



## Diffusion RB

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## ***Explanation of Measurement Program***

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The diffusion capacity of the lungs (DLCO) is defined as the amount of CO-gas that passes the alveolar-capillary membrane per unit of time and pressure difference between the alveolar air and the pulmonary capillary blood. The method most often used for measuring the diffusion capacity is the single breath method, necessitating a cooperative patient who inhales to his vital capacity a diffusion gas mixture and holds breath during approximately 10 seconds. An alternative to this method is the "rebreathing" method. An advantage of this method is that, unlike the single breath method, the patient can continue breathing at a normal FRC level and breath holding is not part of the maneuver.

### **Measurement Principle:**

Determination of the diffusion capacity of the lung (DLCO) according to the rebreathing method.

### **Measurement Sequence:**

The measurement is easy to perform. The results, however, depend on the patient's cooperation. The patient is asked to breathe via a mouthpiece attached to the pneumotach.

First, the patient breathes room air. If breathing is stabilized, the rebreathing phase will start. Now the patient inhales from the breathing bag a gas mixture consisting of about 0,2% CO, 9% Helium and about 30% oxygen. During the rebreathing phase the CO gas diffuses through the lung membrane. In order to be able to measure seriously distribution disordered patients, oxygen is supplied in the rebreathing phase (CO/He wash-in phase) and in addition to this the CO<sub>2</sub> in the breathing gas is absorbed. If an ERV-VC breathing manoeuvre is performed after the wash-in phase, the important parameters TLC and RV will be determined additionally.

### **Evaluation:**

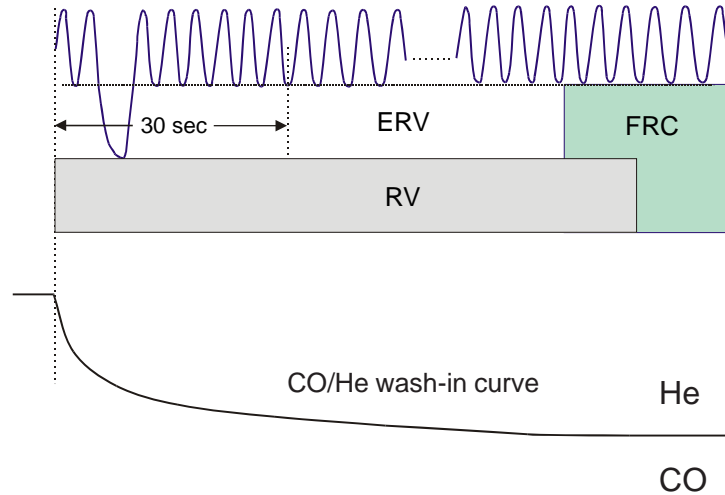
The parameters of each trial are calculated and displayed on the screen with a predicted/actual value comparison.

The assessment of the measurement values as well as the analysis of the CO/He wash-in curve provide information about the presence of possible restrictive or obstructive diseases of the respiratory organs.

An alteration in the diffusion parameters is present in the following diseases: alveolitis, fibrosis, silicosis, sarcoidosis, radiation injury, pulmonary oedema, vascular occlusions, congenital heart defects, etc.



# Parameter Definition



FRC-He	Functional reserve volume	TV	Tidal volume
RV-He	Reserve volume	BF	Breathing frequency
TLC-He	Total lung capacity	MV	Minute volume
T-RB	Duration of rebreathing	ERV	Expiratory reserve volume
V-RB	Sum of rebreathing volume	VCIN	Inspiratory vital capacity
VO <sub>2</sub>	Oxygen uptake	VCEX	Expiratory vital capacity
TLCO RB	Diffusion capacity	FI He	Inspiratory concentration He
TLCO C	TLCO corrected to the standard alveolar volume (VA) and the alveolar ventilation (VA')	FICO RB	Inspiratory concentration CO
VA RB	Alveolar volume	FI O <sub>2</sub>	Inspiratory concentration O <sub>2</sub>
VA'RB	Alveolar ventilation	FA He	Expiratory concentration He
KCO RB	TLCO per VA (Krogh factor)	FACO RB	Expiratory concentration CO
KCO C	KCO, corrected	FA O <sub>2</sub>	Expiratory concentration O <sub>2</sub>



## Notes on Using CO



Trade name: Carbon Monoxide

Chemical characteristics:

CO, carbon monoxide, very potent haemotoxin, combustible, highly flammable, gaseous, colourless, odourless. It is lethal to inhale large quantities of carbon monoxide. Carbon monoxide may possibly damage the unborn fetus.

Observe the following fundamental rules and regulations.

- Adhere to all applicable trade union rules and regulations.
- Only trained personnel are authorized to perform measurements.
- The CO concentration used for the patient must not exceed 0.3 %.

### Safety measures, storage, handling:

Store the container in a well-ventilated area and protect it against flammable sources and interaction with heat.

### In the case of accident and fire:

- If a gas leak should occur: Air the room and always use a breathing apparatus which is independent of ambient air.
- Substances to extinguish fire: water vapour, CO<sub>2</sub> extinguisher, dry quenching agent.
- First aid: Bring those who are injured into the fresh air. If breathing stops, give mouth-to-mouth resuscitation or use a respirator. Get help from a doctor immediately.
- Further information for the doctor: oxygen pressure artificial respiration (pressure cabin) with pure O<sub>2</sub> (3 - 3.5 bars), Supraenin or Pervitin is suitable.

### Toxicology:

Very potent haemotoxin. During inspiration the gas combines with hemoglobin so that oxygen cannot be absorbed (suffocation).

Toxin class 3 DL50 = 50 to 500 mg/kg

Literature:

- Notes on using CO

Hommel: Handbuch der gefährlichen Güter, Blatt 116

Kühn-Birett: Merkblätter gefährlicher Arbeitsstoffe, Blatt K19



## Gas Concentrations and Color-Coding of Gas Cylinders



Only use the indicated min./max. gas concentrations for the individual measurement procedures! For safety reasons we recommend to use ready-mixed gases which can be purchased from **Jaeger**.

