SUDAN UNIVERSITY SCIENCE& TECHNOLOG

COLLEGE OF ENGINEERING

MECHANICAL ENGINEERING

IMPROVING EFFICIENCY FOR PUMP AND COMPRESSOR BY PREVENTIVE MAINTENANCE

تحسين كفاءة الضاغط والمضخة بالصيانة الوقائية

SUBMITTED IN PARTIAL FULFILLMENT OF THE DEGREE OF B.ENG (HONOR) IN MECHANICAL ENGINEERING (POWER)

Presented by:

NAZAR OSMAN MOHAMMED KHIER ELTOM

ABDULRAHMAN AHMED KHOGALY AHMED

ADEL RAMADAN HUSSEIN ALI

Supervised by: *Dr. TAWFIQ AHMED JAMAL ALLDEEN*

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الآيـة

(شَهِدَ اللَّهُ أَنَّهُ لَا إِلَٰهَ إِلَّا هُوَ وَالْمَلَائِكَةُ

وَأُولُو الْعِلْمِ قَائِمًا بِالْقِسْطِ ۚ لَا إِلَٰهَ إِلَّا هُوَ

الْعَزِيزُ الْحَكِيمُ)

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Dedication

Personal, we would like to express our deepest gratitude to the people behind this successful project who stand by us and believe in our abilities.

We would like also to thank the entire teacher's staff, especially our supervisor, Dr. TAWFIQ AHMED JAMAL ALLDEEN for his valuable advices.

Last but not the least; we would like to thank our family: our parents and our brothers and sisters for supporting us spiritually throughout doing this project.

Abstract

The purpose of study is identify the different types of compressors and pumps used and how to choosing the compressor and pump based on the efficiency and flow rate required. And also study the types of maintenance and a comparison between the design efficiency and theoretical efficiency of each compressor and pump before and after preventive maintenance.

المستخلص

الغرض من الدراسه هو التعرف علي الانواع المختلفه من الضواغط والمضخات المستخدمة ، وكيفيه اختيار الضاغط والمضخة المناسبة بناءا علي الكفاءة و معدل التدفق المطلوب وكذلك معرفة أنواع الصيانة ، وعقد مقارنة بين الكفاءة التصميمية والكفاءة النظرية لكل ضاغط ومضخة قبل وبعد الصيانة الوقائية .

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Symbols and units:

M	Mass	kg/s
P	Pressure	Mpa
W	Work	Kw
ρ	Density	kg/m^3
η	Efficiency	%
cp	specific heat for constant pressure	Kj/kg

Subscript:

KRC	Khartoum refinery company
RFCC	residual fluidized continues catalyst
CCR	Continuous catalytic reforming
GDHT	gasoline diesel hydro treating
SEER	Seasonal Energy Efficiency Ratio

Chapter1

Chapter 1

Introduction

1-1 Introduction

Maintenance is a routine and recurring activity of keeping a particular machine or facility at its normal operating condition so that it can deliver its expected performance or service without causing any loose of time on account of accidental damage or breakdown.

Once equipment is designed, fabricated and installed, the operational availability of the same is looked after by the maintenance requirement. The idea of maintenance is very old and was introduced along with inception of the machine. In the early days, a machine was used as long as it worked. When it stopped working, it was either repaired/serviced or discarded. [20]

The high cost sophisticated machines need to be properly maintained/serviced during their entire life cycle for maximizing their availability. The development of mechanization and automation of production systems and associated equipment, with the accompanying development of ancillary services and safety requirements, has made it mandatory for engineers to think about proper maintenance of equipment. [19]

Preventive maintenance is work carried out on equipment in order to avoid its breakdown or malfunction. It is a regular and routine action taken on equipment in order to prevent its break down. [21]

Compressors and pump fall into that category of machinery that is all around us but of which we are little aware. We find them in our homes and workplaces, and in almost any form of transportation we might use.

Compressors serve in refrigeration, engines, chemical processes, gas transmission, manufacturing, and in just about every place where there is a need to move or compress gas. Compressors are widely used in industries to transport gases. It is a mechanical device that compresses a gas. [3]

Pump is a machine or mechanic equipment which is required to lift liquid from low level to high level or to flow liquid from low pressure area to high pressure area and also as a debit booster in a piping network system. This is reached by making a low pressure at suction side of pump and a high pressure at discharge side of pump. [14]

1-2 Project background

In order to determine what type of compressor and pump systems will be needed to accomplish the job, a variety of detailed data will need to be discerned. In addition the following items are needed to help make some subjective decisions when two or more options are available or in the selection of various accessories.

1-3 Problem statement

This project focuses on how to calculate compressors and pump efficiency after Preventive Maintenance, selecting proper compressor and pump.

1-4 Project Aims and objective

- Know the Types of compressors and pump used in (KRC).
- Know the Types of Maintenance.
- Know why this compressor and pump used in (KRC).
- Comparison between design and theoretical efficiency of each compressor and pump after Preventive Maintenance used in (KRC).

Project significant

The choice of compressor and pump is one of the most important things to consider. Therefore, the correct choice of compressor according to the efficiency and size of pressure and flow rate them. when high pressure is required, it is necessary to Know which type of compressor or pump gives high pressure and if we need a high flow rate must know which type of compressor or pump gives that.

1-6 Scope

This project contains three types of compressors and three types of pumps, namely: Reciprocating, single Centrifugal and multi Centrifugal.

Chapter2

Chapter 2

Previses study

2-1 Compressors

Compressors are an important part of the process industries. Compressors increase the pressure of gases and vapors so they can be used in they can be used in a wide variety of applications that require higher pressures applications like compressing gases required to operate instruments or equipment. [5]

2-2 Type of Compressors

Several types of compressors are used in the process industries shown in Figure 2-1.The most common, however, are positive displacement and dynamic. Both of these types of compressors can be single- or multistage.

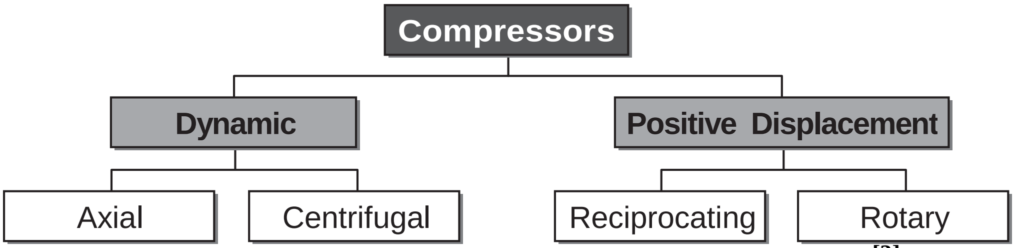


Figure: (2-1) Chart of compressors types [3]

2-2-1 Dynamic compressors

Dynamic compressors are non-positive displacement compressors that use centrifugal or axial force to accelerate and convert the velocity of the gas to pressure (as opposed to positive displacement compressors, which use a piston, lobe, or screw to compress gas)[9][6]

2-2-1-1 Centrifugal compressors

Centrifugal compressors are a dynamic type compressor in which the gas flows from the inlet located near the suction eye to the outer tip of the impeller blade. [1][7]

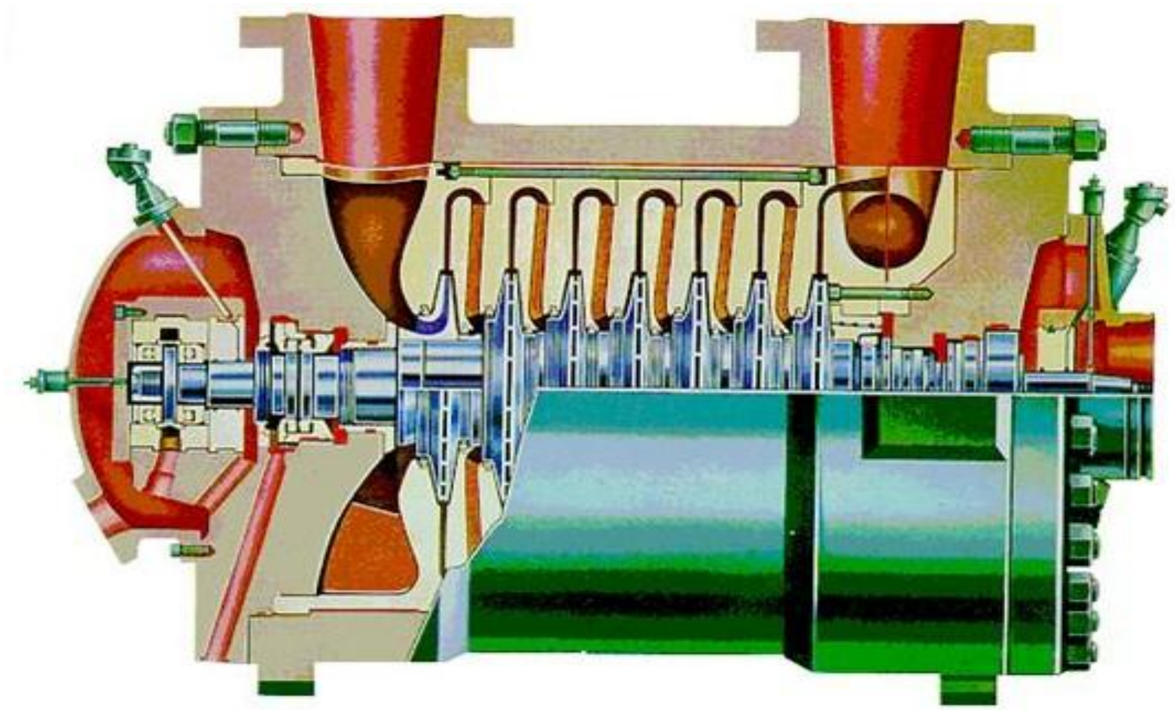


Figure: (2-2) Centrifugal compressor [10]

2-2-1-2 Axial compressors

A typical axial compressor is shown in Figure 2-3. An axial compressor consists of a rotor shaft with a series of rotating blades and a tapered cylindrical casing with fixed stator vanes. Each set of blades is followed by a set of stator vanes. The gas enters the inlet nozzle, which guides the gas to the inlet volute. The inlet volute guides and accelerates the gas stream into the stator vanes. The stator vanes turn the gas stream to properly align the gas with the blades. The blades increase the energy of the gas by increasing the velocity of the gas. The stator vanes act as diffusers to provide resistance to the gas flow, and they cause the gas stream to decrease in velocity and to increase in pressure. The stator vanes also properly orient the gas stream for the next row of blades [9]. Since blades and stator vanes alternate down the length of the casing, the gas is both accelerated and decelerated several times before it leaves the compressor. Pressure is increased each time the gas flow meets a set of stator vanes. The gas exits the compressor through the discharge volute and discharge nozzle [4].

