Hydraulic System Theory of Operation

Section 04-01-02

Komatsu has made every effort to make this manual as accurate as possible based on the information available at the time of publication and printing. Continuous improvement and advancement of product design may cause changes to machines, which may not have been included in this publication. Komatsu reserves the right to make changes and improvements at any time. To ensure the most current information, please contact your service center.

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Scope of This Publication

HYDRAULICS THEORY OF OPERATION contains diagrams showing the hydraulic system theory of operation. It is ESSENTIAL for all personnel associated with the maintenance of this machine to become familiar with this information and the instructions contained in the other publications in this manual BEFORE operating or maintaining the machine.

Customer Responsibilities and Warranty Advisories

P&H wheel loaders are warranted in accordance with the warranty policy provided with the machine. The recommended operating and maintenance procedures set forth shall be followed to ensure warranty coverage is not jeopardized. Failure to comply with recommended operating and maintenance procedures may void machine warranty.

Any questions or problems relating to warranty policy or administration should be directed to Komatsu Service Center. Include the model and serial number, in-service date of the machine, and hour meter reading. **We especially draw your attention to the following safety advisors.**

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Safety

This publication contains special instructions that pertain to safety, operation, maintenance, and repair of the machine. Listed below are the signal words and symbols that precede these instructions and their meanings:

DANGER

- **The danger label indicates a hazardous situation which, if not avoided, will result in death or serious injury.**

WARNING

- **The warning label indicates a hazardous situation which, if not avoided, could result in death or serious injury.**

CAUTION

- **The caution label, used with the safety alert symbol indicates a hazardous situation which, if not avoided, could result in minor or moderate injury (includes the safety alert symbol).**

CAUTION

- **The caution label (without safety alert symbol) is used to address practices not related to personal injury only equipment damage.**

NOTICE

The NOTICE graphic is to indicate areas of importance to the reader that are not related to personal injury or machine damage.

Safety, Warnings and Cautions

CAUTION

- **Be sure all oil is suitable for climate at your location. See your oil vendor to assure the oil will flow at minimum temperature experienced. Using lubricants other than what is specified by the manufacturer (including viscosity differences) can cause severe damage to components.**

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General Description of the Loader Hydraulic Systems

The loader hydraulic system consists of the following principal circuits or sub-systems:

- Hydraulic pump gearbox
- Lift arms control and bucket control
- Vehicle steering
- Hydraulic oil cooling
- Engine cooling fan
- Main cooling air blower
- Driver oil filtration

Each of these circuits is equipped with an array of valves and controls to allow ease of handling in vehicle steering, operation of the bucket, and the other services.

A review of the various schematic diagrams in the section for each circuit provides detailed information on how each of these circuits functions. Machine locations for the components of each circuit are illustrated in the individual sections.

The hydraulic system is powered by an array of hydraulic pumps mounted on a hydraulic pump drive (gearbox), which is mounted in the front of the rear frame of the loader. Each of the circuits is powered by these pumps. The gearbox is driven by the generator. The generator is directly coupled to the diesel engine, which inputs a constant rotational speed of ~1800-1900 rpms for Tier I and Tier II engines through the generator to the gearbox. The pump casings are attached to the gearbox structure, and the shafts of the individual hydraulic pumps are coupled to gears internal to the gearbox.

The system hydraulic pumps are supplied in two basic types. The hoist and bucket cylinders, steering cylinders, cooling air blower fan, and engine cooling fan motor are powered with variable displacement pressure compensating axial piston pumps. The hydraulic oil cooling circuit and gearbox lubrication pumps are vane type pumps. Double acting cylinders are used for steering and working the bucket and lift arms while motors provide actuation for the cooling air and engine cooling fans.

The pumps supply hydraulic fluid to each motor or cylinder, depending on the function, via an arrangement of valves and piping. The hoisting and bucket operations requires; L-1350 three pumps, and L-1850/L-2350 four pumps and are therefore all rated at the same flow rate and maximum output pressure.

Fluid flow is managed by; specific function state-of-the-art valving, such as the hoist and bucket control valves (HUSCO valves) and by metering that ensures proper control of bucket and lift arm operations.

The main engine radiator-cooling fan is driven by a hydraulic motor connected via plumbing to one of the gearbox hydraulic pumps. The fan serves to cool the engine coolant, the circulating hydraulic oil, gearbox oil, drive converter cooling fluid and braking grids. A separate vane pump circulates the hydraulic oil through a small finned heat exchanger mounted adjacent to the engine radiator.

Hydraulic System Fundamentals

Several loader hydraulic system fundamentals should be clearly understood at this time:

a. Oil cooler inlet temperature should be about the same to slightly higher than system operating temperature.

b. Given the ambient temperature is LOWER than the inlet temperature, AND there is airflow over the core, the outlet oil temperature will be LOWER than the inlet oil temperature. Where the ambient temperature is HIGHER than the inlet oil temperature, the outlet temperature will rise toward the ambient temperature.

c. If the oil cooler outlet temperature is not lower than oil cooler inlet temperature (delta temperature) by the desired delta temperature, then;

1. The airflow path into or out of the oil cooler core may be blocked and airflow through the oil cooler core is reduced.

