Mining Machinery and Material Handling

Mining Pumps/Power Transmission

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Mining Pumps/Power Transmission

FLUID POWER AND ITS SCOPE

Fluid power is the technology that deals with the generation, control and transmission of forces and movement of mechanical element or system with the use of pressurized fluids in a confined system. Both liquids and gases are considered fluids. Fluid power system includes a hydraulic system (*hydra* meaning water in Greek) and a pneumatic system (*pneuma* meaning air in Greek). Oil hydraulic employs pressurized liquid petroleum oils and synthetic oils, and pneumatic employs compressed air that is released to the atmosphere after performing the work.

The following are the two types of hydraulic systems:

- **Fluid transport systems**: Their sole objective is the delivery of a fluid from one location to another to accomplish some useful purpose. Examples include pumping stations for pumping water to homes, cross-country gas lines, etc.
- **Fluid power systems**: These are designed to perform work. In fluid power systems, work is obtained by pressurized fluid acting directly on a fluid cylinder or a fluid motor. A cylinder produces a force resulting in linear motion, whereas a fluid motor produces a torque resulting in rotary motion.

CLASSIFICATION OF FLUID POWER SYSTEMS

Based on the control system

- **Open-loop system**: There is no feedback in the open system and performance is based on the characteristics of the individual components of the system. The open-loop system is not accurate and error can be reduced by proper calibration and control.
- **Closed-loop system**: This system uses feedback. The output of the system is fed back to a comparator by a measuring element. The comparator compares the actual output to the desired output and gives an error signal to the control element. The error is used to change the actual output and bring it closer to the desired value. A simple closed-loop system uses servo valves and an advanced system uses digital electronics.

Based on the type of control

Fluid logic control: This type of system is controlled by hydraulic oil or air. The system employs fluid logic devices such as AND, NAND, OR, NOR, etc. Two types of fluid logic systems are available:

- **Moving part logic (MPL):** These devices are miniature fluid elements using moving parts such as diaphragms, disks and poppets to implement various logic gates.

- Fluidics: Fluid devices contain no moving parts and depend solely on interacting fluid jets to implement various logic gates.

Electrical control

This type of system is controlled by electrical devices. Four basic electrical devices are used for controlling the fluid power systems: switches, relays, timers and solenoids. These devices help to control the starting, stopping, sequencing, speed, positioning, timing and reversing of actuating cylinders and fluid motors. Electrical control and fluid power work well together where remote control is essential.

Electronic control

This type of system is controlled by microelectronic devices. The electronic brain is used to control the fluid power muscles for doing work. This system uses the most advanced type of electronic hardware including programmable logic control (PLC) or microprocessor (P). In the electrical control, a change in system operation results in a cumbersome process of redoing hardware connections.

The difficulty is overcome by programmable electronic control. The program can be modified or a new program can be fed to meet the change of operations. A number of such programs can be stored in these devices, which makes the systems more flexible.

ADVANTAGES OF A FLUID POWER SYSTEM

Oil hydraulics stands out as the prime moving force in machinery and equipment designed to handle medium to heavy loads. In the early stages of industrial development, mechanical linkages were used along with prime movers such as electrical motors and engines for handling loads. But the mechanical efficiency of linkages was very low and the linkages often failed under critical loading conditions. With the advent of fluid power technology and associated electronics and control, it is used in every industry now.

The advantages of a fluid power system are as follows:

- Fluid power systems are simple, easy to operate and can be controlled accurately: Fluid power gives flexibility to equipment without requiring a complex mechanism. Using fluid power, we can start, stop, accelerate, decelerate, reverse or position large forces/components with great accuracy using simple levers and push buttons. For example, in Earth-moving equipment, bucket carrying load can be raised or lowered by an operator using a lever. The landing gear of an aircraft can be retrieved to home position by the push button.
- **Multiplication and variation of forces**: Linear or rotary force can be multiplied by a fraction of a kilogram to several hundreds of tons.
- **Multifunction control**: A single hydraulic pump or air compressor can provide power and control for numerous machines using valve manifolds and distribution systems. The fluid power controls can be placed at a central station so that the operator has, at all times, a complete control of the entire production line, whether it

be a multiple operation machine or a group of machines. Such a setup is more or less standard in the steel mill industry.

- **Low-speed torque**: Unlike electric motors, air or hydraulic motors can produce a large amount of torque while operating at low speeds. Some hydraulic and pneumatic motors can even maintain torque at a very slow speed without overheating.
- **Constant force or torque**: Fluid power systems can deliver constant torque or force regardless of speed changes.
- **Economical:** Not only reduction in required manpower but also the production or elimination of operator fatigue, as a production factor, is an important element in the use of fluid power.
- **Low weight to power ratio**: The hydraulic system has a low weight to power ratio compared to electromechanical systems. Fluid power systems are compact.
- Fluid power systems can be used where safety is of vital importance: Safety is of vital importance in air and space travel, in the production and operation of motor vehicles, in mining and manufacture of delicate products. For example, hydraulic systems are responsible for the safety of takeoff, landing and flight of aeroplanes and space craft. Rapid advances in mining and tunnelling are the results of the application of modern hydraulic and pneumatic systems.

HYDRAULIC HOISTING SYSTEM

Hydro-mechanical extraction of coal using high-pressure water jets and its transportation by pipelines using water as a carrying medium, and hydraulic transportation of coal won by continuous mining machines have gained increasing importance since 1970s for increasing underground productivity and reducing costs. For long-distance overland transportation of a wide variety of minerals/ores/mine waste, slurry pipeline transportation has been successfully practiced since 1960s.

The slurry transportation system offers the following advantages over the conventional transport systems:

- Higher productivity;
- Continuous flow;
- Variable capacity;
- Possibility of horizontal and vertical transport or their combination;
- Lower operating cost per unit of solid transported, which reduces with increasing tonnage;
- Automated system operation;
- High system availability;
- Energy conservation;

- Less labour-intensive;
- Low storage requirements;
- Transport by ships results in economic handling at ports and eliminates the need for deep ports;
- An economic alternative to increasing the capacity of an established transport system;
- Low sensitivity to inflation;
- Environmental compatibility; and
- Greater safety.

In underground coal mines, slurry transportation as an underground transportation or haulage system offers the following additional advantages:

- It eliminates coal haulage-related accidents due to elimination of belt conveyors and coal trains;
- It is flexible and extensible;
- It allows dirt removal by hydro-cyclone to clean coal as well as chemical processing to reduce sulphur content;
- Unlike conveyors, slurry pipelines can easily transport around bends and do not create any bottlenecks in transportation;
- Secondary dust and the related health and dust explosion hazards are not created;
- Improved firedamp and dust control at the face;
- Smaller roadway cross-sections required;
- It can supply fire-fighting water in large quantities and at good pressure;
- Slurry can be fed into the preparation plant directly. The dewatering problem can be obviated if a high-solids coal slurry (coal-water mixture fuel) can be directly fired in a boiler; and
- Less capital-intensive.

The **disadvantages** of slurry pipeline system, however, are:

- It may lack versatility. On account of large capital investment in immovable pipeline, it cannot be easily adapted to changing distribution pattern; and
- There is a possibility of material degradation.

STAGES IN A SLURRY TRANSPORTATION

A slurry transportation system usually comprises five separate stages:

- Material preparation;
- Slurry preparation and storage;

- Slurry transportation;
- Storage and dewatering of slurry at the pipeline terminal; and
- Processing for utilization.

