

wilo

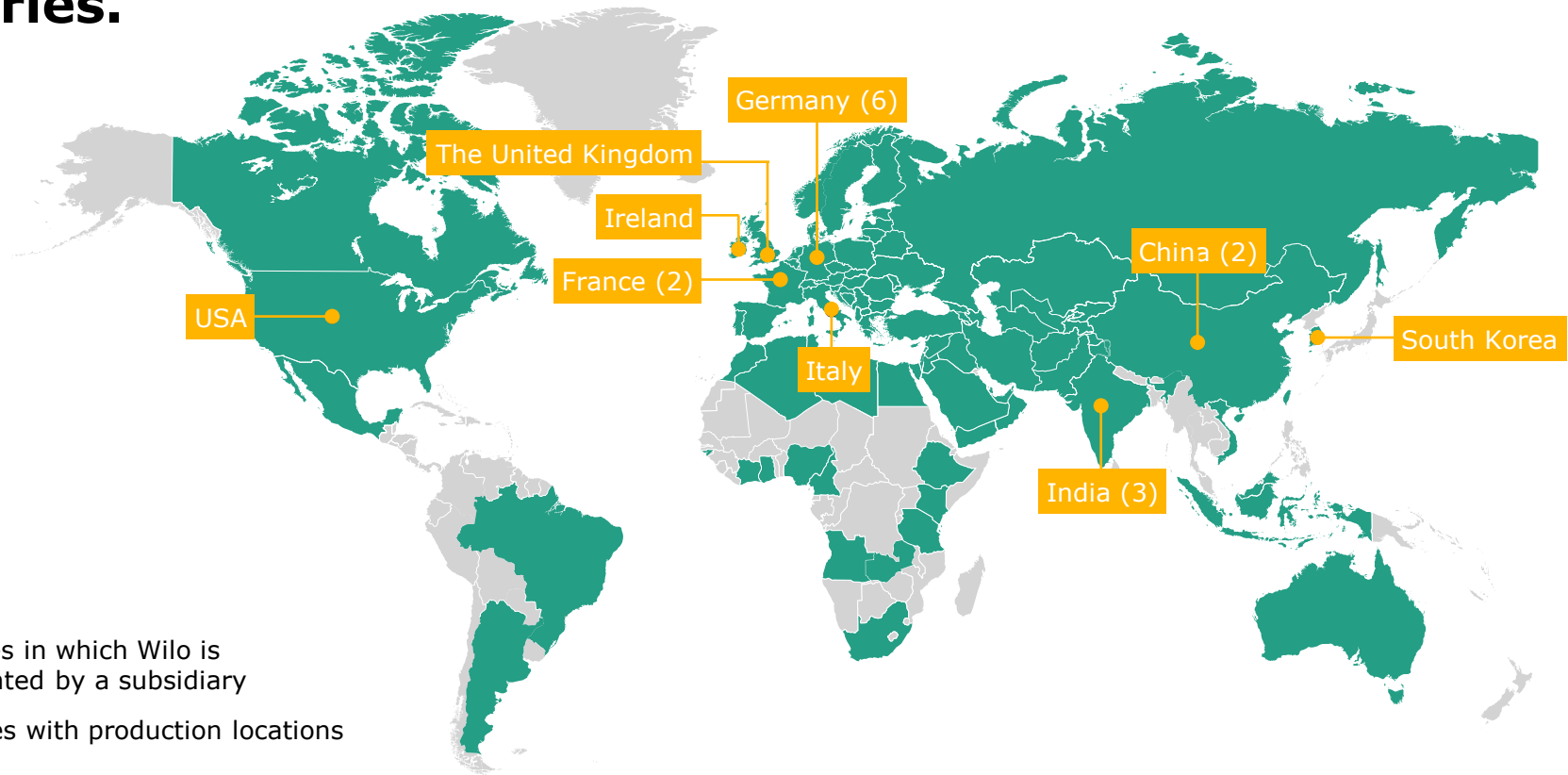


Basics of Pumping Systems by Wilo

Umesh Kulkarni, WILO Mather and Platt Pumps Private Limited, Pune, India

WILO: A Leading German Multinational : Worldwide

More than 60 subsidiaries in 50 countries. 18 production locations in 9 countries.



- Countries in which Wilo is represented by a subsidiary
- Countries with production locations

From a product-oriented to a solution-oriented company



Raw water Intake

Lift Irrigation

Water Supply

Pressure Boosting System

Clear Water Supply & Distribution

NEXOS INTELLIGENCE

HVAC

Water Distribution

Fire Fighting

Chilled Water Circulation

Skid Mounted Fire Pump set

Cooling Water



Real time data of water consumption, statistics, Water Analysis, smart decision making

Optimized & transparent asset

Condition Monitoring of equipment

Digitization of water Infrastructure by using IOT Platforms

Remote Monitoring & Predictive control of asset

Reduced Operation & Maintenance Expenses of system

Smart Farming - Real time optimized water supply to crop based on real time Weather & soil moisture

Real Time Interactive Reports

WILO Product Range

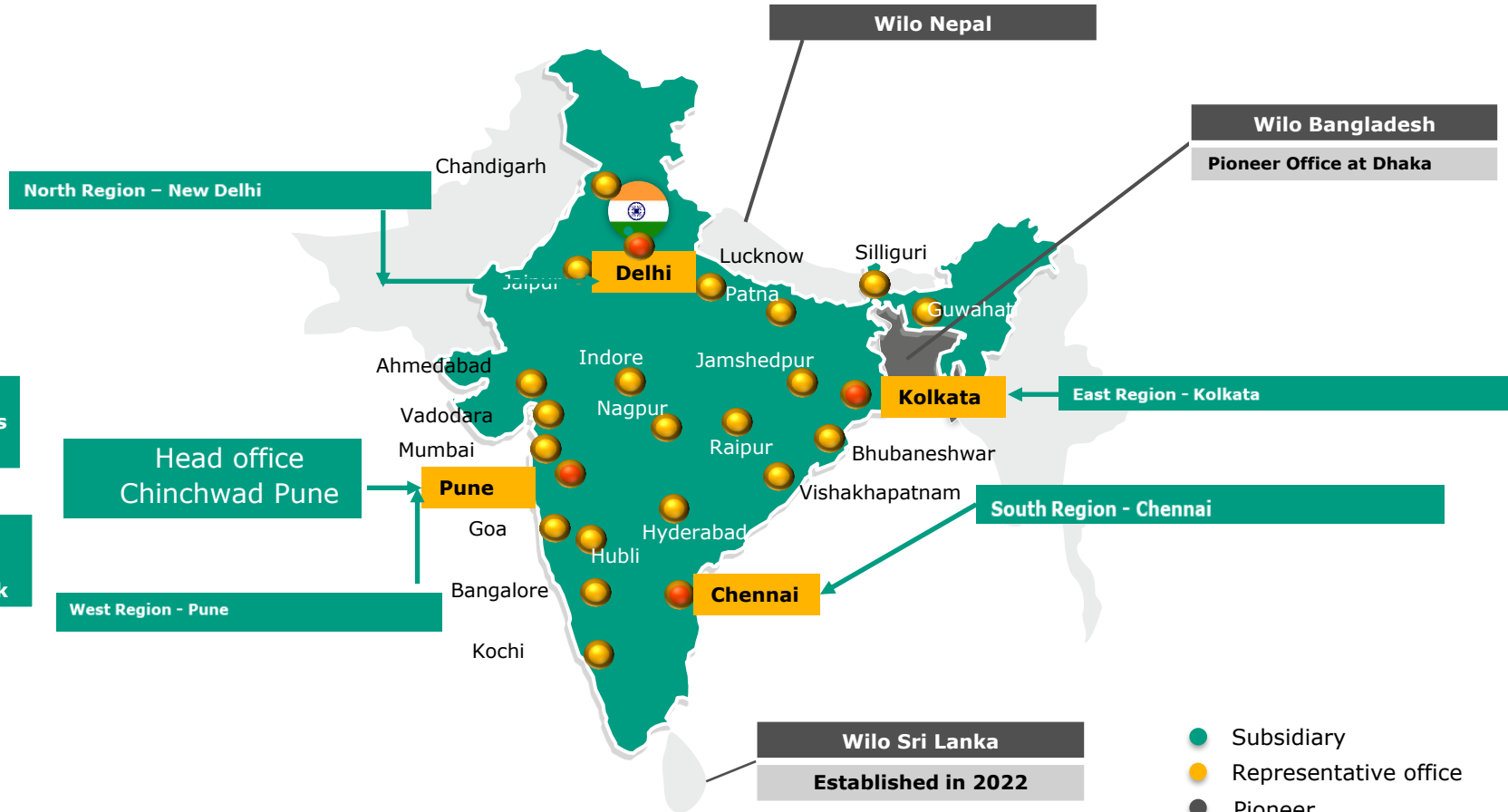


Product range

- Horizontal Split Case pumps
- Vertical Turbine pumps
- Horizontal / Vertical Multistage pumps
- End Suction pumps / Monobloc pumps
- Single Pump Boosters / Multi Pump Boosters
- Sewage and Dewatering pumps
- Non-Clog pumps / Sump pumps
- Fire Fighting pumps and systems
- Control panels / Circulator pumps
- Borehole Pumps

WILO India Network

- We are available at...**
- 1,100 Employees
 - 4 Regional Offices
 - 22 Branch Offices
 - 200+ Dealer and Distributor Network
 - 200+ Service Partners



WILO Mather and Platt Pumps Private Limited

Facilities



Manufacturing facility at Kolhapur



Manufactured Products

- End Suction Pumps
- Small Split Case Pumps
- Pressure Boosting Systems
- Vertical Inline Multistage

Manufacturing Infrastructure

- In house ferrous / non ferrous foundry
- CNC Machining facility
- Built on green building concept
- Testing and painting facility

Test Lab

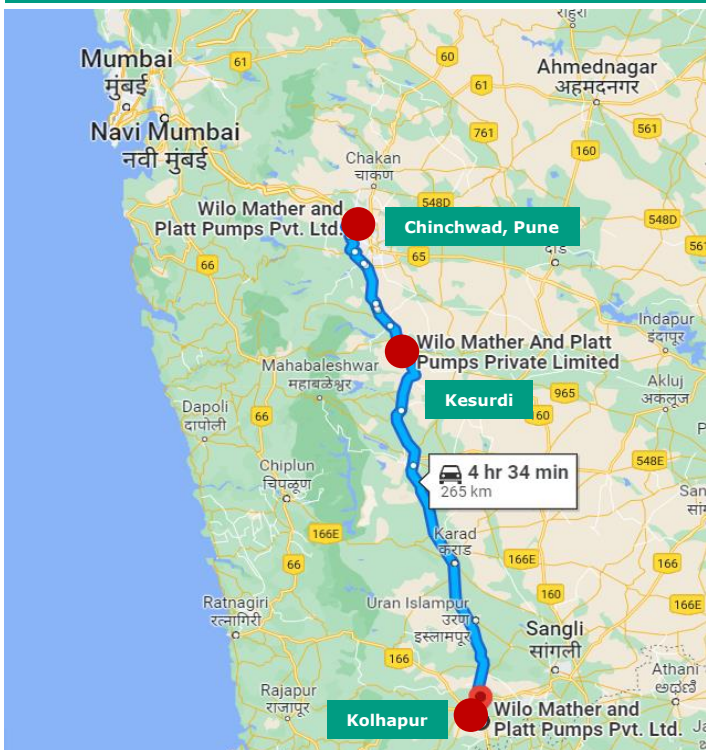
- Flow – 1000 m³/hr
- Motor Power – 200 kW

Production facility at Kesurdi (New Plant)



