The Lungtest System

LUNGTEST

Spirometer service manual
LUNGTEST LAB

How to use the program

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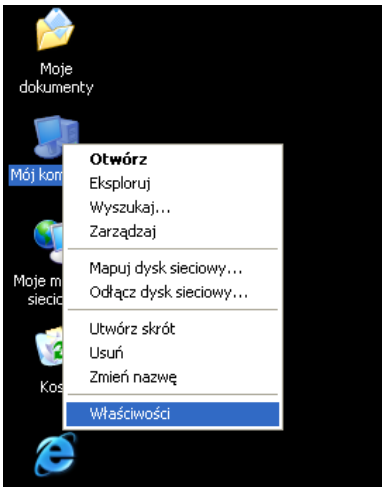
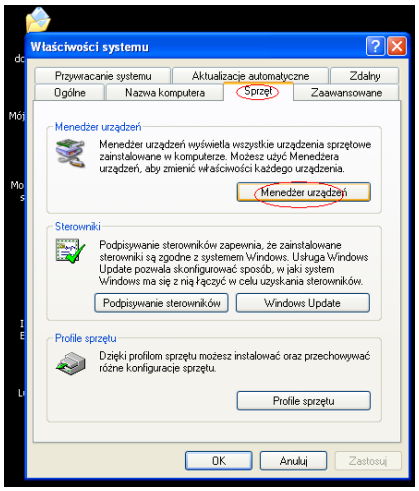
1. Lungtest Startup

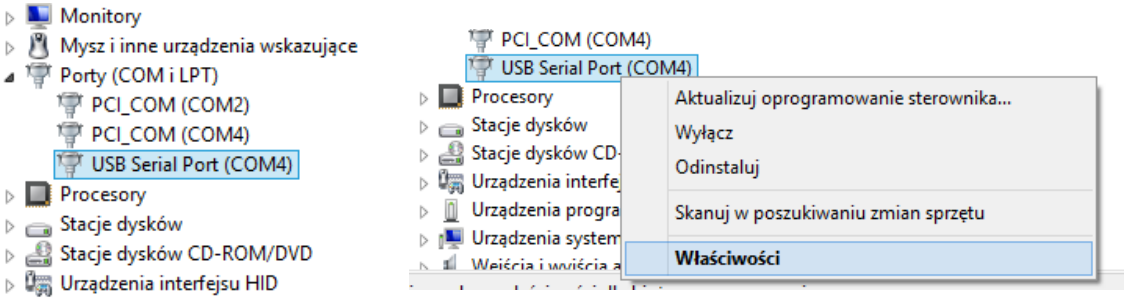
1.1. Software installation

1. Put the Lungtest CD into the CD/DVD drive of Your Computer.
2. Find „Lungtest\USB Drivers” folder.
3. Execute „CDM vxxx WHQL Certified.exe” file and follow the instructions on the screen.
4. Plug Lungtest LAB device to a free USB port, then plug a power supply cable and turn on the device with a switch situated at the back cover.
5. Find „My Computer” icon on your desktop (or „Computer” for Win8 systems) and right click on it. You will see a Menu as pict. below. Choose „Properties”. Then choose “Hardware” tab and press „Device Manager”.

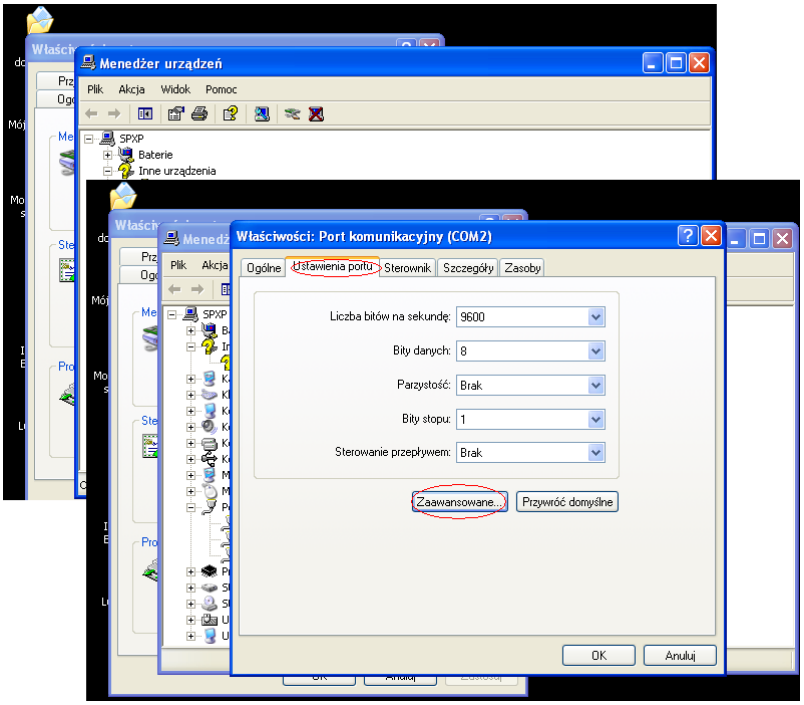




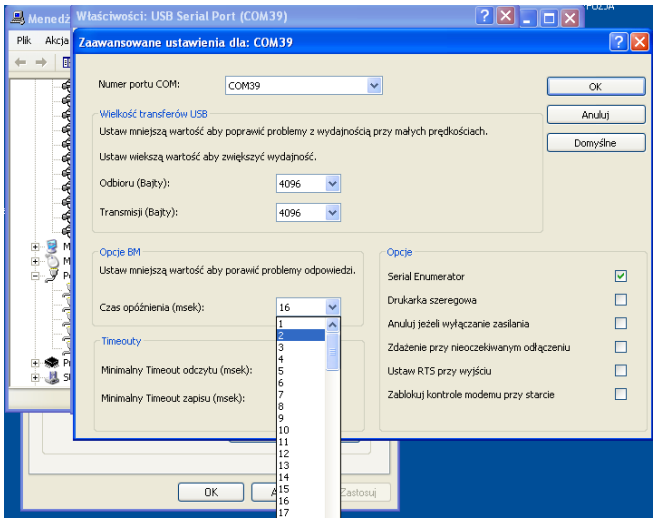
6. Enlarge the branch „Port COM&LPT” and find „USB Serial Port (COM x)” device. Remember the COM port number.



7. Right-click on selected device and select „Properties”. Switch to tab “Port settings” and press „Advanced”.



8. Set the parameter „Delay time” to 2 ms.



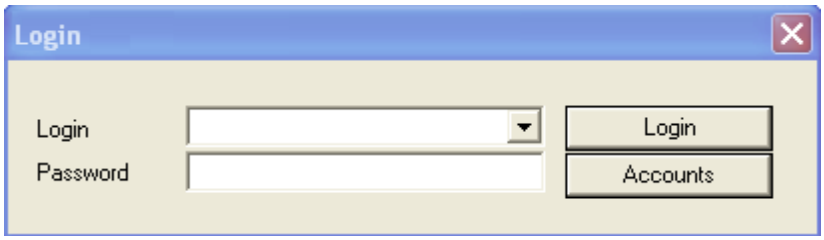
9. Apply changes with „OK”.

10. Find „Lungtest” folder on your CD and execute „setup.exe” file. Follow the instructions on the screen.

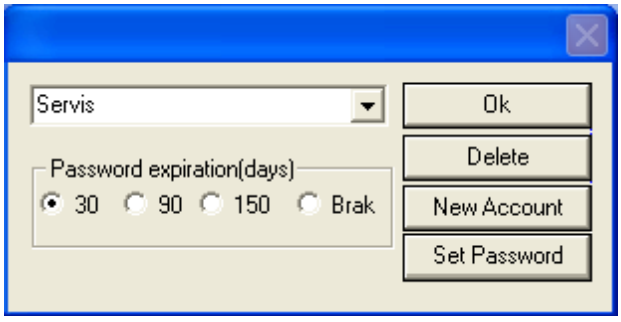
11. After installing „Lungtest” software, find a registry file on your CD called „kalibracja – xxxxxxxx.reg” and actualize the system registry, with double-click on this file and accepting the questions.
CAUTION: During the action sescribed in point 11, Lungtest Software MUST be closed!

1.2. Login

Lungtest LAB application supports administrative work with spirometry test stations for system administrator can use. Logon procedure allows personalization in application access and storing information's about logged users in Mes apps if required. Lungtest LAB can also be set in autologon mode where loging to apllication is skipped. Login mode is set by default and can be change by Mes service staff **only!** System administrator or it's users shod not attempt to change the login mode at any circumstances and always contact Mes support if such change is required.
In Login mode after user click's Lungtest LAB icon following form displays:

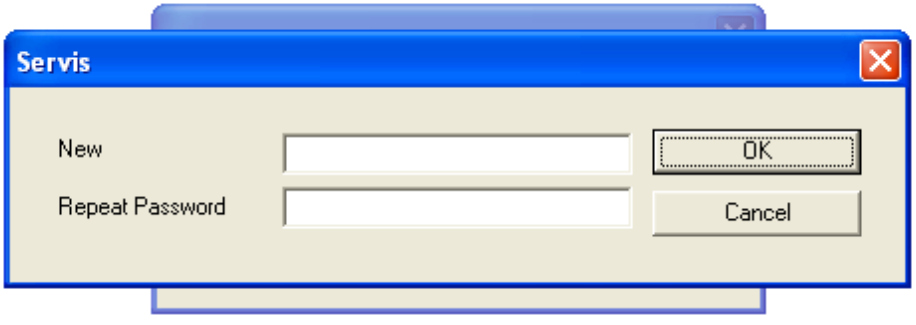


Use comb box to choose user or enter user name using keyboard. Enter password and click "Login" or "Manage" If you chose "Login" program will run and user will be auto-logged in every Mes application until instance of logged program exists. Pressing "Manage" will lead to following screen:



Manage panel allows to create new account, or delete/modify currently logged. There is no super user or admin account. Instead every logged user can create new account or modify account he owns. To create new account type user name, password expiration time and press "New". Program will create account with chosen name with default "123" password. To delete current account press delete.

To set new password press "Set password" button. During logon if the password become expired user will also be asked to choose new password with following screen:



2. Patient's Data

By patient's data we mean a set of information necessary for patient's identification and determination of test parameters . (⇨ Chapter 3).Without this information no test can take place. Patient's data can be entered in four ways:

1. New patient's data (⇨ Chapter 2.1).
2. Selecting patient form data base (⇨ Chapter 2.2).
3. Selecting a file with earlier test results. Command *Patient from file*(menu *File*).
4. Opening and closing the file with earlier patient's test results (⇨ Chapter 10).

After entering patient's data all test will be done for this patient. In order to test another patient, their data must be entered.

2.1. New Data

New patient's data are entered through the dialogue box *Patient's data* (⇨ fig.1) which is accessible after the command *New patient* (menu *File*). The box has a set of fields where information compatible with the label which is near each field should be typed.

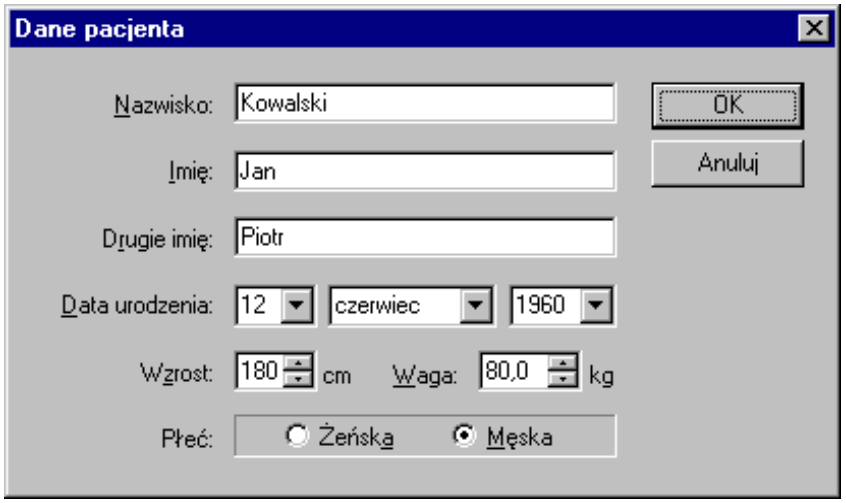


Fig. 1. Dialogue box *Patient's data*

2.2. Selecting from data base

The patient can be selected from the data base through the command *Select patient* (menu *Data base*). For information on selecting the patient from the data base see Data base manual.

2.3. Modification

Patient's data can be modified through the dialogue box *Patient's data* (⇨Fig.1) which opens after the command *Edit patient's data* (menu *File*). Data modification is possible only after its earlier entering (⇨Chapt.2) but before any tests have been started. Only patient's *Height and Weight* can be modified.

2.4. Data review

Patient's data review, i.e. the review of its daily contents is done through the dialogue box *Patient's data* (⇨Fig.1) which opens after the command *Edit patient's data* (menu *File*). The data of the same patient coming from different tests can differ only in *Height and/or Weight.*

3. Reference values

By reference values we mean a set of expected values of measured elements. Such values are derived from findings resulted from tests on a certain population taking into account such features as height, weight, sex, and race.

3.1. Configuration of standards

Reference values is configured from the dialogue box *Configure reference values*(⇨ Fig.2) opened with *Configure reference data* command in *Tool* menu.

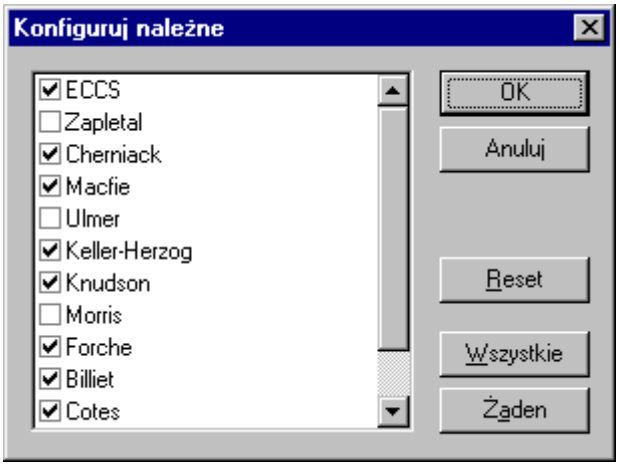


Fig. 2. Dialogue box *Configure reference data*.

The dialogue window *Configure reference values* is identical with the dialogue box *Configure parameters* (⇨ Fig. 4) and is used in the same way (⇨ Chapter 0).

Reference values are calculated according to the authors indicated with ✓, in the same order as shown in the list. Example: we are calculating *MVV* parameter according to configuration shown in fig.2. *ECCS* – no result, *Zapletal* – does not take part in the calculation , *Cherniak* – no result, *Macfie* – result found – our search is completed. We can change order of standards as follows: click the left mouse cursor on the required position, drag to a selected place. When you reach the selected place, release the button.

Note: Authors should be selected carefully. Reference values for particular parameters given by various authors may significantly differ from one another. Please note, that particular parameters of reference set based on many authors may be contradictory.

