Wallace Eannace Associates, Inc.

Centrifugal Pump

Fundamentals

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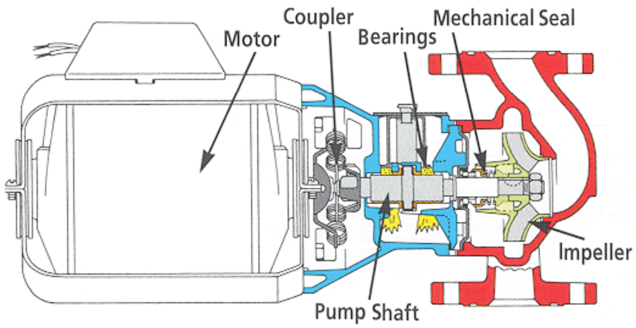
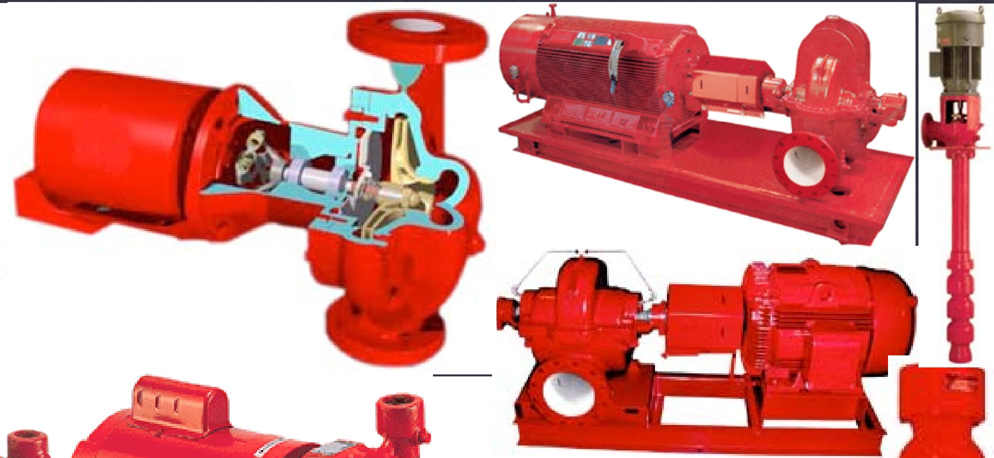
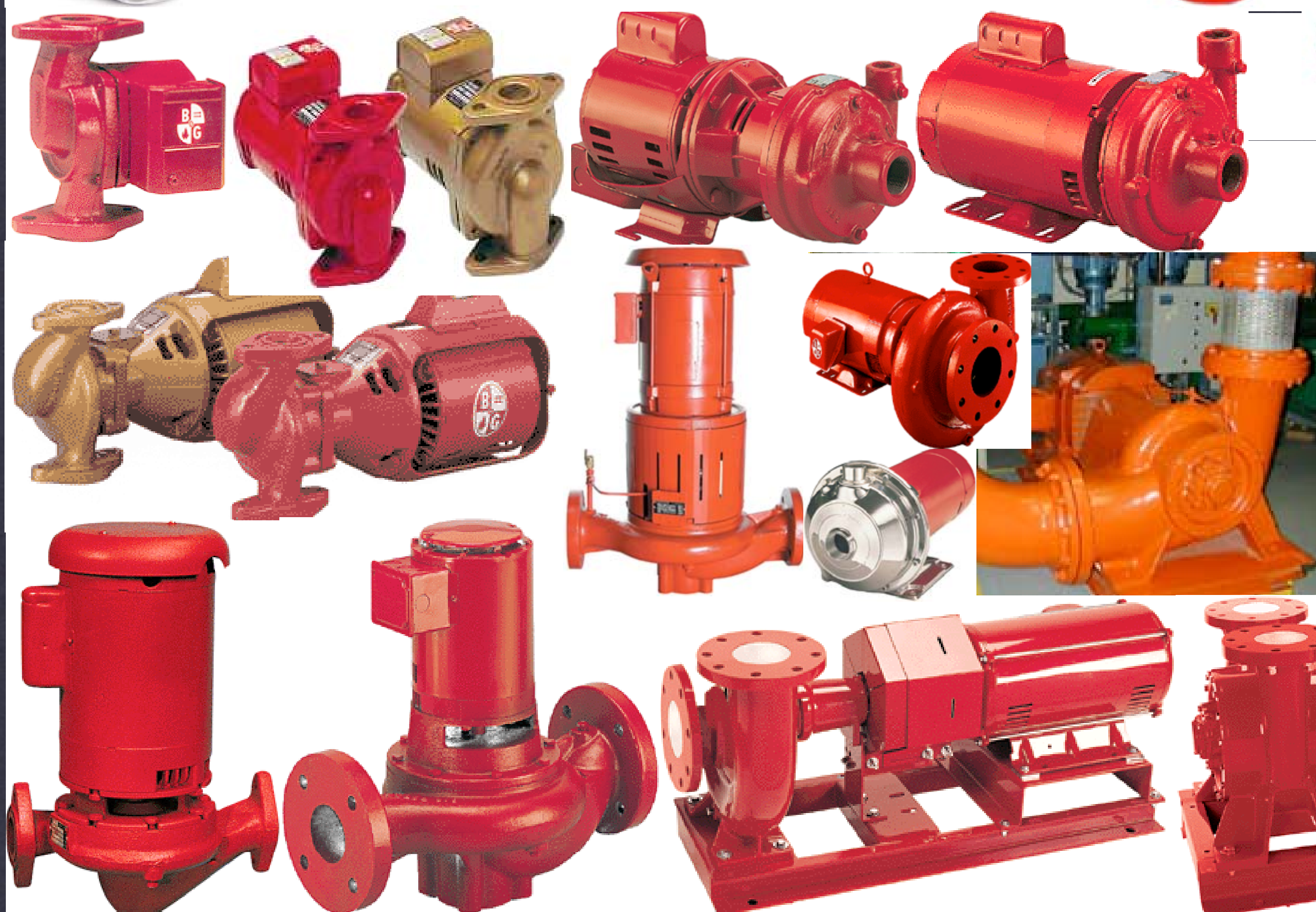
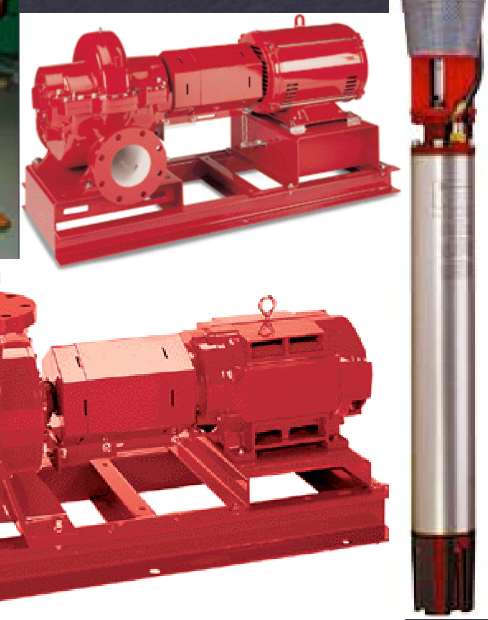
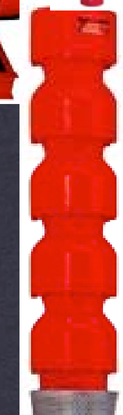




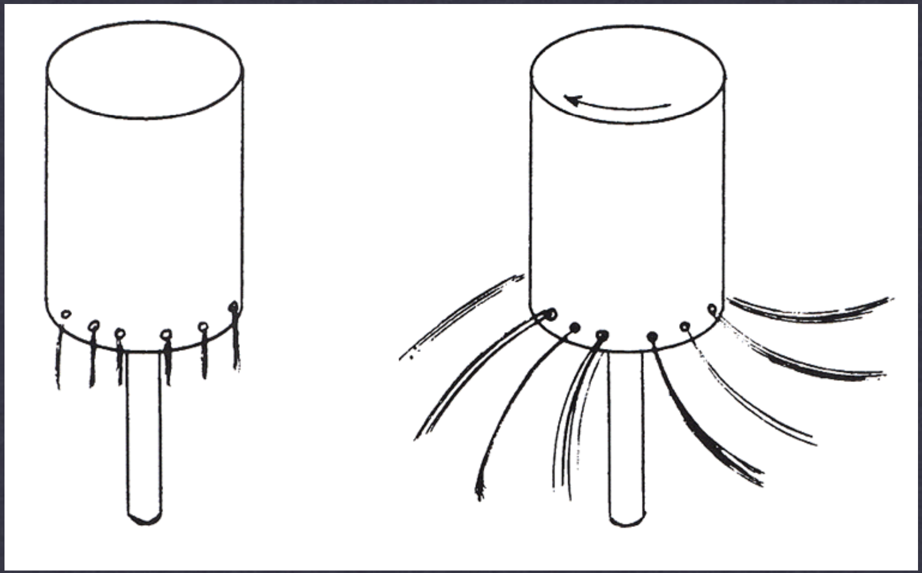






B&G Family of Centrifugal Pumps

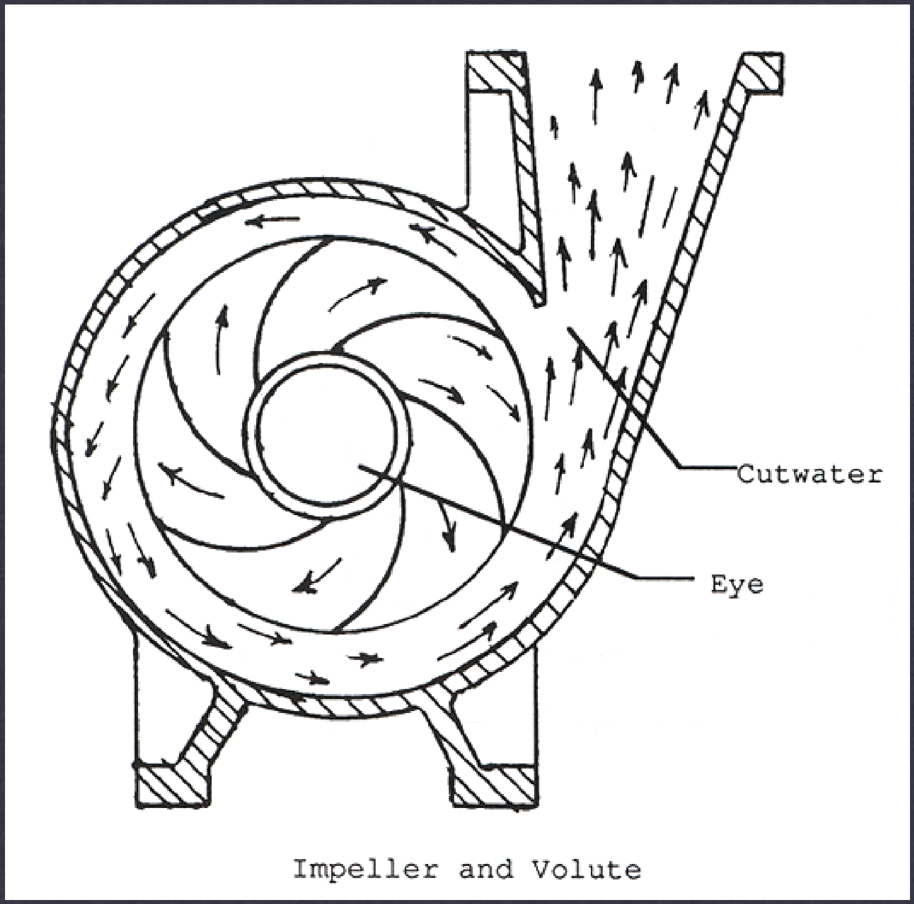
Principles of Centrifugal Pump Operation



The Centrifugal pump is designed on the principle of imparting velocity to the liquid it is handling, then directing the liquid with its higher velocity to the point of use.

The velocity is created using “centrifugal force”, which is generated whenever an object is rotated around a central axis.

Pump Design

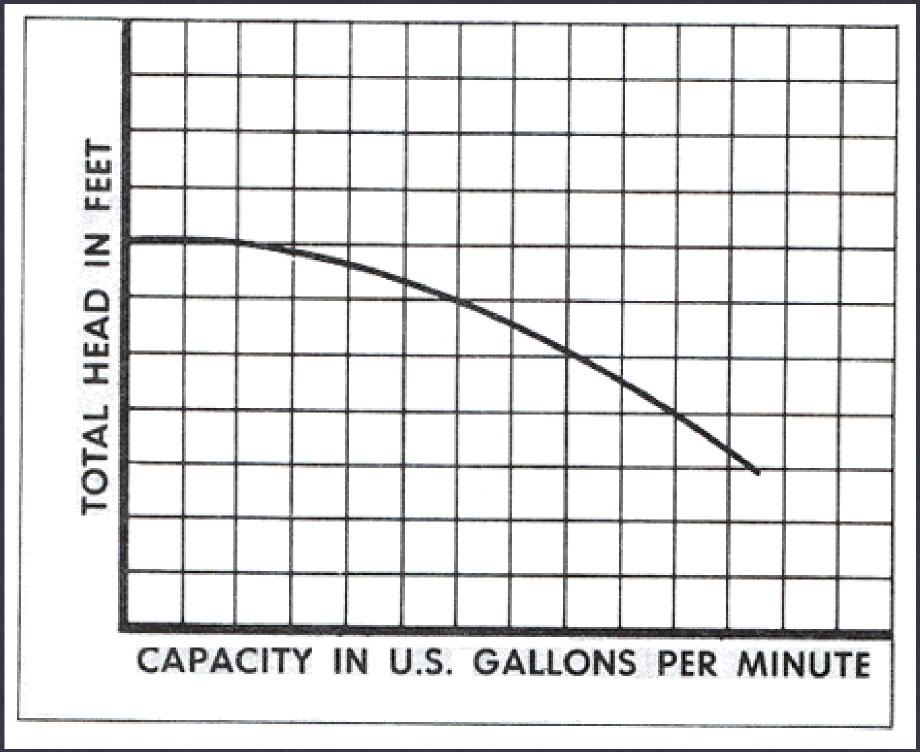


Kinetic energy (high velocity) can be converted into potential energy (pressure) and back again.

The velocity pressure created by the pumps speed and narrow cambers expanses towards the volute discharge converting the energy to static pressure or static head.

Note: Reverse rotation of the impeller will greatly reduce the flow rate, cause turbulence and greater motor loading.

Developing the pump curve



Head is a measurement of energy

Pump performance is shown by measure of a plotted curve which relates to flow (gpm) to pressure head produced (head in (ft) of fluid)

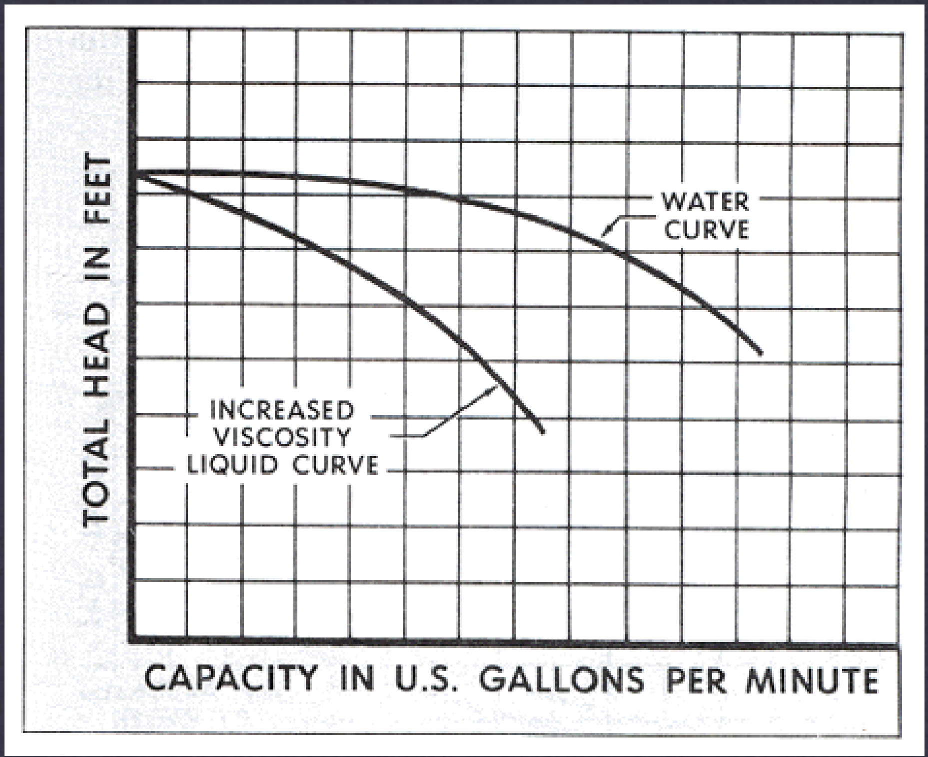
The centrifugal pump produces energy in the form of foot pounds per pound of water pumped, and dependent on the volume flow rate passing through the impeller.

