# Pumps And Piping



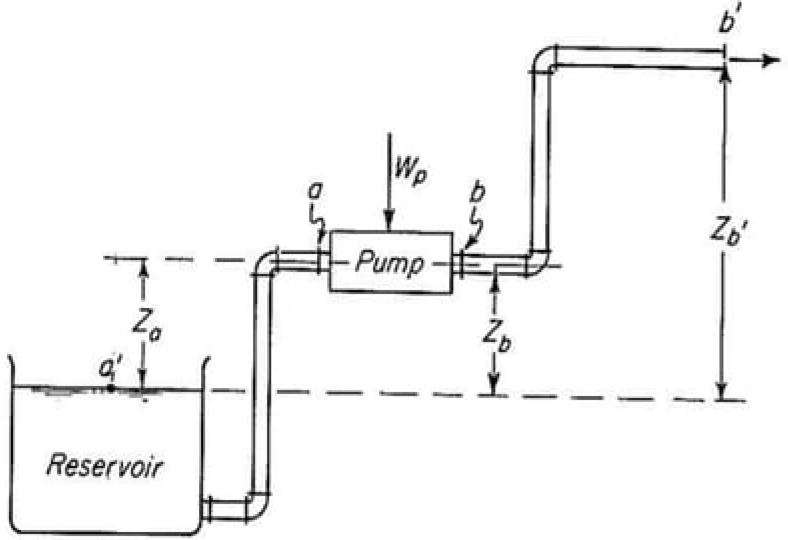
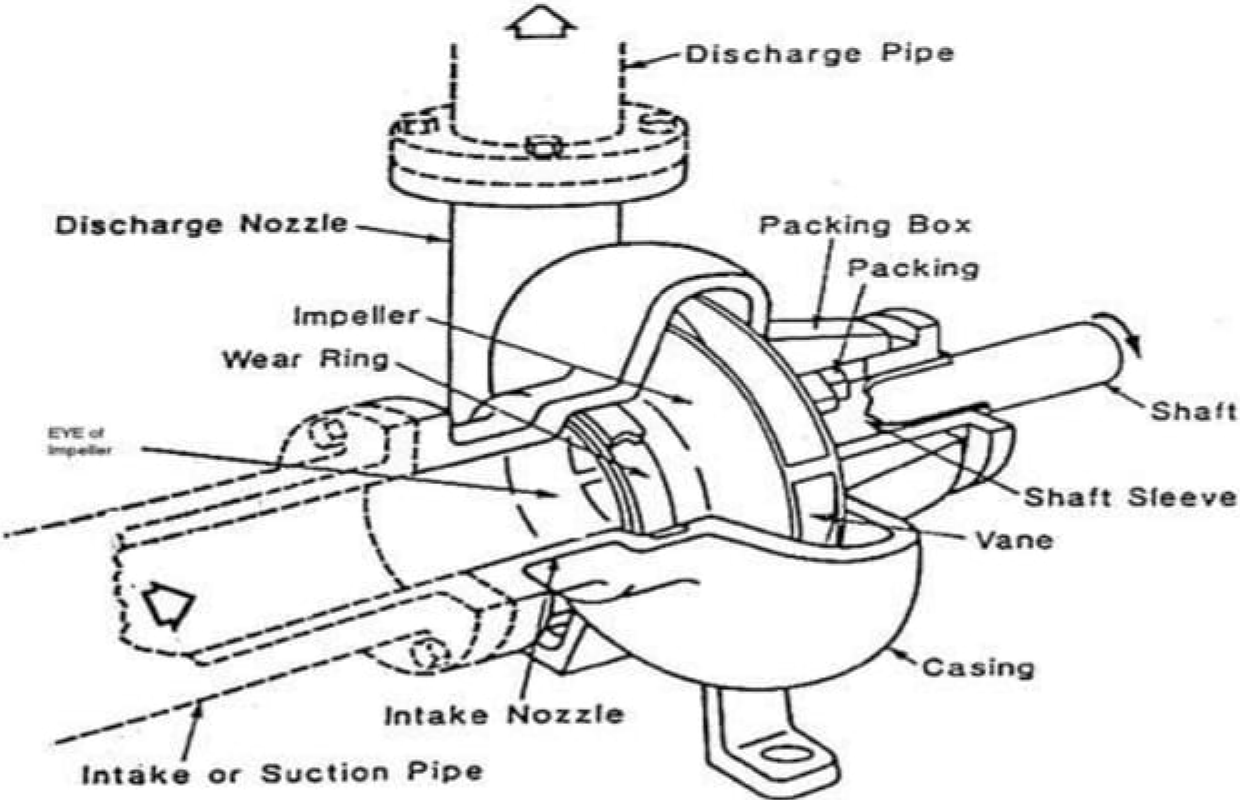
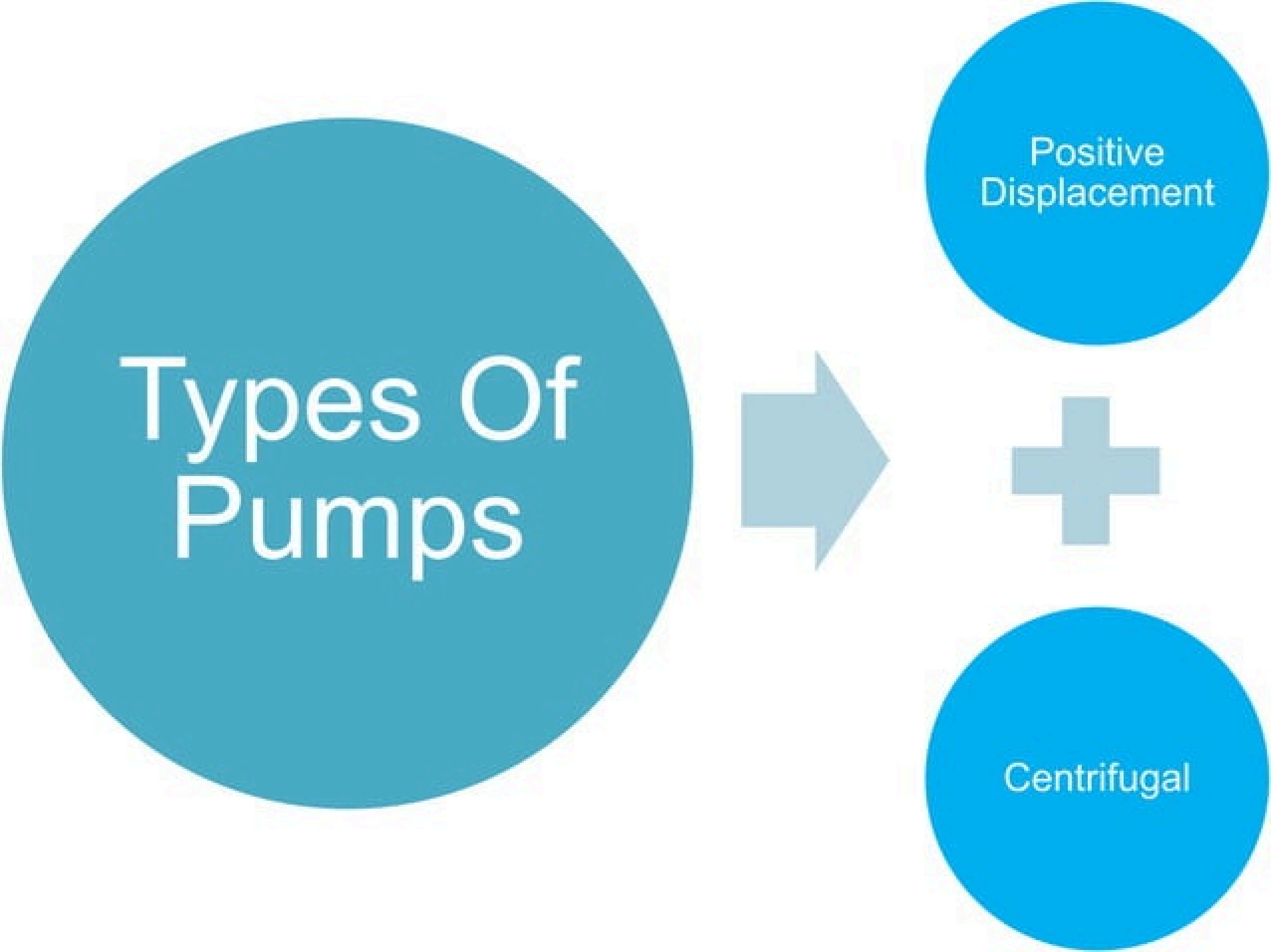


