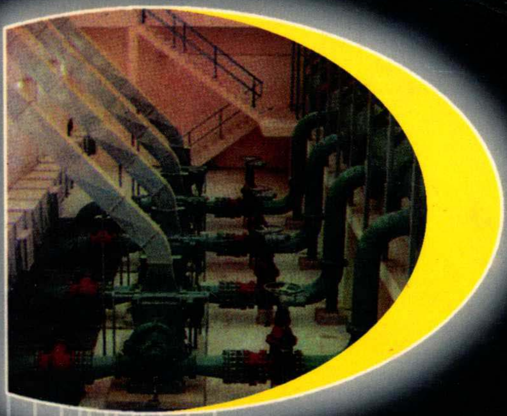
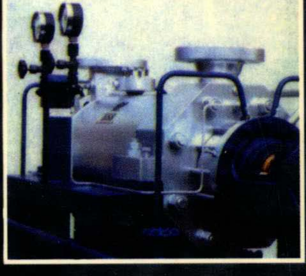


刘景植
刘梅清 编著

Pumps and Pumping Stations



武汉水利电力大学出版社

(鄂) 新登字 15 号

图书在版编目（CIP）数据

泵及泵站：英文/刘景植　刘梅清编著. —武汉：武汉水利电力大学出版社，1999
ISBN 7 -81063 -062 -8

Ⅰ.泵… Ⅱ.①刘…②刘… Ⅲ.①泵－基本知识－英文②泵站－基本知识－英文 Ⅳ.①TH38②TV675

中国版本图书馆 CIP 数据核字（1999）第 51728 号

责任编辑：刘业冰　　责任校对：徐　虹　　封面设计：涂　驰
武汉水利电力大学出版社出版发行
（武汉市武昌东湖南路 8 号，邮编 430072）
武汉水利电力大学印刷厂印刷
*
开本：787×1 092 1/16　　印张：15.75　　字数：388 千字
2000 年 5 月第 1 版　　2000 年 5 月第 1 次印刷
ISBN 7-80163-062-8/TH·3　　定价：25.00 元

Preface

Since the 1950s, construction, management and research of pumps and pumping stations for irrigation and drainage have got a rapid and great development in China. At present more and more projects of pumping station are involved with foreign affairs. We write this book mainly to help engineers and technicians who are engaged in pumping station projects concerning foreign affairs to study and know well the specialized English knowledge in the field of pumps and pumping stations. On the other hand, we hope that our successful experience in construction and management of pumping stations in China can be introduced to foreign nations by this book.

The fundamental theory, concepts of pumps and pumping stations and planning, design, maintenance and management of pumping station for irrigation and drainage are completely introduced in this book. There are 13 chapters in this book. Chapter 1 to Chapter 6 mention the related contents of pumps, and the contents of pumping stations are in the rest chapters.

This book applies the SI unit (standard international unit).

The co-authors of this book include Liu Jingzhi (Introduction, Chapters 1,6.2,6.4,6.5,7 and 13), Liu Meiqing (Chapters 10 to 12), Chen Jian (Chapters 2, 6.1 and 6.3), Zhu Jinmu (Chapters 5 and 9), and Long Xingping (Chapters 3, 4 and 8). The chief editors of this book are Liu Jingzhi and Liu Meiqing. Upon the release of this book, we express our many thanks to the Department of Water Resources for its help and the printers for their strenuous work. We believe that mistakes in this book are unavoidable, so any pointing out of them is sincerely welcome by the authors.

July, 1999

Introduction

The pump is probably the earliest form of machine and today is the most widely used machine in the world next to the electric motor. There is hardly a piece of equipment, which does not in the same way depend on pumps for its successful operation. Pumps for land improvement are one of the basic key facilities for agricultural irrigation and drainage. Since the 1950s, construction, management and research of pumps and pumping stations for irrigation and drainage have got a rapid and great development in China. By the end of 1995, about 500 thousand pumping stations for irrigation and drainage had been built up. The total installed capacity of pumping power had reached 40 million kW and the area of irrigation and drainage with pumps amounted to 33 million hectare, which was about 60% of total irrigated and drained area. These pumping stations have greatly brought into play to the increase of agriculture yield and the development of national economy.

The purpose of this book is to aid in providing a better understanding of the applied technology of pumps and the problems of planning, operation and management of pumping stations. In general, the former is the basis of the latter, and the latter is the practical uses of the former. The former takes performance and application of pumps as a stress, and construction, operating principle, affinity law and specific speed of pumps are mentioned around the pump performance. And the determination of operation point and setting height of pumps is the practical use of pump performance. In the part of pump performance of this book, fundamental performance equations and complete performance equations, and theoretical characteristic curves, experimental characteristic curves and complete characteristic curves are overall introduced. In the part of pumping stations, this book will emphatically introduce how to make planning of pumping stations, selection of pumps and auxiliary equipment under the principle of dynamic economy, and design principle, method and steps of pumping station structures. In the last part of this book contents related to optimum operation of pumping stations, main technical and economic indexes of pumping stations and technical and economic analysis of pumping stations are introduced in detail.