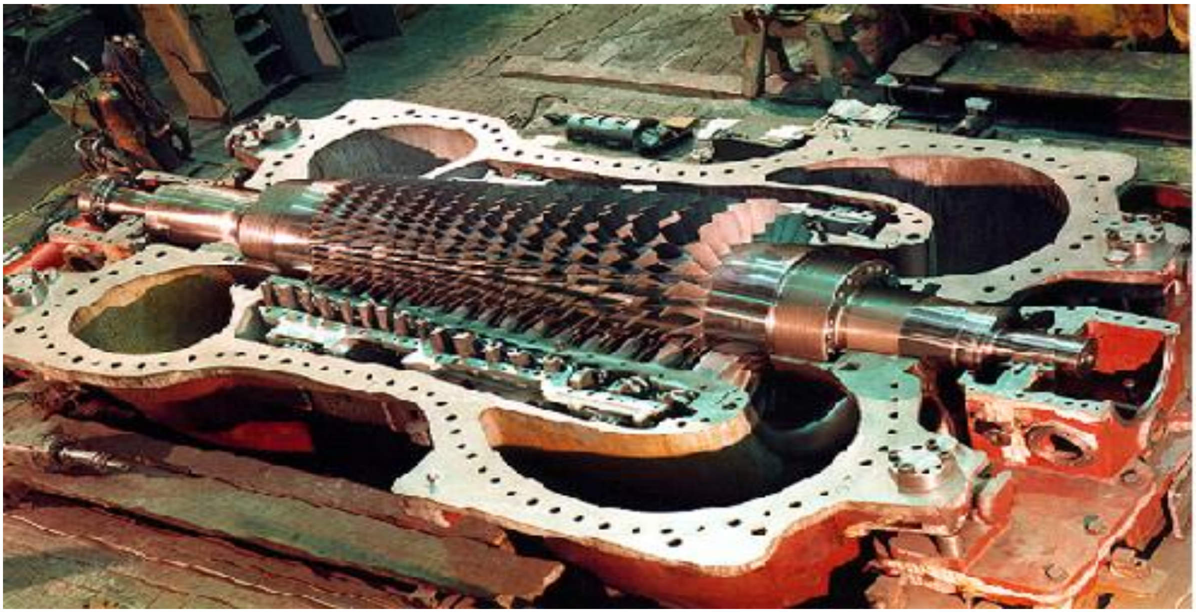


Figure: (2-3) axial compressor [3]

2-2-2 Positive Displacement Compressors

Positive displacement compressors are devices that may use screws, sliding vanes, lobes, gears, or a piston to deliver a set volume of gas with each stroke. Positive displacement compressors work by trapping a set amount of gas and forcing it into a smaller volume. The two main types of displacement compressors are reciprocating and rotary, with reciprocating being the most commonly used. [2] [8]

2-2-2-1 Reciprocating compressors

Reciprocating compressors are the best known and most widely used compressors of the positive displacement type. They operate on the principal of reducing the volume (increase in pressure), of specified quantity of trapped gas in an enclosure and then compressed gas is pushed out of the enclosure.

Reciprocating compressors have inherent advantages over other compressors in the ability to adopt a wide range of loads and pressure ratios. The load may vary from 0 to 100% of the capacity. [1]

The term reciprocating refers to the back and forth movement of the compression device (a piston or other device is positioned in cylinder). Reciprocating compressors use the inward stroke of a piston to draw (intake) gas into a chamber and then use an outward stroke to positively displace (discharge) the gas. A common application for the reciprocating compressor is in an instrument air system. [6] [5]

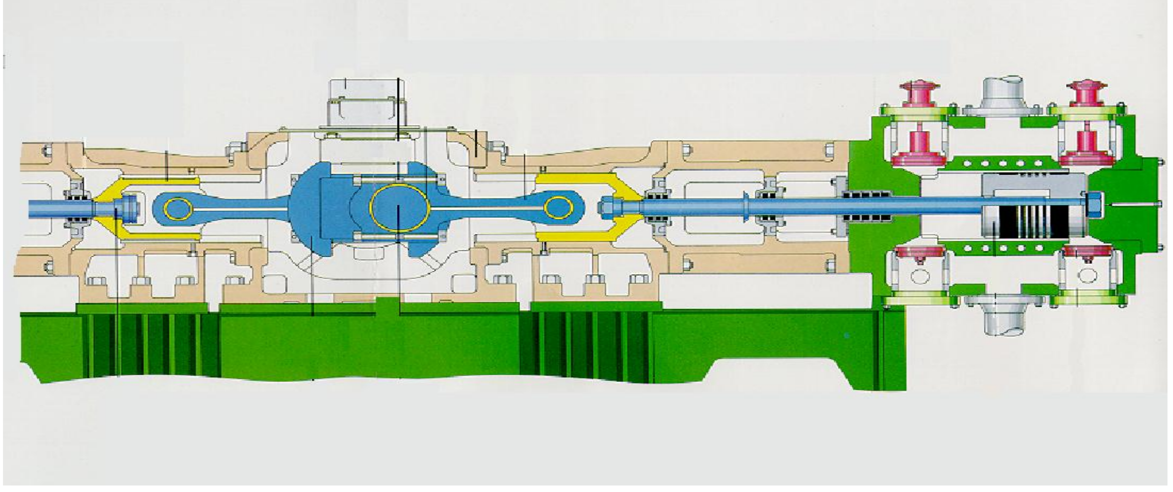


Figure (2-4) Reciprocating compressor [1]

2-2-2-2 Rotary compressors

Rotary compressors move gases by rotating a set of screws, lobes, or vanes. As these screws, lobes, or vanes rotate, gas is drawn into the compressor by negative pressure on one side and forced out of the compressor (discharged) through positive pressure on the other. Rotary compressors do not require a constant suction pressure to produce discharge pressure. [9]

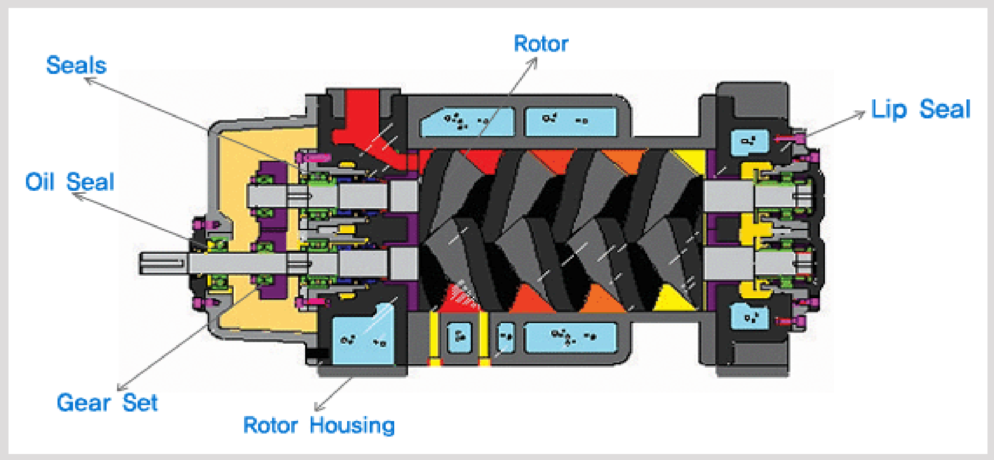
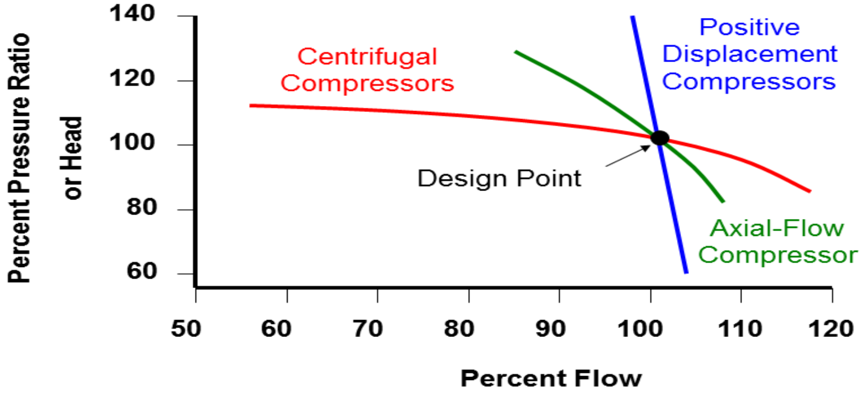


Figure (2-5) Rotary compressor [10]



Figurer: (2-6) General Performance compressor Curve [11]

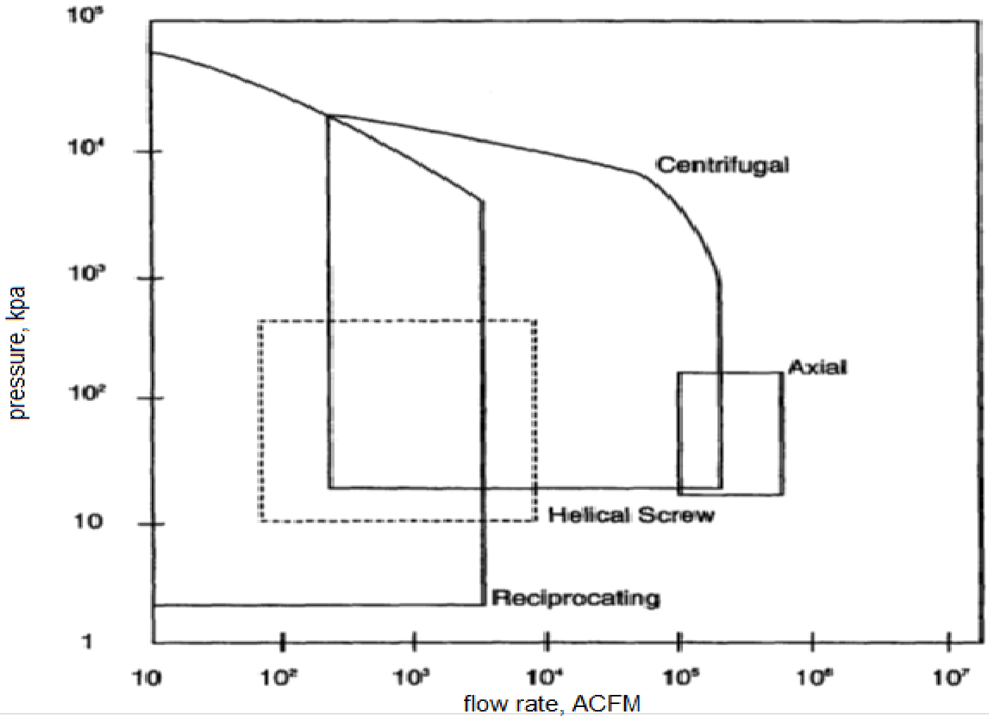


Figure: (2-7) Compressors selection diagram [12]

2-3 application

Air compressors have many uses, including: supplying high-pressure clean air to fill gas cylinders, supplying moderate-pressure clean air to a submerged surface supplied diver, supplying moderate-pressure clean air for driving some office and school building pneumatic HVAC control system valves, supplying a large amount of moderate-pressure air to power pneumatic tools, such as jackhammers, filling high pressure air tanks (HPA), for filling tires, and to produce large volumes of moderate-pressure air for large-scale industrial processes (such as oxidation for petroleum coking or cement plant bag house purge systems).[1]

2-4 pump

A pump is a device used to move fluids, such as liquids, gases or slurries. [13] [14]

2-5 Types of pump

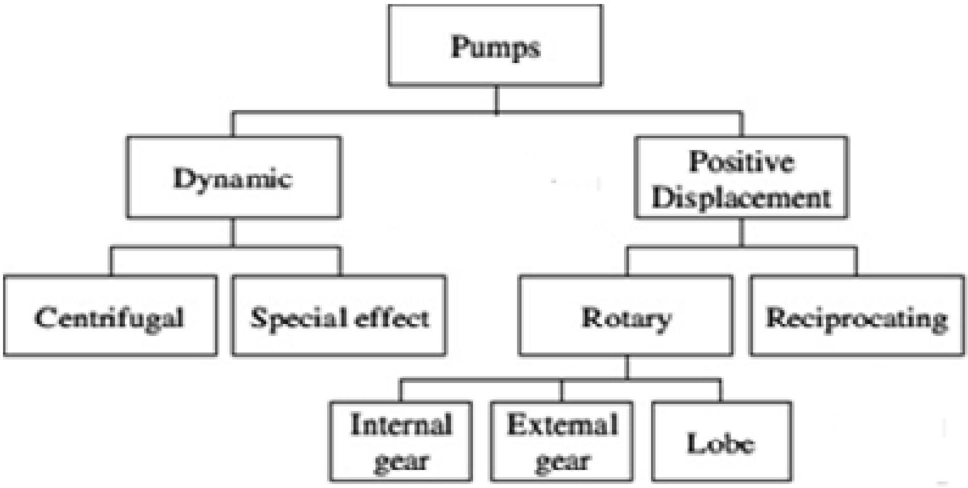


Figure: (2-8) Chart of pumps types [16]