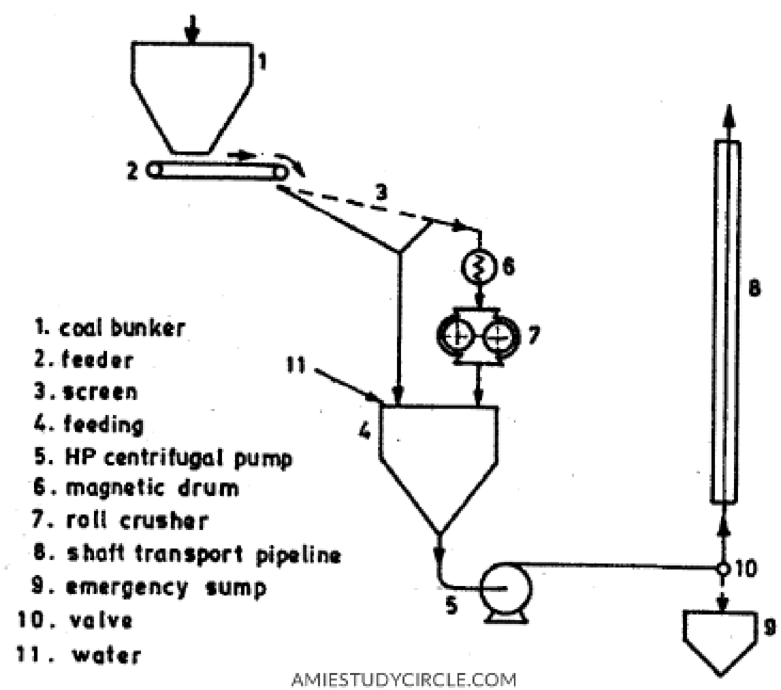
HYDRAULIC HOISTING METHODS

These are following

- Airlift method
- pumping method
- feeder method
- combined hydraulic and mechanical hoisting method

PUMPING METHOD

Hydraulic hoisting by direct pumping using high-pressure centrifugal pumps is limited to a head of 200 m by operating two pumps in series and horizontal distances up to 2 km. High-pressure centrifugal pumps can handle solid particles of maximum size up to 150 mm compared to -2 mm with positive displacement pumps. The hoisting plant (hydro hoist) may consist of a bunker, a screening and crushing plant, and a pumping plant (see figure).



The solid-water ratios lie between 1:2 and 1:5 with slurry velocities of 2-4 m/s depending on the type of material and size of particles used. Coal slurry pumps usually have a capacity of 900 m^3/h for coals up to 100 mm size.

CENTRIFUGAL (ROTODYNAMIC) PUMP

These are specially designed for transportation of homogeneous, heterogeneous, and complex slurries. They, the “work horse” of in-plant commercial slurry transportation systems, serve as booster pumps for providing suction pressure required for mainline positive displacement pumps. They are designed for large flow rates at moderately high pressures and their application is generally restricted to short distances because of their limited head capacity, lower allowable casing pressure, and lower efficiencies. They are selected for discharge pressure under 45 bar, which is the limit set by the casing pressure capacity. Solids may be handled with a size up to one-half the smallest impeller channel width.

For natural rubber, the tip speed must not exceed 30 m/s to minimize wear, thereby limiting the pump speed and the maximum head that can be developed. Their use is limited to fine slurries in which the maximum particle size is less than 18 mesh. Wear-resistant metal-lined pumps are commonly used for pumping coarse particle slurries. A higher impeller tip speed can be allowed with such pumps and consequently, higher head capabilities can be achieved. By using heavy-duty bearings, mechanical seals, and double-walled casing design using replaceable metal liners, high-pressure centrifugal pumps have been designed which develop heads per stage up to 100 m for hydraulic hoisting of coarse-particle abrasive slurries with top particle size of 100 mm.

The efficiency of centrifugal slurry pumps is low because of the presence of solids, robust nature of the impeller design, and the relatively wide throat impeller clearance. Efficiencies of 65 per cent are common, compared to 85-90 per cent with positive displacement pumps. Power consumption increases proportionally with the specific gravity of the slurry.

To protect the gland from abrasive solids, a seal water flush system is commonly employed, where clean water is injected on the slurry side of the gland packing to flush solids clear of the gland and to keep the packing cool. Where dilution by seal water is not acceptable, for example, in coal and limestone slurry pumping systems, mechanical seals may be used which do not require sealing water.

Pump sizes are denoted by their discharge diameters. They are available is sizes up to 500 mm discharge diameter. With discharge velocity of slurries normally not exceeding 4 m/s, maximum flow rates can be calculated. For abrasive and dense concentration slurries, an ‘oversized’ pump may be used, though with a higher power consumption.

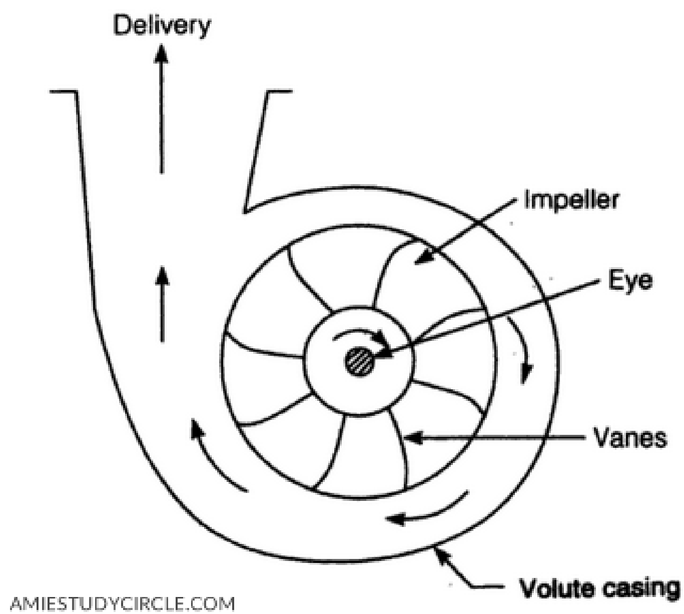
It is not advisable to use multi-stage centrifugal slurry pumps. Single stage pumps arranged in series may be used.

The head-capacity characteristic for a centrifugal slurry pump is relatively flat. If for any reason, the system capacity drops to a point where the flow velocity would fall below the critical velocity, solids will be deposited in the pipeline which could cause plugging of the pipeline. In considering the head-capacity of pumps handling settling slurries, it would be safe to rate the pump at 10-20% lower head than when pumping clear water. In most installations of multiple pumps in series, such a condition is overcome by installing one or two pump units with variable speed drives so that when the system head increases, the capacity is maintained by increasing the speed by means of the variable speed drive(s).

When designing a pumping system, standby spare capacity is generally provided by a second parallel set of pumps which would increase the total cost of the system.

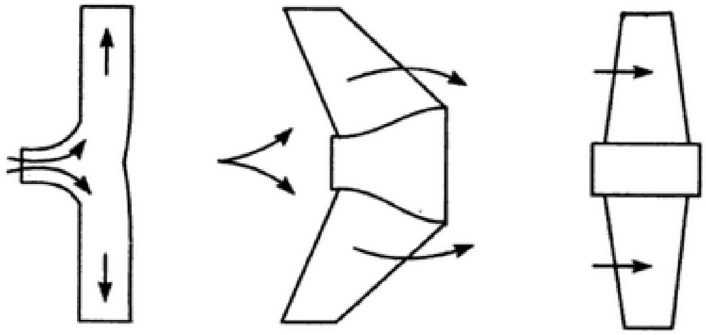
Construction

These are so called because energy is imparted to the fluid by centrifugal action of moving blades from the inner radius to the outer radius. The main components of centrifugal pumps are (1) the impeller, (2) the casing and (3) the drive shaft with gland and packing.



