Pulmonary Waveform Generator

PWG-33 and PWG-33BT

User Manual

- Installation
- Maintenance
- Operation
- Technical files of firmware and software

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Contents

1. Introduction

Pulmonary waveform generator is the most essential equipment for developing and testing spirometers and other flow/volume measuring devices.

PWG-33 is the ideal test equipment for R&D companies, for manufacturers and for authorized test laboratories as well.

The PWG-33 Pulmonary Waveform Generator provides predefined *flow*(*time*) and *volume*(*time*) waveforms for validation and calibration of Spirometers and other equipments measuring flow and volume.

1.1. Covered standards

Waveforms generated by PWG-33 and evaluations of test results are fully compatible with the following standards and recommendations:

- "Standardization of Spirometry" issued by American Thoracic Society on 11 November 1994
- EN ISO 26782:2009 – "Anaesthetic and respiratory equipment - Spirometers intended for the measurement of time forced expired volumes in humans"
- EN ISO 23747:2009 – "Anaesthetic and respiratory equipment - Peak expiratory flow meters for the assessment of pulmonary function in spontaneously breathing humans"
  (former referenced as „EN 13826:2003 - Peak expiratory flow meters")

1.2. Generated waveforms

The PWG-33 generates the following standard waveforms:

- 24 ATS Standard *volume*(*time*) waveforms
- 26 ATS Standard *flow*(*time*) waveforms
- 13 Standard waveforms according to EN ISO 26782:2009 Annex C
- 10 Standard waveforms according to EN ISO 23747:2009 Annex C, profile A
- User configured waveforms according to EN ISO 23747:2009 Annex C, profile B

User defined waveforms:

- Sine waveforms
- Square waveforms
- *Volume*(*time*) waveforms
- *Flow*(*time*) waveforms

Number of user defined waveforms is unlimited.

1.3. Main features

Extreme powerful design

- Volume up to 10 l
- Maximal flow rate of 20 l/s

Automatic operation

- Full automatic resistance measurement
- Full automatic calibration of PWG's internal resistance
- Full automatic tests via software interface mode
- Remote control port (optional)

BTPS simulation (optional in PWG-33BT)

- PWG is providing heated and humidified air
- Adjustable air temperature

Automatic evaluation of test results

- error analysis
- flow resistance calculation

according to given standards.

Full support of individual control of the device

- Public USB communication protocol
- Utilities for data conversion
- Command-line (DOS) control tools

Technical support

- Software updates
- Firmware updates

are free of charge

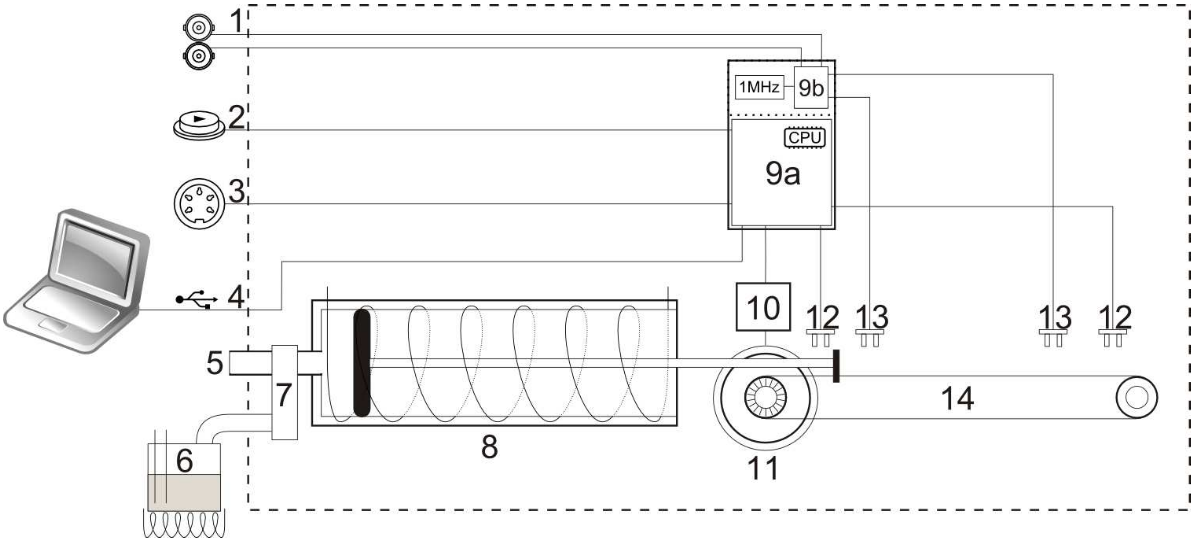
Sleep Mode

PC software automatically sets PWG to a low power state after a given idle time. In Sleep Mode the motor current is turned off. Any commands will wake PWG from Sleep Mode.

1.4. Principle of operation

PWG-33 is a pneumatic syringe driven by a stepper motor. Each step moves the cylinder by a constant volume of 0.345 ml. This step volume equals to the theoretical volume resolution of the generator. Desired flow rates are achieved by setting the precise delay time between two consecutive steps in a resolution of 12.5 ns. Generated *volume*(*time*) and *flow*(*time*) waveforms are transformed to *step-delay-time*(*volume*) functions.

Block diagram



Items' description

Item	Description
1	Calibration ports
2	Control button
3	Remote control port
4	USB plug
5	Pneumatic outlet
6	Humidifier connected to the BTPS inlet
7	Two way (BTPS) valve
8	Heated syringe
9	Circuit board
9a	Main circuit with the internal microcontroller
9b	Separate calibration circuit
10	Schneider Electric SD326 stepper motor controller
11	Berger-Lahr stepper motor
12	Photo interrupters: end-position sensors
13	Photo interrupters for kinematic test
14	Timing belt driving the piston

Phases of operation

- Objects being tested must be connected to the pneumatic outlet.
- A stepper motor drives the piston by a timing belt.
- PC software converts desired waveforms to *step-delay-time*(*volume*) functions.
- Converted waveforms are copied to an internal SD memory card built into the PWG.
- Waveform generation can be started via
  - USB protocol (PC software)
  - Start button on the device
  - Remote Control Port (optional)
- PWG's microcontroller feeds a timer through a DMA with timing data read from the SD card.
- The timer event sends a pulse to the stepper motor controller forcing the motor to make a step. The generated waveform consists of consecutive steps.
- Rotation of the motor is supervised by a built in photo interrupter and a stroboscope disc. When step is impossible to perform due to the overload an error message is generated.
- A heated humidifier is providing tempered and vaporized air for BTPS simulation. The pneumatic syringe is also tempered to avoid condensation.
- During BTPS inhalation the BTPS valve is opened towards the humidifier.
- During expiration the BTPS valve is opened towards the pneumatic outlet.
- Two extra photo interrupters are built in at constant piston positions for kinematics checking.

1.5. General consideration on certain flow meters

Some flow meters may show undesired side effect due the volume step sequence of the generated waveforms. It is easy to recognize this phenomenon because the measured flow rates and volumes will be unexpectedly high. According to our experience this side effect may occur to the turbine type and to the differentiating flow meters like Pitot-tubes.

☞ In this case some pneumatic filter has to be installed in between the device being tested and the pneumatic outlet of the generator.

A good choice could be a laminar flow element like a Fleisch-tube or a simple PFT bacterial and viral filter. Be moderated in increasing the dead space and the resistance of the system apply serial pneumatic filtration only up to the necessary extent.

1.6. Technical data

1.6.1. Pneumatic information

Pneumatic outlet ....ISO-30 Medical taper Male OD=30,2 mm Basic taper 1:20
Maximal back-pressure of the object being tested... 4.0 kPa at 12 l/s
Volume resolution..0.345 ml
Maximal volume ....10.00 l
Maximal flow rate.. 20.0 l/s
Minimal rise time to flow rate16 l/s at back-pressure 3 kPa .... 4 ms
Maximal slew rate to flow rate16 l/s at back-pressure 3 kPa ....$4000\ l/s^2$

1.6.2. Accuracy

Volume..0.2 % or 10 ml which ever is larger
Flow ....0.3 % or 15 ml/s which ever is larger
Time ....0.02 % or 1 ms which ever is larger
Temperature of air with BTPS simulation... 37 °C ± 1 °C
Relative humidity of air with BTPS simulation.. 92 % ± 5 %
Distance between photo interrupters for verification (nominal value).......................127 mm

1.6.3. Environmental conditions

The equipment complies with the EN 606001-1:1997 standard

Transporting conditions
Temperature...-30 °C ÷ +60°C
Relative humidity.. 10% ÷ 100% (non condensing)
Ambient pressure ....500 ÷ 1060 mbar

Storage conditions
Temperature... 0 °C ÷ +50°C
Relative humidity.. 10% ÷ 85%
Ambient pressure ....500 ÷ 1060 mbar

Operating conditions
Temperature...+10 °C ÷ +35°C
Relative humidity.. 30% ÷ 75%
Ambient pressure ....700 ÷ 1060 mbar

1.6.4. Electrical data

Nominal voltage *(switchable)*.. 115 or 230 VAC
Mains voltage tolerance at 115 VAC... 100 ÷ 130 VAC
Mains voltage tolerance at 230 VAC... 170 ÷ 240 VAC
Frequency.. 50 / 60 Hz
Power consumption; PWG-33 .... max. 25VA
Power consumption; PWG-33BT .... max. 770VA

1.6.5. Mechanical properties

Size without humidifier ....1100 mm × 370 mm × 265 mm
Weight... 38 kg

1.7. List of accessories

PWG-33 equipment ....1 set
External piston rod..1 piece
USB cable ....1 piece
SD Card – 2 GB ....1 piece (built in)
Software ....On the built in SD card
Users’ Manual.. 1 copy
Additional items for PWG-33BT
Heated humidifier ....1 set
Tubing, connectors as listed in the section 2.1.4: Humidifier ....1 set

1.8. Minimal PC configuration

Operating system .... Windows XP, Vista, 7
Computing capacity ....See operating system recommendations
Platform ....booth 32 and 64 bit supported
Free USB 1.1 or 2.0 compatible port...1 port

2. Installation

2.1. Installing device

2.1.1. Appropriate placement

PWG-33 should be positioned so that at least 10 cm distance is kept around the ventilation openings on left and back side. Always place PWG-33 on a stable horizontal surface. Keep in mind that weight of the device is close to 40 kg (90 pounds) and due to the high acceleration of internal mechanical parts it might cause horizontal shake of the table (maximal momentum of 0.6 kgm/s).

2.1.2. Selecting mains voltage

Mains voltage is factory set to 115 or 230 VAC. Factory setting can be checked on the yellow label next to the power connector.

WARINIG!

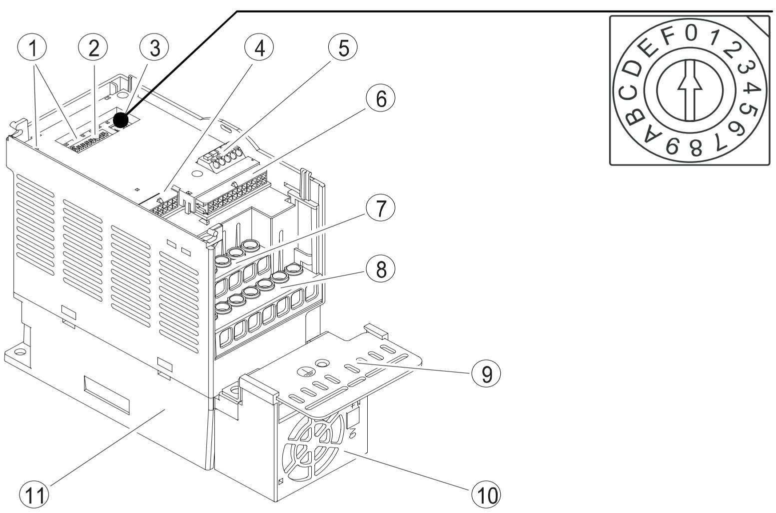
⚠	**Connecting the device to improper line power will damage the Schneider Electric stepper motor controller!**

To switch mains voltage, contact the manufacturer for detailed instructions.

2.1.3. Adjusting motor current

Under special application conditions the device might require extra power to generate high speed waveforms without step error; for example working with high flow resistance test object at high flow rate. In such situations the design of the device provides the possibility to increase the maximal motor current.

- ☞ Turn off the device and unplug power cord
- ☞ Remove the cover of the device as described at paragraph 10.2.2: Removing the cover.
- ☞ Locate the Schneider Electric SD326 stepper motor controller
- ☞ Locate the Rotary switch (3) for setting the motor current



☞ Use the rotary switch to select the desired motor current.

Pos	**I_{max} [A]**	**Pos**	**I_{max} [A]**
0	0.6	8	1.6
1	0.8	9	1.8
2	0.9	A	1.9
3	1.0	**B**	**2.0** (factory default)
4	1.1	C	2.1
5	1.3	D	2.3
6	1.4	E	2.4
7	1.5	F	2.5

WARNING!

⚠

Increase the current only step-by step! Test each setting!

Use the minimal current level that complies with your needs!

Never increase the current to levels that are causing even temporary mechanical deformations during waveform generation!

☞ Reconnect power cord and turn on the device to test your settings using an adequate waveform. Be careful while operating the generator with opened casing!

☞ If the motor current is sufficient turn the device off, remove power cord and reinstall casing. Reconnect power cord.

2.1.4. Humidifier (only for PWG-33BT)

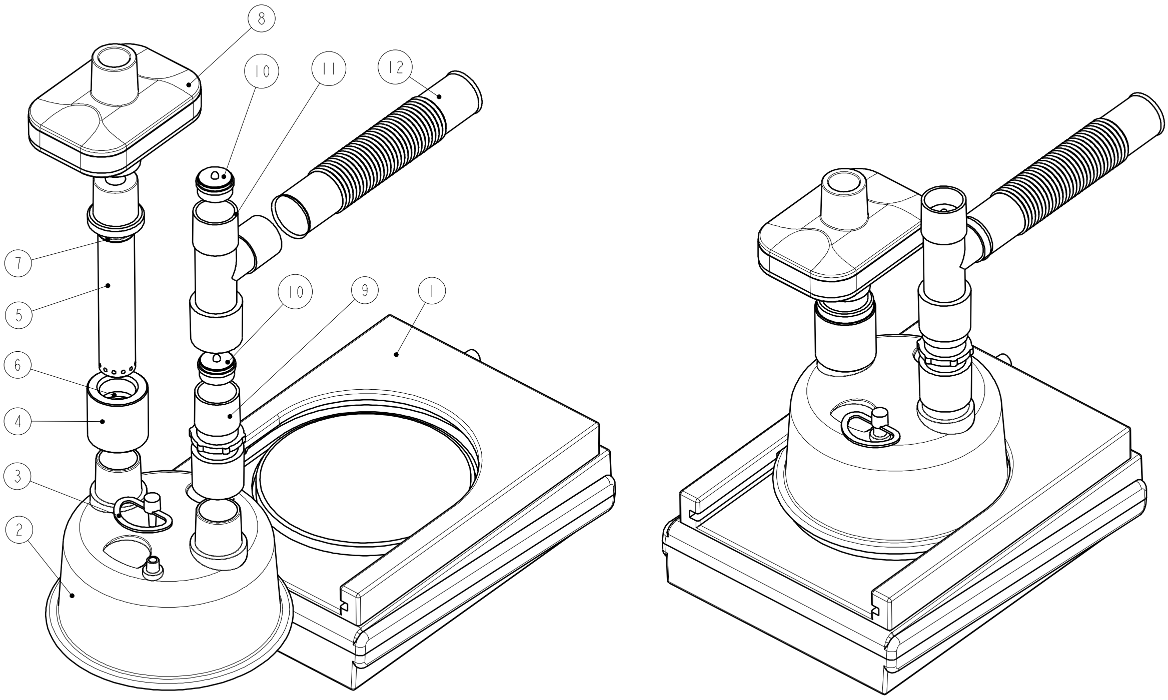
Before using BTPS simulation mode install the humidifier module in the following order.

☞ Connect the heater module’s electrical cable to PWG’s humidifier port.

☞ Connect the hose to the BTPS inlet of the device.

☞ Fill the humidifier chamber with distilled water

☞ Assemble the humidifier module in the order shown on the scheme.



Item list

Item	Name	Manufacturer	Part number
1	Heater module	Contact supplier	PWG-33-HUM
2	Humidifier chamber	Fisher & Paykel	MR250
3	Chamber's plug	Fisher & Paykel	part of MR250
4	Bubbler adapter	Contact supplier	PBM22/f
5	Bubbler inlay	Contact supplier	PBM22/m
6	O-ring 22x2 NBR70	Superseal	OR22x2
7	O-ring 14x2 NBR70	Superseal	OR14x2
8	Filter	Intersurgical	IS1944
9	Straight connector 22M-22F	Intersurgical	IS1961
10	Check valve	Intersurgical	IS1920
11	T-piece connector 22M-22M-22F	Intersurgical	IS1982
12	Aerosol hose D22	Intersurgical	IS1573

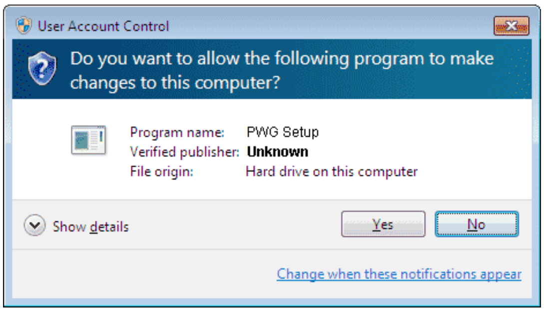
2.2. Device drivers

PWG-33 Pulmonary Waveform Generator is a composite device of a generic HID device plus a generic mass storage drive. You do not need any device drivers to be installed on supported operating systems. Connect the device to a free USB port of the computer.

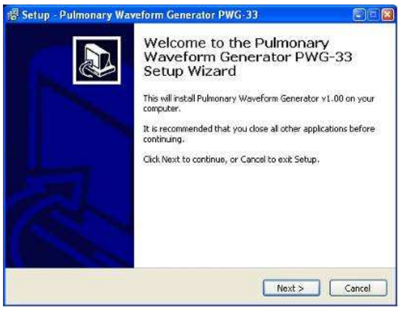
2.3. Installing software

Once the device is connected to the PC the built in SD card will be recognized as a mass storage drive.

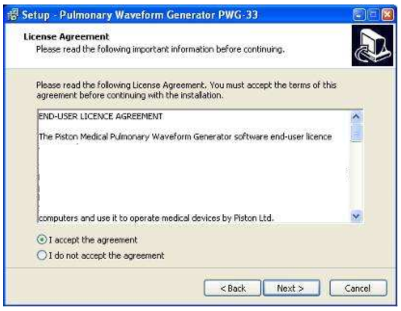
- Open My Computer (Windows XP) or Computer (Windows 7)
- Locate the drive letter associated to PWG's SD card (for example E:)
- Locate and launch pwg_setup.exe
- Click "Run", "Yes", etc. if security messages are asking for confirmation



- Follow the instructions of the setup application to install the PC software



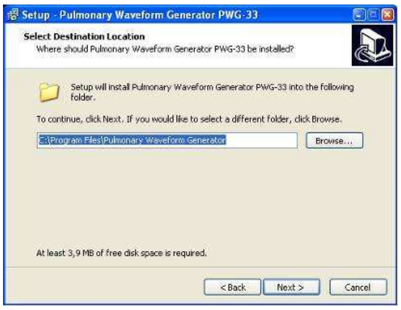
Click [Next] to skip Welcome screen



Read the license agreement

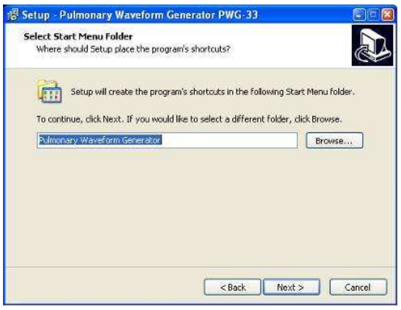
Select "I accept the agreement"

Click [Next]



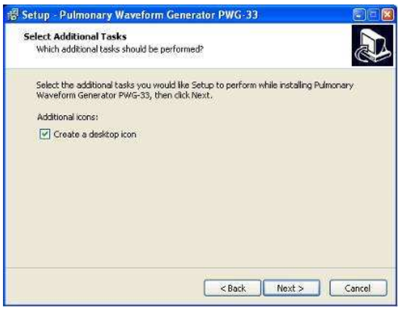
If required, select a different destination folder

Or click [Next] to skip this step



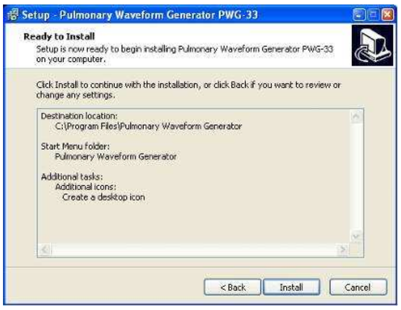
If required, select a different Start menu program group

Or click [Next] to skip this step

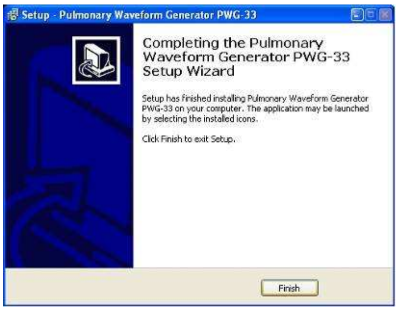


Uncheck the checkbox if you do not want to create a desktop icon

Or click [Next] to skip this step



Click [Install] to start copying files



Click [Finish] to close setup application

☞ Open the Start menu to launch the installed application

2.4. Post-install configuration

Launch the installed application. You will arrive at the welcome screen. The PWG Software automatically recognizes if the device is connected or not. Drive letter assigned to the built in SD card is also detected. If the device is connected a confirmation text will appear at the top of the window:

```
Device connected as DRIVE:
```

where DRIVE: is the actual drive letter assigned to the SD card.