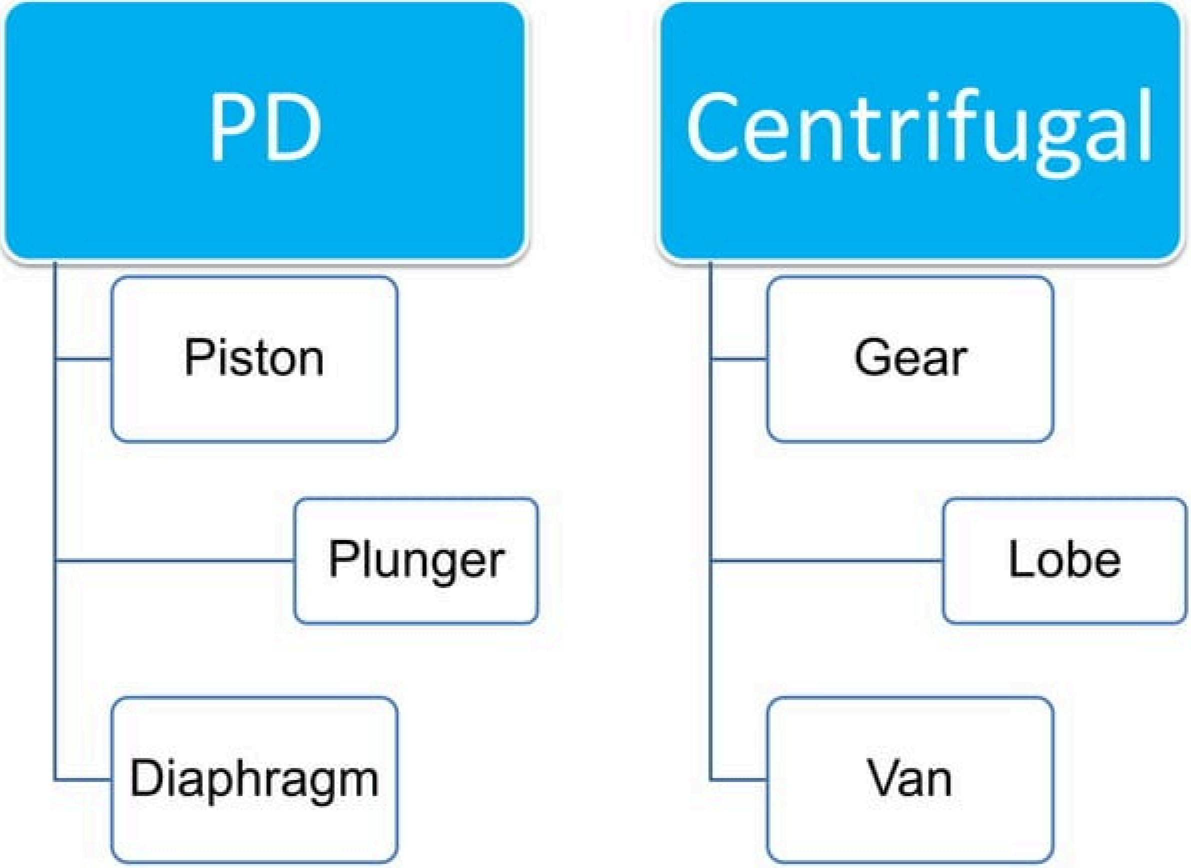

**FIGURE 8.5**
Pump flow system.

- PUMPS

# A Centrifugal Pump




Types Of Pumps
Positive Displacement
Centrifugal


PD
Piston
Plunger
Diaphragm
Centrifugal
Gear
Lobe
Van

# P.D Pumps

**Piston pump**

- Apply direct pressure to liquid by reciprocating piston
- Contain stationary piston or plunger to displace liquid
  - Piston pump
  - Plunger pump
  - Diaphragm pump

# Centrifugal Pumps

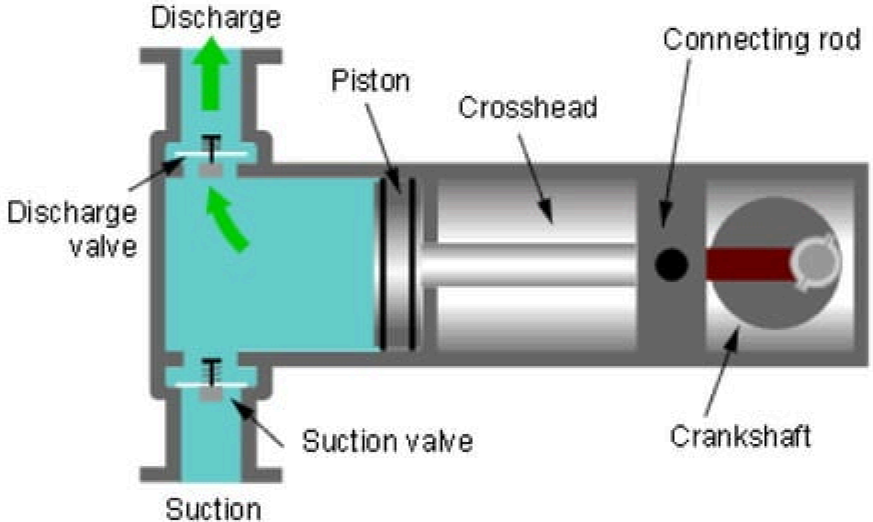
**Rotary pumps**

- The chamber movies from inlet to discharge and back to the inlet
  - Gear pumps
  - Lobe pump
  - Van pump

# Positive Displacement Pump

## Piston Pump

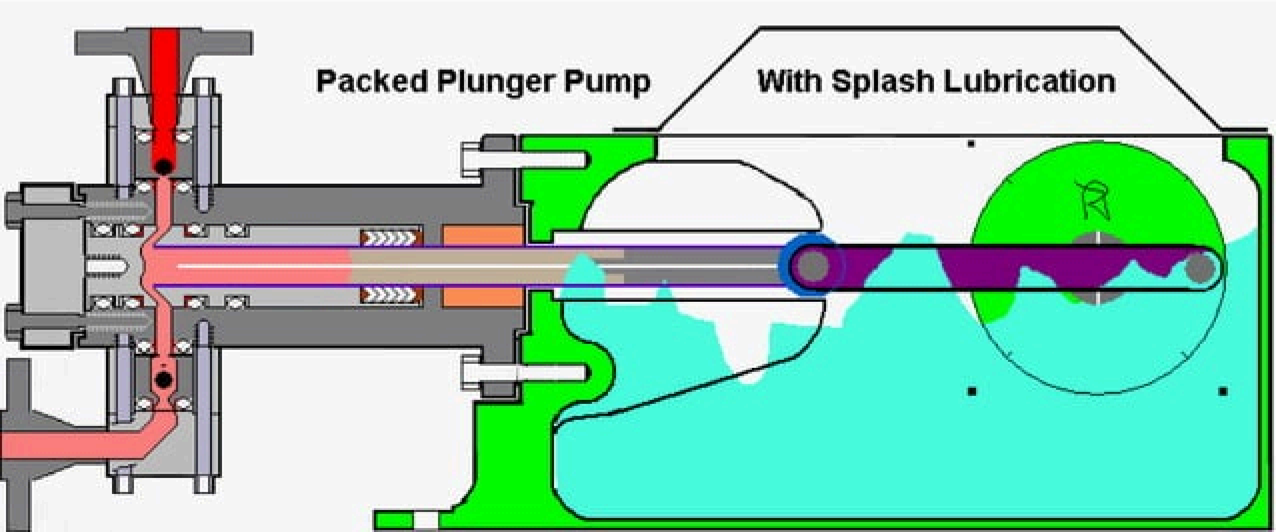
- Discharge pressure up to 50 atm…
- It's application is areas where high pressure is required… it is not necessary that every P.D pump be of 50 atm…



