

EXXON EXXON ENGINEERING	PUMPS PUMP TYPES PROPRIETARY INFORMATION - For Authorized Company Use Only	DESIGN PRACTICES	
		Section X-C	Page 1 of 16
		Date December, 1999	

CONTENTS

Section	Page
SCOPE	2
REFERENCES	2
INTERNATIONAL PRACTICE	2
OTHER REFERENCES	2
BACKGROUND	2
BASIC DESIGN CONSIDERATIONS	2
PUMP TYPE SELECTION	2
POSITIVE DISPLACEMENT PUMPS	3
SEALLESS PUMPS	3
CENTRIFUGAL PUMPS	3
CENTRIFUGAL PUMP TYPES COMMONLY APPLIED	6
Horizontal Single Stage Overhung Pumps	6
Vertical Single Stage Overhung (In-line) Pumps	7
Integral Gear Driven Pumps	7
Horizontal Single Stage Between Bearings Pumps	7
Horizontal Two Stage Between Bearings Pumps	8
Horizontal Multistage Between Bearings Pumps	8
Vertically Suspended-Wet Pit Pumps	8
Vertically Suspended-Double Casing Pumps	8
FIGURES	
Figure 1 Integral Gear Driven Centrifugal Pump Hydraulic Coverage	9
Figure 2 Centrifugal Pump Impeller Nomenclature	10
Figure 3 Volute and Vaned Diffusers	10
Figure 4 Horizontal Single Stage Overhung Pump	11
Figure 5 Vertical Single Stage Overhung (Inline) Pump	11
Figure 6 Single Stage Integral Gear Pump	12
Figure 7 Horizontal Multistage Integral Gear Pump - Top View	12
Figure 8 Horizontal Single Stage Between Bearings Pump	13
Figure 9 Horizontal Two Stage Between Bearings Pump	13
Figure 10 Horizontal Multistage Between Bearings Pump (Single Casing)	14
Figure 11 Horizontal Multistage Between Bearings Pump (Double Casing)	14
Figure 12 Vertically Suspended Wet Pit Pump	15
Figure 13 Vertically Suspended Double Casing Pump	16

Revision Memo

12/99 Added Note (1), page 2. Minor editorial revisions made without change to technical content.

DESIGN PRACTICES		PUMPS PUMP TYPES	
Section X-C	Page 2 of 16		
Date December, 1999			
PROPRIETARY INFORMATION - For Authorized Company Use Only			

SCOPE

This section presents information on the types of pumps commonly used in process, chemical, and utility applications. It is intended to aid the service designer in specifying the best general type of pump for a service and present those factors which affect the selection of construction styles and specific design features. ⁽¹⁾

REFERENCES

INTERNATIONAL PRACTICE

IP 10-1-1, Centrifugal Pumps

OTHER REFERENCES

ANSI/ASME B73.1 *Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process.*

ANSI/ASME B73.2 *Specification for Vertical In-Line Centrifugal Pumps for Chemical Process.*

API 610 *Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services.*

Karassik I. J., Krutzsch W. C., Fraser W. H., & Messina J. P., *Pump Handbook*, Second Edition, McGraw Hill.

BACKGROUND

Pumps can be classified as either dynamic or positive displacement types. Dynamic types, centrifugal or axial, impart velocity to the pumped liquid and convert the velocity to pressure in a diffusing flow passage. They tend to have a lower efficiency than positive displacement pumps but operate at relatively high speed and allow a high flow rate in relation to pump physical size. Dynamic pumps tend to have lower maintenance requirements than positive displacement pumps.

Positive displacement pumps operate by forcing a fixed volume of liquid from the inlet zone to the discharge zone of the pump. This is done intermittently in the case of reciprocating pumps and continuously in the case of rotary gear and screw pumps.

The vast majority of pumps applied in refinery, chemical plant, and utility services are centrifugal pumps. The changeover from positive displacement pumps, principally reciprocating, began in the 1930's and was virtually complete by the 1950's.

In the Design Specification, the pumping service designer usually specifies a general pump type. The selection of pump construction style and design features is usually done during detail engineering. Sometimes, however, a construction style and/or design feature is important to service design and will also be specified.

The general pump types used are centrifugal, axial, reciprocating, metering, diaphragm, and rotary.

BASIC DESIGN CONSIDERATIONS

PUMP TYPE SELECTION

The following aspects of the pumping service design have the strongest influence on the selection of the most economic pump type, usually in this order:

- Flow rate
- Head requirement
- Maintenance requirements and reliability
- Viscosity at pumping and ambient temperatures
- Flow control requirements

The particular construction style, within the general type, is influenced most by:

- Discharge pressure
- NPSH available
- Fluid temperature
- Installation constraints and opportunities such as space limitations, in-line mounting, direct mounting of pump on a pressure vessel etc.

Note:

(1) Pump data sheets specify pressure in psi, bar and kPa. In this section, bar is the metric unit used for pressure.

	PUMPS PUMP TYPES PROPRIETARY INFORMATION - For Authorized Company Use Only	DESIGN PRACTICES	
		Section X-C	Page 3 of 16
		Date	December, 1999

BASIC DESIGN CONSIDERATIONS (Cont)

Centrifugal pumps are the preferred pump type due to their generally lower initial and maintenance costs and higher reliability as compared to positive displacement type pumps. However, the use of positive displacement pumps may be required for certain applications. Consider, with machinery specialist consultation, the use of a positive displacement type pump under the following circumstances:

- Reciprocating pumps are used in high head low flow services when service conditions are outside the hydraulic coverage range of integral gear driven centrifugal pumps. See **Figure 1**. Careful review of centrifugal pump NPSH and efficiency characteristics should be made as high speed pumps have NPSH requirements in excess of those of conventional centrifugal pumps and efficiencies, at low flows, significantly less than those of reciprocating pumps.
- Viscosity above 200 cSt can be expected. High-speed centrifugal pumps are generally limited to 100 cSt or less.
- Head requirements may vary over a large range. For instance, high pressure may occasionally be required to overcome line acceleration or "packing" problems due to cooling of the pumpage.
- Required capacity is expected to be constant over a wide range of head requirements.
- Accurate control of flow rate in low flow applications may necessitate the use of a positive displacement type metering pump.

POSITIVE DISPLACEMENT PUMPS

For guidance in selecting and specifying positive displacement pumps of all types, see **Section X-F, Positive Displacement Pumps**.

SEALLESS PUMPS

There are currently no industry standards or International Practices covering sealless pumps. For a description of this pump type, its application range, and guidance in selection and specification, see **ER&E Manual TMEE-23, Pump Sealing Technology Manual**.

CENTRIFUGAL PUMPS

Performance Characteristics - The performance characteristics of centrifugal pumps are discussed in **Section X-E**. Also see **Section X-A, Pumping Service Design Procedures, Figures 1A and B** through **5A and B** for information on the hydraulic application range, efficiency, and NPSH requirements for the various centrifugal pump construction styles.

Pressure Generation - Centrifugal pumps generate pressure by adding energy or head to the pumped liquid by raising its velocity in an impeller and then converting the velocity energy to pressure in a diffusing section of the casing. There are no valves in a centrifugal pump and flow is uniform and free of low frequency pulsations.

When operating at a fixed speed and flow rate, the centrifugal type pump will increase the velocity of the pumped stream by the same amount regardless of fluid density. However, the pressure rise will depend on fluid density. The velocity energy or head that can be added is determined primarily by the pump speed (rpm), impeller diameter, and number of impellers in series.

Viscosity Sensitivity-Viscosity levels have a significant impact on pump type selection because of the deterioration of centrifugal pump performance with increasing viscosity. The effects of viscosity on centrifugal pump performance are discussed in **Section X-E, Centrifugal Pump Performance Characteristics**. Because deterioration is continuous and gradual, rules applying to specific viscosity levels are necessarily arbitrary. The following guidelines represent typical practice.

VISCOSITY, CENTISTOKES	GUIDELINE
7	Nominal minimum viscosity for rotary positive displacement type pumps. Efficiency of centrifugal pumps begins to decrease as viscosity rises to this level.
< 30	Centrifugal always preferred over a rotary where conditions allow application of either type.
30	The head capacity capability of a centrifugal begins to deteriorate.
30 to 100	Centrifugal normally preferred over rotary despite some efficiency falloff.
100 to 220	Positive displacement pumps are almost always used if the expected viscosity exceeds this level.
220 to 660	Rotary preferred if viscosity is usually in this range; centrifugal preferred if viscosity is seldom as high as this.
660	Centrifugal pumps should not be specified when viscosity is expected to reach this level

DESIGN PRACTICES		<i>PUMPS</i> PUMP TYPES	 EXXON ENGINEERING
Section	Page		
X-C	4 of 16		
Date	December, 1999		
		PROPRIETARY INFORMATION - For Authorized Company Use Only	

BASIC DESIGN CONSIDERATIONS (Cont)

Design Features - A variety of mechanical design features are used in the commonly applied types of centrifugal pumps. The following will acquaint the service designer some of the most significant.

- **Impeller Style** - See **Figure 2**. Most impellers used in refinery and chemical plant services are enclosed with full discs and shrouds and are termed "closed." Semi-open impellers having a full back disc but no shroud are occasionally used. Open type impellers, which have vanes but little or no disc material, are often used in low flow high head integral gear high-speed pumps.

Most impellers are arranged for liquid to enter from one side only and are termed "single suction" design. High flow pump models use impellers which accept flow from both sides and are termed "double suction." Most impellers used in refinery and chemical plant pumps are radial flow type, characterized by low specific speed. High flow rate, high specific speed, pumps use "mixed flow" impellers which provide a significant axial component to the fluid flow direction. For a discussion of specific speed and related impeller profiles, see **Section X-E, Centrifugal Pump Performance Characteristics, Impeller Classification-Specific Speed**.

- **Wear Ring Arrangement** - Most pumps for refinery and heavy duty chemical plant applications are designed with close clearances between the impeller and pressure casing to separate the discharge pressure zone of the impeller from the inlet pressure zone and minimize back leakage or slip flow. Wear rings are fitted at the close clearance location in the pump casing and usually at an opposing position on the impeller. See **Figure 4**. The use of wear rings permits easy restoration of internal clearances by replacing rings in the event that clearances open during operation. These rings are called "case" and "impeller" wear rings.

- **Axial Thrust Control-Single Stage Pumps** - The axial forces on a pump impeller are not perfectly balanced and the net load is carried by the pump thrust bearing. To keep axial thrust low and provide adequate thrust bearing life, the pump designer must balance the axial thrust forces as well as possible.

The forces resulting from internal liquid pressure levels plus atmospheric pressure at the coupling end of the shaft act on various rotor projected areas. In pumps designed for high suction pressure, the principal unbalanced force is caused by suction pressure acting against the shaft end area of a single stage pump with overhung rotor.

In pumps with discharge pressure across the back of the impeller, there is a thrust toward the inlet side of the impeller. To reduce this force and minimize the pressure acting on the seal chamber, wear rings are provided on the back of the impeller and balance holes are drilled through the disc to reduce the pressure behind the inlet area of the impeller to basically suction pressure. See **Figure 4**. The close clearance of the wear rings keeps the recirculation flow through the balance holes to a minimum. Pumping vanes, as illustrated in **Figure 2**, are also sometimes used on the back of an impeller to reduce thrust load and the pressure acting on the seal chamber.

- **Axial Thrust Control-Multistage Pumps** - Multistage pumps for moderate pressures are arranged to have a unidirectional thrust load on the rotor. The thrust bearing absorbs the sum of the of the thrust loads. For high differential pressures, opposed impeller arrangements are used so that the axial thrust force from one group of impellers is opposite in direction to that of another group. This holds the net thrust load to a low value. See **Figure 10**.

- **Pressure Conversion, Volute & Diffusers** - Most commercial pumps have diverging channels called volutes cast into the discharge portion of the casing. Liquid leaving the impeller at a high velocity enters the volute and has its velocity reduced causing a pressure rise.

Single volute designs, **Figure 3A**, are used in most pump designs. The single volute design imposes a radial force on the impeller due to variations of pressure around the impeller periphery above and below best efficiency point flow. In cases where this radial force results in excessive shaft deflection, a double volute design, **Figure 3B**, is used. The twin channels tend to balance the radial forces at all flow rates.

Some process pump designs employ a vaned diffuser rather than volutes. See **Figure 3C**. These include some in-line, some axial flow pumps, and some pumps designed for high head low flow applications. The advantages are balanced radial force, higher efficiency, and, compact size. Disadvantages are they are higher cost and more complicated to manufacture and repair and the stage performance curve is more likely to droop. Efficiency also tends to drop more severely at flows below 50% of best efficiency point flow.

- **Casing Construction-Single & Double** - Most centrifugal pumps have single casings, i.e., a single wall between the liquid under discharge pressure and the atmosphere. **Figure 4** illustrates a single casing pump. In a double casing multistage pump, the working parts are enclosed in an inner casing and a second casing is built around the inner casing. The most common style of horizontal multistage high pressure pumps surrounds the stack of individual stage stator parts with a radially split barrel shaped casing. The inner stack of stator parts is called the inner casing and the barrel, the outer casing. Boiler feed water pumps often use this construction. See **Figure 11**.

A vertical double cased pump is illustrated in **Figure 13**. It consists of a vertical outer casing, generally located in the ground, into which a pumping element is inserted. Liquid enters the outer casing and flows to the bottom to enter the pumping element.

	PUMPS PUMP TYPES PROPRIETARY INFORMATION - For Authorized Company Use Only	DESIGN PRACTICES	
		Section X-C	Page 5 of 16
		Date December, 1999	

BASIC DESIGN CONSIDERATIONS (Cont)

- **Casing Joint Orientation** - Pump casings are jointed to permit assembly and disassembly. The casing may be axially split with a casing joint parallel to the shaft centerline or radially split with a casing joint perpendicular to the shaft centerline. Axially split horizontal pumps are frequently termed "horizontally split," radially split horizontal pumps are frequently termed "vertically split".

IP 10-1-1 (API 610) requires that centrifugal pumps have radially split casings if any of the following operating conditions are specified:

- Pumping temperature of 401°F (200°C) or higher.
- A flammable or hazardous pumped liquid with a specific gravity less than 0.7 at the specified pumping temperature.
- A flammable or hazardous pumped liquid at a rated discharge pressure above 1450 psig (100 barg).

These limits reflect the fact that it is difficult to seal an axially split joint in light liquid and high pressure and temperature services. Exceptions to these requirements are allowed based on satisfactory experience with a vendor's design in similar service.

- **Casing Support** - Horizontal pumps have their pressure casings supported by a baseplate with their bearing housings supported from the casing. Most casing supports are located at the casing centerline and rest on baseplate pedestals. This arrangement is known as "centerline mounted." Movement of the shaft centerline due to casing temperature changes is minimized and pump to driver shaft alignment is better maintained. Casings for pumps at ambient to moderate pumping temperatures are sometimes supported at the bottom of the casing. This arrangement is known as "foot mounted."
- **Suction Line Priming & Pump Casing Venting** - Conventional centrifugal pumps are not self priming. That is, they can not evacuate vapor from their suction line so that liquid can fill the line and pump casing. Their suction lines must be filled before starting. Positive displacement pumps can usually prime themselves by pumping vapor from the suction system; however, they will not prime themselves if their suction lift capability is exceeded.

Most of the centrifugal pump types applied to process services have casing arrangements that are self venting by the arrangement of the suction and discharge nozzles. Generally a pump is considered self venting if the nozzle arrangement and casing configuration permit adequate venting of gases from the first stage impeller and volute area to prevent loss of prime during the starting sequence. That is, a minor amount of vapor trapped within the casing after suction priming is swept out by fluid flow when the pump is started. Some centrifugal pump types such as axially split casing designs having inlet and discharge connections in the bottom casing half are not self venting and are provided with valved vents which require manual operation to release trapped vapor and adequately fill the casing with liquid for starting. Single stage centrifugal pumps with top discharge are generally self venting although the casing shape allows a small high point vapor pocket in the top of the discharge volute. Determination of whether or not a construction style is self venting depends upon whether or not it is necessary to bleed off casing vapor pockets to achieve startup and adequate performance.

- **Slurry Construction** - Slurry pumps are pump models provided with features to combat severe slurry service conditions. Special features frequently employed are:
 - Use of wide flow passages and open or semi-open impellers to avoid clogging.
 - Impeller and inlet arrangement that disintegrate large particles.
 - Materials selection for erosion and corrosion resistance.
 - Special casing linings such as rubber, some of which are replaceable.
 - Replaceable wearing plates and pumping vanes on impeller back to avoid wear rings, which erode, and minimize pressure at the seal chamber.
 - Designs with adjustable rotor axial position to restore axial clearance without dismantling the pump.
 - Use of variable or adjustable speed to limit impeller peripheral speed to the minimum required to meet the head requirements.