Software Description GFS-3000
Control Unit Model 3000-C

Software Manual

Supplement to the 6th Edition of the GFS-3000 Manual:
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1 Intruduction

This manual describes the operating software of the GFS-3000 with Control Unit Model 3000-C. For information on the hardware, safety instructions and complete operation follow the latest manual for the GFS-3000 (edition 6 or higher). It can be downloaded from the Walz homepage (www.walz.com). This manual here only documents the software installed on the instruments with Control Unit Model 3000-C sold until end of 2011. The GFS-Win software will operate on the Panel-PC of the Control Unit Model 3100-C. The latest GFS-Win software can also be used to operate the GFS-3000 with Control Unit Model 3000-C from an external PC. The latest GFS-Win version, which can only operate Control Unit Model 3000-C, but not Model 3100-C is GFS-Win 3.24. The first version capable of operating both models in external mode is GFS-Win 3.30.

2 Software Update

2.1 Software Update

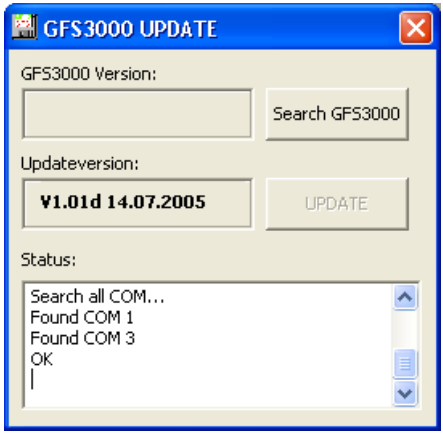
2.1.1 Using the GFS-3000 Panel PC Update Software

The latest available Panel PC software version can be found and downloaded from the Walz homepage (www.walz.com). The software comes with an update-program, which serves to load the software to the panel-PC of the Control Unit Model 3000-C. The update-program works with the following windows systems: Windows 95, 98, 2000, Me, NT, XP, 7. Please note that also the GFS-Win software should be updated.

IMPORTANT NOTE:

Do not disconnect or switch off the GFS-3000 during the update process (if the status window is colored red, Panel PC shows messages of Zmodem). If an error occurred during the process, repeat update.

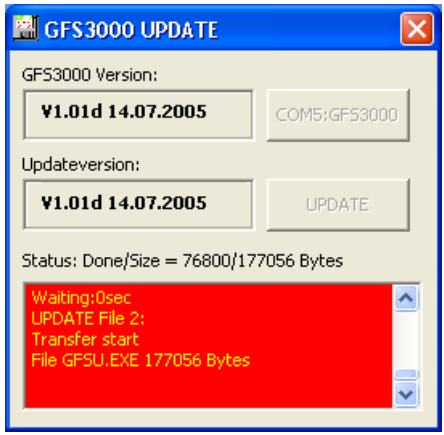
Three exe-files are necessary to run a correct update. The program transferring the software (GFS-3000upd.exe) and two exe-files (gfsu.exe and gfsu2.exe), which will be transferred. Start the program GFS-3000upd.exe and follow the instructions, shown in the first message window.



After pressing *OK* the application window will appear and show the status of its automated search for Com-Ports in its lower screen. Having checked the Ports, the program asks for switching on the GFS-3000. Before further proceeding make sure that the Panel PC is completely started and approve by

pressing *OK*. Afterwards press *Search GFS-3000* to find the currently installed software version.

When the GFS software version is found, an *OK* will appear in the status window. Press *UPDATE* to start the process. The window will appear red to show you that the update is running.



This may take a few minutes.

After the File transfer the GFS-3000 will reset and start again (a message box appears).

When the GFS-3000 is completely started, the update is complete and the instrument can be switched off and disconnected or used.

2.1.2 Updating the GFS-Win Software

The latest available GFS-Win software version can be found and downloaded from the Walz homepage (www.walz.com). GFS-Win has been extensively tested with Windows XP. It also runs with Windows98, 2000, ME and Windows 7. The GFS-Win Software is required for downloading data files or uploading program files. It can also be used to run the instrument with an external PC. For installation of GFS-Win and file transfer see chapter 4.

3 Software Description, Panel PC Software

3.1 Introduction

The Panel PC software is software assigned to the **GFS-3000 Portable Photosynthesis System**. It runs on the Panel PC of the GFS-3000 with Control Unit Model 3000-C. It is specialized to assess the photosynthetic performance of plant samples by gas exchange measurement.

3.2 Start

After the *GFS-3000* power has been switched on and the software has been loaded, the display shows the *Settings window* (*see* Fig. 1).

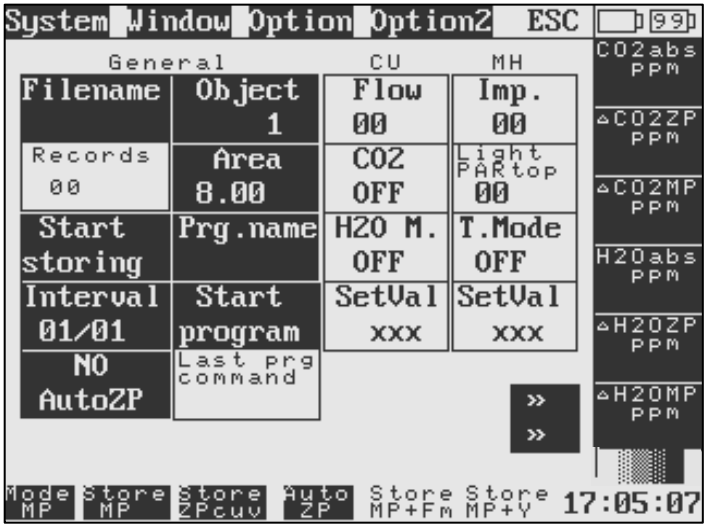


Fig. 1: Panel PC surface after the power has been switched on, but also showing the bottom-bar, which only appears after the Measure Mode has been switched on.

3.3 General Information on the User Interface

The GFS-3000 can be operated via touching certain areas on the touch-panel either with the provided plastic pen or simply with fingers. Areas with a black back-ground are active, which means they can be selected. The graphical user interface is divided into six zones:

- The upper bar displays the main menu and the information about the remaining battery capacity. It also contains a button *ESC*. If this button is active, it can be used to escape from the chosen function.
- The central window displays chosen windows or chosen sub-menus and dialogs. In Fig. 1 the Window *Settings* is displayed.
- A *Quick-View Column* on the right displays six user-selectable values.
- After the Measure Mode has been switched on, a bar appears at the bottom of the screen containing six buttons with *frequently used commands*.
- Above the frequently used commands is an empty area, where information may be shown.
- In the lower right corner the system time is displayed.
- Since version 1.31 there is a button above the time for changing the contrast of the display.

3.4 Main-Menu

The Main-Menu contains four topics: *System*, *Window*, *Option* and *Option2*. Fig. 2 gives an overview of the sub-menus, which will appear under these four topics.

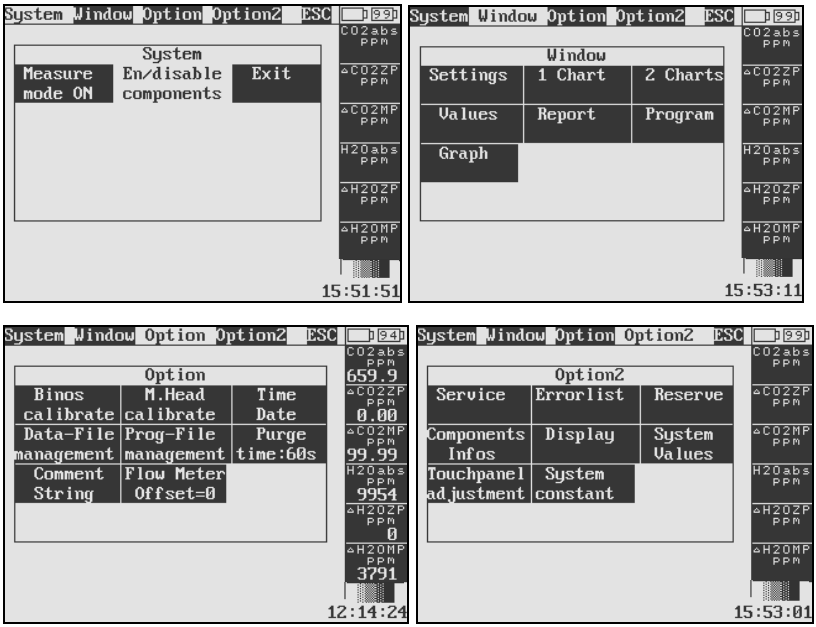


Fig. 2: Overview of the four Sub-Menus under the different topics of the Main Menu

The *System* submenu serves to switch the system on or off or to enable connected hardware. The *Window* submenu gives access to different windows for managing the measurement. *Option* gives access to less frequently used functions and settings, like calibration or file-management. *Option2* contains mainly information about the system, but also hosts the function for the adjustment of the touch panel.

3.5 Quick-View Column

The *Quick-View Column* on the right side of the main window shows six values, which are user-selectable. To allocate a new value to a certain field of the *Quick View Column* select this field. A table with all available values will appear. Select your value of choice. It will now be shown in the *Quick-View Column*.

3.6 Frequently Used Commands Buttons

A bar with *frequently used command*s is located at the bottom of the main window. The Mode-Button on the left shows the state of the solenoid valves controlling the gas flow. The Mode can be MP or ZP. Depending on the Mode the next three buttons change their appearance and function.

If *Mode MP* (*Measuring Point*) is chosen, the reference gas is flowing through the reference cell and the measuring gas is flowing through the sample cell of the analyzer. If a leaf is enclosed, a *Measuring Point* (*MP*) can be stored, using the button *Store MP*. If the cuvette is empty, a *Zero Point* which includes the cuvette, can be stored using the button *Store ZPcuv*.. This button is disabled if *Measure Mode* is off, *Start Storing* is activated or if a program is running.

Once an hour or after changing CO_2- or H_2O absolute concentration a *Zero Point* must be measured to compensate differences between the two gas analyzers. If samples are enclosed for a short time, *ZPcuv* should be preferred. For long term measurements it is not possible to measure ZPcuv, but only Zero Points of the infrared gas analyzer alone (*ZPirga)*.