(**Ref**) column contains information on standards applied for calculation of reference value of a given parameter. Letter symbols are explained on the printout below the table.

Note: Standards for patients 71+ do not exist. MES software approximates ECCSs up to the age of 95. Information about approximation is entered in the test comment – *"Values of standards for patients ≥ 71have been calculated by approximation"*.

List of standards applied in the software – types of tests referred to by a standard are given in brackets:

1. **Billiet** (Diffusion SB);
2. **Cherniack** (MVV);
3. **Cotes** (Diffusion SB);
4. **ERS** (Bodypletysmography, Compliance, Diffusion SB, Flow – Volume, RRS, Spirometry, FRC);
5. **Forche** (Diffusion SB, MVV, Spirometry, FRC);
6. **KellerHerzog** (Diffusion SB, Spirometry, FRC);
7. **Knudson** (Diffusion SB, FRC, Flow-Volume, Spirometry);
8. **Macfie** (Flow-Volume);
9. **Morris** (Flow-Volume);
10. **Ulmer** (Diffusion SB, S Spirometry, FRC);
11. **Zapletal** (Bodypletysmography, Compliance, Diffusion SB, Flow-Volume, MVV, Spirometry, RRS, FRC);
12. **ZPIGiCHPRabka** (Flow-Volume, RRS);
13. **IGiCHPWarszawa** (Respiratory model);
14. **Hankinson** (Flow-Volume);
15. **Polgar** (Flow-Volume);
16. **Crapo** (Flow-Volume);
17. **HSE** (Flow-Volume);
18. **NHannes** (Flow-Volume);
19. **GLI** (Flow-Volume);

4. Test description procedure

Next chapters are devoted to descriptions of tests which can be done using *LungTest* application. Each of them contains sub-chapters common for all tests and sub-chapters specific for each test. Common sub-chapters are:

1. **Test parameters**

The sub-chapter presents the set of all parameters which are determined during the test, i.e. their names, units and a short description.

2. **Test options**

The sub-chapter contains a description of settings (options) which influence the way the tests are done. These settings are modified through the dialogue box *Test options* (menu *Tools*). The box has several folds , each of which represents one test and bears the name compatible with the test name. Moreover, the box has two buttons *OK and Cancel*. The first button is used to accept, the second one – to cancel the modifications.

3. **Test procedure**

The sub-chapter contains the procedure of the test.

4. **Test result.**

The sub-chapter shows a sample result of the test. Each result contains, among others, a set-up of test parameters shown as a table ((⇨Chapt.4.1). Flow and volume axes have identifiers IN and EX which show the flow direction.

4.1. Table with test results.

Table (⇨Fig.3) is a part of the test result containing all its parameters.

Lp.	Parametr	Jdn	Ref	Nal	Akt 1	A1/N%	SR 1	P 1
1	VC	l	E	5,25				
2	FEV 1	l	E	4,21	4,75	113	+1,06	86
3	FVC EX	l	E	5,02	5,61	112	+0,97	83
4	MEF 50	l/s	E	5,39	6,49	120	+0,83	80
5	MEF @ FRC	l/s						
6	TPEF	s			0,05			
7	AEX	l*l/s	E	27,06	31,67	117		

Fig. 3. Table with test results

The table has the following nine columns:

No.	Name	Description	Comments
1	No.	Parameter number	
2	Parameter	Parameter name	
3	Unit	Parameter unit	
4	Ref	Author of standards in **Ref** column	Letter symbols are explained on the printout below the table
5	Ref value	Parameter reference value	⇨ Chapt. 3
6	Act	Actual parameter value	Value obtained as measurement result
7	±A/N %	Comparison between actual	±A/N % – deviation of actual value from reference value

	or A/N %	and reference values	expressed in % A/N % – relation between actual and reference values expressed in %.	
8	SR	Number of standard deviations	$SR = \frac{Akt - Nal}{\delta}$	where δ is a reference value standard deviation
9	P	Percentile	*N* grade percentile informs that *n*% persons of the population have parameter value at the level not exceeding *actual value.*	

Note:

In tests where several sets of parameters can be the result, the table has an additional column in each set. Each of these columns has the comparison of actual values from each set with the actual values that have been indicated as reference values through the command *Next comparison* (table system menu (⇨ Chapt.4.1.1)). The heads of the columns are *+Ai/Aj%* or *Ai/Aj%* where *i* is the set index and *j* – is the index of the set which is the basic one. The name depends on the selected way of comparison (relative or absolute).

4.1.1. Table configuration

Table is configured through the commands in its system menu. The menu is accessible after clicking on the icon on the left of the title bar  .

The menu has the following commands:

No.	Name	Description	
1	Compare relatively Compare absolutely	Changes the way of comparing actual value to the basic one into relative or absolute	
2	No.	Shows or hides a column	*No.* ⇨ Fig.3
3	Author	– II –	*Ref.* ⇨ Fig.3
4	Refrence values	– II –	*Ref value*
5	Actual	– II –	*Act*
6	Comparison	– II –	*±A/N %* lub *A/N %*
7	Number of standard deviations	– II –	*SR*
8	Percentile	– II –	*P*
9	Comparing actual	– II –	$\pm A_i/A_j$ % or A_i/A_j %
10	Next comparison	Enlarges the column index to which actual values of each parameter sets are compared	
11	Configure parameters	⇨ Chapt. 0	
12	*Standard system commands*	Standard *Windows* commands, e.g. Move, Close, etc.	

NOTE ! The set configuration is common for all tests. "Test comparison" for which a separate configuration exists, is an exception.

4.1.2. Parameter configuration

Parameter configuration, i.e. the selection of parameters which are to be placed in the table and the selection of their sequence is done through the dialogue box *Configure parameters* (⇨Fig.4) which opens after the command of the same name as the one in the table system menu (⇨Chapt.4.1.1).

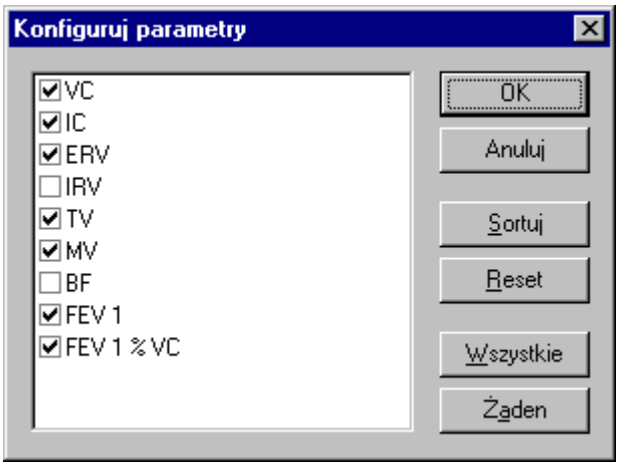


Fig. 4. Dialogue box *Configure parameters.*

The box has the following elements:

1. **Parameter list**:
The list contains parameters necessary for the test. Fig.4 shows parameters used in spirometry.

2. ***OK* button**:
Serves for accepting the actual parameter selection.

3. ***Cancel* button**:
Serves for cancelling all modifications done since the dialogue box has been opened.

4. ***Sort* button**:
Sorts the contents of the *Parameter list* alphabetically.

5. ***Reset* button**:
Resets the initial parameter configuration, i.e. the one done by the manufacturer

6. ***All* button**:
Highlights all elements of the *Parameter list*.

7. ***None* button**:
Unmarks all elements of the *Parameter list*.

The parameter is marked and unmarked by click on a square which is on its left hand side on the list. The parameter position can be modified by dragging its name onto the required position. Dragging is done as follows: place the mouse cursor on the parameter the position of which you want to change, press the left mouse button, keep it pressed and move the cursor up or down. When you reach the required position, let the button go free.

5. Spirometry

5.1. Test parameters

Parameter name:	Unit:	Description:
VC	L	Vital capacity
IC	L	Inspiratory capacity
ERV	L	Expiratory reserve volume
IRV	L	Inspiratory reserve volume
TV	L	Tranquil breath volume
MV	l/min	Minute ventillation
BF	1/min	Tranquil breath frequency
FEV 1	L	Forced Expiratory Volume in 1 second
FEV 1 % VC	%	Relation of *FEV 1* to *VC* in [%].

5.2. Test options

Test options are accessible on the fold *Spirometry* (⇨Fig.5) of the dialogue box *Test options* (⇨Chapt.3, item 2).

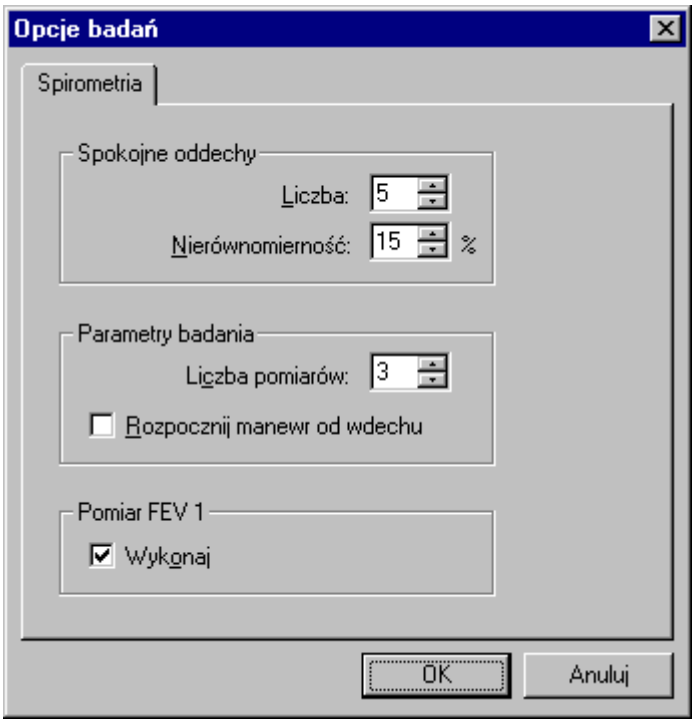


Fig. 5. Dialogue box *Test options – Spirometry*.

The box contains the following elements:

:

1. ***Tranquil breaths*** **field:**
    a) ***Number*** **edition line:**
        Here we state how many tranquil breaths are needed before a patient starts next phase of the test (⇨ Chapt. 5.2.1).

    b) ***Irregularities*** **edition line:**
        Here we state permissible irregularity of tranquil breaths.

2. ***Test parameter*** **field:**
    a) ***Number of tests*** **edition line:**
        Here we state a number of spirometric measurements we are planning to make. When the stated number of measurements is completed , the test will automatically finish or move to FEV 1 measurement if *Do* option is clicked in *FEV 1* field.
    b) ***Start manoeuvre with inhalation*** **option:**
        When the option is off, the system accepts only spirometries starting with expiration to *RV* level. However, when the option is on, the system accepts only spirometries started with inhalation to *TLC* level.

3. ***FEV 1*** **field:**
    a) ***Do*** **option:**
        The option should be on if we want to measure *FEV 1* parameter during a spirometric test.

5.2.1. Tranquil breath phase

Tranquil breath phase is used for calculation of *TV* and *BF* parameters(⇨ Chapt. 5.1), and for checking whether a patient is breathing quietly and regularly. Breath stability is evaluated on the basis of regularity criterion (⇨ Chapt. 13.3) taking into consideration options *Number* and *Irregularity* in *Tranquil breath* field (⇨ Chapt. 5.2). Only when the patient's breath fulfills this criterion, it will be possible to pass on to the next test phase. This transition cannot disturb breath regularity. If the regularity is disturbed then it may be necessary to repeat the whole tranquil breath phase.

During the whole tranquil breath phase there is a message *Breathe quietly and regularly* on the prompt bar. When the regularity criterion is fulfilled, the prompt changes to another one which matches the activity the patient is supposed to do during the test. It does not mean, however, that the patient has to do the activity immediately. On the contrary, they can continue to breath regularly and the activities can be done after a while.

5.3. Test procedure

1. Select *Spirometry* (menu *Test*).
2. Check test options (⇨Chapt. 5.2)
3. Start the test by selecting *Start test* (menu *Tools*)
4. Do the test following the phases:

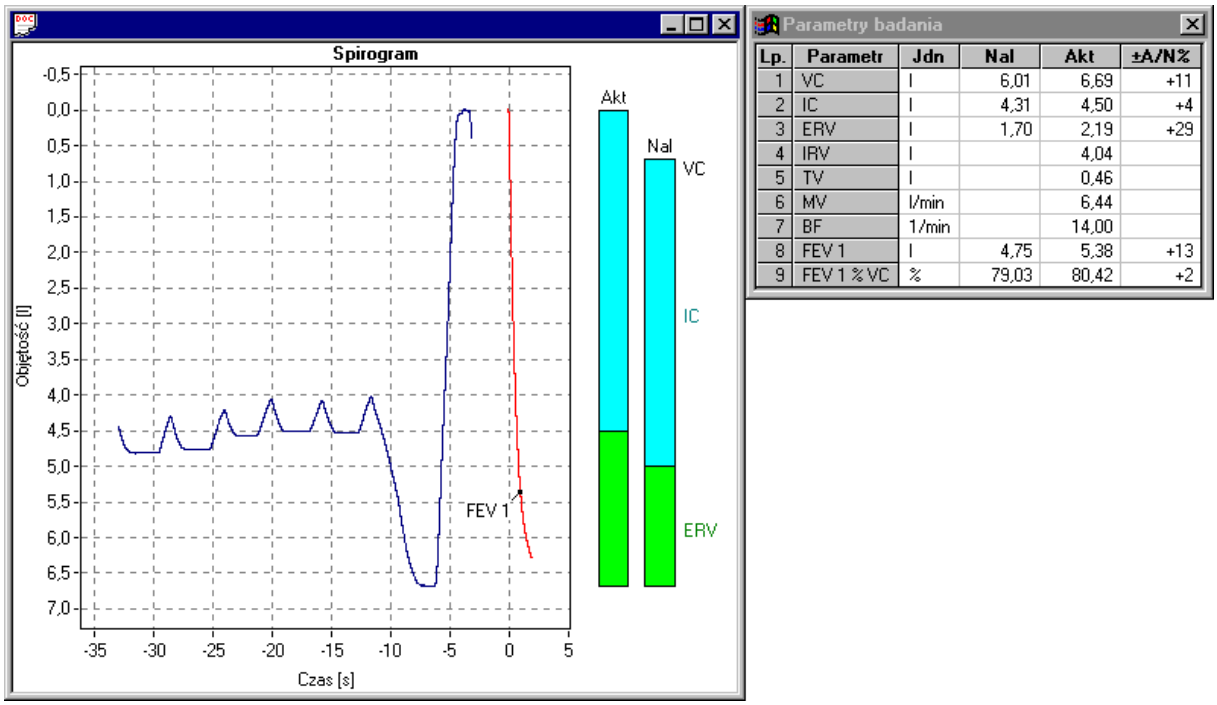
a) **Tranquil breaths.** (⇨ Chapt. 5.2.1). When the breaths get stabile , the message *expire maximally after inhalation* will appear on the prompt bar.
b) **Expiration to *RV* level.** A patient is making maximal breath-out , so that only residual volume remains in the lungs. When a spirogram does not show any changes in the volume we go on to the next phase. As far as breath dynamics in the spirometric phase is concerned (points b) thru d) , both breathes-in and breathes-out should be similar to sighs. Breathing cannot be slowed down or forced.
c) **Inhalation to *TLC* level.** A patient is making maximal breath-in of *VC* value. As in the previous phase, we go on to the next phase when spirogram does not show any changes in volume.
d) **Letting air out of lungs.** A patient lets air out of the lungs to about *ERV* level and starts tranquil breathing.
e) **End of test.** Breathing-out from *TLC* level of *TV* or *¼ VC* value, depending which value is lower, is the signal to finish the test. If all phases have been correctly completed, *LungTest* accepts the measurement and enlarges correct measurement index (⇨ Chapt. 15.5).
f) **Repeated test.** If *number of tests* option (⇨ Chapt. 5.2) is larger than 1 , the test is repeated, i.e., application moves to phase a) until the required *number of te*sts is reached.
g) ***FEV 1* parameter measurement.** This parameter will be measured after spirometric measurements have been completed but only when option *Do* in *FEV 1* field is ticked *1* (⇨ Chapt. 5.2). The course of measurement is described in *Flow-Volume* chapter (⇨ Chapt. 6.3).

