TROUBLESHOOTING FOR RELIEF VALVES USED IN HYDRAULIC SYSTEMS

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***Abstract**: This study relates to the description of a relief valve briefly and troubleshooting due to pressure rise in hydraulic system. In any hydraulic system, it is essential to limit the maximum pressure generated by the constant displacement pump. For this purpose, usually pressure relief valve is used and pressure across the relief valve can be balanced. Many of the failures in a hydraulic system show similar symptoms such as, a gradual or sudden loss of high pressure, resulting in loss of power or speed in the cylinders. Due to possible malfuntions, the cylinders may stall under light loads or may not move at all. Often the loss of power is accompanied by an increase in pressure which must be taken away by a relief valve.*

Keywords: TROUBLESHOOTING, RELIEF VALVE, PRESSURE-SENSITIVE VALVE, HYDRAULIC SYSTEM.

1. Introduction

It is believed that the French scientist Denis Papin was the inventor of the safety valve at the end of the seventeenth century. The safety valve was kept closed by means of either a spring or a lever and a movable weight; sliding the weight along the lever to regulate the pressure. Some believe that, Papin was only the inventor of some improvements and that safety valves were already being used some 50 years earlier on a steam digester designed by Rudolf Glauber, a German-Dutch alchemist. Timothy Hackworth developed an open-ended safety valve for the steam trains and boilers that were first being built around 1830 when the starting of the safety valve designs as we use today [1].

Hydraulic systems are used in so many automatic machines. It is equipped with a pressure relief valve to maintain the operation pressure of the system at a pre-determined level. Relief valve protects the hydraulic pump and in turn the prime mover from overload quickly in case the system is exposed to overpressure. That's why, characteristics of such a valve like the other system components are very important in designing the hydraulic system. The basic pressure relief valve is dynamically undesirable due to relatively low viscous damping. This kind of valve provides low damping during upward movement of the relief valve arbor [2].

Pressure relief valves used in hydraulic systems are spring-loaded valves designed to open and relieve excess pressure, then immediately close, preventing any loss of flow of fluid after normal conditions have been renovated [3]. They are designed and manufactured to act as a safety measure in pressurized liquid system. The relief valve is a device utilized to divert excess pressure (sudden surges) in the discharge side of the pump into the suction side. Generally, these changes are so rapidly and of such magnitude, that the pump operator can not correct quickly enough. The properly set and maintained relief valve can make these corrections for the operator [4].

The pressure relief valve shall safely control increase in pressure by venting the pressurized liquid from the location. Another application is to protect equipment from overpressure. The valves are generally "back-pressure dependent", so can be discharged to atmosphere easily. Once a valve has discharged, replacement is usually adviced, as the set pressure can no longer be guaranteed. It is recommended to have a relief valve pressure setting at least 25% higher than the maximum system operating pressure. One must be sure that set pressure should not be higher than the design pressure of the hydraulic system [5].

2. Description of Relief Valves Design

A historic introduction to the pressure relief valve evolution leads to the definition of the best performance characteristic of pressure relief valves. The salient features of the valve's best performance characteristic as a combination of the valve 'best dynamic performance' and the valve 'best discharge capacity' and factors leading to distortions of the best performance characteristics [6].

Relief valves are classified in two types. In the direct acting type, the pressure to be relieved acts directly on the fluid regulating element. This type is commonly employed in systems with relatively low flow rates. For high flow rates, a pilot operated type is commonly employed. In this type the pressure to be controlled acts on a pilot. As soon as this pilot allows flow, the pressure difference across the main regulating element becomes large enough to provide a force. It causes the valve to open rapidly because the spring controlling the main element is light. A relief valve may be installed wherever there is a need to protect a probably the most common application. It would be protecting a pump against an excessive pressure rise when the motion of an actuator or motor becomes blocked. Although the load may be abnormal, actuator motions are often blocked deliberately, for example in a clamping application [7].

