Mechanics

Aerodynamics and hydrodynamics
*Introductory experiments in aerodynamics*

Static pressure
in a reduced cross section
− measuring the pressure with a
pressure sensor and CASSY

Objects of the experiment

■ To measure the relative static pressure in a Venturi tube.

■ To know the static pressure in a Venturi tube as a function of the cross-section.

Fig. 1: Venturi tube: cross sectional areas A_0 and A_1,
flow velocities v_0 and v_1.
The numbers 1 to 4 denote the measuring points.
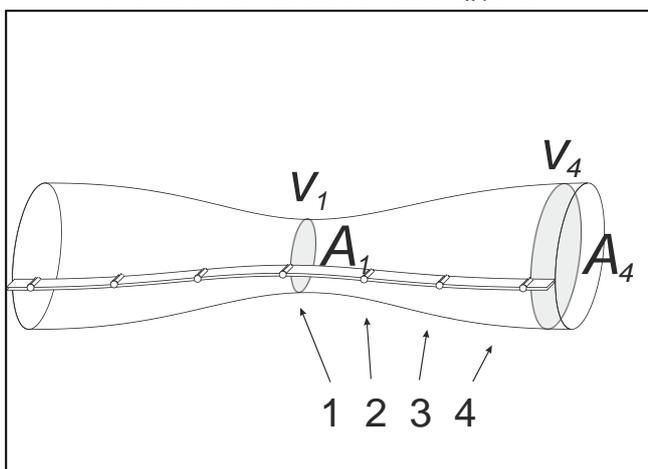
Principles

The total pressure p_{tot} is determined by the static pressure p_s and the dynamic pressure p_d:

$$p_{tot} = p_s + p_d = \text{const.} \tag{I}$$

For non-turbulent flows the Bernoulli equation of ideal fluids leads to:

$$p_1 + \frac{\rho}{2}v_1^2 = p_2 + \frac{\rho}{2}v_2^2 \tag{II}$$

ρ: density of the flow medium

Combined with the continuity equation

$$v_1 \cdot A_1 = v_2 \cdot A_2 \tag{III}$$

v: flow velocity

it approximates the flow of air through a tube with changing cross section A.

In this experiment the relative static pressure Δp is measured at cross sections A_1 to A_4 of a Venturi tube (see Fig. 1).

$$\Delta p = p_s - p_{tot} \tag{IV}$$

Δp: relative static pressure

Remark: The experiment is closely related to P1.8.5.5 where the volume flow through a Venturi tube is determined.

Apparatus

1	Suction and pressure fan	373 041
1	Venturi tube with multimanoscope	373 091
1	Sensor-CASSY 2	524 013
	or	
1	Mobile-CASSY	524 009A
	or	
1	Pocket-CASSY 2 Bluetooth............................	524 018
1	CASSY Lab 2	524 220
1	Pressure sensor S, ±70 hPa	524 066
1	Stand base, V-shaped, small	300 02
1	Stand rod, 25 cm, 12 mm Ø	300 41
1	Leybold multiclamp	301 01

Additionally required: 1 PC with Windows XP or higher

Setup

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

– Plug pressure sensor S, ±70 hPa into Input A of the Sensor-CASSY 2 (Fig. 2) or into the Mobile-CASSY (Fig. 4).

– Connect the 3 mm hose coming out of pressure connection p_1 of pressure sensor S to the 5 mm hose delivered with the Venturi tube.

– Connect the other end of the 5 mm hose to measuring point 1 (middle, see Fig. 1) of the Venturi tube by means of a hose nipple.

– Pressure connection p_2 of the pressure sensor S remains open in order to be able to measure the difference to the atmospheric pressure p_0.

