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Nile Valley University

Faculty of Post Graduate Studies

Mechanical Department

Master Degree by Research in Mechanical Engineering

Study of Failure in Hydraulic Systems

(Case study of machinery used in local gold mining)

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ACKNOWLEDGMENT

A journey is easier when you travel together. This project is the result of one year of work whereby I have been accompanied and supported by many people. It is a pleasant aspect that now I have opportunity to express my gratitude for all of them. I would like to express my deep gratitude to my supervisor assistant professor Osama Elmardi , for supporting the subject matter when introduced to him, for his encouragement and belief in me, for the uncountable number of hours spent sharing his knowledge and discussing various ideas, and for many useful comments and suggestions while examining my work. I would also like to express my thanks to faculty members of Mechanical Engineering Department and post graduate studies, who contributed a lot in completing and helping to finish this work in time.

I dedicated my work to my parents, and family members for their continual support and encouragement in attaining my academic achievements. Of all above, i would like to thank God almighty for having blessed me to carry out my research.

الملخص

تم تناول فكرة المشروع من خلال بحث عملي للمشاكل والمعوقات والصعوبات التي تتعرض لها الآليات والمعدات التي تعمل في حقل تنقيب الذهب المحلي، وهي دراسة المشاكل الهيدروليكية المختلفة بالإضافة للحلول لها.

ايضا تم الاطلاع علي الافكار السابقة التي طرحت لحل المشاكل الهيدروليكية والتخلص من مسبباتها والمساعدة على تطوير عمليات الصيانة بالتماس عوامل النجاح بتدريب الكوادر العاملة في مجالها.

الهيدروليك اصطلاحاً تعني التحكم في نقل الحركة والقوة داخل الاليات والمعدات مستخدمة السوائل المضغوطة سواء كانت زيت او هواء، هذا الضغط يحرك الاجسام بسلاسة ويعطى عزم اكبر لتحريك الاجسام الساكنة.

لقد بدأ هذا البحث بمقدمه عن الخلفية التاريخية لنظام الهيدروليك وذلك تمهيدا للقارئ المبتدئ، ثم استعراض للعناصر والمكونات الاساسية للدائرة الهيدروليكية وذلك تدريباً للقارئ المتخصص والمهتمين بالشأن الهيدروليك، ثم بعد ذلك تم تناول الفكرة الاساسية لهذا المشروع هي دراسة لحالات الفشل الهيدروليكي التي تحدث في الدائرة الهيدروليكية ويتم تحديدها ومعالجتها بعد الرجوع الى جذور المشكلة تفادياً لتكرارها وللحد من الصرف الغير مبرر في عمليات الصيانة، كل هذا إشباع لرغبة القارئ المحترف، أيضاً تم تناول السلامة في العمل في دائرة الهيدروليك (تقليل الضغط بالتنفيس) والمخاطر التي تنجم عنها وذلك حفاظاً على سلامة العامل والمُعدّة.

أخيراً أرجو من الله أن ينفعني وإياكم بالعلم النافع.

Abstract

This project describes different case studies of hydraulic failure in gold mining machines, the research was conducted to know and understand the components, construction, location, function, circuit diagram and the case studies of different failures in the hydraulic systems.

The case study includes all mobile machines that are used in the gold mining site which they have different types, sizes and applications. Hydraulic system consists of a prime mover engine or electrical motor to help in driving the hydraulic pump which draws the hydraulic oil from the reservoir via filter in the suction line and delivers it to the direction control valve via relief valve in the delivery line. Work is done smoothly by converting mechanical energy into hydraulic energy and then back to mechanical energy which is used to move the hydraulic cylinder linearly or rotate the hydraulic motor. Most problems of hydraulic failure in gold mining machines on field site are caused by either contamination or climate condition (temperature). Also usage of old and outdated of machines and lack of maintenance are other factors affecting the machines performance. These problems lead to increase the down time and decrease the productivity.

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Chapter One

Introduction

1-1 Historical background.

Hydraulic systems are used to transfer energy by converting mechanical energy to fluid energy and then back to mechanical energy. The principal or main reason for converting mechanical energy to fluid energy is the convenience of transferring easily to a new location .The transmission and control of power by means of fluid under pressure is used extensively in all branches of industries and mobile equipment, lifting machines, pressing machines, drilling machines …etc.

The present thesis deals with the study of hydraulic system of equipment used in local gold mining industry. As we all know gold mining is the process of mining gold or gold ore from the ground by using several techniques and processes of extraction and therefore can be classified as, surface mining and underground mining. Surface mining entails removing vegetation, top soil, and overburden materials above a mineral deposit and removing the deposit. In open-pit mining, waste is transported to a disposal site, and ores are transported to a downstream processing site. In underground mining the deposit is accessed from the surface via vertical shafts, horizontal edits, or inclines. The deposit itself is developed by traversing the ore body to enable human access, the extraction of blocks of ore, the transport of ore and waste and the easiness of ventilation. In hard-rock mines drilling and blasting techniques are used.

The main equipment used in local gold miming are wheel loader, excavator, backhoe, bulldozer, drilling machine and dump truck...etc. They perform a variety of functions like preparation of ground, excavation, haulage of material, dumping/laying in specified manner, material handling, road construction etc. These equipments are required for both construction and mining activities. The hydraulic systems in gold mining equipments are typically exposed to solid particles and fluid contamination which causes a rapid wearing and components failure. Lack of maintenance of hydraulic systems is the leading cause of components and system failure. Yet, most maintenance personnel don't understand proper maintenance techniques of hydraulic systems. If the study is focused on preventing system failure, then, less time and cost could be saved. Maintenance is the combination of all technical and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform its required function as stated in Ref. [1]. The maintenance of mining equipment is both challenging and expensive. Over the years, remarkable progress has been made in maintenance equipment in the field, but factors such as complexity, size, competition, cost, and safety continue to challenge maintenance engineers. (Refer to Ref. [2]).

Increased mechanization, automation, and amalgamation of the processes within mines have further complicated the issue as it is clarified in ref. [3].

Mining equipment maintenance costs range from 20% to over 35% of total mining operating costs, and they are continuing to increase. To control these higher value of expenses, mining companies have focused on areas such as optimizing scheduled maintenance operations, deferring non-essential maintenance ,reducing maintenance manpower, controlling inventories of spare parts more effectively and using contract maintenance support as stated in ref.[2]. They look for better maintenance practices for their mobile equipment, especially in underground mining operations where control of maintenance costs requires effective maintenance planning. Better control of maintenance through team work, proper and timely accomplishment of tasks such as data recording and reporting also play a major role in maintenance.

1-2 Challengers

Machinery is fundamental to the function of mining operations .Having high functioning equipment which is regularly maintained is a challenging factor in the smooth running of project and increasing productivity. However, many mining companies are using old machinery which is usually a ticking time bomb with a history of glitches and failures. Not only is this unsafe, but the breakdowns mean downtime while equipment is getting repaired and the time factor required in maintenance means more money to pay. Breakdown in drives are a regular occurrence on the mine site and can cost the business thousands of dollars. There are a number of problems associated with existing, ageing equipment including unreliability, where the chance of frequent failures is high and drives up the maintenance costs, as well as inefficiency due to the long periods of downtime. According to recent studies, 41% of open pit equipment costs are maintenance related and maintenance can for mining companies, represent, up to 30% of operating costs. The high cost and long turnaround time for repairs due to unavailability of spare parts or replacements, results in high losses of production time. With cost reduction a prominent factor in keeping operations float, companies need to invest in initiatives around equipment that lower unplanned maintenance and repair costs, provide quick turnaround for part replacements decrease inventory carrying costs and reduce the risk of injury and accidents, refer to refs.[12,13,16,19,28,60,68] . Figures (1-1 - 1-5) below show surface and underground mining.

Figure 1-1 Surface mining using CAT loader and CAT dump truck

Figure 1- 2 Surface mining using Hitachi excavators and dump truck

Figure (1-3): Underground mining using Horizontal Drilling Equipment and cable for lighting

Figure (1-4): Underground mining using Horizontal Drilling Equipment

Figure 1-5 Underground mining, using loading Equipment, dump truck and Horizontal Drilling machine.

Chapter Two
Theoretical study of hydraulics

2-1 Theoretical study of hydraulic components

The main components of hydraulic system are, reservoir, pump, control valve, actuators, hoses and pipes, hydraulic fluid, oil cooler ,and filters, they must be arranged properly to perform a useful task. In this section we will study the components of the hydraulic system. Refer to refs. [23, 61, 65, 66].
Figure (2-1 and 2-2) below show the basic components of hydraulic circuit and the hydraulic components of an excavator.

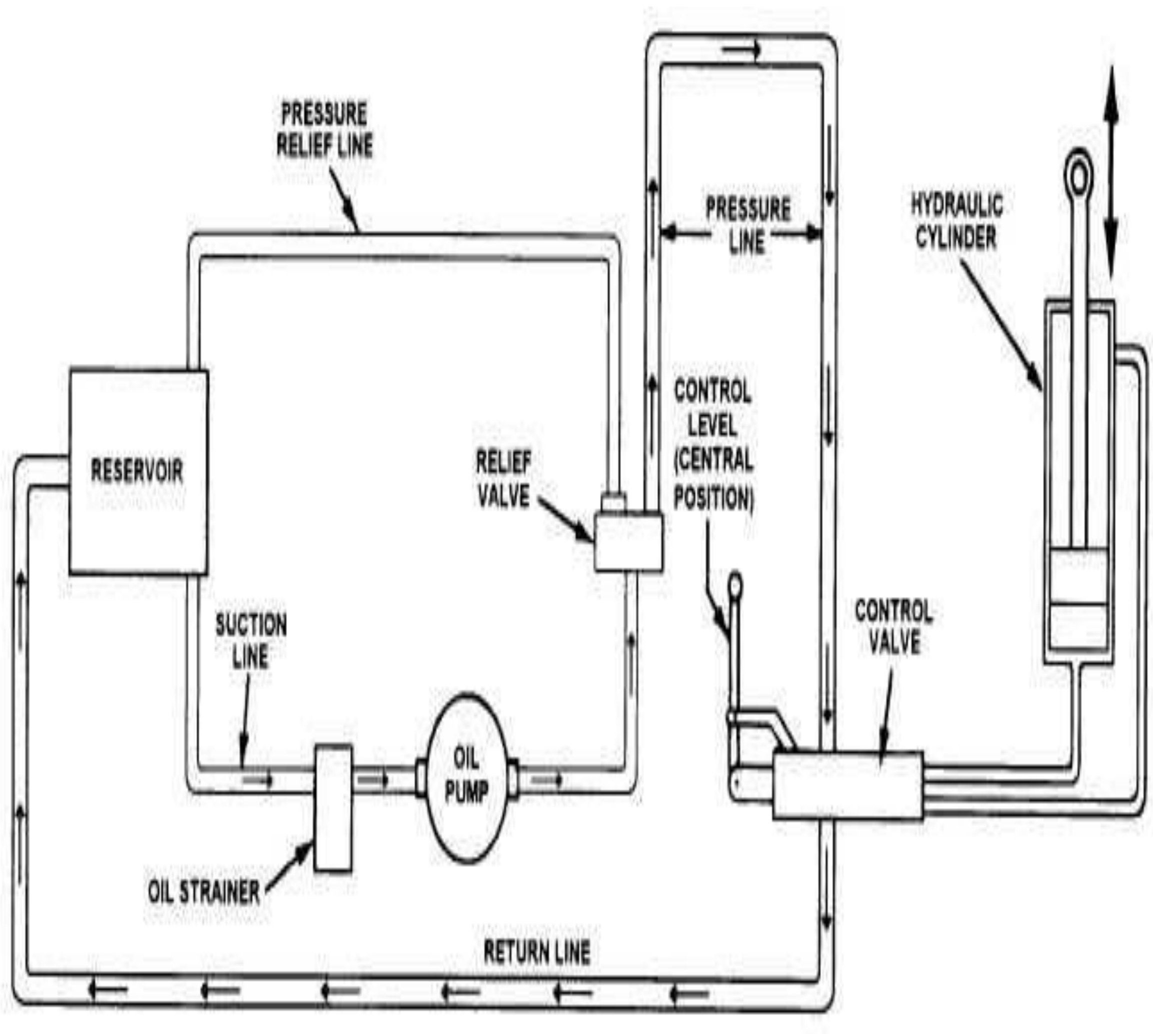


Figure: 2-1 Basic components of hydraulic circuits

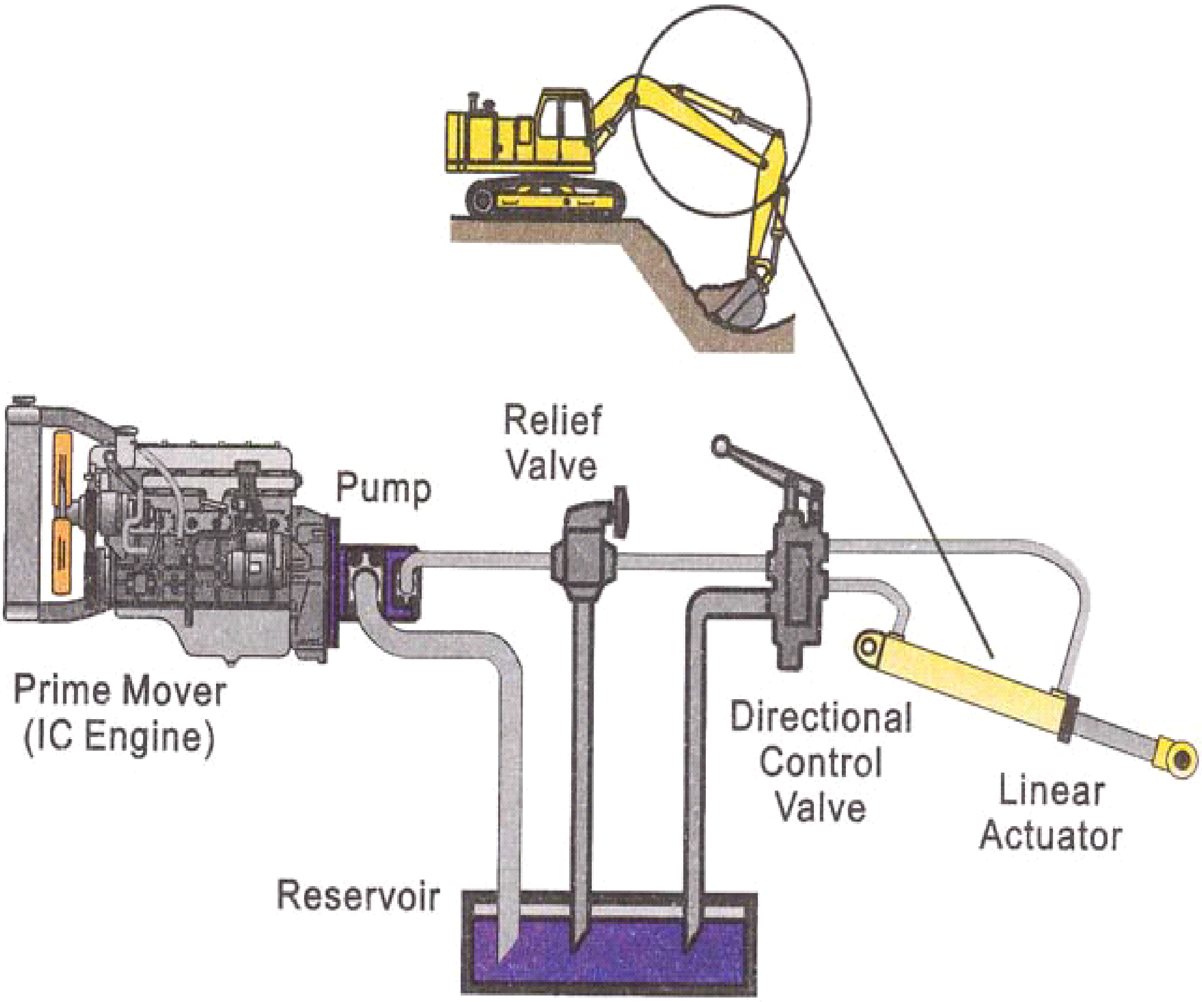


Figure 2- 2 Excavator hydraulic components

1- Reservoir

Every hydraulic system includes a reservoir to supply hydraulic fluid to the pump and to provide storage for fluid retuning from hydraulic circuit .The reservoir must have sufficient volume to allow the returning fluid sufficient resident time to cool and to allow air to escape before the fluid re-enters the pump. If the reservoir can't provide sufficient cooling, an oil cooler may be needed .The return line is normally below fluid level in the reservoir to prevent air entrainment and foaming of the fluid. The reservoir designer can use careful placement of the two reservoir ports and baffles to prevent the returning fluid from immediate entry into the pump port, otherwise the fluid would not have time to cool .The reservoir normally operates at atmospheric pressure and thus it is vented to the atmosphere, The reservoir will allow contaminates to settle on the bottom and dissipate heat.. Figure (2-3) below shows the main components of atypical reservoir. (Refer to refs. [34, 40]).

