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Venture meter

The object of this experiment is to:

1. Find the coefficient of discharge (Cd) of a venturi meter and to demonstate how it can be used to measure fluid discharge through a pipeline.

2. Show how the head lost as the fluid passes through the meter varies with the velocity head.

This page shows a diagrammatic representation of the main equipment needed to undertake the investigation. You will require the following items:

- Fluid Friction Apparatus
- Stop Watch

This investigation is concerned with the Venturi Meter, which is illustrated above. It will be useful if you obtain a printout of this diagram, by accessing the above PRINT rectangle. After you have studied this diagram and noted the abbreviations for the dimensions, you may scroll this window to move onto the Theory Page.

T H E O R Y

Nomenclature:-

g = acceleration due to gravity (9.81 m/s^2)

Z = height from horizontal datum

Hu = upstream piezometric height

Hd = downstream piezometric height

Ht = throat piezometric height

Hl = head loss through meter (Hu - Hd)

H = Hu - Ht

Ha = difference between upstream and throat manometer heightsچ

in mm of mercury or mm of water depending on the manometerچ

Hb = difference between upstream and downstream manometerچ

heights in mm of mercury or mm of water depending on theچ

manometer used.

u = upstream suffix

t = throat suffix

d = downstream suffix

V = fluid velocity in pipe

P = fluid pressure

p = density

Qa = actual flow rate

Qt = theoretical flow rate

Qincpt = apparent flow rate from graph when H=0

A = cross sectional area

Cd = coefficient of discharge

K = meter constant

Cd =

Bernoulli's equation :

Zu + + = Zt + +

Zu = Zt hence:

= 1

because P = p g h and H = Hu - Ht :

Hu - Ht =

H = and from 1 H =

Continuity:- $Q_t = A_u.V_u = A_t.V_t$

$V_t =$

substitute:

rearranging:

rearranging:

$V_u = SQRT[2gH / ((A_u^2 / A_t^2) - 1)]$ (SQRT = ^0.5)

substituting in continuity

$Q_t = A_u\, SQRT[2gH / ((A_u^2 / A_t^2) - 1)]$ (SQRT = ^0.5)

Let:- $K = A_u\, SQRT[2g / ((A_u^2 / A_t^2) - 1)]$

$Q_t = K\, SQRT(H)$

This is the theoretical flow rate. Introducing the coefficient o discharge (Cd) takes account of friction:

ACTUAL FLOW RATE (Q_a) = $C_d. K. SQRT(H)$

If Cd as well as K is constant a graph of Qa against SQRT(H) will be a straight line having a slope equal to Cd.K .

Qa and H are found by experiment, K can be calculated from Au and At. Hence the best value of the coefficient of discharge (Cd) may be found.

HEAD LOSS

The overall losses (Hl = Hu - Hd) increase as the flow rate increases and should be proportional to the velocity head (V^2/2g). This can be confirmed by plotting a graph of Hl against V^2/2g.

ASSUMPTIONS

If the Cd graph appears to be a straight line, for practical purposes it is reasonable to assume that the relationship is linear and hence Cd is constant. However it can be seen that this assumption results in an apparent discharge Qincpt when H=0.

Once Cd has been determined experimentally the meter may be used to measure any flow rate by observing the manometer readings and using the formula:

Q = Cd K SQRT(H)

However to be really accurate Qincpt should be taken into account

Q = Cd K SQRT(H) + Qincpt

CAUTION:- The above theory relates to practical turbulent flow and should not be used for laminar and small flows, and may account for "apparent" error resulting from the graph not passing through the origin.

MANOMETERS:- Differential manometers only record the difference in pressure head when the tapping points are at the same level. If the tapping points are at different levels the manometer will record the difference in PIEZOMETRIC HEAD (sum of pressure and potential head).

