PIP

Process Industry Practices
Machinery

PIP REEP006
Pump Selection Guidelines

Process Industry Practices
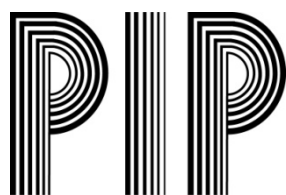**Machinery**

PIP REEP006
Pump Selection Guidelines

Table of Contents

1.   Introduction

1.1   Purpose

This Practice provides guidelines for the selection of centrifugal and positive displacement pumps.

1.2   Scope

This Practice describes guidelines for selecting appropriate types of centrifugal and positive displacement pumps for specific process services. This Practice does not cover every pump application or every type of pumping device available.

2.   References

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1   Process Industry Practices (PIP)

–   PIP REIE686/API RP686 - *Recommended Practices for Machinery Installation and Installation Design*

–   PIP REIE686A – *Recommended Practice for Machinery Installation and Installation Design (Supplement to PIP REIE686/API RP686)*

–   PIP REEE003 - *Guidelines for General Purpose Non-lubricated Flexible Couplings*

–   PIP RESP73H - *Application of ASME B73.1 - 2001 Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process*

–   PIP RESP73V - *Application of* ASME B73.2 - 2003 *Specification for Vertical In-Line Centrifugal Pumps for Chemical Process*

2.2   Industry Codes and Standards

•   American Petroleum Institute (API)

–   API 610/ISO 13709 - *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries*

–   API 611 - *General-Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services*

–   API 614 - *Lubrication, Shaft-sealing, and Control-Oil Systems and Auxiliaries for Petroleum, Chemical, and Gas Industry Services*

–   API 685 - *Sealless Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services*

•   American Society of Mechanical Engineering (ASME)

–   ASME B73.1 - *Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process*

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

–   ASME B73.3 - *Specification for Sealless Horizontal End Suction Metallic Centrifugal Pumps for Chemical Process*

2.3 Additional References

Centrifugal pumps which suction specific speeds are acceptable Hydrocarbon Processing, April 1982, 195-197, J.L. Hallam

Selection criteria for suction impellers of centrifugal pumps, World Pumps, 2001, J.F. Gulich

2.4 Other References (Not Cited in Practice Narrative)

The following references are not cited in the narrative of this Practice but are shown here as good sources for further information.

– ANSI/Hydraulic Institute Standard 3.1-3.5 2008 *Rotary pump nomenclature definitions applications and operations*

– ANSI/Hydraulic Institute Standard 12.1-12.6-2005 *Rotodynamic (Centrifugal) Slurry Pumps for Nomenclature, Definitions, Applications and Operation*

– ANSI/Hydraulic Institute Standard 1.1-1.2-2008 *Rotodynamic (Centrifugal) Pumps for Nomenclature and Definitions*

– ANSI/Hydraulic Institute Standard 1.3-2009 *Rotodynamic (Centrifugal) Pumps for Design and Application*

– API 614 - *Lubrication, Shaft-sealing, and Control-Oil Systems and Auxiliaries for Petroleum, Chemical, and Gas Industry Services*

– API 674 - *Positive Displacement Pumps - Reciprocating*

– API 675 - *Positive Displacement Pumps - Controlled Volume*

– API 676 - *Positive Displacement Pumps - Rotary*

– API 682 - *Pumps-Shaft Sealing Systems for Centrifugal and Rotary Pumps*

– PIP RESP003H - *Specification for Horizontal Centrifugal Pumps for Water Service*

– PIP RESP003V - *Specification for Vertical Centrifugal Pumps for Water Service*

– *Cameron Hydraulic Data*, Flowserve, C.C. Heald

– *Metering Pump Handbook*, Industrial Press Inc., Robert E. McCabe, Philip G. Lanckton, William, V. Dwyer

– *Pump Handbook,* 3rd ed., McGraw Hill Publishing Co., Igor J. Karassik, William C. Krutzsch, Warren H. Fraser, and Joseph P. Messina

3. Definitions

Some of the following definitions are not cited in the narrative of this Practice and are shown here for information only.

absolute pressure: Pressure measured from absolute zero (i.e., from an absolute vacuum). Absolute pressure is equal to the algebraic sum of the atmospheric pressure and the gauge pressure.

absolute temperature: Temperature above absolute zero

acceleration head: Pressure change because of changes in velocity in the piping system

axial split: Pump case that is split parallel to the pump shaft

best efficiency point (BEP): Flow capacity (rate) of a centrifugal pump at which efficiency is maximum

capacity: Volume rate of flow of liquid, expressed in cubic meters/hr (m³/hr) or gallons per minute (gpm)

cavitation: The physical phenomenon of forming bubbles in a region of a flowing liquid where the pressure falls below the vapor pressure. As the pressure in the liquid increases above the vapor pressure, the bubbles collapse at the speed of sound of the liquid sending shock waves throughout the liquid.

diffuser: Pump design in which an impeller is surrounded by diffuser vanes where the gradually enlarging passages change liquid velocity head into pressure head

discharge pressure: Pressure at the discharge flange of a pump

displacement: Average volume displaced per unit time by the piston of reciprocating pump or by vanes, screws and lobes of rotary pumps. If used to indicate size or rating, displacement should be related to a specified speed.

dry sump method: Lubrication method using only oil mist on a bearing. This is also referred to as pure oil mist method.

dynamic pump: Pumps that continuously increase fluid velocity to values greater than those occurring at the discharge such that subsequent velocity reduction within or beyond the pump produces a pressure increase

flow rate range: The variation in flow rates from minimum to maximum

head: Measure of pressure that is dependent on the relative density of the liquid. See also, total dynamic head.

impeller: Bladed member of rotating assembly of a centrifugal pump which imparts force to a liquid

impeller, double suction: Impeller with two opposing suction eyes that has liquid entering from both sides

impeller, single suction: Impeller with one suction eye

inducer: a low head, axial flow impeller that is placed in on the same shaft and in front of the first stage impeller of a conventional centrifugal pump. The purpose is to increase suction pressure, and therefore NPSHA, to the impeller

miscibility: Ability of two liquids, not mutually soluble, to mix

net positive suction head (NPSH): Total suction head in meters (feet) of liquid absolute determined at the suction nozzle and referred to datum elevation, minus the vapor pressure of liquid in meters (feet) absolute. The datum elevation is defined in *PIP RECP001*. For vertical turbine pumps, the datum is the top of the foundation. Note that the impeller eye may not be at the same elevation as the suction nozzle.

net positive suction head available (NPSHA): NPSH in meters (feet) of liquid determined by the purchaser for the pumping system with the liquid at rated flow and normal pumping temperature

net positive suction head 3 (NPSH3), formerly NPSH required (NPSHR): NPSH in meters (feet) of liquid determined by the pump supplier by testing, typically with water. NPSH3 is measured at the suction flange and corrected to the datum elevation. NPSH3 is the minimum NPSH at rated capacity required to prevent a head drop of greater than 3% (i.e., first stage head in multistage pumps) because of cavitation within the pump.

net positive suction head (NPSH) margin ratio: Ratio of NPSHA at the pump suction to NPSH3

parallel pumping: Operating two or more pumps together sharing suction and discharge piping to increase flow capacity

radial split: Pump case that is split transverse to the pump shaft

recirculation, also called recycle or spill back: Controlling the quantity of flow through a pump by sending part of the flow back to the suction, either the suction vessel (preferred) or the suction pipe sufficiently upstream of the pump suction nozzle to avoid turbulence. Recycle is typically used to keep a centrifugal pump operating near its BEP.

relative density: The density of the pumped liquid relative to a reference material. Standard convention is to use water at 4°C (38.6°F) as the reference material. Using water at the specified conditions, relative density is also referred to as specific gravity.

Series pump operation: Operating two or more pumps with the discharge of the first pump supplying suction to the second pump

shut off: Point on a pump curve at which the flow rate is zero. This typically corresponds to the maximum total dynamic head.

sealless pump: Pump without a mechanical seal, but uses a magnetic or current induced drive with a pressure containing housing to isolate the liquid

series pump operation: Operating two or more pumps with the discharge of one supplying suction to the second pump

service life: Time period that a lubricant can reliably serve 99% of bearings in similar service without detrimental effect on bearing life

specific speed: Dimensionless number, N_s, used for dynamic pumps to select the optimum impeller geometry for a given rotational speed, flow rate, and head developed.
$N_s = N \times Q^{0.5}/H^{0.75}$; where N is rotational speed in rpm, Q is flow rate in M^3/hr or GPM, and H is head in meters or feet.

spill-back: See recirculation

static pressure: Gage pressure that results from static liquid levels

suction energy: Momentum of the liquid in the suction eye of a centrifugal pump. Also, the amount of energy in a pumped liquid that flashes into vapor and then collapses back to a liquid in the higher pressure area of the impeller inlet.

suction energy ratio: Ratio of a pump's suction energy to the start of high suction energy

suction eye: The area of an impeller, just before the vanes, where the liquid enters

suction pressure: Pressure at or near the inlet flange of the pump

suction specific speed: Dimensionless number or index, N_{ss}, used to evaluate and compare pumps against historical data for the purpose of predicting reliability. $N_{ss} = N \times Q^{0.5} / NPSH3^{0.75}$ where N is rotational speed in rpm, Q is flow rate in M^3 /hr. or GPM at BEP of the maximum diameter impeller. For double suction impellers, Q is divided by 2. NPSH3 is net positive suction head 3.

total dynamic head: Pressure, in meters or meters (feet) of head, that the pump develops. Discharge pressure minus suction pressure corrected for relative density.

Turn down: The minimum flow requirement as related to the rated flow rate. Usually expressed as a percentage.

wet sump method: Static lubrication method using immersion or partial immersion of a bearing in oil. This is also referred to as oil-flooded method.

4. General

4.1 Proper selection and application of pumping technology can greatly improve the reliability of a pumping system. A pump selection flow chart is included in Appendix A.

> *Comment:* Manufacturers should be consulted for references for similar pump applications (i.e., pumps operating under analogous conditions).

4.2 Pumps are the prime movers of liquids in process applications. Pumps are used to increase the static, or inlet, pressure of the liquid and deliver the liquid at the specified discharge pressure and flow rate in a process application. Part of the increase in static pressure is required to overcome frictional resistance in the process.

4.3 Pumps are available in a variety of types, models and sizes, each of which is designed for specific applications. The selection should represent the best available configuration in accordance with a prescribed set of requirements.

4.4 Mechanical integrity, process safety, maintainability, and environmental protection are important considerations for pump applications. Pumps shall be manufactured from materials acceptable to the process. Materials shall be corrosion and erosion resistant. Special consideration should be given to pump applications if the environment can degrade material properties (e.g., embrittlement). Positive material identification is be required when alloy steel materials are specified.

4.5 The process requirements should be determined before selecting a pump system. Pump system selection requires matching pump capabilities to process requirements and process liquid properties as follows:

a. Provide the head and flow required for all flow paths, piping configurations, process flow characteristics, and alternate product properties. Product properties to be considered are specific gravity, viscosity, vapor pressure, specific heat, and temperature range.

b. Pumps used in parallel service shall be identical in design and size, shall be operated at the same speed, and shall be installed with identical impellers. It is the responsibility of the customer to ensure that piping configurations of pumps in parallel service are geometrically identical to achieve equal load sharing between the pumps.

    c.   Pumps operated in series shall have the same design flow rate.

        Note: See *PIP REIE686A* for additional requirements of pump piping systems.

    d.   NPSHA

    e.   Head required for all flow paths

    f.   Flow rate range, including turn down requirements for all flow conditions

    g.   Control systems

    h.   Suction pressure

    i.   Temperature

        Comment: Close clearance axial gaps in open and semi-open face impellers may cause mechanical interference because of thermal expansion.

    j.   Vapor pressure

    k.   Heat of vaporization

    l.   Heat capacity

    m. Relative density or specific gravity

    n.   Viscosity

    o.   Percent solids, hardness, and maximum particle size

    p.   Propensity to polymerize or crystallize

    q.   Corrosiveness

    r.   Toxicity

    s.   Entrained gas

4.6   A pump system typically includes the following components:

    1.   Pumps

    2.   Associated piping

    3.   Lubrication systems

    4.   Seal systems

    5.   Drivers, fixed or variable speed

    6.   Couplings

    7.   Speed changers, either gearboxes or belt drives

    8.   Control and monitoring systems

    9.   Base-plates and foundations

   10. Installation including piping, ergonomics, and accessibility

   11. Utilities

4.7   All components of a pump system determine its capacity, reliability and life-cycle costs. Life-cycle costs include initial capital, and operating and maintenance costs. Safety and environmental concerns should also be considered during the selection process.

4.8 Technically appropriate and fit-for-service equipment must be selected. Factors to consider should include experience with the intended service and technical innovations that may be applicable.

4.9 If more than one type or size of pump initially appears suitable for a given application, a more detailed analysis may be required to make an appropriate final selection.

4.10 Careful selection for the process application, proper installation in accordance with *PIP REIE686/API RP686* and *PIP REIE686A*, and operation of the pump in accordance with the selection criteria and manufacturer's recommended safe operating limits should provide a reliable pumping system.

4.11 Specifications and additional guidelines for specific equipment types covered in this Practice may be found in *PIP REIE686/API RP686, PIP REIE686A,* and *PIP REEE003*.

4.12 Full disclosure of information between the facility owner, engineering contractor (if applicable), and pump manufacturer should improve the results of the pump selection process.

4.13 Pump manufacturer shall determine the rated shaft power required by the pump assembly based on the operating conditions provided by the purchaser. Determination of the rated shaft power should consider the following variables as a minimum:

    a. Relative density

    b. Viscosity, including changes because of variation in the operating temperature

    c. Losses in mechanical seals and bearings

    d. Seal chamber pressure/stuffing box pressure/suction pressure

    e. Gear assembly

    f. Couplings

    g. Hydraulic tolerances

4.14 Unless the considerations shown in Section 4.13 require a larger driver, motor driver should be sized in accordance with Table 1.

    Note: If the driver is not rated to end of curve capacity, overloading may result when initially starting against an empty piping system.

Table 1. Electric Driver Sizing

Rated Pump Shaft Power kW (Bhp)	Multiplier for Sizing % of Rated Pump Shaft Power
< 22 (30)	125
22-75 (30-100)	115
> 75 (100)	110

    Note: Electric motors should be sized to avoid running into the service factor.

    Note: Refer to Section 5.1.1.2 for the sizing of steam turbine drivers

4.15   Pumps shall have a shaft-sealing mechanism designed for all operating conditions. Sealing mechanisms should have adequate cooling, lubrication, and support systems consistent with process conditions and seal requirements. Seal area/chamber on the process side should be self-venting.

4.16   Pumps selected for a system should provide the head and flow required for all flow paths, piping configurations, process flow characteristics, and alternate product properties. Product properties to be considered are relative density, viscosity, vapor pressure, specific heat, and temperature range.

4.17   Pumps used in parallel service should be identical in design and size, operated at the same speed, and installed with identical impellers. Piping configurations for pumps in parallel service should be geometrically identical to achieve equal load sharing between the pumps.

4.18   Pumps operated in series should have the same design flow rate.

4.19   Pump piping systems should be in accordance with *PIP REIE686/API RP686* and *PIP REIE686A*.

5.   Pump Classifications

5.1   Kinetic Type Pumps

5.1.1   Centrifugal Pumps

5.1.1.1 Configuration

1. *PIP REIE686/API RP686* and *PIP REIE686A* should be used for designing pumping systems that use centrifugal pumps.

2. A centrifugal pump has an impeller with fixed blades. The impeller is mounted on a rotating shaft and enclosed in a stationary casing. Centrifugal force and subsequent increase in momentum applied to liquid is used to transfer liquid from the inlet/suction to the outlet/discharge. The head developed by the pump is proportional to the square of the angular velocity of the liquid at the tip of the impeller. Head is measured in meters or feet of liquid.

3. A performance map for a typical centrifugal pump is provided in Figure 1.

4. The impeller design and the shape of the casing determine how liquid is accelerated through the centrifugal pump. The kinetic energy is converted to pressure by slowing the liquid in the volute. This differential pressure through the pump is the total dynamic head. A true centrifugal pump uses an impeller consisting of a series of blades (vanes) set between discs, giving a radial velocity of flow through the space. Other impeller designs may direct flow in both an axial and a radial direction or in an axial direction only. Pumps with this impeller are known as mixed flow and axial flow pumps, respectively.

