MET 335

Module 6 – Centrifugal Pump Performance

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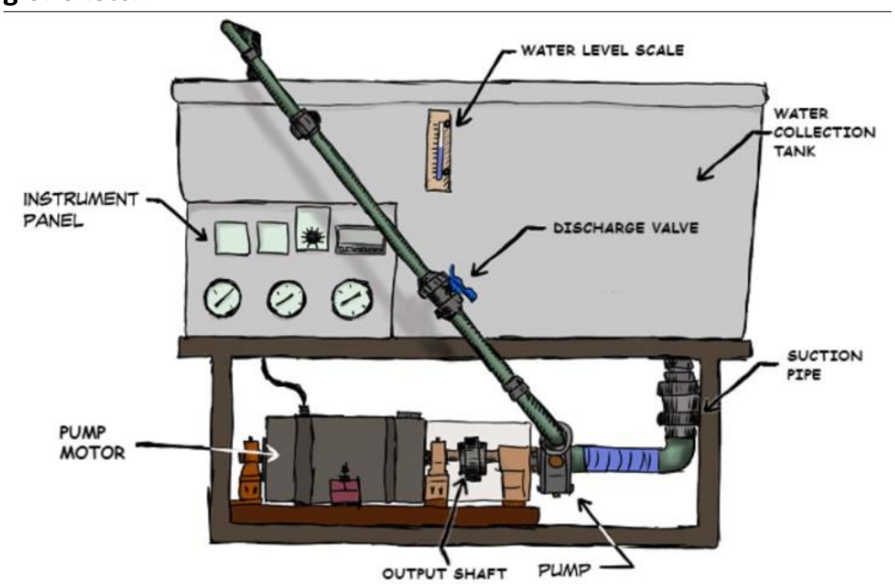
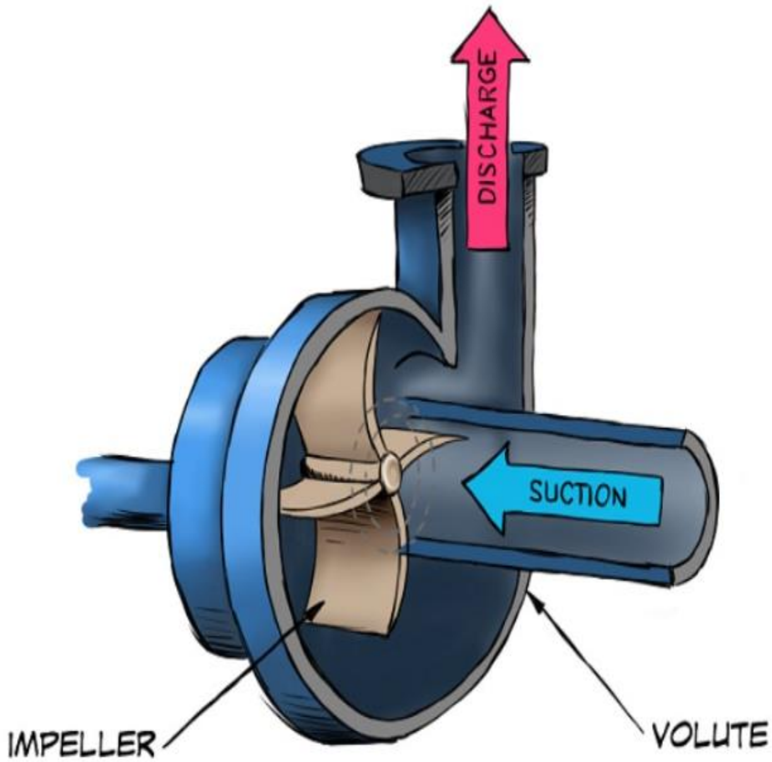
Purpose, Theory, and Procedure