2.4.1. Check device connection

To test device connection and check its basic mechanical and electrical parameters click the button [Device Info]. The following information will be displayed:

Property	Description
Type	Type of generator. PWG-33 or PWG-33BT
Serial number	Serial number of device: PWG-33[BT]-20yy-nnn where *yy* is the year of construction *nnn* is the serial number of device
Volume	Functional volume of the generator
Dead space	Volume of the syringe including dead space
Peak flow	Maximal allowed flow rate
Peak BTPS flow	Maximal allowed flow rate during BTPS inhalation
Slew rate (Accel.)	Maximal acceleration speed
Slew rate (Decel.)	Maximal deceleration speed
Step volume	Volume in/expired during a single step of the motor
Calib. steps	Step count between the two calibration photo interrupters

2.4.2. Set institute data

Institute data will be printed on reports and stored in project files. To change this data perform the following steps:

- ☞ Click the button [Configure]; the Setup dialog box will pop up.
- ☞ Choose the tab [Institute Data].
- ☞ Fill the form implicitly
- ☞ To store settings, click [OK]

2.4.3. Configuration of the Waveform Generator

Some device-related parameters should be set before the first use. To change this settings perform the following steps:

- ☞ Click the button [Configure]; the Setup dialog box will pop up.
- ☞ Choose the tab [Device setup].

Return to zero speed
Speed of the piston (in l/s) moving to basic zero position. This setting is stored in the device itself; option is only available if the device is connected. Default value is 5 l/s.

BTPS inspiration speed
Speed of the piston (in l/s) during inhalation of heated and vaporized air. Default value is 0.5 l/s. Adjust this option carefully as too high values can lead to step error or direct water inhalation!

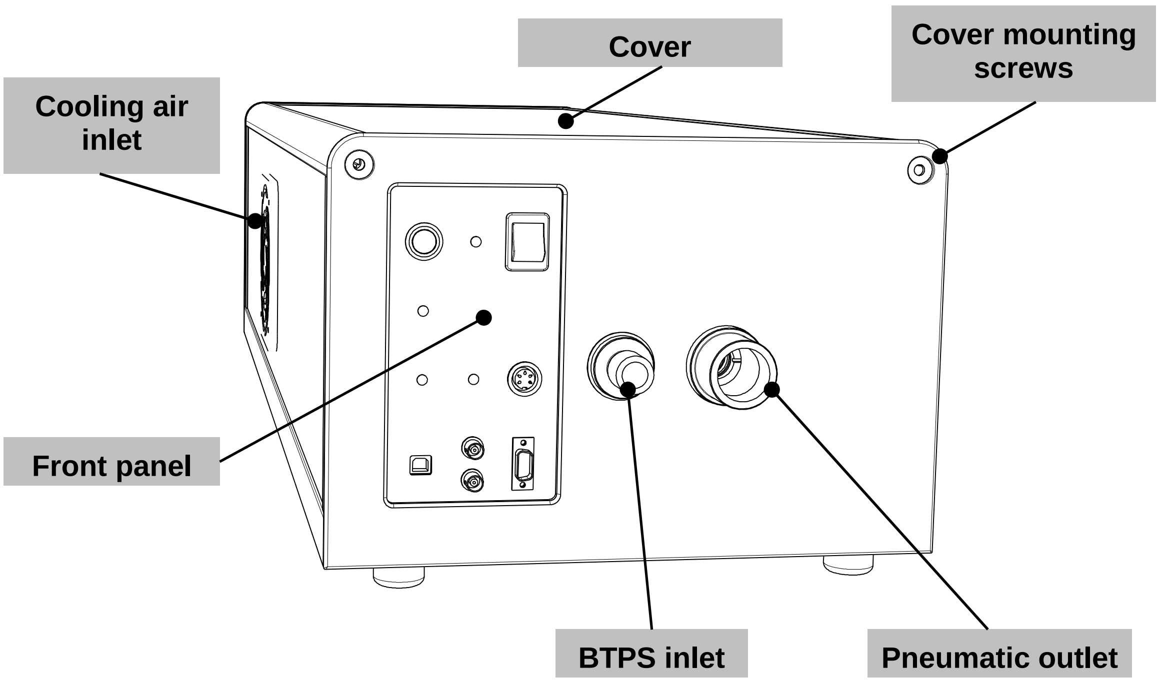
Store piston temperature log
Piston’s temperature is logged when the PWG application is started. This log can be stored for later analysis. Default value is “No”.

Enter sleep mode after...
When the PWG application is started the device is set to Sleep Mode after the idle time that was set here.

3. Device overview

3.1. Design

Main components of the device are shown on the following figure.



Front panel
The most important controls and indicators of the PWG are placed on the front panel.

BTPS inlet
BTPS inlet is the pneumatic plug that receives the humidifier's flexible hose.

Pneumatic outlet
Interchangeable pneumatic plug for receiving objects that are being tested.

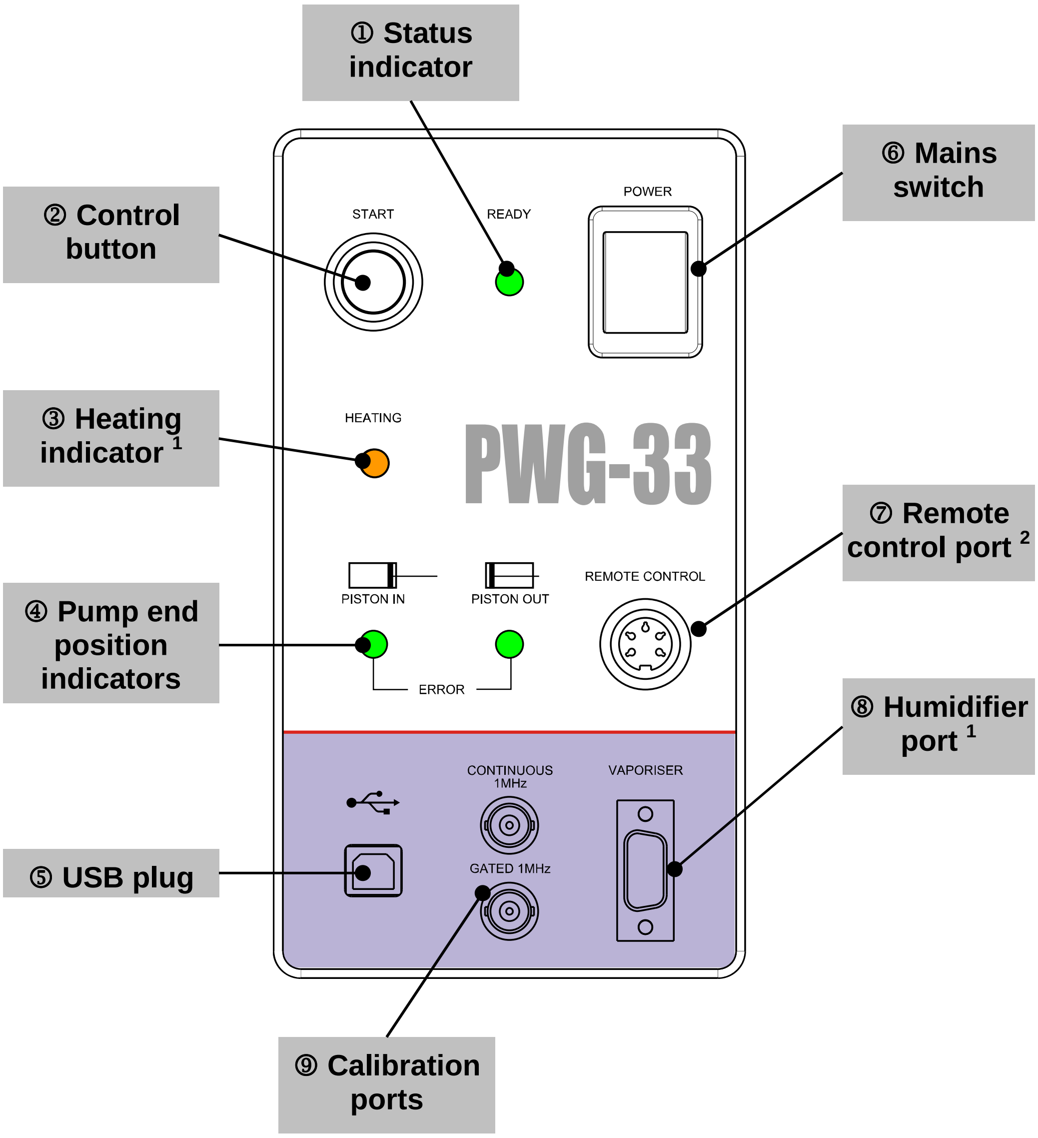
Cooling air inlet
Never cover ventilation openings

Cover
The removable housing covers the top and both sides of the device.

Cover mounting screws
The four hex socked bolts placed in the four upper corners are fastening the cover.

3.2. Front panel

Complete set of controls and indicators of the front panel are shown on the following figure. Some of these controls are optional.



[1] Available on PWG-33BT
[2] Available with remote control option

3.2.1. Basic components

Mains switch
The mains switch interrupts the power supply of the device. To turn on the device switch it to position I.

Humidifier port
Power supply and data interface port of the humidifier.

USB plug
Connect the waveform generator to the PC’s USB 1.1 compatible port.

3.2.2. Indicators

LED light indicators are displaying basic status information about the PWG. LEDs can be turned of, they can light, or they also can blink with different frequencies.

Status indicator ①

- Lighting status indicator refers that the device is ready to generate a waveform.
- Blinking status indicator refers that the device is in sleep mode. (Blinking frequency is 50 / min)
- Status indicator blinking briskly after turning on PWG refers that the device is ready for firmware update.

Heating indicator ③

- Turned off heating indicator refers that the BTPS simulation is turned off
- Blinking heating indicator refers that BTPS simulation is turned on and the device is in warming up state.
- Lighting heating indicator refers that the device is ready for BTPS simulation.

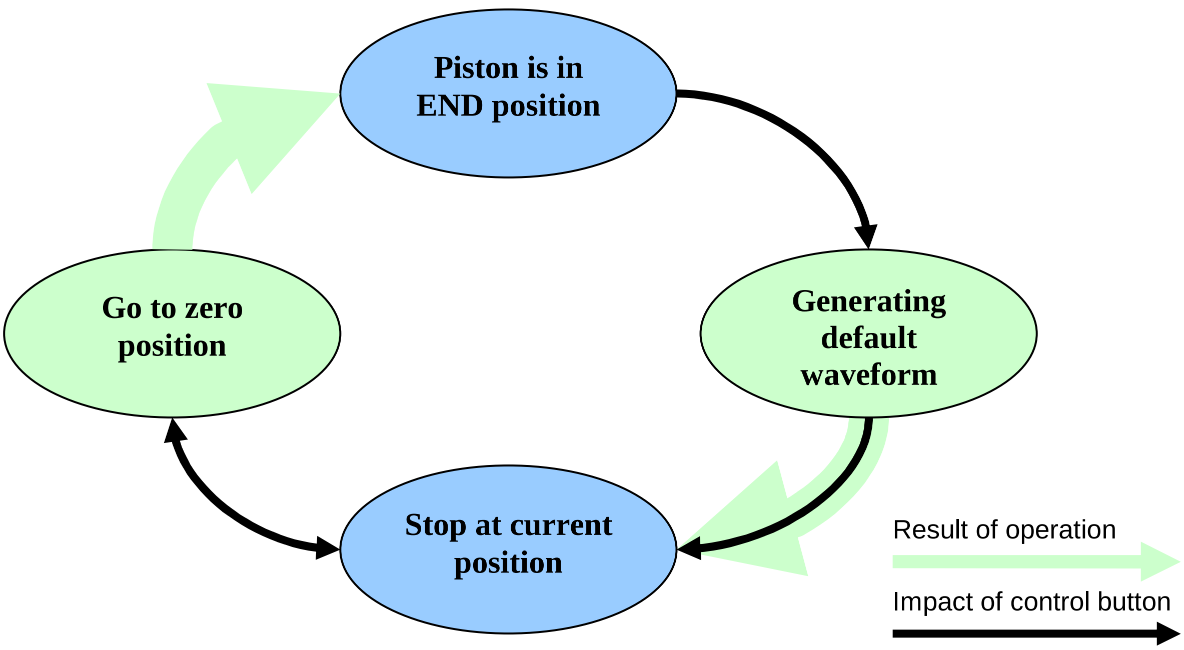
Pump end position indicators ④

The two LED's of Pump end position indicators can light up together or separate.

- Turned off indicators are referring that the piston is not in any of its end positions.
- Lighting only one of the two indicators refers that the piston is in the signed end position.
- One indicator lighting another blinking refers that the piston ran out of range at the end signed by the blinking indicator.
- Both indicators blinking are referring to step error.

3.2.3. Control button

Use Control button to manually send the piston to zero position, start waveform generation or stop any movement. Pressing the Control button will raise the following events:



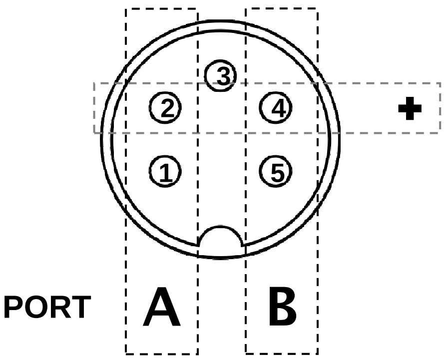
Control cycle

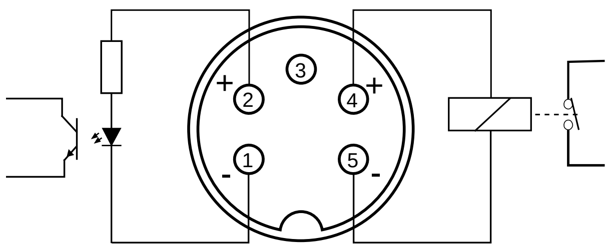
- When the piston is in zero position, control button will start generating the default waveform, if present.
- During waveform generation, control button will stop the piston at current position.
- When the piston is not in zero position, control button will move it to zero position.
- Control button interrupts even the “go to zero” operation and will stop the piston at the current position.

⚠ **Control button can only be used in NORMAL mode. The user is responsible to use a non-inverse waveform.**

3.2.4. Remote control port (optional)

Remote control port was designed to control the PWG from an external electrical device. The DIN 45322 (5-pin at 60°) plug has two control ports on two different pair of wires:





Port	Pin	Technology	Voltage range	Polarity
A	1-2	Optocoupler	3 ÷ 25 VDC	Pin 2 is ✚
B	4-5	Reed relay	4 ÷ 7 VDC	Pin 4 is ✚

Schematics are showing the **female DIN** plug on the front panel and **external view**.

Principle of device control corresponds with the mechanism described for control button.

3.2.5. Calibration port

These two BNC connectors can be used for kinematics checking. See chapter 4.2: Kinematics checking for details.

3.3. Error messages

Heating indicator ③

- Heating indicator blinking briskly after setting Ambient valve refers to valve error.

Pump end position indicators ④

- One indicator lighting another blinking refers that the piston ran out of range at the end signed by the blinking indicator.
- Both indicators blinking are referring to step error.

3.4. Firmware update

Firmware is the internal software of the PWG's built-in microcontroller. Do not mix it up with the software running on the PC. Updating the firmware is necessary only when your supplier calls your attention for that.

WARNING!

⚠ **Improper implementation of firmware update can permanently lose device functionality! Always keep instructions of this documentation!**

Firmware update of PWG-33 is possible via standard USB connection. Firmware update tools are bundled with the firmware binary file.

Firmware update tool:
PIC32UBL.exe

3.4.1. Checklist

Before you continue read the following remarks carefully:

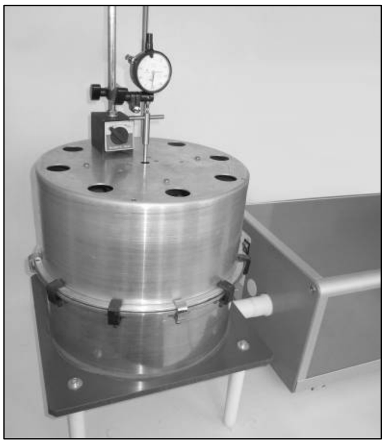
- Never try to update the firmware if not necessary!
- Always consult the manufacturer before doing a firmware update!
- Check the documentation of the firmware release about compatibility!
- Always use an uninterruptable power supply to avoid power loss of device and PC during the operation

3.4.2. Step by step

Perform the follow the instructions:

- ☞ Plug the PC to an uninterruptable power supply or use a notebook with fully charged batteries
- ☞ Copy the firmware update tools and the binary file holding the new firmware to the PC
- ☞ Use the PWG configuration tool to store device parameters (see firmware release notes)
- ☞ Turn off the device
- ☞ Connect the device to an uninterruptable power supply
- ☞ Do NOT turn on the device; press and hold the Control button
- ☞ Holding the Control button, now turn the device on
- ☞ The Status indicator will start to blink briskly
- ☞ Now release the Control button
- ☞ Start the firmware update tool
- ☞ Follow the instructions supplied with the firmware to perform the upgrade process
- ☞ Turn off PWG, wait 15 seconds then turn it on again
- ☞ Use the PWG configuration tool to restore device parameters (see firmware release notes)

4. Validation

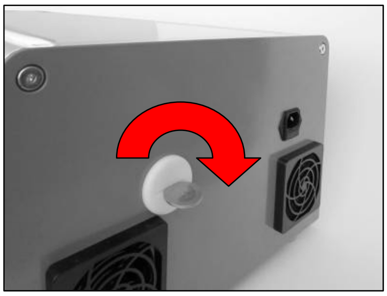


There are two main factors determining the accuracy of the waveforms generated by the generator:

- Proper sealing
- Proper movement of the piston

4.1. Check of sealing

Sealing should be checked in the total stroke of the piston under a certain working pressure. For this purpose a closed circuit constant pressure generator is needed. The most convenient device for checking the sealing is a “rolling seal” spirometer with a weight on the upper moving part providing the necessary working pressure.



Install the rolling seal spirometer in a way that the movement of piston was vertical. Calculate the appropriate weight, which could provide pressure in the range of 800 Pa to 1.2 kPa.

- ☞ Turn off the PWG.
- ☞ Remove the white plug on the back panel turning with a coin.
- ☞ Screw in the External piston rod.
- ☞ Connect the spirometer to the PWG with a solid wall tube.
  Push and pull till impact the piston with the External piston rod.
- ☞ Repeat this step 20 times.
- ☞ The loss of the volume due to the leakage can not be higher than 10 ml in a full stroke pro cycle.

4.2. Kinematics checking

Accuracy of the generator should be tested without load and with the maximal load. To achieve the maximal load use a laminar artificial resistance.

4.2.1. Principle of the test

Measure piston’s transit time between the two photo interrupters built in at dedicated points of the full range.

Just a TTL level frequency and event counter is needed to measure the time intervals.

There are two BNC connectors at the right side of the generator:

- The upper BNC connector [Continuous 1 MHz] is an output with the basic clock frequency.

- The lower BNC connector [Gated 1 MHz] is an output with the gated 1 MHz.

The two photo interrupters at the position of 1 liter and 5 liter gate out the basic clock frequency. The time interval can be measured by a TTL level event counter. The value of the LSB is 1 μs.

4.2.2. Calculation of transit times

The kinematics checking of the equipment should be done in square wave mode. The actual number of the steps between the two photo interrupters can be read out from the device as described in the section 2.4.1: Check device connection.

- ☞ Read the actual number of the steps N_{nom} between the two photo interrupters form the device. Values of N_{nom} are dedicated for each individual generator.
- ☞ Read the actual step volume V_{step} from the device. Value is in ml. Divide it by 1000 to get value in liter
- ☞ Create testing waveforms of 10 liters of volume and of different flows
- ☞ Measure the precise frequency f and pulse time T_{1MHz} of the [Continuous 1 MHz] output
- ☞ Calculate number of pulses $N_{pulse,n}$ between the two photointerrupters for each flow rate n ($\dot{V}_n$):

Nominal pulse count

$$N_{pulse,n} = \frac{N_{nom} \times V_{step} \times f}{\dot{V}_n}$$

4.2.3. Examples

Clicking [Device Properties] button at the welcome screen reports the following data:

N_{nom} = 11532 *steps* (Number of steps is dedicated for each individual generator)

V_{step} = 0.345 *ml*

Measuring the continuous 1 MHz results

f = 1 000 063 *Hz*

Calculations

1 liter / s

$$N_{pulse,n} = \frac{11532 \times 0.000345 \times 1000063}{1} = 3978565\,pulses$$

5 liter / s

$$N_{pulse,n} = \frac{11532 \times 0.000345 \times 1000063}{5} = 795713\,pulses$$

5. Software overview

5.1. Main features

5.1.1. Waveform library

PWG software is cataloguing waveforms in the Waveform Library. All waveforms have their own name. Similar purpose waveforms can be grouped together. Waveform groups are separated to factory default library and custom waveforms. Catalogued waveforms can be then added to custom waveform sets. Waveform sets can be used to test a couple of waveforms automatically.

5.1.2. Generating periodic signals

PWG-33 can generate sine and square (trapezoidal) waveforms configured by the user. Variable parameters are peak flow, expired volume, period time and rise times. This periodic waveforms then can be repeated a given number or even infinite times. Defined sine and square waveforms can be stored in the Waveform Library.

5.1.3. Generating predefined waveforms

PWG-33 provides four main groups of predefined waveforms:

- 24 ATS Standard *volume*(*time*) waveforms
- 26 ATS Standard *flow*(*time*) waveforms
- 13 Standard waveforms according to EN ISO 26782:2009 Annex C
- 10 Standard waveforms according to EN ISO 23747:2009 Annex C, profile A and profile B

User can define further custom waveforms and waveform groups. Any waveforms can be completed by leading tidal cycles and can be generated with BTPS simulation.