5. Axial flow centrifugal pumps have a high specific speed and should be used for handling large capacities at low heads.
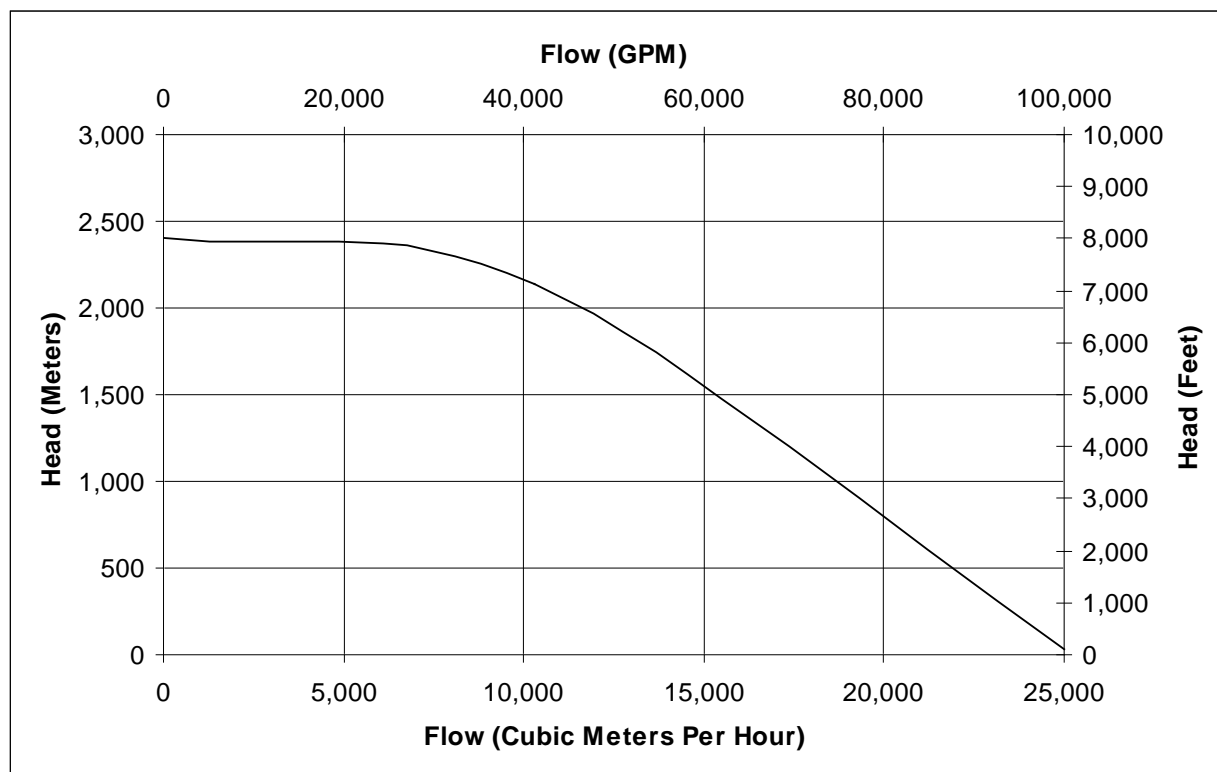
Note: This performance map is typical and not all inclusive of the capabilities of centrifugal pumps. The maximum total dynamic head or pressure is typically developed at zero flow, also called blocked in, shut off or dead head condition.

Figure 1 – Sample Performance Map for a Centrifugal Pump

6. Centrifugal pumps with medium specific speed provide the highest efficiency for this type of pump.

7. Centrifugal pumps with low specific speed can achieve high heads but at relatively low flow rates. This type of pump is less efficient.

8. Pump flow control is typically performed by throttling the pump discharge. Varying the speed of the pump may also be used to control the capacity of the pump. Throttling the pump suction to control flow should not be permitted.

9. Centrifugal pump sizes are typically designated using the following format:

   Discharge Nozzle Diameter x Suction Nozzle Diameter x Maximum Impeller Diameter

   For example in metric units, a 75 x 100 x 200 centrifugal pump has a 75 mm discharge nozzle, a 100 mm suction nozzle, and 200 mm maximum impeller diameter. For example in U.S. units, a 3 x 4 x 8 centrifugal pump has a 3 inch discharge nozzle, 4 inch suction nozzle, and 8 inch maximum diameter impeller.

10. Critical speeds should be a minimum of 20% outside the operating speed range of a pump.

    Note: This is to provide adequate separation margin between the operating speed and critical speeds to minimize the possibility of rotor instability.

11. If a flow orifice is used to artificially increase the slope of a pump curve as seen by the system, the orifice should be installed in the piping downstream from the pump.

    Comment: Because the orifice is subject to wear due to the high pressure drop, the installation should be designed for ease of inspection and replacement of the orifice.

    Comment: A flow control valve may be a better choice than a flow orifice in the pump discharge piping.

12. A pump shall have an impeller sized and designed to accommodate all operating conditions. Semi-open or closed impellers should be used in high-temperature applications to prevent a pump from locking up during warm-up and cool-down.

    Comment: Close clearance axial gaps in open and semi-open face impellers may cause mechanical interference because of thermal expansion.

5.1.1.2 Drivers

1. Motors

   a. If the end-of-curve power is greater than 75 kW (100 hp), the motor should be sized to cover the end-of-curve power or 110% of rated power, whichever is less.   Horsepower is directly affected by the process conditions and fluid properties specified versus actual conditions. Horsepower is especially sensitive to specific gravity, viscosity, and vapor pressure.

   b. For pump applications expected to operate at the end-of-curve (e.g., cooling-water circulating pumps), motors should be sized to operate at the end-of-curve.

   c. Motor and coupling should be sized to meet any specified future increase in power or head requirement.

   d. Motor should have adequate power for initial run-in on water with the pump throttled to 50% of rated capacity. If this requirement results in an increase in motor size, an alternate quote for the larger motor should be requested from the manufacturer. If a larger motor is required solely for water runs, it should first be verified that a water run is required, and if so, alternate methods of accomplishing the water run should be investigated before deciding to use the larger motor.

2. Turbines

   a. Steam turbine drivers should be in accordance with *API 611*.

      b. Steam turbine power rating should be 110% of the greatest calculated power requirement of the pump at any operating condition while operating at the minimum available steam supply pressure and temperature and maximum exhaust pressure and temperature.

5.1.1.3 Advantages

1. Centrifugal pumps typically have very little pulsation in flow although vane pass pulsations can be quite large.

2. Centrifugal pumps can provide variable capacity with or without variable speed drive.

3. Typically, centrifugal pumps can be used for liquids containing some solids.

4. Centrifugal pumps provide good reliability, typically more reliability than other types of pumps. Reliability is dependent on proper selection, installation, and operation. These factors are covered in more detail in Sections 5.1.4, and 5.1.5.

5. Centrifugal pumps have a relatively low installed cost.

6. Typically, centrifugal pumps can tolerate blocked in condition for brief periods without damage. Each case must be evaluated by a rotating equipment engineer. This is only appropriate for blocked discharge pressure testing of low energy and low suction specific speed pumps.

7. The discharge of a centrifugal pump can be throttled for control without damage and with acceptable loss of efficiency.

5.1.1.4 Disadvantages

1. Centrifugal pumps are not suited for high viscosity liquids (i.e., greater than 65 centistokes (CS) or 300 Saybolt Seconds Universal (SSU)).

   Comment: As the viscosity of pumped liquids increases, centrifugal pumps lose efficiency, produce less head, and have lower capacity. Pumped liquids with viscosities greater than 45 CS (200 SSU) can cause severe inefficiencies in centrifugal pumps. For liquids with viscosities greater than 20 CS (100 SSU), positive displacement pumps should be considered. For liquids with viscosities equal to or greater than 65 CS (300 SSU), positive displacement pumps are recommended.

2. The head developed by a centrifugal pump is limited.

3. Centrifugal pumps have limited ability to pump fluids containing vapors.

4. Typically, centrifugal pumps are not self-priming.

5.1.1.5 Types of Centrifugal Pumps

1. Centrifugal pumps are typically divided into the following categories:

      a. Overhung

      b. Between bearing

      c. Vertical suspended

      d. Sealless

      e. Submersible

      f. Horizontal self-priming

2. Overhung Pumps

a. A centrifugal pump with the impeller cantilevered from the bearing assembly is classified as an overhung pump. Impellers may be cantilevered in the horizontal or vertical plane. Horizontal pumps may be foot mounted or centerline mounted. Vertical pumps are in-line design, with or without integral high-speed gearboxes. These pumps have a single impeller (single stage) and are of single suction design.

b. Close coupled overhung centrifugal pumps do not have couplings and are not subject to the alignment issues of a coupled pump and driver. They can, therefore, be installed without a foundation. However, they are limited in horsepower and temperature, and require the motor to be moved to perform maintenance.

c. A foot mounted overhung centrifugal pump is supported from the underside of the casing. See Figure 2. *PIP RESP73H* for pumps in accordance with *ASME B73.1* should be used to specify this type of pump. Typical services include acid, caustic, and contaminated water with the following recommended limitations:

(1) Maximum pump operating temperature: 150°C (300°F)

(2) Maximum pump speed: 3,600 rpm

(3) Maximum discharge pressure: 2.0 MPa (275 psig)

(4) Flow rate: 135 m^3/hr (600 GPM)

(5) Maximum suction pressure: 0.5 MPa (75 psig)

(6) Within process units of refineries, these pumps are typically restricted to non-hydrocarbon services.

d. A centerline mounted overhung centrifugal pump is supported along the pump's horizontal centerline. See Figure 3. The *API 610* designation for this type of pump is OH2. This arrangement permits the pump casing to expand upward and downward from the shaft centerline when operated in hot service. Hot service is typically defined as service over 150°C (300°F). These pumps are typically used for hydrocarbon services within process units.
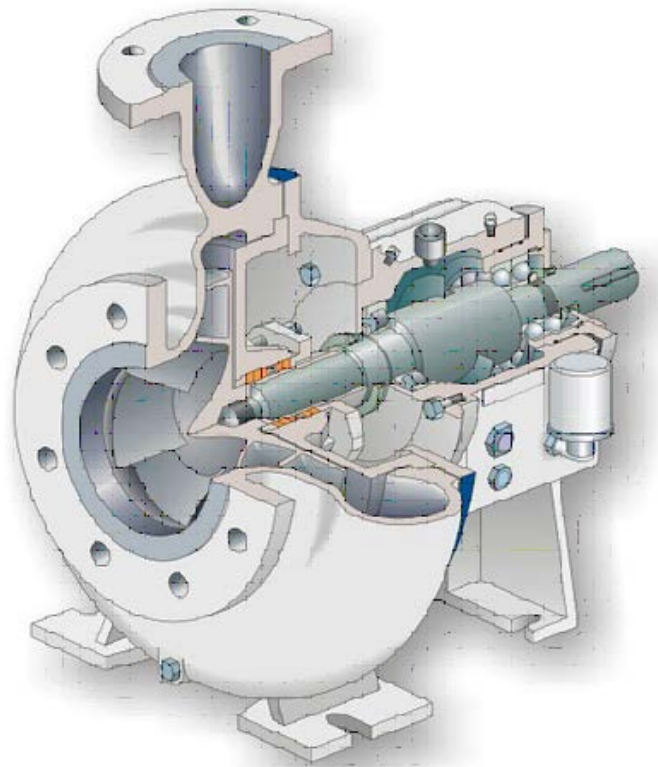
Figure 2 – Typical Foot Mounted Overhung Pump
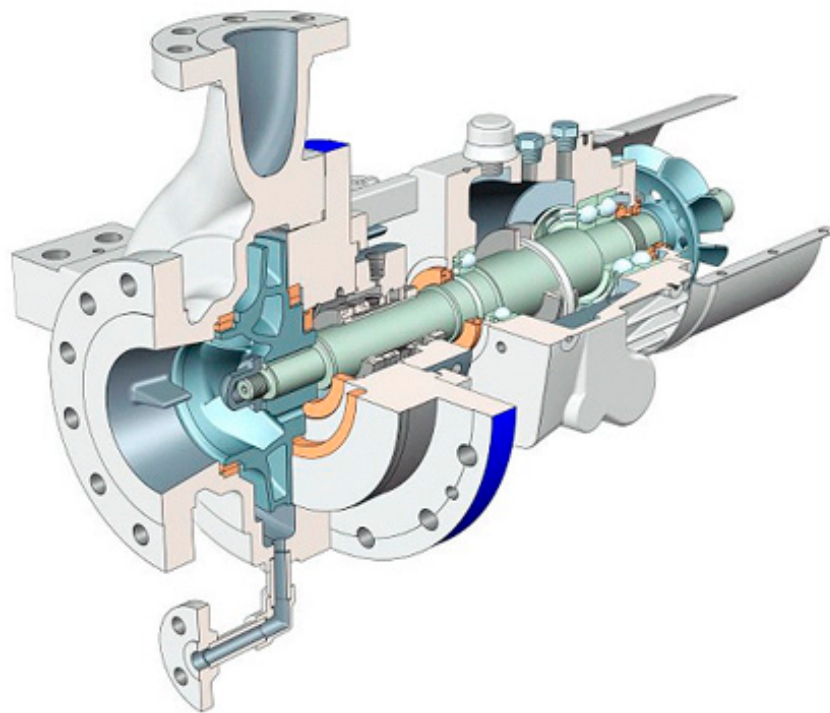
Figure 3 – Typical Centerline Mounted Overhung Pump

e. For a vertical in-line centrifugal pump, the shaft axis is in the vertical plane and the suction and discharge nozzles have a common centerline. The four styles of vertical in-line pumps are as follows:

(1) Vertical coupled design with driver and pump shafts connected by a flexible coupling. See Figure 4. The *API 610* designation for this type of pump is OH3.

(2) Vertical coupled design with the driver and pump shafts rigidly coupled.

(3) Vertical close coupled pump and motor. The impeller is mounted on the motor shaft.

(4) High speed design with an integral gearbox to increase the speed of the pump.
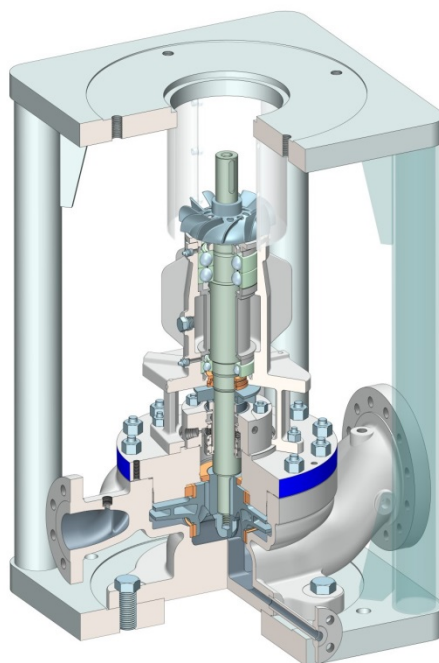
Figure 4 – Typical Flexibly Coupled In-Line Pump

3. Between Bearings Pumps

a. A centrifugal pump with impellers located between the bearings is classified as a between bearings pump. The pump may be single-stage (i.e., one impeller), two-stage, or multistage. The pump casing may be axially or radially split. The pump may also be foot or centerline mounted.

b. See Figures 5 and 6 for illustrations of typical between bearings centrifugal pumps for single stage and multi-stage, respectively. The *API 610* designation for these types of pumps are BB1 (foot mounted), BB2 (centerline mounted) and BB3 for single stage and multi-stage, respectively.