1. **Experiment Title**
   a. Centrifugal Pump Performance
2. **Purpose**
   a. To develop an understanding of the operation and performance of a centrifugal pump and to create the performance curves for the TecQuipment Tutor Pump. I will calculate flow rates, water power, brake power, and efficiencies of the pump. I will place these results in tabular form. I will plot values for 100% motor control and 50% motor control and then discuss the results and curves obtained in the experiment. Wrapping up the report, I'll discuss the sources of error in the experiment.
3. **Theoretical Considerations**
   a. Water Power
      i. $WP = \gamma Q \Delta H$
         1. $\Delta H = head\ added = (pump\ discharge - pump\ suction)$
         2. $Q = volumetric\ flow\ rate\ of\ water$
         3. $\gamma = specific\ weight\ of\ water$
   b. Brake Power
      i. $BP = 2\pi NT$
         1. $N = shaft\ speed\ (revolutions\ per\ minute)$
         2. $T = shaft\ torque$
   c. Efficiency
      i. $\eta = \dfrac{WP}{BP}$
4. **Drawing or Sketch**



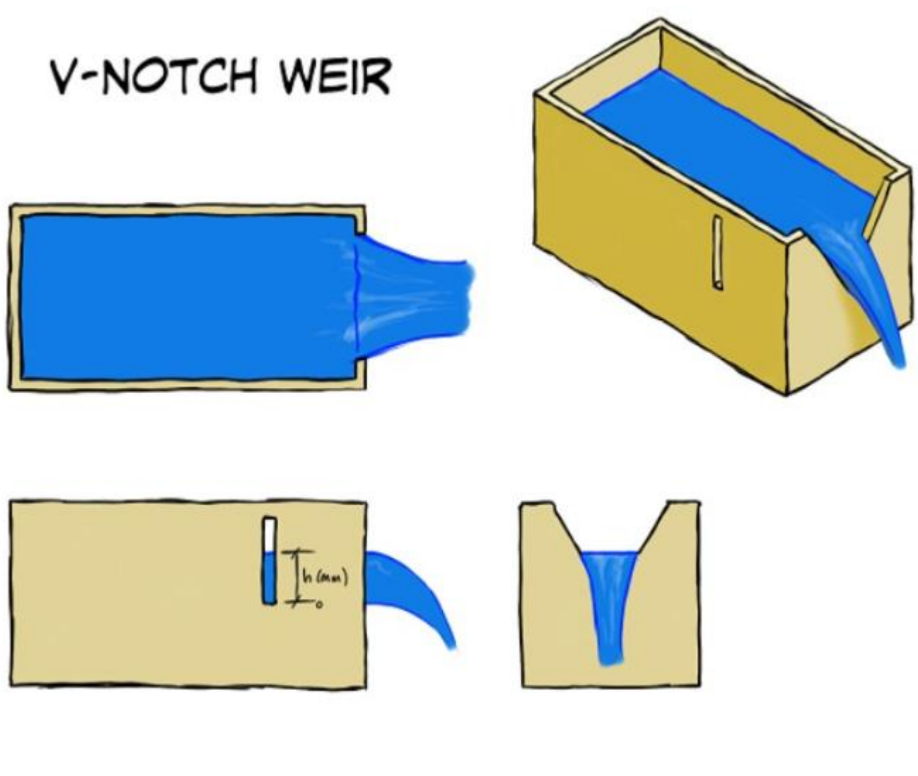
   a.

i. Illustration of the entire apparatus and the instrumental panel, minus the turbine attachment



