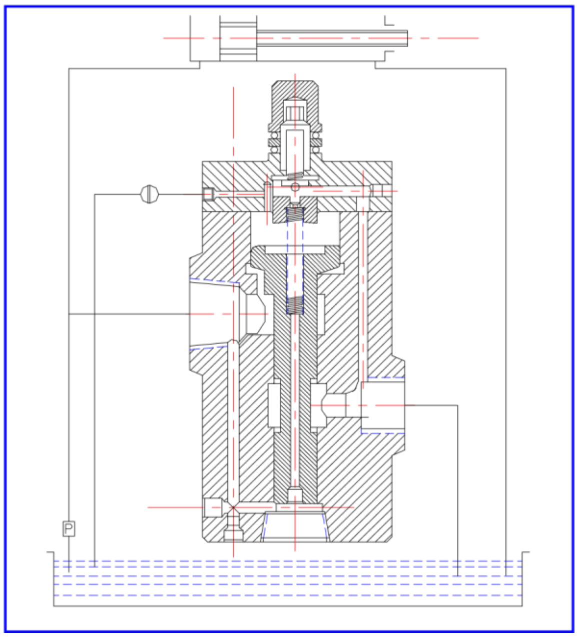
INDUSTRIAL HYDRAULIC SYSTEMS & CIRCUITS



By

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PREFACE

A hydraulic system is called a logical and sequential arrangement of various elements to obtain the desired function through a fluid. Industrial hydraulics was introduced as a useful medium for power transmission at the beginning of the 20th century. Since then, technology has continuously evolved by responding to the challenging demands posed by various applications. Over the years, it has competed with other competitive power transmission technologies to find its present place. The strengths of hydraulic drives that make them the preferred choice are their high force and acceleration capability, ability to operate at full torque even at zero speed, continuous speed variability, and stiffness.

These superior features, combined with the development of components that can interface with complex electronic controls, have created an undisputed domain for hydraulics in power transmission. Hydraulic systems are being used on a wide variety of machines today, and they form subsystems of many machines deployed in agriculture, construction, mining, earthmoving, material handling, defense, and airplanes. Hydraulics has long provided the muscle for mobile equipment to load and unload heavy and voluminous materials. The system is more widely used in machine tools as principal and feed movement drive, providing rotary and translatory motion with stepless regulation of feed and speed rate, speed changing devices, automatic control of machine cycle, etc.

Nowadays, oil hydraulics principles have successfully replaced even mechanical and electrical drives in some machine tools and equipment. This extensive use of hydraulic systems is due to their capability of providing infinitely variable speed over a wide range, smooth reversal of moving machine members, automatic overload protection, easy lubrication, etc. All this development raised demand for a team of engineers and technicians well-trained in industrial hydraulic systems and circuits.

Since Oil hydraulic systems can be built using readily available standard elements together with electrical/ pneumatic interface to perform any complicated sequence of operation, technological developments in this field were carried out primarily by their manufacturers who have been reluctant to share their knowledge with others. So, different types of books, manufacturer's catalogs, and manuals need to be referred to for the application of hydraulic systems and circuits. Attempts, therefore, have been made to collect all such study material and compile it as a book.

Preface: contd…

This book covers literature regarding various types of standard hydraulic system elements like different types of pumps, pressure-controlling elements, flow control valves, check valves, and direction control valves. Details of different types of tailor-made auxiliaries, like a hydraulic tank and their accessories, filters, piping, fittings, accumulators, etc., have also been described. In addition to the above, special devices, from the conventional copying attachment system to the latest electro-hydraulic systems, like proportional valves and servo valves with electronic controls, are given in this book.

Since the hydraulic circuit of equipment is devised purely by intuition, there may be hundreds of types of circuits. Many circuit variations are possible by using essential components of standard hydraulic systems. A few typical hydraulic circuits are described here. To illustrate further, practical applications of the system and circuits in hydraulic drives, hydraulic controls, hydrostatic transmission, and hydrostatic bearings have been given in detail. Installation, maintenance, and testing of the various hydraulic systems and elements have been added as the concluding chapter to make this book more valuable on the shop floor.

