Pump ED 101

Joe Evans, Ph.D
http://www.pumped101.com

Centrifugal Pump Intro

Part 1 - Elementary Mechanics & Hydraulics

What is a Centrifugal Pump?

- It is a machine that imparts energy to a fluid causing it to flow, rise to a higher level, or both.

- It uses acceleration (not centrifugal force) to transform mechanical (rotational) energy into hydraulic energy.

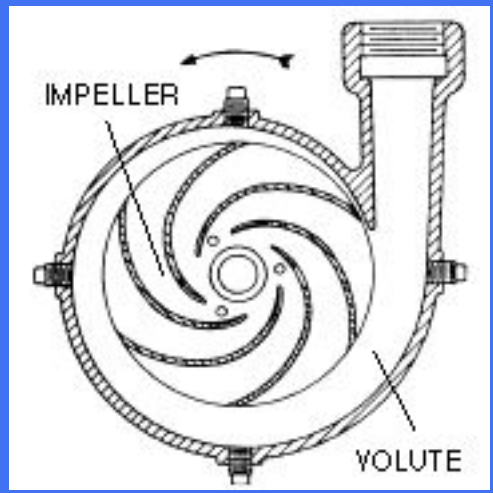
How Does It Work?

- A centrifugal pump consists of an impeller and a volute (most end suction pumps) or a diffuser (submersible turbine pumps).

- Rotation of the impeller forces water from its entry point, at the impeller eye, through the impeller's vanes and into the volute or diffuser.

As water moves from the center of the circular impeller to its periphery, its velocity increases. When it reaches the volute, velocity is transformed into pressure.

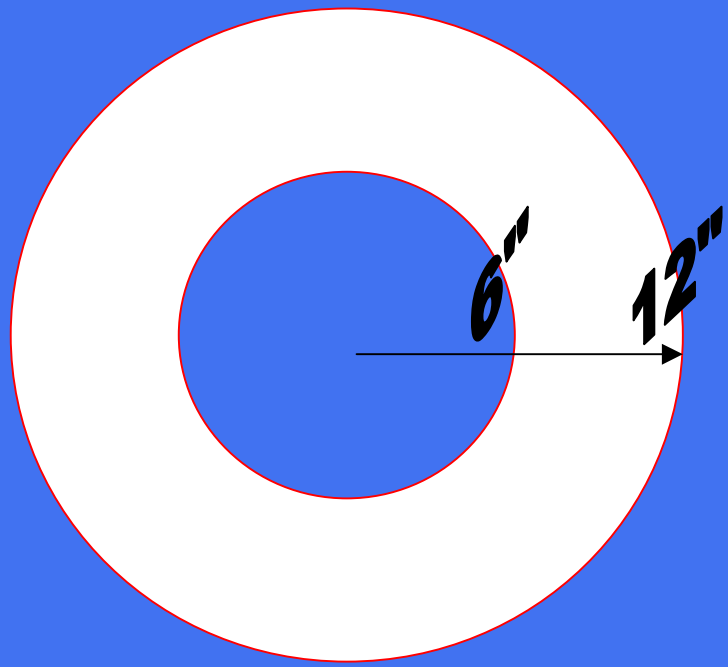
The flow and pressure created by a centrifugal pump depends upon the design of its impeller and its peripheral velocity. An impeller's peripheral velocity is dependent upon its diameter, its rotational speed, or both.



Peripheral Velocity

On the disc below there are two points, one at 6” from its center and one at 12”. The circle described at 6” has a circumference of 37.7” and the one at 12” a circumference of 75.4”.

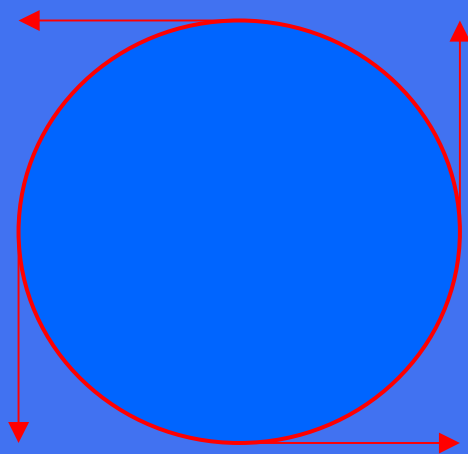
At a speed of one rotation per second a point 12” from the center will travel twice the distance of a point that is 6” from the center. Therefore its velocity must be twice as great.



Circular Motion

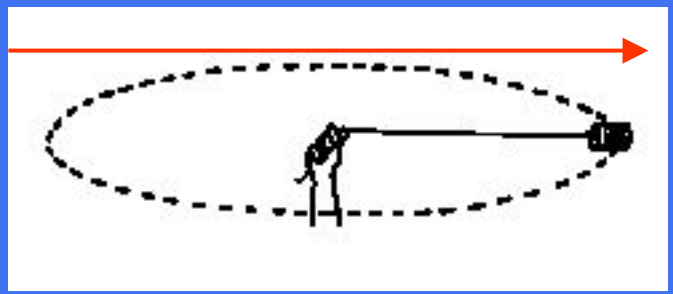
- When an object is traveling in a circle, it is actually moving in a straight line at any single point in time.