If *Start manoeuvre with inhalation* option (⇨ Chapt. 5.2) has been selected, a patient, having stabilised breathing inhales to *TLC* level , expires to *RV* level and passes to tranquil breathing.

If N*umber of tests* option is larger than 1 and *Do* option in *FEV 1* measurement is ticked, than after completion of at least one measurement of *FEV 1* parameter, it is possible to give up other measurements and go to *FEV 1* measurement by selecting *Next phase* command (*Test* menu). If this command is not chosen, application will automatically move to *FEV 1* measurement when a number of spirometric measurements reaches the value equal to *Number of tests* option.

5.4. Test result

The test result is the best of performed measurements. *VC* value is the criterion for election. In case of *FEV 1* measurement, the best result is selected. The graphic representation includes a spirogram illustrating the measurement and a table with test parameters (⇨ Chapt.6).



Lp.	Parametr	Jdn	Nal	Akt	±A/N%
1	VC	l	6,01	6,69	+11
2	IC	l	4,31	4,50	+4
3	ERV	l	1,70	2,19	+29
4	IRV	l		4,04	
5	TV	l		0,46	
6	MV	l/min		6,44	
7	BF	1/min		14,00	
8	FEV 1	l	4,75	5,38	+13
9	FEV 1 % VC	%	79,03	80,42	+2

Fig. 6. *Spirometry* **test result.**

6. Flow – Volume

6.1. Test parameters

Parameter name:	Unit:	Description:
FEV 0,5	L	½ second forced expiratory volume
FEV 1	L	1 second forced expiratory volume
FEV 2	L	2 second forced expiratory volume
FEV 3	L	3 second forced expiratory volume
FEV 6	l	6 second forced expiratory volume
FEV 1 % FEV 3	%	FEV 1 to FEV 3 expressed in %
FEV 1 % FEV 6	%	FEV 1 to FEV 6 expressed in %
FVC EX	l	Forced expiratory vital capacity
FIV 1	l	Forced inspiratory vital capacity
FVC IN	l	Forced inspiratory vital capacity
VC	l	Vital capacity
VC MAX	l	Vital capacity as maximal value with VC and FVC EX
TV	l	Tranquil breath volume
VPEF	l	Volume at *PEF*
VPIF	l	Volume at *PIF*
FEV 1 % FVC EX	%	*FEV 1* to *FVC EX* in %
FEV 1 % FVC IN	%	*FEV 1* to *FVC IN* in %
FEV 1 % VC	%	*FEV 1* to *VC* in %
PEF	l/s	Peak expiratory flow
MEF 75	l/s	Maximal expiratory flow at 75% *FVC EX* before the end of expiration
MEF 50	l/s	Maximal expiratory flow at 50% *FVC EX* before the end of expiration
MEF 25	l/s	Maximal expiratory flow at 25% *FVC EX* before the end of expiration
MEF 50 % FVC EX	%	*MEF 50* to *FVC EX* in %
MEF 75 % VC	%	*MEF 75* to *VC* in %
MEF 50 % VC	%	*MEF 50* to *VC* in %
MEF 25 % VC	%	*MEF 25* to *VC* in %
MEF @ FRC	l/s	Maximal expiratory flow at *FRC*
FEF 75/85	l/s	Forced expiratory flow between 75 and 85% *FVC EX*
FEF 25/75	l/s	Forced expiratory flow between 25 and 75% *FVC EX*
PIF	l/s	Peak inspiratory flow
MIF 50	l	Maximal inspiratory flow at 50% *FVC IN* before the end of inspiration
MTT	s	Medium transient time
TPEF	s	Time at *PEF*
TMEF 75	s	Time at *MEF 75*
TMEF 50	s	Time at *MEF 50*
TMEF 25	s	Time at *MEF 25*

TPIF	s	Time at *PIF*
FET	s	Forced expiration time
FIT	s	Forced inspiration time
TTOT	s	Forced breathing total time (*FET* + *FIT*)
TPEF % FET	%	*TPEF* to *FET* in %
TPIF % FIT	%	*TPIF* to *FIT* in %
FET % FIT	%	*FET* to *FIT* in %
TC 25/50	1/s	Time constant between 25 and 75% *FVC EX*
AEX	l²/s	Expiratory area o flow-volume curve

6.2. Test options

Test options are accessible on the fold *Flow-Volume*(⇨ Fig.7) of *Test options* dialogue box (⇨ Chapter 3, item 2).

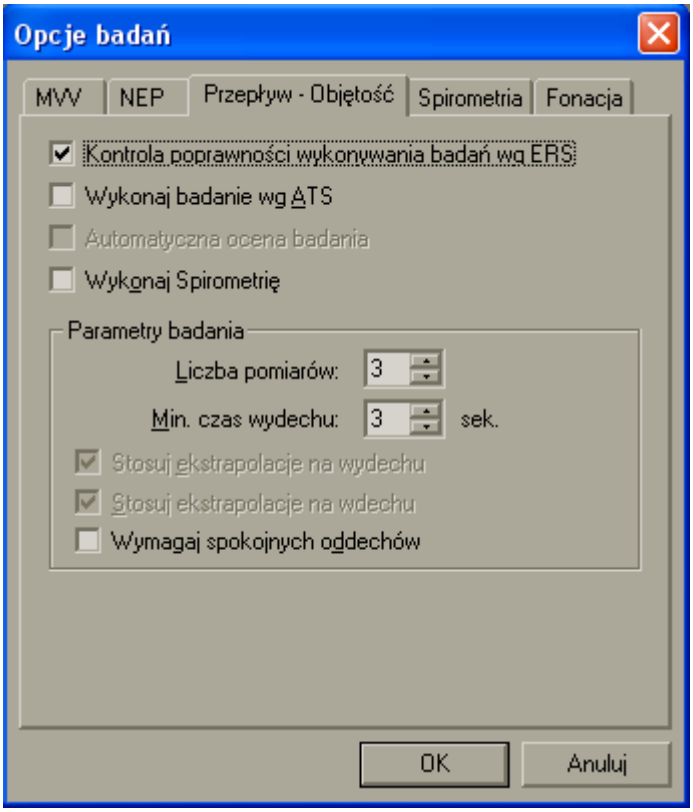


Fig. 7. Dialogue box *Test options – Flow-Volume*

The box contains the following elements:

1. ***Control of test conformity with ERS recommendations*** field***:***
   Tick ERS option to run a test conforming recommendations of *Europe Respiratory Society*, that is, *Minimal number of correct curves* – 3, *Minimal number of repeatable curves* – 2, *Minimal expiration time* – 3 sec, applying extrapolation at expiration.
2. ***ATS test*** field:

Tick ATS option to run a test conforming recommendations of *American Thoracic Society*, that is, *Number of measurements* – 8, *Minimal expiration time* – 3 sec, applying extrapolation at expiration.

3. ***Automatic diagnosis*** field

   Tick this field to get an automatic diagnosis based on the values measured during the test. In case of diagnosis indicating an illness, relevant information will be added to the printout. Automatic diagnosis is also possible for ERS or ATS tests.

4. ***Spirometry* field:**

   Activate this option if you want to run spirometric test during *Flow-Volu*me test. The test will be run according to *Spirometry* options (⇨ Chapt. 5.2).

5. ***Test parameters* field:**

   a) ***Number of tests* edition line:**

   Here we state a number of flow-volume measurements we are planning to make. When the stated number of measurements is completed , the test will automatically finish.

   b) ***Min. expiration time edition line*:**

   Here we state minimal forced expiration time. If the expiration is shorter than minimal time, the measurement will be rejected.

   c) ***Extrapolation at expiration* option:**

   Tick this option if reverse extrapolation will be applied in calculation of *FEV* parameters.

   d) ***Extrapolation at inspiration* option:**

   Tick this option if reverse extrapolation will be applied in calculation of *FIV* parameters.

   e) ***Tranquil breathing* option:**

   Tick this option to obtain a phase of tranquil breathing before each manoeuvre of the forced respiration (⇨ Chapt. 5.2.1).

Note: If you select "*Control of test conformity with ERS recommendations"* or "*ATS test*" option, a counter of curves meeting ERS/ATS standard will be displayed during Flow-Volume test (⇨ Fig.8). When ERS/ATS requirements are met, the test will be deemed correct and colour of the counter will change to green. *Measurement* field shows the number of the analysed curves; *FV(>50%)* shows the number of the curves with FV parameter larger than a half of FV maximal value of in all the analysed curves; *3FV(ATS)* and *FV(ERS)* will increase when the repeatable curve has been recorded, and 8*FV(ATS)* when the curve is correct.

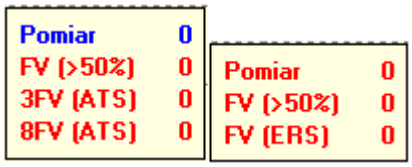


Fig. 8. ERS/ATS compliance counter.

Other options:

Tranquil breathing field functions of *Spirometry* test (⇨ Chapt. 5.2).are used in *Flow-Volume* test with a phase of tranquil respiration.

6.3. Test procedure

1. Select *Flow-Volume* command (menu *Test*).
2. Check test options (⇨ Chapt. 6.2).
3. Start the test with *Start test* command (menu *Tools*).
4. Run the test according to the following phases:

a) Tranquil breathes (⇨ Chapt. 5.2.1). When breaths are stabile, a message ”*Follow inspiration with maximal expiration*” will appear on the prompt bar followed with *Accept manoeuvre* command (menu *Test*). This command is available at expiration and blocked at inspiration. Availability of this command means: *Is the patient just breathing out before the forced inspiration*? If you accept, you will move to the next phase..

h) Expiration to *RV* level . A patient is making maximal expiration (not the forced one yet) so that only residual volume remains in the lungs. When spirogram does not show any changes in the volume, pass to the next phase,

b) Inhalation to *TLC* level. A patient is making maximal breath-in of *FVC IN* value. When spirogram does not show any changes in the volume, pass to the next phase,

c) Forced expiration to *RV* level. A patient is making forced maximal breath-out of *FVC EX* value so that only residual volume remain in lungs.

d) End of test. Forced expiration is ended when:

- inspiration starts
- expiration exceeds 15 sec.
- change in volume during last two seconds does not exceed 50 ml.

If all phases have been correctly completed, *LungTest* accepts the measurement and enlarges correct measurement index (⇨ Chapt. 15.5).

e) Repeated test. If *number of tests* option (⇨ Chapt. 6.2) is larger than 1 , the test is repeated, i.e., application moves to phase a) until the required *number of te*sts is reached.

f) *Spirometry*. Spirometry is run before flow-volume tests only when this option is ticked (⇨ Chapt.. 6.2). Spirometry test procedure is described in (⇨ Chapt.. 5.3).

Note: If *Tranquil breathing* option (⇨ Chapt. 6.2) has not been ticked, phase of tranquil breathing does not take place: a), and dynamics of each breath is analysed. In case of repeated test, forced expiration is followed immediately with the forced inspiration phase. It is possible to repeat forced breaths one by one. Naturally, application does not expect that all breaths will be forced. On the contrary, forced and tranquil breaths may alternate., though tranquil breaths are not analysed for regularity.

Additionally , if *Tranquil breath* option has not been ticked , flow-volume test will not be automatically ended, even when the preset *Number of tests* is reached. Such a test must be ended with *Discontinue test* command (menu *Test*) because it is impossible to determine, especially if *Extrapolation at expiration* option is off, whether the accepted measurements are forced manoeuvres or they are close to tranquil breaths. .

In flow-volume tests only measurements where *FVC EX* parameter is at least 95% of the largest *FVC EX* in all performed measurements are accepted. This procedure may result in decreasing or keeping the counter of correct measurements after the just finished measurement has been accepted if this measurement is the best of all already performed measurements.

A graphic time counter in the form of a circle (Fig.9) is being drawn in the flow graph. It is filled with colours : red – during first 3 seconds, yellow – during next 3 seconds and green during subsequent 6 seconds.

Fig. 9. Grapgic time counter.

6.4. Test result

The test result is a set of all the accepted measurements and a table with corresponding parameters. The obtained curves are manipulated from *Curve selection* bar (⇨ Chapt. 15.4).