The subject matter has been well illustrated, with over 100 figures in more than 160 pages covering more than 30 typical hydraulic circuits. The book will be handy for practicing engineers, designers, mechanical and production engineering students, and technical personnel handling different types of machinery.

CONTENTS

CHAPTER 1

INTRODUCTIONTOHYDRAULICSYSTEM

1.1. PRINCIPLES OF HYDRAULICS

The name ‘Hydraulics’ has been taken from the Greek word ‘HYDOR,’ meaning water, and ‘AULOS,’ meaning pipe. For the first time, ‘Hydraulics’ was used by the person who converted the energy of flowing water into useful mechanical energy utilizing the water wheel. Later, the idea of Industrial Hydraulics or Oil Hydraulics emerged. It is the science of transmitting energy through the medium of pressurized fluid. Advancement of this science started when Pascal discovered a fundamental law called Pascal’s law which states: “Pressure generated at one point in a confined liquid acts actually in all directions and acts perpendicular to the surface of the container.” The law helped develop this new field of hydraulics, dealing with power transmission, mechanical motion control, and fluids under pressure characteristics. The developments resulted in the use of a network of high-pressure fluid pipes from the pressure generating station, i.e., the pump, to the application points through the controlling system. Various auxiliaries, like valves, accumulators, seals, etc., were invented during this process. The principle of oil hydraulics is applied for power transmission and control and has successfully replaced even mechanical and electrical drives in some machine tools and equipment.

A hydraulic system is called a logical and sequential arrangement of various elements to obtain the desired function through a fluid. Oil hydraulic systems can be built using readily available standard elements together with an electrical/ pneumatic interface to perform any complicated sequence of operations. The system is more widely used in machine tools as principal and feed movement drive, providing rotary and translatory motion with step-less regulation of feed and speed rate, speed-changing devices, automatic control of machine cycle, etc. The innovation of electro-hydraulic servo valves and proportional valves, which could conveniently interface with electrical and electronic measuring and signaling devices, led to the popular use of electrohydraulic servo drives in CNC machines. The latest is the application of electro-hydraulic stepping motors with hydraulic torque amplifiers for feed drives in an open loop configuration. This extensive use of hydraulic systems is due to their capability of providing infinitely variable speed over a wide range, smooth reversal of moving machine members, automatic overload protection, easy lubrication, etc. Among their shortcomings are leakage of hydraulic fluid through seals and gaps, air ingress into fluid, temperature and time effect on fluid properties, etc.

1.2. HYDRAULIC FLUIDS

Fluids for hydraulic systems are subject to a wide range of pressures, velocities, and temperatures.

During the system's operation, the hydraulic fluid's temperature changes due to heating and cooling. In the suction line, the liquid supply is affected by the vacuum formed at the suction end of the pump. In the pressure piping, the fluid is subjected to high pressure.

The index is an empirical number that indicates the effect of a change in temperature on the oil viscosity. A higher viscosity index signifies a smaller change in viscosity with a change in temperature than a lower viscosity index. Oil based on petroleum products' viscosity index of 90-100 is supposed to be very good if it is not doped with a viscosity index improver. So hydraulic oil should have been made from predominantly paraffinic refined base oil, with a sufficiently high viscosity index required for such applications.

Viscosity temperature relations can be stated approximately as $\mu_t = \mu_{20} \frac{20^K}{t}$

μ_t or μ_{20} = Viscosity at 20 c° or t c°

K = 1.63 for Ex light oil

= 1.88 for light oil

= 2.08 for heavy medium oil

= 2.55 for heavy oil

The higher the viscosity index, the smaller the change in viscosity with temperature variation. To improve VI further, say up to 200, a viscosity-index improver is added. Those in everyday use are Poly isobutylene, polymethacrylate esters, and polyfumarite ester-derivatives between 1% and 5% being added to the oil. Paratone is a polymer of butylenes with the formula (C4H8)n, where n may vary from 180 to 270; the large molecule size is typical of viscosity index improvers.