The liquid enters the eye of the impeller axially due to the suction created by the impeller motion. The impeller blades guide the fluid and impart momentum to the fluid, which increases the total head (or pressure) of the fluid, causing the fluid to flow out. The fluid comes out at a high velocity which is not directly usable. The casing can be of simple volute type or a diffuser can be used as desired. The volute is a spiral casing of gradually increasing cross section. A part of the kinetic energy in the fluid is converted to pressure in the casing.

Rotodynamic pumps, also known as centrifugal pumps, can be broadly classified into three categories, namely radial, axial and mixed. Following figure shows the three types of pumps; radial pumps are more often used.



(a) Radial (b) Mixed (c) Axial

Blades of vanes can be straight, radial, bending backwards or bending forwards. Their number varies from six to twelve.

A simple disc with blades mounted perpendicularly on it is called open impeller. If another disc is used to cover the blades, this type is called shrouded impeller. This is more popular with water pumps. Open impellers are well adopted for use with dirty or water containing solids. The third type is just the blades spreading out from the shaft. These are used to pump slurries. Impellers may be of cast iron or bronzes or steel or special alloys as required by the application. In order to maintain constant radial velocity, the width of the impeller will be wider at entrance and narrower at the exit.

The blades are generally cast integral with the disc. Recently even plastic material is used for the impeller. To start delivery of the fluid the casing and impeller should be filled with the fluid without any air pockets. This is called priming. If air is present the there will be only compression and no delivery of fluid. In order to release any air entrained an air valve is generally provided The one way foot value keeps the suction line and the pump casing filled with water.

Characteristics

For a given pump, D, A, β_2 and N are fixed. So at constant speed we can write

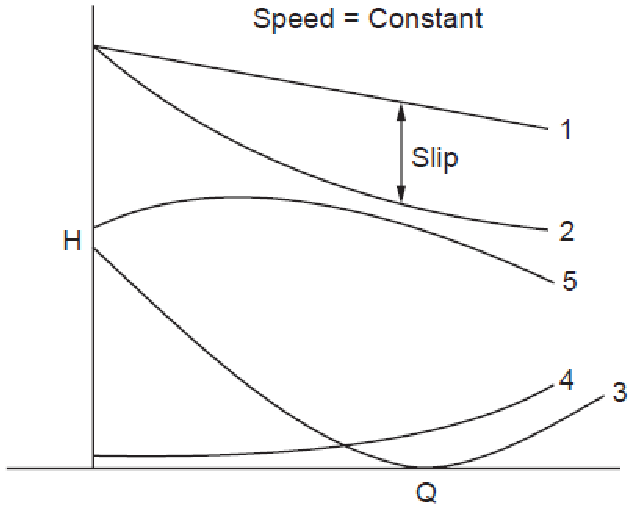
$$H_{th} = k_1 - k_2 Q$$

where k_1 and k_2 are constants and

$$k_1 = \pi^2 D^2 N^2$$

and $$k_2 = \left(\frac{\pi DN}{A}.\cot_2\right)$$

Hence at constant speed this leads to a drooping linear characteristics for backward curved blading. This is shown by curve 1 in following figure.



Characteristics of a centrifugal pump

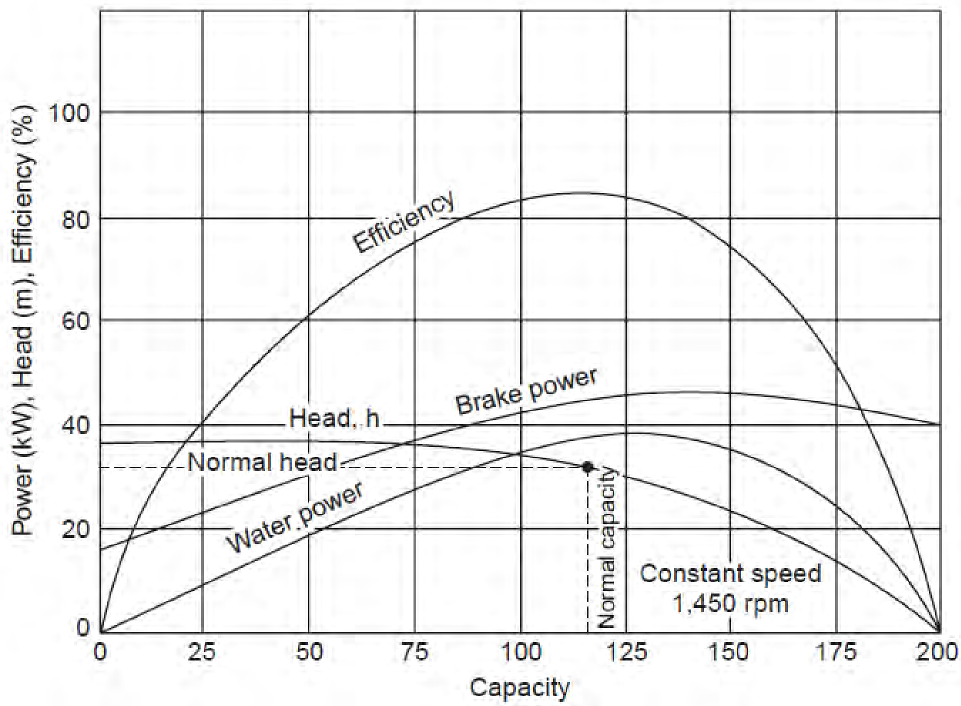
The slip causes drop in the head, which can be written as σ V_{u2} u_2/g. As flow increases this loss also increases. Curve 2 shown the head after slip. The flow will enter without shock only at the design flow rate. At other flow rates, the water will enter with shock causing losses.

This lose can be expressed as

$$h_{shock} = k_3(Q_{th} - Q)^2$$

The reduced head after shock losses is shown in curve 5. The shock losses with flow rate is shown by curve 3. The mechanical losses can be represented by $h_f = k_4 Q^2$. The variation is shown by curve 4. With variation of speed the head characteristic is shifted near parallel with the curve 5 shown in given figure.