CONTENTS

Chapter 1 Fundamental Conception of Pumps

1.1 Definition, Classification and Uses of Pumps

1.1.1 Definition

Pumps are a kind of fluid machines imparting energy to fluids (liquids). They are used to move the fluid from one point to others or to lift fluids from one elevation to a higher level or to add pressure to the fluids.

1.1.2 Classification of pumps

Pumps may be classified on the basis of the applications they serve, the materials which they are constructed, the liquids they handle, and even their orientation in space. All such classifications, however, are limited in scope and tend to substantially overlap each other. A more basic system of classification, the one used in this textbook, first defines the principle by which energy is added to the fluid, goes on to identify the means by which this principle is implemented, and finally delineates specific geometry commonly employed.

According to their operating principle all pumps may be divided into rotodynamic types, displacement types (including reciprocating pumps, spiral screw pumps, gear pumps), and other types (including airlift pumps hydraulic rams, and jet pumps). Displacement and other types of pumps are rarely used for land irrigation and drainage, so this textbook deals only with rotodynamic or turbo pumps.

The classification of rotodynamic pumps is shown in Fig. 1.1.

Rotodynamic pumps supply energy to fluids by the action of a rotating impeller and are divided into three categories according to their operating principle: centrifugal pumps, mixed-flow pumps, and axial flow pumps.

(1) Centrifugal pumps

The centrifugal pump is so called because the pressure increase within its rotor due to centrifugal action is an important factor in its operation. In brief, it consists of an impeller rotating within a case (see Fig. 1.2). Fluid enters the impeller in the central portion, flows radically outward, and is discharged around the entire circumference into a casing. During flowing through the rotating impeller the fluid receives energy from the vanes, resulting in increases in both pressure and absolute velocity. Since a large part of the energy in fluid leaving the impeller is kinetic, it is necessary to

