Mechanical Equipment - Course 330.1

CENTRIFUGAL PUMPS

INTRODUCTION

An outline of the principle of operation of the centrifugal pump, and of the nomenclature and classifications applied to describe the structure of the pump, was presented in 430.10-1.

In this chapter the classifications applied to centrifugal pumps are discussed in more detail. The major pump installations in the Pickering and Bruce Generating Stations and at the Bruce Heavy Water Plant are examined in terms of classification of the structure and the basic reasoning behind the selection of pump type for that particular application.

This chapter deals only with the pump prime mover and pump casing. Other pump components, namely bearing, seals, couplings, etc, are dealt with elsewhere in Mechanical Equipment course notes.

CLASSIFICATION OF STRUCTURE

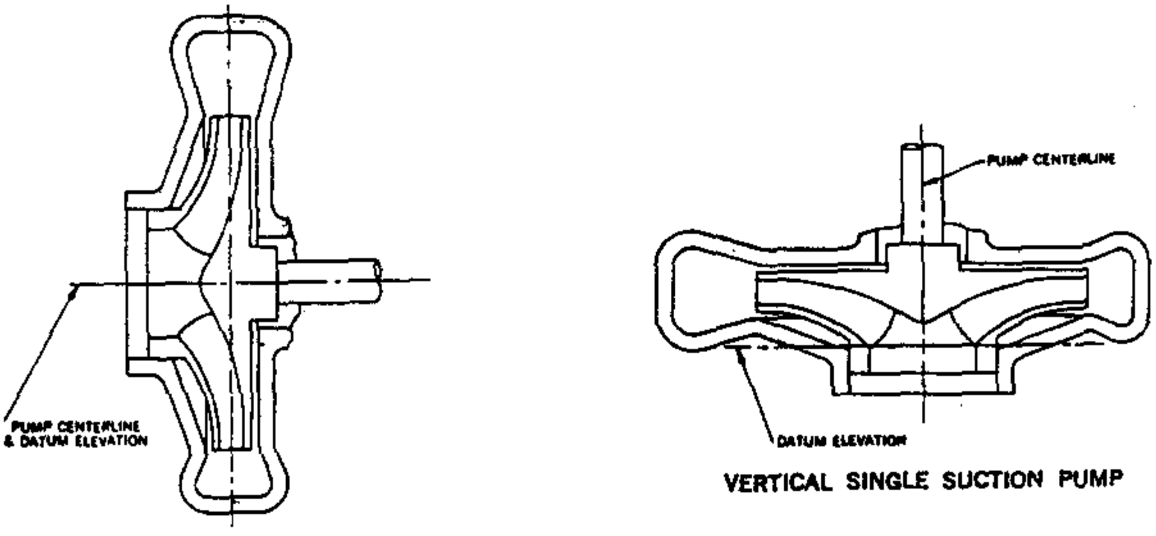
The classifications listed in Level 4, namely,

1. mount
2. staging
3. impeller type
4. direction of flow
5. casing split
6. energy conversion

are reviewed below with a short discussion on the relative merits of each design type.

1. MOUNT: Figure 1: a) Horizontal
   b) Vertical

Space is obviously a major criterion in the choice between a vertical or a horizontal mount. A conventional horizontally mounted pump/motor set will occupy approximately three times the floor space which a similarly rated vertical pump will occupy. The headroom requirement for these pumps is, however, reversed.



HORIZONTAL UNIT

VERTICAL SINGLE SUCTION PUMP

FIGURE 1

A further important consideration in a very large pump installation is that of the method of pump/motor support.

The size and rigidity of base plate required to support a large pump/motor set horizontally leads to a more expensive installation. With a vertical mount, however, the full weight can be taken on tie bars slung from an overhead member with only relatively small lateral supports to maintain stability and alignment.

A further advantage of a vertical mount is that the application may allow the pump impeller to be immersed in the liquid to be pumped, thus eliminating the requirement for intake piping and pre-start priming.

On small pump/motor installations, however, the horizontal mount is often preferred due to the ease of maintenance which it can provide.

2. STAGING: a) Single Stage
   b) Multistage

A single stage pump is one in which the head is developed by a single impeller. Often the total head to be developed requires the use of two or more impellers operating in series, each taking its suction from the discharge of the preceding impeller. For this purpose two or more single stage pumps may be connected in series or all the impellers may be incorporated in a single casing. The latter unit is called a Multistage Pump. See Figure 2.

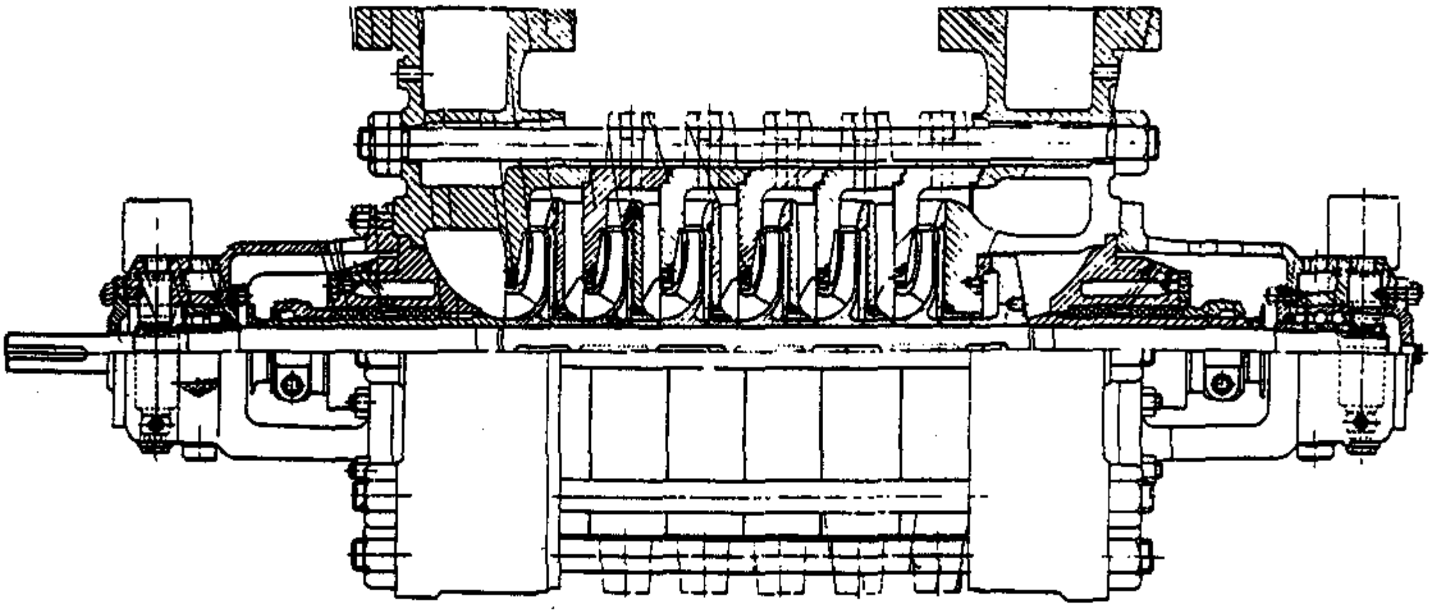


FIGURE 2: Multiple Stage Pump

When more than one impeller is used the impellers are often mounted on the shaft back to back or opposed (Figure 3). Opposed impellers have the effect of reducing the axial thrust on the shaft, thus decreasing the size of thrust bearing required.

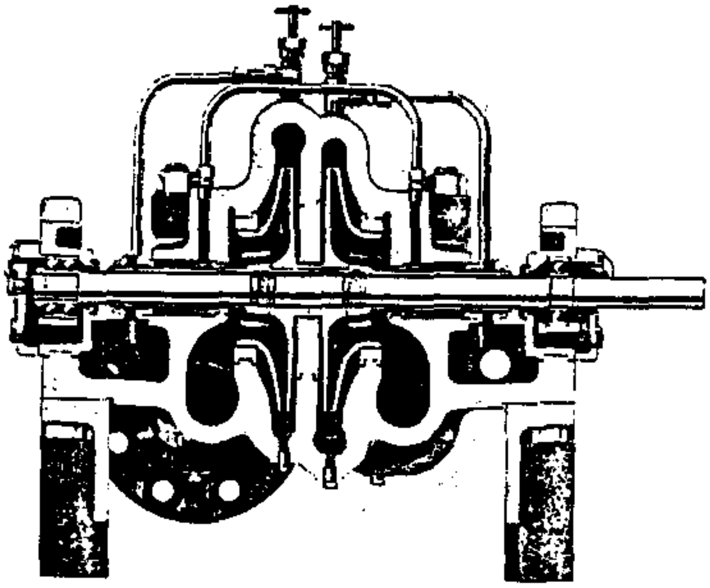


FIGURE 3: Two-stage horizontally split pump with opposed impellers

3. IMPELLER TYPE

The impeller of a centrifugal pump can be classified under the following categories:

a) single suction or double suction
b) shrouding design.

a) Single/Double Suction

In a single suction design the liquid enters the suction eye on one side of the impeller only. A double suction impeller is in effect, two single suction impellers arranged back to back in a single casting, the liquid entering the impeller from both sides. See Figure 4.

The two suction casing passageways are supplied from a common intake pipe.

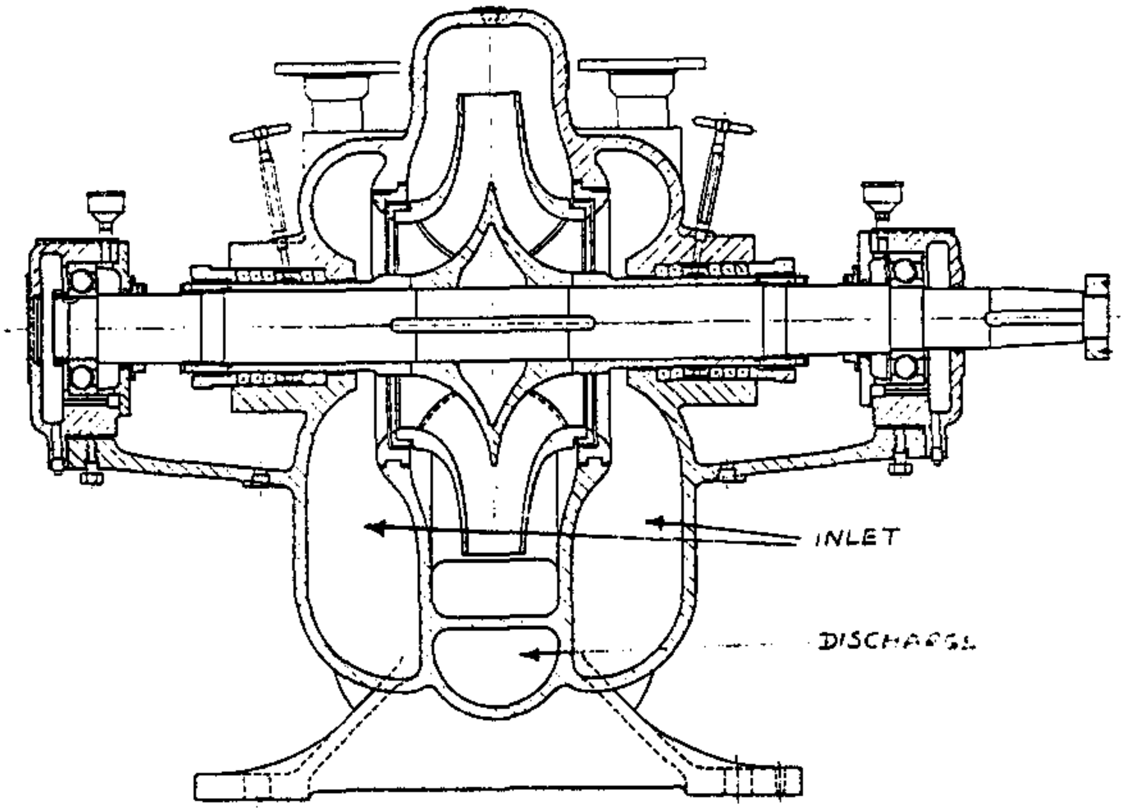


FIGURE 4: Double Suction Pump

A double suction impeller may be favoured for two reasons:

1. It is in axial hydraulic balance, reducing the size of thrust bearing required.
2. The greater impeller suction area (compared to a single suction design) permits the pump to operate with a lower pressure at the suction, for a given capacity, without cavitating.

An advantage of a single suction pump is that an overhung impeller design may be used - where the impeller is mounted on the end of the shaft. (Figure 5). Flow is allowed directly from the suction pipework to the eye of the impeller uninterrupted by the shaft. This reduces the turbulence at the entrance to the impeller and so reduces pressure losses.