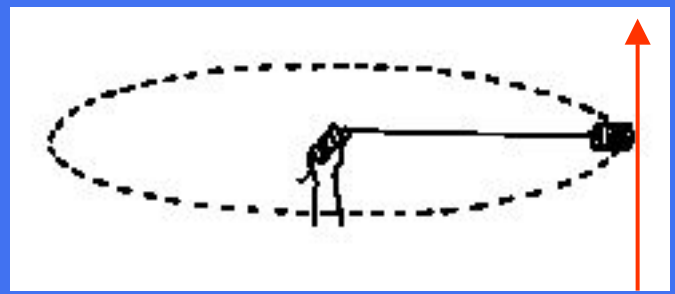
- The arrows at 12, 3, 6, and 9 o'clock show the direction of travel at that instant in time.



Centrifugal Force (farce?)

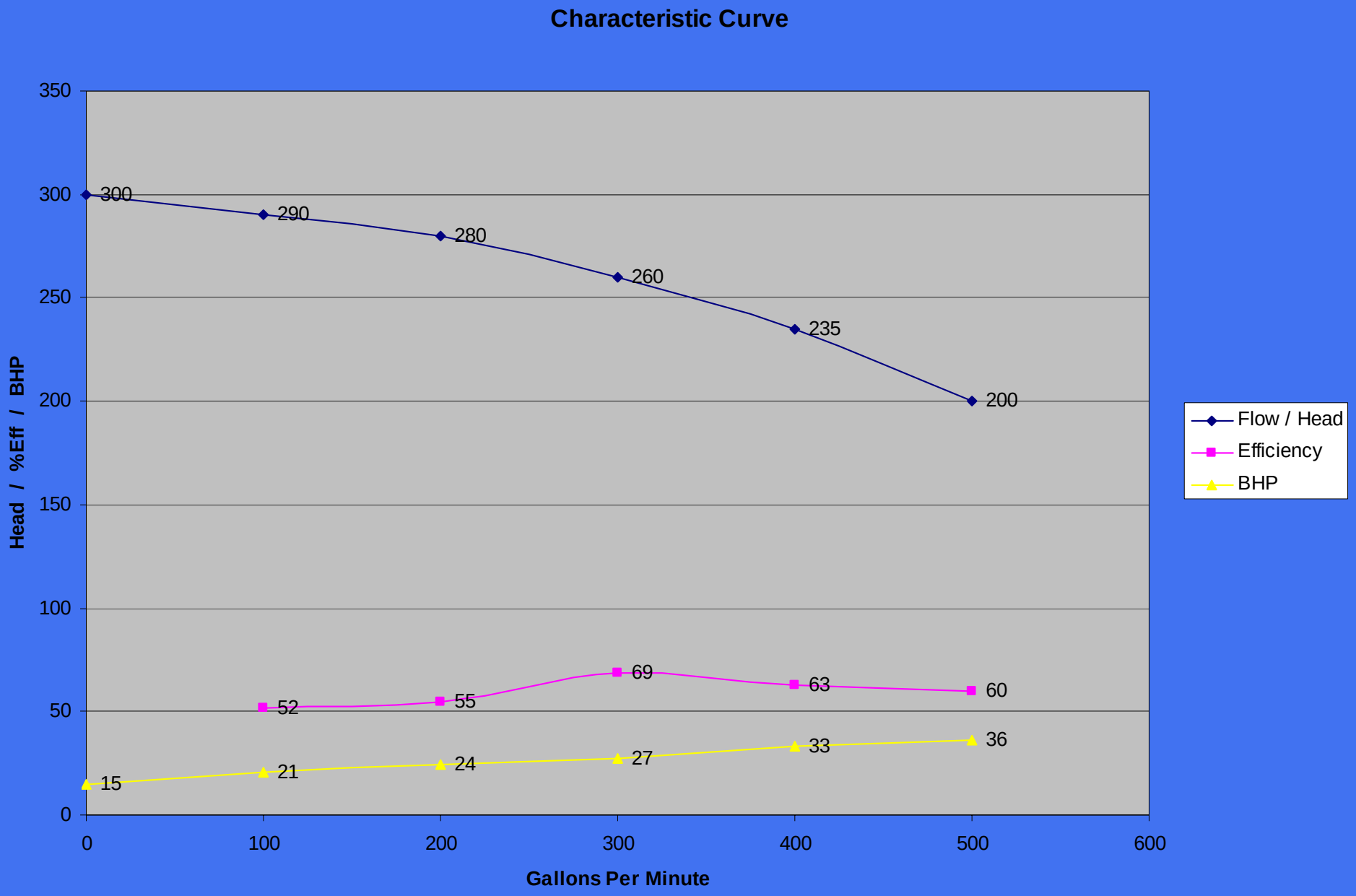
- If centrifugal force were a true outward force the swinging can would move in the direction of the red arrow when the string is released.
- Instead it actually moves in the same direction it was traveling at the exact moment it is released.





