SUDAN UNIVERSITY OF SCIENCE & TECHNOLOGY
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THE PREVENTIVE MAINTENANCE FOR HYDRAULIC SYSTEM IN EXCAVATOR

الصيانة الوقائية للنظام الهيدروليكي للحفار

A Project as Partial Requirement for Bachelor Degree In Mechanical Engineering [Production]

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DEDICATION

We dedicate this research to our Parents and Teachers, who taught us to think, understand, and express our knowledge. We earnestly feel that without their inspiration, guidance, and dedication we would not be able to pass through the tiring process of this research.

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ABSTRACT

In this research were studied preventive maintenance of hydraulic system and parts for excavator-type (VOLVO EC210B), this excavator was selected for the study because of it is a typical hydraulic heavy-duty human operated machine used in general versatile construction operations in our lives such as digging, ground leveling, carrying loads, dumping loads and straight traction and many other useful applications.This search is focus on hydraulic system which is powered the excavator, including the oil tank which supply the hydraulic oil to pumps, and pumps deliver oil flow to the main control valves passing through hoses to actuators (bucket cylinder, boom cylinder, stick cylinder, write and left travel motors and swing motor), based on the main causes of failure and malfunctions of this parts, a preventive maintenance plan was developed in this research for the hydraulic system.The findings of this research was made through collection of information from life visits to the official agent for Volvo in Sudan, and the specializing maintenance workshops for this type of excavator, plus the available scientific references.On the other hand, the effect of some hydraulic system parameters such as pressure and flow have been studied using (Automation Studio) software as a simulation tool for the hydraulic circuit. while (Microsoft Excel 2007) was used to develop the preventive maintenance plan.As a conclusion, the research highlighted the main reasons leading to the failure of the hydraulic parts, which include non-compliance with preventive maintenance plan developed by the manufacturer, and misuse, and finally the use of parts not conforming to the specifications required.

ملخص الدراسة

في هذا البحث تمت دراسة الصيانة الوقائية للأجزاء الهيدروليكية لحفار من نوع (VOLVO EC210B) ودراسة النظام الهيدروليكي له، وهذا يرجع لأهمية هذا الحفار واستخدامه في تطبيقات كثيرة جداً في حياتنا مثل أعمال الحفر لأساسات المنشآت والطرق والزراعة وغيرها من التطبيقات المفيدة. تم إستعراض الأجزاء الهيدروليكية للحفار ابتداءً من المضخة التي تقوم بضخ السائل الهيدروليكي من الخزان الرئيسي عن طريق خراطيم خاصة، مروراً بصمامات التحكم التي تقوم بتوجيه السائل الهيدروليكي إلى الاسطوانات أو الموتورات الهيدروليكية المعنية والتي بدورها تقوم بالشغل اللازم، وكما تم حصر الأعطال وأسبابها للأجزاء السالفة الذكر مع وضع خطة للصيانة الوقائية لتجنب حدوثها. وقد تضمن البحث جمع المعلومات عن طريق الزيارات الميدانية للوكيل الرسمي لشركة فولفو في السودان، وأيضاً للورش المتخصصة في صيانة هذا النوع من الحفار بالإضافة إلى المواد العلمية المتخصصة في علم الهيدروليك وتطبيقاته. ومن ناحية أخرى فقد تم استخدام برنامج (Automation Studio) في رسم الدائرة الهيدروليكية وعمل محاكاة لها، وتم استخدام برنامج (Microsoft Excel 2007) لجدولة الأجزاء الهيدروليكية وأعطالها والأسباب وفترة الصيانة الوقائية لها. ولخص البحث في نهايته الأسباب الرئيسية المؤدية إلى فشل الأجزاء الهيدروليكية والتي تشمل عدم الالتزام ببرنامج الصيانة الوقائية الذي وضعه المصنع وسوء الاستخدام بالإضافة إلى استخدام قطع غيار غير مطابقة للمواصفات المطلوبة.

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CHAPTER ONE

INTRODUCTION

1 - 1 Introduction

The excavator is the basic type of digging cargo handling machines, the excavators can be divided into two large categories based on its work principle, the bucket wheel excavators or rotor excavators (continuous action) and done bucket hydraulic excavators (cyclic action). As it is clear from the name, the working equipment of the excavator of continuous action includes some buckets continuously moving on closed territory, here we will be limited to consideration the one bucket hydraulic excavators, as most typical representatives of the given class of construction equipment.

The main components of the excavator are: the working and power equipment, control system, rotary platform and transmission.

The working equipment of excavators with a direct and return shovel consists of a bucket (as a rule), arrows and handles. The working equipment of excavator with dragline has no handles, and the bucket is suspended to an arrow on a rope by means of a team.

The blocks directing the devices and ropes which transfer movements to various elements of the working equipment concern the working equipment also besides a bucket other hinged.

1 - 2 Problem Statement

According to frequent defect that occurs in hydraulic components we try to find optimum solution by applying preventive maintenance program so we can reduce failure and decrease cost of repair.

1 - 3 Importance of The Project

Hydraulic excavator is one of the most useful construction equipment because of its versatility, flexibility, and efficiency, this project improve this equipment through applying maintenance program and simulate hydraulic circuit to control important parameter with the performance of excavator, by above tool we can find better approach to push construction application because it is depend on this type of equipment.

1 - 4 Objectives Of Project

- Identify common defects in hydraulic system and its causes.
- Develop preventive maintenance plan for excavator's hydraulic system.
- Identify the preventive maintenance to avoid the failures and defects in excavator's hydraulic system.
- Simulate the excavator hydraulic circuit to show the effect of parameters change in the performance.

1 - 5 Project Scope

In this project we take Volvo excavator 210B as a sample to improve and apply it is preventive maintenance program specifically in environment of Khartoum and preventive maintenance apply for hydraulic components only

1 - 6 Project Layout

This document is organized into five chapters, a brief revision of each Chapter is presented as follows:

- Chapter one shows introduction about EC210B and describes it is improvement, also content project problem, project significant, objectives of project, project field and project scope.
- Chapter two presents literature review that presented in the field of hydraulic, describes definition of hydraulic components and defines briefly preventive maintenance.
- Chapter three describes methodology which was used to accomplish objectives of project.

- Chapter four shows specification of excavator 210B like engine model, pumps, actuators, and other components found in excavator EC210B and shows results that achieved by excel 2007 (preventive maintenance schedule) and automation studio 5.2 (simulation of hydraulic circuit).
- Chapter five presents conclusion and recommendation of project.

CHAPTER TWO

LITERATURE REVIEW

2 - 1 The Basic Components of The Excavator Hydraulic System

Introduction

Hydraulic systems are extremely important to the operation of heavy equipment.

Hydraulic principles are used when designing hydraulic implement systems, steering systems, brake systems, power assisted steering, power train systems and automatic transmissions.

Hydraulics play a major role in mining, construction, agricultural and materials handling equipment and is used to operate implements that lift, push and move materials.

Hydraulics is the study of liquids in motion and the force generated in pipes and cylinders, in hydraulic systems, forces that are applied by the liquid are transmitted to a mechanical mechanism.

it wasn't until the 1950s that hydraulics was widely used in earthmoving equipment, since then, this form of power has become standard to the operation of machinery. All hydraulic circuits consist of some combination of six basic components:

1. Pumps: the pump is a device used to impart motion to a liquid and thereby convert mechanical energy to hydraulic energy. It provides the force required to transmit power.

   Pumps are rated in terms of flow and pressure. The flow rating (volumetric output) is the amount of liquid which can be delivered by the pump per unit time at a specified speed. A pump does not produce pressure. The pressure developed at the outlet depends on the resistance to flow in the circuit.

The resistance to the flow causes pressure, resistance can be caused by flow through hoses, orifices, fittings, cylinders, motors, or anything in the system that hinders free flow.

2. Actuator: actuators are used to convert pressure into mechanical motion, in another words, actuators are device for converting hydraulic energy to mechanical energy, and thus has a function opposite that of a pump. An actuator, or fluid motor, can be used to produce linear, rotary, or oscillatory motion.
3. Fluid-transfer piping: the hydraulic piping serves to contain and conduct the hydraulic fluid from one part of the system to another. Inadequate attention to piping design can lead to poor system operating characteristics and low efficiency.
4. Valves: the valves are used to control pressure, flow direction, or flow rate, they utilize mechanical motion to control the distribution of hydraulic energy within the system.
5. Hydraulic Tank**:** the hydraulic tank functions as a storage place for the hydraulic oil, a device to remove heat from the oil, a separator to remove air from the oil and allows particles to settle out of the oil.
6. A hydraulic fluid: The output of the hydraulic circuit is determined by the manner in which the various components are arranged.

The Basic Components of Hydraulic System Which Used in Excavator

2 - 1 - 1 Hydraulic Tank

- When construction machines and equipment are in the design stage, considerable thought is given to the type, size and location of the hydraulic oil tank.

- The hydraulic oil tank's main function is to store oil and ensure there is enough oil for any requirements of the system.
- Tanks must have sufficient strength, adequate capacity and keep dirt out.
- Hydraulic tanks are usually but not always sealed.
- Tanks are mounted in any convenient location, sometimes as part of a major component housing.

The components of the tank are:

1. Fill Cap: The fill cap keeps contaminants out of the opening that's used to fill and add oil to the tank and seals pressurized tanks
2. Sight Glass: The sight is used to check the oil level according to the operation and maintenance manual, the oil level is usually correct when the oil is in the middle of the sight glass.

   The oil level should be checked when the oil is cold, refer to manufacturer's specifications for the correct procedures for reading oil level.
3. Breather**:** The breather is fitted to unpressurised tanks and allows atmospheric pressure to flow in and out of the tank
4. Drain: Located at the lowest point in the tank, the drain is used to remove old oil from the tank.

2 - 1 - 2 Hydraulic Pumps

Pumps can generally be classified into two types:

1. Positive displacement Pumps.
2. Non-positive displacement Pumps.

2 - 1 - 2 - 1 Positive Displacement Pumps:

A positive displacement pump will discharge a specified amount of fluid during each revolution or stroke, almost regardless of the restriction on the outlet side, because of this characteristic, positive displacement pumps are nearly always the pump of choice in hydraulic systems.

Positive displacement hydraulic pumps are designated by their volume of displacement, such as gallons per minute, liters per minute, cubic inches or cubic centimeters per revolution.

This designation is usually a theoretical displacement and does not allow for any losses that may occur within the pump due to internal leakage.

Positive displacement pumps have small clearances between components, this reduces leakage

and provides a much higher efficiency when used in a high-pressure hydraulic system.

The output flow in a positive displacement pump is basically the same for each pump revolution. Both the control of their output flow and the construction of the pump classify positive displacement pumps.

Type of Positive Displacement Pumps:

1. Gear Pumps: Gear pumps are the most widely used pumps for hydraulic systems. They are available in a wide range of flow and pressure ratings, the drive and gears are the only moving parts.

   Gear pumps deliver the same amount of oil for each revolution of the input shaft, changing the speed of rotation controls the pump's output the maximum operating pressure for gear pumps is normally limited to approximately 27,579 kPa (4000 psi), but will depend on manufacturer's specifications.

   Type of Gear Pumps Positive Displacement:

i. External Gear Pumps: In external gear pumps, two or more gears mesh with minimum clearance Fig (2 - 1). The gear motion generates a suction at the inlet, which causes fluid to be drawn into the pump housing.

The liquid is drawn through the pump and is displaced as the teeth mesh on the outlet side.

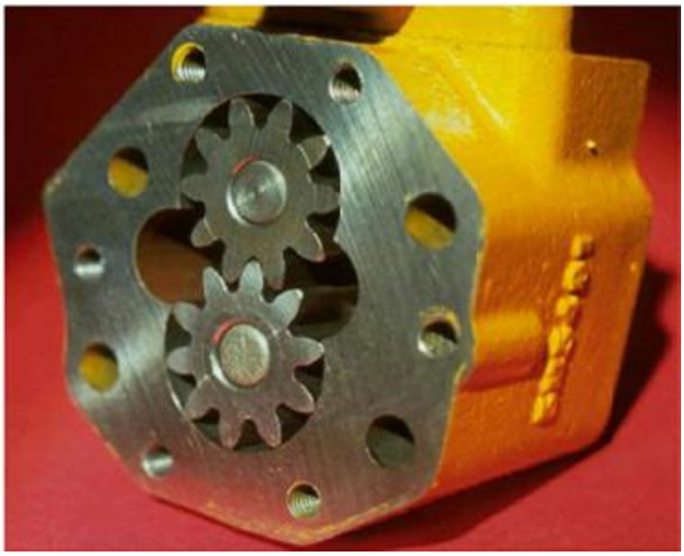


Figure (2 - 1) External Gear Pump

ii. Internal Gear Pumps:

There are two types of internal gear pumps: the crescent seal pump and the geroter pump.

A. Crescent seal pumps: The crescent seal pump consists of an inner and outer gear separated by a crescent shaped seal (Fig 3 - 2) The gears rotate the same direction, with the inner gear rotating at a higher speed.

The liquid is drawn into the pump at the point where the gear teeth begin to separate and is carried to the outlet in the space between the crescent and the teeth of both gears. The contact point of the gear teeth forms a seal, as does the small tip clearance at the crescent.

This pump is generally used for low output applications at pressures below 1,000 psi.

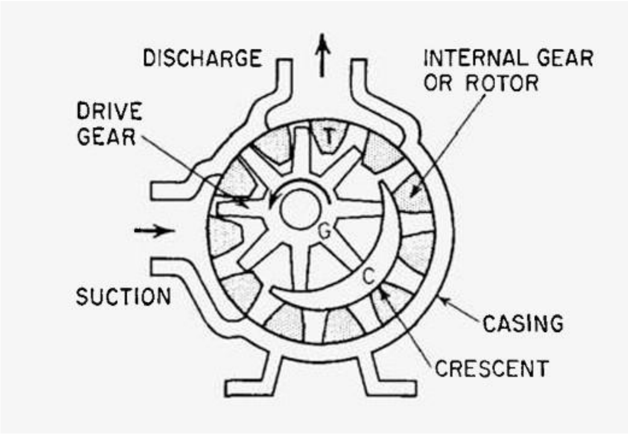


Figure (2 - 2) Crescent Seal Internal Gear Pump

B. Gerotor pumps: The gerotor pump consists of a pair of gears which are always in sliding contact (Fig 2 - 3), the larger internal gear has one more tooth than the external gear. Both gears rotate in the same direction.

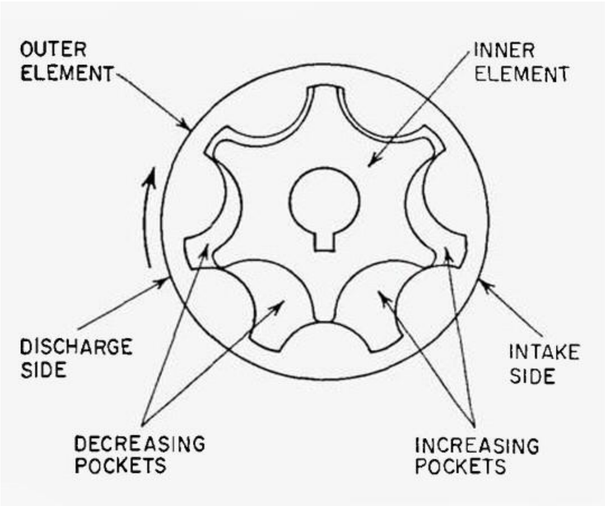


Figure (2 - 3) Gerotor Internal Gear Pump

Liquid is drawn into the chamber where the teeth are separating, and is ejected when the teeth again start to mesh.
The seal is provided by the sliding contact.
Gerotor pumps are restricted to low pressure operation because of the loads generated by the hydraulic unbalance[3].