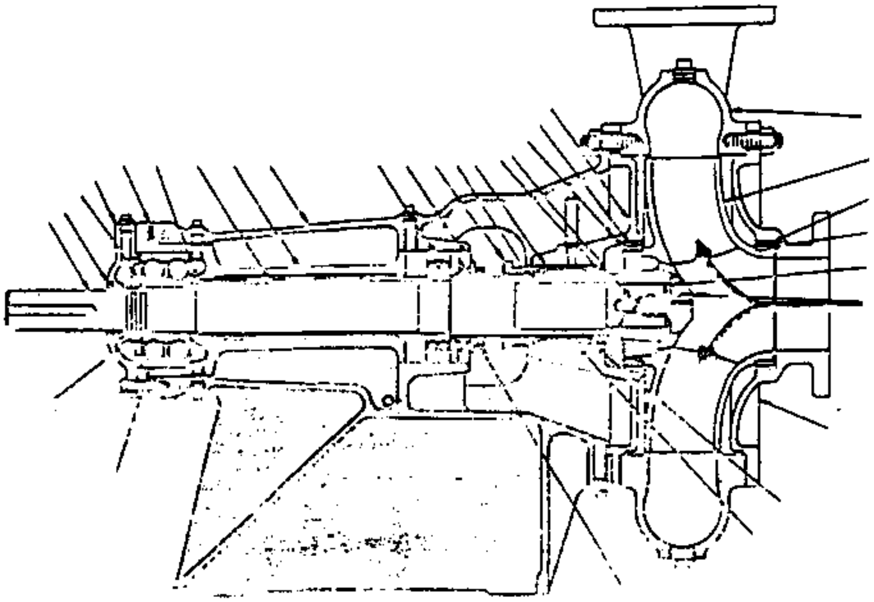


FIGURE 5: Single Suction Pump With 'Overhung' Impeller

b) Shrouding Design

Impellers may be:
(i) Open
(ii) Semi Shrouded
(iii) Fully Shrouded

(i) Open Impeller - Figure 6 A, E, F, G

Consists of vanes attached to central hub without any form of integral backplate or shroud.

The liquid is channelled through the impeller by static ducting or shrouds, past which the impeller rotates with a clearance small enough to minimize back slip of liquid. The slippage increases as wear increases. To restore the pump to its original efficiency both the impeller and the sideplates must be replaced, involving a considerable expense.

The main disadvantages of the impeller is its structural weaknesses. If the vanes are long they must be strengthened by ribs or a partial shroud.

(ii) Semi Shrouded Impeller - Figure 6 B

Incorporates one shroud or integral sidewall. This shroud increases the strength of the impeller. Some slippage across the open face will still occur but the efficiency of the impeller is higher than that of the open impeller.

(iii) Fully Shrouded Impeller - Figure 6 C & D

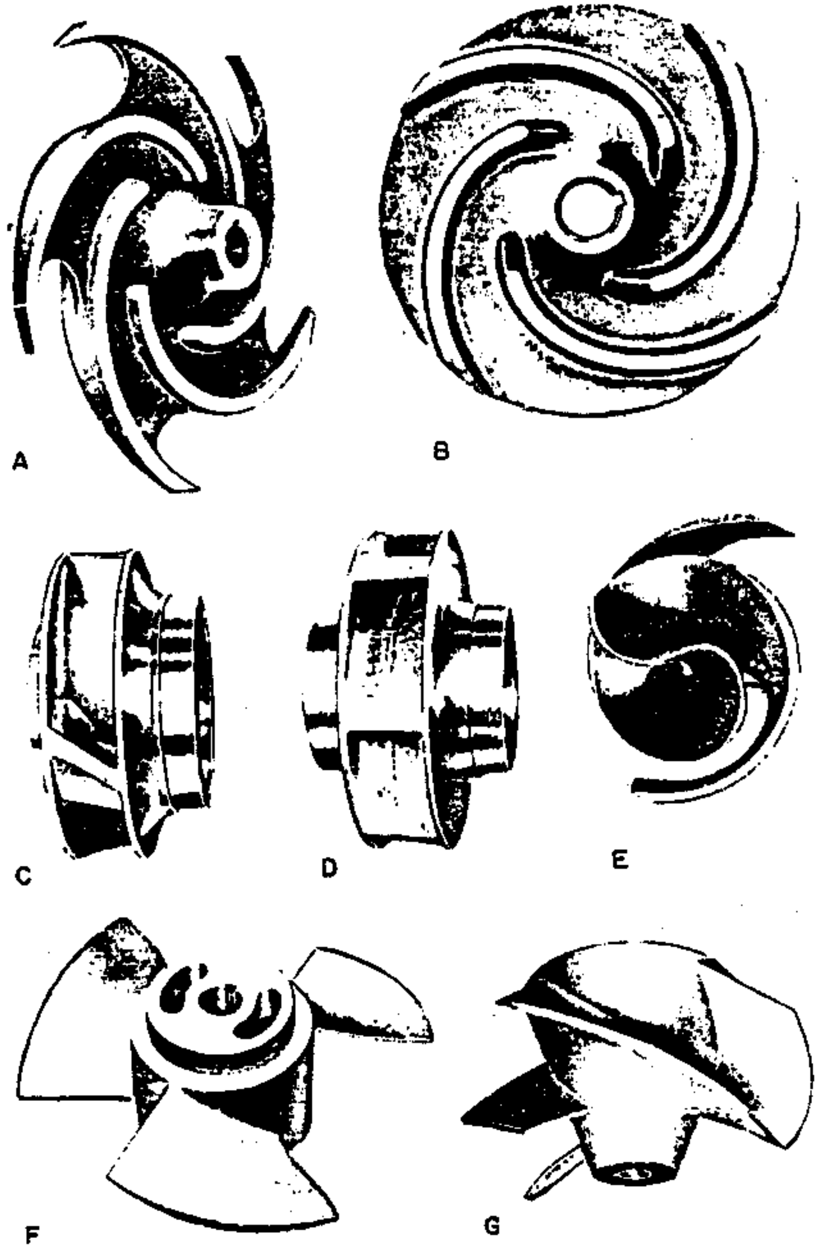
Used for handling clear liquids. Incorporates integral shrouds which totally enclose the impeller waterways from the suction eye to the periphery.

This design provides the highest efficiency in that no slippage can occur between the vanes and the shrouds. This design is, of course, expensive.

4. DIRECTION OF FLOW THROUGH IMPELLER

The direction of liquid flow through the impeller leads to the classifications:

i) Radial Flow Impeller
ii) Mixed Flow Impeller
iii) Axial Flow Impeller (Propeller)



A - Open Impeller with partial shroud
B - Semi shrouded impeller
C - Fully shrouded impeller
D - Double Suction fully shrouds impeller
E - Open impeller for viscous liquids
F - Axial flow impeller
G - Open mixed flow impeller

FIGURE 6

(i) Radial Flow Impeller

The liquid enters the impeller axially at the eye and flows radially to the periphery. The fluid is given Kinetic energy by the action of the centrifugal force causing the fluid to accelerate radially through the impeller. The kinetic energy gained in the impeller is converted to pressure energy as the liquid passes through the volute, (Figure 7a) which has a gradually increasing cross sectional area, reaching a maximum at the pump discharge.

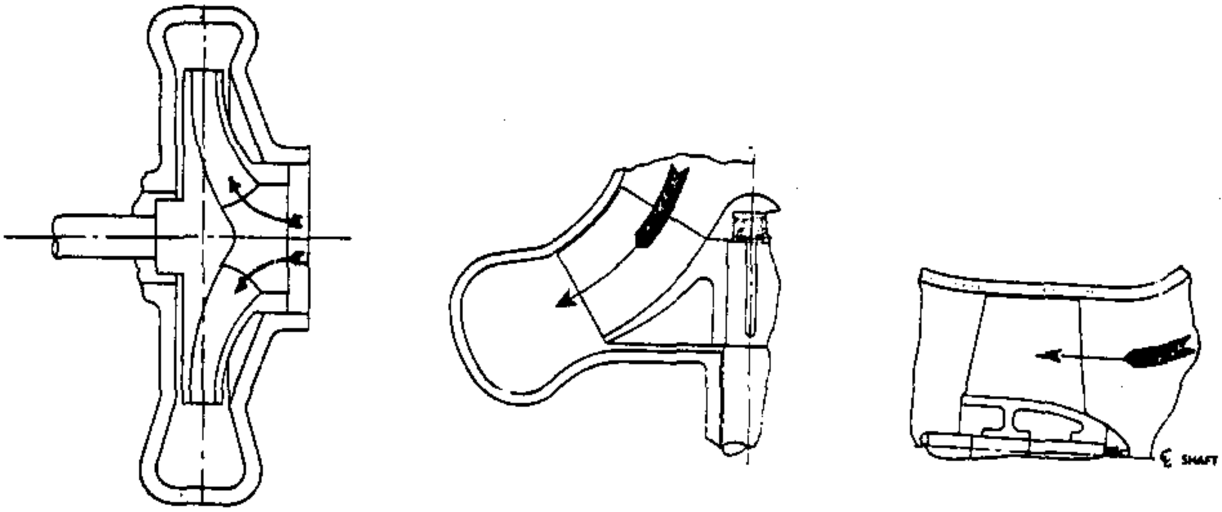
(ii) Mixed Flow Impeller

The head is developed partly by centrifugal force and partly by the lift of the vanes on the liquid. The flow enters axially and leaves with both a radial and axial component. (Figure 7b).

(iii) Axial Flow Impeller

The head is developed by the propelling or lifting action of the vanes on the liquid. The flow passes axially through the impeller with little change in direction. (Figure 7c).

The Radial Flow impeller is generally used when higher discharge pressures are required together with relatively low flow rates. An axial flow impeller would be used in high flow rate applications when just sufficient head is required to overcome friction losses. The mixed flow impeller is a compromise where some pressure rise, together with a reasonably high flow rate, is required.



a. Radial Flow Impeller

b. Mixed Flow Impeller

c. Axial Flow Impeller

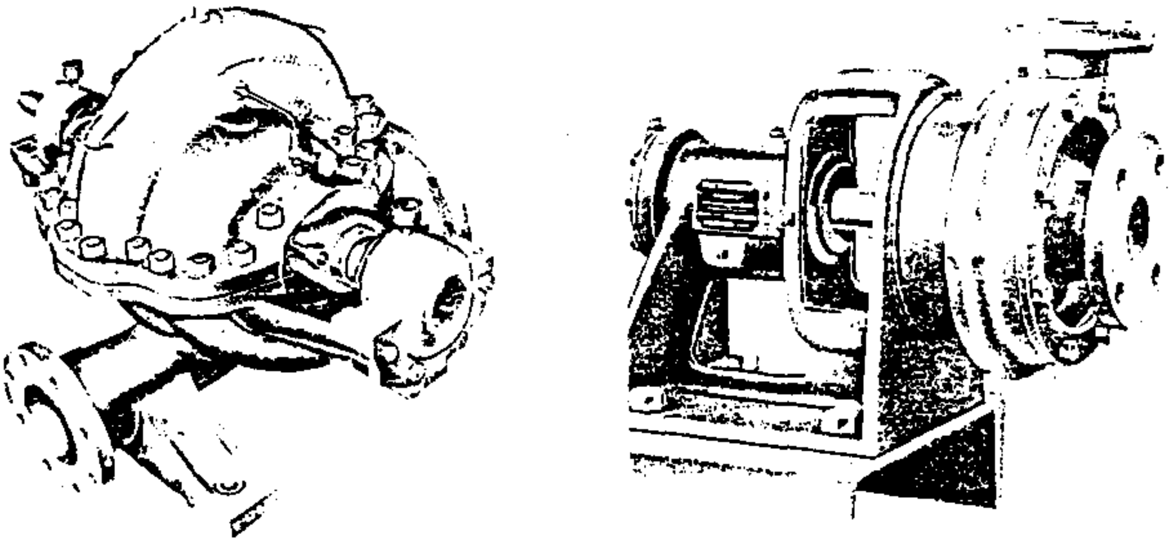
FIGURE 7

5. CASING SPLIT: a) Axial Split
b) Radial Split
c) Double Casing - Barrel

a) Axial Split - Figure 8a.

The joint between the two casing halves runs parallel to the shaft. The axially split casing has the advantage that a complete half casing may be removed to allow inspection of the pump internals without disturbing the bearings, seals or pipework.

The main disadvantage, however, is that the high pressure within the pump tends to force the casing halves apart, reducing the squeeze on the joint and leading to possible jointing problems.



a. Axial Split Casing

b. Radial Split Casing

FIGURE 8

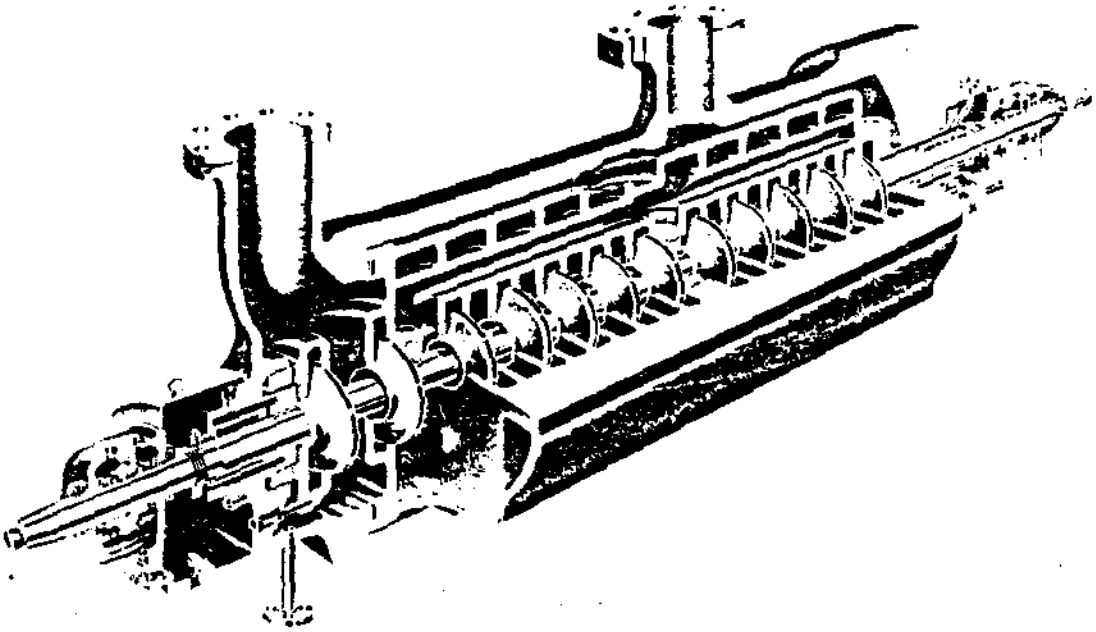
b) Radial Split - Figure 8b

The casing is split in a plane perpendicular to the axis of the pump.

