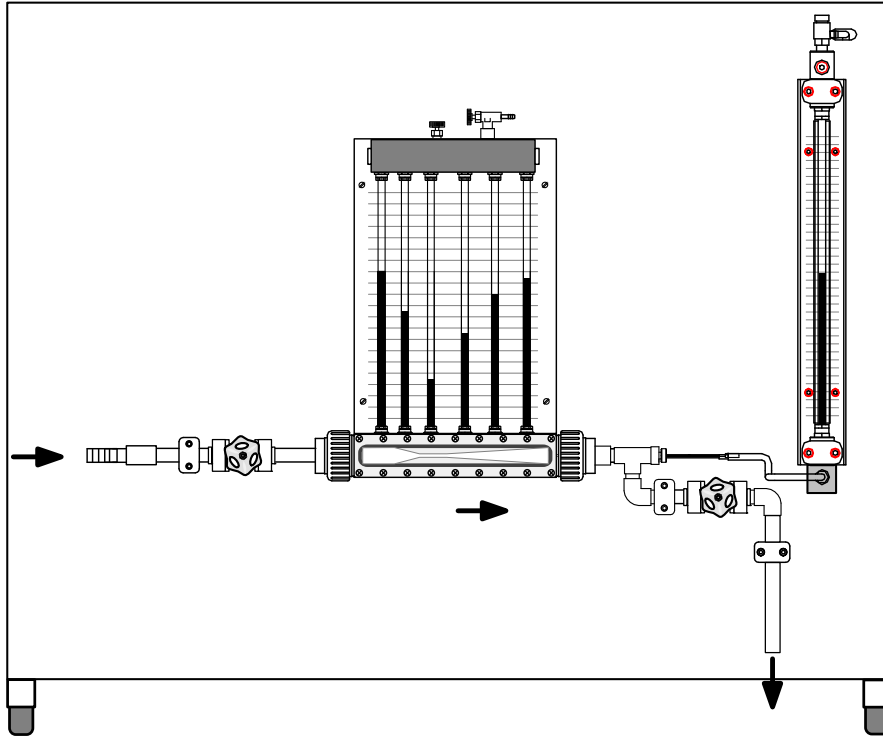


## **Experiment Instructions**

HM 150.07    Bernoulli's Principle  
Demonstrator



## Experiment Instructions

**This manual must be kept by the unit.**

**Before operating the unit:**

- Read this manual.**
- All participants must be instructed on handling of the unit and, where appropriate, on the necessary safety precautions.**

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**HM 150.07** ***BERNOULLI'S PRINCIPLE DEMONSTRATOR*****1 Introduction**

The **HM 150.07** is used to investigate Bernoulli's law. The measurement object is a Venturi nozzle with six pressure measurement points.

The six static pressures are displayed on a board with six water pressure gauges.

The overall pressure can also be measured at various locations in the Venturi nozzle and indicated on a second water pressure gauge. Measurement is by way of a probe which can be moved axially with respect to the Venturi nozzle. The probe is sealed by way of a compression gland.

Water is supplied either from the **HM 150** Fluid Mechanics Basic Module or from the laboratory mains.

The **HM 150** enables a closed water circuit to be constructed.

