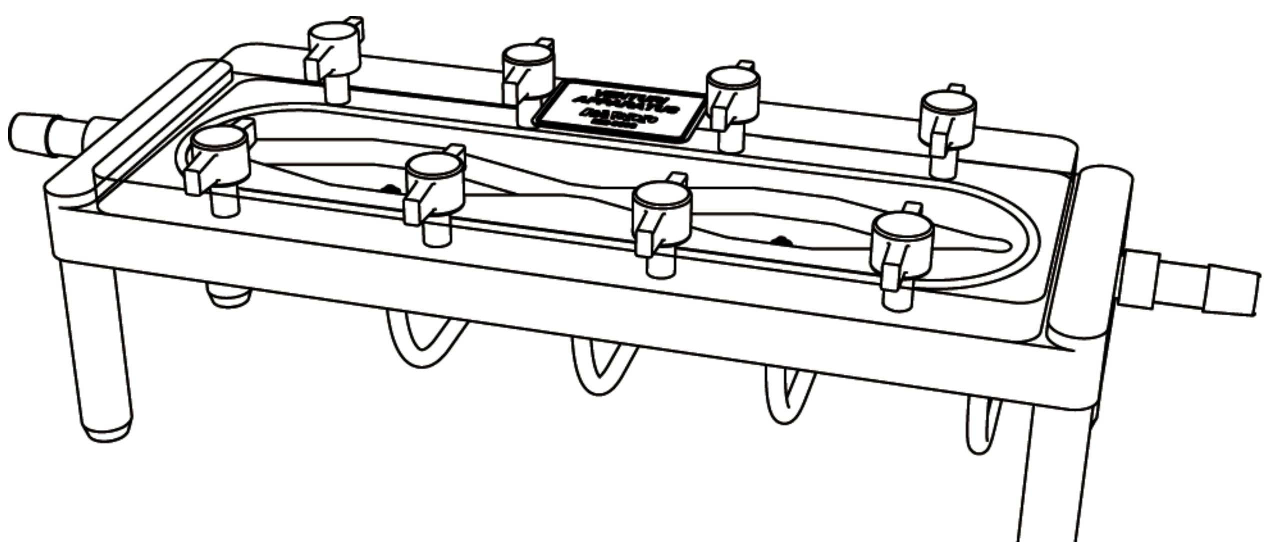
PASCO®

Instruction Manual
012-09486B

Venturi Apparatus

ME-8598



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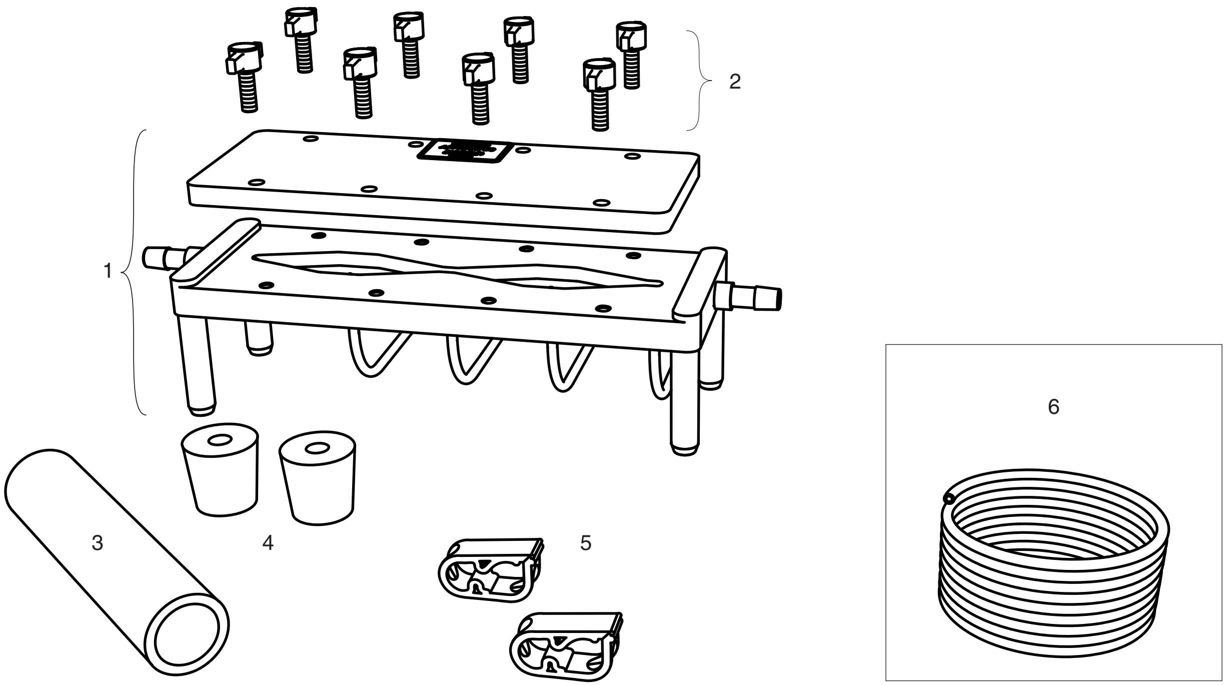
Venturi Apparatus

