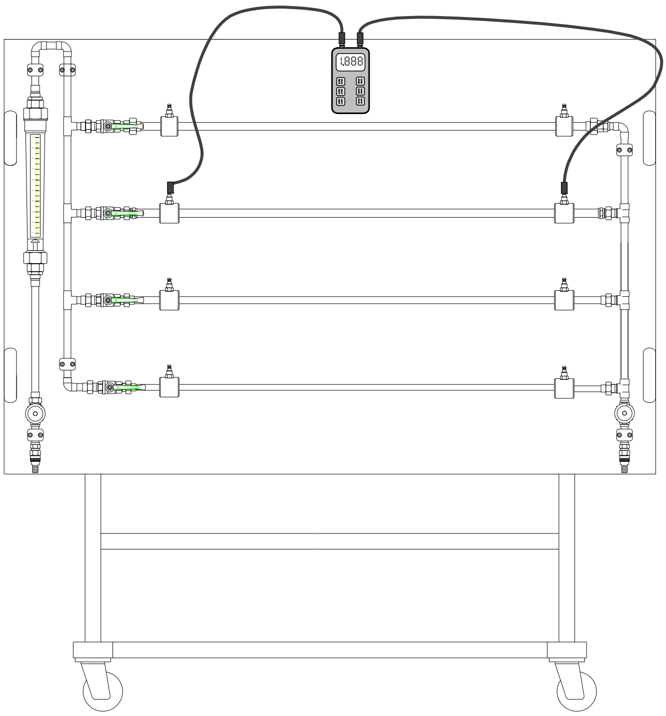
Instruction Manual

HL 102 Pipe Friction Training Panel

HL 102 **PIPE FRICTION TRAINING PANEL**



Instruction Manual

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.

Table of Contents

1 Introduction

The **G.U.N.T. Pipe Friction Training Panel HL 102** for the investigation of losses in pipework permits flow losses in pipes to be checked experimentally. The following specific topics can be investigated on the training panel:

- Effect of different pipe diameters
- Effect of different materials and surface roughness
- Effect of the flow velocity
- Measurement of differential pressures
- Comparison between experiment and calculation

In addition, the student obtains general skills in the preparation and performance of series of experiments, and knowledge of the use of pressure and flow rate measuring equipment.

Pressures are measured via a **digital differential pressure measuring unit**.

Pressure acquisition is performed using **toroidal chambers**.

The connections between the differential pressure measuring unit and the toroidal chambers are made using quick action couplings. As a result of the use of flat face sealing fittings, **it is possible to change the four pipe sections**. The user can make up own pipe sections at any time and fit them, equipped with toroidal chambers, to the measuring system for investigation.

The flow rate is read off on a **variable area flow meter**.

Handles make the training panel easier to carry.

1.1 Intended Use

The unit is to be used only for teaching purposes.

2 Safety

2.1 Structure of the Safety Instructions

The signal words DANGER, WARNING or CAUTION indicate the probability and potential severity of injury.

An additional symbol indicates the nature of the hazard or a required action.

Signal word	Explanation
⚠ DANGER	Indicates a situation which, if not avoided, will result in death or serious injury.
⚠ WARNING	Indicates a situation which, if not avoided, may result in death or serious injury.
⚠ CAUTION	Indicates a situation which, if not avoided, may result in minor or moderately serious injury.
NOTICE	Indicates a situation which may result in damage to equipment, or provides instructions on operation of the equipment.

