SELECTION CRITERIA

FOR

PUMPS

PAKISTAN WATER OPERATORS NETWORK

(March-2022)

PREFACE

On behalf of All water utilities in Pakistan PWON is thankful to JICA for providing Support for ***Management of Water & Sanitation Services in Punjab against Covid-19*** through which lectures / webinars were arranged January 2022, to end March 2022, for ***Better Management of Water & Sanitation Services during Outbreak*** as well *as* ***Awareness & Preventive Measures against Covid-19*** *and* ***Preparation of in house Disinfection by Water & Sanitation Utilities*****.**

On demand of PWON members, lectures for capacity building of utilities in Pakistan about various important technical topics were also added along with above lectures / webinars / seminars. All these events were well participated and appreciated by all utilities

On demand of member utilities PWON has published these lectures for capacity building and references for improvement of their day to day working for the benefit of their consumers at large. This book on the topic of **SELECTION CRITERIA FOR PUMPS** is published by PWON for the benefit of all its members.

PWON is thankful to Capt. (R) Muhammad Hafeez for Preparing this valuable document.

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CHAIRMAN
PWON, Pakistan

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1.GENERAL CRITERIA

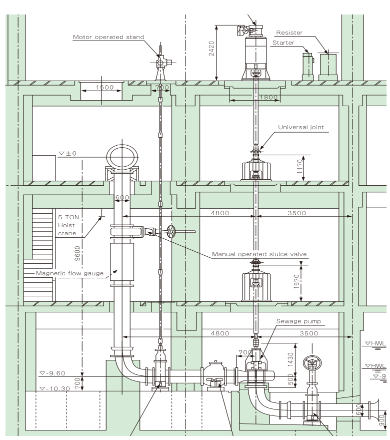
- Pump should be technically suitable for site conditions.
- Velocity in the discharge piping shall range from 2ft/s to 10 ft/s
- Life cycle cost should be minimum if it possesses acceptable technical requirements.
- In case of a small pumping station with provision of 2 pumps only, discharge capacity (to handle maximum flow) should be same.
- Where more pumps are provided there should be always standby pumps to be operated during any breakdown.
- If during off peak hours the flow is less than the individual pump capacity, there should be a small pump available to handle this flow
- Minimum solid passaging size for wastewater application may be 75 mm. For very small pump applications, the solid passing diameter may be reduced.

1.1 BIGGER IS BETTER & SLOWER IS BETTER

- Non clog centrifugal 25hp: 65%
- Vertical Turbine water,30hp:81%
- Bigger is better: add about 5 points at 200hp
- Slower is better: add a couple points below 1200 rpm
    - *(A 16 pole motor can have 375rpm)*

2.Selecting type of pump for wastewater

- Dry well pumps
    - ◆ Vertical
    - ◆ Horizontal
- Submersible Pumps



2.1 Conventional dry well pumps

- Traditional dry-well pump installations are designed mainly in conjunction with large, vertical pumps.
- The dry well is located separate to the wet well, connected via a series of pipes. Traditional dry well pumps involve the use of non-submersible motors.
- Traditional dry-well pump designs have either been close-coupled, or long-coupled.
- Close-coupled pumps contain a motor that is bolted directly to the pump end, with the motor shaft extended through the pump. They benefit from automatic correct alignment, as well as a more compact footprint for smaller civil structures.
- In long-coupled pumps, the motor is connected to the pump with a separate coupling device with bearings in a housing which forms part of the pump end. The advantage of such a design is that the motor can be removed without disturbing the rest of the pump. It is also easier to access the mechanical seal and bearings without removing the motor.

2.2 Submersible Pumps

• A **submersible pump** is a device the whole assembly is submerged in the fluid to be pumped.

• It has a **hermetically sealed motor** connected to the pump body that helps to push the fluid toward the surface.

2.3 ADVANTAGES SUBMERSIBLE PUMPS

- The significant benefit of this pump is that it can **prevent the pump from cavitation**—
- It has quiet working
- Pumping stations with submersible pumps do not require a dry well.