2-5-1 positive displacement pumps

Displacement pumps are used in conditions where relatively small, but not change their volume precise, volumes are required. Displacement pumps will Displacement pumps are also called positive with a change in discharge pressure. displacement pumps.[15]

2-5-1-1 Rotary pump

Rotary pumps are positive displacement pumps that utilize rotary, rather than reciprocating, motion in their pumping action. They can be designed to pump liquids, gases, or mixtures of the two. As is the case with reciprocating pumps, their capacity per rotation is independent of driven speed. Unlike reciprocals, however, they develop a dynamic liquid seal and do not require inlet and discharge check valves. Since the rotating element of the pump is directly connected to its driver via a shaft, some sort of drive shaft sealing arrangement is required.[13]

1-Gear pump

One of the most common rotary pumps is the gear pump. It consists of two gears (rotors), one of which is driven by a shaft. The other acts as an idler and rotates through meshing action with the driven gear. Unlike the peristaltic pump, the gear pump has extremely close tolerances between its rotors and the walls of the pump case. It is these clearances and the meshing of the gear teeth that allow the liquid sealing process to occur.[16]

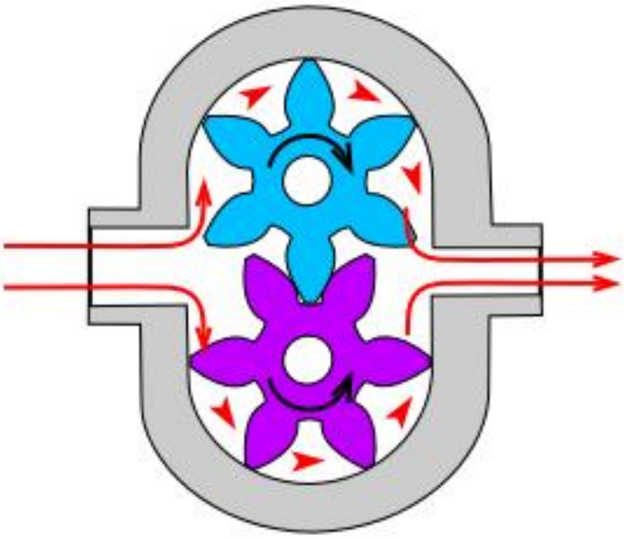


Figure: (2-9) Gear pump [16]

2-LOBE PUMPS

A major difference between lobe and gear pumps is that the rotors are designed to remain in close contact throughout rotation. By close contact, I mean that exterior timing gears are required to maintain proper rotation. As before the pumping cycles are readily apparent. The lower rotor while the inlet and outlet volumes are bounded by both rotors. Pumping torque I s shared equally by both rotors; however, their individual loading at any given point in time depends upon their axial position to one another.[14]

2-5-1-2 Reciprocating pump:

Reciprocating pumps are those which cause the fluid to move using one or more oscillating pistons, plungers or membranes (diaphragms) Reciprocating-type pumps require a system of suction and discharge valves to ensure that the fluid moves in a positive.

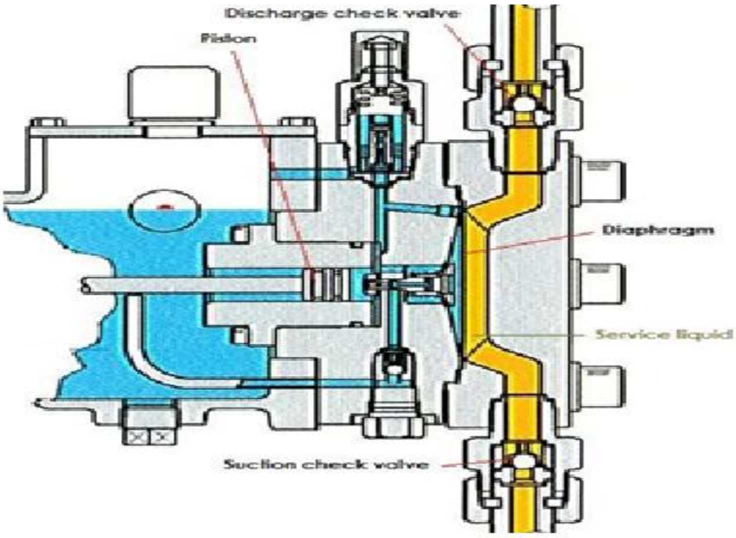


Figure: (2-10) Reciprocating pump [15]

1- diaphragm pump

In diaphragm pumps, the plunger pressurizes hydraulic oil which is used to flex a diaphragm in the pumping cylinder. Diaphragm valves are used to pump hazardous and toxic fluids [16]

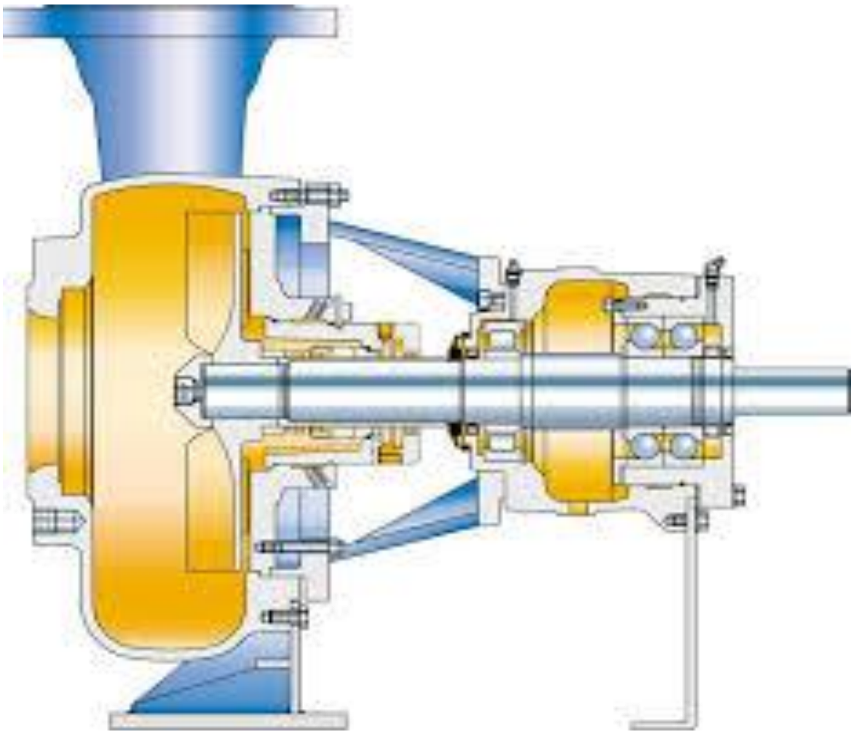


Figure: (2-11) diaphragm pump [17]

2-5-2 Dynamic pumps:

Dynamic pumps are used in conditions where high volumes are required and a change in flow is not a problem. As the discharge pressure on a dynamic pump is increased, the quantity of water pumped is reduced. One type of dynamic pump, centrifugal pumps, are the most common pump used in water systems. Dynamic pumps can be operated for short periods of time with the discharge valve closed. [13]

2-5-2-1 Centrifugal pump

A centrifugal pump is a rot dynamic pump that uses a rotating impeller to increase the pressure and flow rate of a fluid. Centrifugal pumps are the most common type of pump used to move liquids through a piping system. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward or axially into a diffuser or volute chamber, from where it exits into the downstream piping system.[17]

Centrifugal pumps are typically used for large discharge through smaller heads.

Centrifugal pumps are most often associated with the radial flow type. However, the term "centrifugal pump" can be used to describe all impeller type rot dynamic pump [13] including the radial, axial and mixed flow variations. [16]

1- Radial flow pumps

Often simply referred to as centrifugal pumps. The fluid enters along the axial plane, is accelerated by the impeller and exits at right angles to the shaft (radially). Radial flow pumps operate at higher pressures and lower flow rates than axial and mixed flow pump. [17]

2- Axial flow pumps

Axial flow pumps differ from radial flow in that the fluid enters and exits along the same direction parallel to the rotating shaft. The fluid is not accelerated but instead "lifted" by the action of the impeller. They may be likened to a propeller spinning in a length of tube. Axial flow pumps operate at much lower pressures and higher flow rates than radial flow pumps. [14]

3- Mixed flow pumps

Mixed flow pumps, as the name suggests, function as a compromise between radial and axial flow pumps, the fluid experiences both radial acceleration and lift and exits the impeller somewhere between 0-90 degrees from the axial direction. As a consequence mixed flow pumps operate at higher pressures than axial flow pumps while delivering

Higher discharges than radial flow pumps. The exit angle of the flow dictates the pressure head-discharge characteristic in relation to radial and mixed flow. [16]

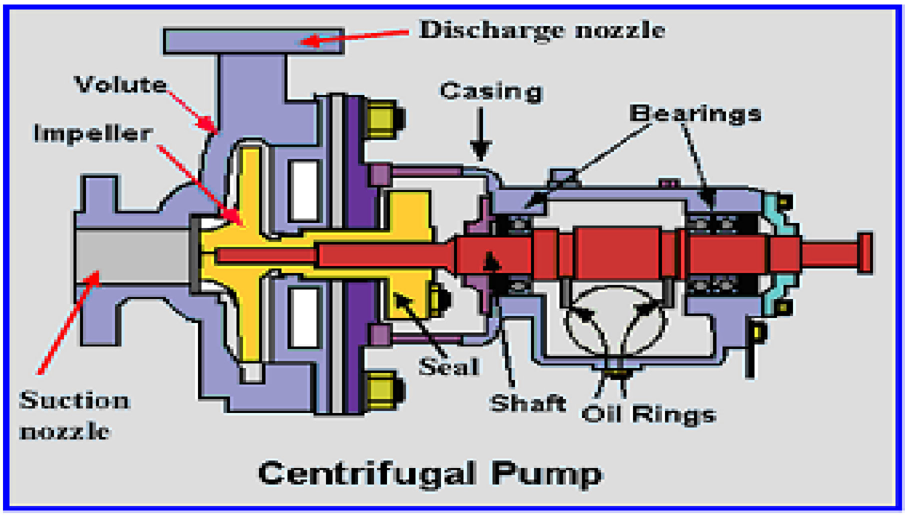


Figure: (2-12) Centrifugal pump [17]

2-5-2-2 special effect

1- Gas lift pumps

The Gas (air) lift is a device for raising liquid by means of compressed air. In the past it was widely used for pumping wells, but it has been less widely used since the development of efficient centrifugal pumps. It operates by introducing compressed air into the liquid near the bottom of the well. The air-and-liquid mixture, being lighter than liquid alone, rises in the well casing. The advantage of this system of pumping lies in the fact that there are no moving parts in the well. The pumping equipment is an air compressor, which can be located on the surface. [14]

2- Jet pumps

Jet pumps are a class of liquid-handling device that makes use of the momentum of one fluid to move another. Ejectors and injectors are the two types of jet pumps.

