



Uni Heidelberg

Gas tightness tester

User's manual

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If you don't like reading, go directly to section 7.2.

1. About this device

This device is intended for quick measurement of gas tightness of various vessel using the pressure decay method. It uses a single, high-resolution barometric pressure sensor (BME280), giving satisfactory results for working (relative) pressure as low as 10 mbar.

A standard pressure source for the device is just a medical syringe with a typical volume of 10-100 ml. However, also external pressure sources can be used as long as they fulfill the requirements regarding device's working pressure.

Current firmware version allows for working with both over- and underpressure scenario. It automatically detects whether over- or underpressure is used.

Both raw measurement data and results can be stored in device's non-volatile memory and further uploaded to a PC using USB port and a dedicated software.

2. About this manual

This manual focuses on use of the device. Neither the details of the pressure decay method nor the detailed design description are presented here. In case of any questions or doubts, please simply ask Michał (mdziewiecki@physi.uni-heidelberg.de).

3. Connections and controls



4. Working conditions

4.1. Absolute maximum ratings

The absolute pressure of **2 bar must never be exceeded**, as it can destroy the sensor.

4.2. Recommended conditions

Pressure:

The sensor's full range is 0.3-1.7 bar. For best accuracy, the absolute pressure in any measurement phase should not exceed the range of 0.7 – 1.3 bar (ca. +/- 300 mbar relative pressure). A maximum relative pressure of 10 - 100 mbar is recommended.

Temperature:

The device is calibrated to work in room temperature (25°C). No temperature correction is applied to the sensor data, which may cause a little offset in the absolute pressure measurement, when working at a different temperature. However, this will not significantly affect the measurement results.

5. Preparing to work

5.1. Batteries

The device is powered with two AA batteries which can be exchanged by the user (rear side of the device).

The battery voltage is measured and reported each time after turning on the device, during a self-test procedure. The batteries should be exchanged when the voltage falls below 2.7V.

Using the device with lower voltages may lead to improper operation, including loss of stored data.

It is expected that the device can operate for ca. 100 hours with one set of alkaline batteries.

5.2. Gas connections

The device has a terminal for connecting two standard 6mm pneumatic hoses. They are intended for connecting a pressure source and the measured vessel. They are connected in parallel.

A pump or syringe (preferably with known volume) or any source of compressed gas can be used to feed the system. Aggressive gases should be avoided (see sensor's documentation for details).

5.3. Switching on and self-test

The device gets turned on with the red button. First, it reports hardware and firmware versions, as well as its unique serial number. After a warm-up period (ca 30 s in total), a self-test will be performed which includes checking the battery voltage and checking the operation of the pressure sensor. If the self-test fails, please refer the Troubleshooting section of this manual.

6. Main menu

```
MAIN MENU
Decay nearmnt
```

The main menu appears on the screen right after passing the self-test. User can navigate through it using up/down keys.

6.1. Decay measrmnt

Perform a decay measurement. Both vessel volume and normalized leak rate will be calculated. See section 7.2 for details.

6.2. Decay w/preset

Same as previous, but vessel volume will not be calculated. Instead, a fixed preset value will be used for calculating the leak rate. This option is intended for testing vessels of known volume. See section 7.3 for details.

6.3. View storage

View all stored measurement data and edit comments for measurements. See section 8 for details.

6.4. Clear storage

Clear all stored data.

6.5. Edit presets

Edit presets for 'Decay w/preset' measurements. Intended injected volume, total volume and a short textual description can be set for each of the 8 available presets.

6.6. Clear presets

Clear all stored presets.

6.7. Stack monitor

This option is solely for debugging. It shows minimum free space on stack for each thread (yes, this application is multi-threaded!).

6.8. Settings

Edit basic device settings. They include device's serial number (it should be always consistent with the number on the rear wall) and some measurement constants (measurement time, preset time and minimum peak pressure).

6.9. Power off

Switch off the device. Note that if the device is not used, it will switch off automatically after 2 minutes. In this case, any non-saved data for the last measurement will be lost.

7. Measurement flow

7.1. Some theory

The measurement process is divided into few phases, in which some pressure values are registered (see the figure below):