2.4 DISADVANTAGES SUBMERSIBLE PUMPS

- The submersible water pump is **hermetically sealed, which rusts over time.** Therefore, water can enter the motor and damage its parts.
- Require **sufficient time for repair** due to shifting to manufacturers workshops for motor or seal repairs.
- Lack of water can lead to motor overheating.
- The pump is submerged, so the pump failure can't be found quickly.
- If the pump is not completely submerged, it may cause significant damage.
- Submersible pumps are not successful for wastewater due to heavy amount of floating material and poor screening in Pakistan Utilities.

2.5 Selecting Pumps for Tubewells

Submersible pumps

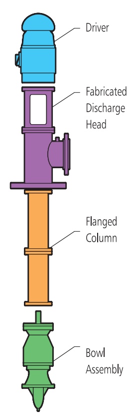
- Submerged motor and pump with cables coming outside to the electric panel
- Only discharge pipe outside

Vertical turbine pumps

- VT pump is installed with control at ground level.
- Motor is at ground level.


2.6 Comparison of Submersible and Line shaft turbine pumps for tubewells

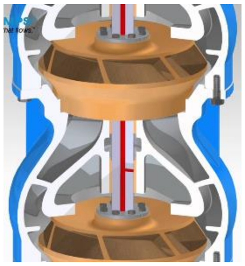
Submersible	Line shaft
If the seal or the motor fail for any reason, the whole pump (and motor) must be pulled for repair.	Installing the pump motor at ground level significantly reduces the cost of installation, repair, inspection
Sufficient time taken for repair due to shifting to manufacturers workshops for motor or seal repairs.	Line shaft pumps are repaired locally as qualified technical staff and spares are available in all big cities
Power factor is less	Power factor is more than submersible motor
A submersible motor is more susceptible to failure due to overload conditions,	Above ground motor is more reliable
Less operation noise	More operation noise



2.7 How do bowl assembly works?

- Vertical turbine pumps work when water enters the pump at the bottom through a bell-shaped part called the suction bell.
- From there it moves into the first stage impeller, which raises the water's velocity.
- The water then enters the diffuser bowl immediately above the impeller, where this high velocity energy is converted into high pressure.

- The bowl also directs the fluid into the next impeller located immediately above the bowl, and this process continues through all of the stages of the pump.



2.8 All stages have equal flow rate.

Consider 3 pumps in series

1. Number of stages/impellers/bowls are increased or decreased as per requirement of head only.
2. All stages have equal flow rate are are interchangeable.

3 Selection Criteria for all types of pumps

1. **Flow rate** – volume of water pumped by a pump per unit of time. It is denoted by letter Q and has dimension in m^3/h
2. **Head :** The height to which a pump can raise the water is the pump head and it is measured in meters (feet)
3. **Shaft power** – power consumed by pump during operation.
4. **Efficiency:** Efficiency
5. **NPSH available** must be greater than NPSH required given by the manufacturer.
6. **Installation type** (vertical, Horizontal)
7. **Material** [cast iron, steel, SS]
8. **Liquid Type** [clean water, wastewater]

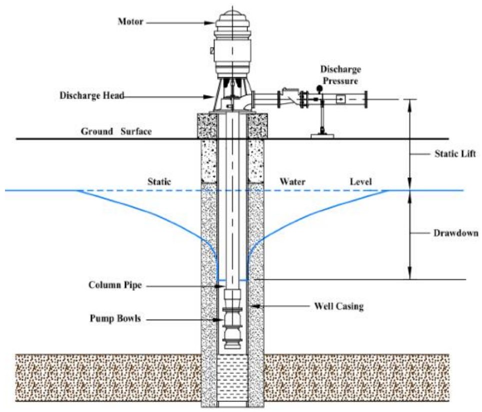
3.1 Additional information for Pump Selection for Tubewells

1. Static Water Level
2. Pumping water level
3. Well yield
4. Well Tests/Specific Capacity
5. Depleting water table trend

3.2--CALCULATION OF FLOW RATE

1. Peak dry weather flow+ ground water infiltration+ Rain water and infiltration for wastewater
2. For clean water, as per requirement of capacity
3. For a tubewell, Well yield:
1. Determining the balance between the maximum amount of water that can be pumped out of the well and the amount of water that recharges back into the well from the surrounding ground water source.
2.