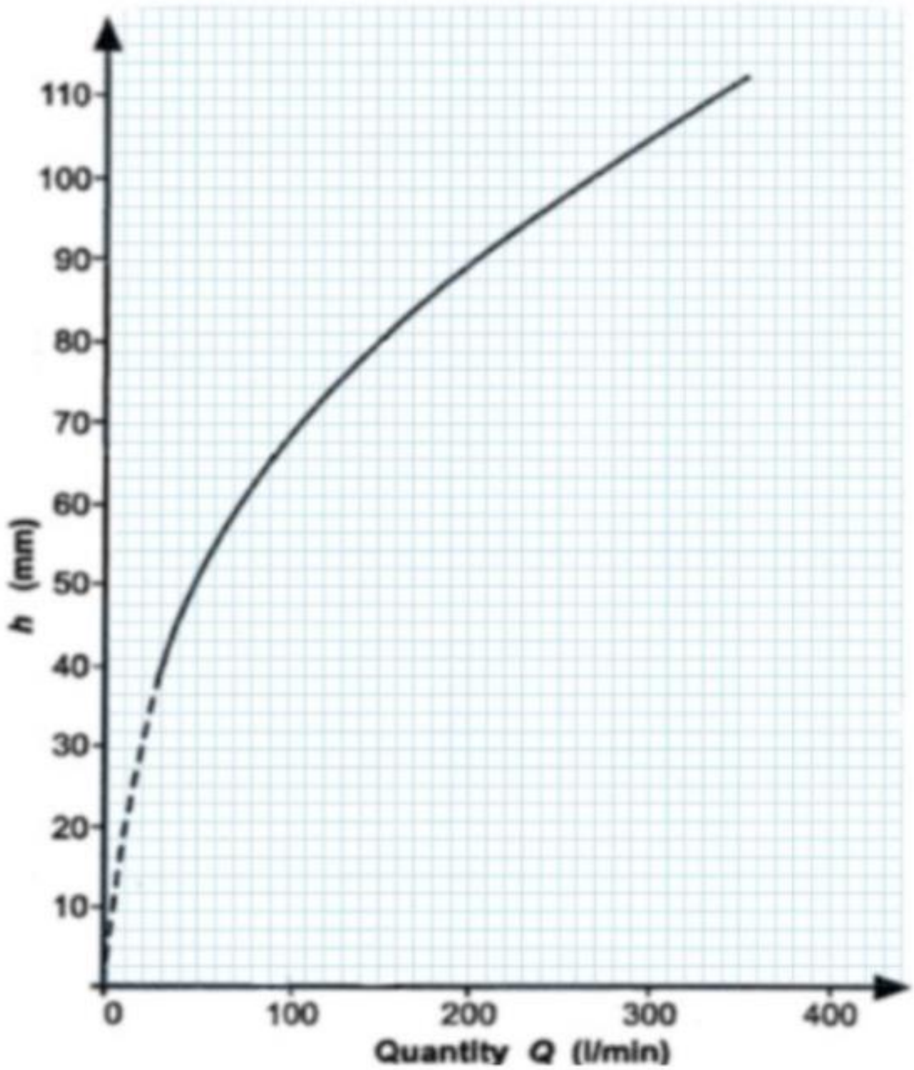
b.

i. The centrifugal pump consists of an inlet duct, an impeller, and volute



c.

V-notch weir



d. *90° V-notch calibration chart*

5. **Verbal Description**
   a. The pump test set gives the ability to study the characteristics of a centrifugal pump under various conditions of head and flow rate. Volumetric flow rate and be measured within the tank using the V-notch weird and sight glass with the scale. The tank itself uses glass reinforced plastic (GRP). Under the tank is the motor and the pump including the shafts and discharge valve. The output of the centrifugal pump delivers the water inside of the tank, via a ball valve, to the side inlet of the Francis turbine. The delivery of water then lets the user know the head of the water using the water level scale. As flow increases, the pressure generated in the centrifugal pump reduces.

6. **Step-by-Step Procedure**
    a. Entered lab room
    b. Identified components used for the lab:
        i. Instrument Panel
        ii. Water Level Scale
        iii. Water Collection Tank
        iv. Discharge Valve
        v. Suction Pipe
        vi. Pump
        vii. Output Shaft
        viii. Pump Motor
    c. Identified components of the instrument panel:
        i. Motor Drive
        ii. Motor Control
        iii. Pump Section
        iv. Pump Discharge
        v. Pump Torque
    d. Turned the pump motor on
    e. Adjusted motor control knob to 100% setting
    f. Tabulated pump speed using Tachometer at 3310 rpm
    g. Recorded pump suction, pump discharge, and pump torque readings
        i. Pump suction = 0.125m
        ii. Pump discharge = 29m
        iii. Torque = 2 Nm
    h. Recorded flow rate using water level scale
        i. Flow rate = 0mm
        ii. 0 because discharge valve is still closed
        iii. Since discharge valve is still closed, no water is flowing in the water collection tank
    i. Opened the discharge valve slighty (first notch)
    j. Recorded pump suction, pump discharge, and pump torque readings
        i. Pump suction = 0.125m
        ii. Pump discharge = 29m
        iii. Torque = 2.14 Nm
    k. Recorded flow rate using water level scale
        i. Flow rate = 34mm
    l. Opened the discharge valve slighty (second position)
    m. Recorded pump suction, pump discharge, and pump torque readings
        i. Pump suction = 0.063m
        ii. Pump discharge = 29m
        iii. Torque = 2.39 Nm