ME-8598



Included Equipment	Part Number
1. Venturi Apparatus base and top plate	ME-8598
2. T-knob Screws (qty. 8)	617-024
3. Spirometer Tubing, 2.5 cm ID, 15 cm long	640-053
4. Rubber Stoppers, 1-hole (qty. 2)	648-09597
5. Restriction Clamps (qty. 2)	640-052
6. Fluid Tubing, 6 mm ID, 6 m long	640-012
Required Equipment	
Quad Pressure Sensor	PS-2164
PASPORT Interface [5]	See PASCO catalog or www.pasco.com

Air Method: Recommended Equipment [1]	Part Number
Spirometer Sensor [2]	PS-2152
One of the following:	
Shop Vacuum (or similar air supply) [3]	
Balloon and balloon pump	
Water Method: Recommended Equipment [4]	
Water Reservoir (or similar container)	ME-8594
Container to catch water	
Table Clamp	ME-9472
120 cm rod	ME-8741
2 Three-finger clamps	SE-9445
One of the following:	
Motion Sensor [2]	PS-2103
Rotary Motion Sensor [2]	PS-2120
Force Sensor [2]	PS-2104
Stopwatch	SE-8702B

[1] *See page 8 for more information.*
[2] *The use of this sensor and the Quad Pressure Sensor simultaneously requires a multi-port PASPORT Interface (such as Xplorer GLX or PowerLink) or two single-port interfaces.*
[3] *See pages 8–10 for more information.*
[4] *See pages 10–13 for more information.*
[5] *PASPORT interfaces include Xplorer GLX (PS-2002), PowerLink (PS-2001), AirLink (PS-2005), Xplorer (PS-2000), and USB Link (PS-2100)*

Introduction

In the Venturi Apparatus, air or water flows through a channel of varying width. As the cross-sectional area changes, volumetric flow rate remains constant, but the velocity and pressure of the fluid vary. With a Quad Pressure Sensor connected to the built-in Pitot tubes, the Venturi Apparatus allows the quantitative study and verification of the Continuity Equation, Bernoulli's principle, and the Venturi effect.

The model ME-8598 Venturi Apparatus includes the connectors and tubing needed for doing the experiment with either air or water. This manual contains complete experiment instructions, including several options for fluid supply and flow-rate measurement.

Theory

An incompressible fluid of density ρ flows through a pipe of varying diameter (see Figure 1). As the cross-sectional area decreases from A_0 (large) to A (small), the speed of the fluid increases from υ_0 to υ.

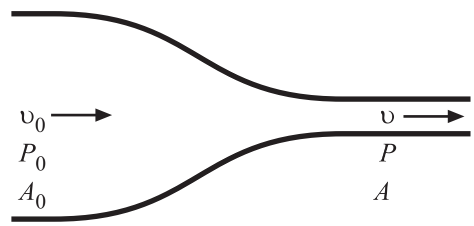


Figure 1: Fluid flow through a pipe of varying diameter

The flow rate, R, (volume/time) of the fluid through the tube is related to the speed of the fluid (distance/time) and the cross-sectional area of the pipe. The flow rate must be constant over the length of the pipe. This relationship is known as the Continuity Equation, and can be expressed as

(eq. 1)
$$R = A_0\upsilon_0 = A\upsilon$$

As the fluid travels from the wide part of the pipe to the constriction, the speed increases from υ_0 to υ, and the pressure decreases from P_0 to P. If the pressure change is due only to the velocity change, Bernoulli's Equation can be simplified to:

(eq. 2)
$$P = P_0 - \frac{1}{2}\rho(\upsilon^2 - \upsilon_0^2)$$

Experiment

This experiment can be conducted with either air or water. Appendix B contains equipment lists and instructions specific to each method.

Note: You can use a PASPORT interface (or interfaces) connected to a computer running DataStudio software or on an Xplorer GLX interface in standalone mode (without a computer). For instructions on collecting, graphing, and analyzing data, press F1 to open DataStudio on-line help, or see the Xplorer GLX Users' Guide.

