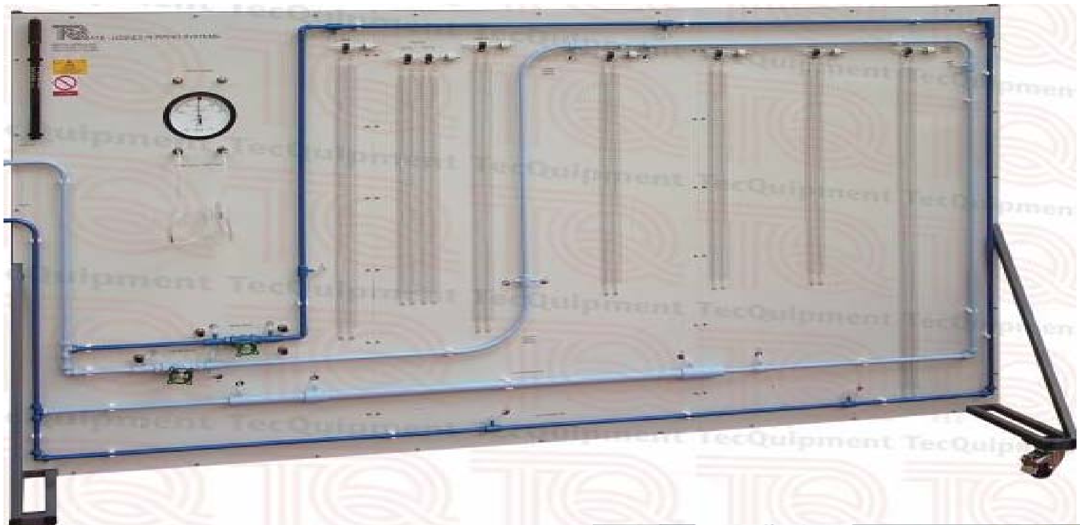
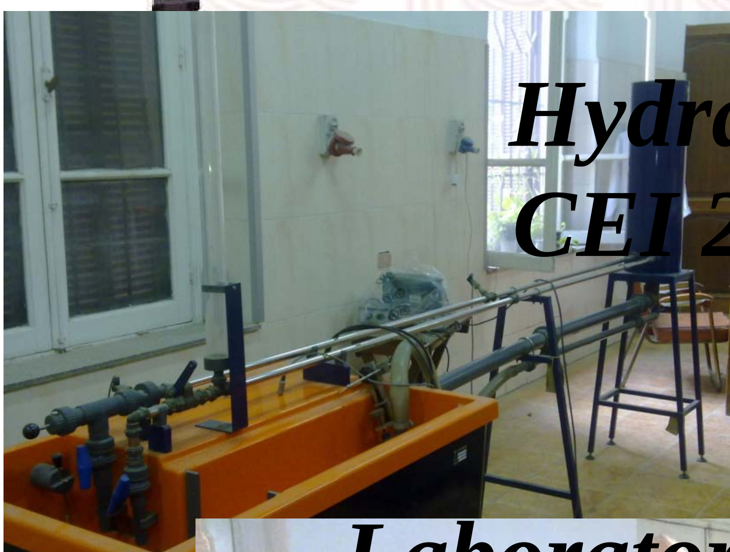
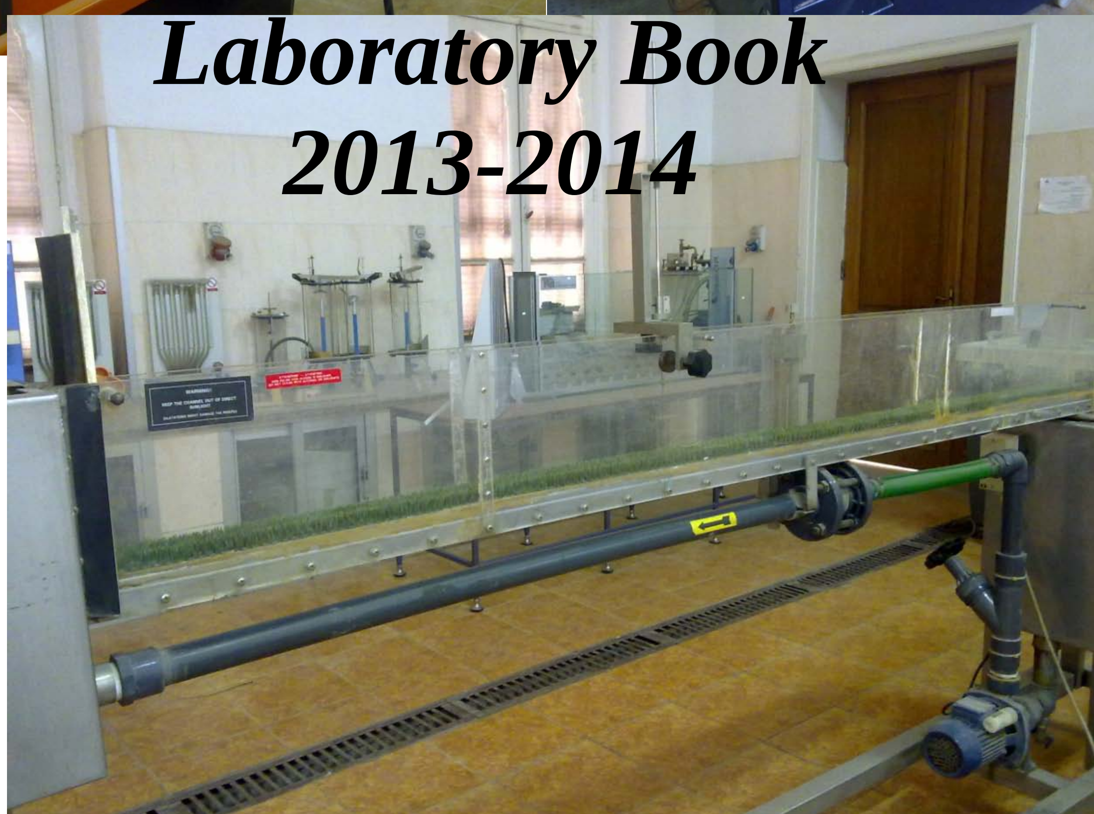




Hydraulics
CEI 231



Laboratory Book
2013-2014

Name: Section: B.N.:

Name:

Section:

B.N. :

Experiment No. (1)

Flow through pipes Laminar Flow

Name: Section: B.N.:

Experiment No. (1)

Flow through pipes Laminar Flow

Objectives

To determine:

- The Darcy-Weisbach coefficient of friction (F).
- To check the type of flow (calculate Reynolds' Number R_N)
- The dynamic viscosity (μ).