Symbol	Explanation
	Notice

2.2 Safety Instructions

NOTICE

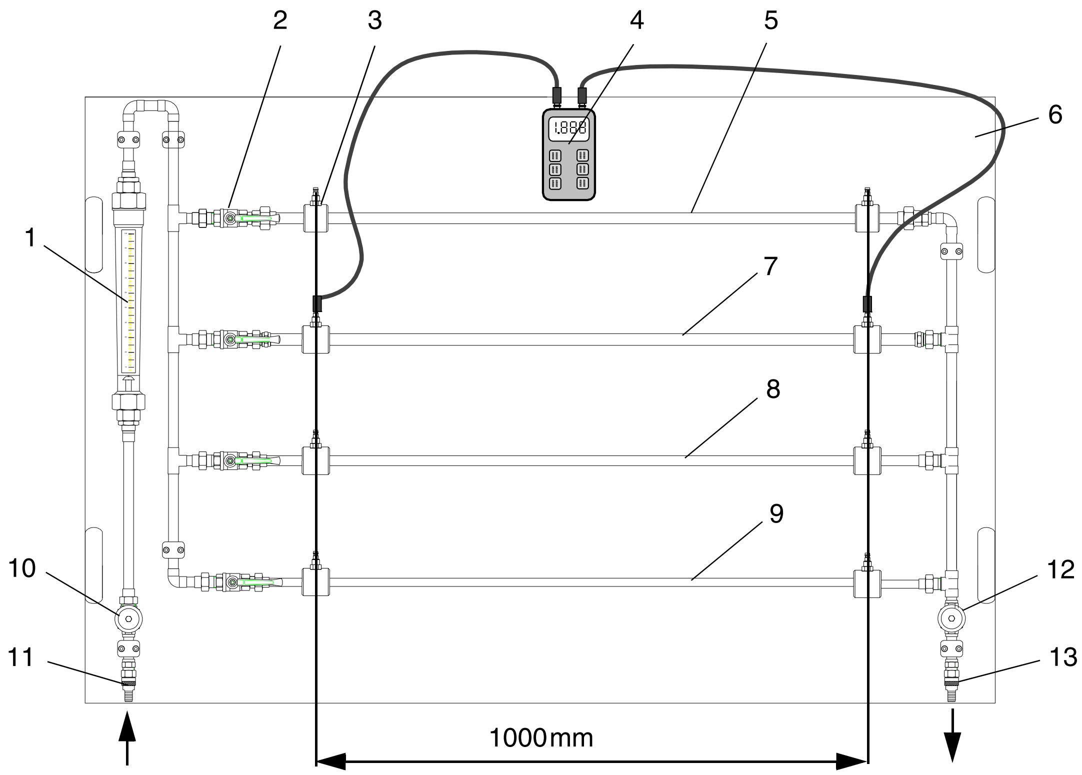
The differential pressure measuring unit must not be connected to the toroidal chambers when the pipe system is being filled and flushed, otherwise the intense pressure pulse may exceed the pressure measurement range.

3 Unit Description

The HL 102 training panel is a fully equipped unit for experiments on the losses in pipes. The training panel has the following features:

- The complete experiment setup is contained on one training panel
- Flow rate measurement via variable area flow-meter
- 1 digital pressure measuring system for measuring differential pressure
- Correct pressure acquisition via toroidal chambers
- Straightforward, quick connection of measuring points to the pressure measuring unit via hoses and quick action couplings
- 4 different pipe sections rigidly installed
- Pipe sections can be changed, in this way own pipe sections can be used
- Straightforward pipe section selection via spherical valves
- Standardised measuring length of 1 m for pipe friction measurements

3.1 Layout of the Training Panel



1	Variable area flowmeter	8	Pipe section, copper DN 15
2	Ball cock	9	Pipe section, copper DN 12
3	Toroidal chamber with quick action coupling	10	Regulator valve, water inlet
4	Electric differential pressure manometer	11	Water inlet with quick action coupling
5	Artificially roughened plexiglass pipe	12	Regulator valve, water outlet
6	Training panel with handles	13	Water outlet with quick action coupling
7	Pipe section, steel 1/2”		

