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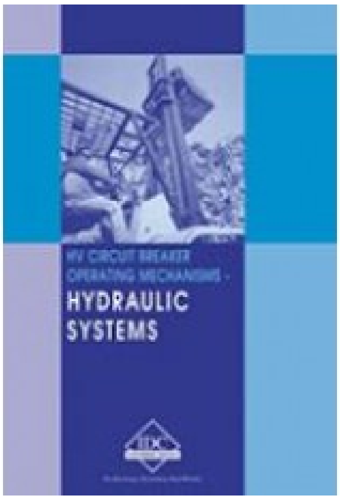
HH-E - HV Circuit Breaker Operating Mechanisms - Hydraulic Systems



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Short Description

This book covers basic hydraulics for circuit breakers, operation of electro-hydraulic operating system, maintenance of circuit breaker hydraulic systems plus much more...

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First Chapter
Basic Hydraulics for Circuit Breakers

1

Basic hydraulics for circuit breakers

1.1 What is hydraulics?

Hydraulics is the transmission and control of power using a liquid as the flowing medium. In other words, it is a fluid power system which uses liquids.

Power in a machine can be transmitted to its various parts by using electricity, mechanical connections, pneumatics or hydraulics. Generally a combination of the methods is used for power transmission.

Hydraulics has the following advantages over other means of power transmission. See Figure 1.1.

Figure 1.1

Features and advantages of a hydraulic system

1. Infinite control of speed and pressure
2. Instant reaction to change of direction, including stopping and starting
3. Self lubrication
4. Large forces can be easily transmitted
5. The pipelines can be relatively easily installed and can be run at any angle
6. Leaks are easily detectable
7. The system is relatively compact for the forces transmitted and it is easy to make the system flexible

1.2 Base units

The S.I (Systéme International) system is the system of measurement used in Australia. It is based on the metric system and makes use of the decimal system.

The base units of measurement are as follows

Quantity	Unit of measurement	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s

Measurements which are made up from combinations of base units are called derived units. ‘Force’ and ‘Area’ are derived units.

The definition of ‘Force’ as applied to hydraulics is ‘Any cause that tends to produce or modify motion’.

Force = mass × acceleration = ma

Force is measured in Newtons. One Newton (N) is the force required to accelerate a mass of one kilogram at a rate of one meter per second squared.

Newton = kilogram × meters per second squared

$N = kg \times m/s^2$

Acceleration due to gravity is commonly used for calculations and it is equal to $9.81\ m/s^2$.

Area

Area is the measure of the size of a surface. Area is measured in meters squared – m^2

Area of a circle $$A = \frac{? \times \text{diameter} \times \text{diameter}}{4}$$

$$A = \frac{? D^2}{4}$$

Pressure

Pressure is the result of application of force on an area. The unit of pressure is Pascal. One Pascal is the pressure resulting from the application of 1 Newton force on an area of 1 square meter.

$$\text{Pressure (P)} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A} = \frac{N}{m^2}$$

See Figure 1.2 for the pressure-force relationship

Figure 1.2

Pressure–force relationship

Pressure can also be expressed in terms of bar, where

1 bar = 105 N/m^2

Pressure in the US unit is measured in terms of lb/in^2 or psi where;

1 psi = 0.0703 kg/cm^2

Pressure and flow are key parameters involved in the study of hydraulics. Pressure in a hydraulic system comes from resistance to flow. This can be best understood from Figure 1.3.

Figure 1.3

Pressure buildup in a hydraulic system

Consider the flow from a hydraulic pump as shown. Here, the pump produces only flow and not pressure. However, any restriction in the flow from the pump results in the formation of pressure. This restriction or resistance to flow normally results from the load induced in the actuator in a hydraulic system. The various conductors and components of the hydraulic system such as pipes and elbows also act as points of resistance and contribute to the generation of pressure in the system.

Pressure is expressed in three different ways

- Atmospheric pressure
- Gauge pressure – both positive and negative (vacuum) pressure
- Absolute pressure

1.2.1 Atmospheric, gauge, absolute pressure and vacuum

Atmospheric pressure

The earth is surrounded by an envelope of air called the atmosphere, which extends upwards from the surface of the earth. Air has mass and, due to the effect of gravity, exerts a force called weight. The force per unit area is called pressure. This pressure exerted on the earth's surface is known as atmospheric pressure.