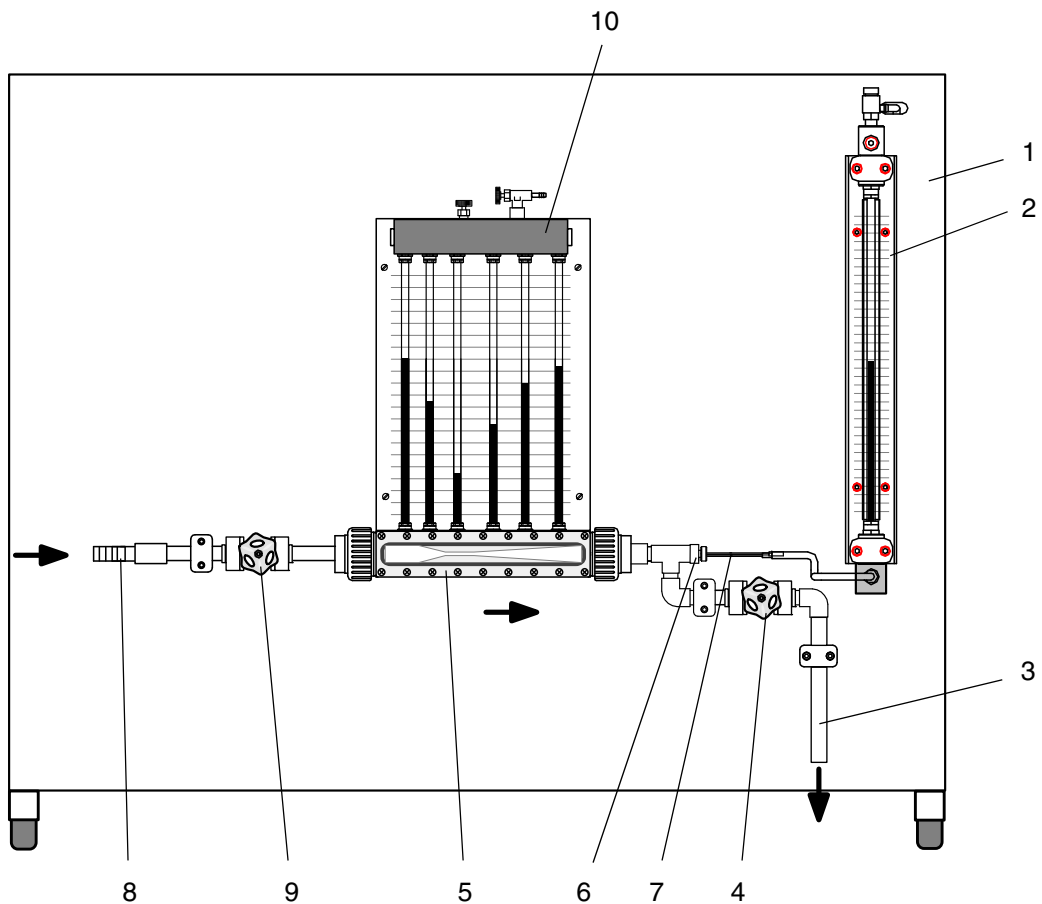
Possible experiments:

- Demonstration of Bernoulli's law
- Pressure measurements along Venturi nozzle
- Determination of flow rate factor  $K$

**1.1 Intended Use**

The unit is to be used only for teaching purposes.

## 2 Unit Description



1	Assembly board
2	Single water pressure gauge
3	Discharge pipe
4	Outlet valve
5	Venturi nozzle with six measurement points
6	Compression gland
7	Probe for measuring overall pressure (can be moved axially)
8	Hose connection, water supply
9	Inlet valve
10	6-fold water pressure gauge (pressure distribution in the Venturi nozzle)

Fig. 2.1 Design of the assembly board

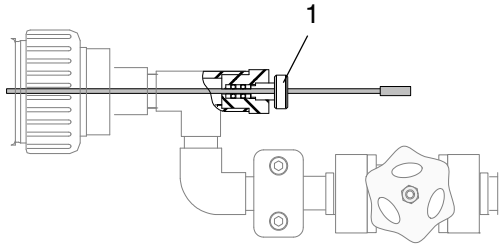
**HM 150.07****BERNOULLI'S PRINCIPLE DEMONSTRATOR****3 Experiments****3.1 Performance of Experiment**