Kesurdi Manufacturing facility

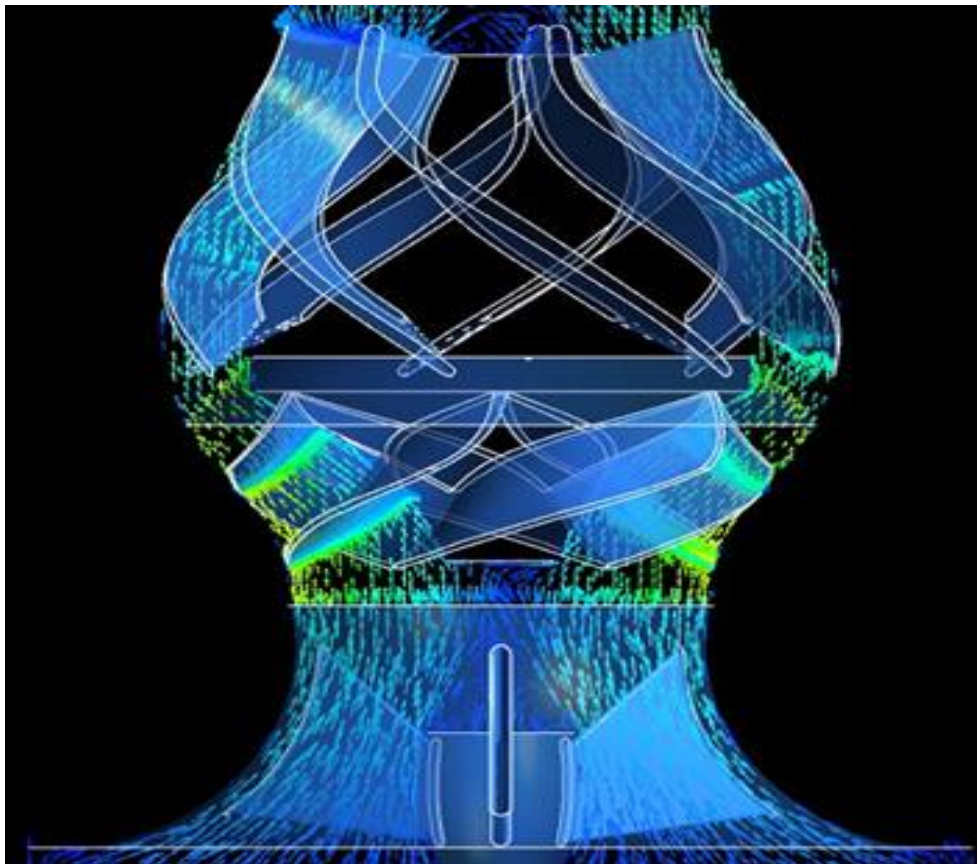
- Green field project is a part of industrial park.
- Total land area is 93,732 sq. meters.
- Total construction area is 29,164 sq. meters.



Pump Testing Facility @ Kesurdi Plant

No. of Test Beds	19
Flange joints	'O' ring
Closed loop facility for SCP and Multistage pump	Yes
Max Power (MW)	6
Max Flow (m3/hr)	110,000
NPSH available (meters)	4.5
Online Testing	Yes
Sump Capacity M ³	7500
Max. Setup (mm)	2600
Crane Height (meters)	14.5
Max. sump depth (meters)	13

Wilo India Design and Engineering Centre



Process and Capability

- IDEC in India working in close co-ordination with Group RIandT, Germany
- Design team of 36 qualified engineers
- CFD and Finite Element Analysis
- Reverse Engineering

Centrifugal Pump

A Rotodynamic pump or dynamic pressure pump.

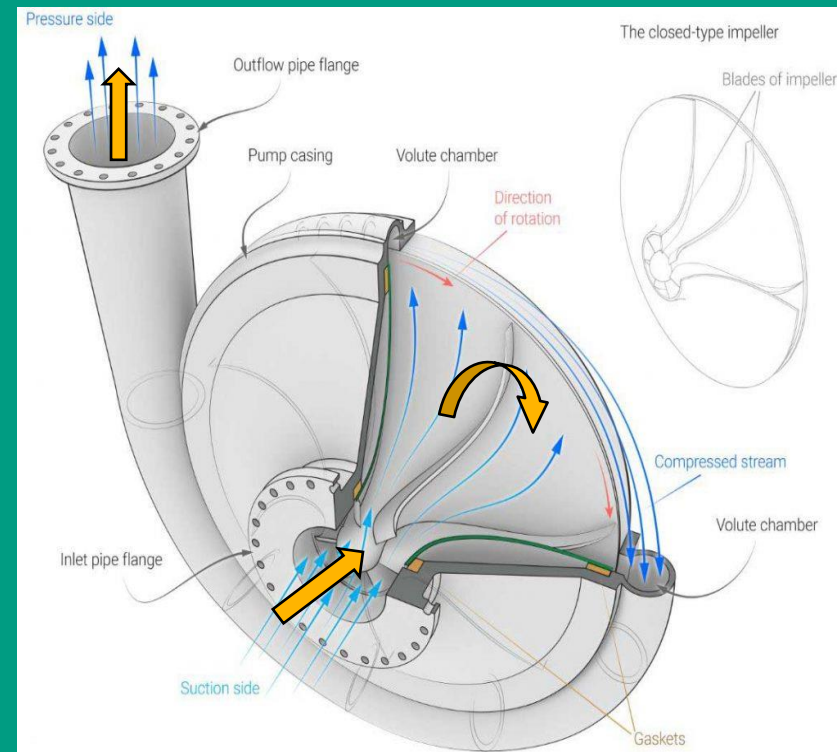
A hydraulic machine. Converts mechanical energy into hydraulic energy or pressure energy

Works on the principle of centrifugal force

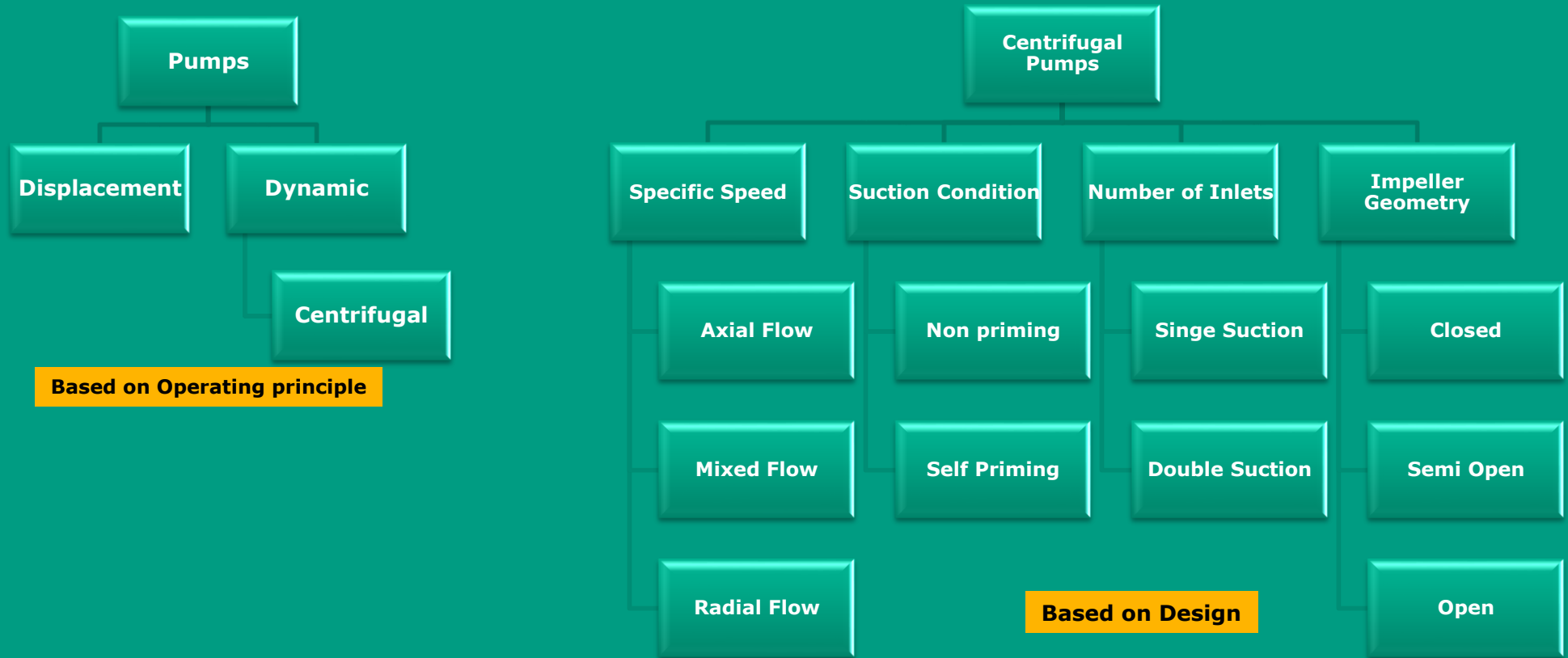
Liquid enters at the suction nozzle and enters the eye of the impeller

Kinetic energy is imparted to the liquid by the rotation of the impeller

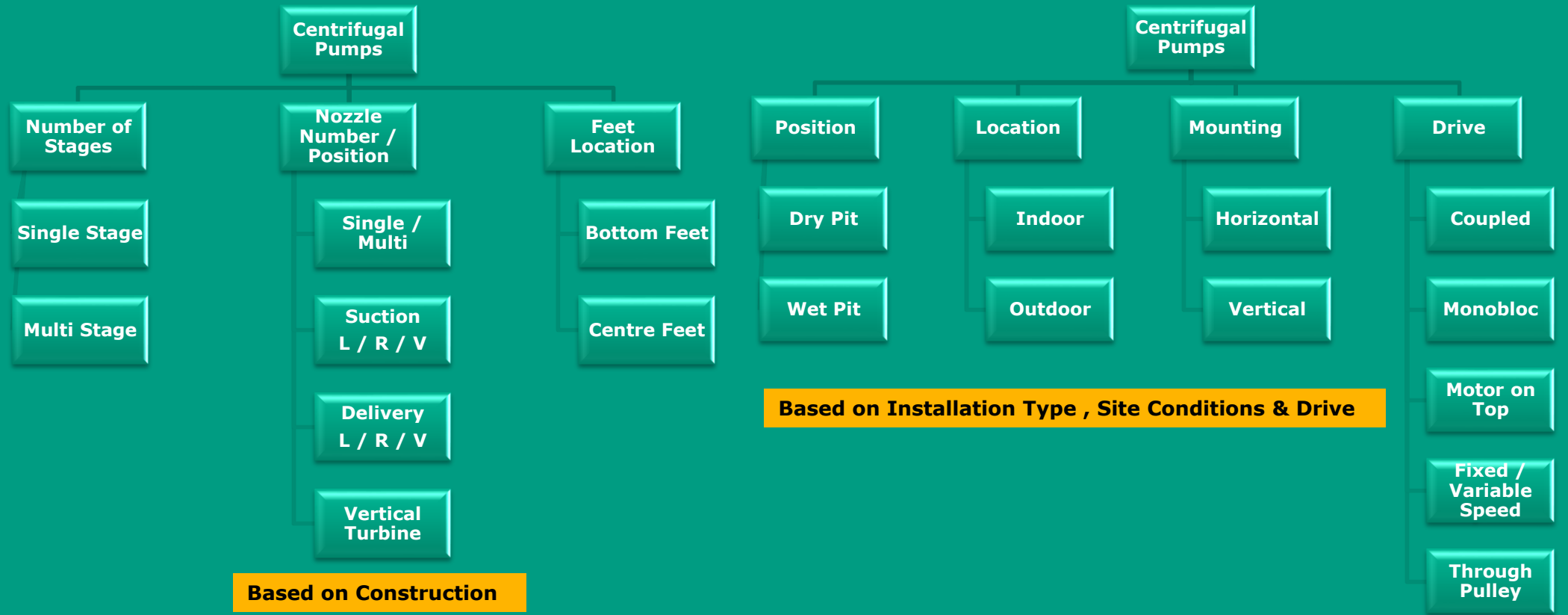
The high velocity liquid is diffused out of the pump casing.



