

KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions		Page : 1 of 51
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KLM Technology Group #03-12 Block Aronia, Jalan Sri Perkasa 2 Taman Tampoi Utama 81200 Johor Bahru.	Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Co Authors Rev 01 - A L Ling Rev 02 – Viska Mulyandasari Rev 03 – K Kolmetz
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TABLE OF CONTENT

INTRODUCTION

Scope	5
General Design Consideration	
Type of Pump	6
Process Requirements Parameters	9

DEFINITIONS	11
--------------------	----

NOMENCLATURE	13
---------------------	----

THEORY

A) Working Principle of Pump	15
I) Centrifugal Pump	15
Centrifugal Pump Impeller & Shaft (Rotating Component)	16
Working Theory-Conversion of Kinetic Energy to Pressure Energy	17

KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 2 of 51
		Rev: 03
		May 2012

II) Positive Displacement Pump	17
B) Pump Selection	18
Industry Codes and Standards for Pump Selection & Design	23
C) Cavitation	24
D) Total Head	25
E) Net Positive Suction Head – NPSH	26
F) Pump Power and Efficiency	28
I) Power	28
II) Hydraulic Power	29
III) Brake Power	29
IV) Pump Efficiency	30
G) Pump Sizing- Step by Step Calculation	31
TROUBLESHOOTING OF THE PUMP PROBLEMS	33
I) Seal Leakage	33
II) Loss of flow	33
III) Loss of Suction	34
IV) Low Discharge Pressure	34
V) Excessive Noise and Vibration	34
VI) Excessive Power Consumption	34
VII) Rapid Pump Wear	35
MATERIAL OF CONSTRUCTION	40

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 3 of 51
		Rev: 03
		May 2012

APPLICATION

Example Case 1: Pump Sizing for water flow	42
Example Case 2: Pump Sizing for Hydrocarbon flow	46

REFERENCES	50
-------------------	----

LIST OF TABLE

Table 1: General selection method for centrifugal pumps	19
Table 2: General selection method for positive displacement pumps	21
Table 3: General Centrifugal Pump Problem and Solution	35
Table 4: Pump Material of Construction for specific services	41

LIST OF FIGURE

Figure 1: Foot mounted overhung pump	7
Figure 2: Centerline mounted overhung pump	8
Figure 3: Radically split multistage-single & double casing	8
Figure 4: Simple Centrifugal Pump	15
Figure 5: Seven-stage centrifugal pump	16
Figure 6: Positive-displacement gear-type rotary pump	18
Figure 7: Selection guides for various type of pumps	29
Figure 8: Centrifugal Pump Efficiency	30

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 4 of 51
		Rev: 03
		May 2012

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INTRODUCTION

Scope

This design guideline assists engineers and operations personnel to understand the selection and sizing of pumps. A pump is one of the most important pieces of mechanical equipment that is present in industrial processes. A pump moves liquid from one area to another by increasing the pressure of the liquid above the amount needed to overcome the combined effects of friction, gravity and system operating pressures.

There are two types of pump which are generally used in industrial processes: positive displacement pump and centrifugal. It is important to choose the suitable type of pump based on process requirement and fluid process properties. The functions and types of pump are explained in detail under the General Design Guideline section.

The theory section covers the selection method of the pump based on their application and engineering calculations for the sizing of the pump. When sizing the pump, the understanding of concept of cavitation is very important. Cavitation is an abnormal condition that can result in loss of production, equipment damage and worst of all, personnel injury. To prevent pumps from having this problem, the correct design should be followed by applied the correct theory when carrying out the activities of pump sizing and selection.

In the application section of this guideline, four case studies are shown and discussed in detail, highlighting the way to apply the theory for the calculation. Generally used theory, such as Bernoulli's theory, is used as the basic of calculation because it is applicable for various conditions. This theory is applied in calculation of the NPSH of the pumps, which is shown in detail in this section. The case studies will help the engineer do the selection and sizing for the pumps base on their own plant system.

Example Calculation Spreadsheets is attached in the end of this guideline. This Example Calculation Spreadsheets is made based on case studies in the application section to make the reader easier to learn.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 5 of 51
		Rev: 03
		May 2012

INTRODUCTION

General Design Consideration

Type of Pump

The selection of type and construction of a pump is very important to meet the process specification and proper application. Knowledge of the variety of pumps in the market should be review. It is mentioned before, that there are two general types of pump in today's industry: positive displacement and centrifugal (dynamic) pumps.

Positive Displacement Pumps

Positive displacement (PD) pumps work by allowing a fluid to flow into some enclosed cavity from a low-pressure source, trapping the fluid, and then forcing it out into a high-pressure receiver by decreasing the volume of the cavity. Some examples of PD pumps are: fuel and oil pump in most automobiles, the pumps on most hydraulic systems, and the heart of most animals.