c. Single-stage axially split, foot mounted between bearings pumps are typically used for high volume, low pressure water services
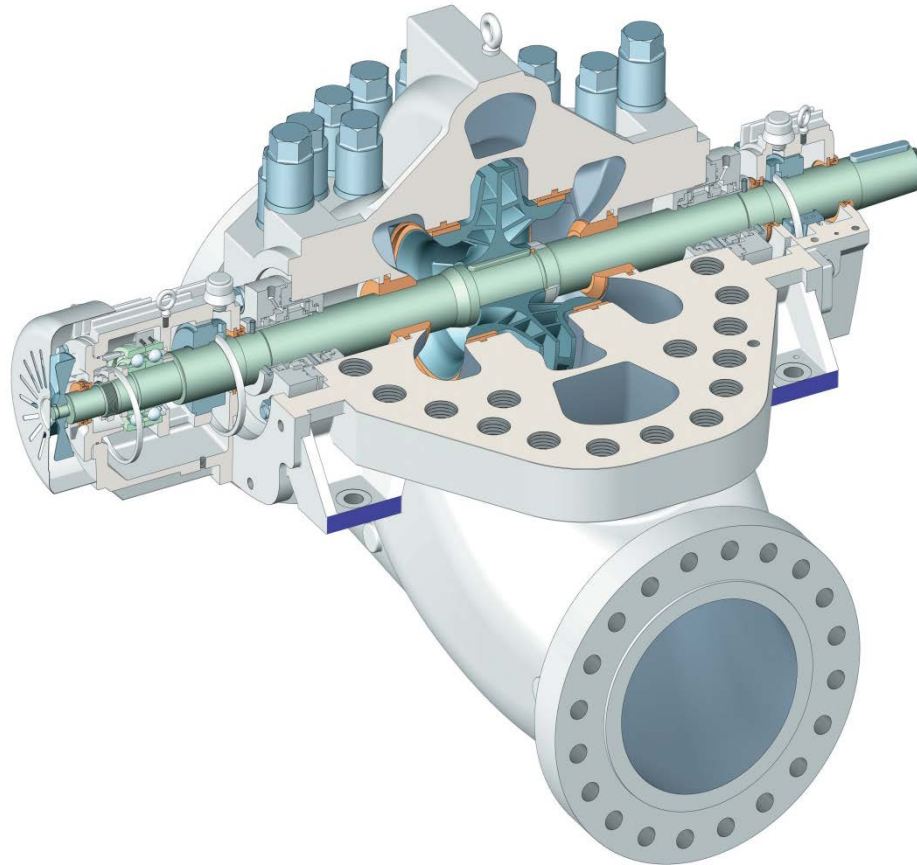
Figure 5 – Typical Between Bearings Single Stage Double Suction Pump (BB2)
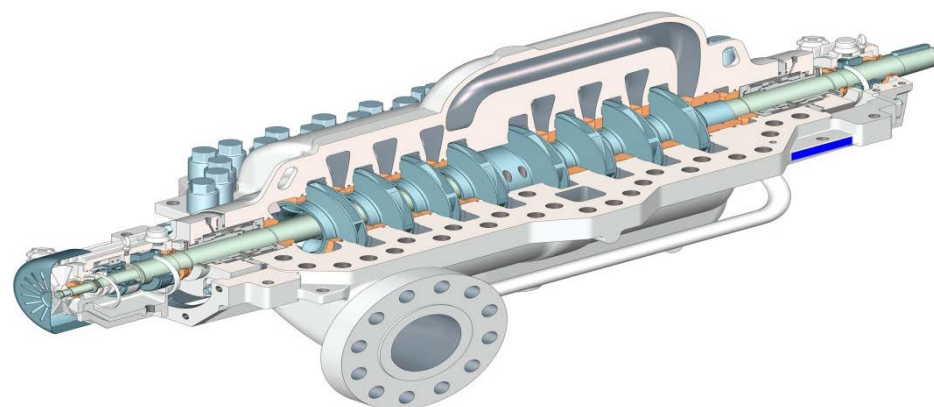
Figure 6 – Typical Between Bearings Multi-Stage Pump (BB3)

d. Between bearing pumps of single or multistage, with axially or radially split casings may be used in hydrocarbon and high pressure applications. However, axially split pumps should be limited to temperatures less than 200° C (400° F) because the split line is prone to leak above this temperature.

e. Between bearing pumps, particularly BB2 types, are susceptible to neutral thrust loads resulting in low bearing loading and ball skidding.

4. Vertically Suspended Pumps

a. A centrifugal pump with the impellers cantilevered vertically and the suction nozzle typically submerged is classified as a vertically suspended pump.

b. Vertical cantilevered pumps, and vertical turbine pumps, may be used for cooling water circulation, coke pit, oily water, and sanitary sewers services.

c. The five basic styles of vertically suspended pumps are as follows:

(1) Vertical turbine design (also known as wet pit, diffuser) with diffuser vanes in pump bowls. Flow follows the axis of the pump shaft. See Figure 7. The *API 610* designation for this type of pump is VS1. This pump is used if there is insufficient NPSHA for a horizontal pump.

(2) Wet pit, volute design with volute casing design in the pump bowls. Flow follows the axis of the pump shaft.

(3) Wet pit, axial flow design with propeller like impellers without bowls to pump liquid axially up the casing. Flow follows the axis of the pump shaft.

(4) Line shaft cantilever, sump pump design typically with a single impeller. Typically used as sump pumps. Flow follows separate flow path from the impeller.

(5) Double casing, diffuser design. Pump suction and discharge flanges are at grade. Basically a wet pit pump enclosed in a can or casing to take suction from a process vessel. These pumps are typically considered for applications with low NPSHA. Services include, but are not limited to, hydrocarbons and steam condensate.

d. If a vertical pump is to be started against a closed discharge, quick venting of pump head and column is required for adequate lubrication of column bearing immediately after start-up.

5. Sealless Pumps

a. General

(1) Sealless centrifugal pumps do not require mechanical shaft seals. There are two types of sealless pumps: canned motor and magnetic drive or coupled.
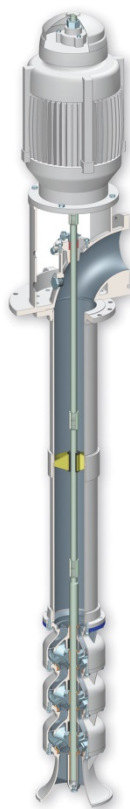
Figure 7 – Typical Vertical Turbine Pump

(2) Sealless designs have been developed for a wide variety of pumps listed in this Practice (e.g., overhung, multistage, gear, regenerative turbine, vertical in-line, and others).

b. Application Considerations

(1) Sealless pumps are typically used in services in which the pumped liquid is extremely hazardous and no leakage can be tolerated. Other applications include services with low emission requirements (e.g., volatile organic compounds (VOC)). Because of low installation cost, canned motor pumps may also be considered for applications outside of these traditional uses.

(2) Because the bearings are lubricated by the process liquid, the bearings are subject to excessive wear if the liquid contains particulates.

(3) If the pump is operated at low flow conditions that provide insufficient hydrodynamic forces to lift the shaft, the pump can fail.

(4) If the pump is operated at flow rates higher than BEP, unbalanced thrust loads can result which can lead to excessive wear of the thrust bearing and the impeller.

(5) Proper selection requires more information than is typically provided for sealed pumps (e.g., heat of vaporization, and specific heat).

c. Canned Motor Pumps (CMP)

    (1) General

        (a) A sealless pump in which the motor driver and the impeller are enclosed together as a unit with the impeller mounted on the motor shaft is classified as a CMP. See Figure 8 for a CMP in accordance with *ASME B73.3*.
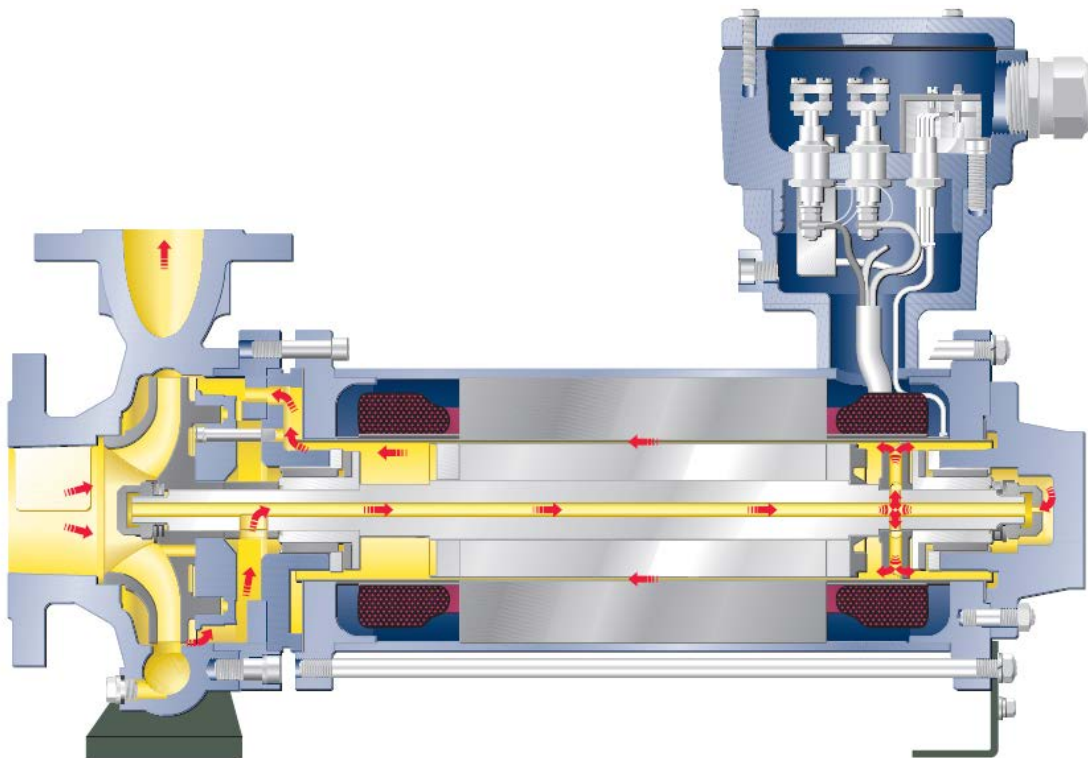
Figure 8 – Typical Canned Motor Pump

        (b) Because the rotor is contained by the stator liner and the stator is fully enclosed by the outer can, a CMP provides dual containment in the event that the stator liner is breached.

        (c) The stator cavity is capable of withstanding the same pressure as the primary containment area.

        (d) The process fluid lubricates the bearings and provides cooling for the motor. Careful consideration of

viscosity, vapor pressure, and heat of vaporization of the pumped liquid is critical to the success of the application.

(2) API vs. ASME Requirements

(a) *API 685* and *ASME B73.3* provide requirements for CMP. The primary differences between API and ASME CMP are as follows: API CMP are center flange mounted. Thermal growth is not a factor in CMP because there are no coupling and alignment issues. This applies to all CMP, not just ASME. However, if the case is constrained to grow in one direction, the thermal growth may exceed the wear ring clearances and lead to a bound rotor.

(b) API CMP usually have higher allowable flange loads. However, properly designed and installed piping will meet the allowable nozzle load capability of ASME pumps. CMP should preferably be stilt mounted, not grouted in, to reduce nozzle loads.

(c) API CMP are designed for higher maximum allowable working pressures, typically 7.58 megapascal (1,100 PSI). ASME CMP are designed for 1.5 times the maximum pressure of an application.

(3) Advantages

Advantages of CMP include the following:

(a) No mechanical seals or rolling element bearings (i.e., eliminates the two most frequent pump failure mechanisms). The motor bearings are hydrodynamic and immersed in the process liquid.

(b) CMP are totally enclosed liquid cooled

(c) Low initial cost relative to dual seal pumps, and may be competitive with single seal pumps

(d) Compact with a small foot-print

(e) May be installed without a concrete foundation which lowers cost

(f) Only one set of bearings; therefore, no alignment issues

(g) Capability to monitor bearing wear for proactive maintenance is available and inexpensive

(h) Secondary containment is rated to a minimum of 150% of maximum specified pressure

(i) Smaller power framed pumps may be wound for temperatures greater than 400° C (750° F) without external cooling

(j) Sitting idle with product inside is not detrimental to the pump

(k) Repairs are typically simple bearing replacements

(l) Quiet operation

(m) Minimal preventive maintenance

(4) Disadvantages

Disadvantages of CMP include the following:

(a) Information during the quote phase is required to be more thorough than is typical for a sealed pump to insure that the pump is not misapplied. Fluid properties such as heat of vaporization and specific heat are two examples of the additional information required.

(b) Latent heat of the stator dissipates into the fluid after the motor is turned off. This can cause the liquid in the motor area to vaporize and require venting before restarting.

(c) High horsepower applications may be less efficient than conventional sealed pumps because of fluid drag of the rotor in the process liquid. A true comparison requires that losses from the coupling, seal, and motor efficiency of a sealed pump be accounted for when comparing to a CMP.

(d) Instrumentation is required to determine direction of rotation

(e) Applications with particulates require discussion with the manufacturer

(f) If a liner is breached, the motor cannot be repaired at site. It requires disassembly, and decontamination prior to transport for repair at the manufacturer's repair facility

d. Magnetic Drive Pump (MDP)

(1) General

(a) A sealless pump in which the pump impeller is mounted on a drive shaft that has magnets attached and is surrounded by a containment shell is classified as a MDP. MDP are also known as magnetically coupled pumps. See Figure 9 for a MDP in accordance with *ASME B73.3*.
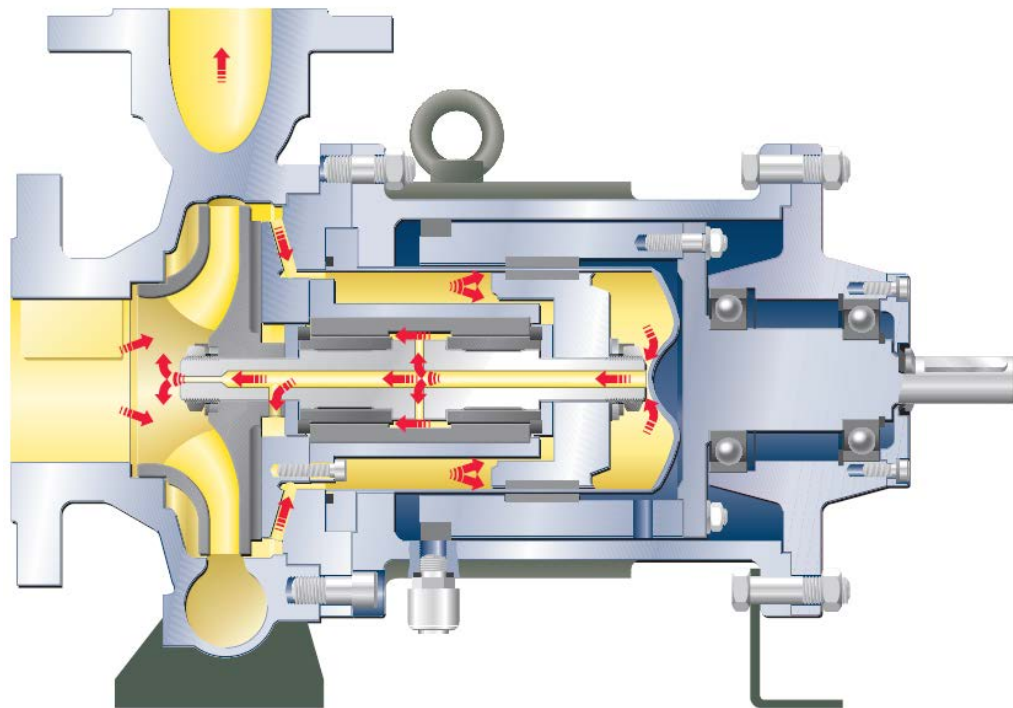
Figure 9 – Typical Magnetic Drive Pump

(b) The MDP magnets are driven by a (drive) shaft that has magnets mounted to it. The drive shaft is coupled to a motor or turbine that drives the pump.

(c) To provide dual containment, a second containment shell or a dry running mechanical seal may be used to seal the magnetic drive shaft.

(d) MDP are driven by an external device. They can be close coupled or have a spacer coupling to connect to the driver. If a spacer coupling is used, a foundation and baseplate are required

(2) Advantages

Advantages of MDP include the following:

(a) No mechanical seals

(b) Standard motor drivers

(c) Can be configured for dual containment

(3) Disadvantages

Disadvantages of MDP include the following:

(a) Information furnished to the manufacturer during the quote phase is required to be more thorough than is typical for a sealed pump. Fluid properties such as heat

of vaporization and specific heat are two examples of the additional information required.

(b) High horsepower applications may be less efficient than conventional sealed pumps because of fluid drag of the rotor in the process fluid

(c) Require three shafts and sets of bearings; two for close coupled pumps

(d) Horsepower is limited because of decoupling of the magnets

(e) Temperature is limited because of the magnets

(f) Applications with particulates require discussion with the manufacturer.

(g) The liquid lubricated bearings cannot be monitored. Typically, MDP use silicon carbide bearings which are abrasion resistant.

6. Submersible Pumps

a. Submersible pumps are designed for the pump and driver to be completely surrounded by the pumped fluid.

b. Advantages of submersible pumps are the following:

(1) Simple installation

(2) Inexpensive

(3) Short shaft which increases stiffness

(4) Seal leakage is not an issue

(5) Flexible discharge pipe

(6) No coupling and no alignment

c. Disadvantages of submersible pumps are the following:

(1) Pump and driver are submerged in the process liquid. Use of expensive wetted components may be essential in certain services (e.g., corrosive fluids).

