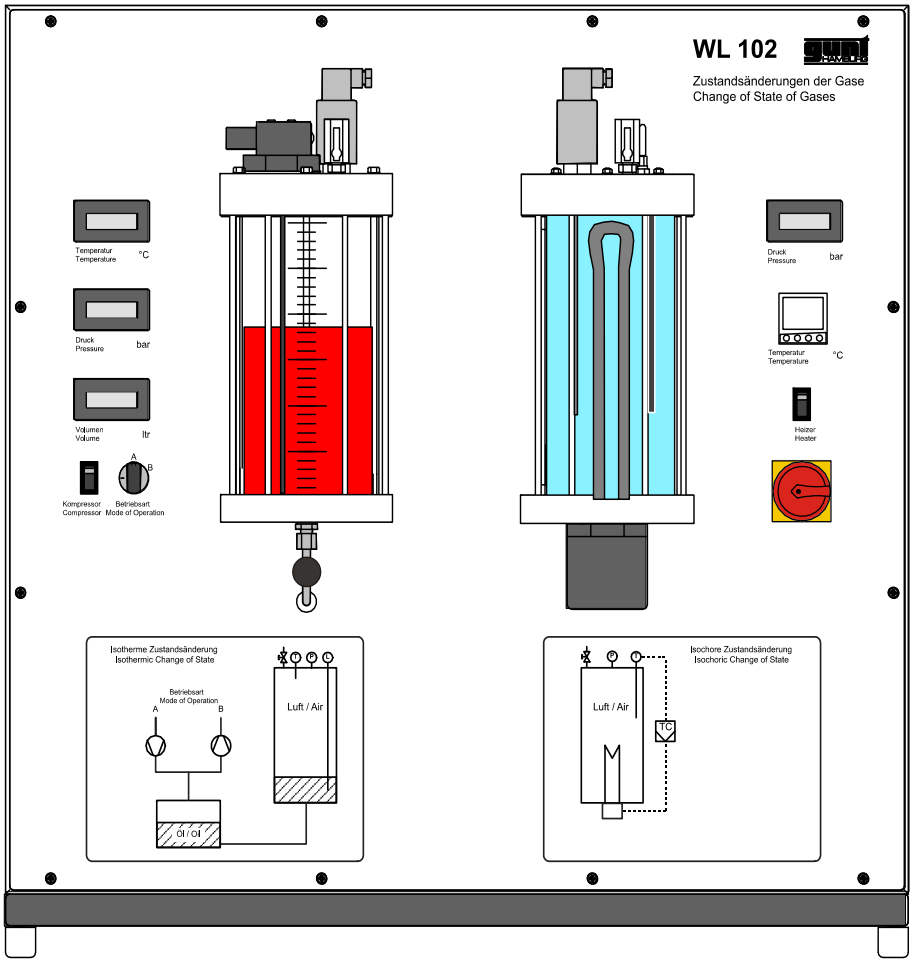
WL 102 Change of State of Gases



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 **WL 102** table unit is for demonstrating Boyle's law and checking the state equation for ideal gases.

It clearly shows the relationship between change in volume and the associated change in pressure of an enclosed gas.

For this experiment air is used as the experimental gas, this can be compressed or expanded in a perspex vessel. The sealing liquid works like a piston. It enlarges or reduces the enclosed gas volume. The processes during the experiment are sufficiently slow to ensure isothermic changes.

In another vessel, a fixed volume of air can be heated to check the state equation and the corresponding pressure change observed.

The data acquisition with which the experimental unit is equipped facilitates the recording and processing of all measured values on a PC.

The unit is suitable for both demonstrations performed by the lecturer, and also for student experiments as part of laboratory practical experiments.

1.1 Intended Use

The unit is to be used only for teaching purposes.

2 Security

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
	Electrical voltage
	Hazard (general)
	Hot surfaces

Symbol	Explanation
	Notice
	Wear gloves

2.2 Safety Instructions

⚠ WARNING

Reaching into the open control cabinet can result in electric shocks.

- Disconnect from the mains supply before opening.
- Work should only be performed by qualified electricians.
- Protect the control cabinet against moisture.