Energy as foot pound per pound is shortened to foot head (FT*LB/LB) = FT

Because the curve is a statement of energy (FT Head) it is not affected by temperature or density.

Density does affect pump power requirements however.

Developing the pump curve



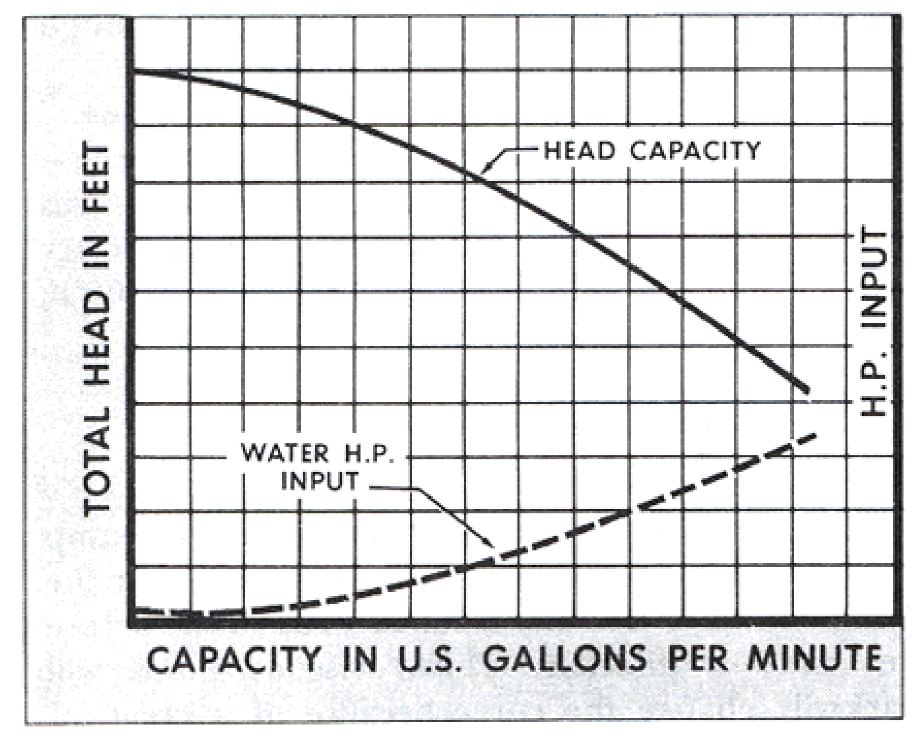
Viscosity affects pump curves

A change in viscosity of the fluid being pumped can change the pump curve.

Thick, viscous fluids will markedly change the curve because of a greater increase in the viscous shear force of the fluid being pumped.

Increased fluid viscosity will also affect pump power requirements because of increased "drag" of the fluid within the pump.

Water Horse Power Input



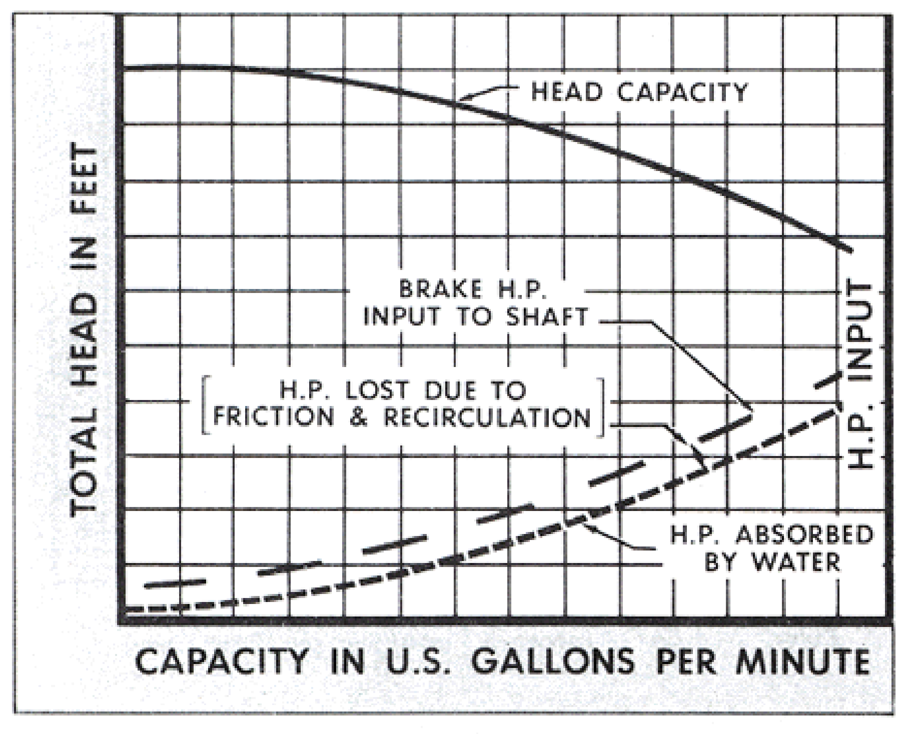
$$\text{Water HP} = \frac{\text{GPM} \times \text{Head} \times \text{sp. gr.}}{3960}$$

Water horsepower is zero at no delivery and increases with increasing flow - illustrating one of the important characteristics of centrifugal pumps -

Power requirements generally increase with flow - even thought head decreases.

This is important since an oversized pump - a unit operating at greater flow than design point - will draw more horsepower and may overload the motor.

Total BHP Curve



Pump efficiency in per cent is: $\frac{WHP \times 100}{BHP}$

$$BHP = \frac{WHP}{Eff./100}$$

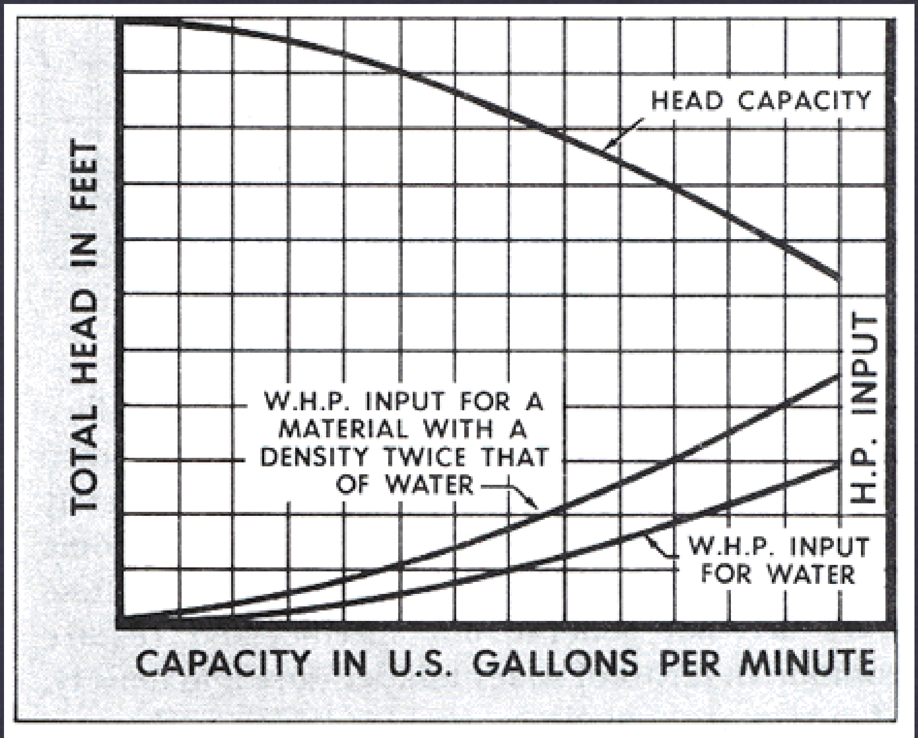
Actual power requirements at the pump shaft are greater than the power absorbed by the pumped water.

This is because of friction losses in the bearings, water friction itself, and recirculation within the pump.

These additional losses factor into the pump efficiency.

The difference in power requirements from the ideal is referenced as pump efficiency.

Fluid Density effects on Water HP



$$\text{Water HP} = \frac{\text{GPM} \times \text{Head} \times \text{sp. gr.}}{3960}$$

$$\text{Pump efficiency in per cent is: } \frac{\text{WHP} \times 100}{\text{BHP}}$$

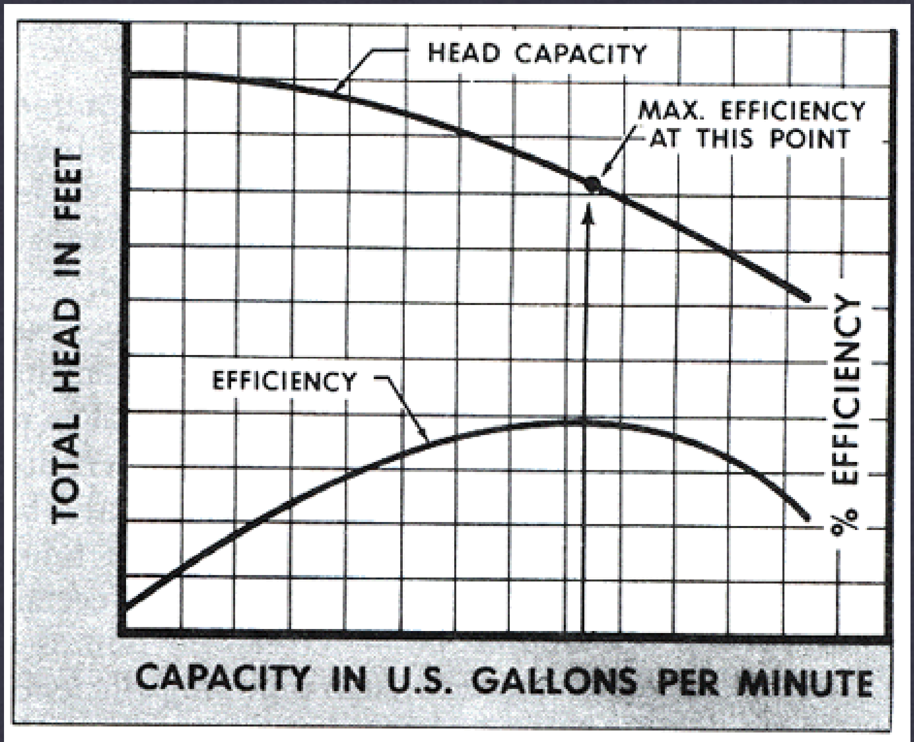
Water horsepower also increases with fluid density - even though the head capacity curve is not changed.

This is because at any fixed flow point (gpm) more mass (more pounds per minute of fluid) is being pumped at the higher fluid density.

If a fluid with twice the density of water is pumped, the required water horsepower would be doubled.

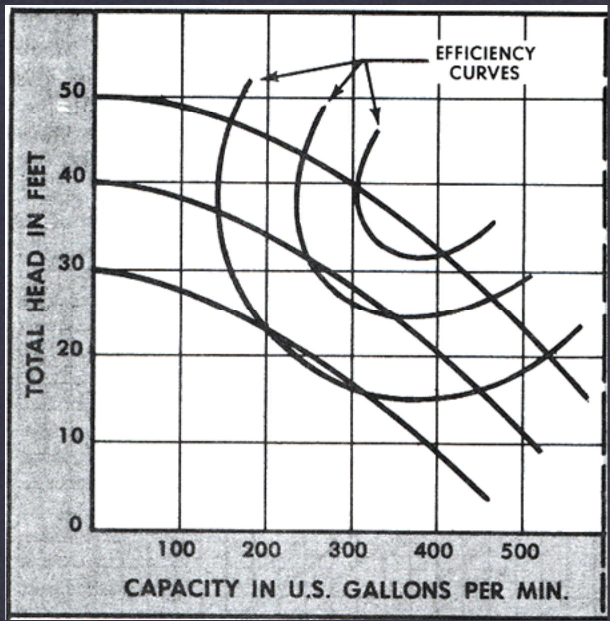
The affect of fluid density must be taken into account when evaluating horsepower requirements for fluids other than water.

Pump Efficiency Curves



Efficiency decreases as flow either increase or decreases from its design point.

Pump efficiency tends to increase with larger pump sizes. This is because bearing and other mechanical and internal hydraulic losses become a smaller proportion of required pump shaft BHP.



Maximum efficiency occurs at a particular point or within a range on the pump curve.

Pump Affinity Laws

Flow (gpm) ~ Speed (rpm) ~ Impeller Diameter
[Head (ft)]^2
[Power (bhp)]^3

	GPM Capacity	Ft. Head	BHP
Impeller Diameter Change	$Q_2 = \frac{D_2}{D_1} Q_1$	$H_2 = \left(\frac{D_2}{D_1}\right)^2 H_1$	$P_2 = \left(\frac{D_2}{D_1}\right)^3 P_1$
Speed	$Q_2 = \frac{R_2}{R_1} Q_1$	$H_2 = \left(\frac{R_2}{R_1}\right)^2 H_1$	$P_2 = \left(\frac{R_2}{R_1}\right)^3 P_1$

Where Q = GPM, H = head, P = BHP
D = impeller dia., R = RPM

$$\frac{Flow\_b}{Flow\_a} = \frac{Speed\_b}{Speed\_a} = \frac{Imp.\ Dia.\_b}{Imp.\ Dia.\_a} = \frac{[Head\_b]^2}{[Head\_a]^2} = \frac{[Power\_b]^3}{[Power\_a]^3}$$

1. Pump flow (gpm) capcity varies directly with the speed (rpm) or the impeller diameter ratio change

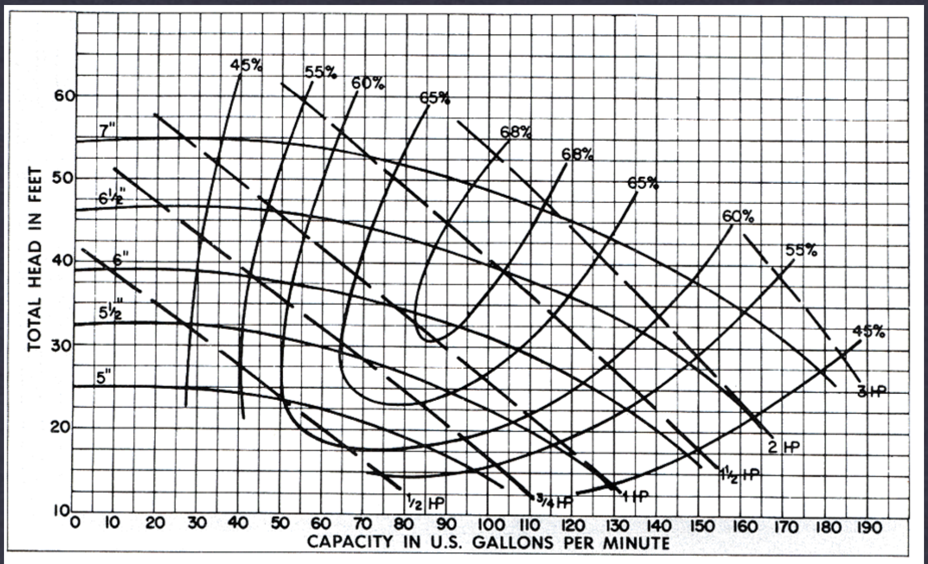
2. Pump heat (ft) varies directly as the square of the speed (rpm) or impeller ratio change or flow (gpm)

3. Power (BHP) varies directly as the cube of the speed (rpm) or (dia) or (gpm)

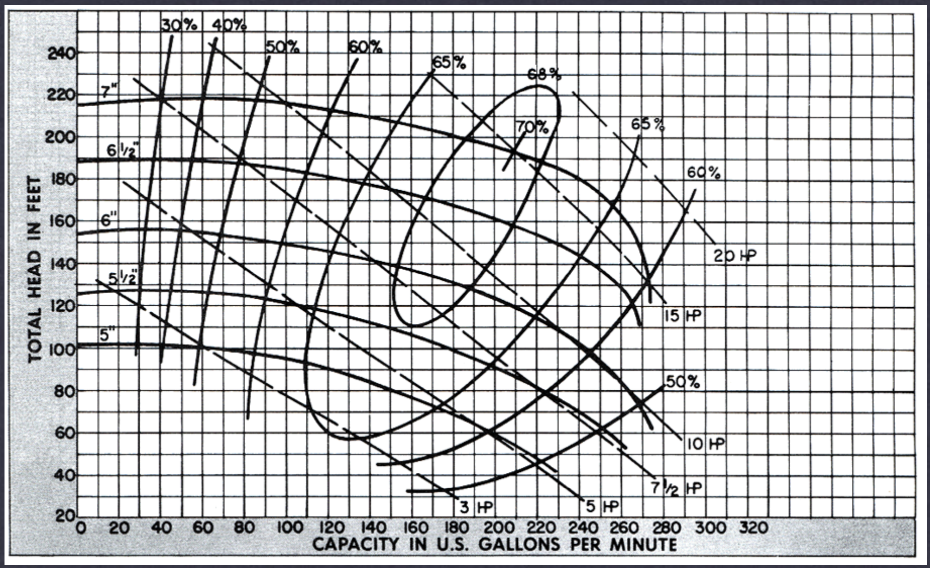
Pump affinity laws can be used to resize impellers on pumps known to be providing excessive system flows.

