PumpTech Customer Education

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Pump Ed 101

Centrifugal Pump Hydraulics

Three Reasons BEP Operation is Important

Joe Evans, Ph.D

http://www.PumpEd101.com

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Centrifugal Pumps

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Impellers

Hint

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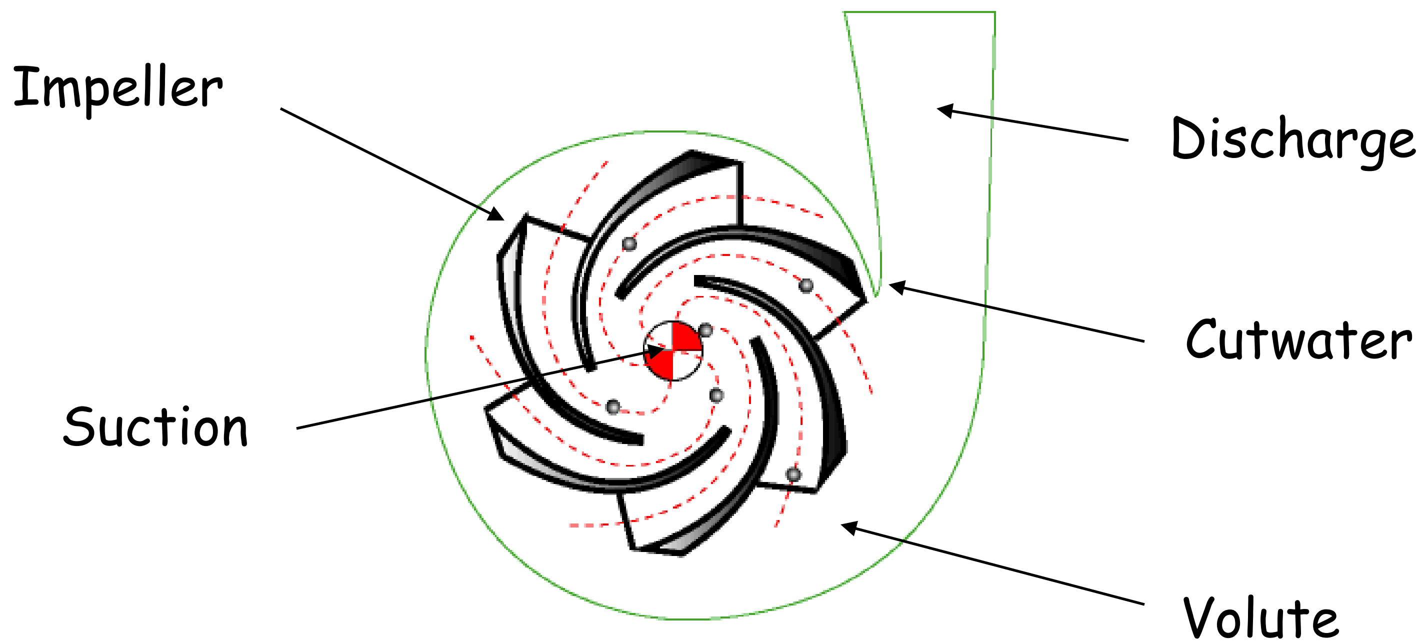
Centrifugal Pump Dynamics



What Type of Energy is Added by the Impeller ?

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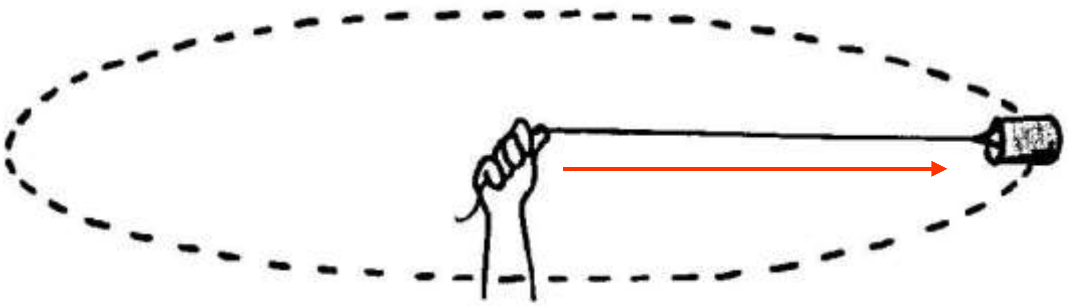
Centrifugal Force

- It is defined as "center fleeing"



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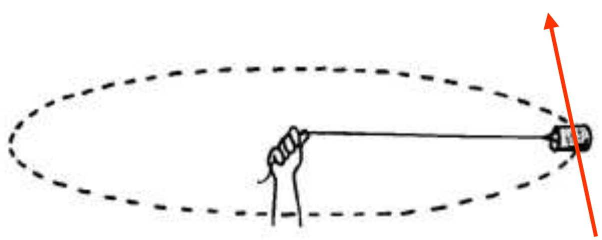
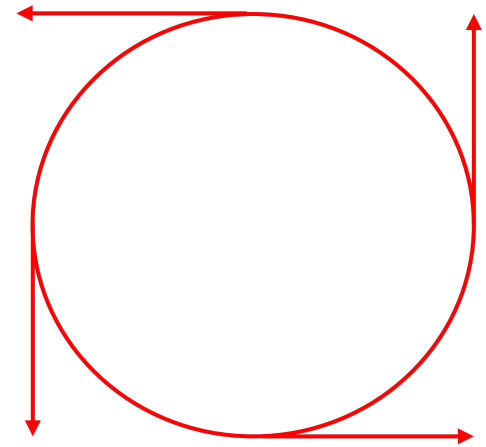
Centrifugal Farce

- Instead it actually moves in the same direction it was traveling at the exact instant it is released.



- When an object is traveling in a circle, it is actually moving in a straight line at any single point in time.



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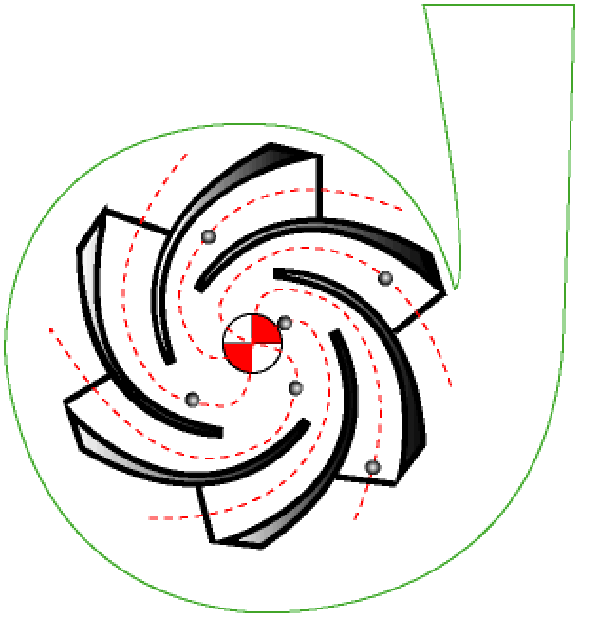
So, How Does It Work ?

1 Rotation of the impeller forces water from its entry point, at the eye, into its vanes.

2 Water moving through the vanes creates a partial vacuum at the eye allowing atmospheric, or some other outside pressure, to force more water into the eye.

3 As water travels through the vanes, it gains rotational velocity (kinetic energy) and reaches its maximum velocity just as it exits the vanes.

4 Upon exiting the vanes, water enters the volute where most of its kinetic energy of motion is transformed into pressure energy.