⚠ WARNING

Risk of burns at hot surfaces.

- Do not remove safety devices such as the guard.
- Cool down the unit before removing the guard.
- Wear suitable gloves when removing the guard.

⚠ WARNING

Risk of bursting because of overpressure.

- Compress the air contained in the pressure cylinder as a maximum to a residual volume of 1 litre.

NOTICE

- Prior to compressing the air in the pressure cylinder, it is imperative to ensure that the air discharge valve on the top of the pressure cylinder is closed.
- Risk of the escape and loss of sealing liquid

NOTICE

- Do not operate the unit unsupervised.

NOTICE

- fill in 3 to 3,5 litre oil max.

3 Unit Description

3.1 Unit Design and Function

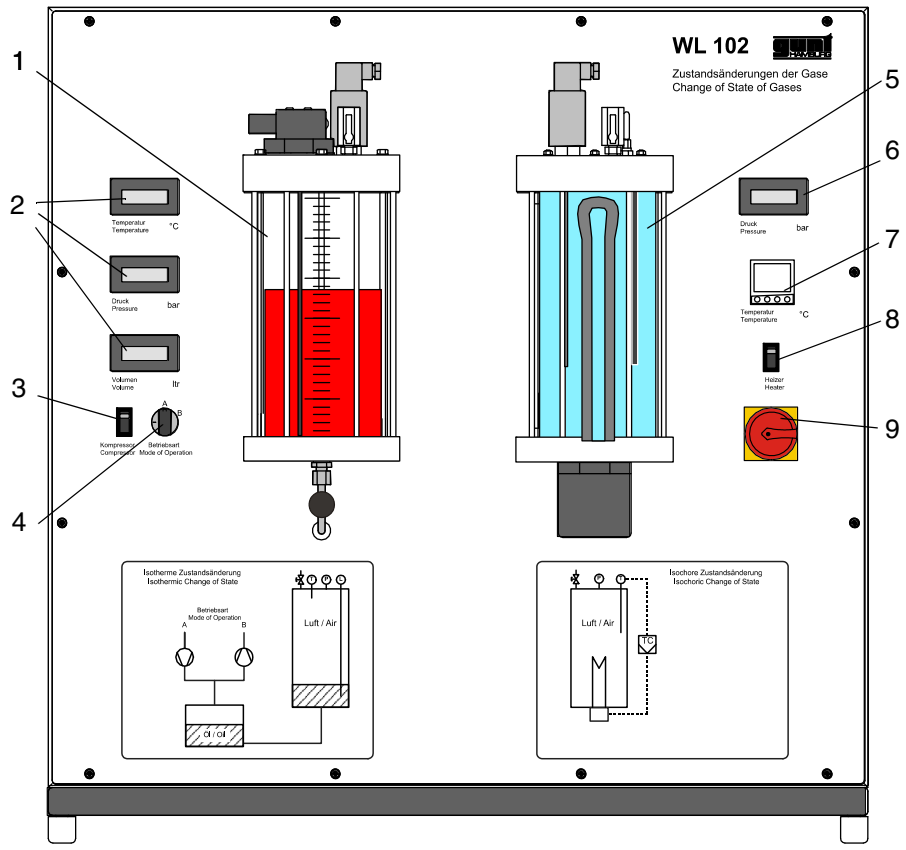


Fig. 3.1 Complete view of the **WL 102**

The experiments on the **WL 102** are performed in two different vessels. A liquid can be pumped into a **pressure cylinder** (1) with the aid of a compressor. In this manner, the volume of air enclosed in the cylinder is compressed.

Fig. 3.3, Page 6 illustrates the operating principle.