Centrifugal Pump



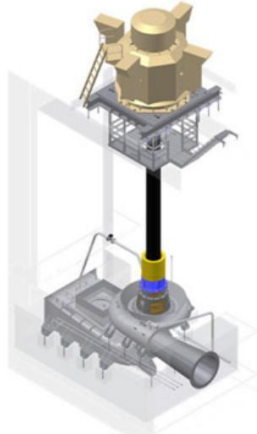
Centrifugal Pump



Constructional Types of Centrifugal Pump



Horizontal Split Casing Pump



Reversible Turbine Pump



Vertical Turbine Pump



Vertical Sump Pump



Canned Motor Pump



End Suction Pump



Multistage Pump

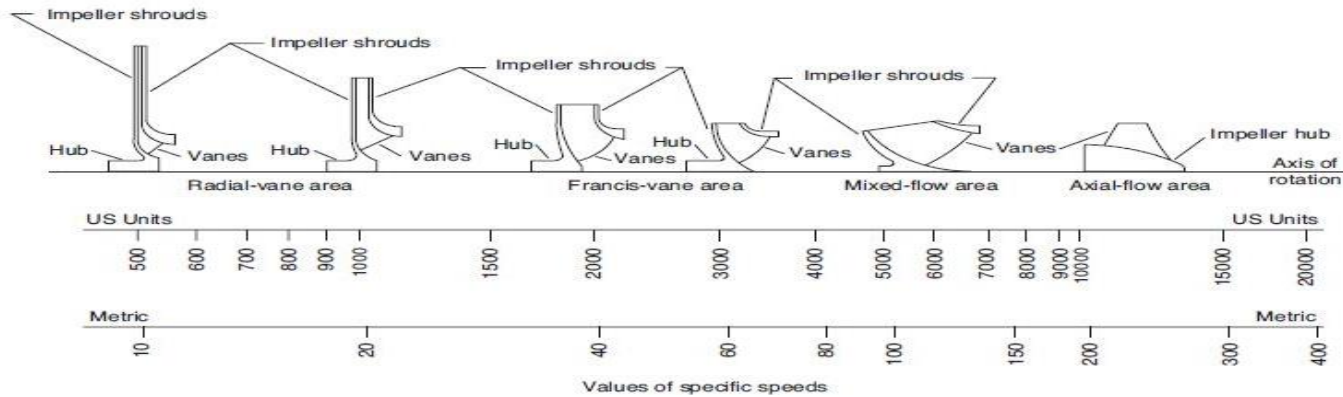


Axial Flow Submersible Pump



Submersible Pump

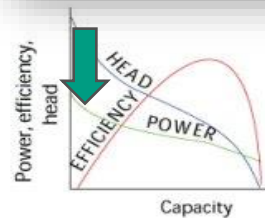
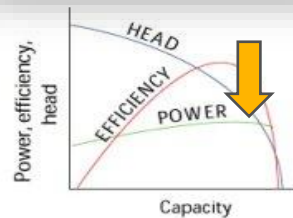
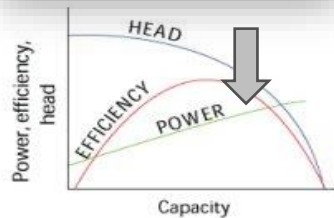
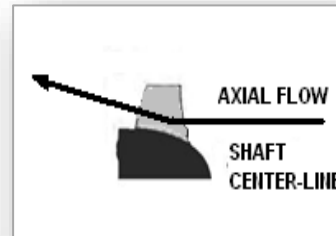
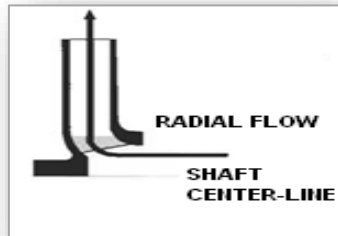
Specific Speed & Nature of Performance Curve



$$\text{Specific Speed } (N_s) = \frac{N \sqrt{Q}}{H^{3/4}}$$

N = The speed of the pump in RPM.
 Q = The flow rate in liters per second.
 H = The total dynamic head in meters

In case of double suction pump, Flow rate Q is half of the BEP rated flow
In case of multistage pump, Pump head 'H' is head generated per stage



At low specific speed, power consumption is lowest at shut off and rises as flow increases

At medium specific speed the power curve peaks at approximately the best efficiency point

High specific speed pumps have a falling power curve with maximum power occurring at minimum flow

Suction Specific Speed

- Suction specific speed N_{ss} as defined in EN 12723
- It is used to classify the suction characteristics of centrifugal pumps
- N_{ss} is determined at the BEP rate of flow with the maximum diameter impeller
- It is considered as guide to prevent the cavitation

$$N_{SS} = \frac{N\sqrt{Q}}{NPSHR^{0.75}}$$

- When denominator is $NPSH_r$ then output is N_{ssr}
- When denominator is $NPSH_a$ then output is N_{ssa}
- N_{ssa} should always be greater than N_{ssr}
- N_{ss} for most pumps ranges between 7,000 and 11,000
- **Generally considered maximum as 8500**
- For axial flow pump, it can be max. 11000

Significance of suction specific speed is to determine maximum allowable operating speed of the pump based on $NPSH_a$ to avoid possibility of cavitation of the pump during operation

$$n = \frac{S \times NPSH_A^{0.75}}{Q^{0.50}}$$

In case of double suction pump, Flow rate Q is half of the BEP rated flow

Net Positive Suction Head

NPSH can be defined as two parts:

NPSH Available ($NPSH_a$):

The absolute pressure at the suction port of the pump.
It is the site related parameter.
It is a function of system which should be calculated.

and

NPSH Required ($NPSH_r$):

The minimum pressure required at the suction port of the pump to avoid cavitation.
It is a function of pump design and should be provided by the pump manufacturer.

To avoid pump cavitation during operation, $NPSH_a$ must be greater than $NPSH_r$ at least by 0.5 meters

$$NPSH_a = H_a \pm H_z - H_f + H_v - H_{vp}$$

H_a : Atmospheric Pressure

H_z : The vertical distance between the minimum water level in the suction tank and the impeller centerline. Positive when minimum Water level is above the centerline of the pump (called static head). Negative when minimum water level is below the centerline of the pump (called suction lift)

H_f : Friction losses in the suction piping

H_v : Velocity head at the pump suction

H_{vp} : Absolute vapor pressure of the liquid at the pumping temperature

Correcting NPSH Margin & Avoiding Cavitation

- Detailed analysis of the proposed or existing suction conditions before selecting the pump
- Increase minimum water level in the suction reservoir
- Lower the pump elevation
- Reduce the head losses in suction piping
- Select the pump at lower speed i.e. Low specific speed
- Select the pump with larger suction diameter
- Abnormal obstructions to smooth flow like too many bends, reducers, valve in suction pipe, there will increase the frictional head loss and thus resulting in increased suction lift.

Significance of Specific Speed & Pump Operating Speed

Condition	Specific Speed & Pump Operating Speed Considerations
Abrasives	Lower RPM is better. Less wear & tear of rotating components. Lower RPM increases the size of hydraulic design & thus solid handling capacity can be better as compared to higher RPM Pump.
Solids handling	As specific speed increases, impeller free passage increases
Efficiency	General trend of maximum efficiency is observed in between 4000-7500 specific speed
Cavitation	Lower RPM pumps generally have lower NPSHr and a broader allowable operating range
Capital costs	Higher RPM pumps are physically smaller than lower RPM pumps for the same duty point. Both motors and pumps are often less expensive. Space required for installation is also less as compared to lower RPM pumps.
Reliability	Higher RPM pumps are often less tolerant to difficult service conditions. Factors such as solids, cavitation, and off design-point (BEP) operation may severely impact reliability. Any capital cost benefit may be eliminated by pre-mature equipment failure. For difficult applications, especially where high horsepower is involved, it is good practice to be conservative with equipment speed.

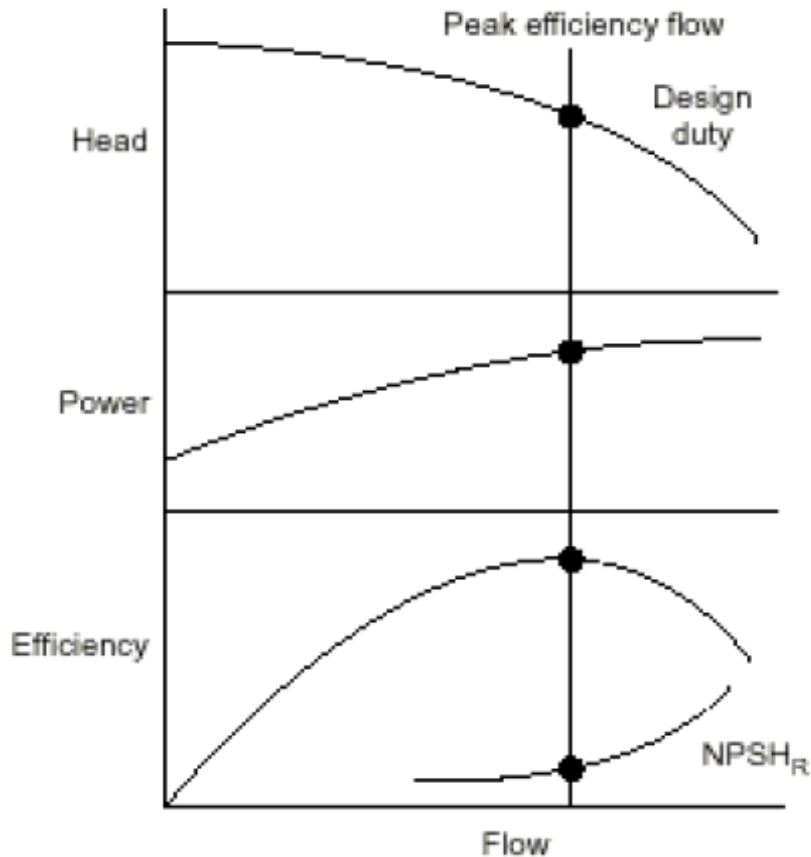
Affinity Laws

The affinity laws is a set of formulas' that calculates the impact of a change in rotational speed or impeller diameter on the head and flow produced by a pump and power consumed by a pump

When only impeller dia. changes & speed Remains the same	When only speed changes & impeller dia. Remains the same	When both dia. & speed change
$Q_1/Q_2 = (D_1/D_2)$	$Q_1/Q_2 = (N_1/N_2)$	$Q_1/Q_2 = (D_1/D_2) \times (N_1/N_2)$
$H_1/H_2 = (D_1/D_2)^2$	$H_1/H_2 = (N_1/N_2)^2$	$H_1 /H_2 = \{ (D_1/D_2) \times (N_1/N_2) \}^2$
$P_1/P_2 = (D_1/D_2)^3$	$P_1/P_2 = (N_1/N_2)^3$	$P_1/P_2 = \{ (D_1/D_2) \times (N_1/N_2) \}^3$

The Affinity Laws are valid only under conditions of constant efficiency

Best Efficiency Point (BEP) of the pump



The best efficiency point (BEP) is the flow rate where a pump has its highest efficiency, and is normally based on its performance at maximum impeller diameter.

Preferred Operating Range (POR) of pump: 80% to 110% of BEP

Why to operate pump near to BEP or in between POR

- 1) Energy conservation
- 2) Axial & Radial loads acting on rotating component are minimum
- 3) Internal disturbing forces are minimum
- 4) Vibrations & Noise are very less
- 5) Less wear & Tear of rotating components
- 6) Less pressure pulsations
- 7) No chances of cavitation

At minimum flow: Temperature buildup, excessive radial thrust, suction recirculation, discharge recirculation, and insufficient NPSH_A

At maximum flow: Combined torsional and bending stresses or shaft deflection may exceed permissible limits; Erosion, noise, and cavitation may occur because of high fluid velocities.

