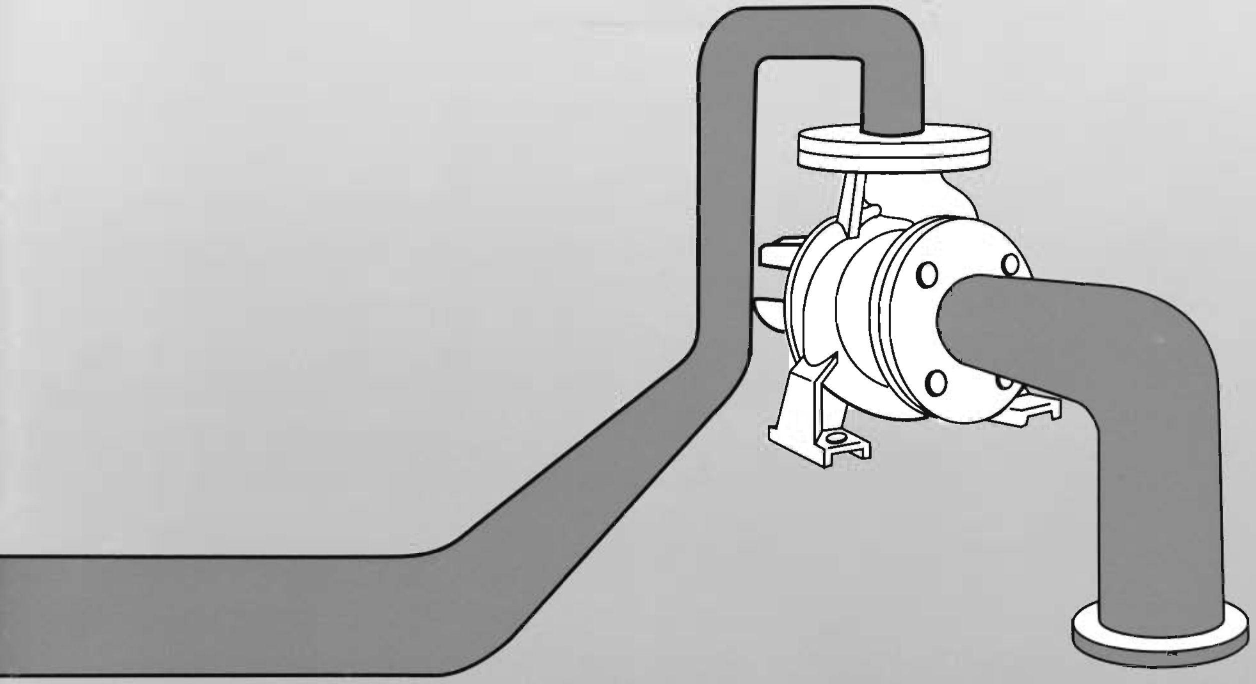
Pump Basics



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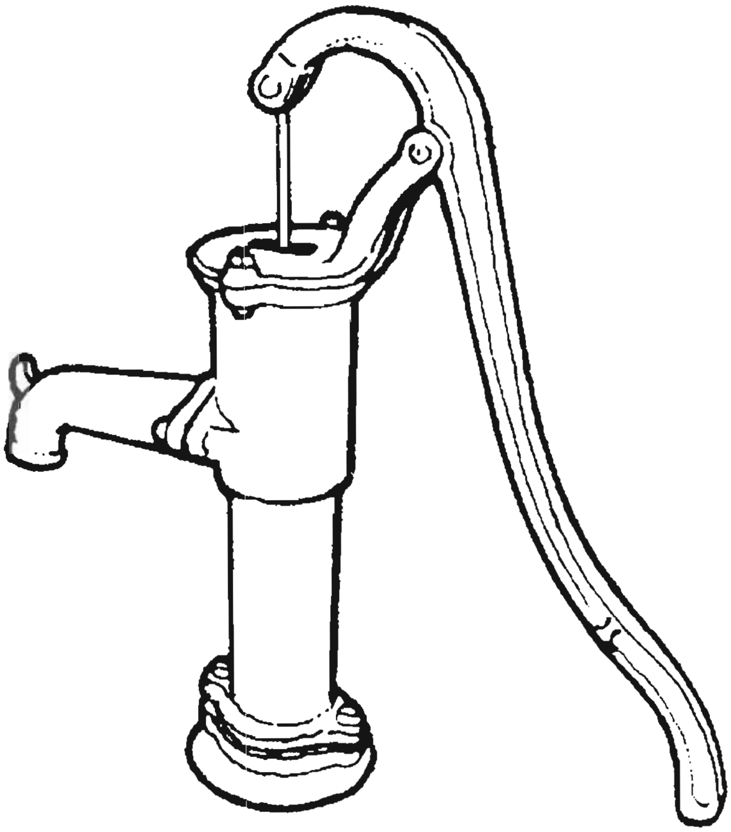
Pump Basics for Plumbers

By

JOHN DNISTRIANSKY

B.A., B.Ed., Dip.Tchg (Tech)



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This Publication

This publication grew from the author's concern that practising plumbers had a general lack of understanding and a perceived fear of pump technology.

Given the importance of applied pump technology in plumbing services, plumbing personnel need to be equippped with the necessary knowledge of basic hydraulic concepts as the plumbing industry enters into the 21st century.

It is with this in mind that this handbook is, foremost, a self-learning resource which provides basic pump principles for the plumbing practitioner.

Pumps are becoming more prevalent in the day-to-day activities of plumbers and will continue to do so while spa baths, pools, fountains, decorative waterfalls and rainwater tanks increase in popularity.

From the foregoing, it can be appreciated that there is no further need to avoid plumbing work involving pump applications, as plumbers can increase their business by developing this area of specialization.

The Author

John Dnistriansky is currently a lecturer at the Regency Institute of TAFE in South Australia. He is well qualified with previous experience in urban and rural water supply.

He is a co-author of the national text "Plumbing Services" and has written pump related articles in the trade journal Plumbing and Mechanical Connections.

Acknowledgement

In a publication of this kind, of which a large part deals with the different types of available equipment, one must lean heavily upon the generosity of manufacturers.

I take this opportunity to express my appreciation for the time and co-operation offered by the various pump manufacturers and resellers, without which this book would not have been possible.

A special thank you to the following organizations who have permitted the use of material contained in this handbook:

- ☺ *Grundfos Pumps Pty Ltd*
- ☺ *KSB Ajax Pumps Pty Ltd*
- ☺ *ITT Flygt Ltd*
- ☺ *onga pumps Pty Ltd*
- ☺ *Southern Cross Machinery Pty Ltd*
- ☺ *Weir Engineering Pty Ltd*

Finally, to the APMA technical committee who reviewed the draft and gave constructive advice, a sincere thank you.

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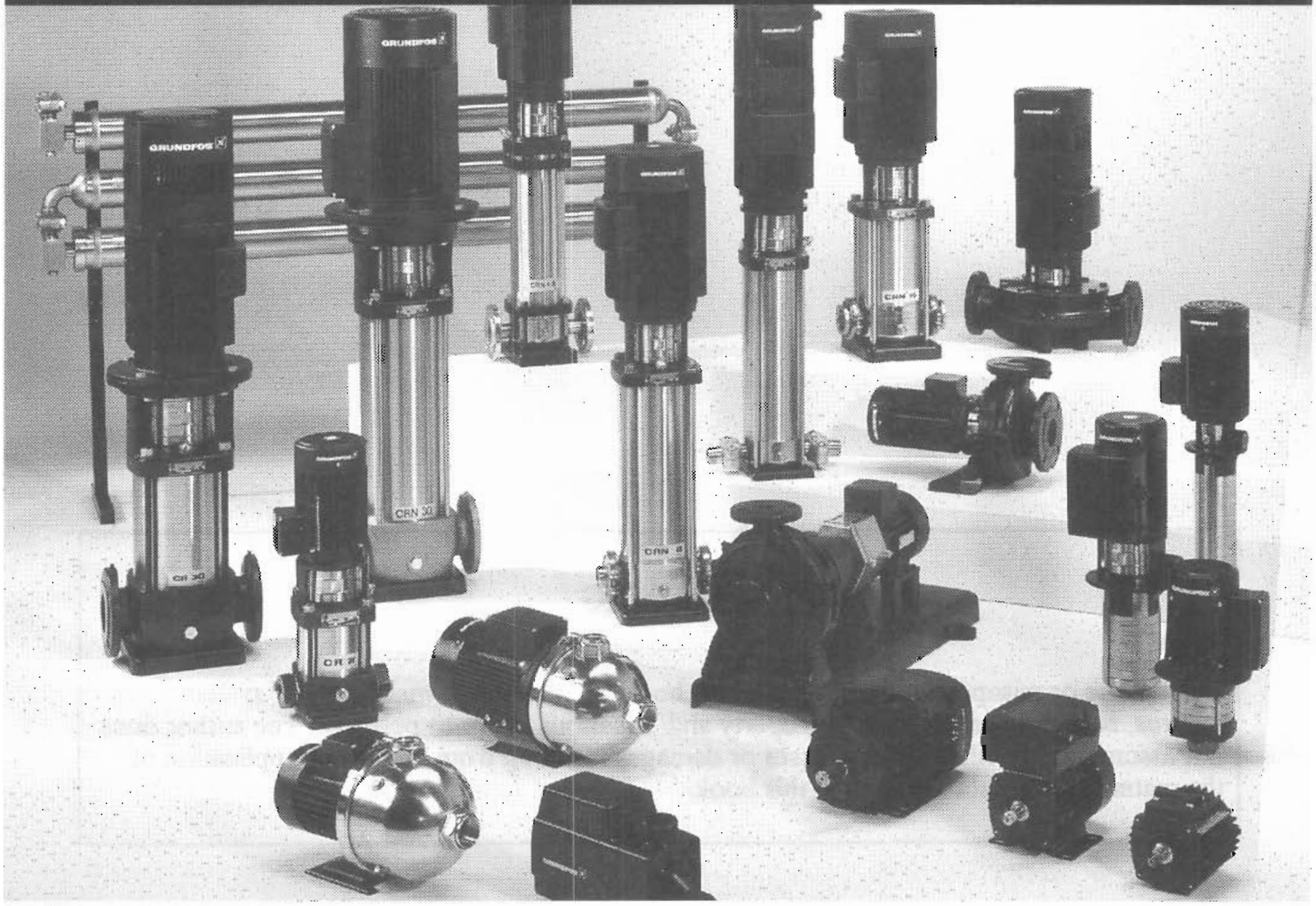

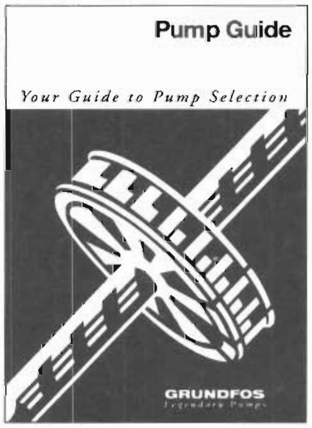

WARNING

The misuse or misapplication of data in this book could result in machinery or system failures, severe damage to other property and/or serious injury to persons. The author does not assume any liability for any losses or damages resulting from the use or application of the materials and data set forth in this book.

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PREFACE

The purpose of this publication primarily is to provide basic pump principles and information for plumbers, plumbing consultants and students involved in the plumbing services industry. However, distributors of water equipment, contractors, sales and installation personnel will also find it a handy source of reference.

The data contained within this handbook are those required for use as a quick ready reference on a daily basis. It is presented in a manner which, it is hoped, will be convenient to the user and readily applicable in a practical sense.

With these objectives in mind emphasis has been placed, wherever possible, on the presentation of the data in the form of graphs, tables, charts, formulae and other visual representations useful in problem-solving and installation design. It is also the intention that this handbook be of benefit to anyone interested in pumping problems. Thus, worked examples which involve basic hydraulic calculations have been included in the text.

This handbook covers such broad topics as pump types and their suitability and classification. Emphasis is directed specifically at the use of centrifugal pumps because of their frequent and almost exclusive use in industry, irrigation and building services.

Reference is made to centrifugal pump characteristics, including capacity head relationships, speed, power and efficiency. An important section includes information dealing with selection, installation, operation and maintenance as well as a trouble-shooting guide outlining causes and remedies.

A useful addition is a comprehensive section of technical terms which is set out at the beginning of the handbook.

The complete work is comprised of relevant pump information, divided into specific sections as outlined in the *Table of Contents*. It is hoped that those using the handbook will derive valuable assistance from this readily accessible information.

INTRODUCTION

Without exception, the pump is possibly man's earliest contrivance used for the conversion of natural energy to useful work.

The most positive mode of fluid transfer from one location to another is by pumps and piping. Conveyance is accomplished through piping whilst pumps supply the energy necessary for flow in overcoming various resistances in the pipe circuit, changes in elevation and pressure of the fluid.

The pump and piping must therefore be considered as an integral transfer system. For maximum efficiency the transfer system must be properly designed with considerations made for such factors as materials, movement, support, fixing, anchorage, arrangement, accessibility as well as provision to future changes or extensions.

Pumps are produced in an endless variety of types, sizes, shapes and materials to suit specific duties and applications.

Pumping is necessary where a water supply at its natural pressure cannot be piped directly to a building or storage.

The duties of pumps as part of building equipment or plumbing services are usually confined to the raising of water to elevated storage tanks, the supply of water for fire prevention sprinkler systems, the removal of sump waters and sewage wastes, the circulation of fluids for heating and air conditioning systems for the comfort and well-being of individuals.

TERMINOLOGY

Absolute pressure: One of two commonly used pressure measurements and is the sum of gauge pressure plus atmospheric pressure.

Belt drive: When the prime mover drives a pump through belts and pulleys.

Cavitation: Rapid formation and collapse of vapour bubbles in a moving fluid in regions of low pressure.

Characteristic curve: A graph showing the pump performance under varying conditions of flow, head, power, speed and efficiency.

Diffuser vane: Fixed curved vanes fitted in some centrifugal pumps for the purpose of converting velocity head to pressure head.

Direct coupling: When a prime mover is directly connected in line with the driven unit by means of a coupling.

Displacement: The volume of liquid swept through or displaced by a piston or plunger in any single stroke.

Driven unit: A machine used for moving fluids, can take various forms using rotary or reciprocating motion.

Driving unit: Can take the form of an internal combustion engine, either diesel or petrol, or an electric motor requiring power, mainly A.C. Sometimes referred to as a prime mover.

Efficiency (pump): Ratio of the water horse power output to mechanical power input and expressed as a percentage.

Entry head: Head required to overcome the frictional resistance leading into a pipe entrance.

Equivalent length: A pressure loss through valves and fittings due to flow and is expressed in terms of a straight pipe length of the same pipe diameter.

Flooded suction: An expression used in connection with pumps when the reservoir from which the liquid is drawn is above the centreline of the pump. Sometimes referred to as positive suction.

Foot valve: A non-return valve fitted at the bottom of a pump suction pipe in order to retain the water in the pipe.

Forced circulation: The imparting of flow motion by mechanical means (pump) to a fluid in any system circuit.

Friction head: Entrance and exit head losses due to velocity of flow in a pipe system and include pipe skin friction, as well as losses through valves and fittings.

Gauge pressure: One of two commonly used pressure measurements but refers to pressure above atmospheric.

Head: Is the vertical height measured from a datum point to the free surface of water in a system.

Pressure gauge: An instrument which is used for measuring fluid pressure, generally that above atmospheric.

Priming: The expulsion of air by completely filling the suction pipe and pump casing with liquid.

Pump datum: Term used in relation to the position of the pump suction and discharge and normally taken as being the centreline of the pump shaft, i.e. the pump suction eye.

Pump rating: A sized pump selected on the basis of the required flow and total head.

R.P.M. curve: A curve on a graph which shows the speed of a prime mover which drives the pump.

Rate of flow: Sometimes referred to as capacity or quantity and is stated in units of volume per unit time.

Shut off head: Refers to a head condition at no flow.

Split casing: A term applied to a centrifugal pump indicating that the pump casing is composed of two sections which are normally bolted together.

Static suction head: The vertical distance between the centreline of a pump and the pumped liquid level.

Suction lift: An expression used in connection with pumps when the reservoir from which the liquid is drawn is below the centre line of the pump.

Throttle: When the flow of a liquid is reduced or controlled by means of a regulating device such as a globe valve.

Total equivalent length: The length of the longest circuit through which the liquid is pumped plus a length equivalent to the resistance offered by valves and fittings.

Total delivery head: The sum of static delivery head and friction head in the discharge pipe and fittings.

Total suction lift: The sum of static suction lift and friction head in the suction pipe and fittings.

Total head: The summation of both total suction lift and total delivery head in a pumping circuit. Commonly referred to as total dynamic head.

Velocity head: Kinetic energy due to directional travel equivalent to the height through which a body must fall in order to obtain a given velocity.

Volute casing: An impeller chamber which is constructed with a gradually enlarging passageway.

Vortex: A whirling fluid forming an area of low pressure or cavity at the centre of a rapid circular path resembling a whirlpool.

Water hammer: Is a pressure that results from a sudden arresting of the velocity of flow of water in a closed circuit.

PUMP CLASSIFICATION

Pumps may be listed, described or categorized in a number of ways. The most satisfactory is according to the mechanics by which they move the fluid.

Pumps can be grouped according to the method by which they discharge their contents, pulsating flow in which there is a period of no discharge such as with positive displacement pumps or in a continuous flow as with roto-dynamic pumps. In addition, pumps can be classified according to whether or not the capacity of fluid discharged can be varied without changing the speed, i.e. variable or constant delivery.

Classification also includes factors such as application, materials from which they are constructed, the liquids they handle as well as geometry and structural features.

Overall pump selection must, however, refer to the classification previously mentioned, namely the mechanics by which they move the fluid, leading to three main types:-

(i) Reciprocating
(ii) Rotary
(iii) Centrifugal.

Additionally, there are other special pump types outside the main classifications, employing entirely different principles such as hydro-pneumatic, jet, electromagnetic, etc. A more basic grouping however includes two major categories:-

(i) Rotodynamic
(ii) Displacement.

Reference to classification and types is indicated in Table 'A'.

(i) **Reciprocating**

Direct acting or power driven including the sub-types:

- piston
- plunger
- simplex
- duplex
- multiplex.

Also included are the rotary piston, ram and diaphragm as well as similar machines dependent upon reciprocating motion.

(ii) **Rotary**

Those employing positive displacement characteristics similar to that of reciprocating pumps but include a moving element in the form of a rotor. Classified by their geometry and include:

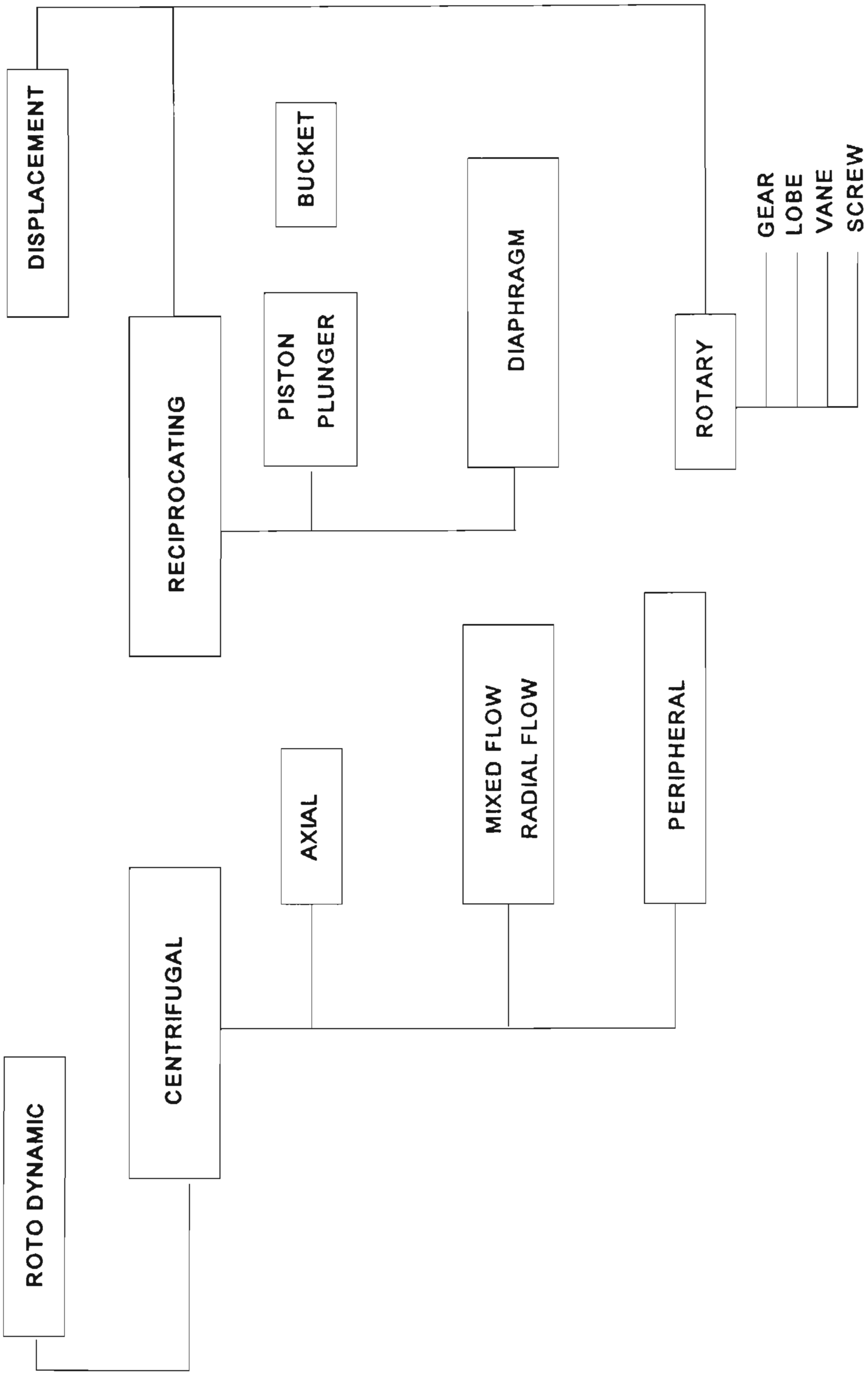
- gear
- lobe
- screw
- vane.

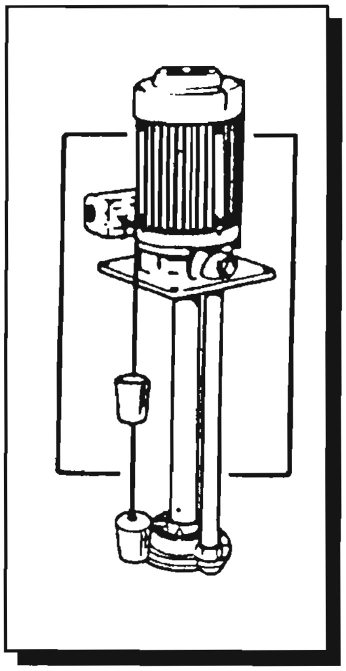
(iii) **Centrifugal**

Classified as a rotodynamic pump. Includes a rotating element in the form of an impeller and a stationary element, that of a casing, scroll or volute shape. Centrifugal pumps do not possess positive displacement characteristics. Rotodynamic pumps are divided into the following sub-types:

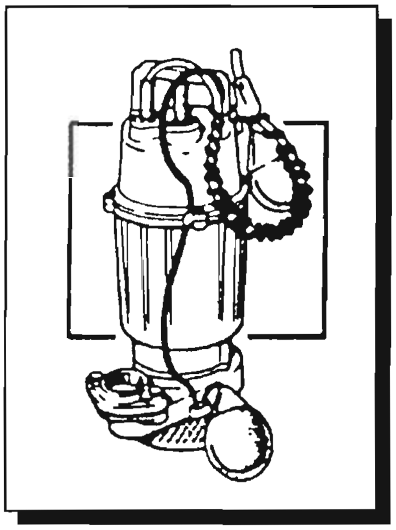
- volute
- diffuser
- turbine
- mixed flow
- axial flow
- radial flow
- propeller.