The ejector, also called the siphon, exhauster, or educator, is designed for use in operations in which the head pumped against is low and is less than the head of the fluid used for pumping.

The injector is a special type of jet pump, operated by steam and used for boiler feed and similar services, in which the fluid being pumped is discharged into a space under the same pressure as that of the steam being used to operate the injector. [17]

3- Electromagnetic Pumps

All electromagnetic pumps utilize the motor principle. A conductor in a magnetic field, carrying a current which flows at right angles to the direction of the field, has a force exerted on it, the force being mutually perpendicular to both the field and the current. In all electromagnetic pumps, the fluid is the conductor. This force, suitably directed in the fluid, manifests itself as a pressure if the fluid is suitably contained. The field and current can be produced in a number of different ways and the force utilized variously.

The major classifications of electromagnetic pumps, either conduction or induction, is based on the method employed to cause the electric current to flow in the pumped liquid. [13]

4- Screw Centrifugal Pumps

these pumps have a large diameter screw instead of the more common radial impeller found in centrifugal pumps. Thick sludge and large solids can be moved because of low NPSH requirement resulting from the use of the inducer –like impeller. As the pumped material enters at a low entrances angle, a low shear, low turbulence condition exists, resulting in very gentle handling of the fluid. The gentle handling makes it possible to pump slurries of fruits and vegetables, without undue breakup of the constituents. The pump can also be operated in reverse rotation, which is advantageous for clearing clogged suction lines. [17]

5- Viscous Drag (Disc Pump)

The disc pump system operates solely using the principles of boundary layer and viscous drag, two phenomenon well- known in fluid engineering. Although superficially the disc pump looks like a centrifugal unit, it has no impeller in the traditional sense, and used instead a series of parallel, rotating disc (disc assembly) to generate the energy necessary to move product.

The key difference between the disc assembly and a standard centrifugal pump impeller is that, with the disc assembly, pump age does not impinge on the rotating pump mechanism, so that it generates a pulsation- free, laminar flow pattern through the pump. The disc pump can operate effectively in hard-to-pump applications because it lacks an “impingement” device, which results in nominal contact between the pump and pump age. [16]

6- Rotating casing (pilot pump)

The basic principal for pilot pump is the liquid enters the intake manifold and passes into a rotating case where centrifugal force accelerates it a stationary pick-up tube positioned on the inner edge of case, where pressure and velocity are greatest, coverts the centrifugal energy into a steady, pulsation-free, high-pressure stream. The simplicity of the pump lies in the fact that there is only one rotating part, the seal is exposed only to suction pressure and no seal is required at the high-pressure discharge. [14]

7- Gravity pumps

Gravity pumps include the syphon and Heron’s fountain - and there also important qanat or foggara systems which simply use downhill flow to take water from far-underground aquifers in high areas to consumers at lower elevations. The hydraulic ram is also sometimes referred to as a gravity pump.[13]

8- Steam pumps

Steam pumps are now mainly of historical interest. They include any type of pump powered by a steam engine and also pistonless pumps such as Thomas Savery's pump and the Pulsometer steam pump.

9-Valveless pumps

Valveless pumping assists in fluid transport in various biomedical and engineering systems. In a valveless pumping system, no valves are present to regulate the flow direction. The fuid pumping efficiency of a valveless system, however, is not necessarily lower than that having valves.[14]

2-6 Applications

Pumps are used throughout society for a variety of purposes. Early Applications includes the use of the windmill or watermill to pump Water. Today, the pump is used for irrigation, water supply, gasoline Supply, air conditioning systems, refrigeration (usually called a Compressor), chemical movement, sewage movement, flood control Marine services, etc.

Because of the wide variety of applications, pumps have a plethora of shapes and sizes: from very large to very Small, from handling gas to handling liquid, from high pressure to low pressure, and from high volume to low Volume[13] .

2-7 Compressor Efficiency

Compressor efficiencies vary with compressor type, size, and through put. They can only be determined (afterward) by a compressor test, although compressor manufacturers can usually provide good estimates. For planning purposes.

$$\eta = \frac{\text{output(kw)}}{\text{input(kw)}} \quad \text{-------------------- (1-2)}$$

Where:

$\eta = \text{efficency } \%$

Output work from eq.2

$$W = m * cp * \Delta T \text{---------------------- } (2-2)$$

Where:

W=work output (kW)

m=mass (kg/s)

T= temperature (℃)

Find: m (kg/s) from eq.3

m= v*ρ -------------------------- (3-2)

Where:

v=flow rate (m3/s)

$\rho = \text{dencity}\ (\text{kg/m}^3)$

2-8 Pump efficiency:

Pump efficiency is defined as the ratio of the power imparted on the fluid by the pump in relation to the power supplied to drive the pump. Its value is not fixed for a given pump, efficiency is a function of the discharge and therefore also operating head. For centrifugal pumps, the efficiency tends to increase with flow rate up to a point midway through the operating range (peak efficiency) and then declines as flow rates rise further. Pump performance data such as this is usually supplied by the manufacturer before pump selection. Pump efficiencies tend to decline over time due to wear (e.g. increasing clearances as impellers reduce in size).

One important part of system design involves matching the pipeline head loss-flow characteristic with the appropriate pump or pumps which will operate at or close to the point of maximum efficiency. There are free tools that help calculate head needed and show pump curves including their Best Efficiency Points (BEP). [16]

Pump efficiency is an important aspect and pumps should be regularly tested. Thermodynamic pump testing is one method.

Pump selection is done by performance curve which is curve between pressure head and flow rate. And also power supply is also taken care of. Pumps are normally available that run at 50 Hz or 60 Hz. [13]

$$\eta = \frac{\text{output(Pw)}}{\text{input(PS)}} \quad \text{--------------------- (4-2)}$$

Where:

η = efficiency

P_w= the water power per kw.

P_s= the shaft power per kw.

Output work from

$P_w = Q * \mathbf{g} * \boldsymbol{\rho} * H$ **-------------------- (5-2)**

Where:

Q = flow rate (m^3/s)

H = energy Head added to the flow (m)

$\rho =$ fluid density (kg/m3)

$g =$ standard acceleration of gravity (9.80665 m/s2)

2-9 Types of maintenance systems

Basically, maintenance can be into two groups divided:

1- Breakdown maintenance

2-Planned maintenance

2-9-1 Breakdown Maintenance

The basic concept of breakdown maintenance is not to do anything as long as eve thing is going on well. Hence, no maintenance or repair work is done until a component or equipment fails or it cannot perform its normal performance. In other words, the maintenance work is called upon when the machine is out of order, and repairs are required to bring back the equipment to its original working condition.[19][21]

2-9-2 Planned Maintenance

The planned maintenance is said to be an organized type of maintenance. In this type of maintenance, the maintenance activities are planned well in advance to avoid random failure. It will be predetermined not only the when and what kind of the maintenance work, but also by whom it would be undertaken. The prerequisites for planned maintenance include the conduction of work study that decides the periodicity of maintenance work. [20]

The planned maintenance can be further classified into:

-Scheduled Maintenance (SM)

-Preventive Maintenance (PM)

-Corrective Maintenance (CM)

-Reliability Centered Maintenance (RCM)

2-9-2-1 Scheduled Maintenance

This is a stitch-in-time procedure to avoid break-downs. The actual maintenance program is scheduled in consultation with the production department, so that the relevant equipment is made available for maintenance work. The frequency of such maintenance work is decided well in advance from experience so as to utilize the idle time of the equipment effectively. This also helps the maintenance department to use their manpower effectively. [22]

2-9-2-2 Preventive Maintenance

It is said to be preventive maintenance when planned and coordinated inspections, repairs, adjustments, and replacements are carried out to minimize the problems of breakdown maintenance. This is based on the premise that prevention is better than cure. This practice involves planning and scheduling the maintenance work without interruption in production schedule and thus improves the availability of equipment. Under preventive maintenance, a systematic inspection of each item of equipment or at least the critical parts will be carried out at predetermined times to unfold the conditions that lead to production stoppage and harmful depreciation. There is no readymade preventive maintenance plan that suits for any industry. It should be customized to make it suitable to the requirements of the particular industry. [19]

Planning and implementation of a preventive maintenance practice is a costly affair because it involves the replacement of all deteriorated parts/components during inspection. However, the higher cost of maintenance usually gets compensated by the prolonged operational life of the equipment. To avoid serious breakdowns, the preventive mode of maintenance is usually implemented in complex plants. [20]

2-9-2-3 Corrective Maintenance

The practice of preventive maintenance brings out the nature of repetitive failures of a certain part of the equipment. When such repetitive type of failures are observed, corrective maintenance can be applied so that reoccurrence of such failures can be avoided. These types of failures can be reported to the manufacturer to suggest modifications to the equipment [22]

2-9-2-4 Reliability Centered Maintenance (RCM):

It is used to identify the maintenance requirements of equipment. The RCM establishes the functional requirements and the desired performances standards of equipment's and these are then related to design and inherent reliability parameters of the machine. [19]

2-10 Previses study:

John Petersen and Rodger Jacoby [1] they say most positive displacement pumps can be adapted to handle a wide range of applications, but some types are better suited than others for a given set of circumstances. The first consideration in any application is pumping conditions. Usually the need for a positive displacement pump is already determined, such as a requirement for a given amount of flow regardless of differential pressure, viscosity too high for a centrifugal pump, need for high differential pressure, or other factors. Inlet conditions, required flow rate, differential pressure, temperature, particle size in the liquid, abrasive characteristics, and corrosiveness of the liquid must be determined before a pump selection is made.

Susumu Kawaguchi [2] he said the efficiency of compressors optimized for each refrigerants is theoretically figured out, and it is also experimentally confirmed. As the results, the upper limit of cooling capacity range, in which efficiency of rotary type is higher than that of scroll type.

Scott Hex [3] he say that Most of these analyses conclude that the current SEER method is not adequate as a predictor of "real" energy cost or peak demand on utilities across the country. Most of the work done in this regard focuses on the variation in climate, humidity, building load, accuracy of rating data, etc. on the real energy use vs. the SEER rating. So while the conclusion is generally accepted that the current SEER rating method does not well predict actual energy use or efficiency, it seems to be generally accepted that the method does allow for a simple comparison between various manufacturers and models of equipment.

Lemurs and Guillaume [4] they said the technical constraints inherent to each machine (rotational speed, pressure ratios, maximum temperatures, volumetric expansion ratios, etc.) are listed and the performance mentioned in the open technical and scientific literature is presented.

Different simulation models are proposed: black-box, grey-box and white-box models. These three categories of modeling are specifically adapted to different purposes.

N. Hillier [5] he say that Various types of mechanical pumps are presented together with their pumping mechanisms and main characteristics. The combination of these elements to construct a roughing station is discussed in terms of reliability and efficiency. Various situations corresponding to real accelerators are considered to give guidelines for the design of roughing stations.

D. Braymer and Yusuf [6] the research work investigates the maintenance of an air compressor used in quarries. The objectives of the research were achieved through the selection of a compressor. Reciprocating compressor was selected maintained as it will give the required volume of air at a very high pressure. It has capacity of 1200 m/hr. which makes it to work with any types of pneumatic drilling machine at a very high pressure. For every 3000 hours and 6000 hours, the preventive maintenance is required.

Before the selection of the bought compressor various types of compressor were compared and the one that has the highest quality was selected which is reciprocating compressor. The efficiency and capacity of the selected compressor were determined to be 96% and 12000 m^3/hr. respectively. Preventive maintenance used on the compressor was listed and a troubleshooting method by EMGLO in 1993 was adopted which has suggested assisted in putting the compressor in good order. Check list for the preventive maintenance was also generated

Chapter3

Chapter 3

Methodology

3-1 Preventive maintenance to compressor

Preventive maintenance and inspection are essential for continued optimum performance and long service life of the compressor and its components. The following are general requirements and schedules for periodical inspection and preventive maintenance. Since unusual service Conditions and environment affect equipment reliability, these items and schedules should be adjusted in frequency and contents as necessary to suit your specific requirements.