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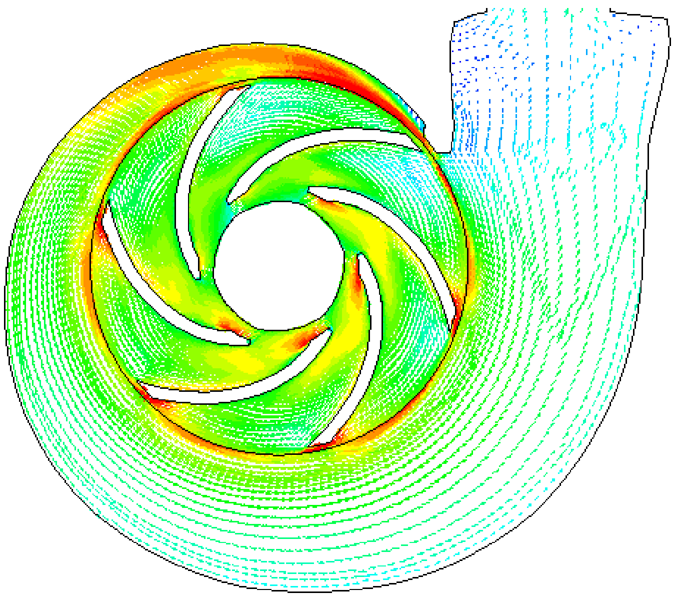
The Volute and its Function

The volute houses the impeller and is the "receptacle" for the water exiting its vanes.

Its smooth, nearly circular, geometry guides the flow from the impeller towards its discharge. During this trip, the flow encounters an ever increasing volume.

The volute converts the kinetic energy (velocity) imparted by the impeller into pressure.



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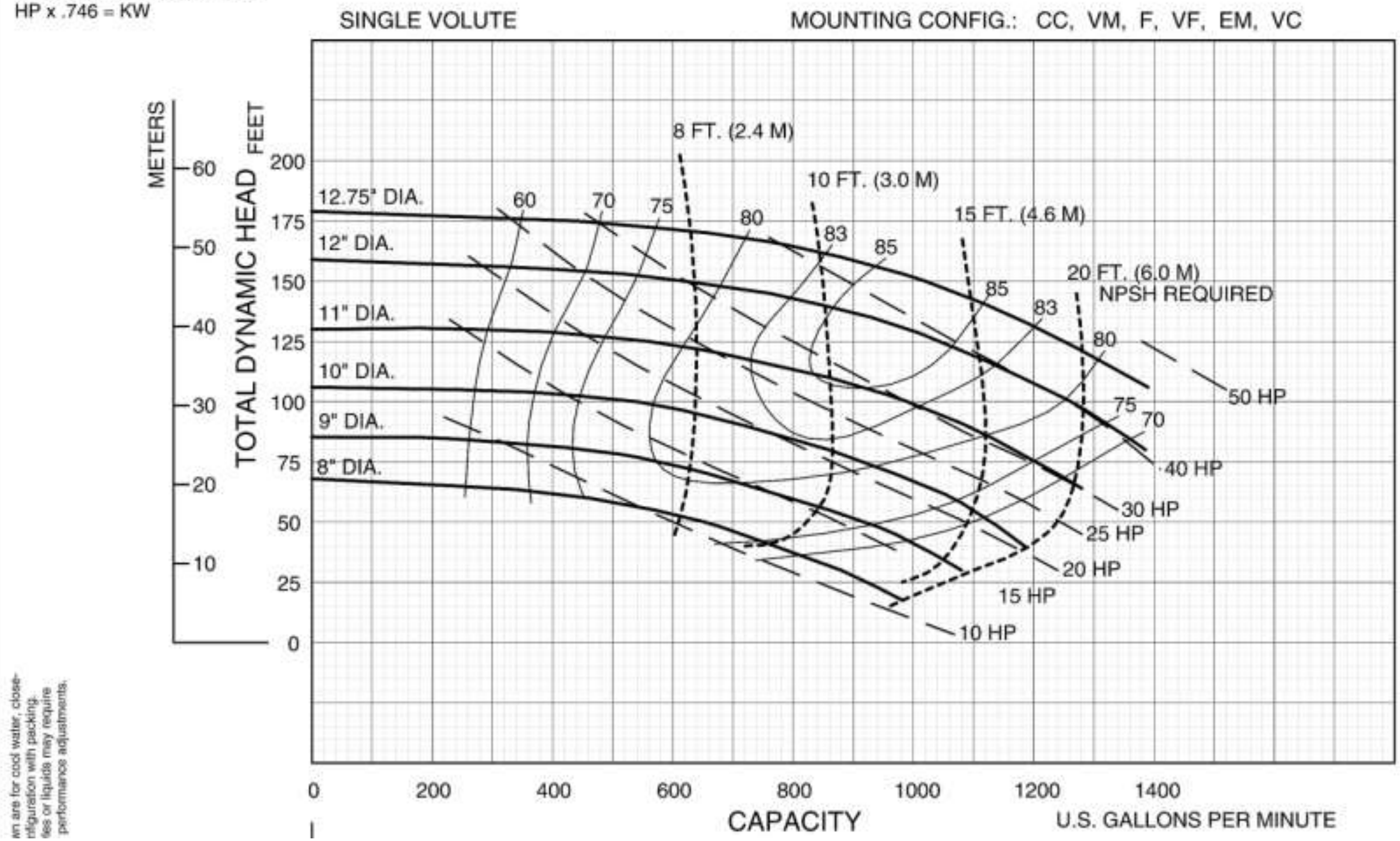
The Performance Curve

- Pump Information
- Flow and Pressure at Several Points
- Hydraulic Efficiency
- Horsepower
- Net Positive Suction Head Required (NPSHr)