A radially split casing has the advantage that the ducting (volute) which carries the high pressure liquid discharge from the impeller periphery to the discharge pipework is made from one casting.

This feature leads to an inherently stronger design than the axially split casing. The radially split casing generally requires that progressive removal be carried out of pump components, eg, pipework, bearing assembly, seals, etc, to gain access to the pump impeller. This disadvantage is particularly significant in a multistage pump.

c) Double Casing or Barrel - Figure 9



Double-casing multistage pump with axially split inner casing

(Courtesy Allis-Chalmers.)

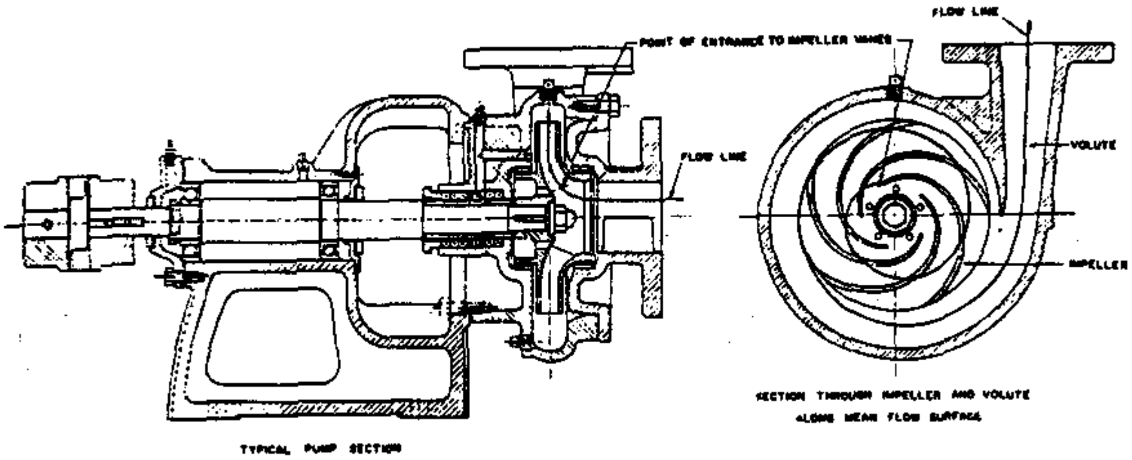
FIGURE 9

The Double Casing or "Barrel" casing has evolved out of the requirement for the convenience and expediency of an axial split casing together with the strength of the radial split casing. The basic principle consists of enclosing the working parts of a multistage centrifugal pump in an axial split casing and then locating a second radial casing or barrel around the inner casing. The space between the two casings is maintained at the discharge pressure of the pump. This arrangement ensures that the inner casing is under compression and the axial flanges will remain tight. This system does not, however, completely insure against interstage leakage.

6. **ENERGY CONVERSION:**
   a) Volute
   b) Double Volute
   c) Diffuser Vanes

a) Volute - Figure 10

The volute is a chamber surrounding the impeller of which the cross sectional area increases steadily towards the discharge. This increase in cross-sectional area causes the conversion of the Kinetic Energy of the liquid to Pressure energy as it is directed from the impeller periphery to the pump discharge. The volute is used generally in pumps with radial flow impellers.

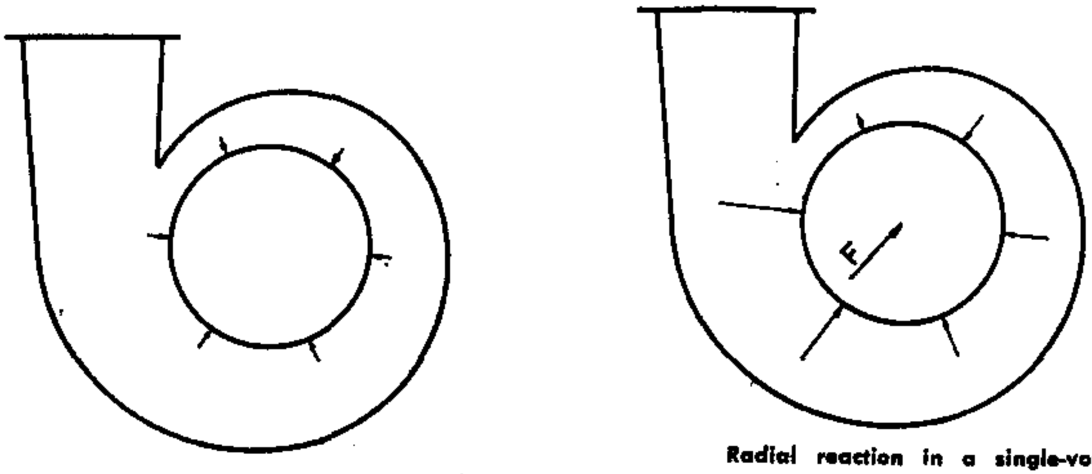


TYPICAL PUMP SECTION

SECTION THROUGH IMPELLER AND VOLUTE ALONG MEAN FLOW SURFACE

FIGURE 10

When a single volute pump casing design is used uniform pressures act around the periphery of the impeller only when the pump is operating at design capacities. At other capacities the pressures around the impeller, and therefore the radial forces acting on the impeller, are not uniform, and there is a resultant radial thrust. This thrust is usually the greatest at shut off (zero flow). (Figure 11). This thrust is not of great significance in small low pressure pump applications but pumps utilizing a large impeller with a high pressure rise across the pump require the use of a Double Volute.



Zero radial reaction in single-volute casing
Uniform pressures exist at design capacity.

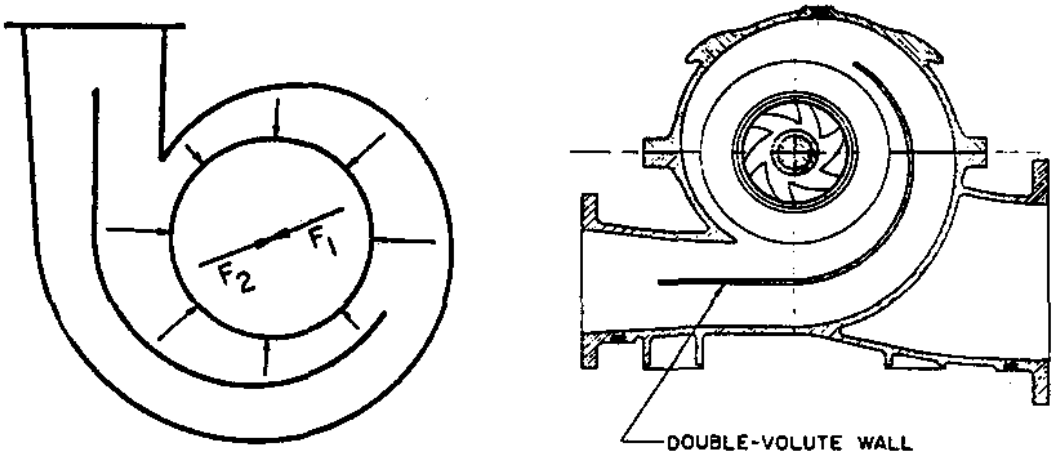
Radial reaction in a single-volute casing
Uniform pressures do not exist at reduced capacities.

FIGURE 11

b) Double Volute

The Double Volute casing incorporates a wall which divides the original single volute into two 180° volutes. This design contributes towards a balance in the radial thrust exerted on the impeller. The reduction in radial thrust allows the use of a smaller diameter pump shaft with a smaller bearing surface area. (Figure 12).

An additional benefit is that the central rib in the volute helps to strengthen the pump casing.



Radial reactions in double-volute pump

Transverse view of double-volute casing pump

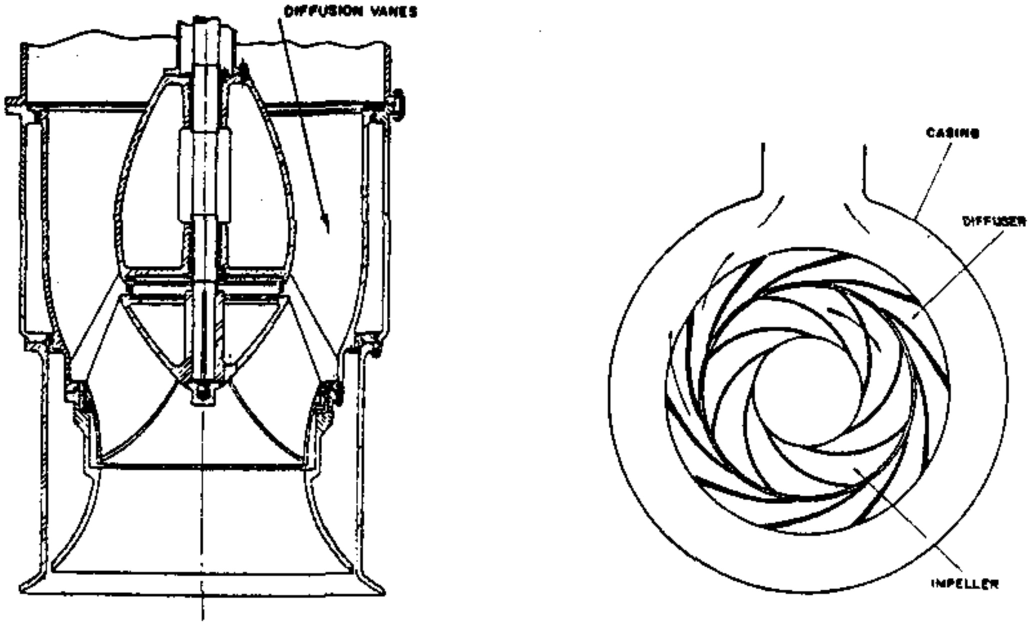
FIGURE 12

c) Diffuser Vanes

Diffuser vanes may be fitted to the discharge from a centrifugal pump impeller to reduce the turbulence generated in the flow as the liquid emerges from the impeller.

The diffuser is now seldom used in radial flow pumps since impeller/volute design has advanced to the degree that addition of diffuser vanes will not improve efficiency significantly. They are, however, used extensively in mixed and axial flow applications where a volute is impractical. (Figure 13).

A disadvantage of the diffuser vane is that the diffuser will generally improve the pump efficiency only at design flow conditions, when the angle of the vanes corresponds to the angle at which the liquid leaves the impeller. At other capacities the diffuser vanes can cause shock and increase turbulence.



a. Vertical mixed flow pump with diffuser

b. Radial flow pump with diffuser in volute

FIGURE 13

AXIAL THRUST IN CENTRIFUGAL PUMPS

Axial hydraulic thrust is the resultant of the forces acting on the impeller in the axial direction. (Figure 14a).

Reliable large capacity thrust bearings are now readily available so axial thrust in single stage pumps remains a problem only in larger units.

Methods by which axial load on a thrust bearing may be reduced are:

a) Double Suction Impeller - Figure 14b

Theoretically a double suction impeller is in hydraulic axial balance, with the pressures on one side equal to the pressures on the other. In practice the balance may not be achieved due to unequal or non uniform flows to the two sides caused by external conditions, such as an elbow being too close to the pump suction or due to internal casing conditions, such as assymetry of the suction passages or volutes.

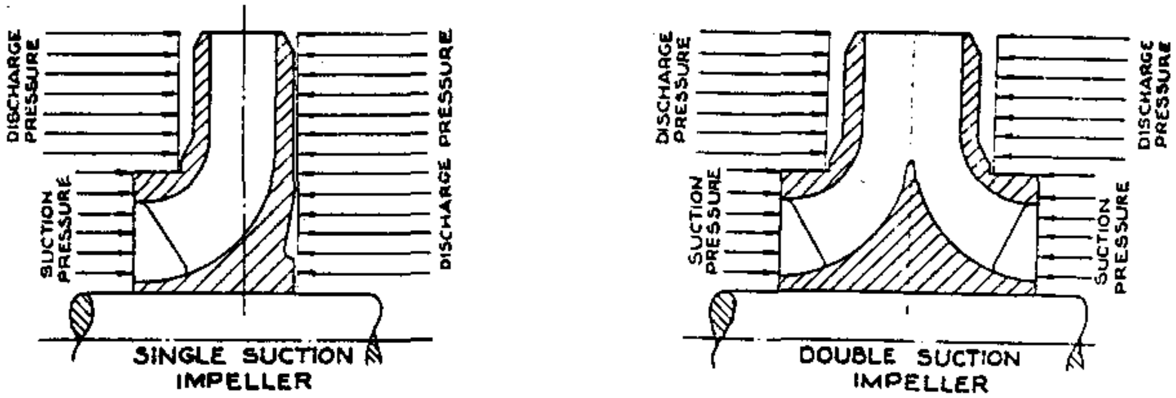


FIGURE 14

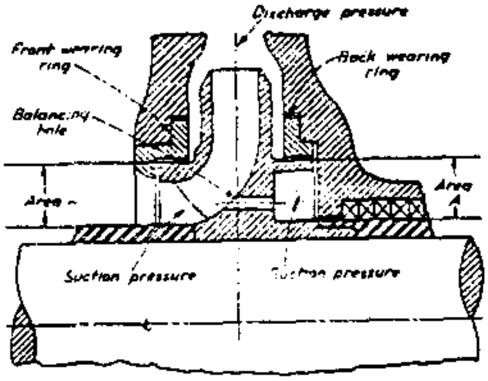
Combined, these factors create axial unbalance. To compensate for this, all centrifugal pumps, including those with double suction impellers, incorporate thrust bearings.

b) Balancing Holes

The high pressure behind the impeller is reduced by allowing liquid from the back of the impeller to be bled through to the front of the impeller by drilled holes.

c) Black Waring Rings - Figure 15

A single suction impeller can be provided with both front and back wearing rings. To equalize thrust areas, the diameter of both rings is made the same. Pressure approximately equal to the suction pressure is maintained in a chamber located under the back wearing ring by the use of balancing holes through the impeller.

