

Isolating and Troubleshooting Problems in a Hydraulic Circuit with Step-by-Step Testing Procedures

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Abstract

There can be many reasons for a hydraulic system failure. In this paper, various methods of isolating the problem are presented. The central idea of isolating the problem is to first trace it to one area, and then either check or replace each component of that area till the problem is fixed. As the hydraulic circuit consists of many components, it is often not possible to detect the cause of the problem by its symptoms. That's why it is important to know the steps and procedures to isolate a problem for fixing it.

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INTRODUCTION

Many of the failures in a hydraulic system show similar symptoms: a gradual or sudden loss of high pressure, resulting in loss of power or speed in the cylinders. In fact, the cylinder may stall under light loads or may not move at all. Often the loss of power is accompanied by an increase in pump noise, especially as the pump tries to build up pressure. Any major component, i.e., pump, relief valve, directional valve, or cylinder, could be at

fault. In a sophisticated system other components could also be at fault, but this would require the services of an experienced technician.

ISOLATING PROBLEMS IN A HYDRAULIC CIRCUIT

By following an organized step-by-step testing procedure in the order given here, the problem can be traced to a general area. Then, if necessary, each component in that area can be tested or replaced.

Pump Suction Strainer

Cavitation of the hydraulic pump is the most frequent mode of hydraulic system failure. The most frequent source of cavitation is suction flow restrictions caused by dirt buildup on the suction strainer. This can happen on both new and older systems. It produces the symptoms just described: increased pump noise and loss of high pressure and/or speed.

If the strainer is not located in the pump suction line, it will be found immersed below the oil level in the reservoir. Some operators of hydraulic equipment never give the equipment any attention or maintenance until it fails. Under these conditions, sooner or later, the suction strainer will probably become sufficiently restricted to cause a breakdown of the whole system and damage to the pump.

The suction strainer should be removed for inspection and should be cleaned before reinstallation. Wire mesh strainers can best be cleaned with an air hose, blowing from the inside out. They can also be washed in a solvent that is compatible with the reservoir fluid. Kerosene may be used for strainers operating in petroleum-based hydraulic oil. Do not use gasoline or other explosive or flammable solvents. The strainer should be cleaned even

though it may not appear to be dirty. Some clogging materials cannot be seen except by close inspection. If there are holes in the mesh or if there is mechanical damage, the strainer should be replaced.

When reinstalling the strainer, inspect all joints for possible air leaks, particularly at union joints. There must be no air leaks in the suction line. Check reservoir oil level to be sure it covers the top of the strainer by at least 3 inches at minimum oil level, which is with all cylinders extended. If it does not cover to this depth, there is danger of a vortex forming that may allow air to enter the system when the pump is running.

Pump and Relief Valve

If cleaning the pump suction does not correct the trouble, isolate the pump and relief valve from the rest of the circuit by disconnecting so that only the pump, relief valve, and pressure gauge remain in the pump circuit. Cap or plug both ends of the plumbing that has been disconnected. The pump is now deadheaded into the relief valve. Start the pump and watch for pressure buildup on the gauge while tightening the adjustment on the relief valve. If full pressure can be developed, obviously the pump and relief valves are operating correctly, and the trouble is to

be found further down the line. If full pressure cannot be developed in this test, continue with step 3.

Pump or Relief Valve

If high pressure cannot be obtained in step 2 by running the pump against the relief valve, further testing must be conducted to see whether the fault lies in the pump or in the relief valve. Proceed as follows. If possible, disconnect the reservoir return line from the relief valve. Attach a short length of hose to the relief valve outlet. Hold the open end of this hose over the reservoir filler opening so that the rate of oil flow can be observed. Start the pump and run the relief valve adjustment up and down while observing the flow through the hose.

If the pump is bad, there will probably be a full stream of oil when the relief valve adjustment is backed off, but this flow will diminish or stop as the adjustment is increased. If a flowmeter is available, the flow can be measured and compared with the pump catalog rating. If a flowmeter is not available, the rate of flow on small pumps can be measured by discharging the hose into a bucket while timing with the sweep hand on a watch. For example, if a volume of 10 gallons is collected in 15 seconds, the pumping rate is 40 gpm.