TABLE 'A'

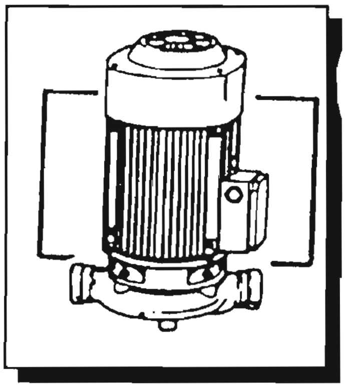

ROTO DYNAMIC
CENTRIFUGAL
AXIAL
MIXED FLOW
RADIAL FLOW
PERIPHERAL
DISPLACEMENT
RECIPROCATING
BUCKET
PISTON
PLUNGER
DIAPHRAGM
ROTARY
GEAR
LOBE
VANE
SCREW



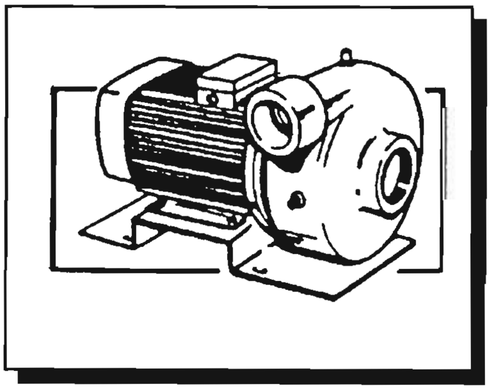
Submersible Sump Pump



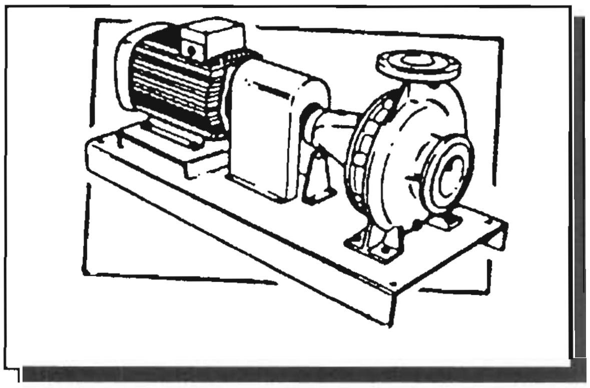
Submersible Drainage Pump



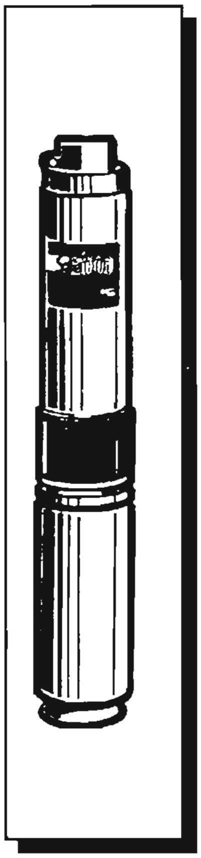
In line pump



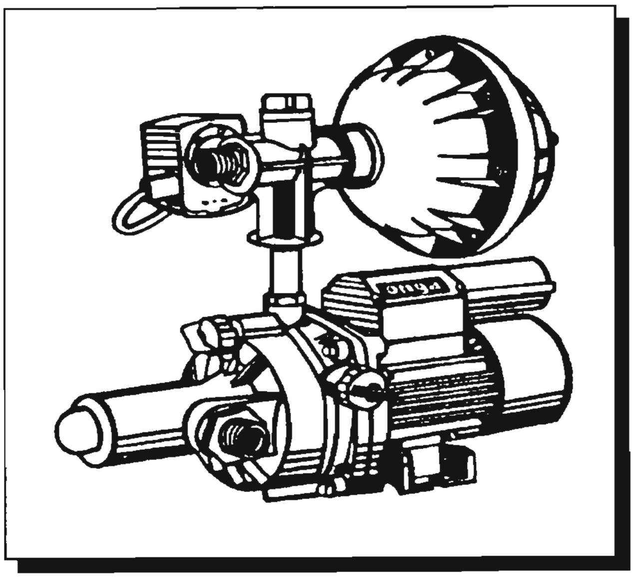
Close Coupled Centrifugal Pump



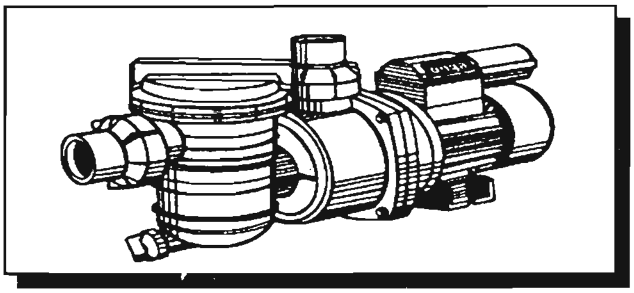
Long Coupled Centrifugal Pump



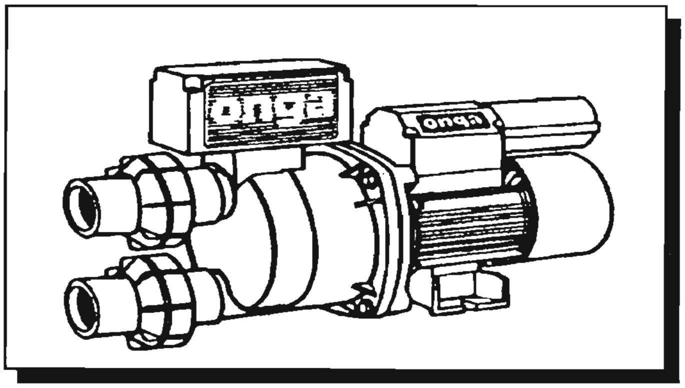
Submersible Borehole Pump



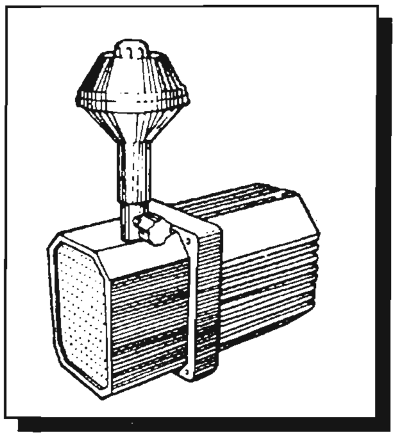
Pressure Unit



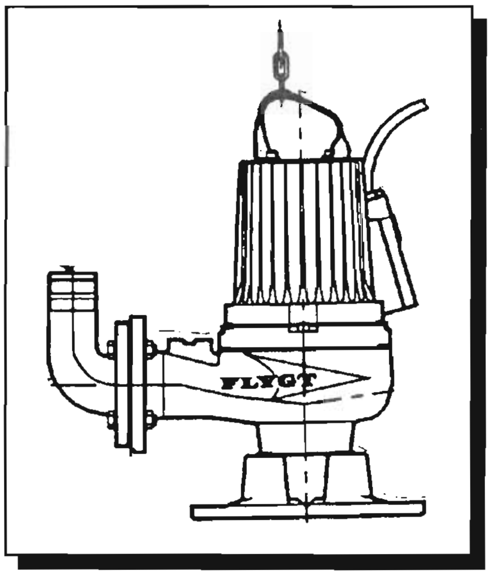
Swimming Pool Pump



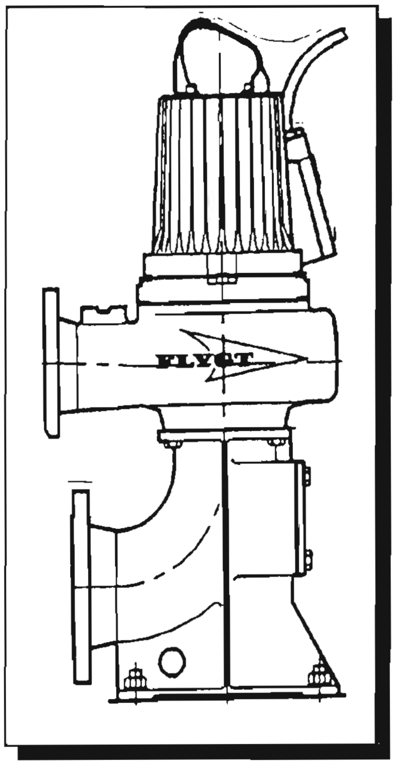
Spa Pump



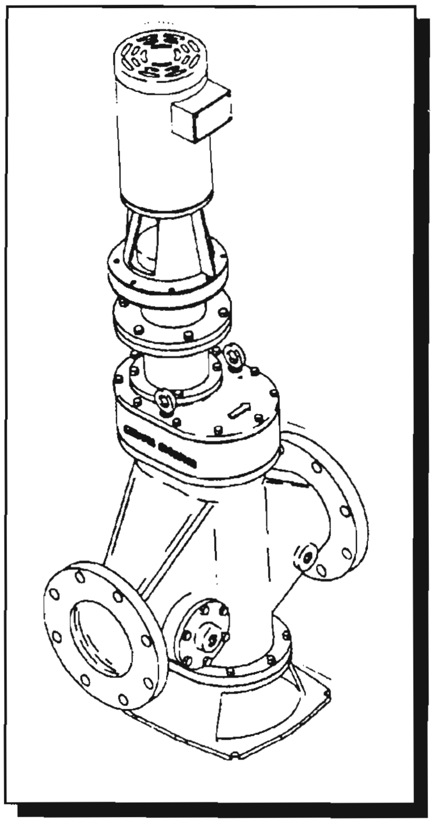
Fountain Pump



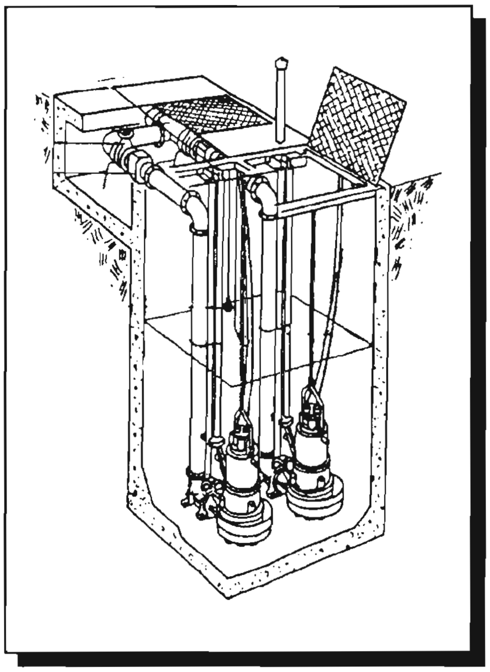
Wet Well Submersible Pump



Dry Well Submersible Pump



The Muffin Monster Macerator



Sewage Pumping Station

MECHANICS OF PUMPS

(i) Reciprocating

Reciprocating pumps may be defined as those operating with a constant motion, employing a straight line path, also having a to and fro motion, moving backwards and forwards or up and down, as distinguished from a circular motion.

Description : In view of the above definition a reciprocating pump may be of the piston, plunger or bucket type as distinguished from a centrifugal or rotary pump. Reciprocating pumps comprise of three moving elements necessary for their operation and consist of:

(i) Inlet valve
(ii) Piston or plunger
(iii) Outlet valve.

In essence, a reciprocating pump consists of a cylinder and piston (or plunger) with an arrangement of valves, as in Figs. 1a and 1b.

Typical Reciprocating Windmill Pumps

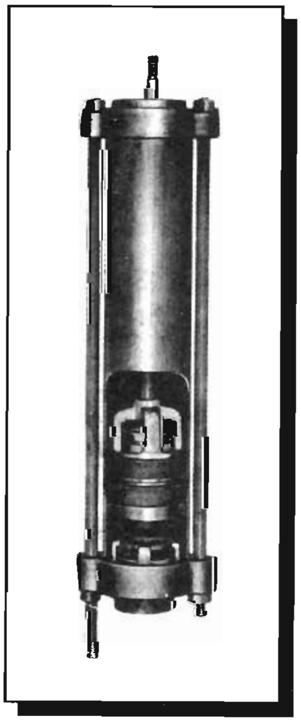


Fig. 1a

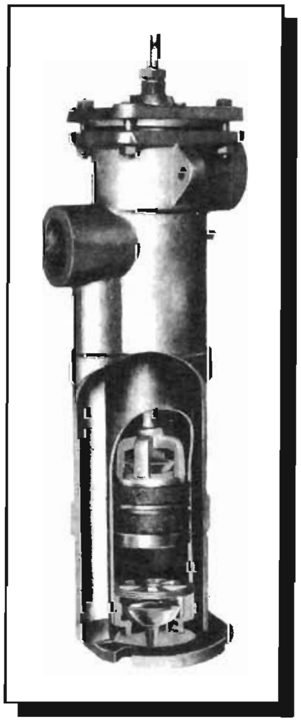


Fig. 1b

Operation : As the piston moves in one direction it draws the liquid into the cylinder, whilst on the reverse stroke the inlet valve closes, the outlet valve opens and the liquid is forced into the delivery pipe. This operation depends upon atmospheric air pressure which is always acting upon the liquid surface.

Power pumps : These are positive displacement pumps which deliver a fixed capacity with constant speed. Modern power pumps are designed with totally enclosed, self-lubricating power ends, thereby being protected against damage by leakage of the pumped fluid, as well as from dirt in the immediate vicinity.

Application : The power pump is useful for both high and low head applications, although mostly used where high discharge pressures are required. They are frequently used for pumping from surface supplies to storage tanks in stock watering systems. Refer to Fig. 2.

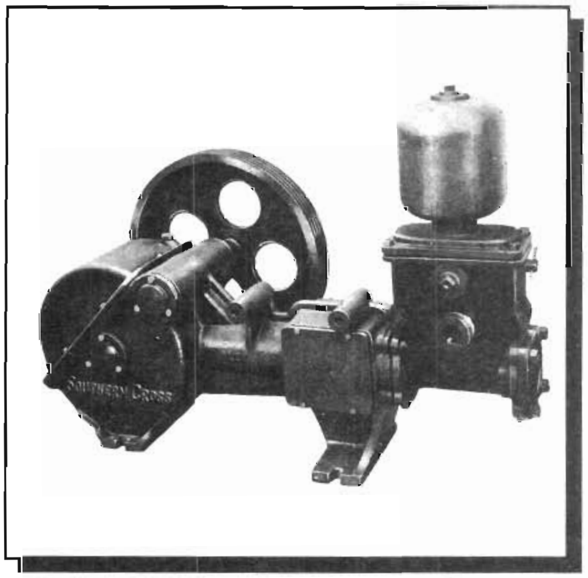


Fig. 2 - Reciprocating Power Pump

Diaphragm pumps : These are displacement pumps in which a flexible diaphragm replaces the piston, as with other reciprocating pumps. The diaphragm is usually made from heavy duty rubber to resist abrasion.

Operation : The reciprocating motion of the diaphragm has a similar effect to that of a piston. The constant flexing of the diaphragm, as well as A.A.P., is responsible for the admission of fluid into the pump and subsequent discharge from the delivery end.

Application : Diaphragm pumps are intended for handling abrasive as well as corrosive fluids and sludges. They are particularly useful for low head applications such as dewatering of trenches and building sites. Small 25mm diaphragm pumps are suitable for priming centrifugal pumps, as shown in Fig. 3.

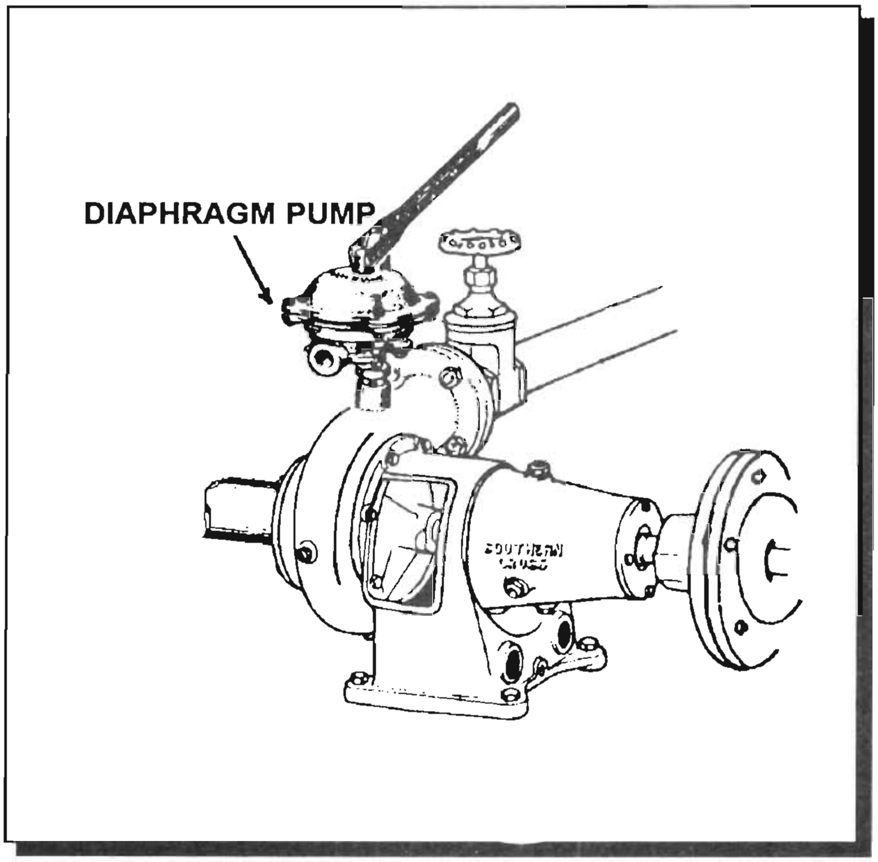


Fig. 3 - Diaphragm Pump used as a priming pump

(ii) **Rotary**

Description: Rotary pumps are positive displacement pumps consisting of a chamber and housing such elements as gears, cams, screws, vanes and lobes which are activated by the rotation of a drive shaft.

These pumps are characterized by the close-running clearances and the absence of suction and discharge valves. They are usually lubricated by the fluid being pumped. Fig. 4 illustrates a typical gear pump.

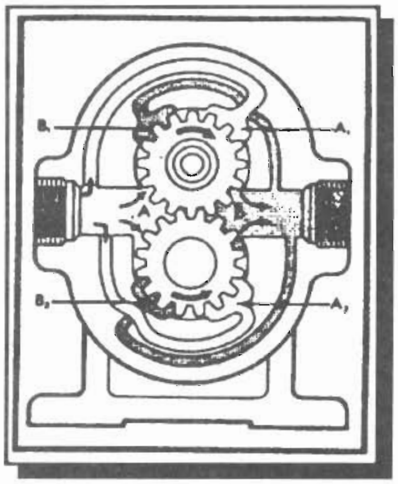


Fig. 4 - Rotary Gear Pump

Application : Rotary pumps have an extremely wide range of applications and have replaced the reciprocating pump in a number of industrial operations. Because of their simple construction, compactness and direct coupling to an electric motor drive, the rotary pump is especially adapted to handle liquids over a wide range of viscosities. Lubricating and heavy fuel oils (high viscosity) gasoline and benzine (low viscosity) are but a few petroleum products handled by rotary pumps.

(iii) Centrifugal

Volute type:

Description : Volute pumps comprise an impeller which rotates inside a chamber or casing. The casing has a circular inlet and outlet, the outlet nozzle being at right angles to the inlet. The impeller is built up of a number of blades or vanes around its periphery which curve backwards, and opposite to the direction of rotation (Fig. 5).

On rotation, the impeller vanes throw the liquid in the direction of rotation inside the casing and discharges from the outlet nozzle being the point of least resistance. The purpose of the casing is to convert high velocity pressure into static pressure.

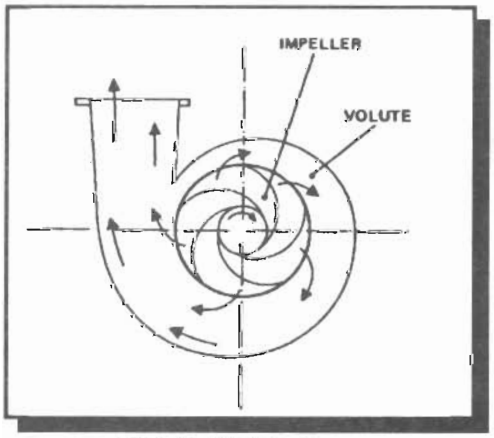


Fig. 5 - Volute Pump

Centrifugal pumps generally fall into three (3) classes, namely:

(i) Radial flow
(ii) Axial flow
(iii) Mixed flow.

The essential elements consist of a rotating element being the impeller and fixed onto a shaft and a stationary element consisting of a chamber or casing. Pumps designed with a scroll casing are referred to as volute pumps; those with diffusion vanes are known as diffuser pumps.

The design of the casing may be further classified as either axially and radially split. If the pump casing houses one impeller only, it is known as a single stage centrifugal pump. When two or more impellers operating in series are used, as in Fig. 6, the pump is referred to as a multi-stage centrifugal pump.

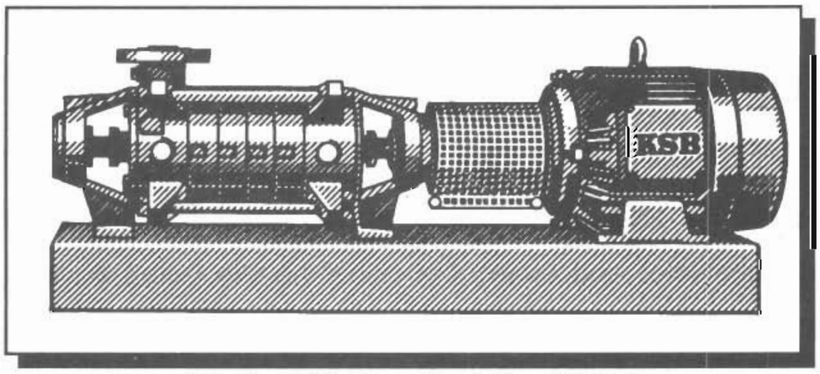


Fig. 6 - Multi-stage Centrifugal Pump

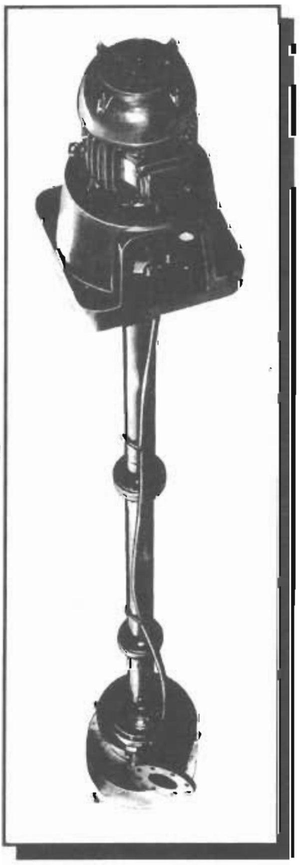


Fig. 7 - Sump Pump

The axis of rotation determines whether the pump is a horizontal or vertical shaft pump.

The centrifugal pump can operate in a liquid source with the suction end entirely submerged as illustrated in Fig. 7 and is known as a wet well or sump pump.

Most pumps, especially those used with building services (Fig. 8), operate when the pumped liquid gains entrance into and away from the pump by means of piping; these are known as surface pumps and include both close and long coupled units.

Centrifugal pumps may either be belt driven or coupled directly to electric motors, as in Figs. 9 and 10.

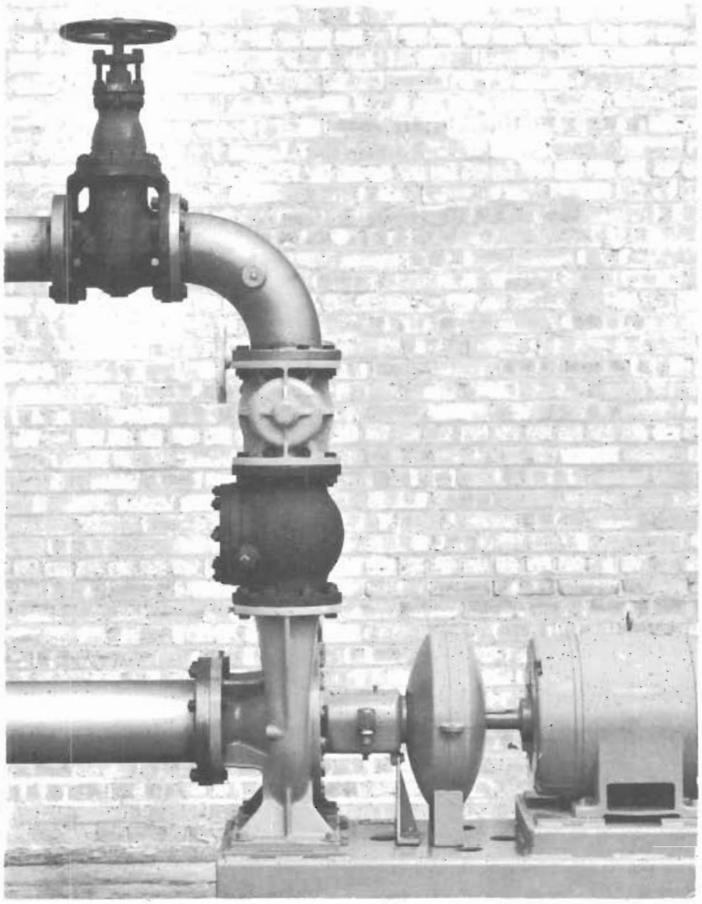


Fig. 8 - Long Coupled Pump Unit

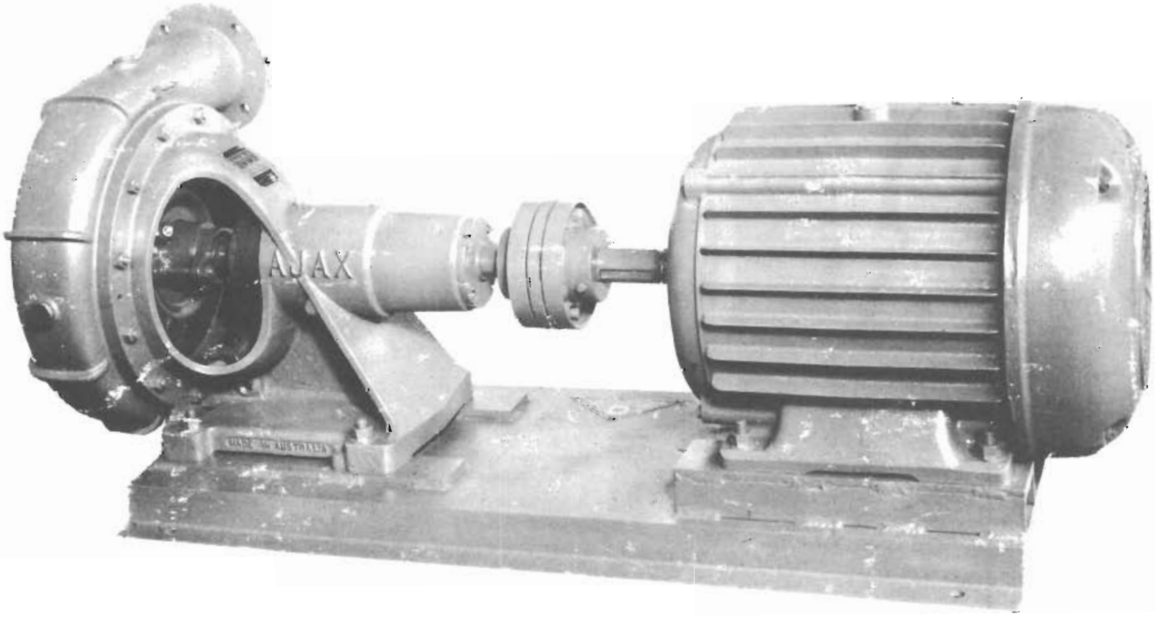


Fig. 9 - Direct Coupled Pump Unit

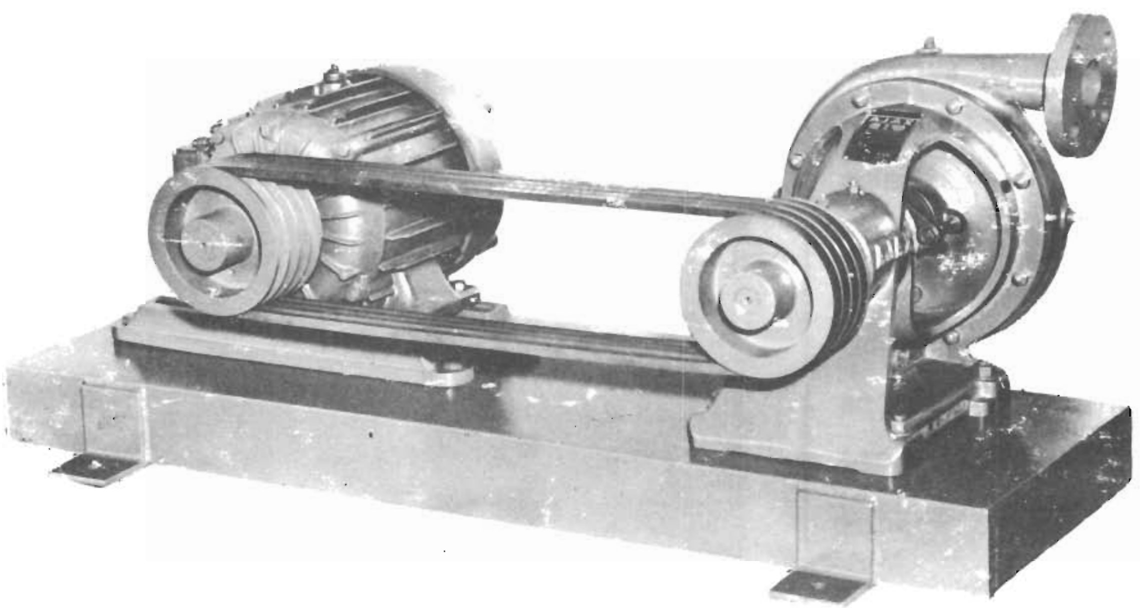


Fig. 10 - Belt Driven Pump Unit

The pump outlet nozzle can be adjusted to a number of alternative discharge positions or angles, as shown in Figs. 11, 12 and 13.