If Flow-Volume test has been performed according to ATS criteria , curve repeatability is graded:

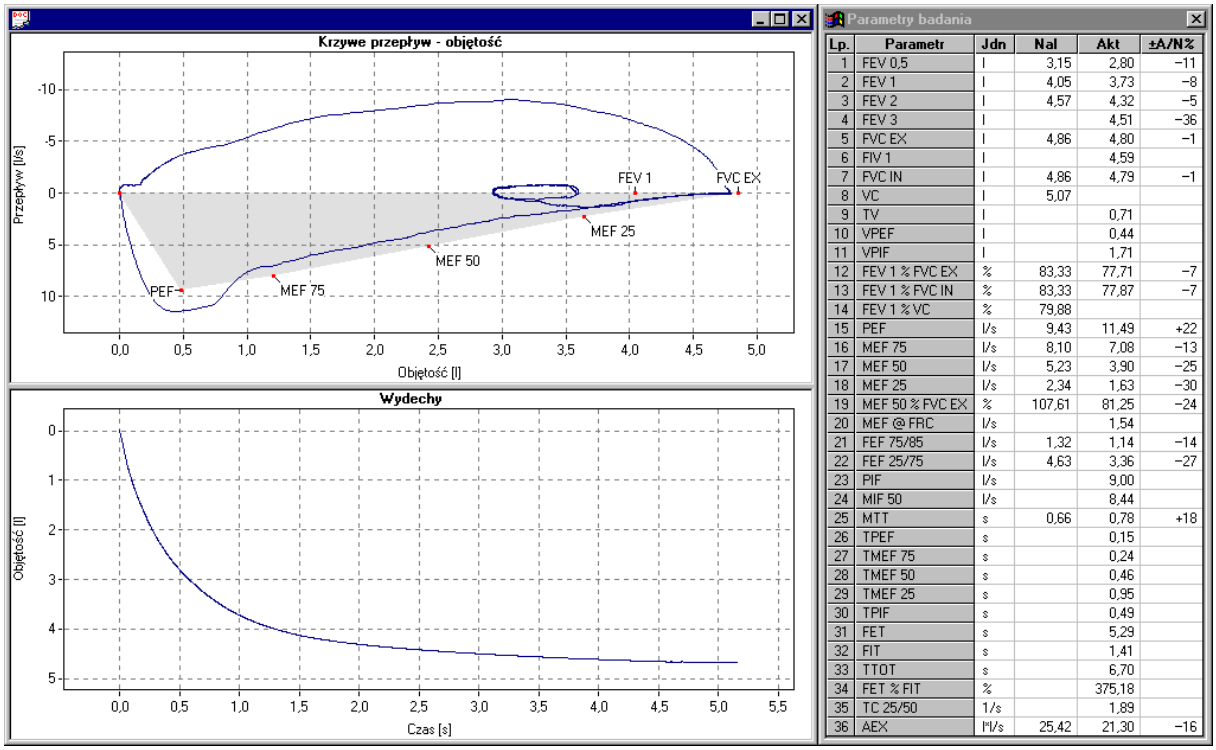
Grade A – at least two correct repeatable manoeuvres (difference between FEV 1 and FEV 6 does not exceed 100 ml)

B – at least two correct manoeuvres where difference in FEV1 parameter does not exceed 150ml

C – at least two correct manoeuvres where difference in FEV1 parameter does not exceed 200ml

D – at least one correct manoeuvre (not to be interpreted)

F – no correct manoeuvres (not to be interpreted)



Parametry badania

Lp.	Parametr	Jdn	Nal	Akt	±A/N%
1	FEV 0,5	l	3,15	2,80	−11
2	FEV 1	l	4,05	3,73	−8
3	FEV 2	l	4,57	4,32	−5
4	FEV 3	l		4,51	−36
5	FVC EX	l	4,86	4,80	−1
6	FIV 1	l		4,59	
7	FVC IN	l	4,86	4,79	−1
8	VC	l	5,07		
9	TV	l		0,71	
10	VPEF	l		0,44	
11	VPIF	l		1,71	
12	FEV 1 % FVC EX	%	83,33	77,71	−7
13	FEV 1 % FVC IN	%	83,33	77,87	−7
14	FEV 1 % VC	%	79,88		
15	PEF	l/s	9,43	11,49	+22
16	MEF 75	l/s	8,10	7,08	−13
17	MEF 50	l/s	5,23	3,90	−25
18	MEF 25	l/s	2,34	1,63	−30
19	MEF 50 % FVC EX	%	107,61	81,25	−24
20	MEF @ FRC	l/s		1,54	
21	FEF 75/85	l/s	1,32	1,14	−14
22	FEF 25/75	l/s	4,63	3,36	−27
23	PIF	l/s		9,00	
24	MIF 50	l/s		8,44	
25	MTT	s	0,66	0,78	+18
26	TPEF	s		0,15	
27	TMEF 75	s		0,24	
28	TMEF 50	s		0,46	
29	TMEF 25	s		0,95	
30	TPIF	s		0,49	
31	FET	s		5,29	
32	FIT	s		1,41	
33	TTOT	s		6,70	
34	FET % FIT	%		375,18	
35	TC 25/50	1/s		1,89	
36	AEX	l/s	25,42	21,30	−16

Fig. 10. Result of *Flow-Volume test.*

6.5. Motivational system

Motivational system has been developed to help small children reach better test results. The system may be also used for young adults and adults. The system is activated with *Motivational system* command (menu *Tools*) following *Flow-Volume* command (menu *Test*).

The motivational system consists of six candles (⇨ Fig.11), which a subject should blow out.

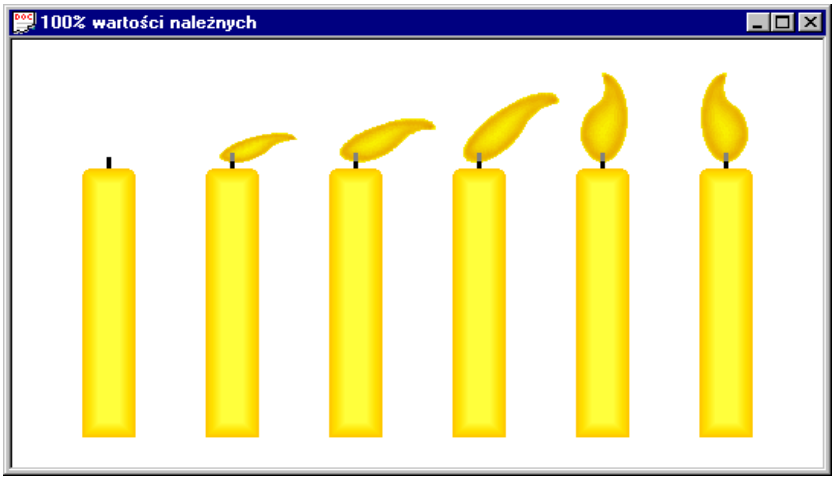


Fig. 11. Motivational system in flow-volume test.

Simulation of candle flame and the moment of blowout are based on reference values of a patient as presented in the table below. This table contains exemplary reference values.

Candle no	Parameter	Value	Reached at	Calculation of reaching
1	PEF	10,0 l/s	0,50 l	0,10 FVC EX
2	MEF 75	7,5 l/s	1,25 l	0,25 FVC EX
3	MEF 50	5,0 l/s	2,50 l	0,50 FVC EX
4	MEF 25	2,5 l/s	3,75 l	0,75 FVC EX
5	FEV 1	4,0 l	2,0 l/s	Extrapolation
6	FVC EX	5,0 l	0,0 l/s	End of expiration

Each candle has corresponding volume and flow. A candle will be blown out when current volume will be larger than or equal to the volume corresponding to this candle and the current volume will be larger than or equal to the volume corresponding to this candle, but only when a previous candle has been put out. It means that expiration curve must enclose the reference values spot.

The motivational system may be rescaled in such a way that candles are blown out at other volume and flow values. Rescaling consists in multiplication of all parameters corresponding to candles by a coefficient obtained from *% reference values* (contextual menu of the motivational system). Coefficient may be changed only before the test or during a pause in the tests (*Pause* command in *Test* menu). Actual coefficient is displayed on a bar of motivational system window.

In result of rescaling we obtain linear decrease or increase of the reference values spot. Candles connected with volumetric parameters FEV 1 and FVC EX will go out when the ratio of parameters obtained in the test to reference parameters exceeds the value of the coefficient of motivational system scaling. In case of flow parameters PEF, MEF 75, MEF 50 and MEF 25, candles may go out before the above described ratio exceeds the value of the coefficient of motivational system scaling. Example: if scaling coefficient is 80%, we multiply all the parameters by 0,8 and obtain:

Candle no	Parameter	Value	Reached at
1	PEF	8,0 l/s	0,4 l
2	MEF 75	6,0 l/s	1,0 l
3	MEF 50	4,0 l/s	2,0 l
4	MEF 25	2,0 l/s	3,0 l
5	FEV 1	3,2 l	1,6 l/s
6	FVC EX	4,0 l	0,0 l/s

Analysing MEF 25 parameter we will see that in case of 80% reference value MEF 25 is 2 l/s and it is reached at the volume of 3 l, and in case of 100% – MEF 25 is 2,5 l/s at 3,75 l volume. For 80% – at 3,75 l volume, the required flow is only 0,5 l/s (calculated on etrapolation basis.). When a respiratory curve encloses the rescaled spot of reference values , all candles will go out , despite the facrt that MEF 25 may be only 20% of the reference value (0,5 / 2,5).

7. Maximal voluntary ventilation

7.1. Test parameters

Parameter name:	Unit:	Description:
MV	l/min	Minute ventilation
MVV	l/min	Maximal voluntary ventilation
BF MVV	1/min	Breath frequency during maximal ventilation
BR	%	Breath reserve

7.2. Test option

Test options are available at *MVV* fold (⇨Fig.12) of *Test options* box (⇨ Chapt. 3, item 2).

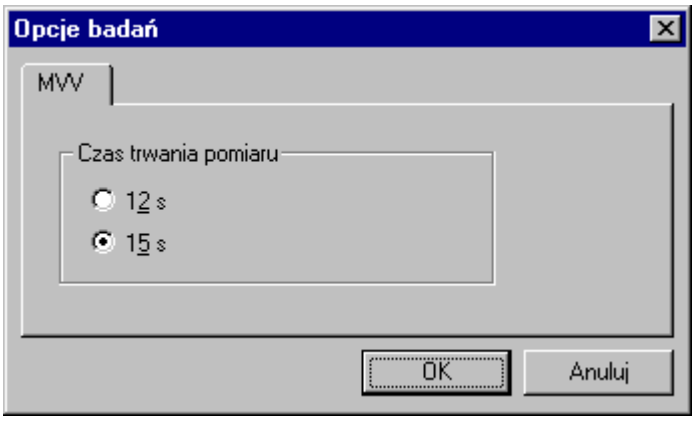


Fig. 12. Dialogue box *Test options – MVV*.

The box contains following elements:

1. ***Measurement time* field :**
   This box serves for determination of maximal voluntary breath measurement time.

Other options:

In tranquil breath phase , options of *Tranquil breath* field for *Spirometry* tests are used for *Maximal Voluntary Ventilation* test. (⇨ Chapt. 5.2).

7.3. Test procedure

1. Select command *MVV* (menu *Test*).
2. Check a test option (⇨ Chapt. 7.2).
3. Start the test with *Start test* command (menu *Tools*).
4. Perform the test according to the following phases:

a) Tranquil breaths. (⇨ Chapt. 5.2.1). When breathing is stabilised *Start maximal ventilation phase* message will appear at the prompt bar, as well as command *Accept manoeuvre* (menu *Test*) will be available.

b) Maximal ventilation. The patient is breathing as deep and fast as possible during the whole *Measurement time*. Time is displayed at the prompt bar. When the time of the test ens , the test is automatically finished.

7.4. Test result

As result we get a spirogram illustrating the measurement and a table with test parameters.

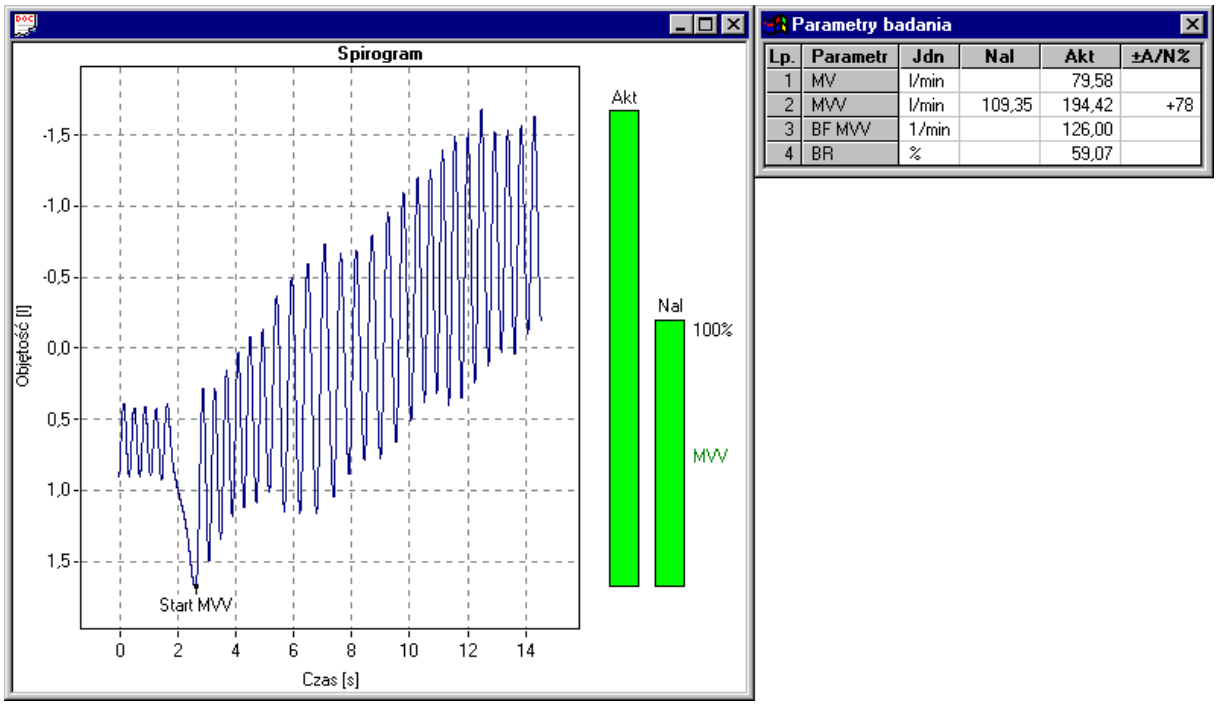


Fig. 13. Test result - ***Maximal voluntary ventilation*****.**

8. Subordinate test procedure

Tests that are subordinate in relation to another test known as the main test, is the test which is done after it. Usually, the patient has received a medicine, the provoking agent or another substance. The main test is also called the *pre-* test, while the subordinate test – the *post* test. The main test can have many subordinate tests whereas the subordinate test can have only one main test. Each test that has no subordinate test is, by nature, the main test. The subordinate test can be done in relation to the test which is not itself subordinate in relation to another test.

How to do the subordinate test:

1. Open the test which is going to be the main one.
2. Select *Do subordinate test* (menu *Tools*).

8.1. Reversibility test procedure

Reversibility tests consists of two tests of the same type, when the second test is done after a patient has been given a medication. This test is done in patients with lung disease changes to check whether such changes are reversible.

How to do a reversibility test:

1. Do the first of two tests.
2. Give medication to the patient
3. Do the second test as a subordinate test (⇨ Chapt.. 8).

Compare both tests as described in chapter11.

If a reversibility test is done by means of flow-volume tests, changes are deemed reversible when:

Δ FEV 1 > 12% **and** $FEV\ 1_2 - FEV\ 1_1 > 0{,}2$ l/s

and / or

Δ FVC EX > 12% **and** $FVC\ EX_2 - FVC\ EX_1 > 0{,}2$ l

Comment on the result of the reversibility test is automatically added to the printout of flow-volume test comparison.

9. Saving test results

9.1. Saving to data base

Saving the test result into the data base is done through *Save* (menu *Data base*). For tests in which the result is one curve and one parameter set, this curve and this set are saved. For tests in which the result can be many stets of curves and parameters, the actually active curve with the corresponding parameter set are saved. For tests in which it is possible to activate many curves at the same time, the first activated curve with the corresponding parameter set are saved. If in the flow-volume test, the envelope is activated, then it is saved in the data base together with the corresponding parameter set.

