MET 335W

Centrifugal Pump Performance

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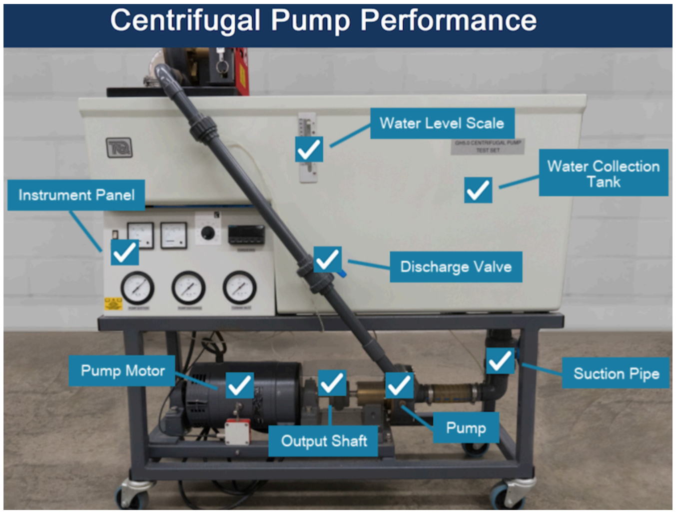
Experiment Title: Centrifugal Pump Performance

Purpose:
The purpose of this experiment is to develop an understanding of the operation and performance of a centrifugal pump and create the performance curves for the TecQuipment Tutor Pump Set.

Theoretical Considerations:
Centrifugal pumps consist of three main components: inlet duct, impeller, and volute. Liquid enters the inlet duct and is conducted to the center of the impeller. With the impeller rotation in a spiral or curved fashion, the fluid is centrifuged to outward toward the outside diameter of the impeller. High velocity of the fluid, as it exits the impeller is converted to pressure energy. The high-pressure fluid passes from pump discharge to the discharge pipe. As flow increases, pressure generated reduces.

Description of Apparatus:



1. Instrument control panel, to include the following:
    a. Motor drive
    b. Motor control
    c. Pump suction
    d. Pump discharge
    e. Pump Torque
2. Water level scale
3. Water collection tank
4. Discharge valve
5. Suction pipe
6. Centrifugal pump
7. Output shaft (connected to the centrifugal pump)
8. 115 volt AC pump motor
9. Digital tachometer

Step-by-Step Procedure:

1. The rocker switch controlling power to the pump motor was switched on.
2. The tare was reset to zero on the digital readout for the torque.
3. The ball valve on the discharge line was turned to a closed position (zero flow rate).
4. The motor control knob was rotated clockwise to adjust motor speed to 100% (full power).
5. The motor shaft speed was measured using a digital tachometer and recorded on the data sheet.
6. The readings for the pump suction (inlet head) and pump discharge (outlet head) was recorded in meters on the data sheet.
7. The pump torque on the digital readout was recorded on the data sheet.
8. The reading on the water level scale, indicating the height of water over the bottom of the v-notch weir, was recorded on the data sheet.
9. The ball valve on the discharge line was turned very slightly to allow a small amount of water to flow over the v-notch weir in the tank.
10. The new flow rates from the pump suction, pump discharge, pump torque, and the water level scale were recorded on the data sheet.
11. The ball valve on the discharge line was again turned very slightly to allow an increasing amount of water to flow.
12. The new flow rates from the pump suction, pump discharge, pump torque, and the water level scale were recorded on the data sheet.
13. The process was repeated until the ball valve had been turned to all 10 positions up to fully open, and the accompanying data recorded in the data sheet.
14. Upon completion of the 100% flow test, the discharge valve was returned back to the closed position.
15. The motor control knob was turned counterclockwise to the 50% position.
16. The pump speed was again measured with a digital tachometer and recorded in the data sheet.
17. The readings for the pump suction (inlet head) and pump discharge (outlet head) was recorded in meters on the data sheet.
18. The pump torque on the digital readout was recorded on the data sheet.
19. The reading on the water level scale was recorded on the data sheet.
20. The ball valve on the discharge line was turned very slightly to allow a small amount of water to flow over the v-notch weir in the tank.
21. The new flow rates from the pump suction, pump discharge, pump torque, and the water level scale were recorded on the data sheet.
22. The entire process was repeated using the 50% motor speed setting for 10 flow settings as before, and all data was recorded on the data sheet.