Pump affinity laws can also be applied to pump selection for speeds different than the illustrated curve RPM base.

3450 RPM Considerations



1750 RPM Curve



3450 RPM Curve (same volute)

Operation at higher speeds raises the pump capacity curve.

The 3450 RPM pumps are generally not recommended for comfort heating air-conditioning applications, because of the possibility of noise transmission into the system. This is less of an issue on small booster pumps.

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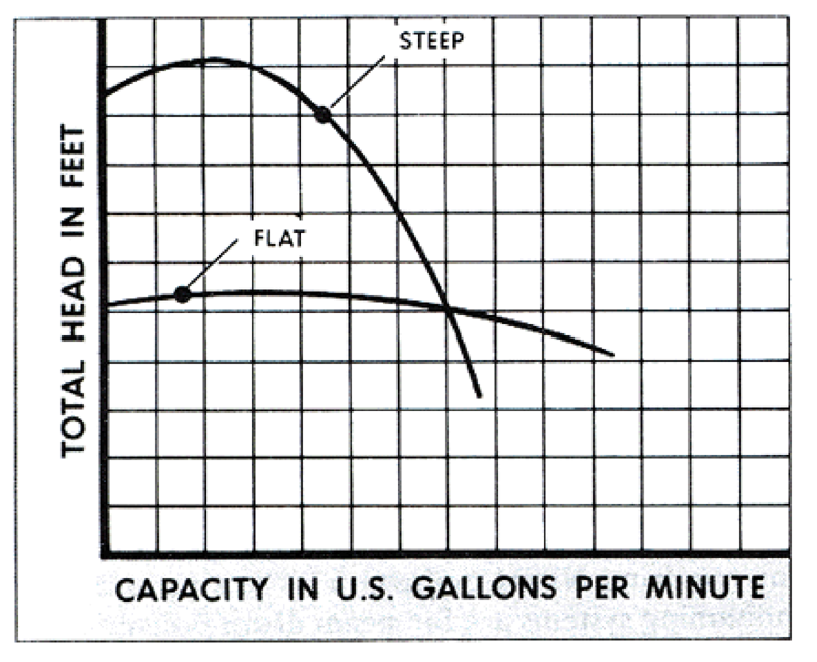
Curve Selection

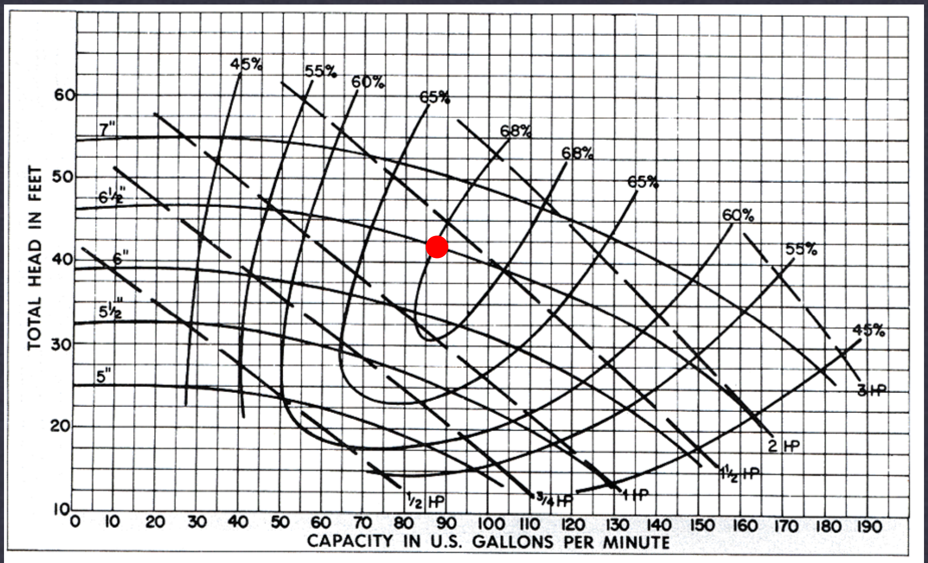


Large changes in capacity (flow) can be achieved with a small change in head. This helps with balancing.

A flat curve offers a more stable pressure drop across valves as they go to the closed position which decreases control valve “force open” possibilities.

Flat-curve pumps are generally preferred for closed circuit systems because of the influence of the pump curve on the system operating components.

Pump Selection

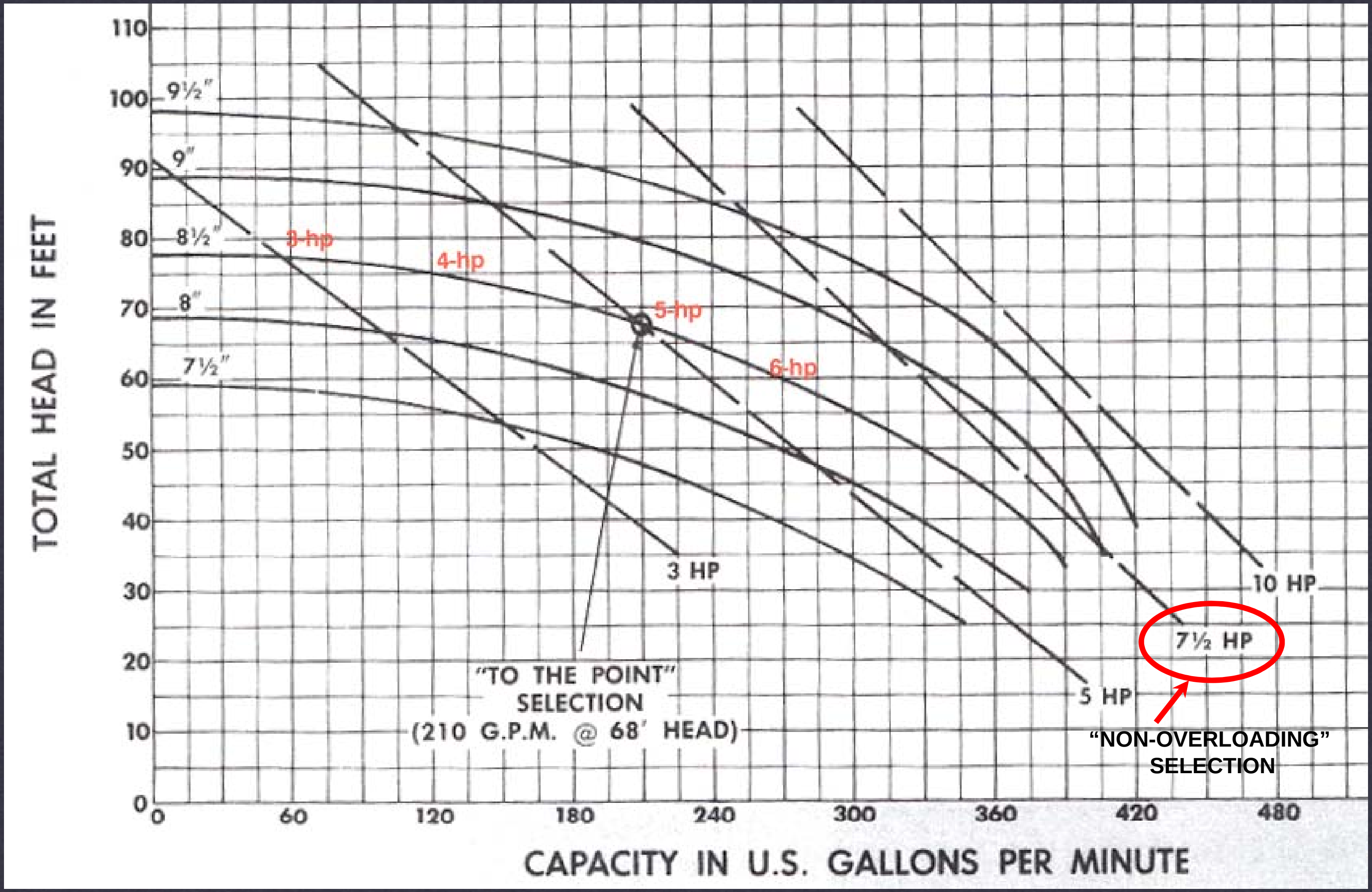


Selection to the left of the curve midpoint will provide a cushion against possible operation beyond the end to the published curved.

Operation "off the curve" can result in noisy and damaging cavitation. Cavitation harms the impeller leading to reduced flow and enviable premature pump failure.

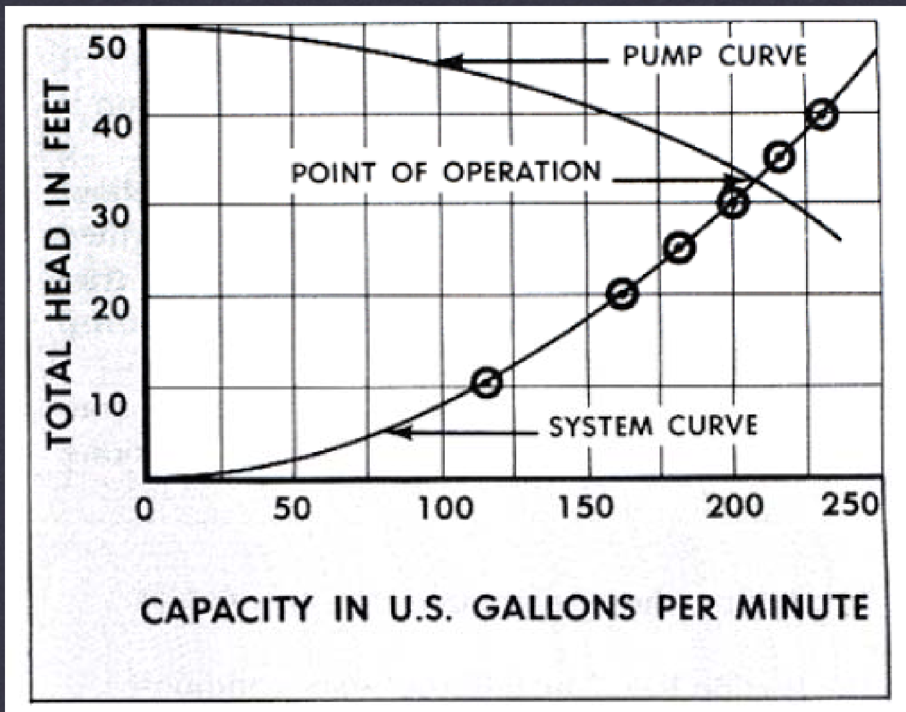
Pick pumps with operation points "to the left of center".

Non-Overloading Motor Selections



"To the Point" vs "Non-Overloading" motor selection

Developing the System Curve



Closed Systems

The system curve is simply a plot of the change in energy head resulting from a flow change in a fixed piping circuit.

System curve analysis will help to define the operating relationships between the pump, control valves, piping circuitry, and heat transfer elements.

Head = Flow^2

$$\left(\frac{Q_2}{Q_1}\right)^2 = \frac{h_2}{h_1}$$

Where:

Q_1 = known (design) flow

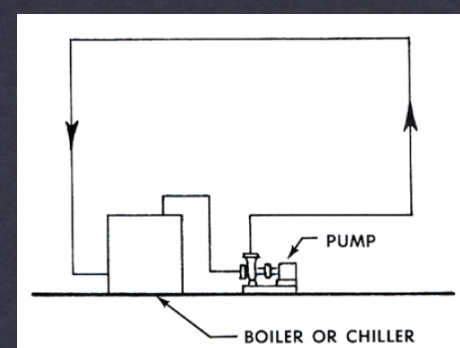
Q_2 = final flow

h_1 = known (design) head

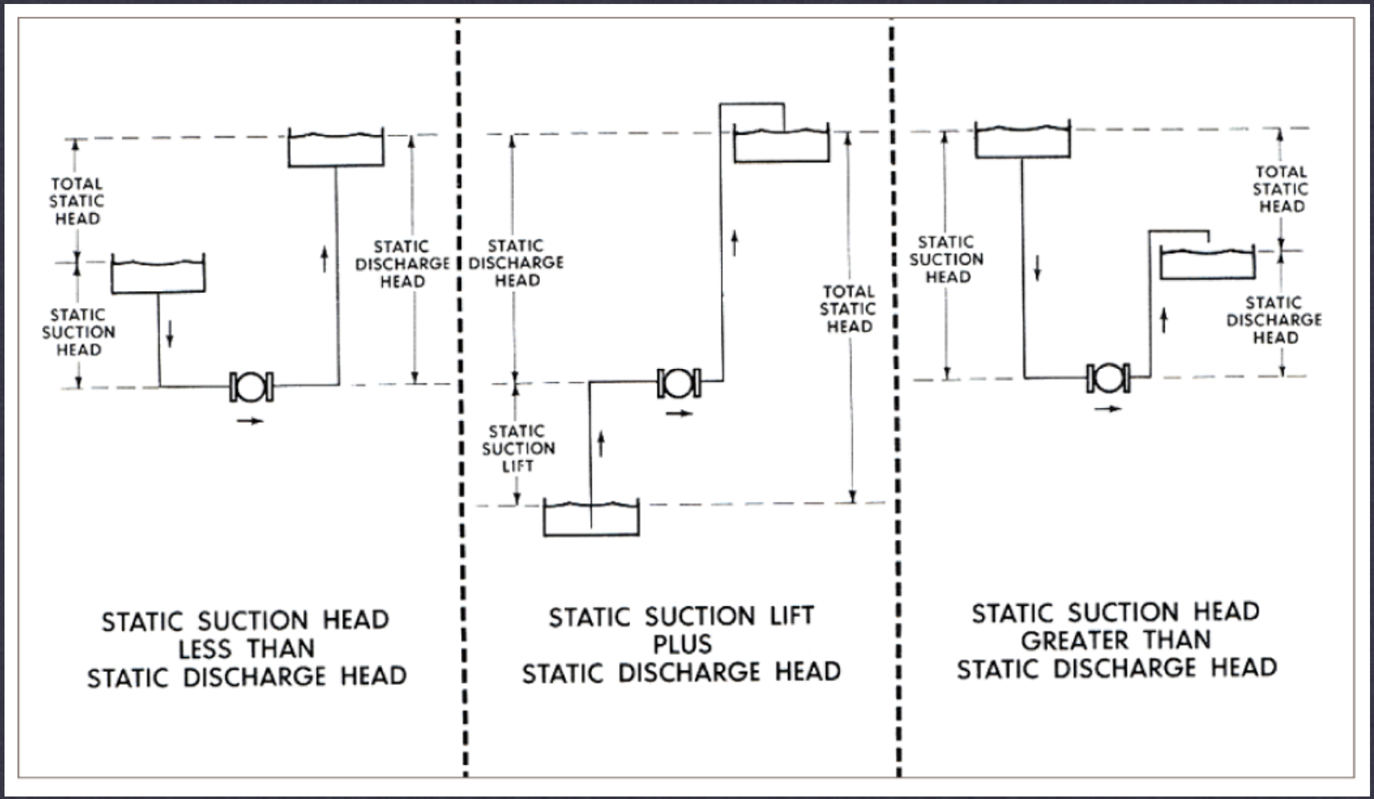
h_2 = final head

Knowing one point (head & flow) will allow you to calculate the system curve

Closed System

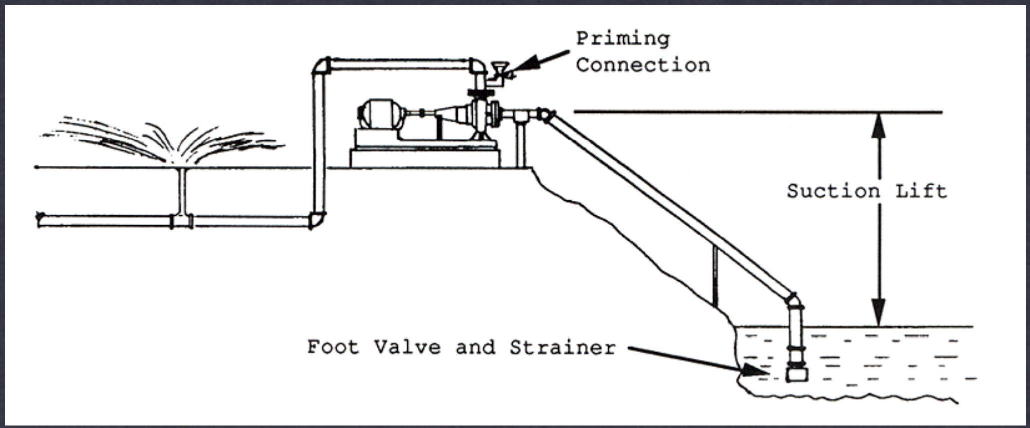


Developing the System Curve



Open Systems

The system curve is developed using the design point (total friction in the system @ the design flow rate)
AND
through evaluation of the static head



