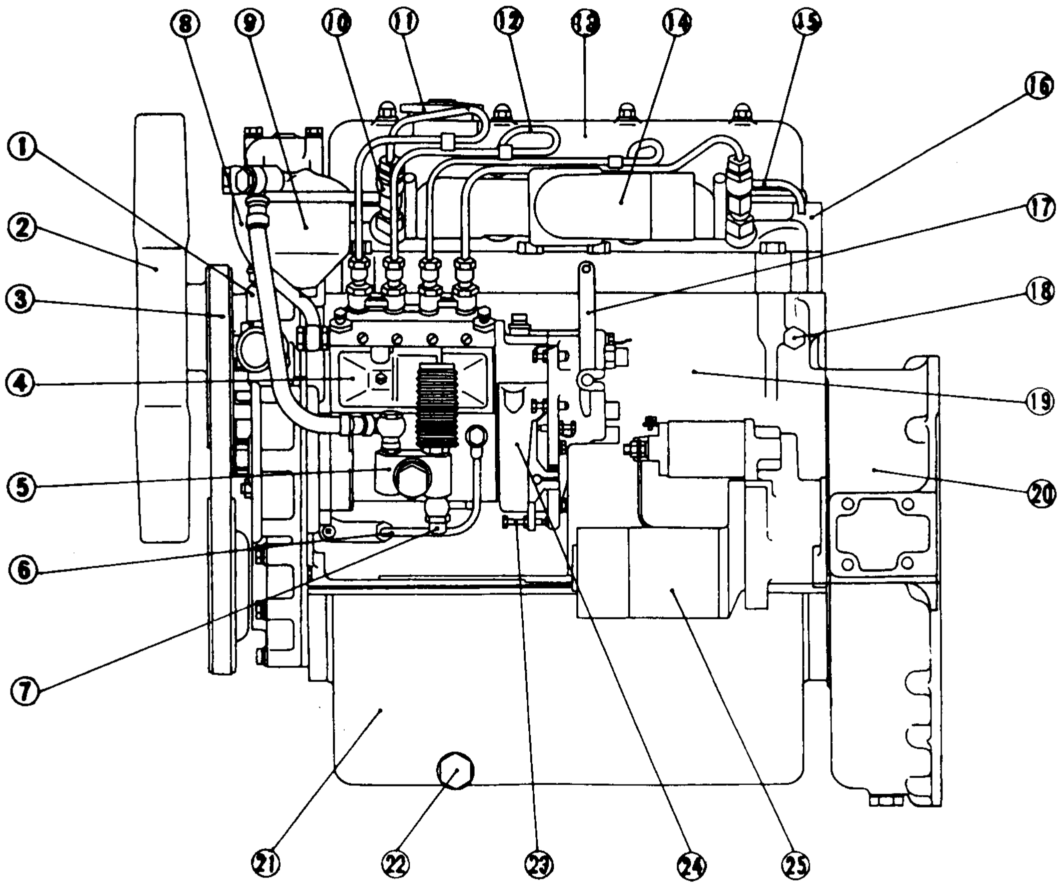
Visit an authorized Nippondenso service dealer for repair work on the fuel injection pump - especially during the warranty period. Repairs made by non-authorized dealers could void the pump's warranty. Also, contact the Nippondenso service dealer BEFORE removing the pump from the engine.

The terminology used for "horsepower" in this book is PS.
PS = 1.014 x HP

GENERAL

1. Major component parts

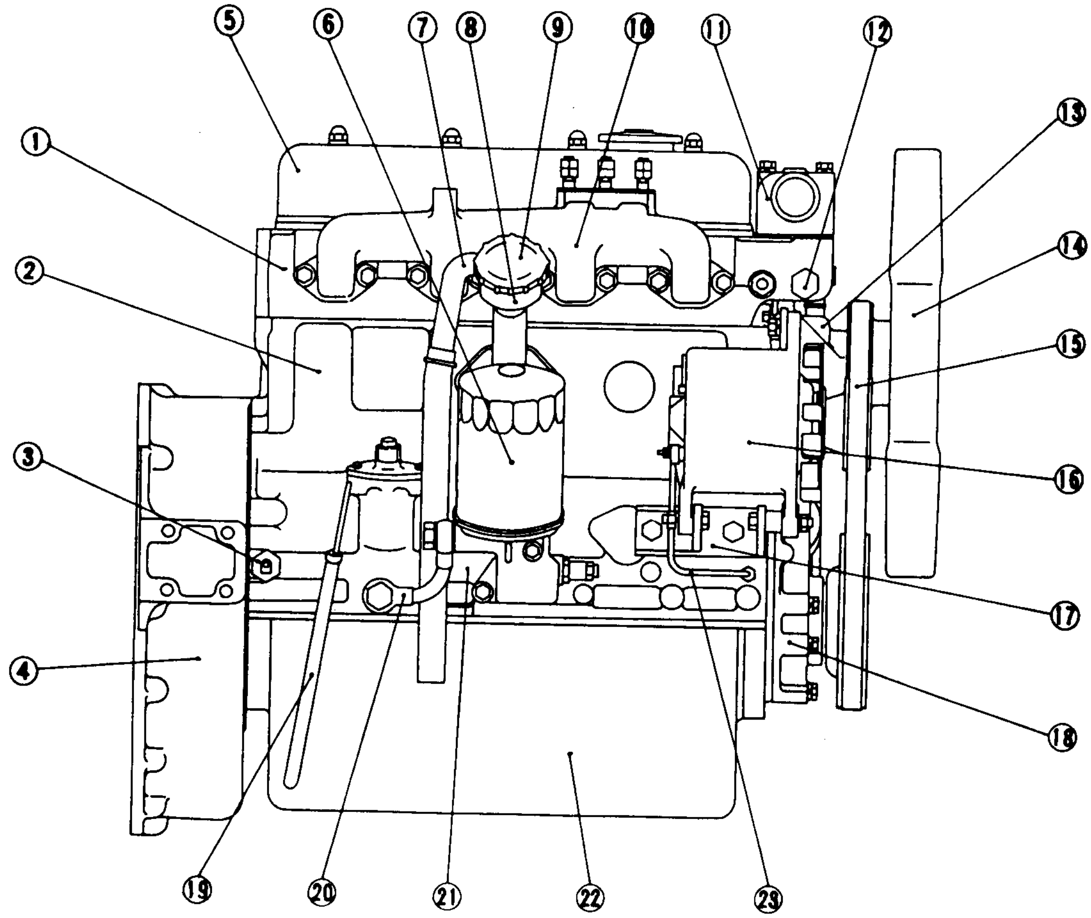
1-1 Left-hand side view



402500

1-Water pump
2-Fan (not used)
3-Fan belt
4-Fuel injection pump
5-Fuel feed pump
6-Oil pipe
7-Fuel inlet connector
8-Fuel feed pipe
9-Fuel filter
10-Fuel injection nozzle
11-Oil filler cap
12-Fuel injection pipe
13-Rocker cover
14-Intake manifold
15-Fuel leak-off pipe
16-Cylinder head
17-Adjusting lever
18-Hanger
19-Crankcase
20-Flywheel housing
21-Oil pan
22-Drain plug
23-Control rack stopper
24-Governor
25-Starter

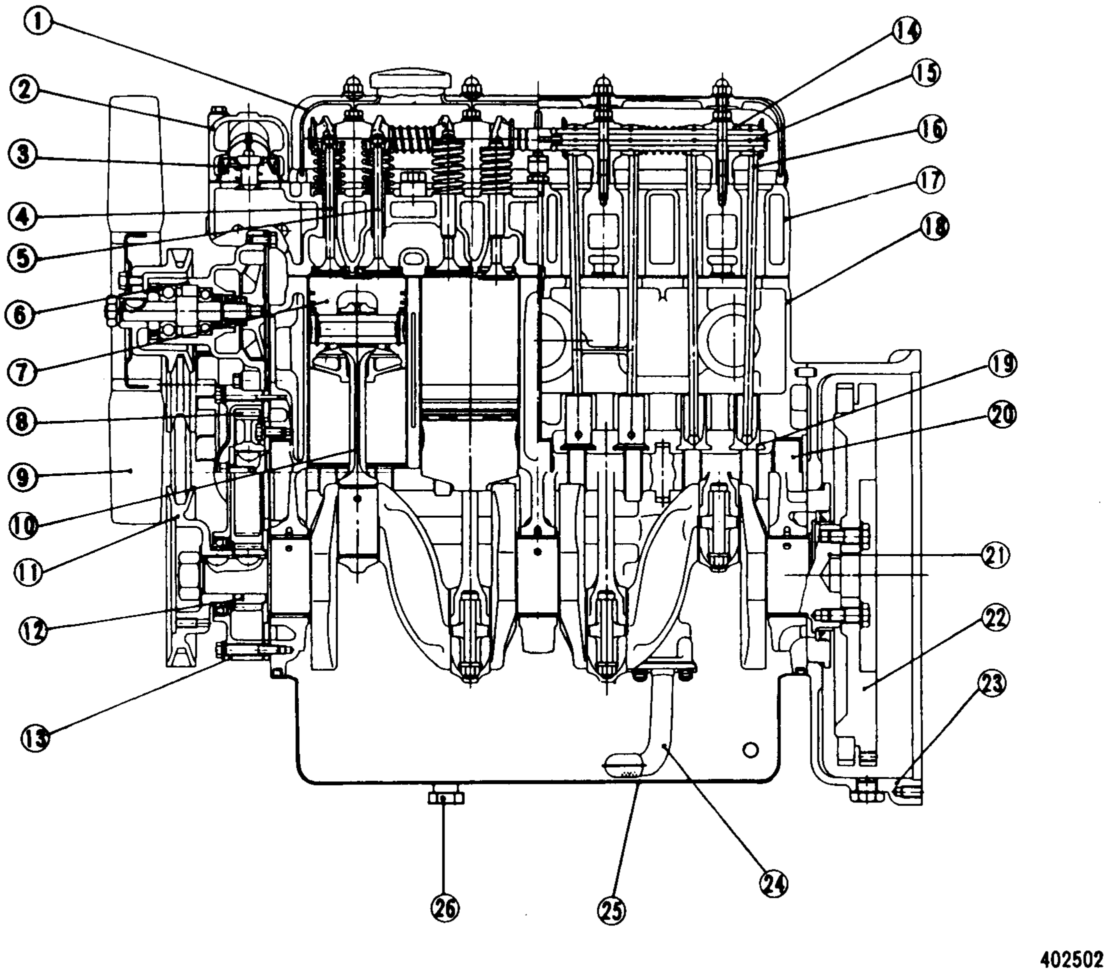
1-2 Right-hand side view



402501

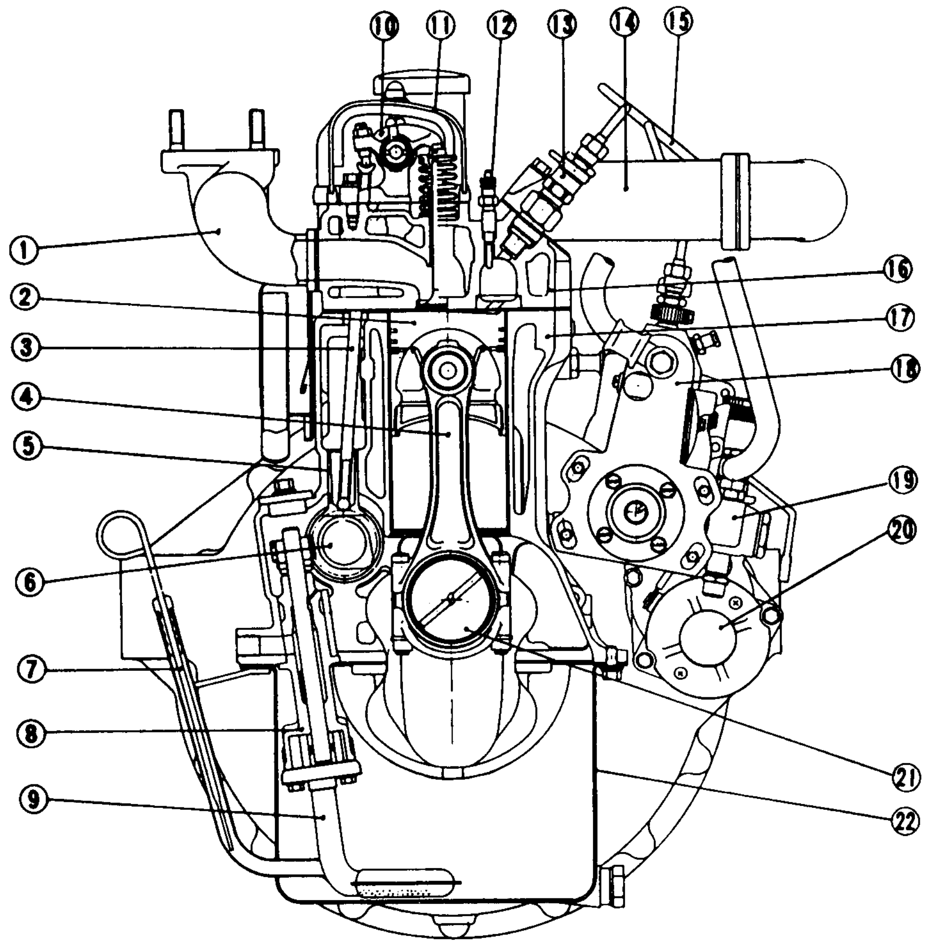
1-Cylinder head
2-Crankcase
3-Indicator switch
4-Flywheel housing
5-Rocker cover
6-Oil filter
7-Breather
8-Oil filler
9-Oil filler cap
10-Exhaust manifold
11-Elbow
12-Screw plug
13-Water pump
14-Fan (not used)
15-Fan belt
16-Alternator
17-Alternator bracket
18-Timing gear case
19-Oil level gauge
20-Oil pipe
21-Oil bypass alarm switch
22-Oil pan
23-Oil pipe

1-3 Longitudinal sectional view



1-Rocker cover	10-Connecting rod	19-Tappet
2-Thermostat case	11-Crankshaft pulley	20-Camshaft
3-Thermostat	12-Crankshaft gear	21-Crankshaft
4-Exhaust valve	13-Timing gear case	22-Flywheel
5-Intake valve	14-Rocker shaft bracket	23-Flywheel housing
6-Water pump	15-Rocker shaft	24-Oil strainer
7-Piston	16-Valve push rod	25-Oil pan
8-Camshaft gear	17-Cylinder head	26-Drain plug
9-Fan (not used)	18-Crankcase	

1-4 Transverse sectional view



402503

1-Exhaust manifold
2-Piston
3-Valve push rod
4-Connecting rod
5-Tappet
6-Camshaft
7-Oil level gauge
8-Oil pump
9-Oil strainer
10-Rocker arm
11-Rocker cover
12-Glow plug
13-Fuel injection nozzle
14-Intake manifold
15-Fuel injection pipe
16-Cylinder head
17-Crankcase
18-Fuel injection pump
19-Fuel feed pump
20-Starter
21-Crankshaft
22-Oil pan

MAJOR DATA AND SPECIFICATIONS

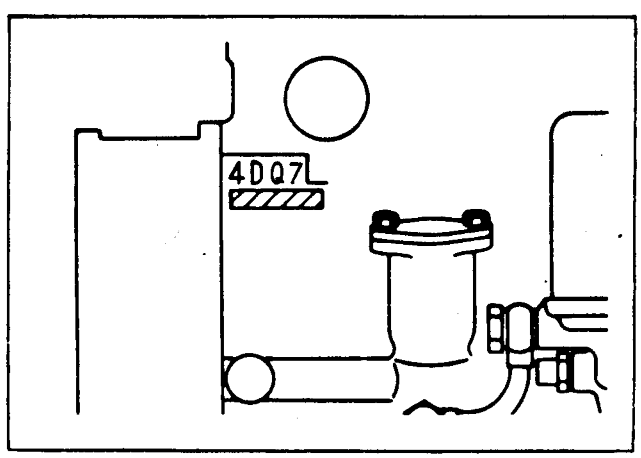
Engine model				4DQ7
General	Type			Water-cooled, 4-stroke, swirl-combustion chamber type diesel
	No. of cylinders-arrangement			4-in line
	Bore x stroke		mm (in.)	88 x 94 (3.465 x 3.701)
	Piston displacement		cc (cu in.)	2286 (139.5)
	Compression ratio			21.7 : 1
	Compression pressure		kg/cm^2 (psi)	26 (369.7), min (at 150 ~ 200 rpm)
	Firing order			1 – 3 – 4 – 2
	Direction of rotation			Counterclockwise as viewed from flywheel side
	Burns (fuel)			Grade No. 2D diesel fuel (ASTM specification)
	Engine oil			Class-CC or better (API service classification)
	Dimensions	Overall length	mm (in.)	778.5 (30-5/8)
		Overall width		509 (20)
		Overall height		651.5 (25-5/8)
	Weight, dry		kg (lb)	200 (441)
	No. of piston rings	Compression rings		2
		Oil ring		1 (w/spring expander)
	Valve arrangement			Overhead
	Valve timing	Intake valves	Open at:	30° BTDC
			Close at:	50° ABDC
		Exhaust valves	Open at:	74° BBDC
			Close at:	30° ATDC
	Valve clearance (both intake and exhaust valves) (cold)		mm (in.)	0.25 (0.0098)
	Starter			Electric
Fuel system	Governor	Model		RUV (for prime power)
		Type		Centrifugal flyweight, all-speed
	Fuel injection nozzles	Type		Throttle
		Type of nozzle holders		Bosch CA17SD

Engine model				4DQ7
Fuel system	Fuel injection nozzles	Type of nozzle tips		Bosch ND-DN0SD21
		Spray hole diam	mm (in.)	1 (0.04)
		Spray angle		0°
		Injection pressure	kg/cm^2 (psi)	120^{+10}_{0} (1706^{+142}_{0})
	Fuel filter			Paper-element type
Lubrication system	Oil pump	Type		Trochoid
		Speed ratio to crankshaft		1/2
		Capacity at oil temp. 50 ± 5°C (122 ± 9°F); pressure 3 kg/cm^2 (42.7 psi)	liter (cu in.)/ min/rpm	8.37 (510.8), min/1000 (pump rpm)
	Oil pressure	At duty run	kg/cm^2 (psi)	3 ~ 4 (42.7 ~ 56.9)
		At idling		1 ~ 2 (14.2 ~ 28.4)
	Oil filter			Paper-element type
	Relief valve	Type		Piston-valve
		Valve opening pressure	kg/cm^2 (psi)	3 ± 0.2 (42.7 ± 2.8)
	Refill capacity	Oil pan	liter (U.S. gal)	6.5 (1.7)
		Oil filter		0.7 (0.18)
	Oil bypass valve	Type		Piston-valve
		Valve opening pressure	kg/cm^2 (psi)	0.8 ~ 1.2 (11.4 ~ 17.1)
Cooling system	Water pump	Type		Centrifugal type
		Speed ratio to crankshaft		1.3
		Capacity	liter (cu in.)/ min/rpm	105 (6408)/3900 (pump rpm)
	Thermostat	Type		Wax
		Valve opening temperature		76.5 ± 2°C (169.7 ± 3.6°F)
		Valve lift temperature		90 ± 2°C (194 ± 3.6°F)
	Drive belt	Type		Low-edge cog B
		No. of belts		1
	Refill capacity (engine water jacket)		liter (U.S. gal)	4.5 (1.2)

Engine model				4DQ7
Electrical equipment	Working voltage		volt	12
	Polarity			Negative (–) ground
	Glow plugs	Type		Sheathed
		Rated voltage – current	volt – ampere	10.5 – 8.3
		Resistance at normal temperature	ohm	1.26
	Starter	Model		M002T54172
		Type		Totally enclosed, drip-proof, pinion-shift type with overrunning clutch
		Manufacturer		Mitsubishi-Electric
		Voltage-output	volt – kilowatt	12 – 2
		No. of pinion teeth/ No. of ring gear teeth		11/121
	Alternator	Model		A001T25070
		Type		3-phase AC type
		Voltage-output	volt – ampere	12 – 35
		Manufacturer		Mitsubishi-Electric
		Rated speed	rpm	5000
		Working speed	rpm	1000 ~ 13500
		Speed ratio to crankshaft		1.68
	Regulator	Type		IC type built in alternator
		Regulated voltage	volt	14.4 ± 0.3

* Normal intake vacuum is 30.0 inches of water
* Normal exhaust backpressure is 2.0 inches of mercury

The engine identification number is on the exhaust manifold side of the engine, near the front, and cast into the block. The engine's serial number is stamped into the pad located directly below the engine's model number.

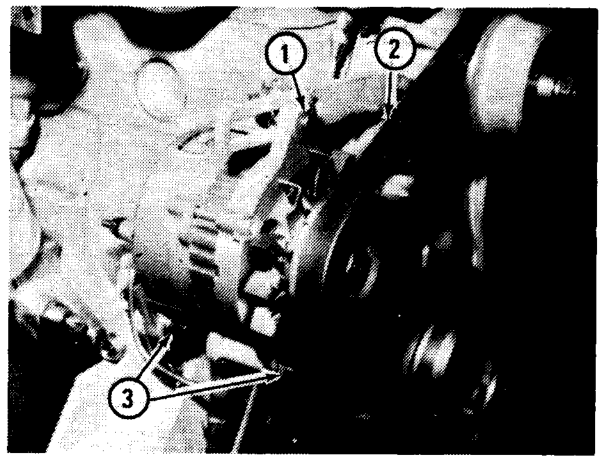


(1) Drain the oil.

(2) Remove the fan belt and alternator as follows:

(a) Loosen bolt (1) securing fan belt adjusting plate and alternator, and remove fan belt (2).

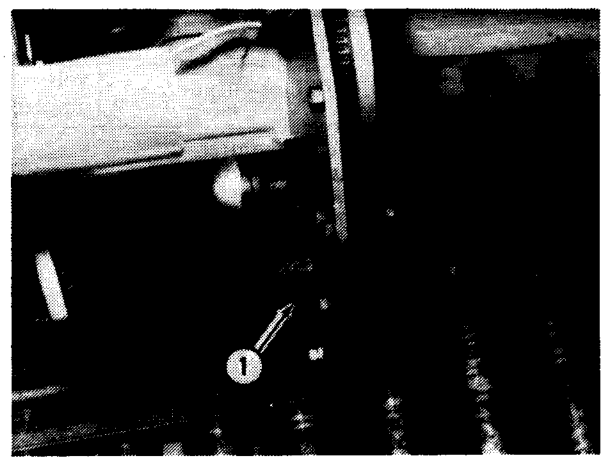
(b) Remove bolts (1) and (3) and remove alternator.



(3) Remove the starter as follows:

(a) Loosen attaching nuts (1).

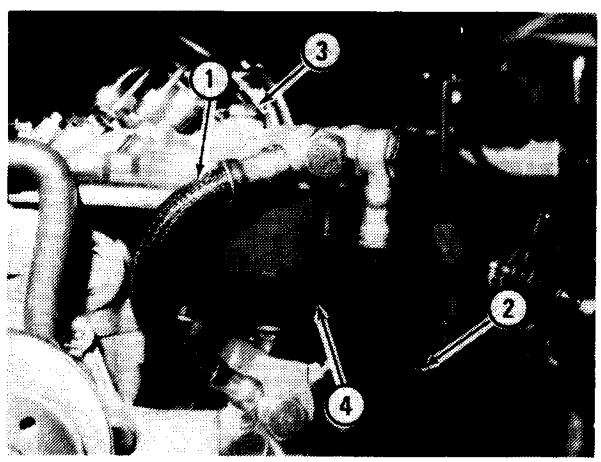
(b) Remove starter from rear plate.



(4) Remove the fuel filter as follows:

(a) Disconnect fuel feed pipes (1) (2).

(b) Loosen attaching bolts (3) and remove fuel filter (4).



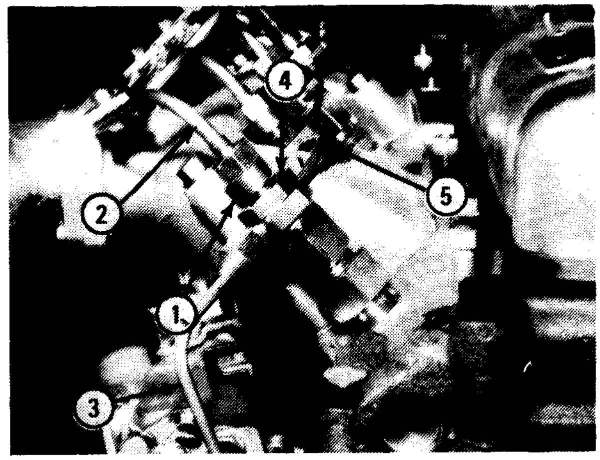
(5) Remove the injection pipes and injection nozzles as follows:

(a) Loosen connectors (1) and disconnect injection pipes (2).

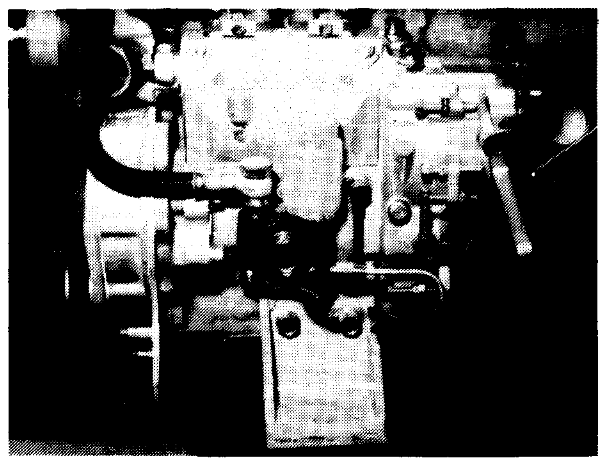
(b) Remove fuel return pipe (3) by loosening union nut.

(c) Loosen nuts (4) and remove fuel leak-off pipe (5).

(d) Remove nozzle assemblies.



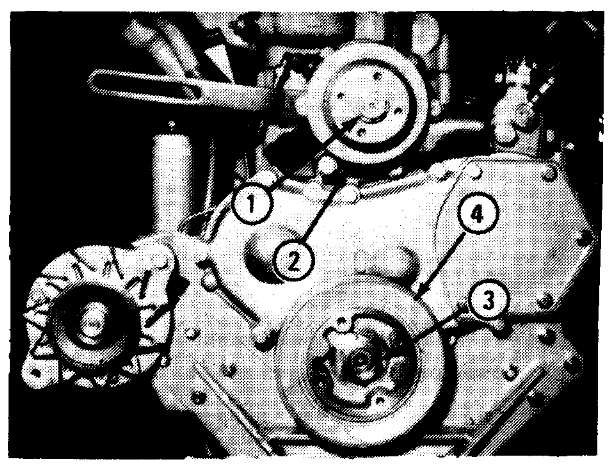
(6) Remove the lube oil pipe from injection pump.



(7) Remove the water pump pulley and crankshaft pulley as follows:

(a) Loosen water pump shaft nut (1) and remove water pump pulley (2).

(b) Loosen crankshaft nut (3) and remove crankshaft pulley (4).



(8) Remove the timing gear case.

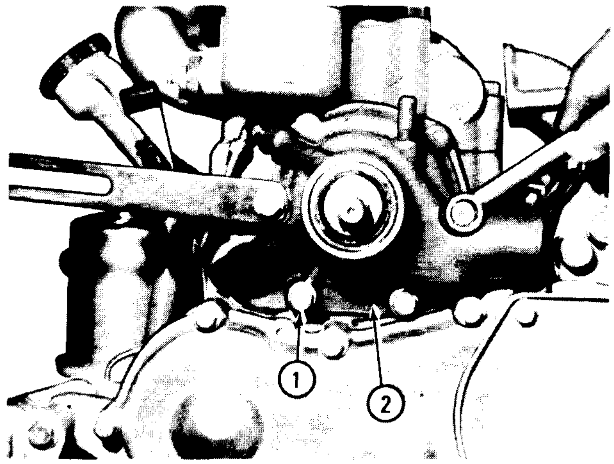
(9) Remove the rocker cover.

(10) Disconnect the water pump bypass hose and oil pipe. To disconnect bypass hose, displace thermostat elbow and water pump clamp.

(11) Remove the water pump as follows:

(a) Loosen attaching bolts (1).

(b) Remove water pump assembly (2).



(12) Remove the rocker shaft assembly as follows:

(a) Loosen union nut (1).

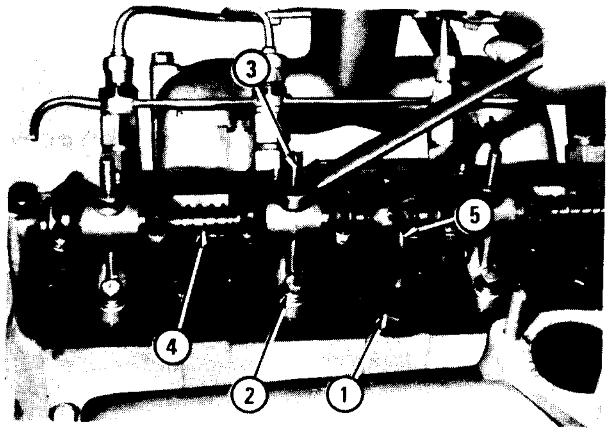
(b) Loosen short bolts (2) and long bolts (3).

(c) Remove rocker shaft assembly (4).

(d) Remove oil pipe (5) and "O" rings (2 pcs – to be replaced with new ones).

(e) Remove valve push rods and valve caps.

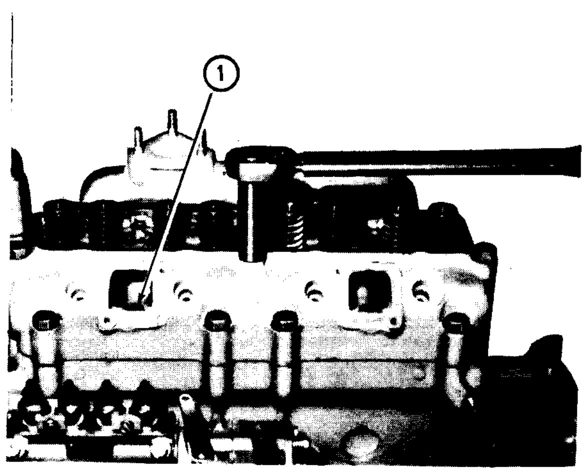
(f) Remove intake manifold.



(13) Remove the cylinder head assembly as follows:

(a) Loosen cylinder head bolts (1).

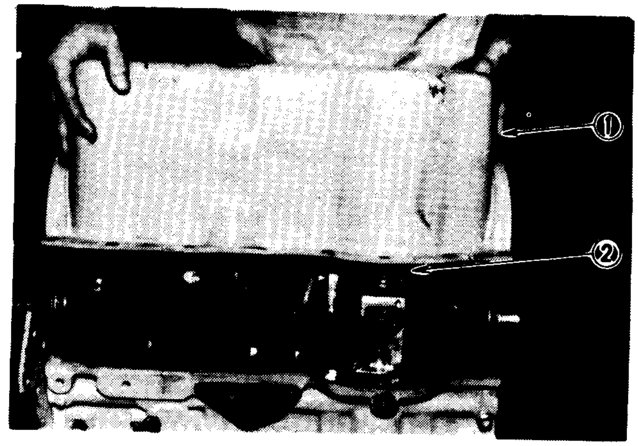
(b) Remove cylinder head and gasket.



(14) Remove the oil pan and oil pump assembly as follows:

(a) Loosen attaching bolts and remove oil pan (1) and gasket.

(b) Loosen attaching bolts and remove oil pump (2) assembly.



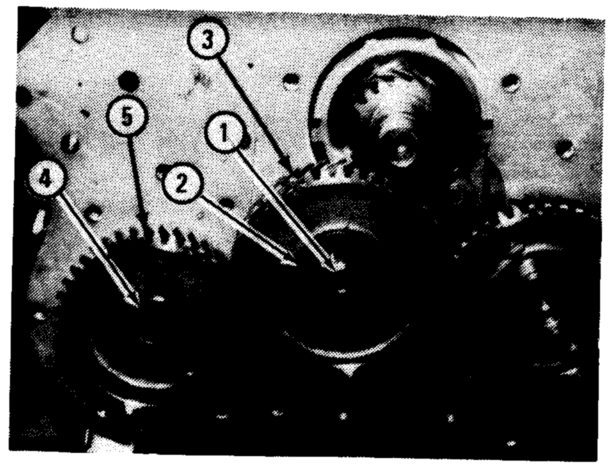
(15) Remove the timing gear train as follows:

(a) Loosen idler gear bolt (1).

(b) Remove thrust plate (2) and idler gear (3). (Draw idler gear while twisting it in the direction of its helix.)

(c) Loosen injection pump drive gear nut (4).

(d) Remove injection pump drive gear (5).

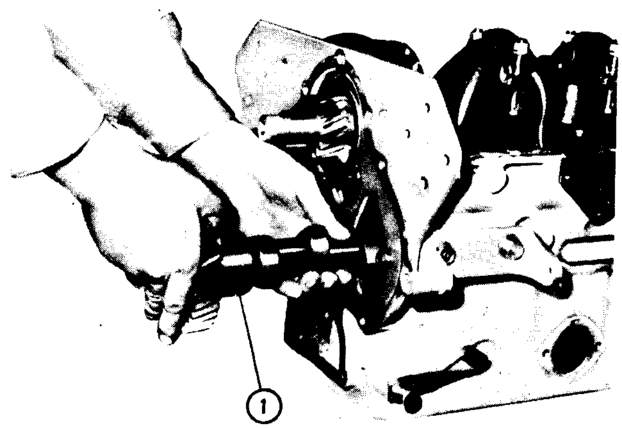


(16) Remove the camshaft assembly as follows:

Take out camshaft assembly (1) from crankcase.

NOTE

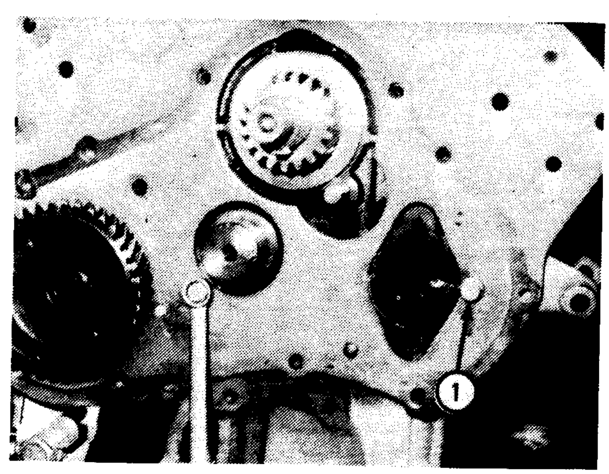
There are tappets in crankcase; this makes it necessary to turn crankcase upside down when removing camshaft assembly.



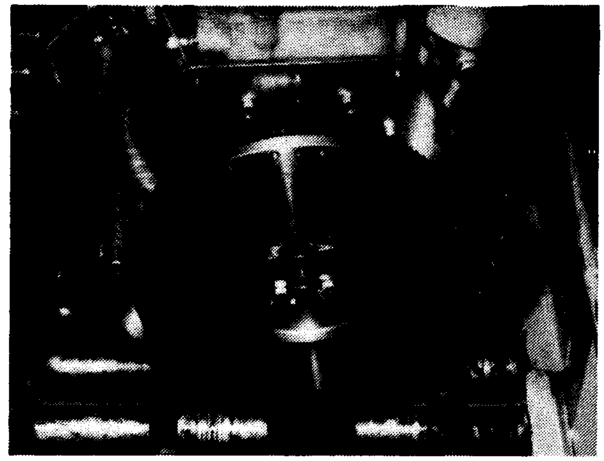
(17) Remove the front plate and injection pump assembly as follows:

(a) Loosen attaching bolts (1).

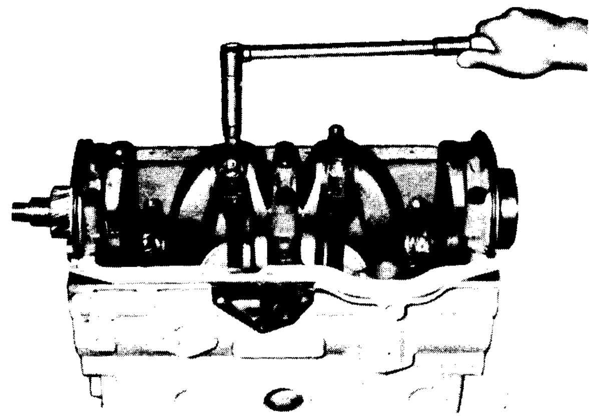
(b) Remove front plate and injection pump assembly.



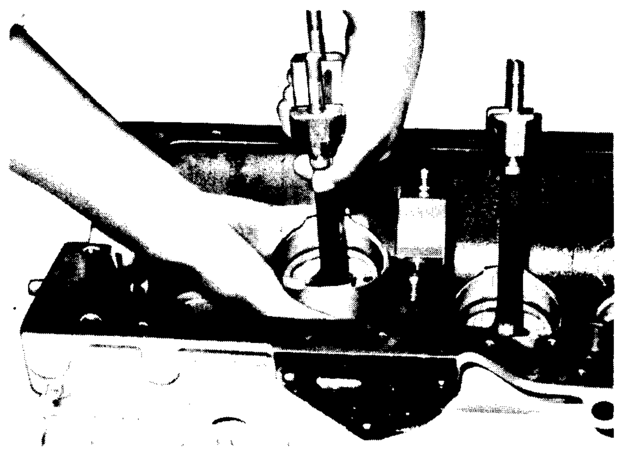
(18) Remove the flywheel and rear plate.



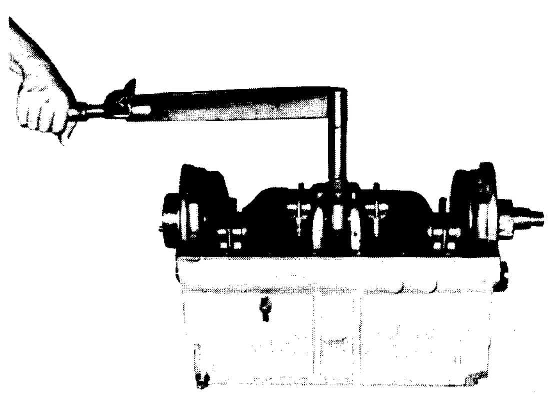
(19) Remove the connecting rod bearing caps and bearings (lower shells) by loosening attaching bolts.



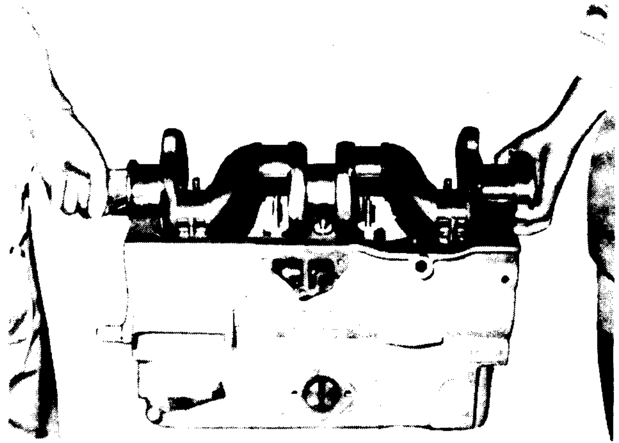
(20) Remove the connecting rods and pistons.



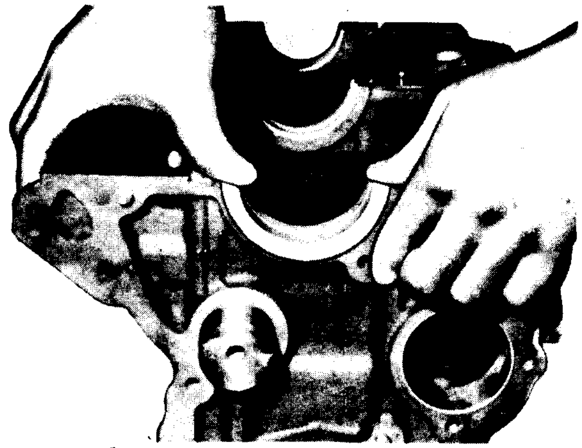
(21) Remove the main bearing caps by loosening attaching bolts.



(22) Remove the crankshaft.



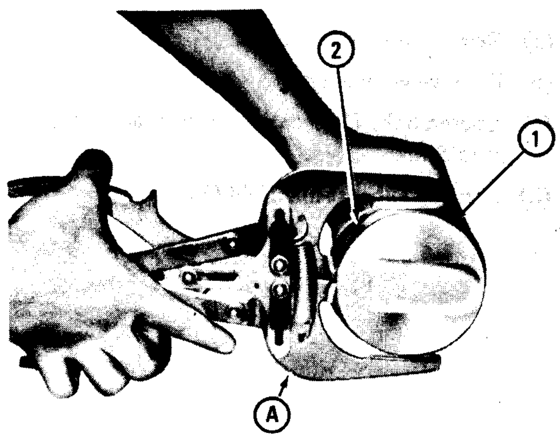
(23) Remove the main bearing shells.



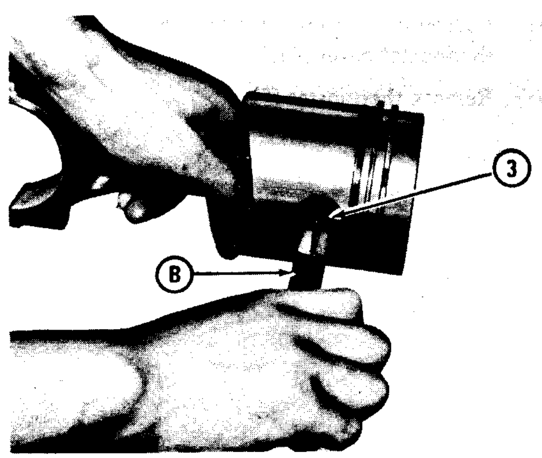
(24) Disassemble piston and connecting rod as follows:

(a) Remove compression rings (1) and oil ring (2) by using piston ring tool (A).

(b) Remove oil ring spring.

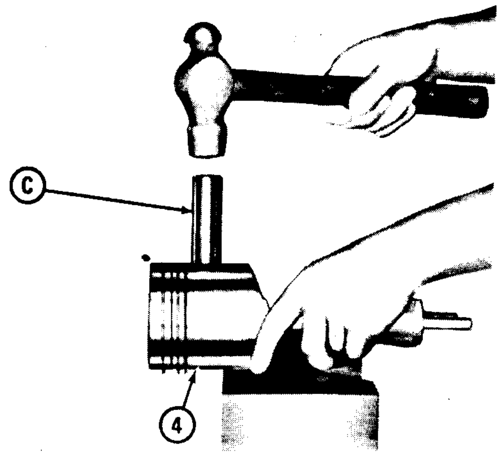


(c) Remove snap rings (3) by using snap ring tool (B).



(d) Remove piston pin (4) by using drift (C).

(e) Remove piston pin bushing and connecting rod bearing (upper).



(25) Disassemble the rocker shaft assembly as follows:

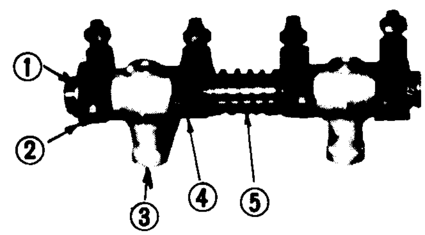
(a) Remove snap rings on both ends (1).

(b) Remove rocker assembly (2).

(c) Remove rocker bracket (3).

(d) Remove rocker assembly (4).

(e) Remove spring (5).



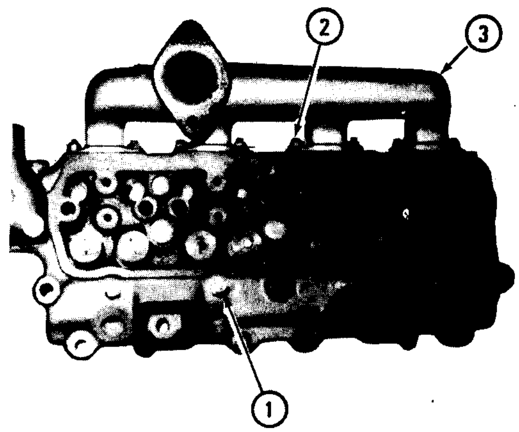
(26) Disassembly the cylinder head as follows:

(a) Remove nozzle holders.

(b) Remove glow plugs (1).

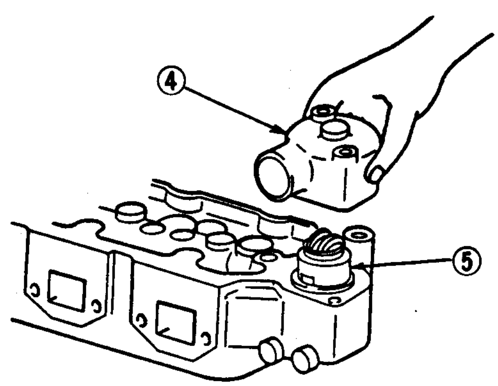
(c) Loosen bolts (2) securing exhaust and intake manifolds.

(d) Remove exhaust manifold (3).



(e) Loosen thermostat cover bolts and remove thermostat cover (4).

(f) Remove thermostat (5).

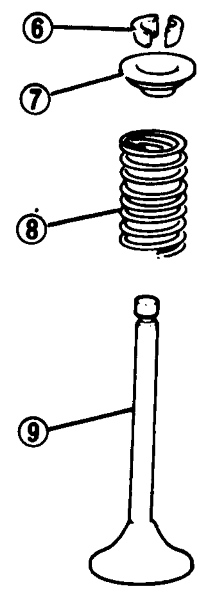


(g) Remove valve cotters (6).
(Depress valve spring by valve lifter.)

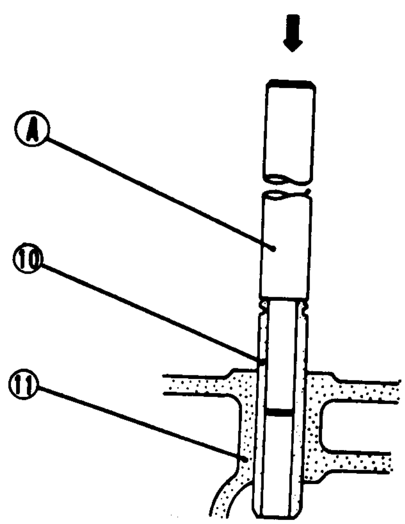
(h) Remove retainer (7).

(i) Remove valve spring (8).

(j) Take out valve (9).



(k) Remove valve guide by using valve guide remover (A).



10-Valve guide
11-Cylinder head

A-Valve guide remover

Cylinder head

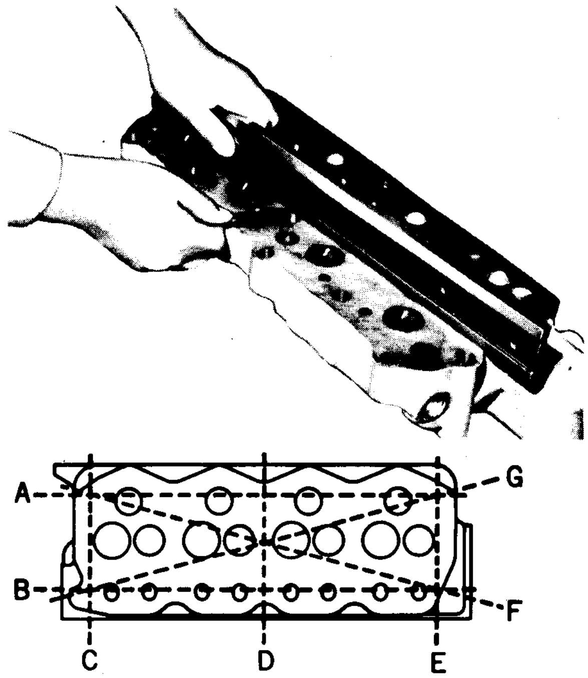
(1) Inspection

Check the gasketed surface of the cylinder head for flatness by using a straightedge and thickness gauge as in the case of checking the crankcase surfaces. This check is to be made with the precombustion chamber jets removed.

Use a surface grinder to reface the cylinder head, as necessary, to the specified flatness.

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Warpage of gasketed surface of cylinder head	0.05, max (0.0020)	0.20 (0.0079)



Checking cylinder head gasketed surface for flatness

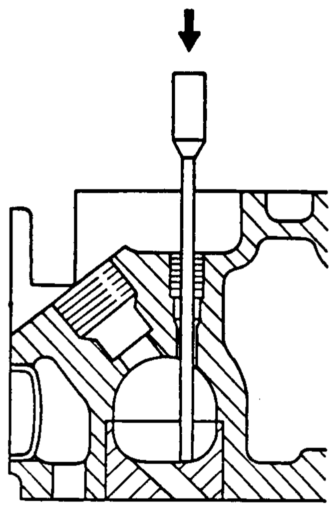
(2) Precombustion chamber jet replacement

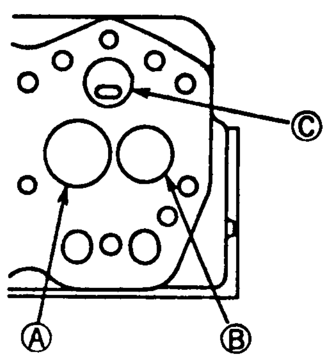
Do not remove the precombustion chamber jets unless their replacement is necessary. To remove the jet, as when cracks are noted in it, ease it out by driving with a flat-faced drift pin inserted through the glow plug hole, as shown.

Before installing the jet, wash the precombustion chamber cavity clean, and drive the jet into position, with its orifice pointing to the center of the cylinder. Calk one portion with a punch.

Due to mechanical damage (eg. a loose screw in the combustion chamber that damages jet).

Cracks in the jet are permissable.


Removing precombustion chamber jet



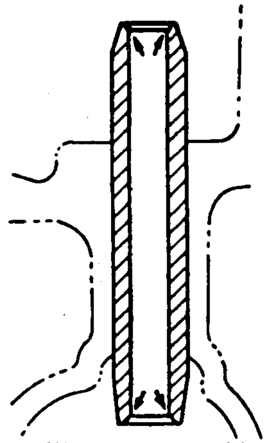
A-Intake port C-Jet
B-Exhaust port

Direction of precombustion chamber jet orifice in installed state

Valve guides and valve seats

(1) Check each valve for carboning, burning, wear or other defect on head; also check cap end and stem for cracks. Replace the valve if damaged.

(2) Check each valve guide for wear. Remember, the guide wears down more rapidly at its both ends than at any other parts. Measure the inside diameter of the guide at its ends and at its middle part in two directions. Measure the outside diameter of each valve stem. If the measurement exceeds the repair limit in Table below, replace the valve guide.



Wear on valve guide

(3) Valve face and valve seat
Check valve face and valve seat for wear and contact. If valve face is found excessively worn, reface it by using a valve refacer. To reface the valve, proceed as follows:

NOTE:
Standard = size of part when new from the factory

Repair Limit = maximum size of a used part that may still be used or reworked.

Service Limit = size of the part that would require replacement of that part.

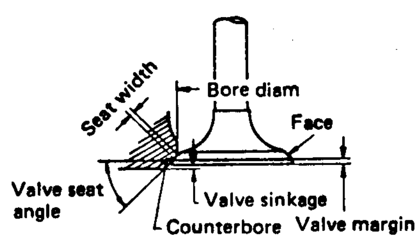
Specifications

Unit: mm (in.)

Item		Standard	Repair limit
Clearance of valve stem in valve guide	Intake	0.055～0.085 (0.00217～0.00335)	0.15 (0.0059)
	Exhaust	0.070～0.105 (0.00276～0.00413)	0.20 (0.0079)
Valve guide length outside hole		18 ± 0.3 (0.709 ± 0.012)	
Valve stem diameter	Intake	$8^{-0.045}_{-0.060}$ ($0.315^{-0.00177}_{-0.00236}$)	−0.10 (−0.0039)
	Exhaust	$8^{-0.060}_{-0.080}$ ($0.315^{-0.00236}_{-0.00315}$)	−0.15 (−0.0059)

Specifications

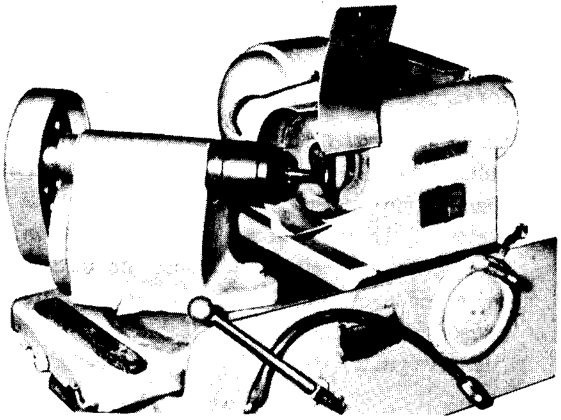
Unit: mm (in.)

Item		Nominal value	Standard	Repair limit	Service limit
Valve seat	Angle	30°			
	Sinkage	0.8 (0.031)	±0.2 (±0.008)	1.3 (0.051)	
	Width	1.4 (0.055)	±0.14 (±0.0055)	1.6 (0.063)	
Valve margin		1.7 (0.067)		Reface up to 1.2 (0.047)	

Valve refacer

(a) Set a valve refacer to an angle of 45 degrees.

(b) Grind the valve stock to a minimum and, if the margin is less than 1.2 mm (0.047 in.), replace the valve.



Valve seat cutter

Repair an excessively worn valve seat by using a valve seat grinder or valve seat cutter.

(c) When using a valve seat cutter, exercise care so as to apply a uniform pressure to valve seat to prevent uneven cutting. After cutting, reface the seat by rotating the cutter with No. 400 sandpaper put between the cutter and seat.

(d) If valve seat width is overcut, repair it using a 30-degree cutter. If valve seat width exceeds 1.6 mm (0.063 in.) due to wear, replace the seat. Also replace the seat when valve sinkage exceeds 1.3 mm (0.051 in.).

Valve seat installation

Chill the valve seat inserts in ether or alcohol containing dry ice. Heat the cylinder head to a temperature of 80°C to 100°C (176°F to 212°F). Press the inserts in the cylinder head by using the insert calking tools (30691-02700 for intake valve, 30691-02800 for exhaust valve). Leave the cylinder head and the inserts in the air until shrinkage-expansion fit is obtained between the two. Calk around the inserts with the insert calking tool to machine the seat width.

NOTE

The insert calking tool may be used both for pressing and calking the valve seat inserts by reversing the calking ring.

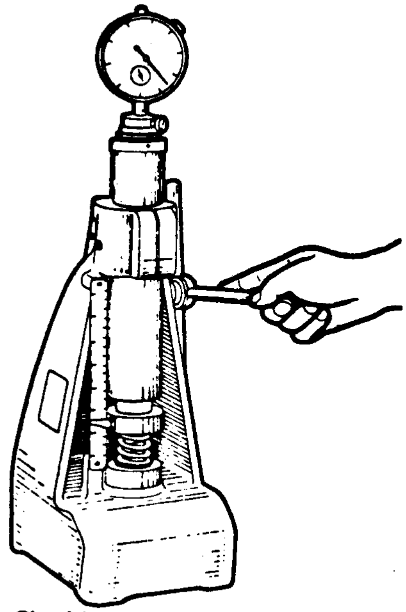
Valve springs

Inspect each spring for cracks, and check it for squareness, free length and as-installed length against these specifications:

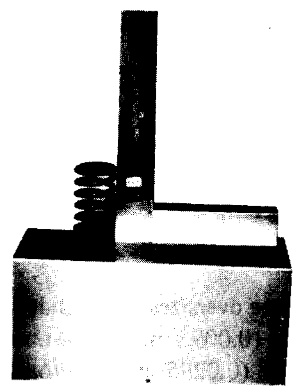
Specifications

Unit: mm (in.)

Item	Standard	Repair limit
Valve spring free length	48.85 (1.9232)	47.6 (1.874)
Valve spring squareness	1.5°, max	
Load compress spring to initial working length [43 mm (1.69 in.)] kg(lb)	19 ± 1 (41.9 ± 2.21)	15 (33.08)



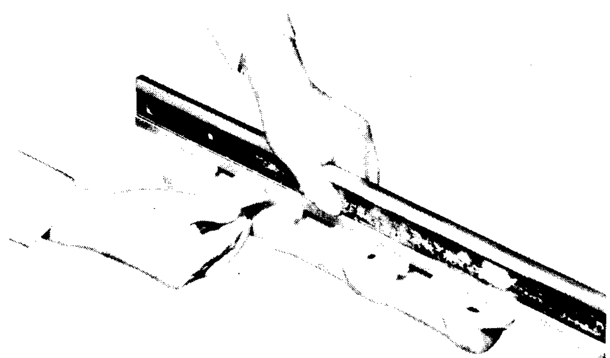
Checking valve spring



Checking valve spring for squareness

Exhaust manifold

If the flange faces are warped by more than 0.2 mm (0.0079 in.) when checked as shown, grind them smooth and flat. If any flange is found cracked, replace the manifold.



Checking exhaust manifold flange surface for flatness

Cylinder sleeves

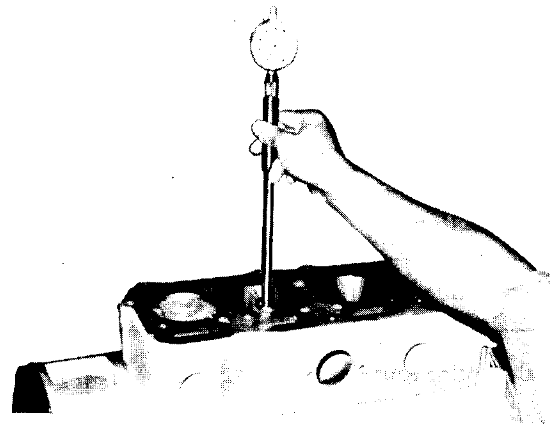
(1) Using a cylinder gauge, take ID measurements in two directions (parallel and transverse to crankshaft axis) on each cylinder bore, at three places indicated below.

If wear reaches the repair limit, rebore the cylinder to the next specified oversize.

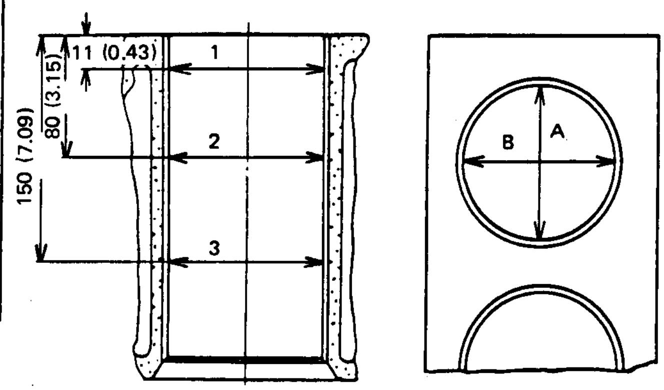
Specifications

Unit: mm (in.)

Item	Standard	Repair limit	Service limit
Cylinder sleeve ID	$88^{+0.035}_{0}$ ($3.465^{+0.00138}_{0}$)	+0.20 (+0.008)	0.70 (0.0276)
Out of roundness	0.1 (0.004), max		
Taper	0.015 (0.0006), max		



Taking ID measurements on cylinder sleeves



Positions for checking sleeve bore diameter

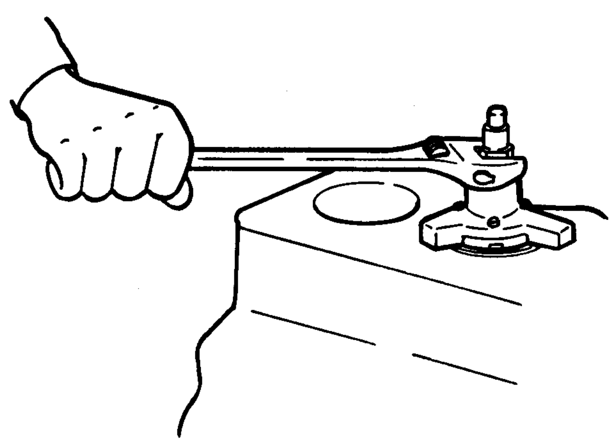
(2) There are three oversizes for cylinder bores, namely, +0.25 mm (0.0098 in.), +0.50 mm (0.0197 in.). The tolerance to which the cylinder should be refinished by boring is 0 – 0.035 mm (0.0014 in.). When the cylinders are rebored, oversize pistons and piston rings should be used.

(3) An oversize to which any cylinder worn taper and/or out of round is to be rebored should be determined by relying on the most worn part of the cylinder. A cylinder whose abnormal wear is 0.4 mm (0.0157 in.) should be rebored to 1 mm (0.0394 in.) oversize, for example.

NOTE

a) All cylinders should be rebored to one and the same oversize.

b) When the cylinders are not worn beyond the repair limit, but the piston rings have to be renewed, correct stepped wear on the top part of the sleeve by using a ridge reamer and, if necessary, refinish the sleeves by honing.



Removing ridge with ridge reamer

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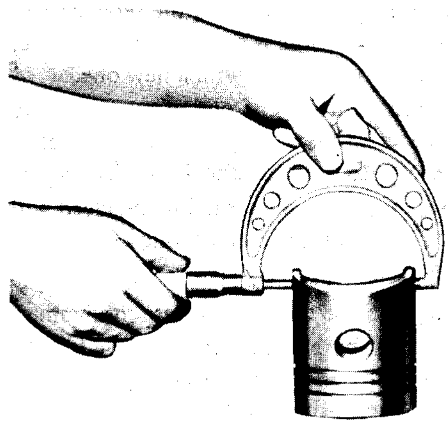
Pistons and piston rings

(1) Pistons

Inspect each piston for any abnormal wear of its sliding surface, for cracks at the crown and for evidence of melting or fusion. Examine the ring grooves for stepped wear and sloped wear. Replace pistons found in bad condition.

(2) Measure the outside diameter of piston in two directions perpendicular to each other. If the diameter exceeds the service limit, replace the piston.



Specifications

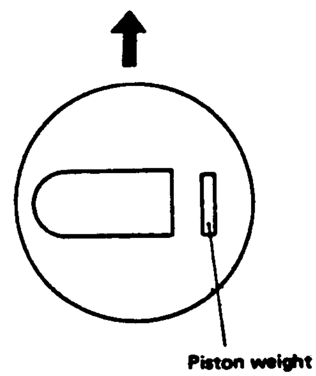
Unit: mm (in.)

Item		Standard	Service limit
Diameter (at skirt)	Standard	87.9 (3.4606)	–0.2 (–0.008)
	0.25 (0.0098) oversize	88.15 (3.4705)	
	0.50 (0.0197) oversize	88.40 (3.4803)	

(3) Replacing pistons

Replace the piston with a new one if the measurement exceeds the service limit. Where any pistons have to be replaced, the variance in weight among the pistons must not exceed the limit. It is recommended that cylinder number be stamped on a piston selected to be used in a particular cylinder for convenience.

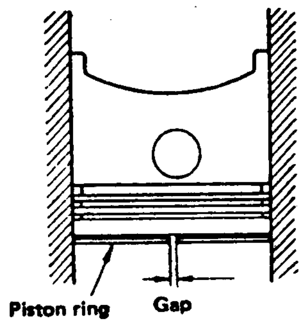
When the cylinder sleeves are bored to the oversize, pistons and piston rings of the same oversize should be used. There are three oversizes for pistons and piston rings, namely, +0.25 mm (0.00984 in.), +0.50 mm (0.01969 in.). The variance in weight among the pistons per engine should be ±5 grams (±0.18 oz), max.



Piston weight marking

(4) Piston ring gaps

Check the ring gap with a thickness gauge by placing the ring in a new cylinder sleeve, and pushing the piston true and square in the bore.



Checking piston ring gap

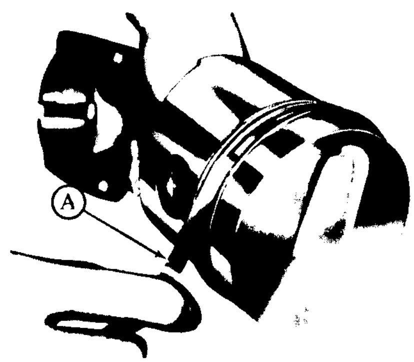
Specifications

Unit: mm (in.)

Item	Standard	Service limit
Piston ring gap	0.30 ~ 0.50 (0.0118 ~ 0.0197)	1.5 (0.059)

(5) Piston ring grooves

Insert the compression and oil rings of known thicknesses into the grooves, and measure the side clearance with a straightedge and thickness gauge Ⓐ.



Measuring piston ring groove

Specifications

Unit: mm (in.)

Item		Standard	Repair limit
Fit in ring grooves	No. 1 compression ring	0.050 ~ 0.085 (0.00197 ~ 0.00335	0.20 (0.0079)
	No. 2 compression ring	0.025 ~ 0.060 (0.00098 ~ 0.00236)	0.15 (0.0059)
	Oil ring		

(6) **Replacing piston rings**

If the rings are replaced, the gap width will exceed the standard value, but this is not a matter of concern, provided that the service limit is not exceeded.

(7) **Piston pin bosses**

Check the piston pin bosses by referring to the topic, Piston pins, piston pin bosses and piston pin bushings, which follows.

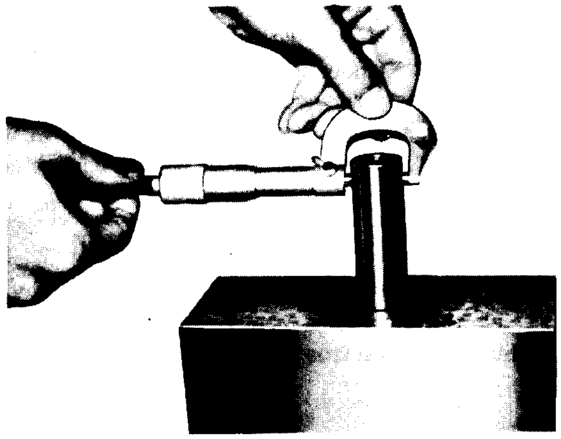
Piston pins, piston pin bosses and piston pin bushings

(1) Check the pin clearance in the pin boss of the piston by computing the difference between the two diameter readings, one taken on the pin and the other in the boss. If the computed difference (clearance) exceeds the repair limit, replace the piston pin with a new one.

Specifications

Unit: mm (in.)

Item	Standard	Repair limit
Piston pin diameter	$25^{\ 0}_{-0.006}$ ($0.984^{\ 0}_{-0.00024}$)	



Miking piston pin bushing and piston pin

(2) Check the clearance of the pin in the bushing fitted to the small end of the connecting rod by computing the difference between the two diameter readings. If the computed difference (clearance) exceeds the repair limit, replace the pin or the bushing whichever is badly worn.

Specifications

Unit: mm (in.)

Item	Standard	Repair limit
Piston pin boss ID	$25^{\ 0}_{-0.006}$ ($0.984^{\ 0}_{-0.00024}$)	
Piston pin clearance in piston pin boss	0 ~ 0.016 (0 ~ 0.00063)	0.05 (0.0020)
Piston pin bushing ID	$25^{+0.020}_{+0.045}$ ($0.984^{+0.00079}_{+0.00177}$)	
Piston pin clearance in piston pin bushing	0.020 ~ 0.051 (0.00079 ~ 0.00201)	0.08 (0.0031)

Connecting rod alignment and bearings

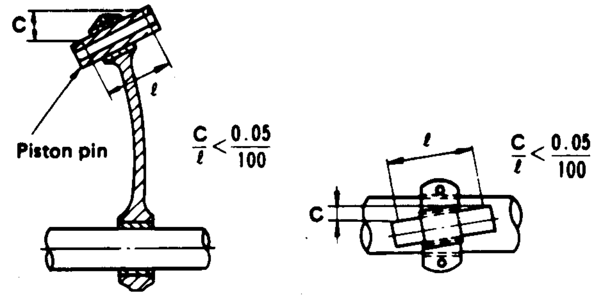
(1) Check the connecting rod for evidence of cracks, especially cracks in the fillets of its small and big ends. Replace the rod if any crack is noted in the fillets.

(2) Mount each connecting rod in the connecting rod aligner and check for bend and twist as shown below. In a twisted connecting rod, the bearing is not trued to the small end bushing. Such a rod must be corrected with the use of a press.

(3) If the connecting rod aligner is not available, the rod may be checked as follows:

(a) To check the rod for bend, measure "C" and "ℓ" as shown in the figure "a." If the measurement at "C" is larger than 0.05 mm per 100 mm (0.00197 in. per 3.937 in.) of "ℓ," straighten the rod with the use of a press.

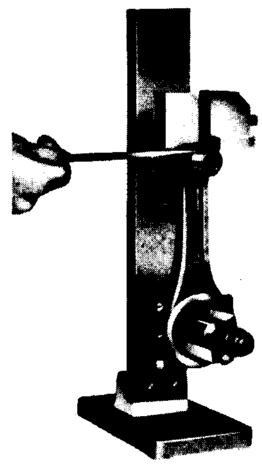
(b) To check the rod for twist, measure "C" as shown in the figure "b." If the measurement at "C" is larger than 0.05 mm per 100 mm (0.00197 in. per 3.937 in.) of "ℓ," correct the rod.



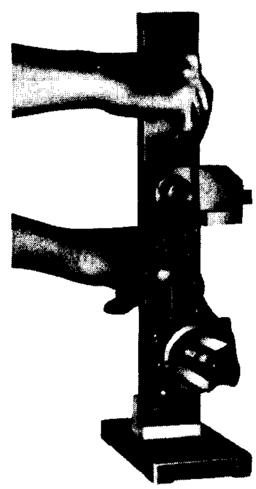
a. Checking the connecting rod for bend

b. Checking the connecting rod for twist

Checking connecting rod



Checking connecting rod for bend



Checking connecting rod for twist

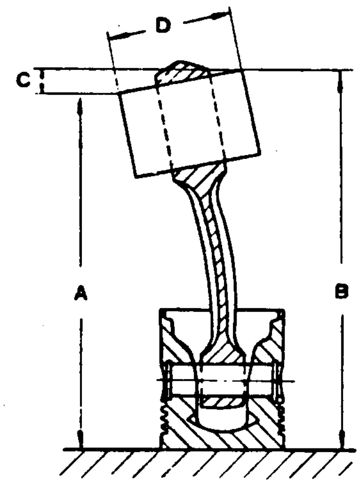
(4) To check the rod with a piston, place the rod on the surface plate as shown below, insert a round bar of the crankpin diameter into and through its big end bore, and take measurement at "A" and "B." The difference between the two measurements tells the straighteness of the rod.

When one or more, or all connecting rods are to be replaced, select new rods so that the variance in weight among the rods is within the value given in the specification.

Specification

Unit: gram (oz)

Variance in weight among connecting rods	±25 (±0.83)

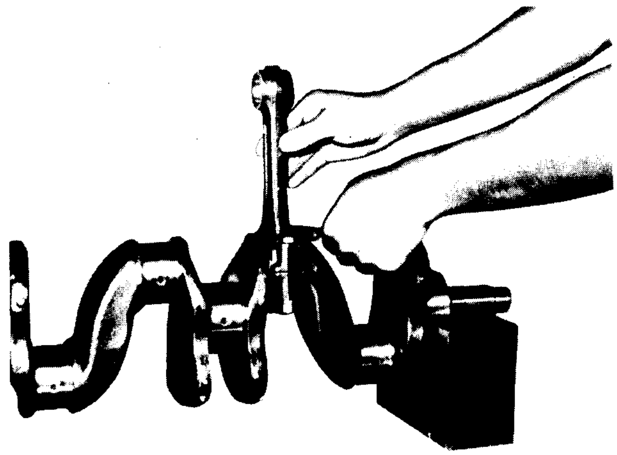


Checking connecting rod on surface plate

(5) Check the connecting rod end play as follows:
Check each connecting rod for end play in the manner illustrated, with the cap bolts tightened to 5.5 kg-m (39.8 lb-ft). Use a thickness gauge to measure the end play (which is the clearance between big end and crank arm). If the clearance measured exceeds the service limit, replace the connecting rod or bearing.

Specifications Unit: mm (in.)

Item	Standard	Service limit
Connecting rod end play	0.15 ~ 0.35 (0.0059 ~ 0.0138)	0.50 (0.0197)



Checking end play of connecting rod

(6) Check the bearings as follows:

(a) Inspect each bearing for evidence of wiping or fatigue failure, for scratches by dirt particles imbedded in and for improper seating on the bore. Determine whether the bearing should be re-used or replaced on the basis of findings.

(b) Check the radial clearance between crankpin and bearing; if the repair limit specified below is exceeded by the checked clearance, replace the bearing. Where the crankpin is to be ground to the next undersize, use a replacement bearing of that undersize.

The two bearing undersizes are 0.25 mm (0.00984 in.) and 0.50 mm (0.01969 in.).

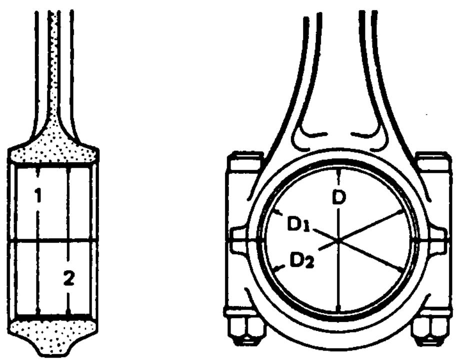
Specifications

Unit: mm (in.)

Item	Standard	Repair limit
Crankpin diameter	$58^{-0.035}_{-0.055}$ ($2.283^{-0.00138}_{-0.00217}$)	
Radial clearance between bearing and crankpin	0.035 ~ 0.100 (0.00138 ~ 0.00394)	0.20 (0.0079)

To measure the inside diameter of the bearing, the bearing fitted to each connecting rod must be secured by tightening the cap bolts to 5.5 kg-m (39.8 lb-ft). Measure the diameter in two positions, 1 and 2, and in two directions D_1 and D_2, as shown below. Obtain the average by the following formula:

$$D = \frac{D_1 + D_2}{2}$$

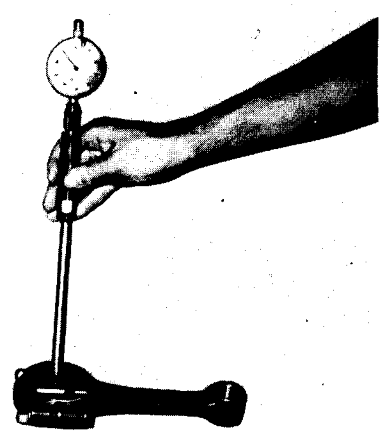


Positions for miking connecting rod bearing

(c) Check the contact pattern of bearing on crankpin by fitting the big end in the normal manner to the crankpin, with the crankshaft laid out on the bench, and by using a paste of red lead or Prussian blue to visualize the contact. Be sure to tighten the cap bolts to the specified torque, that is, 5.5 kg-m (39.8 lb-ft). The contact should occur over at least 75% of the entire surface; if not, replace the bearing.

NOTE

The above job of checking the contact pattern may be eliminated where the crankpin is ground to the specified tolerance and the bearing has been replaced. This is because a replacement bearing is precision-finished to ensure the specified extent of contact.



Miking connecting rod bearing

Crankcase

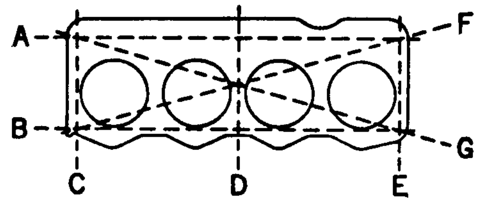
(1) Inspect the outside and inside surfaces for evidence of cracking. Visually examine the cylinder bores for scuffing, rusting, erosion or any abnormal wear. Using a straightedge, check the top face (for mating with cylinder head), front face (for mating with front plate) and rear face (for mating with rear plate) for flatness.

(2) Make sure that the top face of the crankcase is flat within the standard specified below. If the standard is found to be exceeded, reface the top by using a surface grinder to make it flat within the specified standard.

Specifications

Unit: mm (in.)

Item	Standard	Repair limit
Warpage of crankcase gasketed surface	0.05, max. (0.0020)	0.20 (0.0079)



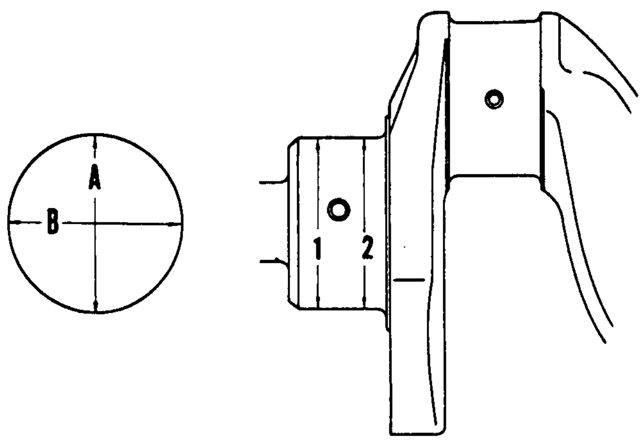
Checking crankcase top for flatness

Crankshaft

(1) **Journals**

(a) Inspect each journal for surface flaws such as roughing, scratches, pitting and burns, and, as necessary, repair the journals by grinding to the next undersize or replace the crankshaft.

(b) Mike each journal to take a total of four readings to determine the wear, out-of-round and taper (cylindricity). If any of the limits is exceeded, repair by grinding to the next undersize or replace the crankshaft.

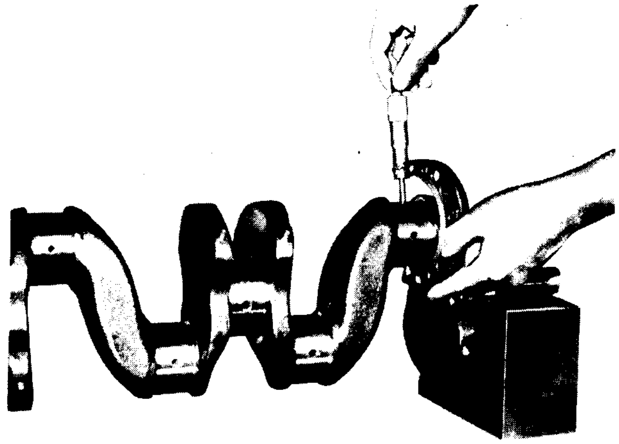


Positions for miking journal

(2) **Crankpins**

(a) Inspect each crankpin for surface flaws such as roughing, scratches, pitting and burns, and, as necessary, repair the crankpins by grinding to the next undersize or replace the crankshaft.

(b) Mike each crankpin to take a total of four readings to determine the wear, out-of-round and taper. If any of the limits is exceeded, repair by grinding to the next undersize or replace the crankshaft.



Miking crankshaft crankpins

Specifications

Unit: mm (in.)

Item	Standard	Repair limit	Service limit
Diameter of journals	$65^{-0.015}_{-0.035}$ ($2.559^{-0.00059}_{-0.00138}$)	−0.15 (−0.0059)	−0.9 (−0.035)
Out of roundness of crankpins and journals	0.01 (0.0004), max	0.03 (0.0012)	
Taper of crankpins and journals			
Diameter of crankpins	$58^{-0.035}_{-0.055}$ ($2.283^{-0.00138}_{-0.00217}$)	−0.20 (−0.008)	
Fit of journals in main bearings	0.03 ~ 0.089 (0.0012 ~ 0.00350)	0.2 (0.0079) Uneven wear: 0.03 (0.0012)	

(c) Grinding the crankshaft

The crankshaft journals and crankpins must be refinished to a dimension smaller by 0.100 to 0.120 mm (0.00394 to 0.00472 in.) than the undersize of bearings to be used.

Example: If 0.50-mm (0.01969-in.) undersize bearings are to be used:

The journals must be refinished to
65 – 0.5 – (0.100 ~ 0.120)
[2.55905 – 0.01969 – (0.00394 ~ 0.00472 in.)]

The crankpins must be refinished to
58 – 0.5 – (0.100 ~ 0.120)
[2.28346 – 0.01969 – (0.00394 ~ 0.00472 in.)]

When grinding the crankpins and journals, be sure to produce the same filler radius (shoulder radius) as the original one. Too small a radius of fillet will result in fatigue failure of crankshaft while too large a fillet radius is sure to cause the bearing to ride on the radius and thereby to result in a bearing failure. Be extremely careful not to grind off the radius part beyond the desired dimension. An over-ground radius part can be corrected only by grinding off the shoulder face and this, if effected, will present problems in obtaining a proper end clearance.

Also check the crankpins and journals for hardness. They should have a hardness of 620 or more in terms of Vickers Hardness Number. If necessary, re-harden the crankpins and journals, and check them for cracks by conducting a magnaflux (magnetic particle) test.

Specifications Unit: mm (in.)

Undersize	Journals to be refinished to
0.25 (0.0098)	$64.75^{-0.015}_{-0.035}$ ($2.54921^{-0.00059}_{-0.00138}$)
0.50 (0.0197)	$64.50^{-0.015}_{-0.035}$ ($2.53937^{-0.00059}_{-0.00138}$)
0.75 (0.0295)	$64.25^{-0.015}_{-0.035}$ ($2.52952^{-0.00059}_{-0.00138}$)

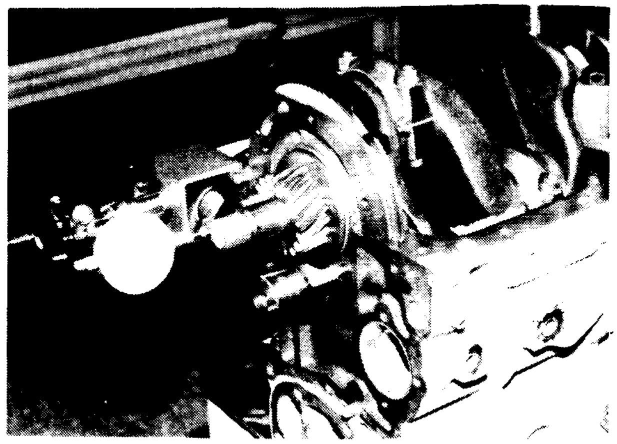
(3) **End play**

Check the crankshaft for end play, as shown, by using a thickness gauge at the thrust bearing. If the limit is reached replace the thrust plate.

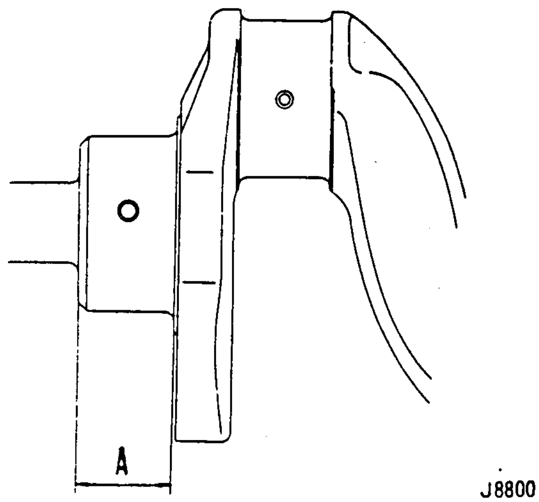
Specifications Unit: mm (in.)

Item	Standard	Repair limit
Journal width for thrust bearing	0.100~0.189 (0.00394~0.00744)	0.3 (0.012)

The end play is due to the difference between the width of thrust bearing and the dimension (A) indicated below:



Checking crankshaft end play



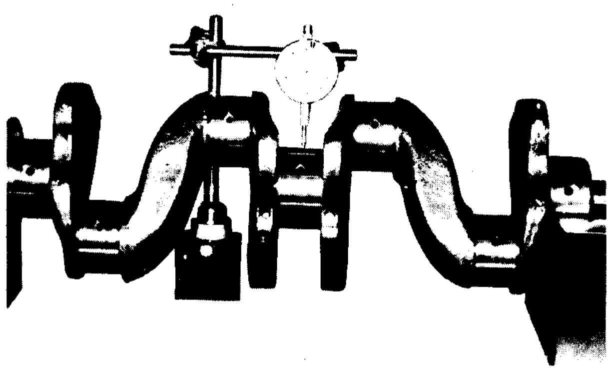
Journal width for thrust bearing

(4) **Runout**

Support the crankshaft as shown and roll it to measure its deflection with a dial gauge. "Distortion" is one-half of the deflection (dial gauge reading); if it exceeds the standard, reduce it by bending the crankshaft in a press.

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Crankshaft runout	0.02 (0.0008), max	0.05 (0.0020)



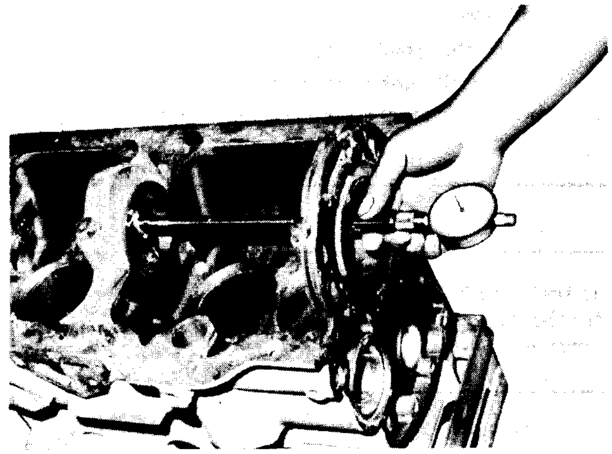
Checking crankshaft for runout

(5) **Main bearings**

Inspect each main bearing for evidence of wiping or fatigue failure, for scratches by dirt particles imbedded and for improper seating on the bore (bearing cap). On the basis of findings, determine whether the bearing should be replaced or not.

Check each main bearing to be used in engine reassembly to see whether it will provide the specified radial clearance. This can be accomplished in this manner.

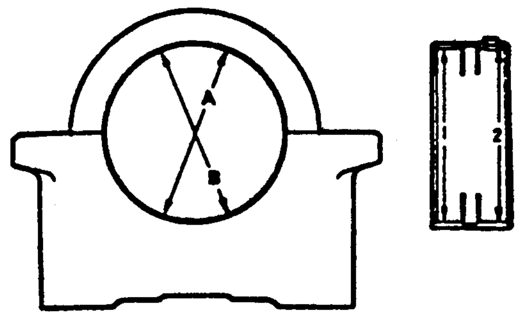
Install the main bearings on the crankcase, less the crankshaft, securing each bearing cap by tightening its bolts to 8.5 kg-m (61.5 lb-ft) and read the diameter in the two directions (A) (B), in indicated below. Mike the journal and, from these readings, compute the radial clearance.



Measuring main bearing ID

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Fit of main bearings on journals	0.03 ~ 0.089 ((0.0012 ~ 0.00350)	0.200 (0.00787)



Positions for miking main bearing

Camshaft

(1) Check the camshaft end play as outlined for the timing gears. Where the end play exceeds the repair limit, replace the thrust plate with a new one.

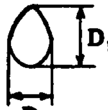
Specifications Unit: mm (in.)

Item	Nominal value	Standard	Repair limit
Camshaft end play	5.0 (0.197)	0.05 ~ 0.112 (0.00197 ~ 0.00441)	0.3 (0.012)

(2) Inspect the camshaft journals for abnormal wear and damage; the camshaft must be replaced if any of its three journals is found in bad condition beyond repair.

(3) Mike each cam of the camshaft to read D_1 (cam height) and D_2 (diameter), and compute the difference between D_1 and D_2. If this difference is less than the service limit, replace the camshaft.

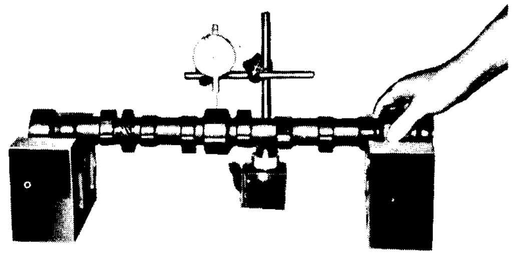
Specifications Unit: mm (in.)

Item		Standard	Service limit
Intake cam profile	$(D_1 - D_2)$ 	D_1: $46.916^{+0.1}_{-0.3}$ ($1.84708^{+0.00394}_{-0.01181}$) $D_1 - D_2 = 6.684$ (0.26315)	$D_1 - D_2 =$ 6.184 (0.24346)
Exhaust cam profile		D_1: $45.944^{+0.1}_{-0.3}$ ($1.80882^{+0.00394}_{-0.01181}$) $D_1 - D_2 = 7.344$ (0.28913)	$D_1 - D_2 =$ 6.844 (0.26945)

(4) Check the camshaft for runout. Straighten the camshaft in a press or replace it, as necessary.

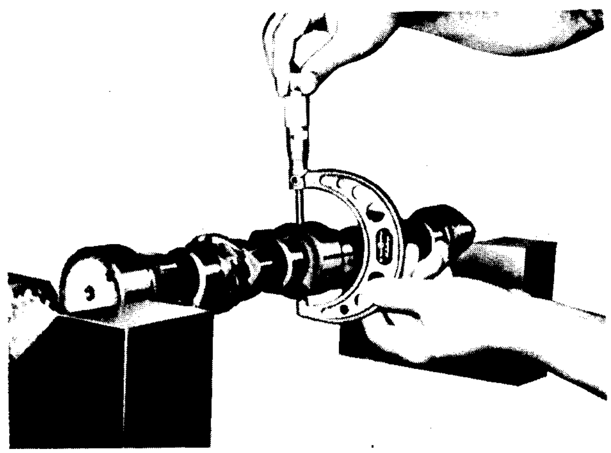
Specifications Unit: mm (in.)

Item	Standard	Repair limit
Camshaft runout	0.02 (0.0008), max.	0.05 (0.0020)



Checking camshaft runout

(5) Measure the diameter of each journal in two directions to compute the fit or clearance in the camshaft hole.



Miking camshaft journals

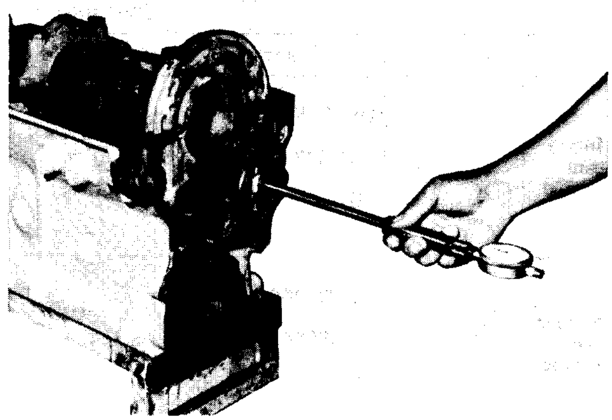
(6) Measure the ID of camshaft holes (bushings) and compute the fit on each journal. If the fit exceeds the repair limit, machine the holes and install bushings.

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Fit of camshaft journals in holes (bushings)	0.040 ~ 0.090 (0.00157 ~ 0.00354)	0.15 (0.0059)

Specifications Unit: mm (in.)

Item		Standard	Service limit
Camshaft bushing inside diameter	No.1, 2	$54H7\ ^{+0.030}_{0}$ ($2.126H7\ ^{+0.00118}_{0}$)	
	No.3	$53H7\ ^{+0.030}_{0}$ ($2.087H7\ ^{+0.00118}_{0}$)	
Camshaft journal outside diameter	No.1, 2	$54\ ^{-0.040}_{-0.060}$ ($2.126\ ^{-0.00157}_{-0.00236}$)	-0.1 (-0.004)
	No.3	$53\ ^{-0.040}_{-0.060}$ ($2.087\ ^{-0.00157}_{-0.00236}$)	



Miking camshaft hole ID

Tappets and tappet holes

(1) Inspect the riding face of each tappet for wear, contact pattern and crack. Replace defective tappets.