The Performance Curve

- Flow and Pressure at several points
- Hydraulic Efficiency
- Horsepower
- Net Positive Suction Head Required (NPSHR)


Characteristic Curve
Head / %Eff / BHP
Gallons Per Minute
0
50
100
150
200
250
300
350
0
100
200
300
400
500
600
300
290
280
260
235
200
52
55
69
63
60
15
21
24
27
33
36
Flow / Head
Efficiency
BHP

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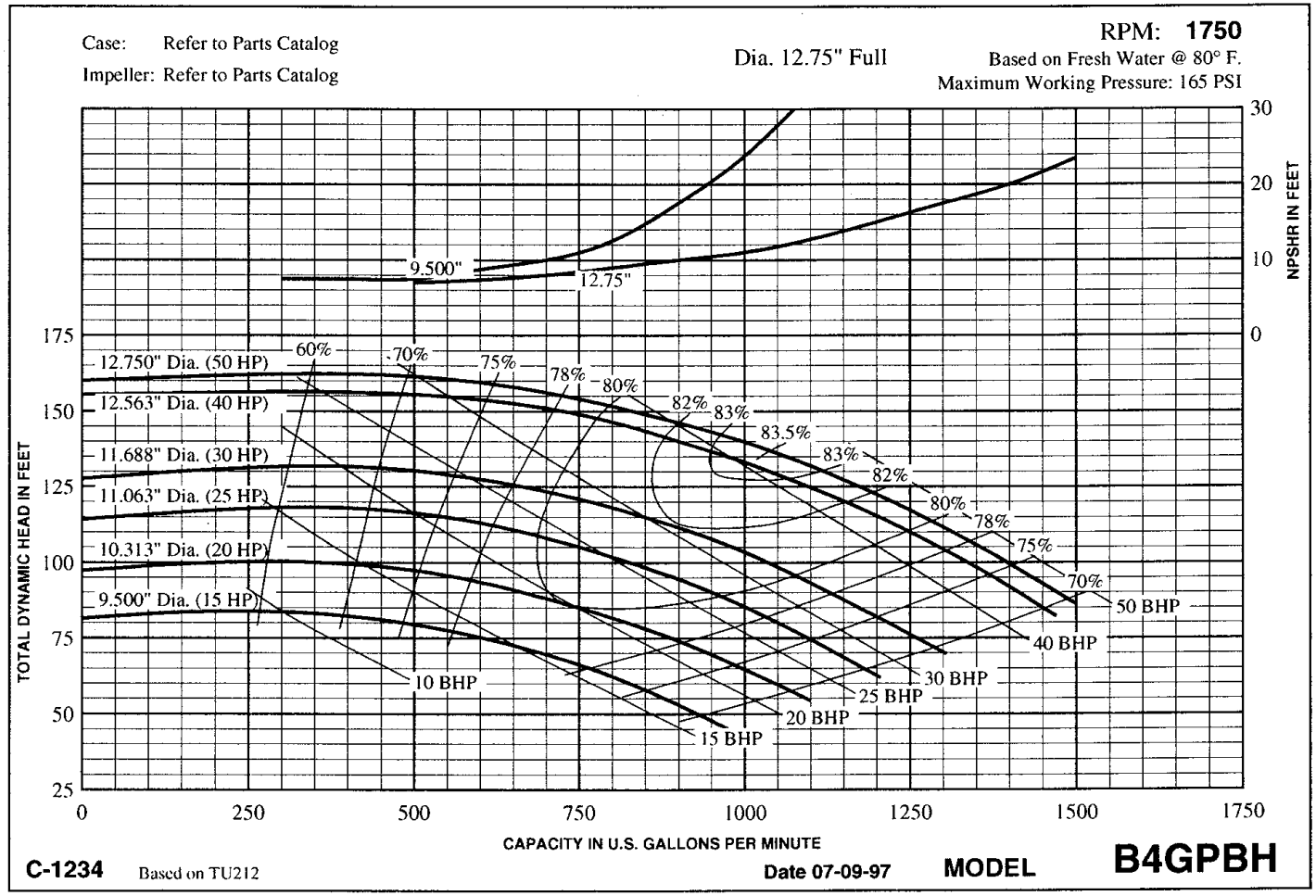
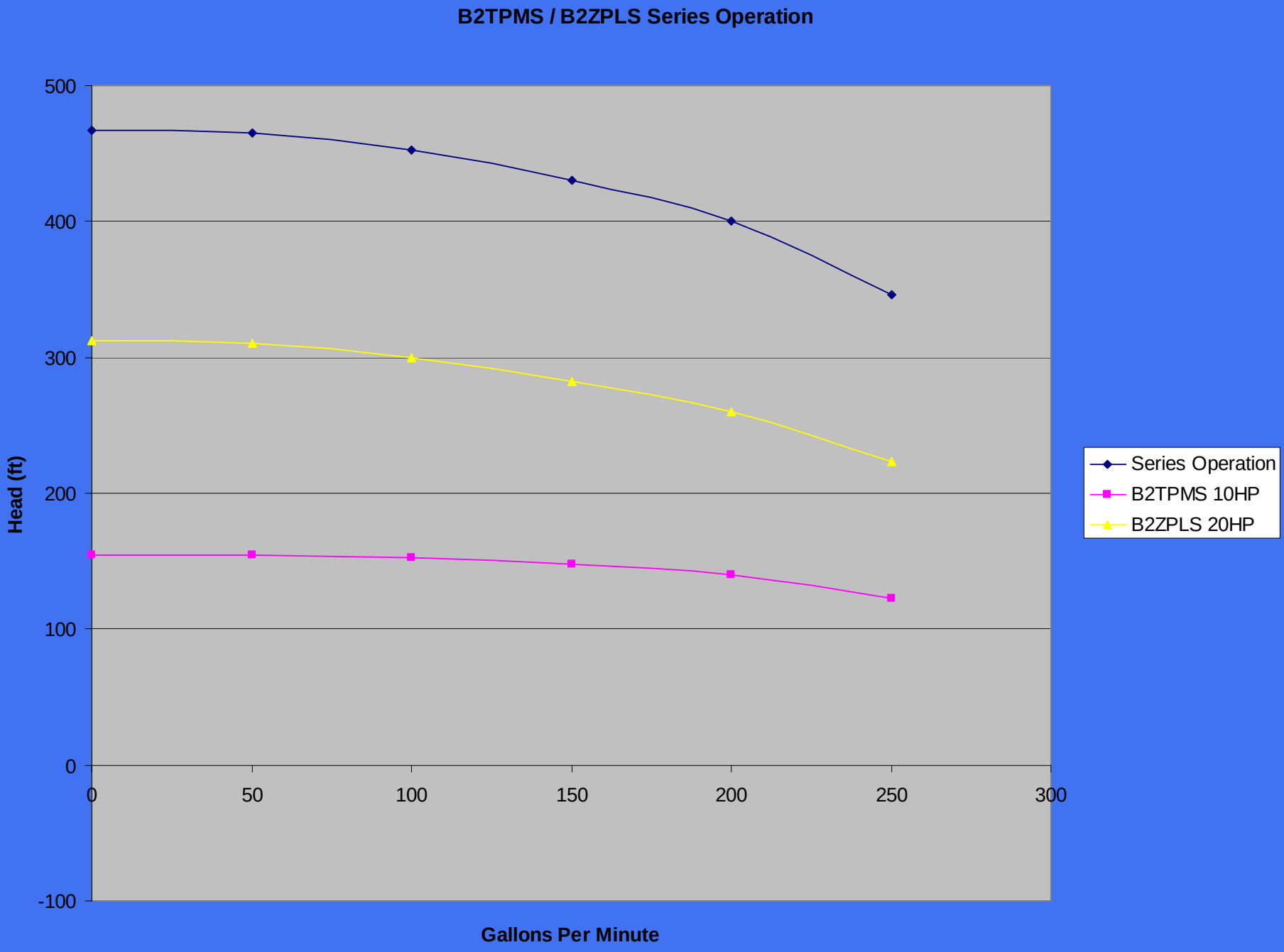
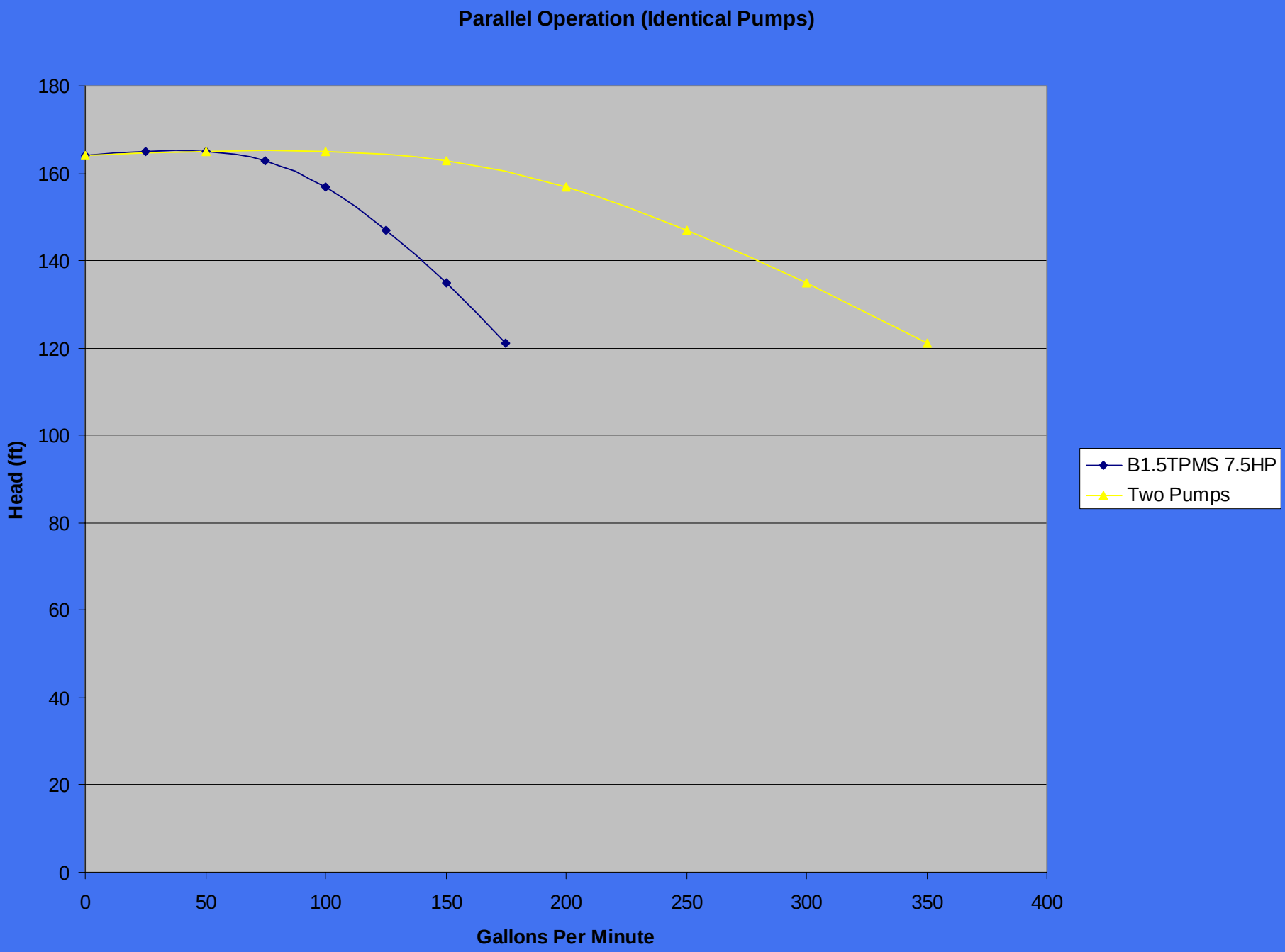


Series & Parallel Operation

- A unique feature of centrifugal pumps is their ability to operate in series (one discharging into another) or parallel (common suction and discharge).

