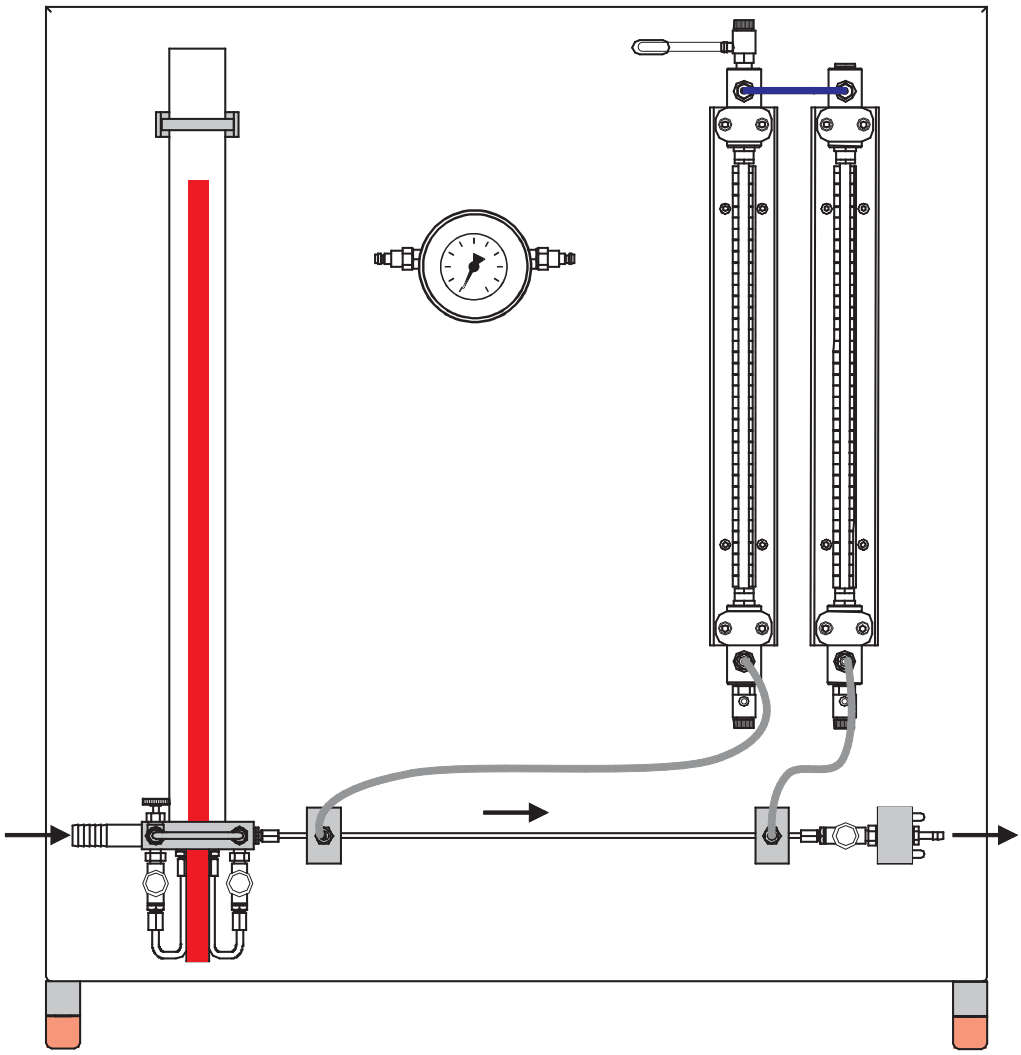
Experiment Instructions

HM 150.01 Pipe Friction Apparatus

HM 150.01 PIPE FRICTION APPARATUS



Experiment Instructions

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1 Introduction

The G.U.N.T. **HM 150.01** experimentation stand can be used to investigate pipe frictional losses with laminar and turbulent flows.

The pipe section is a brass pipe with an internal diameter of 3 mm. The distance between the pressure measuring fittings and thus the length of the experimental pipe section is 400 mm.

The pressure losses for laminar flow are measured using a water manometer. The static pressure difference is displayed.

A head tank is available to create a laminar flow and ensures a constant water inlet pressure in the pipe section at a constant water level.

For turbulent flow, the pressure difference is measured using a dial manometer.