Some general types of the positive displacement pumps are as below:

a) Reciprocating Pump

Reciprocating pumps create and displace a volume of liquid, their "displacement volumes", by action of a reciprocating element. Liquid discharge pressure is limited only by strength of structural parts. A pressure relief valve and a discharge check valve are normally required for reciprocating pumps

Reciprocating pumps can be further classified into three types of pump as below,

- i) Piston Pumps
- ii) Packed Plunger Pumps
- iii) Diaphragm Pumps

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 6 of 51
		Rev: 03
		May 2012

b) Rotary Pump

Rotary pumps function with close clearances such that a fixed volume of liquid is displaced with each revolution of the internal element. Rotary pumps include:

- i) Gear Pump
- ii) Lobe Pump
- iii) Vane Pump
- iv) Screw Pump

All those pumps above have the similar working principles: pumping the liquid with the help of rotating elements. The difference lies on the rotating elements; they could be gear, lobe, vane, or screw.

Centrifugal Pumps

Centrifugal pumps are dynamic pumps. A centrifugal pump raises the pressure of the liquid by giving it a high kinetic energy and then converts it into pressure energy before the fluid exits the pump. It normally consists of an impeller (a wheel with blades), and some form of housing with a central inlet and a peripheral outlet. The impeller is mounted on a rotating shaft and enclosed in a stationary casing. Casings are generally of two types: volute and circular. The impeller design and the shape of the casing determine how liquid is accelerated through the pump.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 7 of 51
		Rev: 03
		May 2012

Some general types of the centrifugal pumps are as below:

a) Overhung pump

A pump with the impeller(s) cantilevered from its bearing assemblies is classified as an overhung pump.

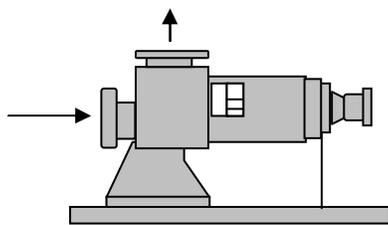


Figure 1: Foot mounted overhung pump

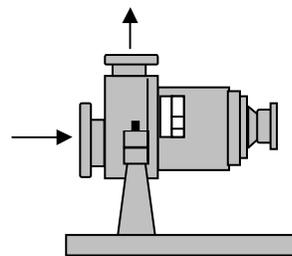


Figure 2: Centerline mounted overhung pump

b) Between bearings pump

A pump with the impeller(s) located between the bearings is classified as a between bearings pump. The pump may be single-stage (one impeller), two-stage, or multistage. It can be axially (horizontally) split or radially split.

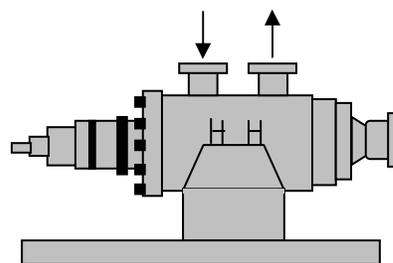


Figure 3: Radially split multistage-single & double casing.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 8 of 51
		Rev: 03
		May 2012

c) Vertically suspended pump

A pump with the impeller(s) cantilevered vertically and the suction nozzle typically submerged is classified as a vertically suspended pump.

c) Seal-less pump

Seal-less pumps are special pumps which do not require shaft seals. Construction for seal-less pumps is driven by canned motors or magnetic couplings. It is normally used in process involve extremely hazardous fluid, where leakage cannot be tolerated.

d) Submersible pump

Submersible pumps are designed to prevent pump cavitation .The driver components inside are completely surrounded by the pumped fluid.

e) Horizontal self-priming pump

Horizontal self-priming pumps are designed to create a vacuum at the pump inlet. This enables the pump to “suck” fluid into its casing. The suction nozzle of the pump can therefore be located above the level of liquid being pumped.

Centrifugal pumps are used in more industrial applications than any other kind of pump. This is primarily because these pumps offer low initial and upkeep costs. Traditionally these pumps have been limited to low-pressure-head applications, but modern pump designs have overcome this problem unless very high pressures are required.⁽⁴⁾ The single-stage, horizontal, overhung, centrifugal pump is by far the most commonly type used in the chemical process industry. ⁽³⁾

Basically, pump selection is made on the flow rate and head requirement and with other process considerations, such as material of the construction pumps for the corrosive chemical service or for the fluid with presence solids in the stream.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 9 of 51
		Rev: 03
		May 2012

Process Requirements Parameters

In designing the pump, the knowledge of the effect of parameters; such as pump capacity, NPSH, pumping maximum temperature, specific gravity, fluid viscosity, fluid solid content, and the other process requirements are very important. All of these parameters will affect the selection and design of the pump which will affect the performance of the pump in the process.