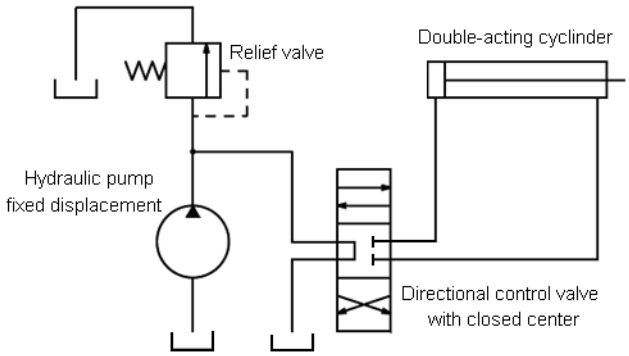

***Fig.1.** Pump protection circuit with relief valve [10]*

The function of the relief valve is to limit the maximum pressure that can exist in a system [8]. Under ideal condition, the relief valve should provide alternative flow path to tank for the system fluid while keeping the system pressure constant. There are two types of valves that are commercially available such as, direct and pilot type (9).

3. Types of Relief Valves

3.1. Direct Acting Type

It is usually a poppet, but other geometries such as a ball or a spool may be encountered. During normal system operation, the regulating element is held in a fluid blocking position by a spring. If the system pressure reaches a preset value, the force on the regulating element will equal the spring preload force. This is called the cracking pressure. Further, increase in pressure will cause movement for the regulating element from its fluid blocking position. Then it allows fluid to flow to the system reservoir [11].

3.2. Pilot Operated Type

Element can be quite small because this pilot is only required to pass a small flow in a hydraulic circuit (see Figure 2). During the normal closed condition of the valve, there is no flow through the orifice in the main regulating element, so there is no pressure difference across the main element. Thus, the main element can be held in a closed position by a light spring [11].

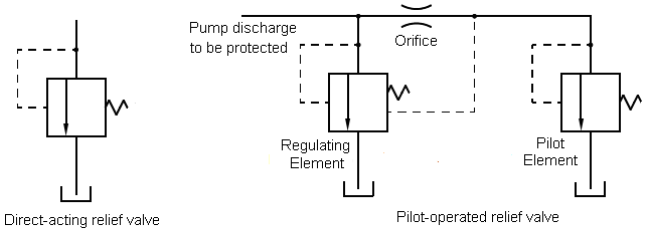

***Fig.2**. Basic types of relief valves for different operations [5]*

4. Operation of Relief Valves in Hydraulic Systems

The machine tolerances are critical and even a small amount of dirt can cause the relief valve system to malfunction. A good preventive maintenance program is essential to prevent the problems in relief valve system. It is important to realize that for the relief valve to function properly, the discharge pressure should be at least 3-4 bar greater than the suction or incoming pressure. If not, the relief valve opens but the fluid will not be able to flow from the discharge to the suction area.

It is a common fallacy of some pump operators to think the installed relief valves protect them under all conditions. Normal relief valve systems *cannot* relieve discharge pressure below the incoming or suction side pressure. Surges such as those encountered in a relay operation, if not controlled, it will be transmitted to the discharge side of the pump. If companies get involved in relay operations over 3 bar, a suction side relief valve must be installed [12]. These are usually a one-piece unit (entirely separate from those previously discussed) in which pre-settting the pressure by adjusting a spring-loaded valve. When the pressure rises above the setting level, the valve opens and dumps the fluid to the tank. This continues up to the pressure drops below the preset pressure. Without a suction-type relief valve you are risking the possibility of excess pressure cracking the pump body or, even worse, the inability of your engineer to be able fully to control discharge pressure.

A conventional pressure relief valve is to be designed to open at a preset liquid pressure. A spring exerts a force on a valve seat via a piston assembly. At the set pressure, the piston begins to lift resulting in a small amount of flow through the valve and the pressure force. This force acts on the piston that increases importantly, and overcomes the spring force. The imbalance of forces cause the valve to fully open. By design, the difference in pressure from the valve set point to the fully open condition is no more than 10 %. The valve then re-closes at a pressure where the spring force overcomes the piston force. Under normal system operating conditions, the pressure at the valve inlet is below the set pressure. Only under abnormal operating conditions should the pressure relief valve be open [12]. The reasons for the usage of relief valves are listed below.