(2) Special electrical cabling

(3) Specific maintenance required to maintain liquid tight motor

(4) Reverse rotation should be monitored

(5) Motor sizing issues may result from expected cooling from the process that may not be available

7. Self-Priming Pumps

a. Self-priming pumps have a specially designed case that submerges the impeller in liquid that has been retained after the pump has stopped running. This permits the pump, after its'

initial prime, to lift liquids from sumps and regain prime. See Figure 10 for a self-priming pump.

Figure 10 – Typical Self-Priming Pump

b. Advantages of self-priming pumps are the following:

(1) Has some suction lift capability, limited by the vacuum ability of the pump and vapor pressure of the liquid

(2) Pump and motor are not submerged in the process fluid

(3) Maintenance does not require entry permit for confined space

(4) Standard motor drivers

(5) Eliminates the need for a foot valve

c. Disadvantages of self-priming pumps are the following:

(1) Seal does not have circulation during the air venting period. Seal is running in vapor until the pump has cleared the air.

(2) Limited lift capability

(3) Suction and discharge piping design is critical to successful operation

(4) Priming time may take minutes as it is affected by temperature, suction lift, and viscosity

5.1.2   Regenerative Turbine Pumps

5.1.2.1 Configuration

1. A regenerative turbine pump has an impeller with vanes cut into the rim that revolves in an annular channel. Pressure is produced by

helical rotation of the liquid. See Figure 11 which shows a detail of the impeller/channel configuration.
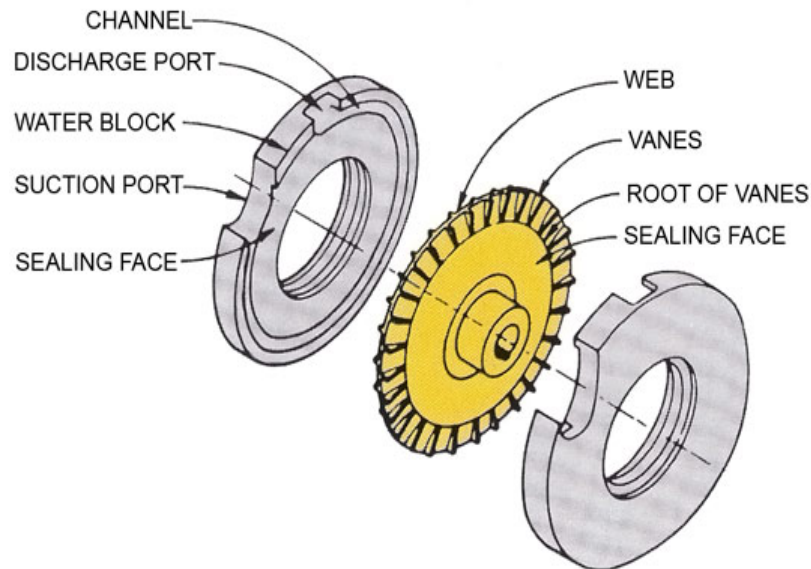
Figure 11 – The Heart of a Regenerative Turbine Pump

2. Regenerative turbine pumps are low flow, high head pumps that require clean service (i.e., no or very few particulates). Horsepower requirements decrease as flow rate increases. Head decreases rapidly with increasing flow rate. Viscosities are limited to about 200 centistokes (1,000 SSU).

3. A performance map for a typical regenerative turbine pump is provided in Figure 12.

4. See Figure 13 for an example of a regenerative turbine pump.

5.1.2.2 Advantages

1. Regenerative turbine pumps provide low flow, high head capability.

2. Regenerative turbine pumps have moderate efficiency.

3. If provided with a low NPSH impeller, regenerative turbine pumps are capable of low NPSH3.

4. Regenerative turbine pumps have small physical size for high head.

5. Regenerative turbine pumps are capable of handling up to 40% entrained vapor.
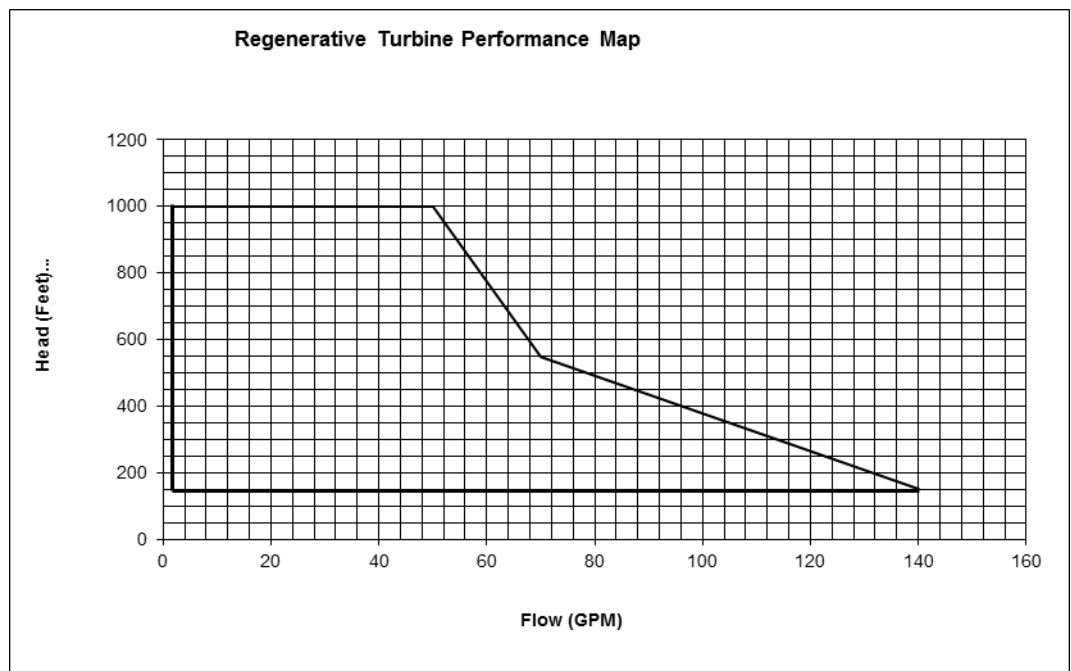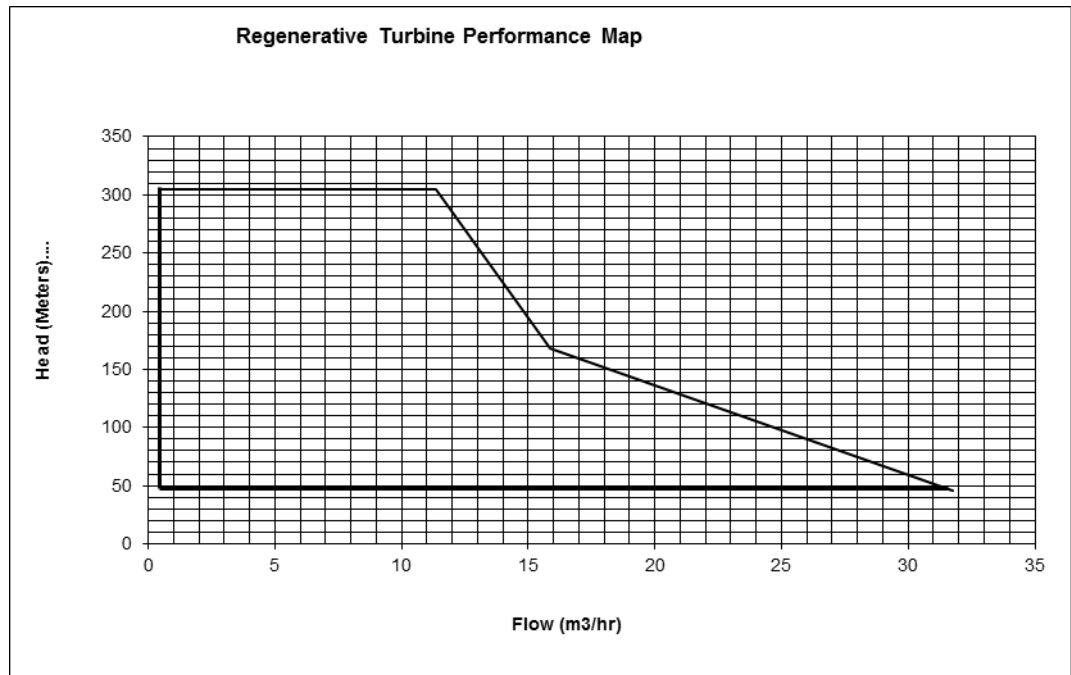
Figure 12 – Performance Map for Regenerative Turbines
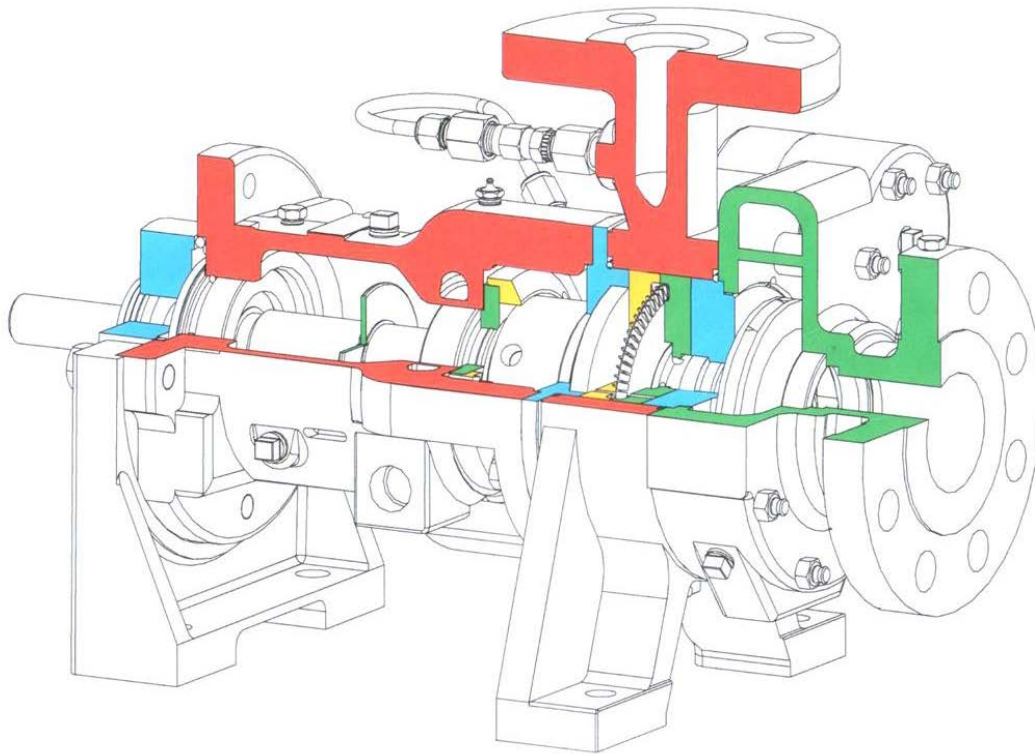
Figure 13 – Regenerative Turbine Pump with Low NPSH3 Impeller First Stage

5.1.2.3 Disadvantages

1. Regenerative turbine pumps require clean service.

2. Regenerative turbine pumps are limited to low and moderate flow rates.

3. Pressure protection can be required for downstream equipment at low flow rates.

4. Require higher skilled mechanics due to the precision and tolerances required by the pump for proper performance.

5.1.3 Special Effect Pumps (Rotating Case)

5.1.3.1 Configuration

1. Special effect pumps have a pitot tube to capture liquid that is accelerated by the rotating case. Special effect pumps are single stage pumps that achieve varying capacities by changing the pitot tube or speed of rotation. These pumps are also known as rotating case pumps.

2. A performance map for a typical special effect pump is provided in Figure 14.

3. See Figure 15 for a typical special effect pump.
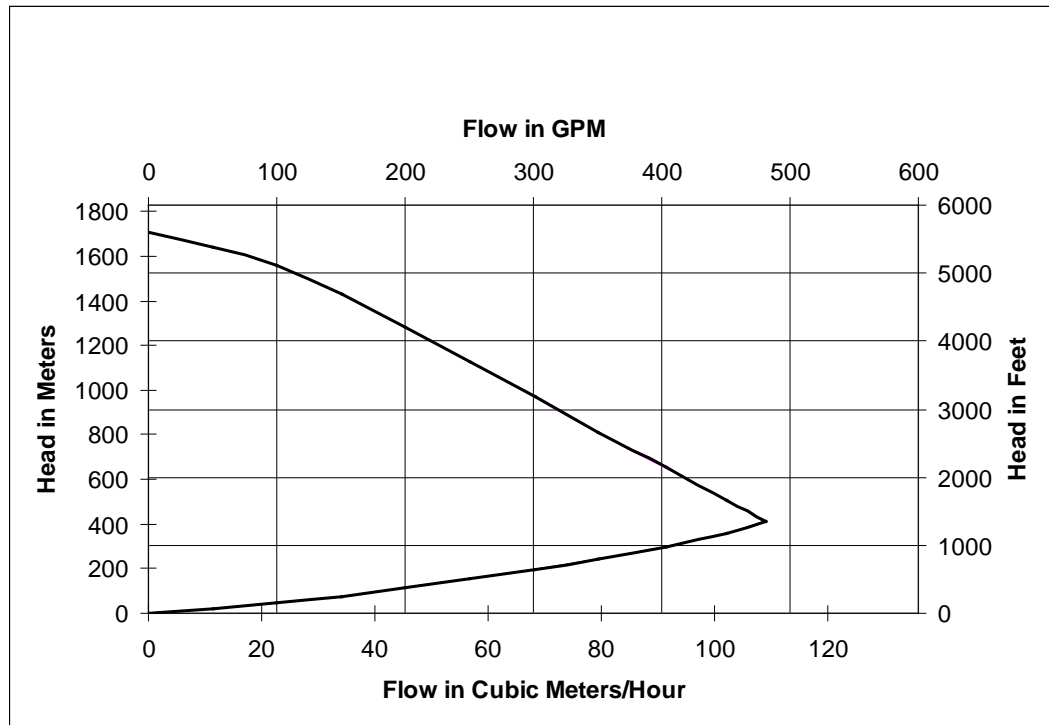
Figure 14 – Performance Map for Special Effect Pumps
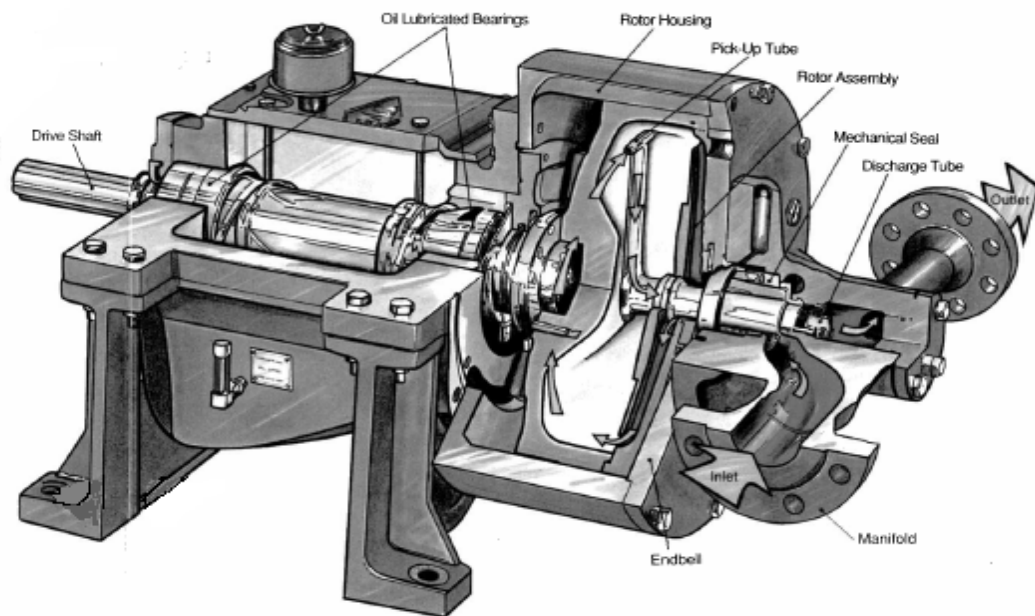
Figure 15 – Typical Special Effect Pump

5.1.3.2 Advantages

1. Special effect pumps provide low flow, high head capability.

2. Special effect pumps have small physical size for high head.

3. Special effect pumps have a wide operating range relative to BEP, and can be operated at very low flow rates without damaging the pump while maintaining good reliability

4. Operating range of special effect pumps can be changed by installing a different pick up (i.e., pitot) tube as well as altering the speed.

