



Process engineering

Pumps, turbines and compressors

Centrifugal pumps (4)

This lesson covers pumps for corrosive liquids. If such pumps are made of metal, then the material that come into contact with the liquid require a protective coating. Sealless pumps can also be used for pumping these liquids. Furthermore, we will discuss the application of submersible pumps. These pumps are used when the suction head is too high for normal pumps. We will also discuss a special process industry pump in detail: the Sundyne pump. This pump operates at a high speed and the impeller only increases the velocity of the liquid and does not increase its pressure. The pressure is increased by a diffuser downstream of the impeller. The lesson concludes with a description of diffuser pumps.

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- 1 Pumps for corrosive liquids
- 2 Design of sealless pumps
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- 4 Sundyne pump
- 5 Seal casing and seal port marking of Sundyne pumps
- 6 Volute or diffuser pumps



Lesson

1. Pumps for corrosive liquids

- strength

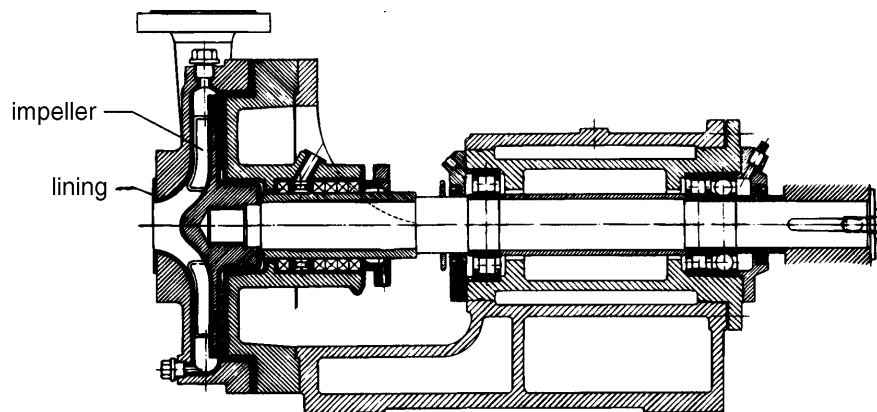
Because metals are attacked by corrosive liquids, metal pumps are not particularly appropriate for pumping corrosive liquids. However, we may want to use metal because of its mechanical strength. There are materials which resist the effects of corrosive liquids but they are generally vulnerable and not strong enough. Examples of such materials include glass, ceramics, cast iron with a high silicon content, etc. There are also corrosion-resistant metals but these are less appealing because of their high cost and because they are difficult to machine.

- lining

This explains why metal pumps are still used for pumping corrosive liquids. However, this means that we have to avoid all contact between the metal of the pump and the corrosive liquid being pumped. Figure 1 illustrates a pump of this type. All components which may come into contact with the liquid ('wetted parts') are lined. The lining is indicated by heavy black lines; it may be ebonite, rubber, synthetic or another material. The selected material depends on the medium and the cost of the coating.

Question 1

What condition must be met if metal is used in pumps suitable for pumping corrosive liquids?



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Figure 1

Lined pump for pumping corrosive liquids

- corrosion-resistant material

The only metal part in the pump which comes into contact with the process liquid is the shaft at the stuffing box. For this reason, this section of the shaft is provided with a protective sleeve of corrosion-resistant material.

Currently, pumps that are completely made of synthetic material are sometimes used instead of clad pumps. If the type of synthetic material is carefully selected, the strength and corrosion-resistance can be adequate.



2. Design of sealless pumps

- canned motor pump

Extremely toxic, highly flammable, malodorous and very expensive liquids are sometimes pumped with sealless pumps which are also known as canned motor pumps. These pumps are even used for handling radioactive liquids.