5.1.4. Scalable waveforms

Any predefined *volume*(*time*) and *flow*(*time*) waveforms can be scaled on both flow and volume axis of an FVC Spirogram. This feature can unveil a cheat based on shape recognition of ATS curves observed in connection with some poor quality spirometers.

5.1.5. Automatic measurement of flow resistance

PWG software is measuring flow resistance of tested objects in full automatic mode. User has only to configure the tested flow range. Determination of the internal resistance of the PWG is also being performed automatically.

5.1.6. Composing complete Spirograms

PWG-33's capabilities allow to move more than 150 000 liter of air in a single waveform (alternately in- and expiration maneuvers). PWG software provides a Spirogram editing tool where the user can assemble complete Spirograms of multiple forced in- and expirations, tidal cycles and simple IC/EC maneuvers.

5.1.7. Support of ambient data measuring module

PWG software supports PAM-201 ambient module that provides temperature, relative humidity and barometric pressure data.

5.2. Welcome screen

The welcome screen collects the basic tasks in a single window:

5.2.1. Main menu

Quick Test
Open a Quick test to generate periodic signals (sine, square), predefined waveforms or measure flow resistance. See chapter 6: Quick test and chapter 7: Resistance test.

Create a new Spirogram
Start here to create a new Spirogram. See chapter 8: Complete Spirograms.

Open project
Open an existing Spirogram.

5.2.2. Buttons

Device info
Show device properties: type, serial number, mechanical and pneumatic parameters, etc.

Configure
Open configuration window.

Close
Close PWG software.

5.3. Configuration

Click the button [Configure] on the Welcome Screen to open configuration window.

5.3.1. Set institute data

Institute data will be printed on reports and stored in project files. To change this data perform the following steps:

- ☞ Choose the tab [Institute Data].
- ☞ Fill the form implicitly

5.3.2. Custom logo

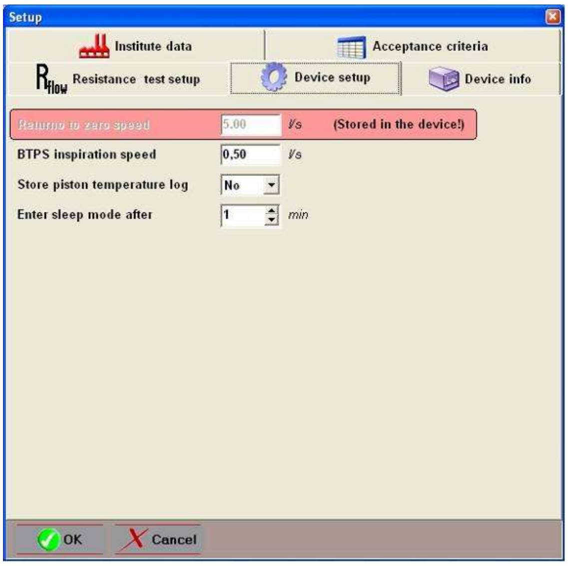
Custom logo will appear on screen and will be printed on reports. To use custom logo:

- Create a logo image of 620×320 pixels in size
- Store it in standard 24 bit bitmap format
- Copy the logo to PWG software's installation folder (replace existing logo)

5.3.3. Configuration of the Waveform Generator

To change device-related parameters:

- Choose the tab [Device setup].



Return to zero speed
Speed of the piston (in l/s) moving to zero position. This setting is stored in the device itself; option is only available if the device is connected. Default value is 5 l/s.

BTPS inspiration speed
Speed of the piston (in l/s) during inhalation of heated and vaporized air. Default value is 0.5 l/s. Adjust this option carefully as too high values can lead to step error or direct water inhalation!

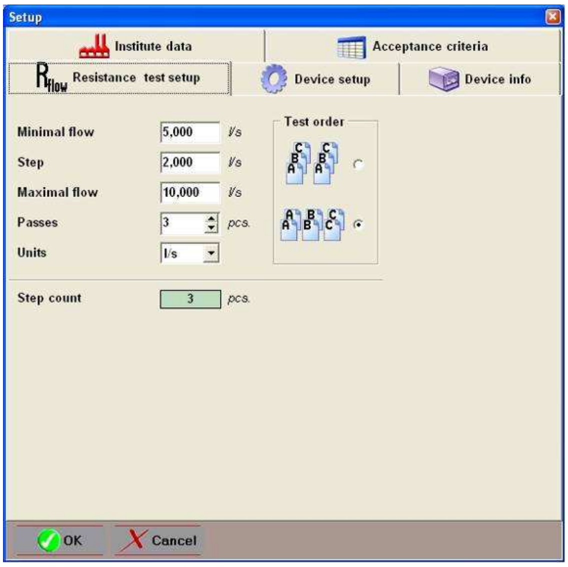
Store piston temperature log
Piston's temperature is logged when the PWG application is started. This log can be stored for later analysis. Default value is "No".

Enter sleep mode after...
When the PWG application is started the device is set to Sleep Mode after the idle time that was set here.

5.3.4. Configuration of flow resistance test

To set up flow resistance test:

- Choose the tab [Resistance test setup].



Resistance test starts with an initial flow rate that is increased in each cycle with a constant flow rate until a maximal flow rate is achieved but not exceeded.

Passes
Each flow rate will be repeated the given times.

Units
Entered flow values and the test report will use the selected units, liters/sec or liters/min.

Step count
Shows number of iterations between initial flow and maximal flow rate.

Test order
Defines how passes should follow each other: run the first flow rate test the given of times before doing the next flow rate step, or do the whole test the given of times.

5.3.5. Acceptance criteria

To set up custom acceptance criteria

☞ Choose the tab [Acceptance criteria].

Accuracy of waveform generator
The accuracy of waveform generator according to referred standards:

- For volume parameters: ± 0.5 % or ± 50 ml whichever is greater
- For flow parameters: ± 2 % or ± 85ml/s whichever is greater

Additional error of BTPS simulation
The additional error of the BTPS simulation according to referred standards:

- For volume parameters: ± 1.0 % or ±100 ml whichever is greater

Accuracy of the device under test
The accuracy of results is calculated according to referred standards:

Deviation
Deviation = average – standard

Deviation %
Deviation % = 100 * (average – standard) / standard

Repeatability of the device under test
The deviation of results is calculated according to ATS publication (Appendix: B, Expressions: B1 and B2, Page: 1128)

Range
Range = maximum - minimum

Range %
Range % = 100 * (maximum – minimum) / average

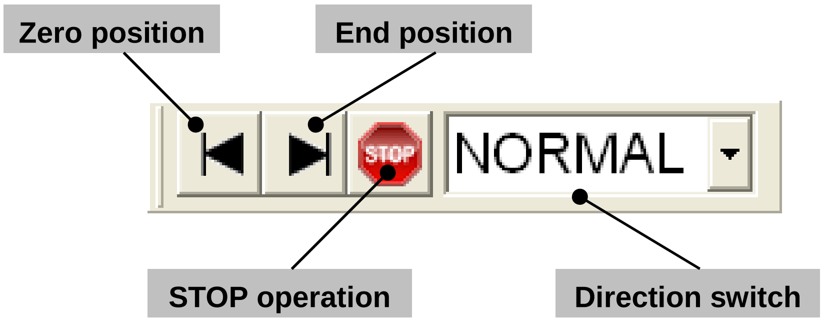
Enabling error analysis
Error analysis can be turned on or off for each parameters. To enable analysis check the checkbox preceding the parameter's name.

5.4. Measurement windows

Both measurement windows, Quick Test and Spirogram Editor have a common toolbar for controlling and monitoring basic functions of the PWG.

5.4.1. Device control toolbar

PWG's basic control functions are placed in the first toolbar group.



Direction switch
PWG is able to operate in a so-called *Inverse Mode* which means that any steps are performed in the opposite direction. For example, this makes it possible to generate standard waveforms as inspiration maneuvers.

Zero position
In consideration of the actual direction of waveform generation, moves the piston to zero position (farthest position from the pneumatic outlet).

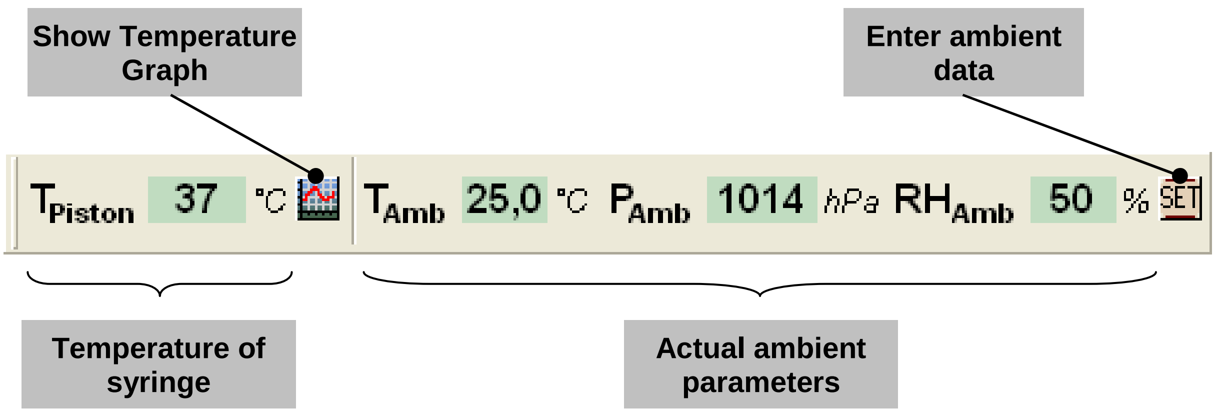
End position
In consideration of the actual direction of waveform generation, moves the piston to the end of the syringe (closest position to the pneumatic outlet).

Easier to say, in inverse mode the two buttons [Zero position] and [End position] are working in the opposite way.

STOP operation
Immediately stops any movement of the piston.

5.4.2. Ambient toolbar

Ambient data toolbar group shows the actual ambient parameters that will be showed in the report and displays the syringe's actual temperature.

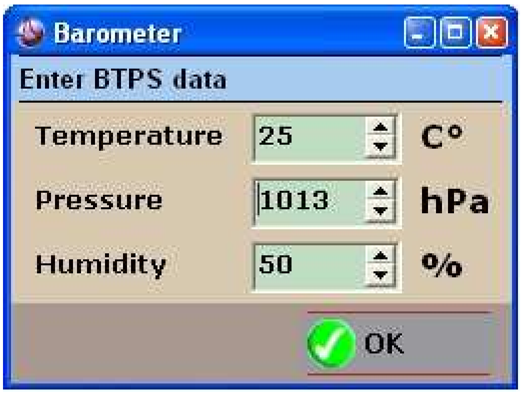


Temperature of syringe
Shows weighted average of syringe's thermometers.

Show Temperature Graph
Shows a *temperature*(*time*) graph in a separate window.

Actual ambient parameters
Last entered or actually measures ambient parameters.

Enter ambient data
Displays an input dialog for entering the current ambient parameters: temperature, barometric pressure and relative humidity.



5.4.3. BTPS toolbar

Abut using BTPS simulation mode, read the relevant chapter 5.5: BTPS simulation. BTPS toolbar groups two controls:

BTPS mode switch
Click BTPS switch to enable or disable BTPS mode.

 Blue icon: BTPS mode disabled

 Red icon: BTPS mode enabled; heating

 Green icon: BTPS mode enabled; Desired temperature reached

Desired temperature
Use spin buttons to set desired temperature.

5.5. BTPS simulation

ATS and ISO standards prescribe to test spirometers by discharging gas at BTPS conditions.

5.5.1. BTPS simulation in general

Heated air can be provided any time by turning on BTPS simulation even without connecting the humidifier.

Any waveforms can be generated using full BTPS simulation mode but BTPS conditions can only be guaranteed if the waveform contains only expiration maneuvers.

With BTPS simulation turned on, PWG will automatically move the piston to its end position and inhale the required amount of heated and vaporized air to discharge the selected waveform.

5.5.2. BTPS maneuver

If BTPS simulation is turned off the process of waveform generation goes as follows:

- The piston is starting from its zero position
- The requested waveform is generated

If BTPS simulation is turned on the process of waveform generation goes as follows:

- Dry air is first discharged
- PWG is inhaling the sufficient amount of vaporized air until the remaining volume in the cylinder equals to the volume of the curve to be generated.
- The requested waveform is generated

5.5.3. ATS

According to ATS publication (Appendix: B, Paragraph: #8, Page: 1128) diagnostic devices should be also tested by injecting at least four waveforms using heated and humidified air. The first four standard waveforms should be generated in three trials. The time interval between trials should be less than 2 minutes. The temperature of the air injected should be 37 ^{o}C ± 1 ^{o}C.

5.5.4. ISO 23747

According to ISO 23747 standard (Annex: B, Paragraph: B.3.6, Page: 10) diagnostic devices should be also tested by injecting heated and humidified air. All the standard waveforms should be generated in five trials using gas at a temperature of 34 °C ± 2 °C and a relative humidity above 90 % with air conditions at BTPS. The time interval between trials should be less than 2 minutes.

5.5.5. ISO 26782

According to ISO 26782 standard (Annex: B, Part B.3, Paragraph e), Page: 17) diagnostic devices should be also tested by discharging defined test profiles C12 and C13 with gas at a temperature of 34 °C ± 2 °C and a relative humidity above 90 % to the spirometer, including its accessories and detachable parts The time interval between trials should be less than 2 minutes.

5.5.6. Testing multiple devices

When testing multiple devices, it is recommended to perform ATP test (BTPS turned off) first on all devices.

- Perform the ATP tests in a row on each device
- Store a report file for each device
- Turn on BTPS simulation

For each device in a row

- Perform the BTPS tests
- Update the report file by storing it again
- Print the test report

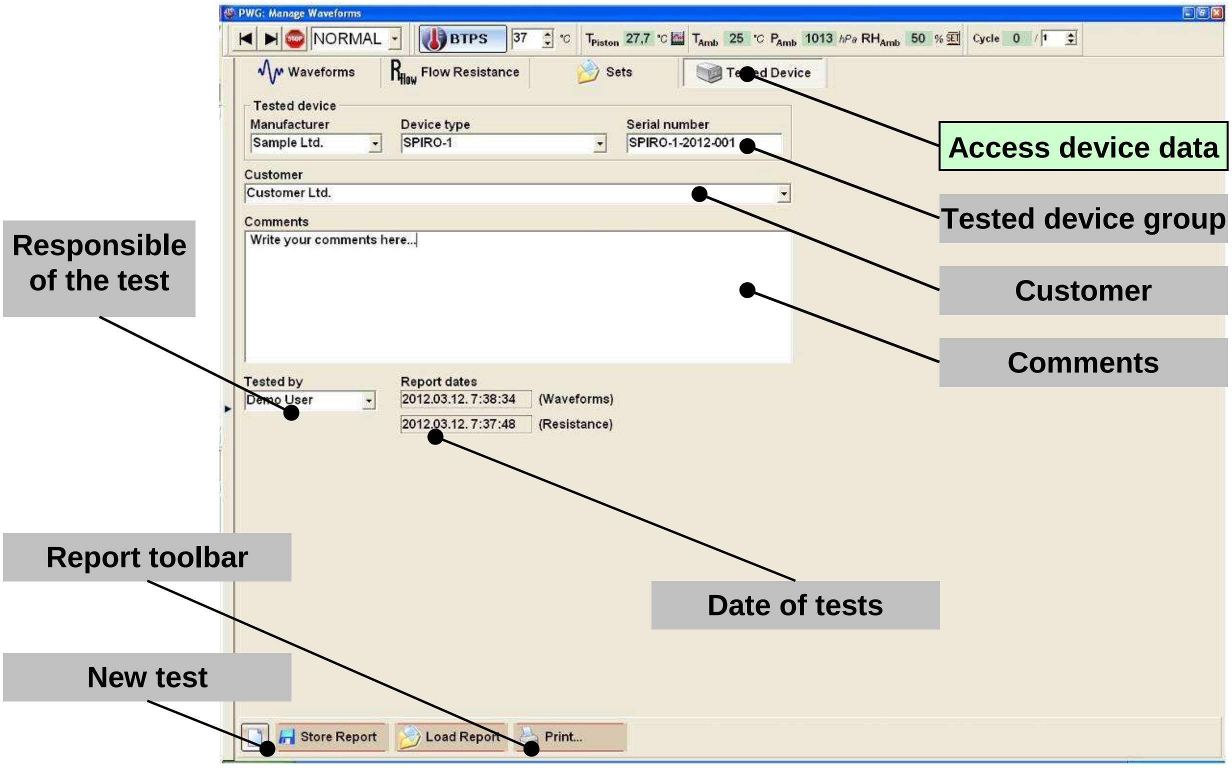
5.6. Restrictions

BTPS simulation mode can be used for any waveforms with trivial physical restrictions:

- Full BTPS simulation is only available in Quick test mode. Complete Spirograms can only be generated with heated air. Explanation of this is that the BTPS inhalation can not be performed through the flowmeter being tested and so the maneuver would break the Spirogram.
- BTPS simulation is obviously not available in inverse mode.
- BTPS simulation is obviously not available if tidal breathing cycles are preceding the main waveform of the test for the same reason as completes Spirograms can not be generated.

5.7. Device under test

Parameters of the device under test must be shown in the test report. To enter required data, select the [Tested Device] tab in the measure screens.



History of entered data is automatically stored, and [Manufacturer], [Device type], [Customer] and [Tested by] fields have auto complete feature.

Tested device group
Enter Manufacturer, model number and serial number – if present – of the tested device

Customer
Enter name and other data to identify the customer.

Comments
Enter your comments in connection with the performed tests.

Responsible of the test
Name of the person who performs or who validates the test.

Date of tests
Date and time of tests performed. Timestamp of resistance is recorded when the test was started. Timestamp of waveforms is recorded when the last waveform was generated.

Report toolbar
Load, store and print functions.

5.8. Reports

Reporting functions are available on the [Tested device] panel of all measure windows. PWG-33 is creating common reports for all tests performed. The user can mix different test profiles and test modes, as they are sorted automatically. Sorting method

- First aspect is the waveform group (ATS-24, ATS-26, ISO 26782, ISO 23747 ...)
- Second aspect is if BTPS simulation is turned on or not

These results are then stored in a single report file.

5.8.1. Contents of the reports

Required contents of spirometer’s test reports is listed under EN ISO 26782:2009 Annex B; Section 5.

Required contents of peak-flow meter’s test reports is listed under EN ISO 23747:2009 Annex B; Section 5.

PWG-33 provides test reports including most of the required measured or calculated test results however some tasks are requiring some subjective aspects to be performed.

Report header is including

- Name and contact information of institute
- Manufacturer, type and serial number of the device being tested
- Date and time of printing
- Ambient temperature, humidity and pressure

Footer of the test is including

- Responsible of the test
- Comments
- Signature

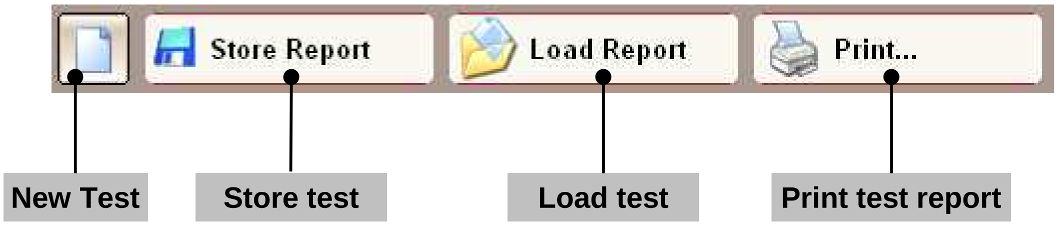
Resistance test report is including

- Report header
- Report footer
- Measured back pressure values for up to 5 passes (for both phases of the test, and for inspiration and expiration)
- Average pressure values
- Effective pressure measured on test object
- Calculated resistance to flow

Waveform test report is including

- Report header
- Report footer
- Temperature of syringe in BTPS simulation mode for each waveform
- Measured parameters values for up to 5 passes
- Calculated error for each value and for each pass
- Absolute and percentage range of measured values
- Absolute and percentage deviation of measured values

5.8.2. Reporting functions



New test
Click the button [New Test] to create a completely new test. This will clear data of device being tested, results of resistance test and waveform tests.

Storing test results
Click the button [Store Report] to store all test results. All results will be stored into a single results file. Configuration used for resistance test is also stored. Waveform files are not stored.

Loading test results
Load results from a report file for all tests. Configuration of resistance test will also be loaded. Starting resistance test after loading a report file will perform the same test structure as defined in the report file. To perform a test according to the procedure described in the current configuration of the PWG software, click the button [New test] on the [Resistance test] tab first.