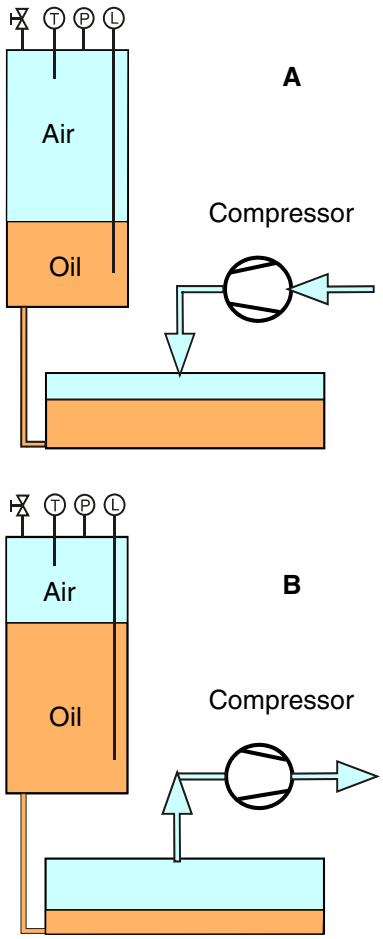


Fig. 3.2 Basic principle of the compression of air inside a cylinder

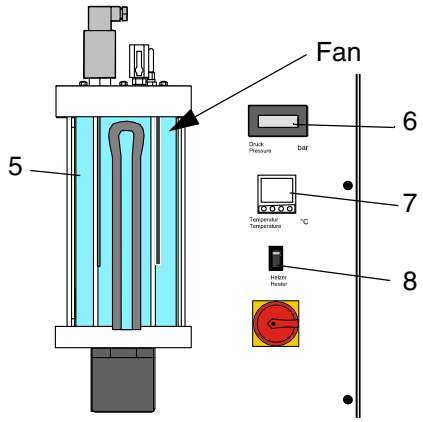


Fig. 3.3 Cylinder for heating the air volume

The advantages of this technique are, firstly, the gastight sealing liquid which prevents losses through leakages in air flow and, secondly, eheat sink effect which contributes significantly toward isothermal testing characteristics.

Displays for **temperature, pressure** and **compressed volume** (2) indicate the corresponding values measured in the vessel. The **selector switch** (4) is used to switch between compression and expansion of the air inside the pressure vessel. A **switch** (3) is used to turn on the compressor.

In a second, **heatable cylinder** (5), a closed, constant volume of air is heated and the resulting change in pressure observed. The heater is activated with a **switch** (8).

A **heater control** (7) permits adjustment of the desired temperature by means of upward and downward **arrow keys** and indicates the actual temperature. The parameter to be selected by pressing the upward and downward arrow keys. Dynamically alteration of parameter to be made by pressing the key for as long as the key is kept pressed. For manually taking over of entry the **„P“ key** to be pressed. After 2s the entry will be automatically adopted.

For cancelling the entry the **Exit/F key** to be pressed. Change to the manual mode using function key **Exit/F** (> 2s). Exit the manual mode using function key **Exit/F** (> 2s).

The resulting pressure inside the cylinder is indicated by a **display** (6).

The experimental unit is switched on and off using the main switch (9). On the rear of the unit is a **USB port** which can be used to connect the unit to the PC via cable.

3.2 Filling of Oil

⚠ WARNING

Reaching into the open control cabinet can result in electric shocks.

- Disconnect from the mains supply before opening.
- Do not touch the electrical components.
- Protect the control cabinet against moisture.

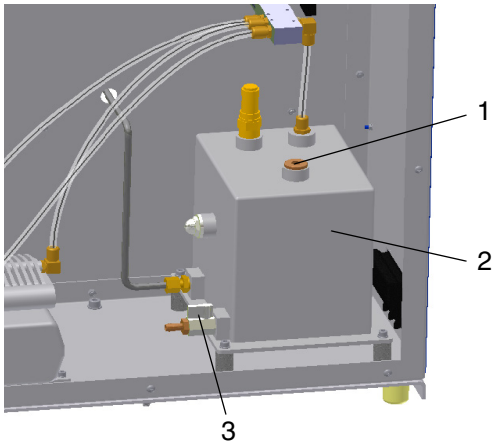


Fig. 3.4 Back view of **WL 102** with dismantled rear panel

For filling of oil, at first unscrew the rear panel. At bottom, on the right hand side, you will find the reservoir (2).

- Unscrew the sealing screw (1) of the reservoir.

NOTICE

Make sure that the discharge valve (3) is closed.

- Use, for example, a filling funnel to fill the oil into reservoir.
- For proper operation an amount of approx. 3 to 3,5 litre of Oil are required.