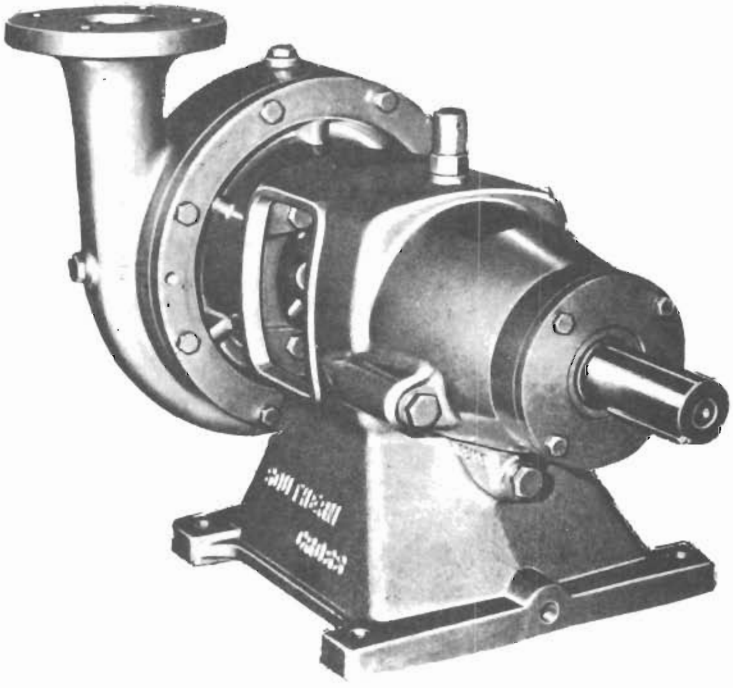


Fig. 11 - Vertical Discharge

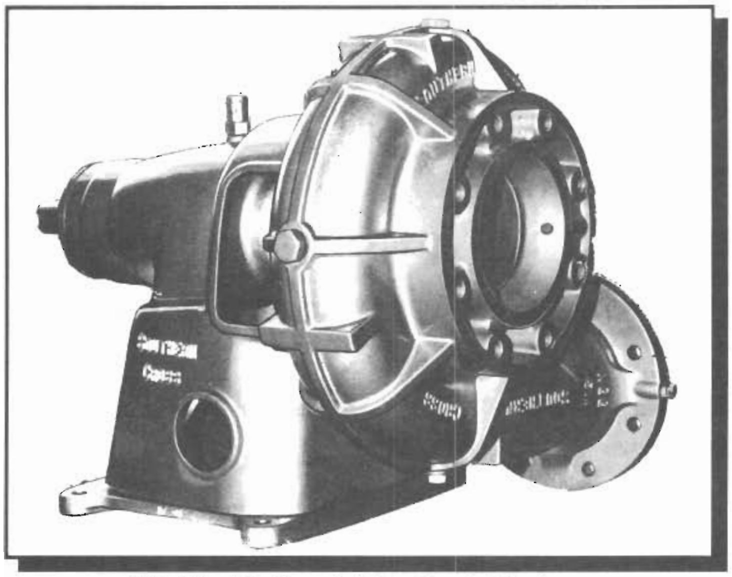


Fig. 12 - Horizontal (bottom) Discharge

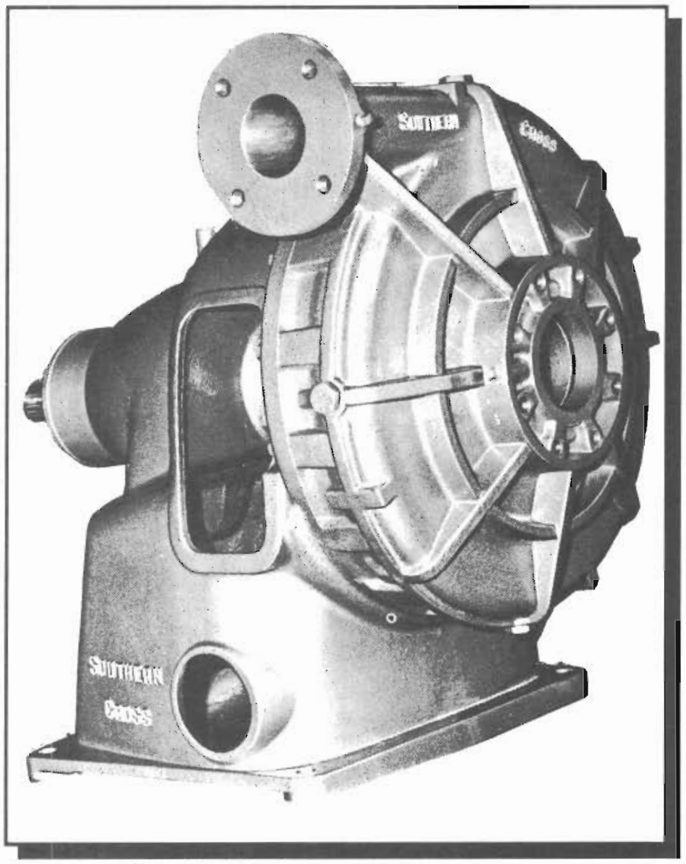
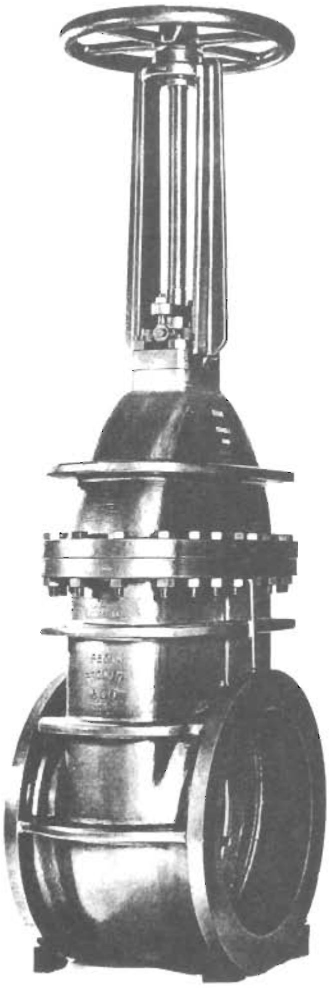


Fig. 13 - Horizontal (top) Discharge



Materials : Standard centrifugal pumps, including those that handle clear, non-corrosive and abrasive fluids are normally constructed from standard materials. The standard materials used are cast iron casing, steel shaft, cast iron impeller and bronze wear ring. According to Hydraulic Institute terminology for a standard fitted pump the standard materials used are:

- cast iron casing
- steel shaft
- bronze impeller, wear rings and shaft sleeve (when used).

A pump so constructed is termed *bronze fitted*.

Pumps handling corrosive liquids should be all bronze and constructed from special composition to resist the corrosive effects of the liquid being pumped. All parts which come in contact with the pumped liquid are termed *all bronze*.

Recent additions as materials for pump components are:

- stainless steel
- zinc-free bronze
- gunmetal
- plastics.

There are many varieties and possibilities, however the ultimate choice of materials depends upon the specific needs of the user.

Applications : Centrifugal pumps are designed to meet the requirements of a wide variety of services and are recommended for use in general industry. They are particularly suitable for the lifting and circulation of fluids used in high rise building applications. Centrifugal pumps apply to installations involving air conditioning, heating, fire prevention systems, tank storage, basement drainage, in fact anywhere normal mains pressure is insufficient to be piped directly for use by the various services.

Bore hole pumps:

(A) *LINE SHAFT (TURBINE) TYPE*

Line shaft pumps of the type as illustrated in Fig. 14 are widely used for the raising of water from boreholes.

The pump end is fully submerged below natural water level in the borehole. the electric motor being located at the ground surface.

<u>Mechanics</u> : The pumping action is similar to that of a conventional centrifugal pump except that the flow through the impellers is in a direction between radial and axial and referred to as mixed flow.

The discharge from each impeller is directed into vaned passages in the stage casing hence into the eye of the following impeller.

Multi-staging is used to develop sufficient head to raise the water to ground surface, as well as pressure necessary for the operation of the system.

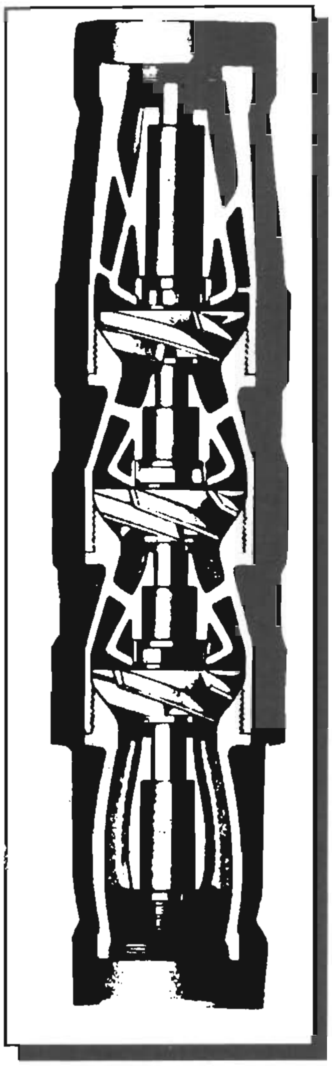


Fig. 14 - Line Shaft Pump

<u>Description</u> : Line shaft pumps consist of a number of impellers attached to a shaft, each impeller is enclosed in a stage casing or bowl. The lower stage is fitted with an inlet strainer and the upper bowl is fitted with an outlet to which is attached a delivery column and from which the pump is suspended in the bore casing.

The drive shaft is supported within a delivery column in bearings carried in housings and fitted into the column at each joint. The drive shaft emerges from the discharge head through a packing gland and is connected to the drive head.

Application : This type of pump unit is used primarily for lifting water from underground sources for irrigation systems but may be readily applied for booster distribution systems or the supply pipes of buildings as in some countries (Fig. 15).

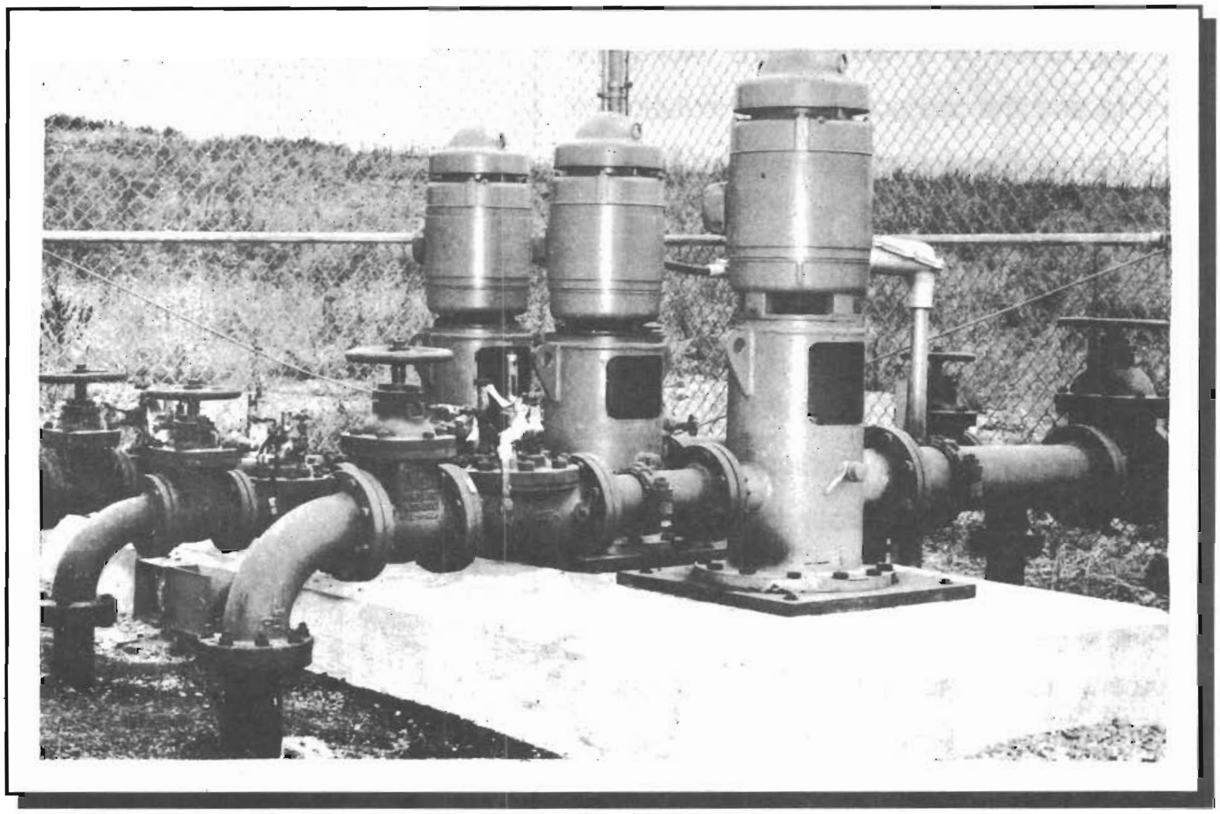


Fig. 15 - Booster System

(B) *ELECTRO-SUBMERSIBLE* TYPE

Description : The submersible pump unit comprises a multi stage centrifugal pump and an A.C. electric motor, designed to operate when fully submerged in water.

With this arrangement a very compact, portable pump unit is obtained completely self-contained, which eliminates long lengths of shafting, as used with the lineshaft or turbine type of unit. Fig. 16 fully illustrates a typical submersible pump unit.

Application : The application of submersible pumps in borehole pumping has a distinct advantage over other designs, in carrying out similar functions. There are no prepared foundations or pump houses because the whole unit is suspended inside the borehole and supported by a rising main. Adequate cooling and the protection and insulation of the motor windings are essential features with this type of pump unit.

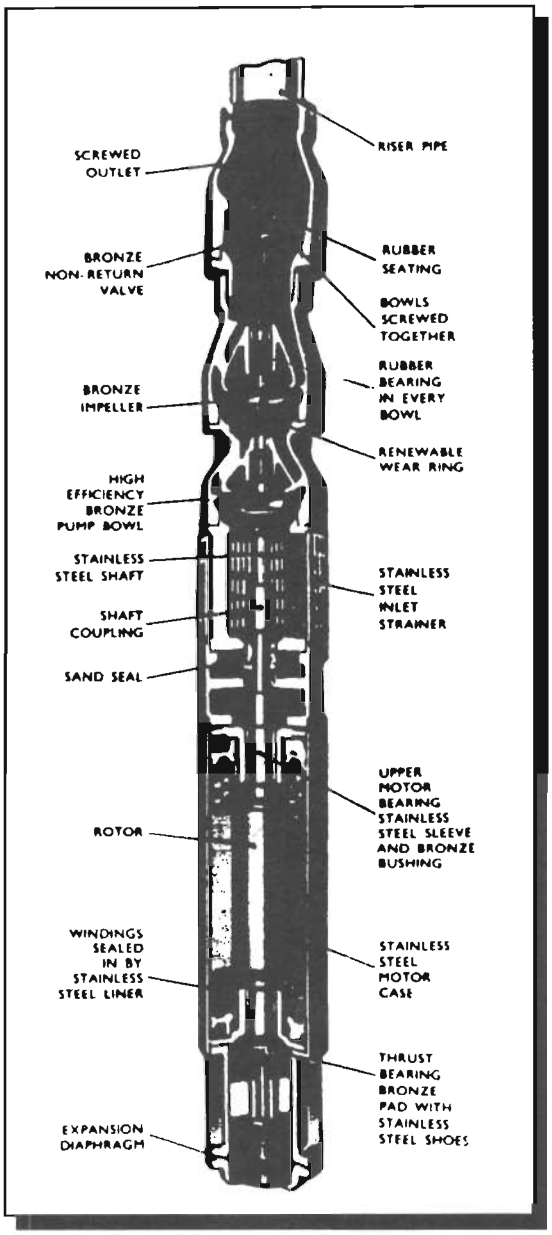


Fig. 16 - Submersible Borehole Pump

Pressure unit :

Description : The pressure unit is a compact, automatic pressure pump which is capable of providing water at controlled pressure. In addition to the pump motor unit, a pressure tank, pressure switch and a constant pressure valve are included for automatic operation. A butyl rubber diaphragm inside the pressure tank separates water from the air chamber and eliminates water logging.

Operation : The pressure unit pumps water into the pressure tank. The water is forced into the tank under pressure and compresses the air above the diaphragm inside the pressure tank. When a tap is opened, the air expands, acting like a spring, forcing the water out as required. As the pressure drops, the pressure switch, set for a pre-determined pressure, starts the pump.

Application : Where reticulated pressure water is unavailable, rural communities depend on private water supplies from rain water systems for domestic use. Holiday retreats, which are often built outside of reticulated water supply areas, also require an alternative form of water supply. Pumping equipment in the form of a pressure unit (Fig. 17) is the current trend for the provision of water supply for these types of applications.

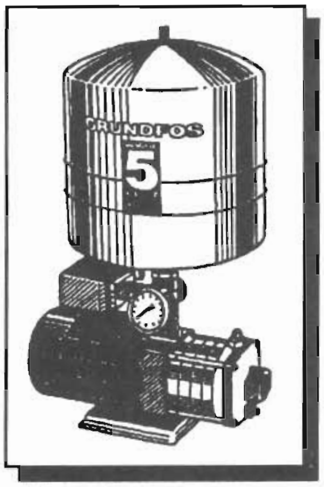


Fig. 17 - Pressure Unit

The popularity of pressure systems is brought about by their ability to provide water at close to reticulated mains pressure.

CENTRIFUGAL PUMP PERFORMANCE

The performance of a centrifugal pump is usually expressed in terms of the following of its characteristics and include:

(i) Capacity (Q) - expressed in volumetric units in a given time,
i.e. litres per second (l/s)
(ii) Head (H) - metres (m)
(iii) Power (P) - kW
(iv) Speed (N) - r.p.m.
(v) Efficiency (η) - as a ratio of useful work performed against power input,
i.e.

$$\frac{\textit{Water kW} \times 100}{\textit{Input kW}}$$

A pump performance curve is possibly the most satisfactory method of indicating graphically the relationship between head, capacity, power and speed.

The quantity of fluid delivered by a centrifugal pump is variable depending on the head or pressure against which the pump operates. This relationship can be established and plotted on a pump performance curve as in Fig. 18.

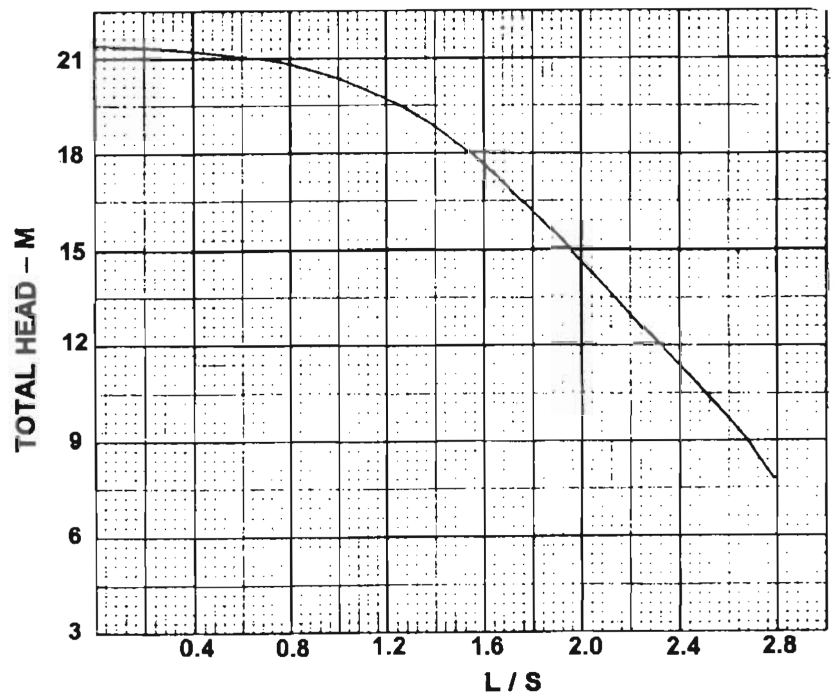


Fig. 18 - Typical HQ Curve

In addition to capacity and head, the other factors, namely speed and power, influence the pump performance and together with the pump efficiency, form the basis of a pump performance curve. (Refer to Fig. 19)

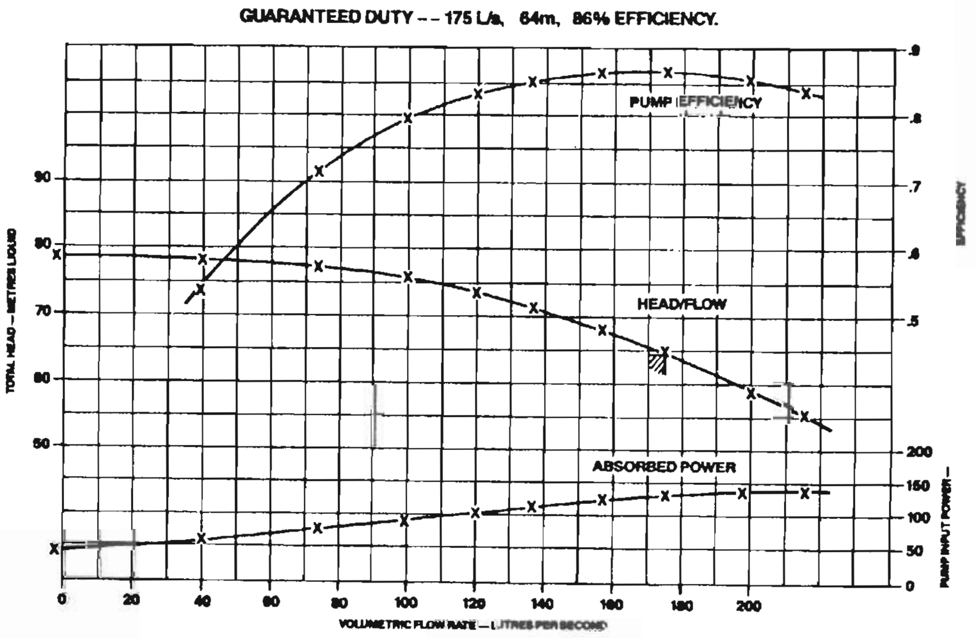


Fig. 19 - Pump Performance Curve

Pump impellers are designed to give maximum performance. Over the working range of a pump, the volume of fluid pumped and the head developed are approximately inversely proportional, that is to say, the head increases as volume decreases.

The quantity of fluid pumped and the power absorbed are roughly proportional. Discharge from a centrifugal pump operated at a constant speed can vary between no flow (shut off head or closed valve), to a maximum depending upon design and operating conditions.

Characteristics are represented by plotting head (H), power (P) and efficiency (η) against capacity (Q) as in Fig. 20.