Pre-Setup Measurements

Remove the top plate from the apparatus. Measure the depth of the channel and the widths of the wide and narrow sections. Calculate the largest cross-sectional area (A_L) and the smallest cross-sectional area (A_S).

Setup

1. Connect the Quad Pressure Sensor to your PASPORT interface (but do not connect tubing to the pressure ports yet). If you are using a computer, start DataStudio.

2. Calibrate the Quad Pressure Sensor (see Appendix A).

3. Connect each of the four pressure tubes extending from the underside of the apparatus to the ports of the Quad Pressure Sensor as indicated in Figure 2.

Important: *Do not allow water to enter the sensor. Ensure that there is no water near the sensor end of the pressure tubes.*

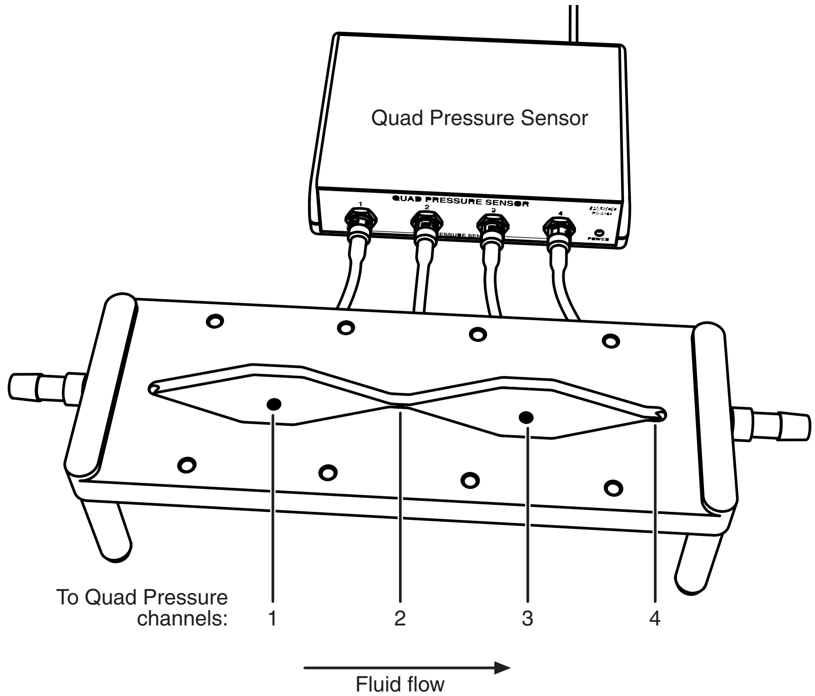


Figure 2: Quad Pressure Sensor connected to apparatus

4. Place the top plate on the apparatus and secure it with eight T-knob screws. Tighten the screws no more than necessary to prevent leaking.

5. Set up the fluid supply and flow-rate measurement as described in Appendix B.

Procedure

1. Start fluid flow.

2. Start data collection on the computer or interface.

3. Continue data collection while observing the pressure measurements on a graph display. Obtain a few seconds' worth of good data before stopping data collection and fluid flow.

Analysis

1. View your data on a graph of pressure versus time.

2. Select a time interval of about 2 seconds in which all off the pressure measurements are relatively clean (though not necessarily constant or noise-free).

3. Within this time interval, determine the average of each pressure measurement: P_1, P_2, P_3 (and P_4 if you will do the Further Analysis below).

4. Over the same 2-second interval, determine the average flow rate, R.

5. If there were no friction or turbulence in the channel, the pressures in both wide sections (P_1 and P_3) would be equal; however, you will find that this is not the case. Because the channel is symmetrical about Point 2, you can estimate the pressure lost at Point 2 due to friction and turbulence by assuming that it is half of the pressure lost between Point 1 and Point 3. In other words, if the tube were straight, the pressure at Point 2 would be the average of P_1 and P_3. Calculate this theoretical pressure:

(eq. 3)
$$P_0 = \frac{P_1 + P_2}{2}$$

6. Use the measured flow rate, R, and Equation 1 to calculate the fluid speed in the wide parts of the tube (υ_0), and the speed in the venturi constriction (υ).

7. Use these values of υ_0 and υ and Equation 2 to calculate the theoretical pressure (P) in the venturi constriction. Compare this to the actual pressure measured by the sensor (P_2).

Further Analysis

Repeat the analysis above for Points 2, 3, and 4.

Clean-up

1. Allow the water reservoir to run empty. Tilt the apparatus to empty water from it.

2. With the apparatus empty of water, disconnect the pressure tubes from the sensor. (Leave the tubes connected to the underside of the apparatus.)