# Positive Displacement Pump

## Plunger Pump

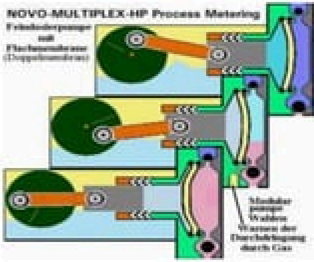
- Used to produce 1500 atm or more…
- Usually motor driven and single acting…

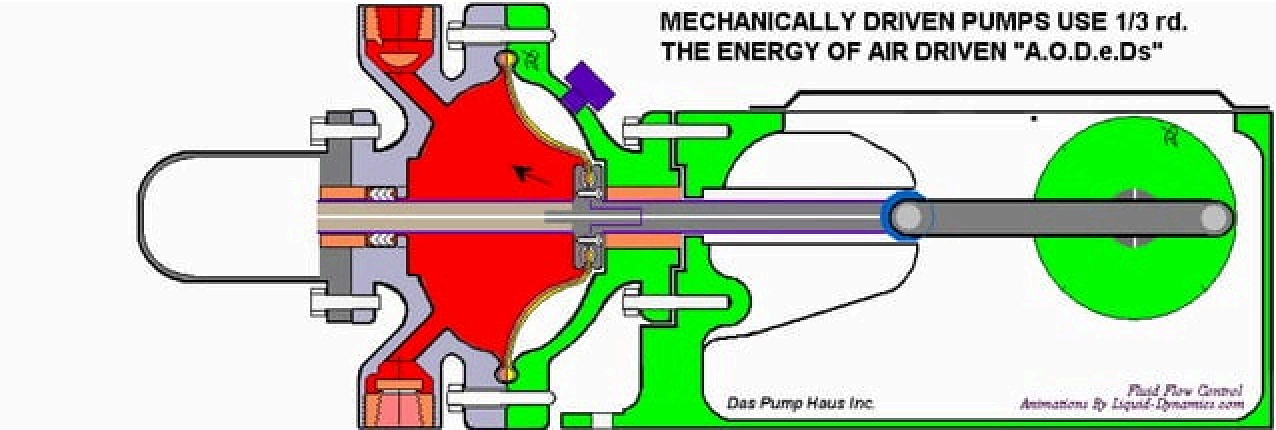


# Positive Displacement Pump

## Plunger Pump

- Used to produce 100 atm. These are employed for corrosive liquid handling… Used for corrosive/toxic liquids…



- **Efficiency For P.D Pumps**

- For small pumps: 40 to 50 %...
- For large pumps: 70 to 90%...
- Efficiency independent of speed under normal conditions.
- Decrease slightly with a increase suction pressure.

- **Volume efficiency**

The ratio of the volume of fluid discharge to the volume swept by the piston or plunger is called *volumetric efficiency*...

Effect Of Leakages On Volumetric Efficiency

Volumetric efficiency is nearly constant with pressure but slightly decrease due to leakages.

What Are Metering Pumps

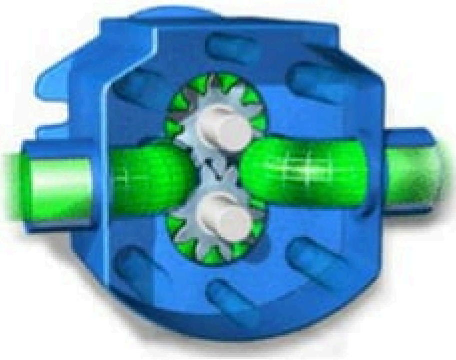
Plunger and diaphragm pumps are "metering pumps" and can provide a constant volumetric rate (adjustable) to the process system.

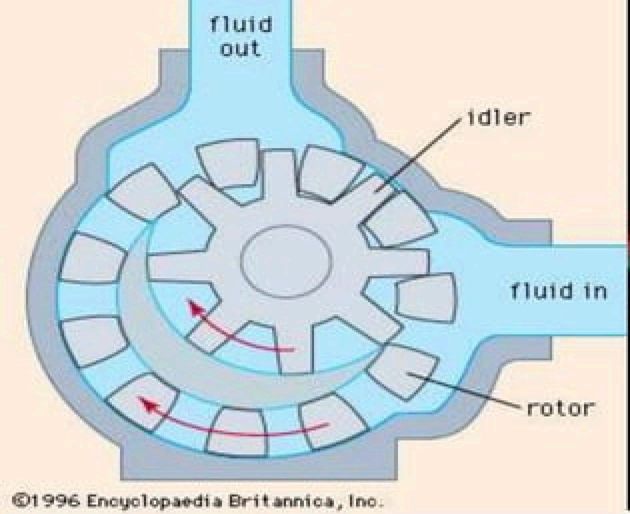
# Rotary Pumps

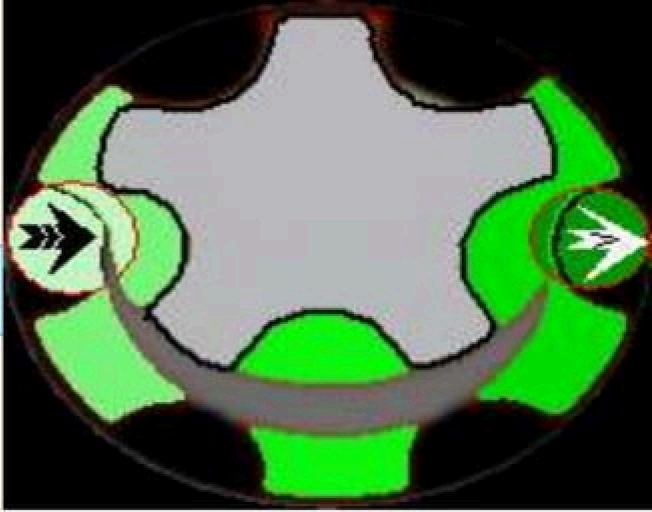
## The chamber movies from inlet to discharge and back to the inlet…

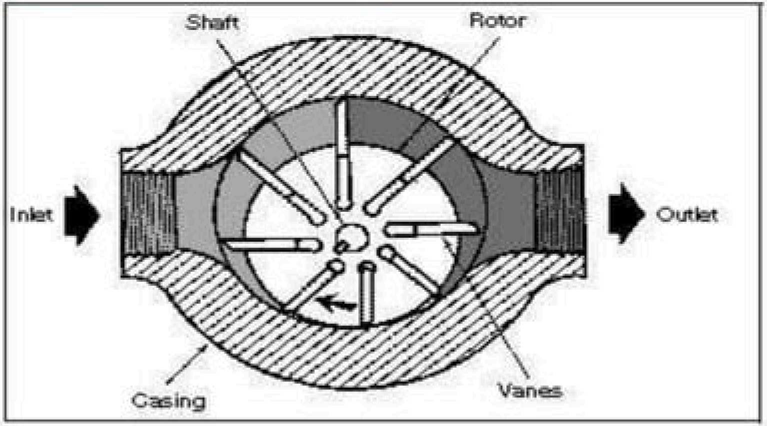
## Gear Pump

- Minimize leakage due to close tolerance between moving and stationary parts…
- Liquid must be clean, moderately viscous fluids i.e. light lubricating oil…




fluid out
idler
fluid in
rotor
©1996 Encyclopaedia Britannica, Inc.