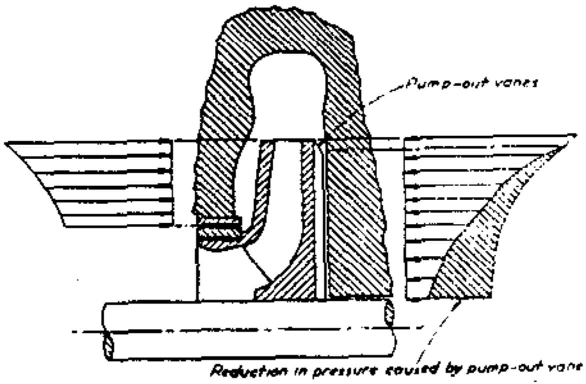


Balancing axial thrust of single-suction impeller with wearing ring on the back and balancing holes

FIGURE 15

d) Pump Out Vanes - Figure 16

Pump out vanes on the back shroud of single suction impellers have the effect of reducing the pressure acting on the back of the impeller by opposing the flow of the handled liquid from the volute towards the shaft behind the impeller.



Reducing axial thrust of single-suction impeller with pump-out vanes

Open impeller with partial shroud

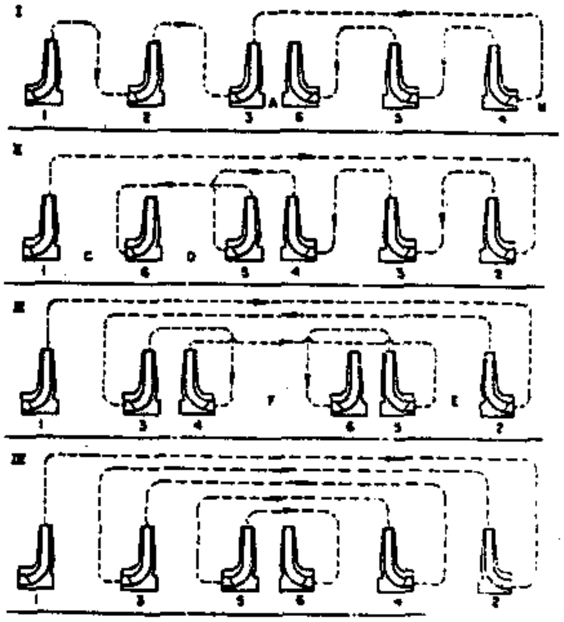
Front view (left) and back view (right) show pump-out vanes.

FIGURE 16

e) Opposed Impellers - Figure 17

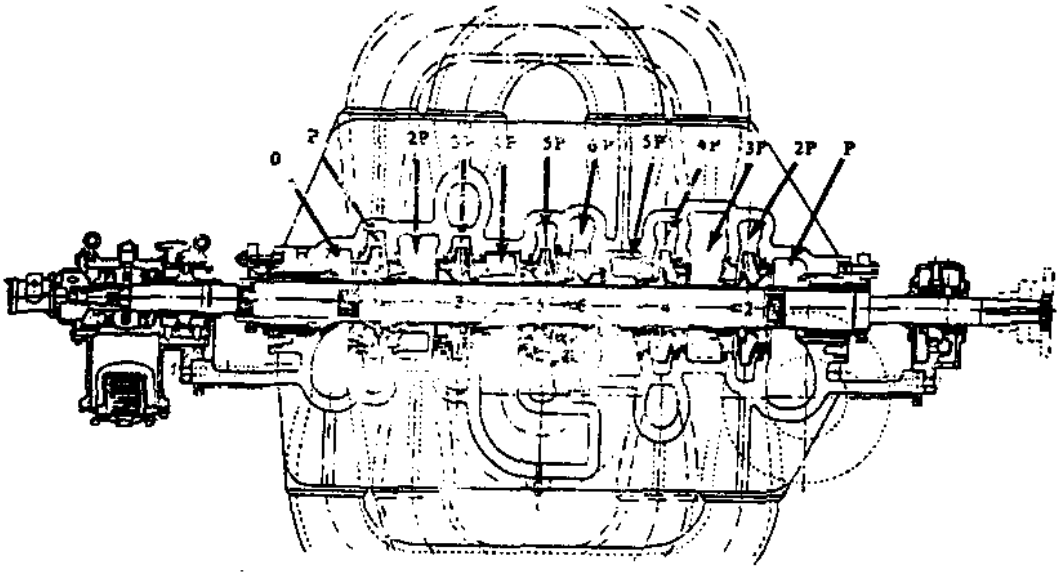
In multistage pumps axial thrust may be minimized by arranging the impellers on the shaft such that a number of impellers face the opposite direction to the remainder.

The sequence in which the individual impellers are to be arranged in the pump is decided by the manufacturer as a result of analysis of the number of running joints acceptable, the pressure differential across running joints and the pressure to which the end seal (stuffing box or mechanical seal) will be subject.



I. Joint A subject to three-stage pressure differential; one stuffing box under high pressure at B. II. Arrangement with two high-pressure joints, including four-stage pressure differential at C and two-stage differential at D. III. Joints E and F under two-stage pressure differential. IV. All running joints subject to only one-stage pressure differential.

Stage arrangements for six-stage axially balanced pump



Section of six-stage opposed-impeller pump

Suction pressure equals zero; pressure generated by each impeller is indicated by P.

FIGURE 17

f) Hydraulic Balancing Devices

i) Balancing Drum - Figure 18

A balancing chamber at the back of the last stage impeller is either keyed or screwed to the shaft and therefore rotates with the shaft. A small radial clearance separates the rotating drum from the static casing.

The pressure in the balance chamber situated behind the drum is maintained at pump suction pressure by interconnecting pipework. Thus a differential pressure exists across the drum creating an axial end force on the shaft. By careful design of the balancing drum can be made to balance the axial rotor thrust which would exist without the drum.

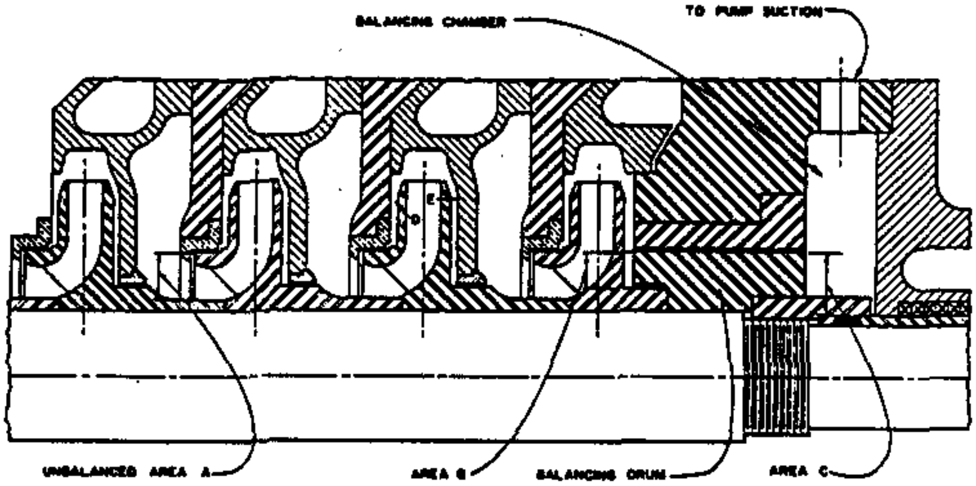


FIGURE 18: Balancing Drum

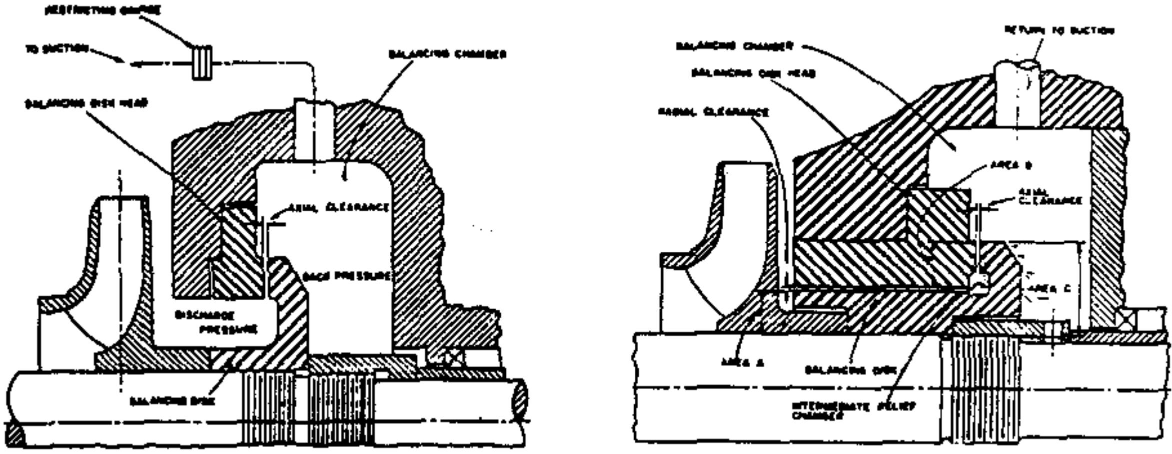
ii) Balancing Disc - Figure 19

The balancing disc is fixed to, and rotates with, the pump shaft, and is separated from the stationary balancing disc head by a small axial clearance. The liquid from behind the pump impeller can leak through this clearance to the balance chamber, from where it can flow back to the pump suction.

The pressure in the balance chamber will therefore act on the whole of the rear face of the balance disc and full pump discharge pressure will act on the smaller exposed area at the front of the disc. Small axial movement of the rotor shaft will adjust the clearance between the balancing disc head and the balance disc thus altering the flow through the clearance and causing the pressure in the balance chamber to vary. Altering the pressure in the balance chamber will change the axial force on the back of the balance piston.

Referring to Figure 19a, if the axial force on the impeller increases to the right, then the shaft will move in that direction increasing the axial clearance between the balancing disc and balancing disc head. The increase in clearance increases the flow into the balance chamber and hence increases the pressure in the balance chamber. This in turn increases the axial force on the back of the balancing disc and opposes the original increased impeller axial thrust.

It can be seen, therefore, that the balancing disc provides automatic compensation for any change in axial thrust caused by varying system characteristics at differential operating conditions. The thrust bearing must prevent excessive movement of the rotating element. This automatic compensation is the major feature that differentiates the balancing disc from the balancing drum.



a. Simple balancing disc

b. Combination balancing disc and drum

FIGURE 19

APPLICATIONS OF CENTRIFUGAL PUMPS

The classifications discussed in this chapter are applied to the following major pumps used in Candu and Heavy Water Plants.

Candu:
1. Primary Heat Transport Circulating Pump
2. Primary Heat Transport Pressurizing Pump
3. Boiler Feed Pump
4. Condenser Circulating Water Pump

BHWP:
5. In Line, Close Coupled Process Pump
6. Canned Rotor Process Pump
7. Cooling Water Pump

1. PRIMARY HEAT TRANSPORT CIRCULATING PUMP

The Byron Jackson PHT Circulating Pumps at both Pickering Generating Station and Bruce Generating Station are similar in construction although the BGS'A' pump is considerably larger than that at Pickering GS'A'. The Pickering PHT Circulating pump is shown in Figure 20, the Bruce PHT Circulating pump in Figure 21.