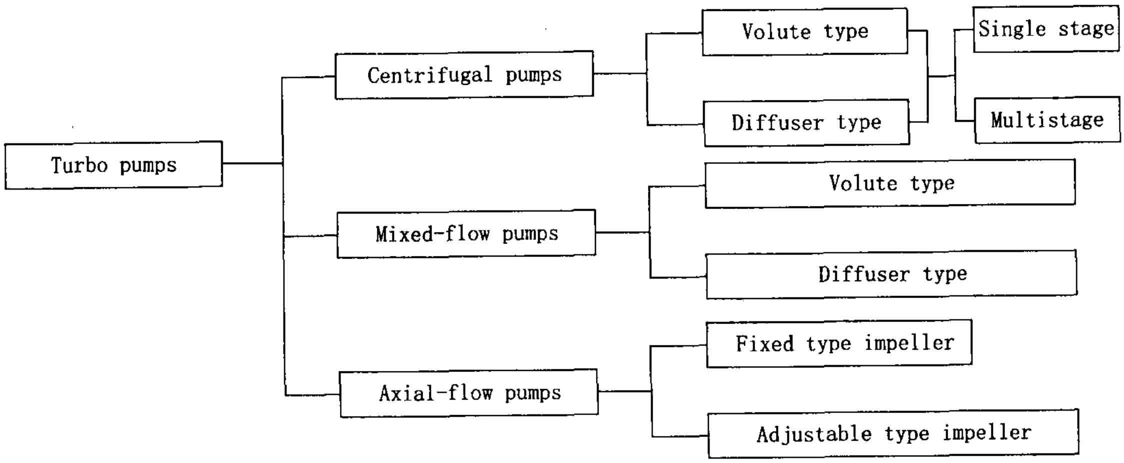


Fig. 1.1 Classification of turbo pumps

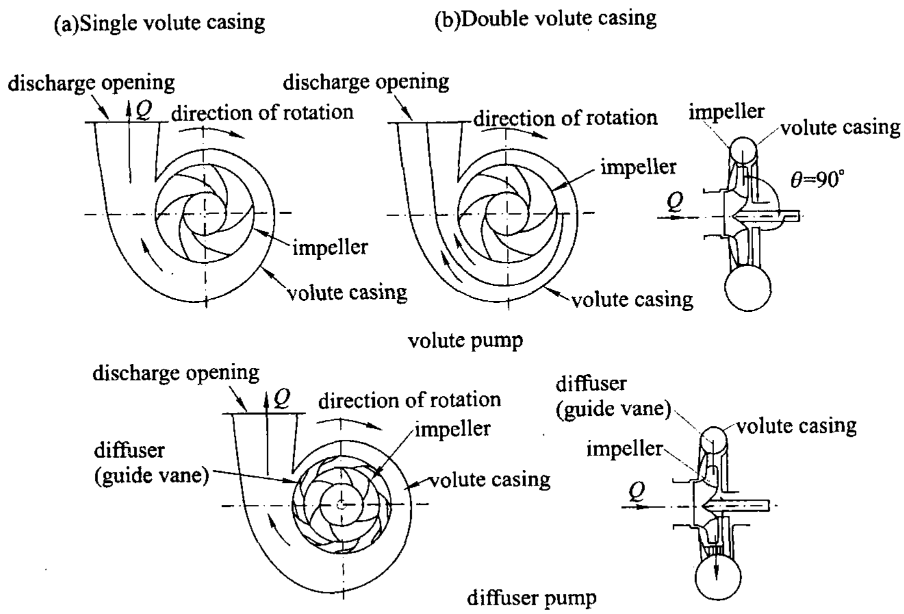


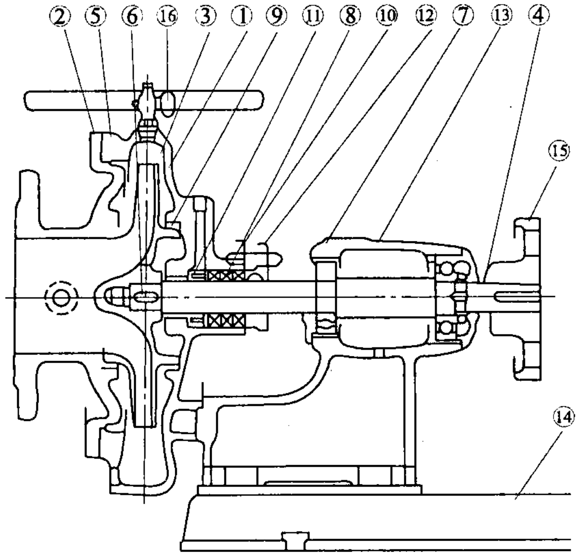
Fig. 1.2 Volute casing and diffuser pumps

reduce the absolute velocity and transform the large portion of this velocity head into pressure head. This is accomplished in the volute casing surrounding the impeller or by diffuser vanes.

Centrifugal pumps are divided into two general classes: volute casing pumps and diffuser or turbine pumps, as in Fig. 1.2. In the former the impeller is surrounded by a spiral case, the outer boundary of which may be a curve called a volute. The absolute velocity of the fluid leaving the impeller is reduced in the volute casing, with a resultant increase in pressure. In the diffuser pump, the impeller is surrounded by diffuser vanes, which provide gradually enlarged passages to affect a gradual reduction in velocity. These diffusion vanes are usually fixed or immovable, but in a very few instances they have been pivoted like the guide vanes in a turbine in order that the angle might be changed to conform to conditions with different rates of flow.

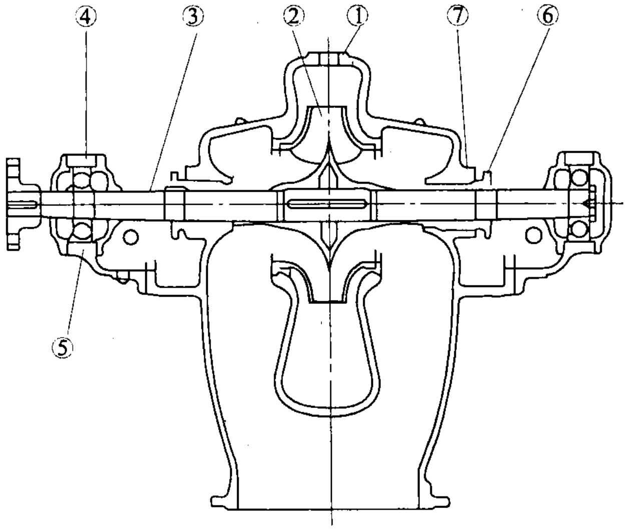
Centrifugal pumps are also divided into single-suction and double-suction pumps (see Fig 1.3). The latter have the advantage of symmetry,, and can eliminate end thrust. They also provide a large inlet area with lower intake velocity.

No.	Part name
1	Casing
2	Suction cover
3	Impeller
4	Pump shaft
5	Impeller nut
6	Impeller key
7	Deflector
8	Gland packing
9	Casing ring
10	Packing gland
11	Sealing ring
12	Gland bolt
13	Frame
14	Common base
15	Shaft coupling
16	Air vent cock



(a) Single-suction pump

No.	Part name
1	Casing
2	Impeller
3	Pump shaft
4	Bearing housing
5	Ball bearing
6	Gland
7	Gland packing



(b) Double-suction pump

Fig. 1.3 Single and double-suction pumps

(2) Mixed-flow pumps

Mixed-flow pumps (see Fig. 1.4), supply pressure and velocity energy to fluids by centrifugal force and lifting function of the impeller. In pump of this type fluids enter the impeller from a direction parallel to the shaft and exit in an oblique direction. The velocity energy of the liquid leaving the impeller is converted into pressure energy by either diffusers (guide vanes) or a volute casing.