The 'Acryloid or plexor' range of additives consists of concentrates of methacrylate polymers. The viscosity index improves pour points depressants or low-temperature sludge depressants suitable for use in crankcase oil, automatic transmission fluids, or hydraulic oils. Indicting additives must be kept in mind that low additive molecule weight decreases sheer loss, while high molecular weight gives a reduced cost of doping. The development of viscosity index improvers has facilitated the production of multigrade motor oils.

3. Anti-wear properties

Anti-wear properties are more specifically required for oil used in hydraulic and hydrostatic transmission systems because of the involvement of more close fitting and rubbing elements. Anti-wear properties are necessary to produce chemical polishing at lower temperatures. Popular anti-wear additives are tricresylphosphate and zinc dialkylidethiophosphate. The latter is also a good antioxidant.

4. Anti-oxidation properties

Several elements like heat, water, pressure, and metal surface accelerate Oxidation. Oxidation reduces the service life of hydraulic components. Tests have shown that below 55°C, oil oxidizes very slowly. But the rate of oxidation doubles for every increase in temperature. The general deterioration is due to the formation of oxidation products. The oil may become more viscous and undesirably acidic in nature because of the presence of oxidized oil. Though sulfur and phosphorus are effective oxidation inhibitors, they have corrosion action on certain nonferrous metals. For oil required to work at normal temperatures, phenolics and di-thiophosphates are generally used as oxygen-inhibitor.

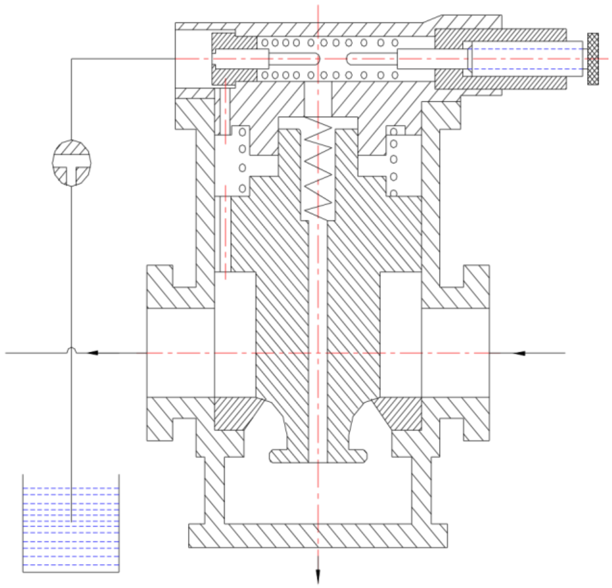

Fig.4.2 Pilot-operated compound relief valve (poppet type)