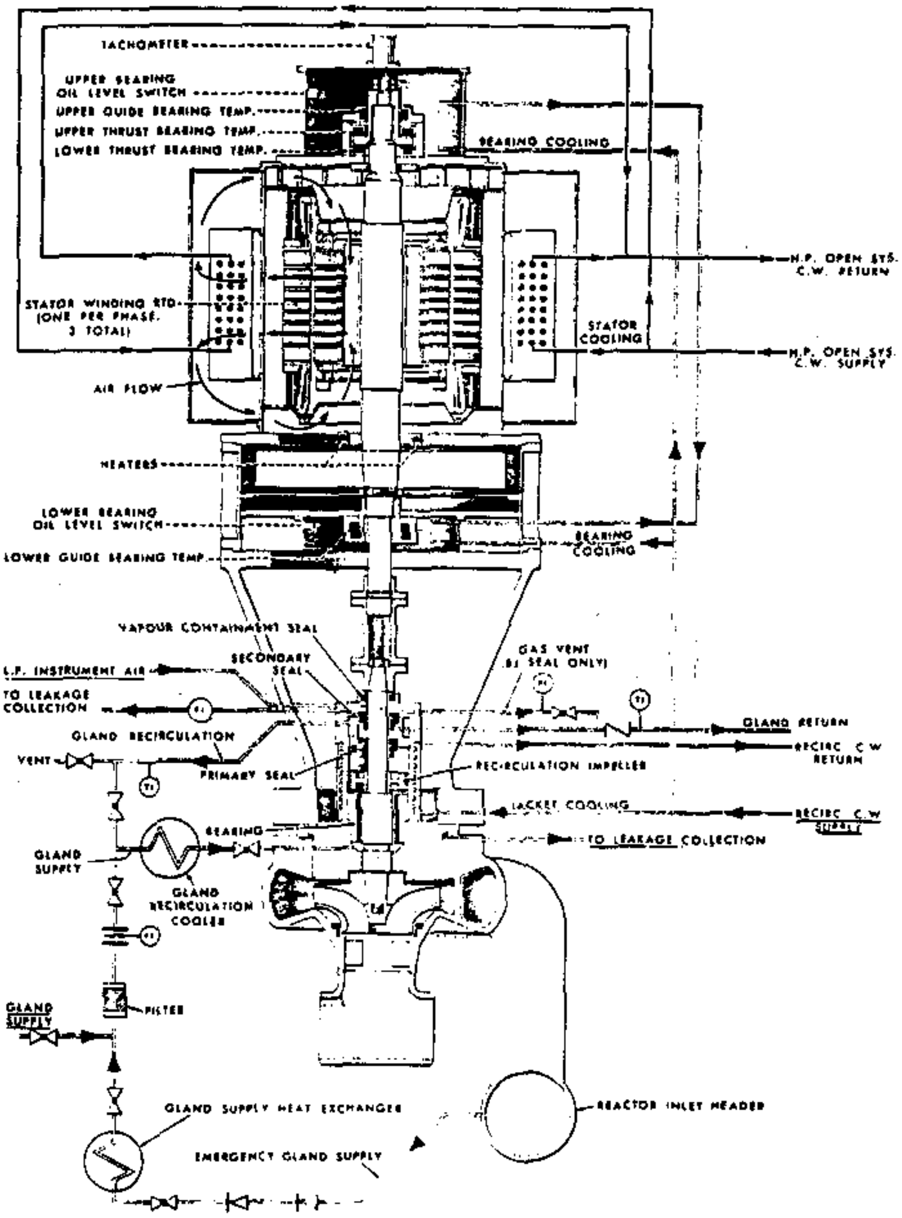
The purpose of the pump is to maintain a high flow rate of D_2O through the reactor to transport heat generated in the reactor to the Steam Generators.

a) Mount - Vertical

Reasons:
- a) Cheaper - fewer components - no base plate
- b) Occupies minimum floor space
- c) Suspended, therefore free to move slightly, easing pipework expansion problems
- d) Seal replacement less complex.

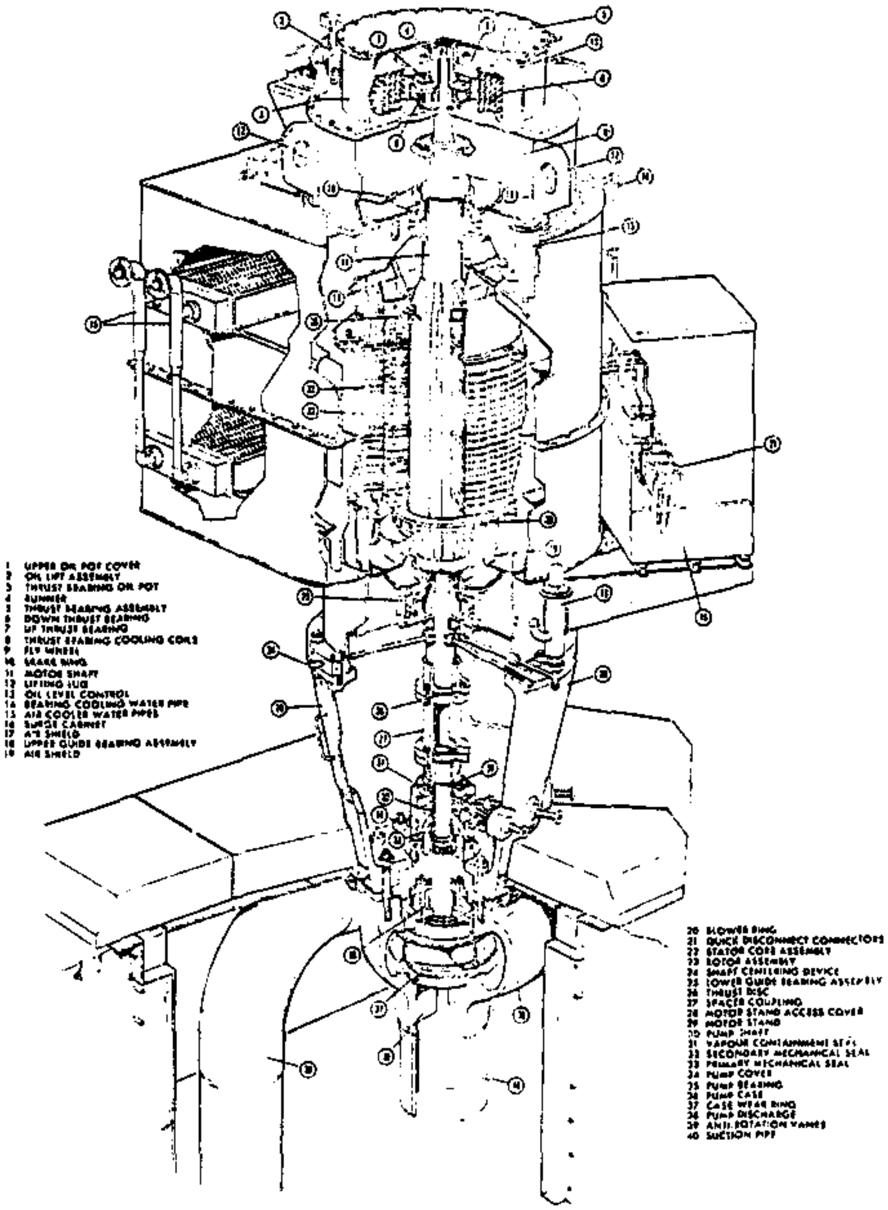
b) Staging and Impeller
- Single Stage
- Single Suction
- Radial Flow
- Fully Shrouded
- Stainless Steel.

The above combination enables the total design PHT flow rate of 12.1 m^3/s (160,000 Igpm) per reactor against a head of 144 m (480 ft) to be met at Pickering by 16 PHT pumps utilizing a 584 mm (23 in) diameter impeller, each with a rating of 0.76 m^3/s (10,000 Igpm).



Pickering GS'A' Heat Transport Pump - Instrumentation and Auxiliary Circuits Schematic

FIGURE 20



Bruce GS'A' Heat Transport Pump

FIGURE 21

The higher flow requirement at Bruce of 13.2 m^3/s (174,000 Igpm) against a head of 210 m (700 ft) is provided by a 4 PHT circulating pumps per reactor, each with a 800 mm (31.4 in) diameter impeller and a rating of 3.3 m^3/s (43,600 Igpm).

c) Casing Split - Radial

The design of the casing assembly is such that all internal pump components, except the shaft and the impeller, can be removed from the pump without disturbing the motor, providing ease and speed of maintenance. The rotating element, pump cover and all internal components can be removed vertically as a unit from the pump case after first removing the motor and motor mount.

d) Energy Conversion - Double Volute

The size of impeller dictates the use of a double volute to reduce the radial thrust on the impeller. This in turn reduces the required shaft diameter and the area of the bearing surface.

e) Axial Thrust Compensation - Impeller rear wearing ring and balance holes

The impeller has a rear wear ring of equal diameter to the front wear ring. Pressure balancing holes are drilled through the impeller inside the rear wear ring. A thrust bearing is fitted at the top of the motor shaft above the upper guide bearing.

f) Special Features - Flywheel

The flywheel increases the Moment of Inertia of the pump/motor rotating assembly to give the pump a rundown time sufficient to maintain reactor cooling until power is re-established after an electrical power failure.

h) Auxiliary Systems Required for Pump Operation

Before operation of the PHT circulating pump can be considered, the following auxiliary supplies must be established at the pump.

i) Gland Supply and Return - High pressure water from the PHT Pressurizing System for cooling and lubricating glands, seats and bearings.

ii) Pump seal leakage Collection & Venting - Leakage from mechanical seals is piped to the D_2O Collection System. Continuous venting is required to ensure that seals are completely immersed in water.

iii) Pump Jacket and motor bearing cooling - supplied by the Service Water Recirculating Cooling Water System.

iv) Motor Stator Cooling - 2 motor stator coolers for pump are cooled by the Service Water High Pressure Open System.

v) Vapour Containment Seal Air Supply - supplied from Reactor Building Instruments Air System.

2. PRIMARY HEAT TRANSPORT PRESSURIZING PUMP

The Primary Heat Transport pressurizing pumps are required to maintain PHT system pressure. They also supply the flow required for the PHT purification system, for PHT circulating pump gland sealing water, for the bleed condenser sprays and for pressurizing flow to the fuelling machines.

The two 100% Byron Jackson 363 BHP Type 15 HHH Hydropress centrifugal pumps are described below.

a) Mount - Vertical

b) Staging & Impeller - Multiple Stage (20)
- Single Suction
- Radial Flow
- Fully Shrouded

The very high head requirement of 890 m (2970 ft) with a low flow rate of 0.018 m^3/s (233 Igpm) at 38°C (100°F) has led to a multiple stage centrifugal pump design using 20 impellers of 0.165 m (6 in.) diameter. Fully shrouded, radial flow impellers are used for maximum efficiency.

c) Casing Split - Barrel, Figure 22

The inner casing is axially split to allow ease of inspection of the pump assembly. To minimize the difficulty involved in producing a leak tight flange to seal against the last stage discharge pressure of approximately 10 MPa(g) an external barrel is located over the axially split casing and the space between the two casings is pressurized by the pump discharge.

d) Energy Conversion - Volute

Each of the 20 stages has its own volute, the discharge of which is led to the eye of the next impeller.

e) Axial Thrust Compensation - Opposed Impellers - Figure 22

The impellers are arranged with the first 7 stage impellers being mounted on the shaft in the opposite direction to the last 13 to equalize axial thrust.

The Pressurizing Pumps at Bruce GS'A' are similar in principle but are horizontally mounted and have ten stages of fully shrouded, radial flow impellers. The casings are axially split with no barrel. This arrangement has called for an inherently stronger and heavier casing.

3. BOILER FEED PUMP

The Main Boiler Feed Pump at Pickering GS and Bruce GS are identical in all but impeller size. Both plants utilize three Byron Jackson pumps per unit, each of which are 50% capacity. These pumps take a suction from the Deaerator feedwater storage tank and discharge via a header, through two banks of feedwater heaters and feedwater regulating valves to the Steam Generator.

a) Mount - Horizontal

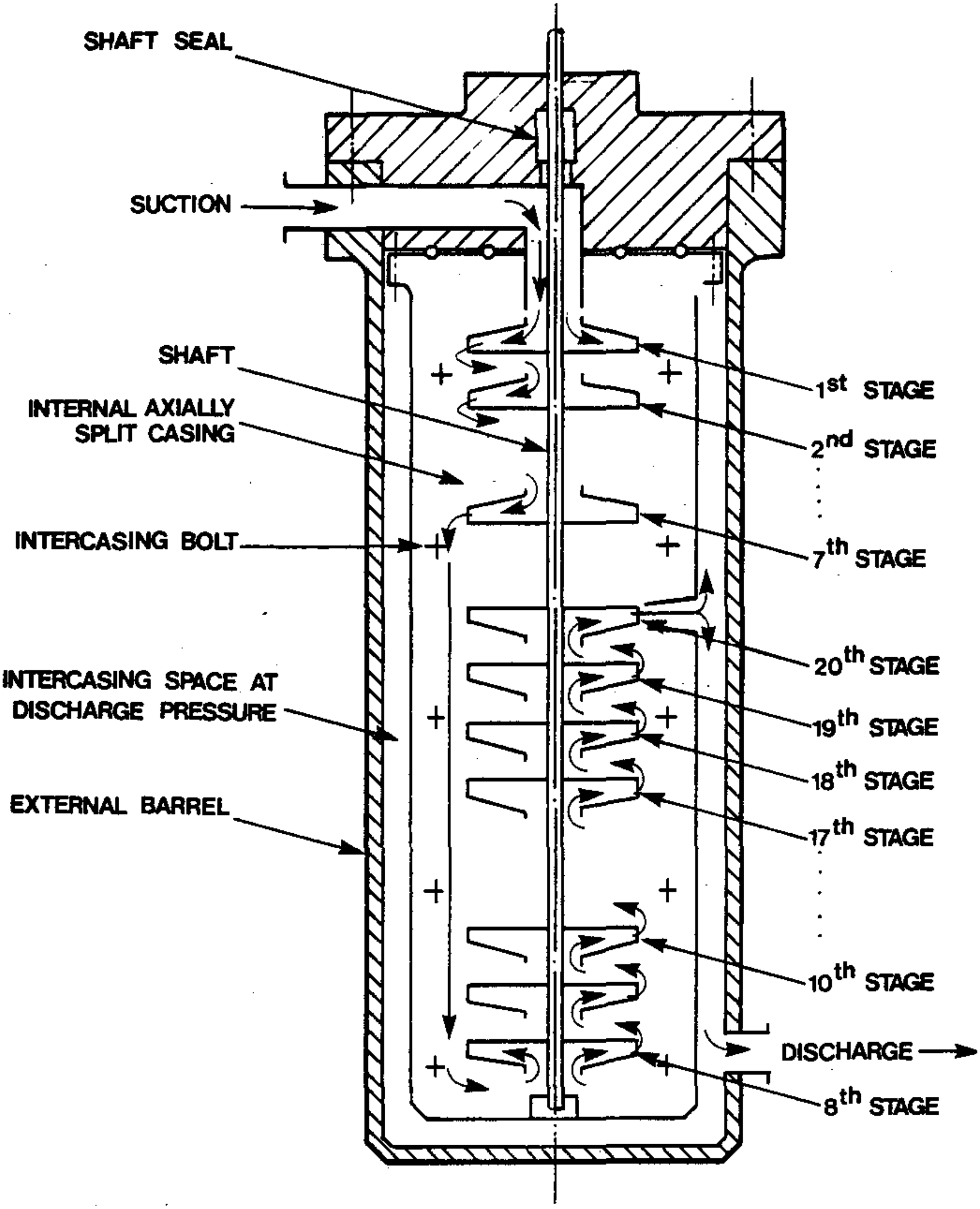
Being relatively small pumps the horizontal mount allows ease of maintenance without incurring high cost through the use of a large bed plate.

b) Staging & Impeller - Two Stage
- Single Suction
- Radial Flow
- Fully Shrouded

The two stage design is necessary to allow the pump to operate with a total head of 538 m (1765 ft) and a capacity of 0.651 m^3/s (8600 Igpm) at Bruce GS.

c) Casing Split - Axial

The maximum working pressure of 6.9 MPa(g) (1000 psig) can be contained by an axial split casing. The external pipework is attached to the lower half of the casing allowing the top cover to be removed without disturbing the pipework.