n. Recorded flow rate using water level scale
    i. Flow rate = 45mm
o. Opened the discharge valve slighty (third position)
p. Recorded pump suction, pump discharge, and pump torque readings
    i. Pump suction = 0.0m
    ii. Pump discharge = 28m
    iii. Torque = 2.64 Nm
q. Recorded flow rate using water level scale
    i. Flow rate = 51mm
r. Opened the discharge valve slighty (fourth position)
s. Recorded pump suction, pump discharge, and pump torque readings
    i. Pump suction = 0.0m
    ii. Pump discharge = 27m
    iii. Torque = 2.78 Nm
t. Recorded flow rate using water level scale
    i. Flow rate = 56mm
u. Opened the discharge valve slighty (fifth position)
v. Recorded pump suction, pump discharge, and pump torque readings
    i. Pump suction = 0.0m
    ii. Pump discharge = 26m
    iii. Torque = 2.90 Nm
w. Recorded flow rate using water level scale
    i. Flow rate = 59mm
x. Opened the discharge valve slighty (sixth position)
y. Recorded pump suction, pump discharge, and pump torque readings
    i. Pump suction = -0.1m
    ii. Pump discharge = 26m
    iii. Torque = 3.21 Nm
z. Recorded flow rate using water level scale
    i. Flow rate = 66mm
aa. Opened the discharge valve slighty (seventh position)
bb. Recorded pump suction, pump discharge, and pump torque readings
    i. Pump suction = -0.125m
    ii. Pump discharge = 25m
    iii. Torque = 3.36 Nm
cc. Recorded flow rate using water level scale
    i. Flow rate = 69mm
dd. Opened the discharge valve slighty (eighth position)
ee. Recorded pump suction, pump discharge, and pump torque readings
    i. Pump suction = -0.125m
    ii. Pump discharge = 25m

iii. Torque = 3.41 Nm

ff. Recorded flow rate using water level scale

    i. Flow rate = 70mm

gg. Fully opened discharge valve

hh. Recorded pump suction, pump discharge, and pump torque readings

    i. Pump suction = -0.250m
    ii. Pump discharge = 25m
    iii. Torque = 3.45 Nm

ii. Recorded flow rate using water level scale

    i. Flow rate = 73mm

jj. Concluded readings at 100% motor setting

kk. Returned discharge valve back to the closed position

ll. Adjusted motor control knob to 50% setting

mm. Tabulated pump speed using Tachometer at 1590 rpm

nn. Recorded pump suction, pump discharge, and pump torque readings

    i. Pump suction = 0.125m
    ii. Pump discharge = 7.5m
    iii. Torque = 0.55 Nm

oo. Recorded flow rate using water level scale

    i. Flow rate = 0mm
    ii. 0 because discharge valve is still closed
    iii. Since discharge valve is still closed, no water is flowing in the water collection tank

Recorded Data Table(s)

Motor Control Setting	100%	Pump Speed (rpm)	3310

Discharge Valve Position	Flow (mm)	Head inlet (m) (H_20)	Head exit (m) (H_20)	Torque (Nm)
Closed (1)	0	0.125	29	2.00
2	34	0.125	29	2.14
3	45	0.063	29	2.39
4	51	0	28	2.64
5	56	0	27	2.78
6	59	0	26	2.90
7	66	-0.1	26	3.21
8	69	-0.125	25	3.36
9	70	-0.125	25	3.41
Open (10)	73	-0.25	25	3.45

Motor Control Setting	50%	Pump Speed (rpm)	1590

Discharge Valve Position	Flow (mm)	Head inlet (m) (H_20)	Head exit (m) (H_20)	Torque (Nm)
Closed (1)	0	0.125	7.5	0.55
2	12	0.125	7.5	0.61
3	19	0.125	7.5	0.65
4	25	0.125	7.5	0.70
5	31	0.125	7.5	0.75
6	39	0.125	7.5	0.84
7	46	0.125	7.0	0.89
8	48	0.125	7.0	0.95
9	48	0.125	7.0	0.96
Open (10)	49	0.125	7.0	0.97

