AHSANULLAH UNIVERSITY OF SCIENCE & TECHNOLOGY

Department of Mechanical and Production Engineering (IPE)

ME 3178: Fluid Mechanics and Machinery Sessional

(Fluid Mechanics and Machinery Laboratory: Basement)

List of the Experiments

1. Study of Bernoulli's Theorem
2. Study of flow through Venturimeter
3. Study of series and parallel pump configuration in a flow
4. Study of Pelton turbine

General Instructions

1. Attend to the lab 5 minutes prior to the scheduled time.
2. Sessional grade will be calculated in the following way: (It can be changed)

a) Attendance	10%
b) Lab reports	20%
c) Viva	20%
d) Quiz (End of semester)	50%
Total	100%

3. Students must bring the necessary instruments, data sheet (for particular experiment), calculator, normal graph paper.
4. Report should be submitted in the following week during the sessional time.
5. Write report on one side of an 80 gms A4 paper and follow the following format
    a) Top sheet
    b) Objectives
    c) Apparatus (including technical specifications)
    d) Figure/Experimental Setup
    e) Data Sheets/Result
    f) Sample calculation
    g) Graphs
    h) Discussion
        i) Discuss the graphs and results
        ii) Discuss the experimental setup, whether it could be improved
        iii) Discuss the different parameters that could affect the result
        iv) Discuss any assumptions made
        v) Discuss any discrepancies in the experimental procedure and result
        vi) Discuss what you have learnt and the practical application of this knowledge

Experiment No.: 1
Study of Bernoulli's Theorem

Objectives:

1. To calculate the total head loss $h_L = h_1 - h_{11}$
2. To plot the pressure head against the length of the passage in one plain graph paper.
3. Verification of total head loss by plotting head loss in each passage or segment.
4. To plot the inlet kinematic head, $\frac{V^2}{2g}$ against the length of the passage for different inflow conditions in plain graph paper.

Description of apparatus:

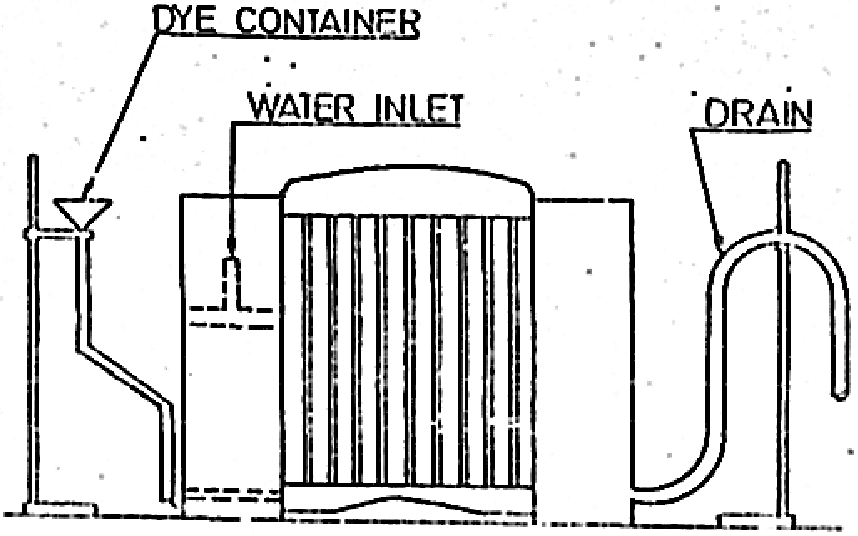
The unit is constructed as a single Perspex fabrication. It consists of two cylindrical reservoirs interconnected by a Perspex Venturi of rectangular cross-section. The Venturi is provided with a number of Perspex piezometer tubes to indicate the static pressure at each cross-section. An engraved plastic backboard is fitted, which is calibrated in British and Metric units. This board can be reversed and mounted on either side of the unit so that various laboratory configurations can be accommodated. The inlet vessel is provided with a dye injection system. Water is fed to the upstream tank through a radial diffuser from the laboratory main supply. For satisfactory results, the main water pressure must be nearly constant. After flowing through the venture, water is discharged through a flow-regulating device. The rate of flow through the unit may be determined either volumetrically or gravimetrically. The equipment for this purpose is excluded from the manufacturer's supply. The apparatus has been made so that the direction of flow through the venture can be reversed for demonstration purpose. To do this the positions of the dye injector and discharge fitting have to be interchanged.