Apparatus

- Hydraulic Bench, Constant head tank, Friction Pipe, Pressurized water manometer, Volumetric measuring cylinder, Stop watch.

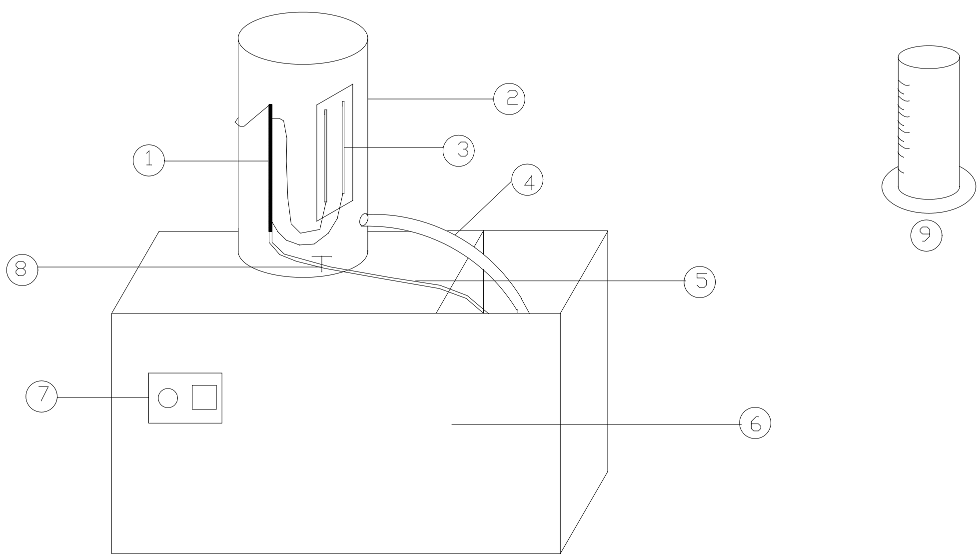


Figure 1

1- The pipe

2- Constant head tank

3-Water manometer

4- The outlet pipe to keep the head constant

5-The flow outlet pipe

6- Hydraulic Bench

7-Valve of the hydraulic Bench and the on off button for pump

8- The control flow valve

9- Volumetric measuring cylinder

Name: Section: B.N.:

Theory

In general words; when the liquid flow through pipes, a main losses occurred due to friction between the liquid and the pipe walls. Darcy Weisbach studied the flow through pipes and find the governing equation for the head loss in the pipes as the following:

$$h_f = \frac{FLv^2}{2gd}$$ **Equation 1**

Where:

hf = the friction head loss through a pipe

F=the Darcy Weisbach friction coefficient of losses

L = length of pipe

v =mean velocity through a pipe

g = gravitational acceleration

d = diameter of pipe

After that many scientists had tried to find out the values of (F)

It was found that for laminar flow as a special case that the coefficient of friction F=64/RN

So equation 1 becomes

$$h_f = \frac{32\mu Lv}{\gamma d^2}$$ **Equation 2**

Where

μ= dynamic viscosity

γ=the specific weight

Note, equation 2 is only valid for laminar flow

Experimental Procedure

1. Open the pump and the valve of the hydraulic bench carefully with small opening.
2. Wait to be sure that the water head in the tank is constant (see water comes out from the outlet pipe No.4 in figure 1).
3. Measure the length of pipe L and the diameter d.
4. Open the flow control valve

5. Collect a certain volume of water (V)in the measuring cylinder during time (T). (Note collect water from the small outlet pipe).
6. Read the water manometer deflection it represents the head loss h_f.
7. During collecting the water and reading the manometer deflection, the outlet pipe must be fixed to be sure that the reading of the h_f won't change.
8. Repeat the steps from 3 to 6 by Changing the opening of control valve.
9. Close the control valve first then close the pump

Results and Analysis

1. Record the results on table.1
2. Calculate the discharge Q=V/T
3. Calculate the velocity v=Q/A where A= $\frac{\pi}{4}d^2$
4. From equation 2 get μ
5. Then get Reynolds' Number R_N to make sure the flow is laminar($R_N = \frac{\rho v d}{\mu}$)

   If R_N<2000 the flow is laminar
6. If The flow is laminar, the coefficient of friction F=64/R_N
7. Draw the relation between the head loss h_f and the velocity v

   $h_f = \frac{32\mu L v}{\gamma d^2}$

   μ and γ are constant for the same liquid

   L and d constant for the same pipe

   So we can say that: $hf = constant \times v$ linear relationship

   The theoretical slope of the line= $\frac{32\mu L}{\gamma d^2}$

   And the theoretical intersection with Y axis= 0
8. Draw the relation between log F and the log R_N

   For laminar flow

   $F = \frac{64}{R_N}$

   $F = 64 \times R_N^{-1}$

   $\log F = \log 64 - \log R_N$

   $\log F = constant - \log R_N$ linear relation

   The theoretical slope of the line= -1

   And the theoretical intersection with Y axis= log 64

Table 1

Test No.	1	2	3	4	5	6	7
$V(cm^3)$							
T(sec)							
$Q=\frac{V}{T}(cm^3/sec)$							
v(cm/sec)							
μ(poise)							
R_N							
h_f(cm)							

Name: Section: B.N.:

Experiment No. (2)

Losses in Piping Systems

Name: Section: B.N.:

Experiment No. (2)

Losses in Piping Systems

DESCRIPTION

- The Losses in Piping Systems apparatus should be comprised a vertical panel with two separate hydraulic circuits, colour-coded for clarity. Each circuit should include various pipe system components.
- To measure pressure loss across components, the panel must include piezometer tubes and U-tube manometers.
- Both circuits should be controlled by valves.