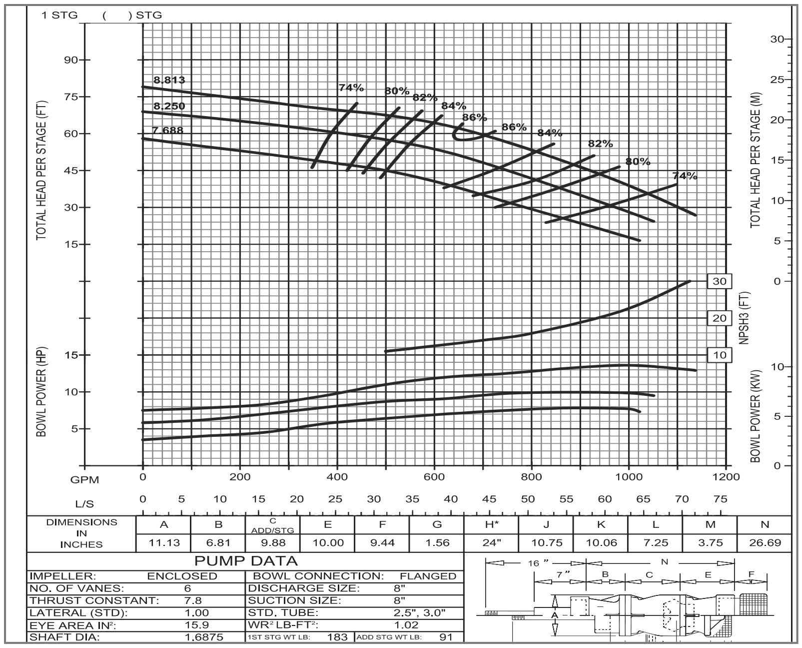
3.3 --Calculation of Head



1. Static water level=100
2. Drawdown=20
3. Pressure at delivery=20psi=46.2
4. assumed loss per foot of column=0.05
5. total length of column=250
6. Total loss of head =250*0.05 =12.5feet
7. Total head required= 100+20+46.2+12.5 =**178.7 feet**

3.5 CALCULATION OF NUMBER OF STAGES/BOWLS FOR VT PUMP

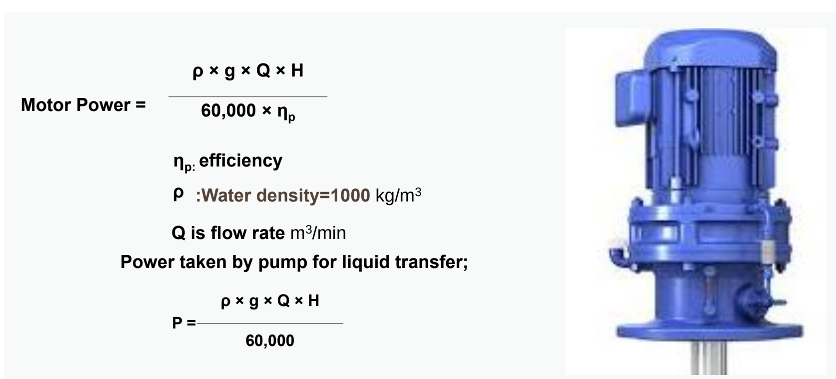
1. Head per stage from performance curve=45 feet
2. Number of stages/bowls required =178.7/45 =3.97=4
3. Shaft diameter =1.6875 inches



3.6 Calculation of tubewell screen dia, Length & well yield

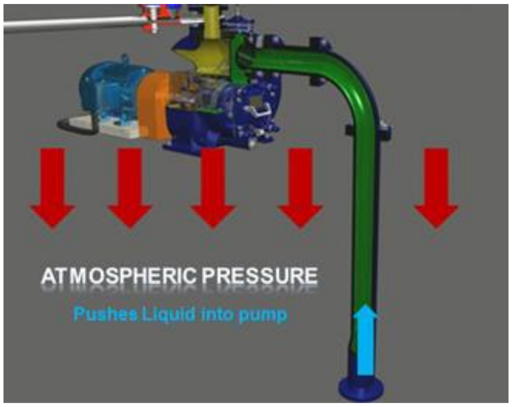
1. Calculation of possible well yield for the design of screen length
2. Q = πD× Length of screen× opening ratio×(1 – Clogging ratio)×V
3. D: Screen Diameter (m)
4. L: Screen length (m)
5. Opening ratio of screens (10%)
6. Clogging ratio of screens (30%)
7. V: Inflow velocity into screens (USA standard = 0.03 m/sec)
8. 3.1428×D×30×0.1(1-0.3) ×0.03=0.0283m3/sec=1 cusec
9. D=0.143m=5.6 inches
10. say 6 inches