3. Remove the top plate from the apparatus. Allow the apparatus and tubing to dry completely.

Storage

Store the apparatus with the top plate loose to avoid permanently deforming the seal.

Appendix A: Quad Pressure Calibration

The purpose of this calibration is to fine-tune all four pressure measurements so they read the same when exposed to the atmosphere. This will allow the small pressure differences that occur in the apparatus to be measured more accurately.

Conduct this procedure with all four pressure ports exposed to the same pressure.

DataStudio

1. Click the **Setup** button to open the **Experiment Setup** window.
2. Click the **Calibrate Sensors** button to open the calibration window (see Figure 3).
3. At the top of the **Calibrate Sensors** window, select **Quad Pressure Sensor**.
4. Select the **Calibrate all similar measurements simultaneously** option.
5. Select the **1 Point (Adjust Offset Only)** option.
6. Click **Read From Sensor** (in the Calibration Point 1 section of the window).
7. Click **OK**.

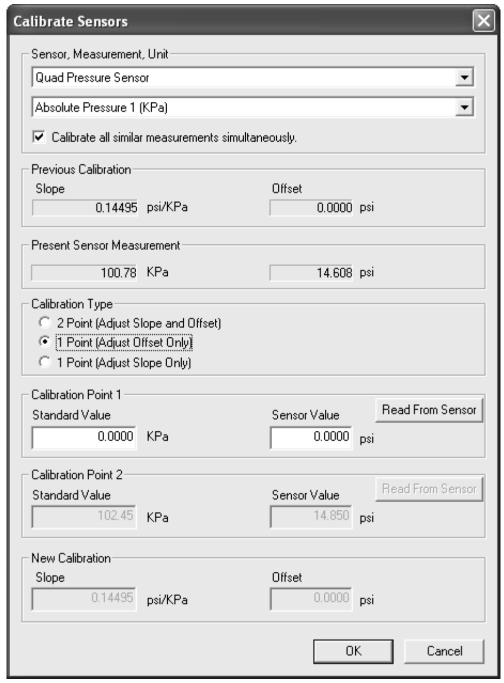


Figure 3: DataStudio calibration window

Xplorer GLX (Standalone Mode)

1. Press ⌂ + F4 to open the Sensors Screen.
2. Press F4 again to open the Sensors menu.
3. From the menu, select **Calibrate** to open the **Calibrate Sensors** window (see Figure 4).
4. In the first box of the window, select **Quad Pressure Sensor**.
5. In the third box of the window, select **Calibrate All Similar Measurements**.
6. In the **Calibration Type** box, select **1 Point Offset**.
7. Press F3 (Read Pt 1).
8. Press F1 (OK).

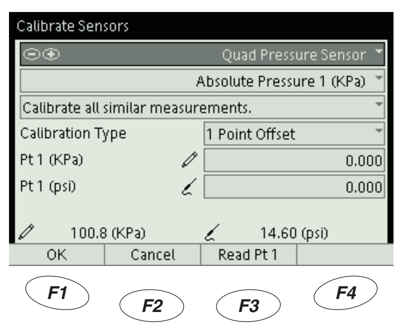


Figure 4: GLX calibration window

Appendix B: Fluid Supply and Flow Rate Measurement Options

You can conduct the experiment using air or water as the fluid. In either case, you have a range of options for how to handle the fluid and how to measure the flow rate. Some of the possibilities are described in this appendix.

In many of these setups, a PASPORT sensor is used to measure the flow rate. You can connect this sensor and the Quad Pressure Sensor to a single multi-port interface (such as the Xplorer GLX or PowerLink) or use two single-port interfaces connected to your computer. If you have only one single-port interface, measure the flow rate and pressures in two separate data runs.

Air

Air Supply Method 1: Shop Vacuum

Included Parts Required
Rubber stopper with hole

Other Parts Required
Shop vacuum or similar air supply

This method will typically produce a flow rate of 2 L/s or more.

Use a shop vacuum cleaner (Shop-Vac® brand or similar) as an air supply. Almost any model will work, but one that has a hose connection for blowing air out may be preferable since it can push (as well as suck) air through the apparatus. Air supplies designed for airtracks will work, but they may produce less air flow than a shop vacuum.

The Venturi Apparatus includes two rubber stoppers with holes. Use one of them to connect the hose of the shop vacuum to the inflow port of the apparatus (see Figure 5). Connect the hose to the air-blowing port of the shop vacuum.

To measure airflow, connect a spirometer sensor as described on page 9.

Note: Observe the correct direction of airflow through the apparatus indicated in Figure 5. If you will be using the shop vacuum to suck air through the apparatus, connect it to the outflow port, and connect the spirometer to the inflow port.