Best Efficiency Point (BEP) of the pump

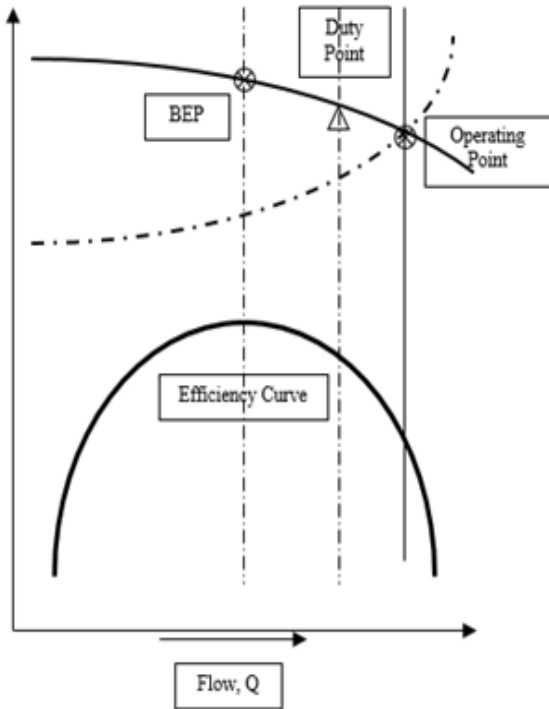


Fig.1 Figure showing the BEP, Duty point & Operating point

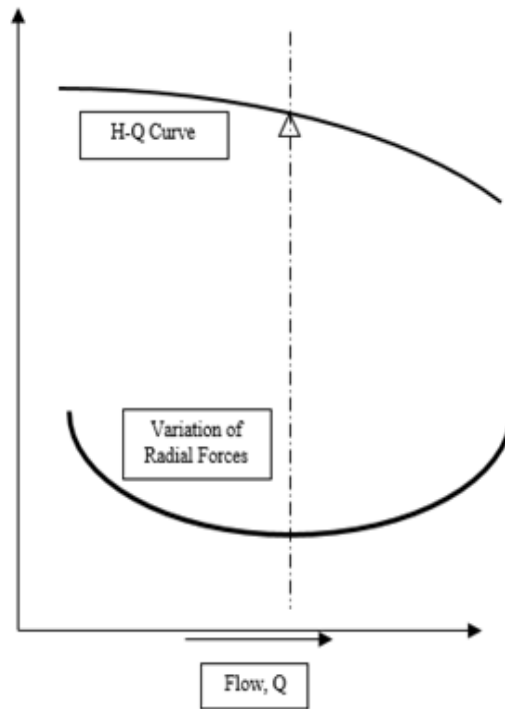
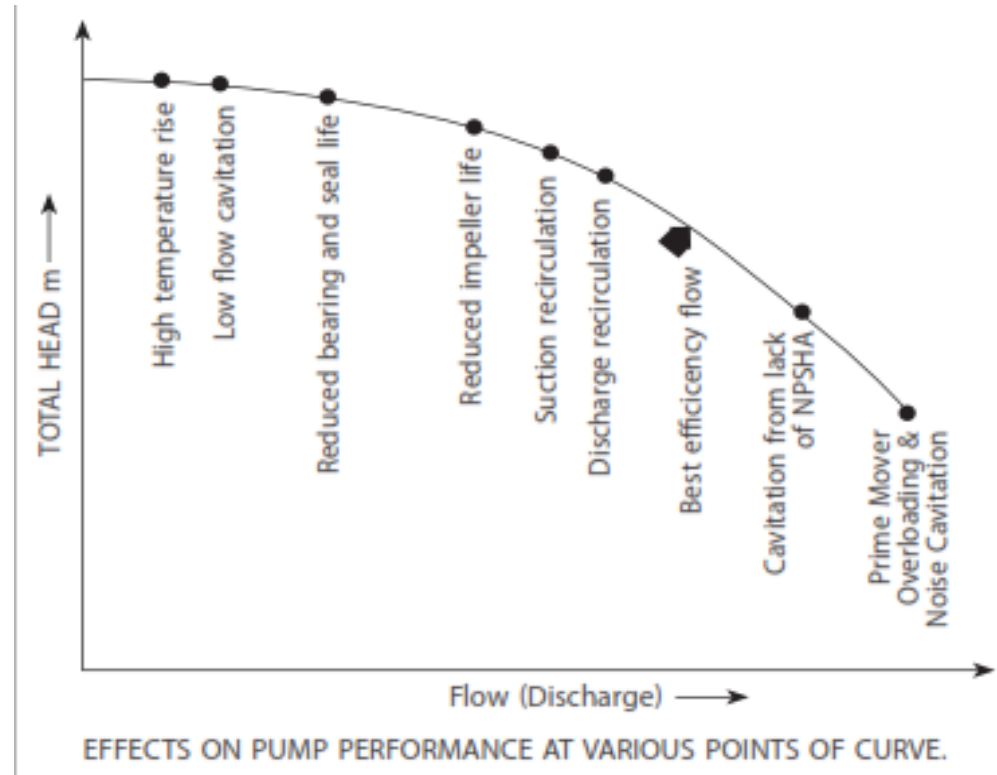
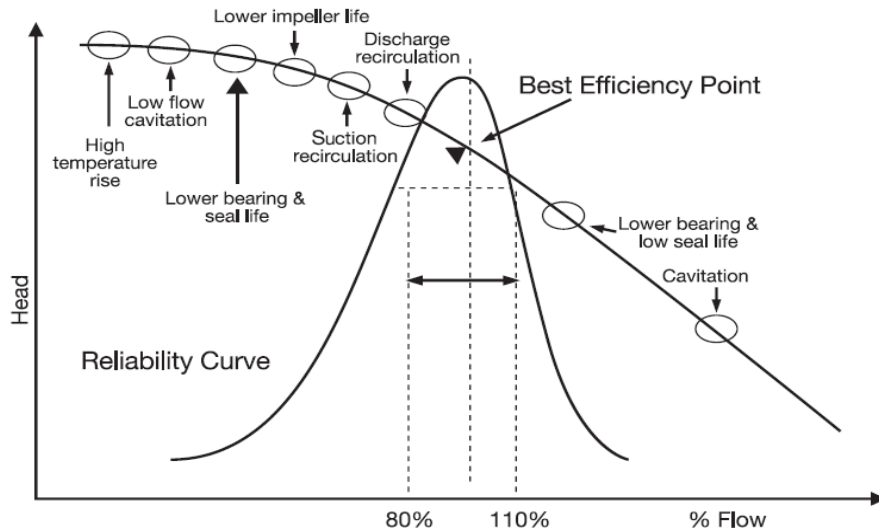


Fig 2. Figure showing radial force variation



EFFECTS ON PUMP PERFORMANCE AT VARIOUS POINTS OF CURVE.

Pump Operational Reliability



Preferred operating Range (POR)

Flow remains well controlled within a range of capacities

Service life of the pump will not be affected significantly by hydraulic loads, vibration, or flow separation

Allowable operating Range (AOR)

Limits for minimum and maximum flow in a pump

Temperature rise effect at Shut Off Condition

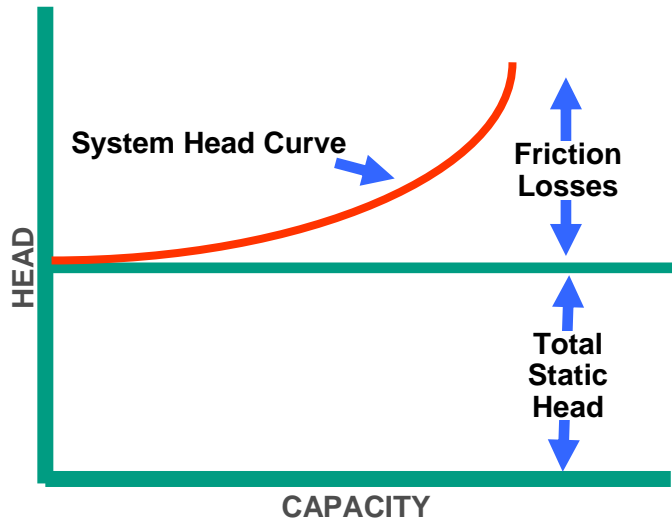
The power losses are equal to BHP at shut off & since there is no flow through the pump (Due to closed valve), the entire power goes in to heating the small amount of liquid available in the pump casing.

Pump casing heats up & a certain amount of heat is dissipated by radiation & convection to the surrounding atmosphere.

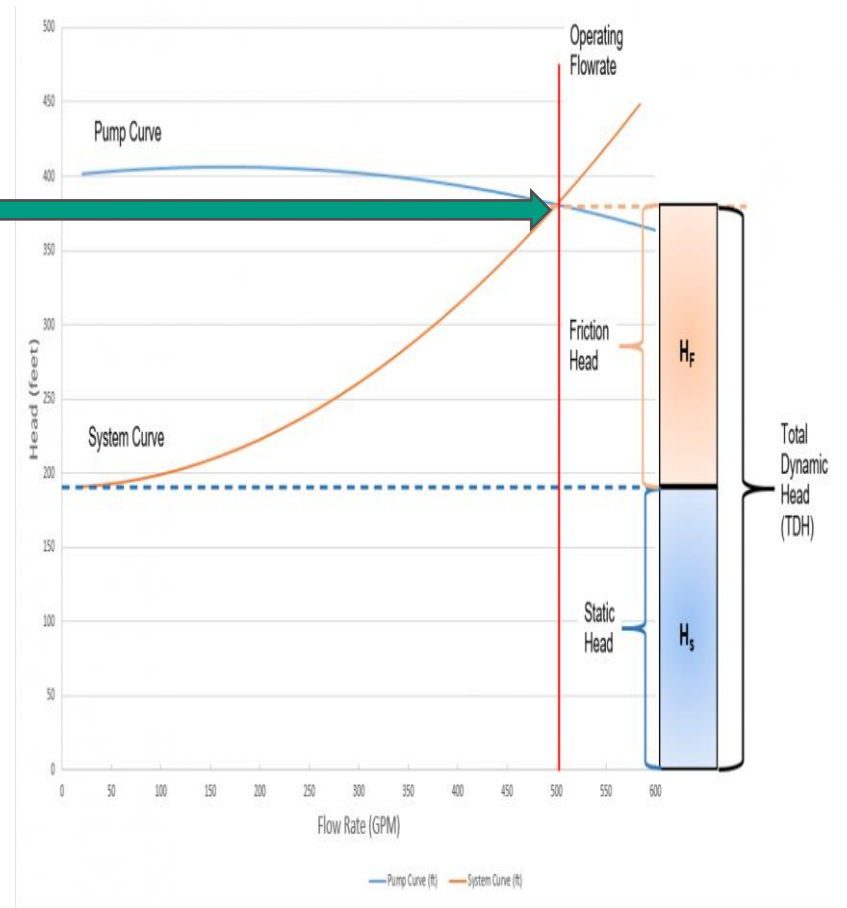
If the amount of heat added to the liquid is small, it can be transmitted through casing with a low differential in temperature between the liquid in the casing & outside air.

However, if the power loss is very high, the liquid temperature may reach to exceedingly high value, far in excess of the boiling temperature at suction pressure. This is dangerous & disastrous situation.

System Resistance Curve or System Head Curve



It is important to remember that a pumping system will always operate at the intersection of the pump performance curve and the system resistance curve.



System resistance or system head curve is the change in flow with respect to head of the system.

It must be developed by the user based upon the conditions of service. This include physical layout, process conditions, and fluid characteristics.