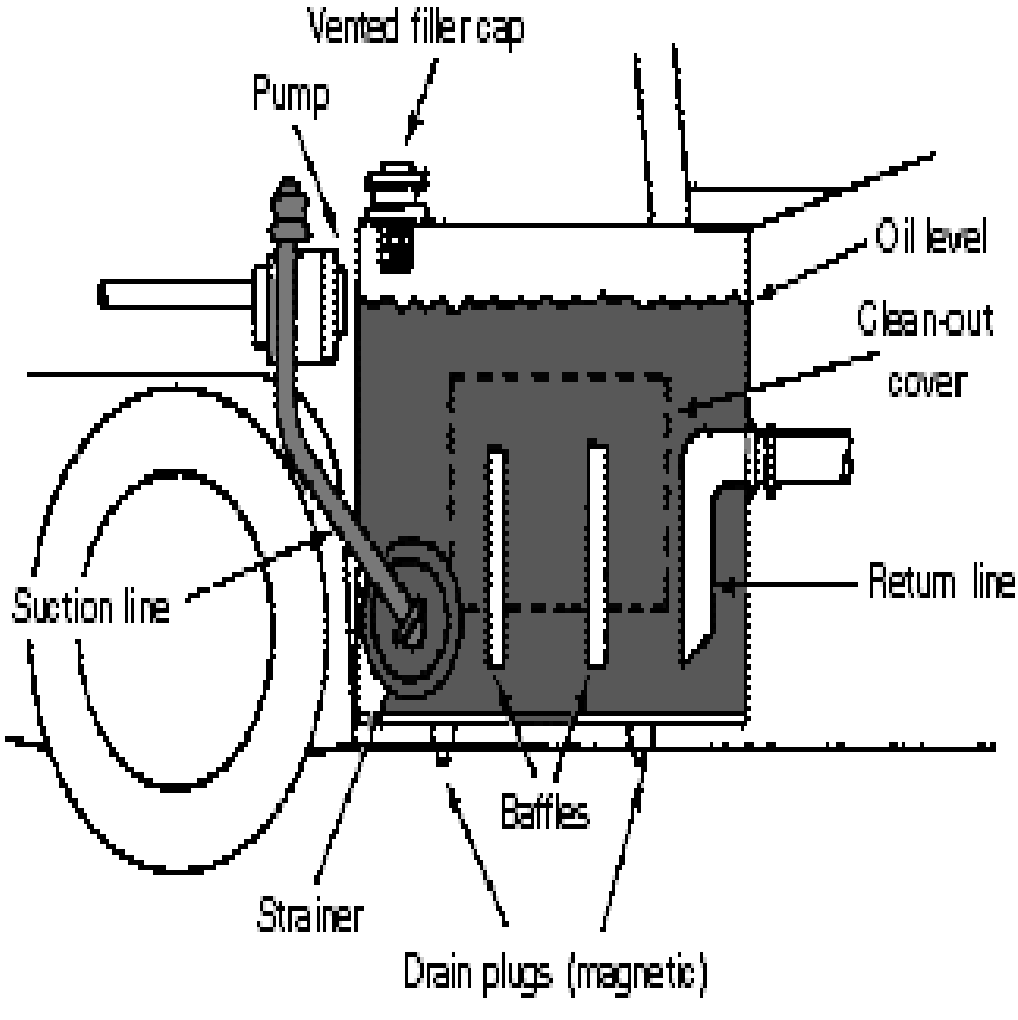


Figure 2-3 the main components of a reservoir

2- Hydraulic fluid

The most important property of hydraulic fluid is its viscosity. Manufacturers generally recommend fluid viscosity at operating temperatures. Oil viscosity is highly dependent on temperature, and viscosity control is important because pump and motor efficiencies depend on it.

Functions of hydraulic fluid

● **Power transmission**:-

This is the primary function of hydraulic oil, it is very important that hydraulic fluid transfers power efficiently and economically.

● **Lubrication of all moving parts (reciprocating and rotary parts**).

This is essential to reduce friction and wear, proper lubrication extends equipment life span, and also reduce both operating and maintenance costs

● **Heat medium**:-

If excessive heat builds up it will severely reduce the system efficiency and may even make the system non-functional.

● **Sealing medium:-**

It acts as sealing medium, because whirling action of the fluid helps the seals to function properly so as to reduce losses due to leakage. This action optimizes the full power and the system efficiency.

● **Anti – Oxidant medium**:-

The hydraulic fluid maintains the system in good working order, and it must be provided with an anti- oxidant medium to preserve the system from oxidation which leads to rusting, corrosion and erosion [7, 20, and 41]

3- Hydraulic pump:-

In any hydraulic system the pump creates flow of fluid, doesn't creates pressure but has to overcome the resistance to flow in the circuit. There are two basic groups of pumps, positive displacement and non-positive displacement pump, the use of non-positive displacement in the hydraulic circuit is limited to providing boosted supply to the main positive displacement pump. The pump is composed of main pump and pilot pump. The main pump is a variable displacement axial plunger pump. It provides high pressure oil for the hydraulic system. The pilot pump is a fixed displacement gear pump; it supplies oil for the control system. The main pump is driven by the engine through a coupler. The pilot gear pump is connected directly by the drive shaft of the main pump at the same rotate speed [25]. Figure (2-4) below shows a photograph of the main hydraulic pump and pilot pump for an excavator, and Figure (2-5) below shows a diagram containing the different types of pumps using in hydraulic system.

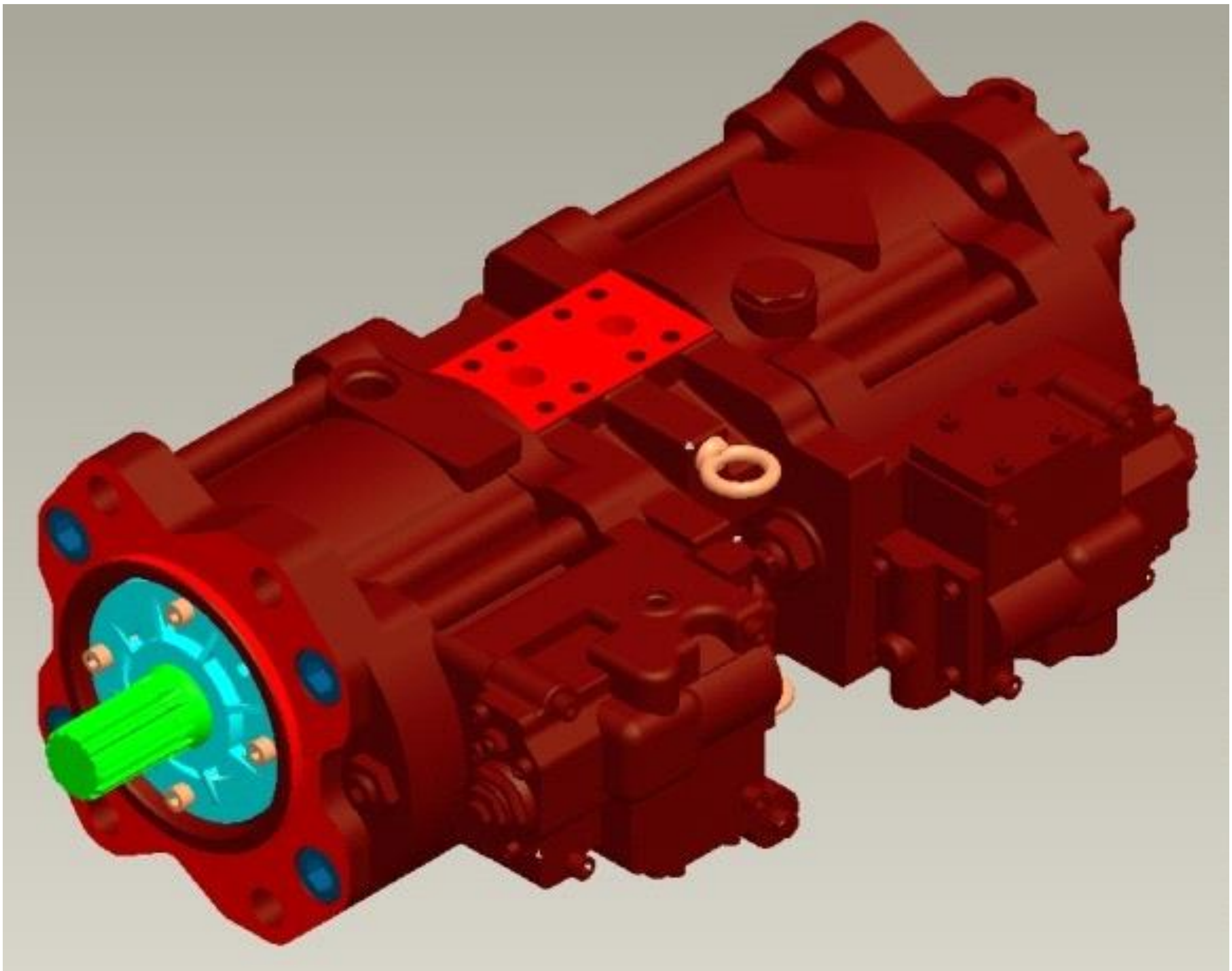


Figure 2-4 a photograph of the main hydraulic pump and pilot pump

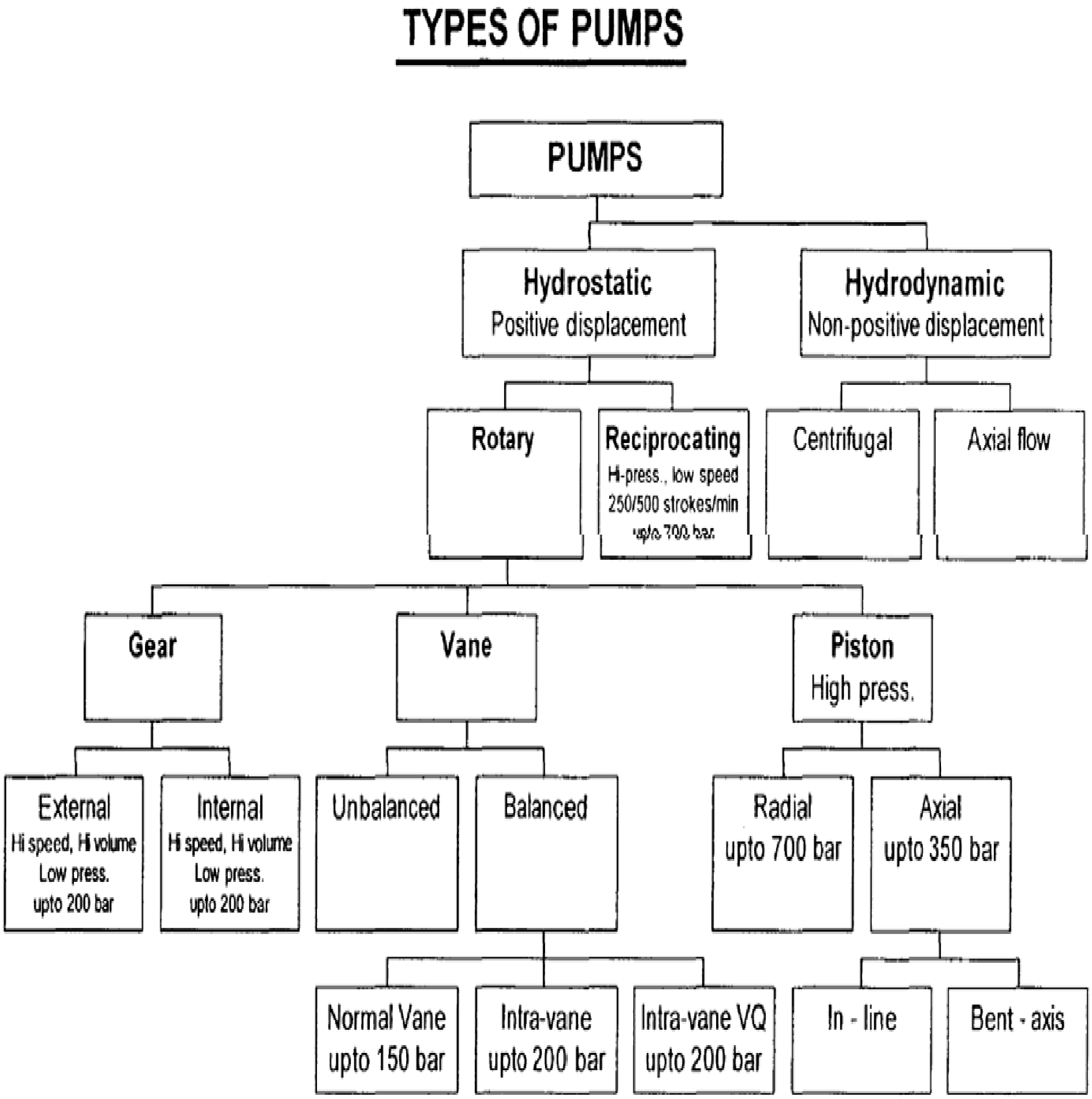


Figure 2-5 types of pumps

4- Hydraulic control valves.

Valves are used in hydraulic circuits to control pressure, volume flow rate, and direction of flow .The most common type of pressure control valves can be summarized in the following categories :-

I- The pressure relief valve

This is used to limit the pressure in a hydraulic circuit to a safe level. In a hydraulic circuit in which flow is supplied by fixed displacement pump, for example the pump may continue to produce flow even when an actuator is stalled and incapable of accepting flow [21, 23]. In the absence of a pressure relief valve, the pressure would climb rapidly until the circuit ruptured at some point and provided an escape path for the flow. Pressure relief valve is set to a specific pressure at which it will open and begin to dump flow to the tank; until system pressure reaches the cracking pressure the valve is closed. Unloading valve is used to unload the pump when the pressure at some point in a hydraulic circuit reaches a desired level. Figure (2-6) below shows a longitudinal section of a pressure relief valve, and Figure (2-7) shows a pictorial view of a relief valve.

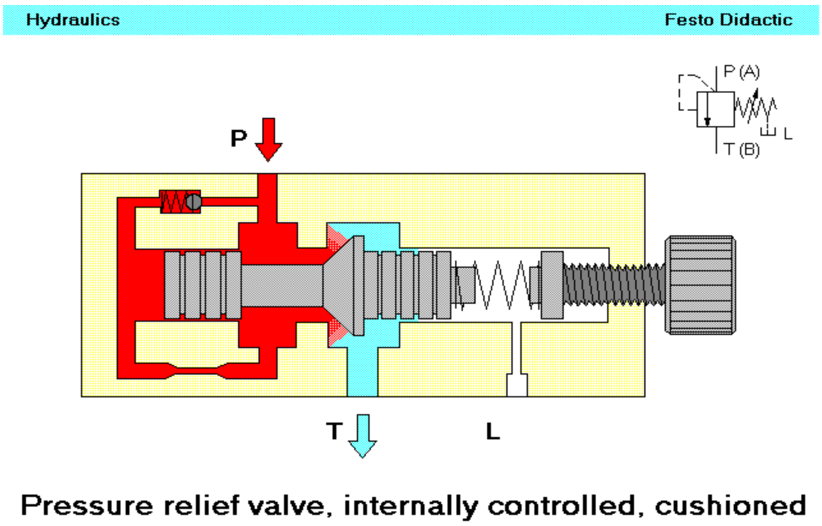


Figure 2-6 a longitudinal section of a pressure relief valve

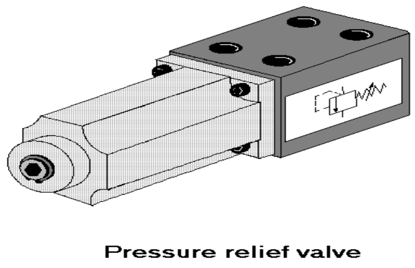


Figure 2-7 pictorial view of pressure relief valve

II- Direction control valve (DCV)

The main control valve is located between the main pump and actuators (all of the cylinders and motors).It is used to control the oil direction, pressure, and flow rate for all of the actuators. It consists of valve body with passage and ports and sliding spool, it can be operated manually (lever) or by electrical solenoid to slide the spool to different positions, the ports, P and T provide pressure and return, while A and B are for the connection to the actuator or circuit to be controlled by the valve. The valve spool can be slide inside the box to align with the ports, refs [3, 22, and 23]. Main control valve is pilot control, open negative flow control, and paralleling monolithic multi-ported directional valve composed of nine spools. It includes spools for the boom, Arm, bucket swing travel and auxiliary devices. Figure 2-8 below shows a pictorial view of a directional control valve which is operated manually and figure 2-9 below shows a solenoid operated control valve.

Figure 2-8 Direction control valve operated manually

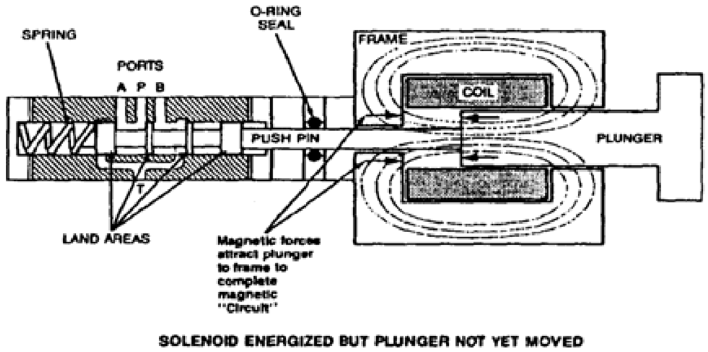


Figure 2-9 Solenoid operated control valve

5- Hydraulic lines

Hydraulic lines or conduits are used to transfer hydraulic fluid between components. Rigid lines are made from steel, while flexible lines are made from wire-reinforced rubber. The line must be strong enough to withstand the maximum pressure to which it will be subjected, and large enough to convey the hydraulic fluid without excessive pressure drop. Manufacturers of hydraulic hoses normally specify the limiting pressure rating of their hoses.