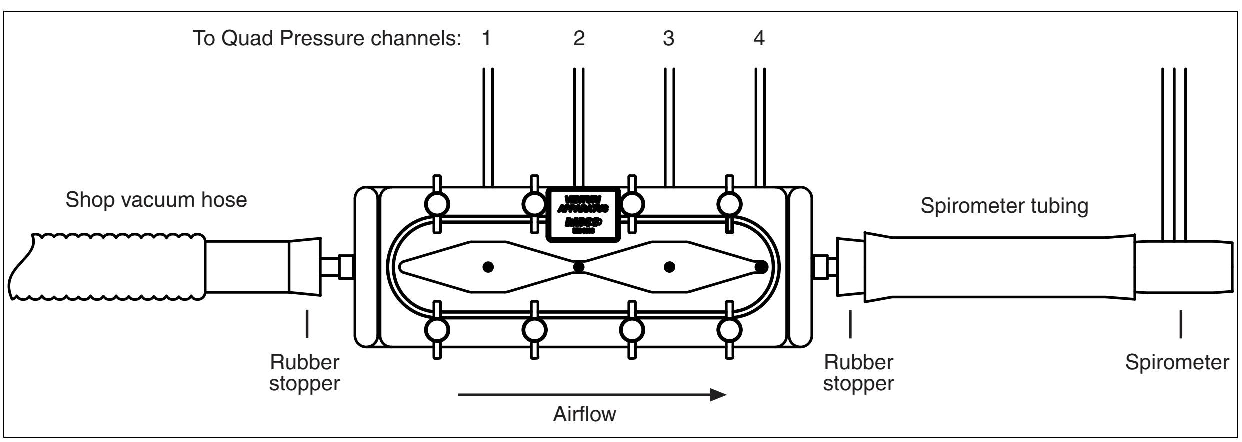


Figure 5: Setup for air with a shop vacuum

Air Supply Method 2: Balloon

Included Parts Required
Rubber stopper with hole
Short piece of fluid tubing (about 10 cm)
Restriction Clamp

Other Parts Required
Rubber balloon
Balloon pump (available at party supply stores)

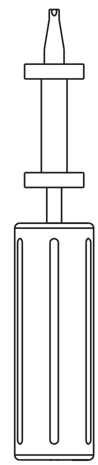


Figure 6: Balloon pump

This method will produce a flow rate of about 0.5 L/s.

Stretch the mouth of the balloon around the rubber stopper. Insert the piece of fluid tubing into the hole in the stopper. Place the restriction clamp on the tubing. Use a pump to inflate the balloon through the tubing. Close the clamp to hold the air in the balloon. Remove the pump, and connect the tubing to the inflow port of the apparatus (see Figure 7). Open the clamp to start the flow of air.

To measure airflow, connect a spirometer sensor as described below.

Note: Using a pump to inflate the balloon ensures that the air will be relatively dry. A balloon inflated by mouth will introduce moisture into the apparatus.

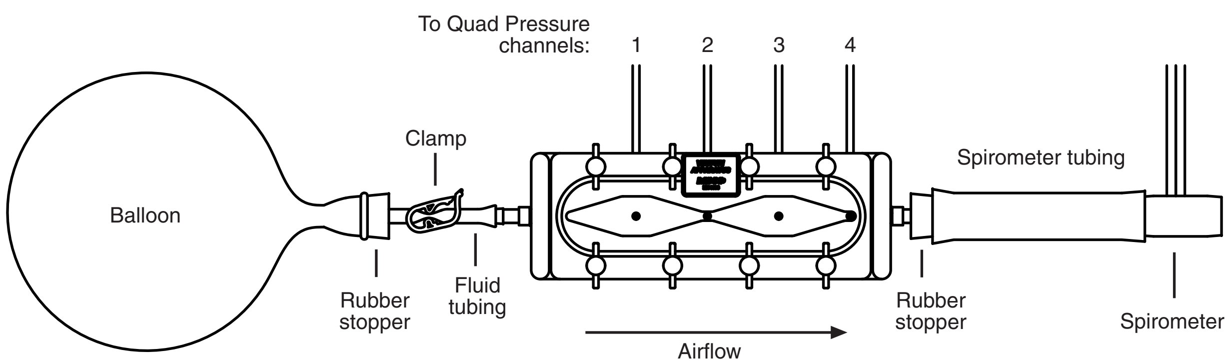


Figure 7: Setup for air with a balloon

Airflow Measurement

In this method, a Spirometer sensor measures the airflow rate.