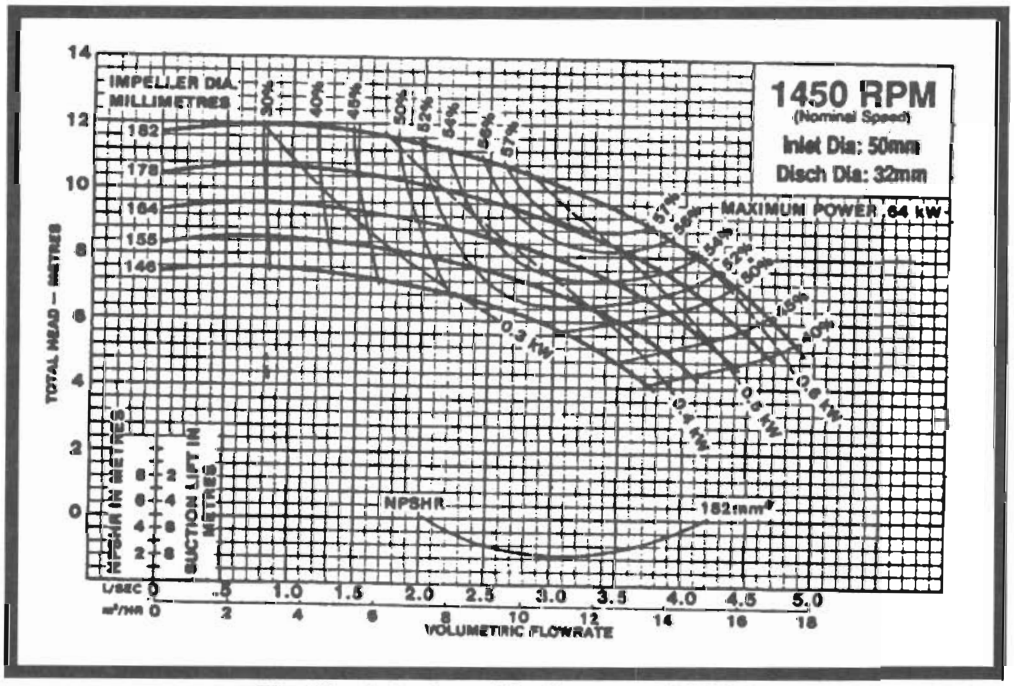


Fig. 20 - A Series of Performance Curves

Fig. 20 also shows a series of performance curves for the same pump. Variation occurs because the same impeller is machined to different diameters.

The shape of the head-capacity (HQ) curve may vary considerably, rising or falling steeply or being reasonably flat, depending upon the design of the impeller.

If the pump has a humped head-capacity whilst the power-discharge curve continues to rise beyond the 'design point', the pump is said to possess an unstable head and overloading power characteristic, as in Fig. 21.

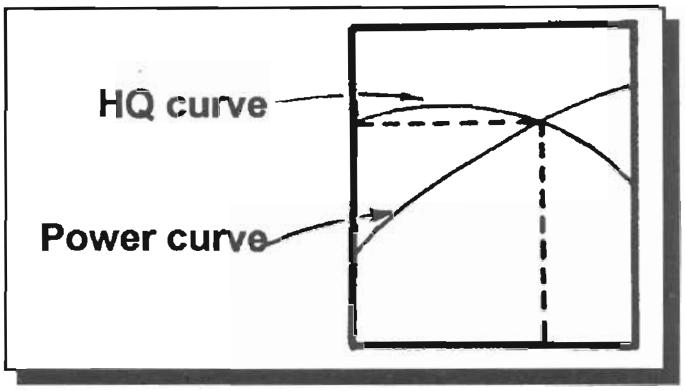


Fig. 21
shows an unstable HQ Curve and overloading Power Curve

Conversely, when the head curve falls continuously and the power curve reaches a maximum near the design point, the pump is said to be stable with non-overloading power characteristics, as shown in Fig. 22.

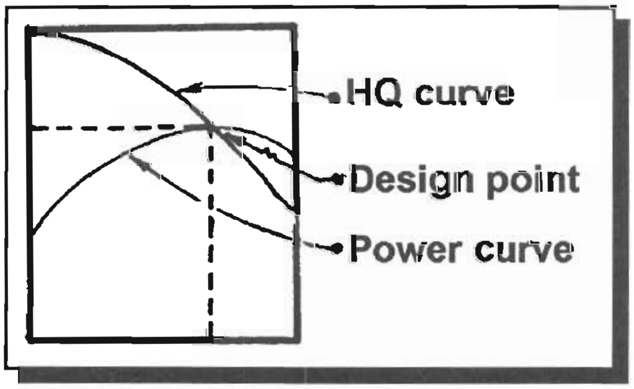


Fig. 22
shows a stable HQ Curve and non-overloading Power Curve

Relationship between capacity (Q), speed (N), head (H), power (P)

A performance curve of any pump varies with speed and is expressed by the following *pump laws.*

(i) The quantity of water delivered varies directly with the speed.

(ii) The head pressure varies directly as the square of the speed.

(iii) The power consumed varies directly as the cube of the speed.

The significance of these laws lies in the fact that if, for example, the quantity of fluid flowing through a system is doubled by doubling the pump speed, all the other conditions remaining the same, then the head is increased $(2)^2$ or four times and the power consumed is increased $(2)^3$ or eight times the original requirements. These relationships, indicating variations of flow and head for different speeds, are therefore best represented by a series of curves known as pump characteristic or performance curves.

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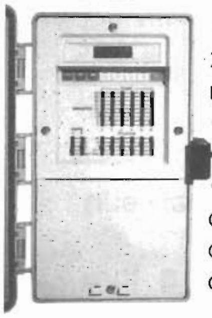

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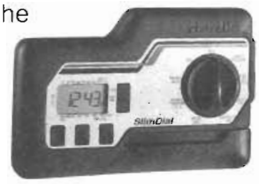

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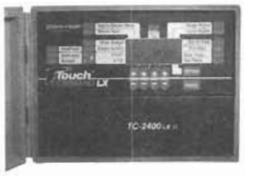

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CAPACITY

The capacity of a centrifugal pump refers to the quantity of fluid delivered in a definite time. It can be stated in any of the following metric units.

(i) litres per second (l/s)

(ii) litres per minute (l/m)

(iii) cubic metres per hour (m^3/h).

Every centrifugal pump has its characteristic curve which is the relation between capacity and head against which it will pump. An essential virtue of a true characteristic curve is that it is 'characteristic' of one particular pump only - it shows how that machine alone will behave. Any change in the shape or design of the pump rotor or casing will therefore be reflected in a change in the shape of the pump performance curve.

As resistance to flow external to the pump increases, capacity decreases until at maximum pressure, flow ceases entirely. This point is known as shut off head or closed valve with no useful work produced.

Between maximum discharge and shut off head the capacity and head vary in a fixed relationship at constant r.p.m.

Small capacity centrifugal pumps are usually fitted with large diameter and narrow water way impellers having simple curved vanes. As the desired capacity is increased, the diameter of the impeller is reduced, the width of the waterways increased and the vanes are designed with a compound, twisted curvature. For higher capacities and low head applications the mixed flow impeller is used. For maximum capacity and minimum head (little or no lift) the axial flow or propeller type impeller is the obvious choice.

Centrifugal pumps are manufactured in an endless variety of shapes and capacities. They are produced having fractional outputs ranging through to thousands of cubic metres per hour and operating against enormous discharge pressures, limited only by the strength of the materials involved.

HEAD

The required power to drive a centrifugal pump is a function of its capacity and head, against which it operates. The accuracy of head determination is important as a mistake in the calculation of head may result in the selection of a pump with unsuitable characteristics.

A centrifugal pump must develop sufficient head to discharge the required capacity of fluid while overcoming all the necessary resistances in the flow circuit. Pumps are rated in respect to the quantity of fluid pumped against a specific head.

Total head comprises a number of components and include suction and discharge conditions. The head necessary in overcoming friction in the conveyance system must be included, in addition to suction head or suction lift and discharge head, with velocity head being taken into consideration. The sum of all these elements needs to be considered in deriving the total dynamic head for every pump installation (Fig. 23).

Total head is basically composed of the following components:

(i) Static head
(ii) Pressure head
(iii) Friction head
(iv) Velocity head.

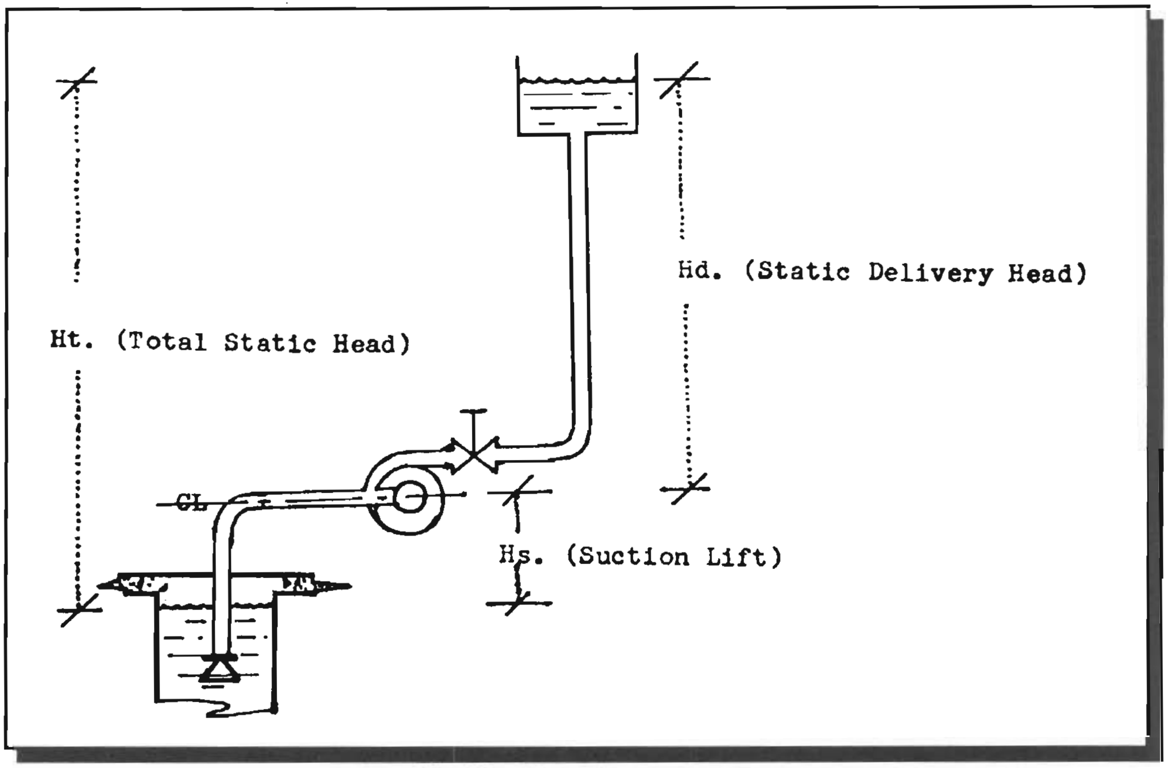

Fig. 23 - Head Components

(i) : Static Head

Static head is the vertical distance from the standing water level of the source of supply to the point of discharge.

A pump may operate against a fluctuating static discharge head such as in the case where the delivery column enters the bottom of a tank. If the liquid level in the tank is allowed to vary, say 1.8m, between high and low, the static head will change correspondingly as in Fig. 24. However, when calculating the total dynamic head on the pump, it is usual to take the vertical distance from the pump datum or centreline to the highest pumped liquid level in the tank.

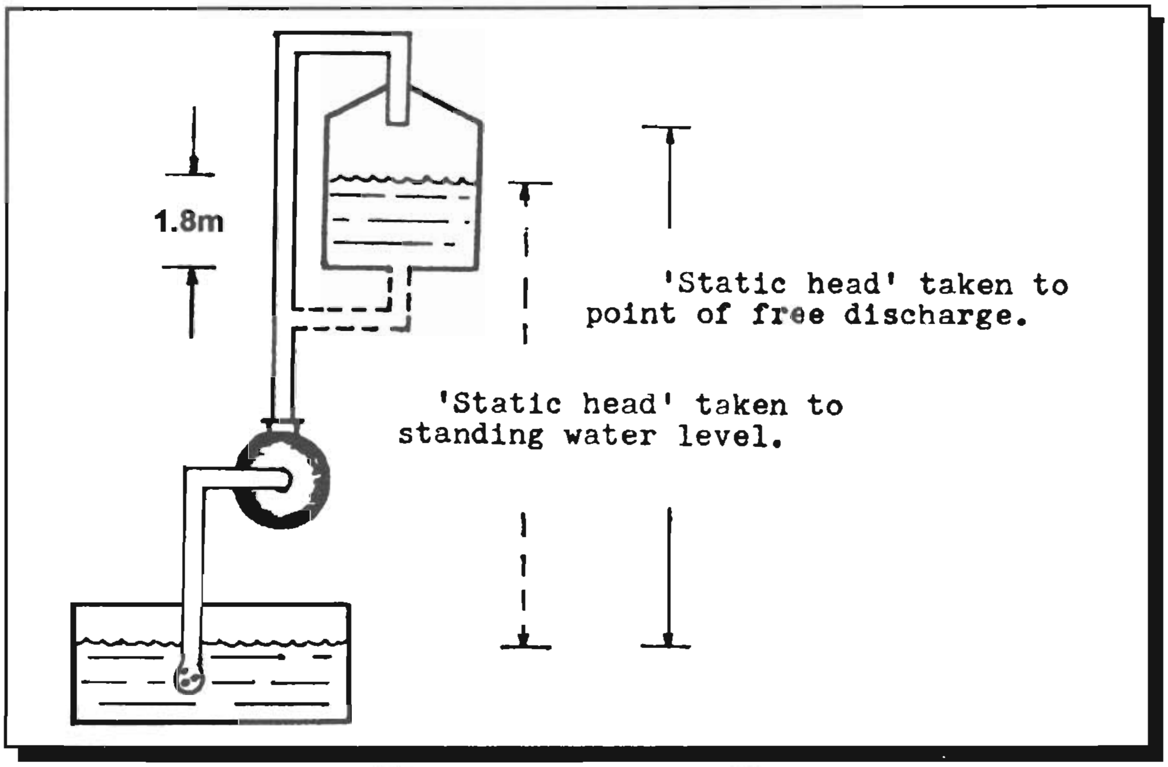

Fig. 24 - Distinction in Static Head

In closed systems, static pressure is balanced by the static pressure on the suction side and does not enter into pump selection. In an open system such as in a tank filling application, the static head is the height to which the liquid is raised and is the pressure due to the weight of a column of liquid which increases with height.

(ii) : Pressure head

Pressure head concerns closed receivers. For example, if pumping into a boiler or similar vessel, the pump must overcome the pressure in the vessel. This pressure must be added to the total head requirements. Conversely, the pressure head must be subtracted if the contents are pumped out of the vessel.

(iii) : Friction head

Friction head is the pressure absorbed in a liquid in motion between itself and its bounding surfaces. Friction losses are parasitical head losses due to velocity of flow, turbulence and changes in direction in a pipe transfer system. Friction losses usually embrace not only the skin friction between the piping and the moving liquid, but also other head losses arising from valves and fittings fitted to the piping. These can usually be determined from hydraulic data and are expressed as an equivalent length of straight pipe.

Friction head varies with the type of liquid being pumped, the material and its age as well as the pipe diameter. For a particular flow rate, friction increases as the pipe diameter decreases and length run increases.

Straight line friction is usually shown in chart or table form and is available in piping handbooks and manufacturers' information data sheets.

(iv) : Velocity head

The velocity head of a liquid moving with a given velocity is the equivalent head through which it would have to fall to acquire the same velocity. A pump develops velocity head when the velocity of the liquid being discharged is greater than the velocity entering at the pump suction.

Velocity head is generally so small that it is insignificant and can be neglected for most practical purposes. It should, however, be considered when the total dynamic head is small and suction lift is high.

SPEED

There is a fixed relationship between the performance of a centrifugal pump and changing rotor speeds. By running a centrifugal pump at a speed other than the design speed, a new head discharge and power characteristic can be plotted. Fig. 25 illustrates this principle. Speed is always expressed in revolutions per minute (r.p.m. or revs per min.).

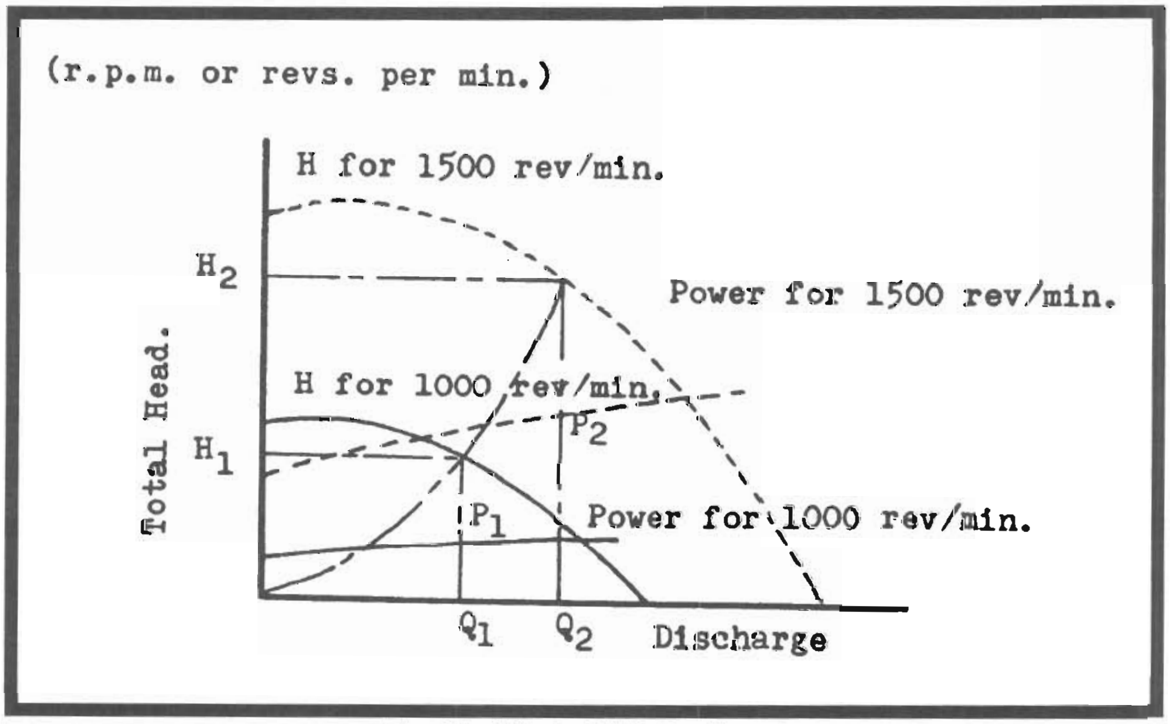

Fig. 25 - Effect of Altering Speed

If the pump performance at one speed is known, the characteristics at any other speed may be determined from a set of pump laws. Knowledge of these pump laws is useful for estimating the effect of changing the operating pump speed and are as follows:

(i) Quantity varies directly with the speed
(ii) Head varies as the square of the speed
(iii) Power varies as the cube of the speed.

If Q_1 (capacity), H_1 (head) and P_1 (power) are known for speed N_1, then Q_2, H_2 and P_2 corresponding to speed N_2 may be obtained from the relations:

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} \qquad \frac{H_1}{H_2} = \frac{(N_1)^2}{(N_2)^2} \qquad \frac{P_1}{P_2} = \frac{(N_1)^3}{(N_2)^3}$$

If Q_2 is required then

$$Q_2 = \frac{Q_1 \, x \, N_2}{N_1}$$

If H_2 is required then

$$H_2 = H_1 \, x \, \frac{(N_2)^2}{(N_1)^2}$$

If P_2 is required then

$$P_2 = P_1 \, x \, \frac{(N_2)^3}{(N_1)^3}$$

An important limitation of a centrifugal pump is that, at any particular speed, there is only one obtainable flow rate for a given head. Any change in the rate of discharge for a given head can be obtained by varying the pump speed. Fig. 26 shows a characteristic curve where speed is increased from 700 r.p.m. to 800 r.p.m., changing the pump capacity from 2.7 l/s to 5.3 l/s against an 18m head.

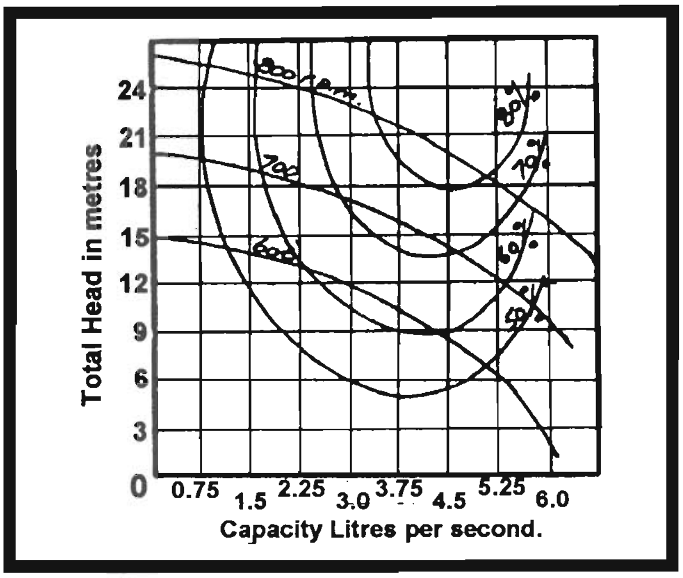

Fig. 26 - Speed: Capacity Relationship

Relationship between size of impeller and speed

The effects of impeller speed and diameter changes are analogous, although the calculation is less exact for large changes in diameter.

It is therefore possible to modify a pump duty by reducing the diameter of the impeller (sometimes referred to as impeller turndown) without altering the original speed.

This is a direct advantage, especially if dealing with direct coupled pump units where the speed cannot be easily modified to meet specific operating requirements.

From a standard range of pumps, manufacturers can match specified duties, more or less precisely, by selecting a pump having the required range of conditions, by altering a pulley diameter, hence the speed for belt driven pump units; or by cutting the diameter of the impeller for direct-driven pump units.

POWER

With centrifugal pump operation two power requirements may be evaluated:

(i) liquid power (water kW)

(ii) mechanical power (kW).

Water kW power is the product of the weight of the fluid being pumped, pump head and the conversion factors. Water kW is the theoretical power that would be necessary if the pump was 100 per cent efficient. Of the total work done in pumping liquids, part is expended in raising the fluid from one level to another, part is used to produce velocity of flow and part is dissipated in overcoming frictional resistances in a pump circuit.

The work done per unit weight of liquid in pumping is expressed as follows:

$$ht = hr + \frac{V^2}{2g} + hf$$

where

ht = total head against which the pump operates

hr = vertical height fluid is raised

V = velocity of flow from pump discharge (m/s)

g = gravitational acceleration (9.81 m/s^2)

hf = frictional head losses.

Due to the liquid turbulence in the pump, friction arising from the pumped fluid in the pump casing and friction loss in bearing and other moving parts, the energy output is always less than the input, (e.g.) output = input - losses.

Mechanical kW power is the actual power output at the shaft of the prime mover and is calculated by dividing the pump efficiency into the water kW. kW power is indicated on a pump performance curve as illustrated in Fig. 27.

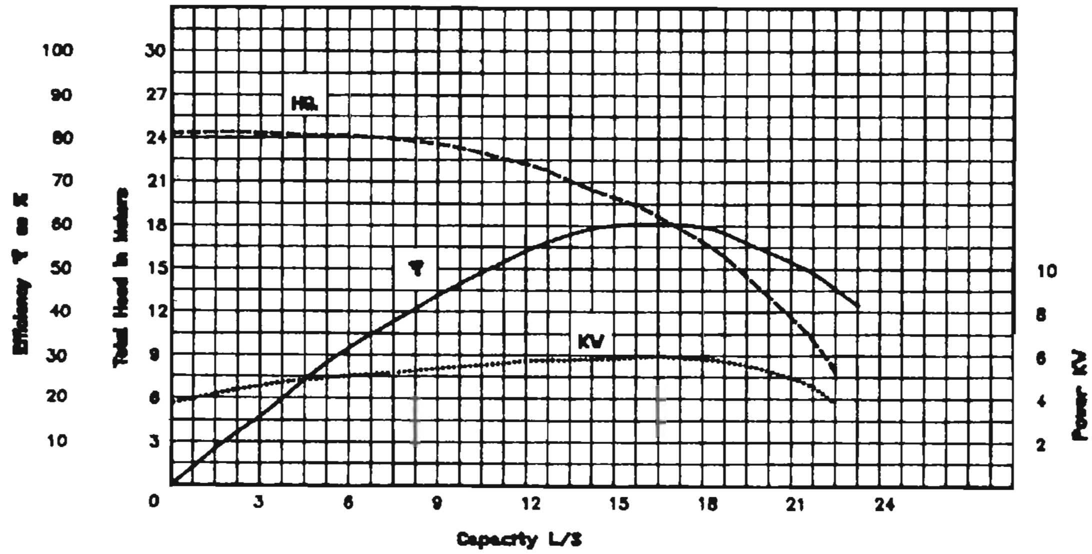

Fig. 27 - Performance Curve

Power consumption is least at pump shut-off and increases with an increase in capacity. The power curve shown on the above pump performance curve reaches a maximum value, then drops. The drop-off point normally occurs in the area of maximum capacity, which is beyond the most desirable operating range of the pump. It is evident from Fig. 27 that a 6kW motor would operate under all conditions, irrespective of the system head. This means that the pump motor would not be overloaded over the full working range of the pump.