(3) Axial-flow pumps

Axial-flow pumps (see Fig. 1.5), supply pressure and velocity energy to fluid by lifting action of the impeller vanes. In axial-flow pumps, water enters the impeller in a direction parallel to the

No.	Part name
1	Upper casing
2	Lower casing
3	Suction casing
4	Inspection hole cover
5	Impeller
6	Impeller cap
7	pump shaft
8	Packing sleeve
9	Submerged bearing sleeve
10	Impeller key
11	Deflector
12	Gland packing
13	Casing ring
14	Packing gland
15	Sealing ring
16	Submerged bearing
17	Shaft coupling

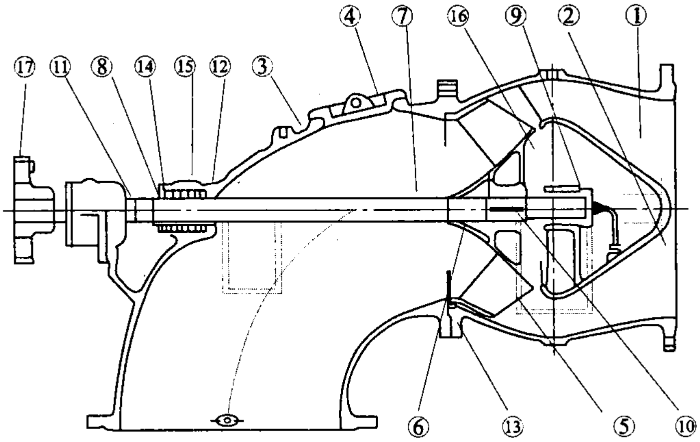


Fig. 1.4 Construction of horizontal shaft type mixed-flow pump

No.	Part name
1	Upper casing
2	Lower casing
3	Suction casing
4	Inspection hole cover
5	Impeller
6	Pump shaft
7	Packing sleeve
8	Submerged bearing sleeve
9	Impeller nut
10	Deflector
11	Gland packing
12	Casng liner
13	Packing gland
14	Sealing ring
15	Submerged bearing
16	Shaft coupling

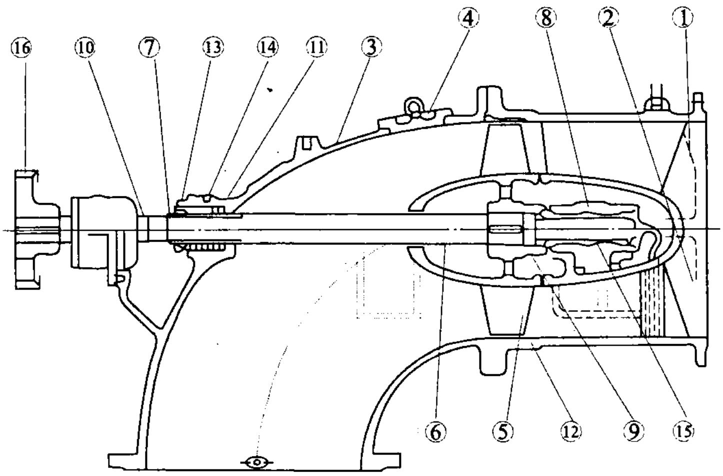


Fig. 1.5 Construction of horizontal shaft type axial-flow pump

pump shaft, and is pushed out in the same direction by the rotating impeller very similar to a ship's propeller. Some velocity energy is converted into pressure energy by the diffusers.

Individual pumps are classified by a variety of aspects.

(1) Shaft type

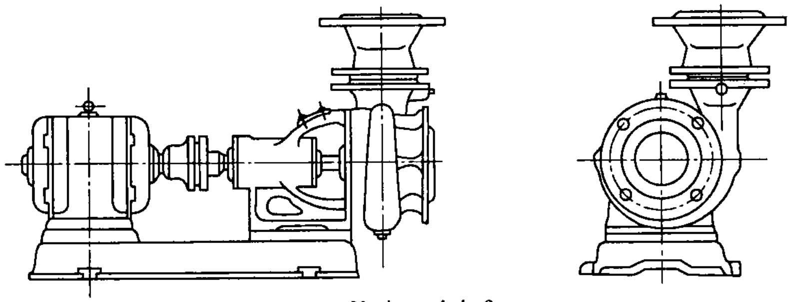
Shaft type is classified, according to the direction of the main shaft which rotates the pump, into horizontal, vertical and inclined shaft types (see Fig. 1.6).