Included Parts Required
Rubber stopper with hole
Spirometer tubing (15 cm long, 2.5 cm inside diameter)

Other Parts Required	Part Number
Spirometer Sensor	PS-2152

Use the PASCO Spirometer sensor to measure airflow rate. The Spirometer is primary designed for measuring airflow in and out of a person’s lungs, but works well to measure the airflow through the Venturi Apparatus.

Insert the rubber stopper into the rubber spirometer tubing,[1] and connect the stopper to the outflow port of the apparatus. Insert the mouthpiece of the spirometer into the

[1]The tubing isolates the spirometer from turbulence occurring at the apparatus’s outflow port.

other end of the spirometer tubing (see Figure 5 or 7). Assemble the mouthpiece and spirometer handle, and connect the spirometer to your PASPORT interface.

The spirometer automatically calibrates itself every time you start data collection. During the first few seconds of data collection, it must remain still and away from air currents. A red WAIT light and green READY light illuminate to indicate when the sensor is calibrating and when it is ready to measure air flow. Start data collection (by pressing or clicking the Start button) with the air supply off, and wait until the spirometer is ready before turning the air supply on.[2]

[2]For more information on the spirometer, see the instructions included with it (PASCO instruction sheet 012-08856).

Water

Water Supply

Included Parts Required
Fluid tubing (at least 1.5 m)
2 restriction clamps

Other Parts Required or Recommended	Part Number
Water Reservoir (or other container of at least 1 liter)	ME-8594
Container to catch water	
Equipment to elevate and secure reservoir:	
Table Clamp	ME-9472
120 cm rod	ME-8741
2 Three-finger clamps	SE-9445

Set up the apparatus with at least 1.5 m of vertical drop from the top surface of the water reservoir to the bottom of the drain tube. Elevate the reservoir above your lab bench and put the catch basin on the floor (see Figure 8).

Cut the water tubing into two pieces of suitable length. Connect one piece of tubing to the outflow port of the apparatus and run it over the side of the lab bench into the catch basin. Secure the tubing so water will not spill onto the floor. Place both hose clamps on the outflow tubing. Close one of the clams partially to regulate the flow rate. Close the other clamp completely; you will open and close this clamp to start and stop water flow.

Run the other piece of tubing from the reservoir to the inflow port of the apparatus. Connect the tubing to the bottom hose fitting of the model ME-8594 Water Reservoir, or (if you are using a container without a hose fitting) set up the tubing as a siphon.

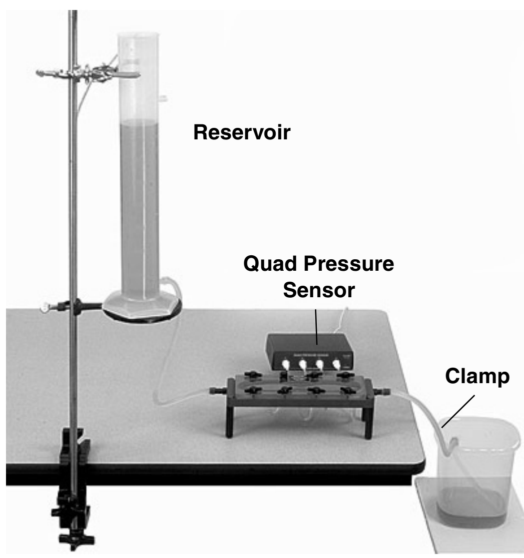


Figure 8: Setup for water

Note: Observe the correct direction of water flow through the apparatus indicated in Figure 2.

Connect the Quad Pressure Sensor if it is not already connected (see page 5).

***Important**: Do not allow water to enter the sensor's pressure ports. Connect the quad pressure sensor to the apparatus before filling it with water. Once water is in the apparatus, do not disconnect the sensor; otherwise water will flow through the pressure tubes.*

Fill the reservoir with water. (If you are using the tubing as a siphon, fill it and the apparatus with water as well, or use suction to draw water into them.)

Open the clamp to let some water through the apparatus; then close it. Initially, there will be air in the apparatus; tilt it so that the air moves to the outflow port. Let some more water through to flush out the air. Repeat this process until all air has been removed from the apparatus and inflow tubing. Do not let the reservoir run empty, or new bubbles will enter. Close the clamp. Refill the reservoir.

Water-flow Measurement Method 1: Motion Sensor

In this method a motion sensor measures the velocity of the descending water surface in the reservoir.