3.7 Motor power required

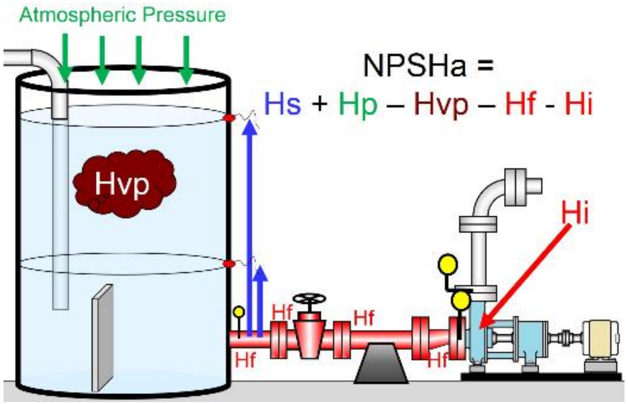


3.8 PUMPS DON'T SUCK

1. Pumps DO NOT SUCK liquid into the pump.
2. Rather, atmospheric pressure pushes water into the pump keeping the liquid in its natural state.
3. Even self-priming pumps don't suck liquid into the pump. Because of their design and ability to handle air, atmospheric pressure pushes liquid into the pump by lowering the pressure on the suction side of the pump.
4. Atmospheric pressure is 14.7 psi=33.9 feet
5. So this is the atmospheric pressure minus pressure losses that reaches at suction port of a pump
6.



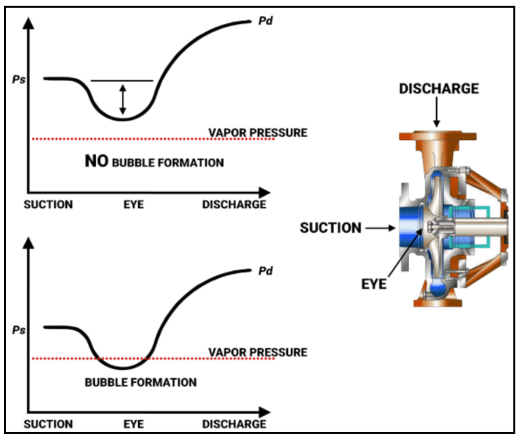
4.Net Positive Suction Head (N.P.S.H)



1. "N.P.S.H. can be defined as the combination of atmospheric pressure and static suction head that causes liquid to flow thru the suction piping and finally enter the eye of the impeller."
2. The difference between inlet pressure and the lowest pressure level inside the pump is called NPSH:
3. NPSH is therefore an expression of the pressure loss that takes place inside the first part of the pump housing.

4.1 NPSH REQUIRED & NPSH AVAILABLE

1. NPSH Required (NPSHR): The minimum pressure required at the suction port of the pump to keep the pump from cavitating is called NPSHR .
2. (NPSH)R is provided by the manufacturer.
3. NPSH Available (NPSHA):
4. The absolute pressure at the suction port of the pump.
5. NPSHA is a function of your system and must be calculated.
6. NPSHA must be greater than NPSHR for the pump system to operate without cavitating.
7. Put another way, you must have more suction side pressure available than the pump requires.

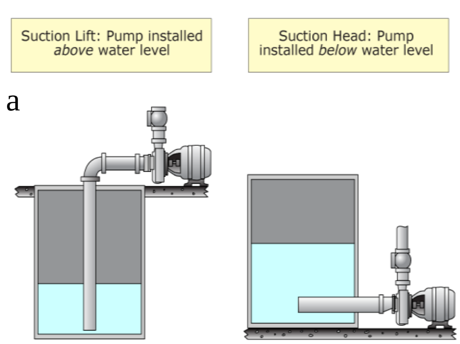


1. The pressure drops considerably as the fluid enters the eye of the pump.
2. This happens for two main reasons:
    1. the velocity as the fluid approaches the eye increases which decreases pressure
    2. also friction and turbulence further decreases pressure.