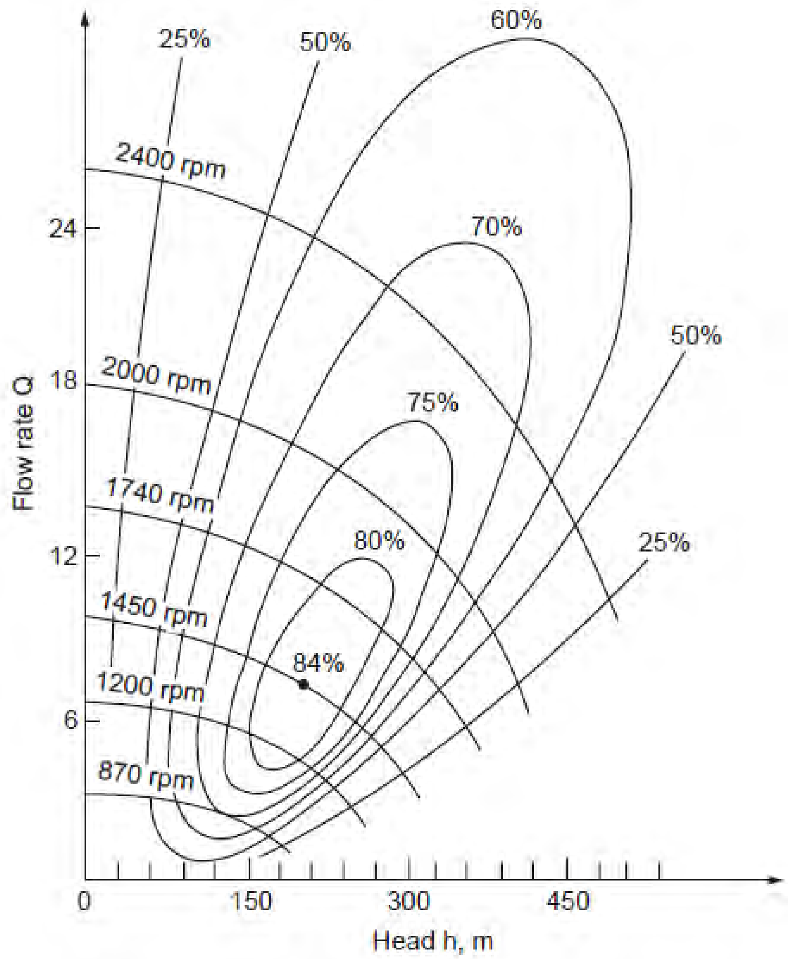
The characteristic of a centrifugal pump at constant speed is shown in following figure.



Centrifugal pump characteristics at constant speed

It may be noted that the power increases and decreases after the rated capacity. In this way the pump is self limiting in power and the choice of the motor is made easy. The distance between the brake power and water power curves gives the losses.

The pump characteristics at various speeds including efficiency contours in shown in following figure. Such a plot helps in the development of a pump, particularly in specifying the head and flow rates.



Pump characteristics at various speeds

Turbine type or diffuser type centrifugal pump

- Impeller is surrounded by stationary guide vanes which reduces the velocity of water before water enters the casing.
- The casing is generally circular and concentric with impeller.
- Velocity of water is more completely converted into pressure head
- High efficiency

Advantages of centrifugal pumps

- Initial and maintenance cost are comparatively low
- Their size is compact and can be installed in limited space
- Their mechanism is simple. Less skilled labour is required for its operation and repairs.
- Can be operated with high speed electric motors, or gas engines and steam turbines
- Discharge is steady and non pulsating

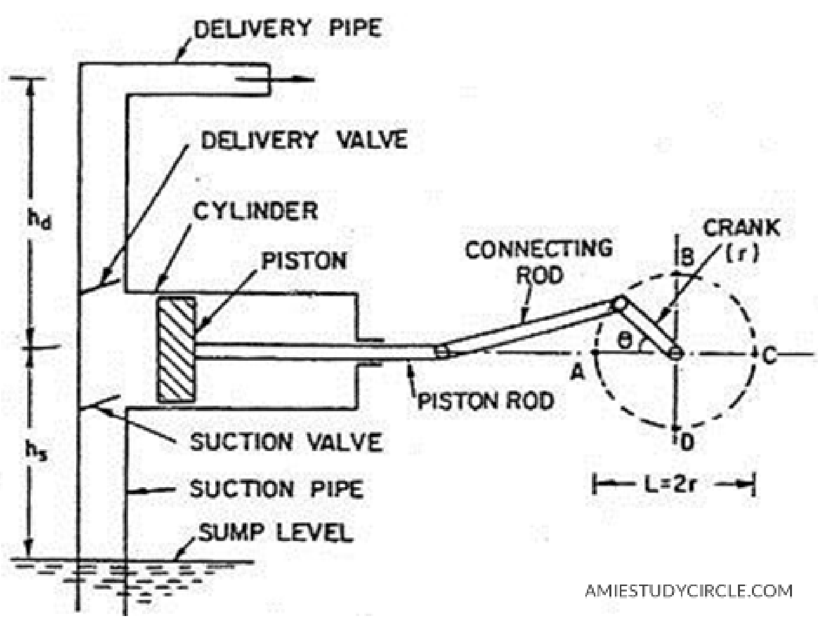
- Can be used for pumping water containing silt, sand etc.,
- Durable and safe against pressure.

Disadvantages of centrifugal pumps

- Requires priming
- For higher head, efficiency is low
- The discharge pipe has to be provided with check
- valve, to avoid the backflow when the pump suddenly
- stops due to power failure, etc., with the discharge
- valve open.
- Discharge varies with the head of water. When uniform discharge is required at varying heads, the pumps has to be rotated at variable speeds which is neither, practical nor economical.
- Their ordinary suction lift is limited(about 6m or so).

DISPLACEMENT PUMPS - RECIPROCATING PUMPS

- Simplest form of reciprocating pump - Hand operated well pump(commonly called hand pump).
- Can be used in any depth. For wells, where water table is within 6m or so.
- Requires foot valve at the end of the suction pipe to avoid priming.
- Single acting pumps -discharge occurs at alternative piston strokes.
- Double acting pumps -Delivers water at each stoke -more uniform flow



Components

- Cylinder- It is made of cast iron or steel alloy.
- Piston - The piston reciprocates inside the cylinder.
- Connecting rod - It connects piston and rotating crank.
- Suction pipe - It connects the source of water and cylinder.
- Delivery pipe - Water sucked by pump is discharged through the delivery pipe.
- Suction valve - It adjusts the flow from the suction pipe into delivery pipe.
- Delivery valve - It admits the flow from the cylinder into the delivery pipe.

Advantages

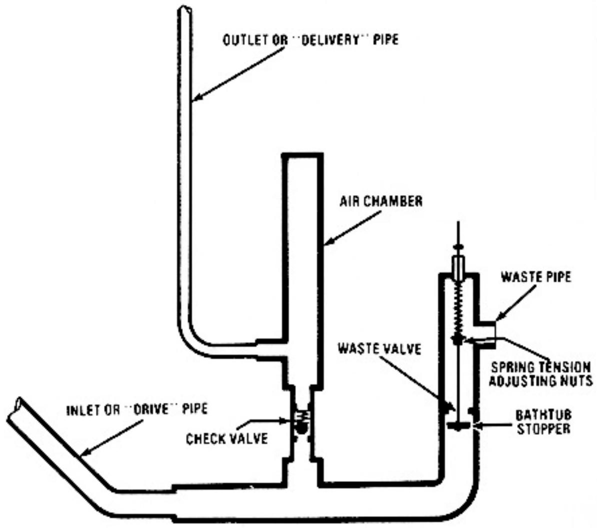
- High efficiency
- No priming needed
- Can deliver water at high pressure
- Can work in wide pressure range
- Continuous rate of discharge if provided with two pistons or more.

Disadvantages

- More parts mean high initial cost
- High maintenance cost
- Occupies more space.
- Needs skilled supervision during operations
- Low discharging capacity
- Pulsating flow
- High wear in parts

HYDRAULIC RAM

- A kind of pumping arrangement which does not utilise any outside power and uses the principle of water hammer pressures developed when a moving mass of water is suddenly stopped.
- A large amount of water must be available at moderate head, so as to lift small amount of water to higher head.
- Can be used for lifts of order of 30 m or so.