9.2. Saving to file

Saving the test result to file is done through *Save* and *Save as* (menu *File*). Each test is saved in a separate file. Each patient has their catalogue on the disk as '*C:\MES\Test results\Surname and Name Second Name, Date of Birth'*. In this catalogue there will be other catalogues whose names will correspond to the names of tests the patient has been given. As a standard, test results will be placed in these catalogues and the default name of each file will be the date and time of the test. It is advised to save the files under their default names since it will enable automatic recognition of the files during reviewing and comparing of the tests. Naturally, the test result can be saved under any name indicated by the user in any catalogue.

10. Test results review

LungTest application enables the review of tests which were earlier saved on the disk (⇨Chapt.0). The test can be opened through *Open* (menu *File*).

10.1. Patient's tests list

It is possible to load the list of all the tests for one currently selected patient (⇨ Chapt.2). Only these tests which have been saved under standard names (Chapt.0) are attached to the list. After loading, the tests can be reviewed using the *Test Manager* toolbar (⇨Chapt.15.3).

Loading test list can be done as follows:

1. Enter patient's data whose tests you want to load (⇨Chapt.2).

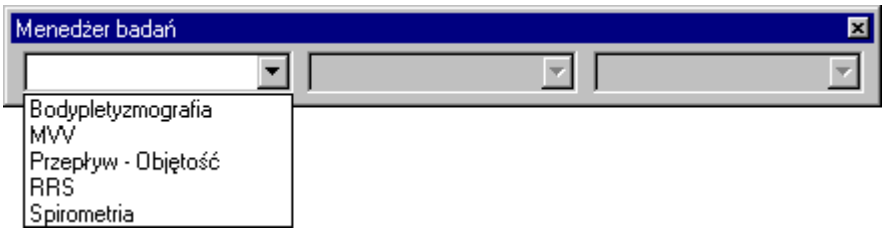


Fig. 14. Test Manager with the pulled out list *Test Type* **.**

1. Select the item for the test you want to review on the list *Test type*. Then, the list *Main test date* (⇨Fig. 15) will be pulled out. For main and subordinate tests see chapter 8.

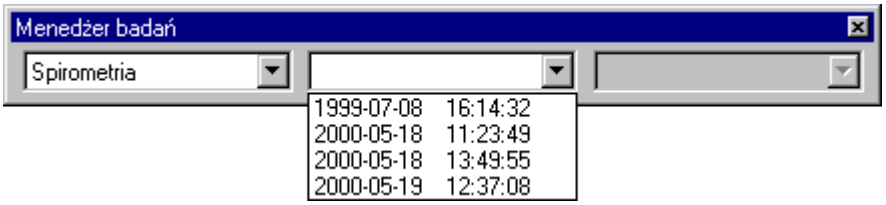


Fig.15. ***Test manager*** **with the pulled out list** ***Main test date***

2. On the list *Main test date* select the item with the date of the test you want to open. Then, the selected test will be loaded and shown on the screen.

   To open another selected test, click on its date on *Test date* list. To change the test type, select its name on *Test type* list.

3. If the test opened in item 4 has its subordinate tests, after its opening the list *Subordinate test date* will be pulled out. (⇨Fig.16).

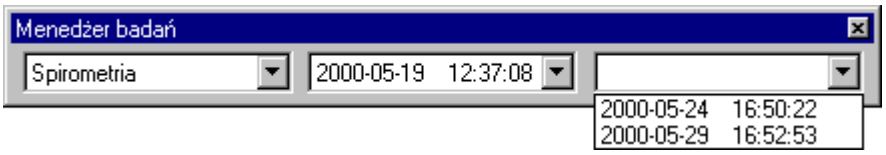


Fig.. 16 Test manager with the pulled out list *Subordinate test date***.**

In order to review a subordinate test, select its date on the list *Subordinate test date*. To return to the main test, again select its date on the list *Main test date*.

2. Select *Load tests* (menu *File*). Then, a list of tests belonging to the patient will be loaded and the list *Test type* in *Test Manager* will be pulled out (⇨Fig.14).

10.2. Patient search

The program enables to search for a patient whose test is already in the catalogue *Mes/Test results*. Either select *Patient search* or click on the toolbar the button showing binoculars. The box as in Fig.17 will appear.

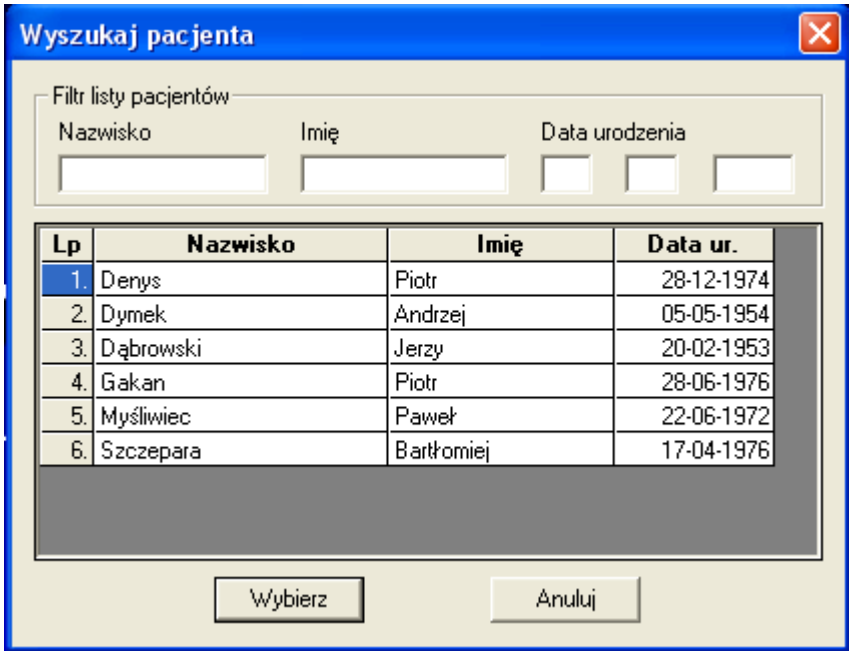


Fig 17. Patient search.

Patients can be searched by name, surname and date of birth. By typing relevant criteria in the adequate field, the list of patients will change accordingly to the conditions. After selecting the patient we can use Test manager (⇨Chapt.10.1).

11. Test comparison

To compare the tests select *Compare* (menu *File*). It is done by calculating changes of the parameters of one test type (⇨Chapt.4, item 1). Graphic presentation of these changes is also possible. Tests of the same type belonging to the same patient can be compared. The main test can be compared to other main ones or its subordinate tests. The subordinate test can be compared to its main one and/or other subordinate tests in relation to its main test. For main and subordinate tests see Chapter 0.

Test comparisons can be saved and printed like test results (⇨Chapt.97 and 12).

1. Open one of the compared tests (⇨Chapt.11). If we compare the main test to other main ones, then we open this test. If we compare the main test with its subordinates, then we open on of the subordinate tests.
2. Select *Compare* (menu *File*). The dialogue box *Compare tests* (⇨Fig.18) appears on the screen. On the list *Test date* an item with the test date that was open in item 1 will be highlighted.
3. Highlight other test dates on the list and click *OK*. The, the test comparison will appear.
4. To add or delete tests form the comparison select *Compare tests* using the command *Compare* (menu *File*).

11.1. Selecting tests for comparison

Tests for comparison are selected using the dialogue box *Compare tests* using the command *Compare* (menu *File*).

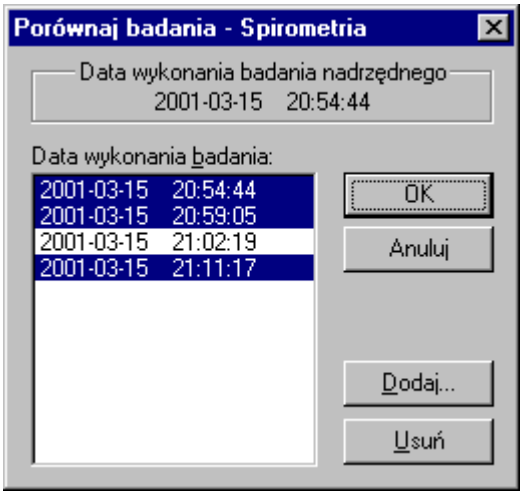


Fig. 18. Dialogue box *Compare tests* **(Spirometry).**

The box includes the following elements:

1. **Title bar:**
   Contains the inscription *Compare tests* and the type of the compared tests.

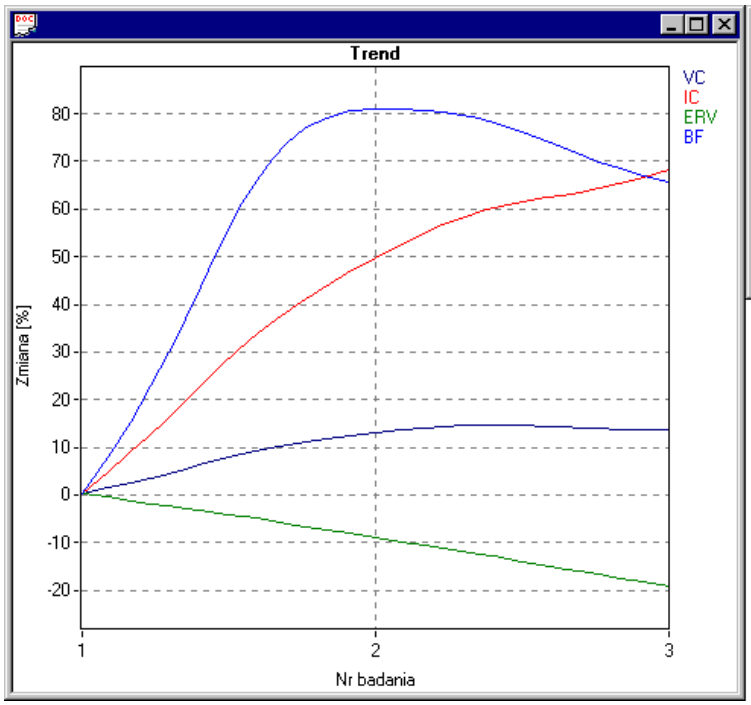
2. ***Main test date*** **field:**
   When we compare the main tests with its subordinate ones, the field shows the main test date. When we compare the main test with other main ones, this field is empty.
3. ***Test date*** **list:**
   Shows test dates which were found automatically or added using *Add*.
4. ***OK*** **button**:
   Accepts the selection of the test, closes the box and does the comparison
5. ***Cancel*** **button:**
   Cancels all modifications in the dialogue box and closes it.
6. ***Add*** **button**:
   Adds tests to the *Test date* list. Only tests of the same type for the same patient can be added. Moreover, if we compare the main test with other main ones, we can add only main tests. But if we compare the main tests with its subordinates, we can add only tests that are subordinate in relation to the main one.
7. ***Delete*** **button**:
   Deletes all tests highlighted on the list *Test date.*

NOTICE: The selection of parameters of the test which will appear in the comparison is done in the same way as the selection while saving to the data base (⇨Chapt.9.1).

11.2. Comparison result

The figure below shows an exemplary test comparison result (here: two spirometry tests). The result shows a graph comparing changes of selected parameters and a table presenting actual parameter values of the compared tests. It is also possible to include those table columns which contain the comparison of actual values (⇨ Chapt. 4.1.1).

When comparing Posterior and Anterior tests, the result shows also the graph of the flow in pressure function with the curves representing the compared tests.



Parametry badania

Lp.	Parametr	Jdn	Akt 1	Akt 2	Akt 3
1	VC	l	3,00	3,39	3,41
2	IC	l	1,13	1,69	1,90
3	ERV	l	1,87	1,70	1,51
4	IRV	l	0,61	1,09	1,36
5	TV	l	0,52	0,60	0,54
6	MV	l/min	51,48	107,40	88,56
7	BF	1/min	99,00	179,00	164,00
8	FEV 1	l		3,12	3,13
9	FEV 1 % VC	%		92,04	91,79

Fig. 19. Exemplary test comparison result.

11.3. Selecting trend parameters

Trend parameters, i.e. these parameters whose change will be shown on the graph is done by clicking *Select parameters* in the graph context menu. The context menu can be accessed by clicking the right mouse button on the graph. Trend parameters are selected in the same way as table parameter (⇨Chapt. 0).

12. Test result printout

The test result can be printed after the command *Print* (menu *File*). The print can be set using the commands *Print settings* and *Print configuration* (⇨Fig. 20). The print preview(the way the print looks on the screen) can be seen after selecting *View print* command. These commands are in menu *File*.

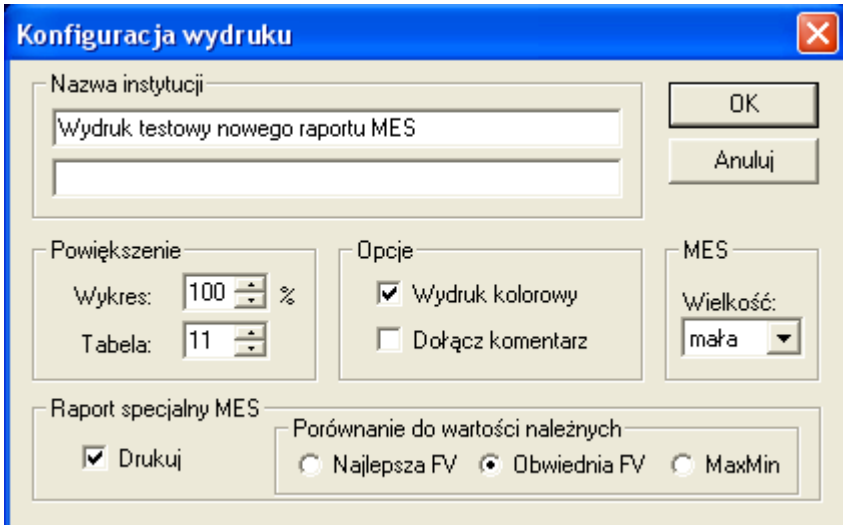


Fig. 20. Dialogue box Printout configuration.

The box contains the following elements:

1. ***Institution name* field:**
   Contains two Edit lines where you write the name of the health centre doing the tests. The name appears in the printout heading.
2. ***Zoom* field:**
   a) ***Graph* edit line**:
   Makes giving the zoom co-efficient of the printed graph possible. The coefficient is expressed in per cents.
   b) ***Table* edit line**:
   Makes giving the zoom coefficient of the table possible. The coefficient is a multiplier.
3. ***Option** field*:
   a) ***Colour print* option:**
   Selecting this option means a colour printout. Naturally, only when the system has a color printer.
   b) ***Attach command* option:**
   Selecting this option means attaching a commentary to the printout. The commentary is edited in *Comment editor* (menu *Tools*).
4. ***Special MES report* field**
   a) ***Print*** option
   Tick this option to get a non-standard printout (Chapt. 12.1).
   b) ***Reference value comparison* field**

Here we select a reference values column (Chapt.12.1).