General

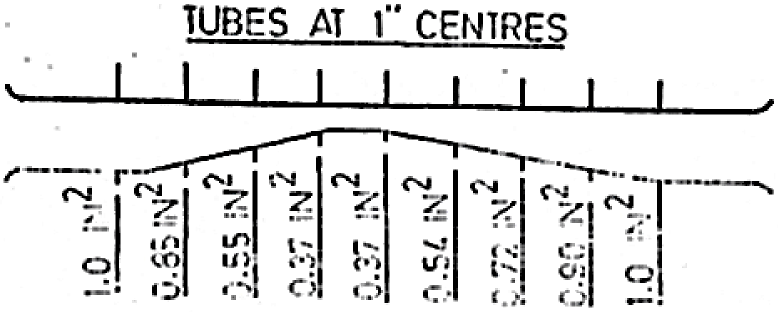
Energy is the ability to do work. It manifests in various forms and can change from one form to another. These various forms of energy present in fluid flow are elevation, kinetic, pressure and internal energies. Internal energies are due to molecular agitation and manifested by temperature. Heat energy may be added to or subtracted from a flowing fluid through the walls of the tube or mechanical energy may be added to or subtracted from the fluid by a pump or turbine. Daniel Bernoulli in the year 1738 stated that in a steady flow system of frictionless (or non-viscous) incompressible fluid, the sum of pressure, elevation and velocity heads remains constant at every section, provided no energy is added to or taken out by an external source.

Practical application

Bernoulli's Energy Equation can be applied in practice for the construction of flow measuring devices such as venturimeter, flow nozzle, orifice meter and Pitot tube. Furthermore, it can be applied to the problems of flow under a sluice gate, free liquid jet, radial flow and free vortex motion. It can also be applied to real incompressible fluids with good results in situations where frictional check is very small.



SKETCH OF APPARATUS



VENTURI DETAILS

Governing Equation:

Assuming frictionless flow, Bernoulli's Theorem states that, for a horizontal conduit

$$\frac{P_1}{\gamma}+\frac{V_1^2}{2g}=\frac{P_2}{\gamma}+\frac{V_2^2}{2g}=\frac{P_3}{\gamma}+\frac{V_3^2}{2g}=\ldots\ldots\ldots\ldots$$

where, P_1, P_2 = pressure of flowing fluid at sections 1 and 2

γ = unit weight of fluid

V_1, V_2 = mean velocity of flow at sections 1 and 2

g = acceleration due to gravity.

The equipment can be used to demonstrate the validity of this theory after an appropriate allowance has been made for friction losses.

For actual condition, there must be some head loss in the direction of flow. So, if the head loss between sections 1 and 2 is h_L , Bernoulli’s theorem is modified to

$$\frac{P_1}{\gamma}+\frac{V_1^2}{2g}=\frac{P_2}{\gamma}+\frac{V_2^2}{2g}+h_L$$

Procedure:

1. The apparatus should be recurrently leveled by means of screws provided at the base.
2. Connect the water supply to the radial diffuser in the upstream tank.
3. Adjust the level of the discharge pipe by means of the stand and clamp provided to a convenient position.
4. Allow water to flow through the apparatus until all air has been expelled and steady flow conditions are achieved. This can be accomplished by varying the rate of inflow into the apparatus and adjusting the level of the discharge tube.
5. Readings may then be taken from the piezometer tubes and the flow through the apparatus measured.
6. A series of readings can be taken for various through flows.

Experiment No. 01
STUDY OF BERNOULLI’S THEOREM
Experimental Data Sheet

Course No.: **Student ID no.:**

Group no.: **Date:**

Collection time =

Volume of water =

Discharge, Q =

<u>Both inlet and outlet are open:</u>

Piezometer tube no.	1	2	3	4	5	6	7 (Pitot Tube)	8
A								
$V = Q/A$								
$\frac{V^2}{2g}$								
$\frac{P}{\gamma}$								
$h = \frac{P}{\gamma} + \frac{V^2}{2g}$								

Head loss in each segment	0	$h_{2-1} = h_1 - h_2$	$h_{3-1} = h_1 - h_4$	$h_{4-1} = h_1 - h_4$	$h_{5-1} = h_1 - h_5$	$h_{6-1} = h_1 - h_6$	$h_{7-1} = h_1 - h_7$	$h_{8-1} = h_1 - h_8$
h_L	0							

Signature of the Teacher

Assignment Questions

1. Why does pressure become lower when a pipe becomes narrower?
2. Can Bernoulli’s theorem be applied to turbulent flow? Why or why not?