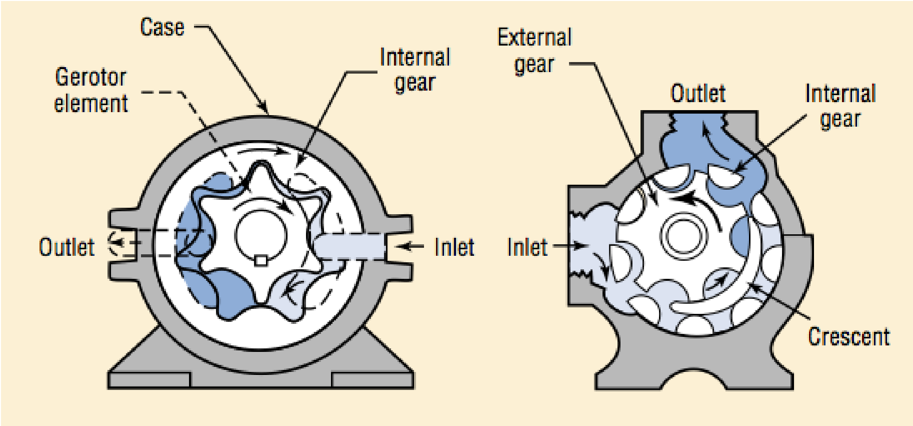


Figure (2 - 4) Gerotor and Crescent Gear Pumps

2 - 1 - 2 - 2 Non-Positive Displacement Pumps:

The outlet flow of a non-positive displacement pump is dependent on the inlet and outlet restrictions. The greater the restriction on the outlet side, the less flow the pump will discharge, an example of anon-positive displacement pump is the water pump on an engine.

Type of Positive Non-Displacement Pump:

1. Piston Pump: The applications for which the piston pump is well suited are determined by its two principal advantages high-pressure capability and high volumetric efficiency.

   In addition, the piston pump can operate at speeds over 2,000 rpm; is available in a wide range of output ratings; and provides a compact, lightweight unit for high power applications, low noise level when flow path is linear, and better system economy in the higher power ranges (above 20 hp).

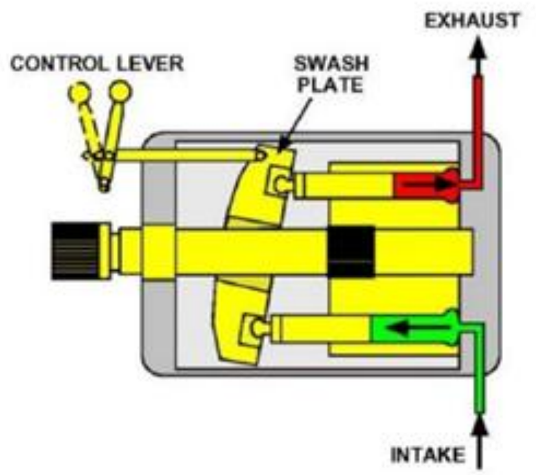
   Piston pumps are classified by the motion of the piston relative to the drive shaft. There are three categories-axial, radial, or rotating.

   A. Axial-piston Pumps: In the axial-piston pump, rotary shaft motion is converted to axial reciprocating motion which drives the piston.

Most axial-piston pumps are multi-piston designs and utilize check valves or port plates to direct liquid flow from inlet to discharge, shows in Fig (2 - 5).

Output can be controlled by manual, mechanical, or pressure-compensated controls. An axial-piston pump is rotary drive motion is converted to reciprocating, axial piston motion by means of the thrust cam, or wobble plate, mounted on the drive shaft.

Variable displacement volume is provided by the internal valving arrangement. Axial-piston pumps are available with output ratings of over 100 gpm, and some types are rated at pressures above 5,000 psi.



Figures (2 - 5) Axial Piston Pump

B. Radial-piston Pumps: In a radial-piston pump, the pistons move perpendicularly to the shaft centerline, two basic types of radial-piston pumps are available.

   One uses cylindrical shaped pistons and the other uses spherical-shaped pistons.

   In the pump shown in (Fig. 2 - 6), the pistons move in a rotating cylinder block and are forced outward by centrifugal force In (Fig 2 - 7), only one piston is shown (in four positions); however, most pumps are multi piston.

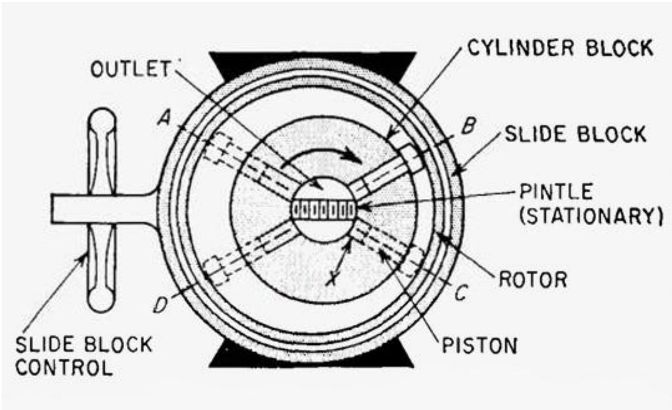


Figure (2 - 6) Radial-Piston Pump with Rotating Pistons Housing

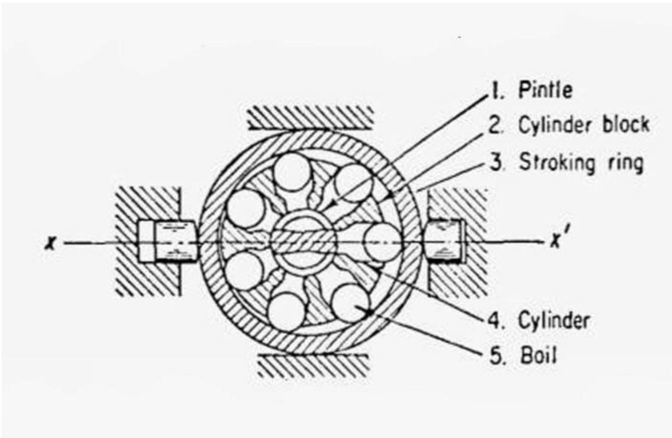


Figure (2 - 7) Radial-Piston Pump with spherical pistons

C. Rotating Piston Pumps: The rotating piston pump (sometimes called the rotary abutment pump) has three parallel synchronous shafts (Fig 2 - 8), Piston rotors are mounted on the outside shafts and seal dynamically against the cylindrical housing.

The rotor mounted on the center shaft forms an abutment valve. The rims of the piston rotors pass through a bucket cut in the center rotor.

Except when the rim is meshed with the abutment valve, a rolling-contact seal is maintained between the rotors.

Liquid is drawn into the right cylinder shown in (Fig 2 - 8), pumped through to the left cylinder, and discharged by the left piston.

Pumps of this type are available with ratings to over 150 gpm at 1,500 psi.

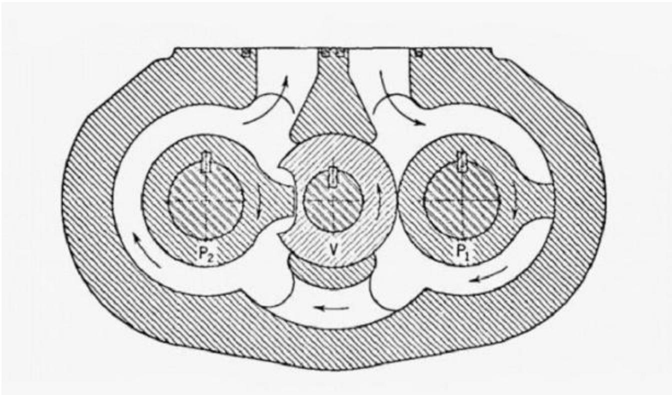


Figure (2 - 8) Rotating Piston Pump

2 - 1 - 3 Valves

Valves are classified according to their function in the hydraulic system, these basic types are pressure control valves, directional control valves, and volume control valve.

2 - 1 - 3 - 1 Directional Control Valves

Controlling where and when the hydraulic fluid is delivered to various parts of the system is the function of directional-control valves, these valves are used to control the operation of actuators shows in Fig (2 - 9).

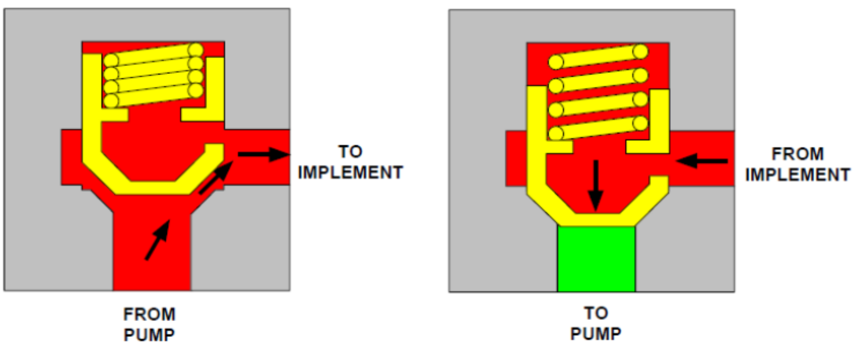


Figure (2 - 9) Directional-Control Valves

Types of Directional Control Valves

1. Check Valve: The purpose of a check valve is to readily permit oil flow in one `check valve is sometimes called a "one way" check valve, most check valves consist of a spring and a tapered seat valve, however, a round ball is sometimes used instead of the tapered seat valve.

   In some circuits, the check valve may be free floating (has no spring).

   In the valve on the left, when the pump oil pressure overcomes the oil pressure in back of the check valve plus the check valve slight spring force, the check valve opens and allows the oil to flow to the implement.
2. Position valves: The function of the position valve is to control the introduction of liquid to the lines of the system, when the valve is operated, the liquid lines within it are shifted, position valves are classified in terms of the number of valve positions and the number of liquid ports, e.g., a four-way, three-position valve.

   Two-way valves are generally shut-off valves.

   There are several types-spool, poppet, plug, ball, and rotary. Unlike a check valve, the two-way valve can block flow in both directions. Three-way and four-way valves are available with either two or three positions and with open or closed centers. There are six basic types spool, poppet, packed plunger, plug, plate, and rotary, a three-way valve can be used, for example, to control a single-acting linear actuator. One of the many applications of a four-way valve is control of double-acting actuators. Special valves are available in five- and six-way versions [1].

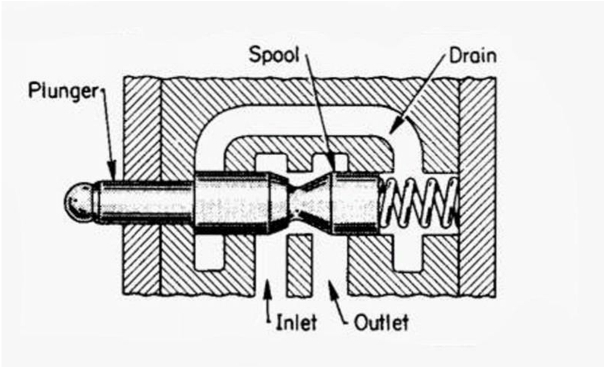


Figure (2 - 10) Nonadjustable Deceleration Valve

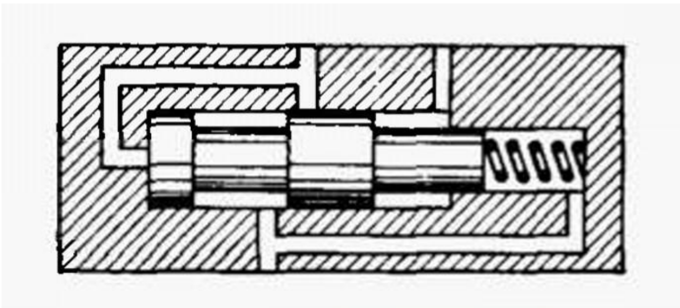


Figure (2 - 11) Load Dividing Valve

Solenoid Actuated Control Valves In a solenoid actuator, an electro-magnetic field moves an armature which moves a push pin. The push pin moves the valve spool.

The two most popular solenoid actuators are the air gap and the wet armature.

1. Air Gap Solenoid**:** An air gap solenoid is shown in (Fig 2 - 12), when the coil is energized, an electro-magnetic field is created, such a field develops whenever electricity flows through a wire.

   When the wire is straight the field is relatively weak. When the wire is wound into a coil, the electro-magnetic field becomes much stronger. The field takes a circular shape around the coil. The higher the number of turns in the coil, the stronger the field.

When the flow of electricity through the coil remains constant, the electro-magnetic field acts very much like the field of a permanent bar magnet, the electromagnetic field attracts the armature The armature moves a push pin and the push pin moves the valve spool in the control valve.

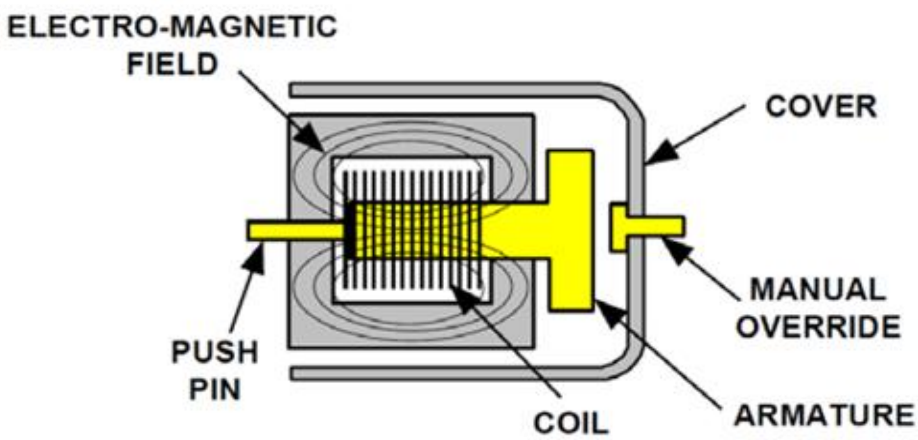


Figure (2 - 12) Air Gap Solenoid

2. Wet Armature Solenoid: The wet armature solenoid consists of a rectangular frame, coil, tube, armature, push pin and manual override, the coil and rectangular frame is encapsulated in plastic. The tube fits into a hole that runs through the coil center and two sides of the frame, the armature is housed within the tube and is bathed with hydraulic fluid from the directional valve, shows in the Fig (2 - 13)

   The hydraulic fluid is a better conductor of the electro-magnetic field than air, therefore, the wet armature solenoid works with greater force than the air gap solenoid.

When the coil is energized, an electro-magnetic field is created, the electro-magnetic field moves the armature, the armature moves a push pin and the push pin moves the valve spool in the control valve.

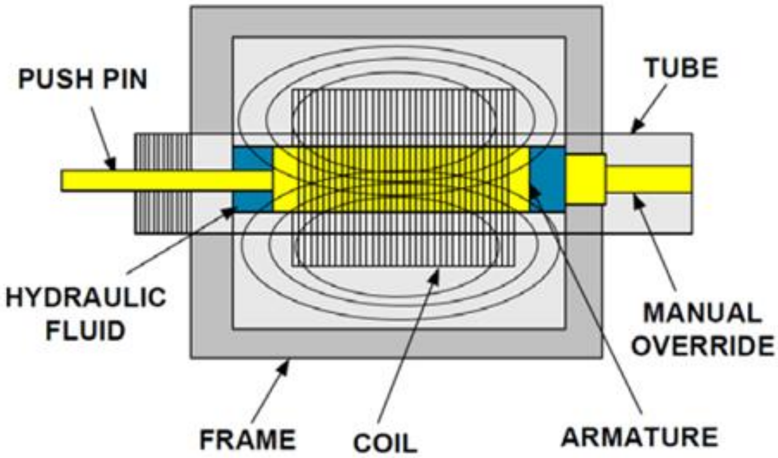


Figure (2 - 13) Wet Armature Solenoid

2 - 1 - 3 - 2 Pressure Control Valves

Pressure control valves either limits the pressure in various circuit components or changes the direction of all or part of the flow when the pressure at a certain point reaches a specified level. Such controls are directly or indirectly actuated by some system pressure level

1. Relief valves: A relief valve limits the maximum pressure that can be applied to the part of the system to which it is connected. It acts as an orifice between the pressurized region and a secondary region at a lower pressure Fig (2 - 14). In most applications, the relief valve is closed until the pressure attains a specified value. Then the flow through the valve increases as the system pressure rises until the entire system flow is vented to the low-pressure region, as the system pressure decreases, the valve closes.