Recorded Data Tables:

Motor control setting 100% Pump Speed 3310 rpm

Flow (mm)	Head inlet, H_2O (m)	Head exit, H_2O (m)	Torque (Nm)
0	0.125	29	2.00
34	0.125	29	2.14
45	0.063	29	2.39
51	0.000	28	2.64
56	0.000	27	2.78
59	0.000	26	2.90
66	-0.100	26	3.21
69	-0.125	25	3.36
70	-0.125	25	3.41
73	-0.250	25	3.45

Motor control setting 50% Pump Speed 1590 rpm

Flow (mm)	Head inlet, H_2O (m)	Head exit, H_2O (m)	Torque (Nm)
0	0.125	7.5	0.55
12	0.125	7.5	0.61
19	0.125	7.5	0.65
25	0.125	7.5	0.70
31	0.125	7.5	0.75
39	0.125	7.5	0.84
46	0.125	7.0	0.89
48	0.125	7.0	0.95
48	0.125	7.0	0.96
49	0.125	7.0	0.97

Sample Calculations:

1) Water Horsepower (Hydraulic Horsepower), work required to change a liquid from one elevation, pressure, and velocity to another elevation, pressure, and velocity:

•WHP $= \gamma\ Q^*\ \Delta\ H = \left(\frac{9810\ N}{m^3}\right)\ \left(\frac{0.00035 m^3}{sec}\right)\ (28.875\ m)$

$= 99.14\ W$

*Q, volumetric flow rate was found from the 90-degree v-notch calibration chart.
→(21 L/min) (1min/60 s) (m^3/1000 L) = 0.00035 m^3/s

2) Brake Horsepower, power supplied to the pump:

•BHP $= 2\ \pi\ N\ T = (2)\ (3.14)\ (55.17\ rps^*)\ (2.14\ N\text{-}m)$

$= 741.8\ W$

*Revolutions/minute→ (3310 rpm) (1min/60 s) = 55.17 rps

3) η, Efficiency, any piece of machinery will have an efficiency less than 100%, meaning less work is delivered by the machine than is put into it:

•$\eta = \frac{WHP}{BHP} = \frac{99.14\ W}{741.8\ W} = 13.4\ \%$

Calculated Data Tables:

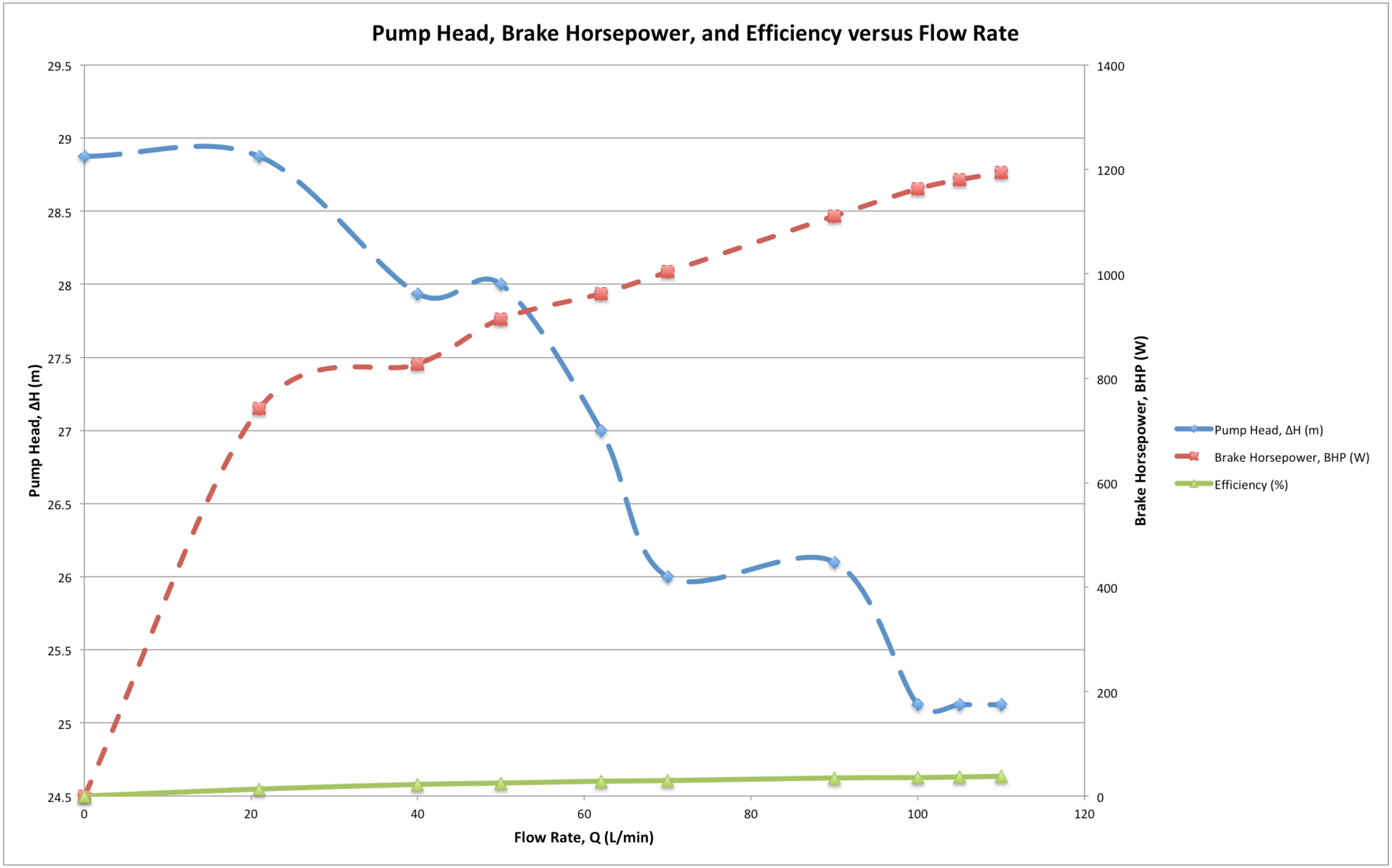
Table 1
Motor Control Setting: 100%
Pump Speed: 3310 rpm