Gauge pressure

Most pressure measuring instruments measure the difference between the pressure of a fluid and the atmospheric pressure. This is referred to as gauge pressure.

Absolute pressure

Absolute pressure is the sum of the gauge pressure and the atmospheric pressure.

Vacuum

If the pressure is lower than the atmospheric pressure, its gauge pressure is negative and the term vacuum is used when the absolute pressure is zero (i.e. there is no air present whatsoever). Refer to Figure 1.4 which shows the relationship between the various pressures.

P= 0

Figure 1.4

Relationship between absolute, gauge and vacuum pressure

In the above figure:

P_a is the atmospheric pressure

P_{gauge} is the gauge pressure

P_{ab} is the absolute pressure

P_{vacuum} is the vacuum pressure

1.2.2 Differential Pressure

Pressure is always measured relative to some reference. If the reference is absolute vacuum, the pressure that is measured is absolute pressure. If the reference is local ambient pressure, the pressure that is measured is gauge pressure. If a pressure measured is the difference between two points without regard to the absolute or gauge pressure, the measurement is differential pressure. Refer to Figure 1.5. Differential pressure is the difference in pressure between two points of measurement. If the pressure at one point in a system is 20000 kPa and at another point is 25000 kPa, the differential pressure is 5000 kPa. The lower of the two pressures is normally taken as the reference pressure.

Figure 1.5

Various types of Pressure

1.3 Pascal’s Law

Pascal’s law states that “pressure applied to a confined static fluid is transmitted equally and undiminished in all directions throughout that fluid and acts with equal force on equal areas”.

Figure 1.6

Pascal's Law – pressure in a confined space is transmitted equally in all directions

1.3.1 Force multiplication

The force acting on the piston in a large cylinder is greater than the force on the piston in a smaller cylinder for the same pressure due to the relationship formula shown below.

Force = Pressure × Area

For the same pressure, if the cross sectional area of the cylinder is doubled, then the force is also doubled. This principle is used in hydraulic systems where much larger forces can be generated on a bigger sized piston by using the same pressure developed by a smaller sized piston as shown in Figure 1.7.

Figure 1.7

Multiplication of force in a hydraulic system

1.4 Energy

A body is said to possess energy when it is capable of doing work. Therefore, energy may be broadly defined as the ability to do work. In other words, energy is the capacity of a body for producing an effect. In hydraulics, the method by which energy is transferred is known as fluid power. The energy transfer takes place from a prime mover or input power source to an output device or actuator.

Energy is further classified as

- Stored energy: E.g. chemical energy in fuel and energy stored in water, and
- Energy in transition: E.g. heat and work

The following are the two forms of energy:

Potential energy

Potential energy is the energy stored in the system due to its position in the gravitational field. If a heavy object such as a large stone is lifted from the ground to the roof, the energy required to lift the stone is stored in it as potential energy. This stored potential energy remains unchanged as long as the stone remains in its position.

Kinetic energy

Kinetic energy is the energy possessed by a body by virtue of its motion. This energy will remain stored in the body as long as it continues in motion at a constant velocity. When the velocity is zero, the kinetic energy is also zero.

1.5 Fluids

The basic purpose of the fluid in a hydraulic system is to transmit force and motion throughout the system. The other functions of the hydraulic fluid are:

- To lubricate the moving parts in the system such as valve spools, cylinder rods, pump pistons, etc.
- To help sealing within the valve and other moving parts
- To help flush the contaminants back to the reservoir
- To help disperse heat from the system
- To minimize corrosion; the mineral oil forms a protective coating on the surfaces and prevents rust and corrosion.

1.5.1 Properties of hydraulic fluids

The single most important material in a hydraulic system is the working fluid itself. Hydraulic fluid characteristics have a major influence on the equipment performance and life and it is therefore important to use a clean, high quality fluid so that an efficient hydraulic system operation is achieved.

Essentially, a hydraulic fluid has four primary functions:

1) Transmission of power: The incompressibility property of the fluid due to which energy transfer takes place from the input side to the output side (see Figure 1.8).

Figure 1.8

Energy transfer property of a hydraulic fluid

2) Lubrication of moving parts: Lubrication of the fluid minimizes friction and wear (see Figure 1.9).