Experiment No.: 2

STUDY OF FLOW THROUGH A VENTURIMETER

Objectives

1. To Find C_d for the Venturimeter
2. To plot Q_a against H in log-log paper and to find (a) exponent of H and (b) C_d.
3. To calibrate the Venturimeter.

Apparatus

- Venturimeter
- manometer
- Pump
- Control valve
- Measuring (collecting) tank
- Stopwatch

General

The converging tube is an efficient device for converting pressure head to velocity head, while the diverging tube converts velocity head to pressure head. The two may be combined to form venturi tube. As there is a definite relation between the pressure differential and the flow, the tube may be made to serve as a metering device.

Venturimeter consists of a tube with a constricted throat that produces an increased velocity accompanied by a reduction in pressure, followed by a gradual diverging portion in which velocity is transformed back into pressure with slight friction loss.

Practical Application

The Venturimeter is used for measuring the rate of flow of both compressible and incompressible fluids.

The Venturimeter provides an accurate means for measuring flow in pipelines. Aside from the installation cost, the only disadvantage of the venturimeter is that it introduces a permanent frictional resistance in the pipelines.

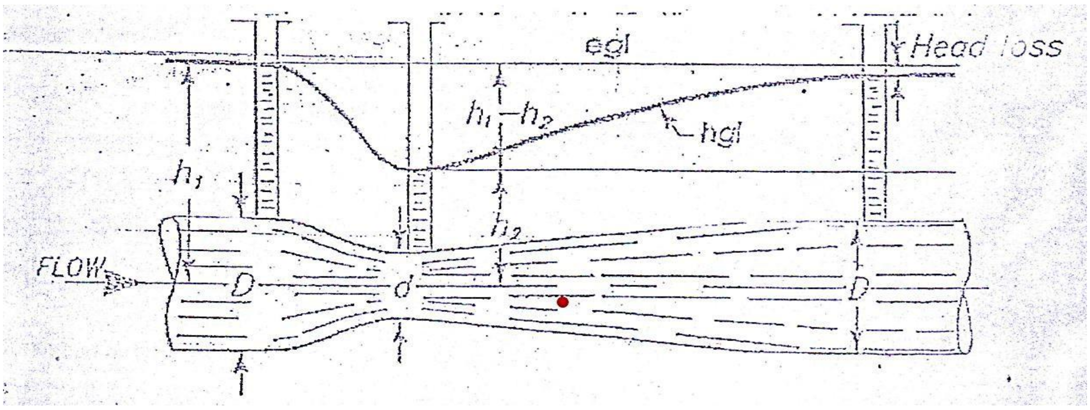


Figure 1: Schematic diagram of a Venturimeter showing flow dynamics and head loss

Theory

Consider the Venturimeter shown in Figure 1. Applying Bernoulli's equation between point 1 at the inlet and point 2 at the throat, we obtain

$$\frac{P_1}{\gamma}+\frac{V_1^2}{2g}=\frac{P_2}{\gamma}+\frac{V_2^2}{2g} \tag{1}$$

Where $P1$ and $V1$ are the pressure and velocity at point 1, $P2$ and $V2$ are the corresponding quantities at point 2, γ is the specific weight of the fluid and g is the acceleration due to gravity. From continuity equation, we have

$$A_1V_1=A_2V_2 \tag{2}$$

Where, A_1 and A_2 are the cross-sectional areas of the inlet and throat, respectively.

Since,

$$A_1=\frac{1}{4}\pi {D_1}^2\,,\, A_2=\frac{1}{4}\pi {D_2}^2$$

From Equations (1) and (2), we have

$$V_1=\sqrt{\frac{2g}{\left(\frac{D_1}{D_2}\right)^4-1}\cdot\frac{(P_1-P_2)}{\gamma}}$$

$$=K_1H^{1/2} \tag{3}$$

Where,

$$K_1=\sqrt{\frac{2g}{\left(\frac{D_1}{D_2}\right)^4-1}}$$

And,

$$H=\frac{(P_1-P_2)}{\gamma}$$

The head H is indicated by the piezometer tubes connected to the inlet and throat.