(2) Number of impellers

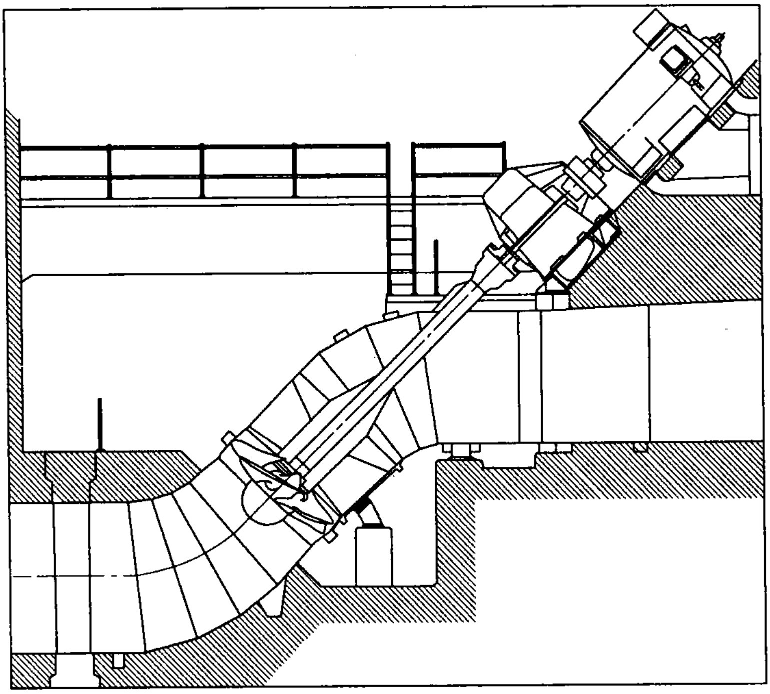
Volute pumps and turbine pumps with one impeller are called single-stage pumps, and those with two or more impellers arranged in series are called multistage ones. A multistage pump is illustrated in Fig. 1.7.

(3) Casing division

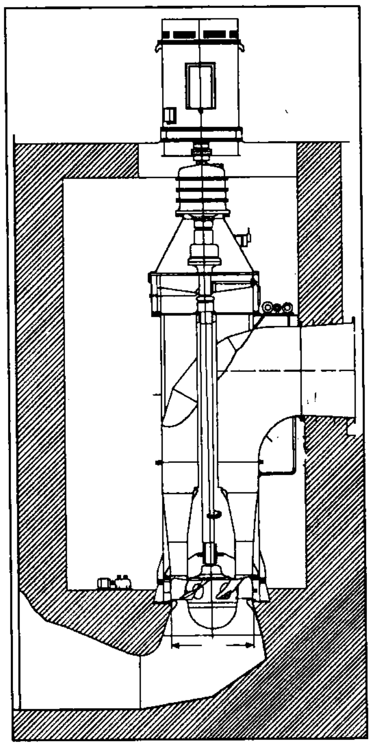
Pumps are classified, according to the direction of division of the pump casing, into two groups: ①the radically or vertically split type in which the pump casing is divided perpendicular to the shaft when the pump is installed in place; ② the horizontally split type in which the pump casing is divided horizontally in the center of the main shaft.



Horizontal shaft type



Inclined shaft type



Vertical shaft type

Fig. 1.6 Horizontal, vertical and inclined shaft types of pump

1.2 Construction of Impeller Pumps

A pump consists of a set of rotating vanes, enclosed within a housing or casing and used to impart energy to fluid. Stripped of all refinements, a pump has two main parts: a rotating element, including an impeller and a shaft, and a stationary element made up of a casing, seals, and bearings.

No.	Part name
1	Discharge casing
2	Suction casing
3	Interstage casing
4	Balancing chamber cover
5	Impeller
6	Pump shaft
7	Shaft sleeve
8	Sleeve nut
9	Balancing dise
10	Impeller key
11	Deflector
12	Gland packing
13	Guide vane
14	Casing ring
15	Packing gland
16	Sealing ring
17	Interstage bushing
18	Balancing bushing
19	Balancing seat
20	Sealing pipe
21	Balancing pipe
22	Tie bolt
23	Shaft couping
24	Priming funnel

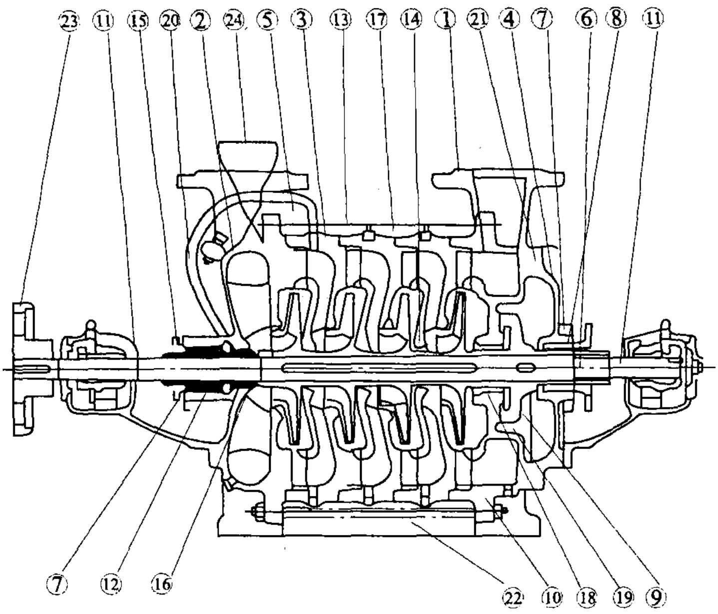


Fig. 1.7 Construction of a horizontal shaft type multistage pump

1.2.1 Impellers

Impellers are classified, according to the major direction of flow in reference to axis of rotation, into (see Fig. 1.8): ①radial-flow impellers; ②axial-flow impellers; and ③mixed-flow impellers.