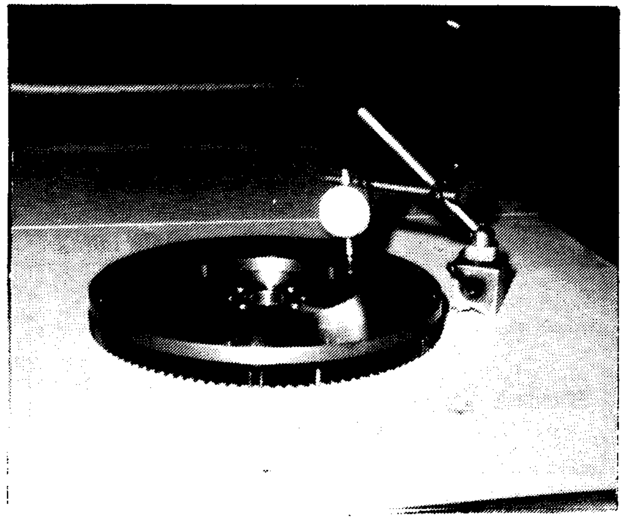
(2) Check the fit of the tappet in the hole against the repair limit, indicated below. If the limit is exceeded, then replace the tappet. If the hole is worn down so much as to provide an excessive radial clearance even with a new tappet, the crankcase must be replaced.

Specifications Unit: mm (in.)

Item	Standard	Repair limit	Service limit
Fit of holes on tappets	0.035 ~ 0.098 (0.00138 ~ 0.00386)	0.12 (0.0047)	+0.10 (hole) (+0.0039)
Tappet hole diameter	22 (0.87)		+0.10 (+0.0039)

Flywheel

(1) Check the flywheel for scoring or a sign of overheating of the friction surface, cracks, or any other damage. When any of these damages are presented, repair or replace the flywheel.

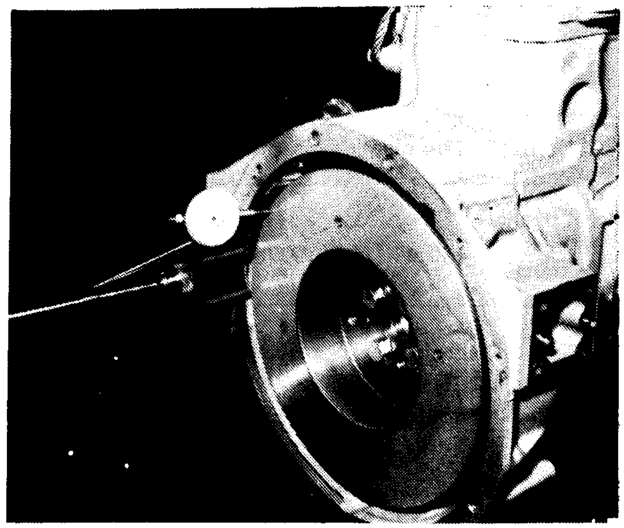


Checking flywheel friction surface for warpage

(2) Check the friction surface for warpage and/or face runout. When warpage or face runout exceeds the repair limit, repair or replace the flywheel. The face runout may be measured by means of a dial gauge with the flywheel installed on the crankshaft.

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Warpage	0.15(0.0059), max.	0.5 (0.020)
Face runout	0.15(0.0059), max.	0.5 (0.020)



Checking flywheel friction surface for face runout

(3) Check the flywheel attaching bolt threads for condition and replace a damaged bolt, if any.

(4) Check the ring gear for condition and replace it if damaged.

(5) Clean the pilot bushing which is fitted into the center bore in the flywheel, and check it for condition. Replace the bushing if damaged.

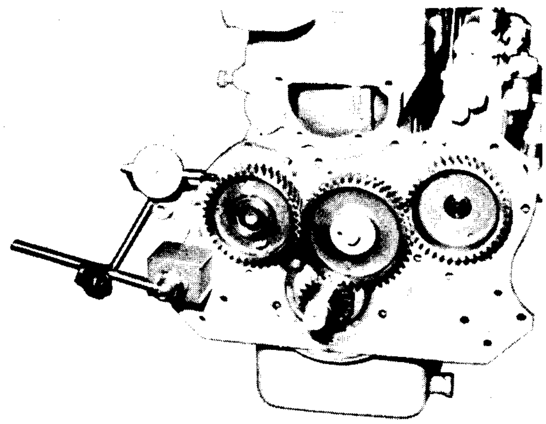
Timing gear case and oil seal

(1) Check the timing gear case for any signs of cracks; also check the dowel pin holes for condition.

(2) Check the oil seal for wear, and replace it if it is excessively worn or otherwise defective. Check it more carefully if oil leakage from the crankshaft end is excessive.

Timing gears

(1) Be sure that the backlash in each mesh is within the repair limit. If the limit is exceeded, reduce the backlash by replacing the worn gear. To measure backlash, use a thickness gauge: put the gauge squarely into between two gear teeth.



Specifications Unit: mm (in.)

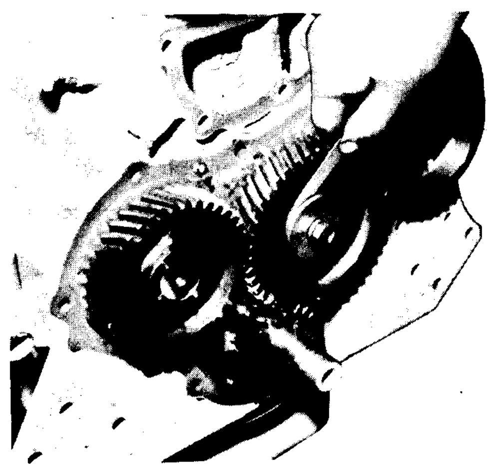
Item	Standard	Repair limit
Backlash	0.05 ~ 0.20 (0.0020 ~ 0.0079)	0.25 (0.0098)

(2) Check the radial clearance between idler bushing and shaft by miking. Compute the clearance from the readings taken and, if the repair limit is exceeded, replace the bushing.

Specifications Unit: mm (in.)

Item	Nominal	Standard	Repair limit
Fit of shaft in idler bushing	36 (1.417)	0.025 ~ 0.075 (0.00098 ~ 0.00295)	0.1 (0.004)

(3) Check the idler end play with a thickness gauge. Replace the thrust plate to reduce the play if the thickness gauge reading exceeds the repair limit.



Checking idler end play

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Idler end play	0.05 ~ 0.15 (0.0020 ~ 0.0059)	0.35 (0.0138)

(4) If the idler shaft has to be replaced, use the idler shaft puller to remove it, as shown. When installing the replacement shaft, check to be sure that the oil holes are aligned.

(5) Inspect the timing gears as follows:

(a) Camshaft gear
Replace the gear if its teeth show evidence of flaking or excessive wear, or if its keyway is galled, worn or otherwise disfigured. Make sure that the camshaft gear as mounted on the camshaft has no more end play than 0.4 mm (0.0157 in.): to check the end play, use a dial gauge. If the reading exceeds the repair limit, replace the thrust plate. (Remember, this gear is shrink-fitted to the camshaft.)

Specifications

Unit: mm (in.)

Item	Standard	Repair limit
Camshaft end play	0.05 ~ 0.112 (0.00197 ~ 0.00441)	0.3 (0.012)

(b) Injection pump drive gear
Inspect the gear teeth for damage and also the mounting bolt holes for malcondition. Replace the gear if found in badly damaged condition.

(c) Crankshaft gear
Replace the gear if its teeth show signs of defective tooth contact, or are excessively worn or otherwise defective.

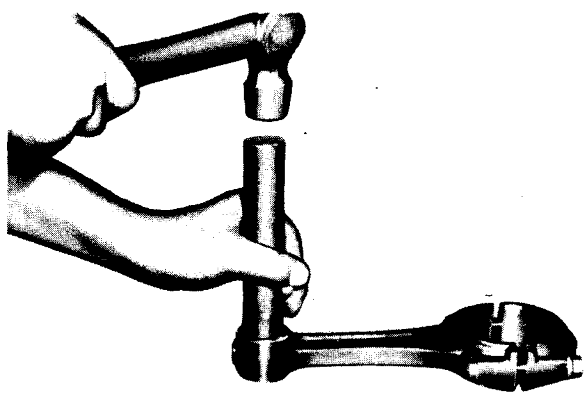
(d) Idler gear
Inspect the idler gear teeth and, as necessary, replace the gear.

(6) Inspect the gear case for cracks, and for evidence of oil leakage at the part ahead of the crankshaft. A cracked case must be replaced. Inspect the crankshaft pulley, too, examining condition of surface in contact with the oil seal and checking the keyway and key for wear. Replace the pulley if found in defective condition.

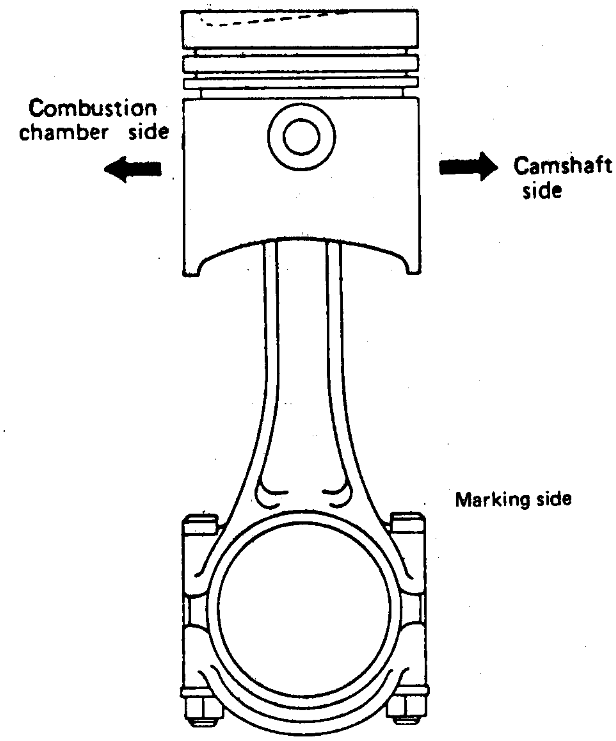
REASSEMBLY

(1) Reassemble the connecting rod and piston as follows:

(a) Drive in bushing into connecting rod small end. The oil holes in bushing and rod must be aligned.

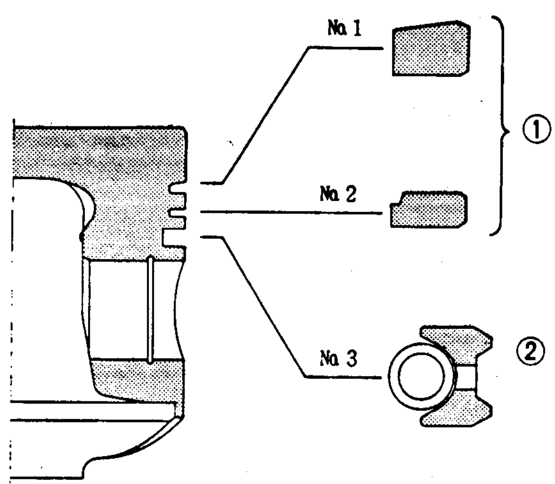


(b) Heat piston with piston heater up to 100°C to 120°C (212° F to 248°F). Install small end of connecting rod into boss and connect piston and piston pin by slowly inserting piston pin into piston. Insert snap ring in one end in advance. Install connecting rod to piston so that the marking side of the connecting rod big end comes to the camshaft side.



PISTON AND CONNECTING ROD ASSEMBLY

(c) Install compression rings and oil control ring as shown by using piston ring tool.

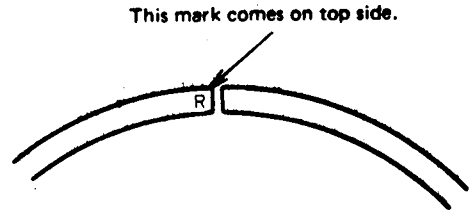


PISTON RINGS INSTALLED
1–Compression rings 2–Oil control ring

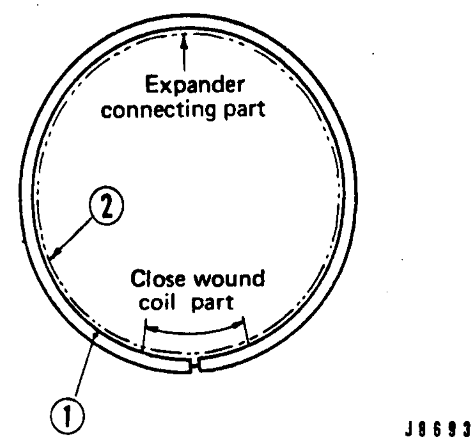
NOTE

No. 2 ring has "R" or "RN" mark on its top side. Be sure that this side is on top when the ring is in the groove.

This mark comes on top side.



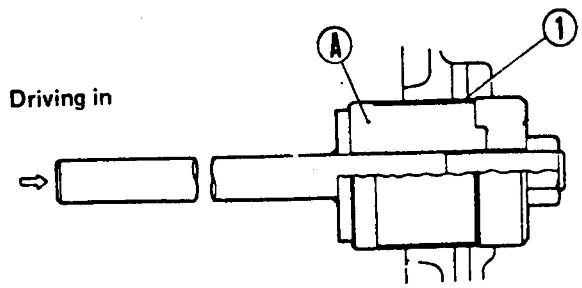
(d) Install No. 3 oil control ring (1) and expander (2) as shown below.



OIL CONTROL RING AND EXPANDER INSTALLED

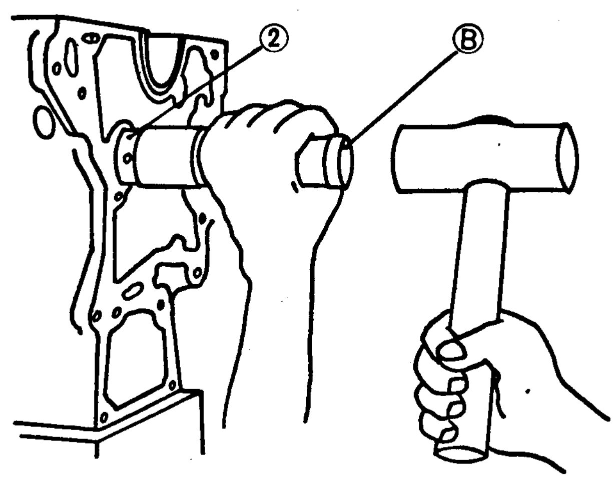
(2) Reassemble the crankcase as follows:

(a) Drive three camshaft bushings (1) into camshaft holes in crankcase by using adapter (A). (If the fit exceeds the repair limit, machine the holes and install bushings.)

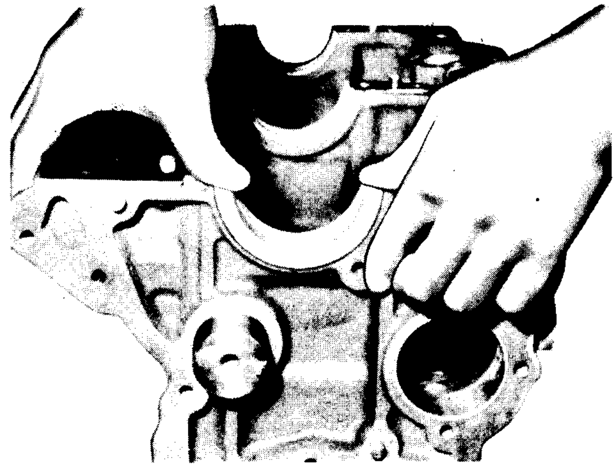


DRIVING IN CAMSHAFT BUSHING

(b) Drive idler shaft (2) into crankcase by using installer (B).

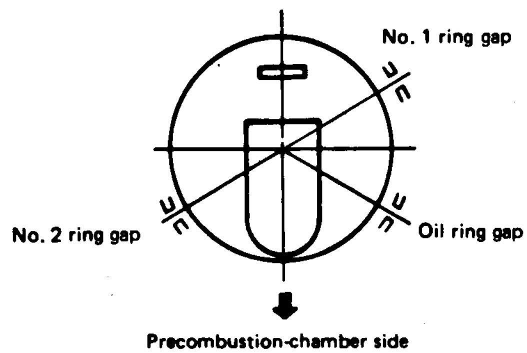


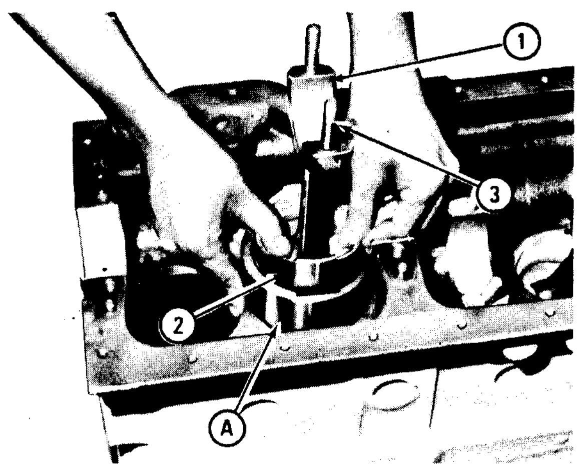
(c) Lightly apply engine oil to the crankpins and install main bearings (upper). Securely engage the bearings with the crankpins.



(3) Install the piston assembly as follows:

Install connecting rod bearing (upper) (1) into the big end of connecting rod. Apply engine oil in the internal surface of bearing and on the external periphery of piston. Position piston rings so that ring gaps are located 90°in respect with each other as shown, and then insert piston assembly (2) into crankcase. Alignment marks on the connecting rod must face the camshaft side. Put cap attaching bolts (3) into rod in advance. Insert piston assembly into crankcase by using piston guide (A).

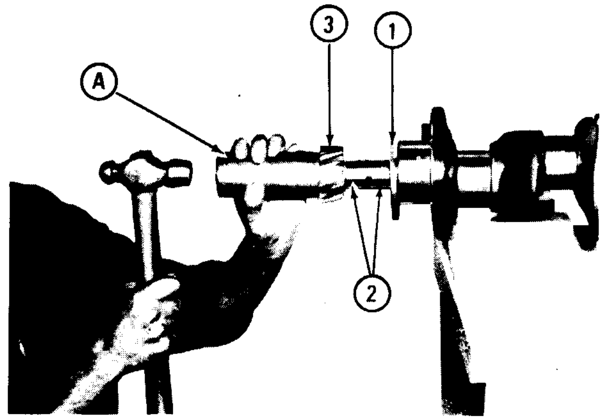




(4) Install the crankshaft as follows:

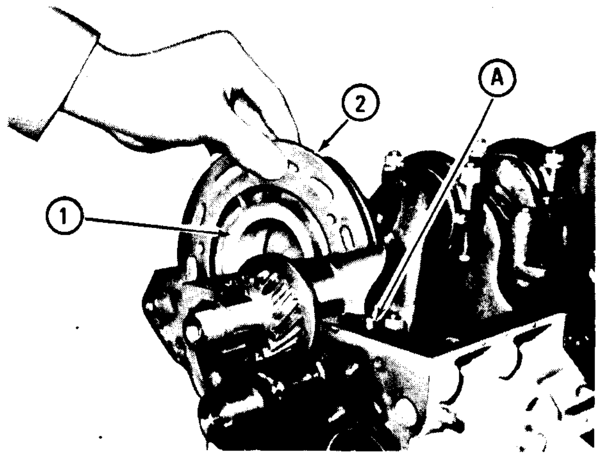
(a) Install thrust plate (1) and two woodruff keys (2) to the crankshaft and drive in crankshaft gear (3) by using installer (A).

(b) Install crankshaft to the crankcase.

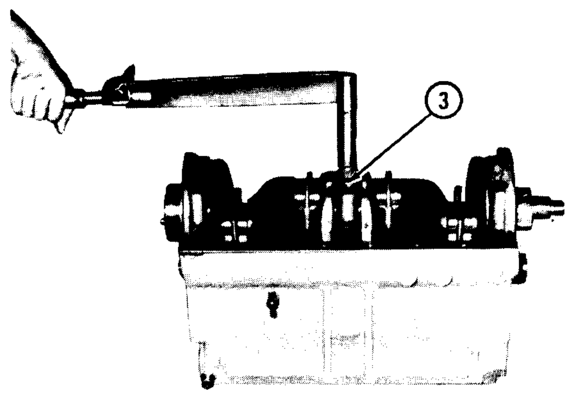


(5) Install the main bearing caps as follows:

(a) Apply engine oil to the crankshaft journals and pins, and install the crankshaft in the crankcase securely. Attach main bearing (lower) (1) to main bearing cap (2) (front, center and rear) and install the cap in place aligning it with dowel pin (A) of crankcase.

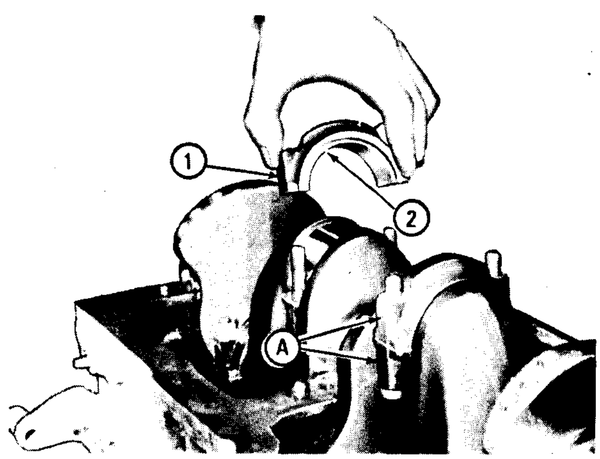


(b) Measure the crankshaft end play with a thickness gauge. Replace No.1 main bearing if the end play is out of specification. Tighten main bearing cap bolts (3) to a torque of 8.5 kgm (61.463 lb.ft).

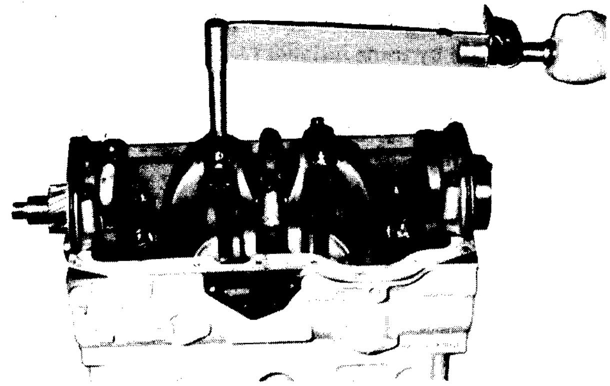


(6) Install the connecting rod bearing caps as follows:

(a) Install connecting rod bearing (lower) (2) into cap (1) and apply engine oil to the internal surface of the bearing, and then install the cap with the matching mark on the cap aligned with the mark (A) on the rod.

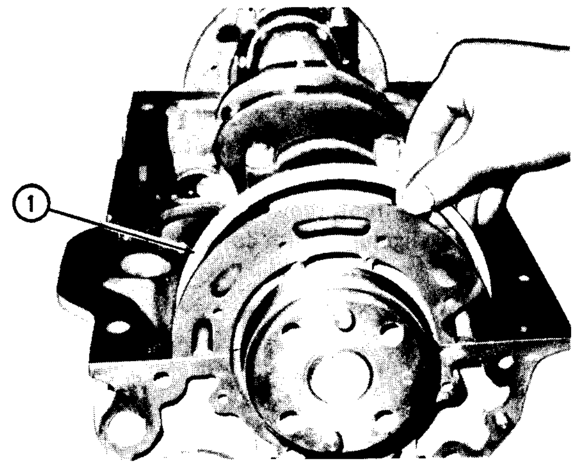


(b) Tighten connecting rod clamping nuts to a torque of 5.5 kgm (39.771 lb.ft).

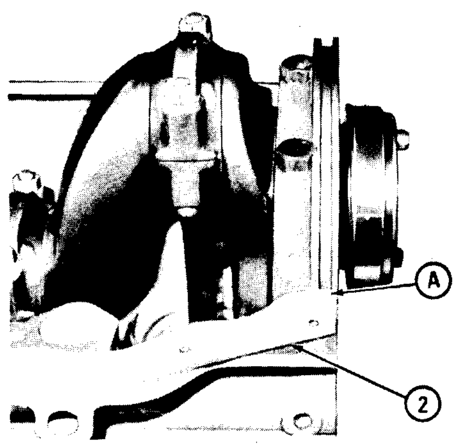


(7) Install the retainers and gaskets as follows:

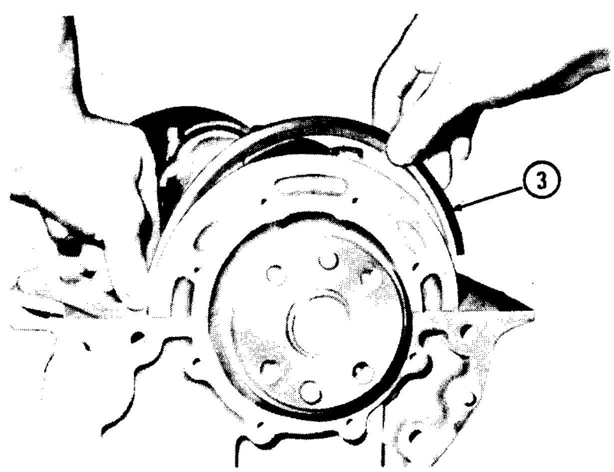
(a) Install retainers (1) to the external peripheries of main bearing caps No. 1 and No. 3 with the flange facing the case inside.



(b) Apply ThreeBond 1102 (adhesive) on both sides of oil pan gasket (2) and attach it to crankcase. Make sure that the gasket is completely attached in the grooves (A) in the caps.

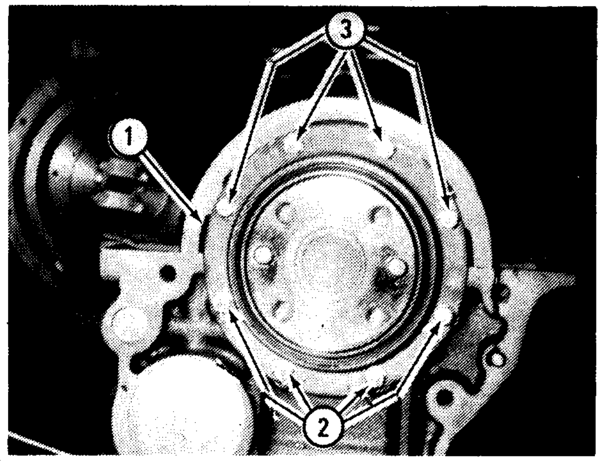


(c) Apply Atomjet on the both ends of rubber packing (3) and insert the packing into cap.



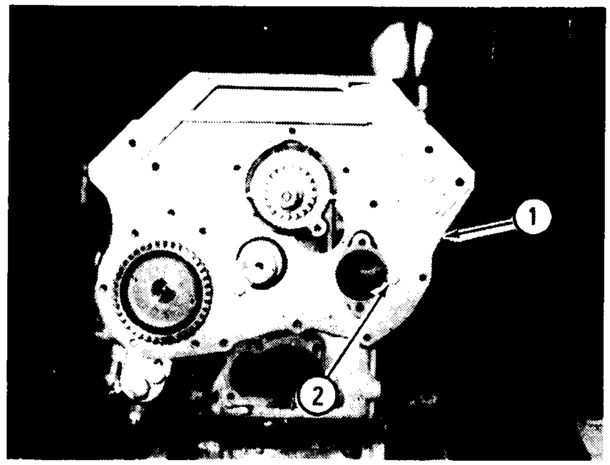
(d) Install sleeve onto the rear end of crankshaft.
Apply clean engine oil to the internal surface of oil seal (1) and secure it with bolts (2) by using oil seal aligner.

(e) Apply Atomjet at the tip of bolts (3) as they fit into four through-bolt holes in the bearing cap. Tighten the bolts to a torque of 0.4 kgm (2.9 lb.ft).

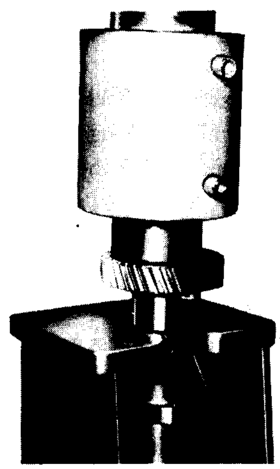


(8) Install the front plate as follows:

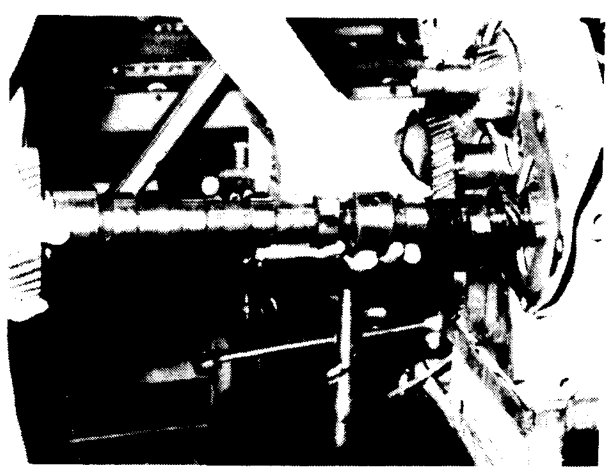
(a) Apply ThreeBond 1102 to the both sides of front plate packing and attach the packing to the front face of crankcase. Secure front plate (1) with injection pump installed with two bolts (2). The tightening torque of the bolts is 2.1 kgm (15.2 lb.ft).



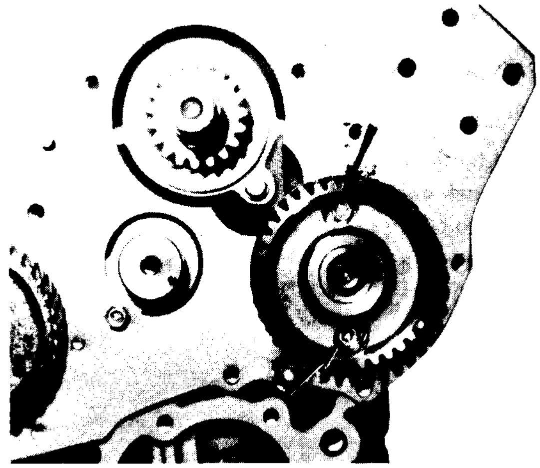
(b) Heat camshaft gear to 150°C to 180°C and fit it to shaft.



(c) Slowly insert camshaft into crankcase.

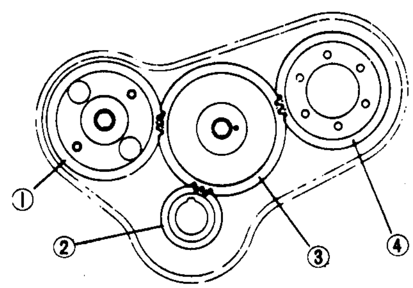


(d) Tighten camshaft thrust plate to crankcase by using machining holes in camshaft gear.



(9) Install the idler gear as follows:

(a) Install idler gear by matching the timing mark on each gear.



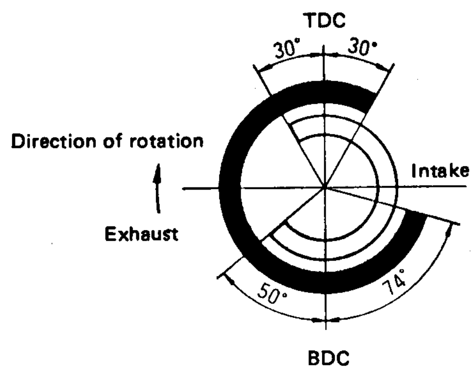
Timing gear match marks meeting each other

1-Camshaft gear 3-Idler gear
2-Crankshaft gear 4-Injection pump gear

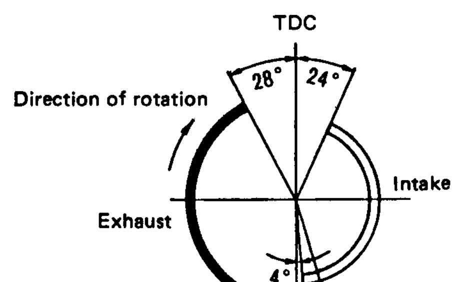
(b) Inspecting valve timing after installation of timing gears

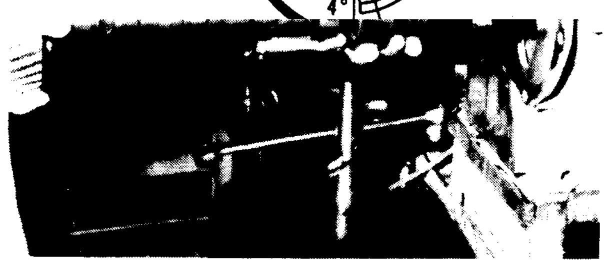
It is not necessary to check the valve timing, provided that all matching marks on the timing gears are aligned. Check the timing for verification as follows:

Using a 3 mm (0.12 in.) thick smooth steel plate, add 3 mm (0.12 in.) clearance to intake and exhaust valves of No. 1 cylinder. Then, insert a 0.05 mm (0.0020 in.) thickness gauge into between the top of valve cap and rocker, and slowly turn the crankshaft, trying to find a position where the thickness gauge is firmly gripped (the valve starts opening) and a position where the gauge is just ungripped (the valve starts closing). Check to make sure that these positions coincide with the angular positions shown in the valve timing diagram with 3 mm (0.12 in.) clearance added to the valves.



Valve timing diagram

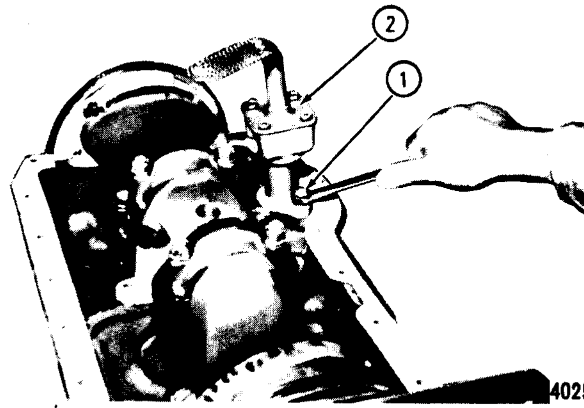




(10) Install the oil pump assembly as follows:

(a) Install oil pump into the oil pump installation hole in the crankcase and mesh the pump drive gear with camshaft pump drive gear.

(b) Tighten bolt and secure the oil pump.



(11) Install the oil pan.

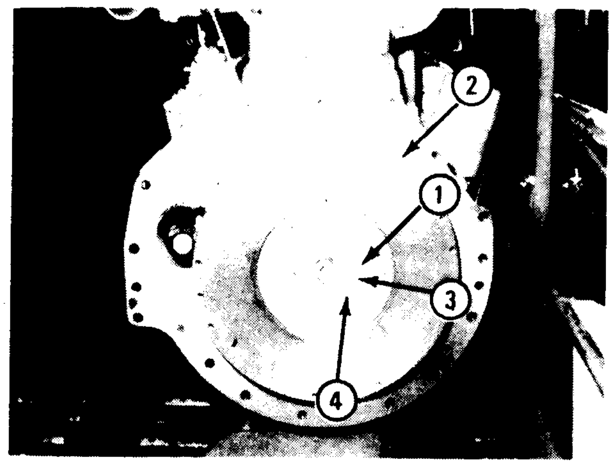
(12) Install the rear plate and flywheel as follows:

(a) Drive in dowel pin (1), and secure flywheel (2) complete with pilot bearing in place with bolts (4) and lock washers (3).

(b) Bend lock washers properly to lock bolts.

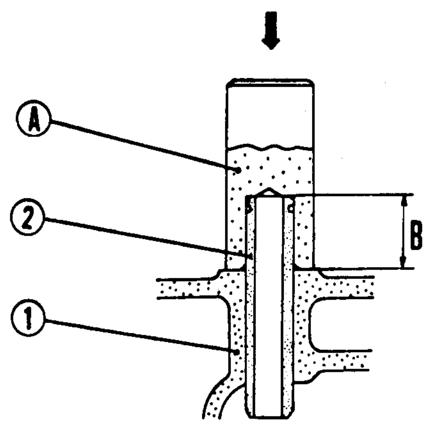
Unit: kg-m (lb-ft)

Flywheel bolt tightening torque	8.5 ± 0.5 (61.5 ± 3.6)



(13) Reassemble the cylinder head as follows:

(a) Drive valve guide (2) into cylinder head (1) as shown.

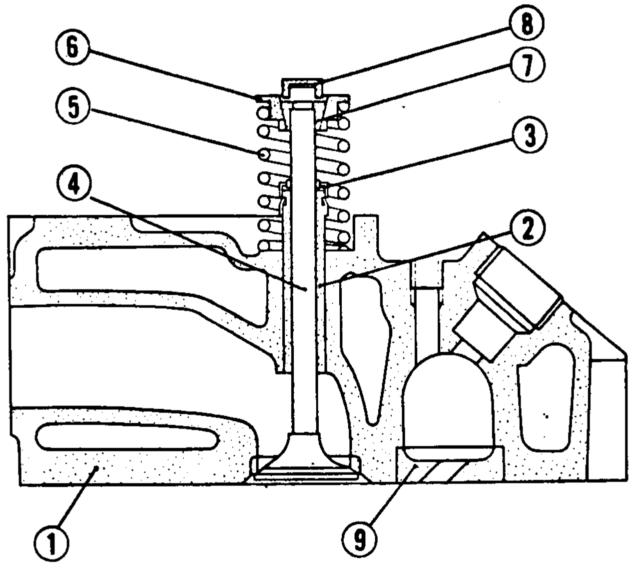


1—Cylinder head 2—Valve guide A—Valve guide installer B—As-installed length: 18mm(0.709 in)

Install stem seal (3) to the valve guide. Completely fit the breast of the seal in the guide groove.

(b) Install valve (4), valve spring (5) and retainer (6) in this order. Compress the spring with a valve lifter to install valve cotter (7) securely. Install caps (8) when installing rocker shaft assembly.

(c) Install thermostat, nozzle holders, glow plugs and exhaust manifold in the cylinder head.

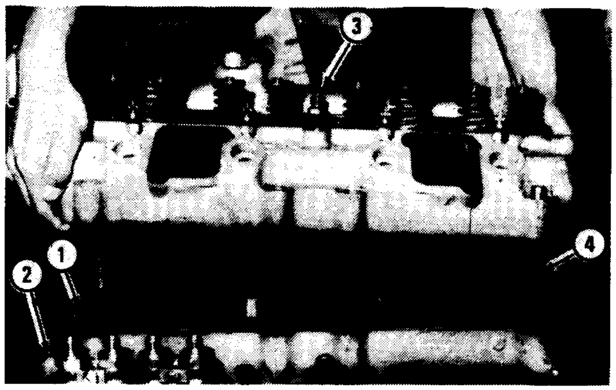


CYLINDER HEAD ASSEMBLY

1—Cylinder head 2—Valve guide 3—Stem seal 4—Valve
5—Valve spring 6—Retainer 7—Valve cotter 8—Valve cap
9—Combustion chamber jet

(14) Install the cylinder head assembly as follows:

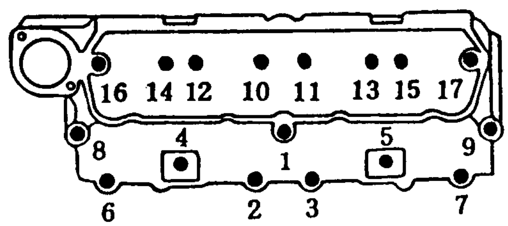
(a) Place the gasket (1) to crankcase (2) and install cylinder head (3). Use two guide bolts (4) to prevent the gasket from moving when placing cylinder head to the crankcase.



CAUTION

Do not apply any sealant to the gasket.

(b) Tighten the cylinder head bolts to a torque of 12 kg-m (86.8 lb·ft) at exhaust side and at intake side in the sequence shown below.



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(15) Install the push rods and rocker shafts as follows:

(a) Insert the push rods (1) into the tappets.

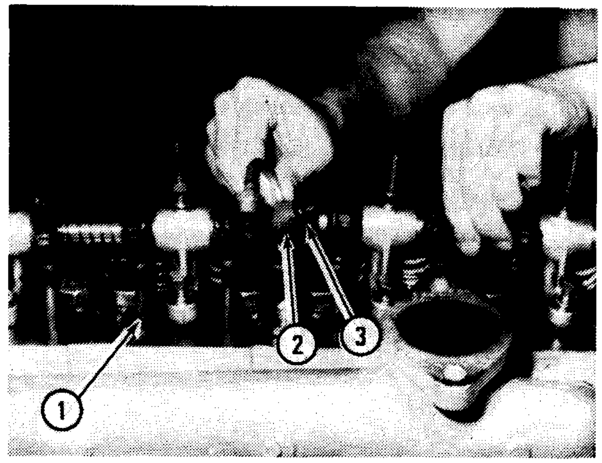
(b) Install rocker shaft assembly as follows:

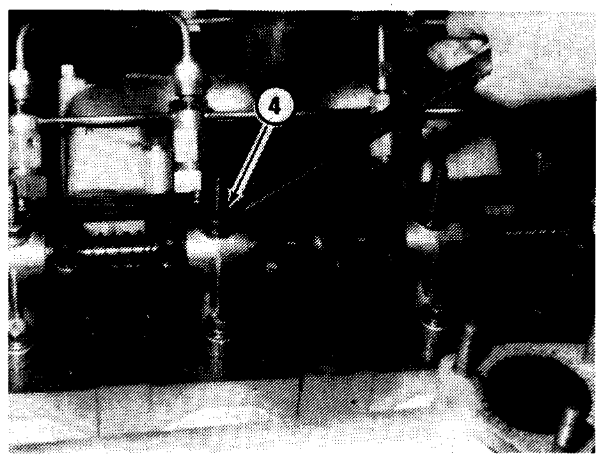
(c) Insert "O" rings (3) into oil pipe (2) and connect the oil pipe to the front and rear rocker shafts. Then temporarily install each bracket to the cylinder head.

(d) Temporarily tighten two or three threads on the oil pipe union nut and connector.

(e) Secure the preinstalled brackets by tightening four bolts at the front and rear sides uniformly to a torque of 1.5 kg-m (10.85 lb-ft). Tighten the long bolts (4) first.

(f) Connect oil pipe to connector securely. Then adjust the valve clearance to 0.25 mm (0.01 in.) for both intake and exhaust valves in cold setting.



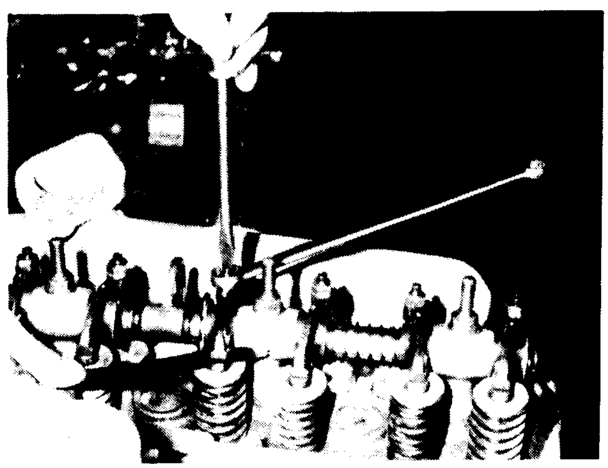


(16) Adjust valve clearance as follows:

The valve clearance specification for this engine is 0.25 mm (0.0098 in.) for both intake and exhaust valves. This value assumes that the engine is at normal temperature, there being no temperature difference throughout the body of the engine. The checking and adjusting procedure is as follows:

(a) Rotate the crankshaft slowly to bring the piston in No. 1 cylinder to Top Dead Center (TDC). This can be accomplished by observing rocker arms of No. 4 cylinder. As you turn the crankshaft, exhaust-valve rocker arm of this cylinder rises: stop turning the crankshaft just when intake-valve rocker arm begins to go down after exhaust valve rocker arm has come up all the way. Under this condition, adjust valve clearance in the usual manner on intake and exhaust valves of No. 1 cylinder, intake valve of No. 2 cylinder, and exhaust valve of No. 3 cylinder.

(b) Turn the crankshaft one complete rotation (360°), and hold it there. Adjust the clearance on intake and exhaust valves of No. 4 cylinder, exhaust valve of No. 2 cylinder, and intake valve of No. 3 cylinder.



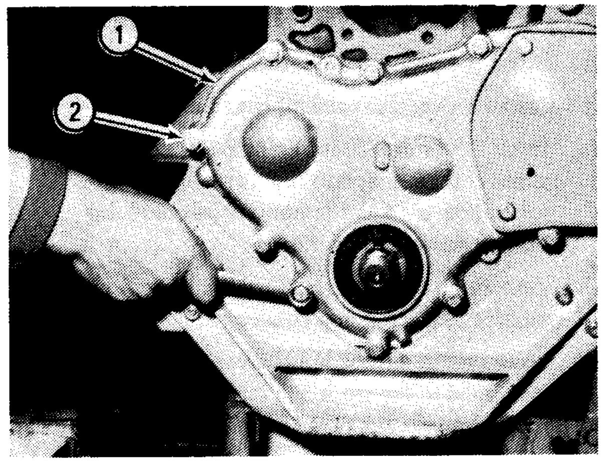
(17) Install the rocker case.

(18) Install the water pump assembly as follows:

(a) Install water pump assembly.

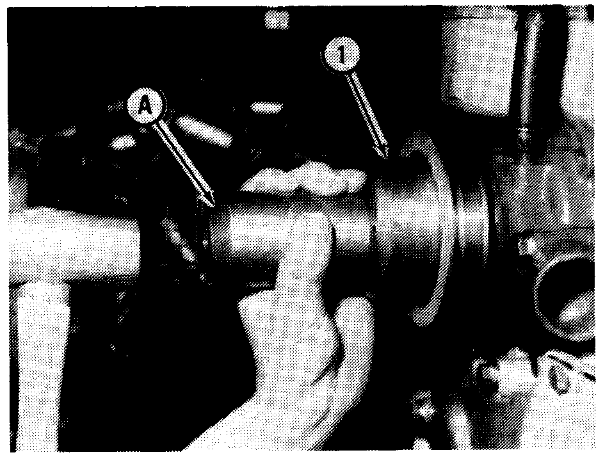
(b) Install bypass hose and oil pipe.

(19) Install the timing gear case (1) to the front plate properly. Use copper packing for bolts (2) to prevent oil leakage.

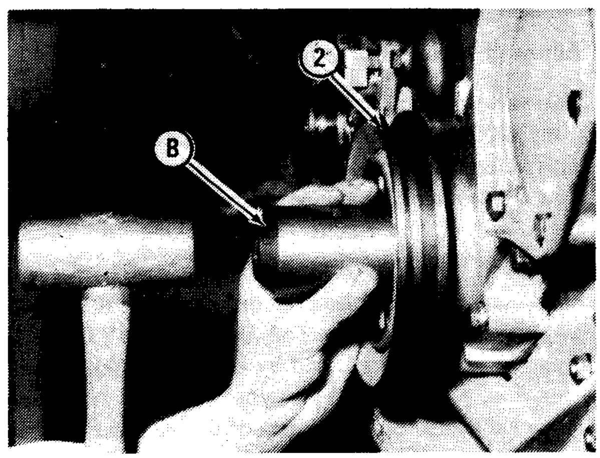


(20) Install the water pump pulley and crankshaft as follows:

(a) Drive in water pump pulley (1) and crankshaft pulley (2) by using installers (A) and (B).



(b) After driving in the crankshaft pulley, install washer and tighten nut. Then bend the lock washer to lock the nut.



(21) Install the alternator.

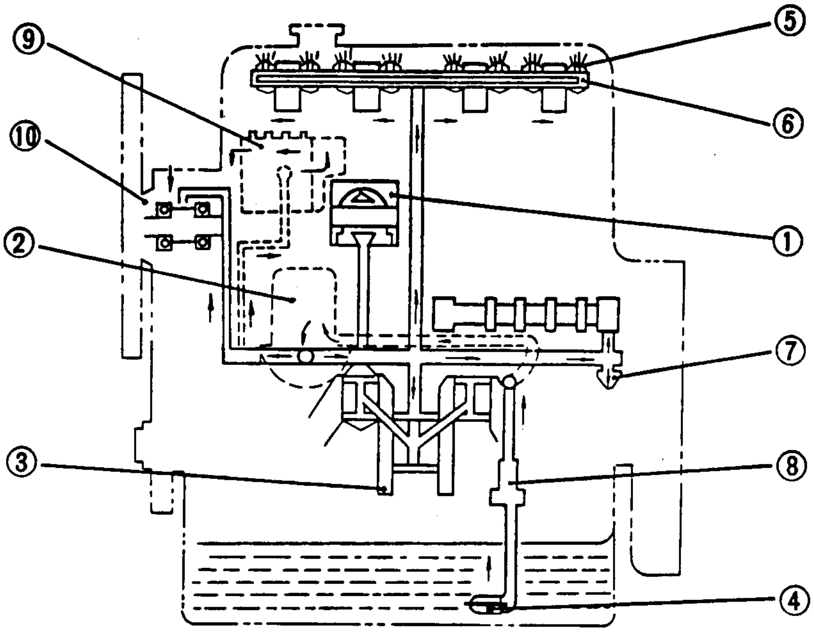
(22) Install the fan belt as follows:

(a) Attach fan belt to the pulley.

(b) Adjust the fan belt tension in such a way to have a slack of 12 mm (1/2 in.)

(23) Install the starting motor.

(24) Install the oil filter.



1-Piston
2-Oil filter
3-Crankshaft
4-Oil strainer
5-Rocker arm
6-Rocker shaft
7-Oil pressure alarm switch
8-Oil pump
9-Fuel injection pump
10-Water pump

Lubrication oil circuit

1. Lube oil circulation

A trochoid rotary pump draws oil in the oil pan and delivers it under pressure to a full-flow oil filter, from which the cleaned oil is forwarded into the oil gallery inside the crankcase. From the gallery, the oil is distributed to the various parts of the engine. The pump is driven from the camshaft.

The oil filter is of a cartridge type containing a replaceable element through which the oil is forced.

2. Oil pump

The pump is located inside the crankcase at its right-hand rear portion. Its main shaft is driven from the skew gear formed of the camshaft.

2-1 Disassembly

(1) Loosen bolts securing oil strainer (2) and separate the strainer from oil pump case.

(2) Loosen bolts (3) securing oil pump cover (4) and separate the cover from oil pump case.

(3) To facilitate removal of outer rotor (5), turn the pump case upside down

(4) Drive out pump drive gear taper pin (6) and remove drive gear (7) from main shaft (8). Pull out the main shaft from pump case.

(5) Drive out inner rotor pin (9) and separate inner rotoro (10) from main shaft.

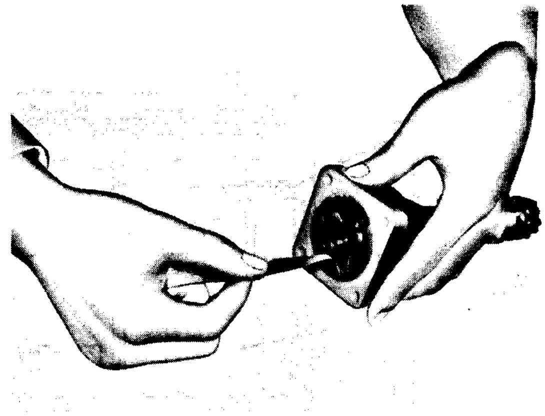
2-2 Inspection

(1) Running clearance between outer rotor and inner rotor

Using a thickness gauge, check the clearance at various positions. If the reading exceeds the service limit, replace both rotors.

Specifications — Unit: mm (in.)

Item	Standard	Service limit
Clearance between inner rotor and outer rotor	0.013 ~ 0.15 (0.00051 ~ 0.0059)	0.25 (0.0098)



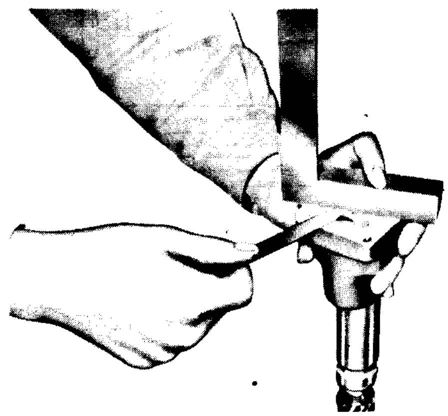
Checking rotor-to-rotor clearance

(2) Sliding clearance between rotors and cover

This clearance is required to be not greater than 0.15 mm (0.00591 in.). If this limit is exceeded, grind off the mating face of the body to reduce the clearance.

Specifications — Unit: mm (in.)

Item	Standard	Repair limit
Clearance between rotors and cover	0.04 ~ 0.09 (0.0016 ~ 0.0035)	0.15 (0.0059)



Checking rotor-to-cover clearance

(3) Radial clearance between outer rotor and pump body

Insert a thickness gauge into between outer rotor and body. If the clearance checked is greater than the limit, replace the worn part.

Specifications — Unit: mm (in.)

Item	Standard	Repair limit
Clearance of outer rotor in body	0.2 ~ 0.275 (0.0079 ~ 0.01083	0.50 (0.020)

Checking rotor-to-body clearance

(4) Rotor shaft diameter

Inspect the shaft for damage, and check it for wear by miking. Determine the available clearance of the shaft in the pump body from the mike readings; if the service limit in terms of clearance value is exceeded or if the shaft is in badly damaged condition, replacement is necessary.

Specifications — Unit: mm (in.)

Item	Standard	Service limit
Rotor shaft diameter	$13^{\ 0}_{-0.015}$ $(0.5118^{\ 0}_{-0.00059})$	
Shaft to body clearance	0.032 ~ 0.074 (0.00126 ~ 0.00291)	0.15 (0.0059)

2-3 Reassembly

(1) Install inner rotor to pump shaft with pin.

(2) Place pump shaft in pump case. Install pump drive gear to the shaft with pin.

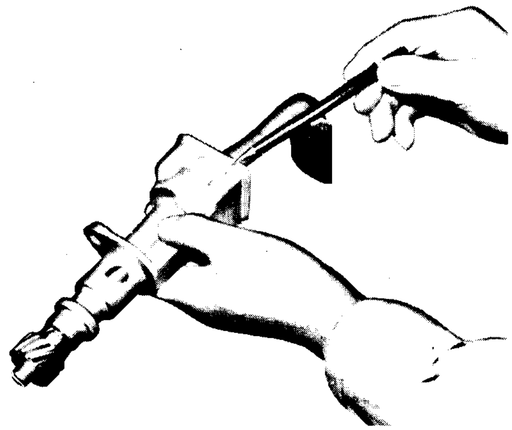
(3) Place outer rotor in pump case, and install pump case cover complete with gasket and oil strainer.

NOTES

a) If pump shaft or drive gear has been replaced, a new pin hole must be made by drilling through the gear mounted on the shaft.

b) After putting on the cover, check to be sure that the match marks are correctly indexed. If the cover is in a wrong position relative to the case, the pump will not draw in oil. Tighten the bolts after checking to be sure that the marks are correctly matched.

c) After reassembling the pump complete with its strainer, immerse the strainer in a pool of oil and run the drive gear by hand to make sure that the pump is capable of sucking oil in.



Fitting cover to case by matching marks

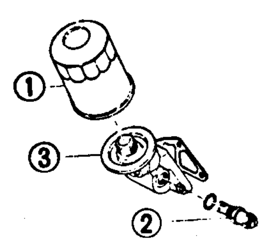
3. Oil filter

The filter is mounted on the right-hand side of crankcase at its center part. The oil bypss valve for letting the oil bypass the element is actually a relief valve located in the center portion of the element. This valve is set to open when the differential pressure across the element rises to 1.0 ± 0.2 kg/cm^2 (14.2 ± 2.8 psi); when the valve opens, the oil flows directly from inlet side to outlet side. The filter element must be serviced regularly or before the element becomes so dirty as to actuate this bypass valve.

The oil filter has a built-in relief valve operating in response to the oil pump discharge pressure. This valve starts relieving when the pressure rises to 3 ± 0.2 kg/cm^2 (43 ± 2.8 psi), thereby bleeding the excess oil to the oil pan and limiting the pressure of oil reaching the engine oil gallery to a constant level.

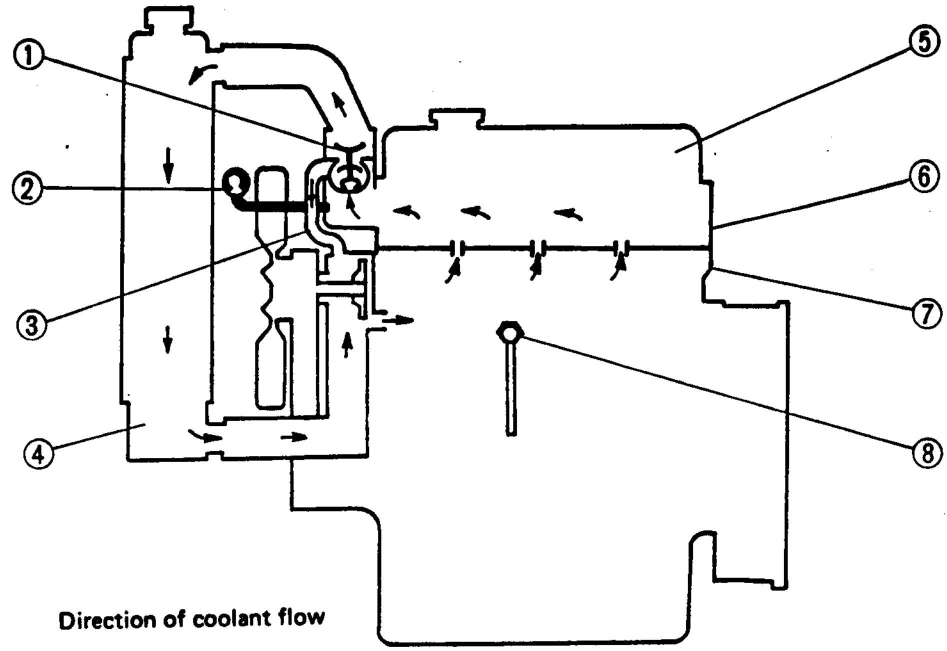
3-1 Disassembly

(1) Remove filter (1) and relief valve (2) from filter bracket (3).



3-2 Inspection

The filtering element is prescribed to be replaced after each 300 hours of operation or whenever its filtering performance is noted to have deteriorated. Inspect the element to see if it has any signs of rupture or fissure; and if so, replace it by a new one. Visually examine the filter bracket for distortion and cracks.



1-Thermostat
2-Water temperature {
3-Bypass hose
4-Radiator
5-Water jacket
6-Cylinder head
7-Crankcase
8-Drain plug

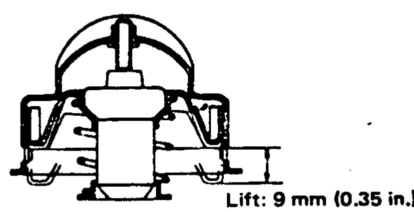
1. Coolant circuit

Referring to the diagram, above, the coolant is set in forced recirculation by the water pump, which is a centrifugal pump driven by cooling-fan belt. The pump draws coolant from the lower tank section of radiator ④ and forwards it to the water inlet of crankcase ⑦.

As the rising coolant temperature reaches 76.5°C (169.7°F), the thermostat valve begins to open increasingly wide and the coolant begins to flow to radiator ④ at a rising rate of flow, with a corresponding decreases in the amount of coolant being bypassed. As the temperature reaches 90°C (194°F), the valve becomes full open, shutting off the bypass passage.

2. Thermostat

The thermostat is of wax type, designed to start opening its valve at 76.5 ± 2°C (169.7 ± 3.6°F) of rising temperature and opens it fully at 90°C (194°F), lifting it off the seat by 9 mm (0.35 in.).



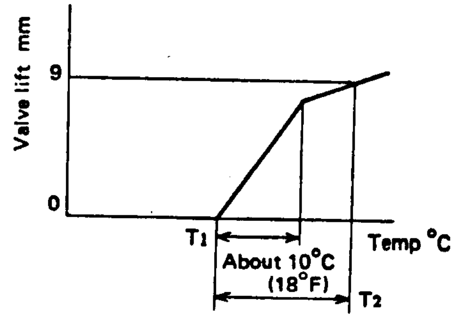
2-1 Disassembly

(1) Remove thermostat cover (2) by loosening bolts (1).

(2) Take out thermostat (3).

2-2 Inspection

Clean the thermostat, place it in a hot-water tub, and test it for thermostatic action by heating the tub to raise the water temperature. The valve should start opening at 76.5 ± 2°C (169.7 ± 3.6°F) and be fully open at 90 ± 2°C (194 ± 3.6°F) with a valve lift of not less than 9 mm (0.35 in.). A thermostat whose valve fails to operate in this manner in the test must be replaced with a new one.



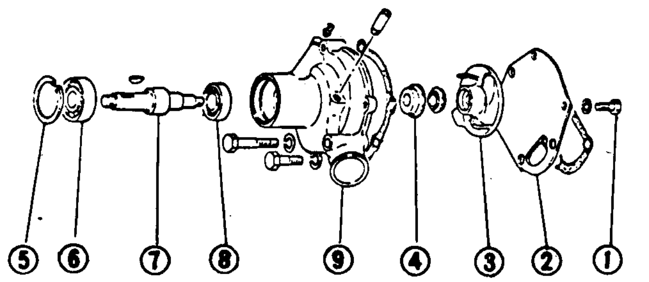
T1 : Temperature [76.5° ± 2°C (169.7° ± 3.6°F)] that makes valve start opening

T2 : Temperature [90° ± 2°C (194° ± 3.6°F)] that makes valve fully open with a lift of not less than 9 mm (0.35 in.)

Thermostat performance curve

3. Water pump

The water pump is of centrifugal type. Its bearings are lubricated by engine oil fed from the main gallery within the crankcase. The impeller is threadedly mounted on the pump shaft.



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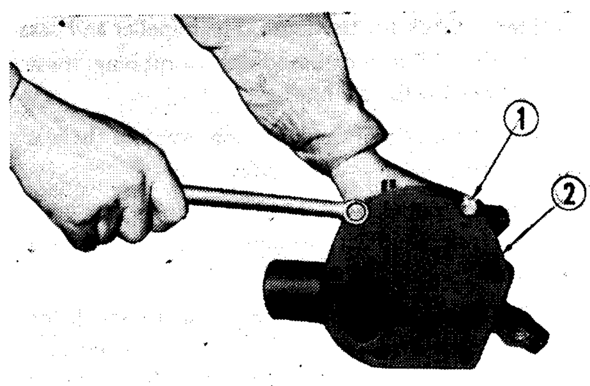
1-Bolt
2-Cover
3-Impeller
4-Unit seal
5-Snap ring
6-Bearing
7-Shaft
8-Bearing
9-Pump case

3-1 Disassembly

(1) Remove pump cover (2) by loosening cover attaching bolts (1).



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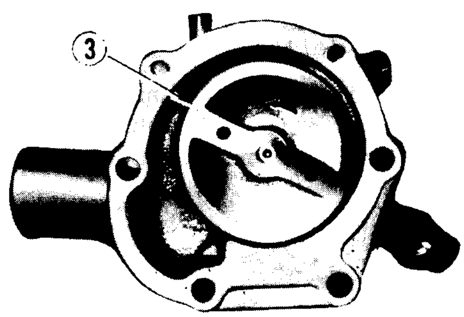
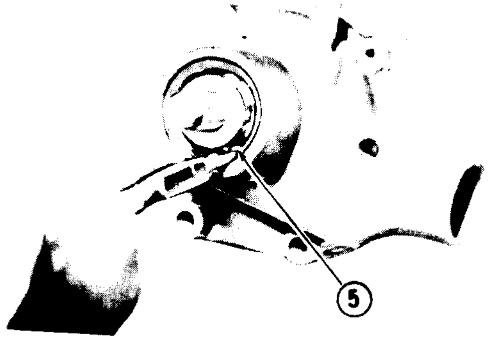
(2) Support the shaft with a stand to remove impeller (3).



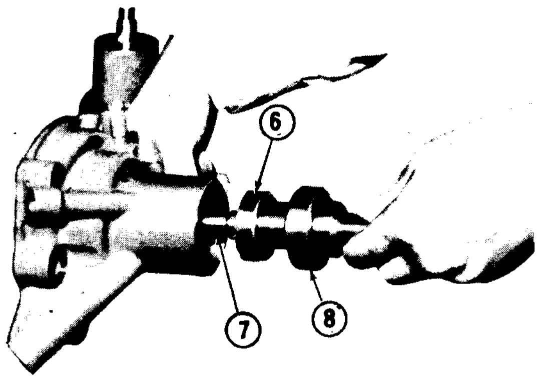
NOTE

Impeller is threadedly mounted on shaft. The thread is of right-hand screw.

(3) Remove snap ring (6) from the water pump shaft.



(4) Pull shaft (8) off the pulley side on pump case and remove bearings (7) and (9) from the shaft.



3-2 Inspection

(1) Examine the pump operation by slowly rotating it. If the pump is erratic in rotation, replace the bearings with new ones.

(2) Visually check the impeller for corrosion or breakage. Replace a defective impeller. Also check the impeller for signs of rubbing. If such rubbing is evident, check for the cause. The impeller and case or covèr, if found damaged due to rubbing, must be replaced with new ones.

(3) Check the unit seal for condition. Replace the seal if it is badly worn or damaged.

(4) Check the pump shaft bearing journals for wear. Replace the shaft if the journals are excessively worn.

(5) Check those surfaces of pump case to which the bearings are fitted for excessive wear or damage. Replace the case or the pump assembly if the case is found in bad condition on those surfaces.

NOTE

Upon assembling the water pump, turn it by means of the pulley, making sure that the pump rotation is smooth without signs of binding.

3-3 Reassembly

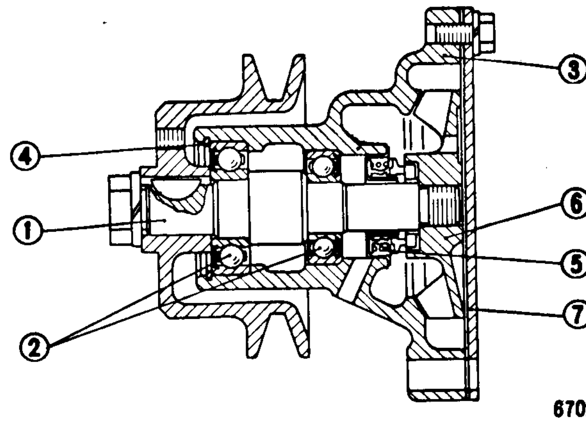
(1) Install bearings (2) on pump shaft (1) and install the shaft in pump case (3).

(2) Install snap ring (4) in case on pulley side.

(3) Install unit seal (5) in impeller (6) and secure the impeller to the shaft.

(4) Install cover (7).

(5) Rotate the shaft to check to see that the impeller does not interfere with cover.



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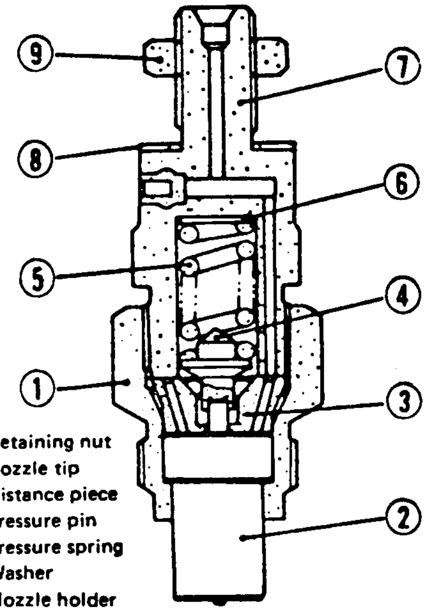
5. Injection nozzles

The injection nozzle provides a means of spraying into the precombustion chamber the fuel oil delivered under pressure from the injection pump. It sprays oil out in a conical pattern consisting of finely atomized droplets of oil. The mating surfaces of the nozzle holder body, distance piece and nozzle are precision-finished to form an oil-tightness.

The injection pressure adjustment may be made by means of adjusting washer. Increasing the thickness of the washer will increase the spring tension and, hence, the injection pressure, and vice versa.



1-Retaining nut
2-Nozzle tip
3-Distance piece
4-Pressure pin
5-Pressure spring
6-Washer
7-Nozzle holder
8-Gasket
9-Nut

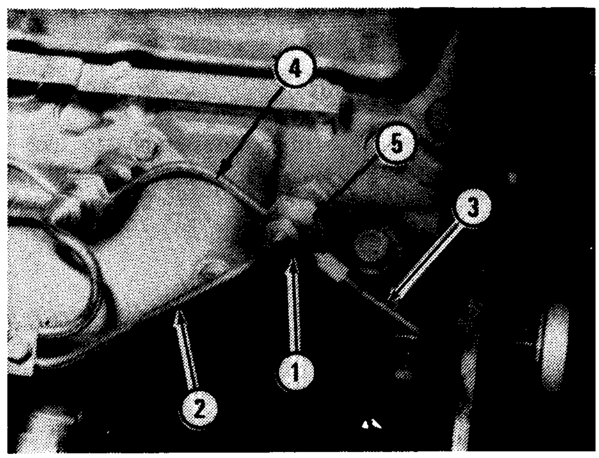
5-1 Removal

(1) Remove injection pipe connectors (1) to disconnect injection pipes (2).

(2) Disconnect leak-off pipe (3) (4) connecting nozzles by loosening nuts (5).

(3) Using a wrench, remove nozzles from cylinder head as shown. Also remove nozzle packings with a wire or screw driver. Replace a defective packing, if any.

(4) Install injection nozzles in the reverse order of removal. Tighten nozzle holders to a torque of 5 kg-m (36.2 lb-ft).



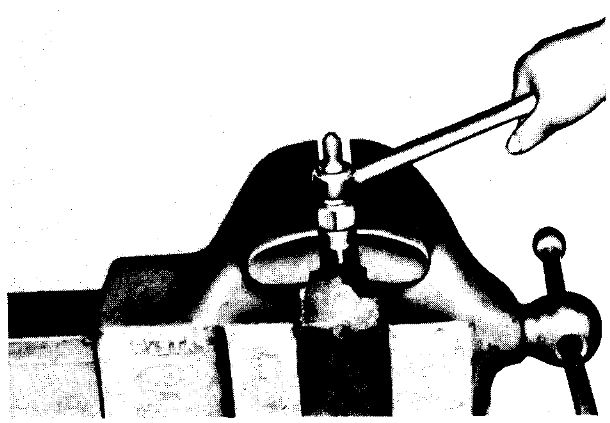
NOTE

Cover the injection pipe and cylinder head openings to prevent entry of dust or foreign matter after removing the nozzles.

5-2 Disassembly

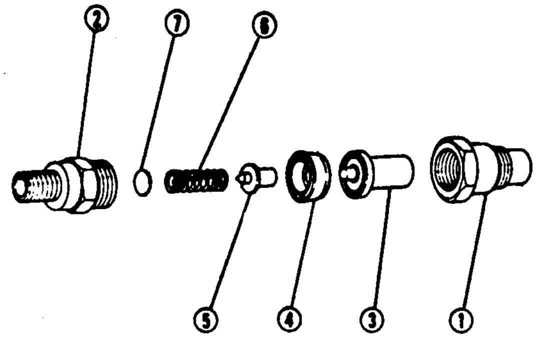
(1) Before disassembling injection nozzles, check the nozzle injection beginning pressure, the spray pattern and adjust if necessary. Carry out oil-tightness test and repair if necessary.
Exercise care not to damage the points of needle valves during disassembly, washing and assembly of nozzles.

(2) Hold retaining nut (1) in a vice and loosen nozzle holder (2) with a wrench.



(3) Remove nozzle tip (3), distance piece (4), pressure pin (5), spring (6) and washer (7) from nozzle holder.

(4) All the parts disassembled should be washed in clean kerosene and dried with compressed air. Decarbon the nozzles removed with a wooden scraper and clean them thoroughly in gasoline.



5-3 Inspection

(1) Needle valve and nozzle body

(a) Immerse needle valve and nozzle body in a pool of clean kerosene, insert the valve into the body, and move the valve back and forth to be sure that the sliding contact is smooth without evidencing any excessive clearance. The injection nozzle as a whole must be replaced if the fit is found defective.

(b) Visually examine the nozzle body with a magn. fying glass having a power of 4 or 5.

(c) Inspect the needle valve for distortion or damage at its seating part and for wear of its end face in contact with the pressure pin.

(d) Poor seating contact may be corrected, if the defective condition is not advanced too far, by lapping the valve against the seat with a coat of clean lube oil applied to the seating faces. If this does not help, the injection nozzle must be replaced.

(2) Nozzle holder and distance piece

Check the fit between nozzle holder and distance piece. Determine the quality of the fit from contact patterns obtained with the use of red lead paste: defective fit will be evidenced by an abnormally high rate of return oil (leak-off) flow.

(3) Pressure spring and pressure pin

(a) Replace any pressure spring broken, cracked or otherwise defective, or out of square. Inspect each spring for these defects.

(b) Inspect each pressure pin for wear at its end faces, one for pressure spring and the other for needle valve.

(4) Leak-off pipe packing

If the packing is found in deteriorated condition, replace it.

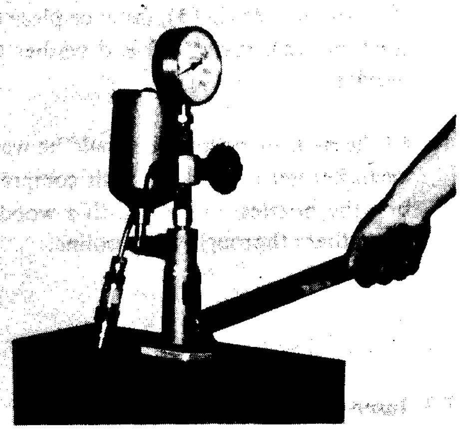
5-4 Testing and adjustment

(1) **Injection pressure**

The pressure at which the needle valve unseats itself against the force of the pressure spring is referred to as "valve opening pressure" or "beginning-of-injection pressure," but will be called here "injection pressure" for short. The value of this pressure is specified; it is checked and adjusted as follows:

(a) Install the injection nozzle in the nozzle tester, and operate the manual pumping handle of the tester several strokes to prime the nozzle.

(b) Move the lever up and down slowly, completing each up-and-down cycle in about a second, to pressurize the injection nozzle, while observing the indication of the test pressure gauge. As the nozzle begins to spray, the indicating pointer of the gauge being deflected will start perceptively oscillating: read the pressure right then as the injection pressure.



Specifications Unit: kg/cm² (psi)

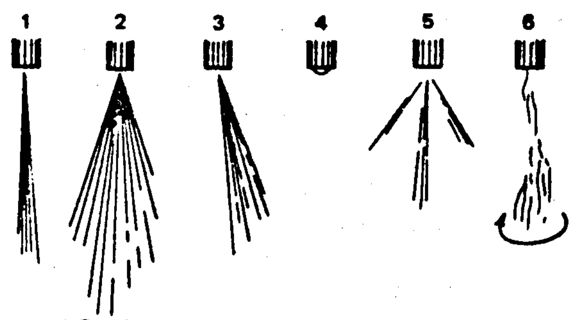
Item	Standard	Repair limit
Injection pressure	120^{+10}_{0} $(1706.4^{+142.2}_{0})$	110 (1564.2), minimum

(c) If the reading taken is below the limit, increase the thickness of the shim used on the pressure spring. Increasing the shim thickness by 1 mm (0.04 in.) raises the injection pressure by about 10 kg/cm² (142 psi). Adjusting shim stock for this purpose is available in 20 sizes, from 1.0 mm (0.0394 in.) up to 1.95 mm (0.0768 in.) in increments of 0.05 mm (0.0020 in.) each.

(2) **Spray pattern**

The injection nozzles used in the present engine are of throttle type. Some throttling action takes place when the needle valve begins to unseat, thereby limiting the amount of fuel being sprayed out during the initial stage of each fuel injection. Thus, each slug of fuel sprayed out may be regarded as consisting of two parts: initial throttled spray and terminating main spray.

When tested on the nozzle tester, the injection nozzle can be made to produce these two kinds of spray for visual inspection. Initial throttled spray comes about when the tester lever is operated at a rate of 60 cycles per minute (up and down in one second); terminating main spray occurs when the lever is operated rapidly at a rate of, say, 4 to 6 cycles per second.



1-Good
2-Spray cone too large
3-Off-center spray
4-After-dribble
5-Fissured spray
6-Whirling spray

Possible patterns of spray

(a) Initial throttled spray

When the nozzle is producing only this spray, atomization is generally poor and the pattern is rather straight than conical, there being more or less after-dribble, that is, fuel dribbling after injection. All these are due to the fact that the fuel being injected is being throttled by the pintle prptruding from the valve.

While the nozzle is making this spray, see if the needle valve chatters in synchronism with the cyclic motion of the lever; if so, then the needle valve is free from any sticking or hitching tendency and, if not, the nozzle and needle valve must be cleaned by washing and re-tested.

Off-center spray or directionally erratic spray, if noted, should be taken to mean that the injection nozzle needs thorough cleaning.

(b) Terminating main spray

With the tester lever operated at a rate of 4 to 6 cycles per second, the initial throttle spray is hardly visible. The spray under this condition may be regarded as main spray.

The main spray should be a good straight cone, consisting of finely atomized fuel particles without any large droplets, and should terminate with no dribble at the tip, not to mention of any fuel dripping.

(3) Seating tightness

An injection nozzle tested and adjusted as above, and found to produce a good spray pattern may be re-used in the engine provided that it passes this final test – seating tightness test. .

With the injection nozzle mounted on the nozzle tester, raise the pressure slowly to 100 or 110 kg/cm^2 (1422 or 1564 psi) (without exceeding the set pressure of 120 kg/cm^2 (1706 psi), so that the needle valve will not unseat). Hold the pressure and observe the nozzle tip: there should be no evidence of fuel oozing out to form a dribble. If such evidence is noted, then the contacting faces of the needle valve and seat must be repaired by lapping in the manner already suggested or the injection nozzle as a whole must be replaced.

5-5 Reassembly

Assemble injection nozzles in the reverse order of disassembly. Be sure to assemble nozzle assembly in kerosene.
When using new needle vavles, remove sealing cover (synthetic resin) from the valves and wash them in kerosene to remove rust and corrosion inhibitor sprayed over them by sliding the valves in the nozzles immersed in kerosene.

NOTE

If the needle valve and nozzle proper have to be replaced, be sure to wash the replacement parts in the pool of kerosine after removing their protective film of plastic: wash off the rust-preventive oil from the nozzle proper by stroking the needle valve back and forth in the needle valve stem bore.

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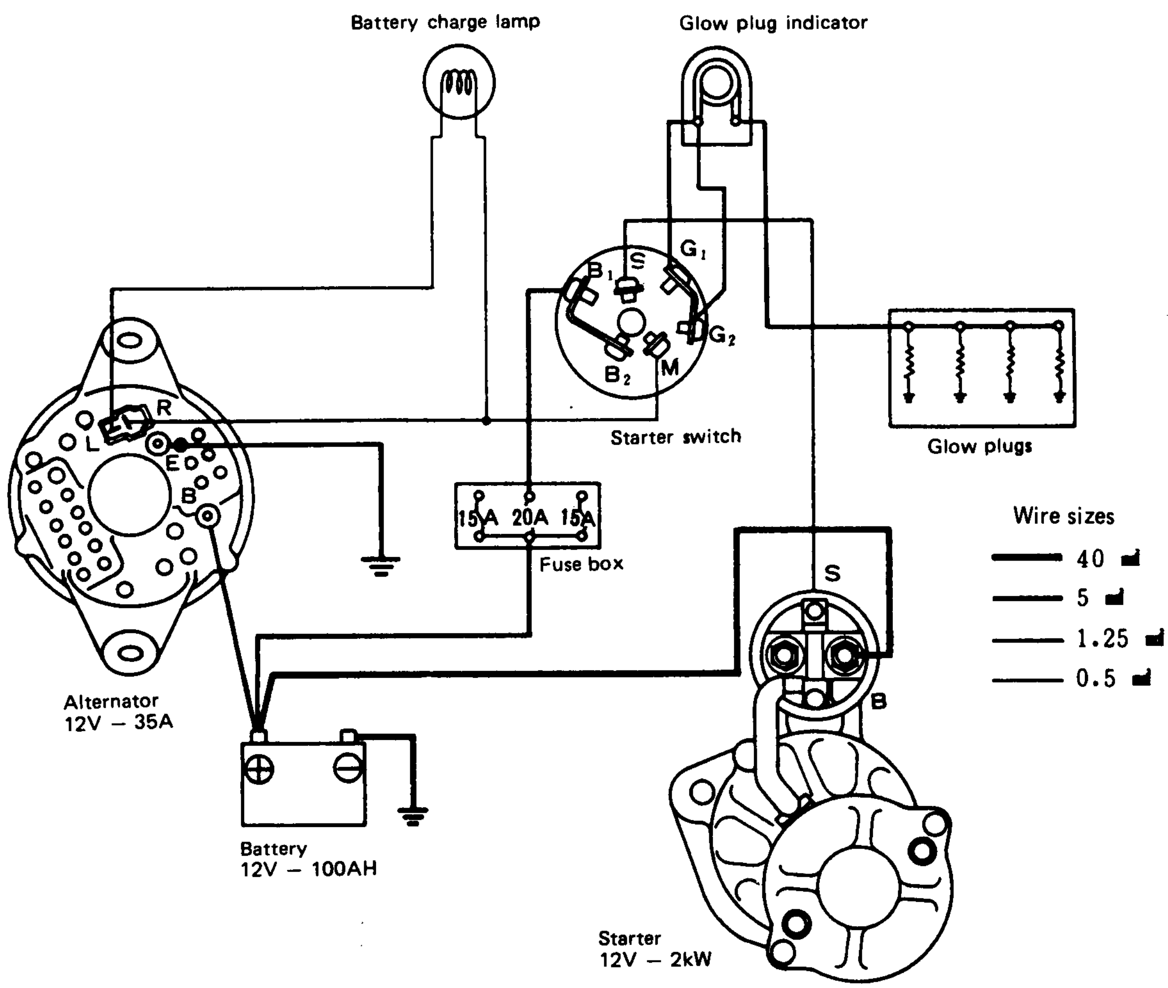
1. General

	Model	Manufacturer
Starter	M002T54172	Mitsubishi Electric
Alternator	A001T25070	Mitsubishi Electric
Glow plugs	Sheathed type	Hiyoshi Electric



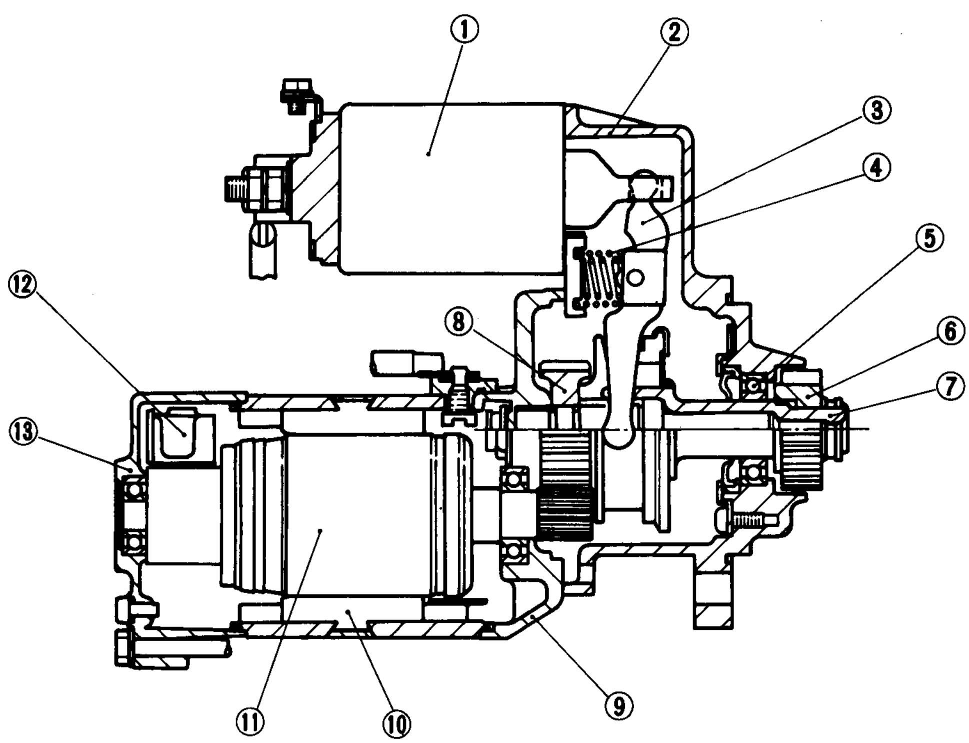
Wiring diagram

1-1 Starter

(1) Tabulated data

Model	M002T54172
Type	Pinion-shift type with overrunning clutch
Voltage	12V
Output	2 kW
Armature winding	Series
Yoke diameter	80 mm (3.15 in.)
Rating	30 seconds
Rotation	Clockwise as viewed from pinion side
Weight	5.8 kg (12.8 lb), approx.

Performance item	Condition	Specification	
No-load characteristics	Voltage: 11 V	Current Speed	130 A, max. 4000 rpm, min.
Locked characteristics	Voltage: 3 V	Current Torque	1000 A, max. 2.8 kg·m (20.3 lb·ft), min.
Switch-in voltage		8 V, max.	



1-Switch assembly
2-Front bracket
3-Lever assembly
4-Spring set
5-Bearing
6-Pinion
7-Pinion shaft
8-Gear
9-Center bracket
10-Yoke
11-Armature
12-Brush holder
13-Rear bracket

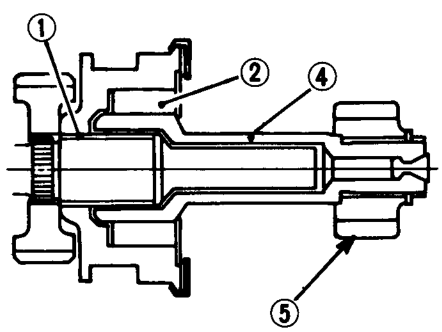
(2) Reduction gear train and overrunning clutch

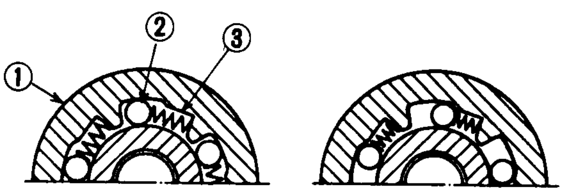
The inner end of armature shaft carries a drive gear which is in mesh with a driven gear splined to the pinion shaft to provide speed reduction. The pinion shaft is fitted loosely to the outer race of overrunning clutch through helical spline engagement. The pinion is fitted to the sleeve – the inner race of the clutch – and held in place by a snap ring.

Five clutch rollers are fitted between the outer race (thrust splines) and inner race (sleeve) of overrunning clutch, each being pressed against the cam face internally formed of the outer race by a spring.

Thus the drive or torque is transmitted from the armature shaft through the reduction gears, pinion shaft, thrust splines (clutch outer race), rollers and sleeve (clutch inner race) to the pinion.

(3) Overrunning clutch operation





Pinion meshed in flywheel

Engine starts

1-Outer race
2-Roller
3-Spring
4-Inner race
5-Pinion

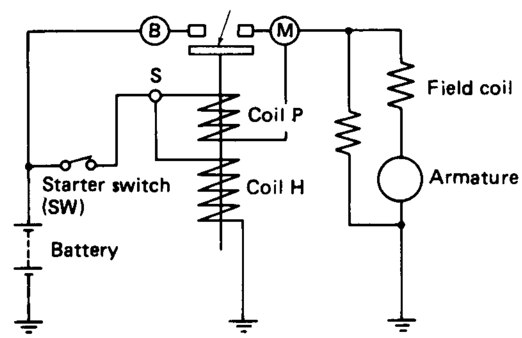
(a) Pinion meshed in flywheel

As the outer race rotates, the rollers are jammed tight between the inner and outer races to lock these races. Now the torque from the armature is transmitted from the outer race to the inner race and then to the pinion.

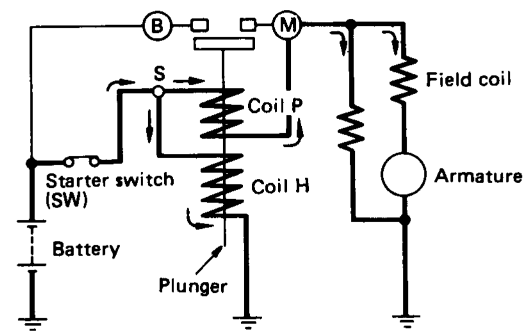
(b) After the engine starts, it spins the pinion (inner race) faster than outer race. The rollers are rotated into the free state by the springs to unlock the inner and outer races. This allows the pinion to spin independently of, or overrun, the remainder of the clutch.

(4) Starter operation

(a) Starter switch (SW) in OFF position

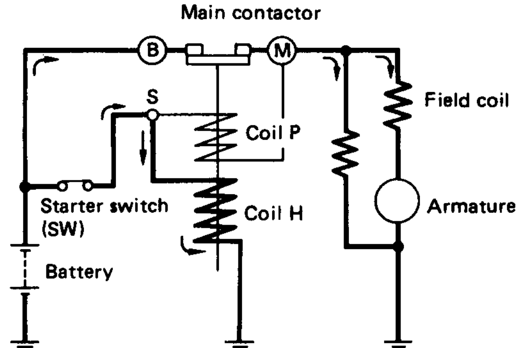


(b) Starter switch (SW) turned to ON position



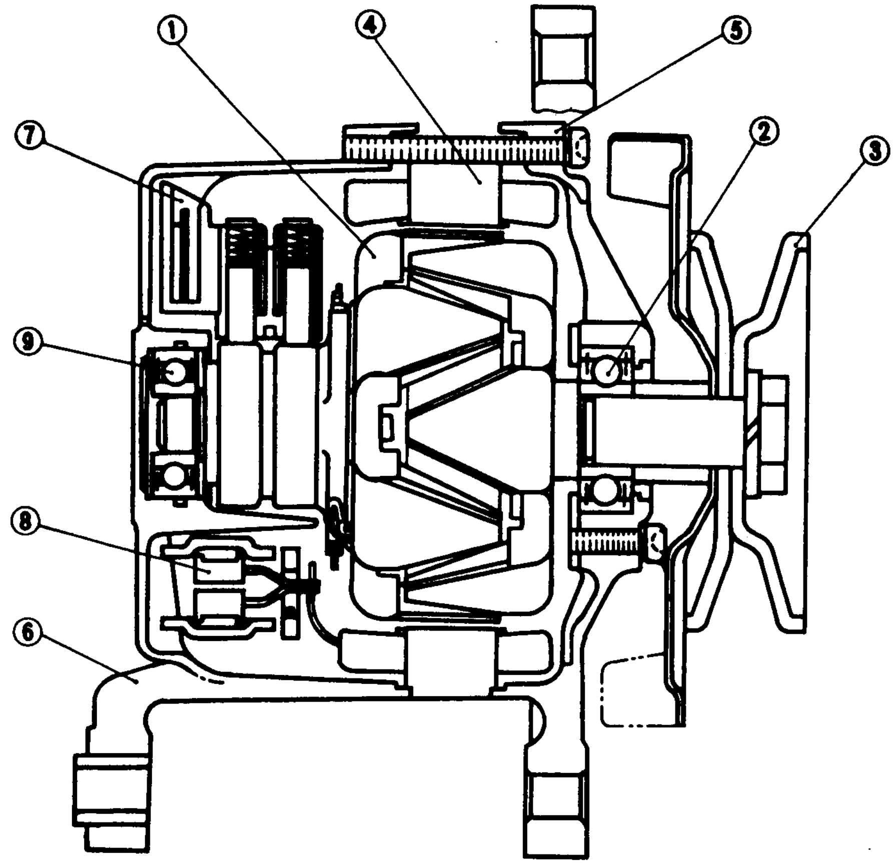
The plunger is pulled. This allows the lever to push the pinion into mesh with the flywheel ring gear. Now the starter begins to crank the engine.

(c) Starter switch (SW) in ON position (with contactor closed)



A large current flows into the motor. The starter now cranks the engine with full force while picking up speed at the same time.