Abb. 3.1

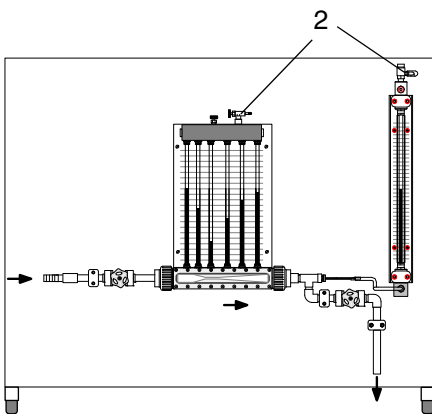


Abb. 3.2

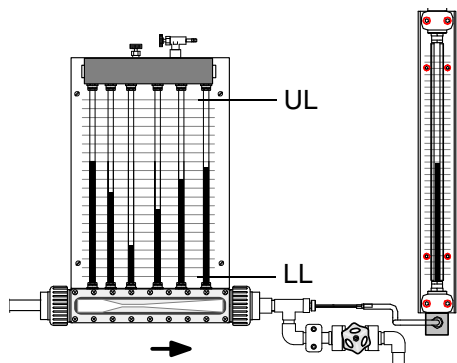


Abb. 3.3

Arrange the experimentation set-up on the **HM 150** such that the discharge routes the water into the channel

- Make hose connection between **HM 150** and **HM 150.07**
- Open discharge of **HM 150**
- Set cap nut (1) of probe compression gland such that slight resistance is felt on moving probe
- Open inlet and outlet valves
- Switch on pump and slowly open main cock of **HM 150**
- Open vent valves (2) on water pressure gauges
- Carefully close outlet valve until pressure gauges are flushed
- By simultaneously setting inlet and outlet valve, regulate water level in pressure gauges such that neither upper nor lower range limit (UL, LL) is overshoot or undershot
- Record pressures at all measurement points. Then move overall pressure probe to corresponding measurement level and note down overall pressure
- Determine volumetric flow rate. To do so, use stopwatch to establish time  $t$  required for raising the level in the tank of the **HM 150** from 20l to 30l

**HM 150.07*****BERNOULLI'S PRINCIPLE DEMONSTRATOR*****NOTICE**

The experimental set-up should be arranged absolutely plane to avoid falsification of measurement results (use of spirit level recommended).

**NOTICE**

For taking pressure measurements, the tank of the **HM 150** must be empty and the outlet valve open, as otherwise the delivery head of the pump will change as the water level in the tank increases. This results in fluctuating pressure conditions. A constant pump delivery pressure is important with low flow rates to prevent biasing of the measurement results.

**NOTICE**

Both valves must be reset whenever the flow changes to ensure that the measured pressures are within the display ranges.

### 3.2 Assessment of Experiment

The measured values are to be compared to Bernoulli's equation.

Bernoulli's equation for constant head  $h$ :

$$\frac{p_1}{\rho} + \frac{w_1^2}{2} = \frac{p_2}{\rho} + \frac{w_2^2}{2} = \text{const.} \quad (3.1)$$

Allowance for friction losses and conversion of the pressures  $p_1$  and  $p_2$  into static pressure heads  $h_1$  and  $h_2$  yields:

$$h_1 + \frac{w_1^2}{2g} = h_2 + \frac{w_2^2}{2g} + h_v \quad (3.2)$$

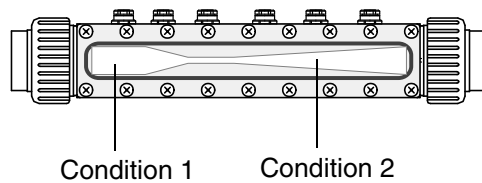


Fig. 3.4

$p_1$ : Pressure at cross-section  $A_1$

$h_1$ : Pressure head at cross-section  $A_1$

$w_1$ : Flow velocity at cross-section  $A_1$

$p_2$ : Pressure at cross-section  $A_2$

$h_2$ : Pressure head at cross-section  $A_2$

$w_2$ : Flow velocity at cross-section  $A_2$

$\rho$ : Density of medium = constant for incompressible fluids such as water

$h_v$ : Pressure loss head



The mass flow is constant in closed systems.

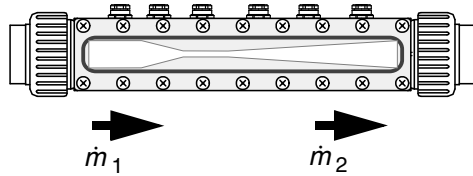


Fig. 3.5

$$\dot{m}_1 = \dot{m}_2 \quad (3.3)$$

Given

$$\dot{m} = \dot{V} \cdot \rho \quad (3.4)$$

$$\dot{V}_1 \cdot \rho = \dot{V}_2 \cdot \rho \quad (3.5)$$

$$\dot{V}_1 = \dot{V}_2 \quad (3.6)$$

Given

$$\dot{V} = A \cdot w \quad (3.7)$$

$$A_1 \cdot w_1 = A_2 \cdot w_2 = \dot{V} = \text{const.} \quad (3.8)$$

### 3.2.1 Velocity Profile in the Venturi Nozzle

The Venturi nozzle used has six measurement points.