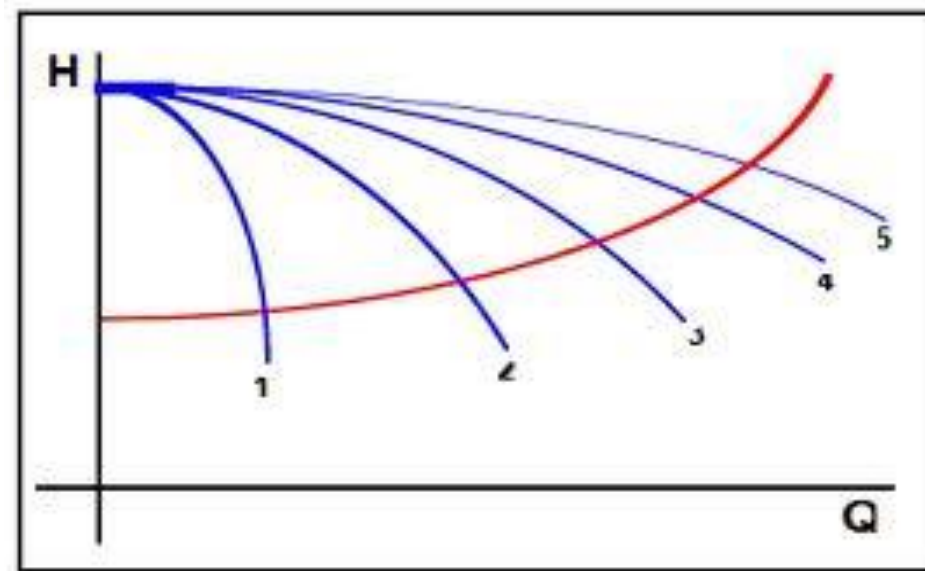
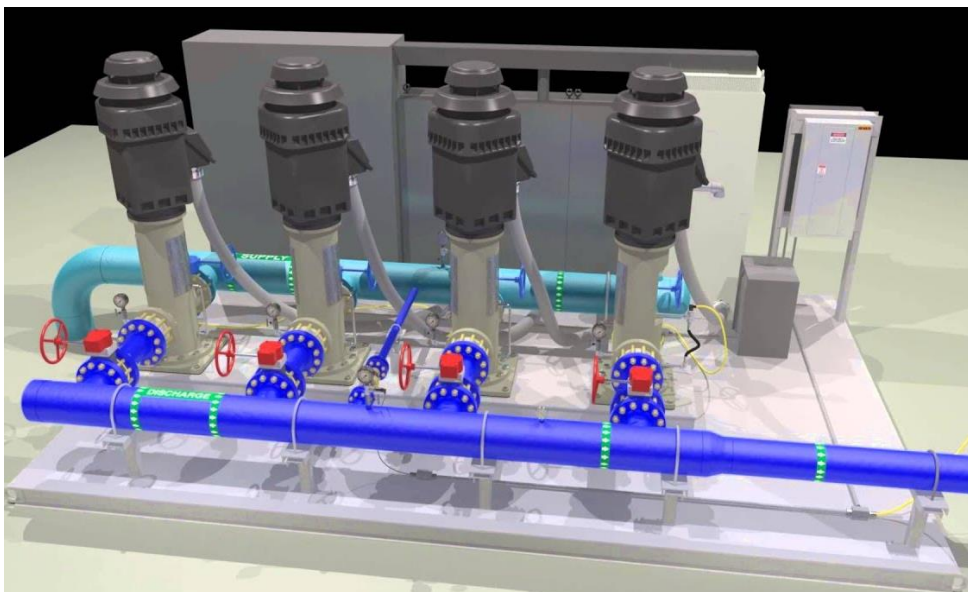
It represents the relationship between flow and hydraulic losses in a system in a graphic form and, since friction losses vary as a square of the flow rate, the system curve is parabolic in shape.

Parallel Operation of Pumps

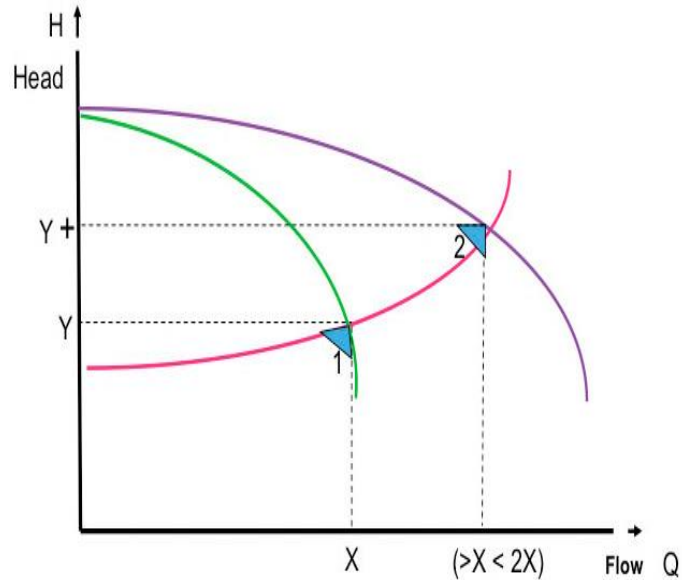
Pumps Operating in parallel should have identical shutoff head and similar specific speeds

Pumps with dissimilar characteristics curves can operate in parallel, if the system head does not exceed the shut of head of any pump at any capacity produced by a combination of other pumps on the system.

Duty points should lie in best efficiency zone or slightly towards the left side of best efficiency point

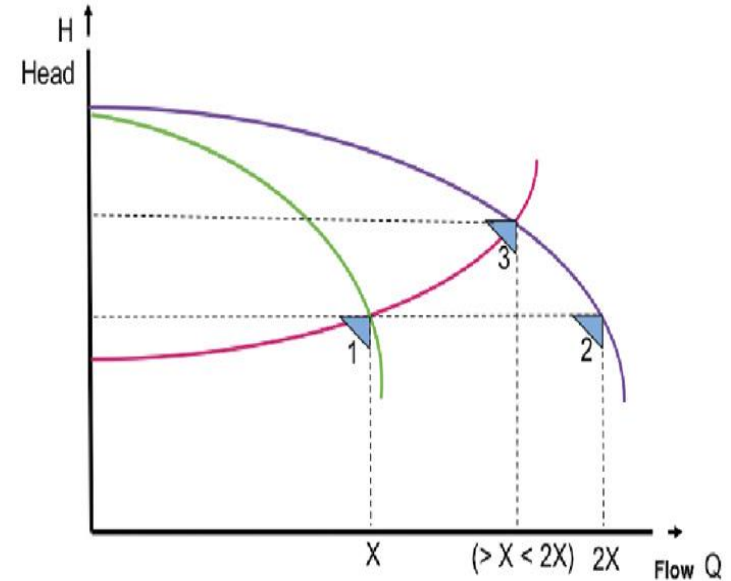


Parallel Operation of Pumps



With one pump operating (Intersection Point 1), the system curve remains relatively flat, and flow is X with corresponding head Y.

When the second pump is started (Intersection Point 2), the friction due to higher flows makes system curve slightly steeper. While the flow will be more than X but total flow of both the pumps will not be exactly 2X.

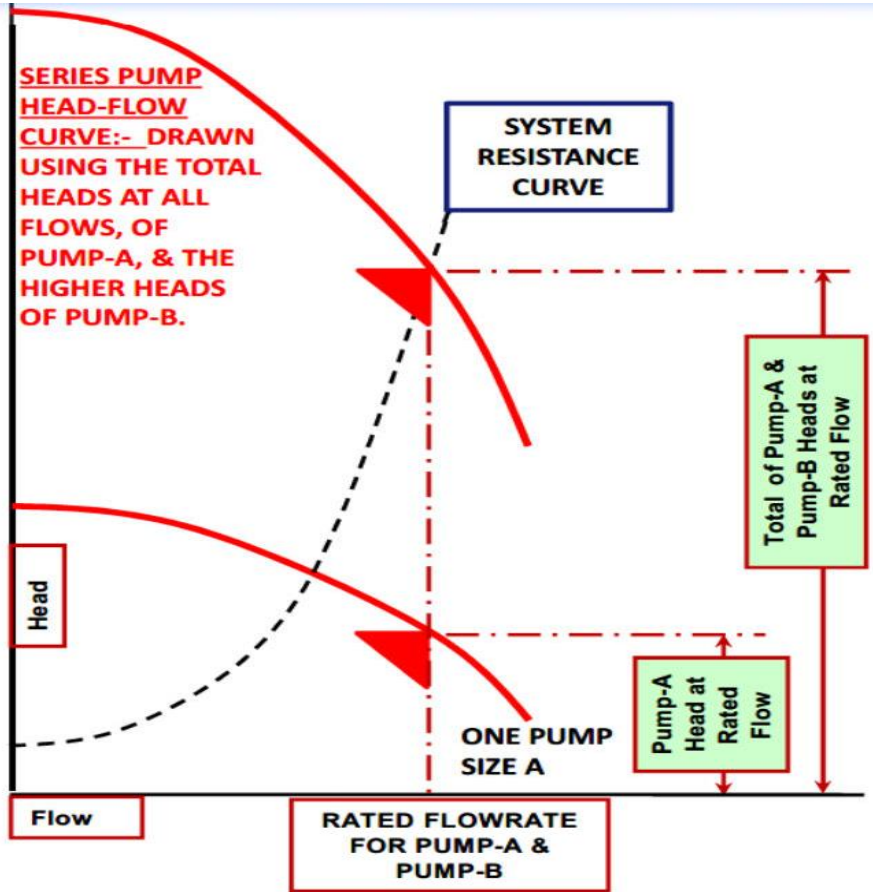


Operation of Pump 1 (Intersection Point 1) and the subsequent parallel operation of Pump 2.

Common understanding is that after starting the second pump, the flow rate will double to Intersection Point 2.

In reality, the actual operating point will be at Intersection Point 3.

Series Operation of Pumps



Series operation of centrifugal pumps is used to overcome large system head loss, or to gain pressure increase

- Flow rates of both the pumps should be same
- Pumps in series increases the head developed at the same flow condition point.
- The second pump must be capable of operating at the higher suction pressure, which is produced by pump number one.
- This mode of operation is a very cost effective way of overcoming high discharge heads when the flow requirement remains the same.

Material of Construction

Following criteria should be considered in the selection of the material for a centrifugal pump hydraulic components which should be based upon properties of liquid being handled by the pump

- Corrosion resistance
- Abrasive-wear resistance
- Cavitation resistance
- Strength (primarily for the casings)
- Casting and machining properties
- Cost

Material	Life Factor
Aluminum Bronze	8.0
Titanium	6.0
Bronze	4.0
Stainless Steel	4.0
Monel	2.0
Cast Iron	1.5
Brass, gun metal	1.2
Mild Steel	1.0

Higher impeller tip speeds increases the Impeller diameter & Impeller speed. Tip speed must be kept within limits to avoid excessive erosion due to suspended particles.

$$\text{Impeller tip speed m/s} = \frac{\pi \times D \times N}{1000 \times 60}$$

**D: Impeller diameter in mm,
N: RPM of the pump / Impeller**

Table 2.01 Maximum permissible tip speed of impeller dependent on materials.

Material	example	$u_{max\ all}$ in m/s
Grey cast iron	EN-JL1040 EN-GJL-250	40
Spheroidal graphite cast iron	EN-JS1030 EN-GJS-400-15	50
Bronze and brass	2.1050 G-CuSn 10	
Stainless steels (normal)	1.4008 GX7CrNiMo12-1	95
Stainless steels (special)	1.4317 GX4CrNi13-4	110

Material of Construction

- The material selection largely depends on customer specifications
- However, following table can be useful when so specifications are available
- Special care for sea water applications for non-wetted parts/ aggressive surrounding

Liquid Specifications/ Operating Condition	Impeller	Line shaft Bushing	Fasteners	Shaft & Sleeve	Shaft Tube /Rising Pipe	Remarks
Clear Water	CI	Cutless Rubber/ CIP Marine	HTS	SS 410	Mild Steel	
Raw Water	Bronze/ NiCi/ Steel	Cutless Rubber/ Feroform/ CIP Marine	HTS	SS 410	Mild Steel	Cutless rubber based on ppm with FWL
Screened sewage	Stainless Steel	Feroform/Thordon/CIP Marine	SS 304	SS 410	Mild Steel	Check free ball size
Sea water	CD4MCuN (Duplex/SuperDuplex)	Feroform*/Thordon/CI P Marine		UNS/SS 316L		For higher TDS , use UNS Feroform with FWL