2. The fan speed is not correct (too low) and the airflow through the oil cooler is reduced.

3. The oil passages through the oil cooler core may be partially blocked and oil flow through the oil cooler core is reduced. Oil supplied to the oil cooler circuit would bypass the oil cooler core and the oil cooler regulator valve. See NOTE following item “4.”

4. The oil cooler pressure regulator valve is faulty (open) and is bypassing oil around the oil cooler core.

NOTICE

Items “3” and “4” above: For the main oil cooler, these problems would result in a LOWER oil temperature for the outlet oil, as the cooler pressure regulator valve is located on the hydraulic reservoir side of the temperature sensors, and the oil flow would bypass the oil cooler via the oil cooler pressure regulator valve. The reduced oil volume flowing through the main oil cooler would be exposed to the core for a longer time and therefore, more heat would be dissipated for the small oil flow passing the outlet temperature sensor.

- **The air temperature entering the oil cooler core is significantly LOWER than the inlet oil temperature.**

- **One or more temperature sensors are not reading correctly.**

Delta Temperatures

Typically, the delta temperatures will be the best indicator of hydraulic cooling system performance and condition.

Where hydraulic system temperatures are elevated, the increase in temperature is inversely proportional to the effectiveness of the system sealing and the hydraulic hose life. A single instance of the hydraulic system temperature rising above 175° F (80° C) starts the deterioration of the system sealing and reduces hydraulic hose life. Repeated instances tend to have an exponential effect on hydraulic system component life. O-rings, seals and hoses have shorter lives when the system runs hotter.

Maintaining the system in good condition means a reduction in oil leaks, less unplanned downtime and maintenance man hours for field repairs of leaks and hose failures, reduced cost in premature hose replacements and cost savings in extended component life of cylinders, pumps and control valves. The reduction in oil leaks has a very positive “flow-on” effect in other maintenance practices too, like reduced wash-down times for repairs and a cleaner environment for maintenance personnel, encouraging better maintenance practices.

All loaders have a warning system for high hydraulic oil temperature. While the command points for maximum fan speed enable are set at lower temperature levels, continuing operation of a machine with an oil cooler fault, e. g. the airway plugged with dust and dirt, would raise the temperature of the system to an unacceptably high level before the operator is informed of the fault.

