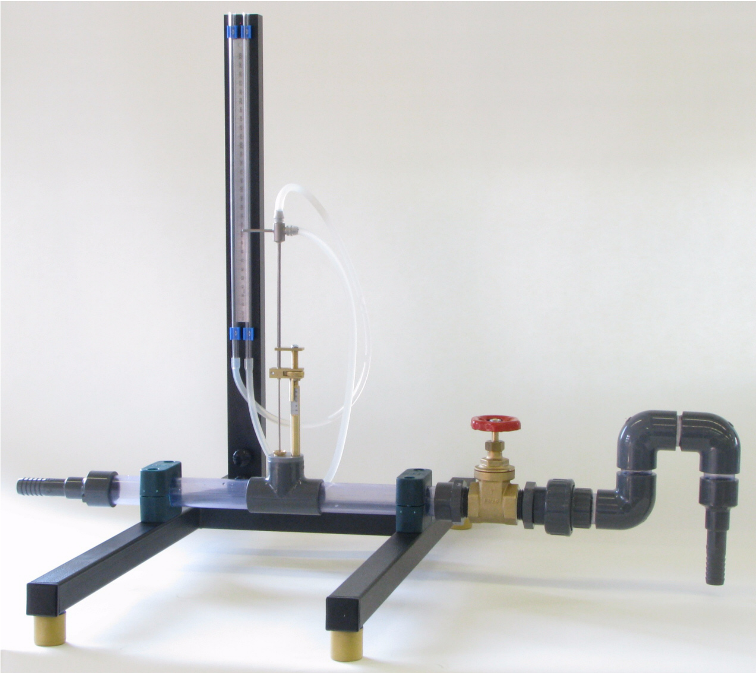
Technical Information

HM 150.36 Pitot-Static Tube Apparatus

HM 150.36 PITOT-STATIC TUBE APPARATUS



Technical Information

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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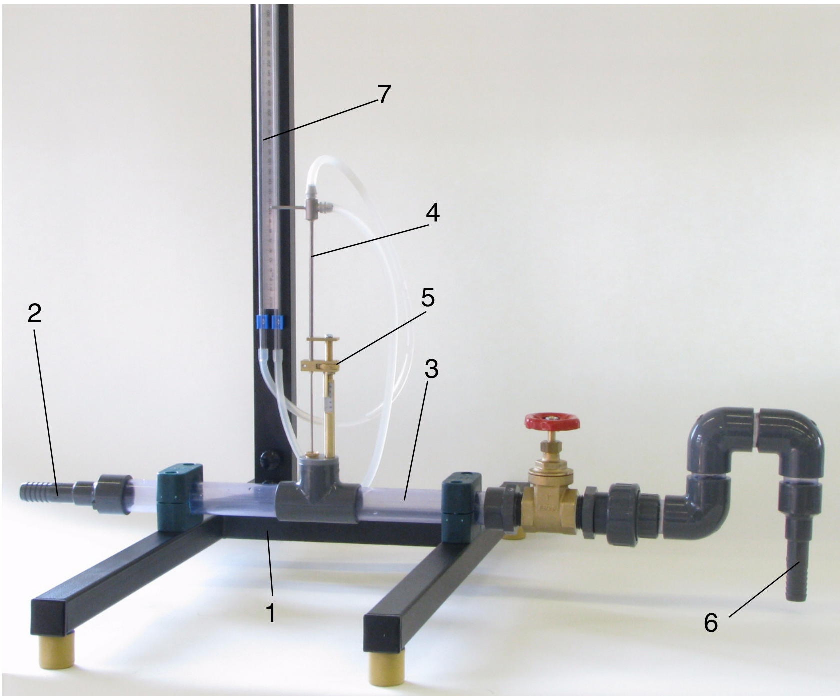
1 Layout and Connection



1	Support
2	Water Inlet Hose Connection
3	Measuring Tube (D = 27 mm, Transparent)
4	Prandtl Tube (D = 2,3)
5	Height Adjustment Device for the Prandtl Tube
6	Water Outlet Hose Connection
7	Double tube manometer

Fig. 1.1

The **HM 150.36** unit is part of the **HM 150.xx** series, which, with its range of experiments on the flow of fluids, covers the basic principles of fluid mechanics almost entirely. The pitot-static tube module is constructed such that it can be placed on the **HM 150 (Basic Hydraulics Bench)**. The

Basic Hydraulics Bench contains a tank and a submersible pump so that all additional modules can be operated in a closed circuit without an external water supply.