Figure 1.9

Lubrication property of a hydraulic fluid

Hydraulic fluids should have good lubrication properties to prevent wear and tear between the closely fitting moving parts. Direct metal-to-metal contact of the hydraulic components is normally avoided by employing fluids with adequate viscosity, which tend to form a lubricating film between the moving parts. The hydraulic components that suffer the most from conditions arising out of inadequate lubrication include pump vanes, valve spools, rings and rod bearings. This has been illustrated in Figure 1.10.

Figure 1.10

Lubricating film prevents metal-to-metal contact

Wear and tear is the removal of surface material due to the frictional force between two mating surfaces. Wear and tear is avoided by having adequate lubrication between the moving components.

3) Sealing of clearances between mating parts: The fluid between the piston and the wall acts as a sealant (see Figure 1.11). The centre portion of the valve contains fluid under high pressure, whereas the fluid at the left portion is at a lower pressure. The arrow marks show the locations where the fluid provides sealing between the moving and stationary parts of the valve.

Figure 1.11

Sealing property of a hydraulic fluid

4) Dissipation of heat: Heat dissipation due to the heat transfer property of the hydraulic fluid (see Figure 1.12).

Figure 1.12

Heat transfer property of a hydraulic fluid

The heat produced in the hydraulic system is dissipated by the fluid by conduction and convection. The movement of the fluid in the system transfers the heat from the heat generation source to the cooler sections of the system, thereby effectively reducing the temperature of the system.

For the hydraulic fluid to properly accomplish these primary functions, the following properties are essential:

- Good lubricity
- Ideal viscosity
- Chemical and environmental stability
- Large bulk modulus
- Fire resistance
- Good heat transfer capability
- Low density
- Foam resistance
- Non toxicity
- Low volatility

Last but not the least, the fluid selected must be cost-effective and readily available.

It is quite obvious that a clear understanding of the fundamentals of fluids is required to fully comprehend the concepts of hydraulics. We shall therefore briefly review certain important terms and definitions that are often used in hydraulics.

1.5.2 Terminology used for fluid properties

The important terms used in fluids are

- Viscosity
- Viscosity index
- Oxidation resistance
- Foam resistance

Viscosity

Viscosity is probably the single most important property of a hydraulic fluid. It is a measure of the sluggishness with which the fluid flows or, in other words, a measure of a liquid's resistance to flow. A thicker fluid has higher viscosity and thereby increased resistance to flow. A higher viscosity fluid flows with more difficulty than a fluid with low viscosity. Viscosity is measured by the rate at which the fluid resists deformation. The viscosity property of the fluid is affected by temperature. An increase in the temperature of a hydraulic fluid results in a decrease in its viscosity or resistance to flow. In a hydraulic system, the viscosity should neither be too high nor too low. If the viscosity of the fluid is high, it does not flow easily in the circuit. There is too much heat generated and power lost. On the other hand, if the viscosity is very low, this results in leaks in the system. Viscosity is measured in centistokes.

Too high a viscosity results in:

- Higher resistance to flow, causing sluggish operation
- Increase in power consumption due to frictional losses
- Increased pressure drop through valves and lines
- High temperature conditions caused due to friction

Too low a viscosity results in

- Increased losses in the form of seal leakage
- Excessive wear and tear on the moving parts

Viscosity can be further classified as:

- Absolute viscosity and
- Kinematic viscosity

Absolute viscosity

Also known as the coefficient of dynamic viscosity, absolute viscosity is the tangential force on a unit area of either one or two parallel planes at a unit distance apart when the space is filled with liquid and one of the planes moves relative to the other at unit velocity. It is measured in poise. The most commonly used unit is centipoise, which is 1/100th of a poise.

Kinematic viscosity

Most of the calculations in hydraulics involve the use of kinematic viscosity rather than absolute viscosity. Kinematic viscosity is a measure of the time required for a fixed amount of fluid to flow through a capillary tube under the force of gravity. It can also be defined as the quotient of absolute viscosity in centipoise divided by the mass density of the fluid.

It is usually measured in centistokes.

Viscosity index

The viscosity index is an empirical number indicating the rate of change of viscosity of an oil within a given temperature range. A low viscosity index indicates a relatively large change in viscosity with temperature, whereas a high viscosity index indicates a relatively small change in viscosity with temperature. The viscosity index does not have units and is expressed as a plain number.