If the report file refers to waveforms or waveform sets that are not present, an error message will appear.

```
Waveform [group] / [name] not found in the library!
```

5.8.3. Suspending or postponing test

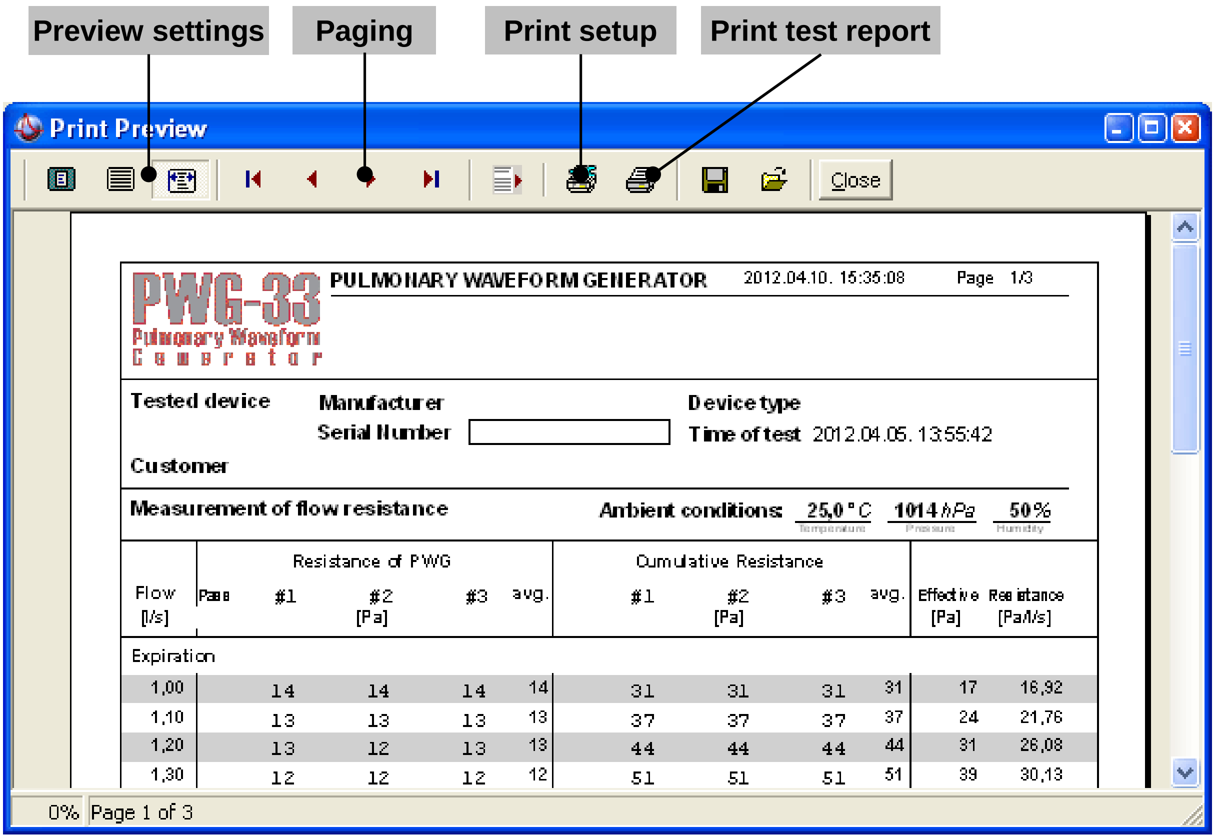
All tests performed can be interrupted, suspended or postponed.

- Store test results
- Do other tests or even you can close the software
- Load the test results later
- Continue working with the same device

This feature can be used if testing multiple devices. See chapter 5.5.6: Testing multiple devices.

5.8.4. Printing test report

Click the button [Print...] to open Print Preview window. Print preview shows both waveform and resistance test report. Printing options also can be set from here.



Preview settings

Preview settings toolbar provides different zoom levels for the selected page

Paging

Use paging toolbar to navigate between the pages of the report

Print setup

The button [Print setup] pops a standard windows Printer Setup dialog for selecting and configuring printer and for select pages to print.

Print test report

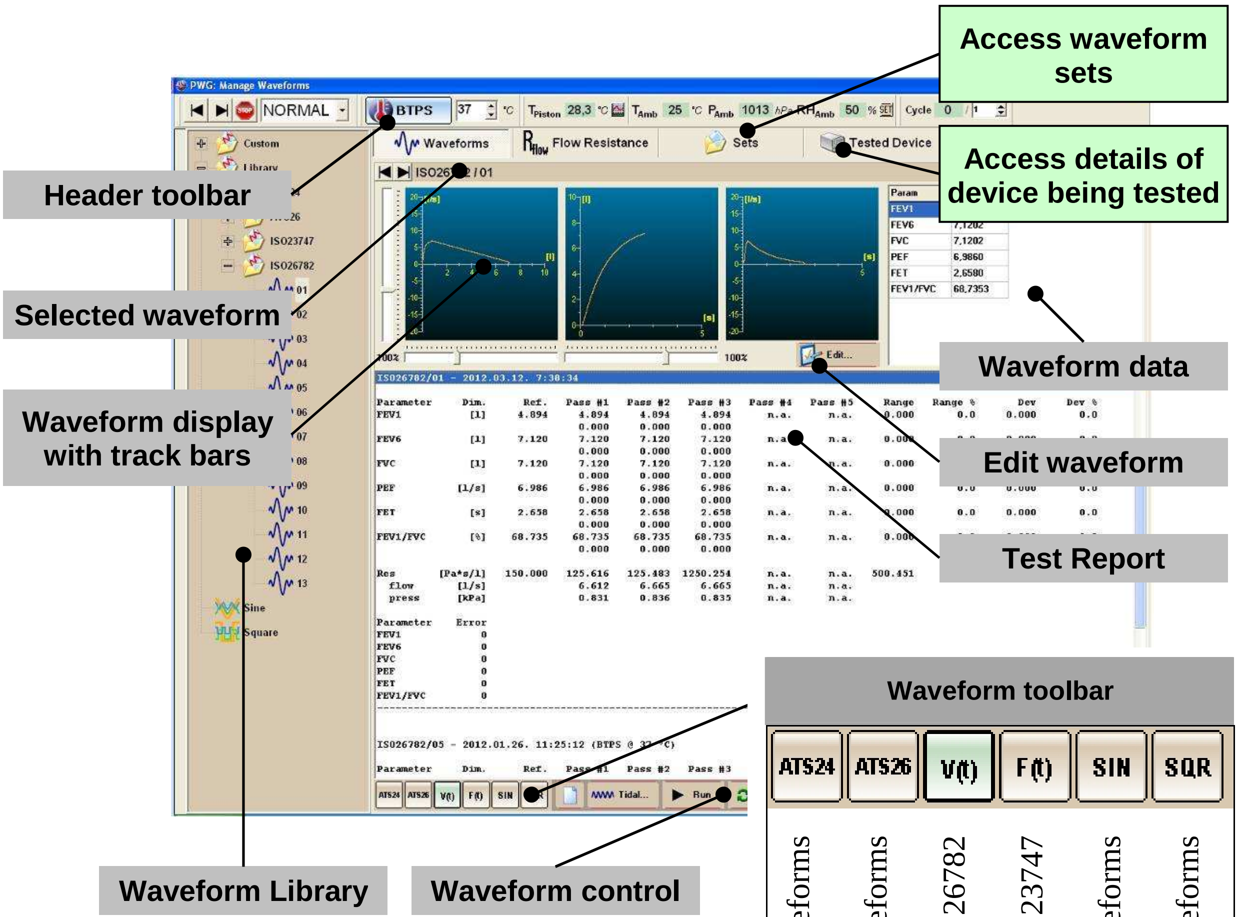
Starts printing test report with the specified options.

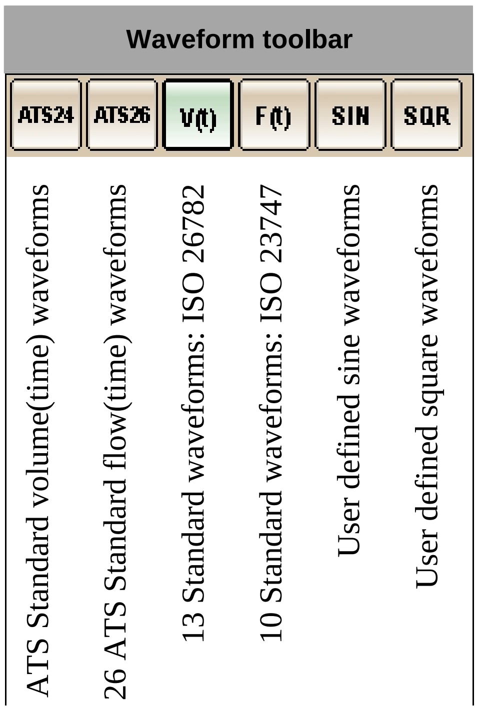
6. Quick test

6.1. User interface

User interface of Quick test mode collects the basic features of PWG:

- Generating standard waveforms
- Generating custom waveforms
- Measuring flow resistance
- Load, store, export and report functions





6.2. Managing waveforms

Waveforms can technically be separated into two main groups:

- Periodic signals (sine, square)
- Predefined waveforms

While flow values of periodic signals are calculated on fly according to some parameters entered by the user, predefined waveforms are described by a series of volume or flow data points in function of time.

6.2.1. Selecting waveforms

Waveform toolbar
Use waveform toolbar to quick access main waveform groups.

Waveform library
Click the arrow button [▶] at the left edge of the screen to show waveform library. Waveform library grants direct access to predefined waveforms in [Library] section, and user defined waveforms under the [Custom] section.

Selected waveform
Selected waveform field shows the group and the name of the selected waveform, for example:

```
ISO23747 / Prof A 0100 l/min
```

Use the arrow buttons [◀] and [▶] to select next waveform in the current group.

Waveform display
Waveform display shows *flow*(*volume*), *volume*(*time*) and *flow*(*time*) graphs of the selected waveform. Track bars around this display are allowing the user to transform waveforms.

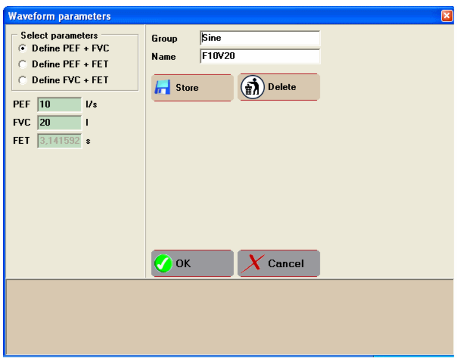
Waveform data
Waveform data field shows pre-defined parameters of the waveforms. These are the reference values for test reports

Waveform control
Waveform control toolbar collects basic control functions as Start or repeat waveform generation. For details, see chapter 6.4: Generating waveforms.

Edit waveform
[Edit waveform] button shows waveform properties in a separate window. After editing, the modified waveform can be named and stored in the library.

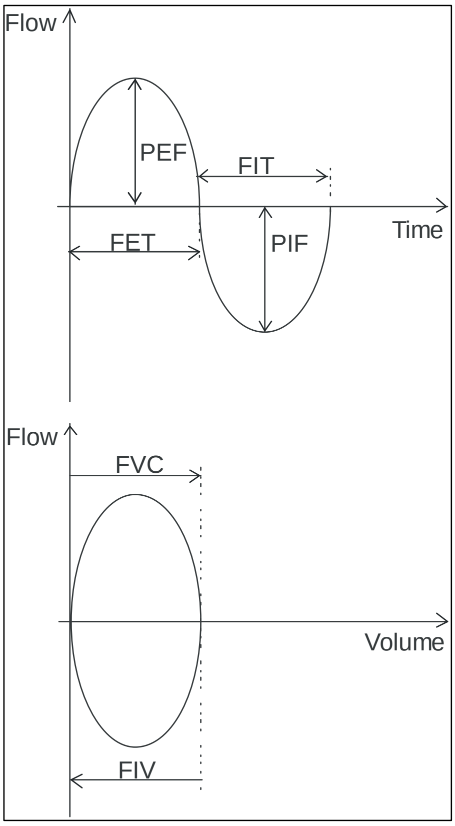
6.2.2. Sine and Square waveforms

To create a new custom Sine or Square waveform, click the proper tool button on the waveform toolbar. Former defined sine and square waveforms can be accessed in the waveform library:



- ☞ Click the arrow button [▶] at the left edge of the screen to show waveform library.
- ☞ Open the [Custom] section
- ☞ Select the desired group Sine or Square
- ☞ Select the desired waveform

6.2.3. Editing sine waveforms



To modify waveform parameters, click the [Edit waveform] button bellow the graphs.

First select the two independent parameters to describe the sine function. Three options are available:

- Define PEF + FVC
- Define PEF + FET
- Define FVC + FET

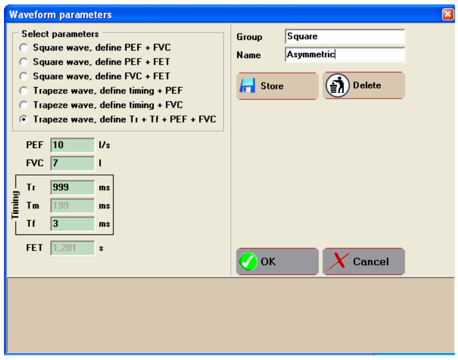
The third parameter is automatically calculated. To finish configuration of sine waveform

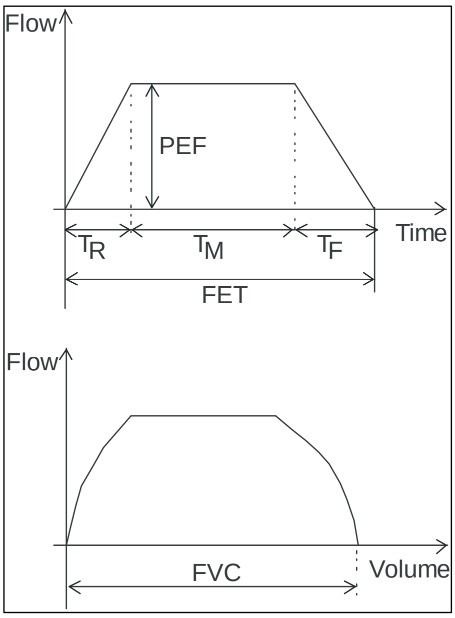
- Enter a value for the two selected parameters
- Enter a name for the new sine waveform
- Click [Store] to store the new waveform in Waveform Library

or

- Click [OK] to close this window preserving modifications
- To reject changes, click [Cancel]

6.2.4. Editing square waveforms





To modify waveform parameters, click the [Edit waveform] button bellow the graphs.

The software distinguishes two different versions of square waves:

- Clean square waveform
- Trapezoidal waveform

Whereas PWG itself has some mechanical limitations, peak acceleration and peak deceleration of the piston is predefined. Thereby clean square waves also have small trapezoidal distortion however the software is automatically calculating the shortest raise and fall times.

First select the independent parameters to describe the square function. Six options are available:

- Square wave, define PEF + FVC
- Square wave, define PEF + FET
- Square wave, define FVC + FET
- Trapezoidal wave, define timing + PEF
- Trapezoidal wave, define timing + FVC
- Trapezoidal wave, define Tr + Tf + PEF + FVC

Rest of the parameters is automatically calculated. To finish configuration of square waveform

- ☞ Enter a value for the selected parameters
- ☞ Enter a name for the new square waveform
- ☞ Click [Store] to store the new waveform in Waveform Library

or

- ☞ Click [OK] to close this window preserving modifications
- ☞ To reject changes, click [Cancel]

6.2.5. Automatic analysis of entered parameters

Entered waveform parameters are automatically evaluated. If entered data (or any that is calculated from them) exceeds the limitations of device, error messages are displayed including possible corrections at the bottom of the screen. If an error can be corrected in more different ways all possibilities will be listed.

Example: Creating a sine with PEF = 20 l / s and FET = 2 seconds will produce more than 25 liters of volume. Since the device has a maximal volume of 10 liters the software will promote two options:

```
FVC exceeds device limit. Correct PEF.
FVC exceeds device limit. Correct FET.
```

To automatically correct the error

- ☞ Double click one of the solutions above to correct your waveform.

Staying at our example, selecting “Correct PEF” will order the software to change PEF value to 7.85 l/s, preserving FET = 2 in addition to get FVC = 10 liters.

6.2.6. Selecting standard waveform sets

Standard waveforms can be accessed on the Waveform toolbar or similar to custom waveforms, they are accessible in the waveform library too.

- ☞ Click the proper tool button on the waveform toolbar

or

- ☞ Click the arrow button [▶] at the left edge of the screen to show waveform library.
- ☞ Open the [Library] section
- ☞ Select the group of desired standard
- ☞ Select the desired waveform

User parameterized waveforms can be modified and then stored to a different group on a different name.

Use the arrow buttons [◀] and [▶] to select next waveform in the current group.

6.2.7. Selecting custom waveforms

Custom waveforms are accessible in the waveform library.

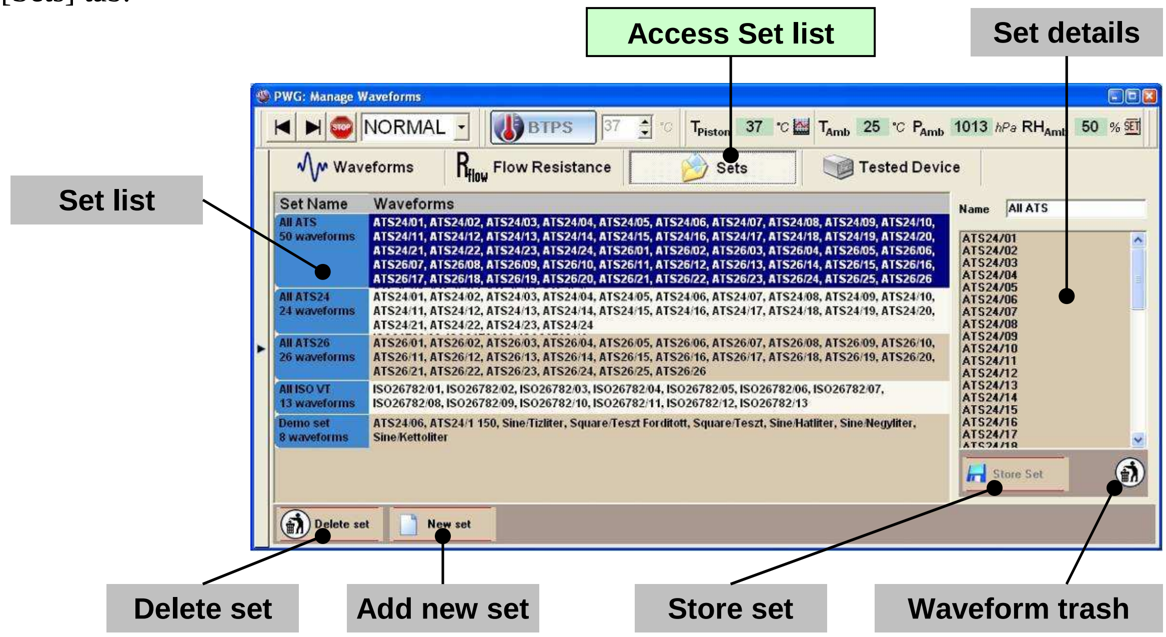
- ☞ Click the arrow button [▶] at the left edge of the screen to show waveform library.
- ☞ Open the [Custom] section
- ☞ Select the desired group
- ☞ Select the desired waveform

User parameterized custom waveforms can be modified again and then stored to a different group on a different name.

Use the arrow buttons [◀] and [▶] to select next waveform in the current group.

6.3. Waveform sets

Different waveforms can be categorized into waveform sets. Waveform sets are used to collect waveforms that are frequently tested together. To manage waveform sets select the [Sets] tab.



Set list
Shows list of the available waveform sets. Click an item to view or edit details.

Set details
Shows details of the selected waveform set. You also can edit the set; see next chapter for more information.

6.3.1. Add new set

Click the button [New set] to add a new set. Unlimited number of waveform sets can be added.

Name of set
Enter a name for the set.

Adding waveforms to the set
To add new waveforms

- Open waveform library
- Use the mouse to drag ‘n’ drop waveforms to the set details list

Reorder waveforms within a set
To reorder waveforms within the set

- Use the mouse to drag ‘n’ drop waveforms within the set details list

Remove waveform from set
To remove a single waveform from the set

- ☞ Use the mouse to drag ‘n’ drop the waveforms over the waveform trash

Clear waveform set
To remove all waveforms from the set

- ☞ Double click the waveform trash

Store set
Click the button [Store set] to save changes of waveform set.

6.3.2. Delete set

To delete a waveform set

- ☞ Select the waveform from the set list
- ☞ Click the button [Delete set]

6.3.3. Using Waveform sets

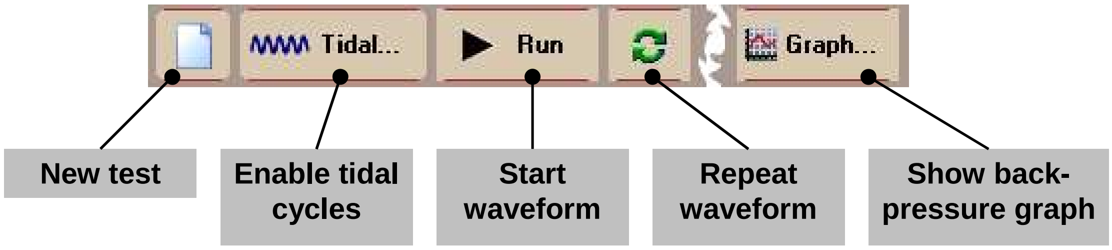
Stored Waveform Sets are listed in the waveform library under the top level node [Sets]. To work with these waveform sets, select one of them from the library. Waveform sets are behaving like Waveform Groups.

- ☞ Click the arrow button [►] at the left edge of the screen to show waveform library.
- ☞ Open the [Sets] section
- ☞ Select the desired Waveform Set
- ☞ Select the desired waveform

Use the arrow buttons [◀] and [▶] to select next waveform in the current group.

6.4. Generating waveforms

The waveform control toolbar is used to configure leading tidal breathing cycles and to start or repeat waveform generation.



New test
Clear current waveform test results

Enable tidal cycles
Turn on or off leading tidal breathing cycles preceding the main waveform of the test.

Start waveform
Download selected waveform to the device and start waveform generation.

Repeat waveform
Repeat the last downloaded waveform.

Show back pressure graph
Shows a back-pressure diagram for the last generated waveform including the waveform and the estimated shape of the actual airflow at the pneumatic outlet.

6.4.1. Starting a new test

To start a completely new test, select the [Tested Device] tab in the measure screens, and click the [New Test] button.

To clear Resistance test results only, select the [Tested Device] tab in the Quick Test measure screen, and click the [New Test] button.

To clear waveform test results only, select the [Waveform] tab in the Quick Test measure screen, and click the [New Test] button.

6.4.2. Scaling waveforms

Any predefined *volume*(*time*) and *flow*(*time*) waveforms can be scaled on both flow and volume axis of an FVC Spirogram.

Use track bars around waveform displays to scale waveforms flow rate or volume.