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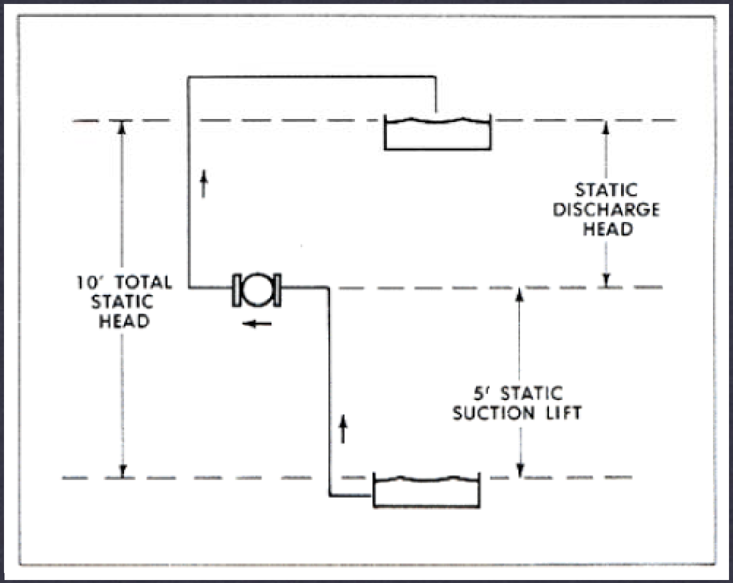
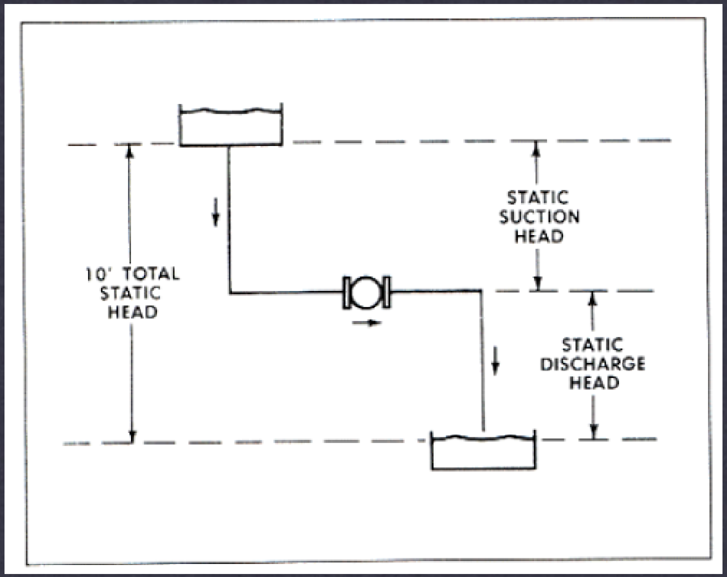
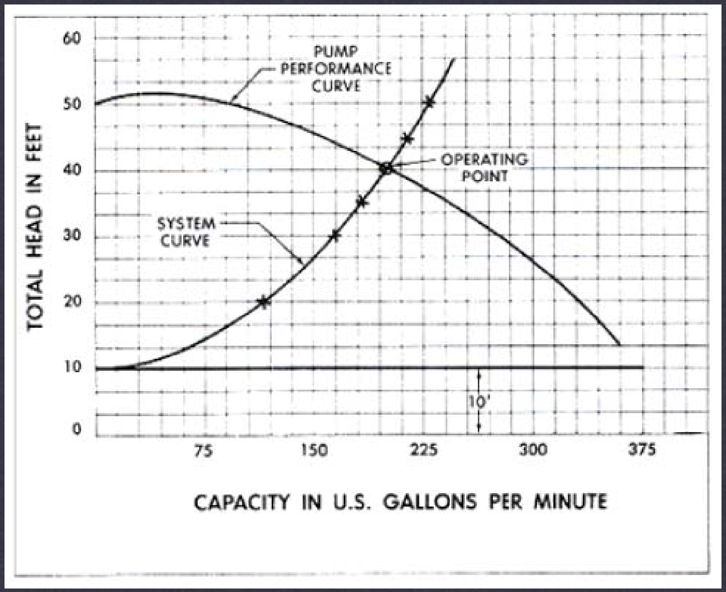
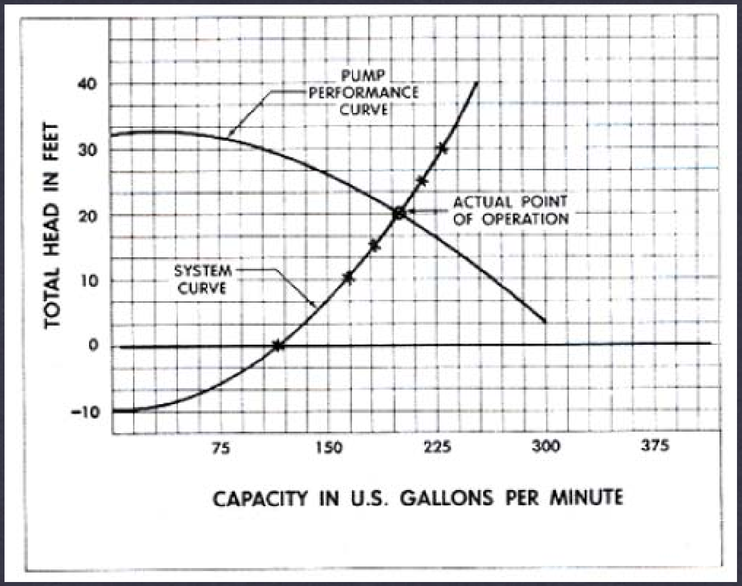
Developing the System Curve Open Systems



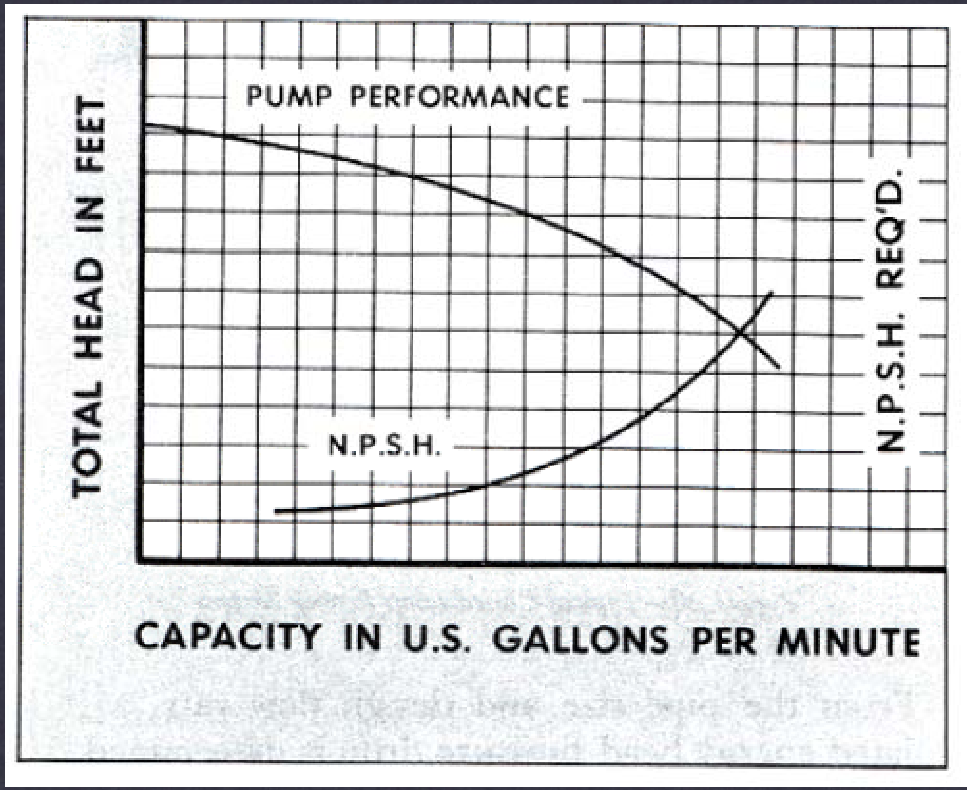






NPSH

Net Positive Suction



All centrifugal pumps operate at lower pressure in the impeller eye than the pressure existing at the pump suction flange.

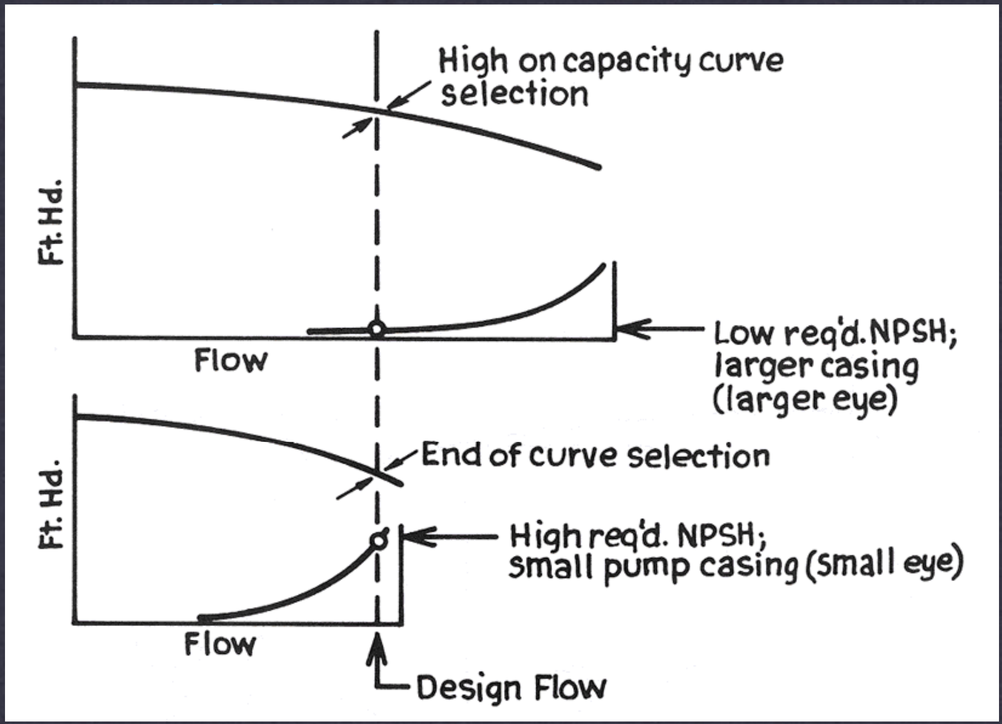
The NPSH defines the pressure required to prevent fluid flash point; the vaporization pressure threshold.

The curve represents the required NPSH and it increases with increased flow (increased water velocity)

This is an important concept for Open Loop Systems and when pumping volatile fluids.

NPSH

Net Positive Suction



As shown, “end of curve” selections can result in cavitation issues because the NPSH requirements increase greatly.

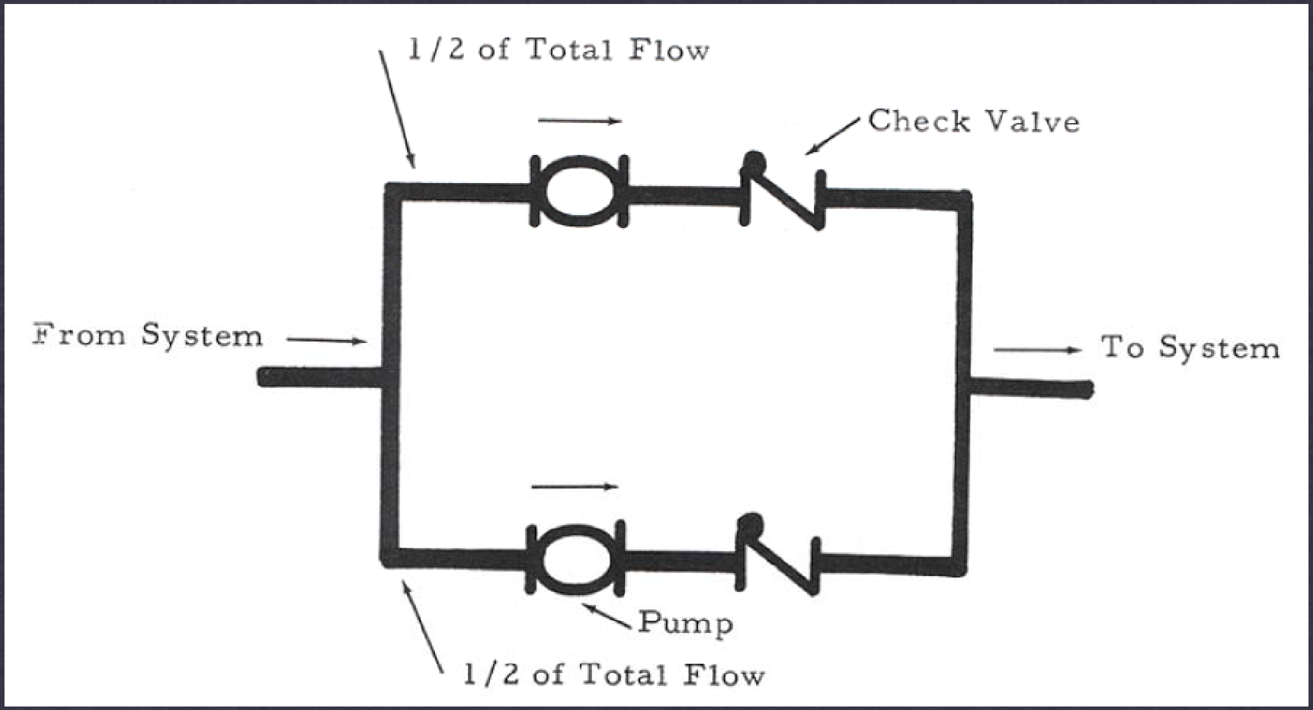
Note: Ensure that the pressure available at the pump suction flange is great enough to keep the fluid from boiling.