The hose used is composed of three basic layers; an inner tube, the reinforcement layer and the outer cover. The inner tube is made of a plastic material and the reinforcement layer is a fabric braid which provides the necessary strength to resist internal pressure (or external pressure in the case of suction/vacuum). The three basic types of reinforcement are braided, spiraled and helical.

The outer cover is a plastic cover that will resist some heat splatter such that produced by welding. HWH hose has a heat tolerance of about (180) degrees Fahrenheit, constant temperatures exceeding this can damage the hose and create leaks especially at the hose ends.

Bubbling of the outer cover is usually an indication of a heat issue. Engine or exhaust heat and even engine cooling systems (the engine radiator) can cause heat issues. (Refer to [8, 56, and 67]). Figure (2-10) below shows the basic components of hydraulic hose and Figure (2-11) below shows hose poor design twisting and good design not twisting.

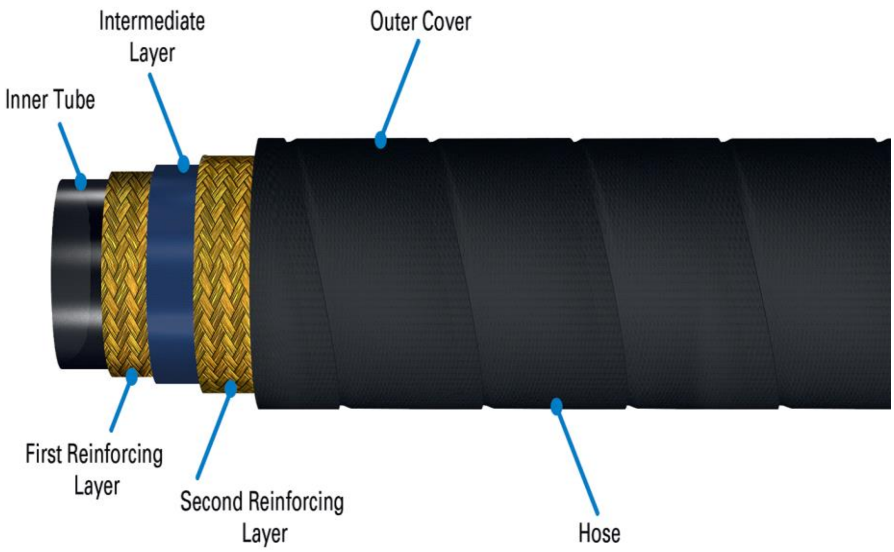
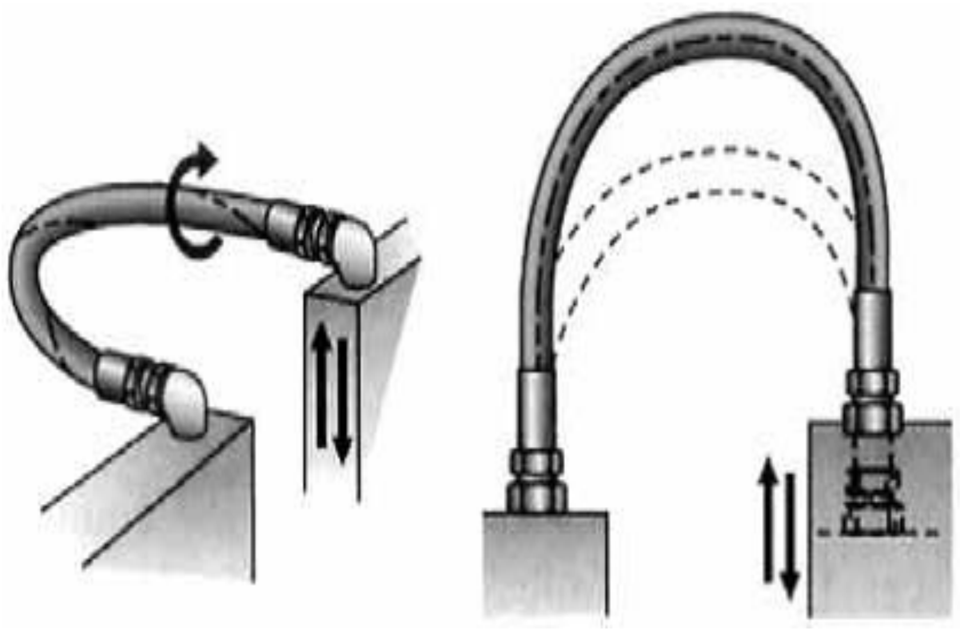


Figure 2-10 basic constituents of hydraulic hose.



good design- Movement flexes hose but does not twist Poor design- Movement causes twisting

Figure 2-11 hose poor design twisting and good design not twist

6- Hydraulic filters

Clearances between mating parts in some hydraulic components are (10 micrometer or less), and if particles of that size or larger pass between mating parts severe damage can result. Filters are used to remove solid particles just upstream of the reservoir return port. To prevent large particles (150 micro meters or large) from entering the pump, a strainer or porous filter is usually placed on the reservoir withdrawal tube. Refer to [17, 33]. Figure 2-12 below shows different sizes of filters used in hydraulic circuits.

Figure 2-12 Different sizes and types of filters (cartridge and element) used in hydraulic circuits

7- Hydraulic Actuators

A hydraulic actuator is a device used for converting hydraulic power into mechanical power. There are two types of actuators, rotary and linear. Rotary actuators are called hydraulic motors, while linear actuators are called hydraulic cylinders.

1- Hydraulic motors:-

They are similar in appearance to hydraulic pumps. pumps and motors can often be used interchangeably .The important factors that can be noted, is the speed of hydraulic motor which is effected by , Internal leakage from the inlet port to the out let port of the motor, volumetric efficiency of the motor and the torque produced by the motor.

The Travel and swing motors.

Reducer consists of a hydraulic motor and a reduction gear. It is used to control the forward, backward, left turn and right turn operation of the machine. The travel speed can be controlled by travel speed control switch. There are two speed positions, Low Speed and High Speed.

Figure 2-13 and 2-14 below show a hydraulic travel and swing motors respectively.

The travel motor is used to moves the machine forward and backward. The swing motor and reducer which consists of a hydraulic motor and reduction gear, is used to rotate the upper structure of the excavator, as in refs. [23.70].

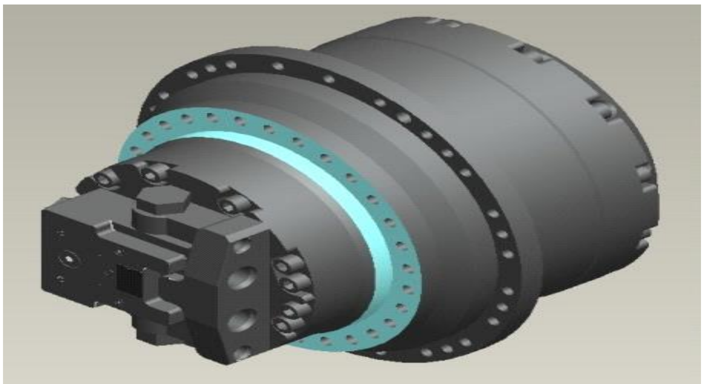


Figure 2-13 Hydraulic Travel Motor

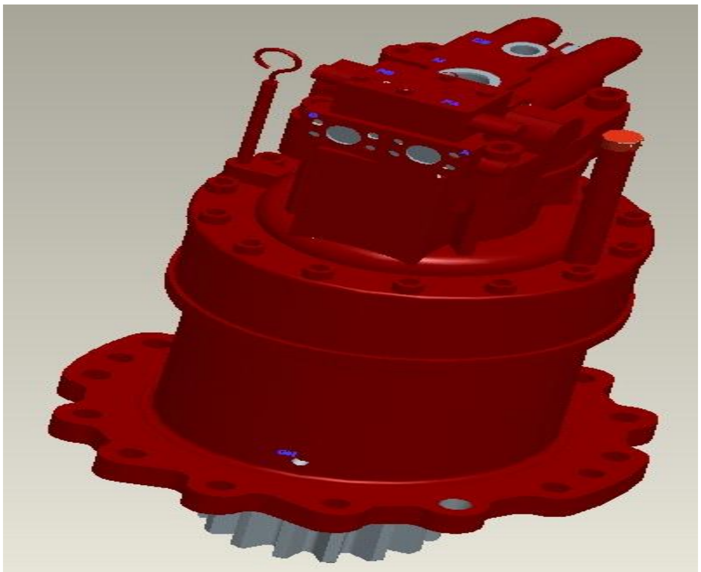


Figure 2-14 Hydraulic swing Motor

2- Hydraulic cylinders

Can be divided into two main groups which are:-

i- Single acting.

ii- Double acting.

Each is used to convert the pressure energy of a fluid into a linear thrust

i- **Single acting cylinder**

This can be powered in one direction only (either extend or retract) by hydraulic force, the return movement is brought about by either spring built into the cylinder or external force.

Figure 2-15 below shows a longitudinal section of a Single acting cylinder.

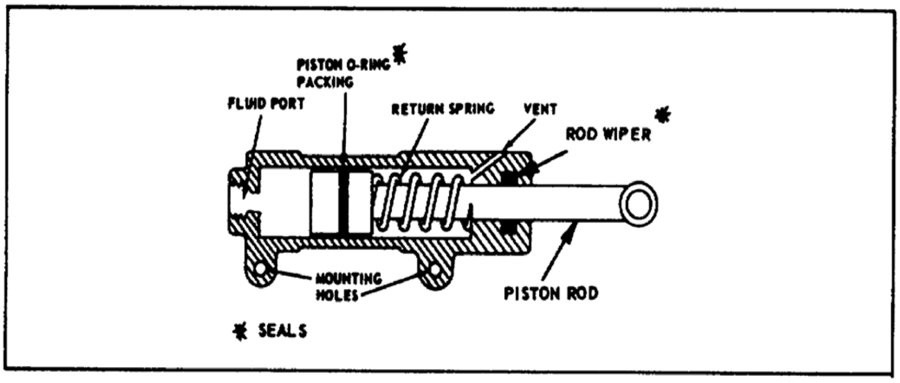


Figure 2-15 Single acting cylinders

ii- **Double acting cylinder**

This can be hydraulically powered in both directions by applying fluid pressure to the appropriate side of the piston. Figure (2-16) below shows a longitudinal section of a double acting cylinder. Refer to ref. [23]

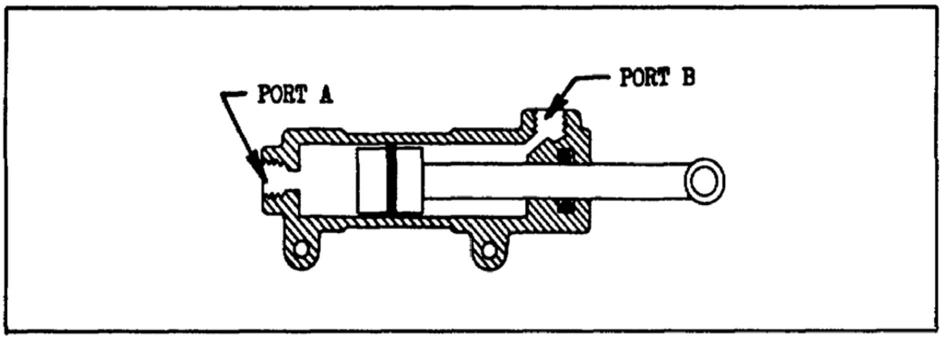


Figure 2-16 double acting cylinders

8- Hydraulic orifice

In hydraulic circuit design it is often necessary to restrict flow to some segment of the circuit and/or to create a pressure difference; this goal can be achieved by using a hydraulic orifice. Many valves form orifices that are used to control flow of the fluid. Figure (2-17) below shows a hydraulic orifice.

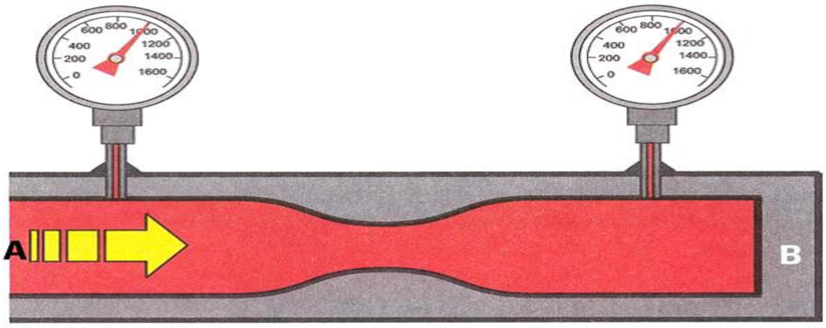


Figure 2-17 orifices

9- O-ring Kit seal

Elastomeric O-rings are unlike most of the materials that engineers and designers encounter. The reason, O-rings must deform to function properly. As the name implies, O-rings are shaped like a donut. (Torus is the geometric term.) They are installed in cavities known as glands and then compressed. The resulting zero clearance within the gland provides the seal that blocks the flow of liquids and gases. This simple arrangement serves many fluid-power systems very well, but O-rings are the most commonly used seals in fluid-power systems. However, success still requires careful design, selection, and installation procedures. O-rings typically fail in their applications because of the combined adverse effects of several environmental factors. Figure (2-18): Below shows different sizes of o- rings. (Refs. [9, 10, 38])

Figure 2-18 Different sizes of O-rings seal

10- Pressure Gauges and Volume Meters

Pressure gauges are used in liquid-powered systems to measure pressure so as to maintain efficient and safe operating levels. Pressure is measured in psi or bar. Flow measurement may be expressed in units of rate of flow meter cubic per second (cms). It may also be expressed in terms of total quantity-gallons or cubic feet.

1- Pressure Gauges.

Figure (2-10) shows a simple pressure gauge. Gauge readings indicate the fluid pressure set up by an opposition of forces within a system. Atmospheric pressure is negligible because its action at one place is balanced by its equal action at another place in a system.

2- Volume Meters.

Measuring flow depends on the quantities, flow rates, and types of liquid involved. All liquid meters (flow meters) are made to measure specific liquids and must be used only for the purpose for which they were made. Each meter is tested and calibrated. (Ref. **[**39**])**.

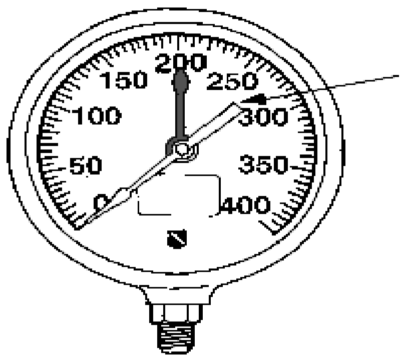


Figure 2-19 Pressure Gauges

11- Hydraulic accumulators

An inert gas above the diaphragm is compressed when hydraulic fluid is forced into the space below the diaphragm. The compressed gas represents potential energy that can be reconverted into hydraulic energy when needed.

Because the compressed gas provides cushioning, an accumulator can also be used as shock absorber to reduce maximum stresses when the system is subjected to unusual loads. Figure 2-20 and 2-21 below show a sectional view of a hydraulic accumulator and hydraulic accumulator in brake circuit**,** [23, 70].