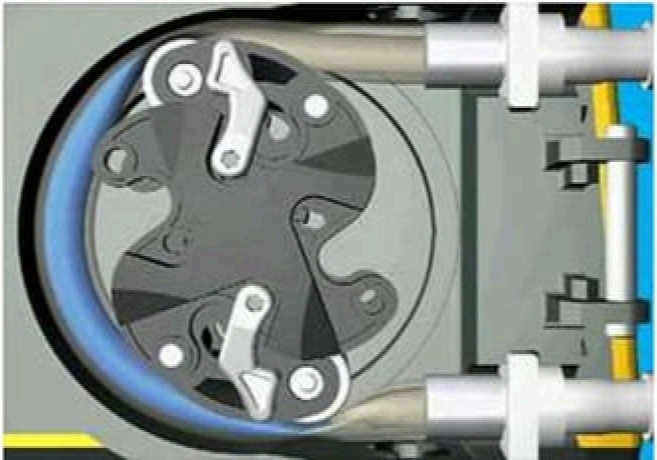



Shaft
Rotor
Inlet
Outlet
Casing
Vanes

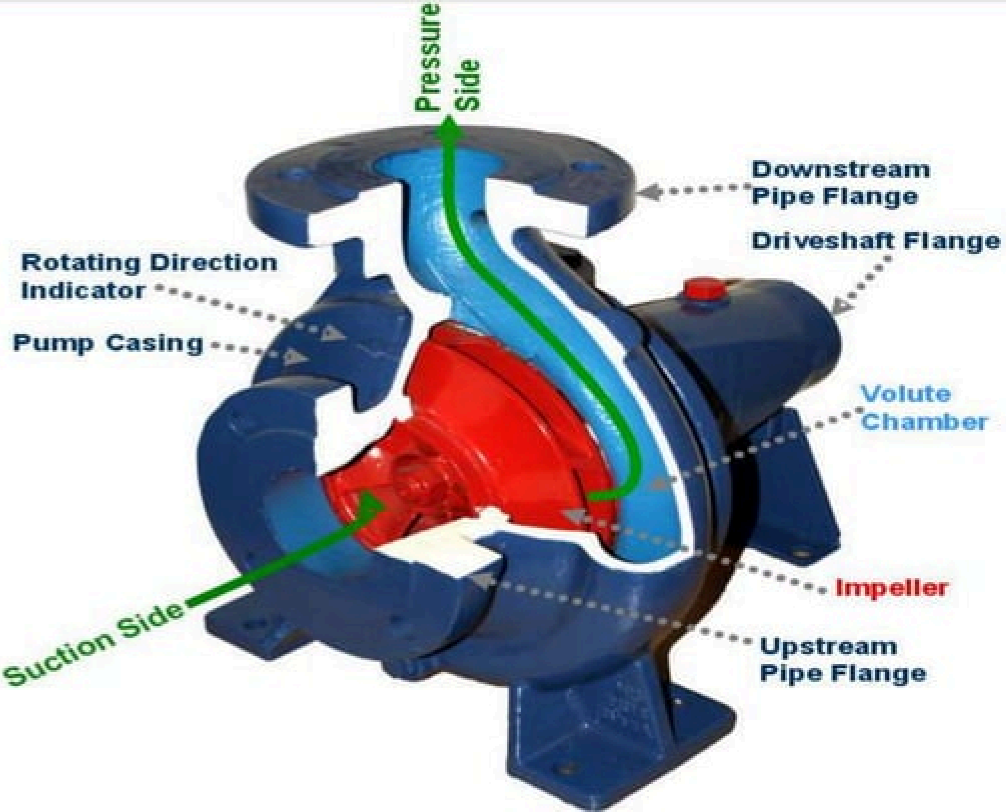
# Rotary Pumps

## Peristaltic

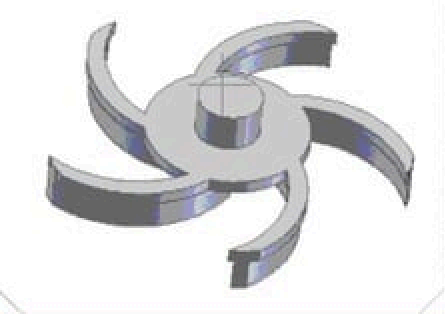
- Use for small flow rates and constant flow rates…
- No air leakage or possibility to air (leak proof)…
- **Application**
- Production of biomedical, pharmaceuticals etc…