Sample Calculations

$$\Delta H = 29m - 0.125m = \boxed{28.875m}$$

$$WP = \gamma Q \Delta H = (9.81)(22)(28.875) = \boxed{6232}$$

$$BP = 2\pi NT = (2)(3.14)(3310)(2) = \boxed{41595}$$

$$\eta = \frac{WP}{BP} = \frac{3035}{8891} = \boxed{0.34}$$

Calculated Data Table(s)

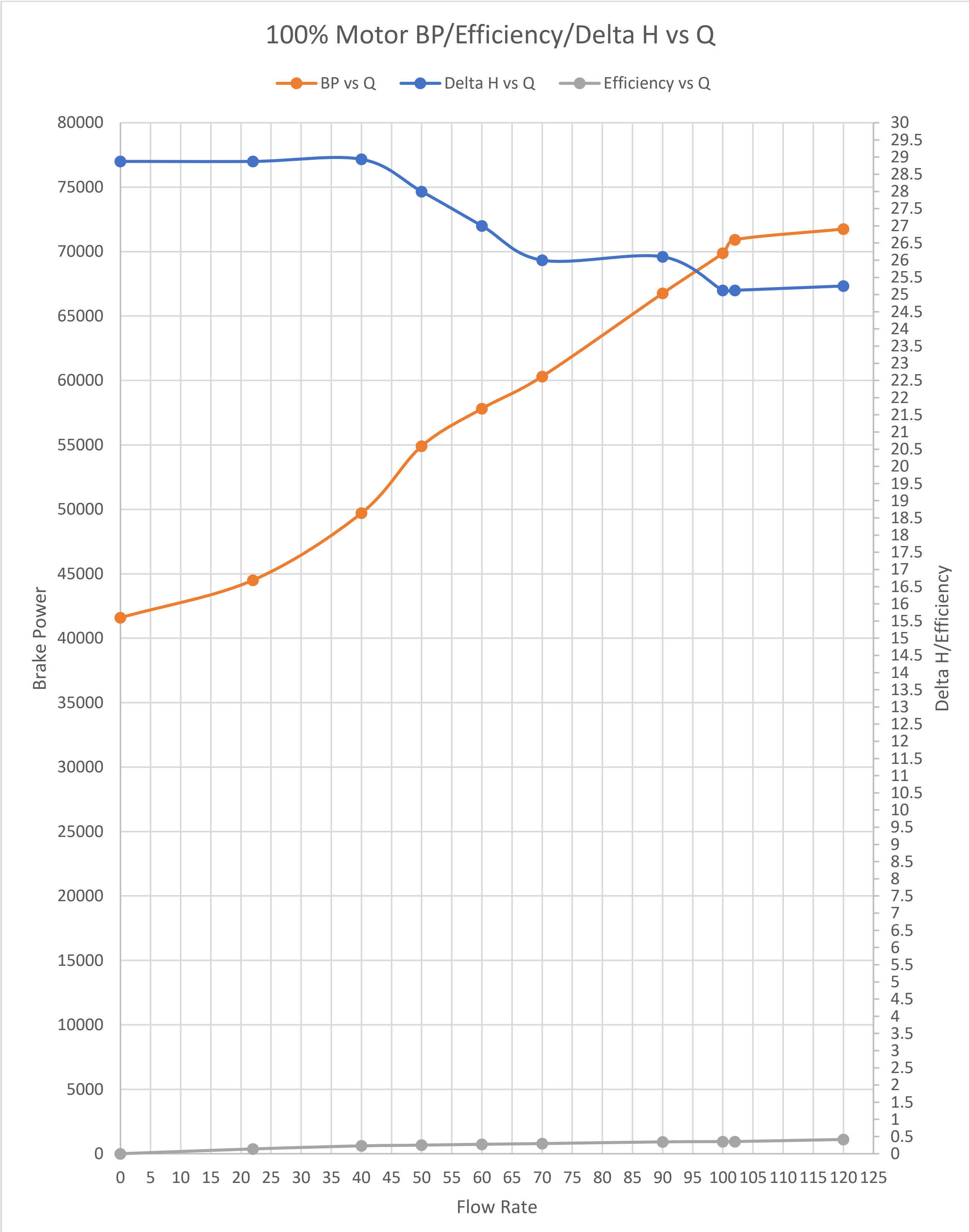
Discharge Valve Position	Head inlet (m) (H_20)	Head exit (m) (H_20)	Delta H
Closed (1)	0.125	29	28.875
2	0.125	29	28.875
3	0.063	29	28.937
4	0	28	28
5	0	27	27
6	0	26	26
7	-0.1	26	26.1
8	-0.125	25	25.125
9	-0.125	25	25.125
Open (10)	-0.25	25	25.25