(1) Protect system operators
(2) Prevent the demolotion of capital investment
(3) Preserve the production
(4) Reducing downtime of the system
(5) Comply with codes and standards
(6) Protect the environment

In the daily operation of hydraulic system overpressure can happen due to incidents like a blocked discharge, fire exposure, tube rupture, check valve failure. This can lead to a major incident in plant if the pressure relief system is not in place or not functional. It is very important to properly select, size, locate and maintain the pressure relief systems to prevent or minimize the losses from major incident like fire or other issues [2].

4.1. Causes of overpressure

Overpressure is significant in preliminary steps of pressure relief system design. It helps the designer to understand the cause of overpressure and minimize the effect. It is the result of an unbalance or disruption of the normal flows of material and energy that causes the material or energy, or both, to build up in some part of the system.

4.1.1 Blocked Discharge

Blocked discharge can be explained at any system, pump or other equipment is the closure of blockage at outlet either by mechanical failure or human error. This exposes the system to a pressure that exceeds the maximum allowable working pressure. So, the relief valve is required unless administrative procedures to control valve closure.

4.1.2. Fire Exposure

Fire may occur in hydraulic systems. So, all equipments must be protected from overpressure which is controlled by pressure relief valves.

4.1.3. Check Valve Failure

It is generally placed at a pump outlet. Malfunction of the check valve can lead to overpressure in hydraulic system. When a fluid is pumped into a system, failure of the check valve causes reversal of the liquid flow back to pump. When the liquid is displaced into a suction system and high pressurizied fluid enters, overpressure is occured.

4.1.4. Thermal Expansion

If isolation of a piping on the cold side of system can result in overpressure due to heat input from the warm side, then the line or cold side of the system must be protected by a relief valve [12]. Hydraulic systems for the pressure protection, following categorization can be used for the product standards especially in EU countries.

EN ISO 4126-1: Presssure safety relief valves
EN ISO 4126-2: Bursting disc safety devices
EN ISO 4126-3: Safety valves and bursting disc safety devices in combination
EN ISO 4126-4: Pilot operated safety valves
EN ISO 4126-5: Controlled safety pressure relief systems
EN ISO 4126-6: Application, selection and installation of bursting disc safety devices
DIN EN 12953-8: Shell boilers, safety devices against excessive presssure
DIN EN 764-7: Sizing and spring-Setting

4.2. Troubleshooting the relief valves

Listed below are the areas that you can troubleshoot the relief valves [7]. When working on a specific machine for more information technical manual is prefered.

If low or erratic pressure occurs for the sake of troubleshooting, the following items must be considered.

- Adjustment is incorrect.
- Dirt, chip, or burrs may cause the valve partially open.
- Poppets or seats may be worned or damaged.
- Valve piston in the main body may be sticked.
- Selection of spring is wrong
- Spring ends may be damaged.
- Valve in the body may be cocked.
- Orifice or balance hold may be blocked.

If relief valve has no pressure, the following items must be considered.

- Orifice or balance hole may be plugged.
- Poppet does not seat.
- Valve may have a loose fit.
- Spring may be broken.
- Dirt, chip, or burrs may cause the the valve partially open.
- Poppet or seat may be worned or damaged.
- Valve in the body may be cocked.

If excessive noise occurs consider the following items;

- Oil viscosity may be too high.
- Poppet or seat may be faulty or worned.
- Line pressure may have an excessive return.
- Pressure setting is too close to that of another valve in the circuit.
- Spring may be broken.

If adjustment of the relief valve can not be achieved properly, consider the following items;

- Spring may be broken.
- Fatique for spring material may come across.
- Improper spring may have been used.
- Drain line in system may be restricted.