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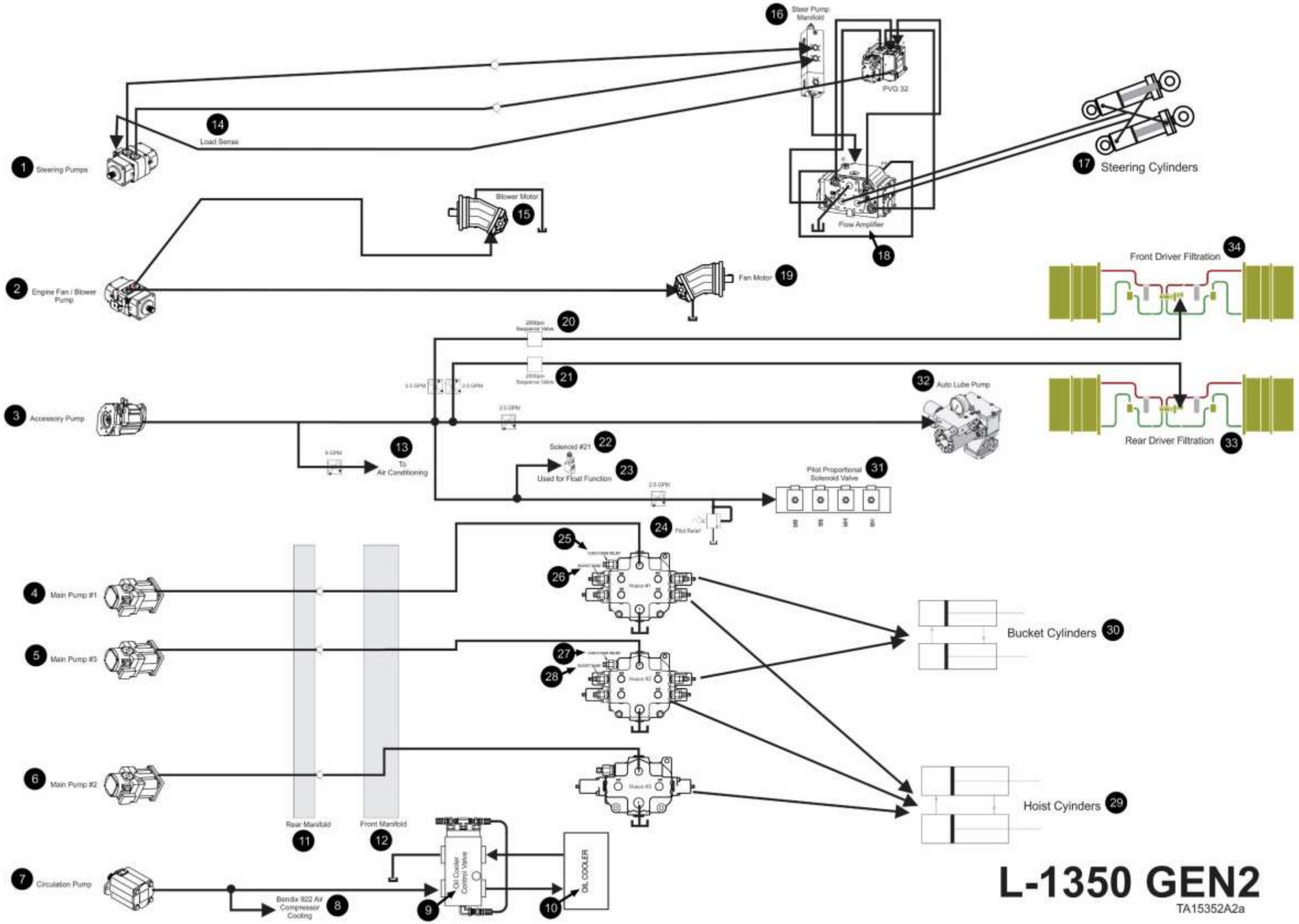
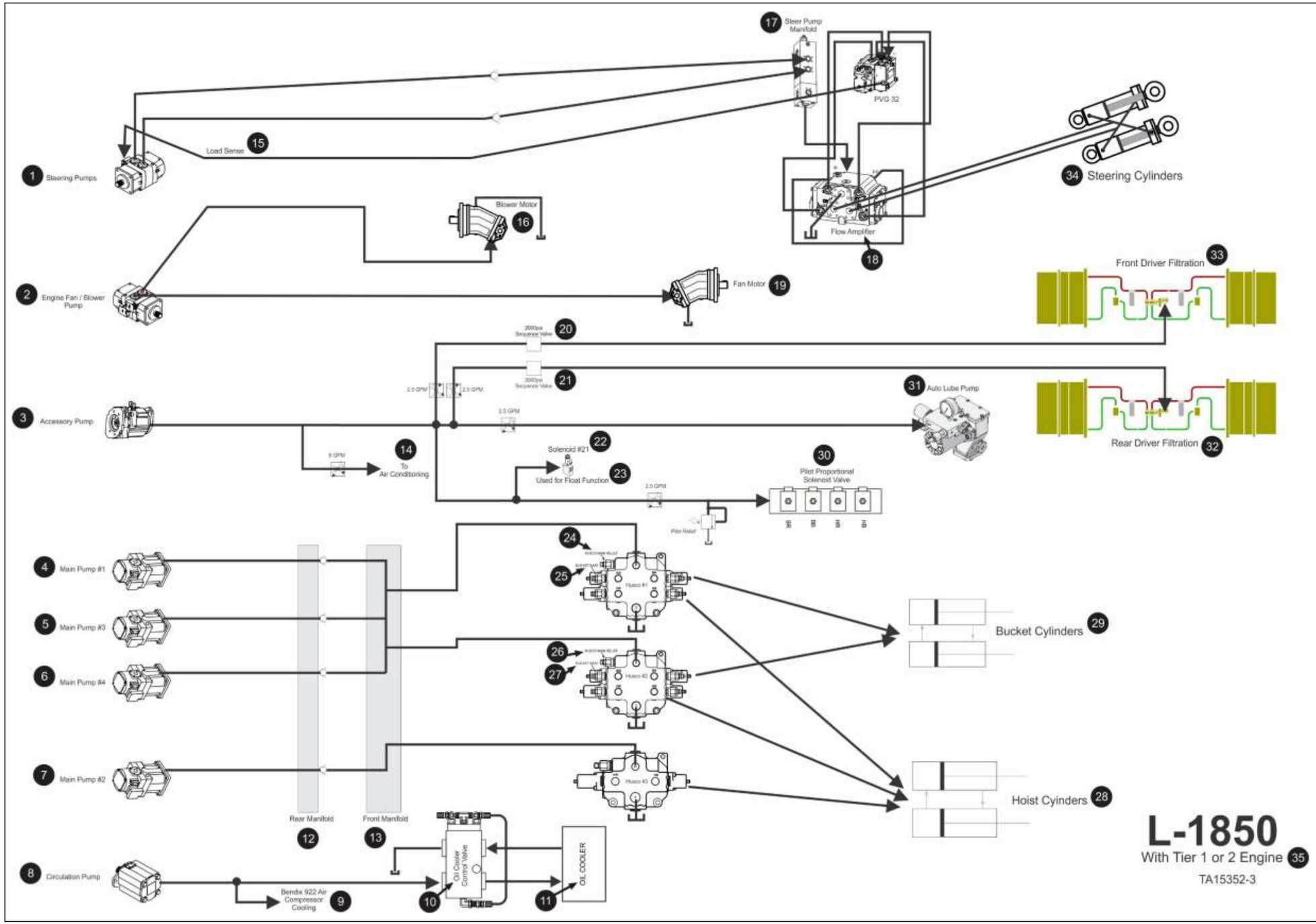