Discharge Valve Position	Head inlet (m) (H_20)	Head exit (m) (H_20)	Delta H
Closed (1)	0.125	7.5	7.375
2	0.125	7.5	7.375
3	0.125	7.5	7.375
4	0.125	7.5	7.375
5	0.125	7.5	7.375
6	0.125	7.5	7.375
7	0.125	7.0	6.875
8	0.125	7.0	6.875
9	0.125	7.0	6.875
Open (10)	0.125	7.0	6.875

Pump at 100%					
Discharge Valve Position	Flow (mm)	Flow Rate using V-notch Calibration Chart (Q) (L/min)	Water Power (WP=Gamma*Q*Delta H) (WHP)	Brake Power (BP=2*PI*N*T) (BHP)	Efficiency
Closed (1)	0	0	0	41595	0.00
2	34	22	6232	44506	0.14
3	45	40	11355	49706	0.23
4	51	50	13734	54905	0.25
5	56	60	15892	57817	0.27
6	59	70	17854	60312	0.30
7	66	90	23044	66759	0.35
8	69	100	24648	69879	0.35
9	70	102	25141	70919	0.35
Open (10)	73	120	29724	71751	0.41

Pump at 50%					
Discharge Valve Position	Flow (mm)	Flow Rate using V-notch Calibration Chart (Q) (L/min)	Water Power (WP=Gamma*Q*Delta H) (WHP)	Brake Power (BP=2*PI*N*T) (BHP)	Efficiency
Closed (1)	0	0	0	5495	0.00
2	12	5	362	6094	0.06
3	19	10	723	6494	0.11
4	25	15	1085	6993	0.16
5	31	20	1447	7493	0.19
6	39	40	2894	8392	0.34
7	46	45	3035	8891	0.34
8	48	50	3372	9491	0.36
9	48	50	3372	9591	0.35
Open (10)	49	50	3372	9691	0.35

Graph(s)