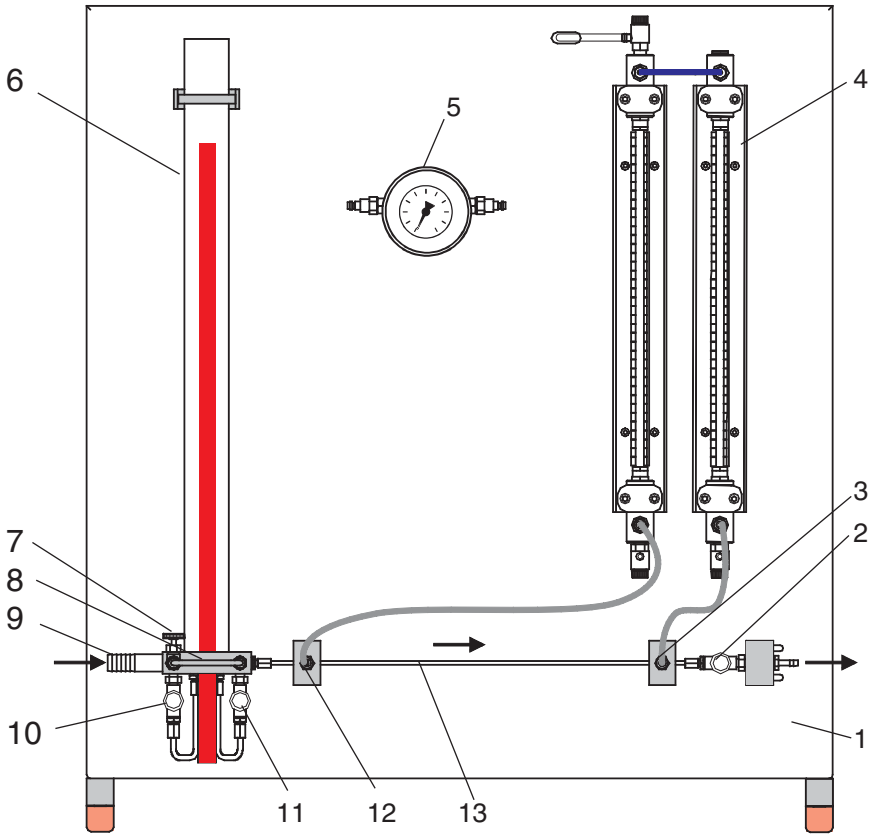
The head tank is not used to create a turbulent flow. The water is fed directly into the pipe section from the water supply via a bypass.

The flow is adjusted using shut-off valves at the beginning and end of the pipe.

The water supply is provided either by the **HM 150 Basic Hydraulics Module** or from the mains supply in the laboratory. The **HM 150** can be used to set up a closed water circuit.

2 Description of the unit

The unit essentially comprises:



1 Instrument panel
2 Drain valve
3 Pressure measuring fitting
4 Water manometer
5 Dial manometer
6 Head tank
7 Shut-off valve for water feed at bypass
8 Bypass
9 Hose connection for water inlet
10 Shut-off valve for water inlet on head tank
11 Shut-off valve for water outlet on head tank
12 Pressure measuring fitting
13 Pipe section

3 Experiments

The experiments are performed with laminar and turbulent flow.

The selection of experiments makes no claims of completeness but is intended to be used as a stimulus for your own experiments.

The measured results listed should not be viewed as reference or calibration values for all conditions. Depending on the construction of the individual components, experimental skills and environmental conditions, deviations may occur in the experiments.

3.1 Preparations for experiment

Connect the hose connection (9) for the water supply from the **HM 150.01** either to the **HM 150 Basic Hydraulics Module** or the mains supply in the laboratory.

Place the unit on a flat surface.

3.1.1 Determining the volumetric flow

The volumetric flow is determined using a measuring tank and a stopwatch.

$$\dot{V} = \frac{V}{t} \qquad (3.1)$$

V Volume of medium [l]

t Time [s]

The flow velocity is given by:

$$w = \frac{\dot{V}}{A} \qquad (3.2)$$

$\dot{V}$ Volumetric flow [l/s]

A Cross-sectional area of pipe $= \frac{\pi \cdot d^2}{4}$ [mm²]

d Internal diameter of pipe section = 3 mm

3.1.2 Changing from laminar to turbulent flow

You can also investigate whether laminar or turbulent flow is present. The change from laminar flow to turbulent flow occurs at:

$Re_{kr} \approx 2300$

$Re_{lam.} \leq 2300$ means laminar flow

$Re_{tur.} \geq 2300$ means turbulent flow

The Reynolds number is calculated from

$$Re = \frac{w \cdot d}{\nu} \qquad (3.3)$$

d Internal diameter of pipe section [mm]

w Flow velocity [m/s]

ν Viscosity of medium [m²/s]

3.1.3 Determining the pipe friction factor

The **pipe friction factor** λ is calculated as follows:

$$\lambda = \frac{2 \cdot h_v \cdot d}{\rho_{H_2O} \cdot l \cdot w^2} \qquad (3.4)$$

l Length of pipe measuring section 400 mm

ρ Density of medium

ρ_{H_2O} = 998 kg/m³

h_v Head loss

The **head loss h_v** is adjusted using the drain valve (2) and measured on the water manometer (4) (see Fig. 3.1).