- When operated in series, pressure is additive while flow remains the same. In parallel, flows are additive while pressure remains the same.


B2TPMS / B2ZPLS Series Operation
500
400
300
200
100
0
-100
Head (ft)
0
50
100
150
200
250
300
Gallons Per Minute
Series Operation
B2TPMS 10HP
B2ZPLS 20HP


Parallel Operation (Identical Pumps)
Head (ft)
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
Gallons Per Minute
B1.5TPMS 7.5HP
Two Pumps

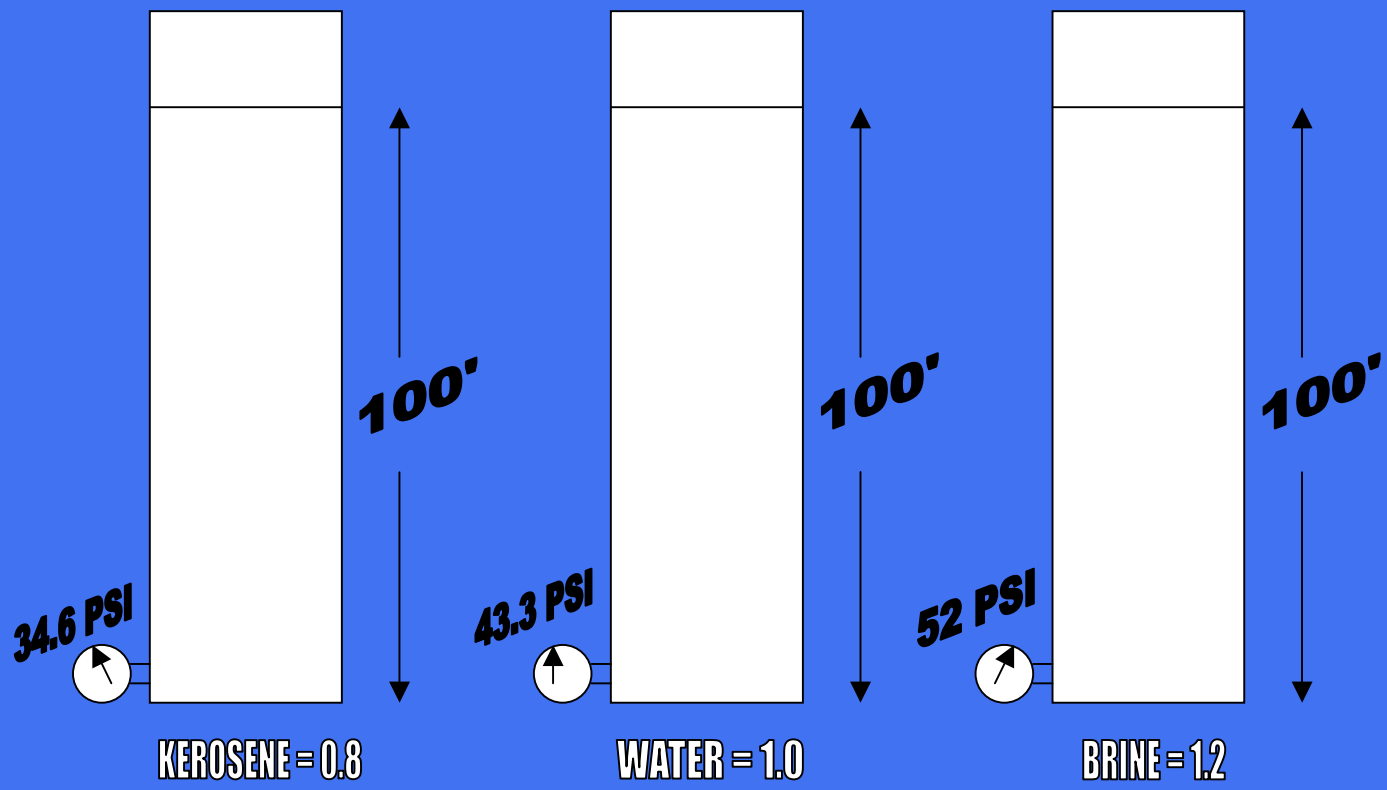
Pressure in Feet vs PSI

- Why is pump pressure usually stated in feet rather than PSI?
- It has to do with something known as specific gravity.

Specific Gravity

- The Specific Gravity of a liquid is the ratio of its weight of a given volume to that of an equal volume of water.
- A centrifugal pump will always develop the same head in feet regardless of a liquid's specific gravity (weight).
- Pressure in PSI varies directly with specific gravity.
- Brake HP required varies directly with specific gravity.