Fig. 3.1 Layout of the HL 102 Training panel

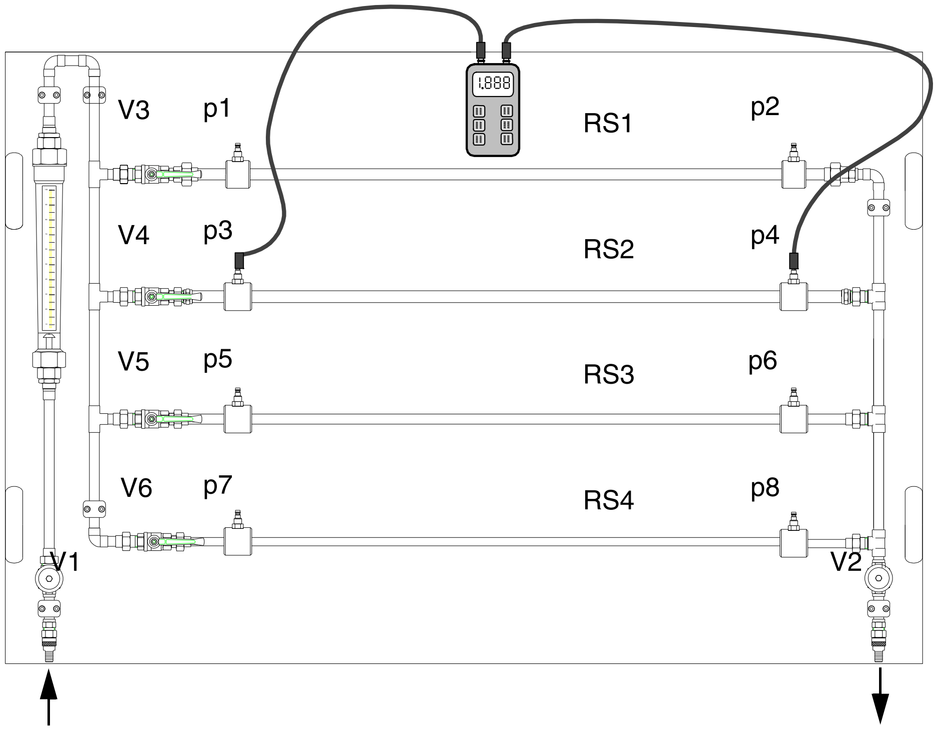


Fig. 3.2 Measuring and shut-off point labels

To be able to describe the operation of the valves consistently and straightforwardly in the subsequent experiments, the following identifiers are used:

- V1 - V6 Shut-off valves
- p1 - p8 Pressure measuring points
- RS1 - RS4 Pipe sections

3.2 Function of the Training Panel

Water from an external source first flows through the flow rate sensor.

Following the measurement of the flow rate, the water is fed to the pipe sections to be investigated via ball cocks.

At the start and end of the pipe section, the pressure is acquired via toroidal chambers and output on the digital differential pressure measuring unit as a differential pressure.

The flow rate can be regulated by means of the gate valves in the inlet and outlet pipes.

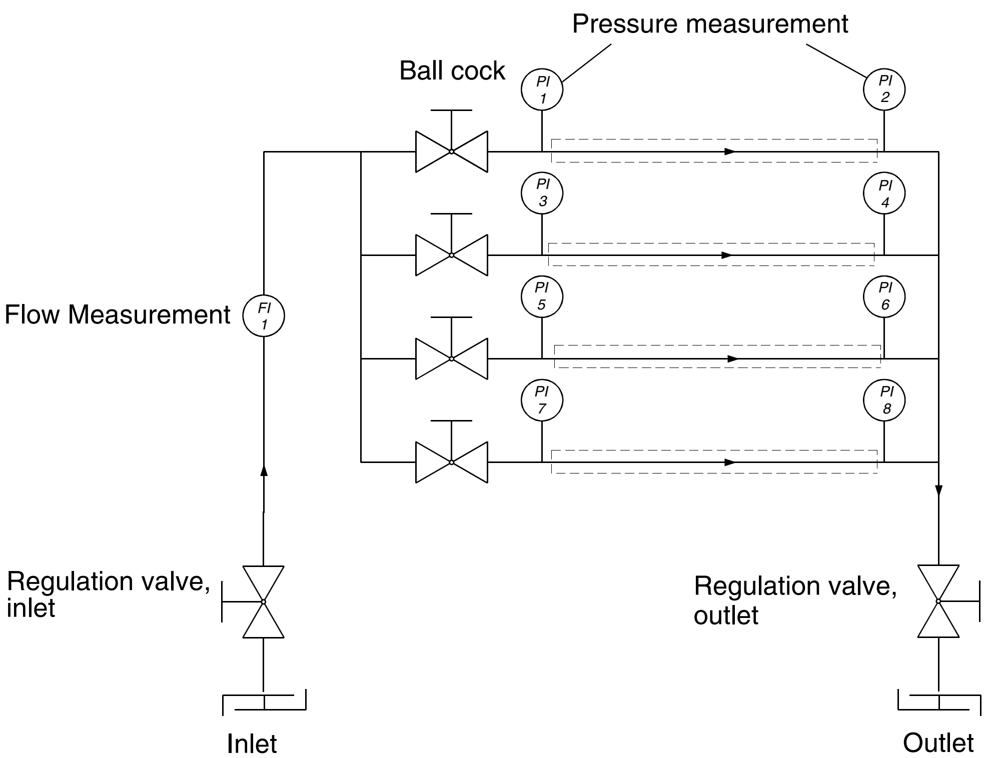


Fig. 3.3 Process schematic of the experiment setup

3.3 Placing in Operation

Hang the training panel on the Universal Support for Training Panels, HL 100, or the Supply Table for Training Panels, HL 090, and secure the support against unintended movement by operating the brakes.