If the gauge pressure does not rise above a low value, say 100 psi, and if the volume of flow does not substantially decrease as the relief valve adjustment is tightened, the relief valve is probably at fault and should be cleaned or replaced as instructed in step 5.

Pump

If a full stream of oil is not obtained in step 3, or if the stream diminishes as the relief valve adjustment is tightened, the pump is probably at fault. Assuming that the suction has already been cleaned and the inlet plumbing has been examined for air leaks, as in step 1, the oil is slipping across the pumping elements inside the pump. This can mean a worn-out pump, or too high an oil temperature. High slippage in the pump will cause the pump to run considerably hotter than the oil reservoir temperature. In normal operation, with a good pump, the pump case will probably run about 200° above the reservoir temperature. If the temperature difference is greater than this, excess slippage, caused by wear, may be the cause.

Check also for slipping belts, a sheared shaft pin or key, a broken shaft, a broken coupling, or a loosened set screw.

Relief Valve

If the test for step 3 has indicated the trouble to be in the relief valve, the quickest remedy is to replace the valve with another one known to be good. The faulty valve may later be disassembled for inspection and cleaning. Pilot-operated relief valves have small orifices that may be blocked with accumulations of dirt. Blow out all passages with an air hose and run a small wire through orifices. Check also for free movement of the spool. In a relief valve with pipe thread connections in the body, the spool may bind if pipe fittings are overtightened. If possible, test the spool for binding before unscrewing threaded connections from the body, or screw in fittings tightly during inspection of the valve.

Cylinders

If the pump will deliver full pressure when operating across the relief valve in step 2, both the pump and relief valve can be considered good. If so, the trouble must be further downstream. The cylinder should be tested first for worn-out or defective packing.

The easiest method for testing a hydraulic cylinder is to run the piston to one end of its stroke and leave it stalled in this position under full pressure. Crack the

fittings on the same end of the cylinder to check for fluid leakage. After checking, tighten the fittings and run the piston to the opposite end of its stroke and repeat the test. Occasionally a cylinder will leak at one point in its stroke because of a scratch or dent in the barrel. Check suspected positions in midstroke by installing a positive stop at the suspected position and run the piston rod against it for testing. Once in a great while a piston seal may leak intermittently. This is usually caused by a soft packing or O-ring moving slightly or rolling into different positions on the piston, and is more likely to happen on cylinders of large bore.

When making this test on hydraulic cylinders, the line should be completely removed from a cylinder port during the test and an open line from the valve should be plugged or capped, since a slight back pressure in the tank return would spill oil from the line if not plugged. Pistons with metal ring seals can be expected to have a small amount of leakage across the rings, and even those leak-tight soft seals may have a small bypass during break-in of new seals or after the seals are well worn.

Directional Control Valves

If the cylinder has been tested and found to have reasonably tight piston seals, the fourway valve should be checked next. Although it does not often happen, an excessively worn spool can slip enough oil to prevent buildup of maximum pressure. Symptoms of this condition are a loss of cylinder speed together with difficulty in building up to full pressure even with the relief valve adjusted to its highest setting. This condition would be more likely to occur with high-pressure pumps of low-volume output, and it would develop gradually over a long period of time.

For testing four-way valves, it is necessary to obtain access to the tank return ports so that the amount of leakage can be observed. To make the test, disconnect both cylinder lines and plug these ports on the valve. Start up the system and shift the valve to one working position. Any flow out the tank return port while the valve is under pressure is the amount of leakage. Repeat the test in all other working positions of the valve.

FAILURE MODES OF HYDRAULIC COMPONENTS

Each of the components that make up a hydraulic circuit has inherent strengths and weaknesses. These design

characteristics define the more common failure modes that may affect each of these components.

Positive-Displacement Pumps

Most hydraulic pumps are positive displacement and are more tolerant to variations in system demands and pressures than centrifugal pumps. However, they are still subject to a variety of common failure modes caused directly or indirectly by the process.