The theoretical discharge, Q_t is given by

$$Q_t=A_1V_1 \tag{4}$$

$$=KH^{1/2}$$

Where,

$$K=K_1A_1 \tag{5}$$

Coefficient of discharge

Theoretical discharge is calculated from theoretical formula, neglecting losses, friction losses. For this reason, we introduce a coefficient named coefficient of discharge, which is the ratio of actual discharge to theoretical discharge.

Now, if C_d is the coefficient of discharge (also known as the meter coefficient) and Q_a is the actual discharge, then,

$$C_d = \frac{Q_a}{Q_t}$$

$$Q_a = C_d Q_t$$

$$= C_d K H^{1/2}$$

$$= C H^n \tag{6}$$

The value of C_d may be assumed to be about 0.99 for large meter and about 0.97 or 0.98 for small ones, provided the flow is such as to give a reasonably high Reynolds number.

Calibration

One of the objectives of the experiment is to find the values of C and n for a particular meter so that in the future we can measure actual discharge only by measuring H. Here, C and n are called calibration parameters.

For five sets of actual discharge and H data, we plot Q vs H in log-log paper and draw a best-fit straight line.

The Equation of line

$$\log Q_a = \log C H^n$$

$$\log Q_a = \log C + n \log H \tag{7}$$

Now, from the plotting, we take two points on the straight line say (H_1, Q_{a1}) and (H_2, Q_{a2}). So, from equation (7) we get

$$\log Q_{a1} = \log C + n \log H_1$$
$$\log Q_{a2} = \log C + n \log H_2$$

Solving,

$$n = \frac{\log \frac{Q_{a1}}{Q_{a2}}}{\log \frac{H_1}{H_2}}$$

$$C = anti\log\left[\log Q_{a1} - n \log H_1\right]$$

So, the calibration equation is

$$Q_a = CH^n$$

Now,

$$C_d = C / K$$

Now, from the calibration equation, we can calculate actual discharge for different H and plot on a plain graph paper. In practice, we can use the plot to find actual discharge for any H. Thus, the venturimeter is calibrated.

Assignment

a) Why does the coefficient of discharge differ from unity? What are the factors that cause these deviations in a Venturimeter?

b) In the log(Q_a) vs log(H) and the resulting slope of the straight line is 0.48, what does this slope indicate?

c) How does the Reynolds number affect the performance of the Venturimeter?

Experiment No. 2
STUDY OF FLOW THROUGH A VENTURIMETER

Experimental Data Sheet

Course No: **Student ID:** **Group No:** **Date:**

Cross-sectional area of the measuring tank, A = ___________________________
Pipe diameter, D_1 = _________________________, Area of the pipe, A_1 = _______________________________
Throat diameter, D_2 = _________________________, Area of the throat, A_2 = _____________________________
Temperature of water, t = _____________________, Kinematic viscosity of water, ν = ___________________________
Initial point gage reading = _____________________, Final point gage reading =

No. of obs.	**Height of water, *h***	**Volume of water, *v***	**Collection time, *T***	**Actual Discharge, Q_a**	**Piezometer reading**			**K_1**	**K**	**Theoretical discharge Q_t**	$C_d = \frac{Q_a}{Q_t}$	$V_2 = \frac{Q_2}{A_2}$	**Reynolds number, Re**
					Left h_1	Right h_2	Diff H						

Group No					
Actual discharge, Q_a					
Head difference, *H*					
Coefficient of discharge					
Reynolds number					

Signature of the Teacher

Experiment No.: 3
Study of series and parallel pump configuration in a flow

Objectives:

1. To operate the setup in parallel and series combination subsequently
2. To find the pressure head and flow rate in both parallel and series combinations
3. To plot Flow rate vs No. of observation graph for parallel operation compared to single pump operation
4. To plot Head vs No. of observation graph for parallel operation compared to single pump operation
5. To plot Flow rate vs No. of observation graph for series operation compared to single pump operation
6. To plot Head vs No. of observation graph for series operation compared to single pump operation

Theory

In parallel operation of several pumps, the overall flow-rate is the summation of the flow-rates of individual pumps. Hence the flow-rate is measured as

$$Q_{parallel} = Q_1 + Q_2 + Q_3 + \dots\dots\dots + Q_n = \sum_{i=1}^{i=n} Q$$

Where,

$Q_{parallel}$= Flow rate of pumps parallel operation

Q= Flow rate of individual pumps

n = Number of pumps

Head is parallel operation remains constant and is same as the head of individual pumps which are considered to be run at same speed.