All the following maintenance operation and inspection shall have to be carried out wearing the required protective clothes to avoid any possible personnel injury. All the consumable and replaced parts must be disposed in accordance with the governing local rules and regulations.

3-1-1 Daily and at each start-up

- Check and record the oil temperature to the compressor casing.
- Check and record the compressor oil pressure.
- Check and record the vibration levels on each stage of the compressor.
- Check and record the inter stage air pressure.
- Check and record the inter stage air temperature.
- Check and record the inlet air temperature.
- Check and record the cooling water temperature, both to and from compressor manifold.
- Check and verify condensate traps operation.
- Vent the air coolers if they are not continuously vented. Vent valves are located on top of the casing or outside the sound enclosure.

- Drain the condensate from the inlet airline, the discharge header and from the bypass airline, drip leg.
- Drain the drip legs on any other horizontal run of air piping.
- Check the compressor reservoir oil level, maintain required level.
- Check for eventual oil leaks.
- Check for eventual water leaks.
- Check for eventual instrument at air system leaks.
- Check the control airline filter (if installed). Drain any moisture which may have collected and replace the filter element if necessary.
- Check the instrument airline filter (if installed). Drain any moisture which may have collected and replace the filter element if necessary.
- Check and adjust instrument air supply pressure.
- Check lubrication oil level.
- Check seal air pressure.
- Check inlet air filter drop of pressure.

3-1-2 Checks to be carries out every 90 days

- Check the inlet and bypass valve calibration (please refer to "Commissioning/first start up" section).
- Visually inspect the inlet air filter element. Clean (if filters can be cleaned) or replace as necessary.
- Visually inspect the oil mist arrestor and refill the U pipe, if necessary. Clean the housing and replace the element if saturated (please refer to the mist arrestor enclosure).
- Drain and clean the instrument air filter by replacing the cartridge, if necessary.
- Inspect air filter internal parts, verifying the absence of cracks and ensuring correct seal.

3-1-3 Semi-annual checks

- Visually inspect the discharge check valve.
- Check the condensate traps. (Please refer to condensate traps enclosure). Not applicable for nitrogen compressors.
- Lubricate the motor coupling if necessary.
- Replace the oil filter element. If not using Techtro-Gold oil, this operation must be carried out every three months.

3-1-4 Annual checks

- Inspect the main driver per the manufacturer's instructions found in this instruction manual.
- Check the bull gear bearings for roughness by hand turning the main shaft.
- Inspect and clean the oil reservoir suction screens. Visually inspect the oil cooler tubes. Clean the shell and tube sides of the oil cooler if necessary.
- Calibrate the control and protective devices.
- Visually inspect the inlet throttle valve.
- Visually inspect the bypass valve.
- Check the Physical and Chemical characteristics of the lubricant oil; if the results are not in accordance to required values, change the oil.
- If using mineral oil, change the oil
- Carry out vibration analysis on stages rotors.
- Carry out compressor sucked air analysis.

3-2 Type of compressor

3-2-1 Reciprocating compressor

This compressor pressurizes the nitrogen after separating it from the oil ore in the (CCR) unit.

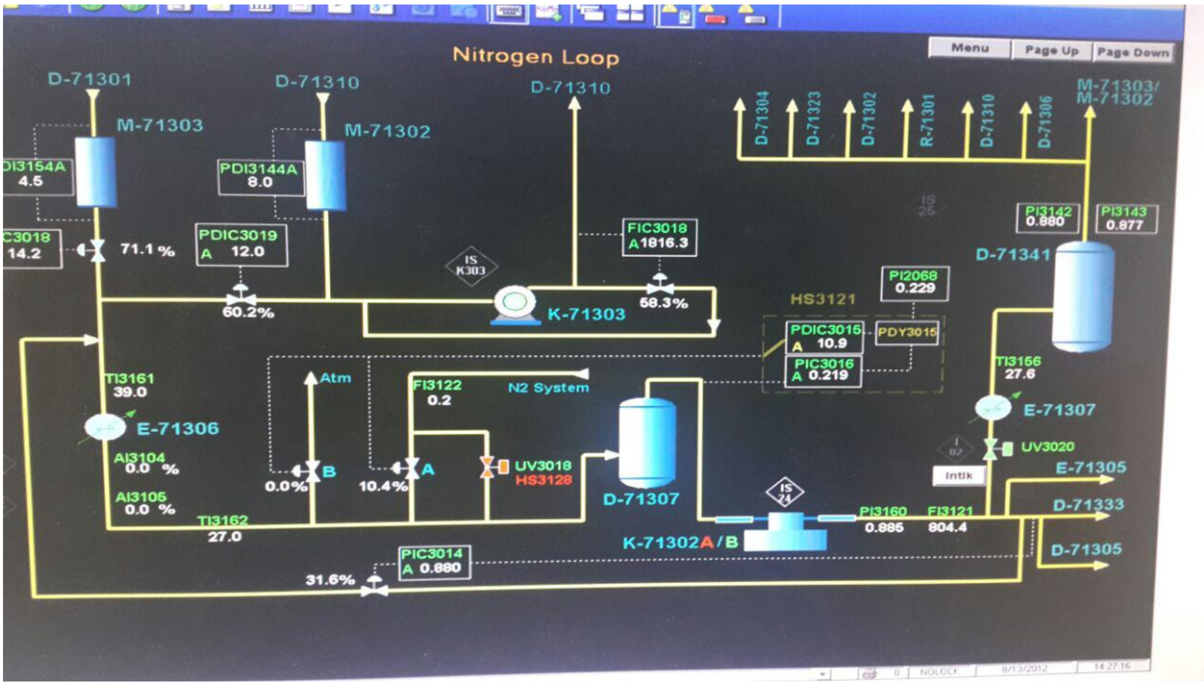


Figure: (3-1) flow scheme of reciprocating compressor

In figure: 3-2 showing reciprocating compressor are used in the unit

Figure: (3-2) reciprocating compressor

3-2-1-1 Technical specification of reciprocating compressor

No	Read the specific position	Before preventive maintenance	After preventive maintenance
1	Suction gas pressure mpa	0.220	0.219
2	Discharge gas pressure mpa	0.870	0.885
3	Suction temperature c	202	195
4	Discharge temperature c	293	281
5	Flow rate m^3/sec	12.6	13.4
6	kJ/(kg K) Cp	1.039	1.039
7	Density	1.165	1.165
8	Input power kw	55	55

Table: 3-1Reciprocating Compressor

3-2-2 Multi stage centrifugal compressor

It is used on (GDHT) unit which is essential for producing hydrogen

3-2-2-1 The reasons of using this multi stage centrifugal compressor

The required pressure and flow will be achieved by the multi stage centrifugal compressor. The is enough steam garneted in the furnace the access steam is used in the prime mover of the compressor which is condensate steam turbine (cost wise).

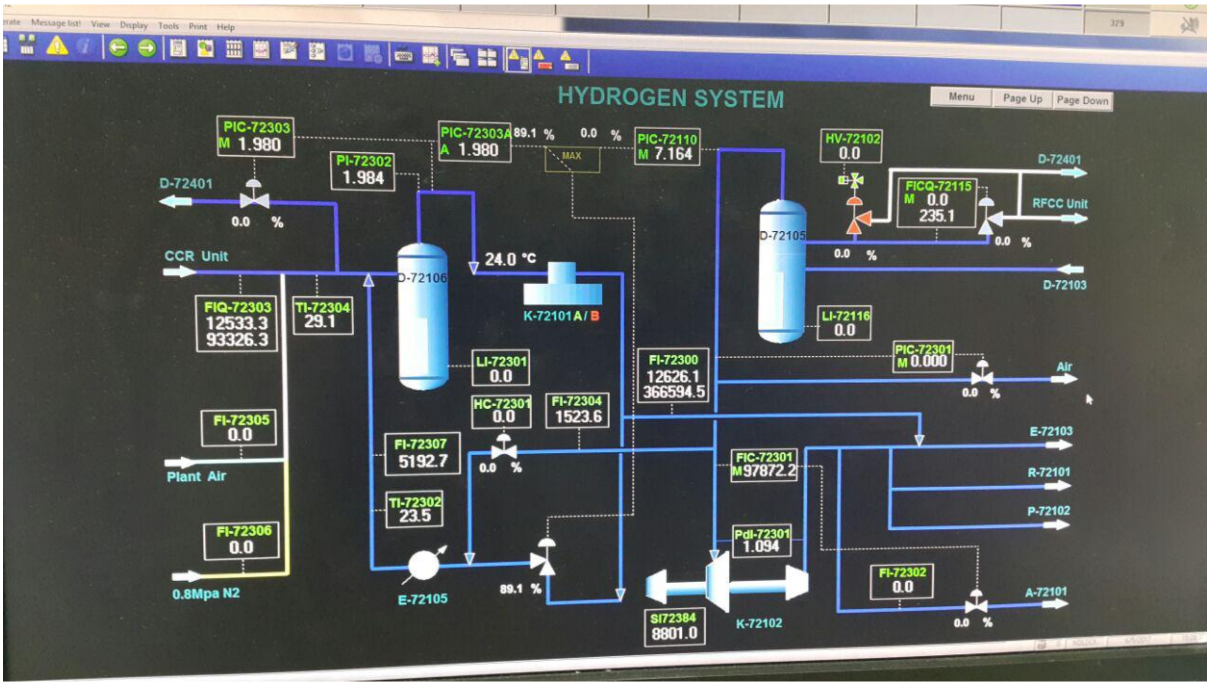


Fig: (3-3) Multi stage centrifugal compressor flow diagram

Figure (3-4) multi stage centrifugal compressor

3-2-2-2 Technical specification of Multi stage centrifugal compressor

No	Read the specific position	Before preventive maintenance	After preventive maintenance
1	Suction gas pressure Mpa	7.164	7.150
2	Discharge gas pressure Mpa	8.258	8.30
3	Suction temperature C	105	98
4	Discharge temperature C	305	290
5	Flow rate m^3/h	97872	109978
6	Cp	13.53	13.53
7	Density kg/m^3	0.23	0.23
8	Input power KW	1302	1302