For the Inverted WATER Manometer:

DIFFERENCE IN PIEZOMETRIC HEAD = DIFFERENCE IN MANOMETER WATER

LEVEL READINGS

For the MERCURY U Tube Manometer:-

DIFFERENCE IN PIEZOMETRIC HEAD = DIFFERENCE IN MERCURY LEVEL

READINGS x 12.6

Method

Use the Armfield Venturi Meter on the Fluid Friction equipment to carry out the following procedure:

Prime the pipe network with water. Open the appropriate valves to obtain flow of water through the flow meters, For several different flow rates ranging from a very small flow rate to the maximum for which readings can be obtained, measure the time taken to collect a known quantity of fluid in the measuring tank. For each measured flow rate record the height of the fluid in the manometer tubes, and the manometers used. The computer will then be able to calculate: Hl , Q, V^2 / 2g, SQRT(H), Cd for each set of readings.

A graph of Q against SQRT(H) is then drawn to find the accurate Cd for the meter, and a graph of Hl against V^2 / 2g is also drawn to show their relationship.

You should ensure that you calculate one set of results for the first set of readings (ie the first Cd). These results should agree with the computed results and be included in your report.

experimental constants. Check to make sure that these constants are correct for the equipment you are using. The Meter Constant has been calculated from the upstream and throat diameters.

This is the Readings Page. As the readings are entered the appropriate graphs are drawn.The graph scales have been preset, however you may alter the graph axes to suit your readings. Note that the units used on the graph are more appropriate to the calculations, whereas the units used for entering the readings are more appropriate for the equipment.

Move the cursor to appropriate rectangles and enter the sets of experimental readings in the following order:

1. Select the water/mercury manometer used for measuring the difference in head between the upstream and throat tapping positions by toggling.

2. Ha (mm) The difference between the upstream and throat manometer readings in mm of manometer fluid

3. Select the water/mercury manometer used for measuring the difference in head between the upstream and downstream tapping positions by toggling.

4. Hb (mm) The difference between the upstream and downstream manometer readings in mm of manometer fluid

5. Vol (l) The volume of water collected in litres.

6. t (s) The time taken to collect that volume of water.

After each set of readings have been entered the following will be calculated and displayed:

1. Hl (mm) The head loss through the meter in mm of water.

2. H^.5 (m^0.5) The square root of Ha

3. Q (m^3/s x 10^-3) or (l/s) The flow rate.

4. V^2 /2g (mm) The velocity head

5. Cd The apparent coefficient of discharge calculated for that unique set of readings only.

This is the Conclusion Page. The coefficient of discharge and the intercept on the Q axis has been calculated from graph1. The constant of proportionality relationship between the head loss and velocity head has been calculated from graph2.

QUESTION 1

Would you expect the pressure at the throat to be more or less than the inlet pressure ?

a) Less

b) More

c) Same

Observation of the manometer levels should indicate that the pressure at the throat is less than that at the inlet.

QUESTION 2

It is possible to explain the answer to question 1 in terms of energy. We already know that the energy in a fluid comes only in three forms:

a) Pressure energy

b) Kinetic energy

c) potential energy

Which of the three energies increases at the throat ?

The answer is (b) because the velocity has increased at the throat.

QUESTION 3

The kinetic energy has increased. This increase can only be acquired if another type of energy decreases. Which of the three energies has reduced at the throat ?

a) Pressure Energy

b) Kinetic Energy

c) Potential Energy

The answer is (a) because the kinetic energy has increased and since the tube is horizontal the potential energy remains constant. This therefore only leaves the pressure energy.

QUESTION 4

After the fluid has diverged back to its original (upstream) diameter, the pressure energy is less than at the original upstream tapping point.

Is this due to:

a) rubbing of the fluid on the pipe sides ?

b) an increase in kinetic energy ?

c) turbulence ?

d) friction within the fluid ?

Answer a,b,c or d. Which of these answers is ALWAYS correct ?

(d) is always the correct answer. However, if the flow is turbulent (as is usually the case in practical flows of water), then (c) would also be correct since turbulence causes more fluid friction.

QUESTION 5

After the fluid has diverged back to its original (upstream) diameter, will the pressure be:

a) greater than the upstream pressure

b) less than the upstream pressure

c) same as the upstream pressure

The correct answer is (b). The pressure should be slightly less than that at the upstream position, because of head loss through the meter.