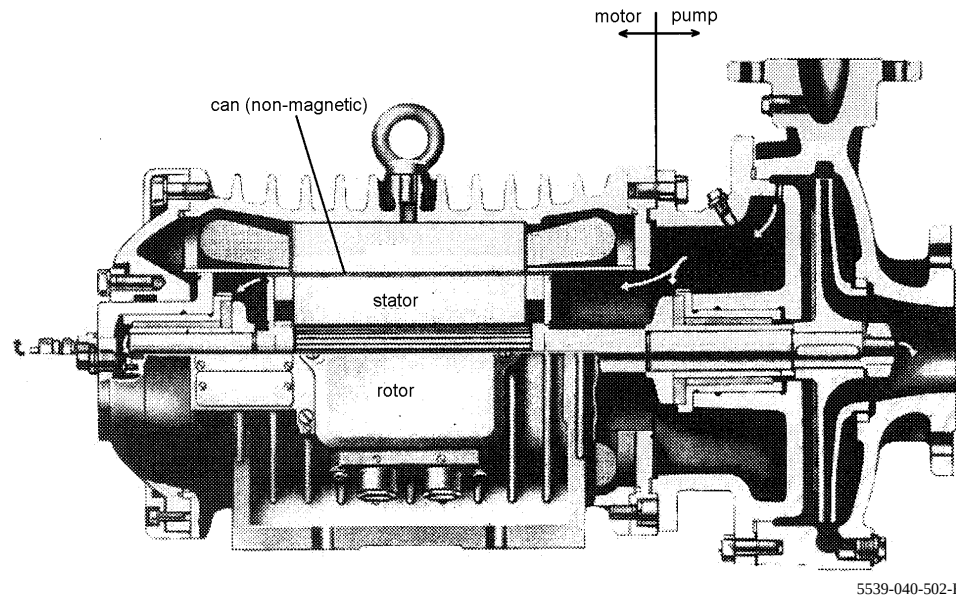


Figure 2
Example of a sealless pump

The motor rotor and the impeller are fitted onto a single shaft (see Figure 2). Several impellers may be fitted onto the shaft. The pump casing in which the impeller rotates is coupled directly to the motor casing. As there is no stuffing box, the liquid can enter the electric motor. The rotor and stator are separated by a can of non-magnetic material which can provide a hermetic seal between the rotor system and the stator connections. The bearings are lubricated and cooled by the liquid being pumped (see arrows).

- bearing material

The choice of bearing material depends on the type of liquid and the temperature. If the product is a poor lubricant then materials, such as carbon, synthetic material or silicon carbide, are often used for the bearings.

The heat generated in the bearings and in the motor has to be removed to maintain the temperature at an acceptable level. Hence, part of the liquid flows from the discharge side through the bearings and between the rotor and the stator back to the suction side (see arrows).

- started with liquid

These pumps must always be filled with liquid before they are started up. This is to ensure lubrication of the bearings and cooling. An interruption of this flow, for example by dirt, can result in serious wear of the bearings.

- venting

When these pumps are started up special attention should be paid to venting the pump. If they contain air (or gas), the heat removal can be seriously reduced.



3. Submersible pumps

Submersible pumps are often used when liquids have to be pumped from low-level locations.

Question 2

Why are standard centrifugal pumps unsuitable for this application?

- suspension tube
- intermediate bearing
- axial balancing
- stuffing box

Figure 3 shows a submersible pump. The pump itself is completely immersed in the liquid. The pump is connected by a suspension tube to a base plate fitted above the liquid. The electric motor is installed on the base plate. The long pump shaft has bearings in the base plate and in the pump casing. If the shaft is very long then an intermediate bearing may be used. The impeller generally has two wearing rings and is perforated for axial balancing.

These pumps do not need stuffing boxes as minor leaks are not important. After all, the pump is surrounded by the medium it is pumping. Any leaks will only effect the volumetric efficiency of the pump: the impeller pumps more liquid than is obtained at the discharge. Of course, the pump is designed to minimise this leakage.