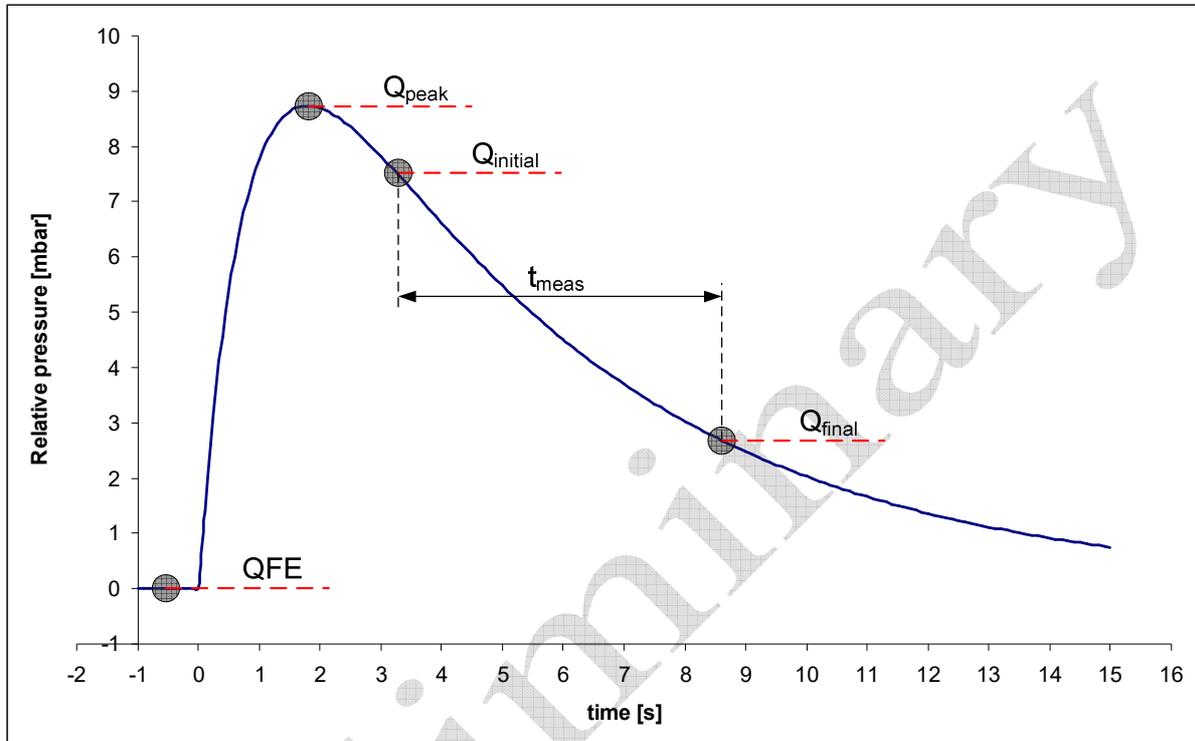


Fig. 7-1: A typical decay curve with registered pressures shown

- The *preparation phase*, which ends with measuring ambient pressure (Q_{FE}). All further pressures will be registered as relative to Q_{FE} .
- The *pumping phase*, in which the pressure gets increased. It ends with registering the peak pressure (Q_{peak}). The peak pressure might be used to calculate the vessel volume, if injected volume is known:

$$V_{total} = \frac{Q_{FE}}{Q_{peak}} \cdot V_{injected}$$

Remark: The calculated volume might be underestimated by up to **40%** due to semi-adiabatic character of the pumping process. In general, the faster pumping, the bigger underestimation is expected.

- The *hold phase*, which is an intermediate state between pumping and the right decay measurement.

- The *decay phase*, which begins with registering the initial pressure ($Q_{initial}$) and ends with registering the final pressure (Q_{final}). Also the measurement time (t_{meas}) gets registered. Typically $Q_{final}=Q_{initial}\cdot e^{-t}$, unless timeout occurs (which may happen for low leak rates). The three registered values allow for decay time calculation:

$$\tau = t_{meas} / \ln\left(\frac{Q_{final}}{Q_{initial}}\right)$$

Also, the normalized leak rate can be calculated if the vessel volume is known or has been calculated in the pumping phase:

$$leak_rate = \frac{V_{total}}{QFE \cdot \tau}$$

7.2. Performing a decay measurement

To perform a measurement, first switch on the device and wait until main menu is displayed.

```
MAIN MENU
Decay measmnt
```

Select 'Decay measmnt' and press the green button.

```
Press GREEN
to start
```

Ensure that the device is disconnected from the measured vessel or the pipework is depressurized in another way. Then press the green button.

```
Injected volume
Don't know
```

Select gas volume to be injected using up/down keys. You can select between 1, 2, 5, 10, 20, 50 and 100 ccm. If the pressure source doesn't allow for injection of a known volume, select 'Don't know' (default setting). In this case, the vessel volume and normalized leak rate can't be calculated, but the decay time constant can be still measured.

```
Initializing...
QFE=1000.00hPa
```

The device is on the initialization phase. Simply wait until it finishes. The current ambient pressure will be displayed.

```
Preset piston,
press GREEN.
```

Set the piston to desired volume if using syringe and specific injected volume was selected, then press the green button.

```
Connect tip,
press GREEN.
```

Connect the device to measured vessel. From this point, all connections must be tight. Press green button when ready.

```
PUSH!  
dP=999Pa
```