Operation of Pickering GS'A' HT Pressurizing Pump

FIGURE 22

d) Energy Conversion - Double Volute

The high pressure rise across the pump leads to a large radial thrust acting on the impeller. To minimize the radial thrust a double volute is used, allowing a smaller diameter pump shaft and a smaller bearing surface area to be used.

e) Axial Thrust Compensation - Opposed Impellers

The two impellers are opposed, contributing towards a balance in axial forces. The resulting reduced axial thrust is compensated by a thrust bearing.

f) Special Fittings - Continuous By-pass Flow

During plant power reduction the pump may be required to operate against a shut Boiler Feed Regulating Valve. Operation against a shut discharge valve leads to churning of the impeller with consequent overheating and eventual damage to the pump. To overcome this problem a recirculating line is fitted which allows 10% of the pump design flow to be directed from the discharge upstream of the Feed Regulating Valve back to the deaerator storage tank, allowing a continuous cooling flow to be maintained through the pump at all times.

4. CONDENSER CIRCULATING WATER PUMP

The Bruce GS condenser circulating water pump, (Figure 23) manufactured by Ingersoll Rand, provides a lake water coolant flow of 12.88 m^3/s (170,000 Igpm) to the Main Condensers for condensation of exhaust steam from the L.P. turbines. The pumps operate against a 6.4 m (21 ft) head.

a) Mount - Vertical

The pumps are vertically mounted submerged impeller (wet pit type) pump. Since the pump is below lake level there is no requirement for priming or for suction pipework. Also water lubricated cutless rubber bearings can be used since the lubricant will always be present at the bearing surface, although the primary bearing coolant and lubricant supply is from L.P. service water.

The pump casing is, in fact, part of the condenser inlet pipework. The pump shaft extends vertically up to the gearbox and motor above lake level.

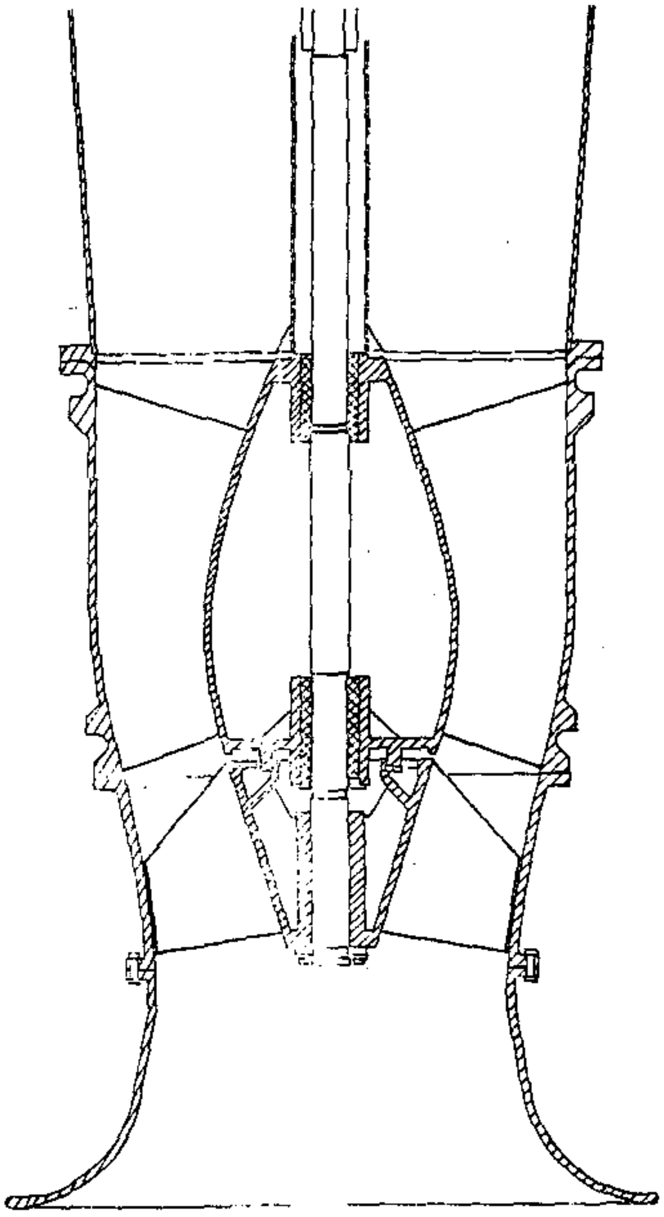


FIGURE 23: Pickering Condenser Circulating Water Pump

b) Staging & Impeller - Single Stage
- Single Suction
- Axial Flow

In installations requiring very high flow rates an axial flow impeller is used. The disadvantage of the axial flow impeller is that the discharge head which the impeller can supply is limited. To overcome this problem in the CANDU CCW installation the Main Condenser CCW System is completely primed by use of the Vacuum priming pumps. This allows coolant flow to be maintained by a syphon effect, with the CCW pumps supplying only sufficient head to overcome friction losses of the water through the system.

The 0.546 m (21.5 in) diameter impeller is capable of supplying the flow rate required at the head necessary to overcome friction losses using a single stage.

c) Casing Split - Radial

Since the casing is part of the Condenser inlet pipework an axial split casing would not be feasible.

d) Energy Conversion - Diffuser

A diffuser vane ring is the only practical method of energy conversion when an axial flow impeller is used. The operating conditions are constant, the only variation being due to build up of deposits on the pipework or partial blockage of condenser tubes or travelling screens, thus the impeller and diffuser vanes can be designed for maximum energy conversion with minimum turbulence at the design operating point with little anticipated deviation from that point.

e) Axial Thrust Compensation - Helical Gearing

Since the action of the axial flow impeller is that of lifting the water through the pump there is a downthrust on the impeller which must be compensated. This compensation is carried out by the use of single helical cut gearing in the gearbox between motor and pump. The gearing arrangement chosen provides an upward force on the pump shaft.

f) Special Features - Gearbox

Since the axial flow impeller is designed to run at low speed (200 rpm) a reduction gearbox must be used if it is chosen to run the pump using an induction motor. The gearbox, therefore, reduces the speed from 18000 to 200 rpm.

5. BHWP - Vertical, In Line, Close Coupled Centrifugal Pumps

United vertical, in line, close coupled centrifugal pumps (Figure 24) are used in the enriching units at the Bruce Heavy Water Plant in the following applications:

i) 1st, 2nd and 3rd Stages. Dehumidifier Pumps.
ii) 1st Stage Humidifier Pumps.
iii) 2nd and 3rd Stages Hot Tower Bottom Pumps.
iv) Effluent Strippers Reflux Pumps.
v) Steam Tracing Condensate Return Pumps.
vi) Tempered Water Pumps.

a) Mount - Vertical in line

Vertical in line pumps are common in industrial process service since they are designed with the same size suction and discharge pipework on the same vertical and horizontal centrelines 180° apart. Although similar pumps in small sizes may be supported by the pipe itself with no special supporting foundation the pumps used at BHWP are large enough to require considerable support.

b) Staging & Impeller - Single Stages
- Fully Shrouded
- Radial Flow

Since these pumps in effect act as Booster pumps they are required to be capable of increasing system pressure sufficient for the next stage of the process. To allow this pressure rise a radial flow impeller is used, sufficient pressure rise being available with one such impeller. To minimize the pump motor size a fully shrouded impeller is used providing maximum efficiency.

c) Energy Conversion - Volute

The Volute allows conversion of kinetic energy picked up in a radial flow impeller to pressure energy.

d) Casing Split

In line pumps invariably have radially split casings allowing dismantling of the pump without disturbing the pipework.

e) Axial Thrust Compensation

Axial thrust is reduced by the use of a rear wearing and balance holes in the impeller. Residual thrust is absorbed by the motor thrust bearing.

f) Special Features

Close coupled pumps do not have bearings within the pump assembly. The motor is connected directly to the pump via a solid coupling, the pump impeller is then completely supported by the motor bearings.

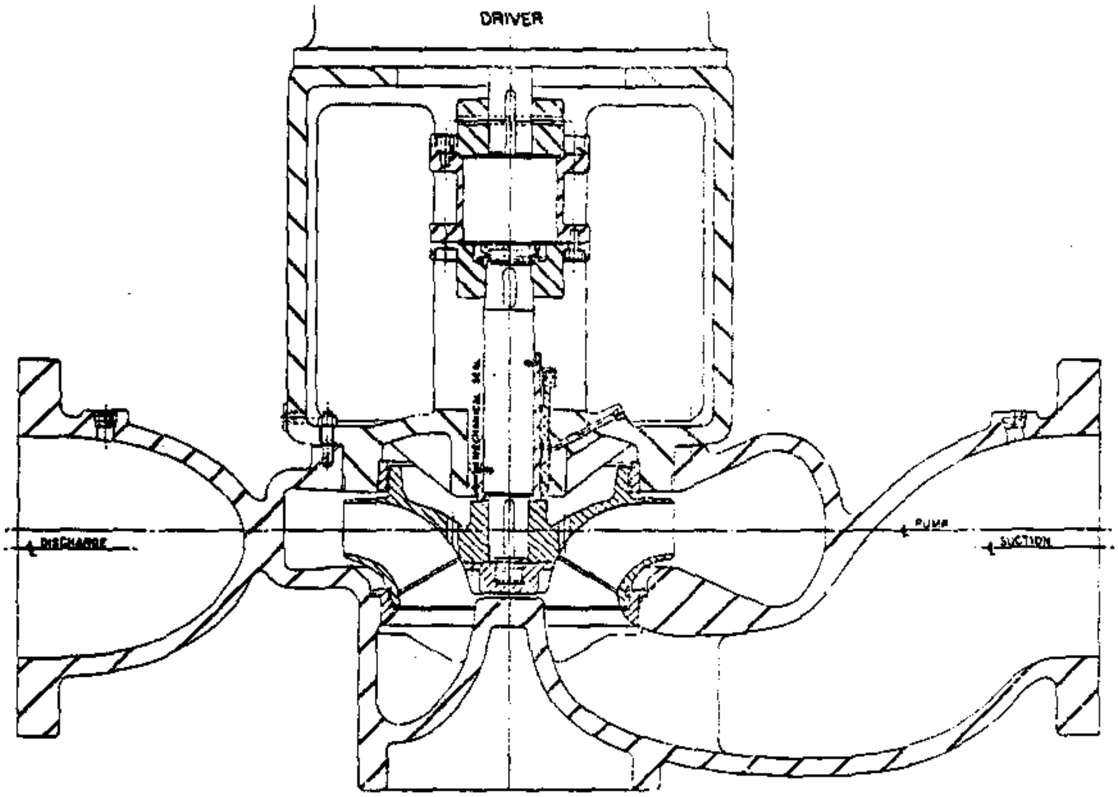


FIGURE 24

6. BHWP - Horizontal Canned Motor Centrifugal Pumps

Canned Motor Centrifugal Pumps are used in the Bruce Heavy Water Plant Finishing Units in the following applications:

i) Feed Storage Tank Fuel Pumps.
ii) D_2O Storage Transfer Pumps.
iii) 1st and 2nd Stage Bottoms Pumps.
iv) 1st Stage Reflux Pumps.

Application i) and ii) above use a pump with structures as shown in Figure 25. Appliction iii) and iv) differ from Figure 25 in that motor cooling is supplied by external ducting of liquid from the pump discharge. The design of the axial thrust compensation features. also differs in that applications iii) and iv) use a balance drum whereas applications i) and ii) use an automatic thrust control valve.

a) Mount - Horizontal

b) Staging & Impeller - Simple Stage
- Fully Shrouded
- Radial Flow

The impeller enables the pump to discharge a capacity of 1.43 l/s ( ) at 3600 rpm. The pump is powered by a 0.8 KW motor.

c) Energy Conversion - Volute

d) Casing Split - Radial, Canned rotor

In canned rotor pumps both motor and pump are enclosed in a common casing. The motor stator and rotor assemblies are sealed in two jackets or 'cans'.

