DANFOSS Steering System
Operation & Troubleshooting

Foreword
For a number of years Danfoss has marketed a hydrostatic steering system designed especially for large vehicles. Many large vehicles, such as loaders, dumpers, graders, etc., have articulated steering. This steering method makes large demands on the regulation of oil flow to the steering cylinders.

The kind of conditions involved can be illustrated by Figure 1.

The diagram shows that the rear section will try to drive straight ahead when the vehicle is steered to the right. This results in negative steering forces. The steering system must be able to control these forces to prevent jack-knifing. Additionally, alternation between negative and positive steering forces occur, which must also be controlled by the steering system.

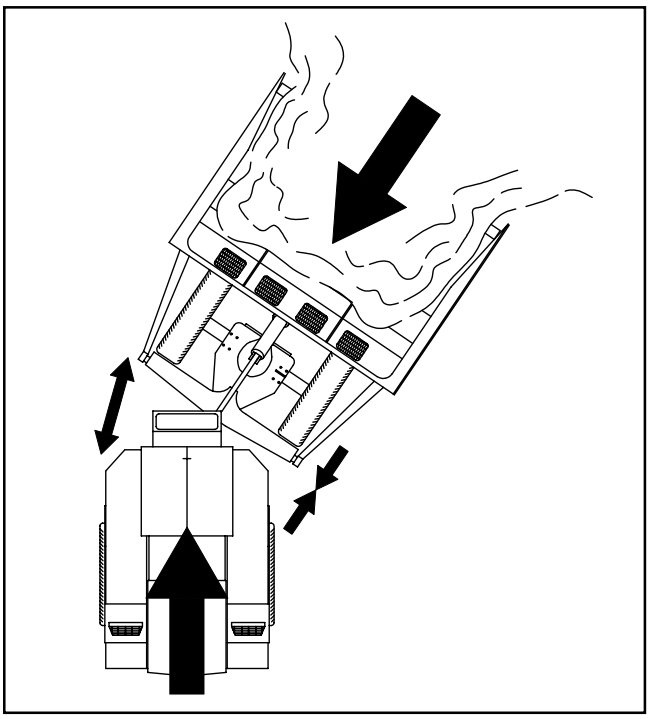

Figure 1

Another consideration on vehicles with articulated steering is the effect of side acceleration on the driver. The steering system must reduce side acceleration as much as possible, but not adversely affect directional stability. Steering systems with the Danfoss flow amplifier are designed to cope with all these factors.

Description
The steering system consists of the steering control unit and a flow amplifier valve.

When the steering unit is activated, a controlled oil flow is directed to the flow amplifier valve. This oil flow is amplified and the total flow is directed to the steering cylinders.

The steering unit provides a fixed displacement of oil per revolution of the steering wheel and the amplification factor of the flow divider valve is 8. Therefore, total oil output is eight times the output of the steering control unit.

With this system it is possible to combine the steering and working hydraulics. As can be seen in Figure 2, a priority valve is built into the flow amplifier valve. The priority valve ensures that the steering has first priority on oil flow from the hydraulic pump. The oil flow not used for steering is then sent via the "EF" line (external flow) to the working hydraulics. If the steering wheel is not turned, the entire oil flow is directed to the working hydraulics at minimal pressure loss.

The principle applied to the controlled operation of this system is called "load sensing." As the name suggests, it is a system in which the load is sensed or registered. The sensed signal is used, in this example, to control the priority valve in the flow amplifier valve so that oil flow and oil pressure precisely match momentary demands.