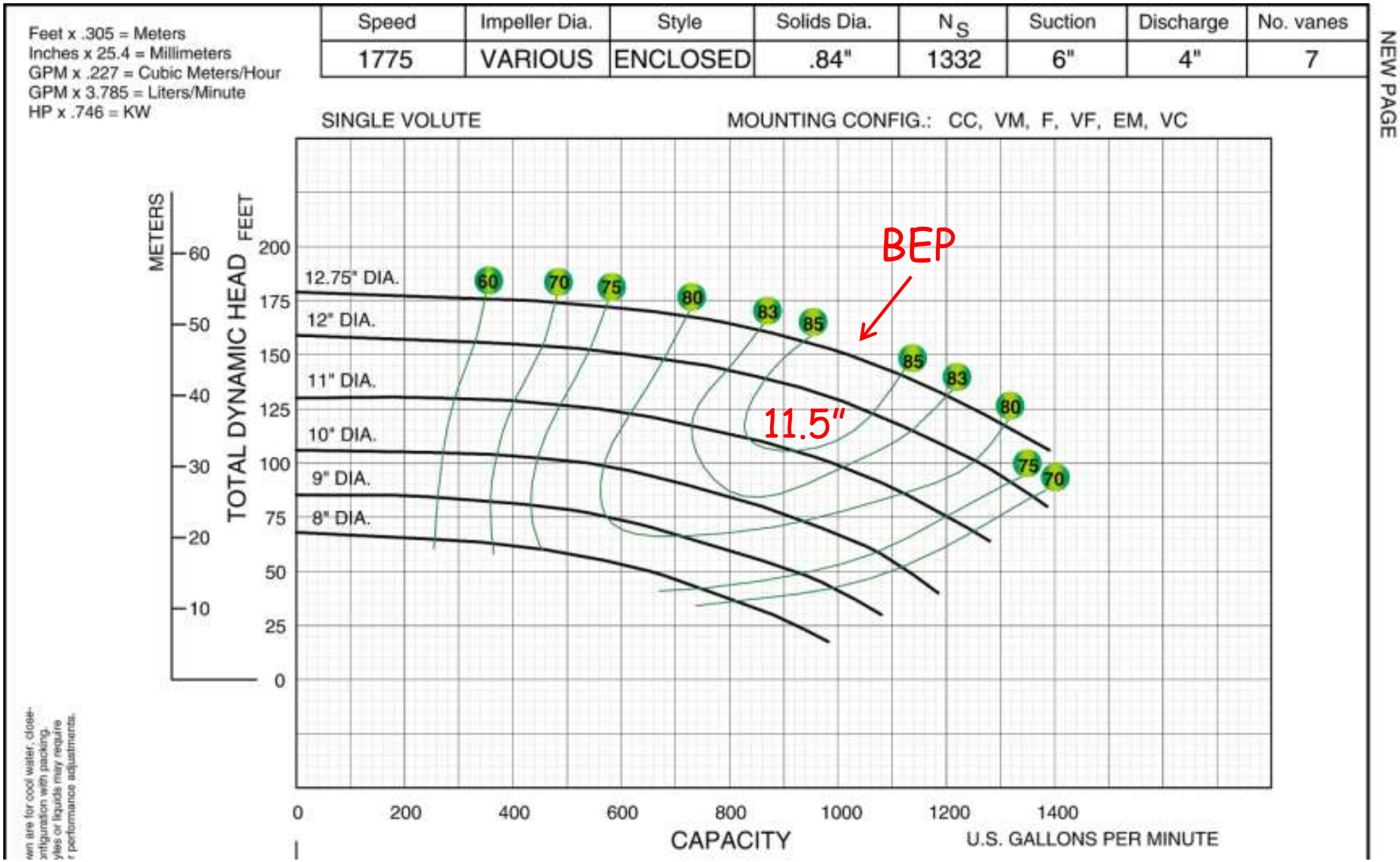
The Performance Curve

Feet x .305 = Meters
Inches x 25.4 = Millimeters
GPM x .227 = Cubic Meters/Hour
GPM x 3.785 = Liters/Minute
HP x .746 = KW

Speed	Impeller Dia.	Style	Solids Dia.	N_S	Suction	Discharge	No. vanes
1775	VARIOUS	ENCLOSED	.84"	1332	6"	4"	7



The Performance Curve



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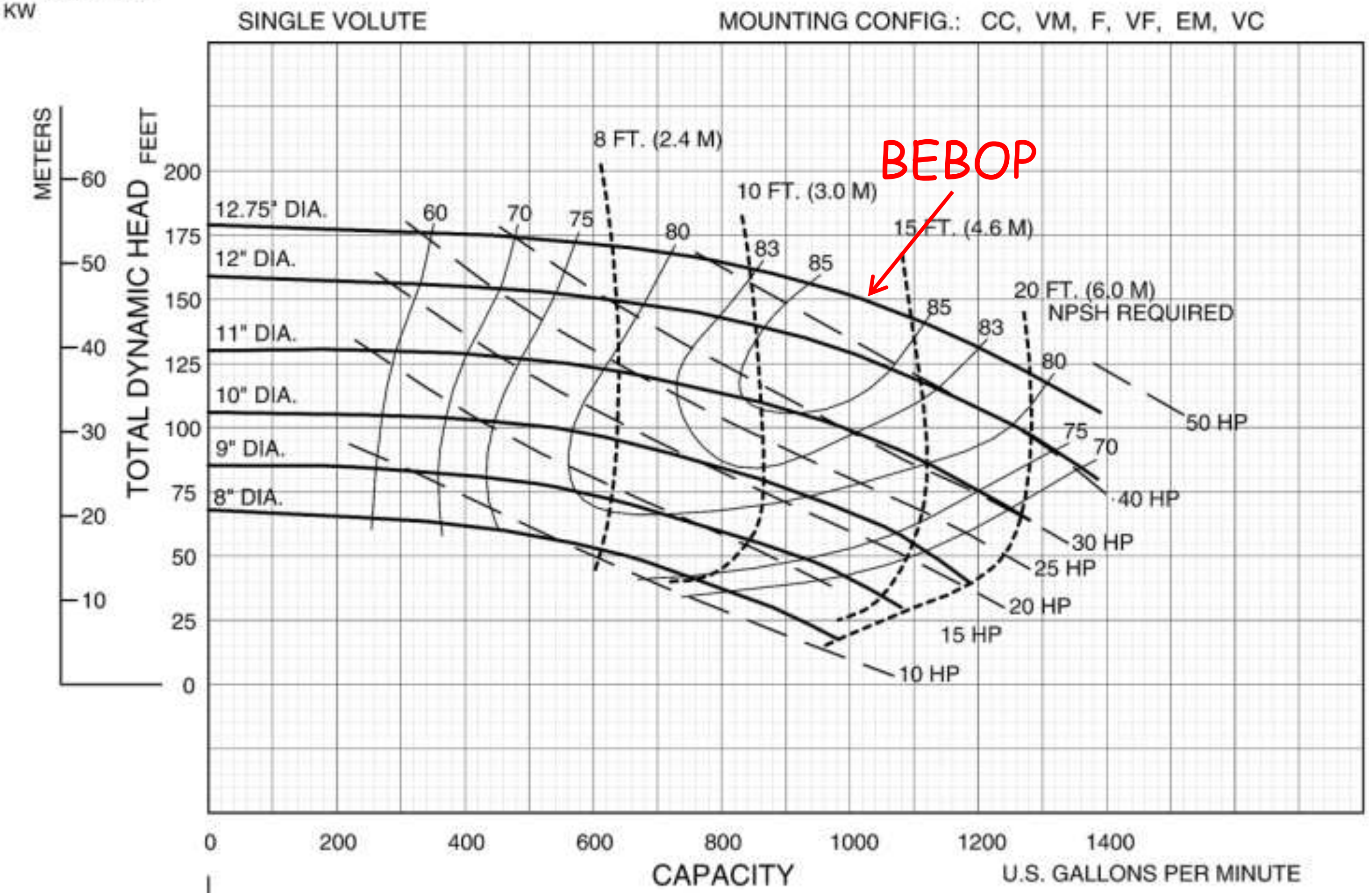
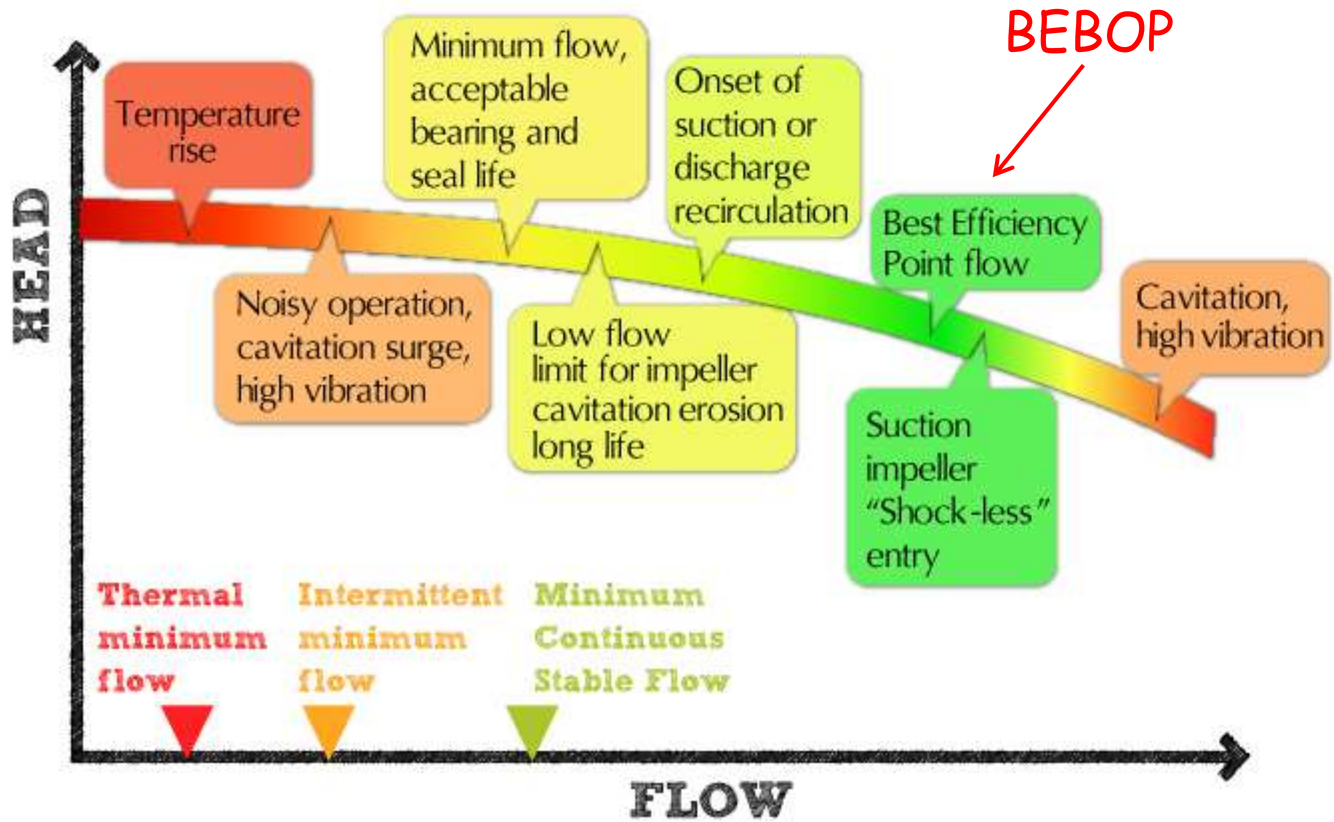