1-2 Alternator



1-Rotor
2-Bearing
3-Pulley
4-Stator
5-Front bracket
6-Rear bracket
7-IC regulator
8-Rectifier
9-Bearing

(1) Tabulated data of alternator

Model designation	A001T25070
Nominal output	12 V – 35 A
Polarity of ground	Negative
Outside diameter	114 mm (4.48 in.)
Direction of rotation	Clockwise as viewed from pulley side
Weight	3.4 kg (7.5 lb)
Regulator	IC type
Voltage regulation	14.4 ± 0.3 V

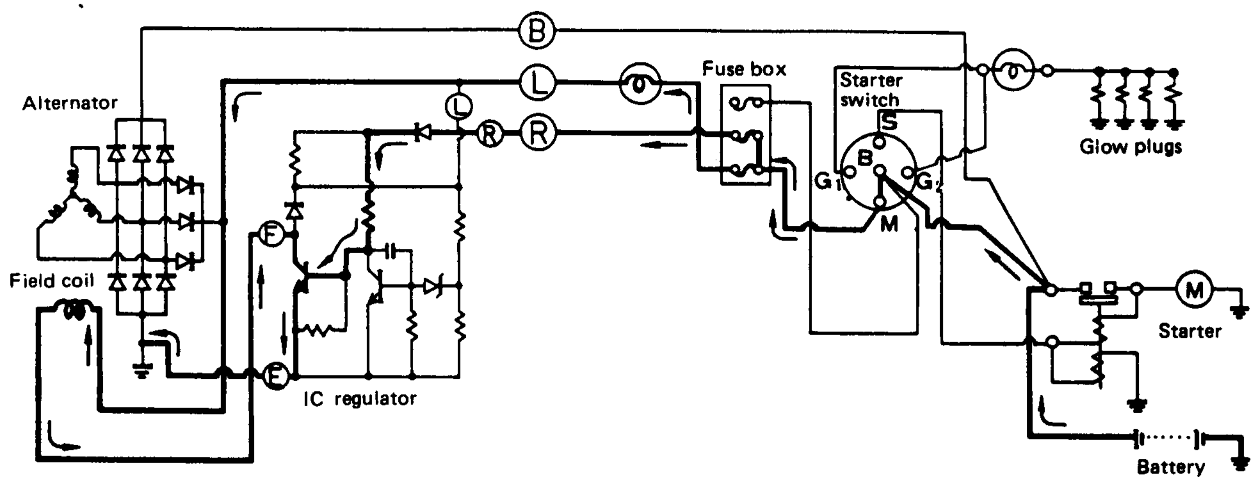
(2) Construction of alternator

This alternator has a built-in IC regulator. The rotary parts are: rotor, ball bearings, fan and pulley. The stationary parts are: stator, front bracket and rear bracket.

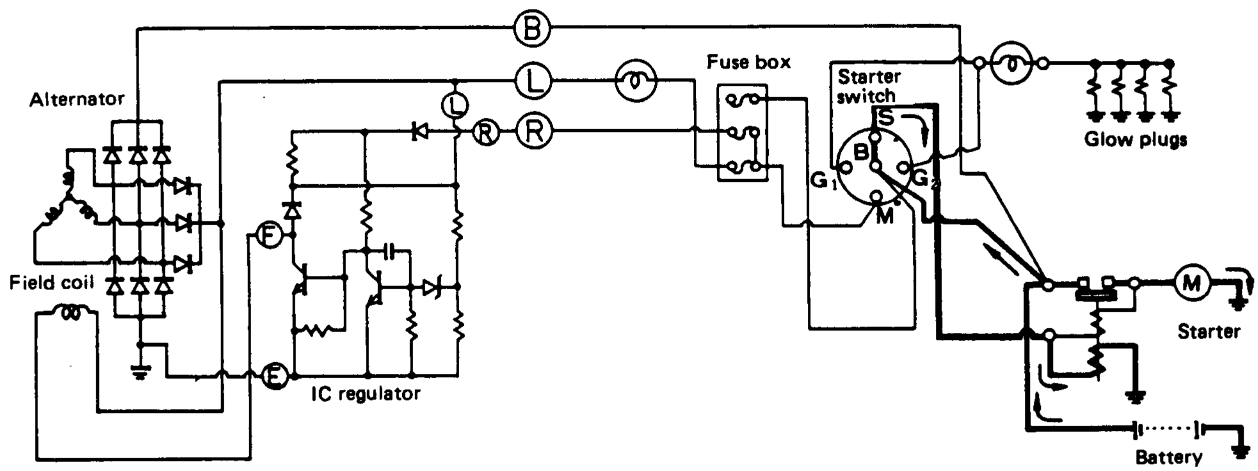
The rectifier consists of a total of six diodes: three diodes on the positive side are mounted on the heat sink and the other three on the negative side are mounted on the rear bracket.

(3) Alternator operation

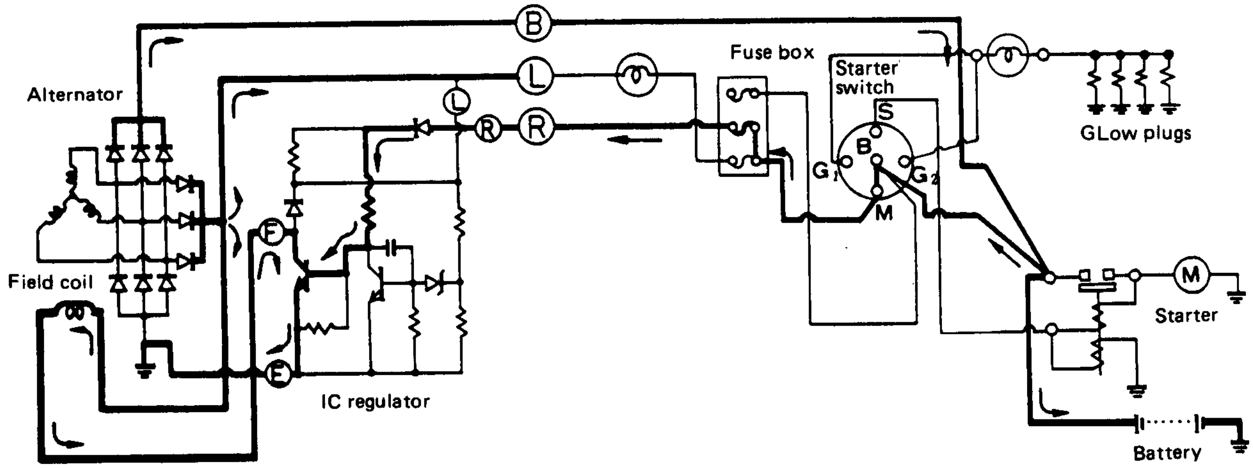
(a) Starter switch in M position



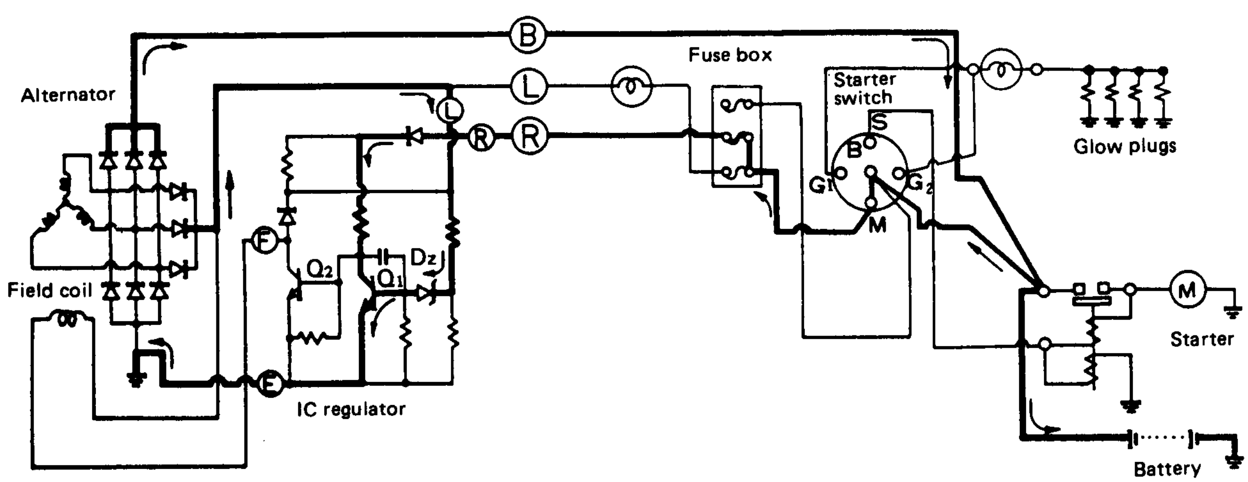
(b) Starter switch in S position and starter operates



(c) Engine starts and alternator charges battery



(d) Alternator charges battery excessively



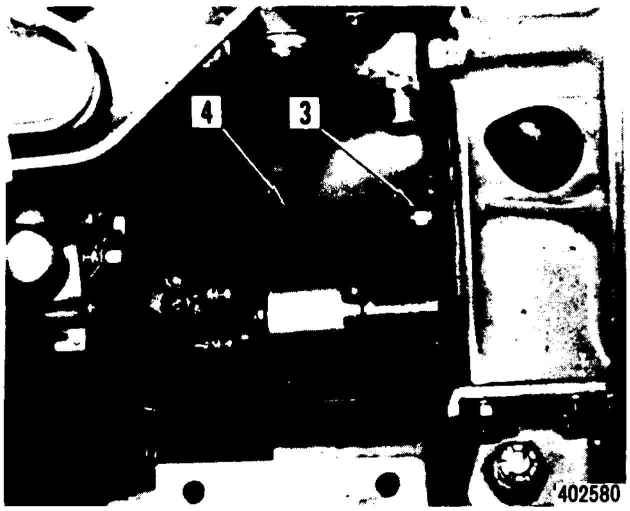
As alternator output voltage rises higher than the regulated voltage, zener diode DZ permits the current to flow to the base of transistor Q_1.
As transistor Q_1 turns on, the current flows from the three diodes to transistor Q_1, causing transistor Q_2 to turn off. Under this condition, the field current is reduced to weaken excitation of the rotor and, consequently, output voltage begins to fall.

When output voltage has sufficiently dropped, zener diode DZ permits no current to flow. Now transistor Q_1 turns off and transistor Q_2 turns on and, consequently, the field current increases and output voltage rises again. This process is endlessly repeated to keep output voltage at a virtually constant level.

2. Starter removal and installation

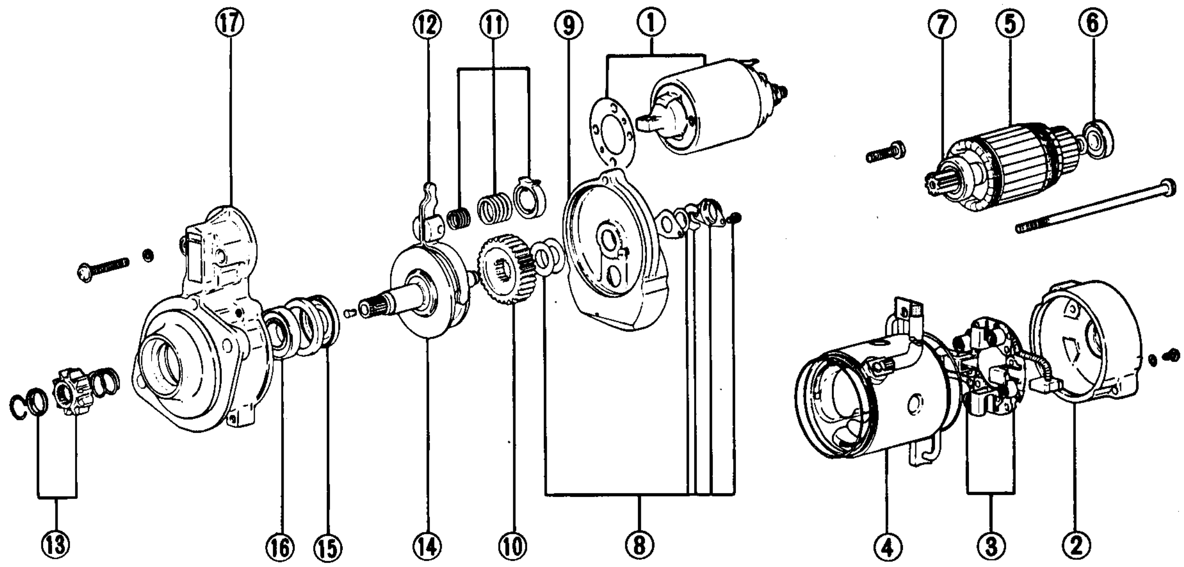
(1) Disconnect wire (1) between the battery and starter and wire (2) between the starter and starter switch.

(2) Unscrew mounting nuts (1), and remove starter assembly (2) from the engine. To install, follow the reverse of removal procedure.



1-Nut and washer (2 pcs each)
2-Starter assembly

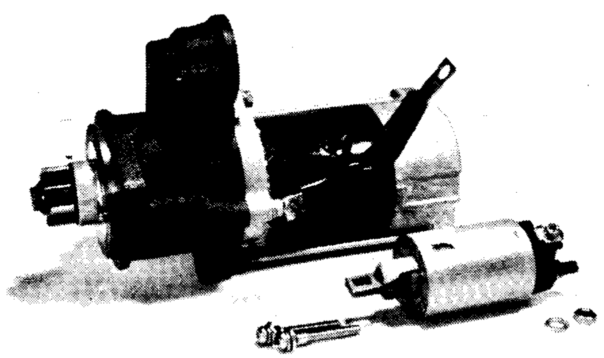
3. Starter disassembly and reassembly



1-Switch	10-Gear
2-Rear bracket	11-Spring set
3-Brush holder	12-Lever
4-Yoke	13-Pinion set
5-Armature	14-Pinion shaft
6-Ball bearing	15-Oil seal
7-Ball bearing	16-Ball bearing
8-Cover set	17-Front bracket
9-Center bracket	

(The parts are numbered in the sequence of removal for disassembly.
To reassemble, follow the reverse of disassembly procedure.)

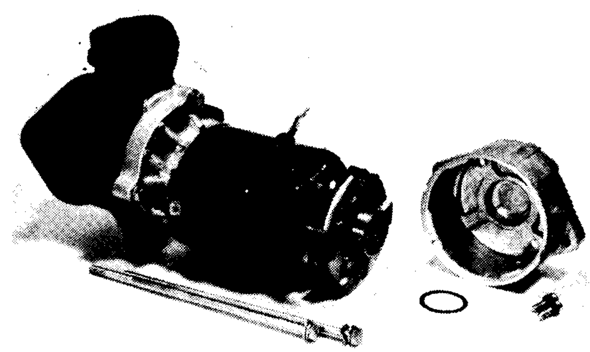
(1) Loosen the nut on the switch terminal (M), and remove the connector. Remove the switch by pulling the screws (2 pcs).



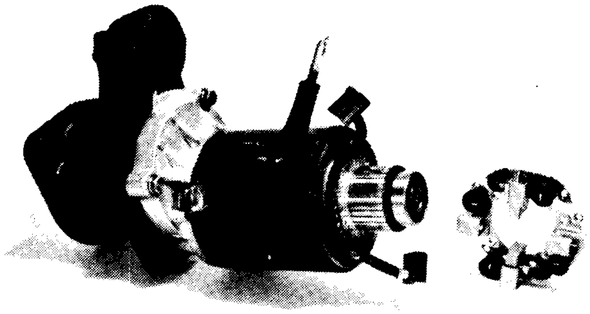
(2) Pull the through bolts (2 pcs), remove the brush holder screws (2 pcs) and remove the rear bracket.

NOTE

Take care not to drop the washers which are used in the rear bracket.



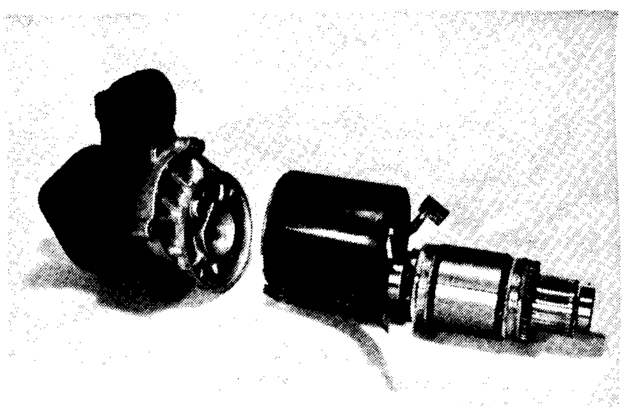
(3) Remove two brushes on the positive side, and take off the brush holder.



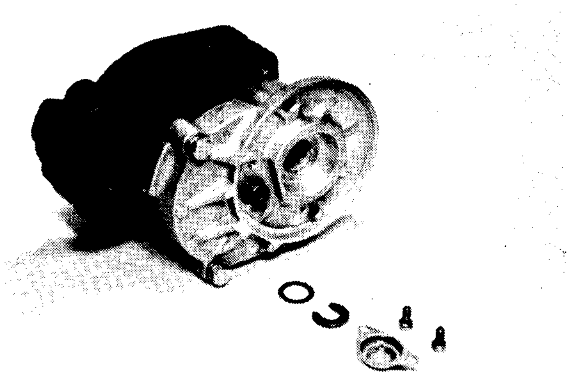
(4) Remove the yoke, and pull off the armature.

NOTE

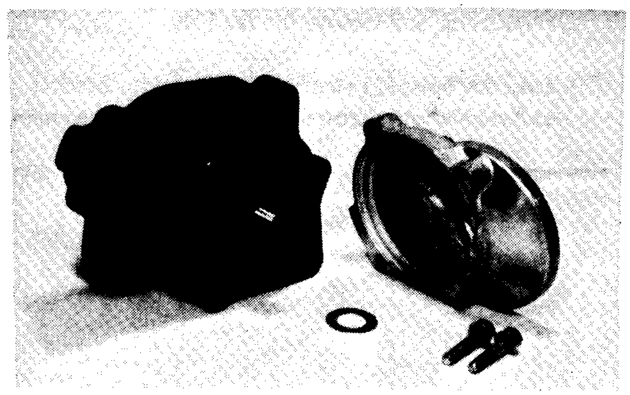
Replace rubber packings fitted to the ends of yoke with new ones. Check and record the position of locating notch for the yoke.



(5) Remove the cover, and take off the washer and snap ring.



(6) Remove the center bracket by unscrewing two bolts. Remove washers (several pieces) for adjusting the pinion shaft axial play.

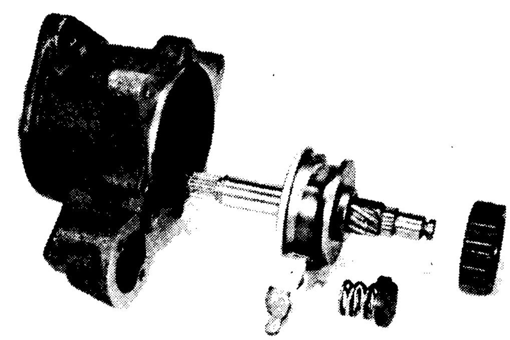


(7) Remove the snap ring holding the pinion, and remove the pinion.

(8) Remove the lever springs (large and small), lever, reduction gears, pinion shaft, etc.

NOTE

Lay the lever and springs in the order removed so that they can be restored to their original positions.

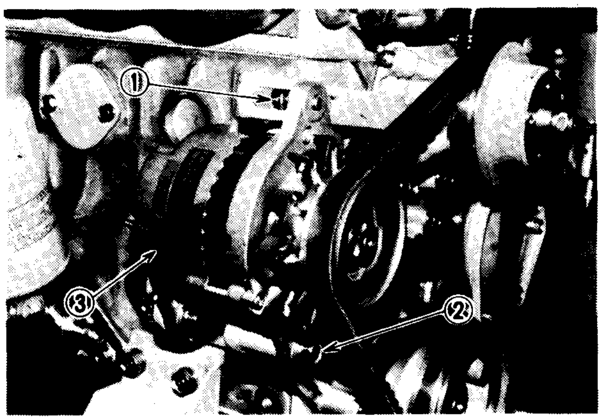


(9) Replace the ball bearings. The ball bearings fitted to the ends of armature can be removed with a bearing puller. The front bracket bearing and sleeve bearing (fitted to the inner race of ball bearing) cannot be removed for replacement. These bearings are to be replaced as an assembly including the front bracket.

4. Alternator removal and installation

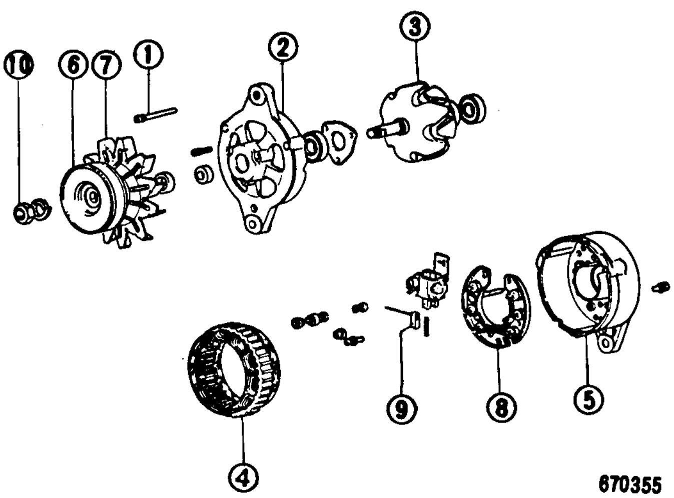
(1) Disconnect wire (1) between the alternator and relay and ground harness, unscrew the adjusting plate bolts, and remove the fan belt.

(2) Unscrew bolts (2) securing the alternator bracket, and remove alternator assembly (3) from the engine.



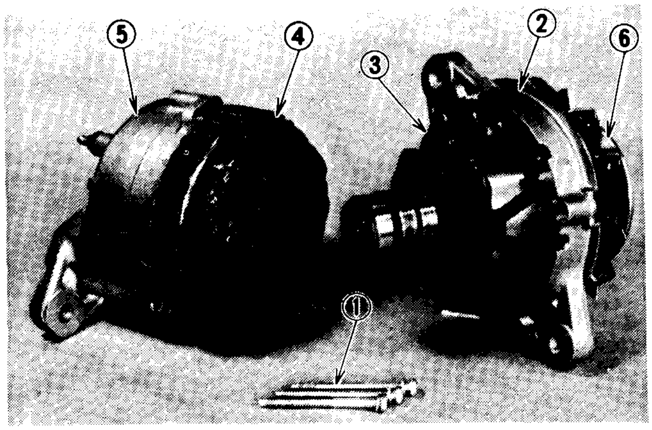
1-Bolt and washer
2-Bolt, nut and washer (2 pcs each)
3-Alternator assembly

5. Alternator disassembly and reassembly



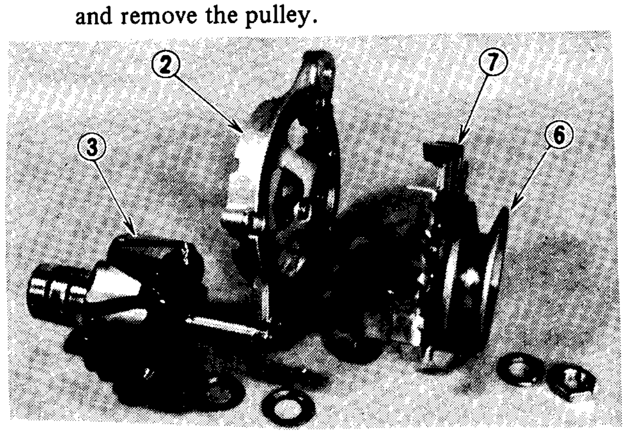
1-Bolt (3 pcs)	6-Pulley
2-Front bracket	7-Fan
3-Rotor	8-Diode
4-Stator coil	9-Brush
5-Rear bracket	10-Nut

(1) Pull the three through bolts, and break the alternator into the rotor (complete with front bracket and pulley) and stator (complete with rear bracket).



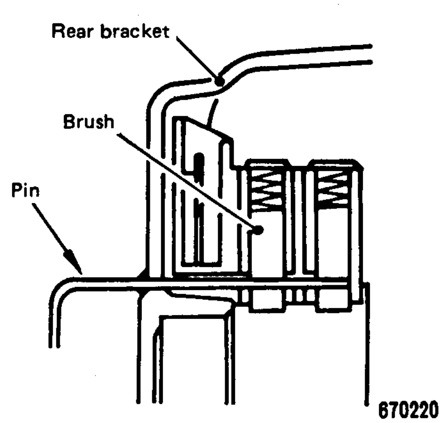
1-Bolt (3 pcs)	4-Stator coil
2-Front bracket	5-Rear bracket
3-Rotor	6-Pulley

(2) Hold the rotor in a vise. Unscrew the pulley nut, and remove the pulley.



2-Front bracket	6-Pulley
3-Rotor	7-Fan

(3) To reassemble, follow the reverse of disassembly procedure. Lift two brushes up into the brush box and pass a pin through the screw holes in the box and brushes to keep the brushes depressed. After reassembling the alternator, be sure to remove the pin.

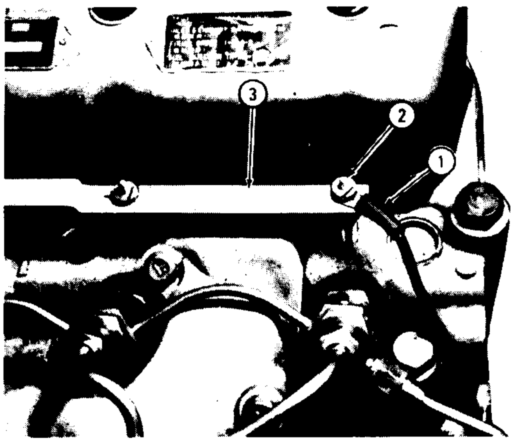


6. Preheating system

Removal and installation of glow plugs

(1) Before removing glow plugs from the engine, be sure to disconnect battery terminals.

(2) Disconnect cable (1) from No. 4 cylinder glow plug. Loosen glow plug connection plate attaching nut (2) and remove connection plate (3).



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1-Cable 3-Connection plate
2-Nut

(3) Remove all glow plugs from the cylinder head. Take out packings from glow plug installation holes.

(4) To install, follow the reverse of removal procedure.

7. Inspection and adjustment

7-1 Starter

(1) Inspection before disassembly

(a) Checking the starting circuit for operation

With the starter in place, check to be sure that –

1) The battery is in good condition, with its cell plates showing no evidence of "sulfation" or any other faulty condition, and is in fully charged state.

2) The battery terminal connections are clean and tight.

3) The starter terminal connections are tight.

4) The wires are securely connected to terminals, and are free of any insulation stripping due to fraying, there being no signs of grounding or breaking.

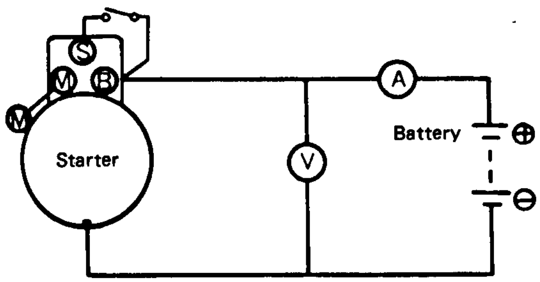
5) The starter switch closes and opens the circuit positively at each position.

Do not jump into a conclusion that the starter is in trouble when the engine refuses to fire up upon cranking: the engine could be in trouble.

(b) No-load test

If the starter is suspected of trouble, take it down from the engine and run a no-load test on it to find out if it is really in trouble.

When removing the starter, be sure to have the battery switch turned off.



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No-load test circuit

Here's how to carry out the no-load test: Form a test circuit with a voltmeter and an ammeter, as shown, using a fully charged 24-volt battery; close the switch to run the starter until its speed rises to and above 4000 rpm; and then read the voltmeter and ammeter when the starter is spinning. The ammeter should show that the starter is drawing not more than 130 amperes, with the voltmeter indicating at least 11 volts (at the speed of at least 4000 rpm); if not, estimate the cause of the trouble by consulting the troubleshooting guide, which follows:

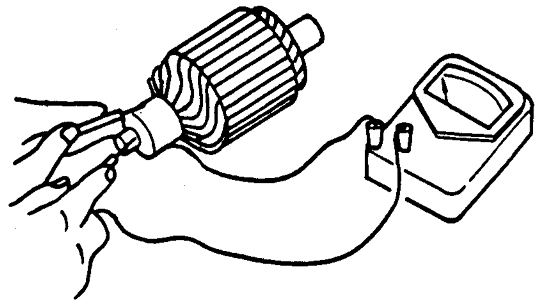
Starter troubleshooting guide

Symptom	Possible cause
Large current and low speed	1) Bearings are dirty, or need lubrication. 2) Rotor (armature core) is rubbing the pole pieces. 3) Grounded coil in the armature or in the field. 4) Short-circuit in the armature coils.
Large current but no speed	1) Magnetic switch is grounded and is not working. 2) Grounded coil in the armature or in the field. 3) Seized bearing.
No current and no speed	1) Open-circuited coil in the armature or in the field. 2) Broken brush pigtail. 3) No conduction between brushes and commutator because of "high mica" condition or dirty commutator surface.
Small current and low speed and torque	Loose coil connection in the field.
Very large current, very high speed and low torque	Short-circuited field coil.

The best way of testing the starter is to run it under loaded condition, but that requires special testing equipment. For ordinary servicing purposes, the no-load test and troubleshooting guide will do.

(2) Inspection after disassembly

(a) Using a ground tester or megger, check armature coil and commutator for short circuit. If there is any continuity between commutator and armature shaft, armature coil and commutator are short circuited.



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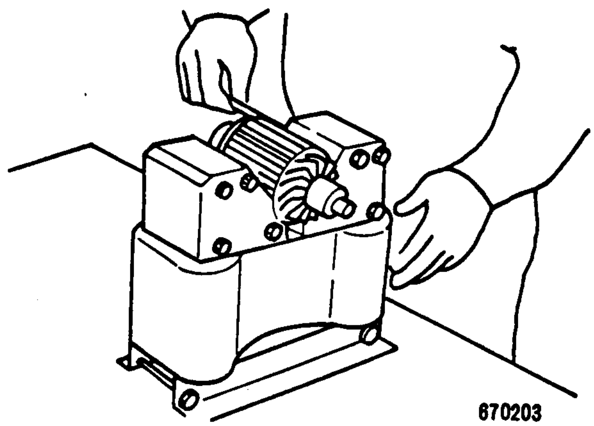
(b) A growler is generally used to test armature for short circuit in its winding. Place armature on a growler, and rotate it slowly while holding a steel strip over armature. If there is any short circuit between cores, the strip will vibrate and be attracted to armature. If so, replace armature.



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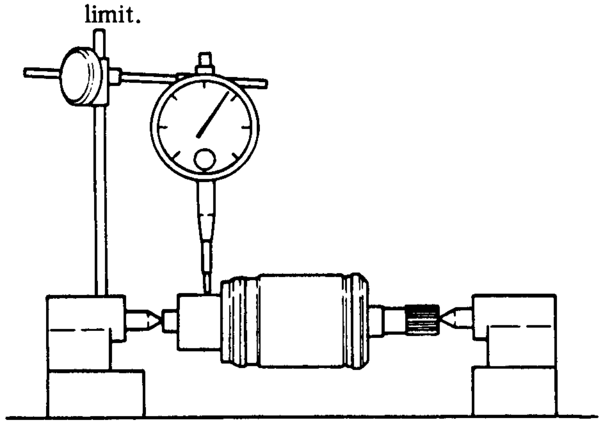
(c) Measure commutator runout with a dial gauge. Repair commutator if the runout exceeds the limit.

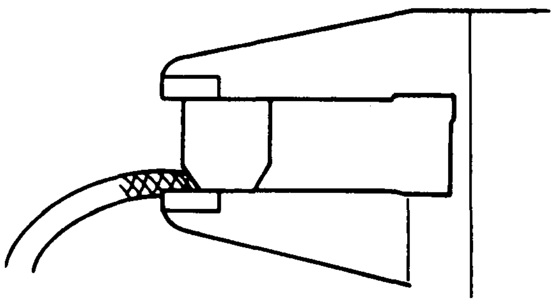


Specifications Unit: mm (in.)

Item	Assembly standard	Repair limit	Grinding limit
Commutator runout	0.05 (0.0020)	0.3 (0.012)	31 (1.22)

(d) Brushes and brush springs

1) Measure brush length. Replace brush if the length exceeds the service limit.



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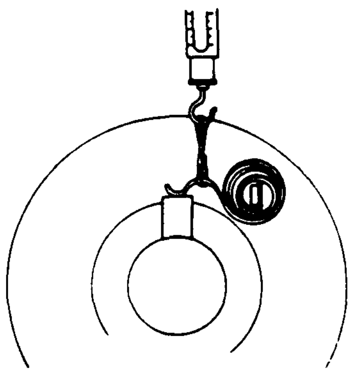
Specifications Unit: mm (in.)

Item	Assembly standard	Service limit
Brush length	18 (0.71)	11 (0.43)

2) Using a spring balance and new brush, check spring pressure. Replace spring if the pressure is below the service limit.

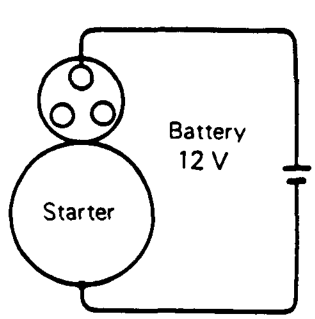


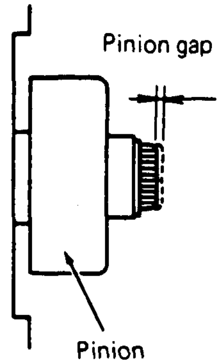
Specifications Unit: kg (lb)

Item	Assembly standard	Service limit
Spring pressure	3.5 (7.7)	2 (4.4)

(e) Pinion gap adjustment

Connect starter and battery as shown to allow pinion to shift against stopper. Under this condition, push pinion back, and measure gap.





Specifications Unit: mm (in.)

Item	Assembly standard
Pinion gap	0.5 ~ 2.0 (0.020 ~ 0.079)

NOTE

To adjust pinion gap, increase or decrease thickness of washers used between mating faces of magnetic switch and front bracket.

(f) No-load test

After adjusting pinion gap, connect starter and battery with an ammeter and voltmeter as shown, and test starter for performance.

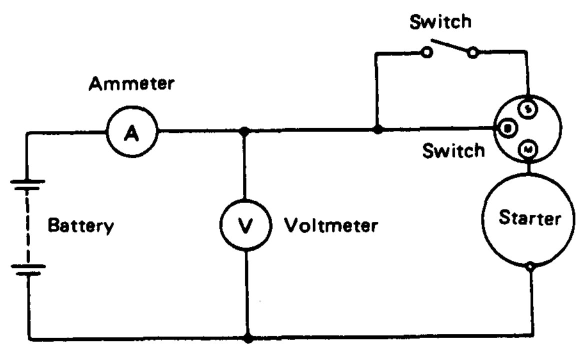
NOTE

Use thick wires and tighten terminal securely.

If current and speed meet the following specifications when battery voltage is 11 volts, starter is satisfactory:

Specifications

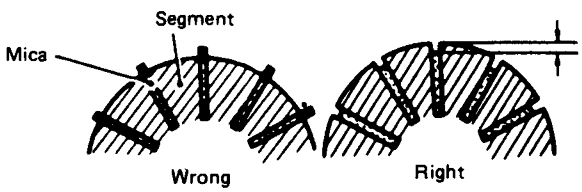
Current	Speed
130 (A), max.	4000 rpm, min.



(3) Inspection of brushes and commutator

(a) Check the brushes for wear. A brush worn down excessively should be replaced by a new one. When the brush is replaced, grind the brush against the commutator surface by using #250 sandpaper so that it makes a full-face contact with the commutator.

(b) Check the mica insulation for condition. It should be "undercut," that is, the segment between two adjacent mica should be slightly proud of the mica surface, as viewed in the cross section. Since the commutator surface is subject to gradual wear, a point will be reached in the course of service, where the segments become flush with the mica. If the commutator in such a condition is kept in service, the mica will tend to interfere with the satisfactory commutation. Before this point is reached, it is necessary to recondition the commutator surface by regrinding or sanding with #400 sandpaper and to undercut the mica properly, as shown below:



Checking mica insulation

7-2 Alternator

(1) Alternator and regulator inspection before disassembly

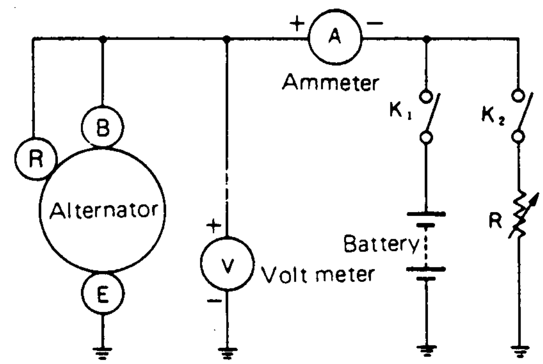
(a) If charging system is found defective, check for items below before making adjustment or repair:

- Fan belt tension
- Loose connections, open short circuit in charging system wiring
- Trouble of charging system due to defective battery

(b) Output test on a test bench

Remove the alternator from the engine. Connect it in a test circuit as shown at upper right, and operate it by a motor for testing.

Close the switches K_1 and K_2 under the state where very little load current flows in the test circuit by varying load resistance to the maximum. Gradually increase alternator speed while keeping the terminal voltage at constant 13.5 volts, and read the ammeter at 2500 rpm. The alternator is satisfactory if the ammeter registers at least 30 amperes.



(c) Output test on a machine

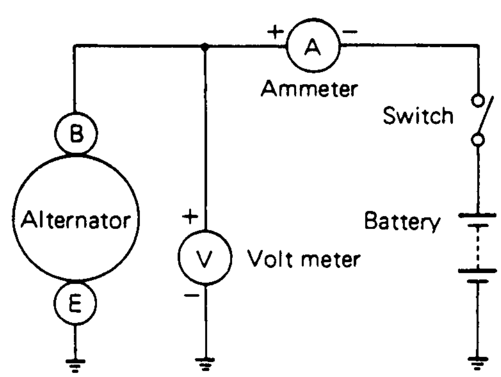
Place a switch in the circuit between the battery and alternator. With the switch kept open, connect an ammeter (60-ampere class) and a voltmeter to the circuit.

Make sure that the voltmeter registers the battery voltage when the switch is closed.

Start the engine, and turn on the lamp switch. Increase the engine (alternator) speed, and read the ammeter when the alternator speed is 5000 rpm. The alternator is satisfactory if the ammeter registers at least 70% of the nominal output.

NOTE

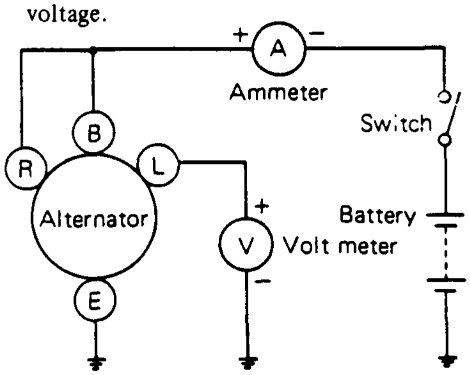
This test is a first-aid test. It is recommended that the alternator be tested on a test bench for close inspection.



(2) Regulator voltage test

(a) Test on a test bench

Use a fully charged battery. Close the switch, and gradually increase the alternator speed. Make sure that the current is below 5 amperes and the voltage is 14.1 to 14.7 volts when the alternator speed reaches 5000 rpm. If this requirement is nor met, replace the regulator assembly. It is impossible to reset the regulator voltage.



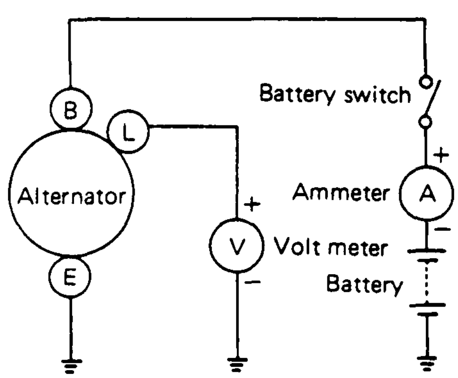
(b) Test on a machine

Connect a voltmeter in the circuit between the terminal L and ground. Turn on the battery switch to make sure that the voltage is 0 (zero). If the voltmeter needle defects, the alternator is defective, or the circuit is misconnected. With the ammeter terminals short-circuited to prevent the starter current from flowing to the ammeter, start the engine.

If the charging current is below 5 amperes when the engine is running at about 2000rpm, read the voltmeter.

If it exceeds 5 amperes, charge the battery for a while, or replace the battery with a fully charged one. Another method is to connect a 1/4 ohm (25 W) resistor in series with the battery to limit the charging current.

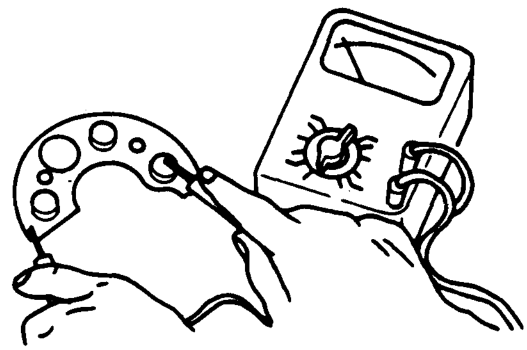
The regulated voltage should be 14.1 to 14.7 volts; if not, replace the regulator assembly.



(3) Alternator inspection after disassembly

(a) Inspection of each diode

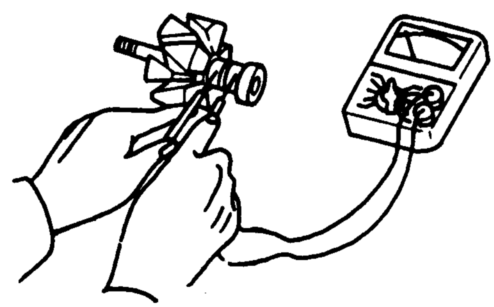
Check for continuity between the wire lead and the heat sink. Any continuity, if noted, means that the diode is shorted; no continuity means an open diode.



Checking diodes

(b) Field coil inspection

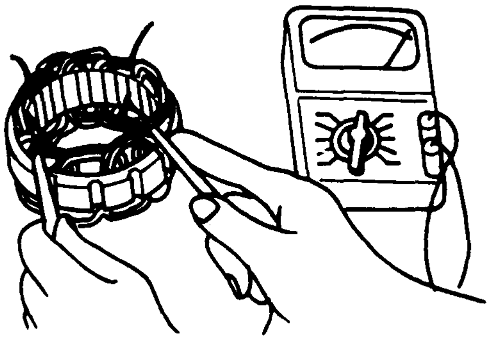
The field coil is in good condition if the resistance between the slip rings is approximately 14.3 ohms at a temperature of 20°C (68°F).



Checking field coil

(c) Armature inspection

Alternatively check four wire leads of the armature coil for continuity with a tester as shown:

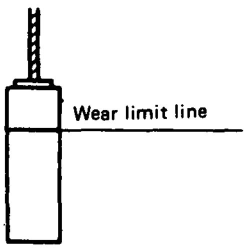


Checking armature

If there is no continuity between the wire leads, it is an indication that the armature has open circuit. Replace the armature with a new one. Then, check the armature for continuity between the wire lead and core. If there is continuity, it is an indication that there is a grounded circuit between the wire and core. In this case, too, the armature should be replaced.

(d) Brushes

Any brush which is worn beyond the service limit should be replaced with a new one.



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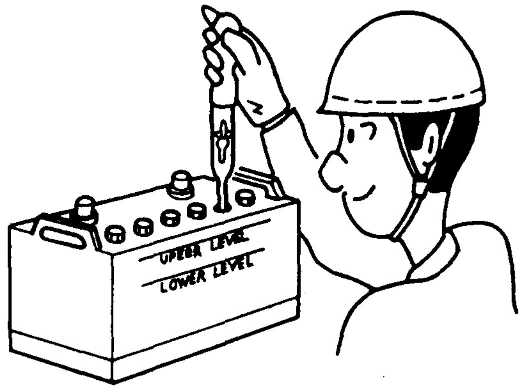
7-3 Battery

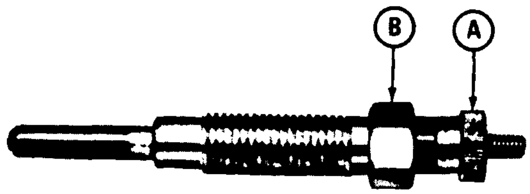
Check the electrolyte level in the battery cells, making sure that it is 10 mm (5/16 in.) above cell plates. Check the specific gravity of electrolyte. If it is below 1.260 at 20°C (68°F), prepare an electrolyte of 1.260 specific gravity and add it to the battery. A specific gravity below 1.190 means that the battery is half discharged; in such a case recharge the battery.



Checking electrolyte specific gravity

7-4 Glow plugs

Connect the positive (+) lead to the portion A of the plug with the portion B grounded to see if the plug glows red. The plug is in good condition if it glows red.



Checking glow plug

BENCH TEST

When the engine is overhauled, it is advisable to conduct the bench tests for checking the engine performance. The purpose of bench tests is to make sure that each major component has been properly serviced.

1. Visual inspection

Couple the engine to the dynamometer and inspect as follows:

(1) Starting the engine

(a) Check the amounts of cooling water, lubricating oil and fuel oil. Bleed air out of the fuel system.

(b) Place the starter switch in PREHEAT position to preheat the combustion chambers. The glow plug indicator lamp will glow red within 20 seconds. If not, check the preheating system for condition.

(c) Place the starter switch in START position to start the engine. Do not move the governor control lever to INCREASE position.

(d) After starting the engine, manipulate the governor control lever to run the engine at idling speed.

(2) After starting the engine

Check the following items and repair if necessary.

(a) Abnormal oil pressure and oil leakage.

(b) Abnormal noise.

If knocking is heard while water temperature is low and the noise dies away as water temperature rises, the engine is in good condition.

(c) Color of exhaust gases.

(d) Leakage of cooling water.

(e) Leakage of fuel oil.

(f) Fuel injection.

(3) Running-in the engine

While running-in the engine, check the following items and repair if necessary.

(a) Oil pressure ($3 \sim 4$ kg/cm^2 or $42.7 \sim 56.9$ psi).

(b) Temperature of cooling water ($75 \sim 85$°C or $167 \sim 185$°F).

(c) Temperature of lubricating oil ($60 \sim 70$°C or $140 \sim 158$°F in oil pan).

(d) Abnormal noise.

(e) Excessive blow-by, water leakage and oil leakage.

(f) The relationship between the load and running-in period is as follows:

After running-in the engine, check the valve clearance.

Engine speed rpm	Load PS	Time min
1000	0	30
1500	7.5	30
2000	15	60
2500	20	60

2. Performance tests

(1) Test condition

The engine must be equipped with the air cleaner and alternator.

(2) Test items

- No-load maximum speed test (governor set)
- Fuel injection quantity test (control rack set)
- No-load minimum speed test (idling speed set)

(3) Test procedures (with dynamometer pointer in OFF position)

(a) No-load maximum speed test (governor set)

While the temperatures of cooling water and oil are still high after engine running-in, set the no-load maximum speed.

(b) Fuel injection quantity test (control rack set)

The fuel injection quantity can be set by means of the governor fuel set lever. Loosening the set screw at the top of the fuel set lever will increase the fuel injection quantity, and vice versa.

(c) Move the control lever toward LOW SPEED position and adjust the stop screw to set the idling rpm to 650 to 700.

(d) Tune-up of engine output

The diesel engine output is based on the atmospheric pressure and temperature. Therefore, the output must be tuned up under standard conditions. Multiply the output measured by the factor. This factor can be computed by the following equation.

$$K = \frac{760 - 11.4}{H - Hw} \sqrt{\frac{273 + t}{293}}$$

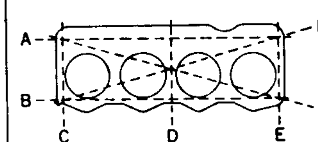
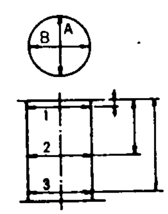
Where: H = atmospheric pressure in mmHg

Hw = partial pressure of vapor in atmosphere in mmHg

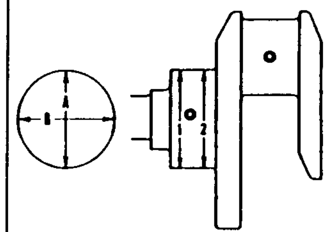
t = room temperature in °C (°F)

MAINTENANCE STANDARDS

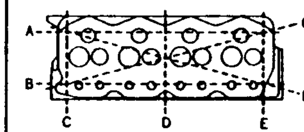
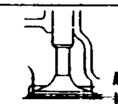
Unit: mm. (in.)

Group	Item			Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
General	Maximum rpm (no-load)			Varies according to customers' specifications.				Asjust governor.	
	Minimum rpm (no-load)			650 ~ 700					
	Compression pressure			26 kg/cm² (370 psi), min (at 150 ~ 200 rpm)		20 kg/cm² (284 psi)			Oil and water temperatures: 20 ~ 30°C (68 ~ 86°F)
	Engine oil pressure			3 ~ 4 kg/cm² (43 ~ 57 psi) (at 1500 rpm)		2 kg/cm² (28.4 psi)			Oil temperature: 70°C (158°F)
				1 ~ 2 kg/cm² (14.2 ~ 28.4 psi), min (at idle speed)		0.5 kg/cm² (7.1 psi)			
	Valve timing [3 mm (0.12 in.) added to valve side]	Intake valves	Open	24° ATDC	±3°				These values are to be referred to in measuring timing and differ from actual timing.
			Close	4° BBDC					
		Exhaust valves	Open	16° BBDC					
			Close	28° BTDC					
	Fuel injection timing			Engine specifications (rpm): 1500, 1800, 2000, 2200, 2500, 3000, 3600 BTDC (°): 23, 24, 25, 26, 28, 30, 33					Standard values are shown. Check timing on caution plate.
Crankcase and main moving parts	Warpage of gasketed surface				0.05 (0.0020), max	0.20 (0.008)		Regrind if warpage is minor.	
	Cylinder sleeve	Inside diameter		88 (3.465)	$^{+0.035}_{0}$ ($^{+0.00138}_{0}$)	+0.20 (+0.008)	0.70 (0.0276)	Hone cylinder to 0.25 (0.0098), 0.50 (0.00197) or oversize with prescribed tolerance. Oversize pistons and piston rings should be used.	
		Out of roundness			0.01 (0.0004), max				
		Taper			0.015 (0.0006), max				

Unit: mm (in.)

Group		Item		Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
Crankcase and main moving parts	Main bearings	Clearance on crankshaft journal (in two directions at right angles to each other with bearing in place)		65 (2.559)	[0.035～0.100 (0.00138～0.00394)]	[0.20 (0.0079)]	−0.9 (−0.035) (at crankshaft journal OD)	Replace bearing if repair limit is reached. Regrind crankshaft journals and use undersize bearings 0.25 (0.0098), 0.50 (0.0197) or 0.75 (0.0295) if service limit is reached.	1) Replace crankcase and bearing cap as an assembly. 2) Upper bearing shells have oil groove. 
		Thrust clearance		3.7 (0.1457)	[0.1～0.189 (0.004～0.00744)]	[0.30 (0.0118)]		Replace thrust bearing.	
	Tappet holes	Inside diameter		22 (0.87)	$^{+0.033}_{0}$ $\left(^{+0.00130}_{0}\right)$		+0.10 (+0.0039)		
		Fit on tappets			[0.035～0.098 (0.00138～0.00386)]	[0.12 (0.0047)]	+0.10 (0.0039) (at tappet hole dia.)	Replace tappet if repair limit is reached.	
	Camshaft bushing holes	Fit on camshaft journals	No. 1	54 (2.126)	With bushings [0.040～0.090 (0.00157～0.00354)] Without bushings [0.06～0.11 (0.0024～0.0043)]	[0.15 (0.0059)]		Rebore holes and insert bushings if repair limit is reached.	
			No. 2						
			No. 3	53 (2.087)					

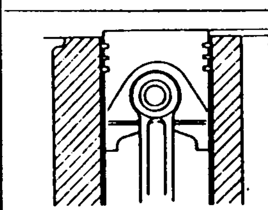
Unit: mm (in.)

Cylinder head	Cylinder head	Warpage of gasketed surface			0.05 (0.0020), max	0.20 (0.0079)		Regrind if warpage is minor.	
		As-installed thickness of gasket		1.35 (0.0531)	±0.05 (±0.0020)				
	Valves	Diameter of valve stem	Intake	8 (0.315)	−0.045 (−0.00177) −0.060 (−0.00236)	−0.10 (−0.004)			
			Exhaust		−0.060 (−0.00236) −0.080 (−0.00315)	−0.15 (−0.0059)			
		Clearance of valve stem in guide	Intake	8 (0.315)	[0.055 ~ 0.085 (0.00217 ~ 0.00335)]	[0.15 (0.0059)]		Replace valve guide if repair limit is reached.	
			Exhaust		[0.070 ~ 0.105 (0.00276 ~ 0.00413)]	[0.20 (0.0079)]			
		Valve sinkage		0.8 (0.031)	± 0.2 (± 0.008)	1.3 (0.051)			
		Margin (valve head thickness)		1.7 (0.067)			*1.2 (0.047)		* Refacing limit
		Face runout of stem			0.03 (0.0012), max (prependicularity to valve face)				
	Valve guide length outside hole			18 (0.709)	± 0.3 (± 0.012)				
	Valve seat angle			30°					
	Valve seat width			1.4 (0.055)	± 0.14 (± 0.0055)	1.6 (0.063)			
	Valve springs	Free length		48.85 (1.9232)			47.6 (1.8740)		
		As-installed length		43 (1.69)		44 (1.73)		Adjust by means of shim(s) if repair limit is reached.	
		Load compress spring to initial working length [43 mm (1.69 in.)] kg (lb)			19 ± 1 (41.9 ± 2.21)	15 (33.08)			
		Squareness			1.5°, max				Squareness of each end with respect to center line

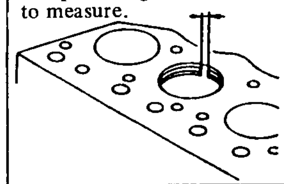
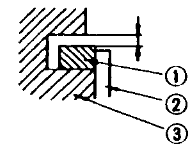
Unit: mm (in.)

Group	Item		Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
Cylinder head	Valve clearance		0.25 (0.0098) (cold setting)					0.25 (0.0098) clearance may also be obtained by warm setting if intake and exhaust valves are at the same temperature.
	Rockers	Inside diameter	18 (0.709)	$^{+0.061}_{0}$ ($^{+0.00240}_{0}$)				
		Diameter of rocker shaft	18 (0.709)	$^{-0.016}_{-0.034}$ ($^{-0.00063}_{-0.00134}$)				
		Fit on shaft	18 (0.709)	[0.016 ~ 0.095 (0.00063 ~ 0.00374)]	[0.10 (0.0039)]		Replace bushings if repair limit is reached. Replace shaft if the limit is exceeded.	
	Push rods	Runout		0.4 (0.016), max				With both ball ends supported.
	Exhaust manifold	Warpage on gasketed surface			0.2 (0.008)			
Main moving parts	Crankshaft	Runout (measured with end journals held in "V" blocks)		0.02 (0.0008), max	0.05 (0.0020)		Straighten or replace crankshaft.	
		Diameter of journals	65 (2.559)	$^{-0.015}_{-0.035}$ ($^{-0.00059}_{-0.00138}$)	−0.15 (−0.0059)	−0.9 (−0.035)		
		Out of roundness of crankpins and journals		0.01 (0.0004), max	0.03 (0.0012)			
		Taper of crankpins and journals						
		Diameter of crankpins	58 (2.283)	$^{-0.035}_{-0.055}$ ($^{-0.00138}_{-0.00217}$)	−0.20 (−0.008)			
		Fillet radius	3 (0.12)	±0.2 (0.008)				
		Variance in angle among crankpins		±20′				

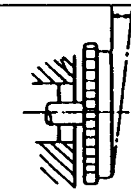
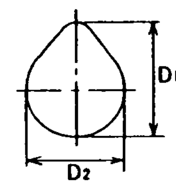
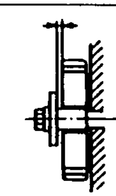
Unit: mm (in.)

	Crankshaft	Center-to-center dimension between journals and crankpins		47 (1.850)	± 0.05 (± 0.0020)				
	Crankshaft	Parallelism between crankpins and journals			0.01 (0.0004), max as runout				
	Pistons	Diameter (at skirt)	Standard	87.9 (3.4606)	± 0.015 (± 0.00059)		−0.2 (−0.008)		Measure in the direction transverse to piston pin.
	Pistons	Diameter (at skirt)	0.25 (0.0098) oversize	88.15 (3.4705)					
	Pistons	Diameter (at skirt)	0.50 (0.0197) oversize	88.40 (3.4803)					
	Pistons	Diameter (at skirt)							
	Pistons	Protrusion above crankcase			0.35 ~ 0.75 (0.0138 ~ 0.0295)			Check bearing clearance.	
	Pistons	Difference in weight among pistons per engine			± 5 g (± 0.18 oz)				

Unit: mm (in.)

Group			Item	Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
Main moving parts	Piston rings		Gap		[0.30 ~ 0.50 (0.0118 ~ 0.0197)]	[1.5 (0.059)]			Compress rings to 84 (3.31) dia. to measure. 
		Fit in ring grooves	No. 1 compression ring	2.5 (0.098)	[0.050 ~ 0.085 (0.00197 ~ 0.00335)]	[0.20 (0.0079)]		Replace rings if service limit is reached. Replace pistons if the limit is exceeded.	1) Ring side clearance Measure side clearance with ring kept flush with second land.  1-Compression ring 2-Straightedge 3-Piston 2) When replace oil ring, replace it together with expander.
			No. 2 compression ring	2.0 (0.079)	[0.025 ~ 0.060 (0.00098 ~ 0.00236)]	[0.15 (0.0059)]			
			Oil ring	4.0 (0.157)					
	Piston pins		Diameter	25 (0.984)	$\begin{smallmatrix}0\\-0.006\end{smallmatrix}$ $\left(\begin{smallmatrix}0\\-0.00024\end{smallmatrix}\right)$				
			Clearance in pistons		[0 ~ 0.016 (0 ~ 0.00063)]	[0.05 (0.0020)]		Replace piston pin if repair limit is reached. Replace piston if the limit is exceeded.	
			Fit in piston pin bushings		[0.020 ~ 0.051 (0.00079 ~ 0.00201)]	[0.08 (0.0031)]		Replace piston pin or bushing. (Ream if necessary.)	
	Connecting rods		Inside diameter of piston pin bushing	25 (0.984)	$\begin{smallmatrix}+0.020\\+0.045\end{smallmatrix}$ $\left(\begin{smallmatrix}+0.00079\\+0.00177\end{smallmatrix}\right)$				
			Bend, twist		0.05/100 (0.002/4), max	0.15/100 (0.0059/4)			
			Crankpin diameter and fit in connecting rod bearing	58 (2.283)	[0.035 ~ 0.100 (0.00138 ~ 0.00394)]	[0.20 (0.0079)]		Replace bearings if repair limit is reached. Regrind crankpins and use undersize bearings if repair limit is exceeded.	Cap must be installed with marks on cap and rod on the same side.

Unit; mm (in.)

Main moving parts	Connecting rods	End play			$\left[\begin{matrix}0.15 \sim 0.35\\(0.0059 \sim 0.0138)\end{matrix}\right]$	$\left[\begin{matrix}0.50\\(0.0197)\end{matrix}\right]$		Replace connecting rods.	
		Difference in weight among rods per engine			±25g (±0.88 oz)				
	Flywheel	Flatness			0.15 (0.0059), max	0.5 (0.020)		Grind or replace.	
		Runout						Replace flywheel.	
Timing gear train	Camshaft	Cam height	Intake	D_1 $46.916^{+0.1}_{-0.3}$ $\left(1.84708^{+0.00394}_{-0.01181}\right)$	$D_1 - D_2 = 6.684$ (0.26315)		$D_1 - D_2$ = 6.184 (0.24346)	Replace camshaft.	
			Exhaust	D_1 $45.944^{+0.1}_{-0.3}$ $\left(1.80882^{+0.00394}_{-0.01181}\right)$	$D_1 - D_2 = 7.344$ (0.28913)		$D_1 - D_2$ = 6.844 (0.26945)		
		Diameter of journal	No. 1, 2	54 (2.126)	$\begin{matrix}-0.04\\-0.06\end{matrix}\left(\begin{matrix}-0.0016\\-0.0024\end{matrix}\right)$				
			No. 3	53 (2.087)					
		Runout			0.02 (0.0008), max	0.05 (0.0020)		Straighten or replace.	
		End play		5 (0.197)	$\left[\begin{matrix}0.05 \sim 0.112\\(0.00197 \sim 0.00441)\end{matrix}\right]$	$\left[\begin{matrix}0.3\\(0.012)\end{matrix}\right]$		Replace thrust plate.	
	Idler	Inside diameter of bushings		36 (1.417)	$\begin{matrix}+0.025\\0\end{matrix}\left(\begin{matrix}+0.00098\\0\end{matrix}\right)$				
		Diameter of shaft			$\begin{matrix}-0.025\\-0.050\end{matrix}\left(\begin{matrix}-0.00098\\-0.00197\end{matrix}\right)$				
		Fit of shaft in bushing			$\left[\begin{matrix}0.025 \sim 0.075\\(0.00098 \sim 0.00295)\end{matrix}\right]$	$\left[\begin{matrix}0.1\\(0.004)\end{matrix}\right]$		Replace bushing.	
		End play		26 (1.02)	$\left[\begin{matrix}0.05 \sim 0.15\\(0.0020 \sim 0.0059)\end{matrix}\right]$	$\left[\begin{matrix}0.35\\(0.0138)\end{matrix}\right]$		Replace thrust plate.	

Unit: mm (in.)

Group		Item	Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
Timing gear train	Idler	Thrust journal width in boss	26 (1.024)	[0.05 ~ 0.15 (0.0020 ~ 0.0059)]	[0.35 (0.0138)]		Replace thrust plate.	
		Fit of shaft in holes in crankcase	30 (1.181)	[0.09T ~ 0.045T (0.0035T ~ 0.0018T)]				
	Gear backlash			0.05 ~ 0.20 (0.0020 ~ 0.0079)	0.25 (0.0098)		Replace gear.	
Lubrication system	Oil pump	Running clearance between inner and outer rotors		[0.013 ~ 0.015 (0.00051 ~ 0.00059)]		[0.25 (0.0098)]		
		Sliding clearance between outer rotor and cover	24 (0.9449)	[0.04 ~ 0.09 (0.0016 ~ 0.0035)]	[0.15 (0.0059)]		Reface case cover or case.	
		Clearance between outer rotor and body	40.5 (1.5945)	[0.20 ~ 0.275 (0.0079 ~ 0.01083)]		[0.50 (0.020)]		
		Outside diameter of rotor shaft	13 (0.5118)	$^{0}_{-0.15}$ $(^{0}_{-0.0059})$				
		Fit of rotor shaft in body		[0.032 ~ 0.074 (0.00126 ~ 0.00291)]		[0.15 (0.0059)]	Replace pump case.	
	Pressure that makes relief valve open		3.0 kg/cm² (42.7 psi)	± 0.2 kg/cm² (± 2.84 psi)				Oil pressure varies 0.15 kg/cm² (2.13 psi) per 1 mm (0.04 in.) shim .

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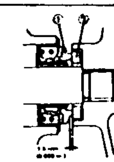
Unit: mm (in.)

Fuel system	Fuel injection nozzle	Injection pressure		120 kg/cm^2 (1706.4 psi)	$^{+10}_{0}$ kg/cm^2 ($^{+142.2}_{0}$ psi)	110 kg/cm^2 (1564.2 psi)		Adjust by means of shim(s).	Injection pressure varies 10 kg/cm^2 (142.2 psi) per 0.1 mm (0.004) of shim thickness.
		Spray angle		0°				Test by means of hand tester, using diesel fuel at, 20°C or 68°F approx. If spray pattern is improper even after nozzle is washed in clean kerosene, replace nozzle tip.	Spray of fuel oil should be uniform and consists of fine droplets. No dribbling should be observed after each injection. "Throttle injection" should occur when the tester lever is operated slowly.
		Needle valve seat oil-tightness		Seat shall show no sign of leakage under a pressure of 100 kg/cm^2 (1422 psi).				Wash needle valve seat or replace nozzle tip.	Replace nozzle tip when needle surface is scratched or scored.
Cooling system	Water pump bearings	Clearance of outer race in pump casing	Front	47 (1.850)	[-0.018T~0.014T (0.00071T~0.00055T)]			Replace pump case or pump assembly.	
			Rear	40 (1.575)					
		Clearance of inner race on pump shaft	Front	20 (0.787)	[-0.001T~0.025T (0.00004T~0.00098T)]				
			Rear	17 (0.669)	[-0.002T~0.020T (0.00008T~0.00079T)]				
		Radial play	Front	20 (0.787)	[0.010~0.025 (0.00039~0.00098)]		[0.045 (0.00177)]	Replace bearing.	Replace bearing if it does not rotate smoothly.
			Rear	17 (0.669)	[0.010~0.022 (0.00039~0.00087)]				
	Water pump impeller, vane-to-casing clearance (front and rear sides)			0.5 ~1 (0.020 ~0.039)				Replace impeller and bearing if vanes are binding.	 1-Floating seat (carbon) 2-Seal ring (ceramic)
	Unit seals	Carbon protrusion		1.5 (0.059)		0			
		Height (free length)		18.1 (0.713)					
	Thermostat	Temperature that makes valve start opening		76.5°C (169.7°F)	± 2°C (± 3.6°F)				
		Valve lift		9 (0.35)					
		Temperature that makes valve open fully		90°C(194°F)	± 2°C (± 3.6°F)				
	Belt, tension			Deflection: 12 (about 1/2)					

Unit: mm (in.)

Group		Item		Nominal dimension	Assembly standard [Standard clearance]	Repair limit [Clearance]	Service limit [Clearance]	Remedy	Remarks
Electrical system	Starter	Commutator runout		0.05 (0.0020)	0.03 (0.0012)	0.1 (0.004)			
		Brush	Height		18 (0.71)		11 (0.43)		
			Spring pressure		3.5 kg (7.7 lb)		2 kg (4.4 lbf)		
		Pinion-to-stopper clearance			[0.5 ~ 2.0 (0.020 ~ 0.079)]				

Starter:

No-load characteristic			Locked-rotor characteristic			Magnetic switch operating voltage	
Voltage (V)	Current (A)	Rpm	Voltage (V)	Current (A)	Torque	Switch IN	Switch OFF
12	130, max	4000, min	3	1000, max	2.8 kg-m (20.3 lb-ft), min	8V, max	When circuit is opened.

Alternator:

No load (battery connected)			Under load (battery resistance load 30A connected)			IC regulator
Voltage (V)	Current (A)	rpm	Voltage (V)	Current (A)	rpm	Adjusting voltage (V)
13.5	0	1050, max	13.5	30	2500, max	14.4 ±0.3

Ball bearing		Field resistance Ω at 20°C (68°F)
Rear side	#6201	3.4
Front side	#6302	

SEALANT APPLICATION DATA

Where to apply	Mating face or parts	Sealant	Remarks
Oil pan gasket	Crankcase	ThreeBond 1102	Apply to bottom face for oil pan.
	Front/rear attaching faces	Atmojet	Apply to both sides of cork packing.
		ThreeBond 1207C	Apply to periphery of rubber packing.
Main oil gallery plug	Crankcase	Hermeseal H-1	Apply to hole in crankcase and also to plug after installing.
Crankcase screw plug	Crankcase	Hermeseal H-1	Apply to threaded portion.
Front plate gasket	Front plate	ThreeBond 1102	Apply when reassembling temporarily.
	Crankcase		Apply to the whole surfaces at reassembling.
Timing gear case gasket	Gear case	ThreeBond 1102	Apply when reassembling temporarily.
	Front plate		Apply to the whole surfaces at reassembling.
Water pump gasket	Plate	ThreeBond 1102	Apply when reassembling temporarily.
	Water pump		Apply to the whole surfaces at reassembling.
Pump plate gasket	Plate	ThreeBond 1102	Apply when reassembling temporarily.
	Crankcase		Apply to the periphery of port.
Oil filler attaching bolts	Oil filler/crankcase	ThreeBond 1102	Apply to threaded portion in assembly.
Water bypass hose fitting	Thermostat cover/ water pump	Hermeseal H-1	Apply to threaded portion.
Gear case mounting bolts	Crankcase/gear case	Hermeseal H-1	Apply to threaded portion of one upper bolt and two lower bolts.

TIGHTENING TORQUE

Important bolts and nuts

Unit: kg-m (lb-ft)

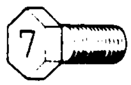
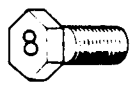
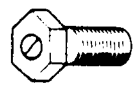
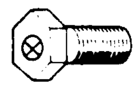
Item	Torque
Cylinder head bolts	12.0 ± 0.5 (86.8 ± 3.6)
Main bearing cap bolts	8.5 ± 0.5 (61.5 ± 3.6)
Connecting rod cap bolts	5.5 ± 0.5 (39.8 ± 3.6)
Rocker shaft bracket bolts	1.5 ± 0.5 (10.8 ± 3.6)
Front plate bolts	1.0 ± 0.5 ((7.2 ± 3.6)
Timing gear case bolts	1.0 ± 0.5 (7.2 ± 3.6)
Camshaft thrust plate bolts	1.8 ± 0.5 (13.0 ± 3.6)
Idler thrust plate bolt	3.5 ± 0.5 (25.3 ± 3.6)
Crankshaft pulley nut	40.0 ± 0.5 (289.3 ± 3.6)
Rear plate bolts	3.5 ± 0.5 (25.3 ± 3.6)
Rear oil seal bolts	0.4 (2.9)
Flywheel bolts	8.5 ± 0.5 (61.5 ± 3.6)
Oil pan bolts	0.7 (5.1)
Oil pan drain plug	10.0 ± 0.5 (72.3 ± 3.6)
Nozzle holder retaining nuts	5.0 ± 0.5 (36.2 ± 3.6)
Injection pump delivery valve holders	3.0 ± 0.5 (21.7 ± 3.6)
Governor round nut	2.5 ± 0.5 (18.1 ± 3.6)

General bolts and nuts

(1) The values listed in this chart are for standard bolts. For other bolts, nuts and screws, refer to the related sections in this manual.

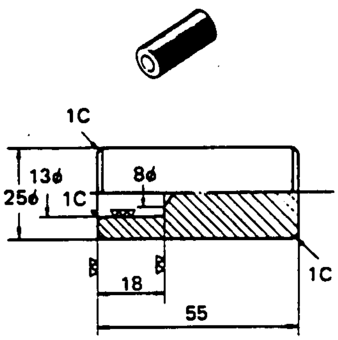
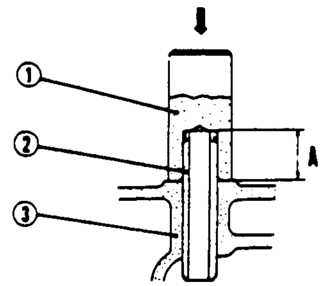
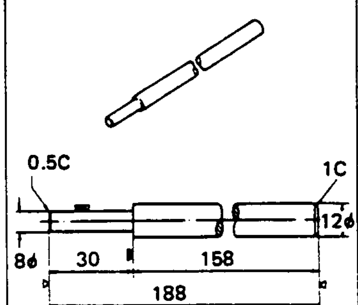
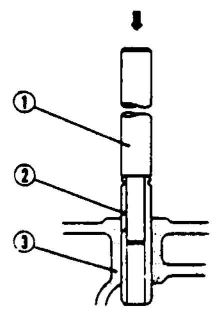
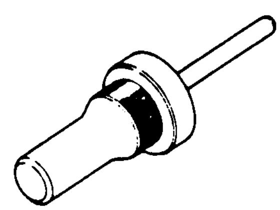
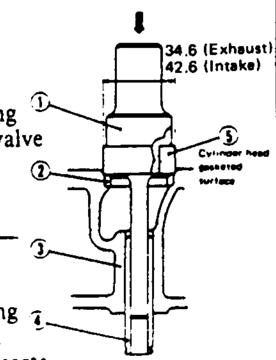
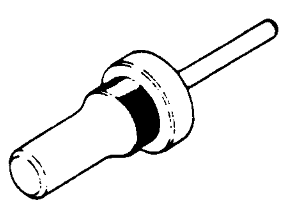
(2) The values listed below have a tolerance of ±10%. When an impact wrench is used, a torque up to and including 14 kg-m (101 lb-ft) has a tolerance of ±20% and a torque above 14 kg-m (101 lb-ft) has a tolerance of ±15%.

Unit: kg-m (lb-ft)

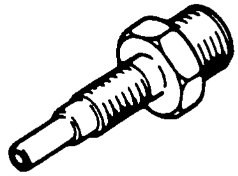
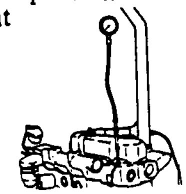
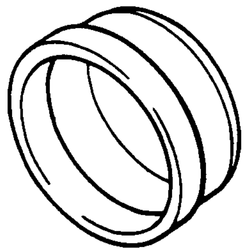
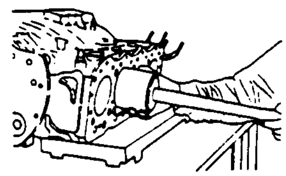
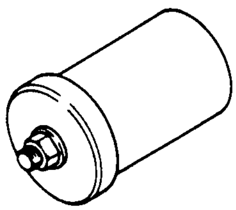
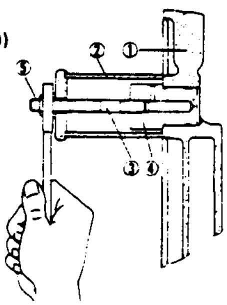
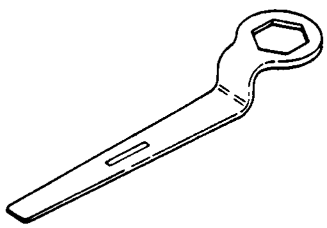
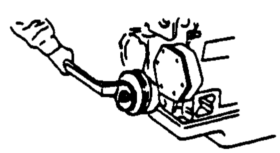
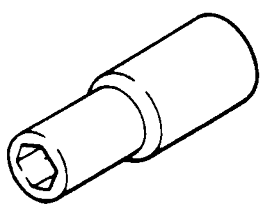
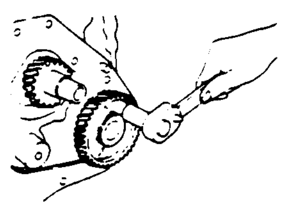
Automotive screw thread					Metric coarse screw thread				
Indication of bolt material	 "7" stands for "7T."		 "8" stands for "8T."		Indication of bolt material	 "⊘" stands for "7T."		 "⊗" stands for "8T."	
	w/spring washer		w/o spring washer			w/spring washer		w/o spring washer	
Bolt material	7T	8T	7T	8T	Bolt material	7T	8T	7T	8T
M6 × 1	0.6 (4.3)	0.9 (6.5)	0.7 (5.1)	1.0 (7.2)					
M8 × 1.25	1.4 (10.1)	1.9 (13.7)	1.7 (12.3)	2.2 (15.9)					
M10 × 1.25	2.9 (21.0)	3.8 (27.5)	3.4 (24.6)	4.5 (32.5)	M10 × 1.5	2.8 (20.3)	3.7 (26.8)	3.3 (23.9)	4.3 (31.1)
M12 × 1.25	5.2 (37.6)	6.8 (49.2)	6.1 (44.1)	8.0 (57.9)	M12 × 1.75	4.9 (35.4)	6.5 (47.0)	5.8 (42.0)	7.6 (55.0)
M14 × 1.5	8.4 (60.8)	11.1 (80.3)	9.9 (71.6)	13.1 (94.8)	M14 × 2	8.1 (58.6)	10.5 (75.9)	9.5 (68.7)	12.4 (89.7)
M16 × 1.5	12.6 (91.1)	16.6 (120.1)	14.8 (107.0)	19.5 (141.0)	M16 × 2	12.1 (87.5)	15.9 (115.0)	14.2 (102.7)	18.7 (135.3)
M18 × 1.5	18.2 (131.6)	23.9 (172.9)	21.4 (154.8)	28.1 (203.2)	M18 × 2.5	16.8 (121.5)	22.2 (160.6)	19.8 (143.2)	26.1 (188.8)
M20 × 1.5	25.2 (182.3)	33.2 (240.1)	29.7 (214.8)	39.0 (282.1)	M20 × 2.5	23.5 (170.0)	30.9 (223.5)	27.7 (200.4)	36.4 (263.3)
M22 × 1.5	33.4 (241.6)	43.9 (317.5)	39.3 (284.3)	51.7 (373.9)	M22 × 2.5	31.5 (227.8)	41.3 (298.7)	37.0 (267.6)	48.6 (351.5)
M24 × 1.5	42.2 (305.2)	55.5 (401.4)	49.7 (359.5)	65.3 (472.3)	M24 × 3	40.5 (292.9)	53.4 (386.2)	47.7 (345.0)	62.8 (454.2)

SPECIAL SERVICE TOOLS

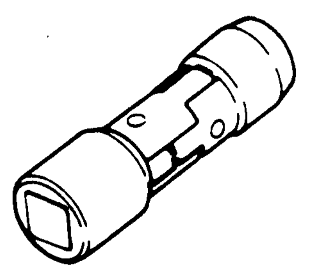
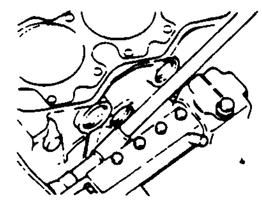
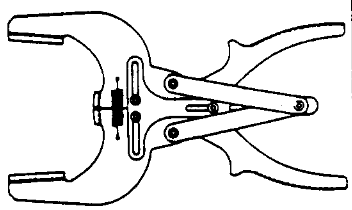
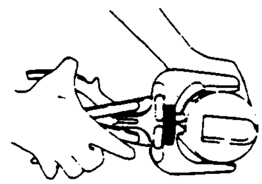
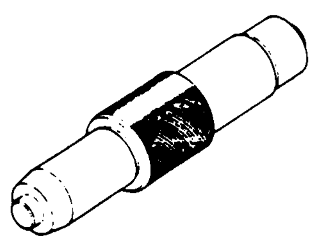
Unit: mm

Tool No.	Tool name	Drawing or sketch	Qt.	Used for:
	Valve guide installer	 Material: S53C	1	Installing valve guides  1-Valve guide installer 2-Valve guide 3-Cylinder head A-Guide length outside hole
	Valve guide remover	 Material: S53C	1	Removing valve guides  1-Valve guide remover 2-Valve guide 3-Cylinder head
	Intake valve insert caulking tool		1	Installing intake valve inserts 
	Exhaust valve insert caulking tool		1	Installing exhaust valve inserts 1-Caulking body 2-Valve insert 3-Cylinder head 4-Valve guide 5-Caulking ring

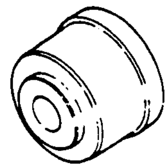
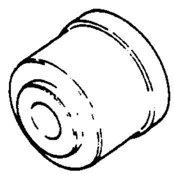
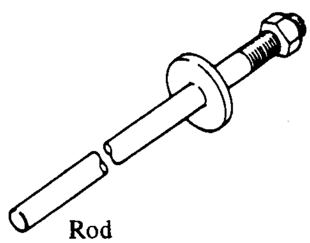
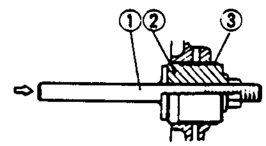
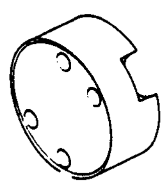
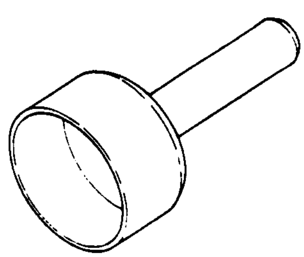
Unit: mm

Tool No.	Tool name	Drawing or sketch	Qt.	Used for:
	Adaptor		1	Connecting pressure gauge to engine for compression measurement 
	Piston guide		1	Placing pistons in crankcase 
	Idler shaft puller		1	Removing idler shaft 1-Crankcase 2-Puller 3-Stud (M10) 4-Idler shaft 5-Nut 
	Cranking handle		1	Rotating crank pulley for engine cranking 
	Socket		1	Installing camshaft thrust plate 

Unit: mm

Tool No.	Tool name	Drawing or sketch	Qt.	Used for:
	Universal extension		1	Tightening fuel injection pump mounting bolts 
	Piston ring tool		1	Removing/installing piston rings 
	Idler bushing puller		1	Removing/installing idler bushing

Unit: mm

Tool No.	Tool name	Drawing sketch	Qt.	Used for:
	Camshaft bushing installer set	 Adaptor  Adaptor  Rod	1	Removing/installing camshaft bushings  1-Rod 3-Camshaft bushing 2-Adaptor To be used together with guide piece (30891-04700) as a set
	Sleeve installer set	 	1	Installing crankshaft rear oil seal sleeve

TROUBLESHOOTING

System	Possible cause \ Complaint	Engine will not start – Engine turns over but does not start – No exhaust smoke	Engine will not start – Engine turns over but does not start – A little exhaust smoke	Engine will not start – Engine turns over but does not start – Too much exhaust smoke	Engine will not start – Starting motor does not turn over sufficiently to crank engine	Engine will not start – Engine does not turn – Engine can be cranked manually	Engine will not start – Engine does not turn – Engine cannot be cranked manually	Glow plugs do not glow red	Glow plugs glow red too early	Engine lacks power – A little exhaust smoke	Engine lacks power – Too much whitish exhaust smoke	Engine lacks power – Too much black exhaust smoke	Abnormal exhaust smoke – When idling	Abnormal exhaust smoke – When operating – Whitish exhaust smoke	Abnormal exhaust smoke – When operating – Black exhaust smoke	Engine knocks excessively	Engine is noisy	Engine runs rough	Engine hunts – When idling	Engine hunts – When operating
Fuel system	Insufficient fuel supply to injection pump	○	○	—	—	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—
	Greater variance of injection quantity	—	—	○	—	—	—	—	—	—	—	○	○	—	○	○	—	○	○	○
	Defective injection pump seals	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Insufficient injection quantity	○	○	—	—	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—
	Excessive injection quantity	—	—	—	—	—	—	—	—	—	—	—	—	—	○	—	—	—	—	—
	Improper fuel spray from injection nozzles	—	—	○	—	—	—	—	—	—	—	○	○	○	○	○	—	○	○	○
	Excessive fuel return from injection nozzles	—	○	—	—	—	—	—	—	○	—	—	—	—	—	—	—	○	○	—
	Injection timing too advanced	—	—	○	—	—	—	—	—	—	○	—	—	○	○	○	—	—	—	—
	Injection timing too retarded	—	—	○	—	—	—	—	—	—	—	○	○	—	—	—	—	○	○	—
	Defective governor control spring	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Maladjusted governor damper spring	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	○	○
	Engine speed too low	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	○	—
	Failure of engine to stop properly	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Poor grade of fuel oil	—	—	○	—	—	—	—	—	—	○	○	○	○	○	○	—	—	—	—
	Fuel viscosity too high	○	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lubrication system	Poor grade of oil	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Oil viscosity too high	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Oil viscosity too low	—	—	—	—	—	—	—	—	—	—	—	—	○	—	—	—	—	—	—
	Low oil pressure	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Excessive oil leakage	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Pumping up of oil	—	—	—	—	—	—	—	—	—	—	—	—	○	○	○	—	—	—	—
	Clogged oil filter	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Defective oil indicator switch or lamp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Air system	Insufficient air	—	—	○	—	—	—	—	—	—	—	○	—	—	○	—	—	—	—	—
	Poor compression	—	—	○	—	—	—	—	—	—	○	○	○	○	○	○	—	○	○	○
	Low pressure at high atomospheric temperature (or altitude)	—	—	—	—	—	—	—	—	—	—	○	—	—	○	—	—	—	—	—

(● For detailed information refer to the separate chart.)

Engine vibrates excessively	Engine stalls	Poor response for deceleration	Engine does not pick up speed	Engine operates at high speeds but fails to stop	Engine turns in reverse direction	Excessive fuel consumption	Excessive oil consumption	Oil is diluted by fuel	Water in oil	Excessive blow-by	Defective lubrication system: When engine stops, warning lamp does not come on	Defective lubrication system: Warning lamp comes on at low-speed operation	Defective lubrication system: Warning lamp comes on at high-speed operation	Abnormal water temperature rise: Water temperature too high (Engine overheats)	Abnormal water temperature rise: Water temperature too low	Defective alternator: Indicator lamp does not come on when engine stops	Defective alternator: Indicator lamp comes on at high-speed operation	Remedy
—	○	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●
○	○	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	●
—	—	—	—	—	—	—	—	○	—	—	—	—	—	—	—	—	—	Check and replace if necessary.
—	○	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●
—	—	—	—	—	—	○	—	○	—	—	—	—	—	○	—	—	—	●
○	○	—	—	—	—	○	—	○	—	—	—	—	—	—	—	—	—	●
—	○	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	Replace nozzle tips.
○	○	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	●
—	○	—	—	—	—	○	—	—	—	—	—	—	—	○	—	—	—	●
—	—	○	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Check and replace spring if necessary. Then adjust governor setting on bench.
—	○	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Adjust.
○	○	—	—	—	—	—	—	—	—	—	—	○	—	—	—	—	—	Adjust idling set bolt. Hold lever in STOP position.
—	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	—	
—	○	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	●
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Use fuel for cold weather.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Use good quality oil.
—	—	—	—	—	—	—	—	—	—	—	—	—	○	—	—	—	—	Use proper viscosity oil.
—	—	—	—	—	—	—	○	—	—	○	—	○	—	—	—	—	—	Use proper viscosity oil.
—	—	—	—	—	—	—	—	—	—	—	—	○	—	—	—	—	—	●
—	—	—	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	Retighten and replace packing if necessary.
—	—	—	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	●
—	—	—	—	—	—	—	—	—	—	—	—	—	○	—	—	—	—	Change element and oil.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Check and replace if necessary.
—	○	—	○	—	—	○	—	—	—	—	—	—	—	—	—	—	—	●
—	○	—		—	—	○	—	—	—	—	—	—	—	—	—	—	—	●
—	—	—	—	—	—	○	—	—	—	—	—	—	—	○	—	—	—	(Adjust full-load setting of governor.)

Possible cause \ Complaint		Engine will not start						Glow plugs do not glow red	Glow plugs glow red too early	Engine lacks power			Abnormal exhaust smoke			Engine knocks excessively	Engine is noisy	Engine runs rough	Engine hunts	
		Engine turns over but does not start			Starting motor does not turn over sufficiently to crank engine.	Engine does not turn								When operating						
		No exhaust smoke	A little exhaust smoke	Too much exhaust smoke		Engine can be cranked manually	Engine cannot be cranked manually			A little exhaust smoke	Too much whitish exhaust smoke	Too much black exhaust smoke	When idling	Whitish exhaust smoke	Black exhaust smoke				When idling	When operating
Cooling system	Engine is too cold.	—	—	○	○	—	—	—	—	—	—	—	○	—	—	○	—	—	—	—
	Radiator dissipates heat excessively	—	—	—	—	—	—	—	—	—	○	—	○	○	—	○	—	—	—	—
	Insufficient coolant	—	—	—	—	—	—	—	—	—	—	○	—	—	○	—	—	—	—	—
	Failure of radiator to dissipate heat properly	—	—	—	—	—	—	—	—	—	—	○	—	—	○	—	—	—	—	—
	Water leak through cylinder head gasket	—	—	—	—	—	—	—	—	—	○	—	○	○	—	—	—	○	—	—
	Cracks in crankcase water jacket	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electrical system	Defective starter switch	—	—	—	—	○	—	○	—	—	—	—	—	—	—	—	—	—	—	—
	Defective starter magnetic switch	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Defective starting motor	—	—	—	○	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Defective starting motor free wheel	—	—	—	○	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Defective flywheel ring gear and pinion	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Battery voltage drop	—	—	○	○	○	—	○	—	—	—	—	—	—	—	—	—	—	—	—
	Open circuit in heater plugs or pilot lamp	—	—	○	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	—
	Short circuit in heater plugs	—	—	○	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—
	Defective alternator	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Defective alternator relay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Improper wiring	—	—	○	○	○	—	—	○	—	—	—	—	—	—	—	—	—	—	—
Main moving parts	Jammed moving parts	—	—	—	○	—	○	—	—	—	—	○	—	—	○	—	○	○	—	—
	Worn cylinders, pistons or piston rings	—	—	○	—	—	—	—	—	—	○	—	○	○	—	○	○	—	—	—
	Sticking piston rings	—	—	○	—	—	—	—	—	—	○	—	○	○	—	○	—	—	—	—
	Excessive main bearing clearance	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	○	—	—	—
	Loose connecting rod cap bolts	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	○	—	—	—
	Interference between valve and piston	—	—	—	—	—	○	—	—	—	—	—	—	—	—	—	○	—	—	—
	Broken valve springs	—	—	○	—	—	—	—	—	—	○	—	○	○	—	—	○	○	○	○
	Excessive valve clearance	—	—	—	—	—	—	—	—	—	—	○	—	—	○	—	○	○	○	○
	Foreign substances in cylinders	—	—	—	—	—	○	—	—	—	—	—	—	—	—	—	○	—	—	—
	Excessive gear backlash	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	○	—	—	—

(● For detailed information refer to the separate chart.)

											Defective lubrication system			Abnormal water temperature rise		Defective alternator		
Engine vibrates excessively	Engine stalls	Poor response for deceleration	Engine does not pick up speed	Engine operates at high speeds but fails to stop	Engine turns in reverse direction	Excessive fuel consumption	Excessive oil consumption	Oil is diluted by fuel	Water in oil	Excessive blow-by	When engine stops, warning lamp does not come on	Warning lamp comes on at low-speed operation	Warning lamp comes on at high-speed operation	Water temperature too high (Engine overheats)	Water temperature too low	Indicator lamp does not come on when engine stops	Indicator lamp comes on at high-speed operation	Remedy
—	○	—	—	—	—	—	—	—	—	—	—	—	○	—	—	—	—	Heat oil pan from bottom side at starting. After starting, warm up engine thoroughly.
—	—	—	—	—	—	○	—	—	—	—	—	—	—	—	○	—	—	●
—	—	—	—	—	—	—	○	—	—	○	—	○	—	○	—	—	—	●
—	—	—	—	—	—	—	○	—	—	○	—	○	—	○	—	—	—	●
—	—	—	—	—	—	—	—	—	○	—	—	—	—	—	—	—	—	Retighten and replace gasket if necessary.
—	—	—	—	—	—	—	—	—	○	—	—	—	—	—	—	—	—	Replace crankcase.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Check for connections and repair. Replace if necessary.
—	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	—	—	Repair or replace if necessary.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Repair or replace.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Repair or replace motor if necessary.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Repair or replace ring gear. Replace pinion.
—	—	—	—	—	○	—	—	—	—	—	○	—	—	—	—	○	—	Recharge or replace battery. If necessary heat it.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Replace.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Replace copper packings and if necessary heater plugs.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	○	Replace alternator if necessary.
—	—	—	—	—	○	—	—	—	—	—	—	—	—	—	—	○	○	Adjust or replace.
—	—	—	—	—	—	—	—	—	—	—	○	—	—	—	—	○	—	Connect wires properly.
—	○	—	○	—	—	○	○	—	—	○	—	—	—	○	—	—	—	●
—	○	—	—	—	—	○	○	○	—	○	—	—	—	—	—	—	—	Repair or replace.
—	○	—	—	—	—	○	○	○	—	○	—	○	○	—	—	—	—	Repair or replace.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Check and replace bearing(s) with undersize one(s) if necessary.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Retighten.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Re-time timing gear train or adjust valve sinkage properly.
○	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Replace.
○	○	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Adjust valve clearance to 0.25 mm (0.0098 in.).
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Repair.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Replace gears or idler bushing.