- Replace and tighten the sealing screw (1).

Before starting operation of apparatus, the rear panel has to be fixed properly.

3.3 Level Sensor

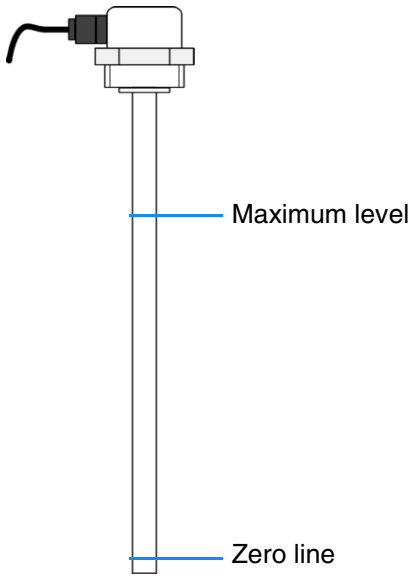


Fig. 3.5 Level sensor

The **Level Sensor** is a capacitively working sensor. The measuring rod dipped in the water is an electric capacitor. Since the dielectric constants of water and air differ greatly, the capacity of the capacitor will change measurably depending on the water level.

Calibrating the level sensor

NOTICE

Every so often, check whether the level indicator on the controller is the same as the level according to the scale on the level-controlled tank.

If the values on the controller and the level-controlled tank are different, adjust the level sensor.

There are two types of head for the level sensor:

- with potentiometers
- with push buttons

Determine which model has been used on your device and then follow the calibration procedure described below.

Calibration of the level sensor head using potentiometers

On the head are two potentiometers: *Zero* and *Span.*

- Open the air discharge valve (see Fig. 5.1, page 15) on the lid of the cylinder.
- Move the selector switch to position B.
- Turn on the compressor using the switch (3) until the oil level is at *3L*.
- Adjust the *Zero* potentiometer until the level display shows *3L*.
- Move the selector switch to position B.
- Using the needle valve (see Fig. 5.1, page 15), set the filling speed.
- Turn on the compressor using the switch (3) until the oil level is at *0L*.
- Adjust the *Span* potentiometer until the level display shows *0L*.

Fig. 3.6 Head of the level sensor

Calibration of the level sensor head using push buttons

On the head are two push buttons: *Zero* and *Span.*

- Open the air discharge valve (see Fig. 5.1, page 15) on the lid of the cylinder.
- Move the selector switch to position A.
- Using the needle valve (see Fig. 5.1, page 15), set the filling speed.
- Turn on the compressor using the switch until the oil level is at *0L*.
- Press the *Zero* and *Span* push buttons simultaneously.
- Press the *Span* push button to set the minimum value.
- The level display shows *0L*.
- Move the selector switch to position B.
- Turn on the compressor using the switch until the oil level is at *3L*.
- Press the Zero push button. This sets the maximum value.
- The level display shows *3L*.

3.4 Recording Measurement Data

This experimental device is delivered together with a program for recording measurement data on a PC. The recording software offers the following advantages:

- Measured values of pressure, volume and temperature are available as data which can be directly processed and saved.
- Clearly arranged screen displays elucidate relationships and facilitate an understanding of the processes involved.
- Values in tables and diagrams can be output to a printer.

3.4.1 Installation of the Program

The following is needed for the installation:

- A fully operational PC with USB port (for minimum requirements see Chapter , Page 21).
- G.U.N.T. CD-ROM.

All components necessary to install and run the program are contained on the CD-ROM delivered by G.U.N.T.

Installation Routine

NOTICE

The trainer must not be connected to the PC's USB port during the installation of the program. Only after the software has been installed can the trainer be connected.

- Boot the PC.
- Load the G.U.N.T.-CD-ROM.
- From the “Installer” folder, launch the **“Setup.exe”** installation program.
- Follow the installation procedure onscreen.
- After starting, the installation runs automatically. During the course of the installation, various program components are loaded onto the PC:
  - Programm for PC-data acqisition
  - Driver routines for the „LabJack®“ USB converter
- Reboot the PC after installation is finished.