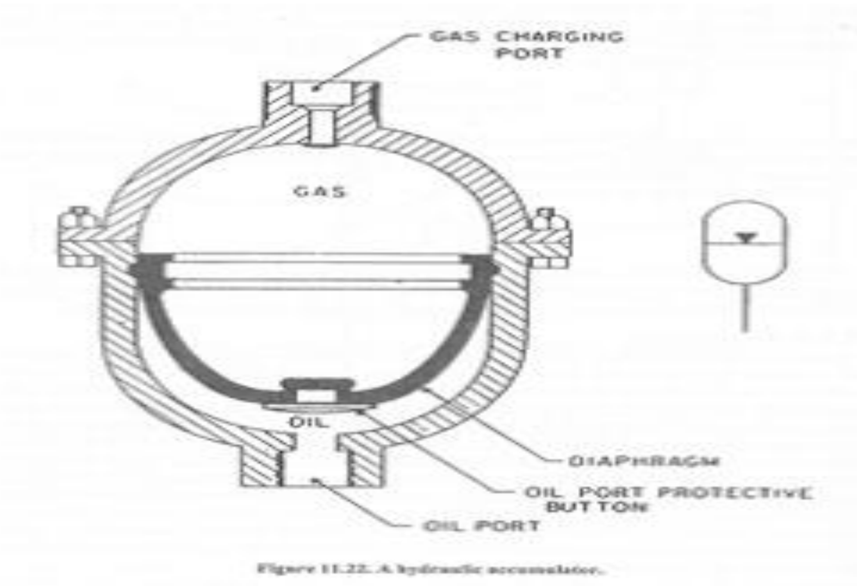


Figure 2-20 Hydraulic accumulators

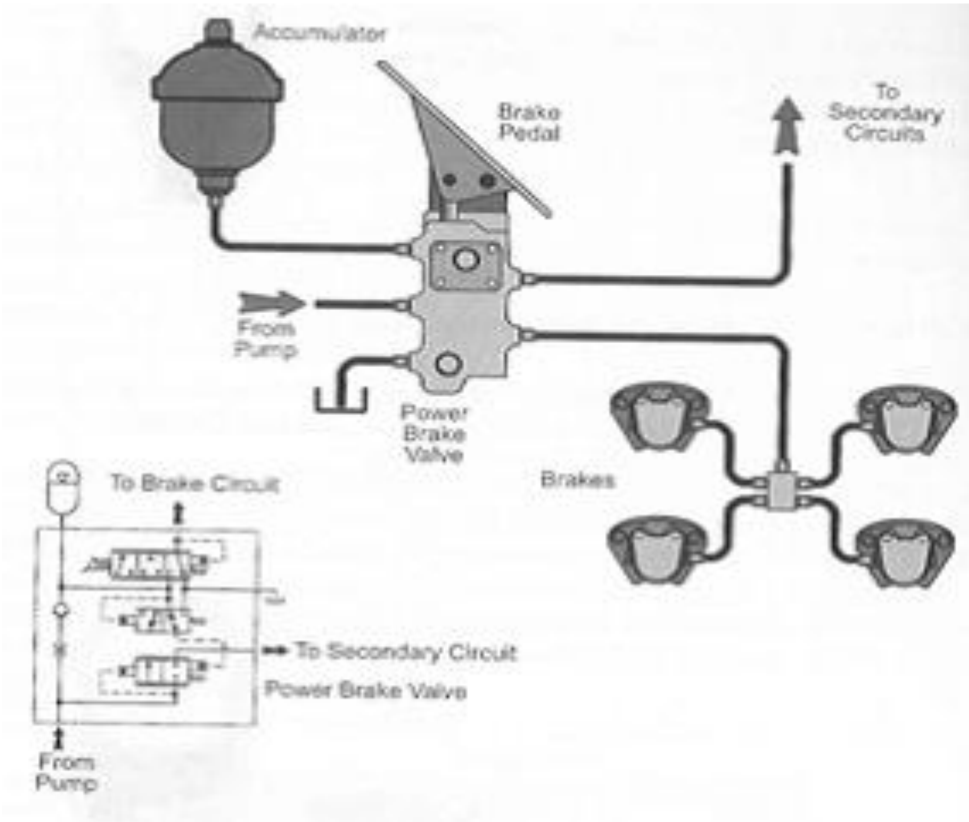


Figure 2-21 Hydraulic accumulators in brake system.

12 - Hydraulic oil cooler

If reservoir volume is too small to allow sufficient cooling of the hydraulic fluid, oil cooler may be used; typically the oil cooler is a liquid to liquid heat exchanger that transfers heat from the hydraulic fluid to the engine coolant. Figures 2-22 and 2-23 below show a hydraulic water and air coolers and Figure 2-24 Below shows hydraulic oil cooler physically, the arrow shows water flow and full(black) arrow shows oil flow, and it's location on the symbol hydraulic circuit.(Refs. [36, 50]).

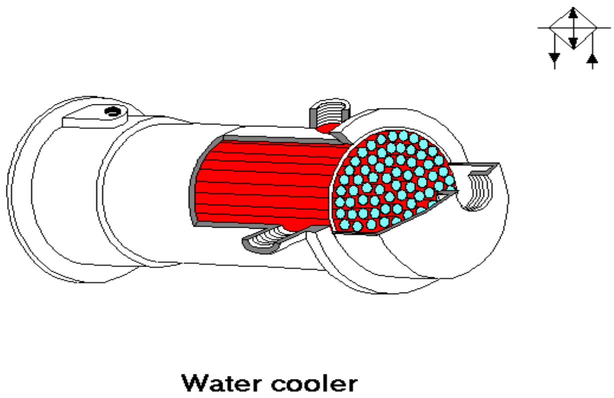


Figure 2-22 hydraulic water coolers

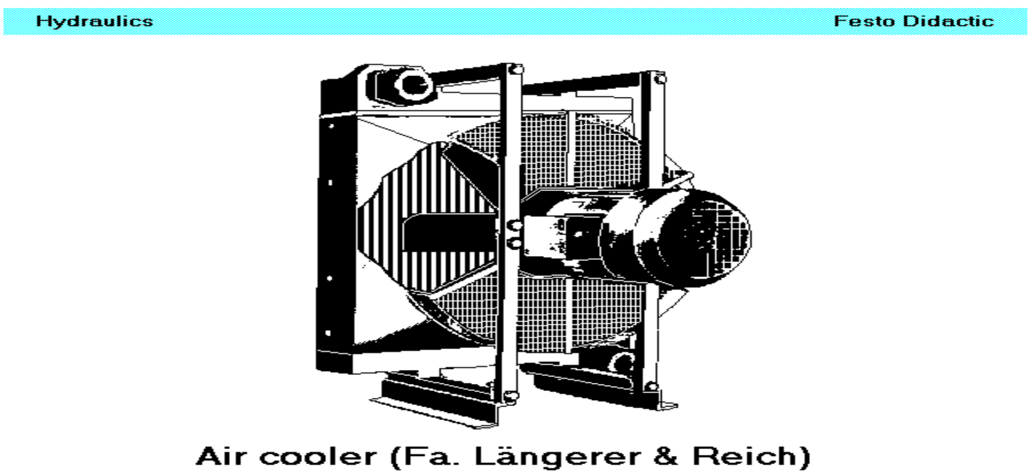


Figure 2- 23 Hydraulic air cooler

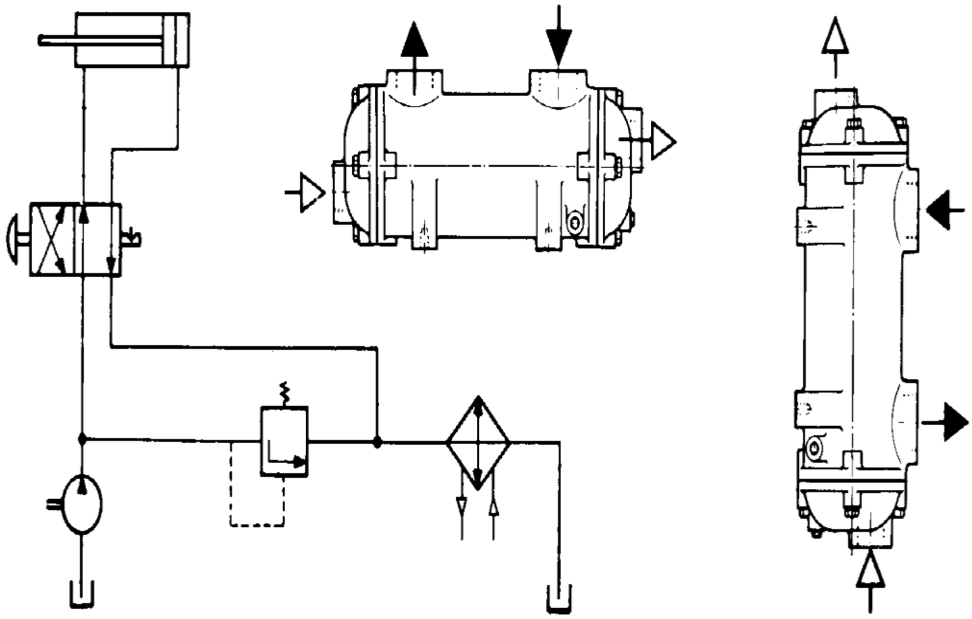


Figure 2-24 physical representation of hydraulic oil cooler

2-2 Circuit Diagrams

1- Hydraulic circuit and components

Figure (2-13): Below depicts a basic hydraulic system. For a basic hydraulic system to operate (e.g. cylinder extend and retract), it must contain the following components.

- Fluid (A)
- Reservoir (B)
- Filter (C)
- Pump (D)
- Direction control valve (E)
- Actuator or hydraulic cylinder (F)
- Lines (G)
- Pressure control valve (H)
- Cooler (I)

Most manufacturers use graphic symbol circuits to identify the circuit components, and to illustrate the circuit function and operation.(Ref. [23]).

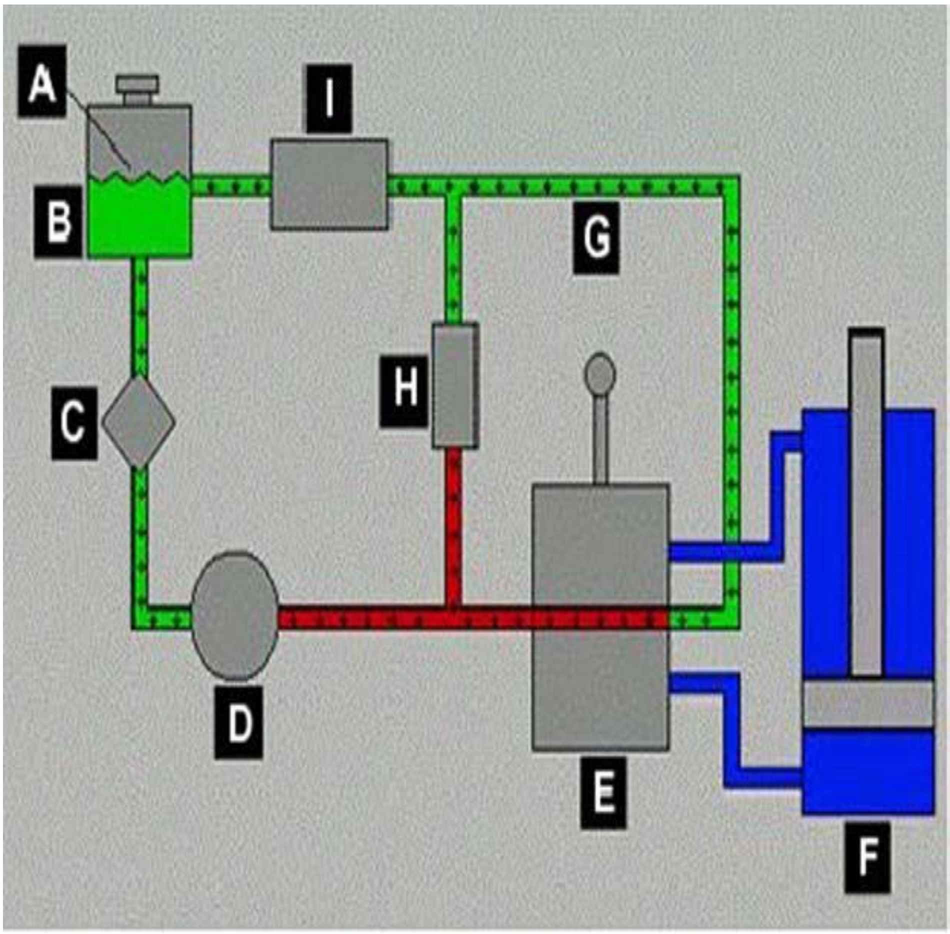


Figure 2-25 basic hydraulic system components

2- Complete Hydraulic Schematic representation:-

Here we have a simple hydraulic schematic using the symbols that are shown below. You can see that we have a hydraulic pump which gets its fluid from the reservoir, pulls the fluid through the filter then sends it to the valve. The direction control valve directs the oil to the hydraulic cylinder or to the hydraulic motor. Figure 2-26 and 2-27 below show simple and complex hydraulic circuits. Figure 2-26 illustrates the components of simple circuit which are reservoir, filter, pump, relief valve, direction control valve, cylinder respectively. In Figure (2-27) the components of a complex circuit are shown and they consists of reservoir, filter, pump, relief valve, direction control valve, and motor respectively by using hydraulic symbols. Refer to refs. [4, 24, 46, 48].