Mitsubishi 4DQ7 Diesel Engine Service Manual

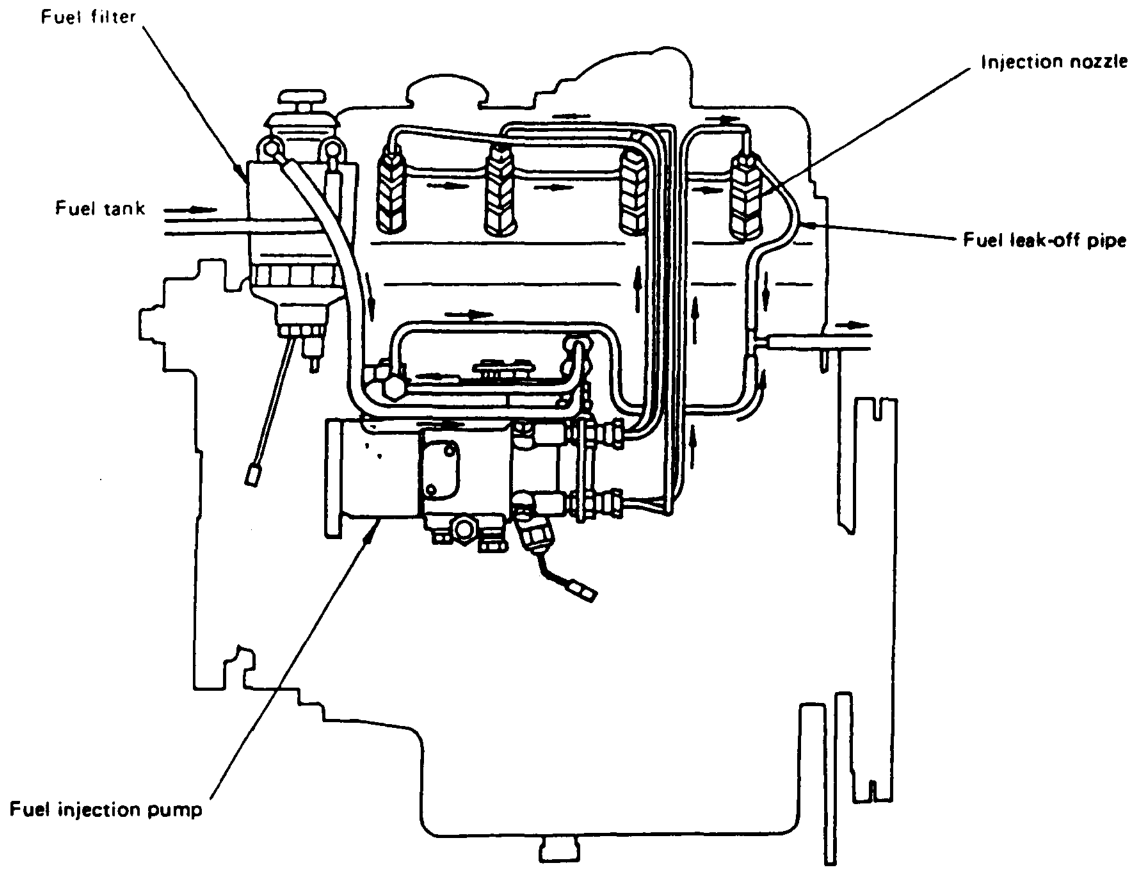
Fuel System

Reelmaster® 4500-D

TORO

FUEL SYSTEM

DESCRIPTION



(Arrows show fuel flow in the circuit.)

Fuel circuit

The fuel system consists of fuel tank, fuel filter, fuel injection pump, injection pipes, injection nozzles and leak-off pipe, as shown.

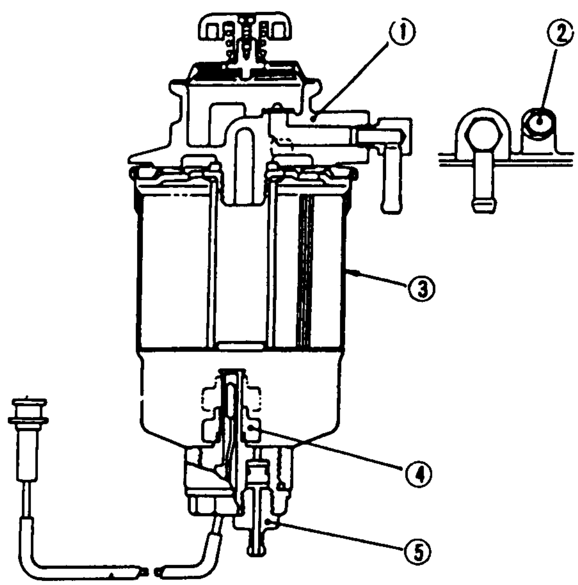
The fuel is fed from the fuel tank to the injection pump through fuel filter. The injection pump delivers high-pressure fuel through injection pipes to the injection nozzles, from which it is injected into the cylinders.

Specifications

Injection pump	Distributor type (DPA)
Injection nozzle	Throttle type
Fuel filter	Paper-element type

FUEL FILTER

Description



1-Body assembly (with priming pump)
2-Air plug
3-Cartridge filter
4-Water level sensor
5-Drain plug

Fuel filter – Sectional view

The fuel filter is equipped with a diaphragm type priming pump built in its top section and a sedimenter (water separator). In the bottom section of the filter is built in a water level sensor which detects settlement of moisture in the filter and sends it as an electric signal to the warning lamp of OK monitor.

Removal and installation

Removal sequence

(1) Drain plug ① (Drain fuel.)

(2) Fuel hose ②

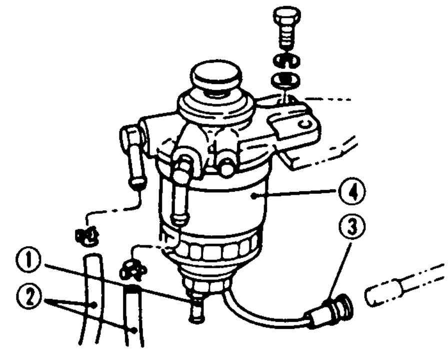
(3) Water level sensor connector ③

(4) Fuel filter ④

NOTES

a) When disconnecting fuel hose, wrap the disconnected end with cloth to prevent fuel from spilling out.

b) Install a blind plug to the disconnected end of hose to prevent fuel from spilling out and dirt from getting inside.



Removing fuel filter

Installation sequence

(1) Follow the reverse of removal sequence.

(2) Prime the fuel system (referring to the topic, Priming fuel system).

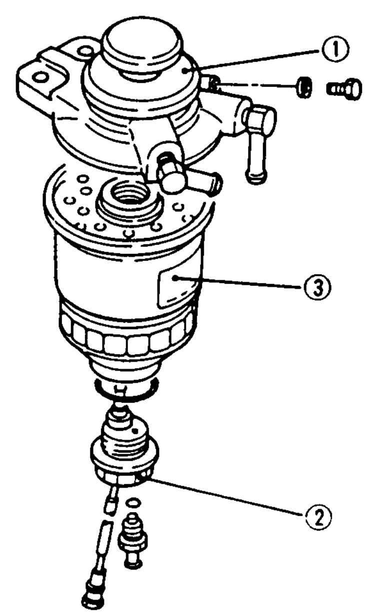
Disassembly and reassembly

Disassembly sequence

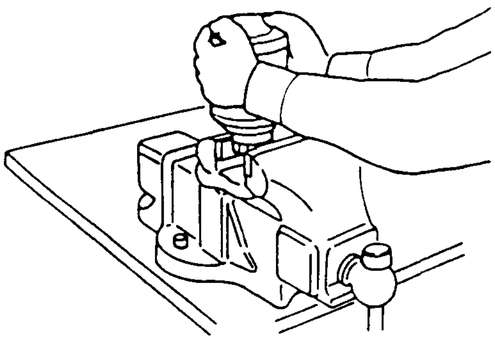
(1) Body assembly ①

(2) Water level sensor ②

(3) Cartridge filter ③



Disassembling fuel filter



Removing water level sensor

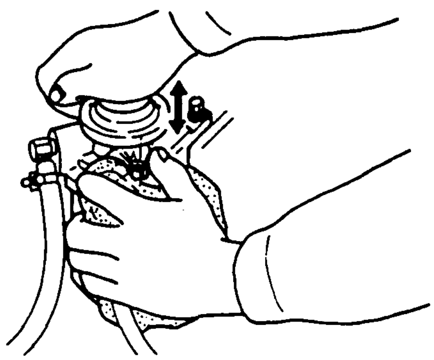
Reassembly sequence

Follow the reverse of disassembly sequence.

Priming fuel system

(1) Loosen the air plug at the top of fuel filter. Cover the plug with cloth, and operate the priming pump until fuel flows without bubbles.

(2) Tighten the air plug, check the filter for fuel leaks, and operate the pump until resistance is encountered.

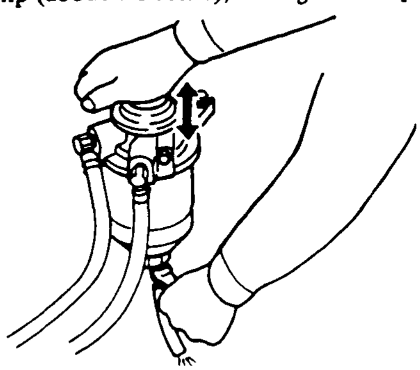


Priming fuel system

Draining moisture

(1) Connect a 6-mm (1/4-in.) hose to the drain plug at the bottom of fuel filter.

(2) Loosen the drain plug, and operate the priming pump (about 7 strokes), and tighten the plug.



Draining moisture

Inspection

(1) Replace the element after every 6 months or 1200 operating hours.

CAUTION

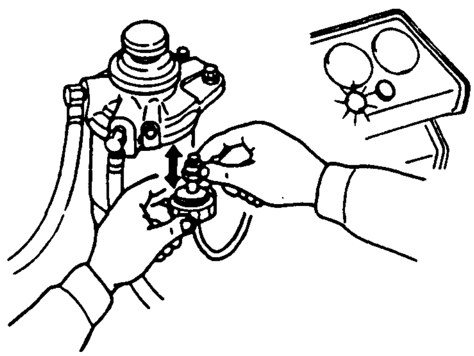
Do not wash paper element.

(2) Replace the packings and other sealing parts at the time of disassembling filter.

(3) Check the body assembly for cracks, distortion, stripped threads and other defects, and replace it if defective.

(4) Replace the plugs if their threads are stripped.

(5) Check to make sure that the warning lamp glows when the float of water level sensor is moved upward, the connector kept connected.

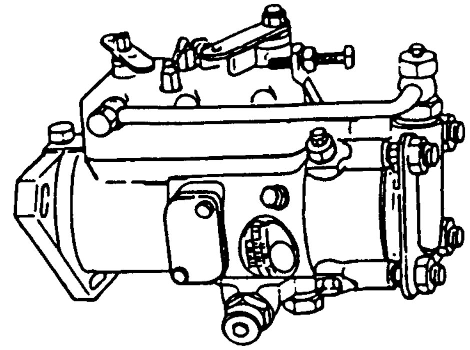


Checking water level sensor

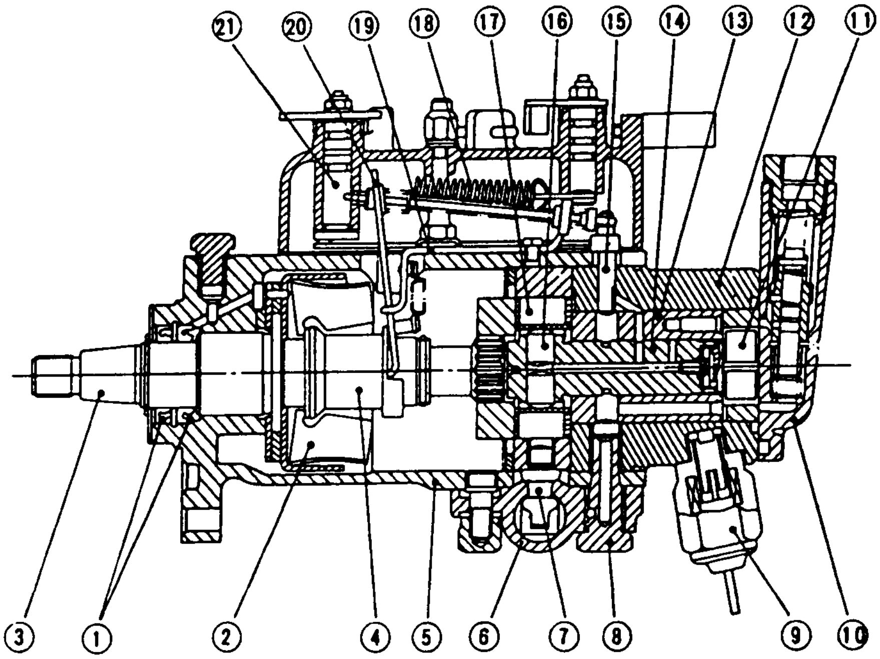
FUEL INJECTION PUMP (DPA)

Description

The DPA injection pump is a distributor type pump consisting of a transfer pump, fuel pumping plunger, distributing device, automatic advance, mechanical governor and control linkage, which are built in a compact, lightweight pump housing. Functionally, this pump features a pair of pumping plunger for metering and delivering fuel.



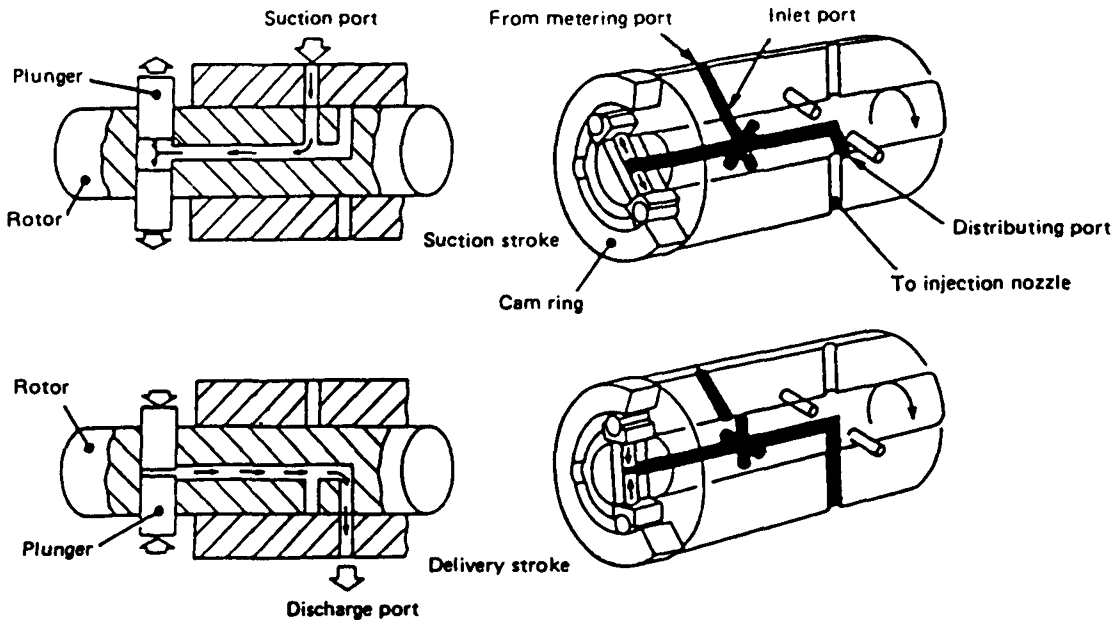
DPA fuel injection pump



1-Drive hub seal
2-Governor weight
3-Drive shaft
4-Thrust sleeve
5-Pump housing
6-Automatic advance
7-Cam advance screw
8-Head locating stud
9-Shut-off solenoid valve
10-End plate (regulating valve)
11-Transfer pump
12-Head & rotor assembly
13-Hydraulic head
14-Rotor
15-Metering valve
16-Plunger
17-Cam roller
18-Governor spring
19-Governor arm bracket
20-Governor arm
21-Shut-off shaft

DPA fuel injection pump — Sectional view

Pumping and distributing principle



Pumping and distributing principle

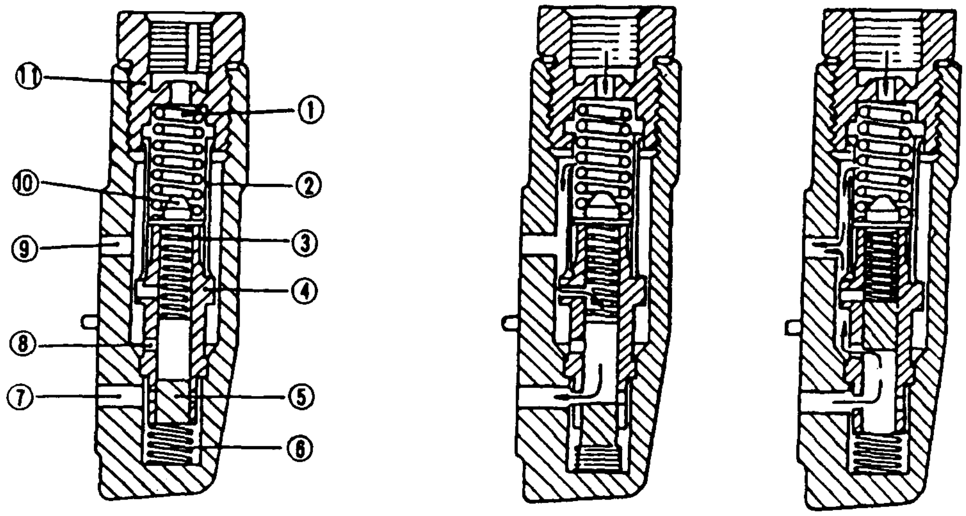
The rotor has a center fuel passage communicating to the cylinder of plunger pump and a radial distributing port.

The hydraulic head, in which the rotor revolves, has radial outlet ports equally spaced and leading to the injectors through high-pressure pipes. As the rotor revolves, its radial port comes over the radial outlet ports of hydraulic head one by one to force out the fuel. On the distributing-port side of the rotor is mounted the rotor of a vane-type transfer pump. The pump liner of this pump is installed to the hydraulic head and covered with an end plate. The end plate has an inlet connection and a built-in regulating valve for limiting the transfer pump discharge pressure.

Fuel entering the inlet connection is delivered by the transfer pump to the metering port of hydraulic head through the regulating valve, the passage in hydraulic head and the groove located close to plunger pump.

The port diagonally drilled in the hydraulic head is a metering port communicating to the metering valve through the diagonal port of head & rotor assembly. The inlet side of the metering port acts as a metering orifice which is adjusted by the metering valve.

Regulating valve



(a) Injection pump at standstill

(b) Priming pump in operation

(c) Injection pump in operation

1-Retaining sleeve spring
2-Nylon filter
3-Regulating spring
4-Valve sleeve
5-Piston
6-Piston retaining spring
7-Port leading to discharge side of transfer pump
8-Regulating port
9-Port leading to suction side of transfer pump
10-Regulating plug
11-Inlet connection

Regulating valve action

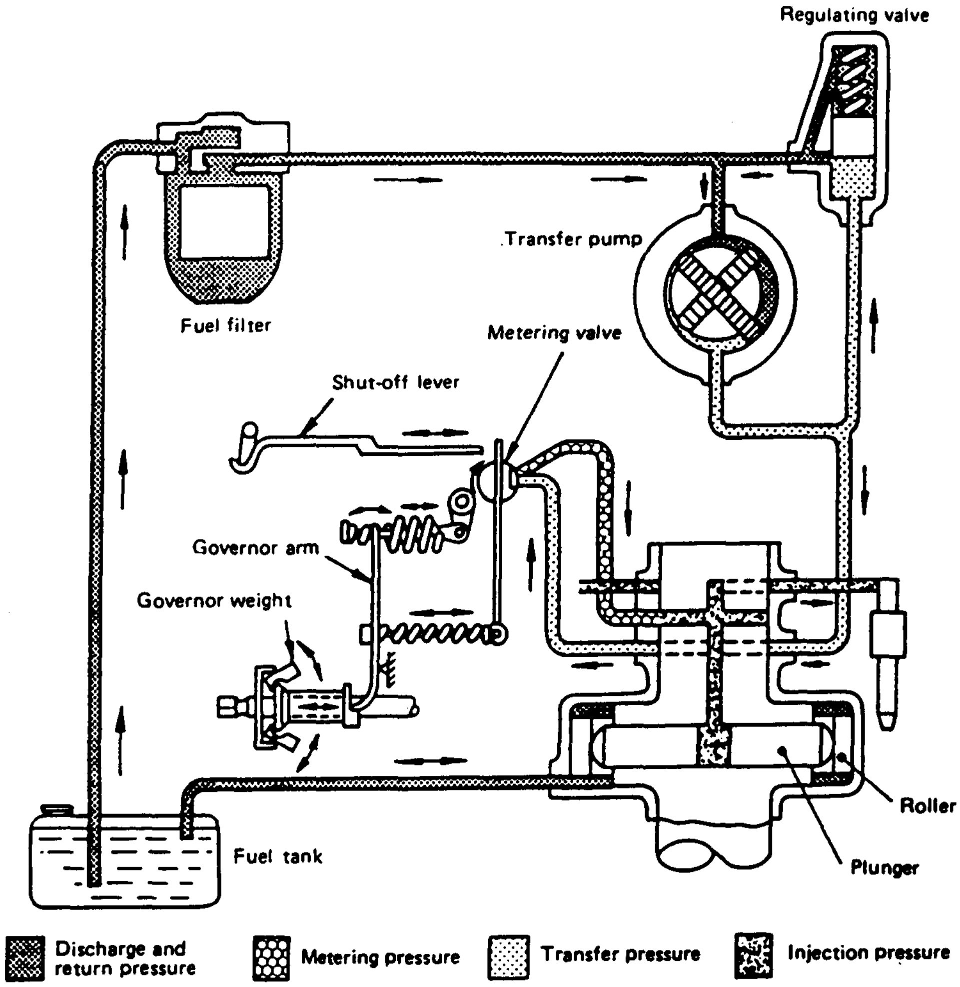
The regulating valve built in the end plate serves two functions:

(1) To limit the transfer pump discharge pressure in order to balance the pressure and pump speed.

(2) To allow fuel to bypass the transfer pump for flowing direct to the passage of hydraulic head when the pump is not operated.

When the pump is at standstill, no pressure acts on the end plate as shown in Fig. (a). In the priming position shown in Fig. (b), pressure developed by the priming pump acts on the piston to push it downward, opposing the force of piston retaining spring. Under this condition, the port leading to the discharge side of transfer pump is uncovered, and fuel bypasses the transfer pump at standstill and flows to the hydraulic head. Fig. (c) shows the regulating valve in action. In this position, the piston is being pushed upward by the pressure developed by the transfer pump to keep the regulating port uncovered. The fuel pressure now acts on the regulating spring through the piston in such a manner that a condition of equilibrium is sought by the two forces. The transfer pump pressure varies with the force of regulating spring.

Metering valve



Fuel circuit

The metering valve is located on the hydraulic head and has a linkage connected to the throttle lever and the arm of governor (mechanical).

This valve is of rotary type and has an axial groove on its periphery. As the valve is rotated by the throttle lever or the governor arm. The groove changes its position with respect to the metering port to provide a metering action.

It is by this metering action that the amount of fuel entering the plunger pump during suction stroke is controlled. The amount of fuel is determined by the opening of orifice, the length of time of suction stroke and the transfer pressure.

Fuel is fed to the transfer pump with "feed pressure" and is delivered from the pump with "transfer pressure." The transfer pressure increases with an increase in the pump speed; it drops to the minimum level when the pump is at idling speed.

If the engine speed is increased with the throttle lever set in a given speed position, the governor acts to control the injection quantity automatically regardless of the throttle lever position.

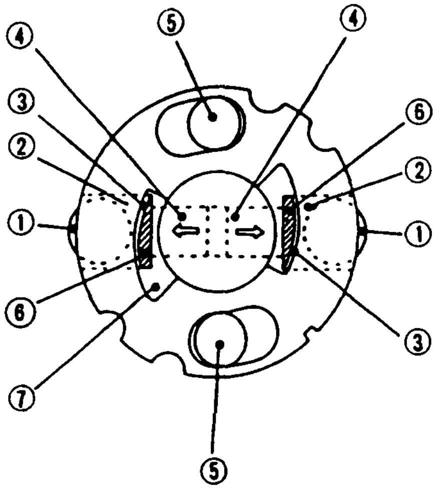
Injection quantity control

The injection quantity is controlled by varying the amount of plunger stroke. The cam rollers are held in place by the roller shoes which are in contact with the plungers and slide in the guide grooves formed of the rotor.

Each roller shoe has a "lug" which is fitted in the eccentric grooves formed of the top and bottom adjusting plates holding the rotor. The top and bottom adjusting plates are located in place by the bent portion of the top adjusting plate.

The top adjusting plate is secured by two drive plate screws in between the end of rotor and the drive plate. These screws extend through the oblong holes in the adjusting plate; loosening the screws make it possible to move the adjusting plate.

The outward stroke of plungers is maximized when the lugs of roller shoes come to the curved sides of the eccentric grooves of the adjusting plate.

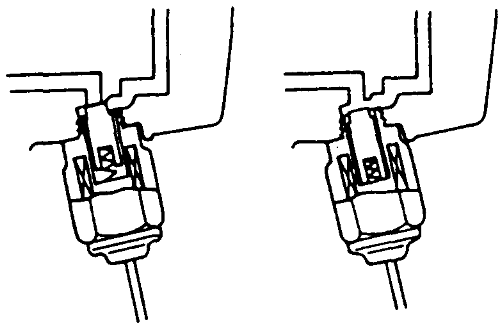


1-Cam rollers
2-Roller shoes
3-Clearance between adjusting plate
• groove and roller shoe lug
4-Plunger
5-Drive plate screws
6-Roller shoe lugs
7-Eccentric groove in adjusting plate

Injection quantity control mechanism

Shut-off solenoid valve

This valve is controlled by the engine starter switch. In "ON" position of the starter switch, it opens the fuel passage leading to the suction port of the cylinder. In "OFF" position of the switch, it closes the fuel passage.

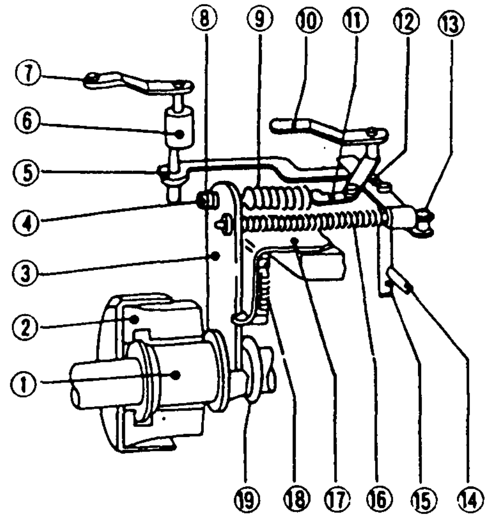


Engine stopped　　Engine running

Shut-off solenoid valve

Governor

This mechanical governor is constructed as shown. The governor weights are pinned to the weight retainer fitted to the drive shaft. The drive hub and drive shaft rotate together in operation. One side of each weight has its bell-crank portion abutting to the thrust sleeve, so that the expanding motion of the weights causes the sleeve to move on and along the drive shaft.



1-Thrust sleeve
2-Governor weight
3-Governor arm
4-Idling spring guide
5-Shut-off bar
6-Shut-off shaft
7-Shut-off lever
8-Idling spring
9-Governor spring
10-Throttle lever
11-Throttle shaft link
12-Metering valve lever
13-Linkage hook
14-Metering port
15-Metering valve
16-Linkage spring
17-Governor arm bracket
18-Governor arm spring
19-Drive shaft

Mechanical governor

The governor arm has a pivot point at the knife-edge portion of governor arm bracket and is connected to the thrust sleeve on one end and to the linkage hook for rotating the metering valve on the other. The arm is spring-loaded by a tension spring called governor spring. The tension of this spring opposes the force of thrust sleeve due to centrifugal force of the weights in such a manner that, for a given setting of the throttle lever, a condition of equilibrium is sought by the two forces.

As the throttle lever is moved in such a direction of pulling the governor spring (of increasing the engine speed), the tension of governor spring overcomes the force of thrust sleeve due to centrifugal force to rotate the metering valve in the direction of increasing the injection quantity. When the engine speed increases and the centrifugal force overcomes the tension of the spring, the thrust sleeve is moved back to the position where the two forces balance with each other for steady-state speed regulation.

Exactly, the governor arm is loaded by two springs, governor spring and idling spring, which are installed across the arm. Except when the engine is idling, the force of idling spring does not act on the arm. When the engine is idling, the idling spring takes the place of governor spring to keep the steady idling speed. This idling spring is provided with an adjusting screw for varying the idling and maximum rpm.

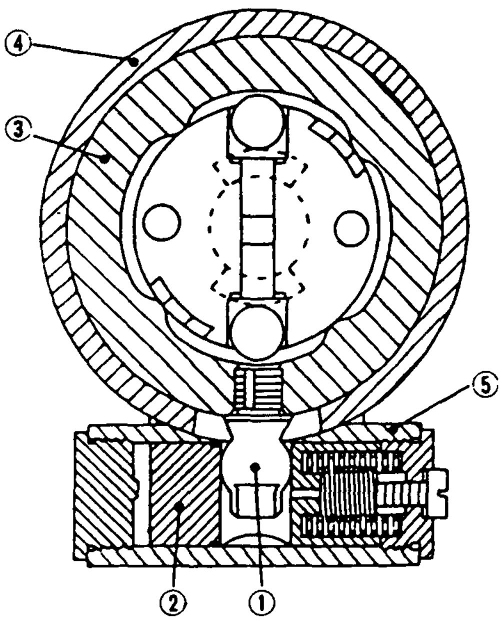
The eccentric shaft located below the shut-off shaft moves the metering valve lever through shut-off bar. As the shut-off shaft is rotated, the metering valve is closed regardless of the throttle lever.

Automatic advance

In full-load operation of the engine, the cam rollers move to the outermost ends of the grooves in the adjusting plate and come in contact with the inside lugs of the cam ring.

In light-load operation, only the amount of fuel just enough to move the cam rollers to the middle points of the adjusting plate grooves is fed to the plunger cylinder. Under this condition, the cam rollers come in contact with the upper portions of the lugs to advance the injection timing (beginning of the injection) according to the engine speed. This action takes place because the injection timing is more retarded in light-load operation than in full-load operation.

The cam advance screw is fitted to the piston on one side and to the cam ring on the other. The movement of the piston is transmitted through this screw to the ring to rotate the ring in either direction. This piston is loaded by a spring on one side toward the position in which the injection timing is most retarded.



1-Cam advance screw
2-Piston
3-Cam ring
4-Pump housing
5-Automatic advance housing

Automatic advance

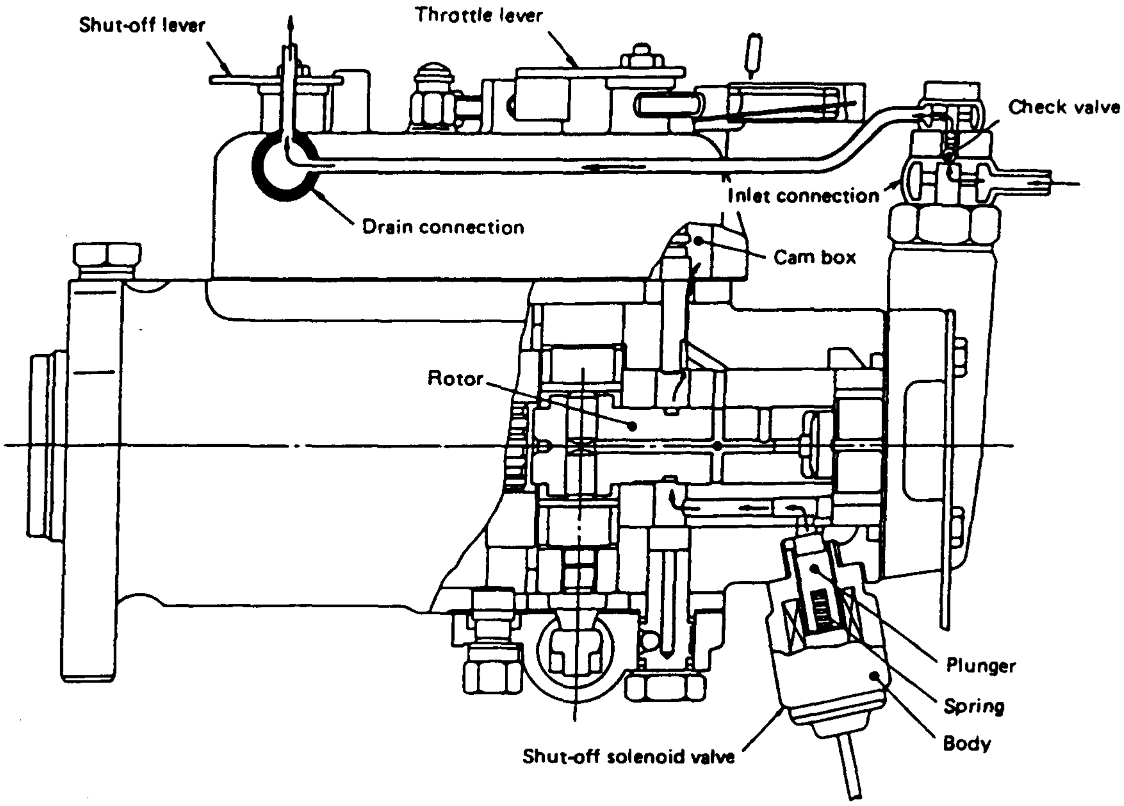
Fuel under transfer pressure enters the side of automatic advance housing opposite to the spring through the passage in the bolt. In the pump housing, the transfer pressure and spring force balance with each other across the piston. As the engine speed increases and the transfer pressure rises, the piston is moved, against the spring force, to rotate the cam ring counterclockwise for advancing the injection timing.

As the engine speed reduces and the transfer pressure drops, the piston is pushed by the spring to force fuel out of the cylinder through the passage between the cylinder and piston to retard the injection timing.

The cam ring tends to rotate in the direction of retarding the injection timing at the beginning of injection. This can be prevented by installing a non-return valve in the fuel passage to the automatic advance.

The advance range of the pump is 12 deg.; this range can be varied by adjusting the spring tension to meet a given engine speed.

Self-vent mechanism



Self-vent mechanism

The fuel system can be primed for venting air by operating the priming pump.

Air trapped in the circuit between the fuel tank and the injection pump suction side can be carried through the check valve to the drain connection for venting. Air in the injection pump is carried through the metering valve groove to the cam box for venting.

After the engine has been started, the transfer pump built in the injection pump draws fuel. Under this condition, the pressure in the circuit between the filter and injection pump drops to close the check valve to prevent air from entering the injection pump.

A small amount of air entering the injection pump during operation is carried through the metering valve groove to the cam box for venting.

Tabulated data of DPA injection pump

Model	4DQ5	S4E, S4E2
Cam lift	1.5 mm (0.06 in.) one side	
Plunger diameter	6.5 mm (0.26 in.)	7 mm (0.28 in.)
Injection order	1-3-4-2	
Injection interval	90°	
Maximum cam rate	0.120 mm (0.005 in.)/deg	
Advance angle	2 deg in pump angle	
Steady speed regulation	7%, max.	
Maximum governor set speed	1200 rpm	

Cold advance device

Description

The cold advance device provides a means of advancing the injection timing just after the engine is started in cold state in order to prevent it from emitting white exhaust smoke during warm-up period.

- **Thermal switch**

  This switch is located at the outlet port of water jacket of the engine, just ahead of the thermo valve. It detects the coolant temperature for controlling the solenoid valve.

- **D-C solenoid valve**

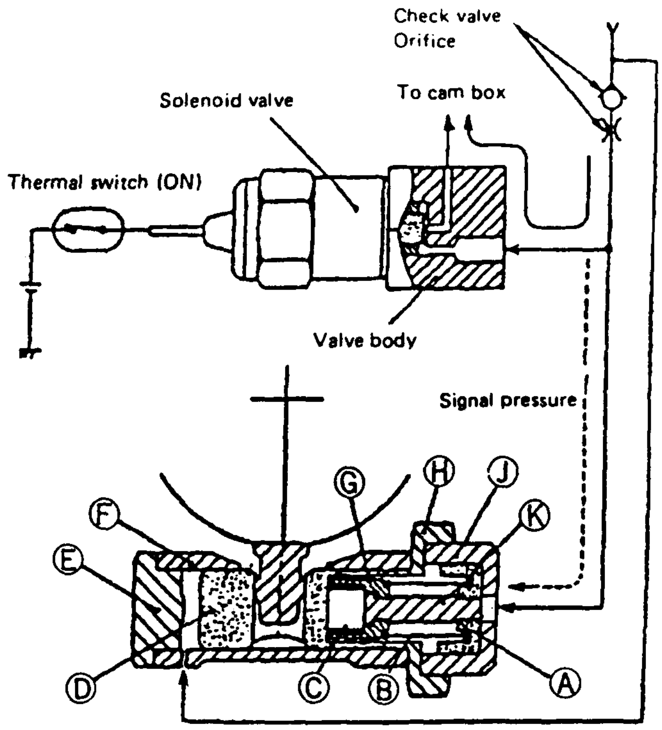
  This valve, when opened by the thermal switch, lets the signal pressure escape through the valve body.

- **Cold advance piston**

  The cold advance piston (A) is larger than the advance piston (D) as far as the pressure area is concerned. As the signal pressure is applied to the piston (A), this piston moves the piston (D) until it is limited by the adaptor (H) to keep the injection timing for normal engine operation. When the signal pressure acting on the piston (A) drops, the piston is moved back by the piston (D) to cold-advance the timing.

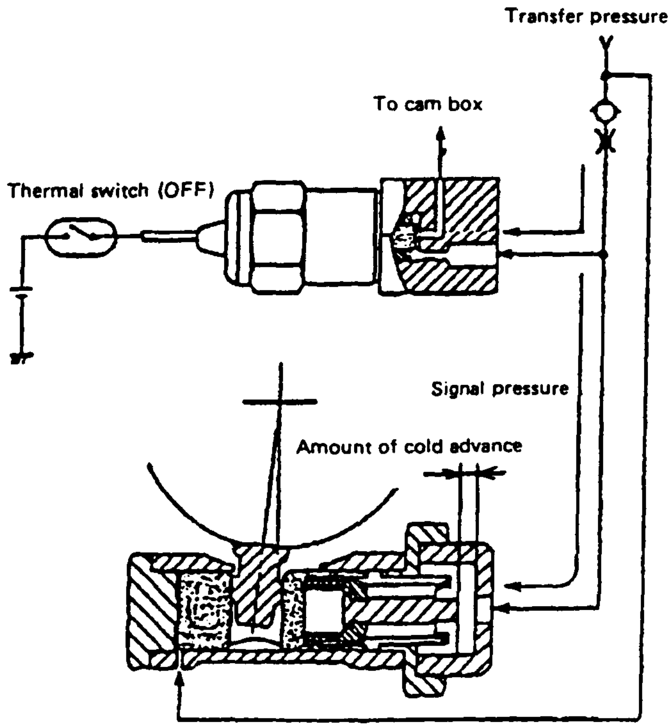
- **Orifice and check valve**

  During cold advance of the injection timing, the fuel flows to the cam box through the solenoid valve. In this circuit is located the orifice to throttle the flowrate of fuel to prevent the transfer pressure from dropping. As the starter switch is turned to OFF position and the signal pressure acting on the piston (A) drops, the piston is returned by the force of retard spring (C), forcing the fuel back to the injection pump. This is the reason why the check valve is located in this circuit to prevent such a reverse flow of fuel for making it easy to stop the engine. The orifice and check valve are built in the banjo bolt assembly.



A-Cold advance piston
B-Advance spring
C-Retard spring
D-Advance piston
E-End plug
F-Advance housing
G-Spring retainer
H-Adaptor
J-Cap
K-Rod

Cold advance action (before warm-up)

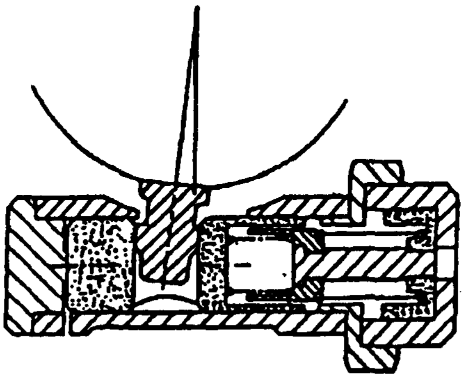


Cold advance action stopped (after warm-up)

- **Operation**

1) Engine stopped

The pistons (A) and (D) are being pushed all the way outward by the force of retard springs.



When engine stopped

2) Cold advance action (before warm-up)

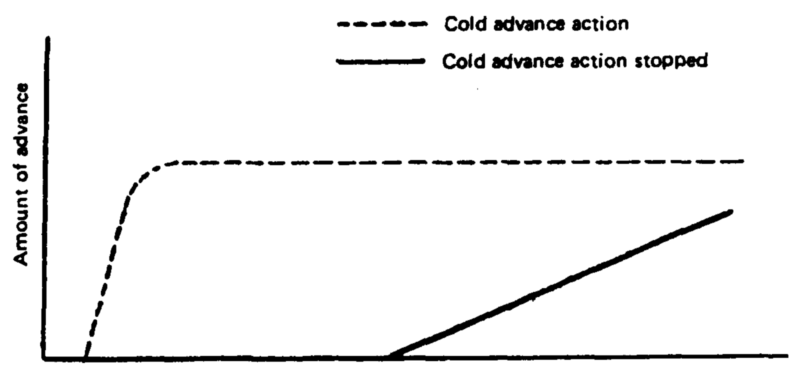
As the starter switch key is turned ON, the thermal switch is turned on to open the solenoid valve. When the engine starts with the solenoid valve open, the transfer pressure (TP) rises to move the piston (D) in the direction of advancing the injection timing. On the other hand, the signal pressure for piston (A) escapes through the valve body (opened) to the cam box. Under this condition, the pistons (A) and (D) are pressed toward the right side to advance the injection timing for the engine being warmed up. The characteristic curve of this cold advance action is as shown below.

3) Cold advance action stopped (after warm-up)

As the coolant temperature reaches about 60°C (140°F), the thermal switch is turned off to close the solenoid valve, causing the signal pressure to rise. Because the transfer pressure is nearly equal to the signal pressure, the piston (A) moves back the piston (D) until it is limited by the adaptor (H) to switch cold-advance action to normal-advance action.

As the engine speed increases in normal-advance action, the transfer pressure rises. Under this condition, the piston (D) moves in such a direction as to advance the injection timing, pushing the spring retainer (G) and compressing the spring (B).

As long as the coolant temperature is above 50°C (122°F), the thermal switch is kept off even if the engine is stopped and no cold-advance action takes place when the engine is restarted.

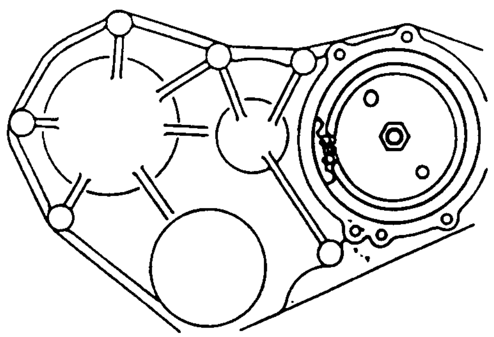


Cold advance characteristic curve

Removal and installation

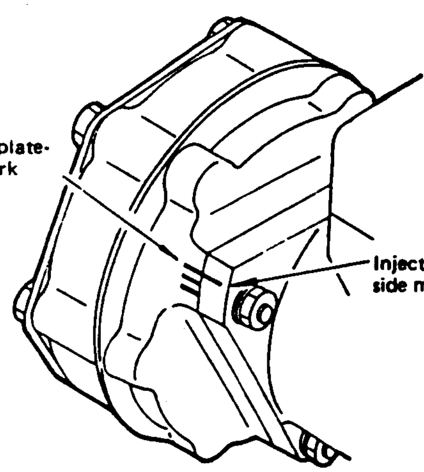
Removal

Bring the No. 1 cylinder piston to top dead center on compression stroke, check the mesh of injection pump drive gear with the idler gear, and remove the injection pump.

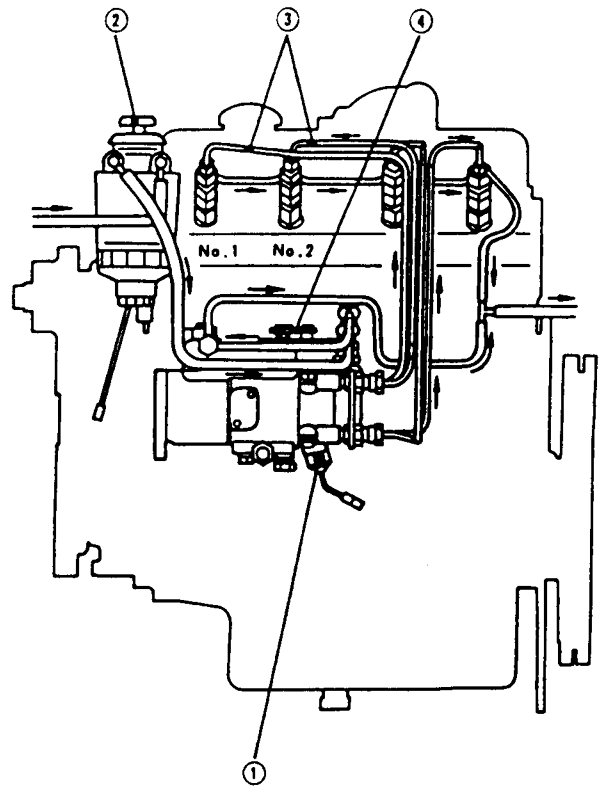


Installation

Install the injection pump to the engine front plate by aligning the marks on the pump and flange plate on one hand and the marks on the injection pump drive gear and idler gear on the other.



Air venting (when fuel tank runs empty or injection pump is replaced)



Air venting

(1) Turn the starter switch to "ON" position to operate shut-off valve ①.

(2) Operate priming pump ② (about 20 times) to feed fuel.

(3) Loosen the nuts of injection pipes ③ (for No. 1 and No. 2 cylinders).

(4) Move throttle lever ④ to the maximum speed position.

(5) Crank the engine by means of the starter, and tighten the nuts loosened in step (3) above when fuel flows without bubbles from the nozzle side.

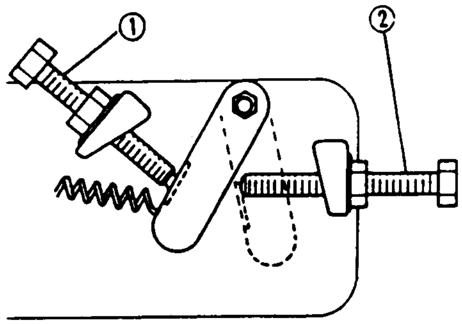
(6) With the throttle lever in the maximum speed position, start the engine, and run the engine at idle speed for 30 to 60 seconds.

Idling and maximum speed adjustments

After installing the injection pump on the engine, be sure to adjust the idling and maximum speeds.

(1) Start the engine, and reposition the throttle lever on the top of control cover by means of adjusting screw ① so that the idling speed is 800 to 850 rpm.

(2) With the throttle lever kept in contact with adjusting screw ②, reposition the lever by means of adjusting screw ② so that the maximum speed is 2900 to 2950 rpm.

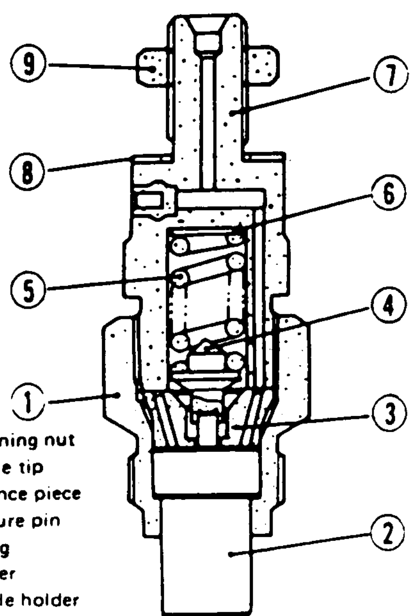


FUEL INJECTION NOZZLES

Description

The injection nozzle provides a means of spraying into the precombustion chamber the fuel oil delivered under pressure from the injection pump. It sprays oil out in a conical pattern consisting of finely atomized droplets of oil. The mating surfaces of the nozzle holder body, distance piece and nozzle are precision-finished to form an oil-tightness.

The injection pressure adjustment may be made by means of adjusting washer. Increasing the thickness of the washer will increase the spring tension and, hence, the injection pressure, and vice versa.



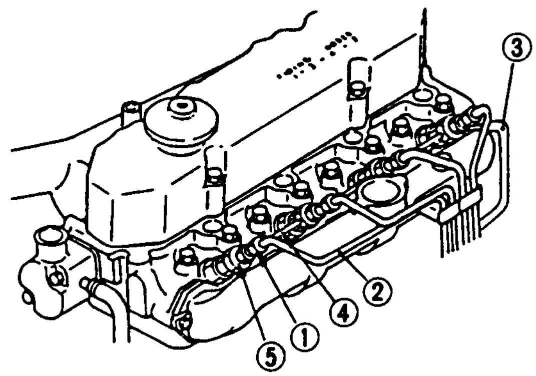
1-Retaining nut
2-Nozzle tip
3-Distance piece
4-Pressure pin
5-Spring
6-Washer
7-Nozzle holder
8-Gasket
9-Nut

Injection nozzle – Sectional view

Removal and installation

Removal sequence

(1) Connectors ① (4 pcs)
(2) Fuel feed pipes ②
(3) Fuel return pipe ③
(4) Fuel leak-off pipe ④ (nuts ⑤ 4 pcs)
(5) Fuel injection nozzle assemblies



Installation sequence

Follow the reverse of removal sequence.

Unit: kg-m (lb-ft)

Fuel injection nozzle tightening torque	5 ± 0.5 (36.2 ± 3.6)

CAUTION

After removing injection nozzles, be sure to cover disconnected ends of injection pipes and nozzle holes in cylinder head to prevent entry of dirt.

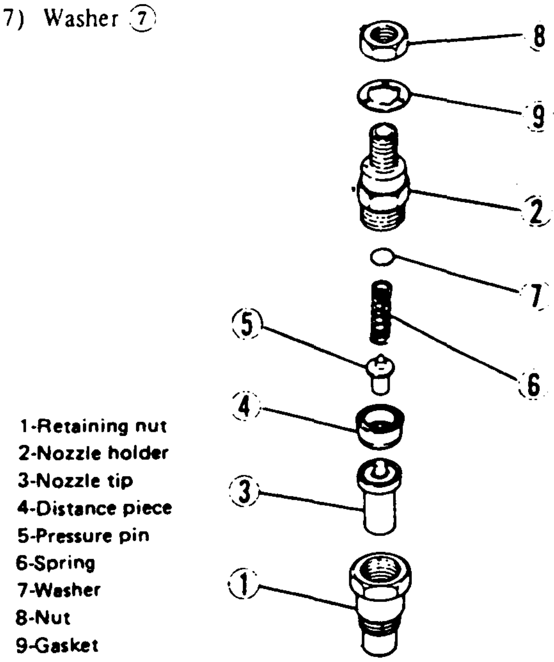
Disassembly and reassembly

NOTE

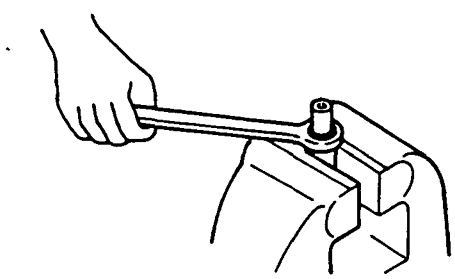
Before disassembly, collect data on the nozzle by testing it for injection pressure (beginning of injection), spray pattern and internal oil-tightness, all in the manner already described. Throughout the disassembly, cleaning and reassembly work, handle each nozzle assembly with care to protect, in particular, the nozzle tip.

Disassembly sequence

(1) Retaining nut ① (Hold it in a vise.)
(2) Nozzle holder ②
(3) Nozzle tip ③
(4) Distance piece ④
(5) Pressure pin ⑤
(6) Spring ⑥
(7) Washer ⑦



Injection nozzle assembly – Disassembled view



Disassembling nozzle holder

Reassembly sequence

Follow the reverse of disassembly sequence.

NOTE

If the needle valve and nozzle proper have to be replaced, be sure to wash the replacement parts in the pool of kerosine after removing their protective film of plastic: wash off the rust-preventive oil from the nozzle proper by stroking the needle valve back and forth in the needle valve stem bore.

Inspection

(1) Needle valve and nozzle body

(a) Immerse needle valve and nozzle body in a pool of clean kerosene, insert the valve into the body, and move the valve back and forth to be sure that the sliding contact is smooth without evidencing any excessive clearance. The injection nozzle as a whole must be replaced if the fit is found defective.

(b) Visually examine the nozzle body with a magnifying glass having a power of 4 or 5.

(c) Inspect the needle valve for distortion or damage at its seating part and for wear of its end face in contact with the pressure pin.

(d) Poor seating contact may be corrected, if the defective condition is not advanced too far, by lapping the valve against the seat with a coat of clean lube oil applied to the seating faces. If this does not help, the injection nozzle must be replaced.

(2) Nozzle holder and distance piece

Check the fit between nozzle holder and distance piece. Determine the quality of the fit from contact patterns obtained with the use of red lead paste: defective fit will be evidenced by an abnormally high rate of return oil (leak-off) flow.

(3) Pressure spring and pressure pin

(a) Replace any pressure spring broken, cracked or otherwise defective, or out of square. Inspect each spring for these defects.

(b) Inspect each pressure pin for wear at its end faces, one for pressure spring and the other for needle valve.

(4) Leak-off pipe packing

If the packing is found in deteriorated condition, replace it.

Testing and adjustment

(1) Injection pressure

The pressure at which the needle valve unseats itself against the force of the pressure spring is referred to as "valve opening pressure" or "beginning-of-injection pressure," but will be called here "injection pressure" for short. The value of this pressure is specified; it is checked and adjusted as follows:

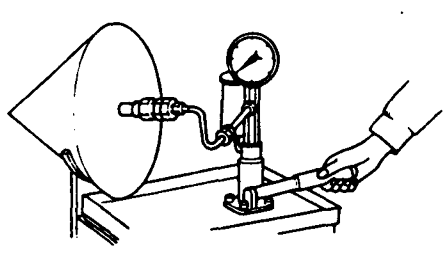
(a) Install the injection nozzle in the nozzle tester, and operate the manual pumping handle of the tester several strokes to prime the nozzle.

(b) Move the lever up and down slowly, completing each up-and-down cycle in about a second, to pressurize the injection nozzle, while observing the indication of the test pressure gauge. As the nozzle begins to spray, the indicating pointer of the gauge being deflected will start perceptively oscillating: read the pressure right then as the injection pressure.

Specifications Unit: kg/cm² (psi)

Item	Standard	Repair limit
Injection pressure	120^{+10}_{0} $(1706.4^{+142.2}_{0})$	110 (1564.2), max

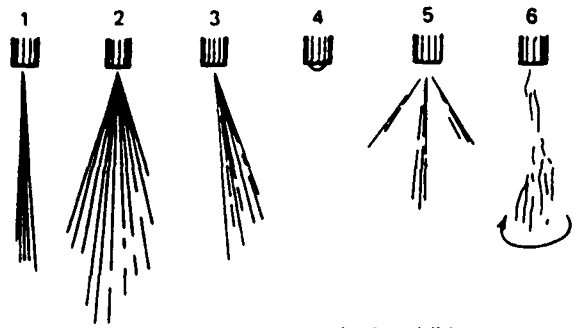
(c) If the reading taken is below the limit, increase the thickness of the shim used on the pressure spring. Increasing the shim thickness by 1 mm (0.04 in.) raises the injection pressure by about 10 kg/cm² (142 psi). Adjusting shim stock for this purpose is available in 20 sizes, from 1.0 mm (0.0394 in.) up to 1.95 mm (0.0768 in.) in increments of 0.05 mm (0.0020 in.) each.



Checking injection pressure on nozzle tester

(2) **Spray pattern**

The injection nozzles used in the present engine are of throttle type. Some throttling action takes place when the needle valve begins to unseat, thereby limiting the amount of fuel being sprayed out during the initial stage of each fuel injection. Thus, each slug of fuel sprayed out may be regarded as consisting of two parts: initial throttled spray and terminating main spray.



1-Good
2-Spray cone too large
3-Off-center spray
4-After-dribble
5-Fissured spray
6-Whirling spray

Possible patterns of spray

When tested on the nozzle tester, the injection nozzle can be made to produce these two kinds of spray for visual inspection. Initial throttled spray comes about when the tester lever is operated at a rate of 60 cycles per minute (up and down in one second); terminating main spray occurs when the lever is operated rapidly at a rate of, say, 4 to 6 cycles per second.

(a) Initial throttled spray

When the nozzle is producing only this spray, atomization is generally poor and the pattern is rather straight than conical, there being more or less after-dribble, that is, fuel dribbling after injection. All these are due to the fact that the fuel being injected is being throttled by the pintle protruding from the valve.

While the nozzle is making this spray, see if the needle valve chatters in synchronism with the cyclic motion of the lever; if so, then the needle valve is free from any sticking or hitching tendency and, if not, the nozzle and needle valve must be cleaned by washing and re-tested.

Off-center spray or directionally erratic spray, if noted, should be taken to mean that the injection nozzle needs thorough cleaning.

(b) Terminating main spray

With the tester lever operated at a rate of 4 to 6 cycles per second, the initial throttle spray is hardly visible. The spray under this condition may be regarded as main spray.

The main spray should be a good straight cone, consisting of finely atomized fuel particles without any large droplets, and should terminate with no dribble at the tip, not to mention of any fuel dripping.

(3) Seating tightness

An injection nozzle tested and adjusted as above, and found to produce a good spray pattern may be re-used in the engine provided that it passes this final test – seating tightness test.

With the injection nozzle mounted on the nozzle tester, raise the pressure slowly to 100 or 110 kg/cm^2 (1422 or 1564 psi) (without exceeding the set pressure of 120 kg/cm^2 (1706 psi), so that the needle valve will not unseat). Hold the pressure and observe the nozzle tip: there should be no evidence of fuel oozing out to form a dribble. If such evidence is noted, then the contacting faces of the needle valve and seat must be repaired by lapping in the manner already suggested or the injection nozzle as a whole must be replaced.

NOTE

Check injection nozzle for spray pattern every 1200 hours and remove carbon deposited arround nozzle tip.

Chapter 4

Hydraulic System

Table of Contents

Specifications

Item	Description
Traction Pump Traction Relief Pressure Charge Pressure	Variable displacement axial piston pump 5000 – 5200 PSI 50 – 150 PSI (2WD) 75 – 150 PSI (4WD)
Steering Pump Steering Relief Pressure	Gear pump with flow divider 1200 – 1300 PSI
Traction Motor (front)	Fixed axial piston motor
Traction Motor (rear w/4WD)	Geroler type wheel motors
Reel Pump Cutting Circuit Relief Pressure	Gear pump 2650 – 2750 PSI
Reel Motor Cross–over Relief Pressure	Gear Motor 1500 PSI
Lift Control Valve Lift Relief Pressure Counterbalance Pressure (Max. RPM)	Spool type directional control valve 2650 – 2900 PSI Hot oil 500 – 550 PSI, cold oil 600 – 650 PSI
Hydraulic Filter (Fig. 1)	Spin–on cartridge type
Hydraulic Oil	* Mobil DTE 26/Shell Tellus 68 or equivalent
Reservoir (Fig. 2)	Reservoir capacity 15 gal. U.S. System capacity approximately 18.2 gal. U.S.

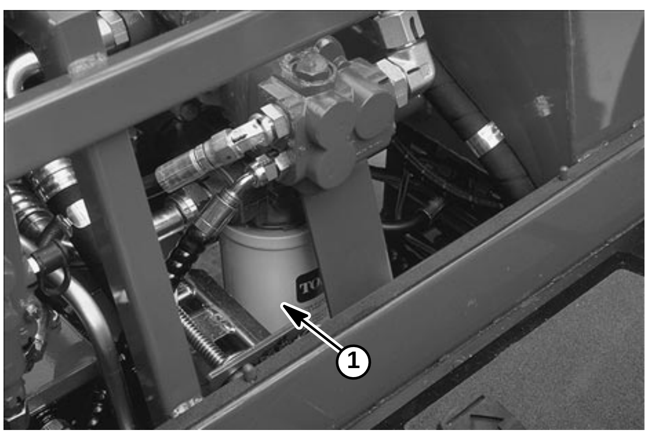


Figure 1
1. Hydraulic Filter

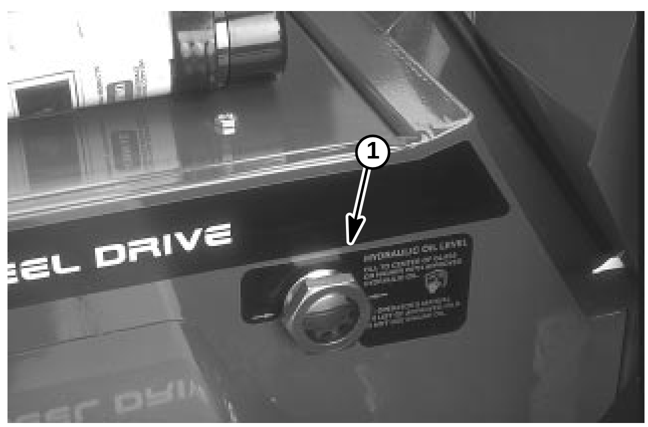


Figure 2
1. Hydraulic Reservoir Sight Gauge

*** Equivalent Hydraulic Oils (interchangeable):**

Amoco Rykon Oil 68
Conoco Super Hydraulic Oil 68
Exxon Nuto H 68
Kendall Kenoil R & O AW 68
Pennzoil Penreco 68
Phillips Magnus A 68
Standard Energol HLP 68
Sun Sunvis 831 WR
Union Unax AW 68

General Information

Hydraulic Hoses

Hydraulic hoses are subject to extreme conditions such as, pressure differentials during operation and exposure to weather, sun, chemicals, very warm storage conditions or mishandling during operation or maintenance. These conditions can cause damage or premature deterioration. Some hoses are more susceptible to these conditions than others. Inspect the hoses frequently for signs of deterioration or damage.

When replacing a hydraulic hose, be sure that the hose is straight (not twisted) before tightening the fittings. This can be done by observing the imprint on the hose. Use two wrenches; one to hold the hose straight and one to tighten the hose swivel nut onto the fitting.

WARNING

Before disconnecting or performing any work on hydraulic system, all pressure in system must be relieved by stopping the engine and lowering or supporting the box and/or other attachment.

Keep body and hands away from pin hole leaks or nozzles that eject hydraulic fluid under high pressure. Use paper or cardboard, not hands, to search for leaks. Hydraulic fluid escaping under pressure can have sufficient force to penetrate the skin and do serious damage. If fluid is injected into the skin, it must be surgically removed within a few hours by a doctor familiar with this type of injury or gangrene may result.

Hydraulic Fitting Installation

O–Ring Face Seal

1. Make sure both threads and sealing surfaces are free of burrs, nicks, scratches, or any foreign material.

2. Make sure the O–ring is installed and properly seated in the groove. It is recommended that the O–ring be replaced any time the connection is opened.

3. Lubricate the O–ring with a light coating of oil.

4. Put the tube and nut squarely into position on the face seal end of the fitting and tighten the nut until finger tight.

5. Mark the nut and fitting body. Hold the body with a wrench. Use another wrench to tighten the nut to the correct flats from finger tight (F.F.F.T.). The markings on the nut and fitting body will verify that the connection has been tightened.

Size	F.F.F.T.
4 (1/4 in. nominal hose or tubing)	.75 ± .25
6 (3/8 in.)	.75 ± .25
8 (1/2 in.)	.75 ± .25
10 (5/8 in.)	1.00 ± .25
12 (3/4 in.)	.75 ± .25
16 (1 in.)	.75 ± .25

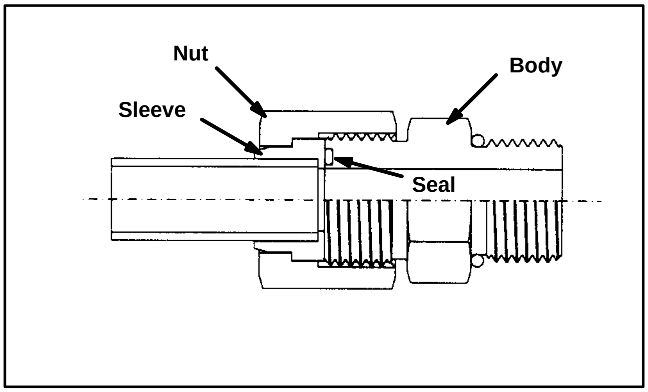


Figure 3

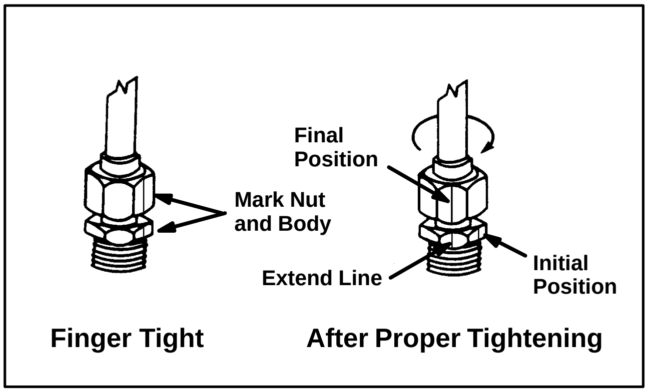


Figure 4

Hydraulic System

SAE Straight Thread O–Ring Port – Non–adjustable

1. Make sure both threads and sealing surfaces are free of burrs, nicks, scratches, or any foreign material.

2. Always replace the O–ring seal when this type of fitting shows signs of leakage.

3. Lubricate the O–ring with a light coating of oil.

4. Install the fitting into the port and tighten it down full length until finger tight.

5. Tighten the fitting to the correct flats from finger tight (F.F.F.T.).

Size	F.F.F.T.
4 (1/4 in. nominal hose or tubing)	1.00 ± .25
6 (3/8 in.)	1.50 ± .25
8 (1/2 in.)	1.50 ± .25
10 (5/8 in.)	1.50 ± .25
12 (3/4 in.)	1.50 ± .25
16 (1 in.)	1.50 ± .25

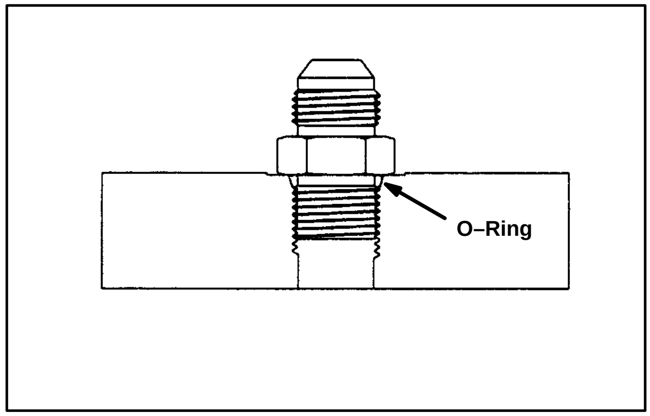


Figure 5

SAE Straight Thread O–Ring Port – Adjustable

1. Make sure both threads and sealing surfaces are free of burrs, nicks, scratches, or any foreign material.

2. Always replace the O–ring seal when this type of fitting shows signs of leakage.

3. Lubricate the O–ring with a light coating of oil.

4. Turn back the jam nut as far as possible. Make sure the back up washer is not loose and is pushed up as far as possible (Step 1).

5. Install the fitting into the port and tighten finger tight until the washer contacts the face of the port (Step 2).

6. To put the fitting in the desired position, unscrew it by the required amount, but no more than one full turn (Step 3).

7. Hold the fitting in the desired position with a wrench and turn the jam nut with another wrench to the correct flats from finger tight (F.F.F.T.) (Step 4).

Size	F.F.F.T.
4 (1/4 in. nominal hose or tubing)	1.00 ± .25
6 (3/8 in.)	1.50 ± 25
8 (1/2 in.)	1.50 ± .25
10 (5/8 in.)	1.50 ± .25
12 (3/4 in.)	1.50 ± .25
16 (1 in.)	1.50 ± .25

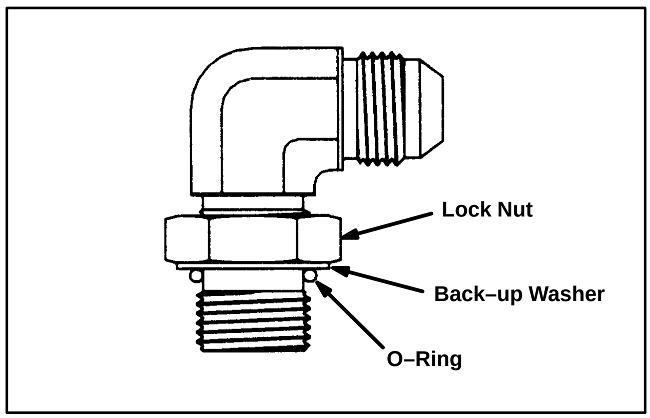


Figure 6

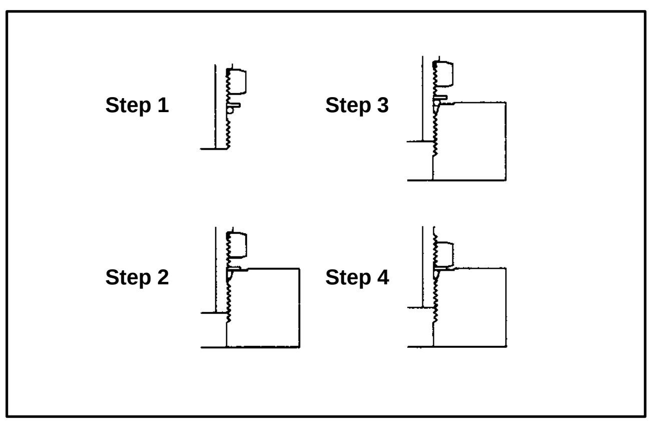


Figure 7

Pushing or Towing Traction Unit
Using Traction Pump By–Pass Valve

In an emergency, the traction unit can be pushed or towed for a very short distance by using the traction pump by–pass valve.

IMPORTANT: Do not push or tow the traction unit faster that 2 to 3 MPH (3 to 5 Km/Hr) because the hydraulic system may be damaged. If traction unit must be moved a considerable distance, transport it on a truck or trailer.

1. Remove the retainer clip from seat lock rod.

2. Raise seat and support it in upright position with seat support rod.

Figure 8

3. Lift and remove front panel.

Figure 9

4. Rotate by–pass valve 90 degrees. Opening the valve opens an internal passage in the traction pump, thereby by–passing hydraulic oil. Because oil is by–passed, traction unit can be moved without damaging the hydraulic system.

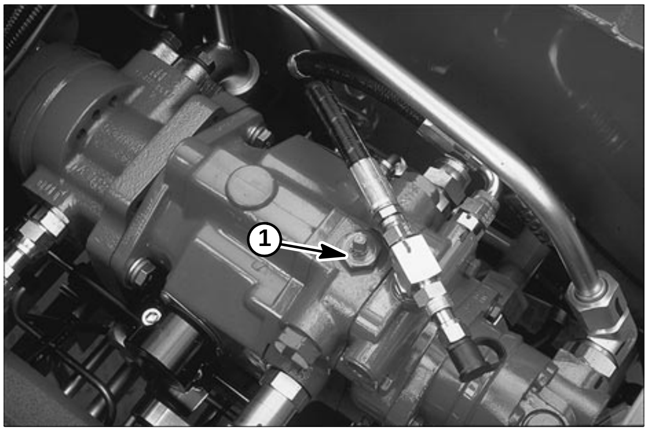


Figure 10
1. By–Pass Valve

IMPORTANT: Make sure that hand brake is engaged before opening the by–pass valve.

5. Before starting engine, close by–pass valve. Do not start engine when valve is open.

IMPORTANT: Running the machine with the by–pass valve open will cause the hydraulic system to overheat.

Hydraulic System

Disengaging Planetary Wheel Drives

In an emergency, the Reelmaster 4500–D can be moved by unlocking the front wheel hubs and towing the machine.

DANGER

Vehicle will roll with front wheel motors disengaged. Vehicle must be on level surface or wheels must be blocked. There is no effective braking with wheel motors disengaged.

If towing with front wheel motors disengaged, Tow Bar Assembly, Toro part no. 58–7020, must be used.

NOTE: The machine can also be moved slowly a short distance by opening the by-pass valve on the variable displacement hydraulic pump and pushing or towing the machine (See Pushing or Towing in the General Information section of Chapter 4 – Hydraulic System).

1. Block the wheels or connect the machine to a towing vehicle with a rigid towing device.

2. Remove bolts securing disengage covers to both front wheel hubs (Fig. 11).

Figure 11

3. Install disengage covers so dimple on cover is facing in towards hub. Wheel hubs are now unlocked. (Fig. 12).

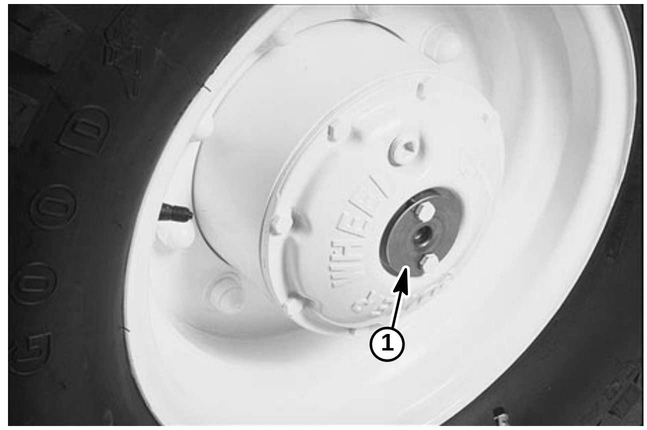


Figure 12

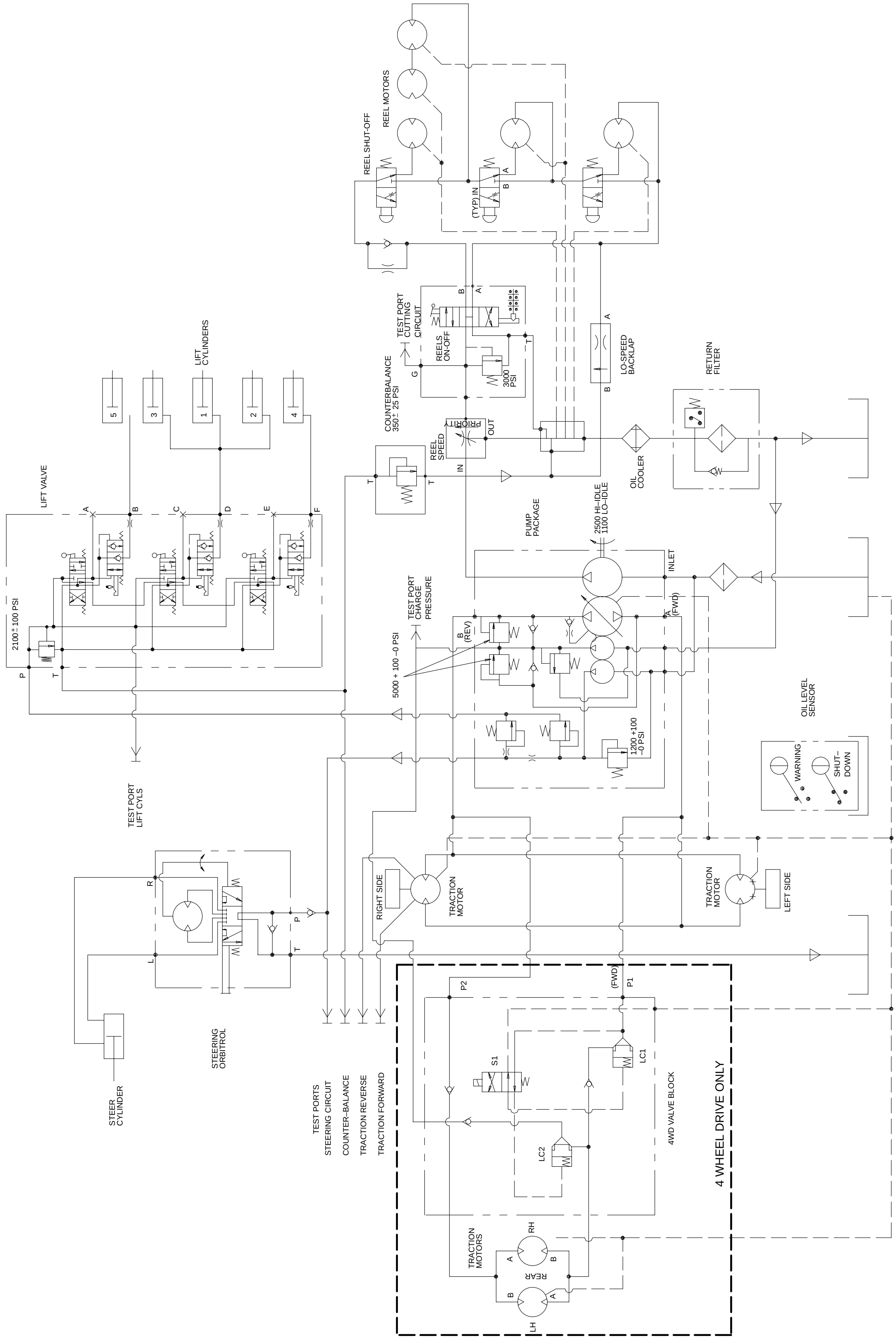
1. Disengage cover – engaged (dimple facing out)

4. Lock the wheel hubs immediately after towing is completed. Remove disengage covers and reinstall so dimple on cover is facing away from hub.

CAUTION

Do not remove wheel blocks or towing devices until wheel hubs are securely locked.

Hydraulic Schematic



Hydraulic System

Hydraulic Flow Diagrams (2WD Machines Only)

General Pump Flow

Refer to "Engine Run – No Functions" Flow Diagram

The traction, reel, and auxiliary pumps are directly coupled to the engine. With all controls in neutral and the engine running, the steer–lift pump draws oil through the suction line from the reservoir. Priority output flow is directed to the steering function. Excess flow exits the secondary output of the pump and is directed to the lift valve.

The flow continues through the lift valve where it meets the counterbalance valve. The counterbalance valve "super–charges" the incoming oil before allowing the oil to continue on its return path back to the sump tank. The counterbalance pressure may be monitored at pressure tap port 3.

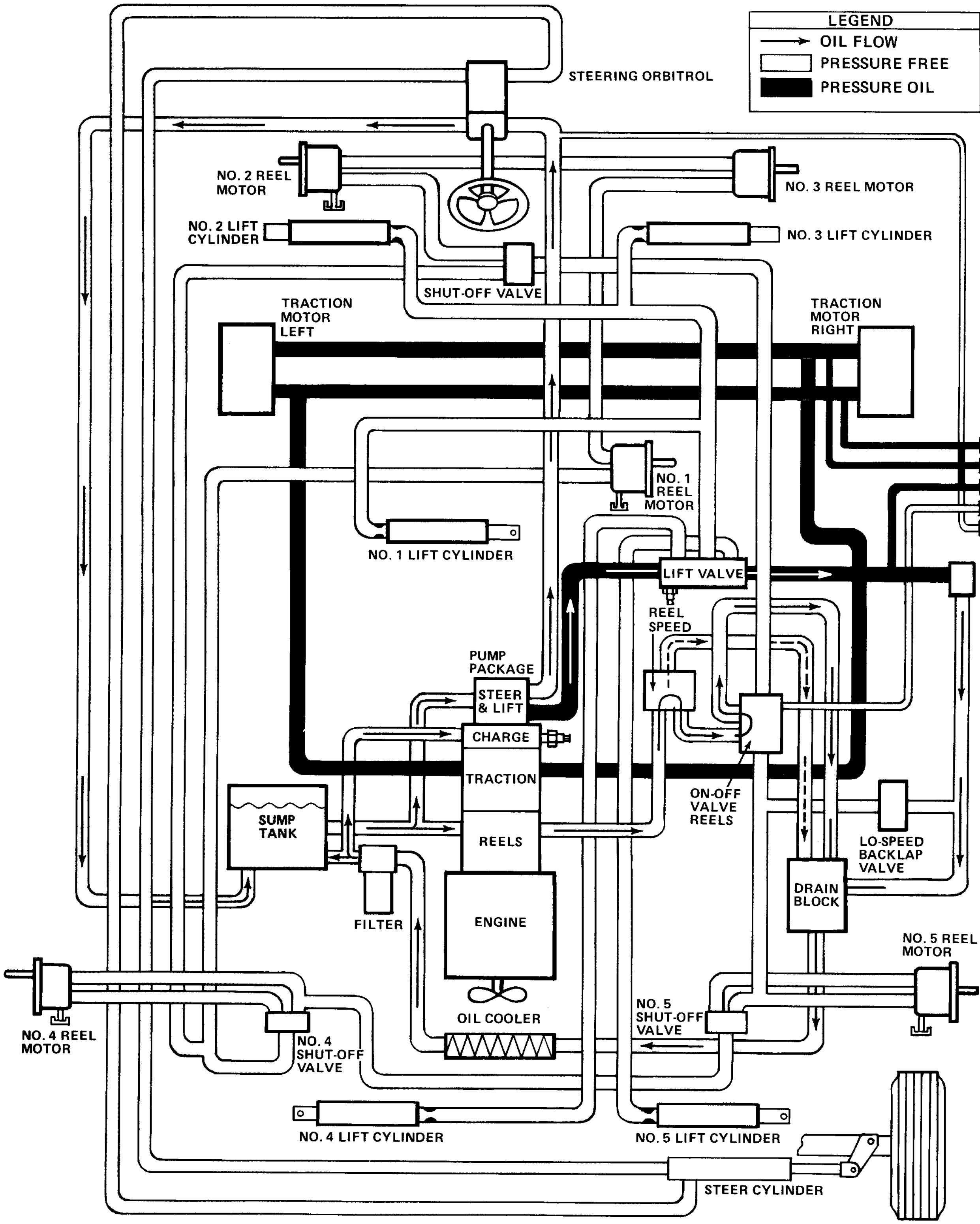
The oil pressure provided by the counterbalance valve will be used to reduce the cutting unit weight on the turf during the mowing function.

After joining with oil returning from other functions through the drain block, the oil flows through the oil cooler to dissipate heat from the hydraulic system and then through the filter to collect any particles in the hydraulic system.

Clean oil is collected at the filter by the charge pump. This oil is used to maintain a supply of oil to the closed–loop traction circuit to prevent cavitation. The charge pressure is regulated by a relief internal to the traction pump. The charge pressure may be monitored at the pressure tap port on top of the charge pump.

Oil collected by the reel pump is directed to the reel speed valve and split into two variable flows. Primary oil is directed to the reel "On–Off" control valve. With the valve in the "Off" position, the oil is returned directly to the drain block. The remaining oil will also return to the tank through the drain block.

Engine Run – No Functions



Hydraulic System

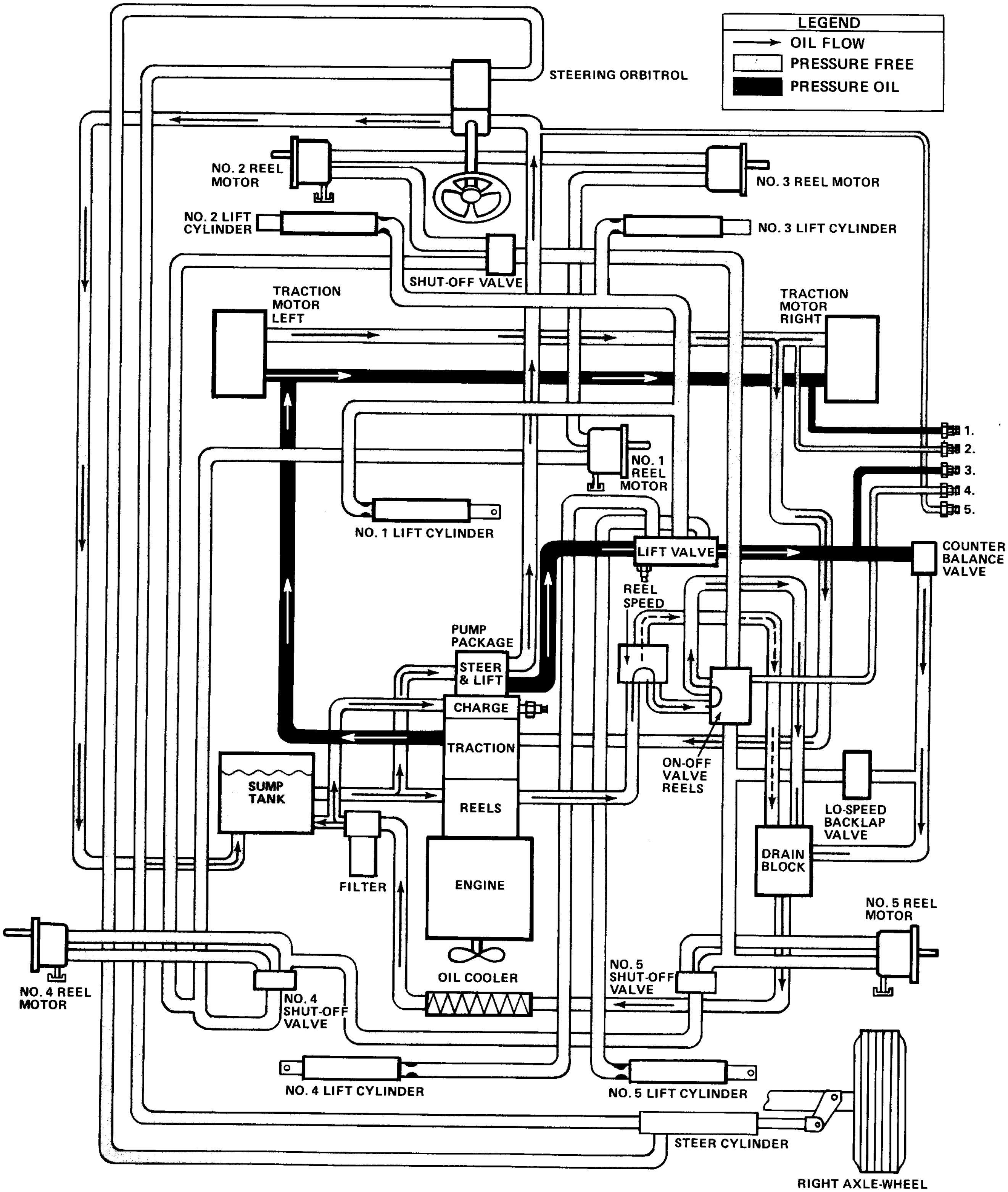
Traction Circuit

Refer to "Traction Circuit – Forward" Flow Diagram

A mechanical interlock between the traction pedal linkage and the parking brake prevents traction pedal movement unless the brake is released.

Depressing the top of the traction pedal will shift the traction pump swash plate to direct a flow of oil to the forward inlet of the traction motors. The oil returns from the motor to the pump where it continues through the pump in a closed–loop circuit. System pressure may be monitored at pressure tap port 1.

Traction Circuit – Forward



Steering Circuit

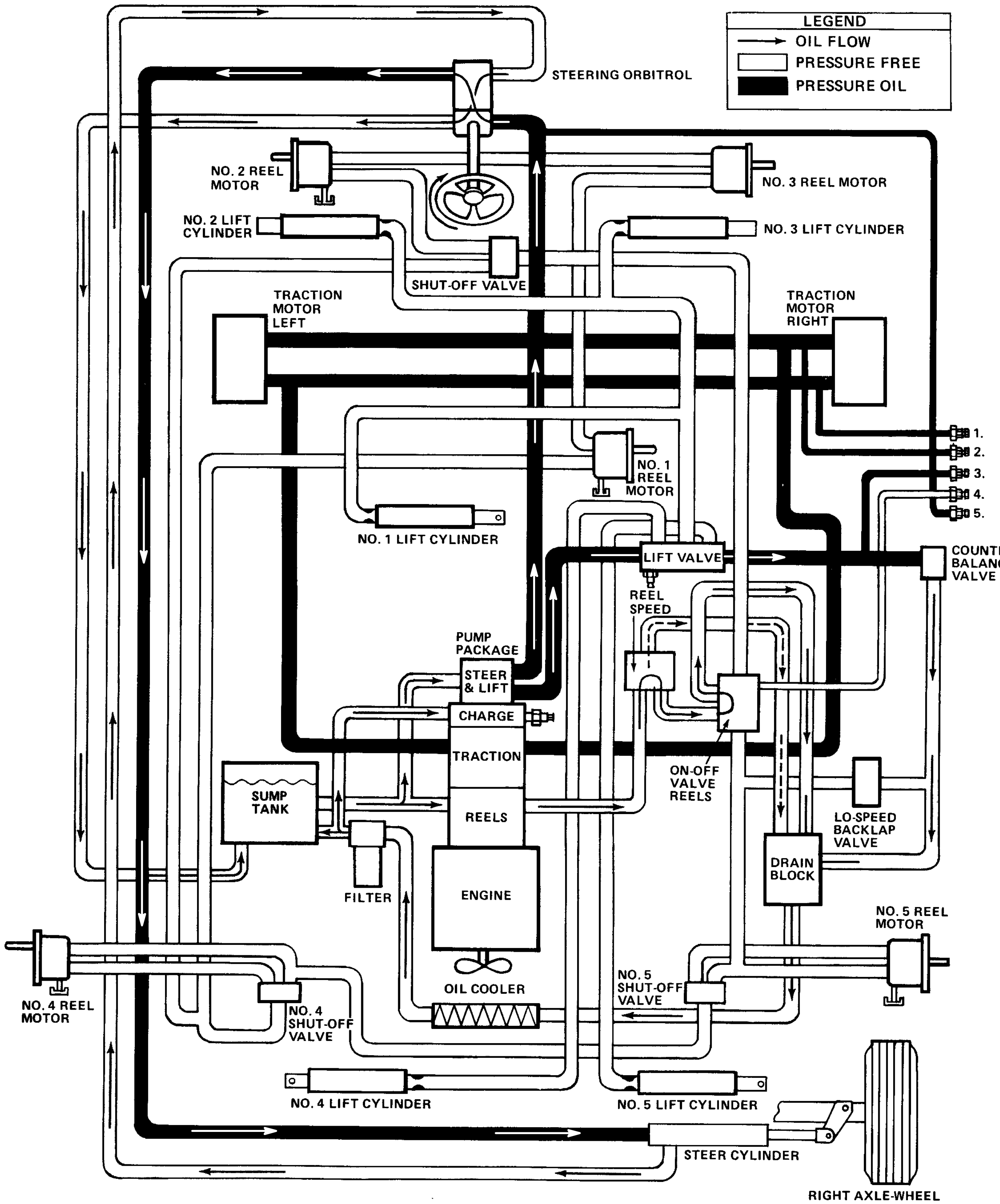
Refer to “Steering Right” Flow Diagram

With the engine running, the priority flow of oil from the steer–lift pump is directed to the power steering unit at the base of the steering column and returns to the reservoir.

Turning the steering wheel to the right moves the control spool in the steering unit to direct the oil to the steering cylinder for a right–hand turn. Turning the steering wheel to the left has the opposite effect. Cylinder movement returns oil from the low pressure side back through the power steering unit to the reservoir.

System pressure may be monitored at pressure tap port 5.

Steering Right



Lift/Lower Circuit

Refer to “Lift Circuit” Flow Diagrams

The lift cylinders are controlled by an open center valve with three spools. The number 4 and 5 cutting units are independently controlled. The center spool controls the number 1, 2, and 3 cutting units.