Instead of flow-rate, head in series operation is the summation of the heads of the individual pumps. Hence, the head in series operation is measured by,

$$H_{series} = H_1 + H_2 + H_3 + \dots\dots\dots + H_n = \sum_{i=1}^{i=n} H$$

Where,

H_{series}= Total head in series operation

H= Head of individual pumps

n = Number of pumps

Here, in series operation flow-rate of the total configuration is considered to be constant and same as the flow rate of individual pumps.

Components of Setup

1. Gazi tank- 2 pcs
2. Angle bar bases- 2 pcs
3. Marquis pumps- 2 pcs
4. Globe valves- 0.75 inch
5. GI pipe- 0.75 inch
6. Pressure gauges- 3 pcs
7. Water meters- 2 pcs
8. Pipe fittings
9. Level tubes- 2 pcs
10. Flexible pipe

Experimental Setup Layout

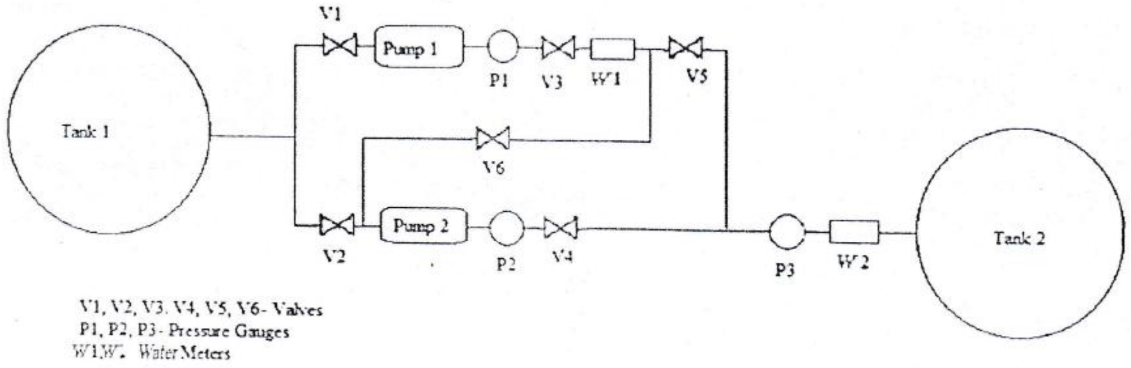


Figure: P&ID Sketch of Basic Experimental Setup

Working Procedure

Parallel

1. When pumps are in parallel connection both pump-1 and pump-2 are active and all the valves are open except valve-6.

2. Both pressure gauges 1 and 2 will show the same reading assuming both the valves 1 and 2 are equally open.

3. Calculating the time period of certain flow (50 liters/ 0.05 m^3) by stopwatch the volumetric flow-rate can be measured.

4. Water-meter 1 indicates the volume of water flowing through the single pump. Pressure gauge 1, 2, 3 shows the pressure head readings of the single pump (pump 1), both pump (when in series) or pump 2 (when in parallel) and the overall system respectively.

5. Water-meter 2 shows the volume of water flowing through the double pumps.

Series

6. When pumps are in series connection both pump 1 and pump 2 are active and all valves remain open except valve 2 and 5.

7. Pump 2 is started after the pump 1 initiation

8. Pressure gauge readings and flow-rate measurements are taken similarly as process 3, 4 & 5.

Experimental Data

Specifications

Pipe diameter-0.75 inch

Tank volume- 1000 liter or 1m^3 each

Pimp power- 1 HP each

Water meter readings- 0.01 m^3 = 10 liter

Parallel Connection

Observation No.	**Volume, V Liter (L)**	**Time, t (sec)**	**Flow Rate, Q (L/s)**	**Average Flow Rate, Q (L/s)**	**Pressure, P (Kg/cm)**
Single Pump					
1	50				
2					
3					
4					
5					
Both Pump					
1	50				
2					
3					
4					
5					

Series Connection

Observation No.	**Volume, V Liter (L)**	**Time, t (sec)**	**Flow Rate, Q (L/s)**	**Average Flow Rate, Q (L/s)**	**Pressure, P (Kg/cm)**
Single Pump					
1	50				
2					
3					
4					
5					
Both Pump					
1	50				
2					
3					
4					
5					