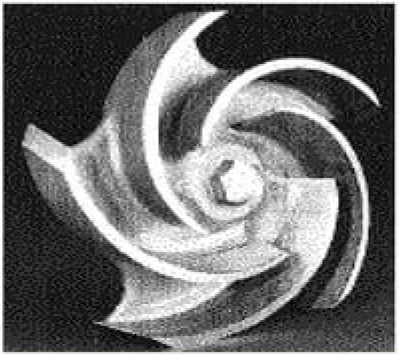


# A Centrifugal Pump



# Impellers



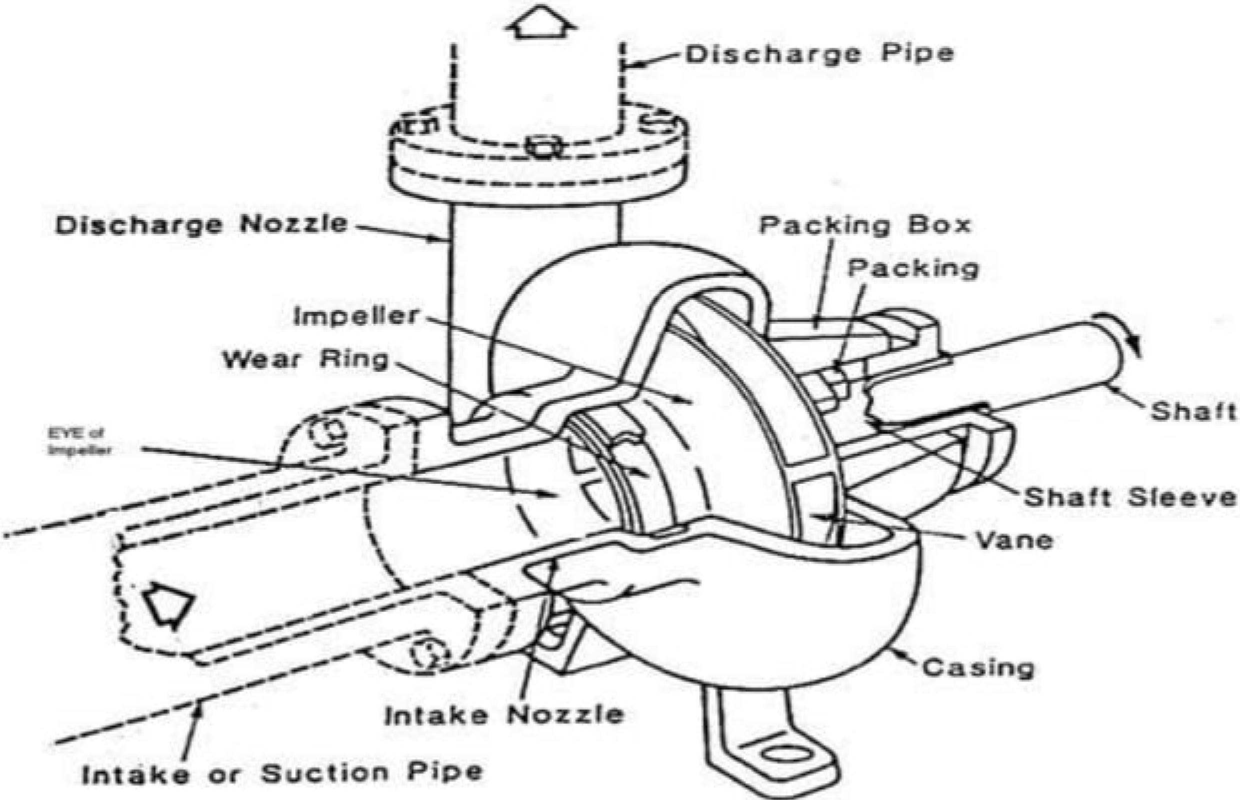


Open Impeller Semi Open Closed

# Impellers

## Closed Impellers

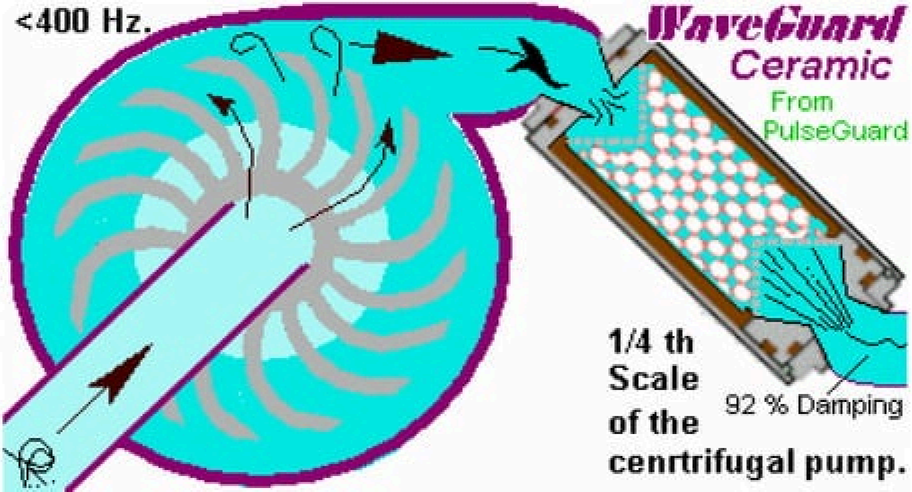
# A Centrifugal Pump



# Rotary Pumps

## Centrifugal

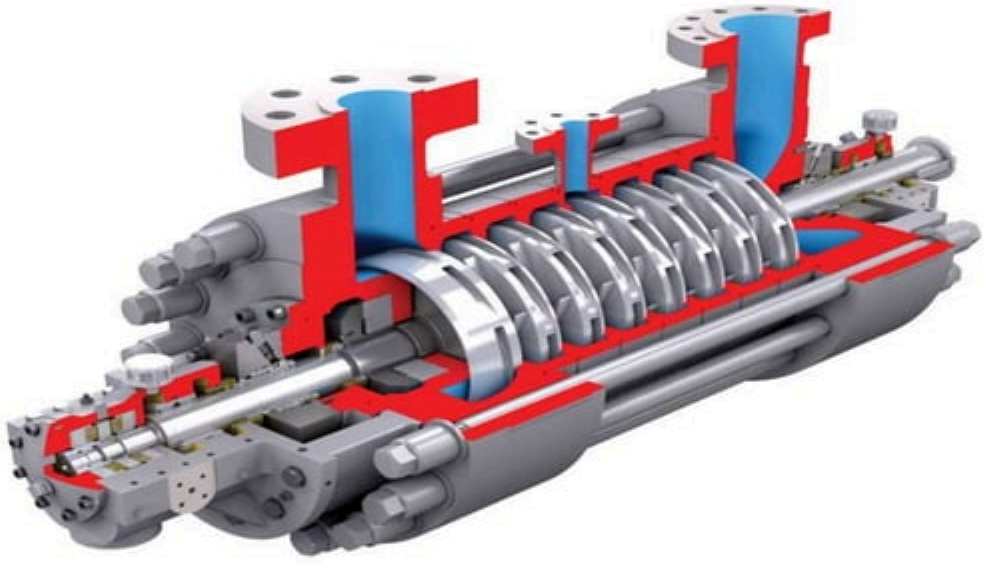
- Increase of mechanical energy, pressure by centrifugal force…
- Most commonly used in the industry…
- The impellers are curved backward…



# Rotary Pumps

## Multi Stage Centrifugal Pumps

- High energy centrifugal can generate a head of 200 m only.
- To increase the head (>200 m), multistage centrifugal pumps is used where multiple impeller is installed on a single shaft.



# Rotary Pumps

## Leak Proof Centrifugal Pumps

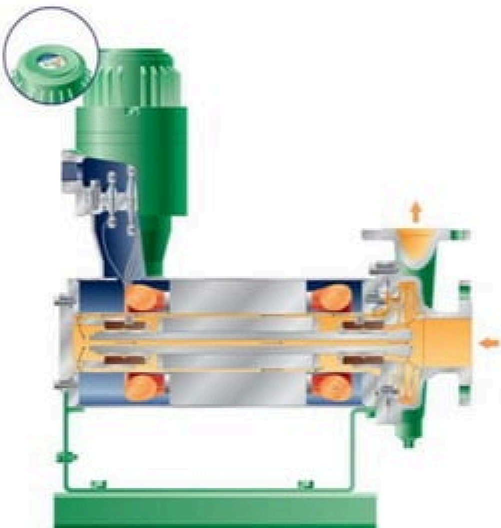
(Two types use which doesn't contain any seals or stuffing boxes)

1) Canned-rotor pumps

A canned like stainless steel structure cover the rotor which keep the pumped fluid away from the rotor.

2) Magnetic-derive pump

Impeller carries magnetic is driven by the magnetic disk on the other side of casing walls…



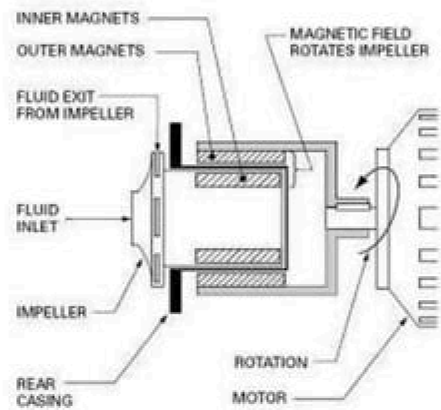



FIGURE 2: PUMP MAGNETIC DRIVE

# Pump Priming

- **What is it?**
- To remove the entrapped air inside the pump is called pump priming
- When we do it?

1. First start up after a long time
2. First start up after maintenance
3. First start up for a new pump

- **How we do it?**
- If there is any air entrapped  in the suction line, we need to replace this air with liquid.
- Air can be displaced by liquid from any tank into the suction line and submerge the pump impeller…

**Positive displacement pump can compress the gas to a required discharge pressure, that’s why they are known to self priming…**

# Pump Priming

Priming of a pump is very essential step in start up of a centrifugal pump.

Fact is that centrifugal pump are not capable of pumping air or vapors.

Priming is the process in which the impeller of a centrifugal pump will get fully sub merged in liquid without any air trap inside. This is especially required when there is a first start up. But it is advisable to start the pump only after primping.

Liquid and slurry pumps can lose prime and this will require the pump to be primed by adding liquid to the pump and inlet pipes to get the pump started. Loss of "prime" is usually due to ingestion of air into the pump. The clearances and displacement ratios in pumps used for liquids and other more viscous fluids cannot displace the air due to its lower density.

# Pump Safety

A note about centrifugal pump is that it doesn't require a safety valve while a P.D pump must have a safety valve because at certain pressure C.F pump will stop producing any further pressure while the P.D pump will continue to increase pressure with every stroke until or unless the safety valve blows or the discharge is opened…

## Turbulence

Turbulence may be generated in other ways than by flowing fluid in a pipe… in general however it results from either of these scenarios, one is the flowing fluid gets In contact with a solid boundary called as the wall turbulence or two fluid layers moving with varying velocities contact called as the free turbulence… Free turbulence is especially important in mixing…

# Characteristic Curves

- The performance of a given pump is commonly illustrated by plots of actual head, power consumption, and efficiency versus volumetric flow rate. These plots are called characteristic curves.
- ΔH is head capacity
- P is power of the pump
- Ƞ is the pump efficiency