3.4.2 Operating the Program

- The program is selected and started by choosing: **Start / All Programs / G.U.N.T. / WL 102**
- When the software is run for the first time after installation, the language to be used for the program is requested.
- The language selected can subsequently be changed at any time on the “**Language**” menu.
- Various pull-down menus are provided for additional functions.
- For detailed instructions on use of the program refer to its Help function. This **Help function** is accessed by opening the pull-down menu **„?”** and choosing **„Help”**.

Fig. 3.7 Language selection

4 Principles

In every gas there is a certain pressure. If the volume of an enclosed quantity of gas is reduced by compression, this pressure increases. If the volume is increased, the pressure drops. Boyle's law describes this relationship:

$$p \times V = const. \qquad (T = const.) \qquad (4.1)$$

The product of pressure and volume is constant. The two parameters are inversely proportional to each other. (cf. Fig. 4.1)

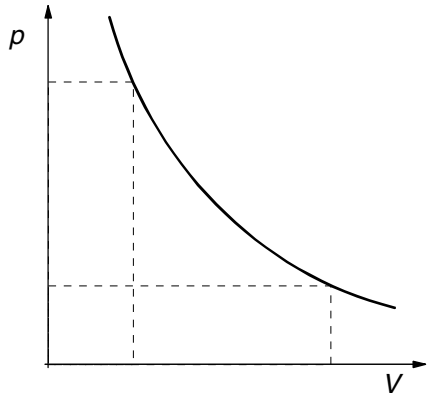


Fig. 4.1 $v \sim \frac{1}{p}$

This law is, however, only applicable if the amount of gas and the temperature do not change.

During the performance of the experiments, the heat produced by the compression can produce erroneous results. The experiment must therefore be performed sufficiently slowly that the temperature remains constant. In this case the term isothermic change of state is used.

The value for the constant *(p x V)* represents, in formal terms, an energy parameter, the so-called internal energy.

Strictly, Boyle's law only applies for ideal gases. If noticeable deviations occur, the term real gas is used, in the case of large deviations - vapour.

In the case of values for pressure and temperature in the range of normal conditions, e.g., air, hydrogen and the noble gases behave like ideal gases, chlorine and carbon dioxide like real gases, propane and butane like vapours.

A further relationship is described by the Gay-Lussac law. This states that if a fixed quantity of gas is contained in a constant volume, the pressure is proportional to the absolute temperature.

$$p \sim T \qquad (V = const.) \tag{4.2}$$

The combination of both laws leads to the general gas equation:

$$\frac{p_1 \cdot V_1}{T_1} = \frac{p_2 \cdot V_2}{T_2} = const. \tag{4.3}$$

For a fixed quantity of gas, the expression *(p x V) / T* always remains constant.

5 Experiments

5.1 Isothermic Compression

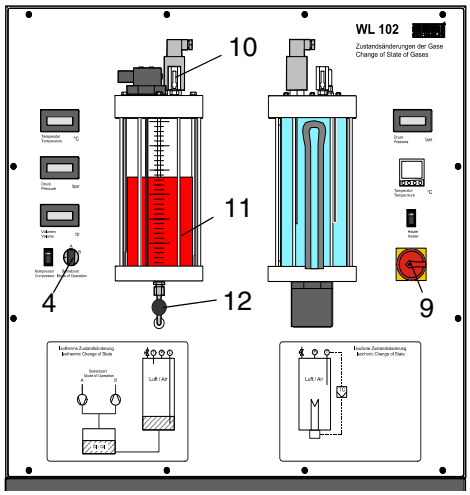


Fig. 5.1 Settings for the compression experiment

In this experiment, to check Boyle's law a fixed quantity of gas of approx. 3 litre volume is compressed to approx. 1 litre at constant temperature and the associated pressure change measured.

- Turn on the unit at the main switch (9).
- Open the air discharge valve (10) on the lid of the cylinder.
- Open the needle valve (12) and set the required filling speed.
- Move the selector switch (4) to position B.
- Turn on the compressor using the switch until the oil level reaches the *3L* mark on the vessel scale (11).
- Turn off the compressor.

NOTICE

Risk of escape of the sealing liquid.