1. Steering Pump
1. Engine Fan/Blower Pump
2. Accesory Pump
3. Main Pump #1
4. Main Pump #3
5. Main Pump #2
6. Circulation Pump
7. Bendix 922 Air Compressor Cooling
8. Oil Cooler Control Valve
9. Oil Cooler
10. Rear Manifold
11. Front Manifold
12. To Air Conditioner
13. Load Sense
14. Blower Motor
15. Steer Pump Manifold
16. Steering Cylinder
17. Flow Amplifier
18. Fan Motor
19. 2000psi Sequence Valve
20. 2000psi Sequence Valve
21. Solenoid #21
22. Used for Float Function
23. Pilot Relief
24. HUSCO Main Relief
25. Bucket Base
26. HUSCO Main Relief
27. Bucket Base
28. Hoist Cylinder
29. Bucket Cylinder
30. Pilot Propotional Solenoid Valve
31. Auto Lube Pump
32. Rear Driver Filtration
33. Front Driver Filtration

Figure 1. Hydraulic operation overview (L1350 GEN2)



1. Steering Pump
2. Engine Fan/Blower Pump
3. Accesory Pump
4. Main Pump #1
5. Main Pump #3
6. Main Pump #4
7. Main Pump #2
8. Circulation Pump
9. Bendix 922 Air Compressor Cooling
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12. Rear Manifold
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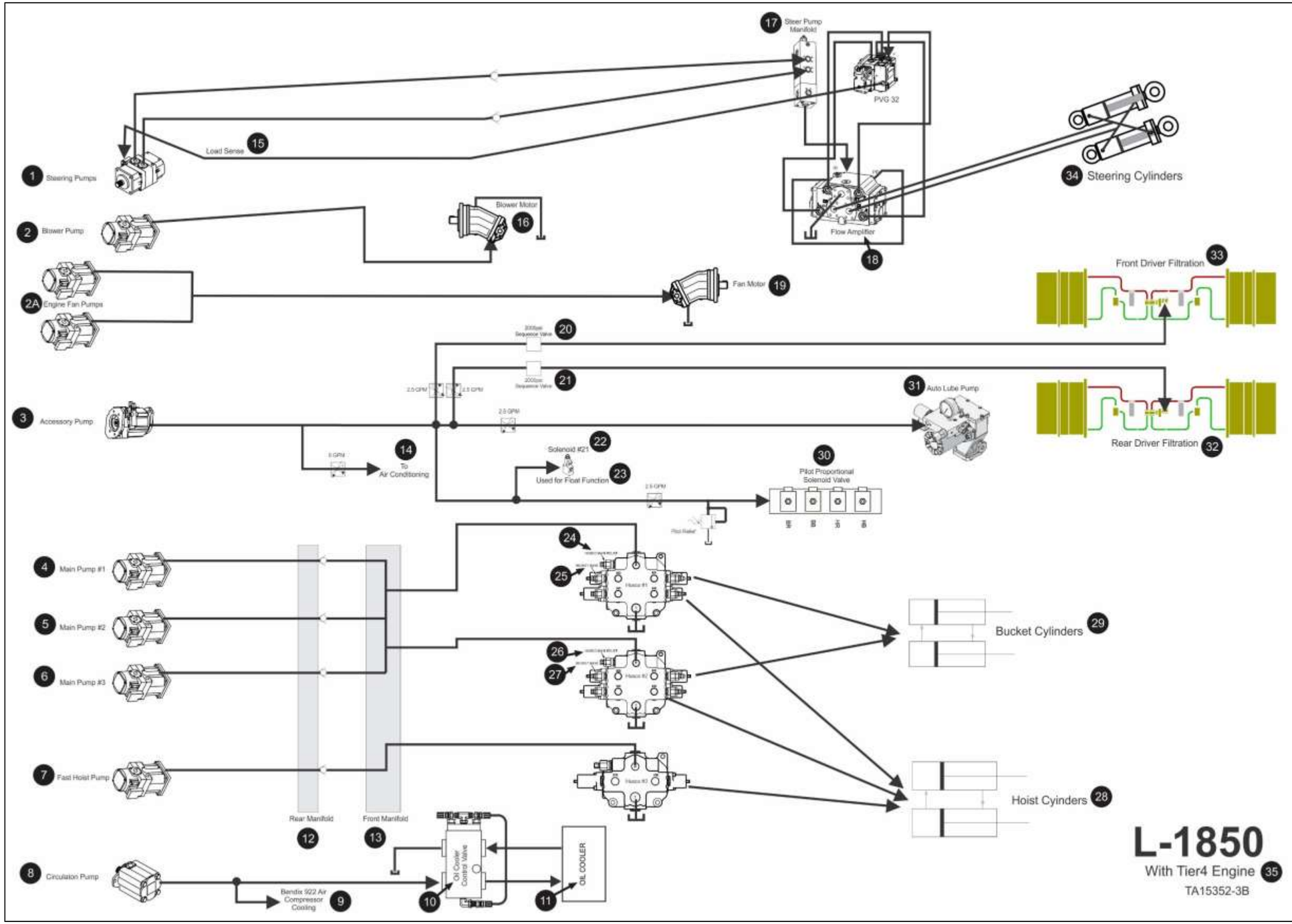
19. Fan Motor
20. 2000psi Sequence Valve
21. 2000psi Sequence Valve
22. Solenoid #21
23. Used for Float Function
24. HUSCO Main Relief
25. Bucket Base
26. HUSCO Main Relief
27. Bucket Base
28. Hoist Cylinders
29. Bucket Cylinders
30. Pilot Proportional Solenoid Valve
31. Auto Lube Pump
32. Rear Driver Filtration
33. Front Driver Filtration
34. Steering Cylinders
35. With Tier 1 or 2 Engine