Table: 3-2 Multi stage centrifugal compressor

3-2-3 single stage centrifugal compressor

This type of compressor is used on the (RFCC) unit to compressed the air

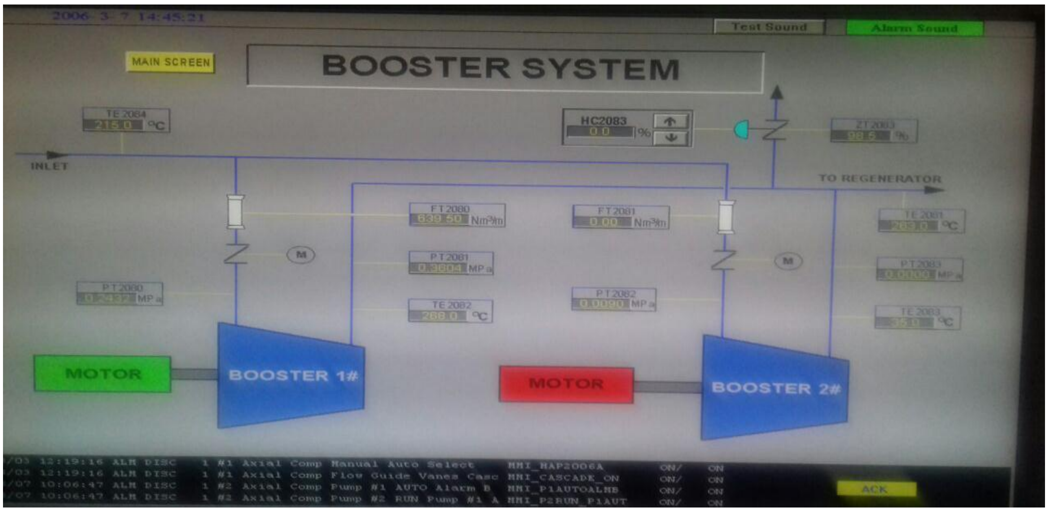


Figure: (3-5) single stage centrifugal compressor flow diagram

In figure 3-6. Showing centrifugal compressor are used in the unit

Figure (3-6) single stage centrifugal compressor

3-2-3-1 Technical specification of single stage centrifugal compressor

No	Read the specific position	Before preventive maintenance	After preventive maintenance
1	Suction gas pressure MPa	0.2402	0.2432
2	Discharge gas pressure MPa	0.3592	0.3604
3	Suction temperature c	215	215
4	Discharge temperature c	268	265
5	Flow rate Nm^3/min	639	665
6	Cp kJ/(kg K)	1.004	1.004
7	Density	1.2	1.2
8	Input power KW	1000	1000

Table: 3-3 single stage centrifugal compressor

3-3 Preventive maintenance to pump

Preventive maintenance includes these types of inspections:

• Routine maintenance

• Routine inspections

• Three-month inspections

• Annual inspections

Shorten the inspection intervals appropriately if the pumped fluid is abrasive or corrosive or if the environment is classified as potentially explosive.

3-3-1 Routine maintenance

Perform these tasks whenever you perform routine maintenance:

• Lubricate the bearings.

• Inspect the seal.

3-3-2 Routine inspections

Perform these tasks whenever you check the pump during routine inspections:

• Check the level and condition of the oil through the sight glass on the bearing frame.

• Check for unusual noise, vibration, and bearing temperatures.

• Check the pump and piping for leaks.

• Analyses the vibration.

• Inspect the discharge pressure.

• Inspect the temperature.

• Check the seal chamber and stuffing box for leaks.

• Ensure that there are no leaks from the mechanical seal.

• Adjust or replace the packing in the stuffing box if you notice excessive leaking.

3-3-3 Three-month inspections

Perform these tasks every three months:

• Check that the foundation and the hold-down bolts are tight.

• Check the packing if the pump has been left idle, and replace as required.

• Change the oil every three months (2000 operating hours) at minimum.

• Change the oil more often if there are adverse atmospheric or other conditions that might contaminate or break down the oil.

• Check the shaft alignment, and realign as required.

3-3-4 Annual inspections

Perform these inspections one time each year:

• Check the pump capacity.

• Check the pump pressure.

• Check the pump power.

If the pump performance does not satisfy your process requirements, and the process requirements have not changed, then perform these steps:

1. Disassemble the pump.
2. Inspect it.
3. Replace worn parts.

3-4 Type of pump

3-4-1 Reciprocating pump

This type of pump is used on the (CCR) unit to pump the Ethanol

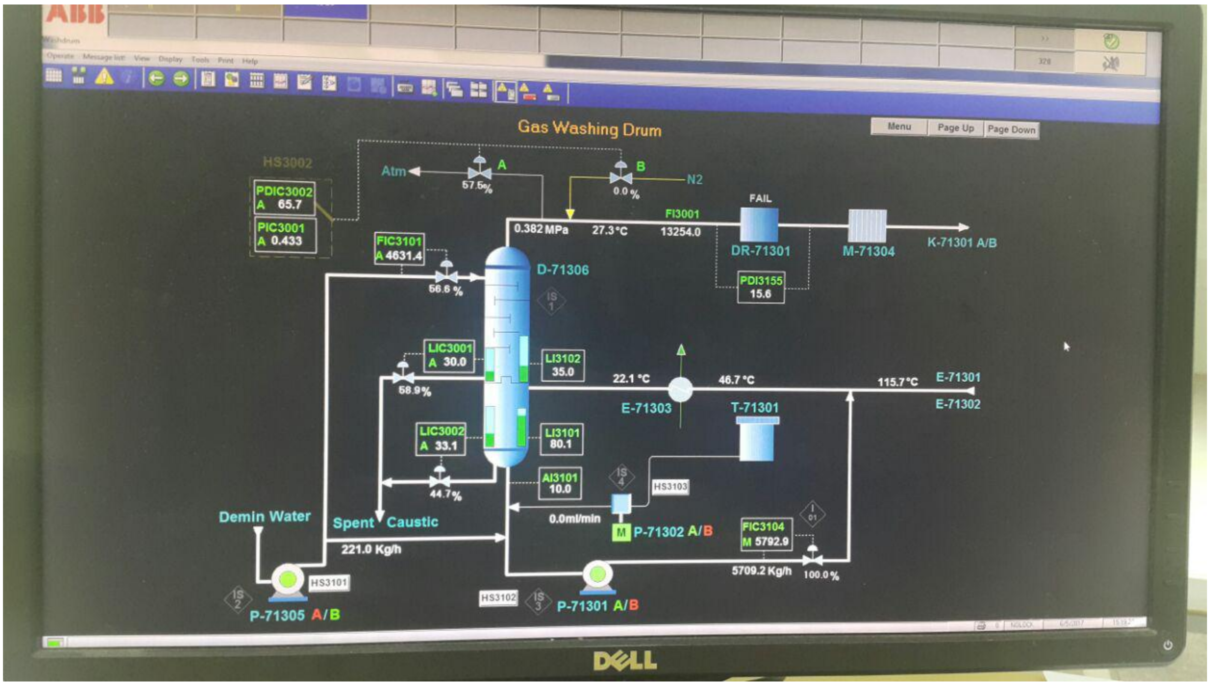


Figure: (3-7) Reciprocating pump flow diagram

In figure: 3-8 showing reciprocating pump are used in the unit

Figure: (3-8) reciprocating pump

3-4-1-1 Technical specification of reciprocating pump

No	Read the specific position	Before preventive maintenance	After preventive maintenance
1	Flow rate cm^3/min	1.2	1.3
2	energy Head	58	58
3	Fluid density kg/m^3	789	789
4	acceleration of gravity	9.81	9.81
5	Input power kw	0.63	0.63

Table: 3-4 Reciprocating pump

3-4-1-2 Multi stage centrifugal pump

This type of pump is used on the (GDHT) unit to pump the (gasoil& naphtha)

3-4-1-2-1 The reasons of using this multi stage centrifugal pump

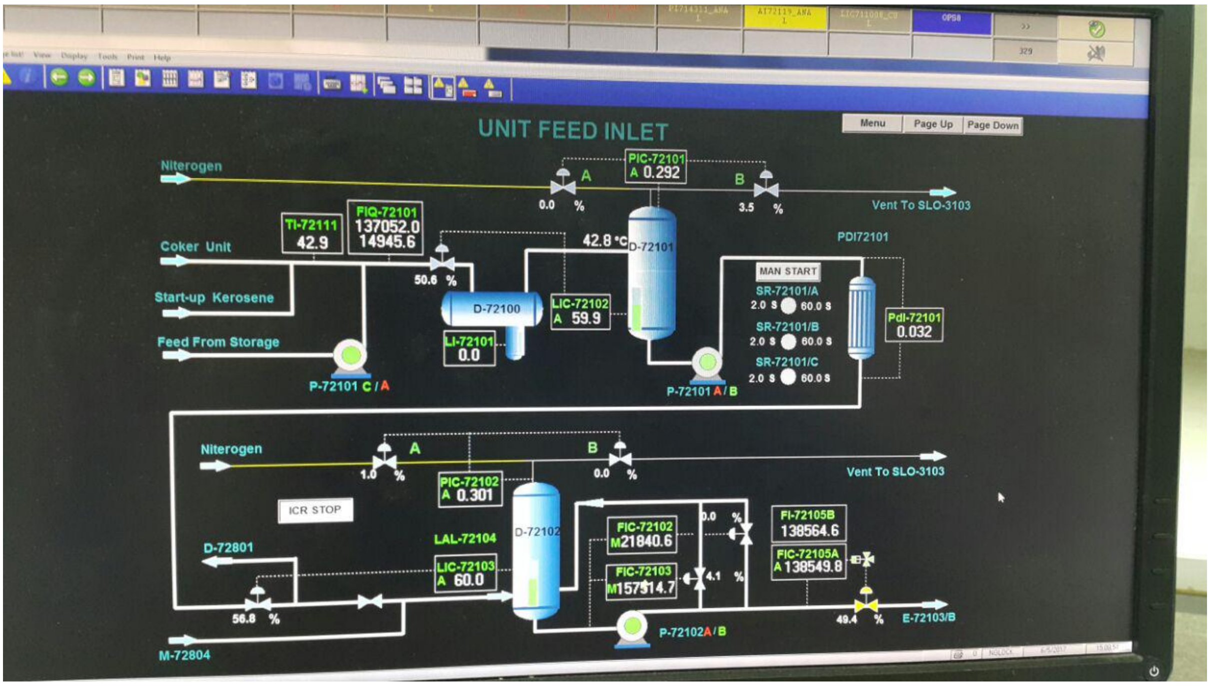


Fig: (3-9) multi stage centrifugal pump flow diagram

Figure (3-10) multi stage centrifugal pump

3-4-1-2-2 Technical specification of Multi stage centrifugal compressor

No	Read the specific position	Before preventive maintenance	After preventive maintenance
1	Flow rate kg/h	146188	150255
2	Head	1184 m	1184 m
3	acceleration of gravity	9.81	9.81
4	Density kg/m^3	813	813
5	Input power	900	900

Table: 3-5 Multi stage centrifugal pump

3-4-3 single stage centrifugal pump

This type of pump is used on the (CCR) unit to pump the water.