Advantages

- Its working is simple and when once it starts functioning, practically no attention is required.
- The Ram is durable.
- It is cheap as it does not require any fuel.

Disadvantages

- Considerable amount of water is wasted through a waste valve, and cannot be used at places where water is scarce.
- It produces considerable noise while working.

POWER TRANSMITTING SYSTEMS

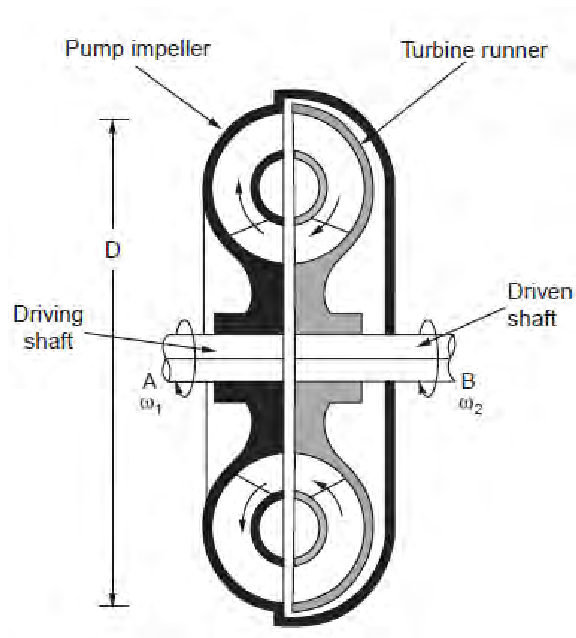
Ordinarily power is transmitted by mechanical means like gear drive or belt drive. In the case of gear drive there is a rigid connection between the driving and driven shafts. The shocks and vibrations are passed on from one side to the other which is not desirable. Also gear drives can not provide a step less variation of speeds. In certain cases where the driven machine has a large inertia, the driving prime mover like electric motor will not be able to provide a large starting torque. Instead of the mechanical connection if fluids can be used for such drives, high inertia can be met. Also shock loads and vibration will not be passed on. Smooth speed variation is also possible. The power transmitting systems offer these advantages.

There are two types power transmitting devices. These are

- Fluid coupling and
- Torque converter or torque multiplier.

Fluid Coupling

A sectional view of a fluid coupling is shown in following figure.

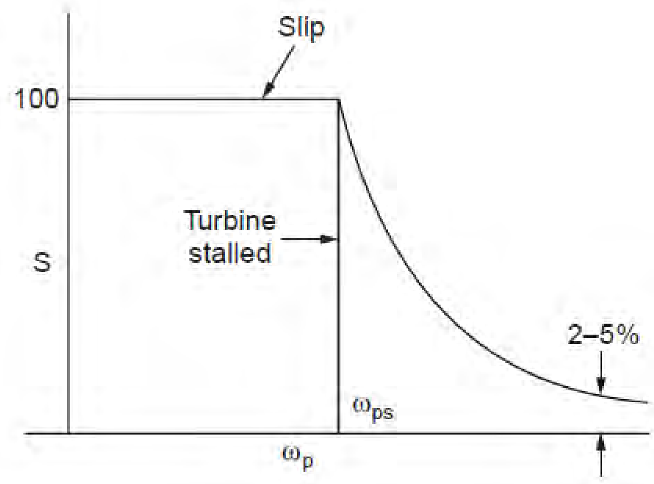


In this device the driving and driven shafts are not rigidly connected. The drive shaft carries a pump with radial vanes and the driven shaft carries a turbine runner. Both of these are enclosed in a casing filled with oil of suitable viscosity. The pump accelerates the oil by imparting energy to it. The oil is directed suitably to hit the turbine vanes where the energy is absorbed and the oil is decelerated. The decelerated oil now enters the pump and the cycle is repeated. There is no flow of fluid to or from the outside. The oil transfers the energy from the drive shaft to the driven shaft. As there is no mechanical connection between the shafts, stock loads or vibration will not be passed on from one to the other. The turbine will start rotating only after a certain level of energy picked up by the oil from the pump.

Thus the prime mover can pick up speed with lower starting torque before the power is transmitted. In this way heavy devices like power plat blowers can be started with motors with lower starting torque. The pump and turbine can not rotate at the same speeds. In case these do run at the same speed, there can be no circulation of oil between them as the centrifugal heads of the pump and turbine are equal, and no energy will be transferred from one to the other. The ratio of difference in speeds to the driver speed is known as **slips**, S.

$$S = \frac{\omega_p - \omega_T}{\omega_p}$$

where ω_p is the pump speed and ω_T is the turbine speed. The variation of slip with pump speed is shown in given figure.



As shown up to the pump speed ω_{ps} the turbine will not run and slip is 100%. As the driver speed increases slip rapidly decreases and at the operating conditions reaches values of about 2 to 5%.

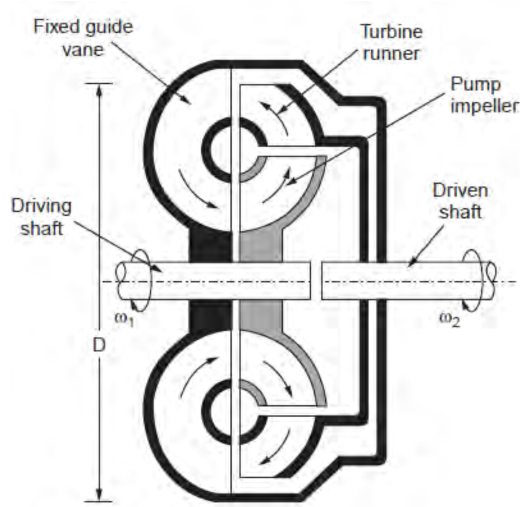
Efficiency of system will be

$$\eta = (1 - S)$$

Torque Converter

In the case of fluid coupling the torque on the driver and driven members are equal. The application is for direct drives of machines. But there are cases where the torque required at the driven member should be more than the torque on the driver. Of course the speeds in this case will be in the reverse ratio. Such an application is in automobiles where this is achieved in steps by varying the gear ratios.

The torque converter is thus superior to the gear train with few gear ratios. A sectional view of torque converter is shown in following figure.



converter consists of three elements namely pump impeller, a turbine runner and a fixed guide wheel as shown in figure. The pump is connected to the drive shaft. The guide vanes are fixed. The turbine runner is connected to the driven shaft. All the three are enclosed in a casing filled with oil. The oil passing through the pump impeller receives energy.

Then it passes to the turbine runner where energy is extracted from the oil to turn the shaft.

Then the oil passes to the stationary guide vanes where the direction is changed. This introduces a reactive torque on the pump which increases the torque to be transmitted. The shape and size and direction of the guide vanes controls the increase in torque. More than three elements have also been used in advanced type of torque converters. It may be noted that the speed ratio will be the inverse of torque ratio. The efficiency is found to be highest at speed ratio of about 0.6.

Example

Find the power required to drive a centrifugal pump which delivers 0.04 m^3/s of water to a height of 20 m through a 15 cm diameter pipe and 100 m long. The overall efficiency of the pump is 70% and co-efficient of friction "f" = 0.15 in the formula $h_f = \frac{4flV^2}{dx2g}$.

