

Determining the volume flow with a Venturi tube – measuring the pressure with a pressure sensor and CASSY

Objects of the experiment

- To know the typical properties of a Venturi tube
- To determine the air velocity in the centre of a Venturi tube by measuring the pressure difference between two points of the tube with known cross-sections
- To determine the quantity of air flowing through a Venturi tube per unit of time by pressure difference measurements

Principles

Bernoulli's law states the relationship between static pressure p and flow velocity v , whereby the following applies to a friction-free, horizontally flowing stream through a stationary flow tube between two points labeled with indices 0 and 1:

$$p_0 + \frac{\rho}{2} v_0^2 = p_1 + \frac{\rho}{2} v_1^2 \quad (I)$$

ρ : density of the flow medium

In the experiment described here, air flows through a Venturi-tube whose diameter varies between 100 mm (at both ends) and 50 mm (at the centre). The cross-sectional areas are therefore in a ratio of 1 to 4. We shall measure the static pressure p_0 at the tube entrance and the static pressure p_1 at the centre of the Venturi-tube.

Due to the incompressibility of air, which we can assume for the flow velocities occurring in this experiment without restriction, the following equation applies to the flow velocities v_0 and v_1 and the cross-sectional areas A_0 and A_1 at the two measuring points (Fig. 1):

$$v_0 A_0 = v_1 A_1 \quad (\text{continuity equation}) \quad (II)$$

The products $v \cdot A$ in the continuity equation represent the volume flowing through the tube cross section per unit time.

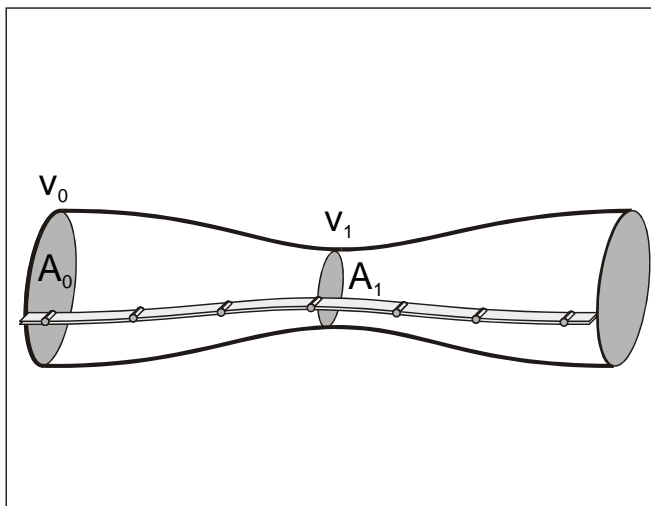
From equation (I) follows:

$$p_0 - p_1 = \frac{\rho}{2} (v_1^2 - v_0^2) \quad (III)$$

We can substitute the velocity v_0 in equation (III) by a term derived from the continuity equation (II):

$$v_0 = v_1 \cdot \frac{A_1}{A_0} \quad (IV)$$

Fig. 1: Venturi-tube schematically: cross sectional areas A_0 and A_1 , flow velocity v_0 and v_1



Apparatus

1 Suction and pressure fan.....	373 04
1 Venturi tube with gauge points.....	373 09
1 Sensor CASSY	524 010USB
or	
1 Pocket CASSY.....	524 006
with	
1 CASSY Lab.....	524 200
or	
1 Mobile-CASSY	524 009
1 Pressure sensor S, ± 70 hPa.....	524 066
1 Stand base, V-shaped, 20 cm.....	300 02
1 Stand rod, 25 cm	300 41
1 Leybold multiclamp	301 01

additionally required: 1 PC with Windows 98 or higher

Setup

Equip the air blower with the small nozzle (100 mm) and the Venturi tube. Set up these devices horizontally on the base like shown in Fig. 2. Additionally, support the Venturi tube using the stand base, stand rod 25 cm and Leybold multiclamp. Do not overtighten screw of the Leybold multiclamp.

- Plug the pressure sensor S, ± 70 hPa to the Input A of the Sensor CASSY (Fig. 2) or to the Mobile CASSY (Fig. 3).
- Connect the overpressure nipple (left side) of the pressure sensor to the first measuring outlet of the Venturi tube using a hose and a brass nipple.
- Connect the vacuum nipple (right side) of the pressure sensor to the central measuring outlet at the smallest diameter of the Venturi tube by means of a hose and a brass nipple.

Thus it is possible to resolve equation (I) for the velocity v_1 at the centre of the tube:

$$v_1 = \sqrt{\frac{2(p_0 - p_1)}{\rho \left(1 - \frac{A_1^2}{A_0^2}\right)}} \quad (V)$$

v_1 can be calculated by means of pressure difference measurement for known cross-sectional areas A_0 and A_1 (Fig.1).

The flow rate to be determined is the product of v_1 and A_1 .