See vapor pressure tables to confirm

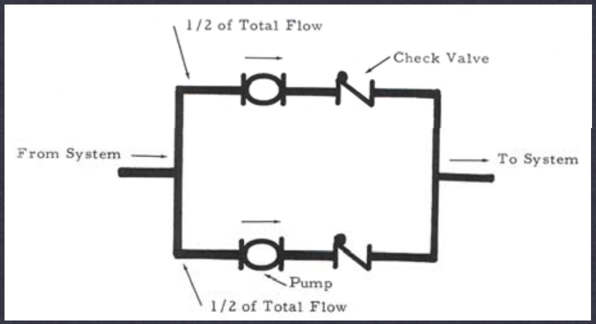
Parallel Operation

Parallel Pumping has advantages:

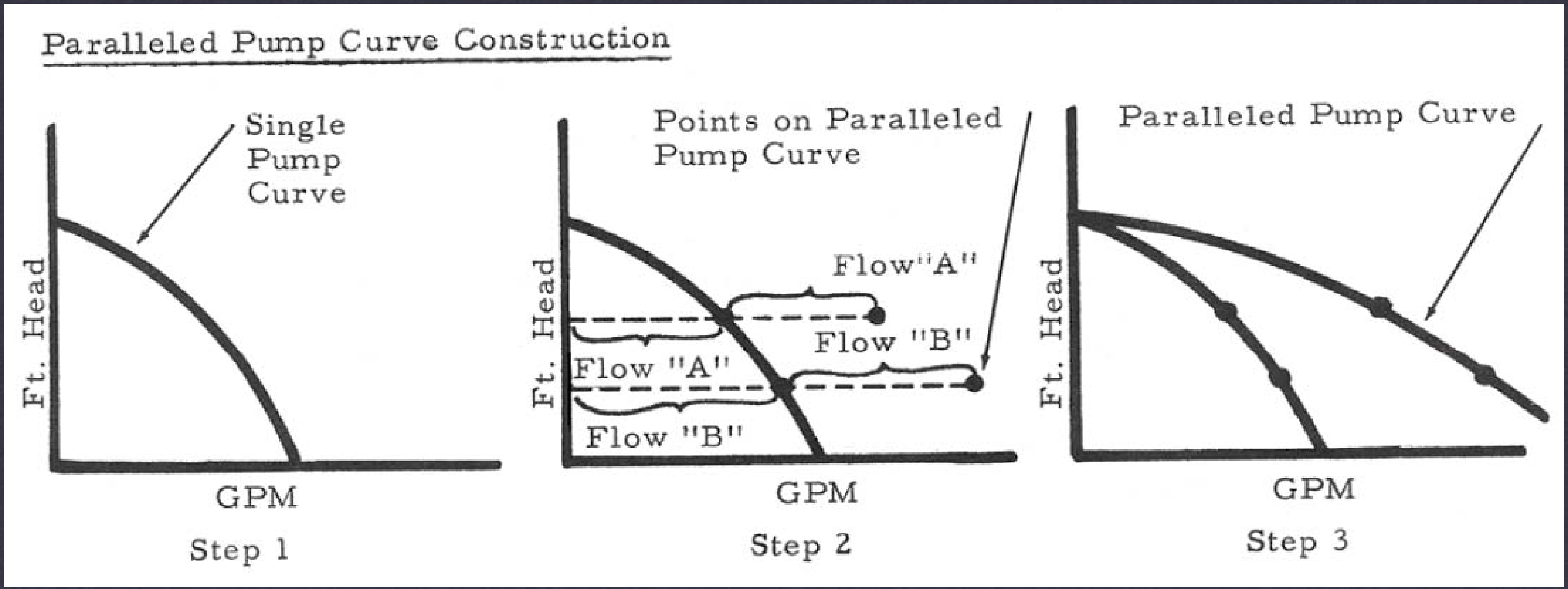
1) Reduced costs (sometimes) - Line mounted pumps instead of based mounted
2) Redundancy (70% - 90%) flow - Utilize centrifugal properties to your advantage
3) Non-standard curve options - "New" curves available with parallel selections



Parallel Operation

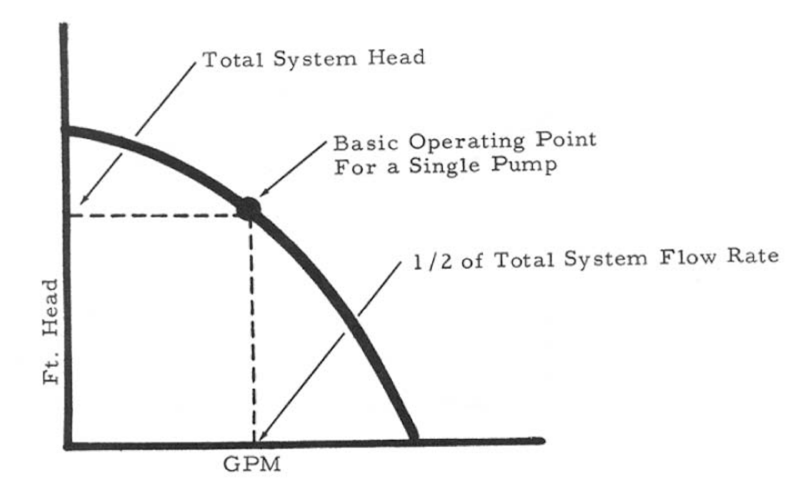


It's easy, just double the flow at each head condition



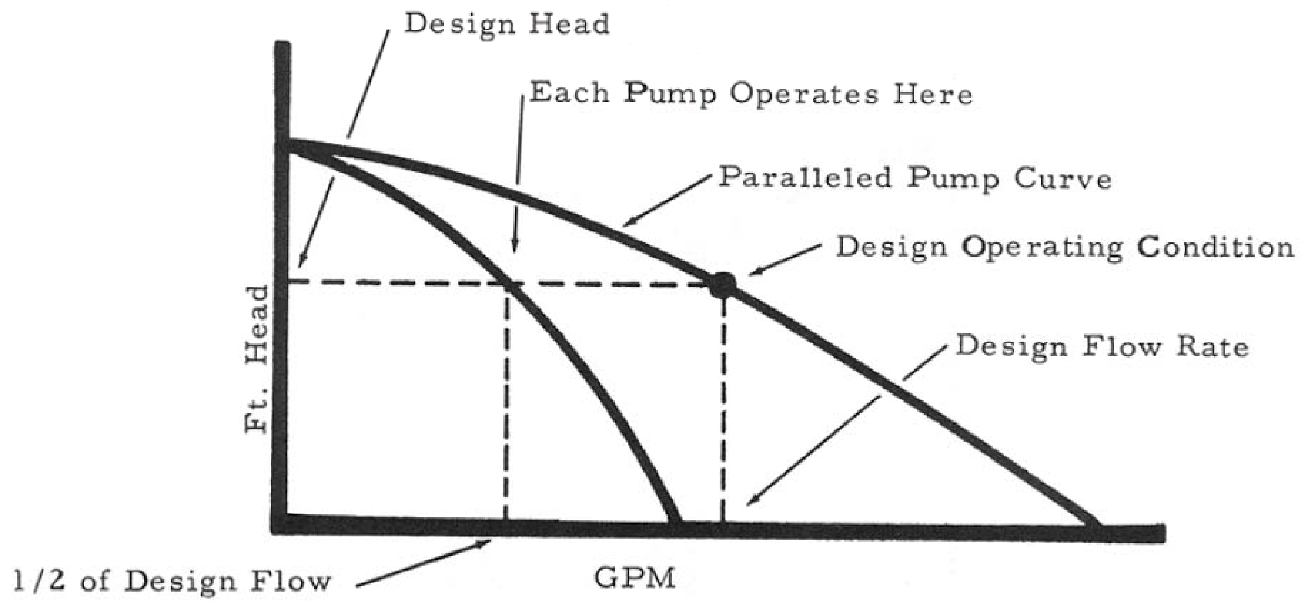
Operation

Single Pump Curve



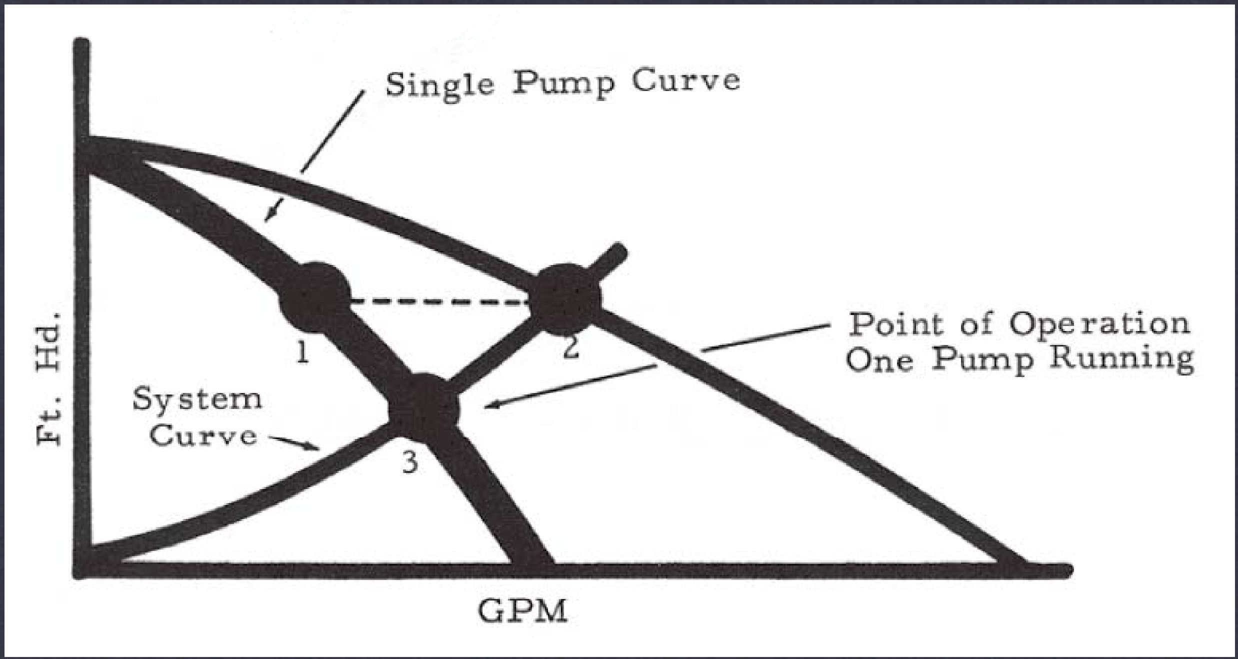
Double the Flow (gpm x 2) for a given Head (ft)

Parallel Pump Curve



Parallel Operation

Inherent Redundancy

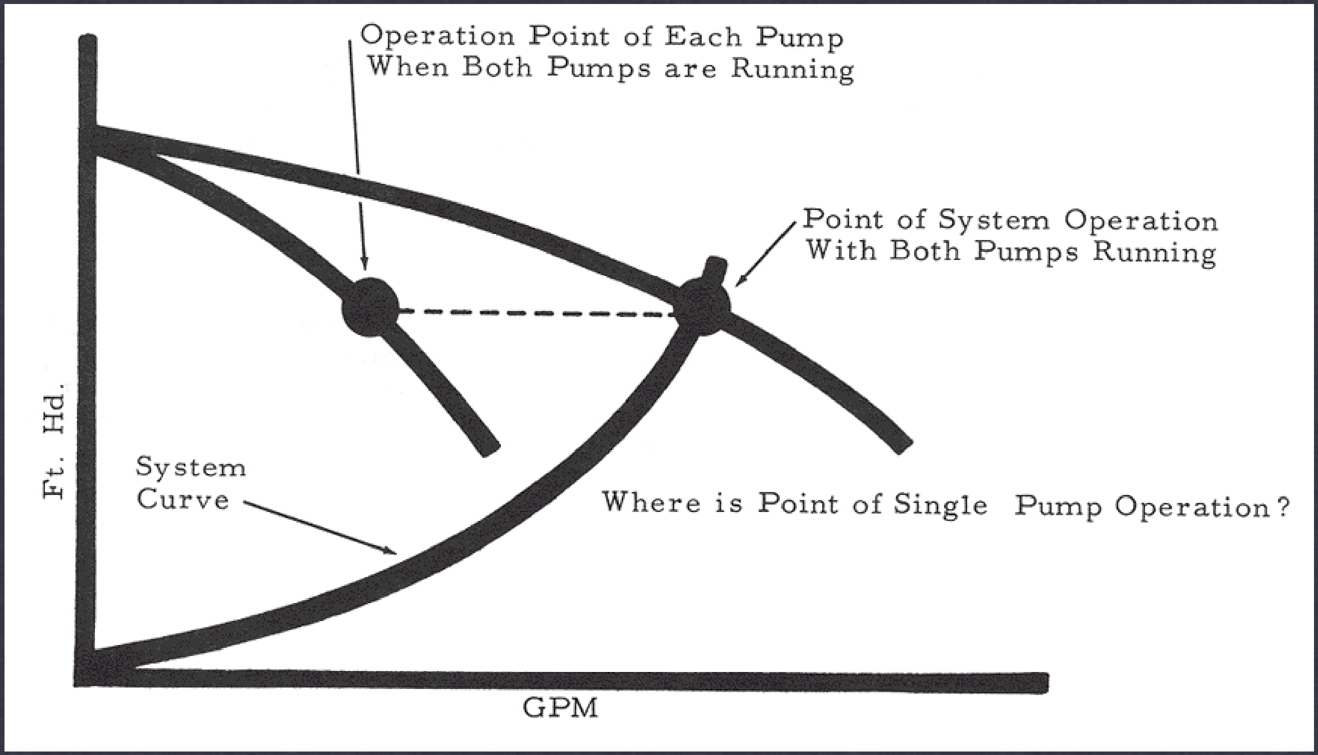


Note: The flow rate for the single pump will increase when the second pump is not running until it intersects the system curve.

When one pump is running, it will draw more current than when it is running in parallel operation. It is therefore a good idea to select non-overloading motors for the single pump operation condition

Parallel Operation

End of the Curve

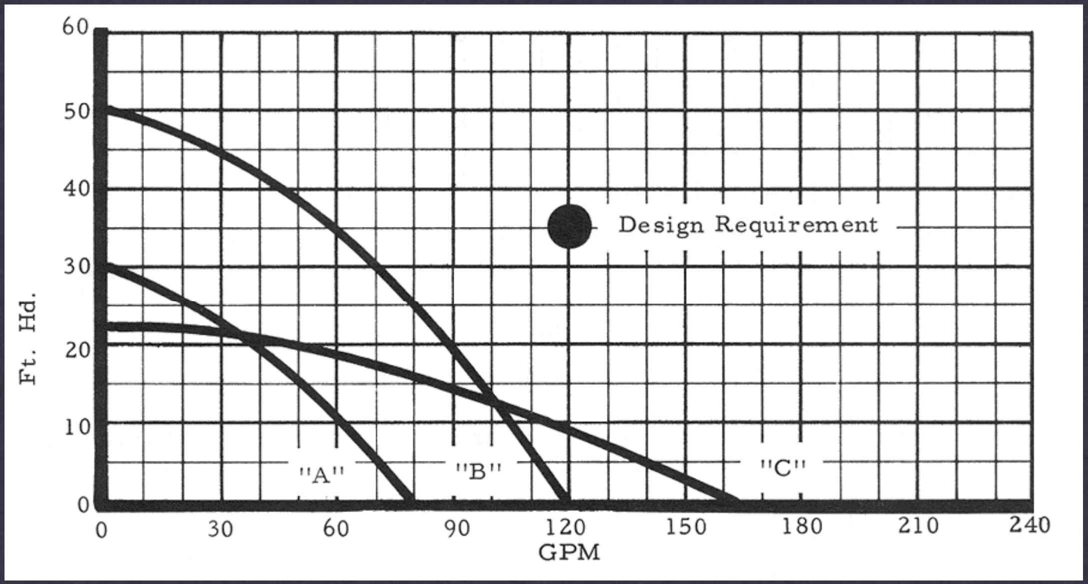


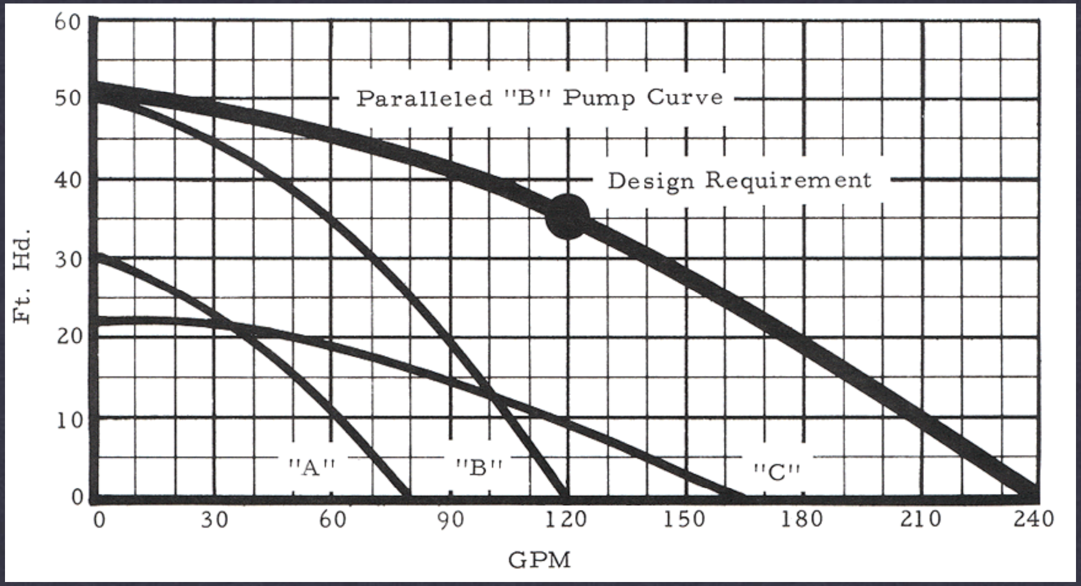
Possible cavitation with unstable operation and poor efficiency may result beyond the published curve end point.