Experiment No.: 4
Performance Test of Pelton Turbine

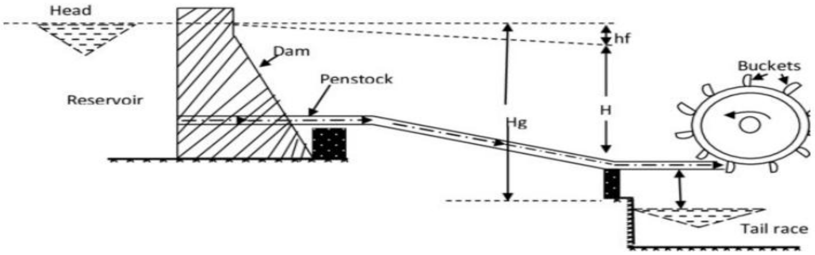
Objectives

1. To determine the coefficient of velocity (C_v) for the nozzle.
2. To find the efficiency (η) of the wheel.
3. To find the performance characteristics curves i.e. to plot:
   i. Head vs. Flow rate
   ii. Speed vs. Flow rate
   iii. Torque vs. Flow rate
   iv. Output power vs. Flow rate
   v. Output power vs. input power

Apparatus

Pressure gauge, water meter, stopwatch, tachometer and spring balance.

Schematic Diagram



Schematic diagram of a Pelton wheel driven power station

Theory

a) Head, H (m) = $\Delta z + \frac{P}{\rho g} + \frac{V^2}{2g}$

Note that the velocity head is around 1% of the total head, and is usually neglected. Again $\Delta z = 0$. Because nozzle and pressure gauge is on same plane.
Thus the head becomes,
H (m) = $\frac{P}{\rho g} = \frac{P}{\gamma}$; where γ = specific weight of water.

b) Power:
   i. Flow of water can be measured by a water meter. Thus using a stop watch, flow rate can be calculated.
   ii. Inlet hydraulic power (P_i):
   $$P_i\ (\text{watt}) = \gamma\times Q(m^3/s)\times H(m)$$
   iii. Output power (P_o):
   Can be measured by dynamometer.
   $$P_o(\text{watt}) = (T_1 - T_2)(kg)\times g(ms^{-2})\times \omega(rad.s^{-1})\times R(m)$$
   Where,
   $T1$ and $T2$ are the tensions at the brake drum.
   R is the radius of the brake drum.
   ω is the angular speed of the wheel = $2\pi N/60$
   N is the rpm of the wheel.

c) Overall Efficiency, $\eta = \frac{P_o}{P_i}$

d) Flow rate, $Q = Av_a$
   $v_a = Q/A = 4Q/\pi d^2$

e) Coefficient of velocity, $C_v = \frac{v_a}{\sqrt{2gH}}$

f) Peripheral Speed of the wheel, $u = \pi DN/60$; D= mean diameter of wheel = 12 inch

g) Speed ratio, $\varphi = u/v_a$; $u = (\omega.r)$; v_a =Actual velocity of water at the nozzle tip

h) Specific speed, $N_s = \frac{N\sqrt{P_o}}{H^{\frac{5}{4}}}$; where N is rpm, P_o in kW, H in meter.

Experimental Procedures

- Open the gate valve of main pipe line.
- Initially apply 2 lb load to brake drum with the help of nut bolt which is attached with the frame.
- After applying the load, open the ball valve ahead of nozzle. As a result, jet will strike the buckets. The runner will start rotating as well as the brake drum.
- Set a pressure using ball valve.
- Measure the flow rate of water using the water meter & stopwatch.
- Measure the speed, NN of the wheel using tachometer.
- Take the reading from spring balance.
- Repeat the same process for different pressures (12psi-30psi).
- When the experiment is over, remove the load from the brake drum and close all the valves.

Data Table

- Radius of the brake drum = 0.09 m
- Diameter of nozzle = 0.45 inch = 0.01143 m

No. of obs.	Time (s)	Volume (m^3)	Flow Rate, Q (m^3/s)	Pressure, P (psi)	Pressure, P (Pa)	Speed, N (rpm)	T_1 (lb)	T_2 (lb)	Load for Braking Torque (T_1-T_2) (lb)	(T_1-T_2) (kg)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Calculation

Area of nozzle, A = $\frac{\pi}{4}d^2$ = $\frac{\pi}{4}(0.01143)^2$ = 1.026 x 10^{-4} m

No. of obs.	Head (m)	Q (m^3/s)	V_a (ms^{-1})	C_v	P_i (W)	P_o (W)	Speed Ratio, φ	Efficiency η (%)	Specific Speed N_s (rpm)	Torque, T (Nm)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										