Figure 2. Hydraulic operation overview (L1850 GEN2 With Tier 1 or 2 Engine)



1. Steering Pump
2. Blower Pump
2A. Engine Fan Pumps
3. Accesory Pump
4. Main Pump #1
5. Main Pump #3
6. Main Pump #4
7. Main Pump #2
8. Circulation Pump
9. Bendix 922 Air Compressor Cooling
10. Oil Cooler Control Valve
11. Oil Cooler
12. Rear Manifold
13. Front Manifold
14. To Air Conditioner
15. Load Sense
16. Blower Motor
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18. Flow Amplifier
19. Fan Motor
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22. Solenoid #21
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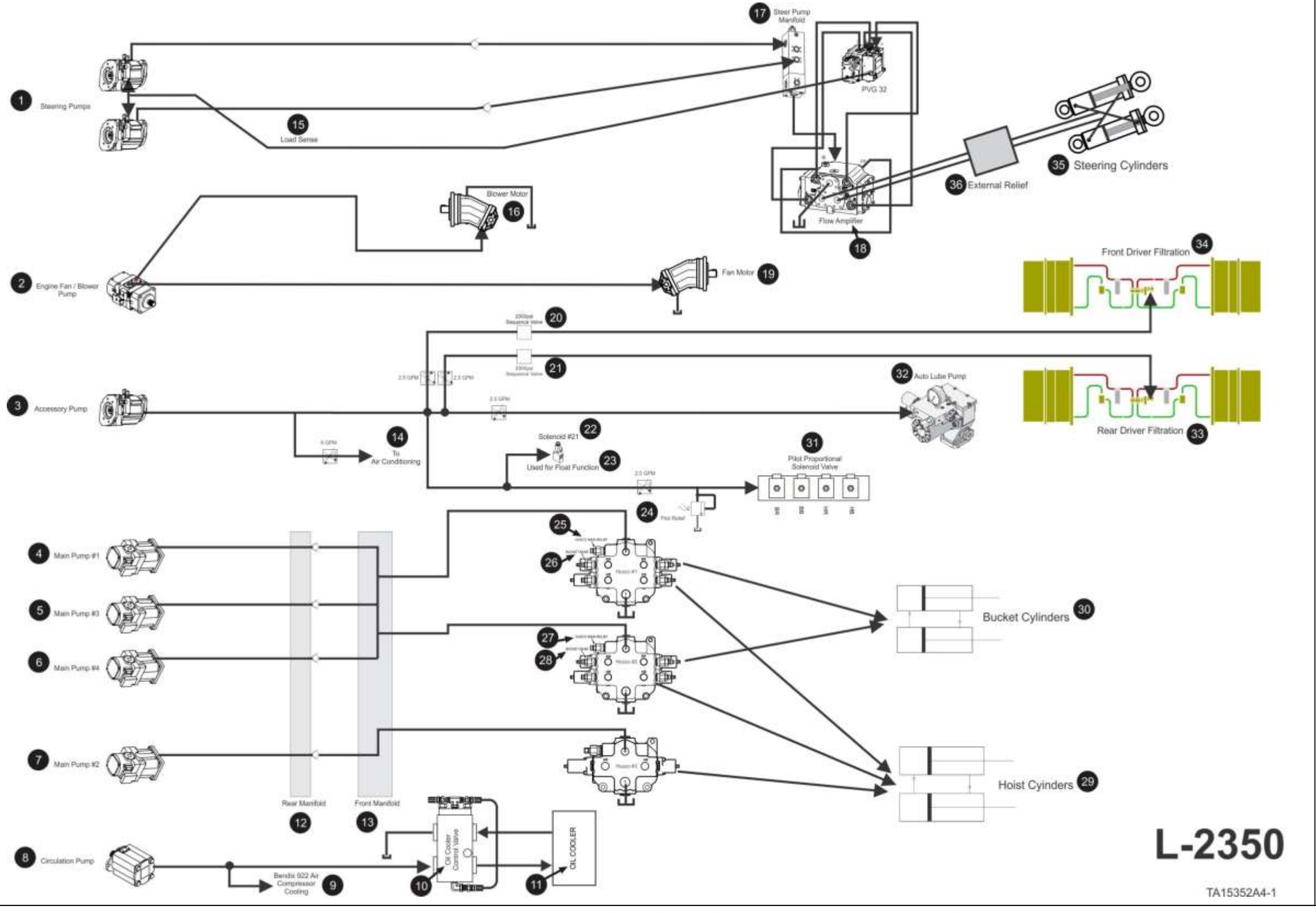
25. Bucket Base
26. HUSCO Main Relief
27. Bucket Base
28. Hoist Cylinders
29. Bucket Cylinders
30. Pilot Proportional Solenoid Valve
31. Auto Lube Pump
32. Rear Driver Filtration
33. Front Driver Filtration
34. Steering Cylinders
35. With Tier4 Engine