SERVICES REQUIRED

- A comprehensive range of investigations into losses in a variety of pipes and pipe system components, must be included:
- Straight pipe loss
- Sudden expansion
- Sudden contraction
- Bends
- Valves
- Flow in a roughened pipe – needs the optional Roughened Pipe

APPARATUS FEATURES

- The panel must by movable and space-saving
- Must Include two colour-coded water circuits
- Include different pipe bends and valves for students to compare losses
- Fitted with range of manometers and piezometers to give accurate, fundamental pressure measurement

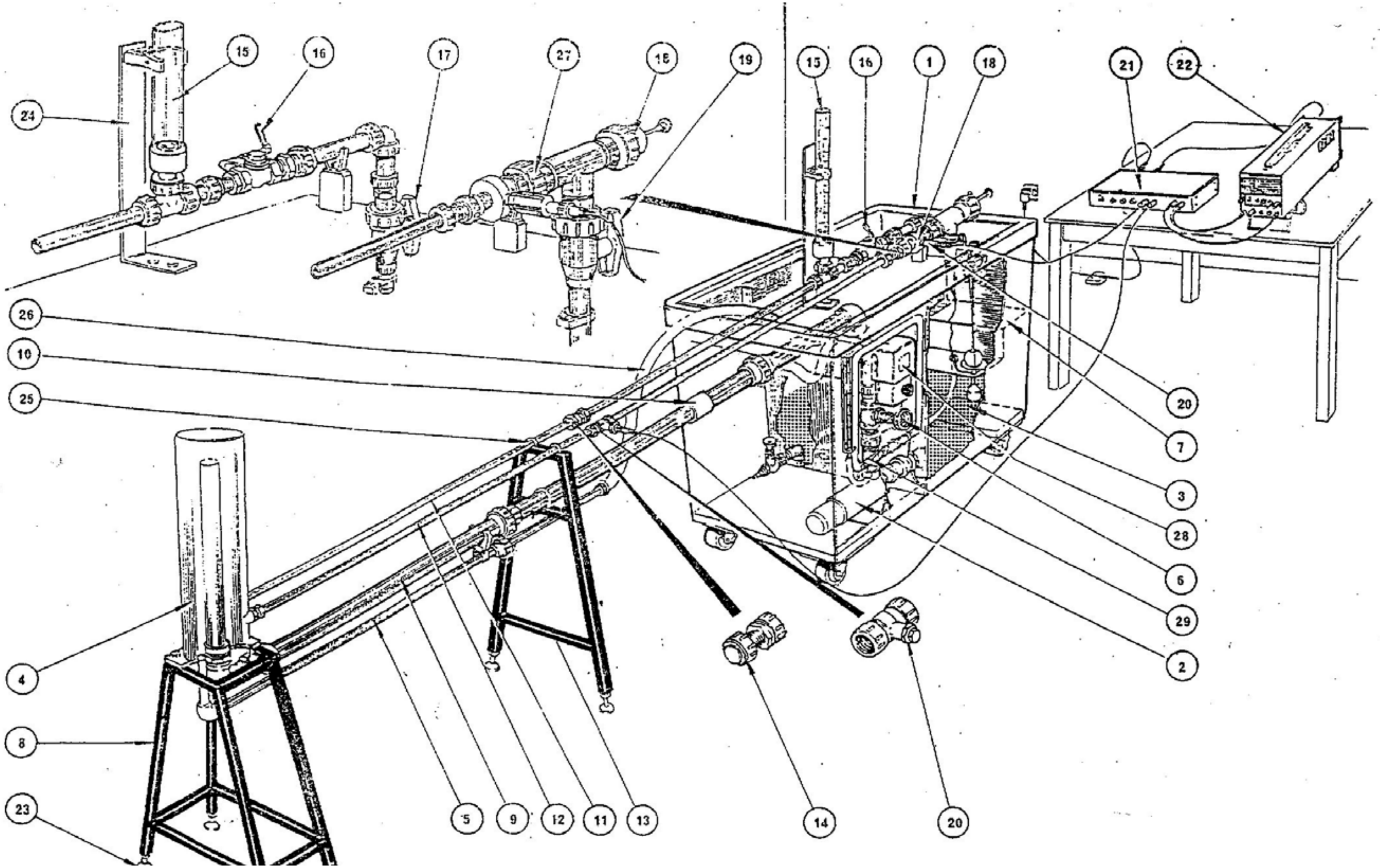
Experiment No. (3)

Water Hammer Experiment

Name: Section: B.N.:

Experiment No. (3)

Water Hammer Experiment



Name: Section: B.N.:

i) Objective:

To determine experimentally the pressure increase (ΔP) and the reflection time (t_r).

ii) Implemented equations and data sheet :-

a) Theoretical equations:

1) $1/K_e = 1/K_w + D / (E \times T)$

2) $c = (K_e / \rho)^{1/2}$, where c = wave celerity (m/s)

3) $\Delta H = - c \times \Delta v / g$, where $\Delta v = v_f - v_i$ and v_f = zero

4) $\Delta P = \Delta H \times \gamma$

5) $t_r = 2L / c$

b) Experimental equations:

6) $\Delta P = N_V \times A \times C$

Where: N_V is the average number of vertical divisions (amplitude) of the sensor reading

7) $t_r = N_h \times T$

Where: N_h is the horizontal divisions (durations) of the sensor reading

c) Data sheet:

ρ = density	= 1000 kg / m^3
L =pipe length	= 3.00 m
D= pipe diameter	= 22 mm
K_w= water bulk modulus (at NTP)	= 2.05 GN/ m^2
T= pipe thickness	= 0.90 mm
E= pipe Young ‘modulus	= 215.3 GN/m^2
a = pipe cross section area	=o.3204 $\times 10^{-3}$ m^2
A= constant (setting of volts/division control)	= 50 mm. Volt/ division
C= constant (calibration of transducer)	= o.135 Bar /mm. Volt
T=constant (setting of time base control)	= 2.5(mm. second / division)

Name: Section: B.N.:

iii) Steps:

1 - Close flow control valve (17) on pipe surge, and then close supply control valve (16).

2 - Open last-acting valve (18), then open flow control (19) in pipe water hammer circuit.

3 - Switch on starter (28) and slowly open supply control valve (6).

4 -Allow the constant head tank (4) to fill, and adjust supply control valve (6) until a steady trickle of water returns to the sump tank (3) via the return feed pipe (9). So, a steady flow is established.

5 - Collect certain volume of water in the sump tank (3) during time (t).

6 - Press the release button (18) on the fast-acting pipe. The pressure pulses generated will now appear stored on the oscilloscope screen (22).

7 - Record average amplitude value of peak wave form and the duration of pulse.

iv) Experimental Results:

It is necessary here to convert measurements of voltage on the oscilloscopic to readings of pressure for use in the calculations:

Pressure (Bar) = $N_V \times A \times C$

Where

$N_{V:}$ Number of divisions measured vertically from the datum setting on oscilloscope (division)

A: Setting of Volts/Div control (mm. Volt /division)

C: Calibration constant of transducer (Bar / mm. Volt)

$t_r = N_h \text{ x } T$

Where

N_h : Number of divisions of the sensor reading measured horizontally from start to finish of pulse (or start of first pulse to start of second pulse) which the durations

T=constant (setting of time base control) (mm. second / division)

v) Observations :

Item	Reading (1)	Reading (2)	Reading (3)
V_{1i} (liter)	V_{11}	V_{12}	V_{13}
V_{2i} (liter)	V_{21}	V_{22}	V_{23}
t_i (seconds)	t_1	t_2	t_3
N_{Vi}	N_{V1}	N_{V2}	N_{V3}
N_{hi}	N_{h1}	N_{h2}	N_{h3}

vi) Calculations:

Parameters	**Equations**	**Results and remarks**
ΔV_i (liter)	$V_{2i} - V_{1i}$	i = 1 , 2 or 3
Q_i (meter^3 / second)	$(V_{2i} - V_{1i}) \times 10^{-3} / t_i$	i = 1 , 2 or 3
v_i (meter / second)	Q_i / a	$a = \pi D^2/4 = 0.3204 \times 10^{-3}$ m^2 D = 22 mm D =0.022 m
K_e	$1/K_e = 1/K_w + D / (E \times T)$ {Equation no. (1)}	$K_e = (1/2.05) + [22/(215.3 \times 0.9)] = 1.663$ GN/ m^2 $K_w = 2.05$ GN/ m^2 E =215.3 GN/ m^2 T = 0.9 mm
c : wave speed {celerity} (m/ second)	$c = (K_e / \rho)^{½}$ {Equation no. (2)}	$c = (1.663 / 1000)^{½}$ =1289.57 (m / second) $\rho = 1000$ (kg / m^3)
ΔH : {theoretical} (m)	$\Delta H = - c \times \Delta v / g$ {Equation no. (3)}	$\Delta v = v_f - v_i$ and v_f = zero g : { gravity acceleration} g = 9.81 (m / second^2)
ΔP : {theoretical} (Kilo. Newton / m^2)	$\Delta P = \Delta H \times \gamma$ {Equation no. (4)}	$\gamma = \rho \times g$ $\gamma = 9.81$ (KN/ m^3)
t_r : {theoretical} (seconds)	$t_r = 2L / c$ {Equation no. (5)}	L = 3.00 m
ΔP : { experimental} (Bar)	$\Delta P = N_V \times A \times C$ {Equation no. (6)}	A =50 (mm Volt/ division) C = O.135(Bar / mm. Volt)
t_r : { experimental} (seconds)	$t_r = N_h \times T$ {Equation no. (7)}	*T* =2.5 (mm. second / division)

vii) Discussion and Comments:

1 –Compare between the theoretical increase of pressure and the experimental results. Comment on the results.

2 –Compare between the theoretical reflection time and the experimental results. Comment on the results

Experiment No. (4)

Pumps series and parallel experiment

Name: Section: B.N.:

Experiment No. (4)

Pumps series and parallel experiment

Introduction

The specific hydraulic model that we are concerned with for this experiment is the series/parallel pump test. The apparatus consists of a single pump used with the pump of the hydraulic bench to generate a number of pump configurations.