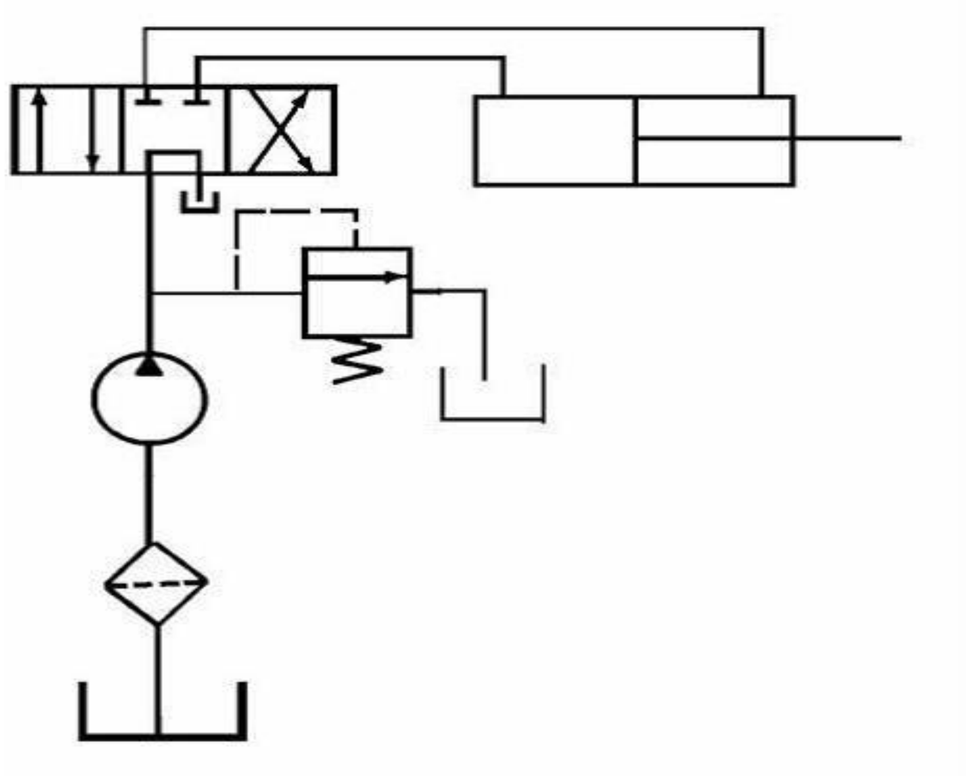


Figure 2-26 simple hydraulic circuit

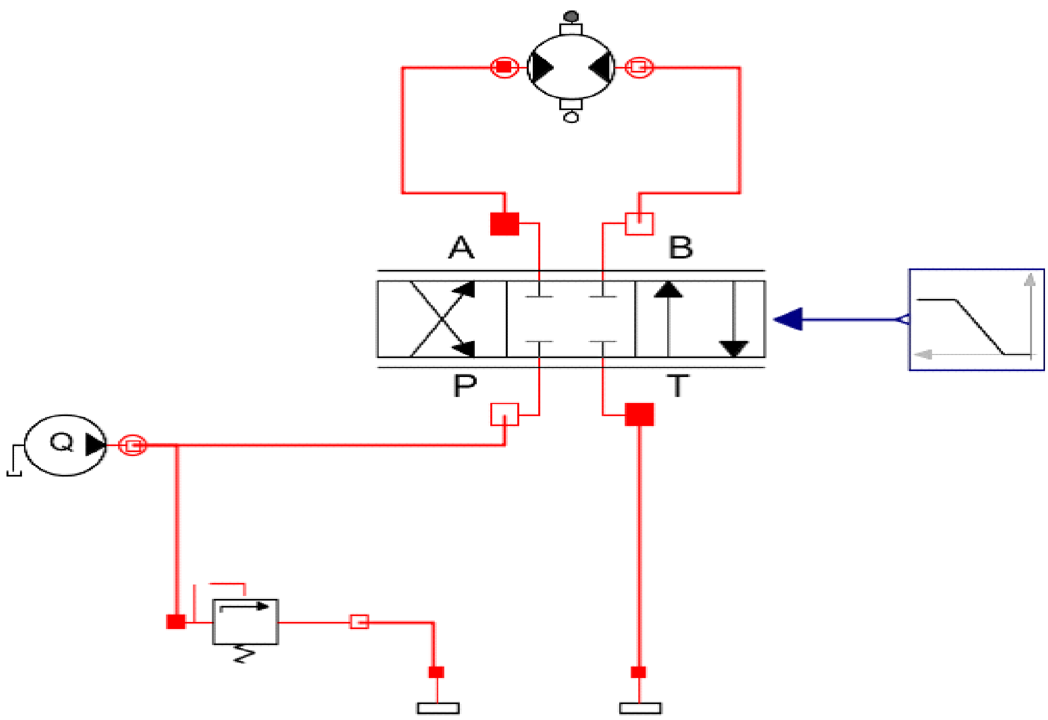


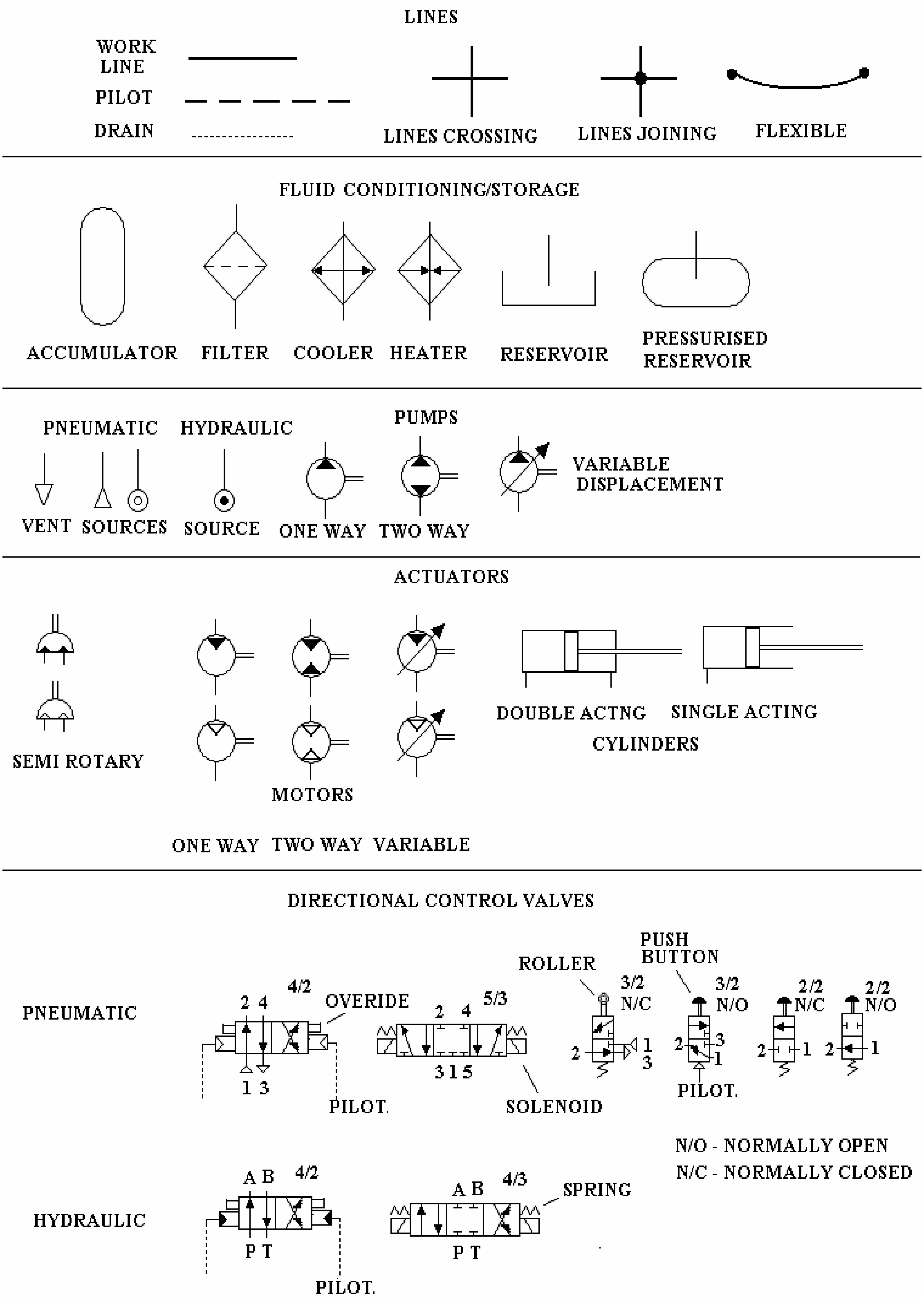
Figure 2-27 Complex hydraulic circuit

2.3 Basic symbols of hydraulic components.

A schematic diagram is a line drawing composed of hydraulic symbols that indicate the types of components which the hydraulic circuit contains and how they are interconnected.

A schematic diagram is a road map of hydraulic system and to a technician skilled in reading and interpreting hydraulic symbols , is a valuable aid in identifying possible causes of problems and therefore can save a lot of money when trouble shooting problems, refer to refs. [4, 56]. Figure 2-28 below shows different types of symbols used in hydraulic circuits.

BASIC FLUID POWER SYMBOLS - NOT DRAWN TO SCALE



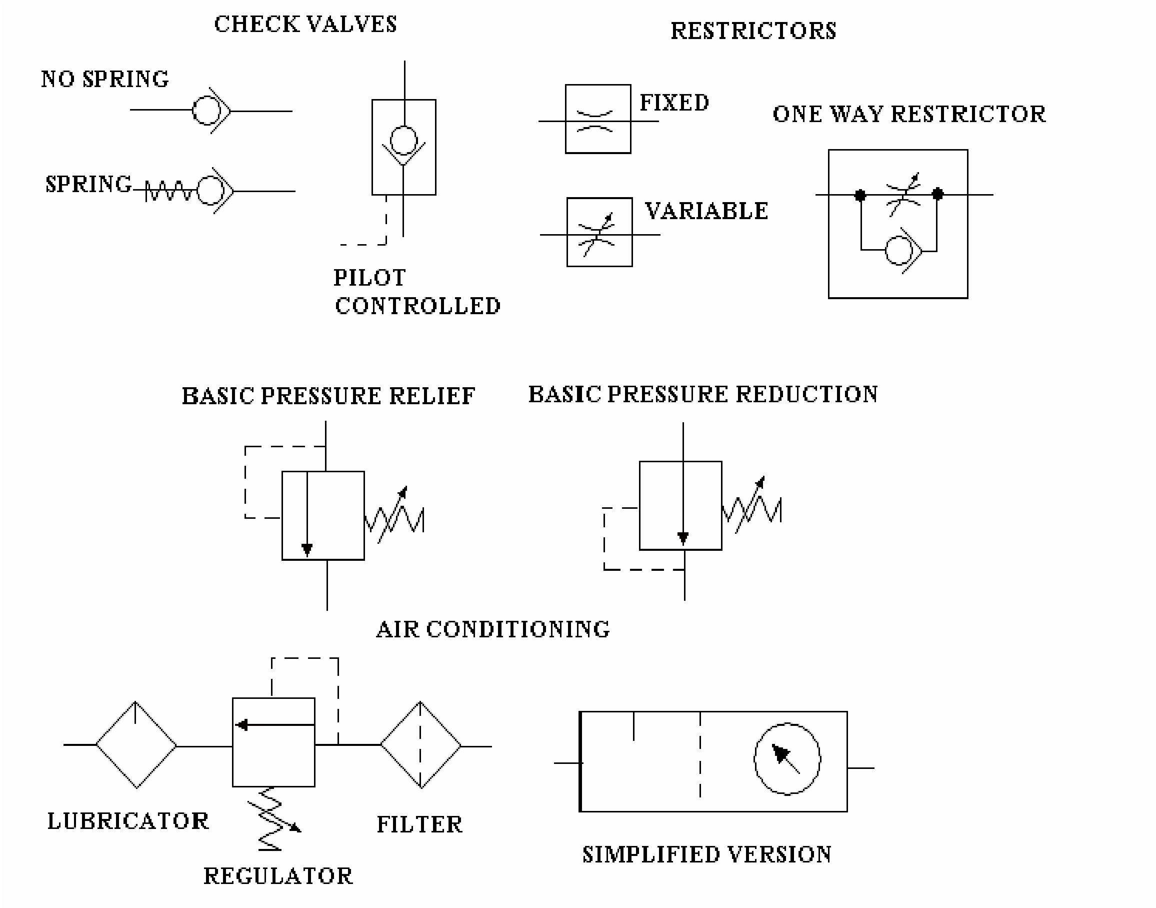


Figure 2-28 Types of symbols used in hydraulic circuits.

2-4 Contamination control in hydraulic systems

Figure 2-29 below shows a contamination damage which is apparent in the rod seal. Figures 2-30 and 2-31 show a contamination level and chart of a components contamination level.

Contamination Control in a hydraulic system is a very wide and complex matter; the following is just a short summary. The function of the fluid in the hydraulic systems is transmitting forces and motion. In view of a reliable and efficient operation of the system, it is very important to select the fluid considering the requirements of the system and the specific working conditions (working pressure, environment temperature, location of the system, etc.).Depending on the required features (viscosity, lubricant capacity, anti-wear protection, density, resistance to ageing and to thermal variances, materials compatibility, etc.), the proper oil can be selected among a number of mineral oils (the most popular), synthetic fluids, water based fluids, environmental friendly fluids, etc. All the hydraulic fluids are classified according to international standards.

Solid contamination is recognized as the main reason for malfunction, failures and early decay in hydraulic systems; it is impossible to be eliminated completely, but it can be well kept under control with proper devices (filters). No matter which fluid is used, it must be kept at the contamination level required by the most sensitive component used on the system. The contamination level is measured by counting the number of particles of a certain dimension per unit of volume of the fluid; this number is then classified in Contamination Classes, according to international standards. Measuring is made with Automatic Particle Counters that can make the analysis on line (through sampling connectors put on the system for this purpose) or from sampling bottles. The calculations and sampling of the fluid must be done according to the specific ISO norms, to attest their validity. The most popular standard for Contamination Classes in the hydraulic systems is ISO 4406:1999.

i- **Sources of Hydraulic System Contamination.**

New oil out of shipping containers is usually contaminated to a level above what is acceptable for most hydraulic systems. Never assume your oil is clean until it has been filtered. There are a surprising number of different sources of system contamination in hydraulic filtration which could be cited below:-

1- Most new fluid is not acceptable for use in hydraulic systems and must be filtered first.

2- Particles introduced during normal maintenance or system operation.

3- Wear generation contamination caused by the pump, actuators, cylinder or the hydraulic motor rubber.

4- Degradation of rubber compounds and elastomers products.

5- Failure to thoroughly clean conductor lines after replacing a failed pump. Clean conductor lines after replacing a failed pump.

ii- Types of Contaminant.

Many different types of contamination may be present in hydraulic fluid. Contaminants grind and wear at the surface of moving parts, introducing even more particles into the system. These surface degradation contaminants cause more than 70%of all hydraulic system downtime.

Particulate ingresses, and built-in (dust, dirt, sand, rust fibers, elastomers, paint chips) Wear metals, silicon, and excessive additives (aluminum – chromium, copper ,iron, lead, tin, silicon, sodium, zinc, barium, phosphorous) - water sealant (tape, pastes - sludge, oxidation, and other corrosion products - acids and other chemicals. all these above can be source of contamination from the hydraulic components.(Refs. **[**2, 42, 43]).

Figure 2-29 Contamination damage is apparent in this rod seal, where the serrations are worn completely away. The seal on the right is a new one, shown for comparison.

Amount of contamination in 100 gallons hydraulic oil

Donaldson Hydraulic Filter	Standard Hydraulic Filter	New, Unfiltered Hydraulic Oil

ISO 14/9/3	ISO 19/17/14	ISO 22/21/18
.400 gram dust	.363 gram dust	4.73 grams dust

Figure 2-30 show contamination level

Contamination Levels of Different ISO4406Codes Vary Dramatically.

New unfiltered hydraulic oil can contain 100 times more contaminant than oil that has passed through filter media. Protect your hydraulic system from costly repairs and downtime with filter media technology –designed to meet equipment filtration requirements and strength needs. (Refs. [17] and [43]).

Contamination Level Chart for SYSTEMS

Sr. No.	Hydraulic System	Recommended Absolute Filtration Rating	Attainable Oil cleanliness Class	
			NAS 1638 with parts >5 Microns.	ISO 4406
1	System with Servo valves	3	4 to 5	13/10 to 14/11
2	Systems with precision Proportional Valves	5	7 to 8	15/12 to 17/14
3	Systems with Simple Proportional Valves	10	9	18/15
4	General Hydraulic Systems	10 to 20	9 to 10	18/15 to 19/16
Source: Principles & Applications of Hydraulic Filters-				

Contamination Level Chart for COMPONENTS

Sr. No.	Hydraulic Component	Oil Cleanliness Class		Recommended Absolute Filtration ratings
		NAS 1638	ISO 4406	In Microns.
1	Gear Pumps	10	19/16	20
2	Cylinders	10	19/16	20
3	Direction Control Valves	10	19/16	20
4	Relief Valves	10	19/16	20
5	Throttle Valves	10	19/16	20
6	Piston Pumps	9	18/15	10
7	Vane Pumps	9	18/15	10
8	Proportional Valves	9	18/15	5
9	Servo Valves	7	16/13	3
10	Servo Cylinders	7	16/13	3
Source: Principles & Application of Hydraulic Filters-				

Figure 2-31 chart of component contamination level

2-5 Temperature

The operating temperature is one of the factors governing the efficiency of a hydraulic system. Where the temperature of the hydraulic fluid depends on.

- The power losses.
- The place of installation.
- The surface area of heat radiating components (such as tank) and the maximum permitted fluid temperature depends on:-

1-The type of fluid.

2-The requirements of the system.

If the temperature is too low, the flow resistance is increased and difficulties are experienced with the suction of the pump. If the temperature is too high, there are more fluid leaks so losses and wear are greater. A hydraulic system that could operate at constant temperature, including start-up, would function at optimum efficiency at all times if the proper fluid viscosity had been selected. Unfortunately, such a hydraulic system is purely theoretical because a typical hydraulic system converts about 20%of its input horsepower into heat. Heat in the hydraulic system may be caused by two things-friction and external temperature. As the result of losses arising from transmission in the hydraulic components, the temperature of hydraulic fluid rises when passing through the system. In addition to additional cooling system, the tank itself also emits a large proportion of heat through the surface in surrounding area. The radiated power of heat primary depends on the size of those areas in contact with the surrounding, and the temperature difference between the hydraulic oil and surrounding area, when designing the hydraulic tank a designer should properly form the tank in order to increase the size of area through which heat is emitted, so as to provide better natural cooling. Figure 2-32**,** below shows wiper seal damage caused by excessive heat. (Refs. **[**50, 63]).

Figure 2-32 wiper seal damage caused by excessive heat

Chapter Three

Case Study of Machinery Used In Local Gold Mining

This chapter discusses case study of hydraulic failure in gold mining machines, besides identifying major causes of equipment breakdown, analyzing the problem and finding the root causes of failure.

Hydraulic failure studies are field performance assessments that include broad-based surveys of the hydraulic failure for a large number of mobile equipment on-site systems.

As mentioned in chapter one the main mobile equipment used in local gold mining areas are excavators, wheel loaders, Bulldozers ,and Rock drilling machines, and Dump trucks, and backhoe ....etc.

3-1 Case study of excavators:-

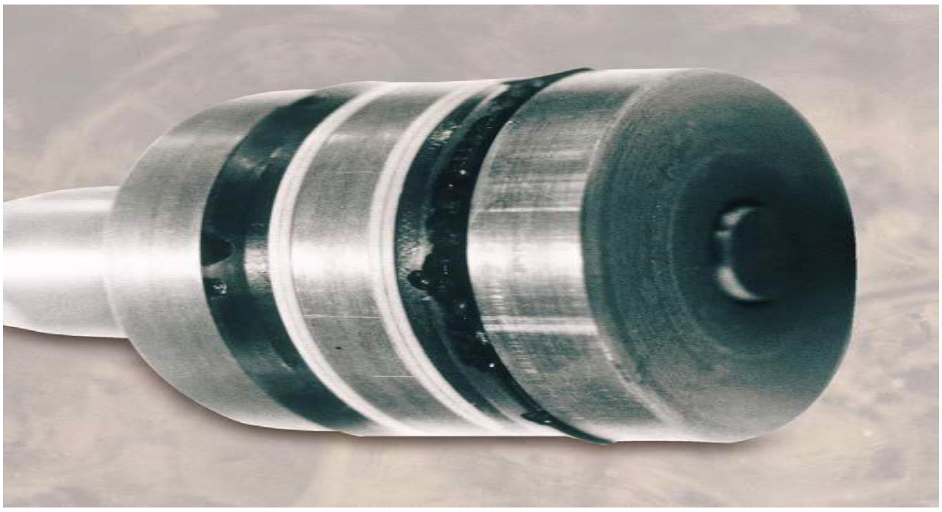
1- Case study of an excavator (HITACHI type)

Problem:-

Boom lifting power and speed are normal but bucket tilt-back power or speed is abnormal.

Analysis and Solution:-

All probable causes are checked out but finally it is found that the failure is of damaged seals of piston rod of the bucket cylinder which in turn causes internal leakage. This failure occurs due to different reasons including the contamination of the hydraulic oil and misusing the correct type of seals, therefore these problems must be avoided in future maintenance operations. Figures (3-1) and (3-2) below show piston rod of a bucket cylinder and an excavator operating near a river bank. (Ref. **[**33]).



Figures 3-1 piston rod of bucket cylinder

Figures 3-2 Excavator operating near a river bank

2- Case study of an excavator (komatsu pc 400 type):-

Problem:-

Figure (3-3) below shows an excavator (pc-400). The problem associated with this excavator is that its hydraulic motor is not functioning well. The motor has been replaced twice by another one, but the working life is less than three weeks.

Analysis and Solution:-

It is found that most of motor components were worn out and therefore they were replaced, but the root cause of failure is not defined .Therefore, another check had been made and the cause of failure was found to be a blockage on the drain line of the motor.

Figure 3-3 Excavator excavating around a hill

3-2 Case study of wheel loaders:-

1- Case study of a wheel loader 950F.

Problem:-

Figures 3-4 below shows a wheel loader 950F .The problem associated with this loader is that its hydraulic pump is not functioning well. The pump has been replaced by another one before completing its expected service life which is estimated to be 10,000 hours. The pump only serviced 2000 hours which is one fifth of its expected life time.