Parts Required or Recommended	Part Number
Motion Sensor	PS-2103
Water Reservoir (or other narrow, straight-sided container)	ME-8594
Equipment for mounting sensor:	
Multi clamp	SE-9492
Mounting rod	SA-9242

Figure 9: Motion sensor and water reservoir

1. Set the switch on the motion sensor to the near-range setting.

2. Clamp the motion sensor above the reservoir. Position the sensor very close to the top of the reservoir so it will measure the distance to the surface of the water (see Figure 9). The water surface should be at least 15 cm from the sensor.

3. Test the setup: Start data collection and start the water flow. Look at velocity versus time data on a graph display. Adjust the position and angle of the sensor so that you get good velocity data as the water drains. (It is not necessary to get good data over the entire range of water level, since you will only need about 2 seconds' worth of data.) Stop water flow and refill the reservoir. Delete your test data.

4. Create a flow-rate calculation: In the DataStudio Calculator window (or GLX Calculator screen) enter the following definition:

$$R = v * A$$

Define the variable v as the velocity measurement. Define A as a constant equal to the horizontal cross-sectional area of the inside of the reservoir. Measure the area in units of m^2. In this way, R is calculated in units of m^3/s.

Water-flow Measurement Method 2: Rotary Motion Sensor

In this method a rotary motion sensor measures the velocity of the descending water surface in the reservoir.

Parts Required or Recommended	Part Number
Rotary Motion Sensor	PS-2120
Water Reservoir (or other narrow, straight-sided container)	ME-8594
Float (such as a piece of wood)	
Small weight (weighing less than the float)	
Equipment for mounting sensor:	
Multi clamp	SE-9492
Mounting rod	SA-9242

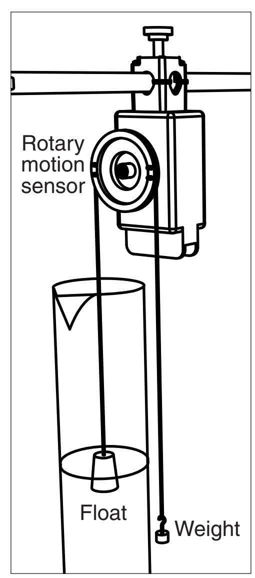


Figure 10: Rotary motion sensor and water reservoir

1. Install the three-step pulley on the rotary motion sensor.

2. Clamp the rotary motion sensor above the reservoir (see Figure 10).

3. Tie the float to one end of the string and the weight to the other end. Place the float in the reservoir, run the string over the large step of the pulley, and let the weight hang freely. Ensure that the weight will be free to move up as the water drains.

4. In DataStudio (or on the GLX) enable the **Linear Velocity** measurement of the rotary motion sensor and set the **Linear Scale** value to **Large Pulley**.[3]

5. Create a flow-rate calculation: In the DataStudio Calculator window (or GLX Calculator screen) enter the following definition:

R = v * A

Define the variable v as the velocity measurement. Define A as a constant equal to the horizontal cross-sectional area of the inside of the reservoir. Measure the area in units of m^2. In this way, *R* is calculated in units of m^3/s.

[3]In DataStudio, click the **Setup** button to open the **Experiment Setup** window. Enable **Linear Velocity** under the **Measurements** tab. Set the **Linear Scale** under the **Rotary Motion Sensor** tab.

On the GLX (in standalone mode), go to the Setting Screen by pressing ⌂ + F4.

Water-flow Measurement Method 3: Force Sensor

In this method, a force sensor measures the increasing weight of the water in the catch basin.

Other Parts Required or Recommended	Part Number
Force Sensor	PS-2104
Equipment for mounting sensor:	
Multi clamp	SE-9492
Mounting rod	SA-9242
or Force Sensor Balance Stand and Pan	CI-6460
Container for catching water (with a handle if it is to be hung from the force sensor)	

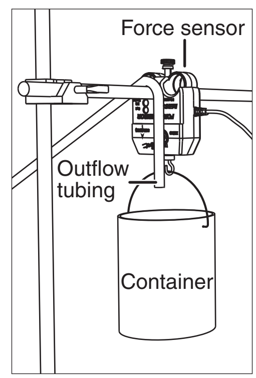


Figure 11: Force sensor and container

1. Clamp the force sensor under the lab bench with the hook pointed down and hang the container from the sensor's hook (see Figure 11).

   or

   Setup the force sensor on the floor with the Balance Stand and Pan and place the container on the pan.

2. Position and secure the end of the outflow tubing so it will drain water into the container but not interfere with the weight measurement.

3. Create a flow-rate calculation: In the DataStudio Calculator window enter the following definition:[4]

R = -derivative(2,F)/(9.81*1000)

Define the variable F as the **Force (push positive)** measurement. In this way, *R* is calculated in units of m^3/s.