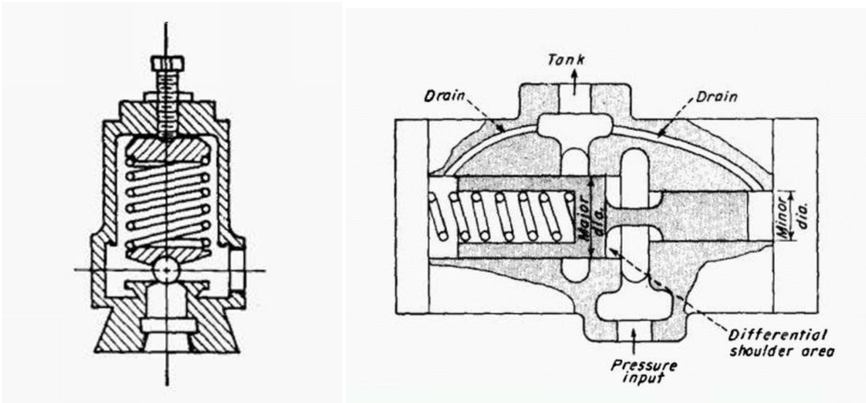


Figure (2 - 14) Pressure Relief Valve

2. Unloading valves: An unloading valve provides a vent to a low pressure area when a specified pilot pressure is applied.

   The signal is provided by an external source. These valves can be applied in circuits which allow a pump to build up to a specified pressure and then discharge to a reservoir at very low pressure.

   A typical application is in a double pump system where a high volume, low pressure pump is completely loaded at maximum pressure, while a low volume, high-pressure pump continues to develop higher pressure.

3. Load Dividing Valves: In a circuit with two pumps operating in series, the load can be equally divided between the pumps by a load-dividing valve (Fig 2 - 15), the low-pressure pump discharge is connected to a larger piston area.

   The low-pressure flow tends to open the valve and relieve the pump discharge to the reservoir. The high-pressure pump discharge is connected to the small area and, assisted by the spring, tends to close the valve, the ratio of the pressure produced at the low-pressure pump to the discharge pres- sure of the high pressure pump is the same as the valve area ratio

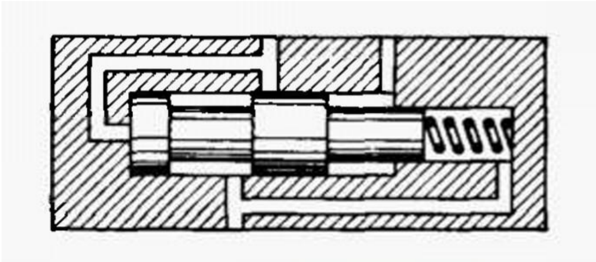


Figure (2 - 15) Pressure Regulating

4. Sequence valves: The order of flow to different parts of a hydraulic system can be controlled by sequence valves, this is accomplished by controlling minimum pressure, either an internal or external pilot pressure can be applied.
5. Back Pressure Valves: The counterbalance back- pressure valve can be used to allow free flow in one direction but restricted flow in the opposite direction (Fig 2 - 16), the pilot pressure can be external or internal. This valve can be used, for example, to prevent the weight of a vertically mounted piston from causing the piston to descend. The spring setting produces a back pressure on the piston which counterbalances the force of gravity

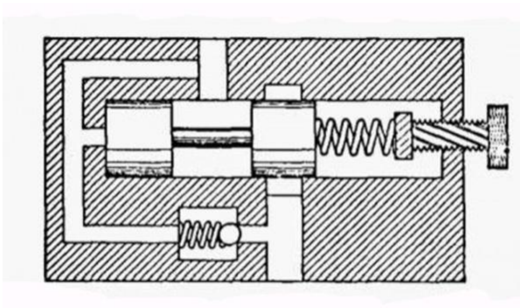


Figure (2 - 16) Counter balance Back Pressure Valve

6. Regulator valves: The function of one type of pressure-regulator valve, or pressure-reducing valve, is to supply a prescribed reduced outlet pressure regard- less of the pressure at the valve inlet. In this type, the outlet pressure is balanced against a spring.

   A drop in downstream pressure allows the spring to increase the valve opening and increase the downstream pressure. In the second type of regulator valve, the inlet pressure is balanced against both the spring and the outlet pressure.

The spring setting then determines the amount of pressure reduction across the valve. Hence, this type is used to maintain a fixed pressure differential across the valve for all values of upstream pressure.

7. Pressure switch: When a pressure-actuated electric signal is required for system control, a pressure switch is used (Fig 2 - 17), the system pressure acts against an adjustable spring used to preset the switch. When the pressure reaches the specified value, the micro switch is actuated. The signal can be used to actuate a variety of control elements. Although the pressure switch is not a valve, it is a valuable control element in valving systems.

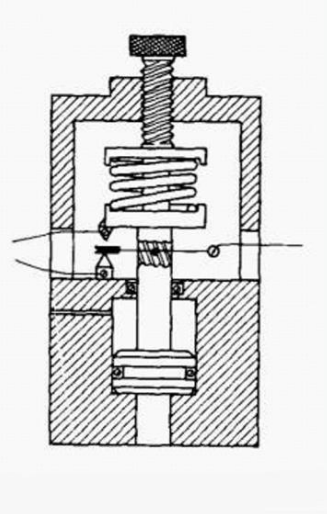


Figure (2 - 17) Pressure Switch

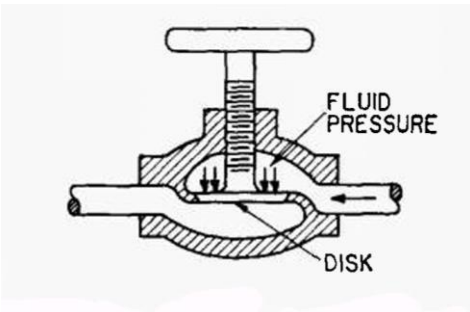
8. Hydraulic fuzes**:** A hydraulic fuze employs a frangible diaphragm or similar device which fractures at a preset pressure. It can thus be used as a substitute for, or in conjunction with, a pressure control valve. Hydraulic fuzes can be used with safety valves to pre- vent hydraulic fluid loss under normal operating conditions. They usually do not have automatic reset capabilities. It is necessary to

manually replace the diaphragm if the hydraulic fuze is actuated [1].

2 - 1 - 3 - 3 Flow Control Valves

Volume-control valves are used to regulate the rate of liquid flow to different parts of a hydraulic system. Control of flow rate is a means by which the speed of hydraulic machine elements is governed. The rate of flow to a particular system component is varied by throttling or by diverting the flow

1. Globe And Needle Valves: Flow rate is changed in a globe valve by means of a disk, plug, or ball which nests against a seat (Fig 2 - 18), the needle valve uses a tapered stem which nests against a seat and, in so doing, gradually reduces the flow area (Fig 2 - 19), needle valves have a smaller flow area and higher pressure drop than the globe valve, but are more suitable in throttling the flow. The globe valve is used to throttle only in lines where the liquid velocity is relatively low. Changes in the pressure drop across globe or needle valves produce variations in the flow rate, i.e., they are not pressure-compensated. This shortcoming limits their utility in applications where precise flow-rate control is required.



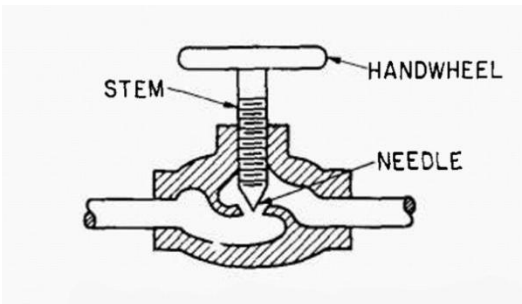


Figure (2 - 18) Globe Valve   Figure (2 - 19) Needle Valve

2. Pressure Compensated Flow Control Valves: A constant pressure drop across the valve orifice is required to assure accurate flow control. This is accomplished with the pressure-compensated flow control valve. In such valves the pressure drop across the metering orifice is used to assist a spring in moving a balanced spool.

   A change in pressure drop produces a rapid compensation in the form of spool motion. This spool adjustment causes the pressure drop to return quickly to its original value, thus maintaining constant flow. The orifice pressure drop, determined by spring force and spool area, is relatively low.

3. Positive Displacement Metering Valves: An intermittent flow of a specific volume of liquid can be obtained by using a positive displacement metering valve. The valve consists of a free-floating piston whose stroke can be changed by an adjustment screw.

   Such valves can be applied, for example, to control flow to a linear actuator used to obtain accurate, intermittent motion.

4. Flow Divider Valves: Flow-divider valves utilize sliding elements to change the orifice area, they distribute the flow to multiple lines, each of which then has the same flow rate downstream of the valve. They are generally pressure compensating valves and are frequently used to synchronize the motion of several linear actuators.

2 - 1 - 4 Actuators

Actuator is a generic term used to describe the output device of a hydraulic system. Actuators are basically placed into two main groups:

- Linear actuators.
- Rotary actuators.

2 - 1 - 4 - 1 Linear actuators:

Actuators are an essential part of a hydraulic system because they actually do the work.

In the case of cylinders, force and motion are created in a straight line to enable the operation of machine implements such as blades, buckets, rippers, cranes etc.

1. Cylinder**:** There are two basic types of cylinder:
   A. Single Acting: The dark area represents oil under pressure and lighter colored area is oil at atmospheric or tank pressure, single acting cylinders use pressure oil from one end of the cylinder and provide force in one direction only. They are retracted using the weight of the load or spring force.
   B. Double Acting: Darker shaded oil is oil under pressure and lighter shaded oil is at tank pressure, this is the most common hydraulic actuator used today on plant equipment. It is used on the implement, the steering and other systems where the cylinder is required to do work in both directions. Double acting means that the cylinder will provide force and movement in each direction, shows in Fig (2 - 20).

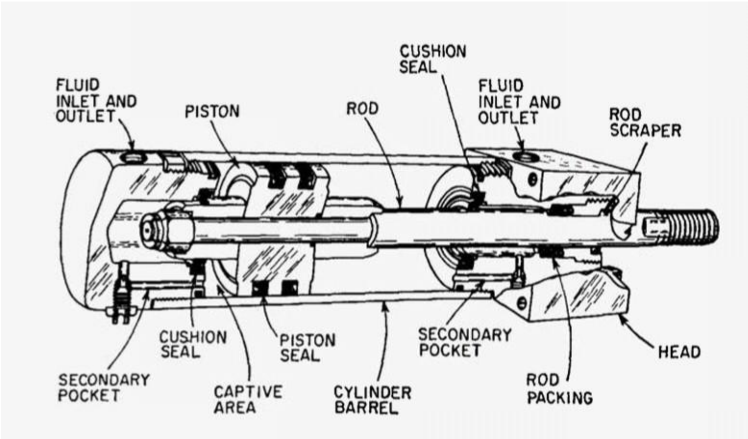


Figure (2 - 20) Double Acting Cylinder

Telescopic Cylinders The majority of telescopic cylinders (Fig 2 - 21) are single acting. Telescopic cylinders comprise of a series of tubular rods called sleeves. Each sleeve pushes out individually during extension There may be two, three, four and possibly up to five sleeves in a cylinder.

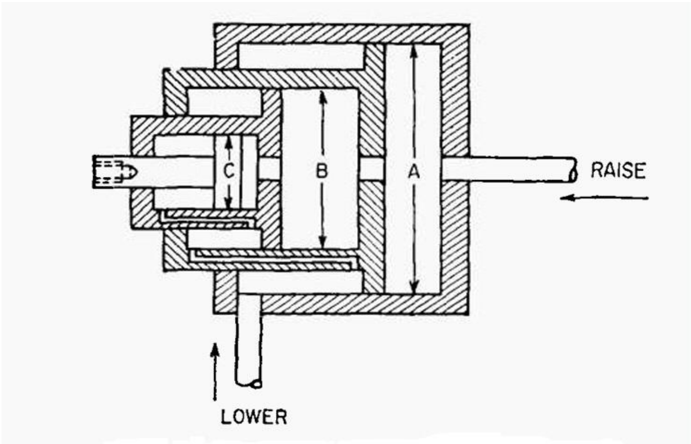


Figure (2 - 21) Telescopic Cylinders

A long working stroke and a short collapsed length result, making them ideal for applications such as industrial lift trucks and large tilt bed or dump trucks. A natural feature of telescopic cylinders, due to the sequencing of smaller diameters of sleeves, is a reduction of force capability and an increase of velocity of each succeeding stage

2 - 1 - 4 - 2 Rotary actuators:

Deliver their power in a rotating or circular motion. Linear actuators convert fluid power to linear motion. Rotary actuators convert fluid power to rotary motion. Hydraulic fluid is forced into the inlet of the rotary actuator and this makes the output shaft rotate. Resistance to rotation by the external load attached to the rotary actuator creates pressure in the hydraulic circuit and in the inlet of the motor.

Type of Motor:

1. Gear Motor: A cross sectional view of an external gear hydraulic motor is shown in (Fig 2 - 22), this design is referred to as an external gear design because the gear teeth are machined on the outside of the gears, one of the gears will be connected to an output shaft, and the other will be an idler gear, not shown in the illustration are the side plates, which create a sealing wear surface on the sides of the gear set (and are similar to these used in a gear type pump).

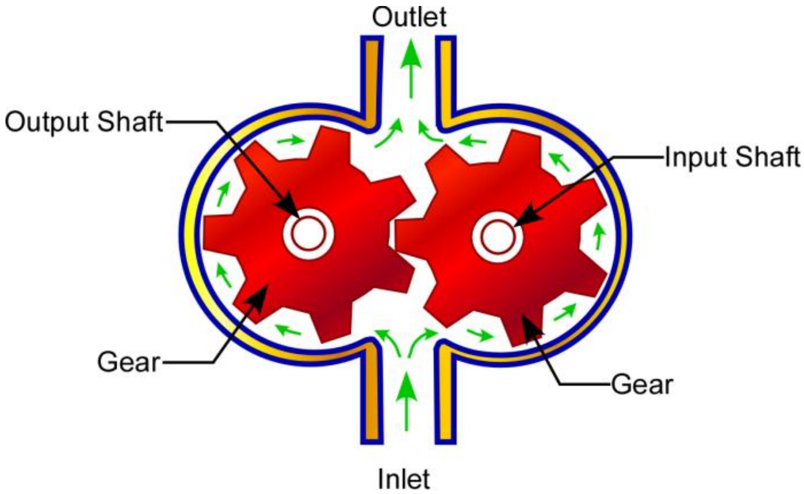


Figure (2 - 22) Gear Motor

2. Vane Motors: A cross sectional view of a balanced vane type rotating group.

   The elements shown are the cam (cam ring or displacement ring), rotor and vanes, the output shaft of the motor is connected to the center of the rotor, the vanes slide in and out of the slots in the rotor so as to make contact with the cam surface, the same as that of a vane type pump.
3. In-line Piston Motors: An in-line piston motor cutaway view is shown in (Fig 2 - 23), the components that make up a piston motor rotating group are a cylinder block, pistons and

shoes, shoe hold down plate, swash plate, valve plate and drive shaft.

The drive shaft is connected by splines to the cylinder block and the shoes are held down to the swash plate by a hold-down plate.