Solution

Given data

Discharge, Q = 0.04 m^3/s

Height, $H_s = h_s + h_d = 20$ m

Dia of pipe, $D_s = D_d = 15$ cm = 0.15 m

Length, $L_s + L_d = L = 100$ m

Overall efficiency, $\eta_o = 70\% = 0.70$

Coefficient of friction, f = 0.015

Velocity of water in pipe

$$V_s = V_d = V = \frac{Discharge}{Area\ of\ pipe} = \frac{0.04}{\frac{\pi}{4}(0.15)^2} = 2.26\,m/s$$

Frictional head loss in pipe

$$(h_{fs} + h_{fd}) = \frac{4flV^2}{dx2g} = \frac{4x0.015x100x2.26^2}{0.15x2x9.81} = 10.41m$$

Manometric head

$$H_m = (h_s + h_d) + (h_{fs} + h_{fd}) + \frac{V_d^2}{2g}$$

$$= 20 + 10.41 + \frac{2.26^2}{2x9.81} = 30.67\, m$$

Overall efficiency

$$\eta_o = \frac{\left(\frac{WH_m}{1000}\right)}{S.P.} = \frac{\rho gxQxH_m}{1000xS.P.}$$

$$\therefore \quad SP = \frac{\rho QH_m}{1000\eta_o} = \frac{1000x9.81x0.04x30.67}{1000x0.70} = 17.19\, kW$$

S.P. is the power required to drive the centrifugal pump.

PNEUMATIC HOISTING SYSTEMS

Pneumatic conveying of materials has been practiced successfully for many years in various engineering industries throughout the world. Pneumatic conveying sometimes solves problems which could not be solved by any mechanical systems. Its flexibility, relative low capital cost, increasing labour costs, environmental factors, and other reasons have tended to rapidly increase its application in mining and construct inn industries.

Pneumatic transportation of relatively large particles of abrasive materials in pipelines has been used for many years in the mining industry in different pm In of the world. Its main application has been in the back-filling of mined-out areas, muck removal from boring machines, building compact gateside packs for immediate disposal of waste rock from rippings and dintings, muck disposal from tunnelling machines, and hoisting minerals to surface.

The **main problem** with pneumatic transportation is that different materials behave totally different from one another, being considerably influenced by the type of the material being conveyed, operational velocity range, phase density, and conveying distance.

The selection of **optimum velocity** range which results in the maximum material mass flow rate is not easy. For a given material, the conveying velocity should not be so low that the pipeline gets blocked not too high, greater than 30 m/s, which will adversely affect the pressure drop as well as capital and operating costs. Typical minimum air velocities are of the order of 13 m/s for horizontal conveying and slightly lower for vertical conveying.

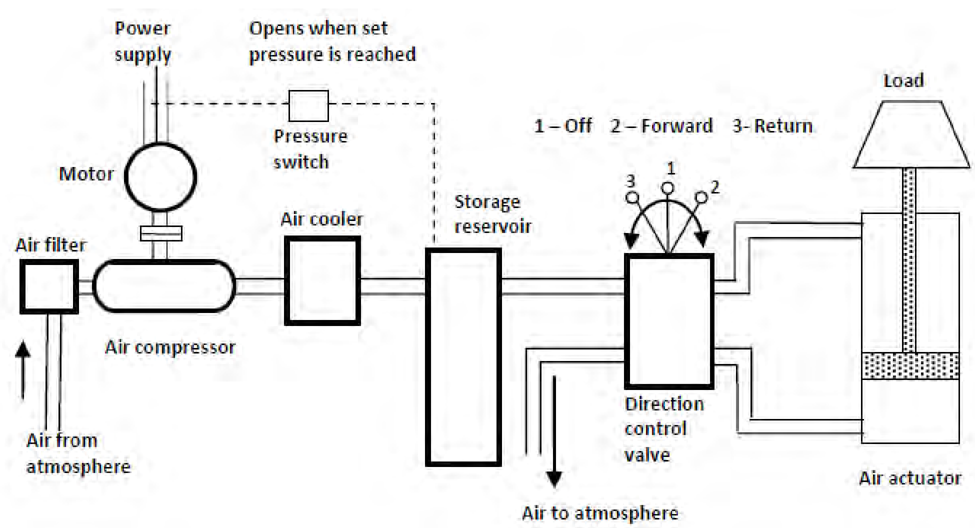
Phase density is the ratio of the mass flow rate of the material being conveyed to the mass flow rate of the air used. The terms dilute or lean, medium, and dense phase are often used in pneumatic conveying. A flow is usually considered to be in dilute or lean phase if the phase density is below about 8, in dense phase if the phase density i s above 40, and in medium phase if the phase density lies between the two limits.

The **low-pressure pneumatic pipeline systems** are of the lean-phase type in which the material is conveyed in suspension in the air in dilute phase and a minimum air velocity must be maintained so that the material does not drop out of suspension. The minimum conveying air velocity is difficult to give as it is affected by particle shape, size and density, as well as the phase density of the conveyed material. In dense phase, the material is not conveyed in suspension but is fluidized and swept along the pipeline in slugs and plugs by the air so that conveying at much lower velocities is possible.

For **optimum design of a pneumatic conveying system** with correct air velocity and flow rate, it is necessary to determine the conveying characteristics experimentally for a given material over the required conveying distance and over the range of conveying conditions likely to be encountered in appropriate phase density range. A special test facility is needed for this. In vertical upward conveying through a pipeline, the flowing air must have the necessary energy to carry and transport the solids. For this purpose, the air must have a minimum air velocity which is greater than the settling velocity of the heaviest particle. The solid particles have first to be accelerated by the air stream as quickly as possible to the minimum conveying velocity. Once this velocity is attained, further passage of air serves to increase the particle velocity to the transport velocity due to the expansion of air. Operation below the conveying velocity causes choking of the pipeline due to separation of the particles out of the carrier medium.

Basic Components of a Pneumatic System

A pneumatic system carries power by employing compressed gas, generally air, as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. Following figure shows a simple circuit of a pneumatic system with basic components.



Components of a pneumatic system

The functions of various components are as follows:

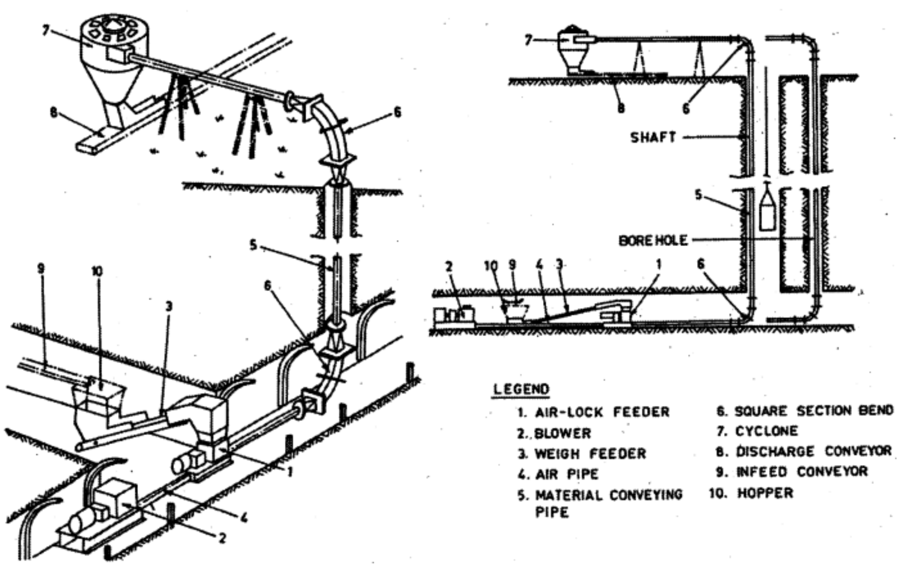
- The pneumatic actuator converts the fluid power into mechanical power to perform useful work.
- The compressor is used to compress the fresh air drawn from the atmosphere.
- The storage reservoir is used to store a given volume of compressed air.
- The valves are used to control the direction, flow rate and pressure of compressed air.
- External power supply (motor) is used to drive the compressor.
- The piping system carries the pressurized air from one location to another.