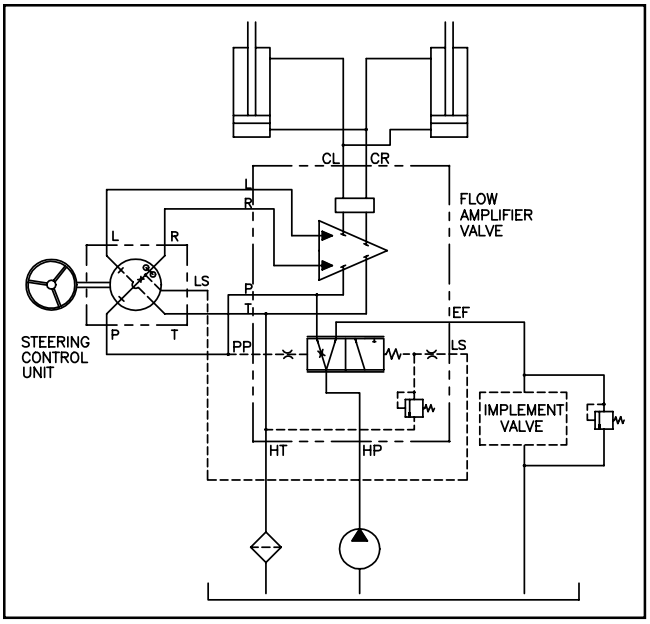

Figure 2

Technically, what happens is that the load signal (a pressure) is registered between the load (steering cylinder) and the down-stream side of a variable metering orifice in the steering unit. This signal (a pressure) is led to the priority valve spring chamber which regulates the oil flow so that the pressure drop (△p) across the metering orifice is always constant.

Hydraulic Circuit Arrangement

The hydraulic system is supplied by a hydraulic gear type pump. The output is directed to the flow amplifier via a high pressure filter.

Oil flow is directed to the auxiliary hydraulics via the "EF" port of the flow amplifier and is subject to pressures of up to 4,000 psi. This is the load pressure developed in the working (implement) circuits.

Description Of Operation

Figure 3 shows a diagram of the DANFOSS steering system which includes the following:

Pump
Pressure Filter
Steering Unit
Flow Amplifier

The following valves are integrated in the flow amplifier (refer to item numbers in Figures 3 and 4):

1. Relief valve.
2. Priority valve.
3. Combined pressure control/amplifier and emergency valve.
4. Counter pressure valve with suction (only flow amplifiers intended for displacements from 2,000 cm /rev and up).
5. Combined shock and suction valves.
6. Directional valve.

Neutral Position

Important observations to be made in the neutral position are as follows:

(A) The steering unit "P" port is closed and the amplification valve is closed at circular chamber "M."

(B) The steering unit ports L, R and T are interconnected and drained to tank via the T port of the flow amplifier. This connection allows the directional valve (Pos 6.) to always be spring-centered in the neutral position. Therefore in neutral, knocks and impacts from the steering cylinders are not transmitted to the steering unit. For this reason the flow amplifier is termed a non-reactive type valve.

(C) The priority valve spring chamber is also drained to tank via the amplifier "feed back" LS line and its interconnection with steering unit ports L, R and T.

(D) Also, prior to start up the 7 bar bias spring forces the priority valve hard over to the left, which will in fact almost close off the "EF" port of the flow amplifier.

On start up the oil flow enters the "HP" port of the flow amplifier and is dead headed at the steering unit "P" port and at the amplification spool. Pilot pressurel, which is shown externally connected to the "PP" port, rapidly increases and as the spring chamber of the priority valve is drained to tank in the neutral position, the priority valve is forced to the right sufficiently to achieve a balance against the 7 bar bias spring. This also has the effect of uncovering the "EF" port and allowing pump flow to divert to auxiliary hydraulics.

This pressure balance provides a priority stand-by pressure of approximately 7 bar at the steering unit "P" port and amplification spool circular chamber "M." The pump flow passing from "HP" to "EF" would also have a similar pressure drop at lower flow rates. Of course this pressure drop (AP) would change at higher flow

rates due to port sizing and downstream line losses in the auxiliary hydraulics. This increased pressure drop across "HP" to "EF" which is also sensed at "PP" could possibly have some negative effect on priority valve response time, resulting in steering "hard point" on certain applications.