The device entered pumping phase. Push (or pull) the syringe piston or apply pressure from an external source. From this time on, the current over/underpressure will be constantly visible on the screen.

```
STOP!  
dP=1999Pa
```

The overpressure has reached the needed value for beginning the right decay measurement. Stop pumping if selected 'Don't know' for injected volume. Otherwise, continue to pump the whole planned volume.

```
HOLD!  
dP=1500Pa
```

Peak pressure has been reached. The device switches to hold phase and subsequently to measurement phase. If using syringe, avoid any piston movements.

```
Leak rate  
12.5 ccm/s/bar
```

The measurement has finished and the results can be viewed. Use up/down buttons to navigate through results. All registered pressures, measurement time, as well as calculated values can be displayed. The two following screens are worth mentioning:

```
Description
```

A comment for measurement (up to 15 characters, 0-9 A-Z) can be edited by pressing green button. User can then navigate through the string using left/right buttons and select characters with up/down buttons. Green button accepts the comment, red button **clears** it.

This comment may be also edited later by the 'view storage' option of the main menu.

```
Save & quit?
```

Press green button to save the measurement data in the device's non-volatile memory.

Remark: The measurement can be cancelled at any time by pressing the red button.

7.3. Decay with preset measurement

In this case the measurement flow is similar, however user will not be asked for injected volume. Instead, software will ask to select one of the presets before starting the measurement:

```
Preset 1/ 8:  
MY MEASUREMENT
```

Use up/down buttons to select a preset. Alternatively, a ‘Manual setting’ option can be selected. In this case, injected volume and total (vessel) volume have to be input manually. Use left/right and up/down keys to edit numbers.

After selecting or manually defining a preset, a regular measurement starts. Please refer to section 7.2 for details.

8. Data storage

The device can store up to 50 measurement results in its non-volatile memory. After filling the last free slot, oldest measurements will be overwritten. The contents of the memory can be viewed by the ‘View storage’ option of the main menu. They can be also uploaded to a PC.

Each measurement is stored as a structure of the following form:

Name	Type	Unit	Description
type	uint16	-	0x00 for empty slot, 0x01 for decay test, 0x02 for decay test w/preset
nr	uint16	-	unique number of the measurement
qfe	float	Pa	measured ambient pressure
qpeak	float	Pa	measured relative peak pressure, always positive
qinitial	float	Pa	measured relative initial pressure, always positive
qfinal	float	Pa	measured relative final pressure, always positive
time	float	s	time between reaching qinitial and qfinal
tau	float	s	calculated decay time constant
volume_total	float	cm ³	calculated vessel (total) volume
leak_rate	float	cm ³ /s/Pa	calculated normalized leak rate
volume_injected	float	cm ³	injected volume
dir	float	-	+1 for overpressure measurement, -1 for underpressure
comment	char[16]	-	user comment (C-standard, 15 characters + trailing zero)

All floats are of single precision (32-bit IEEE 754).

9. PC software

9.1. Requirements

The software is developed in QT and distributed as source code. No OS-specific libraries are used, so it should be compilable for any system supported by QT.

An FTDI chip is used to support USB communication, which is known to be well supported by all today’s operating systems.

9.2. Overview

The main window is shown in the figure below. After pressing the “Connect!” button, the software will look for a connected device among all serial ports. If a device is found, the remaining buttons will be activated.

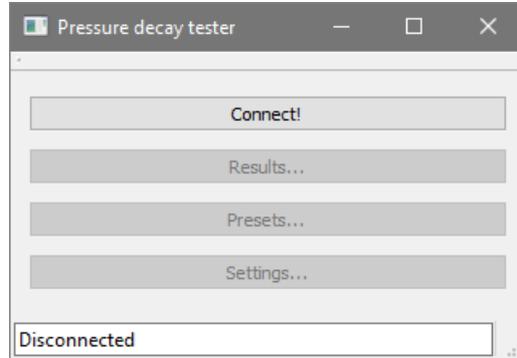


Fig. 9-1: Main window

Remarks:

- The process of port scanning includes opening all available ports and sending data to them. This could – in some cases – cause some kind of (mis-)operation of other connected devices.
- The software is currently single-threaded. This causes some remarkable delays when exchanging data with the device.

9.3. Managing data

The measurement data can be accessed by clicking the “Results...” button. A new window will be opened (see figure below) and all data will be automatically downloaded from the device.