- Select a level, water resistant surface for the support (when changing the measuring lines, small amounts of water can escape)
- Connect water supply to gate valve V1 using quick action coupling (V1 closed)
- Connect water outlet to gate valve V2 using quick action coupling

Check the training panel for leaks:

- Open outlet valve
- Open water supply
- Slowly open all ball cocks one after the other and bleed the pipe sections.
- Close outlet valve. The pipework is then subject to the full system pressure (this is dependent on the chosen water supply)
- The test setup must continue to be flushed until no air bubbles rise through the variable area flowmeter after briefly closing and then reopening all valves

NOTICE
Quick action couplings for the differential pressure measuring unit must not be connected to the toroidal chambers, otherwise the sensor in the measuring unit may be irreparably damaged by pressure pulses.

- Check all pipes and joints for leaks.

3.4 Electric differential pressure manometer

See manufacturer's operating instructions

3.4.1 Bleeding

Abb. 3.4 Digital differential pressure manometer

The connecting hoses must be bled before connection to the electric differential pressure manometer to prevent falsification of the measured results. For example, an air bubble of 10 mm WS corresponds to a pressure of 0,98 mbar.

The procedure is as follows:

- Connect the connecting hoses to the relevant pipe section.
- Open closed quick-release fasteners at the free ends of the hoses as follows:
  - Carefully press in the cylindrical inner section within the relevant connection opening with a sharp object (the enclosed pin).
- Slowly open the inlet valve for the pipe section to be measured.
- Rinse out the pipe section and connecting hoses by a flow of water, until the water emerges at the free ends of the hoses.
- Then connect the free ends of the connecting hoses to the differential pressure manometer. Bleeding the two lines means that the pressure of the hose lines filled with water acts on both sides of the measurement cell.

- Press the zero button on the electric differential pressure manometer.
  On the electric measuring instrument, the differential pressure can be measured without including the different measuring point heights in the calculation.
  To achieve this, press the zero button with the manometer connected and a flow of "0", before performing the actual measurement with a flow. This means that only the dynamic pressure component is measured, with no static pressure component.

3.4.2 Ending the measurement

- Close the inlet to the pipe section.
- Open the pipe section outlet. The differential pressure manometer and connecting hoses empty and the pipe section is depressurised.
- The connecting hoses can be detached and changed over.

3.4.3 Flow Rate Measurement

To measure the flow rate, a variable area flow-meter with the following characteristics is used.

- Precision measuring tube made of plastic
- Replaceable float made of stainless steel
- Scale that can be read directly
- Max. flow rate 1600ltr/h
- Accuracy class 2,5

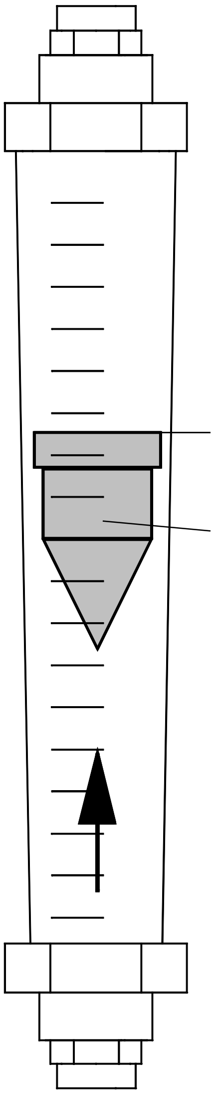


Abb. 3.5

The flow rate is to be read off at the top edge of the tapered shoulder.

Air bubbles or particles of dirt on the float can affect measurement accuracy. To wash these away, operate the training panel at maximum flow rate. For this purpose, open all valves fully.

4 Experiments

In this section, a few experiments that can be performed with this unit are described as examples. The selection of experiments is not intended to be exhaustive, instead it is intended to generate ideas for your own series of experiments.

The descriptions of the experiments are divided into a **basic principles section** with the most important formulae for calculations, the actual **performance of the experiment** with the acquisition of measured values, and the **comparison of calculated results with experimental results**.

The measurement results given are not to be seen as reference or calibration values that should be obtained under all circumstances. Depending on the design of the individual components used and the way in which the experiment is performed, variations may occur during own experiments to a greater or lesser degree.

4.1 Pipe Flow with Friction

In the following experiments, the **pressure loss** p_V on flow in a pipe subject to friction is to be determined experimentally. The measured values are then compared with the calculated results.