Objective

To determine the head/flow rate characteristics of

1- A single pump
2- Two pumps connected in series
3- Two pumps connected in parallel

Method

By measurements of the pressure at the pump inlet and outlet

Equipment

- The hydraulics bench which contains an internal pump, the hydraulics bench allows us to measure flow by timed volume collection
- The external pump accessory
- A stopwatch allows us to determine the flow rate of water

Technical data

The following dimensions from the equipment are used in the calculations

Head correction Values

Datum to the manifold gauge h_d= 0.960 m

Datum to the external pump outlet gauge h_d= 0.170 m

Datum to the external pump inlet gauge h_d= 0.020 m

Datum to the bench pump gauge h_d= 0.240 m

Theory

Applying the energy equation between the pumps inlet (1) and the pumps outlet (2)

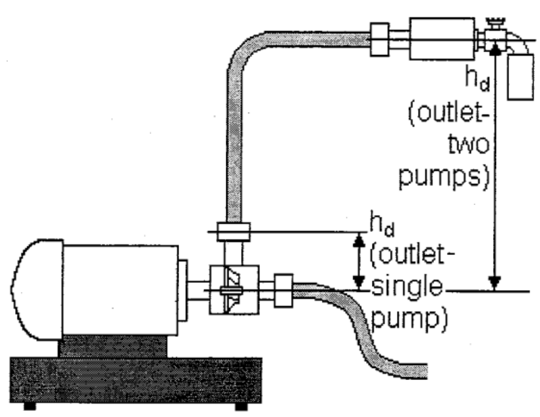
$$\frac{P_1}{\gamma}+\frac{v_1^2}{2g}+z_1+H=\frac{P_2}{\gamma}+\frac{v_2^2}{2g}+z_2$$

On the apparatus the pipes diameters are similar, so the velocity heads cancel each other

$$H=(z_2-z_1)+\frac{(p_2-p_1)}{\gamma}$$

$$H = (z_2 – z_1) + (h_2 – h_1)$$

The relative vertical positions of the inlet and outlet are represented by (z_2 – z_1) term. Each head measurement is at a different relative vertical position. The positions are therefore taken relative to a datum position, the horizontal plane running through the center of the external pump impeller. Each position is given a datum correction factor, h_d, as the example shown on the diagram below:



The relative vertical distance between the inlet and outlet may then be expressed as a head difference, H_d

$H_d = (z_2 - z_1) = h_d(\text{outlet}) - h_d(\text{inlet})$

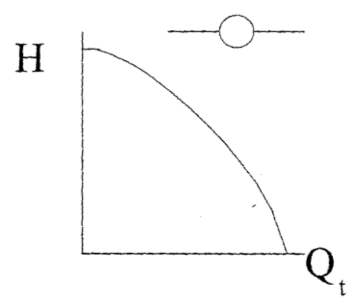
Substituting into the pumps head equation

$H = H_d + (h_2 - h_1)$

The datum head correction factor for each measurement position can be found in the Technical data section of this experiment.

Single pump operation

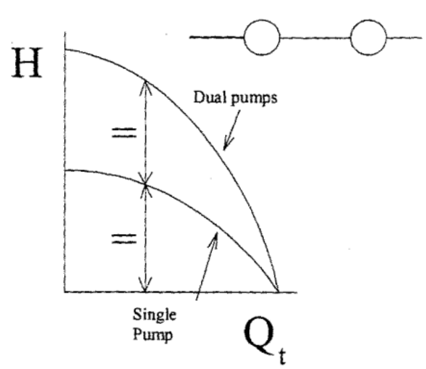
The characteristics of a pump can be described through the use of a characteristic curve of total head versus the flow rate



This figure shows the relation of Total Head H and flow rate Q_t for a typical pump

Series Pump Operation

Should the head of a single pump not be sufficient for an application, pumps can be combined in series to obtain an increase in head at the same flow rate as the single pump.

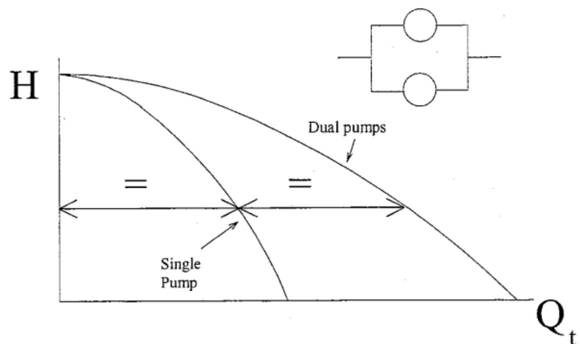


As shown, when two pumps having similar head-flow rate characteristics are operated in

series the combined pump head-flow rate curve is obtained by adding the heads of the single pump curves at the same flow rate.

Parallel Pump Operation

Should the flow rate of a single pump not be sufficient for an application, pumps can be combined in parallel to obtain an increase in flow rate at the same head as the single pump.



As shown, when two pumps having similar head-flow rate characteristics are operated in parallel the combined pump head- flow rate curve is obtained by adding the flow rates of the single pump curves at the same head.

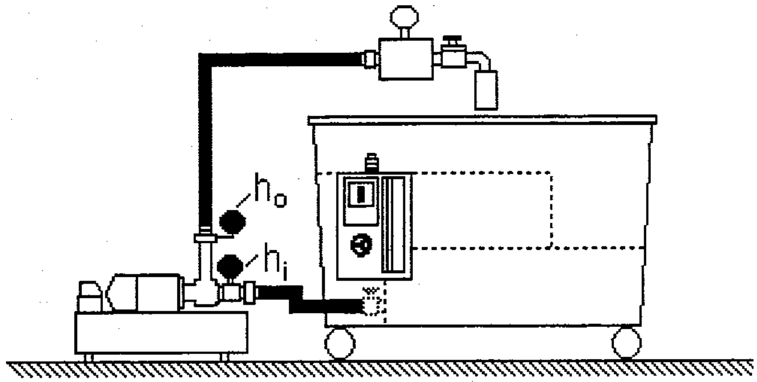
Procedure - Equipment Set Up

Three test configurations are available;

single pump operation, two pumps in series and two pumps in parallel.

To set up these demonstrations we need to modify the those configurations as shown below .