Remark: The left measuring points are not used for didactic reasons. Since air is not an ideal gas, it results in a positive pressure on the left side –due to friction.
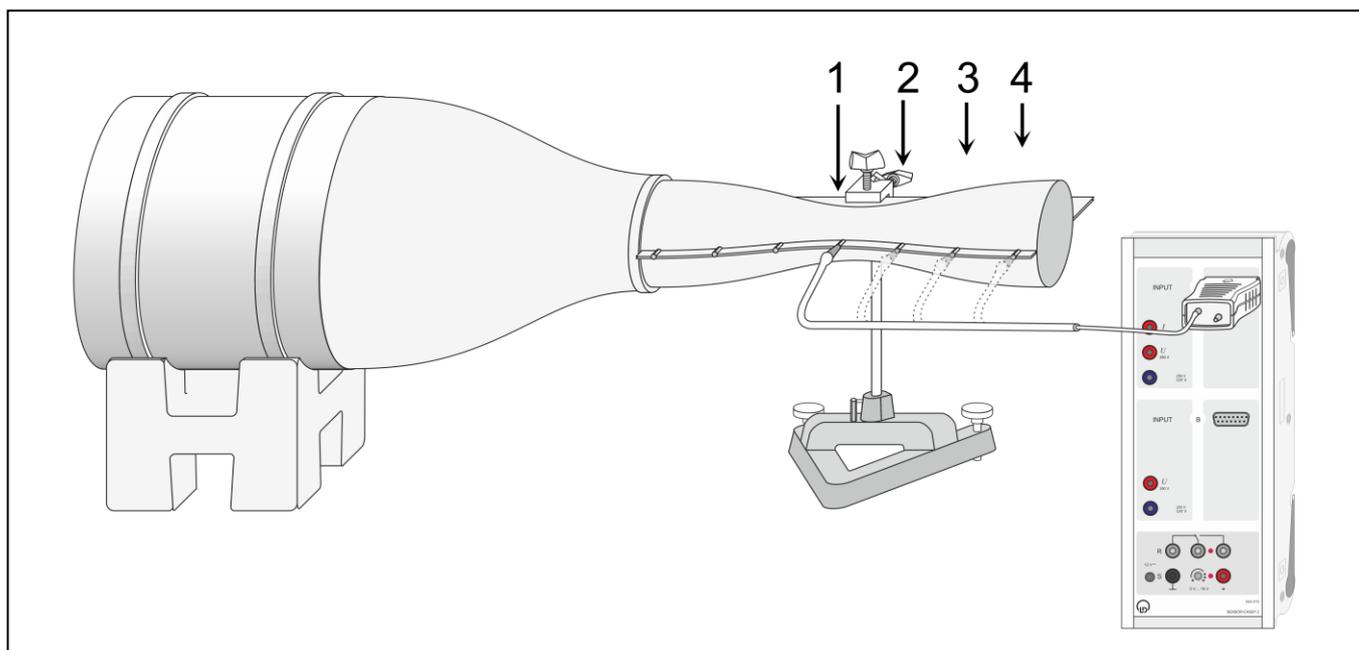
Safety notes

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 and
■ Wait for at least 30 seconds until the suction and pressure fan comes to a complete stop.

Fig. 2: Experimental setup with Sensor-CASSY 2.

Carrying out the experiment

Remark: Repeat one measurement several times for estimating measuring errors.

a) Measuring with Sensor-CASSY 2

– If not yet installed, install the software CASSY Lab 2 and open the software.

– Load the settings in CASSY Lab 2.

– The connected pressure sensor S should be displayed if Sensor-CASSY 2 is connected to the computer via the USB port.

– Activate the connected pressure sensor S at Input A by clicking the pressure sensor S.
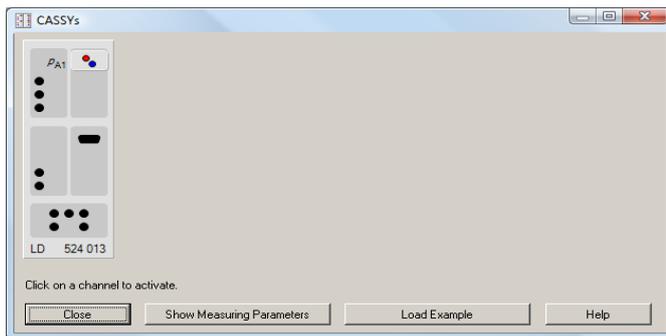
Remark: Further details about connecting sensors to Sensor-CASSY 2 can be found in the CASSY Lab 2 manual or in the web help.