100% Motor BP/Efficiency/Delta H vs Q
BP vs Q
Delta H vs Q
Efficiency vs Q
Brake Power
Delta H/Efficiency
Flow Rate
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
30
29.5
29
28.5
28
27.5
27
26.5
26
25.5
25
24.5
24
23.5
23
22.5
22
21.5
21
20.5
20
19.5
19
18.5
18
17.5
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16.5
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15
14.5
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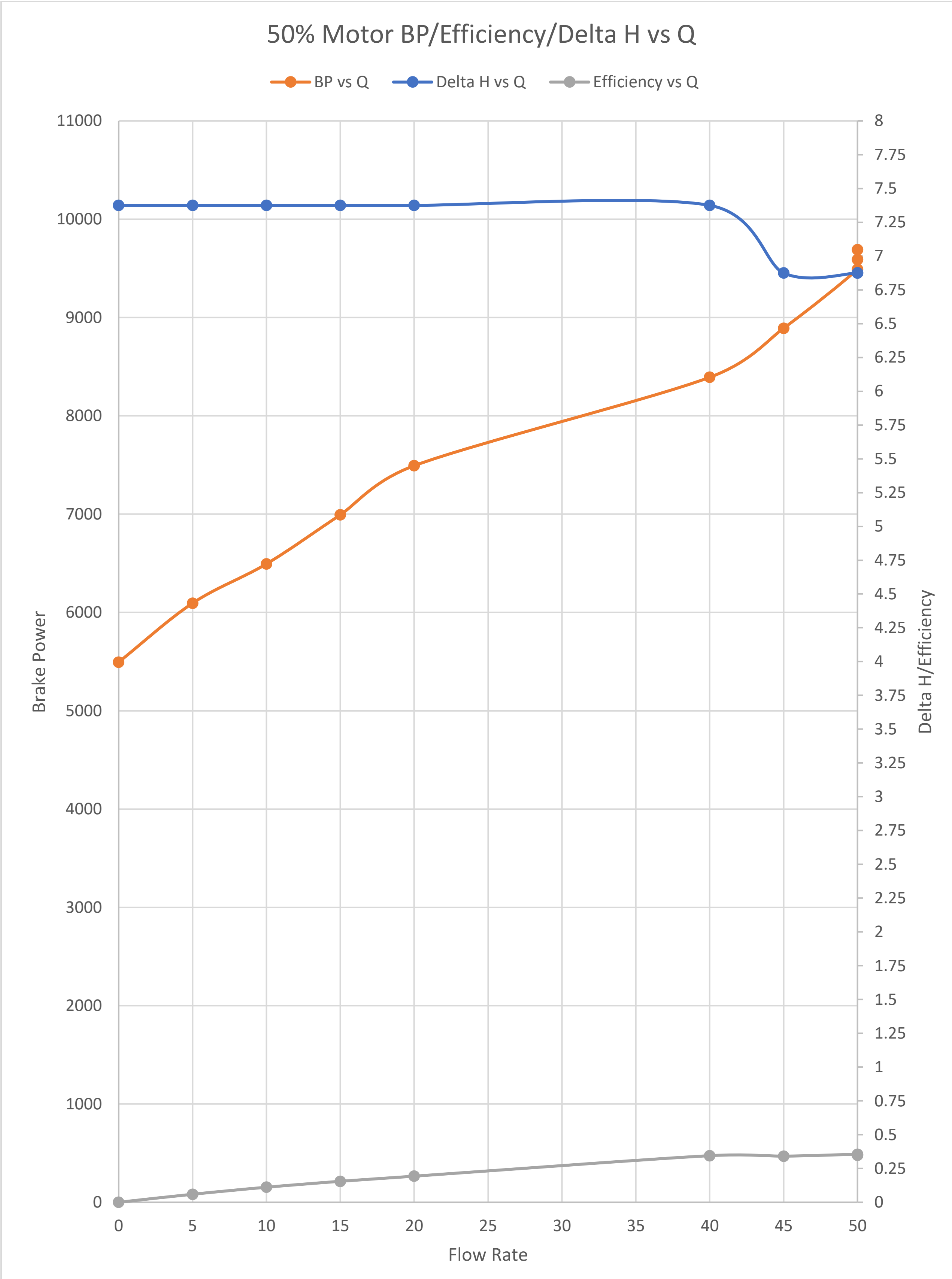
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125



50% Motor BP/Efficiency/Delta H vs Q
BP vs Q
Delta H vs Q
Efficiency vs Q
Brake Power
Delta H/Efficiency
Flow Rate
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
4.25
4.5
4.75
5
5.25
5.5
5.75
6
6.25
6.5
6.75
7
7.25
7.5
7.75
8
0
5
10
15
20
25
30
35
40
45
50

Discussion of Results and Conclusions

In the 100% motor graph, the curves on the graph have a large gap in between them all the way to at least 95 L/min flow rate. In the 50% motor graph, the gap is not as large (only 4500 compared to 30000). The 50% motor graph, the crossover between the two curves happens earlier at 50 L/min flow rate.

It can also be noted that the in the 50% motor Delta H vs Q curve, the curve is almost linear to at least 40 L/min flow rate. In the 100%, the line follows the same trajectory but has a little variation versus none.

In my opinion, the 100% motor graph looks cleaner than the 50% motor graph. This may be because there's a specific flow rate for each point on the BP vs Q and the Delta H vs Q curve. In the 50% motor graph, the flow rate is the same (50 L/min) at three different points.

Now, to discuss the sources of error during this experiment. First, it's quite possible that the user could use 3.14 for the value of PI instead of 3.1415927. This would alter the brake power calculation by a few as well as alter the efficiency calculation because that calculation uses the brake power value. Another source of error is the 90% v-notch calibration chart. This chart seems a little outdated, so it was difficult to get an accurate value for the flow rates based upon the flow head. It would be recommended to use a v-notch calibration calculator to ensure that the flow rate calculated is accurate instead of "best guess" using the chart points.