Impellers are further classified, according to the flow direction into the suction opening of the impeller into (see Fig. 1.9): ①single-suction, with a single inlet on one side; and ②double-suction, with water flowing to the impeller symmetrically from both sides.

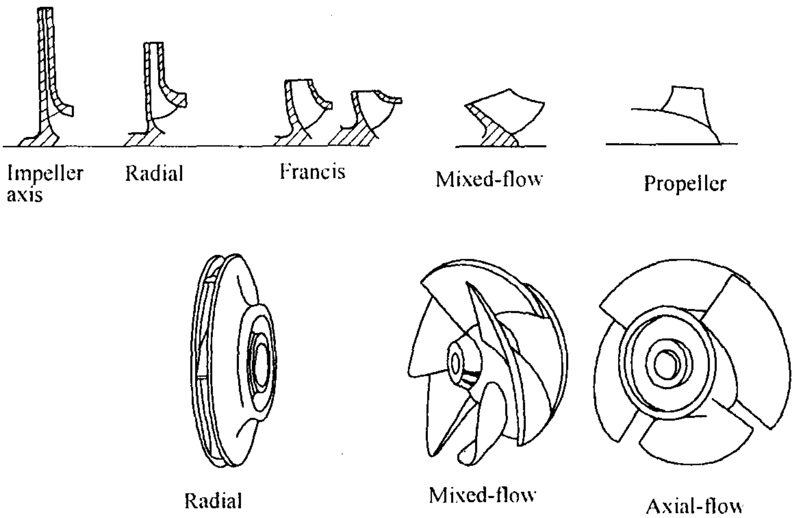
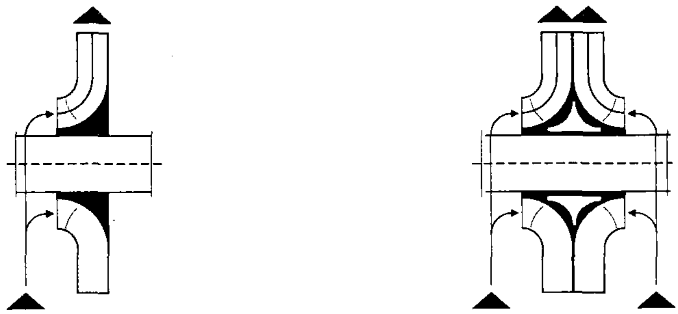


Fig. 1.8 Radial, mixed and axial-flow impellers



Single-suction impeller Double-suction impeller

Fig. 1.9 Single and double-suction impellers

In a single-suction impeller, the liquid enters the suction eye on one side only. But a double-suction impeller has, in effect, two single-suction impellers arranged back in a single casing and the liquid enters the impeller simultaneously from both sides.

For the general service single-stage axially split casing design, a double-suction impeller is favored because it is theoretically on axial hydraulic balance and because the greater suction area of a double-suction impeller permits the pump to operate with less net absolute suction head. For small units, the single-suction impeller is more practical for manufacturing reasons, as the water ways are not divided into two very narrow passages. It is also sometimes preferred for structural reasons. End-suction pumps with single-suction overhung impellers have both first-cost and maintenance advantages not obtainable with double-suction impellers. Most radically split-casing pumps therefore use single-suction impellers because an overhung impeller does not require the extension of a shaft into the impeller suction eye. Single-suction impellers are preferred for pumps handling suspended matter, such as sewage. In multistage pumps, single-suction impellers are almost universally used because of the design and first-cost complexities that double-suction staging introduces.

Mechanical design also determines impeller classification, accordingly, impellers may be completely open, semiopen, or closed (see Fig. 1.8).

Strictly speaking, an open impeller consists of nothing but vanes attached to a central hub for mounting on the shaft without any form of sidewall or shroud. The disadvantage of this impeller is structural weakness. If the vanes are long, ribs or a partial shroud must strengthen them. Generally, open impellers are used in small, inexpensive pumps. One advantage of open impellers is that they are better suited for handling liquids with stringy materials. It is also sometimes claimed that they are better suited for handling liquids containing suspended matter because the solids in such matter are most likely to clog in the space between the rotating shrouds of a closed impeller and the stationary casing walls. It has been demonstrated, however, that closed impellers do not clog easily, thus disproving the claim for the superiority of the open-impeller design. In addition, the open impeller is much more sensitive to wear than the closed impeller and therefore its efficiency deteriorates rather rapidly.

The open impeller rotates between two side plates, between the casing walls of the volute or between the stuffing box head and the suction head. The clearance between the impeller vanes and the sidewalls allows a certain amount of water slippage which increases as wear increases. To restore the original efficiency, both the impeller and the side plate must be replaced. This, incidentally, involves a much larger expense than would be entailed in closed-impeller pumps, where simple rings form the leakage joint.