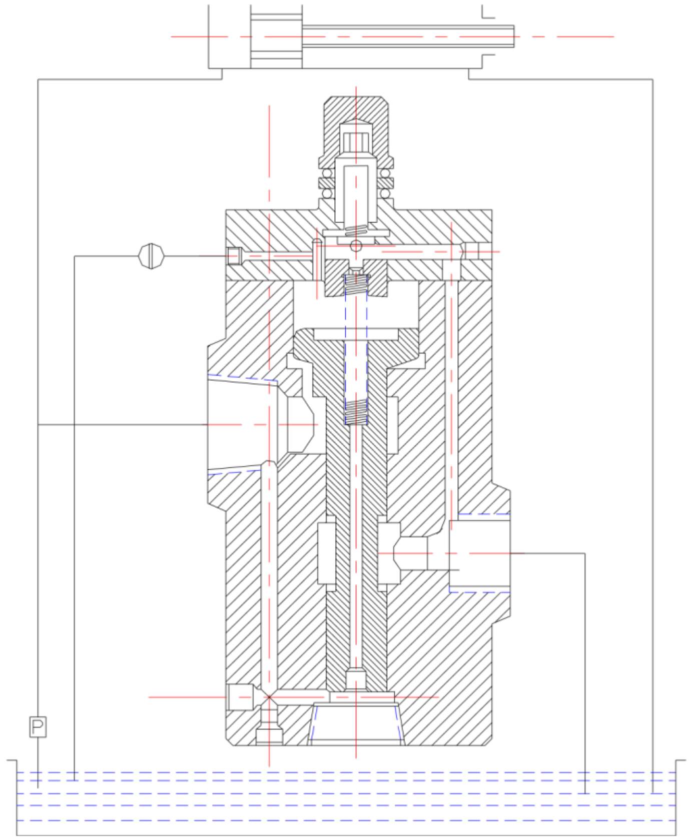

Fig.4.3 Pilot-operated compound balance piston valve (spool type)

CHAPTER10

ELECTROHYDRAULIC SYSTEM

10.1 INTRODUCTION TO ELECTROHYDRAULIC

Electronics are being successfully integrated with hydraulics to make the best use of the muscle power of hydraulics, retaining the precision controllability of electronics. This hybridization of hydraulics with electronics is termed electro-hydraulics. The electrohydraulic system combines the electrical systems' flexibility with the hydraulic systems' power handling ability. Hydraulic systems can be designed to be consistent, smooth, quiet, and trouble-free by adapting electro-hydraulic controls. The electronics care for fluid compressibility, low system stiffness, and dynamic load behavior. It also ensures that forces and speeds are always available in the correct ratio, leading to energy conservation. In power hydraulics, there are only three functions to control pressure, flow, and direction. The introduction of electro-hydraulic devices added new dimensions like remote and multifunction control. Any physical quantity, position, velocity, acceleration, force, or pressure that can be measured electrically can be controlled electrohydraulically. Thus, the significant benefits of an electro-hydraulic system over a conventional hydraulic system can be listed as follows:

- ♦ Precision controllability to achieve motion control
- ♦ Higher operating efficiency
- ♦ Capability to perform multiple functions
- ♦ Introduction of fail-safe features
- ♦ Flexibility of expansions and modification
- ♦ Positioning of remote control and fingertip controls.

The advantages of electrohydraulic drives over other types of drives are stiffness, high response, and good low-speed characteristics. Electrohydraulic proportional valves and servo valves are the principal units under this category, having wide application in several engineering fields, like the aerospace industry, winch control, antenna drives, earth moving, mobile equipment, and N.C. machine tools. Machine tools are used primarily to control the position of the machine slide. Packages of electro-hydraulic proportional valves and cylinders with position feedback signals and matching electronics are readily available to match the electrical circuits and sensors with the hydraulic system.

10.2 PROPORTIONAL VALVES

A proportional valve is electrically controlled, enabling the volumetric flow rate at the valve output to be controlled proportionately to an electrical input signal. Nowadays, proportional valves are being introduced in place of conventional valves to achieve fast control of hydraulic cylinders and motors' pressure, velocity, and acceleration. Proportional control valves are solenoid-operated valves with electrical position feedback control. The solenoids mounted with such valves are proportional and can be modulated electrically. An inductive position sensor measures spool movement, and the output is fed back to the proportional amplifier, which helps compensate for the input signal. Thus, the valve could be regulated proportionally.