5. ***MES* field:**
   a) ***Size* selection list**:

Makes the setting the size of the bitmap MES, which appears in the page heading, possible.

6. ***OK* button**:

Accepts all changes done.

7. ***Cancel* button:**

Cancels all changes done.

12.1. Special report.

When we select ***Special MES print*** option we will get a special table instead of the standard table. **This applies only to "Flow-Volume" test.**

Parametr	Jdn	Ref	Nal	Act1	Act2	Act3	MaxMin	Env	E/Nal%	SR(E)	P(E)	R%
MEF 50 % FVC E	%	E	107,87	110,17	L99,31	H116,78	H116,78	113,86	106			15
VC	l	E	4,50									
FEV 0,5	l			2,73	L2,69	H2,75	H2,75	2,75				2
FEV 1	l	E	3,50	3,38	L3,38	H3,47	H3,47	3,47	99	-0,06	48	3
FEV 2	l			L3,84	3,86	H3,94	H3,94	3,94				3
FEV 3	l			L4,02	4,05	H4,13	H4,13	4,13				3
FEV 6	l	H	4,58									
FEV 1 % FEV 6	%	H	80,43									
FVC EX	l	E	4,32	L4,23	H4,33	4,29	H4,33	4,33	100	0,02	51	2
FIV 1	l											
FVC IN	l	E	4,32	L4,36	4,42	H4,50	H4,50	4,49	104	0,28	61	3
VC MAX	l	E	4,50	L4,36	4,42	H4,50	H4,50	4,49	100	-0,02	49	3
ERV	l											
TV	l											
VPEF	l			0,27	H0,30	L0,26	L0,26	0,27				13
VPIF	l			L1,00	1,37	H1,41	L1,00	1,41				29
FEV 1 % FVC EX	%	H	77,74	79,91	L78,06	H80,89	H80,89	80,14	103	0,41	66	3
FEV 1 % FVC IN	%			H77,52	L76,47	77,11	H77,52	77,28				1
FEV 1 % VC	%	E	78,21									
FEV 1 % VC MAX	%	E	78,21	H77,52	L76,47	77,11	H77,52	77,28	99	-0,13	45	1
PEF	l/s	E	8,62	H9,84	L9,60	9,61	H9,84	9,84	114	1,01	84	2
MEF 75	l/s	E	7,53	H7,97	7,96	L7,56	H7,97	7,96	106	0,25	60	5
MEF 50	l/s	E	4,66	4,66	L4,30	H5,01	H5,01	4,93	106	0,20	58	14
MEF 25	l/s	E	1,88	1,32	L1,29	H1,34	H1,34	1,31	70	-0,73	23	4
MEF 75 % VC	%											
MEF 50 % VC	%											
MEF 25 % VC	%											
MEF @ FRC	l/s											
FEF 75/85	l/s	M	0,94	0,89	L0,84	H1,05	H1,05	0,98	104			20
FEF 25/75	l/s	E	3,91	3,47	L3,24	H3,61	H3,61	3,75	96	-0,15	44	10
TMEF 75	s			0,12	L0,12	H0,13		0,11				8
TMEF 50	s			L0,29	H0,31	0,30		0,28				6
TMEF 25	s			0,73	H0,79	L0,72		0,69				9
FET	s			5,38	H5,96	L5,37		5,96				10

(E) - ECCS, (Z) - Zapletal, (C) - Cherniack, (Mc) - Macfie, (U) - Ulmer, (Kh) - Keller-Herzog, (M) - Morris, (F) - Forche, (B) - Billiet, (C) - Cotes, (Ig) - Inst. Gruźlicy i Chorób Płuc, (H) - Hankinson, (P) - Polgar, (Cr) - Crapo, (Hs) - HSE
B - Best, E - Envelope, M - MaxMin, H - Highest, L - Lowest

Fig. 21. MES special report.

Sequence and number of parameters are the same as in the standard test (Chapt. 4.1.2). the table contains actual parameter values of the active curves. The column containing the best curve is indicated with vertical lines. ***MaxMin*** column contains maximal and minimal parameters indicating if the best best value is the highest one (**H**) or the lowest one (**L**). Further, each line contains **H** and **L** in columns of actual values. **H** and **L** indicate the highest and the lowest values of all active curve parameters. ***E/Nal%*** column shows percentage of reference values from a column selected in *Printout configuration*. It may be a column with values of envelope parameters [E], the best curve [B] or *MaxMin* (M). On the basis of value of parameters in the selected column , percentile, number of standard deviations, and parameter range [R] (maximal value –

minimal value) in relation to maximal value (in %) are calculated. The envelope column shows the values of the measured parameters only when curves needed for development of such a column have been included (active button  in *Curve selection* bar).

13. Spirometer calibration

Spirometer calibration is done using the dialogue box *Volume calibration* (⇨Fig. 22) which is accessed after selecting *Calibrate spirometer* (menu *Tools*). Calibration consists of several manoeuvres with the calibration pump of several liter volume. As a result, two calibration coefficients are obtained: *EX* – for expirations and *IN* – for inspirations. They are calculated as the quotient of the assumed pump volume and the actual pump volume which has been read by the measuring system.

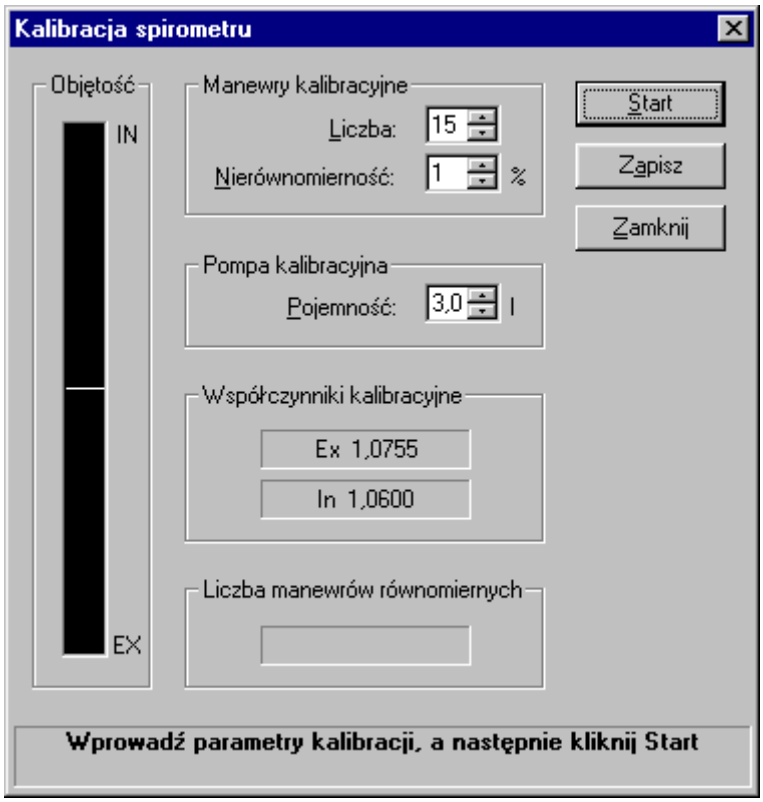


Fig. 22. Dialogue box Spirometer calibration.

The box has the following elements:

1. *Calibration* manoeuvre field

a) Edit line *Number* :

In this line, the number of successive maneuvers which will be done with the calibration pump during calibration, keeping the assumed *Non-uniformity*, should be given (⇨Chapt. 13.3).

b) Edit line *Irregularity:*

In this line, the maximum deviation of individual maneuvers from their standard in order to regard them as correct, should be given.

2. *Calibration pump* field:

a) Edit line *Volume*:

In this line the volume of the pump which is going to do calibration should be given.

3. ***Calibration coefficients*** **field:**

a) Field *EX*:

Contains the calibration coefficient for expirations.

b) Field *IN*:

Contains the calibration coefficient for inspirations.

4. ***Number of uniform manoeuvres*** **field:**

During calibration this field shows the number of maneuvers done so far which fulfill the uniformity criterion (⇨Chapt. 13.3) and have been assumed as correct.

5. **Prompt field:**

This field shows prompts instructions for the person doing calibration.

6. ***Volume*** **field:**

This field shows the volume in the form of a bar diagram.

7. ***Start*** **button:**

Begins calibration.

8. ***Stop*** **button:**

Stops calibration.

9. ***Save*** **button:**

Saves calibration results. Accessible only after calibration has been finished.

10. ***Close*** **button:**

Closes the dialogue box. If, after the calibration, the box is closed without clicking *Save*, then the calibration result is lost.

13.1. Preparation for calibration:

Check the connection of the pneumotachograph head made with flexible cables. During calibration, the head should be fastened directly to the calibration pump outlet.This head cannot be placed directly in 4-way head (⇨ Chapt.), as in *Diffusion* test, and canot be fixed to the shutter.

13.2. Calibration procedure:

1. Open dialogue box *Volume calibration* by selecting *Calibrate spirometer* (menu *Tools*).
2. Fill in fields *Calibration maneuvers* and *Calibration pump* and click *Start.*
3. Move the calibration pump quietly and smoothly. Calibration is finished automatically when the number of required manoeuvres fulfilling regularity criterion have been reached (Chapt. 13.3).
4. Click *Save* to save calibration results.

13.3. Regularity criterion of subsequent breaths

There are two parameters used in the uniformity criterion:

1. **N** - number of successive breaths
2. **Δ** - acceptable irregularity

N of successive breaths is regarded as regular if the deviation of no inspiration from the mean calculated of all inspirations and the deviation of no expiration from the mean calculated of all expiration do not exceed the acceptable irregularity **Δ**.

Example: N = 5 successive inspirations: 1.0, 0.8, 1.1, 1.2, 0.9 [1]. Average = 1.0

- **a)** For **Δ** = 10%, i.e. 0.1 the criterion is not fulfilled because the deviation of the second and fourth inspiration form the mean is 0.2 and exceeds 10%.
- **b)** For **Δ** = 20%, i.e. 0.2 the criterion is fulfilled because the deviation of no inspiration exceeds 20%.

14. Command menu

14.1. *File* menu:

New patient	⇨ Chapt. 2.1
Edit patient's data	⇨ Chapt. 2.3
Patient from file	Selects patient from the file
Open	⇨ Chapt. 10
Close	Closes active document
Save	⇨ Chapt. 0
Save as	Saves test result under the given name
Load tests	⇨ Chapt. 10
Compare	⇨ Chapt. 11
Send e-mail	Mails test results. Available if you have e-mail program installed.
Print	⇨ Chapt. 12
Print preview	⇨ Chapt. 12
Export to PDF	Prints test to PDF file.
Export to Excell	Export test data to CSV file.
Print settings	⇨ Chapt. 12
Print configuration	⇨ Chapt. 12
Recently opened files	List of recently opened files .
Quit	Finishes work with application

14.2. *Data base menu:*

Select patient	⇨ Chapt. 2.2
Save	⇨ Chapt. 9.1
Load tests	Not available in this program version.

14.3. *View* menu:

Tool bars	Shows or hides the toolbar indicated in the menu
Status line	Shows or hides the status line (⇨ Chapt. 15.7).
Box background	Changes the colour of the box background
Table	Shows or hides the table with parameters (⇨ Chapt. 4.1).

14.4. *Test* menu:

Bodypletysmography	*Initiates Bodypletysmography* test
Diffusion SB	– II – *Single Breath diffusion test*.
MVV	– II – *Minute voluntary ventilation*.
Compliance	– II – *Compliance*.
Flow – Volume	– II – *Flow-Volume*.
RRS	– II – *Respiratory resistance*
Spirometry	– II – *Spirometry*.
Confirm manoeuvre	Confirms beginning of the manoeuvre.
Pause	Stops or restarts the test.
Next phase	Begins next phase of the test.
Stop test	Stops the test. If minimal number of measurements have been completed the test is ended..

14.5. *Tools menu:*

Start test	Starts test procedure
Do subordinate test	⇨ Chapt. 8
Motivational system	⇨ Chapt. 6.5
Test options	⇨ Chapt. 3
Atmospheric conditions	Shows dialogue box for giving atmospheric conditions.
Comment editor	Shows dialogue box for writing comments on the test
Clear spirometer	Clears spirometer.
Calibrate spirometer	⇨ Chapt.. 13
Calibrate flow sensor	⇨ Chapt.
Calibrate gas symbol	⇨ Chapt.
Calibrate cabin	⇨ Chapt.
Select connection	Shows dialogue box which makes giving the connection type of the computer to the spirometer possible

14.6. *Box* Menu:

Cascade	Cascades boxes within the main application window
Tile H	Tiles boxes horizontally so that they do not cover each other
Tile V	Tiles boxes vertically so that they do not cover each other
Arrange icons	Arranges minimised boxes by the lower application edge.

14.7. *Help menu:*

Index	Starts *LungTest* help
About the program	Gives information about the program, version no, copyright, etc.

15. Toolbars

Toolbars mostly repeat menu commands. Thanks to their structure they enable a quicker access to commands. The user can place toolbars at any edge of the application main window as well as any place of that window.

15.1. Standard toolbar

Fig. 23. Standard toolbar.

The toolbar has following buttons:

	Menu *File*, command *New patient* Menu *File*, command *Edit patient's data* Menu *file*, command *Open* Menu *File*, command *Save*	⇨ Chapt. 2.1 ⇨ Chapt. 2.3, 2.4 Opens the file with test result ⇨ Chapt. 0
	Menu *File*, command *Print* Menu *File*, command *Print preview* Command Print to PDF	⇨ Chapt. 12 ⇨ Chapt. 12 Prints test results to PDF file
	Menu *Data base*, command *Select patient* Menu *Data base*, command *Save* Menu *Data base*, command *Load test*	⇨ Chapt. 2.2 ⇨ Chapt. 9.1 Not possible in this program version
	Menu *View*, command *Table*	Shows or hides the table with test parameters
	Menu *Tools*, command *Start test* menu *Test*, command *Stop test*	⇨ Chapt. *Test procedure*. ⇨ Chapt. 14.4
	Menu *Test*, command *Confirm manoeuvre* Menu *Test*, command *Pause* Menu *Test*, command *Next phase*	⇨ Chapt. 14.4 ⇨ Chapt. 14.4 ⇨ Chapt. 14.4
	Command *Move to zero*	Moves graph to the zero of the coordinate system

	Command *Light all candles*	Lights all candles of the motivational system (⇨ Chapt. 6.5).
	menu *Tools*, command *Clear spirometer*	Clears spirometer.
	Menu *Help*, command *About the program*	Displays information about the program like copyright, version, etc.
	Menu *Help*, command *Context help*	Not available in this program version.

15.2. Tests

Fig. 24.Toolbar – *Tests*.

The toolbar *Tests* has buttons repeating the commands of the menu *Test* which prepare the application for a given test procedure.