The semiopen impeller incorporates a single shroud, usually at the back of the impeller. This shroud may or may not have pump-out vanes, which are vanes located at the back of the impeller shroud. This function is to reduce the pressure at the back hub of the impeller and to prevent foreign matter from lodging in the back of the impeller and interfering with the proper operation of the pump and the stuffing box.

The closed impeller, which is almost universally used in centrifugal pumps handling clear liquids, incorporates shrouds or enclosing sidewalls that totally enclose the impeller waterways from the suction eye to the periphery. Although this design prevents the liquid slippage that occurs between an open or semiopen impeller and its side plates, a running joint must be provided between the impeller and the casing to separate the discharge and suction chambers of the pump. This running joint is usually formed by a relatively short cylindrical surface on the impeller shroud that rotates within a slightly large stationary cylindrical surface. If one or both surface is made renewable, the leakage joint can be repaired when wear causes excessive leakage.

If the pump shaft terminates at the impeller so that the latter is supported by bearings on one side, the impeller is called an overhung impeller. This type of construction is the best for end-suction pumps with a single-suction impeller.

1.2.2 Shafts

The basic function of a pump shaft is to transmit the torque encountered in starting and during operation while supporting the impeller and other rotating parts. It must do this job with a deflection less than the minimum clearance between rotating and stationary parts. The loads involved are the torque, the weight of the parts, and both radial and axial hydraulic forces. In designing a shaft, the maximum allowable deflection, the span or overhung, and the location of the loads all have to be considered, as does the critical speed of the resulting design.

Shafts are usually proportioned to withstand the stress set up when a pump is started quickly, for example, when the driving motor is thrown directly across the line. If the pump handles hot liquid, the shaft is designed to withstand the stress set up when the unit is started cold without any preliminary warm-up.

1.2.3 Casing

There are two types of pump casings: volute casing and pipe-like casing. A volute casing pump has the spiral-shaped casing surrounding the impeller. This casing section collects the liquid discharged by the impeller and converts velocity energy into pressure energy.

A centrifugal pump volute increases in area from its initial point until it encompasses the full 360°around the impeller and then flares to the final discharge opening. The wall dividing the initial section and the discharge nozzle portion of the casing is called the tongue of the volute. The diffusion vanes and concentric casing of the diffuser pump fulfill the same function as the volute casing in energy conversion.

In propeller and other pumps in which axial-flow impellers are used, it is not practical to use a volute casing, instead, the impeller is enclosed in a pipe-like casing. Diffusion vanes are generally used following the impeller, but in certain extremely low-head units these vanes may be omitted.

Pump casing may be solid or split casing. Solid casing implies a design in which the discharge waterways leading to the discharge nozzle are all contained in one casing, or fabricated piece. The casing must have one side open so that the impeller may be introduced into it. As the sidewalls surrounding the impeller are in reality part of the casing, a solid casing, strictly speaking, cannot be used, and designs normally called solid casing are really radically split (see Fig. 1.10).

A split casing is made of two or more parts fastened together. The term "horizontally split" had regularly been used to describe pumps with a casing divided by a horizontal plane through the shaft centerline, or axis (see Fig. 1.11). The term "axially split" is now preferred. Since both the suction and discharge nozzles are usually in the same half of the casing, the other half may be removed for inspection of the interior without disturbing the bearings or the piping. Like its counterpart horizontally split, the term "vertically split" refers to a casing split in a plane perpendicular to the axis of rotation (see Fig. 1.12).