The Euro-Norm EN 1089-3 indicates the color-coding of gas cylinders. This norm, however, is only binding from 1. July 2006. That means two types of color-coding are available at the moment.

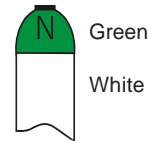
**Diffusion RB** with MasterScreen:

**Measuring gas, item no. 892533 (SB gas), 10 Liters**

min. 0.25 % CO      max. 0.28 % CO

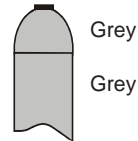
min. 8.9 % He      max. 9.7 % He

Rest: synthetic air



Green  
White

New color code



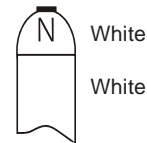
Grey  
Grey

Old color code

**Diffusion RB** with MasterScreen:

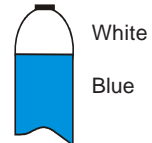
Measuring gas, item no. 892501 (oxygen), 10 Liters

100 % O<sub>2</sub>, medically pure



White  
White

New color code



White  
Blue

Old color code

**NOTE**

The pure oxygen (100 %) which is available in hospital can also be used as oxygen.



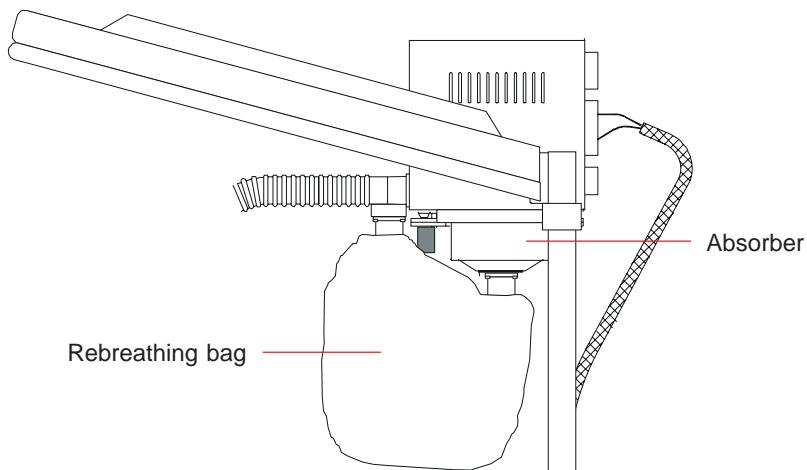
Observe the chapter "Safety Precautions and Operational Procedures" which contains further important information on the safe handling of gases!



## Preparing for a Measurement

The following must be checked before every measurement:

1. Is a new, disinfected mouthpiece attached to the new, disinfected pneumotach?
2. Are the valves of the Single Breath- and  $O_2$  gas cylinder open?
3. Is the rebreathing bag connected?
4. Are the absorbers checked? (See "Check Absorbers".)





### Setting up for the procedure

#### 1. Attaching the pressure reducer

Before you attach the pressure reducer, **carefully** and quickly open and close the cylinder valve to get rid of any dust which may be in it.

Screw on pressure reducer. Please make sure that the pressure reducer is gas-tightly connected to the cylinder valve via the attachment nut.

As a sealing ring ensures the gas-tight connection, the pressure reducer must be attached **carefully**.

#### 2. Open cylinder valve

The manometer indicates the cylinder pressure.

**NOTE**

**Close the cylinder valve if work is interrupted or ended!**

**NOTE**

**Do not empty the gas cylinder completely!**

If you get below 10 bars residual pressure, close the cylinder valve, remove the pressure reducer and send the gas cylinder back to **Jaeger**, or whoever your supplier is, to be refilled.

### Connection of new gas cylinders

When a new gas cylinder is to be connected, the sealing ring between gas cylinder and **Jaeger** pressure reducer must be replaced. Every **Jaeger** gas cylinders is delivered together with a new sealing ring.

More detailed information can be found in the leaflet "Connecting the pressure reducer to the gas cylinder" which is added to every **Jaeger** gas cylinder.



## Check List after Preparation

1. Valve head attachment checked?
2. Absorbers checked?
3. SB and O<sub>2</sub> gas cylinder open?

The pressure must not be changed between calibration and measurement. If pressure is changed, calibration must be repeated. That means, calibration and measurement have to be performed with the same pressure!

4. Filling volume of rebreathing bag entered?

**IMPORTANT**

Check these four points mentioned above prior to every measurement.