– Disconnect the hose from the Venturi tube.

– Reset the pressure sensor S by clicking $\rightarrow 0 \leftarrow$ in the "*Settings*" pane when "*relative pressure p_1*" is marked.

– Connect the hose to the Venturi tube again.

– Set the suction and pressure fan to its minimum speed (i.e. left limit position of fan control) and only then switch it on.

– Slowly increase speed of the suction and pressure fan until the "*relative pressure p_1*" reaches approx. -2 hPa at measuring point 1 (middle of the Venturi tube).

– Read off the "*relative pressure p_1*" (in this experiment = Δp).

Remark: For the reset button $\rightarrow 0 \leftarrow$ to appear in the ❉ "Settings" pane "relative pressure p_1" has to be marked in the submenu of "CASSYs". It is recommended to press the reset button $\rightarrow 0 \leftarrow$ before each measurement.

– To record the pressure values with CASSY Lab 2 click ⏱ or press the function key F9 when table "*Δp(A) [autom.]*" is displayed.

– Change the measuring points one by one and repeat the last step for cross sections A_2 to A_4.

b) Measuring with Mobile-CASSY

*Remark: To record the pressure values automatically, follow the instructions as described in **a**).*

– Switch on the Mobile-CASSY with the [MENU ⏻] key.

– Open the main menu by pressing the [MENU ⏻] key again.

– 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.

– Choose "Compensate Offset" and set the pressure to zero by pushing the right [•] key.

– Press [MENU ⏻] key and then the left [•] key to display the measured pressure value.

– Set the suction and pressure fan to its minimum speed (i.e. left limit position of fan control) and only then switch it on.

– Slowly increase speed of the suction and pressure fan until the relative static pressure reaches approx. -2 hPa at measuring point 1 (middle of the Venturi tube).

– Read off the relative static pressure.

– Load the settings in CASSY Lab 2 and type in the pressure values in table "*Δp(A) [manu.]*".

– Change the measuring points one by one and read off the relative static pressure for each cross section A_2 to A_4.

Remark: For further hints on using Mobile-CASSY (524 009A) refer to the instruction sheet.

Measuring example

Tab. 1:   Relative static pressure Δp at measuring points 1 to 4 and at cross sections A_1 to A_4 in the Venturi tube (see Fig. 1).

MP	1	2	3	4
$\dfrac{A}{\text{cm}^2}$	19.6	36.3	72.4	78.5
$\dfrac{\Delta p}{\text{hPa}}$	-2.22	-0.33	-0.28	-0.13

Fig. 3:   Relative static pressure Δp as function of cross section A.

Evaluation and result

The relative static pressure decreases in the reduced cross section of the Venturi tube.
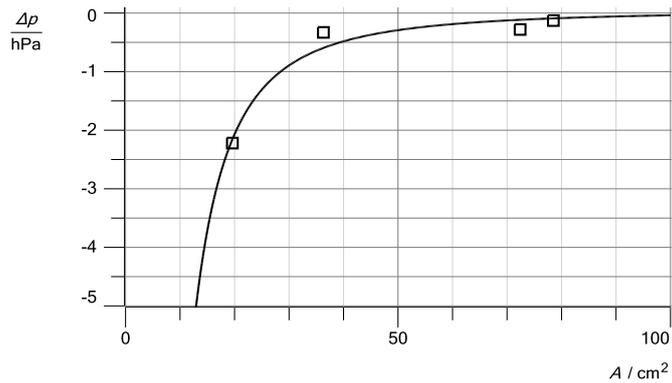
$$\Delta p \propto -\frac{1}{A^2}$$

Fig. 4: Experimental setup with Mobile-CASSY.