Oxidation resistance

Oxidation resistance of oil is the resistance of the oil for chemical breakdown. When oil comes in contact with the oxygen in air, oxidation occurs in the oil and gives rise to the following deterioration:

- Formation of acids, varnishes and sludge which can block the system
- Increase in viscosity of the fluid
- Corrosion as a result of the contaminants

Foam resistance

Foam resistance is the ability of the fluid to resist the formation of foam and reject air from the fluid. Foaming can result due to poor system design or faults which allow air to mix with the fluid.

Demulsibililty

This is the ability of the fluid to separate from or resist mixing with water.

1.5.3 Cavitation

Cavitation is the formation of vapor in a working fluid and is different from aeration. Aeration is the phenomenon of mixing air with fluid. Cavitation is the phenomenon of creating vapor in the fluid during the working of the fluid. The symptoms of cavitation are as follows:

- Overheating of the fluid
- Excessive pump wear
- Excessive pump noise

The causes of cavitation are as follows:

- High viscosity of the fluid
- Fluid head is too high
- Speed of the pump is too high
- Bore of the inlet pipe line is too small
- Blocked inlet strainer
- Tank breather being blocked
- Collapsed inlet line
- Too many bends or restrictions in the inlet line

1.5.4 Aeration

The symptoms of aeration are similar to those of cavitation. The following are the causes and the remedies for aeration:

- Low oil level in the reservoir – Top up oil level in the reservoir
- Leaky pump shaft seals – Replace the defective pump seals
- Loose oil intake fittings – Tighten the loose intake fittings
- Broken oil intake fittings – Replace the broken intake fittings
- Using fluid with low foam resistance – Use a high foam resistance fluid or add anti-foaming agent to the fluid
- Return line above the fluid level – Ensure that the return line is terminated below the fluid level

1.6 Hydraulic circuits

Hydraulic circuits are represented by symbols and diagrams and are similar to electrical circuit diagrams in the following ways:

- Schematic diagrams are used to show the operation of the system
- Standard symbols are used to show the components of the circuit

The following are the differences between hydraulic circuit and electrical circuit representations:

- There are different international standardsl; Australia uses AS 1101
- Graphical symbols can indicate the particular function of a component and how it operates in a hydraulic circuit
- Different graphical symbols are used to represent flow lines, depending upon their function in the hydraulic circuit

1.6.1 Hydraulic symbols

Standard 1101, Part-1 provides the symbols for hydraulic circuits. The working lines are continuous lines drawn between connection points and the component symbols. These lines are used to represent supply lines, return lines and feed lines and are represented as shown by the line below:

The pilot control lines are represented by a series of long dashes as follows:

Drain and bleed lines are represented by series of short dashes as follows:

In hydraulic circuit diagrams, two or more components are put together as one complete unit and surrounded by enclosure lines to represent an assembly, instead of as separate components.

Mechanical Connection

Pressure Line

Control Line

Enclosing Line

Mechanical Connection

Two Ports Closed

Hydraulic Pump

	Gauge
	Linear Actuator
	Pressure Switch
	Pressure Relief
	Accumulator
	Bleed
	Check Valve
	Restrictor
	Shuttle Valve

Table 1.1

Hydraulic circuit symbols

1.7 Recommendations for working on hydraulic systems

- Wear protective clothing when handling hydraulic fluids and if clothing

becomes contaminated, remove and clean it immediately
- Always use clean tools and containers to avoid contamination of the fluid
- Use a pre-filter when filling up to prevent external contaminants from entering into the system
- Use only the recommended fluid
- Do not mix different fluids; pay special attention when topping up a system

1.8 Safety precautions

Due to high pressures encountered in hydraulic systems, great caution should be exercised while working on them.

- The fluid and the components may often be hot enough to burn
- Spillage of hydraulic fluid on the floor can make the floor slippery
- Some hydraulic fluids can become inflammable under the right conditions of pressure and temperature
- Some hydraulic fluids can cause skin problems, e.g. dermatitis
- The pressures in hydraulic systems can be high enough to penetrate the skin
- Heavy loads are sometimes suspended in the air due to the breakdown of hydraulic systems