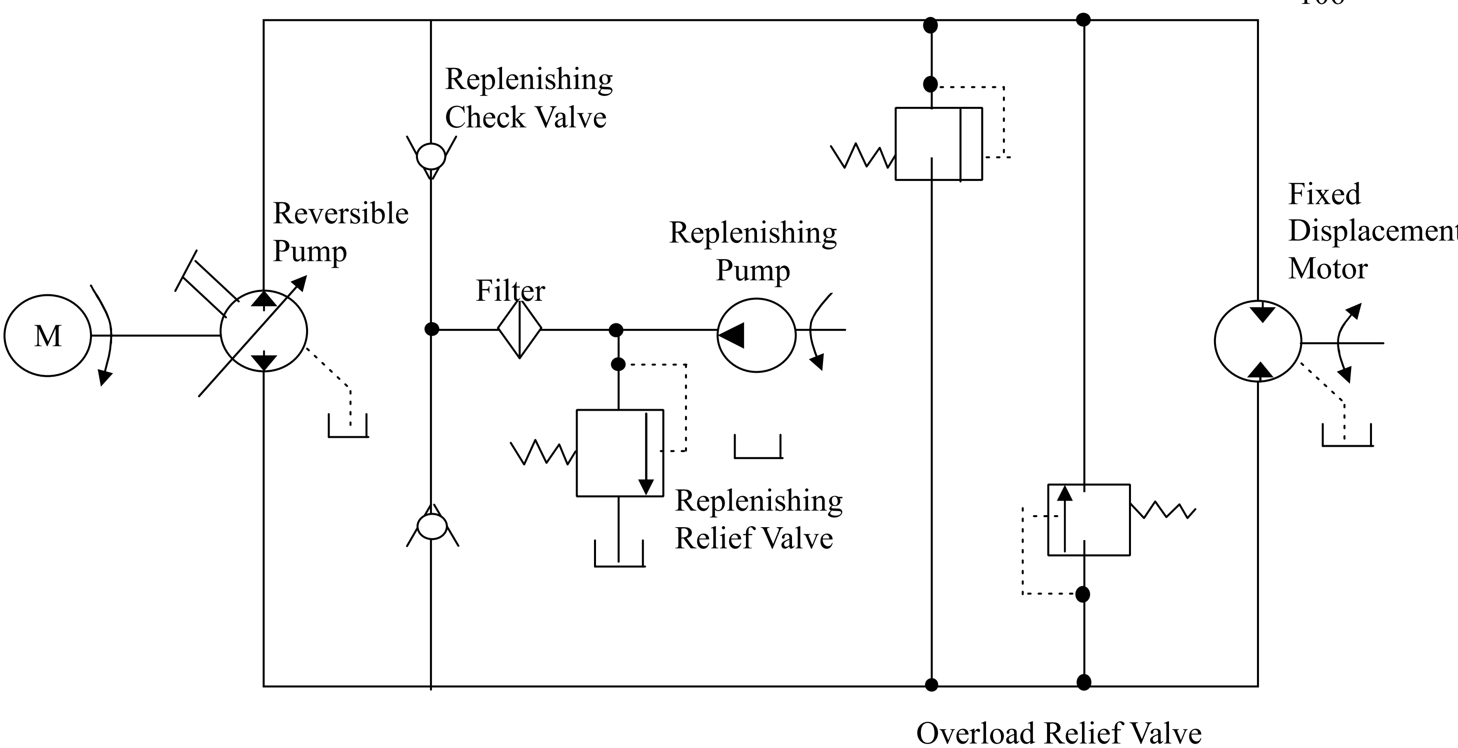

Fig.11.18 Closed-loop drive circuit-Reversible

11.10 PREFILL CIRCUITS

A pre-fill circuit provides an efficient method for filling the main ram on large presses, eliminating the need for a high-volume pump.