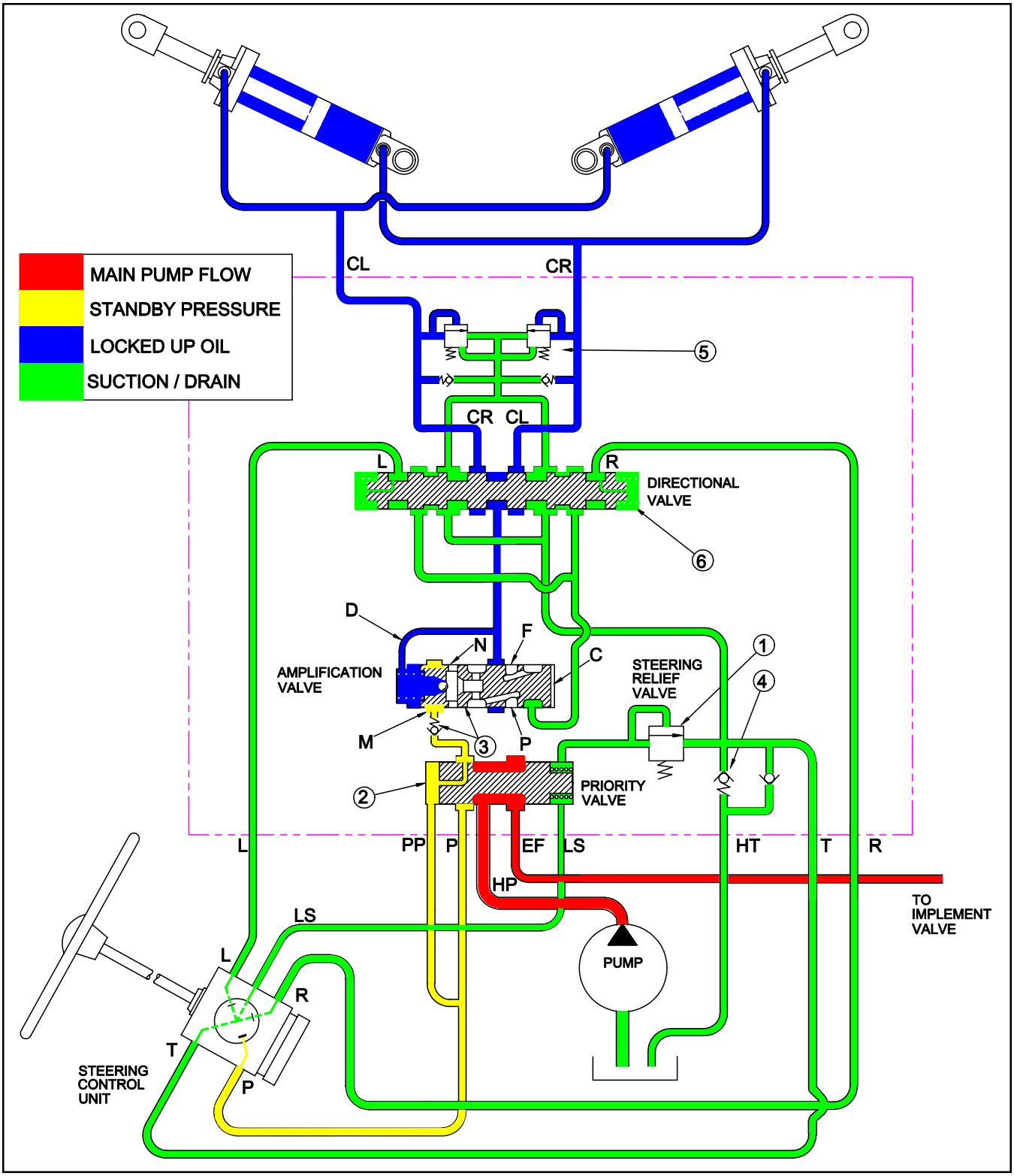

Figure 3

Steering Position

Figure 4 shows steering to the right. When the steering unit is activated, a load signal sensed downstream of the metering orifice is passed to the priority valve via the amplifier feed back "LS" line.