The pressure can be low enough that the liquid will start to boil at this low pressure

4.2 SUCTION HEAD

1. Positive suction head occurs when the top of the water source is above the suction Inlet of the pump.
2. Negative suction head refers to suction lift (like from a pond, tank lower than the pump, etc.)



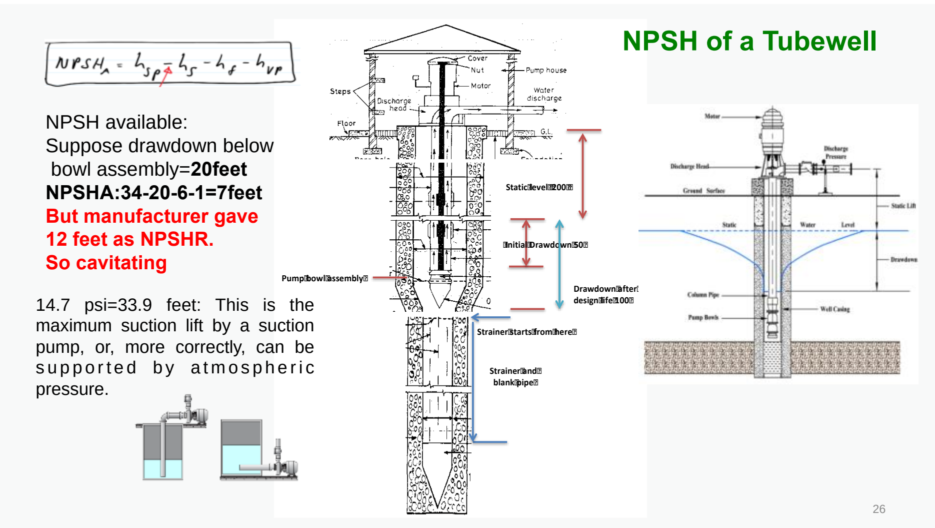
4.3 CALCULATING NPSH AVAILABLE

$$\boxed{NPSH_A = h_{sp} - h_s - h_f - h_{vp}}$$

1. Suppose Suction Head (hs) is 22 feet
2. Atmospheric pressure(hsp) may be taken as 14.7PSI or 34 feet.
3. Friction losses in the suction piping(hf)=1feet
4. Absolute vapor pressure of the liquid at the pumping (hvp)=1 feet
5. $NPSH_A$=34-22-1-1=10 feet
6. A rule of thumb is NPSHA should be at least 10 feet more than NPSHR.
7. hsp: Atmospheric pressure
8. hs: Suction Head
9. hf: Friction losses in the suction piping
10. hvp: Absolute vapor pressure of the liquid at the pumping temperature

4.4 NPSH AVAILABLE

1. Now if manufacturer has given NPSHR less than 10 feet it is ok,
2. but if NPSHR is greater than 10 it means that either the design of civil structure is wrong and made without consulting the pump curves or pumps have been selected without calculating available NPSH according to foundation of the pump, placement of suction and wet well and delivery pipe with fittings etc.
3. In this case the pumps may be cavitating (less efficient, noisy, vibrating and damaging parts)



4.5 CAVITATION Popping sounds, or sound like it's pumping marbles

1. In a centrifugal pump, the fluid's pressure is at a minimum at the eye of the impeller.
2. If the pressure here is below the vapour pressure of the fluid, bubbles are formed.
3. As the bubbles pass into this higher pressure region, they can spontaneously collapse in a damaging process called cavitation.
4. Cavitation also results in vibration and noise in the pump, damaging other parts also.
5. When each of these tiny bubbles collapses or bursts, around impeller due to high pressure, it creates a high energy shock wave inside the liquid.