In **turbulent pipe flow**, this is characterised by a Reynolds' number $Re > 2320$, the pressure loss is proportional to the

- Length l of the pipe
- Pipe friction coefficient λ
- Density ρ of the flowing medium
- Square of the flow velocity v.

Furthermore, the pressure loss increases as the pipe diameter d reduces. It is calculated as follows

$$p_v = \frac{\lambda \cdot l}{2 \cdot d} \cdot \rho \cdot v^2 \qquad (4.1)$$

In turbulent pipe flow ($Re > 2320$), the pipe friction coefficient λ is dependent on the pipe roughness k and the Reynolds' number Re. The pipe roughness k defines the height of the protrusions on the wall in mm. The roughness of the pipes used in the experiments is given in the Appendix in Tab. 5.2, Page 22. The relationship between Re, λ and k is in shown in the diagram after Colebrook and **Nikuradse**. The wall roughness k refers to the pipe diameter d.

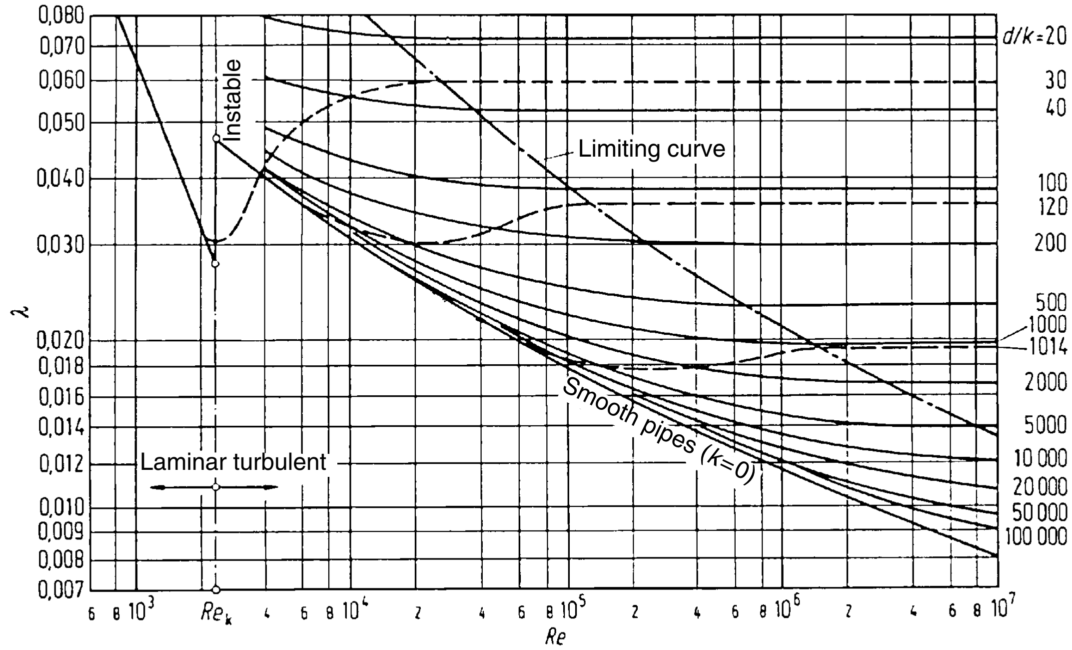


Fig. 4.1 Pipe friction coefficient λ after Colebrook and (dotted) after Nikuradse

The **Reynolds' number *Re*** is calculated from the diameter of the pipe *d*, the flow velocity *v* and the kinematic viscosity ν.

$$Re = \frac{v \cdot d}{\nu} \tag{4.2}$$

The kinematic viscosity of water as a function of temperature can be found in Tab. 5.1, Page 22.

The **flow velocity *v*** is calculated from the volumetric flow rate $\dot{V}$ and the pipe cross-section

$$v = \frac{4 \cdot \dot{V}}{\pi \cdot d^2} \tag{4.3}$$

For **hydraulically smooth pipes (*Re* < 65 *d/k*)** and a Reynolds' number in the range from $2320 < Re < 10^5$ the pipe friction coefficient is calculated using **Blasius'** formula

$$\lambda = \frac{0,3164}{\sqrt[4]{Re}} \tag{4.4}$$

For **pipes in the transition area to rough pipes (65 *d/k* < *Re* < 1300 *d/k*,** area in the diagram underneath the boundary curve) the pipe friction coefficient after **Colebrook** is calculated as follows

$$\lambda = \left[2 \cdot lg\left(\frac{2,51}{Re \cdot \sqrt{\lambda}} + \frac{0,27}{d/k}\right)\right]^{-2} \tag{4.5}$$