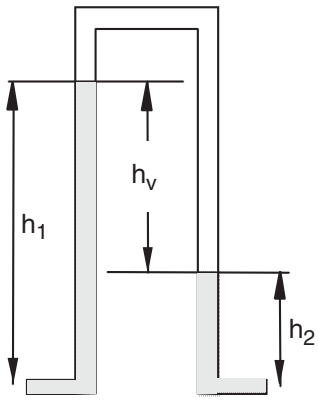


Fig. 3.1 Measuring the head loss h_v at the water manometer

$$h_v = h_1 - h_2 \qquad (3.5)$$

h_1 Static pressure head at pipe inlet [mm]

h_2 Static pressure head at outlet [mm]

When calculating the pipe friction factor λ using equation (3.4), the measured head loss must be converted into a differential pressure and inserted into the formula with the unit [Pa].

Conversions,:

1 cmWS = 1 mbar = 100 Pa

3.1.4 Determination of theoretical pipe friction coefficient

The **theoretical pipe friction coefficient** λ_{th} can be compared with the pipe friction factor.

For **laminar flow**:

$$\lambda_{th} = \frac{64}{Re} \tag{3.6}$$

For **turbulent flow**:

$$\lambda_{th} = \frac{0{,}3164}{\sqrt[4]{Re}} \tag{3.7}$$

3.2 Performing the experiment for laminar flow

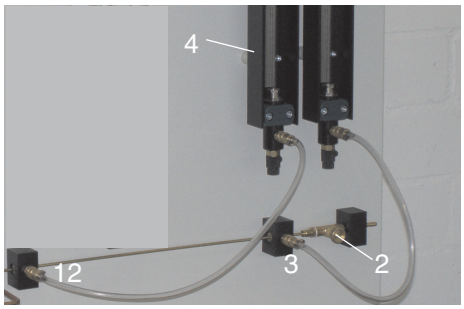


Fig. 3.2 Connecting the water manometer

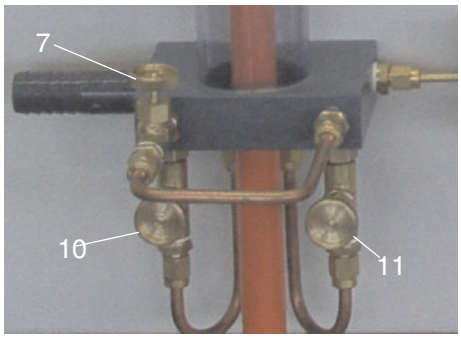


Fig. 3.3 Shut-off valves on head tank

- Connect the water manometer (4) to the two pressure measuring fittings (3; 12).
- Open the shut-off valve at the drain (2).
- Close the valve (7) on the bypass.
- Open the valves (10) and (11) on the head tank.
- Turn on the pump on the HM 150 (or the laboratory mains water supply) and adjust the valve controlling the flow such that a constant water level is established at the head tank overflow (6). Fine adjustment can then be carried out using the shut-off valve (10).
- Regulate the flow using the shut-off valve at the drain until the water manometer shows a constant pressure difference of 2 cm WS. This corresponds to the head loss h_v.
- Then measure the volumetric flow using a measuring tank and a stopwatch.
- Continue the experiment by increasing the flow in increments (h_v rises) and repeating the head difference and volumetric flow measurements.
- Note the measured values. Section 4 in the Appendix contains worksheets for doing this.

3.2.1 Measured values

The following example measured values can be obtained for laminar flow.

Caution!While performing the experiment, make sure that the water level in the head tank remains constant.