Figure 3. Hydraulic operation overview (L1850 GEN2 With Tier 4 Engine)



1. Steering Pumps
2. Engine Fan/Blower Pump
3. Accesory Pump
4. Main Pump #1
5. Main Pump #3
6. Main Pump #4
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27. HUSCO Main Valve
28. Bucket Base
29. Hoist Cylinders
30. Bucket Cylinders
31. Pilot Proportional Solenoid Valve
32. Auto Lube Pump
33. Rear Driver Filtration
34. Front Frame Filtration
35. Steering Cylinders
36. External Relief

Figure 4. Hydraulic operation overview (L2350)

Cleanliness Targets

To prevent particle contamination from reducing component life, a fluid cleanliness level must be maintained on a continuous basis. With regular sampling and proper analysis, used oil analysis should provide an early warning of machine faults unless severe damage resulted from a transient condition. Wear debris irregularities should always be followed up with further analysis to determine its source and severity.

The recommended cleanliness target is a two-digit ISO Code (ISO 4406). The two digits represent particles 5 micron and 15 microns in size respectively. The Particle Count data is obtained from the regularly scheduled oil sampling program. In addition to the ISO Cleanliness Level, the amount of Silicon and Water introduced into the fluid is considered as is the Viscosity and Total Acid Number (TAN).

Field Operations	
Hydraulic Systems	ISO 18/15 minimum
PTO Gearbox	ISO 19/16 minimum
Drivers	ISO 19/16 minimum
Silicon	<25 ppm
Water	<200 ppm
Viscosity	+15%/-10%
TAN	+2 over base oil
Fill Oils	
ISO 16/13 minimum	

Table 1. Recommended cleanliness targets

NOTICE

The used oil analysis limits provided are intended to be used as general interpretation guidelines and should not be the sole criteria judgment of fluid reclamation, continued use or change-out.

Analysis of Engine Lubrication Oil

Engine oil should be changed immediately if any contamination is present in concentrations exceeding limits shown in the engine manufacturer's service manuals for that particular engine. It should not be concluded that the engine is worn out based on a single measurement that exceeds manufacturer's limits. Imminent engine wear-out can only be determined through a continuous oil analysis program wherein the change in data or deviation from baseline data can be used to interpret condition of engine parts.

Characteristics relating to lubricating oil dilution should trigger corrective action to identify and fix the source(s). Confirmation of the need for engine overhaul should be based on operational data, increasing oil consumption, crankcase pressure, and physical inspection of the parts.

NOTICE

It is important to verify that the testing methods used will provide data as specified by the engine manufacturer's manuals.

NOTICE

The ultimate success of a lubricating oil analysis program rests with the owner or equipment manager. If good samples are taken, forwarded promptly, and the feedback used wisely, a lubricating oil analysis program will be very effective.

Lubrication Specifications

CAUTION

Be sure all lubrication/oil is suitable for the climate at your location. See your oil vendor to assure the oil will flow at minimum temperature experienced. Using lubricants other than what is specified by the manufacturer (including viscosity differences) can cause severe damage to components

Hydraulic Oil Lubrication Requirements

General Requirements

Hydraulic oils used in P&H wheel loaders must be category HV oils with improved viscosity/temperature properties, and zinc additives for wear in addition to those modifiers to inhibit oxidation, foam, rust, and corrosion.