The Performance Curve

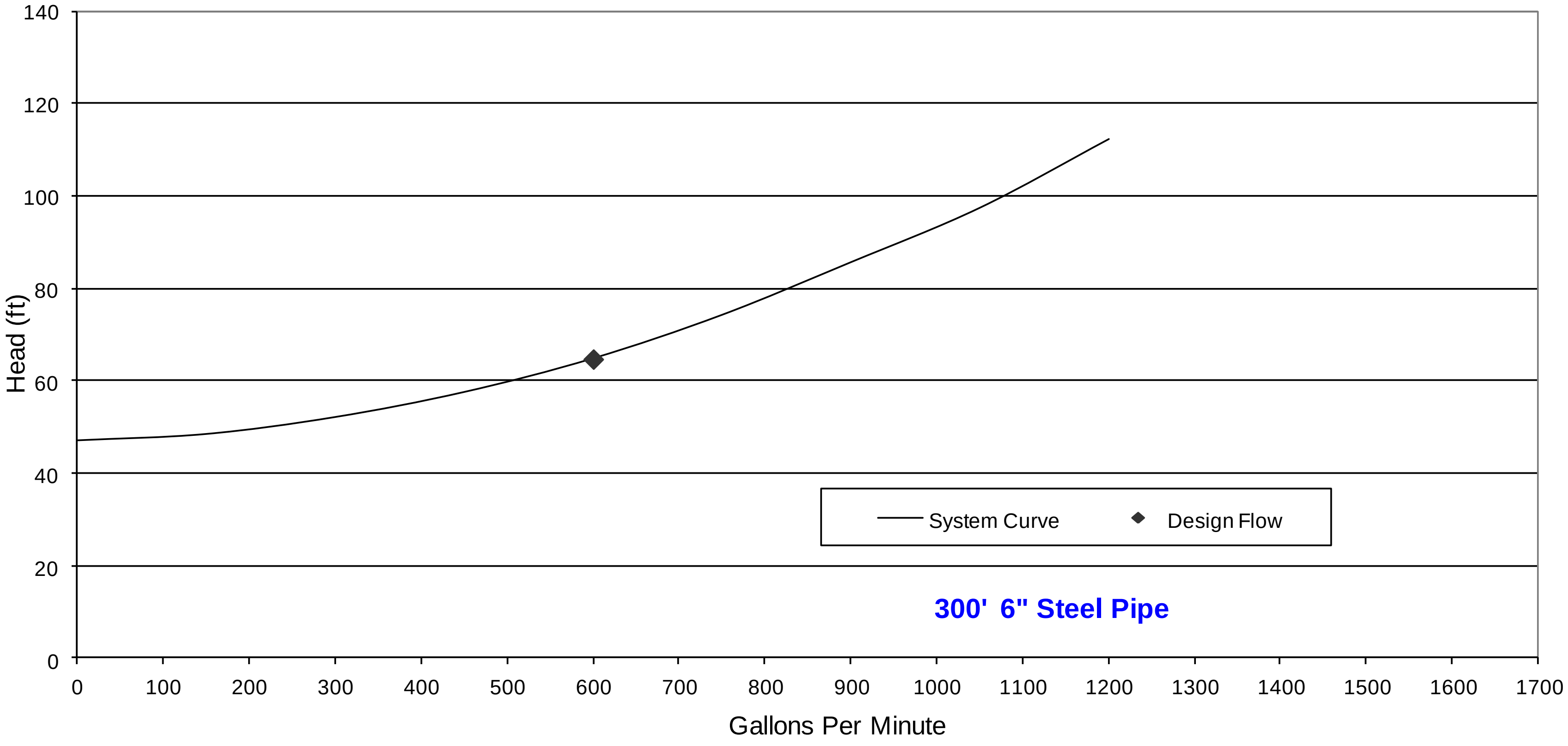


BEBOP & The Cost of Pump Operation

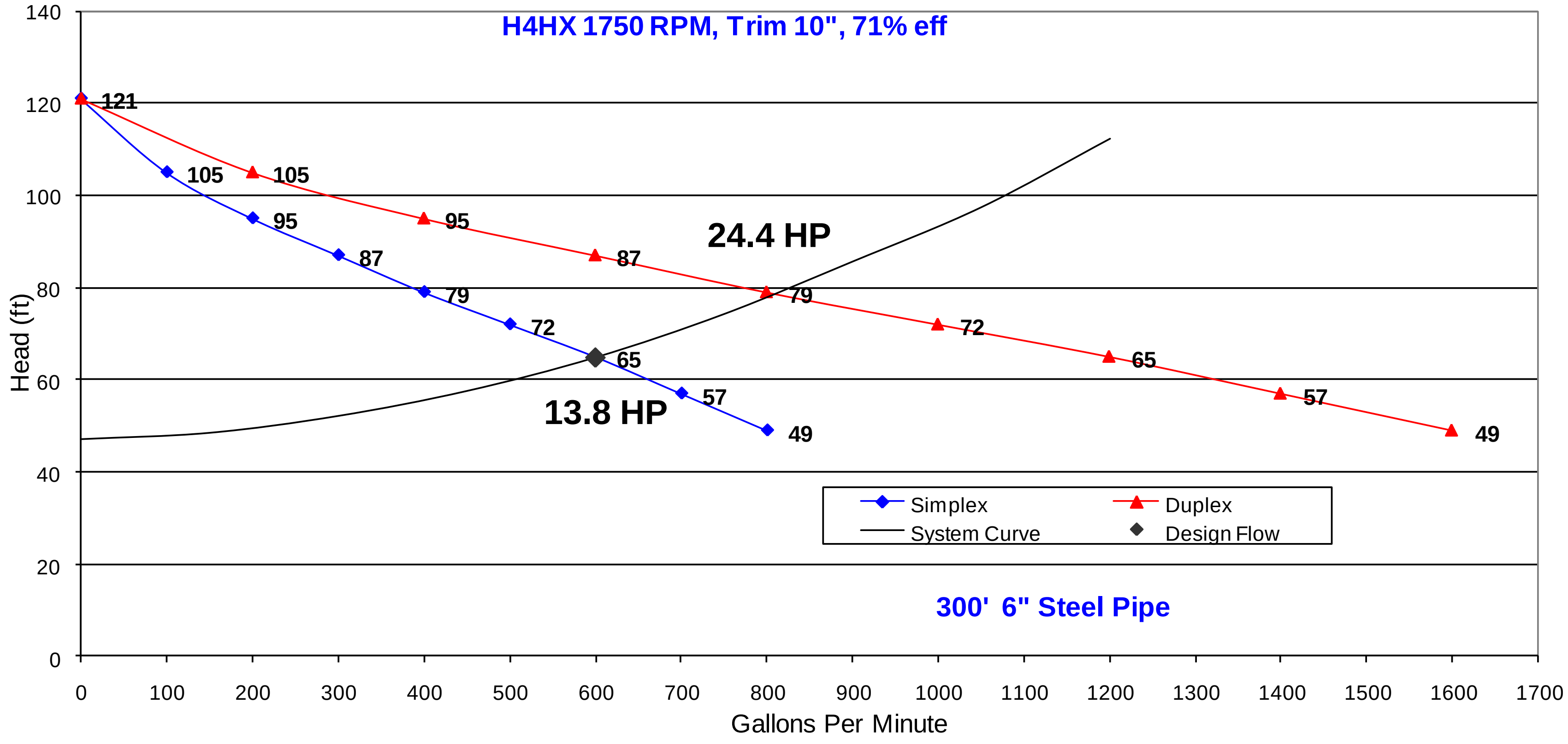
When a centrifugal pump is operated at BEBOP