Analysis and solution:-

The analysis reveals that the hydraulic pump has not actually failed. The defect is caused by excessive oil contamination.

This defect leads to the increase of maintenance costs, and the reduction of equipment availability. The contaminants of the hydraulic oil, includes solid particles, water, air, or any other matter that impairs the function of the oil particle, the contamination also accelerates wear of hydraulic components. The rate at which damage occurs is dependent on the internal clearance of the components within the system, the size and the quantity of the particles present in the fluid and the system pressure. The type of failure described above is Unusual in properly designed hydraulic systems that are correctly maintained, this highlights the importance of monitoring hydraulic fluid cleanliness levels at regular intervals. As in this case, if the high levels of silt particles present in the hydraulic fluid had been identified and the problem rectified early enough, the damage of this hydraulic pump and significant expense of its repair could have been avoided. (Refs. [50, 52])

Figures 3-4 Wheel loader 950F

2- Case study of a wheel loader 950G.

Figure 3-5 below shows a wheel loader (950G).

Problem:-

The problem associated with this loader is that its transmission oil level is too high, above the full mark of the dipstick.

Solution and analysis:-

The above problem is caused by leaked hydraulic oil into the transmission oil pan causing over filling. All the probable causes are checked out but finally it is found that this failure is due to damaged seals of the hydraulic pump shaft. The seal of the transmission pump shaft has been replaced but the problem is still not eliminated. The hydraulic pump has been removed for the second times, the hydraulic pump is removed from the machine and checked up again, the new shaft seal of the pump was damage, replaced, and installed again then the problem is eliminated. Maintenance personnel don't used proper maintenance technique to install the new seal; therefore the seal is damaged during installation. This poor technique of the maintenance personnel, increase the down time of the machine, and decrease the productivity, cost of maintenance cost of spare part and hydraulic oil. This failure could be avoided if the maintenance personnel used proper technique of installing the shaft seal. (Ref. [61]).

Figure 3-5 wheel loader 950G- loading dump truck

3- Case study of a wheel loader 966C (steering system)

This case study considers closed-center, full time hydrostatic power steering systems using two double-acting cylinders with a variable piston pump.

The first problem:-

Figure 3-6 and 3-7 below show a wheel loader and steering system components. The problem associated with this loader is that its Steering wheel is heavy when turned in either direction (left or right).

Analysis and Solution:-

The following checks have been done:-

1- The oil level and types of oil in the hydraulic tank is found to be correct.
2- The steering wheel column is checked for abnormality.
3- The hydraulic hoses, valves, or cylinders are checked for leakage.
4- There is no any scuffing in the center hinge pin bearing and steering cylinder pin or bushing.
5- Tire inflation pressure is checked. After checking the above five expected problems, it found that the defect is inside the steering cylinder (piston seals are damaged) causes internal leakage. Therefore this problem must be avoided in future by regular maintenance and immediate remedy.

Figure 3-6 wheel loader 966C - steering cylinder

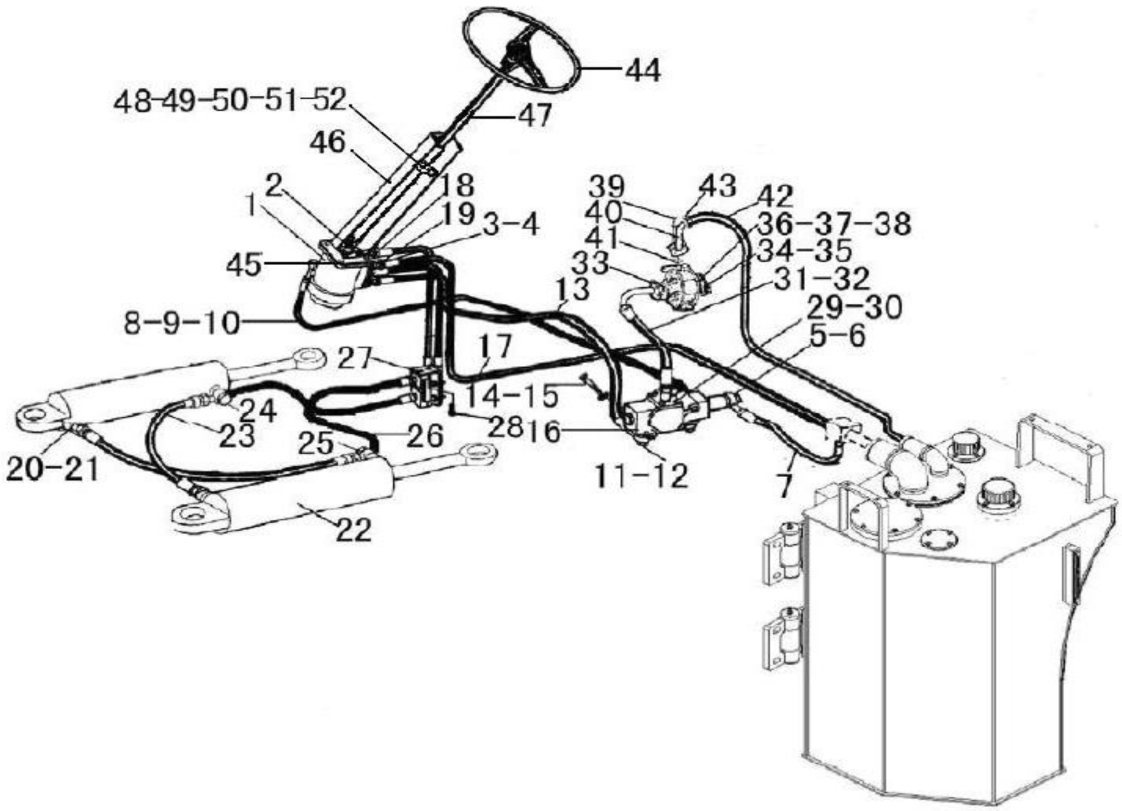


Figure 3-7 steering system components.

Figure 3-7 above shows the construction of steering system [35, 51], hydraulic circuit which consists of many components but the main components is:-

1-Hydraulic tank..

2-Hydraulic cylinders.. (22)

3-Hydraulic hoses………………………………………………………..

4-Steering wheel.. (44)

5-Steering column.. (47)

6-Steering valve.. (1)

7-Control valve.. (29)

8-Steering pump.. (33)

9-Cross over relief valve.. (27)

The second problem:-

The pressure rises in the hydraulic system (pressure gauge pointer above the specified limits) when operating the loader not more than half an hour continuously.

Analysis and Solution:-

After checking all expected problems, it is found that the defect is cause by clogged hydraulic oil filter in the return line. Therefore this problem must be avoided in future by following the regular preventive maintenance of changing the hydraulic oil filter within the recommended period. Figure 3-8 below shows a hydraulic oil pressure gauge.

Figure 3- 8 Hydraulic oil pressure gauge

The Third Problem:-

The same loader has another problem which is:-

The temperature rises in the hydraulic system (temperature gauge pointer reaches the red zone) when operating the loader not more than half an hour continuously.

Analysis and Solution:-

For the hydraulic temperature rising or overheating, all the probable causes associated with this problem have been checked, but finally it is found that the hydraulic oil cooler is clogged. Therefore, this problem must be avoided in future by regular cleaning the outside surface of the cooler to allow air to pass through it to dissipate the heat, and or any other source which can cause this defect must be checked first and eliminated.

Figure 3-9 below shows hydraulic oil temperature gauge and Figure 3-10 shows hydraulic oil cooler which is clogged [50].

Figure 3-9 Hydraulic oil temperature gauges

Figure 3-10 hydraulic oil cooler.

3-3 Case study of bulldozers:-

Case study of bulldozer type D and R.

Figures 3-11 below shows a bulldozer which is an excellent machine for land cleanings. Cleaning operations are always preferable and usually necessary before undertaking earth moving operation.

Figure 3-12 below shows the bulldozer transmission control valve, body, spools and hydraulic circuit.

The first problem:-

Machine does not start travel in any transmission range.

Analysis and Solution:-

The flowing checks have been done:-

1-The pump pressure must be within the specified limit

2-The torque converter must be in a good condition

3-The validity of the transmission components

After checking the above three expected problems, it is found that the transmission control valve is defected. Therefore it is replaced, and hence the problem is solved completely.

Transmission control valve consists of a body and spools. when these components wear, they causes excessive clearance between the control spools and the body, which allow oil to pass in between and therefore, affects its function.

The root causes of this problem are:-

1-The oil viscosity is too low

2-The oil is contaminated

Figure 3-11 A typical bulldozer cleaning surface mining site

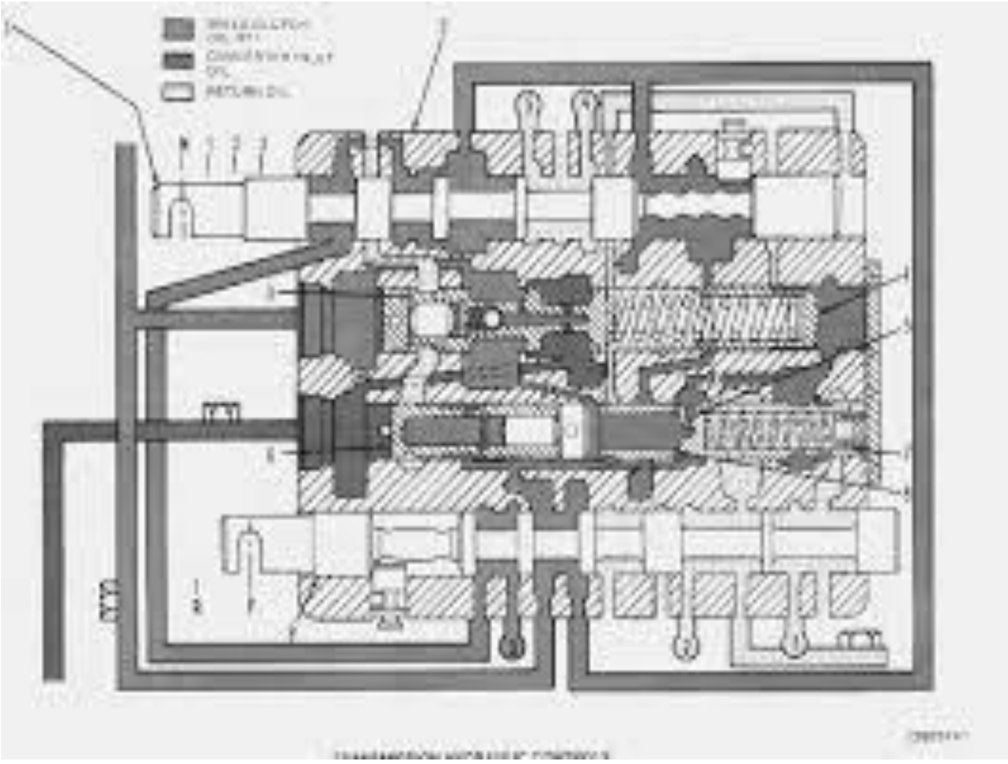


Figure 3-12 Bulldozer transmission control valve

The second problem:-

Machine hesitation or slipping during the travel in any transmission range.

Analysis and Solution:-

The flowing checks have been done.

1- Linage out of adjustment
2- Linage not free
3- Low fluid level
4- Wrong oil used
5- Incorrect pressure settings

After checking the above five expected problems, it is found that the defect is caused by transmission plates and discs which are wearing out. Therefore, it is replaced, and hence the problem is solved completely.

Before opening the transmission to repair two other checking confirm the above problem.

1- It is found that high level of copper (Cu), iron (Fe), and lead (Pb) in the transmission oil which indicate that abnormal wear of the bronze friction discs and steel separator plate.

2- Cut open the transmission oil filter which has large particles of above materials.

When these components wear out, they cause excessive clearance, which do not allow it to transmit the full power and therefore, affect its function.

The root causes of this problem are:-

1- Lag of preventive maintenance

2- Wrong oil used

Figure 3-13 below shows a typical bulldozer transmission and Figure 3-14 shows the different components of the transmission. (Refs. [46, 52, 61]).

Figure 3-13 Bulldozer transmission assembly

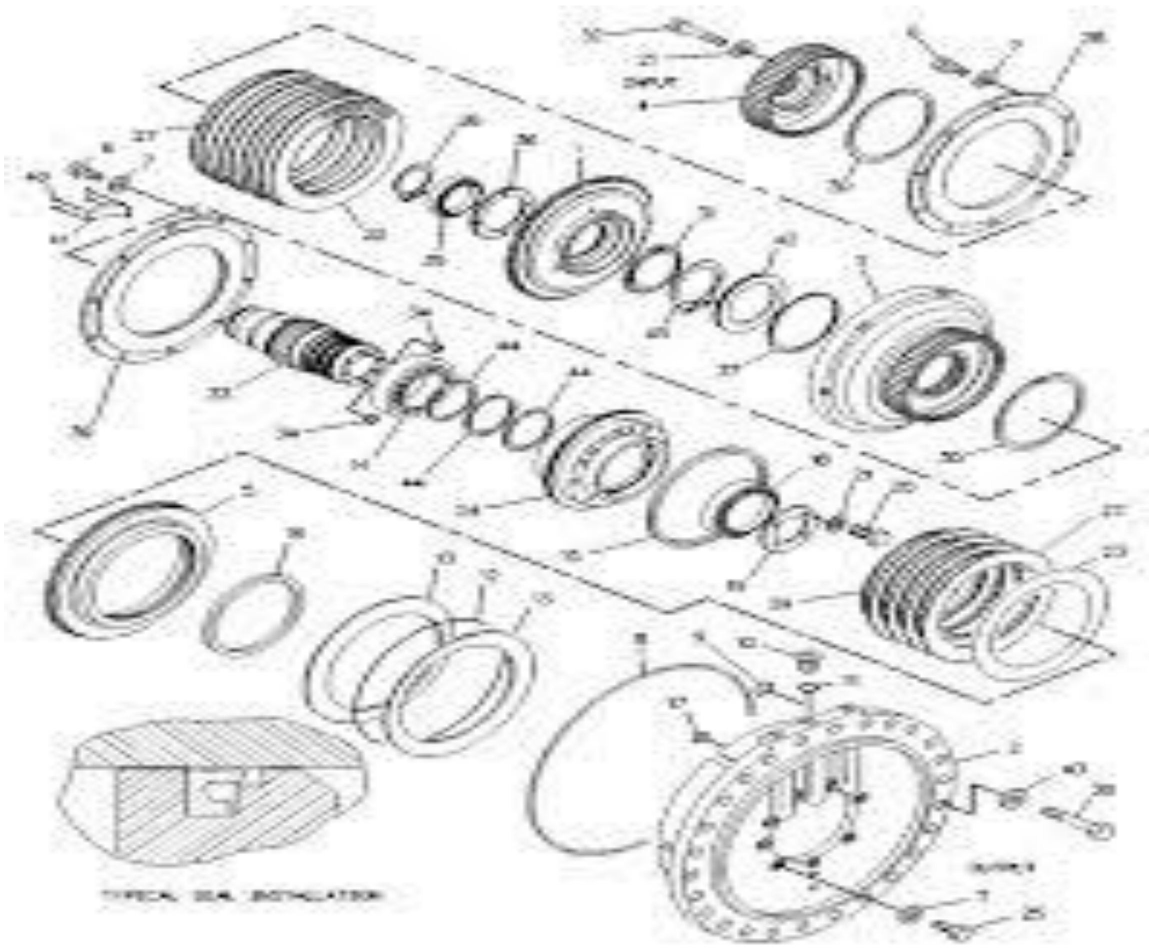


Figure 3-14 bulldozer transmission components

3-4 Case studies of hydraulic hoses:-

Hydraulic hoses are flexible joint used to carry and transmit hydraulic oil to the different components of the system.

The first Problem:-

Figure 3-15 below shows a damaged hose due to abrasion

Analysis and Solution:-

The analysis reveals that the hydraulic hose has not actually completed its life time. The defect is caused by abrasion, therefore these problems must be avoided in future maintenance operations by reroute the hose to keep it away from abrasive sources or guard the hose with a protective sleeve.

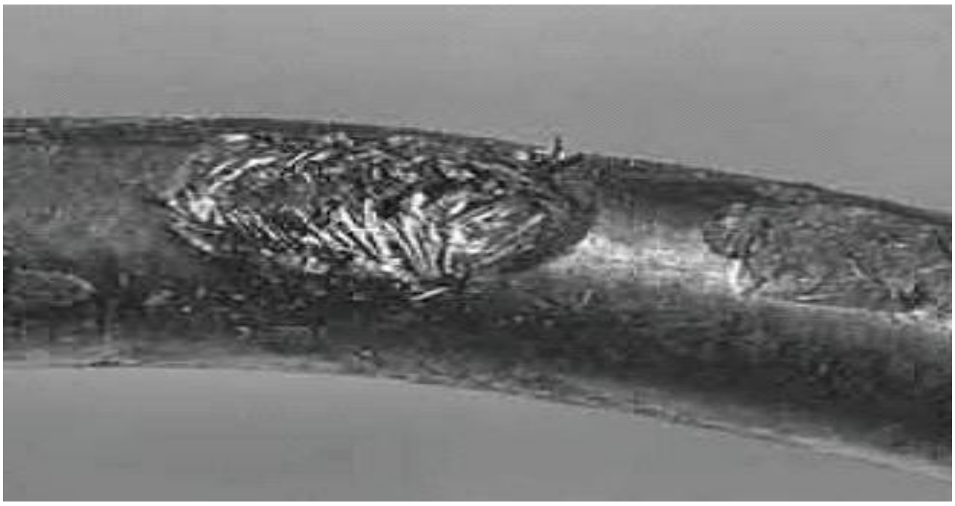


Figure 3-15 hose damaged by abrasion

The second Problem:-

Hose Burst Away

Figure 3-16 below shows hose damaged by bursting away.