Flow (mm)	Head Inlet, H_2O (m)	Head Exit, H_2O (m)	Δh (m)	Flow Rate, Q (L/min)	Flow Rate, Q (m3/s)	Torque (N-m)	HP_{water} (W)	BHP (W)	Efficiency, η (%)
0 (closed)	0.125	29	28.875	0	0	2.00	0	0	0
34	0.125	29	28.875	21	0.00035	2.14	99.14	741.8	13.4
45	0.063	29	27.937	40	0.00067	2.39	183.62	827.2	22.2
51	0.000	28	28	50	0.00083	2.64	227.98	913.7	24.9
56	0.000	27	27	62	0.00103	2.78	272.82	962.2	28.4
59	0.000	26	26	70	0.00117	2.90	298.42	1003.7	29.7
66	-0.100	26	26.1	90	0.0015	3.21	384.59	1110.9	34.6
69	-0.125	25	25.125	100	0.00167	3.36	411.62	1162.9	35.4
70	-0.125	25	25.125	105	0.00175	3.41	431.33	1180.2	36.5
73 (open)	-0.250	25	25.125	110	0.00183	3.45	451.05	1194	37.8

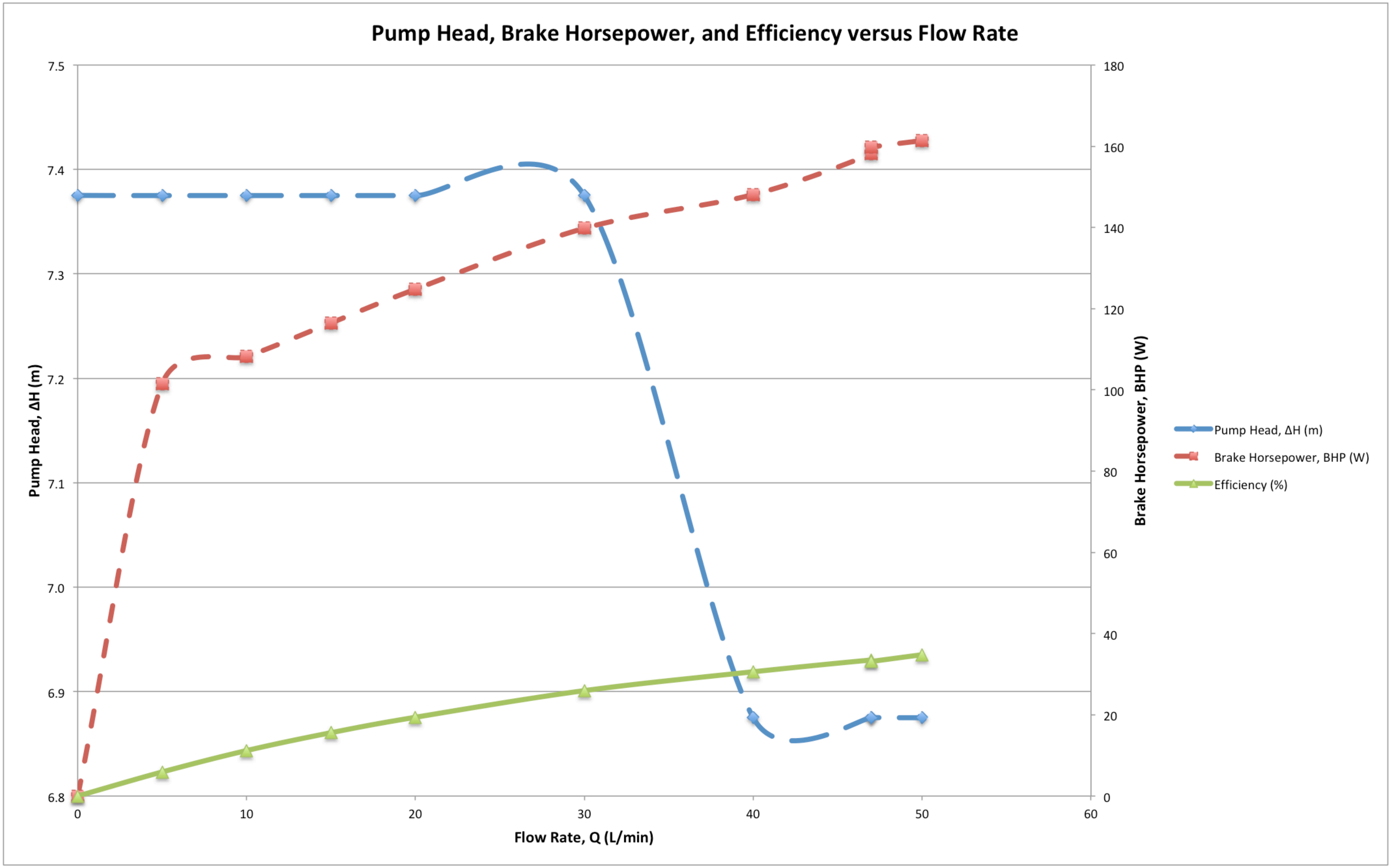
Table 2
Motor Control Setting: 50%
Pump Speed: 1590 rpm