The table below shows the standardised reference velocity  $\bar{w}$ . This parameter is derived from the geometry of the Venturi nozzle.

$$\bar{w}_i = \frac{A_1}{A_i} \quad (3.9)$$

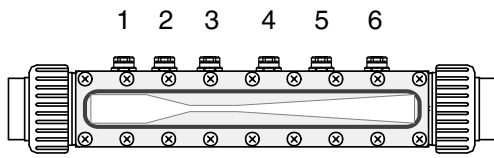


Fig. 3.6

Point $i$	$A$ in $\text{m}^2 \cdot 10^{-4}$	Reference velocity in $\bar{w}$
1	3,38	1,00
2	2,33	1,45
3	0,846	4,00
4	1,70	2,00
5	2,55	1,33
6	3,38	1,00

Tab. 3.1

Multiplying the reference velocity values with a starting value, the student can calculate the theoretical velocity values  $w_{calc}$  at the six measuring points of the Venturi nozzle.

At constant flow rate, the starting value for calculating the theoretical velocity is found as:

$$w_1 = \frac{\dot{V}}{A_1} \quad (3.10)$$

**HM 150.07****BERNOULLI'S PRINCIPLE DEMONSTRATOR**

The results for the various flow rates can be found in the following table.

<i>i</i>	<i>h</i> <sub>1</sub> in mmWS	<i>h</i> <sub>2</sub> in mmWS	<i>h</i> <sub>3</sub> in mmWS	<i>h</i> <sub>4</sub> in mmWS	<i>h</i> <sub>5</sub> in mmWS	<i>h</i> <sub>6</sub> in mmWS	<i>t</i> for 10l	$\dot{V}$ in l/s
<i>h</i> <sub>stat.</sub>	270	260	66	167	187	195	67s	0,15
<i>h</i> <sub>total</sub>	290	282	257	236	231	230		
<i>h</i> <sub>dyn.</sub>	20	22	191	69	44	35		
<i>w</i> <sub>meas.</sub>	0,63	0,66	1,94	1,17	0,93	0,63		
<i>w</i> <sub>calc.</sub>	0,44	0,64	1,76	0,88	0,59	0,44		
<i>h</i> <sub>stat.</sub>	194	186	66	124	138	143	83s	0,12
<i>h</i> <sub>total</sub>	200	197	164	162	159	159		
<i>h</i> <sub>dyn.</sub>	6	11	98	38	21	16		
<i>w</i> <sub>meas.</sub>	0,11	0,15	0,44	0,27	0,20	0,18		
<i>w</i> <sub>calc.</sub>	0,36	0,52	1,44	0,72	0,48	0,36		

Tab. 3.2

The table makes allowance for the following relationships.

Calculation of dynamic pressure head:

$$h_{dyn.} = h_{total} - h_{stat.} \quad (3.11)$$

The velocity  $w_{meas}$  was calculated from the dynamic pressure:

$$w_{meas.} = \sqrt{2 \cdot g \cdot h_{dyn.}} \quad (3.12)$$

The graph below illustrates the measured and calculated velocity profile along the Venturi nozzle at a flow rate of 0,15 l/s.

The deviations can be attributed to inexact measurements.