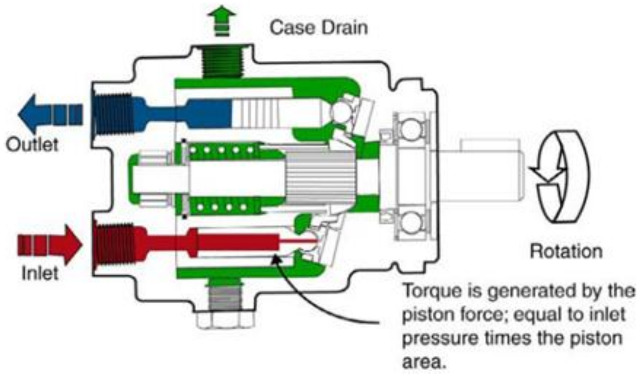


Figure (2 - 23) Piston Motor

4. Bent Axis Piston Motors: A bent axis piston motor is shown in (Fig 2 - 24), The main elements are a cylinder block, pistons and shoes, drive shaft and flange, a universal link and valve plate. The piston shoes are wedged in the drive shaft flange and the universal link sustains alignment between the cylinder block and the drive shaft to ensure that they turn together.

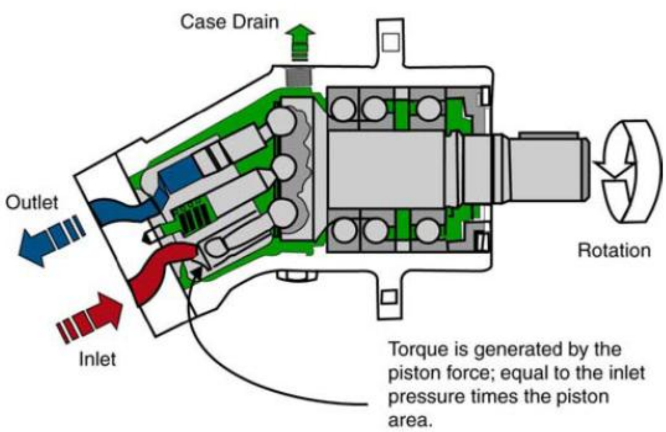


Figure (2 - 24) Bent Axis Piston Motor

2 - 1 - 5 Accumulators

An accumulator is a device which can store hydraulic energy. It is useful in intermittent operation of hydraulic machines when the accumulator can be charged at a low flow rate during the idle portion of the cycle of the driven machine.

Accumulators can be used for pressure compensation, pulse damping, leakage compensation, emergency power auxiliary pressure, and several other applications, they can also be used to apply pressure across a physical boundary between two liquids without contact or mixing of the liquids, this feature permits the pressurization of hazardous fluids, e.g., a volatile liquid, by means of a second liquid which can be safely pumped.

Accumulators are classified in terms of the manner in which the load is applied. This is the major factor which influences design, accumulators can be.

1. Weight Loaded.
2. Spring Loaded.
3. Pneumatic Loaded shows in Fig (2 - 25) and (2 - 26).

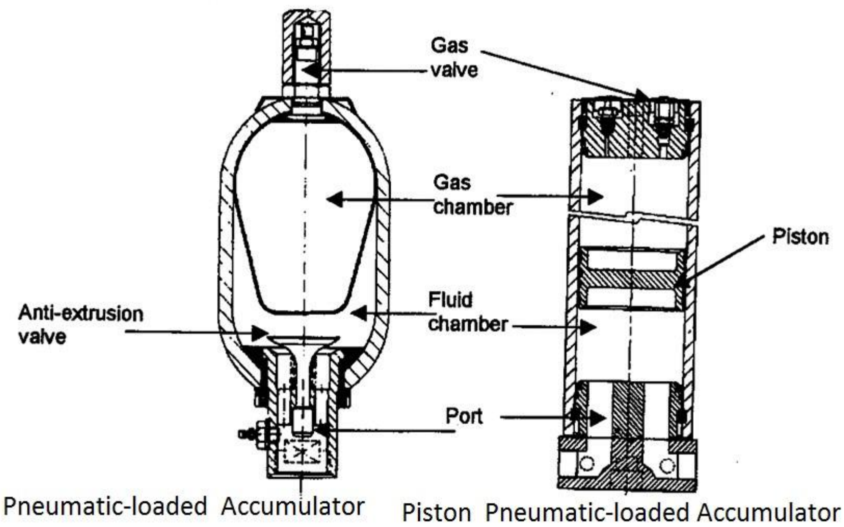


Figure (2 - 25) Type of Accumulator

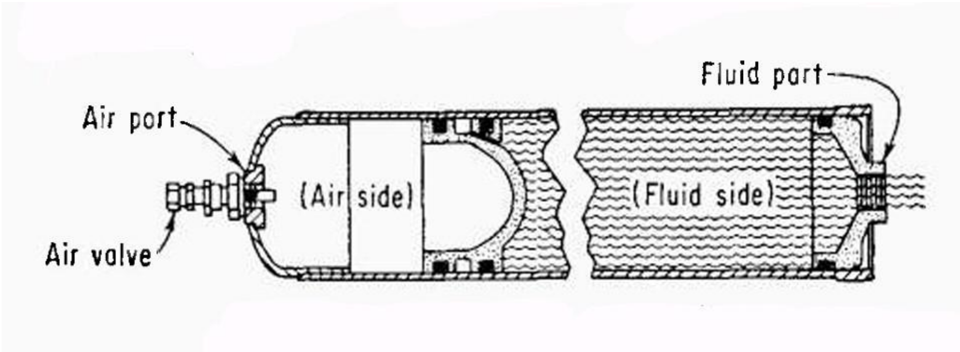


Figure (2 - 26) Accumulator charged with air and fluid pressure Piston

2 - 1 - 6 Hydraulic Fluid

The selection and care of the hydraulic fluid will have an important effect on the life of the system. Just like the hardware components of a hydraulic system, the hydraulic fluid must be selected on the basis of its characteristics and properties to accomplish the designed task.

Research has shown that incorrect oil or oil containing dirt or other contaminants cause approximately 70% of hydraulic system problems.

The fluid in the hydraulic system is the component that is used to transfer the flow energy generated by the pump to the mechanical components, which convert fluid energy into mechanical energy, to do work. Examples of these components may be cylinders and hydraulic.

Functions of Hydraulic Liquids:

- Power transmission.
- Lubrication.
- Sealing.
- Cooling.

1. Power Transmission: Because hydraulic fluids are virtually incompressible, once the hydraulic system is filled with fluid it can instantly transmit power from one area to another.

However, this does not mean that all hydraulic fluids are equal and will transmit power with the same efficiency, choosing the correct hydraulic fluid depends on the application and the operating conditions.

2. Lubrication: Hydraulic fluid must lubricate the moving parts of the hydraulic system. The rotating or sliding components must be able to function without touching other surfaces. The hydraulic fluid must maintain a thin film between the two surfaces to prevent friction, heat and wear.
3. Sealing: Many hydraulic components are designed to use hydraulic fluid instead of mechanical seals within the component.

   The viscosity of the fluid helps to determine its ability to function as a seal.
4. Cooling: The hydraulic system develops heat as it transfers mechanical energy to hydraulic energy and hydraulic energy back to mechanical energy.

   As the fluid moves throughout the system, heat flows from the warmer components to the cooler fluid. The fluid gives up the heat to the reservoir or to coolers that are designed to maintain fluid temperatures within design limits.

Properties of Hydraulic Fluids:

1. Viscosity**:** Viscosity is a measurement of a fluid's resistance to flow at a specific temperature. A fluid that flows easily has a low viscosity. Viscosity in hydraulic oil is very important because if oil becomes too thin (low viscosity as the temperature rises), it may leak past seals, joints, valves and internally leak in pumps and motors. Any area of leakage will affect the performance of the system

2. Viscosity Improver: These types of additives help maintain the oil's viscosity over a wide range in temperatures, when the oil is cold the system will operate correctly and when the oil is hot the system will also operate correctly.
3. Anti-wear Additives: Hydraulic oil contains a selected number of additives to increase and insure its anti-wear capabilities, It must provide good lubrication to lower and hold to a minimum, the friction between components in the system.
4. Anti-foaming: Foaming in hydraulic oil refers to the oil being mixed with air bubbles.

   A liquid cannot be compressed, but air can, so these anti foaming additives help the oil absorb the air

   to ensure it does not affect the operation of the system. The oil will foam if the oil is mixed with an amount of air that is greater than it can absorb. When the oil becomes foamed the system will operate with a slower response to direction changes and load changes; in other words, an unsatisfactory operation.

   The air in the system will also affect the oils ability to lubricate the system components, cause system overheating and erratic operation.

Types of Hydraulic Fluids:

1. Petroleum Oils: All petroleum oil becomes thin as the temperature goes up and thickens as the temperature goes down. If the viscosity is too low, there may be excessive leakage past seals and from joints. If the viscosity is too high, sluggish operation may be the results and extra power is needed to push the oil through the system.

2. Synthetic Oils: Synthetic oils are formed by processes that chemically react to materials of a specific composition to produce a compound with planned and predictable properties.

   Synthetic oils are specifically blended for extreme service at both high and low temperatures.

   Oil Life:

   Hydraulic oil never wears out, although a breakdown of the chemical additives will eventually cause the base oil to become ineffective as hydraulic oil. The use of filters to remove solid particles and some chemicals add to the useful life of the oil, the contaminants in the oil may also be used as indicators of high wear and prospective problem areas.

   The hydraulic oil should be analyzed at scheduled intervals. No matter what type of filtering system is used, eventually the oil will become so contaminated that it will have to be replaced, Oil should be replaced according to manufacturer's specifications.

2 - 1 - 7 Filters and Strainers

Strainers provide course filtration and are usually constructed of fine wire mesh. Filters provide fine filtration; they are usually constructed of porous treated paper. The difference between a filter and a strainer is their filtering ability.

2 - 1 - 7 - 1 Strainers

Inlet strainers, similar to that shown in (Fig 2 - 27), are usually mounted inside the reservoir and prevent large particles from entering the inlet side of the pump.

Figure (2 - 27) Strainer

2 - 1 - 7 - 2 Filters

Oil filters may be located in a number of positions in the hydraulic circuit. Inlet filters are mounted in the reservoir or in the line going to the pump. Strainers are preferred because they are not as fine as high-pressure filters.

High-pressure filters protect sensitive valves in the system. They are usually located after the pump and can be recognized by their heavy pressure proof housing. Return line filters are mounted in the line returning oil back to the reservoir.

This system has a major disadvantage in that it is filtering oil after it leaves the circuit, this type of filter is housed in a low pressure housing or may be a spin on type, a full flow system filters the entire supply of oil each time it circulates in the hydraulic system. For this reason, they are the most commonly used system.

Normal flow is from the outside of the filtering element to the center of the filter. Should the filter become blocked, pressure will build up around the outside of the filter and open a bypass valve fitted to the circuit.

Filter Construction:

As the name implies, surface filters (Fig 2 - 28) trap contaminants on the surface of the element. The element is usually constructed of treated porous paper and is pleated to increase the surface area. This is the most common type of filter element.

A partial flow or bypass filter system only filters part of the oil that flows through the system. These filters rely on the oil flowing through the system several times to clean the oil properly and are generally used in special applications only and have the advantage that they can remove very fine contaminants [2].

Figure (2 - 28) Filter Construction

2 - 1 - 8 Coolers

Any fluid used in machinery absorbs and carries heat away from heat generating components such as cylinders and pumps. The fluid then must be allowed to circulate as much as possible against the heat dissipating sides of a reservoir before it is allowed to reenter the pump.

Some system designs may not allow sufficient transfer of fluid to the reservoir, particularly with long lines from the rod end of cylinders.

This can cause a buildup of heat and oxidized fluid in an isolated segment of a circuit and result in destruction of the fluid and components. Provision should be made in machine design to circulate the oil through oil coolers.

in machine design to circulate the oil through oil coolers. Inefficiency in the form of heat can be expected in all hydraulic systems.

Even well designed hydraulic systems can be expected to turn some portion of its input horsepower into heat. Hydraulic reservoirs are sometimes incapable of dissipating all this heat. In these cases, a cooler is used. Coolers are divided into water cooler sand air coolers:

2 - 1 - 8 - 1 Water Cooler

A water cooler basically consists of a bundle of tubes encased in a metal shell as shows in the Figure (2 - 29), in this cooler, a system's hydraulic fluid is usually pumped through the shell and over the tubes, which are circulated with cooling water.

This cooler is also known as a shell-and-tube type heater exchanger. It is a true heat exchanger since hydraulic fluid can also be heated with this device by simply running hot water through the tubes.

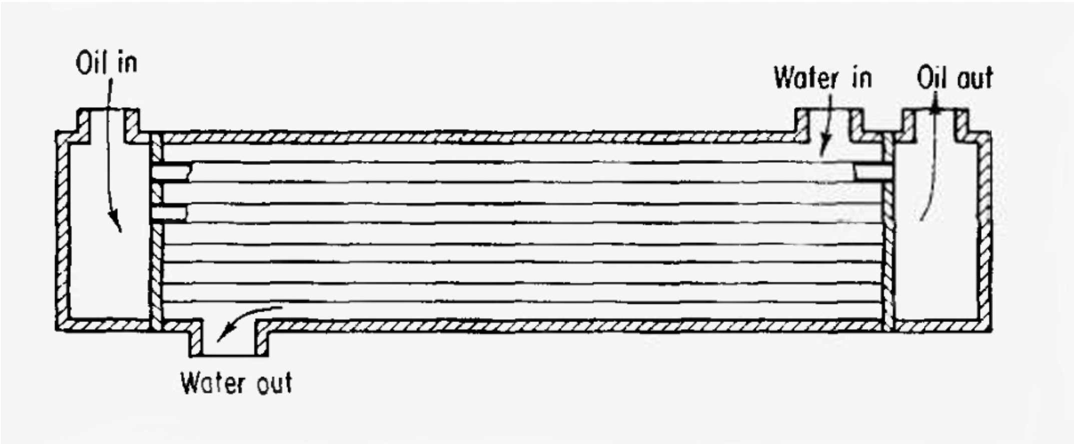


Figure (2 - 29) Water Cooler

2 - 1 - 8 - 2 Air Cooler

In an air cooler, fluid is pumped through tubes to which fins are attached. To dissipate heat, air is blown over the tubes and fins by a fan. The operation is exactly like an automobile radiator. Air coolers are generally used where water is not readily available or too expensive [1].

2 - 1 - 9 Hydraulic Lines

Hydraulic lines are used to connect the various components together to allow fluid flow in the circuit. The lines can be either tubes or hoses.

1. Tube: Tube is a rigid hydraulic line, usually made of steel. Tubes are used to connect components that do not move in relation to each other. Tubes also generally require less space than hoses and can be firmly attached to the machine, resulting in better protection to the lines and a better overall machine appearance.
2. Hoses: Hydraulic hoses are used whenever flexibility is needed, such as when components move in relation to each other. Hoses absorb vibration and resist pressure variations.

2 - 2 Preventive Maintenance

Preventive maintenance (PM) is an important component of a maintenance activity Within a maintenance organization it usually accounts for a major proportion of the total maintenance effort. PM may be described as the care and servicing by individuals involved with maintenance to keep equipment/facilities in satisfactory operational state by providing for systematic inspection, detection, and correction of incipient failures either prior to their occurrence or prior to their development into major failure.

Some of the main objectives of PM are to: enhance capital equipment productive life, reduce critical equipment breakdowns, allow better planning and scheduling of needed maintenance work, minimize production losses due to equipment failures, and promote health and safety of maintenance personnel.

From time to time PM programs in maintenance organizations end up in failure (i.e., they lose upper management support) because their cost is either unjustifiable or they take a significant time to show results. It is emphasized that all PM must be cost effective. The most important principle to keep continuous management support is: “If it is not going to save money, then don’t do it!” Preventive Maintenance elements, plant characteristics in need of a PM program, and A principle for selecting items for PM .There are seven elements of PM each element is discussed below.

1. Inspection: Periodically inspecting materials/items to determine their serviceability by comparing their physical, electrical, mechanical, etc., characteristics (as applicable) to expected standards.
2. Servicing**:** Cleaning, lubricating, charging, preservation, etc., of items/ materials periodically to prevent the occurrence of incipient failures.
3. Calibration**:** Periodically determining the value of characteristics of an item by comparison to a standard; it consists of the comparison of two instruments, one of which is certified standard with known accuracy, to detect and adjust any discrepancy in the accuracy of the material/parameter being compared to the established standard value.