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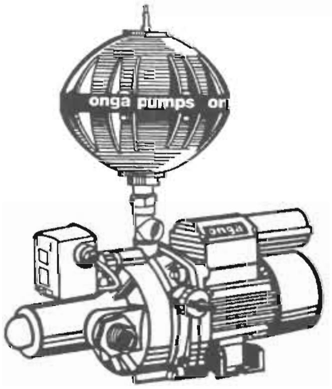
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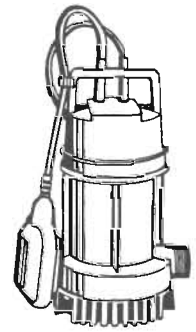
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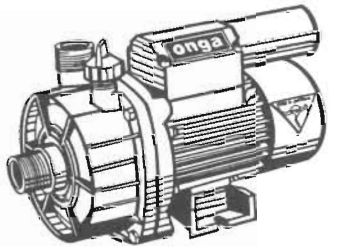
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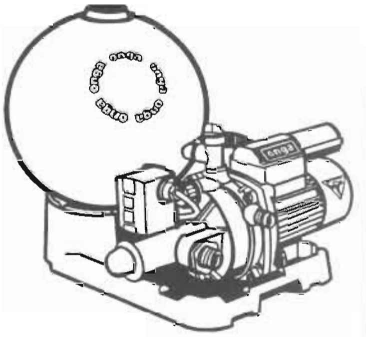
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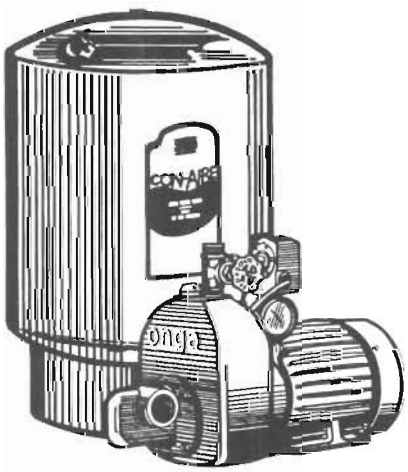
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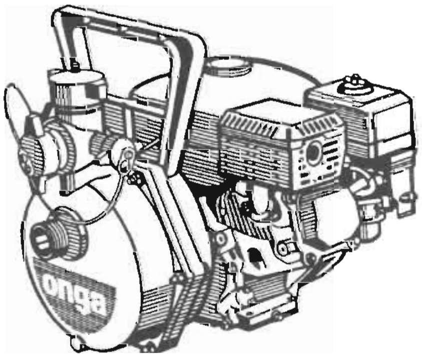
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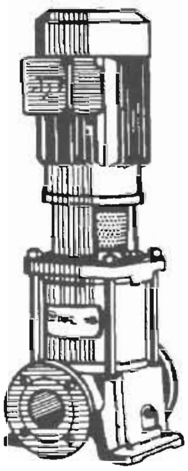
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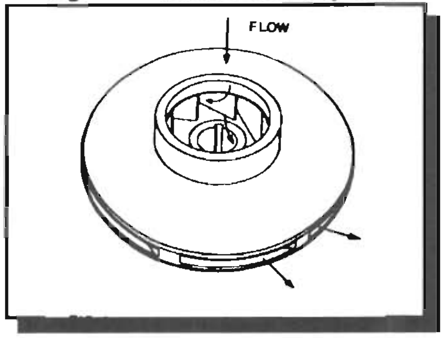
IMPELLERS

Without doubt the two major elements of any centrifugal pump are a rotating impeller which is fixed on to a shaft fitted with seals and bearings and a surrounding casing. The impeller imparts velocity to the fluid being pumped whereas the casing converts the energy into pressure.

Fig. 28 - Radial Flow Impeller



Centrifugal pumps are distinguished from one another, apart from obvious features and geometry, by the type of impeller design; that is, they are categorized according to the direction of fluid flow through the impeller. Impellers are also classified by the shape of their vanes.

The variety of impeller designs include the following types:

(i) Radial or straight flow
(ii) Axial flow
(iii) Mixed flow.

Radial flow impellers are shaped so that the liquid leaves at right angles to its axis (Fig. 28). Axial flow impellers are designed so that the liquid enters and leaves the impeller parallel to its axis (Fig. 29).

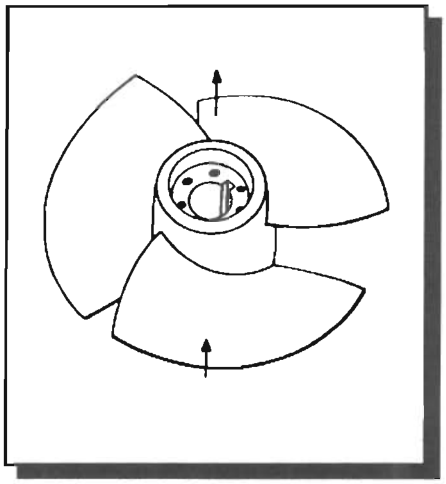


Fig. 29 Axial Flow Impeller

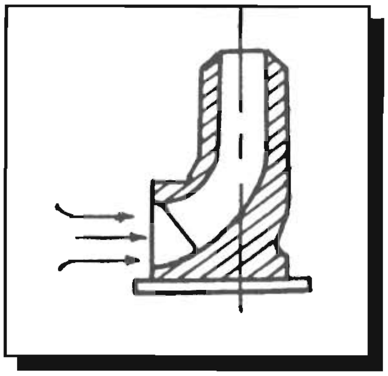


Fig. 30 - Section: Single Entry Impeller

Mixed flow impellers are constructed so that the liquid being pumped enters the impeller in an axial direction and leaves it in a radial and axial path (Fig. 31).

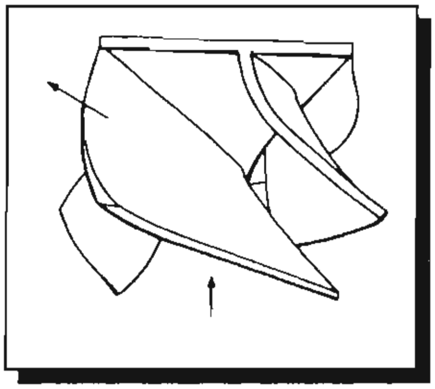


Fig. 31 Mixed Flow Impeller

Impellers are further classified according to the flow arrangement into the impeller and fall into two categories:

- (i) single suction entry
- (ii) double suction entry.

Single suction impellers have a single inlet, therefore the liquid enters from one side only (Fig. 30).

A double suction impeller is, in effect, two single suction impellers arranged back to back with the liquid gaining entry into the impeller from both sides (Figs. 32 and 33).

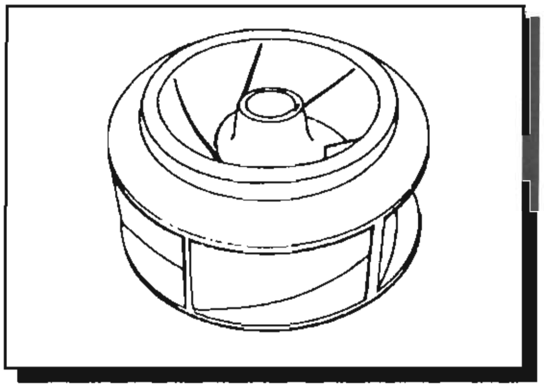


Fig. 32 - Double-Suction Impeller

Impeller design by and large is dependent upon pump application and duty but fall into three groups:

- (i) open impeller type
- (ii) semi-enclosed
- (iii) enclosed.

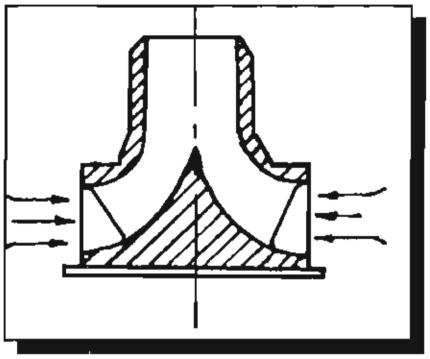


Fig. 33 - Double Entry Impeller

The open impeller has no side walls and the vanes are attached to a central hub (Fig. 34).

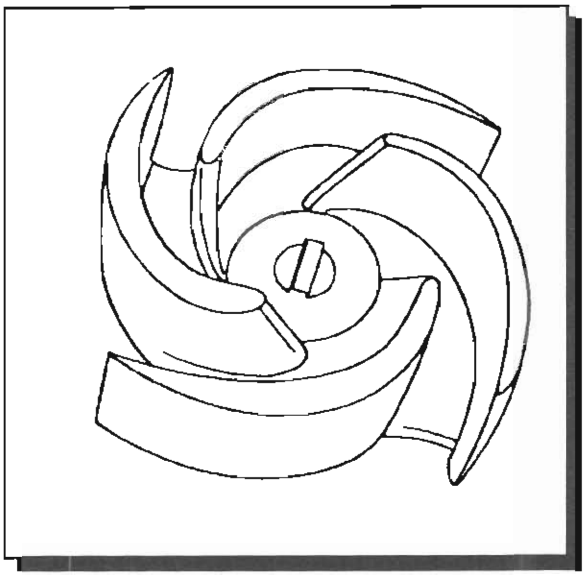


Fig. 34 - Open Impeller

Open impellers are generally used in pump applications where fluid material contains a large proportion of entrained solids; e.g. sewage, as this material has a tendency to clog. The semi-enclosed impeller has one side wall or shroud, making it structurally stronger than the open type (Fig. 35).

The totally enclosed or shrouded impeller is the most commonly used impeller for the pumping of clear fluid. The side walls completely enclose the impeller waterways, water slip is therefore overcome because of the shrouded design (Fig. 36).

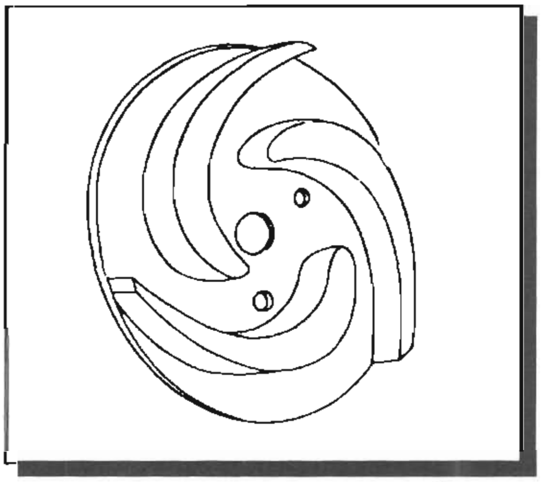


Fig. 35 - Semi-enclosed Impeller

It is the plain flow (radial) shrouded impeller that is the most popular design in the mechanical services area.

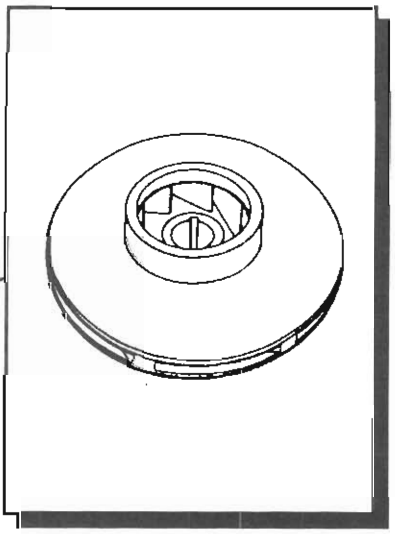


Fig. 36 - Enclosed Impeller

CAVITATION

Cavitation is a term given to the formation of vapour bubbles in areas of low pressure and their subsequent collapse upon reaching regions of higher pressure. This is the direct result of the pump selected having insufficient NPSH (Nett Positive Suction Head) at the suction eye of the impeller.

The property which concerns cavitation is the fact that liquids do not have to be hot to boil and the temperatures at which liquids boil vary with pressure. If the pressure is brought down low enough, for example, to the point of the 'vapour pressure' of the liquid, it will boil and vapour bubbles will form even though the water may be quite cold.

Water boils at 100°C at a pressure of one atmosphere at sea level in an open vessel. Now, if the vessel were to be sealed and pressurized to 690 kPa the water would boil at about 165°C. When water is hot, cavitation will be more rapid as only a slight reduction of pressure may bring it down to vapour pressure and cause boiling.

The lowest pressure region of a centrifugal pump is in the eye of the impeller where there is a substantial local pressure drop and is dependent upon pump design, flow rate and pump speed.

In a centrifugal pump the liquid travels at a high velocity into the eye of the impeller and is already at a considerably reduced pressure. A change in direction of flow from axial to radial may further reduce the pressure so that vapour bubbles form in low pressure regions of an impeller. Almost immediately these bubbles are carried along to regions of higher pressures where they will suddenly collapse or implode with a tremendous shock. The bubbles cannot exit if the surrounding pressure is in the slightest above the vapour pressure of the liquid.

Effects of cavitation

(i) If the bubbles happen to be in contact with the walls of the passage, the liquid rushing in to fill the spaces generates a type of water hammer. Continuous and persisting collapse of these bubbles will eventually result in the metal walls being damaged.

(ii) Chemical reactions between the gases in the bubbles and the metal often occur and result in additional damage of the metal.

(iii) Because of flow disturbances set up in areas subject to cavitation, the entire performance of the pump may deteriorate.

When cavitation occurs in a centrifugal pump audible crackling sounds are produced which can be likened to a pump pumping stones.

In many cases it is necessary to have positive suction heads to avoid cavitation when pumping hot liquids.

Precautions taken by pump manufacturers against cavitation problems with modern pumps include specifying minimum pressures which are required at the pump inlet above fluid vapour pressure.

Tests are carried out under the most severe conditions and the figures are represented on pump performance curves.

NPSH (Nett Positive Suction Head)

Nett positive suction head is a pressure above the vapour pressure for any pumped liquid and is measured at the pump suction by means of a pressure gauge fitted at the centre line of the pump.

Centrifugal pumps are generally incapable of handling quantities of air or vapour without losing prime. Now sufficient pressure on the liquid at the pump suction is necessary to prevent the liquid from flashing into vapour at the point of the lowest pressure, which is the eye of the impeller.

The required NPSH by the pump is dependent upon the particular pump design and its operating speed. NPSH required also varies with flow rate, increasing considerably at higher flow rates.

Cavitation will be avoided if the available NPSH is not less than the appropriate value required by the pump.

The available NPSH is dependent upon the system, i.e. suction lift or suction head, friction loss, barometric pressure (barometric pressure varies with altitude) and the vapour pressure of the fluid at its operating temperature.

The pump manufacturer is responsible for testing and publishing data for NPSH required by the pump for varying capacities and speeds.

Minimum required NPSH is the value read off the graph for the maximum flow rate in question. The system available NPSH is pressure of the fluid above absolute zero at the pump inlet minus the vapour pressure.

For Suction Lift:

$$(Hb - H_L - Hf) - hv = NPSH.A$$

For Positive Suction

$$(Hb + Hs - Hf) - hv = NPSH.A$$

where Hb = barometric pressure

H_L = suction lift

Hs = suction head

Hf = frictional losses in suction system

hv = vapour pressure.

Available NPSH must always be greater than the required NPSH in order for the pump to operate satisfactorily and avoid cavitation. It is recommended practice to have a safety margin of at least 0.5 metres between NPSH.A and NPSH.R for mass produced pumping equipment. Special considerations may apply to large and/or high speed pumps.

SELECTION

Centrifugal pumps are selected primarily on the basis of capacity and the total head against which the pumped fluid is to be delivered through the transfer system.

With the extensive range of rotodynamic pumps offered today, there is little difficulty in selecting pump units to meet the necessary requirements.

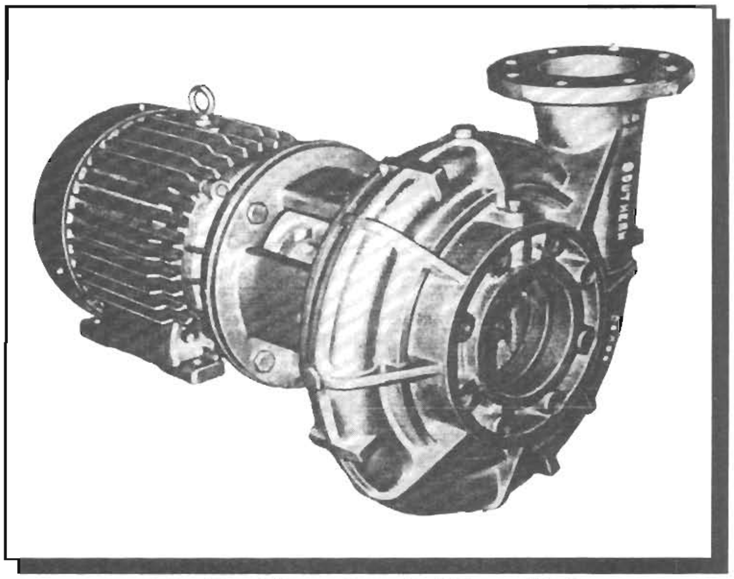


Fig. 37 - Close Coupled Pump Unit

Many types are available, for a variety of duties and applications. There are, for example, direct-coupled and close-coupled, single-stage, volute designs fitted with either enclosed, semi-enclosed or open type impellers (Fig. 37).

Other designs include single and double entry impellers, with radial, mixed flow and axial flow configurations; split horizontal and vertical casings to facilitate maintenance or inspection procedures (Fig. 38) and single or multi-stage operation.

Small single stage centrifugal pumps are relatively inexpensive and normally embody a single stage impeller.

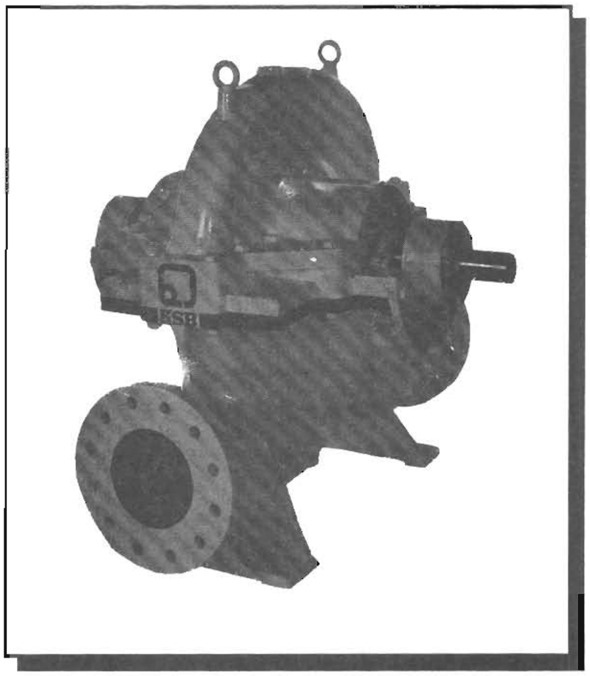


Fig. 38 - Horizontally Split Pump

Multi-stage designs incorporating a series of impellers fixed onto a common shaft are used in high pressure applications (Fig. 39). There is a wide variation in the functioning, initial cost and operating costs of the many designs.

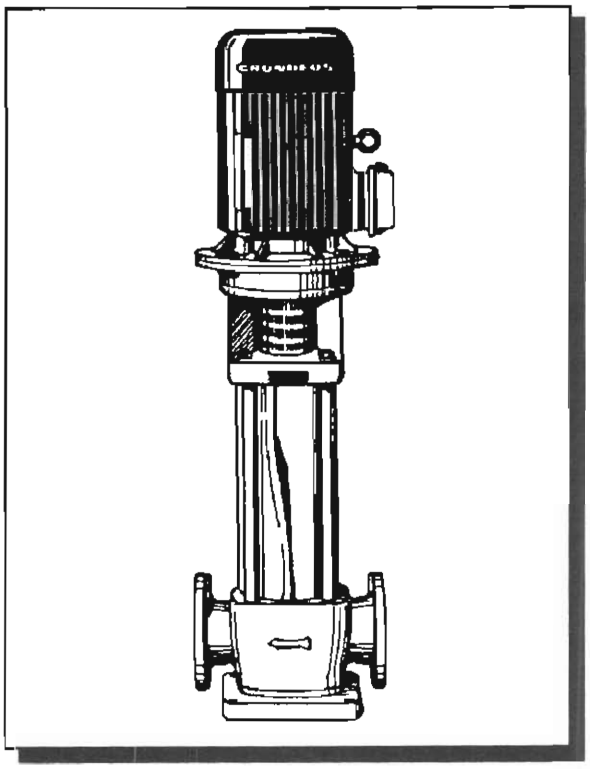


Fig. 39 - Multi-stage Pump

The fluid to be handled will influence the selection and the type of material used for the construction of the pump casing and components. Generally, the price of materials increases with their resistance to corrosion.

Different pump sizes vary as to the duties they can perform and reference to manufacturers' curves give guidelines to pump selection (Fig. 40).

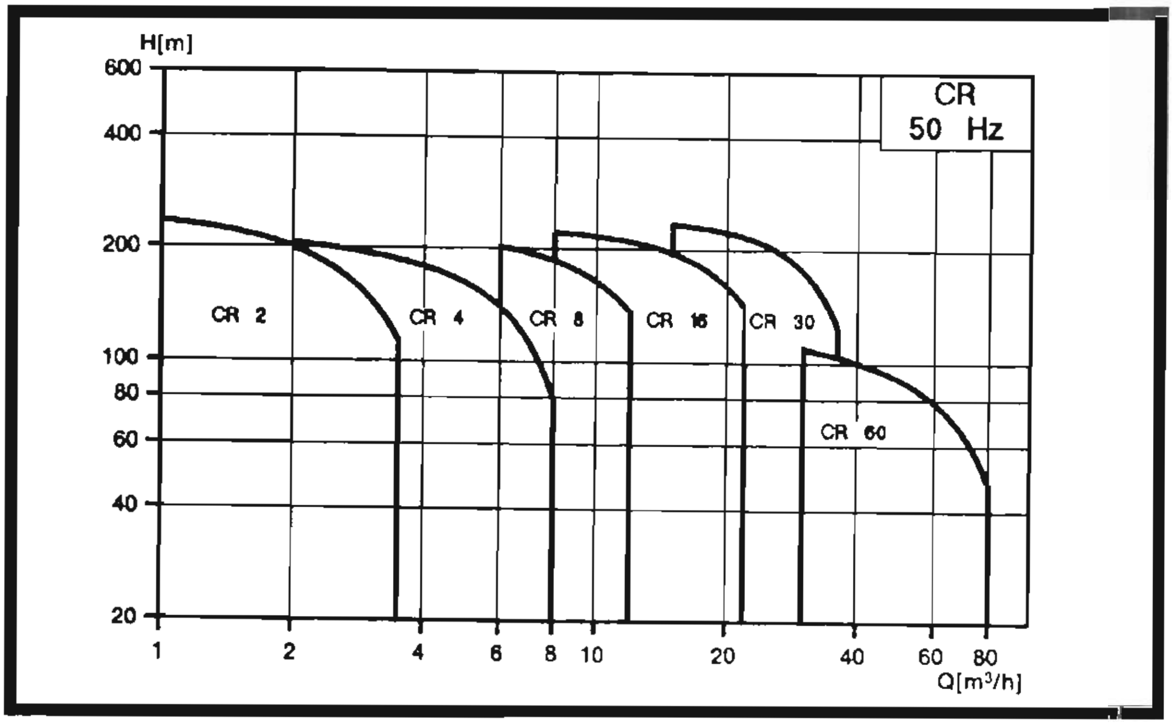


Fig. 40 - Typical Pump Selection Curves

Pumps are frequently rated in terms of their discharge size (diameter).

The power (kW) of the prime mover necessary to drive the pump is also an important consideration in the overall selection of a suitable pump unit. There is always the danger of the pump characteristics being altered from the original operating point and overloading the motor. A safety margin should therefore be provided. Protection against overloading can be satisfactorily accounted for by selecting a motor having a power potential in excess of that required by the pump system.

It is most important that all relevant information be given to the pump manufacturer, including the conditions under which the pump will have to operate, regarding its environment.

INSTALLATION

The correct installation procedures with centrifugal pumps is essential to gain maximum efficiency and, if properly installed and given reasonable care and maintenance, should operate in peak operating conditions giving trouble-free service. Important considerations should include such features as:

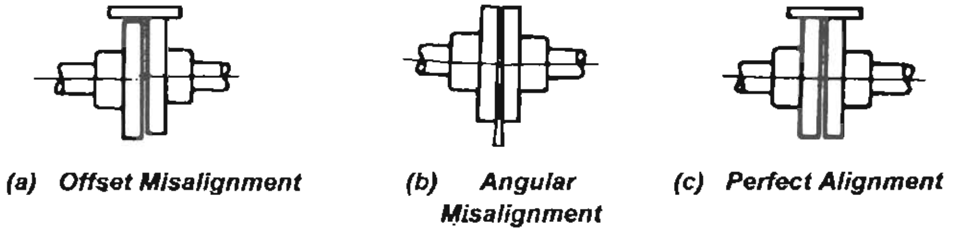
- adequate space, head room, ventilation and lighting in order to facilitate maintenance and repair work
- correct alignment procedures of pump and motor shafts with direct coupled units
- provision for adjustment and proper pipe support fitted to selected flanged fittings for ease of dismantling.

Obvious conditions such as suction lift should be avoided or reduced to a practical minimum.

When installing a centrifugal pump the general rule is to locate it as close as possible to the pumped liquid source. To ensure maximum performance, a pump site having a short, direct suction pipe with minimum lift is favoured. For practical purposes it is recommended to locate the pump within 4.5m of the lowest liquid level.

Alignment is facilitated by the use of wedges and shims under the base plate and on both sides of the mounting bolts. This will level the pump unit on the supporting base. The pump must also be aligned with the prime mover and, in most cases, is carried out in the factory workshop. It should, however, be checked for angular and parallel alignment when placed in situ. (Ref Figs. 41 a, b, and c.)

Figs. 41 - Pump Alignments



(a) Offset Misalignment   *(b) Angular Misalignment*   *(c) Perfect Alignment*

Grouting of the pump base is usual and consists of pouring a thin mortar under the base to prevent lateral movement of the base plate and reduce vibration. With large pumps it is usual to provide a concrete base and mount the pump unit separately and secure to steel bolts set into the concrete as in Fig. 42.