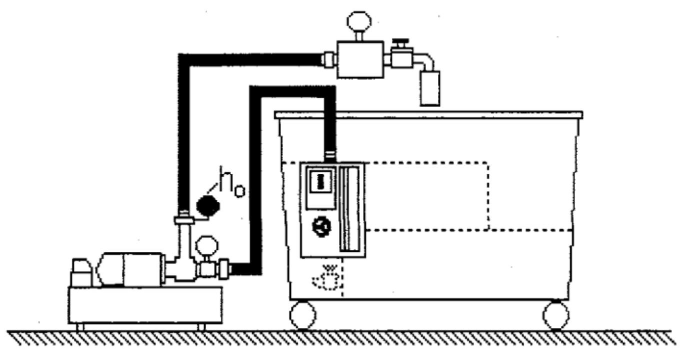
Single Pump Operation



For single pump operation the inlet of the external pump should be connected to the sump drain valve on the hydraulics bench. The outlet should be connected to the discharge manifold.

The gauges used for measurement of inlet and outlet heads for this experiment are the external pump inlet gauge, h_i, and the external pump outlet gauge, h_o.

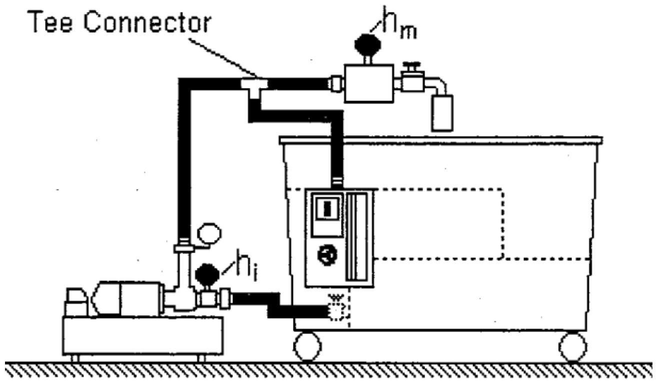
Series Pump Operation



For series pump operation the inlet of the external pump should be connected to the water inlet on the hydraulics bench. The outlet should be connected to the discharge manifold.

The gauge used for measurement of outlet head is the external pump outlet gauge, h_o. The inlet to the hydraulics bench pump is assumed to be at atmospheric pressure, modified by the datum head correction factor given in the Technical Data section

Parallel Pump Operation



For parallel pump operation the inlet of the external pump should be connected to the sump drain valve on the hydraulics bench. The outlet should be connected to the supplied Tee connector. The outlet of the hydraulics bench pump should also be connected to the Tee connector. Finally the remaining outlet on the Tee connector should be connected to the discharge manifold.

The gauges used for measurement of inlet and outlet heads for this experiment are the external pump inlet gauge, h_i (both pumps are assumed to be at similar inlet heads), and the discharge manifold gauge, h_m.

Procedure - Taking a Set of Results

Single Pump Operation

1- Open the hydraulics bench sump drain valve and close the discharge control valve on the discharge control manifold.
2- Switch on the external pump pump.
3- Open the discharge control valve fully.
4- Take a set of readings for flow rate at a range of head values.
5- To vary the head, use the discharge control valve, starting with the valve fully open, and including a reading with the valve fully closed.
6- The readings for inlet flow to the pump should be taken from the external pump inlet gauge.

7- The readings for the pump output should be taken from the external pump outlet gauge

$H = H_d + (h_o - h_i)$

where

$H_d = h_d$(external pump outlet) – h_d(external pump inlet) = 0.170 – 0.020 = 0.150 m

h_d = vertical distance of gauge position from the center of the external pump impeller

h_i = head taken from external pump inlet gauge

h_o = head taken from external pump outlet gauge

Series Pump Operation

1- Close the sump valve and close the control valve on the hydraulics bench.
2- Close the discharge control valve on the discharge control manifold.
3- Switch on the bench pump.
4- Open the bench control valve.
5- Switch on the external pump.
6- Open the discharge control valve fully and then allow the pumps a few minutes to stabilize.
7- We can now take a set of readings for flow rate at a range of head values.
8- The outlet head is measured using the external pump outlet gauge.
9- The inlet head is taken as the head in the sump tank of the hydraulics bench, and is assumed to be at zero relative to the outlet.
10- This must still be modified by the datum head correction factor given in the Technical Data section, to account for the difference in height between the sump tank water level and the hydraulics bench pump inlet.
11- To vary the head we need to use the discharge control valve, starting with the valve fully open, and including a reading with the valve fully closed.

$H = H_d + h_o$

where

$H_d = h_d$(external pump outlet) – h_d(bench pump inlet) = 0.170 – 0.240 = – 0.070 m

h_d = vertical distance of gauge position from the center of the external pump impeller

h_o = head taken from external pump outlet gauge

Parallel Pump Operation

1- Open the sump valve and close the control valve on the hydraulics bench.
2- Close the discharge control valve on the discharge control manifold.
3- Switch on the bench pump.
4- Open the bench control valve.
5- Switch on the external pump pump.
6- Open the discharge control valve fully and then allow the pumps a few minutes to stabilize.
7- We can now take a set of readings for flow rate at a range of head values.
8- The inlet head is assumed to be similar for both pumps, and is measured using the external pump inlet gauge.
9- The outlet head is measured using the discharge manifold gauge
10- To vary the head we need to use the discharge control valve, starting with the valve fully open, and including a reading with the valve fully closed.

$H = H_d + (h_m – h_i)$

where

$H_d = h_d$(manifold gauge) – h_d(external pump inlet) = 0.960 – 0.020 = 0.150 m

h_d = vertical distance of gauge position from the center of the external pump impeller

h_i = head taken from external pump inlet gauge

h_m = head taken from discharge manifold

Experiment No. (5)

Roughness of Open Channel

Name: Section: B.N.:

Experiment No. (5)
Roughness of Open Channel

1- Objectives

To determine an average value of both manning (n) and chezy (c) coefficients for the laboratory flume

2- Introductory theory

An open channel is a waterway, canal or conduit in which a liquid flows with a free surface. In this case, water flows with a uniform depth (normal depth) at which the weight component in the direction of the flow balances with the friction force induced by the flow resistance with the bed and sides.