- Power consumption is at its lowest
- Maintenance costs are their lowest
- Useful life is at its maximum

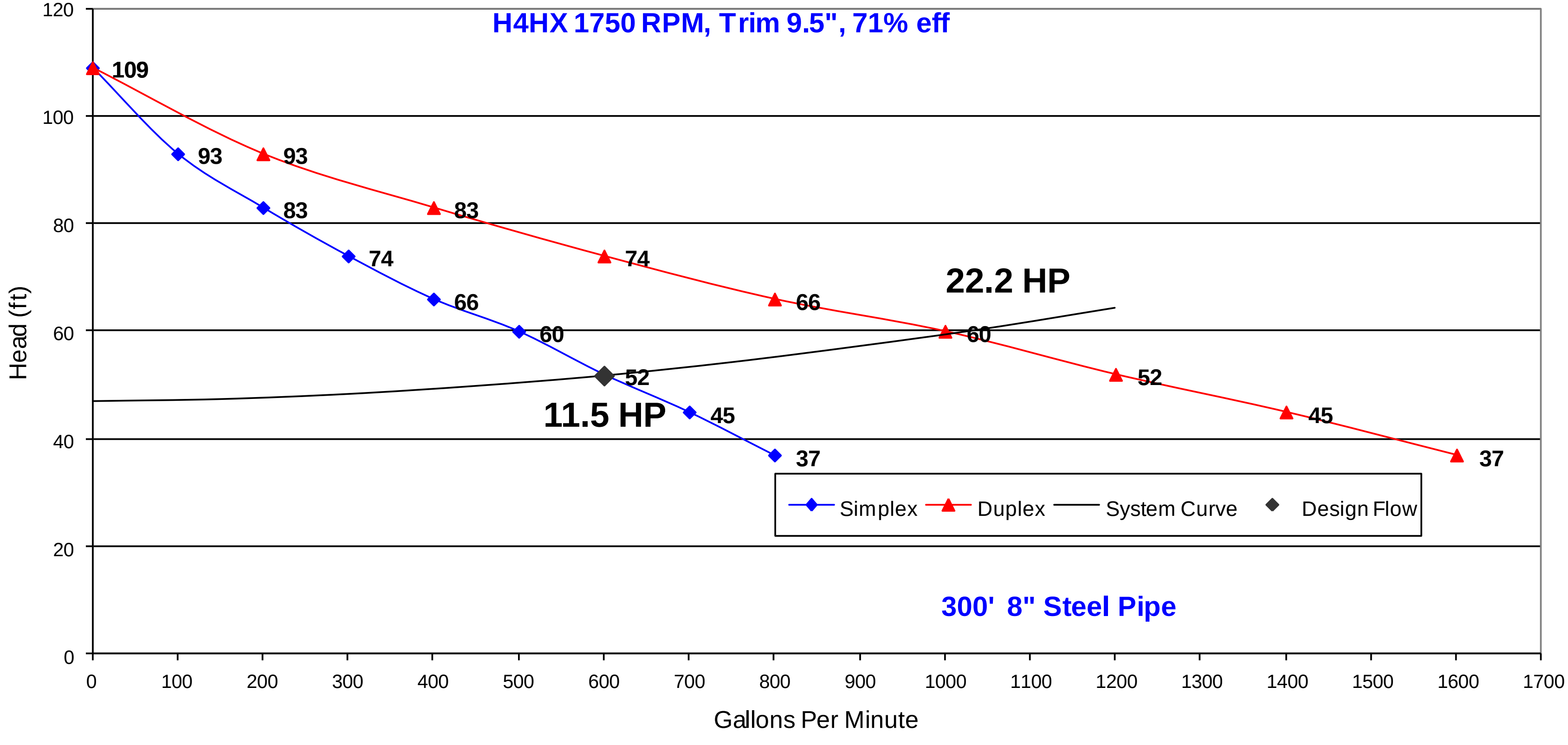
The System Curve



The System Curve



The System Curve

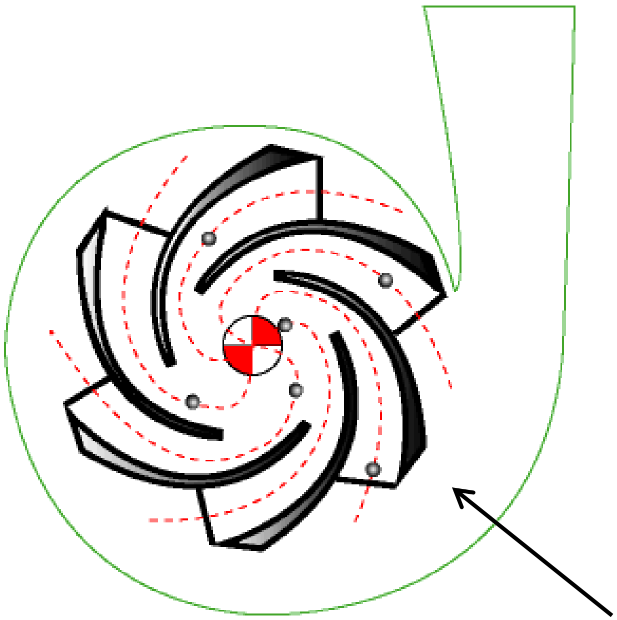


System Hydraulics – Radial Thrust

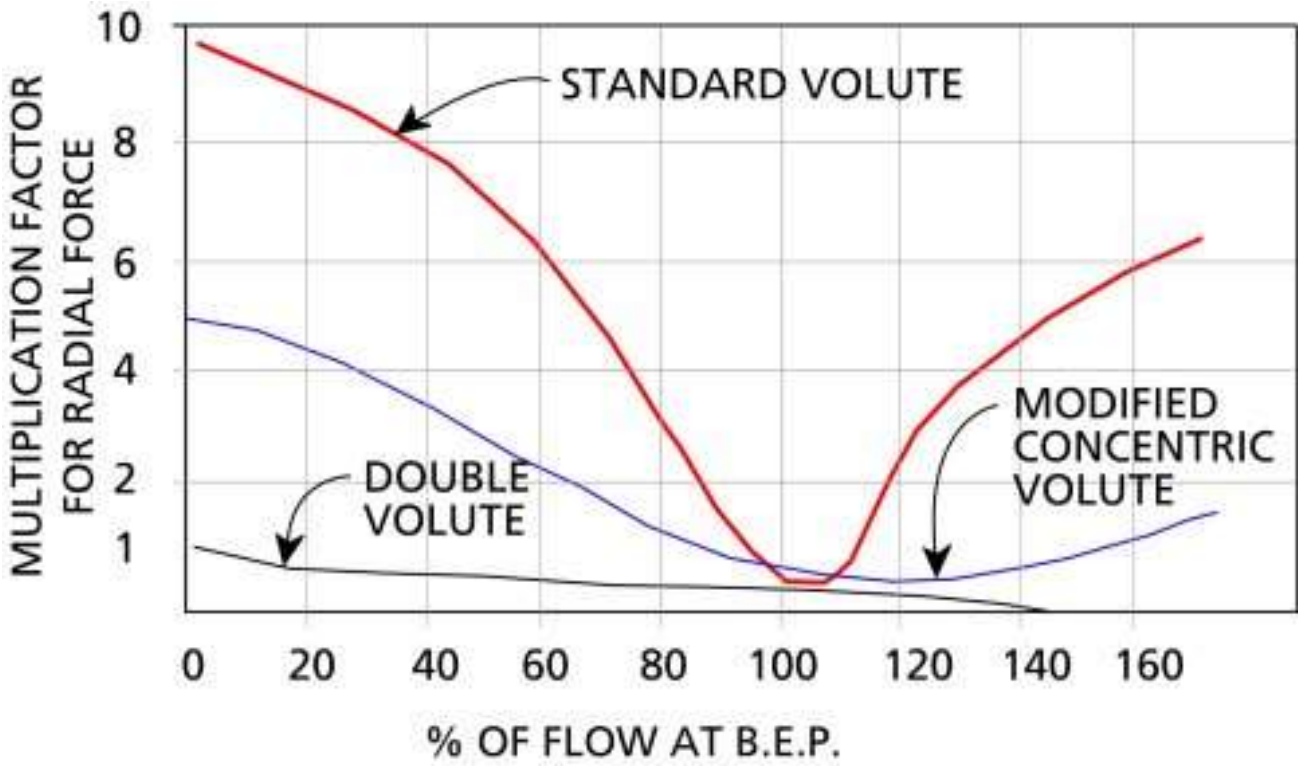
- Ideally a pump should operate between 90% and 110% of its BEBOP.
- If it does not, the radial forces that act upon a centrifugal pump's impeller can account for a large percentage of premature failures.
- The increased shaft deflection will decrease mechanical seal, wear ring, and bearing life.
- Worse case - shaft breakage

Radial Thrust

- Forms about the periphery of the impeller due to uneven volute geometry
- A function of total head, width and diameter of the impeller
- Usually reaches a maximum at or near shut off head



Radial Thrust Factor



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Radial Thrust Calculator

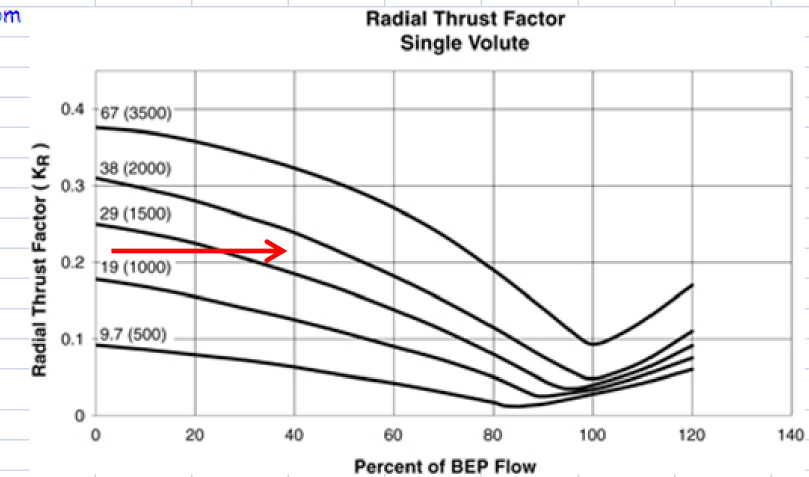
G11 138

Radial Thrust Calculator - Joe Evans www.PumpEd101.com

Radial Thrust (PSI): $F_R = K_R \times (H \times s/2.31) \times D_2 \times b_2$

Enter the required data in the highlighted cells. If you do not know the pump specific speed use the Ns calculator below.

Thrust Factor (KR) @ flow point (from graph)	0.21
Head (H) per Stage @ flow point in feet	138