Pump capacity is a parameter plays an important role when selecting the pump. Capacity means the flow rate with which liquid is moved or pushed by the pump to the desired point in the process. It is commonly measured in either gallons per minute (gal/min) or cubic meters per hour (m³/hr). The capacity usually changes with the changes in operation of the process. A minimum required flow rate need to be specified, this is important to determining if a minimum flow bypass is required for the selected pump to avoid pump overheating and mechanical damage.

NPSH as a measure to prevent liquid vaporization or called cavitation of pump. Net Positive Suction Head (NPSH) is the total head at the suction flange of the pump less the vapor pressure converted to fluid column height of the liquid. The design engineer should always remember that pumps can pump only liquids, not vapors because when a liquid vaporizes its volume increases greatly. For example: 1ft³ of water it will vaporize to produce 1700ft³ of steam. This will cause the rise in temperature and pressure drop in the fluid and pump will stop functioning because it has not sufficient suction pressure present.

Pumping maximum temperatures is important in deciding pump construction style and pump cooling and mechanical seal requirements. The minimum operating temperature is to ensure that the material has adequate impact strength.

Specific gravity is parameter determines the pump head required to produce a desired pressure increase. For pumps with limited head capability such as centrifugal pumps, it affects pressure rise capability. Pump power requirements are also affected by specific gravity.

Viscosity is important in the selection of pump type and has a significant effect on centrifugal pump performance. Minimum values of viscosity are important in determining rotary pump (positive displacement pump) performance, while maximum viscosity is important in determining debits to centrifugal pump performance.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 10 of 51
		Rev: 03
		May 2012

Fluid solid content will affect the pump design. It affected the aspects of the design for the flow characteristic, consideration design of erosion resistance, flow passage size, impeller style, peripheral speed, design features to disintegrate large particles, and shaft sealing design. This parameter has to be added in the data sheet for design.

Other process requirement such as flexibility for expansion should be consider as well. This is important for future capacity expansion; it helps to minimize the cost of expansion because to replace the pump will be a large sum of money. Working capacity of pump should always be design for more than 20% extra design capacity.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 11 of 51
		Rev: 03
		May 2012

DEFINITION

Bearing Housing -The bearing housing encloses the bearings mounted on the shaft. The bearings keep the shaft or rotor in correct alignment with the stationary parts under the action of radial and transverse loads. The bearing house also includes an oil reservoir for lubrication, constant level of oil, jacket for cooling by circulating cooling water.

Capacity - Is the water handling capability of a pump commonly expressed as either gallon per minute (gal/min) or cubic meter per minute (m³/min).

Cavitation - Is the result of vapor bubbles imploding. This occurs when the amount of fluid flowing into the pump is restricted or blocked.

Discharge Port —Point where the discharge hose or pipe is connected to the pump.

Datum Elevation – It use as reference of the horizontal plane for which all the elevations and head are measured. The pumps standards normally specify the datum position relative to a pump part, eg. Centrifugal horizontal pump datum position is at the impeller shaft centerline.

Dynamic Discharge Head- The static discharge head plus the friction in the discharge line also referred to as Total Discharge Head.

Dynamic Suction Head - The static suction lift plus the friction in the suction line also referred to as Total Suction Head.

Endurance limit – Is the stress below which the shaft will withstand an infinite number of stress reversals without failure. Since one stress reversal occurs for each revolution of the shaft, this means that ideally the shaft will never fail if the maximum bending stress in the shaft is less than the endurance limit of the shaft material.

Friction Head-The head required to overcome the resistance to flow in the pipe and fittings. It is dependent upon the size, condition and type of pipe, number and type of pipe fittings, flow rate, and nature of the liquid.

Friction Loss - Refers to reductions in flow due to turbulence as water passes through hoses, pipes, fittings and elbows.

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 12 of 51
		Rev: 03
		May 2012

Impeller — A disk with multiple vanes. It is attached to the pump engine or motor and is used to create the centrifugal force necessary for moving water through the pump casing.

Mechanical Seal — A common wear part that forms a seal between the pump and the engine or motor. Also prevents liquid from seeping into the engine or motor.

Net Positive Suction Head (NPSHa) - Is the total head at the suction flange of the pump less the vapor pressure converted to fluid column height of the liquid

Net Positive Suction Head Required (NPSHr) - NPSH in meters (feet) determined by Supplier testing, usually with water. NPSHR is measured at the suction flange and corrected to the datum elevation. NPSHR is the minimum NPSH at rated capacity required to prevent a head drop of more than 3% (first stage head in multistage pumps) due to cavitation within pump.