- Ensure that the air discharge valve is in the correct position.

- Close the air discharge valve on the lid of the cylinder!
- Start the data acquisition program and make the corresponding settings.
- Move the selector switch to position A.

NOTICE

At the latest at 1 litre residual volume for the enclosed air, turn off the compressor.

- Turn on the compressor using the switch until the oil level reaches the mark on the vessel scale (*1L*).
- Open the graph of measured values and interpret.
- Leave the pressure cylinder unchanged and continue immediately with the expansion experiment.

As can be seen in the graph in Fig. 5.2 the pressure clearly increases in proportion to the reduction in volume.

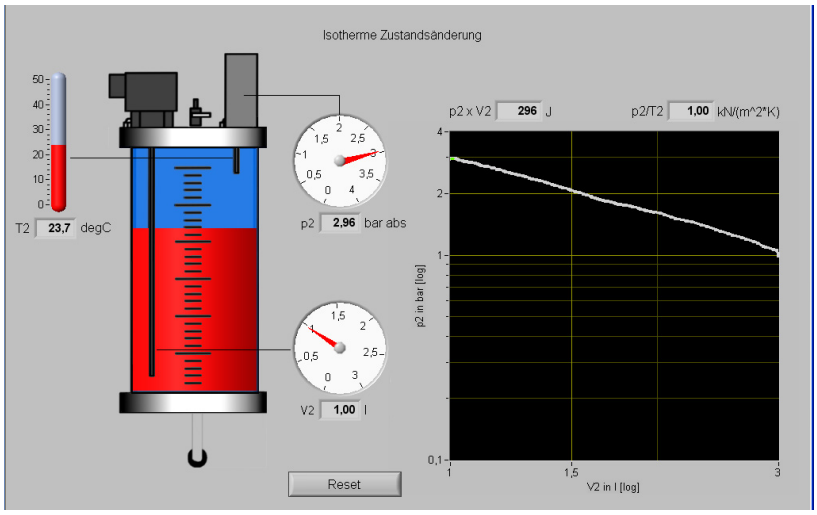


Fig. 5.2 Graph of the isothermic compression experiment

5.2 Isothermic Expansion

As an alternative, during this experiment a fixed volume of air is expanded and the change in pressure plotted.

NOTICE

Risk of escape of the sealing liquid.

- Open the air discharge valve slowly.

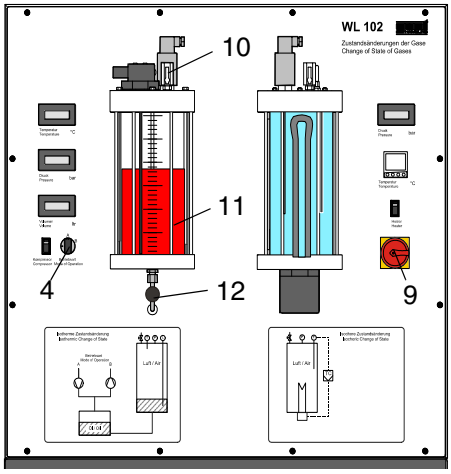


Fig. 5.3 Settings for the compression experiment

- Carefully open the air discharge valve (10) on the lid of the pressure cylinder and release the compressed air until ambient pressure is reached.
- Close the air discharge valve again.
- Open the needle valve (12) and set the required filling speed.
- Move the selector switch (4) to position B.
- Start the data acquisition program and make the corresponding settings.
- Turn on the compressor and expand the gas volume until the *3L* mark on the vessel scale (11) is reached.
- Open the graph of measured values and interpret.
- Carefully open the air discharge valve on the lid of the pressure cylinder and allow air to flow into pressure cylinder until ambient pressure is reached.

Similar to the compression experiment, this experiment produces a comparable measured result.