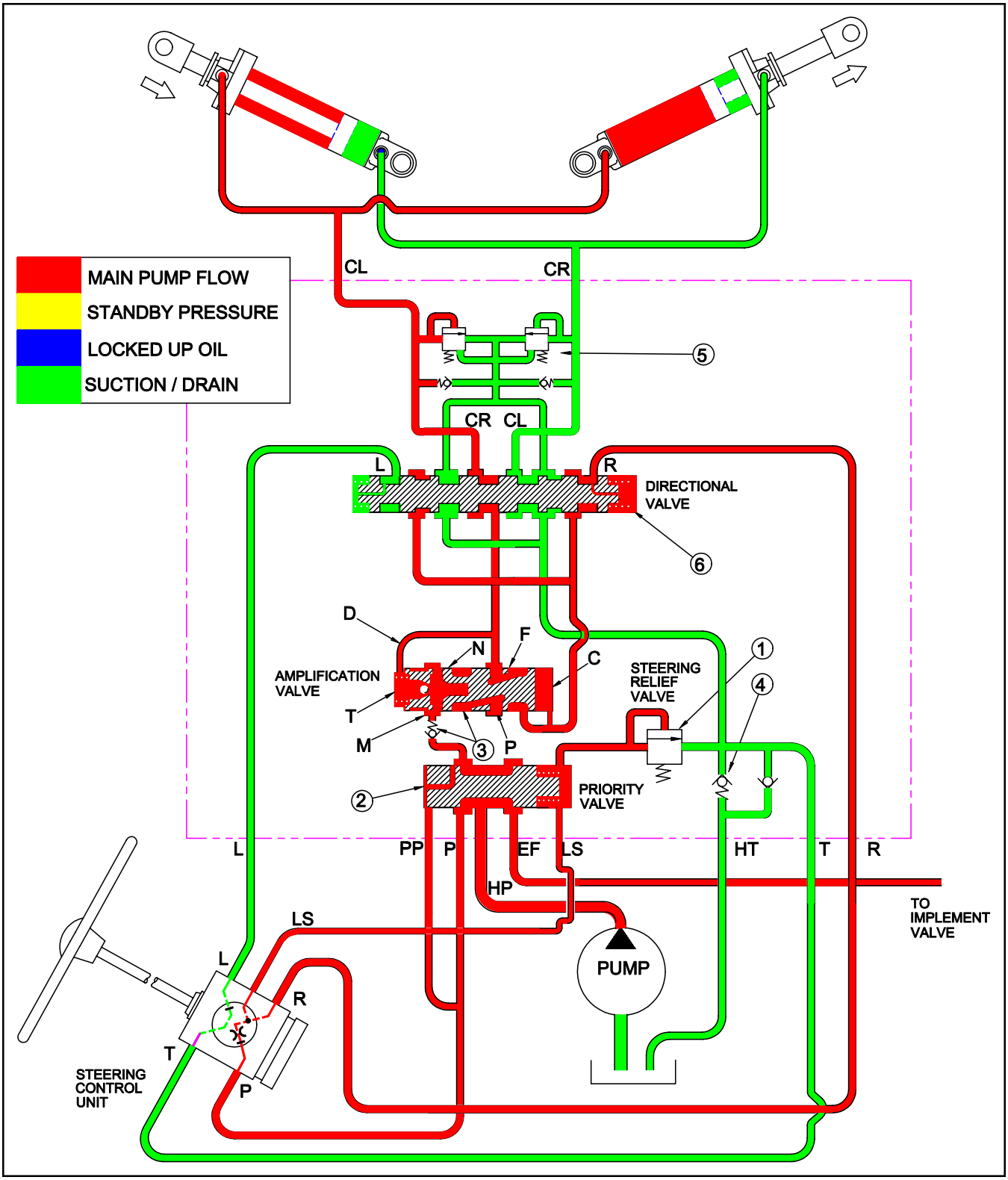

Figure 4

The priority valve then takes a position corresponding to the requirement in the steering system and allows oil to pass across the "P" port of the steering unit for discharge through to the "R" port of the flow amplifier. The directional valve (item 6) is activated by precisely matched oil flow and oil pressure being transmitted across a drilling (orifice) in the spool whereby the spool is moved to the left.

Oil at the opposite end of the directional valve is metered back to tank via a similar drilling and orifice, thus providing controlled spool movement.

The opening now allows connection between the pilot flow and the pressure control/amplifier valve (Pos. 3). The pilot pressure in chamber "C" will move the valve to the left and a passage for pilot flow will therefore be possible across the holes "F."

The main pump flow will now pass from the priority valve to the circular channel "M." As the spool was moved to the left, the passage will now be open across the holes "N" to the chamber “T.”