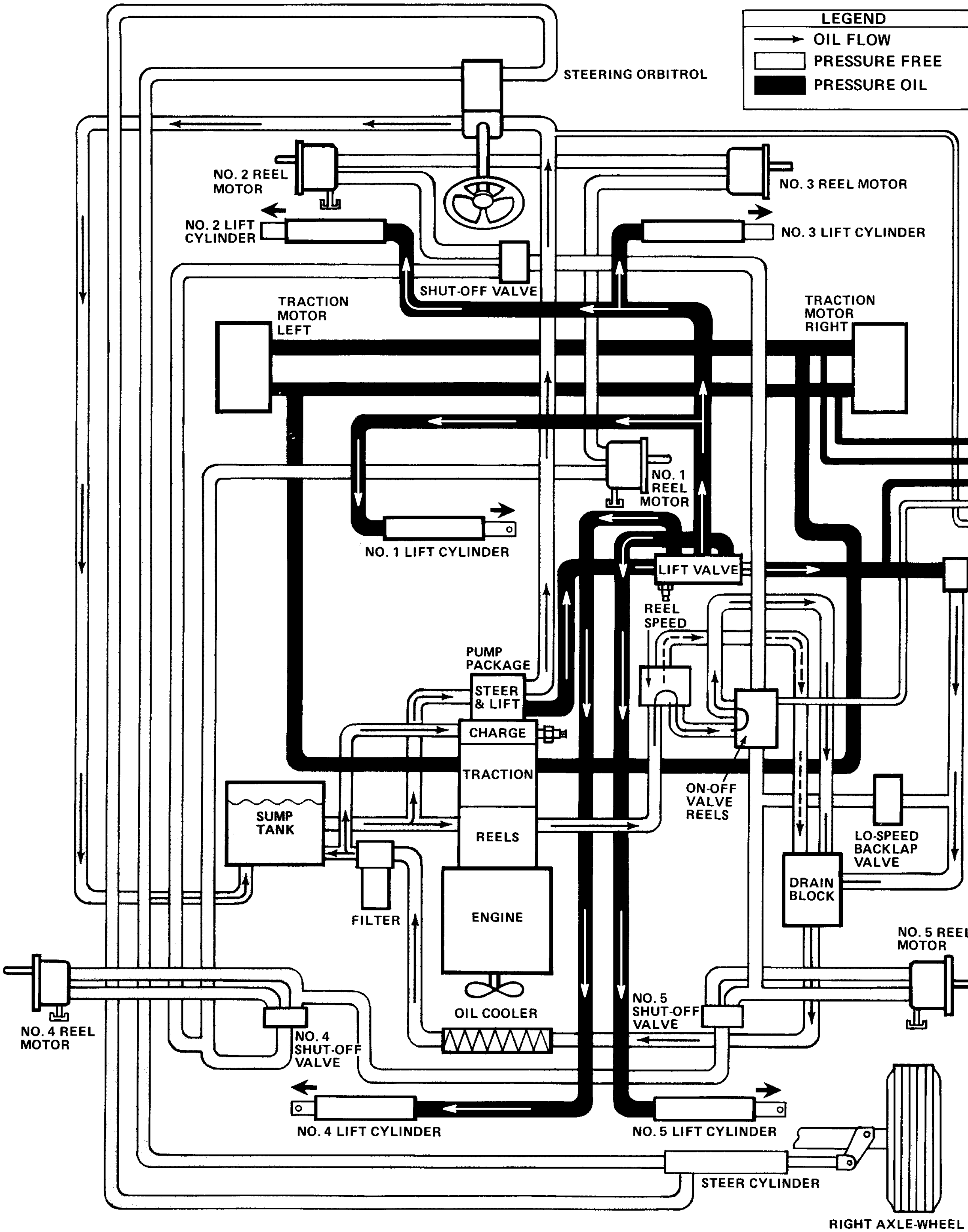
To lift the cutting units, the engine must be running above half throttle. The flow of oil from the steer and lift pump is used to accomplish the lift function. Holding a lever in the “LIFT” position will direct the flow of oil to the lift cylinder and raise the cutting unit. Oil pressure to the lift cylinder is monitored during LIFT by a relief at the valve inlet. System pressure may be monitored at the pressure tap port on the lift valve.

Moving the lever forward will open a path for oil to escape from the lift cylinder. The weight of the cutting unit will push oil from the cylinders through the valve allowing the cutting unit to lower. Moving the lever into “LIFT” while the cutting unit is lowering will lock the cutting unit at any position by trapping oil between the valve and cylinder.

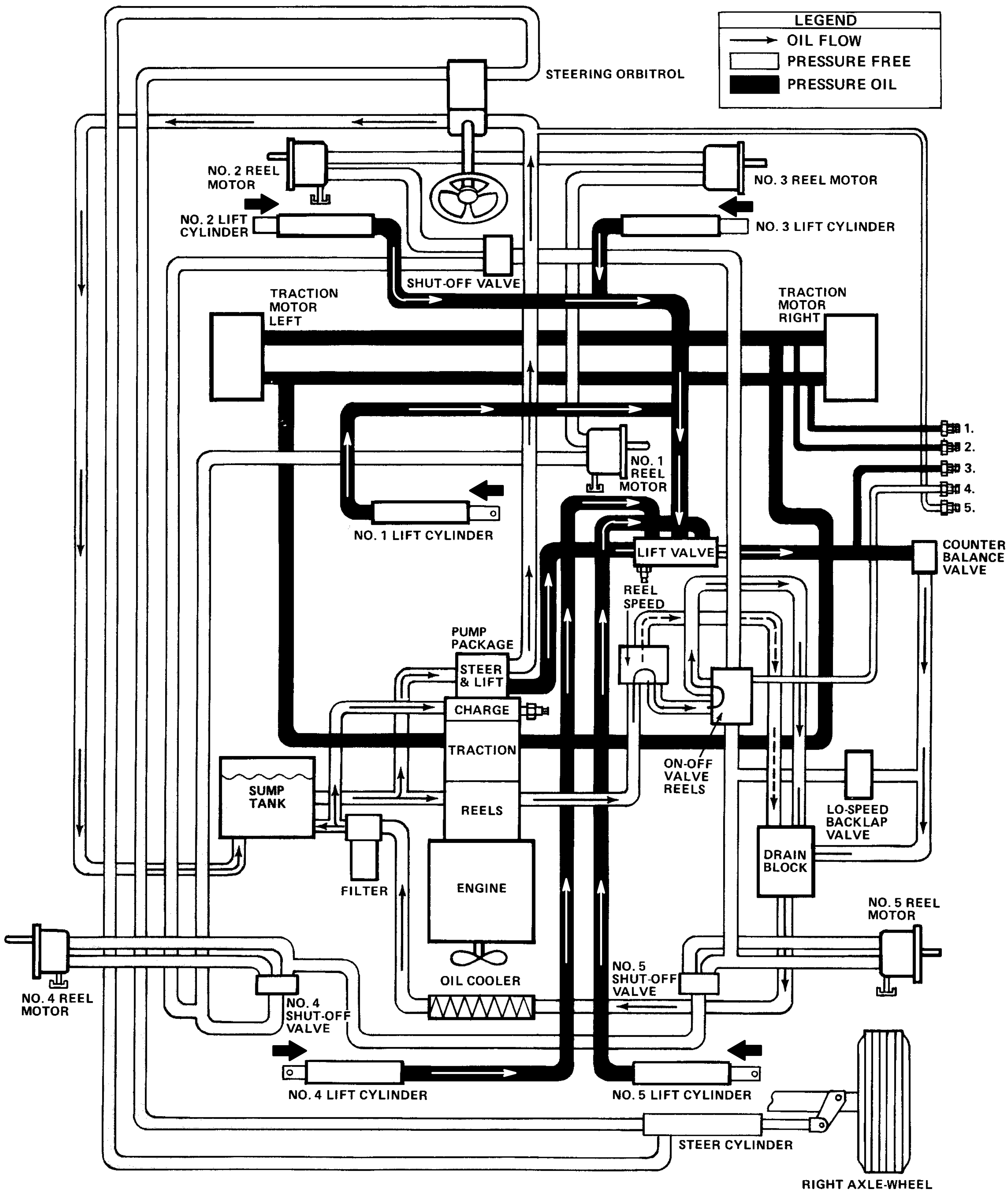
The cylinders work against counterbalance pressure during lowering. For this reason, the cutting units will drop faster at slow engine speeds or low counterbalance pressures compared to full engine speed or high counterbalance pressures. The counter balance pressure may be monitored at pressure tap port 3.

Since the lift levers are spring loaded from return to neutral, a detent plunger latches the spool in the valve to hold the spool in a “Free Float” position. The position enables the cutting units to follow ground contours by allowing a two–way flow between the lift valve and lift cylinders.

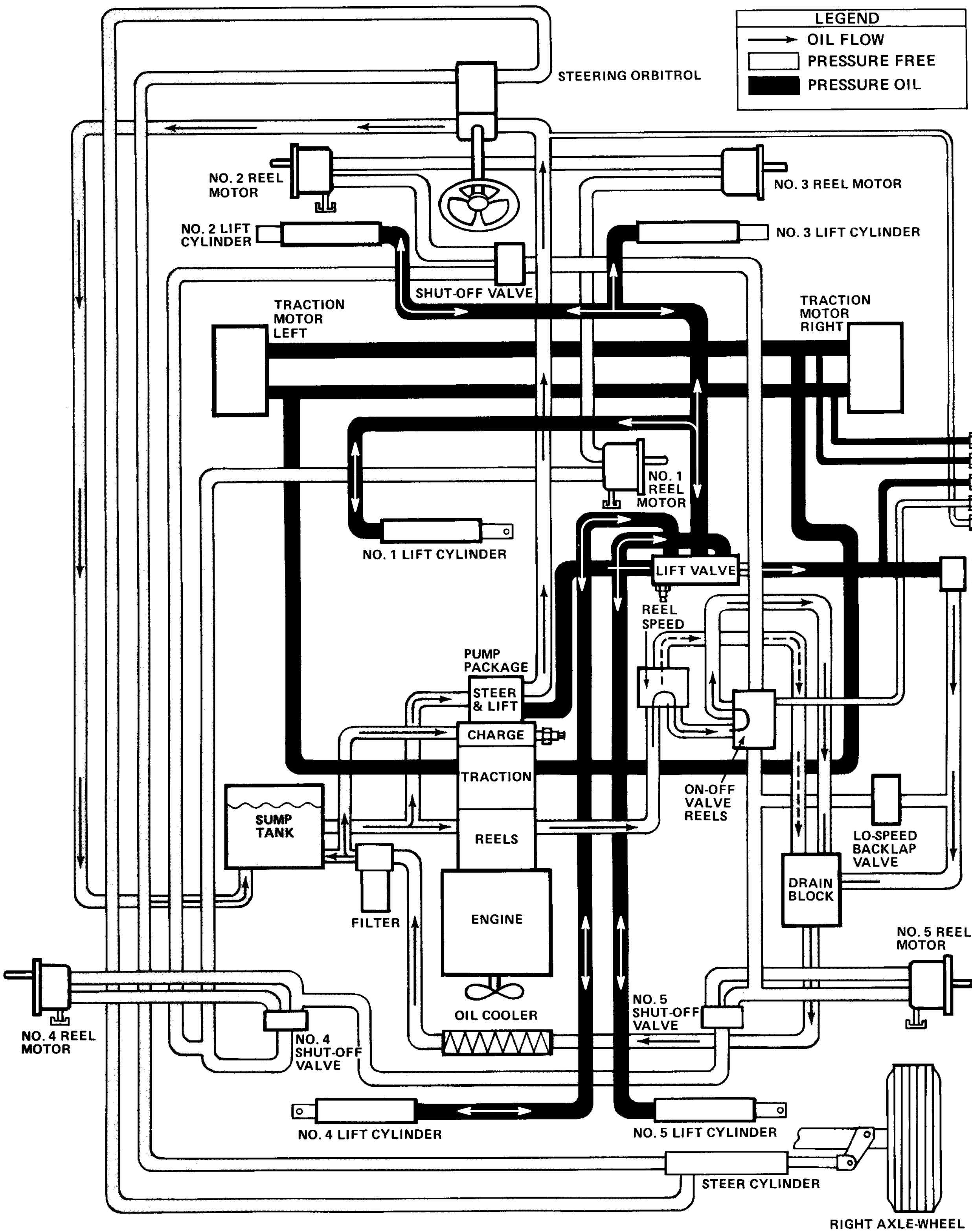
Lift Circuit – Lift All Units



Lift Circuit – Lower All Units



Lift Circuit – Free Float (Detent)



Reel Circuit

Refer to "Reel Circuit" Flow Diagrams

The three reel shut–off valves in this circuit enable the cutting units to be operated in several configurations for easier control, better clearance, or closer trimming.

The reel pump supplies a constant flow of oil to the reel speed control valve. The reel speed is variable and adjustable by the operator to supply a flow of oil to the reel "On–Off" valve. Oil not needed to obtain the selected reel speed is directed back to the sump tank through the drain block, oil cooler, and filter.

When the reel "On–Off" valve lever is moved into "Mow" to engage the reels, a spool in the valve is shifted to direct oil to the shut–off valve at the front of the unit. With the Number 1, 2, and 3 cutting units in mowing position, the shut–off valve will allow oil to flow to the Number 2, 3, and 1 reel motors. The oil is also available for use at the Number 4 shut–off valve. If the Number 1, 2, and 3 cutting units are in the raised position, the oil will bypass these motors and be available directly to the Number 4 shut–off valve.

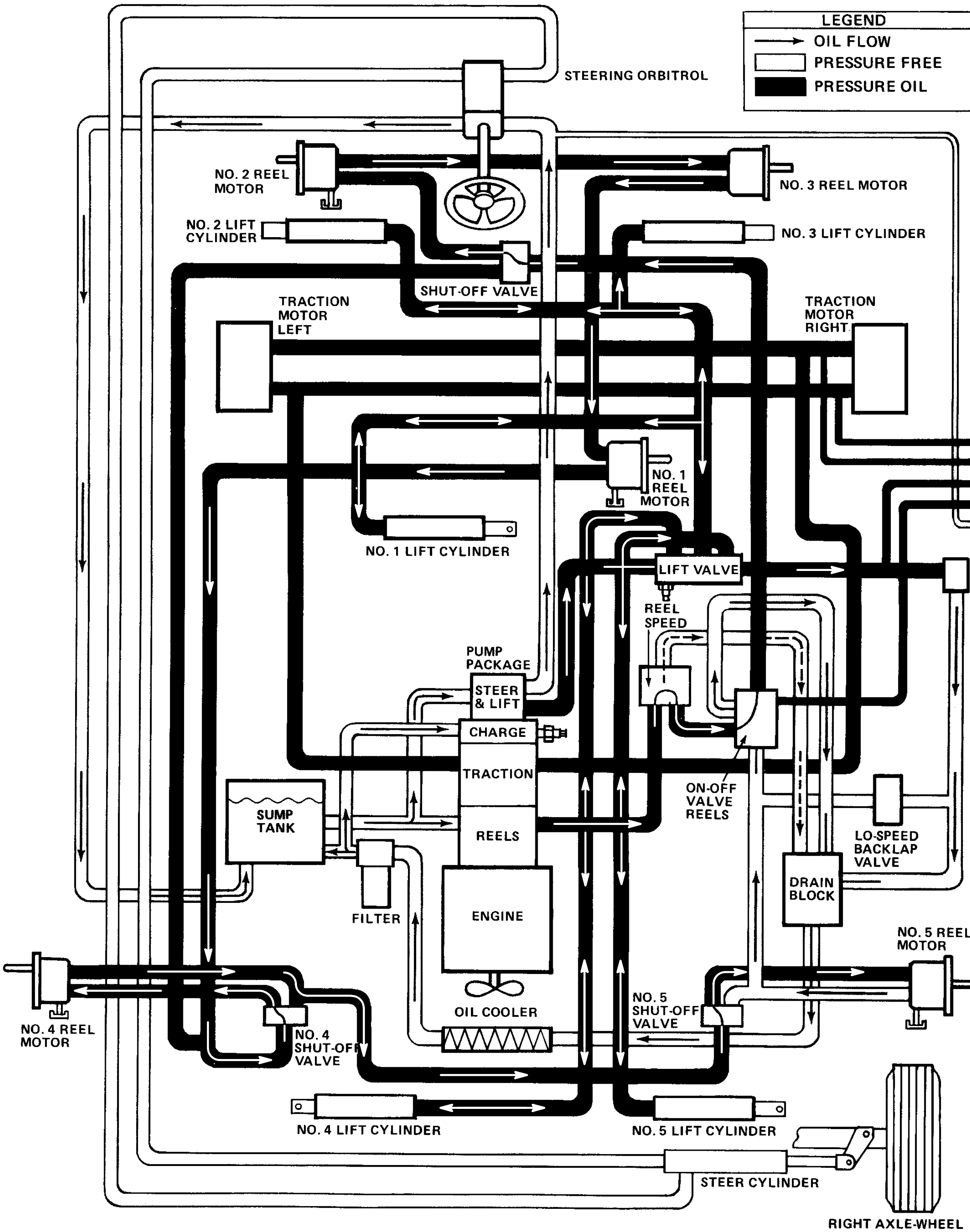
With the Number 4 cutting unit in the down and mowing position, the Number 4 shut–off valve will allow the oil through to drive the reel motor and then to the Number 5 shut–off valve. If the Number 4 cutting unit is in the raised position, the oil will bypass the Number 4 reel motor and be available directly to the Number 5 shut–off valve.

With the Number 5 cutting unit in the down and mowing position, the Number 5 shut–off valve will allow the oil through to drive the reel motor. If the Number 5 cutting unit is in the raised position, the oil will bypass the Number 5 reel motor and return to the reel "On–Off" valve. From the reel "On–Off" valve, the oil returns to the sump tank through the drain block, oil cooler, and filter.

"Backlap" is provided by pulling the reel "On–Off" valve lever up and back. The backlap function requires that the lever be held in this position for safety. The direction of flow in "Backlap" is the opposite of "Mow". Some units will include a low–speed backlap valve in the circuit to remove some oil flow from the circuit during the backlap function. The reduced oil flow results in a slower reel speed in "Backlap", but does not affect performance during "Mow".

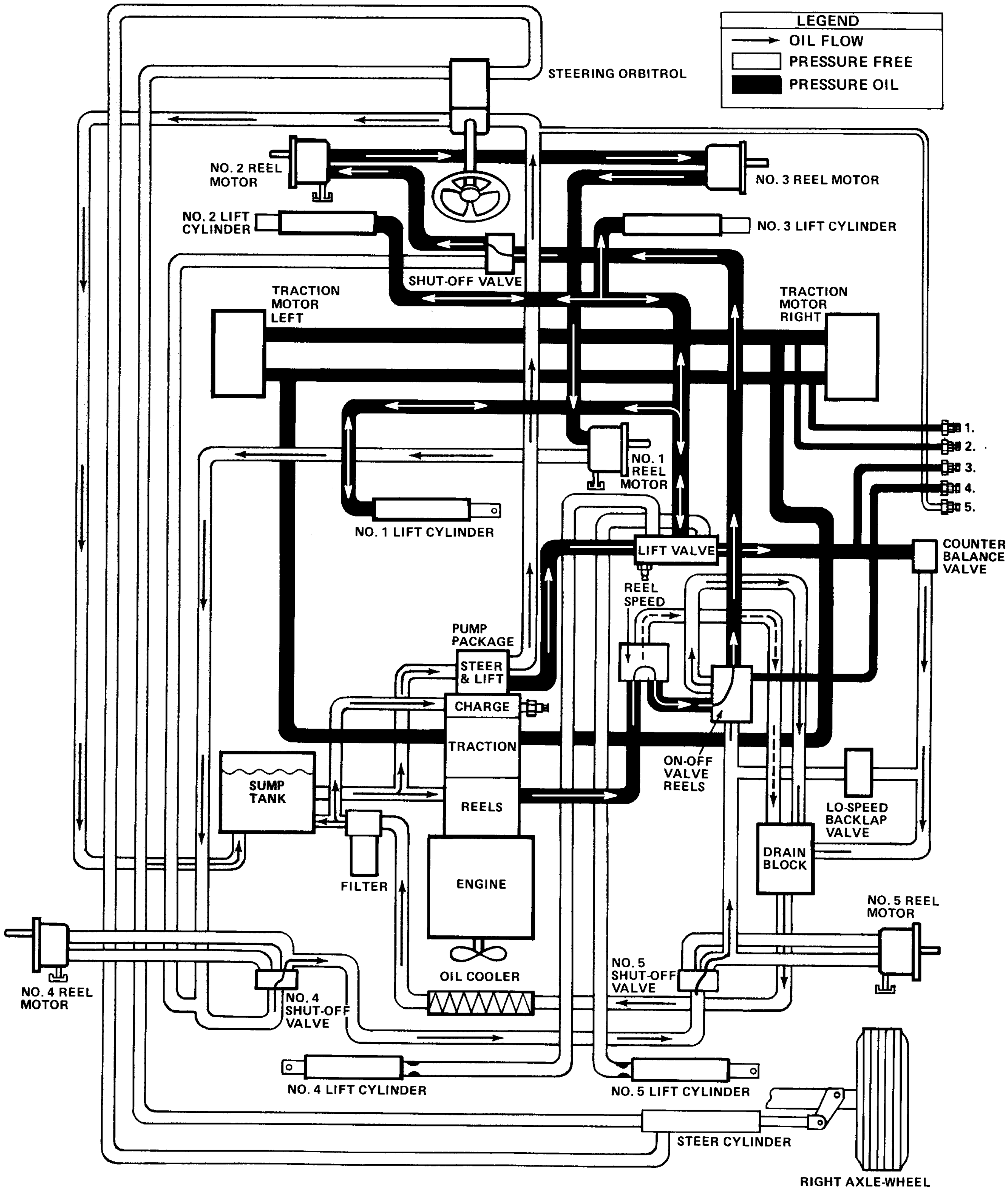
System pressure may be monitored at pressure tap 4 for either "Mow" or "Backlap".

Reel Circuit – All Units Mow (Free Float)

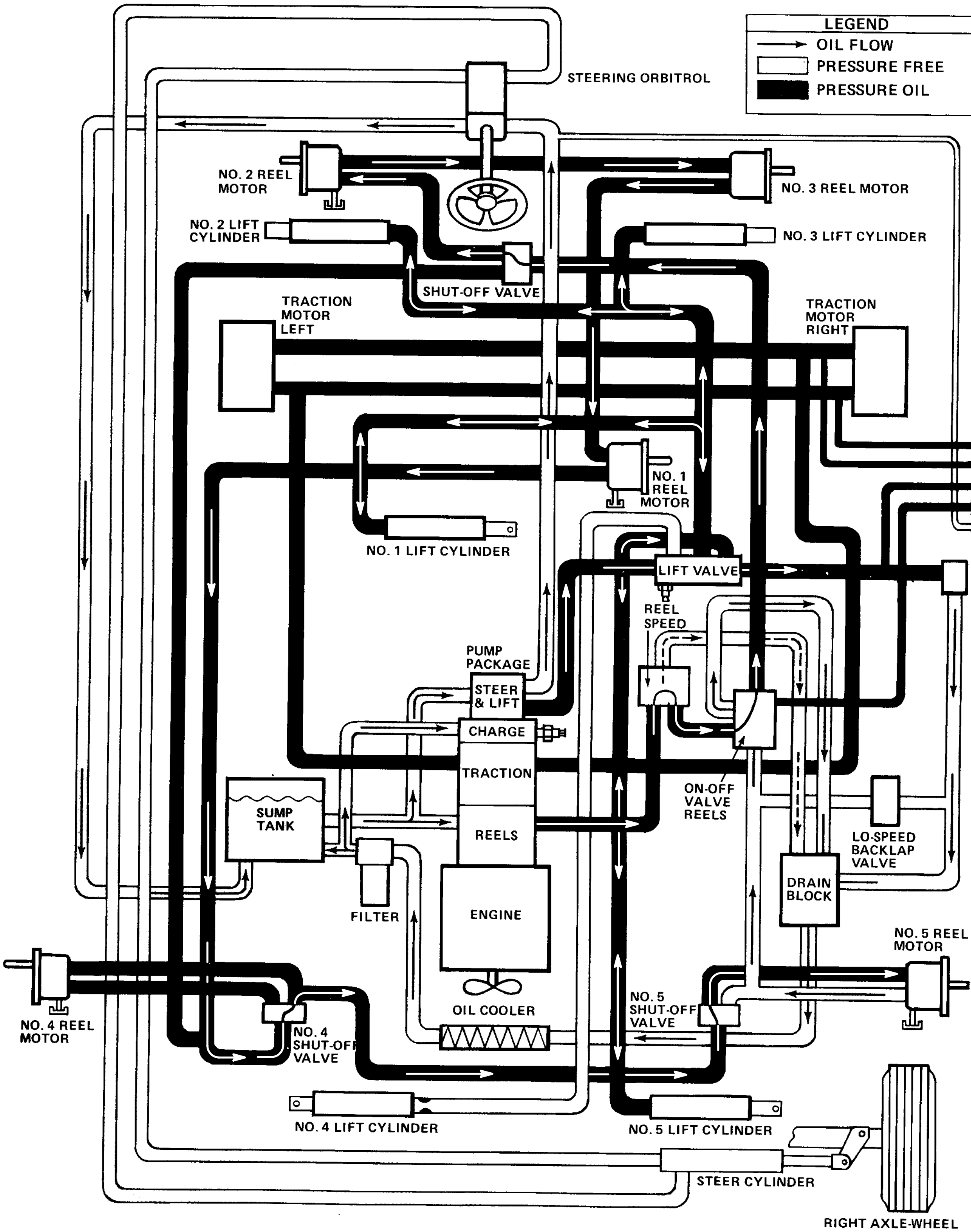


Hydraulic System

Reel Circuit – Units 1, 2 & 3 Mow (Free Float)

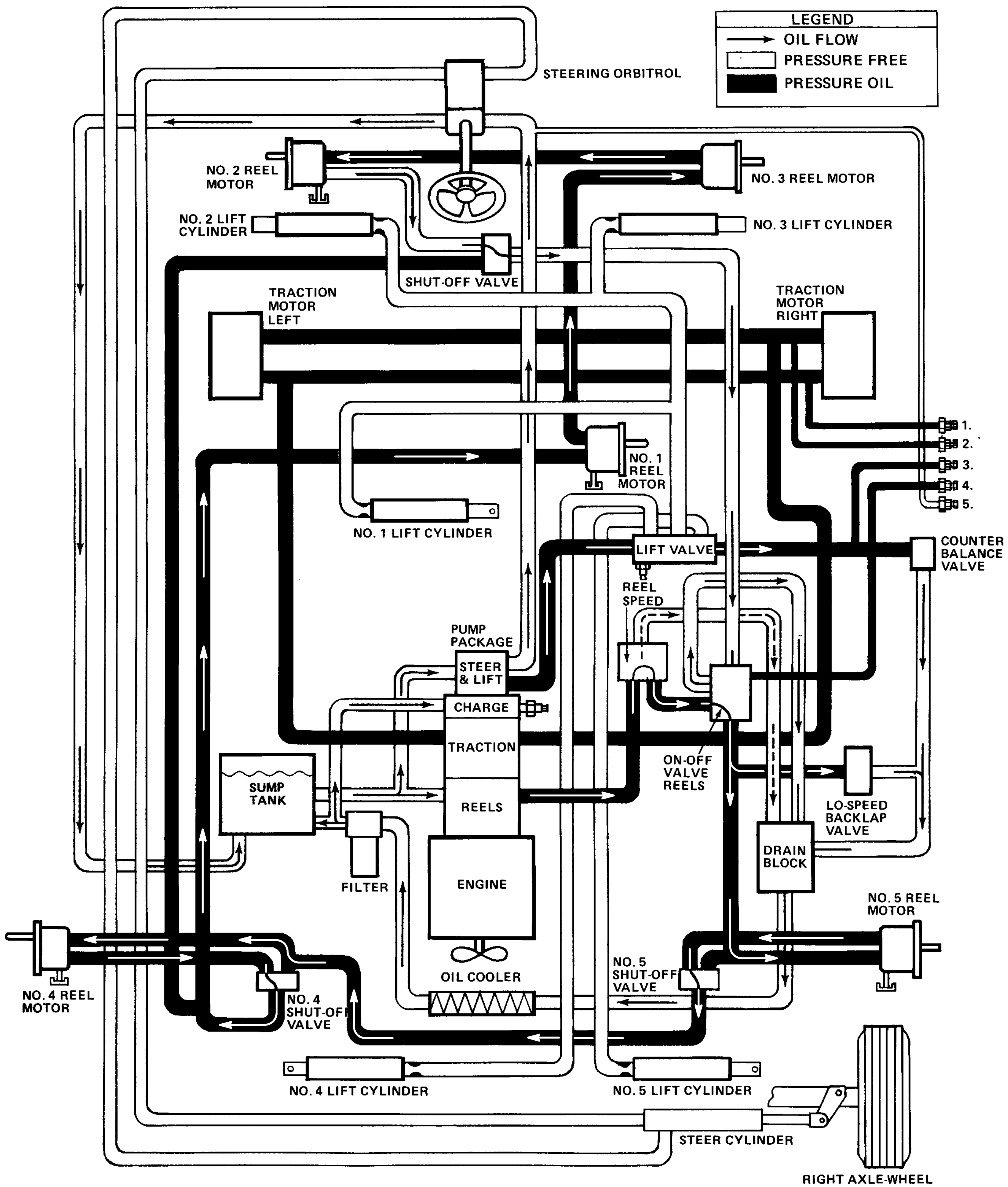


Reel Circuit – Units 1, 2, 3 & 5 Mow (Free Float)

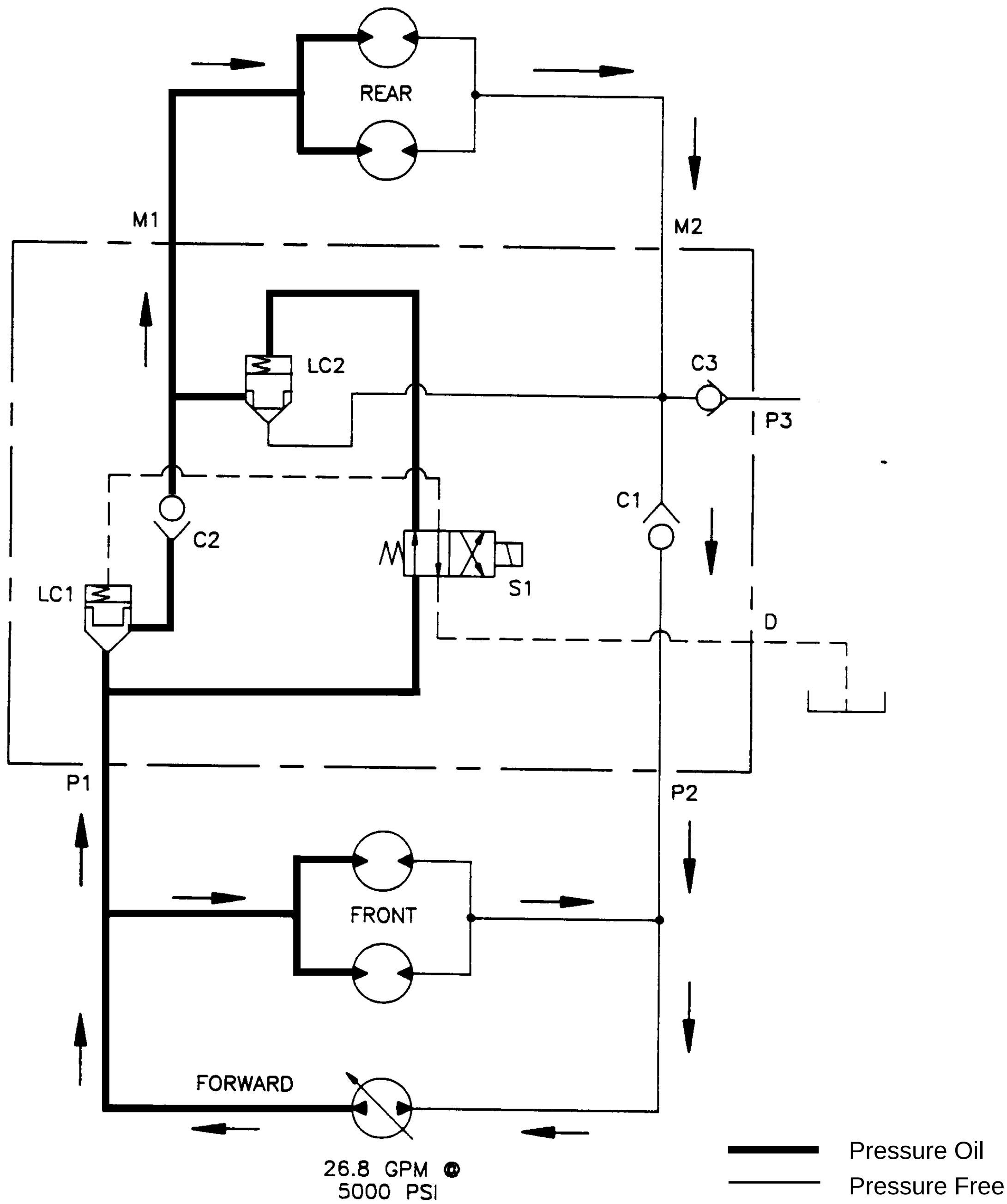


Hydraulic System

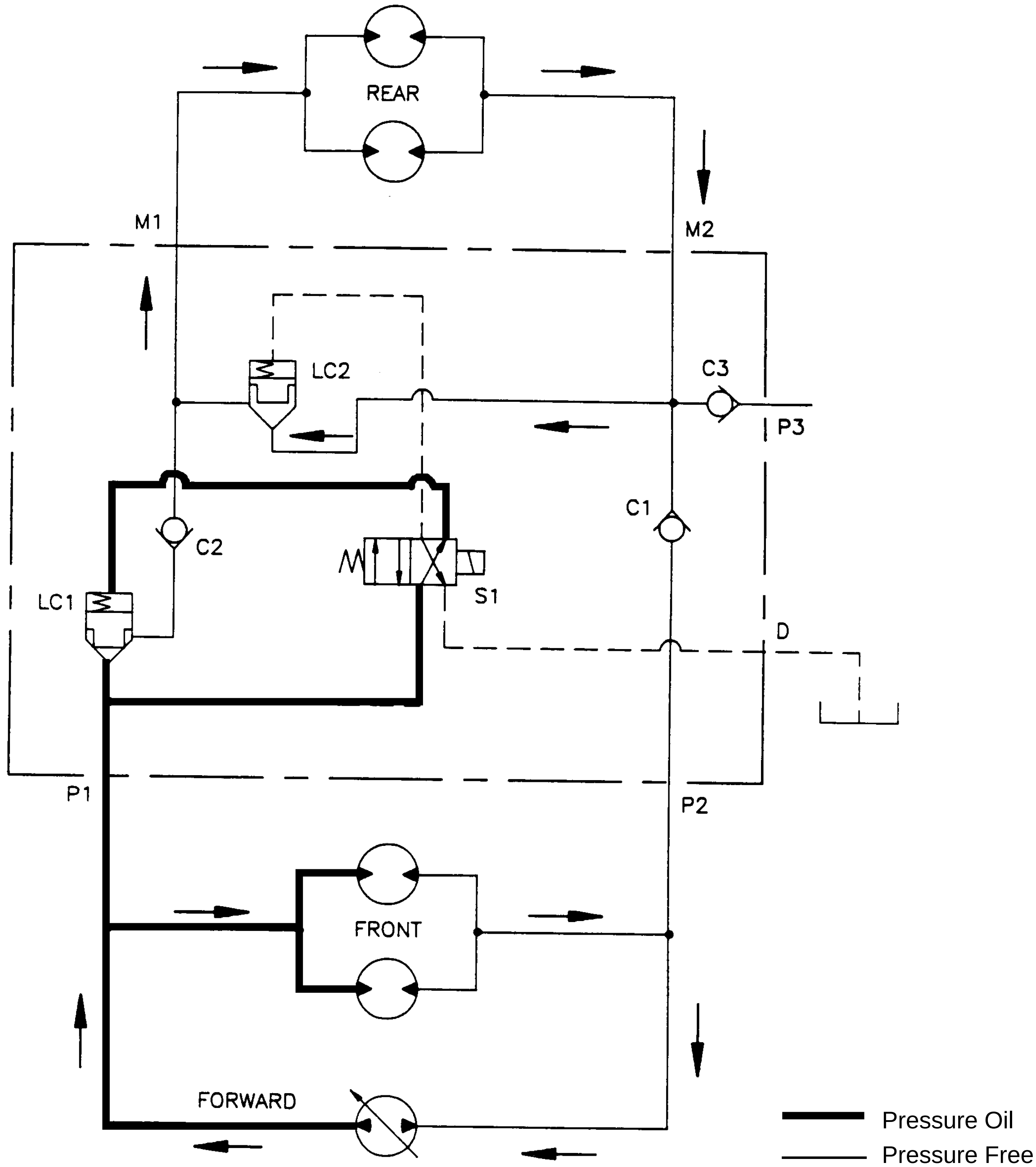
Reel Circuit – Any Unit Backup



4WD Forward (“S1” OFF)



2WD Forward ("S1" ON)



Special Tools

NOTE: Order special tools from the *TORO SPECIAL TOOLS AND APPLICATIONS GUIDE (COMMERCIAL PRODUCTS*). Some tools may also be available from a local supplier.

Hydraulic Pressure Test Kit

Use to take various pressure readings for diagnostic tests. Quick disconnect fittings provided attach directly to mating fittings on machine test ports without tools. A high pressure hose is provided for remote readings. Contains one each, 1000, 5000 and 10000 PSI gauges. Use gauges as recommended in Testing section of this chapter.

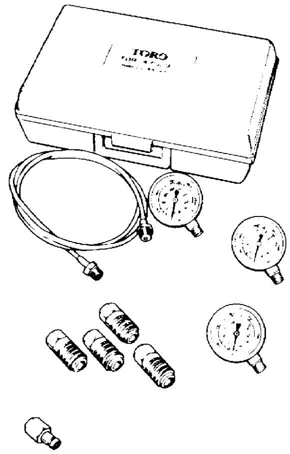


Figure 13

Hydraulic Tester – With Pressure and Flow Capabilities

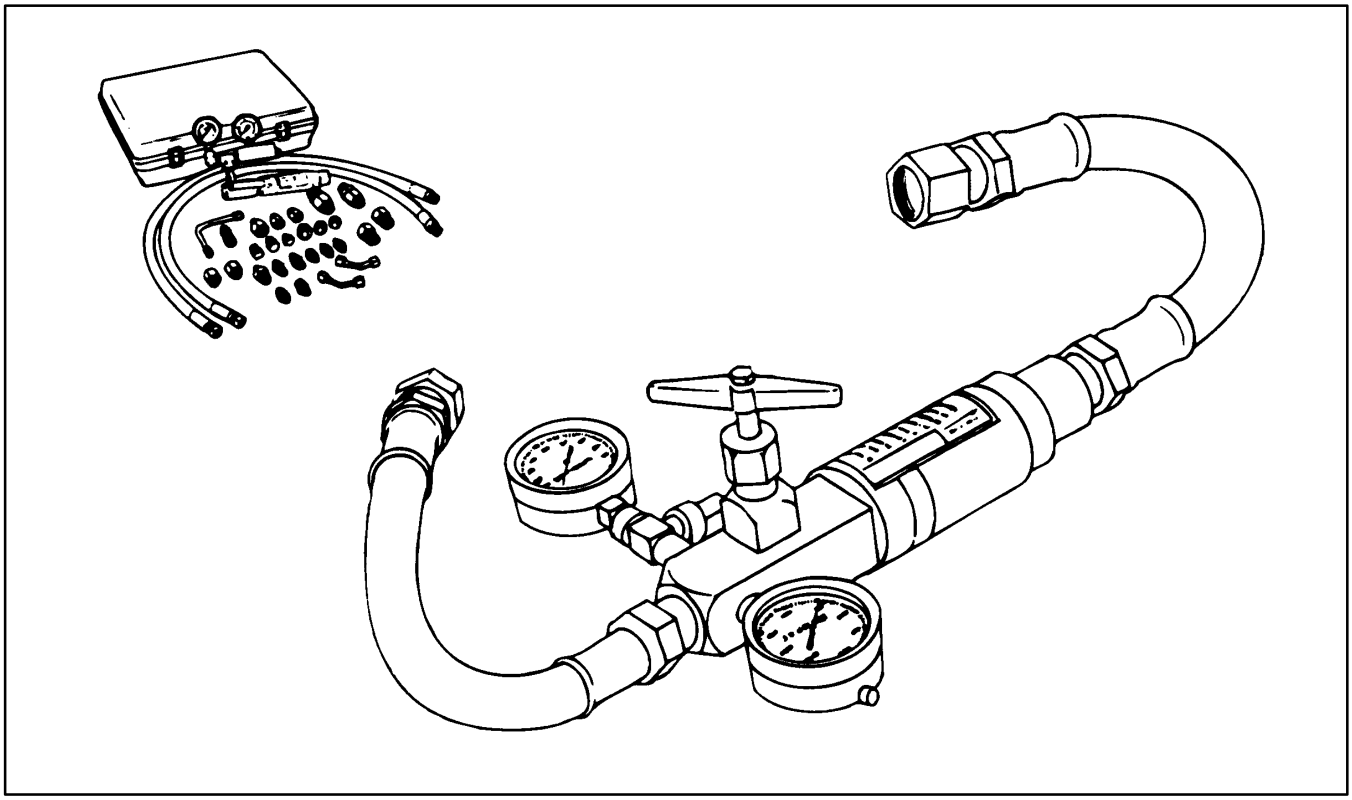


Figure 14

You must have o–ring face seal (ORFS) adapter fittings for this tester to use it on this machine.

1. INLET HOSE: Hose connected from the system circuit to the inlet side of the hydraulic tester.

2. LOAD VALVE: If required, upon turning the valve to restrict flow, a simulated working load is created in the circuit.

3. LOW PRESSURE GAUGE: Low range gauge to provide accurate reading at low pressure, 0 – 1000 PSI.

This gauge has a protector valve which cuts out when pressure is about to exceed the normal range for the gauge. The cutout pressure is adjustable.

4. HIGH PRESSURE GAUGE: High range gauge to accommodate pressure beyond the capacity of the low pressure gauge, 0 – 5,000 PSI.

5. FLOW METER: This meter measures actual oil flow in the operation circuit, with a gauge rated at 15 GPM.

6. OUTLET HOSE: Hose from the outlet side of the hydraulic tester to be connected to the hydraulic system circuit.

Troubleshooting

The cause of an improperly functioning hydraulic system is best diagnosed with the use of proper testing equipment and a thorough understanding of the complete hydraulic system.

A hydraulic system with an excessive increase in heat or noise is a potential failure. Should either of these conditions be noticed, immediately stop the machine, turn off the engine, locate the cause of the trouble, and correct it before allowing the machine to be used again.

Continued use of an improperly functioning hydraulic system could lead to extensive internal component damage.

The charts that follow contain information to assist in troubleshooting. There may possibly be more than one cause for a machine malfunction.

Refer to the Testing section of this Chapter for precautions and specific test procedures.

Problem	Possible Causes
Hydraulic oil leak(s).	Fitting(s), hose, or tube loose or damaged.
	Missing or damaged o–ring.
Slow or no traction in either direction.	Low engine RPM.
	Low hydraulic oil level.
	Open or damaged traction pump by–pass valve.
	Disengaged or damaged final drive.
	Loose or damaged traction linkage.
	Low charge pressure. (See Test No. 8.)
	Low traction pressure. (See Test No. 1.)
	Damaged or worn traction motors.
Reels slow or won’t turn.	Low engine RPM.
	Low hydraulic oil level.
	Reel to bedknife adjustment too tight.
	Improper reel drive motor belt adjustment.
	Low reel shut–off valves.
	Low reel system pressure. (See Test No. 3.)
	Worn or damaged priority flow divider.
	Low flow to reel motors. (See Test No. 4.)
	Inefficient reel motor. (See Test No. 5.)

Problem	Possible Causes
Steering loss.	Thermal shock after washing.
	Note: Normal functions will return after orbitrol temperatures stabilize (approximately 15 minutes). DO NOT ATTEMPT TO TURN STEERING WHEEL UNTIL TEMPERATURES STABILIZE WHEN THERMAL SHOCK IS NOTED.
	Improper cylinder action.
	Low steering relief pressure. (See Test No. 6.)
	Worn or damaged steering cylinder.
	Worn or damaged steering pump.
	Worn or damaged steering control unit.
Cutting units lift slowly or won't lift.	Low engine RPM.
	Low hydraulic oil level.
	Binding lift arm pivot points or bushings.
	Worn or damaged bushings.
	Worn or damaged cylinders.
	Improper counterbalance pressure. (See Test No. 2.)
	Worn or damaged counterbalance valve.
	Low lift relief pressure. (See Test No.7.)
	Plugged cylinder orifice.
	Worn or damaged lift valve.
	Worn or damaged steering/lift pump.
Cutting units won't drop or follow ground contours.	Low engine RPM.
	Low hydraulic oil level.
	Binding lift arm pivot points or bushings.
	Worn or damaged bushings.
	Worn or damaged cylinders.
	Improper counterbalance pressure. (See Test No. 2.)
	Worn or damaged counterbalance valve.
	Plugged cylinder orifice.
	Worn or damaged spool detent in lift valve.
	Worn or damaged lift valve.

Testing

The most effective method for isolating problems in the hydraulic system is by using hydraulic test equipment such as pressure gauges and flow meters in the circuits during various operational checks. (See the Special Tools section in this Chapter.)

CAUTION

Failure to use gauges with recommended pressure (psi) rating as listed in test procedures could result in damage to gauge and possible personal injury from leaking hot oil.

Before Performing Hydraulic Tests

All obvious areas such as oil supply, filter, binding linkage, loose fasteners, or improper adjustments must be checked before assuming that a hydraulic component is the source of the problem being experienced.

WARNING

Before disconnecting or performing any work on the hydraulic system, all pressure in the system must be relieved by stopping the engine and lowering or supporting the cutting units or other implements.

Keep body and hands away from pin hole leaks or nozzles that eject hydraulic fluid under high pressure. Use paper or cardboard, not hands, to search for leaks. Hydraulic fluid escaping under pressure can have sufficient force to penetrate skin and do serious damage. If fluid is injected into the skin, it must be surgically removed within a few hours by a doctor familiar with this type of injury or gangrene may result.

1. Thoroughly clean the machine before disconnecting or disassembling any hydraulic components. Always keep in mind the need for cleanliness when working on hydraulic equipment.

2. Put caps or plugs on any hydraulic lines left open or exposed during testing or removal of components.

3. The engine must be in good operating condition. Use a tachometer when making a hydraulic test. Engine speed can affect the accuracy of the tester readings.

4. To prevent damage to tester or components, the inlet and the outlet hoses must be properly connected, and not reversed (tester with pressure and flow capabilities).

5. To minimize the possibility of damaging components, completely open load valve in hydraulic tester (when using tester with pressure and flow capabilities).

6. Install fittings finger tight, far enough to insure that they are not cross–threaded, before tightening with a wrench.

7. Position the tester hoses so that rotating machine parts will not make contact with them and result in hose or tester damage.

8. Check the oil level in the reservoir.

9. Check the control linkage for improper adjustment, binding or broken parts.

10. All hydraulic tests should be made with the hydraulic oil at normal operating temperature.

TEST NO. 1: Checking Traction Circuit Working Pressure Or Relief Pressure

Procedure for Working Pressure Check:

1. Install a 10,000 psi gauge into the traction circuit quick disconnect for the function to be checked.

2. Operate the unit while monitoring gauge. NOTE: If the machine is equipped with 4WD, check working pressure in both 2WD and 4WD modes.

RANGE OF TESTER READINGS: 50 – 5200 PSI

NOTE: Typical working pressure during operation while going uphill, would be approximately 4000 PSI in 2WD and 2500 PSI in 4WD.

3. If working pressure is too low in 2WD, perform the traction circuit relief pressure check.

NOTE: If pressure is good in 2WD but to low in 4WD, check the cartridge valve seals in the 4WD valve block. If 4WD pressure is low after making repairs to the valve block the rear wheel motor(s) should be suspected of wear and inefficiency. Maximum allowable bypass for each rear wheel motor is 2 GPM.

Procedure for Relief Pressure Check:

1. Hydraulic oil must be at operating temperature.

2. Install a 10,000 psi gauge into the traction circuit quick disconnect for the function to be checked.

3. Set traction pedal stop for minimum ground speed (1 mph).

4. Start the engine and move throttle to full speed (2500 rpm) and release the parking brake.

5. Carefully drive the machine into position so it will push against a strong wall or other immovable obstacle. Continue an attempt to go forward with the machine against the obstacle and read the pressure gauge.

TESTER READING TO BE APPROXIMATELY 5000 – 5200 PSI

6. If traction pressure is too low, inspect the traction pump check valves and relief valves. Clean or replace relief valve(s) or check valves as necessary. If check valves and relief valves are in good condition, the traction pump and / or motors should be suspected of wear and inefficiency.

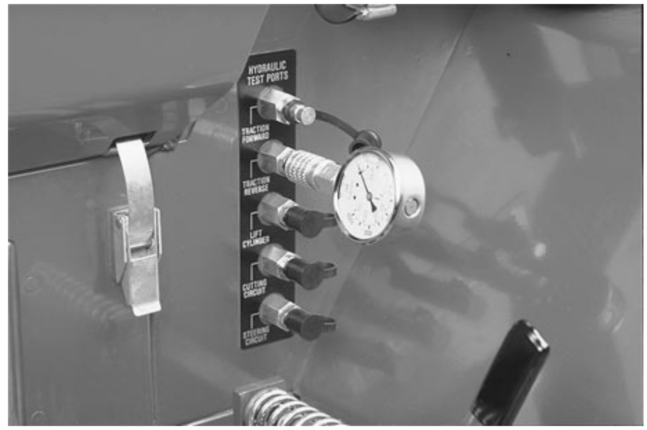


Figure 15

TEST NO. 2: Checking Counterbalance Oil Pressure

Procedure:

1. Install a 10,000 psi gauge into the center quick disconnect as shown.

2. Start the engine and move throttle to full speed (2500 rpm).

3. Tester reading should be within the range listed:

COLD OIL: 600 – 650 PSI

HOT OIL: 500 – 550 PSI

NOTE: Due to special conditions or customer preference, the counterbalance may require setting outside this recommended range. However, the range listed will be adequate for most conditions.

4. If necessary, adjust the relief valve screw until the desired pressure is attained. Turn the screw in to increase counterbalance pressure and turn the screw out to decrease counterbalance pressure. Adjust nearer the high end of the range for improved hill climbing or nearer the low end for improved quality–of–cut.

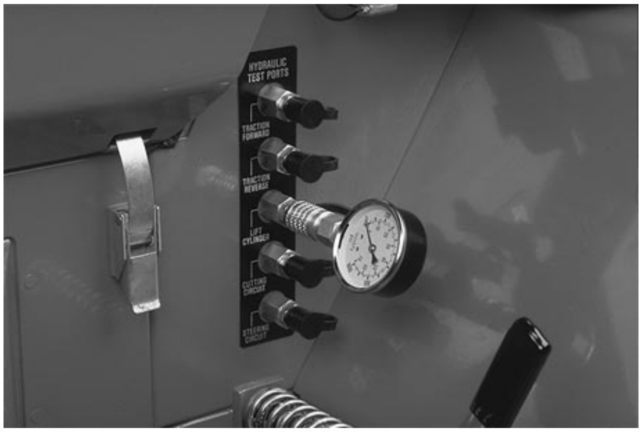


Figure 16

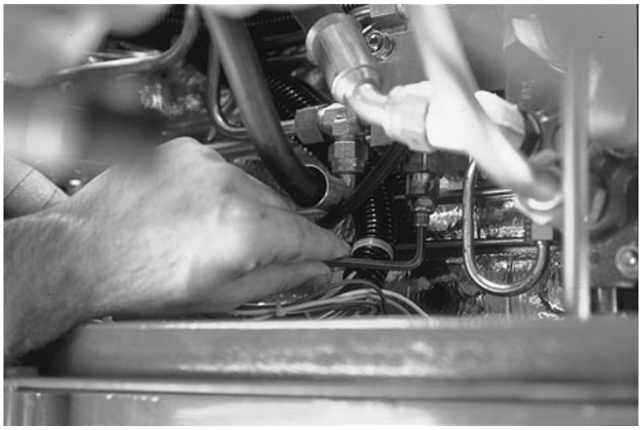


Figure 17

TEST NO. 3: Checking Reel Circuit Working Pressure or Relief Pressure

Procedure For <u>Working</u> Pressure Check:

1. Install a 5,000 psi gauge into the cutting circuit quick disconnect.

2. Operate the unit while monitoring the gauge.

RANGE OF TESTER READINGS 0 – 2750 PSI

3. If working pressure is too high or too low, perform relief pressure check.

NOTE: Normal pressure during operation is 1500 – 2000 psi. However, the gauge may spike higher during initial engagement of the control lever.

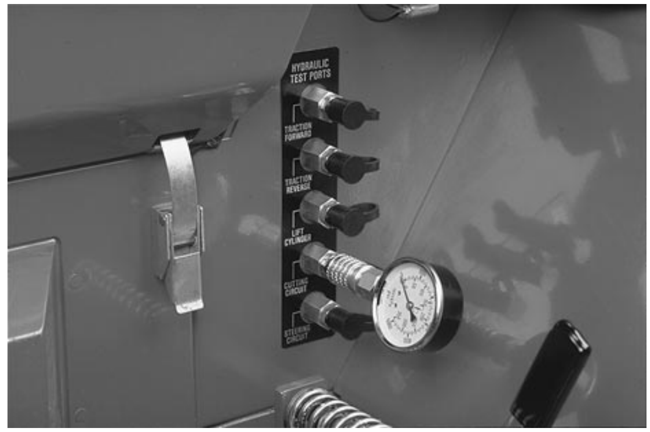


Figure 18

Procedure For <u>Relief</u> Pressure Check:

1. Hydraulic oil must be at operating temperature.

2. Install a 5,000 psi gauge into the cutting circuit quick disconnect.

3. Start the engine and lower the No. 2 (left front) and 3 (right front) cutting units to the ground.

4. Turn the engine OFF.

5. Block the reel of the No. 2 cutting unit to prevent rotation. The No. 2 cutting unit motor is the first in series flow from the pump. Use a substantial hardwood block inserted between the reel blades.

CAUTION

Stand clear of the reels during the following procedures.

6. Place reel speed control knob at minimum.

7. Start engine and position throttle at idle.

8. Ease the reel control lever into "MOW" while monitoring the gauge.

NOTE: It may be necessary to raise the throttle slightly to prevent the engine from stalling.

TESTER READING TO BE 2650 – 2750 PSI

9. If reel circuit relief pressure is above 2750 psi or below 2650 psi, clean or replace relief valve in reel control valve.

TEST NO. 4: Checking Reel Circuit Hydraulic Oil Supply

Procedure:

1. Hydraulic oil must be at operating temperature.

2. Start the engine and lower the No. 2 and 3 cutting units to the ground.

3. Turn the engine OFF.

4. Disconnect inlet hose at No. 2 reel motor.

5. Install tester in series between disconnected hose and reel motor (flow direction is from hose to motor). Make sure gate valve of tester is OPEN.

6. Position reel speed control knob at middle range (90 degree position).

7. Start engine and move throttle to full speed (2500 rpm).

8. Engage the reel control lever into the “MOW” position.

CAUTION

Reels will rotate when reel control lever is moved into the “MOW” position. Keep clear of rotating reels.

TESTER READING TO BE APPROXIMATELY 14 – 15 GPM.

9. If reel circuit oil flow is too low, check for restriction in pump intake line. If not restricted, remove pump and repair or replace as necessary.

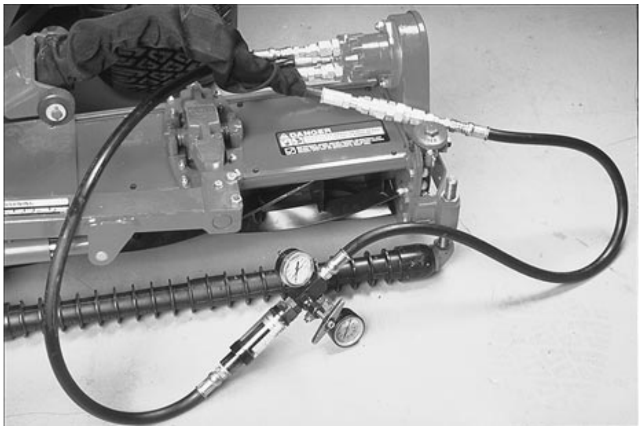


Figure 19

Hydraulic System

TEST NO. 5: Checking Reel Motor Efficiency

Procedure:

1. Hydraulic oil must be at operating temperature.

2. Start the engine and lower the cutting unit to be checked.

3. Turn the engine OFF.

4. Block the reel to be checked to prevent rotation. Use a substantial hardwood block inserted between the reel blades.

5. Disconnect inlet hose at reel motor.

6. Install tester in series between disconnected hose and reel motor (flow direction is from hose to motor). Make sure gate valve of tester is OPEN.

7. Position reel speed control knob at minimum speed.

8. Start engine and move throttle to idle speed (1200 rpm).

CAUTION

Stand clear of reels during the following procedures.

9. Gently ease the reel control lever into “MOW” while monitoring the tester.

NOTE: It may be necessary to raise the throttle slightly to prevent the engine from stalling.

TESTER READING NOT TO EXCEED 1.5 GPM at 1500 PSI

10. If flow is above 1.5 gpm, remove motor and repair or replace as necessary.

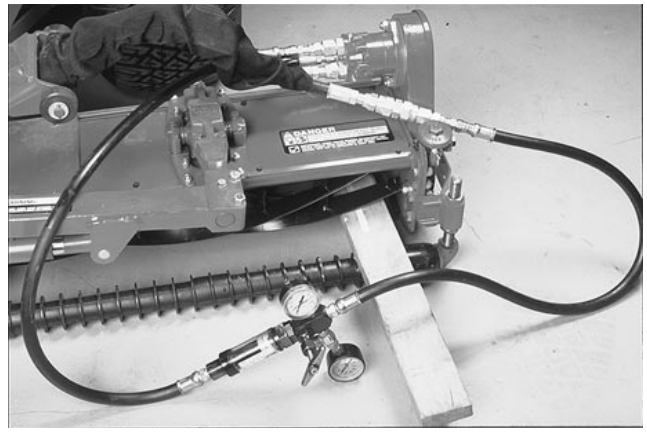


Figure 20

TEST NO. 6: Checking Steering Circuit Working Pressure or Relief Pressure

Procedure For Working Pressure Check:

1. Install a 5,000 psi gauge into the steering quick disconnect.

2. Operate the unit while monitoring the gauge.

RANGE OF TESTER READINGS 0 – 1300 PSI

3. If working pressure is too high or too low, perform relief pressure check.

Procedure For Relief Pressure Check:

1. Hydraulic oil must be at operating temperature.

2. Install a 5,000 psi gauge into the steering quick disconnect.

3. Start the engine and move the throttle to full speed (2500 rpm).

4. Turn the steering wheel until heavy resistance is felt indicating that the cylinder has reached maximum stroke.

5. Momentarily hold the steering wheel against the resistance and read gauge.

TESTER READING TO BE APPROXIMATELY 1200 – 1300 PSI

6. If pressure is too high, clean and adjust relief valve in steering pump by removing the required shims. If pressure is too low, check for restriction in pump intake line. Check the steering cylinder for internal leakage. If cylinder is not leaking, adjust the relief valve by adding the required shims. If pressure is still too low, repair or replace steering pump.

Figure 21

Hydraulic System

TEST NO. 7: Checking Lift Circuit Working Pressure or Relief Pressure

Procedure For <u>Working</u> Pressure Check:

1. Install a 5,000 psi gauge onto the quick disconnect of the lift valve.

2. Operate the unit while monitoring the gauge.

RANGE OF TESTER READINGS 500 – 2900 PSI

3. If working pressure is too high or too low, perform relief pressure check.

Procedure For <u>Relief</u> Pressure Check:

1. Hydraulic oil must be at operating temperature.

2. Install a 5,000 psi gauge onto the quick disconnect of the lift valve.

3. Start the engine and move the throttle to full speed (2500 rpm).

4. Engage the control lever into the “LIFT” position. Momentarily hold the lever in the engaged position after full cylinder extension and read gauge.

TESTER READING TO BE APPROXIMATELY 2650 – 2900 PSI

NOTE: Always set counterbalance pressure to desired amount before attempting to adjust lift pressure.

5. If pressure is too high, clean and adjust relief valve in lift valve by removing the required shims. If pressure is too low, check for restriction in pump intake line. Check the lift cylinder for internal leakage. If cylinder is not leaking, adjust the relief valve by adding the required shims. If pressure is still too low, repair or replace steering/lift pump.

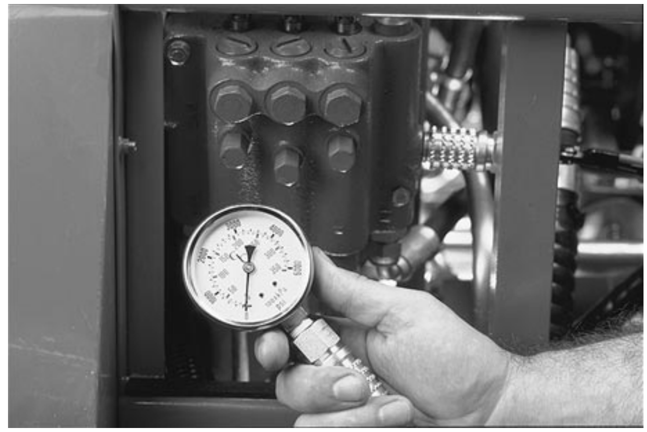


Figure 22

TEST NO. 8: Checking Charge Pressure For Traction

Procedure:

1. Hydraulic oil must be at operating temperature.

2. Install a 1000 psi gauge onto the quick disconnect at the top of the pump package.

3. Start the engine and position throttle at idle (1200 rpm).

TESTER READING TO BE APPROXIMATELY 75 – 150 PSI

4. If there is no pressure or pressure is too low, check for restriction in pump intake line. Inspect charge relief valve and valve seat. Check for sheared charge pump key. Disassemble charge pump and check for internal damage or worn parts. If the charge pump is in good condition (no scoring, scratches, or excessive wear), the general condition of the piston pump might be suspected of wear and inefficiency.

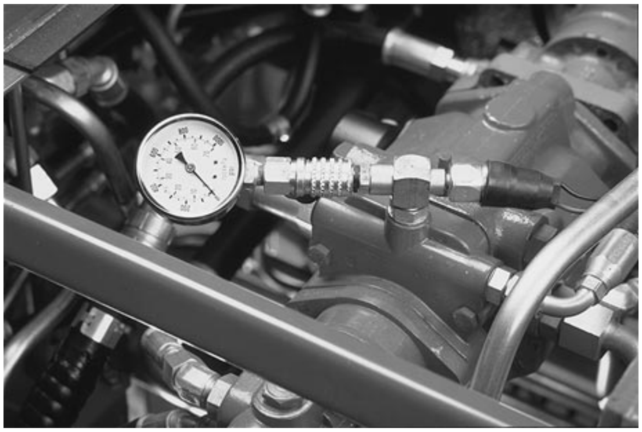


Figure 23

Hydraulic System

Repairs

Removing Hydraulic System Components

1. Thoroughly clean the machine before disconnecting, removing or disassembling any hydraulic components. Always keep in mind the need for cleanliness when working on hydraulic equipment.

2. Put caps or plugs on any hydraulic lines or fittings left open or exposed.

3. Put labels on disconnected hydraulic lines and hoses for proper installation after repairs are completed.

After Repair or Replacement of Components

1. Check oil level in hydraulic reservoir and add correct oil if necessary. Drain and refill hydraulic system reservoir and change oil filter if component failure was severe or system is contaminated.

2. After repairs, check control linkage for proper adjustment, binding or broken parts.

3. After disconnecting or replacing any hydraulic components, operate machine functions slowly until air is out of system.

4. Check for hydraulic oil leaks. Shut off engine and correct leaks if necessary. Check oil level in hydraulic reservoir and add correct oil if necessary.

Steering Control Unit

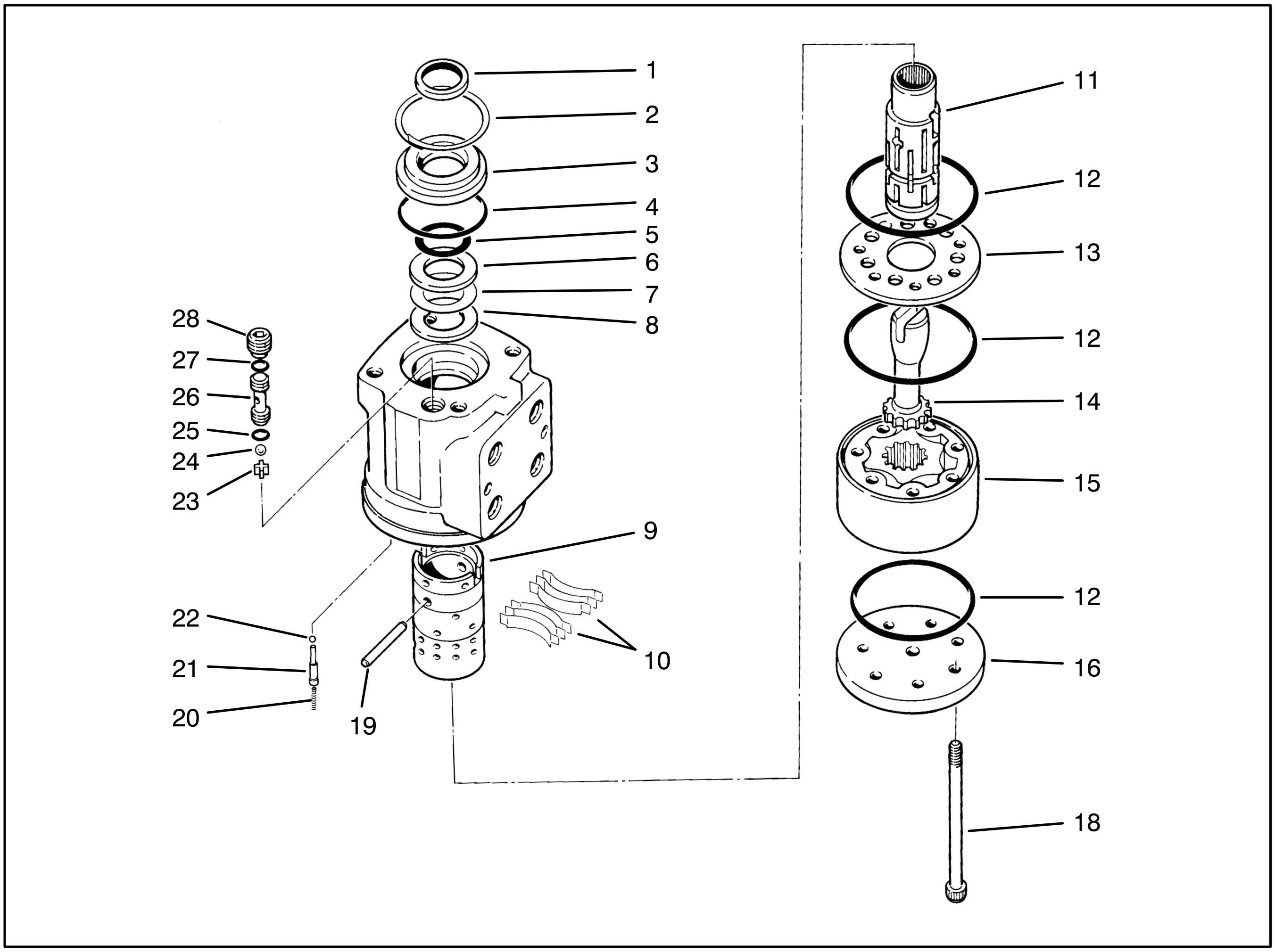


Figure 24

1. Seal 1" I.D.
2. Retaining Ring
3. Seal Gland Bushing
4. Seal 1.875 I.D.
5. Quad Ring Seal, 1.062 I.D.
6. Bearing Race
7. Thrust Bearing, Needle
8. Housing
9. Control Sleeve
10. Centering Spring Kit
11. Control Spool
12. Seal
13. Spacer Plate
14. Drive
15. Gerotor
16. End Cap
18. Cap Screw
19. Pin Kit, Centering
20. Spring
21. Retainer Plug
22. Check Ball
23. Check Ball, Retainer
24. Check Ball
25. Seal
26. Check Ball Seat
27. Seal
28. Set Screw

Disassembly

Cleanliness is extremely important when repairing a steering control unit. Work in a clean area. Before disconnecting lines, clean port area of unit thoroughly. Use a wire brush to remove foreign material and debris from around exterior joints of the unit.

NOTE: Troubleshooting information defines terms and problems, possible causes for problems, and recommends procedures for correcting problems.

Although not all drawings show the unit in a vise, we recommend that you keep the unit in the vise during disassembly. Follow the clamping procedure explained throughout the manual.

Meter (Gerotor) End Disassembly

1. Clamp unit in vise, meter end up. Clamp lightly on edges of mounting area, see Fig. 25. Use protective material on vise jaws. Housing distortion could result if jaws are over–tightened.

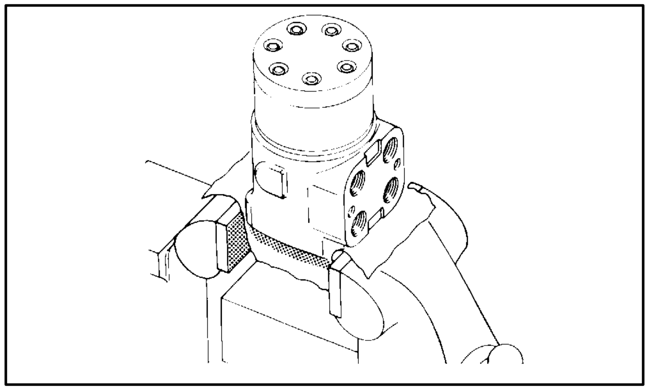


Figure 25

2. Remove 5/16” cap screws.

3. Remove end cap.

4. Remove seal from end cap.

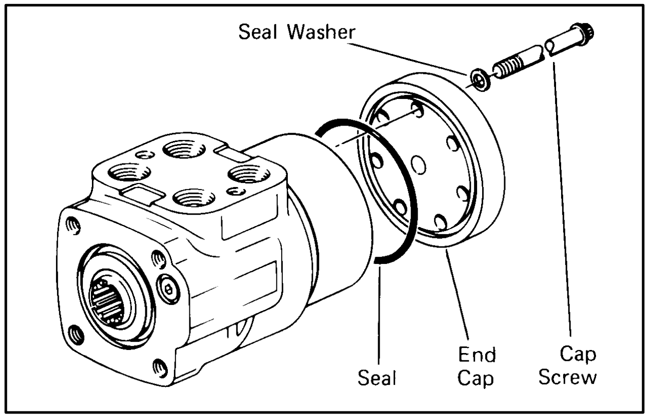


Figure 26

5. Remove meter. Be careful not to drop star.

6. Remove seal from meter.

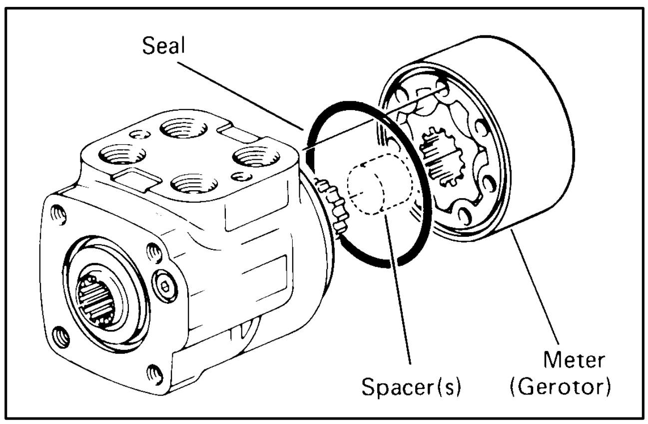


Figure 27

7. Remove drive spacer(s) (not used on 4.5 cu. in. displacement units).

8. Remove drive.

9. Remove spacer plate.

10. Remove seal from housing.

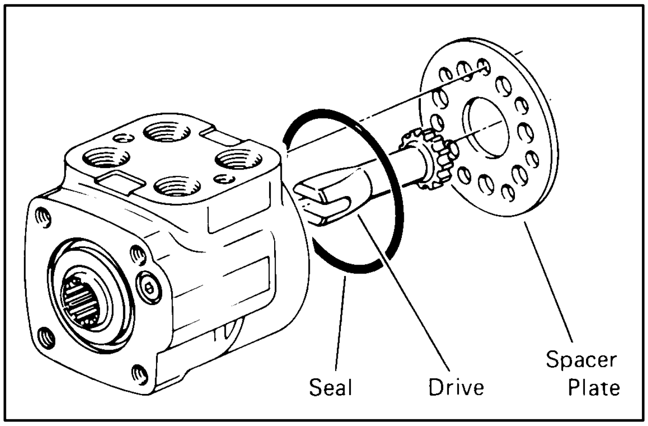


Figure 28

Control End Disassembly

11. Remove housing from vise. Place housing on a clean soft cloth to protect surface finish. Use a thin–blade screwdriver to pry retaining ring from housing, as shown in Fig. 29.

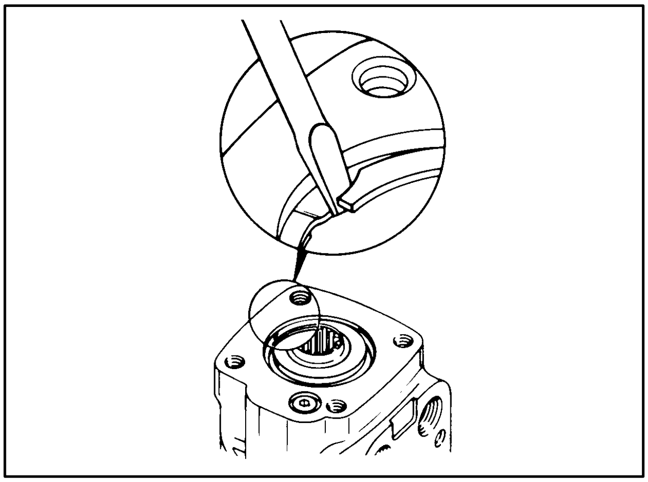


Figure 29

12. Rotate spool and sleeve until pin is horizontal. Push spool and sleeve assembly forward with your thumbs just far enough to free gland bushing from housing, see Fig. 30. Remove bushing.

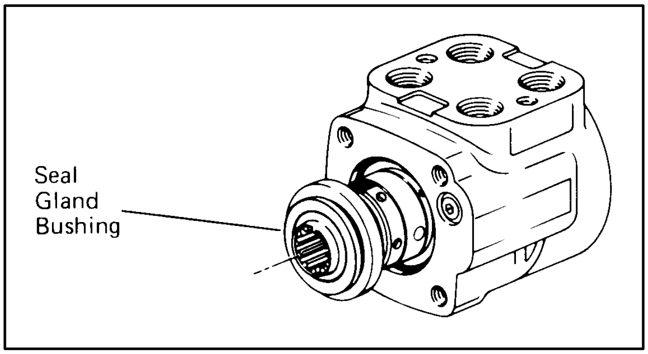


Figure 30

Hydraulic System

13. Remove quad ring seal from seal gland bushing.

14. Use a thin–blade screwdriver to pry dust seal from seal gland bushing. Do not damage bushing.

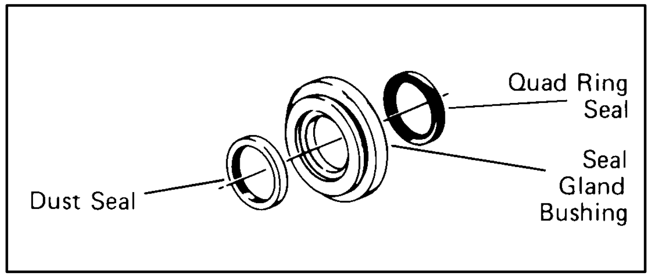


Figure 31

15. Remove 2 bearing races and the needle thrust bearing from spool and sleeve assembly.

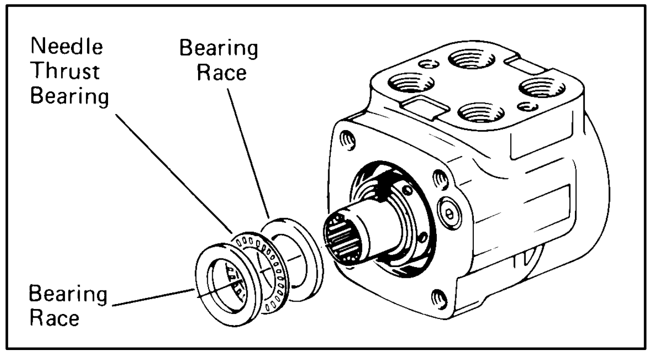


Figure 32

16. Remove spool and sleeve assembly from 14–hole end of housing, see Fig. 33.

Attention: Do not bind spool and sleeve in housing. Rotate spool and sleeve assembly slowly when removing from housing.

17. Push pin from spool and sleeve assembly.

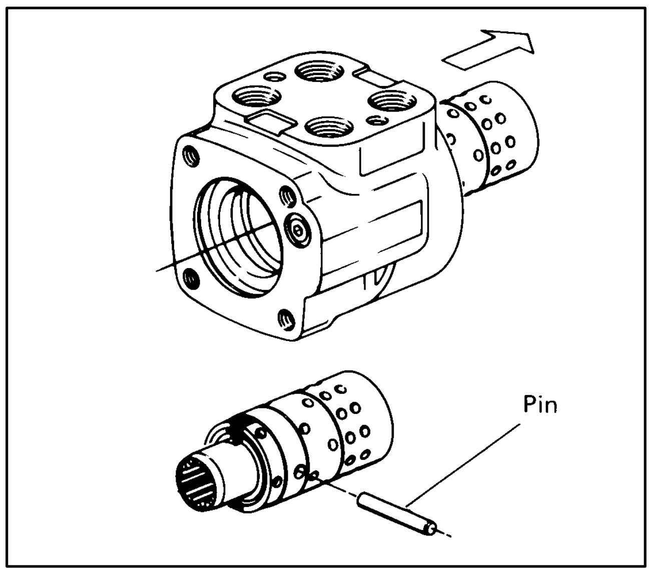


Figure 33

18. Push spool partially from control end of sleeve, then remove 6 centering springs from spool carefully by hand, see Fig. 34.

19. Push spool back through and out of sleeve, see Fig. 34. Rotate spool slowly when removing from sleeve.

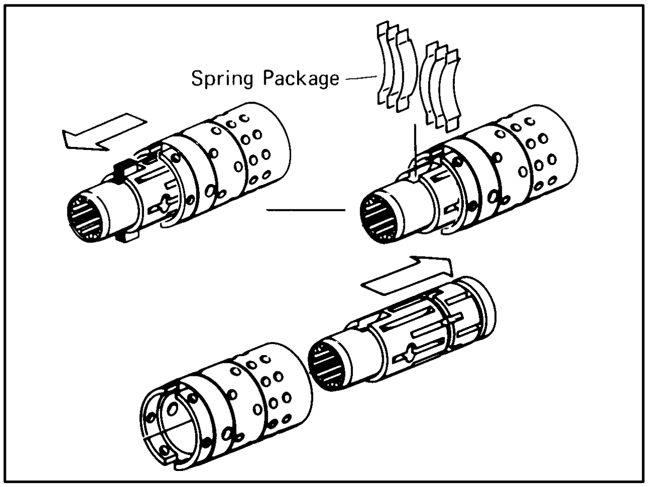


Figure 34

20. Remove seal from housing, see Fig. 35.

21. Screw a #10–24 machine screw into end of check ball seat. Then, by pulling on screw with a pliers, lift seat out of housing, see Fig. 35.

22. Remove 2 seals from check valve seat.

23. Tip housing to remove check ball and check ball retainer.

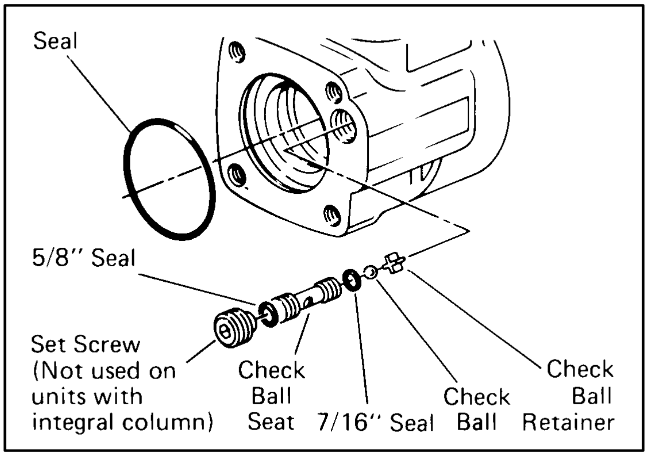


Figure 35

Hydraulic System

Reassembly

Check all mating surfaces. Replace any parts that have scratches or burrs that could cause leakage. Clean all metal parts in clean solvent. Blow dry with air. Do not wipe dry with cloth or paper towel because of lint or other matter can get into the hydraulic system and cause damage. Do not use a coarse grit, try to file or grind these parts.

NOTE: Lubricate all seals with clean petroleum jelly such as Vaseline.

Do not use excessive lubricant on seals for meter section.

Refer to parts listing covering your steering control unit when ordering replacement parts. A good service policy is to replace all old seals with new seals.

Control End Reassembly

1. Use a needle–nose pliers to lower check ball retainer into check valve hole of housing. Make sure retainer is straight (not tilted on edge) in housing, see Fig. 36.

2. Install check ball in housing.

3. Lubricate 5/8” diameter seal and 7/16” diameter seal. Install seals on check ball seat as shown in Fig. 36.

4. Lubricate check ball seat and seals thoroughly before installing seat in housing. When installing seat, do not twist or damage seals. Install check ball seat in housing, insert open end of seat first, see Fig. 36. Push check ball seat to shoulder of hole.

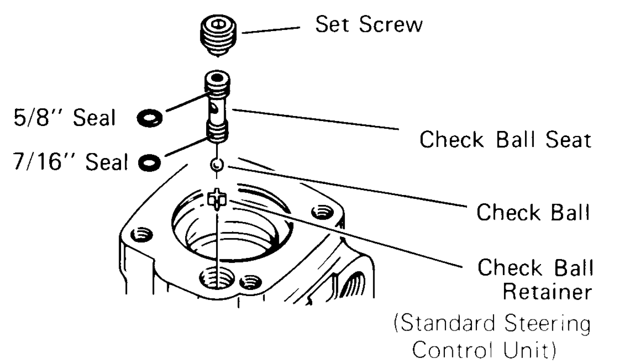


Figure 36

5. Assemble spool and sleeve carefully so that the spring slots line up at the same end. Rotate spool while sliding parts together. Some spool and sleeve sets have identification marks, align these marks as shown in Fig. 37. Test for free rotation. Spool should rotate smoothly in sleeve with finger tip force applied at splined end.

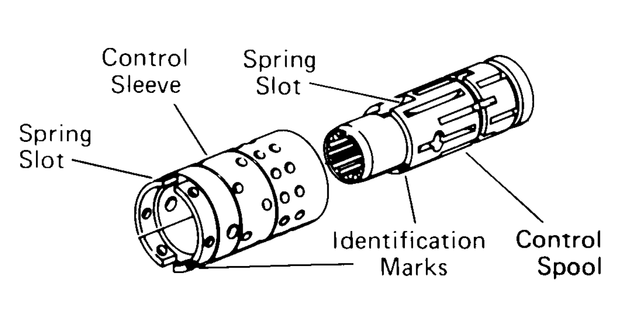


Figure 37

6. Bring spring slots of both parts in line and stand parts on end of bench. Insert spring installation tool through spring slots of both parts. Tool is available from an Eaton hydraulics supplier as Eaton part no. 600057. Position 3 pairs of centering springs (or 2 sets of 3 each) on bench so that extended edge is down and arched center section is together. In this position, insert one end of entire spring set into spring installation tool, as shown in Fig. 38, with spring notches facing sleeve.

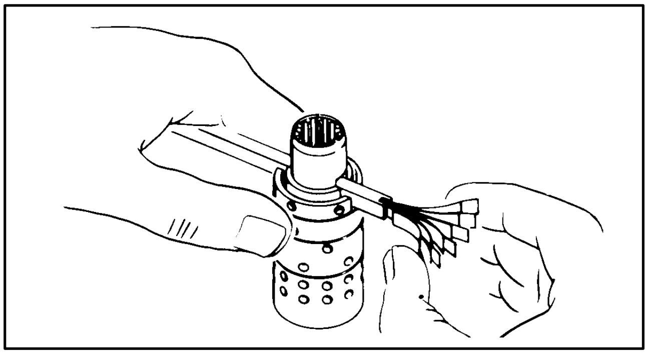


Figure 38

7. Compress extended end of centering spring set and push into spool sleeve assembly withdrawing installation tool at the same time.

8. Center the spring set in the parts so that they push down evenly and flush with the upper surface of the spool and sleeve.

9. Install pin though spool and sleeve assembly until pin become flush at both sides of sleeve.

10. Position the spool and sleeve assembly so that the splined end of the spool enters the 14–hole end of housing first, see Fig. 39.

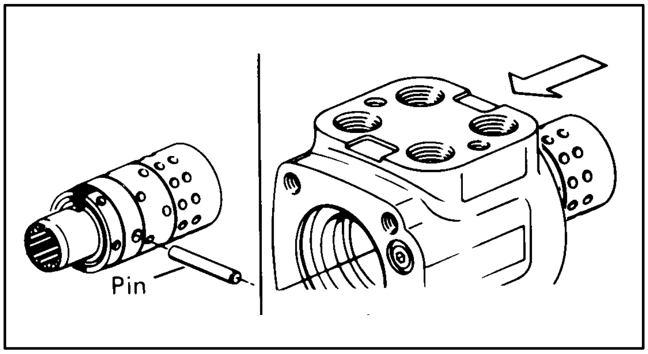


Figure 39

Attention: Be extremely careful that the parts do not tilt out of position while inserting. Push parts gently into place with slight rotating action, keep pin nearly horizontal. Bring the spool assembly entirely within the housing bore until the parts are flush at the meter end or 14–hole end of housing. Do not pull the spool assembly beyond this point to prevent the cross pin from dropping into the discharge groove of the housing. With the spool assembly in this flush position, check for free rotation within the housing by turning with light finger tip force at the splined end.

Hydraulic System

11. Place housing on clean, lint free cloth. Install 2–1/8” diameter seal in housing, see Fig. 40.

12. Install 2 bearing races and the needle thrust bearing in the order shown.

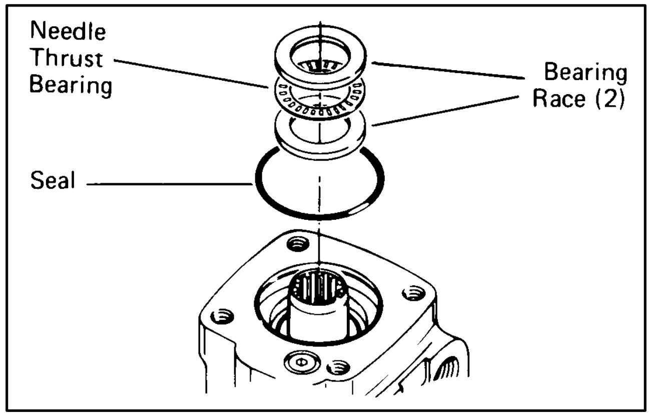


Figure 40

13. Install 1–1/4” diameter dust seal in seal gland bushing, flat or smooth side of dust seal must face down towards bushing, see Fig. 42.

14. Install the quad ring seal in seal gland bushing. Smooth seal in place with your finger. Do not use any seal that falls freely into pocket of bushing, see Fig. 42.

15. Install seal gland bushing over the spool end with a twisting motion. Tap the bushing in place with a rubber hammer. Make sure the bushing is flush against the bearing race.

16. Install retaining ring (see Fig. 41 and 42) in housing. After installing ring, tap on ring end or pry with screwdriver around entire circumference of ring to properly seat ring in groove.

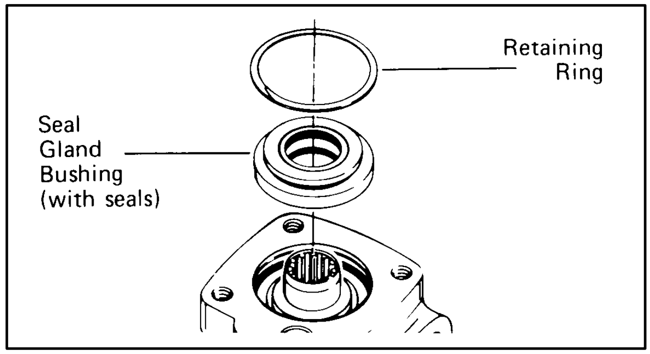


Figure 41

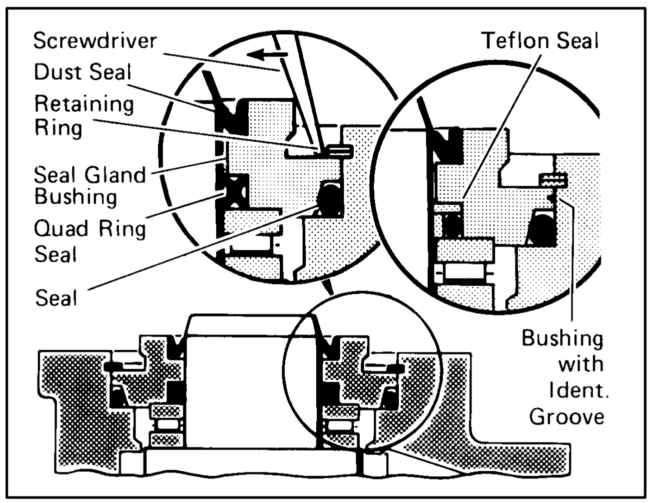


Figure 42

17. Clamp housing in vise, as shown in Fig. 43. Clamp lightly on edges of mounting area. Do not over–tighten jaws.

NOTE: Check to insure that the spool and sleeve are flush or slightly below the 14–hole surface of the housing.

Attention: Clean the upper surface of the housing by wiping with the palm of clean hand. Clean each of the flat surfaces of the meter section part in a similar way when ready for reassembly. Do not use cloth or paper to clean surfaces.

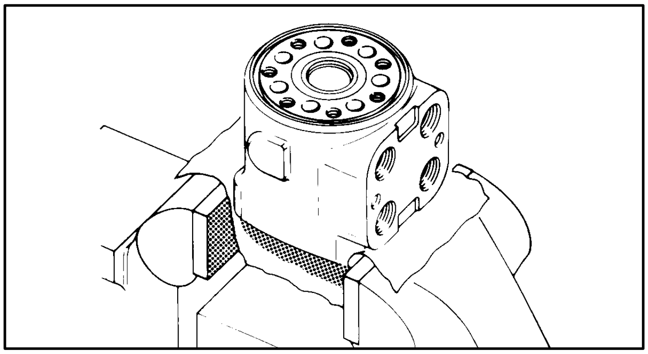


Figure 43

18. Install 3” diameter seal in housing, see Fig. 44.

19. Install spacer plate. Align bolt holes in spacer plate with tapped holes in housing.

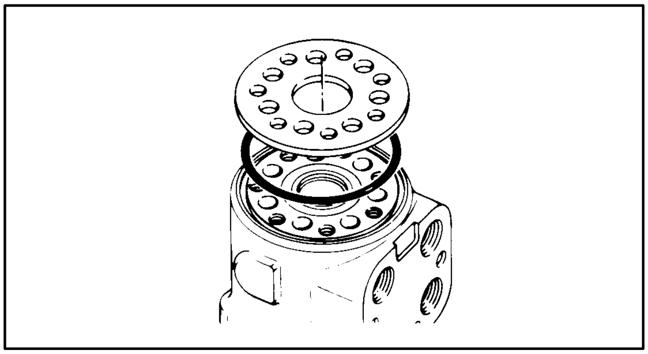


Figure 44

20. Rotate spool and sleeve assembly until pin is parallel with port face, see Fig. 45. (Install drive, make sure you engage drive with pin. To assure proper alignment, mark drive as shown in Fig. 47 (ref. B). Note the relationship between slotted end of drive to splined end of drive when marking.