The three track bars are in fact only two: flow and time will be moved parallel, while volume track bar changes *volume* data point values beside a constant input frequency and that causes proportional increase in flow.

This goal of this feature not to create exact lung diagnostic parameter values but to unveil a cheat based on shape recognition of ATS curves observed in connection with some poor quality spirometers. According to this, lung diagnostic parameter values are not recalculated yet.

6.4.3. Tidal cycles

PWG software provides leading tidal breathing cycles preceding the main waveform of the test simulating a real forced expiration maneuver ahead with some normal breathing cycle.

- ☞ Click the button [Tidal...] to open the tidal breathing cycles setup box

Waveform
Tidal breathing cycles are generated from previously defined sine waveforms stored in the Waveform Library.

Follow the steps described in chapter 6.2: Managing waveforms to create predefined sine waveforms.

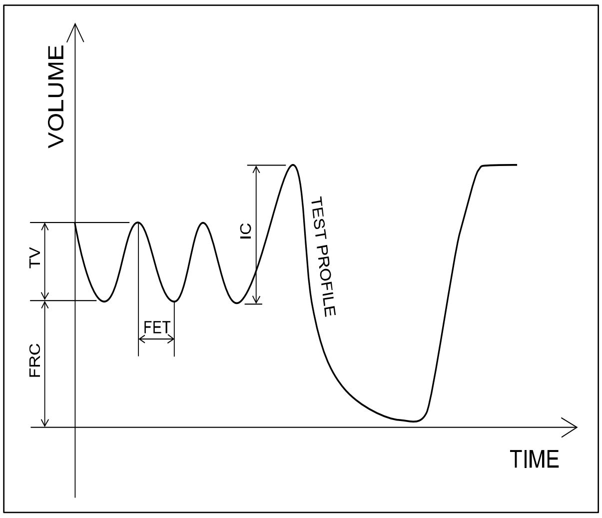
- ☞ Select an item from the drop-down list

Open editor
Click the button [Edit...] to change waveforms parameters.

FRC level
Define FRC (Functional Residual Capacity of the Lung) level of the Spirogram formed by this tidal breathing cycles and the main waveform of the test. The piston will be moved towards to its end position prior to waveform generation. This feature is also allows reducing dead space of the piston.

IC level
Define IC (Inspiration Capacity) level of the Spirogram formed by this tidal breathing cycles and the main waveform of the test. This defined amount of air will be inhaled between the tidal breathing cycles and the main waveform of the test.

Cycle count
Define count of leading tidal breathing cycles.



- ☞ Click [OK] to apply settings. The button [Tidal...] will turn to green indicating that leading tidal breathing cycles feature is turned on. Waveform data will be downloaded automatically - this can take some seconds.

or

- ☞ Click [Cancel] do close windows without activating leading tidal breathing cycles.
- ☞ To turn off leading tidal breathing cycles later, click the button [Tidal...] button again. The button [Tidal...] will turn to back to grey.

6.4.4. BTPS simulation

Use the BTPS toolbar to enable BTPS simulation. Desired temperature can be set any time. BTPS check button is indicating if the device is ready for BTPS simulation. Open temperature graph to check visually the warming up process.

If BTPS simulation is enabled,

- Leading tidal breathing cycles are turned off
- If inverse mode was set, PWG is set back to normal mode

6.4.5. Normal and Inverse mode

In normal mode

- Pre defined waveforms are generated as expiration maneuvers.
- The first half cycle of sine and square waveforms is generated as expiration and the second half of them is generated as inspiration.
- The button [Zero position] will move the piston to “pump in” position, the farthest position from the pneumatic outlet.

If switching to inverse mode, any waveforms are generated in the opposite way.

- The piston is moved automatically to “pump out” position, the closest position to the pneumatic outlet.
- Leading tidal breathing cycles are turned off

- BTPS simulation is turned off
- Pre defined waveforms are generated as inspiration maneuvers.
- The first half cycle of sine and square waveforms is generated as inspiration and the second half of them is generated as expiration.
- The button [Zero position] will move the piston to “pump out” position.

6.4.6. Start or repeat test

After selecting the desired waveform and waveform generation options

☞ To start waveform, click the button [Start waveform].

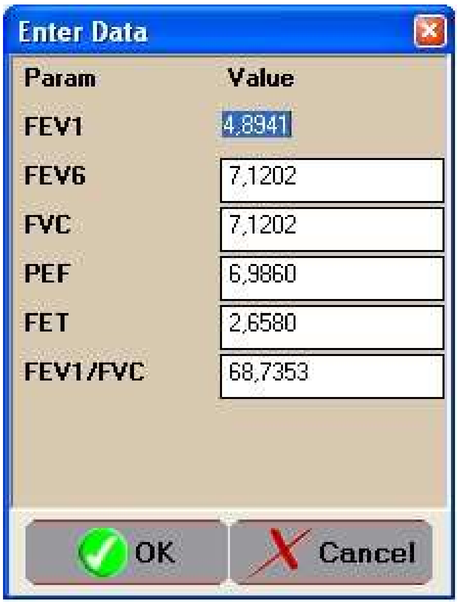
- The waveform will be downloaded to the device
- Waveform generation will start automatically

☞ To repeat the last waveform without downloading it again, click the button [Repeat waveform]

- Waveform generation can be aborted any time by clicking the button [STOP]

6.4.7. Recording test results

PWG software can record five series of test results for each waveform. After each test the software pops a results table to enter measured parameter values. Switch between parameters by pressing [Enter] on the keyboard to speed up data input. Pressing [Enter] at the last parameter will close the window and record the entered parameters in the test report.

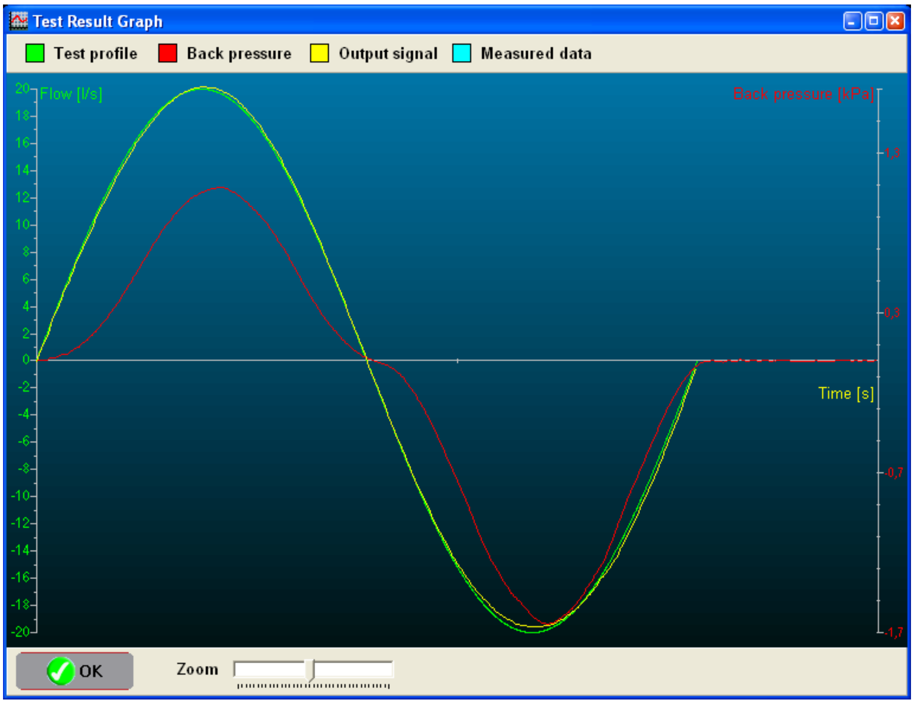


6.4.8. Back-pressure graph

Click the button [Show back-pressure graph] to shows the back-pressure diagram of the last generated waveform including the waveform and the estimated shape of the airflow on the pneumatic outlet. Take into consideration that the backpressure represents the total internal pressure of the syringe. Obviously the effective backpressure of the device being tested is only a part of this value.

Estimated shape of the airflow on the pneumatic outlet is calculated from the measured back-pressure and the volume remained in the syringe. Entering proper ambient pressure is also required for the calculation.

Back pressure graph is refreshed automatically after each test.



Content of the graph

- Shape of selected waveform (green)
- Measured back pressure (red)
- Estimated output signal (yellow)
- Measured data reported by the device being tested (in interface mode)

6.5. Reports

After finishing tests

- Store results
- Print reports

Quick tests also can be suspended.

See chapter 5.8: Reports for details.

7. Resistance test

7.1. About the test

7.1.1. Purpose

Main goal of resistance testing is to precisely determine an object's resistance to flow in an automatic way. While ATS recommendation does not regulate the way resistance has to be measured, ISO standards are describing some methods to determine if the tested device is having resistance to flow below a specific limit.

☞ To start resistance test, open Quick Test and click [Resistance test] tab.

7.1.2. Configuration

To configure resistance test

- Open software setup from the Welcome screen.
- Chose the tab [Resistance test setup]

For details see chapter 5.3.4: Configuration of the Waveform Generator.

7.1.3. ATS recommendations

According to ATS publication (Chapter: Equipment Recommendations, Table: #2, Page: 1111) the resistance of the flow meter can not exceed the limit of:

```
1,5 cm H2O/L/s or 150 Pa/l/s
```

☞ Use resistance test to determine resistance to flow.

7.1.4. Measuring resistance according to ISO standards

According to standard ISO-26782 (Chapter 7.9 Expiratory impedance):

```
The expiratory impedance of the SPIROMETER,
including its ACCESSORIES and detachable parts,
shall not exceed 0,15 kPa/(l/s) for the defined
test profiles listed in Table C.1 with flows up to
14 l/s.
```

Described method (Annex B; Chapter 2; paragraph d)):

```
Record the pressure throughout each defined test
profile with and without the SPIROMETER, including
its ACCESSORIES and detachable parts, attached.
Measure the peak impedance once the 1,0 l volume
has been discharged.
```

According to standard ISO-23742 (Chapter 7.3 Resistance to flow):

```
The resistance to flow across the measurement range
of the PEFM shall not exceed 0,35 kPa/l/s.
```

Described method (Annex B; Chapter 2; paragraph d)):

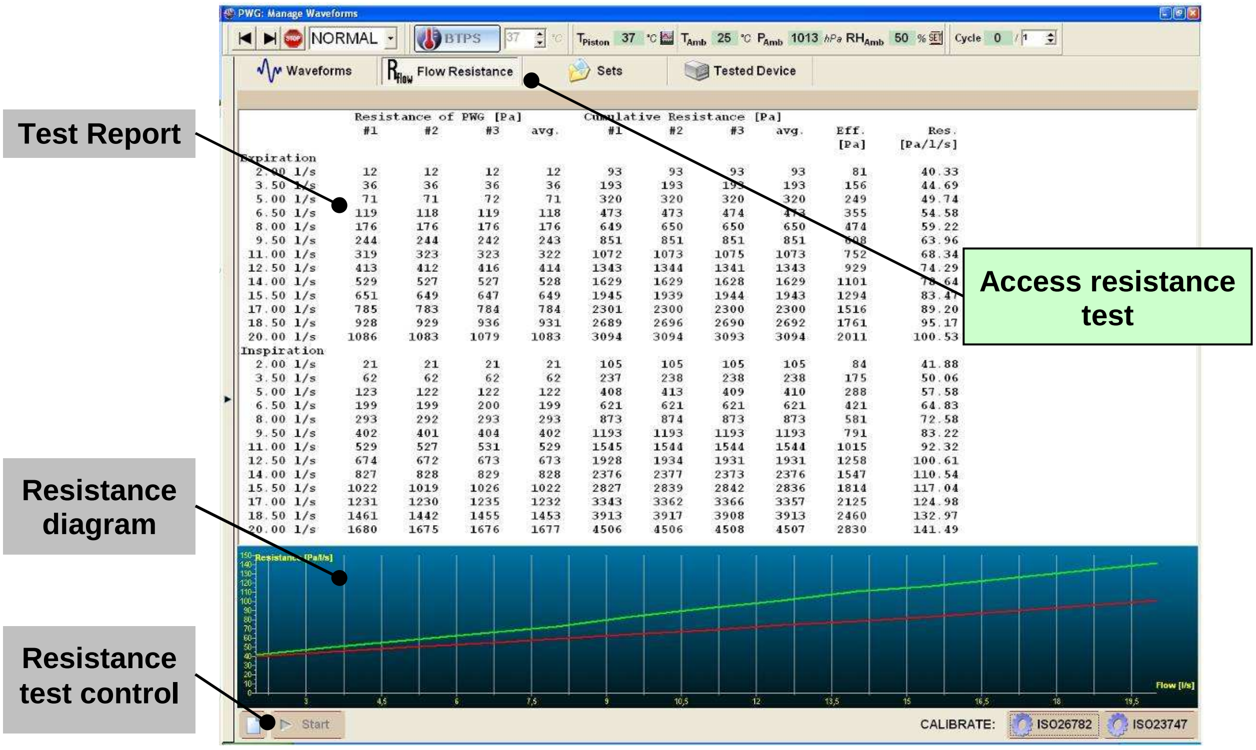
```
Calculate the resistance, R, to flow for each
reference flowrate, n, using Equation B.3:

Rn = pn / qref,n (B.3)

where

pn is the peak pressure for reference flowrate n;
qref,n is the reference flowrate for flow rate n.
```

To calculate this resistance values, PWG's own internal resistance has to be measured first. For details see chapter 7.3.2: Calibration of ISO Test profiles.

7.2. User interface

User interface of Resistance test mode collects the following features:

- Resistance testing
- Measuring resistance of PWG during generation of ISO test profiles



Test Report
For normal resistance test, Test report includes

- PWG calibration data for in- and expiration
- Cumulative resistance of PWG and tested device for in- and expiration
- Effective resistance of the object being tested for in- and expiration

During calibration of ISO Test profiles Test report field shows the measured resistance of PWG without any objects connected.

Resistance Diagram
Resistance diagram show the measured resistance in function of flow. The graph is displayed for inspiration in green and for expiration in red.

7.2.1. Resistance test control

New test
Clear current Resistance test results.

- ☞ Use [New test] also if configuration of resistance test has been changed.
- ☞ Opening a former report will override default settings. Repeating a test will be also done according to the method stored in the report file.

Start test
Start automatic measurement of resistance to flow. Previous data will be overwritten.

Calibration of ISO Test profiles
Start automatic measurement of PWG's own resistance to flow according to methodology of the referred ISO standards. Previous data will be overwritten.

- ☞ Calibration must be performed manually for both normal and inverse mode according to your current needs.

7.3. Performing tests

7.3.1. Resistance test

Resistance test is technically performed in two phases:

- First phase is measuring the internal resistance of PWG plus the pneumatic adapter if necessary.
- Second phase is measuring the total resistance of the generator, the pneumatic adapter and the object being tested.

Resistance test is performed with a flow rate increased in equal steps between a minimum and a maximum level. Resistance at each flow rate is measured several times with and without the object being tested. Final result is calculated form the average of the particular values.

To start resistance test

- ☞ Click the button [Start Test]. The following message will appear:

```
Remove any object being tested from the pneumatic
outlet!
```

- ☞ Remove the object being tested form the pneumatic outlet
- ☞ Attach or leave on the pneumatic adapters that are required during the test to fit the test device but are not part of it in normal use.
- ☞ Click [OK] after you verified the pneumatic outlet.

First phase of the resistance test is now performed automatically. After the calibration has finished, the following message will appear:

```
Connect the object being tested to the pneumatic
outlet!
```

☞ Click [OK] after you have connected the object being tested.

Second phase of the resistance test is now performed automatically.

7.3.2. Calibration of ISO Test profiles

Calibration of ISO Test profiles is performed in a single phase, but it is only performed for the selected type of waveforms and only in the selected mode, inverse or normal.

During calibration, all test profiles are generated as many times as is set for resistance calibration.

To start resistance calibration, according to the test following calibration

☞ Select normal on inverse mode

☞ Click the button [ISO26782] or [ISO23747]. The following message will appear:

```
Remove any object being tested from the pneumatic
outlet!
```

☞ Remove the object being tested form the pneumatic outlet

☞ Attach or leave on the pneumatic adapters that are required during the test to fit the test device but are not part of it in normal use.

☞ Click [OK] after you verified the pneumatic outlet.

Measurement of PWG’s resistance is now performed automatically.

Results of calibration are stored automatically

☞ Always repeat these test if pneumatic connector is changed!

7.4. Reports

After finishing tests

- Store results
- Print reports

Resistance tests can not be suspended, but calibration of ISO Test profiles is kept.

For details see chapter 5.8: Reports.

8. Complete Spirograms

8.1. About Spirogram editor

8.1.1. Purpose

Taking advantage of PWG's flexible and powerful design, Spirogram editor was designed to make possible functional testing of spirometer software. Among others complex waveform series can be used to

- Create multiple flow level calibration sign for non-linear flow meters
- Test detection of different lung function test maneuvers in a single recording
- Test calculation of lung diagnostic parameters computed or averaged from multiple maneuvers
- Test control sequences of more sophisticated diagnostic systems

8.1.2. Principle of operation

Spirograms are assembled from blocks. Blocks are basic waveforms stored in the waveform library. Before Spirogram playback, waveform blocks are generated one by one in a row and are mounted into a single waveform file.

8.1.3. Type of blocks:

The following types of blocks are available:

Main block types

- Tidal breathing: accepts sine waveforms
- Inspiration and Expiration: accepts any waveforms or waveform sets

Auxiliary block

- Binding block: automatically generated quarter period of sine used to bind tidal breathing and inspiration or expiration maneuvers or shift FRC point.

8.1.4. Flexible architecture

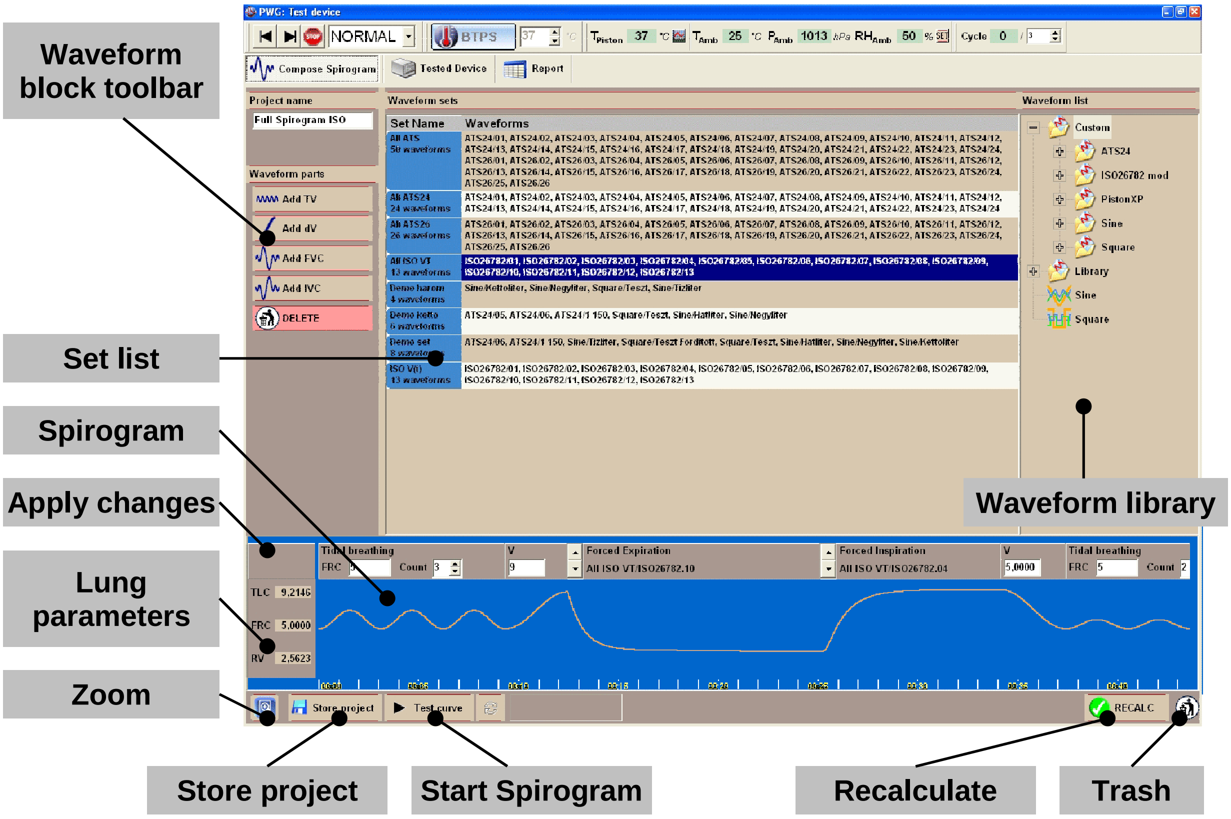
Based on the available blocks, almost any frequently used lung diagnostic maneuvers can be simulated with PWG. You can combine an unlimited number and type of blocks to get the desired breathing pattern. When using waveform sets for inspiration and expiration blocks, standard test profiles can be switched with a single click.

8.1.5. Reporting

Tests with complete Spirograms are producing the same test reports as Quick Test. Beside the report files, also Spirograms can be stored for later use.

8.2. User interface

User interface of the Spirogram editor:



Waveform library and Set list
Use Waveform library and Set list to select the content of waveforms blocks.

Spirogram
Shows the composed breathing pattern and a timeline. Click on the Spirogram, to select a block.

Zoom
Clicking [Zoom] button shows a track bar to scale the Spirogram

Waveform block toolbar
Add a new or remove the selected waveform block.

Trash
To remove a single waveform block from the Spirogram

☞ Use the mouse to drag 'n' drop the block over the waveform trash

Lung parameters
Shows three basic lung diagnostic parameters that are describing the range of the syringe in which the piston will pass during waveform generation.

- TLC: Total Lung Capacity – the effective volume measured from the pneumatic outlet.
- FRC: Functional Residual Capacity – distance of the lower end of the first tidal breathing block measured from the pneumatic outlet.