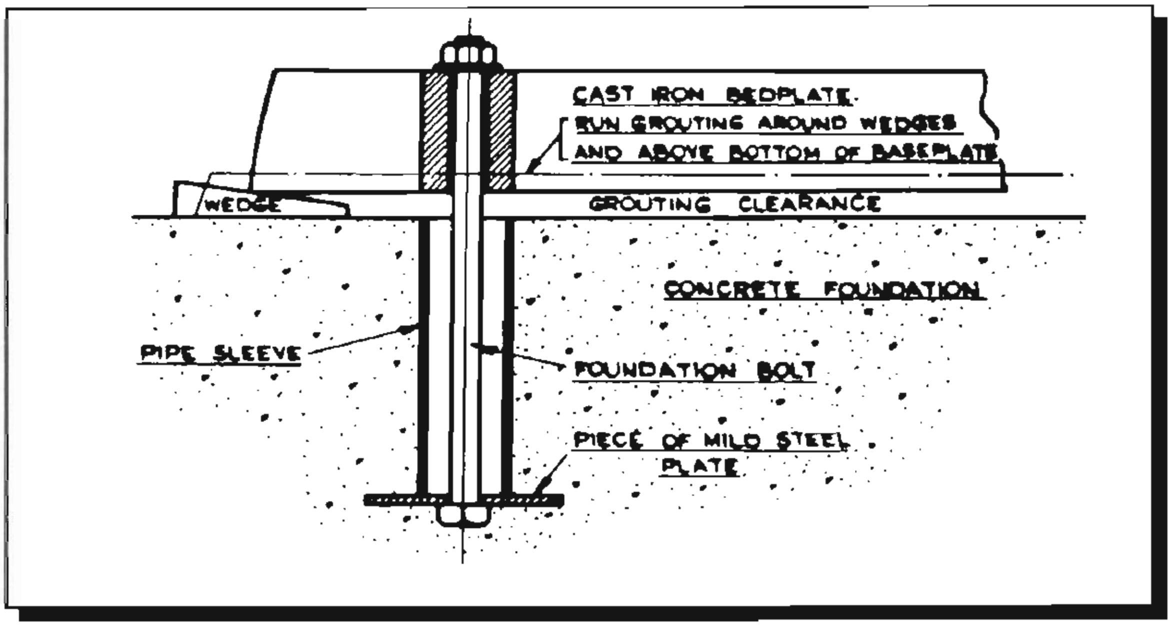


Fig. 42 - Grouting of Pump Base

Piping

Suction and delivery lines must be supported independently of the pump and fitted with vibration eliminators (as in Fig. 43), especially in building applications in which reduction of noise and vibration is of paramount importance.

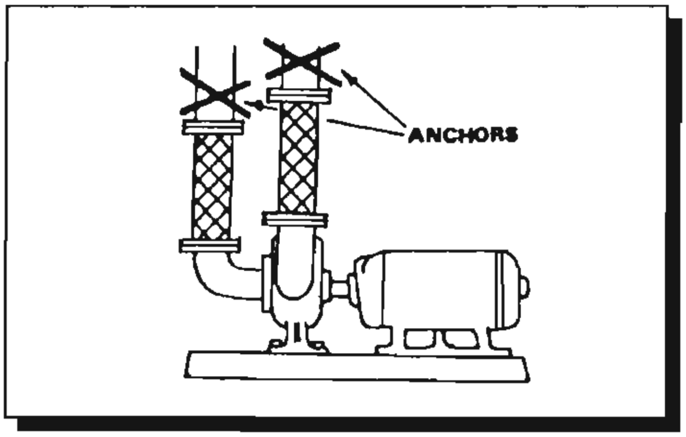


Fig. 43 - Vibration Eliminator

Piping must match up with its respective flanges without imposing unnecessary strain on to the pump casing. Forced alignment results in a distorting effect on the pump housing and could also interfere with the alignment of the pump unit, causing excessive wear and heat on the pump bearings.

Installation of pumps used for hot water applications must be treated with particular caution. Adequate provision for expansion in the form of flanged expansion joints shown in Fig. 44 must be allowed for so that stresses do not influence.the pump operation.

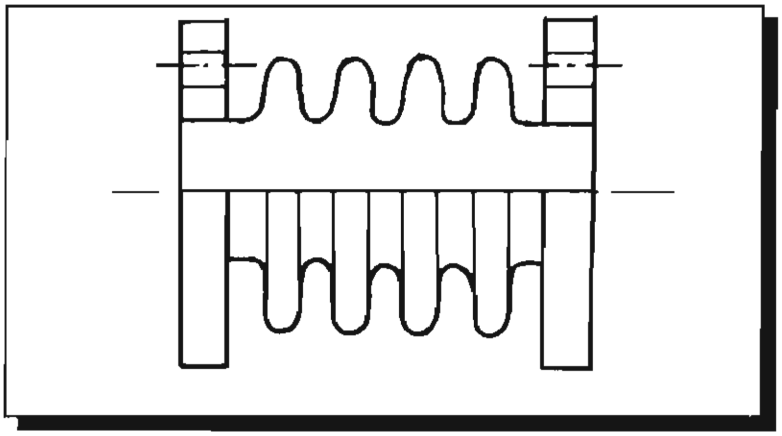


Fig. 44 - Typical Expansion Joint

As previously stated, the suction pipe should be as short and direct as possible and must never be smaller than the pump suction nozzle. Bends should be used in preference to short radius elbows as the latter increases entrance losses.

Every precaution must be taken to ensure that the suction pipe is absolutely air tight and free from air pockets (Figs. 45 and 46). It is necessary that a continuous fall be maintained from the pump inlet to the liquid intake, to prevent potential air pockets forming.

The discharge piping should be of sufficient diameter to convey the required pump capacity without creating excessive friction head. The discharge line should always be fitted with an appropriate regulating valve. In the majority of cases a conventional gate valve is used, although a globe valve should be fitted if throttling is necessary.

Suction Details

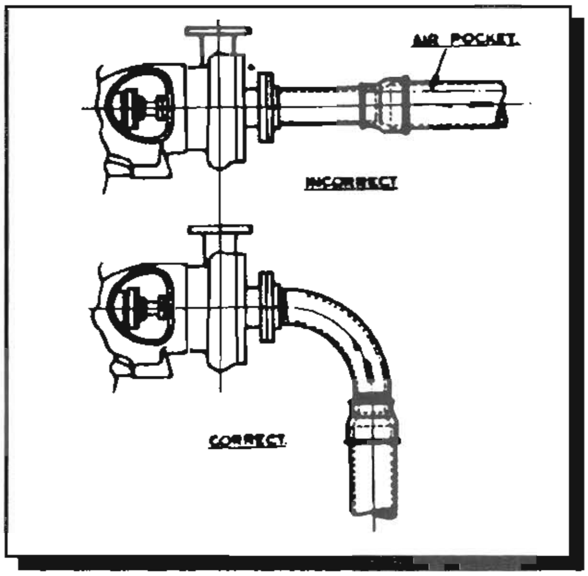


Fig. 45

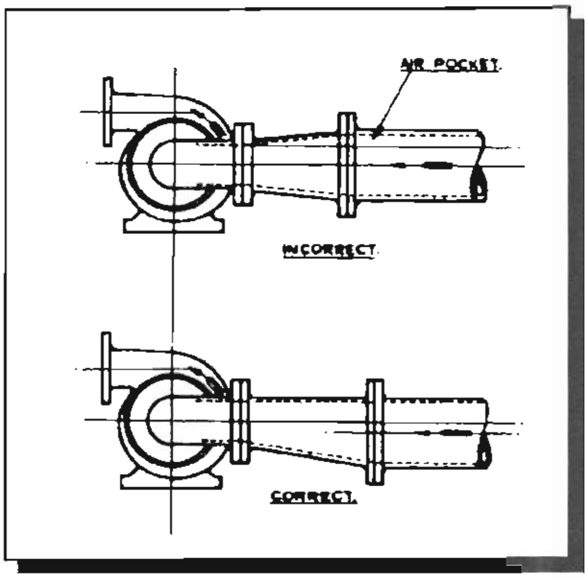


Fig.46

It is also advisable to have a reflux valve fitted on the discharge pipe as in Fig. 47. The function of this valve is to prevent back flow back into the pump.

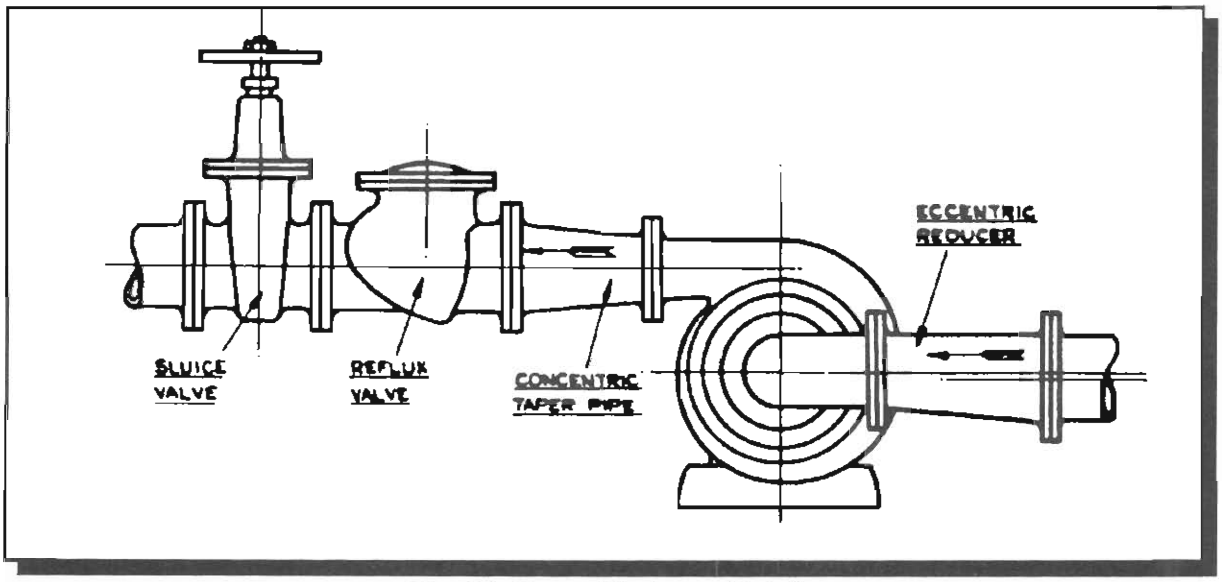


Fig. 47 - Pump Discharge Details

It should be realized that the complete installation must be considered and not only the pump. This is particularly brought out with rotodynamic pumps, whose performance may be directly altered by the system of which they form part.

OPERATION

Centrifugal pumps are capable of operating over a variety of capacities and pressures, ranging from no flow (shut off head) to a maximum rated capacity. This unique behaviour is sometimes made use of, if the pump is required for operation where duties change from the most severe to normal working conditions.

In starting a centrifugal pump, the procedure depends to some extent on the size of the pump unit. Pumps requiring up to 2kW for full load operation can be started under load without special precautions. Under other circumstances it may be necessary to start the pumping unit with the regulating valve at the discharge end fully closed, then gradually opened as the pressure builds up in the pump casing. This procedure will guard against the risk of overloading the driving motor. Operating at shut off head for prolonged periods is not recommended as this will lead to overheating of the pump by the pumped fluid.

In routine operation of centrifugal pumps consideration should be given to the following:

Rotation: The direction of the pump rotation must be checked. This is determined when viewed from the suction end of the pump in the majority of cases and is then said to be running anti-clockwise. A further check can be made by turning by hand at the unit coupling to see that the rotating parts are free.

Piping: Pipework cleanliness is necessary for the proper functioning of the pump. Centrifugal pumps, especially multi-stage units, have close clearance parts which need to be protected from abrasive material such as fillings, often found in new piping systems. Complete flushing of pipework is advisable prior to running the pump.

Priming: Pumps other than self-priming or the submerged type units require priming prior to operation. This means that the suction piping, together with the pump casing, must be filled with liquid. The pump should not be operated unless it is completely filled with the fluid to be pumped. There is a danger of damaging housed components which depend upon liquid for operation.

Priming includes the complete expulsion of air for efficient operation. Provision for an air-relief valve at the top of the pump casing may sometimes be necessary to purge unwanted trapped air.

Lubrication: Lubrication may depend on grease or oil and the cups containing the lubricating medium should be topped up. Packing may bind or run hot; if so, the packing gland should be freed sufficiently to allow water to drip from them. Packing should be constantly kept wet.

Noises: Pump noises other than mechanical are a sure indication of trouble. These noises can be caused by a number of reasons and, in the majority of cases, are a product of poor design and installation. Pipework noise, cavitation, water hammer and unbalanced impeller are the chief factors responsible for undesirable hydraulic noises.

Operating requirements vary with pump types as well as specific installation. Recommended procedures are specified by the pump manufacturer and, if carried out, will result in trouble-free operation.

MAINTENANCE

Modern centrifugal pumps are designed to operate efficiently over extended periods provided they are selected wisely. They will, however, require regular inspection, care and maintenance to prevent breakdown and to obtain longer service life.

Replacement of wearing parts may be necessary depending upon the service conditions to which the pump is applied. Periodic inspection procedures will enable a close check to be kept on the wearing parts so that replacement can be effected during scheduled maintenance times and not during operation.

Maintenance operations fall into two categories and include:

(i) Routine preventive maintenance
(ii) Overhaul or repair operations.

Routine maintenance may be classified as work carried out primarily to rectify the effects of normal pump wear.

Overhaul or repair operations include repair work which is carried out to rectify the effects of excessive wear. Pumps operating continuously under load and damage to the water end of the pump as a result of cavitation are typical examples of the latter category.

A complete progressive record card should be kept on the pump, detailing check data, maintenance intervals and operations carried out at these intervals. The card should include details regarding the pump type, size, serial number, rated conditions and name of manufacturer. This information is extremely useful when ordering replacement parts and during maintenance.

Most manufacturers specify the intervals for general maintenance such as lubricant changes and the replacement of gland packing and seals; this could vary, however, depending upon the service conditions.

In some pump designs which are built for severe service conditions, provision is made for ease of inspection, removal and replacement of worn components such as in horizontal split casing centrifugal pumps. This construction eliminates the complete stripping down of the pump.

Internal wear can usually be predicted by a fall-off in pump performance and will be apparent from pressure gauge readings. An increase in power consumption will indicate a loss of pump efficiency and can be checked against the record card.

It is not possible from general instruction to define close limits of wear. Such limits depend on the purpose for which the pump is supplied and the extent to which it becomes necessary to maintain the pump in as new condition. The amount of wear permissible must be judged against increased operating costs due to lower operating pump efficiency.

It is recommended that a full inspection of the unit be carried out within a reasonable time after commissioning. Such an inspection will determine the frequency of future inspections.

TROUBLE SHOOTING

The following trouble shooting table is included as a guide to assist in locating trouble if problems arise during pump operation.

TROUBLE	PROBABLE CAUSE	POSSIBLE REMEDY
A. No discharge	1. Pump not primed.	1. Check priming.
	2. Speed too low.	2. Correct wrong or poor electrical connections. Check belt drive pulley diameters or excessive slip. Check engine condition and performance.
	3. Discharge head too high.	3. Check discharge pipe diameter and clear obstructions, if any.
	4. Suction lift higher than that for which the pump was designed.	4. Relocate unit to reduce suction lift.
	5. Impeller completely plugged.	5. Back flush with clean water. Disassemble pump to remove obstruction, if necessary.
	6. Wrong direction of rotation.	6. Correct drive rotation.

TROUBLE	PROBABLE CAUSE	POSSIBLE REMEDY
B. Insufficient discharge	1. Air leaks in suction or gland.	1. Locate and seal.
	2. Speed too low.	2. See A2.
	3. Discharge head too high.	3. See A3.
	4. Suction lift too high or insufficient NPSH	4. Check with gauges. Check for clogged suction line.
	5. Impeller partly plugged.	5. See A5.
	6. Mechanical defects. Parts badly worn.	6. Check and replace where necessary.
	7. Wrong direction of rotation.	7. See A6.
	8. Impeller diameter too small.	8. Fit impeller with larger diameter.
C. Insufficient pressure	1. Speed too low.	1. See A2.
	2. Air or gases in liquid.	2. Check pump application and endeavour to prevent ingress of air or gases.
	3. Mechanical defects. Parts badly worn.	3. See B6.
	4. Impeller diameter too small.	4. See B8.
	5. Wrong direction of rotation.	5. See A6.
D. Loss of suction following period of satisfactory operation	1. Leak in suction line.	1. See B1.
	2. Water seal plugged.	2. Strip and insert new packing.
	3. Suction lift too high or insufficient NPSH	3. See B4.
	4. Air or gases in liquid.	4. See C2.
	5. Casing gasket defective.	5. Replace gasket.

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TROUBLE	PROBABLE CAUSE	POSSIBLE REMEDY
E. Excessive power consumption	1. Speed too high.	1. See A2.
	2. Head lower than rating; pumps too much liquid.	2. If direct coupled - reduce impeller diameter. If belt driven - reduce speed by fitting larger pump pulley.
	3. Specific gravity or viscosity of liquid too high.	3. Fit new driver with higher rating.
	4. Mechanical defects: shaft bent or broken.	4. Replace shaft.
	Rotating elements bind.	Reset impeller clearance.
	Gland too tight.	Replace and/or re-adjust packing.

PUMP CALCULATIONS

For all practical purposes the total head against which a pump operates consists of the sum of the following:

(i) Static suction lift

(ii) Suction pipe friction:
Head loss in the suction pipe and fittings varies with pipe size, material and quantity of liquid being pumped.

(iii) Static delivery suction head

(iv) Discharge pipe friction:
Head loss in delivery pipe and fittings and also varies with pipe size, material and quantity.

The equivalent pipe lengths for various valves and fittings is shown in the Appendices.

The following examples will serve to illustrate the effect of pipe friction on the total head. The need for proper pipe sizing has an ultimate bearing upon the size of the pumping unit and, more importantly, the cost of pumping.

Example 1

System requirement

Pump unit to deliver 3.8 l/s of clear water using galvanized steel pipe into an overhead storage tank. Pump to operate against a static suction lift of 1.5m and static discharge head of 6m.

Example 1

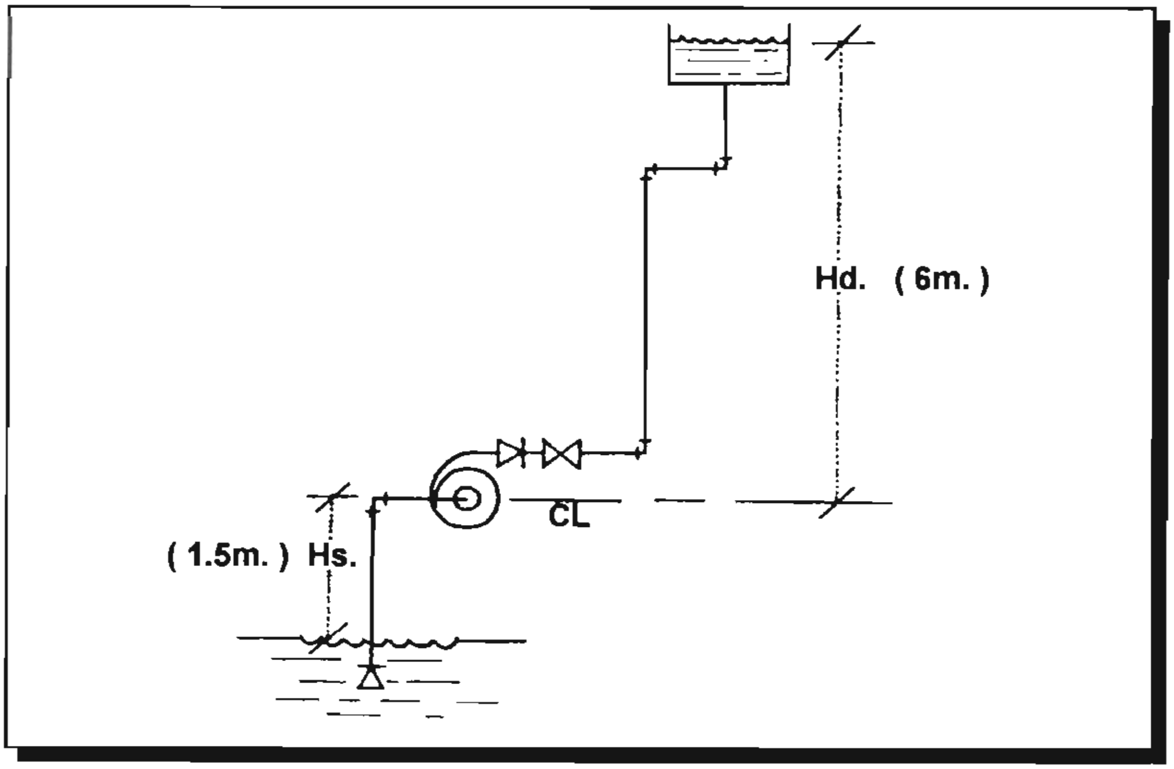


Fig. 48

Example 2

System requirement: Pump to deliver 106 l/s of clear water to a point 39m above the source of supply. The static discharge head (Hd) is 36m and the static suction lift (Hs) 3m. A total of 46m of galvanized steel piping is required for the complete installation which is made up of 200mm diameter for the delivery and 250mm diameter for the suction end.

Calculation of Total Head

	Using 50mm suction 40mm delivery		Using 50mm suction 50mm delivery	
Suction	e.l. of str pipe in m.	Head in m.	e.l. of str. pipe in m.	Head in m.
F/V and Strainer	0.73		0.73	
90° Bend	1.52		1.52	
3m of str. pipe	3.00		3.00	
	5.25	0.64	5.25	0.64
Delivery				
Gate Valve	0.37		0.52	
Check Valve	0.49		0.67	
90° Bend (3 off)	3.39		4.56	
9m of str. pipe	9.00		9.00	
	13.25	4.82	14.75	1.65
Static suction lift		1.50		1.50
Static discharge head		6.00		6.00
Total Head		12.96		9.79

From the given comparison it can be seen that, by using 50mm piping on the delivery end, results in a decrease in the total head of approximately 3.2m or 26 per cent. This means that the power necessary to drive the pump is less, resulting in reduced pumping costs.

Example 2

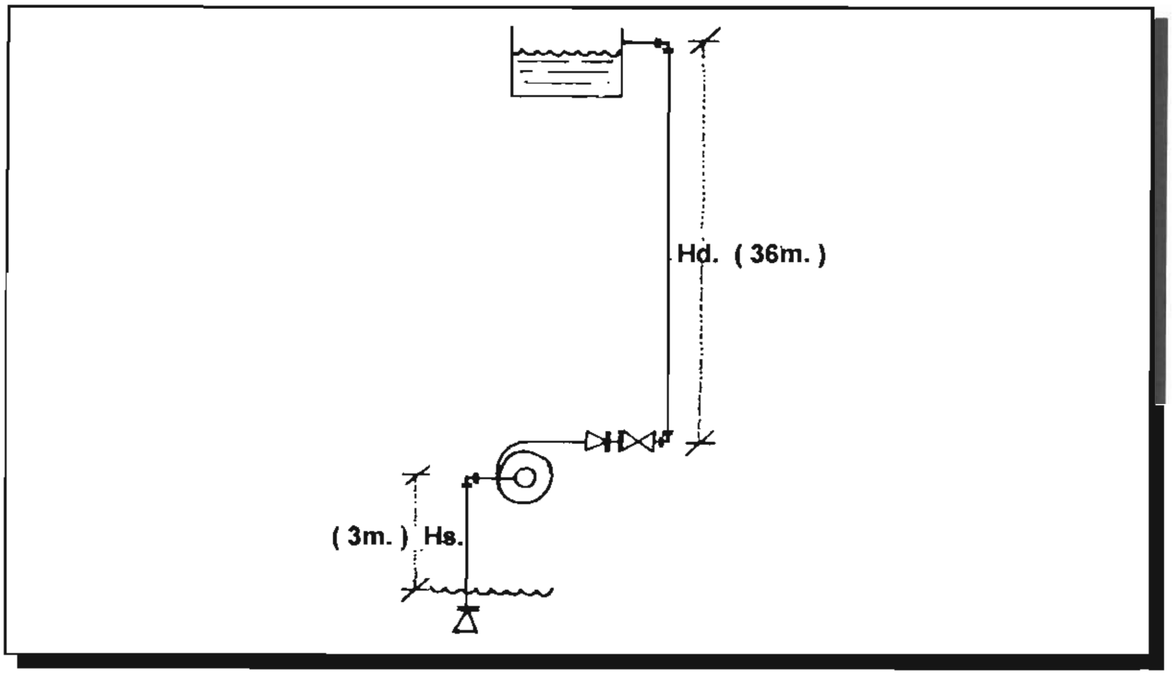


Fig. 49

Calculation of Total Head

	Using 250mm suction 200mm delivery	
Suction	e.l. of straight pipe	Head in m.
F/V and Strainer	4.54	
90° Bend	9.75	
6m of str. pipe	6.00	
	20.29	0.55
Delivery		
Gate Valve	2.44	
Check Valve	3.35	
90° Bend (2 off)	15.24	
40 m of str. pipe	40.00	
	61.03	5.09
Static Suction Lift		3.00
Static Delivery Hd		36.00
Total Head		44.64

Note : Refer to appropriate charts to determine friction head.

Cost of pumping 106 l/s of clear water against a total head of 45m.

(Assume the tariff rate is 13 cents/kW hr.
pump efficiency is 70% (0.7)
motor efficiency is 90%) (0.9).

<u>Note</u>: Operating cost is calculated for pumping 1,000 litres of water.

Pump water kW $= \frac{106 \times 1 \times 45}{102.04}$

$= 47\text{kW}$

kW input (to pump) $= \frac{47}{0.7}$

$= 67\text{kW}$

kW input (to motor) $= \frac{67}{0.9}$

$= 74.4\text{kW}$

kW hr/m^3 $= \frac{kW}{3.6 \times l/s}$

$= \frac{74.4}{3.6 \times 106}$

$= 0.195$ kW hr/m^3

∴ Cost $= 0.195 \times 13$

$=$ 2.5 cents (approx.)