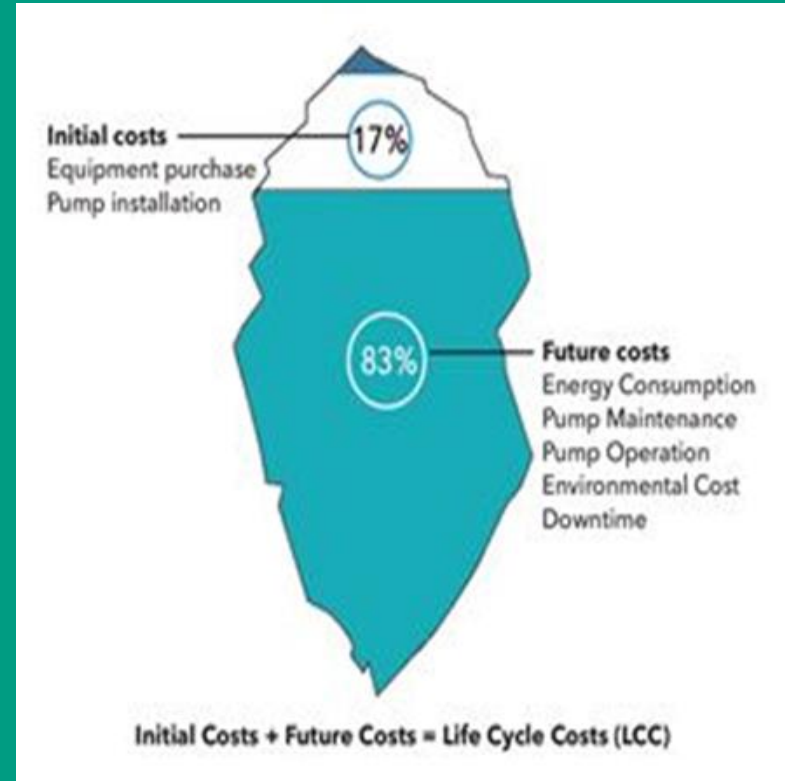
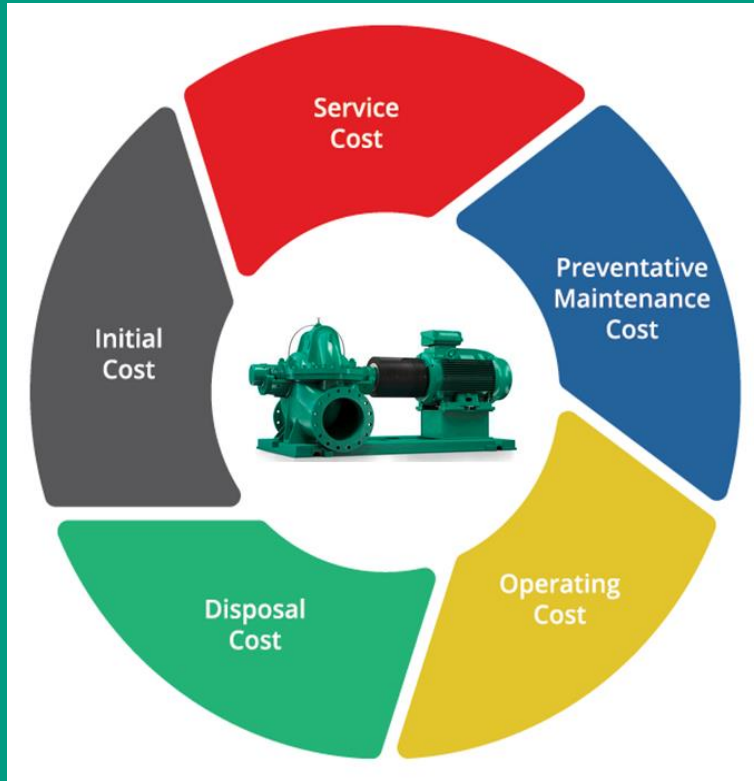
Effect of Liquid Properties on Pump

Liquid Parameter	Effect
Specific Gravity	<ul style="list-style-type: none"> ➤ Direct effect on pump input power ➤ Maximum static suction lift varies inversely with Sp. Gravity
Viscosity	<ul style="list-style-type: none"> ➤ Fluid friction and Disc friction ➤ Due to disc friction, efficiency gets decreased & hence power consumption is more ➤ Open or semi-open impeller can reduce the disc friction in case of viscous fluid handling application ➤ Head, Flow & Efficiency viscosity correction factor to be used for converting pump performance achieved for water to the pump performance for viscous liquid
Temperature	<ul style="list-style-type: none"> ➤ As temperature increases, specific gravity & viscosity decreases ➤ Vapour pressure of the liquid changes as the temperature changes & hence maximum permissible suction lift reduces
Corrosion & Erosion	<ul style="list-style-type: none"> ➤ Large cross sections of flow are necessary both in the impeller and the volute casing ➤ Erosion can be reduced by selecting pumps with low speed which have lower water velocities and lesser disc friction ➤ Epoxy coating is also suitable for avoiding corrosion & erosion

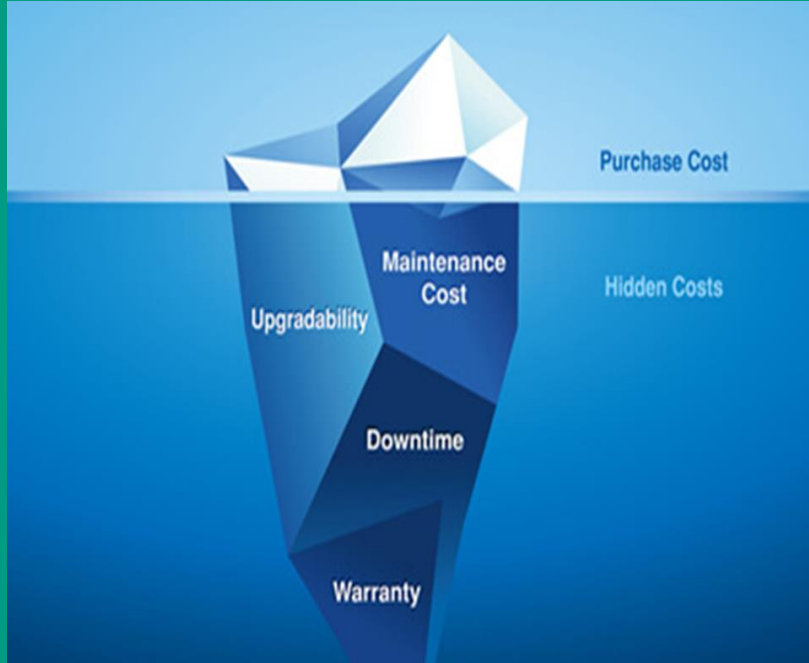
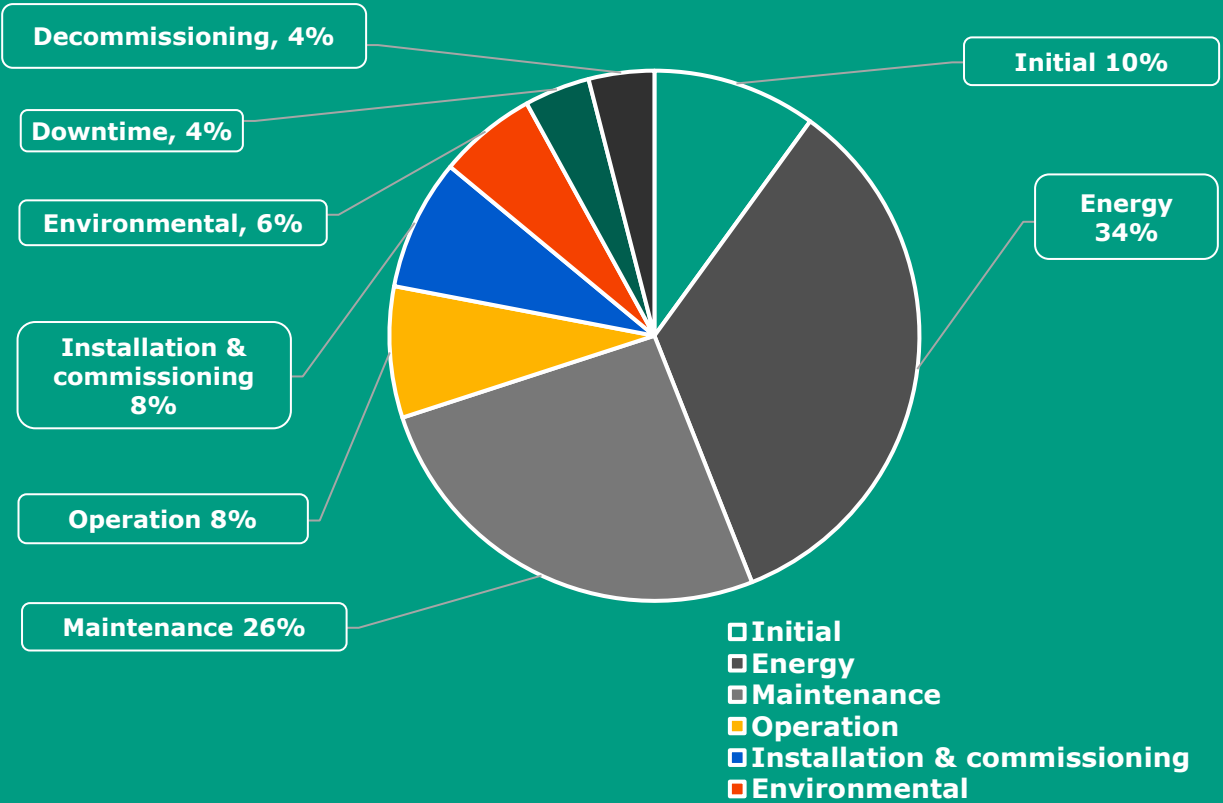
Inputs required for right Pump Selection

- 1) Rate of flow and Total Head
- 2) Type of installation: Vertical / Horizontal / Inclined / Wet pit / Dry Pit
- 3) Application
- 4) Properties of liquid : Viscosity, Specific Gravity, Temperature, Chemical contents, Suspended solids
- 5) Type of drive: Motor / Engine
- 6) Type of Operation –Constant speed /variable speed
- 7) Pump efficiency required
- 8) NPSH Available
- 9) Water Level Details
- 10) System resistance curve
- 11) Starting Method – Soft Starter/ VFD

Life Cycle Cost

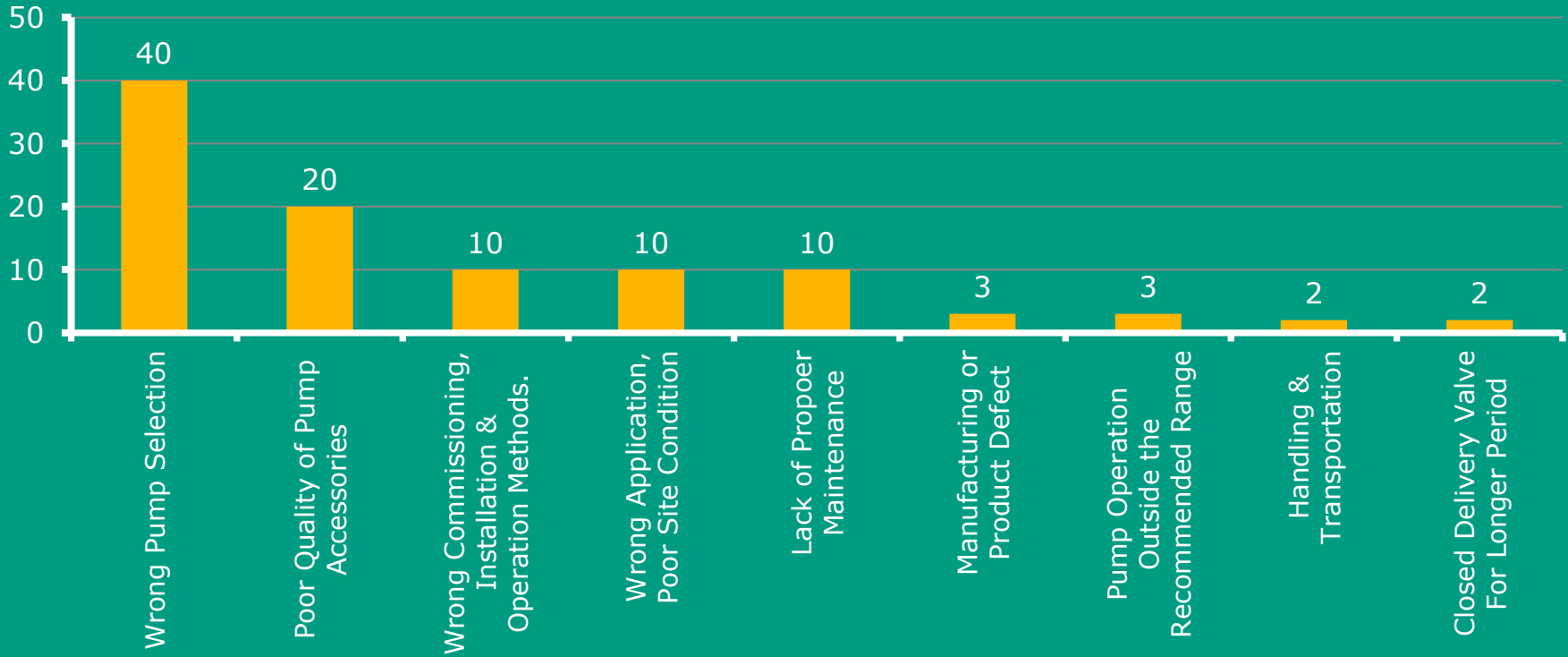


Typical Life Cycle Cost of Pumping System



Operation & Maintenance Expenses

Reasons to Increase O&M Expenses of Pumping System in Percentage



Cost Drivers, Effects & Solutions

Extra margin on Head

Increases no.of Stages & motor rating

Extra Margin on flow

Leads to higher pump model

Estimated losses on higher side

Leads to higher model and power

Sealing arrangements

Gland packing – less expensive
Mechanical Seal – adds to cost

Application based MOC
e.g. For Sea water

Select duplex Steel, why Titanium ?