The calculator definition above can be express in standard notation as

Figure 12: Balance Stand and Pan

[4]If you are using a GLX in standalone mode, calculate *R* manually after data collection using the slope of the force versus time graph.

$$R = \frac{dF}{dt}\frac{1}{g\rho} \qquad \textit{(eq. 4)}$$

where dF/dt is the rate of increasing force, g = 9.81 N/kg, and ρ = 1000 kg/m^3.

Water-flow Measurement Method 4: Stopwatch

In this method, you measure a volume and elapsed time to determine the average flow. Do this before collecting pressure data.

Other Parts Required or Recommended	
Stopwatch	SE-8702B
Water Reservoir (or other graduated cylinder)	ME-8594

If are using the model ME-8594 Water Reservoir, or similar container, a separate graduated cylinder is not necessary; simply note the initial and final volumes in the reservoir.

1. Start with the catch basin empty.
2. Start the stopwatch and open the clamp to start water flow.
3. After a measurable amount of water has flowed through, stop the stopwatch and close the clamp.
4. Measure the volume of water that flowed out of (or into) the apparatus.
5. Calculate the average flow rate:

$$R = \Delta V/\Delta t \qquad \textit{(eq. 5)}$$

where ΔV is the volume of water and Δt is the elapsed time.

Typically the flow rate varies with the level of water in the reservoir. To keep the flow rate close to constant, make the pressure measurements with the water level approximately the same as it was for the flow rate measurement.

Appendix C: Constants

Density of dry air at 20 °C and 1 atm:	1.2 kg/m^3
Density of water:	1000 kg/m^3
Wide cross-sectional area of channel:	1.99 cm^2
Narrow cross-sectional area of channel:	0.452 cm^2

Technical Support

For assistance with any PASCO product, contact PASCO at:

Address: PASCO scientific
10101 Foothills Blvd.
Roseville, CA 95747-7100

Phone: 916-786-3800 (worldwide)
800-772-8700 (U.S.)

Fax: (916) 786-3292

Web: www.pasco.com

Email: techsupp@pasco.com

For more information about the ME-8598 Venturi Apparatus and the latest version of this manual, go to the PASCO web site and enter ME-8598 in the Search window.

Limited Warranty
For a description of the product warranty, see the PASCO catalog.

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Material Safety Data Sheet

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I. Product

Product Name:	**Barium Grease**
Product Type:	Petroleum Grease

II. OSHA Components

CAS #	WT % Range	Component
64742-52-5	70-75	Petroleum Nephthenic Oil
68201-19-4	25-30	Barium Soap- Insoluble

III. Effects of Overexposure

Eyes: Contact with eyes may cause redness. Flush eyes with copious amounts of water for 15. minutes. If irritation persists contact a physician.

Skin: Contact with skin causes a slight irritation. Wash contacted areas with soap and water.

Ingestion: If ingested drink 2 glasses of water, seek prompt medical attention and Induce vomiting.

IV. Protective Equipment For Handling

Eyes:	Safety Goggles or Glasses
Skin:	Gloves
Ventilation:	Not Required

V. Handling and Storage

Handling:	No special requirements
Storage:	Normal storage

VI. Transport Information

Class or Type: DOT and IATA: Non-Hazardous

VII. Spill and Disposal Procedures

Cleaning up Spills: Use absorbent material to collect and contain material for disposal

Recommendation of Disposal Dispose in accordance with Federal, State and Local regulations

VIII. Reactivity Data

Stability:	Stable
Hazardous Polymerization:	Will Not Occur
Incompatibilities:	Strong oxidizing materials
Hazardous Decomposition:	Carbon Monoxide and various hydrocarbons

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Revision: 3 4/1/2005

Material Safety Data Sheet

Page 2-2

Product # **Barium Grease**

IX.Flammability

Flash Point:	435 open cup
Estimated HMIS Code:	100
Health Hazard:	1
Flammability Hazard	0
Reactivity	0
Explosive Limits:	Unknown
Extinguishing Agents:	Carbon Dioxide or dry chemical (small fires), foam or water spray

X. Chemical and Physical Properties

Vapor Pressure	N/A
Vapor Density	N/A
Soluble in Water	Negligible
Specific Gravity	les than 1.0
Boiling Point:	700
Volatile Organic Compound %	N/A
Appearance	Semi-solid, Amber Color, No odor

XI. Other Information

These data are offered in good faith as typical values and not as product specifications. No warranty, either expressed or implied, is hereby made. The recommended industrial hygiene and safe handling procedures are believed to be generally applicable. However, each user should review these recommendations in the specific context of the intended use and determine whether they are appropriate.

Prepared By: POLYSI TECHNOLOGIES, INC.