5. Special effect pumps may be provided with a speed increaser that can be changed to modify the head and flow

6. Special effect pumps have low NPSH3 requirements within normal operating ranges. Warning, NPSH3 requirements can increase significantly at higher flow rates which may cause cavitation on the pitot tube.

5.1.3.3 Disadvantages

1. Special effect pumps require high horsepower on start-up because of the inertia of the pump case

2. The service is required to be very clean because of potential imbalance of the rotating case from accumulated debris

3. Special effect pumps have limited maximum flow rate capability.

5.1.4   Hydraulic Reliability Factors for Centrifugal Pumps

5.1.4.1 Pumps selected for the pumping system should have head capacity characteristic curves that rise continuously as flow is reduced to shutoff.

> *Comment:*   Achieving a continuously rising head characteristic curve with low-flow high-head pumps is not always possible.

> *Comment:*   Pumps with a continuously rising head characteristic may operate in parallel if the hydraulic performance is similar.

> *Comment:*   If operation is required in the area of the curve that two flows are available for a given head, flow must be controlled to maintain total dynamic head at less than TDH at zero flow. Bypass or recycle flow modifications may be required to move the flow out to this area of the performance curve.

5.1.4.2 Pump should be capable of a 5% head increase minimum at rated condition with the installation of a new impeller.

5.1.4.3 If pumping system is designed for pumps to operate in parallel, the head rise to shutoff should be a minimum of 10% of the head at rated capacity.

> *Comment:*   Parallel operation may require bypass or recycle piping to permit operating over the complete system flow range. System requirements should be carefully considered if parallel operation is required. The optimum system is for

each pump to be equipped with individual flow meters and control system.

Comment: Pumps without a substantial rise in characteristic curve, as flow is reduced, are more susceptible to operating at dead head (shut-in) conditions if the pumps are operated in parallel.

5.1.4.4 Minimum diameter of selected pump impeller should be 105% of the minimum diameter impeller for the generic pump curve for the specific pump.

Comment: Suction recirculation increases as minimum diameter impeller is approached. This can result in increased NPSH3 at the same flow rate and in less predictable performance.

Comment: Caution should be exercised if trimming impellers below 75% of maximum impeller diameter. Reducing impeller diameters below this range may induce tip recirculation and vibration. Efficiency also drops as diameters are reduced.

5.1.4.5 If the pumped fluid has a variable specific gravity, the head required to be developed by the pump should be based on the lowest specific gravity and the greatest system differential pressure for the required flow rate.

Comment: "Specific gravity" is used throughout this Practice in lieu of "relative density." Some commonly used equations would otherwise be affected by the shifting temperature reference used in relative density.

5.1.4.6 If viscosity corrections are required, head, capacity, and efficiency corrections should be the responsibility of the pump manufacturer. These corrections should be calculated in accordance with the "Centrifugal Pump" section of *ANSI/HI 1.3*.

5.1.4.7 Suction Specific Speed

1. Suction specific speed can be a good predictor of pump reliability. See Figures 16 and 17 for preferred operating ranges in metric and U.S. units, respectively.

2. Suction specific speed, S, derived using cubic meters per second and meters, multiplied by 51.6, is equal to suction specific speed, N_{ss}, derived using U.S. gallons per minute and feet.

3. Industry has extensively published documentation indicating that pumps with high S (N_{ss}) {i.e., 215 (11,000) and greater} have reduced reliability. See Centrifugal pumps which suction specific speeds are acceptable Hydrocarbon Processing and Selection criteria for suction impellers of centrifugal pumps, World Pumps. At off-design (i.e., off-BEP) conditions, these pumps are susceptible to both suction and discharge recirculation, which may result in high vibration and poor seal life. Pumps with high S (N_{ss}) should not be permitted for services with widely varying operating flow rates. If no reasonable alternative to a high S (Nss) pump exists, steps should be

taken to ensure pump operation at or very near the BEP. A controlled bypass should be considered or a complete shutdown if the pump is used in a batch operation. Vibration instrumentation should be considered for proper monitoring.
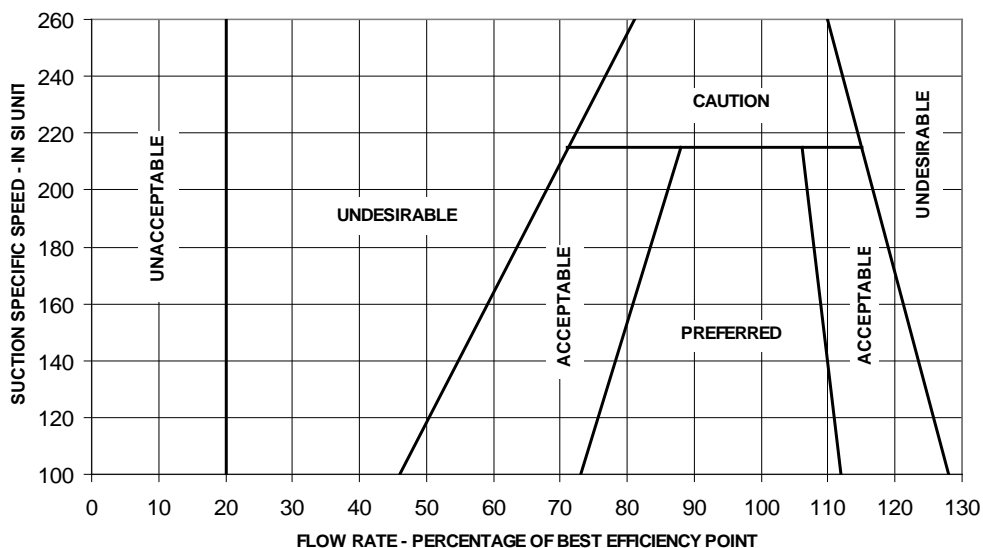
Figure 16 - Preferred Operating Ranges (Metric)
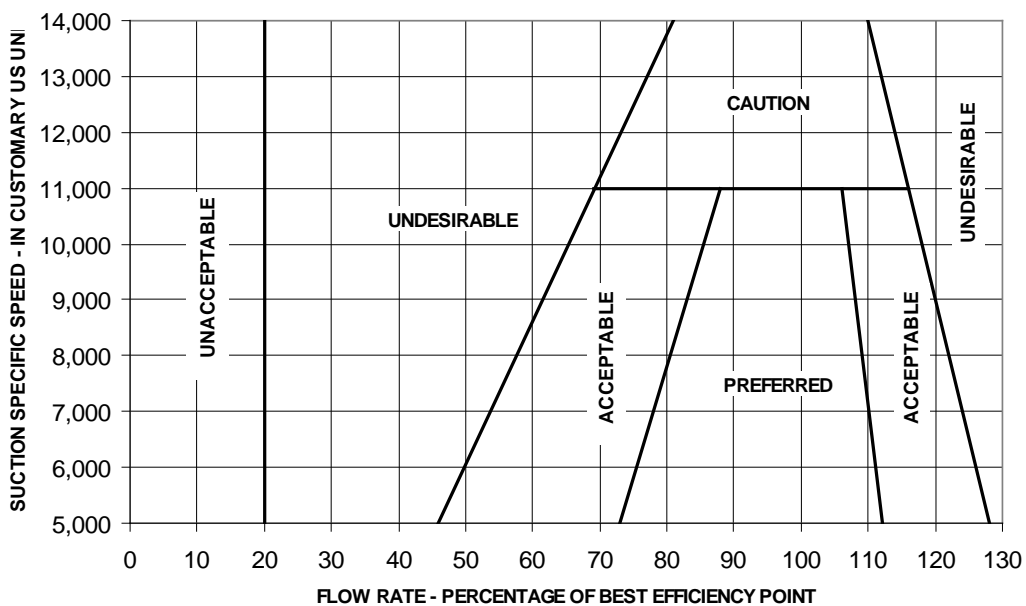
Figure 17- Preferred Operating Ranges (U.S. Customary Units)

4. Inducers have been applied successfully up to S (N_{ss}) of 580 (30,000), although the more common range is 290 to 480 (15,000 to 25,000). If considering inducers, particular attention should be devoted to the NPSH3 curve shape and the pump manufacturer's experience. Care

should be given if selecting inducers for pumps that have a large range in flow rate because a narrow flow range is preferred for inducers.

5. The minimum acceptable NPSHA can be estimated with the following equations:

    a. For metric units:

$$NPSHA \geq [(N/S)^{4/3} * Q^{2/3}] + 1 \text{ meter}$$

Where N is the rotational speed in revolutions per minute.

Q is the flow rate in m^3/hr.

    b. For U.S. Customary units:

$$NPSHA \geq [(N/N_{ss})^{4/3} * Q^{2/3}] + 3 \text{ feet}$$

N is the rotational speed in revolutions per minute

Q is the flow rate in GPM

6. Pump operation at flow rates less than stated minimum continuous stable flow rate causes increased process fluid recirculation within the pump and may cause increased cavitation, which may result in increased noise, high vibration level, bearing or seal failure.

7. Pump operation at flow rates less than the stated minimum continuous thermal flow rate may result in gasket or O-ring failure, seal failure, or flashing in the pump casing.

5.1.4.8 Suction Energy

1. Suction energy is an indication of the liquid's momentum in the impeller eye. Suction energy can be used to evaluate the reliability of a pump and the system in which the pump is installed. Typically, suction energy is used to evaluate the NPSH ratio (i.e., NPSHA/NPSH3) that can improve reliability. See Tables 2, 3, and 4.

2. The following NPSH margin ratios based on suction energy, and limiting flow operating ranges based on suction specific speed can provide superior reliability. NPSH3 can sometimes be reduced by employing double suction impellers to decrease the flow rate per impeller eye to half of the total flow for single suction impellers.

3. Higher SE means the pump is more susceptible to cavitation and vibration, and therefore, more important that the pump operates as close to BEP as possible.

4. SE should be calculated using the following equations:

    a. For metric units:

$$SE = (De)(N)(S)(RD)$$

where: De = Impeller eye diameter in millimeters

If unknown, De can be estimated using the following equations:

For end suction pumps:

De = Suction nozzle diameter times 0.9

For horizontal split case or radial inlet pumps:

De = Suction nozzle diameter times 0.75

N = Pump speed in rpm

S = Suction specific speed from pump data sheet or calculated as follows:

$$S = (rpm) \times (m^3/hr.)^{1/2} / (NPSH3)^{3/4}$$

RD = Relative density of the fluid being pumped

b. For U.S. Customary units:

SE = (De)(N)(S)(RD)

where: De = Impeller eye diameter in inches

If unknown, De can be estimated using the following equations:

For end suction pumps:

De = Suction nozzle diameter times 0.9

For horizontal split case or radial inlet pumps:

De = Suction nozzle diameter times 0.75

N = Pump speed in rpm

S = Suction specific speed from pump data sheet or calculated as follows:

$$S = (rpm) \times (gpm)^{1/2} / (NPSH3)^{3/4}$$

RD = Relative density of the fluid being pumped

5. The point of "Start of High Suction Energy" should be determined in accordance with Tables 2 and 3 as appropriate.

Table 2. Suction Energy Thresholds (Metric Units)

Pump Type	Start of "High Suction Energy"	Start of "Very High Suction Energy"
Double Suction Pumps	60×10^6	90×10^6
End Suction Pumps	80×10^6	120×10^6
Vertical Turbine Pumps	120×10^6	180×10^6

Table 3. Suction Energy Thresholds (U.S. Customary Units)

Pump Type	Start of "High Suction Energy"	Start of "Very High Suction Energy"
Double Suction Pumps	120×10^6	180×10^6
End Suction Pumps	160×10^6	240×10^6
Vertical Turbine Pumps	240×10^6	360×10^6

6. Suction Energy Ratio

   a. The suction energy ratio is an indicator of relative suction energy (i.e., suction energy relative to the pump type). Different pumps have different tolerances for suction energy.

   b. Suction energy ratio should be calculated using the following equation:

   Suction Energy Ratio = SE / Start of High Suction Energy

   c. For example for an end suction pump:

   SE = 7.139 in. x 3560 rpm x 14112 x 0.76 = 302,897,595

   SE ratio (high) = 302/160 = 1.89

7. NPSH Margin Ratio

   a. The NPSH margin ratio essentially indicates the pump's susceptibility to cavitation. The higher the ratio, the better the reliability because a higher NPSH margin ratio helps to suppress the formation of vapor bubbles in the pump.

   b. NPSH margin ratio should be calculated using the following equation:

   NPSH Margin Ratio = NPSH Available / NPSH3 (Required)

   where: NPSH Available is taken at the pump suction

   NPSH3 (Required) is provided on the pump data sheet

   c. The minimum NPSH margin ratios recommended by the Hydraulic Institute are shown in Table 4.

Table 4. Minimum NPSH Margin Ratios

Suction Energy Level	NPSH Margin Ratio
Low	1.1 - 1.3
High	1.3 - 2.0
Very High	2.0 - 2.5

   d. Figure 18 can be used to evaluate NPSH3 ratios for reliability. The axes of the graph in Figure 18 are defined as follows:

% Q = Percent of BEP

% H = Percent of head developed at BEP

% $NPSH_3$ = Multiplier of $NPSH_3$ at BEP

For example, a high head, high suction specific speed pump may list an NPSH3 of just a few meters (feet). However, if operation away from BEP is expected, the NPSHA needs to be increased significantly (see scale on the right hand axis of Figure 18) to achieve a reliable pump.

TREND OF PROBABLE NPSH$_R$ FOR ZERO CAVITATION-EROSION

VARIOUS PUMPS (HIGH HEAD) = > 650 ft. (~200m), FIRST STAGE
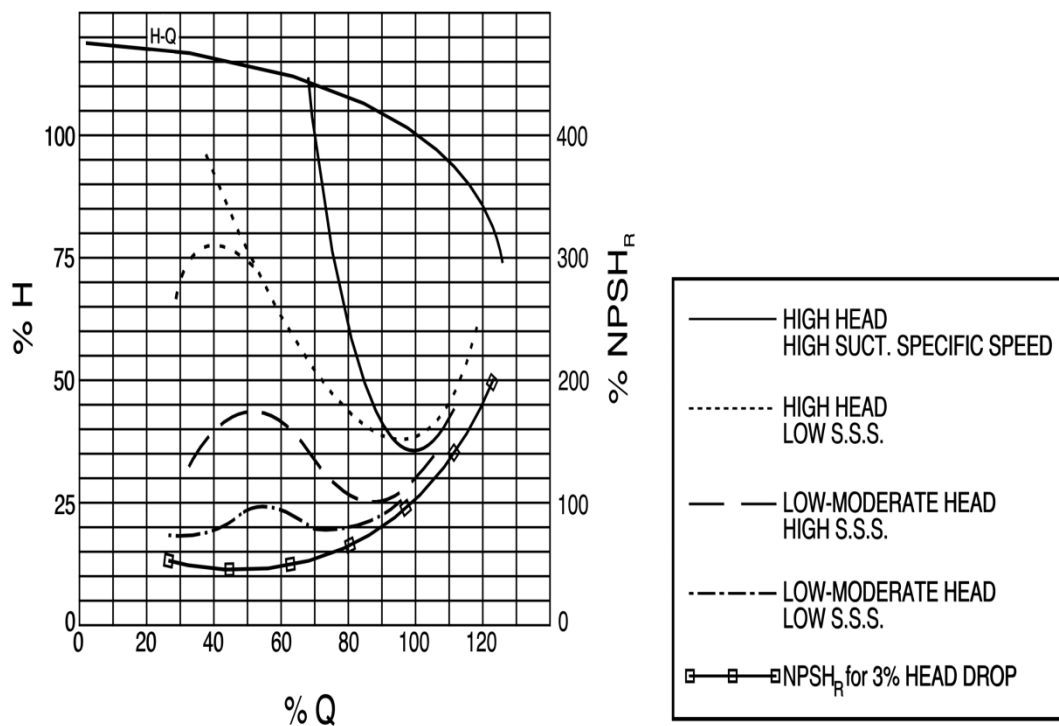
Note: The axes of the graph are defined as follows:
    % Q = Percent of BEP
    % H = Percent of head developed at BEP
    % $NPSH_3$ = Multiplier of $NPSH_3$ at BEP

Figure 18 - NPSH Margin Ratio Analysis Graph

5.1.4.9 Preferred Operating Flow Range

1. Minimum flow rates for reliability depend on many factors, including the preferences of the person setting the limit. Effects of operating at flows less than the BEP include discharge recirculation,

        suction recirculation, decreased impeller life, reduced bearing and seal life, low flow cavitation, and (at very low flow rates) high temperature rise.