If *Mode ZP* is chosen (by pressing the field Mode MP) the measuring gas is vented after passing the *Measuring Head*. The reference gas is split and flows through the reference and sample cell of the analyzer.

A zero point of the differential signal of the infrared gas analyzer can be stored using the button *Store ZPi* (short for *Store ZPirga*). It will be marked as *ZPi* in the record file. A leaf can be enclosed in the cuvette during this procedure. For more detailed information on ZP and MP see GFS-3000 manual.

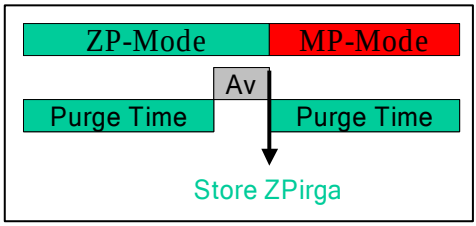


Fig. 3: Time course of an Auto ZPirga measurement

Auto ZP does the following procedure, which is illustrated in Fig. 3, to measure a *ZPirga*: The solenoids of the gas ways are switched into *ZP-Mode*, the gas analyzers are purged for a defined period of time, a *ZPirga* is stored, After storing *ZPirga* the solenoids will be switched back to MP mode and again the gas analyzers are purged.

The *Purge time* can be set with *Purge time* in the submenu *Option*. The averaging time for *Zero Points* is the same as the averaging time chosen for *Measuring Points*. It can be set in the *Settings Window* with the button *Interval*.

The additional two buttons on the right *Store MP+Fm* and *Store MP+Y* are only active, if a fluorescence module is connected and enabled.

 In the lower right-hand corner, above the time there is a field serving to adjust the contrast of the display. Touching it continuously, will change the contrast into one direction. Touching it again, will change the contrast into the other direction.

3.7 Submenu System

Measure mode ON

Opens up the dialog for system configuration (*see* Fig. 4). First select the Standard Head. Only then a Fluorescence module may be selected. After OK has been pressed, the infrared gas analyzer is switched on, and all modules of the system are initialized.

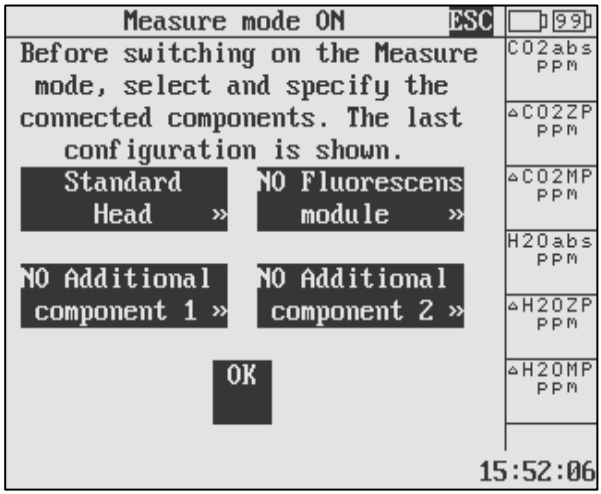


Fig. 4: Dialog for system configuration

Measure mode OFF

After the Measure Mode has been switched on, the button changes and can now be used to switch the system off. Most important the gas analyzers are switched off with this button. During the switch-off procedure, the system is flushed with dry air to avoid condensation in the stored system or during cold transport. For this

to be effective, the Measuring Head needs to be closed and the drier needs to be functional. With Esc the flushing can be stopped. After flushing, the H_2O control is turned off. Now, the power of the system may be switched off. Also the actual configuration is stored when the Measure Mode is switched off.

The button for standby mode switches all controls off. The gas analyzer remains switched on and warmed up.

Allows to change the system configuration (Fig. 2), when the Measure Mode is on.

3.8 Submenu Window

The available windows are:

- *Settings*; to change measuring parameters.
- *1Chart*; to display one full-size chart of any measured magnitude.
- *2Char*; to display two half-size charts of any measured magnitude.
- *Value*; to obtain an overview over all current values.
- *Report*; to see stored values.
- *Program*; to write, read or change user-programs.
- *Graph*; to plot two magnitudes versus each other (the data points from the report file are used).

3.8.1 Window: Settings

The *Settings window* opens automatically after the start of the system (*see* Fig. 1). In general clicking on the parameter whose value has to be

changed starts an input-dialog. The control elements in the Settings-Window are arranged in four different groups: *General, Control Unit, Measuring Head, Fluorescence Module*. The Fluorescence group is on the second page of the *Settings window*. Only the *General* group is active when the *Measure mode* is off. After pressing *Measure Mode ON* all buttons in the *Settings window* can be accessed.

3.8.1.1 General

The *Filename* button allows to entitle an upcoming measurement or to open an existing file. Newly collected data will be appended to the chosen record file. If a new file is created, the reference for the calculation (*Area* or *Weight*) must be entered. Area is suitable for flat leaves; *Weight* should be used for Conifers, Lichens or Mosses. The lower part of the button counts the lines stored in the record file. The reference (*Area* or *Weight*) cannot be changed within a file. To delete files use *Data Management* in the submenu *Option.*

The three buttons *Start Storing, Interval* and *NoAutoZP* serve to control the automatic storage of record sets. (Automatic storage should not be mixed up with running a user-program). The *Start Storing* button starts the recording. First *System*/*Measure mode ON* must be enabled and a filename selected. The other two buttons control the measuring sequence. Three different sequences are available.

1. *n*MP:* records a series of n *Measuring Points* using a defined interval (*see* Fig. 5a). Mode MP and NoAutoZP must be selected.

2. *n*ZP*: *:* records a series of n *Zero Points* using a defined interval. Mode ZP and *NoAutoZP* must be selected. The difference between sequence 1 and 2 is just the Mode of the gas ways, MP or ZP (*see* manual for GFS-3000).

3. *n/x*(AutoZP + x*MP* repeats the sequence AutoZP + x*MP (*see* Fig. 5b) using a defined interval between MPs. The sequence starts with a *Zero Point*. The sequence is repeated until the requested amount of Measuring Points (n) are stored.

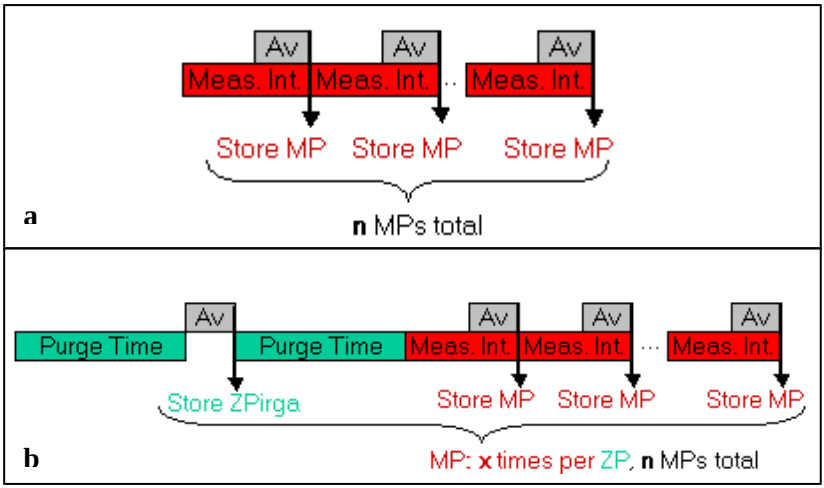


Fig. 5: Illustration of measuring sequences, **a**: sequence 1, **b**: sequence 3.

The *Interval* button defines the averaging time (s) and the measuring interval (s) for the storage of record sets (*see* Fig. 5). First, the measuring interval is requested. It can range from 1 to 600s. Afterwards an averaging time has to be entered. It can range from 1s to the time that was assigned to the measuring interval. The averaging time entered here, is not only used during automatic storage, but always when record sets are stored.

The *NoAutoZP*-button defines how often the system shall switch into the ZP mode and measure a zero point of the gas analyzer. If *NoAuto ZP* is chosen, a cycle of n *Measuring Points* (n*MP*)* or n *Zero Points* (n*ZP) will be stored depending on the selected mode (MP or ZP). This sequence is recommended for short-term experiments, a ZP must be measured directly before. If *AutoZP + x*MP* is selected and start storing is clicked, the cycle (AutoZP + x*MP) will be repeated. The sequence n/x *(AutoZP + x*MP) is recommended for long-term experiments. *Zero Points* will automatically be measured between series of *Measuring points*, giving a higher accuracy.

When a fluorescence module is used, additional choices for the measuring sequence can be made (*see* chapter 3.8.1.4 and manual for GFS-3000).

The *Object* number will be stored with the measured data in the record file.

Input of the value for the reference *Area* or *Weight*, which is used for calibration and stored with each following data record. The value, unlike the *reference type*, can be changed within a file. The *reference type* is fixed, when a new file is created.

The three buttons, *Prg.name*, *Sart program*, and *Last prg command* control the execution of user-programs. A user-program is a user programmable experiment like e.g. a Light Curve, which can be edited in the Program-Window (for further information proceed to chapter 3.8.6 and *see* GFS-3000 manual). With *Prg.name*, a user-program can be selected and with *Start program* it is started or stopped. Before a program can be started "*System→Measure mode ON*" must be enabled and a Filename and program name has to be entered.

3.8.1.2 Control Unit

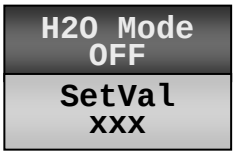
Input of the *Flow* rate between 600 and 900 µmol/s (equivalent to 800 to 1200 ml/min). The *Flow* can only be switched off, when neither H_2O nor CO_2 are controlled by the instrument (*H_2O mode* and *CO_2 mode* are *off)*. Vice versa the *H_2OMode* and *CO_2Mode* can only be switched on, when *Flow* is on.

The user can choose between two different options:

1. *CO_2 control off*; to use ambient air. In this case the CO_2 absorber tube has to be exchanged against the provided mixing volume (3000-C/MV). A solenoid valve closes, so that no CO_2 can diffuse to the system.

2. Set an absolute CO_2 concentration in *ppm*: the set-value can be chosen between 0 and 2000 ppm. The CO_2 can only be changed, when the flow is switched on and also requires the connection of the CO_2 absorber tube. (The CO_2 absorber needs to be functional. It has to be exchanged, when turned violet even if the color has turned back to pale. In dry climate the indicator may not work well)

A small cartridge supplies the CO_2, into a storing vessel. If the *CO_2 mode* is *on* and the pressure in the vessel drops below 2.5 bar, a warning appears, that the CO_2 cartridge has to be exchanged. After the first warning the CO_2 control can still run for a few hours. Do not exchange the CO_2 cartridge before the warning appeared. If you want to force the warning to appear, release the pressure with the screw at the front of the CO_2-control unit. Before closing the screw, open it so far that the seal-ring can pull back into the groove of the screw.



The user can choose between *off* and two further modes:

1. *H_2O Mode off;* The air is directed straight through the H_2O valve, without passing the *Drier* or *Humidifier*.

2. *H_2O Mode absolute* concentration in *ppm*; the resulting relative humidity inside the cuvette depends on the cuvette temperature.

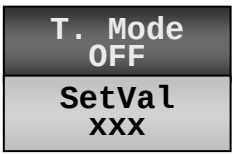
3. *H_2O Mode relative humidity* in *%;* the Measuring Head has to be connected and the *TempMode* must be set to *Tcuv*. Note that not the relative humidity of the cuvette is controlled, but the relative humidity entering the cuvette. The humidity required is calculated from the set value for *Tcuv*, it is adapted when *Tcuv* is changed.

For option **1** or **2** a set value must be entered. After the control mode has been defined the button underneath for the set value is active, and serves to change the value. The unit of the set-value is *ppm* or relative humidity (rH), depending on the H_2O control mode.

3.8.1.3 Measuring Head

Impeller speed to ventilate the cuvette volume effectively. The values can be set between 0 and 9, setting 7 is recommended. At lower speed the response time is slower, the temperature control gets less effective and the boundary layer is thicker.

The *Light Mode* determines which light sensor is used to control the light intensity, *PARtop* (sensor in the upper chamber side), *PARbot* (sensor in the lower chamber side), or *PARamb* (MQS-B/GFS sensor for ambient light). The Light-Source Factor (*see* chapter 5.1.2) is effective for the indicated light value of the chosen sensor, if *PARtop* or *PARbot* are chosen and the light is switched on, but remains ineffective, if *PARamb* is chosen or the light is switched off. To set a light value a light source must be connected and mounted onto the cuvette. A set value between 0 and 2000 µmol m^{-2} s^{-1} can be chosen.



For the temperature control, the user may choose between *off* and three further modes:

1. *off:* No temperature control.

2. *Follow ambient temperature*: The ambient temperature is measured at the external heat exchanger fan of the lower cuvette half and for the control of the cuvette temperature. An offset can be entered, which is the set difference between Tcuv and Tamb.

3. *Set cuvette temperature*: the cuvette temperature is kept constant at the set value.

4. *Set leaf temperature:* Leaf temperature is kept constant.

When options **3** or **4** are chosen, a set value must be entered which can be changed, using the *SetVal* button below. The temperature control is slow to avoid a large temperature overshoot, which could cause water condensa-

tion. The minimal temperature, the standard measuring head can reach, is about 10 °C below ambient temperature and can be increased up to 50 °C.

3.8.1.4 LED-Array/PAM-Fluorometer 3055-FL - Optional

The control elements for the fluorescence module are located on the second page of the Settings Window and become active, when the LED-Array/PAM-Fluorometer 3055-FL is connected.

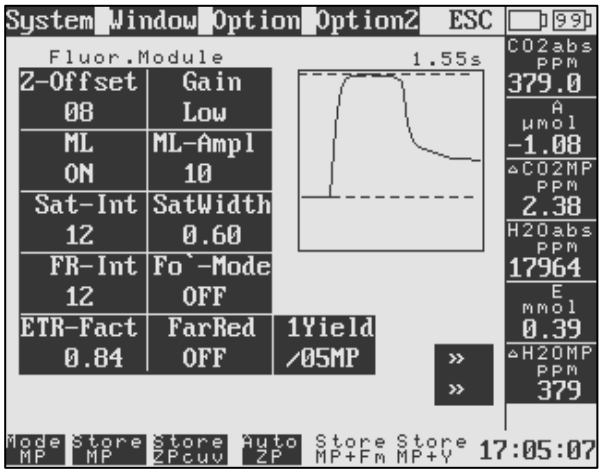


Fig. 6: Second page of the Settings-Window hosting the Fluorescence Module 3055-FL

It is enabled in *System* → *En/disable components*. Create a file for data storage (with *Filename* in *Window Settings*), before performing any fluorescence measurements. The fluorescence will be measured in mV. It can be continuously observed (as Ft) in the Chart Window.

Z-Offset 08

Determination of fluorescence Z-Offset. This offset is caused by background fluorescence and some small preset offset. Its value will be subtracted from every fluorescence measurement. For its determination, the fluorescence module needs to be placed in its proper measuring position, the sample in the cuvette needs to be replaced with black non-fluorescing foam, and the measuring light needs

to be on for at least 5 s. The Z-Offset needs to be determined again after any change in the *Gain* or *ML-Ampl* (*see* below), or any change in the optical setup (e.g. new cuvette). It is good practice to determine it after the system has been started.

Pressing the *Gain*-button changes the sensitivity of the sensor between low and high by a factor of 3.7. A high gain is only recommended for small samples. It improves the resolution, but not the signal to noise ratio. It can be set to high, if the signal remains below 200 mV, even after adjusting the measuring light. After the adjustment of *Gain* or *ML-Ampl* the *Z-Offset* needs to be determined.

Switches the measuring light (*ML*) *on* or *off*. The button indicates the actual state of the light

.

ML-Ampl changes the intensity of the measuring light. The higher the intensity, the better is the signal to noise ratio. Nevertheless, it should not be chosen to high to avoid an actinic effect or overloading of the fluorescence signal during Fm determination. To test, whether the measuring light causes an actinic effect, observe the fluorescence in a dark-adapted sample after switching the measuring light on, or after inserting the sample. If the measuring light causes a slow fluorescence increase by itself, it is to high. To avoid overloading, the fluorescence value for the dark adapted sample should range between 100 and 600 mV. The recommended value for *ML-Ampl* is 10. After the adjustment of *Gain* or *ML-Ampl* the *Z-Offset* needs to be determined.

Sat-Int changes the intensity of the saturating light pulse in steps from 1 to 12

.

SatWidth changes the duration of the saturation pulse in steps of 0.2s within the range from 0.2 to

1.2s.

The saturating light pulse serves to fully reduce photosystem II. It is activated with the button *Store MP+Fm* or the button *Store MP+Yield* at the bottom of the screen. After every saturating light pulse, the kinetic of the fluorescence signal is displayed in a small graph. The Fm or Fm' fluorescence values are determined between the point, where the plateau is reached and the point, where the light pulse is switched off. The level of the stored Fo and Fm or F and Fm' values are indicated by broken lines. The intensity and duration of the saturating light pulse should be adjusted so that the plateau lasts for 200 to 300 ms. If no proper plateau is reached, the intensity of the saturation pulse is to low. If the fluorescence is quenched during the pulse, it is to high or long. For most applications maximal pulse intensity can be recommended.

Changes the intensity of the *far red* light (*FR-Int*) in steps from 1 to 12.

Switches the *far red* light on or off.

Enables or disables the *Fo'-Mode* in conjunction with *Yield* measurements. Usually *Fv/Fm* of a dark adapted sample is measured before a series of *Yield* measurements. The *Fo* of the *Fv/Fm* measurement is used for the calculation of *qP* and *qN*. At higher light intensities, *Fo* quenching can occur, leading to an overestimation of *qP* and *qN*. If the *Fo'-Mode* is enabled, the actinic light is automatically switched off after every saturating light pulse, then far-red light is applied for 2 s before the actinic light is switched back on. During the far-red illumination the *Fo'* is measured and used instead of *Fo* for the calculation of *qP* an *qN*.

Definition of the *ETR-Factor*, which relates to the fraction of the incident light, which is absorbed by the

leaf. It is used for the calculation of *ETR*. A mean value for green leaves in moderate climate is 0.84, which should be used, if the ETR-Factor can not be determined. When using the Imaging-PAM, the ETR-Factor is automatically determined during the absorption measurement.

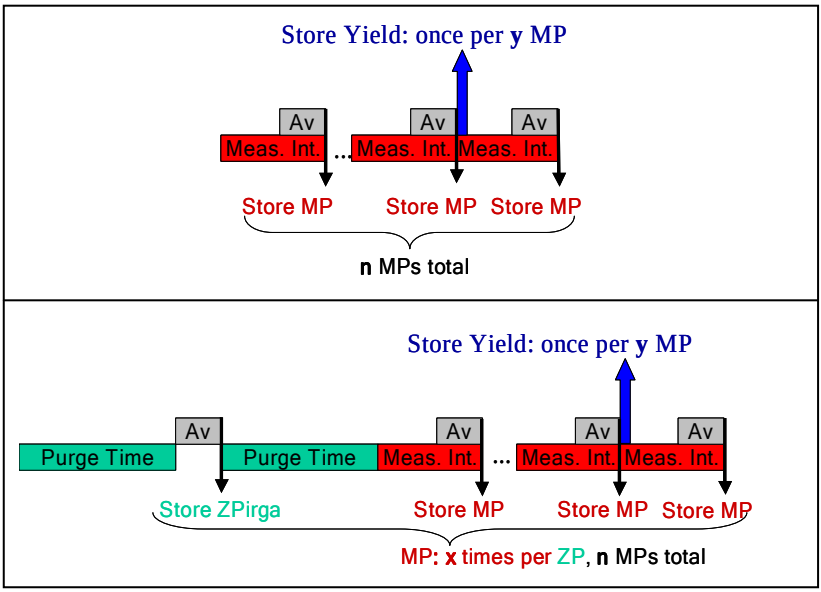


Fig. 7: Illustration of Measuring Sequence, with automatic yield measurements

This button works in cooperation with the buttons *Start Storing* and *Interval* from the first page of the settings window. In addition to the available measuring sequence shown in Fig. 4 also a yield-measurement can be automatically triggered after a certain amount of *Measuring Points*. The sequences in Fig. 5 then change to the sequences in Fig. 7.

When the fluorescence module is enabled, the two buttons of the bottom bar on the right, which serve to trigger saturating light pulses, become active. They are inactive for 10 s after each saturating light pulse to allow cooling time for the LEDs.

Store MP+Fm Serves to store a *Measuring Point* including gas exchange data, automatically triggers a saturating light pulse and stores the fluorescence data, *Fo*, *Fm* and *Fv/Fm*. The leaf should be dark adapted before an *Fv/Fm* measurement. A healthy dark adapted leaf reaches values around 0.8 for *Fv/Fm*. If the user is interested in *qP*, *qN* and *NPQ*, an *Fv/Fm* measurement must be recorded prior to a sequence of *Yield* measurements, since the calculation of *qP*, *qN* and *NPQ* require *Fo* and *Fm*. With every new sample a new *Fv/Fm* measurement is required

Store MP+Y Serves to store a *Measuring Point* including gas-exchange data, automatically triggers a saturating light-pulse and stores *F, Fm', Yield* and *ETR*. If the user is also interested in *qP, qN* and *NPQ*, a *Fv/Fm* measurement must be made before a sequence of *Yield* measurements, since the calculation of *qP*, *qN* and *NPQ* depends on *Fo* and *Fm*. The calculation of *Yield* and *ETR* is independent of *Fv/Fm*.

3.8.1.5 Fiberoptics/PAM-Fluorometer 3050-F - Optional

The Fiberoptics/PAM-Fluorometer 3050-F works very similar to the Fluorescence module 3055-FL. In the GFS-Win software or at the Panel PC enable the Fiberoptics-version.

ML-Frq Low In difference to the Fluorescence module 3055-FL, the frequency of the measuring light can be set manually. It is recommended to use the low frequency in low light and in the dark, where the measuring light would otherwise have an actinic effect on the sample. The high frequency results in a smoother signal. It can be used, when the environmental light intensity is so high that the measuring

light is weak in comparison. During a saturating light flash, the frequency is changed automatically.

The intensity of the Measuring light should be set to 10 unless, it needs to be decreased, when the distance to the sample is very low.

The Gain should be set to high, when the Fluorescence signal of a dark adapted sample is lower than 200 mV.

3.8.2 Window: “1 Chart” and “2 Charts”

The *Chart windows* simulate the function of a chart recorder Fig. 7 shows the window "2 Charts" (Fig. 8). The record starts instantly when the measure mode is switched on. The chart holds the data of all values from the last hour. Two magnitudes can freely be chosen for display.

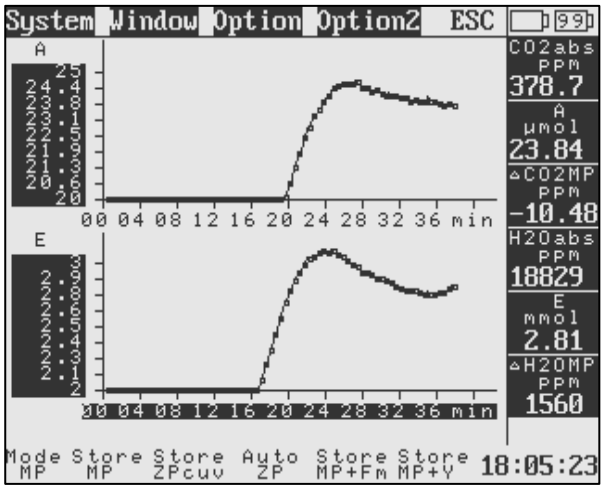


Fig. 8: *Chart window*, A (CO_2-Assimilation) and E (H_2O-Evaporation) being displayed.

To change the y-axis select the y-scale. Now on the right hand side a control-column appears. It has the following functions: *upper limit Y↑, Y↓, Value, lower limit Y↑, Y↓, fine/full scale*, which serve to change the scale and *Value*, with which a new magnitude can be chosen.

Y↑, Y↓ change the upper or lower limits of the scale in steps of 5% of the maximum range.

The buttons *fine*/*full scale* fit the curve automatically. In f*ull scale* the y-scale becomes the maximum range of the displayed magnitude. In *fine scale* the y-scale becomes 5% of the

maximum range. It also shows the curve, if it is outside the full-scale range. To leave the y-scale options press *ESC*.

To change the x-axis select the x-scale. Now on the right hand side a control-column appears. The horizontal arrow keys can modify the scaling of the time-axis. The minimum time range displayed are the last five minutes, maximum is 60 minutes.

Also stored data can be displayed in the chart. To do this, press *Option: Report→Chart.* The data in the chart memory will be deleted and replaced by the data stored in the report. Now the data will not be plotted versus time as with life data, but versus measuring point. The system goes back to collecting life data after pressing the button again *(Option: Life→Chart).*

3.8.3 Window: Graph

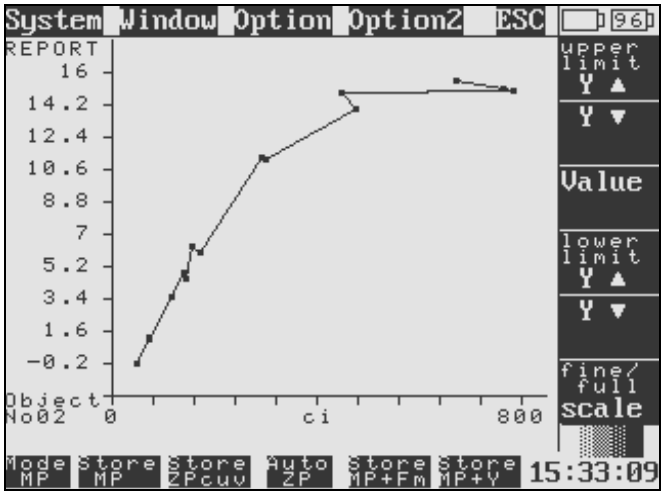


Fig. 9: Graph window

In difference to the *Chart window*, where magnitudes are plotted versus time in the *Window Graph* the magnitude for the x-axis can be freely chosen.

Only the data stored in the report and only the data belonging to one object are plotted. In Fig. 9 the data of *Object No. 2* are shown. This choice can be changed by pressing on the field with the wording *Object No 02*. The data points are connected in dependence of the order in which they have been measured.

3.8.4 Window: Values

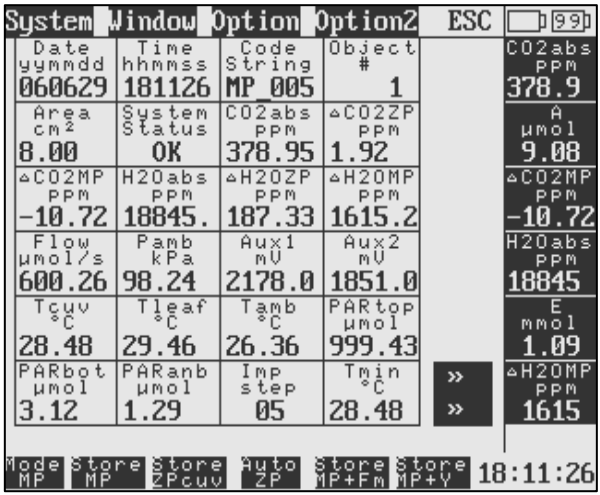


Fig. 10: Values window

The *Values window* (Fig. 10) shows all the measured and calculated parameters that also appear in the *Report File* after saving *Measuring Points* or Z*ero Points*. The second page of the *Values window* can be reached with the double arrow button. For further information about the underlying calculations see manual for the GFS-3000**.**

3.8.5 Window: Report

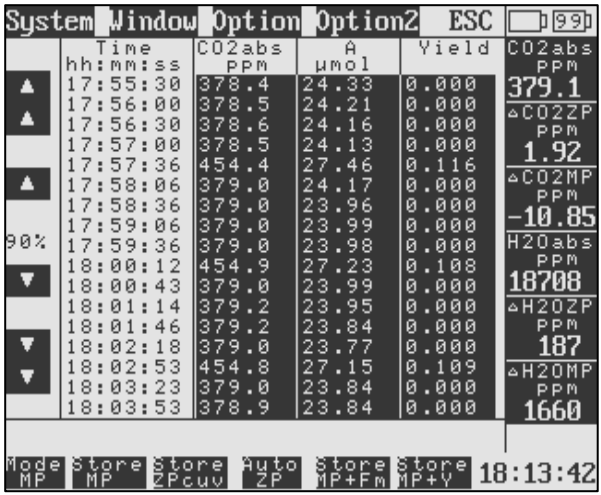


Fig. 11: Report window

The *Report window* shows all parameters that are stored with each *Measuring Point*, *ZPcuv* or *ZPirga*. The displayed magnitudes can be chosen by selecting a column. With the arrow keys on the left allow navigation within the data record. For more details on the parameters stored, please read the GFS-3000 manual.

3.8.6 Window: Program

User-programs can serve two different purposes. They can be used to store the actual settings to simplify the start-up of measurements once the settings have been established. Or they can be used to run complete measurements.

The user-programs can be listed with the *Program window* and started with the button *Start* in the *Settings window* . A program consists of a list of command lines and will be executed line by line. Almost all commands in Table 1 (below) are commands for entering a set value (e.g. for flow, light, cuvette temperature, storing interval).

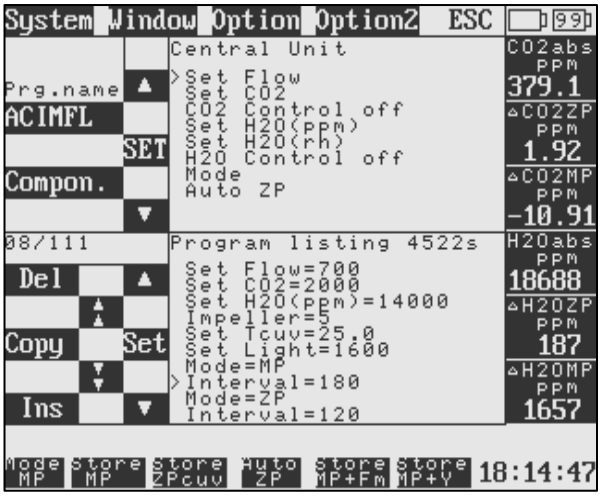
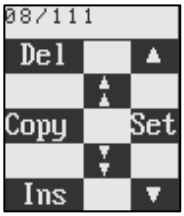


Fig. 12: Program window

Also programs, which have been received from an external PC running *GFS-Win* can be displayed and changed with the *Program window*. Every change is saved directly in the program-file. The upper half of the window shows a listing of selectable commands, it serves to enter new program code. The lower half serves to display the user-program. Beside the headline *Program listing* the total time is displayed the program-run will take.

To change a program, select the line, which shall be changed. If the command requires a value, an input box will appear. The user will be very familiar with these input dialogs, because they are the same or similar to the dialogs, which appear, when settings shall be changed directly. The change will be saved immediately. Keep a safety copy of the program file before making changes. The process is explained in more detail below:

With *Prg. name* a new or existing *program file* can be opened. The button underneath, *Compon.*, serves to scroll through the subsets of available commands. The subsets are *General, Control Unit, Measuring Head* and *Fluorescence Module.* With the arrow keys a certain command can be selected. A small arrow points to the selected command in the command listing. After *Set* has been pressed the selected command will be entered into the program listing. The position of insertion is after the line selected in the program listing. If a value is required for the command, an input-dialog will appear.



The arrow keys serve to navigate within the program listing. The number in the upper line, here 08/111, indicates which line is selected and the total amount of lines in the user-program. *Del* deletes the selected line, *Copy* copies the selected line. The line copied to the memory is shown in the line above the bottom bar. With *Ins* it can be inserted multiple times. With *Set* the selected line of the program listing can be changed.

It is more convenient to write a program in GFS-Win and upload it to the GFS-3000 and only change single commands, if necessary in the field. The changed user-program can be downloaded with GFS-Win (*see* chapter 4.3)

3.8.6.1 Start and Stop user programs

The user-program can be started and stopped in the *Settings window*. With the button "Start program".

If a program is started, the manual input of a file name, set-values or other parameters is blocked. Only the button "Stop" for stopping the program will be enabled. Also comments can be entered. They will be stored with the next data-record.

The program will stop after the last command is carried out. If the storage of data-records is enabled at the end of the program, it will be stopped. All other settings made during the program-run, remain active. Of course, they can now be changed manually.

3.8.6.2 Command List

Table 1: Command List, this list only contains the commands implemented on the Panel-PC. With GFS-Win there are more commands available.

	General Commands
Interval =	to define an interval (s), which has to elapse before the next command of the program is carried out: With "Start storing" before the "Interval"-command, data points will be stored during the interval.
Storing Interval =	to set the Measuring Interval- and Averaging Time for the storage of data points:
Start storing	to initialize the storage of data records: This command is only performed, if it is followed by the command "Interval =".
Stop storing	to stop the storage of data points.
Repeat Run	to repeat the run from start.
Comment =	to enter a comment for the report-file:

	The comment will be stored in the report-file with the next storage of gas exchange data, like usual comments entered manually.
Count up Object No	Increases the value for Object number by 1.
Store MP ZP	performs the same action as pressing the button *Store MP* or *Store ZP* depending on the actual mode.
	Central Unit
Set Flow =	to set the gas flow rate (µmol/s) through the measuring cuvette. This command needs to be given before switching the CO_2 control or H_2O control on, but after switching them off.
Set CO2 =	to set the CO_2 control to the indicated value (ppm). This command needs to be given after switching the flow on, otherwise it will not be performed.
CO2 Control off	to switch the CO_2 control off.
Set H2O(ppm) =	to set the H_2O control to the indicated value (ppm). This command needs to be given after switching the flow on, otherwise it will not be performed.
Set H2O(rh) =	to set the H_2O control to the indicated value (relative humidity % entering cuvette). Give the commands "Set Tcuv" and "Set Flow" before this command.
H2O Control off	to switch the H_2O control off.
Mode =	to chose between MP- and ZP-Mode:
Auto ZP =	to set the purge time and averaging time (temporarily), and perform an automatic ZPirga determination: Firstly, the solenoids switch to ZP-Mode, then the system is purged for the indicated time, ZPirga is averaged over the indicated time and stored. Afterwards, the solenoids switch back to MP-Mode, and

	the system is purged for the indicated time before the run continues. Auto ZP replaces the following series of commands: Stop Storing Mode = ZP Interval = Purge Time Storing Interval = Av Time/ Interval Time equal Store_MP_ZP Storing Interval = Back to what it was Mode = MP Interval = Purge Time Start Storing, if it was active before
	Measuring Head
Impeller =	to set the impeller speed. If the impeller speed is set to 0, the light and the Temperature Control needs to be switched off first.
Follow Tamb + =	to set the temperature control for Tcuv to follow the ambient temperature Tamb. A positive or negative offset value can be entered, if Measuring Head Version is higher than 1.20.
Set Tcuv =	to enter a set value for cuvette temperature; the TempMode will be set to Tcuv. Set impeller speed beforehand ("Impeller =").
Set Tleaf =	to enter a set value for leaf temperature; the TempMode will be set to Tleaf. Set impeller speed beforehand ("Impeller =").
TempControl off	to switch the temperature control off. Don't use this command, if the H2O mode is set to relative humidity.
	The commands for setting the light have changed with Panel-PC Software Ver.1.35
PARtop = PARbot =	to control the light. The command determines, which sensor is used to control the light source.

PARamb =	PARtop/PARbot: The light source will be regulated with the sensor in the upper/lower cuvette half. With PARtop and PARbot, the Light-Source Factor will be taken into account. PARamb: The ambient sensor needs to be placed under the light source. The value determines the light value in µmol m^{-2} s^{-1}.
PARtop follows PARamb PARbot follows PARamb	only for Measuring Head Version 1.20 and higher. These commands can be used to imitate the light measured with the external sensor PARamb with the Fluorescence Module 3055-FL. The light is controlled with PARtop or PARbot according to the value measured by PARamb. The Light-Source Factor is taken into account.
Light Control off	to switch the light off
	Fluorescence Module 3055 or 3050-F
1Yield/y*MP	to set the clock for giving saturating pulses during fluorescence measurements. A yield will be measured every yth MP.
Fv/Fm	to trigger a single Fv/Fm measurement: An Fv/Fm measurement includes a saturating light pulse with Fo and Fm determination. Gas exchange data will be determined and stored beforehand. They will be averaged according to the actual Averaging Time, which can be set with the command "Storing Interval".
Yield	to trigger a single Yield measurement: A yield measurement includes a saturating light pulse with F and Fm' determination. In dependence on the Fo-Mode an Fo' determination will be performed after the light pulse. Gas exchange data are averaged and stored before the yield measurement. They will be averaged according to the actual Averaging Time, which can be set with the command "Storing Interval".

Fo'-Mode FL =	to set the Fo-Mode: On/Off: Fo' is determined/not determined with every Yield determination.
Gain FL =	to set the gain (high/low). After changing the gain, the Zero-Offset of the Fluorescence Module needs to be set again.
FarRed FL =	to switch the far red light on or off.
M-Light FL =	to switch the Measuring Light on or off.
SatWidth FL =	to set the duration (s) of the saturating light pulse.
Sat-Int FL =	to set the light intensity (steps) of the saturating light pulse.
ML-Amp FL =	to set the amplitude (intensity) of the modulated measuring light. Note, after changing this setting, the Zero-Offset of the Fluorescence Module needs to be set again.
FR-Int FL =	to set the intensity of the far red light without switching it on (use command "FarRed FL").
Set Z-Offset FL	to set the zero-offset for the fluorescence module: This command will interrupt the user-program and ask the user to insert a black non-fluorescent foam into the cuvette. The user can circumvent this measurement by choosing "Cancel". The user-program will proceed after ok or cancel have been chosen.
ETR-Fact FL =	to set the ETR-Factor, which is the factor used to calculate the electron transport rate (ETR) from yield measurements and PAR.
ML Frequency F =	The frequency of the measuring light can be set to high or low with the Fiberoptics PAM-Fluorometer 3050-F.

3.8.6.3 Programming Rules

When the GFS-3000 is controlled manually via the Settings window, some settings are blocked if another setting is not made before. For example: the CO_2 control cannot be switched on, if the flow was not set before. The same is true for most settings during the program-run. When programming, please pay attention to the rules and recommendations for the sequential order of commands:

Switching the system or controls on: First Measuring Head: Impeller followed by Temperature and Light (chose Light Control before value). Then Control Unit: Flow followed by gas concentrations.

Switching the system or controls off: Use reverse order: First Control Unit: gas concentrations, followed by Flow. Then Measuring Head: Temperature and Light followed by Impeller.

The "Storing Interval" shall be set before any measurements, also before fluorescence measurements.

It is recommended to define all parameters in the program instead of setting the parameters manually via the Settings window before starting a program-run.

3.8.6.4 Timing during Programming

The Panel PC conducts one command per second, in contrary the *GFS-Win* software executes several of those commands within a second. Some commands require some time to elapse. The most prevalent is "Interval". It is used to define a time that has to elapse before the next command is carried out. If it is preceded by "Start storing", values are recorded during this Interval. Another command requiring time is "Auto ZP". It is equivalent to the button "Auto ZPirga" in the Settings Window. Also the fluorescence commands: "Fv/Fm" and "Yield" require some time. This time is longer with the Panel PC than with GFS-Win.

The timing in user-programs is sometimes ambiguous. In general, ambiguous situations can be avoided by generous timing of the storing interval. In the following the proceeding of the program in ambiguous situations is described.

Fluorescence measurements performed with the command "1Yield/y*MP=" take additional time, especially if they include Fo'-measurements, because the saturating light pulse is given after the gas exchange measurements has been taken. Usually the idle time of the next measuring interval (Fig. 7, idle time = measuring interval -averaging time), which has been set with "Storing Interval =" is used. The maximal time required for a Yield measurement in *Fo'-mode* is 8s. If the idle time of the given measuring interval is to short, the measuring interval of the following MP is prolonged. As a result, the total Interval set with "Interval =" might contain less MPs then intended. If a yield measurement has been started at the end of an Interval. The count-down is paused the yield measurement is finished before proceeding with the program.

If averaging of gas exchange data, has not been finished at the end of an Interval, the program proceeds without storing the data-set.

3.8.7 Submenu Option

Binos calibrate

Full calibration of the infrared gas analyzer needs to be performed with the *GFS-Win* software, but the absolute zero calibration for CO2abs or H2Oabs may be accessed here (*see* chapter 5.2.1).

M.head calibrate

With this function, the light source factor and the Offset for the Tleaf sensor can be set (see chapter 5.1.1 and 5.1.2). Other calibrations of the measuring head need to be performed with the external GFS-Win software.

Time Date

To set the system time

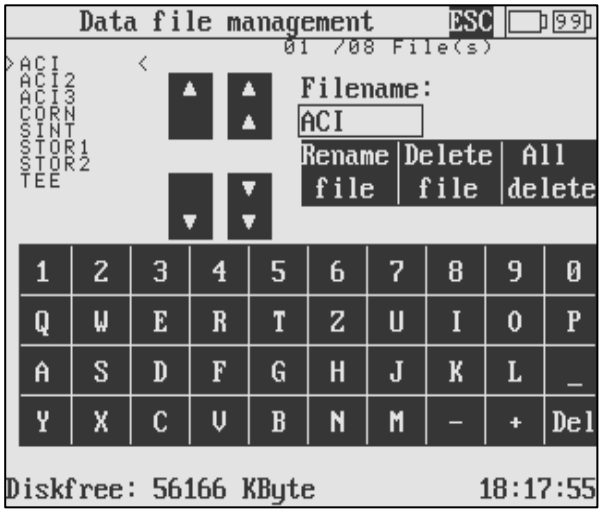


Fig. 13: Dialog for Data file management

Data-File management

Data-File management opens a dialog and keypad on the screen (Fig. 13). With the arrow keys a file can be selected. The selected file is indicated with small arrows, but also its name is shown in the *Filename*-box. With *Rename file* or *Delete file*

the selected file can be renamed or deleted. Please do not use the symbol + within a filename. With *all delete* all data files are deleted. At the bottom of the screen the available disk space is shown. With *ESC* the data file management dialog is left.

Program-File management works analog to the *Data-File management*.

Purge time is required for the command button Auto ZP (*see* chapter 3.6).

Comment opens a dialog. Enter maximal 32 characters and press OK. The comment will be stored with the next MP or ZP in the comment column of the report file.

Flow Meter Offset Recalibrate the flow meter offset with this button. Make sure that the flow is switched off and also the Impeller is switched off before this button is pressed (*see* chapter 5.3).

Report → Chart clears the chart memory. Afterwards the data of the report-file will be read into the chart memory and displayed. The button face will turn into *Live Data→ Chart.* If the button is now pressed again, live data will be collected in the chart memory and displayed in the chart.

3.8.8 Submenu Option2

Error list To display the list of errors (as numbers), which might have occurred during operation. A more detailed error list, which also indicates the time, when these errors occurred can be downloaded using the *GFS-Win*-software (*see* chapter 6.3) For interpretation of error number *see* chapter 6.3.

Chart Clear Clears the chart memory. The chart will be empty after pressing this button.

Components Infos Displays the version and serial numbers of components within and attached to the control unit.

Display To adjust the contrast and brightness of the screen.

System Values Displays values, concerning the function of the system.

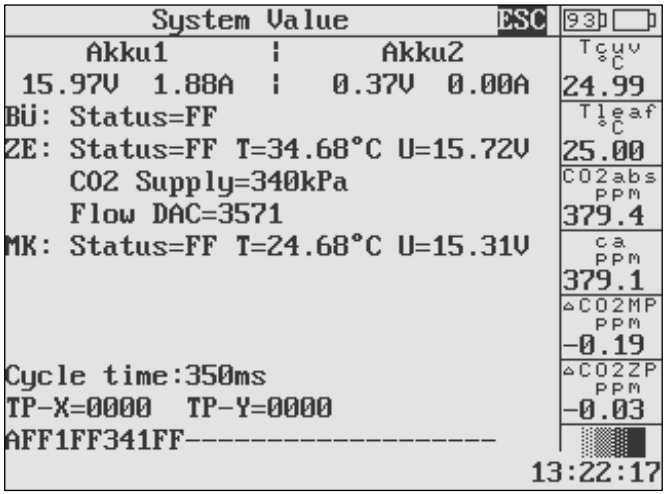


Fig. 14: System values

Under Akku1 and Akku2 are the voltages and current at battery/DC in. Underneath is the status of the Battery Control (BÜ). FF means ok, other-

wise the error number is shown. For the Central Unit (ZE) the status, temperature of electronics (T), voltage (U), the pressure in the CO_2 supply vessel (Central Unit Ver. 1.04 or higher) and the numeric value for the pump regulation (Flow DAC) are given. For the Measuring Head, the status, temperature of electronics (T) and voltage (U) are indicated. The cycle time indicates the time required for reading and calculating the data. TP-X and TP-Y are values of the touch panel adjustment. The lowest line indicates the status string. See GFS-3000 manual for interpretation of the status string.

Touchpanel adjustment To adjust the coordinates of the touch panel.

System constant Displays calibration constants and settings (Fig. 15).

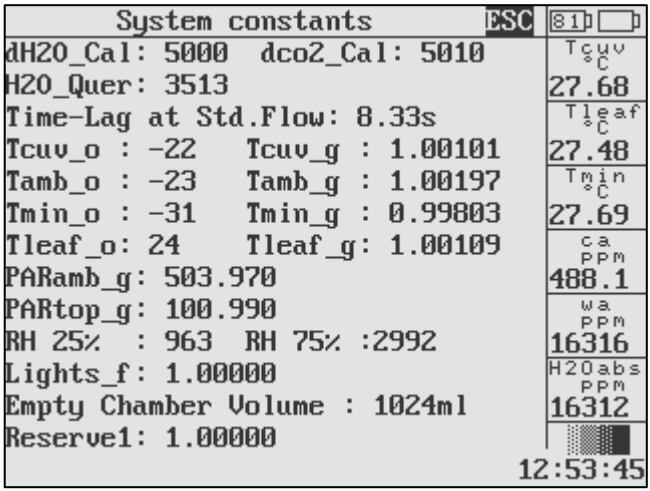


Fig. 15: System constants

dH2O_Cal, dCO2_Cal, H2O_Quer concern the gas analyzer. The other values concern the Measuring Head, here (Fig. 15) the Gas Exchange Chamber 3010-GWK1: time lag between sample gas and reference gas,

offset and gain of temperature sensors, gain of PAR sensors, 25 and 75% value of relative humidity sensor, light source factor (Lights_f), volume of the chamber. For adjustment of Tleaf offset (Tleaf_o) and light source factor (Lights_f), *see* chapter 5.1.1 and 5.1.2.

4 GFS-Win: Installation and File Transfer

4.1 Installation of the GFS-Win Software

Updates of the GFS-Win software can be downloaded at: www.walz.com. Start the setup-file. The installation will start (see Fig. 16). Press *Next* to read the installation information and *Next* again.

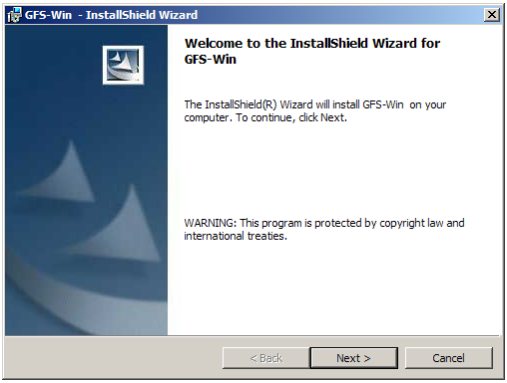


Fig. 16: Installation of GFS-Win.

The installation directory needs to be confirmed or changed.

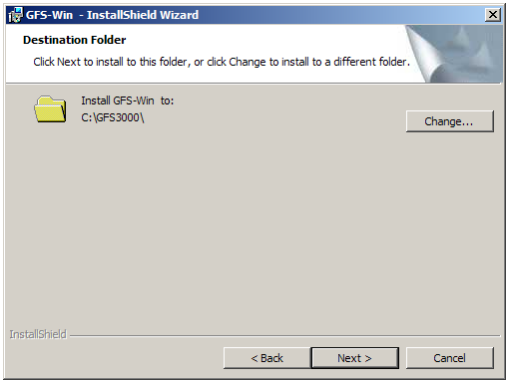


Fig. 17: Dialog for destination folder.

Please note that Windows versions higher than Windows XP have special restrictions in the subdirectory "Program Files". Operation will be more convenient, if GFS-Win is not installed within this subdirectory.

The installation type needs to be changed. Chose the lower option, *GFS-Win (external Computer),* and click *Next.* In the end of the installation press *Finish.*

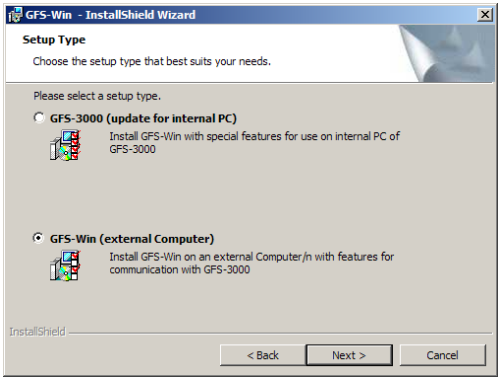


Fig. 18: Dialog for installation type.

After installation, the USB-Port driver needs to be installed, see next chapter.

If the wrong software type has been installed, it may be necessary to remove the software. Also old software sometimes need to be removed before installation. To remove a GFS-Win version press *Start → Control Panel →Add or Remove Programs → GFS-Win (Read support info, which contains version number) →Remove.* In Windows 7, software can be removed with the explorer (Windows-key + e). If the address *Computer* is selected, the command line contains a button for removing programs. The external installation provides an uninstall shortcut at *Start → Programs →GFS 3000 →Uninstall GFS-Win* for software removal.

Before starting GFS-Win, adjust the regional settings of the external PC to point for the decimal character and space for the thousand-separator, also use a semi colon as list separator. The 24 h time-format should be used (*Start →Settings →Control Panel →Regional Settings →customize*) or (*Start →Run →"intl.cpl" →customize*).

4.2 USB-Driver Installation

4.2.1 Windows 95, 98, ME

The GFS-3000 can be connected to an external computer using the supplied USB null-modem cable (NMC). When the USB-null modem cable is connected to an external computer for the first time, the PC automatically recognizes the new hardware and the "*New Hardware Wizard*" window appears.

Select the option *Install from a list or specific location (Advanced).* Click *Next* and browse for the location on the provided CD with the appropriate USB-Port driver. After clicking *Next* the Hardware Wizard gives a warning. Click on *Continue anyway* and *Finish.* If the procedure starts once more, please repeat the procedure as described before for the next hardware port.

4.2.2 Windows 2000

Start the program CDM_Setup.exe from the subdirectory C:\GFS-WIN\USBPORT. It will take some time until the installation will be confirmed. CDM_Setup.exe is also suitable for Windows XP.

4.2.3 Windows XP and Windows 7 (32 or 64 bit)

The program CDM(version number).exe needs to be started to install the USB-driver. To do this chose *Start → Programs →GFS 3000 →Install USB-Port*.

4.3 File Transfer

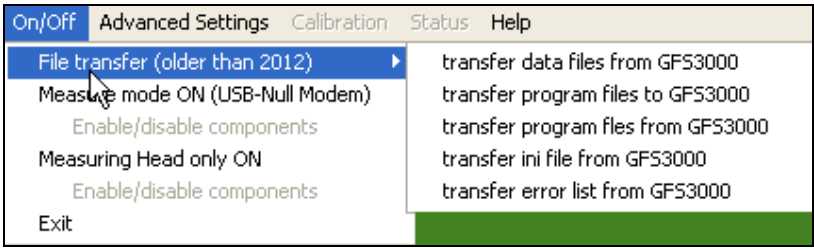


Fig. 19: pull-down list under the menu point *On/Off → File transfer*

Connect the PC with the GFS-3000 via the provided USB-cable. Start the GFS-Win software on the PC. The measure mode needs to be off or in standby mode for file transfer. The GFS-3000 needs to be in the *Window Settings*. During file transfer the baud rate will be 115200 instead of 19200 for normal operation. In the GFS-Win software press Menu point *On/Off → File transfer* and chose between several transfer options.

Data files will be downloaded from the GFS-3000 and translated into .csv-files. Downloaded files will be stored in the actual subdirectory for data. It is possible to change this subdirectory by opening an existing or new report file in GFS-Win with *Settings-> Filename* in the subdirectory intended for data storage.

User-program files (.prg) can be transferred to the GFS-3000 or downloaded from it. The actual subdirectory for the user program files during file transfer is the same subdirectory as used during GFS-Win operation. It can be changed by opening a new or existing user-program in another subdirectory within the program window of the GFS-Win software.

Also the ini-file and error list, GFS3000.ini and GFS3000.err, can be downloaded. These files will be stored in the subdirectory of the GFS-Win software or in the subdirectory *My Documents\ GFS3000\ini* depending on how the GFS-Win software is setup.

5 Calibration and Adjustments

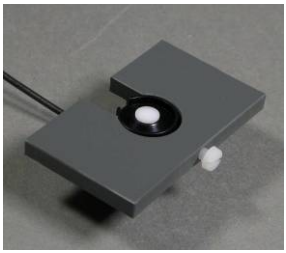
Withthe Panel-PC only the most important calibrations can be carried out. For more calibration options read the manual for the GFS-3000 and use the external software GFS-Win.

5.1 Measuring Had

5.1.1 Offset of Thermocouple for leaf temperature (Tleaf_o)

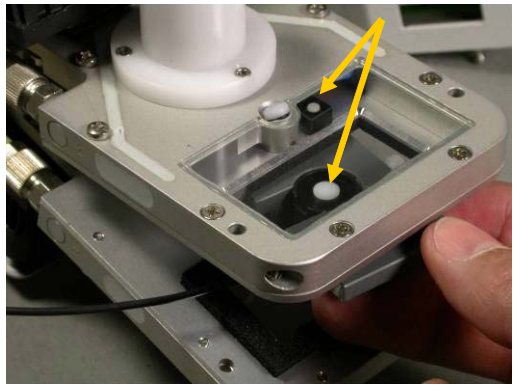
The thermocouple measures the temperature difference between *Tcuv* and its tip touching the leaf. During the offset adjustment, this difference will be set to zero. It is important, that the temperature control is off and has not been used for a while before this function is used. Insert a piece of paper, close the cuvette. The impeller speed will be set to 5 after choosing the menu point *Tleaf-Offset*. Now wait 5 min and watch the values in the quick-view column until the temperature of Tcuv and Tleaf have stabilized. Press *Option* → *Measuring Head Cal.* → *Tleaf-Offset*. The Offset will be set to a new value and stored in the Measuring Head.

5.1.2 Adjustment of Light Source Factor



The intensity of the light source is measured with the *PARtop* or *PARbot* sensor inside the cuvette in dependence of the side of attachment. These light sensors are located at the rim of the cuvette frame, respectively. In contrast to sunlight, which is uniform over large areas, the light coming from an artificial light source may decrease towards the rim, where the light sensor is located. Whenever one of the light sources (LED Light Source 3040-L, LED-Array/PAM-Fluorometer 3055-FL, or the Imaging-PAM) are switched on, the measured intensity of *PARtop* or *PARbot*, depending on the chosen *light mode*, is multiplied with the *light-source fac*tor stored in the measuring head. The *light-source factor* is specific for every light source. If the light source is changed, a new adjustment is re-

quired. Once the *light-source factor* is determined for a given light source, the known value can be entered without a new determination.



For carrying out the determination of the *light-source factor* the external Miniature Quantum Sensor MQS-B/GFS and the provided adapter plate (*see* picture) will be necessary. If a fluorometer is used, it must be enabled.

Open the cuvette and hold the external light sensor mounted in the adapter plate at leaf-level in the center of the cuvette. Set the light to mode PARamb and enter the set value 1000 µmol m^{-2} s^{-1} . Read the value indicated for PARtop (or if the light source is at the lower side fro PARbot). Calculate the light source factor, which is the indicated value for PARamb (1000 µmol m^{-2} s^{-1}) divided by the indicated value for PARtop (or PARbot respectively). The result is the light source factor - usually a number between 1.2 and 1.5. It needs to be entered into the measuring head with *Option → Measuring Head Cal. → Light source factor*. Adjust the light mode back to PARtop or another intended mode before starting measurements.

5.2 Gas Analyzer

5.2.1 Calibration of Gas Analyzer

The calibration procedure has been improved since GFS-Win version 3.31. We recommend doing the calibration with the set-up described here (e.g. air-cycling) and with the latest version of GFS-Win for both types of instruments, having Control Unit Model 3000C or 3100C. With the Panel-PC software the absolute zero-point calibrations is possible. For a full calibration, the external GFS-Win software needs to be used. Also with the

Panel-PC software the set-up with air-cycling as described here may be used.

The full calibration includes the zero point and span calibration of the absolute signals. In order to carry out a zero-calibration, the analyzer should be purged with zero gas until the measured values no longer display a drift. There are two causes for drift, the warm-up drift and the purge-drift. The warm-up drift is a consistent drift after the gas analyzers have been switched on. Take your time for calibrations.

The warm-up drift is typically 15 min for CO_2 and 30 min for H_2O, but may take up to 1 h for CO_2 and up to 2 h for H_2O. The calibration is best performed after this warm-up period. For calibration purposes, we recommend a longer waiting time than for measurements. If the gas analyzer can be kept on overnight the warm-up drift would be avoided. It may be advisable to calibrate the analyzer in the evening after measurements for the next day (or week) rather than in a hurry in the morning. The gas analyzer is switched on, when the *measure mode* is switched on. It is only switched off, if the *measure mode* or *Power* is switched off, but not, if the GFS-3000 is switched into *standby mode*. It is possible to feel by hand whether the analyzer is/was on, because the instrument would have become warm. The purge-drift is short for CO_2 less than 5 min, but very long for H_2O 1-2 hours.

5.2.2 CO_2 Zero using CO_2 Absorber

- The CO_2 zero calibration requires fresh soda lime (CO_2 absorber) connected. Note that the indicator of the soda lime only indicates violet directly after usage. The next day the violet color may have disappeared. Nevertheless the soda lime is used. With very dry gas, the indicator may not work.
- The Drier tube must be replaced by the Mixing Volume 3000-C/MV.
- The humidifier may be replaced by a tube.
- Connect the Measuring Head and close it. Alternatively the gas connections for the measuring head can be replaced with a short tube.

Fig. 20: Set-up of the system for CO_2 absolute zero calibration with air-cycling.

- Although it is possible to calibrate the CO_2 zero with an open flow, air-cycling will save CO_2 absorber material In order to establish air-cycling, connect all outlets with AIR IN via tubes as shown in the picture. The air-cycling tube may be any clean tube made from any material since it is located before the CO_2 absorber. Only(!)

during zero calibrations the air may be cycled. Please, do not forget to take the air-cycling tube off directly after zero-calibration.

- Chose *Option→ Cal. Gas Analyzer→ CO2 zero*.
- The settings for Flow, CO_2 control and H_2O control will be adjusted automatically. In order to speed up the purging process, valve 5 may be opened for a short period of time. Also the Measure Mode is automatically switched between MP and ZP to flush all gas ways with calibration gas.
- In mode ZP the flow through the analyzers may be increased by opening valve 1. It can be opened while watching the increase of flow in the flow indicators. If valve 1 is not changed, reaching zero will take longer, but its readjustment can be avoided.
- Click OK to go to the next step.
- The two upper fields in the Quick-View Column of the GFS-Win main window and the Chart show the CO_2 absolute value of the reference cell (CO2abs) and the CO_2 absolute value of the sample cell (CO2sam). If both values have stabilized without drift *OK* may be clicked. The Info line will display a count-down while performing the calibration, please wait. If the calibration shall be cancelled, press *Stop*.
- Check the calibration: Is CO2abs and CO2sam (or dCO2ZP) close to 0?
- Either set-up the system for the next calibration (CO_2 span or H_2O zero) or for measurements:

  Disconnect air-cycling tube.

  If valve 1 has been opened, it should be readjusted. To do this, the system needs to be in mode MP, the measuring head needs to be connected and closed. Switch the flow on. Adjust valve 1 until both

flow indicators show equal height (*see* chapter 5.4 and manual for GFS-3000).

If valve 5 has been changed, chose *Option2 → System Values*. In mode MP adjust valve 5 until the value for Flow DAC shows 1500 ± 100, or close valve 5 for high flow rates.

If necessary, enable the measuring head with *On/Off →Enable Components*.

5.2.3 H_2O Zero using the H_2O Absorber

H_2O is a small molecule, which is well absorbed by surfaces. Hence it takes a while until the system is completely dried for the H_2O zero calibration. We therefore recommend regular checking of the H_2O zero value, but only a complete calibration, if there is enough time for good drying. In order to be able to dry as long as desired even in wet climates, without flushing too long, so that the silica gel would become wet during the drying procedure, we recommend air-cycling (*see* Fig. 21). Please, do not forget to take the air-cycling tube off directly after zero-calibration.

- Use freshly dried Silica Gel in the DRIER tube. Note, if silica gel is burnt, it may stay orange-black although being wet.
- Remove the tube CO_2 absorber and replace it by the Mixing Volume 3000-C/MV.
- The humidifier may be removed and replaced with a tube.
- Use an air-cycling tube to connect all outlets with the filter at AIR IN. The air-cycling tube may be any clean tube made from any material since it is located before the drier. Please, do not forget to take the air-cycling tube off directly after zero-calibration.

Fig. 21: Set-up for H_2O zero calibration with air-cycling .

- The Measuring Head must be connected and the cuvette closed. Alternatively, the gas connections for the Measuring Head can be shortened with a tube.
- Chose *Option→ Cal. Gas Analyzers→ H2O zero*.
- The parameters for Flow, CO_2 control and H_2O control will be adjusted automatically. In order to speed up the purging process, valve 5 may be opened for a short period of time. Also the Measure Mode is automatically switched between MP and ZP to flush all gas ways with calibration gas.
- Click OK to go to the next step.
- In ZP mode, opening valve 1 will increase the air flow through the analyzer and therefore speed-up the drying procedure. Watch the mechanical flow indicators rise as the flow through the analyzers increases while opening valve 1.

- The two upper fields in the Quick-View Column show the H_2O absolute value of the reference cell (H2Oabs) and the H_2O absolute value of the sample cell (H2Osam). If both values have stabilized (after 10 to 30 min), a H_2O zero point calibration can be carried out via *OK*. Both H_2O absolute values will be set to 0. The calibration can be cancelled by pressing *Stop*.
- Check the calibration: Is H2Oabs and H2Osam (or dH2OZP) close to 0?
- Either set-up the system for the next calibration or for measurements:

  Disconnect air-cycling tube.

  If valve 1 has been opened, it should be readjusted for measurements, to do this, the system needs to be in MP mode, measuring head needs to be connected and closed. Switch flow on. Adjust valve 1 until both flow indicators show equal flow through both sides of the gas analyzer.

  If valve 5 has been changed, chose *Option2 → System Values*. In mode MP adjust valve 5 until the value for Flow DAC shows 1500 ± 100, or close valve 5 for high flow rates, where DAC values that low can not be reached.

  If necessary, enable measuring head with *On/Off →Enable Components*.

5.3 Offet of Flow meter

With flow meter and impeller set to zero, press *Options→ Flow Meter Offset*. The momentary *Offset* and actual flow will be indicated. After pressing OK the *Offset* will directly be changed in the Flow Meter, so that the indicated flow becomes zero.

5.4 Valve adjustment

A short description is given on how the valves shall be adjusted with the software of the Panel-PC. For more detailed information on the valve adjustment and function see manual for the GFS-3000.

Table 2: Valve adjustment, valves are listed in the order of adjustment. It may be necessary to roughly adjust valve 3 and 5 before starting.

Valve	Mode	Adjustment
4	ZP	Equal flow at flow indicators ANALYZER REF and SAMPLE.
3	MP	Flow through Analyzer 800 ml/min at flow indicator ANALYZER SAMPLE or until closed (with low flow rate). It might be necessary to close valve 5 first.
1	MP	Equal flow at ANALYZER REF and SAMPLE.
5	MP	Adjust so that *DAC Flow* is 1500 +- 200 (voltage for pump) or until closed (with high flow). DAC-Flow can be found with *Option2 →System Values*
2	MP ↔ ZP	Total flow in ZP Mode: Watch the DAC-Flow value (*Option2 →System Values*) while switching between ZP and MP. Adjust valve 2 in ZP-Mode, so that the DAC-Flow value is the same in MP- and ZP-Mode. A user-program may be used during adjustment: Mode MP Interval = 20 Mode ZP Interval = 40 Repeat Run Flow indicators will be lower in ZP- than in MP-Mode.

6 Appendix

6.1 Technical data of Control Unit 3000-C

Design: Aluminum housing featuring integrated PC module, large graphical LC-display with touch screen, 4-channel CO_2/H_2O gas analyzer, flow control, CO_2 control (supplied via small cartridges or cylinders) and H_2O control (for drying and humidifying). Pneumatic connectors for air inlet, measuring head and four vents. Sockets for cable connections with Measuring Head 3010-S (or other measuring heads supplied by us), PC (USB interface), two Auxiliaries, two Li-ion Batteries 3025-A (or AC Power Supply 3020-N or external DC) and one additional component

CO_2/H_2O gas analyzer, Mass flow measurement, CO_2 control, H_2O control, Auxiliaries:

- same as Control Unit 3100-C

Integrated user interface: Panel PC 486 SX/33 MHz with transflective graphical LC-display 320 x 240 dots (effective display area 11.5 cm x 8.6 cm) with backlight and touch screen

Data storage capacity: 64 MB flash card

Measured and calculated parameters: CO_2 absolute, CO_2 difference, H_2O absolute, H_2O difference, flow, ambient pressure, 2x auxiliaries, cuvette temperature (upper and lower half), leaf temperature, ambient temperature, PAR in upper part of the cuvette, PAR in lower part of the cuvette, external PAR, impeller frequency, evaporation, VPD, H_2O conductance, net photosynthesis, internal CO_2 concentration. Recalculation of stored data is possible,

In combination with LED-Array/PAM Fluorometer 3055-FL (GFS-3000FL): Fo, Fm, Fm', F, Fo', Fv/Fm (max. PS II quantum yield), $\Delta F/Fm' = Y(II)$ (effective PS II quantum yield), qP, qN, NPQ, ETR (i.e. PAR x $\Delta F/Fm'$)

PC interface: USB 2.0

Input Voltage: 14-16 V

Power Supply: Field replaceable rechargeable Li-ion Battery
14.4 V/15 Ah 3025-A (two batteries supplied), external 16 V DC, AC Power Supply 3020-N for laboratory operation

Operating time: 2 to 4 hours typ. with one Li-ion battery, 4 to 8 hours typ. with two Li-ion batteries

Operating temperature, Dimension, Weight: same as Control Unit 3100-C

6.2 Symptoms and Solutions

Table 3: Symptoms and Solutions

Panel PC	
The screen of the Panel PC is black	Occurs, when it is hot. Try to cool the screen. Adjustment of the contrast can be done by pressing this field  at the lower right-hand corner of the screen. Generally, the screen contrast and brightness can be adjusted under *Option2→Display*. Also the contrast can be set to its default setting during the start-up of the system by pressing the letter "W" of the Walz-logo, which can not be seen, if the screen is black, but the location can be guessed.
Battery Charger	
Battery Charger shows "LiIon error"	Battery charger is not switched on or battery has been discharged to low, disconnect and reconnect battery (see manual for GFS-3000 chapter on batteries for more details). Model LC-02: Note that, if the charger is not switched on, the display of the charger is powered by the connected battery and the battery will discharge.

6.3 Error Messages

Table 4: Errors notified by Panel PC.

Error Code	**Explanation**
0001	Memory error
0002-0005, 0007, 0008	Com-port initialization error
0006, 0009-0016	Communication error (Panel PC to external computer): Check cables, try again
0020-0051	File error, read or write errors to memory card. If no strange letters and not more than 8 letters have

	been used in filenames, call Walz
0300-0315	Initialization error, Measuring Head (Memory error, Run-time error, Initialization failure, Voltage error or Communication errors)
1001	Memory error, Battery Control
1002-1005, 1007, 1008	Com-port initialization error, Battery Control
1006, 1009-1015	Communication error, Battery Control
11xx	*see* manual of the GFS-3000
2001	Memory Error, Central Unit
2002-2005, 2007, 2008	Com-port, initialization error, Central Unit
2006, 2009-2015	Communication error, Central Unit
21xx	*see* manual of the GFS-3000
3001	Memory error, Measuring Head
3002-3005, 3007, 3008	Com-port initialization error, Measuring Head
3006, 3009-3015	Communication error, Measuring Head
31xx	*see* manual of the GFS-3000
4001	Memory error, Fluorescence Module
4002-4005, 4007, 4008	Com-port initialization error, Fluorescence Module
4006, 4009-4015	Communication error, Fluorescence Module

6.4 LED-Code

Table 5: Power LED of Central Unit 3000-C"

LED	**Meaning**
off	Power is off,
green blinking	Power is on, operation ok
green permanently	Program crash or hardware error. Switch power off and back on
red permanently	Program crash or hardware error. Switch power off and back on
red/green blinking	Supplied voltage to low.
red blinking	Error detected by Software, read error code
orange blinking	Error detected by Software, read error code

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