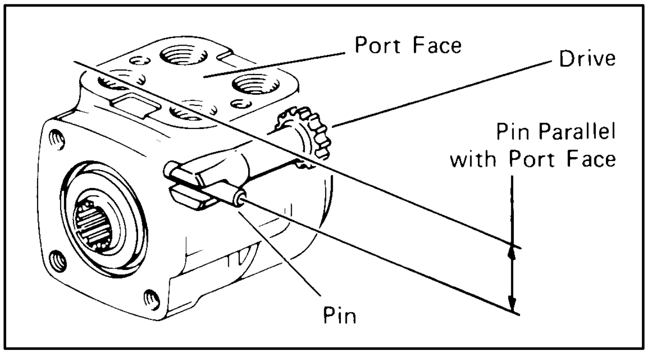


Figure 45

21. Install 3” diameter seal in meter.

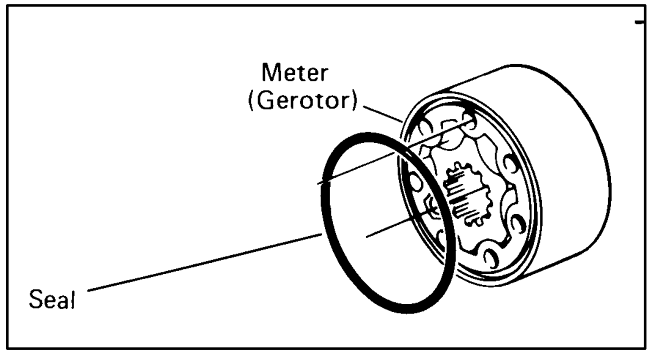


Figure 46

22. With seal side of meter toward spacer plate, align star valleys (ref. A) on drive (ref. B). Note the parallel relationship of reference lines A, B, C, and D in Fig. 47. Align bolt holes without disengaging meter from drive.

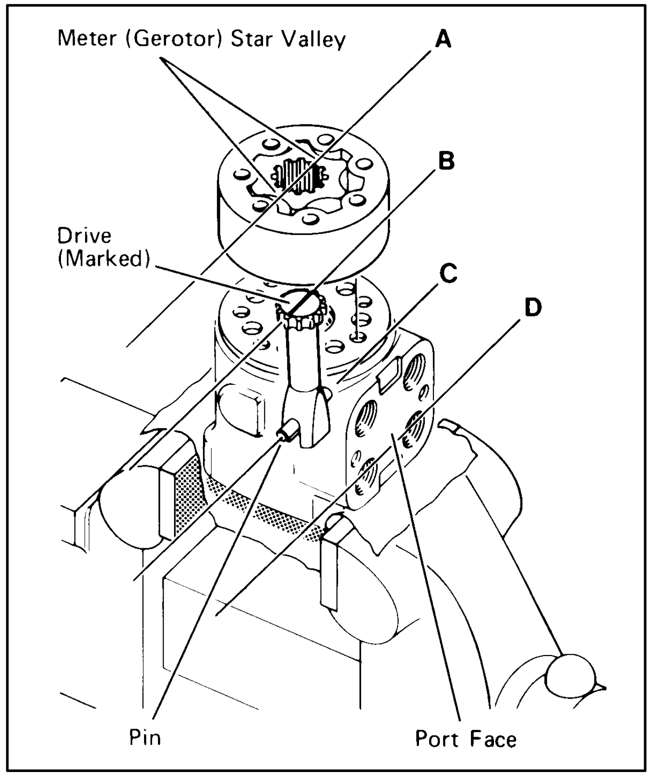


Figure 47

23. Install drive spacer(s), when used, in meter, see Fig. 48.

24. Install 3” diameter seal in end cap.

25. Install end cap on gerotor, align holes.

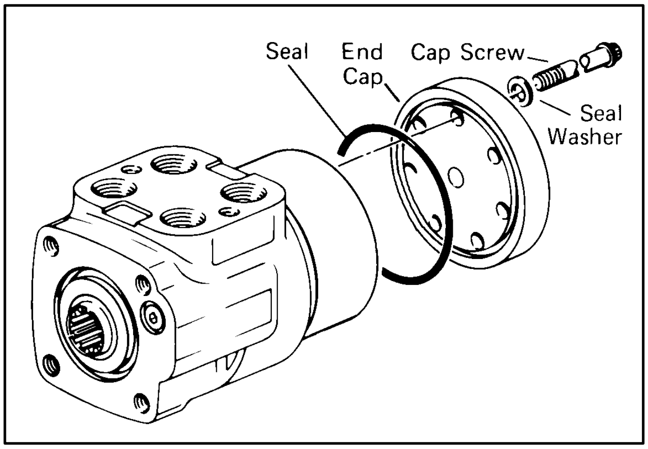


Figure 48

26. Install 7 dry cap screws with new seal washers in end cap. Pre–tighten screws to 150 inch pounds, ten torque screws to 275 inch pounds in sequence shown in Fig. 49.

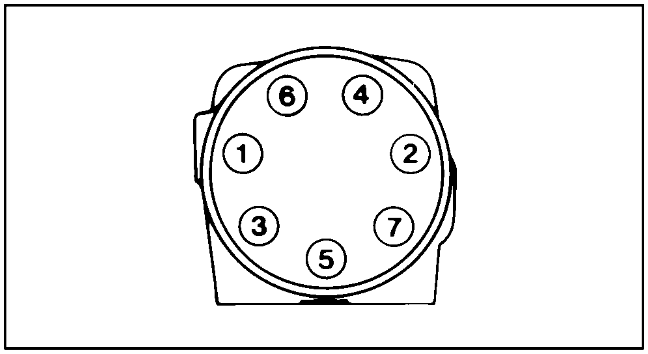


Figure 49

Hydraulic System

Reel Motor Repair

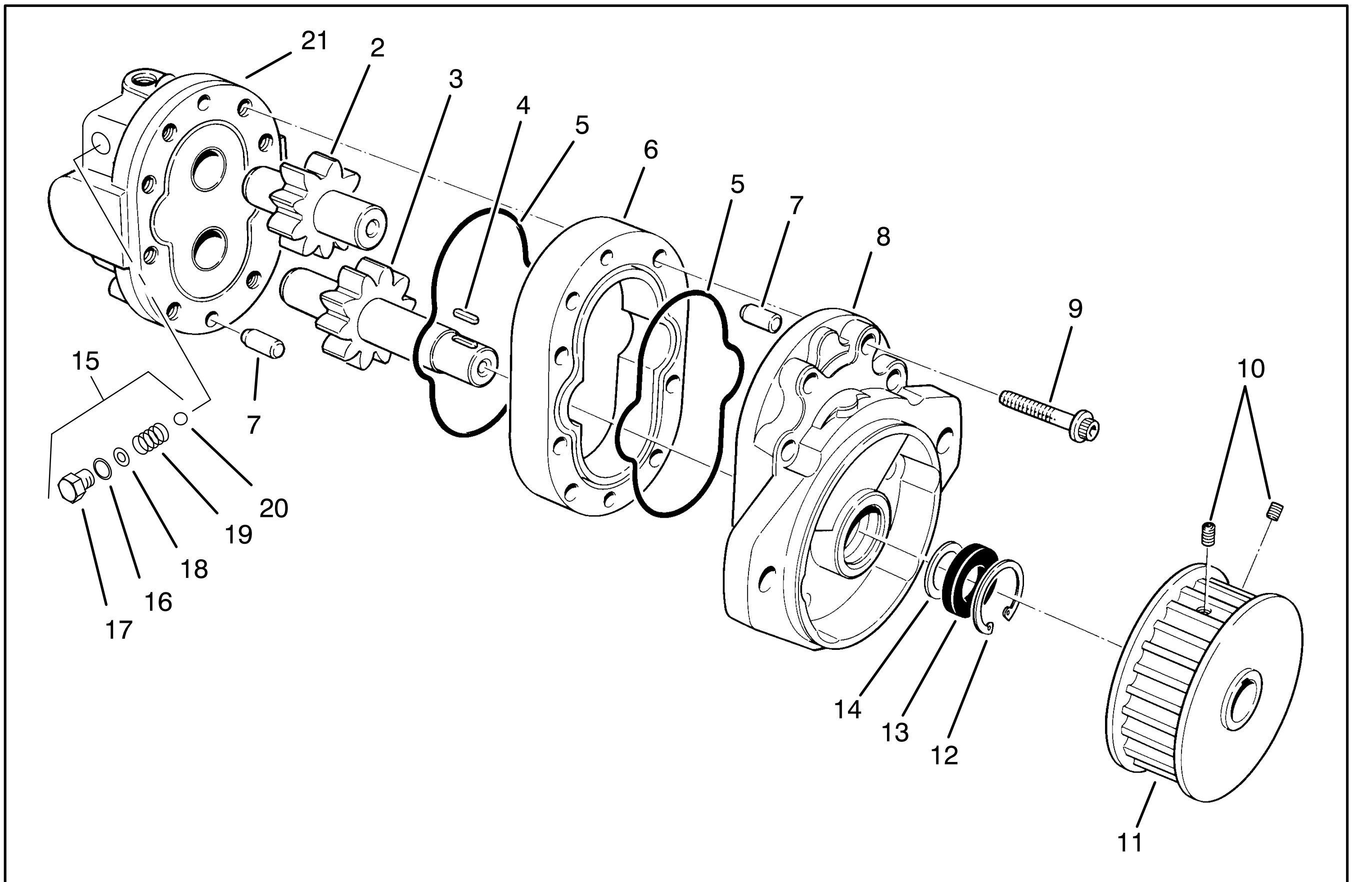


Figure 50

2. Idler Gear	12. Retaining Ring
3. Drive Gear	13. Shaft Seal
4. Key	14. Backup Washer
5. O–Ring	15. Relief Valve Kit
6. Body	16. O–Ring
7. Dowel Pin	17. Plug
8. Plate & Bushing Assembly	18. Shim
9. Socket Head Cap Screw	19. Spring
10. Set Screw	20. Ball
11. Drive Pulley	21. Back Plate/Relief Assembly

Disassembly of Reel Motor

1. Remove set screws (10) from drive pulley (11).

2. Remove drive pulley (11) from drive shaft.

3. Remove key (4) from drive shaft.

4. Clean outside of motor thoroughly. Scribe a line along front plate assembly (8), body (6), and back plate assembly (21) to assure proper reassembly.

5. Clamp motor in vise, shaft up.

6. Remove eight cap screws (9).

7. Remove motor from vise, hold motor in hands and bump shaft against wooden block to separate the front plate assembly (8) from the back plate assembly (21). The body (6) will remain with either the front or back plate.

8. Separate body (6) from either the front or back plate.

9. Remove drive gear (3) and idler gear (2).

10. Remove retaining ring (12), shaft seal (13), and back–up washer (14) from front plate assembly (8).

11. Remove the two O–rings (5) and two dowel pins (7) between front plate assembly (8) and body (6), and between body (6) and back plate assembly (21).

Inspection of Reel Motor

GENERAL

1. Clean and dry all parts.

2. Remove nicks and burrs from all parts with emery cloth.

GEAR ASSEMBLY

1. Inspect drive gear assembly (3) for broken or cracked keyway.

2. Inspect both the drive gear (3) and idler gear (2) shafts at bearing point for rough surfaces and excessive wear.

3. If shaft measures less than .686 in bearing area, the gear assembly should be replaced. (One gear assembly may be replaced separately. Shafts and gears are available as assemblies only.)

4. If gear width is below 1.327, gear assembly should be replaced.

5. Inspect gear face for scoring and excessive wear.

6. Retaining ring (12) on shaft assemblies should be in groove.

7. If edge of gear teeth are sharp, break edge with emery cloth.

FRONT PLATE, BODY, BACK PLATE

1. Inspect I.D. of bushings in front plate (8), body (6), and back plate (21). If I.D. exceeds .693, front plate, body, or back plate should be replaced. (Bushings are not available as separate items.)

2. Back plate assembly (21) should be replaced if I.D. of gear pocket exceeds 1.719.

3. Check for scoring on face of front plate (8), body (6), and back plate (21). If wear exceeds .0015, front plate, body, or back plate should be replaced.

Reassembly of Reel Motor

1. Retaining ring (12), shaft seal (13), back–up washer (14), and O–rings (5) should be replaced as new parts.

2. Install O–rings (5) in grooves of front plate (8) and body (6).

3. Install body (6) in front plate assembly (8) noting position of scribe line.

4. Install dowel pins (7) in body (6) and front plate assembly (8).

5. Dip gear assemblies (2 & 3) into oil and slip into body and front plate bushing.

6. Install back plate assembly (21) noting position of scribe line. Install cap screws (9), draw up bolts evenly and torque to 22–25 ft. lbs.

7. Install new back–up washer (14) on drive shaft.

Oil shaft seal (13) liberally. Work shaft seal (13) over drive shaft taking care not to cut rubber sealing lip.

8. Seat shaft seal (13) by tapping with plastic hammer. Install new retaining ring (12).

9. Replace key (4) in drive shaft (3).

10. Install drive pulley (11) on drive shaft.

11. Tighten set screws (10) in drive pulley (11).

Steering Pump Repairs

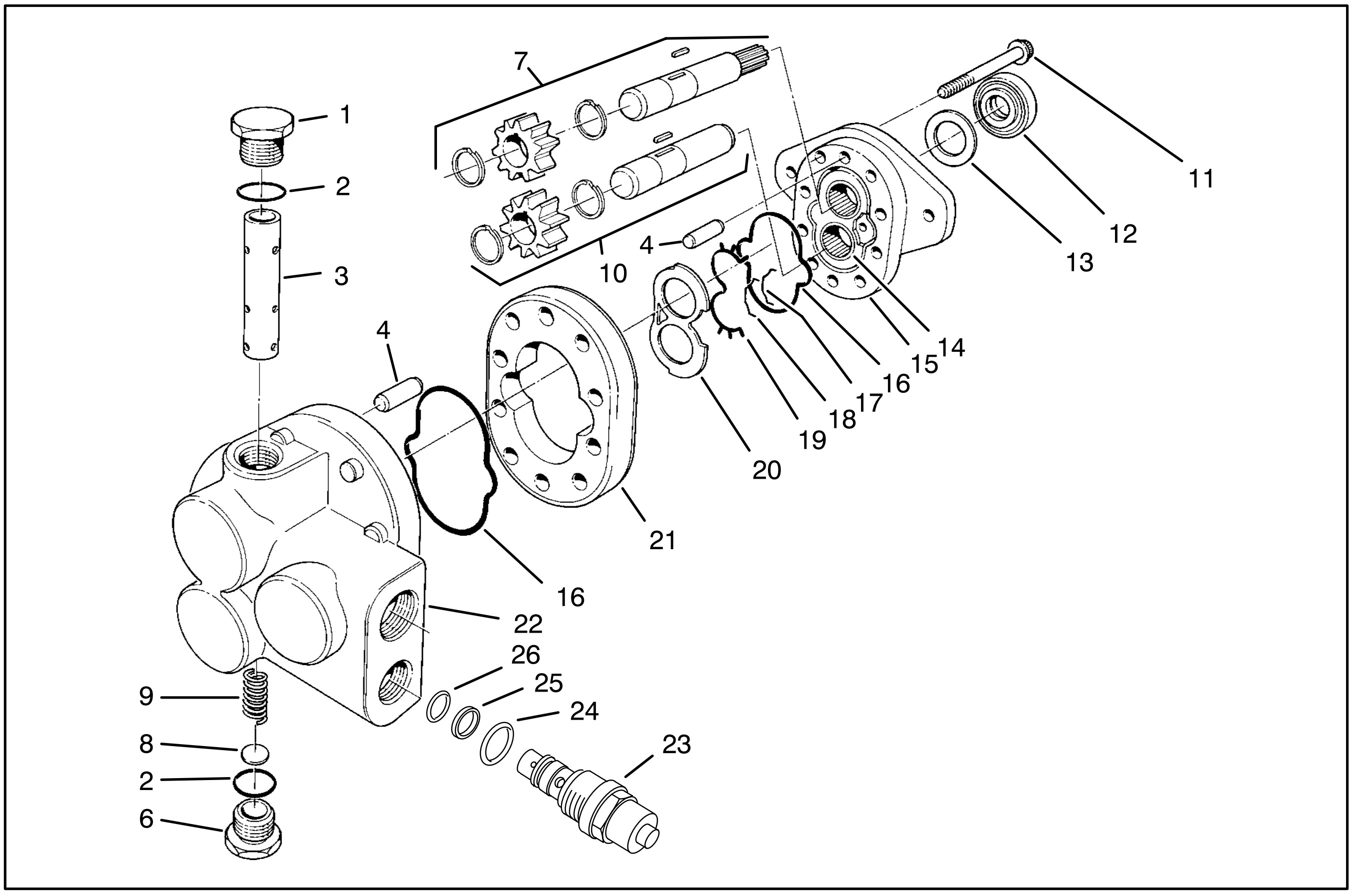


Figure 51

1. Plug (includes #2)
2. O–Ring
3. Spool
4. Dowel Pin
6. Plug (includes #2)
7. Drive Gear Assembly
8. Disc
9. Spring
10. Idler Gear Assembly
11. Hex Head Cap Screw
12. Shaft Seal
13. Washer
14. Bushing
15. Front Plate Assembly
16. O–Ring
17. Molded O–Ring
18. Bearing Seal
19. Backup Gasket
20. Wear Plate
21. Body Assembly
22. Back Plate Assembly
23. Relief Valve Assembly
24. O–Ring
25. Back Up Washer
26. O–Ring

Disassembly of Steering Pump

1. Thoroughly clean outside of pump.

2. Use a sharp tool or marker to mark across front plate (15), body (21) and back plate (22). This will assure proper reassembly.

3. Clamp pump in a vise, with the shaft up.

4. Remove capscrews (11).

5. Remove pump from vise, hold pump in hands and bump shaft against a wood block to separate front plate (15) from back plate (22). Body (21) will remain with either front plate or back plate.

6. If front plate (15) was removed first, remove wear plate (20) from body gear pockets.

7. Remove drive gear assembly (7) and idler gear assembly (10) from body (21).

8. To separate body (21) from plate it remains with, put drive gear assembly (7) in a bushing and tap protruding end with a plastic hammer or soft mallet.

9. Remove O–ring (16) from front plate (15) and back plate (22).

10. Remove backup–up gasket (19) from front plate (15).

11. Remove bearing seal (18) from front plate (15) by prying with a sharp tool.

12. Remove molded O–ring (17) from front plate (15) by prying with a screwdriver.

13. Remove shaft seal (12) from front plate (15) by prying with a screwdriver.

Disassembly of Back Plate Assembly (Flow Divider / Flow Control / Relief Valve)

1. Remove relief valve (23) from back plate (22).

NOTE: Do not disassemble relief valve cartridge assembly – it must be replaced as an assembly.

2. Remove hex plugs (1, 6) flow divider spool (3), spring (9) and disk (8).

Inspect Steering Pump Parts

GENERAL

1. Clean and dry all parts.

2. Remove all nicks and burrs from all parts with emery cloth.

GEAR ASSEMBLY

1. Check drive shaft spline for twisted or broken teeth.

2. Inspect both drive gear (7) and idler gear (10) shafts at bushing points and seal area for rough surfaces and excessive wear.

3. If shaft measures less than 0.748” in bushing area, the gear assembly should be replaced (one gear assembly may be replaced separately; shafts and gears are available as assemblies only).

4. Inspect gear face for scoring and excessive wear.

5. If gear width is less than 0.636”, the gear assembly should be replaced.

6. Be sure snap rings are in grooves on either side of drive and idler gears.

7. If edge of gear teeth are sharp, break edge with emery cloth.

FRONT PLATE AND BACK PLATE

1. Oil groove in bushings in both front plate and back plate should be in line with dowel pin holes and 180° apart.

2. If I.D. of bushings in front plate (15) or back plate (22) exceed 0.755”, front or back plate should be placed (bushings are not available separately).

3. Bushings in front plate should be flush with face of front plate.

4. Check for scoring on face of back plate. If wear exceeds 0.0015”, back plate should be replaced.

BODY

1. Check inside gear pockets for excessive scoring or wear.

2. Body (21) should be replaced if I.D. of gear pocket exceeds 1.713”.

FLOW DIVIDER / FLOW CONTROL / RELIEF VALVE

1. Check disk (8) for wear.

2. Check spring (9) for weakness or breakage.

3. Wash back plate (22) in clean solvent, then direct compressed air into relief valve and flow divider cavities in back plate to remove any contamination.

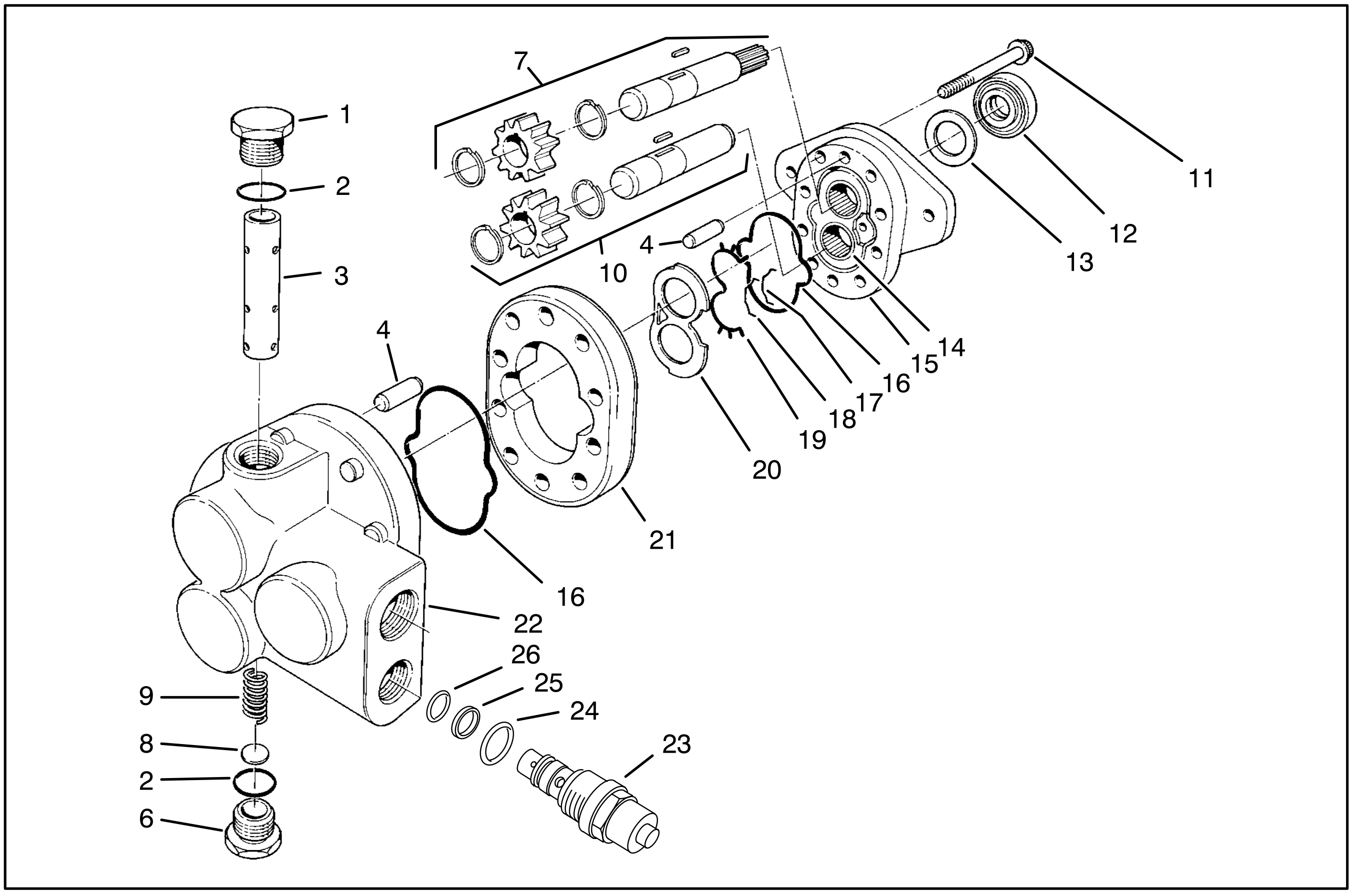


Figure 52

1. **Plug (includes #2)**
2. **O–Ring**
3. **Spool**
4. **Dowel Pin**
6. **Plug (includes #2)**
7. **Drive Gear Assembly**
8. **Disc**
9. **Spring**
10. **Idler Gear Assembly**
11. **Hex Head Cap Screw**
12. **Shaft Seal**
13. **Washer**
14. **Bushing**
15. **Front Plate Assembly**
16. **O–Ring**
17. **Molded O–Ring**
18. **Bearing Seal**
19. **Backup Gasket**
20. **Wear Plate**
21. **Body Assembly**
22. **Back Plate Assembly**
23. **Relief Valve Assembly**
24. **O–Ring**
25. **Back Up Washer**
26. **O–Ring**

Assembly of Steering Pump

It is important that the relationship of the back plate (22), body (21), wear plate (20) and front plate (15) is correct. You will note two half moon cavities in the body which must face away from the front plate.

NOTE: The smaller half moon port cavity must be on the pressure side of the pump. Side of wear plate with mid section cut out must be on suction side of pump. Suction side of back plate is always side with larger port boss.

1. Install relief valve (23) with new O–ring (24), back–up washer (25), and O–ring (26).

2. Install flow divider spool (3), plug (1) with new O–ring (2), and other plug (6) with new O–ring (2).

3. The wear plate (20), bearing seal (18), molded O–ring (17), back–up gasket (19), shaft seal (12), and O–rings (9) should be replaced as new parts.

4. Install O–ring (16) in groove of front plate (15).

5. Tuck back–up gasket (19) into groove in front plate with open part of “V” section down.

6. Put molded O–ring (17) in groove in front plate. Put bearing seal (18) over molded O–ring – groove side down.

7. Apply a thin coat of heavy grease to both milled faces of body (21). Slip body onto plate – half moon port cavities in body must face away from front plate.

NOTE: The small half moon port cavity must be on the pressure side of the pump.

8. Put wear plate (20) on top of back–up gasket (19) with bronze face up. The side with the mid section cut away must be on suction side of pump.

Dip gear assemblies (10, 7) into oil and slip into front plate bushings.

9. Install O–ring (16) in groove in back plate (22).

10. Slide back plate (22) over gear shafts until dowel pins (4) are engaged.

Install bolts (11) and washers (13). Tighten evenly to a torque of 25 – 28 ft.–lb.

11. Install washer (13). Liberally oil shaft seal (12) and carefully work over drive shaft, being careful not to cut rubber sealing lip.

12. Put a 1–5/16” O.D. sleeve over the shaft and press in shaft seal until flush with front surface of front plate.

Lift Control Valve

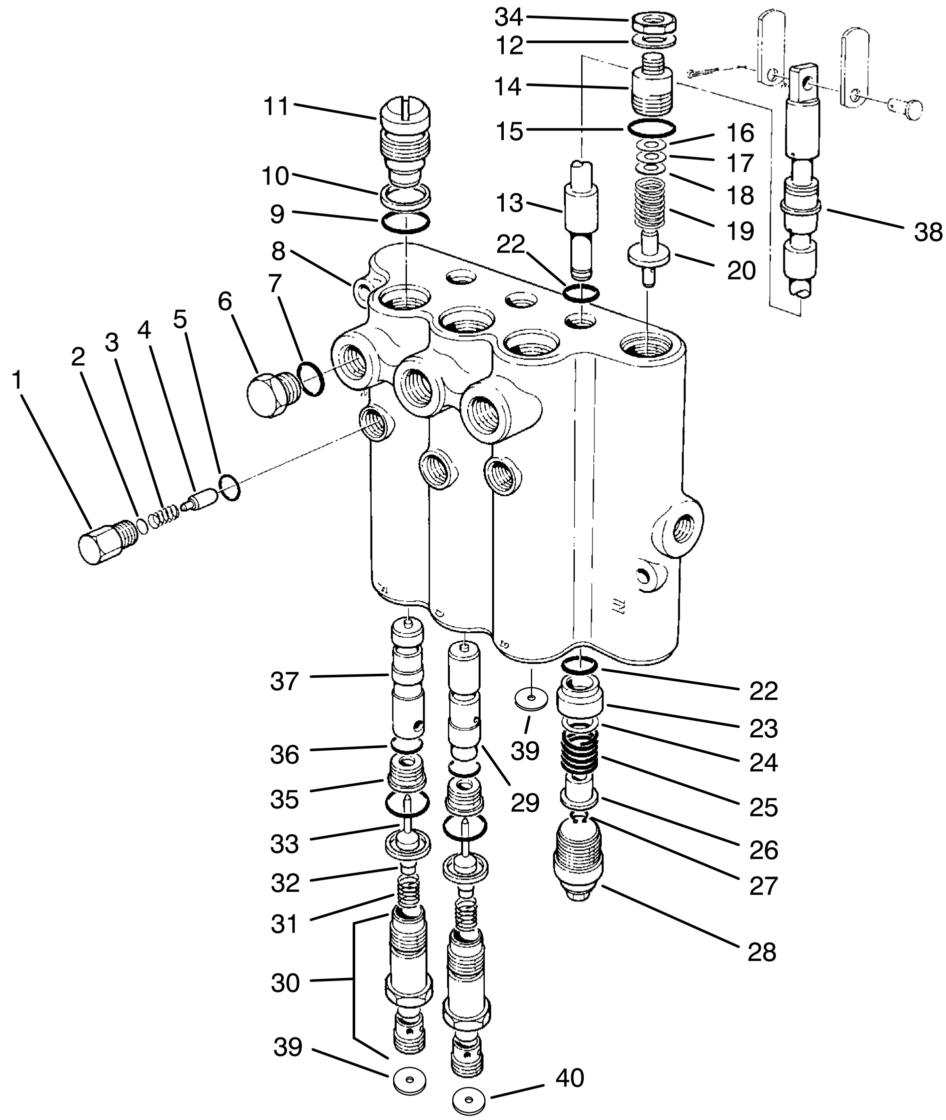


Figure 53

1. **Plug Assembly**
2. **Disc**
3. **Spring**
4. **Detent Plunger**
5. **O–Ring**
6. **Plug Assembly**
7. **O–Ring**
8. **Body**
9. **O–Ring**
10. **Backup Washer**
11. **Plug Assembly**
12. **Washer**
13. **Spool**
14. **Plug Assembly**
15. **O–Ring**
16. **Washer**
17. **Washer**
18. **Washer**
19. **Spring**
20. **Poppet**
22. **O–Ring**
23. **Bushing**
24. **Washer**
25. **Spring**
26. **Spacer**
27. **Retaining Ring**
28. **Cap Assembly**
29. **Plunger**
30. **Plug Assembly**
31. **Spring**
32. **Eyelet**
33. **Poppet Assembly**
34. **Locknut**
35. **Seat Assembly**
36. **O–Ring**
37. **Plunger**
38. **Seal Wiper**
39. **.047 Dia. Orifice**
40. **.052 Dia. Orifice**

Disassembly of Lift Control Valve

1. Plug all ports and clean outside of valve thoroughly.

2. Remove cap assemblies (28). Do not remove retaining rings (26) from spools unless spring (25) is broken.

3. Remove spools (13) from body (8).

NOTE: Spools and spool bores are matched sets. Be sure each spool is identified with the correct body spool bore.

4. Remove bushings (23) and O–rings (22) from spools.

5. Remove plugs (11).

6. Remove plugs (30), springs (31), poppets (33), seats (35) and plungers (37, 29).

IMPORTANT: Check location and positioning of plungers when removing from body to assure proper assembly.

7. Remove plugs (6).

8. Remove plugs (1), discs (2), springs (3) and detent plungers (4).

9. Remove locknut (34), washer (12), plug (14), washers (16, 17, 18), spring (19) and poppet (20).

10. Remove all O–rings and back–up rings from all plugs and seats.

Inspection of Lift Control Valve

1. Remove all nicks and burns from parts and inspect for excessive wear.

2. Inspect all plungers and poppet seats for burrs or roughness.

3. Inspect spool springs (25), relief valve spring (19), lockout springs (31), and detent springs (3) for breakage.

4. If spools (13) have excessive wear, the valve becomes non–serviceable as the spools and spool bores are matched and damaged spools cannot be replaced.

5. Inspect relief valve poppet (20) for breakage or wear.

Assembly of Lift Control Valve

1. Thoroughly clean and dry all parts. Apply a light coating of clean hydraulic oil to parts prior to assembly.

NOTE: All O–rings, back–up washers, wiper seals and nylon poppets should be replaced as new items.

2. Install new O–rings (22) in proper grooves in spool bores.

3. Install relief valve components (20, 19, 18, 17, 16) with new O–ring (15) on plug (14).

4. Install plugs (11) with new back–up washers (10) and O–rings (9).

5. Install plungers (37, 29).

IMPORTANT: Check location and positioning of plungers during installation.

6. Install new O–rings (36) on seats (35). Install new back–up washers (10) and O–rings (9) on plugs (30).

7. Install seats (35), new poppets (33), and plugs (30).

8. Install plugs (6) with new O–rings (7).

9. Install detent plungers (4), springs (3), discs (2), and plugs (1) with new O–rings (5).

10. If retaining ring (27) has been removed to replace spool spring (25), install washer (24), spring (25), spacer (26), and secure with retaining ring (27).

11. Slide bushings (23) over spools. Slide new O–rings (22) over spools and position next to bushings. Dip spools in clean hydraulic oil and install spool assemblies in proper location.

12. Install spool caps (28) and tighten to a torque of 20 – 25 ft–lb.

13. Install new wiper seals (38).

Priority Flow Divider

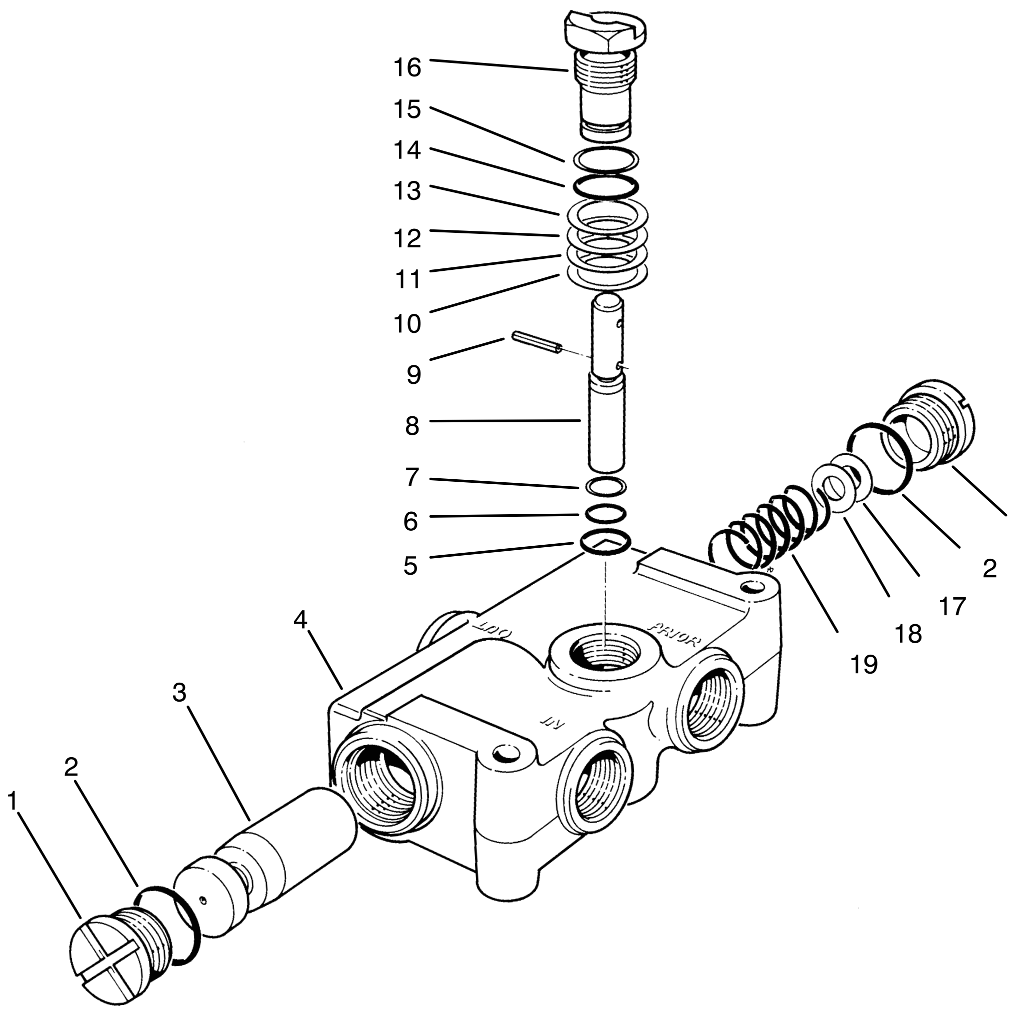


Figure 54

1. Plug Assembly
2. O–Ring
3. Spool
4. Body
5. O–Ring
6. O–Ring
7. Backup Washer
8. Metering Stem
9. Groove Pin
10. Shim
11. Shim
12. Shim
13. Shim
14. O–Ring
15. Backup Washer
16. Metering Plug
17. Shim
18. Shim
19. Spring

Disassembly of Priority Flow Divider

1. Plug all ports and thoroughly clean outside of valve.

2. Remove plug (1), shims (17 & 18), spring (19), and flow control spool (3) from body (4).

NOTE: Notice the position of the spool in relation to valve body when removing spool (3).

3. Remove metering plug (16).

4. Remove shims (10, 11, 12, & 13) from metering plug (16).

5. Remove O–rings (5 & 14) and back–up washer (15) from metering plug (16).

6. Remove groove pin (9) and remove metering stem (8) from metering plug (16).

7. Remove O–ring (6) and back–up washer (7) from inside metering screw (16).

Inspection of Priority Flow Divider

1. Thoroughly clean and dry all parts.

2. Remove all nicks and burrs with emery cloth.

3. Inspect the spool bore inside the body, the surface should be smooth and free of deep score marks.

4. Inspect O.D. of spool, it should be smooth and free of nicks and burrs. Spool should slide freely inside the body bore.

5. Inspect surface of metering stem (8) for deep scratches and burrs.

Reassembly of Priority Flow Divider

1. Install new back–up washer (7) inside metering plug (16).

2. Install new O–ring (6) inside metering plug (16).

3. Oil metering stem (8) and install in metering plug (16). Secure with groove pin (9).

4. Install new back–up washer (15) and new O–rings (5 & 14) on metering plug (16).

5. Install shims (10, 11, 12, & 13) on metering plug (16).

NOTE: Install the same number of shims that were removed.

6. Install metering plug assembly and tighten.

7. Install new O–ring (2) on plug (1) and install plug.

8. Install flow control spool (3), spring (19) shims (18 & 17).

NOTE: Install same number of shims as were removed.

9. Install new O–ring (2) and plug (1) and install plug.

Lift Cylinder

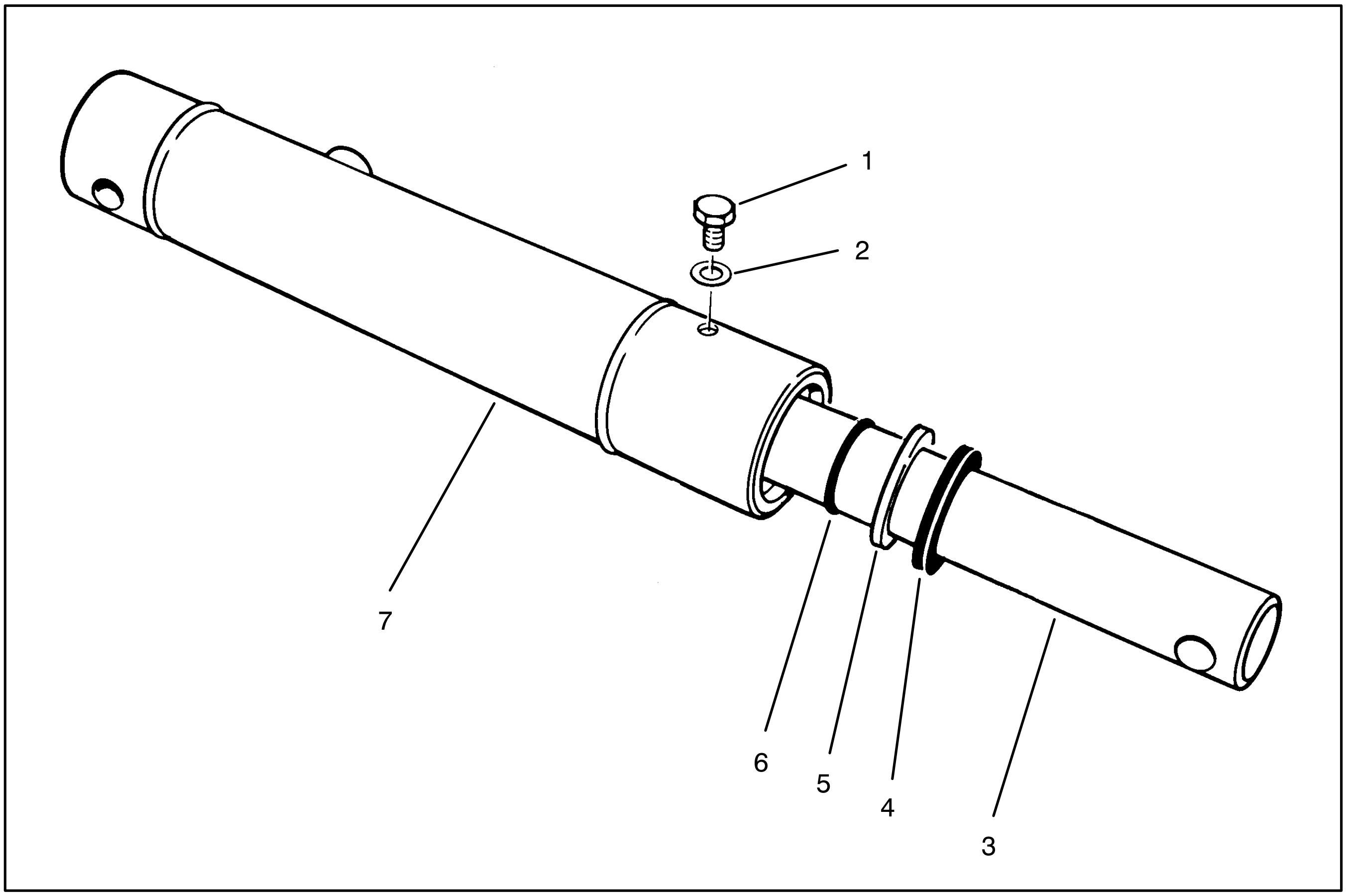


Figure 55

1. Bleed Screw
2. Washer
3. Rod
4. Wiper
5. Seal
6. Snap Ring
7. Seal Kit

Disassembly of Lift Cylinder

1. Thoroughly clean outside of cylinder assembly.

2. Pull rod (3) out until end of rod and snap ring (6) can be seen through inlet port.

3. Insert screw driver in inlet port and slide snap ring (6) into deep groove in the rod assembly.

4. Remove rod assembly (3) from barrel assembly (7).

5. Remove wiper seal (4) and seal (5) from I.D. of barrel assembly.

Inspection of Lift Cylinder

1. It is not necessary to inspect wiper (4), seal (5), or snap ring (6). These parts should be replaced as new items and are included in the seal repair kit available for this cylinder.

2. Thoroughly clean all parts and remove all nicks and burrs with emery cloth.

3. Inspect I.D. of barrel assembly (7) for excessive wear or scoring.

4. Inspect O.D. of rod (3) for nicks, scratches or scoring.

Reassembly of Lift Cylinder

1. All parts should be cleaned and dried thoroughly. Metal parts should be lightly oiled prior to reassembly.

2. Install new seal (5) in barrel. Install new wiper (4) in barrel with lips facing outward.

3. Install new snap ring (6) in deep groove of rod end (3).

4. Oil outside of piston rod (3) and carefully insert rod in barrel assembly (7).

5. Push rod into barrel assembly until snap ring area of rod can be seen through port.

6. By using screwdriver through port, pop snap ring (6) into lock position.

7. Extend rod (3) to full out position to make sure snap ring (6) is locked.

8. Cycle cylinder and check for leaks.

Reel Control Valve

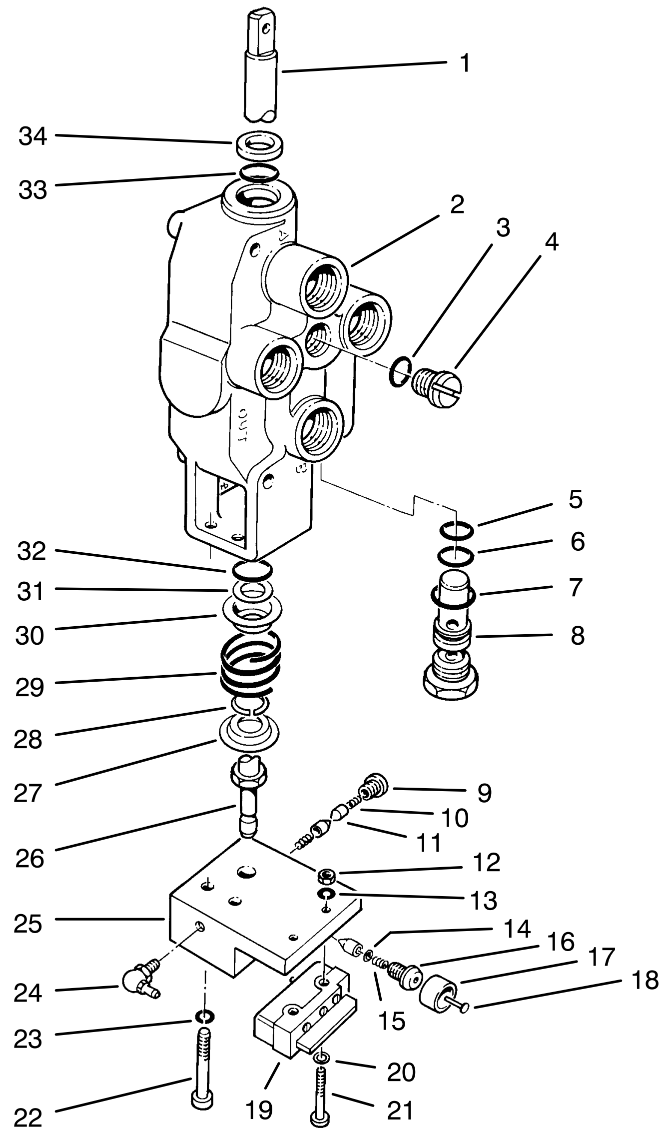


Figure 56

1. **Spool**
2. **Body**
3. **O–Ring**
4. **Plug**
5. **O–Ring**
6. **Backup Washer**
7. **O–Ring**
8. **Relief Valve**
9. **Detent Plug**
10. **Detent Spring**
11. **Detent Pawl**
12. **Locknut**
13. **Lock Washer**
14. **Circlip**
15. **Spring**
16. **Plug**
17. **Sleeve**
18. **Plunger**
19. **Micro Switch**
20. **Flat Washer**
21. **Machine Screw**
22. **Cap Head Screw**
23. **Lock Washer**
24. **Grease Fitting**
25. **Block Detent**
26. **Screw Spool**
27. **Shallow Washer**
28. **Wire Washer**
29. **Spring**
30. **Deep Washer**
31. **Washer**
32. **O–Ring**
33. **O–Ring**
34. **Wiper**

Disassembly of Reel Control Valve Assembly

1. Plug all outlets and thoroughly clean outside of valve.

2. Remove plug (4) and O–ring (3).

3. Remove relief valve components (8, 7, 6, & 5).

4. Remove screws (22) and lock washers (23).

5. Remove detent block (25).

6. Remove detent plug (9), spring (10), and pawls (11) from detent block (25).

7. Remove screw spool (26).

8. Remove shallow washer (27), wire washer (28), spring (29), deep washer (30), washer (31), and O–ring (32).

9. Remove spool (1).

10. Remove all O–rings and back–up washers from all plugs, relief valves, and body bore.

11. Thoroughly clean all parts.

Inspection of Reel Control Valve Assembly

1. Remove nicks and burrs from all parts.

2. Inspect spool and body bore for excessive wear.

NOTE: If internal leakage with the spools in spring–centered position has been experienced, wear is indicated between the spool and body bore. This can be corrected by replacing the spool and body as an assembly. Spools or bodies cannot be serviced separately.

3. Inspect relief valve.

NOTE: The pilot–operated cartridge–type relief valve is not adjustable and is pre–set at the factory. However, to ensure cleanliness in the system; snap ring, washer, and screens may be removed, cleaned with air, and replaced.

4. Inspection of O–rings and back–up washers is not necessary. It is recommended that these be replaced as new parts.

5. Inspect seats in body for wear.

Reassembly of Reel Control Valve Assembly

1. Thoroughly clean and dry all parts. Metal parts should be lightly oiled prior to assembly.

NOTE: All O–rings and back–up washers should be replaced as new parts.

2. Position O–rings (5, 32, & 33) in body bore.

3. Install O–rings and back–up washers on relief valve and plugs.

4. Install plug (4).

5. Install O–ring (32), washer (31), deep washer (30), spring (29), wire washer (28), and shallow washer (27) into proper position in body casting.

6. Insert spool (1) into body bore and screw spool screw (26) into spool.

7. Install spring (10), pawls (11), spring (10) and detent plug (9) into detent block (25).

8. Slip detent block (25) over spool screw (26) and secure to valve body (2) with lock washers (23) and cap screws (22).

9. Install relief valve (8).

10. Run operational check.

Reel Shut Off Valve

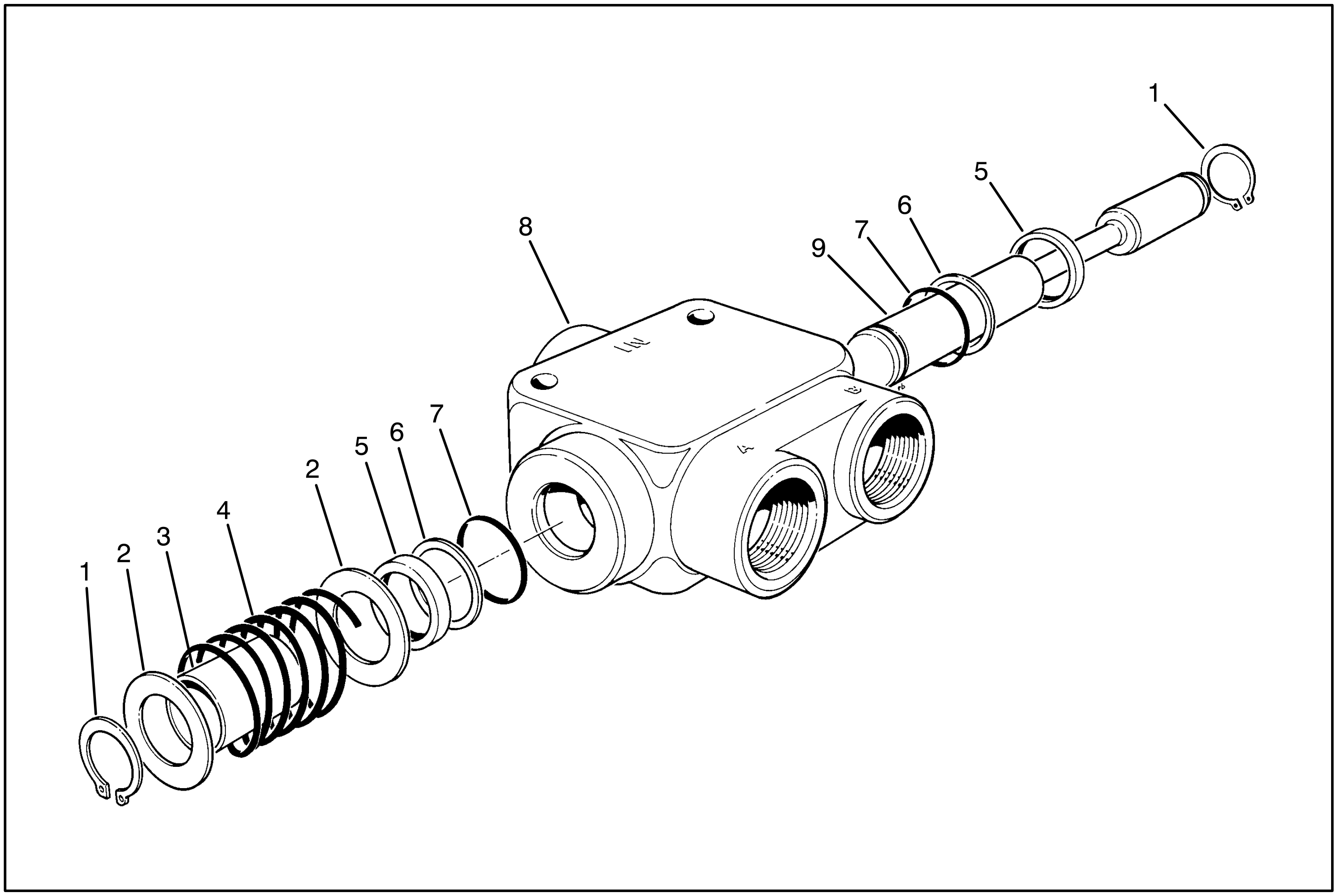


Figure 57

1. **Circlip**
2. **Washer**
3. **Spacer**
4. **Spring**
5. **Wiper**
6. **Backup Washer**
7. **O–Ring**
8. **Body**
9. **Spool**

Disassembly of Reel Shut–Off Valve Assembly

1. Thoroughly clean outside of valve.

2. Remove retaining ring (1) from end of spool (9).

3. Remove spool (9) from valve body (8).

4. Remove washers (2), spring (4), and spacer (3) from spool (9).

5. Remove wipers (5), back–up washers (6), and O–rings (7) from spool bore.

Inspection of Reel Shut–Off Valve Assembly

1. Thoroughly clean and dry all parts.

2. Inspect the spool bore inside the body. The surface should be smooth and free of deep scratches.

3. Inspect O.D. of spool (9). It should be smooth and free of nicks and burrs.

4. Inspect spring (4) for breakage.

Reassembly of Reel Shut–Off Valve Assembly

1. Install new O–rings (7) and back–up washers (6) in spool bore, with O–rings to the inside of the back–up washers.

2. Install new wipers (5) in spool bore.

3. Install washer (2), spacer (3), spring (4), and washer (2) on spool (9).

4. Dip spool (9) in oil and slide in body bore, taking care not to cut O–rings (7). Be sure spool is installed in the proper position.

5. Install retaining ring (1) on end of spool (9).

Traction Pump

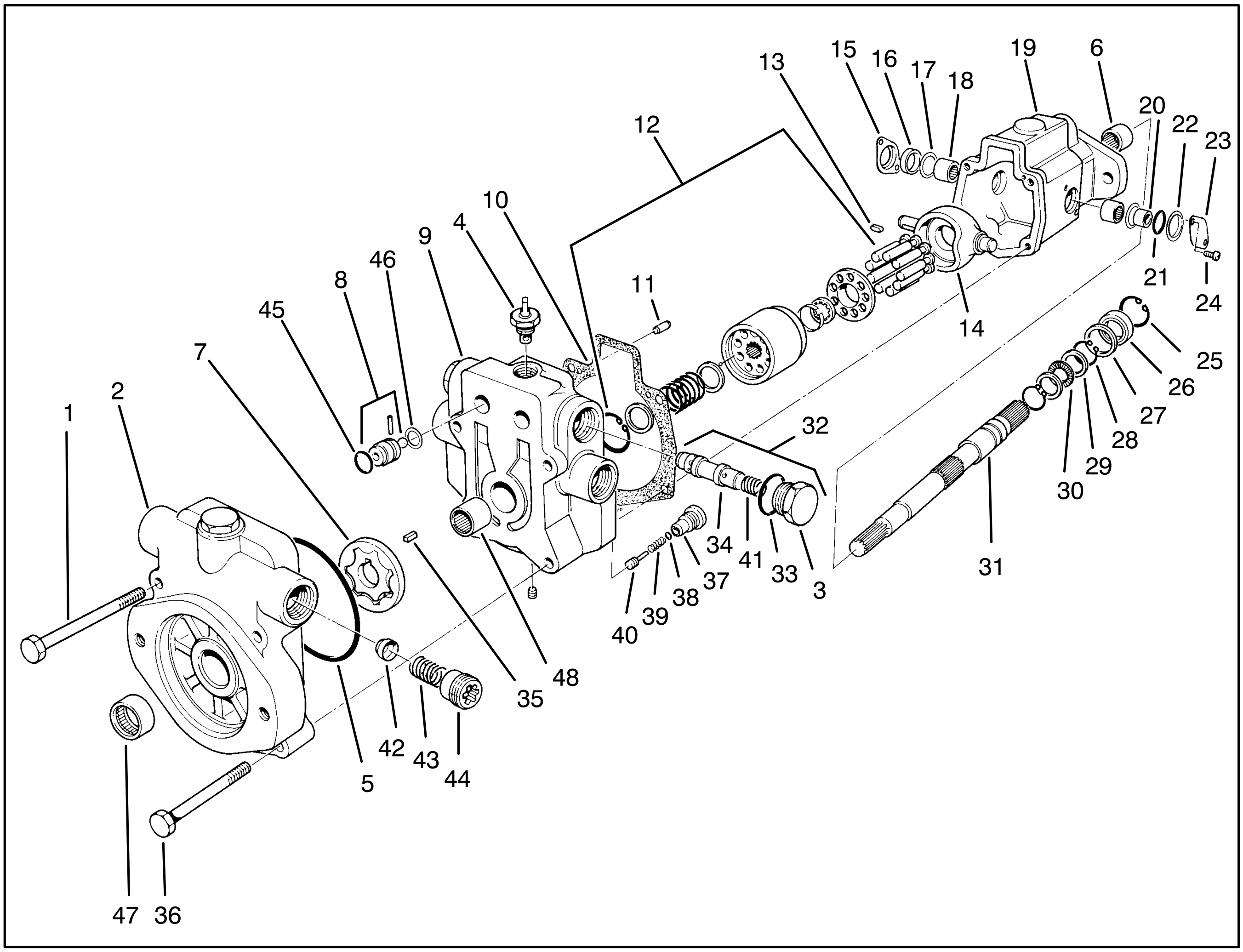


Figure 58

1. **Hex Head Cap Screw**
2. **Charge Pump Adapter Assembly**
3. **Plug Assembly**
4. **Tow Valve Assembly**
5. **O–Ring**
6. **Needle Bearing**
7. **Gerotor Gear Assembly**
8. **Check Valve Assembly**
9. **Back Plate Assembly**
10. **Housing Gasket**
11. **Dowel Pin**
12. **Rotating Kit Assembly**
13. **Key**
14. **Camplate**
15. **Seal Cover**
16. **Shaft Seal**
17. **Washer**
18. **Needle Bearing**
19. **Housing Assembly**
20. **Inner Race**
21. **O–Ring**
22. **O–Ring Cover**
23. **Trunion Cover**
24. **Screw**
25. **Retaining Ring**
26. **Shaft Seal**
27. **Washer**
28. **Retaining Ring**
29. **Thrust Ring**
30. **Needle Bearing , Thrust**
31. **Drive Shaft**
32. **Relief Valve Kit**
33. **O–Ring**
34. **Relief Valve Assembly**
35. **Key**
36. **Hex Head Cap Screw**
37. **Cartridge**
38. **O–Ring**
39. **Spring**
40. **Poppet**
41. **Spring**
42. **Poppet**
43. **Spring**
44. **Spring Retainer**
45. **O–Ring**
46. **Back–up Washer**
47. **Bearing**
48. **Bearing**

Disassembly of Traction Pump

1. Disconnect all control linkage, hydraulic lines and remove pump assembly from vehicle.

2. Plug all ports and thoroughly clean outside of pump.

3. Clamp the end of the drive shaft in a protected jaw vise with the body of the pump up and remove the four cap screws (1 & 36) from the adapter plate of the pump.

4. Use a plastic mallet and tap the charge pump adapter (2) to loosen it, then pull the adaptor straight up until it is free.

5. Remove spring retainer (44) and remove spring (43) and poppet (42) from adaptor assembly (2).

6. Remove the gerotor gear (7) and key (35) from the pump shaft.

7. Remove the two check valve assemblies (8) from back plate (9). Pin is loose fitting. Caution should be taken when removing check valve assembly so that pin and ball are not lost.

8. Use screwdriver slots in housing and pry up on back plate (9) or tap with plastic mallet to loosen, then pull the back plate straight up to remove. Remove housing gasket (10).

9. Remove the tow valve (4) from back plate (9). To disassemble tow valve, remove retaining ring from spreader, and pull spreader from spreader plug.

10. Remove plug assembly (3), spring (41) and relief valve assembly (34) from back plate.

11. Remove pump from vise and remove rotating kit assembly (12) from housing (19).

12. If pistons did not come out with piston block, you may remove them, spider, and spider pivot.

13. DO NOT attempt to disassemble the piston block and spring. The parts are not serviceable separately. The rotating kit (12) must be replaced as an assembly.

14. Remove retaining ring (25) from housing. Press drive shaft (31) from housing (19) and remove shaft seal (26) and washer (27).

15. Remove retaining ring (28) from shaft and remove thrust race (29) and thrust bearing (30).

16. To remove the camplate (14) from housing, remove screws (24) from the sides of the housing. Remove trunnion cover (23), seal cover (15), O–ring cover (22), O–ring (21), washer (17), inner race (20), and needle bearing (18). Remove shaft seal (16), washer (17), and needle bearing (18).

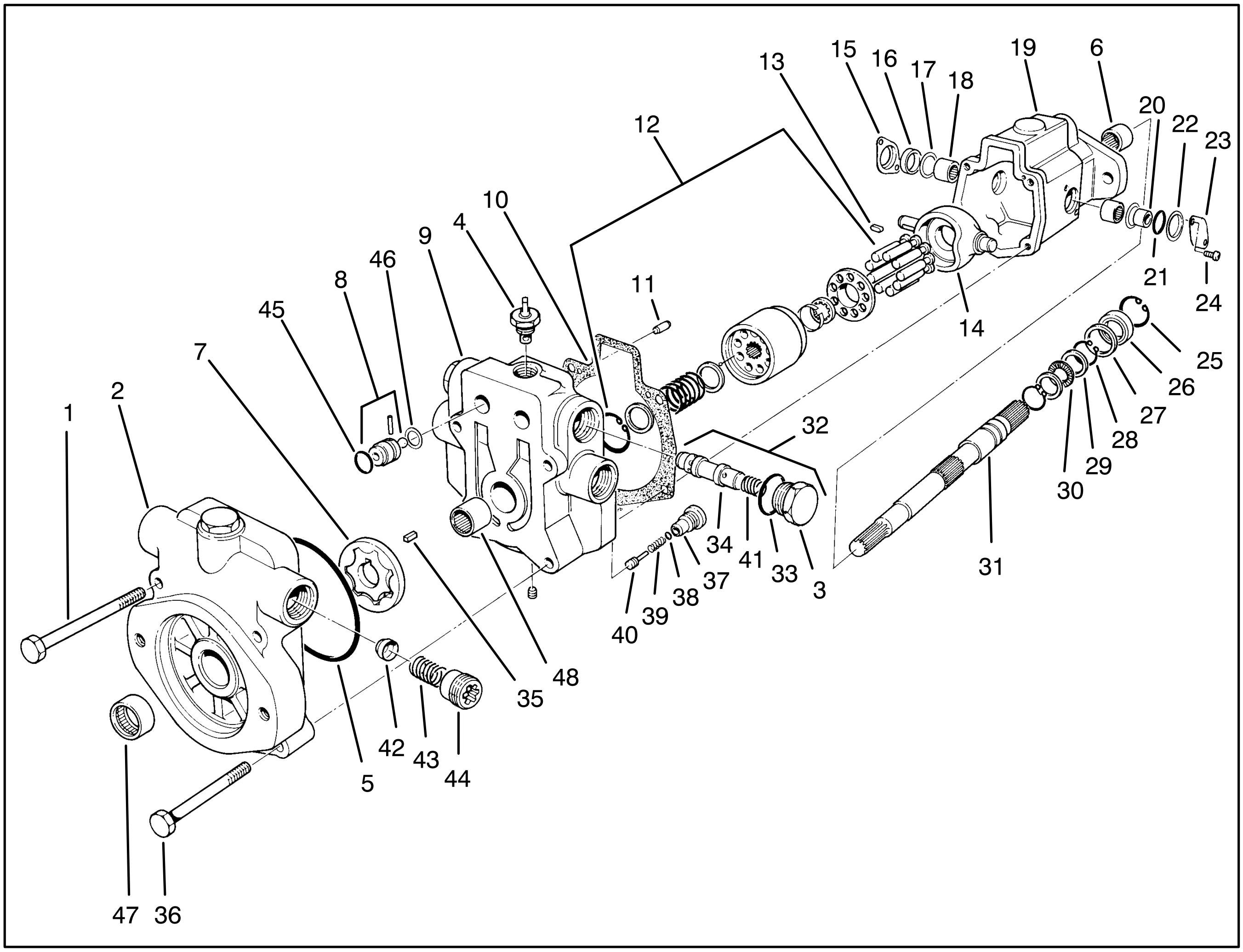


Figure 59

1. Hex Head Cap Screw
2. Charge Pump Adapter Assembly
3. Plug Assembly
4. Tow Valve Assembly
5. O–Ring
6. Needle Bearing
7. Gerotor Gear Assembly
8. Check Valve Assembly
9. Back Plate Assembly
10. Housing Gasket
11. Dowel Pin
12. Rotating Kit Assembly
13. Key
14. Camplate
15. Seal Cover
16. Shaft Seal
17. Washer
18. Needle Bearing
19. Housing Assembly
20. Inner Race
21. O–Ring
22. O–Ring Cover
23. Trunion Cover
24. Screw
25. Retaining Ring
26. Shaft Seal
27. Washer
28. Retaining Ring
29. Thrust Ring
30. Needle Bearing , Thrust
31. Drive Shaft
32. Relief Valve Kit
33. O–Ring
34. Relief Valve Assembly
35. Key
36. Hex Head Cap Screw
37. Cartridge
38. O–Ring
39. Spring
40. Poppet
41. Spring
42. Poppet
43. Spring
44. Spring Retainer
45. O–Ring
46. Back–up Washer
47. Bearing
48. Bearing

Inspection of Traction Pump

1. Inspect the charge pump relief valve seat inside the charge pump adaptor. It should be smooth and free of burrs or other defects.

2. Inspect the charge pump relief valve poppet (42) and spring (43).

3. Inspect the gerotor pocket inside the charge pump adaptor assembly (2). It should not be scored excessively.

4. Inspect the bearing (47) inside the charge pump adaptor assembly, if the needles are free of excessive play and remain in the bearing cage there is no need to replace the bearing.

5. Inspect the check valve assembly (8), make sure the ball seat is in good condition and the ball is free to move.

6. Inspect the flat surfaces of the back plate (9), the finish on the gerotor side should show on galled surface. The finish on the piston block side should be smooth and free of grooves. The back plate should be replaced if it shows any of the wear characteristics outlined above. The cam stop should be tight in the back plate.

7. Inspect the piston block. The surface that contacts the back plate should be smooth and free of grooves.

8. The pistons should move freely in the piston block bore. If they are sticky in the bore, examine the bore for scoring or contamination.

9. Examine the O.D. of the pistons for finish condition, they should not show wear or deep scratches. The shoes should be snug fit on the ball end of the pistons. The flat surfaces of the shoes should be flat and smooth. DO NOT LAP THE PISTON SHOES.

10. Examine the spider. It should be flat, no cracks and no signs of wear in the pivot area.

11. Examine the pivot. It should be smooth and show no signs of wear.

12. The camplate (14) should be inspected for the condition of the finish of the polished shoe surface. It should show no signs of scoring.

13. Inspect the drive shaft (31) for fretting in the bearing and spline areas.

14. Inspect thrust bearing (30) and thrust race (29) for wear.

15. Inspect the needle bearing (6) in the housing assembly. If the needles are free of excessive play and remain in the bearing cage, there is no need to replace the bearing.

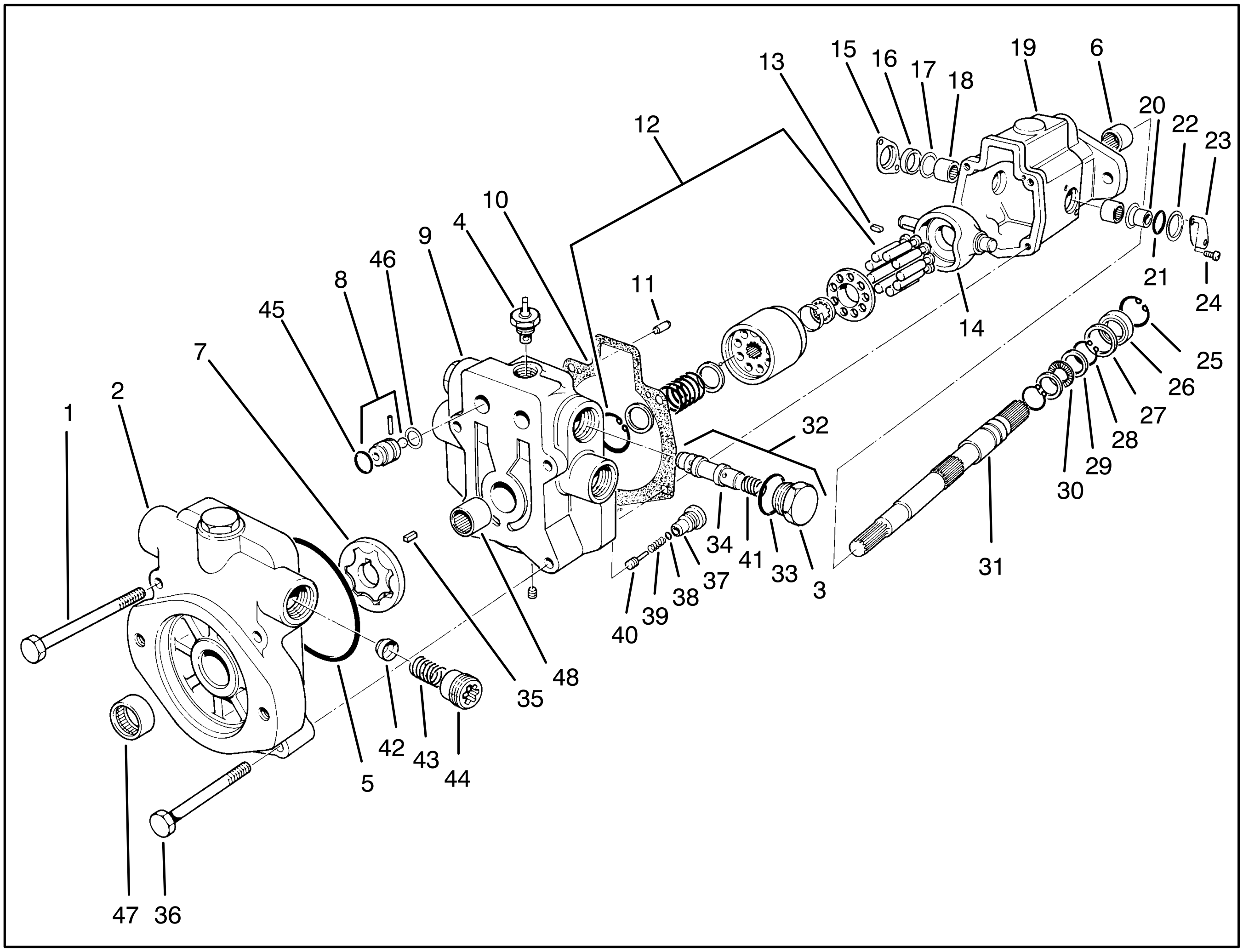


Figure 60

1. **Hex Head Cap Screw**
2. **Charge Pump Adapter Assembly**
3. **Plug Assembly**
4. **Tow Valve Assembly**
5. **O–Ring**
6. **Needle Bearing**
7. **Gerotor Gear Assembly**
8. **Check Valve Assembly**
9. **Back Plate Assembly**
10. **Housing Gasket**
11. **Dowel Pin**
12. **Rotating Kit Assembly**
13. **Key**
14. **Camplate**
15. **Seal Cover**
16. **Shaft Seal**
17. **Washer**
18. **Needle Bearing**
19. **Housing Assembly**
20. **Inner Race**
21. **O–Ring**
22. **O–Ring Cover**
23. **Trunion Cover**
24. **Screw**
25. **Retaining Ring**
26. **Shaft Seal**
27. **Washer**
28. **Retaining Ring**
29. **Thrust Ring**
30. **Needle Bearing , Thrust**
31. **Drive Shaft**
32. **Relief Valve Kit**
33. **O–Ring**
34. **Relief Valve Assembly**
35. **Key**
36. **Hex Head Cap Screw**
37. **Cartridge**
38. **O–Ring**
39. **Spring**
40. **Poppet**
41. **Spring**
42. **Poppet**
43. **Spring**
44. **Spring Retainer**
45. **O–Ring**
46. **Back–up Washer**
47. **Bearing**
48. **Bearing**

Reassembly of Traction Pump

1. Clean all parts in suitable solvent, lubricate all critical moving parts before reassembly. If necessary, install new needle bearings in the housing. The camplate pivot bearings are slip fit; the needle bearing (6) is press fit, install with numbered end of the bearing outward.

2. Insert camplate into housing. Insert the needle bearings (18) over the arm and slide into the housing.

3. Install washers (17) and shaft seal (16) over cam pivot bearing. Install seal cover (15) and secure with screws (24).

4. On the opposite side of housing install needle bearing (18), inner race (20) with chambered I.D. inward, washer (17), O–ring (21), and O–ring cover (22), and secure with trunion cover (23) and screws (24).

5. Install retaining ring (28) on drive shaft (31). Install thrust race (29), thrust bearing (30), and second thrust race (29), secure with second retaining ring (28).

6. Install shaft in housing and install washer (27), shaft seal (26), and retain with retaining ring (25).

7. Install the pivot, spider and the piston assemblies in the piston block. Install rotating assembly in the housing assembly, the piston shoes must be in contact with the camplate.

8. Clamp pump assembly in a protected jaw vise with the open end of the housing up.

9. Install new housing gasket (10).

10. Install back plate (9).

11. Install ball and pin into check valve housing if removed. Install new O–ring (45) and back–up washer (46) on check valve assembly (8). Install O–ring nearest pin. Install in back plate (9) with pin in back plate.

12. Install key (35) on shaft and install gerotor gear (7) over shaft.

13. Install new O–ring (5) in groove in charge pump adaptor (2), hold in place with clean clear grease. Assemble adaptor on pump back plate. Retain with four cap screws (36 & 1) and torque to 27/31 ft. lbs.

14. Reassemble tow valve assembly (4) by installing new O–rings, inserting spreader into separater plug, and securing with retaining ring.

15. Install tow valve assembly (4) in back plate (9) and torque 27/30 ft. lbs.

16. Install relief valve assemblies (34) in back plate.

17. Install new O–ring (33) and spring (41) on plug (3). Install plugs (3) in back plate and torque 55/60 ft. lbs.

18. Remove pump from vise and install poppet (42), spring (43), and spring retainer (44).

Front Traction Motor

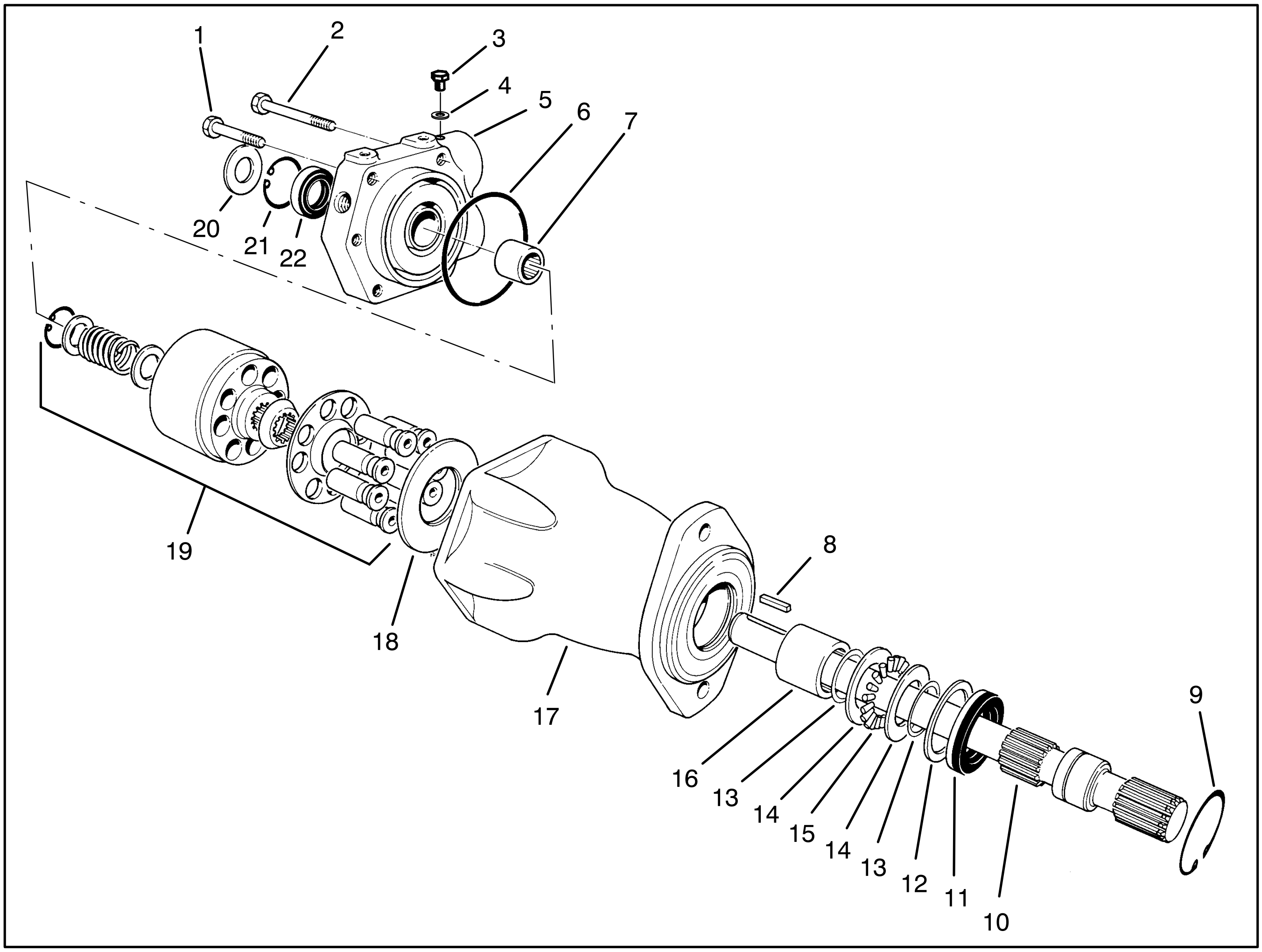


Figure 61

1. **Hex Head Cap Screw**
2. **Hex Head Cap Screw**
3. **Plug**
4. **O–Ring Seal**
5. **Back Plate Assembly**
6. **O–Ring**
7. **Bearing**
8. **Key**
9. **Retaining Ring**
10. **Drive Shaft**
11. **Shaft Seal**
12. **Washer**
13. **Retaining Ring**
14. **Thrust Ring**
15. **Thrust Bearing**
16. **Bearing**
17. **Housing Assembly**
18. **Camplate Assembly**
19. **Rotating Assembly**
20. **Grass Shield**
21. **Retaining Ring**
22. **Shaft Seal**

Disassembly of Traction Motor

1. Clean outside of unit thoroughly.

2. Remove retaining ring (9) from housing assembly (17).

3. Clamp shaft in a protected jaw vise with backplate end up.

4. Remove retaining ring (21) and shaft seal (22) from backplate (5).

5. Remove capscrews (1 & 2) from backplate (5).

6. Use a plastic mallet and tap the backplate (5) to loosen it; then pull the backplate straight out.

7. Remove O–ring (6) from backplate.

8. Remove the complete rotating assembly (19) from the housing assembly (17).

9. Remove piston assemblies, spider, and pivot from the rotating assembly (19).

10. DO NOT attempt to disassemble the piston block and spring. The parts are not serviceable separately. The rotating assembly (19) must be replaced as an assembly.

11. Remove camplate assembly (18) from housing.

12. Remove shaft seal (11) from housing.

13. Remove washer (12) and drive shaft (10) from housing.

14. Remove the two retaining rings (13), thrust races (14), and thrust bearing (15) from drive shaft (10).

Inspection of Traction Motor

1. Wash all parts thoroughly in a suitable solvent.

2. Examine bearings (16) and (7) in housing (17) and backplate (5). If the needles are free of excessive play and remain in the bearing cage, there is not need to replace the bearing.

3. Inspect thrust races (14) and thrust bearing (15). All surfaces should be free of any signs of wear or fretting.

4. Inspect spider and pivot; conical surfaces should be free of wear and score marks.

5. Inspect the pistons; the O.D. surface should be smooth and free of scoring. The shoes should be snug fit to the piston. The face of the shoes should be flat and free of scoring and flaking. Do not lap piston shoes.

6. Inspect the piston block; the bores should be free of scoring. The surface that contacts the backplate should be smooth and free of grooves or metal build–up.

7. Inspect the camplate assembly (18); the surface opposite the chamfered side should show no signs of scoring.

8. Inspect the flat surface on the backplate (5); it should be free of excessive scoring or metal build–up.

9. Inspect the drive shaft (10) for fretting in the bearing areas. Check spline area for twisted or broken teeth. If keyed shaft, check for cracked or chipped keyway.

Reassembly of Traction Motor

1. Lubricate all critical moving parts before assembly.

2. Install one retaining ring (13) in rear groove on drive shaft (10). Install one thrust race (14), thrust bearing (15), and second thrust race (14) on drive shaft (10). Install second retaining ring (13) in front groove on drive shaft.

3. Replace needle bearing (16) in housing (17) if necessary. Install shaft in housing assembly (17). Install washer (12), shaft seal (11) and retain with retaining ring (9).

4. Install the pivot, spider, and the piston assemblies in the piston block assembly.

5. Lubricate camplate assembly (18) and install in housing assembly with chamfered edge of race against housing surface.

6. Install piston block assembly in housing assembly. The piston shoes must contact the camplate assembly (18). Be sure all parts are in their proper position.

7. Install new bearing (7) in backplate (5) if necessary.

8. Install new O–ring (6) on backplate.

9. Install backplate (5) on housing.

10. Install capscrew (1 & 2) and torque 15–18 ft. lbs.

Reel Pump

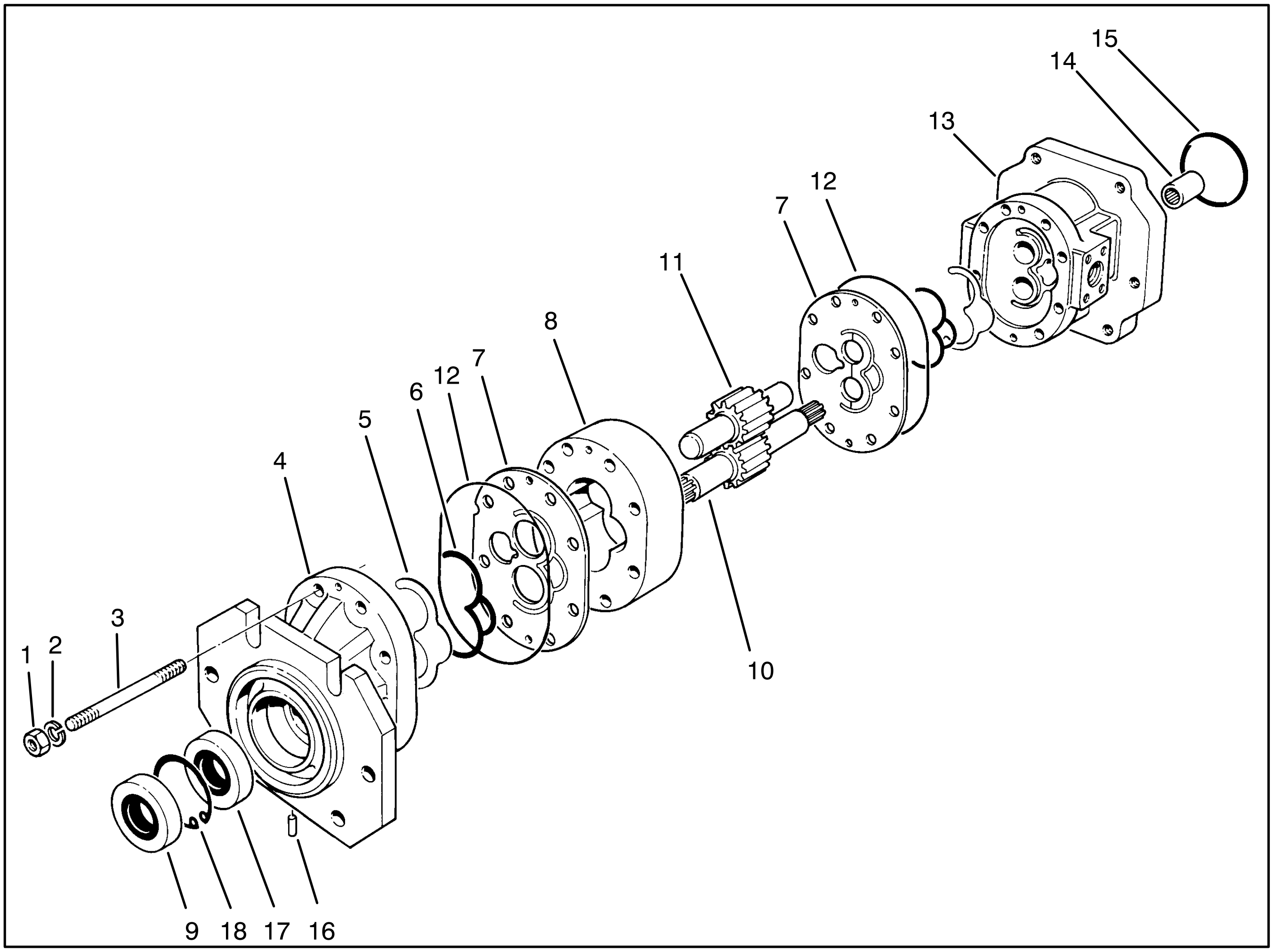


Figure 62

1. Nut
2. Lock Washer
3. Stud
4. Stud
5. Front Cover
6. Gland Seal
7. Wear Plate
8. Center S/A Section
9. Shaft Seal
10. Spline Drive Gear
11. Driven Gear
12. O–Ring Seal
13. Rear Port Section
14. Coupling
15. O–Ring
16. Plug
17. Shaft Seal
18. Retaining Ring

Disassembly of Reel Pump

During disassembly, pay particular attention to identification of the parts for correct assembly.

1. Clamp the port section (13) in a vise with protective jaws to avoid damage to the port section's machined surfaces.

2. Remove gear coupling (14) from port section (13).

3. Remove eight nuts (1) and eight washers (2).

4. Remove front cover (4) from wear plate (7).

5. Remove seal retainer (6) and gland seal (5) from front cover (4) and discard.

6. Remove wear plate (7) from center section (8).

7. Remove spline drive gear (10) and driven gear (11) from center section (8).

8. Removal of the center section (8) may require the use of a plastic hammer.

9. Remove wear plate (7) from port section (13).

10. Remove seal retainer (6) and gland seal (5) from port section (13) and discard.

Inspection of Reel Pump

All parts must be thoroughly cleaned and kept clean during inspection and assembly. The close tolerance of the parts makes this requirement very important. Paint found on the edges of all parts must be removed. Clean all removed parts, using a commercial solvent that is compatible with the system fluid. Compressed air may be used in cleaning, but it must be filtered to remove water and contamination.

New seal kits (5 & 6) are required for assembly. Wash the metal parts, blow dry them with air, and place on a clean surface (Kraft paper) for inspection.

1. Place front cover S/A (4) in a vise (mounting flange up). Using a screwdriver, pop out the outer shaft seal (9), being careful not to raise a burr on the shaft seal bore.

2. Remove the retaining ring (18) with internal retaining ring pliers.

3. Remove front cover S/A (4) from vise and place on work bench with mounting flange down. Using a bronze drift and hammer, drive inner shaft seal (17) out through mounting flange, being careful not to damage bearing.

4. Inspect the drive and driven gear bushings of front cover (4) for pickup, scoring, discoloration, or excessive wear. Any of the preceding conditions shall warrant replacement of the front cover S/A (4). Inspect mounting flange for nicks and burrs. Remove with india stone.

5. Inspect wear plates (7) for erosion, pitting, scratching, an/or scoring. Replace if necessary.

6. Inspect the center S/A section (8) for porosity, cracks, and scratches (.010 or deeper). Replace if necessary. DO NOT deburr the figure eight section of the center section.

7. Inspect splines on the drive gear (10) and driven gear (11) for nicks or excessive wear. Inspect gear journals fro scratches and discoloration. *Any discoloration warrants replacement*. Inspect gear teeth for spalling, scratches, and/or excessive wear. Replace if necessary. Stoning teeth to remove burrs is permissible. The face of the gear teeth should also be inspected for scratches.