4. Testing**:** Periodically testing or checking out to determine serviceability and detect electrical/mechanical-related degradation.
5. Alignment**:** Making changes to an item's specified variable elements for the purpose of achieving optimum performance.
6. Adjustment**:** Periodically adjusting specified variable elements of material for the purpose of achieving the optimum system performance.
7. Installation**:** Periodic replacement of limited-life items or the items experiencing time cycle or wear degradation, to maintain the specified system tolerance.

Some characteristics of the need of a good preventive maintenance program are as follows:

- Low quality equipment used and caused failures.
- Large volume of scrap and rejects due to unreliable equipment.
- Rise in equipment repair costs due to negligence in areas such as regular lubrication, inspection, and replacement of worn items/components.
- High idle operator times due to equipment failures.
- Reduction in capital equipment expected productive life due to unsatisfactory maintenance [5].

CHAPTER THREE

METHODOLOGY

3 - 1 Introduction

Our research methodology requires gathering relevant data about the hydraulic system of excavator and defectiveness points in its hydraulic power systems in different hydraulic circuit levels, the collected data will be used to identify the common defects in hydraulic system and its causes, Accordingly, a preventive maintenance plan will be developed to avoid the common defects in excavator hydraulic system and insure that it will works well under operating conditions. This chapter outlines the methods used to conduct this research and address these issues

3 - 2 Research Methods

This research used a case study research design to perform facts finding procedures on hydraulic system of excavator and develop a preventive maintenance for its hydraulic system. The reason for choosing the case study:

> excavators deliver maximum power and performance in all applications – from site preparation, trenching and excavation to demolition, truck loading and more. On crawler tracks or on the road, compact or larger in size, one of the well-known excavator is Volvo excavator which include dependable Volvo engines for class-leading fuel economy and Volvo Care Cabs to reduce operator fatigue and increase productivity. These machines are equipped with highly responsive advanced hydraulics and versatile quick fit systems for easy bucket and tool change out.

3 - 3 Information Collection

To collect information about hydraulic system we visited the biggest dealers of hydraulic equipment in the Sudan.

1. CAT (Caterpillar)
2. SUDANESE GERMAN HYDRAULIC SYSTEM FACTORY
3. VOLVO
4. KOMATSU

Based on the field visit and meetings with the expertise at the dealers of hydraulic equipment in the Sudan, we clearly identified how hydraulic system in excavator work, and we learn how to identify weaknesses in hydraulic circuit and apply Preventative Maintenance such as:

- Maximize machine availability
- Schedule service efficiently and continently
- Minimize overall costs
- Extend the life of the equipment
- Improve fuel consumption
- Increase productivity

The study focus on Volvo excavators (EC210B) The company has provided us with all the information about this excavators.

CHAPTER FOUR

VOLVO EXCAVATOR EC210B

4 - 1 Introduction

The three first Volvo hydraulic excavators were introduced at the Intermat exhibition in 1997 – EC280, EC340 and EC390. They were soon followed by both smaller and bigger models as well as wheeled ones. These were all built in the Eslöv plant.

In 1999 a new generation of excavators saw the light of day, the two first models in this generation were the EC210 and EC240 and they were built in the Changwon plant in South Korea.

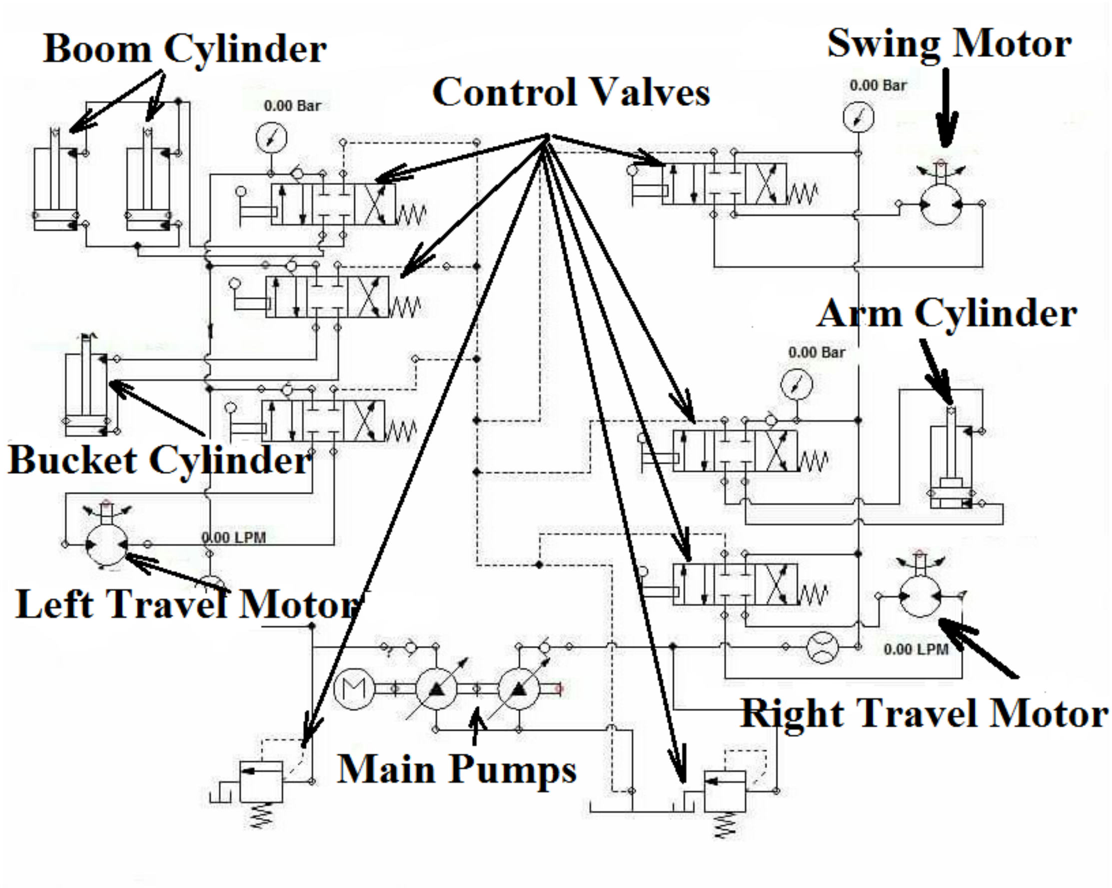
The following generation of excavators came in 2001, the B-series excavators, the updated B-series Prime version excavators came in 2009 VOLVO EC210B Specification

Table (4 - 1) Shows the EC210B Specification

Engine		
Make	Volvo	
Model	D6D EFE2	
Gross Power	159 hp	118.6 kw
Net Power	143.5 hp	107 kw
Power Measured @	1900 rpm	
Displacement	347.8 cu in	5.7 L
Torque Measured @	1425 rpm	
Max Torque	477.2 lb ft	647 Nm
Aspiration	turbocharged	
Number of Cylinders	6	

Operational		
Operating Weight	46958.5 lb	21300 kg
Fuel Capacity	92.5 gal	350 L
Cooling System Fluid Capacity	7.3 gal	27.5 L
Hydraulic System Fluid Capacity	77.9 gal	295 L
Engine Oil Capacity	6.6 gal	25 L
Operating Voltage	24 V	
Alternator Supplied Amperage	80 amps	
Hydraulic System Relief Valve Pressure	4974.8 psi	34300 kPa
Hydraulic Pump Flow Capacity	5 gal/min	19 L/min
Swing Mechanism		
Swing Speed	11.6 rpm	
Undercarriage		
Number of Shoes per Side	49	
Shoe Size	27.6 in	700 mm
Number of Carrier Rollers per Side	2	
Number of Track Rollers per Side	9	
Max Travel Speed	3.4 mph	5.5 km/h
Buckets		
Reference Bucket Capacity	0.98 yd3	0.75 m3
Minimum Bucket Capacity	0.98 yd3	0.75 m3
Maximum Bucket Capacity	2 yd3	1.6 m3

VOLVO EC210B basic hydraulic component:



Figures (4 - 1) VOLVO EC210B basic hydraulic component

4 - 2 EC210B Hydraulic Pumps

The Volvo EC210 powered by two main pumps type of variable displacement axial piston pumps with maximum flow: 200 l/min and the displacement is 111 cc/rev to each pump shows in the Figure (4 - 2) , and controlled by pilot pump type of gear pump with 10 cc/rev and maximum flow: 19 l/min shows in the Figure (4 - 3).

The pilot pump is independent from the main pumps and controls the front linkage, swing and travel operations.

The pilot control valve operation is proportional to control lever movement, delivering outstanding controllability.

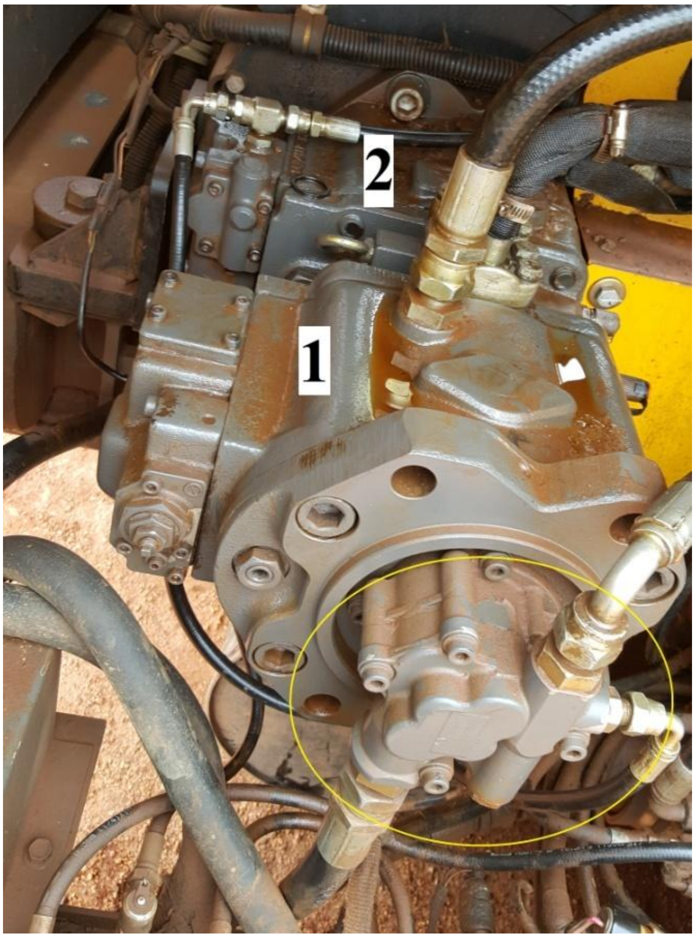


Figure (4 - 2) Main Pumps

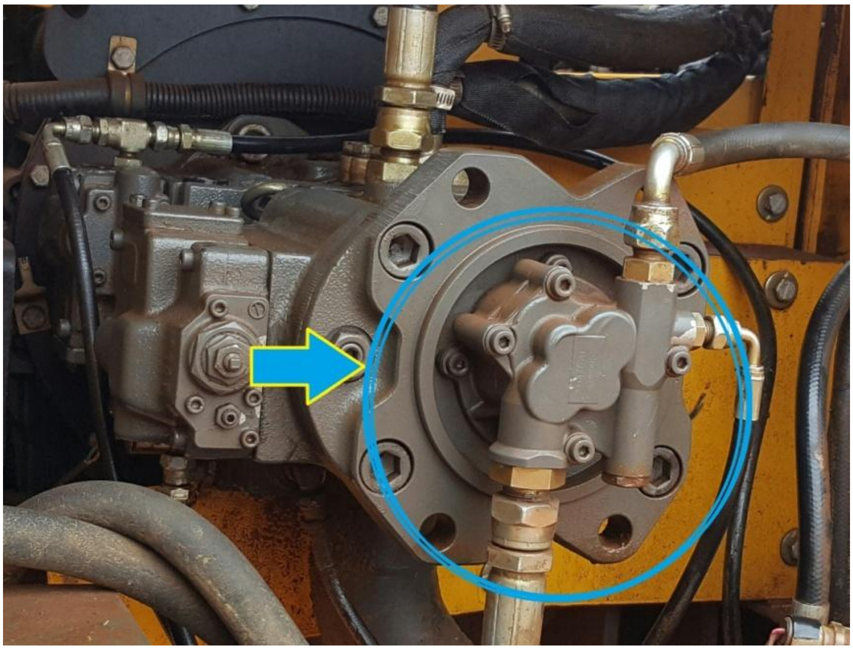


Figure (4 - 3) Pilot Pump

4 - 3 EC210B Main Control Valves

The main control valves include the flow control valves and direction control valves and pressure control valve , shows in the Figure (4 - 4). The maximum pressure of hydraulic components shows below and controlled be setting the Relief valve.

- Implement . . . . .32,4 / 34,3 Mpa
- Travel circuit . . . . . 34,3 Mpa
- Slew circuit . . . . . . .26,5 Mpa
- Pilot circuit . . . . 3,9 Mpa

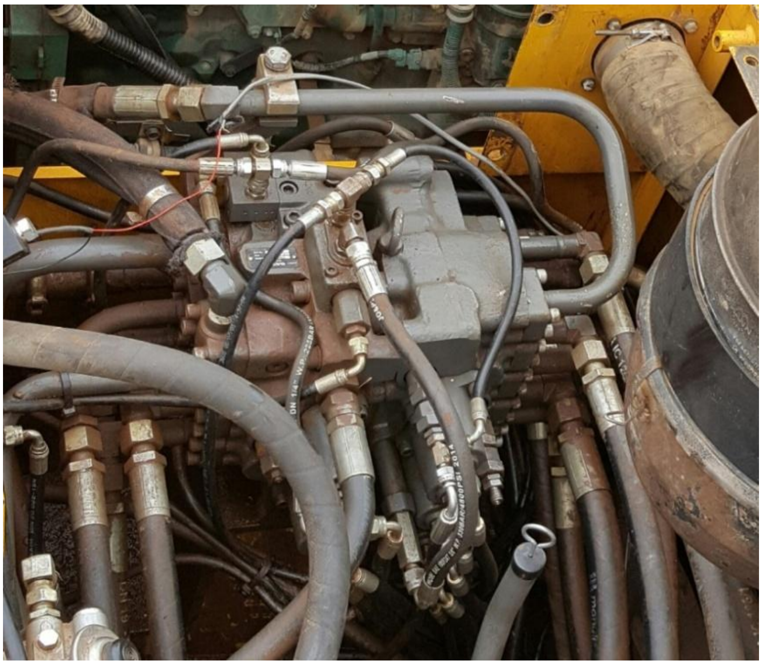


Figure (4 - 4) Main Control Valves

4 - 4 EC210B Hydraulic cylinders

There are three type of cylinders, Boom, Arm, and Bucket shows in the Figure (4 - 5).

- Two boom cylinders (Bore x Stroke 125 x 1 235 mm)
- One Arm cylinder (Bore x Stroke 135 x 1 540 mm)
- One Bucket cylinder (Bore x Stroke 120 x 1 065 mm)

Figure (4 - 5) EC210B Cylinders

4 - 5 EC210B Hydraulic motors:

There are two type of motors in EC210B

1. Travel: Variable displacement axial piston motor with mechanical brake shows in the Figure (4 - 6).

   Each excavator track is powered by an automatic two speed shift travel motor.

   Track brakes are multi-disc, spring-applied and hydraulically released. The travel motor, brake and planetary gears are well protected within the track frame.
2. Swing: Fixed displacement axial piston motor with mechanical brake shows in the Figure (4 - 7). The swing system uses an axial piston motor, driving a planetary gearbox for maximum torque. An automatic holding brake and ant-rebound valve are standard [6].