Specific Gravity (S)	1
Impeller Diameter (D2) in inches	11.88
Impeller Width (b2) @ discharge in inches	3.5
F_R (Unbalanced Radial Thrust in lbf) =	522



Pump Specific Speed: $Ns = N\sqrt{Q} / H^{0.75}$

Enter the required data in the highlighted cells

Pump RPM (N)	1750
Flow (Q) @ BEP	1200
Head (H) @ BEP	110
Ns =	1785

Instructions

The numbers in ( ) are Pump Specific Speed (Ns). The curves represent the radial thrust factor from 0 to 120% of BEP flow for that particular specific speed. Select a point on the X axis that corresponds to the point to be evaluated on the pump H/Q curve. The thrust factor is the value on the Y axis where the curve intersects the selected X axis value. For values of Ns that fall between the ones shown you may interpolate the intersection. Impeller width (b2) is the width in inches at the discharge including the shroud(s). The example shown is for a sewage pump with a specific speed of 1785, operating at 40% of BEP flow. At 100% of BEP flow, radial thrust is reduced to 59 lbs. Worst case? This pump is approved by the manufacturer for flows as low as 21% of BEP. At that flow point, radial thrust reaches 660 lbs.

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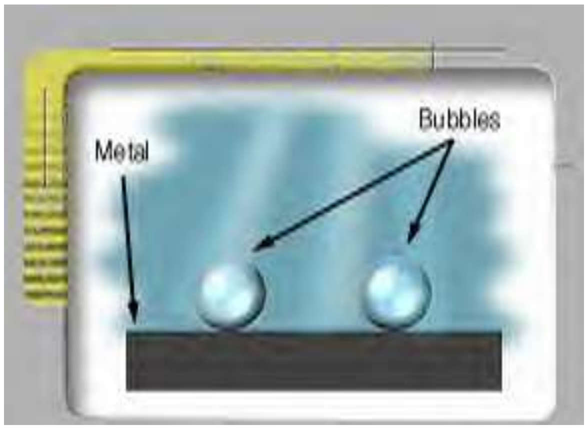
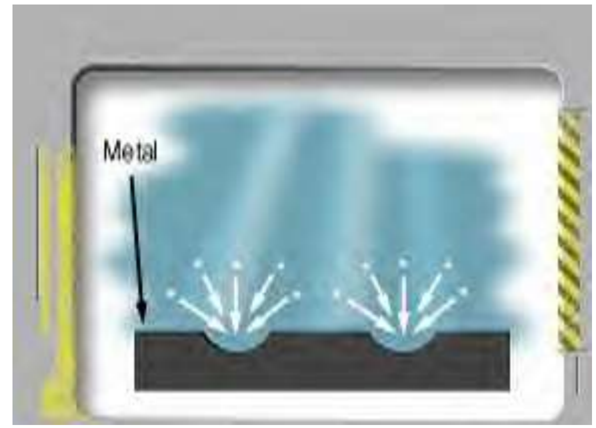
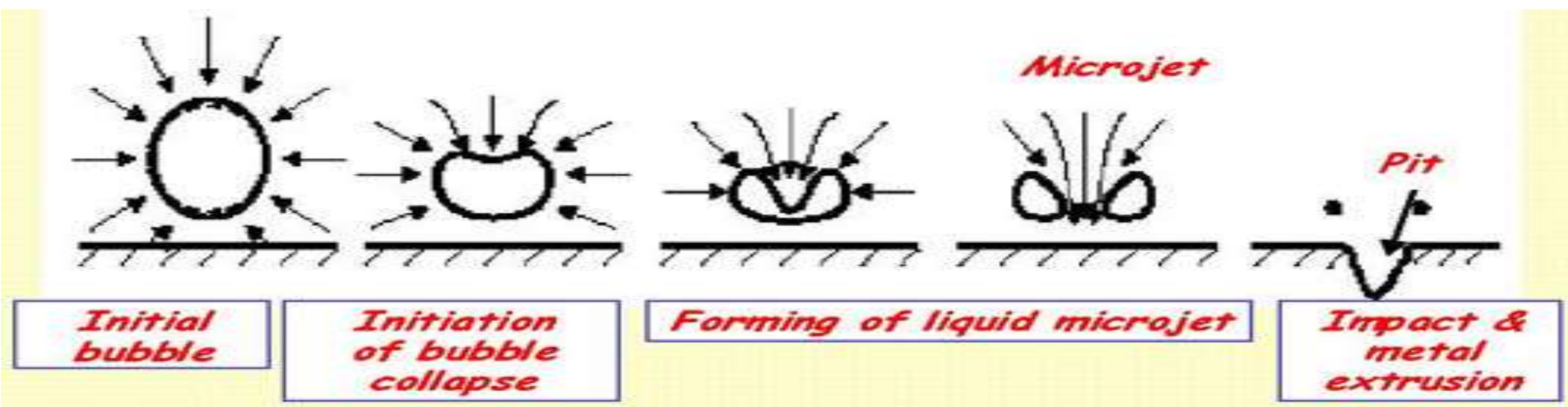
Cavitation


