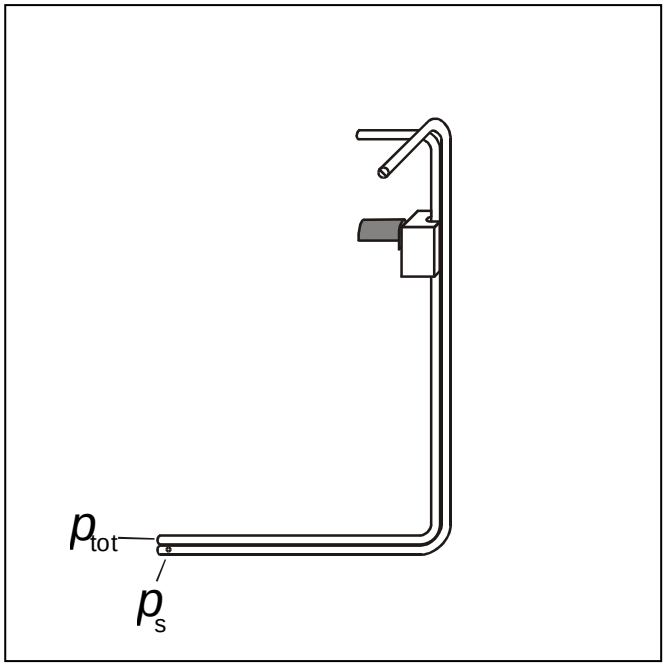
Determining the wind speed with a Prandtl pressure probe – Measuring the pressure with the precision manometer

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 to measure the total pressure p_{tot} (head opening positioned against the direction of flow) and the static pressure p_s (head opening positioned perpendicular to 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 the precision manometer. In P1.8.5.6 the pressure sensor S, ±70 hPa and CASSY are used.

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Apparatus

1 Suction and pressure fan 373 041
1 Prandtl pressure probe 373 13
1 Precision manometer 373 10
1 Stand base, V-shaped, small 300 02
1 Stand rod, 47 cm, 12 mm Ø 300 42

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

Optional:
1 CASSY Lab 2 .....524 220
Additionally required: 1 PC with Windows XP or higher

Setup

– Equip the suction and pressure fan with the small nozzle (100 mm) on the pressure side.
– 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!
– Align the precision manometer exactly horizontal. If needed, refill the reservoir for manometer fluid.
– Connect the hose of the precision manometer to the precision manometer's tube attachment nipple for high-pressure (left). Connect the other end of the hose to the Prandtl pressure probe outlet for p_{tot} (see Fig. 2).
– Connect the hose of the precision manometer to the precision manometer's tube attachment nipple for low-pressure (right). Connect the other end of the hose to the Prandtl pressure probe outlet for p_s (see Fig. 2).

Remark: For further hints refer to instruction sheets 373 10 and 373 13.

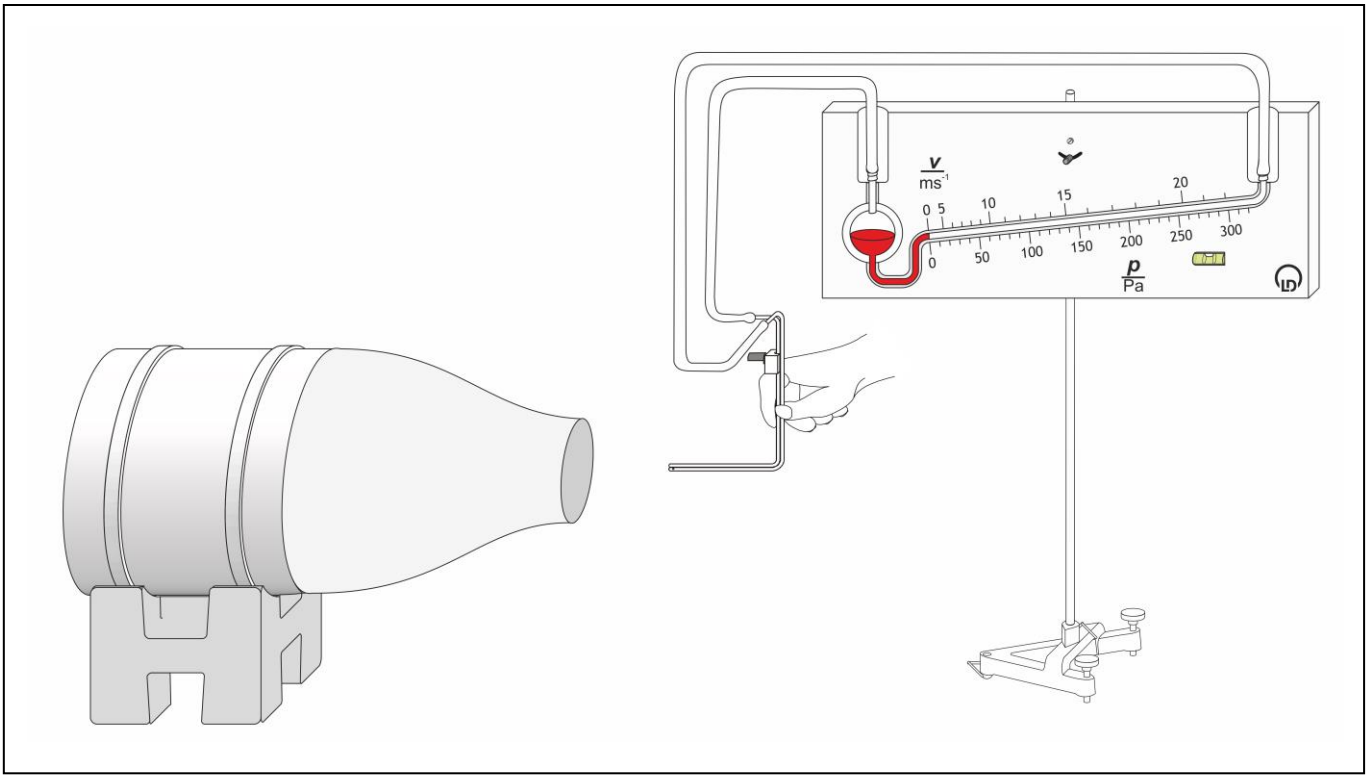
Safety notes

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 the precision manometer.



Carrying out the experiment

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

a) Measuring without CASSY Lab 2

– 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.)
– Read off the pressure values.
– 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.

b) Measuring with CASSY Lab 2

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

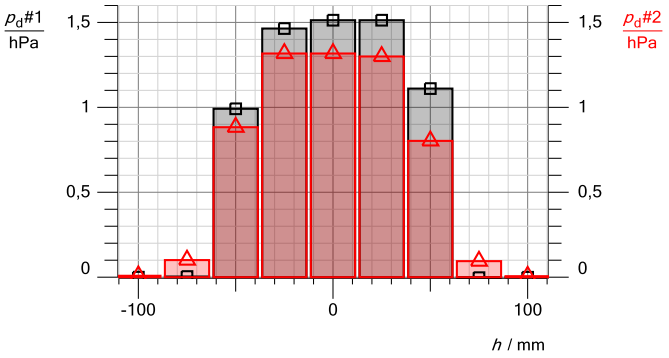
Remark: To record more than the prepared measurement series open "Measurement" in the menu bar and select "Append new Measurement Series". Select table "$p_d(h)$ [manu.]" and click once. Open the "Settings" pane and mark "$p_d(h)$" in the submenu "Displays". Push the button "Add new Curve" and select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