The spool will now go to a position so that the pressure in chamber "T" will equal the pressure In chamber "C." The passage is now also open for the main pump flow across holes "P."

The main pump flow and pilot flow will now merge in the ratio of 8:1 (being the area ratios of holes "F" and "P") and will be passed across the directional valve (item 6) to the steering cylinders.

The return oil from the opposite end of the steering cylinders will pass across the directional valve to tank via the "HT" port of the flow amplifier.

The surplus oil not required for steering is passed to the "EF" port of the flow amplifier and on to the working (implement) hydraulics.

If, for example, the steering speed is increased, it will result in a larger opening of the LS metering orifice in the steering unit. This will cause a fall in pressure drop across the metering orifice. The priority valve will immediately compensate for this by allowing more oil to the steering unit so that the pressure drop across the LS orifice will again reach its constant level of approximately 7 bar $\triangle$P.

This of course will also allow more of the main pump flow to pass through the amplification spool and merge with the increased pilot flow in exactly the same ratio, in this case, of 8:1.

With the increased steering flow it should be noted that less oil is now passing to the implement hydraulics via the "EF" port.

Maximum Steering Pressure

When steering against a lock position the pressure in the amplifier feed back LS line will rise to the set pressure of the pressure relief valve (Pos. 1). This makes the priority valve maintain a constant pilot pressure to the flow amplifier corresponding to the relief valve setting pressure plus the stand-by pressure.

In this situation the entire flow will be passed on to the auxiliary hydraulics via the "EF" port. In other words the priority valve in this situation operates just like a compound type relief valve.

Over-run/Negative Forces

In these situations, the directional control valve (Pos. 6) will throttle the return oil from the steering cylinders; therefore, there will be complete control under any steering maneuver.

Kick Back

Kick back cannot normally be transmitted to the steering unit on early design valves. This is because the pressure control/amplifier valve (Pos. 3) will open only when the pilot pressure in chamber "C" is higher than the pressure in chamber "T." The "T" chamber is connected to the cylinder side.

However, in amplifier valves designed later, the "C" pilot chamber is not readily drained to tank in the neutral position. Therefore, it is necessary to incorporate a small check valve in the "P" line connecting the steering unit to the flow amplifier to prevent any possible kick back occurring.

Pressure Peak Protection

In order to avoid pressure peaks in the steering cylinders, the flow amplifier is supplied with shock valves in both "CR" and "CL" ports (Pos. 5). Suction valves are also incorporated within each shock valve in order to avoid cavitation.

Flow amplifier valves with a displacement from 2,000 cm/rev and up will incorporate a counter-pressure valve (Pos. 4). This valve will ensure a proper charge of the suction valves.

Manual Steering

If the hydraulic pump should fail, it will be possible to operate the steering manually, depending on machine/vehicle weight on the steered wheels.

In these situations, the steering unit will act as a hand pump. The manually operated pressure from the steering unit will displace all the valves in the flow amplifier as during normal operation, except there will be no amplification, since only the flow from the steering unit will be passed to the steering cylinders.

Troubleshooting

Before removing pipes, hoses and hydraulic components, it is extremely important to not only clean the defective component carefully, but also to clean the surrounding area and neighboring parts. You should also remove paint from pipes, couplings, etc.

In order to prevent dirt from entering the system, holes, hoses and pipes should be plugged immediately after removal.

Teflon tape should never be used for system mounting. Residues from teflon may enter the system and upset the operation.

Before inspecting the steering in order to determine the cause of malfunction, the oil level should be checked with the pump operating (at low speed). The entire steering system may also need to be bled. Ensure the oil filter and the orifice in the charge plug are not clogged.

Also, it is important to maintain extremely good filtration, such as using a pressure filter with an absolute rating. The correct type of oil should be used as well.