4.6 The power of bubble implosion

1. Sound travels at **4,800 ft** per second in water.
2. The velocity head formula gives a close approximation of the energy contained in an imploding cavitation bubble.
3. Using the velocity head formula:
4. $Hv=V^2/2g=$ **$(4{,}800)^2$ /2** x **(32.16)** =**358,209 ft**
5. **=155,000 PSI**
6. This is the reason that the damage from cavitation appears like someone was beating on your impeller with a large ball pin hammer

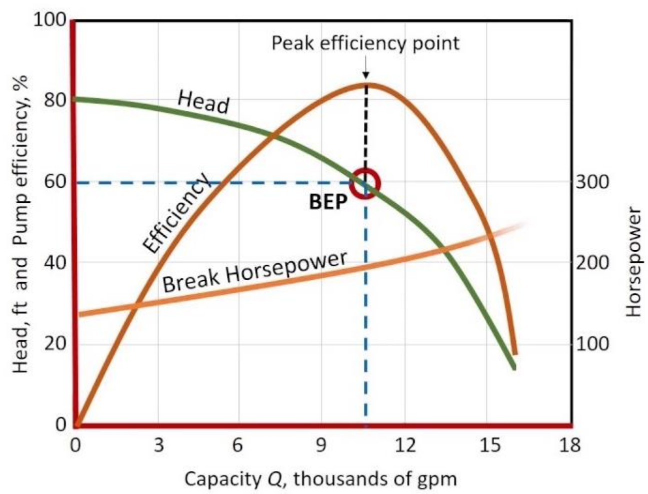
4.7 DAMAGE DUE TO CAVITATION

1. As cavitation can destroy pump parts and is usually accompanied by vibration.
2. Cavitation in pumps has to be avoided by providing adequate submergence to suit the limitations of the pump.

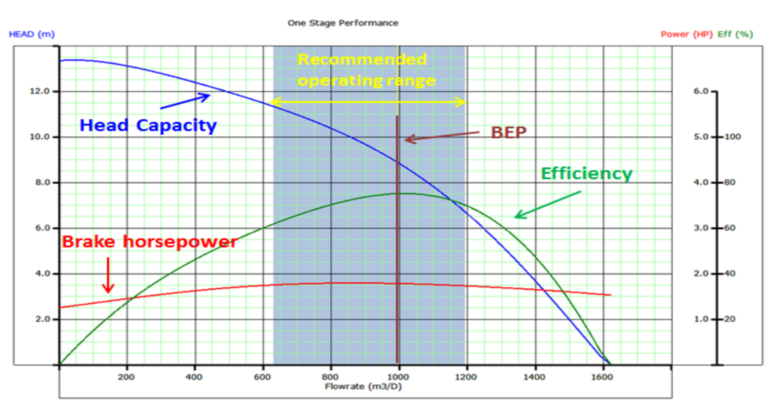
5--Final selection is made on pump performance curves

- Now you have all the requisite data like:
- pump efficiency,
- flow rate,
- Pump head
- NPSH(A).
- The final selection will be made on pump performance curves. Manufacturer will give the NPSH(R)

5.1 PUMP PERFORMANCE CURVES



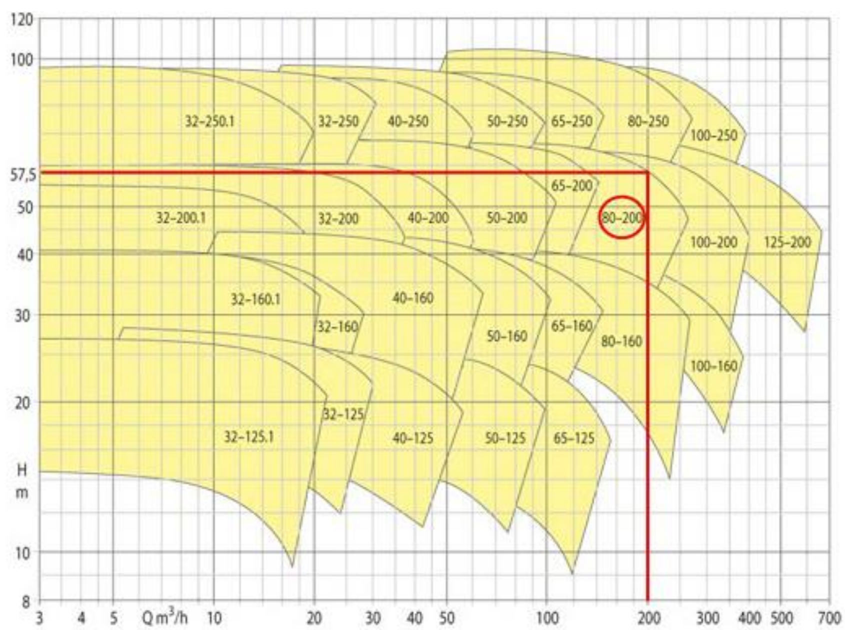
5.2 Further explanation: Pump operating Region