Effect of Specific Gravity upon Pressure in PSI



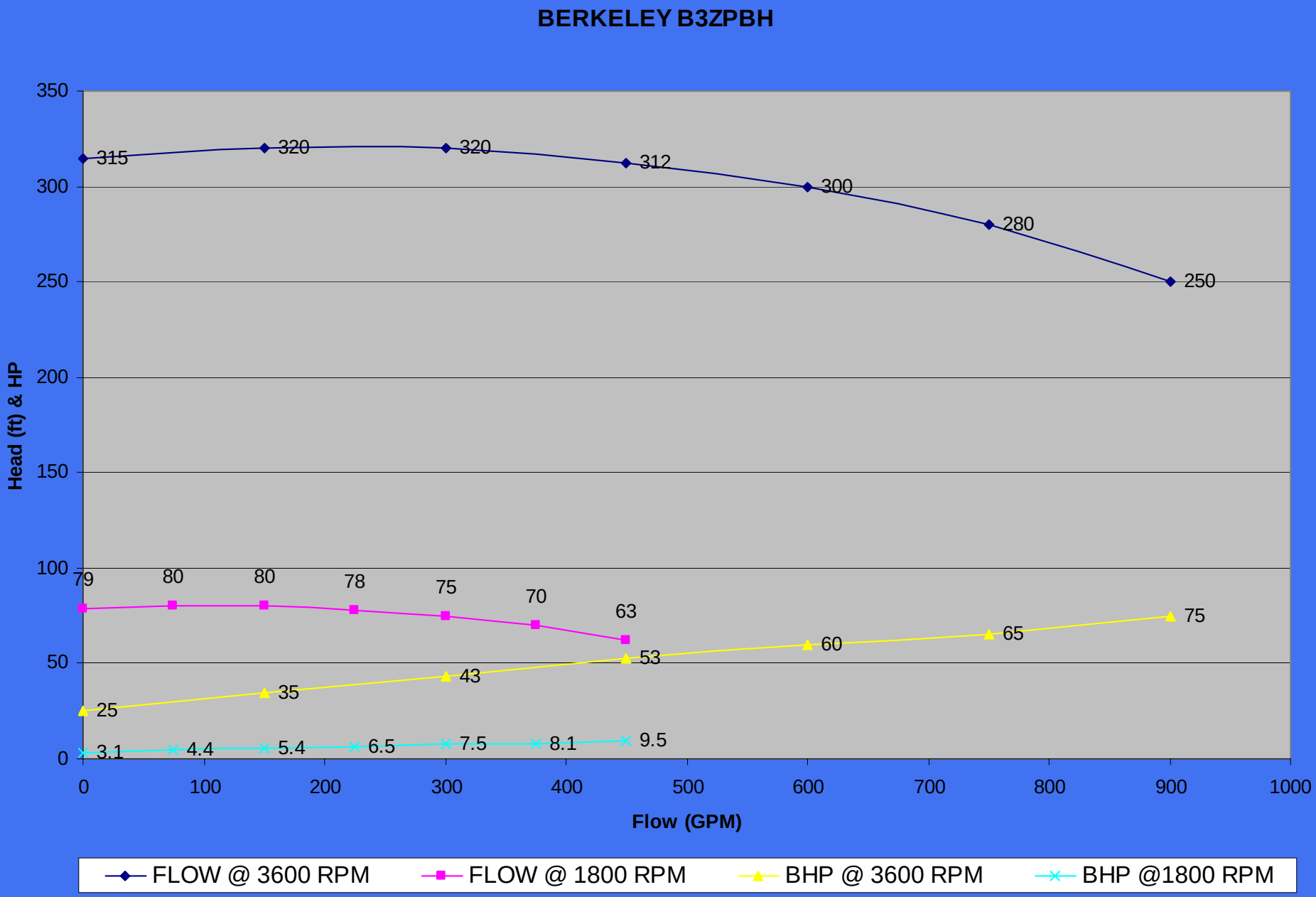
Affinity

- Affinity - (definition) closely related or connected; a resemblance of structure or behavior

- When the driven speed or impeller diameter (think peripheral speed) of a centrifugal pump changes, its operation changes in accordance with three fundamental laws.