2. Maximum flow rates for reliability depend on many of the same factors that determine minimum flow rates. Effects on reliability of operating a pump at flows greater than BEP include reduced bearing and seal life, and cavitation as the NPSH3 curve continues to rise.

3. A spillback or recycle line may be employed to control the flow rate through a pump at a high enough value to meet acceptable minimum criteria. If a spillback line is available, running a pump closer to BEP typically results in improved reliability.

5.1.5   Mechanical Reliability Factors for Centrifugal Pumps

5.1.5.1 Mechanical factors affecting reliability of centrifugal pumps are covered in the following industry standards and PIP Practices as appropriate for the type of pump:

API 610/ISO 13709, API 685, ASME B73.1, ASME B73.2, ASME B73.3, PIP RESP73H, PIP RESP73V, DIN, JN, ISO

5.1.5.2 For sealed pumps, deflection of the shaft at the seal area can be a good indicator of pump reliability. For single stage overhung pumps, the stiffness ratio or shaft flexibility index, defined as follows, can be a good indicator:

Stiffness Ratio $= L^3/D^4$

where: L = Distance from center of radial bearing to center of impeller vane, mm (inches)
D = Diameter of shaft at seal area, not including a sleeve, mm (inches)

A lower shaft stiffness ratio means a stiffer shaft, and more stable seal environment for longer life. Industry reliability experience for pumps with steel shafts having a stiffness ratio less than 215 mm^{-1} (60 $inches^{-1}$) is significantly better than higher stiffness ratios, and is a good selection criterion for improved reliability. For nonmetallic pumps, suitable stiffness ratios may vary because the goal of minimizing shaft deflection at the seal faces may be met by using certain materials of construction.

5.1.5.3 Single stage between bearing pumps may have a stiff shaft and run well below the first lateral critical speed. However, multistage pumps typically have flexible shafts and may need to have a rotor dynamic analysis performed. For between bearing pumps, the shaft flexibility factor, defined as follows, is directly related to shaft deflection and is a factor in the run out and balance that affects seal life:

Shaft Flexibility Factor $= L^4/D^2$

where: L = Length of span between bearing centers, mm (inches)

D = Largest shaft diameter at the impeller, mm (inches)

A lower number means a stiffer shaft and more stable seal environment for longer life. *API 610/ISO 13709* has requirements for shaft and rotor runout.

5.1.6 Pump Bearing Lubrication Methods

5.1.6.1 General

The lubrication method best suited for bearings in a centrifugal pump application should be based on the type of bearing, the size of the pump, available infrastructure, and life cycle cost considerations.

5.1.6.2 Product-Lubricated Bearings

1. Product-lubricated bearings are typically provided in vertical turbines and sealless pumps with sleeve bearings.

2. Product is used as a hydrodynamic fluid for supporting the pump shaft within one or more sleeve bearings.

3. In some cases, an external source of clean product may be required for the lubrication of the bearings.

4. Product-lubricated bearings may have axial or helical grooves to promote cooling and lubrication.

5. Except for sealless pumps, sleeve bearings are typically made of rubber, carbon, carbon-filled polytetrafluoroethylene (PTFE), or metal (e.g., bronze). Compatibility of the pumped fluid with the bearing material is critical to the success of product-lubricated bearings. If the pumped fluid is chemically active or contains solids, special considerations are required for selection of bearing materials.

6. For sealless pumps, pump manufacturer should be consulted for recommendations regarding product-lubricated bearing materials and design.

5.1.6.3 Rolling Element Bearings

1. General

   a. Lubrication methods for rolling element bearings include grease, wet sump, and dry sump.

   b. The reliability of rolling element bearings is heavily influenced by the loading, size, speed, bearing fit, alignment, and the temperature, viscosity, and cleanliness of the lubricant. Consequently, the lubricant should be maintained uncontaminated and within the appropriate temperature range to permit required flow and avoid deterioration.

2. Grease Method

   a. The grease lubrication method is typically limited to non-critical pumps that operate at relatively low speeds and temperatures, and horizontal pumps that have a driver power of 7.5 kW (10 hp) or less.

b. The grease lubrication method is used more often in vertical pumps than in horizontal pumps because of the difficulty of retaining oil in vertical pump bearing housings.

c. Grease may be packed in a bearing and sealed at the factory, or packed in a bearing housing surrounding the bearing. This is not always consistent among pump manufacturers and should be confirmed by the manufacturer before a pump is commissioned.

d. Grease in a bearing should be replaced or supplemented when it reaches its service life. Service life of grease depends on the type of grease; load, size, and speed of the bearing; and the environment. A bearing environment consisting of high temperatures and contaminants negatively influences service life.

e. The cost of lubrication is generally significantly less than the resulting cost of failing to lubricate often enough. Therefore, there exists the common tendency to over-grease the bearing. However, significant damage to a pump can often be attributed to over-greasing. Therefore, procedures developed for filling a bearing with grease should include instructions for the bearing drain plug to be removed and left open through the filling process and until the pump has been operated for a time at a stable temperature.

f. Sealed-for-Life Bearings

(1) Sealed-for-life bearings do not require lubrication for the life of the bearing. Sealed-for-life does not mean for the life of the pump but the life of the bearing. Therefore, an appropriate bearing life should be calculated to confirm the suitability of sealed-for-life bearings for a particular pump application.

(2) Sealed-for-life bearings may be considered for applications where the bearing lubrication interval, determined by the service and environment, is sufficiently long and greasing is not required between pump overhauls. Bearing accessibility for relubrication should also be considered.

(3) Sealed-for-life bearings should not be used in heavily loaded pump applications where lubrication is required at intervals shorter than acceptable for the overhaul of the equipment.

3. Mixing Greases

a. During the operating life of a pump, it may be required to use a new type of bearing grease because of the unavailability of the current grease or if the type of current grease is unknown. Procedures should be provided to ensure that the miscibility of the new and old greases is considered.

b. Greases with the same thickener (e.g., sodium, calcium, or lithium) and similar base oil can be mixed. Typically, lithium- and calcium-based greases are miscible with each other but not with sodium-based greases.

    c. Typically, mixing incompatible greases reduces the consistency of the mixture and, because the load capacity and operating temperature of the grease are affected, can cause bearing damage.

    d. Caution is still warranted when mixing similar greases because the consistency of the resultant mixture can be less than that of either of the two constituents.

4. Wet Sump Methods

    a. General

        (1) The wet sump lubrication method is the most common type used in horizontal centrifugal pumps.

        (2) Variations of the wet sump method are the following:

            (a) Simple-Wet-Sump Method

            (b) Wet-Sump-with-Ring-Oil Method

            (c) Wet-Sump-with-Flinger Method

            (d) Wet-Sump-with-Purge-Mist Method

        (3) Wet sump lubrication methods should be used in conjunction with the following features for bearing isolation and lubrication monitoring:

            (a) Bearing isolator seals that provide a positive static seal (e.g., dynamic O-ring) or magnetic-type bearing isolation seals. These types of bearing isolation seals provide a tight seal that precludes the ingress of atmospheric contaminants. Some labyrinth-type bearing isolation seals do not provide an atmospherically tight seal.

            (b) A diaphragm expansion chamber or a desiccant breather used in place of a vent. These devices preclude the ingress of atmospheric contaminants. These devices are not appropriate for wet-sump-with-purge-mist method lubrication applications.

            (c) A level gauge showing bearing oil level.

                Note: There are varieties of level gauges with different options. Consult with the pump manufacturer on the options available and the benefits and problems of each type.

            (d) A bearing housing water boot or sump drain sight glass to detect contaminated oil. (Figure 19)

Figure 19 – Oil Sump Sight Glass

b. Simple-Wet-Sump Method

(1) The simple-wet-sump method is the standard lubrication method on many horizontal pumps.

(2) If oil contamination or heat buildup in the bearing can occur, other lubrication methods should be considered for improved reliability.

(3) For the simple-wet-sump lubrication method, the lower section of the bearing housing serves as a small sump. The sump oil level should be maintained at the centerline of the lowest roller element in the bearing. This is accomplished by a constant level oiler with a typical capacity of 100 cc (4 ounces).

(4) Problems that can occur with the simple-wet-sump method include the following:

(a) If the oil level is high, frothing and foaming can occur, causing unnecessary heat to be generated and requiring additional power.

(b) Proper oil level is confined to a small range. If the oil level falls below the lower rolling element, further lubrication is not possible.

(c) In vented bearing housings that are not equipped with desiccant breathers, water vapor tends to condense inside the bearing housing, particularly on standby units. Water condensate displaces the lubricant and causes pitting of the lower rotating elements, resulting in shortened bearing life.

c. Wet-Sump-with-Ring-Oil Method

(1) For the wet-sump-with-ring-oil method, a ring rides on the top of the shaft and within the oil sump. The ring is not

attached but merely rests on top of the shaft. Typically, the ring rotates at about 50% of the shaft speed.

(2) Maintenance of the proper oil level is critical to reliable operation. The ring bore should be immersed 6 mm to 9 mm (1/4 inch to 3/8 inch) in the oil.

(3) The oil level is maintained so that the bottom of the ring is immersed in the oil sump. The oil is lifted and distributed as the ring turns.

(4) An advantage of the wet-sump-with-ring-oil method, as compared with the simple-wet-sump method, is that the oil level is below the lowest rolling element, thus eliminating frothing and reducing heat and energy requirements.

(5) Problems that can occur with the wet-sump-with-ring-oil method include the following:

(a) During pump startup or in cold climates if the oil in the sump is too viscous, the ring can rotate at a significantly reduced speed which can restrict the oil from adequately lubricating the rolling elements.

(b) For variable speed pump applications, if the minimum speed of operation is too low, lubrication provided by the ring may not be adequate for reliable operation.

(c) Rings that are out-of-round can fail to provide adequate lubrication.

d. Wet-Sump-with-Flinger Method

(1) The wet-sump-with-flinger method is a commonly available lubrication method for most single-stage overhung pumps.

(2) For the wet-sump-with-flinger method, a flinger (i.e., disc) is attached to the pump shaft. The flinger is immersed in the oil in the same manner as the ring-oil method.

(3) Advantages of the wet-sump-with-flinger method include the following:

(a) Typically more reliable than the simple-wet-sump method

(b) Lubricates better than the ring-oil method for cold starts when the oil viscosity is higher

e. Wet-Sump-with-Purge-Mist Method

(1) The wet-sump-with-purge-mist method incorporates features from the wet sump methods with the addition of an oil mist purge.

(2) The oil mist purge is typically supplied from a central oil-mist-generating console. The droplet size of the oil mist

purge is smaller than produced in the dry sump method (see Section 6.4) and does not directly wet or lubricate a bearing.

(3) Because the bearing housing is under a slight positive pressure from the oil mist purge, the following advantages are realized:

(a) Elimination of atmospheric contamination

(b) Increased mean time between bearing failures similar to the dry sump method

(4) The wet-sump-with-purge-mist method does not take full advantage of the energy savings that can be attributed to the dry sump method.

(5) Consideration should be given to the pressure balancing of this lubrication method by using proper venting.

(6) Drain provisions should be considered with the wet-sump-with-purge-mist method because the sump oil level increases gradually.

5. Dry Sump Method with Pure Mist

a. The dry sump lubrication method uses a central oil mist generator that provides compressed dry air, saturated with oil mist, directly to the bearing housing.

b. Advantages of the dry sump method include the following:

(1) Because the lubricating oil is once through, bearing wear particles are washed out and not recycled.

(2) Rolling element bearings tend to operate at a cooler temperature compared with wet sump oil systems.

(3) A transparent collection chamber at the bottom of the dry sump collects the oil mist condensate. The oil can be examined for color changes or spectrometric tested, enabling early detection of bearing distress.

(4) Less energy is consumed than the wet sump methods.

(5) The positive pressure within the bearing housing eliminates atmospheric contaminants, reducing the potential for corrosion or wear.

(6) Lubrication-based bearing failures and associated maintenance costs are reduced.

(7) A central oil mist generator can serve multiple pumps.

c. Disadvantages of the dry sump method include the following:

(1) Higher installation costs

(2) Once-through use of lubricating oil

(3) Potential for emitting oil-mist into the environment

(4) Housekeeping issues (e.g., may leave an oil film in the area)

5.1.6.4 Hydrodynamic Bearings

1. Hydrodynamic bearings are more typically used on horizontal between-bearing-type pumps. They are seldom used on overhung-type pumps.

2. Hydrodynamic bearings are typically lined with bearing babbitt. Babbitt materials normally operate below 90°C (200°F) and lose strength rapidly with increasing temperature. At 120°C (250°F), a bearing babbitt retains only half of its room temperature strength.

3. For pumps with hydrodynamic radial or thrust bearings, pressure-fed lubrication may be used.

4. The pressure-fed lubricant acts as both a lubricant and coolant.

5. This type of lubrication system is typically used for pumps with driver power greater than 225 kW (300 hp) and to remove the heat generated in the bearings.

6. Pressure-fed lubrication should be designed in accordance with *API Std.614*.

7. The oil film in pressure-fed lubrication may be as thin as 0.005 mm (0.0002 inch). Therefore, the oil should be filtered to remove particles larger than the minimum oil film thickness. Oil filtration is critical in pressure-fed lubrication applications and should be a part of the design of the lubrication system. The filter beta ratio should be given special consideration in accordance with *API Std. 614*.

8. Because the oil also serves as a coolant, pressure-fed lubrication should have oil coolers. Typically, coolers are water or air-cooled.

5.1.6.5 Outdoor Pumps

1. The selection of a bearing lubrication method for outdoor pump applications, especially standby pumps, should also consider the risk of contamination of bearing lubricant.

2. For new facilities with many pumps, the following lubrication methods should be considered:

   a. Wet-sump-with-purge-mist method

   b. Dry sump method

3. For facilities with only a few pumps, the following lubrication methods should be considered because they are more economical:

   a. Simple-wet-sump method

   b. Wet-sump-with-ring-oil lubrication method

   c. Wet-sump-with-flinger lubrication method

5.2 Positive Displacement Type Pumps

5.2.1 General

5.2.1.1 Positive displacement pumps operate by enclosing a volume of liquid and moving that volume mechanically. This operation results in a direct increase in fluid pressure to whatever value is necessary to move the liquid.

> *Note:* A pressure relieving system on the discharge of all positive displacement pumps is recommended because the pressures that can be reached if the discharge is restricted can exceed the allowable pressures for the pump and downstream components. The pressure relieving device must be located upstream of the first discharge isolation valve.

5.2.1.2 Volume movement is accomplished by one of the following:

a. Piston reciprocating in a cylinder

b. Reciprocating flexing of a diaphragm

c. Eccentric rotation of a volume in a sealed cavity (i.e., sliding vane pump)

d. Matched rotating lobes in a volume cavity

e. Gear pumps

f. Screw

g. Progressing cavity

h. Peristaltic

i. Pressure powered diaphragm pumps

j. Pumping traps

5.2.1.3 Typically, positive displacement type pumps operate more efficiently than kinetic type pumps. They are also better suited when the flow capacity requirement is constant but discharge pressure is varying.

5.2.1.4 A pressure relieving system on the discharge of all positive displacement pumps is recommended because the pressures that can be reached if the discharge is restricted can exceed the allowable pressures for the pump and downstream components. Typically, an external relief valve is provided, even if the pump has an internal relief valve. See *PIP REIE686/ API RP686*. If the relief system discharges to the suction piping, see *PIP REIE686/API RP686* for guidelines on the tie in location.

5.2.2 Piston Reciprocating in a Cylinder

5.2.2.1 Configuration

1. Reciprocating pumps operate on a two stroke cycle. Stroke one lowers the pressure in the cylinder by increasing the volume (i.e., intake stroke) and then stroke two decreases the volume (i.e., discharge stroke) to increase the pressure. Check valves built into the pump prevent liquid from being displaced toward the suction.

2. See Figure 20 for configuration of a typical reciprocating pump.

3. Reciprocating pumps develop a constant flow rate for a specific speed (i.e., rpm) and piston stroke and diameter. The speed or piston stroke may be able to be changed during operation to change flow rate.