8. Inspect the drive and driven gear bushings on the port section (13) for pickup, scoring, discoloration, and/or wear. *Any of the preceding conditions shall warrant replacement of the port section*. Inspect inlet flange for nicks and burrs. Stone to remove. Inspect studs (3) for cross threads, cracks, and burrs. if studs are defective, remove as follows: Install a nut (1) on the stud as far as possible. Then install another nut over the first one and tighten to lock in place. Apply torque to the first nut and remove the stud. Refer to the parts drawing for stud part numbers and installation instructions

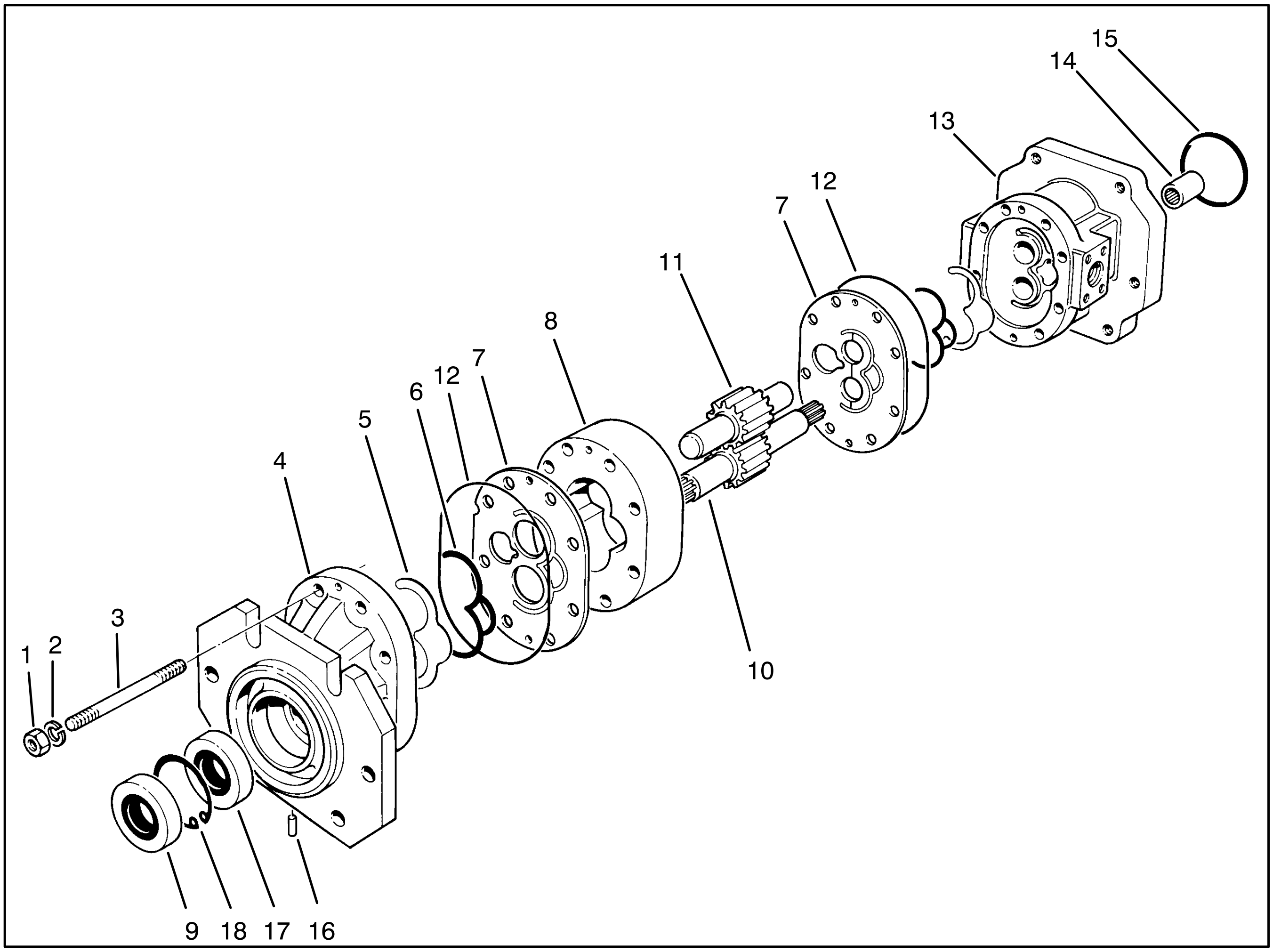


Figure 63

1. Nut
2. Lock Washer
3. Stud
4. Stud
5. Front Cover
6. Gland Seal
7. Wear Plate
8. Center S/A Section
9. Shaft Seal
10. Spline Drive Gear
11. Driven Gear
12. O–Ring Seal
13. Rear Port Section
14. Coupling
15. O–Ring
16. Plug
17. Shaft Seal
18. Retaining Ring

Reassembly of Reel Pump

NOTE: Coat all parts with clean hydraulic fluid to facilitate assembly and provide initial lubrication. Use small amount of petroleum jelly to hold seal glands (5) and retainers (6) in place during assembly.

1. Assemble seal packs by inserting the seal glands (5) into the seal retainers (6). Install a seal pack into the cavity located on the face of the port section (13) with the seal retainer pointing up.

2. Place port section (13) in vise with studs (3) facing up.

NOTE: The next five steps pertain to installation of front cover shaft seals (9 & 17). Lubricate the shaft seals with Marfak grease to provide initial lubrication.

3. Install inner shaft seal (17) into front cover (4). Make sure the spring loaded member of shaft seal faces the inside of pump. Place the shaft seal (17) on shaft seal driver and press in place.

4. Install retaining ring (18) into front cover on top of shaft seal (17).

5. Place a guide over the pilot diameter of front cover (4).

6. Install a new outer shaft seal (9) on the driver. Make sure the spring loaded member of shaft seal faces the inside of pump.

7. Insert the driver and shaft seal though the guide and press in place.

8. Place wear plate (7) on port section (13) with bronze face up and notch facing inlet port.

9. Lubricate bronze face of wear plate (7). Install center section (8) on top of wear plate (7) and into locating holes of port section (13) with major diameter facing port section and notch facing inlet port. Make sure wear plate and center section set flush against port section.

10. Tape the spline area (long spline) of drive gear (10) to prevent cutting shaft seal(s) during assembly.

11. Lubricate drive gear (10) and driven gear (11). Install drive gear (10) into port section (13) with short spline towards port section. Install driven gear (11).

12. Lubricate bronze face of wear plate (7). Install wear plate (7) over locating pins of center section (8) with bronze face towards center section and notch facing inlet port.

13. Install seal pack (5 & 6) into cavity located on face of front cover (4). Apply petroleum jelly around seal pack area on face of front cover.

14. Carefully position front cover (4) over studs (3), gears (10 & 11), and center section guide pins. Gently slide front cover over the gears until it is flush against wear plate (7).

15. Lubricate stud (3) threads with hydraulic fluid. Install washer (2) and nuts (1) on ends of studs. Cross torque nuts to 60 –5 lb. ft.

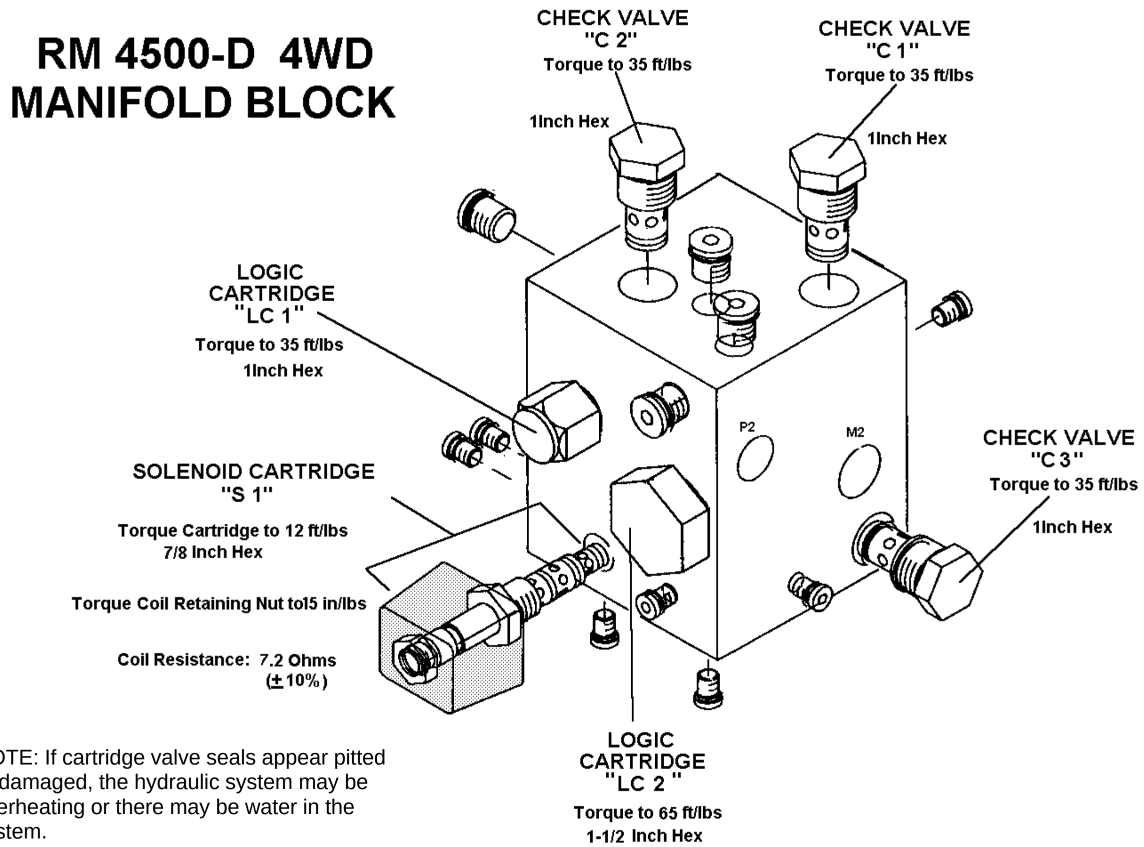
16. Clamp port section (13) into vise with studs facing down. Make sure port section is clamped securely.

17. Install O–ring (15) into groove located on face of port section (13).

18. Install lubricated coupling (14) on spline of drive gear (10).

19. Turn the drive gear (10) one revolution with a suitable socket wrench. Not binding shall be evident during this operation. The breakaway torque necessary to turn the drive gear must not exceed 140 lb. in.

Rear Wheel Drive Valve Block



NOTE: If cartridge valve seals appear pitted or damaged, the hydraulic system may be overheating or there may be water in the system.

Figure 64

Cleaning Solenoid Actuated Cartridge Valve

Use a deep socket to remove the valve cartridge. Use mineral spirits to clean solenoid actuated cartridge valves. Submerge the valve in clean mineral spirits and use a probe to push the internal spool in and out 20 to 30 times to flush out contamination. Mineral spirits does not affect the O–ring material. Particles as fine as talcum powder can affect the operation of high pressure hydraulic valves.

NOTE: Apply clean hydraulic oil to the O–rings before installing the valve. Use a deep socket to install the valve into the manifold block. Tighten to a torque of 35 ft–lb (48 Nm). Install the solenoid coil. Make sure there is an O–ring at each end of the coil. After putting the solenoid onto the valve stem apply Loctite 242 or equivalent to the threads on the stem before installing the nut. Tighten the nut to a maximum torque of 15 in–lb (1.7 Nm) to secure the solenoid; do not over–tighten.

Figure 65

Rear Wheel Drive Motor

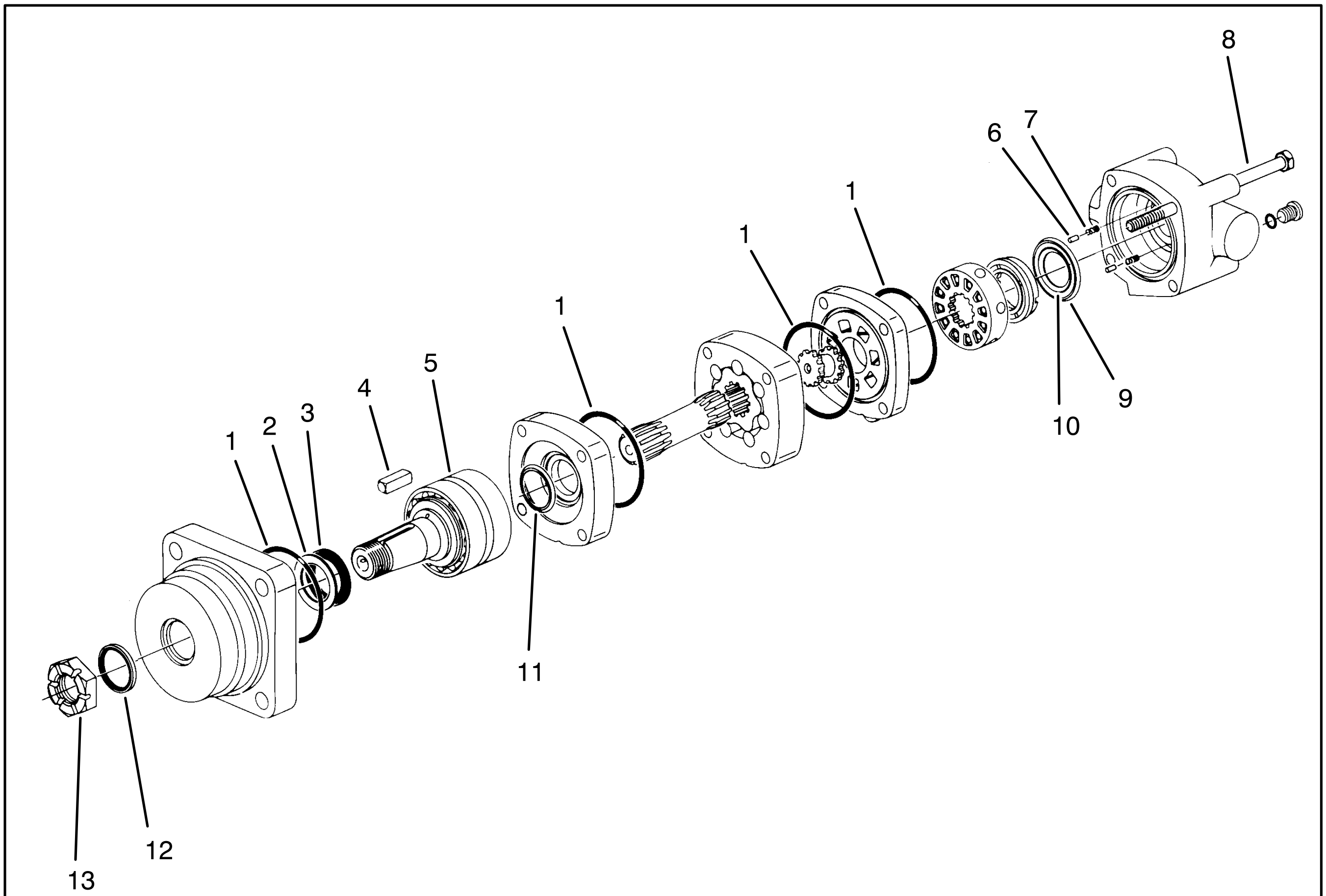


Figure 66

1. O–Ring Seal
2. Backup Washer
3. Shaft Seal
4. Key
5. Sub Shaft Assembly
6. Pin
7. Spring
8. Bolt
9. Outer Seal
10. Inner Seal
11. Shaft Seal
12. Dust Seal
13. Slotted Nut

Disassembly of the Rear Wheel Drive Motor

Cleanliness is extremely important when repairing a hydraulic motor. Work in a clean area. Before disconnecting the lines, clean the port area of the motor thoroughly. Use a wire brush to remove foreign material and debris from around the exterior joints of the motor. Check the shaft and keyslot, remove all nicks, burrs or sharp edges that might damage the bearing housing seals when installing the shaft and bearing assembly. Before starting the disassembly procedures, drain the oil from inside the motor.

1. Place the motor in a vise with the output shaft down. Clamp across the mounting flange of the motor not the housing. Excessive clamping pressure will cause distortion. When clamping, use some protective device on the vise, such as special soft jaws, pieces of hard rubber or board.

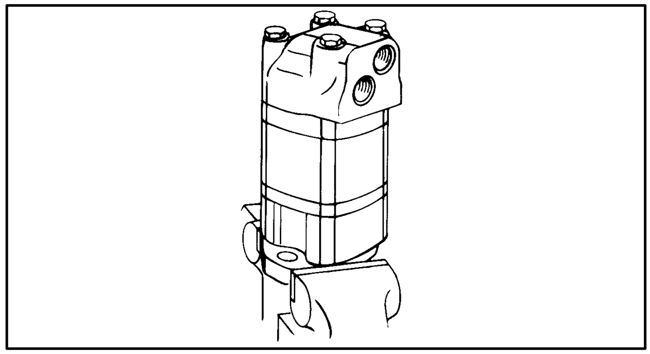


Figure 67

Although not all drawings show the motor in a vise, we recommend that you keep the motor in the vise during disassembly and reassembly. Follow the clamping procedures explained throughout the manual.

2. Remove 4 bolts from motor.

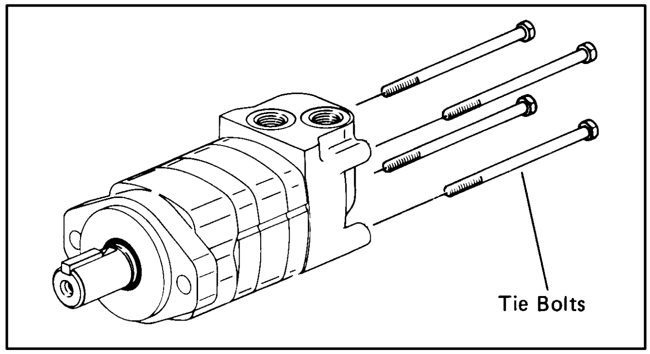


Figure 68

3. Lift valve housing straight up. If done carefully the pins, springs, balance ring assembly, and valve will remain on the valve plate.

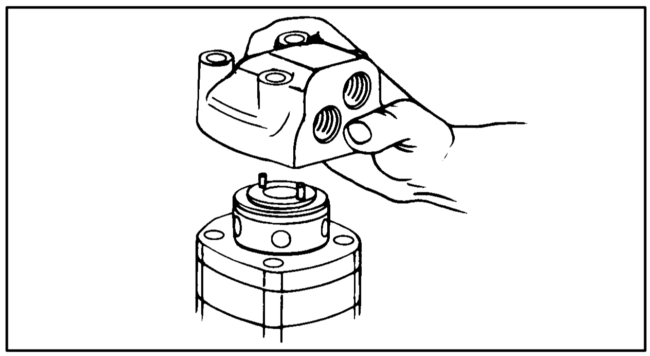


Figure 69

4. Carefully remove 3[76] diameter seal from valve housing.

5. Remove case drain plug–with seal, from front valve housing.

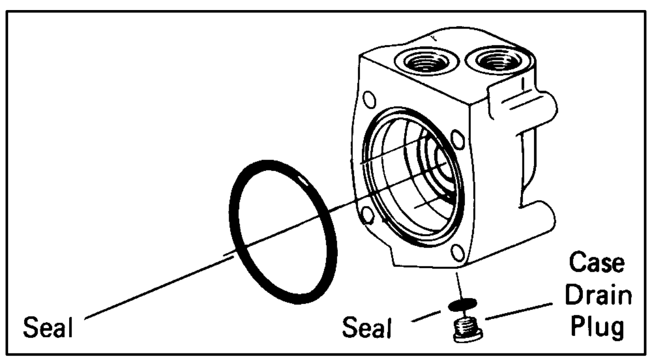


Figure 70

6. Remove 2 pins and 2 springs from balance ring assembly, see Fig. 71.

7. Remove balance ring assembly.

8. Remove inner and outer face seals from balance ring.

9. Remove the valve.

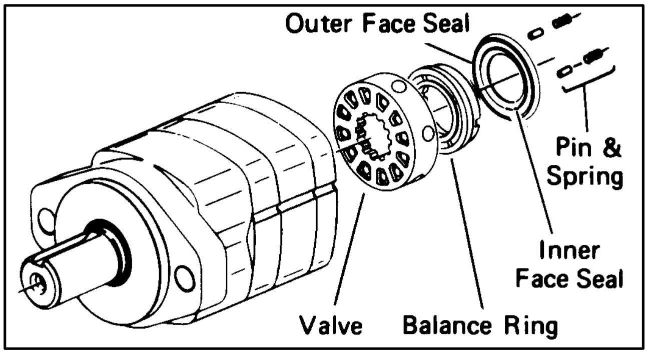


Figure 71

10. Remove the valve plate.

11. Remove the 3[76] diameter seal from valve plate.

12. Remove the valve drive.

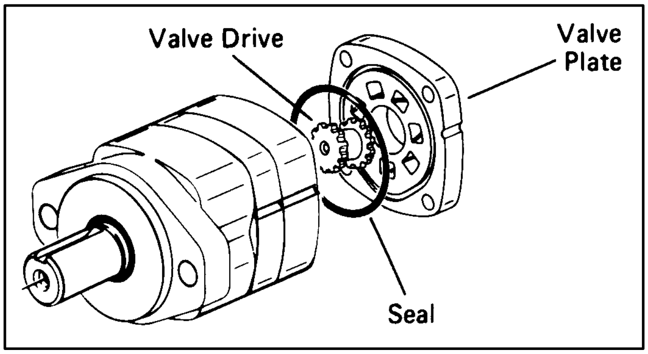


Figure 72

13. Remove the Geroler. Be sure to retain the rollers in the outer ring if they are loose.

14. Remove the drive.

15. Remove the 3[76] diameter seal from wear plate, see Fig. 73.

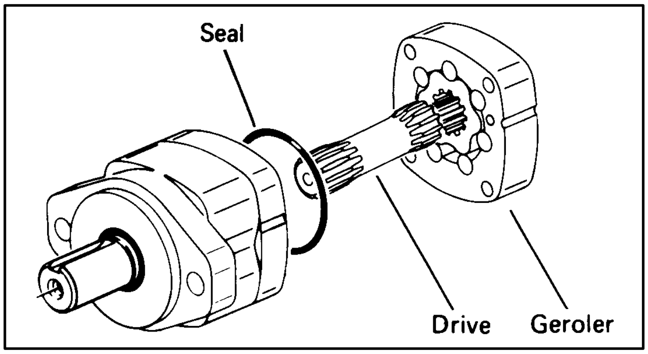


Figure 73

16. Remove the wear plate.

17. Remove the shaft face seal from the wear plate.

18. Remove the 3[76] diameter seal from bearing housing.

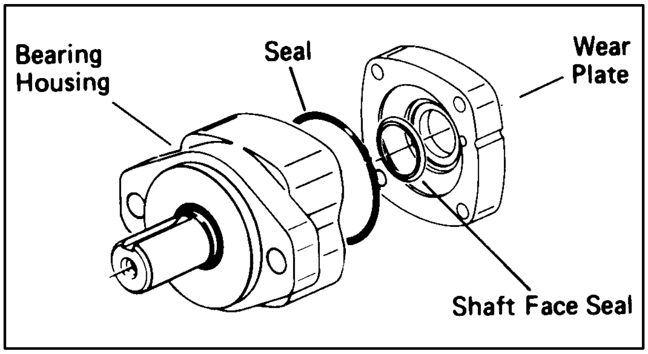


Figure 74

19. You may need a press to remove shaft and bearing assembly from bearing housing. (Key must be removed before removing shaft.)

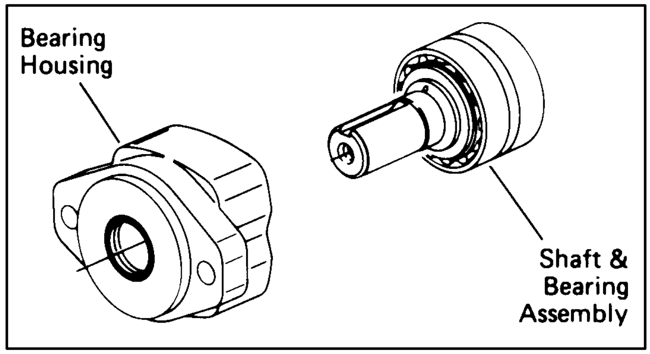


Figure 75

20. Use a small screwdriver to remove shaft seal, back–up washer and exclusion seal from bearing housing, see Fig. 76. Do not damage bore of housing.

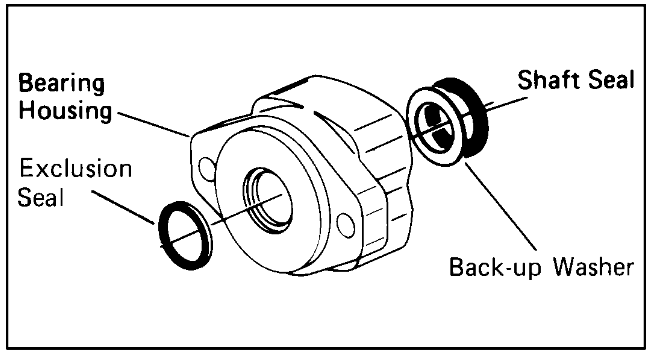


Figure 76

NOTE: Individual parts of shaft and bearing assembly are not sold separately. Replace as a unit.

Check all mating surfaces. Replace any parts that have scratches or burns that could cause leakage. Clean all metal parts in clean solvent. Blow dry with air. Do not wipe dry with cloth or paper towel because lint or other matter can get in the hydraulic system and cause damage. Do not use a coarse grit or try to file or grind these parts. Check around the keyway and chamfered area of the shaft for burrs, nicks or sharp edges that can damage the seals when reassembling the bearing housing.

NOTE: Lubricate all seals (prior to installation) with petroleum jelly such as Vaseline. Use new seals when reassembling this motor.

21. Use a press to install exclusion seal in outer bore of bearing housing. Lip of seal must face outward. See Fig. 77. If a press is not available use a plastic or rubber hammer, being careful not to damage or cock seal in the bore.

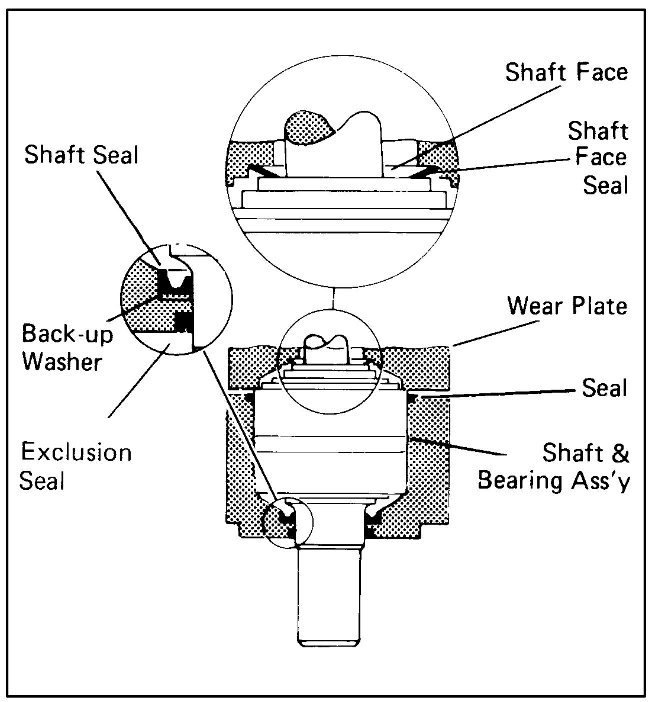


Figure 77

22. Place back–up washer into seal bore. Place shaft seal onto installation tool and press seal into seal bore of the housing.

23. Clamp housing in vise, see Fig. 67.

24. Place protective bullet over shaft. Apply petroleum jelly to inside diameter of dust and shaft seal. You may need a press to install shaft and bearing assembly. Do not distort shaft seal. Damage to this seal will cause leakage.

NOTE: Use tape over other shafts to prevent cutting the seats.

25. Apply petroleum jelly to the 3[76] diameter seal. Install seal into the bearing housing.

26. Alignment studs can be very helpful in reassembly of the motor. If you use studs, install 2 studs diagonally opposed in the bearing housing.

27. Install the shaft face seal in the wear plate as shown in Fig. 77. Do not distort seal.

28. Install the wear plate, see Fig. 77.

29. Apply a light film of petroleum jelly to the 3[76] diameter seal and install seal in the wear plate.

30. Install the drive into the output shaft.

31. Align the notch on the outside of the Geroler with the notch on the wear plate. Install the Geroler against the wear plate. Be sure to retain the rollers in the outer ring if they are loose.

32. Install the valve drive in the Geroler.

NOTE: Installation at this time involves 3 steps in the timing of the motor. Timing determines the direction of rotation of the output shaft. Timing parts include:

1. Geroler
2. Valve Drive
3. Valve Plate
4. Valve

Timing Step #1–Locate the largest open pocket in the Geroler and mark it on the outside edge of the Geroler.

33. Apply a light film of petroleum jelly to the 3[76] diameter seal. Install seal in groove of valve plate.

34. Align the notch on the outside of the valve plate with the notch on the Geroler as shown in Fig. 78.

Timing Step #2–Locate the slot opening in the valve plate which is in line with the largest open pocket of the Geroler.

Timing Step #3–Locate any one of the side openings of the valve and align this opening with the open slot of the valve plate that is in line with the largest open pocket of the Geroler. Install the valve by rotating it clockwise until the spline teeth engage (1/2 spline tooth max). This will provide the proper rotation when pressurized as shown in Fig. 79.

35. Install 2 springs and 2 pins in the holes located in the bore of the valve housing, as shown in Fig. 77.

36. Apply a light film of petroleum jelly to the 3[76] diameter seal. Install seal in the valve housing.

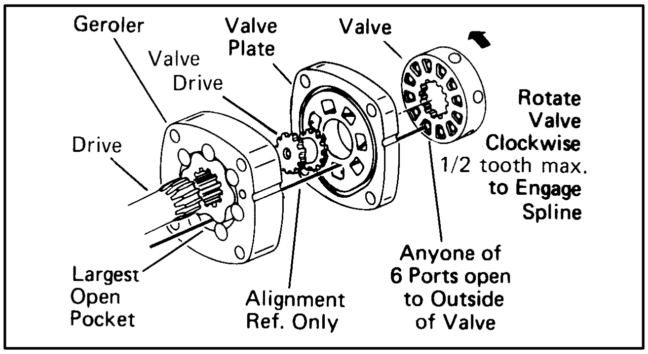


Figure 78

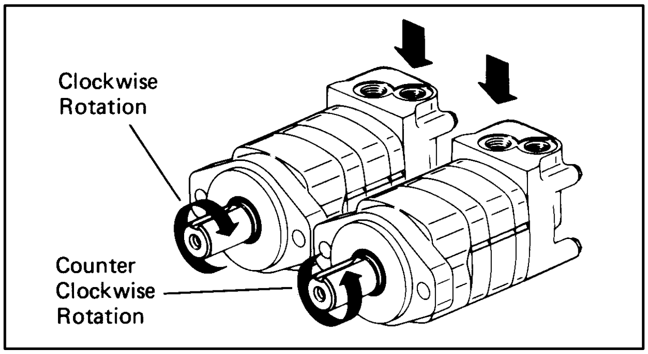


Figure 79

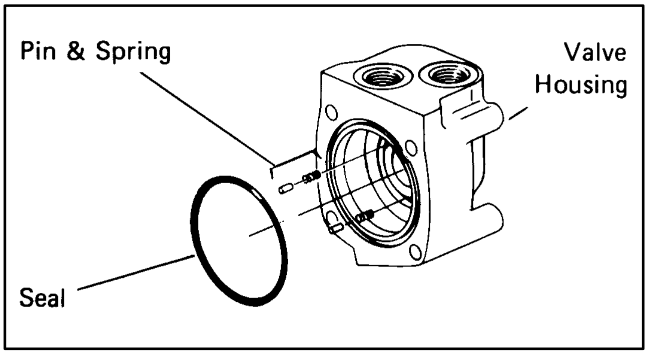


Figure 80

37. Apply petroleum jelly to inner and outer face seals. Install seals on balance ring as shown in Fig. 81.

IMPORTANT: Install face seals in the positions shown in Fig. 81. or the motor will not operate properly. Do not force or bend the face seals. Any damage to these seals will affect the operation of the motor.

38. Align pin notches in balance ring with pins in bore of valve housing. Install balance ring assembly in valve housing.

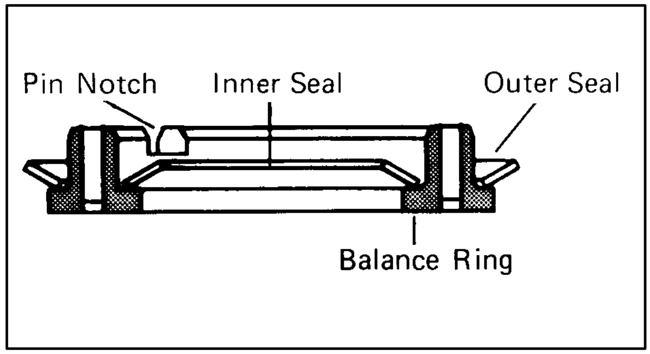


Figure 81

39. Insert your finger through port of valve housing. Apply pressure to side of balance ring as shown in Fig. 82. Hold ring in position until valve housing is in place against valve plate. See Fig. 83.

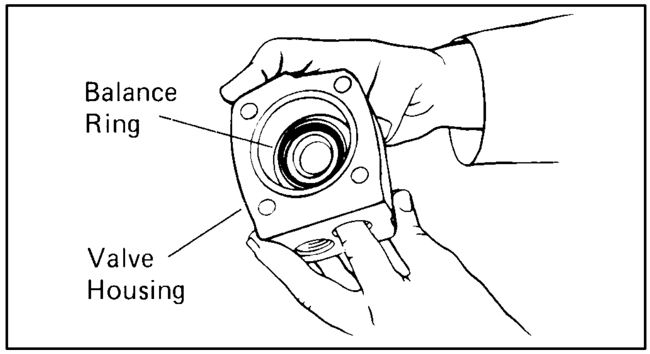


Figure 82

NOTE: After installing the valve housing on the valve plate check for proper placement. Push down on the valve housing. You should get a slight spring action.

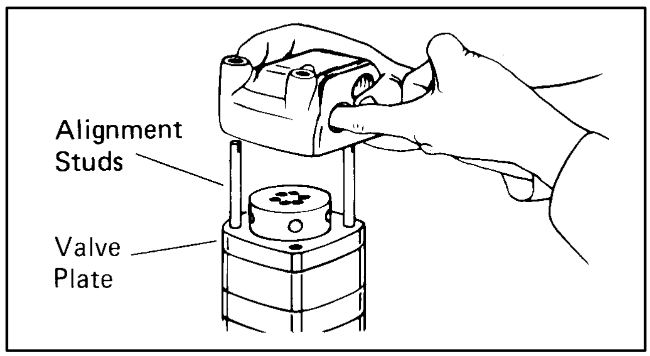


Figure 83

40. Install the tie bolts. If you use alignment studs, install 2 bolts opposite the studs. Finger tighten the bolts. Remove the alignment studs and replace with the 2 remaining bolts. Torque all 4 bolts alternately to 450 lb–in[50Nm].

41. Install seal on case drain plug then install in valve housing. Torque to 50 lb–in[6Nm].

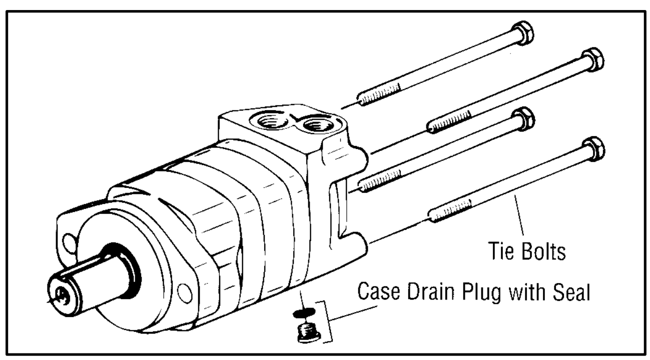


Figure 84

Wheel Motor

On wheel motors, a different bearing housing is used, see Fig. 85. Other than this the parts are the same as the standard motor and the same disassembly and reassembly procedures apply.

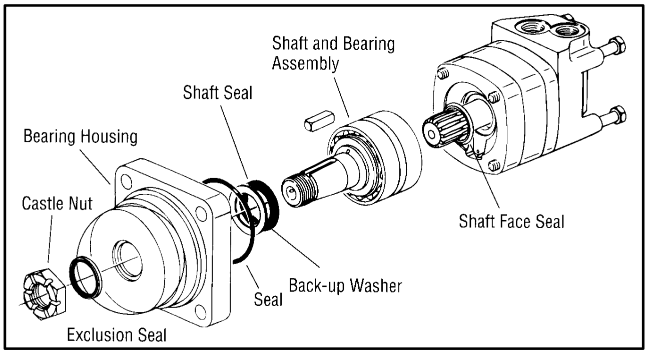


Figure 85

Hydraulic System

Steering Cylinder

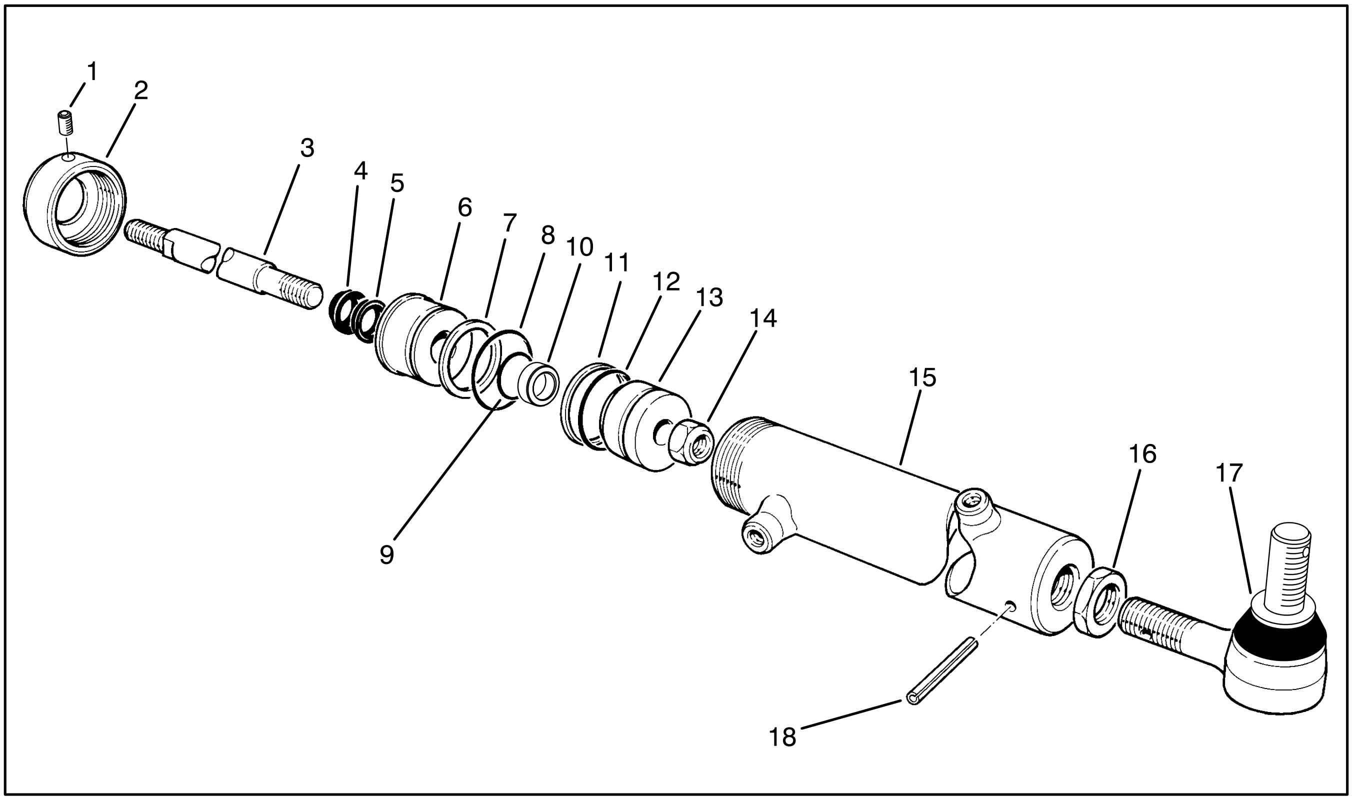


Figure 86

1. Set Screw
2. Threaded Cap
3. Rod
4. Rod Wiper
5. U–Cup
6. Cap Head
7. Backup Washer
8. O–Ring
9. O–Ring
10. Spacer
11. Servon
12. O–Ring
13. Piston
14. Locknut
15. Barrel Assembly
16. Jam Nut
17. Rod Tie, End
18. Roll Pin

Steering Cylinder Repair

IMPORTANT: To prevent damage when clamping cylinder barrel or rod in a vise, clamp only on pivotal ends.

1. After removing cylinder, pump oil out of cylinder in to a drain pan by SLOWLY moving rod and piston in and out of cylinder bore.

2. Plug ports and clean outside of cylinder.

3. Mount cylinder in a vise so piston rod end of cylinder is tilted up slightly. Do not close vise so firmly that cylinder tube could become distorted.

4. Loosen set screw and remove threaded cap.

5. Grasp clevis end of piston rod and use a twisting and pulling motion to carefully extract piston, piston rod, and head from cylinder barrel.

6. Securely mount piston, piston rod, and head into vise and remove nut.

IMPORTANT: Do not clamp vise jaws against smooth piston rod surface; the piston rod will become damaged.

7. Remove piston. Slide head off of piston rod.

8. Remove all seals and O–rings.

9. Wash part in a safe solvent. Dry parts with compressed air. DO NOT wipe them dry with a cloth or paper as lint and dirt may remain.

10. Carefully inspect internal surface of barrel for damage (deep scratches, out–of–round, etc.). Replace entire cylinder if barrel is damaged. Inspect head, piston rod, and piston for evidence of excessive scoring, pitting, or wear. Replace any damaged parts.

11. Use a complete repair kit when rebuilding the cylinder. Put a coating of oil on all new seals, and O–rings. Install the new seal and O–rings.

12. Install head onto piston rod.

13. Install piston onto piston rod with O–ring seal (9) and tighten hex nut.

14. Put a coating of oil on all cylinder parts to ease assembly.

15. Slide piston rod assembly into cylinder tube.

16. Install head into tube. Install threaded cap and tighten set screw.

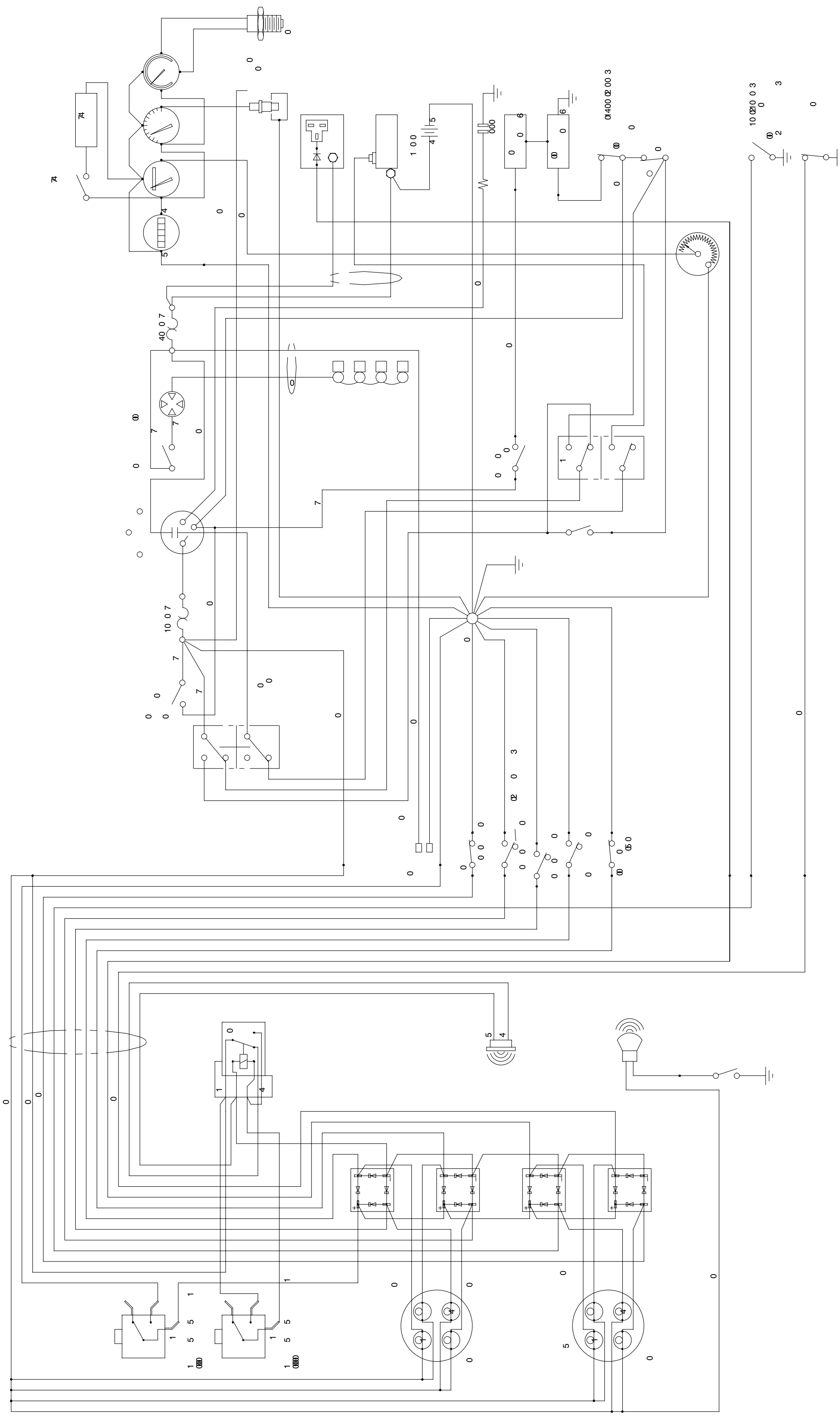
Chapter 5

Electrical System

Table of Contents

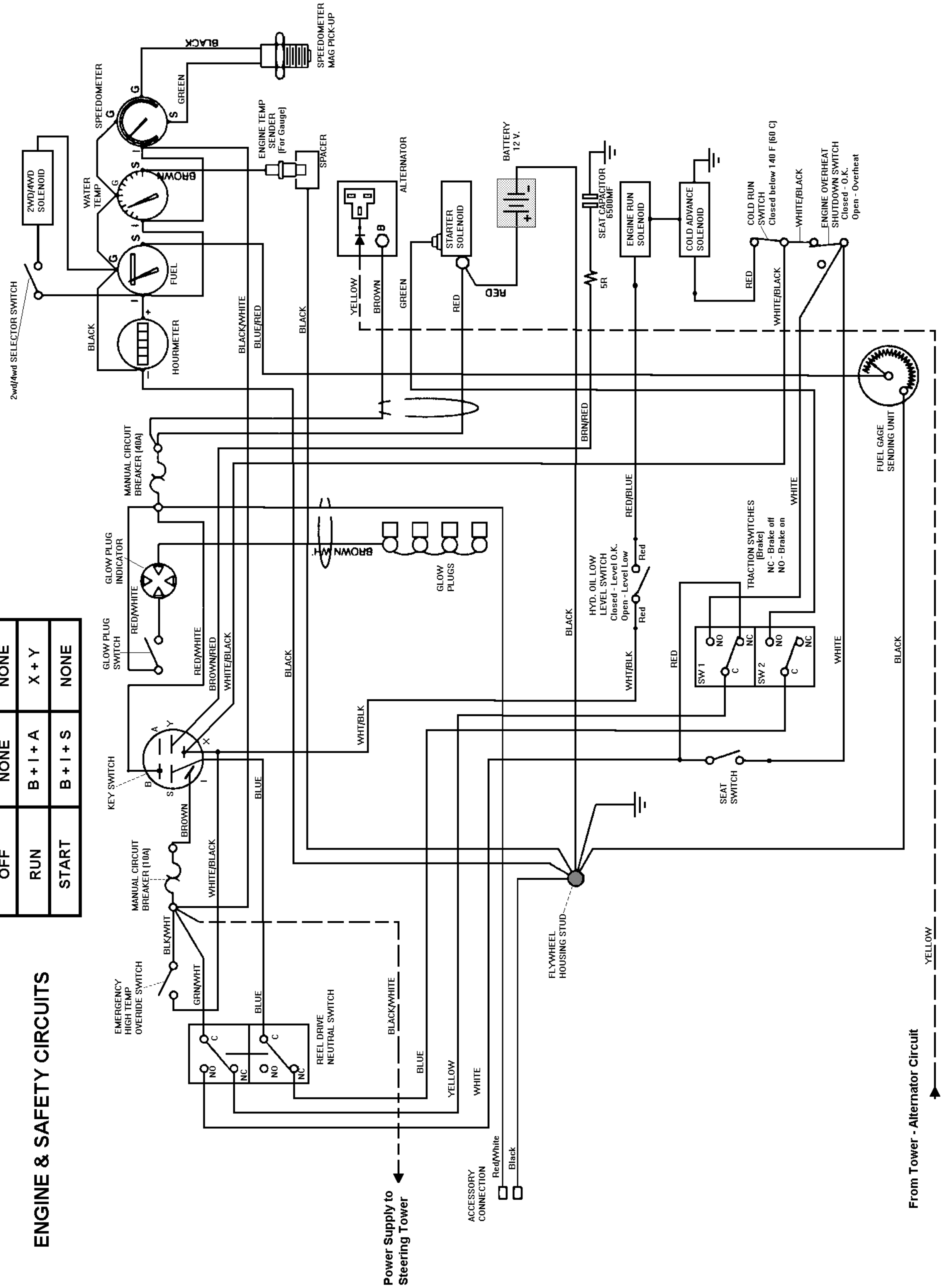
Electrical System

Wiring Schematics

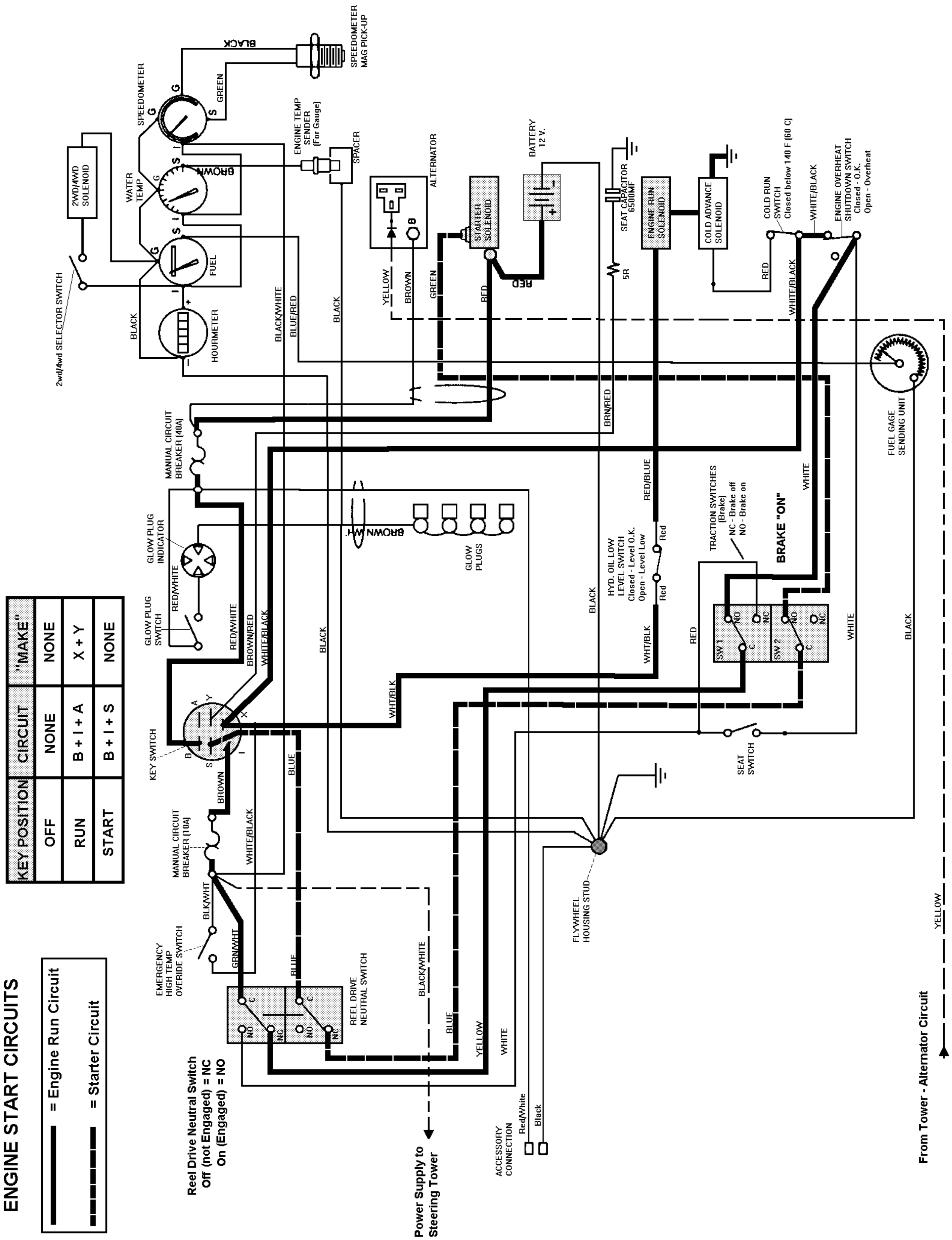


ENGINE & SAFETY CIRCUITS

KEY POSITION	CIRCUIT	"MAKE"
OFF	NONE	NONE
RUN	B + I + A	X + Y
START	B + I + S	NONE



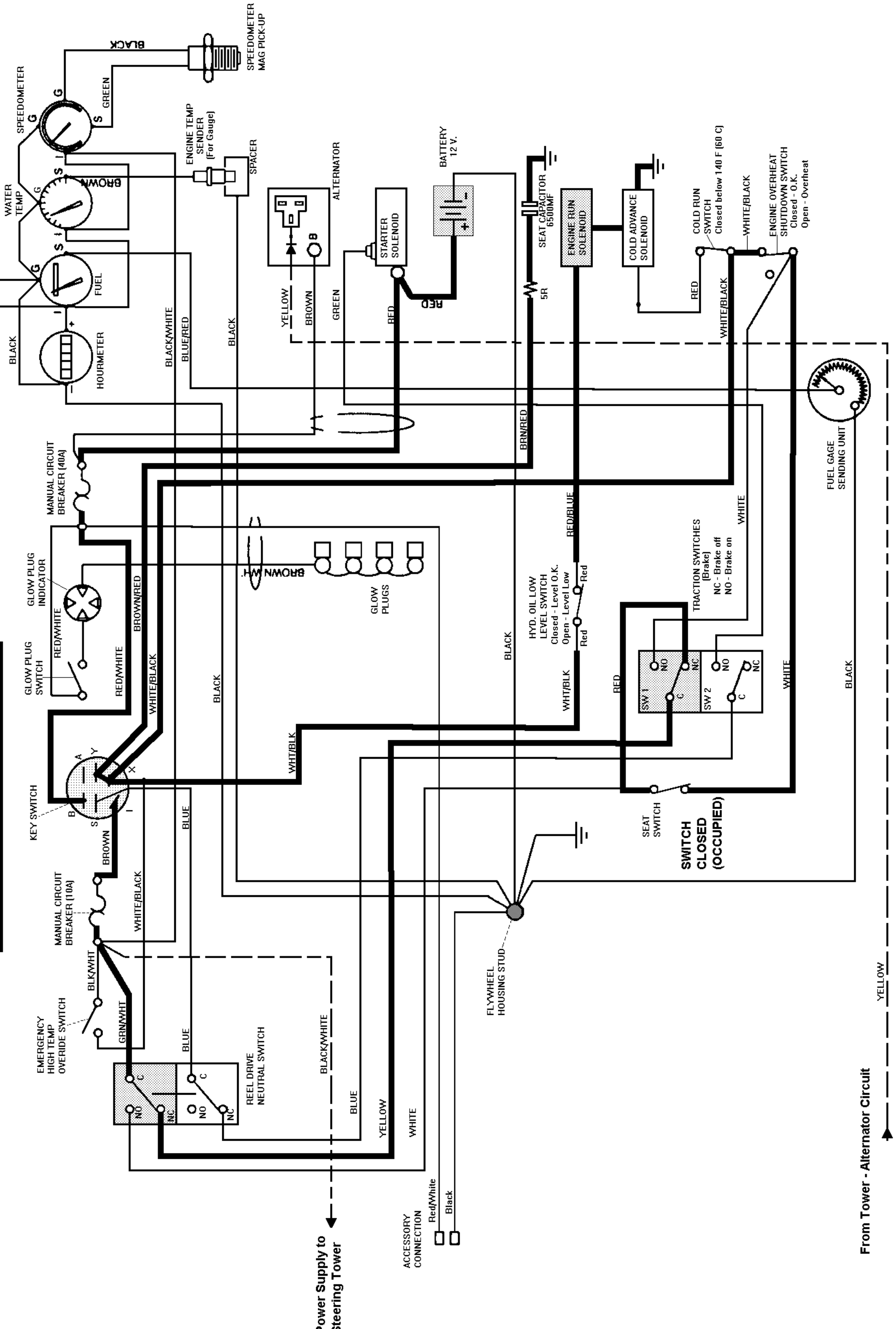
Electrical System



KEY POSITION	CIRCUIT	"MAKE"
OFF	NONE	NONE
RUN	B + I + A	X + Y
START	B + I + S	NONE

ENGINE RUN CIRCUITS TRANSPORT - NO MOW

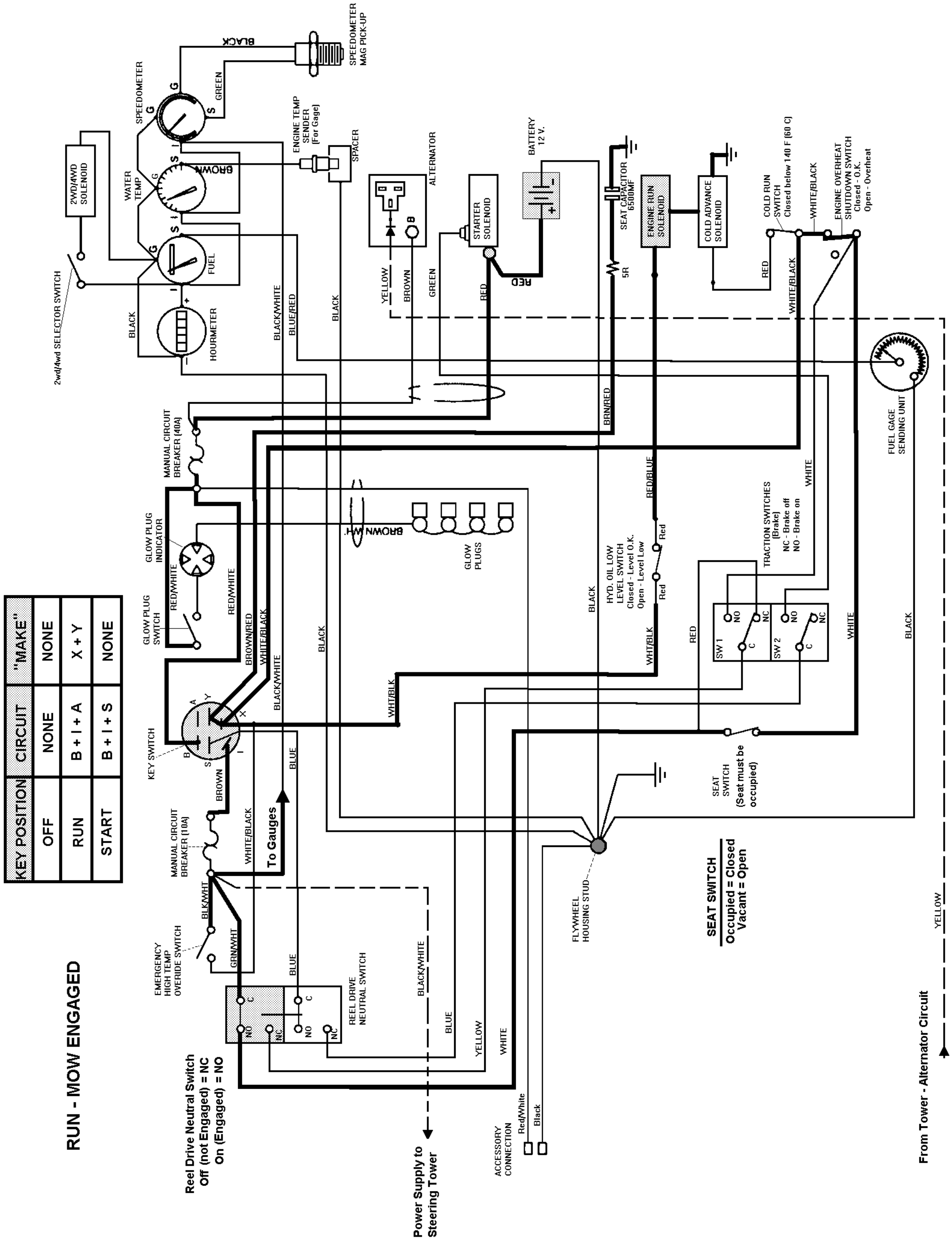
KEY POSITION	CIRCUIT	"MAKE"
OFF	NONE	NONE
RUN	B + I + A	X + Y
START	B + I + S	NONE



Electrical System

RUN - MOW ENGAGED

KEY POSITION	CIRCUIT	"MAKE"
OFF	NONE	NONE
RUN	B + I + A	X + Y
START	B + I + S	NONE

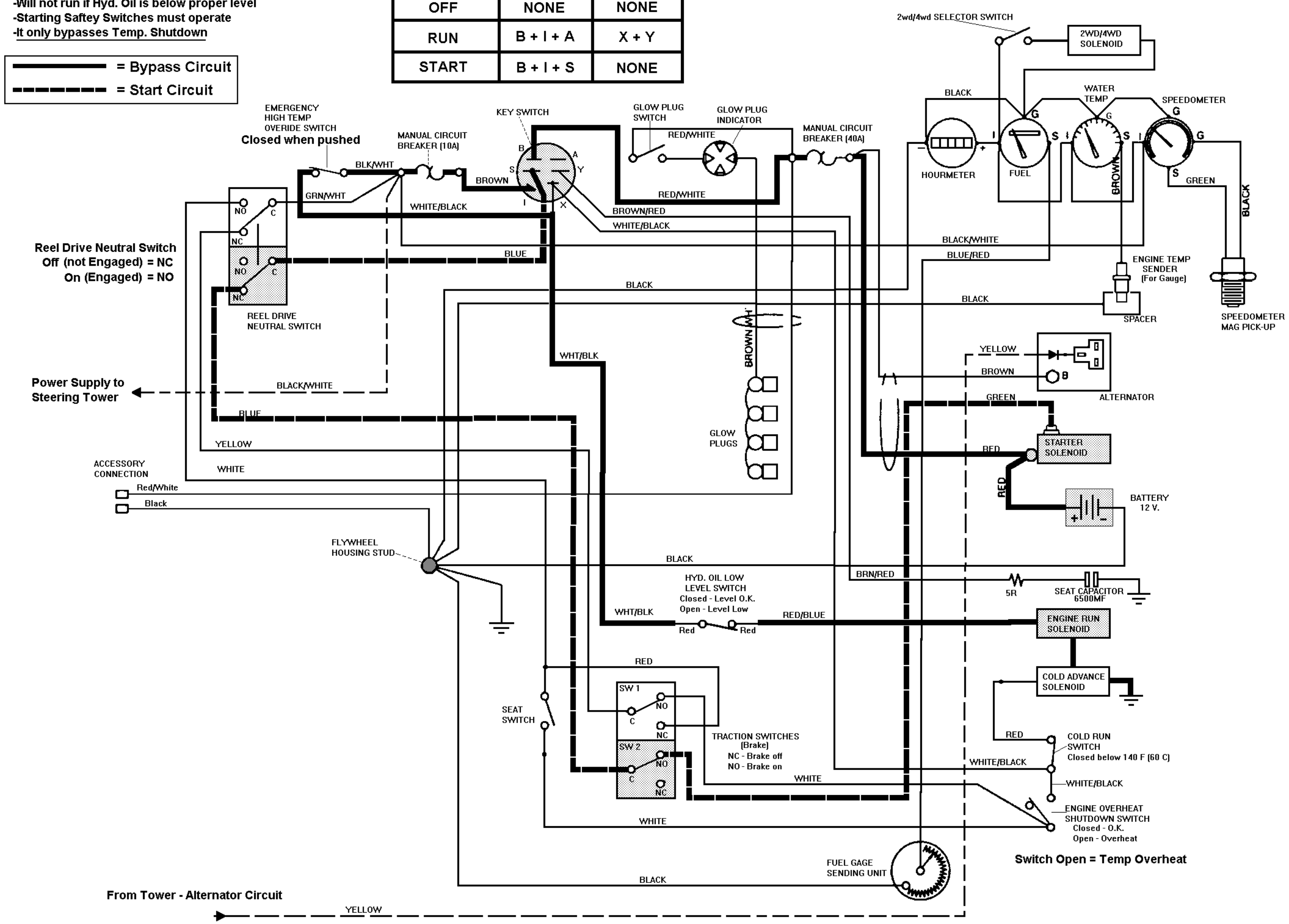


EMERGENCY OVERIDE OPERATION

NOTE:
- **Will not run if Hyd. Oil is below proper level**
- **Starting Saftey Switches must operate**
- **It only bypasses Temp. Shutdown**

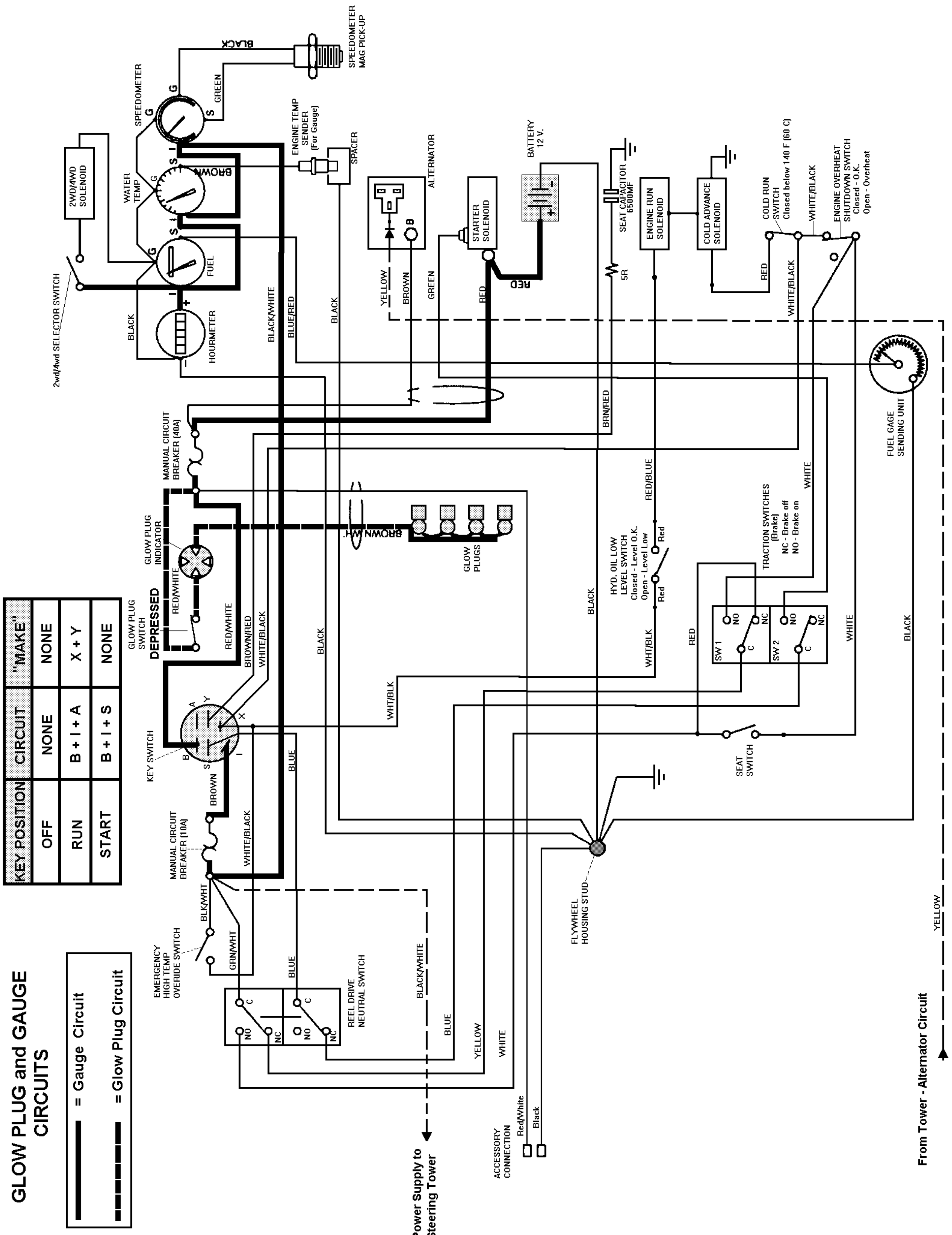
━━━━━ = Bypass Circuit
━ ━ ━ ━ = Start Circuit

KEY POSITION	CIRCUIT	"MAKE"
OFF	NONE	NONE
RUN	B + I + A	X + Y
START	B + I + S	NONE

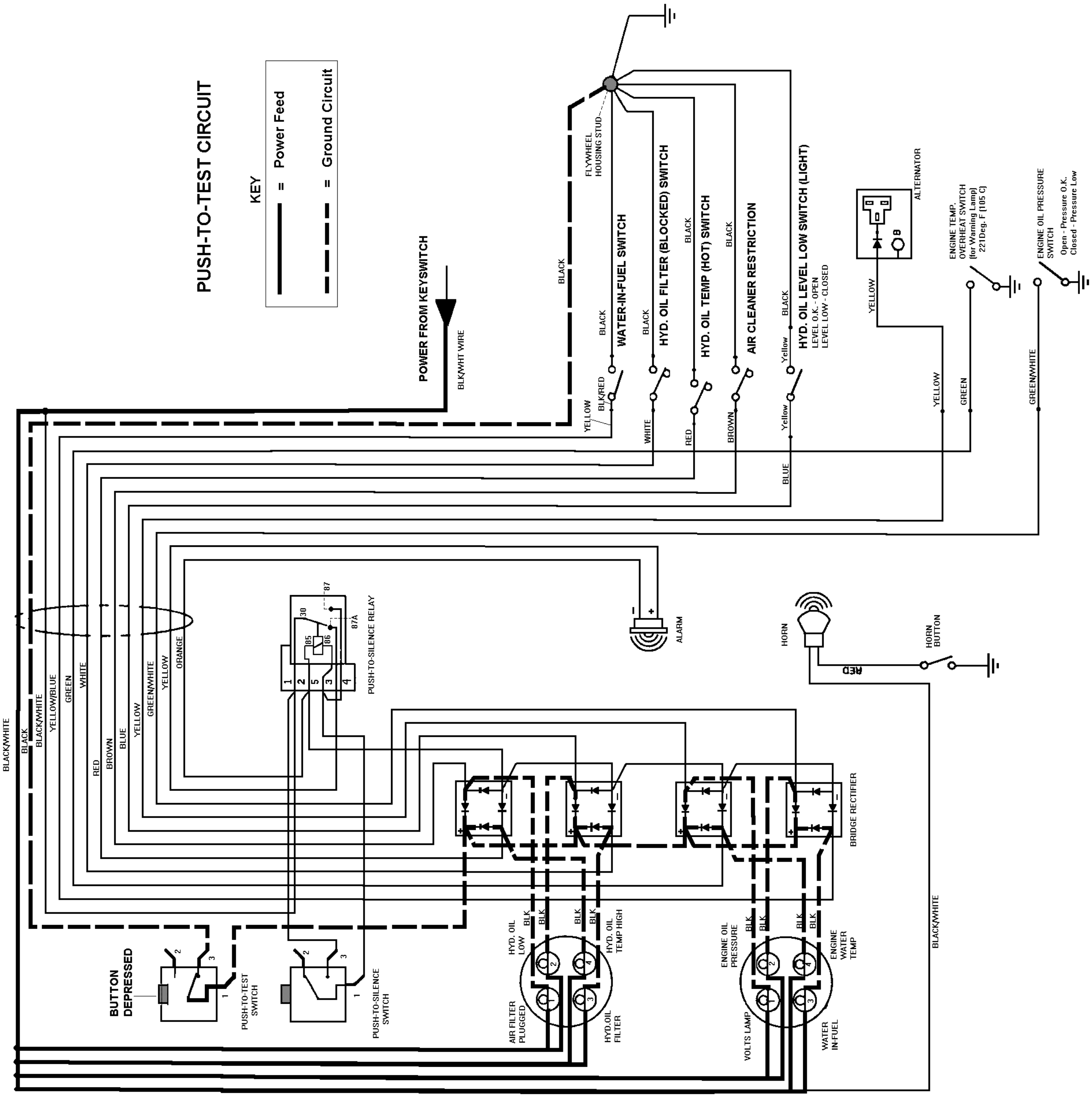


Electrical System

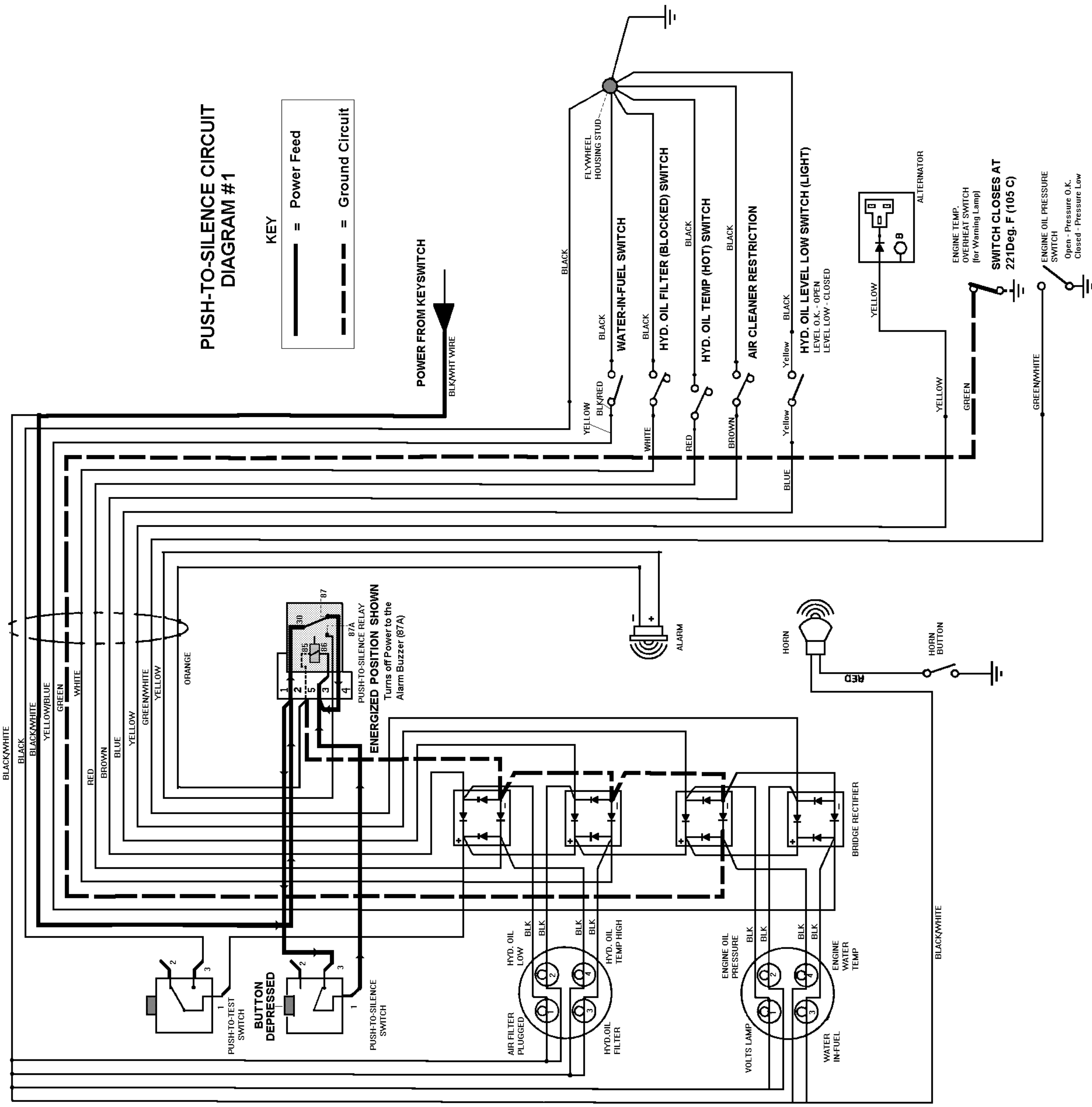
GLOW PLUG and GAUGE CIRCUITS

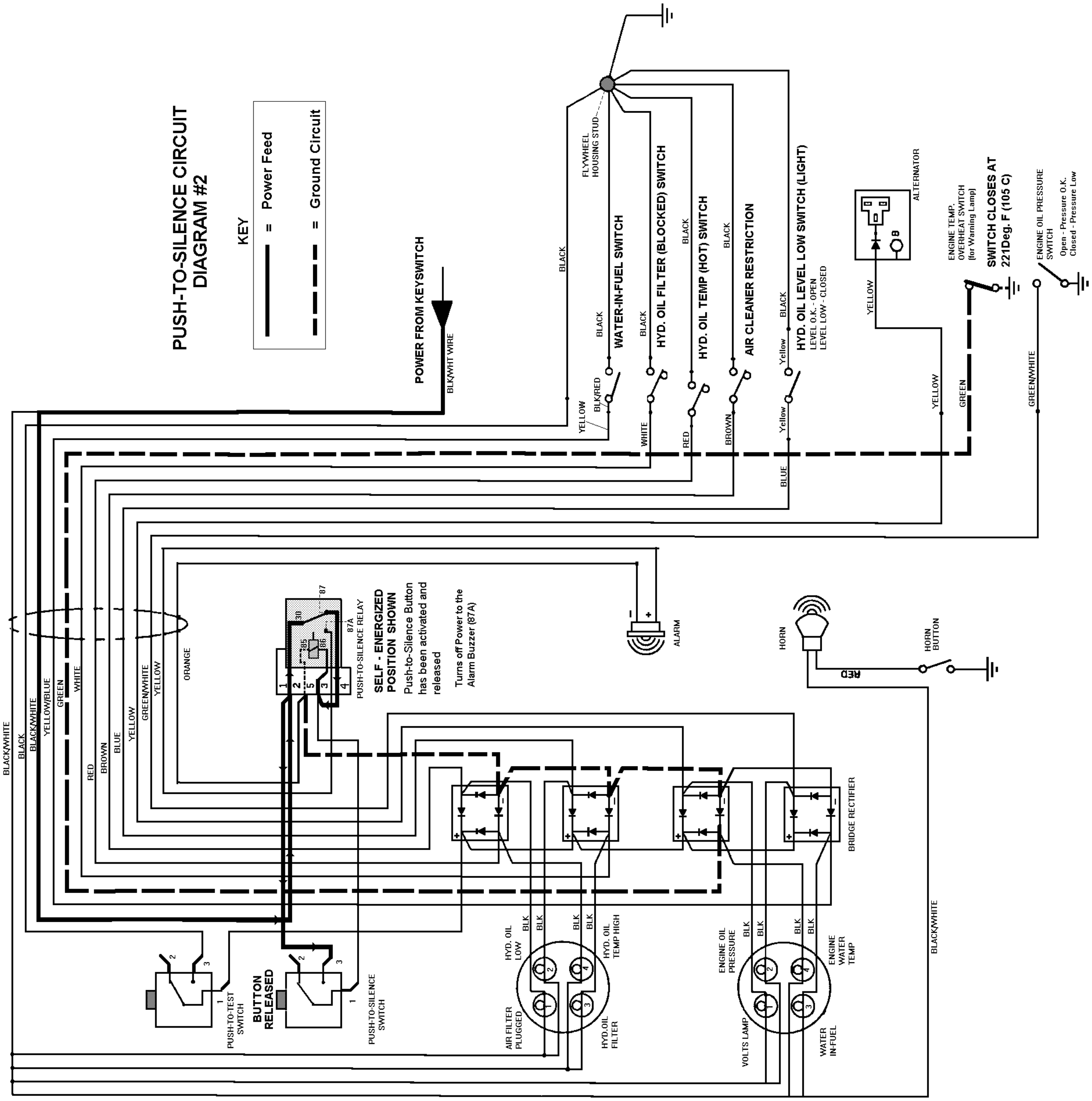


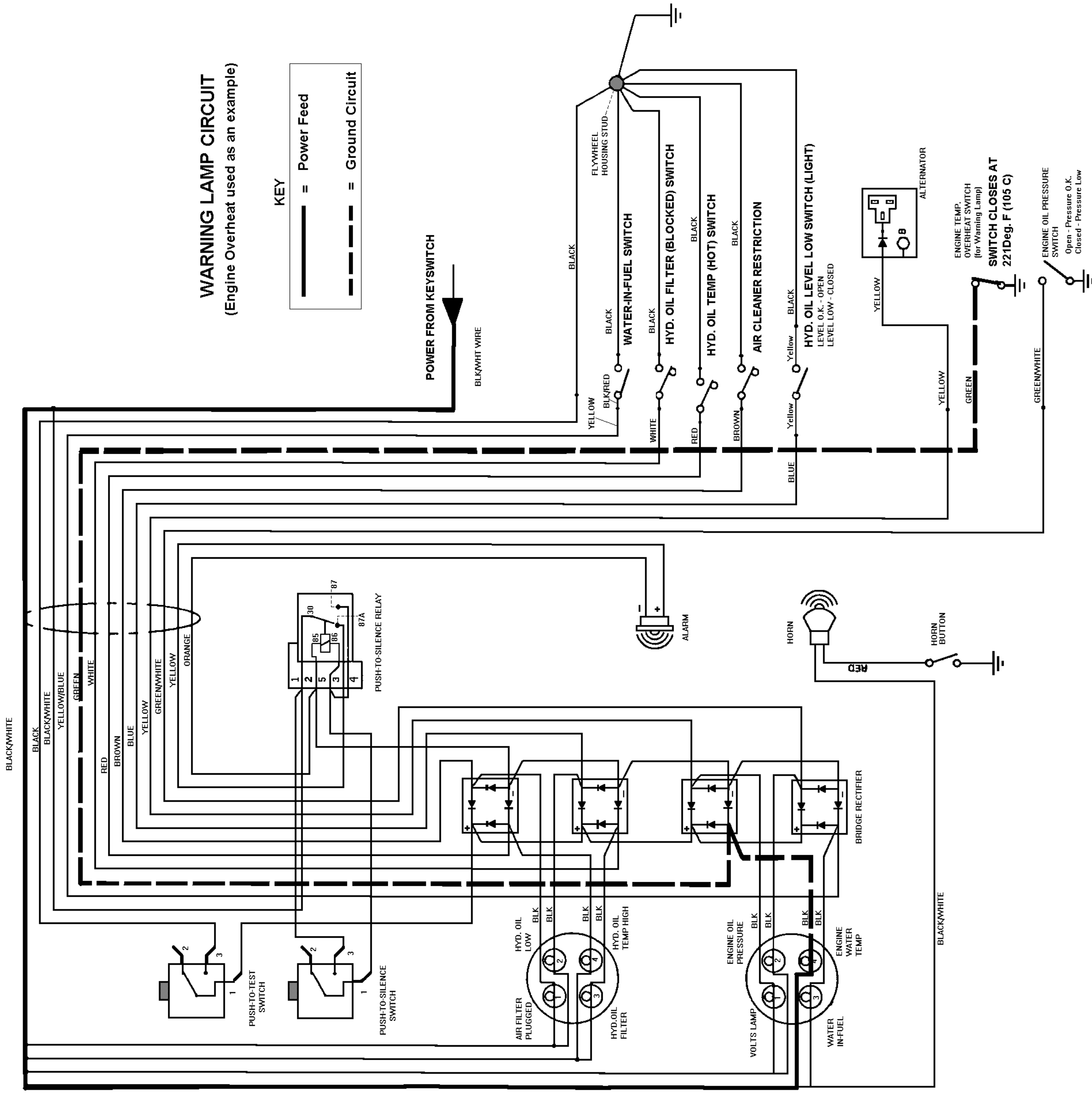
KEY POSITION	CIRCUIT	"MAKE"
OFF	NONE	NONE
RUN	B + I + A	X + Y
START	B + I + S	NONE



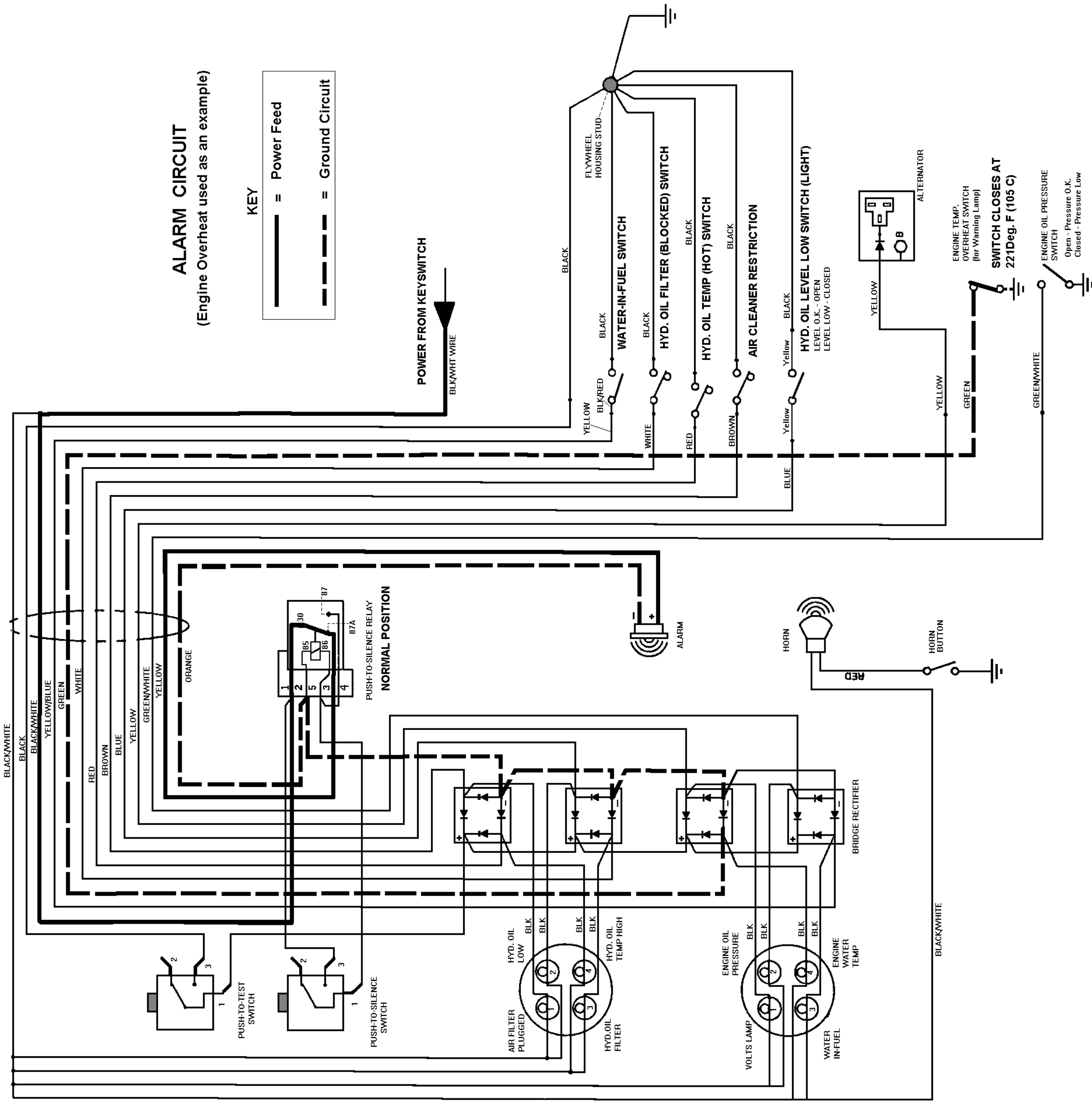
Electrical System


PUSH-TO-SILENCE CIRCUIT DIAGRAM #1
KEY
= Power Feed
= Ground Circuit
POWER FROM KEYSWITCH
BLK/WHT WIRE
FLYWHEEL HOUSING STUD
WATER-IN-FUEL SWITCH
HYD. OIL FILTER (BLOCKED) SWITCH
HYD. OIL TEMP (HOT) SWITCH
AIR CLEANER RESTRICTION
HYD. OIL LEVEL LOW SWITCH (LIGHT)
LEVEL O.K. - OPEN
LEVEL LOW - CLOSED
ALTERNATOR
ENGINE TEMP. OVERHEAT SWITCH (for Warning Lamp)
SWITCH CLOSES AT 221Deg. F (105 C)
ENGINE OIL PRESSURE SWITCH
Open - Pressure O.K.
Closed - Pressure Low
ALARM
HORN
HORN BUTTON
RED
PUSH-TO-SILENCE RELAY
ENERGIZED POSITION SHOWN
Turns off Power to the Alarm Buzzer (87A)
BRIDGE RECTIFIER
PUSH-TO-TEST SWITCH
BUTTON DEPRESSED
PUSH-TO-SILENCE SWITCH
AIR FILTER PLUGGED
HYD. OIL LOW
HYD. OIL TEMP HIGH
HYD.OIL FILTER
ENGINE OIL PRESSURE
VOLTS LAMP
ENGINE WATER TEMP
WATER IN-FUEL
BLACK/WHITE
BLACK
YELLOW/BLUE
GREEN
WHITE
RED
BROWN
BLUE
YELLOW
GREEN/WHITE
ORANGE


PUSH-TO-SILENCE CIRCUIT DIAGRAM #2
KEY
= Power Feed
= Ground Circuit
POWER FROM KEYSWITCH
BLK/WHT WIRE
FLYWHEEL HOUSING STUD
WATER-IN-FUEL SWITCH
HYD. OIL FILTER (BLOCKED) SWITCH
HYD. OIL TEMP (HOT) SWITCH
AIR CLEANER RESTRICTION
HYD. OIL LEVEL LOW SWITCH (LIGHT)
LEVEL O.K. - OPEN
LEVEL LOW - CLOSED
ALTERNATOR
ENGINE TEMP. OVERHEAT SWITCH (for Warning Lamp)
SWITCH CLOSES AT 221Deg. F (105 C)
ENGINE OIL PRESSURE SWITCH
Open - Pressure O.K.
Closed - Pressure Low
PUSH-TO-SILENCE RELAY
SELF - ENERGIZED POSITION SHOWN
Push-to-Silence Button has been activated and released
Turns off Power to the Alarm Buzzer (87A)
ALARM
HORN
HORN BUTTON
BRIDGE RECTIFIER
PUSH-TO-TEST SWITCH
BUTTON RELEASED
PUSH-TO-SILENCE SWITCH
AIR FILTER PLUGGED
HYD. OIL LOW
HYD. OIL TEMP HIGH
HYD.OIL FILTER
VOLTS LAMP
ENGINE OIL PRESSURE
ENGINE WATER TEMP
WATER IN-FUEL



WARNING LAMP CIRCUIT
(Engine Overheat used as an example)
KEY
= Power Feed
= Ground Circuit
POWER FROM KEYSWITCH
BLK/WHT WIRE
FLYWHEEL HOUSING STUD
WATER-IN-FUEL SWITCH
HYD. OIL FILTER (BLOCKED) SWITCH
HYD. OIL TEMP (HOT) SWITCH
AIR CLEANER RESTRICTION
HYD. OIL LEVEL LOW SWITCH (LIGHT)
LEVEL O.K. - OPEN
LEVEL LOW - CLOSED
ALTERNATOR
ENGINE TEMP. OVERHEAT SWITCH (for Warning Lamp)
SWITCH CLOSES AT 221Deg. F (105 C)
ENGINE OIL PRESSURE SWITCH
Open - Pressure O.K.
Closed - Pressure Low
PUSH-TO-SILENCE RELAY
ALARM
HORN
HORN BUTTON
BRIDGE RECTIFIER
PUSH-TO-TEST SWITCH
PUSH-TO-SILENCE SWITCH
HYD. OIL LOW
HYD. OIL TEMP HIGH
AIR FILTER PLUGGED
HYD.OIL FILTER
ENGINE OIL PRESSURE
ENGINE WATER TEMP
VOLTS LAMP
WATER IN-FUEL


ALARM CIRCUIT
(Engine Overheat used as an example)
KEY
= Power Feed
= Ground Circuit
POWER FROM KEYSWITCH
BLK/WHT WIRE
FLYWHEEL HOUSING STUD
WATER-IN-FUEL SWITCH
HYD. OIL FILTER (BLOCKED) SWITCH
HYD. OIL TEMP (HOT) SWITCH
AIR CLEANER RESTRICTION
HYD. OIL LEVEL LOW SWITCH (LIGHT)
LEVEL O.K. - OPEN
LEVEL LOW - CLOSED
ALTERNATOR
ENGINE TEMP. OVERHEAT SWITCH (for Warning Lamp)
SWITCH CLOSES AT 221Deg. F (105 C)
ENGINE OIL PRESSURE SWITCH
Open - Pressure O.K.
Closed - Pressure Low
PUSH-TO-SILENCE RELAY
NORMAL POSITION
ALARM
HORN
HORN BUTTON
RED
BRIDGE RECTIFIER
PUSH-TO-TEST SWITCH
PUSH-TO-SILENCE SWITCH
AIR FILTER PLUGGED
HYD. OIL LOW
HYD. OIL TEMP HIGH
HYD.OIL FILTER
VOLTS LAMP
ENGINE OIL PRESSURE
ENGINE WATER TEMP
WATER IN-FUEL
BLACK/WHITE
BLACK
YELLOW/BLUE
GREEN
WHITE
RED
BROWN
BLUE
YELLOW
GREEN/WHITE
ORANGE
BLK/RED
BLK

Special Tools

Order special tools from the *TORO SPECIAL TOOLS AND APPLICATIONS GUIDE (COMMERCIAL PRODUCTS)*.