**Pump efficiency**
Ratio of fluid power to the total power consumed by the pump…

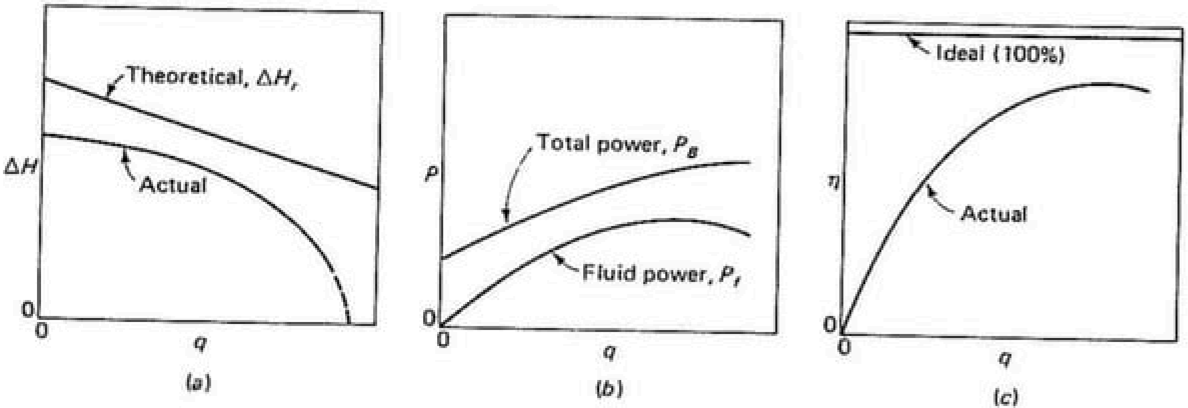



**FIGURE 8.12**
Characteristic curves of a centrifugal pump: (*a*) head capacity; (*b*) power; (*c*) efficiency.

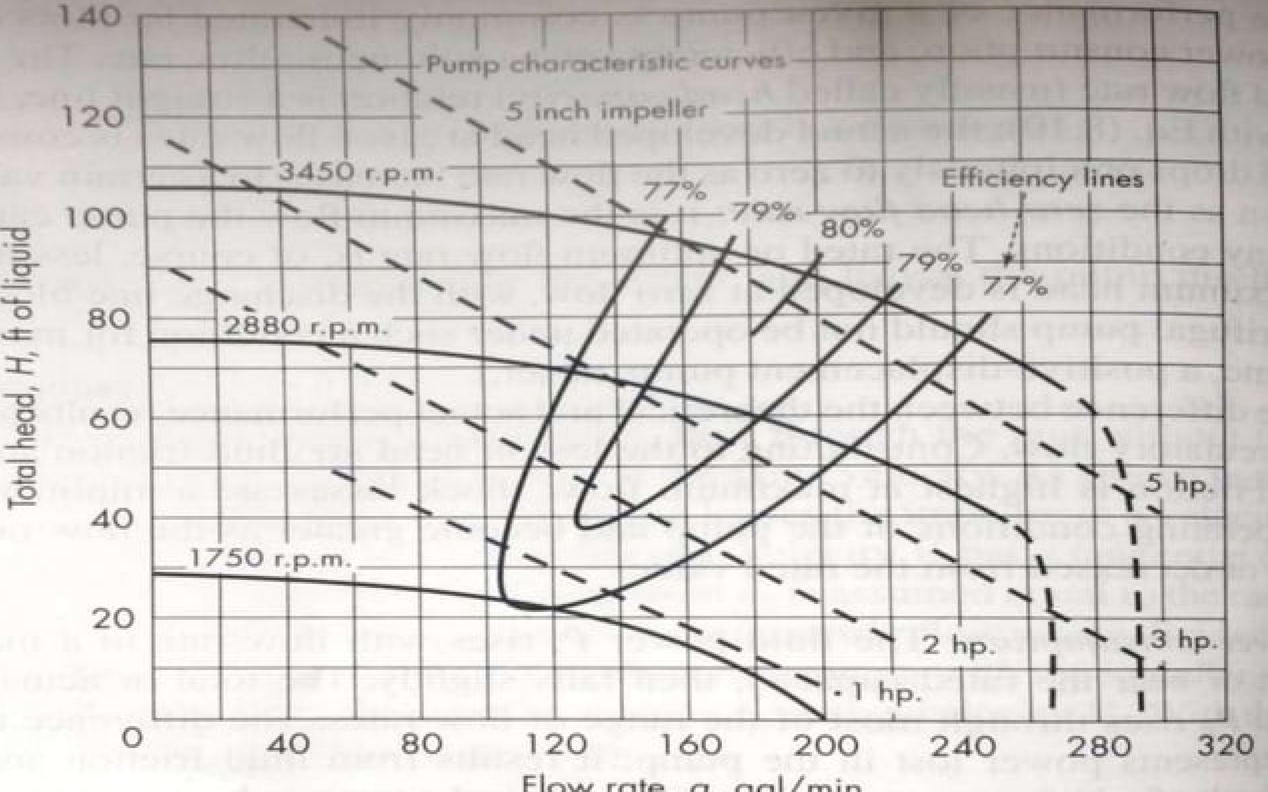
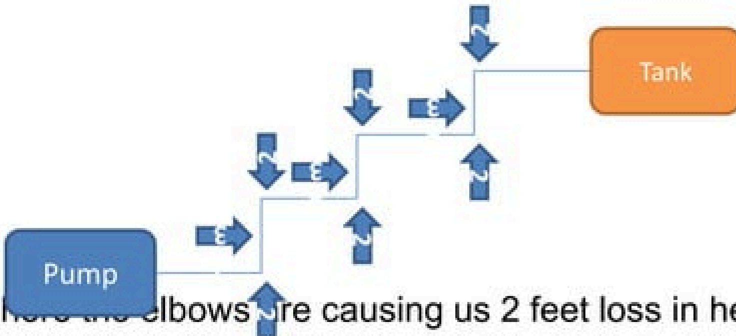



**FIGURE 8.10**
Characteristic curves of a centrifugal pump operating at various speeds. (*By permission from Perry's Chemical Engineers' Handbook,*

- **Pump Head**
- From an industrial point of view pump head is very important, for every elbow/bend in pipe you have to add in a certain no. of head usually in feet in order to accommodate the losses… i.e. 1elbow=2feet then you'd have to add in 2 feet for every time that elbow appears in the piping…

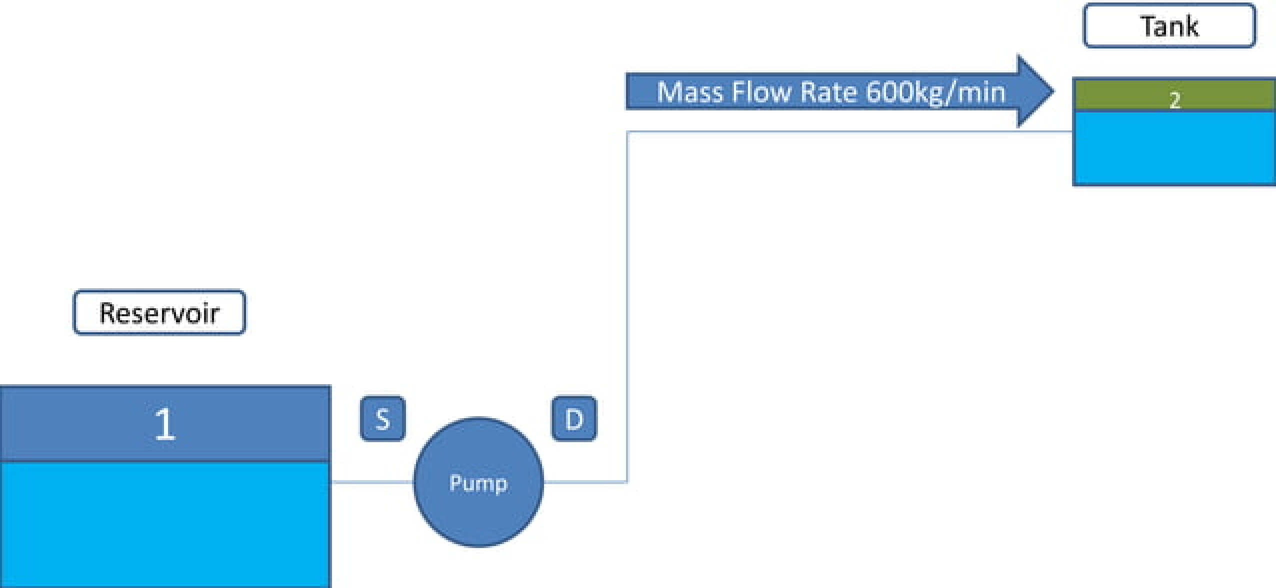



- So, you can see here the elbows are causing us 2 feet loss in head every time they appear so we have to add that in order to compensate the losses… We also have 3 ft. loss in head due to the vertical piping, we don't count in horizontal piping…
- **So, Total Head = 9ft. + 12ft. + some excess feet to be safe...**

- **Cavitations And NPSH**
- If the suction pressure is only slightly greater than the vapor pressure some liquid may flash to vapor inside the pump a process called as cavitations which greatly reduces the pump capacity and causes severe erosion. If the suction pressure is actually less than the vapor pressure there will be vaporization in the suction line and no liquid can be drawn into the pump.
- To avoid the cavitations the pressure at pump inlet must exceed the vapor pressure by a certain value called as the net positive suction head. The required value of NPSH is about 2 to 3 m (5 to 10 ft) for small centrifugal pumps but It increases to 15m (50 ft) are recommended for larger pumps.