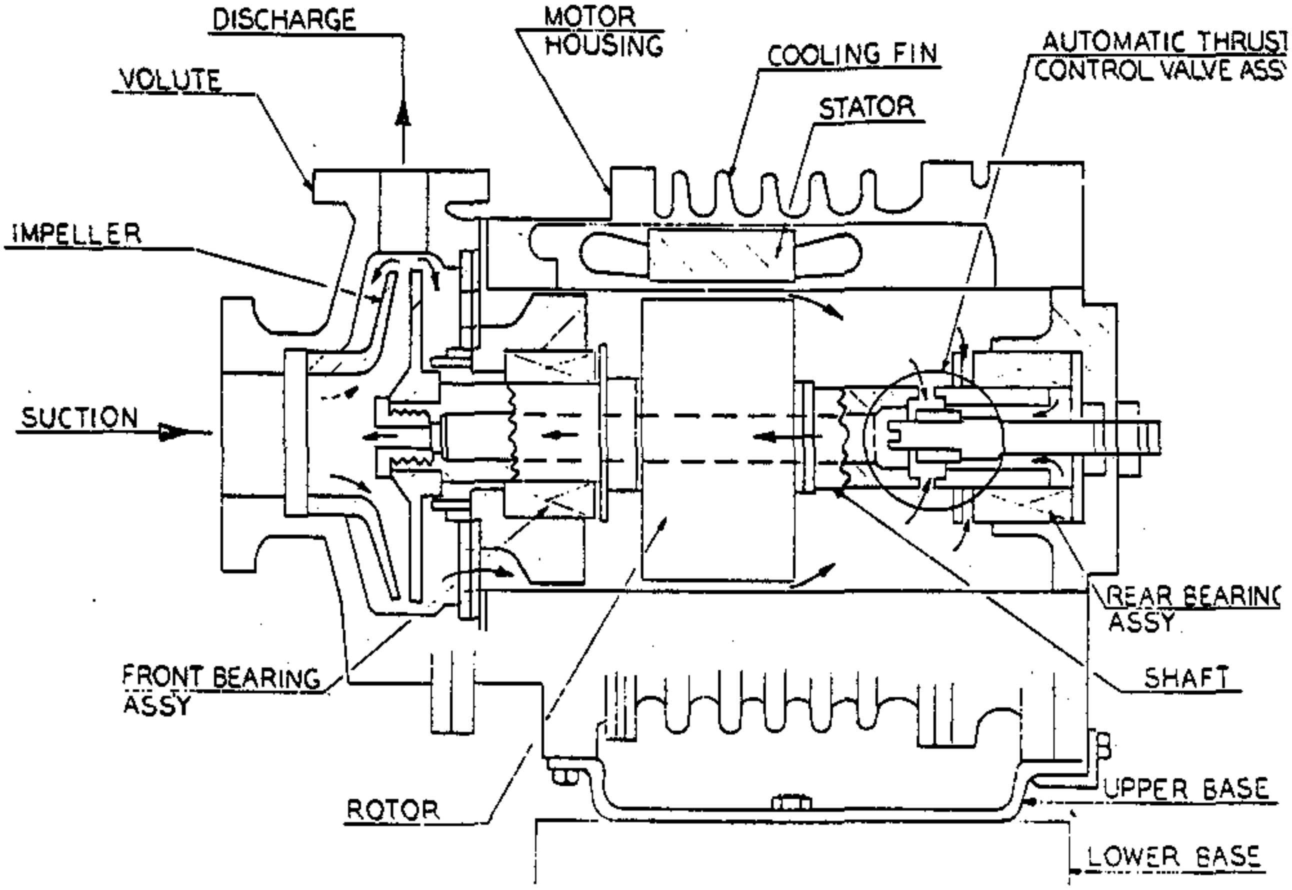
The canned rotor and shaft assembly is immersed in the fluid being pumped. Cooling for stator, rotor and bearings as well as liquid for bearing lubrication is provided by internal circulation of the pumped fluid, assisted by air cooling of the finned motor housing.

e) Axial Thrust Compensation - Automatic Thrust Control Valve

Liquid used for bearing and motor cooling returns to the impeller eye by means of a duct down the centre of the pump/motor shaft. Axial movement of the shaft due to a change in operating conditions causes a change in the flow-rate of cooling liquid return down the duct in the shaft by altering the opening of the automatic thrust motor valve. This change in liquid flow rate leads to a change in differential pressure between the front and back of the pump/motor shaft which tends to create a force opposing the original movements of the shaft and thus restore axial balance.

f) Special Features - Zero Leakage

Since the process liquid is used for motor cooling no conventional gland assemblies are required for canned centrifugal pumps. This eliminates the problems of prevention of leakage past a seal or contamination of process fluid due to leakage of seal coolants. This zero leakage feature makes canned rotor pumps dead for use in high grade D_2O systems where relatively small volumes are being transferred.



BHWP-Canned Rotor Centrifugal Pump With Internal Recirculation

FIGURE 25

7. BHWP - Common Services Cooling Water Pump

Two of the five Cooling Water Pumps, installed in the Cooling Water Pumphouse, supply the cooling water required for BHWP B, two will supply BHWP D and the fifth is available as a standby to replace any of the others.

The STORK VOA 80-75 pumps (Figure 26) are each capable of supplying a capacity of 5500 l/s (72,700 igpm) at a discharge pressure of 360 KPa (52 psig). Each pump is driven by a 2.5 MW (3300 Hp) motor.

a) Mount - Vertical Submerged

The submerged impeller removes the requirement for suction pipework and prestart priming. It also ensures that the water lubricates resin sleeve pump bearings are constantly immersed in water.

b) Staging & Impeller - Single Stage
- Fully Shrouded
- Mixed Flow

In view of the large pump size and high capacity a fully shrouded impeller is used to maximize efficiency and hence minimize motor size. The use of the mixed flow impeller is due to the requirement for a compromise believes the high capacity obtainable with a radial flow impeller and the pressure rise obtainable from a radial flow impeller. The impeller chosen is capable of meeting the pressure requirement in a single stage.

c) Energy Conversion - Diffuse

The diffuser allows the conversion of kinetic energy gained by the water in the mixed flow impeller to pressure energy.

d) Casing Split - Radial

Since the pump casing forms the cooling water ducting a radial split must be used.

e) Axial Thrust Compensation

The axial thrust excited downwards on the shift during operation is reduced by the use of balance holes in the hub of the impeller and a rear wear ring. Residual thrust is absorbed by a motor thrust bearing.

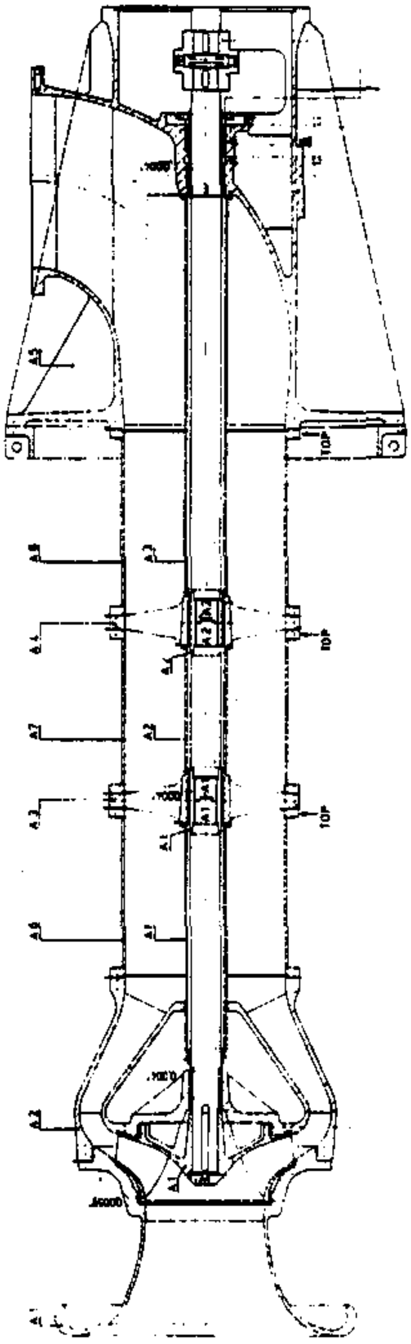


FIGURE 26: BHWP Cooling Water Pump

ASSIGNMENT

1. Draw a simple chart showing the major classifications of centrifugal pumps and the subdivisions of each of those classifications.

2. Give four applications of centrifugal pumps in a Nuclear Power Plant or Heavy Water Plant. Describe briefly the type of pump used in each case.

3. List and describe briefly five methods of compensating for axial thrust in a centrifugal pump. How can a large radial thrust on an impeller be compensated?

4. (a) Study the sectional drawings of centrifugal pumps shown in Figures 27 - 33. Classify each one in terms of:

   Number of stages
   Impeller type and direction of flow
   Energy conversion
   Casing split

   (b) Determine the means by which axial thrust in each of those pumps is compensated.

   (c) State the nature of the application for which you consider each pump might be used.