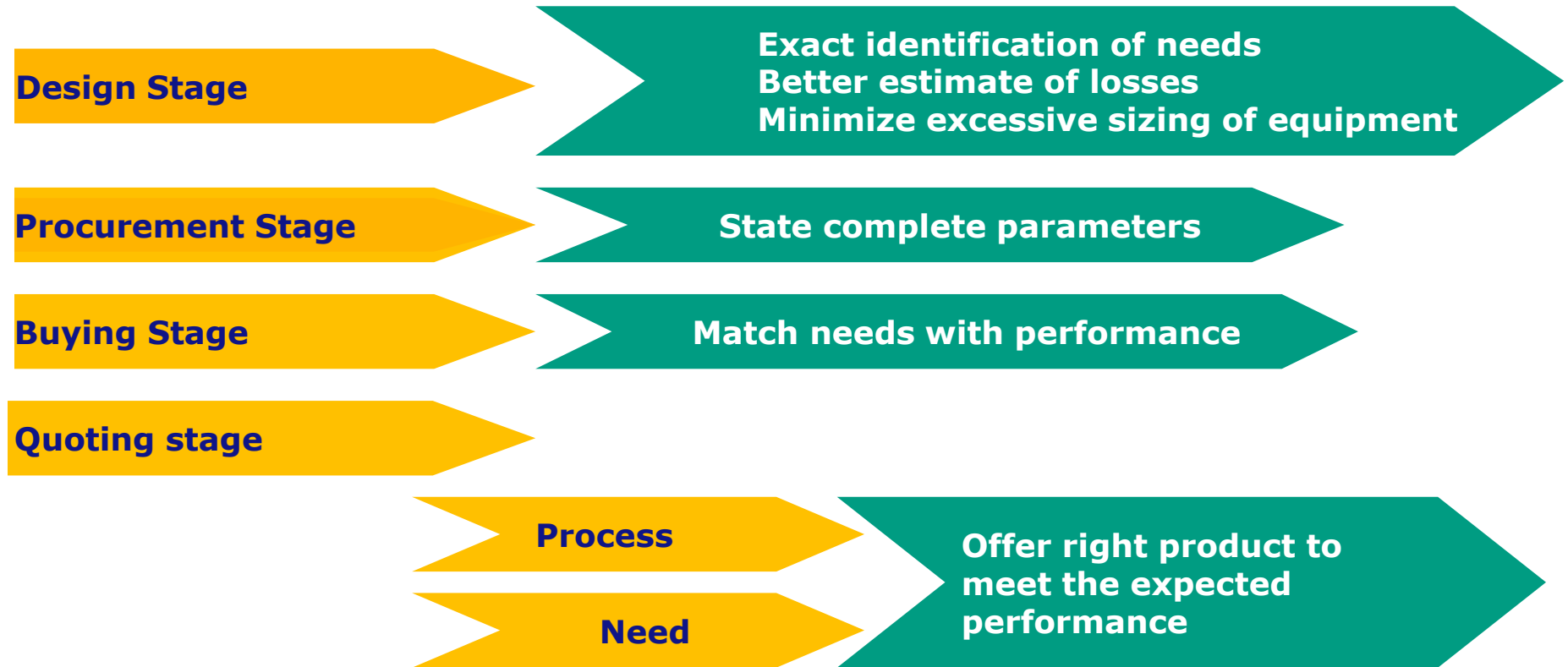
Downtime

For lower downtime , opt for Hori. Split case or End Suction pumps

Sourcing pump, motor,
Accessories from Different suppliers

Leads to Higher indirect cost, lack of synchronisation,
higher inventory

Achieving Cost effectiveness



Energy Efficient Water Transfer....

Design the system to operate the pump between 80 % to 110 % of BEP to gain following benefits

- Pump is operating near to maximum efficiency point results in saving of energy cost
- The risk of damage to the pump components due to cavitation is reduced
- At BEP, pump will run very smoothly, thereby minimizing internal disturbing forces which reduces undue wear & tear and premature failure of pump internals such as wear rings, bushes, shaft sleeves, mechanical seals, couplings etc.
- Noise & vibrations at BEP operation are less
- Reduction in pressure pulsations, avoiding risk of problems in pumping system

An OFF-BEP operation has following effects on the pumping system:

- Reduced operating efficiency, Increased power consumption.
- Increased radial forces which causes seal, bearing , shaft failure which in turn increases the O&M expenses.
- Reduces life of pumps and motors

Efficiency, Reliability, Sustainability

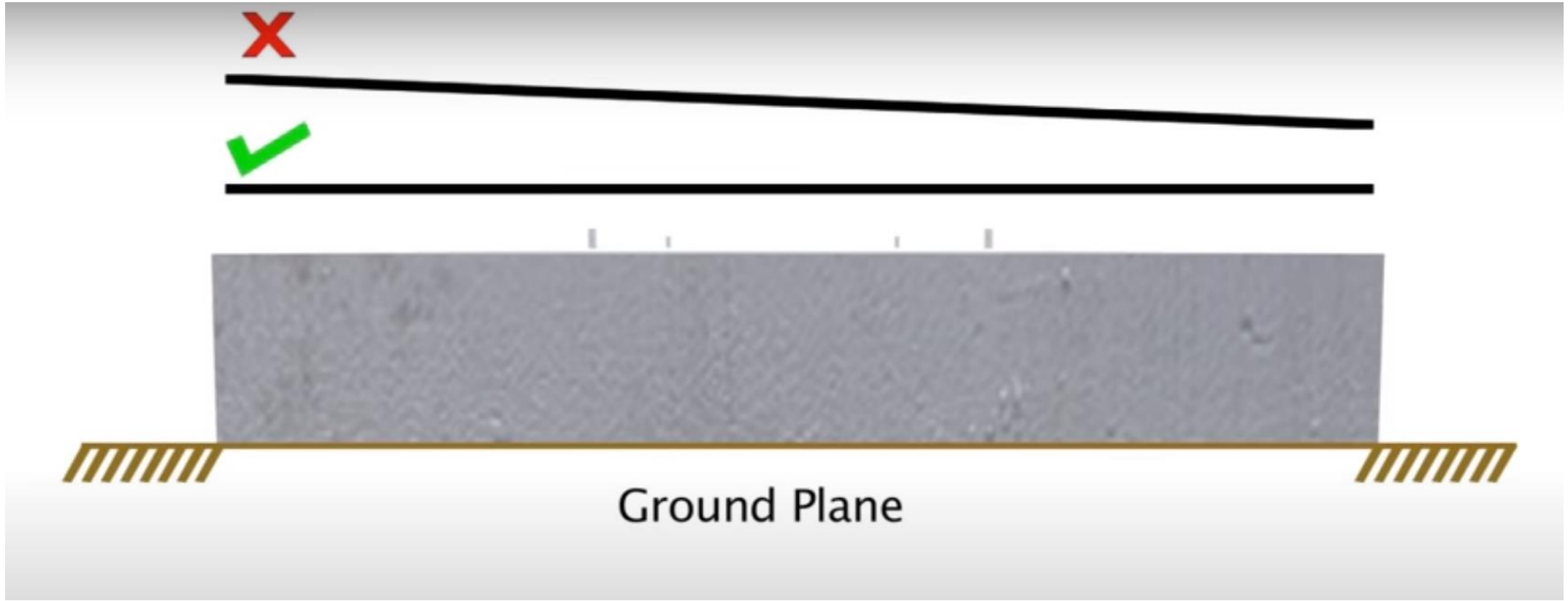
- Periodic monitoring of.....
 - Lubrication, Alignment, Vibration, Operating point, Motor temperature
- Instead of going for low initial investment i.e. Low cost Product), prefer for premium brands & evaluate LCC - Total "Lifetime" cost before making final decision on supplier.
- Lifetime energy and maintenance cost will have major contribution in Life Cycle Cost which should not remain untouched during purchasing the pumps.

The most important factor of achieving BEST EFFICIENT PERFORMANCE OF THE PUMPING SYSTEM is to select a correct service provider who understands importance of energy efficiency, correct operational logic & philosophy and periodic maintenance of pumping system and give proper & effective solutions.

Proper maintenance of the pumps & pumping system

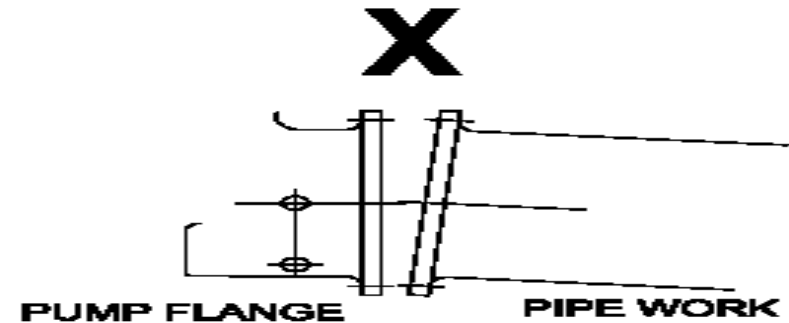
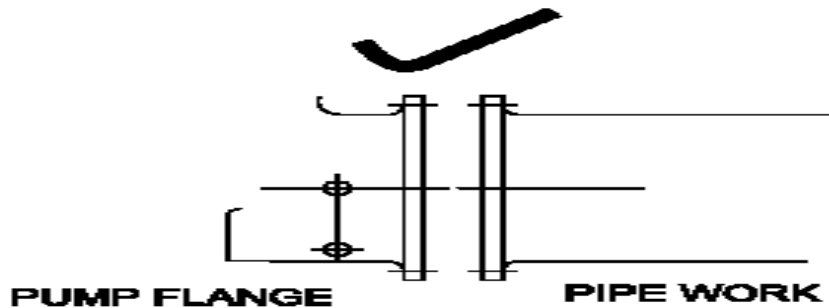
Component	Design Consideration
System considerations	Ensure a whole-system approach is used, Optimise pumping demand, Optimise pumping needs through good plant design, Avoid leakages, Optimise pumping system flow rate, Optimise the operating pressure, Select efficient pumping components, Use the latest energy prices in calculation of operating costs
Controls and operating philosophy	Consider variable-speed drives for flow management rather than throttling valves, Put pressure or flow sensors in the location that will help ensure process requirements are met without excess pumping energy, Record system trend data, Provide metering of components (such as flows, kWh)
Pump stations	Consider multiple size pumps for varying flows, Pay attention to pipework design with multiple pumps
Piping system configuration	Maximise pipe diameter, Optimise pipe layout to minimise pressure loss, Minimise pressure losses through valves and fittings, Minimise bypass flow rates.
Throttling controls	Avoid bypass lines, Avoid throttle valves, Optimise use of throttling and adjustable/ variable speed drives.
Pumps and motors	Ensure high motor efficiency, Ensure high pump efficiency, Ensure pump operates close to its BEP, Don't oversize pump, Ensure the right impeller size, Ensure the right pump type (axial, centrifugal and so on), Ensure compatibility with variable-speed drives, Check sealing method (gland packing, mechanical seal and so on).
Operations and maintenance	Put a maintenance schedule in place, Design for easy maintenance