Bubbles
Metal


Metal


Microjet
Pit
Initial bubble
Initiation of bubble collapse
Forming of liquid microjet
Impact & metal extrusion

Types of Cavitation

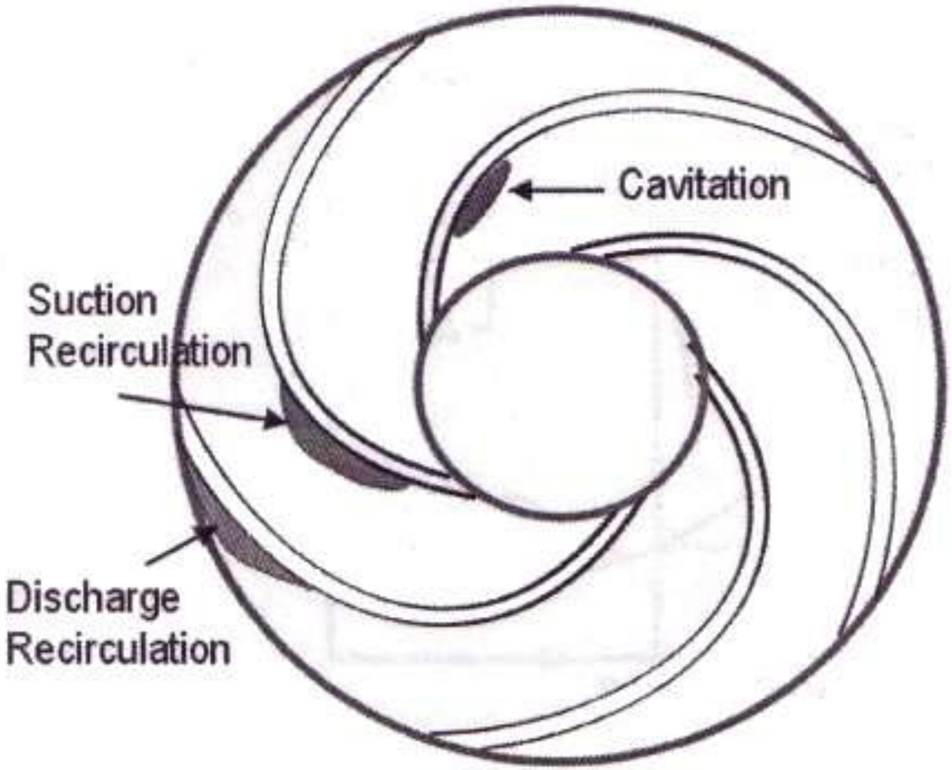
Normal Cavitation – Low NPSHa

Wear Ring Recirculation – Low Flow

Discharge Recirculation – Low Flow

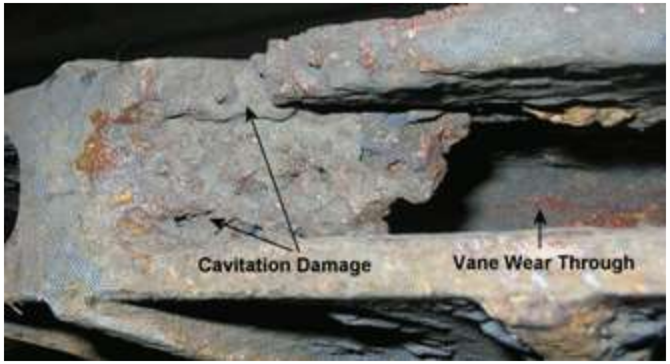
Suction Recirculation – Low Flow

Types of Cavitation



Wear Ring Recirculation Cavitation

Discharge Recirculation Cavitation



Occurs on the high pressure side of the vane

Discharge Recirculation Cavitation Two Vane

Suction Recirculation Cavitation

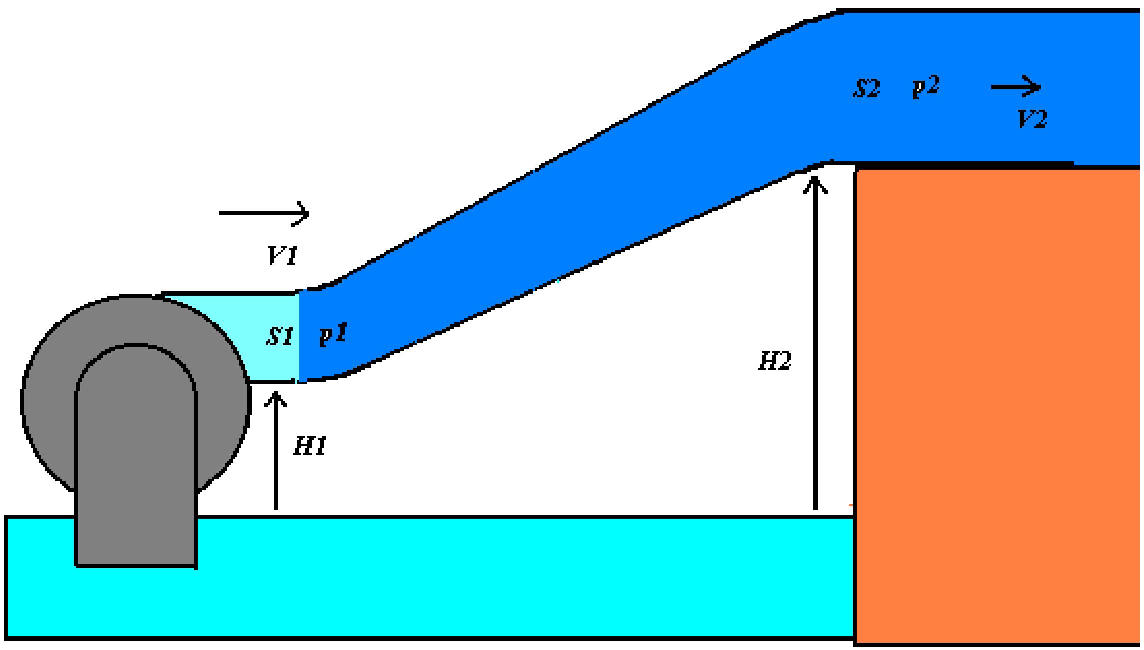
Occurs on the high pressure side of the vane

Suction Recirculation Cavitation

Suction & Discharge Recirculation Cavitation

Conservation of Energy

Bernoulli's theorem states that, during steady flow, the energy at any point in a conduit is the sum of the velocity head, pressure head, and elevation head. It also states that this sum will remain constant if there are no losses. Daniel Bernoulli 1700-1782



Total Dynamic Head

Total Dynamic Head

$H = h_d - h_s$

Where:

h_d = discharge head

h_s = suction head

Total Suction Head

$h_s = \pm h_{gs} + h_{vs} \pm Z_s$

Total Discharge Head

$h_d = h_{gd} + h_{vd} \pm Z_d$

Where:

h_g = gauge head

h_v = velocity head

Z = gauge distance above or below datum

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What is Velocity Head ?