User can switch between viewing device data and database data (i.e. data which is stored in the PC). The ‘copy data’ button copies all non-empty records from the device to database. Records with the same device serial number and measurement number will be overwritten. In both views, the data can be exported to a text file. In database view, user can also delete selected records.

	device	nr	type	comment	leak_rate	tau
1	3	1	1	COKE	1.340654216619...	607.0046997070.
2	3	2	1	COKE	2.923552347056...	279.6057739257.
3	3	3	1	COKE	0.000104410006...	85.68545532226.
4	3	4	1	COKE T	1.825199615268...	515.1870117187?
5	3	5	1	COKE T	0	-784.068908691.
6	3	0	0		0	0
7	3	0	0		0	0
8	3	0	0		0	0
9	3	0	0		0	0
10	3	0	0		0	0
11	3	0	0		0	0
12	3	0	0		0	0
13	3	0	0		0	0
14	3	0	0		0	0

Fig. 9-2: Results window

Remarks:

- Tab is used as a delimiter in exported files.
- The database is stored in a text file: ‘database.csv’ in program’s main directory.
- See section 8 for used units.

9.4. Managing presets

Presets are managed in a similar way as data. There are two main differences:

- There’s only a single view (no database). However, presets still can be saved and loaded from text files.
- Table contents can be edited.

Presets can be also viewed and edited via device firmware, without connecting to a PC.

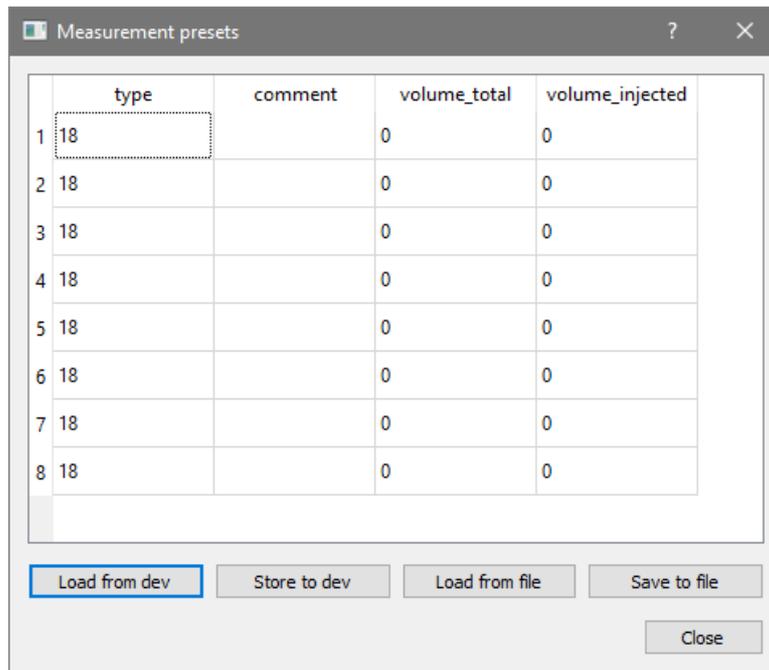


Fig. 9-3: Preset window

9.5. Managing device settings

The settings window allows viewing and changing device settings. Use ‘Load from device (EPROM)’ and ‘Store to device (EPROM)’ buttons to exchange data between the device and the PC. Other buttons are for development use.

Settings can be also viewed and edited via device firmware, without connecting to a PC.

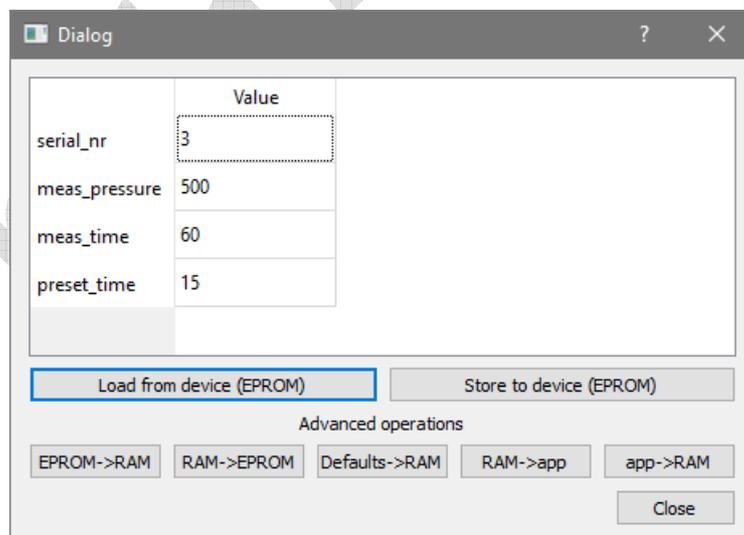


Fig. 9-4: Settings window

10. Troubleshooting

In case of any troubles, just ask Michał: mdziewiecki@physi.uni-heidelberg.de.

11. More information

All project files, this manual and software are available under <https://gitlab.cern.ch/lhcb-scifi/gastightness>. CERN login is required.

Preliminary