Flow (mm)	Head Inlet, H_2O (m)	Head Exit, H_2O (m)	Δh (m)	Flow Rate, Q (L/min)	Flow Rate, Q (m3/s)	Torque (N-m)	HP_{water} (W)	BHP (W)	Efficiency, η (%)
0 (closed)	0.125	7.5	7.4	0	0	0.55	0	0	0
12	0.125	7.5	7.4	5	8.3 E-5	0.61	6.02	101.5	5.93
19	0.125	7.5	7.4	10	16.7 E-5	0.65	12.12	108.2	11.2
25	0.125	7.5	7.4	15	0.00025	0.70	18.15	116.5	15.6
31	0.125	7.5	7.4	20	0.000333	0.75	24.17	124.8	19.4
39	0.125	7.5	7.4	30	0.0005	0.84	36.3	139.8	25.96
46	0.125	7.0	6.9	40	0.00067	0.89	45.35	148.1	30.6
48	0.125	7.0	6.9	47	0.000783	0.95	53	158.1	33.5
48	0.125	7.0	6.9	47	0.000783	0.96	53	159.7	33.2
49 (open)	0.125	7.0	6.9	50	0.000833	0.97	56.18	161.4	34.8

Graph 1: Centrifugal Pump Motor Control Speed at 100%



Graph 2: Centrifugal Pump Motor Control Speed at 50%



Discussion of Results and Conclusions:

One of the most ubiquitous pumps in the world is the centrifugal pump. Our particular system contained a main tank of water (with no external water supply). Within this tank was a V-notch weir and scaled sight glass to allow for volumetric flow measurement.

Reading of the water height was a bit subjective, as was the conversion using the small graph 90-degree V-notch calibration chart. Digital readings or a clearer and larger graph would have been a great help.

Per our graphs, the relationship between the pump head versus capacity and the brake horsepower versus capacity, and the efficiency versus were all plotted to determine the performance characteristics of our centrifugal pump. Thus, it would seem logical that it would be helpful to use to choose a pump operating near peak efficiency.

The constant between each of the three curves is our x-axis or capacity. Both the Centrifugal Pump Motor Speed at 100% and the Centrifugal Pump Motor Speed at 50% had an intersection point. In addition, the efficiency pump curve was overarching for the actual power that must be supplied, keeping in mind the head requirements.

Efficiency, as in any piece of machinery is never 100%. For our centrifugal pump, energy is lost by friction in the pump, turbulence or liquid in the pump, friction loss at packing,, and friction loss at bearings. Thus, it is important to try to overcome the friction losses inn piping, valves, and fittings in the system prior to delivery.

As a final thought, cavitation should be avoided.