- **Rotary-Type**

Rotary-type, positive-displacement pumps share many common failure modes with centrifugal pumps. Both types of pumps are subject to process-induced failures caused by demands that exceed the pump's capabilities. Operating methods that result in either radical changes in their operating envelope or instability in the process system also cause process-induced failures. Table 1 lists common failure modes for rotary-type, positive-displacement pumps. The most common failure modes of these pumps are generally attributed to problems with the suction supply. They must have a constant volume of clean liquid in order to function properly.

- **Reciprocating**

Table 2 lists the common failure modes for reciprocating-type positive-displacement pumps. Reciprocating pumps can generally withstand more abuse and variations in system demand than any other type. However, they must have a consistent supply of relatively clean liquid in order to function properly. The weak links in the reciprocating pump's design are the inlet and discharge valves used to control pumping action. These valves are the most frequent source of failure. In most cases, valve failure is due to fatigue. The only positive way to prevent or minimize these failures is to ensure that proper maintenance is

performed regularly on these components. It is important to follow the manufacturer's recommendations for valve maintenance and replacement.

Because of the close tolerances between the pistons and the cylinder walls, reciprocating pumps cannot tolerate contaminated liquid in their suction-supply system. Many of the failure modes associated with this type of pump are caused by contamination (e.g., dirt, grit, and other solids) that enters the suction side of the pump. This problem can be prevented by the use of well-maintained inlet strainers or filters.

Table 1 Common Failure Modes of Rotary-Type Positive-Displacement Pumps

THE CAUSES	THE PROBLEM										
	No Liquid Delivery	Insufficient Discharge Pressure	Insufficient Capacity	Starts, But Loses Prime	Excessive Wear	Excessive Heat	Excessive Vibration and Noise	Excessive Power Demand	Motor Trips	Elevated Motor Temperature	Elevated Liquid Temperature
Air Leakage into Suction Piping or Shaft Seal	●	●					●			●	
Excessive Discharge Pressure		●			●			●	●	●	●
Excessive Suction Liquid Temperatures			●	●							
Insufficient Liquid Supply		●	●	●	●		●		●		
Internal Component Wear	●	●	●				●				
Liquid More Viscous Than Design								●	●	●	●
Liquid Vaporizing in Suction Line		●	●	●			●				●
Misaligned Coupling, Belt Drive, Chain Drive					●	●	●	●		●	
Motor or Driver Failure	●										
Pipe Strain on Pump Casing					●	●	●	●		●	
Pump Running Dry	●	●			●	●	●				
Relief Valve Stuck Open or Set Wrong		●	●								
Rotating Element Binding					●	●	●	●	●	●	
Solids or Dirt in Liquid					●						
Speed Too Low		●	●						●		
Suction Filter or Strainer Clogged	●	●	●				●			●	
Suction Piping Not Immersed in Liquid	●	●		●							
Wrong Direction of Rotation	●	●								●	

Table 2 Common Failure Modes of Reciprocating Positive-Displacement Pumps

THE CAUSES	THE PROBLEM								
	No Liquid Delivery	Insufficient Capacity	Short Packing Life	Excessive Wear Liquid End	Excessive Wear Power End	Excessive Heat Power End	Excessive Vibration and Noise	Persistent Knocking	Motor Trips
Abrasives or Corrosives in Liquid			●	●					
Broken Valve Springs		●		●			●		
Cylinders Not Filling		●	●	●			●		
Drive-train Problems							●		●
Excessive Suction Lift	●	●							
Gear Drive Problem							●	●	●
Improper Packing Selection			●						
Inadequate Lubrication						●	●		●
Liquid Entry into Power End of Pump						●			
Loose Cross-head Pin or Crank Pin								●	
Loose Piston or Rod								●	
Low Volumetric Efficiency		●	●						
Misalignment of Rod or Packing			●						●
Non-condensables (Air) in Liquid	●	●	●				●		●
Not Enough Suction Pressure	●	●							
Obstructions in Lines	●						●		●
One or More Cylinders Not Operating		●							
Other Mechanical Problems: Wear, Rusted, etc.					●	●	●	●	
Overloading					●				●
Pump Speed Incorrect		●				●			
Pump Valve(s) Stuck Open		●							
Relief or Bypass Valve(s) Leaking		●							
Scored Rod or Plunger		●							●
Supply Tank Empty	●								
Worn Cross-head or Guides			●			●			
Worn Valves, Seats, Liners, Rods, or Plungers	●	●		●					

Control Valves

Although there are limited common control valve failure modes, the dominant problems are usually related to leakage, speed of operation, or complete valve failure. Table 3 lists the more common causes of these failures.