Figure (4 - 6) Travel Motor

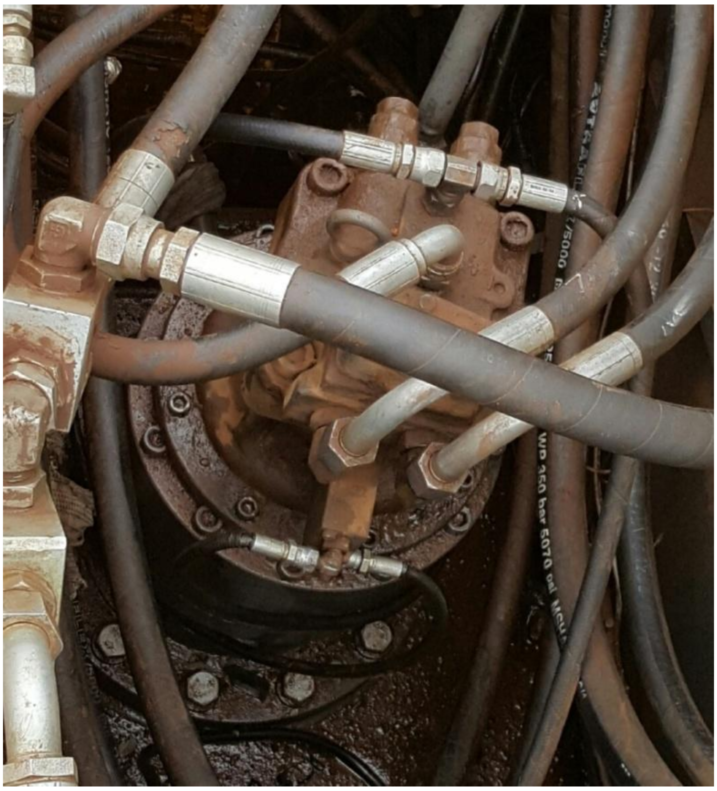
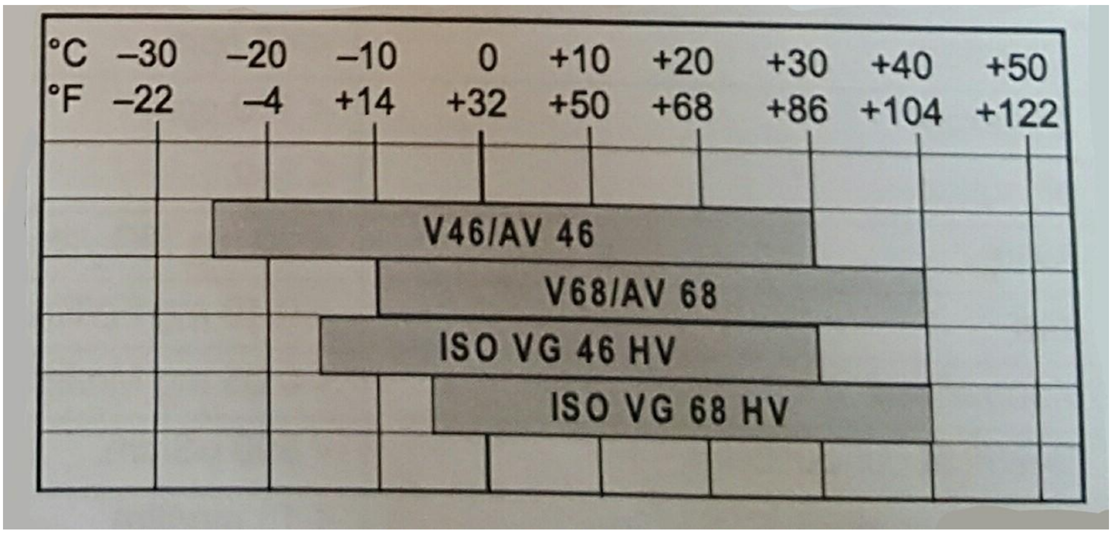


Figure (4 - 7) Swing Motor

4 - 6 EC210B Hydraulic Fluid

The best hydraulic oil in Sudan is ISO VG 68 HV according to Volvo oil specification which show in the table below hydraulic oil specification

Table (4 - 2) shows the oil specification



4 - 7 EC210B Filters And Strainers

Every minute, approximately one million particles that are larger than (1 micron) (0.001 mm or 1 μm) can enter a hydraulic system.

These particles can cause damage to hydraulic system components because hydraulic oil is easily contaminated, the wear of hydraulic system components is dependent on this contamination, because of that a filters and strainers as shows in Figure (4 - 8) are used to remove contaminants from the hydraulic oil [6].

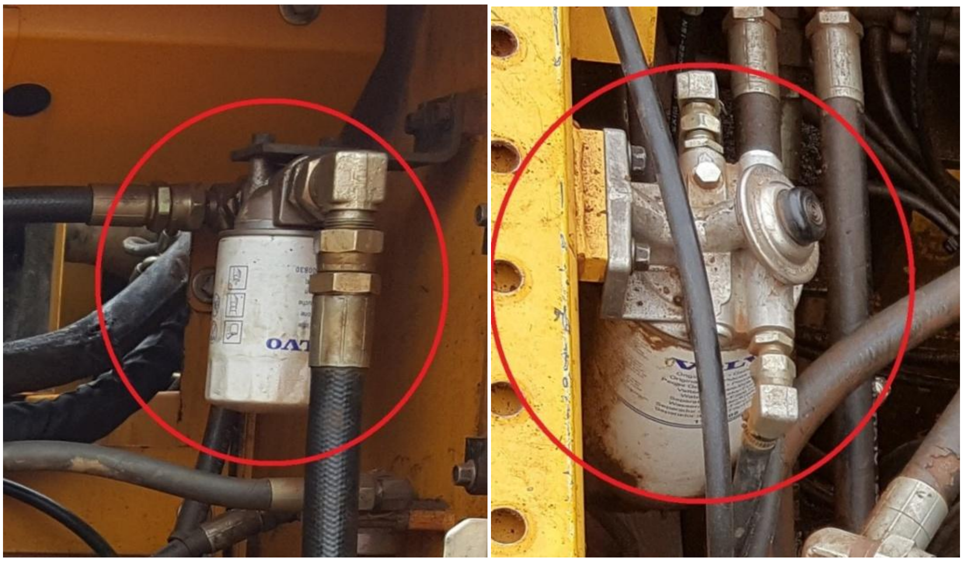


Figure (4 - 8) Oil Filters

4 - 8 EC210B Accumulator

Table (4 - 3) shows the accumulator specifications

DESCRIPTION	UNIT	SPECIFICATION
Type of gas		Nitrogen gas
Volume of gas	cc	320
Charging pressure of gas	MPa	1.47
Max. operating pressure		4.4
Max. actuating pressure		17.6

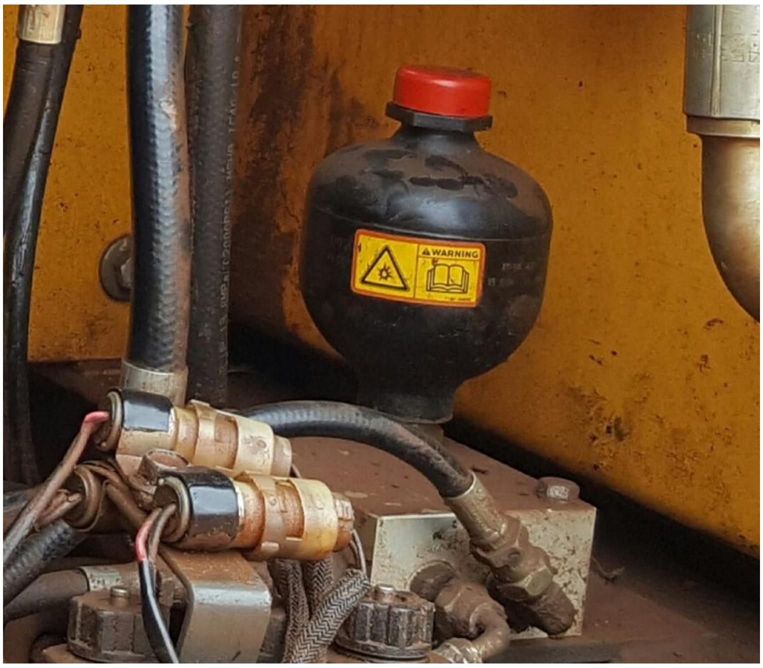


Figure (4 - 9) Accumulator

4 - 9 Type of Failures In The EC210B Hydraulic Systems

Failure is the dangerous enemy to engineers, and they are trying as much as they can to minimize and decrease the failures, the Table (4 - 4) below show the common failure in EC210B hydraulic systems and it is causes.

Table (4 - 4) shows the common failure in EC210B hydraulic systems and it is causes

COMPONENT	TYPE OF FAILUR	FAILUR CAUSES
Main Piston Pump	Oil leakage up normal.	• Life time of seals O-Rings. • Overheating of hydraulic pump.
	Overheating of pump.	• Bad setting of relief valves. • oil specification not match the recommended (viscosity) .
	Excessive wear .	• suction strainer (filter) is blocked or opened. • oil over life.
Main Control Valve	Spool stuck. Oil leakage. Internal component stuck. Spring stuck or loosing. Characteristic. Grooves wearing. Galleries closed.	• Contamination which comes from several sources like oil surrounded environment….ect. • there could be other reason like part life time receive heating.

COMPONENT	**TYPE OF FAILUR**	**FAILUR CAUSES**
Travel Motor and Swing Motor	Wear in internal component. Faulty sealing rings. Weak in function or one function. Wear in reduction gear.	• Contamination for hoses or environment • Parts life time. • Excessive heating.
Cylinder (Boom , Arm , Bucket)	Leakage from the piston.	• contamination, part life time.
	Pitting the rod.	• the main reason is moisture. • sun directly (stocking).
Hydraulic Oil	The main failure could accord in the hydraulic oil is time out internal which is calculated by the machine operating hour. Quantity (below the level) Other failure could be low quality Effect like heat and contamination moisture Characteristic	Environment issue Quality issue Stocking issue Using issue

COMPONENT	TYPE OF FAILUR	FAILUR CAUSES
Accumulator	Faulty device , bad quality	Bad use
Hydraulic Tube and Hoses	Scratches inside due to operation	Contamination in oil
	Damage in the sealing kiting (the piston could cause damage in tube)	Faulty sealing ring for piston
	Tube leakage	Cause by bushing failure in the rod
	For hose Damage due the pressure setting	pressure setting

CHAPTER FIVE

RESULTS AND RECOMMENDATION

5 - 1 Result

We make two activities

1. Maintenance Schedule of Hydraulic System.
2. Simulation Result of Working Hydraulic System.

5 - 1 - 1 Maintenance Schedule of Hydraulic System

Microsoft Excel was used to develop the preventive maintenance plan to VOLVO EC210B , and the results it is show blew.

The Figure (5 - 1) show the preventive maintenance schedule interface in excel , and the figures from Fig (5 - 2) to the Fig (5 - 9) show the maintenance details in (10 , 50 , 100 , 200 , 250 , 500 , 1000 , 2000) hours, sequentially.