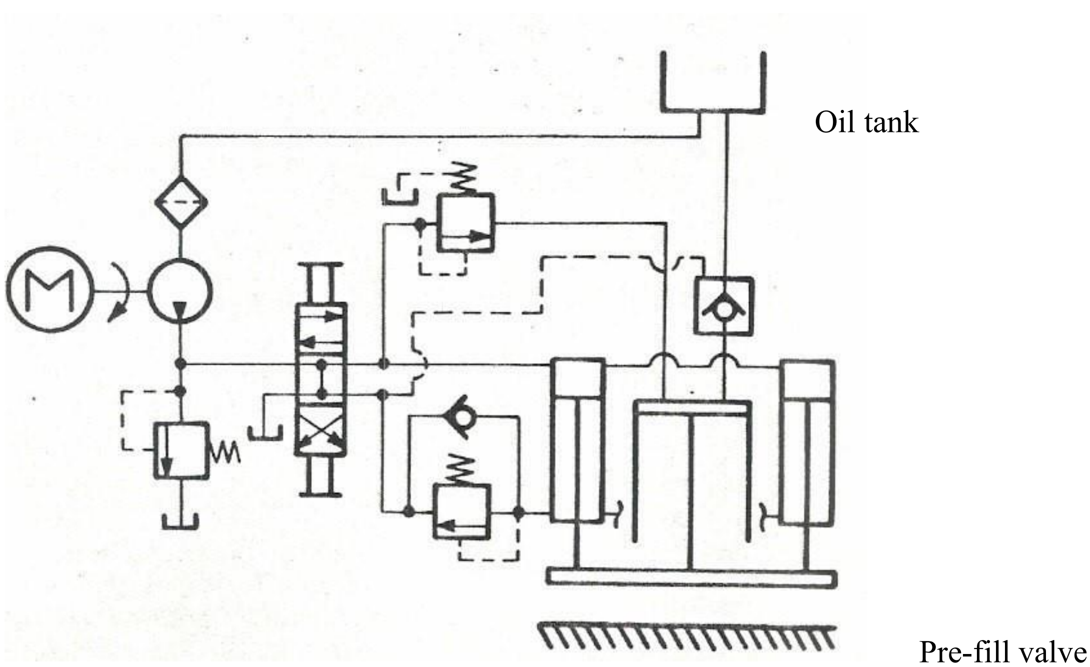

Fig. 11.19 Pre-fill circuit of a typical hydraulic press

HYDRAULIC DRIVES FOR STEPLESS SPEED REGULATION

The usual hydraulic system for spindle drive is based on a constant-speed electric motor driving a hydraulic pump, which then supplies hydraulic oil under pressure to drive a hydraulic motor. The pumps and motors may be of either the fixed or the variable displacement type. The closed circuit is most suitable for frequently reversible speed and feeds drive where jerking or stick-slip motion is not permissible. The following two methods are commonly used for varying the hydraulic motor speed.:

(i) Varying the discharge of the pump.
(ii) Varying the incoming quantity of oil sent to the hydraulic motor.

This is analogous to the Leonard method of electrical circuits. That is why it is termed the "hydraulic Leonard rule."

The advantages of hydraulic systems incorporating both variable delivery pumps and variable displacement pumps are:

a) Wide range of steplessly variable speeds.
b) High rotating rigidly
c) Possibility of repeated and sudden reversal
d) No backlash
e) Transmission of high power and torque

Excessive heating of oil takes place in this process. So, an effective heat exchanger should be provided to cool the oil.

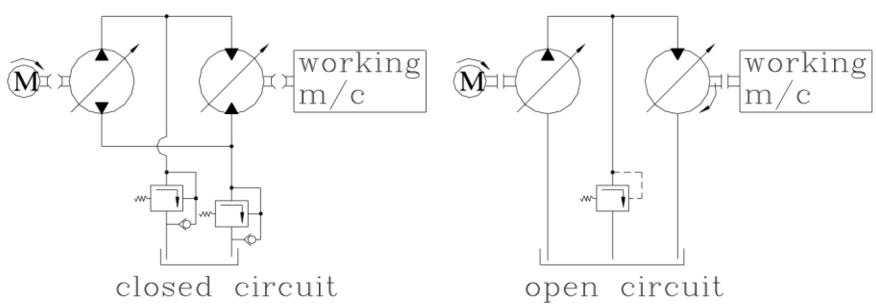

Fig 12.1 Hydraulic circuits for stepless speed regulation

HYVARIDRIVE

It is a compact hydraulic drive with an axial piston pump and hydraulic motor housed in a single body. Input shaft (1) drives the pump (2), which delivers the pressurized oil to the axial piston motor (3) through a control disc located in the middle between the pump and the motor. Finally, the rotary motion of the motor is transmitted to the driven shaft (4) through rotary housing (6), which is fitted in the stationary body (5).

The function of the system can be described as follows:

If pump delivery at the outlet is blocked in a hydraulic pump with stationary pump housing, the oil pressure would theoretically increase until a few parts get damaged. But here, the pump housing is mounted on bearings to rotate at the same speed as its rotor. In this process, a part of the oil delivered by the pump is passed into the