4. Because a reciprocating pump moves a constant flow rate, the pump develops pressure to meet system requirements. Pressure in a blocked or restricted system increases until limited by a protective device, the mechanical strength of the pump, or pressure capability of the piping.

5. A diaphragm may be added between the piston and the process to isolate the pump mechanical items from the process. Adding a diaphragm may be advantageous for hazardous, corrosive, or abrasive liquids. Strength of the diaphragm limits the pressure capability of the pump.
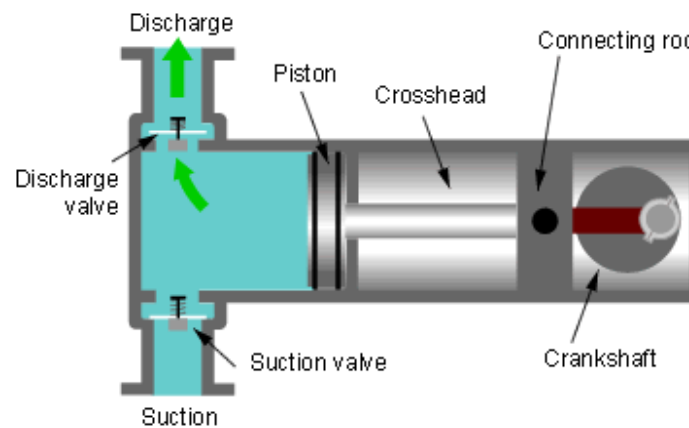
Figure 20 – Typical Reciprocating Piston Pump

5.2.2.2 Advantages

1. Reciprocating pumps provide constant flow rate at whatever pressure is necessary to move the liquid.

2. Reciprocating pumps are very efficient.

3. Reciprocating pumps can be sized for very specific flow rates. Belt driven or variable speed drive pumps can vary flow rate quickly and easily.

4. Reciprocating pumps are capable of handling liquids of high viscosity, or if a number of liquids with varying viscosities are required to be pumped.

5. Reciprocating pumps can be used in intermittent services.

6. Flow rates can be adjusted to specific rates by selecting piston size, speed, and stroke.

5.2.2.3 Disadvantages

1. Flows from reciprocating pumps have high pressure pulsations, and therefore, require pulsation suppression devices on inlet and discharge piping.

2. Reciprocating piston pumps have a low tolerance for solids. Reciprocating plunger pumps can be made tolerant of particulates.

3. Reciprocating pumps require a large foot print because the units include a driver, speed reducer, and pump.

4. Reciprocating pumps require large foundations because of the reciprocating forces.

5. Reciprocating pumps have a relatively high installed cost.

6. Pressure developed is limited only by the mechanical strength of the equipment, including piping.

5.2.2.4 Diaphragm Pump

A diaphragm pump is a modified reciprocating pump. A flexible diaphragm separates the process liquid from the piston. Hydraulic oil fills the volume between the piston and the diaphragm to apply the force from the piston to move the diaphragm and the process liquid. Isolating the piston from the process liquid permits the pump to handle more corrosive or abrasive liquids. It also prevents leakage of the process liquid past the piston rings.

5.2.3 Sliding Vane

5.2.3.1 Configuration

1. Sliding vane pumps are a type of rotary positive displacement pump in which liquid moves inside spaces created by vanes mounted in a rotor. The slotted rotor is eccentrically supported. The rotor is located close to the wall of the cam so a crescent-shaped cavity is formed. Vanes or blades fit within the slots of the impeller. Bearings are oil or grease lubricated. Vane pumps have one shaft seal.

2. As the rotor rotates and fluid enters a sliding vane pump, centrifugal force or springs push the vanes to the walls of the housing. Fluid enters the pockets created by the vanes, rotor and side plates. As the rotor continues around, the vanes sweep the fluid to the opposite side of the crescent where it is squeezed through discharge holes as the vane approaches the point of the crescent. Fluid then exits the discharge port.

3. See Figure 21 for a typical sliding vane pump.
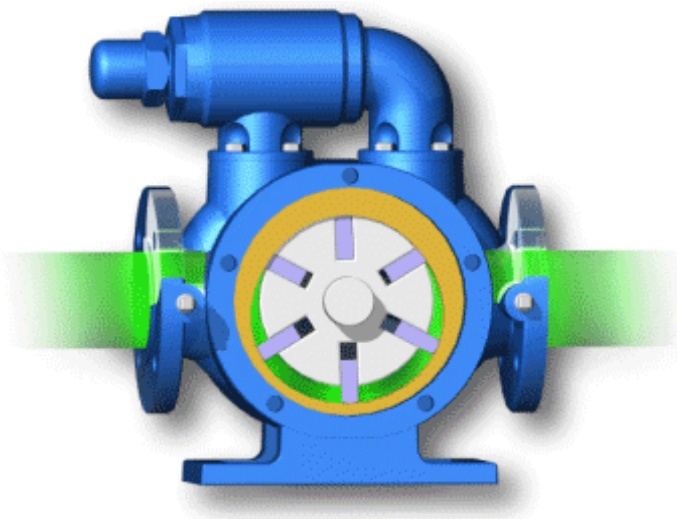
Figure 21 – Typical Sliding Vane Pump

5.2.3.2 Advantages

1. Sliding vane pumps are used for low viscosity liquids (e.g., solvents and LPG).

2. Sliding vane pumps compensate for wear through vane extension.

3. Sliding vane pumps can run dry for short periods.

4. Sliding vane pumps have one seal or stuffing box.

5. Sliding vane pumps can develop a vacuum.

5.2.3.3 Disadvantages

1. Vanes are wearing components.

2. Sliding vane pumps have a low tolerance for abrasives.

3. Pressure capability of sliding vane pumps needs to be confirmed and is affected by the design and materials. Typical operating pressures are limited to 1.72 megapascals (250 psig).

4. Sliding vane pumps are not suitable for high viscosity liquids.

5.2.4 Lobe

5.2.4.1 Configuration

1. Lobe pumps are a type of rotary positive displacement pump in which the liquid flows around the interior of the casing. Lobe pumps are non-contacting and have large pumping chambers. Lobes may be single, bi-wing, tri-lobe, and multi-lobe. The lobes are timed by external timing gears located in the gearbox. The lobes do not make contact with each other. Bearings are generally grease lubricated. Depending on the design, lobe pumps may have one or four shaft seals.

2. As the lobes come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by

the lobes as they rotate. Liquid travels around the interior of the casing in the pockets between the lobes. The meshing of the lobes forces the liquid through the outlet port.

3. See Figure 22 for a typical bi-wing lobe pump.
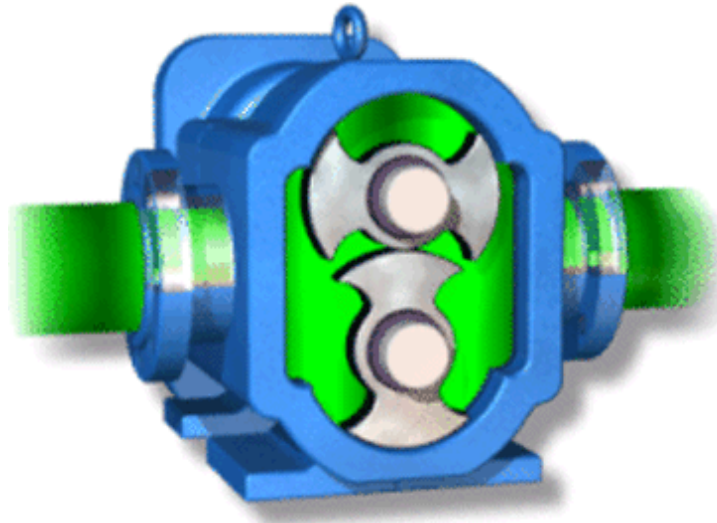
Figure 22 – Typical Bi-Wing Lobe Pump

5.2.4.2 Advantages

1. Lobe pumps can pass medium size soft solids with minimum shear.

2. The lobes have no metal-to-metal contact.

3. If the seals remain lubricated, lobe pumps are capable of long term dry run.

4. Lobe pumps can pump fluids with varying viscosities.

5. Lobe pumps can pump non-Newtonian fluids.

5.2.4.3 Disadvantages

1. Lobe pumps are not suitable for high pressures.

2. Lobe pumps require timing gears.

3. Lobe pumps require two or four mechanical seals.

4. If pumping low viscosity fluids, the capacity of lobe pumps is reduced.

5.2.5 Gear

5.2.5.1 Configuration

1. There are two types of gear pumps: external and internal.

2. External gear pumps have gear shaped rotors. The gear shape of the rotor may be spur, helical, or herringbone gear teeth and may use timing gears. See Figure 23 for a typical external gear pump.

3. Internal gear pumps have one rotor with internally cut gear teeth meshing with an externally cut gear. See Figure 24 for a typical internal gear pump.
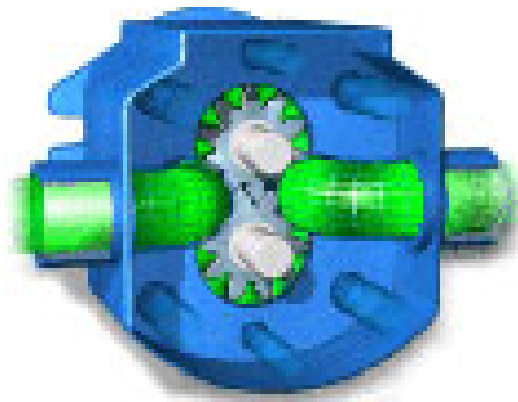
Figure 23 – Typical External Gear Pump

Figure 24 – Typical Internal Gear Pumps

4. As the gears come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the gear teeth as they rotate. Liquid travels around the exterior of the casing in the cavity. The meshing of the gear teeth forces the liquid through the outlet port.

5.2.5.2 Advantages

1. Gear pumps provide constant flow rate at whatever pressure is necessary to move the liquid.

2. Gear pumps can pump fluids with varying densities and viscosities.

3. Gear pumps are very efficient.

4. Gear pumps have low NPSH3 requirements.

5. Gear pumps are inexpensive.

5.2.5.3 Disadvantages

1. Gear pumps can be less reliable for low viscosity fluids (i.e., viscosity less than 5 cP).

2. Low viscosity fluids can cause slippage which will limit differential pressure developed and reduce pump capacity.

   Comment: Internal slip rotary pumps increases with lower or reduced viscosity, therefore it affects capacity of rotary pumps.

3. If cavitation occurs in high-energy applications, vapor collapse can cause pressure pulsations and violent vibration in the pump and hydraulic hammer in the piping.

4. Caution is required for high temperature applications because the clearances change.

5.2.6   Screw

5.2.6.1 Configuration

1. Screw pumps are a type of rotary positive displacement pump in which the liquid moves through spaces created by rotating, meshing screws. Liquid agitation is minimized relative to other positive displacement pumps.

2. As the screws come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the screws as they rotate. The liquid is carried between screw threads on one or more rotors, and is displaced axially as the screws rotate and mesh.

3. See Figure 25 for a typical screw pump.
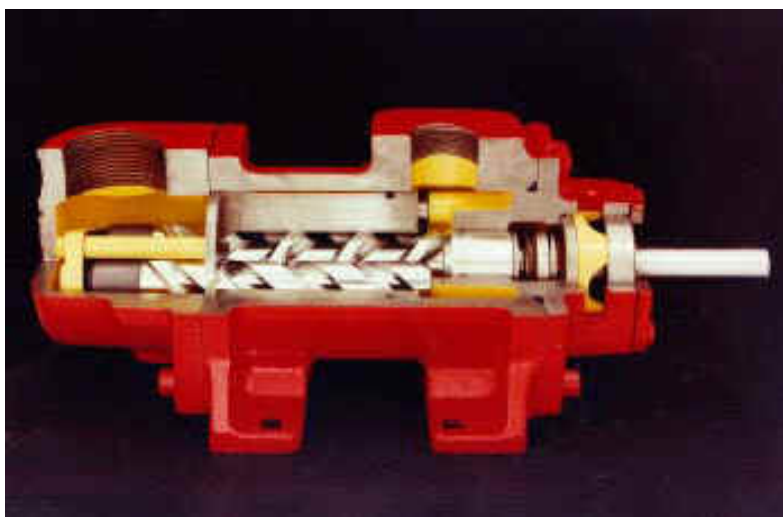
Figure 25 – Typical Screw Pump

5.2.6.2 Advantages

1. Screw pumps can be used for high pressure applications.

2. Screw pumps can pump fluids with varying density and viscosity.

3. Screw pumps have low pulsations.

4. Liquid agitation is minimized relative to other positive displacement pumps.

5. Screw pumps have low NPSH3.

6. Externally timed screw pumps can accommodate some solids

7. Screw pumps produce low shear

5.2.6.3 Disadvantages

1. Screw pumps cannot handle solids. Inlet strainers are required to keep contaminants and abrasives out of the pump.

2. If pumping low viscosity fluids, the capacity of screw pumps is reduced.

3. Screw pumps have temperature limitations because the clearances decrease.

4. If cavitation occurs in high-energy applications, vapor collapse can cause pressure pulsations and violent vibration in the pump and hydraulic hammer in the piping.

5. May have from one to four seals.

5.2.7 Progressing Cavity

5.2.7.1 Configuration

1. A progressing cavity pump moves fluid through a sequence of discrete fixed shape cavities that progress through the pump as the rotor turns. The cavities generally taper and overlap with adjacent cavities in such a way that very low or no pulsations are transmitted to the fluid.

2. Progressing cavity pumps are typically used for fluid metering and pumping of viscous or shear sensitive fluids because of the following:

   a. The volumetric flow rate is proportional to the rotation rate.

   b. The shear rate applied to the pumped fluid is low.

3. See Figure 26 for a typical progressing cavity pump.

5.2.7.2 Advantages

1. Progressing cavity pumps are self priming.

2. Progressing cavity pumps provide virtually pulsation free operation. The pump supplier should provide an estimate of the pressure pulsations at the rated operating pressure to assist in piping design.

3. Progressing cavity pumps develop low shear in the process stream (e.g., does not damage long polymer chains such as in paint).

4. Progressing cavity pumps can be used in high density services.
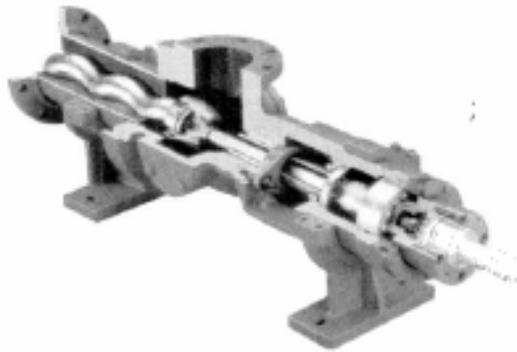
Figure 26 – Typical Progressing Cavity Pump

5. Progressing cavity pumps can be used for high viscosity fluids.

6. Progressing cavity pumps can handle up to 20% solids in the fluid without special equipment.

7. Progressing cavity pumps can handle up to 80% solids in the fluid with feed augers.

8. Progressing cavity pumps can handle liquids with entrained gas

9. Progressing cavity pumps have high efficiency

10. Progressing cavity pumps have low flow with high head capability.

11. Pump seal operates at suction pressure.

12. Pump flow rate is speed dependent

13. Pump baseplates are simply designed

14. Replacement of wetted parts can be performed quickly

5.2.7.3 Disadvantages

1. Progressing cavity pumps can take greater plot space.

2. Temperature is limited by materials of construction of the pump stator. Typical limits are $180^{\circ}C$ ($350^{\circ}F$).

3. Standard design mechanical seals and couplings may not be available for small capacity pumps.

4. Pump drive linkage is exposed to the process liquid. The sealing system needs careful evaluation.

5. Pump stator material of construction can limit application and will affect maintenance costs.

6. Pump stator life will be shortened if the pump is allowed to run dry.

7. Progressing cavity pumps require external bypass or pressure relief.

5.2.8 Peristaltic

5.2.8.1 Configuration

1. Peristaltic pumps have a flexible tube, typically in a circular pump case, with a rotor that has a number of rollers, shoes, or wipers attached to the perimeter. As the rotor turns, the part of the tube under a roller is closed by compression which forces the liquid to move through the tube. After the roller passes, the tube opens to an uncompressed state creating a vacuum in which liquid is pulled into the pump.