Installation Checks :- Levelling of pump set



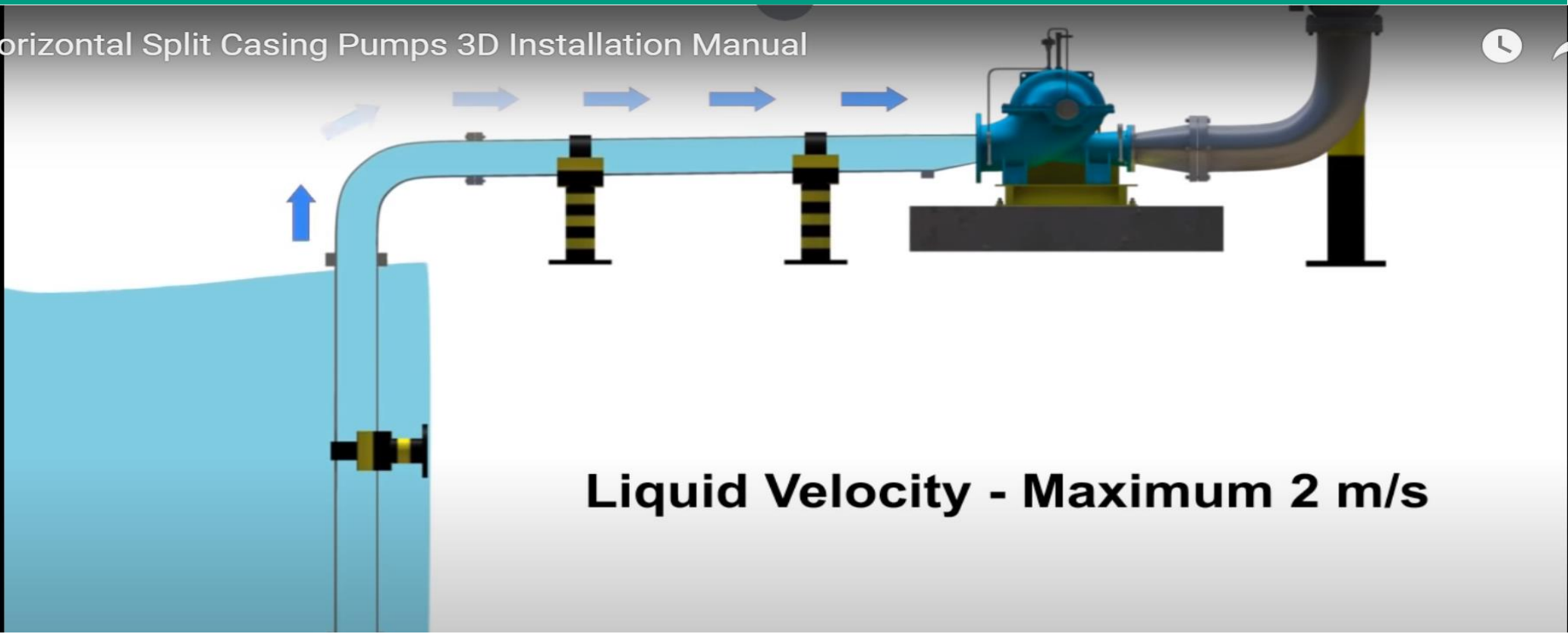
Installation Checks : Steps for Installation of Pipelines

- Piping Stress- No stress must be imposed on pump casing by pipe work- i.e. by weight of the pipe or tightening of badly fitted pipe.
- Alignment shall be rechecked before and after piping works.
- Suction line shall be with less bends and air tight i.e gaskets must be intact
- all pipe work attached to the pump must be fully supported and the mating faces of pump and pipe flanges should be parallel & bolt holes concentric



Installation Checks : Steps for Installation of Pipelines

Horizontal Split Casing Pumps 3D Installation Manual

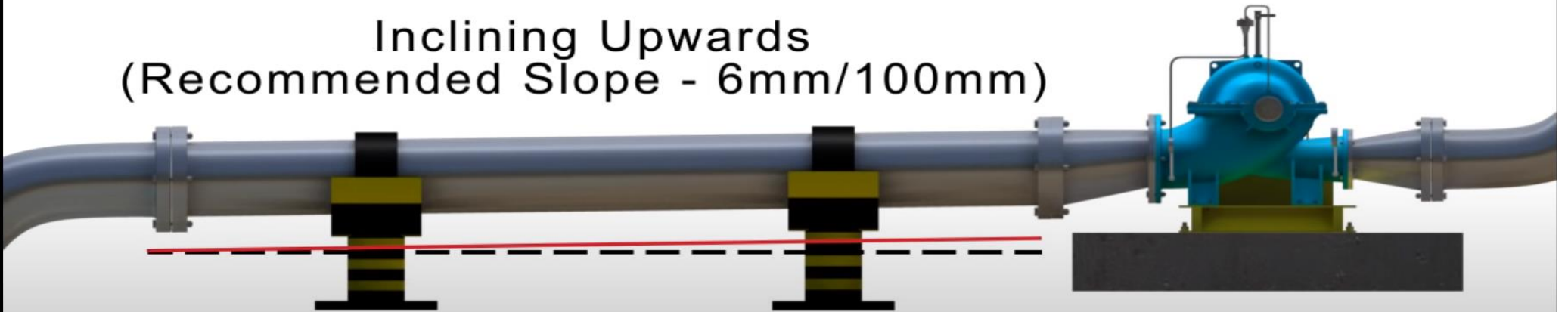


Liquid Velocity - Maximum 2 m/s

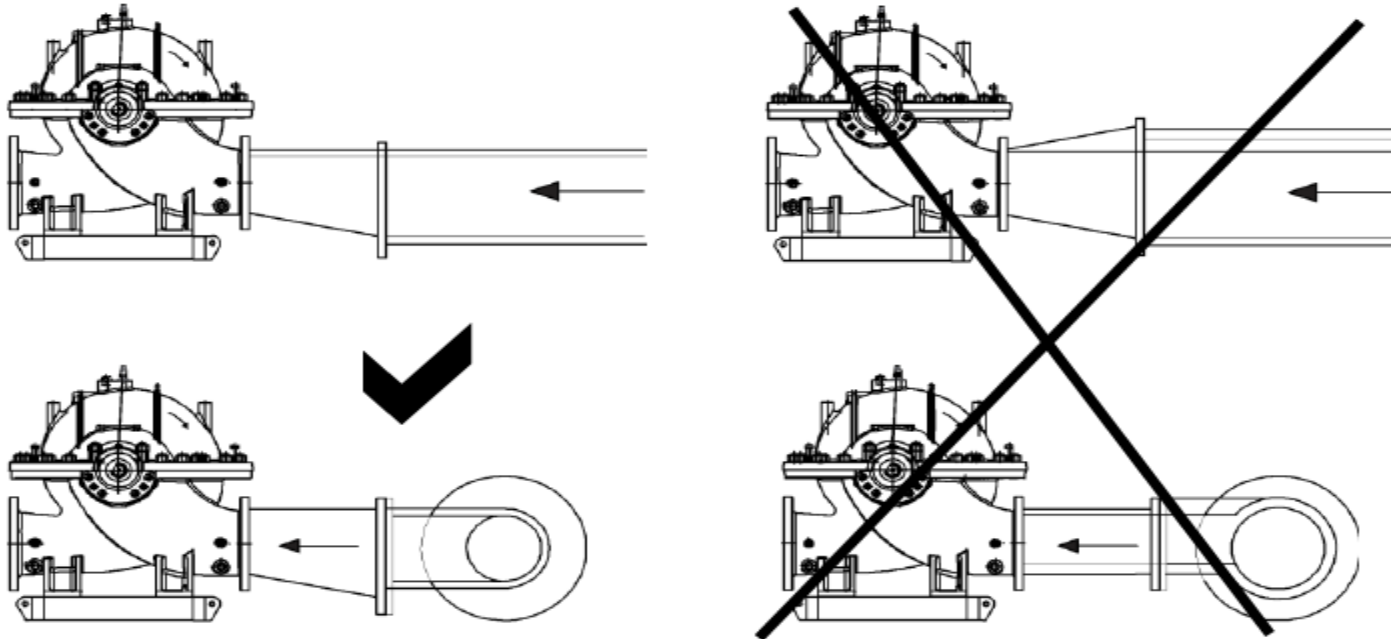
Installation Checks : Steps for Installation of Pipelines

Horizontal Split Casing Pumps 3D Installation Manual

Inclining Upwards
(Recommended Slope - 6mm/100mm)



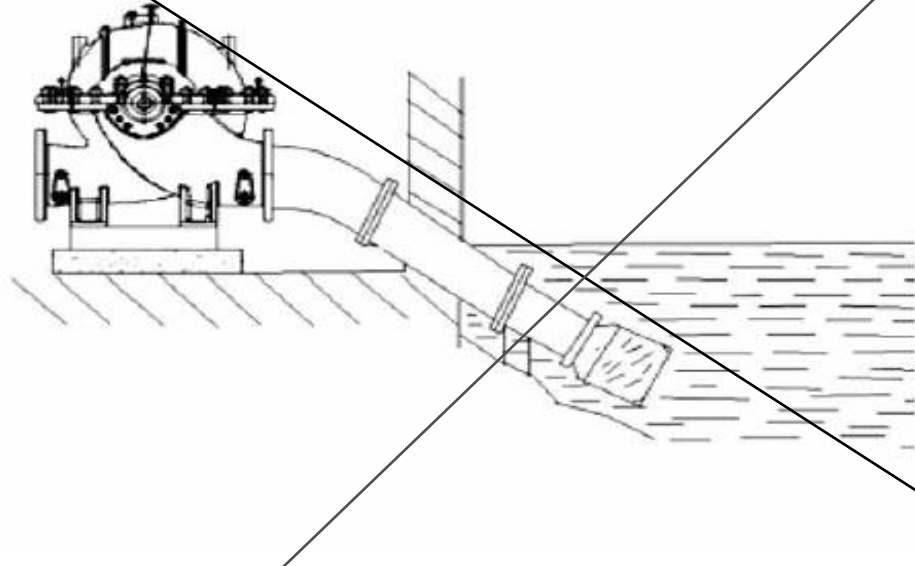
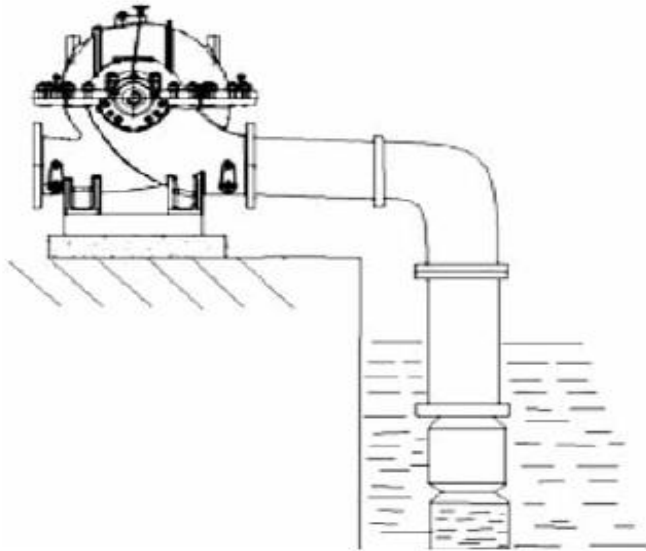
Installation Checks : Steps for Installation of Pipelines



- CORRECT ECCENTRIC REDUCER FOR SUCTION PIPELINE

- WRONG POSITION OF ECCENTRIC REDUCER IN SUCTION PIPELINE

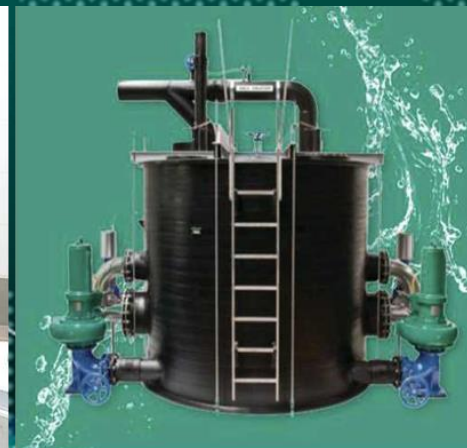
Steps for Installation of Pipelines



• CORRECT SUCTION PIPELINE

• WRONG SUCTION PIPELINE

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Thank You !

wilo