# • How To Choose A Pump

- Usually we choose a pump on the basis of it's head which is basically a generic term for all the force that a pump can muster up whether it in the form of fluid velocity, pressure or something alike… let us draw a diagram…



- So, for very basic calculations we only need to know the flow rate (gal/min or m^3/ min) and the friction caused by the pipe from a table, add them up and you're good to go… basically equation would be…

$$P_D\text{-}P_S/⍰(\text{Head}) = \text{height}(2\text{-}1) + \text{Friction Losses}(2\text{-}1)$$

- This equation has two main things that need to be calculated…

1. Height from point 1 to point 2, in our case it is 22ft…
2. You also need to account for the head you're going to be losing because of the friction and you need to accommodate that, you can calculate the lost head due to friction by the use of tables, here you need to know the nominal diameter of your pipe and flow rate in gal/min…… Now all you have to do is add them up…

$$P_D\text{-}P_S/⍰(\text{Head}) = 22\text{ft} + 1.88987\text{ft} = 23.88987\text{ft}$$

- Also you ought to add a factor of 15-20 % for a commercial design to the values of the table...
- So that makes this 23.88987ft…

- PIPING

- **Piping And Fittings**

| Piping | Tubing |
| --- | --- |
| Heavy walled, relatively large diameter in diameter and comes in moderate lengths of 20-40 ft… | Thin walled and often comes in coils several hundred feet long… |
| Rough Walls | Smoother Walls |
| Joined by screwed, flanged or welded fittings… | Compression, flare or solder fittings… |
| Made by welding, welding or piercing a billet In a piecing mill… | Made by extrusion or cold drawing… |

# Schedule Number

(Schedule number refers to  the wall thickness of the pipe)


So, this pipe with large dia. Will have greater thickness at same schedule no. and will sustain pressure equivalent to small one...

# Measurement

- Pipes and tubing are specified in terms of their diameter and their wall thickness… Iron pipe size (IPS) or Normal pipe size (NPS)…
- The designation "2 inch nickel IPS pipe" means nickel pipe having the same outside diameter as standard 2 inch pipe…

| Piping | Tubing |
|---|---|
| Nominal diameters | Sizing indicated by outside diameter… |
| **1/8 till 30 inches**<br>**>12 inches nominal diameter = actual diameter** | **The normal value is the actual outer diameter, to within very close tolerances…** |
| Wall thickness | Wall thickness |
| **Schedule numbers 10,20,30,40,60,80,120,140,160 are in use…**<br>**But for <8 inches 40,80,120,160 are common…** | **Wall thickness is given by the BWG (Birmingham Wire Gauge) number ranging from 24 (very light) to 7(very heavy)…** |

| Outside diameter, in. | Wall thickness BWG no. | Wall thickness in. | Inside diameter, in. | Cross-sectional area metal, in.$^2$ | Inside sectional area, ft$^2$ | Circumference, ft or surface, ft$^2$/ft of length Outside | Circumference, ft or surface, ft$^2$/ft of length Inside | Velocity, ft/s for 1 U.S. gal/min | Capacity at 1 ft/s velocity U.S. gal/min | Capacity at 1 ft/s velocity Water, lb/h | Weight, lb/ft‡ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\frac{5}{8}$ | 12 | 0.109 | 0.407 | 0.177 | 0.000903 | 0.1636 | 0.1066 | 2.468 | 0.4053 | 202.7 | 0.602 |
| | 14 | 0.083 | 0.459 | 0.141 | 0.00115 | 0.1636 | 0.1202 | 1.938 | 0.5161 | 258.1 | 0.479 |
| | 16 | 0.065 | 0.495 | 0.114 | 0.00134 | 0.1636 | 0.1296 | 1.663 | 0.6014 | 300.7 | 0.388 |
| | 18 | 0.049 | 0.527 | 0.089 | 0.00151 | 0.1636 | 0.1380 | 1.476 | 0.6777 | 338.9 | 0.303 |
| $\frac{3}{4}$ | 12 | 0.109 | 0.532 | 0.220 | 0.00154 | 0.1963 | 0.1393 | 1.447 | 0.6912 | 345.6 | 0.748 |
| | 14 | 0.083 | 0.584 | 0.174 | 0.00186 | 0.1963 | 0.1529 | 1.198 | 0.8348 | 417.4 | 0.592 |
| | 16 | 0.065 | 0.620 | 0.140 | 0.00210 | 0.1963 | 0.1623 | 1.061 | 0.9425 | 471.3 | 0.476 |
| | 18 | 0.049 | 0.652 | 0.108 | 0.00232 | 0.1963 | 0.1707 | 0.962 | 1.041 | 520.5 | 0.367 |
| $\frac{7}{8}$ | 12 | 0.109 | 0.657 | 0.262 | 0.00235 | 0.2291 | 0.1720 | 0.948 | 1.055 | 527.5 | 0.891 |
| | 14 | 0.083 | 0.709 | 0.207 | 0.00274 | 0.2291 | 0.1856 | 0.813 | 1.230 | 615.0 | 0.704 |
| | 16 | 0.065 | 0.745 | 0.165 | 0.00303 | 0.2291 | 0.1950 | 0.735 | 1.350 | 680.0 | 0.561 |
| | 18 | 0.049 | 0.777 | 0.127 | 0.00329 | 0.2291 | 0.2034 | 0.678 | 1.477 | 738.5 | 0.432 |
| 1 | 10 | 0.134 | 0.732 | 0.364 | 0.00292 | 0.2618 | 0.1916 | 0.763 | 1.310 | 655.0 | 1.237 |
| | 12 | 0.109 | 0.782 | 0.305 | 0.00334 | 0.2618 | 0.2047 | 0.667 | 1.499 | 750.0 | 1.037 |
| | 14 | 0.083 | 0.834 | 0.239 | 0.00379 | 0.2618 | 0.2183 | 0.588 | 1.701 | 850.5 | 0.813 |
| | 16 | 0.065 | 0.870 | 0.191 | 0.00413 | 0.2618 | 0.2278 | 0.538 | 1.854 | 927.0 | 0.649 |
| $1\frac{1}{4}$ | 10 | 0.134 | 0.982 | 0.470 | 0.00526 | 0.3272 | 0.2571 | 0.424 | 2.361 | 1,181 | 1.598 |
| | 12 | 0.109 | 1.032 | 0.391 | 0.00581 | 0.3272 | 0.2702 | 0.384 | 2.608 | 1,304 | 1.329 |
| | 14 | 0.083 | 1.084 | 0.304 | 0.00641 | 0.3272 | 0.2838 | 0.348 | 2.877 | 1,439 | 1.033 |
| | 16 | 0.065 | 1.120 | 0.242 | 0.00684 | 0.3272 | 0.2932 | 0.326 | 3.070 | 1,535 | 0.823 |
| $1\frac{1}{2}$ | 10 | 0.134 | 1.232 | 0.575 | 0.00828 | 0.3927 | 0.3225 | 0.269 | 3.716 | 1,858 | 1.955 |
| | 12 | 0.109 | 1.282 | 0.476 | 0.00896 | 0.3927 | 0.3356 | 0.249 | 4.021 | 2,011 | 1.618 |
| | 14 | 0.083 | 1.334 | 0.370 | 0.00971 | 0.3927 | 0.3492 | 0.229 | 4.358 | 2,176 | 1.258 |
| 2 | 10 | 0.134 | 1.732 | 0.7855 | 0.0164 | 0.5236 | 0.4534 | 0.136 | 7.360 | 3,680 | 2.68 |
| | 12 | 0.109 | 1.782 | 0.6475 | 0.0173 | 0.5236 | 0.4665 | 0.129 | 7.764 | 3,882 | 2.22 |

† Condensed, by permission, from J. H. Perry (ed.), *Chemical Engineers' Handbook*, 5th ed., p. 11-12. Copyright © 1973, McGraw-Hill Book Company, New York.