This is an implicit formula that must be solved iteratively. First an estimate for λ is made, this is then inserted in the formula and an initial approximation calculated. The result is inserted in the formula and a second approximation calculated. If the estimated value is taken from the diagram after Colebrook and Nikuradse, in general the first approximation is sufficiently accurate and the values only differ in the third decimal place. For rough pipes, Nikuradse derived the following formula

$$\frac{1}{\sqrt{\lambda}} = 2 \cdot \log\left(\frac{d}{k}\right) + 1{,}138 \quad (4.6)$$

Reorganising this formula for λ yields:

$$\lambda = \left(\frac{1}{2 \cdot \log\left(\frac{d}{k}\right) + 1{,}138}\right)^2 \quad (4.7)$$

4.2 Performing the Experiment

Experiments are performed on four pipes made of different materials and with different diameters. The measured length l is 1000 mm.

On pipe section RS1, a Plexiglass tube is used, for the purpose of increasing the resistance, the inside of this pipe has been artificially roughened. RS1 has an inside diameter of approx. 16 mm.

Pipe section RS2 consists of a length of 1/2" gas pipe with an internal diameter of 16 mm.

Pipe section RS3 consists of a length of 18 mm copper pipe with an internal diameter of 16 mm.

Pipe section RS4 consists of a length of 15 mm copper pipe with an internal diameter of 13 mm.

The flow rate $\dot{V}$ is read off directly on the variable area flowmeter.

The displays on the differential pressure manometer and flowmeter are noted in the tables (Chapter 5.4, Page 23).

The manometer is connected and the measurements made in accordance with Chapter 3.3, Page 9.

Flow is only passed through one pipe section at a time. The ball cocks on the inlet end of the other three pipe sections must be closed.

Volumetric flow rate $\dot{V}$ in ltr/h	200	400	600	800	1000	1200
Differential pressure Δp in mbar	0	11	33	51	80	125

Tab. 4.1 Pipe section: RS1, plexiglass, artificially roughened inside, inside diameter 16mm

Volumetric flow rate $\dot{V}$ in ltr/h	200	400	600	800	1000	1200
Differential pressure Δp in mbar	0	2	7	12	18	22

Tab. 4.2 Pipe section: RS2, steel gas pipe 1/2”, inside diameter 16mm

Volumetric flow rate $\dot{V}$ in ltr/h	200	400	600	800	1000	1200
Differential pressure Δp in mbar	0	1	6	10	15	20

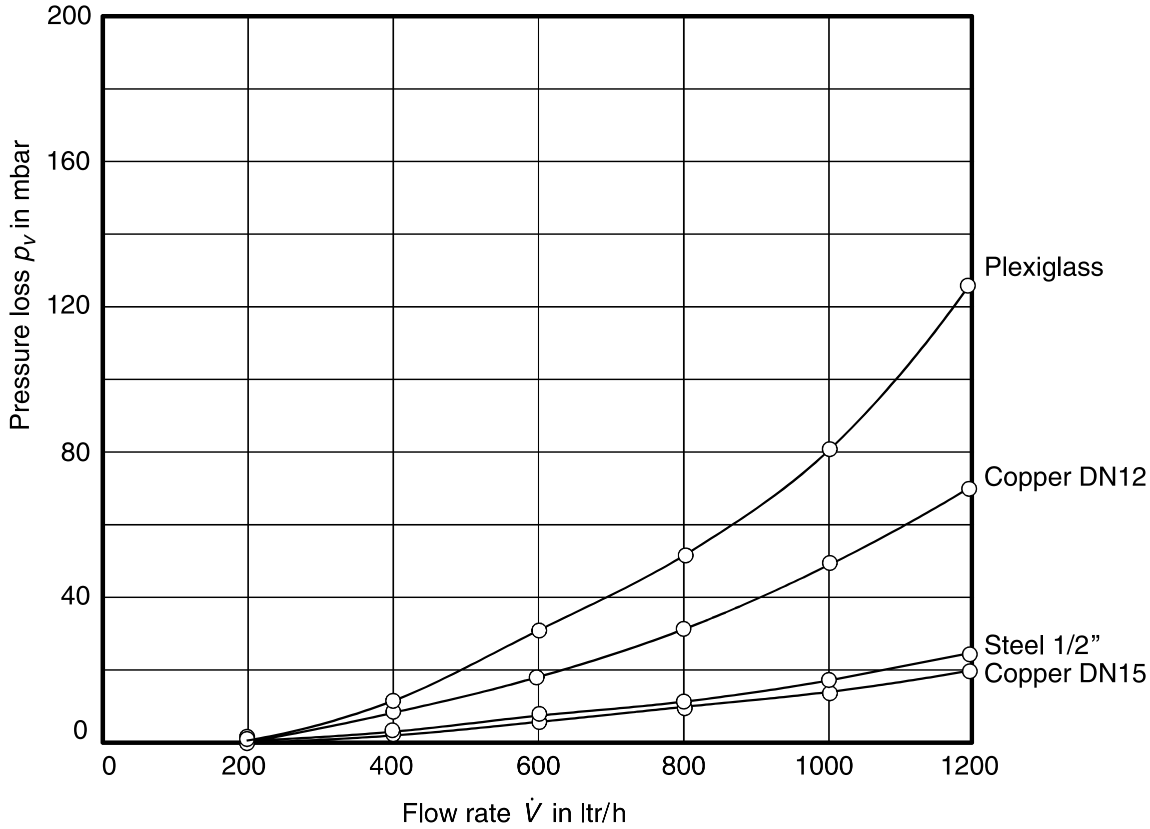
Tab. 4.3 Pipe section: RS3, copper pipe 18mm, inside diameter 16mm