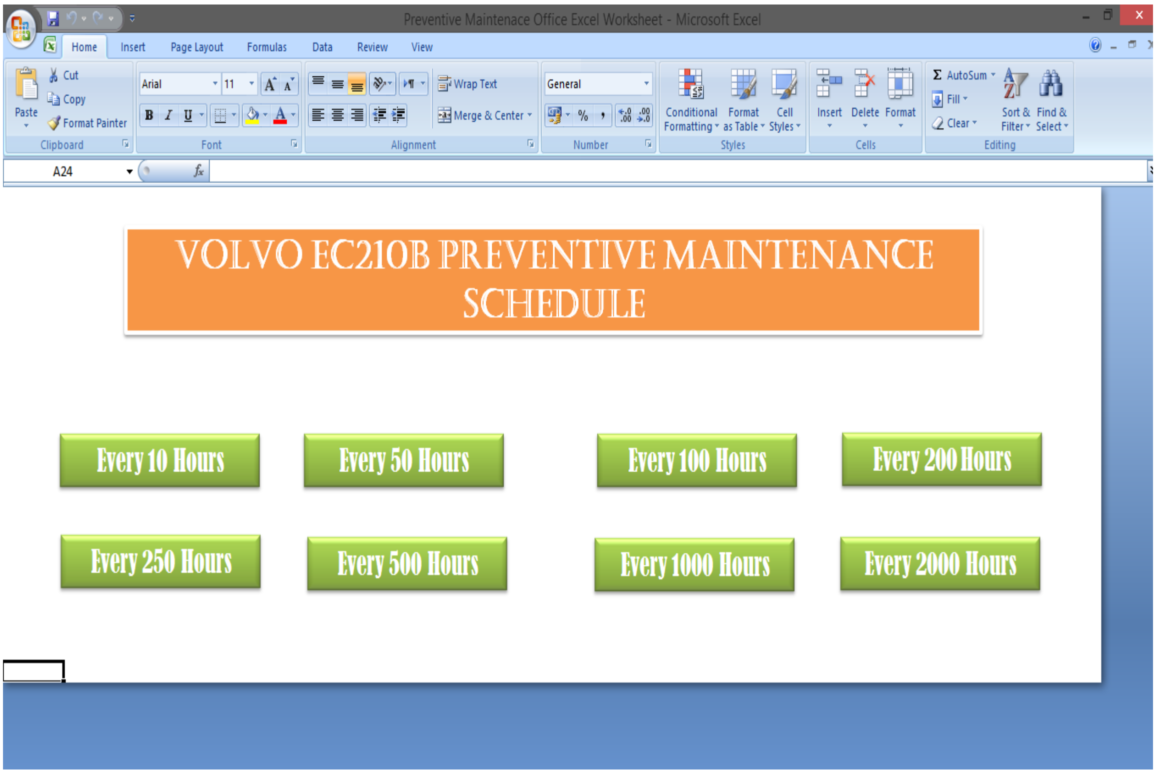


Figure (5 - 1) Excel Interface

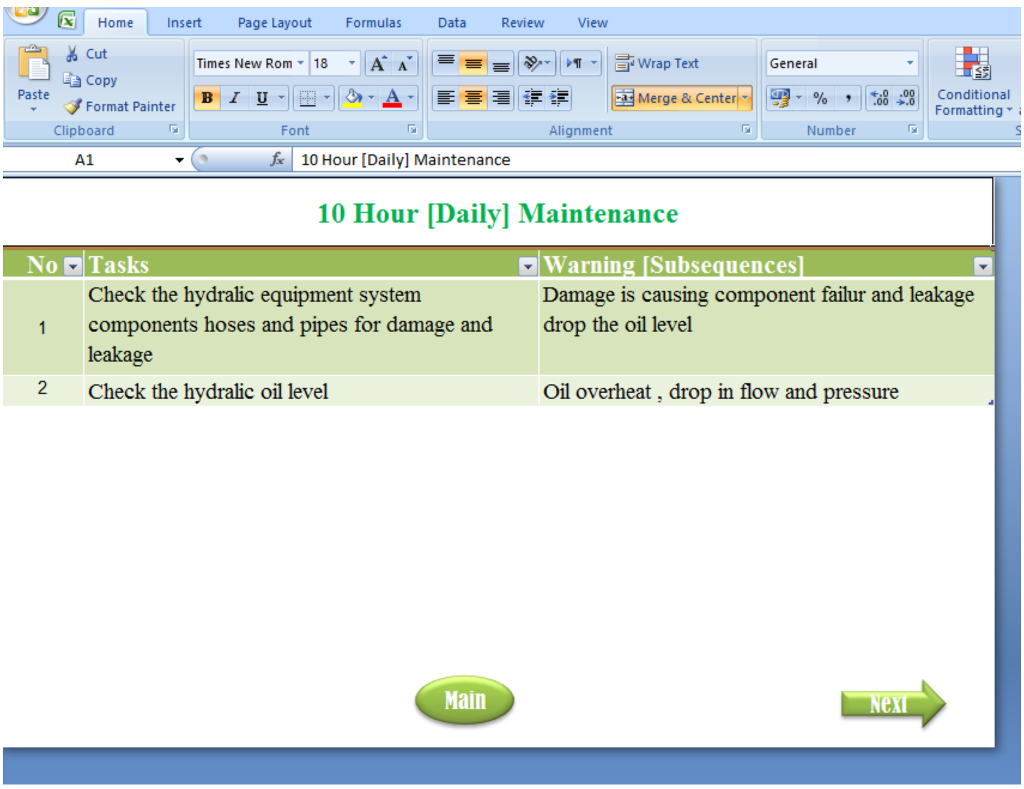


Figure (5 - 2) 10 Hour Maintenance

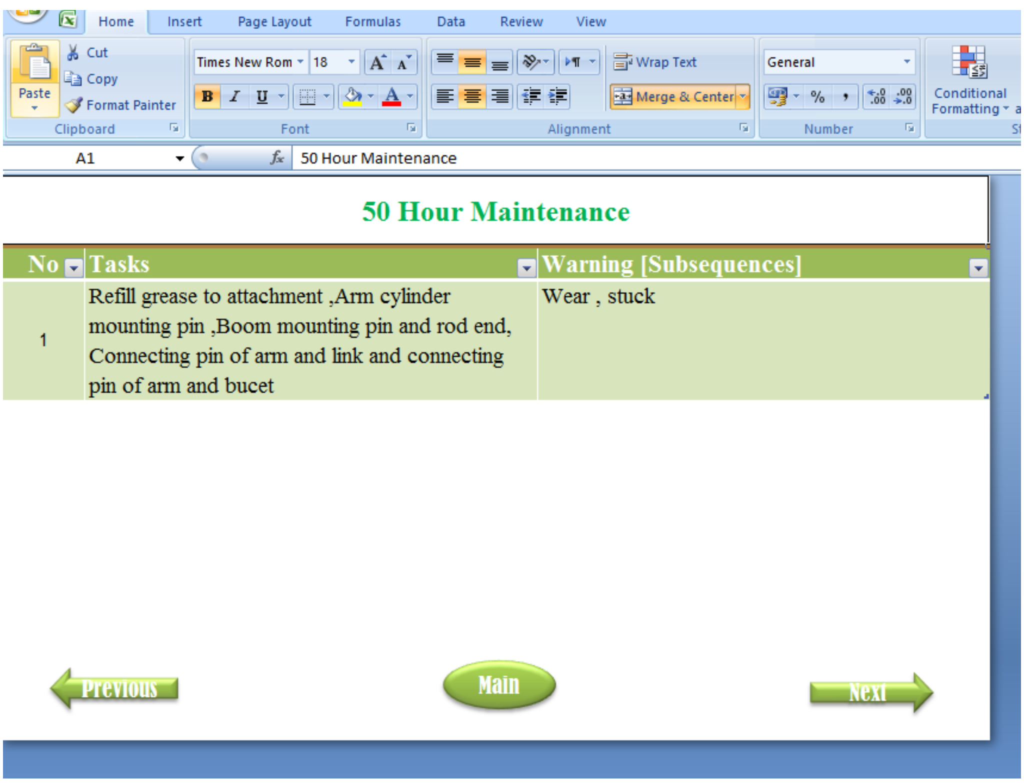
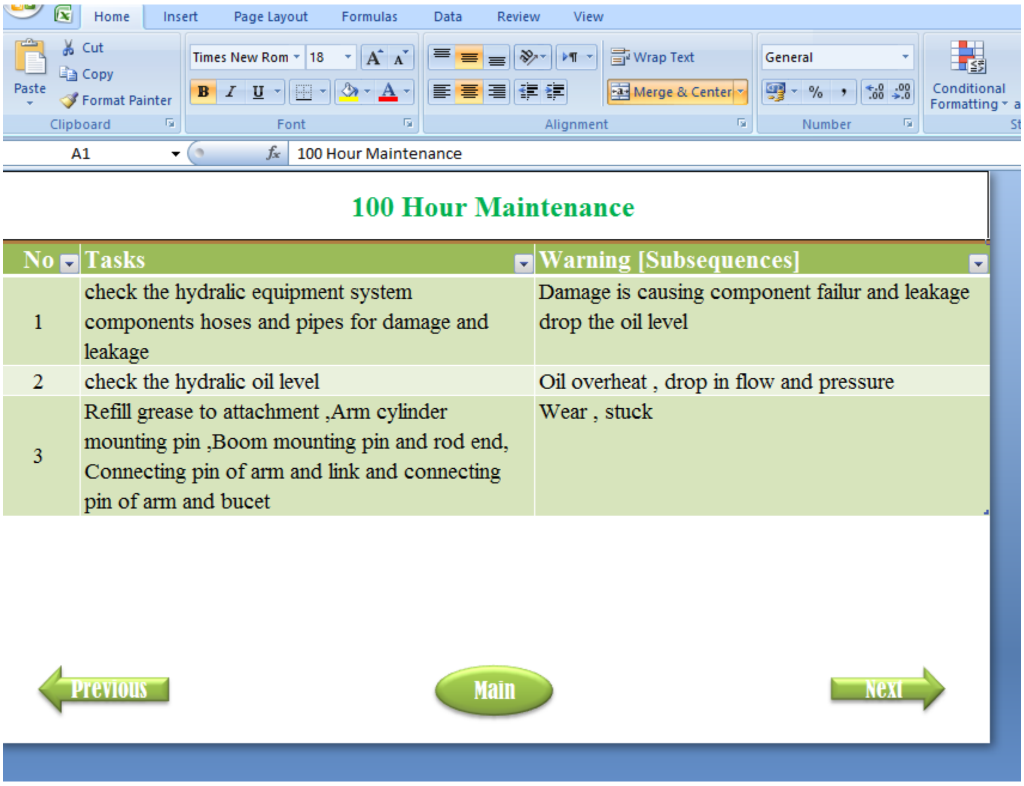


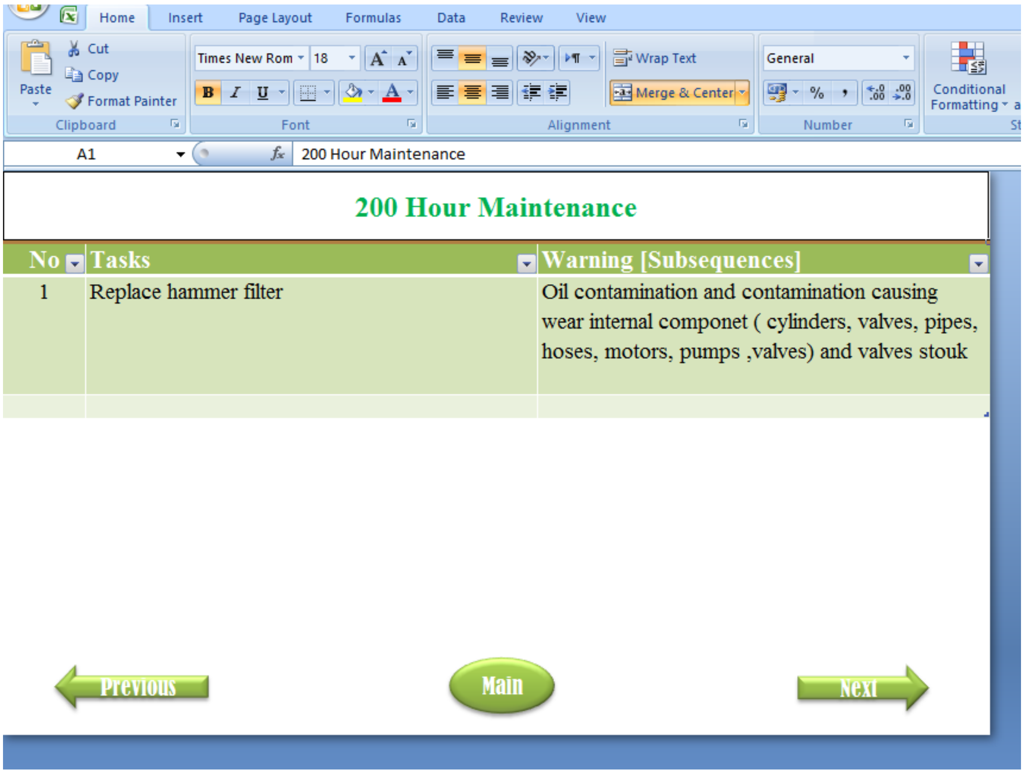
Figure (5 - 3) 50 Hour Maintenance



100 Hour Maintenance

No	Tasks	Warning [Subsequences]
1	check the hydralic equipment system components hoses and pipes for damage and leakage	Damage is causing component failur and leakage drop the oil level
2	check the hydralic oil level	Oil overheat , drop in flow and pressure
3	Refill grease to attachment ,Arm cylinder mounting pin ,Boom mounting pin and rod end, Connecting pin of arm and link and connecting pin of arm and bucet	Wear , stuck

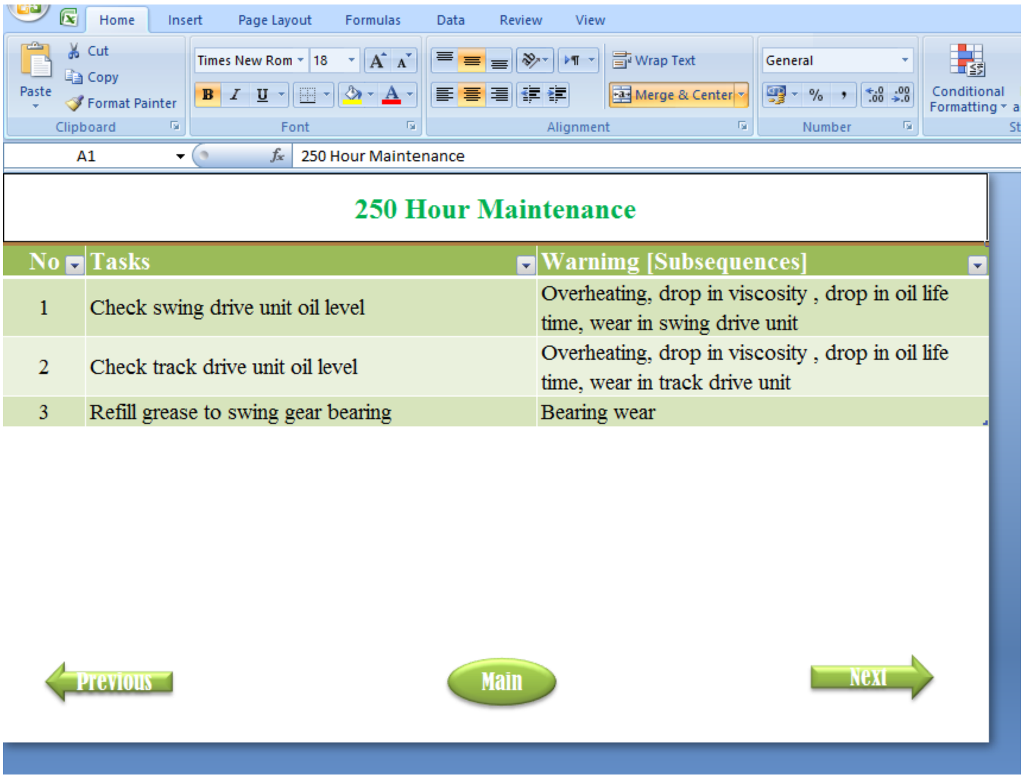
Figure (5 - 4) 100 Hour Maintenance



200 Hour Maintenance

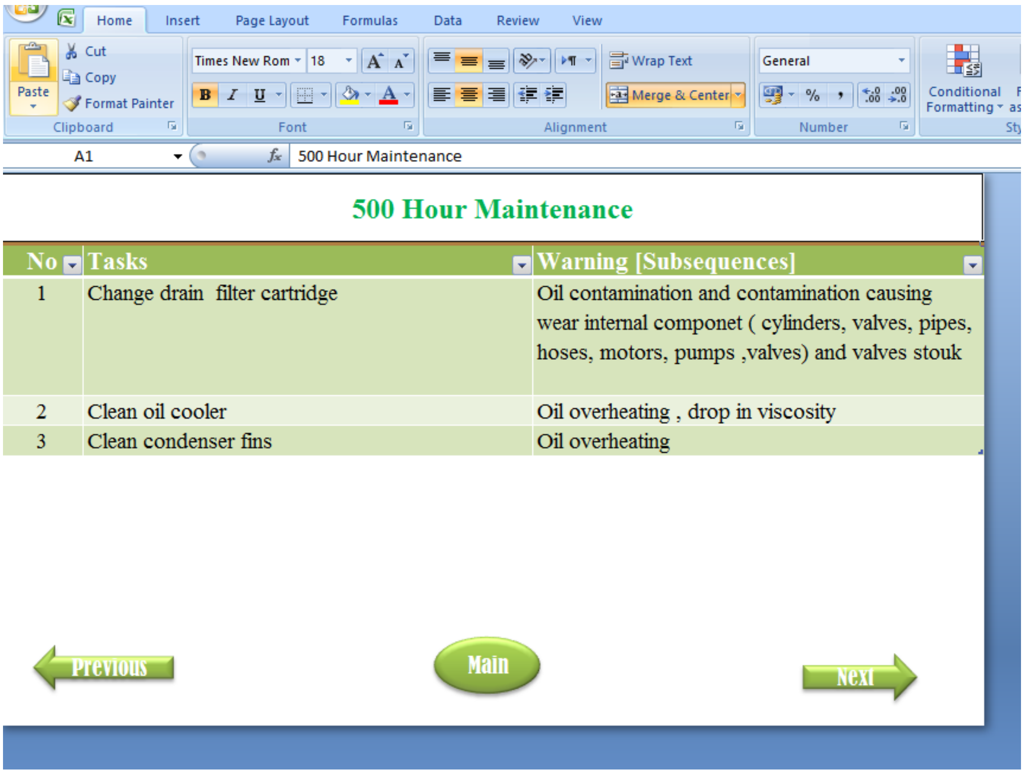
No	Tasks	Warning [Subsequences]
1	Replace hammer filter	Oil contamination and contamination causing wear internal componet (cylinders, valves, pipes, hoses, motors, pumps ,valves) and valves stouk

Figure (5 - 5) 200 Hour Maintenance



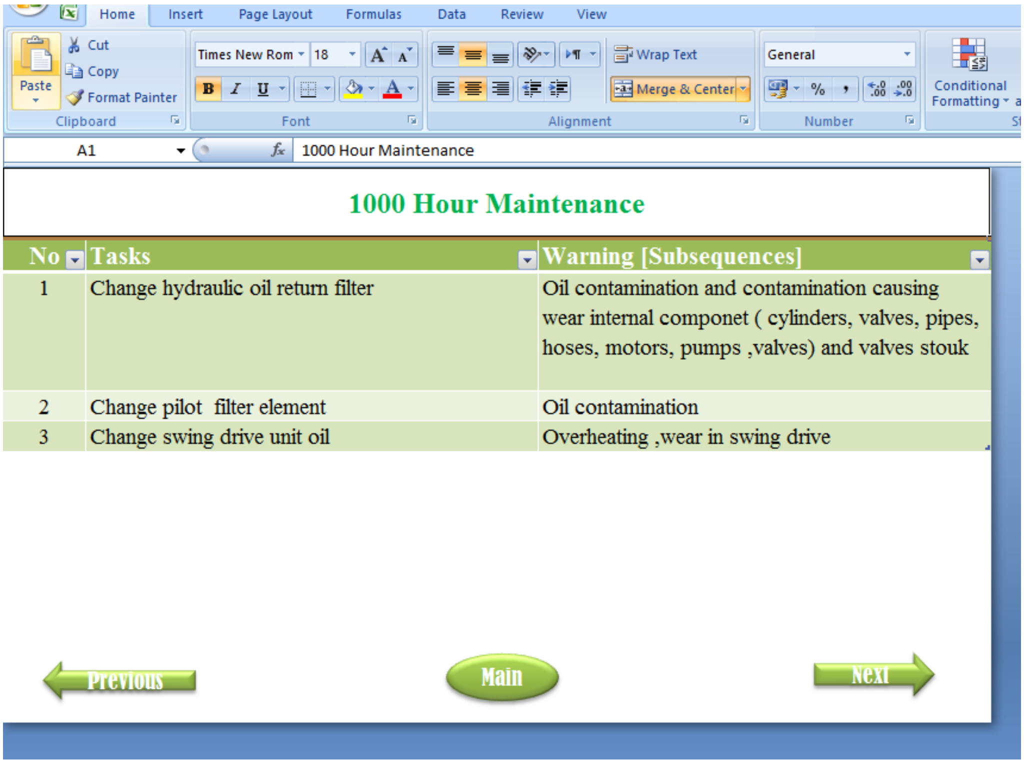
No	Tasks	Warnimg [Subsequences]
1	Check swing drive unit oil level	Overheating, drop in viscosity , drop in oil life time, wear in swing drive unit
2	Check track drive unit oil level	Overheating, drop in viscosity , drop in oil life time, wear in track drive unit
3	Refill grease to swing gear bearing	Bearing wear