The lower bearing of the pump in Figure 3 is lubricated by a grease reservoir but there are also designs where lubrication is effected by process liquid itself, which is returned from the discharge to the bearing.

This pump design is unsuitable for dirty liquids. One should also make sure that this pump, like many other designs, does not run dry.

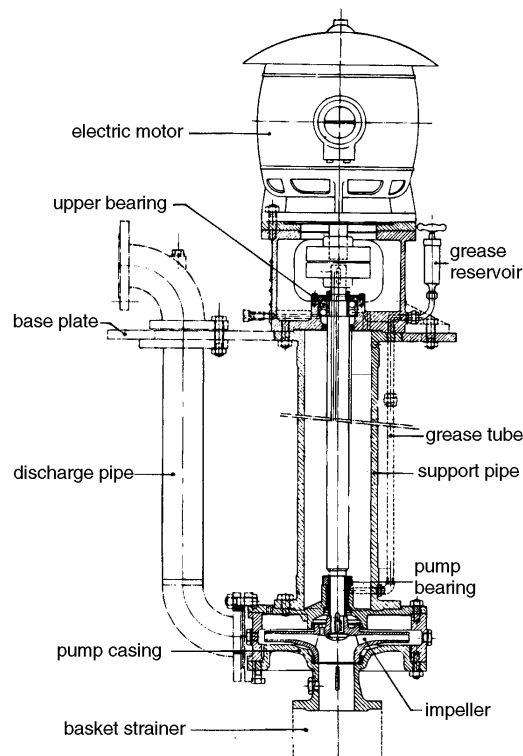


Figure 3
Submersible pump

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**- basket strainer**

A basket strainer is often installed in the suction nozzle to prevent large dirt particles from entering the pump, which would lead to serious damage.

However, such a strainer increases the flow resistance.

The discharge pipe of the pump generally extends to the base plate where it is connected to the pipe system.

4. Sundyne pumps

- high speed of rotation

The operation of a Sundyne pump is somewhat different to that of conventional centrifugal pumps. The main difference is the high speed of rotation, of up to 23,700 rpm, at which they operate.

- velocity converted into pressure

In conventional centrifugal pumps, the impeller increases the pressure and the velocity of the medium. Then, the increase in velocity is further converted into pressure in the diffuser or in the volute casing, which may contain a set of guide vanes.

However, in a Sundyne pump the impeller only imparts a high velocity to the liquid. Figure 4 illustrates one of these pumps, and figure 5 shows a cross-section of the pump unit.