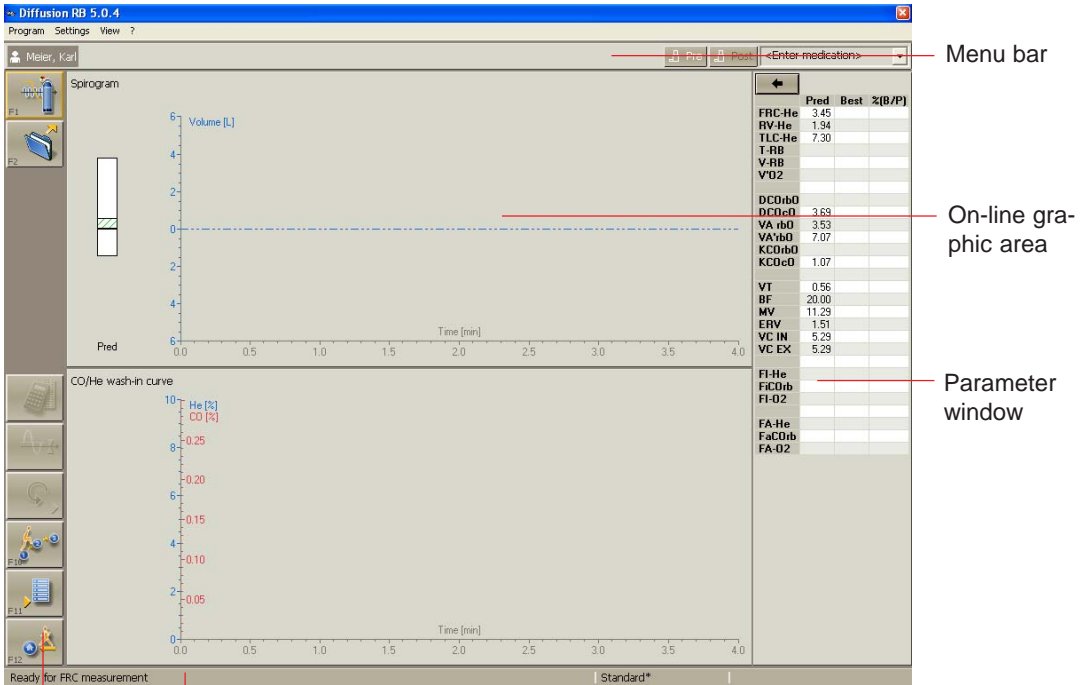




# Program Start



The "DCO RB" measurement program is called up from the main group by clicking the appropriate icon.  
The program appears as follows:



Icon bar

Status line

Information about the present phase of the program or about the icons appears in the status line.

The screen is divided into four main components:

1. Menu bar
2. On-line graphic area
3. Parameter window
4. Icon bar

provides the command menus with which the default settings of the program can be determined.

Display area for the graphics (depending on the current program phase)

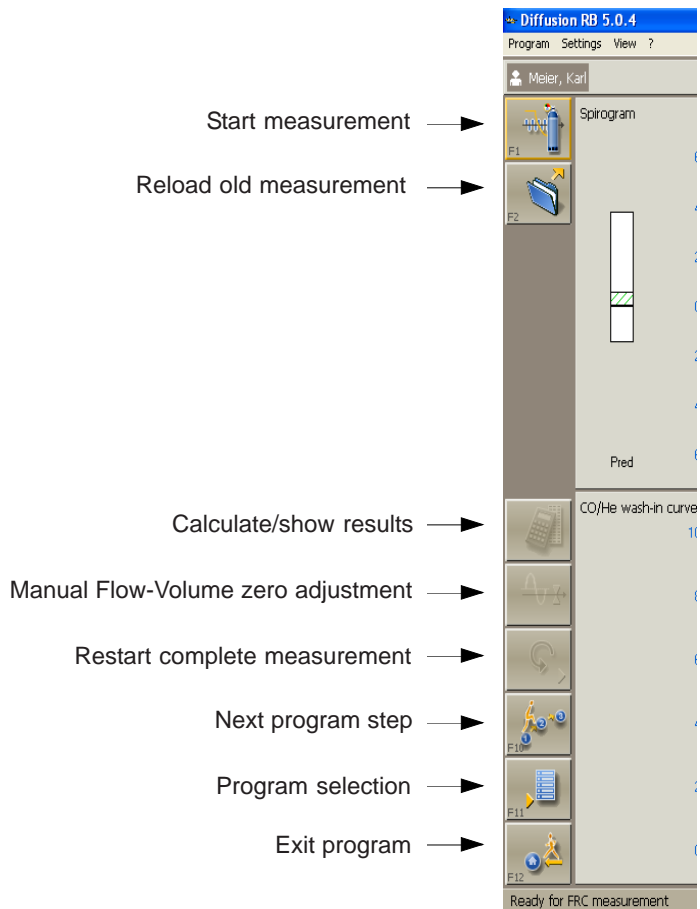
Predicted values, measuring values (actual values) and predicted value comparison.

The icons in the icon bar control the sequence of the measurement program.



## Icon Bar

With regard to the current phase of the program, different icons are displayed in the icon bar. Each icon starts a specific routine.





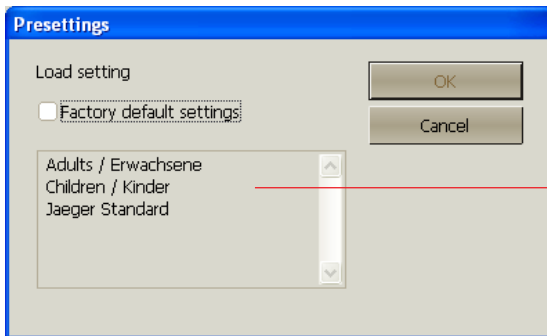
## Load Settings

The measurement program "DCO RB" allows specific modules for different patient groups (for example children, adults) to be generated, saved under a specific name and loaded before starting the measurement.

Default settings are, for example:

- axis scalings
- filling volume

Activate a module by clicking "Settings..." in the menu bar.



When the system is delivered, modules for children and adults are already preset.

Preset modules



Mark the required module and accept it with (OK).

You will find a detailed description on how to set and change preset modules on page 20.



## Medication

It is easy to enter a so-called "Medication" for any test in each of the measurement programs. Medication means that the medicine, its dose and its concentration are entered and referenced to the test (for example bronchospasmolysis) performed, thereafter.

"Medication" is called up from the common menu bar.



If "Pre" or "Post" is selected in the patient's test list, this indicates that a test has been performed before or after a medication was administered.

If you want to document the administered medication, simply overwrite the <Enter medication> field.

Press the "Return" key and the entry appears in the selection window and is saved automatically in the database.





The basis for bronchial response tests are profound questions as to trend assessment and therapy effectivity of bronchospasmolysis and/or broncho-provocation tests from the diagnostic point of view.

## Bronchospasmolysis Test

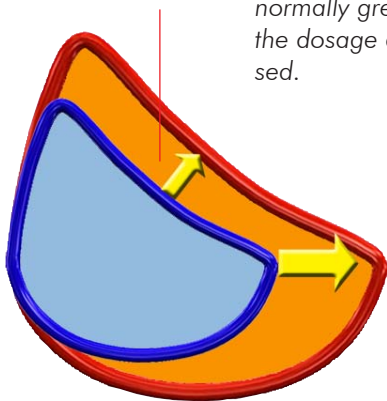
After an airway obstruction has been detected, the question as to its **reversibility** (curability) becomes essential.