Troubleshooting Chart

PROBLEM	CAUSE	REMEDY
Heavy turning of wheel.	1. Insufficient oil pressure or no oil pressure at all. a. Pump not operating. b. Pump defective. c. Incorrect pump rotation. d. Pump worn. 2. Relief valve sticking when open or the valve pressure is too low. 3. Blocked LS orifice or dirt particles delaying spool movement in flow amplifier. 4. Very high implement system pressures acting on EF port. 5. Misplaced anti-cavitation ball in steering unit.	1. a. Make the pump operate. b. Repair or replace the pump. c. Alter direction of pump rotation. d. Replace the pump. 2. Repair, clean and reset the relief valve. 3. Remove and clean the whole system. Change all filter elements. 4. Contact your dealer for help under these special circumstances. 5. Dismantle steering unit and reposition or replace anti-cavitation ball.
"Motoring" – steering wheel turning by itself.	1. Leaf springs have sagged and thus have reduced elasticity or no elasticity at all (broken springs or otherwise). 2. Squeezed spool/sleeve. Possible insufficient spool/sleeve clearance.	1. Replace leaf springs in control unit. 2. Contact your dealer. In the meantime, lower the relief valve setting.
Repeated steering wheel corrections required. Impossible to make steering go to neutral position. Steering to left or right on own accord.	1. Leaf springs without elasticity or broken. 2. Steering column out of alignment with steering unit. 3. Insufficient clearance between steering column and coupling.	1. Replace leaf springs in control unit. 2. Align steering column with steering unit. 3. Adjust the clearance.
Backlash.	1. Splines of cardan shaft worn or broken. 2. Leaf springs without elasticity or broken.	1. Replace cardan shaft. 2. Replace leaf springs in steering unit.
Shimmy – abnormal vibration of steering (tire pattern can cause vibration)	1. Air accumulation in steering system. 2. Worn mechanical connections and wheel bearings. 3. Leaky dual shock valves and suction valves or broken springs.	1. Bleed the cylinders and find the source of the air accumulation and have it removed. 2. Replace worn parts. 3. Repair or replace dual shock valves, suction valves or the springs.
The steering wheel can be turned continuously without turning the wheels.	1. No oil in the tank. 2. Steering cylinder piston seals leaking badly. 3. Shock valve failure.	1. Fill system with clean oil and bleed the system. 2. Repair or replace cylinder(s). 3. Remove shock valves and repair or replace, then reset pressure level.

Troubleshooting Chart

PROBLEM	CAUSE	REMEDY
The operator cannot feel resistance when the steered wheels turn to the stops.	1. Shock valves are set to approximately the same setting as steering PRV. 2. Dirt particles causing shock valve erratic operation.	1. Adjust shock valve settings to at least 500 psi (34 bar) higher than steering PRV setting. 2. Clean system and fill with clean oil.
Heavy impacts in steering wheel in both directions.	1. Incorrect setting of cardan shaft and gear wheel setting (timing).	1. Adjust setting (timing).
Kickback from system.	1. Dirt particles delaying spool movement in flow amplifier.	1. Remove and overhaul flow amplifier. Sample test oil to determine contamination source. Clean system, change filter elements and fill with fresh oil.
Slow steering.	1. Insufficient oil to the steering unit due to defective or worn pump. 2. Weak or damaged priority valve spool bias spring.	1. Replace the pump. 2. Check or replace spring.
The steering wheel does not pass to neutral position – tendency to "motor."	1. Dirt particles between spool and spring. 2. Squeezing between spool and sleeve caused by a too-high system pressure. 3. Leaf spring broken or without elasticity. 4. Mechanical binding in steering column.	1. Clean spool and sleeve, or replace steering unit. Clean entire system. 2. Adjust pump pressure to the correct value at steering PRV. 3. Replace with new springs. 4. Correct and adjust where necessary.
When turning the steering wheel, the steered wheels are activated in the opposite direction.	1. The hydraulic hoses to the steering cylinders have been reversed. 2. Incorrect mounting and setting of cardan shaft and gear wheel set.	1. Correctly connect the hoses. 2. Correct the setting.
Steering power too low (possibly to one side only).	1. Pump pressure too low. 2. Malfunctioning shock valve.	1. Correct the pump pressure or adjust the steering PRV in the flow amplifier valve. 2. Remove and repair or replace shock valve.
Leakage at input shaft, end cover on gear wheel set.	1. Defective shaft seal. 2. Screws have come loose. 3. Defective discs or O-rings.	1. Replace shaft seal. 2. Tighten the screws to 266 in-lb (3 N-m). 3. Replace discs or O-rings.