Measured values:

hv [cm]	*t* [s]	*V* [l]	$\dot{V}$ [l/s]	*w* [m/s]	*Re*	λ	λ_{th}
2	230	0.2	0.00087	0.123	344	0.198	0.186
3	148	0.2	0.00135	0.191	535	0.123	0.119
4	98	0.2	0.00204	0.289	810	0.072	0.079
5	76	0.2	0.00263	0.372	1042	0.054	0.061
6	66	0.2	0.00303	0.429	1202	0.049	0.053
8	54	0.2	0.00370	0.523	1465	0.043	0.044
12	35	0.2	0.00571	0.808	2263	0.028	0.028

3.3 Performing the experiment for turbulent flow

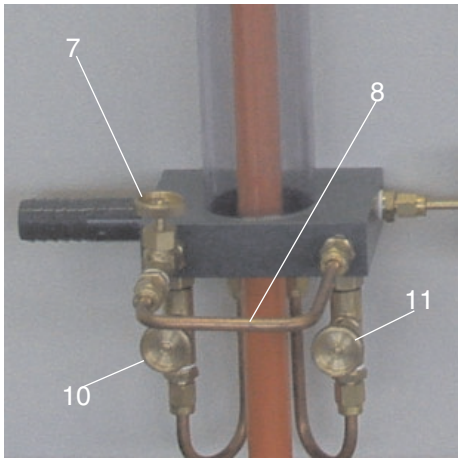


Fig. 3.4 Bypass and shut-off valves on head tank

The head tank is not used for this experiment. A higher flow velocity is required for turbulent flow. The water is therefore fed directly from the HM 150 or the laboratory water supply connection into the pipe section (13) via a bypass (8).

- Connect the dial manometer (5) to the two pressure measuring fittings (3 and 12).
- Open the shut-off valve at the drain (2).
- Open the valve (7) on the bypass.
- Close the valves (10) and (11) on the head tank.
- Turn on the pump on the HM 150 (or the laboratory mains water supply) and adjust the valve controlling the flow such that a constant flow is established.
- Regulate the flow using the shut-off valve (2) at the drain until the dial manometer shows a constant pressure difference, e.g. 50 mbar.
- Then measure the volumetric flow using a measuring tank and a stopwatch.
- Continue the experiment by increasing the flow in increments (Δp rises) and repeating the pressure difference and volumetric flow measurements.
- Note the measured values. Section 4 in the Appendix contains worksheets for doing this.

3.3.1 Measured values

The following measured values were obtained for turbulent flow.

Measured values:

Δp [mbar]	t [s]	V [l]	$\dot{V}$ [l/s]	w [m/s]	Re	λ	λ_{th}
50	26	0.4	0.0154	2.18	6106	0.0158	0.0358
100	23	0.4	0.0174	2.46	6890	0.0248	0.0347
125	20	0.4	0.0200	2.83	7927	0.0234	0.0335
150	18	0.4	0.0222	3.14	8796	0.0228	0.0327
175	17	0.4	0.0236	3.34	9356	0.0235	0.0322
200	16	0.4	0.0250	3.54	9916	0.0239	0.0317
225	15	0.4	0.0266	3.76	10532	0.0239	0.0312
240	14.5	0.4	0.0276	3.90	10924	0.0237	0.0309

4 Appendix

4.1 Worksheets

Measured values for laminar flow:

hv [cm]	t [s]	V [l]	$\dot{V}$ [l/s]	w [m/s]	Re	λ	λ_{th}

Measured values for turbulent flow:

Δp [mbar]	t [s]	V [l]	$\dot{V}$ [l/s]	w [m/s]	Re	λ	λ_{th}

4.2 Technical data

Dimensions:

LxWxH: 1100 × 640 × 840 mm

Weight: Approx. 40 kg

Water manometer:

Measuring range: 500 ... 0 ... 500 mm

Dial manometer:

Measuring range: 0 ... 0.4 bar

4.3 Symbols

A	Cross-sectional area of pipe section	[mm]
d	Internal diameter of pipe section	[mm]
h_v	Head loss	[mm]
h_1	Static head at measuring section inlet	[mm]
h_2	Static head at measuring section outlet	[mm]
l	Length of measuring section	[mm]
λ	Pipe friction factor	
λ_{th}	Theoretical pipe friction coefficient	
ρ	Density	[kg/m²]
Re	Reynolds' number	
Re_{kr}	Critical Reynolds' number	
$Re_{lam.}$	Reynolds' number for laminar flow	
$Re_{tur.}$	Reynolds' number for turbulent flow	
t	Time	[s]
V	Volume	[l]
$\dot{V}$	Volumetric flow	[l/s]
w	Flow velocity	[m/s]
ν	Viscosity	[m²/s]

4.4 Items Supplied

1 x HM 150.01 unit

1 x HM 150.01 instruction manual