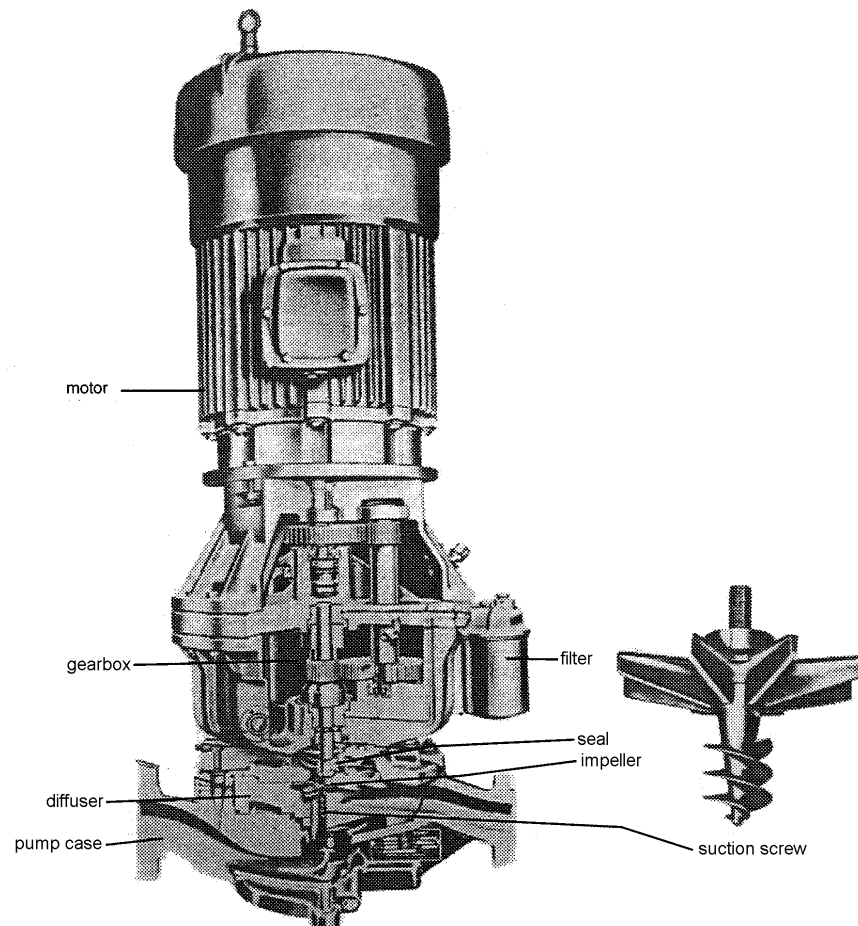


Figure 4
Sundyne pump

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**- no gap losses**

The velocity is converted into pressure in the diffuser, outside the pump impeller. As a result of this, there are no significant gap losses along the impeller and there is therefore no need for wearing rings. This means that the pump has a very high volumetric efficiency.

- sensitive to erosion

The q_V - p_{man} curve is hardly affected by impeller wear. Only damage to the bore? and the diffuser will cause problems. Together with the high speeds at which they operate this makes the pumps very sensitive to erosion by solids or hard crystals in the liquid. This should be considered when selecting the pump.

Sundyne pumps are no more sensitive to cavitation than conventional centrifugal pumps. If a suction screw (see the detail in figure 4) is used, the minimum required NPSH can be reduced to approximately 0.1 bar. If cavitation occurs this may take place throughout the pump.

Question 3

Why may cavitation occur throughout this type of pump?

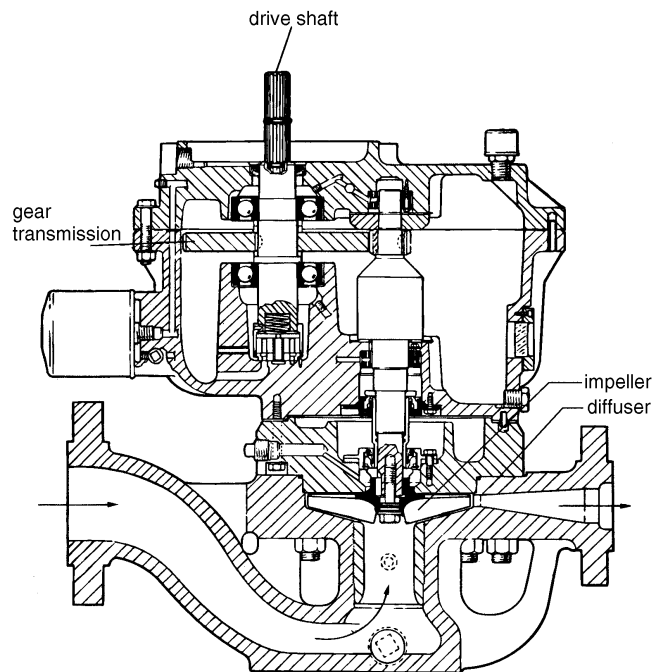
As with other pumps, the minimum possible flow is determined by vapour formation due to internal heating and vibration, which is more likely to affect Sundyne pumps at lower capacities.