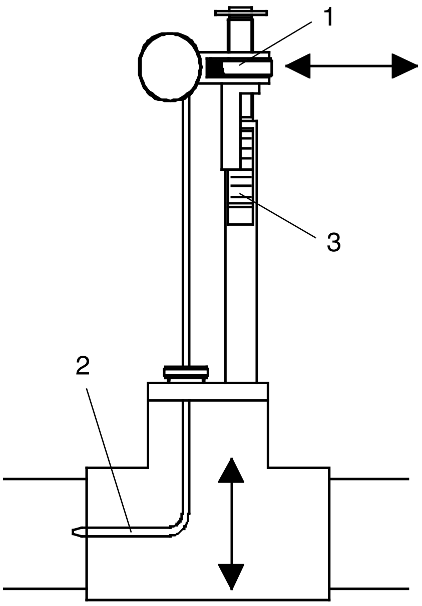


Fig. 1.2

Using the pitot-static tube module the change in the flow speed within a tube can be determined. The Prandtl tube can be moved across the entire cross-section of the tube. The position of the Prandtl tube (2) within the experiment tube can be changed by turning the wheel (1). It is possible to read how many millimetres the measuring head is positioned from the center of the tube on the scale (3). In case of a value of 0 mm, the measuring head is exactly in the middle of the flow.

To perform an experiment, a water supply is first connected to the inlet on the experiment tube. The volumetric flow rate can be adjustable by means of a valve. The correct measurement of the pressure is only possible if the experiment tube is completely filled with water and there are no more air bubbles inside the tube. For this reason to achieve, the volumetric flow rate must be regulated with the valve at the outlet of the experiment tube.

1.1 Intended Use

The unit is to be used only for teaching purposes.

2 Measuring Principle and Theoretical Principles

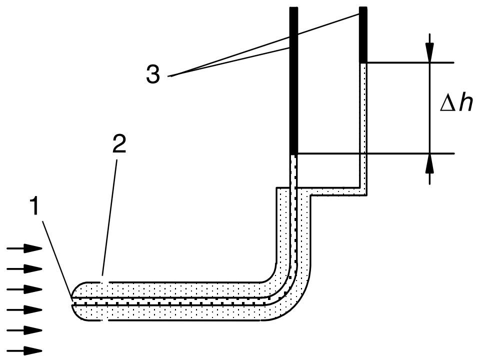


Fig. 2.1

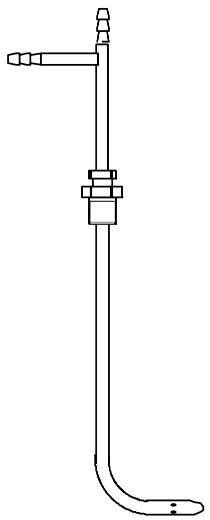


Fig. 2.2

The Prandtl tube comprises a combination of a Pitot tube for the measurement of the total pressure and a measuring point for the measurement of the static pressure.

The two pressures are transferred to the connections via a double-wall tube. If the connections are connected to the double-tube manometer (3), then when there is a flow through the Prandtl tube two columns of liquid of different heights can be seen. The height difference Δh is dependent on the flow speed.

The measuring point (1) for the total pressure is on the front of the sensor facing the flow. For the measurement of the static pressure, further measuring holes (2) are located evenly around the circumference on the side. By means of the formation of the mean of the measuring points around the circumference the influence of an oblique flow can be minimised.

The speed w is calculated as follows

$$w = \sqrt{\frac{2 \cdot \Delta p}{\rho}}$$

In the flow of a fluid drag forces occur due to friction both between all the fluid particles moving past each other at different speeds, and also between moving fluid particles and fixed surfaces of bodies; these affect the theoretical laws of the ideal fluid.

There are two types of flows:

- Laminar flow:
  The individual fluid particles move in well-organised layers sliding past each other.

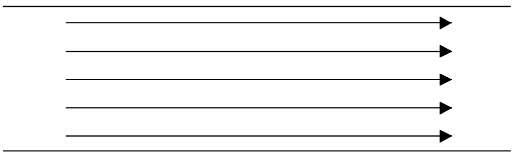


Fig. 2.3 Laminar Flow

- Turbulent flow:
  In a flow in a pipe with the laminar form of flow, on the gradual increase of the flow speed the flow behaviour changes at a certain speed. Continuously changing additional movements are superimposed on the actual, axially aligned flow movements at all points in the flow, these move in all directions without any form of regularity such that the flow paths interact and form small vortices.

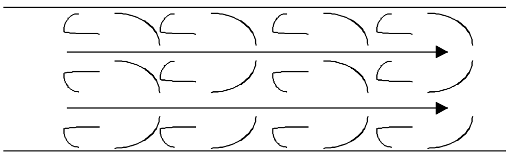


Fig. 2.4 Turbulent Flow

Due to the small differential pressures at low speed, which dominate at laminar flow, the Pitot-Static tube Apparatus is not suitable for measuring. For that reason, the turbulent flow will be considered in the following.

The following factors define the transition from laminar to turbulent flow:

- External dimensions of the pipe with the flow
- Flow speed
- Viscosity of the flowing medium

These factors correspond to the state variables from which the Reynolds number is formed. The change from laminar to turbulent flow actually occurs in the area of a specific number, the so-called critical Reynolds number.

In the case of flow in pipes and channels, i.e., for all flows inside a body, this number can be determined with reasonable precision:

$$Re_{cri} \approx 2300$$

The Reynolds number is calculated as follows:

$$Re = \frac{w \cdot d}{\nu}$$

w: flow speed in $\frac{m}{s}$

d: pipe inside diameter in m

ν: dynamic viscosity in $\frac{m^2}{s}$

Depending on which flow dominates in the tube, different speed profiles form across the cross-section of the pipe.

