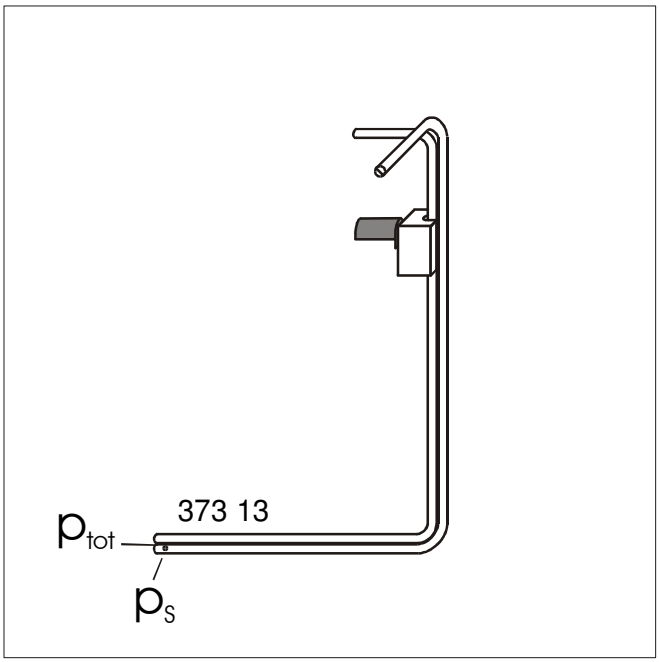
Determining the wind speed with a pressure head sensor – Measuring the pressure with the precision manometer

Objects of the experiment

- To measure the total pressure
- To measure the static pressure
- To determine the wind speed

Fig. 1: Pressure head for measuring the static pressure p_S and total pressure p_{tot}.



Principles

The pressure head used in this experiment allows to measure:

P_{tot}: total pressure
(head opening positioned against the direction of flow)

and

p_S: static pressure
(head opening positioned across the direction of flow)

The pressure head can be used with the fine manometer (Fig. 2).

The wind velocity can be determined from a differential measuring method. The wind velocity can be read off directly from the upper scale of the fine manometer. To obtain more precise results it is recommended to calculate the wind velocity from the dynamic pressure Δp which is read off from the pressure scale.

$$v = \sqrt{\frac{2\,\Delta p}{\rho}} \qquad (I)$$

$\Delta p = P_{tot} - p_S$: dynamic pressure

ρ: density of the air

Bi 1005

LD Didactic GmbH · Leyboldstrasse 1 · D-50354 Huerth / Germany · Phone: (02233) 604-0 · Fax: (02233) 604-222 · e-mail: info@ld-didactic.de

Apparatus

1 Suction and pressure fan 373 04
1 Precision manometer 373 10
1 Pressure head 373 13
1 Stand base, V-shape, 20 cm 300 02
1 Stand rod, 47 cm 300 42
1 Leybold multiclamp 301 01

Setup

Assemble the fan with the nozzle and the precision manometer with the pressure head as shown in Fig 2. For further hints see also instruction sheets 373 04 and 373 10/13.

Carrying out the experiment

- Measure for example the pressure profile with the pressure head in front of the nozzle at a distance x, e.g. approximately 5 cm and 20 cm.
  The grid of the nozzle may serve as a guide for the lateral location s.

Measuring example

Table 1: Dynamic pressure at a distance x from the nozzle (pressure profile). s corresponds to the lateral location.

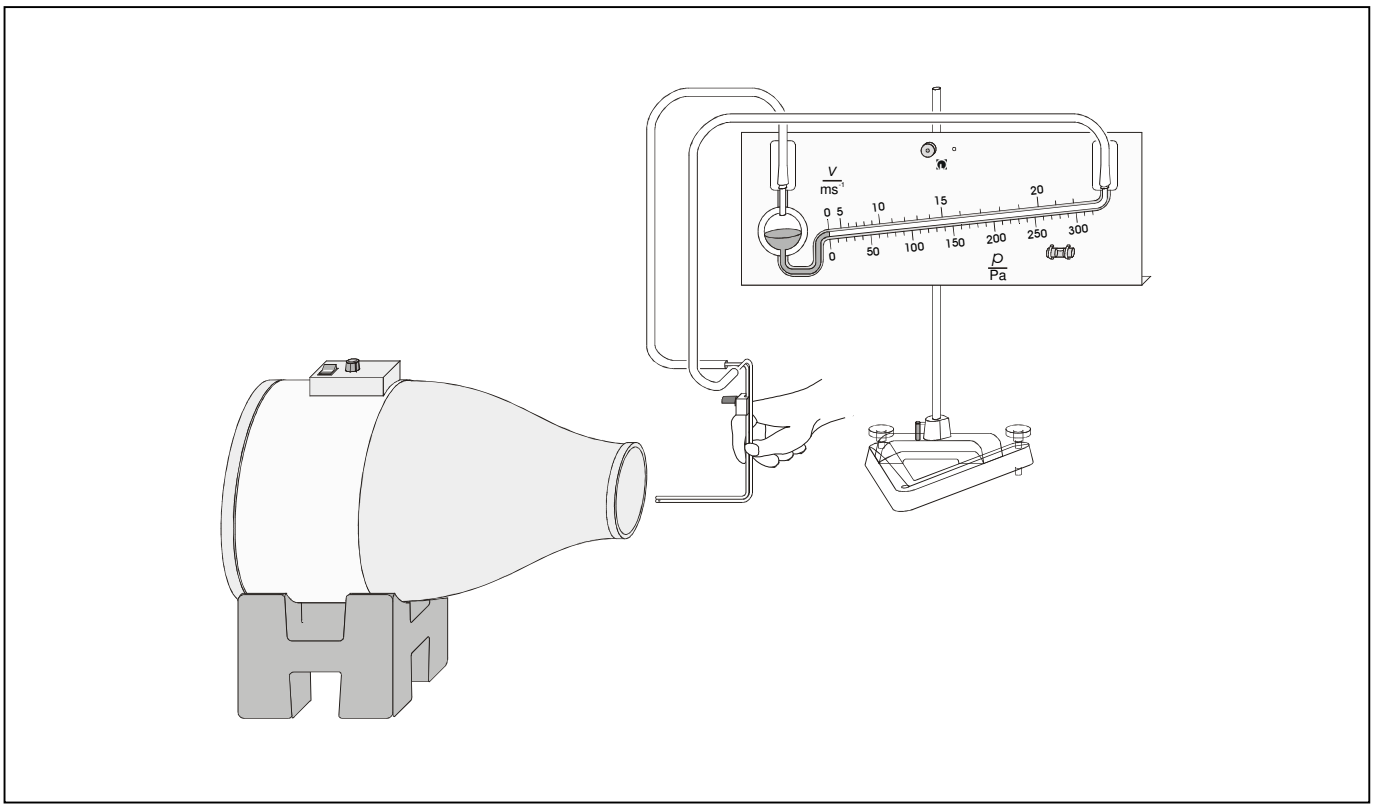
$\frac{x}{cm}$	$\frac{s}{mm}$	-50	-25	0	+25	50
5	$\frac{p}{hPa}$	70	138	150	137	65
20	$\frac{p}{hPa}$	90	146	147	145	80

Evaluation and results

Table 2: Wind speed calculated with equation (I) for the pressure values of table 1. s corresponds to the lateral location.

$\frac{x}{cm}$	$\frac{s}{mm}$	-50	-25	0	+25	50
5	$\frac{v}{m/s}$	10.5	14.8	15.4	14.7	10.2
20	$\frac{v}{m/s}$	12.0	15.2	15.3	15.2	11.3

Fig. 2: Experimental setup for measuring the pressure with the fine manometer schematically.



LD Didactic GmbH · Leyboldstrasse 1 · D-50354 Huerth / Germany · Phone: (02233) 604-0 · Fax: (02233) 604-222 · e-mail: info@ld-didactic.de

Printed in the Federal Republic of Germany
Technical alterations reserved

Verifying the Bernoulli equation – measuring with the precision manometer

Objects of the experiment

- To verify the total pressure remains constant
- To verify that the product of the cross-section and the square root of the dynamic pressure is constant
- To verify the Bernoulli equation

Principles

Bernoulli's law states the relationship between static pressure p and flow velocity v, whereby the following applies to a frictionless, horizontally flowing stream through a stationary flow between two points labeled with indices 0 and 1 (Fig. 1):

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

p_0, p_1: static pressure

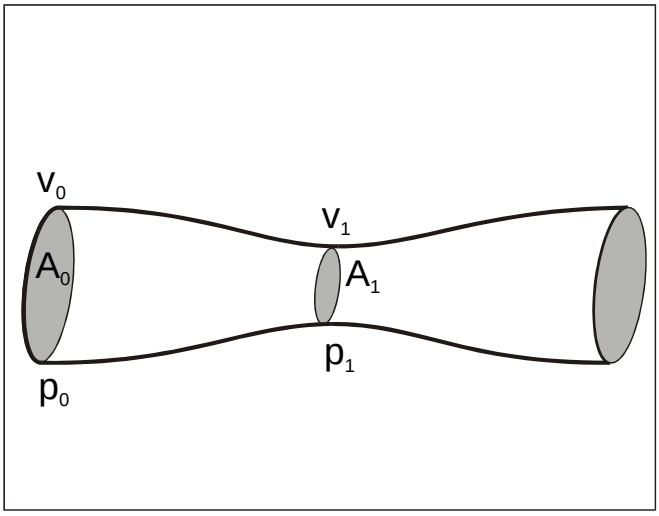
v_0, v_1: flow rate

ρ: density of the flow medium

In particular, equation (I) states that the total pressure p_{tot} has the same value everywhere:

$$p_1 + \frac{\rho}{2} v_1^2 = p_{tot} = \text{const} \qquad \text{(II)}$$

Fig. 1: Bernoulli equation schematically: cross sectional areas A_0 and A_1, flow velocity v_0 and v_1, static pressure p_0 and p_1



In the experiment described here, air flows through a wind tunnel whose cross-section decreases progressively in the direction of flow. Due to the incompressibility of air (which can always be assumed at the given flow rates) the flow velocities v_0 and v_1 at two different locations in the wind tunnel with cross-sectional areas A_0 and A_1 are given by the continuity equation:

$$v_0 A_0 = v_1 A_1 \qquad \text{(continuity equation)} \qquad \text{(III)}$$

The Bernoulli's equation (II) allows to eliminate v_1 in equation (III). By rearranging we obtain:

$$\sqrt{\Delta p} \cdot A_1 = \sqrt{\frac{\rho}{2}} \cdot v_0 \cdot A_0 \qquad \text{(IV)}$$

with

$$\Delta p = p_{tot} - p_1 \qquad \text{(V)}$$

LD Didactic GmbH · Leyboldstrasse 1 · D-50354 Huerth / Germany · Phone: (02233) 604-0 · Fax: (02233) 604-222 · e-mail: info@ld-didactic.de

Apparatus

1 Wind tunnel 373 12
1 Suction and pressure fan 373 04
1 Pressure head 373 13
1 Measurement trolley 373 075
1 Precision manometer 373 10
1 Leybold multiclamp 301 01

The dynamic pressure Δp is determined by measuring the pressure difference. The cross-sections are stated at the various measuring points in the wind tunnel.

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.

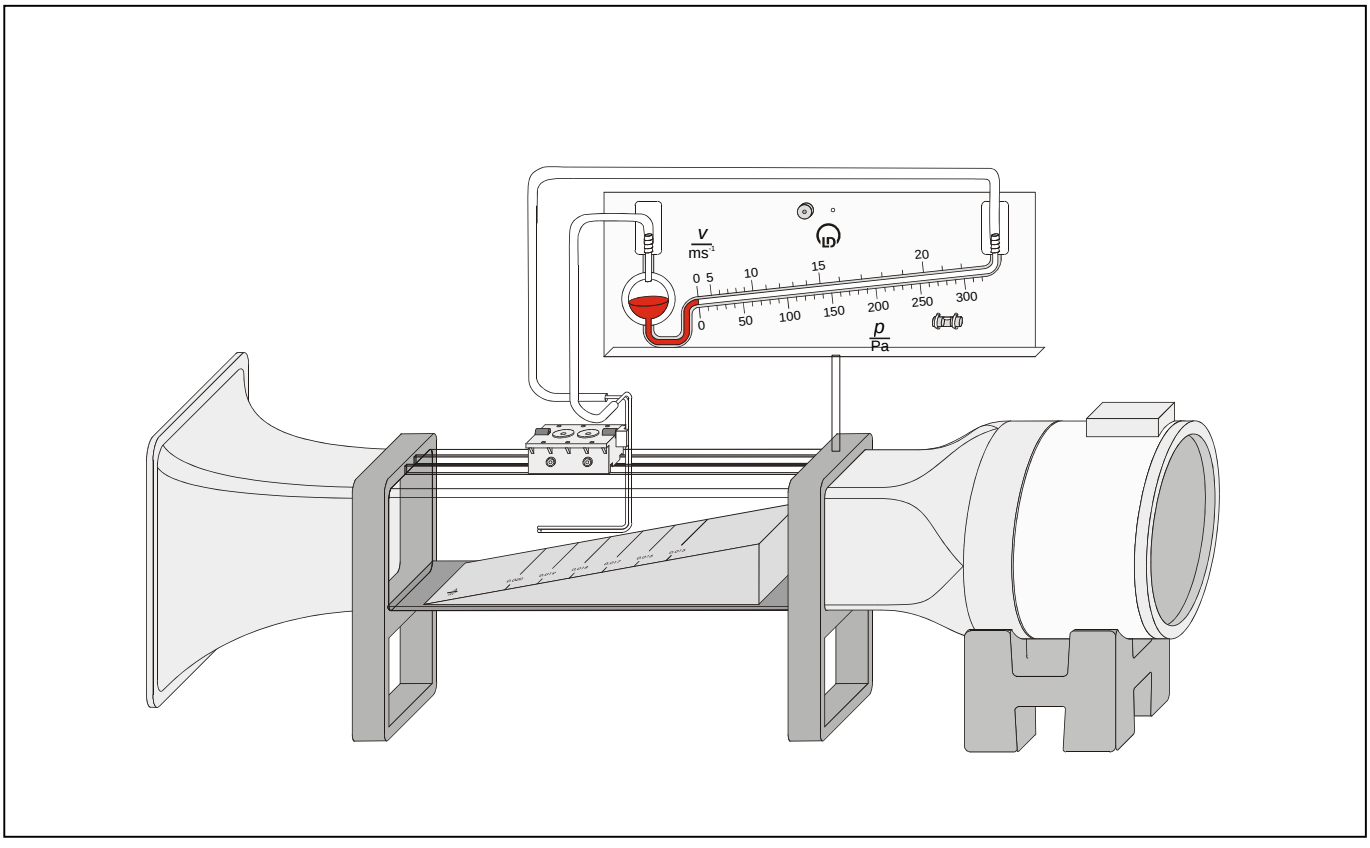
Mind the safety note in the instruction sheet of the precision manometer 373 10

Setup

Assemble the wind tunnel and the fan as shown in Fig 2. Insert in the fan into the outlet nozzle so that the air is drawn through the wind tunnel during the experiment. Ensure a clearance of approx. 1 m in front of the suction nozzle and behind the fan so that the air can be drawn into the wind tunnel without any turbulence.

- Mount the smoothing screen on the inlet.
- With the aid of the four screws secure the Bernoulli ramp underneath the plexiglass canopy so that the ramp height increases in the direction of flow.
- Mount the sealing strip (included in the equipment for the wind tunnel) on the sliding rails.
- Guide the pressure probe carefully bent section first, through the foam rubber seal of the sealing strip and secure the trolley.
- Push the probe down fully to the stop so that it reaches a position approx. 2 cm higher than the highest point of the ramp.
- Mount the precision manometer to the wind channel as shown in Fig. 2.
- Connect the total pressure probe by means of a hose to the nipple (left side) of the precision manometer.
- Connect the static pressure probe by means of a hose to the nipple (right side) of the precision manometer.

Fig. 2: Experimental setup with precision manometer schematically.



LD Didactic GmbH · Leyboldstrasse 1 · D-50354 Huerth / Germany · Phone: (02233) 604-0 · Fax: (02233) 604-222 · e-mail: info@ld-didactic.de

Printed in the Federal Republic of Germany
Technical alterations reserved

Carrying out the experiment

- Place the measurement trolley at with end of the pressure head at the position F.
- Read off the pressure difference from the precision manometer.
- Repeat the measurement for the positions “A” to “E”.
- Repeat this measurement procedure several times and calculate the mean average.

Note: The experiment may also be performed for different speeds of the fan.

Measuring example

Table 1: Pressure difference Δp (mean average over 3 measurement series) at the positions A to F.

position	$\frac{A}{m^2}$	$\frac{\Delta p}{Pa}$
A	0.020	47
B	0.019	51
C	0.018	57
D	0.017	63
E	0.016	68
F	0.015	75

Evaluation and results

Table 2: Flow velocity v and volume flow J evaluated from the pressure difference Δp of table 1 at the positions A to F.

position	$\frac{v}{m/s}$	$\frac{J}{m^3/s}$
A	8.74	0.175
B	9.02	0.171
C	9.63	0.173
D	10.12	0.172
E	10.52	0.168
F	11.04	0.162

The flow velocity $v = \sqrt{\frac{2 \cdot \Delta p}{\rho}}$ increases with decreasing cross-section A.

The volume flow J = v·A is constant over the entire decreasing cross-sectional area (Fig. 3). Thus the predictions based on the Bernoulli’s equation (I) are verified quantitatively.

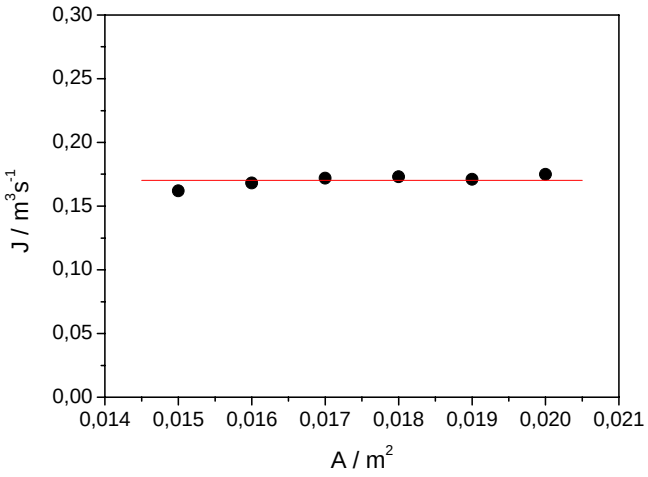


Fig. 3: Volume flow J as a function of the cross section A. The solid lines correspond to the mean average in accordance with continuity equation (III).

Supplementary information

Additionally, the total pressure can be measured along the progressively decreasing cross section. Therefore the hose is connected to the total pressure head only (see instruction sheet of precision manometer 373 10).

The result of the measuring the total pressure is depicted in Fig. 4. The measurement verifies that the total pressure remains constant over the entire measurement section.

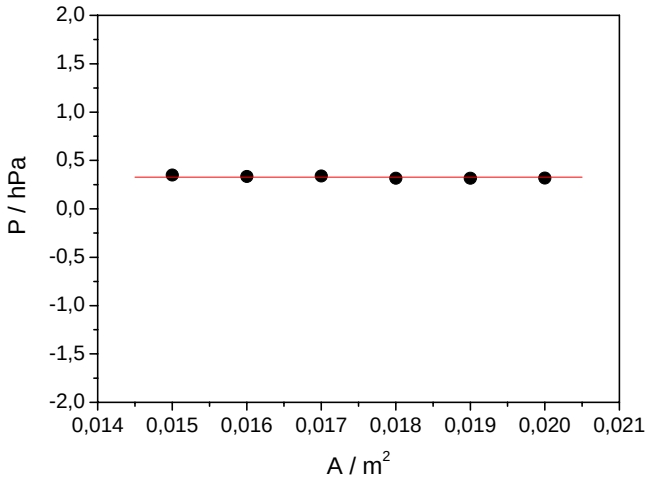


Fig. 4: Total pressure as function of the cross section A. The solid line corresponds to the mean value.

Additionally the static pressure can be investigated. An example measurement is given in supplementary information of leaflet P1.8.7.4.

LD Didactic GmbH · Leyboldstrasse 1 · D-50354 Huerth / Germany · Phone: (02233) 604-0 · Fax: (02233) 604-222 · e-mail: info@ld-didactic.de