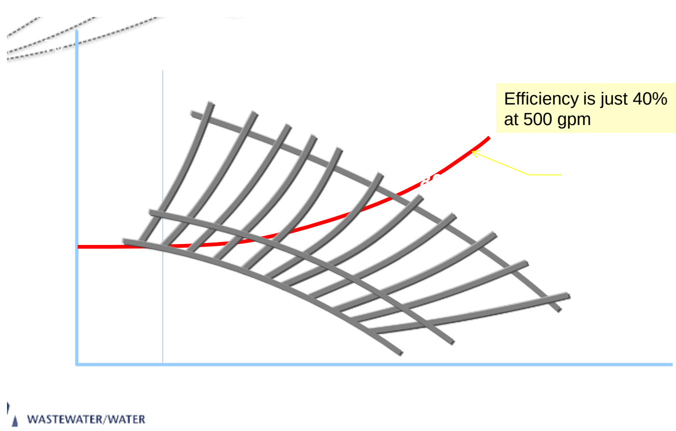
The Hydraulic Institute (HI) has defined pumps operating regions (ANSI/HI 9.6.3) as flows:

- Preferred Operating Region from 70% to 120% of flow at BEP for most centrifugal pumps.
- Allowable Operating Region (AOR). This is the region that comprises all of the points that this pump can operate at continuously. 40 % of BEP

Selection of suitable model of Pump from performance Curves



5.3 What if pump rpm changed?



With impeller diameter (D) held constant

$$\frac{Q_1}{Q_2} = \left(\frac{N_1}{N_2}\right)$$

Law 1b. Pressure or Head is proportional to the square of shaft speed:

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$$

Law 1c. Power is proportional to the cube of shaft speed:

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3$$

Law 2. With shaft speed (N) held constant: [1]

Law 2a. Flow is proportional to the impeller diameter:

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)$$

Law 2b. Pressure or Head is proportional to square of impeller diameter:

$$\frac{H_1}{H_2} = \left(\frac{D_1}{D_2}\right)^2$$

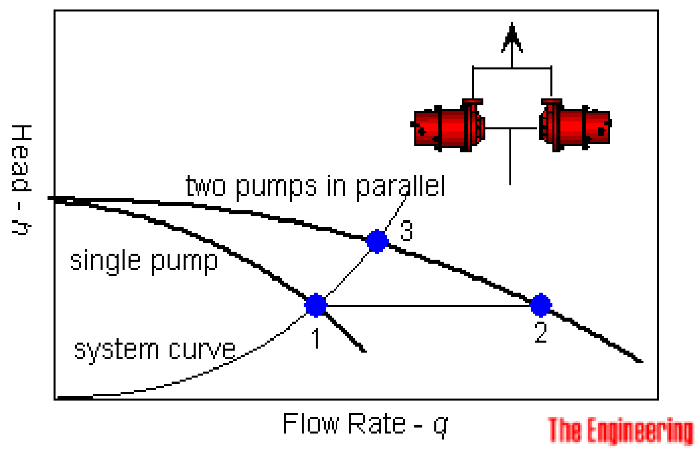
Law 2c. Power is proportional to the cube of impeller diameter:

$$\frac{P_1}{P_2} = \left(\frac{D_1}{D_2}\right)^3$$

6 Criteria for selection of additional pump for an existing pumping station

6.1 Two identical pumps parallel operation

- For two identical pumps in parallel and the head kept constant - the flow rate doubles compared to a single pump as indicated with point 2
- In practice the combined head and volume flow moves along the system curve as indicated from 1 & 3.