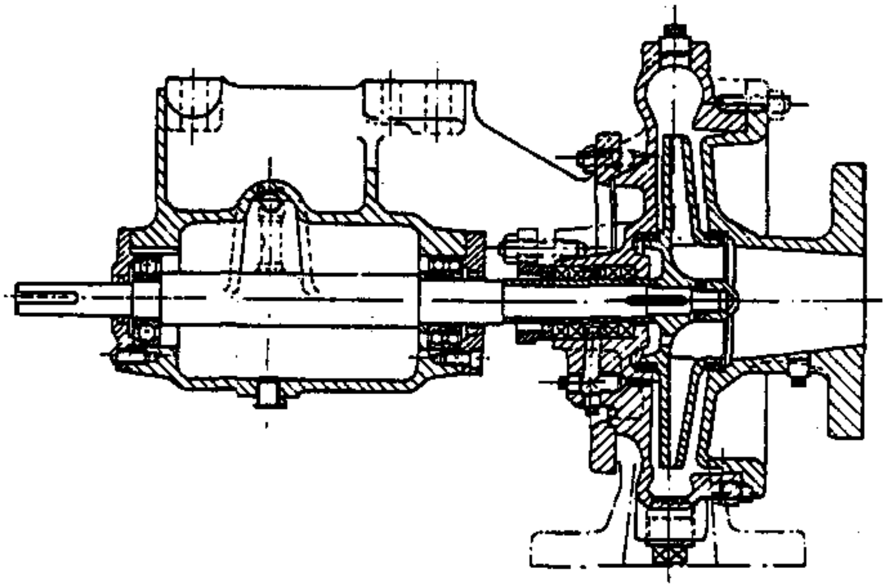


FIGURE 27

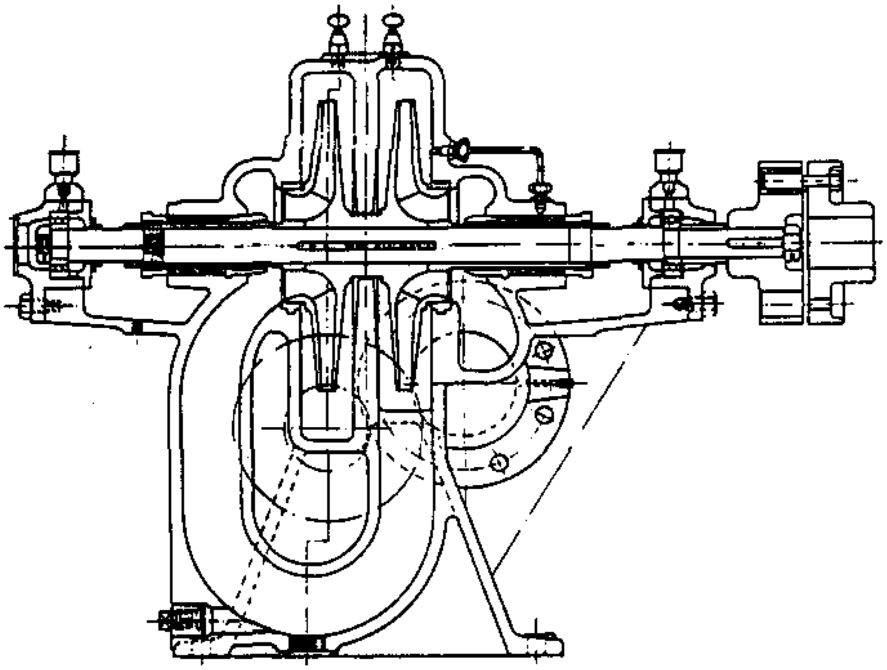


FIGURE 28

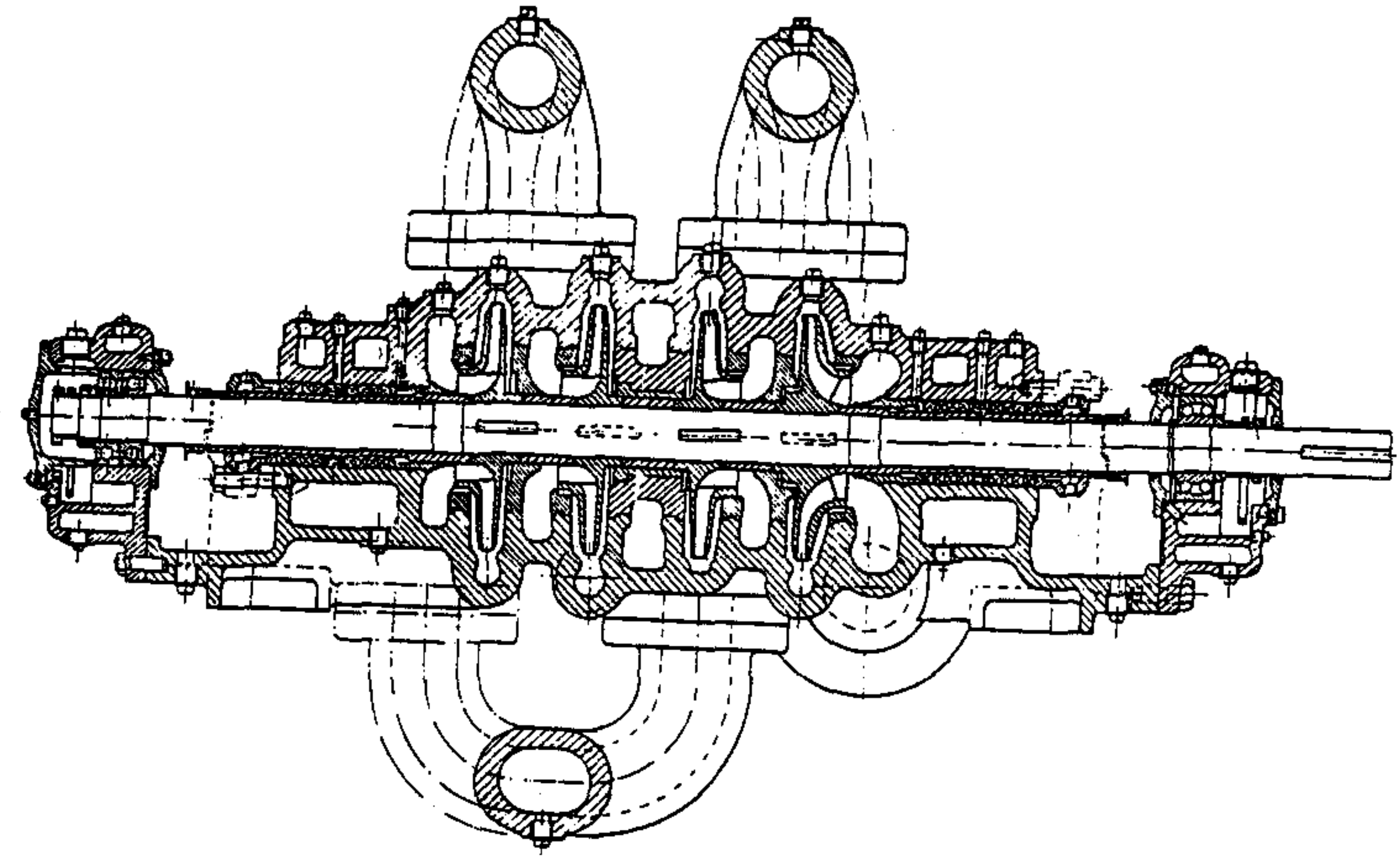


FIGURE 29

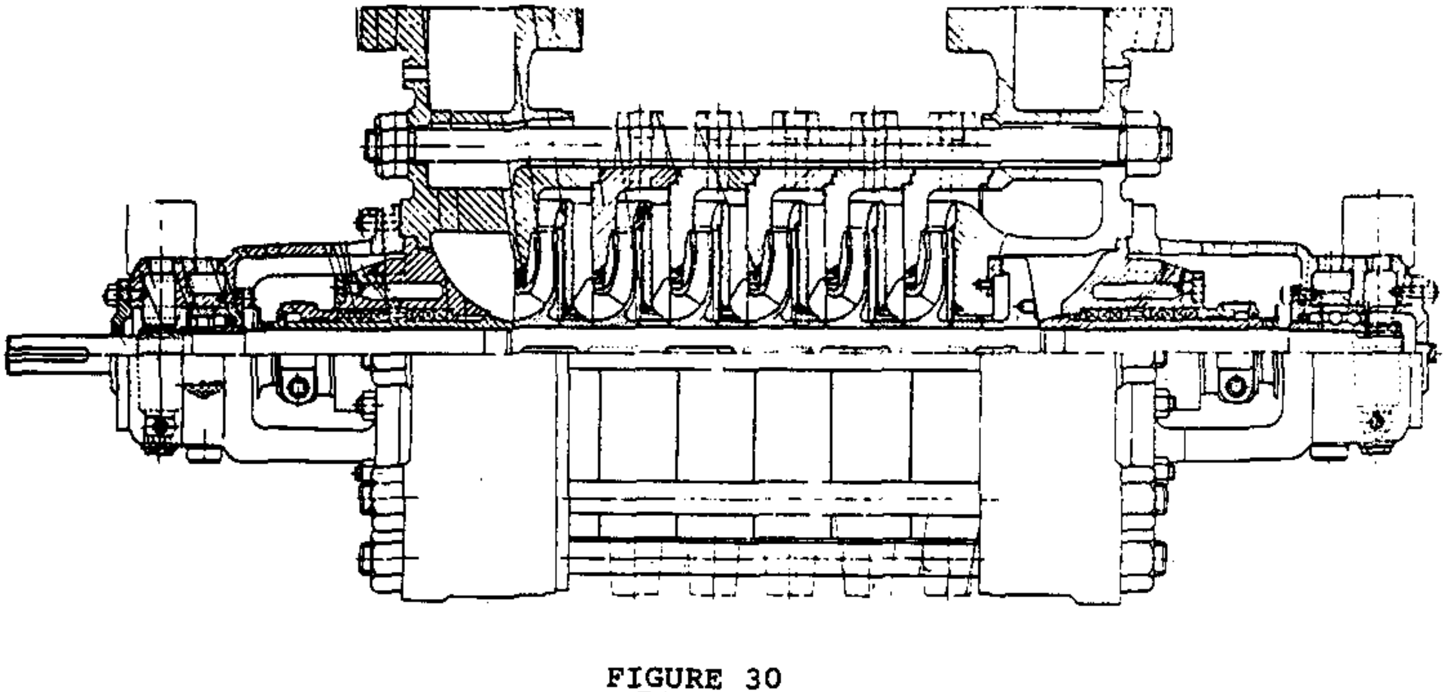


FIGURE 30

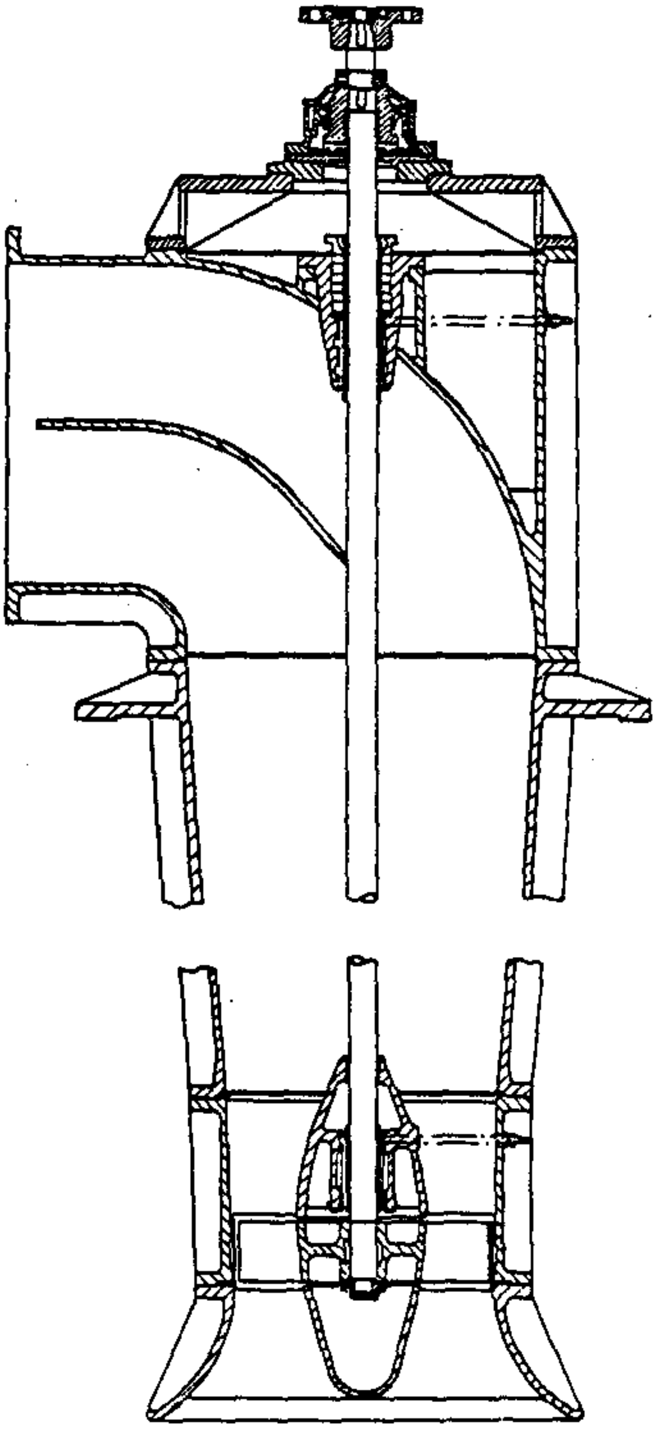


FIGURE 31

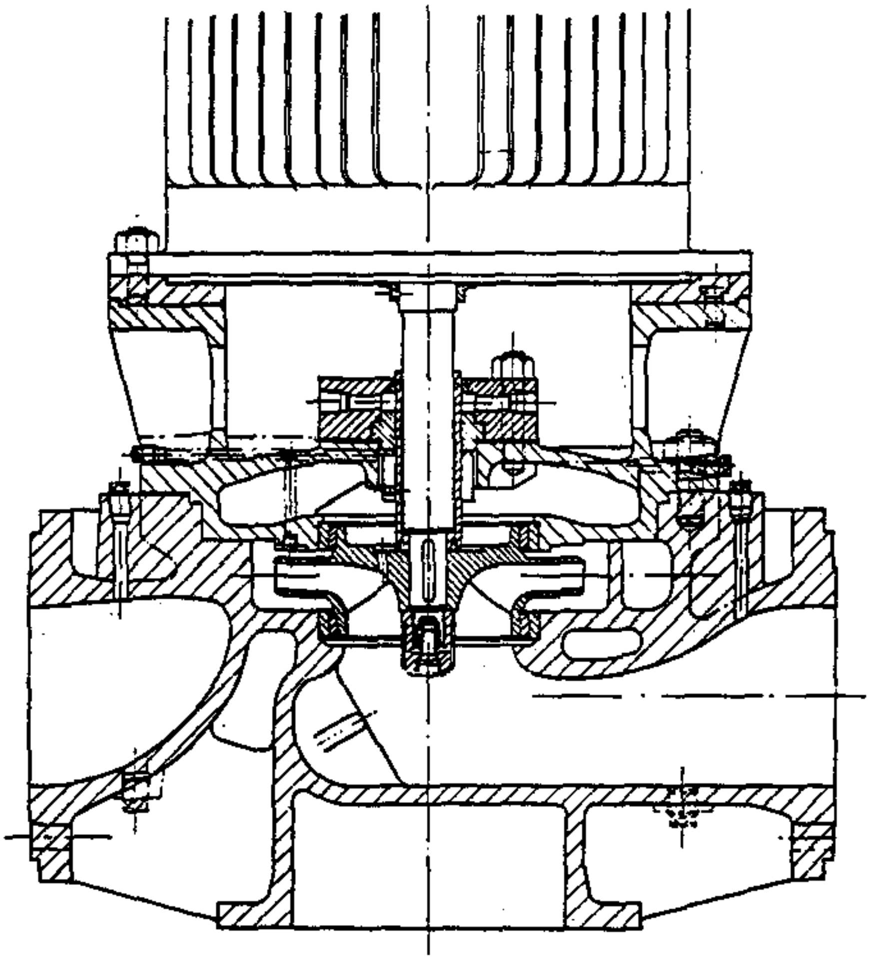


FIGURE 32

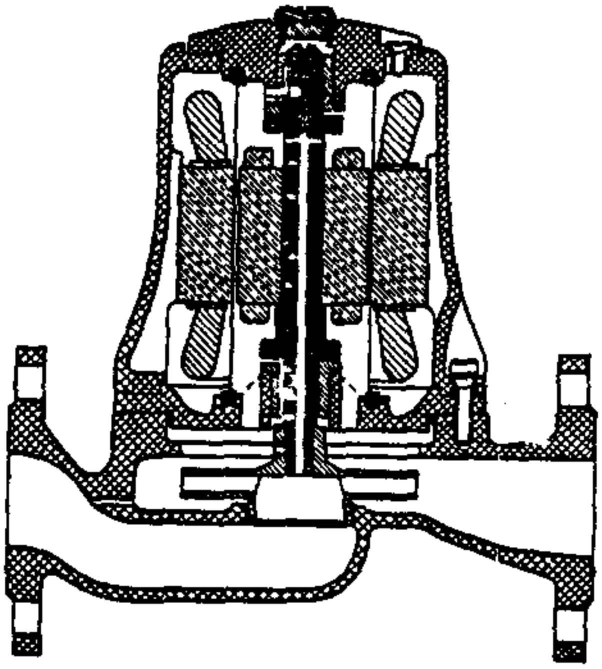


FIGURE 33