Volumetric flow rate $\dot{V}$ in ltr/h	200	400	600	800	1000	1200
Differential pressure Δp in mbar	0	7	18	31	46	71

Tab. 4.4 Pipe section: RS4, copper pipe 15mm, inside diameter 13mm

The differential pressures measured can now be plotted against the flow rate.

Here the quadratic dependency on flow rate and thus the flow velocity is clear.



Pressure loss against flow rate

Fig. 4.2 Graph of the measured results

4.3 Comparison with the Calculation

Here the measured differential pressures are compared with the calculated values. For the calculation, it is first necessary to know the wall roughness of the pipes used.

Material	Surface	Wall roughness *k*
Copper pipe, Cu	physically smooth	0,001 mm
Plexiglass pipe	artificially rough	2,6 mm
Steel pipe, St	galvanised	0,1 mm

Tab. 4.5 Wall roughness on the experiment pipes

For the kinematic viscosity of the water, for a temperature of 25 °C, a value of $\nu = 0{,}894 \cdot 10^{-6} \mathrm{m}^2/\mathrm{s}$ is read from Tab. 5.1, Page 22. Using this data, the differential pressures can be calculated.

Pipe section	Inside diameter *d* in mm	Volumetric flow rate $\dot{V}$ in m³/s	Flow velocity *v* in m/s	Reynolds' Number *Re*	*d/k*	smooth/ rough
1 Plexi 20x1,5	16	$33{,}33 \cdot 10^{-5}$	1,65	23280	6	rough
2 St. galvanised 1/2"	16	$33{,}33 \cdot 10^{-5}$	1,65	23280	160	rough
3 Cu 18x1	16	$33{,}33 \cdot 10^{-5}$	1,65	23280	16000	smooth
4 Cu 15x1	13	$33{,}33 \cdot 10^{-5}$	2,51	30241	13000	smooth

Pipe section	λ Calculation after	Pipe friction coefficient λ	Calculated differential pressure p_v in bar	Measured differential pressure p_v in bar	Variation in %
2 Plexi 20x1,5	Nikuradse	0,1380	117	125	-7
3 St. galvanised 1/2"	Colebrook	0,0347	29	22	+25
4 Cu 18x1	Blasius	0,0256	21	20	+5
7 Cu 15x1	Blasius	0,0232	56	71	-26

Tab. 4.6 Calculation of the differential pressures

5 Appendix

5.1 Technical Data

Powder coated steel sheet panel

Colour:	grey white

Overall dimensions:

L x T x H	1650 x 200 x 1100	mm
Weight:	52	kg

Cold water connection:

Quick action coupling with hose connection

Water outlet connection:

Quick action coupling with hose connection

Electric differential pressure manometer

Measuring range	-350 ... 350	mbar
Max. over-pressure	1000	mbar
Battery type	9	V

Variable area flowmeter

Measuring range	0...1600	ltr/h

Pipe sections

Measured length:	1000	mm
Nominal diameters:		
Steel:	1/2	"
Copper:	18 x 1	mm
Copper:	15 x 1	mm
Plexi:	20 x 1,5	mm