The Affinity Laws

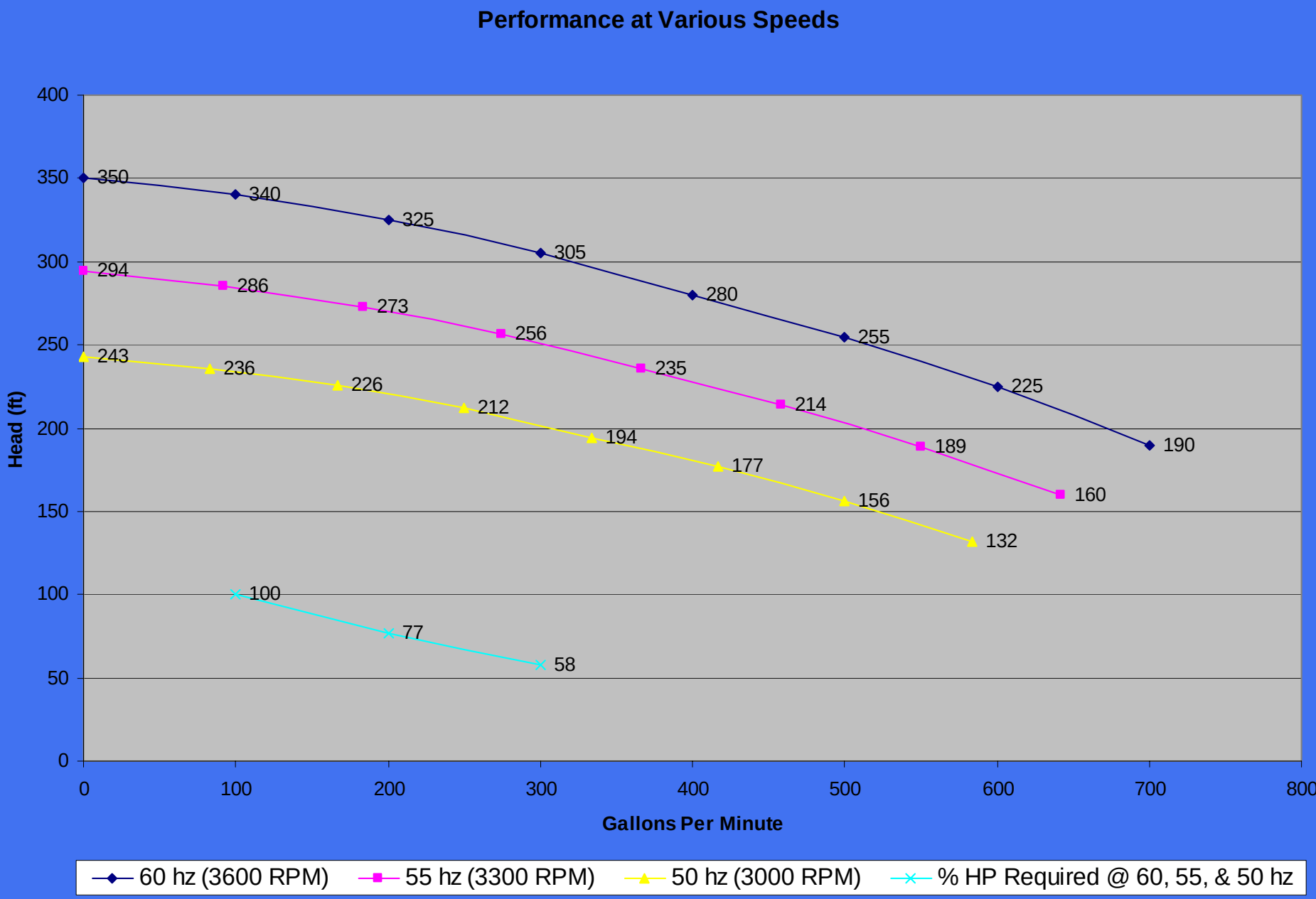
- Capacity (GPM) varies directly with a change in speed or impeller diameter.
- Head (Feet or PSI) varies as the square of a change in speed or impeller diameter.
- Brake horsepower (HP) varies as the cube of a change in speed or impeller diameter.


BERKELEY B3ZPBH
Head (ft) & HP
Flow (GPM)
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
1000
315
320
320
312
300
280
250
79
80
80
78
75
70
63
25
35
43
53
60
65
75
3.1
4.4
5.4
6.5
7.5
8.1
9.5
FLOW @ 3600 RPM
FLOW @ 1800 RPM
BHP @ 3600 RPM
BHP @1800 RPM

Variable Frequency Operation

- The rotational speed of an AC induction motor depends upon the frequency (hz) of the current and the number of poles (coils) in its stator. At 60 hz, a two pole motor will complete 3600 rotations each minute.

- For each frequency reduction of 1 hz, a motor's speed will be reduced by 1/60 of its 60 hz speed (or 60 RPM in this case).


Performance at Various Speeds
Head (ft)
Gallons Per Minute
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
350
340
325
305
280
255
225
190
294
286
273
256
235
214
189
160
243
236
226
212
194
177
156
132
100
77
58
60 hz (3600 RPM)
55 hz (3300 RPM)
50 hz (3000 RPM)
% HP Required @ 60, 55, & 50 hz

Suction Conditions

- A pump cannot pull or “suck” water into its impeller because water has no tensile strength.
- It lifts water by creating a low pressure area in its impeller eye thus allowing atmospheric or some other outside pressure to push the water into its suction.

Suction Lift

- Maximum suction lift depends upon the pump design (NPSHR), the pressure applied to the surface of the water, and the vapor pressure of the water under existing conditions. The last two conditions are components of NPSHA.

Net Positive Suction Head

- Net Positive Suction Head (NPSH) can be broken down into two components.
- NPSHR - The NPSH Required
- NPSHA - The NPSH Available

Net Positive Suction Head Required

- NPSHR is a function of a specific pump design.

- In simple terms it is the pressure, measured at the centerline of the pump’s suction, necessary for the to function satisfactorily at a given flow.