Air is drawn from the atmosphere through an air filter and raised to required pressure by an air compressor. As the pressure rises, the temperature also rises; hence, an air cooler is provided to cool the air with some preliminary treatment to remove the moisture. The treated pressurized air then needs to get stored to maintain the pressure. With the storage reservoir, a pressure switch is fitted to start and stop the electric motor when pressure falls and reaches the required level, respectively.

The three-position change over the valve delivering air to the cylinder operates in a way similar to its hydraulic circuit.

Pneumatic Vertical Pipeline Hoists

Following figure illustrates a typical pneumatic pipeline hoist designed by Radmark Engineering (U.K.) Ltd. for practical application in mines.



Pneumatic hoist

The essential underground equipment comprises a hopper, a weigh belt feeder, a rotary air-lock feeder, a Roots blower, and a vertical pipe range with a square-section bend at its bottom. The surface equipment consists of a square section bend at the top of the pipe range, a collection cyclone, and a discharge on to a belt conveyor which discharges on to a washery feed conveyor.

A hydraulic power pack drives both the weigh belt feeder and the air-lock rotary feeder. The feeder introduces the material into the fast-moving low-pressure air stream and is equipped with adjustable and replaceable wear parts. A permanent magnet is suspended over the feeder belt to eliminate tramp iron.

The Roots blower is a valve less positive displacement blower in which no internal compression takes place. It consists of two identical two-lobed intermeshing rotors set at 90° which rotate in opposite directions inside a compression chamber so that their movement captures a volume of air from the inlet side and delivers it to the discharge side. The compression space is not lubricated. Although the Roots blowers are rugged and quickly attain the full r.p.m., they are not capable of producing high pressure like turbo blowers. On account of very steep nature of the characteristics curve, the conveying air velocity once chosen can only be altered at great expense, The conveying steel pipelines have an inner diameter of 300, 350, or 400 mm and a wall thickness of 10 mm. The shaft pipe range is supported throughout its vertical length by steelwork in the shaft and is thoroughly earthed to eliminate electrostatic charges.

The discharge cyclone on the surface has its own dust suppression system.

The entire hoisting installation is designed so that not only the individual items of equipment are protected against malfunctioning of the various protective devices installed on them, but the entire plant can be shut down.

COMPARISON BETWEEN HYDRAULIC AND PNEUMATIC SYSTEMS

Usually hydraulic and pneumatic systems and equipment do not compete. They are so dissimilar that there are few problems in selecting any of them that cannot be readily resolved. Certainly, availability is one of the important factors of selection but this may be outweighed by other factors. In numerous instances, for example, air is preferred to meet certain unalterable conditions, that is, in “hot spots” where there is an open furnace or other potential ignition hazard or in operations where motion is required at extremely high speeds. It is often found more efficient to use a combined circuit in which oil is used in one part and air in another on the same machine or process. Table 1.2 shows a brief comparison of hydraulic and pneumatic systems.

Hydraulic System	Pneumatic System
It employs a pressurized liquid as a fluid	It employs a compressed gas, usually air, as a fluid
An oil hydraulic system operates at pressures up to 700 bar	A pneumatic system usually operates at 5–10 bar
Generally designed as closed system	Usually designed as open system

The system slows down when leakage occurs	Leakage does not affect the system much
Valve operations are difficult	Valve operations are easy
Heavier in weight	Lighter in weight
Pumps are used to provide pressurized liquids	Compressors are used to provide compressed gases
The system is unsafe to fire hazards	The system is free from fire hazards
Automatic lubrication is provided	Special arrangements for lubrication are needed

COMPARISON OF DIFFERENT POWER SYSTEMS

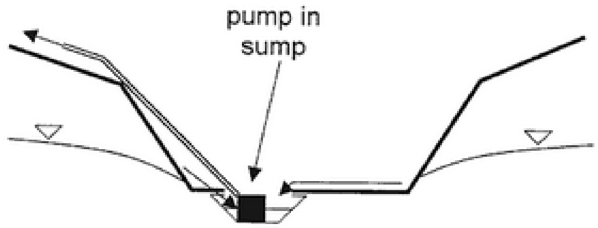
There are three basic methods of transmitting power: electrical, mechanical and fluid power. Most applications actually use a combination of the three methods to obtain the most efficient overall system. To properly determine which method to use, it is important to know the salient features of each type. For example, fluid systems can transmit power more economically over greater distances than mechanical types. However, fluid systems are restricted to shorter distances compared to electrical systems. Following table lists the salient features of each type.

Property	Mechanical	Electrical	Pneumatic	Hydraulic
Input energy source	IC engines electric motor	IC engines water/gas turbine	IC engine Pressure tank	IC engine electric motor air turbine
Energy transfer element	levers, gears, shafts	electrical cables and magnetic field	pipes and hoses	pipes and hoses
Energy carrier	rigid and elastic objects	flow of electrons	air	hydraulic liquids
Power-to-weight ratio	poor	fair	good	best
Torque/inertia	poor	fair	good	best
Stiffness	good	poor	fair	best
Response speed	fair	best	fair	good
Dirt sensitivity	best	best	good	fair
Relative cost	best	best	good	fair
Control	fair	best	good	good
Motion type	mainly rotary	mainly rotary	linear or rotary	linear or rotary

SUMP PUMP AND SUMP DEWATERING

Virtually all deep and surface mines which work below the water table will require some form of dewatering.

Sump dewatering involves the creation of basins in the floors of workings, to which all water is diverted, and from which it is all pumped out of the mine (see figure).

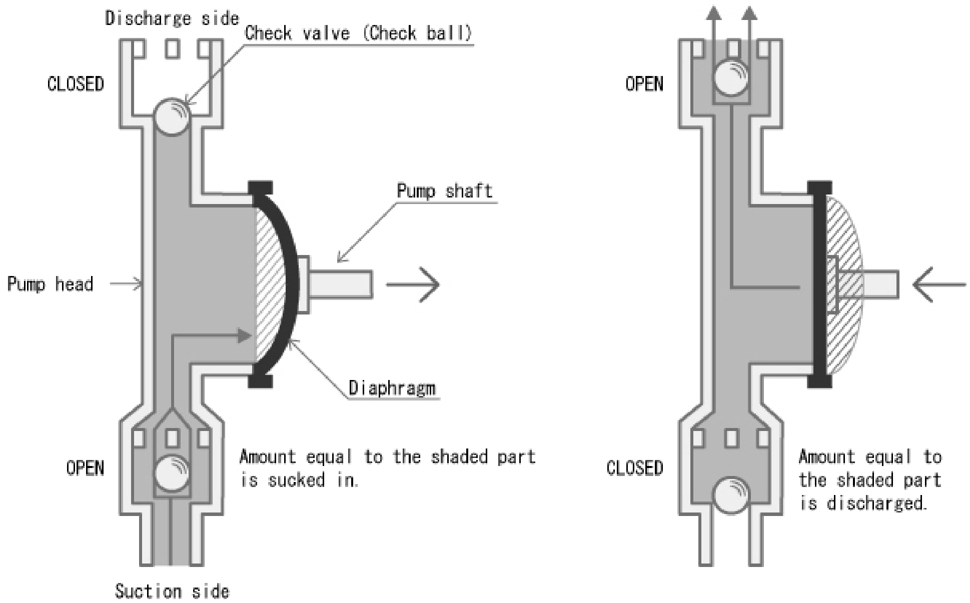


Sump dewatering is the most widespread dewatering method in both surface and deep mines world-wide Indeed, even where other dewatering methods are employed to handle the bulk of the water make, there will nearly always be some need to support these with some localised sump dewatering.