Therefore, select pumps where the "inside" curve interests the system curve.

Parallel Operation

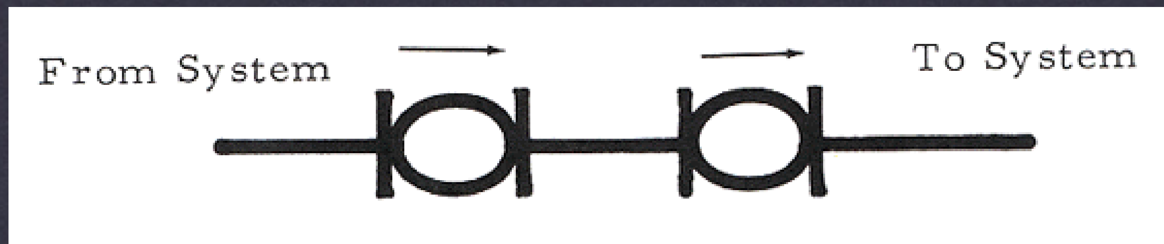
Non-Standard Curves

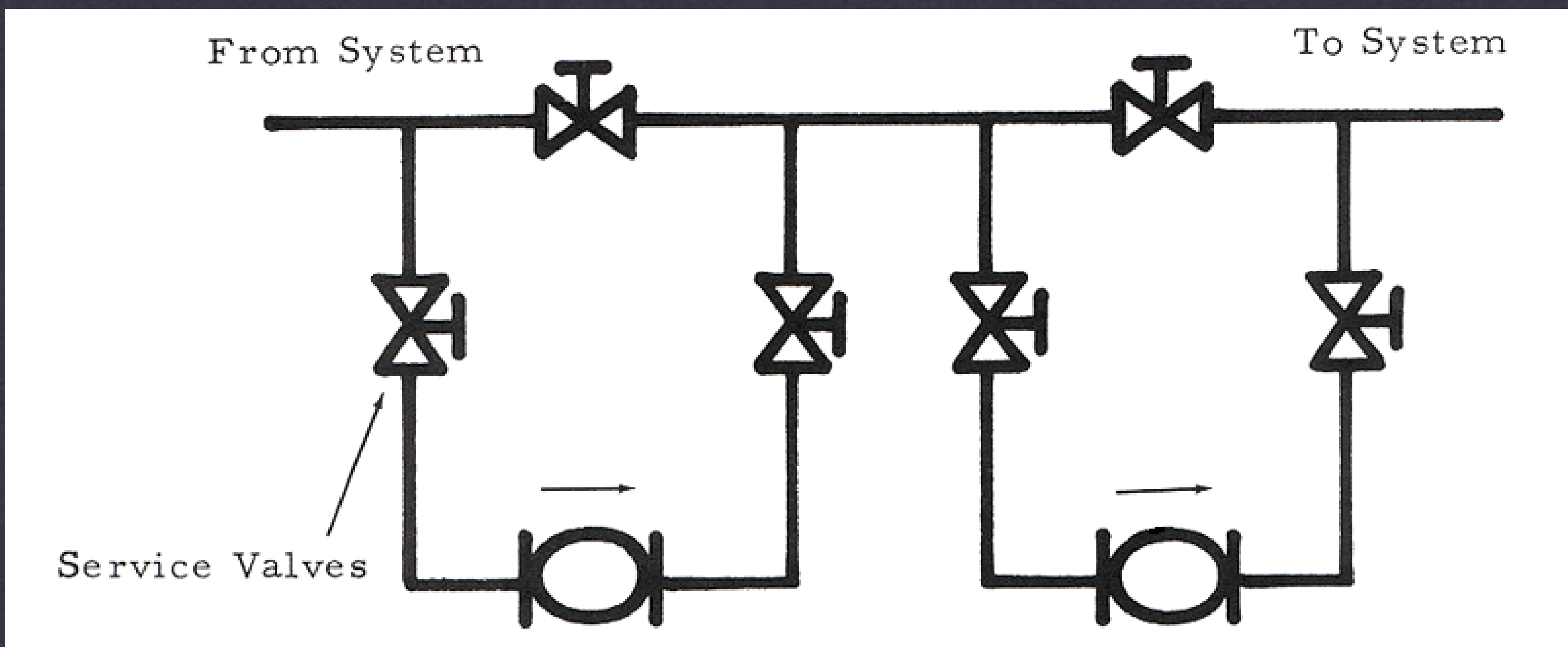




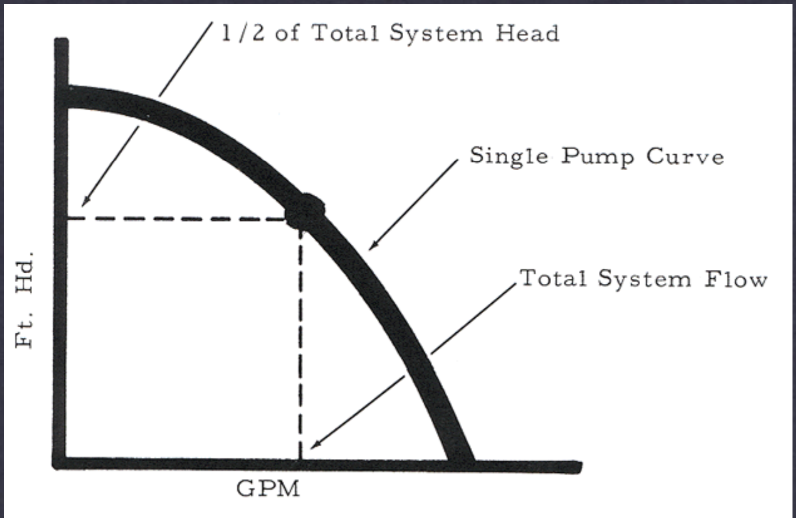
If you can not find the right pump, "build" one you like.

Series Operation



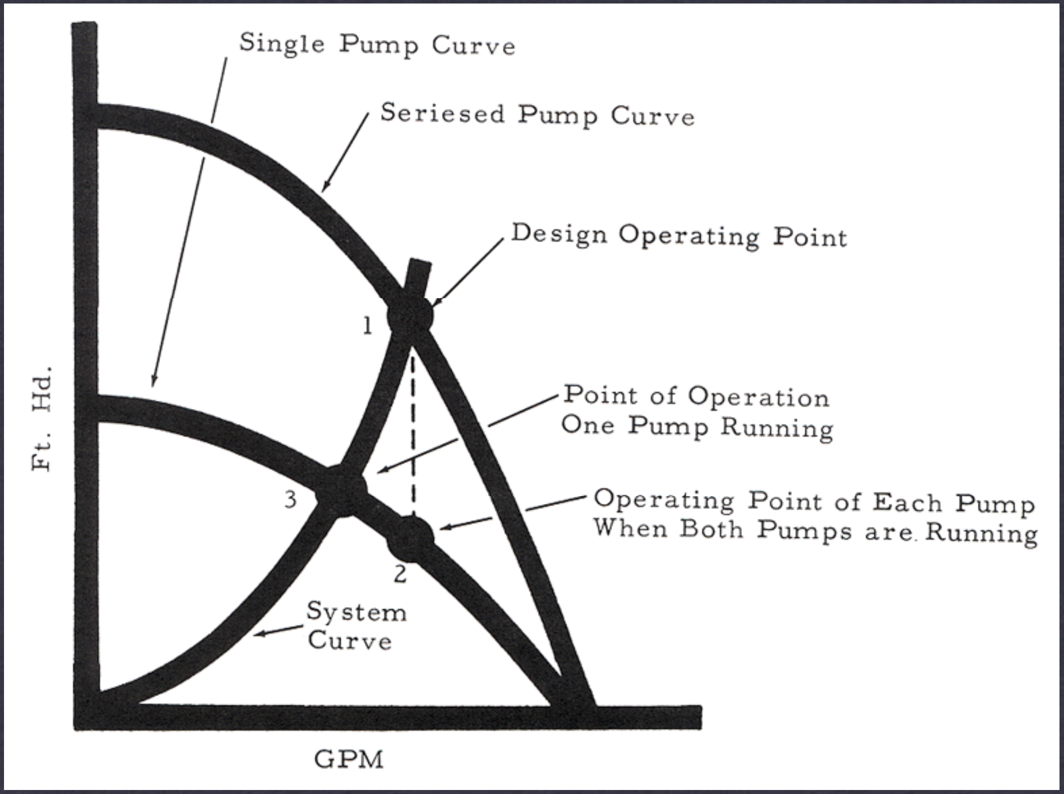


Series Operation



Each pump supplies (1/2) the head while both in operation

Double the Head (ft x 2) for a given Flow

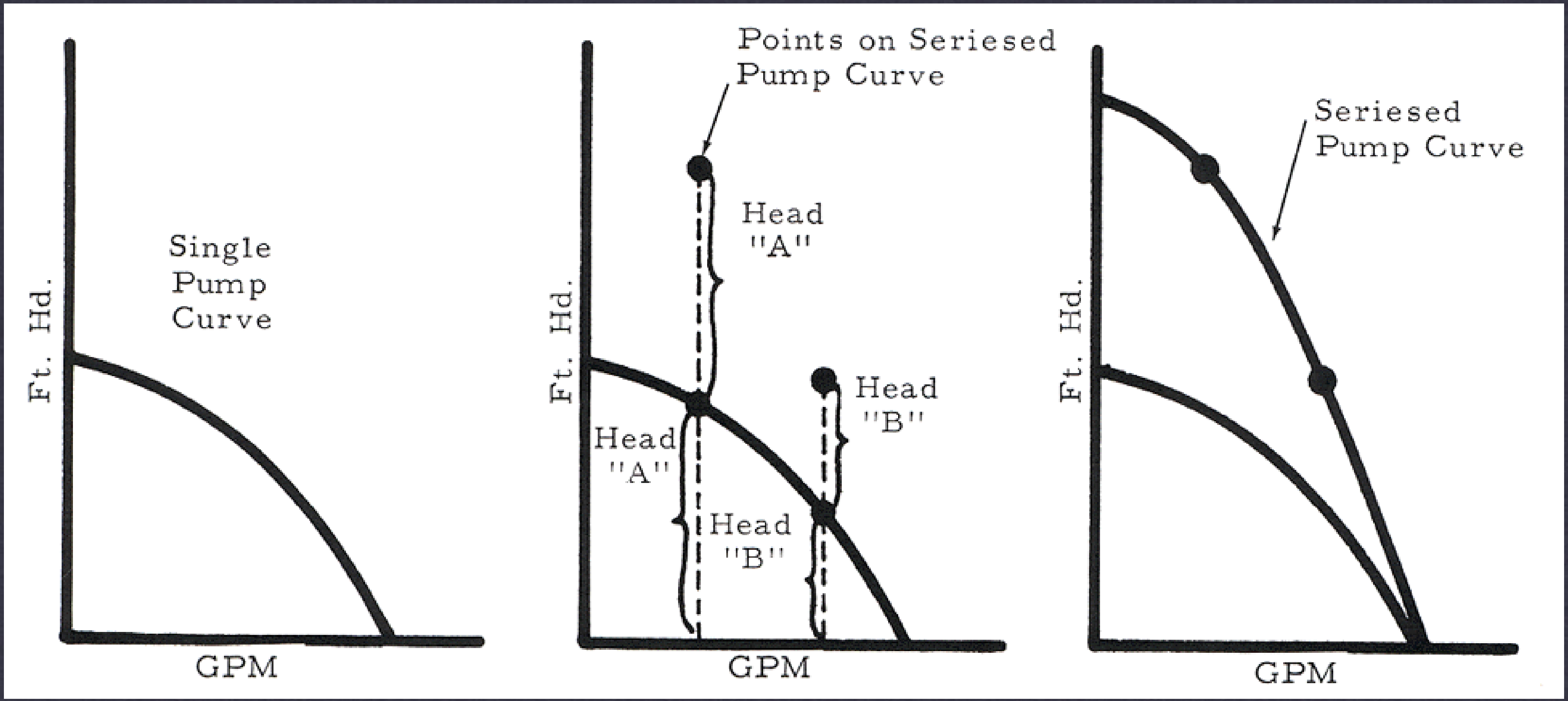


During single pump operation, the delivered flow will decrease

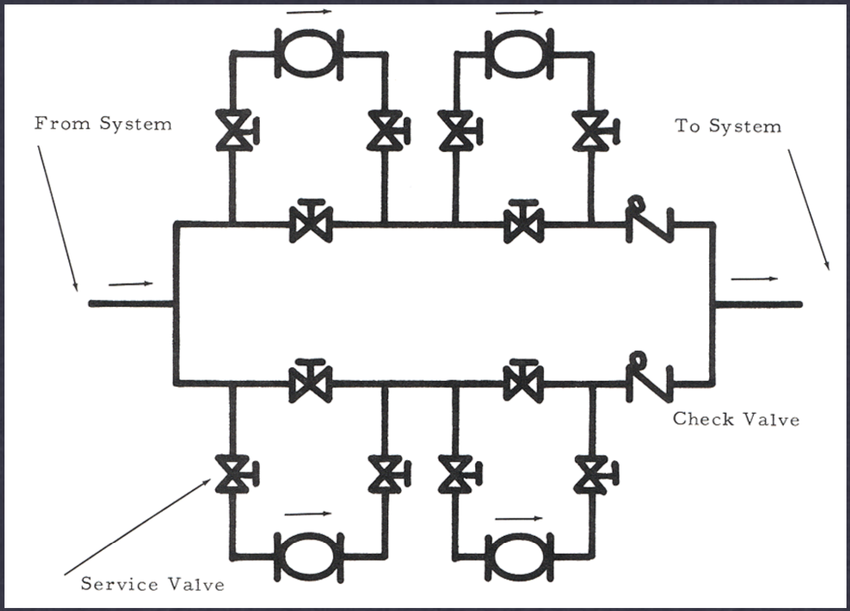
The power draw for each pump is greater when both are in operation