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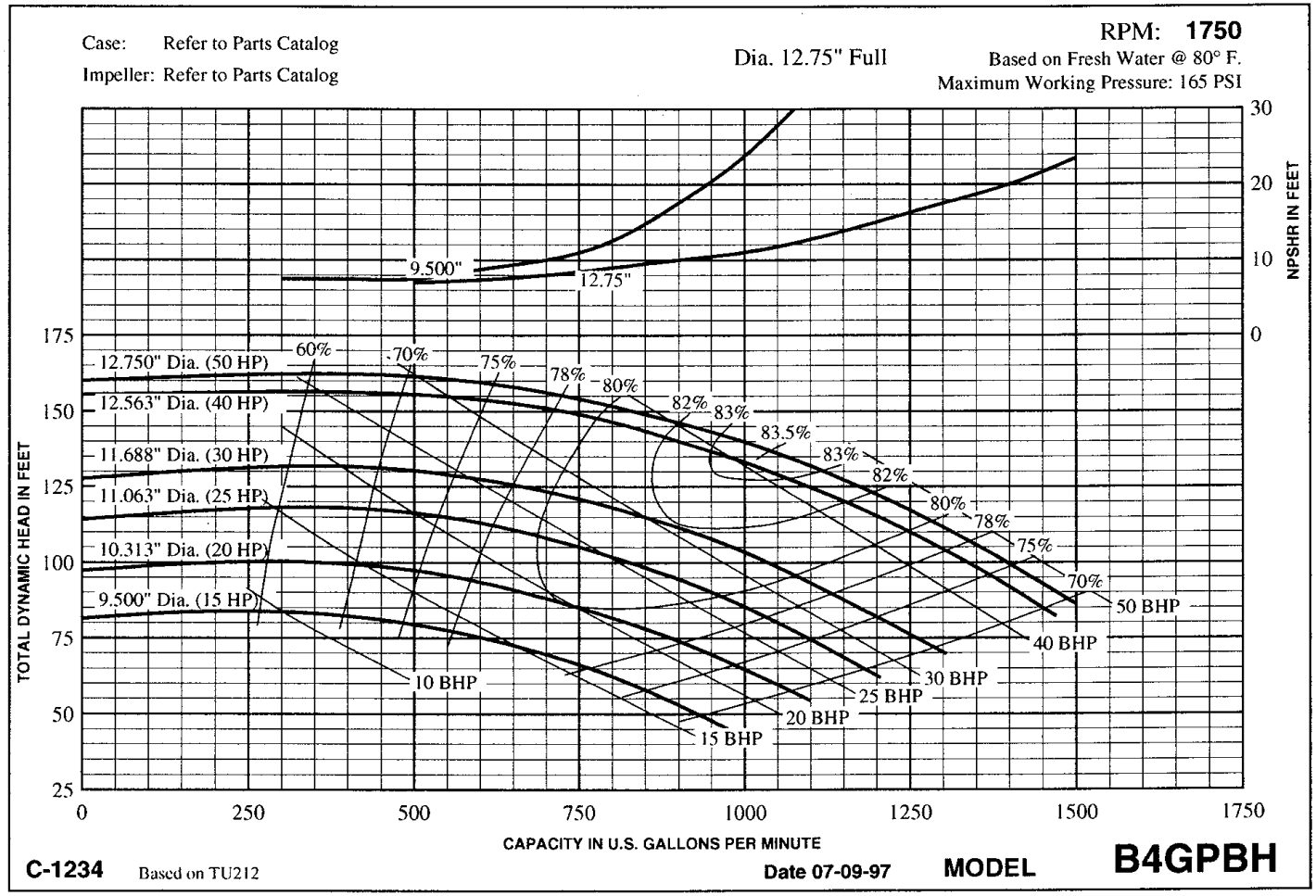


Net Positive Suction Head Available

- NPSHA depends upon the elevation or pressure of the suction supply, friction in the suction line, elevation of the installation, and the vapor pressure of the liquid being pumped.

- NPSHA = Ha + - Hs - Hvp

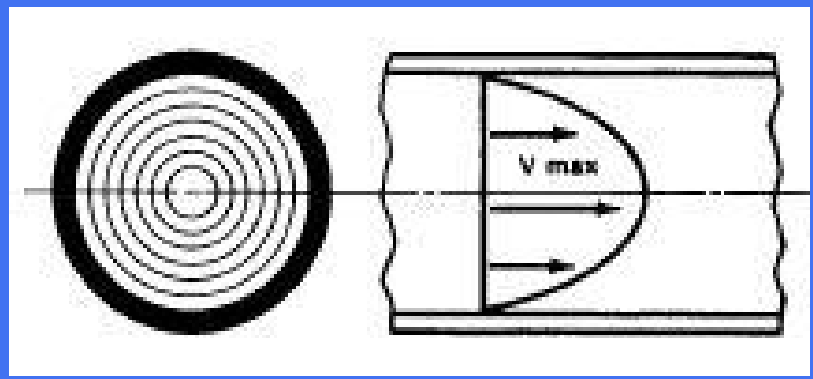
EFFECT OF ATMOSPHERIC PRESSURE & TEMPERATURE ON NPSHA

(NET POSITIVE SUCTION HEAD AVAILABLE)

ELEVATION IN FEET	ATM PRESSURE PRESSURE in ft of H2O	DEDUCTION IN ft of H2O	TEMPERATURE IN DEG F	VAPOR PRESSURE IN ft of H2O
0	34.0	0.0	50	0.41
500	33.3	0.7	60	0.59
1000	32.8	1.2	70	0.84
1500	32.2	1.8	80	1.17
2000	31.6	2.4	90	1.62
2500	31.0	3.0	100	2.20
3000	30.5	3.5	110	2.96
3500	29.8	4.2	120	3.95
4000	29.4	4.6	130	5.20
4500	28.7	5.3	140	6.78
5000	28.2	5.8	150	8.74
5500	27.8	6.2	160	11.20
6000	27.3	6.7	170	14.20
6500	26.6	7.4	180	17.85
7000	26.2	7.8	190	22.30
7500	25.7	8.3	200	27.60
8000	25.2	8.8	210	34.00
8500	24.8	9.2	220	41.45
9000	24.3	9.7	230	50.35
10000	23.4	10.6	240	60.75

Liquid Friction

- The friction created by a liquid flowing in a pipe depends upon its velocity and the diameter of the pipe.
- Friction increases with an increase in velocity.
- Laminar or Viscous Flow



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