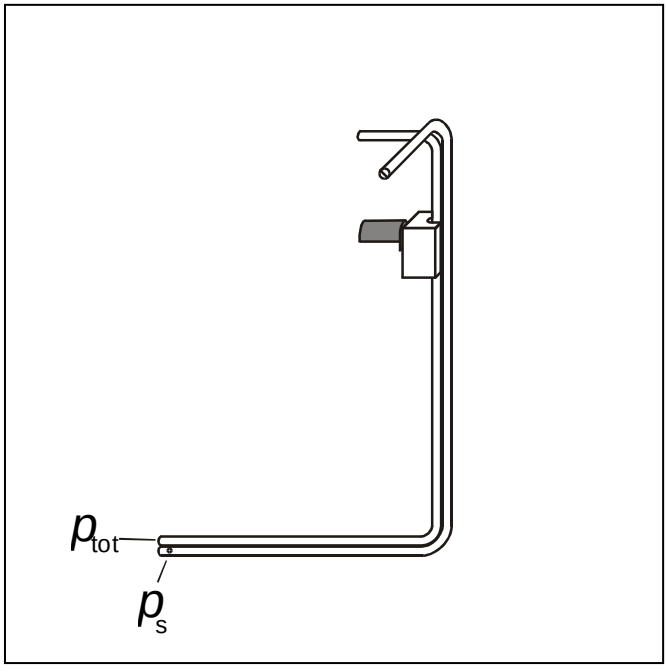
Determining the wind speed with a Prandtl pressure probe – Measuring the pressure with a pressure sensor and CASSY

Objects of the experiment

- To measure the dynamic pressure.
- To determine the wind speed.
- To record pressure profiles from different distances.

Fig. 1: Prandtl pressure probe for measuring the static pressure p_s and the total pressure p_{tot}.



Principles

The Prandtl pressure probe used in this experiment allows measuring the total pressure p_{tot} (head opening positioned against the direction of flow) and the static pressure p_s (head opening positioned across the direction of flow).

The wind speed v can be determined by measuring the pressure difference Δp while the Prandtl pressure probe is pointing against the direction of flow. In this case the pressure difference is identical with the dynamic pressure p_d:

$$\Delta p = p_d = p_{tot} - p_s \qquad \text{(I)}$$

The average wind speed can now be calculated with the following equation:

$$v = \sqrt{\frac{2}{\rho} \cdot p_d} \qquad \text{(II)}$$

Density of the air: $\rho = 1.2 \frac{kg}{m^3}$

Remark: In this experiment the Prandtl pressure probe is used in combination with CASSY and the Pressure sensor S, ±70 hPa (Fig. 2). A precision manometer is used in P1.8.5.3.

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Apparatus

1 Suction and pressure fan 373 041
1 Prandtl pressure probe..... 373 13
1 Pressure sensor S, ±70 hPa 524 066
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

Additionally required: 1 PC with Windows XP or higher

Optional:
1 Stand base, V-shaped, small 300 02
1 Stand rod, 25 cm, 12 mm Ø 300 41
1 Leybold multiclamp 301 01

Setup

– Equip the suction and pressure fan with the small nozzle (Ø 100 mm).
– Position the pressure fan horizontally on the base as shown in Fig. 2.
– Optional: Fix the Prandtl pressure probe 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 (top) of pressure sensor S to the 5 mm hose delivered with the Prandtl pressure probe.
– Connect the other end of the 5 mm hose to the Prandtl pressure probe outlet for p_{tot}.
– In the same way, connect pressure connection p_2 (bottom) of the pressure sensor S to the p_s outlet of the Prandtl pressure probe (see Fig. 1).

Remark: For further hints refer to instruction sheets 373 041, 373 13 and 524 066.

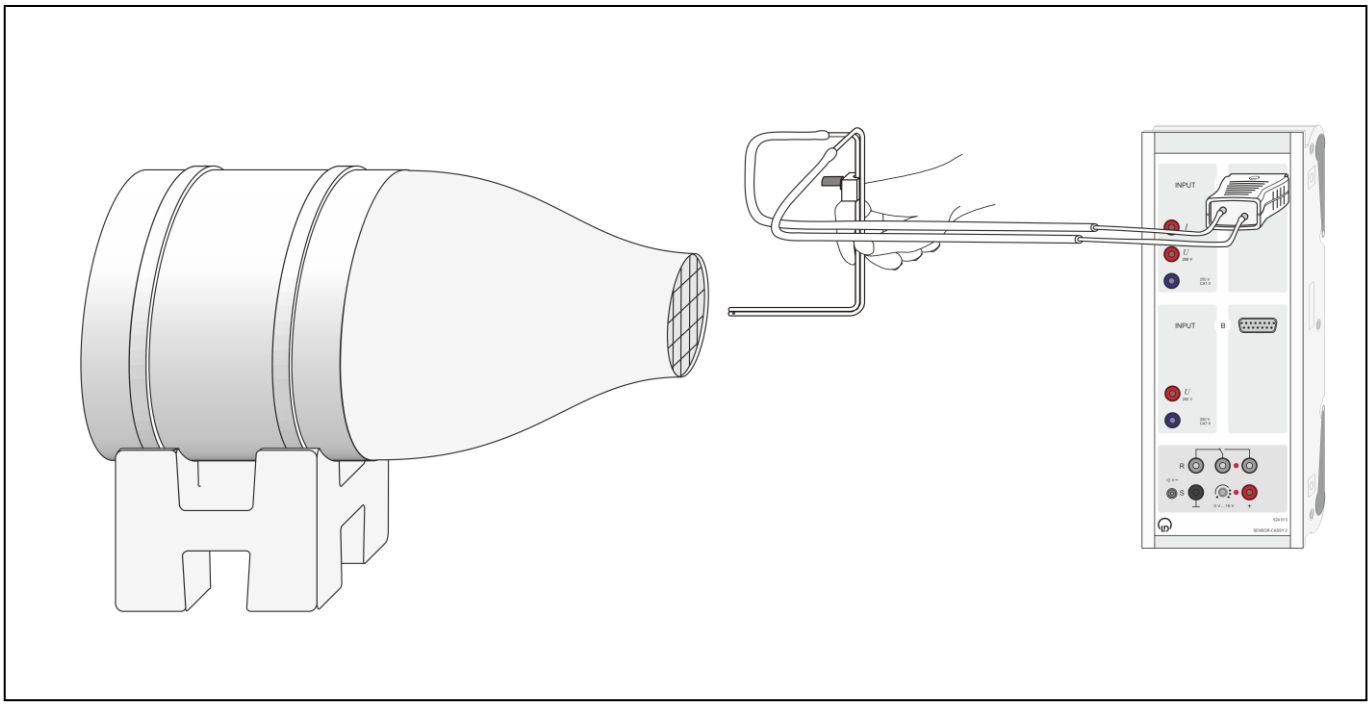
Safety notes

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.

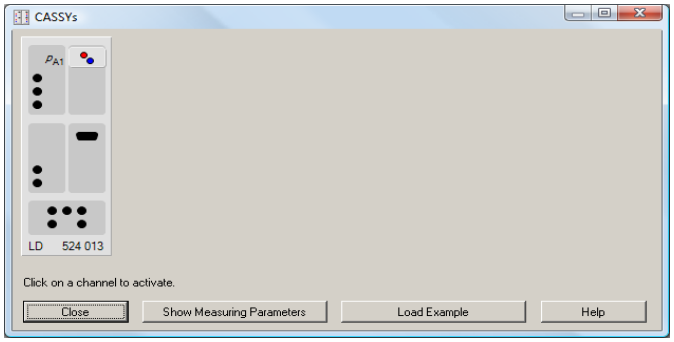


Carrying out the experiment

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 both hoses from the Prandtl pressure probe.
– Reset the pressure sensor S by clicking →0← in the "*Settings*" pane when "*relative pressure* p_{A1}" is marked.
– Connect both hoses to the Prandtl pressure probe 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 the speed of the suction and pressure fan until the "*relative pressure* p_{A1}" reaches approx. 1.5 hPa in a central position (h = 0 cm) in front of the nozzle (distance x = 10 cm.)
– Read off the "*relative pressure* p_1" (in this experiment = $\Delta p = p_d = p_{tot} - p_s$).
– To record the pressure values with CASSY Lab 2 click or press the function key F9 when table *"$p_d(h)$ [autom.]"* is displayed.
– Repeat these steps and read off the dynamic pressure p_d (=Δp) at various heights h and distances x in front of the nozzle. The grid of the nozzle may serve as a guide for the vertical position h.

Remark: For the reset button →0← to appear in the "Settings" pane "relative pressure p_{A1}" has to be marked in the submenu of "CASSYs". It is recommended to press the reset button →0← before each series of measurements.

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 current 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 the speed of the suction and pressure fan until the pressure difference Δp (= p_d) reaches approx. 1.5 hPa in a central position (h = 0 cm) in front of the nozzle (distance x = 10 cm.)
– Load the settings in CASSY Lab 2 and type in the pressure values in table "$p_d(h)$ [manu.]".
– Repeat these steps and read off the dynamic pressure p_d (=Δp) at various heights h and distances x in front of the nozzle. The grid of the nozzle may serve as a guide for the vertical position h.

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

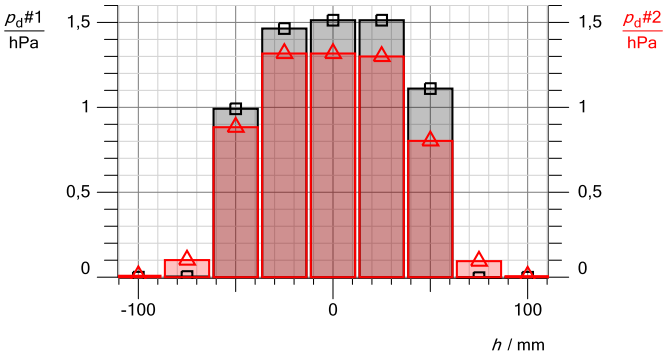
Remark: To record more than the prepared measurement series open "Measurement" in the menu bar and select "Append new Measurement Series". Select table "$p_d(h)$ [manu.]" and click once. Open the "Settings" pane and mark "$p_d(h)$" in the submenu "Displays". Push the button "Add new Curve" and select "p_d#3" in the drop down menu for "y-axis".

Measuring example

Tab. 1: Pressure profile: Dynamic pressure at a distance x from the nozzle. h corresponds to the vertical offset.

$\frac{x}{\text{cm}}$	$\frac{h}{\text{mm}}$	-100	-75	-50	-25	0	25	50	75	100
10	$\frac{p_d}{\text{Pa}}$	0	0	99	146	151	151	111	0	0
40	$\frac{p_d}{\text{Pa}}$	1	10	88	132	132	130	80	9	1

Fig. 3: Pressure profiles at two different distances: $x_{\#1}$ = 10 cm, $x_{\#2}$ = 40 cm.



Results and evaluation

The wind speed v can be obtained with the measuring results of Tab. 1, equation (II) and the density ρ of the flow medium air:

$$\rho = 1.2 \frac{\text{kg}}{\text{m}^3}$$

From this it follows:

Tab. 2: Wind speed v calculated with the pressure values of Tab. 1. h: vertical offset, x: distance from the nozzle.

$\frac{x}{\text{cm}}$	$\frac{h}{\text{mm}}$	-100	-75	-50	-25	0	25	50	75	100
10	$\frac{v}{\frac{\text{m}}{\text{s}}}$	0.0	0.0	12.8	15.6	15.9	15.9	13.6	0.0	0.0
40	$\frac{v}{\frac{\text{m}}{\text{s}}}$	1.3	4.1	12.1	14.8	14.8	14.7	11.5	3.9	1.3

Within the diameter of the nozzle the pressure difference – and therefore the wind speed– varies little. Quadrupling the distance x from 10 cm to 40 cm results in a small decrease of wind speed due to the friction in the air.

In contrast to that, the lateral (h = ±75 cm) measured wind speeds are, at first, increasing with greater distance (x = 40 cm) from the nozzle. The cone of wind slightly fans out.

Fig. 4: Experimental setup with Mobile-CASSY.