Series Operation

It's easy, just double the Head at each Flow condition



Parallel & Series Operation



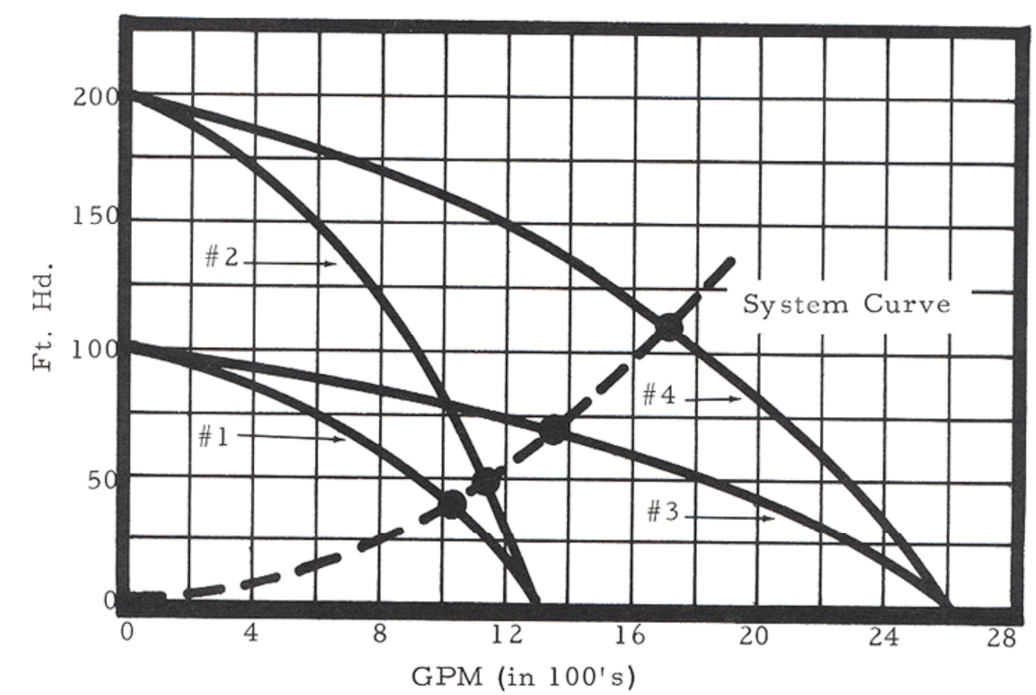
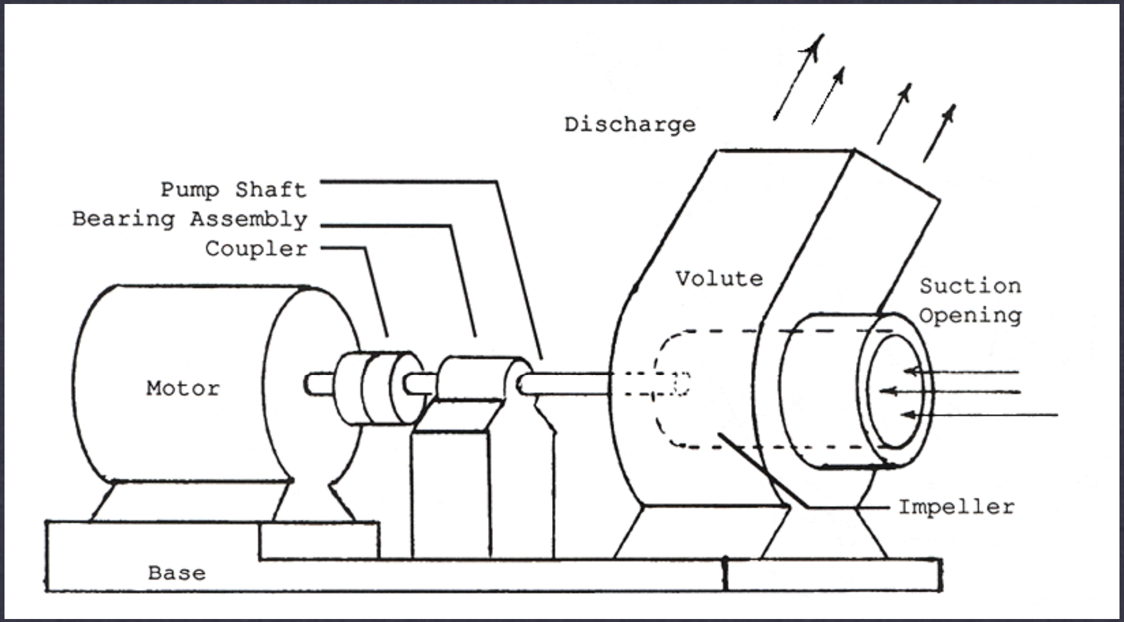


FIGURE #32 - Combination Parallel & Series Pump Curves

● POSSIBLE OPERATING POINTS

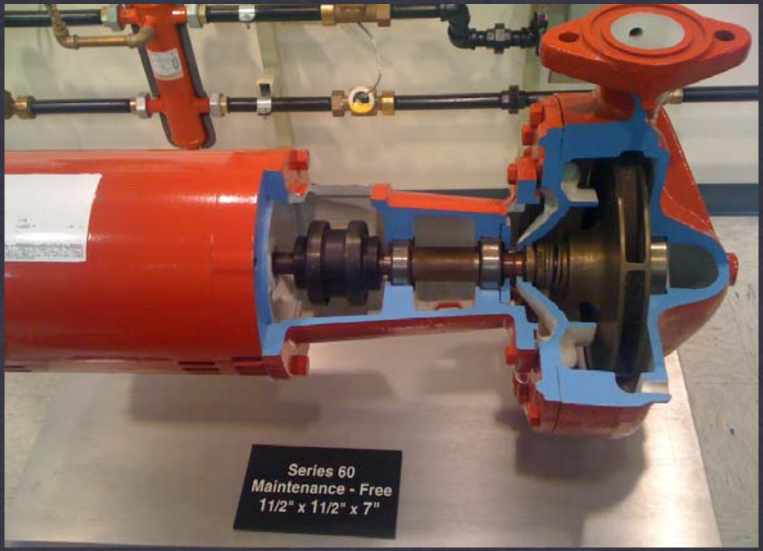
#1 - Single Pump
#2 - Two Pumps in Series
#3 - Two Pumps in Parallel
#4 - Two Parallel Groups of Two Pumps in Series

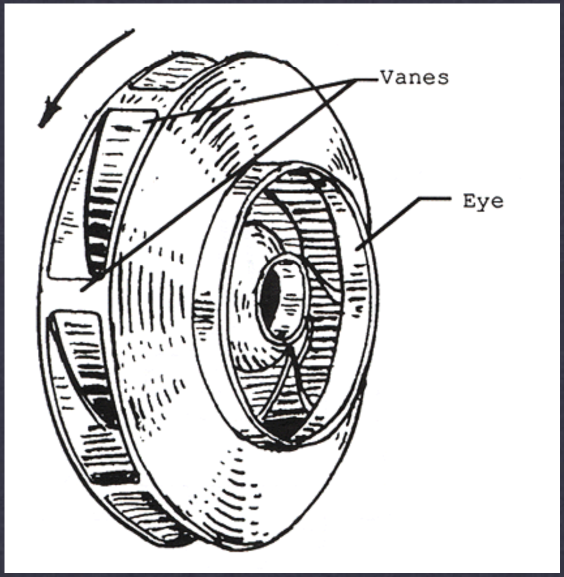
Pump Components



Typical Pump Components

1) "The Pump" - the volute, Impeller, seals, shaft
2) Bearings (2-sets)
3) Coupler
4) Motor (which has its own shaft and set of bearings)

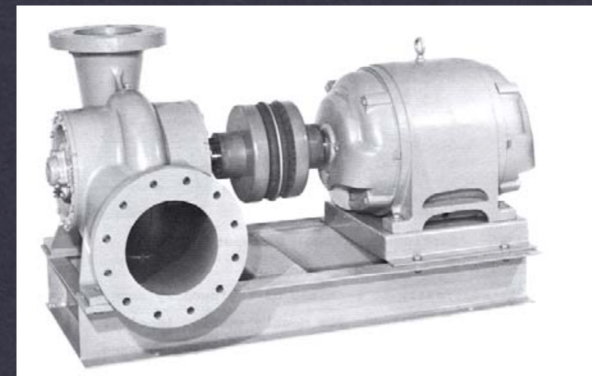




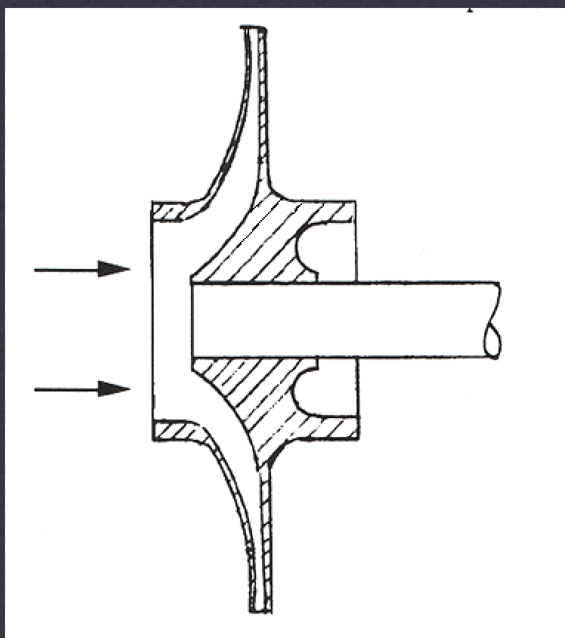
Pump Impellers are designed to increase fluid velocity while minimizing turbulence.

The vanes of a pump always "slap" the water.

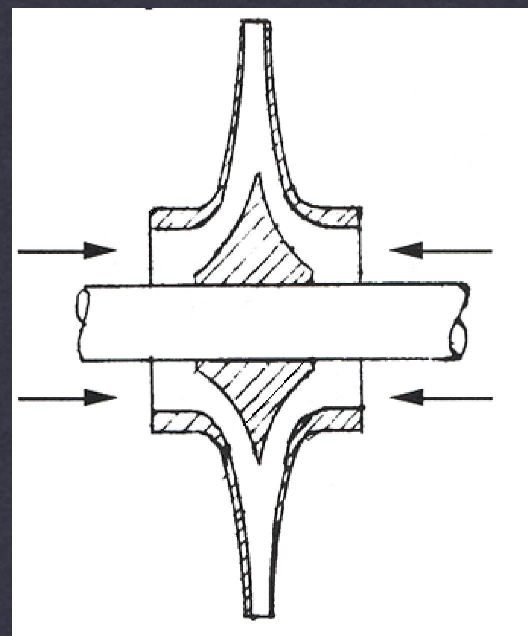
Pump Design

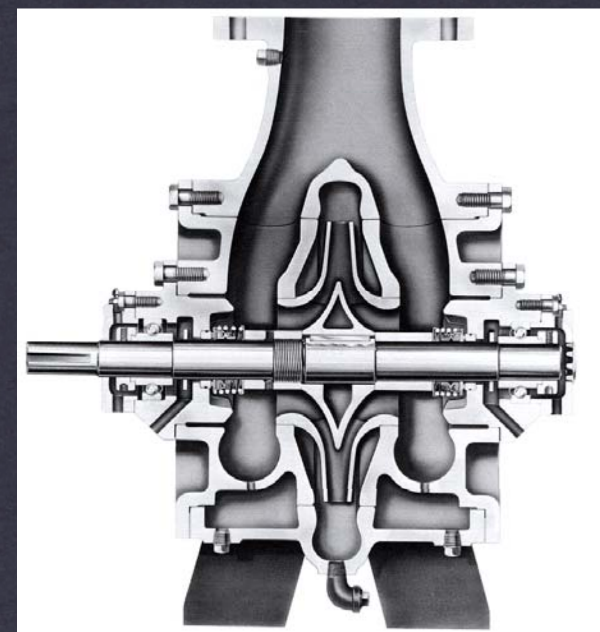


Single Suction



Double Suction

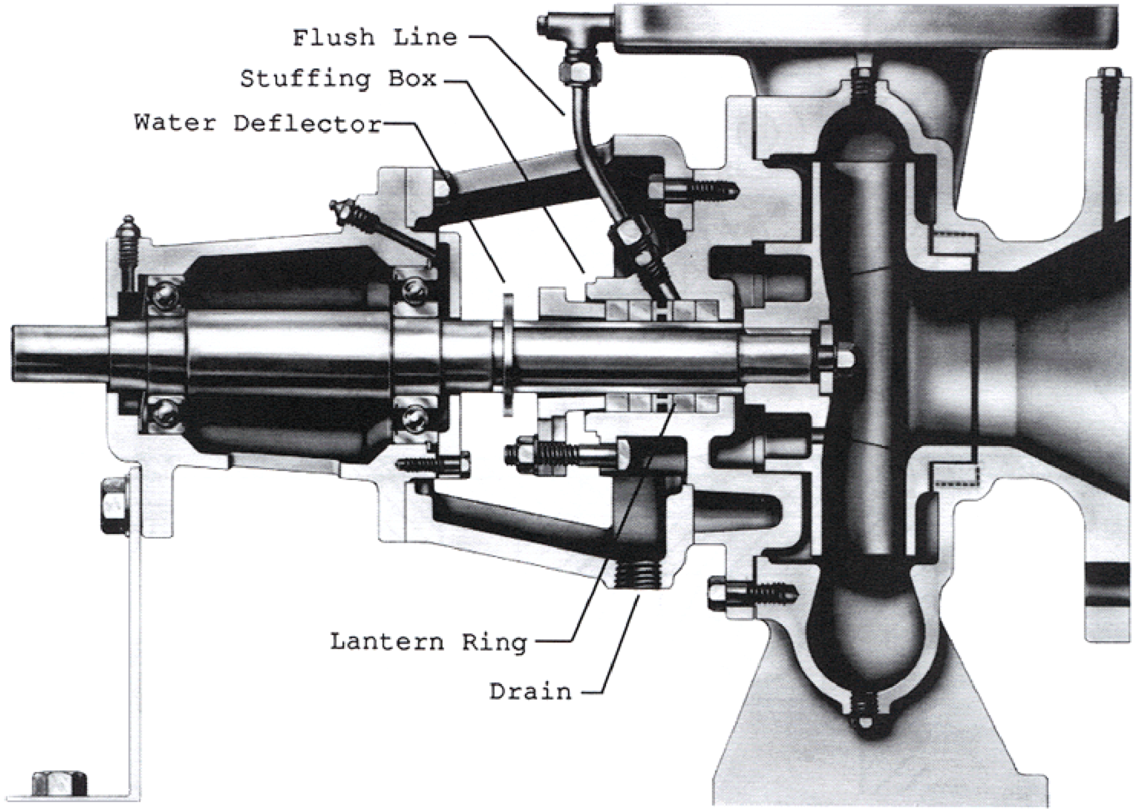




Double suction pumps are used on for large head & flow applications. The allow for a “balanced” bearing arrangement which provides greater stability and longer equipment life.

Pump Design

Stuffing Box Construction & Flushing

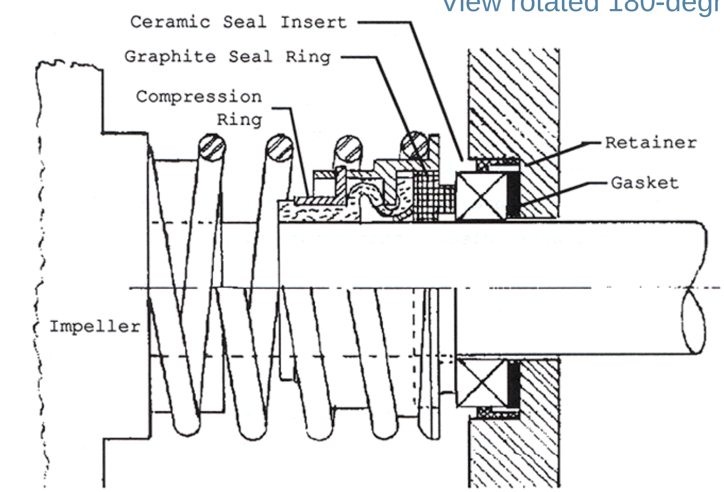


Bell & Gossett Series 1510 Pump With Stuffing Box Construction and Flushed Packing