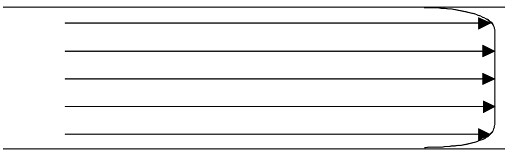


Fig. 2.5 Speed Profile for Turbulent Flow

In the case of turbulent flow, the flow speed of the fluid reaches, even very close to the pipe wall, a speed that is approaching the same as speed for

$$\text{friction-free motion } w = \frac{\dot{V}}{A}$$

As the speed at the wall surface is zero due to adhesion, there is a thin transition layer (boundary layer) in which there is a step velocity gradient.

At tubulent flow, the differential pressure across the pipe cross section is measured as a basic for calculating the volumetric flow of medium by the help of the Pitot-Static tube Apparatus. It can be moved nearly at every position across the entire cross section of tube.

It has to be observed, that the Pitot-Static tube Apparatus is not located next to the wall of pipe. In this section there is a boundary layer which has to be avoided. Furthermore does the measurement of static pressure only work at unobstructed flow at Pitot-Static tube Apparatus.

3 Example calculation

In the following the volumetric flow rate is calculated at which it is certain that turbulent flow is created.

Assumption: $Re = 10000$

Given: $d = 27\,\mathrm{mm}$, $\nu = 1{,}004 \cdot 10^{-6}\,\frac{\mathrm{m}^2}{\mathrm{s}}$

Calculation:

$$w = \frac{Re \cdot \nu}{d}$$

$$w = \frac{10000 \cdot 1{,}004 \cdot 10^{-6}\,\frac{\mathrm{m}^2}{\mathrm{s}}}{0{,}027\,\mathrm{m}} = 0{,}372\,\frac{\mathrm{m}}{\mathrm{s}}$$

$$\dot{V} = w \cdot A = w \cdot \frac{\pi}{4} \cdot d^2$$

$$\dot{V} = 0{,}372\,\frac{\mathrm{m}}{\mathrm{s}} \cdot \frac{\pi}{4} \cdot (0{,}027\,\mathrm{m})^2 = 2{,}13 \cdot 10^{-4}\,\frac{\mathrm{m}^3}{\mathrm{s}}$$

$$\dot{V} = 767\,\frac{\mathrm{ltr}}{\mathrm{h}}$$

4 Examples of measurement results

The following measurement results have been achieved at a volumetric flow of approx. 1350 ltr/h. and turbulent flow.

Lfd.-Nr.	Position mm	h_g mmWS	h_s mmWS	Δh mmWS
1	-11	217,5	195	22,5
2	-10	218	195	23
3	-8	218	195	23
4	-5	218	195	23
5	-2	218	195	23
6	0	218	195	23
7	2	218	195	23
8	4	218,5	195	23,5
9	6	219	195,5	23,5
10	8	218	194,5	23,5
11	10	217	193,5	23,5
12	11	217	194,5	22,5

Tab. 4.1 Measurement results at turbulent flow

The measurement results indicate that Δh is nearly constant across the entire cross section at turbulent flow. For this reason, only one measurement is needed for determination of volumetric flow.

Determination of volumetric flow

$$w = \sqrt{\frac{2 \cdot \Delta p}{\rho}} = \sqrt{\frac{2 \cdot 24\text{mmWS} \cdot 10\text{Pa m}^3}{1000\text{kg mmWS}}}$$

$$w = \sqrt{\frac{460\ \text{mmW(S kg m m}^3)}{1000\ \text{k(g s}^2\ \text{m}^2\ \text{mmWS)}}}$$

$$w = \sqrt{0{,}46\ \frac{\text{m}^2}{\text{s}^2}} = 0{,}68\ \frac{\text{m}}{\text{s}}$$

$$\dot{V} = w \cdot A = w \cdot \frac{\pi}{4} \cdot d^2$$

$$\dot{V} = 0{,}68\ \frac{\text{m}}{\text{s}} \cdot \frac{\pi}{4} \cdot (0{,}027\text{m})^2 = 3{,}9 \cdot 10^{-4}\ \frac{\text{m}^3}{\text{s}}$$

$$\dot{V} = 1400\ \frac{\text{ltr}}{\text{h}}$$

In accordance to the calculation, the volumetric flow is about 1400ltr/h. In consideration of the inaccurate reading of measuring points at double tube manometer, is this a good result.

5 Technical Data

Overall Dimensions of the Module		
Length:	850	mm
Width:	640	mm
Height:	400	mm
Weight:	4	kg
Supply	Water	
Pipe Section		
Material:	Transparent PVC	
Inside Diameter:	27	mm
Length:	600	mm
Hose Connection:	DN20	
Prandtl Tube		
Total Length:	305	mm
Tube Diameter:	4	mm
Head Diameter:	2,3	mm
Head Length:	37,2	mm
Hose Connection:	4	mm