- RV: Residual Volume – the volume of the unused range measured from the pneumatic outlet.

Apply changes and Recalculate
Click to apply changes and recalculate Spirogram parameters.

Store project
Click to store the Spirogram.

Start waveform
Download the complete Spirogram to the device and start waveform generation.

Repeat waveform
Repeat the last downloaded Spirogram.

8.3. Composing Spirograms

8.3.1. Creating a new Spirogram

To create a new Spirogram:

☞ Use Quick test screen to create each special sine and square waveform that are required for your project.

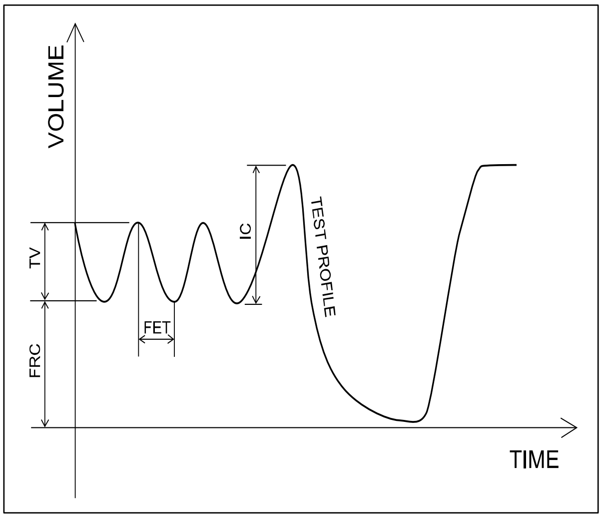
If finished:

☞ On the Welcome screen select [Create new Spirogram]. The Spirogram editor will appear.

☞ Enter a name for the Spirogram

☞ Compose your Spirogram

☞ You can use the button [Store project] any time to save your changes



8.3.2. About waveform blocks

Each waveform blocks have a header and a display area. The header contains the configurable parameters of the block and the display area shows the waveform itself.

To select a block, click either the display area or any controls placed in the header. For drag ‘n’ drop operations always drag the display area.

8.3.3. Adding tidal block

Tidal blocks are the basic elements of a Spirogram containing a sine waveform starting at a definable breathing level. A Spirogram begins typically with a series of tidal breathings. Configurable parameters are

FRC level
Exact vertical position of the tidal breathing can be defined. The first tidal block added will determine the FRC level of the whole Spirogram.

Cycle count
Number of tidal breathing cycles

To add a new tidal block

- ☞ Click the button [Add TV] on the Waveform block toolbar. The new block will be placed at the end of the Spirogram
- ☞ Use the mouse to drag ‘n’ drop the new block within the Spirogram
- ☞ Use the mouse to drag ‘n’ drop sine a waveform to the block

A tidal block always starts on its FRC level.

8.3.4. Adding forced in or expiration

Forced inspiration and expiration blocks can contain predefined waveforms or a single cycle of sine and square waveforms. They also accept waveform sets. If a waveform set was added, included waveforms can be selected by the two arrow buttons [▲] and [▼].

To add a new inspiration or expiration block

- ☞ Click the button [Add FVC] or [Add IVC] on the Waveform block toolbar. The new block will be placed at the end of the Spirogram
- ☞ Use the mouse to drag ‘n’ drop the new block within the Spirogram
- ☞ Use the mouse to drag ‘n’ drop a waveform or waveform set to the block

An inspiration or expiration block always starts at the position where the preceding block ends.

8.3.5. Binding blocks

Binding blocks are containing an automatically generated sinusoidal volume step to bind two other blocks.

Configurable parameter is

V (volume)
Volume level, on what the quarter sine signal of the block should rise or fall.

- If a tidal block is following the binding block the FRC level of that block will override this parameter.
- If an inspiration or expiration block is following the binding block it will start at this volume level. In an FVC maneuver, the binding block represents the full deep inspiration preceding the forced expiration.
- ☞ Click the button [Add dV] on the Waveform block toolbar. The new block will be placed at the end of the Spirogram
- ☞ Use the mouse to drag ‘n’ drop the new block within the Spirogram

A binding block always starts at the position where the preceding block ends.

8.3.6. Block sequence

Block sequence in a complete Spirogram has some restrictions:

- As they start from a given volume level, tidal blocks must be either placed manually to the correct position or they has to be preceded by a binding block

Blocks can be reordered:

- ☞ Use the mouse to drag ‘n’ drop a block within the Spirogram

After editing the Spirogram, use the button [Apply] or [Reorder].

8.3.7. Deleting blocks

To delete a block

- ☞ Select the unneeded block
- ☞ Click the button [Delete] on the Waveform block toolbar

Or

- ☞ Use the mouse to drag ‘n’ drop the block to the [Trash]

8.4. Open Spirogram

To open stored Spirograms

- ☞ Use the main menu on Welcome screen to create a new or open an existing Spirogram.

8.5. Generating Spirograms

In many aspects generating Spirograms is very same to generating simple waveforms.

8.5.1. BTPS simulation

According to former described physical reasons, BTPS simulation is not available when generating Spirograms.

8.5.2. Normal and Inverse mode

Normal and inverse mode are both usable and acting the same way as described for simple waveforms.

8.5.3. Generating Spirograms

Opening or create the desired Spirogram.

Before generating Spirograms

- ☞ Verify if there is no break in the volume curve. Use binding blocks to fix them.
- ☞ Select curves for inspiration and expiration maneuvers if they are containing waveform sets.

Start or repeat test

- ☞ To start Spirogram, click the button [Start Spirogram].
- ☞ The Spirogram will be downloaded to the device
- ☞ Spirogram generation will start automatically
- ☞ To repeat the last Spirogram without downloading it again, click the button [Repeat Spirogram]
- ☞ Spirogram generation can be aborted any time by clicking the button [STOP]

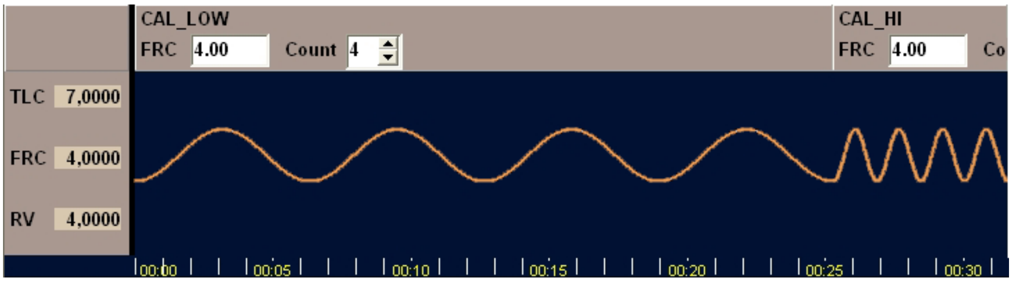
8.5.4. Recording test results

PWG software can record five series of test results for each Spirogram. After each test the software pops the same results table as for simple waveforms to enter measured parameter values. Switch between parameters by pressing [Enter] on the keyboard to speed up data input. Pressing [Enter] at the last parameter will close the window and record the entered parameters in the test report.

8.6. Examples

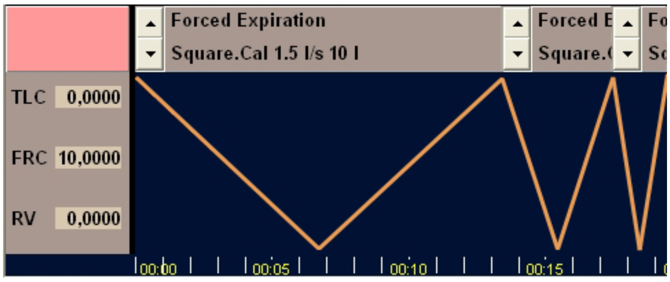
8.6.1. Calibration signal: sine, two speeds

- Create two sine waveforms having PEF of the required flow rates, for example 1.5 l/s and 6 l/s and define a proper FVC
- Create a new Spirogram
- Add two tidal blocks
- Drag 'n' drop the two sine waveforms
- For both of them set FRC level to 0 liter to minimize signal distortion effect of back pressure
- Set the number of cycles to the required count
- Store and test curve



8.6.2. Calibration signal: three constant flow rates

- Create three square waveforms having PEF of the required flow rates, for example 1.5 l/s, 5 l/s and 10 l/s and define a proper FVC
- Create a new Spirogram
- Add three expiration blocks
- Drag 'n' drop the three square waveforms
- Store and test curve



8.6.3. Full FVC maneuver with ISO 26782 test profiles

- Create a sine waveform for tidal breathing cycles
- Create a set containing all ISO 26782 curves
- Create a new Spirogram
- Add the following blocks:
    - Tidal: FRC = 5 l; Count = 4
    - Binding: Volume = 9 l
    - Forced expiration
    - Forced inspiration
    - Binding
    - Tidal: FRC = 5 l; Count = 2
- Drag ‘n’ drop ISO 26782 set to both expiration and inspiration blocks
- Browse the sets to select a test profile for both inspiration and expiration
- Store and test curve

9. Custom waveforms

9.1. About custom waveforms

9.1.1. Purpose

PWG software allows creating unlimited number of custom *volume*(*time*) and *flow*(*time*) waveforms, to meet all user demands and to comply with possible standards introduced in the future.

9.1.2. Format

Waveforms are described by its *volume* or *flow* data points as function of time. Waveforms can contain positive and negative volume changes (flow values with positive or negative signs; inspiration and expiration maneuvers). Sampling interval and reference values for lung diagnostic parameters must be defined.

9.1.3. Requirements

Device capabilities can be read from PWG:

- Piston volume
- Peak flow
- Maximal acceleration / deceleration

Always keep in mind these restrictions and never exceed them. Also never define a flow rate of 0 l/s. Principle of operation is based on time intervals between two steps taken by the stepper motor. Null value for flow will divide to an infinite time interval.

9.2. Waveform properties

Waveforms have the following properties

Parameter	**Type**	**Comment, example**
Group	String	ISO26782 mod
Name	String	02
Type	String	VT = *volume*(*time*); FT = *flow*(*time*)
Freq	Unsigned	minimum 10 Hz; at least 500 Hz recommended
ExpStart	Unsigned	Experimental; not used
fZoom	Float	Default flow zoom; 1.00 = no change
vZoom	Float	Default volume zoom; 1.00 = no change

9.3. Waveforms parameters

9.3.1. Parameter database

Software install folder contains a CSV (Comma Separated Values) file called Params.csv. This file contains a list of parameters with name, dimension, acceptance range, etc. Select parameters you need from second column of the file. Further information on CSV files can be found on Wikipedia (http://en.wikipedia.org/wiki/Comma-separated_values). Contact the manufacturer if you need to expand this table with new parameters.

9.3.2. Reference values

In the waveform file, all parameters that must appear in the test report must be listed including reference values for them.

9.4. File format

Waveform files have a standard windows INI file format header and parameter descriptor section plus a data section listing all the data points of the waveform.

- Decimal separator for all values can be
  - '.' – period / full stop / dot / US decimal separator sign
  - ',' – comma, European decimal separator
- Section and variable names are all case sensitive

9.5. Adding waveforms to library

To add your custom waveforms to PWG waveform library

☞ Copy your files to

```
c:\Program Files\Pulmonary Waveform
Generator\Custom\[Subfolder]
```

☞ You can create one level of subfolders

9.6. Example

```
[Header]
Group=ISO26782 mod
Name=02
Type=VT
Freq=500
ExpStart=0
fZoom=1.68
vZoom=0.89

[Parameters]
FEV1=3.2716549999999998
FEV6=5.1675380000000041
FVC=5.1793880000000032
PEF=4.9900000000000021
FET=8.5860000000000003
FEV1/FVC=63.166830709999993

[Data]
0.0000000
0.0000802
0.0003195
...
```

10. Maintenance

10.1. Basic tasks

10.1.1. Replacing fuses

Fuse box is built into the line power connector housing located on the back panel of the equipment.

- Use a screwdriver to open the fuse box

WARNING!

Replacing fuses with wrong type and value can result in serious damage to the equipment.

Recommended fuses:

Line power	Fuse
115 VAC	250V / 10 A “T”
230 VAC	250V / 6.3 A “T”

10.1.2. Periodic lubrication

After 100.000 cycles lubrication is recommended. That means testing approximately 1000 spirometers according to standards ISO 26782 and ISO 23747 or 2000 peak flow meters according to ISO 23747 standard.

Piston and cylinder
Use lubricant only specified by the manufacturer:

- Interflon Ltd. — Fin Food Lube + Teflon®
- Suggested quantity — Spray one (1) second

Procedure:

☞ Move the piston to “PISTON IN” position, the farthest position from the pneumatic outlet.

☞ Apply the lubricant through the pneumatic outlet to the inner surface of the cylinder.

☞ Generate a few 10 liter square waves to smooth the grease

☞ Repeat the two previous steps a few times

☞ Use the drain valve located at the left lower corner of the equipment to remove surplus lubricants from the cylinder.

BTPS valve

Check the BTPS valve according to section 10.4.1: Adjusting BTPS valve. If necessary adjust it.

Use lubricant only specified by the manufacturer:

- Interflon Ltd. Fin Food Lube + Teflon®
- Suggested quantity Spray one (1) second

Procedure:

- ☞ Apply the lubricant specified in the above section (or silicone spray) through the pneumatic outlet to the surface of the valve.
- ☞ Turn the device off and then on. Startup procedure will move the BTPS valve that will smooth the lubricant
- ☞ Repeat the two previous steps a few times

Linear bearing and shaft

- ☞ Turn off the device
- ☞ Remove the cover as described at paragraph 10.2.2: Removing the cover.
- ☞ Clear the shafts from dirt and add some machinery oil on it, or use the lubricant specified in the previous sections
- ☞ Move the linear slide between the end positions with your hands back and forth a few times.
- ☞ Wipe excess oil off the shaft ends and replace the cover.

10.1.3. Quick leakage test

The manufacturer recommends performing a quick leakage test after a long term storage or transport.

- ☞ Turn off the device.
- ☞ Remove the white plug from the back panel, turning it with a coin and screw in the external piston rod.
- ☞ Block the pneumatic outlet with your hand.
- ☞ Strongly push the piston rod and hold it for minimum 10 seconds with a nearly constant force to generate a nearly constant pressure in the cylinder.

- ☞ After that push it again stronger a second, then use the previous constant force again. The piston rod should move in, then return to the previous position.
- ☞ Repeat the test in both directions.

If leakage test fails then see the troubleshooting guide on section 10.5: Troubleshooting guide.

10.2. Disassembling

WARNING!

Before opening the device, please make sure it is disconnected from line power!

10.2.1. Tools

List of tools needed for disassembling:

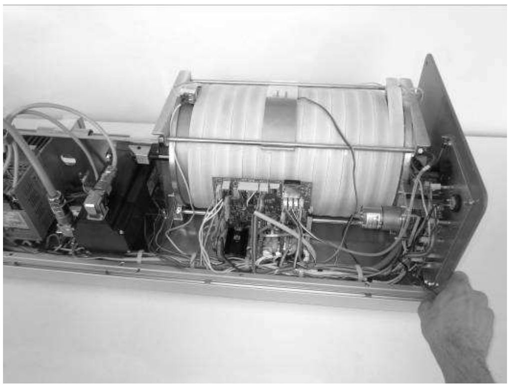
- Hex key 5 mm (min. 200 mm long, with spherical head and T-handles)
- Hex key 4 mm (min. 100 mm long, with spherical head and T-handles)
- Hex key 3 mm (min. 100 mm long, with spherical head and T-handles)
- Hex key 2.5 mm (min. 100 mm long, with spherical head and T-handles)
- Open-end wrench 10 mm (2 pcs)
- Socket wrench 13 mm
- Slotted screwdriver (min. 100 mm long, 4 mm blade with)

10.2.2. Removing the cover

Unscrew the 4 screws with 4mm hex key.

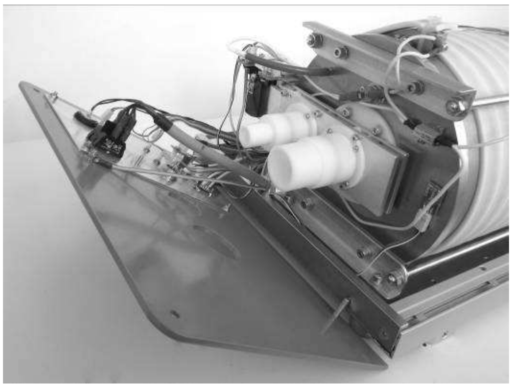
You can pull up the cover by grabbing on the edge of the upper aluminum profile with both hands.

10.2.3. Removing the main front panel



Use 10 mm wrench to loosen the nuts on both side.

Take care of the cables and connectors.



Carefully fold down the main front panel, taking care of the cables connected to it.

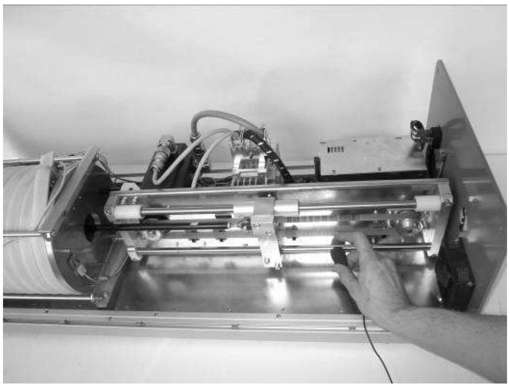
10.3. Timing belt

10.3.1. Check tension

Tension of the timing belt should be checked after every 100.000 cycles or after a long term storage or transport.

Proper belt tension can be estimated by plunking the belt and measuring its frequency. The required frequency range for the specified belt is:

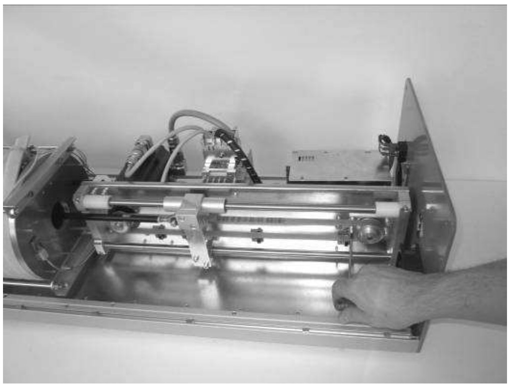
- 160 Hz (~$D^{\#}_3$ musical note) - 200 Hz (~G_3 musical note)



Plunk the lower part of the belt to generate sound. You can use a universal belt tension meter or a simple PC microphone and chromatic FFT tuner software to measure the frequency.

☞ If the frequency is too low, then you should readjust the tension.

10.3.2. Adjusting tension



Loosen the 4 screws fixing the rear bearing block with 4mm hex key.

Loosen the safety nut with 10 mm wrench.

Use the 10 mm wrench to adjust belt tension by tightening or loosening the screw.

After finishing the adjustment fasten the safety nut and the 4 screws and check the frequency again.

10.3.3. Replacement

Timing belt should be replaced if it is worn or it is over stretched

Use timing belt only specified by the manufacturer:

- Optibelt Alpha T2.5-950/12

Procedure:

- ☞ Release the timing belt as shown in the previous section.

Move the piston by hand until the fastening plate coincides with the mounting hole

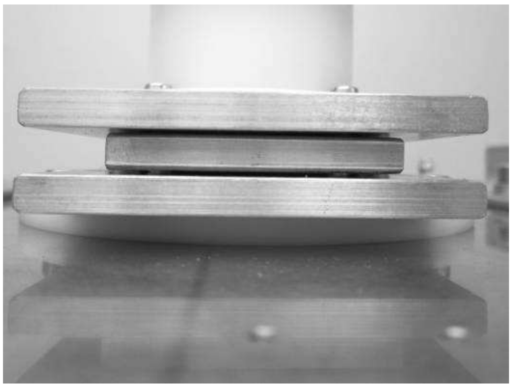
Unscrew the 2 slotted head screws from the timing belt fastening plate.

- ☞ Replace the timing belt to a new one and fix it
- ☞ Adjust pre-tension of the new timing belt

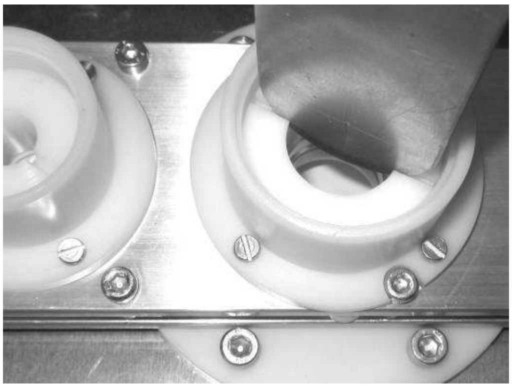
10.4. Sealing

10.4.1. Adjusting BTPS valve

The abrasion of the PTFE rings should be checked after every 10.000 cycles of the BTPS valve.



The slider plate should be in middle position.

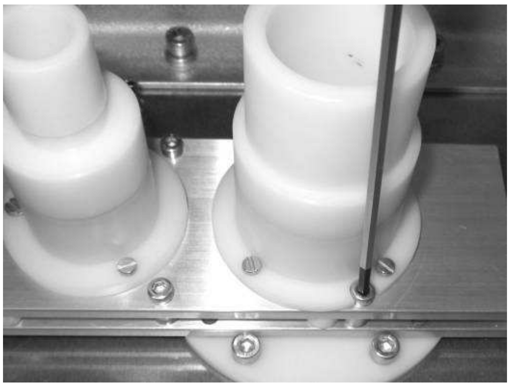


Remove the pneumatic outlets.