Pump Design

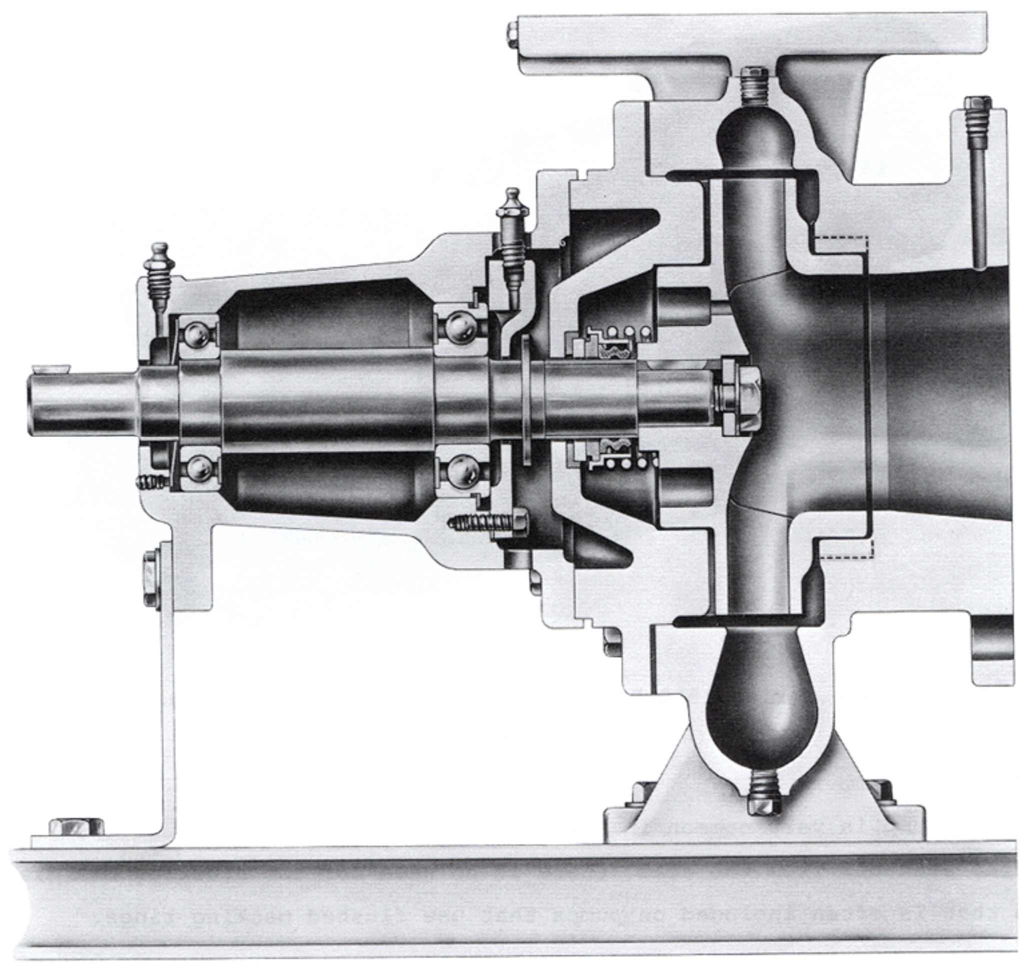
Internally Flushed Mechanical Seals

View rotated 180-degrees



Internally Flushed Mechanical Seal

Bell & Gossett Series 1510 Pump with Internally Flushed Mechanical Seal

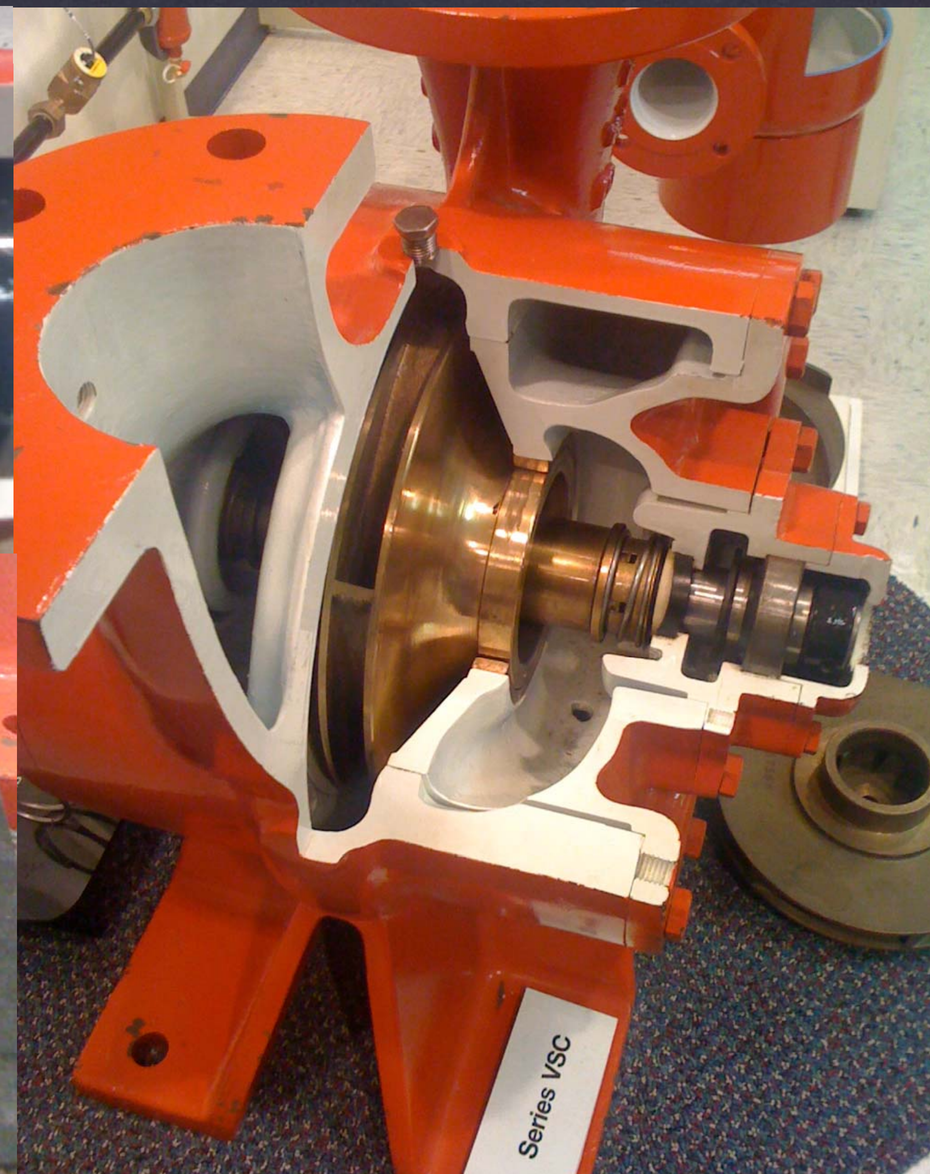


Bell & Gossett Series 1510 Pump With Internally Flushed Mechanical Seal

Wallace Eannace Associates, Inc.

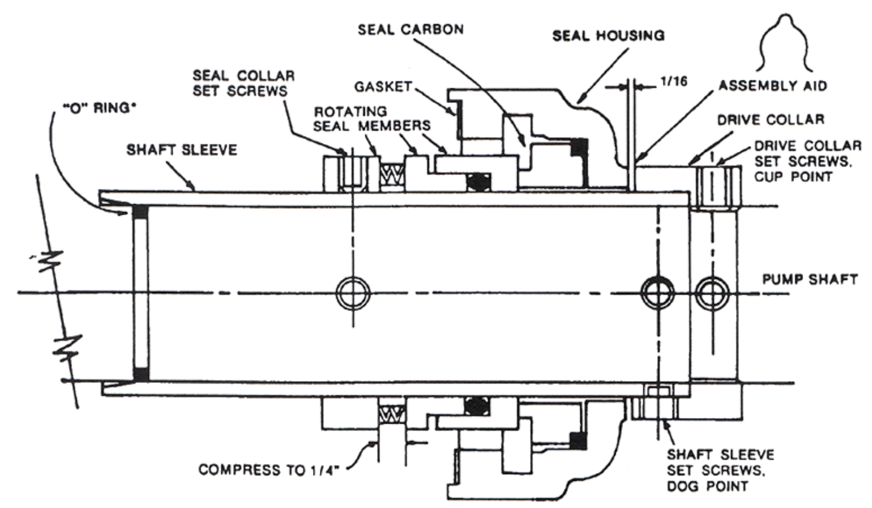
Pump Design

Internally Flushed Mechanical Seals



Pump Design

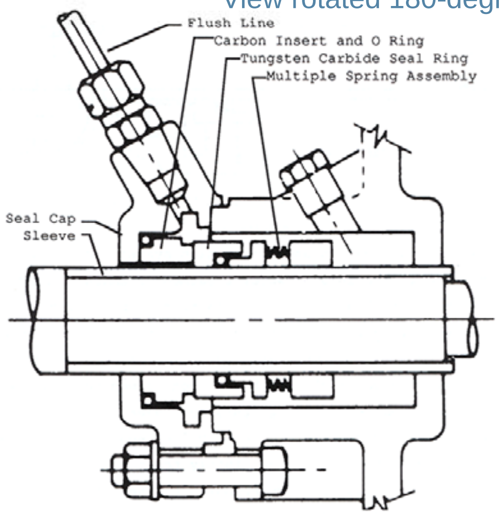
Externally Flushed Mechanical Seals



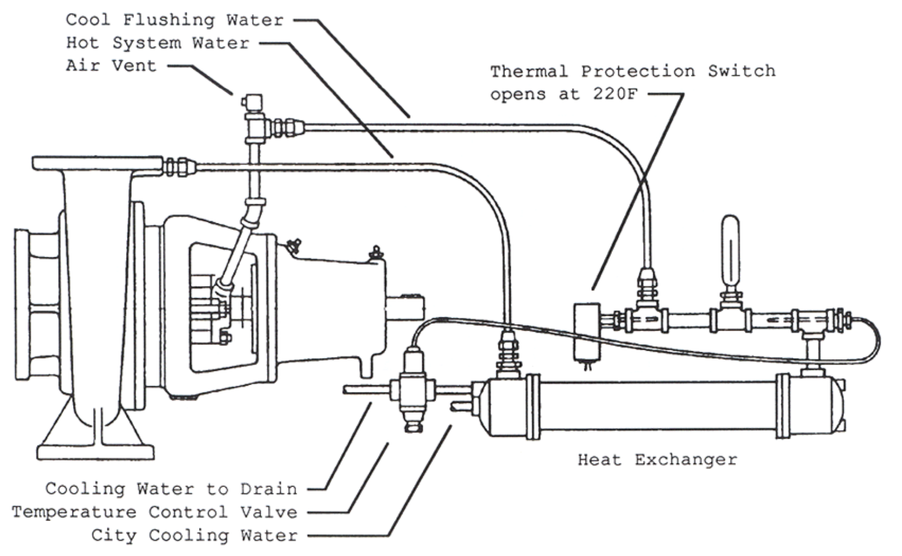
Typical Externally Flushed Mechanical Seal

Used for high temperature, high alkalinity, or high concentrations of water treatment chemicals might cause internally flushed mechanical seals to fail prematurely.

View rotated 180-degrees



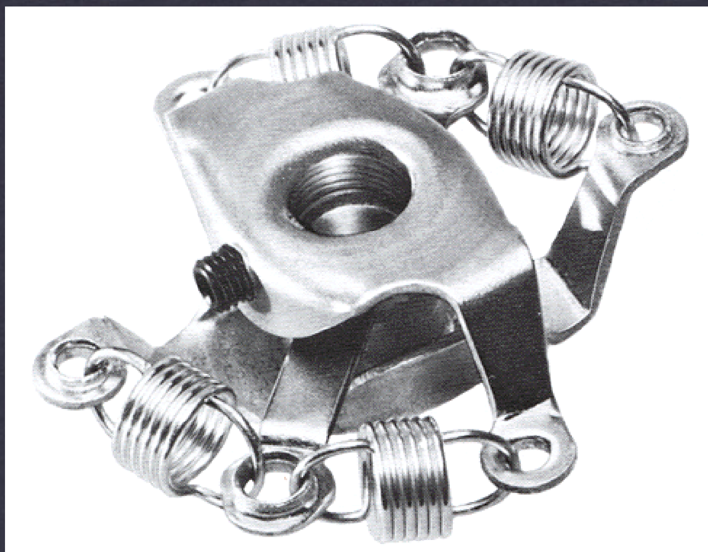
Externally Flushed Mechanical Seal



Heat Exchanger to Cool Seal Flushing Water

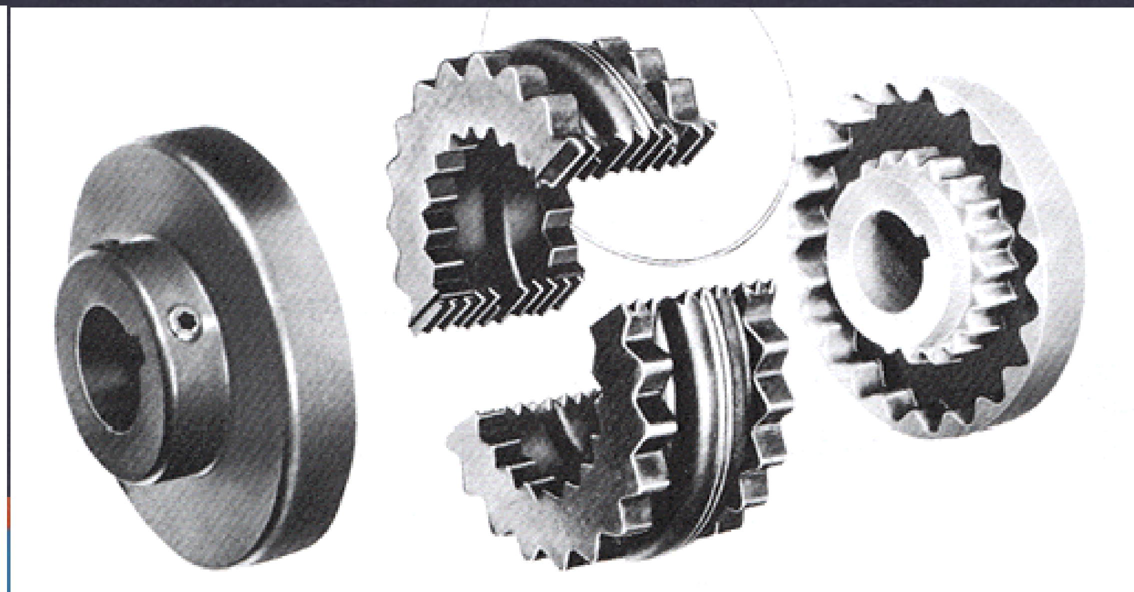
Couplings

Small Pumps



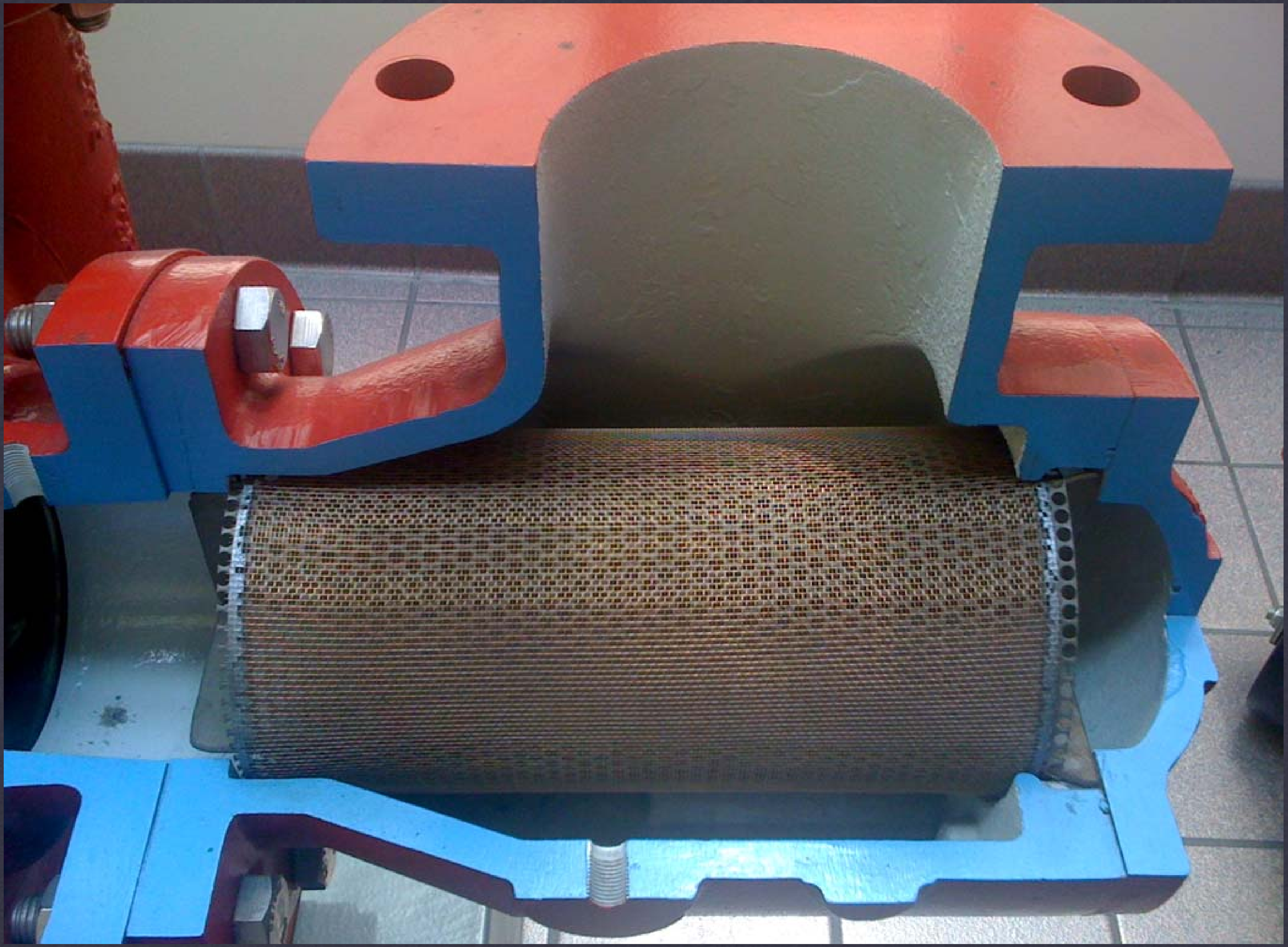
Equalized Spring Coupler

Larger Pumps



Wet Rotor Pumps

Suction Diffusers



Triple Duty Valve

Balancing, Check, Shut-off

B&G Family of Centrifugal Pumps