APPENDIX 1

Useful Pumping and Hydraulic Information

Symbols and Abbrevations

Hydraulic Data (S.I. Units)

Pumping Formulae

SYMBOLS and ABBREVIATIONS

A.A.P.	Atmospheric air pressure
A.C.	Alternating current
°C	Degrees celsius
e.l.	Equivalent length
H.T.W.	High temperature water
kPa	Kilopascals
kW	Kilowatts
l/m	Litres per minute
l/s	Litres per second
m^3/h	Cubic metres per hour
m	Metres
mm	Millimetres
m/s	Metres per second
NPSH	Nett positive suction head
NPSH.A.	Nett positive suction head - Available
NPSH.R.	Nett positive suction head - Required
r.p.m.	Revolutions per minute
S.G.	Specific gravity
s.p.	Static pressure
s.p.m.	Strokes per minute

USEFUL HYDRAULIC DATA (S.I. UNITS)

LINEAR MEASUREMENT	
Hydraulic head	metre (m)
Pipe diameters	millimetre (mm)
Storage depths (tank)	metre (m)
Pipe lengths	metre (m)
AREA	
Cross sectional	
Small pipes	square millimetre (mm^2)
Surface	
Tank	square metre (m^2)
VOLUME	
Domestic supply	kilolitre (kl)
Sewerage	cubic metre (m^3) or kilolitre (kl)
Storage capacity	cubic metre (m^3)
Water distribution	cubic metre (m^3)
Note: Units may be expressed as "per day" or "per year" if the total volume is delivered over a particular period. Instantaneous flow rates should be expressed as "per second", i.e. (m^3/s).	
VELOCITY	
Pipe flows	metre per second (m/s)
POWER	watt and kilowatt (kW)
PRESSURE	pascal (Pa) and kilopascal (kPa)
TEMPERATURE	degree celsius (°C)
PUMP CHARACTERISTICS	
Pump discharge against head in metres	litres per second (l/s)
Pump curves	watts of power against discharge in litres/sec % efficiency against discharge in litres/sec.

USEFUL PUMPING INFORMATION

EFFECT OF SPECIFIC GRAVITY

Power (kW) varies directly with specific gravity. If the liquid has a specific gravity other than water, multiply the kW power for water by the specific gravity of the liquid to be handled. Providing the pump is delivering the same quantity, the pressure will be increased or decreased in direct proportion to the specific gravity, while the head will be unaffected.

EFFECT OF VISCOSITY

Viscous liquids tend to reduce the pump capacity, head and efficiency and to increase pump kW and increase pipeline friction.

EFFECT OF HOT LIQUIDS

Hot liquids vaporize at higher absolute pressures than cold liquids; therefore, the suction lift must be reduced when handling hot liquids. When handling liquids of a high vapour pressure, the liquid must flow to the pump suction under pressure.

EFFECT OF ALTITUDE

Suction lift is based on values at sea level where atmospheric pressure is 10.3m (approximately). As altitude is increased, atmospheric pressure is reduced and the suction lift must be reduced proportionately.

FORMULAE

S.I. UNITS

$$\text{Pump water kW} = \frac{l/s \times m(head) \times relative\ density}{102.4}$$

$$\text{or} \quad \frac{m^3h \times m(head) \times relative\ density}{367.35}$$

$$\text{kW input (to pump)} = \frac{pump\ water\ kW \times 100}{motor\ efficiency}$$

$$\text{kW input (to motor)} = \frac{kW\ input\ to\ pump \times 100}{motor\ efficiency}$$

$$\text{kW h/m}^3 = \frac{kW}{Number\ of\ m^3h}$$

Note: lm^3 = 1,000 litres).

MISCELLANEOUS

Circumference of circle	diameter of circle x 3.1416
Area of circle	diameter squared x 0.7854
Diameter of circle	circumference x 0.31831

- Theoretical velocity due to head = square root of head x 8.02.
- Doubling the diameter of a pipe increases the capacity by four.
- Friction of fluids in pipes increases as the square of velocity.

APPENDIX 2

Conversion Factors and Tables

CONVERSION FACTORS

1 atmosphere	= 14.7 lb/sq. in. = 33.95 ft. head of water = 760 mm. mercury = 29.92 in. mercury
Water colum 1 ft. high	= 0.4325 lb/sq. in. = 0.885 in. mercury
1 cubic ft. of water	= 6.235 gallons (imp.) = 28.3116 litres = 62.35 lb.
1 cubic in. of water	= 0.03604 lb. = 0.0036 gallons (imp.)
1 cubic metre of water	= 220 gallons (imp.) = 35.315 cubic ft. = 1,000 litres
1 cusec	= 374.1 gallons/min.
1 imperial gal. of water	= 277.463 cubic inches = 10 lb. = 4.546 litres
1 imperial gal. per min	= 0.0757 litres per second
Head in ft.	= lb/sq. in. x 2.312
1 in. column of mercury	= 1.13 ft. head of water = 0.49 lb/sq.in. = 0.344 metre head of water
1 litre of water	= 0.22 imp. gal. = 61 cubic in.
1 lb. of water	= 27.7463 cubic in. = 0.1 imp. gal.
1 lb. per sq. in.	= 2.312 ft. of water = 0.7047 metre of water
1 litre per sec.	= 13.21 gal./min.
1 metre head of water	= 1.42 lb/sq. in. = 2.9 in. mercury
1 horsepower	= 0.746 kW
Pressure lb. per sq. in.	= head in ft. x 0.4325
Temperature °F	= $\frac{9 x\, {}^{\circ}C}{5} + 32$
Temperature °C	= $\frac{5}{9}({}^{\circ}F - 32)$

UNITS OF LENGTH

Conversion from	Factors for conversion to		
	m	ft	in
Metres (m)	1.0	3.281	39.372
Feet (ft)	0.3048	1.0	12.0
Inches (in)	0.0254	0.0833	1.0

UNITS OF VOLUME

Conversion from	Factors for conversion to			
	ft^3	Imp. gal.	l	m^3
Cubic feet (ft3)	1.0	6.229	28.32	0.0283
Imperial gallons	0.1605	1.0	4.546	0.0045
Litres (l)	0.0353	0.22	1.0	0.001
cubic metres (m^3)	35.315	220.0	1000.0	1.0

UNITS OF PRESSURE AND HEAD

Conversion from	Factors for conversion to				
		Height of water			
	psi	ft	m	in Hg	atm
Pounds per square inch (psi)	1.0	2.31	0.703	2.04	0.068
Feet of water (ft water)	0.433	1.0	0.305	0.882	0.029
Metres of water (m water)	1.422	3.281	1.0	2.896	0.097
Inches of mercury (in Hg)	0.491	1.133	0.345	1.0	0.033
Atmospheres (atm)	14.70	33.90	10.33	29.92	1.0

UNITS OF RATE OF DISCHARGE

Conversion from	Factors for conversion to			
	ft^3/s	gal/min	l/s	m^3/h
Cubic feet per second (ft^3/s)	1.0	373.7	28.32	101.94
Imperial gallons per minute (imp. gal/min)	0.00267	1.0	0.0758	0.272
Litres per second (l/s)	0.0353	13.199	1.0	3.6
Cubic metres per hour (m^3/h)	0.0098	3.666	0.278	1

LENGTH

Feet into metres

Ft	0	1	2	3	4	5	6	7	8	9
	m (metres)									
0		0.305	0.610	0.914	1.219	1.524	1.829	2.134	2.438	2.743
10	3.048	3.353	3.658	3.962	4.267	4.572	4.877	5.182	5.486	5.791
20	6.096	6.401	6.706	7.010	7.315	7.620	7.925	8.230	8.534	8.839
30	9.144	9.449	9.754	10.058	10.363	10.668	10.073	11.278	11.582	11.887
40	12.192	12.497	12.802	13.106	13.411	13.716	14.021	14.326	14.630	14.935
50	15.24	15.545	15.850	16.154	16.459	16.764	17.069	17.374	17.678	17.983
60	18.288	18.593	18.898	19.202	19.507	19.812	20.117	20.422	20.726	21.031
70	21.336	21.641	21.946	22.250	22.555	22.860	23.165	23.470	23.774	24.079
80	24.384	24.689	24.994	25.298	25.603	25.908	26.213	26.518	26.822	27.127
90	27.432	27.737	28.042	28.346	28.651	28.956	29.261	29.566	29.870	30.175
100	30.480	30.785	31.090	31.394	31.699	32.004	32.309	32.614	32.918	33.223

Metres into feet

m	0	1	2	3	4	5	6	7	8	9
	ft (feet)									
0		3.281	6.562	9.842	13.123	16.404	19.685	22.966	26.247	29.528
10	32.808	36.089	39.370	42.651	45.932	49.212	52.493	55.774	59.055	62.336
20	65.617	68.897	72.178	75.459	78.740	82.021	85.302	88.582	91.863	95.144
30	98.425	101.71	104.99	108.27	111.55	114.83	118.11	121.39	124.67	127.95
40	131.23	134.51	137.79	141.08	144.36	147.64	150.92	154.20	157.18	160.76
50	164.04	167.32	170.60	173.88	177.16	180.45	183.73	187.01	190.29	193.57
60	196.85	200.13	203.41	206.69	209.97	213.25	216.53	219.82	223.10	226.38
70	229.66	232.94	236.22	239.50	242.78	246.06	249.34	252.62	255.90	259.19
80	262.47	265.75	269.03	272.31	275.59	278.87	282.15	285.43	288.71	291.99
90	295.27	298.56	301.84	305.12	308.40	311.58	314.96	318.24	321.52	324.80
100	328.08	331.36	334.64	337.93	341.21	344.49	347.77	351.05	354.33	357.61

Feet into metres

Ft
0
10
20
30
40
50
60
70
80
90
100

Metres into feet

m
0
10
20
30
40
50
60
70
80
90
100

CAPACITY

Gallons into litres

gal	0	1	2	3	4	5	6	7	8	9
	l (litres)									
0		4.54609	9.09218	13.6383	18.1844	22.7305	27.2765	31.8226	36.3687	40.9148
10	45.4609	50.0070	54.5531	59.0992	63.6543	68.1913	72.7374	77.2835	81.8296	86.3757
20	90.9218	95.4679	100.014	104.560	109.106	113.652	118.198	122.744	127.291	131.837
30	136.383	140.929	145.475	150.021	154.567	159.113	163.659	168.205	172.751	177.298
40	181.844	186.390	190.936	195.482	200.028	204.574	209.120	213.666	218.212	222.758
50	227.305	231.851	236.397	240.943	245.489	250.035	254.581	259.127	263.673	268.219
60	272.765	277.311	281.858	286.404	290.950	295.496	300.042	304.588	309.134	313.680
70	318.226	322.772	327.318	331.865	336.411	340.957	345.503	350.503	354.595	359.141
80	363.687	368.233	372.779	377.325	381.872	386.418	390.964	395.510	400.056	404.602
90	409.148	413.694	418.240	422.786	427.332	431.679	436.425	440.971	445.517	450.083
100	454.609									

Litres into gallons

litres	0	1	2	3	4	5	6	7	8	9
	gal (gallons)									
0		0.21997	0.43994	0.65991	0.87988	1.09985	1.31982	1.53978	1.75975	1.97972
10	2.19969	2.41966	2.63963	2.85960	3.07957	3.29954	3.51951	3.73948	3.95945	4.17942
20	4.39938	4.61435	4.83932	5.05929	5.27926	5.49923	5.71920	5.93917	6.15914	6.37911
30	6.59908	6.81905	7.03902	7.25899	7.47895	7.69892	7.91889	8.13886	8.35883	8.57880
40	8.79877	9.01874	9.23871	9.45868	9.67865	9.89862	10.1186	10.3386	10.5585	10.7785
50	10.9985	11.2184	11.4384	11.6584	11.8783	12.0983	12.3183	12.5382	12.7582	12.9782
60	13.1982	13.4181	13.6381	13.8581	14.0780	14.2980	14.5180	14.7379	14.9579	15.1779
70	15.3978	15.6178	15.8378	16.0578	16.2777	16.4977	16.7177	16.9376	17.1576	17.3776
80	17.5975	17.9175	18.0375	18.2574	18.4774	18.6974	18.9174	19.1373	19.3573	19.5773
90	19.7972	20.0172	20.2372	20.4571	20.6771	20.8971	21.1170	21.3370	21.5570	21.7770
100	21.9969									

MASS

Pounds into kilograms

lb	0	1	2	3	4	5	6	7	8	9
	kg (kilograms)									
0		0.454	0.907	1.361	1.814	2.268	2.722	3.175	3.629	4.082
10	4.536	4.990	5.443	5.897	6.350	6.804	7.257	7.711	8.165	8.618
20	9.072	9.525	9.979	10.433	10.886	11.340	11.793	12.247	12.701	13.154
30	13.608	14.061	14.515	14.969	15.422	15.876	16.329	16.783	17.237	17.690
40	18.144	18.597	19.051	19.504	19.958	20.412	20.865	21.319	21.772	22.226
50	22.680	23.133	23.587	24.040	24.494	24.948	25.401	25.855	26.308	26.762
60	27.215	27.669	28.123	28.576	29.030	29.484	29.937	30.391	30.844	31.298
70	31.752	32.205	32.659	33.112	33.566	34.019	34.473	34.927	35.380	35.834
80	36.287	36.741	37.195	37.648	38.102	38.555	39.009	39.463	39.916	40.370
90	40.823	41.277	41.731	42.184	42.638	43.091	43.545	43.999	44.452	44.906
100	45.359	45.813	46.266	46.720	47.174	47.627	48.081	48.534	48.988	49.442

Kilograms into pounds

kg	0	1	2	3	4	5	6	7	8	9
	lb (pounds)									
0		2.205	4.409	6.614	8.819	11.023	13.228	15.432	17.637	19.842
10	22.046	24.251	26.456	28.660	30.865	33.069	35.274	37.479	39.683	41.888
20	44.093	46.297	48.502	50.706	52.911	55.116	57.320	59.525	61.729	63.934
30	66.139	68.343	70.548	72.753	74.957	77.162	79.366	81.571	83.776	85.980
40	88.185	90.390	92.594	94.799	97.003	99.208	101.410	103.620	105.820	108.030
50	110.230	112.440	114.640	116.850	119.050	121.250	123.460	125.660	127.870	130.070
60	132.280	134.480	136.690	138.890	141.100	143.300	145.510	147.710	149.910	152.120
70	154.320	156.530	158.730	160.940	163.140	165.350	167.550	169.760	171.960	174.170
80	176.370	178.570	180.780	182.980	185.190	187.390	189.600	191.800	194.010	196.210
90	198.420	200.620	202.830	205.030	207.240	209.440	211.640	213.850	216.050	218.260
100	220.460	222.670	224.870	227.080	229.280	231.490	233.690	235.900	238.100	240.300

VOLUME

Cubic feet into cubic metres

ft	0	1	2	3	4	5	6	7	8	9
	m^3 (cubic metres)									
0		0.0283	0.0566	0.0850	0.1133	0.1416	0.1699	0.1982	0.2265	0.2549
10	0.2832	0.3115	0.3398	0.3681	0.3964	0.4248	0.4531	0.4814	0.5097	0.5380
20	0.5663	0.5947	0.6230	0.6513	0.6796	0.7079	0.7362	0.7646	0.7929	0.8212
30	0.8495	0.8778	0.9061	0.9345	0.9628	0.9911	1.0194	1.0477	1.0760	1.1044
40	1.1327	1.1610	1.1893	1.2176	1.2459	1.2743	1.3026	1.3309	1.3592	1.3875
50	1.4158	1.4442	1.4725	1.5008	1.5291	1.5574	1.5857	1.6141	1.6424	1.6707
60	1.6990	1.7273	1.7556	1.7840	1.8123	1.8406	1.8689	1.8972	1.9256	1.9539
70	1.9822	2.0105	2.0388	2.0671	2.0955	2.1238	2.1521	2.1804	2.2087	2.2370
80	2.2654	2.2937	2.3220	2.3503	2.3786	2.4069	2.4353	2.4636	2.4919	2.5202
90	2.5485	2.5768	2.6052	2.6335	2.6618	2.6901	2.7148	2.7467	2.7751	2.8034
100	2.8317	2.8600	2.8883	2.9166	2.9450	2.9733	3.0016	3.0299	3.0582	3.0865

Cubic metres into cubic feet

m^3	0	1	2	3	4	5	6	7	8	9
	ft^3 (cubic feet)									
0		35.3	70.6	105.9	141.3	176.6	211.9	247.2	282.5	317.8
10	353.1	388.5	423.8	459.1	494.4	529.7	565.0	600.3	635.7	671.0
20	706.3	741.6	776.9	812.2	847.6	882.9	918.2	953.5	988.8	1024.1
30	1059.4	1094.8	1130.1	1165.4	1200.7	1236.0	1271.3	1306.6	1342.0	1377.3
40	1412.6	1447.9	1483.2	1518.5	1553.9	1589.2	1624.5	1659.8	1695.1	1730.4
50	1765.7	1801.1	1836.4	1871.7	1907.0	1942.3	1977.6	2012.9	2048.3	2083.6
60	2118.9	2154.2	2189.5	2224.8	2260.1	2295.5	2330.8	2366.1	2401.4	2436.7
70	2472.0	2507.3	2542.7	2578.0	2613.3	2648.6	2683.9	2719.2	2754.5	2789.9
80	2825.2	2860.5	2895.8	2931.1	2966.4	3001.8	3037.1	3072.4	3107.7	3143.0
90	3178.3	3213.6	3249.0	3284.3	3319.6	3354.9	3390.2	3425.5	3460.8	3496.2
100	3531.5	3566.8	3602.1	3637.4	3672.7	3708.0	3743.4	3778.7	3814.0	3849.3

PRESSURE

Pounds-force per square inch into kilopascals

lbf/in²	0	1	2	3	4	5	6	7	8	9
	kPa (kilopascals)									
0		6.895	13.790	20.684	27.579	34.474	41.369	48.263	55.158	62.053
10	68.948	75.842	82.737	89.632	96.527	103.421	110.316	117.211	124.106	131.000
20	137.895	144.790	151.685	158.579	165.474	172.369	179.264	186.159	193.053	199.948
30	206.843	213.738	220.632	227.527	234.422	241.317	248.211	255.106	262.001	268.896
40	275.790	282.685	289.580	296.475	303.369	310.264	317.159	324.054	330.948	337.843
50	344.738	351.633	358.528	365.422	372.317	379.212	386.107	393.001	399.896	406.791
60	413.666	420.580	427.475	434.370	441.265	448.159	455.054	461.949	468.844	475.738
70	482.633	489.528	496.423	503.317	510.212	517.107	524.002	530.897	537.791	544.686
80	551.581	558.476	565.370	572.265	579.160	586.055	592.949	599.844	606.739	613.634
90	620.528	627.423	634.318	641.213	648.107	655.002	661.897	668.792	675.686	682.581
100	689.476	696.371	703.266	710.160	717.055	723.950	730.845	737.739	744.634	751.529

Kilopascals into pounds-force per square inch

kPa	0	1	2	3	4	5	6	7	8	9
	lbf/in² (pounds-force per square inch)									
0		0.145	0.290	0.435	0.580	0.725	0.870	1.015	1.160	1.305
10	1.450	1.595	1.740	1.885	2.031	2.176	2.321	2.466	2.611	2.756
20	2.901	3.046	3.191	3.336	3.481	3.626	3.771	3.916	4.061	4.206
30	4.351	4.496	4.641	4.786	4.931	5.076	5.221	5.366	5.511	5.656
40	5.802	5.947	6.092	6.237	6.382	6.527	6.672	6.817	6.962	7.107
50	7.252	7.397	7.542	7.687	7.832	7.977	8.122	8.267	8.412	8.557
60	8.702	8.847	8.992	9.137	9.282	9.427	9.573	9.718	9.863	10.008
70	10.153	10.298	10.443	10.588	10.733	10.878	11.023	11.168	11.313	11.458
80	11.603	11.748	11.893	12.038	12.183	12.328	12.473	12.618	12.763	12.908
90	13.053	13.198	13.343	13.489	13.634	13.779	13.924	14.069	14.214	14.359
100	14.504	14.649	14.794	14.939	15.084	15.229	15.374	15.519	15.664	15.809

POWER

Horsepower into kilowatts

hp	0	1	2	3	4	5	6	7	8	9
	kW (kilowatts)									
0		0.746	1.491	2.237	2.983	3.729	4.474	5.220	5.966	6.711
10	7.457	8.203	8.948	9.694	10.440	11.185	11.931	12.677	13.423	14.168
20	14.914	15.660	16.405	17.151	17.897	18.643	19.388	20.134	20.880	21.625
30	22.371	23.117	23.862	24.608	25.354	26.100	26.845	27.591	28.337	29.082
40	29.828	30.574	31.319	32.065	32.811	33.557	34.302	35.048	35.794	36.539
50	37.285	38.031	38.776	39.522	40.268	41.014	41.759	42.505	43.251	43.996
60	44.742	45.488	46.233	46.979	47.725	48.471	49.216	49.962	50.708	51.453
70	52.199	52.945	53.690	54.436	55.182	55.928	56.673	57.419	58.165	58.910
80	59.656	60.402	61.147	61.893	62.639	63.385	64.130	64.876	65.622	66.367
90	67.113	67.859	68.804	69.350	70.096	70.842	71.587	72.333	73.079	73.824
100	74.570	75.316	76.061	76.807	77.553	78.299	79.044	79.790	80.536	81.281

Kilowatts into horsepower

kW	0	1	2	3	4	5	6	7	8	9
	hp (horsepower)									
0		1.341	2.682	4.023	5.364	6.705	8.046	9.387	10.728	12.069
10	13.410	14.751	16.092	17.433	18.774	20.115	21.456	22.797	24.138	25.479
20	26.820	28.162	29.503	30.844	32.185	33.526	34.867	36.208	37.549	38.890
30	40.231	41.572	42.913	44.254	45.595	46.936	48.277	49.618	50.959	52.300
40	53.641	54.982	56.323	57.664	59.005	60.346	61.687	63.028	64.369	65.710
50	67.051	68.392	69.733	71.074	72.415	73.756	75.097	76.438	77.779	79.120
60	80.461	81.802	83.143	84.484	85.825	87.166	88.508	89.849	91.190	92.531
70	93.872	95.213	96.554	97.895	99.236	100.58	101.92	103.26	104.60	105.94
80	107.28	108.62	109.96	111.31	112.65	113.99	115.33	116.67	118.01	119.35
90	120.69	122.03	123.37	124.72	126.06	127.40	128.74	130.08	131.42	132.76
100	134.10	135.44	136.78	138.13	139.47	140.81	142.15	143.49	144.83	146.17