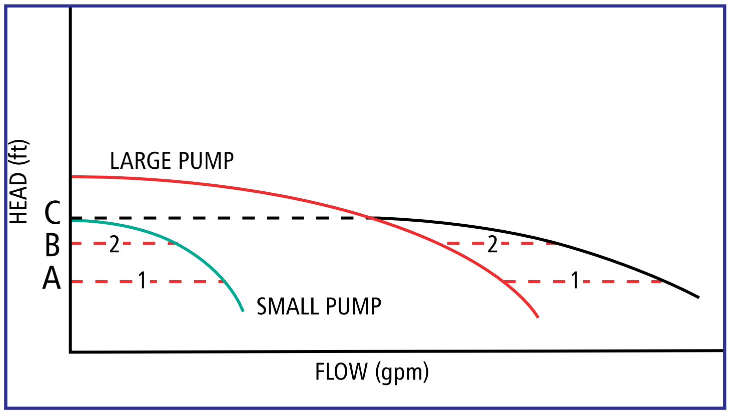


- point 3 is where the system operates with both pumps running
- point 1 is where the system operates with one pump running
- In practice, if one of the pumps in parallel stops, the operation point moves along the system resistance curve from point 3 to point 1 - the head and flow rate are decreased.
- Two pumps in parallel will deliver less than twice the flow rate of a single pumps in the system because of the increased friction in the delivery pipe.
- **You will need to increase the delivery pipe size**

6.2 Dis-similar Pumps in Parallel

- When two or more pumps are arranged in parallel their resulting performance curve is obtained by **adding the pumps flow rates** at the same head.

- At "A" head, the small pump provides Flow "1", which is added to the greater flow provided by the larger pump.
- At "B" head, the smaller pump adds Flow "2" to that of the larger pump.
- Point "C" is the shut-off head for the smaller pump, so at that value of head, the smaller pump can't add anything to the flow of the larger pump. This produces a discontinuity.



Small Lower Head Pump; "Piggybacks" its Flow-Head Curve onto Larger Pump

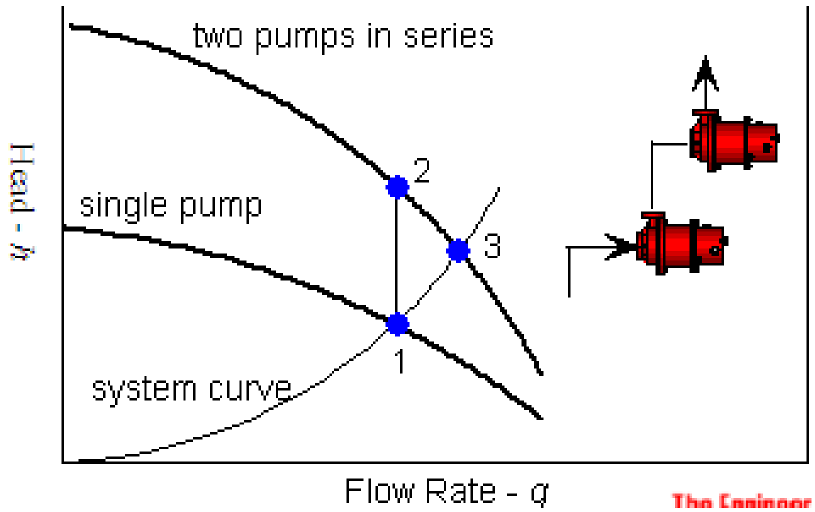
6.3 Dis-similar Pumps in Parallel

- If the larger pump will provide more head than the smaller pump's shut-off head, closing the smaller pump's check valve.
- Prolonged operation against a closed discharge valve (dead heading) can result in severe damage to a centrifugal pump.
- As a general rule, always start the weaker pump first.
- When running one pump for small loads and then starting the second pump to pick up larger loads, do not let the first pump run out on its curve too far before the second pump is started. The first pump may be cavitating for some time before the second pump picks up.

6.4 Series Pumping

- For two identical pumps in series the head will be twice the head of a single pump at the same flow rate - as indicated with **point 2.**
- With a constant flow rate the combined head moves from 1 to 2 -
- **BUT** in practice the combined head and flow rate moves along the system curve to point 3.
- **point 1** is where the system operates with **one pump** running

- when the system goes to single pump operation, the flow delivered by the single pump will decrease because of system friction losses (because system is designed for a certain head and flow.



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