Analysis and Solution:-

The analysis reveals that the hydraulic hose has not actually completed its life time. Therefore these problems must be avoided in future by the following:-

The operating pressure should be within the specified range.

1- Rerouting the hose to prevent excessive flexing or keep the hose from exceeding its maximum bend radius.

Figure 3-16 hose burst away

The Third Problem:-

Figure 3-17 below shows hose burst at coupling.

Analysis and Solution:-

The analysis reveals that the hydraulic hose has not actually completed its life time.

This problem is attributed to the following factors:-

1- Weak hose assembly to accommodate contraction under pressure.

2-The hose bend radius is mall and/or there is no bend restrict ors.

To solve this problem the hose assembly should be replaced with a properly crimped assembly, so as to avoid this problem in the future.

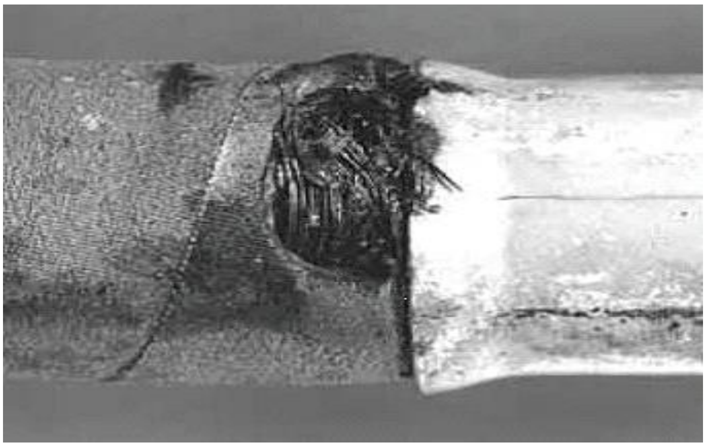


Figure 3-17 hose burst coupling

The fourth problem:-

Figure 3-18 below shows hose leaks at thread end caused by damage of O-ring seal.

Analysis and Solution:-

The analysis reveals that the hydraulic hose has not actually completed its life time. The defect is caused by damage of O-ring seal; therefore these problems must be avoided in future.

The problem causes are:-

1- Certain couplings require the use of an O-ring. If it's missing, replace it. If an O-ring is used, check for damage caused during installation or possible material breakdown from heat or fluid incompatibility. Alternative O-ring materials may be required.

2- Check the threads and/or seat angle on both mating surfaces for damage that may have occurred prior to or during installation. Any ding or burr may be a potential leak path.

Figure 3-18 O-ring seal damaged

3- If the coupling was misaligned during installation, threads may have been damaged. Replace and carefully install.

4- It is possible to thread together some components that are not compatible. Use Gates thread I.D. kit to assist in identifying mating components. Some thread end configurations have better seal ability than others. Also, ensure proper coupling selection.

5- Over-torque of a threaded connection can damage threads and mating seat angles. Over-torque can also damage the staking area of the nut causing cracking of either the nut or seat. Under-torque does not allow proper sealing. Use of a torque wrench can alleviate such problems.

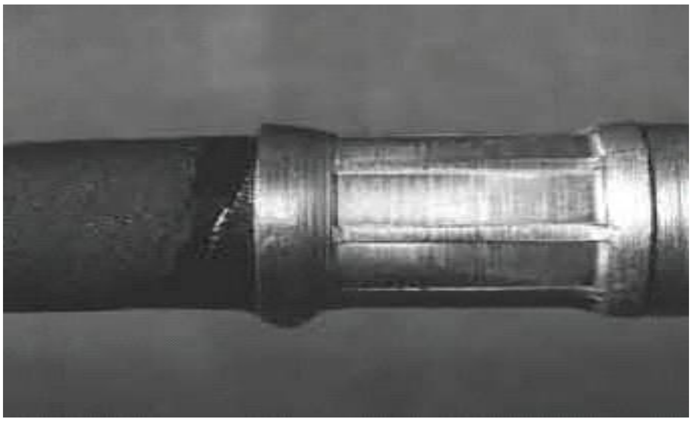


Figure 3-19 hose leak at thread end

The Fifth Problem:-

Figure 3-20 below shows hose coupling blow -off

Analysis and Solution:-

The analysis reveals that the hydraulic hose has not actually completed its life time. The defect is caused by Coupling Blow Off therefore this problems must be avoided in future by striking to the following procedures:-

1- Select proper crimping pressure.

2- Examine and replace the hos assembly to ensure proper assembly procedures.

3- Modify hose length and/or routing to accommodate potential hose length reduction under pressure.

2- Never mix different manufacturers' hose, couplings or crimpers.

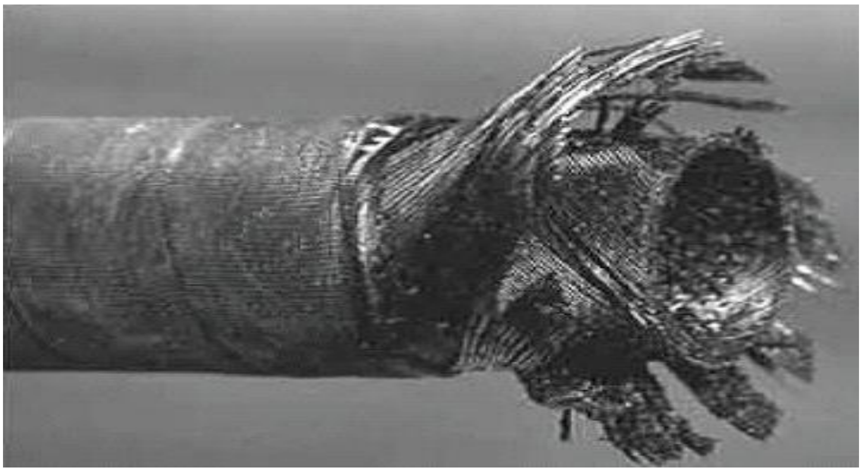


Figure 3-20 hose Coupling Blow- Off

The Sixth Problem:-

Figure 3-21 below shows hose cracked.

Analysis and Solution:-

The analysis reveals that the hydraulic hose has not actually completed its life time. The defect is caused by cracks, therefore these problems must be avoided in future by sticking to the following procedures:-

1- Select a hose that meets the temperature and flow requirements of the application.
2- Identify the heat source and consider rerouting it away from the source to minimize the effects.
3- Examine reservoir size (if necessary).

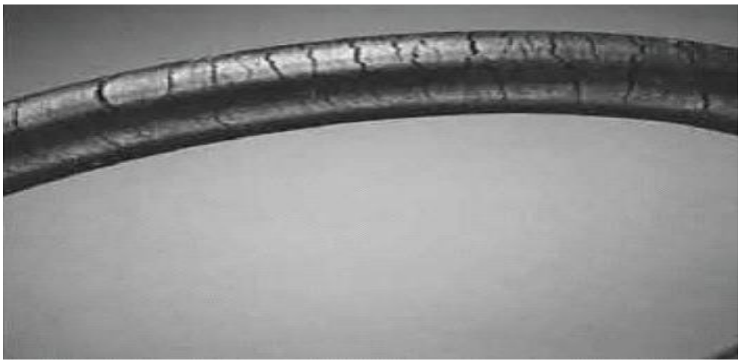


Figure 3-21 Hose Cracks

The seventh problem:-

Figure 3-22 below shows damaged hose caused by twisting.

Analysis and Solution:

The analysis reveals that the hydraulic hose has not actually completed its life time. The defect is caused by twist, therefore these problems must be avoided in future maintenance operations through the following procedures:-

1- Replace and reroute the hose to ensure that bending occurs only in one plane.

2- The use of bent tube or block style couplings and adapters may improve routing.

3- When installing the assembly, hold the backup hex to prevent it from turning and applying a twist.

3- If male and female couplings are used on the same hose assembly install the male (non-swivel) end first.

Figure 3-22 Hose Twist

The Eighth Problem:-

Figure 3- 23 below shows hose damaged caused by hose cover blisters.

Analysis and Solution:-

The analysis reveals that the hydraulic hose has not actually completed its life time. The defect is caused by cover blisters. Therefore these problems must be avoided in future maintenance operations by sticking to the following steps:-

1- Replace the hose with one that is recommended as compatible with the fluid being used.

2- If it is compressed gas, the cover can also be perforated (pin-pricked) to allow the gas to seep through the cover.

3- Textile hose covers eliminate blistering.

4- Bleed the system to eliminate any trapped air.

Figure 3-23 Hose cover blisters

3-5 Case study of hydraulic cylinder leaking

Problem:-

Figure 3-24 below shows hydraulic cylinder rod seal is damaged. The problem associated with this hydraulic cylinder is that its rod seal is leaking and has been replaced with another one but still leaking.

Analysis and solution:-

The analysis reveals that the rod seal has not actually completed its life time. The defect is caused by the bended cylinder rod. Therefore these problems must be avoided in future maintenance operations, by checking, the root causes of this failure. Bend rods are common cause of rod seal failure, bending of cylinder rods can be caused by insufficient rod diameter, material strength or improper cylinder mounting arrangement or combination of all three. (Misalignment could cause the seal to wear). Rod straightness should always be checked when hydraulic cylinders are being re sealed or repaired. This is done by placing the rod on rollers and measuring run-out with dial gauge. (Refs. [8, 9])

Figure 3-24 Hydraulic cylinders leaking

3-6 Case Study of Hydraulic motor Failure

Problem:-

The hydraulic motor is damaged

Figure 3-25 and Figure 3-26 below show hydraulic motor failure.

Analysis and Solution:

Two piston hydraulic motors had failed well short of their expected service life. The inspection reveals that the defect is caused by using low oil viscosity resulting in adequate lubrication. Therefore these problems must be avoided in future maintenance operations, by using recommended hydraulic oil, as the temperature of the oil increases, its viscosity decreases, if the oil temperature increases to a point where viscosity falls below the level required to maintain a lubricating film between the internal parts of the components , wear and damage will result. It is important not to allow oil temperature to exceed the point at which viscosity falls below the optimum level for the system components. Whenever a hydraulic system starts to overheat, the system must be shut down, so as to find the cause of the problem and try to fix it. (Refs. [45, 49, 53]).

Figure 3-25 motor pistons damaged

Figure 3-26 motor plate damaged

3-7 Case study of transmission pump shaft Broken.

Problem:-

The transmission pump shaft was Broken

Figure 3-27 and Figure 3-28 below show transmission pump shaft Broken. As soon as the pump is dismounted from the machine, it is found that the shaft has been broken and replaced by another one before completing its expected service life.

Analysis and Solution:-

Below are the most common causes of pump shaft failure which are checked out:-

1- Relief valve fails to function, which produces one extreme surge and immediately failure occurs.

2- The relief valve setting is too high, which results in repeated pressure peaks, damage the pump shaft.

After checking the above two expected problems, it is found that the suction strainer is completely clogged. Therefore it is replaced by another one, and hence the problem is solved completely. The analysis reveals that when the prime mover turns the pump shaft while the strainer filter in the suction line is clogged .The pump will be subject to two opposed forces which cause the pump shaft to shear or torsion and result in broken pump shaft Therefore, this problems must be avoided in future maintenance operations by replacing the strainer filter regularly. (Refs. [11, 26]).

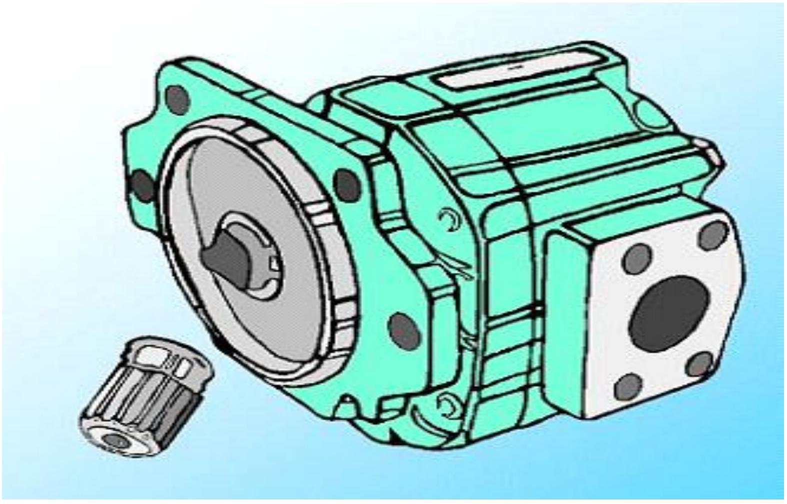


Figure 3-27 pump shaft broken

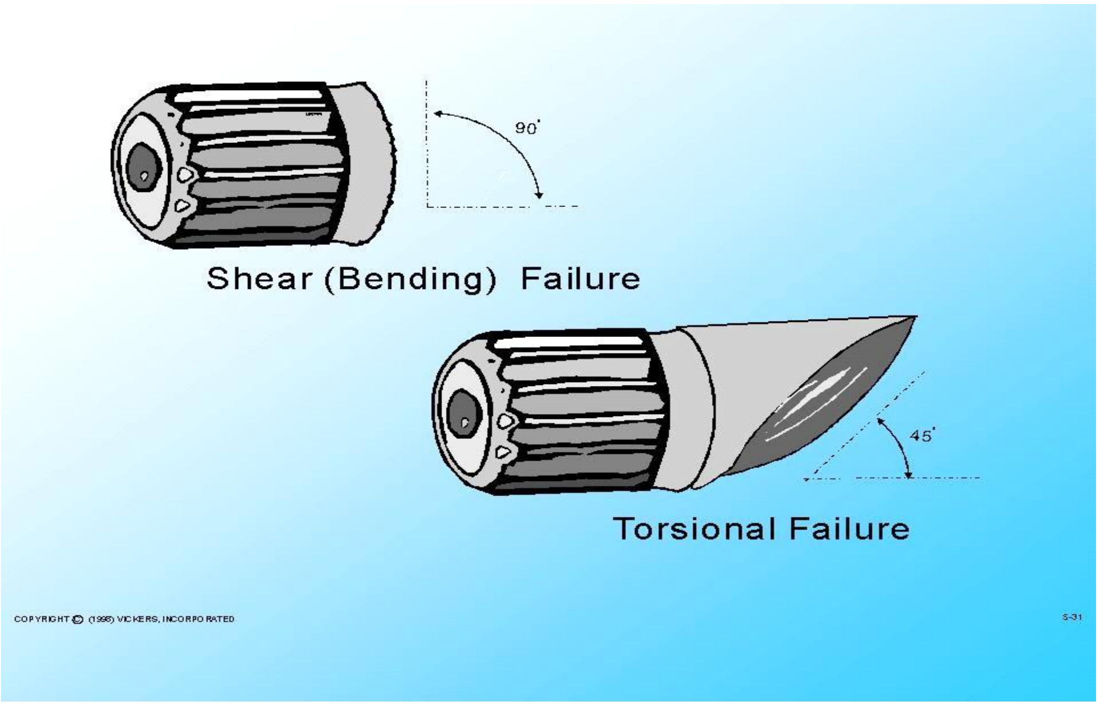


Figure 3-28 shaft sheared and shaft twisted.

3-8 Case study of Rock Drilling Machine:-

Drilling rigs are machines that create holes (bore holes) in the ground. They are equipped with deck engines or truck engines, compressors..
Figure 3-29 and Figure 3-30 below show drilling machine which is used mainly in surface mining.

Problem:-

Levers of the control valve are heavy during operation which causes the system malfunction.

Analysis and Solution:-

All probable causes are checked but finally it is found that the failure is due to control valve spools sticking. The analysis reveals that the spool has not actually completed its life time. The defect occurred due to the contamination of solid particles which fill the clearance between main control valve body and spool. Therefore this problem must be avoided in future maintenance operations, by replacing the dust protector seal when damaged. (Refs. [30, 31, 54]).

Figure 3-29 FRD drilling machine which is used in surface mining

Figure 3-30 another type of drilling machine which is used in surface mining

3-9 Case study of Dump Truck (body condition):-

Dump truck type HINO ZS is important machinery in mining construction sector which is used to pick up and deliver loads of materials on site.

First Problem:-

The dump truck is raised slowly when unloading.

Figure 3-31 below shows a dump truck.

The problem associated with this truck is that its control valve is not functioning well.

Analysis and Solution:-

The following checks have been done:-

The hydraulic pump output pressure is found equal to 172 bars

1- The output pressure within the specified limit

2- No pump cavitation

3- The body hydraulic cylinder is found to be in a good condition.