4.1 Advantages of Sundyne pumps

1. Simple high-pressure pump design, requiring little maintenance.
2. High reliability.
3. Extensive standardisation, resulting in possibilities to exchange pump parts and for converting the pumps.
4. Possibility to apply different shaft seals within the same pump design.
5. Simple construction facilitates rapid disassembly and assembly for maintenance and inspection.
6. There is no pressure drop across the impeller, hence there is no need for wearing rings and there are no gap losses. This results in a high volumetric efficiency.

4.2 Disadvantages of Sundyne pumps

1. Lower efficiency than multi-stage centrifugal pumps, therefore a higher power requirements (overall efficiency 30 - 50%).
2. The high speed renders the pumps sensitive to wear if the liquid contains abrasive particles or crystals.
3. The pumps require minimum and maximum flow protection which means that more instrumentation may be needed than for other pumps.



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Figure 5
Cross-section of a Sundyne pump. The gear transmission is clearly visible

5. Seal casing and seal port marking of Sundyne pumps

- service life

Providing the right operating environment for mechanical seals is critically important to the service life and performance of the seals.

- standard seal casing

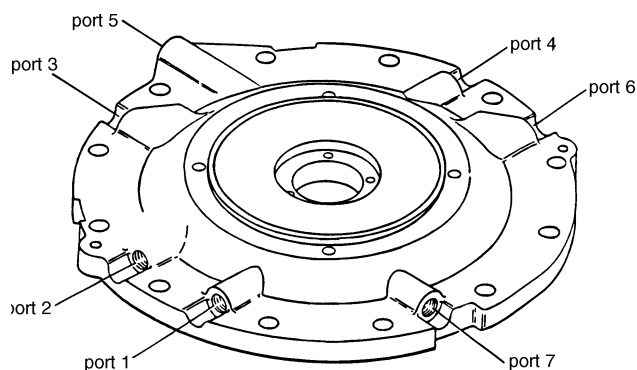
Sundyne pump seal casings are extensively standardised. They can be used for single, double and tandem mechanical seals. The standard seal casing is fitted with the required ports. The ports which are actually used depend on the type of pump.

- same material

Figures 6 and 7 show the seal casings and figures 8 and 9 show how they are connected, depending on the pump type.

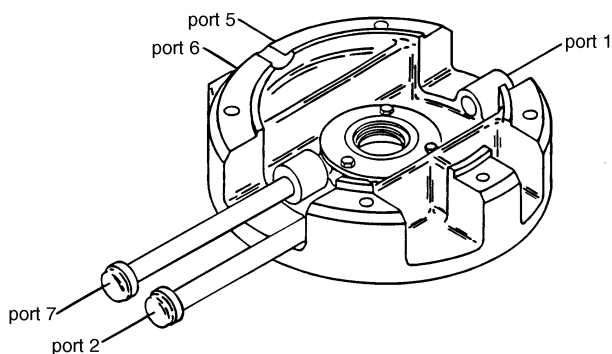
The seal casing is generally made of the same material as the pump casing. The seal ports are threaded.

The pumps are fitted with a plate specifying which ports should be plugged and which ones should remain open. This must always be checked during installation.



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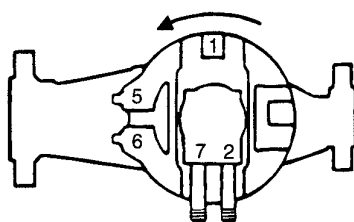
Figure 6
Seal casing for a Sundyne pump, type LMV-311



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Figure 7
Seal casing for a Sundyne pump, type LMV-322

Pumps: LMV-322 and 802

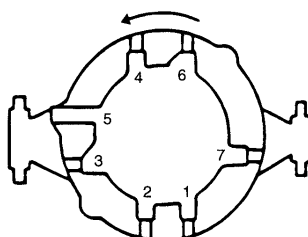


1. seal drain
2. seal drain or buffer/in
3. not fitted
4. not fitted
5. seal liquid
6. vent or seal liquid
7. seal drain or buffer/out