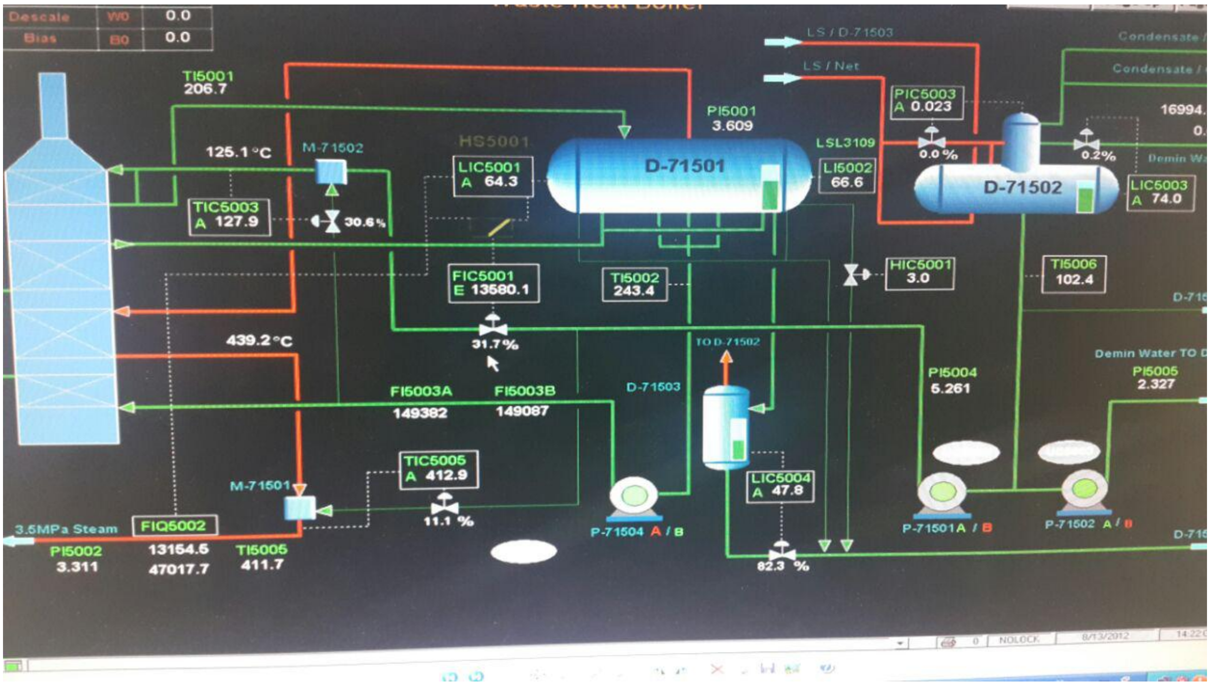


Figure: (3-11) single stage centrifugal pump flow diagram

In figure 3-12. Showing centrifugal compressor are used in the unit

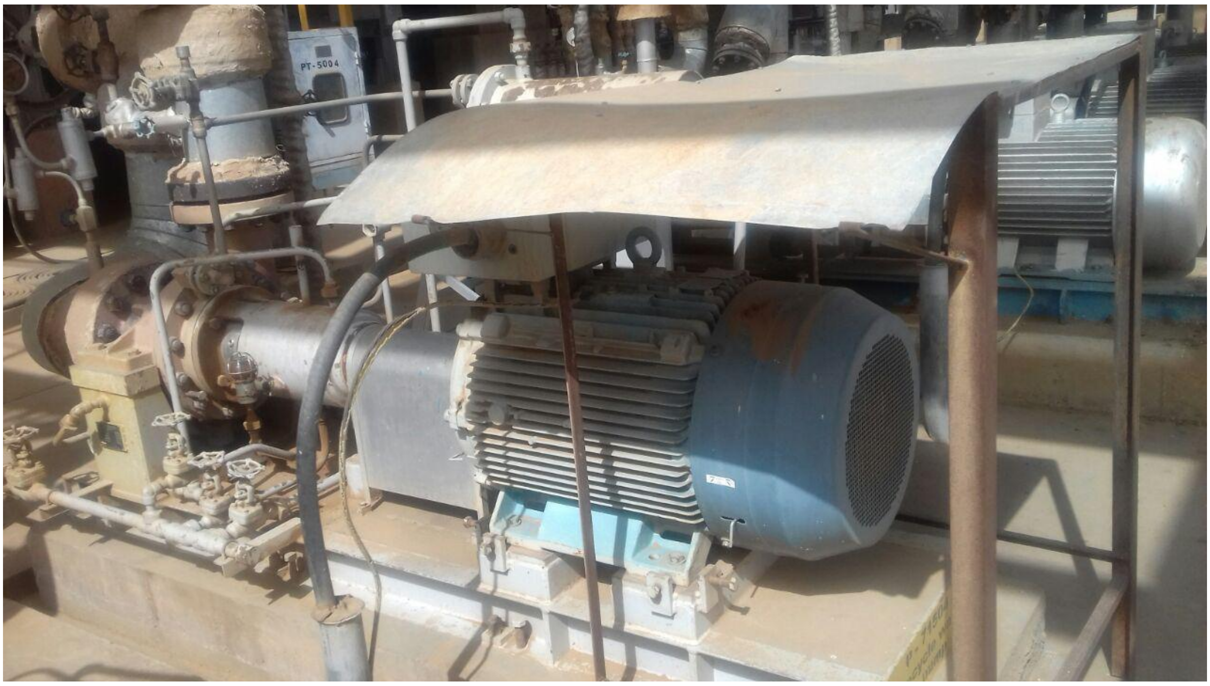


Figure (3-12) single stage centrifugal pump

3-4-3-1Technical specification of single stage centrifugal pump

No	Read the specific position	Before preventive maintenance	After preventive maintenance
1	Flow rate m^3/s	135492	149504
2	energy Head m	60	60
3	Fluid density kg/m^3	1000	1000
4	acceleration of gravity	9.81	9.81
5	Input power kw	55	55

Table: 3-6 single stage centrifugal pump

Chapter4

Chapter4

Analysis and discussion

4-1 Reciprocating Compressor

From Table 3-1 can be calculated:

- **Before preventive maintenance**

Power out = 12.6*1.03*1.165*(38-35) =45.3kw

$$\eta = \frac{45.3}{55} \quad = .82$$

- **After preventive maintenance**

Power out = 12.9*1.03*1.165*(37-34) =46.4kw

$$\eta = \frac{46.4}{55} \quad = .84$$

4-2 Multi stage centrifugal compressor

From Table 3-2 can be calculated:

- **Before preventive maintenance**

Power out = 27.2***.**23*14.2***(43-30) =1154.85kw**

$$\eta = \frac{1154.85}{1302} \quad =0.88$$

- **After preventive maintenance**

Power out = 28.5***.**23*14.2***(43-30) = 1210kw**

$$\eta = \frac{1210}{1302} \quad = 0.92$$

4-3 single stage centrifugal compressor

From Table 3-3 can be calculated:

- **Before preventive maintenance**

Power out = 11.65*1.004*1.2*(268-215) =743.9kw

$$\eta = \frac{743.9}{1000} = .74$$

- **After preventive maintenance**

Power out = 12.4*1.004*1.2*(267-215) = 777.48kw

$$\eta = \frac{777.48}{1000} = .78$$

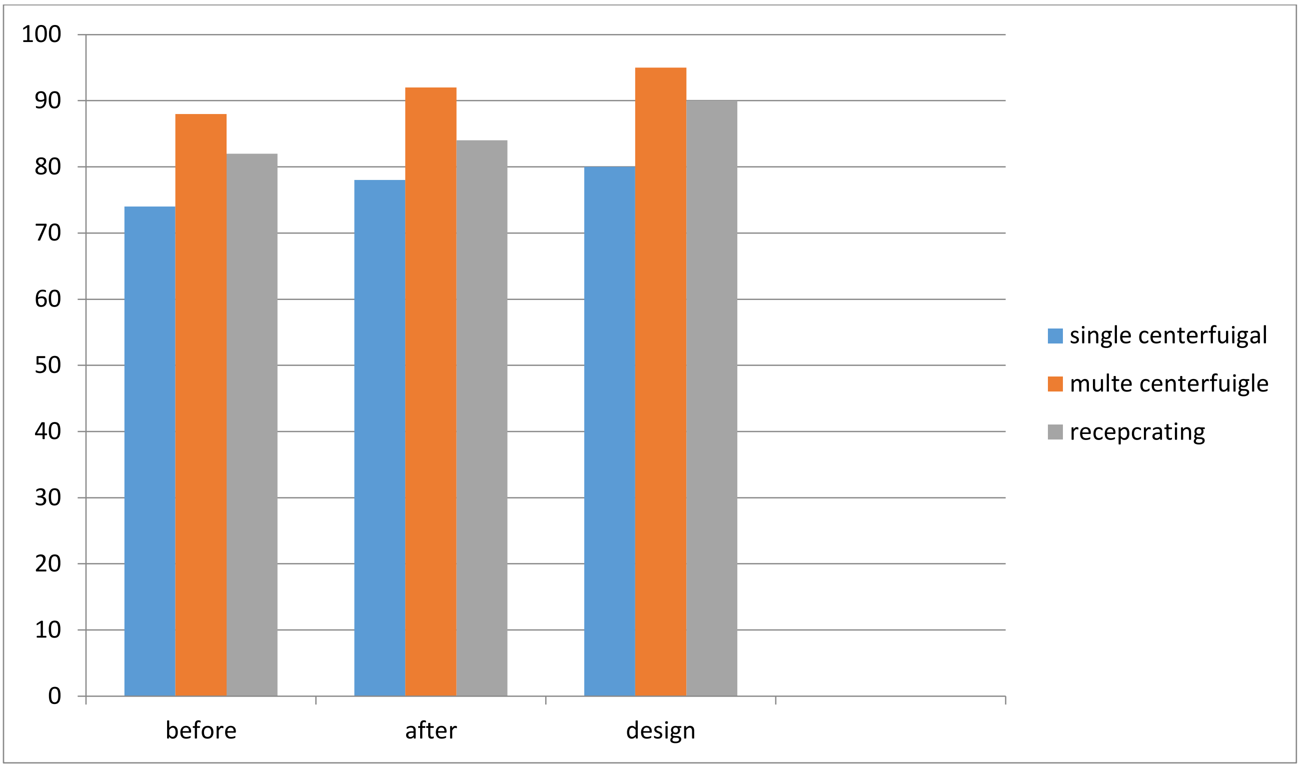


Figure (4-1) efficiency chart compressors

The above diagram show the efficiency of compressors after preventive maintenance is higher than the efficiency of compressors before preventive maintenance this is due to increased flow rate and reduce the temperature and increase pressure.

The design efficiency of the compressors is higher than the efficiency before and after the preventive maintenance. This is due to the frequent use of compressors or operating load higher than the load design in the case of large quantities are to be pressed quickly.

4-4 Compressor Selection:

Table 4-1 shows the comparison between the important compressor types.

Item	**single stage centrifugal**	**Multi stage centrifugal**	**Reciprocating**
Efficiency	Low	high	Medium
Size	Small	Medium	Large
Noise level	Quiet	Quiet-if enclosed	Noisy
Oil carry over	Low	Low-medium	Moderate
Vibration	Almost none	Almost none	High
Maintenance	Sensitive to dust in air	Few wearing Parts	Many wearing parts
Capacity	Low	Medium	High
Pressure	Low	Very high	Medium- very high

Table 4-1 Compressor Selection

Comparing the three types of compressor (reciprocating, single stage centrifugal and Multi stage centrifugal) as shown in Table 4-1, Multi stage centrifugal has high efficiency at full load, high efficiency at part load due to staging, moderate in oil carry over, high capacity and medium to very high pressure although the reciprocating compressor is noisy with high vibration and their many wearing parts to maintain. Going by these qualities, Multi stage centrifugal has been selected as it will give the required volume of air at a very high pressure as compare to single stage centrifugal.

The required routing maintenance required for reciprocating compressor is presented in Table 4-1 the lubricants in every part of compressor are always checked in every 8 hours. The lubricant pressure, cylinder jacket cooling water temperatures, capacity control operation, operation of automatic condensate drain trap and intercooler pressure on multi-stage machines are being checked every 8 hours. In every 360 hours, piston rod packing for leaks and for blow-by at gland and motor amperes at compressor full capacity and pressure are checked. The selected compressor's lubricant scraper rings is inspected for leakage and air intake filter is also inspected. For every 3000 hours and 6000 hours, the preventive maintenance that will be done on the machine is as presented.

The corrective maintenance which involve replacing some part of the machine like cylinder, fuel pump, lubricants and electric motor among others were replaced with new ones to put the compressor in good working condition.