Reversibility of an airway obstruction from the point of view of measuring technology is the indication for a bronchospasmolytic therapy. In addition, it provides an important incentive to the patient.

*The immediate bronchospasmolytic effect known as "room of improvement" can be illustrated with the flow/volume curve. The trend of the expiratory portion of the flow/volume curve changes and consequently, a change of the maximal peak flow (PEF) and the peak flows at 50 and 25 % of the thoracic vital capacity (FEF50, FEF25) can be observed.*

*The extent of the immediate bronchospasmolytic effect depends on circadian rhythm, airway width and to a great extent also on the patient's discipline during therapy. In the morning the immediate bronchospasmolytic effect is normally greater than in the evening. If the patient does not consistently use the dosage aerosol, the immediate bronchospasmolytic effect will be increased.*

"room of improvement"



Flow/volume curve before and after bronchospasmolysis. Before bronchospasmolysis, the curve trend of the expiratory portion is typical for an obstruction of the central and peripheral respiratory tract. After bronchospasmolysis the curve trend returns to normal. During an intrathoracic airway obstruction inspiration will not change.

Comparison of predicted and actual values measured for flow/volume key parameters before and after bronchospasmolysis.

How to perform and document a bronchoprovocation test is described in detail in chapter 28 "**Bronchial Test**".



## Perform Diffusion RB Measurement

The basic parameter **VCmax** and **ERV** are required for the calculation of **TLC-He** and **RV-He**.

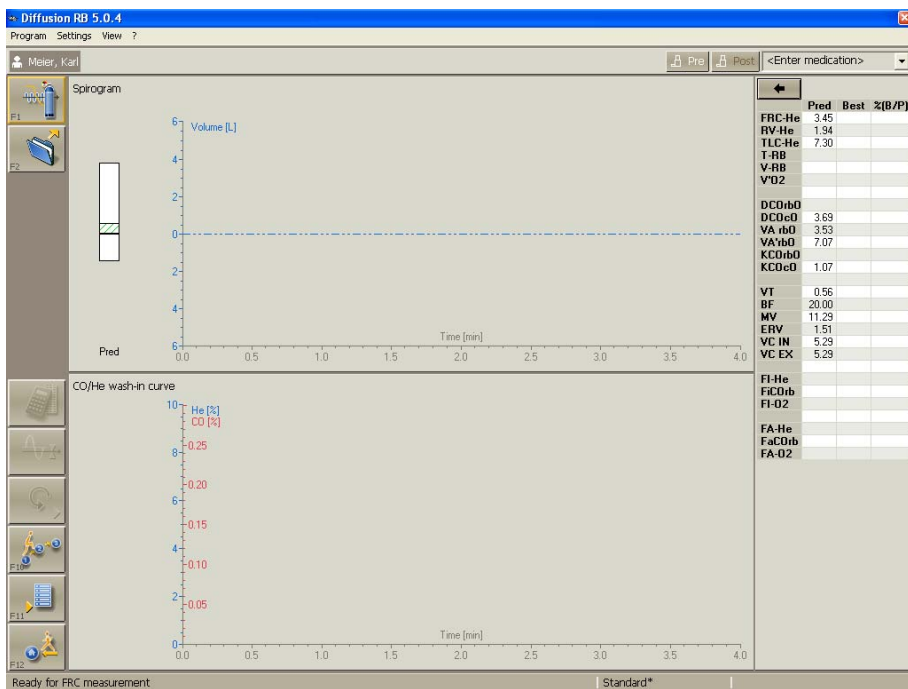


When the current patient has already performed, for example, a Spirometry, Bodyplethysmography or DCO-SB measurement, that measurement can be reloaded with "F2". TLC and RV will be calculated automatically.

If the patient has not yet performed a measurement, a Spirometry maneuver can be performed immediately after the DCO-RB measurement.



When starting the measurement program, the rebreathing bag is emptied, flushed with ambient air and a zero adjustment of the gas analyzers is performed.





Following that the RB bag will be filled with carbon monoxide, helium and oxygen.

**Notes on filling volume:**

Presetting: 5 liters

*If measurements on children are performed, the filling volume should be reduced.*



If the preparing phase (Fi gas analysis) is ended, the "F1" icon shown on the left will appear in the icon bar and the following message will appear in the status line:

**"Ready for FRC measurement"**

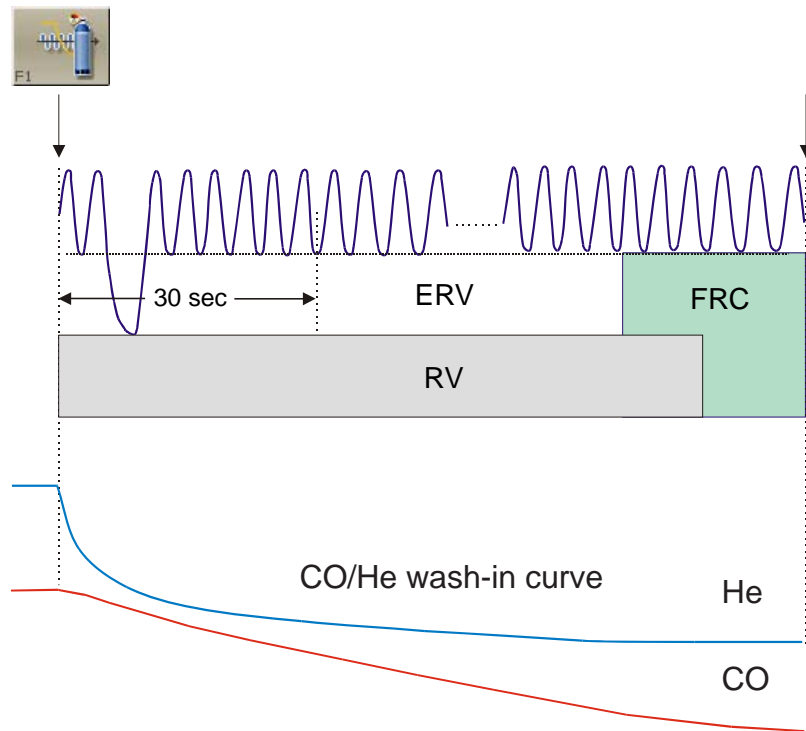
Now ask the patient to close his nose with the nose clip and to approach the mouthpiece.