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Figure 8
Connection specification for LMV-322 and 802 pumps

LMV-311, 801 and 331 pumps



1. seal drain
2. seal drain or buffer/out
3. cooling
4. cooling
5. seal liquid or vent
6. seal liquid or vent
7. seal drain or buffer/in

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Figure 9
Connection specification for LMV 311, 801 and 331 pumps



6. Volute or diffuser pumps

- discharge nozzle
- maximum efficiency
- varying pressure

In centrifugal pumps without a diffuser, the impeller creates a gradually increasing flow of liquid around the circumference which is discharged at one place. This is the reason for the familiar volute (snail) shape of these pumps. Velocity is converted into pressure in the discharge nozzle if the pump is operating at the right speed of rotation and the pressure and flow are at the design point of the pump (maximum efficiency). In practice, the flow will vary and the flow pattern in the volute will be imperfect.

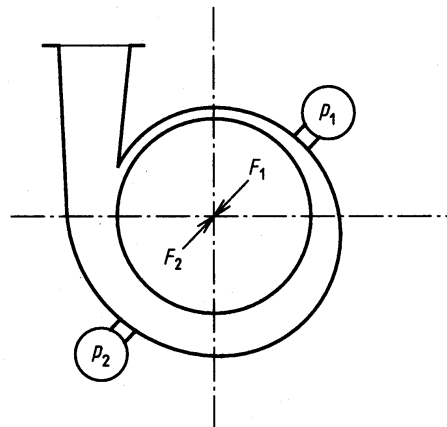
Experiments have shown that in this case the pressure varies throughout the volute casing. An example of an experiment is shown in figure 10.

Question 4

a sketch showing the location of the 'tongue' in a centrifugal pump.

Let us assume that the pressure at pressure gauge p_2 is lower than at pressure gauge p_1 . This results in a pressure difference around the periphery of the impeller. As this pressure difference acts on the peripheral surface, the resulting force $F_2 - F_1$ will act on the impeller. This radial force bends the shaft and imposes an unfavourable load on the bearings. The bending force on the shaft may result in fatigue failure.

- fatigue failure



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Figure 10

Volute casing measurement set-up

- energy conversion

The use of a set of guide vanes or a diffuser is an improvement as the conversion from velocity to pressure now occurs in the diffuser. The great advantage of this is that the energy conversion, despite changes in the capacity, is now equally distributed around the periphery unlike volute pumps where this conversion only occurs completely in the discharge nozzle when operating at the design point.

Question 5

Which energy conversion is meant in the text above?

- more expensive

The efficiency is also increased by the lower hydraulic losses (reduced eddies). The diffuser construction is more expensive than the casting of a volute casing. Most simple pumps with a single impeller have only a volute casing.



Single-stage pumps with a high differential pressure and low capacity, vertical single-stage pumps, high-pressure pumps, close-coupled pumps and multi-stage pumps are generally designed as diffuser pumps.

Question 6

Why are pumps with a high lift pressure generally designed as diffuser pumps?

**- widening
discharge nozzle**

To optimise the flow out of the diffuser, the casing around the diffuser is sometimes designed as a volute casing. The differences are shown in figures 11 and 12.

The energy is converted in the diffuser which means that the pressure is the same everywhere around the impeller. The discharge from the diffuser in figure 12 is even. This is because as the flow at the periphery of the diffuser increases, the volume in the volute casing also increases. Simultaneously the velocity in the widening discharge nozzle decreases as a result of which the pressure further increases.