4. 3. Relief Valve Failures and Remedies

Hydraulic valves are precision-made and must be very accurate in controlling a fluid pressure, direction, and volume within a hydraulic system. Contaminants, such as dirt, in the oil are the major problems in valve failures. Small amounts of dirt, lint, rust, or sludge can cause annoying malfunctions and extensively damage valve parts. Such material will cause a valve to stick, plug small openings, or abrade the mating surfaces until a valve leaks. Only the specified oils must be used in a hydraulic system.

Following recommendations are advisable before servicing a relief valve [1].

- Disconnect the electrical power source before removing a hydraulic relief valve's components.
- Release the system's hydraulic pressure before disconnecting any hydraulic valve components.
- Lower all hydraulic working units to the ground before disconnecting any parts.
- Clean a valve and its surrounding area before removing any part for service.
- Paint thinner or acetone for cleaning is not advisable.

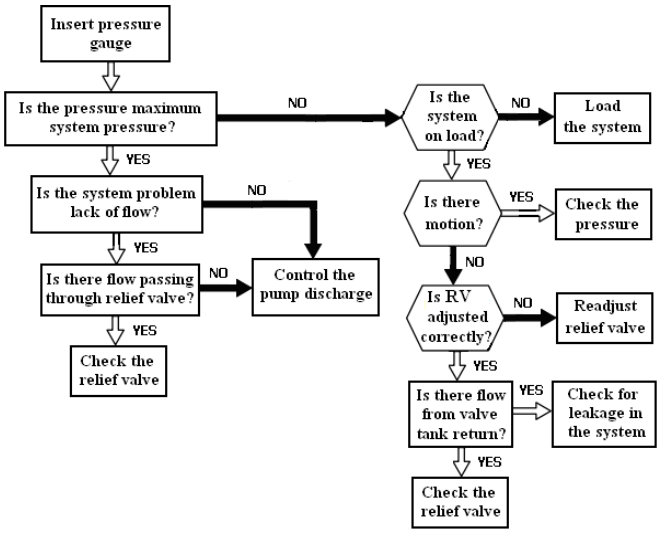

***Fig.3**. Troubleshooting nomogram for hydraulic system with relief valve*

The following must be fulfilled when disassembling a valve.

- Maintenance operator must be certain that all tools are clean and free of grease and dirt.
- One must be careful to identify the parts when disassembling for later reassembly. The valve sections to be reassembled in the same order.
- If possible, use a vise equipped with lead or brass jaws, or protect the component by wrapping component in a protective covering.
- Sealing all the valve's housing openings to remove the components during service work is advisable.

If the shut down for pressurized equipment is reduced, the intervals between relief valve examinations need to be similarly extended, or systems developed to allow the examinations to be carried out on-line [13]. Besides these above mentioned remedies, we also use Figure 3 in order to troubleshoot the problem arising in relief valves [14].

5. Conclusion

As with all troubleshooting techniques, knowledge of components and their function in a system is vitally important. It is probably fair to say that, when all the components of a hydraulic system have been identified, their function determined and the operation of the system as a whole understood, the troubleshooter has gone 51% of the way towards finding the problem. It is important to make the use of advices given for relief valves effectively, a good understanding of the basic principles of relief valves with a knowledge of the operation and application of them.

Hydraulic systems are getting more and more complex as methods of controlling machines become increasingly developed. Technological advances in many hydraulic system components such as, relief valves were exhibited in the last twenty years. The object of this study is to provide procedure for a logical approach on troubleshooting which can be extended when necessary to cover specific machines in all areas of industry either using the advices or flow charts given. In order to control pressure of flow, the fundamentals for this procedure must be developed.

The main problem in philosophy of the troubleshooting procedure is determining the aspects of the hydraulic system, such as fault, flow, pressure or direction. By consulting the circuit diagram, a list of possible causes can be drawn up. The next stage is to search for the obvious remedy. Certain controls that are achieved on a hydraulic system using the human senses of sight, touch and hearing which can be carried out very quickly.

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