**NOTE**

**During the following measurement the patient should sit still so that his oxygen uptake and breathing baseline (FRC level) remain stable.**



## Graphic display of measurement sequence



He should breathe quite normally.

If the patient breathes quite normally, the wash-in phase can be started by clicking "F1".

**Ask the patient to perform an ERV breathing maneuver within the next 30 secs, i.e. from normal breathing the patient slowly breathes out as deeply as possible and then continues to breathe normally. Do not perform a full inspiration to allow determination of enclosed volumes.**

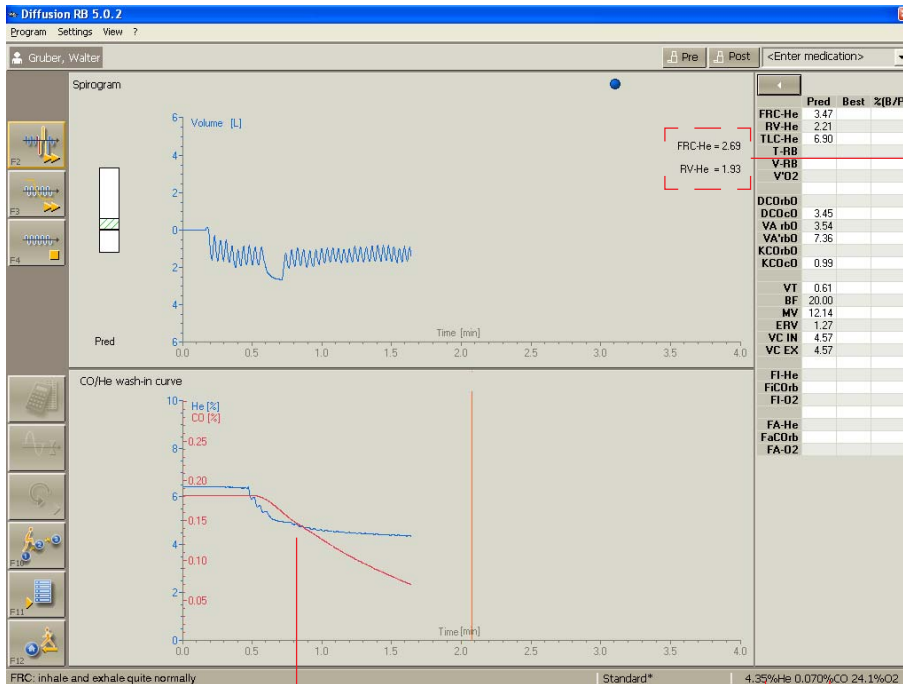
The patient breathes the gas mixture consisting of about 0.2 % CO, 6 % helium and 25 % oxygen contained in the RB bag. In order to keep the oxygen content in the RB bag constant, about 250 - 300 ml oxygen per minute will be added. The oxygen supply is triggered by the O<sub>2</sub> concentration in the RB bag.

**The inhaled CO/He gas mixture now spreads out evenly into the lung-spirometer system.**





Now observe the trend of the CO-He-wash-in curve, the values displayed in the status line and the continuously updated FRC values shown in the parameter window.



Calculated FRC-HE and RV-HE

CO/He wash-in curves

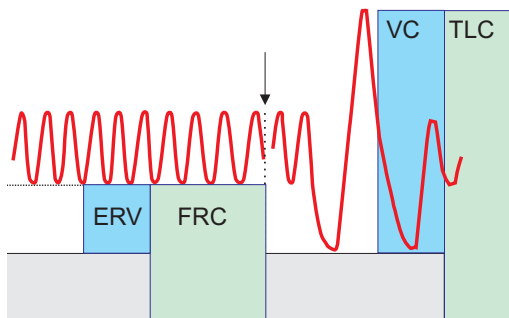
FE-CO  
FE-He

**IMPORTANT**

A patient with healthy lungs needs about 1 - 2 minutes for washing in. Wash-in periods of more than 3 - 5 minutes are signs of a distribution disorder. Seriously distribution-disordered patients sometimes need wash-in periods of up to 10 minutes.



If the He wash-in curve is horizontal and the He and FRC values are stable, the diffusion is measured. Continue the rebreathing for at least one more minute. The displayed **vertical line** is the minimum time required to evaluate the diffusion.

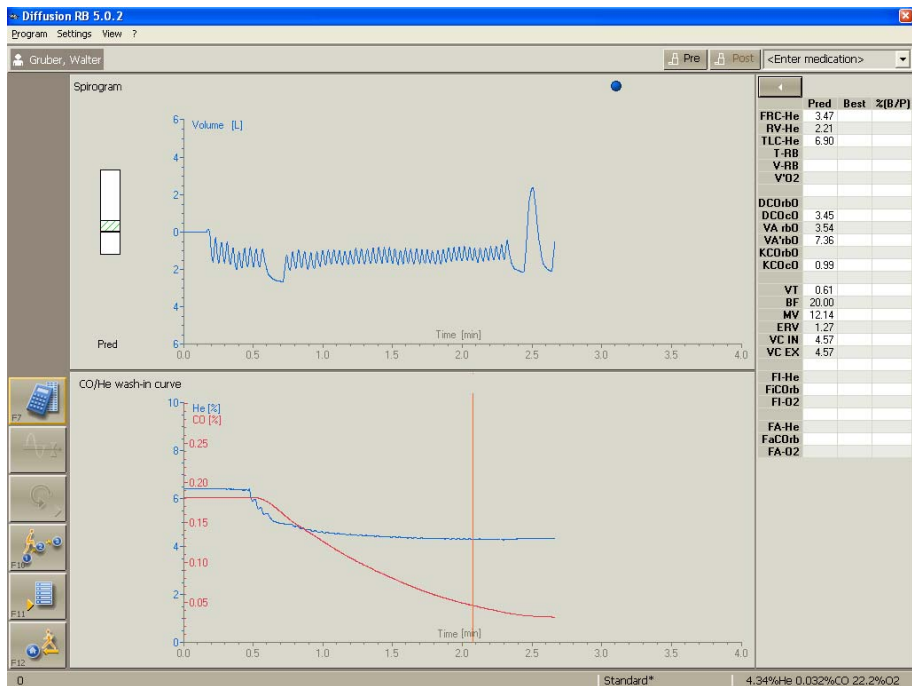


**Please note:**

If a spirometry measurement has not yet been performed on this patient, the parameter VC is missing for calculating the total lung capacity (TLC). In this case, a slow spirometry measurement should be performed, now.



Start with "F2".

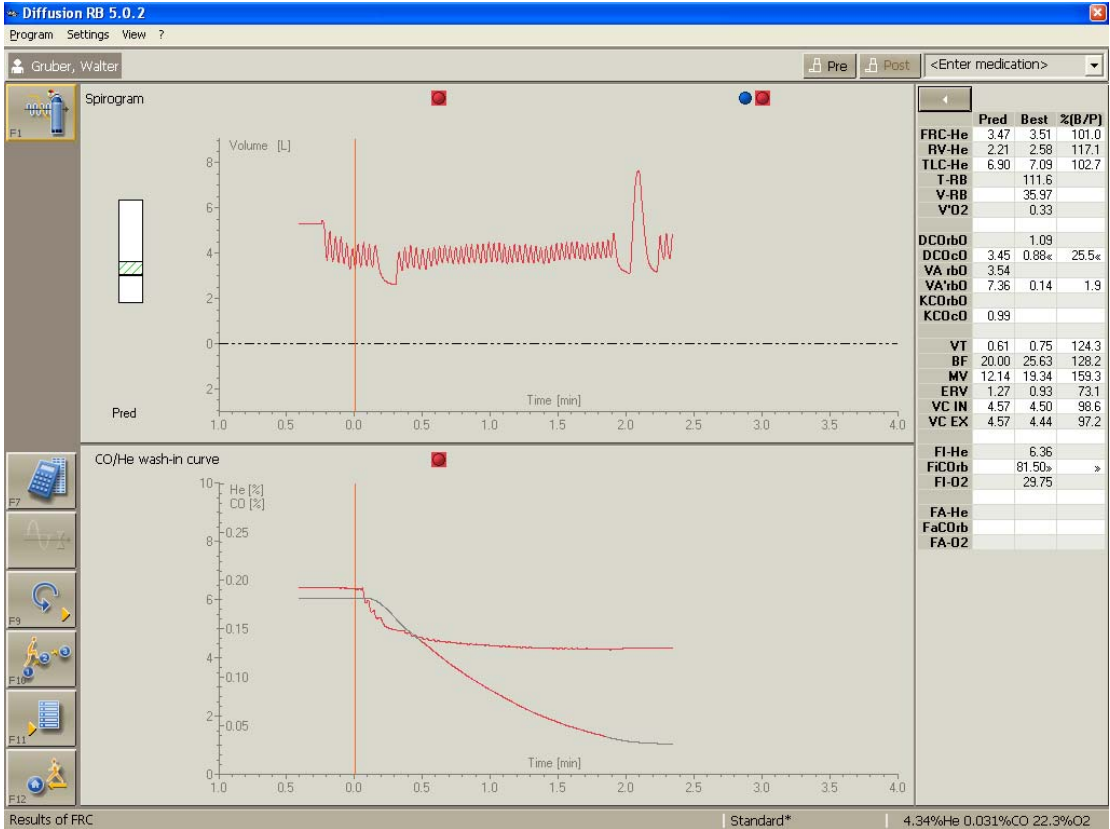


Ask the patient to breathe out deeply and completely (ERV), slowly to inhale to a maximum (VCIN) and then to continue to breathe normally.



The FRC measurement is ended with "F7".

The parameters will be calculated and displayed on the screen with a predicted/actual value comparison.



**Please note:**

If another trial is to be performed, a pause of about 10 minutes should be kept (in order to wash out CO/He).



If the measurement is interrupted or ended, the cylinder valve is to be closed.

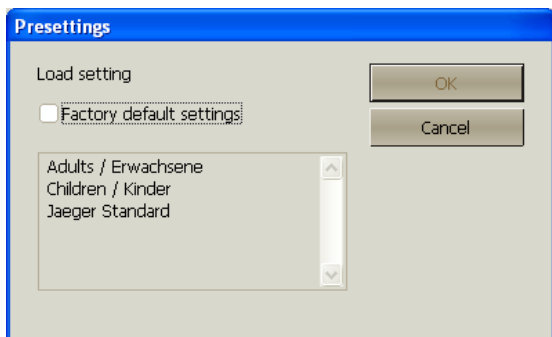


## Modify Default Settings

The measurement program **"DCO RB"** allows specific setting modules for different patient groups (for example children, adults, ...) to be generated, saved under a specific name and loaded before starting the measurement (also see "Load Settings").

In order to generate setting modules or change existing modules, the menu item **"Modify settings"** in the command menu **Program** is to be activated. A tick in front of the menu item indicates its activation.

If an existing setting module is to be modified, click the item **"Read..."** in the command menu **Settings**.



(OK) and the marked module will be loaded.

Click **Settings** again and the default settings can be changed.

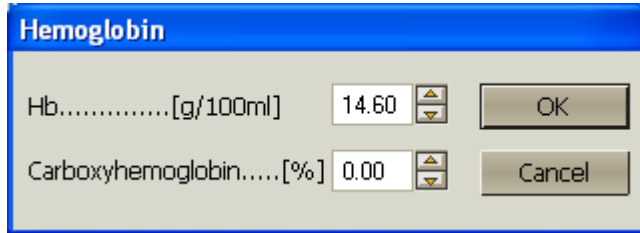


## Description of Settings

- Settings
- Read...
- Save as...
- Delete...
- Hb entry...**
- Evaluation, Display...
- Parameter list...
- Load default settings

### Hb entry

In order to calculate the hemoglobin-corrected parameter  $TLCOC_c$ , the concentration of hemoglobin in the blood is to be entered manually.



### Carboxyhemoglobin correction

The routine DLCO calculation assumes that the CO partial pressure in the blood is equal to zero. Cigarette smoke or other environmental influences, however, influence the CO partial pressure and the CO hemoglobin. The same is valid for the DLCO measurement. The COHb is increased by about 0.7 % per measurement.

According to ATS, a COHb correction is not absolutely necessary but it is recommended if the COHb values are increased.

Calculation:

$$COHb_{corrected} = DLCO_{measuring\ value} (1 + (\%COHb/100))$$

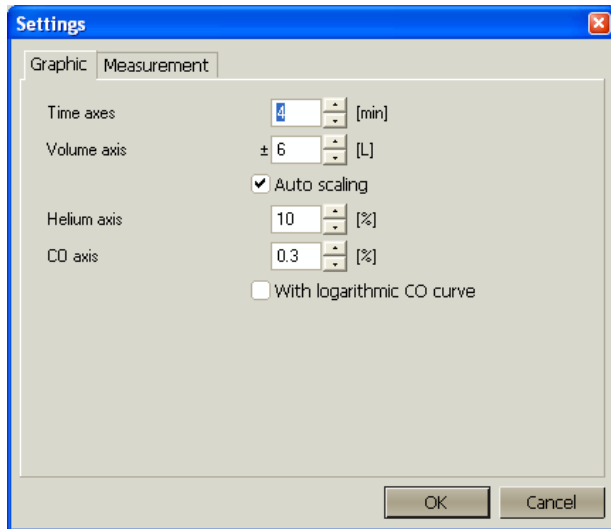


Continue with (OK).



Select **"Evaluation, Display..."** in the **Settings** command menu.  
The settings can be found and changed in so-called "file-cards".

### File card "Graphic"



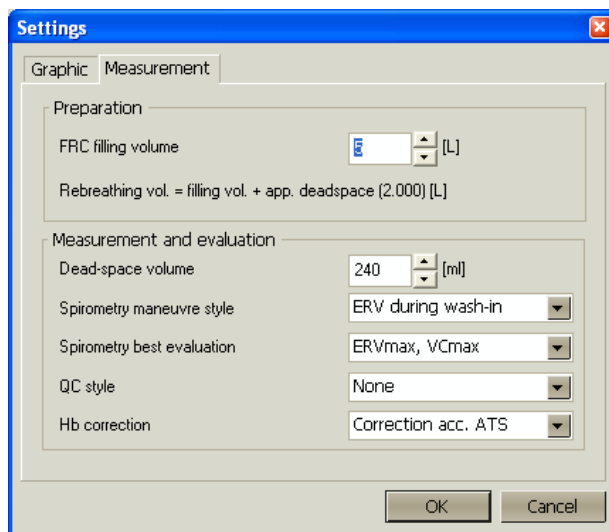
In **"Axis scaling"** the scaling of the volume-, time- and helium axis can be changed.

Presetting:	Time axis	4 min
	Volume axis	6 L
	Helium axis	8 %
	CO axis	0.3

If **"Auto scaling"** is selected and the breathing volume is greater than the preset volume axis, the volume axis will be rescaled automatically.



## File card "Measurement":



The FRC filling volume can be changed in **"Preparation"**.

In case of a FRC measurement, the rebreathing bag will automatically be set to the preset filling volume as soon as the program is started.

Presetting: 5 liters.

*If measurements are performed on children, a filling volume of, for example, 3 liters (depending on patient's height) should be set.*

In **"Measurement and evaluation"** the following can be set:

### **Deadspace volume:**

If the apporative deadspace is changed, for example for measurements with a preset bacteria filter, the volume of the filter (about 50 ml) will have to be added.

Deadspace volume plus filter = 180 ml

Preset deadspace volume = 130 ml

**Spirometry maneuver style:**

The parameter ERV can either be determined **"during the wash-in phase"** or **"at the end of the measurement"**. We recommend to determine the ERV during the wash-in phase.

**Spirometry best evaluation:**

Here, the criteria are preset according to which the best Spirometry measurement is to be calculated.

**Quality style**

The quality of a measurement can be checked according to several quality criteria. The following quality criteria can be selected:

**none**

**Mayo**

The quality of the measurement is indicated by a "traffic light" and depends on the preset quality criteria.

Grey = No valid trial

Red = Not reproducible

Yellow = Reproducible, but less than two valid trials.

Green = All criteria fulfilled.

More detailed information can be found under "Appendix: Quality Criteria for the Measurement, Error Code Lists".





### Hb correction

Hemoglobin-corrected TLCOc can be calculated according to different formulas.

1. **Hb correction according to ATS** based on a predicted value of 14.6 g/100 ml

Formula:

$\text{TLCOc} = \text{Actual value}/k$ $k_{\text{male}} = 1.7 \cdot \text{Hb} / (10.22 + \text{Hb})$ $k_{\text{female and teenager < 15 year}} = 1.7 \cdot \text{Hb} / (9.38 + \text{Hb})$
--

2. **Hb correction according to Hilpert** based on a predicted value of 13.5 in females and 14.6 in males.

Formula:

$\text{TLCOc} = \text{Actual value}/k$ $k_{\text{male}} = 0.0646 \cdot \text{Hb} + 0.0568$ $k_{\text{female}} = 0.0646 \cdot \text{Hb} + 0.1279$
--

**OK**

(OK) accepts the setting.

(Cancel) cancels without alteration.

### General Notes on Presetting:

1. Even after a measurement, all presettings for a curve display can be changed.

Settings which influence the type of evaluation/display can only be changed before starting the measurement.

**Example:** The displayed curve is outside the visible range or the curve is too small or too large as compared to the scaling.

2. If the changed settings are not saved with "**Save as ...**" in the command menu **Settings**, the question "**Save settings? Yes/No?**" automatically appears when the program is ended.

With **(Yes)** the settings are saved as default settings.



## Appendix

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### Appendix: Quality Criteria for the Measurement, Error Code List

For every possible error message an error code number is saved in the data base. This code number can then be output on screen or printer just like a measuring parameter.

If several error messages apply to one measurement, the corresponding error code numbers are added.

#### Example:

Code no. 11 means:      Code no. 1 **plus** no. 10

#### ATS and Mayo:

Based on the experience of specialists of the Mayo Clinic, a leading hospital in the USA, and the ATS guidelines, extended criteria have been introduced. The error code is saved with parameter #46 of the Diffusion SB program; the parameter is determined and saved independent of the selected QC criteria.

#### Error code    Description:

- |   |  |
|---|--|
| 1 | only one accepted trial available.   |
| 3 | No reproducibility: no valid trial   |
| 2 | No reproducibility: TLCO <sub>c</sub> differs too much. The difference between the highest and the lowest measuring value is calculated. The reference value is the mean value calculated from both values. There are three different ranges depending on this reference value: <ol style="list-style-type: none"> <li>1. TLCO<sub>c</sub> &lt; 3.68 mmol/min/kPa (&lt; 10 ml/min/mmHg): The difference is greater than 0.67 mmol/min/kPa (corresponds to 2.0 ml/min/mmHg)</li> <li>2. TLCO<sub>c</sub> between 3.68 mmol/min/kPa (10 ml/min/mmHg) and 10.05 mmol/min/kPa (30 ml/min/mmHg): The difference exceeds 10% of the reference value.</li> <li>3. TLCO<sub>c</sub> &gt; 10.05 mmol/min/kPa (&gt; 30 ml/min/mmHg): The difference is greater than 1.005 mmol/min/kPa (corresponds to 3.0 ml/min/mmHg)</li> </ol> |



- 4 No reproducibility: VA differs too much. The difference between the highest and the lowest measuring value is calculated. The reference value is the mean value calculated from both values. There is no reproducibility if the difference exceeds 10 % of the reference value.
- 10 Inspiration time longer than or equal to 2.0 secs.
- 20 Expiration time (i.e. time from the opening of the valve until the middle of the sample volume) longer or equal to 15 secs.
- 40 Breath holding time out of the interval of 9 to 11 secs.
- 100  $V_{in}$  lower than 90 % of  $V_{Cmax}$ .  $V_{Cmax}$  is calculated from the  $V_{Cmax}$  measurements of Spirometry/Flow-Volume, Bodyplethysmography, FRC-He and  $V_{in}$  of all other trials.
- 1000 The TLC determined in a Single-Breath Diffusion measurement is extremely higher than the TLC determined in a previous Bodyplethysmography measurement, i.e. the difference must be greater than 500 ml.

**Literature:**

Private communication.



## Check Absorber

The CO<sub>2</sub> absorber connected to the analyzer unit has to be checked in regular intervals. The absorber vessel is filled with soda lime which chemically absorbs the CO<sub>2</sub> from the breathing gas.

### Please note:

The CO<sub>2</sub> absorption capacity decreases from measurement to measurement. An optical check is only possible, if the Jaeger offered soda lime with colour indicator is used.

Due to this indicator, the soda lime changes its colour from white to violet with increasing absorption. Its absorption capacity is completely exhausted if it has a deep violet colour.

**A few minutes after a measurement, soda lime loses its colour again so that you cannot recognize whether its absorption capacity is exhausted.**

### How many measurements can be performed with one filling and when has the filling material to be exchanged?

The quality of the soda lime differs dramatically. With a high-quality soda lime about 10 measurements with average wash-in periods of 10 minutes can be performed with one complete filling.

The absorber material has to be exchanged, if it shows a rich change in colour (only applies to soda lime with colour indicator). A slight or no change in colour indicates a still sufficient absorption capacity.

A further indicator is a ripple on the He-curve in phase with the patient breathing. This indicates incomplete CO<sub>2</sub> absorption and we recommend to exchange the absorber material after this test.

Absorber material which considerably changed its colour once, should be exchanged immediately after the measurement. We point out that we absolutely advise you against mixing exhausted material with new absorber material.



## ***Handling and Storage of Soda Lime***

### **Storage**

Soda lime must be protected from moisture loss. Open vessels result in moisture loss so that they should immediately be closed. Sealed vessels are usable for at least one year. High temperatures in the storeroom have no influence on the material. Temperatures below zero, however, result in a decomposition of the granules.

### **Filling the Absorber Vessel**

It is very important to fill the absorber vessel carefully. Only then is good absorption guaranteed. Filling the absorber vessel is quite easy. Fill the soda lime into the absorber vessel by slowly rotating the vessel at the same time. Tap the absorber vessel on the table so that the granules distribute evenly. The absorber vessel should be filled completely but it should not be over-filled. This procedure ensures a regular distribution of the granules and restricts the dust production to a minimum.

### **First Aid**

Should a person get into contact with soda lime, the affected area is to be rinsed with clear water for a long period of time. If even smallest quantities of soda lime - in solid form or in a solution - get into someone's eyes, his/her eyes have to be doused immediately and carefully for at least 15 minutes.

Swallowing soda lime may cause serious acid burns of the oral mucosa, pharyngeal mucosa, esophagus and gastric mucosa. In such a case, a chemical neutralisation should take place. If available, slightly acidic fluids (diluted vinegar, lemon juice, sour milk, acid wine, 5 % ammonium chloride solution) should be administered in sufficient quantities. If such fluids are not available, the patient should immediately drink a large quantity of water. Mucic substances (such as egg-white) give local relief.



## Exchange Soda Lime

### Procedure:

1. Remove RB bag.
2. Open both clamping levers of the absorber holder.
3. Pull out the absorber holder (see picture).
4. Remove filter and exhausted soda lime.
5. Insert new filter in the absorber, fill in new soda lime and cover the soda lime with a second filter.
6. Put in absorber holder and fix it with the clamping levers.