‡ For steel; for copper, multiply by 1.14; for brass, multiply by 1.06.

| Nominal pipe size, in. | Outside diameter, in. | Schedule no. | Wall thickness, in. | Inside diameter, in. | Cross-sectional area of metal, in.$^2$ | Inside sectional area, ft$^2$ | Circumference, ft or surface, ft$^2$/ft of length: Outside | Circumference, ft or surface, ft$^2$/ft of length: Inside | Capacity at 1 ft/s velocity: U.S. gal/min | Capacity at 1 ft/s velocity: Water, lb/h | Pipe weight lb/ft |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/8 | 0.405 | 40 | 0.068 | 0.269 | 0.072 | 0.00040 | 0.106 | 0.0705 | 0.179 | 89.5 | 0.24 |
| | | 80 | 0.095 | 0.215 | 0.093 | 0.00025 | 0.106 | 0.0563 | 0.113 | 56.5 | 0.31 |
| 1/4 | 0.540 | 40 | 0.088 | 0.364 | 0.125 | 0.00072 | 0.141 | 0.095 | 0.323 | 161.5 | 0.42 |
| | | 80 | 0.119 | 0.302 | 0.157 | 0.00050 | 0.141 | 0.079 | 0.224 | 112.0 | 0.54 |
| 3/8 | 0.675 | 40 | 0.091 | 0.493 | 0.167 | 0.00133 | 0.177 | 0.129 | 0.596 | 298.0 | 0.57 |
| | | 80 | 0.126 | 0.423 | 0.217 | 0.00098 | 0.177 | 0.111 | 0.440 | 220.0 | 0.74 |
| 1/2 | 0.840 | 40 | 0.109 | 0.622 | 0.250 | 0.00211 | 0.220 | 0.163 | 0.945 | 472.0 | 0.85 |
| | | 80 | 0.147 | 0.546 | 0.320 | 0.00163 | 0.220 | 0.143 | 0.730 | 365.0 | 1.09 |
| 3/4 | 1.050 | 40 | 0.113 | 0.824 | 0.333 | 0.00371 | 0.275 | 0.216 | 1.665 | 832.5 | 1.13 |
| | | 80 | 0.154 | 0.742 | 0.433 | 0.00300 | 0.275 | 0.194 | 1.345 | 672.5 | 1.47 |
| 1 | 1.315 | 40 | 0.133 | 1.049 | 0.494 | 0.00600 | 0.344 | 0.275 | 2.690 | 1,345 | 1.68 |
| | | 80 | 0.179 | 0.957 | 0.639 | 0.00499 | 0.344 | 0.250 | 2.240 | 1,120 | 2.17 |
| 1 1/4 | 1.660 | 40 | 0.140 | 1.380 | 0.668 | 0.01040 | 0.435 | 0.361 | 4.57 | 2,285 | 2.27 |
| | | 80 | 0.191 | 1.278 | 0.881 | 0.00891 | 0.435 | 0.335 | 3.99 | 1,995 | 3.00 |
| 1 1/2 | 1.900 | 40 | 0.145 | 1.610 | 0.800 | 0.01414 | 0.497 | 0.421 | 6.34 | 3,170 | 2.72 |
| | | 80 | 0.200 | 1.500 | 1.069 | 0.01225 | 0.497 | 0.393 | 5.49 | 2,745 | 3.63 |

| Nominal pipe size, in. | Outside diameter, in. | Schedule no. | Wall thickness, in. | Inside diameter, in. | Cross-sectional area of metal, in.$^2$ | Inside sectional area, ft$^2$ | Circumference, ft or surface, ft$^2$/ft of length: Outside | Circumference, ft or surface, ft$^2$/ft of length: Inside | Capacity at 1 ft/s velocity: U.S. gal/min | Capacity at 1 ft/s velocity: Water, lb/h | Pipe weight lb/ft |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2.375 | 40 | 0.154 | 2.067 | 1.075 | 0.02330 | 0.622 | 0.541 | 10.45 | 5,225 | 3.65 |
| | | 80 | 0.218 | 1.939 | 1.477 | 0.02050 | 0.622 | 0.508 | 9.20 | 4,600 | 5.02 |
| 2 1/2 | 2.875 | 40 | 0.203 | 2.469 | 1.704 | 0.03322 | 0.753 | 0.647 | 14.92 | 7,460 | 5.79 |
| | | 80 | 0.276 | 2.323 | 2.254 | 0.02942 | 0.753 | 0.608 | 13.20 | 6,600 | 7.66 |
| 3 | 3.500 | 40 | 0.216 | 3.068 | 2.228 | 0.05130 | 0.916 | 0.803 | 23.00 | 11,500 | 7.58 |
| | | 80 | 0.300 | 2.900 | 3.016 | 0.04587 | 0.916 | 0.759 | 20.55 | 10,275 | 10.25 |
| 3 1/2 | 4.000 | 40 | 0.226 | 3.548 | 2.680 | 0.06870 | 1.047 | 0.929 | 30.80 | 15,400 | 9.11 |
| | | 80 | 0.318 | 3.364 | 3.678 | 0.06170 | 1.047 | 0.881 | 27.70 | 13,850 | 12.51 |
| 4 | 4.500 | 40 | 0.237 | 4.026 | 3.17 | 0.08840 | 1.178 | 1.054 | 39.6 | 19,800 | 10.79 |
| | | 80 | 0.337 | 3.826 | 4.41 | 0.07986 | 1.178 | 1.002 | 35.8 | 17,900 | 14.98 |
| 5 | 5.563 | 40 | 0.258 | 5.047 | 4.30 | 0.1390 | 1.456 | 1.321 | 62.3 | 31,150 | 14.62 |
| | | 80 | 0.375 | 4.813 | 6.11 | 0.1263 | 1.456 | 1.260 | 57.7 | 28,850 | 20.78 |
| 6 | 6.625 | 40 | 0.280 | 6.065 | 5.58 | 0.2006 | 1.734 | 1.588 | 90.0 | 45,000 | 18.97 |
| | | 80 | 0.432 | 5.761 | 8.40 | 0.1810 | 1.734 | 1.508 | 81.1 | 40,550 | 28.57 |
| 8 | 8.625 | 40 | 0.322 | 7.981 | 8.396 | 0.3474 | 2.258 | 2.089 | 155.7 | 77,850 | 28.55 |
| | | 80 | 0.500 | 7.625 | 12.76 | 0.3171 | 2.258 | 1.996 | 142.3 | 71,150 | 43.39 |
| 10 | 10.75 | 40 | 0.365 | 10.020 | 11.91 | 0.5475 | 2.814 | 2.620 | 246.0 | 123,000 | 40.48 |
| | | 80 | 0.594 | 9.562 | 18.95 | 0.4987 | 2.814 | 2.503 | 223.4 | 111,700 | 64.40 |
| 12 | 12.75 | 40 | 0.406 | 11.938 | 15.74 | 0.7773 | 3.338 | 3.13 | 349.0 | 174,500 | 53.56 |
| | | 80 | 0.688 | 11.374 | 26.07 | 0.7056 | 3.338 | 2.98 | 316.7 | 158,350 | 88.57 |

- **Selection Of Pipe Sizes**
- The optimum size of pipe depends upon the…
- Relative cost of investment
- Power
- Maintenance
- Stocking pipe
- Fittings
- **Low velocities should be favored especially in gravity flow from overhead tanks…**
- Let's talk Reynolds number here (Newtonian Fluids) according to Reynolds transition of laminar flow to the turbulent flow depends upon diameter of the tube, average linear velocity of the fluid, density and it's viscosity.
- Usually laminar flow is <2100 while from 2100-4000 is the transition region, >4000 is turbulent region.

TABLE 8.1
**Fluid velocities in pipe**

| Fluid | Type of flow | Velocity range ft/s | Velocity range m/s |
|---|---|---|---|
| Thin liquid | Gravity flow | 0.5–1 | 0.15–0.30 |
| | Pump inlet | 1–3 | 0.3–0.9 |
| | Pump discharge | 4–10 | 1.2–3 |
| | Process line | 4–8 | 1.2–2.4 |
| Viscous liquid | Pump inlet | 0.2–0.5 | 0.06–0.15 |
| | Pump discharge | 0.5–2 | 0.15–0.6 |
| Steam | | 30–50 | 9–15 |
| Air or gas | | 30–100 | 9–30 |