4- The relief valve setting is within the specified limit. No dirt, no foreign particles. After checking the above four expected problems, it is found that the spool valve travel is not complete. The pin of the spool linkage push wears and therefore causing excessive backlash. To solve the problem the pin and push must be replaced. (Refs. [14, 32, 44]).

Figure 3-31 Dump truck HINO ZS- unloading

Figure 3-32 below shows the dump truck hydraulic components

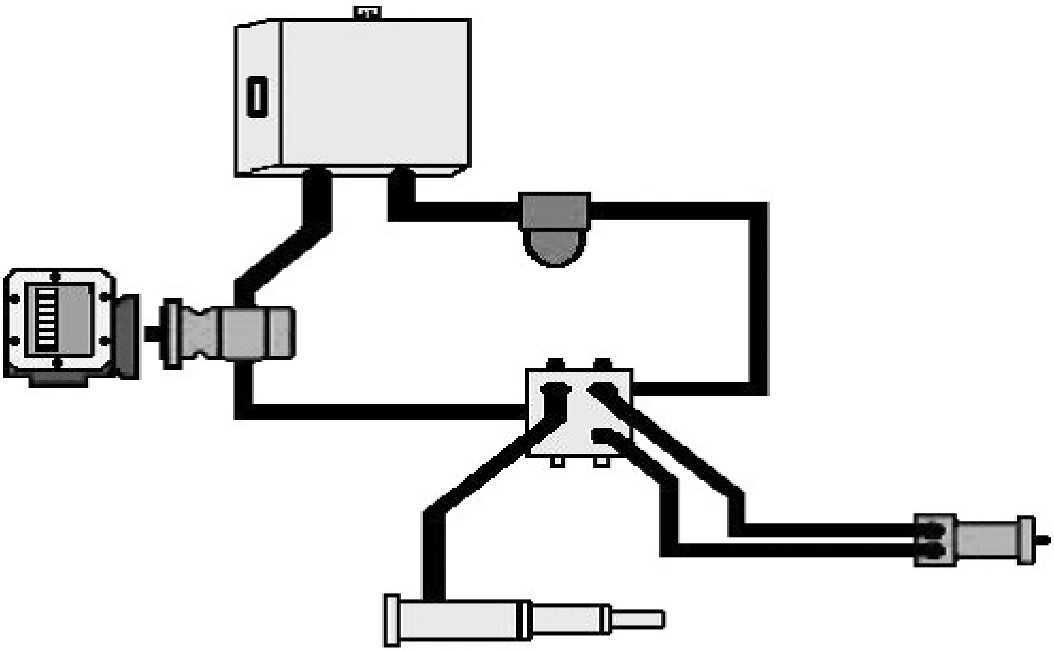


Figure 3-32 Dump truck hydraulic components.

Dump truck hydraulic system components and circuit of the body hoist. The components are:-

Reservoir, pump, control valve, cylinder, pilot valve which operate the cylinder, filter. (Refs. [47, 59]).

The second Problem:-

The dump truck is raised but not hold on the body during unloading. Figure (3-33) below shows a dump truck of **Nissan UD**. The problem associated with this truck is that its hydraulic cylinder was leaking.

Analysis and Solution:-

All probable causes which leads to this problem are checked out but finally it is found that the failure is of damaged seals of the piston of hydraulic cylinder. This failure occurs due to different reasons which include the contamination of the hydraulic oil, misusing the correct type of seals, types of oil used and temperature. Therefore and due to the seal damage the oil by passes between body cylinder and a piston seal (internal leaks) which causes the body not hold on. (Refs. **[**5, 57, 58]).

Figure 3-33 dump truck Nissan UD- failed to unload

Chapter Four

Safety

4-1 Risks

The risks of working with pressure systems of any type are well documented and respected by those involved in work that brings them into contact with pressure systems. Comprehensive risk mitigation and safe working practices are drafted and adhered to by the vast majority of responsible commercial organizations and professional technicians working with pressure systems and equipment as part of their routine work process. A common aspect of risk mitigation when working with pressure systems is, where possible, to use hydraulic power in preference to pneumatic power. In some instances however, such as lifting, cutting and pressing applications, hydraulic power is the preferred and often the only choice. Viewed as the safe option for pressurized equipment, the risk mitigation process can often end with the choice of hydraulic over pneumatic power. A common risk to all hydraulic systems, irrespective of volume, is hydraulic injection injury. This often overlooked mode of injury can and has resulted in the loss of limb function, amputation and in some cases, death. Although the reported instances of injury through hydraulic injection are comparatively rare in the UK, the potential severity of the consequences to the injured party dictate that understanding, acknowledging and mitigating the risk of injury through hydraulic injection, is essential for any individual or commercial organization utilizing hydraulic systems or equipment. Although the more serious instances of hydraulic injection injuries occur at higher pressures, anecdotal evidence suggest that injection can occur at pressures as low as seven bars. Hydraulic injection injury occurs when a jet of fluid under pressure penetrates the skin of an individual, most commonly the hand or the digits of the hand. An individual may come into contact with a pressurized jet of fluid due to the nature of the equipment they are using, such as paint spraying equipment, or when an equipment failure occurs. Types of failure in hydraulic equipment can be broadly categorized as:

- Functional failure, where the piece of equipment stops working completely following catastrophic component failure.
- Material failure, where a small leak has occurred but the equipment remains operational.

Examples of material failure in hydraulic equipment are fatigue cracking in high pressure fuel lines, pin holing in hydraulic hoses, seal failure and bulk material cracking. While both modes cracking. While both modes of failure can result in injection injury Figure 4-1 below shows fluid injection injury it is perhaps the latter that presents the greater risk to an operator in relation to sustaining a hydraulic injection injury. This is due to the fact that a piece of hydraulic equipment may remain pressurized and in use while ejecting a pressurized jet of fluid. An individual may sustain an injection injury by being in direct contact with a piece of equipment when a failure occurs, by using equipment with an existing failure, or while inspecting a piece of pressurized equipment following a reduction in performance due to a material failure. The tests carried out as part of this research suggested that the smaller the jet, such as those associated with pin holing, the more likely the chance of injection occurring. Figure 4-2 below shows hydraulic oil injected into human hand, as in refs. [5, 15, 57, 58].

Figure 4-1 Fluid Injection Injury

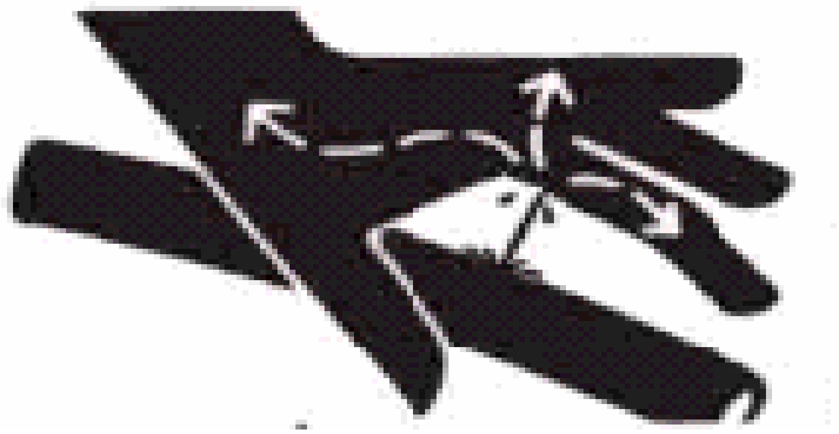


Figure 4-2 hydraulic oil injected into human hand

4-2 Hydraulic Systems Safety Procedures

Hydraulic systems operate under very high pressures. Shut the system down and relieve system pressure before opening any part of the system that is under pressure. Do not allow spray from any high pressure leak to contact any part of the body, as serious injection injuries may result. Pumps, valves and motor may become hot; be cautious of incidental contact between bare skin and hot surfaces. Keep hands and clothing away from moving parts of the system.

4-3 Personal Protection Equipment

Safety glasses need to be worn at all times when working on a hydraulic system. This is to protect eyes from dirt, metal chips, high pressure fluid leaks, etc. Additional personal protection equipment should be worn in accordance with OSHA or local government requirements.

4-4 Preventing injuries when working with hydraulic machines (excavator backhoe)

Swinging arms, booms, rollers, presses and anything that moves can be dangerous if a hose fails. For example, when a hose bursts, objects supported by fluid pressure may fall, and vehicles or machines may lose their brakes. Figure 4-3 below show an excavator bucket damages and falling down. (Refs. [5, 6, 54, 55, 56, 57]).

Figure 4-3 excavator bucket damage and falling down

Chapter Five

Discussion

How to get thousands of hours in extra service life from your hydraulic equipment, eliminate unnecessary breakdowns, reduce unscheduled downtime and slash thousands of dollars off your operating costs.

Dear Hydraulic Equipment User, Hydraulic components are expensive, right? So when you don’t get maximum mileage from them it hurts your bottom line. If you're an owner-operator, it hurts your wallet directly. If you're a manager or supervisor, it hurts your budget - and maybe even your performance bonus. But the fact is more than 70% of spare parts sold for hydraulic equipment are replacements for defective components. I also discovered that the reason for 90% of these defects is improper maintenance. So when you understand just how big the spare parts business is, you know that poor maintenance practices are costing hydraulic equipment users billions of dollars every year. If modern hydraulic components are installed and maintained properly, the spare parts business wouldn't be viable.

For as long as there are hydraulic equipment owners, mechanics and maintenance people out there who believe that hydraulic equipment doesn't require any special kind of attention, this vicious circle will continue. Over the past 30 years, the performance, sophistication and operating pressures of hydraulic equipment have increased significantly. This is particularly true in the case of mobile hydraulic equipment. As a result, modern hydraulic equipment is not only more expensive to fix when it breaks, proactive maintenance is imperative to maximize service life and minimize operating costs. It's not realistic to expect to run a hydraulic machine for 10,000 hours, without checking anything more than the oil level, and not have any problems.

Machinery is fundamental to the function of mining operations. Having high functioning equipment which is regularly maintained is a large factor in the smooth running of a project and increasing productivity. However, many mining companies are using old machinery which is usually a ticking time bomb with a history of glitches and failures. Not only is this unsafe, but the breakdowns mean downtime while equipment is getting repaired and time means money, so the result is revenue loss. Breakdowns in drives are a regular occurrence on the mine site and can cost the business thousands of dollars.

There are additional financial implications that come with using dated equipment as companies face excessive on-site inventory requirements, particularly due to the necessity of (custom made) spare parts. Depending on availability, obtaining the parts can take a long time and cost the operation a lot of money.

In this thesis, the main problems related to hydraulic machines in local gold mining as those associated with the contamination of oil used, the dusty environment of the mining sites, the effects of temperature and overheating could be solved easily with proper preventive maintenance by sticking to manufacturer recommendation. The replacement of parts should be done properly and in time. (Refs. [18, 38, 52]).

Chapter Six
Conclusions & Recommendations

6-1 Conclusions

In this thesis case studies of hydraulic failure of different types of equipments that are pertinent to gold mining area have been described, analyzed and solved.

As with all cases study 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 case study has gone 51% of the way towards finding the problem. Hydraulic systems are getting more and more complex as methods of controlling machines become increasingly developed.

Mobile mining equipment often operates in harsh environments characterized by remote locations and highly variable rock and operating conditions. This research explores the hypothesis that the failure behavior of mining equipment is influenced by the physical properties of the ore and waste.

Most hydraulic system failures in gold mining machine result from contamination of hydraulic fluid, therefore good filtration needs to be used to ensure long life and proper operation of the system. Hydraulic system simple or complex needs protection from contamination; Filters are frequently considered as a necessary evil and are added to a system as an afterthought instead of a valuable asset. Proper filter selection and sizing can provide years of reliable equipment operation and save money that is commonly lost battling contamination related failures. Approximately 75% of all hydraulic component failures are attributed to surface degradation caused by contamination and corrosion. The cost of installing and maintaining suitable filtration is estimated 3% of the cost associated with contamination related issues, the tip of the iceberg. Hidden costs of runaway contamination include; unplanned downtime, component replacement or repair, expenses, fluid replacement, disposal, maintenance labor hours, troubleshooting time and energy, and waste [69].

6-2 Recommendations.

1. From the conclusion above of this study, it is recommended that the_fluid Contamination source in the Hydraulic system must be checked. Periodic inspection of the fluid condition and tube or piping connections can save time consuming breakdown and unnecessary parts replacement and the following should be checked regularly.
2. All hydraulic connections must be kept tight. A loose connection in a pressure line will permit the fluid to leak out. If the fluid level becomes as low as to uncover the inlet pipe opening in the reservoir, extensive damage to the system can result. Loose connections also permit air to be drawn into the system resulting in a noisy and/or erratic operation.
3. Clean fluid is the best insurance for long service life, therefore, check the reservoir periodically for dirt and other contaminants. If the fluid becomes contaminated, flush the entire system and add new fluid.
4. Filter elements should also be checked periodically. A clogged filter element will cause higher pressure drops within the system.
5. Air bubbles in the reservoir can ruin the valve and other components. If bubbles are seen, locate the source of the air and seal the leak.
6. When hydraulic fluid is added to replenish the system, pour it through a mesh or fine wire screen (200 micro mesh or finer). When applicable, pump the fluid through a 10 micro filter. Do not use a cloth to strain the fluid.

The service life of the product is dependent upon environment, duty cycle, operating parameters and system cleanliness. Since these parameters vary from application to application, the ultimate user must determine and establish the periodic maintenance required to maximize life and detect potential component failure.

Workers who operate or work near hydraulic machine are at risk of being struck by the machine or its components (boom, bucket) during operating or travelling.

National institute for occupational safety and health recommended that injuries and deaths be prevented through training, proper installation and maintenance work practices and personal protective equipment. (Refs. [27, 29, 56]).

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Appendices

Photographs

Photograph 1 high expensive machine for large gold industrial

Photograph 2 Old dump truck high down time low productivity-spare parts very expensive

Photograph 3 Old dump truck high down time low productivity -spare parts very expensive.

Photograph 4 Dump truck type CAT high reliablety and productivty

Photograph 5 Mining area contamination of solid particles (dust)

Photograph 6 Drilling machine type FLEXIROC

Photograph 7 Large machine type TEREX high cost high productivity used on surface mining

Photograph 8 another type of crawler tractor hauling gold raw material on dump truck

Photograph 9 Haul road design and ramp gradients; on mining site.

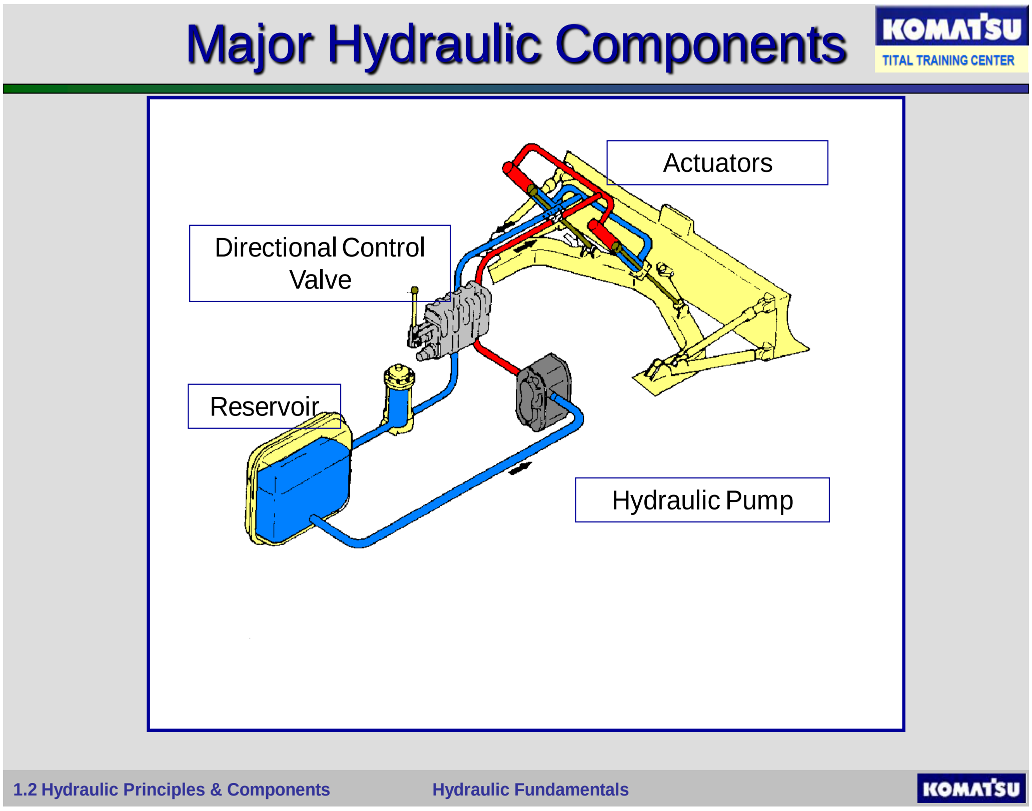
Photograph 10 Excavator 5500 HITACHI loading Dump truck

Photograph 11 orifices and fittings

Photograph 12 Bulldozer cleaning service road to the gold mining site

Photograph 13 - Surface Haulage Accidents...

Photograph 14 Tough design of excavator



Photograph 15 - Basic hydraulic components of bulldozer