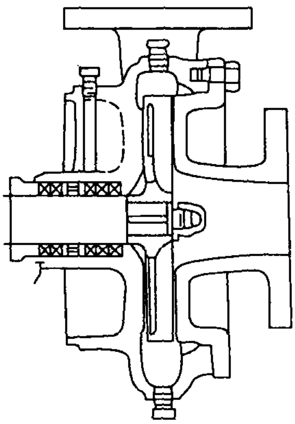


Fig. 1. 10 Radial split casing pump

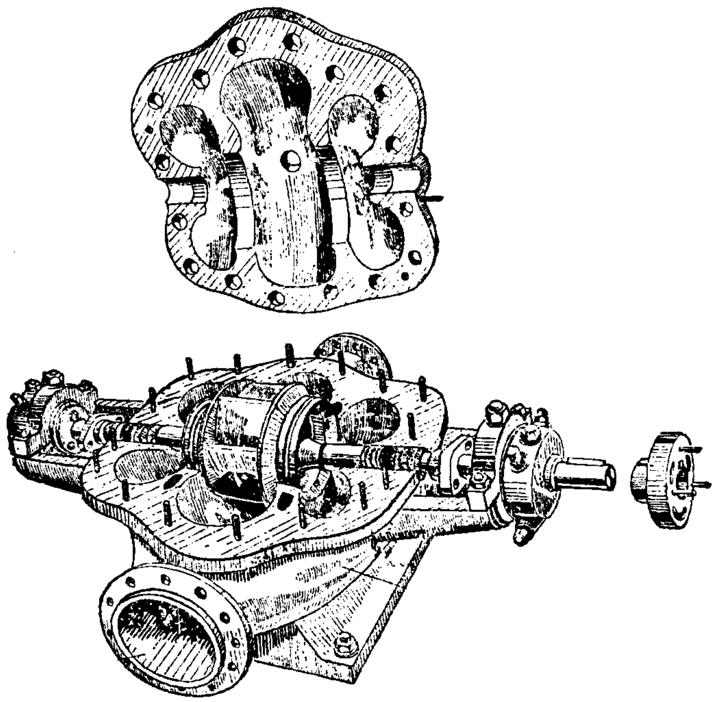


Fig. 1. 11 Horizontally split casing pump

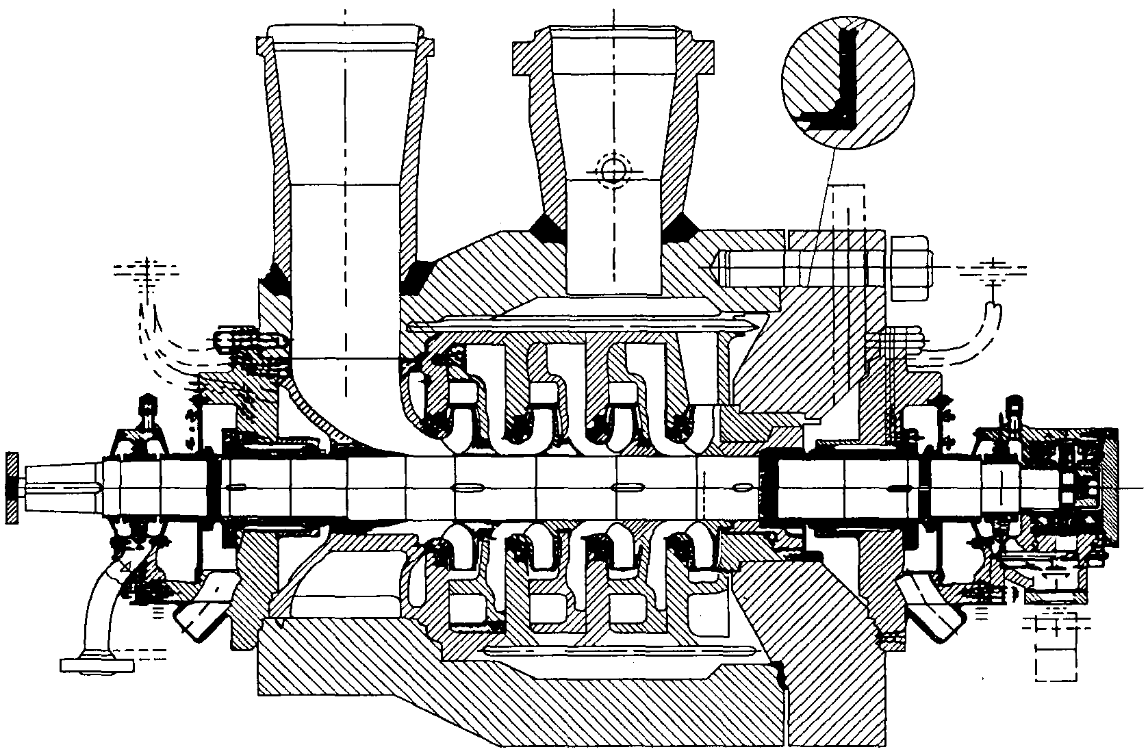


Fig. 1.12 Double casing multistage pump with radically split inner casing

1.2.4 Seals

The pump seals include inner seals (see Fig. 1.13), wearing rings, and outer seals—stuffing boxes, and so on.

(1) Wearing rings

Wearing rings provide an easily and economically renewable leakage joint between the impeller and the casing. To restore the original clearances of such a joint after wear occurs. Renewable casing and impeller rings can then be installed (see Fig. 1.14). Nomenclature for the casing or stationary part forming the leakage joint surface is as follows: casing ring (if mounted in the casing), suction cover ring or suction head ring (if mounted in a suction cover or head) and stuffing box cover ring or head ring (if mounted in the stuffing box cover or head). This part may be identified further by adding the word wearing, for example, casing wearing ring. A renewable part for the impeller wearing surface is called the impeller ring. Pumps with both stationary and rotating rings are said to have double-ring construction.

(2) Stuffing boxes

Stuffing boxes have the primary function of protecting the pump against leakage at the point where the shaft passes out through the pump casing. If the pump handles a suction lift and the pressure at the interior stuffing box end is below atmospheric, the stuffing box function is to prevent air leakage into the pump. If this pressure is above atmospheric, the function is to prevent liquid from leaking out of the pump.