Some tools may also be available from a local supplier.

Continuity Tester

Battery powered test lamp which is helpful in testing for continuity of circuits and electrical components when the current is off.

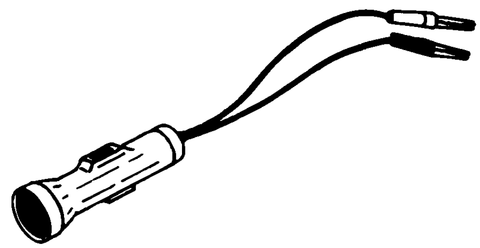


Figure 1

Multimeter

The meter can test electrical components and circuits for current, resistance, or voltage draw.

NOTE: Toro recommends the use of a DIGITAL Volt–Ohm–Amp mutli–meter when testing electrical circuits. The high impedance (internal resistance) of a digital meter will ensure that excess current is not allowed through the meter. Excess current can cause damage to a circuit that is not designed to carry it.

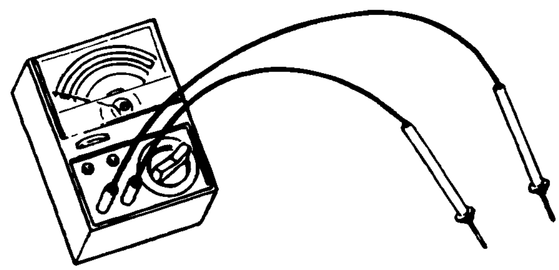


Figure 2

Skin–Over Grease

Special non–conductive grease which forms a light protective skin to help waterproof electrical switches and contacts.

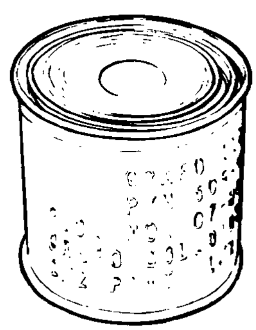


Figure 3

Troubleshooting

> **CAUTION**
>
> **Remove all jewelry, especially rings and watches, before doing any electrical troubleshooting or testing. Disconnect the battery cables unless the test requires battery voltage.**

For effective troubleshooting and repairs, you must have a good understanding of the electrical circuits and components used on this machine (see Wiring Schematics section of this chapter).

If the machine has any interlock switches by–passed, they must be reconnected for proper troubleshooting and safety.

Starting Problems

Problem	Possible Causes
Starter solenoid clicks, but starter will not crank (if solenoid clicks, problem is not in safety interlock system).	Low battery charge. Loose or corroded battery cables. Loose or corroded ground. Faulty wiring at starter. Faulty starter solenoid.
Nothing happens when start attempt is made.	Battery is dead. Loose or corroded battery cables. Loose or corroded ground. Parking brake is off. Mow – backlap lever is engaged. Circuit breaker open. Traction (brake) switch (SW2) out of adjustment or faulty. Traction (brake) switch (SW2) wiring loose, corroded or damaged. Reel drive neutral switch faulty. Reel drive neutral switch wiring loose, corroded or damaged. Key switch faulty. Key switch wiring loose, corroded or damaged. Starter solenoid wiring loose, corroded or damaged. Starter solenoid faulty.

Starting Problems (continued)

Problem	Possible Causes
Engine cranks, but does not start.	Engine run solenoid wiring loose or corroded. Engine run solenoid faulty. Low hydraulic oil level. Hydraulic oil low level switch is faulty. Hydraulic oil low level switch wiring loose, corroded or damaged. Engine is overheated. Engine overheat shutdown switch faulty. Engine overheat shutdown switch wiring loose, corroded or damaged. Traction (brake) switch (SW1) out of adjustment or faulty. Traction (brake) switch (SW1) wiring loose, corroded or damaged. Engine or fuel system problem.
Engine cranks (but should not) with parking brake off.	Traction (brake) switch (SW2) is faulty. Short circuit in Traction (brake) switch circuit.
Engine cranks (but should not) with mow–backlap lever in mow or backlap.	Reel drive neutral switch faulty. Short circuit in Reel drive neutral switch circuit.

General Run and Transport Problems

Problem	Possible Causes
Engine continues to run (but should not) when parking brake is released or mow–backlap lever is now or backlap with no operator on seat.	Seat switch plunger depressed with no operator on seat. Seat switch faulty or out of adjustment. Short circuit or by–pass in seat switch circuit.
Engine kills when parking brake is released or mow–backlap lever is moved to mow or backlap.	Operator sitting too far forward on seat (seat switch not depressed). Seat hinge, support pin or spring binding, preventing seat switch from closing. Seat switch is faulty or out of adjustment. Seat switch wiring loose, corroded or damaged.
Engine kills during operation (operator sitting on seat).	Operator moved too far forward on seat (seat switch not depressed). Low hydraulic oil level. Engine overheated. Wire broke or became disconnected.
4WD does not engage.	4WD selector switch faulty. 4WD selector switch wiring loose, corroded or damaged. 4WD solenoid valve faulty. 4WD solenoid wiring loose, corroded or damaged. Problem is not electrical.
Battery does not charge.	Loose or broken wire(s). Faulty alternator. Dead battery. Alternator warning lamp is faulty or burned out. Alternator warning lamp wiring loose, corroded or damaged.

Verify Interlock System Operation

CAUTION

THE INTERLOCK SWITCHES ARE FOR THE OPERATOR'S PROTECTION, SO DO NOT DISCONNECT THEM. CHECK OPERATION OF THE SWITCHES DAILY TO ASSURE INTERLOCK SYSTEM IS OPERATING. IF A SWITCH IS DEFECTIVE, REPLACE IT BEFORE OPERATING. REGARDLESS IF SWITCHES ARE OPERATING PROPERLY OR NOT, REPLACE THEM EVERY TWO YEARS TO ASSURE MAXIMUM SAFETY.

1. In a wide open area free of debris and bystanders, lower cutting units to the ground. Stop engine.

2. Sit on the seat and engage parking brake (Fig. 4). Turn key and try to start engine with Mow–Backlap lever (Fig. 4) in both the MOW and BACKLAP positions. If engine cranks, there is a malfunction that must be repaired immediately. If engine does not crank, the cutter drive switch is operating properly.

3. Sit on the seat and disengage the parking brake (Fig. 4). Turn key and try to start engine with Mow–Backlap lever (Fig. 4) in the STOP position. If engine cranks, there is a malfunction that must be repaired immediately. If engine does not crank, brake switch is operating properly.

4. Engage parking brake (Fig. 4), start engine and lower cutting units. Move Mow–Backlap lever (Fig. 4) to MOW. Raise off the seat; engine should stop within a few seconds, which indicates the interlock system is operating. Also raise off the seat with lever in the BACKLAP position. Engine should stop, indicating interlock system is operating. If engine does not stop, there is a malfunction that must be repaired immediately.

NOTE: There is a 1 – 2 second delay between rising off seat and engine shut off.

5. Engage parking brake, move Mow–Backlap lever to NEUTRAL, start engine, disengage hand brake and raise off seat. If engine stops, interlock system is operating. If engine does not stop, there is a malfunction that must be repaired immediately.

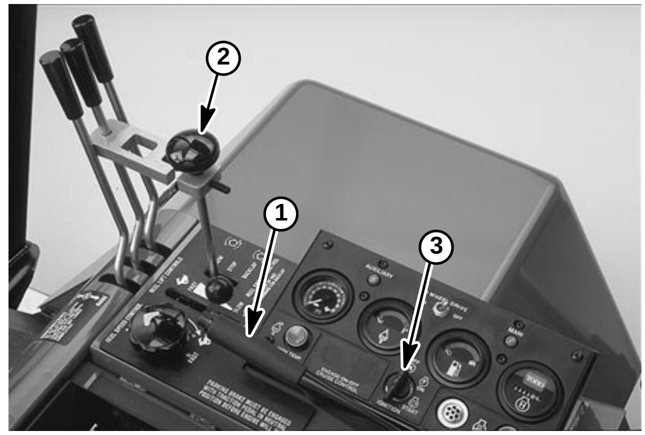


Figure 4

1. Parking Brake
2. Mow / Backlap Lever
3. Key

Electrical System Quick Checks

Battery Test

Use a volt–ohm multi–meter to measure the voltage between the battery terminals.

Set the multi–meter to the DC Volts setting. The battery should be at a temperature of 60° to 100° F. The ignition key should be off and all accessories turned off. Connect the positive (+) Volt meter lead to the positive battery post and the negative (–) Voltmeter lead the the negative battery post.

NOTE: This test provides a relative condition of the battery. Load testing of the battery will provide additional and more accurate information.

Voltage Measured	Battery Charge
12.6 V (or higher)	Fully charged (100%)
12.4 V	75% charged
12.2 V	50% charged
12.0 V	25% charged

NOTE: Regulated voltage will increase to approximately 13.5 Volts when the engine is running.

Charging System Test

This is a simple test used to determine if a Charging system is functioning. It will tell you if the charging system has an output, but not how much (amps) or what it is capable of.

Tool required: Digital Multimeter – DC volts setting.

Test instructions: Connect the positive (+) DVOM test Lead on the positive Battery Post, and negative (–) Lead on the negative Battery Post. Leave test leads connected and start engine and run at 2000 RPM minimum. Test results should be:

At least 1 volt over Open Circuit test results.	
Example: Open Circuit Test results	= 12.5v
Charging System Test results	= 13.5v
Difference	= +1.0 v

Voltage Drop Testing

This is a simple test that should be used to locate excess resistance in an electrical circuit.

Tool required: Digital Multimeter – DC volts setting.

Test instructions: Connect the positive (+) DVOM test lead to the power side (or most positive) of the component, circuit or connection. Connect the negative (–) DVOM test lead to the ground side (or least positive) of the component, circuit or connection. Turn on the circuit to be tested and read the voltage. Remember – when performing voltage drop tests the circuit must be complete and activated to locate the resistance!

Voltage Drop Specifications (Maximums)

High Amperage Circuits (> 20 A.)	Low Amperage Circuits (< 20 A.)
.4 volt feed side	.2 volt feed side
.4 volt ground side	.2 volt ground side

Electrical System

Glow Plug System Test

This is a fast, simple test that can help you determine a Glow Plug system's integrity and operation. The test should be run anytime hard starting (cold) is encountered on a diesel engine equipped with a Glow system. Remember – there are 2 types of Glow Plug systems that Toro uses:

1. Systems with resistors (Glow Plug Indicators) in series (**Reelmaster 450/4500–D**, Groundsmaster 325–D, etc.)

2. Systems without resistors (Reelmaster 335–D, Groundsmaster 455–D, Reelmaster 5100/5300–D, etc.)

Tool(s) required: Digital Multimeter (DVOM) and/or inductive Ammeter.

Test instructions: Properly connect inductive Ammeter to the DVOM (refer to manufacturer's instructions). Set DVOM on Volts scale. With the key off (or Glow Switch in off position), place the inductive Ammeter around the main glow plug power supply wire(s) and read meter prior to activating Glow system. Adjust Meter to read zero (if applicable). Cycle the Glow Plug system at least two times (per instructions in Operator's Manual) and record the final results.

The Reelmaster 4500–D glow plug system should have a reading of **25 – 30 Amps**.

Starting System Test

This is an excellent test to use when a "slow crank/no start" problem is encountered. It will tell you if the problem is due to an electrical open, short or high resistance in the starter circuit.

NOTE: The Battery condition and state of charge must checked before testing the starter system.

Tool(s) required: Digital Multimeter and/or inductive Ammeter.

Test instructions: Properly connect inductive Ammeter to the DVOM (refer to manufacturers instructions). Set DVOM on Volts scale. With the key off place the inductive Ammeter around the main negative (–) Battery Cable and read meter prior to activating the Starter system. Adjust Meter to read zero (if applicable). Crank the engine for at least 3 seconds and record the results. Typical Starter System Draw for the RM 4500–D is **300 Amps at 65°F**.

If current draw is significantly higher than listed – check for shorted condition. If current draw is significantly lower than listed – check for high resistance.

Component Testing

For accurate resistance and/or continuity checks, electrically disconnect the component being tested from the circuit (e.g. unplug the ignition switch connector before doing a continuity check).

NOTE: Electrical troubleshooting of any 12 Volt power connection can also be performed through voltage drop tests without disconnection of the component.

CAUTION

When testing electrical components for continuity with a volt–ohm meter or continuity tester, make sure that power to the circuit has been disconnected.

Ignition Key Switch

The ignition (key) switch has three positions (OFF, START and RUN). The terminals are marked as shown.The circuitry of the ignition switch is shown in the chart. With the use of a continuity tester, the switch functions may be tested to determine whether all circuits are being completed while the key is moved to each position.

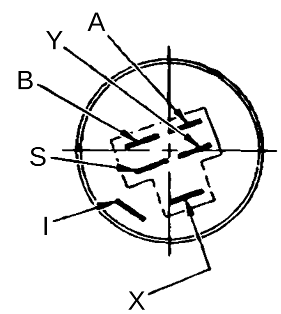


Figure 5

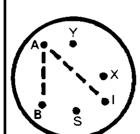
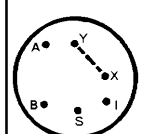
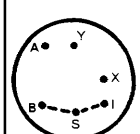
1		
2		
3		

Figure 6

Bosch Relay

To test the relay, disconnect the relay wire connector and install a continuity tester between the relay terminals (terminals 30 and 87). The relay should make and break continuity at terminals 30 and 87 as 12 V.D.C. is connected and disconnected to terminal 85 with terminal 86 connected to ground.

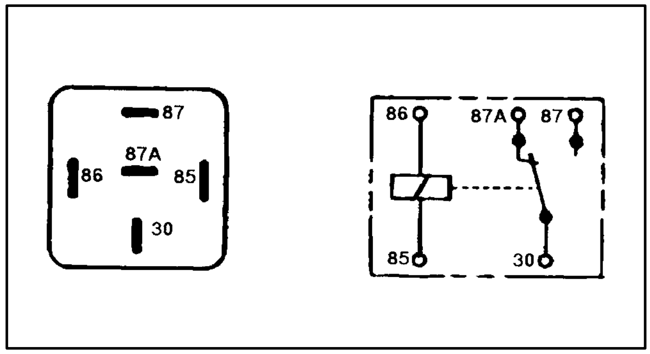


Figure 7

Rear Wheel Drive Solenoid

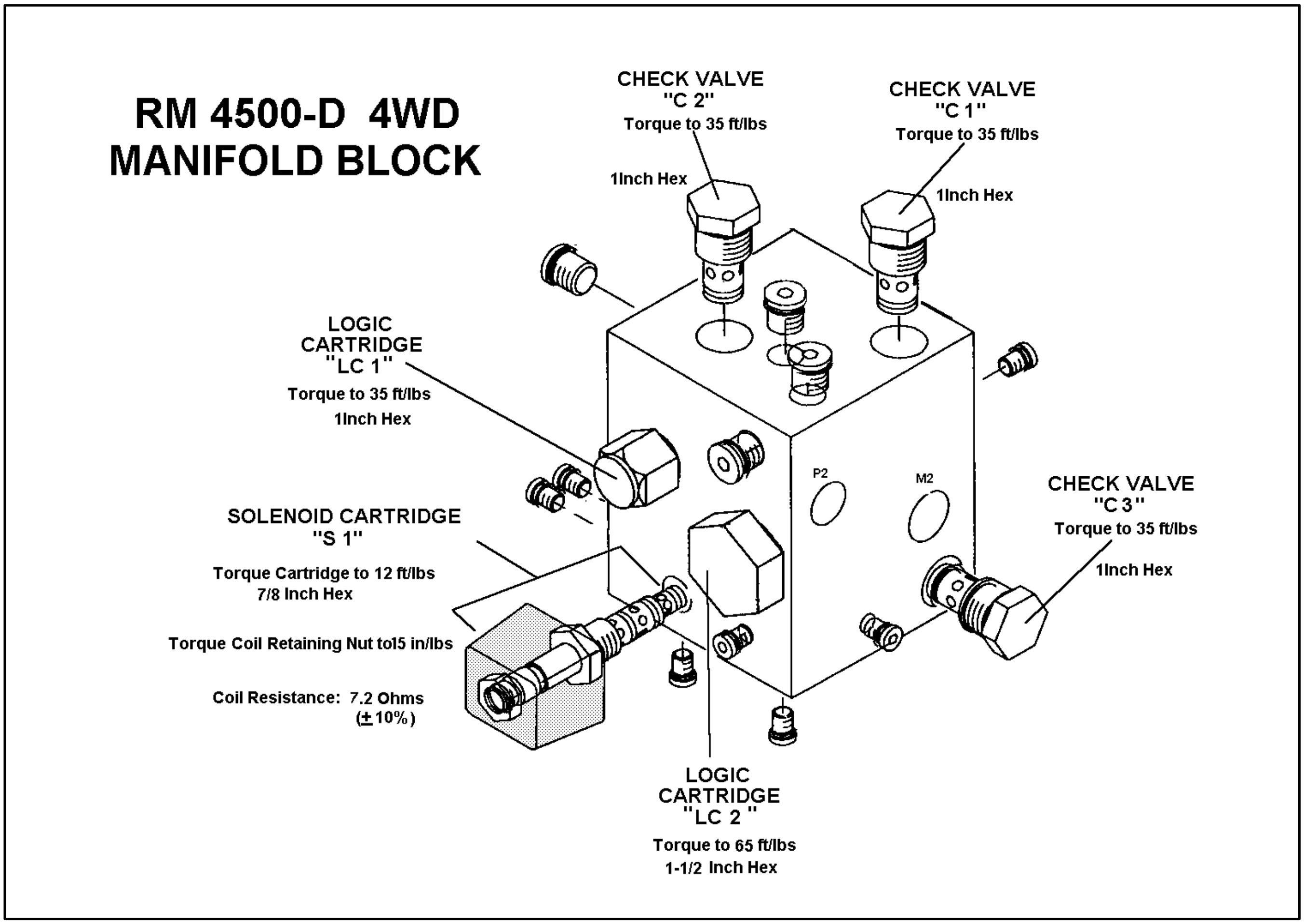


Figure 8

1. Disconnect the wire connector.

2. Connect a 12 volt battery so the positive (+) battery terminal is connected to colored solenoid lead. Connect the negative (–) battery terminal to black lead. The valve spool should retract completely as 12V DC is applied across the leads.

3. If valve spool does not retract, check for binding or damage in valve.

4. If valve operates smoothly, but does not retract when 12V DC is applied to solenoid leads, replace solenoid coil.

5. If valve still does not retract after replacing solenoid coil, replace the valve.

NOTE: To do a quick test without removing the solenoid coil or valve, hold a screwdriver to top of valve. When solenoid is enertized, screw driver should be attracted to valve stem, due to magnetism from energized solenoid. This test will not identify a sticking valve spool.

Figure 9

Electrical System

Repairs

NOTE: See Mitsubishi 4DQ7 Engine Service Manual for more component repair information.

Battery Service

IMPORTANT: To prevent damage to the electrical components, do not operate the engine with the battery cables disconnected.

Keep the terminals and entire battery case clean. To clean the battery, wash the entire case with a solution of baking soda and water. Rinse with clear water. Do not get the soda solution into the battery because damage to the battery will result. Coat the battery posts and cable connectors with skin–over grease, or petroleum jelly to prevent corrosion.

Check for loose battery hold–downs. A loose battery may crack or cause the container to wear and leak acid.

Check the electrolyte solution to make sure the level is above the plates. If the level is low (but above the plates inside the battery), add water so the level is to the bottom of the cap tubes. If the level is below the plates, add water only until the plates are covered and then charge the battery. After charging, fill the battery to the proper level.

CAUTION

Do not charge a frozen battery because it can explode and cause injury. Let the battery warm to 60° F (15.5° C) before connecting to a charger.

Charge the battery in a well–ventilated place so that gases produced while charging can dissipate. Since the gases are explosive, keep open flame and electrical spark away from the battery; do not smoke. Nausea may result if the gases are inhaled. Unplug the charger from the electrical outlet before connecting or disconnecting the charger leads from the battery posts.

Electrolyte Specific Gravity

Fully charged: 1.250 – 1.280
Discharged: less than 1.240

Battery Specifications

BCI Group 48 Battery:
440 Amp Cranking Performance at 0° F (17° C)

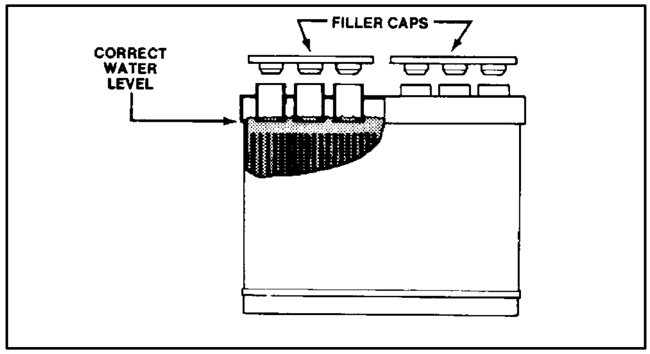


Figure 10

Rear Wheel Drive Solenoid Replacement

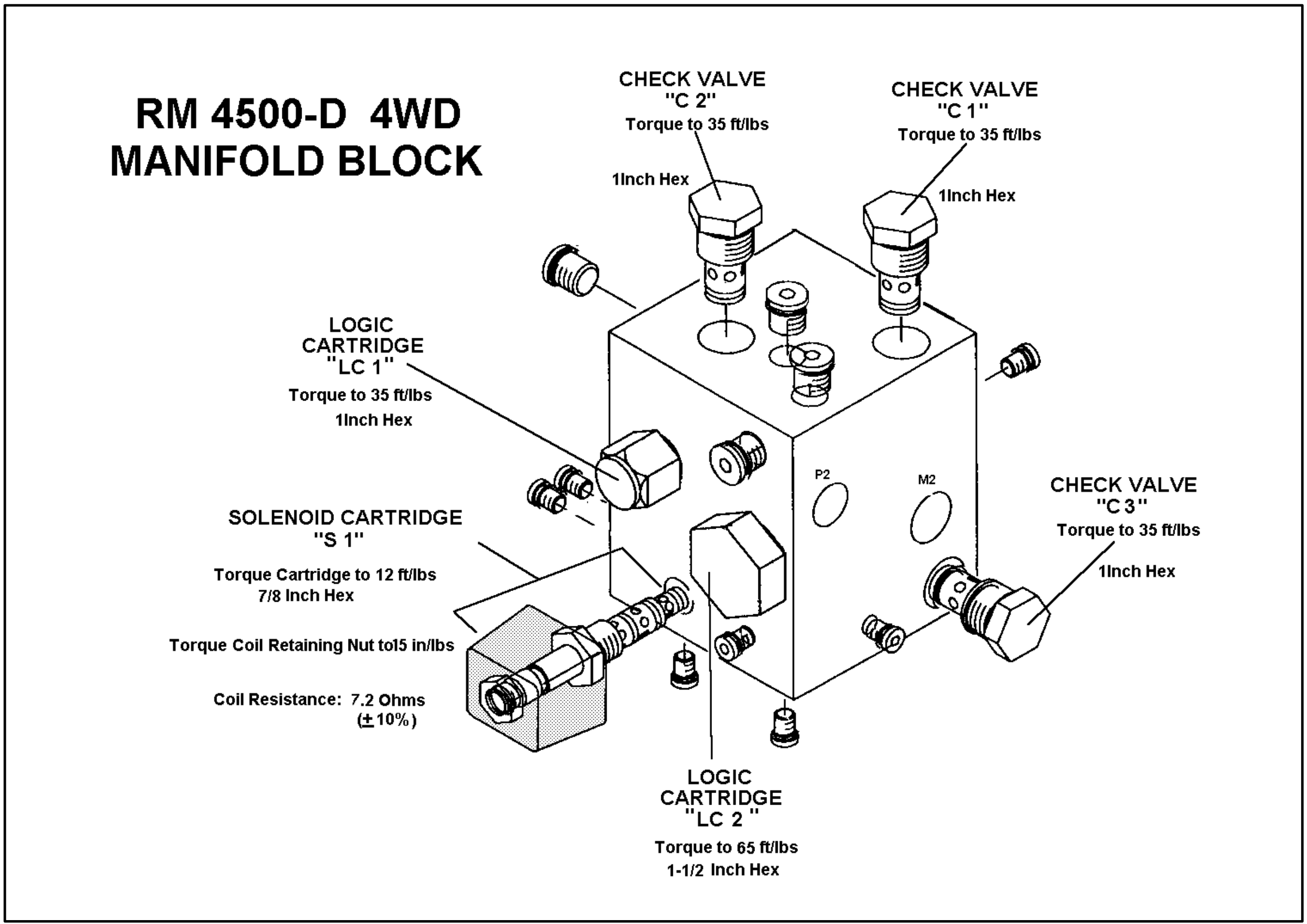


Figure 11

1. Disconnect solenoid electrical connector.

2. Remove nut from solenoid.

3. Remove solenoid coil.

4. Install new solenoid coil. Make sure o–ring is installed at each end of coil. Apply "Loctite 242" or equivalent to threads on end of valve stem before installing nut. Tighten nut to a torque of 15 in–lb. Over–tightening may damage the solenoid or cause the valve to malfunction.

5. Connect wiring connector.

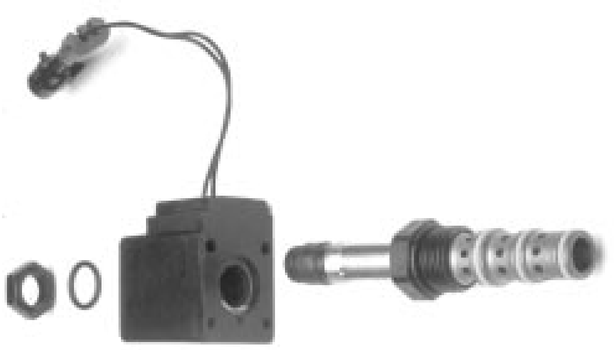


Figure 12

Electrical System

Chapter 6

Axles and Brakes

Table of Contents

Specifications

Item	Description
Tire pressure	13 PSI front, 15 PSI rear
Wheel nut torque	30 – 35 ft–lb rear, 60 – 85 ft–lb front
Wheel planetary mounting cap screw torque	95–110 ft–lb
Rear wheel toe–in	0.25 in.
Wheel planetary lubricant (Fig. 1)	SAE 80–90W EP gear lube 30 oz. capacity

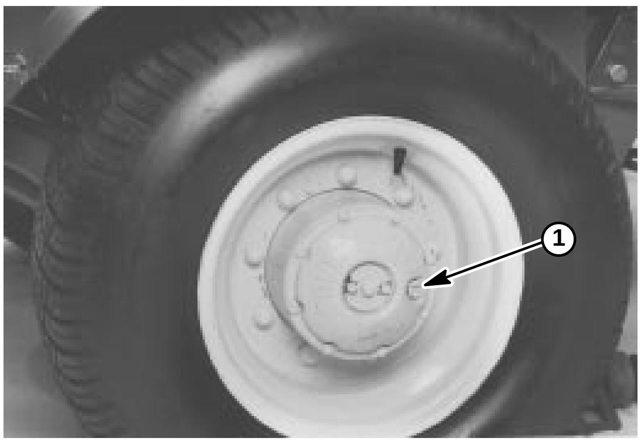


Figure 1

1. Check/Fill Plug

Adjustments

Hand Brake and Traction Switches

In time, the hand brake cable may stretch, causing the engine not to start. If this happens, adjust the cable (Fig. 2).

1. Pull hand brake lever to 3rd click.

2. Pull hand brake up one additional click.

3. Adjust four U–bracket nuts equally so spring has tension. Adjustment affects operation of traction switches.

4. Adjust four U–bracket nuts so engine will start and run when hand brake is at fourth click, but will not start or run when hand brake is at second click.

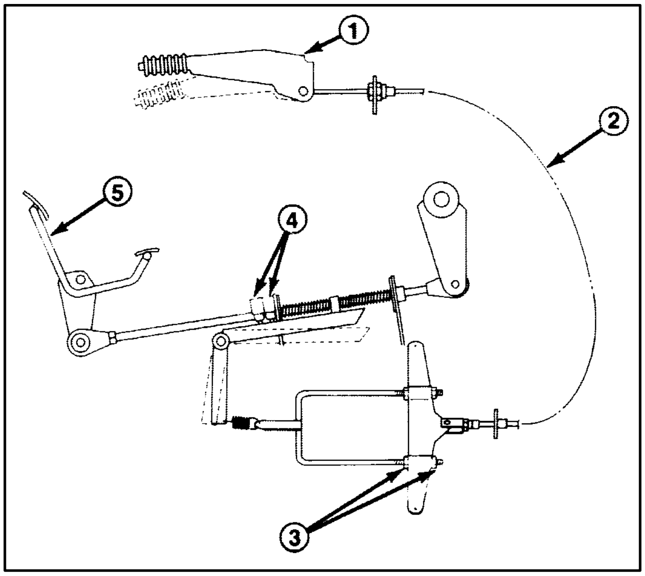


Figure 2

1. Hand Brake
2. Brake Cable
3. U–bracket Nuts
4. Traction Switches
5. Traction Pedal

Axles and Brakes

Rear Wheel Toe–In

After every 800 operating hours or annually, check rear wheel toe–in.

1. Measure center–to–center distance (at axle height) at front and rear of steering tires (Fig. 3). Front measurement must be 1/8 in. less than rear measurement.

2. Loosen clamps at both ends of tie rods (Fig. 4).

3. Rotate tie rod to move front of tire inward or outward.

4. Tighten tie rod clamps when adjustment is correct.

NOTE: Make sure tie rod clamps are positioned so they do not interfere with steering linkage.

Figure 3

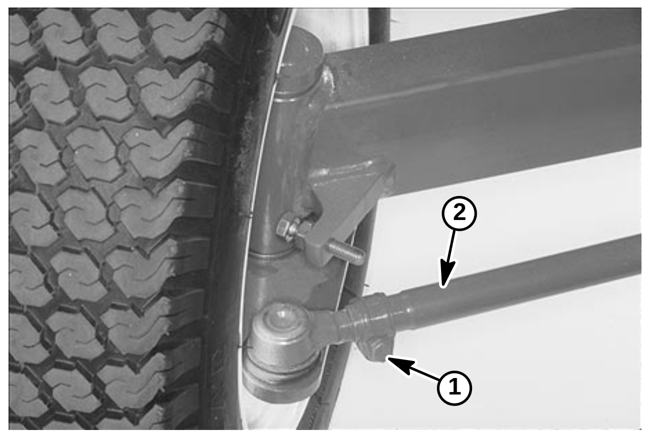


Figure 4
1. Clamp
2. Tie Rod

Rear Wheel Bearing Service (2WD Only)

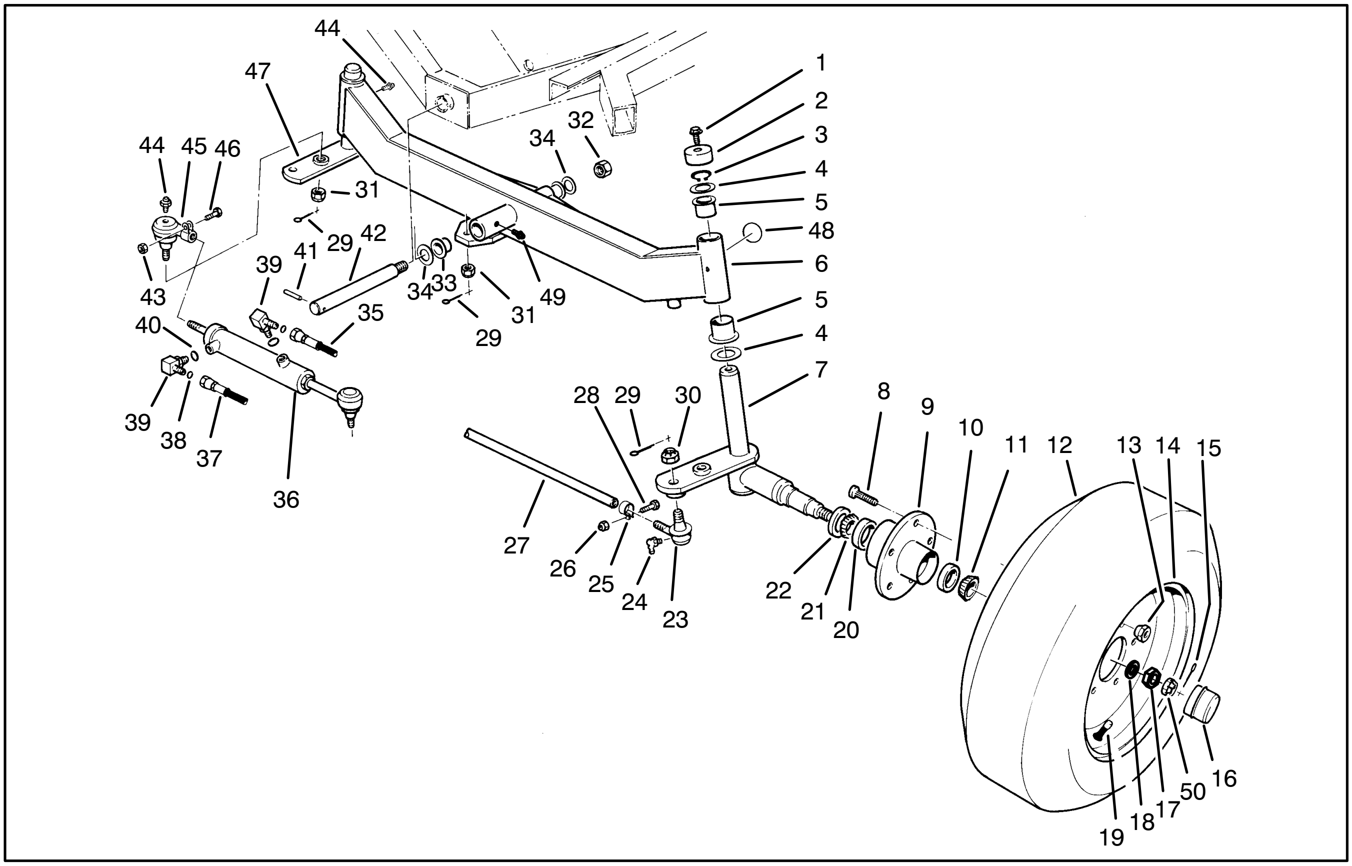


Figure 5

1. Hex Flange Hd. Screw
2. Spindle Cap
3. Retaining Ring
4. Thrust Washer
5. Flange Bushing
6. Rear Axle
7. Wheel LH Spindle
8. Drive Screw
9. Rear Wheel Hub
10. Outer Bearing Cup
11. Outer Bearing Cone
12. Tire
13. Lug Nut
14. Rim
15. Cotter Pin
16. Hub Cap
17. Jam Nut
18. Tab Washer
19. Valve Stem
20. Bearing Inner Cup
21. Bearing Inner Cone
22. Inner Seal
23. Ball Joint, RH
. Ball Joint, LH
24. Grease Fitting
25. Clamp Assembly
26. Lock Nut
27. Tie Rod Assembly
28. Cap Hex Hd. Screw
29. Cotter Pin
30. Castle Nut
31. Castle Nut
32. Lock Nut
33. Flange Bushing
34. Thrust Washer
35. Hydraulic Hose
36. Steering Cylinder
37. Hydraulic Hose
38. O–Ring
39. Hydraulic Fitting
40. O–Ring
41. Roll Pin
42. Pivot Shaft
43. Hex Nut
44. Grease Fitting
45. Ball Joint
46. Hex Hd. Cap Screw
47. Wheel Spidlle, RH
48. Grease Decal
49. Grease Fitting
50. Retainer Nut

Axles and Brakes

1. Jack up rear of machine until tire is off the floor. Support machine with jack stands or blocks to prevent it from falling.

2. Remove dust cap (16) from end of wheel spindle.

3. Remove cotter pin (15), slotted nut and washer (18). Slide wheel off of spindle shaft.

4. Pull seal (22) out of wheel hub (9).

5. Remove bearings (11, 21) from both sides of wheel hub (9). Clean the bearings in solvent. Make sure the bearings are in good operating condition. Clean the inside of the wheel hub (9). Check the bearing cups (10, 20) for wear, pitting or other noticeable damage. Replace worn or damaged parts.

6. If bearing cups (10, 20) were removed from the wheel hub (9), press them into the hub until they seat against the shoulder.

7. Use No. 2 general purpose lithium base grease containing E.P. additive. Pack both bearings (11, 21) with grease. Install one bearing (21) into the cup (20) on inboard side of wheel hub. Lubricate the inside of the new lip seal (22) and press it into the wheel hub.

IMPORTANT: The lip seal must be pressed in so it is flush with the end of the hub. The lip of the seal must be toward the bearing.

8. Pack inside of wheel hub with some grease (not full). Install remaining bearing (11) into bearing cup (10).

9. Slide the wheel onto the spindle shaft and secure it in place with the flat washer (18), nut (17), and retainer nut (50). DO NOT tighten the nut or install the cotter pin.

10. Adjust preload on the wheel bearings (see Adjusting Rear Wheel Bearings).

Adjusting Rear Wheel Bearings

1. Remove dust cap (16) from end of wheel spindle. Remove cotter pin (15) retaining slotted nut (50) in place.

2. Rotate the wheel by hand and tighten the slotted nut until the bearing binds SLIGHTLY. Then, loosen the nut until the nearest slot and hole in the spindle line up. Reinstall the cotter pin (15) to retain the slotted nut (50) in place.

NOTE: The correct end play of the adjusted assembly is 0.002 – 0.005 inches.

3. Remove jack stands or blocks and lower machine to floor.

4. Put a coating of grease on the inside of the dust cap (16). Install dust cap on end of wheel spindle.

Figure 6

Planetary Wheel Drive

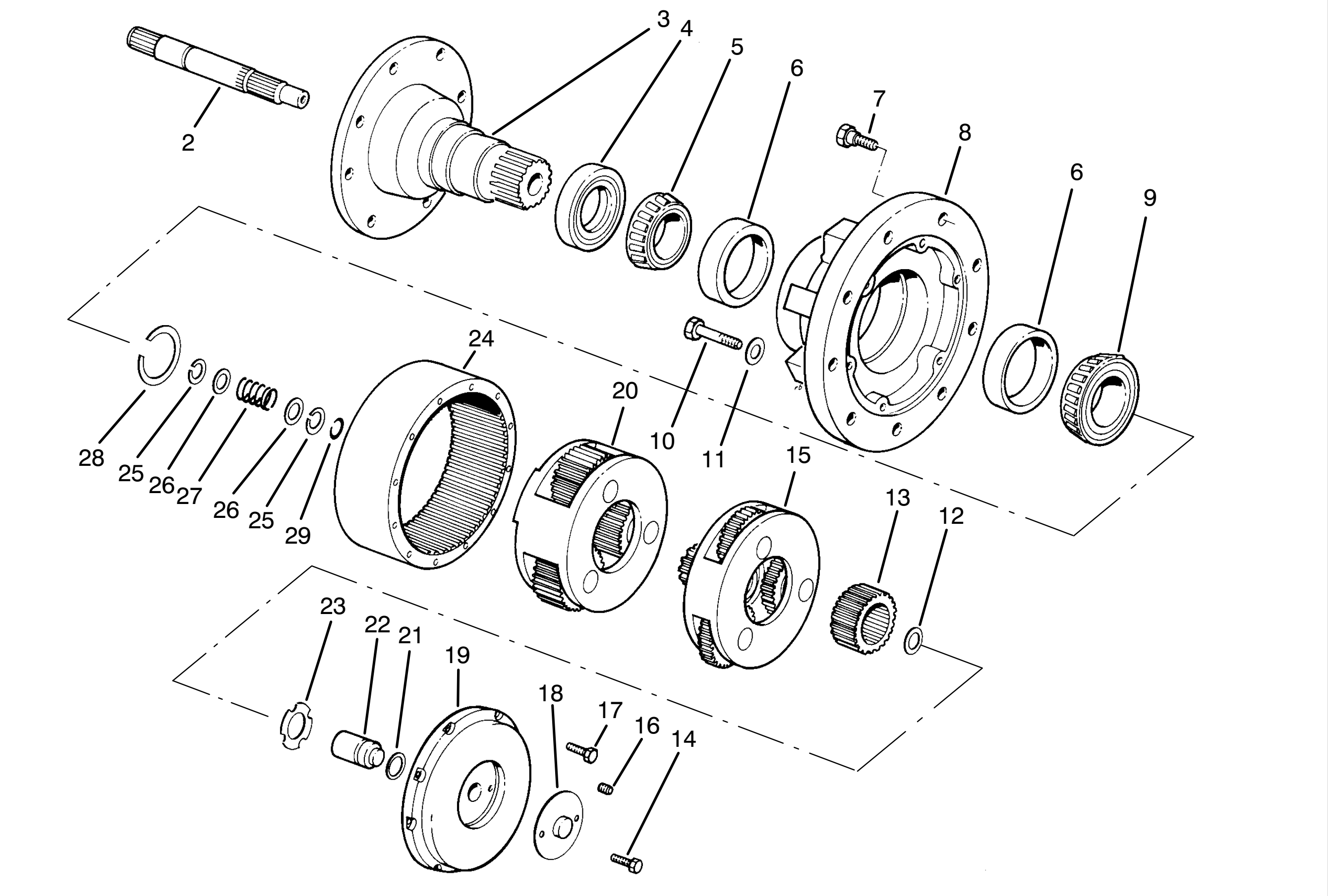


Figure 7

1. Coupling
2. Input Shaft
3. Spindle
4. Oil Seal
5. Bearing Cone
6. Bearing Cup
7. Wheel Bolt
8. Hub
9. Bearing Cone
10. Hex Hd. Bolt
11. Flat Washer
12. Thrust Washer
13. Primary Sun Gear
14. Hex Hd. Bolt
15. Primary Carrier Assembly
16. Pipe Plug
17. Hex Hd. Bolt
18. Disengage Cover
19. Large Cover
20. Secondary Carrier Assembly
21. O–Ring
22. Disengage Plunger
23. Thrust Washer
24. Ring Gear
25. Retaining Ring
26. Washer
27. Disengage Spring
28. Retaining Ring Kit
29. Retaining Ring

Disassembly of the Planetary Wheel Drive

1. Slide the coupling (1) from splines on input shaft (2).

2. Position the assembly upright on face of spindle (3).

3. Remove the disengage cover (18).

4. Remove bolts (17) and large cover (19). The disengage plunger (22) usually remains with cover. Remove plunger and O–ring from cover on end of input shaft.

5. A thrust washer (23) will usually remain in position on thrust face of cover.

6. Remove primary sun gear (13) and thrust washer (12) from end of input shaft.

7. Remove primary carrier assembly (15).

8. Remove the secondary carrier assembly (20). It may be necessary to remove the ring gear (24) first, if difficulty is encountered in removing the carrier.

9. Remove input shaft (2) from spindle (3). Remove the retaining rings, washers, and spring from input shaft only if replacement is required.

10. Remove the 6 or 12 bolts from hub and ring gear and remove ring gear (24). It may be necessary to strike ring gear with a rubber mallet to loosen from hub.

11. Remove the large retaining ring (28) from in front of the tapered bearing and lift hub (8) from spindle. If bearings are not a loose fit, it may be necessary to press spindle from hub.

NOTE: Use a snap ring expander tool to remove retaining ring.

12. Remove the oil seal (4) and bearing cones (5 & 9) from hub. Inspect bearing cups (6) in position and remove only if replacement is required.

Assembly of the Planetary Wheel Drive

1. Press a new bearing cup (6) in each side of the hub (8).

2. Assemble a bearing cone (5) into cup (6) at seal end of hub and press a new oil seal (4) into hub.

3. Position spindle (3) upright on bench. Lubricate lips of oil seal (4) and lower hub onto spindle. Hub (8) should be centered as it is lowered over spindle to prevent seal damage.

4. Assemble bearing cone (9) over spindle and into bearing cup (6). Select the thickest retaining ring (28) that can be assembled into ring grooves of spindle shaft above bearing cone. Bearing should have from .000–.006 inches (.00–.15mm) end play when proper retaining ring is installed.

5. Assemble a retaining ring (25) in groove opposite pilot end of input shaft (2). Assemble a washer (26), spring (27), a second washer (26), a second retaining ring (25), and a third retaining ring (29) in the middle groove of input shaft. Some shafts have a shoulder and require only one retaining ring.

6. Assemble the splined end of the input shaft down into spindle.

7. Assemble secondary carrier splines over splined end of spindle.

8. Apply a bead of RTV compound to hub face that mates with ring gear (24)*. Assemble the end of ring gear having 6 or 12 bolt holes against hub with bolt holes of hub and ring gear aligned. Assemble the six 3/8–24x1–7/8 inch hex head bolts. Torque bolts to 39–49 (52.9–66.4 Nm) pound feet. If grade 8 bolts are used, the bolts should be torqued to 52–60 (70.5–81.3 Nm) pound feet. Grade 8 bolts can be identified by the 6 radial lines on bolt head.

9. Assemble the primary carrier and sun gear into ring gear. It will be necessary to rotate carrier and pinion to align sun gear teeth with secondary pinion and primary pinions with ring gear teeth. Assemble the primary sun gear (13) over input shaft. Rotate sun gear to align shaft to gear splines and gear teeth.

10. Assemble the small thrust washer (12) over input shaft and against shoulder of shaft.

11. Assemble an O–ring (21) in groove of the disengage plunger (22). Assemble plunger over end of input shaft and against thrust washer.

12. Lubricate the O–ring in groove of engage plunger. Assemble the thrust washer (23) with tangs engaged with large cover (19). Apply a bead of RTV compound to end face of ring gear.* Assemble cover over plunger as holes of cover and ring gear are aligned. Assemble the eight 5/16–18x1 inch hex head bolts. Torque bolts to 20–25 (27.1–33.9 Nm) pound feet.

13. Assemble the disengage cover (18) with dimpled center protruding out if wheel is to be used to drive the vehicle. Assemble and torque the two 5/16–18x3/4 inch bolts. Torque bolts to 10–20 (13.6–27.1 Nm) pound feet.

14. Invert the Power Wheel assembly and assemble the coupling (1) with counterbore out to the input shaft.

Chapter 7

Cutting Units

Table of Contents

Cutting Units

Specifications

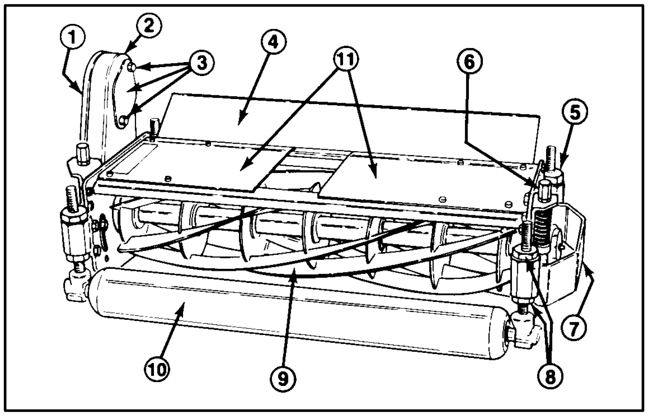


Figure 1

1. Drive housing cover
2. Drive housing
3. Reel motor fasteners, drive plate shield and shipping cover
4. Grass deflector
5. Rear roller adjusting assembly
6. Reel to bedknife adjusting assembly
7. Guard
8. Cone nut
9. Reel assembly
10. Front roller (optional)
11. Top covers

Construction: Welded steel frame and reel with heavy duty, self–aligning ball bearings. Heavy duty steel rear roller with tapered roller bearings. Rear roller and bedbar are isolated and mounted in rubber bushings for quiet, vibration–free operation. Adjustable deflector shields are standard. Stainless steel components are used at key points for added durability.

Reel Configuration: The 5, 7 and 11 blade heavy duty welded reels all have 8 in. (20.3 cm) diameters and are 29–3/4 in. (75.5 cm) wide.

Bedknife/Bedbar Assembly: A replaceable, single edged, alloy steel bedbar is induction hardened. It's fastened with steel screws to a precision ground surface on the high strength, fabricated steel bedbar. The stress–relieved machined bedbar is mounted with four (4) vibration isolation bushings.

Bedknife to Reel Adjustment: Two lockable lead screw adjusters at each side of the frame adjust the reel to bedknife contact.

Rear Roller: 3–1/2 in. (89 mm) diameter steel roller has greaseable tapered roller bearings. A double lip oil seal and wear sleeve isolates grit and moisture from the bearings.

Height–of–Cut: 5 Blade – 1 to 3 in. (25 to 76 mm). 7 Blade – 1/2 to 1–3/4 in. (9.5 to 45 mm). 1 1 Blade – 3/8 to 3/4 in. (9.5 to 19 mm).

Height–of–Cut Adjustment: Quick adjustment and positive locking is provided by locking type cone nuts. Gauge marks of 1/4 in. (6.3 mm) are provided as a reference for easy changes of height–of–cut.

Clip (variable to match cutting conditions):

5 Blade Cutting Unit: .176 in. per mph
(.352 in. at 2 mph – 1.32 in. at 7.5 mph)

7 Blade Cutting Unit: .1 26 in. per mph
(.252 in. at 2 mph – .945 in. at 7.5 mph)

11 Blade Cutting Unit: .080 in. per mph
(.16 in. at 2 mph – .600 in. at 7.5 mph)

Lubrication: Easily accessible grease fittings for bearings and all major pivot points.

Drive: The reel drive motor turns a maintenance–free cog belt which drives the reel. Drive pulley and cog belt are encased in a drive housing for safety and protection from contamination.

Grass Deflector Shields: Fully Adjustable.

Special Tools

Order special tools from the *TORO SPECIAL TOOLS AND APPLICATIONS GUIDE (COMMERCIAL PRODUCTS)*. Some tools may be listed in the Reelmaster 4500–D Parts Catalog. Some tools may also be available from a local supplier.

Gauge Bar Assembly

Use gauge bar to set final height of cut (floating cutting unit with front roller only).

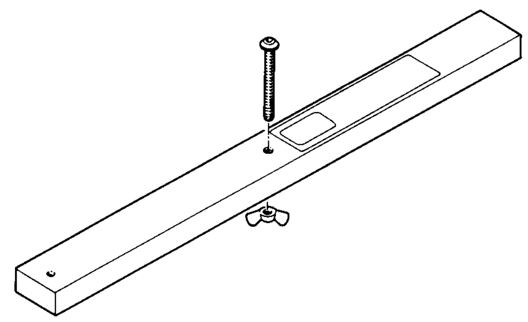


Figure 2

Handle Assembly

For applying lapping compound to cutting units while keep hands a safe distance from the rotating reel.

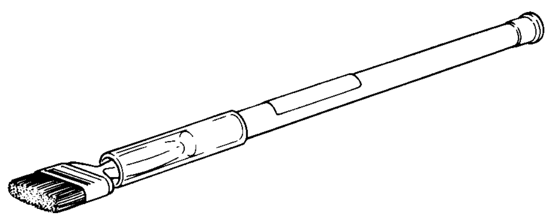


Figure 3

Cutting Units

Bedknife Screw Tool

Fits Toro bedknife attaching screws. Use with torque wrench to secure bedknife to bedbar. With clean bedbar threads and new screws, tighten to a torque of 250 in–lb.

NOTE: Remove all rust, scale and corrosion from bedbar surface before installing bedknife.

DO NOT use and air impact wrench with this tool.

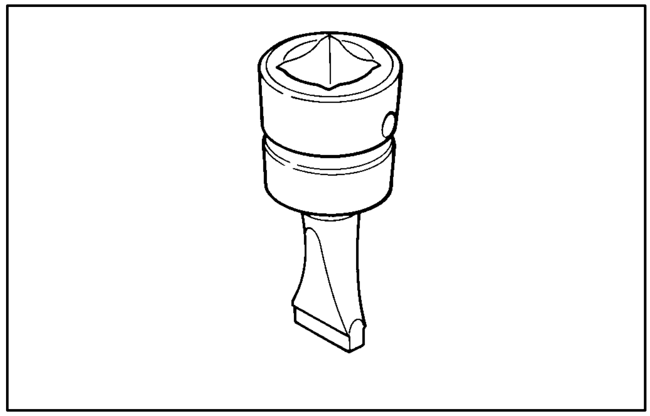


Figure 4

Adjustments

CAUTION

Never install or work on the cutting units or lift arms with the traction unit engine running. Always stop the engine and remove the key first.

Adjusting Reel to Bedknife Contact

Before adjusting height–of–cut and each day before operating, check reel to bedknife contact, regardless if quality of cut had previously been acceptable.

NOTE: A 3/4” wrench is required for making the reel to bedknife adjustment.

A. Slowly and carefully rotate reel,listening for light contact across the full length of the reel and bedknife.

CAUTION

Before adjusting reel to bedknife, raise and fully latch cutting units. Remove key from the ignition switch. Keep others off machine while adjusting cutting units.

B. If no contact – loosen the adjuster locking nut on each adjuster (Fig. 5). Then, equally turn each adjuster knob clockwise until light contact is felt and heard.

C. If excessive contact – Turn the adjusting knobs counter–clockwise until no contact is noticed. Then equally turn both adjusting knobs clockwise, until light contact is felt and heard between the reel and bedknife. Final adjustment should always be in the tightening (clockwise) direction.

D. Tighten adjuster locking nuts when completed making adjustments.

CAUTION

When adjusting the cutting units, wear heavy gloves and use care when turning reels by hand. Sharp edges can cut or pinch hands or fingers.

IMPORTANT: Adjusted correctly, the reel will cut paper (approx. .003” thick) across its entire length.

The cutting units will provide optimum mowing performance when adjusted and maintained correctly. Keeping a precise reel to bedknife adjustment (light contact), at each end of the cutting unit will produce a continual self–sharpening action. Therefore, sharp cutting edges are maintained, good quality of cut assured, and the need for corrective re–sharpening reduced.

IMPORTANT: Cutting units with excessive contact between the reel and bedknife are noisy, consume excessive power, shorten component life and result in overall poor performance. Light contact between the reel and bedknife, once the cutting unit is warmed up, provides optimum mowing performance and component life.

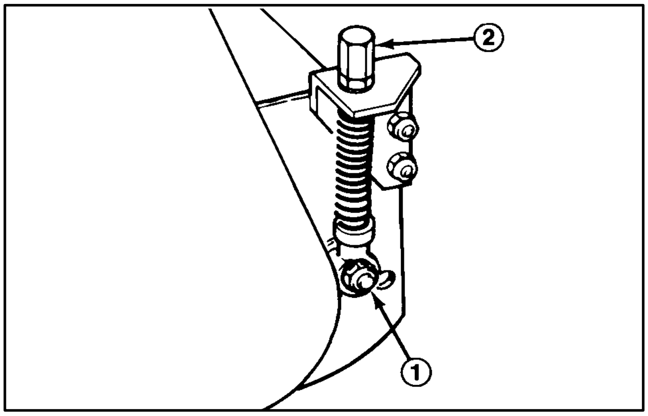


Figure 5

1. Adjuster locking nut
2. Adjustment knob

Cutting Units

Height–of–Cut Adjustment (Floating Cutting Unit)

Overview of Procedure:

1. Adjust reel to bedknife contact
2. Level rear roller to reel
3. Final height–of–cut adjustment using gauge bar.

STEP 1 – Adjust Reel to Bedknife Contact

A. Adjust reel to bedknife contact on all cutting units. (Refer to Adjusting Reel To Bedknife Contact).

STEP 2 – Level Rear Roller to Reel

B. Start engine and lower the cutting units onto a flat surface such as a piece of 3/4" or 1" plywood (at least 20" x 30" in size). Stop engine and remove key from switch. Lock cutting units in the fixed position, by loosen—ing the jam nut on lockout pin (Fig. 6) and screwing pin into hole in pivot arm (Fig. 7). Tighten nut to secure lockout. Raise the front rollers up so they do not contact the flat surface.

C. Insert a piece of bar stock 25" – 28" (70 cm) long (Fig. 8), and approximately 3/8" (9.5 mm) thicker than the desired height–of–cut, under the reel and up against the bedknife cutting edge (Fig. 8). The reel (not bedknife) must contact the bar stock along its full length.

NOTE: Using a bar 3/8" (9.5 mm) thicker than height–of–cut provides proper bedknife attitude (heeled "up" in back) required for excellent low height–of–cut performance.

D. Loosen rear roller jam nuts and adjusting knobs and push roller down against flat surface. At this point the reel should contacting the bar stock and the rear roll contacting the flat surface. Contact should exist along the entire length of the reel a rear roller. Tighten rear roller adjustme knobs and jam nuts. Recheck to be sure roller and reel are both still making contact after jam nuts have been tightened. Check roll contact by trying to slide paper between the roller and the flat surface.

E. Rear roller is now leveled to the reel.

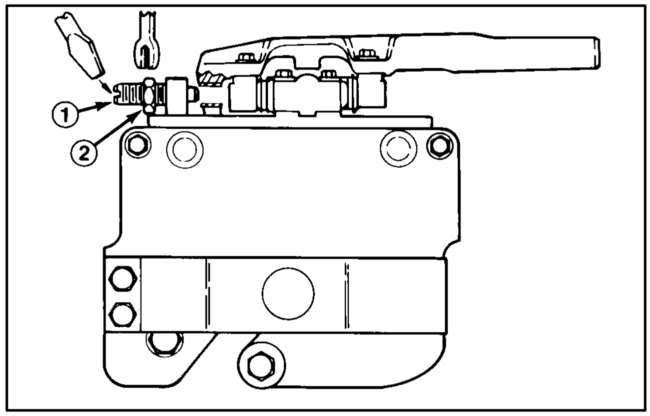


Figure 6
Cutting Unit Float Position

1. Lockouts **2. Jam nut**

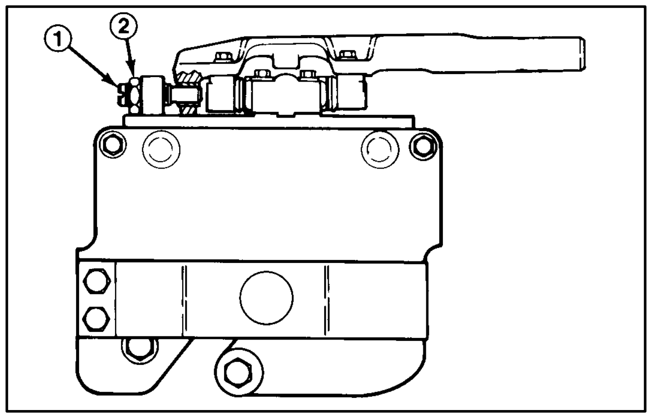


Figure 7
Cutting Unit Fixed Position

1. Lockout pin **2. Jam nut**

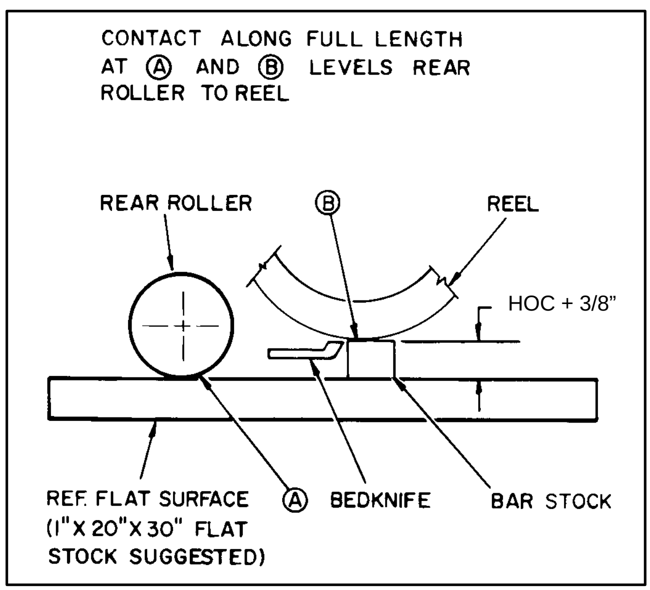


Figure 8
Leveling Rear Roller to Reel

STEP 3 – Final Height–of–Cut Adjustment Using Gauge Bar

F. Raise cutting units and lock in the transport position. Shut off the engine and remove the key.

G. Use gauge bar (Toro Part No. 59–7900) to set final height–of–cut by adjusting front roller only.

H. Loosen the gauge bar jam nut and adjust the screw to set dimension between underside of screw head and gauge bar for desired height–of–cut (Fig. 9). Tighten the jam nut to secure the adjustment. Hook screw head over cutting edge of bedknife and position bar against bottom of front roller (Fig. 10).

I. Loosen front roller nuts and adjust both ends of the front roller until it contacts gauge bar at both ends. With the gauge bar held firmly against the bottom of the rollers adjust the front roller so the screw head just slips over the lip of the bedknife (Fig. 10). Tighten front roller nuts.

IMPORTANT: Set properly, front and rear rollers will contact gauge bar and screw head will be snug over bedknife cutting edge when checked at both ends of the reel.

J. Loosen lockout pin so cutting unit can float freely (Fig. 6).

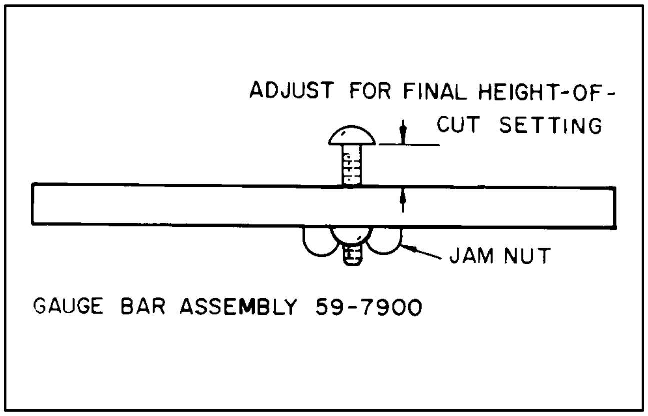


Figure 9
Gauge Bar Assembly

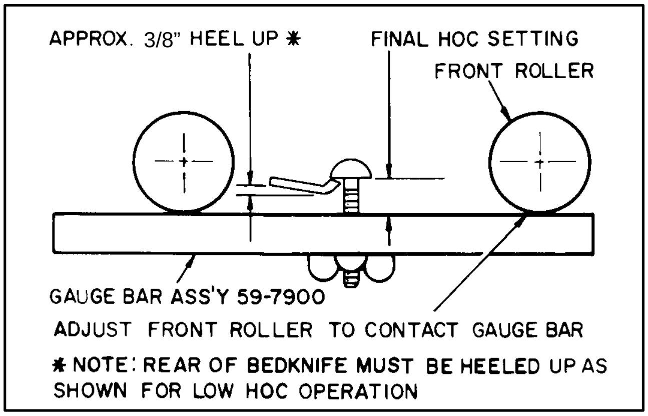


Figure 10
Final Height–of–Cut Adjustment Using Gauge Bar

Quick Method For Changing Height–of–Cut After Initial Set Up of a Floating Cutting Unit

If the reel to bedknife adjustment has been set (STEPÿ1) and the rear roller leveled to the reel (STEP 2), the cutting unit may be quickly changed from one height–of–cut to another by using the gauge bar (Part #59–7900) and adjusting the front roller only. In many cases, an entire machine can be done quickly by using the gauge bar to set the front roller of one cutting unit. The remaining cutting units can then be set by loosening their front roller jam nuts and turning each front roller adjustment knob the same number of turns and in the same direction as the first unit.

Height–of–Cut Adjustment (Fixed Cutting Unit)

1. Adjust reel to bedknife contact.

2. Loosen nuts securing skids or front roller and raise to highest position.

3. Loosen jam nuts securing rear roller. Lower roller beyond desired height–of–cut (assures proper bedknife attitude).

4. Lower cutting unit onto a flat surface, such as a 1" x 20" x 30" piece of plywood. Shut off engine and remove the key.

5. Insert piece of bar stock (Fig. 11) 25"–28" (70 cm) long with thickness equal to desired height–of–cut, under entire length of the reel, next to bedknife.

6. Adjust rear roller adjustment knobs and jam nuts until full length of the rear roller contacts the flat surface and the full length of the reel (not bedknife) contacts the bar stock. Tighten rear roller knobs and jam nuts.

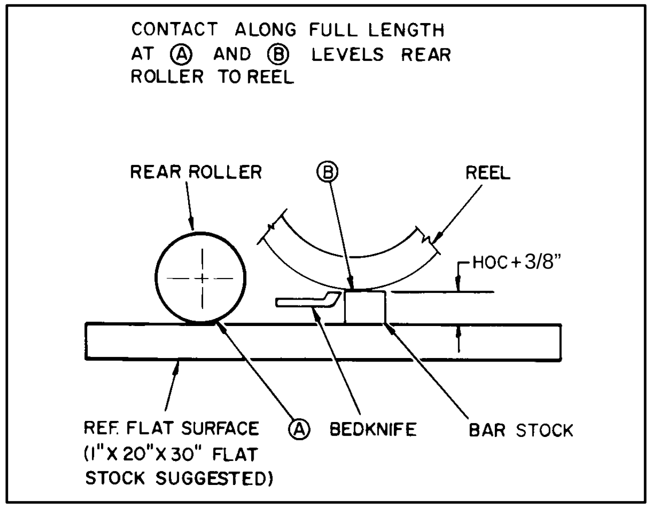


Figure 11

Adjusting Skids and Front Roller (Fixed Head Cutting Unit)

After skid kit or front rollers are installed (installation instructions are included with each option) make the following adjustments to prevent them from pushing down uncut grass or scalping on undulating terrain:

1. Lock each cutting unit in the fixed position (Refer to Cutting Unit Orientation, Fig. 15. Set the reel to bedknife adjustment and height–of–cut adjustment.

2. Position the cutting units on a flat, level surface (a 1" inch (25 mm) thick piece of plywood is ideal).

3. Skids and front rollers used to prevent scalping should not ride on the ground. Adjust each skid or front roller so it is 1/8 – 1/4 in. (3 – 6 mm) or higher above the level surface. Allow greater clearance at the higher height–of–cut settings.

4. Proper adjustment is achieved when the cutting unit does not scalp the grass in normal mowing conditions and yet is set high enough not to mar the turf and create undue wear on the skids or rollers.

NOTE: Skids are used only with the cutting unit in the fixed position. Front rollers may be used with the cutting unit in either the fixed or floating position.

Repairs

CAUTION

Never install or work on the cutting units or lift arms with the traction unit engine running. Always stop the engine and remove the key first.

Backlapping

CAUTION

DURING BACKLAP OPERATION REELS ARE UNDER POWER. CONTACT WITH ROTATING REELS CAN RESULT IN PERSONAL INJURY. DO NOT ADJUST CUTTING UNITS WHILE ENGINE AND REELS ARE OPERATING. INSTRUCT OPERATOR TO STOP THE REELS AND SHUT THE ENGINE OFF WHEN ADJUSTMENT IS NECESSARY.

Use a good grade of medium grit (80 courseness) lapping compound with a water soluble carrier so the compound will be easily washed away after completion of the operation. Dry lapping compound should be mixed with liquid detergent until it has a free–flowing consistency.

Two people are required to perform backlapping. Good communication between one another is necessary and caution should be used when making each move. With one person on the seat to operate the controls (operator) the other performs the backlapping operation.

NOTE: Before starting the engine raise the grass deflector on the #1 cutting unit (center) and tighten fasteners to retain the deflector in the raised position.

1st persons duties (Operator):

A. Sit on the seat and engage parking brake.

B. Start the engine and run at minimum throttle. Lower either:1.) the center cutting unit (#1) or2.) the left hand (#2) cutting unit or3.) the right hand (#3) cutting unit.

With the #2 & # 3 cutting units up and latched (automatically shut off) and the #1 cutting unit down, backlap the center (#1) cutting unit from the rear of the machine with the long handled brush. Backlap the #2 and #3 cutting units from the front of the machine.

C. Wait for 2nd person's instruction to engage reels in BACKLAP mode, then pull up on reel switch and move it to ENGAGE position.

D. Turn REEL SPEED KNOB counterclockwise to the BACKLAP position.

E. Follow 2nd person's instructions. Be prepared to stop reels and engine quickly in case of an emergency.

2nd persons duties:

A. Instruct operator when to start and stop reels.

CAUTION

UNDER NO CIRCUMSTANCES USE A SHORT–HANDLED PAINT BRUSH TO APPLY BACKLAPPING COMPOUND. A ROTATING REEL CAN ACTUALLY PULL A SHORT HANDLED PAINT BRUSH AND THE USERS HAND INTO THE REEL CAUSING SERIOUS PERSONAL INJURY.

B. Dip 3 in. (76 mm) paint brush attached to Toro Part No. 29–9200 Handle Assembly into lapping compound. Stand clear and instruct operator to engage reel into backlap mode.

C. Apply lapping compound evenly over full length of the reel, assuring that all reel blades are covered. Whenever noise of reel against the bedknife begins to disappear or, an uneven concentration of material appears on the reel, redistribute the compound with the brush.

D. When it becomes necessary to adjust the reel to the bedknife, instruct the operator to disengage the reel, stop the engine and remove the key from the ignition switch. Then proceed with the adjustment only after the reels have stopped rotating.

E. Backlap each reel until the cutting edges are sharp, even, and consistent on all blades. Achieve a minimum of 1/32 in. (0.79 mm) land area on newly sharpened reel assemblies. Normally, a reel need only be backlapped for approximately 3 minutes.

F. Upon completion, stop the reel and turn off the engine. Remove the key from the ignition switch. Wash the unit thoroughly with a low pressure stream of water to remove all lapping material. Allow the reel to dry and lubricate the grease fittings.

G. Check sharpness of the reel and bedknife with strips of newspaper. With light reel to bedknife contact, the paper should be cleanly sheared across the entire width of the reel. If the paper is not sheared acceptably, continue backlapping.

H. After backlapping the first cutting unit, raise and latch this unit and proceed with the #2 and #3 cutting units.

NOTE: See the Toro Sharpening Manual (Part #80–300) for additional backlapping/sharpening information.

Hydraulic Motor Installation

1. Install the drive plate shield onto the reel drive motor flange (Fig. 12). Be sure the widest portion of the shield is at the top.

NOTE: Check to see that motor pulley set screws are tight on motor shaft before installing motor onto cutting unit (Fig. 13).

2. Insert the reel drive motor pulley through the housing and slip the cutting unit drive belt over the pulley (Fig. 13).

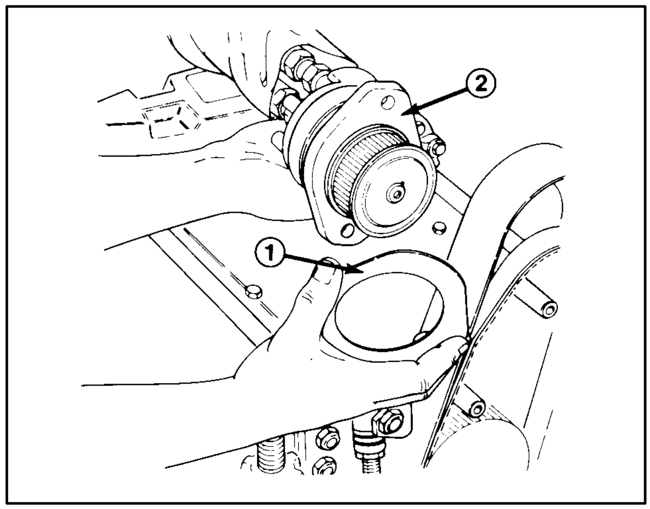


Figure 12

1. Drive plate shield **2. Reel drive motor flange**

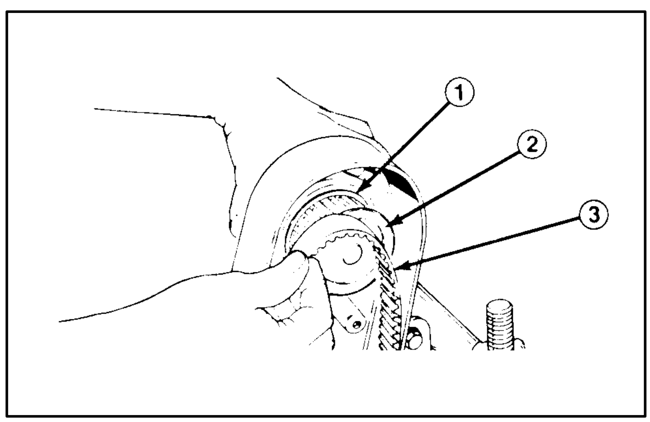


Figure 13

1. Hydraulic motor **2. Motor pulley**
3. Drive belt

3. Insert the two (2) reel drive motor mounting bolts (heads on inside of the drive housing – flat washer on top bolt) through the reel motor flange holes. Thread the locknuts onto the bolts. Rotate reel motor upward in the slotted hole in the housing to tension the drive belt and tighten the fasteners (Fig. 14) to approx. 25 ft–lbs (34 Nm). NOTE: Proper belt tension is achieved when belt deflects approximately 1/8” (3 mm) at mid–point when 7 lbs. force is applied. (Fig. 14).

IMPORTANT: Rotate motors by hand only. Never place a bar between hose fittings on hydraulic motors – motor damage may result.

4. Install the gasket and drive housing cover after making sure the ends of the gasket are at the bottom of the housing to allow for drainage.

IMPORTANT: When hydraulic motors have been mounted to the cutting units make sure hydraulic hoses lay flat and do not contact the frame of the machine when the cutting units are in the raised position. There should also be sufficient slack SO hoses are above and not in contact with the floatation kit. If hoses appear twisted once the hydraulic motors have been mounted and the belts tightened, loosen swivel nuts at the motor and reposition hoses. This can greatly increase the life of the hoses. With cutting units down, all cutting unit hoses should have a flat natural lay and be free from twist.

NOTE: Refer to the Traction Unit Operator’s Manual for instructions on setting the adjustable hydraulic counterbalance.

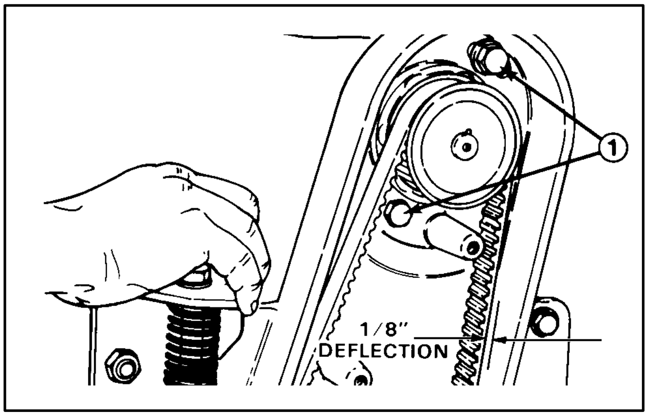


Figure 14

1. Reel motor fasteners

1. #3 Cutting unit
2. Hose bracket

Cutting Units

Servicing the Bedknife/Bedbar Assembly

NOTE: The bedbar on each cutting unit has a precision ground mounting surface to provide an excellent fit with a bedknife. Backlapping of replacement bedknives is often sufficient to achieve an excellent cutting edge with minimum material removed.

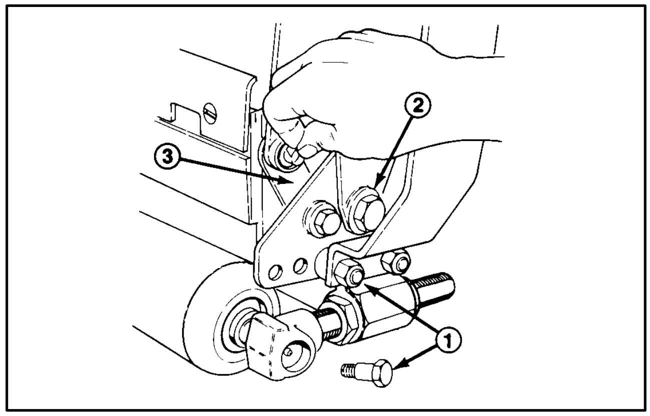


Figure 16

1. Shoulder bolts (2 each side) 2. Bushing 3. Spacer

Bedknife/Bedbar Removal:

1. Remove the shoulder bolts,bushings and spacers from each end of the unit and remove the bedbar/bedknife assembly (Fig. 16).

2. Remove the mounting screws for the bedknife and separate the bedknife from the bar (Fig. 17). Discard the screws.

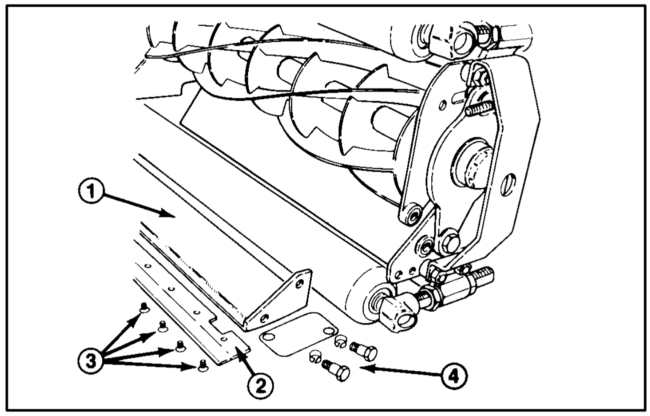


Figure 17

1. Bedbar 3. Bedknife mounting screws
2. Bedknife 4. Bedbar mounting components

Assembly:

1. Thoroughly clean the bedknife mounting face on the bedbar of all rust and scale. Remove any material on the mounting face of the bedbar that will affect a good match–up with the bedknife.

2. Before installation, apply a coating of ”Never Seez”, or any material that will ease future disassembly of the bedknife mounting screws, to the threads before installation.

3. Use a torque wrench and special bedknife screw tool to complete tightening of the screws (Fig. 18). Tighten the screws to a torque of 250 in.–lb (28 Kgm) beginning with the center screw and tightening alternate screws toward each end to insure the bedknife will be flat against the bedbar.

4. Install the bedbar/bedknife assembly to the cutting unit.

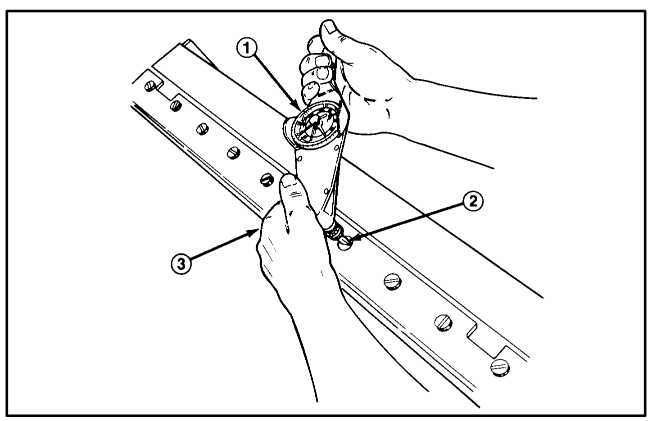


Figure 18

1. Torque wrench
2. Part No. 51–0880 Tool
3. Torque from the center out

Servicing the Reel Assembly

Disassembly:

1. Remove the guards from each end of the cutting unit and the front and rear roller assemblies (Fig. 19).

2. Remove the shoulder bolts, bushings and spacers from each end of the unit and remove the bedbar/bedknife assembly (Fig. 20).

3. Remove the inboard locknut from the adjuster pin, the fasteners for the bracket and remove the adjusting handle assembly from the side plate (Fig. 20).

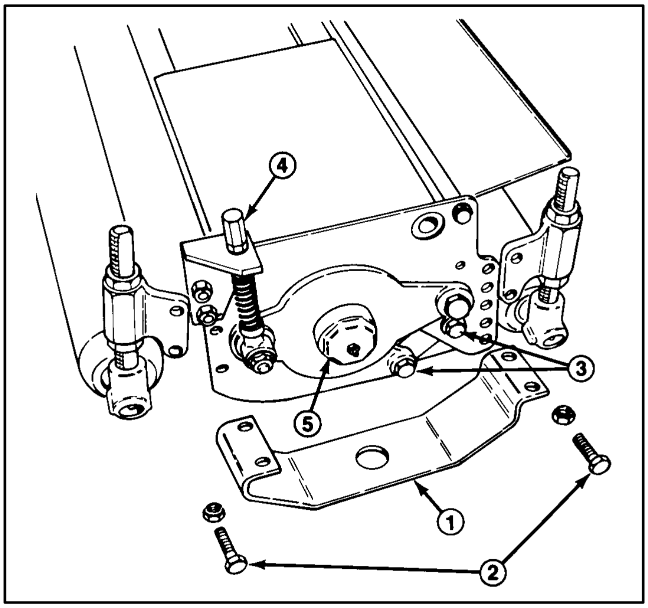


Figure 19

1. Guard
2. Mounting fasteners
3. Bedbar mounting assembly
4. Adjusting assembly
5. Dust cap

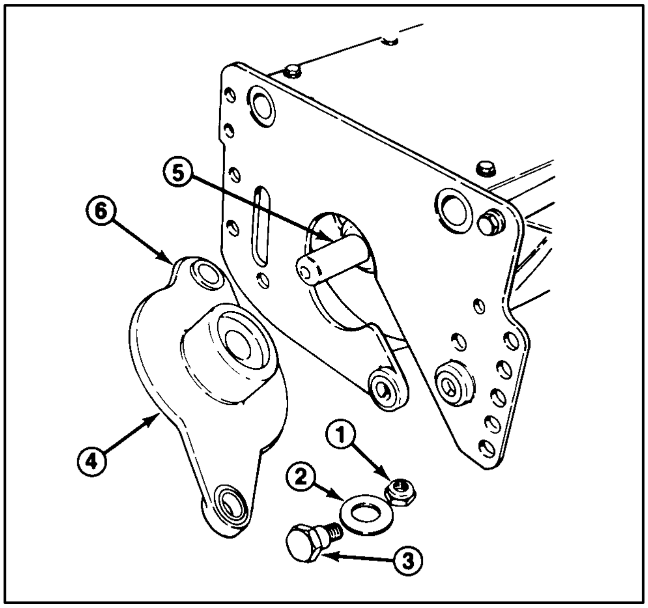


Figure 20

1. Locknut
2. Belleville washer
3. Shoulder bolt
4. Bearing housing
5. Reel shaft
6. Flange bushing

4. Disassemble the cone nut from the shoulder bolt securing the bearing housing to the side plate, remove the belleville washer and bolt and slide the bearing housing off the reel shaft (Fig. 21).

5. Disassemble the cover from the drive housing and remove the drive belt from the housing (Fig. 22).

6. Remove the reel capscrew, toothed washer and pulley washer from the reel shaft (Fig. 22). (Note: Capscrew is assembled with a thread locking compound).

7. Using a puller,remove the driven pulley from the reel shaft (Fig. 22). Remove the woodruff key from the reel shaft.

8. Remove the adjustment assembly and cone nut, belleville washer and shoulder bolt securing the housing to the side plate (Fig. 22). Remove the housing.

9. Slide the reel assembly out of the slots in the side plates.

10. To remove the bearing and seals from the drive housing, remove the retaining ring from inside the housing. Pry the outer seal out of the belt drive case side. Press the bearing and rear seal out from the outer side of the housing.

11. To remove the bearing and seal from the bearing housing, remove the dust cap (Fig. 19) and press the bearing and seal out of the housing.

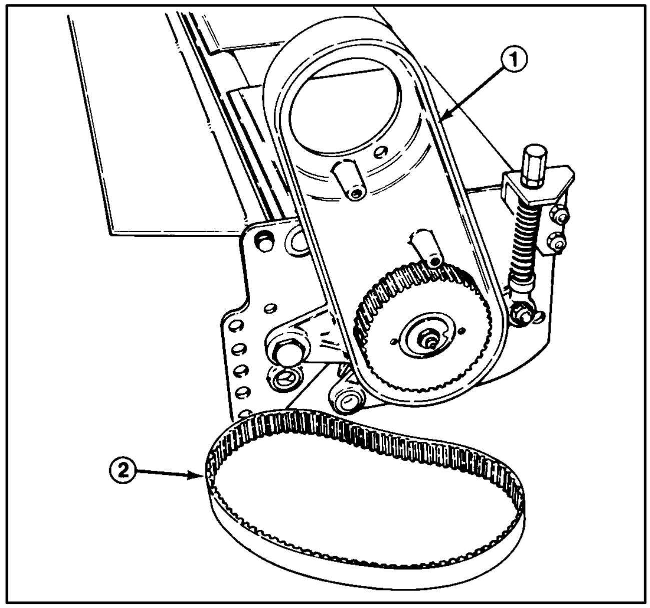


Figure 21

1. Drive housing (cover removed)
2. Drive belt

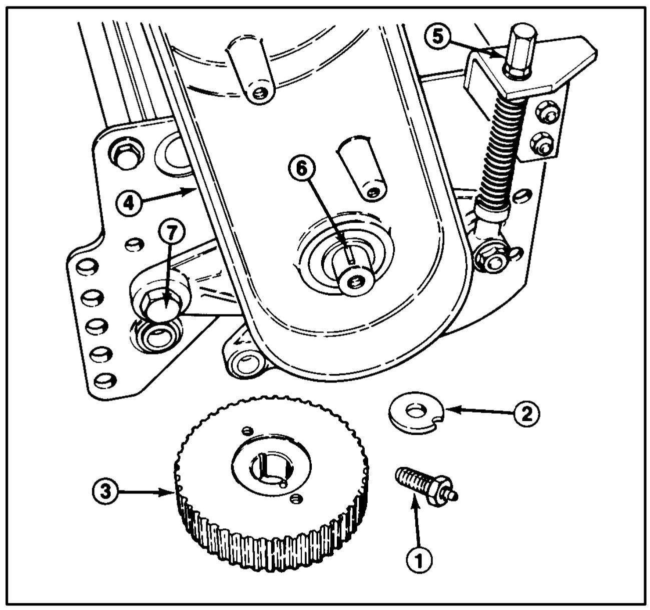


Figure 22

1. Reel capscrew
2. Pulley washer
3. Driven pulley
4. Drive housing
5. Adjustment handle assembly
6. Woodruff key
7. Drive housing fasteners

Assembly:

1. Inspect the flange bushings in the mounting holes for the drive housing and bearing housing for wear (Fig. 20). Replace, if necessary.

2. Assemble the outer seal (lip facing in to retain grease) into the drive housing using Loctite 242 retaining compound on the outer diameter. Apply a light coat of oil to the seal lips and insert the bearing assembly through the seal from the opposite side (Fig 23).

3. Apply a light coating of oil to the inner seal lips and install (lip facing away from the bearing and toward the reel) in the housing. Install the retaining ring to secure the assembly in the housing (Fig. 23).

4. Apply a light coat of oil to the seal lips of the seal for the bearing housing and install (lip facing away from the bearing) over the bearing assembly (Fig. 23).

5. Insert the bearing and seal in the housing and install the dust cap into the housing.

6. Assemble the reel assembly to the frame. Ensure the shield washer is installed on the drive housing end of the reel shaft. Align drive pin on reel shaft with slot in bearing and slide the drive housing onto the shaft.

7. Insert the shoulder bolt through the Belleville washer and rear housing mounting hole. Slide the bolt through the side plate mounting hole (Fig. 20). Install the cone nut locknut onto the bolt. Tighten the cone nut to 45 – 55 ft.–lbs.

8. Align the drive pinon the reel shaft with the notch in the bearing inner race and slide the bearing housing over the opposite end of the reel shaft. Insert the shoulder bolt and belleville washer through the rear bearing housing mounting hole. Slide the bolt through the side plate mounting hole. Install the cone onto the bolt. Tighten the cone nut to 45 – 55 ft.–lbs.

9. Install the woodruff key in the drive housing end of the reel shaft and install the driven pulley onto the shaft.

10. Ensure the slot in the pulley washer is aligned with the roll pin in the pulley and install the washer, toothed washer and reel capscrew (Fig. 21). Apply a medium strength thread locking compound to the reel capscrew during assembly. Torque the capscrew to 45 – 55 ft.–lbs.

11. Install the reel adjustment assemblies to each side plate. Install roll pins before tightening fasteners.

12. Install the bedbar/bedknife assembly.

13. Install the front and rear roller assemblies or skids.

14. To adjust the reel to the bedknife; refer to Reel to Bedknife Adjustment. To adjust the height–of–cut; refer to Height–of–Cut Adjustment section.

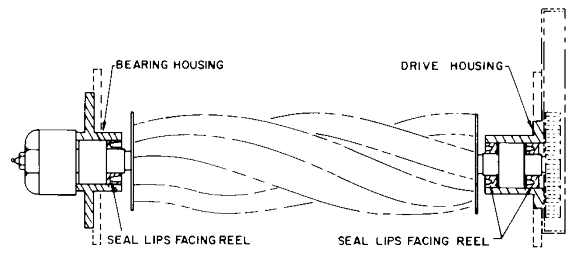


Figure 23

Roller Removal and Installation

1. Remove the fasteners securing the guard and roller adjustment housing to the side plate (Fig. 24) or unscrew the upper cone nut and drop the threaded rod out of the adjustment housing (Fig. 25).

2. The threaded rod and collar assembly can be removed from the roller by sliding it off the shaft at both ends (Fig. 25).

IMPORTANT: When assembling a new roller to the cutting unit mount the roller so that the roller shaft ”locknut” is on the right side of the cutting unit (Fig. 25). (As viewed by the operator sitting on seat of machine). This prevents the lock nut from loosening during operation.

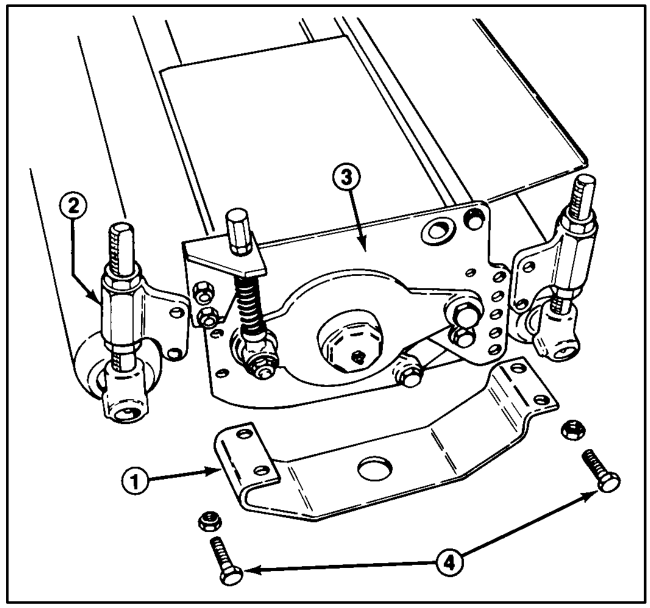


Figure 24

1. Guard
2. Roller adjustment housing
3. Side plate
4. Mounting fasteners

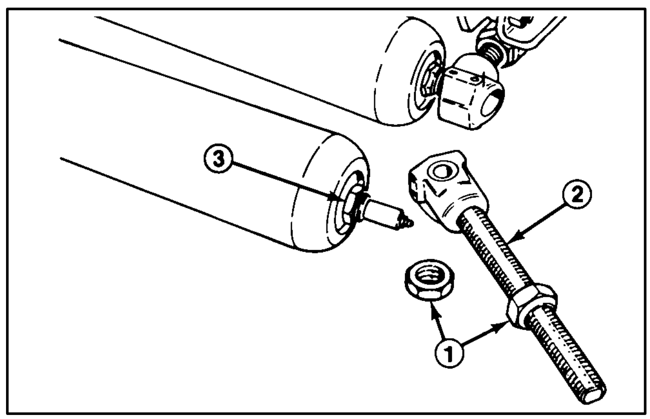


Figure 25

1. Cone nut
2. Rod and collar assembly
3. Flex locknut

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