15.3. Test manager

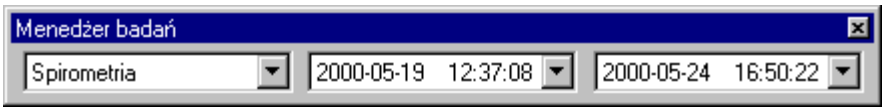
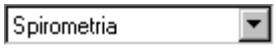
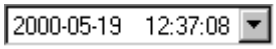
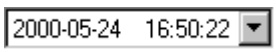


Fig. 25. Toolbar – *Test manager*.

The toolbar has three fold-out lists:

	*Test type* – the list has test types of the currently selected patient .	⇨ Chapt. 10
	*Main test date* – the list has dates and times of main tests of the type selected from the list *Test type*.	⇨ Chapt. 10, 8
	*Subordinate test date* – the list has dates and times of tests which are subordinate to the one selected from the list *Main test date*.	⇨ Chapt. 10, 8

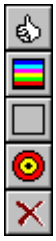
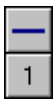
15.4. Curve selection

The toolbar *Curve selection* is used in tests in which the result can have several curves. Commands in this toolbar are used to manipulate curves.

Fig. 26. Toolbar – *Curve selection.*

Fig.. 27.Toolbar – *Curve selection* **(2nd version).**

The toolbar has following buttons:

	Command *Best*	Selects the best curve.
	Command *Activate all*	Activates all curves
	Command *Disactivate all*	Disactivates all curves .
	Command *Envelope*	Creates envelopes for activated curves.
	Command *Delete disactivated*	Deletes disactivated curves.
	Command *Change curve*	Changes the curve of a given colour.
	Command *Change curve*	Activates the curve of a given number, disactivating others.

15.5. Compensation

Compensation toolbar is used in tests requiring correction of curves. Compensation is done with the scroll bar. Actual value of the compensation coefficient is displayed on the left side of the slider.

Fig. 28. Toolbar – Compensation.

15.6. Prompt bar

The prompt bar is located by the bottom edge of the main application window, above the status line ((⇨Chapt. 15.7). Its location cannot be changed. During the test, the bar shows information about the activities the patient should presently do.

A counter of sample measurements is located on the right of the bar. It shows the number of the correctly done and accepted measurements of a given type. For example, in Fig. 29, the counter shows that spirometry is being done and two correct measurements have been done so far.

By the measurement counter, there is a field informing about the accessibility of the command *Confirm manoeuvre*. When *Enter* is seen in this field it means that this command is accessible and the start of the maneuver requires its confirmation. This manoeuvre can be confirmed either by selecting the command *Confirm maneuver* or pressing *Enter* key. For maneuvers which require their confirmation read chapters *Test procedure* about each test.

Fig .29. Prompt bar.

15.7. Status line

The status line is located by the bottom edge of the main application window. Its location cannot be changed, however the line can be hidden through the command *Status line* (menu *View*).

The status line shows explanations of menu commands and elements which are found on toolbars. In order to see the explanation, place the mouse cursor on the element.

During the test the status line shows also information about errors which do not require stopping the test. For example, if, in the flow-volume test the option *Min. expiration time* (⇨ Chapt. 6.2) at 4 seconds and the patient's expiration lasts only 3 seconds, then, the measurement will be rejected and the status line will show the message 'expiration too short'.

On the right of the status line there are three fields informing about the keys *CapsLock, NumLock* and *ScrollLock.*

Fig.. 30. Status line.

16. Body plethysmography

16.1. Examination parameters

Parameter:	Unit:	Description:
R tot	kPa/l/s	Total resistance
R ex	kPa/l/s	Expiratory resistance
R in	kPa/l/s	Inspiratory resistance
R peak	kPa/l/s	Peak flow resistance
G tot	l/s/kPa	Total conductance
SR tot	kPa/s	Specific resistance
SG tot	s/kPa	Specific conductance
TLC	l	Total lung capacity
VC	l	Vital capacity
IC	l	Inspiratory capacity
ERV	l	Expiratory reserve volume
RV	l	Residual gas volume
ITGV	l	Intrathoracic gas volume
RV % TLC	%	Percentual ratio *RV* vs. *TLC*
ITGV % TLC	%	Percentual ratio *ITGV* vs. *TLC*

16.2. Examination options

The examination options are available on the tab *Body* (⇨Fig. 14) in the dialogue box *Examination options* (⇨ Chapter. 3, Point 2).

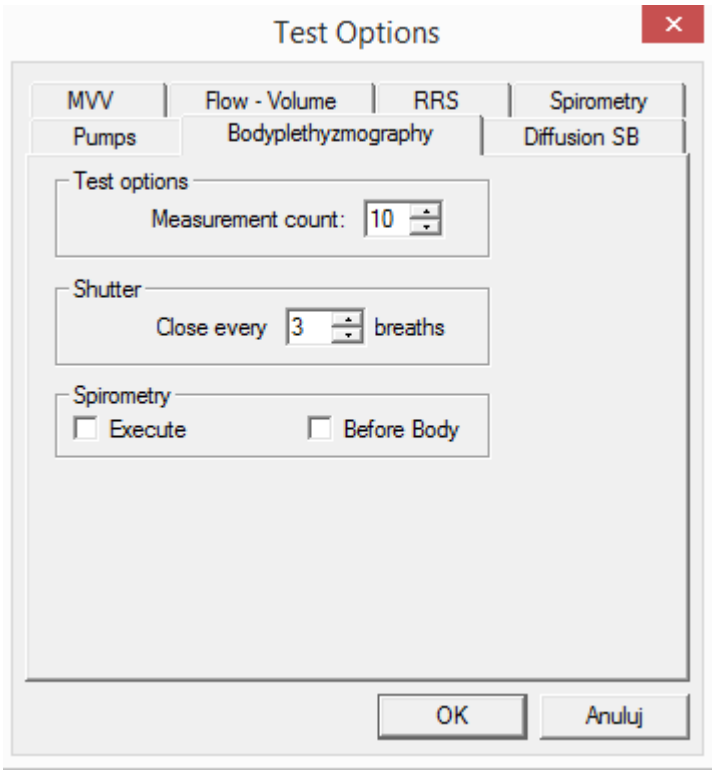


Fig. 14. Dialog box *Examination options – Body*.

The box contains the following elements:

1. **Field *Examination parameters*:**
   a) **Edition line *Number of measurements*:**
      In this line you should enter the number of measurements of resistances and residual gas volume you wish to perform. Upon completion of this number of measurements, the examination will be automatically ended.

2. **Field *Shutter*:**
   a) **Edition line: Close every ? breaths*:***
      In this line you should enter the interval of breaths at which the shutter is to be closed. *Shutter* is closed automatically.

1. **Field *Spirometry*:**
   1. **Option *Execute*:**
      Actuate this option when you intend to perform spirometry during body plethysmography.

      This examination will be conducted according to the options belonging to S*pirometry* (⇨ Chapter. 5.2).

16.3. How to execute the examination

ATTENTION!!!
The body plethysmography chamber is low and its upper entrance edge is yet lowered, but protected with a special cover. Before a patient enters the chamber, he/she must be informed they should bow their heads to avoid a hit against the covered upper entrance edge. During the manufacturing process covered were also additionally the entrance side edges of the chamber.

3. Select the command *Body plethysmography* (menu *Examination).*
4. Check the examination option (⇨ Chapter. 16.2).
5. Lock the patient in the chamber.
6. Start the examination with the command *Start examination* (menu *Tools*).

1. Execute the examination according to the following phases:

a) Expecting thermal stabilization. This phase is used for eliminating excessive pressure in the chamber. Such an excess is caused by the patient who, while breathing, warms up the air in the chamber which, in turn, causes the pressure value to go up. In this phase, the prompt bar displays the time to elapse so as to end this phase. When this time is over, the examination will be continued. The application may pass to the status of expecting the thermal stabilization at any time during the examination when the pressure has exceeded the permissible value.

b) Measurement of resistances. The patient breathes calmly and comfortably, and the application will register resistance loops. Having recorded a correct curve, increased are the counter indications of correct measurements. (⇨ Chapter. 15.6). When the number of curves recorded has reached the option value *Number of measurements* (⇨ Chapter 16.2), the application will automatically go on to measuring parameter *ITGV*.

c) Preparation for resistance measurement. The patient breathes calmly and comfortably. In the screen drawn are resistance loops which should spin clockwise and be as narrow as possible. The loop shape can be corrected by the toolbar *Compensation* (⇨ Chapter. 15.5). If the loop shapes are considered to be OK, go on to resistance measurements by selecting the command *Confirm manoeuvre* (menu *Examination*).

d) *ITGV* Measurement The patient breathes calmly and comfortably. The shutter is closed at several breathes' intervals according to the setting of option *Close every ? breaths*. When the shutter is closed, the patient should try to breathe. Naturally, this will be impossible, but the chest motions will cause pressure changes both in the patient's lungs and the chamber as well. Such changes recorded through the application will be used for determining *ITGV*. Having reopened the shutter, the patient will resume comfortable breathing. After each correct measurement increased is the counter indication of correct measurements. When the number of measurements has reached the value of option *Number of measurements* (⇨ Chapter. 16.2), the examination will be automatically ended.

e) Execution of *Spirometry*. Spirometry is performed before body plethysmography, but only when option *Execute* in the field *Spirometry* (⇨ Chapter 16.2) is selected. The execution of measurement is described in the chapter dealing with spirometry (⇨ Chapter 5.3).

16.4. Examination result

The examination results in a set of recorded resistance curves, a set of *ITGV* curves and a table with examination parameters. The parameters are calculated basing upon the curves selected from among all recorded in the examination.

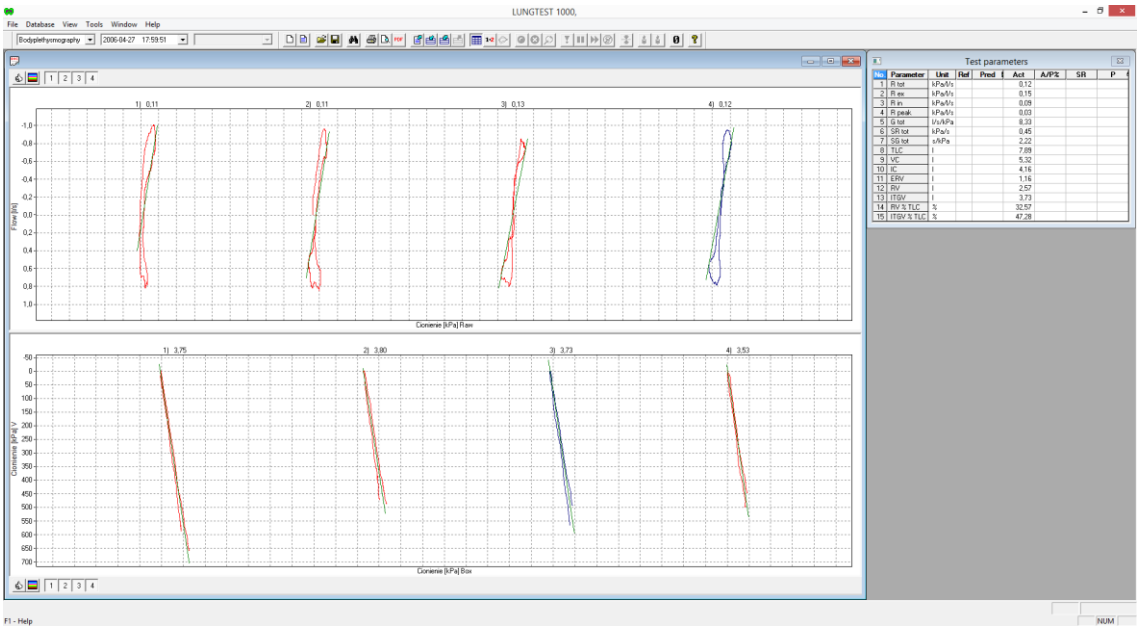


Fig. 15. Examination result, type: *Body plethysmography*.

16.5. Chamber calibration

The chamber is calibrated with the dialog box *Chamber calibration* (⇨ Fig. 16) called up after selecting the command *Calibrate chamber* (menu *Tools*).

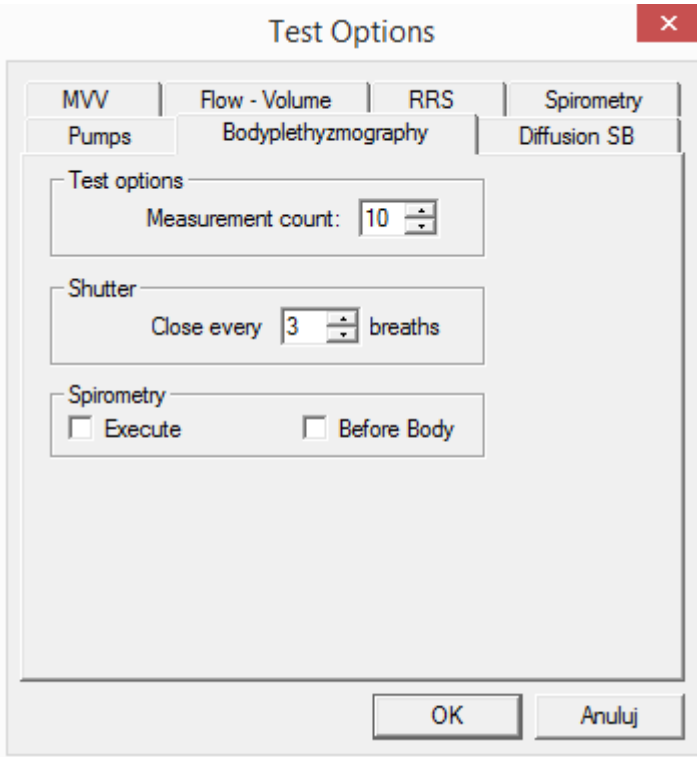


Fig. 16. Dialog box *Calibrate chamber*

In the box provided are the following items:

c) Field *Calibration coefficients*

2. Field *Pressure V*:

Contains the pressure calibration coefficient *V*.

5. Field *Pressure Box*:

Contains the pressure calibration coefficient *Box*.

d) Field *Time constant*:

Contains the time constant of the chamber.

e) Field *Calibration date*:

Contains the date of calibration execution.

f) Field *Prompts*:

This field shows some instructions pertinent to the actions to be performed by the person who calibrates the chamber

g) *OK* button:

Prepares the application for calibration.

h) *Save* button:

Saves the result of a calibration executed correctly.

i) *Close* button:

Closes the dialog box.

16.5.1. Calibration procedure

1. Select the command *Calibrate chamber* (menu *Tools*). Displayed will be the dialog box *Calibrate chamber* (⇨ Fig.17). In this box you will initiate the calibration by clicking on *OK*.
2. Close the chamber door.
3. Start calibration by selecting the command *Start examination* (menu *Tools*).