ISO Viscosity Grade

ISO viscosity grade of hydraulic oil must be as follows:

Hydraulic System Operating Temperature Range*	ISO Viscosity Grade
45°C to 60°C (113°F to 140°F)	32
49°C to 74°C (120°F to 165°F)	46
57°C to 85°C (135°F to 185°F)	68

* Arctic conditions are defined as an ambient temperature consistently below 0°F (-18°C). These conditions represent a specialized field where extensive use is made of heating equipment before starting, and/or use specially developed oils for arctic conditions, such as synthetics.

Hydraulic Oil Properties

Properties of oil must comply with the following table:

Property	Value		
	ISO 32 Grade	ISO 46 Grade	ISO 68 Grade
Kinematic Viscosity at 40°C (cSt), min	28.8-35.2	41.4-50.6	61.2-74.8
Kinematic Viscosity at 100°C (cSt), min	5.0	6.1	7.8
Viscosity Index, minimum	150	140	140
Pour point, maximum [1]	-30°C	-30°C	-25°C
FZG Gear Scuffing (ISO 14635-1) Failure Load Stage, min.	10	10	10
Vane Pump Testing (DIN 51389-2) mass loss in mg, ring/vane, max.	120/30	120/30	120/30
Copper Corrosion (DIN EN ISO 2160 – 3 hrs@100°C), max	2		
Foaming (ISO 6247) maximum (ml/ml)	150/0		
Rust protection (DIN ISO 7120, Proc. A)	Passed		

1 Oil with different pour point may be used, provided the pour point is 5°C lower than the minimum ambient temperature.

Special Conditions

Special operating conditions or limited hydraulic oil availability may necessitate the use of oils having properties that fall outside this specification. Approval for use of these oils will be considered on a case-by-case basis. The use of non-recommended oils or the mixing of incompatible oils may damage components and void the warranty. Refer to the following information for a list of approved oils.

Approved Oils

Hydraulic oils listed in the following table are granted approval for use in loaders, within the specifications and conditions stated for each. Oils may be submitted for approval by providing the associated product data sheet to the Joy Mining Products engineering department. Oils submitted for approval will be considered on a case-by-case basis. Some may be required to go through a performance trial period prior to approval that is at the user's risk. Length of trial period will be determined by engineering review of the oil properties. The use of non-recommended oils or the mixing of incompatible oils may damage components and void the warranty. Approvals may be revoked at any time without notice.

Properties of the oil and conditions for use must comply with the following table:

Source	Description	Nominal Operating Temp (deg.C)[1]	ISO Viscosity Grade	Kinematic Viscosity at 40°C (cSt)	Kinematic Viscosity at 100°C (cSt)	Viscosity Index	Flash Point (deg.C)	Pour Point (deg.C)	Denison Spec	Rexroth Spec	Conditions / Notes
BP	Bartran HV	57-85	68	70.5	10.8	142	208	-39		Yes	approval based on history of use
BP	HLP-HM	45-65	46	46.0	6.8	95	215	-27	HF-0	RE90220	
BP	HLP-HM	55-75	68	68.0	8.8	95	226	-24	HF-0	RE90220	approval based on history of use
Caltex	Rando HD	45-65	46	44.0	6.8	110	238	-33	HF-0	---	approval based on history of use
Castrol	Hyspin AWH-M	45-70	46	46	8.32	150	215	-42	HF-0	RE90220	
Fuchs	Renolin B HVI Plus	47-73	46	46	8.1	149	186	-45	HF-0	---	approval based on history of use
Mobil	DTE 10 Excel	38-62	32	32.7	6.6	164	250	-54	HF-0	RE90220-01	
Mobil	DTE 10 Excel	46-72	46	45.6	8.5	164	232	-45	HF-0	RE90220-01	Ref. Joy p/n 4123226
Mobil	DTE 10 Excel	57-84	68	68.4	11.2	156	240	-39	HF-0	RE90220-01	
Mobil	DTE 20 (25)	45-65	46	44.2	6.7	98	232	-27	HF-0,-1,-2	---	
Mobil	Mobilfluid 424	51-77	---	55.0	9.3	145	198	-42	HF-0,-1,-2	Approved	Ref. Joy p/n 4123226
Shell	Tellus S3 M	46-67	46	46	6.8	105	220	-33	HF-0,-1,-2	---	approval based on history of use
Shell	Tellus S68	54-77	68	68	8.7	97	222	-30	HF-0,-1,-2	Yes	approval based on history of use
Shell	Tellus S100	63-86	100	100	11.2	96	234	-24	---	Yes	approval based on history of use
Shell	Tellus 68	54-77	68	68	8.7	98	225	-27	HF-0,-1,-2	Yes	approval based on history of use

1. Approval based on oil operating temperatures within range shown.

Table 2. Approved hydraulic oils

Model	Component	Capacity		Lubrication
L1350/L1850/L2350	Hydraulic Pump Drive Gearbox[2]	7 gallons	27 liters	SAE 75W-140W synthetic gear oil or SAE 80W-90W gear oil.
1 ARCTIC CONDITIONS represent a specialized field where extensive use is made of heating equipment before starting. 2 Refer to Section 3 of this manual. The hydraulic pump drive gearbox is factory equipped with synthetic oil.				