The plant employed includes a diaphragm or a self priming centrifugal pump, a suction line and a discharge line. The pipes may be rigid or flexible, the suction line being equipped with a strainer at the intake end to prevent clogging.

Diaphragm sump pump

Diaphragm pumps are known as *positive displacement pumps* as the diaphragm plays the role of the limited displacement piston. When the diaphragm is forced into reciprocating motion using the mechanical linkage, compressed air or any fluid from the external source the pumps starts functioning. There is no contact between the liquid that is pumped and the source of energy so the possibility of leakage is not there. As no leakage is possible such pumps are very useful in handling toxic or any other expensive liquid. There are certain cons of using these pumps. These pumps have limited head and capacity range. The check valves are necessary In the suction and discharge nozzles of these pumps.



Diaphragm sump pump

There are three main types of diaphragm pumps:

- Those in which the diaphragm is sealed with one side in the fluid to be pumped, and the other in air or hydraulic fluid. The diaphragm is flexed, causing the volume of the pump chamber to increase and decrease. A pair of non-return check valves prevent reverse flow of the fluid.
- Those employing volumetric positive displacement where the prime mover of the diaphragm is electro-mechanical, working through a crank or geared motor drive, or purely mechanical, such as with a lever or handle. This method flexes the diaphragm through simple mechanical action, and one side of the diaphragm is open to air.
- Those employing one or more unsealed diaphragms with the fluid to be pumped on both sides. The diaphragm(s) again are flexed, causing the volume to change.

When the volume of a chamber of either type of pump is increased (the diaphragm moving up), the pressure decreases, and fluid is drawn into the chamber. When the chamber pressure later increases from decreased volume (the diaphragm moving down), the fluid previously drawn in is forced out. Finally, the diaphragm moving up once again draws fluid into the chamber, completing the cycle. This action is similar to that of the cylinder in an internal combustion engine. Diaphragm Pumps deliver a hermetic seal between the drive mechanism and the compression chamber, allowing the pump to transfer, compress, and evacuate the medium without a lubricant.

An elastomeric diaphragm can be used as a versatile dynamic seal that removes many of the limitations found with other sealing methods. They do not leak, offer little friction, and can be constructed for low pressure sensitivity. With the right material consideration, diaphragms can seal over a wide range of pressures and temperatures without needing lubrication or maintenance.

Air compressors

Small mechanically activated diaphragm pumps are also used as air compressors and as a source of low-grade vacuum. Compared to other compressors, these pumps are quiet, cheap and, most importantly, have no moving parts in the airstream. This allows them to be used without added lubrication in contact with the air, so the compressed air produced can be guaranteed clean.

In deep excavations, it may often be necessary to have a staged series of pumping sumps (or ‘lodges’) installed at various elevations above the base of the workings, with separate batteries of pumps lifting the water from one stage to another. Similarly, in widespread workings, it may be necessary to have more than one major basal sump to ensure adequate drainage of the entire mine.

The principal **advantage** of sump dewatering is the flexibility it offers in pumping arrangements: throughout the life of a mine, pumping stations can be relocated as needs arise, and as areas of working are abandoned. The principal **disadvantage** of sump dewatering is that water flowing to the sumps can continue to cause a considerable nuisance as it passes through the mine, which might only be minimised by considerable investment in ditching and pipe-work. There are a number of circumstances in which it can be desirable to keep the void as dry as possible. For instance:

- to avoid contamination of the water make with suspended solids or contaminants leached from the crushed ore/gangue, which might necessitate expensive treatment of the mine water prior to its disposal to a natural watercourse
- to avoid slurring of roadways and destabilisation of unsupported faces
- to minimise problems related to freezing of water during the winter

ASSIGNMENT

Q.1. (AMIE W11, 20 marks): Explain with neat illustrations, the construction, operation and maintenance of a turbine pump and a mono pump.

Q.2. (AMIE S14, 14 marks): Explain turbine pump used in underground mine with its constructional details. Also, explain its characteristic curves.

Q.3. (AMIE S13, 11 marks): Give a general account of the use of "fluid power system" in mining equipment. Give examples. Name the various components that are involved to form a fluid power system and their functions. Which is the hydraulic law utilized to transmit fluid power to the operating points?

Q.4. (AMIE W14, 5 marks): What is fluid coupling? How it helps conveyor to start smoothly?

Q.5. (AMIE S13, 12 marks): Describe with the aid of sketches, the layout scheme for a main sump pump showing the position of various accessories in the layout. Also, mention the purpose for which those accessories are installed in the pipeline.

Q.6. (AMIE S13, 8 marks): Compare ram pumps and centrifugal pumps and give advantages and disadvantages of each type. Where are they particularly suitable in mining use.

Q.7. (AMIE S13, 8 marks): A pump is required to lift 360 m^3/hr against a total head of 240 m, taking all losses together. Calculate the power of the motor, if the pump has an efficiency of 75%. If the pump operates 10 hour a day and the motor efficiency is 90%, determine the daily electricity consumption and the energy cost. (Given 1 litre of water weighs 1 kg and one kWh of energy costs ₹ 9).

Q.8. (AMIE S14, 6 marks): Calculate the power of electric motor for a pump which can be used for dewatering at the rate of 900 litre/min in an underground mine having depth 612 m. Consider efficiency of pump be 90%.

Hint: For fluid in open circuit, P = QρH x 9.81 where P = Power transmitted to the fluid by the pump in Watt, Q = Flow in m^3/s, ρ = Density of the liquid in kg/m^3, H = Piezometric height in meter of water, 9.81 = Average Intensity of gravity.

Q.9. (AMIE W14, 7 marks): An electrically driven colliery turbine pump lifts 160 m^3 of water per hour against a total head of 120 m. Allowing an overall efficiency of 70% for the motor and pump, calculate the input power (in kW) to the motor. If the pump is in operation for an average of 10 hr/day for 300 days in a year, calculate the energy consumed (in kWh) and the cost of the energy at Rs. 8/kWh. Assume 1 m^3 of water weighs 1000 kg.

Q.10. (AMIE S14, 10 marks): Explain the principle of hydraulic power transmission. Compare hydraulic vs. pneumatic power transmission system.

Q.11. (AMIE W14, 13 marks): Name the various fittings and attachments that are expected in a colliery turbine pump installation. Indicate their location in piping system and the functions they carry out. Illustrate your answer with a neat sketch.

Q.12. (AMIE W14, 5 marks): What is the relative merits of compressed air and electricity for use in underground?

Q.13. (AMIE W14, 5 marks): Describe the type of power loading machine.

Q.14. (AMIE W16, 7 marks): Write comparable applicability of mechanical, hydraulic and pneumatic power transmission.

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