4-5 Reciprocating pump

From Table 3-4can be calculated:

- **Before preventive maintenance**

Power out = 0.00127*58*789***9.81 =570.1w**

$$\eta = \frac{.5701}{.63} \quad = 0.90$$

- **After preventive maintenance**

Power out = 0.0013*58*789***9.81 =580w**

$$\eta = \frac{.58}{.63} \quad = 0.92$$

4-6 Multi stage centrifugal pump

From Table 3-5 can be calculated:

- **Before preventive maintenance**

Power out = .082*1184*813***9.81 =774.3kw**

$$\eta = \frac{774.3}{900} \quad = 0.86$$

- **After preventive maintenance**

Power out = .084*1184*813***9.81 =793.2kw**

$$\eta = \frac{793.2}{900} \quad = 0.88$$

4-7 single stage centrifugal pump

From Table 3-6 can be calculated:

- **Before preventive maintenance**

Power out = 0.07*60*1000*9.81 =41.2kw

$$\eta = \frac{41.2}{55} \quad = 0.75$$

- **After preventive maintenance**

Power out = 0.075*60*1000*9.81 =43.5kw

$$\eta = \frac{43.5}{55} \quad = 0.79$$

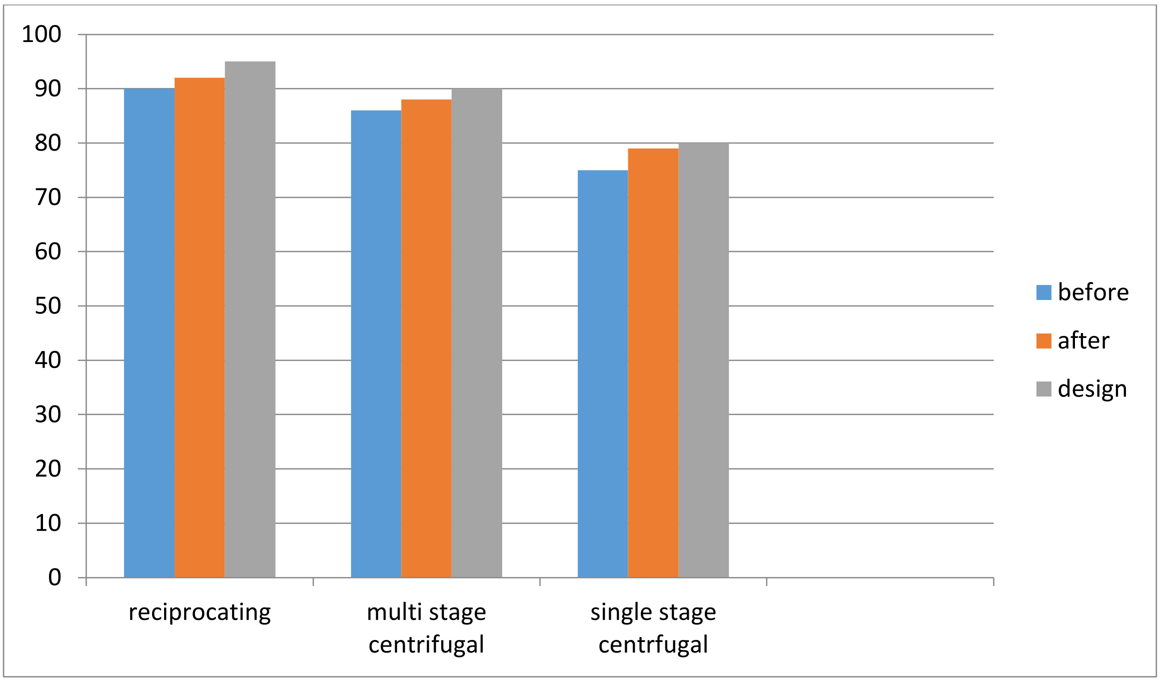


Chart (4-2) efficiency chart pumps

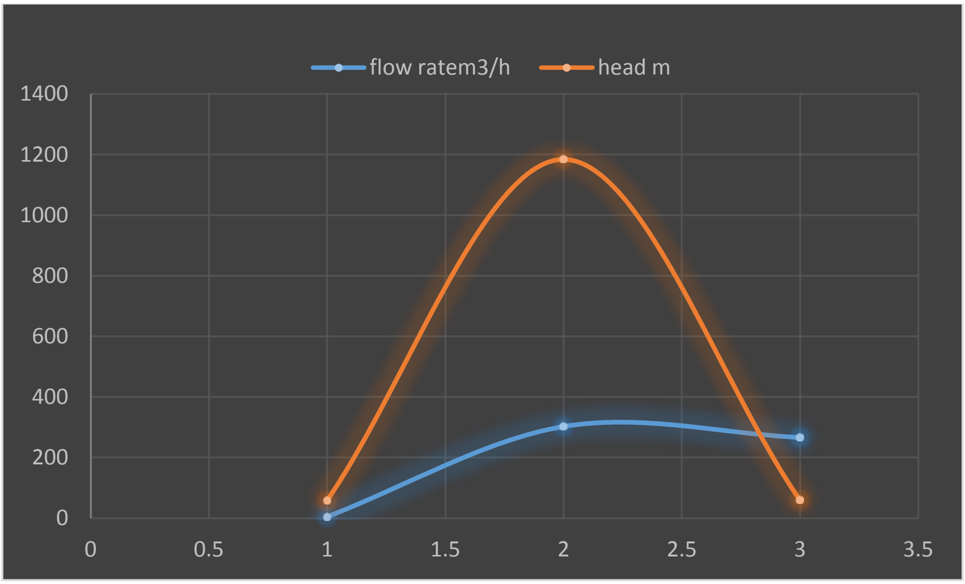


Chart (4-3) head-flow rate curve pumps

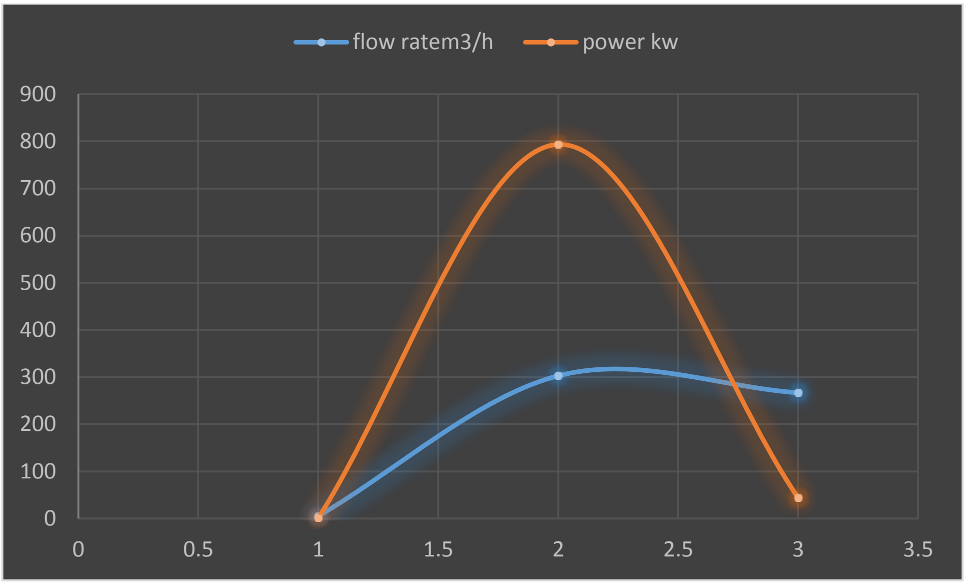


Chart (4-4) power-flow rate curve pumps

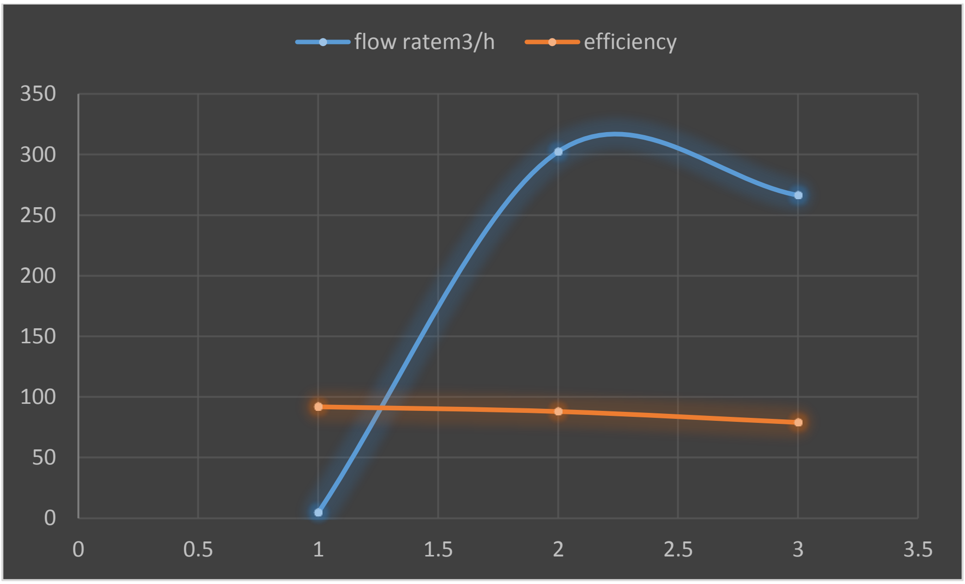


Chart (4-5) efficiency-flow rate curve pumps

1- Reciprocating pump.

2- Multi stage centrifugal pump.

3- Single stage centrifugal pump.

The above diagram shows the efficiency of the pumps after preventive maintenance is higher than the efficiency of the pumps before preventive maintenance. This is due to increasing the rate of turnover and increases the energy.

The design efficiency of the pumps is higher than the efficiency before and after preventive maintenance. This is due to the frequent use or operation of a load higher than the load design in the case of large quantities to be pumped quickly.

4-8 Pump Selection:

Table 4-2 shows the comparison between the important pump types

Item	**single stage centrifugal**	**Multi stage centrifugal**	**Reciprocating**
Method of pushing	Kinetic energy of impeller	Kinetic energy of impeller.	Forced by piston.
Discharges	It continuously discharges the fluid.	It continuously discharges the fluid.	It does not discharge the fluid continuously.
Viscous	It is used for pumping high viscous fluid.	It is used for pumping medium viscous fluid.	It is used for pump low viscous fluid.
Efficiency	Low	Medium	High.
Problem	have problem of priming	have problem of priming	It does not have any problem of priming.
Transfer energy	It uses impellers to transfer energy to fluid.	It uses impellers to transfer energy to fluid.	It uses piston cylinder device to transfer energy to fluid
Weight	Less weight	medium weight	These are heavier compare to centrifugal pump.
Discharge-heads.	It gives higher discharge at low heads.	It gives higher discharge at high heads.	This gives low heads at low discharge.
Cost	It is less costly	Medium costly	These are costly.
Maintenance	These pumps required less maintenance	These pumps required Medium maintenance	These required higher maintenance
Required floor	less floor	Medium floor space.	More floor area.

Table (4-2) **Pump Selection**

Comparing the three types of compressor (reciprocating, single stage centrifugal and Multi stage centrifugal) as shown in Table 4-2, Multi stage centrifugal has high efficiency at full load, high efficiency at part load due to staging, moderate in oil carry over, high capacity, Medium floor space, It gives higher discharge at high heads, and medium to very high pressure

Chapter5

Chapter 5

Conclusion & Recommendations

5-1 Conclusion

- We have found the best types of compressors in the project is Multi stage centrifugal in terms of efficiency.
- We calculated the efficiency of the Multi stage centrifugal compressor was be 92% and102600m^3/hr flow rate.
- We have found the best types of pump in the project is reciprocating pump, in terms of efficiency.
- We calculated the efficiency of the reciprocating pump was be 92% and 4.68m^3/hr flow rate.

5-2 Recommendations:

- Kindly ask the distinguished professors in the Department of Mechanical Engineering to enter the maintenance material within the curriculum.
- We recommend engineers are working at Khartoum Refinery Company to be more attention to preventive maintenance.

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