Chezy's formula (1769)

$$Q = CR^{\frac{1}{2}}s^{\frac{1}{2}}A \qquad (2.1)$$

Where

Q = flow rate

C = Chezy roughness coefficient

R= hydraulic radius (A/P) [area (A)= by, and wetted perimeter (P)=b+2y]

S= bed slope (uniform flow)

Manning equation (1890)

It is considered one of the most widely used equation for open channel flow

$$Q = \frac{1}{n}R^{\frac{2}{3}}s^{\frac{1}{2}}A \qquad (2.2)$$

Where

n = Manning roughness coefficient

3- Experimental Work

Apparatus:

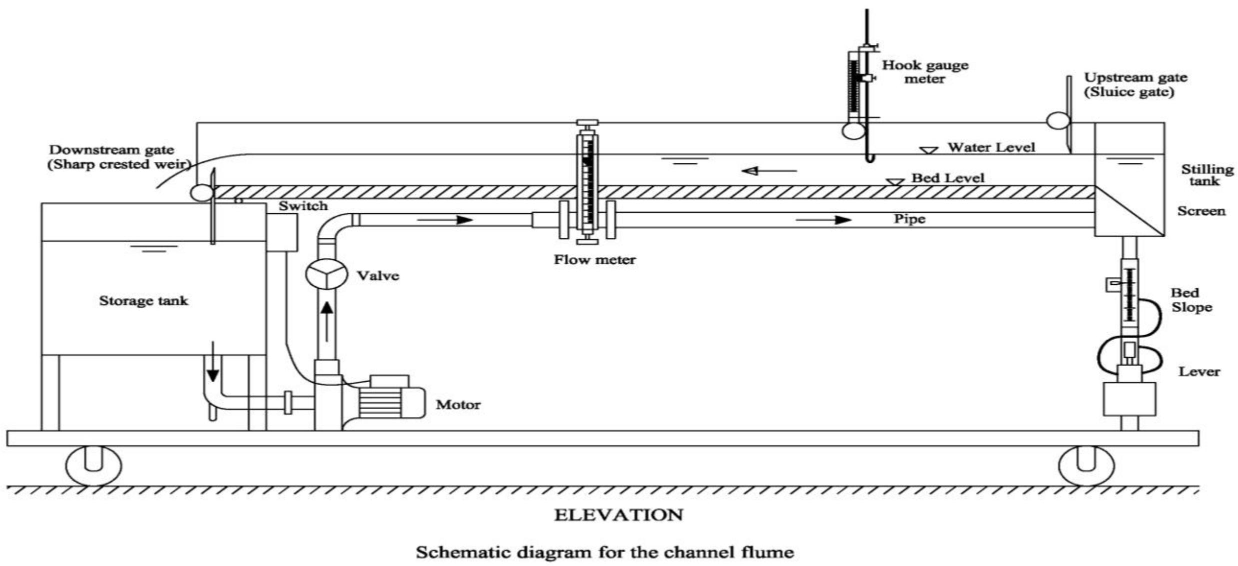


Figure (1): Schematic Diagram for the Channel Flume

Measurements

- Bed level (h_o), water surface level (h_1) in cm
- Flume width (b).
- Flow rate (Q) in m^3/h.
- Bed slope (S)

Procedure

1. Start the pump. ☐
2. Regulate the control valve and wait to achieve the steady flow. ☐
3. Measure the flow rate using the flow meter in "m^3/hr". ☐
4. Use the hook water gauge to measure the bed level (h_o) ☐
5. Use the hook water gauge to measure the water surface level (h_1). ☐
6. Change the control valve opening to get a different flow rate. ☐
7. Repeat steps from 3 to 5. ☐
8. Stop the pump ☐

Name: Section: B.N.:

No.	Flow Rate (m3/hr)	h_o (cm)	h_1 (cm)

4- Results and Analysis

- Calculate the water depth $y= h_1 – h_o$.
- Calculate n from equation (2.1)
- Calculate C from equation (2.2).

No.	Flow Rate (Q)	Water depth (y)	Area (A)	Wetted perimeter (p)	Hydraulic radius (R)	Manning coefficient (n)	Chezy coefficient (C)

Plot the relation between Q and n,

Plot the relation between Q and C.

5-Conclusions

Write your conclusions referring to the following issues:

1. Describe the relation between Q and n,C.

Name: Section: B.N.:

Experiment No. (6)

Hydraulic Jump

Name: Section: B.N.:

Experiment No. (6)

Hydraulic Jump

1- Objectives

To study the characteristics of a simple hydraulic jump both by rational analysis and by observation.

2- Introductory theory

Hydraulic jump is a natural phenomenon in open channel which is considered as one of is the forms of rapidly varied flow. It is an abrupt reduction in flow velocity by means of sudden increase of water depth in the downstream direction.

Hydraulic jump is formed in open channels when the flow regime is changed from supercritical to subcritical flow. This change in flow regime takes place in certain locations in the open channel; downstream weirs and regulators and at bed slope transition from steep to mild slope for example. Hydraulic jump is used downstream irrigation structures to reduce the high water velocity and energy to prevent scour in earth canals.

In order to determine the relation between the upstream and the downstream water depth and velocity at a hydraulic jump, the principle of specific force is applied. The specific force function is obtained by applying the momentum principle between the two sections at the upstream and the downstream.