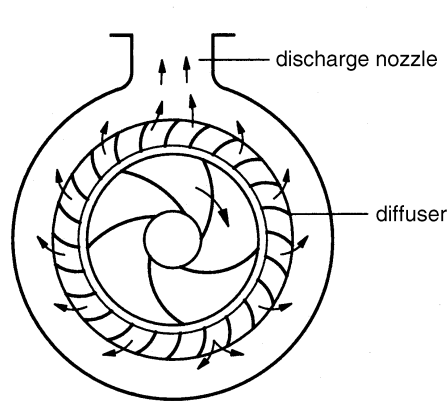
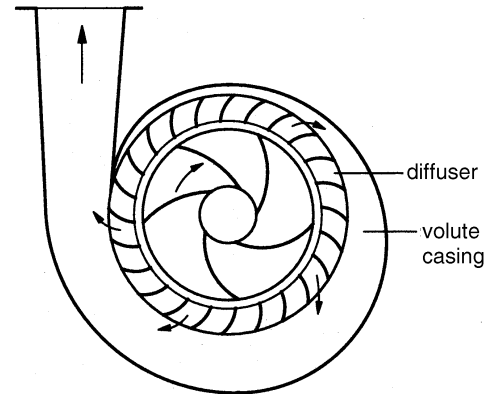


Figure 11
Centrifugal pump with diffuser ring



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Figure 12
*Centrifugal pump with diffuser
ring and a volute casing*



Summary

This lesson introduced pumps used for hazardous and malodorous liquids. Some corrosive liquids cannot be transported using conventional pumps. This means that pumps have to be used in which all the parts that come into contact with these types of liquids are lined with or made from synthetic materials.

We also discussed submersible pumps. If the suction head is too large and bearing in mind that these pumps are not usually self-priming the obvious choice is to install the pump below the liquid level.

Sundyne pumps are a special design of pump used in the process industry. The impellers in these pumps only increase the velocity of the liquid. Immediately downstream of the impeller the velocity of the liquid is reduced in a diffuser. As a result, the pressure of the liquid increases. In other words, the diffuser converts the velocity into static pressure.

There is no static pressure difference across the impeller. As a result, there is little flow of the liquid to the suction side. This means that these pumps do not need to be fitted with wearing rings.

The use of diffusers improves the hydraulic balancing of the impeller. This results in more favourable loads on the pump shaft and bearings. The discharge of the liquid from the pump casing should not create any eddies, hence there is a conventional volute casing around the diffuser.



Test

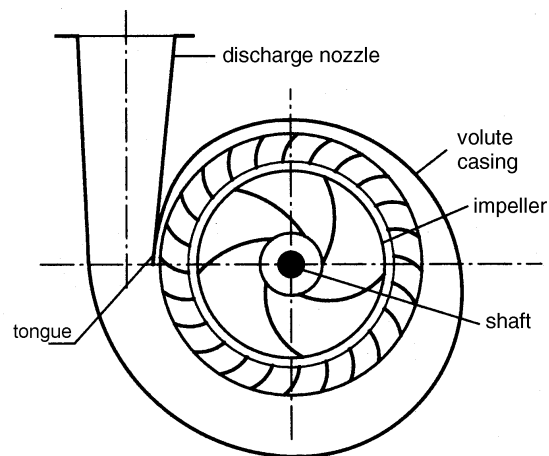
Exercises

Do not sent in your answers for correction

1. List some materials which are generally corrosion resistant. Indicate the disadvantages of these materials, i.e. the reasons why they are rarely used.
2. The bearings of sealless pumps are often lubricated by the liquid being pumped. If the liquid being pumped is a poor lubricant, another approach has to be used. Which one?
3. List some applications of sealless pumps.
4. How are the stator connections in an electric motor of a sealless pump separated from the rotor system?
5. Why are wearing rings not used in Sundyne pumps?