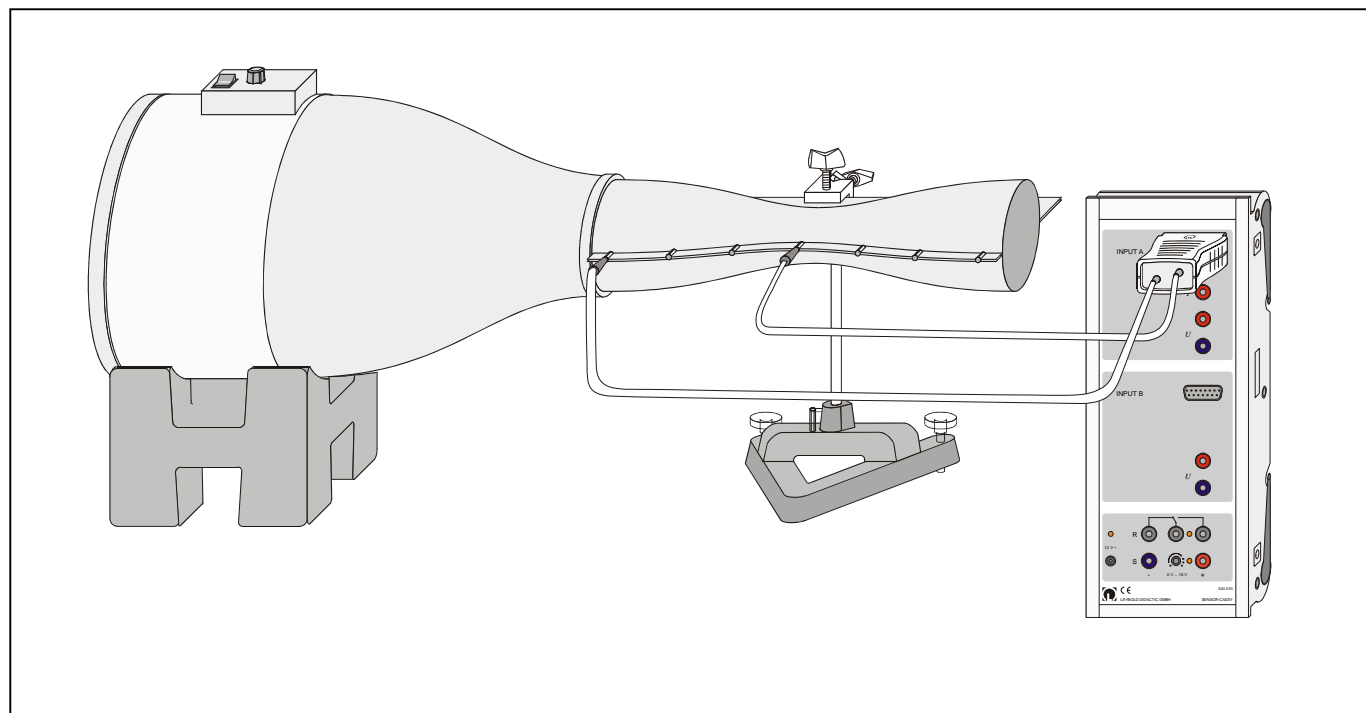
Safety notes

Mind the safety notes in the instruction sheet of the suction and pressure fan.

Before removing the protective grid or the nozzle:


- pull out the mains plug
- wait for at least 30 seconds until the rotor comes to a complete stop.

Fig. 2: Experimental setup with Sensor CASSY schematically.



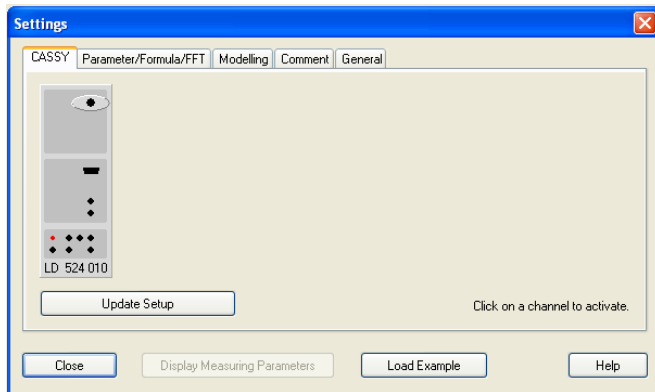
Carrying out the experiment

a) Measuring with Sensor CASSY

- If not yet installed install the software CASSY Lab and open the software.
- Open the window "Settings" using the tool box button  or function key F5 from the top button bar:

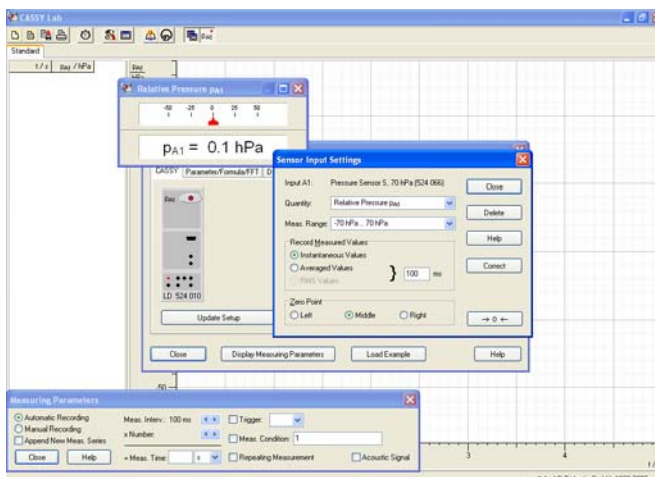


- Sensor CASSY with the connected pressure sensor S at "Input A" should be displayed at the tab "CASSY" if Sensor CASSY is connected via the USB port to the computer.

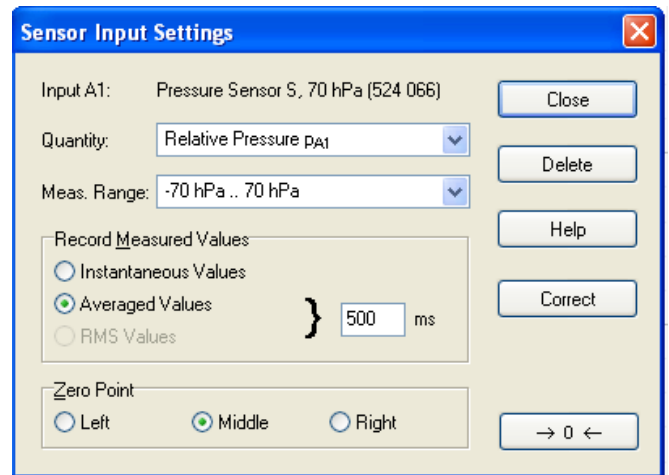


- Activate the connected sensor at Input A by clicking at the pressure sensor S.

Note: Further details about connecting sensors to Sensor CASSY can be found in the manual "CASSY Lab Quick Start".



- In the window "Sensor Input Settings" select "Averaged Values" and enter the value "500 ms".
- Disconnect the pressure sensor S from the Venturi tube.
- Set the pressure sensor by clicking in the window "Sensor Input Settings" at the button "-> 0 <-".




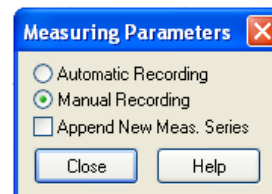
- Connect the pressure sensor S to the Venturi tube.
- Set the blower to its minimum speed (i.e. left limit position of blower control) and only then switch it on.
- Slowly increase speed of the air blower until the air pressure reaches approx. 50 hPa.
- Read off the pressure difference.
- Repeat this measurement procedure several times and calculate the mean average. It is recommended to apply the reset button "-> 0 <-" before each measurement.


Note:

To apply the reset button "-> 0 <-" the window "Sensor Input Settings" have to be invoked if not open. This can be achieved e.g. by clicking the right mouse button on the pressure button in the top menu bar.










Note:

- To obtain the mean value several values can be recorded with CASSY. To do so double click on the button  and select "Manual Measurement".



- To record a value click on the button  or use the function key F9.

b) Measuring with Mobile CASSY

- Switch on the Mobile CASSY with the  key.
- Call the main menu using the  key.
- Select the submenu "Quantities" by using the arrow keys  or  and enter the submenu using the right  key.
- Go to the submenu "p" using the right  key.
- Chose "Compensate Offset" and set the pressure to zero by pushing the right  key.
- Press  key and then the left  key to display the measured pressure value.
- Read off the pressure difference.
- Repeat this measurement procedure several times and calculate the mean average. It is recommended to compensate the offset before each measurement.

Note: For further hints using Mobile CASSY refer to the instruction sheet 524 009.

Measuring example

$$\Delta p = p_0 - p_1 = 50 \text{ hPa}$$

$$\frac{A_1}{A_0} = 0.25$$

Evaluation and results

With

$$\rho_{\text{air}} = 1.26 \frac{\text{kg}}{\text{m}^3}$$

in equation (III) we obtain

$$v_1 = \sqrt{\frac{2 \cdot 50}{1.26 (1 - 0.25^2)}} \frac{\text{m}}{\text{s}} = 9.2 \frac{\text{m}}{\text{s}}$$

With

$$A_1 = \pi \cdot (0.025)^2 \text{ m}^2 = 1.96 \cdot 10^{-3} \frac{\text{m}^2}{\text{s}}$$

follows for the flow rate:

$$v_1 \cdot A_1 = 0.018 \frac{\text{m}^3}{\text{s}} = 18 \frac{\text{litre}}{\text{s}}$$

Supplementary information

The Venturi tube is used to determine the flow rates of liquids or gases in engineering applications.

Fig. 3: Experimental setup with Mobile CASSY schematically.