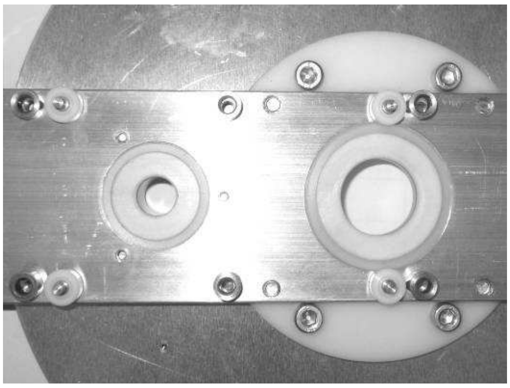
You can adjust the preload on the inside tensioner O-rings with a sheet of metal or with a coin.

10.4.2. Replacement of PTFE rings in BTPS valve

PTFE rings should be replaced if they are excessively worn or scratched.



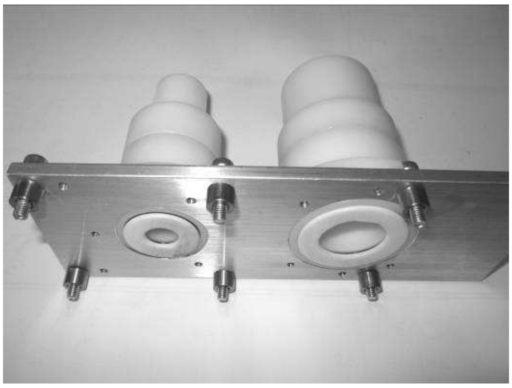
Unscrew the 6 screws with 4mm hex key. Carefully pull off the front plate of the BTPS valve.



The rollers with their shafts should be put back in place if they fall off.

Treat the sealing surfaces with lubricant.

Replace the PTFE rings. Replace the tensioner O-rings too if necessary.



Pull the spacer rings on the screws and screw the front plate back to place.

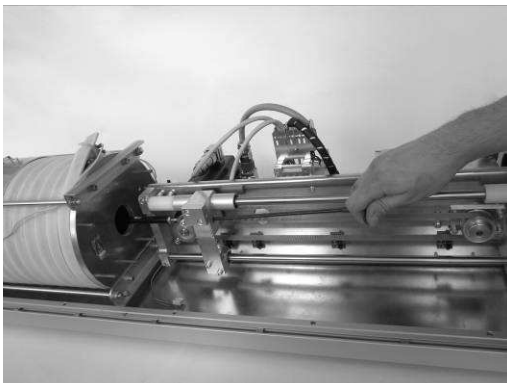
Use a rod to center and hold in place the PTFE rings during the operation.

10.4.3. Replacement of piston O-ring

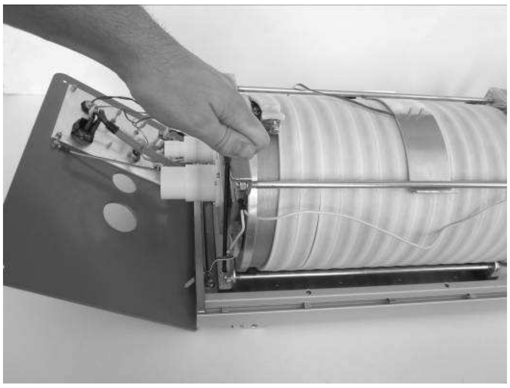
Use O ring only specified by the manufacturer or equivalent in size and type:

- Trelleborg ORAR00443; 189,9x7 mm; NBR 70 ShA

The O ring seal of the main cylinder should be replaced after every 1.000.000 cycles or after a failed leakage test.

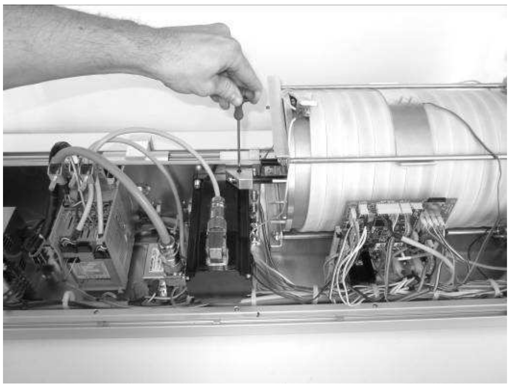


Remove the piston rod from the linear slide using 5 mm hex key

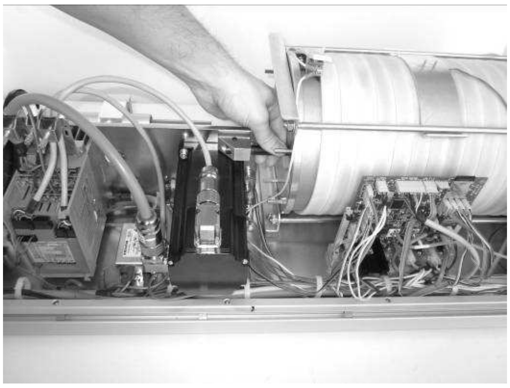


Unscrew the 4 screws on the cylinder’s feet with 5 mm hex key.

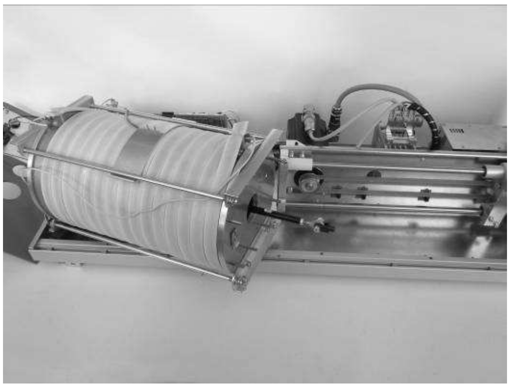
Disconnect the temperature sensor on the cylinders back end.



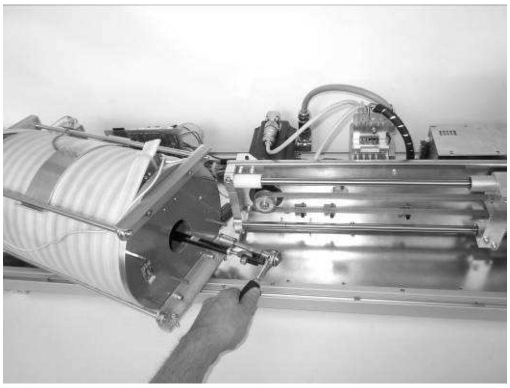
Loosen the grub screw on the fixing element with 3 mm hex key.



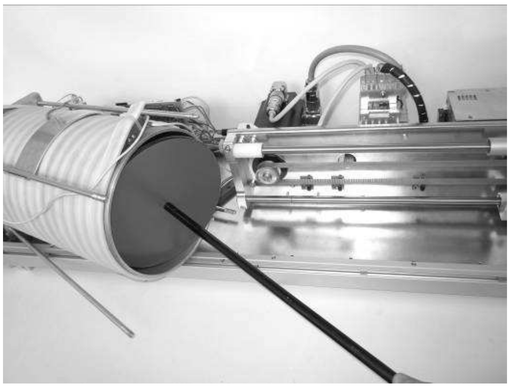
Unscrew the fixing rod from the cylinder’s back end.



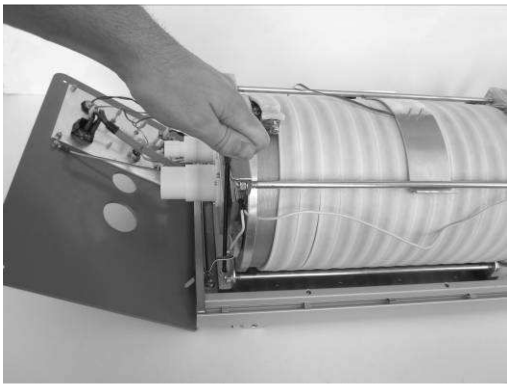
Turn the cylinder about 30° degrees, taking care of the cables connected to it.



Unscrew the 4 nuts on the tightening screws with 13 mm wrench and remove the cylinder's back end.



Pull out the piston and remove the old O-ring seal. Before replacing it clear the inside surface of the cylinder and the groove on the piston from old lubricant and dirt.



After replacing the piston, put the back cylinder plate in place and loosely screw the nuts on the tightening screws.

You can align the two cylinder end plates to place and tighten the screws on the cylinder's feet.

Tighten the nuts on the tightening screws.

10.5. Troubleshooting guide

10.5.1. Potential leakage points

In case of a failed leakage test the following examinations should be performed:

Drain valve

- Check if the valve is closed
- Check the drain tube for damages
- Block the barb connector on the cylinder bottom and perform a quick leakage test without the drain valve

BTPS valve

- Check the connection and the O-ring sealing of the pneumatic connectors
- Perform the periodic lubrication process
- Check the slider plate position and if necessary, readjust the pre-tension on the PTFE rings
- Perform a visual check on the PTFE rings in action and replace they if necessay

Pressure transfer tube

- Check the tube for damages
- Block the barb connector on the cylinder front plate and perform a quick leakage test

Piston sealing

- Perform the periodic lubrication process of the cylinder
- Check the piston O-ring
- Clear the O-ring groove on the piston

Cylinder front cover sealing

- Check the sealing groove on the cylinders front cover and if necessary, scrape off the old grease and fill it with high viscosity, heat resistant grease.

10.5.2. Mechanical errors

Linear motion jam

- Check the mechanic for runaway particles and loosen screws
- Perform the periodic lubrication process of the linear shaft
- Check the roller bearings on the timing belt pulley

Loud rattling noise

- Check the timing belt pre-tension
- Stepper motor current is too low

Loud humming sound

- This is normal on high stepper motor current

11. Appendix

11.1. PWG Command-line Waveform Complier

PWG-33 Command-line Waveform Complier is a small 32 bit DOS based application that converts standard waveform files to binary files used by the PWG itself.

Location

PWG-33 Command-line Waveform Complier is located in the installation folder of the main application:

```
...\Pulmonary Waveform Generator\pwgcc.exe
```

Usage

```
pwgcc -W filename.wf [-O waveform.bin] [-A]
[-VT|-FT|-SIN|-SQR] [-F value] [-FZ value]
[-VZ value] [-I] [-Q value] [-D] [-P] [-H]
```

Switch	Description
-W	Define input file
-O	Define output file (default is input filename.bin)
-A	Append data to the output file
-D	Display device parameters
-VT	Override input type as Volume(Time)
-FT	Override input type as Flow(Time)
-F	Override input Frequency
-FZ	Override input flow zoom factor
-VZ	Override input volume zoom factor
-I	Inverse mode
-Q	Define quarters for Sine and Square functions *value* is a 1 to 4 digit string used to select quarters of the full period. Examples: 1234, 12, 34, ...
-C	Copy output to device
-P	Wait for [enter] after done
-H	Display help message

11.2. PWG Command-line Controller

PWG-33 Command-line Controller is a small 32 bit DOS based application that can be used to control the PWG from command line. PWG Command-line Controller supports basic control tasks only.

Location

PWG-33 Command-line Controller is located in the installation folder of the main application:

```
...\Pulmonary Waveform Generator\pwgcmd.exe
```

Usage

```
pwgcmd [-A|-B] [-I] [-Z|-E] [-M Flow Volume] [-S]
[-F Folder File] [-N Number] [-SLEEP] [-WAKE]
[-RESET] [-TEMP Piston [Vaporizer]]
```

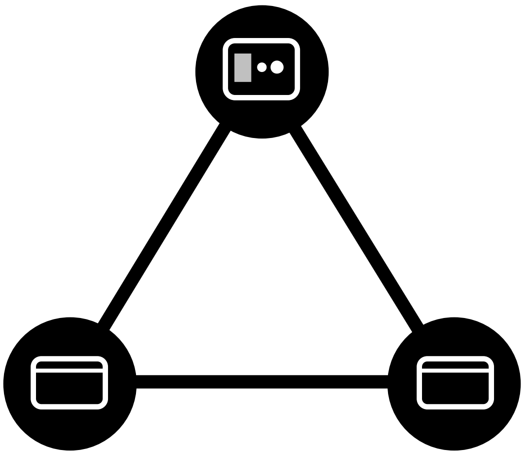
Switch	**Description**
-A	Set BTPS valve to Ambient
-B	Set BTPS valve to BTPS inlet
-I	Inverse mode on
-Z	Move to Zero position
-E	Move to End position
-M	Move piston by a given Volume with a given Flow. Flow can be a positive or negative floating point number. Any decimal separators accepted.
-S	Play default file
-F	Play the given File in given Folder.
-N	Number of iterations
-SLEEP	Enter sleep mode
-WAKE	Wake from sleep mode
-RESET	Reset motor after step error
-TEMP	Test temperature of Piston and Vaporizer Given temperature can be a floating point number. Any decimal separators accepted. Enter values of 0 to turn off heating.
-W	Wait for operation to complete
-P	Wait for [enter] after done

11.3. Software Interface

PWG-33

Software Interface

Developer's Guide



Created:	20/04/2012
Version:	v1.00
Modified:	20/04/2012

1. Contents

2. Introduction

2.1. About PWG Software Interface

PWG Software Interface is a communication interface between main PWG application and spirometer software designed to be used during product development and validation.

2.2. Main purpose

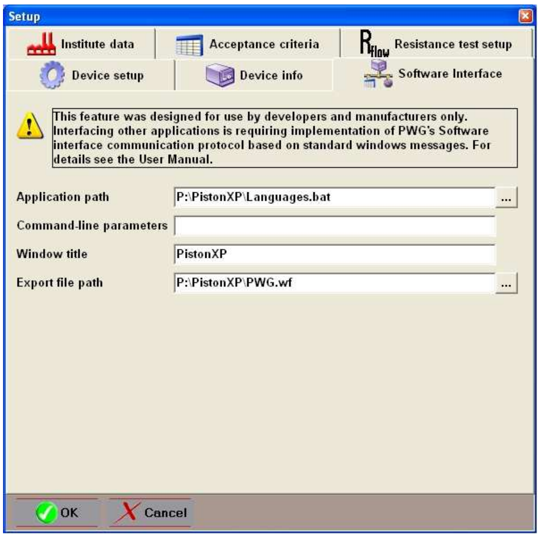
PWG Software Interface makes it possible to do validation test of Spirometers' automatically, without any user interaction. Measurement control and reporting results are controlled by the interface. Key design consideration was to give an easy to understand, easy to implement and easy to use standard for all manufacturers using PWG-33 and leaving further developments at customer side avoiding later compatibility issues.

2.3. Brief description

PWG Software Interface keeps control on PWG's side. PWG Software plays the *master* role while spirometer acts as *slave*. The master controls the slave via standard windows messages. Main phases of communication are:

- Connect / Disconnect
- Initialize (pre-measurement tasks, like zero setting of flowmeter)
- Start / Stop / Cancel measure
- Reporting results via a standard PWG waveform file

2.4. Configuration of Interface



The following information is required for PWG Software to start the interface:

- Application to be launched
- Command-line parameters to be passed
- Title of window to communicate with
- Path to report file

3. Principle of operation

PWG Software Interface can be activated from the PWG Software. See PWG-33 User Manual for details.

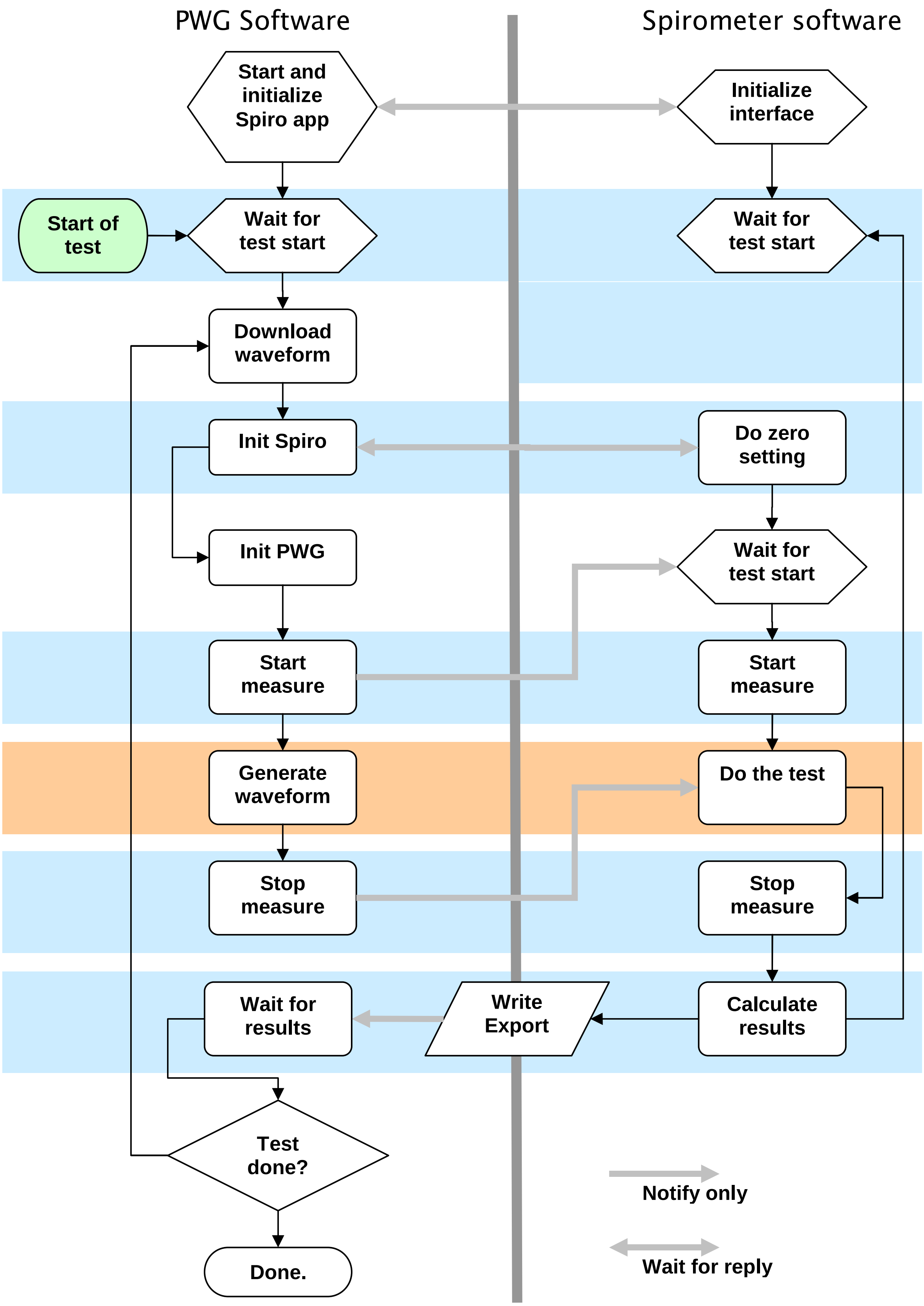
3.1. Activation steps

Activating the Interface will perform the following tasks:

- Launch of spirometer application
- Check for started process running
- Find the handle *HWND* of the window
- Send initialization command

3.2. Measurement control

After startup, the Spirometer application is waiting for commands. The test is started manually by the user.



Operation steps:

- A waveform is downloaded.
- Spirometer is instructed to prepare for measurement. PWG Software is waiting for the result of spirometer's initialization process. If initialization fails, the test is interrupted.
- PWG is prepared for the test (zero setting, move to start position, BTPS inhalation). The spirometer is waiting for measurement to be started.
- Spirometer is instructed to start the measurement. PWG Software is expecting a result code. If initialization fails, the test is interrupted.
- The PWG is generating the waveform; the spirometer is collecting flow samples.
- When the waveform was generated, the spirometer is instructed to stop measure. PWG Software is expecting a result code. If the measurement succeeded the PWG Software will suspend the test process.
- The spirometer software is calculating test results and writes them to an export file.
- The spirometer software is notifying the PWG Software about the test file was created.
- PWG Software is reading test results and resumes the test process.

4. Implementation guide

This chapter will show step by step how to implement PWG Interface in any application. Examples are written for Object Pascal (Delphi).

4.1. Define constants and variables

The following constants are used by the interface:

```
Windows message string constant
str_WM_PWG_INTERFACE = 'WM_PWG_INTERFACE';
```

```
Commands(constants)
pwg_WM_INITINTERFACE   = $00
pwg_WM_INITIALIZE      = $01
pwg_WM_INITDONE        = $02
pwg_WM_STARTMEASURE    = $03
pwg_WM_STOPMEASURE     = $04
pwg_WM_RESULTAVAILABLE = $05
pwg_WM_DISCONNECT      = $FF
```

```
Command replies constants
pwgCMD_OK    = $01;
pwgCMD_FAIL  = $FF;
Result status constants
pwgRES_NONE  = $00;
pwgRES_WAIT  = $01;
pwgRES_DONE  = $02;
```

```
Variables
PWG_APP : HWND;
WM_PWG_INTERFACE : DWORD;
```

4.2. Prepare the interface

First step is to register the *str_WM_PWG_INTERFACE* windows message using *RegisterMessage()* API call in the main unit's *initialization* section:

```
Register a custom message

initialization
  WM_PWG_INTERFACE :=
    RegisterWindowMessage(str_WM_PWG_INTERFACE);
end.
```

Next step is to catch windows messages sent to the application. Override main form's default message handler.

```
Override DefaultHandler()

TMainForm = class(TForm)
  // form declarations

  procedure DefaultHandler(var Message); override;

private
public
end;
```

Create the basic structure of *DefaultHandler()* to preserve functionality of the application. See description and implementation guide and for each command in the next section. Embed their example codes into the following one.

```
Example

procedure TMainForm.DefaultHandler(var Message);
begin
  with TMessage(Message) do begin
    if Msg = WM_PWG_INTERFACE then begin
      if wParam = ...
      // write your code here
    end else
      inherited DefaultHandler(Message);
  end;
end;
```

Each command sent to the spirometer software is located in the unsigned 32bit integer value *Message.wParam*.An extra parameter for some commands is located in the unsigned 32bit integer value *Message.lParam*.

4.3. Initializing interface (pwg_WM_INITINTERFACE)

Instructs the spirometer software to enter interface mode.

Message parameters

wParam	pwg_WM_INITINTERFACE
lParam	Handle to PWG Software

The parameter *lParam* can be used when sending notifications for PWG Software. Store it in the predefined variable *PWG_APP*.