APPENDIX 3

Technical Data

Charts

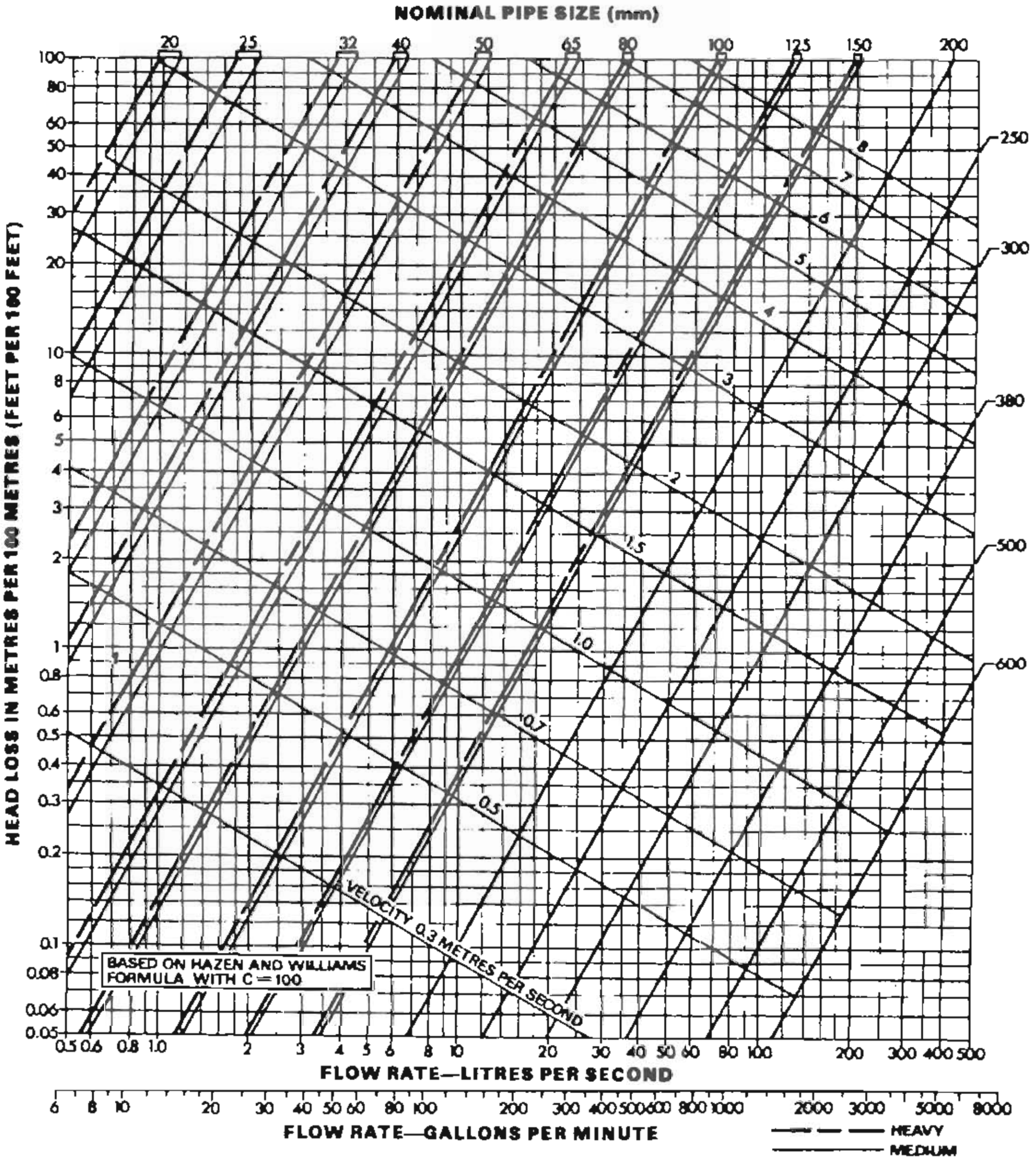
Tables

FRICTION LOSS AND VELOCITY IN GALVANISED PIPE

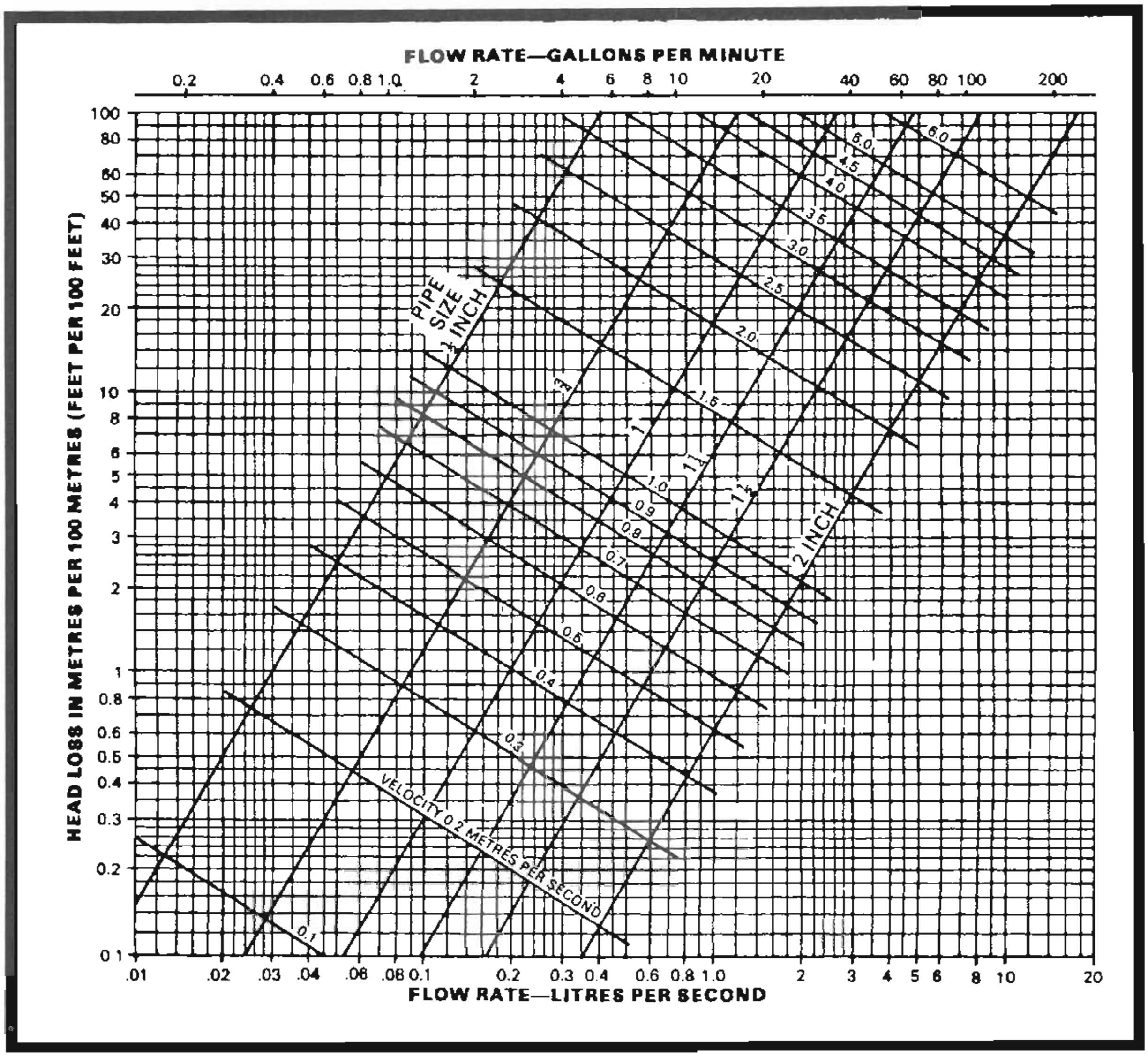
Based on HAZEN & WILLIAMS FORMULA

$$H_f = \frac{3.022 \times L \times V^{1.852}}{C^{1.852} \times D^{1.167}}$$

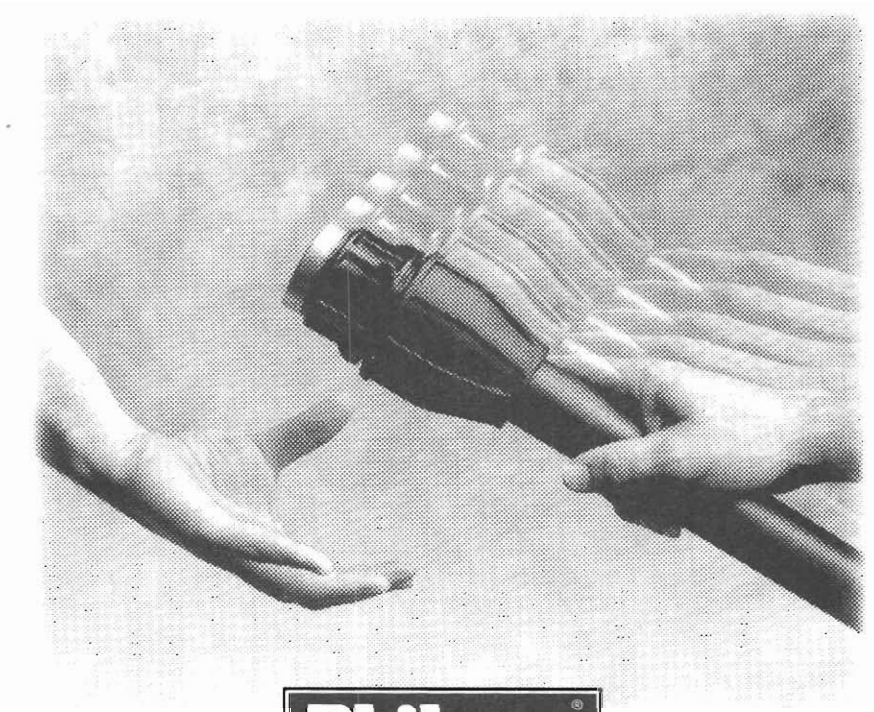
Where C (constant) reduced from 120 (new pipe) to 100 to allow for encrustation.

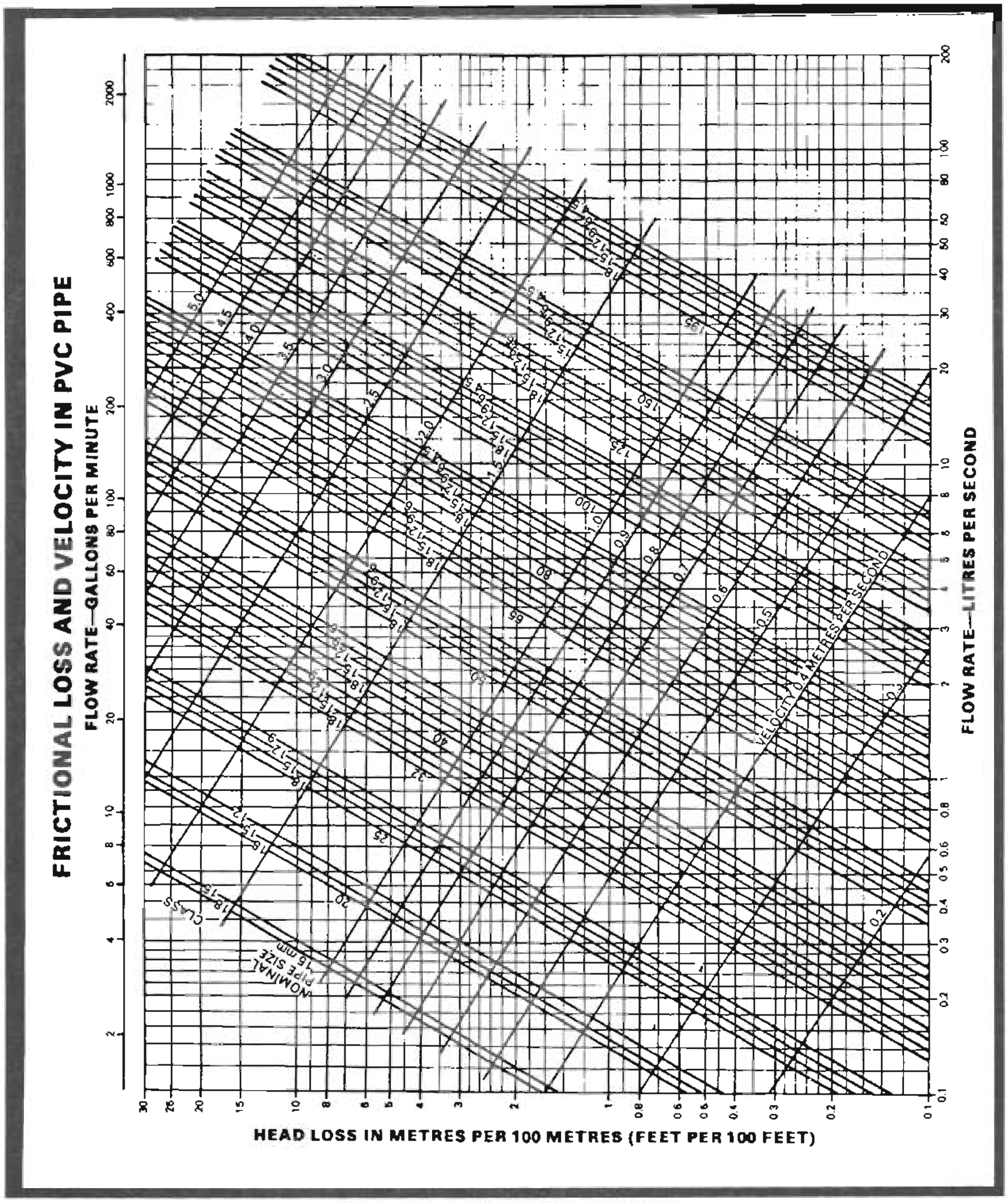


Friction Loss and Velocity in Medium Galvanized Pipe



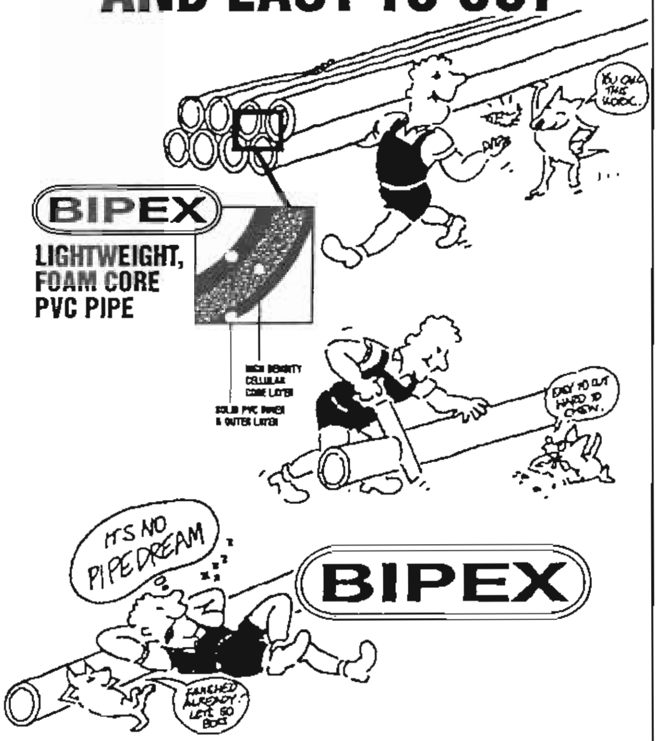
Friction Loss and Velocity in Polythene Pipe





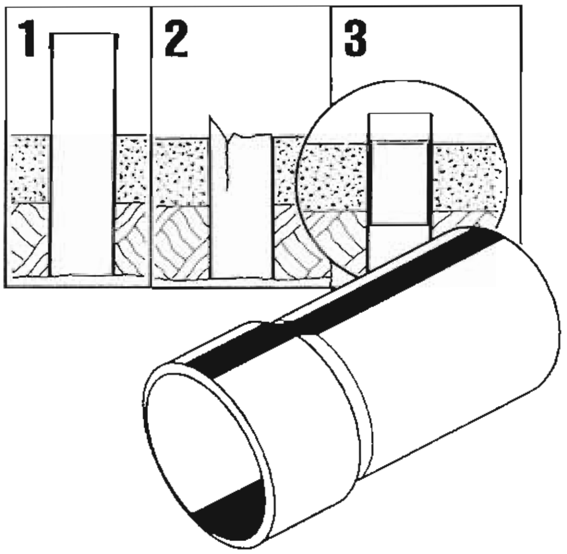
Friction and Velocity in PVC Pipe

A LIGHTWEIGHT PVC THAT'S TOUGH AND EASY TO CUT

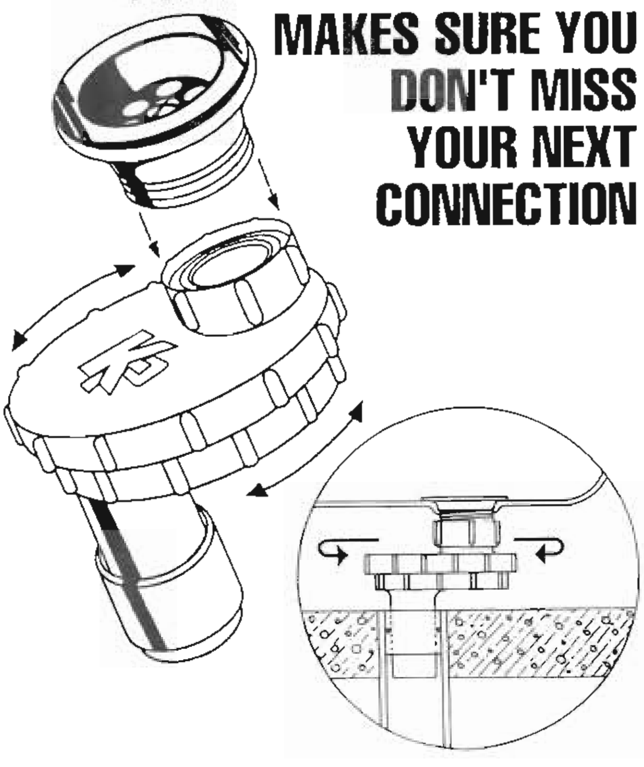


KEY PLASTICS SLAB REPAIR COUPLING

The inexpensive way to repair accidental or vandal damage

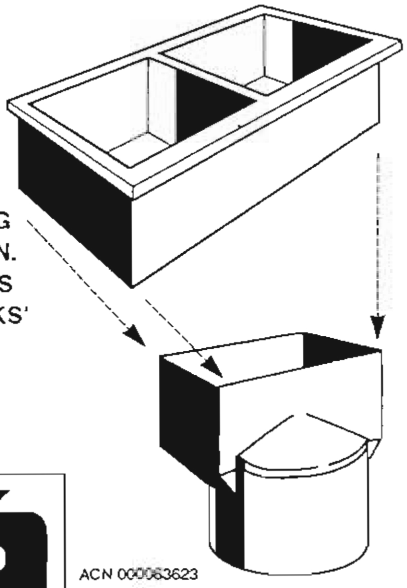


OUR BATH CONNECTOR MAKES SURE YOU DON'T MISS YOUR NEXT CONNECTION



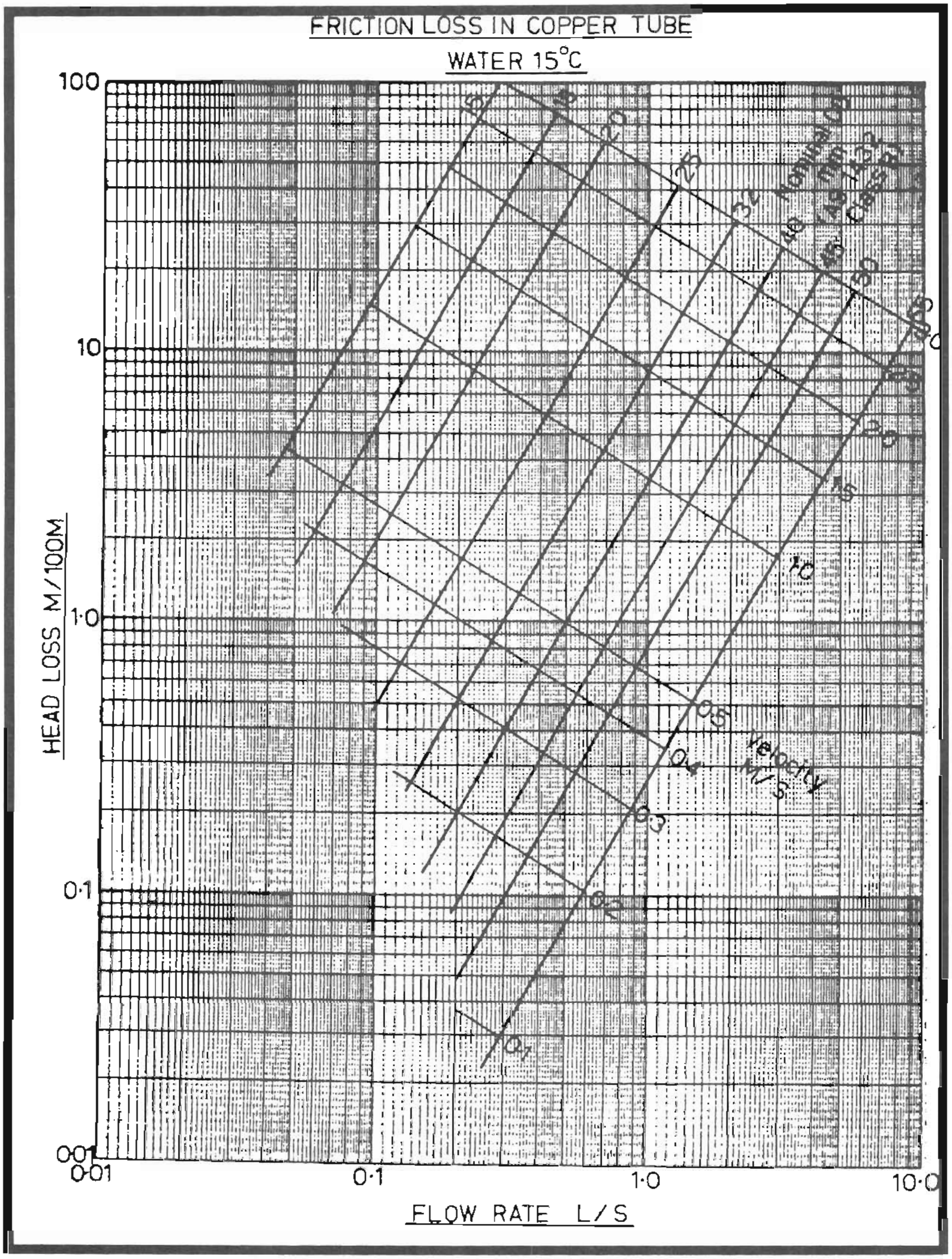
DOWNPIPE ADAPTOR PLUG

PROTECT
STORMWATER
DRAINS DURING
CONSTRUCTION.
NO BLOCKAGES
NO 'CALL BACKS'
PLAY SAFE

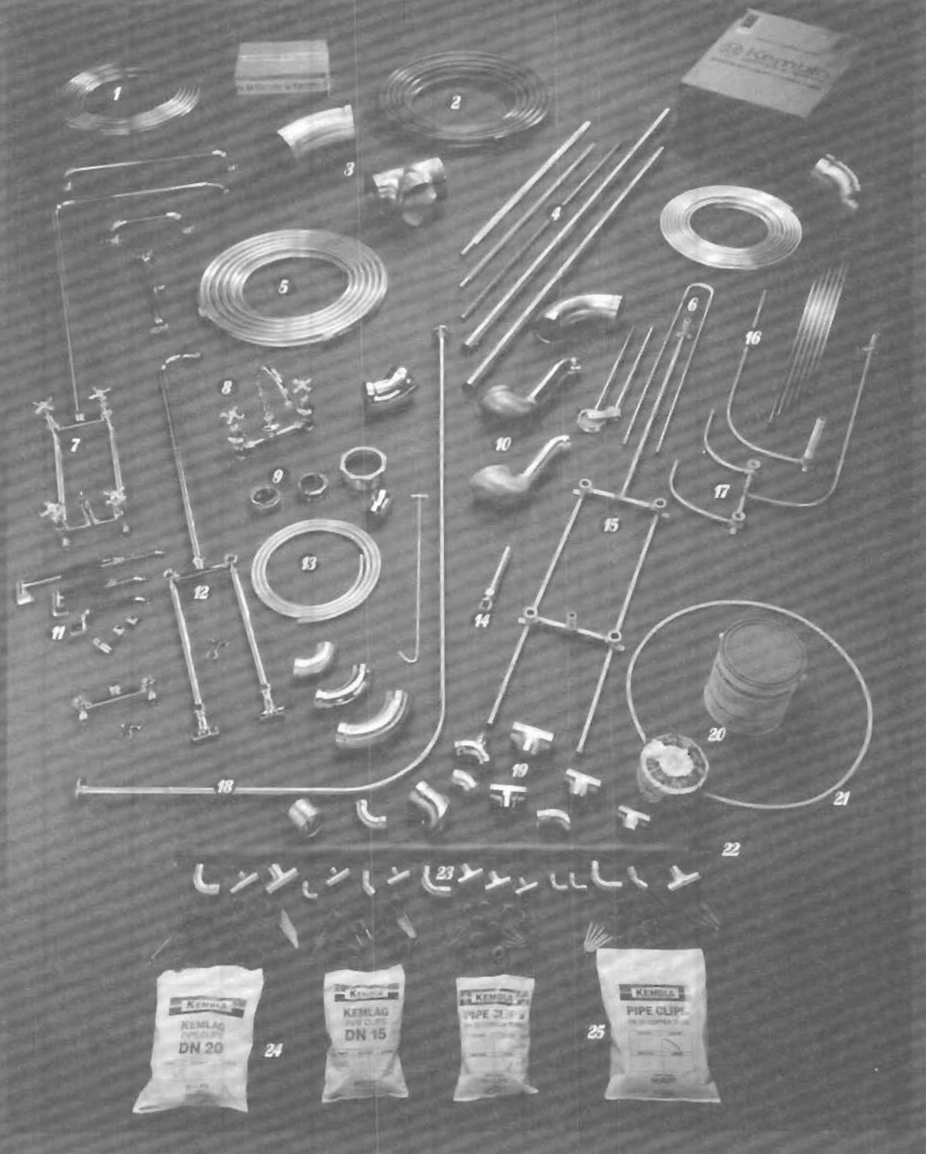


KEY PLASTICS

ACN 000063623
HEAD OFFICE
49 Heathcote Road, PO Box 146,
MOOREBANK, NSW 2170
Telephone: (02) 601 1800
008 25 1374
Facsimile: (02) 600 7840



Friction Loss in Copper Tube



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KEMLAG
DN 20
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KEMBLA
KEMLAG
DN 15
KEMBLA
PIPE CLIPS
25
KEMBLA
PIPE CLIPS

EQUIVALENT LENGTH OF STRAIGHT PIPE FOR VARIOUS FITTINGS

DN mm	25	40	50	65	75	100	Size of pipe		175	200	225	250	300	375
							125	150						
	METRES													
Standard 90° bend	0.76	1.13	1.52	1.95	2.44	3.26	4.27	5.27	6.40	7.62	8.69	9.75	11.89	16.15
Footvalve and large area strainer	0.34	0.52	0.73	0.91	1.10	1.52	2.01	2.47	2.99	3.44	4.02	4.54	5.55	7.47
Non-return valve	0.30	0.49	0.67	0.85	1.07	1.43	1.86	2.32	2.80	3.35	3.81	4.27	5.24	7.01
Gate valve when full open	0.24	0.37	0.52	0.64	0.79	1.10	1.43	1.77	2.13	2.44	2.90	3.23	3.96	5.33
Tee piece or sharp elbow	0.82	1.31	1.80	2.32	2.87	3.96	5.18	6.40	7.62	9.14	10.36	11.58	14.33	18.90

Metres per second					
Litres per minute	Pipe size Millimetres				
	25	32	40	50	65
25	0.82	0.53	0.37	0.21	0.13
50	1.64	1.05	0.73	0.41	0.26
75	2.47	1.58	1.10	0.62	0.39
100	3.29	2.11	1.46	0.82	0.53
150	4.93	3.16	2.19	1.23	0.79
200	6.58	4.21	2.92	1.64	1.05
250	8.22	5.26	3.65	2.05	1.32
300	9.87	6.32	4.39	2.47	1.58
350	11.51	7.37	5.12	2.88	1.84
400	13.16	8.42	5.85	3.29	2.11

Values enclosed by shaded area are recommended suction velocities.

Practical suction lift of water at 20°C							
Elevation		Barometric reading		Suction lift			
				Theoretical		Practical	
Feet	Metres	p.s.i.	Milibars	Feet	Metres	Feet	Metres
Sea level		14.7	1013	34.0	10.36	22.0	6.71
1300	396	14.0	966	32.4	9.88	21.0	6.40
2600	792	13.3	918	30.8	9.39	20.0	6.01
2900	883	12.7	877	29.2	8.90	18.0	5.49
5200	1584	12.0	828	27.8	8.47	17.0	5.18

Practical suction lift of water in metres at elevated temperatures at sea level										
Maximum suction lift ________________ Minimum positive head										
Temp.	50°C	55°C	60°C	65°C	70°C	75°C	80°C	85°C	90°C	95°C
Metres	2.6	1.9	1.2	0.7	0	0.7	1.2	1.9	2.6	3.3