It is a form of energy that cannot be measured with a pressure gauge.

Why is It Important ?

If it is not measured, pump test results will be inaccurate.

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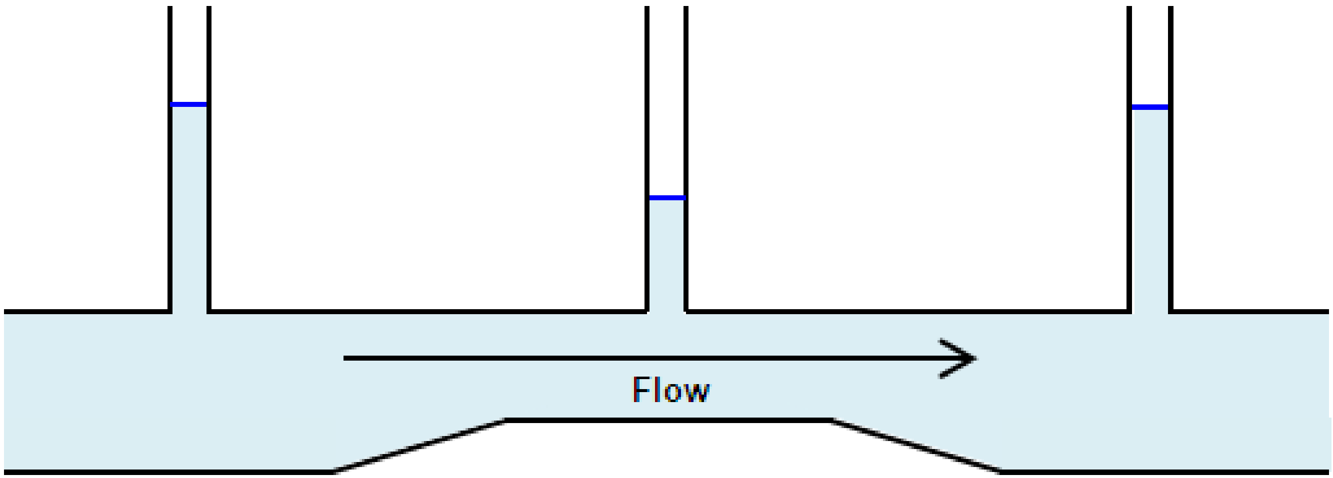
Energy = v + P + z = Constant



Piezometer Measurement

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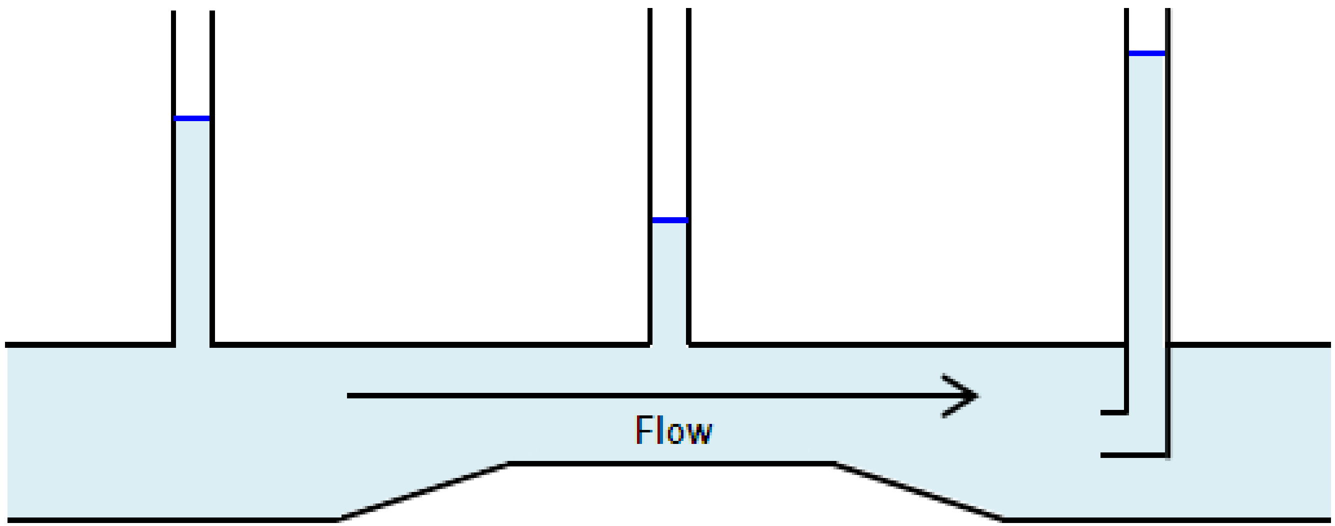
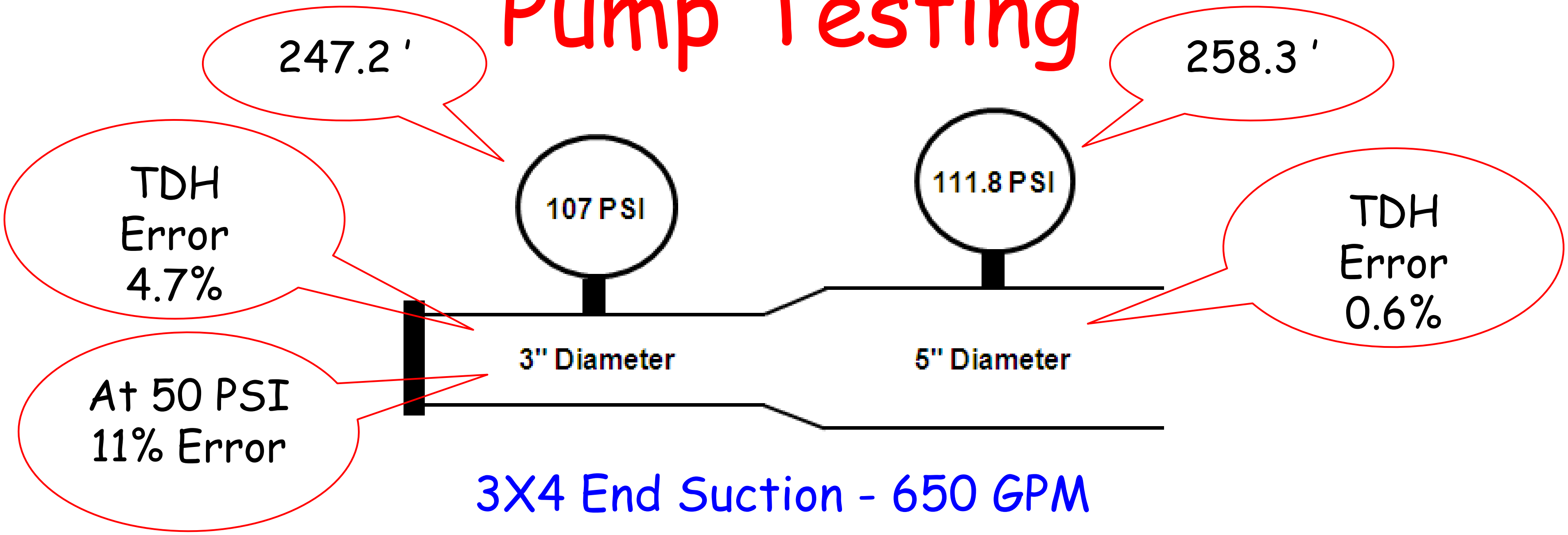
Energy = v + P + z = Constant



Piezometer & Pitot Tube Measurement

Pump Testing



3X4 End Suction - 650 GPM

Velocity 3" = 28.2 ft/sec   Velocity 5" = 10.4 ft/sec

$$h_v = V^2 / 2g$$

3" Section h_v = 12.4 ft   5" Section h_v = 1.7 ft

Actual Pressure = 112.5 PSI (260 ft)

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