Table 3. HPD gearbox fluid specifications

Planetary Drive (Driver) General Lubrication Requirements

Lubricants used in Komatsu wheel loader planetary drives (drivers) must be synthetic gear oils with EP additive packages.

Component	Model and Size		Capacity		Lubricant
Planetary Drive	L-1350	51A2	36 gallons	135 liters	see following chart for approved lubricant
	L-1850	57	40 gallons	151 liters	
	L-2350	57	40 gallons	151 liters	

Table 4. Planetary drive (drivers) capacities

ISO Viscosity Grade

ISO viscosity grade of lubricant must be as follows for individual drivers: (see exception in endnote #3)

Driver	Conditions	
	Standard	Arctic*
51A/51A2/51B	460	220
57	460	220
* Arctic conditions are defined as an ambient temperature consistently below 0°F (-18°C).		

Table 5. Planetary drive lubricant viscosity grade

Lubricant properties

Properties of lubricant must comply with the following table: (see exception in endnote #3)

Property	Value	
	ISO 220 Grade	ISO 460 Grade
Kinematic Viscosity at 40°C (cSt)	198-242	414-506
Kinematic Viscosity at 100°C, minimum (cSt)	25	45
Viscosity Index, minimum	150	
Pour point, maximum [1]	-36°C	
4-Ball EP Test (ASTM D2783): Weld load (kg) [2]	250	
Timken OK Load (lb) [2]	60	
FZG Gear Scuffing (ISO 14635-1) Pass Stage	12	
Copper Corrosion (ASTM D130 – 3 hrs@100°C)	1B	
Foaming (ASTM D892, Sequence I, II, III) maximum values (ml/ml)	5/0, 10/0, 5/0	
Rust protection (ASTM D665 – Method B)	Pass	

Endnotes

[1] Lubricant with higher pour point may be used, provided the pour point is 5°C lower than the minimum ambient temperature.
[2] Oil manufacturer may report either 4-Ball EP test or Timken OK load. However, if both results are reported, fluid must meet requirements of both tests.
[3] **Mobil SHC Gear OH** is available in a lowest viscosity grade of 320. However, this upgraded lubricant will outperform the older-technology MobilGear SHC 220 in arctic temperatures due to its higher viscosity index and lower pour point.

Table 6. Planetary drive lubrication properties

Automatic Lubrication System

**Type of Grease	**Minimum Ambient Temperature	**Grease Grade
Pumpable auto lube grease fortified with extremely high pressure and anti-wear properties for slow speed, high shock application The grease is required to have minimum 3% to maximum 5% MoS_2 "Molybdenum Disulfide" additive.	+70ºF (+20°C) and above	NLGI #2 grease
	+50ºF (+10°C) and above	NLGI #1 grease
	+10ºF(-12°C) to 50ºF(+10°C),	NLGI #0 grease
	-30ºF(-34°C) to +10ºF(-12°C)	NLGI #00 grease

CAUTION

**** The values listed for grade and temperature in the table GREASE SPECIFICATIONS are only general guidelines for grease grade. Grease specifications can vary widely, depending on the location where the grease was blended and local conditions. Each grease meeting the 3-5% Molybdenum Disulfide requirement should also have the Lincoln Ventmeter number verified to make sure it meets system requirements. Use of incorrect grease that does not meet the Ventmeter specification may cause pump problems and the injectors may not cycle and refill properly.**

Depending on the characteristics of the grease it is possible that a thicker NLGI grade of grease may be used at lower temperatures than shown in the table GREASE SPECIFICATIONS as long as the grease meets the Lincoln Ventmeter specifications.

NOTICE

LINCOLN VENTMETER SPECIFICATION

At a temperature that is 10°F (5°C) below the minimum ambient temperature to which the machine will be exposed, the Lincoln Ventmeter reading should be:

Injector Type	Ventmeter Reading
SL-1 injectors	500 psi (34.5 bar) or less
SL-V and SL-V XL injectors	900 psi (62.0 bar) or less

For Example:

- The minimum mine temperature is 0°F (-17.8°C).

Mine site temperature	Minus	10°F (5°C)	Equals	Target Temperature
0°F (-17.8°C)	minus	10°F (5°C)	=	-10°F (-23.3°C)

Examples:

Grease/Grade	Ventmeter Reading	Target Temperature	Acceptability
Brand XYZ	900 psi (62 bar)	15°F (-9.4°C)	Unacceptable
Brand ABC	400 psi (27.6 bar)	-10°F (-23.3°C).	Acceptable

The Lincoln Ventmeter test is typically performed by Lincoln and/or the grease manufacturer, by using a Ventmeter tool as shown.

All Machines	Lincoln Automatic Lubrication Pump	15 oz.	444 ml.	10W30 motor oil

Table 7. Auto lube pump lubrication and grease specifications