5.3 Isochoric Heating

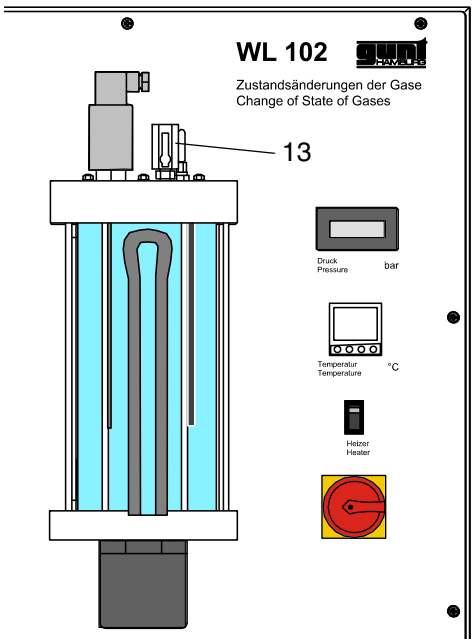


Fig. 5.4 Heatable cylinder

To check the Gay-Lussac law, in this experiment a fixed constant volume of air is heated and the resulting pressure recorded.

- Cylinder must be at the temperature sensor (13) ambient temperature.
- Switch on unit at master switch.
- Open air discharge valve on the lid of the heatable cylinder and set the vessel to ambient pressure.
- Close air discharge valve again.
- Set the required final temperature on the heating regulator using the arrow keys.
- Start data acquisition program and make the corresponding settings.
- Switch on heater and operate as long as necessary until the final temperature is reached.
- Open graph of measured values and interpret.
- Leave the cylinder unchanged and continue immediately with the cooling experiment.

Time *t* in min	Temperature *T* in °C	Pressure *p* in bar	*P* / *T* in $\frac{kN}{m^2 \cdot K}$
0	21,9	1,05	0,356
2	30,4	1,14	0,376
4	43	1,22	0,386
6	62	1,28	0,382
8	81	1,34	0,379
10	100	1,38	0,370

Tab. 5.1 Heating experiment, *V* = *const.*

As expected the pressure increases proportionally to the increasing gas temperature in the cylinder (cf. Tab. 5.1, Page 18). The quotient (p / T) remains almost constant, as expected. Despite the variation in the values of ~ 5%, this statement is still correct.

5.4 Isochoric Cooling

- Switch off heater.
- Open air discharge valve on the lid of the heatable cylinder and set the vessel to ambient pressure.
- Close air discharge valve again.
- Start data acquisition program and make the corresponding settings.
- Leave the vessel to cool to ambient temperature.
- Open graph of measured values and interpret.
- Open air discharge valve on the lid of the cylinder and set the vessel to ambient pressure.
- Switch off unit at master switch.

Temperature T in °C	Pressure p in bar	P / T in $\frac{kN}{m^2 \cdot K}$
81,1	1,00	0,282
71,6	0,98	0,284
60,0	0,94	0,282
50,0	0,92	0,285
39,8	0,90	0,288
35,0	0,89	0,289
33,2	0,88	0,287
26,2	0,87	0,291
23,4	0,86	0,290

Tab. 5.2 Cooling experiment, $V = const$

The pressure in the cylinder drops proportionally to the cooling, as expected (cf. Tab. 5.2, Page 19)). The quotient (p / T) remains almost constant. Despite the variation in the values of ~ 3%, this statement is still correct.

6 Appendix

6.1 Technical Data

Dimensions:		
L x W x H	900 mm x 550 mm x 900	mm
Weight	approx. 45	kg
Supply	230 V, ~50	Hz
Alternatives optional, see type plate		
Total volumen of pressure vessel	approx. 3,5	L
Experiment volume	min. 1	L
	max. 3	L
Pressure masuring range	0...4	bar (abs.)
Diaphragm compressor		
Overpressure	max. 2	bar
Output	max. 23	L/min
Sealing liquid	Hydraulic oil	
Volume of heatable vessel	approx. 2,3	L
Heater rating	300	W
Heater temperature	max. 80	°C
Pressure measuring range	0...2	bar (abs.)

6.2 Data acquisition:

USB communication

Program environment:
LAB-VIEW Runtime

System requirements:

- PC with Pentium IV processor, 1 GHz
- Minimum 1024 MB RAM
- Minimum 1GB available memory on hard disk
- 1 x USB port
- Graphics card resolution min. 1024 x 768 pixels, TrueColor
- Windows XP / Vista / Windows 7

7 Index