2. See Figure 27 for a typical peristaltic pump.
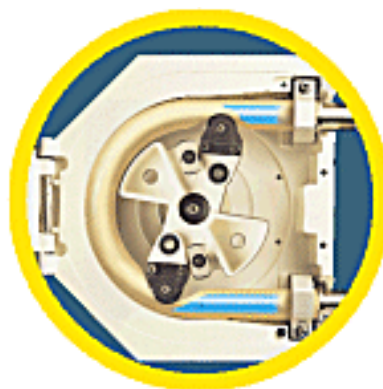
Figure 27 – Typical Two-Roller Peristaltic Pump

5.2.8.2 Advantages

1. Peristaltic pumps provide constant flow rate at whatever pressure is necessary to move the liquid.

2. Peristaltic pumps can pump liquids with varying densities and viscosities.

3. Peristaltic pumps are very efficient.

4. Peristaltic pumps have low NPSH3.

5. Peristaltic pumps are inexpensive.

6. Easy to maintain cleanliness in sanitary services

7. Sealless technology

8. Reversible flow by reversing the direction-of-rotation

9. Extremely accurate flow rate control

10. Self priming

5.2.8.3 Disadvantages

1. Peristaltic pumps can be less reliable for low viscosity fluids (i.e., viscosity less than 5 cP).

2. Low viscosity fluids can limit differential pressure developed and reduce pump capacity.

3. Peristaltic pumps are temperature limited by the tubing material.

4. Resiliency of the tubing is necessary for the pump to function properly.

5. Prone to tubing failure

6. Not suitable for abrasive fluids.

5.2.9 Pressure Powered

5.2.9.1 Configuration

1. Pressure powered pumps move liquid by using a gas to pressurize one side of a mechanism which displaces the liquid either directly, or acts on a piston to move the liquid. One type of pressure powered pump is an air operated diaphragm pump.

2. Double diaphragm pumps consist of two chambers. Each chamber is connected to the suction port on the bottom of the pump with passages that contain check valves. A diaphragm in each chamber isolates the process liquid from the gas that drives the diaphragm. A shaft connects the diaphragms so they move together. When one chamber is filling with liquid on the suction stroke, the other chamber is being emptied on the discharge stroke. The discharge passages also contain check valves and are joined at the discharge port. Double diaphragm pumps operate by applying a pressurized gas to one side of a diaphragm. When the diaphragm reaches the end of its' travel, an internal switch directs the gas to the other diaphragm and the process repeats as long as pressurized gas is supplied.

3. See Figure 28 for a typical pressure powered pump.

5.2.9.2 Advantages

1. Pressure powered pumps have low initial cost.

2. Pressure powered pumps can be installed easily.

3. Pressure powered pumps do not have mechanical seals.

4. By varying the stroke rate (gas supply), pumps can provide variable flow rates.

5. Pump flow rate range can be very low to the maximum the pump is designed for. With small plunger diameters, timers, and low stroke rates, the flow rates can be as low as 1 liter (2 pints) per day.

6. Does not require a motor

7. May be operated submerged in the liquid

8. Pressure powered pumps can be run dead headed, shut in, without damage.
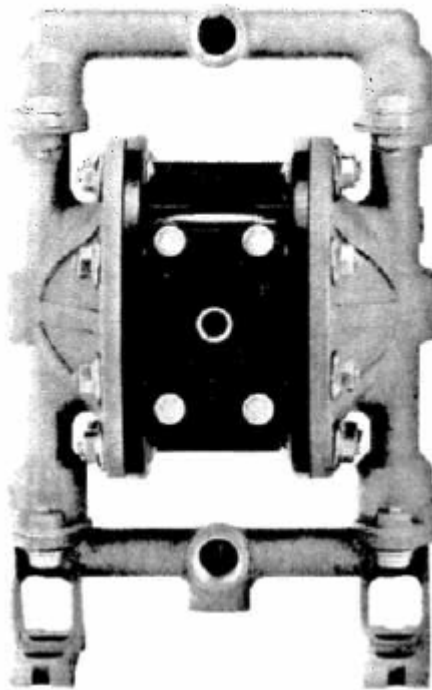
Figure 28 – Typical Pressure Powered Pump

9. If the shuttle valves are not electrically actuated, pressure powered pumps are intrinsically safe (i.e., do not have electrical area classification issues).

10. Pressure powered pumps are inexpensive to repair or replace.

11. Pressure powered pumps develop low shear in the process stream.

5.2.9.3 Disadvantages

1. Cost of compressed air or gas to drive the pump

2. Pressure powered pumps have relatively poor reliability

3. Pump discharge pressure cannot be greater than the drive gas supply pressure

4. Pump pressure and temperature are limited by the diaphragm material.

5. Motive gas pressure requires regulation. Excessive gas pressure can cause the pump to cavitate.

6. Check valve material of construction requires careful consideration to match the process.

7. Pressure powered pumps have low efficiency.

8. Pressure powered pumps have pulsating flow.

9. Insufficiently dried air can cause the shuttle valve to freeze and render the pump inoperable.

5.2.10 Pumping Trap

5.2.10.1 Configuration

A float on a lever arm alternately admits either the process liquid into a holding tank, or the motive gas which discharges the process liquid from the holding tank.

5.2.10.2 Advantages

1. Pumping traps are self-regulating (i.e., empties when liquid reaches a set level within the body).

2. Pumping traps are intrinsically safe (i.e., do not have electrical area classification issues).

3. Standard pump packages are relatively inexpensive.

4. Pumping traps can be configured for various liquid densities and materials.

5. If used in steam/condensate service and the pressure is sufficient to overcome the downstream pressure, the pumping trap can be self-powered.

5.2.10.3 Disadvantages

1. Pumping traps are required to be installed sufficiently below the liquid supply to insure adequate NPSHA.

2. Complete pumping system may take greater plot space.

3. Pumping traps are inefficient because motive gas is vented at the end of the discharge cycle.

4. Internal float linkages and regulating valves wear and can be a maintenance issue.

6. Selection Considerations Checklist

6.1 Safety

6.1.1   Process fluid toxic or hazardous

6.1.2   Process fluid flammable

6.1.3   Process fluid above auto-ignition temperature

6.1.4   High pressure system (i.e., greater than 1,900 kPa (275 psig))

6.1.5   Regulations (e.g. OSHA)

6.2 Environmental

6.2.1 Regulations

1. Federal (e.g., EPA)

2. State (e.g., California Air Resource Board, Texas Commission on Environmental Quality)

3. Local

6.2.2 Odorous

6.3 Process Conditions and Requirements

6.3.1 NPSHA

6.3.2 Flow rates (i.e., minimum, maximum, rated)

6.3.3 Suction pressures

6.3.4 Discharge pressures

6.3.5 Relative density/specific gravity

6.3.6 Head required

6.3.7 Control systems

6.3.8 Temperature

6.3.9 Heat of vaporization

6.3.10 Heat capacity

6.3.11 Specific heat

6.3.12 Viscosity

6.3.13 Solids in process fluid (i.e., percent solids, hardness, and maximum particle size)

6.3.14 Propensity to polymerize or crystallize

6.3.15 Corrosivity

6.3.16 Toxicity

6.3.17 Vapor pressure

6.3.18 Alternative operating applications (i.e. water wash, unit pump out, end of run, variable speed (torsional studies may be needed), etc.)

6.4 Economics

6.4.1 Anticipated life of equipment and installation

6.4.2 Initial purchase price

6.4.3 Cost of installation

6.4.4 Cost of utilities to operate. This includes seal support systems, external flush, and drivers.

6.4.5 Maintenance costs, including cost of critical spares, commonality with other pumps, skill level of the maintenance craft, and preventive maintenance

6.4.6 Cost of meeting safety and environmental regulations

6.4.7 Cost of lost production

6.4.8 Cost to decommission and dispose of equipment

6.4.9 Life cycle cost, also called total cost of ownership

6.5 Site and Location

6.5.1 Minimum and maximum temperatures

6.5.2 Equipment mounted indoors or outdoors

6.5.3 Humidity

6.5.4 Corrosive atmosphere

6.5.5 Dust

6.5.6 Elevation

6.5.7 Available utilities

6.5.8 Remoteness of location and support availability

6.5.9 Area electrical classification

6.5.10 Other unique local conditions such as seismic, wind, rain, or snow

7.   Ancillary Equipment

Ancillary equipment and supporting systems, that play very important roles in the design, installation and reliable operation of pumping systems, and should be part of the selection considerations for pump applications include the following:

1. Drivers

2. Seals and seal support systems

3. Couplings

4. Power transmission (gearboxes, belts, etc.)

5. Heating and cooling systems

6. Pulsation dampeners

7. Control systems, including VFD, recirculation lines, and control valves

8. Noise control systems (e.g., silencers and enclosures)

9. Monitoring systems for performance and vibration

10. Piping systems including pressure protection systems

11. Lubrication systems

12. Foundations, grouting, base-plates, and mounting plates

13. Suction strainers and filters

14. Shut down protection systems, including emergency isolation and environmental monitoring.

APPENDIX A

PUMP SELECTION FLOW CHART

Start

Consult a specialist for the following applications:
1. Zero emissions at temperature > 150°C (300°F)
2. Hydrocarbon Slurry
3. If there are options available for an application

Constant Flow at variable pressure.

Process requires variable flow at nearly constant pressure.

NO

YES

Can a centrifugal pump with an inducer meet the NPSH margin requirements?

YES

NO

NPSHA> 1 Meter (3 feet) at Datum Elevation?

NO

Datum elevation is defined by the Hydraulic Institute. For horizontal pumps, it is the centerline of the impeller. For vertical double suction pumps, it is the center of the impeller vane. For other vertical pumps, it is the bottom of the first stage impeller vane.

YES

Temp.< 200°C (400°F)?

NO

Vertical Double Casing or Centrifugal pump with an inducer

YES

Pressure within Limits of vertical turbine pump bowls?

NO

YES

Vertical Turbine Pump or Centrifugal Pump with an inducer

Hydrocarbon Slurry Catgory?

YES

Consult a Specialist.

YES

Slurry Application?

NO

Fluid Viscosity <300 SSU?

NO

YES

NO

For Heavy Slurry, do any of the following apply:
Main purpose is to transport solids
Solids size>6 mm (0.25")
Non-settling
Slurry S.G.>1.15
>20% solids.

If any of the listed items are "yes" the path choice is "yes"

Consult a Specialist.

Medium Slurry - solids size 200 microns to 0.25" Slurry S.G.<1.15- 5% to 20% solids by weight.

If any of the listed items are "no" the path choice is "no"

NO

Is the service and of the following:
• Non/Low Hazardous
• Water Service
• Oily Water Service.

If any of the listed items are "yes" the path choice is "yes"

Head< 300 Meters (1,000 feet)?

YES

Flow > 80 M³/hr. (350 GPM)?

NO

Do you prefer Positive Displacement Pumps or Centrifugal Pumps?

PD

YES

Centrifugal

Consult a specialist to address the advantages and disadvantages of each style of pump listed.

• High speed centrifugal - May use Variable Frequency Drive as well as speed increaser
• H Pumps - Centrifugal Pump, Number of stages can exceed 200. A canned motor pump may be feasible.
• Regenerative Turbine Pump - Partial Emission.
• May be Canned Motor Pump.
• Special Effects - Rotating Case Pump (Pitot Tube Pump)

Casing Replaceable Wear Liner Pump Hard Metal, Slurry Design Pump

Are the Solids Sharp and/or Abrasive?

NO

Rubber Lined, Open Impeller, Slurry Design Pump

Cast Iron, Slurry Design Pump

Are the Solids Sharp and/or Abrasive?

NO

Rubber Lined, Open Impeller, Slurry Design Pump

YES

Casing Replaceable Wear Liner, Slurry Design Pump

YES

Is the service Hydrocarbon Inside Battery Limits or Chemical Service?

If any of the listed items are "yes" the path choice is "yes"

NO

Non/Low Hazardous or Water Service or Oily Water Service?

NO

If any of the listed items are "yes" the path choice is "yes"

YES

Temp.< 95°C (200°F)?

YES

Is the service Flooded Suction or Off-site Hydrocarbon?

Consult a specialist to address the advantages and disadvantages of each style of pump listed.

• Vertical Turbine/Volute Pump
• Submersible Pump
• Horizontal Self Priming Pump

If any of the listed items are "yes" the path choice is "yes"

YES

General Purpose Pump
• Horizontal Pump
• Vertical Pump
• Canned Motor Pump
• H Pumps - Centrifugal Pump, Number of stages can exceed 200.

Consult a specialist to address the advantages and disadvantages of each style of pump listed.

Is the service Hydrocarbon or Chemical?

YES

NO

NonHazardous/ Water Service?

NO

YES

If any of the listed items are "yes" the path choice is "yes"

Is the service Lube or Seal Oil?

YES

Rotary Positive Displacement Screw Pump

If any of the listed items are "yes" the path choice is "yes"

NO

Temp<95C (200F)?

YES

YES

Flow>225 m³/hr. (1,000 GPM) @ 3,600 RPM or <570 m³/hr. (2,500 GPM) @ 1,800 RPM

If any of the listed items are "yes" the path choice is "yes"

NO

Suction Pressure >0.52 MPa (75 PSIG)?

YES

NO

Metering

Diaphragm Pump

YES

NO

Piston Packed Plunger Pump

Do any of the following apply?
• Is compressed air available?
• Is discharge pressure < air supply pressure <
• Is the Temperature < Diaphragm allowable?

YES

Pneumatic Diaphragm Pump

If all of the listed items are "yes" the path choice is "yes"

Disch. Pressure >1.9 MPa (275 PSIG)?

YES

NO

Zero Emissions Required?

YES

Diaphragm Peristaltic Magnetic Drive Gear

Temp.< 150°C (300°F)?

YES

NO

NO

Fluid w/ Particulates

YES

Diaphragm Pump
• Piston Pump
• Packed Plunger Pump
• Progressing Cavity Pump

Consult a specialist to address the advantages and disadvantages of each style of pump listed.

Driver Power > or = 100 kW (150HP)?

NO

YES

NO

Fluid has Lubricity?

YES

• Lobe Pump
• Gear Pump
• Screw Pump
• Piston Pump
• Plunger Pump
• Diaphragm Pump
• Sliding Vane Pump
• Flexible Vane Pump

Consult a specialist to address the advantages and disadvantages of each style of pump listed.

Zero Emissions Required?

YES

NO

Temp.> 200°C (400°F)?

YES

NO

Product Contami-nation Allowed?

NO

Consult a Specialist.

Temp.< 200°C (400°F)?

NO

Consult a Specialist.

Consult a specialist to address the advantages and disadvantages of each style of pump listed.

YES

NPSH Margin Met at grade?

YES

Relative Density< 0.7?

NO

Driver Power < or = 50 kW (75HP)?

NO

Zero Emissions Required?

YES

ASME Pump: Sealed Horizontal Overhung Canned motor Magnetic drive.

NO

YES

ASME Pump: Sealed Vertical In-Line Horizontal Canned motor.

Consult a specialist to address the advantages and disadvantages of each style of pump listed.

Consult a specialist to address the advantages and disadvantages of each style of pump listed.

• Horizontal Overhung Pump

Vertical Double

• Piston Pump
• Packed Plunger Pump
• Diaphragm Pump

Consult a specialist to address the advantages and disadvantages of each style of pump listed.

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                                                                                    Casing API 610                      Canned motor
• Vertical In-Line Pump           API Pump with Pressureized Dual Seals            VS6 or VS7                          Magnetic drive                        Temp.>
• Canned Motor Pump               • Horizontal Overhung Pump                                                                                                 150°C
• Magnetic Drive Pump             • Vertical In-Line Pump                                                                                                   (300°F)?
                                  • or Canned Motor Pump                          Disch. Pres.                         Consult
                                  • Magnetic Drive Pump                           7 MPa (1,000          YES             Specialist.         YES
                                                                                  PSIG)?
                                                        Consult a specialist to address                                                          Consult a specialist to
                                                        the advantages and                                                                       address the advantages and
                                                        disadvantages of each style of                                                           disadvantages of each style
                                                        pump listed.                                                                             of pump listed.
                                                                                                                                                                    NO
                                         • API Radial Split Case Pump
                                         • Canned Motor Pump                                                                                             ASME Pump:
                                                                                   NO                                                                   • Canned motor
                                                                                                                                                        • Magnetic drive
                                                      Consult a specialist to address
                                                      the advantages and
                                                      disadvantages of each style of
                                                      pump listed.

                                         • Jacketed API Hoirzontal Split Pump              Heat                         • Horizontal Split Case Pump
                                         • Canned Motor Pump            YES               tracing?          NO          • Canned motor
                                                                                                                        • OHH if within pressure limits
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