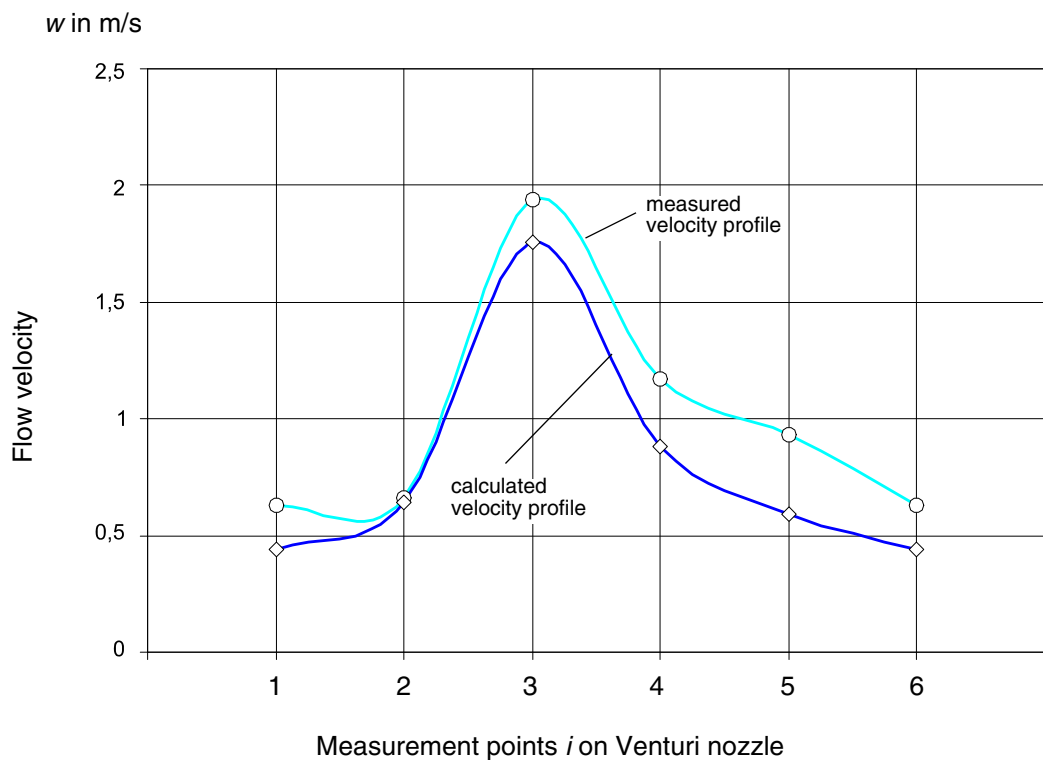


Fig. 3.7 Flow velocity in the Venturi nozzle

### 3.2.2 Pressure Distribution Venturi Nozzle

The pressure changes in the Venturi nozzle can be represented in a graph directly:

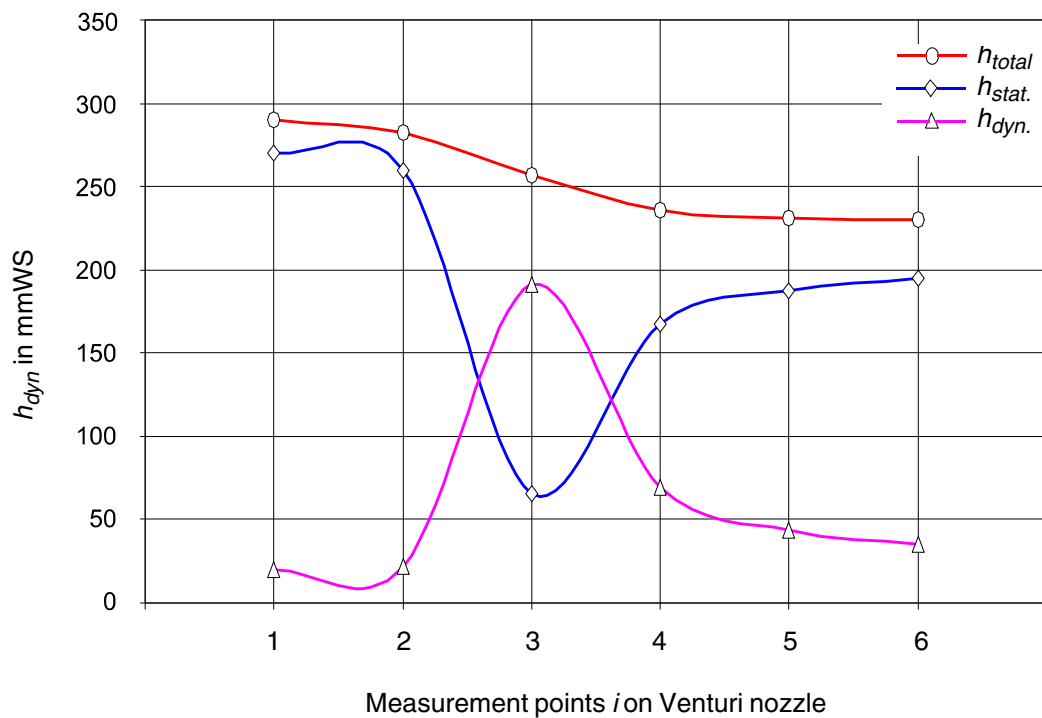


Fig. 3.8 Pressure distribution Venturi nozzle

The graph shows, that the equation

$$h_{dyn.} = h_{total} - h_{stat.} \quad (3.13)$$

is fulfilled at every point in the Venturi nozzle.

Furthermore, it becomes clear, that there is a slight overall pressure loss ( $h_{total}$ ) in the Venturi nozzle.

### 3.2.3 Determination of Flow Rate Factor

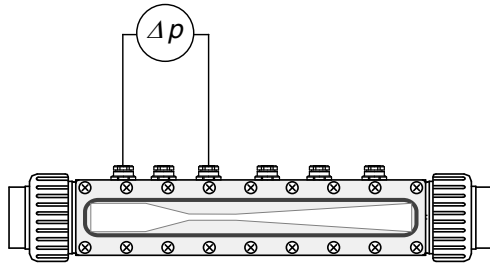


Fig. 3.9

A Venturi nozzle can be used for flow rate measurements. In comparison with orifice or nozzle, there is a far more smaller pressure loss during measurements of flow rate. The pressure loss  $\Delta p$  between largest and smallest diameter of the tube is used as measure for the flow rate:

$$\dot{V} = K \cdot \sqrt{\Delta p} \quad (3.14)$$

The flow rate factor  $K$  is generally made available for the user by the manufacturer of a Venturi nozzle. If the flow rate factor is unknown, it can be determined from the pressure loss  $\Delta p$ :

$$K = \frac{\dot{V}}{\sqrt{\Delta p}} \quad (3.15)$$

The following table shows the pressure loss for various flow rates as well as the flow rate factor  $K$ .

	$\dot{V} = 0,15 \text{ l/s}$		$\dot{V} = 0,12 \text{ l/s}$		$\dot{V} = 0,08 \text{ l/s}$	
Measurement points $i$	$\Delta p$ in mmWS	$K$ in $\frac{\text{ltr}}{\text{s} \cdot \sqrt{\text{bar}}}$	$\Delta p$ in mmWS	$K$ in $\frac{\text{ltr}}{\text{s} \cdot \sqrt{\text{bar}}}$	$\Delta p$ in mmWS	$K$ in $\frac{\text{ltr}}{\text{s} \cdot \sqrt{\text{bar}}}$
1	204	1,05	128	1,06	55	1,08
3						

Tab. 3.3

The pressure loss is read off from the 6-fold manometer in mm water column and set in the equation as bar. The flow rate can be used with unit l/s.

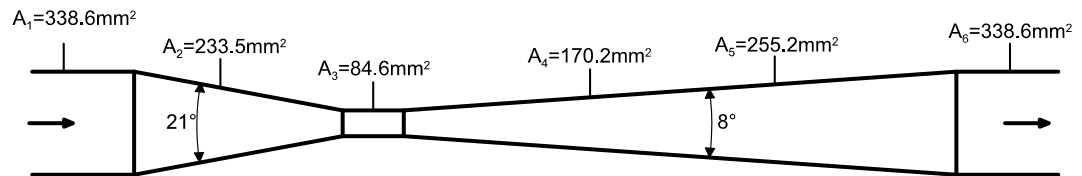
**HM 150.07**    **BERNOULLI'S PRINCIPLE DEMONSTRATOR**
**4**    **Technical Data**


Fig. 4.1