Special attention should be given to the valve actuator when conducting a Root Cause Failure Analysis. Many of the problems associated with both process and fluid-power control valves are really actuator problems.

Table 3 Common Failure Modes of Control Valves

THE CAUSES		THE PROBLEM						
		Valve Fails To Open	Valve Fails To Close	Leakage Through Valve	Leakage Around Stem	Excessive Pressure Drop	Opens/Closes Too Fast	Open/Closes Too Slow
Manually Actuated	Dirt/Debris Trapped In Valve Seat		●	●				
	Excessive Wear		●	●				
	Galling	●	●					
	Line Pressure Too High	●	●	●	●	●		
	Mechanical Damage	●	●					
	Not Packed Properly				●			
	Packed Box Too Loose				●			
	Packing Too Tight	●	●					
	Threads/Lever Damaged	●	●					
	Valve Stem Bound	●	●					
	Valve Undersized					●		●
Pilot Actuated	Dirt/Debris Trapped In Valve Seat	●	●	●				
	Galling	●	●					
	Mechanical Damage (Seals, Seat)	●	●	●				
	Pilot Port Blocked/Plugged	●	●	●				
	Pilot Pressure Too High		●				●	
	Pilot Pressure Too Low	●		●				●
Solenoid Actuated	Corrosion	●	●	●				
	Dirt/Debris Trapped In Valve Seat	●	●	●				
	Galling	●	●					
	Line Pressure Too High	●	●	●	●			●
	Mechanical Damage	●	●	●				
	Solenoid Failure	●	●					
	Solenoid Wiring Defective	●	●					
	Wrong Type of Valve (N-O, N-C)	●	●					

In particular, remotely controlled valves that use pneumatic, hydraulic, or electrical actuators are subject to actuator failure. In many cases, these failures are the reason a valve fails to properly open, close, or seal. Even with manually controlled valves, the true root cause can be traced to an actuator problem. For example, when a manually

operated process-control valve is jammed open or closed, it may cause failure of the valve mechanism. This overtorquing of the valve's sealing device may cause damage or failure of the seal, or it may freeze the valve stem. Either of these failure modes results in total valve failure.

A CASE FOR MAINTENANCE OF HYDRAULIC SYSTEMS

Most companies spend a great deal of money training their maintenance personnel so that they can troubleshoot and correct failures of a hydraulic system. If the focus was shifted to the prevention of system or component failures, less time and money could be spent on troubleshooting. We normally expect hydraulic system failure, rather than deciding not to accept hydraulic failure as the; norm. Let's spend the time and money to eliminate hydraulic failure, rather than to prepare for it.

There are two aspects to the basic foundation for proper maintenance of a hydraulic system. The first is preventive maintenance, which is key to the success of any maintenance program, whether for hydraulics or for any equipment of which we require reliability. The second aspect is corrective maintenance, which in many cases can cause additional hydraulic component failure when it is not performed to standard.

CONCLUSION

When we change our focus from reactive to proactive maintenance of our hydraulic systems, it helps to eliminate unscheduled hydraulic failure. Lack of maintenance of hydraulic systems is the leading cause of

component and system failure, yet most maintenance personnel don't understand the proper maintenance techniques of a hydraulic system. Failures are not caused by an unknown factor' such as "bad luck" or "it just happened" or "the manufacturer made a bad part." We have found that most failures can be analyzed and preventive means taken to prevent their reoccurrence. Establishing teams to review each failure can pay off in major ways. To summarize, maintenance of a hydraulic system is the first line of defense to prevent component failure and thus improve equipment reliability. Discipline is the key to the success of both troubleshooting and proactive maintenance program.

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