5.2 List of the Most Important Symbols of Formulae and Units

Symbol of formula	Quantity	Unit
A	Area	m^2, mm^2
d	Pipe inside diameter	m, mm
k	Wall roughness	mm
l	Length	m, mm
p	Pressure	N/m^2 = Pa, mbar
p_v	Pressure loss	N/m^2 = Pa, mbar
Re	Reynolds' Number	—
v	Velocity	m/s
$\dot{V}$	Volumetric flow rate	m^3/s
λ	Pipe friction coefficient	—
ν	Kinematic Viscosity	m^2/s
ρ	Density	kg/m^3

5.3 Diagrams and Tables

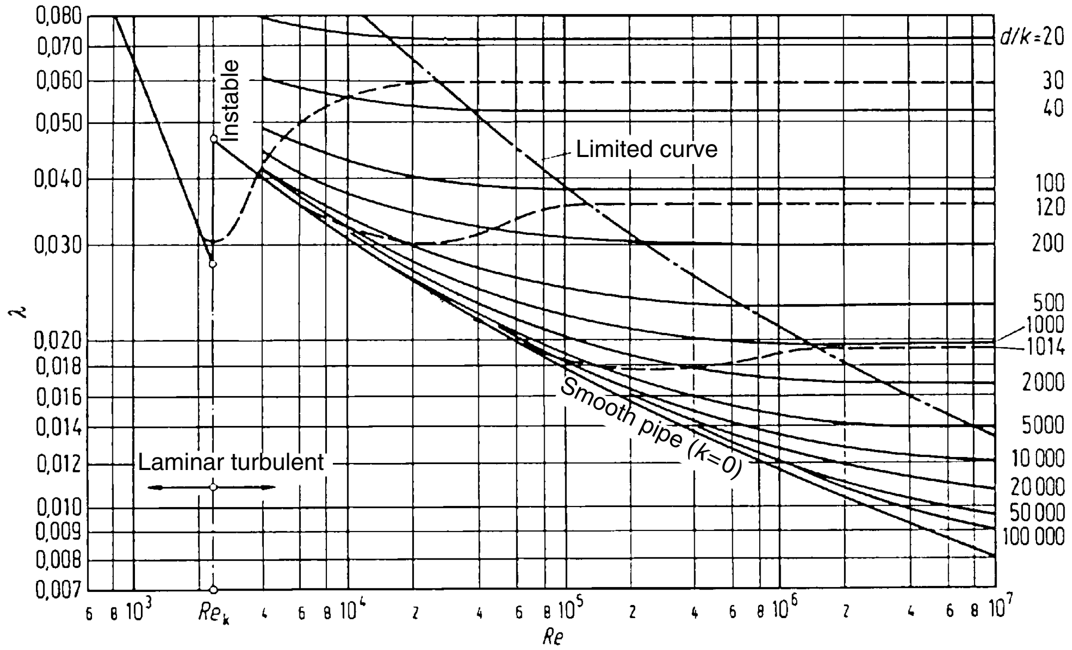


Fig. 5.1 Pipe friction coefficient λ after Colebrook and (dotted) after Nikuradse

Temperature in °C	Kinematic viscosity ν in 10^{-6} m^2/s
10	1,297
11	1,261
12	1,227
13	1,194
14	1,163
15	1,134
16	1,106
17	1,079
18	1,055
19	1,028
20	1,004
21	0,980
22	0,957
23	0,935
24	0,914
25	0,894
26	0,875
27	0,856
28	0,837
29	0,812
30	0,801

Tab. 5.1 Kinematic viscosity of water as a function of the temperature

Material	Surface	Wall roughness k
Copper pipe, Cu	physically smooth	0,001 mm
Plexiglass pipe	artificially rough	2,6 mm
Steel pipe, St	galvanised	0,1 mm

Tab. 5.2 Wall roughness on the experiment pipes

5.4 Worksheet

Pipe section:						
Volumetric flow rate $\dot{V}$ in ltr/h						
Differential pressure Δp in mbar						

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Volumetric flow rate $\dot{V}$ in ltr/h						
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Differential pressure Δp in mbar						

Pipe section:						
Volumetric flow rate $\dot{V}$ in ltr/h						
Differential pressure Δp in mbar						

5.5 Index

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