Answers to the questions in the lesson

1. First of all, the metal must be resistant to the corrosive effect of the liquid being pumped. In all other cases, the metal should not be in direct contact with the liquid. This means that all the parts in a pump that come into contact with the liquid must be clad. Ebonite, rubber, synthetic or other materials can be used for this lining.
2. Every pump has a limited suction head. One of the disadvantages of centrifugal pumps is that they are not self-priming. This problem can be solved by immersing the pump in the liquid. Centrifugal pumps can be modified to be self-priming. However, if the suction head is too large, resulting in an available NPSH which is too small, then the pump will have to be installed at a lower level.
3. The operation of a Sundyne pump is based on increasing the liquid velocity, instead of increasing the pressure. The pressure increase only occurs in the diffuser. This means that there is a low pressure everywhere in the impeller. Vapour bubbles which are created when the vapour pressure is exceeded will therefore develop everywhere in the impeller. The vapour bubbles will disappear as soon as the liquid velocity is reduced, which already happens at the entry in the diffuser. The disappearance of the vapour bubbles is accompanied by damaging cavitation erosion. This means that the creation of these vapour bubbles must be avoided at all times.
4. The position of the tongue in a centrifugal pump is shown in figure 13. This is where the volute casing merges into the discharge nozzle.



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Figure 13

5. This is where the velocity energy is converted into pressure energy.
6. If a pump has to produce a high discharge pressure it would be a good idea if part or all of the pressure increase is generated in a diffuser ring. This will reduce the pressure difference across the impeller which will limit volumetric (leakage) losses across the wear ring(s).

Answers to the exercises

1. Materials which resist corrosive liquids include:
 - glass;
 - cast iron with a high silicon content;
 - porcelain;
 - ceramics.

These materials are rarely used as they are generally fragile and not strong enough.

2. If the process medium is a poor lubricant then carbon, synthetic material or silicon carbide is used for the bearings. Special facilities must also be provided to remove the heat of friction generated in these bearings.
3. Applications of sealless pumps include:
 - pumping highly toxic liquids;
 - pumping highly flammable liquids;
 - pumping malodorous liquids;
 - pumping radioactive liquids.
4. There is a can of non-magnetic material between the rotor and the stator. This provides a hermetic seal for the rotor system.

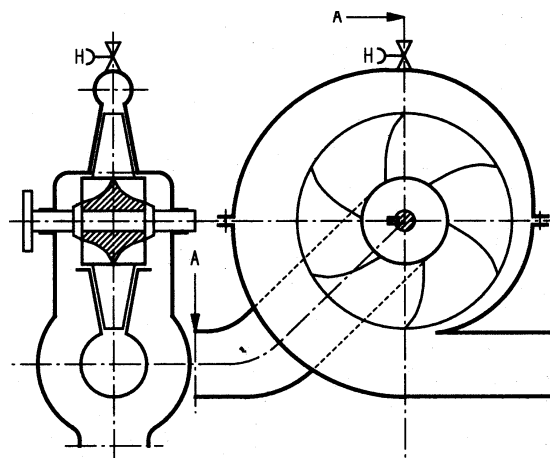


5. The impeller of a Sundyne pump does not increase the pressure of the liquid, but only its velocity. The diffuser immediately downstream of the impeller converts the high velocity into pressure. Hence, there is no pressure difference across the impeller. This means that no liquid will flow from the discharge side back to the suction side. Hence, there is no need for wearing rings to prevent this.

Problems and assignments

Answer and send in for correction

1. Figure 14 shows two views of a centrifugal pump.



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Figure 14

Copy the figure.

- a. Indicate the direction of rotation of the impeller.
 - b. Indicate the direction of flow of the liquid using arrows.
 - c. Draw the wearing rings (not shown). What is the purpose of these rings?
 - d. What is the advantage of this double suction impeller?
2. What is the disadvantage of a volute pump when the operating pressure varies?
 3. Explain why the efficiency of a diffuser pump provided with a volute casing is higher than that of a diffuser pump without a volute casing.
 4. What methods can be used to lubricate the lower bearing of a submersible pump?
 5. What are the reasons for installing a basket strainer at the suction opening of a (centrifugal) pump system? What is the disadvantage of using such a strainer?
 6. Explain the shape of the volute casing of a centrifugal pump.