4. The calibration course can be followed on the diagrams being displayed. The calibration will result in determining the coefficient referred to in Chapter 16.5.
5. After calibration displayed will be the dialog box *Calibrate chamber* (⇨Fig. 16). If the calibration has been successful, there will appear button *Save*, used for saving the calibration result.
6. Open the chamber door.

17. Single Breath Diffusion

Pulmonary diffusing capacity DCO is defined as the rate at which carbon monoxide [CO] diffuses across the alveolocapillary membranes per unit difference in the partial pressure of the gas across the membrane which occurs between the alveolar air and capillary pressure in the lungs.

17.1. Examination parameters

Parameter:	**Unit:**	**Description:**
VC IN	l	Inspiratory vital capacity
VA	l	Alveolar capacity
RV	l	Residual gas volume
FRC	l	Functional residual capacity
TLC	l	Total lung capacity
RV % TLC	%	Percentual ratio *RV* vs. *TLC*
FRC % TLC	%	Percentual ratio *FRC* vs. *TLC*
DCO SB	mmol/min/kPa	Diffusing lung capacity
DCO SB K	mmol/min/kPa	As above, but taking into consideration blood hemoglobin
DCO SB / VA	mmol/min/kPa/l	Ratio *DCO SB* vs. *VA*
TA	s	Breath holding time
FI CO	%	Initial carbon monoxide concentration
FA CO	%	Final carbon monoxide concentration
FI He	%	Initial helium concentration
FA He	%	Final helium concentration

17.2. Examination options

The examination options are available on the tab *Diffusion SB* (⇨ Fig. 17) of dialog box *Examination options* (⇨ Chapter 3, point 2).

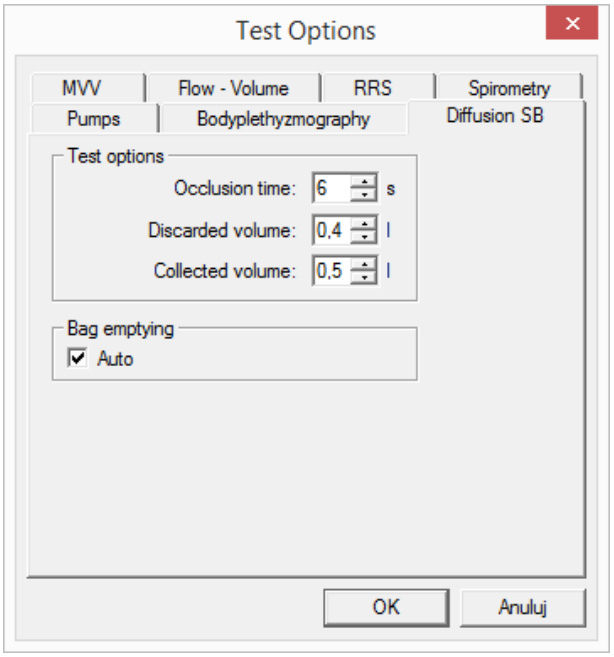


Fig. 17. Dialog box *Examination options – Diffusion SB*.

The box contains the following components:

1. **Field *Examination parameters***
   a) **Edition line: *Breath holding time*:**
   In this line you should enter the breath holding time for the maximum inhalation.
   b) **Edition line *Volume rejected* :**
   In this line you should enter the gas volume rejected during the expiration after holding breath.
   c) **Edition line *Measurement volume***
   In this line you should enter the volume of gas collected in the *FA* sack.

2. **Field *Sack emptying***
   a) **Option *Auto*:**
   When the option is selected, this will mean automatic recognition of the sack emptying status. This command is available only in systems provided with a negative pressure sensor.

Other options:

In the phase of comfortable respiration, the *Diffusion SB* examination makes use of options in the field Comfortable respiration belonging to *Spirometry* examination (⇨ Chapter 5.2)

CAUTION!!!

1. Replace the carbon monoxide absorber always before each calibration of gas sensors!
2. Replace the carbon monoxide absorber always upon completion of not more than 3 tests!
3. Replace the carbon monoxide absorber always after a longer than 3 days' break in conducting tests!

4. Replace the humidity absorber each time its color turns from blue into pink in around 75% of absorber tube volume.
5. Failing to replace the carbon monoxide absorber will cause very series errors in indications of gas analyzers, and thus, the values measured will be unreliable!!!

17.3. Execution of the examination

b) Select command *Diffusion SB* (menu *Examination*).
c) Prepare the measuring system (⇨ Chapter 17.5).
d) Check the examination options (⇨ Chapter. 17.2).
e) Start the examination with command *Start examination* (menu *Tools*).
f) perform the examination according to the following phases:

20. **Comfortable respiration.** (⇨ Chapter. 5.2.1). When respiration is comfortable, the prompt bar will show a message: *After inhalation perform maximum exhalation* .When the patient's expiration exceeds *TV* threshold, available will be the command *Confirm maneuver* (menu *Examiantion*). Making this command available is to be understood as a question: *Is the patient performing the exhalation preceding the maximum inhalation?* If so, select the command said to indicate that the measurement is started. Otherwise, if such a deeper exhalation was accidental, do not select this command, and the patient goes on breathing comfortably.
21. **Exhalation up to *RV* level.** The patient performs the maximum exhalation, and consequently, in the lungs will remain only residual volume. Respiratory dynamics will be like in spirometry (⇨ Chapter. 5.3). The end of exhalation is manifested by no volume changes in the spirogram, which is confirmed by pressing on *Enter* key. Closed will be the diffusion head valve to discharge into the atmosphere, and the patient is connected to the gas valve.
22. **Inhalation up to *TLC level*.** The patient performs a maximum inhalation of gas from the cylinder through the gas valve, its value being *VC IN*. The end of inhalation is manifested by the absence of volume changes in the program, and the system goes on to the successive stage.

23. **Breath holding.** The patient holds his/her breath. And he/she should keep the gas in the lungs by himself/herself, not utilizing the fact that all valves in the diffusion head are closed and no exhalation is possible. In the prompt bar displayed is the time to elapse before exhalation starts. When the time has expired, the prompt bar shows the message: *Perform complete exhalation*.
24. **Exhalation.** The patient exhales the gas from his/her lungs. The first portion of gas is rejected, according to the setting of option *Rejected volume* (⇨ Chapter. 17.2). The successive portion is collected in the diffusion sack, in line with the setting of option *Measurement volume.*
25. **End of examination.** Having collected the *Measurement volume*, the system will automatically start analyzing the gas concentration from the diffusion sack; if the result is successful, displayed will be the examination result.

17.4. Examination result

The examination result is shown as a spirogram illustrating the measurement and a table with test parameters.

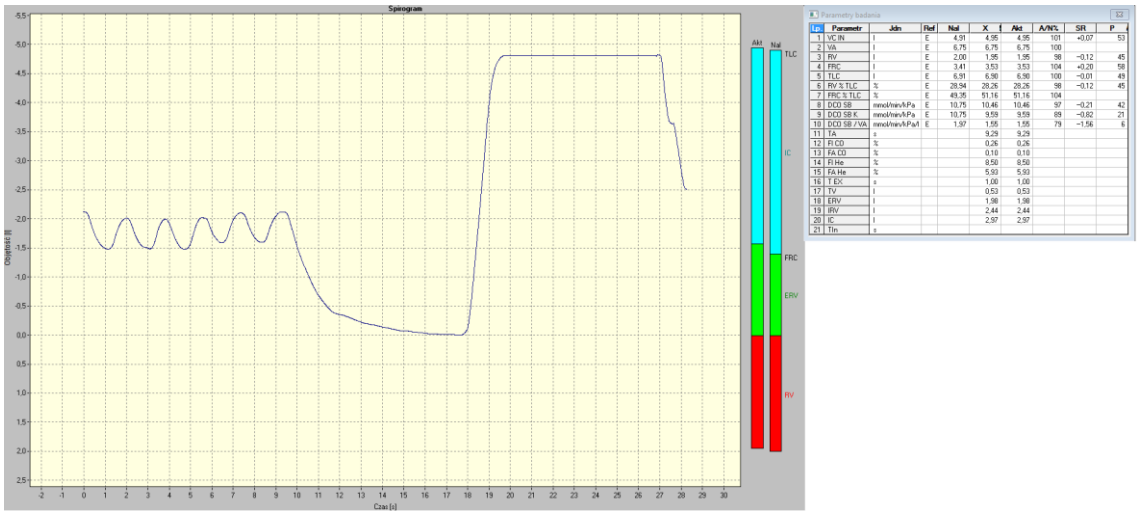


Fig. 18. Examination result, type: *Single Breath* Diffusion

17.5. Preparation of the measuring system for the examination

The measuring system is prepared for testing after selecting the command *Diffusion SB* (menu *Examination*). You should enter the hemoglobin value (⇨ Fig. 20), and open the cylinder valve (Fig. 21)

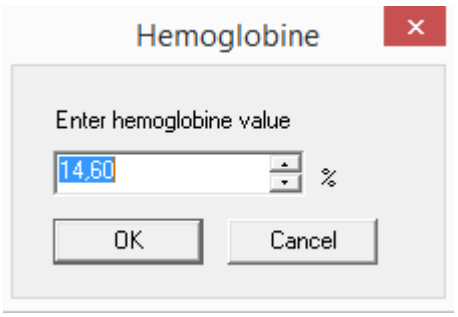


Fig. 19. Dialog box. *Hemoglobin value*

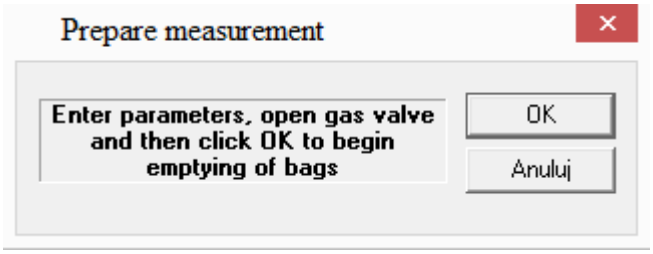


Fig 21. Dialog box *Prepare measuring system*.

17.6. Calibration of gas sensors

The gas sensor calibration is performed in the dialog box *Gas sensor calibration* (⇨ Fig. 22) called up with prior selection of the command *Calibrate gas sensor* (menu *Tools*).

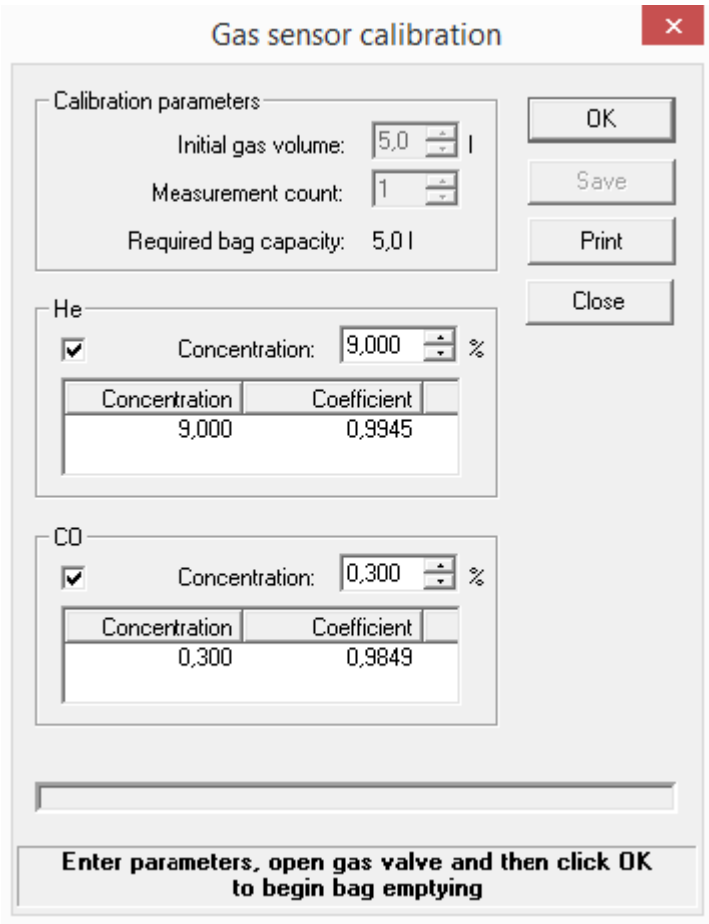


Fig. 22. Dialog box *Gas sensor calibration*

The dialog box contains the following components:

1. **Field *Calibration parameters*:**
   3. **Edition line *Initial gas volume*:**

   In this line you should enter the gas volume at which a calibration will take place.

   6. **Edition line *Number of measurements*:**

   The number of measurements is not subject to changes and always will be 1.

   c) **Information field *Required sack volume*:**

   The field gives the volume the sack must have so that a calibration could be possible.

2. **Fields: *Helium and CO*:**
   a) **Edition line *Concertation*:**

   In this line you should enter the concentration of the gas to calibrate with.

   b) **Table *Measuring concentration and Calibration coefficient*:**

The table shows calibration coefficients for successive measuring concentrations

c) **Progress bar:**

According to the context, this bar shows the volume of gas additionally pumped, progress in the ventilation of gas sensors or progress in gas concentration analysis.

4. **Prompt field:**

This field shows the instructions regarding the actions to be taken up by the person who calibrates the gas sensor.

5. ***OK*** **button:**

The button serves for confirmation of the end of an action (⇨ Chapter. 17.6.2)

8. ***Save*** **button:**

When clicked, the calibration results are saved.

7. ***Cancel*** **button:**

Calibration is interrupted.

7. ***Close*** **button:**

Closes the dialog box. If you do not click on the *Save* button after calibration, the calibration result will be lost.

17.6.1. Preparation for calibration

5. Check the attachment of the diffusion sack.
6. Check all connections with hoses.
7. Check the connection of the cylinder containing the measuring gas mixture.

17.6.2. Calibration procedure

1. Select the command *Calibrate gas sensor* (menu *Tools*) to open the dialog box *Gas sensor calibration* (⇨Fig. 22), and this gas will be used for calibration. Observe *Prompt box* (⇨ Chapter 17.6) to follow what should be done at any moment.
2. Give the concentrations of helium and carbon monoxide, respectively.
3. Click on *OK* button to start emptying the sack in which collected is the gas of calibration. When the sack is emptied, click on OK button again. If the system does not work in the regime of automatic sack emptying recognition. Otherwise, this system will go on to the subsequent phase automatically.
4. The procedure of filling the sack with gas mixture has started. When the sack has been filled, the system will be filled, the system will automatically proceed to analyzing the gas concentration.
5. IF the analysis is successful, the dialog box will show the calibration coefficients. Click on *Save* button, to save the calibration results.
6. Click on *Print* button, to print the calibration results.
7. Close the dialog box by clicking on *Close* button.

17.7. Diffusion head

Fig.. 23. Components of the measuring system.

1. Diffusion sack
2. Gas valve
3. Air duct
4. Pneumotachography head
5. Adapter antibacterial filter
6. Antibacterial filter
7. Mouthpiece