Pressure Head - Pressure Head must be considered when a pumping system either begins or terminates in a tank which is under some pressure other than atmospheric. The pressure in such a tank must first be converted to feet of liquid. Denoted as h_p , pressure head refers to absolute pressure on the surface of the liquid reservoir supplying the pump suction, converted to feet of head. If the system is open, h_p equals atmospheric pressure head.

Static Suction Head -Head resulting from elevation of the liquid relative to the pump center line (datum). If the liquid level is above pump centerline (datum), h_s is positive. If the liquid level is below pump centerline (datum), h_s is negative. Negative h_s condition is commonly denoted as a “suction lift” condition

Static Discharge Head - It is the vertical distance in feet between the pump centerline and the point of free discharge or the surface of the liquid in the discharge tank.

Suction Port — Point where the suction hose or pipe is connected to the pump.

Vapor Pressure Head - Vapor pressure is the absolute pressure at which a liquid and its vapor co-exist in equilibrium at a given temperature. The vapor pressure of liquid can be obtained from vapor pressure tables. When the vapor pressure is converted to head, it is referred to as vapor pressure head, h_{vp} . The value of h_{vp} of a liquid increases with the rising temperature and in effect, opposes the pressure on the liquid surface, the positive force that tends to cause liquid flow into the pump suction i.e. it

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 13 of 51
		Rev: 03
		May 2012

reduces the suction pressure head. (Vapor pressure can be said as the external pressure require to prevent fluid from evaporate become vapor).

Velocity Head - Refers to the energy of a liquid as a result of its motion at some velocity 'v'. It is the equivalent head in feet through which the water would have to fall to acquire the same velocity, or in other words, the head necessary to accelerate the water. The velocity head is usually insignificant and can be ignored in most high head systems. However, it can be a large factor and must be considered in low head systems.

Viscosity — is a mechanist of fluid resistance to flow of a liquid at a given temperature. High viscosity liquids such as motor oil are more resistant to flow than water.

$$\text{Kinematics Viscosity (cSt)} = \frac{\text{Absolute Viscosity (cP)}}{\text{Specific Gravity}}$$

Volute — A stationary housing inside the pump housing in which the impeller rotates. It is used to separate air and water.

Total Head - Pressure required in feet (meter) of head that the pump must produce. The head at the discharge pump flange minus the head at suction flange.

NOMENCLATURE

C	Constant for pump geometry
D	Diameter of impeller, in
g	Acceleration due to gravity, 32.2 ft/s ² (9.81 m/s ²)
H _c	Total head developed from centrifugal pump, ft
H _d	Discharge head, ft (m)
H _s	Suction head, ft (m)
H _t	Total head, ft (m)
h _a	Acceleration for the reciprocating pump only for calculate the head losses due to pulsation in the flow, ft (m)
h _f	Head produce from pressure loss in pipe, fitting, and entrancement, ft (m)
h _{f(d)}	Head produce from pressure loss in pipe, fitting, and entrancement with depend the pipe diameter and type of flow from discharge to destination, ft (m)

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KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	SECTION : Pump Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Page 14 of 51
		Rev: 03
		May 2012

$h_{f(s)}$	Head produce from pressure loss in pipe, fitting, and entrancement with depend the pipe diameter and type of flow at suction section, ft (m)
h_p	Absolute pressure head on surface of liquid, ft (m)
$h_{p(d)}$	Gauge pressure head on surface of liquid at destination, ft (m)
$h_{p(s)}$	Gauge pressure head on surface of liquid at suction point, ft (m)
h_{st}	Head from the elevation between distance from suction surface to pump centerline, ft (m)
$h_{st(d)}$	Head from the elevation between distance from destination surface to pump centerline, ft (m)
$h_{st(s)}$	Head from the elevation between distance from suction surface to pump centerline, ft (m)
h_{vp}	Vapor pressure of the liquid converted, ft (m)
K	A factor representing the relative compressibility of the liquid
L	Length of the suction line from the nearest upstream vessel (or suction stabilizer) to the pump, (ft or m)
n	Impeller RPM (Revolutions per minute)
P	Pressure in system, psi (kg/cm ²)
Q	Capacity, gal/min (m ³ /min)
Q_1	Capacity, (m ³ /s)
r	Radius of shaft (rad)
S	Specific gravity
T_r	Shaft Torque (Nm)
V	Average velocity in the suction line, ft/s (m/s)
v	Velocity of periphery of impeller (tip speed), ft/s (m/s)

Greek letters

η_p	Pump efficiency, %
ρ	Fluid density, lb/ft ³ (kg/m ³)
π	pi (3.142)
ω	Shaft angular velocity (rad/s)

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