Possible results

pwgCMD_OK	initialization successful
pwgCMD_FAIL	unable to initialize

Example

```
      if wParam = pwg_WM_INITINTERFACE then begin
        PWG_APP := lParam;
        // write your code here
        Result := pwgCMD_OK;
      end;
```

4.4. Initializing measurement (pwg_WM_INITIALIZE)

Instructs the spirometer software to run initialization tasks required for a measurement (e.g. zero setting of the flow meter).

Message parameters

wParam	pwg_WM_INITIALIZE
lParam	not used

Possible results

pwgCMD_OK	initialization successful
pwgCMD_FAIL	unable to initialize

Example

```
      if wParam = pwg_WM_INITIALIZE then begin
        if ...
          // write your code here
          then Result := pwgCMD_OK
          else Result := pwgCMD_Fail;
      end;
```

4.5. Starting measurement (pwg_WM_STARTMEASURE)

Instructs the spirometer to start collecting samples.

Message parameters

wParam	pwg_WM_STARTMEASURE
lParam	not used

Possible results

pwgCMD_OK	measurement started successfully
pwgCMD_FAIL	unable to start measure

Example

```
      if wParam = pwg_WM_STARTMEASURE then begin
        if ...
          // write your code here
          then Result := pwgCMD_OK
          else Result := pwgCMD_Fail;
      end;
```

4.6. Stoping measurement (pwg_WM_STOPMEASURE)

Instructs the spirometer to stop collecting samples and calculate results

Message parameters

wParam	pwg_WM_STOPMEASURE
lParam	trigger event

Trigger events

1	normal stop, waveform ended
2	user cancelled

Possible results

pwgCMD_OK	measurement done, calculating results
pwgCMD_FAIL	unable to calculate results

Example

```
      if wParam = pwg_WM_STOPMEASURE then begin
        if ...
          // write your code here
          then Result := pwgCMD_OK
          else Result := pwgCMD_Fail;
      end;
```

4.7. Reporting results (pwg_WM_RESULTAVAILABLE)

Spirometer software notifies PWG Software that the results are calculated and the export file is written to the disk.

Message parameters

wParam pwg_WM_RESULTAVAILABLE

lParam Result of reporting

If result calculation fails, the parameter *lParam* must to $FF. Other values are preserved for further development.

Example: Sending notification

```
SendMessage(PWG_APP, WM_PWG_INTERFACE,
  pwg_WM_RESULTAVAILABLE, pwgCMD_OK);
```

4.8. Closing interface (pwg_WM_DISCONNECT)

Both software may notify the other that the interface is closed for example due to exiting the application.

Message parameters

wParam pwg_WM_RESULTAVAILABLE

lParam not used

Example 1: Sending notification

```
SendMessage(PWG_APP, WM_PWG_INTERFACE, pwg_WM_DISCONNECT, 0);
```

Example 2: Receiving notification

```
      if wParam = pwg_WM_DISCONNECT then begin
        // write your code here
        Result := pwgCMD_OK;
      end;
```

5. Using the interface

Once the interface is configured, a new button [Connect to Spirometer software] appears on the Welcome screen.

- ☞ Click the button to launch Spirometer software
- ☞ Open a Quick test
- ☞ Select a Waveform group of Waveform set

Starting a waveform will automatically initialize the spirometer and start the measurement.

- ☞ Use the button [All] to batch process all waveforms in the group or set.

11.4. USB Protocol specification

PWG-33 Waveform Generator

USB Protocol Specification

Developer's Guide

Created:	01/02/2009
Version:	v2.00
Modified:	23/04/2012

1. Contents

2. Brief protocol description

PWG-33 is an USB composite device, containing two functions:

- MSD drive
- HID device

Booth devices are using OS's integrated drivers to communicate with user software. No additional drivers are necessary.

PWG-33 uses the following Vendor and Product IDs:

Vendor ID: 0x04D8
Product ID: 0xF8D6

3. Communication

The USB communication is packet based. The maximum size of a packet is 64 bytes. The device always sends and receives this 64 bytes. However in most cases we do not use all the 64 bytes just the first few pieces of them all the 64 bytes has to be sent.

All packet starts with the following two bytes:

1	1	P. size	P. counter
byte 0			byte 1

1st byte bit 7 (MSB): 1: command or command response
0: data

1st byte bit 6: 1: PC sent the packet
0: Device sent the packet

1st byte bit 0-5: Packet size 0-63 (the real size is [Packet size]+1)

2nd byte: Packet counter. The device uses two different counters, one for the command packets and another one for the data packets

4. Send a command

Commands are sent only from the PC to the device using the following structure:

1	1	P. size	P. counter	Command		…
byte 0			byte 1	byte 2	byte 3	…

The device is always sending a reply to each command. This response begins with the same 4 bytes like the command, only the 6th bit of the 1st byte is turned to zero.

1	0	P. size	P. counter	Command		…
byte 0			byte 1	byte 2	byte 3	…

5. Supported commands

5.1. Common commands

Command name	Code	Data after the command bytes	Response after command bytes	Comment
Read version	0x0100	-	1st byte: Device Type **(PWG-33 is 0x0F)** 2nd byte: Minor ver. 3rd byte: Mayor ver. 4th byte- list of available channels	[Packet size]-6 is equal to the number of channels `(buf[0] && 0x3F – 6)`
Read channel descriptor	0x05*nn*	-	channel descriptor (60 byte)	*nn*: identification number of the channel
Write channel descriptor	0x06*nn*	new channel descriptor (60 byte)	modified channel descriptor (60 byte)	*nn*: identification number of the channel
Not supported commands		-	-	Response is 0xFFFF

5.2. Device specific commands

Command name	Code	Data after the command bytes	Response after command bytes	Comment
PWG GOTO Zero	0x0A00	1 byte: 0: IN 1: OUT	-	
PWG Set BTPS Valve	0x0A01	1 byte 0: AMBIENT 1: BTPS		
PWG Set Syringe Temperature	0x0A02	2 byte: Temperature × 100		Turn syringe and humidifier heating on. Humidifier's temperature is automatically set 1 ºC higher. Value of 0xFFFF will switch the heating control off.
PWG Set BTPS Temperature	0x0A03	2 byte: Temperature × 100		Sets the humidifier's temperature only. Humidifiers temperature must always be higher than syringe's!

PWG Read Status	0x0A04	-	4 byte Status word 4 byte Status change word	
PWG Set File to play	0x0A05	1st byte: 0: Set filename 1: Set Directory 2nd byte- 0 terminated str.		Max. 1 directory depth level accepted Only 8.3 format filenames accepted
PWG Play Waveform	0x0A06	1st byte: 0: default 1: filename 2nd byte: Play count 0: endless		
PWG Set Speed	0x0A07	1st byte-: Goto zero speed [timing, 4 byte unsigned int.]	1st byte-: Goto zero speed [timing, 4 byte unsigned int.]	Values under 1000 aren't accepted (actual value is always returned)
PWG Go x Steps	0x0A08	1st byte-: Speed timing, [4 byte signed unsigned int.] 5th byte-: Step count [16 bit]		
PWG Reset Motor	0x0A09			
PWG Send Status (notify event)	0x0A0A		4 byte Status word 4 byte Status change flags	Notify Devices' status change; sent automatically
PWG SLEEP Mode	0x0A0B	1st byte 0: OFF (wake) 1: ON (sleep)		In sleep mode the controller turns the motor current off
PWG STOP	0x0A0C	1st byte: 0: Only stop 1: Stop and goto zero 2nd byte: 0: IN 1: OUT		Stops any movement of the piston (but does not stop the ambient valve)

6. Available channels

Name of channel	Identification number	Description	Resolution	Comment
Extra descriptor	00	Contains device name and serial number	-	-
Syringe Pressure	19		2x16 bit of pressure sensors	
PWG status	24		- 32 bit: status word - 32 bit: status change flags	details below
PWG syringe temperature	25		16 bit of front temperature 16 bit of rear temperature 16 bit of syringe temperature 16 bit of humidifier temperature	All values are in ºC × 100 (signed integer)

7. Structure of channel descriptors

Length of the channel descriptor is 60 bytes (indexed 0-59).

ch size	ch ID number	S. time LOW	S. time HIGH	Active	Channel specific area	Reserved
byte 0	byte 1	byte 2	byte 3	byte 4	5-58	byte 59-
					0-53 in other parameters	

Ch size:	The current channel's size in byte
Ch ID number:	Identification number of the channel
Sample time:	Sample time in ms (unsigned integer)
Active:	1: Channel is active, if sampling is started, values are automatically sent 0: Channel is inactive, values are never sent
Channel specific area:	In this area are calibration constants and other user defined parameters stored
Reserved:	Reserved for further development

Non variable parameters	**Variable parameters**
Identification number	Sample time
Channel size	Active
	Channel specific area

7.1. Extra Descriptors (Ch00)

Addresses within [Channel dependent] block

byte	Parameter name	Type
0 19	Name of device (string)	String
20 39	Serial number of device (string)	String

7.2. Syringe pressure descriptor (Ch19)

Addresses within [Channel dependent] block

byte	Parameter name	Type
0 5	Syringe pressure, pressure sensor low Par A	Real48
6 11	Syringe pressure, pressure sensor low Par B	Real48
12 17	Syringe pressure, pressure sensor high Par A	Real48
18 23	Syringe pressure, pressure sensor high Par B	Real48

```
Pressure [kPa] = (R - ParA) / ParB
```

where R is the 16 bit A/D value of syringe pressure channel

7.3. PWG status descriptor (Ch24)

Addresses within [Channel dependent] block

byte	Parameter name	Type
0 5	Maximum BTPS inspiration speed [l/s]	Real48
6. 7	Calibration steps [step]	Unsigned integer (16 bit)
8. ... 11	Main clock frequency [Hz]	Unsigned integer (32 bit)
12. ... 17	Maximum flow [l/s]	Real48
18. ... 21	Minimum delay time [clock]	Unsigned integer (32 bit)
22. ... 27	Peak acceleration [l/s^2]	Real48
28 33	Peak deceleration [l/s^2]	Real48
34 39	Step volume [ml]	Real48
40. ... 45	Sum volume [l]	Real48
46. ... 51	Available volume [l]	Real48

7.4. PWG syringe temperature (Ch25)

No channel descriptor present for this channel (on demand, these bytes can be used to store any data).

```
Temperature [°C] = Rn / 100
```

where R_n is the 16 bit (signed) value of syringe temperature channel n

8. PWG-33 Status word

The device has a 32 bit status word and a 32 bit Change flag. The status word is sent any time when at least one bit changes in it. The Change flag is indicating the bits that are changed within the status word. The status word can be also queried any time by the Read Status (0x0A04) command.

8.1. Structure of status word

Bit	Function	Comment
0	Pump IN	Piston is in the IN zero position
1	Pump OUT	Piston is in the OUT zero position
2	Ready	Device is ready to do something
3	Init ready	Initialization was performed
4	Step error	The motor could not take the steps Use the PWG Reset Motor (0x0A09) command
5	Valve in ambient position	
6	Valve in BTPS position	
7	Valve error	Check the device
8	Heating active	Heating the syringe and the humidifier (if connected)
9	Temperature OK	Temperature is within the range
10	Going zero position	Executing command: PWG GOTO Zero (0x0A00)
11	Play file	Executing command: PWG Play Waveform (0x0A06)
12	Steps	Executing command: PWG Go x Steps (0x0A08)
13	Sleep mode	The motor has no power
14	Switch pressed	
15	Waveform restart	Play of waveform restarted during cyclic play; after command: PWG Play Waveform (0x0A06)
16	Limiter IN	Piston ran out of the work area
17	Limiter OUT	Piston ran out of the work area
18	Device is busy	Device can not perform the command
19-31	not used	

Status change events occur even if there was no real change in the devices physical condition so if the physical status change must be wait, the user software has the possibility to trigger on the status change.

Example

If a command was sent to move the BTPS valve to ambient position but it already was there the following events will be fired:

1. Valve in ambient position - CLEAR
2. Valve in ambient position - SET

The Change flags' [Valve in ambient position] bit will be set in both cases.

9. Programming the generator

9.1. Principle of operation

The PWG-33 is a step motor driven syringe. Exact flow is achieved by the known volume of steps following each other after a proper timing. Generated waveforms are series of timing intervals. Waveforms must be copied to the built in SD card. The default file is **waveform.bin** placed into the root folder.

Calculatiuon of timing:

$$T = V_{Step} \times \frac{f_{PWG}}{\dot{V}}$$

Example

$$T = \frac{0.345 ml}{1000} \times \frac{80000000 Hz}{10 \frac{l}{s}}$$

The following commands are using these timings:

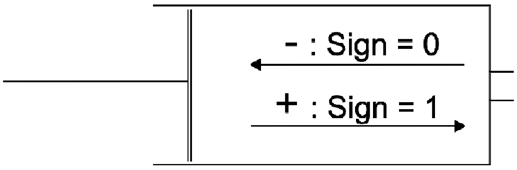
- PWG Go x Steps (0x0A08)
- PWG Set Speed (0x0A07)
- PWG Play Waveform (0x0A06)

9.2. Data format

Timing values are stored in 32 bit unsigned integers (DWORD) with the following supplement. The 31st bit (MSB) is indicating the direction of rotation. These 32 bit data units are called a ***step***.

bit 31	bit 0-30
SIGN	Delay time (in main clock)

Sign and directions



Sign	Interpreted as breathing on PWG side	31st bit
-	Inspiration	0
+	Expiration	1

9.3. Device capabilities

Device capabilities can be read from the device by querying the channel descriptor of the PWG Status channel. Never exceed devices' physical limitations. These parameters can be device specific so it is recommended to read these parameters anytime you connect to a device.

Parameter name	Comment
Maximum BTPS inspiration speed [l/s]	
Calibration steps [step]	Number of steps between the two midway opto gates
Main clock frequency [Hz]	Frequency of the waveform generators main circuit. Use this value to calculate step timings from flow values.
Maximum flow [l/s]	Maximal flow rate of the PWG. Exceeding this speed might result step errors. Extreme range violation can cause mechanical deformation!
Minimum delay time [clock]	Firmware specific lower limit of step time
Peak acceleration [l/s^2]	Calculate speed's raise time for a given flow using this constant
Peak deceleration [l/s^2]	Calculate speed's fall time from a given flow using this constant
Step volume [ml]	Exact volume of one step
Sum volume [l]	Pneumatic dead space of the syringe
Available volume [l]	Volume available for waveform generation

9.4. Minimal flow rate

On the one hand the minimal flow rate is 0 l/s. On the other hand the PWG-33 is a step motor based system where we only can speak about average flow over a given time interval. However if we define a minimal frequency (f_{min}) for steps we can calculate a minimal flow rate.

$$\dot{V}_{\min} = \frac{V_{step} \times f_{\min}}{1000} \quad [l/s]$$

Example:

$$\dot{V}_{\min} = \frac{0.345ml \times 25Hz}{1000} = 0.008625\,\text{l/s}$$

9.5. Structure of played file

Waveform files are pure binary files containing series of ***step***s (see chapter

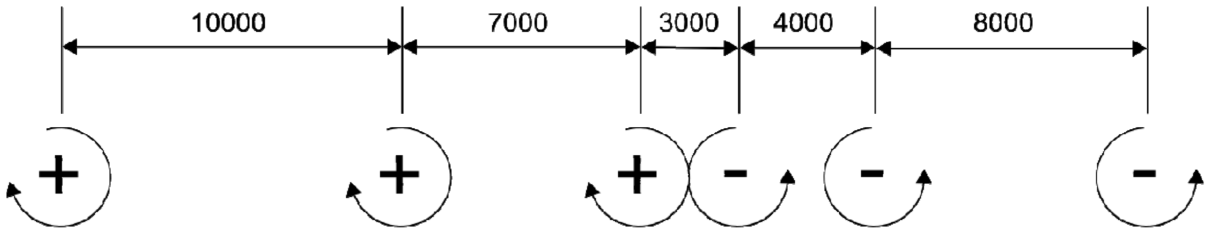
Data format). The device reads all ***step***s form the waveform file in a sequence. The value red is separated into two parts: rotation direction and timing. Any data red generates one pulse for the motor instructing it to make one step into the requested direction and starts a timer to wait the time defined in the timing part of the ***step***. It is obvious that the timing part of the last ***step*** has no impact but its direction flag is used.

Waveform files can hold any breathing samples of any kind and any length, including inspiration and expiration; only the described device limitations must be kept.

You can use PWG Waveform Compiler (pwgcc.exe) command line tool to convert Volume(Time) and Flow(Time) input files to binary data.

Example
Playing 6 pulses:

Step	Signs & values	Binary data in file
1	+10000	`0x80002710`
2	+7000	`0x80001B58`
3	+3000	`0x80000BB8`
4	-4000	`0x00000FA0`
5	-8000	`0x00001F40`
6	-12000	`0x00002EE0`



10. Data transfer format

If sampling is started the device sends all active channels' data in the following format:

Device sends (theoretical)

0	0	P. size	P. counter	Ch. identifier	Ch. data	…	Ch. identifier	Ch. data	...
byte 0			byte 1	byte 2	byte 3	…	2 + 1 + Ch. size.	…	…

Example #1 (only the syringe pressure channel is active):

Data sent by device

0	0	P. size	P. counter	0x13	Plow_DataL	Plow_DataH	Phigh_DataL	Phigh_DataH	0x13	...
byte 0			byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	…

Example #2 (syringe pressure and syringe temperature channels are both active):

Data sent by device

0	0	P. size	P. counter	0x13	Plow_DataL	Plow_DataH	Phigh_DataL	Phigh_DataH	...
byte 0			byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	…

…	0x19	FR_T_L	FR_T_H	R_T_L	R_T_H	SY_T_L	SY_T_H	H_T_L	H_T_H	...
…	byte 7	byte 8	byte 9	byte 10	byte 11	byte 12	byte 13	byte 14	byte 15	…

11. Examples of communication

11.1. Read device descriptors

Read version (theoretical):

PC sends

1	1	3	P. counter	0x00	0x01
byte 0			byte 1	byte 2	byte 3

Device response

1	0	P. size	P. counter	0x00	0x01	Device type	Minor ver.	Major ver.	Channel numb.	Channel numb.	...
byte 0			byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8	…

Read version in case PWG-33:

PC sends

1	1	3	P. counter	0x00	0x01
byte 0			byte 1	byte 2	byte 3

Device response

1	0	001001 (9)	P. counter	0x00	0x01	0x6C	0x01	0x01	0x13	0x18	0x19
byte 0			byte 1	byte 2	byte 3	byte 4	byte 5	byte 6	byte 7	byte 8	byte 9

11.2. Read chanel descriptor

(channel 11)

PC sends

1	1	3	P. counter	0x0B	0x05
byte 0			byte 1	byte 2	byte 3

Device response

1	0	3	P. counter	0x0B	0x05	channel descriptor (60 byte)
byte 0			byte 1	byte 2	byte 3	byte 4-63

11.3. Write chanel descriptor

(channel 11)

PC sends

1	1	3	P. counter	0x0B	0x06	New channel descriptor (60 byte)
byte 0			byte 1	byte 2	byte 3	byte 4-63

Device response

1	0	3	P. counter	0x0B	0x06	New channel descriptor (60 byte)
byte 0			byte 1	byte 2	byte 3	byte 4-63

11.4. Sample start

PC sends

1	1	3	P. counter	0x01	0x02
byte 0			byte 1	byte 2	byte 3

Sampling starts…

Device response

1	0	3	P. counter	0x01	0x02
byte 0			byte 1	byte 2	byte 3

11.5. Sample stop

PC sends

1	1	3	P. counter	0x02	0x02
byte 0			byte 1	byte 2	byte 3

Sampling stops…

Device response

1	0	3	P. counter	0x02	0x02
byte 0			byte 1	byte 2	byte 3

11.6. Send PGW status

Device send

1	0	0x3F	P. counter	0x0A0A	Status word	Status change flags
byte 0			byte 1	byte 2-3	byte 4-7	byte 8-11

11.7. Not supported command

PC sends

1	1	3	P. counter	NOT	SUPPORTED
byte 0			byte 1	byte 2	byte 3

Device response

1	0	3	P. counter	0xFF	0xFF
byte 0			byte 1	byte 2	byte 3

12. Default values

12.1. Extra Descriptors (Ch00)

Channel configuration

Ch size: 0
Ch ID number: 0
Sample time: 0
Active:...0

Other parameters:

Name:...“Waveform Generator”
Serial number:..“PWG33-20XX-xxx”
.... where 20XX is the year of production
.... and xxx is a 3 digit counter

12.2. Syringe pressure descriptor (Ch19)

Channel configuration

Ch size: 4
Ch ID number: 19
Sample time: 4
Active:...1

Other parameters:

Pressure sensor low Par A.: ....4000 ÷ 4200
Pressure sensor low Par B.: ....3500 ÷ 4500
Pressure sensor high Par A.: ....4000 ÷ 4200
Pressure sensor high Par B.: ....100 ÷ 200

12.3. PWG status descriptor (Ch24)

Channel configuration

Ch size: 8
Ch ID number: 24
Sample time: 1000
Active:...1

Other parameters*:

Max flow of BTPS inhalation:.. 0.5 [l/s]
Calibration steps: ....10000 ÷ 12000 [step]
Main clock frequency: ....80000000 [Hz]
Maximum flow: .... 20.0 [l/s]
Minimum delay time: ....500 [clock]
Peak acceleration: .... 3000 [l/s^2]
Peak deceleration: .... 3000 [l/s^2]
Step volume: ....0.34 ÷ 0.36 [ml]
Sum volume: ....10 ÷ 10.5 [l]
Available volume: .... 10 ÷ 11 [l]

* Default values may wary on individual device instances

12.4. PWG syringe temperature (Ch25)

Channel configuration

Ch size: 8
Ch ID number: 25
Sample time: 1000
Active: 1

Other parameters:

Not used (free for any user data)