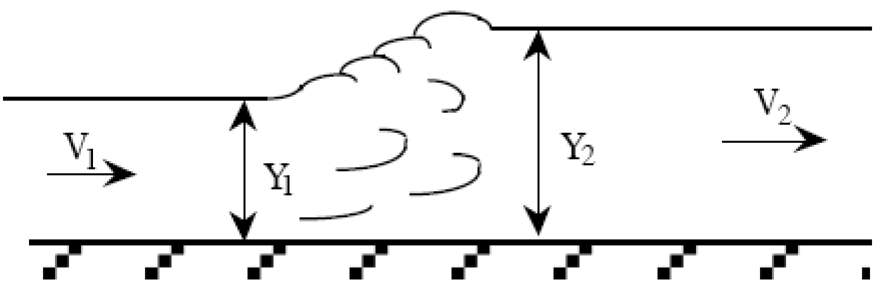


Figure (1) Hydraulic Jump

The principal parameter in the description of hydraulic jump phenomena is the Froude number

$$F_{N1_1} = \frac{v_1}{\sqrt{g \times D_1}} \tag{3.1}$$

Where

$v_1 = \frac{Q}{A_1}$ = average velocity,

$A_1 = b \times y_1$

g = acceleration due to gravity,

D= A/T = average depth, alsocalled "hydraulic depth", A = area of flow cross-section, and T = width of the free surface.

Note: For a rectangular channel, T = B = width of the flow cross-section and, hence, D = y = depth of flow.

A closed-form mathematical analysis of the jump phenomenon is possible only if the flow cross-section is rectangular.The result, known as Belanger equation, is

$$y_2 = \frac{y_1}{2}\left[\sqrt{1+8F_{N1}{}^2} - 1\right] \qquad (3.2)$$

3- Experimental Work

Apparatus:

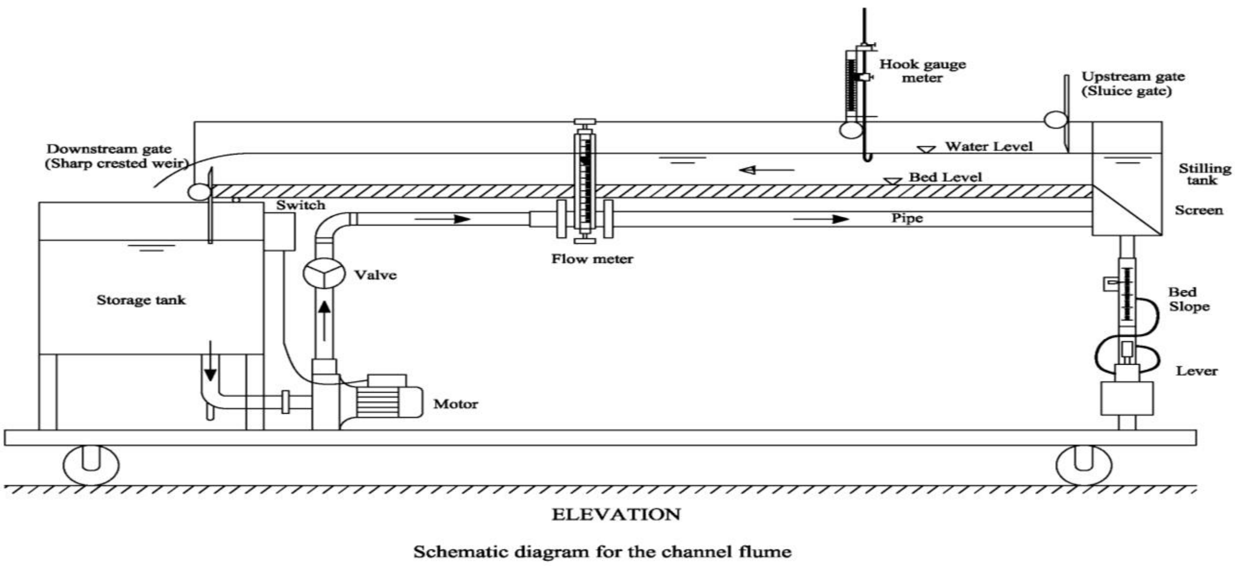


Figure (1): Schematic Diagram for the Channel Flume

Measurements

- Upstream bed level (h_1), upstream water surface level (h_2) in cm
- Downstream bed level (h_3), downstream water surface level (h_4) in cm
- Flume width (b).
- Flow rate (Q) in m^3/h

Procedure

1. Start the pump. ☐
2. Regulate the control valve to achieve the steady subcritical flow regime. ☐
3. Lower the upstream gate of the flume for small opening. ☐
4. Adjust the size of the gate opening to form hydraulic jump at the middle third of the flume. ☐
5. Measure the flow rate using the flow meter in "m^3/hr". ☐
6. Use the hook water gauge to measure the bed level upstream the jump (h_1) ☐
7. Use the hook water gauge to measure the water surface level upstream the jump (h_2). ☐
8. Repeat steps 6, 7 to measure (h_3), (h_4) downstream the jump. ☐
9. Change the control valve opening to get a different flow rate. ☐
10. Repeat steps from 3 to 8. ☐
11. Stop the pump ☐

No.	Flow Rate (m^3/hr)	h_1 (cm)	h_2 (cm)	h_3 (cm)	h_4 (cm)

4- Results and Analysis

- Calculate the initial depth $y_1 = h_2 - h_1$.
- Calculate the measured sequent depth $y_{2\,act} = h_4 - h_3$.
- Calculate F_{n1} from equation (3.1)
- Calculate the theoretical sequent depth $y_{2\,th}$ from equation (3.2).

No.	Flow Rate (m^3/s)	Initial depth y_1 (m)	Initial velocity v_1 (m/s)	Initial F_{N1}	Theoretical sequent depth y_2 (m)	Actual sequent depth y_2 (m)

<u>Plot</u> the relation between the measured and the theoretical values of y_2.

<u>Plot</u> the relation between F_{N1} and (y_2/y_1)

5-Conclusions

Write your conclusions referring to the following issues:

1. What is the relation F_{N1} and (y_2/y_1)?
2. The percentage error between the measured and calculated y_2.

Name: Section: B.N.: