

## Determining the volume flow with a Venturi tube

– Measuring the pressure with a precision manometer

### Objects of the experiment

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

### Principles

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

$$p_{s0} + \frac{\rho}{2}v_0^2 = p_{s1} + \frac{\rho}{2}v_1^2 \quad (I)$$

$\rho$ : 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 (in the middle). The cross-sectional areas  $A_1$  and  $A_0$  are therefore in a ratio of 1:4. We will measure the static pressure  $p_{s0}$  at the entrance of the Venturi tube and the static pressure  $p_{s1}$  in the middle of the Venturi tube.

Due to the incompressibility of air, which we can assume for the flow velocities occurring in this experiment, the continuity equation applies to the flow velocities  $v_0$  and  $v_1$  (see Fig. 1):

$$v_0 \cdot A_0 = v_1 \cdot A_1 \quad (II)$$

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

Rearranging equation (I) results in:

$$p_{s1} - p_{s0} = \frac{\rho}{2}(v_0^2 - v_1^2) \quad (III)$$

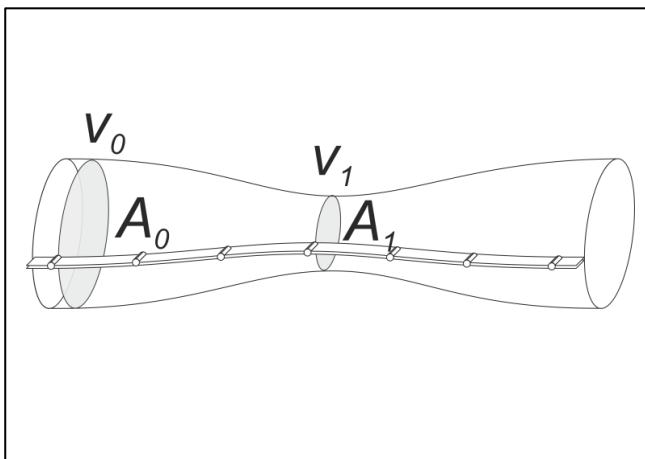
Replacing the flow velocity  $v_0$  in equation (III) by a term derived from the continuity equation (II) leads to:

$$v_1 = \sqrt{\frac{2}{\rho} \cdot \frac{p_{s1} - p_{s0}}{\left(\frac{A_1}{A_0}\right)^2 - 1}} \quad (IV)$$

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

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

Fig. 1: Venturi tube: cross-sectional area  $A_0$  and  $A_1$ , flow velocities  $v_0$  and  $v_1$ .



**Apparatus**

1 Suction and pressure fan.....	373 041
1 Venturi tube with multimanoscope.....	373 091
1 Precision manometer.....	373 10
2 Stand base, V-shaped, small.....	300 02
1 Stand rod, 25 cm, 12 mm Ø.....	300 41
1 Stand rod, 47 cm, 12 mm Ø.....	300 42
1 Leybold multiclamp.....	301 01

*Optional:*

1 CASSY Lab 2 .....	524 220
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*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 on the pressure side. Position the pressure fan 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.

- 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 hose nipple and plug it into measuring point 0 of the Venturi tube (see Fig. 2 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 hose nipple and plug it into measuring point 1 of the Venturi tube (see Fig. 2).

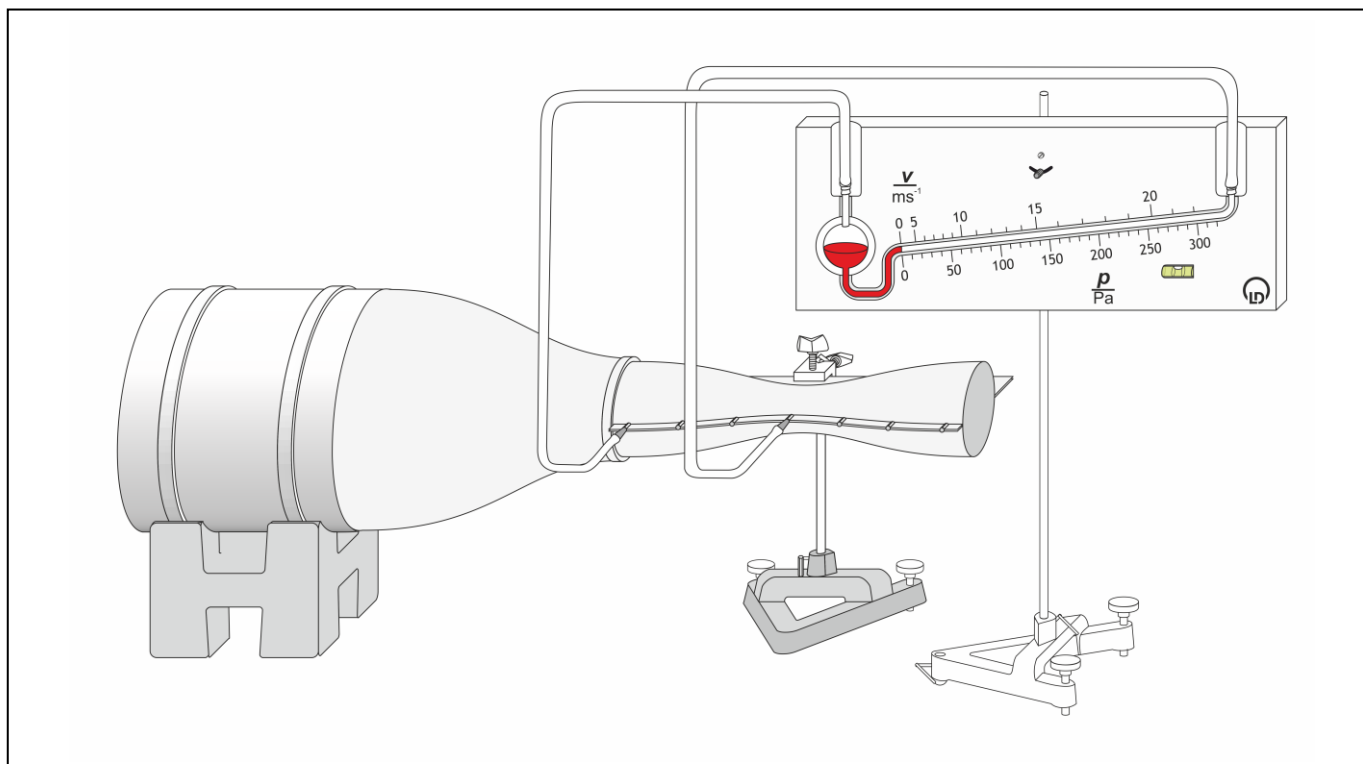
**Safety notes**

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 static pressure difference  $\Delta p (= p_{s1} - p_{s0})$  between measuring points 0 and 1 reaches approx. -140 Pa.

*Remark: Since the static pressure  $p_s$  decreases from measuring point 0 to 1 the static pressure difference  $\Delta p$  is negative.*

- Read off the static pressure difference  $\Delta p$  and note the pressure value in a table.

### b) Measuring with CASSY Lab 2

- If not yet installed, install the software CASSY Lab 2 and open the software.
- 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 static pressure difference  $\Delta p (= p_{s1} - p_{s0})$  between measuring points 0 and 1 reaches approx. -140 Pa.

*Remark: Since the static pressure  $p_s$  decreases from measuring point 0 to 1 the static pressure difference  $\Delta p$  is negative.*

- Read off the static pressure difference  $\Delta p$ .
- [Load the settings in CASSY Lab 2](#) and type the pressure value in table " $\Delta p(n)$  [manu.]".

**Measuring example**

$$\Delta p = p_{s1} - p_{s0} = -1.4 \text{ hPa} = -140 \text{ Pa}$$

$$\frac{A_1}{A_0} = \frac{19.6 \text{ cm}^2}{78.5 \text{ cm}^2} = 0.25$$

Tab 1: Five measurements of the difference in static pressure  $\Delta p$  between measuring points 0 and 1 of the Venturi tube (see Fig. 1) at constant overall wind speed.

n	1	2	3	4	5
$\frac{\Delta p}{\text{Pa}}$	-135	-143	-147	-136	-141
$\overline{\frac{\Delta p}{\text{Pa}}}$	-140				

**Evaluation and results**

With the measuring results, equation (IV) and the density  $\rho$  of the flow medium air

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

we obtain the flow velocity at measuring point 1:

$$v_1 = \sqrt{\frac{2}{\rho} \cdot \frac{p_{s1} - p_{s0}}{\left(\frac{A_1}{A_0}\right)^2 - 1}} = \sqrt{\frac{2}{1.2 \frac{\text{kg}}{\text{m}^3}} \cdot \frac{-140 \text{ Pa}}{(0.25)^2 - 1}} = 15.8 \frac{\text{m}}{\text{s}}$$

With the measuring result

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

we obtain the flow rate:

$$v_1 \cdot A_1 = 0.031 \frac{\text{m}^3}{\text{s}} = 31 \frac{\text{l}}{\text{s}}$$