Figure (5 - 6) 250 Hour Maintenance



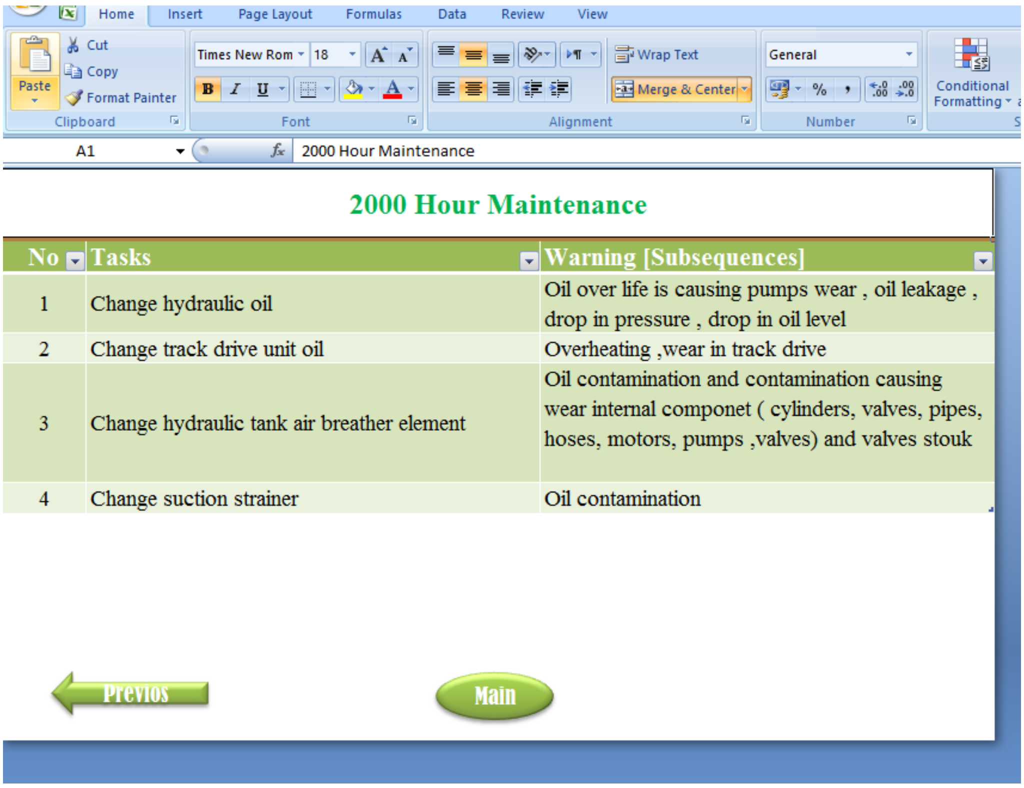
No	Tasks	Warning [Subsequences]
1	Change drain filter cartridge	Oil contamination and contamination causing wear internal componet (cylinders, valves, pipes, hoses, motors, pumps ,valves) and valves stouk
2	Clean oil cooler	Oil overheating , drop in viscosity
3	Clean condenser fins	Oil overheating

Figure (5 - 7) 500 Hour Maintenance



No	Tasks	Warning [Subsequences]
1	Change hydraulic oil return filter	Oil contamination and contamination causing wear internal componet (cylinders, valves, pipes, hoses, motors, pumps ,valves) and valves stouk
2	Change pilot filter element	Oil contamination
3	Change swing drive unit oil	Overheating ,wear in swing drive

Figure (5 - 8) 1000 Hour Maintenance



No	Tasks	Warning [Subsequences]
1	Change hydraulic oil	Oil over life is causing pumps wear , oil leakage , drop in pressure , drop in oil level
2	Change track drive unit oil	Overheating ,wear in track drive
3	Change hydraulic tank air breather element	Oil contamination and contamination causing wear internal componet (cylinders, valves, pipes, hoses, motors, pumps ,valves) and valves stouk
4	Change suction strainer	Oil contamination

Figure (5 - 9) 2000 Hour Maintenance

5 - 1 - 2 Simulation Result of Working Hydraulic System

Automation Studio is a design, animation and simulation software tool. It was created for the automation industry, specifically to fulfill engineering, training, and testing requirements. The workshops associated with the software reflect the prevailing usage in the industry as closely as is possible. The simulation utility makes Automation Studio an efficient tool for the certification of automated processes and programs.

We was used it as a tool to simulate hydraulic circuit and generate different results according to needs in specific steps which should describe below.

Firstly we draw hydraulic circuit after opening software and start to drag components from main hydraulic library until complete the circuit, it show in Fig (5 - 10).

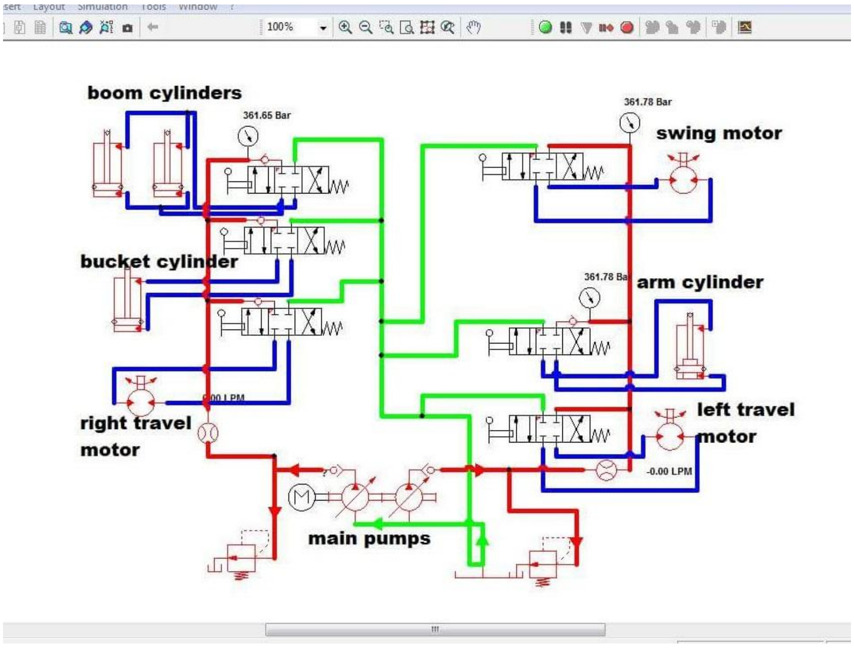


Figure (5 - 10) Hydraulic Circuit

Secondly we started to inter specification of each component (pumps cylinder, motors) like dimensions and other variables (flow, maximum pressure, temperature ...etc.) as show on Fig (5 - 11) and (5 - 12) for example, after that we simulated the circuit through pressing in simulation icon and select simulation type (normal, slow) so you can read different results during simulation like plotting between main pump and arm cylinder as show in Fig (5 - 13) and export plotting result to the table (5 - 1)

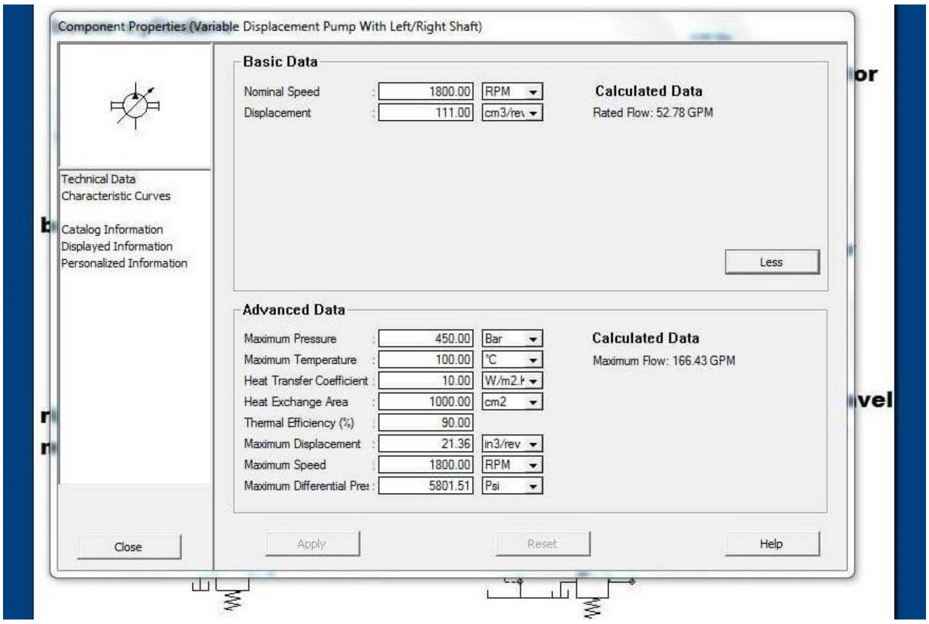


Figure (5 - 11) Pump Conversation Box

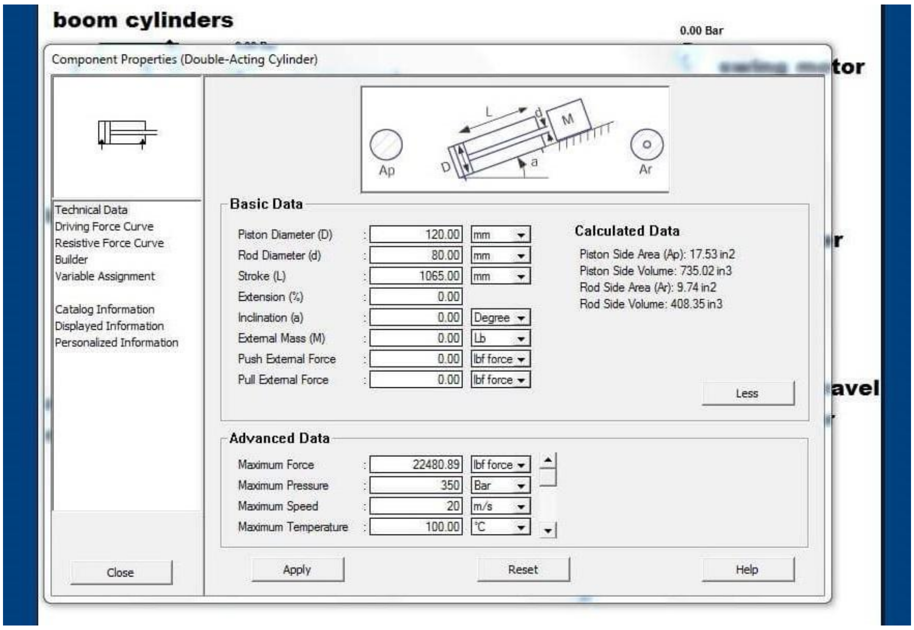


Figure (5 - 12) Cylinder Conversation Box

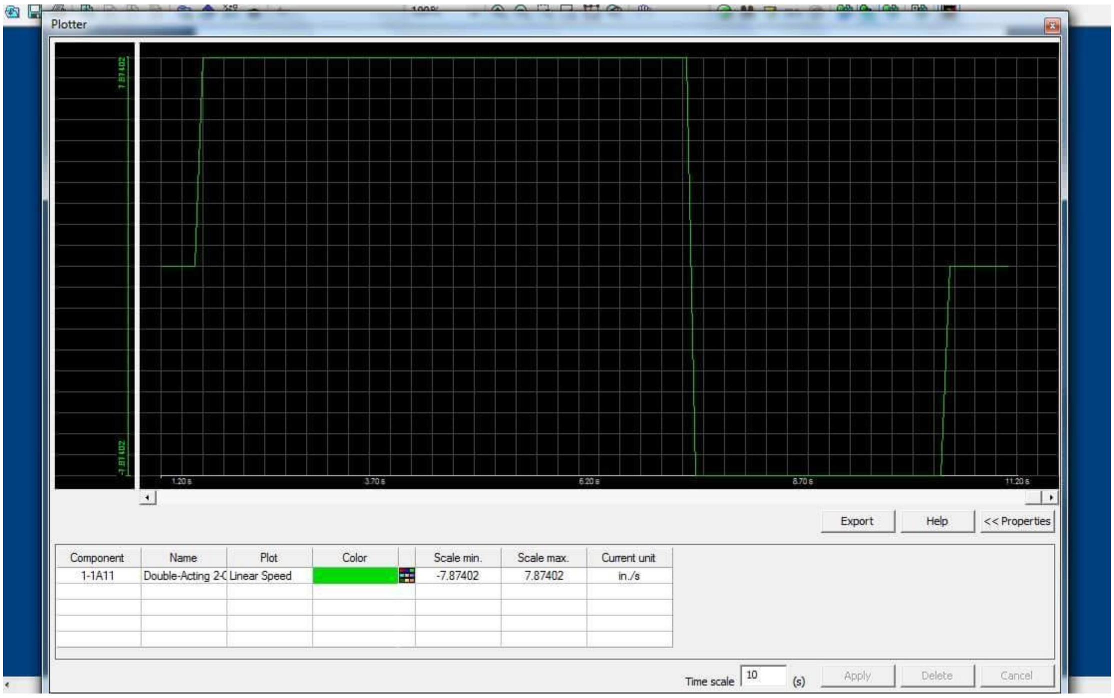


Figure (5 - 13) Arm Speed Plot

Table (5 - 1) Simulation Result for Arm Cylinder

SPEED (inch/s)	**TIME** (s)
0.0	0.200
0.0	0.600
+7.3	2.300
+7.2	2.400
+7.2	2.500
+7.2	3.100
-7.2	7.800
-7.2	7.900
-7.2	8.000
-7.2	8.100

-0.0	8.200
-0.0	8.300
0.0	8.400
0.0	8.500

The table show linear speed of cylinder

- (+) Positive Speed »» Speed of Arm during stroke in up act.
- (-) Negative Speed »» Speed of Arm during stroke in down act.
- Speed scale ±7.87402.

5 - 2 Conclusion

The document has presented the preventive maintenance program for an excavator hydraulic system, in addition to modeling of hydraulic circuit by Automation Studio (5.2 version) with Microsoft Excel 2007 to scheduled failure and causes of hydraulic system.

The finding of the research showed that the failures of hydraulic equipment in an excavator depended on the level of implementation of the preventive maintenance program that recommended by the manufacture, or misusing the equipment, so we recommend all users to follow preventive maintenance program.

The simulation has been done by using automation studio software and the performance of actuator has been obtained, the Arm cylinder was selected as a sample and the result generated depend on plotting between Arm cylinder speed and time, from the result we observe that start of piston motion responses after more than 0.6 second and speed increase through time until to reach maximum speed 7.2 inch/s at 2.4 second.

5 - 3 Recommendation

- We recommend the researchers to improve the research by using practical information to measure how the different environment affect in the maintenance application.
- Finally, we suggest that the heavy equipment dealers in Sudan, including Volvo company, should adopt in future the training program for their customers to insure a proper implementation of the preventive maintenance program.

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